17th European Solar Physics Meeting ESPM-17

Report of Contributions

https://indico.ict.inaf.it/e/espm-17

Contribution ID: **3** Type: **Poster**

Effect of the nonlinear surface inflows into activity belts on the solar cycle modulation

Converging flows are visible around Bipolar magnetic regions (BMRs) on the solar surface, according to observations. Average flows are created by these inflows combined, and the strength of these flows depends on the amount of flux present during the solar cycle. In models of the solar cycle, this average flow can be depicted as perturbations to the meridional flow. Here, we study the effects of introducing surface inflows to the surface flux transport models (SFT) as a possible nonlinear mechanism in the presence of latitude quenching for two possible inflows profiles, profile (I) as inflows whose amplitudes are fixed in every cycle and profile (II) as in profile (I) but with inflows whose amplitudes vary in time within a cycle depending on the magnetic activity. Using a grid based on one-dimensional Surface Flux Transport (SFT) models, we methodically investigated the extent of nonlinearity caused by inflows and latitude quenching (LQ) and their combination. Results confirm that including surface inflows in the model produces a lower net contribution to the dipole moment (3-12\%) in the presence of the latitude quenching mechanism only. Furthermore, the relative importance of LQ vs. inflows is inversely correlated with the dynamo effectivity range (λ_R). With no decay term, introducing inflows to the model results in a less significant net contribution to the dipole moment. Also, results confirm that inflows profile (II) is more robust and favourable to use in this model.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **4** Type: **Poster**

Unravelling the stratification of the chromospheric magnetic field using the Hα line

The Hα line is widely used to study solar chromosphere, but polarimetric studies to infer magnetic fields are scarce. This is partly due to no polarimetric studies of Hα line utilizing 3-D radiative transfer, and earlier 1-D radiative transfer studies suggested a significant contribution of the photospheric fields. By analyzing spectropolarimetric data of a small pore simultaneously recorded in the Hα and CaII8542 lines, Mathur et al. (2023) found that line core of the Hα line probes chromospheric magnetic field. In this study, we analyze spectropolarimetric observations of a complex active region recorded simultaneously in the Hα and CaII8662 lines. The sunspot exhibits multiple structures, 4 umbras and a lightbridge, and a region where CaII8662 line core is in emission, a signature of localized heating. Consistent with the Mathur+2023, we found that the magnetic field inferred from the Hα line core is consistently smaller than that inferred from inversions of the CaII8662 line at $\log\tau500=-4.5$, however, in contrast with Mathur+2023, uncorrelated. The field strength and morphology inferred in the heating region from the inversions at $\log\tau500=-4.5$ is comparable to that of at $\log\tau500=-1$. In the heating region, the WFA over Hα line core and full spectral range are similar in strengths and morphology and uncorrelated with fields at $\log\tau500=-1$. Thus, we suggest that line core of the Hα line always probes the chromospheric magnetic field at higher heights than that probed by Ca2IR triplet, making Hα line spectropolarimetry a valuable diagnostic for studying chromosphere, especially in regions with localized heating.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **7** Type: **Poster**

Towards Realistic Solar Flare Models

Solar flares are complex multiscale phenomena that demand modeling strategies capable of precisely capturing processes at both the microscale and macroscale. At the microscale, kinetic models such as the Particle-In-Cell (PIC) method are crucial for an accurate depiction of physical phenomena, especially particle acceleration near reconnection sites. However, the extensive computational demands of full-scale PIC simulations necessitate a more practical approach. A hybrid system is employed wherein Magneto Hydrodynamics (MHD) governs the large-scale dynamics, while PIC is strategically applied to model the critical reconnection processes.

We have developed a PIC solver and integrated it within the DISPATCH framework. DISPATCH organizes the simulation domain into smaller, manageable 'patches'. Each patch operates semi-autonomously, updating based on local conditions, thereby enabling simulation across diverse time and spatial scales. This modular approach not only achieves near-perfect strong and weak scaling but also enables dynamic solver switching, a critical feature for efficiently addressing the vast scale discrepancies characteristic of solar flare phenomena.

Here, we show the initial validation results of our explicit PIC solver, along with our ongoing efforts towards its integration with MHD. We will underscore the significant advancements in our hybrid modeling approach, demonstrating its potential to enhance our understanding and simulation capabilities of solar flares.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **8** Type: **Poster**

Dimming Inferred Estimation of CME Direction - DIRECD

Coronal mass ejections (CMEs) are powerful solar events involving the expulsion of plasma and magnetic fields, significantly impacting Space Weather. Traditional coronagraphs face challenges in accurately measuring the early evolution of Earth-directed CMEs due to projection effects. Coronal dimmings, characterized by localized reductions in extreme-ultraviolet (EUV) and soft X-ray emissions, serve as crucial indicators of CMEs in the low corona. These dimmings arise from mass loss and expansion during the eruption. This study introduces DIRECD (Dimming InfeRred Estimate of CME Direction), a new method to estimate initial CME propagation direction based on dimming expansion. The approach uses 3D CME simulations with a geometric cone model, exploring parameters like width, height, source location, and deviation from the radial direction. The primary direction of dimming expansion is identified, and an inverse problem is solved to reconstruct a series of CME cones at different heights, widths, and deviations. The 3D CME direction is determined by comparing the CME projections onto the solar sphere with the dimming geometry. Validated through case studies on October 1, 2011, and September 6, 2011, the DIRECD method reveals the initial propagation directions of CMEs which are close to that derived from the 3D tie-pointing of the CME bubble observed in EUV (lower corona) and from the GCS 3D modeling of the white-light CME (higher corona). Additionally, these findings are consistent with the multi-viewpoint coronagraph observations of the CMEs from both SOHO and STEREO. The research highlights the potential of coronal dimming data for early estimation of CME direction.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **9** Type: **Poster**

Wave Conversion and Heating in a Two-fluid partially ionized atmosphere

The solar chromosphere is a highly dynamic layer governed by magnetic forces. Models and observations alike have difficulties in their analysis and interpretation. For instance, what mechanism is responsible for heating the chromosphere needs yet to be determined. Chromospheric plasma contains a significant amount of neutral particles. For phenomena operating at timescales significantly larger than collision times between neutrals and charges, both components move as a whole. Friction between the particles, however, may be able to efficiently raise the temperature of the plasma if the time scales approach those of collisions. Here, we investigate wave dissipation via charge-neutral collisions as a heating mechanism in a two-fluid model for charges and neutrals. We focus on propagation of magneto-acoustic waves in two distinct 2D setups containing an acoustic-to-magnetic (or viceversa) conversion area. In the first scenario, we use a vertically stratified but horizontally uniform atmosphere, with a homogeneous magnetic field set to establish an Alfvén-acoustic equipartition region halfway within the domain. In the second case, we consider the same thermodynamic background but a potential magnetic field, allowing for the presence of a magnetic null point. Moreover, we perform comparative analysis for two distinct atmospheres: a Holmul model that represents a cool atmosphere in radiative equilibrium, and a hot chromosphere represented by a Val3c model. Our simulations demonstrate that magnetic waves are more damped and cause greater dissipation and heating than acoustic waves, in line with the theoretical work of Cally & Gómez-Míguez 2023.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **10** Type: **Poster**

Probing chromospheric fine structures with an Hα proxy using MURaM

The solar chromosphere consists of poorly understood, dynamic fine structures. In this work we use the MURaM code, which has recently been updated to include the NLTE physics required to treat the chromosphere. Our flux emergence simulations of an enhanced network element show finely structured chromospheric features, akin to the rapid red and blue shifted excursions (RREs and RBEs) observed in the wings of the Hα line and dynamic fibrils detected in the line core. Using a proxy for Hα, we identify features in the line wings. We find numerous fine structures detected by the proxy to be rooted at the network patches, similar to observations in Hα. These ubiquitous features could play a crucial role in mass and energy supply to the corona. The dynamics of one such feature (RBE) at a Doppler shift of 37km/s shows that flux emergence and consequent reconnection events drive the formation of this feature. Lorentz forces further expand the field and compress the plasma locally. This drives a flow along the field line carrying the feature, making it behave like a jet. It forms in the mid chromosphere (2-4 Mm above the solar surface) and has a lifetime of 240s. It has a maximum length of 5Mm and also shows lateral displacement during its lifetime. There is strong viscous and resistive heating at the birth of the feature which propagates a heating front at alfvenic speeds.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **11** Type: **Poster**

Unexpected Frequency of Horizontal Oscillations of Magnetic Structures in the Solar Photosphere

It is well known that the dominant frequency of oscillations in the solar photosphere is at ≈3 mHz, which is the result of global resonant modes pertaining to the whole stellar structure. However, analyses of the horizontal motions of nearly 1 million photospheric magnetic elements spanning the entirety of solar cycle 24 has revealed an unexpected dominant frequency ≈5 mHz, i.e., a frequency typically synonymous with the chromosphere. Given the distinctly different physical properties of the magnetic elements examined in our statistical sample, when compared to largely quiescent solar plasma where ≈3 mHz frequencies are omnipresent, we argue that the dominant ≈5 mHz frequency is not caused by the buffeting of magnetic elements, but instead is due to the nature of the underlying oscillatory driver itself. This novel result was obtained by exploiting the unmatched spatial and temporal coverage of magnetograms acquired by the Helioseismic and Magnetic Imager (HMI), onboard NASA's Solar Dynamics Observatory (SDO). Our findings provide a timely avenue for future exploration to better understand the magnetic connectivity between sub-photospheric, photospheric, and chromospheric layers of the Sun's dynamic atmosphere.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **14** Type: **Talk**

Bayes in Space: A Bayesian Deep Learning approach for Coronal Temperature estimation

Thursday 12 September 2024 14:55 (15 minutes)

The Corona, the outermost layer of the Sun, is a region of intense activity and showcases various solar phenomena that affects the thermal distribution of its constituting plasma. The study of the temperature distribution across the corona is essential in understanding different heating mechanisms that lead to the strikingly high temperatures reached by the corona. This distribution can be estimated using photometric observations in multiple bandpasses by imaging surveys like the Atmospheric Imaging Assembly onboard the Solar Dynamics Observatory. However, each bandpass covers a range of plasma temperatures and cannot be estimated directly through these observations. The temperatures can be estimated by inverting the intensity or number of photons hitting the detector through the channel passband. We propose an uncertainty based deep learning approach to generate Differential Emission Measure (DEM) maps from solar images, that contain information of the amount of thermal plasma emitted by the solar corona along a line-of-sight at a certain temperature. A machine learning approach consists of training a neural network to read AIA images from multiple bandpasses and develop their DEM maps across a range of temperatures as output. While this network can be designed to provide real, non-negative DEM value for each input intensity, it can disrupt the DEM map if it is unsure of its predictions and gives out a wrong output. We introduce an uncertainty in deep learning methods for obtaining the DEM maps from AIA images by incorporating Bayesian techniques like variational dropout and bayes by backdrop, and compare these approaches.

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Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **15** Type: **Poster**

Analysis of BMR tilt from AutoTAB catalog: Hinting towards the thin flux tube model?

One of the intriguing mechanism of the Sun is the formation of concentrated magnetic regions of opposite polarities on the surface called bipolar magnetic regions (BMRs). Such regions generally appear tilted with respect to the equatorial line. The thin flux tube model, employing the rising of magnetically buoyant flux loops twisted by the Coriolis force, is a popular paradigm to explain the formation of the tilted BMRs. In this study, we assess the validity of the thin flux tube model by analyzing the tracked (Hale and Anti-Hale) BMR data obtained through the Automatic Tracking Algorithm for BMRs (AutoTAB). Our observations reveal that the tracked BMRs exhibit the expected collective behaviors and the polarity separations of BMRs increase over their normalized lifetimes, supporting the assumption of the rising flux tubes from the CZ. We also observe an increasing trend of the tilt with the flux of the BMR, suggesting that rising flux tubes associated with lower flux regions are primarily influenced by drag force and Coriolis force, while in higher flux regions, magnetic buoyancy dominates. Additionally, we observe Joy's law dependence for emerging BMRs from their first detection, indicating that at least a portion of the tilt observed in BMRs can be attributed to the Coriolis force. Finally, we observe that the lower flux regions exhibit a higher amount of fluctuations associated with their tracked tilt measurements, suggesting that they are more susceptible to turbulent convection. All these results hint towards the thin flux tube model.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **16** Type: **Poster**

Magnetic field extrapolation using analytical 3D MHS equilibrium solutions

With current observational methods it is not possible to directly measure the magnetic field in the solar corona with great accuracy. Therefore, coronal magnetic field models have to rely on extrapolation methods using photospheric magnetograms as boundary conditions. In recent years, due to the increased resolution of observations and the need to resolve non-force-free lower regions of the solar atmosphere, there have been increased efforts to use magnetohydrostatic (MHS) field models instead of force-free extrapolation methods. Although numerical methods to calculate MHS solutions can deal with non-linear problems and hence provide more accurate models, analytical three-dimensional MHS equilibria can also be used as a numerically relatively "cheap" complementary method [T. Wiegelmann et al.(2015), T. Wiegelmann et al.(2017)]. We present an extrapolation method based on a family of analytical MHS equilibria that allows for a transition from a non-force-free region to a force-free region [T. Neukirch and T. Wiegelmann (2019)]. In a subset of cases, asymptotic solutions can be used to make the method numerically more efficient. We shall present some examples of applications of the method.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **17** Type: **Poster**

Wide-Field EUV Image Campaigns with GOES Solar UltraViolet Imager

Traditional approaches to tracking solar outflows for space weather forecasting rely primarily on coronagraph images, which generally observe the solar corona above a minimum height of about 2.5 solar radii. Extreme ultraviolet (EUV) imagers have been widely used to characterize features on the solar disk, but their limited fields of view have prevented their use for tracking outflows through the inner and middle coronae. A series of off-point campaigns with the GOES 16-18 Solar Ultraviolet Imager (SUVI) between 2018 and 2024 have provided an opportunity to assess the value of extended EUV images for space weather forecasting applications. These new results demonstrate that wide FOV EUV images are useful for characterizing the early onset of eruptive events and tracking smaller outflow into the solar wind. Because CMEs generally experience the bulk of their acceleration below the height of white light coronagraphic observations, these images provide information about the origins of these events that has not been traditionally available. Together with coronagraphic measurements, EUV images enable connecting CMEs back to their source regions. Of note are the two campaigns in 2021 and 2024 that were conducted to coordinate with the Solar Orbiter and Parker Solar Probe perihelion observations. The April 2024 campaign provided a trove of valuable data due to the active Sun. The upcoming campaign on GOES-19 has the added benefit of a Compact Coronagraph sharing the same Sun-pointing platform with SUVI. Here, we present these new SUVI observations and discuss their potential use in space weather operations.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **18** Type: **Poster**

On the Response of the Transition Region and the Corona to Rapid Excursions in the Chromosphere

Spicules are the thin, hair/grass-like structures prominently observed at the chromospheric solar limb. It is believed that fibrils and Rapid Blue and Red Excursions (RBEs and RREs; collectively referred to as REs) correspond to on-disk counterparts of type I spicules & type II spicules, respectively. Our investigation focuses on observing the response of these REs alongside similar spectral features in the chromosphere, transition Region (TR), and corona, utilizing space-time plots derived from coordinated observations from SST/Hα, IRIS, and SDO. Our analysis reveals upflowing REs, promptly reaching temperatures characteristic of the TR and corona, indicating a multi-thermal nature. Similarly, downflowing features exhibiting similar spectral signatures over the disk display plasma motion from the corona to chromospheric temperatures, demonstrating a multithermal nature. In addition to distinct upflows and downflows, we observe sequential upflow and downflow along the same path, depicting a distinctive parabolic trajectory in space-time plots of observations sampling TR and various coronal passbands. Similar to isolated upflows and downflows, these REs also exhibit a multi-thermal nature throughout their trajectory. Furthermore, our results reveal a more intricate motion of the REs in which both upflow and downflow coexist at the same spatial location. On a different note, our analysis, utilizing coordinated IRIS spectral observations, shows spatio-temporal redshifts/downflows in both the TR and chromosphere, suggesting that at least subsets of the strong redshifts/downflows observed in TR temperature spectra result from the returning, from the upper atmosphere flow of plasma in the form of bundles of spicules or features exhibiting similar spectra.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **19** Type: **Poster**

The Fast Imaging Solar Scanning Spectro-Polarimeter (FISS-SP): First observations and early results

The feasibility of restoration of spectrograph data was first demonstrated by Keller and Johannesson [1995] based on a speckle-based method. In van Noort [2017] this method was revisited using an MFBD based approach on data acquired with the SST. This new approach allows for the restoration of spectro-polarimetric data over large FOVs with a spatial resolution that can compete with that of restored 2D-filtergraph images.
As a follow-up to the work of van Noort [2017], we have further explored the performance of image restoration of solar spectra on data sets with a considerably higher spatial resolution. The Fast Imaging Solar Spectrograph (FISS) instrument [Chae et al., 2013] installed at the 1.6 meter Goode Solar Telescope (GST) [Cao et al., 2011] at the BBSO offered the right platform. We extended the FISS by spectro-polarimetric capabilities, a fast context imager, and a state-of-the-art large format spectrograph camera. The resulting Fast Imaging Solar Scanning Spectro-Polarimeter (FISS-SP) experiment can accommodate a spectral range in excess of 30˚A at a central wavelength of 5241 A, allowing for the simultaneous full Stokes observation of more than 150 solar absorption lines.
The huge spectral window opens up the possibility of achieving a high polarimetric sensitivity by combining the information of many lines, as proposed by Riethmüller and Solanki [2019]. In this contribution we present restored first light FISS-SP data sets with outstanding spectral and spatial resolution. Furthermore, we present a preliminary analysis based on the new many line inversion technique.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **20** Type: **Poster**

Machine learning time series causal effect analysis of the interplanetary magnetic field's Bz component and geomagnetic Ap on cardiovascular health event frequency

Associations between space weather and events on Earth, e.g., geomagnetic perturbations affecting power grids, are well-known. Effects on human health and physiology are less well investigated, and current evidence, suggesting, e.g., less frequent cardiovascular events during phases of high geomagnetic disturbance, builds on small patient cohorts and a wide array of statistical tests. Recently, the availability of large space weather time series along with huge epidemiologic observational databases facilitates evidence synthesis by employing advanced machine learning approaches to uncover associations between both.
The objective is to investigate potential causal effects of the solar wind's southward IMF component and strong geomagnetic disturbance on cardiovascular health, in particular on cardiac arrest events as a hard endpoint.
Time series of the IMF's Bz component (Wind satellite, L1) and Ap from the year 2015 were merged with emergency service use time data from the U.S. for cardiac arrest events. A causal impact analysis using counterfactual reasoning was performed to test for causal effects of the March 15 CME and the subsequent St. Patrick's day G4 level geomagnetic superstorm, for a 14-day period after the CME.
Statistically significant, negative causal impact on cardiac arrest event frequency in the U.S. are identified for the southward (Bz) IMF component (-7% [-12%, -5%], p=0.001) and Ap (-9% [-10%, -4%], p=0.001).
Results show a significant impact of IMF and geomagnetic disturbance on cardiac arrest frequency in the U.S., potentially due to alterations in the activation of the autonomous nervous system. More research is necessary to uncover mechanistic models.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **21** Type: **Poster**

Validating Fourier Local Correlation Tracking of quiet photospheric vortex flows using MURaM and DKIST

Vortex flows in the solar photosphere are ubiquitous and are thought to inject energy into the upper solar atmosphere in the form of Poynting flux. However, observing photospheric intensity vortices is challenging due to their small size and the fact that the flow field is primarily parallel to the plane-of-sky. Despite this, a large number of photospheric intensity vortices have been observed by applying Fourier Local Correlation Tracking (FLCT) to high-resolution observations. Validating these detections raises two questions: i) Are changes in photospheric intensity a suitable proxy for tracking the plasma velocity field? ii) Are the statistics on the observed properties of photospheric vortices accurate, given a significant number of vortices are considered to remain unresolved by most instruments? To address these questions, we compare observations from the Daniel K. Inouye Solar Telescope (DKIST) with a synthetic observation produced by a radiative magnetohydrodynamic MURaM simulation. We employ FLCT to infer the velocity field from the observations and use the Γ-functions method to identify and track the properties of vortices therein. We find a discrepancy between the number of vortices identified in the DKIST observation, the synthetic observation, and the plasma properties derived from the simulation. Here, we compare the simulated and inferred velocity fields and outline the potential implications of the validity of FLCT. This research draws important conclusions on the photospheric intensity vortices with further consequences on the expected energy transfer to the upper solar atmosphere.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **22** Type: **Poster**

Spectral Irradiance Variability in Lyman-alpha Emission During Solar Flares

The ultraviolet Lyman-alpha line of neutral hydrogen is the brightest emission line in the quiescent solar spectrum and is a significant radiator of flare energy. The study of spectrally resolved Lyman-alpha flare observations may provide a valuable diagnostic of where flare heating occurs in the solar atmosphere. Despite this potential diagnostic use, most contemporary flare observations in Lyman-alpha are not spectrally resolved. SORCE/SOLSTICE provided flux and wavelength calibrated spectral irradiance measurements of the Lyman-alpha line between 2003 and 2013. A number of these scans coincided with the impulsive phase of major solar flares, several of which were also simultaneously observed by RHESSI. This study focused on two flares of class M5.3 and M8.3, both observed by SOLSTICE and RHESSI. We compared the spectral response of the Lyman-alpha line to the properties of non-thermal electrons driving the line's enhancement. The respective flares had electron beam spectral indices of 3.38 and 7.76, with greater enhancement of the Lyman-alpha line wings relative to the line core for the former flare. Our findings illustrate a positive correlation between electron beam hardness and relative enhancement of the Lyman-alpha line wings compared to its core for flares of similar GOES magnitude. These comparisons of Lyman-alpha spectral emission and electron beam spectral index may help guide and interpret radiative hydrodynamic flare simulations such as RADYN. This research may serve as a baseline study for the advent of spectral Lyman-alpha flare observations anticipated from new instruments coming online during Solar Cycle 25, including Solar-C/EUVST and SNIFS.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **23** Type: **Poster**

Insights into the Rotation and Eruption of Magnetic Flux Ropes Influenced by External Toroidal Magnetic Fields

We perform a data-constrained simulation with the zero-beta assumption to study the mechanisms of rotation and failed eruption of a filament in active region 11474 on 2012 May 5. Our simulation reproduces most observational features very well, e.g., the large-angle rotation, the confined eruption and flare ribbons. We discover two flux ropes in the sigmoid system, an upper flux rope (MFR1) and a lower flux rope (MFR2) grows by tether-cutting reconnection during the eruption, which correspond to the filament and hot channel in observations, respectively. Both flux ropes undergo confined eruptions. The rotation of MFR1 is related to the shear-field component along the axis. The toroidal field tension force and the non-axisymmetry forces confine the eruption of MFR1. We also suggest that the mutual interaction between MFR1 and MFR2 contributes to the large-angle rotation and the eruption failure.

Then, we perform three-dimensional magnetohrdronamic simulations to model the eruption of magnetic flux ropes in the magnetic configuration with and without external toroidal magnetic fields, to examine the mechanisms by which the toroidal magnetic field facilitates flux-rope rotation, and in exploring potential alternative rotation mechanisms beyond the effects of sheared fields and kink instability. The behavior of flux ropes in two simulations exhibits significant contrasts. We indicate that toroidal fields facilitate the flux-rope rotation by promoting the release of the initial twist and amplifying the lateral Lorentz force exerted on the flux rope. In addition, slipping magnetic reconnection between flux-rope field lines and sheared-arcade field lines can also contribute to the rotation.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **24** Type: **Talk**

Probing particle acceleration and transport through behind-the-limb gamma-ray Solar flare observations

Thursday 12 September 2024 09:25 (15 minutes)

Observations of greater than 100 MeV gamma-ray emission from solar flares from active regions located behind the visible solar disk pose interesting questions regarding the acceleration sites and mechanism, the transport and interaction points of the accelerated particles during these events. Two of the most popular scenarios to explain these observations are (a) acceleration at the coronal mass ejection (CME)-driven shock with back precipitation to the solar atmosphere and (b) trapping of flare-accelerated ions in extended coronal loops or additional acceleration and release into the loop. In this talk I will discuss the most recent results from the Large Area Telescope onboard the Fermi Space Telescope that show evidence in support of both of these scenarios during behind-the-limb solar flares.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **25** Type: **Poster**

Exploring EUV coronal diagnostics: the Hanle effect of Ne VIII 770 Å

The Hanle effect refers to the modification of degree of linear polarization and rotation of the plane of polarization of the scattered radiation in the presence of an external magnetic field. In a recent publication, we reported spectral lines in the extreme-ultraviolet (EUV) range that exhibit sensitivity to the unsaturated Hanle effect and are, therefore, inherently sensitive to the vector magnetic field in the solar corona. In our current research, we focus on modeling one such EUV line - Ne VIII 770 Å - and compute the polarization signals induced by resonance scattering. We interpret the modifications in these signals due to collisions and magnetic fields through the Hanle effect. By employing 3D magneto-hydrodynamic models (PSIMAS), we synthesize the polarization maps both on the solar disk and off the limb. The polarization degree (defined as L/I= sqrt(Q^2+U^2)/I) and the rotation angle of the plane of polarization (defined as Az= (1/2) arctan(U/Q)) are simulated through the entire solar cycle 24. By FORWARD modeling the polarization of Ne VIII 770 Å, we have explored its potential as a polarimetric diagnostic for the weak coronal magnetic field. Our study demonstrates that this EUV line can be a useful complement to coronal field diagnostics in the FUV, such as O VI 1032 Å and H I 1216 Å, and off-limb spectropolarimetric measurements in the visible and infrared wavelengths, such as those obtained with the Visible Emission Line Coronagraph (VELC), the Upgraded Coronal Multi-Channel Polarimeter (UCoMP) and the Daniel K. Inouye Solar Telescope (DKIST).

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **26** Type: **Poster**

Investigating the Characteristics of Oscillating Bright Points in Different Solar Regions

This study, focused on exploring the properties of Bright Points (BPs) in different regions of the Sun, with a particular emphasis on their oscillatory behavior. They developed a machine learning model to identify and analyze BPs in solar images, achieving a 78% accuracy in BP identification, then used wavelet and Fourier analysis to investigate the oscillatory behavior of the identified BPs.

The study found both differences and similarities in the properties of oscillated and non-oscillated BPs across various regions, including the quiet Sun (QS), active regions (ARs), and coronal holes (CH). The damping per period and the maximum Doppler velocity (MDV) of BPs varied depending on the region. In the QS, internetwork BPs exhibited lower damping times and higher MDV compared to network BPs. In AR, internetwork BPs tended to have higher damping times and wider ranges of MDV compared to network BPs. In CH, both types of BPs displayed similar damping times, but internetwork BPs tended to have higher MDV.

The study also highlighted that the majority of AR network BPs were in the overdamping mode, indicating a stronger damping effect. In QS, internetwork BPs demonstrated overdamping behavior, while oscillated network BPs exhibited critical damping behavior. The researchers emphasized the complex nature of BPs and the need to consider the specific conditions in each region when studying their oscillatory behavior and damping-mechanisms.

The study serves as a valuable contribution to the understanding of BPs and their role in solar-activity, with implications for space-weather forecasting and the Sun-Earth relationship understanding.

Primary author: Ms SADEGHI, Rayhane

Co-author: Dr TAVABI, Ehsan

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **27** Type: **Poster**

Deceleration of CMEs between Mercury and Earth tested by EUHFORIA/ICARUS MHD simulations

Coronal Mass Ejections (CMEs) are the main drivers of the disturbances in interplanetary space. Then, understanding CMEs is crucial for advancing space weather studies. Assessing the numerical heliospheric model capabilities is crucial, as understanding the nature and extent of the limitations can be used for improving space weather predictions. In a statistics study it was shown that among 28 cases observed by the two spacecraft located near Mercury (MESSENGER) and Earth (ACE), 22 cases show a deceleration of 160 km/s. We test this result by considering two cases using the advanced 3D MHD heliospheric modeling tool Icarus recently developed at CmPA, KU Leuven. Icarus applies the radial grid stretching and adaptive mesh refinement to the computational domain to obtain fast simulations. The source regions for the CMEs were identified, and the CME parameters were calculated and optimized. The results were compared to insitu measurements.
The first CME case erupted on SOL2013-07-09T15:24. The modeled time series were in good agreement with the observations both at MESSENGER and ACE. The second CME case, starting on SOL2014-02-16T10:24 was more complicated, three CME interactions have to be taken into account. The CME-CME interactions were modeled in the Icarus simulations, which reconstructed the observed time series much better than considering only one CME. The deceleration of the CMEs observed between Mercury and Earth and attributed to the accumulation of the solar wind plasma upstream of the ICME was not retrieved in the simulations. The modeled time-series and observations are compared for both CME events.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **28** Type: **Poster**

Magnetic Helicity Evolution During Active Region Emergence and Subsequent Flare Productivity

Solar active regions (ARs), which are formed by flux emergence, serve as the primary sources of solar eruptions. However, the specific physical mechanism that governs the emergence process and its relationship with flare productivity remains to be thoroughly understood. In this study, we examined 136 emerging ARs, focusing on the evolution of their magnetic helicity and magnetic energy during the emergence phase. Based on the relation between helicity accumulation and magnetic flux evolution, we found that these emerging ARs can be categorized into three types: Type-I, Type-II and Type-III, accounting for 52.2\%, 25\%, and 22.8\% of the total number, respectively. Type-I ARs exhibit a synchronous increase in both the magnetic flux and magnetic helicity, while magnetic helicity in Type-II ARs displays a lag of increase behind the magnetic flux. Type-III ARs show obvious helicity injections of opposite signs. Significantly, 90\% of the flare-productive ARs (flare index $\geq$ 6) were identified as Type-I ARs, suggesting that this type of ARs has a higher potential to become flare-productive. In contrast, Type-II and Type-III ARs exhibit the low likelihood of becoming active. Our statistical analysis also revealed that Type-I ARs accumulate more magnetic helicity and energy, far beyond those in Type-II and Type-III ARs. Moreover, it is observed that flare-productive ARs consistently accmulate a significant amount of helicity and energy during their emergence phase. These findings provide valuable insights into the flux emergence phenomena, offering promising possibilities for early-stage predictions of solar eruptions.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **29** Type: **Invited**

Disentangling magnetic reconnection in the solar atmosphere.

Monday 9 September 2024 11:30 (25 minutes)

In this presentation, we will explore the fundamental properties of magnetic reconnection, with a particular emphasis on the complexities of three-dimensional (3D) reconnection and the differences with two-dimensional (2D) scenarios. We will present recent state-of-the-art numerical simulations that show how 3D reconnection is key to understanding a variety of phenomena such as braiding, nanojets, and the heating of fundamental blocks in the atmosphere such as Coronal Bright Points, moreover including observations to support the theoretical findings. Additionally, we will address the implications of the differing Prandtl number in simulations versus the actual solar atmosphere. We will also discuss the challenges that need to be addressed in the near future both from theory and observations, and the potential opportunities from future missions such as MUSE and Solar-C.

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Presenter: NÓBREGA-SIVERIO, Daniel (Instituto de Astrofísica de Canarias (IAC) | Rosseland Centre for Solar Physics (RoCS))

Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **30** Type: **Talk**

Mass Cycle and Dynamics of a Virtual Quiescent Prominence

Tuesday 10 September 2024 15:00 (15 minutes)

The mass cycle of solar prominences or filaments is still not completely understood. Researchers agree that these dense structures form by coronal in-situ condensations and plasma siphoning from the underlying chromosphere. In the evaporation-condensation model siphoning arises due to evaporation of chromospheric plasma from localised footpoint heating but this is challenging to justify observationally. Here, we simulate the reconnection-condensation model at extreme-resolutions down to 20.8 km within a three-dimensional magnetohydrodynamic coronal volume. We form a draining, quiescent prominence and associated coronal rain simultaneously. We show that thermal instability –acting as a trigger for local condensation formation –by itself drives siphoning flows from the low-corona without the need of any localised heating. In addition, for the first time we demonstrate through a statistical analysis along more than 1000 magnetic field lines that cold condensations give rise to siphoning flows within magnetic threads. This siphoning arises from the strong pressure gradient along field lines induced by thermal instability. No correlation is found between siphoning flows and the prominence mass, making thermal instability the main in-situ mass collection mechanism. Our simulated prominence drains by gliding along strongly sheared, asymmetric, dipped magnetic arcades, and develops natural vertical fine-structure in an otherwise horizontal magnetic field due to the magnetic Rayleigh-Taylor instability.By synthesising our data, our model shows remarkable agreement with observations of quiescent prominences such as its dark coronal cavity in extreme-ultraviolet emission channels, fine-scale vertical structure and reconnection outflows which, for the first time, have been self-consistently obtained as the prominence evolves.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **31** Type: **Poster**

Unveiling the Dynamic Nature of Solar Bright Points: Damping Characteristics and Energy Dissipation Processes Revealed by Spectral Analysis and Deep Learning Aproach

This study investigates the damping characteristics of Doppler velocity oscillations in solar bright points (BPs) using spectral analysis and deep learning techniques.

This study analyzed Doppler shifts in the solar spectrum captured by the Interface Region Imaging Spectrograph (IRIS), focusing on periodic oscillations within BPs. The damping of red and blue Doppler shifts and employed deep learning to explore the statistical properties of damping in different solar regions.

The results revealed significant variations in damping rates across different regions. The highest damping was observed in coronal hole network BPs, indicating rapid energy dissipation. Internetwork regions showed shorter decay times and half-lives compared to network regions, suggesting higher damping rates. Coronal hole areas also exhibited shorter decay times and half-lives than active regions, likely due to lower density and weaker magnetic fields.

The findings suggest that the underdamped nature of BP oscillations provides sufficient energy to drive the fast solar wind and contribute to quiet corona heating. The rapid damping in internetwork regions and coronal holes is attributed to the influence of small-scale magnetic fields and lower plasma densities in these areas. The potential connection between network BPs and spicule activity is also highlighted, although further research is needed to fully understand this relationship.

This study provides valuable insights into the dynamic nature of solar BPs and their role in the energy balance of the Sun's outer atmosphere. The findings contribute to the ongoing efforts to decipher the complexities of the Sun's behavior and its impact on space weather phenomena.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **32** Type: **Poster**

DeepFiltering: Utilising Generative Networks to Create Quality Images of Coronal Rain

Coronal rain can be a key indicator of coronal heating taking place. To resolve the coronal heating problem it behoves us to fully investigate this link across the full disk of the Sun. There is no lack of observational data, but currently this data is inadequate for a complete analysis of the phenomenon to be carried out. The AIA 304 channel provides the best dataset for coronal rain observations. However, besides the cool component from He II emission, the passband also includes hotter coronal emission from other ions. The contribution of this hotter emission can become comparable to that of the cool emission in off-limb observations, leading to ambiguity when determining the temperature of structures. Conversely, IRIS/SJI 1400 provides higher resolution images with far less ambiguity between hot and cool emission, and therefore higher contrast between both the rain and the surrounding corona. Unfortunately, the small field-of-view of the satellite makes it ill-suited for large scale statistical analysis of the phenomenon.

We present a novel approach to this problem by training a CycleGAN based algorithm to undertake a style translation between AIA 304 images and those belonging to IRIS 1400. This produces a model which can optimally, and without the need of additional data, convert AIA 304 images into those unhampered by the large temperature ambiguity. The structures in these images are then compared to the original IRIS 1400 images, as well as those produced from alternative methods, to show the reliability of this method going forwards.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **33** Type: **Poster**

The relationship between solar flare ribbons and magnetic field changes in the solar photosphere

The changing magnetic field in solar flares has a complex association with the UV emissions of the flare ribbons. These ribbons appear as visual markers indicating the sites where magnetic field lines go through a coronal reconnection processes, which has been determined to be the driving process of flare formation. However, this process is not entirely clear. We aimed to investigate the magnetic field behaviour exclusively within the flare ribbon regions. In this work, we studied six M- class flares to understand the temporal relationship between the line-of-sight magnetic field changes in the photosphere using high-cadence (45 s) magnetograms obtained from the HMI/SDO, and the flare ribbons'UV emission (1600 A) obtained from the AIA/SDO. We found that in 5 out of 6 flares, the positive-field ribbons showed a negative time lag Δt between field changes and ribbon UV brightening indicating that changes in the magnetic field started before the AIA peak time. Similarly, the negative-field ribbons showed a negative time lag. This time delay was determined to be between two and forty-two minutes. Moreover, the average magnitude of the change was around 100 G. Our result suggests that a magnetic field change before the UV emission is consistent with the scenario of magnetic implosion, which is associated with the release of magnetic energy, field contraction and bending of the field at the photosphere. This energy release would cause UV emission after the magnetic field line has changed, however, the size of the time delay remains to be explained.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **34** Type: **Poster**

Sun-as-a-star Analysis of Simulated Solar Flares

Context. Stellar flares has an impact on habitable planets. To study the flares by observations with no spatial resolution, Sun-as-a-star analyses are developed. With the data of Sun-as-a-star observations, a simulation of solar flares is required to provide a systemic clue to the Sun-as-a-star study.

Aims. We aim to develop a model of solar flares and study the relationship between the Sun-as-a-star spectrum with the flare class and location.

Methods. Using 1D radiative hydrodynamics flare model and multi-thread flare assumption, we obtain the spectrum of a typical flare with an enhancement of chromospheric lines.

Results. The preflare-subtracted spectrum of Hα shows an enhanced and shifted component, highly depending on the flare class and location. The velocity sign is well measured by the bisector method. The spectrum of a limb flare tends to be wider and shows a central reversal profile. In particular, we propose two quantities to diagnose the class and location of the stellar flares. Besides, caution must be taken when calculating the radiation energy, since the conversion coefficient from observed flux to energy is dependent on the flare location.

Primary author: YU, Haocheng

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **35** Type: **Poster**

Model of the Si IV emission at the loop footpoints heated by an electron beam

We model Si IV emission originating at footpoints of loops heated by an electron beam. Time dependent plasma parameters (temperature, density, non-Maxwellian beam electron distribution function…) in the transition region are modeled using radiation-hydrodynamical simulations via the FLARIX code for a wide range of the beam parameters. The ionization stages of Si are shown to be out of ionization equilibrium, and also dependent on the electron beam parameters. The Si IV intensities and their evolution are then modelled using a 16-level ion model. The results are compared with Si IV emission observed by IRIS.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **36** Type: **Poster**

Multi-Ionization and Suppression of Dielectronic Recombination for the ionization equilibria of kappa-distributions

Kappa-distributions are particle distributions with a Maxwellian core and high-energy tail. They have strong theoretical support and can originate in the in the solar corona and transition region as a result of heating processes. Distributions with high-energy tail influence individual ionization, recombination and collisional excitation rates what affects the ionization equilibrium, populations of the energy levels and finally the line intensities. Now we included to our calculations of the ionization equilibria for the kappa-distributions also the multi-Ionization and suppression of dielectronic recombination. We have showed that the effect of multi-ionization increases with the importance of the high-energy tail of distribution. Reversely, the effect of the suppression of dielectronic recombination on the ionization equilibria decreases with increasing number of high-energy particles. This new ionization equilibria were added into the latest version of KAPPA package (software and database, http://kappa.asu.cas.cz/), what allows us to calculate synthetic spectra and propose diagnostics for kappa-distributions.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **37** Type: **Poster**

Net radiative cooling rates in cool coronal condensations

We present comprehensive tables of Net Radiative Cooling Rates (NRCR) in cool solar plasma with prominence-like properties. These NRCR are based on the 1D non-LTE radiative transfer modelling of prominences in the transitions of 5-level plus continuum hydrogen, Mg II and Ca II ions. These atomic transitions are the dominant contributors to the radiative energy budget of prominence-like plasmas.

The derived NRCR describe the balance between the radiative losses from the plasma in all considered transitions and the radiative gains in the form of incident radiation illuminating the prominence plasma from the solar disk. In other words, NRCR represent an energy sink/source caused by the dominant radiative processes (both optically thick and thin) in the prominence-like plasma illuminated from the solar surface. As such, the NRCR values can be used in conjunction with other energy source or sink terms in studies of energy balance or transport in the cool coronal condensations - for example, in the evaporation-condensation processes forming the cool plasma, or studies of waves and oscillations in such plasma.

The provided NRCR are tabulated for different values of temperature and gas pressure, and also for different distances of the considered unit volume (voxel) of plasma from the illuminated surface.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **38** Type: **Poster**

Ca II 8542 spectra of an enhanced network region simulated with the MURaM chromospheric extension

The Ca II 8542 line forms in the lower to middle solar chromosphere. Its sensitivity to magnetic fields as well as the accessibility to ground-based telescopes make it a preferred line for chromospheric diagnostics. The spatially averaged spectra of this line show a red-asymmetry in the line core which is often indicated by a line bisector that has an "inverse C-shape". Leenaarts et al. (2014) showed that, in order to reproduce the asymmetry in forward modeled spectra based on 3D rMHD simulations, the isotopes of calcium must be taken into account in the radiative transfer (RT) computation (isotopic splitting). In this work we use a model of the solar chromosphere simulated with the chromospheric extension of MURaM (MURaM-ChE) to study the formation of the line in the new model. Additionally, we compare the full isotope RT computation with a RT computation where an approximate composite model atom model is used. We find that after including isotopes, the spatially averaged spectral line closely matches the observed FTS ATLAS line profile. The close match to the Ca II 8542 line in the new simulations, complements modeling of other chromospheric lines such as Mg II h&k. Our findings confirm the results from Leenaarts et al. (2014) that isotopes play an important role in the formation of Ca II 8542 in the solar atmosphere.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **39** Type: **Talk**

Simulation of a solar prominence with MURaM

Tuesday 10 September 2024 15:15 (15 minutes)

Solar prominences are cool and dense plasma clouds suspended in the hot solar corona, supported by the magnetic field. They are common features in the solar atmosphere, but their exact formation mechanism is still unclear. We use the radiative magnetohydrodynamic code MURaM to simulate the formation and dynamics of a prominence in the solar atmosphere. MURaM includes the relevant physical processes to simulate the solar photosphere, chromosphere and corona.
We create a stable, dipped magnetic arcade configuration in a 3D simulation box and let it evolve. In the course of the simulation, a solar prominence forms self-consistently. First, a dense plasma seed ejected from the chromosphere randomly settles into a magnetic dip of the field configuration and gets cooled by radiative losses. The resulting pressure drop then drives a strong inflow of hot plasma that condenses onto the feature. Like this, a dynamic, cool and dense structure is built up in the solar corona. In this contribution, I will present the formation mechanism and properties of the simulated prominence for different setups of our configuration, as well as results from the chromospheric (NLTE) extension of the simulation.

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Presenter: ZESSNER, Lisa-Marie (Max Planck Institute for Solar System Research)

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **40** Type: **Poster**

Deep Learning study into sunspot evolution for use in flare forecasting

Solar flares are large eruptions of electromagnetic radiation from the Sun which can affect the Earth's atmosphere and the radio communications. Since the delay between the flare event and their near-Earth effects is only 8 minutes, it is essential we can forecast these events in advance. This work aims to train a Deep Learning model to predict flares within a forecasting window. We use images obtained from the Solar Dynamics Observatory (SDO) Space weather HMI Active Region Patch (SHARPs) specifically the radial component of the magnetic field. By using the whole active region image observations as input we want to improve our understanding of the physics leading up to flares and thus also improve our ability to forecast them. We looked at magnetogram images between 2016-2023 with cadence of 24 hours and the corresponding GOES X-ray flux in the next 24 hours to create the image and flare-outcome label pairs. Filtering was performed to limit our set to single NOAA number HARP regions within $\pm 75°$ longitude. With HARP separated data sets for training and testing our model we implemented a Convolutional Neural Network for the binary classification of flare events with GOES X-ray flare class above C1. We present our initial results of applying the data to the CNN and highlight some of the problems we encountered in the data preparation.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **41** Type: **Poster**

Investigating the Coronal Sources of Solar Type III Radio Bursts on a Spotless Day: Insights from September 18, 2021

Understanding the mechanisms of high-energy particle production and propagation from the Sun is crucial for advancing solar physics and enhancing space weather prediction. This work aims to elucidate electron acceleration processes within the solar atmosphere and their journey into the heliosphere. We use data from advanced radio telescopes, such as the Low-Frequency Array and Nançay RadioHeliograph, along with X-ray and extreme ultraviolet observations, to identify energy release and electron acceleration regions in the solar corona. We simulate the trajectories of these electrons along magnetic field lines as they escape into the heliosphere.
Direct measurements of these electrons will be obtained through Parker Solar Probe and Solar Orbiter, positioned close to the Sun. The project is divided into two phases: (1) studying electron acceleration during low solar activity, focusing on small-scale magnetic reconnection events, and (2) during heightened solar activity, concentrating on solar flares and Coronal Mass Ejections.
This work focuses on the first phase by investigating solar type III radio bursts on September 18, 2021, a day without sunspots. Type III radio bursts are caused by electron beams accelerated along open magnetic field lines and are typically associated with magnetic reconnection near sunspots. Preliminary results of this investigation are reported. We aim to uncover new insights into particle acceleration and transport from the Sun by examining major solar eruptions and subtle magnetic reconnection events. The outcomes of this research have significant implications for space weather forecasting, aiding in mitigating potential adverse effects on technology and human activities on Earth.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **42** Type: **Poster**

Ca II K Polar Network as A Proxy for Estimating Historical Polar Magnetic Field of the Sun

The polar magnetic field in the Sun is an important aspect of the solar dynamo process for predicting future solar cycles. However, systematic measurements of this polar field have only been available since 1976 at the Wilcox Solar Observatory (WSO). Prior to 1976, there was a lack of direct information on polar magnetic fields, leading people to utilize various proxies such as polar faculae and polar filaments to infer polar field data. The use of polar faculae, however, introduced uncertainties due to manual counting methods, impacting the accuracy of polar field information. Recently, the polar network has emerged as a more reliable proxy for polar field information. This is attributed to its correlation with polar faculae, along with its observation in higher latitudes compared to polar faculae. In this study, we employed newly calibrated and rotation-corrected Ca II K data from the Kodaikanal Solar Observatory (KoSO) from 1907 to 2007 to detect the polar network automatically and estimate polar magnetic fields. In addition to KoSO data, we utilized PSPT/Rome Ca II K data (1996-2022) to generate a composite polar network index (PNI) series from 1907 to 2022. Our findings revealed a significant correspondence between polar faculae counts from the Mount Wilson Observatory (MWO) and the Polar Network Index (PNI) from KoSO Ca II K data. Additionally, a good correlation was observed between the PNI (KoSO and PSPT/Rome) and the polar field (WSO and Advective Flux Transport (AFT)) during the overlapping analysis period from which we estimated the historical polar field.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **43** Type: **Poster**

Global Coronal Plasma Diagnostics Based on Multislit Extreme-ultraviolet Spectroscopy

Full-disk spectroscopic observations of the solar corona are highly desired to forecast solar eruptions and their impact on planets and to uncover the origin of solar wind. In this paper, we introduce a new multislit design (five slits) to obtain extreme-ultraviolet (EUV) spectra simultaneously. The selected spectrometer wavelength range (184–197 Å) contains several bright EUV lines that can be used for spectral diagnostics. The multislit approach offers an unprecedented way to efficiently obtain the global spectral data but the ambiguity from different slits should be resolved. Using a numerical simulation of the global corona, we primarily concentrate on the optimization of the disambiguation process, with the objective of extracting decomposed spectral information of six primary lines. This subsequently facilitates a comprehensive series of plasma diagnostics, including density (Fe XII 195.12/186.89 Å), Doppler velocity (Fe XII 193.51 Å), line width (Fe XII 193.51 Å), and temperature diagnostics (Fe VIII 185.21 Å, Fe X 184.54 Å, Fe XI 188.22 Å, and Fe XII 193.51 Å). We find a good agreement between the forward modeling parameters and the inverted results at the initial eruption stage of a coronal mass ejection, indicating the robustness of the decomposition method and its immense potential for global monitoring of the solar corona.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **44** Type: **Poster**

Spectroflat: A generic spectrum and flat-field calibration library for spectro-polarimetric data

Flat fielding spectro-polarimetric data with one spatial and one spectral dimension is inherently difficult and therefore its potential is often not fully exploited. Flat fielding approaches for spectrographs are rarely described in detail, approaches for polarimeters have not been described at all so far. Moreover, the tools needed to calibrate data of a similar type are usually re-invented per instrument.

We present an instrument independent approach for diffraction-grating-based, long-slit spectrographs combined with temporally modulated polarimetry from high-resolution solar telescopes.
It allows for flat-field calibration data to be obtained during regular flat fielding procedures in the observational configuration of the instrument.
We have created robust python libraries that can be plugged into existing pipelines or used standalone.
The libraries perform a field-dependent many-line smile correction, extract flat field maps for slit and sensor dust features, and can provide wavelength calibration based on selected solar atlases.

After calibration, the photon noise level can be closely attained in Stokes Our method derives in robust and precise spectropolarimetric inversion results.
Our correction works across the full spectral range. The algorithm was tested for different wavelength regimes with emission (EUV range) or absorption (near-UV, VIS, IR range) spectra, on data acquired with ground-based, balloon-borne, and space-based instruments.

Our tools extends flat-field techniques to modern instruments with large imaging sensors, covering many spectral lines simultaneously, and with polarimetric capabilities, where methods described so far are not adequate.
We invite the solar community to use our library in their instrument pipelines and contribute to its joint development.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **45** Type: **Poster**

Surface Flux Transport Modelling using Physics Informed Neural Networks.

The evolution of the solar magnetic field is the key factor governing space weather drivers. Accurate forecasting of space weather requires precise modelling of the magnetic field's evolution on the solar surface using methods like Surface flux transport (SFT). Conventionally used SFT modelling techniques involve grid-based numerical schemes, making them computationally expensive. In this presentation, we present a novel, mesh-independent machine learning-based approach using Physics-Informed Neural Networks (PINNs) to simulate the temporal evolution of Bipolar Magnetic Regions (BMRs) on the solar photosphere. We compare the PINNs-based model with the state of the art numerical model using the Runge-Kutta Implicit-Explicit (RK-IMEX) scheme for both 1D and 2D SFT equations. We find PINNS to be more accurate with better flux conservation than conventional schemes. We further validate the applicability of PINNs with real data by comparing the magnetic flux results from PINNs with observations from SOHO/MDI. The ability of PINNs to solve advection-diffusion equations make it an efficient and accurate technique to simulate magnetograms. These simulations may serve as input boundary conditions for space weather forecasting tools to predict solar wind plasma parameters at the L1 point.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **46** Type: **Poster**

MHD Wave Propagation and Kelvin–Helmholtz Instability in Asymmetric Magnetic Slab System

Magnetohydrodynamic waves are ubiquitously detected in the highly structured solar atmosphere. At the same time, the solar atmosphere is also a highly dynamic plasma environment, giving rise to flows of various magnitudes, which can lead to instability of the waveguides. Recent studies have not only introduced waveguide asymmetry to generalize "classical"symmetric modelling of the fine structuring within the solar atmosphere, but also considered steady states as well. Building on these studies, here, we investigate magnetoacoustic waves guided by a magnetic slab within an asymmetric magnetic environment, in which the slab has steady background flow. This idealised approach may give us insight into the physics of the lower solar atmosphere. Based on the analytical investigation of how the phase speeds of the guided waves are affected [1], here, we model the behaviour of magnetoacoustic waves in the asymmetric environment. A wider parameter regime is employed as well as we verify the limiting flow speeds required for the onset of the Kelvin–Helmholtz instability obtained through several analytical simplifications. This model is part of a series of studies aimed to generalize, step-by-step, well-known symmetric waveguide models and understand the additional physics stemming from introducing further sources of asymmetry [2,3,4].

[1] Zsámberger, N. K., Tong, Y., Asztalos, B., & Erdelyi, R., 2022, ApJ,935(1), 41.
[2] Barbulescu, M., & Erdélyi, R. 2018, SoPh, 293, 86
[3] Zsámberger, N. K., Allcock, M., & Erdélyi, R. 2018, ApJ, 853, 136
[4] Zsámberger, N. K., & Erdélyi, R. 2020, ApJ, 894, 123

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **47** Type: **Poster**

Bridging the gap between ab initio MHD modelling and avalanche models of solar flares

Solar flares have long puzzled physicists due to their complex and multiscale nature and significant impact on Earth. The prediction of solar flares is challenging because the underlying physical processes are not yet fully understood and cannot yet be observationally resolved. Recent advances have been made using powerful numerical tools such as magnetohydrodynamic (MHD) simulations, though these models are still too computationally prohibitive for real-time prediction. Alternatively, less computationally intensive models, such as avalanche models, have shown promise for real-time solar flare prediction by effectively reproducing solar statistics, such as the distribution of events described by power-laws. However, these cellular automata models suffer from ambiguous physical interpretations.
To bridge the gap between MHD simulations, avalanche models, and real-time forecasting, we investigate the conditions under which cutting-edge MHD simulations can replicate the power-law statistics observed in both the sun and avalanche models. We assess these conditions for simple twisted flaring loops with the PLUTO code and in realistic simulations of the turbulent chromosphere and corona with the Bifrost code. Additionally, we evaluate the validity of the assumptions inherent in avalanche models by verifying if these assumptions are coherent with energy release patterns observed in MHD simulations. Our study aims to provide a solid physical foundation for avalanche models using MHD simulations, thereby providing a robust simplified model for flares that can be used in a variety of applications, such as meteo forecasting, generating synthetic data or studying active regions.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **48** Type: **Talk**

Analysis of flare ribbon fine structures using high-resolution observations

Wednesday 11 September 2024 12:10 (15 minutes)

The mechanism of energy release from solar flares are still not fully understood and the study of small-scale features is an important aspect toward this understanding. Flare ribbons act as the footpoints of a flare and are crucial to know the process of flare reconnection. We present here a study about the fine structures of flare ribbons using a high resolution observations using the Swedish 1-m Solar Telescope (SST), the Atmospheric Imaging Assembly (AIA), and the Interface Region Imaging Spectrograph (IRIS). The high-resolution SST observations offer spectroscopic data in Hα, Ca II 8542 Å and Hβ lines, which we use to analyze plasma blobs along the flare ribbon. Within the eastern flare ribbon, chromospheric blobs were detected in the red wing of Ca II 8542 Å, Hα, and Hβ. A comparison of plasma blobs in Hβ observations and Si IV 1400 Å has also been performed. These plasma blobs are observed as circular structures having widths from 150 km - 180 km. Intensity profiles at these blob locations show a red wing asymmetry. We conclude that the chromospheric plasma blobs in the flare ribbon are likely formed due to a fractured reconnection process within the flare current sheet, supporting the theory of a direct link between fine-structure flare ribbons and flare current sheet tearing. We believe our observations represent the highest resolution evidence of fine-structure flare ribbons to date.

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Presenter: THOEN FABER, Jonas (Rosseland Centre for Solar Physics, University of Oslo)

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **49** Type: **Invited**

Exploring Coronal Mass Ejections: An Overview

Tuesday 10 September 2024 15:30 (25 minutes)

Coronal mass ejections (CMEs) are huge eruptions of magnetized plasma from the Sun that travel into interplanetary space. These energetic and complex phenomena, when they interact with Earth's magnetic field, can cause significant disruptions. Due to their potential impact, there has been a strong focus on studying CMEs to predict them well in advance of their arrival at our planet. In my presentation, I will provide an update on the progress made in this area, highlighting recent findings on CME source regions, eruption mechanisms, and their movement through the solar atmosphere. I will also discuss the challenges and opportunities for studying CMEs, including potential improvements through recent and upcoming space missions.

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Presenter: MIERLA, Marilena

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **50** Type: **Talk**

Predicting geo-effectiveness two days prior to CME impact with EUHFORIA

Friday 13 September 2024 09:50 (15 minutes)

The EUropean Heliospheric FORecasting Information Asset (EUHFORIA, Pomoell and Poedts, 2018), a physics-based and data-driven heliospheric and CME propagation model, can predict the solar wind plasma and magnetic field conditions at Earth. It contains several flux-rope CME models, such as the simple spheromak and more advanced FRi3D and toroidal CME models. This enables the prediction of the sign and strength of the magnetic field components upon the arrival of the CME at Earth and, thus, the geo-effectiveness of the CME impact. EUHFORIA has been coupled to several global magnetosphere models like OpenGGCM, GUMICS-4, and Gorgon-Space. In addition, the synthetic data at L1 (from the EUHFORIA simulation) can be used as input for empirical models and neural networks to predict the geomagnetic indices like Disturbance-storm-time (Dst) or Kp that quantify the impact of the magnetized plasma encounters on Earth's magnetosphere. Hence, we also coupled EUHFORIA to empirical models and machine learning based models to predict the geomagnetic indices. We then compare the results of these models to observational data to evaluate their performance in predicting the geo-effect indices. We obtain the input parameters for running the geomagnetic indices models two to three days in advance.

We perform ensemble modelling considering the L1 monitor precision in its orbit and the uncertainty in the initial CME parameters at launch for error quantification. This study validates various space weather forecasting model chains and checks the best compatibility and predictive capabilities using EUHFORIA data for operational space weather forecasting.

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Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **51** Type: **Poster**

Direct Estimates of the Wilson Depression with Stereoscopic Observations of SO/PHI and SDO/HMI

We present a method for a direct measurement of the height variations in the solar photosphere based on stereoscopy. Our method calculates differences in altitude of the solar surface by shifting and correlating two images, mapped from the same surface feature observed from two different vantage points. We apply this method to simultaneous continuum intensity observations from Solar Orbiter's Polarimetric and Helioseismic Imager (SO/PHI) and Solar Dynamic Observatory' s Helioseismic Magnetic Imager (SDO/HMI) to estimate the Wilson depression of sunspots. We present a description of the calibration and rectification of the observational data and an overview of the correlation method. This stereoscopic method allows for the first time to directly compute height variations on the solar surface. We present the results of the analysis, which yield a Wilson depression of roughly 800 km for the observed sunspot. Finally, we discuss the effect that different parameters, especially the resolution of the data have on the results; and the possible extension of this method's applications.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **52** Type: **Poster**

A multi-wavelength investigation into the photospheric effects of a solar flare on 1 July 2012 using Swedish Solar Telescope observations

The solar flare event of 1 July 2012 13:08 UTC was observed in both the Hα 6563 Å and Fe I 6302 Å lines by the CRisp Imaging SpectroPolarimeter (CRISP) instrument at the Swedish 1-m Solar Telescope (SST), providing information about the connectivity and dynamics of the photosphere, chromosphere and corona. This study focuses on the changes in the sheared photospheric flow pre and post flare. Two pores and several bright points inside the flow pattern in the photosphere are tracked using the Local Correlation Tracking software package YAFTA. The border between two counter flows and the location of a polarity inversion line are identified, while the distance between two pores over time is monitored for the changes in properties of the magnetic field such as polarity, field strength and magnetic energy. The velocity flow vectors show the degree of shearing before and after the solar flare and the Poynting flux quantifies the magnetic energy evolution before and after the flare ribbon formation in the chromosphere. The SST results are combined with results from the Solar Dynamics Observatory (SDO), the Geostationary Orbital Environmental Satellite (GOES) and the FERMI Gamma-Ray Space Telescope providing a multi-wavelength evolution of this event in coronal plasma. The results indicate that the flare is driven by sudden changes in the magnetic field forced in the flows of the photosphere, resulting in the coupling of mass and energy between the layers.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **54** Type: **Talk**

Rare case of the three-part structure of coronal mass ejection observed in low coronal signatures

Tuesday 10 September 2024 17:25 (15 minutes)

We present a rare case of a three-part solar coronal mass ejection (CME) observed in the low corona on March 28, 2022. We observe a bright core/prominence, dark cavity, and a bright CME leading edge in SolO/EUI and STEREO-A/EUVI. We perform 3D reconstructions of the filament eruption from three vantage points: SolO, STEREO-A, and SDO. The filament height increased from 28 to 616 Mm over 30 minutes, with a peak velocity of 648 ± 51 km/s and a peak acceleration of 1624 ± 332 m/s^2. At 11:45 UT, the filament deflected by ~12 degrees, reaching a height of 841 Mm. The bright CME leading edge, a quasi-spherical CME shock, grows from 383 Mm to 837 Mm between 11:25 and 11:35 UT. The distance between the filament apex and the CME leading edge doubled from 93 to 212 Mm over 10 minutes. Using the DIRECD method, we studied the expansion of coronal dimming as an indicator of early CME propagation. This method uses a cone model to approximate an expanding CME at the end of the dimming's impulsive phase, estimating parameters such as direction (inclined 6 degrees from the radial expansion), half-width (21 degrees), and cone height (1.12 Rs), where the CME remains connected to the dimming and leaves footprints in the low corona. The reconstructed cone aligns closely with the observed filament shape. Extrapolating filament and CME outer edge heights to LASCO/COR2 times, we found the cone matched the CME shape, with fainter CME parts corresponding to far-side cone projections.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **55** Type: **Poster**

The relation between magnetic field inclination and apparent motion of penumbral grains

Bright heads of penumbral filaments, penumbral grains (PGs), show apparent horizontal motions inward, toward the umbra, or outward, away from the umbra. Using high-resolution spectropolarimetric observations and numerical simulations of sunspot penumbrae, we aim to prove whether the direction of these motions is related to the inclination of the penumbral magnetic field.
Magnetic-field information in the penumbras' photosphere was retrieved by means of height-stratified spectropolarimetric inversions of 5 data sets obtained with Hinode, Swedish Solar Telescope, and GREGOR. An analogous information was provided by numerical simulations of a sunspot in the form of time series of visible-surface slices and vertical cuts.
On a sample of 444 inward- and 269 outward-moving observed PGs we show that 43 % of the inward-moving PGs have magnetic inclination larger than the inclination in their surroundings and 51 % of the outward-moving PGs have the inclination smaller than the surrounding one. The opposite relation of inclinations is observed at only one-fifth of the inward- and outward-moving PGs. A similar statistics is valid also for 226 inward- and 107 outward-moving PGs tracked in the simulations. Moreover, videos of numerical simulations show that some PGs can change their direction of motion and the relation of inclinations during their evolution.
We conclude that the difference in magnetic field inclinations inside and outside PGs is an important factor that influences the direction of apparent PGs motions, but it is not the only one and the relation is more complex.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **57** Type: **Talk**

Understanding the thermal and magnetic properties of an X-class flare in the low solar atmosphere

Wednesday 11 September 2024 12:40 (15 minutes)

Recent exploitation of spectropolarimetric data has significantly enhanced our understanding of the dynamical and magnetic responses of the photospheric and chromospheric layers during the rapid energy release that occurs in solar flares. In this context, we utilized high-resolution observations from 22nd October 2014, captured during an X1.6 confined flare by the Interferometric Bidimensional Spectropolarimeter (IBIS) instrument, which observes the full Stokes parameters for the Fe I 6173 Å and Ca II 8542 Å transitions.

We employed the newly developed Departure Coefficient Aided Stokes Inversion based on Response Functions (DeSIRe) code to infer the spatial distribution and vertical stratification of the atmospheric parameters in the photospheric and chromospheric layers. Our findings indicate significant temperature increases and pronounced upflows within the chromospheric flare ribbon, suggesting that the flaring event is generating hot material moving upwards. Conversely, the photosphere shows no discernible temperature rise or strong velocities, implying that the flaring event's impact is predominantly in the middle and upper layers.

The magnetic field vector information reveals relatively smooth stratifications with height for both magnetic field strength and inclination. Additionally, we observe that the spatial locations within the flare ribbon exhibit a significant depression in the height of formation (or sensitivity) for the chromospheric line, while no clear indication of this effect is found for the Fe I transition. These results confirm that, in the low atmospheric layers, the primary impact of flaring activity occurs at chromospheric levels.

Primary authors: FERRENTE, Fabiana (Università Degli Studi di Catania); Dr QUINTERO NODA, Carlos (Instituto de Astrofísica de Canarias); ZUCCARELLO, Francesca (Istituto Nazionale di Astrofisica (INAF)); GUGLIELMINO, Salvatore Luigi (Istituto Nazionale di Astrofisica (INAF))

Presenter: FERRENTE, Fabiana (Università Degli Studi di Catania)

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **58** Type: **Poster**

Searching for rapid pulsations in solar flare X-ray data

Many studies of quasi-periodic pulsations in solar flares have identified characteristic periods in the 5 –300s range. These phenomena are crucial to understand as they relate to fundamental energy release on the Sun. Due to observational constraints it is unclear whether the periods of quasi-periodic pulsations extend down into the < 5s period regime. The Fermi Gamma-ray Burst Monitor (GBM) has observed approximately 1500 solar flares to date in high cadence 16 Hz burst mode, providing us with an opportunity to study short-period pulsations at X-ray energies. We systematically analyse every solar flare observed by Fermi/GBM in burst mode, using a stepping analysis window approach to search for time-localized quasi-periodic pulsations in multiple X-ray energy bands. To better understand these results, we complement this with analysis of synthetic solar flare lightcurves, both with and without oscillatory signals present, in order to understand the likely false alarm and true positive rates in the real solar GBM data. Overall, we do not find strong evidence for widespread short-period quasi-periodic pulsations, indicating either low base occurrence rates or low signal-to-noise ratios –less than 1 –of such signals in the Fermi/GBM data. Our investigation does however identify several flares showing strong evidence of short-period quasi-periodic pulsations, including multi-periodic events.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **59** Type: **Poster**

Stellar Physics and General Relativity

As seen in most textbooks of astrophysics, most astronomical bodies such as main sequence stars have been investigated only by Newtonian gravity. This is presumably based on a belief that Newtonian physics could be sufficient to extract important physics of most astronomical bodies except compact stars and General Relativity would be too precise to be suitable.

In this talk, I will explain that this belief is not correct any more and General Relativity plays an important role in extracting new physics of luminous stars like the Sun.

I will explain it based on my recent work arXiv:2306.16647, in which I have investigated the relativistic extension of the classic stellar structure equations and proposed a closed set of differential equations as the basic relativistic structure equations for a hydrostatic equilibrium system with spherical symmetry.

The following characteristic results will be explained as much as possible within given time:

(i) The proposed structure equations are consistent with the expected local thermodynamic relation.

(ii) The exact forms of the relativistic Poisson equation and steady-state heat conduction equation were derived.

(iii) They were solved exactly or non-perturbatively in the Newton constant for a system consisting of ideal gas of particles with their number conserved, and thermal observables were exactly determined to exhibit the power law behavior.

(iv) This power law behavior is expected also inside the Sun, which is in tension with results in textbooks.

(v) The conventional argument using the Newtonian approximation in coronal region is invalid.

Primary author: Dr YOKOYAMA, Shuichi (Ritsumeikan University)

Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **60** Type: **Poster**

Radiative Losses in a Flaring Chromosphere: Approximations and Applications

In the solar atmosphere, radiation plays an important role in the energy balance. Extinctions or emissions of photons from transitions between atomic energy levels can either heat or cool the local atmosphere, and their contributions are expressed as the radiative flux divergence, referred to as the radiative losses. Detailed calculations could be computationally expensive, especially in the chromosphere, where the local thermodynamic equilibrium assumption breaks.
Based on the recipe of approximate radiative losses for the quiet Sun, we construct a new recipe for solar flares where the chromosphere undergoes drastic changes. We tabulate the optically thin radiative loss, escape probability, and ionization fraction using a grid of flare models from radiative hydrodynamic simulations as our dataset.
We have also evaluated the performance of different recipes for chromospheric radiative losses in flare simulations. We find that our recipe provides a better approximation of the detailed radiative losses, especially for large flares.
Height-integrated radiative losses imply how much energy is escaped from the deep atmosphere as free photons. Previous studies found that there is a good relation between height-integrated radiative losses and the wavelength-integrated emergent intensity of certain spectral lines like Ca II K. Thus, we propose to use height-integrated radiative losses as a proxy to synthesize Ly□ images from MHD simulations. We apply this method to a Bifrost simulation and find that the synthesized image looks similar to the one of detailed radiative transfer calculations.

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Co-authors: TIAN, Jun (Stockholm University); CARLSSON, Mats (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **61**   Type: **Poster**

Fast Downflows Observed during a Polar Crown Filament Eruption

Solar filaments can undergo eruptions and result in the formation of coronal mass ejections (CMEs), which could significantly impact planetary space environments. Observations of eruptions involving polar crown filaments, situated in the polar regions of the Sun, are limited due to their remarkable stability. In this study, we report a polar crown filament eruption, characterized by fast downflows below the filament. The downflows appear instantly after the onset of the filament eruption and persist for approximately 2 hours, exhibiting plane-of-sky (POS) velocities ranging between 92 and 144 km/s. They originate from the leading edge of the filament and no prominent acceleration is observed. Intriguingly, these downflows appear at two distinct sites, symmetrically positioned at the outer sides of the opposite ends of the conjugate flare ribbons. Based on the observations, we propose that the filament might be supported by a magnetic flux rope (MFR), and these downflows possibly occur along the legs of the MFR. The downflows likely result from continuous reconnections between the MFR and the overlying magnetic field structures. We also observed horizontal drifting of the locations of downflows, which might correspond to the MFR's footpoint drifting. This type of downflows can potentially be utilized to track the footpoints of MFRs during eruptions.

Primary author: SUN, Zheng (Peking University)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **62** Type: **Poster**

Why “solar tsunamis”rarely leave their imprints in the chromosphere

Solar coronal waves frequently appear as bright disturbances that propagate globally from the eruption center in the solar atmosphere, just like the tsunamis in the ocean on Earth. Theoretically, coronal waves can sweep over the underlying chromosphere and leave an imprint in the form of Moreton wave, due to the enhanced pressure beneath their coronal wave front. Despite the frequent observations of coronal waves, their counterparts in the chromosphere are rarely detected. Why the chromosphere rarely bears the imprints of solar tsunamis remained a mystery since their discovery three decades ago. To resolve this question, all coronal waves and associated Moreton waves in the last decade have been initially surveyed, though the detection of Moreton waves could be hampered by utilizing the low-quality Hα data from the Global Oscillations Network Group. Here, we present eight cases (including five in the Appendix) of the coexistence of coronal and Moreton waves in inclined eruptions where it is argued that the extreme inclination is key to providing an answer to address the question. For all these events, the lowest part of the coronal wave front near the solar surface appears very bright, and the simultaneous disturbances in the solar transition region and the chromosphere predominantly occur beneath the bright segment. Therefore, evidenced by observations, we propose a scenario for the excitation mechanism of the coronal-Moreton waves in highly inclined eruptions, in which the lowest part of a coronal wave can effectively disturb the chromosphere even for a weak (e.g., B-class) solar flare.

Primary author: ZHENG, Ruisheng (Shandong University)

Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **63** Type: **Poster**

Localising QPPs in HXR, microwave and Lya emissions of an X6.4 flare

We report the simultaneous observations of quasi-periodic pulsations (QPPs) in wavelengths of hard X-ray (HXR), microwave, Lyα, and ultraviolet (UV) emissions during the impulsive phase of an X6.4 flare on 2024 February 22 (SOL2024-02-22T22:08). The X6.4 flare shows three repetitive and successive pulsations in HXR and microwave wavebands, and they have an extremely-large modulation depth. The onset of flare QPPs is almost simultaneous with the start of magnetic cancellation between positive and negative fields. The wavelet power spectra suggest the presence of double periods, which are centered at $\sim$200 s and $\sim$95 s, respectively. The long-period QPP can also be detected in Lyα and UV wavebands at the flare area, and it could be observed in the adjacent sunspot. Our observations indicate that the flare QPPs are most likely triggered by accelerated electrons that are associated with periodic magnetic reconnections. The long period at $\sim$200 s is probably modulated by the slow magnetoacoustic wave originating from the neighboring sunspot, while the short period at $\sim$95 s could be regarded as its second harmonic mode.

Primary author: LI, Dong (PMO)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **64** Type: **Talk**

Comparison of ”homologous” solar eruptive events from two different solar rotations

Friday 13 September 2024 10:05 (15 minutes)

With March 2022 we entered a new era of complex solar eruptions in the wake of solar cycle 25. Several of these so-called Big Solar Storms were observed in the past years in remote sensing image data and measured in-situ. Some of them even caused aurorae in low latitudes, repeatedly confirming that the interaction between multiple CMEs, as well as CIRs, lead to extreme conditions in near-Earth space. For the enhanced solar activity period at the end of 2023, we study a set of "homologous"eruptive events on the Sun. The two episodes of enhanced solar activity involve similar (active) regions and the same coronal hole but are separated by a full solar rotation. We point out the complexity for each set of events and aim to understand their similarities and differences as they arrive at Earth.

Primary authors: TEMMER, Manuela (Institute of Physics); DUMBOVIC, Mateja (Hvar Obs.); MARTINIC, Karmen (Hvar Observatory, Faculty of Geodesy, University of Zagreb); CAPPELLO, Greta (University of Graz); REMESHAN, Akshay K. (Hvar Observatory, Faculty of Geodesy, University of Zagreb); MILOSIC, Daniel (Institute of Physics, University of Graz, Austria); MATKOVIC, Filip (Hvar Observatory, Faculty of Geodesy, University of Zagreb); KOLLER, Florian (University of Graz); CALOGOVIC, Jasa (Hvar Observatory, Faculty of Geodesy, University of Zagreb)

Presenter: TEMMER, Manuela (Institute of Physics)

Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **65** Type: **Poster**

Kink-and-Disconnection Failed Eruption in 3D

We report the first stereoscopic observations of HXR emission sources registered by STIX onboard Solar Orbiter and HXI on ASO-S. This is a case study of a two-stage failed eruption. First, it was slowed down due to a helical kink. However, the legs of the kinked structure started to reconnect and the second stage of eruption started. This eruption failed a few minutes later due to reconnection below the magnetic flux rope and confinement by overlying magnetic fields. We identified three X-ray sources located in the corona which are related to the reconnection sites and the magnetic cloud confined by overlying fields. Combining stereoscopic X-ray observations from STIX and HXI (31.5 degrees vantage point separation) with Differential Emission Measure (DEM) maps based on SDO/AIA observations we were able to locate X-ray source sites in the corona in the 3D space. The unveiled real geometry allowed us to estimate de-projected values of velocity and acceleration/deceleration which are extremely high. Moreover, real locations of HXR sources are not fully consistent with a standard solar flare scenario.

Primary author: MROZEK, Tomasz (Space Research Centre Polish Academy of Sciences)

Co-authors: Dr LI, Zhentong (Purple Mountain Observatory, Chinese Academy of Sciences); Prof. KARLICKÝ, Marian (Astronomical Institute ASCR); Dr CHRYSAPHI, Nicolina (Sorbonne Université, École Polytechnique, Institut Polytechnique de Paris, CNRS, Laboratoire de Physique des Plasmas (LPP)); Prof. SU, Yang (Purple Mountain Observatory, Chinese Academy of Sciences); Dr CHEN, Wei (Purple Mountain Observatory, Chinese Academy of Sciences); Prof. GAN, Weiqun (Purple Mountain Observatory, Chinese Academy of Sciences)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **66** Type: **Poster**

Solar cycle variation in the properties of photospheric magnetic concentrations

It is widely accepted that eruptive phenomena on the Sun are related to the solar magnetic field, which is closely tied to the observed magnetic concentrations (MCs). Therefore, studying MCs is critical in order to understand the origin and evolution of all forms of solar activity. In this paper, we investigate the statistics of characteristic physical parameters of MCs during a whole solar cycle by analyzing magnetograms from 2011 to 2023 observed by the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO). We discover that there are differences between large- and small-scale MCs in different phases of the solar cycle. By analyzing the distributions of the magnetic flux, area, and magnetic energy of MCs, we find that the small-scale MCs obey a power-law distribution, and that the power indices vary very little with the phases of the solar cycle. However, for the large-scale MCs, although they also obey the power-law distribution, the power indices are clearly modulated by the different phases of the solar cycle. We also investigate the relation between the maximum magnetic field strength (Bmax) and the area of MCs (S) and find the same property. The relation for the large-scale MCs is modulated by the phases of the solar cycle, while it is still independent of the phases of the solar cycle for the small-scale MCs. Our results suggest that small- and large-scale MCs could be generated by different physical mechanisms.

Primary author: SONG, Anchuan (University of Science and Techonology of China)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **67** Type: **Talk**

On the sunspot penumbra formation with nonlinear force-free field extrapolations

Monday 9 September 2024 17:45 (15 minutes)

The mechanism behind the formation of the solar penumbra remains a topic of debate, with the magnetic field configuration above the photosphere not yet thoroughly explored. In this study, we examine the formation of sunspot penumbra through a novel approach using the analysis of magnetic fields derived from Non-Linear Force-Free Field (NLFFF) extrapolations. We perform NLFFF extrapolations on HMI/SDO data, capturing the evolution of active region NOAA 12757 before, during, and after penumbra formation. By tracking the magnetic field lines, we present unprecedented insights into the changes in topology and connectivity. Initially, prior to penumbra formation, we observe low-lying sea-serpent magnetic fields that gradually rise and become more vertical. The penumbra forms during this transition, and its extent stabilizes once the rise of the low-lying sea-serpent magnetic field lines ceases.

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Presenter: JURCAK, Jan (Astronomical Institute of the Czech Academy of Sciences)

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **68** Type: **Poster**

Coronal hole and Quiet Sun comparison through observations and simulations

We presents a comparison of plasma dynamics in Coronal Holes (CHs) and Quiet Sun (QS) through observations and 2.5D MHD flux emergence simulations. We observe these regions in chromospheric and transition region lines of IRIS as a function of the underlying photospheric magnetic field (|B|). We find excess intensity (blue, redshifts) in QS(CH) with |B|. We observe persistent upflows, downflows, and bidirectional flows, with an acceleration(deceleration) of upflows(downflows) in CH(QS). We simulate flux emergence in 2.5, forming hot, cool jets due to magnetic reconnection, resulting in a confined jet(surge) in QS(CH). Through spectral synthesis, CHs show reduced intensities, excess upflows (downflows), and widths during the jetting (return downflow) period when compared to QS, with velocity, linewidth correlated with B_z at z=0 in CH. During the jetting period in CH, we find upflows in Si IV to be correlated (anti- correlated) with upflows (downflows) in other lines, and downflows in CH in Si IV to be correlated (anti-correlated) with upflows (downflows) in other lines when compared to QS. During downflow, we find no strong correlation between Si IV and other line velocities. The correlation during the jetting period occurs due to coincident, co-spatial origins of the hot and cool jet, while the lack of correlation during the downflow phase suggests a decoupling of hot and cool plasma. These results demonstrate that flux emergence and resultant reconnection with pre-existing flux in the atmosphere support the picture of a unified scenario for the formation of solar wind and coronal heating.

Primary author: Dr UPENDRAN, Vishal (Bay Area Environmental Research Institute)

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **69** Type: **Poster**

Investigating the effect of thermal collisional plasma and turbulent acceleration in a simulated coronal acceleration region on heliospheric electron spectra

Non-thermal particle acceleration in the solar corona is evident from both remote hard X-ray (HXR) sources in the chromosphere and direct in-situ detection in the heliosphere. Correlation of spectral indices between remote and in-situ energy spectra presents the possibility of a common source acceleration region within the corona, however the properties and location of this region are not well constrained. To investigate this we perform a parameter study for both the properties of the ambient plasma of a simulated acceleration region and the turbulent acceleration profile acting on an initially isotropic thermal electron population. These electrons are propagated out to 1.0 AU with their energy spectra compared between extremes of the tested parameters. We present results of this parameter search and discuss the relative sensitivity of spectral indices across the heliosphere subject to variation in individual plasma properties and turbulent acceleration profiles consistent with a hot, over-dense source region in the lower corona. We also discuss the suitability of the heliospheric spectral index in constraining the properties of an acceleration region and compare the simulated in-situ energy spectra to that of a simulated chromospheric HXR spectra produced with the same properties.

Primary author: PALLISTER, Ross (Northumbria University)

Co-authors: STORES, Morgan (Northumbria University); JEFFREY, Natasha (Northumbria University)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **70** Type: **Invited**

Solar wind, space weather and solar-terrestrial connection

Friday 13 September 2024 09:25 (25 minutes)

This review talk covers the solar-terrestrial connection, especially from the perspective of space weather modelling and forecasting.

Firstly, we give an overview of the effects of space weather and provide examples of their economic, political, and societal costs. This is followed up by a review of the current state-of-the-art operational space weather forecasting and nowcasting tools, such as the portal of ESA's SSA, the European VSWMC, NOAA's SWPC and NASA's CCMC and the wide variety of models included in them. The three categories of space weather effects, i.e., geomagnetic storms, radiation storms and radio blackouts, will be analysed separately.

Next, we discuss the new developments in the field, such as full 3D global coronal models and advanced CME geometries, and how these could contribute to improving understanding and forecasting space weather.

We conclude the review talk by elaborating on the current biggest challenges and uncertainties in this modelling (including the time-dependency of the solar wind, effects of the smaller scales, coronal heating, and uncertainties in the observations that bound our models) and how these could possibly be tackled.

It is also emphasized that while the research-to-operations link is fairly well-established in our community, thanks to initiatives such as VSWMC, the return link is still limited. Better communication must be established with the end-users for feedback regarding i) how well the models perform in practice and ii) how to better design future models to fulfil the actual user needs.

Primary author: BRCHNELOVA, Michaela (KU Leuven)

Co-author: Prof. POEDTS, Stefaan (KU Leuven)

Presenter: BRCHNELOVA, Michaela (KU Leuven)

Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **71** Type: **Talk**

Modelling solar irradiances with proxies of activity along a cycle

Monday 9 September 2024 10:15 (15 minutes)

There is a pressing need to model XUV solar irradiances, given the scarcity of current measurements. One of the measurable effects of a solar cycle is the significant (more than one order of magnitude) variation in XUV irradiance. XUV radiation drives the ionosphere and the thermosphere. As a first step in the modelling, we present EUV irradiances in a sample of strong spectral lines formed in different layers and regions of the solar atmosphere, obtained from the Solar Dynamics Observatory Extreme Ultraviolet Variability Experiment (SDO EVE) during 2010-2024 and the Solar and Heliospheric Observatory Coronal Diagnostic Spectrometer (SOHO CDS) covering the earlier maxima (1998-2014). We used the recently released version 8 EVE data. We present correlations with several proxies of solar activity, such as the Mg II index, sunspot numbers, and cm radio fluxes. Among these, the sunspot number proves to be the poorest proxy, whereas the Mg II index is a very good proxy for coronal lines (hotter temperature lines). We find a relatively strong linear relationship, which enables us to build a model essential for various applications. We find relatively good agreement between the SOHO CDS and SDO EVE irradiances for most of the stronger lines.

Primary authors: DELIPORANIDOU, Evangelia (University of Cambridge); DEL ZANNA, Giulio (University of Cambridge (UK))

Presenter: DELIPORANIDOU, Evangelia (University of Cambridge)

Session Classification: Solar interior, sub-surface flows and long-term variability

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **72** Type: **Talk**

The Open Flux Problem: First steps with Solar Orbiter to investigate the underestimation of magnetic flux

Friday 13 September 2024 10:20 (15 minutes)

The open flux problem is currently an unsolved mystery, representing a 2-3 factor mismatch between the open flux measured at 1 AU and that via remote sensing of the solar atmosphere and extrapolated to 1 AU. One explanation is that the open flux at the photosphere is underestimated, in particular in the polar regions. Until now it was impossible to test this with observations: the Polarimetric and Helioseismic Imager (PHI) on board Solar Orbiter has made this a reality such that in combination with Earth-based assets, such as SDO/HMI, stereoscopy can be employed.
First numerical simulations of the line-of-sight magnetic field centre-to-limb variation will be presented. This theoretical work suggests that the flux is indeed underestimated at all angles off disc centre, and is enhanced the lower the spatial resolution above $\mu = 0.5$. Finally, preliminary stereoscopic analyses of the observed magnetic flux with both SO/PHI-HRT and SDO/HMI will be shown.

Primary author: SINJAN, Jonas (Max Planck Institute for Solar System Research)

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Presenter: SINJAN, Jonas (Max Planck Institute for Solar System Research)

Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **73** Type: **Poster**

Forward and MHD modeling of nanojets driven by magnetic reconnection during MHD avalanches

Magnetic reconnection is a leading candidate for the heating of the non-flaring solar corona. Specifically, heating might stem from numerous, localized and impulsive episodes of magnetic energy release. Though potentially intense, those fleeting "Nanoflares"are generally difficult to observe in the corona as the highly efficient thermal conduction and the low emission measure wash out their signatures. The newly discovered phenomenon of fast and swift "Nanojets" has been taken as a direct observational signature of magnetic reconnection as it overcomes the general difficulties in observing nanoflares.

We performed full 3D MHD simulations of interacting and twisted coronal loop strands. In our model the magnetized atmosphere is stratified from the high-beta chromosphere to the corona through the narrow transition region. Photospheric rotation motions stress the flux tubes until they become kink-unstable and determine an avalanche of reconnection episodes. Misaligned magnetic field lines rupture and reconnect, inducing the formation, fragmentation, and dissipation of current sheets akin to a nanoflare storm.
In this work we address the nanojets which develop from these reconnection episodes, at Parker energies (about 1e24 erg) and typical speeds of few 100 km/s, and we investigate their possible detection, in particular in the EUV band with the Atmospheric Image Assembly (AIA/SDO) and the opportunities that spectra and images from the forthcoming MUltislit Solar Explorer (MUSE) will open up. We also perform a statistical analysis of their occurrence and of their correlation with relevant physical ambient parameters, such as the magnetic field, to constrain the best conditions for detection.

Primary author: Mr COZZO, Gabriele (Università degli Studi di Palermo)

Co-authors: Prof. HOOD, Alan W. (University of St Andrews); Dr DE PONTIEU, Bart (Lockheed Martin Solar & Astrophysics Laboratory); Prof. REALE, Fabio (Università degli Studi di Palermo); Dr REID, Jack (University of St Andrews); Dr MARTINEZ-SYKORA, Juan (Lockheed Martin Solar & Astrophysics Laboratory); Dr TESTA, Paola (Harvard–Smithsonian Center for Astrophysics); Prof. PAGANO, Paolo (Università degli Studi di Palermo); Dr HANSTEEN, Viggo (Lockheed Martin Solar & Astrophysics Laboratory)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **74** Type: **Poster**

Observational Signatures of Tearing Instability in the Current Sheet of a Solar Flare

Magnetic reconnection is a fundamental physical process that converts magnetic energy into plasma energy and particle energy in various astrophysical phenomena. In this talk, I will show a unique dataset of a solar flare where a continually stretched current sheet formed various plasmoids. EUV images captured reconnection inflows, outflows, and particularly the recurring plasma blobs (plasmoids). X-ray images reveal nonthermal emission sources at the lower end of the current sheet, presumably as large plasmoids with a sufficient amount of energetic electrons trapped in them. In the radio domain, an upward slowly drifting pulsation structure was observed, followed by a rare pair of oppositely drifting structures. These structures are supposed to map the evolution of the primary and secondary plasmoids formed in the current sheet. Our results on plasmoids at different locations and scales shed important light on the dynamics, plasma heating, particle acceleration, and transport processes in the turbulent current sheet and provide observational evidence for the cascading magnetic reconnection process.

Primary author: LU, Lei (Purple Mountain Observatory, CAS)

Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **75** Type: **Talk**

The Role of Magnetic Reconnection in the Formation and Evolution of Eruptive Magnetic Flux Ropes

Wednesday 11 September 2024 09:15 (15 minutes)

Magnetic flux rope (MFR) is generally considered the core structure of coronal mass ejections (CMEs). However, how an MFR forms and develops into a CME has been elusive. Through a series of observational studies, we found that a coherent magnetic flux rope may originate from a 'seed'MFR that is formed through magnetic reconnection in a current layer underneath a sheared magnetic arcade, as a result of the convalescence of plasmoids formed in the current layer. During the eruption, while magnetic reconnections continually convert overlying, untwisted magnetic flux into twisted flux to help further build up the pre-existent MFR, they also restructure the MFR through reconnections between the MFR and the ambient field. The restructuring may go as far as to completely replace the original MFR's flux, which is manifested by drastic footpoint migration, highlighting the 3D nature of magnetic reconnection; and alternatively may dissolve the MFR, while simultaneously exciting a shock wave, revealing an imploding process intrinsic to magnetic reconnection.

Primary author: LIU, Rui

Presenter: LIU, Rui

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **76** Type: **Poster**

Horseshoe CME model in EUHFORIA for geo-effectiveness predictions

Coronal mass ejections (CMEs) are giant expulsions of magnetized plasma from the Sun that manifest flux rope structures. Flux rope CME models such as the spheromak model with spherical geometry and the 'Flux Rope in 3D'(FRi3D) model with a global twisted magnetic flux tube geometry are already widely used in studying CME evolution and propagation in the heliosphere within the EUropean Heliosphere FORecasting Information Asset (EUHFORIA). Although the more realistic flux rope geometry of FRi3D is a significant upgrade over the spheromak model, its complex geometrical transformations are a drawback for fast and stable simulations. In this study, we discuss an optimal setup with a geometry more realistic than the spherical plasma blob while the simulations fast and robust enough for operational forecasting setup. This 'Horseshoe'CME model, based on the modified Miller-Turner topology, has been implemented in EUHFORIA and is a modification of the full torus model introduced by Linan et al. (2024). The geometrical implementation of the Horseshoe model is missing the back part of the torus which makes it a more realistic flux rope structure with two legs. In this work, we highlight the methods towards the numerical stability of CME leg disconnection. To make the simulations realistic, we constrain its geometric and magnetic field parameters from observations. We also present the validation of the Horseshoe model with observed CME events and demonstrate how different methods of constraining magnetic field parameters like flux and twist affect the space weather predictions at Earth.

Primary authors: MAHARANA, Anwesha (Centre for mathematical Plasma Astrophysics, KU Leuven); Dr LINAN, Luis (KU Leuven, Belgium); Prof. POEDTS, Stefaan (KU Leuven); MAGDALENIC, Jasmina (Royal Observatory of Belgium)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **77** Type: **Poster**

White-light Emission in the F-CHROMA Grid

Context. Much of a solar flare's energy is thought to be released in the continuum. The optical continuum ("white-light") is of special interest due to the ability of observing it from the ground.
Aims. We aim to investigate the prevalence of white-light emissions in solar flares, what influences them, and what causes them to begin with. We furthermore seek to understand the response of the atmosphere to a flare.
Methods. We utilize the F-CHROMA grid of flare simulations created using the radiative hydrodynamics code RADYN. We probe the spectral index, total energy and low-energy cutoff to draw conclusions about their relationships to white-light emissions. Furthermore, we calculate the 4170 Å continuum emissions, the Balmer and Paschen ratio. Finally, we analyse two particular cases.
Results. 13 of the 83 flares included in the F-CHROMA grid show white-light emissions relative to the pre-flare level that exceed 0.5%. The total energy (or maximum beam flux) seems to be the main factor for deciding whether white-light emissions will be detectable. There is a linear relationship between the Balmer/Paschen ratio and the relative continuum enhancement. Both case studies show the creation of multiple blobs (both hot and cool), as well as H-ionization and subsequent recombination as the most likely reason for Balmer/Paschen continuum emissions.
Conclusions. The parameters of an electron beam impacting the solar atmosphere play a big role in determining several characteristics, such as the white-light emissions and Balmer ratio. White-light emission in the Balmer/Paschen continuum likely result from optically thin hydrogen recombination radiation.

Primary author: Mr ORNIG, Sascha (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Co-author: CARLSSON, Mats (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **78** Type: **Poster**

Inference of atomic line parameters from quiet-sun observations at 1.56 microns

Many spectral lines used for solar observations have poorly determined atomic parameters, such as the transition probability or the central wavelength. Using poor atomic line parameters in spectropolarimetric inversions produces erroneous results for inferred atmospheric parameters. Therefore, we applied a newly developed coupled inversion method to infer the transition probability and wavelength of lines at 1.56 μm from quiet-sun disc-center spectropolarimetric observations taken with the GRIS instrument mounted at the 1.5-meter GREGOR solar telescope. The coupled inversion method relies on the self-consistent inference of the atmospheric and atomic parameters by imposing a spatial coupling in the latter. The retrieved line parameters agree well with previous determinations, in which line parameters were allowed to vary between pixels. However, these modest differences in the atomic line parameters show measurable offsets in atmospheric parameters, mainly in the temperature and line of sight velocity. The retrieved atomic parameters are contrasted against different node placements of the atmospheric parameters. We also considered the variation in the retrieved atomic parameters by inverting different patches from the observed field of view to test the robustness of the coupled method.

Primary author: VUKADINOVIC, Dusan

Co-authors: Dr KORPI-LAGG, Andreas (Max Planck Institute for Solar System Research); SOLANKI, Sami (Max Planck Institut for Solar System Research); NARAYANAMURTHY, Smitha (Max Planck Institute for Solar System Research)

Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **80** Type: **Poster**

Sustained Heating of the Chromosphere and Transition Region Over a Sunspot Light Bridge

The solar chromosphere and transition region (TR) play an important role in coupling the dense, 6000K photosphere to the tenuous, million degree corona. As the plasma beta changes dramatically over these layers, ascertaining the processes that maintain their thermal structure remains a fundamental problem in solar physics. By combining observations from the 50-cm Multi-Application Solar Telescope (MAST) at USO-PRL, the Interface Region Imaging Spectrograph (IRIS), Hinode, the Atmospheric Imaging Assembly (AIA), and the Helioseismic and Magnetic Imager (HMI) we analyze the sustained heating of the chromosphere and TR over several days in a regular sunspot light bridge (LB). In this talk I shall describe the various diagnostics used to infer the thermal and magnetic structure of the LB, as well as the possible processes that could supply the necessary energy to maintain the temperature spanning a range of 8000 K to 2.5 MK over a period of days.

Primary author: LOUIS, Rohan Eugene (Udaipur Solar Observatory, Physical Research Laboratory, Udaipur, India)

Co-authors: Prof. MATHEW, Shibu (USO-PRL); Dr BAYANNA, A. Raja (USO-PRL); Dr BECK, Christian (NSO USA); Dr CHOUDHARY, Debi P. (CSUN USA)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **81** Type: **Poster**

Spectral diagnostics of the solar corona

In most cases, the best spectral diagnostics to measure electron densities / temperatures, chemical composition and non-equilibrium effects in coronal plasma have not been explored at all or only partially (with e.g. little spatial/temporal information).
A few examples, from the X-rays to the infrared are provided, with suggestions for future instruments.

New EUV diagnostics for the outer corona, related to resonance photoexcitation effects are presented, together with new programs and atomic data made available to the community via CHIANTI-VIP, a new member of the CHIANTI family.

New atomic data, line identifications and models for X-ray satellite lines of Fe XVII are also presented. They appear to resolve long-standing problems in some of the strongest X-ray lines. A few problems were known but others were only recently highlighted by the first solar X-ray spectral imaging obtained by the MaGIXS sounding rocket, which indicated a factor of two missing flux around the resonance line.

Primary author: DEL ZANNA, Giulio (University of Cambridge (UK))

Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **84** Type: **Poster**

On the detection of solar flares in a Sun-as-a-star setting

Sun-as-a-star (SAAS) observations provide a valuable link between resolved solar observations and disk-integrated stellar observations, as it gives a unique insight into how well-defined solar activity affects the average spectrum. This activity can affect the integrated spectrum in complex ways, and therefore the values of for example reference spectra and exoplanet characterizations. It is therefore important to understand the magnitude and timescale of these variations. We aim to contribute to this field by focusing on the most rapidly changing type of activity: solar flares. We present the first SAAS detection of solar flares with TNG/HARPS, and discuss its effects on the integrated spectrum. When combined with observations made with SST/CRISP&CHROMIS and SDO/AIA, we are able to point to several evolutionary features of the flares in the HARPS data, as well as discuss their imprints on activity indices and RV measurements. Additionally, we expand this work by converting several other SST flare observations into simulated SAAS observations using the Numerical-Sun-as-a-Star Integrator (NESSI). This allows us to show the wide range of spectral imprints that flares can leave on the integrated spectrum based on their morphology, location, and size.

Primary author: PIETROW, Alex (Leibnitz Institute for astrophysics)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **85** Type: **Talk**

Refining Coronal Mass Ejection Dynamics: A Semi-Analytical Flux-Rope Model Incorporating Magnetic Erosion

Tuesday 10 September 2024 16:55 (15 minutes)

Our study aims to advance our understanding of the complex interactions between Coronal Mass Ejections (CMEs) and the solar wind/interplanetary magnetic field (IMF) system. We introduce a novel flux-rope semi-analytical MHD model that incorporates a comprehensive approach to understanding the impact of magnetic erosion and virtual mass on the propagation of CMEs. This model explores the profound effects of these processes, specifically focusing on the consequences of magnetic reconnection, which progressively diminishes the azimuthal magnetic flux and the mass of the outer shell of CME structures. With this study, we investigate how these forenamed processes can influence the dynamics of fast CMEs, affecting their anticipated arrival times in the near-Earth space environment and the space weather forecasts in general.

Primary author: Mr STAMKOS, Sotiris (University of Ioannina)

Co-authors: Prof. PATSOURAKOS, Spiros (University of Ioannina); Dr VOURLIDAS, Angelos (Johns Hopkins University - Applied Physics Laboratory); Dr PAOURIS, Evangelos (Johns Hopkins University - Applied Physics Laboratory & George Mason University)

Presenter: Mr STAMKOS, Sotiris (University of Ioannina)

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **86** Type: **Talk**

Simulating Energetic Particle Transport in the Solar Corona with COCONUT+PARADISE

Monday 9 September 2024 12:35 (15 minutes)

Solar eruptive events such as coronal mass ejections (CMEs), along with the associated solar energetic particles (SEPs), pose serious threats to spacecraft and astronauts. The growing impact of these harsh space weather events on modern societies has driven the development of numerical models capable of enhancing our understanding of the underlying physics and reliably forecasting these events. A recent example is the particle transport code PARADISE, which is coupled to heliospheric magnetohydrodynamic (MHD) models such as EUHFORIA and Icarus, and is used to model the acceleration and transport of SEPs at radial distances r > 0.1 au.

However, since the evolution of CMEs as well as the acceleration and transport of SEPs occur already deep in the corona (r < 0.1 au), we introduce the novel COCONUT+PARADISE model to address this issue. The data-driven, global coronal MHD model COCONUT, part of the COOLFLuiD platform, uses synoptic magnetograms for the inner boundary conditions and solves the three-dimensional ideal MHD equations to derive coronal background configurations from 1 up to 25 solar radii. To model CMEs in COCONUT, the unstable modified Titov-Démoulin flux rope model is utilised. Subsequently, PARADISE uses these coronal configurations to evolve energetic particles through these backgrounds by solving the focused transport equation (FTE) using a Monte-Carlo approach. We present simulation results that illustrate the propagation of SEPs within the solar atmosphere. Furthermore, we highlight the potential of our model for future work encompassing the study of particle transport from the base of the corona to Earth and beyond.

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Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **87** Type: **Poster**

Forecasting the propagation and evolution of CMEs using the space weather simulation chain: COCONUT + EUHFORIA

EUHFORIA is a space weather forecasting tool used to predict the geo-effectiveness of coronal mass ejection (CME) impacts. In this 3D MHD simulation, magnetic structures evolve in the heliosphere after being injected into the domain at 0.1 AU. The accuracy of EUHFORIA's predictions strongly depends on the coronal model used to initiate the solar wind and the properties of the CME model inserted to model real events. However, by inserting the CME at 0.1 AU, EUHFORIA does not account for the interaction of the CME with the solar wind near the corona.

These interactions, crucial for accurately assessing the magnetic and thermodynamic properties of the CME, can be studied using another simulation—a global MHD coronal model named COCONUT. COCONUT can track the evolution of flux rope models from the solar surface to 0.1 AU within a realistic description of the solar wind derived from observed magnetograms.

I will present how COCONUT can be coupled with EUHFORIA to dynamically track the propagation of a CME from the Sun to Earth. For this purpose, the outer boundary of COCONUT serves as the inner boundary for EUHFORIA. We tested the coupling through a series of joint runs. In all runs, the magnetic structure of the CME model used in COCONUT (either the Titov-Démoulin flux rope model or the RBSL model) successfully transfers from the coronal to the heliospheric model. The same applies to plasma properties. For example, the sheath that formed in COCONUT ahead of the CME continues to develop in EUHFORIA.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **88** Type: **Poster**

Fast Magnetic Reconnection Excites a Global Blast Wave in the Solar Corona

Magnetic reconnection is the key mechanism for various explosive phenomena in astrophysical plasmas, such as jets, flares, and coronal mass ejections (CMEs), yet many details remain elusive. An important piece of the puzzle is whether shock waves, a major particle accelerator in the universe, can be excited directly through flaring reconnections rather than driven by the jet/CME piston. Here, by investigating an isolated episode of fast magnetic reconnection leading up to a global blast wave, we give a definite answer. The reconnection occurs at the apex of a magnetic flux rope (MFR) when it rises obliquely from a behind-the-limb active region toward a coronal streamer visible to the Earth; the MFR disappears with its flux being shed by the reconnection. Both the angle of a V-pattern extending outward from the reconnection site and the MFR's speed relative to the background Alfv$e$n speed indicate a reconnection rate as fast as 0.2. The driven nature of the reconnection is manifested in the velocity profile of the MFR emulating the lightcurves of the impulsive hard X-ray (HXR) and microwave emission. An extreme-ultraviolet front expands centering on the reconnection site immediately after the HXR peak. The shock wave nature of the front is unambiguous as it propagates through a prominence embedded in the streamer, producing a γ-ray burst and a metric type II burst. These observations reveal that magnetic reconnection directs a significant fraction of magnetic free energy into exciting the blast wave, comparable to the energy into accelerating electrons.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **89** Type: **Poster**

Observations of photospheric signatures for pre-eruptive coronal structures

The buildup of the pre-eruptive coronal structure and the eruption onset mechanism are the two most critical yet poorly understood problems. Coronal structures like sigmoids and filaments have been identified as pre-eruptive structures; their associated pre-flare motions as well as pre-flare brightenings have been identified as precursor signatures, yet none of these definitively leads to eruptions, and the cause and effect is always questionable. Most importantly, the associated photospheric magnetic field dynamics are elusive. Here we report the development of pre-flare ribbons of electric currents associated with the buildup of a pre-eruptive structure observed as a bundle of hot low-lying coronal loops collectively taking a sigmoidal shape. Two ribbons of strong vertical electric currents at two sides of the major polarity inversion line (PIL) of the host active region are observed several hours ahead of the appearance of the pre-eruptive structure. More impressively, the buildup of the pre-eruptive structure in the corona is simultaneous with the gradual extension of current ribbons in the photosphere. It is reminiscent of the current-carrying magnetic flux rope (MFR). Continuous brightening were observed along the MFR in the corona when the extension of current ribbon ended in the photosphere, implying the onset of magnetic reconnection. The brightening lasted for 4 hours until the MFR erupted. Quantitative measurements indicate that the MFR's feet, which were well identified by conjugate dimmings occurred during the eruption, possess significant non-neutralized current. Our observations provide a new definitive photospheric signature for the buildup of pre-eruptive structures and imminent eruptions.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **90** Type: **Poster**

The Rapid Filament Restructuring in AR 12975 on 28 March 2022 and its Connection to the Subsequent Eruption

We analyzed a rapid filament restructuring during a confined C2 flare that led to an eruptive M4 flare 1.5 h later. During the C2 flare, the filament's southern half disappeared, and the remaining plasma flowed into a new, longer channel, similar to an EUV hot channel seen during the flare.

We took advantage of the quasi-quadrature position (84°) between SDO and Solar Orbiter, during its first science perihelion, by combining close-up (0.33 AU) and side-on observations from the Solar Orbiter/STIX and EUI instruments with on-disk observations from SDO/AIA and HMI, along with nonlinear force-free field extrapolations.

Our results suggest that loop-loop reconnection occurred in an essentially vertical current sheet at a polarity inversion line below the breakup region and involved field lines surrounding the filament channel. This scenario is supported by concentrated currents and free magnetic energy built up by antiparallel flows. It can explain the extended flare loop arcade, the EUV hot channel, and the filament restructuring as the reconnection progressed to involve the filament itself.

In addition, it provides a general mechanism for the formation of the long filament channel via tether cutting, which was active throughout the filament's continuous rise phase, beginning at least 30 min before the C2 flare and continuing until the eruption. These results demonstrate how rapid changes in a filament's topology can be driven by a confined flare due to loop-loop reconnection (Type I confined flare), and how this can contribute to a prolonged tether-cutting process leading to a full eruption.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **92** Type: **Talk**

Improved reconstruction of solar magnetic fields from imaging spectropolarimetry through spatio-temporal regularisation

Thursday 12 September 2024 11:50 (15 minutes)

Determination of solar magnetic fields with a spatial resolution set by the diffraction limit of a telescope is difficult because the time required to measure the Stokes vector with sufficient signal-to-noise ratio is long compared to the solar evolution timescale. This difficulty becomes greater with increasing telescope size as the photon flux per diffraction-limited resolution element remains constant but the evolution timescale decreases linearly with the diffraction-limited resolution.

The magnetic field vector tends to evolve more slowly than the temperature, velocity, or microturbulence. We exploit this by adding spatio-temporal regularisation terms for the magnetic field to the linear least-squares fitting used in the weak-field approximation, as well as to the Levenberg-Marquardt algorithm used in inversions. The other model parameters can be allowed to change in time and space with far less restrictive constraints. Our results show that the noise in the reconstructed magnetic field vector is greatly reduced by spatio-temporal regularisation, while all other model parameters can capture the faster variability of the atmosphere imprinted in the line profiles.

These methods are fundamentally important for the interpretation of data from the new generation of 4-m telescopes like DKIST and the planned EST, where solar evolution time will be critically low.

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Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **93** Type: **Talk**

High flow speeds and transition-region like temperatures in the chromosphere caused by reconnection

Monday 9 September 2024 17:30 (15 minutes)

Flux emergence in the solar atmosphere is a complex process that causes release of magnetic energy as heat and acceleration of solar plasma. We analyse imaging spectropolarimetric data taken in the He I 1083 nm line at a spatial resolution of 0.26”, a time cadence of 2.8 s, and a spectral range of 150 km s^{-1} around the line. This data is complemented by imaging spectropolarimetric data in the Ca II K, Fe I 617.3 nm, and Ca ii 854.2 nm lines. We compute He I 1083 nm profiles from a radiation-MHD simulation of the solar atmosphere to help interpret the observations.
We find fast-evolving blob-like emission features in the He I 1083 nm line at locations where the magnetic field is rapidly changing direction, and these are likely sites of magnetic reconnection. We fit the lines with a model consisting of an emitting layer located below a cold layer representing the fibril canopy. Numerical modeling provides evidence that this model, while simple, catches the essential characteristics of the line formation. The morpholoigy of the emission in He I 1083 nm is localized and blob-like, unlike the emission in the Ca II K line, which is more filamentary.
Based on the high temperatures needed for He I 1083 nm emission, the high Doppler speeds in the emission features, and their blob-like appearance, we conclude that at least a fraction of them are produced by plasmoids that occur during magnetic reconnection.

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Presenter: LEENAARTS, Jorrit

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **94** Type: **Poster**

Potential Predictions of Magnetic Flux Rope Eruptions

Magnetic flux rope eruptions are one of the primary mechanisms behind large coronal mass ejections. Flux ropes are twisted bundles of magnetic flux in the lower solar corona, which can store vast amounts of magnetic energy and remain in quasi-equilibrium for some time. If the conditions are correct, these ropes can violently erupt –but it is also equally possible for them to diffuse away into insignificance. The mechanisms behind such instabilities have been studied extensively for decades, but any definitive method of predicting the timing or magnitude of future eruptions has so far eluded us. In a slightly unusual approach, we have attempted to determine several scalar quantities measured from the magnetic field which could theoretically be used to predict an imminent eruption. With a large parameter study in 2.5D, we have used both MHD and magnetofrictional models to study thousands of flux rope eruptions, and in these simple cases we have found several such diagnostics which can predict imminent eruptions with up to around 90% certainty, providing the magnetic field is accurately reconstructed. We then consider the potential extension of this approach to full 3D models, and the possibilities of combining it with real-time photospheric magnetogram data to theoretically make useful predictions of eruptions and (by extension) potentially problematic space weather events.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **95** Type: **Poster**

Chromospheric Fe I lines in the NUV solar spectrum

The near-ultraviolet (NUV) part of the solar spectrum contains a dense haze of spectral lines. Some of the Fe I lines in this region show very broad profiles typical of chromospheric lines which contrast the well-studied photospheric Fe I lines in the visible part of the spectrum. The diagnostic potential of these spectral lines is largely unexplored due to a lack of high-resolution observations. With the SUNRISE III balloon-borne observatory we may for the first time have full spectropolarimetric data at high spatial resolution of this region, and ground-based observatories can also observe the broad Fe I lines around 400 nm. The goal of this work is to investigate and discuss the formation properties of the spectral lines and their suitability for interpreting observations. First, an initial investigation into the formation of a selection of lines was conducted in the FAL one-dimensional semi-empirical solar atmosphere models using the non-LTE radiative transfer code RH. In agreement with earlier works on the Fe I spectrum, we find that the lines are largely affected by over-ionization in the wings, and by scattering in the line cores. The line cores form well into the chromosphere in the tested atmosphere models except the colder FALX model where the line cores form in the temperature minimum. The next step is to investigate the formation of these lines in the dynamic atmosphere of a 3D radiation-MHD model, made with the chromospheric extension of MURaM, and preliminary results from this will be presented.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **96** Type: **Poster**

Relation between magnetic field and convective cells morphology.

The emergence and evolution of solar granulation provide important insights into photospheric plasma dynamics. We investigate the temporal evolution of convective cells both in quiet and magnetised regions, tracking their evolution over periods of approximately 30 minutes.
We employed a pattern-recognition algorithm based on multiple intensity thresholds for solar granulation segmentation, termed 'multiple level tracking' (MLT; Bovelet & Wiehr, 2001). This algorithm ensures optimal adaptation to the solar structure under investigation and efficiently detects granular shapes on solar intensity images.
We present a statistical analysis of the temporal evolution of photospheric convective cell morphology and its relationship with the magnetic field properties. This study analyses Swedish Solar Telescope (SST) observations of active region NOAA 11768. The dataset comprises blue continuum images acquired with a 5.6 second cadence, used for individual granule segmentation, and spectropolarimetric maps from the Crisp Imaging Spectropolarimeter (CRISP) with a 30 sec cadence.
Our results indicate that granular cell sizes and shapes are dependent on magnetic field strength, with granules tending to be smaller in regions of stronger magnetic fields. In the presence of highly inclined magnetic fields, granules exhibit increased eccentricity, and symmetric granules are not observed in these regions. Furthermore, mean upflow velocities and intensities of granules decrease with increasing magnetic field strength.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **97** Type: **Poster**

Locating sites of magnetic energy release in the 2022-10-02 X-class flare

Solar flares are driven by the release of free magnetic energy and are often associated with restructurization of the magnetic field topology. Observations of the evolving magnetic field in the flaring volume are limited to only one case, the X8.2 limb flare on 2017-09-10, where a coherent decay of the magnetic field in the corona was detected cospatial with efficient particle acceleration site at a cusp region. It remains unclear if this phenomenon is typical or exceptional. Here, we report another strong solar flare observed on the solar disk, whose microwave data permit mapping the magnetic field over the flaring source and tracking the magnetic field evolution over the course of the flare. This is done by model spectral fitting of the microwave imaging spectroscopy data obtained with NJIT's Expanded Owens Valley Array (EOVSA). The EOVSA images employed in this study were synthesized with overlapping 4 s time intervals and 2 s cadence at many frequencies between 2.5 and 18 GHz during the rise, peak, and early decay phases of the flare. The plasma parameters derived from this fitting display magnetic field decay in the loop top with the decay rate up to 10 G/s and in other locations.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **98** Type: **Poster**

Jacobian-Free Newton-Krylov method for multilevel NLTE radiative transfer problems

The calculation of the emerging radiation from a model atmosphere requires knowledge of the emissivity and absorption
coefficients, which are proportional to the atomic level population densities of the levels involved in each transition. Due to the
intricate interdependency of the radiation field and the physical state of the atoms, iterative methods are required in order to calculate
the atomic level population densities. A variety of different methods have been proposed to solve this problem, which is known as the
Non-Local Thermodynamical Equilibrium (NLTE) problem.

In this study we have developed a Jacobian-Free Newton-Krylov method (JFNK) to solve multilevel NLTE radiative transfer problems. Using the Rybicki & Hummer (1992) method as a reference, our results show that our JFNK solver can achieve up to a factor two speed up when using local approximate operators / preconditioner, while also achieving a lower residual error in the statistical equilibrium equations. Another advantage of this method is that the addition of charge conservation and partial redistribution effects should be straight forward.

Our method can help accelerating the calculation of the emerging spectra from numerical models and also the reconstruction of chromospheric datasets through NLTE inversions.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **99** Type: **Poster**

Monitoring of the solar atmosphere through radio imaging in the 18-100 GHz band: recent results and future challenges

In the frame of single-dish radio monitoring of the solar atmosphere with INAF radio telescopes we are developing and exploiting innovative single-dish radio imaging techniques at high-frequencies up to 100 GHz. Since 2018, we have been monitoring the solar atmosphere in the 18-26 GHz frequency range providing weekly images, in perspective covering the entire current solar cycle (SunDish project). We present an overview of the early scientific results and scientific challenges also in view of the new instrumentation available up to 100 GHz.
In particular, a new solar imaging system at high frequency was recently approved as a permanent observatory in Antarctica (Solaris project). It combines the implementation of dedicated and interchangeable high-frequency receivers on existing small single-dish radio telescope systems (2.6m class) available in our laboratories, on the Alps and in polar regions. Operations in Antarctica will offer unique observing conditions (very low sky opacity and long Solar exposures for nearly 20h/day) and unprecedented Solar monitoring in radio W-band (70-120 GHz). This opens for the continuous monitoring of the chromosphere and the identification and spectral analysis of Active Regions before, after and during the occurrence of Solar flares.
The Solaris observatory will be the only Solar facility offering continuous monitoring at 100 GHz, and it will be able to collect and disseminate data in synergy with the existing national and international network of Space Weather facilities.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **100** Type: **Poster**

Simulating fast on-the-fly scans of the solar disk with the Atacama Large Aperture Submillimeter Telescope (AtLAST)

The Atacama Large Aperture Submillimeter Telescope (AtLAST), a proposed 50m single-dish millimetre telescope, could lead to new discoveries in the field of solar millimetre astronomy. With AtLAST's proposed frequency range from ~30 GHz to 1 THz, it would observe the solar continuum radiation originating in the chromosphere. However, the chromosphere's highly dynamic nature prohibits meaningful observations to have long integration and scan times, which could be remedied by utilising fast on the-fly scanning techniques. Such techniques are already used by facilities such as the Atacama Large Millimeter/submillimeter Array (ALMA), completing a scan of the full solar disk in ~ 10 minutes. A sufficiently large multi-pixel detector at AtLAST could reduce the required scan time considerably, ideally to second time scales. By utilising the maria code, a powerful general-purpose telescope simulator, we thoroughly explore how different instrumental properties, scanning strategies and detector counts affect the full-disk observations. A technically feasible multi-chroic instrument was simulated, with properties in line with current expectations for a 1st generation instrument. Such an instrument would allow for instantaneous coverage of large regions on the Sun, even at the higher frequencies considered. Because of the large instantaneously covered region, it is found to be possible to also scan the full disk on very short time scales, on second time scales for an instrument going up to 700 GHz. This would allow us to monitor the active chromosphere on a global scale at an unprecedentedly high cadence, going beyond the capabilities of current facilities in the (sub-)millimetre regime.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **101** Type: **Talk**

Probing the physical parameters of the solar chromosphere and the corona through radio observations in the 18-26 GHz frequency range

Tuesday 10 September 2024 10:10 (15 minutes)

The radio Sun in the centimetric range (18-26 GHz) is dominated by the quiet-Sun emission, which covers the entire surface of the solar disk as a mostly uniform background. The quiet-Sun is mostly characterised by bremsstrahlung (free-free) emission at local thermal equilibrium. The solar disk at these frequencies shows dynamical chromospheric structures and phenomena – such as Active Regions, Coronal Holes, Polar Brightening, and Flares – whose emission generally takes place by the interaction between the solar matter and the variable local magnetic fields. This kind of radiation provides gyro-magnetic component, in addition to the free-free component typical of the quiet-Sun.

Using about 450 radio solar maps obtained in the context of the SunDish project – devoted since 2018 to the radio imaging and monitoring of the Sun and its atmosphere through the large single-dish radio telescopes of the Italian National Institute for Astrophysics (INAF) – we present the phenomenology of the chromosphere in the radio K-band (18-26 GHz), still characterised today by poor observing coverage. The low noise, the accurate absolute calibration, and the great sensitivity of INAF radio telescopes make these data crucial to probe the physical parameters of the chromosphere and corona in terms of solar size, density, temperature, and magnetic fields. We also describe the instruments and scientific tools that allow us to study the physics of these solar atmospheric layers, developed for our early scientific works and future developments in the context of the SunDish project.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **103** Type: **Talk**

Global coronal models driven with Alfven and kink waves

Tuesday 10 September 2024 12:45 (15 minutes)

In recent years, the so-called AWSOM models are a new generation of solar atmospheric models, which incorporate the heating and forces of Alfvén waves on top of more classical effects. They are outperforming older models capturing most aspects of the solar corona, but are still lacking in open field regions because of the lack of reflections and turbulence development.
In this contribution, I will highlight our development of a new formalism that allows to describe the kink wave on coronal plumes and loops in a similar way as the Alfvén waves in the AWSOM models. In this new development, we generalise the Elsässer variables to Q-variables in order to follow waves that are not Alfvén waves. In the talk, I will explain the governing equations, highlight early outcomes of the proof-of-concept in 1D configurations, where I show that kink wave driving leads to additional coronal heating.

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Presenter: VAN DOORSSELAERE, Tom (KU Leuven)

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **104** Type: **Talk**

Plasma Motions and Compressive Wave Energetics in the Solar Corona and Solar Wind from Radio Wave Scattering Observations

Tuesday 10 September 2024 12:30 (15 minutes)

Radio signals propagating via the solar corona and solar wind are significantly affected by compressive waves, impacting solar burst properties as well as sources viewed through the turbulent atmosphere. While static fluctuations scatter radio waves elastically, moving, turbulent or oscillating density irregularities act to broaden the frequency of the scattered waves. Using a new anisotropic density fluctuation model from the kinetic scattering theory for solar radio bursts, we deduce the plasma velocities required to explain observations of spacecraft signal frequency broadening. The frequency broadening is consistent with motions that are dominated by the solar wind at distances
$gtrsim10\ R_\odot$, but the levels of frequency broadening for
$lesssim10\ R_\odot$ require additional radial speeds $\sim (100-300)$ km s^{-1} and/or transverse speeds $\sim (20-70)$ km s^{-1}. The inferred radial velocities appear consistent with the sound or proton thermal speeds, while the speeds perpendicular to the radial direction are consistent with non-thermal motions measured via coronal Doppler-line broadening, interpreted as Alfvénic fluctuations. Landau damping of parallel propagating ion-sound (slow MHD) waves allow an estimate of the proton heating rate. The energy deposition rates due to ion-sound wave damping peak at a heliocentric distance of $\sim (1-3)\ R_\odot$ are comparable to the rates available from a turbulent cascade of Alfvénic waves at large scales, suggesting a coherent picture of energy transfer, via the cascade or/and parametric decay of Alfvén waves to the small scales where heating takes place.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **105** Type: **Talk**

First Solar Orbiter observation of a Dark Halo in the solar atmosphere

Tuesday 10 September 2024 09:25 (15 minutes)

Dark halos (DHs) are regions of reduced emission compared to the quiet Sun that are observed around active regions (ARs) at various wavelengths and wavebands, corresponding to chromosphere, transition region (TR) and corona. While in the chromosphere DHs are associated with the Hα fibril vortex around the AR cores, in the upper atmospheric layers the origin of their dark emission is still unknown. Because of their different spatial appearances, it is not even clear if the DHs observed at the different layers are related to each other. In this work we present the first Solar Orbiter's observation of a DH in the solar atmosphere which includes EUI, SPICE and PHI data taken on the 19 March 2022, when Solar Orbiter was approaching its fourth perihelion. We take advantage of Solar Orbiter's proximity to the Sun to study the temporal evolution of the 174 Å DH's fine structure with unprecedented spatial resolution. We also show cospatial and cotemporal intensity maps of SPICE's cooler spectral lines to reveal the DH's response to TR temperature increase. Finally, we spatially correlate the DH observed with EUI and SPICE to the PHI's BLOS magnetogram in order to shed light on the dark nature of DHs.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **106** Type: **Poster**

Key Roles of External and Internal Reconnection in Small-Scale Solar Events

Small-scale solar events, such as microflares and mini-filament eruptions, are prevalent in the solar atmosphere. However, their eruption mechanisms are still not understood thoroughly. With a combination of 174 Å images of high spatio-temporal resolution taken by the Extreme Ultraviolet Imager on board Solar Orbiter and images of the Atmospheric Imaging Assembly on board Solar Dynamics Observatory, we investigate in detail an erupting mini-filament over a weak magnetic field region. The eruption exhibited two separating bright ribbons and small-scale blobs of 1–2 Mm, suggesting a sequence of internal followed by external reconnection, which transfers magnetic flux to the ambient corona. Additionally, magnetohydrodynamic simulations reveal that magnetic reconnection plays a crucial role in heating localized chromospheric plasma to coronal temperatures, leading to microflares. The magnetic topology analysis discloses that the reconnection region is located near quasi-separators where both current density and squashing factors are maximal with the specific topology varying from a tether-cutting to fan-spine-like structure. High-resolution magnetograms from the Polarimetric and Helioseismic Imager support MHD simulations suggesting that external reconnection generates jets and transfers mass and magnetic twist to the corona. These findings highlight the critical roles of internal and external reconnection in driving small-scale solar events. External reconnection, in particular, transfers mass to the corona, potentially contributing to the solar wind.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **109** Type: **Poster**

A Strong-flare Prediction Model Developed Using a Machine-learning Algorithm Based on the Video Data Sets of the Solar Magnetic Field of Active Regions

It is well accepted that the physical properties obtained from the solar magnetic field observations of active regions (ARs) are related to solar eruptions. These properties consist of temporal features that might reflect the evolution process of ARs, and spatial features that might reflect the graphic properties of ARs. In this study, we generated video data sets with timescales of 1 day and image data sets of the SHARP radial magnetic field of the ARs from 2010 May to 2020 December. For the ARs that evolved from "quiet" to "active" and erupted the first strong flares in 4 days, we extract and investigate both the temporal and spatial features of ARs from videos, aiming to capture the evolution properties of their magnetic field structures during their transition process from "quiet" (non–strong flaring) to "active" (strong flaring). We then conduct a comparative analysis of the model performance by video input and single-image input, as well as of the effect of the model performance variation with the prediction window up to 3 days. We find that for those ARs that erupted the first strong flares in 4 days, the temporal features that reflect their evolution from "quiet" to "active" before the first strong flares can be recognized and extracted from the video data sets by our network. These features turn out to be important predictors that can effectively improve strong-flare prediction, especially by reducing the false alarms in a nearly 2 day prediction window.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **110** Type: **Poster**

Waves reflection linked with FIP bias

The chemical properties of the solar plasma remain unchanged as it travels unadulterated along open fields from the chromosphere/corona into the heliosphere and can be used as a tracer for the sources of the solar wind.
The solar corona should have the same chemical composition as the solar photosphere. However, It has been found that in the corona, some solar regions exhibit a different chemical composition compared to the lower atmosphere, known as the FIP effect.
For the first time, using spectropolarimetric data from the chromosphere we were able to detect wave reflection, linked with a strong coronal FIP bias, as predicted by the theory.
Unveiling solar wave characteristics from polarimetric measurements still represents a challenge. This detection has been accomplished using phase lag analysis on ground-based chromospheric Stokes V parameters. Using the same theoretical model proposed in 2004 and modified over these 20 years, we found good agreement with the observed results.

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Session Classification: Coffee break and poster session 2

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **111** Type: **Poster**

Solar Orbiter: Science highlights and mission status

This contribution will review recent science highlights of the ESA/NASA Solar Orbiter mission, with a focus on high-resolution observations of the mission's remote-sensing instruments. Solar Orbiter's science return is significantly enhanced by coordinated observations with other space missions, including Parker Solar Probe, SDO, SOHO, STEREO, Hinode and IRIS, as well as new ground-based telescopes like DKIST. This talk with present examples of such collaborative efforts as well as outline future opportunities. Starting in February 2025, Solar Orbiter's highly elliptical orbit will get progressively more inclined to the ecliptic plane, which will enable the first detailed observations of the Sun's unexplored polar regions. In addition to summarising the observing plans for the first half of 2025, I will describe opportunities for involvement of the entire science community

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **113** Type: **Poster**

Investigating plasma waves and flows in a chromospheric spiral structure using SST CRISP.

Twisted magnetic fields in the solar chromosphere are thought to give rise to a plethora of MHD waves and flows, enabling mass and energy channelling from the photosphere to the corona. Here we report on the statistical properties of observations of waves and flows in an apparently stable but relatively large-scale spiral structure (herein referred to as a "giant spiral"), close to disk centre, in H-alpha 656.3nm line core images, from the Swedish 1-m Solar Telescope (SST) CRisp Imaging SpectroPolarimeter (CRISP) instrument. The observations are analysed using CRISPEX in conjunction with a loop tracing algorithm called OCCULT2 allowing us to trace 100s of magnetic loops forming the giant spiral. Extracted magnetic loops are then read into Northumbria University Wave Tracking (NUWT) software to investigate the true nature of field aligned flows and waves. For the first time we reveal interesting new wave behaviour and flow dynamics in environments with varying degrees of magnetic twist. Subsequently, we report on the differing heating signatures, through correlation of the waves, flows and magnetic curvature, with co-spatial and co-temporal observations in the (E)UV with observations taken from the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA).

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **114** Type: **Poster**

Satellite Orbital Decay and Solar Wind Interactions: A Data Driven Case Study of May 2024 Space Weather Events

In May 2024, a G5-class geomagnetic storm, the most intense since the Halloween solar storms of 2003, hit Earth. Over a dozen X-class flares were observed by GOES, and several Coronal Mass Ejections were launched towards Earth. These events caused significant disturbances in the Earth' s upper atmosphere, impacting satellite orbits and causing auroras to be visible at mid-latitudes globally. Our goal is to assess the critical impact of Space Weather on the decay of Earth-orbiting satellites at different altitudes.
We make use of semi-major axis data from a precise orbit determination method and publicly available two-line-element data, to which we apply a robust time series decomposition method iteratively to remove the most significant periodicity in the data. We compute the orbital decay using this processed data, given the absence of accelerometer data, and analyze the correlation between orbital decay and solar wind parameters, solar activity proxies, and geomagnetic indices, accounting for the solar wind propagation time to the orbits.
For the first half of May, we observe a 15-hour delay between solar wind measurements and their effect on the orbits, and strong associations between orbital decay and several parameters. Consequently, we model orbital decay as a function of solar wind inputs and identify flow speed, electric field, proton densities, and magnetic field strength in the Z direction as the most impactful features. Despite challenges posed by satellite maneuvers and varying wind propagation times, we hypothesize that combining real-time orbital decay with these parameters could facilitate predicting its evolution.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **115** Type: **Poster**

Modeling of non-radially propagating CMEs and forecasting their arrival time at Earth

We present the study of several halo CMEs that propagated non-radially and as a result, they impacted Earth as flank-encounters. We utilized the default-setup of EUHFORIA and the Cone model for the CMEs, in order to model the selected events. For the modeling input parameters we used a) the DONKI database and b) the GCS technique (Thernisien et. al 2006, 2009) for reconstructing the CMEs. Our study aims to better understand the importance of the direction of propagation in the input parameters of the Cone model and improve the modeled arrival time at Earth. We selected events that had strong non-radial velocity components so that we could see how important are the effects of the low coronal CME deflections for the final direction of propagation and the forecasting of the CME arrival at Earth.
Our results show that, when we use the input parameters from the GCS fitting, up to the height of 12 Solar radii, the modeled arrival time is very close to the observed one, with their difference being up to around 2 hours. On the contrary, when the DONKI data are used, the modeled arrival time is much further (≥10h) from the observed one. This is because at the height of the GCS fittings, the CMEs have experienced all the low corona deflections and they have taken their final direction of propagation.
We used two other methods, the type II radio bursts and the 2D-speed obtained from the coronagraph white light images to compare our modeling results.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **116** Type: **Poster**

Physical Properties of Sunspots during an Eruption

We analyzed the properties of the magnetic field of a solar sunspot, which was closely associated with a solar eruption in active region AR 13079 observed on August 13, 2022, using modern computational techniques. Spektropolarimetric observations were obtained using the infrared spectrograph GREGOR (GRIS) on the 1.5-meter GREGOR Telescope. Our goal was to examine the magnetic and dynamic properties from the photosphere to the chromosphere above the solar sunspot.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **117** Type: **Poster**

A model for heating the super-hot corona in solar active regions

What physical mechanisms heat the outer solar or stellar atmosphere to million-kelvin temperatures is a fundamental but long-standing open question. In particular, the solar corona in active-region cores contains an even hotter component reaching 10 MK, manifesting as persistent coronal loops in extreme ultraviolet and soft X-ray images, which imposes a stringent energy budget. Here, based on the MURaM code, we present a self-consistent coronal heating model using a state-of-the-art three-dimensional radiative magnetohydrodynamics simulation. We find that the continuous emergence of magnetic flux in active regions keeps driving magnetic reconnections above the coronal loops at a current sheet embedded in a fan-spine-like magnetic topology, which release energy impulsively but are persistent over time on average. As a result, numerous substructures are heated to 10 MK and then evolve independently. These collectively form the long-lived and stable coronal loops that have been observed. This process provides a heating model that explains the origin of the super-hot coronal plasma and the persistence of hot coronal loops in emerging active regions.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **118** Type: **Poster**

On the Origin of the sudden Heliospheric Open Magnetic Flux Enhancement during the 2014 Pole Reversal

Coronal holes are known to be the main source of open magnetic flux (OMF) in the heliosphere. However, there's a notable difference between OMF measured in-situ and the flux estimated from solar observations. This study looks at OMF changes and their link to solar coronal holes and active regions, focusing on a significant OMF increase in September-October 2014.
Firstly, we establish a correlation between the noteworthy OMF increase and the modeled magnetic field on the Sun utilizing the Potential Field Source Surface (PFSS) model. Additionally, we invcestigate the correlation between the OMF and the open flux derived from solar coronal holes and while the OMF evolution is linked to the evolution of the coronal hole open flux, there is no significant correlation with the evolution of the coronal hole area. Furthermore, the temporal increase in OMF aligns well with the disappearance of the residual magnetic field at the southern pole, which resulted from poleward flux circulations induced by the decay of multiple active regions in the southern hemisphere several months earlier.
Additionally, the OMF jump coincided with the emergence of the largest active region of solar cycle 24 in October 2014. This study provides insights into this sudden rise in OMF during this period, enhancing our understanding of Sun-Earth dynamics and helping with space weather prediction and magnetospheric research.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **119** Type: **Talk**

Chromospheric evaporation as observed by STIX from the perihelion of Solar Orbiter

Wednesday 11 September 2024 12:55 (15 minutes)

During the impulsive phase of the flare, beams of non-thermal electrons move from the magnetic reconnection site towards the chromosphere, where the density increases rapidly. Therefore, we can estimate the plasma density distribution along the non-thermal electrons path directly from the observations of the energy-altitude relation obtained for the HXR footpoint sources. Its shape is determined by changing plasma density, the power-law distribution of non-thermal electrons and a degree of ionisation within footpoints. Previous analysis of the chromospheric density showed power-law dependence. Here, we present a moderate solar flare observed by the Spectrometer Telescope for Imaging X-rays (STIX) onboard the Solar Orbiter (SolO) mission. During the flare, SolO was very close to the Sun (~ 0.32 AU) offering imaging of the solar flare's HXR footpoints with a spatial resolution better than previous HXR telescopes. HXR images were reconstructed with 2-5 keV energy and 10 s time resolutions. The observed relation is not power-law. It reveals details showing the chromospheric evaporation on a wide range of altitudes. We identified two regions within the lower part of the flare legs. Deep in the chromosphere, the moving plasma appeared abruptly with velocities at 300 km/s, while in the loop legs plasma flows look to be more gradual (up to 50 km/s). These details show that the HXR images obtained for the perihelion passage contain new pieces of information about plasma dynamics during the impulsive phase of a solar flare.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **120** Type: **Poster**

Electron suprathermalization: from the corona to the solar wind and back

The data transmitted by Parker Solar Probe (PSP) from the young solar wind build on the puzzle of electron properties with many important pieces. Of particular interest are the suprathermal populations responsible for the transport of heat flux in the solar wind. We refer to both suprathermal components, the so-called halo and the strahl or beam component, whose trends suggested by previous analyzes of the heliosphere data are only partially confirmed. The nonmonotonic variation of the halo protperties (density, temperature and suprathermalization by the kappa parameter) suggests a much more complex interplay, not only with the strahl, which can be pitch-angle scattered and suprathermalized by the selfgenerated (e.g., heat-flux) instabilities. Corroboration with the properties of electron core that remains dominant (with a relative density of over 90%), suggests an involvement of the latter, at distances below 0.2 AU. We therefore propose a number of mechanisms for energizing core electrons, for which kinetic-scale wave turbulence also detected by PSP may be responsible. Possible consequences of velocity filtration in the solar corona are also analyzed, for the fact that at the smallest reported distances the slow-wind halo has low densities, below those of the strahl, but is strongly suprathermalized, with a reduced kappa parameter that tends to values found only at large heliocentric distances (after 1 AU). This further motivates an extensive analysis of the physical processes operating in the solar wind to explain the new data from the solar corona.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **122** Type: **Invited**

3D Magnetic reconnection and energy release in solar flares and eruptions

Wednesday 11 September 2024 11:30 (25 minutes)

The three-dimensional magnetic reconnection geometries have recently been shown to be present in solar flares, providing explanations for various observed phenomena, including evolution of sigmoids, drift of the erupting flux rope legs, and the shape of solar flare arcades. We review the observational evidence for these processes and their consequences for space weather. Particular emphasis is paid to related energy release phenomena occuring on short timescales, including HXR and radio bursts, fast slippage of flare loops, intermittent heating of the solar flare atmosphere, and the possibility that the flaring atmosphere is strongly out of equilibrium.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **123** Type: **Poster**

Determine the magnetic flux of active regions from their enclosed sunspots area

The relationship between the total magnetic flux of active regions (ARs) and the area of their enclosed sunspots serves as a fundamental property of ARs. Notably, deducing the historical magnetic flux of the brightening magnetic features on the Sun, i.e., faculae and networks, is compelling for understanding the long-term variations of the solar surface magnetic flux. It is also significant for attaining a dependable long-term reconstruction of solar irradiance which has essential implications for climate modeling. Our objective is to derive a reliable relationship between the total unsigned magnetic flux of ARs and the area of their encompassed sunspots using a large sample of ARs. We utilized the Space-weather HMI Active Region Patches (SHARPs) data series from HMI/SDO, which offers cutout maps and key informations of thousands of automatically identified and tracked ARs, with each monitored from before the time it showed up until after it disappeared. With such data, we discerned sunspots and determined both the area and flux of the sunspots and the ARs they reside in. We took the evolution and position into consideration. From our analysis, 460 ARs meet the study's criteria. We observed that the relationship between an AR's total flux ($\Phi_{\rm AR}$, in Mx) and the area of its associated sunspots (S, in mH) follows a power-law: $\log\Phi_{\rm AR} = (0.760 \pm 0.009)\log S + (20.292 \pm 0.018)$. Additionally, the relationship between a sunspot's flux ($\Phi_{\rm spot}$) and its area (S) is well expressed by another power-law function: $\log\Phi_{\rm spot} = (0.919 \pm 0.003)\log S + (19.520 \pm 0.006)$.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **124** Type: **Poster**

The September 5, 2022, coronal mass ejection characterized by remote observations, numerical simulations, and in situ measurements

Open problems in solar and heliospheric physics are (i) how charged particles are accelerated up to high energies and (ii) how they are transported in the inner heliosphere. Among candidates for particle acceleration there are shocks driven by coronal mass ejections (CMEs). We started a new research project (*) whose main methods are remote observations, numerical simulations, and in situ measurements. Here, we show the results of applying these approaches to the fast CME event of September 5, 2022, which was measured in situ by Parker Solar Probe (PSP) and Solar Orbiter, and observed remotely by Stereo-A, SOHO and PSP.

We carry out the reconstruction of the CME by using SOHO/LASCO, STEREO-A/COR2, and PSP/WISPR data. The obtained CME parameters are used as an input for the RIMAP simulation, which also uses the in-situ solar wind data to describe more accurately the initial interplanetary conditions. Then we analyze the in-situ Solar Orbiter measurements to check the results of the RIMAP simulation and to study the CME-driven shock properties, the level of magnetic turbulence around the shock and energetic particle acceleration due to the shock. As preliminary results, we find that the energetic particles differential flux at Solar Orbiter has a spectral index harder than that predicted by diffusive shock acceleration for the measured compression ratio. The possible reasons for such a discrepancy are discussed.

(*) Project "Heliospheric shocks and space weather: from multispacecraft observations to numerical modeling", funded by the Italian MUR within Next Generation EU.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **125** Type: **Poster**

First detection of small-scale helical flows in the void of a Coronal Mass Ejection with high-cadence coronagraphic images acquired by the Metis coronagraph on-board Solar Orbiter

On March 26, 2022 the ESA Solar Orbiter mission observed the early evolution of a Coronal Mass Ejection (CME). On that day the spacecraft was at a heliocentric distance of 0.32 AU, and a longitude separation from Earth of 74.5 degrees. The CME source region shows no pre-existing filament or flux-rope. The event was first observed in the inner corona by the EUI telescope, showing the initial propagation of the flux-rope in the EUV. Higher up, the event was observed by Metis with the Visible Light channel with an unprecedented time cadence of 20 sec, and a spatial resolution of 20" corresponding to about 4600 km per bin. The sequence of total brightness images shows for the first time small-scale flows going on inside the expanding flux-rope surrounded by multiple nested arch-shaped features. These plasma motions, not observed by EUI, could be connected with the unknown forces accelerating the eruption. Running difference images built with the cadence offered by previous coronagraphs show the well-known three-part structure of this event, but the real identification of these different classical CME parts is less evident in the high-cadence Metis images. Hence, these observations provide new insight into what is normally identified as the global structure of CMEs.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **126** Type: **Poster**

On the common appearance of superstrong magnetic fields in bipolar light bridges

Bipolar light bridges (BLBs) are bright features in sunspots located between two umbrae with opposite magnetic polarity. Recent observations revealed intriguing cases of BLBs with very strong magnetic fields of the order of 8.2 kG, which is at least twice the typical values measured in sunspot umbrae. Since these observations were only a few, it is a question of whether BLBs with extraordinarily strong fields are very rare. To investigate this, we aim to determine the field strength in a large sample of BLBs. For this, we used the most extensive set of spectropolarimetric observations of sunspots with BLBs compiled so far, consisting of data acquired with Hinode/SOT-SP. We analyzed these data using a state-of-the-art inversion technique, which accounts for the data degradation caused by the intrinsic point spread function of the telescope. We identified 98 individual BLBs within 51 distinct sunspot groups. Since 66% of the identified BLBs were observed multiple times, our sample contained a total of 630 spectropolarimetric scans. Our analysis showed that 89% of the (individual) BLBs contain magnetic fields stronger than 4.0 kG, at the height of maximum magnetic sensitivity with even higher field strengths in deeper layers. We also found that BLBs display a unique continuum intensity and field strength combination, forming a population well-separated from the umbrae and the penumbrae. The implications of our work influence our understanding of the magnetic structure of complex sunspot groups, which is one of the pillars of solar physics.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **127** Type: **Poster**

Observations and Numerical Simulations of the Effects of the Gamma Ray Burst 221009A on the Lower Ionosphere

In this contribution we investigated the impact of a powerful gamma ray burst (GRB) that occurred on October 9 2022, on the Earth's environment using a very low frequency receiver (VLF) to probe the lower ionospheric region (the D region). In addition to the VLF data analysis, we employed numerical simulation through the Long Wavelength Propagation Capability code (LWPC) to derive the increase in the D-region electron density. Our results revealed discernible perturbations in amplitude and phase across all transmitter paths (NAA, DHO, ICV, and NSC) to the Algiers receiver persisting for 40 minutes. At the maximum of the signal perturbation, the LWPC simulation results showed a decrease in the mean new reference height h'from 74 km to 65.71 km, along with an increase in the sharpness factor β from 0.3 km-1 to 0.4875 km-1. Under these new conditions, the electron density increased from its ambient value (216.10 cm-3 to 33.7 103 cm-3

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **128** Type: **Talk**

Nanoflare and nanojets in MHD simulations of magnetic reconnection in coronal loops.

Monday 9 September 2024 15:00 (15 minutes)

Reconnection events in coronal loops are singularly too small and fast to be detected (nanoflares), whereas their collective action could be sufficient to sustain the million degrees corona against thermal conduction and radiative losses. Recent studies have observed and modelled the dynamic counter part of nanoflares, i.e. the nanojets, which are a byproduct of the magnetic reconnection and this avenue seems a viable one to crack the nanoflares enigma. It remains to understand if there is a simple relationship between the properties of the nanoflare and the nanojet, so to explain in which cases the latter, when observed, could give away the occurrence of the former. We will analyse the physics of either phenomena to illustrate the detailed mechanism and key aspects which future studies should pay attention to. Moreover, in order to study the nanoflare population, we need to detect and isolate nanojets even when several take place one after the other. In MHD simulations, a number of detection techniques can be developed in increasingly more complex scenarios from the simple tangling of magnetic field lines to kink instabilities and cascade reconnection. These 3D MHD simulations are key to bridge the gap between idealised magnetic reconnection models and future spectroscopic observations (MUSE) providing key indications on what observations can be planned to export this approach from MHD simulations to observations.

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Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **129** Type: **Poster**

Mediterranean D-region ionosphere response to solar flares events

Solar flares significantly ionize the neutral atmosphere, leading to increases in the electron density of the ionosphere. This ionospheric disruption impacts the Earth-Ionosphere waveguide, affecting electromagnetic signal propagation between transmitters and receivers. Such ionization-induced perturbations can be observed as fluctuations in the signal amplitude and phase, and thus can be used to estimate the changes in electron density. In this study, we examine the response of the D-region of the lower ionosphere to solar flares by analyzing the Very Low Frequency (VLF) signals emitted by two separate transmitters in the Mediterranean Sea. By combining signal analysis with the Long Wave Propagation Capability (LWPC) code, we simulated the resulting signal perturbation parameters (amplitude and phase) and obtained an increase in electron density. This approach offers insights into the complex interactions between the solar flares and the ionospheric, which is important for communication and navigation systems.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **130** Type: **Poster**

Magnetic Rayleigh-Taylor instability in Solar Atmosphere: Downward Magnetic Flux Transport

This work dealt with the numerical simulation of the magnetic Rayleigh Taylor instability (IMRT) in a magnetic tube suspended in the chromosphere/photosphere conditions. We solved the compressible nonlinear MHD equations using the 2.5D open-source MPI-AMRVAC numerical code. Therefore we were interested in studying the effect of the horizontal magnetic tension on the development of the IMRT and trying to determine its characteristics. Our results showed that the horizontal magnetic component Bx plays an important role in the development of the IMRT where for higher Bx the number of mushrooms and bubbles decreased and the heat exchange between fluids above the magnetic tube tend to reducing. Moreover, we note that the second horizontal magnetic component Bz we found that this later fellows the displacement of the mushroom toward the photosphere as a frozen field and thus accumulate at the crest of the mushroom. This leads to the increase of the Bz intensity and thus to favorize the buoyancy. As a result of the buoyancy, a coalescence of two mushrooms was observed leading to the formation of a plasmoid with lighter-hot plasma bubbles conditions inside a heavy-colder mushroom and transported toward the photosphere. We also observed that the time variation of the mushroom length contains two phases (slow and fast) and that the time separating the two phases increases when Bx intensity becomes higher. With the process of the IMRT, we were able to explain the rainfall of the prominence plasma material toward the photosphere and reconnection to the surface magnetic field.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **131** Type: **Poster**

UV observations of small- and intermediate-scale enery release phenomena in the solar atmosphere

We present observations of small- to intermediate-scale energy release events occurring in the solar atmosphere, investigated using multiwavelength, multi-instrument high-resolution data. Ultraviolet (UV) observations acquired by satellites, along with complementary simultaneous spectropolarimetric measurements by ground-based telescopes, allow us to shed light on the dynamic interplay between plasma and magnetic fields from the photosphere up to the transition region and corona.

We use data from observing campaigns in 2016, involving the SST telescope in La Palma, and 2023. The latter was a 10-day campaign conducted in August 2023 at the GREGOR telescope in Tenerife, using the High-resolution Fast Imager (HiFI) and GREGOR Infrared Spectrograph (GRIS) in spectropolarimetric mode. Both campaigns were coordinated with IRIS and Hinode observations. IRIS UV observations consist of dense rasters (0.32" slit) and simultaneous slit-jaw images. Continuous coverage by SDO data complements these observations.

IRIS detected a series of small reconnection events and captured a footpoint of a C-class flare. We conducted an initial examination of the evolution of these events using photospheric and chromospheric spectropolarimetric data. These data were investigated using inversion codes to derive the magnetic configuration in the lower atmosphere.

Our analysis suggests that the interplay between emerging flux and other flux systems triggers small- to intermediate-scale energetic events. These results illustrate how magnetic reconnection can explain the occurrence of energy release phenomena. Notably, these science cases pave the way for advancements that will be available with the future MUSE and SOLAR-C missions, together with coordinated spectropolarimetric observations by the European Solar Telescope.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **132** Type: **Talk**

Photospheric driving of sustained kink oscillations in coronal loops

Tuesday 10 September 2024 14:45 (15 minutes)

Sustained kink oscillations in coronal loops have long been observed in TRACE, SDO/AIA, and more recently in SolO/EUI images. Although their properties are quite well-known now, their driver and excitation mechanism remain under active debate. In this contribution I give an overview over recent publications and discuss how the different proposed ideas/theories for photospheric driving can be reconciled with each other and with observations. A 3-D radiative MHD simulation using the Bifrost code (Kohutova et al. 2021, 2023) is explored to get first insights. We then exploit high-resolution coronal and photospheric observations taken recently by SolO/EUI/HRI and the Swedish 1-m Solar Telescope (SST) respectively during a dedicated coordinated campaign run in October 2023. This study provides actual numbers to quantify the driving of coronal loop footpoints that is derived from horizontal flows observed in the photosphere by SST. An attempt is then made to link the driver parameters with the properties of sustained kink oscillations detected in EUI/HRI. This work has been funded by the Research council of Norway (grant 324523).

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **133** Type: **Talk**

Vortex Flows in the Solar Atmosphere: Detection and Heating Mechanisms in 3D MHD Numerical Simulations

Monday 9 September 2024 17:15 (15 minutes)

Vortex flows are structures associated with the rotation of the plasma and/or the magnetic field that are present throughout the solar atmosphere, which have been detected in both numerical simulations and observations. In recent years, their study has become increasingly important, as they are present on a wide variety of temporal and spatial scales and can connect several layers of the solar atmosphere. In this way, it has been proposed as one of the possible mechanisms responsible for the energy transport and heating of the chromosphere and solar corona.

In this work we performed an automatic detection of these structures in 3D MHD numerical simulations using the MANCHA3D code. The code incorporate non-ideal MHD effects and simulations are available in three magnetic fields configurations at different spatial resolutions. To detect vortex structures we proposed to use the novel SWIRL code (Canivete Cuissa & Steiner (2022)), which combines mathematical criteria based on the velocity gradient tensor to identify such structures with an advanced clustering algorithm. By applying this code, we have been able to determine multiple structures associated with small and large scale vortices that extend in height in our simulations. Prior to the detection, simulations have been filtered in order to remove the continuous oscillation caused by the presence of p-modes. We focus our study on the temperature distribution and heating mechanisms (ambipolar diffusion and viscous and ohmic dissipation) that take place in the detected vortices, and how they change as the magnetic field and spatial resolution are modified.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **134** Type: **Poster**

High-order multi-fluid 1D modeling of the solar atmosphere: in-depth look at heavy element abundances

We investigate several mechanisms that may produce abundance variations in the solar atmosphere, called as the First Ionization Potential (FIP) effect. We develop and exploit a multi-specie 1-D model of the solar atmosphere (called IRAP's Solar Atmospheric Model: ISAM) that solves, along a given magnetic field line, the transport of neutrals, electrons and charged particles from the chromosphere to the corona. We follow a high-order approach that allows to solve additional coupled transport equations for the heat flux, and that includes both friction and thermal diffusion effects self-consistently. Thanks to a comprehensive treatment of collisions, we can analyse in detail the collisional coupling of heavy elements to e.g. protons. While the model can be applied to both closed and open magnetic configurations, we focus here primarily on the composition of active region coronal loops. We found that depending of the nature of the interaction with protons, a fractionation between low and high FIP elements settles rapidly in the upper chromosphere up to the typical observed levels. However under constant heating conditions we observed that this fractionation can take much longer to stabilise at the loop top (e.g. up to ~1 day for Iron), and hence also depends on the history of the loop. This study shows the importance of such high-order modelling to better understand abundance diagnostics and how they are connected to plasma heating. This work has been funded by the European Research Council (grant DLV-819189) and the Research Council of Norway (grant 324523).

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **136** Type: **Poster**

The evolution of the coronal loop structure due to the phase mixing of Alfvén waves

Coronal loops are known to host Alfvén waves propagating in the corona from the lower layers of the solar atmosphere and because of their internal structure, phase-mixing is likely to occur. The structure of the coronal loop could be significantly affected by the thermodynamic feedback of the heating generated by phase-mixing. However, this phenomenon can be sensitive to the period of the propagating Alfvén waves due to how short period waves can be easily dissipated and the way long period waves may accumulate considerable energy in resonating coronal loops. Using the Lare 2D code, a coronal loop model of a field-aligned thermodynamic equilibrium and a cross-field background heating profile is created, with an additional forcing term added to drive Alfvén waves with coronal amplitudes between 5-30km/s. We show that high frequency waves can generate heating corresponding to a 10% increase of the initial coronal shell temperature, chromospheric upflows of up to 0.6km/s and a coronal shell mass increase of 15%. These changes are sufficient to alter and maintain a new coronal loop density structure, broadening the region where efficient phase-mixing occurs. In contrast, low frequency waves are unable to be effectively dissipated, resulting in minimal changes to the loop structure. We see little evidence of wave energy accumulation in the corona and are unable to conclude that the dissipation of low frequency Alfvén waves can be an effective heating mechanism in coronal loops.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **137** Type: **Poster**

Signatures of wave activity in the lower solar atmosphere of solar wind source regions

During its first close encounter of 2023, the Solar Orbiter spacecraft was magnetically connected to different areas within an active region-coronal hole (AR-CH) complex. As the spacecraft was close to the Earth-Sun line at the time, IRIS and Hinode EIS were able to provide coordinated observations of the AR-CH complex. These complementary datasets provide the perfect opportunity to characterize wave activity in the different solar wind source regions including coronal holes, active region upflows, and coronal hole boundaries. In this study, we combine magnetic element tracking and power enhancement maps in the photosphere with IRIS observations in the chromosphere/transition region and EIS observations in the corona to characterize the different wave activity and to discern among the possible drivers for each type of solar wind source region. Our findings have implications for solar wind formation and acceleration mechanisms including the S-web.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **138** Type: **Poster**

Synergies between SOLAR-C and MUSE: A case study

SOLAR-C and MUSE are among the next generation solar missions, with launch dates in 2028 and 2027 respectively. Those mission will carry two complementary instruments providing each high resolution spectroscopy in the UV and EUV.

The EUV High-throughput Spectroscopic Telescope (EUVST) onboard SOLAR-C will obtain high temporal, spectral, and spatial resolution spectra of the Sun over a wide wavelength range, from 17 nm to 128 nm, thus providing seamless access to plasma temperatures from 0.01 to 20 MK. The instrument will also provide narrow-band context imaging at 280 nm.

MUSE, on the other hand, will implement a novel multislit approach in three selected wavelength bands, at 10.8, 17.1, and 28.4 nm. This revolutionary new design will allow obtaining spectra in isolated EUV lines over wide areas of the Sun at speeds that are up to two orders of magnitude higher than the classical single-slit approach.

The two missions, therefore, will be highly complementary. We present here a case study of synergistic observations between the two instruments. To this aim, we compute synthetic EUVST and MUSE spectra obtained from a MHD simulation of nanojets, where magnetic reconnection is triggered and leads to simultaneous heating and motion of plasma, making this numerical experiment a perfect showcase for the capabilities of either instruments. We discuss these synthetic observations and a concept of coordinated EUVST and MUSE observations optimized towards the science goal of studying the physics of nanojets.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **139** Type: **Poster**

Realistic Simulations of Real Active regions

We present a method and application of data-driven simulations with the MURaM radiative MHD code. Combined with a bottom boundary driver that reproduces the evolution of observed magnetic field, the sophisticated energy equation accounts for thermal conduction along magnetic fields, optically-thin radiative loss, and heating of coronal plasma by viscous and resistive dissipation, which allows for a more realistic presentation of observational features of solar active regions and eruptions. To validate the method, the photospheric data from Cheung et al. (2019) are used to drive a series of numerical experiments. The data-driven simulation reproduces the accumulation of free magnetic energy over the course of flux emergence in the ground truth with an error of 3\%. The onset time is approximately 8\,min delayed compared to the ground truth. The data-driven simulation resembles key eruption-related emission features and plasma dynamics of the ground truth flare over a wide temperature. We conduct simulations of eruptive and non-eruptive emerging active regions. The model captures growth of magnetic energy in AR11158 for several days prior to a major flux rope eruption that occurs near the real time of the X2.2 class flare.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **140** Type: **Poster**

Synthetic hydrogen Lyman-alpha images from 3D MHD simulation of an eruptive prominence: Towards analysis of Solar Orbiter/Metis observations

Non-LTE radiative transfer in 2D was performed for the hydrogen plasma of a loop-like structure within eruptive prominence obtained by 3D MHD simulation. The simulation made by Fan & Liu (2019) shows evolution of a prominence from quasi-equilibrium to the onset of eruption of a twisted, prominence forming coronal magnetic flux rope which underlays a coronal streamer. The 180th time step of the simulation is particularly suitable for our modeling because the prominence loop is already well formed at this time, is symmetric and not yet twisted. The loop is divided into several segments located from its bottom to its top. Cuts across each of the segments were made and distributions of the temperature and gas pressure within individual 2D cuts are taken as an input for our transfer code. Synthetic profiles of the Lyman alpha line are calculated for each segment using the formal solution of radiative transfer along the line of sight. The segments are approximated by 2D slabs with two finite dimensions across the loop and one infinite along it. The slab is irradiated from its bottom and sides, except of a vertical segment which is irradiated from all sides. Radiative transfer is solved by short characteristics method with usage of the Multilevel Accelerated Lambda Iterations and 5-level plus continuum hydrogen atom. The current version of the code is based on versions developed in Heinzel & Anzer (2001) and Schwartz et al. (2019). In the version used here, any desirable inclination of the slab can be used.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **142** Type: **Poster**

Exploring the variable spectra and magnetic fields of the Active Regions in the chromosphere through high-frequency radio imaging: gyro-resonance emission and flare forecasting

High-frequency radio observations with large single-dish radio telescopes of the INAF network, in the context of the SunDish project, provided ~450 solar images since 2018, useful to monitor the vertical structure and physical conditions of the solar chromosphere both for quiet and active regions, during their evolution at different phases of the solar cycle.
Solar radio mapping in K-band (18-26 GHz) can probe the chromospheric magnetic field of the Active Regions through the detection of gyro-resonance spectral components related to flare events. Enhanced magnetic fields (up 1500-2000 Gauss) determine a spectral flattening ($\alpha<1.5$) in the Active Regions compared to pure free-free emission ($\alpha\sim1.9$) due to the addition of a steeper gyro-resonance component also associated to circular polarization up to ~40%.
When this sporadic anomalous Active Region spectrum is detected, the probability of a strong flare occurrence within 1-2 days is >80%, further rising at >90% also requiring that AR brightness temperature exceeds ~50% the quiet Sun level. We present several examples of 18-26 GHz radio images showing peculiar Active Region spectral and polarization configurations anticipating or following flare events, and through correlation statistics analysis, we discuss the sensitivity and robustness of this flare forecast method and the perspective of coupling it with other multi-messenger Space Weather proxies.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **143** Type: **Talk**

Sunspot Scars: New Features of Solar Flux Rope Footpoints

Wednesday 11 September 2024 09:45 (15 minutes)

The properties of pre-eruptive structures of coronal mass ejections (CMEs) are important for forecasting solar eruptions, the former of which are usually quantified by measuring the properties of their footpoints in observations. However, the matter of how to identify the footpoints of pre-eruptive structures and how to do so with the use of ground-based instruments still remains elusive. In this work, we reveal for the first time an arc-shaped structure intruding in the sunspot umbra, which we call a "sunspot scar", through analysing a CME event on July 12, 2012 and two CME events from observationally inspired magnetohydrodynamic simulations performed by OHM and MPI-AMRVAC. The sunspot scar displays a more inclined magnetic field relative to that in the surrounding umbrae, and it is manifested as a light bridge in the white light passband. For both the pre-eruptive and CME flux ropes, the sunspot scars mark the edges of their footpoints, as the field lines anchored in the sunspot scar are spatially at the transition between the flux rope and the coronal loops and temporally in the process of the slipping reconnection which builds up the flux rope. Therefore, the sunspot scar provides a new method for the identification of pre-eruptive and CME flux rope footpoints. Furthermore, it opens up a new perspective for studying the evolution of solar eruptions with the extremely high-resolution photospheric observations from the current and next-generation giant ground-based telescopes.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **144** Type: **Poster**

Mysterious heating source inside an erupting prominence as observed by Solar Orbiter/Metis and ASO-S/SDI instruments

A prominence eruption associated with a limb CME was observed on April 12, 2023 by the multi-channel Metis Coronagraph on board the Solar Orbiter mission. The prominence, seen in the Metis UV Lyman-alpha images as a very bright and elongated arch propagating southward, is instead much weaker in Metis visible light (VL) images. In our work, we studied the 3D position of the prominence to understand the reason for such a significant difference between these two channels. By considering the different processes responsible for the emissions, we obtained the time evolution of the electron density and the temperature of two prominence portions from VL and UV images, respectively. The derived thermodynamic evolution suggests the existence of unknown physical processes providing additional heating source during the plasma expansion. The Lyman-alpha Solar Telescope (LST) on-board the Advanced Space-based Solar Observatory (ASO-S) mission also observed this eruption along the Earth-Sun view. The solar disk imager (SDI) on board the LST observed the prominence lifting from the south-west solar limb, with the south leg fixed onto the Sun as the prominence expand. The SDI Carrington map in Lyman-alpha line was applied to constrain the radiative component of the Lyman-alpha emission.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **146** Type: **Poster**

What is the mechanism underlying the Parker Solar Probe's finding of the ion-acoustic waves near the Sun?

One of the most stunning discoveries of the Parker Solar Probe mission is the wealth of kinetic scale processes occurring in the low solar atmosphere (Bale et al. 2019). In this work (Afify et al. 2024), we investigate, with a combination of theoretical and numerical tools, the ion-acoustic waves observed by the Parker Solar Probe near the Sun (Mozer et al. 2021, 2023; Kellogg et al. 2024). These observations reveal characteristic sequences of narrow-band, high-frequency bursts exceeding 100 Hz embedded into a slower evolution around 1 Hz, persisting for several hours. Focusing on proton distributions comprising both a core and a beam component,
we explore the potential role of the ion-acoustic instability (IAI) within the parameter regime relevant to PSP
observations. Our findings indicate that the IAI can indeed occur in this regime, albeit requiring electronto-core and beam-to-core temperature ratios slightly different from reported values during electrostatic burst
detection. Furthermore, we validate the growth rates predicted by linear theory and observe the saturation
behavior of the instability. The resultant nonlinear structures exhibit trapped proton beam populations and
oscillatory signatures comparable to those observed, both in terms of time scales and amplitude. Ongoing
work is focusing on the triggering mechanism behind the coupled high/low-frequency IAI observations.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **148** Type: **Talk**

Estimating the total energy content in escaping accelerated solar electron beams

Monday 9 September 2024 15:15 (15 minutes)

Quantifying the energy content of accelerated electron beams during solar eruptive events is a key outstanding objective that must be constrained to refine particle acceleration models and understand the electron component of space weather. Previous estimations have used in situ measurements near the Earth, and consequently suffer from electron beam propagation effects. In this study, we deduce properties of a rapid sequence of escaping electron beams that were accelerated during a solar flare on 22 May 2013 and produced type III radio bursts, including the first estimate of energy density from remote sensing observations. We use extreme-ultraviolet observations to infer the magnetic structure of the source active region NOAA 11745, and Nançay Radioheliograph imaging spectroscopy to estimate the speed and origin of the escaping electron beams. Using the observationally deduced electron beam properties from the type III bursts and co-temporal hard X-rays, we simulate electron beam properties to estimate the electron number density and energy in the acceleration region. We find an electron density (above 30 keV) in the acceleration region of 10^3 cm^-3 and an energy density of 5.74x10^-5 erg cm^-1. Radio observations suggest the particles travelled a very short distance before they began to produce radio emission, implying a radially narrow acceleration region. A short but plausibly wide slab-like acceleration volume of 10^26-10^28 cm^3 atop the flaring loop arcade could contain a total energy of 10^24-10^25 erg (~100 beams), which is comparable to energy estimates from previous studies.

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Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **149** Type: **Poster**

Statistical study of NUV continuum enhancement in Solar flares

So-called White Light Flares (WLFs) show enhancements in the visible spectrum with respect to the solar black-body curve. The Interface Region Imaging Spectrograph (IRIS) has found enhancements in the NUV spectral region, indicating an enhanced Balmer continuum. Statistical studies using imaging instruments have shown such enhancements to occur commonly, but what causes these enhancements is still a matter of debate, despite significant efforts in the field. It is believed that these enhancements are either a result of the electron beams or of the "backwarming"process, which transfers energy into the lower layers of the solar atmosphere. Although simulations of individual flare events may offer a valuable understanding of particle energy and penetration depth, the examination of numerous flares can provide better constraints and probe the energy transfer process.

We perform a statistical study using IRIS NUV spectral data to classify the occurrence of Balmer continuum enhancements. We use Gaussian process regression (GPR) to detect continuum intensities that are more than 4 sigma above the mean level. These "outliers" are then marked as NUV continuum enhancements. Our findings indicate that most of the enhanced pixels are located on the flare ribbon. Higher energy flares exhibit greater enhancement and a larger enhancement area. Our next step will be to simulate the NUV spectra of flares using the RH code (Uitenbroek 2001) and to provide constraints on the energy transport mechanism for WLFs.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **150** Type: **Poster**

Metis Observations of Geoeffective Solar Events

The Metis Coronagraph onboard the Solar Orbiter (SolO) mission is a powerful instrument capable of observing the solar corona simultaneously in the Visible (VL) broad-band light (580-640 nm) and in the Ultraviolet (UV) narrow spectral range centered on the Lyman α line of Hydrogen at 121.6 nm. This multiwavelength approach allows a comprehensive analysis of various eruptive solar events.

Metis can image the solar corona with very high spatial (down to 4000 km) and temporal resolution(≥ 1s) while at its closest approach to the Sun (i.e at 0.28 AU), the field of view ranges from 1.7 to 3 solar radii. The instrument can measure in that critical region of the corona plasma properties (temperature, energy budget, density distributions, etc.), as well as kinematic states (speed, acceleration, geometry,etc) of solar eruptive events, thus, playing a major role in studying how these form and evolve.

The Metis team is compiling a database of solar eruptive events observed with the Metis Coronagraph. Many of these events may have been geoeffective, i.e. potentially linked to the space weather phenomena. We plan to provide an overview of this subset of the Metis catalogue, highlighting selected geoeffective events.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **151** Type: **Talk**

Implementation of thermal conduction energy transfer codes in the Bifrost Solar atmosphere MHD solver

Thursday 12 September 2024 12:35 (15 minutes)

Thermal conductivity provides important contributions to the energy evolution of the upper solar atmosphere, behaving as a non-linear concentration-dependent diffusion equation. Computational discretisation limits the operation of solving such terms due to numerical instabilities and other error build-up. Recently, different methods have been offered as best-fit solutions to these problems in specific situations, but their limitations and total range in other scenarios is rarely discussed. Therefore, we rigorously test the different implementations of solving the conductivity flux, in the massively parallel MHD solver code, Bifrost. We compare the differences and limitations of explicit vs. implicit methods, and analyse the convergence of a hyperbolic approximation. Among the tests, we use a newly derived 1st-order self-similar approximation to compare the efficacy of each method analytically in a 1D pure-thermal scenario. The results give guidelines for when to use each method, and the variables that might affect a certain method's efficiency or accuracy. We discuss the optimisation of parameters in each method, and weaknesses that are not covered suitably by the current implementations.

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Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **153** Type: **Poster**

Beam-driven evaporation in 2.5D flare simulations with an asymmetric magnetic field configuration

The standard flare model is in generally depicted and studied in 2D simulations with an anti-symmetrical magnetic field configuration, symmetrical in magnitude, either side of the polarity inversion line. However, flare observations confirm that most flare have a significantly asymmetrical values of the magnetic field strength.

Here we present the first multi-dimensional magnetohydrodynamic flare simulation featuring evaporation driven by energetic electron beams in an asymmetrical magnetic field configuration. The simulation conditions that we use are known to rely significantly on those beams of electrons to drive the evaporated plasma upwards from the lower atmosphere (Druett et al. 2023). We study the impact of an asymmetrical configuration on the evolution and geometry of the flare-loop system as well as the impacts on the beam-driven evaporation using the MPI-AMRVAC model.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **154** Type: **Poster**

Analysis of solar eruptive events captured by Solar Orbiter during the "Eruption Watch" coordination campaigns.

Solar Orbiter's observations, during Remote Science Windows, a period of ~30 days happening twice per year, are organized into Solar Orbiter Observing Plans (SOOPs). Each SOOP consists of a coordinated set of operations involving multiple instruments to address mission objectives. The Eruption Watch SOOP is a high-resolution plan designed to capture eruptive events, engaging all remote sensing and in-situ instruments.
This presentation focuses on analyzing eruptive events observed during two specific Eruption Watch campaigns in April and October 2023. We have selected events captured by the PHI, EUI, Metis, and SolOHI instruments to study their physical and dynamic properties from the photosphere to the extended corona.
Finally, using observations starting from 2022, we conducted a statistical analysis of the observed erupting events.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **155** Type: **Talk**

The angular dependence of rise and decay times of solar radio bursts using multi-spacecraft observations

Monday 9 September 2024 15:30 (15 minutes)

Radio photons interact with anisotropic density fluctuations in the heliosphere which can alter their trajectory and distort the properties that are deduced from observations. This is particularly evident in solar radio observations, where anisotropic scattering leads to highly-directional radio emissions, meaning that observers at varying locations will measure different radio-source properties. However, it is not known whether the measurements of the decay time of solar radio bursts also depend on the observer's position. Decay times are dominated by scattering effects, and so are frequently used as proxies of the level of density fluctuations in the heliosphere, making the identification of any location-related dependence crucial. We combine multi-vantage observations of interplanetary Type III bursts from four non-collinear, angularly-separated spacecraft with simulations to investigate the dependence of the decay- and rise-time measurements on the separation of the observer from the source. We propose a function to characterise the entire time profile of radio signals, allowing for improved spectroscopic estimations, while demonstrating that the rise phase of radio bursts is non-exponential, having a non-constant growth rate. We determine that the decay and rise times are independent of the observer's position, identifying them as the only properties that do not require corrections for the observer's location. Moreover, we examine the rise-to-decay time ratio and find that it does not depend on the frequency. Therefore, we provide the first evidence that the rise phase is also significantly impacted by scattering effects, adding to our understanding of the plasma emission process.

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Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **156** Type: **Poster**

Investigating Small-Scale Evolution and Energetics of Coronal Hole Boundaries Using High-Cadence EUV Observations

The origin and formation of the slow solar wind remain an open question in solar physics. One possible scenario is that the slow solar wind may arise from coronal hole boundaries (CHBs) via interchange reconnection. This process also dominates the small-scale evolution of coronal hole boundaries. In this study, we investigate the small-scale evolution of magnetic field and plasma properties at the boundary of a large equatorial coronal hole to identify signatures of interchange reconnection. Using data from the Solar Dynamics Observatory, the coronal hole boundary is identified and tracked across a 7-day observation period with very high spatial and temporal resolution. Differential emission measure analysis is used to derive plasma properties such as the emission measure, plasma temperature, plasma density, and thermal energy. We also implement the correlation dimension mapping analysis to measure the irregularities of CHB and correlate them with the change in plasma and magnetic properties. All of these enable us to effectively analyse the shift in CHB and the evolution of relevant magnetic and plasma properties on very short temporal scales, providing insight into the ongoing process of interchange reconnection at the edge of the coronal hole and the surrounding region.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **157** Type: **Poster**

Simulating electron acceleration in shocks: stochastic shock drift acceleration

The presence of energetic electrons in the heliosphere is associated with solar eruptions, but details of the acceleration and transport mechanisms are still unknown. We explore how electrons interact with shock waves under the assumptions of stochastic shock drift acceleration (SSDA). Consideration of the shock wave parameter space, such as shock speed, shock obliquity, shock thickness, and plasma density upstream of the shock, helps determine electron spectra and their highest energies. With suitable simulation parameters, the SSDA model is able to accelerate thermal electrons to relativistic energies and, additionally, able to produce an electron beam upstream of the shock wave, a requirement for the type II radio burst seen in radio observations associated with shock waves and particle acceleration.
This presentation delves into the results of the presented model in regards to electron acceleration and transport within shock waves, contributing to our understanding of solar and interplanetary phenomena and their practical applications in space weather forecasting.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **158** Type: **Invited**

Exploring the connection between the Sun and the Heliosphere

Friday 13 September 2024 11:35 (25 minutes)

One of the main goals of heliospheric physics is to gain a complete picture of the dynamic processes occurring in the solar atmosphere and how these influence the inner heliosphere. Missions such as ESA/NASA's Solar Orbiter, which couples unprecedented, close-up views of the solar atmosphere to solar wind measurements in the inner heliosphere, provide invaluable insights into the sources, release and transport of the solar wind, coronal mass ejections, and solar energetic particles and their space weather impacts. In this review, I will highlight recent results from the latest missions on these topics and discuss what key questions still remain unanswered.

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Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **159** Type: **Poster**

A New Method for Finding SEP Event Onset Times and Evaluating Their Uncertainty: Poisson-CUSUM-Bootstrap Hybrid Method

Solar energetic particles (SEPs) are highly energetic charged particles that have their origin of acceleration in strong space-weather driving phenomena that the Sun produces, e.g., solar flares and coronal mass ejections. These particles pose a radiation hazard to both technological equipment and living organisms in space, which is why the nature of these events is an important subject of study in the modern age where space technology is being applied more and more every day.
The onset time of an SEP event at varying energies is a key piece of information in relating the in-situ particle measurements to the remote-sensing observations of solar eruptions. Accurate knowledge of the onset time is an indispensable requirement for identifying the acceleration mechanisms and the source of the energetic particles. What traditional methods lack, however, is the assessment of the uncertainty related to the onset time.
Our method employs a unique combination of a statistical quality control scheme, Poisson-CUSUM, coupled with statistical bootstrapping. By choosing random samples from the background intensity preceding an SEP event and varying the integration time of the data, the method is able to produce a set of distributions of possible onset times. From this set of distributions we extract the most probable onset time and uncertainty intervals relating to this set of distributions.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **160** Type: **Poster**

Constraining active latitudes from Sun-as-a-star helioseismic travel times

The eleven-year solar activity cycle is known to affect solar acoustic oscillations; higher activity is correlated with an increase in mode frequencies and a decrease in their lifetimes. Activity related frequency shifts have also been observed in other stars, but are difficult to measure mode by mode. Measurements seismic travel times provide an alternate method which is robust to noise (Vasilyev & Gizon 2024, A&A 682). In this work we build a simple forward model to interpret such measurements for the Sun in terms of magnetic activity versus time and latitude. We derive kernels that capture the sensitivity of the travel-times to surface activity at different latitudes. Linear inversions from synthetic and VIRGO data help demonstrate the viability of this method.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **161** Type: **Poster**

Slowly Positively Drifting Bursts generated by Large-Scale Magnetic Reconnection

Solar flares are accompanied by many types of radio bursts. In decimetric range the most frequent types are type III and IV (continua) bursts. The slowly positively drifting bursts (SPDBs) we study are rarely observed in decimetric radio emission of solar flares. To understand with what flare process this kind of radio burst is associated and how these bursts can be generated, we studied the radio observations at 800-5000 MHz range together with SDO/AIA imaging observations of the SPDB-rich C8.7 flare on May 10, 2014. (SOL2014-05-10T0702). We detected three groups of SPDBs along with narrow-band type III bursts which temporarily coincided with large-scale magnetic reconnection among the loops of a half dome magnetic configuration found within the active region and a nearby rising sigmoid.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **162** Type: **Poster**

Clustering of the Solar Wind at 1 AU: Reconnection and the Ambient Solar Wind

Investigating the solar wind is important for our understanding of the dynamics of plasma in the solar system environment. At 1 AU, where the solar wind interacts with the Earth's magnetosphere, we can also identify different transient processes, such as Interplanetary Coronal Mass Ejections (ICMEs) and Corotating Interaction Regions (CIRs), which may result in the occurrence of magnetic reconnection.
In this work we use Self Organizing Maps (SOMs) 1, an unsupervised learning method which achieves dimensionality reduction via neural networks, to transform the observed time series of WIND spacecraft (proton density, proton temperature, solar wind speed and magnetic field strength) into visual maps. We apply clustering techniques to the resulting maps to obtain a classification of the solar wind. Then, by using a reconnection exhausts catalogue from Eriksson et al. 2022 2 the occurrence of magnetic reconnection in the different clusters is examined.

1 T. Kohonen, 'Self-organized formation of topologically correct feature maps', Biol. Cybern., vol. 43, no. 1, pp. 59–69, Jan. 1982, doi: 10.1007/BF00337288.

2 S. Eriksson et al., 'Characteristics of Multi-scale Current Sheets in the Solar Wind at 1 au Associated with Magnetic Reconnection and the Case for a Heliospheric Current Sheet Avalanche', ApJ, vol. 933, no. 2, p. 181, Jul. 2022, doi: 10.3847/1538-4357/ac73f6.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **163** Type: **Poster**

Multi-periodic propagating slow magnetoacoustic waves in a coronal plasma fan.

Magnetohydrodynamic (MHD) waves have been utilised for decades for probing plasmas and increasing understanding of dynamic processes within the solar atmosphere, a technique called MHD seismology. Propagating slow magnetoacoustic (MA) waves are particularly valuable for MHD seismology due to their persistence, propagation along magnetic field lines, and their links to the coronal heating function. Although thought to be generated in underlying layers of the solar atmosphere, the specific mechanism for this process remains debated.
We present an observation of slow MA waves with three distinct periodicities along sunspot-anchored coronal fan feathers, with corresponding chromospheric oscillations, using data from the Atmospheric Imaging Assembly. The waves propagate outwards along three feathers in active region 13100 on September 19th 2022 at 05:00-08:00 ~UT.
Time distance analysis is used to determine wave periods, decay lengths, and projected phase speeds along feathers. Fourier analysis on individual pixel intensity curves is used to create period and narrowband-intensity maps. Distinct periods of 2.47±0.02, 2.81±0.02, and 3.06±0.04 mins are detected in three separate feathers. We observe a decrease in the decay length and projected wave speed from the cooler 171 Å to the hotter 193 Å, and 211 Å channels. An increase in the period intensity is seen in the 304 Å channel, where each feather is anchored, corresponding to the slow wave period detected in the 171 Å data.
These findings indicate that propagating slow waves exhibit fine structuring in coronal fans, corresponding to their anchoring locations, providing insights into the drivers of these waves.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **164** Type: **Poster**

Signature of Self-organized Criticality in Flaring Current Sheets

In solar flares, magnetic reconnection is key to restructuring the coronal magnetic fields and converting magnetic free energy into other forms of energies. The footpoints of newly reconnected magnetic flux tubes are mapped by chromospheric flare ribbons. The ribbons hence provide clues for structures of, and reconnection processes in, the coronal current sheet, which are still poorly understood. Here we adopt the UV (1600 Å and 1700 Å) filters of the Atmospheric Imaging Assembly (AIA) on-board the Solar Dynamics Observatory (SDO) to study the detailed evolution of flare ribbons for a sample of 10 two-ribbon flares. We extract flare ribbons based on the variances of AIA 1600/1700 filter ratio. We find that the frequency distribution for waiting times of the identified pixels on the flare ribbons is well described by a power law of index about 1.5, consistent with the theoretical expectation of the self-organized criticality (SOC) model, but the frequency distributions for flaring duration, peak intensity, area under the light curve, and magnetic field strength of the identified pixels generally deviate from power laws as well as from the SOC expectations. These results suggest that time-wise an avalanche process might be ongoing in the flaring current sheet, but in other aspects, e.g., space- and energy-wise, this avalanche is likely modulated by other physical processes.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **165** Type: **Poster**

Flare accelerated electrons detected at anchor points of erupting filaments

Stiefel et al. (2023) reported on a first observation in hard X-rays of nonthermal emission coming from the anchor points of an erupting filament. We concluded that flare accelerated electrons must have entered the flux rope and precipitated along the erupting filament into the chromosphere producing Bremsstrahlung in the hard X-ray range.

The detection of such events is challenging for present day instrumentations due to limited dynamical range in imaging hard X-rays. Complementary diagnostics in microwaves are therefore used to search for gyrosynchrotron emission from within the erupting filaments. Here we present joint STIX and EOVSA observations of the SOL2023-12-31 X5-class flare.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **166** Type: **Poster**

Investigating the band-splitting of a type II solar radio burst using LOFAR imaging and spectroscopy

Type II solar radio bursts are regarded as signatures of shock-accelerated electrons in the solar corona. They show emission lanes drifting slowly from higher to lower frequencies at the fundamental and/or harmonic of the local plasma frequency. Occasionally, these lanes can be further split into two components. This phenomenon is known as band-splitting, and its origin is still under debate. In this study, we investigate the band-splitting of a type II radio burst with the Low Frequency Array (LOFAR). The type II burst exhibits a fundamental and a harmonic emission lane. Both lanes are further split into a higher-frequency and a lower-frequency band. The type II burst is associated with a faint CME, and the occurrence of a type II burst and herringbone bursts superimposed on the type II indicate the presence of a coronal shock wave accelerating electrons. Using LOFAR's spectro-polarimetric and imaging observations, we track the locations of the type II radio sources across multiple frequencies. We find two distinct sources: one corresponding to the higher-frequency component and the other corresponding to the lower-frequency component of the split harmonic band. We also find no significant change in the degree of circular polarisation between the two bands. Our results suggest that the components of the split emission lane originate in two close but distinct regions upstream of the shock.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **167** Type: **Poster**

Parametric simulations of the propagation of solar jets: investigating the solar origin of switchbacks

The recent discovery of ubiquitous switchbacks, localized magnetic deflections in the nascent solar wind, by the Parker Solar Probe (PSP) has sparked interest in uncovering their origins. A prominent theory suggests these switchbacks originate in the lower corona through magnetic reconnection processes, closely linked to solar jet phenomena. Jets are impulsive phenomena, observed at various scales in different solar atmosphere layers, associated with the release of magnetic twist and helicity. This leads to the question of whether these helical structures can travel into the inner heliosphere and if there is a direct correlation between specific solar jets and the switchback signatures observed by PSP.
To explore this hypothesis, I present parametric simulations using a 3D numerical magnetohydrodynamic (MHD) model of solar-jet-like events. Within the MHD framework, I examine how varying atmospheric plasma beta affects the propagation dynamics of these jets. Employing the ARMS (Adaptively Refined Magnetohydrodynamics Solver) code, I modeled the self-consistent generation of a solar jet based on Pariat et al. (2009).
Producing in-situ velocity and magnetic field measurements, akin to those observed by PSP or SolO, I demonstrated that the magnetic wavefront corresponds to an Alfvénic deflection consistent with switchbacks observations. U-loops, prevalent at jet onset, do not persist in the low-beta corona, hindering the formation of full-reversal switchbacks. This may explain the absence of full reversal switchbacks in the sub-Alfvénic wind. Overall, these simulations unveiled the propagation of magnetic deflections through jet-like events, shedding light on possible switchback formation processes.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **168** Type: **Poster**

Advancing High-Resolution Studies of Sunspot Penumbra Formation and Decay: new opportunities for the solar community provided by IBIS2.0, an upgrade of the Interferometric BIdimensional Spectrometer

Sunspot formation is the primary manifestation of magnetic flux emerging from the convection zone into the solar atmosphere. Among the various features of sunspots, the penumbra is particularly intriguing due to several unresolved issues, such as the interpretation of its formation and decay processes and understanding its bolometric brightness.
Recent high-resolution spectropolarimetric observations have proposed two scenarios for penumbra formation: the trapping of emerging horizontal field lines by a magnetic canopy and the sinking of existing magnetic fields from the chromosphere into the photosphere. These processes remain incompletely understood, although we recently provided new findings on the properties of the penumbral magnetic fields in the chromosphere at atmospheric heights unexplored in previous studies.
Additionally, studies on the dynamics of the Evershed flow during penumbra formation have provided some insights, but many questions remain. We present our results obtained on these topics using the Interferometric BIdimensional Spectrometer (IBIS).
The IBIS 2.0 project, an upgrade of IBIS that operated at the DST from 2003 to 2019, aims to address these gaps in knowledge. The upgraded instrument, to be installed at the Teide Observatory, will provide detailed spectropolarimetric data, capturing information along both photospheric and chromospheric lines in the 580-860 nm range. This will enable a comprehensive examination of magnetic flux emergence and its interactions with the magnetic canopy.
Overall, IBIS 2.0 will significantly enhance our understanding of sunspot penumbra formation and decay, providing a powerful tool for high-resolution solar research.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **169** Type: **Poster**

Moment closure problem: equation discovery and deep learning techniques applied to kinetic plasma simulations

Reduced order modelling (ROM) plays an important role in the descriptions of different plasma environments such as heliosphere, solar wind and beyond. ROMs can be obtained via analytical closures; however, such approaches are limited when distribution functions are far from Maxwellian and/or in weaker guide fields. To push the envelope of ROMs in plasmas we apply machine learning frameworks that seek to extract the relevant terms that need to be kept in the equations for moments (EoMs), identifying terms such as anisotropic pressure in the momentum equation. This is done systematically on several datasets generated via kinetic simulations: 1D Landau damping, 2D decaying turbulence, 2D magnetic reconnection. The sparse/symbolic regression techniques used include wSINDy and PDE-Net. We show examples of successful identification of EoMs. These approaches are compared with multi-layer perceptron trained to reconstruct the pressure tensor as a function of local lower-order moments. We show that the method is successful, assuming the test data comes from simulations with guide fields of comparable values to at least a few runs in the training dataset. Interestingly, accuracy of the predicted pressure tensor increases as we add extra runs corresponding to stronger guide fields. These results are promising for the development of global surrogate models for space plasmas that capture Finite Larmor Radius (FLR) effects.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **170** Type: **Poster**

The Lyman Lines During Solar Flares: Solar Orbiter/SPICE's first high-cadence flare observation

The SPICE instrument on board Solar Orbiter observes in the (extreme-)UV, including the Lyβ and Lyγ lines. Forming in the upper chromosphere, they are very sensitive to energy input and the ionisation stratification, offering important diagnostic information of solar flare energetics. We report here on the first high-cadence (5s) flare observations from SPICE, presenting an overview of the dataset, but focusing our analysis on the Lyman lines. This M-class flare was observed during Solar Orbiter's Major Flare Watch SOOP on 23rd March 2024 ~2348UT. We measure the Lyman decrement (intensity ratio R = Lyβ/Lyγ) as a function of time in an isolated flare footpoint. R decreases impulsively, returning to pre-flare values rapidly, despite the fact that the intensity of each of the Lyman lines (and other EUV spectral lines) returns to pre-flare over a longer duration. In a nearby, weaker, flare ribbon the Lyman decrement shows no meaningful change in response to the flare. A series of field-aligned radiation hydrodynamic simulations were performed, revealing that in electron beam driven flares the synthetic Lyman decrement is very consistent with observations. However, in a flare driven solely by thermal conduction, the Lyman decrement does not exhibit the observed sharp decrease. We conclude that the very strong flare footprint was produced by intense particle precipitation, whereas the weaker conjugate footpoint was more consistent with flare energy transport dominated by thermal conduction. Future analysis will focus on other spectra observed by SPICE, aiming to confirm this picture of differing dominance of energy transport mechanisms.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **171** Type: **Talk**

Identifying and Tracking CME Flux Ropes On The Example of AR12473

Wednesday 11 September 2024 09:30 (15 minutes)

The study of coronal mass ejection triggering and early evolution necessitates numerical modelling, as measuring the coronal magnetic field is challenging. A key ingredient of the modelling efforts is to reliably identify and track the underlying magnetic structure of the eruption, the magnetic flux rope (MFR), in the simulation data. To achieve this, we developed an extraction and tracking scheme for MFRs, wrapped into a user-friendly GUI called GUITAR (GUI for Tracking and Analysing flux Ropes). The method builds upon a suitable MFR proxy, such as the twist of magnetic field lines, and combines it with mathematical morphology (MM) algorithms. The basic principle of MM algorithms is the comparison of an image with a so-called structuring element. In the context of MFRs, these algorithms are useful tools to identify the MFRs. We apply this scheme with GUITAR to a time-dependent data-driven magnetofrictional simulation of active region AR12473. We identify the MFR, analyse the evolution of its properties and track the flux rope from its formation until the eruption from the simulation domain. Furthermore, we demonstrate that it is a multi-MFR structure and analyse its large-scale evolution and triggering mechanism.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **172** Type: **Poster**

On the Application of Warm Target Model in Investigating the Time Evolution of Solar Flares

Solar flares are intense localized eruption of electromagnetic radiation over a wide range of energies in the solar atmosphere. A primary characteristics of solar flares is the acceleration of electrons to higher energies and X-Ray observation serves as the key diagnostic to study them in details. In this study, we are investigating the time evolution of solar flares using the warm-target model. This model better constrains the flare parameters, especially the lower energy cut-off of the electron distribution, than the commonly used cold thick-target model. Here, we are using some well-observed flares observed by the RHESSI and the Solar Orbiter (STIX instrument) spacecrafts. Such observations provide us with an excellent opportunity to test the warm-target model in characterizing the time evolution of solar flares. The time evolution of some of the key parameters, e.g., the lower energy cut-off, the total power of non-thermal electrons, the rate of total injected electrons, the excess emission measure from the accelerated electrons in the warm plasma, are very crucial to characterize the acceleration mechanism of electrons in flares. We find an approximate constancy of the lower energy cut-off along the evolution of the flare. Such behaviour also plays a key role in the time evolution of the total non-thermal power of the electrons, and thus in their energy contain. The outcomes of this study, therefore, help us better understand the overall physics of the solar flares.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **173** Type: **Poster**

Extreme–ultraviolet transient brightenings in the quiet-Sun corona observed with Solar Orbiter/EUI

The extreme-ultraviolet (EUV) brightenings identified by Solar Orbiter (SolO), commonly known as campfires, are the smallest detected, to date, transient brightenings or bursts observed in the non-active regions of the lower solar corona. Our understanding about the role of campfires in the coronal heating stands elusive due to the absence of extensive statistical studies. We perform statistical analysis of the campfires by using the highest possible resolution observations obtained by the Extreme Ultraviolet Imager (EUI) onboard SolO. We use observations in the 17.4 nm passband of the High Resolution EUV Imager (HRIEUV) of EUI obtained during the closest perihelia of SolO in the year of 2022 and 2023. SolO being at a distance 0.29 AU from the Sun, these observations have exceptionally high pixel resolution of 105 km with the fast cadence of 3 s. We report the detection of smallest campfires in the quiet-Sun. The detected campfires have sizes in the range of 0.01 Mm^2 to 10 Mm^2. Their lifetimes vary between 3 s and 1000 s. Their distribution of size and lifetime shows the power-law behaviour. We estimate that about 10^4 campfires appear per second on the whole Sun. Considering the HRIEUV bandpass that is most sensitive to the 1 MK plasma, the increasingly high number of campfires at smaller spatial and temporal scales over the quiet-Sun regions make them one of the contributors for the quiet-Sun coronal heating.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **174** Type: **Poster**

Reconnection within the erupting flux rope during a solar flare

We present indications of reconnection within the erupting flux rope which occurred during the impulsive phase of the Apr 2, 2022 flare. Combining data from ground-based radiospectrometers, EUV and X-ray data from different vantage points (STEREO, AIA/SDO, EUI/Solar Orbiter, STIX/Solar Orbiter, Fermi), we show that rare and unique radio bursts in the GHz frequency range are co-temporal with specific EUV structures. In addition, the X-ray sources are related to hot EUV loops and footpoints that are all located near or inside the magnetic rope and the erupting filament.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **175** Type: **Poster**

Comparison of Methodologies to Estimate the Tilt Angle in Solar Active Regions

Active regions (ARs) are the photospheric manifestation of the emergence of magnetic flux ropes (FRs) formed within the solar interior. A key parameter of their evolution is the inclination of the AR polarity axis with respect to the equatorial direction, known as the tilt angle, which is fundamental in semi-empirical flux transport models proposed to explain the transference from toroidal to poloidal solar field components. In this work, we review the estimation of the tilt angle in a selection of around 120 bipolar ARs from Solar Cycle 23 using two methodologies. The first method, which is commonly used, computes the magnetic baricenters of the polarities to define the bipole axis. The second method employs an emerging FR model to fit magnetograms of emerging ARs using Bayesian inference. The Bayesian method uses a twisted toroidal FR model to generate synthetic line-of-sight (LOS) magnetograms, which are then compared with actual observations of the evolution of the photospheric LOS magnetic field of emerging ARs. Model optimization is done by sampling the posterior distribution of the parameters with the Markov Chain Monte Carlo technique provided by the PyMC5 library. In previous works, we found that this method corrects for projection effects, such as magnetic tongues, providing a more accurate estimation of the intrinsic inclination of the FRs during the early stages of AR emergence. In this work, we perform a statistical analysis of the tilt dispersions obtained with each method.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **176** Type: **Poster**

The coronal power spectrum from MHD mode conversion above sunspots

Sunspots are intense regions of magnetic flux that are rooted deep below the photosphere. It is well established that sunspots host magnetohydrodynamic waves, with numerous observations showing a connection to the internal acoustic or p-modes of the Sun. The p-modes are fast waves below the equipartition layer and are thought to undergo a double mode conversion as they propagate upwards into the atmosphere of sunspots, which can generate Alfvenic modes in the upper atmosphere. We employ 2.5D numerical simulations to investigate the adiabatic wave propagation and examine the resulting power spectra of coronal Alfvenic waves. A broadband wave source is used that has a 1D power spectrum which mimics aspects of the observed p-mode power spectrum. We examine magnetoacoustic wave propagation and mode conversion from the photosphere to the corona. Frequency filtering of the upwardly propagating acoustic waves is a natural consequence of a gravitationally stratified atmosphere, and plays a key role in shaping the power spectra of mode converted waves. We demonstrate that the slow, fast and acoustic waves above the equipartition layer have similarly shaped power spectra, which are modified versions of the driver spectrum. Notably, the results reveal that the coronal wave power spectra have a peak at a higher frequency than that of the underlying p-mode driver. This matches observations of coronal Alfvenic waves and further supports the role of mode conversion process as a mechanism for Alfvenic wave generation in the Sun's atmosphere.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **177** Type: **Poster**

Understanding Precursors of Coronal Mass Ejections and Flares

Coronal mass ejections (CMEs) and solar flares are the most energetic explosive phenomena in our solar system and are able to release a large quantity of plasma and magnetic flux into the interplanetary space, probably affecting the safety of human high-tech activities in the outer space. To predict CME/flares caused space weather effects, we need to elucidate some fundamental but still puzzled questions, one of which concerns how are CME/flares initiated. In this talk, I will first present key observational characteristics before the main phase of CME/flares including the slow-rise precursor and pre-flare activities. I then show a MHD model aiming to understand these disclosed observational characteristics and propose a new CME/flare initiation paradigm.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **178** Type: **Poster**

Falling Filament Material During Solar Eruptions

Mass drainage is frequently observed in solar filaments. During filament eruptions, falling material most likely flows along magnetic field lines, which may provide important clues for the magnetic structures of filaments. Here we study three filament eruptions exhibiting significant mass draining, often manifested as falling threads at a constant speed ranging between 50–300 km s^{-1}. We find that most of the falling material lands onto the hooked part of flare ribbons, only a small fraction lands inside the hooks, and almost none lands onto the straight part of ribbons. Based on these observations we conclude that initially most of the filament mass is entrained by field lines threading the quasi-separatrix layers (QSLs) that wraps around the filament field and dynamically evolves as the hooked ribbon, and that the magnetic reconnection involving these field lines is the major cause of the mass drainage during eruptions. In particular, the earlier QSL boundary is threaded by mass-loaded field lines, but the later QSL is threaded by mass-depleted field lines. Further, by assuming that the constant-speed motion is due to a drag force balancing the gravity, we propose a simplified model to estimate the density contrast of the falling material.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **179** Type: **Poster**

Solar radio flare observations with the Radio Neutrino Observatory Greenland (RNO-G)

The Radio Neutrino Observatory Greenland (RNO-G) hunts for neutrinos at the highest energies interacting in the deep glacial ice. Seven of its 35 stations (24 antennas/station) have been taking data since 2022. RNO-G is sensitive in the 80-750 MHz region and records snapshots of time-domain waveforms of with GSa/s sampling rate whenever signals above the thermal noise floor trigger a station. RNO-G regularly observes solar flares coincidently with dedicated solar observing radio instruments like Callisto and SWAVES, and with X-class GOES X-ray flares. Data is available in full time- and frequency resolution for all flares. The recorded waveforms show significant impulsivity on O(10's ns) timescales. While these pulses constitute a unique calibration source for the absolute pointing of RNO-G, they also indicate small-scale emission in the sub-structure of radio flares.
In this contribution we highlight the time-domain features seen in the solar flares observed with RNO-G in order to promote the availability and potential usefulness of RNO-G data to the solar physics community.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **181** Type: **Poster**

Spectral diagnostics of a bright eruptive prominence detected with the Metis coronagraph

We present unique results of a recent study of bright eruptive prominence embedded in the core of a CME observed by the Metis coronagraph on board the Solar Orbiter on April 25-26, 2021. Metis provides simultaneous imaging in the hydrogen Lyman alpha line and in the VL. Triangulation is used to estimate the de-projected height and velocity of the structure. Based on previous studies of the He-D3 line polarization, we have estimated the intensity of the He-D3 line. These spectral observations are used together with the non-LTE diagnostics to derive physical parameters of this eruptive prominence observed very high in the solar corona.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **182** Type: **Poster**

EUI onboard Solar Orbiter: unique data for high resolution, far corona and connection science

The Extreme Ultraviolet Imager (EUI) onboard Solar Orbiter is composed of three telescopes, the Full Sun Imager (FSI), and two High Resolution Imagers observing in EUV (HRIEUV) and Lyman-alpha (HRILYA). EUI observes the Sun from the smallest features at the base of the corona and in the chromosphere up to the largest scales in the extended corona.
EUI observations are indispensable for heliospheric connection science as they provide essential information about coronal source regions of eruptive events and solar wind. FSI reveals structure and evolution of the corona to unprecedented distances from the Sun (transients being tracked up to 6 solar radii).
EUI's unparalleled spatial and temporal resolution at perihelion naturally leads to discovery of new structures at previously inaccessible scales such as campfires, picojets, and the smallest decayless kink waves observed to date.
This poster aims to show researchers the way to EUI observations and data analysis. The reader is directed to the latest EUI Data Release, tools and overviews, and kindly invited to become part of the EUI community, facilitated by EUI's open data policy and fast data availability. A particularly effective way to join the EUI community is the Guest Investigator Program of the Royal Observatory of Belgium (ROB), which allows selected researchers to spend a few weeks with the EUI, PROBA2/SWAP or PROBA2/LYRA PI team in Brussels to obtain expert knowledge on the instrument, to participate in observation planning according to the needs of their proposal, and to conduct their research in collaboration with ROB scientists.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **183** Type: **Poster**

Coronal dimmings associated with the May 2024 flare/CME events from AR 13664

During the first half of May 2024, Active Region 13664 was the source of 11 X class flares, over 50 M class flares as well as numerous coronal mass ejections (CMEs). The high number of CMEs launched in quick succession caused the largest geomagnetic storm since two decades. The most distinct phenomena in the low corona associated with CMEs and strong flares are coronal dimmings, which are localized regions of transiently reduced emissions observed in extreme ultraviolet (EUV) and soft X-ray (SXR) wavelengths. As such, they are important diagnostics for CME activity (in particular for Earth-directed CMEs) and provide insights on the accompanying physical processes in the low corona. In this contribution, we present a systematic study of the coronal dimmings associated with the flares in AR13664 as observed by the AIA instrument onboard the Solar Dynamics Observatory between the 3rd and 14th of May. We study the dimming parameters (area, brightness, magnetic flux) and relate them with key characteristics of the observed CMEs. We also attempt to understand the magnetic configuration involved in these eruptive events by studying the anchor points of the coronal dimmings and the associated flare ribbons.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **184** Type: **Talk**

Simulation of particle acceleration and transport in 3D turbulent reconnection regions

Monday 9 September 2024 15:45 (15 minutes)

Observation and simulation studies suggest that particles can be accelerated in the current sheet and above the loop-top during solar flares. Considering the flare process is a turbulent 3D phenomenon in reality, 3D models are crucial for understanding and interpreting particle acceleration in flares. Using the Stochastic Differential Equations (SDE) method to solve the Parker Transport Equation, we investigate electron acceleration in the current sheet and above the loop-top in a 3D simulation. We find that in the classical 2D model, in non-classical configurations, the shock distribution can also accelerate particles. However, in the 3D simulations, particles can still be accelerated to hundreds of keV but the particle acceleration capability is significantly reduced. After turbulence appears at the loop-top, the fragmented TS can still accelerate particles without the need for a stable TS as in the classical model. Additionally, we observe particle acceleration in the current sheet. These findings are significant for our understanding of particle acceleration in solar flares.

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Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **185** Type: **Poster**

Comparison of the photospheric line-of-sight velocity measured by SO/PHI-HRT and SDO/HMI

Since its launch in February 2020, Solar Orbiter (SO) has been providing high-quality data from the many layers of the solar atmosphere. The Polarimetric and Helioseismic Imager onboard SO (SO/PHI) is a spectropolarimeter scanning the Fe I line at 617 nm, the same line sampled by SDO/HMI and many other on-ground instruments providing data of the solar photosphere. A first comparison of the magnetic field vector obtained by SO/PHI and SDO/HMI has already been discussed in Sinjan et al. 2023 and Moreno Vacas et al. 2024. Here we compare the line-of-sight velocity measured by the High Resolution Telescope (HRT) of SO/PHI and SDO/HMI. The goal of this comparison is multi-purpose: firstly, reliable measurements of up- and down-flows from SO/PHI-HRT are crucial when SO is facing the far side of the Sun; secondly, a good cross-calibration is mandatory to achieve stereoscopic measurements of horizontal flows from two vantage points. For this purpose, we compare the line-of-sight velocity measured by SO/PHI-HRT and SDO/HMI on 29 March 2023, when SO was crossing the Sun-Earth line at 0.39 au from the Sun. The results show good agreement between the two different instruments. Instrumental effects and large scale velocities on the Sun are also considered, but a deeper investigation is needed to carefully treat and understand the deviation between the two instruments.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **186** Type: **Poster**

Onset of penumbra formation

The formation of penumbrae has been studied by many authors and, yet, many questions remain to be answered. Penumbra formation is a target of opportunity that, due to its relatively fast development, is not common to observe with very high spatial resolution. In this work we present ground-based spectropolarimetric observations of a forming sunspot on the NOAA 11024 recorded with the "Göttingen"Fabry-Pérot Interferometer (GFPI) on 9 July 2009. We tracked the vector magnetic field and line-of-sight velocity in selected regions over a 2-hour period, spanning from the stages preceding formation to fully developed penumbral filaments. We find that each selected region presented a distinctive flow prior to penumbra formation. Despite the influence of projection effects on the retrieval of the plasma parameters, our results indicate that there are no unique flows prior to penumbra formation. However, all the analysed penumbral filaments started forming at the umbral boundary and extended radially outward while exhibiting the Evershed flow right from the beginning of the filament formation.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **187** Type: **Poster**

Benchmarking Solar Simulations: An Analytical Solution for Non-Linear Diffusivity

Numerical simulations have proven invaluable in understanding the physics of the Sun. With increasing computing power available, we launch increasingly complicated multi-physics simulations. Every single physics module requires validation and we must understand the role of each of these physical processes. This work presents an analytical solution for non-linear diffusivity in 1D, 2D, and 3D. We will use it to benchmark the Spitzer conductivity module in the single and multi-fluid radiative MHD codes Bifrost and Ebysus. The solution is based on the self-similar solutions by Pattle, 1959, which required the diffusing quantity to be zero beyond a finite radius. We have surpassed this constraint, allowing for a small non-zero background value. This problem is highly relevant in the Solar atmosphere, where energy released in nanoflares or originating in the hot MK Corona diffuses to the much colder kK Photosphere. Beyond this use, the derivation and argumentation are general and can be applied to other non-linear diffusion problems.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **188** Type: **Poster**

Identifying Alfvén Wave Modes in the Solar Corona

The Solar Atmosphere is subject to a number of oscillatory motions. Magnetic flux tubes acts as wave guides from the lower atmosphere to the upper. In a uniform plasma, there are three distinct magnetohydrodynamic (MHD) wave modes: Alfvén and fast and slow magnetoacoustics waves. In a non-uniform plasma, like the solar atmosphere, these wave modes no longer decouple. It follows that identifying them becomes non-trivial. However, a method for accurate wave mode identification would yield a valuable tool both in coronal seismology and to determine to what extent waves contribute to coronal heating. We have investigated a method which utilises different properties of each wave mode to identify Alfvén-, fast- and slow-like MHD waves in the plasma flow. For the first time, we show how this wave mode identification scheme can be used in actual observations to identify Alfvén-like waves in a coronal loop. This is done by comparing the identifier for the Alfvén-like wave applied to both a numerical simulation of a coronal loop and a synthetic emission of the same coronal loop as if it was observed by the forthcoming Multi-Slit Solar Explorer (MUSE) mission. We have demonstrated two procedures for this identification scheme, depending on the observation line-of-sight, providing a proof-of concept for how this method could be used in observations to identify Alfvén-like waves.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **189** Type: **Talk**

Are Switchbacks the Magnetohydrodynamic Equivalent of Smoke Rings?

Tuesday 10 September 2024 14:30 (15 minutes)

Switchbacks are large Alfvénic deflections , or even reversals, of the magnetic field in the solar wind. Many authors have suggested that switchbacks are linked to interchange reconnection in the solar corona, but the manner of this connection remains unclear. In our previous work we have shown that both the interchange reconnection process itself (Wyper et al. 22) as well as coronal jets and jetlets that involve interchange reconnection (Wyper et al. 18, Pariat et al. 09) launch Torsional Alfvén waves into the solar wind. Furthermore, photospheric swirls are also thought to be an abundant source of coronal Torsional Alfvén waves.

Here we present a new study of how such Torsional Alfvén waves can evolve into switchbacks in an super-radially expanding solar wind. We find that through a combination of length contraction due to the reduction in Alfvén speed with height, and the onset of a Rayleigh-Taylor-like instability the waves evolve into a vortex ring configuration involving Alfvénic radial field reversals. We show that this evolution is relatively insensitive to the injection time or driving speed, provided a sufficient amount of twist is injected overall. We also find that the switchbacks within the vortex rings have a preferential deflection near helmet streamers that may explain observed RTN deflection biases. Overall, our findings support the idea that Torsional Alfvén waves launched into the solar corona can provide seed perturbations for the formation of switchback radial field reversals within the solar wind.

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Presenter: WYPER, Peter

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **190** Type: **Poster**

Predicting Soft X-ray Emissions for Solar Flare Forecasting Using a Self-Supervised CNN Trained on Solar Dynamics Observatory Data

Predicting solar flares is crucial for communications and satellite operations. Previous Machine Learning (ML) work focused on classifying flares with labels such as M and X, overlooking the continuous nature of X-ray flux. Our approach uses Convolutional Neural Networks (CNNs) to predict X-ray flux from Helioseismic and Magnetic Imager (HMI) and Extreme Ultraviolet (EUV) images of the Sun, using a curated dataset from the Solar Dynamics Observatory (SDO). Inputs represent different layers of the solar atmosphere: HMI magnetograms (photosphere) and AIA wavelengths: 94 Å (flaring regions), 171 Å (quiet sun), 193 Å (coronal structures), and 304 Å (chromosphere). Data are processed to match SDO images and GOES X-ray fluxes. Limb-brightening correction is applied to avoid biases. We compare full-disk images versus synoptic maps as CNN inputs.
We utilise the Model Genesis self-supervised framework, originally developed for medical imaging. It consists of an encoder-decoder architecture to reconstruct artificially deformed solar images by transformations such as non-rigid deformations and pixel shuffling. The encoder part is attached to our CNN and pre-trains it. This process facilitates extracting robust features for better performance. Subsequently, we train to predict X-ray flux. We post-process outputs to associate X-ray flux predictions with flare indices to compare our work with other classifications. We benchmark this approach against state-of-the-art methods using True Skill Score (TSS) for categorical predictions and Brier Skill Score (BSS) for probabilistic predictions. Future work includes eXplainable AI (XAI) to identify which active regions and parts of the solar atmosphere contribute most to flare predictions.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **191** Type: **Poster**

Unveiling the dynamics and thermal structures of the jet base from SO high-resolution observation

Solar jets, characterized by small-scale plasma ejections along open magnetic field lines or the limbs of large-scale coronal loops, play a crucial role in the dynamics of the solar atmosphere. They are often associated with other solar activities, including campfires, filament eruptions, coronal bright points, flares, and coronal mass ejections. Although spectral and EUV images have been widely used to analyze the formation and evolution of jets, the detailed three-dimensional structure at the base of the jet has not been extensively studied due to the limitations of observation resolution.

The Solar Orbiter (SO) enables us to investigate the structure of solar jets with much higher spatial and temporal resolutions and from different angles. Using the EUI/HRI data, we observed "firework" structures, which are the dynamic manifestations of the jet base. This bright structure is located above the magnetic neutral line, the region where reconnection occurs. Numerous flows spread out from the reconnection point to the surrounding area at speeds exceeding 100 km/s. By analyzing the evolution of the magnetograms from PHI/HRT, we identified a clear flux cancellation process at the footpoint of the jet. Additionally, we studied the thermal structure of the jet base using the SPICE data.

In conclusion, these high-resolution observations provide new insights into the complex dynamics and thermal structures at the base of solar jets, advancing our understanding of their formation and contribution to solar atmospheric phenomena.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **192** Type: **Talk**

Can we find distinct flare precursors observed with the IRIS spectrograph?

Wednesday 11 September 2024 10:15 (15 minutes)

Solar flare prediction has often been studied with data from the Solar Dynamics Observatory (SDO), which provides images of the full solar disk in different wavelength bands, probing different heights of the solar atmosphere, including the photospheric magnetic field. Recent studies have shown that spectroscopic data such as observations with the Interface Region Imaging Spectrograph (IRIS) may contribute to improving solar flare predictions in the future.
IRIS has a limited field of view and thus variable pointing, and additionally, the spectrograph slit only covers parts of an active region, which limits its potential for long-term forecasting. Therefore, we aim to study short-term spectral flare precursors observed with IRIS, occurring up to 1 hour before flare onset.
We use machine learning techniques to automatically mark where a flare occurs in an active region and extract the time-series of spectra of these pixels. We train classification models specifically to highlight such areas, solely from the shape of the spectra before the flare. Additionally, we investigate if there are distinct spectral shapes occurring before each flare, that can be categorized as strong flare precursors.
We find that the areas highlighted by the machine learning models match well with the later location of the flare, and that the Magnesium II h&k triplet emission is a strong precursor, which often occurs at the future onset location of a solar flare. We speculate that this is because of chromospheric heating before flares.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **193** Type: **Poster**

Solar Flare Forecasting Utilizing Deep Survival Analysis

Solar flares and accompanying coronal mass ejections are drivers of intense space weather, which can have major impacts on e.g., satellite communication, navigation, and power-grid integrity. To this day, precise predictions of solar flare events remain challenging, due to the complexity of the underlying physical processes.
This study aims to improve solar flare forecasting through the application of survival analysis, a method traditionally used in fields like medicine and economics to model the timing of events and their related data features. In extension to previous studies, we aim to model not only the likelihood of a flare happening within the next few days but also its timing.
We demonstrate the time-to-event prediction capabilities of deep survival neural networks based on multivariate time series extracted from solar photospheric vector magnetograms in Spaceweather HMI Active Region Patch (SHARP) series.
Preliminary results indicate that deep survival analysis provides a promising new avenue for more precise event time predictions of solar flare outbursts. We found that including active regions that produce multiple flares in both training and validation sets, while keeping the flares themselves separated, yields highly accurate predictions with hour-level precision.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **194** Type: **Poster**

2D NLTE Modelling of Obsverved Cool Coronal Loops

The modelling of cool coronal loops can aid our understanding of processes in the upper solar atmosphere, and better understand their dynamics and evolution.
In this study, we explored the structure, and principal Lyman, Balmer, and MgII h&k emission of cool loops. This was achieved through the use of a 2D NLTE (i.e. departures from local thermodynamic equilibrium) cylindrical radiative transfer code. Using this, we generated 45 evenly (angularly) spaced circular cross sections of half of the loop. Then, using fourth order weighted essentially non oscillatory interpolation (WENO4), we connected these 45 cross sections together to construct half of the loop, which was subsequently mirrored to construct the full loop. Two loop geometries were considered, semicircle and dipole.
We then compared these simulations with observations from the Interface Region Imaging Spectrograph (IRIS) to see how effectively we could reproduce these observations.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **195** Type: **Talk**

Spectroscopic measurements from Solar Orbiter Full Disk Mosaic

Thursday 12 September 2024 14:40 (15 minutes)

One crucial objective of Solar Orbiter is to explore the connection between the solar surface and the heliosphere. Since March 2022, several Solar Orbiter Observing Plans (SOOP) have been run to address this goal, ranging from Connection Mosaic to Slow Solar Wind. None of these SOOPs gave a global view of the Sun.
A dedicated SOOP, led by the Extreme Ultraviolet Imager, has been designed to scan the full disk using 25 pointings. Each pointing lasted 5-6 minutes, allowing the Spectral Imaging of the Coronal Environment (SPICE) instrument to use only its wider 30" slit to take images, for assembling into the full disk mosaic.

We decided to add a new flavour optimised for SPICE with each pointing lasting 22 minutes. This allowed us to provide proper monochromatic images of the full disk, using the 6" narrow slit, taken in nine spectral lines formed between 10,000K and 1,000,000K.
This SOOP ran twice at a solar distance of 0.7AU, which added the benefit of joint observations with the coronagraph Metis. This allows a thorough view of the spectroscopic features of the full disk, and the preliminary tracking off limb into the heliosphere.

Here we focus on the SPICE spectroscopic measurements, providing intensity maps for the full Sun using selected transition region and coronal lines, and building up basic composition maps to be traced into the heliosphere. This work is ongoing in preparation for the next run (October 2024), and for the first comprehensive polar view from high latitude foreseen for 2025.

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Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **196** Type: **Poster**

Denoising Helioseismic Far-Side Images with Spatial and Temporal filters

Helioseismology can detect active regions on the Sun's far side days before they rotate to the Earth's side, using solar acoustic oscillations. These far-side maps provide an important input for space weather models. Recent advances in theoretical and computational helioseismology have improved far-side imaging, which enables high-confidence detection and daily tracking of medium-size active regions. However, these images still suffer from substantial noise due to the stochastic nature of the oscillations. In practice, temporal averaging and Gaussian smoothing have been used to reduce the noise level. These approaches indeed improved the signal-to-noise ratio, yet, the duration for temporal averaging and width for Gaussian filters are chosen based on experience, which are far from optimal. Our study aims to denoise these images by implementing spatial and temporal filters in spectral space to mitigate this noise.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **197** Type: **Talk**

Turbulent Dynamics in Gradual-Phase Flare Loops: Insights from 3D MHD Simulations

Wednesday 11 September 2024 12:25 (15 minutes)

The gradual phase is a relatively quiet stage in the evolution of a flare, encompassing most of its duration. During this phase, the hot and dense flare loops, formed by reconnection and chromospheric evaporation in the impulsive phase, gradually cool down and decrease in density. We propose and demonstrate with 3D simulation that the seemingly calm gradual-phase flare loops are filled with low-speed turbulent motions until the flare ends. The formation of these motions is related to the characteristics of the flare loops: high density. Due to the relatively small size of the flaring regions, the density variation length scale is much smaller than the atmospheric scale height at the corresponding temperature, involving the Lorentz force in maintaining the density gradient. The force balance between the Lorentz force and thermal pressure is unstable, leading to Rayleigh-Taylor type instabilities that grow on sub-minute timescales within the loops, resulting in sustained turbulent motions until the region returns to typical coronal density. Our research uncovers an energy conversion pathway in flares: chromospheric evaporation carries significant energy into the flare loops, part of which converts into transverse wave energy through instabilities, with these waves then transporting energy back to the lower atmosphere.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **198** Type: **Poster**

MHD Simulation of Three-dimensional Turbulent Magnetic Reconnection within the Solar Flare Current Sheet

Solar flares can release coronal magnetic energy explosively and may impact the safety of near-Earth space environments. Their structures and properties on the macroscale have been interpreted successfully by the generally accepted 2D standard model, invoking magnetic reconnection theory as the key energy conversion mechanism. Nevertheless, some momentous dynamical features discovered by recent high-resolution observations remain elusive.
Here, we report a self-consistent high-resolution 3D magnetohydrodynamical simulation of turbulent magnetic reconnection within a flare current sheet. It is found that fragmented current patches of different scales are spontaneously generated with a well-developed turbulence spectrum at the current sheet, as well as at the flare loop-top region. The close coupling of tearing mode and Kelvin–Helmholtz instabilities plays a critical role in developing turbulent reconnection and in forming dynamical structures with synthetic observables in good agreement with realistic observations.
We also develop an efficient method for identifying locations and configurations of 3D reconnection. It is shown that this method can precisely identify the local structures of discrete magnetic field. Through the information of nonideal electric field and the geometric attributes of magnetic field, the local structures of reconnection sites can be effectively and comprehensively determined. With the aid of this method, we precisely recognize and trace the 3D fine reconnection structures in our simulation and obtain their statistical rules, which intuitively exhibit the multi-scale physical pictures of 3D turbulent reconnection within the flare current sheet.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **199** Type: **Invited**

The never-ending attraction of the Sun's magnetic personality

Thursday 12 September 2024 16:50 (30 minutes)

Its magnetic field turns the Sun from a dull, middle-aged star into a lively, variable, energetic and attractive subject of study. The field relieves our star from the monotony of a placid, somewhat boring existence, providing it instead with a restless and engaging magnetic personality. This is seen in the play of its ever-changing magnetic features such as mighty sunspots and faculae at the solar surface, majestic prominences, plage and spicules in the chromosphere, and towering loops, plumes and holes in the corona. These give the Sun its sparkle, from time to time culminating in the fireworks set off by flares and coronal mass ejections. This talk will provide a very personal selection of aspects of the structure and evolution of the solar magnetic field, how it shapes the Sun's atmosphere and makes the Sun variable and active and how this variability and activity compares with those of other stars.

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Session Classification: Senior Prize Lecture

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **200** Type: **Poster**

The use of artificial intelligence techniques in the prediction of the solar activity cycle 25

Predicting future solar activity cycles is a complex task that requires the incorporation of machine learning techniques. The aim of this study is to apply neural network techniques to the prediction of the 25th period of the solar cycle series. We consider two methods for the prediction models, namely the Nonlinear AutoRegressive eXogenous (NARX) and the Voting Regressor (VR) (with combinations). The input data are the observed sunspot numbers (SSN) of the last four cycles. Several models are constructed and their performance is evaluated using the following metrics: Root Mean Square Error (RMSE), Pearson Correlation Coefficient (PCC) and Nash-Sutcliffe Efficiency (NSE) evaluation metrics. The obtained results from the VR algorithm of the solar maximum activity of the 25th cyles is 119.19 < $R_{max,VR}$ < 126.27 which is expected to be in the period between November - December 2024. The evaluation metrics obtained are 3.4 < $RMSE_{VR}$ < 6.7, 0.997 < r_{VR} < 0.998 and 0.972 < NSE_{VR} < 0.994. The results obtained from the NARX algorithm show a maximum value of $R_{max,NARX}$ = 130.84, which is expected in April 2025. The evaluation metrics are $RMSE_{NARX}$ = 7.515, NSE_{NARX} = 0.972 and r_{NARX}= 0.986. The results of these two models are compared with the observations and used to predict the next solar cycles.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **201** Type: **Poster**

High-resolution observations of small-scale activity in coronal hole plumes

Coronal hole plumes, largely radial ray-like structures located in coronal holes, are often the targets of studies of magnetohydrodynamic waves and of solar wind origins in the corona. The plume bases seem to be very active with many small-scale transients observed, which are likely important to the formation and evolution of plumes and could contribute to the solar wind. We study three plumes within an equatorial coronal hole observed on 13 October 2022 by the High Resolution EUV telescope, part of the Extreme Ultraviolet Imager on board Solar Orbiter. By applying two different identification techniques, we detect tens to hundreds of small-scale brightenings at the plume bases. The statistical analysis of their properties (intensity, lifetime, area, shape, velocity) indicates that the majority of the observed brightenings are characterized by their small-scale nature (occupying an area less than 1.3 Mm^2), transient behavior (with a lifespan of less than 5 minutes), and display slightly elongated morphologies near the plume bases. The intensities of brightenings from different plumes are similar once the plume brightness is taken into account. Most of the brightenings appear to move with a velocity component in the plane of sky of less than 10 km/s. We correct the plane of sky speeds by considering the magnetic field data acquired by the Polarimetric and Helioseismic Imager on Solar Orbiter. Still, their 3-dimensional velocities are found to be substantially lower than (and difficult to reconcile with) the apparent outflow velocities (~100 km/s) detected at greater heights in the plumes.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **202** Type: **Invited**

State-of-the-art observational aspects of MHD waves in the lower atmosphere

Monday 9 September 2024 12:10 (25 minutes)

MHD waves are recognized as significant contributors to the energy budget of the solar atmosphere, the acceleration of the solar wind and the composition of coronal plasma. Recent advancements in instrumentation, techniques, and processing methods have unlocked new diagnostic capabilities for exploring the excitation and propagation of MHD waves within various magnetic structures in the solar atmosphere. In this contribution a broad state-of-the-art overview of recent advancements in the identification, characterization and analysis of oscillations observed in diverse magnetic configurations in the lower solar atmosphere will be provided. Special attention will be given to the perspectives that upcoming instruments will introduce to the field.

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Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **203** Type: **Poster**

Deep learning image burst stacking to reconstruct high-resolution ground-based solar observations

To study and resolve small-scale features in the solar atmosphere, ever larger telescopes are built, such as the European Solar Telescope (EST) or the Daniel K. Inouye Solar Telescope (DKIST). However, diffraction-limited observations are not feasible for large aperture telescopes because the Earth's turbulent atmosphere distorts the raw observations. Therefore, post-image reconstruction techniques must be applied to obtain high resolution, high quality observations.
We provide an AI tool based on deep learning which is capable of translating a short exposure image burst to a single high resolution high quality observation. The neural network we use was developed by Jarolim et al. (2023) and is based on a Generative Adversarial Network (GAN) that employs unpaired image-to-image translation. This allows translating a short exposure image burst consisting of 100 images to a single high quality observation in real time. This approach can outperform state-of-the-art methods such as speckle reconstruction and multi-frame blind deconvolution (MFBD).
We applied the tool to observation from the 1.5 m GREGOR telescope. The results demonstrate that our approach provides faster and more robust reconstructions by showing less artifacts compared to the speckle reconstruction method. We explicitly show that our neural network approach uses the information of 100 short exposure observations for the reconstruction.

References:

Jarolim, R., Veronig, A., Pötzi, W. Podladchikova, T. (2023). "Instrument-To-Instrument translation: Instrumental advances drive restoration of solar observation series via deep learning." under revision, Nature Communications DOI: 10.21203/rs.3.rs-1021940/v1

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **204** Type: **Talk**

CME small-scale structures: new insights from white light observations taken between 0.06 – 1 AU

Tuesday 10 September 2024 17:40 (15 minutes)

Parker Solar Probe (PSP) and Solar Orbiter (SO) observe the Sun from unprecedented close-in orbits out of the Sun-Earth line. Due to the highly elliptical orbits of the respective S/C, they cover varying heliocentric distances during their encounters around the Sun. They both provide high-resolution observations of the heliosphere through their white light heliospheric imagers: PSP/WISPR and SO/SoloHI. Using also observations from the HI-1 heliospheric imager onboard STEREO-A (ST-A) at about 1 AU, we catalog a set of events observed simultaneously from at least two of the imagers and highlight their morphological differences when observed from different viewpoints. This allows us to investigate the 3D location, morphology, and evolution of the internal magnetic fine structures in the interiors of CMEs. We derive the three-dimensional information of small-scale magnetic structures for the events on December 8, 2022, and on September 24, 2023. ST-A/HI1 and PSP/WISPR (between 0.11-0.16 AU) observed the former (a filament-related CME) from a similar longitudinal range. Still, they show a different global appearance of the CME, presumably because of the shorter line-of-sight integration of WISPR. For the event on September 24, 2023, WISPR (at 0.18 AU) and SO/SoloHI (at 0.4 AU) were oppositely located in longitude and, though observing the event from different distances, their observations reveal many common features in their FoV. We demonstrate that the CME consists of various morphological groups of fine structures, which can be related back to the Sun, and explore how CME structures appear differently when observed from different viewpoints.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **205** Type: **Poster**

Anisotropic density turbulence from the Sun to 1 au: remote and in-situ observations

Radio signals propagating via solar corona and solar wind are significantly affected by density fluctuations, impacting solar radio burst properties as well as the observations of sources viewed through the turbulent atmosphere. Using large-scale simulations of radio-wave transport, the radial profile of anisotropic density turbulence from the low corona to 1 au is explored. For the first time, a profile of Heliospheric density fluctuations is deduced that accounts for the properties of extra-solar radio sources, solar radio bursts, and in-situ density fluctuation measurements in the solar wind at 1 au. Combining the anisotropic turbulence model with the space-craft frequency broadening measurements radial and perpendicular to radial velocities are deduced. The deduced properties of turbulence could be used to estimate the energy deposition rates due to Landau damping ion-sound waves and specific energy rate Alfven wave turbulent cascade at large scales.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **206** Type: **Talk**

Impact of small-scale photospheric magnetic reconnection events on the upper atmosphere

Monday 9 September 2024 18:00 (15 minutes)

Ellerman bombs are sites of magnetic reconnection in the deep solar atmosphere. They can be observed as strong enhancements of the hydrogen Balmer lines and display rapid variability on small spatial and temporal scales. They are typically found in young active regions with vigorous emergence of magnetic fields. High-spatial resolution observations with the Swedish 1-m Solar Telescope in La Palma showed that Ellerman bombs can be also be found in large numbers in the quiet Sun. These quiet Sun Ellerman bombs are typically smaller and shorter lived than their active region counterparts. A recent study in the Balmer H-epsilon line showed that the quiet Sun may host more than 750,000 Ellerman bombs at any time. We analysed co-temporal SST and IRIS observations and found that a number of the longer lived quiet Sun Ellerman bombs can be associated with signal in the IRIS transition region SJI 1400Å and Si IV spectral lines. In another study, we found a number of examples that suggest a connection between quiet Sun Ellerman bomb events and spicule activity. This suggest that at least some spicules are driven by magnetic reconnection in the deep atmosphere.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **207** Type: **Poster**

Ca II K brightness as a function of magnetic field strength and characteristics of the observations

Solar observations have often served as benchmarks of stellar conditions. A particularly illustrative example of the above link is given by the observations in the Ca II H and K lines at 396.847 nm and 393.367 nm, respectively, which are the two deepest and broadest absorption lines in the visible spectrum of the Sun. Although widely observed over the years, several aspects of the emission of these lines are however still not fully understood. This is the case of e.g. the exact relationship between Ca II K emission and magnetic field strength. To the aim of reassessing this relationship, we analysed state-of-the-art observations of the solar atmosphere obtained at the Swedish Solar Telescope with the Crisp Imaging Spectropolarimeter and Chromospheric Imaging Spectrometer instruments on regions characterized by a different ambient magnetic field. On these observations we analyzed the dependence of the Ca II K line brightness on different surrounding conditions of the solar atmosphere and characteristics of the observations, such as spectral bandwidth and spatial scale. The results derived from our study are functional to e.g. high-precision transit photometry applied in exoplanets research, investigation of the solar-stellar connection, and accurate reconstructions of the evolution of the solar magnetism over decadal and centennial time scales.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **208** Type: **Poster**

Metis Solar Wind Speed Maps during the first half of the 25th solar cycle: the role of the assumed electron temperature radial profile

The derivation of the coronal proton bulk speed is one of the main goals of the Metis coronagraph on board the Solar Orbiter S/C. Metis is capable of acquiring both visible-light (VL) broadband (580-640 nm) polarized brightness (pB) images and ultraviolet (UV) HI Lyman-alpha (121.6 nm) images simultaneously with high temporal (up to 1 s for the UV and 60 s for VL/pB) and spatial (down to 4500 km/pixel) resolution. The proton outflow speed is derived from these data through the Doppler-dimming diagnostics. Here solar wind speed maps are presented that are derived for four Solar Orbiter Remote Sensing Windows. This outlines the evolution of the solar wind during half of the 25th solar cycle (from the end 2021 to the end 2023). Different literature electron temperature profiles are used as a parametric input for the Doppler-dimming diagnostics, thus deriving the sensitivity of the Doppler-dimming diagnostics to the knowledge of the electron temperature profile of the coronal plasma in different regions in the field of view (e.g. streamer, coronal holes). For the first time, a novel dynamical (DYN) model from literature was used to better constrain the electron temperature profile adopted in the Doppler-dimming diagnostics. Preliminary results show the role played by the knowledge of the coronal electron temperature in the derivation of the solar wind maps.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **210** Type: **Poster**

Magnetic helicity and energy budgets of jet events from an emerging solar active region

Using photospheric vector magnetograms obtained by the Helioseismic and Magnetic Imager on board the Solar Dynamic Observatory (SDO) and a magnetic connectivity-based method, we compute the magnetic helicity and free magnetic energy budgets of a simple bipolar solar active region (AR) during its magnetic flux emergence phase which lasted $\sim$47 hrs. The AR did not produce any coronal mass ejections or flares with an X-ray class above C1.0 but it was the site of 60 jet events during flux emergence. The helicity and free energy budgets of the AR were below established eruption-related thresholds throughout the interval we studied. However, in addition to their slowly-varying evolution, each of the time profiles of the helicity and free energy budgets showed discrete localized peaks, eight of which occurring at times of jets emanating from the AR. These jets featured larger base areas than other jets triggered in the AR. We estimated, for the first time, the helicities and free magnetic energies associated with the jets; they vary in the ranges $(0.5-7.1)\times10^{40}$ Mx^2 and $(1.1-10.4)\times10^{29}$ erg, respectively. The pertinent percentage changes were significant and ranged from 13% to 76% for the normalized helicity and from 9% to 57% for the normalized free energy. Our study indicates that occasionally jets may play a significant role in the evolution and dynamics of emerging solar active regions by having a significant imprint in the evolution of their helicity and free magnetic energy budgets.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **211** Type: **Poster**

Radiative Magnetohydrodynamic Simulation of the Confined Eruption of a Magnetic Flux Rope: Unveiling the Driving and Constraining Forces

Flares and CMEs are different manifestations of the same energy release process, during which flux ropes act as the key magnetic structure. However, due to the lack of in-situ observation, it is still difficult to capture the dynamic evolution of flux rope in detail. Here, we analyze the forces that control the dynamic evolution of a flux rope in a 3D RMHD simulation conducted with the MURaM code, whose eruption gives rise to a C8.5 confined flare. The flux rope rises slowly with an almost constant velocity of a few km/s in the early stage when the gravity and Lorentz force are nearly counterbalanced. After it rises to the height where the decay index of the external poloidal field satisfies the torus instability criterion, the significantly enhanced Lorentz force breaks the force balance and drives the rapid acceleration of the flux rope. Fast magnetic reconnection is immediately induced within the current sheet under the erupting flux rope, which provides strong positive feedback to the eruption. The eruption is eventually confined due to the tension force from the strong external toroidal field. Our result provides a detailed and comprehensive analysis on the dynamic evolution of flux rope eruption, which suggests that the gravity of plasma plays an important role in sustaining the quasi-static stage of the preeruptive flux rope, while the Lorentz force, which is contributed from both the ideal MHD instability and magnetic reconnection, dominates the evolution of flux rope during the eruption process.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **212** Type: **Talk**

What can we learn about coronal mass ejections from their associated coronal dimmings?

Tuesday 10 September 2024 17:10 (15 minutes)

Coronal dimmings are sudden decreases of the solar EUV and soft X-ray emission caused by coronal mass ejection (CMEs). From the solar observations, we know that dimming regions map to the bipolar ends of closed magnetic field lines that become stretched or temporarily opened during an eruption, and the decrease in the emission is a result of the depletion of coronal plasma caused by the expansion and mass loss due to the CME. We present recent statistical studies that showed distinct correlations between characteristic CME mass and speed with key parameters of the associated coronal dimmings such as their spatial extent and intensity drop. We also discuss how the locations of the coronal dimmings may help us to better understand the origin of the eruption. Finally, we outline how full-Sun EUV measurements provide us with a means to connect the solar observations to late-type stars, and to develop methods for the detection of stellar coronal mass ejections.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **213** Type: **Poster**

Oscillatory Reconnection: A Comparison Against Steady-State Solutions

Reconnection is a fundamental process that is at the heart of dynamic events such as solar flares. Despite these phenomena being time-dependent, they are often explained using steady-state theoretical reconnection models such as Sweet-Parker and Petschek. In this presentation I will compare the steady-state models of reconnection with a high-resolution simulation of oscillatory reconnection; a time-dependent, wave-generating form of reconnection. This comparison will include investigations into the reconnection rates, the characteristics of the current sheets and the energy conversion in the models. A shock identification algorithm, ShockID (Snow et al 2021), is also deployed to investigate the myriad of shock phenomena present in the oscillatory reconnection system.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **214** Type: **Poster**

Physically-consistent Riemann solvers for accurate and robust MHD modelling with low plasma beta

The solar atmosphere hosts various physical phenomena driven by strong magnetic fields, but accurate and efficient MHD numerical modelling of such phenomena is challenging. Specifically, high accuracy typically requires low numerical dissipation, which may come with high computational costs and is prone to numerical oscillations. Conversely, efficiency demands sufficient robustness, which needs adequate numerical diffusion. These challenges must be addressed adequately in MHD models, such as the newly developed fully-implicit MHD global solar coronal model, COCONUT.

While COCONUT currently uses finite-volume discretisation and approximate Riemann solvers that are well-established for MHD simulations, their robustness is often challenged under strong magnetic fields or, more precisely, in low-beta plasma. One important reason is that magnetic energy becomes dominant compared to the much smaller thermal energy. Thus, even a small numerical discrepancy in magnetic energy may lead to negative thermal energy, causing the positivity-preservation problem, typically tackled by adding numerical diffusion. This issue, of course, also exists in other plasma MHD simulations.

Without adding numerical diffusion, we ensure physical consistency in HLL-type Riemann solvers, specifically the consistency between the numerically calculated magnetic field and magnetic energy, which is frequently broken in numerical solutions. The resulting Riemann solvers are more robust than their widely used counterparts, yet with less diffusive effects observed in fully implicit global coronal modelling. Additionally, we have discussed the positivity-preservation property of the proposed Riemann solvers and explained the reason behind their improved robustness.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **215** Type: **Talk**

The May 2024 flare sequence: a rich opportunity for QPP analysis

Thursday 12 September 2024 09:55 (15 minutes)

Monster active regions 13663 and 13664 produced not less than 18 X-class solar flares between May 3 and May 15, before rotating out of view from Earth. Despite this, AR 13664 continued to exhibit significant activity, generating numerous events observed by instruments onboard the Solar Orbiter mission. This extraordinary sequence of strong flares not only delighted sky watchers with remarkable auroras but also provides valuable data for the analysis of Quasi-Periodic Pulsations (QPPs).

These flares were recorded by various instruments across multiple spectral ranges and from different vantage points. Some flares were associated with coronal mass ejections (CMEs), filament eruptions, or solar energetic particles (SEPs), and were observed both on-disk and at the solar limb. This dataset presents a unique opportunity to investigate the influence of flare characteristics on QPPs.

In this study, we analyze QPP observations from several solar missions, including GOES, PROBA2, Solar Orbiter, SDO, to investigate if the general trend of QPPs also holds for this serie of very large flares.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **216** Type: **Poster**

CHIANTI version 11 - advanced ionization equilibrium models: density and charge transfer effects

CHIANTI is the most widely-used database in solar physics, and in some cases is the reference dataset for other databases in astrophysics. We present here a significant update to the modelling. CHIANTI has, up until now, used the coronal approximation to calculate ion balances. This is only suitable in the more tenuous, high temperature solar corona. New effects have been added to the models to make them more appropriate for the solar transition region, where densities are higher and temperatures cooler. This includes density effects on ionisation and recombination rates. Also, charge transfer, which occurs during collisions between atoms and ions, has been included in CHIANTI for the first time. We present an example run of the new models by creating a synthetic spectrum for an active region using differential emission measure modelling. Line intensities are enhanced by factors of 2-5 in certain cases compared to the previous modelling. We compare the results with observations from HRTS and find excellent agreement for transition region lines. The results resolve some long-standing discrepancies in predicting emission for the Si IV lines observed by IRIS, as well as for C IV and N V

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **217** Type: **Poster**

Observational discovery of slip-running reconnection during a solar flare

Apparent slipping motions of reconnecting field lines are a prime signature of three-dimensional magnetic reconnection, the process powering flares and eruptions. The existence of slipping motions in the super-Alfvénic regime is a key prediction of 3D magnetohydrodynamic extensions to the standard flare model. Validating these predictions proved challenging as the detection of slipping motions, typically of flare loops and flare kernels, has been limited by the time resolution of space-borne solar imagery. We overcame this issue by utilizing high, 1.8 s cadence flare observations of a confined C4.2-class flare from 2022 September 25 of the Interface Region Imaging Spectrograph (IRIS). Flare ribbon kernels, composing one of the ribbons captured in the 1330 Å filter of the IRIS Slit Jaw Imager, exhibited apparent slipping motions at speeds of thousands of kilometers per second. These dynamics are consistent with the slip-running reconnection, aligning with model predictions. Signatures of kernel motions were further analyzed in observations with varying spatial and temporal resolution. By utilizing a computer vision algorithm we found that fast, super-Alfvénic dynamics can only be resolved in observations with a cadence of a few seconds at most. Preliminary analysis of selected IRIS flare datasets with high (< 2s) time resolution strengthens these results, confirming that the rapid kernel slippage was not limited to a single event.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **218** Type: **Poster**

Partial eruptions by breakout reconnection

Knowing how much of a particular magnetic system will erupt is, naturally, fundamental to predicting a CME event and the hazard it presents. Usually, we speak about full eruptions when most of the magnetic structure escapes from the Sun, producing a CME; and about failed/confined eruptions, when the eruptive process, including flares and filament activation, is halted in the low corona, with no magnetic structure escaping the Sun. However, there is a continuous transition between both cases, depending on the portion of the stressed magnetic system that is expelled. Commonly, these eruptions are denoted as partial filament eruptions and are the most frequently observed.

In this work we present, for the first time, three events of partial filament eruptions that suffer the splitting after the eruption started and produced a CME, instead of a jet outflow. The events were simultaneously observed by STEREO-A, SDO, and Solar Orbiter. Taking advantage of the multiple viewpoints we track the real three-dimentional evolution of different features and segments of the filament material. We model the background coronal magnetic field, showing an interaction between the filament and multipolar structures. We used the CORHEL-CME model to simulate the event and provide an explanation of the physical process behind this kind of partial eruptions. We conclude that the breakout reconnection within the null point of these structures allows the stressed magnetic system to partially erupt and to reconnect with the background field in order to produce a CME structure.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **219** Type: **Poster**

Observing rapid moss variability in active region cores using Solar Orbiter's EUI and PHI

Active region moss forms at the footpoints of 3–10 MK hot loops. Observations with the High-resolution Coronal Imager (Hi-C) revealed some moss regions exhibiting temporal variability on timescales of 30s. This rapid moss variability is hypothesized to be an indirect evidence for the nanoflare heating model of coronal loops. However, since Hi-C was a sounding rocket mission, the observations lasted only a few minutes. The Extreme Ultraviolet Imager (EUI) on the Solar Orbiter spacecraft now provides coronal observations at higher spatial resolution than Hi-C extending to several hours, that will be crucial to better understand the phenomenon of rapid moss variability. To this end, we used high spatial (image scale $\sim$ 180km/pix) and temporal ($\sim$ 5sec) resolution EUI 174 Å images of an active region moss. We detected frequent occurrence of rapid moss variability near the footpoints of hot loops over the course of 100 min of observations. We also found that at any given time about 1% of the moss area is undergoing the phase of rapid variability. Moreover, based on high-resolution magnetic field maps obtained by the Polarimetric and Helioseismic Imager on board Solar Orbiter, we identified that moss regions overlie different types of magnetic configurations (e.g., unipolar plages, penumbral regions around small sunspots). The magnetic configuration may influence the moss variability. Our observations will help constrain nanoflare based heating models and offer better insights into the processes responsible for mass and energy injection into the hot loops.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **220** Type: **Poster**

Magnetic structure of coronal dark halos

At low coronal temperatures of approximately 1 MK, distinct regions show emission at a level significantly below the quiet Sun. Prominent examples are coronal voids in the quiet Sun and dark halos (also referred to as canopies or moats) surrounding active regions. Several models have been proposed, yet the mechanism behind the formation of dark halos remains not fully understood.
Solar Orbiter data from both the PHI and EUI instruments allow us to identify EUV-dark areas and to study the connection to the photospheric magnetic field of the dark halos in the immediate vicinity of an active region. They further allow for a direct comparison between dark halos and coronal voids.
The dark halos show slightly reduced mean unsigned magnetic fields compared to the quiet Sun. However, the difference between the magnetic field density near the inner and outer boundary of the halos is much more significant. At their outer boundary the unsigned magnetic field has decreased by 25% and is even roughly 10% - 20% weaker than outside the halos.
Co-temporal SDO/AIA observations enable us to study the emission at different coronal temperatures. While the emission is reduced and relatively homogeneous throughout the dark halos in the cool 171- angstrom channel, the dark halos show a strong gradient away from the active region in hotter channels. Hence, our EUV and magnetic field observations suggest that the halos might be due to changes in the large-scale magnetic field structure of the active region.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **221** Type: **Poster**

Penetrating waves along spicules to the corona

Alfvénic waves are one of the most promising candidates for heating the solar corona and accelerating the solar wind in polar coronal holes. These are observed as the transverse motion of spicules (jets elongated along the magnetic field lines) in the chromosphere. However, whether sufficient wave energy is carried to the corona remains unclear because the waves in the chromosphere suffer from the reflection in the transition region.
Here, we performed a statistical study of Alfvénic waves along spicules in polar coronal holes using spectroscopy of the *Interface Region Imaging Spectrograph (IRIS)*. We developed a technique for wave detection, wave-mode identification, and energy flux estimation for each detected wave using line-of-sight (LOS) velocity and intensity. 120 waves were detected, consisting of 62 ascending and 41 descending Alfvénic waves, 9 ascending and 8 descending slow-mode waves. If we assume that only the LOS component of random directional oscillations is observed, the averaged energy flux of ascending and descending Alfvénic waves can be estimated to be 2.2×10^5 erg cm^{-2} s^{-1} and 1.1×10^5 erg cm^{-2} s^{-1}, respectively.
Assuming that some fraction of ascending Alfvénic waves is reflected in the transition region and observed as descending Alfvénic waves, energy flux penetrating from the chromosphere to the corona is 1.1×10^5 erg cm^{-2} s^{-1}. This is the first estimation of energy flux penetrating to the corona and shows that it is enough for the coronal heating and the solar wind acceleration, even considering the wave reflection in the transition region.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **222** Type: **Poster**

Numerical Simulations of Coronal Loops Dynamics Emerging from Wave-Turbulence Interactions

Coronal loops are the basic structures of the solar corona resulting from the confinement of the multi-thermal coronal plasma in magnetic flux tubes.
Improving their modeling could help in understanding the physical processes involved in the formation and evolution of loops, and the mechanisms of energy transfer in the solar atmosphere.

In this work we performed several direct numerical simulations of a coronal loop by integrating the compressible 3D MagnetoHydroDynamics (MHD) using a pseudo-spectral code. Equations are solved in a triply periodic elongated box in which we evolve an initial condition given by a turbulent plasma flow perturbed with torsional Alfvén waves.

We explore a parameter space compatible with the observations and investigate how the interaction between turbulence and waves affects the dynamics of the system. Finally, we compute the spectral moments (i.e. line intensity, Doppler velocity) integrated along the line of sight to mimic the future observations of the corona with the MUlti-Slit Explorer (MUSE).

We study the spectra of physical observables from the synthetic data (e.g., intensity , Doppler shift velocities, etc) and relate them to the spectra of the plasma parameters (density, velocity, temperature fields) from the 3D simulations.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **223** Type: **Talk**

High-Resolution Observations from the Solar Orbiter Major Flare SOOP Campaign: Insights from X-ray and Fast Cadence EUV Observations of Solar Flares

Thursday 12 September 2024 09:40 (15 minutes)

The Solar Orbiter's Major Flare SOOP (Solar Orbiter Observing Plan) campaign successfully captured several M- and C-class flares as the spacecraft approached perihelion in Spring of this year (March and April). This campaign provided unprecedented observations of solar flare dynamics through high-resolution extreme ultraviolet (EUV) observations using the High Resolution Imager (HRIEUV) of the Extreme Ultraviolet Imager (EUI), combined with X-ray observations from the STIX instrument. The Major Flare campaign was designed to capture the most detailed images of solar flares. The HRIEUV telescope operated in a short exposure mode, acquiring EUV images at an unprecedented 2-second cadence, achieving the fastest cadence non-saturation images of a flare to date. These observations provide unparalleled detail in the early stages of flare development, and the correlation of X-ray and EUV data offers new insights into the energy release and particle acceleration processes during solar flares. This presentation provides an overview of the campaign and highlights the initial results, focusing on the X-ray data and the fast cadence, short exposure EUV observations obtained from HRIEUV. In particular, a detailed analysis of the March 19th M-class flare will be highlighted.

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Presenter: HAYES, Laura (European Space Agency)

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **224** Type: **Poster**

Observationally driven 3D MHD simulation of a coronal loop above a sunspot group

The solar corona is extremely hot with temperatures above 1 MK. In the decades after this discovery, many different heating methods have been developed to explain the high temperatures. A prominent category of these heating models is direct current (DC) heating, where the dissipation of strong currents, created by the tangling and braiding of magnetic field due to the convective motions in the photosphere. To test this hypothesis, we perform 3D magnetohydrodynamic simulations of the corona, where we want to heat a coronal loop with Ohmic heating. The simulation is driven by high resolution magnetograms and a photospheric velocity field consisting of large scale flows obtained by local correlation tracking and an artificial granulation driver. After around 40 minutes we see that our model produces a heating strong enough to counteract the energy losses. After around 60 minutes, the heating and losses roughly balance each other out and create a loop with a mean temperature of around 1.4 MK. As we drive our simulation with observations, we can compare directly to observations. We find that the synthetic Fe XII emission and Doppler shifts generated with the CHIANTI database match observed emission and Doppler shifts, showing that our heating mechanism is a viable method to heat a coronal loop. We also analyze the helicity density in the simulation box to study the energy buildup due to the photospheric footpoint motion. We find opposite signs of the helicity density at different heights above two sunspots.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **225** Type: **Talk**

Reconstruction of CME-driven shocks detected by multi-spacecraft observations

Friday 13 September 2024 12:25 (15 minutes)

Shocks driven by coronal mass ejections (CMEs) are the most relevant accelerators of solar energetic particles (SEPs) in the inner heliosphere. SEPs are of great scientific interest because they represent a natural hazard in the near-Earth environment, from the instruments on board spacecraft to the electricity networks and astronauts' lives. In this study, we aim at analyzing CME-driven shocks, possibly observed by multiple spacecraft. We use remote sensing observations from Stereo-A, SOHO, Parker Solar Probe and Solar Orbiter to analyse shock waves both in 2D and 3D and to determine their physical parameters, such as the compression ratio and the Mach numbers. Physical quantities estimated through remote-sensing observations can be compared with in-situ measurements from various instruments. Following the evolution of the parameters characterizing the CMEs from the source to space will help space weather models to improve predictions on the arrival of SEPs at the Earth. This study is achieved in the context of the research project "Data-based predictions of solar energetic particle arrival to the Earth: ensuring space data and technology integrity from hazardous solar activity events"funded by the Italian Ministry of Research under the grant scheme PRIN-2022-PNRR.

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Presenter: CHIAPPETTA, Federica (Department of Physics, Università della Calabria)

Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **226** Type: **Poster**

The highest resolution full-disk magnetic field maps, obtained with SO/PHI

The Polarimetric and Helioseismic Imager onboard the Solar Orbiter spacecraft (SO/PHI) has the unique opportunity to scan the entire solar disk within approximately 4 hours with its High Resolution Telescope (HRT). Such a so-called "full-disk mosaic" was produced on March 22, 2023 at a solar distance of 0.495 AU where the SO/PHI-HRT platescale of 0.5" covered a distance of 179.5km on the Sun.

Connecting the 25 tiles of the full-disk mosaic provides a full-disk magnetogram with a solar disk diameter of approximately 8000 pixels. In addition to the line-of-sight magnetogram we will present full disk mosaics of the magnetic field inclination and azimuth, i.e. the entire photospheric magnetic field vector. Beside the magnetic field maps, we will also show mosaics of the Doppler velocity and the continuum intensity in the 617 nm band.

Simultaneously with SO/PHI the Extreme Ultraviolet Imager (EUI) onboard Solar recorded a full-disk mosaic in the 17.4 nm band. A combination of the SO/PHI and EUI observations provide and unique data product with with an unprecedented view of the Sun.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **227** Type: **Poster**

The CAESAR project: Comprehensive spAce wEather Studies for the ASPIS prototype Realization

This work presents the outcome of the CAESAR (Comprehensive spAce wEather Studies for the ASPIS prototype Realization) project, which was supported by ASI and INAF from 21 December 2021 to 24 May 2024 (ASI-INAF n.2020-35-HH.0 agreement). CAESAR was devoted to study the relevant aspects of Space Weather (SWE) science and realize the prototype of the scientific data centre for Space Weather of the Italian Space Agency (ASI) called ASPIS (ASI SPace Weather InfraStructure). To this end, CAESAR gathered a great part of the SWE Italian community, bringing together 10 Italian institutions as partners, and a total of 98 researchers.
CAESAR adopted an unprecedented, multidisciplinary, and integrated approach, encompassing the whole chain of phenomena from the Sun to the Earth up to planetary environments.
The goals, organization, and final results are discussed.
A case study of a well-observed "target SWE event", exhibiting extreme characteristics with respect with the solar source, is presented in order to showcase the CAESAR approach. The causes and evolution of the event are explored and the effects on technological systems are evaluated.
The main features of the implemented ASPIS prototype are shown. It is intended to unify multiple SWE resources through a flexible and adaptable architecture and to integrate currently available international SWE assets to foster scientific studies and advance forecasting capabilities.

Primary author: Dr LAURENZA ON BEHALF OF THE CAESAR TEAM, Monica

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **228** Type: **Poster**

Magnetic implosion of coronal loops: observations and modelling

The equilibrium of coronal structures like loops in active regions is determined by a balance between the inward magnetic tension and the outward magnetic pressure gradient forces. The dissipation of the magnetic energy from the volume below the loops after a flare causes the lack of magnetic support, hence a contraction or implosion of the coronal loops. Such a contraction is also observed with EUV imagers to be accompanied by transverse oscillations.
In this work we provide preliminary results on the analysis of observations of coronal loop implosion from the Solar Dynamics Observatory in the framework of a simple physical model.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **229** Type: **Talk**

On the magnetic source of chromospheric heating

Tuesday 10 September 2024 12:15 (15 minutes)

It is generally believed that the chromosphere is heated by the dissipation of acoustic waves or predominantly acoustic slow modes. Here we propose that some of these essentially acoustic waves have a magnetic origin in that they are generated by torsional Alfénic pulses propagating along small-scale magnetic flux concentrations that root in the photosphere. But how do these torsional Alfvén waves dissipate? Recent observations with the Daniel K. Inouye Solar Telescope (DKIST) by C.E. Fischer et al. reveal propagating, arc-shaped bright fronts emanating from chromospheric bright grains. These are located above corresponding photospheric bright points, which in turn are found to interact with vortical flows prior to the appearance of the chromospheric bright fronts. Corresponding three-dimensional magnetohydrodynamic simulations reveal that the arc-shaped structures are weak shock fronts triggered by the torsional Alfvénic pulse of the underlying magnetic flux concentration. Here, we propose a mechanism by which the torsional Alfvén wave excites a predominantly acoustic weak shock front capable of dissipating the torsional Alfvén wave.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **230** Type: **Talk**

Flux-rope mediated turbulent reconnection

Monday 9 September 2024 11:55 (15 minutes)

Understanding the interplay between magnetic reconnection and turbulence is an important challenge in solar physics, which must be solved to address the fundamental processes and properties of solar flares and other coronal energy releases. In the last few years, exciting advances in this area have been enabled by 3D direct numerical simulations that capture the generation of turbulence inside the reconnection layer. Interestingly, these simulations exhibit features associated with the Lazarian-Vishniac model of 3D turbulent reconnection (turbulence and field line dispersion) and features associated with 2D plasmoid mediated reconnection (flux ropes and a reconnection rate of 0.01 in MHD and 0.1 with collisionless physics). This talk presents a new theoretical model that reconciles aspects of turbulent and plasmoid-mediated reconnection, differing from the Lazarian-Vishniac theory by emphasizing the roles of locally coherent magnetic structures and magnetic helicity, and formally extending the plasmoid-mediated mechanism to 3D. The new conceptual model successfully describes the main features of MHD and PIC simulations of self-generated turbulent reconnection, including the magnetic field structure and reconnection rate.

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Presenter: RUSSELL, Alexander (University of St Andrews)

Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **231** Type: **Poster**

Using Data-driven time-dependent Magnetofrictional modeling to initiate Magnetohydrodynamic simulations of coronal active regions

The data-driven time-dependent magnetofrictional method (TMFM) has proven to be a powerful tool for studying solar coronal eruptive events. Coupling data-driven TMFM with magnetohydrodynamic (MHD) simulations potentially provides a robust and efficient approach to study such events in more detail.

As has been shown by a number of studies, TMFM is capable of incorporating observational data directly. Additionally, it is significantly faster to compute compared to MHD, due to the simplifications of the model. The main aim of this work is to utilize the data-driven TMFM, initiated with observational data, close to the time of the expected eruptive event, and transfer the magnetic field evolved with TMFM to initiate an MHD simulation, providing a more realistic initial condition for the MHD simulation. The goal is to leverage the lower computational cost of TMFM while simulating the fast and more dynamic evolution of eruptive events with the more complete MHD model. As an example case for our approach, we simulated NOAA active region 12673, with the linked data-driven TMFM and ideal zero-β MHD simulation. The main twisted flux system in our simulation was rising during the MHD simulation, however, the final height of the flux system depended on how close to eruption the transformation of the model from TMFM to MHD was performed. Our simulations showed the primary factors in the eruptive event are the torus instability and presence of the slip-running reconnection.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **232** Type: **Poster**

Sub-second Imaging Observations of Decametre Solar Radio Spikes

Solar radio spikes observed as narrow-bandwidth, sub-second bursts are indicative of rapid, small-scale energy release in the corona, yet localising the site of electron acceleration is a significant challenge. Using millisecond imaging from the LOw Frequency ARray (LOFAR) between 30-45 MHz, we present a statistical analysis of solar radio spikes associated with a coronal mass ejection (CME). At fixed frequencies, individual spikes collectively exhibit superluminal, non-radial source motions across the sky plane, expanding on millisecond timescales. These temporal and spatial characteristics are consistent with the radiation propagating through strongly anisotropic density turbulence such that the apparent source motion traces the unobserved magnetic field of a closed loop structure. Consequently, the observed burst locations do not correspond to the sites of radio emission, indicating that acceleration occurred along the loop leg and CME flank. Disentangling the propagation effects not only offers a unique diagnostic to probe the magnetic field geometry and localise the emission site, but also reveals that the energy release timescales are far shorter and more intense than assumed from observations.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **233** Type: **Poster**

Observational Analysis of Line Formation Heights in the Flaring Chromosphere

Solar flares can induce many changes in the Sun's atmosphere, primarily due to the energy deposited in the lower atmosphere by particles accelerated from a magnetic reconnection site in the corona. The majority of this energy is deposited in the chromosphere, although the method of this energy transport is not yet agreed on. Radiation hydrodynamics models predict that an electron beam via the standard thick target model would result in a distribution of the source height in different wavelengths, which should be visible when viewed from an angle. 1D models predict an offset of ~400km between Ca II K (formed in the upper chromosphere and H⊠ (mid-chromosphere). Here we show observational analysis of solar activity over an active region from the Daniel K. Inouye Solar Telescope (DKIST). Images in Hβ and Ca II K across a C-class solar flare were analysed, specifically over a ribbon formed in the umbra of a sunspot around peak of the impulsive phase. Subsections of these images were taken around this ribbon and cross correlation was performed on a sub-pixel level, yielding a lag or physical offset 0.32" or ~ 230km between the images in Hβ and Ca II K. No other cross correlation calculations produced a lag of the same significance, suggesting that it formed with a non-trivial distance between the two line formation heights. This analysis will build on previous works to investigate the transportation of energy through the solar atmosphere.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **234** Type: **Poster**

Association between a Failed Prominence Eruption and the Drainage of Mass from Another Prominence

Sympathetic eruptions of solar prominences have been studied for decades, yet identifying their causal relationships remains challenging. Here, we analyze a failed prominence eruption and subsequent mass drainage from a neighboring prominence, and investigate their potential connections. Leveraging stereoscopic observations from instruments such as LST, CHASE, and EUI, we observe that the southern prominence (PRO-S) erupts with untwisting motions, accompanied by flare ribbons, and new connections form during the eruption. Notably, the northern prominence (PRO-N) rises following PRO-S, and its upper section disappears due to catastrophic mass drainage along an elongated structure. We propose that the eruption of PRO-S was initiated by the kink instability and facilitated by flare reconnection. However, it ultimately failed to erupt due to reconnection with surrounding magnetic fields. The elongated structure connecting PRO-N overlies PRO-S, and PRO-N mass drainage is triggered by PRO-S failed eruption. This study highlights that a prominence may terminate its life through catastrophic mass drainage, where the rising motion and mass drainage reinforce each other, and the mass drainage can be initiated by an underlying eruption.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **235** Type: **Poster**

Using machine learning to unveil wave heating in 3D simulations

Solar atmospheric heating inferred from observations is known to be higher than the equilibrium rate of a static atmosphere, but it is unclear how the heating is supplied. Two leading theories are standing out as the most likely candidates to balance the high radiative losses of the solar atmosphere: heating by waves (AC heating), and magnetic reconnection (DC heating). Understanding AC heating in the chromosphere requires detailed modelling of pressure forces, magnetic field, and non-local radiative transfer (NLTE). We identify wave heating events in the 3D r-MDH simulation Bifrost and associate them with signatures in the chromospheric lines of Mg II, Ca II, and H I. With NLTE spectral synthesis of several hundred snapshots, we investigate the wave heating signatures in the simulated chromosphere. We use a novel approach involving machine learning to automatically detect wave heating signatures from our chromospheric analogues. The spectral signatures that reveal wave heating are used to calculate wave energy contributions to the chromospheric heating rate and energy transfer to higher layers.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **236** Type: **Poster**

Understanding the magnetic field evolution of the 10 March 2022 Coronal Mass Ejection

Understanding the magnetic field evolution of Coronal Mass Ejections (CMEs) is crucial for space weather research. We examined the 10 March 2022 CME, focusing on its magnetic field evolution from the near-Sun space to L1. The Solar Orbiter's in-situ measurements, 7.8 degrees east of the Sun-Earth line at 0.43 AU, provided a unique vantage point, along with the WIND measurements at L1.

We analysed the temporal evolution of the magnetic helicity budget of the source Active Region (AR), NOAA AR 12962. By estimating the helicity budget of the pre- and post-eruption phase in the AR, we estimated the helicity transported to the CME. Assuming a Lundquist flux-rope model and geometrical parameters (length and radius of the flux rope) obtained through the Graduated Cylindrical Shell (GCS) CME forward-modelling technique, we determined the CME magnetic field at a GCS-fitted height of 0.03 AU to be 2067 ± 405 nT.
Combining this estimated magnetic field with in-situ measurements at 0.43 AU and 0.99 AU, we could fit the CME's axial magnetic field decrease with heliocentric distance as a single power law with index -1.23 ± 0.18. Extending previous studies on inner-heliospheric intervals from 0.3 AU to ~1 AU, we refer to estimates from 0.03 AU to measurements at ~1 AU. Our findings suggest a less steep decline in the magnetic field strength with distance compared to previous studies. However, our results align with studies incorporating near-Sun magnetic field measurements, such as those from the Parker Solar Probe mission.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **237** Type: **Poster**

Soft X-ray Solar Flare Spectroscopy: Synergistic Observations from XSM and STIX

We present a detailed analysis of solar flares observed on 30 September 2022 using high-resolution spectroscopic data from the X-ray Spectrometer (XSM) onboard Chandrayaan-2 and the Spectrometer/Telescope for Imaging X-rays (STIX). By leveraging XSM's broad-band spectral sensitivity and STIX's spectra in the softer energy range, we explore the intricate dynamics of solar flare emissions.

We conducted a comparative study of solar flares, focusing on key spectral features such as line emissions and continua in the soft X-ray band. The synergy between XSM and STIX data enables a comprehensive understanding of flare morphology and evolution.

Key findings include determinations of flare temperatures, emission measures, and elemental abundances, providing valuable insights into theoretical models of physical processes crucial for solar flares.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **238** Type: **Poster**

Is the sub-flaring activity of a solar active region a good whistleblower for impending eruption?

Our Sun is a dynamic star, home to a wide range of activities, from subtle, short-duration events to large coronal mass ejections (CMEs) and strong flares. CMEs and flares can overlap; distinguishing between "eruptive"and "confined"flare magnetic configurations is essential. Understanding the intricacies of these solar eruptions and their connections to preceding activity is crucial in heliophysics research. Our goal is to determine whether the small-scale activity of an active region (AR) contains information about its potential for eruptions and could provide insight into future events. To achieve this, we monitor transient activity using data from the Atmospheric Imaging Assembly (AIA) instrument onboard the Solar Dynamics Observatory (SDO). Our primary goal is to discern disparities in AR transient brightenings of various magnitudes and understand their relevance to eruptive configurations. By comparing the spatial distribution of detected transient brightenings to the polarity inversion line (PIL) area derived from the SDO Helioseismic and Magnetic Imager (HMI) line-of-sight magnetograms, we observe significant differences between the pre-eruptive and non-eruptive situations of our sample ARs. The temporal evolution of observations derived from the brightenings, such as their number detected through time, their associated intensity and magnetic unsigned flux, shows significant differences in their order of magnitude and behaviour, and by using multiple wavelengths, we also observe the evolution of the transient activity through the Sun's atmosphere. Over comparative analysis, we seek insights into the pre-eruptive activity of ARs, which could contribute meaningfully to advancing solar event predictive capabilities and our understanding of solar dynamics.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **239** Type: **Poster**

Comparative analysis of the open and closed field topologies reconstructed by different coronal models

When reconstructing the coronal magnetic field topology, which is an essential input to heliospheric space weather forecasting models, one can chose among many coronal models. These range from simple empirical to state-of-the-art magnetohydrodynamic (MHD) models. In this study we try to address how well coronal models agree well with each other regardless of their complexity and simulation set up. In addition, we investigate for each model the sensitivity of the simulation output with respect to variations of the initial set up. We considered four potential field source surface (PFSS)-based models and one full MHD model, all of which were initiated with two different types of HMI ADAPT magnetograms generated for three consecutive dates. One magnetogram included active regions added retrospectively while the other did not. All PFSS based outputs were compared to the one generated by the MHD model. This analysis revealed that all models considered here produce very comparable open and closed field topologies. Taking the work one step further, we selected a coronal hole that was centered within the Earth's field of view, for the three dates studied, and compared its area with the simulated open field topology associated with it. We found that they do not compare well. As a conclusion, despite not agreeing well with observations, simulated topologies from different coronal models agree well with each other.
This work is the result of collective research by members of the International Space Science Institute (ISSI) team "Magnetic Open Flux And Solar Wind Structuring Of Interplanetary Space".

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **240** Type: **Poster**

Flare Accelerated Electrons in Kappa-Distribution from X-Ray Spectra with Warm-Target Model

Flare-accelerated energetic electrons play a critical role in the magnetic energy release and transport during solar flares. X-ray diagnostics provide crucial insights into the acceleration and propagation of energetic electrons. A deeper understanding of the dynamics of energetic electrons after injection is required to improve the X-ray spectral analysis. Previous studies have shown that the dynamics of accelerated electrons with a few thermal speeds are complex. To address this, a model considering energy diffusion and thermalization effects has been developed to characterize flare-accelerated electrons for hard X-ray spectral analysis. This warm-target model has demonstrated how the low-energy cut-off, which can hardly constrained from the cold-target model, can be determined. However, the power-law form may not be the most suitable
representation of injected electrons. The kappa distribution is proposed as a physical consequence of electron acceleration and has exhibited successful application in RHESSI spectral analysis. In this study, we employ the kappa distribution to represent the injected electrons in the warm-target model to analyze well-observed RHESSI and STIX flares. We find that the kappa-form energetic electrons require lower non-thermal energy to produce a similar photon spectrum compared to the power-law form. Additionally, unlike the power-law distribution with a lower energy cut-off, the kappa distribution extends to the entire energy range. The use of the kappa distribution enables the determination of crucial electron properties such as electron number density and average energy in the flare site, thereby offering further constraints on electron acceleration processes.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **241** Type: **Poster**

Observations and modeling of solar flare energetic electrons in hard X-ray, radio and in-situ near 1 AU

The behavior of energetic electrons from solar flares traveling through interplanetary space is crucial for understanding space environment and its impact on Earth. This transport is effectively influenced by the pitch-angle scattering due to the broad existence of interplanetary magnetic turbulence. However, how does the strength of pitch-angle scattering change over the electron energy and other parameters is still to be ascertained. In this work, we present the pitch-angle scattering dependence on the traveling distance and the electron energy. We analyze 14 energetic electron events that are detected in-situ by the Wind 3D Plasma and Energetic Particle instrument and accompanied by coincident hard X-ray (HXR) emission and interplanetary type III radio bursts. These events are with single short-duration electron injection as indicated by HXR light curves, and the injection time is determined from HXR observations. We find that the arrival time of the electrons in energy bands from 27 to 520 keV are delayed for around a thousand seconds with respect to their free-flying time; and find the statistical energy dependence of the rise and decay time of electron flux profiles. We numerically model the transport of electrons considering the pitch-angle scattering and magnetic focusing. By conducting simulation experiments, we obtain the scattering mean free path as well as its dependence on distance from the Sun and the electron energy that best suits the observations.

Primary author: KOU, Yuankun (Nanjing University; University of Glasgow)

Co-author: KONTAR, Eduard (University of Glasgow)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **242** Type: **Poster**

Solar-cycle variations of the high-latitude solar inertial mode

We analyze series of Dopplergrams from MWO (1967-2012), GONG (2001-2022), and SDO/HMI (2010-2022) to characterize the temporal variations of the high-latitude solar inertial mode with azimuthal order $m = 1$. This mode has an amplitude of 10-20 m/s, making it the strongest among all the observed modes in the inertial frequency range. We will present measurements of the mode's power and frequency in sliding time windows of three years.

Primary authors: LIANG, Zhi-Chao (Max Planck Institute for Solar System Research); GIZON, Laurent (Max Planck Institute for Solar System Research)

Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **243** Type: **Poster**

Solar differential rotation in the period 1954–1964 determined by the Kanzelhöhe data set

Kanzelhöhe Observatory for Solar and Environmental Research (KSO) provides daily multispectral synoptic observations of the Sun. The synoptic observations allow us to study the subsurface dynamics of the Sun, such as the profile of solar differential rotation, meridional and zonal flows, and their variability, which are crucial for understanding the solar dynamo. Our goal is to extend the analysis of differential rotation from the KSO data (Poljančić Beljan et al., A&A 606, A72, 2017) to years before 1964. Previous analyses showed that the KSO data set is in a good agreement with the Debrecen Photoheliographic Data and Greenwich Photoheliographic Results (GPR), making it suitable for investigating long-term variations of the solar rotation profile. So, completing the catalog of KSO sunspot group positions and velocities is essential for further long-term analysis of the photospheric differential rotation. In this work, we present the results of solar differential rotation during the solar cycle No. 19 (1954–1964), derived by tracing sunspot groups on KSO sunspot drawings. The positions of sunspot groups were determined using a special software, Sungrabber. Sunspot groups were identified with the help of the GPR. We used two methods to determine synodic angular rotation velocities: the daily shift (DS) method and the robust linear least-squares fit (rLSQ) method. These velocities were then converted from synodic to sidereal ones and used in the least-squares fitting for the solar differential rotation law. Our analysis focused on velocity patterns relative to the solar cycle phases and latitudes.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **244** Type: **Talk**

Helical Structures Captured by Metis During a Polar Crown Prominence Eruption

Tuesday 10 September 2024 18:10 (15 minutes)

We present observations of a solar eruption captured by Metis onboard Solar Orbiter on October 12, 2022, during its perihelion passage. Using total brightness data, we observed the outward propagation of helical structures for more than three hours, extending up to 3 solar radii following a polar crown prominence eruption. These structures exhibited a notable trend: their inclination decreased as their polar angle and height increased. Further analysis, including examination of EUI images, revealed evidence of an eruptive flux rope in the lower corona with distinguishable footpoints as the source of these helical structures.
We also performed a comparative analysis with a high-resolution magnetohydrodynamic simulation of bursty interchange reconnection, finding strong similarities in the evolution of the observed and simulated structures. The white light structures in the simulation form as dense plasmoid plasma intermittently launched along open field lines when the plasmoids are ejected. The same ejection process also launches torsional Alfven waves, which may act as seed perturbations to form magnetic switchbacks within the solar wind. These observations and simulations suggest that sustained bursty interchange reconnection occurred following the eruption. Additionally, they demonstrate a key new observable associated with the bursty interchange reconnection process, providing a link between coronal dynamics and in-situ measurements such as those of switchbacks observed by Parker Solar Probe.

Primary authors: Dr LYNCH, Benjamin (Space Sciences Laboratory, University of California–Berkeley); Dr SPADARO, Daniele (Istituto Nazionale di Astrofisica (INAF)); RUSSANO, Giuliana (Istituto Nazionale di Astrofisica (INAF)); ABBO, Lucia (Istituto Nazionale di Astrofisica (INAF)); Prof. ROMOLI, Marco (Università di Firenze); VIALL, Nicholeen (NASA Goddard Space Flight Center); ROMANO, Paolo (Istituto Nazionale di Astrofisica (INAF)); Dr MACNEICE, Peter (Heliophysics Science Division, NASA Goddard Space Flight Center); WYPER, Peter; VENTURA, Rita (Istituto Nazionale di Astrofisica (INAF)); Dr ANTIOCHOS, Spiro (Heliophysics Science Division, NASA Goddard Space Flight Center); ANDRETTA, Vincenzo (Istituto Nazionale di Astrofisica (INAF))

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **245** Type: **Poster**

Spectroscopic Study of Heating Distributions and Mechanisms Using Hinode/EIS

This study aims to reveal the heating mechanism in coronal loops by observationally deriving the relation among the heating flux F_{H}, the magnetic field B_{base}, and the loop half-length L_{half}. While the previous studies investigated the heating mechanism assuming some parameters (e.g., heating scale height), this study directly derives the parameters from the observations. F_{H} is obtained by the heating distributions derived from *Hinode*/EIS, B_{base} is derived from *SDO*/HMI, and L_{half} is determined by *SDO*/AIA. We estimate the heating distribution by applying a Bayesian analysis to the electron temperature and electron density distributions derived by spectroscopic data from *Hinode*/EIS; we define the heating distribution decreasing with a heating scale height s_{H} toward the loop-top with a heating rate E_0 at the transition region. We obtain s_{H}=4.3–22 Mm for our analysis of 18 loops with L_{half}=24–107 Mm, suggesting the heating concentration near the lower part. Compared to the previous studies using the imaging data, s_{H} is comparable, but E_0 and F_{H} are approximately an order of magnitude larger. We confirm that using the imaging data leads to the underestimation of the electron density due to the assumption of plasma volume, and consequently the underestimation of E_0 and F_{H}. From F_{H}, B_{base}, and L_{half} of 18 loops, we obtain $\beta = 1.04^{+0.18}_{-0.36}$ and $\lambda = -0.99^{+0.04}_{-0.05}$ in $F_H \propto B^{\beta}_{\mathrm{base}} L^{\lambda}_{\mathrm{half}}$; Mandrini et al. (2000) expressed the heating models as the power-law relation and tried to classify them by β and λ. This presentation discusses the heating models allowed by the derived β and λ.

Primary author: ISHIGAMI, Shun (NAOJ/SOKENDAI)

Co-authors: Prof. HARA, Hirohisa (NAOJ/SOKENDAI); Dr OBA, Takayoshi (MPS)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **246** Type: **Talk**

Modeling the polarization of strong chromospheric lines and its magnetic sensitivity

Thursday 12 September 2024 12:05 (15 minutes)

A primary goal in today's solar physics research is to develop remote sensing methods for measuring the elusive magnetic fields of the chromosphere and transition region. A very promising strategy is to exploit the fingerprints that the magnetic field leaves in the polarization of strong resonance lines through the joint action of the Zeeman, Hanle, and magneto-optical (MO) effects. Significant efforts have been put in this research field during the last decade, from both the observational and theoretical point of view. In this talk, we first highlight the diagnostic potential of the aforementioned effects, recalling the underlying physics and pointing out the computational aspects inherent to their modeling. Subsequently, we present a new code capable of solving the radiative transfer problem for polarized radiation in strong resonance lines, accounting for the Zeeman, Hanle, and MO effects, as well as for partial frequency redistribution (PRD) in scattering processes, in comprehensive 3D models of the solar atmosphere. The code, named TRIP, provides synthetic data of unprecedented accuracy, which are crucial to reliably interpret a variety of spectropolarimetric observations of chromospheric lines, including those of HI Ly-α and MgII h and k provided by the three CLASP sounding rocket experiments. Moreover, it can be used to generate accurate datasets for the training of machine learning inversion algorithms.

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Presenter: BELLUZZI, Luca (Istituto ricerche solari Aldo e Cele Daccò (IRSOL))

Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **247** Type: **Invited**

Dynamo of the solar interior: Powering the decadal cycle and Its comparison to stellar magnetic cycles

Monday 9 September 2024 09:10 (25 minutes)

The solar magnetism is generated and sustained through an internal dynamo. This process is driven by the combined action of two main mechanisms: turbulent convective motions and large-scale differential rotation (DR). The subsequent magnetic-field build-up can lead to intense surface eruptive events, but also sustain longer-term magnetic cyclic variabilities, such as the Sun's 11-year cycle. How is this magnetic activity powered? Evidence of magnetic cycles has also been reported on other solar-type stars, ranging from a few years to a few tens of years. How are these cycles controlled, and what can we learn from them?

In this talk, I will provide an overview of our current understanding of the dynamo operating within the solar convective envelope. I will especially focus on an extensive numerical study of the dynamo origins in solar-type stars, based on a series of 15 3D-MHD simulations, and illustrate what we can learn from this stellar context. In particular, this survey allows to propose a possible explanation for why the Sun possesses a long decadal cycle and to assess the power needed to maintain such magnetic activity. Finally, I will discuss how these models can be compared to current observations and further refined to improve our understanding of the solar dynamo.

Primary author: Dr NORAZ, Quentin (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Co-authors: STRUGAREK, Antoine (CEA Paris-Saclay); Dr BRUN, Sacha (LDE3, DAp/AIM, CEA/IRFU, CNRS/INSU, France)

Presenter: Dr NORAZ, Quentin (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Session Classification: Solar interior, sub-surface flows and long-term variability

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **248** Type: **Poster**

Chromospheric heating and flux emergence in coronal hole simulations

Various dynamical processes occur in the solar atmosphere, significantly contributing to its thermal balance. Observations and simulations have particularly highlighted the importance of waves and magnetic reconnection in the chromosphere, which provide the necessary energy to counterbalance radiative cooling. However, the relative contributions of different processes in various solar regions (e.g., coronal holes) remains questioned (Carlsson et al. 2019).

Numerical simulations have notably demonstrated that the braiding of magnetic field lines by photospheric convection can sustain a million-degree corona via Poynting flux injection through the chromosphere (Gudiksen and Nordlund 2005, Finley et al. 2022). Nevertheless, initial magnetic field configurations in these models are not constrained yet, so the impact of flux emergence and subsequent energy injected by magneto-convection is still open for investigation.

We present a parametric study using the Bifrost code (Gudiksen et al. 2011), focusing on coronal holes simulations. By varying the upwardly advected magnetic field at the bottom boundary, we simulate different idealized configurations of flux emergence. Our findings indicate that the coronal temperature achieved after flux emergence is not a monotonic function of the injected magnetic field amplitude. Indeed, increasing the upward transport of magnetized material both triggers heating phenomena and enhanced radiative cooling. To start investigating this subtle equilibrium, we quantify the power contributed by shocks and magnetic reconnection to the chromosphere and find that they actually represent a majority of the heating balance. Additionally, we discuss the resulting changes in those contributions and in the mass loading, as a function of the emergence configuration.

Primary author: Dr NORAZ, Quentin (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Co-authors: AULANIER, Guillaume (Laboratoire de Physique des Plasmas); CARLSSON, Mats (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **249** Type: **Poster**

Testing MURaM chromosphere: ALMA's perspective

In this contribution we use millimeter wavelength diagnostic to test a new model of the solar chromosphere resembling an enhanced network region. The model is based on the recently developed chromospheric extension of the non-equilibrium version of the radiative-MHD code MURaM. We synthesized radio brightness at the operational wavelengths of the Atacama Large Millimeter/Submillimeter Array (ALMA) and compared those with the brightness obtained in the interferometric ALMA observations.

Primary author: LOUKITCHEVA, Maria ((1) MPS, Germany (2) SAO, Russia (3) SPbSU, Russia)

Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **250** Type: **Poster**

Disentangling coronal hard X-ray emission from the total signal through stereoscopic observations with Solar Orbiter/STIX and FERMI/GBM

In this work we take advantage of the unique orbit of the Solar Orbiter spacecraft which enables us to study flares from multi-viewpoints away from the Sun-Earth line. A dataset of flares for which the chromospheric footpoint emission is occulted from Solar Orbiter's point of view and the total flare emission is observed by Earth based observatories (i.e. Fermi/GBM) are identified. This allows the study of coronal hard X-ray emission separately to the total integrated signal in hard X-ray for a given flare. Coronal emission is typically much fainter and thus often challenging to disentangle from the total integrated flux with current hard X-ray instrumentation, due to the limited dynamic range of indirect imaging techniques. The study of the "above the loop-top"source allows us to probe the physics of what is commonly thought to be the acceleration region in flares and to advance our current understanding of particle acceleration. In this on-going investigation the relative flux of non-thermal emission in the corona versus footpoint emission is quantified. This constraint is important as it provides guidance for the required dynamic range of the next generation of hard X-ray instruments. In addition, the time evolution of coronal and footpoint emission is compared in order to investigate whether the purely coronal source shows the same pulsations as the footpoint sources. This analysis will help us better understand quasi-periodic pulsations in flare emission.

Primary authors: COLLIER, Hannah (Fachhochschule Nordwestschweiz, ETH Zürich); KRUCKER, Säm; HAYES, Laura (European Space Agency)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **251** Type: **Talk**

Synthetic Parker Solar Probe Observables of an Idealized Pseudostreamer CME Eruption

Tuesday 10 September 2024 17:55 (15 minutes)

Coronal pseudostreamer flux systems have a specific magnetic configuration that influences the morphology and evolution of coronal mass ejections from these regions. Here we present the analysis of a recent, high-resolution magnetohydrodynamic simulation of a CME eruption from an idealized pseudostreamer configuration through the construction of synthetic remote sensing and in-situ observational signatures. We examine the pre-eruption and eruption signatures in the low corona and through the extended corona corresponding to typical EUV imaging and white light coronagraph fields-of-view. We calculate synthetic observations corresponding to several Parker Solar Probe-like trajectories at ~10Rs to highlight the fine-scale structure of the CME eruption in synthetic WISPR imagery and the differences between the in-situ plasma and field signatures of flank and central encounter trajectories. Finally, we conclude with a discussion of several aspects of our simulation results in the context of interpretation and analysis of current and future Parker Solar Probe data.

Primary authors: LYNCH, Benjamin (Space Sciences Laboratory, University of California–Berkeley); WYPER, Peter

Presenter: LYNCH, Benjamin (Space Sciences Laboratory, University of California–Berkeley)

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **252** Type: **Poster**

Development of a solar/stellar wide-spectral coverage polarimeter for investigating flare energetics

The solar/stellar wide-spectral coverage polarimeter, SOWISP, is a dedicated instrument for investigating time-dependent energetics of solar flares. With four-state polarisation measurements and a field-of-view the size of an average sunspot, the instrument, currently in the R&D phase, will allow to probe changes in the magnetic structure with a spatial resolution of below 20 arcsec. Unique among spectropolarimeters is its large spectral range in the visible regime, which includes the Balmer and Paschen continua from 350 nm, as well as lines from the hydrogen Balmer series, up to the chromospheric Ca II 854.2 nm line. Observations of both the continua and line spectra over this range, with a targeted spectral resolving power of 30k at 600 nm, will elucidate the heating and energy conversion mechanisms at different atmospheric heights in flares and allow to discriminate between models.

The spatial and spectral resolution will be achieved through the use of an integral field unit and a primary Echelle disperser, respectively. Designed for portability and through phased deployment, the instrument also lends itself to the study of stellar magnetic field variations, particularly of bright M dwarfs, by utilising our own 80 cm ZimMAIN telescope at our Zimmerwald Observatory, or by bringing SOWISP as a visitor instrument to other telescopes worldwide.

This presentation will describe the science goals, design and ongoing development of SOWISP, with emphasis on its unique and versatile spectropolarimetric capabilities for investigating the underlying mechanisms behind both solar and stellar flares.

Primary author: GALLOWAY, Michelle (University of Bern)

Co-authors: PAILLON, Dorian (University of Bern); KLEINT, Lucia (University of Bern)

Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **253** Type: **Poster**

Investigating the Effects of Background Subtraction on a Dust-Free Corona

The elusive solar corona, when observed in white light, presents contributions from two main components of scattered photospheric light: the K-corona, due to electrons, and the F-corona, due to dust. While the K-corona corresponds to the "true corona" and displays structuring in the form of helmet streamers, pseudostreamers, coronal holes, and plumes, the diffuse F-corona dominates the measured intensity especially at altitudes $>4R_\odot$. For this reason, background-subtraction techniques have been developed to remove the dust contribution to coronagraph imagery and to reveal the electron corona. However, it is not possible to validate the efficacy of such methods against a "ground truth", hence it is generally unknown how much of the K-corona effectively leaks into the generated backgrounds. In this work, we use a 32-day-long simulation ran with the Magnetohydrodynamic Algorithm outside a Sphere (MAS) code and based on a novel near-real-time, data-assimilative, time-evolving model to investigate for the first time the impact of background subtraction on the structure of the solar corona inferred from white-light imagery. Since the synthetic observables employed here do not suffer from the presence of dust or instrumental scattered light usually exhibited in coronagraphs, we are able to quantify our results against a "true" K-corona. We explore different methods and time-windows to generate a set of synthetic backgrounds to examine the consequences of these choices on the overall appearance of the electron corona and the relative brightness of background-subtracted structures compared to their ground truth as well as the full 3D density of the global corona.

Primary author: Dr PALMERIO, Erika (Predictive Science Inc., USA)

Co-authors: DOWNS, Cooper (Predictive Science Inc., USA); HESS, Phillip (U.S. Naval Research Laboratory, USA); LYNCH, Benjamin J. (University of California, Los Angeles, USA); DAVIDSON, Ryder (Predictive Science Inc., USA); CAPLAN, Ronald M. (Predictive Science Inc., USA); LINKER, Jon A. (Predictive Science Inc., USA)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **254** Type: **Poster**

Modeling of wave dissipation around X-points

Oscillations around the X-points play an important role in corona plasma heating. In this paper we investigate resonance absorption around X points. We have found analytical solutions for the Alfven continuum mode in the presence of a guide field. We also drive a jump conditions in the flux coordinates. Using these conditions, we obtain the dispersion relation and solve it numerically to find the frequencies and damping rates. The results show that resonance absorption can be an effective mechanism for damping the waves around the X points.

Primary authors: Dr SADEGHI, Mohammad (KU Leuven); VAN DOORSSELAERE, Tom (KU Leuven)

Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **256** Type: **Poster**

Modelling of Coronal Mass Ejections Through the Novel FRi3D Model and the Effect of Twist Parameter

Coronal Mass Ejections (CMEs) are large-scale eruptive events originating from the magnetically complex regions of the Sun, and also the most energetic phenomenon in the heliosphere. Even though CMEs have been largely studied in the last several decades, and despite significant advances in our knowledge about them, a lot remains unknown about their internal structure, dynamics, and how they link to their interplanetary counterparts. Determining CMEs configuration and topology is also important for comprehending the amount of magnetic energy stored in the corona prior to CME eruption. Observations indicate that the energy is stored as a highly sheared and/or twisted magnetic field located above the polarity inversion line (van Ballegooijen et al., 2006). In the present work, we analyse Earth-directed CMEs occurring in 2022, where the availability of data from spacecraft in different viewpoints allows for a comprehensive analysis,insight into their evolution and link with the interplanetary counterpart. For the modelling of the CMEs we used the state-of-the-art 3D magnetohydrodynamic (MHD) heliospheric model EUHFORIA (EUropean Heliospheric FORecasting Information Asset). We coupled EUHFORIA with the novel flux-rope CME model FRi3D (Flux-Rope in 3D), which provides a rather realistic morphology of the CME structure. We study how the variation in the twist parameter impacts the predictability of kinematic and magnetic properties of CMEs when using the FRi3D model.

Primary authors: DORSCH, Brenda (Royal Observatory of Belgium); MAGDALENIC, Jasmina (Royal Observatory of Belgium); RODRIGUEZ, Luciano (Royal Observatory of Belgium, Solar-Terrestrial Centre of Excellence)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **257** Type: **Poster**

Parameters' Maps Generated by Intensity of the Lyman-beta and Lyman-gamma Lines from SPICE Data and Non-LTE Modeling

An observation of a prominence on the solar limb took place on April 15, 2023, by several instruments including the Spectral Imaging of the Coronal Environment (SPICE) and the Extreme Ultraviolet Imager (EUI) on board Solar Orbiter. We aim to create parameter maps on the prominence region, including temperature, pressure, and column mass, by studying the integrated intensity of the Lyman-beta and Lyman-gamma lines from SPICE data.
After constraining the altitude and radial velocity in this event, we use a 1D non-LTE radiative transfer code to generate 1000 random models and compute the Lyman-beta and Lyman-gamma line profiles. The computed intensities are compared with observed integrated intensities from SPICE. Then, we find models which simultaneously give a reasonable match with the observed intensities in both the two lines. This enables us to generate models from pixels on the prominence region and use this information to generate parameter maps. We will discuss the results obtained and the potential for future research.

Primary authors: Mr ZHANG, Yong (University of Glasgow); Dr LABROSSE, Nicolas (University of Glasgow); Dr PARENTI, Susanna (Université Paris Saclay); Dr KUCERA, Therese (NASA Goddard Space Flight Center)

Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **258** Type: **Poster**

The ASPIS prototype: the Database, the Web App, and the Python Package

The prototype of the scientific data centre for Space Weather of the Italian Space Agency (ASI) called ASPIS (ASI SPace Weather InfraStructure) has been recently developed and validated by the CAESAR (Comprehensive Space Weather Studies for the ASPIS prototype Realization) project.
The ASPIS prototype unifies multiple Space Weather (SWE) resources (data and models) through a flexible and adaptable architecture to allow scientists to perform studies across the SWE-related fields, e.g., adopting an integrated approach, encompassing the whole chain of phenomena from the Sun to the Earth up to planetary environments or parts of it.
This work presents the solutions adopted for the architecture and the functions defined on the prototype to cope with the challenging requirements of searching heterogeneous datasets, as well as the first results of creating the ASPIS prototype. The database handles the heterogeneity of metadata and data while storing and managing the interconnections of various space weather events.
The pilot database is complete, installed at ASI, and accessible through different user interfaces, including a graphical web interface and an advanced Python module called ASPISpy, which have been specifically developed to facilitate data discovery, access, and analysis.

Primary authors: DEL MORO, Dario (Università di Roma Tor Vergata); LAURENZA, Monica (Istituto Nazionale di Astrofisica (INAF))

Co-authors: Dr BIGAZZI, Alberto (Italian Space Agency); MILILLO, Anna (Istituto Nazionale di Astrofisica (INAF)); Dr PLAINAKI, Christina (Italian Space Agency); Dr POLENTA, Gianluca (Italian Space Agency); Dr SINDONI, Giuseppe (Italian Space Agency); Dr GIARDINO, Marco (Italian Space Agency)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **259** Type: **Poster**

Characteristics of solar differential rotation and activity during solar cycle No. 24

We present results of the behaviour of the solar differential rotation during solar cycle No. 24 derived from the Kanzelhöhe data set (Kanzelhöhe Observatory for Solar and Environmental Research, University of Graz, Austria). Sunspot groups and their properties (umbra, penumbra, size, and position) were identified by morphological image processing of Kanzelhöhe white light images for the time period 2009–2020. Kanzelhöhe Observatory prepares this data every observing day, and it is accessible via the FTP server. The sample was limited to ± 58 deg in the central meridian distance (*CMD*) to avoid solar limb effects leading to high position uncertainties. We used two different methods to calculate the sidereal angular rotation rate ω and subsequently the solar rotation parameters A and B: a daily shift method, where the synodic rotation velocities were calculated from the daily differences of the *CMD* and the elapsed time, and a robust linear least-squares fit method, where synodic rotation velocities were calculated by fitting a line to the measured positions in time *CMD*(t) for each tracer, for at least three consecutive measurements. We determined the dependence of the parameters A and B on the solar activity using the yearly mean total sunspot number obtained from the Sunspot Index and Long-term Solar Observations (SILSO). For the first time, the whole solar cycle No. 24 is examined using the Kanzelhöhe data set.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **260** Type: **Poster**

Solar wind modelling with EUHFORIA and the PSP observations

The recently available observations of the solar wind by Parker Solar Probe (PSP) at close to the Sun distances show large variations. Majority of attempts to model solar wind with EUHFORIA (European heliospheric forecasting information asset, Pomoell & Poedts, 2018), along the PSP trajectory, provided not very accurate modelling results. In attempt to understand the source of this inaccuracy, we studied the solar wind observed during the first ten perihelion of PSP. Number of intervals of enhanced solar wind velocity appearing simultaneously with the decrease of the solar wind density was found, indicating that this solar wind is originating from the coronal holes. Employing the magnetic connectivity tool (developed by ESA's MADAWG group) we confirmed the sources of that enhanced solar wind to be small coronal holes. In this study we present the characteristics of the solar wind flows originating from such a small coronal holes and compare them with characteristics of the fast solar wind originating from the large coronal holes, at close to the Sun distances. We discuss on the possible reasons for the lack of the fast solar wind in the PSP observations. In addition, we compare the characteristics of solar wind observed at close to the Sun distances and at 1 au.

Primary authors: MAGDALENIC, Jasmina (Royal Observatory of Belgium); VALLIAPPAN, Senthamizh Pavai (Royal Observatory of Belgium)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **262** Type: **Talk**

The Sun's differential rotation is controlled by baroclinically-unstable high-latitude inertial modes

Monday 9 September 2024 09:35 (15 minutes)

Helioseismology has revealed that the Sun's differential rotation profile substantially deviates from the well-known Taylor-Proudman theorem. It has been postulated that this deviation arises because the poles are warmer than the equator by a few degrees. Recently, global inertial modes of oscillation have been observed and identified on the Sun, including high-latitude modes with m=1,2,3. These high-latitude inertial modes are baroclinically unstable and thus quite sensitive to the latitudinal temperature difference inside the Sun. In this talk (based on Bekki, Cameron, & Gizon, Science Adv. 10:5643, 2024), we use 3D nonlinear numerical simulations to show that the pole-to-equator temperature difference in the Sun's convection zone is limited to less than 7 K due to the nonlinear feedback of the high-latitude modes. It is also found that these inertial modes control the Sun's differential rotation by transporting heat equatorward and affecting the angular momentum balance. The observed amplitudes of these inertial modes indicate that the Sun's latitudinal differential rotation is near its maximum allowed value.

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Session Classification: Solar interior, sub-surface flows and long-term variability

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **263** Type: **Poster**

Tracing magnetic switchbacks to their source: Are coronal jets the main switchback precursors?

The origin of the sudden deflections of the magnetic field, known as magnetic switchbacks, is still hotly debated. These structures, which are omnipresent in the in situ observations made by Parker Solar Probe (PSP), are likely to have their seed in the lower corona. There is an increasing consensus that small-scale energetic magnetic field reconnection plays a crucial role in establishing the conditions for generating switchbacks.
We aim to present a rigorous way currently possible to compare in situ measurements of switchbacks with small-scale solar eruptions, in an attempt to demonstrate that these eruptions act as seeds in the solar atmosphere that evolve into switchbacks.

We implement a methodology that uses a backmapping strategy, including a parametric analysis of the usual assumptions on the magnetic connectivity. We then visually identify jets, from an equatorial coronal hole, estimated to be the source region for one of the corotating intervals of PSP. We perform jet identification in AIA 193Å images. Their occurrence rate is then compared with the number of switchbacks captured by PSP.

We observe similar trends in the number of jets from the estimated source region and the number of switchbacks measured by PSP. However, no clear matching correlation is found. This result may be due both to event detection limitations caused by instrumental constraints and the jet visual identification. Our limited knowledge of the evolutionary phenomena occurring during solar wind propagation may also influence the result.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **264** Type: **Poster**

High-resolution observations of the upflow region dynamics at the border of an active region

The origin of the slow solar wind remains an open issue. One proposed explanation is that upflows at the border of active regions can be a source of the slow solar wind. The processes generating these upflows are not fully understood. Three potential mechanisms have been proposed: (I) reconnection between closed coronal loop and open magnetic field lines in the lower corona, (II) reconnection between chromospheric loops and open fields, and (III) plasma expansion along open magnetic field lines from the chromosphere to the corona.

Our aim is to determine the importance of different mechanisms in driving plasma upflows and their relationship to observed features in imaging data. To do this, we studied the dynamics of an upflow region in AR13262 on the 29th of March, 2023, using data from Solar Orbiter, IRIS, and Hinode. We analyzed spectroscopic data from Hinode/EIS and IRIS to examine plasma from the lower chromosphere to the corona using Doppler velocity maps. We developed a method to identify and determine the location of each upflow mechanism based on spectroscopic data. Using this unique observation set, we analyzed the temporal evolution of plasma flow at different layers of the solar atmosphere. To investigate the connection between the upflow region mechanisms and solar atmospheric features, we used images from EUI/HRIEUV onboard Solar Orbiter, IRIS and SDO/AIA.

Our preliminary findings suggest that mechanism (I) is the main driver of the upflow region, while the relationship between mechanisms and atmospheric features is complex. The investigation are still ongoing.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **265** Type: **Poster**

Combining the point of view of SO/PHI-HRT and SDO/HMI to characterise facular and solar network brightness at the limb

Close-to-limb magnetic field observations face challenges due to foreshortening, reduced light levels, the influence of the observation angle on the radiative transfer, among other effects. These factors contribute to increased uncertainty in the inferred magnetic field, impacting studies involving magnetograms.

To address these limitations, we can leverage data from a second vantage point. When observing magnetic features near the limb, a second perspective, where the same magnetic features appear closer to the disc centre, provides more accurate information. The Solar Orbiter mission, with its heliocentric orbit and hence varying view angles relative to the Sun-Earth line, presents a good opportunity for such observations. Its spectropolarimeter, the Polarimetric and Helioseismic Imager (SO/PHI), can be used for complementing magnetograms by other intruments, that observe in the Sun-Earth line.

We have previously combined SO/PHI Full Disk Telescope and SDO/HMI data, to demonstrate the benefits of this approach for characterising the intensity contrasts of faculae and solar network features compared to single-instrument observations. In particular, this allows studying weaker magnetic features closer to the limb.

Data from the SO/PHI High Resolution Telescope are now available, and can be combined with other instruments. This presents a good opportunity to improve on previous studies. We present the first results from combining SO/PHI High Resolution Telescope data with SDO/HMI, recorded close to quadrature in their orbits, to study facular and network brightness.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **266** Type: **Poster**

Hard X-ray Flare observations by Solar Orbiter/STIX

The hard X-ray imaging spectrometer STIX onboard Solar Orbiter has been operating continuously for 3.5 years recording over 50'000 solar flares. This poster will present science highlights including results from the Solar Orbiter Flare Watch from Spring 2024.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **267** Type: **Poster**

Characteristics and Energy Flux Distributions of Decayless Transverse Oscillations in Different Coronal Regions

Lim et al. (2023) have recently proposed that the slope (δ) of the power law distribution between the energy flux and oscillation frequency could determine whether high-frequency transverse oscillations give a dominant contribution to the heating (δ<1). Using the meta-analysis of decayless transverse oscillations, it has been found that high-frequency oscillations could play a key role in heating the solar corona. We aim to investigate how (whether) the distributions of the energy flux contained in transverse oscillations and their slopes are influenced by different coronal regions. An analysis of transverse oscillations from 41 quiet Sun (QS) loops and 22 active region (AR) loops observed by SolO/EUI HRIEUV is performed. The energy flux and energy are estimated using analysed oscillation parameters and loop properties, such as periods, displacement amplitudes, loop lengths, and minor radii of the loops. It is found that about 71% of QS loops and 86 % of AR loops show decayless oscillations. We find that the amplitude does not change depending on different regions, but the difference in the period is more pronounced. Although the power law slope (δ=-1.79) in AR is steeper than that (δ=-1.59) in QS, both of them are less than the critical slope of 1. High-frequency transverse oscillations could play a more significant role than low-frequency oscil lations in heating the QS and AR respectively.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **268** Type: **Poster**

The coherent morphology and evolution of solar coronal loops

Coronal loops, the arching structures filled with magnetically confined million Kelvin hot plasma, are the prominent features of the solar atmosphere. These loops are best observed in the extreme ultraviolet (EUV) and X-ray wavelengths. Coronal loop emission generally traces the magnetic field lines in the upper solar atmosphere. Thus probing their spatial morphology and evolution will help us better understand the dynamics of the magnetic field and the nature of plasma heating processes operating in the corona. The spatial morphology of coronal loops is still not fully understood. Some studies have indicated that coronal loops might be apparent optical illusions, similar to veils, caused by folds in the two-dimensional current sheets. Stereoscopic observations of coronal loops will be crucial to decipher their morphology. To this end, we used high-resolution imaging data from the Extreme Ultraviolet Imager (EUI) on the Solar Orbiter spacecraft and the Atmospheric Imaging Assembly on the Solar Dynamics Observatory to stereoscopically analyze a set of coronal loops in an active region. Our findings show that the loops have nearly circular cross-sectional widths and consistent intensity variations along their lengths over timescales of 30 minutes. We suggest that the morphology of coronal loops is consistent with three-dimensional flux tube-like structures and not emissions from randomly aligned two-dimensional current sheets along the line of sight as proposed in the 'coronal veil' hypothesis.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **269** Type: **Poster**

Atmospheric temperature and density stratification for magneto-hydrodynamic models and spectro-polarimetric inversions

Numerical models of the solar atmosphere are an important tool in solar physics. Both, models and spectro-polarimetric inversion techniques require stratifications for the plasma temperature and density. For the case of explicit numerical schemes with high-order derivatives we require an isotropic diffusion equation for numerical stability. Otherwise, wiggles and inaccuracies can occur at steep temperature gradients in the solar transition region. We test a wide parameter range of the isotropic heat conduction to obtain realistic temperature gradients and feasible models. Our goal is to construct an atmospheric stratification that can serve as an initial condition for multi-dimensional models, as well as a more realistic reference atmosphere for inversions. To compensate for energy losses in the corona, we implement an artificial heating function that mimics the expected heat input from the field-line braiding mechanism. We find that our heating function maintains and stabilizes the obtained coronal temperature stratification. Unexpectedly, we find that higher grid resolutions may need larger diffusivity, contrary to the common understanding that high-resolution models are automatically more realistic and would need less diffusivity. The reason is that smaller grid spacing may represent steeper temperature gradients in the transition region, which has larger potential for numerical problems. We conclude that isotropic heat conduction is is required for explicit schemes with high-order numerical derivative. The Spitzer-type heat conduction alone would not be sufficient to maintain numeric stability.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **270** Type: **Poster**

Observation and modelling of decayless kink oscillations in short magnetic loops

Magnetic loops are widely observed structures in the solar transition region and corona. As closed magnetic flux tubes, they can act as important wave guides for MHD waves, particularly transverse waves/oscillations. In recent coronal observations, transverse oscillations in small magnetic loops have been frequently studied, uncovering two different types of decayless kink oscillations. The first type displays shorter periods that exhibit a linear correlation with loop lengths, indicating their nature as standing kink eigenmodes. The second type, first detected by us in 2022, is mainly observed in coronal bright points (CBPs). These oscillations have longer periods that show no linear scaling with loop lengths. Notably, a peak at approximately 5 minutes in the period distribution histogram suggests that these oscillations could be externally driven oscillations or propagating waves excited by photospheric p-modes. With 3D MHD simulations, we find that both types of oscillations can be excited by p-modes in short coronal loops. This implies that p-modes may contribute to coronal heating by exciting decayless transverse oscillations in small loops. On the other hand, the transition region also hosts many small-scale magnetic loop structures, especially in active regions. Our recent observation using the Interface Region Imaging Spectrograph (IRIS) reveals the existence of transverse kink oscillations in these structures for the first time. We also estimate the corresponding energy flux and conduct a seismological diagnosis of magnetic field strength in these loops.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **271** Type: **Talk**

X-ray observations of small-scale flaring energy releases

Wednesday 11 September 2024 11:55 (15 minutes)

X-ray observations provide insight into the energy release in solar flares - the heated material and accelerated particles detectable via thermal and non-thermal bremsstrahlung emission respectively. We present observations of small active regions flares and even smaller quite Sun "flares"observed with the Nuclear Spectroscopic Telescope Array (NuSTAR), a highly sensitive telescope providing imaging spectroscopy > 2 keV. With active region microflares we show that heating to ~10 MK and acceleration of electrons is still present, much like larger flares. We present some microflares that were jointly observed with NuSTAR and the Spectrometer Telescope for Imaging X-rays (STIX) on Solar Orbiter, providing different viewing angles of the energy release. We also present some quiet Sun (non-active region) impulsive energy releases observed with NuSTAR during the recent solar minimum, investigating whether "flare-like"energy release continues outwith active regions. All these observations are also considered in the context of EUV emission seen by the SDO/AIA and softer X-ray with Hinode/XRT.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **272** Type: **Poster**

Oscillatory Reconnection of a 2D magnetic X-point in hot coronal plasma

Oscillatory Reconnection is a fundamental relaxation mechanism, characterised by changes in magnetic connectivity, the oscillatory nature of which requires no external periodic driving force to be sustained. This process has been one of the proposed mechanisms behind phenomena, such as quasi-periodic pulsations (QPPs). Its manifestation through the interaction of the ubiquitous waves with null points in the solar atmosphere opens the possibility of utilizing oscillatory reconnection as a tool for coronal seismology. We will be presenting the results from a series of parameter studies of a 2D X-point in coronal conditions, which we have performed with the PLUTO code. We report on the independence of the oscillation period from the type and strength of the wave pulse, initially perturbing the null. We will also discuss the effects that the equilibrium magnetic field profile, density and temperature distribution, and anisotropic thermal conduction have on the resulting periodicity and decay rate of oscillatory reconnection. This will offer a better understanding this energy release process and allows us to formulate an empirical formula connecting the previous quantities, opening the way in using oscillatory reconnection for coronal seismology.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **273** Type: **Talk**

How changing of source surface height parameter in EUHFORIA affect solar wind simulations

Friday 13 September 2024 12:40 (15 minutes)

A large discrepancy between modelling results and in-situ observations by Parker Solar Probe (PSP) was observed while modelling of solar wind using the 3D MHD model EUHFORIA (Pomoell & Poedts, 2018) at near the Sun distances. The default coronal model used in EUHFORIA consists of potential field source surface extrapolation (PFSS), Schatten current sheet (SCS) model and semi-empirical WSA model, which simulate plasma and magnetic conditions at inner boundary (0.1 AU). The outer boundary of PFSS model, known as source surface height parameter (RSS), and the inner boundary of SCS model are among the free parameters in the coronal model that determine the area of modelled coronal holes, which in turn influences the area of open flux. A default value of RSS = 2.6 R⊠ as suggested by McGregor et al. (2008) is used in solar wind modelling at short radial distances. It is reported that lower RSS value in coronal models better captures the area of coronal holes (Asvestari et al., 2019), reconstructs small-scale features (Badman et. al., 2020), and represents coronal magnetic field topologies during different phases of solar cycles (Lee et al. 2011; Arden et al. 2014).

In this study, we change RSS value and inner boundary of SCS model, while keeping default values for other parameters. We then compare the solar wind modelling results with modified RSS parameter to those obtained using all default parameters in the coronal model, by evaluating their agreement with the in situ observations from PSP for its first ten perihelion encounters.

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Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **274** Type: **Invited**

Small EUV brightenings in the quiet solar atmosphere: new insights from the Solar Orbiter mission

Tuesday 10 September 2024 09:00 (25 minutes)

Small scales EUV brightening in the solar atmosphere are observed everywhere and they have been classified following a variety of observational properties. For instance, they resemble small jets, bright dots or tiny loops. X-ray and EUV observations from the existing imagers, have been used to infer, for instance, the energy budget needed to heat the solar corona, as we expect the heating happening at small and impulsive way. EUV small scales brightenings have also been investigated as possible locations where the nascent solar wind escapes from the solar surface, as the result of small scale interchange-reconnections. These investigations have, however, not provided conclusive observational proofs to these phenomena.
The Solar Orbiter mission, launched in 2020, is providing opportunities for new insight into these problems, as it carries high temporal and spatial resolutions instruments accessing yet unresolved scales. In particular, EUI/HRIEUV telescope has revealed the existence of EUV brightenings down to the spatial resolution of 200 km and few seconds of lifetime, so extending our knowledge of these features to smaller scales. Their link to the photosphere is studied with the telescope PHI, which attains similar spatial resolutions.
In this talk, I will present and discuss these new observations. I will put them in the context of the present knowledge of the small scale EUV dynamical events, and I will discuss their possible link with the deepest regions of the solar atmosphere.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **275** Type: **Poster**

The imaging evidence of low-energy cutoff and the status of spectral cross-calibration of HXI

In this talk, I will show the method to confirm the existence of the nonthermal component down to 6.5 keV in the observed X-ray spectrum of a microflare first reported by Glesener et al., 2020. We report the first imaging evidence for low-energy cutoff of energetic electrons in EM maps of >10 MK plasma, which first appeared as two coronal sources significantly above the chromospheric footpoints. This study reveals the important role of electron thermalization and low-energy cutoffs in the physical processes of microflares. The other topic is about the spectral cross-calibration of HXI onboard ASO-S. Cross calibration of different X-ray instruments is essential for solar X-ray joint studies and is particularly important for studies of X-ray directivity and 3-dimensional properties of HXR sources. I will present the preliminary results of the detector spectral calibrations of ASO-S/HXI by investigating its three total flux detectors, and cross-calibrations using SolO/STIX, Fermi/GBM, and Konus-Wind data. Although it is challenging to perform joint observation studies due to several factors, the close fit of the X-ray observations from different instruments still indicates a favorable perspective for joint studies.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **276** Type: **Poster**

Complex interactions of the shock wave and ambient coronal structures

We present the study of the flare and coronal mass ejection (CME) event observed on 2 November 2021. The double-peak M1.7 GOES X-class flare originated from active region AR 12891 with has beta configuration of its photospheric magnetic field. The CME propagated strongly southward from the Sun-earth line. The CME-flare event was associated with a complex radio event consisting of multiple lane type II radio burst, Type III radio bursts and a Type IV continuum emission. The type II radio emission in the metric range shows two distinctive regimes indicating complex interaction of the shock wave and the ambient coronal structures. The type III radio bursts start mostly in the space-based observations suggesting the lack of the open field lines neighbouring the source region of the CME in the low corona and possible association with the shock wave (so called shock-associated type III bursts).

With the aim to understand complex relationship of the shock wave and its driver we combine analysis of radio observations and modelling of the fast Halo CME (velocity of about 1500 km/s). We employ direction finding technique for radio observations and the 3D MHD model EUHFORIA (European Heliosheric FORecasting Information Asset) for modelling of the CME and background solar wind.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **277** Type: **Poster**

Radiometric cross-calibration of HRI/EUI on Solar Orbiter and AIA/SDO

The extreme ultraviolet High-Resolution Imager (HRI) of the EUI telescope onboard Solar Orbiter observes the solar corona in a ~5
$mathring$A passband near 174
$mathring$A with unprecedented high spatial resolution. We perform radiometric cross-calibration of the HRI and the EUV channels of the Atmospheric Imaging Assembly (AIA) telescope of the SDO in order to allow further mutual analysis of the observational data. We apply differential emission measure analysis using quasi-simultaneous images in 7 spectral channels –HRI and 6 AIA –and compare the real and the simulated images on the per-pixel basis across the mutual field-of-view. The comparison suggests that the real HRI images have 60-80% larger signal than predicted by the DEM analysis. While the DEM analysis is know to be error-prone, a reasonably good re-production of the original images justifies the approach. However, the observed difference in real/simulated signal suggests either AIA absolute calibration or EUI absolute calibration is off. We found also that adding of the HRI signal to the AIA-based DEM inversion procedure brings information about moderate ~1MK plasma. We discuss how the mutual observation can be used to better understand the physics of individual events or structures.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **278** Type: **Poster**

Unveiling the Dynamics and Genesis of Small-scale Fine Structure Loops in the Lower Solar Atmosphere

Recent high-resolution solar observations have unveiled the presence of small-scale loop-like structures in the lower solar atmosphere, often referred to as unresolved fine structures, low-lying loops, and miniature hot loops. These structures undergo rapid changes within minutes, and their formation mechanism has remained elusive. In this study, we conducted a comprehensive analysis utilizing data from the Interface Region Imaging Spectrograph (IRIS) and the Goode Solar Telescope (GST) at the Big Bear Solar Observatory, aiming to elucidate the underlying process behind their formation. The GST observations revealed that these loops, with lengths of ~3.5 Mm and heights of ~1 Mm, manifest as bright emission structures in Hα wing images, particularly prominent in the red wing. IRIS observations showcased these loops in 1330 Å slit-jaw images. TR and chromospheric spectral lines exhibited significant enhancement and broadening above the loops, indicative of plasmoid-mediated reconnection during their formation. Additionally, we observed inverse Y-shaped configurations at their base and jet eruptions above these loops. Furthermore, differential emission measurement analysis reveals that these loops are heated to temperatures exceeding a million degrees. Based on our observations, we propose that these loops and associated jets align with the mini-filament eruption model. Our findings suggest a unified mechanism governing the formation of small-scale loops and jets akin to larger-scale X-ray jets.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **279** Type: **Talk**

Stereoscopic study of energy and mass transfer in the solar atmosphere

Tuesday 10 September 2024 09:40 (15 minutes)

We present the results of coordinated observations of the Swedish 1-m Solar Telescope with Solar Orbiter that took place from October 12th to 26th 2023. The campaign resulted in 7 datasets of various quality. The observational programs were adjusted to the seeing conditions. The observations cover two active regions, a sunspot and a coronal hole. We focus on the morphology and evolution of several targets that are observed from two vantage points. We decipher the findings with numerical simulations.

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Presenter: DANILOVIC, Sanja (Stockholm University)

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **280** Type: **Poster**

TWO DISTINCT ERUPTIVE EVENTS OBSERVED BY METIS ON OCTOBER 28, 2021

On October 28, 2021 the first X-class solar flare of Solar Cycle 25 occurred in active region NOAA AR 12887. It produced the rare event of ground-level enhancement of the solar relativistic proton flux and a global extreme ultraviolet (EUV) wave, along with a fast halo coronal mass ejection (CME) as seen from Earth's perspective. A few hours before the flare, a slower CME had erupted from a quiet Sun region just behind the northwestern solar limb. Solar Orbiter was almost aligned with the Sun-Earth line and, during a synoptic campaign, its coronagraph Metis detected two CME events in both the VL and UV channels. The earlier CME took place in the northwest (NW) sector of Metis field of view, while several bright features of the flare-related event appeared to the southeast (SE).
The NW and SE events have two distinct origins but were both characterized by a bright emission in HI Ly-alpha visible in the images of Metis up to 8 solar radii. This work investigates the evolution of these two almost co-temporal CMEs originating in distinct source regions. To that end, we extensively inspect data sets from numerous remote-sensing instruments observing the Sun in several spatial and spectral regimes. We track the erupting prominences associated with both CMEs with respect to their outer envelopes, from their source regions into the outer corona, by means of three-dimensional reconstruction techniques. Preliminary results of this work point to notable differences between these two events showing significant UV emission in the corona.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **281** Type: **Invited**

Thermal non-equilibrium : its importance for the energy and mass cycles in the atmosphere and its possible solar wind implications

Tuesday 10 September 2024 11:25 (25 minutes)

Thermal non-equilibrium (TNE) is a thermodynamical state set by a stratified (mainly at the foot-points) and quasi-steady heating. It is believed to play a major role in producing a variety of very common solar phenomena, in particular: prominences, coronal rain, and long-period EUV pulsations. These two later phenomena are the two faces of the same coin: the EUV pulsations results of the temperature and density variations in the cooling phases of TNE cycles, while coronal rain is produced by a thermal instability leading to the dramatic condensation of the plasma in the final phases of these cycles.

I will review the current state of knowledge about TNE, the latest developments on TNE observations and modeling in the solar atmosphere, and the remaining puzzles on the topic.
In particular, its recent detection in open-closed topologies lead to many questions on the interplay of TNE with interchange reconnection at coronal null-points and draw interesting perspectives on linking mass and energy transport in the solar atmosphere to solar wind release mechanisms.
Finally, I will talk about future observations with Solar Orbiter and upcoming missions such as MUSE and Solar-C.

Primary author: Dr FROMENT, Clara (CNRS/LPC2E)

Presenter: Dr FROMENT, Clara (CNRS/LPC2E)

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **282** Type: **Invited**

The inversion of spectropolarimetric data and machine learning: a story about old friends and their adventures

Thursday 12 September 2024 11:25 (25 minutes)

Over the past few decades, advancements in solar instrumentation, both ground- and space-based, have resulted in a large amount of high-quality spectral and spectro-polarimetric data. It is of great importance for the solar community to reliably extract the physical information encoded in these observations. The inversion of this type of data has been established as the most precise method to achieve this aim. I will examine the fundamental concepts and difficulties associated with this technique and highlight the endeavors to integrate it into the domain of machine and deep learning.

Primary author: SAINZ DALDA, Alberto (Bay Area Environmental Research Institute/Lockheed Martin Solar and Astrophysics Laboratory)

Presenter: SAINZ DALDA, Alberto (Bay Area Environmental Research Institute/Lockheed Martin Solar and Astrophysics Laboratory)

Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **283** Type: **Poster**

Fully Kinetic Simulations of Proton-Beam-Driven Instabilities from Parker Solar Probe Observations

The expanding solar wind plasma ubiquitously exhibits anisotropic non-thermal particle velocity distributions. Typically, proton Velocity Distribution Functions (VDFs) show the presence of a core and a field-aligned beam. Novel observations made by Parker Solar Probe (PSP) in the innermost heliosphere have revealed new complex features in the proton VDFs, namely anisotropic beams that sometimes experience perpendicular diffusion. This phenomenon gives rise to VDFs that resemble a "hammerhead". In this study, we use a 2.5D fully kinetic simulation to investigate the stability of proton VDFs with anisotropic beams observed by PSP. Our setup consists of a core and an anisotropic beam populations that drift with respect to each other. This configuration triggers a proton-beam instability from which nearly parallel fast magnetosonic modes develop. Our results demonstrate that before this instability reaches saturation, the waves resonantly interact with the beam protons, causing significant perpendicular heating at the expense of the parallel temperature. Furthermore, the proton perpendicular heating induces a hammerhead-like shape in the resulting VDF. Our results suggest that this mechanism may contribute to producing the observed hammerhead distributions.

Primary author: PEZZINI, Luca (KU Leuven & Royal Observatory of Belgium)

Co-authors: Dr MICERA, Alfredo (Ruhr-Universität Bochum,); Dr ZHUKOV, Andrei (Royal Observatory of Belgium); Dr BACCHINI, Fabio (KU Leuven); Prof. LAPENTA, Giovanni (KU Leuven); Dr ARRÒ, Giuseppe (Los Alamos National Laboratory, Los Alamos, USA); Prof. INNOCENTI, Maria Elena (Ruhr-Universität Bochum,); Dr LOPEZ, Rodrigo (P²mc, Comisión Chilena de Energía Nuclear)

Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **285** Type: **Poster**

Cross-scale phase relationship of solar activity with solar wind parameters: a Space Climate focus

Understanding the relationship between solar activity and solar wind is crucial for exploring the interactions among different solar atmospheric layers and the dynamics within the heliosphere. In this work, we used data from five solar cycles to examine the phase relationship between a proxy of solar activity, namely the Ca II K index, and solar wind parameters at 1 AU, such as dynamic pressure and speed. By taking advantage of a powerful tool, the Hilbert-Huang Transform, we decomposed the signals into their intrinsic modes of oscillation and analyzed their phase differences. Despite preserving a certain degree of phase coherence, both solar wind parameters exhibit delayed variations relative to the Ca II K index on space climate scales, showing an anti-phase relationship until 1985, followed by quadrature phase differences. Additionally, we explored how the relationship between the Ca II K index and solar wind parameters varies across different time scales. Our results indicate the presence of a potential bifurcation in the phase-space of the Ca II K index and solar wind speed (dynamic pressure), with the time scale acting as a bifurcation parameter. This suggests that including longer time-scale components enhances the discernibility of their connection. This discovery could be pivotal for understanding the complex interactions between solar activity and solar wind, offering important implications for prediction and interpretation in space climate studies.

Primary author: REDA, Raffaele (University of Rome Tor Vergata)

Co-authors: GIOVANNELLI, Luca (University of Rome Tor Vergata); ALBERTI, Tommaso (INGV--National Institute of Geophysics and Volcanology)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **287** Type: **Invited**

Challenges in forecasting space weather consequences of coronal mass ejections

Thursday 12 September 2024 15:25 (25 minutes)

Intense space weather storms are caused dominantly by coronal mass ejections (CMEs). Their ability to drive significant disturbances in the near-space environments at the Earth and other planets of the solar system is owed to their strong magnetic fields, sustained southward field direction and high solar wind speeds. The magnetic field in CMEs is however difficult to estimate in advance due to the lack of some crucial observations in the solar corona, intrinsic complexities and often drastic evolution and/or interactions occurring during the propagation through the interplanetary medium. This presentation will give an introduction to key challenges pertaining to achieving accurate long-lead time (< 0.5 days) forecasting of the magnetic fields in the heliosphere in two key CME substructures; its turbulent and compressed sheath region and a flux rope where field changes are more organised. Then, an overview of the recent developments in data-driven modelling efforts to estimate the magnetic properties in CME flux rope will be discussed.

Primary author: KILPUA, Emilia (University of Helsinki)

Presenter: KILPUA, Emilia (University of Helsinki)

Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **288** Type: **Poster**

Ellerman Bomb detection in SST and SDO observations with Deep Learning.

Small-scale magnetic reconnection events have a fundamental role in the dynamics and evolution of active regions and flux emergence. To detect them, we can use Ellerman Bombs (EBs), events found across the photosphere of emerging active regions produced by the reconnection of strong field concentrations of opposite polarity. Their main characteristic is the enhancement of the wings of the Hα line while the core remains in absorption. Ellerman Bombs detection has been performed in many studies using high-spatial resolution ground-based telescopes, but limited to short time series and small fields of view. To overcome this, we aim to detect EBs in data sets from the Solar Dynamics Observatory (SDO), allowing for a broader study in both the temporal and spatial domain. However, detecting EBs in SDO is challenging due to the lower spatial resolution compared to high-spatial resolution observatories and the absence of Hα spectroscopy to identify them. To address this problem, we first apply deep learning techniques to observations from the Swedish 1-m Solar Telescope to automatically detect EBs using the Hα line. These detections are then used to translate the observational signatures of EBs to the spectral passbands of the Atmospheric Imaging Assembly (AIA) on board SDO. We do this by means of a neural network-based segmentation process, which we use to find UV EBs signatures. This opens the way to study the relation between small-scale magnetic reconnection events with active regions throughout all their lifetime and across the solar disk.

Primary author: Mr SOLER POQUET, Ignasi Josep (University of Oslo, Institute of Theoretical Astrophysics, Rosseland Centre for Solar Physics)

Co-authors: DIAZ BASO, Carlos Jose (Oslo University); ROUPPE VAN DER VOORT, Luc (Rosseland Centre for Solar Physics, University of Oslo)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **290** Type: **Poster**

Magnetohydrodynamic drag simulations for a coronal mass ejection

Interplanetary coronal mass ejections (ICMEs) are known to drive the most intense geomagnetic storms. The fastest ICMEs can travel from the Sun to 1 AU in less than 24 hours. In order to have fast and reliable time-of-arrival predictions, it is crucial to develop models that are both physically accurate and computationally efficient. A paramount example is the drag-based model (DBM), which describes an ICME as a rigid body subject to an aerodynamic drag exerted by the background solar wind. However, as already hinted by early simulations, such a drag process has a magnetohydrodynamic nature and the aerodynamic DBM might not be the most accurate description. We present results of numerical experiments using high-resolution 2.5D MHD simulations of an ICME moving in different solar wind environments, aimed at improving such model. We focus on studying the resulting drag force both dynamically and parametrically. Thanks to a semi-Lagrangian approach (Expanding Box Model) and its resulting high resolution, we are able to include the effects of expansion, erosion (magnetic reconnection), and turbulence. We present preliminary results on the ICME tracking, deceleration, and drag estimates, and discuss their implications in the context of space weather.

Primary author: SANGALLI, Mattia (Università degli Studi di Firenze)

Co-authors: VERDINI, Andrea (Università degli Studi di Firenze); LANDI, Simone (Università degli Studi di Firenze); PAPINI, Emanuele (INAF-IAPS); NAPOLETANO, Gianluca (Università degli Studi di Firenze)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **291** Type: **Poster**

Energy diagnostics of flare-accelerated electron beams with X-ray and Radio data from Solar Orbiter

Energetic electrons from solar flares can move downward to produce X-rays in the chromosphere and upward to generate type III radio bursts in space. Previous studies found a good temporal correlation but a weak intensity correlation between both emissions due to different emission mechanisms. Theoretically, a link between the speed of outward electron beams (from radio) and the energy density of downward electrons (from X-rays) has been predicted. The **Solar Orbiter mission**, equipped with STIX and RPW instruments, allows for simultaneous X-ray and radio observations to test this theory.
We present results from 36 flares observed by STIX (4-150 keV) and associated with type III radio bursts detected by RPW (<10 MHz). Using X-ray spectroscopy, we obtained the electron spectral index and electron number during the HXR peak to estimate power. We derived the Type III exciter speed using the rise and peak times of the time profiles (V_front an V_peak, respectively) in the 0.4-4 MHz range, finding a V_p/V_f ratio of 0.77 ± 0.07, aligning with previous studies (@ 30-70 MHz, 0.8 ± 0.06) . We observed a correlation between electron power (E>25keV) and V_f **(cc=0.48)**, and a weaker one with V_p **(cc=0.3)**. The peak radio intensities correlate well with the electron spectral index **(CC=0.72)**. These findings suggest that while electron acceleration is temporally correlated, the energy distribution of escaping and confined electrons may be influenced by the geometry of the reconnecting magnetic field. As predicted by simulations, the radio intensity increases with energy density in the accelerated beams.

Primary author: PAIPA LEON, David (LESIA - Observatoire de Paris)

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **292** Type: **Poster**

Solar observations with the Atacama Large Aperture Submillimeter Telescope (AtLAST)

The **Atacama Large Aperture Submillimeter Telescope (AtLAST)** is a proposed single-dish full-steerable 50m telescope that would be located at 5100m altitude in the Chilean Andes near ALMA. Among a large range of scientific topics, AtLAST would be able to observe the Sun, probing the thermal and magnetic structure of the **solar chromosphere**, chromospheric heating, flares, prominences, the solar activity cycle, and much more. A truly novel observational aspect would be a fast-scanning mode to construct full-disk maps at multiple frequencies, resulting in high-cadence sequences and daily maps, thus covering the large range of relevant timescales with the same instrument, which would provide data complementary to observations at shorter wavelengths with, e.g., the European Solar Telescope (EST). In addition, AtLAST observations of our host star would have direct implications for stars and their impact on exoplanets in general.

Here we summarise the white paper on solar observations with AtLAST and highlight the need for an instrument with a large number of detector elements covering a wide frequency range.

Primary author: Dr WEDEMEYER, Sven (Rosseland Centre for Solar Physics, University of Oslo, Norway)

Co-authors: ATLAST SOLAR/STELLAR SCIENCE WORKING GROUP; KIRKAUNE, Mats (Rosseland Centre for Solar Physics, University of Oslo)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **293** Type: **Talk**

Solar Eruptions Triggered by Flux Emergence Below or Near a Coronal Flux Rope

Wednesday 11 September 2024 09:00 (15 minutes)

Observations have shown a clear association of filament/prominence eruptions with the emergence of magnetic flux in or near filament channels. Magnetohydrodynamic (MHD) simulations have been employed to systematically study the conditions under which such eruptions occur. These simulations to date have modeled filament channels as two-dimensional (2D) flux ropes or 3D uniformly sheared arcades. Here we present MHD simulations of flux emergence into a more realistic configuration consisting of a bipolar active region containing a line- tied 3D flux rope. We use the coronal flux-rope model of Titov et al. (2014) as the initial condition and drive our simulations by imposing boundary conditions extracted from a flux-emergence simulation by Leake et al. (2013). We identify three mechanisms that determine the evolution of the system: (i) reconnection displacing foot points of field lines overlying the coronal flux rope, (ii) changes of the ambient field due to the intrusion of new flux at the boundary, and (iii) interaction of the (axial) electric currents in the pre-existing and newly emerging flux systems. The relative contributions and effects of these mechanisms depend on the properties of the pre-existing and emerging flux systems. Here we focus on the location and orientation of the emerging flux relative to the coronal flux rope. Varying these parameters, we investigate under which conditions an eruption of the latter is triggered.

Primary authors: TOROK, Tibor; Dr LINTON, Mark G. (U.S. Naval Research Lab, 4555 Overlook Ave., SW Washington, DC 20375, USA); Dr LEAKE, James E. (NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA); Dr LIONELLO, Roberto (Predictive Science Inc., 9990 Mesa Rim Road, San Diego, CA 92121, USA); Dr TITOV, Viacheslav S. (Predictive Science Inc., 9990 Mesa Rim Road, San Diego, CA 92121, USA); Dr DOWNS, Cooper (Predictive Science Inc., 9990 Mesa Rim Road, San Diego, CA 92121, USA); Dr MIKIC, Zoran (Retired; performed this work while employed with Predictive Science Inc.)

Presenter: TOROK, Tibor

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **294** Type: **Talk**

Chromospheric Magnetic Field Reconstruction through Neural Field Assisted Spectropolarimetric Inversions

Thursday 12 September 2024 14:25 (15 minutes)

Spectropolarimetric observations provide valuable information about the physical conditions in the solar atmosphere, particularly the magnetic field. However, traditional pixel-by-pixel inversion techniques fail to capture the inherent spatial and temporal coherence of the solar atmosphere. To address this limitation, we propose a novel approach that utilizes neural fields (NFs) to perform spectropolarimetric inversions. NFs leverage compact neural network parameterization to represent continuous physical quantities. This allows us to impose spatio-temporal constraints on the inferred magnetic field, improving the fidelity of the reconstruction compared to the standard pixel-wise approach, especially in noisy scenarios.

We demonstrate the superior performance of NFs in performing chromospheric inversions under the weak-field approximation (WFA) in different spectropolarimetric observations from the Swedish 1-m Solar Telescope (SST). Moreover, the NF framework seamlessly integrates external constraints, such as alignment with the orientation of the chromospheric fibrils or similarity to pre-computed magnetic field extrapolations, further improving the fidelity of the inferred magnetic field. This work showcases the potential of NFs for future instruments with large fields of view, thanks to their compact representation and the ability to impose spatio-temporal constraints to improve the magnetic field reconstruction in the solar atmosphere.

Primary author: DIAZ BASO, Carlos Jose (Oslo University)

Co-authors: ASENSIO RAMOS, Andrés (Instituto de Astrofisica de Canarias); DE LA CRUZ RODRIGUEZ, Jaime (Institute for Solar Physics, Stockholm University); ROUPPE VAN DER VOORT, Luc (Rosseland Centre for Solar Physics, University of Oslo)

Presenter: DIAZ BASO, Carlos Jose (Oslo University)

Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **295** Type: **Poster**

Long-Period of Plasma and Magnetic-Helicity Oscillation Prior to Three C-class Flares

The objective of this work is to identify various periods of magnetic helicity and detect the long-periods plasma oscillations in an Active Region NOAA12353 prior to a series of C-class flares in the lower solar atmosphere.
To analyse the magnetic helicity flux in the lower solar atmosphere, linear force-free field extrapolation was used to construct a model of the magnetic field structure of the active region. Subsequently, the location of long-period oscillations in the active region was probed by examining the spectral energy density of the measured intensity signal in the 1700 Å, 1600 Å, and 304 Å channels of the Atmospheric Imaging Assembly (AIA) of the Solar Dynamics Observatory (SDO). Significant periods of oscillations were determined by means of 3D-wavelet analysis. We report the presence of different long periods oscillation in the lower solar atmosphere before and after the flare events.

Primary author: WISNIEWSKA, Aneta (Astronomical Institute Slovak Academy of Sciences)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **296** Type: **Poster**

Investigating the effect of statistically-averaged helicity condensation on ambient increase in the Solar Open Flux

A key problem faced by global models of the solar corona is a consistent underestimation of the amount of Open Flux. Recent studies have shown that introducing bipole twist or helicity condensation to non-potential global models can partially resolve this disagreement between simulated and measured values of the Solar Open flux. Here, we disentangle these effects to focus entirely on the extent of the contribution from helicity condensation to the Open Flux. We make use of global magnetofrictional simulations to model the amount of open flux and its spatial distribution over several solar cycles based on Kitt-Peak synoptic magnetograms. From this we show that statistically-averaged helicity condensation leads to both an ambient increase of Open Flux and a sporadic incease. Additionally, single-case analysis of the relationship between helicity condensation and open flux reveals some fine-detail behaviour that is otherwise obscured by the large-scale temporal analysis.

Primary author: KLOWSS, Jonah (University of St Andrews)

Co-author: Prof. MACKAY, Duncan (University of St Andrews)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **297** Type: **Poster**

Propagation and reflection of MHD waves in the solar wind

Spacecrafts such as Parker Solar Probe (PSP) and Solar Orbiter (SolO) study the solar atmosphere by making in-situ and remote observations at an unprecedented spatial and temporal resolution, shedding light on coronal heating and solar wind acceleration mechanisms. Alfvenic fluctuations such as switchbacks and pure Alfven waves are some of major carriers of magnetic energy, but the energy dissipation mechanisms remain unclear. Phase mixing can be an effective mechanism, that has mostly been studied in the context of closed magnetic field structures such as coronal loops. Along open field lines, trapping and/or dissipating wave energy becomes more difficult. Non-uniformities in the medium can, in general, reflect a fraction of the input wave energy. Not only does this increase the opportunities for energy dissipation, but also has seismological applications in the sense that the transmitted wave spectrum contains information about the non-uniformities in the underlying medium. Using magnetohydrodynamic modelling, we aim to understand these phenomena in the context of a spherically expanding background solar wind. Therefore, our simulations encompass a numerical domain from the chromosphere where waves are generated to the PSP and SolO perihelia and whose propagation and dissipation are studied in an extended solar atmosphere with a supersonic and superalfvenic background solar wind. Our model, in conjunction with space-based solar wind observations, provides an estimate of the conditions and constraints for maximal amount of wave energy trapping available for coronal heating and solar wind acceleration in terms of inherent spatial and temporal scales.

Primary author: KUMAR, Anmol (University of St Andrews)

Co-authors: DE, Ineke (University of St Andrews); PAGANO, Paolo (Università degli Studi di Palermo); HOWSON, Thomas (Abertay University, University of St Andrews)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **298** Type: **Invited**

From multi-decadal to real-time solar wind modelling, connectivity and plasma signatures on and off the ecliptic plane

Friday 13 September 2024 12:00 (25 minutes)

The solar wind streams from compact sources at or near the Sun, accelerates across the low solar corona, and expands into the whole interplanetary space. The physical properties of any wind streams thus reflect the characteristics of their source regions and those of the extended zones of the corona they cross, and are affected by the time-varying strength and geometry of the global background magnetic field. I will discuss the spatial distribution of solar wind sources and relate them to the properties of the interplanetary wind by means of an extended time series of data-driven 3D simulations that cover more than two solar activity cycles. Similarly, I will relate magnetic connectivity jumps with solar wind plasma signatures, and discuss their occurrence frequency and amplitudes at different epochs of the solar cycle, on and off the ecliptic plane.
The same model constitutes the core of a forecasting tool (SWiFT-FORECAST, ESA SWESNET and Virtual Space Weather Modelling Centre), new aided by machine learning methods. Several validation and calibration schemes were introduced to select optimal subsets of the ensemble and to correct for model biases. I will address some of the main challenges related to the implementation and validation of such tools, as well as the pernicious issues that stem from the lack of observables between the two boundaries of the Sun–Earth system, and from the dependence of "point" forecasts on the global properties of the solar atmosphere.

Primary author: PINTO, Rui (IRAP & InforMarty)

Presenter: PINTO, Rui (IRAP & InforMarty)

Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **299** Type: **Poster**

Heat flux asymmetry in the quiet Sun photosphere.

The heat-flow fluctuations along the quiet Sun convective pattern are studied in data provided by high-resolution observations and simulations. Using the methods of stochastic thermodynamics it is shown that heating and cooling of the photospheric flows obey a remarkable thermal relaxation asymmetry which was recently discovered in laboratory experiments.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **300** Type: **Poster**

Using the Sun as Rosetta stone to study the properties of other solar-like systems

We present our new approach to characterize
solar-like stars and their interaction with hosted exoplanets in analogy to the Sun-Earth system. Our investigation allows us to obtain not only a highly accurate characterization of the mother star, but also to study the impact of the star's rotational and activity history on the evolution of its exoplanets.
This information, coupled with
the precise age estimated by asteroseismology, allows determining how long an atmosphere of terrestrial type could resist to the action of stellar wind and the XUV flux enabling to directly quantify the portion of the atmosphere which could potentially be eroded.

Primary author: Dr DI MAURO, Maria Pia (Istituto Nazionale di Astrofisica (INAF))

Co-authors: PEZZOTTI, Camilla (University of Liège); BERRILLI, Francesco (Università degli Studi di Roma "Tor Vergata"); GIOVANNELLI, Luca (University of Rome Tor Vergata); REDA, Raffaele (University of Rome Tor Vergata)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **301** Type: **Talk**

Unveiling the Global Magnetic Topology with Physics-Informed Neural Networks

Wednesday 11 September 2024 10:00 (15 minutes)

The 3D coronal magnetic field is the decisive component to understand the formation and eruption of flux ropes in the solar corona. Non-linear force-free magnetic field extrapolations are a frequently applied method to provide a realistic estimate of the coronal magnetic field from photospheric vector magnetograms but are typically limited to small simulation volumes.
We present a novel approach based on Physics-Informed Neural Networks, to perform force-free magnetic field extrapolations of the global solar magnetic field. Our method uses full-disk vector magnetograms from SDO/HMI, and directly models highly twisted quiet-Sun filaments, coronal holes, and complex active region fields, that are in agreement with observations from SDO/AIA in extreme ultraviolet.
We use our method to study the eruption of a trans-equatorial filament on February 5th 2016 and its connection to a quiet-Sun filament eruption. The global extrapolation reveals the magnetic connectivity across the solar equator and interaction with an open-flux region. Furthermore, our model shows the large-scale connectivity that could link to a sympathetic filament eruption. These findings highlight the importance of the global magnetic topology, both for small scale reconnection and large topological reconfigurations. We conclude with an outlook, where we apply this approach to estimate the open magnetic flux and show that highly twisted field configurations play a significant role for the formation of open flux regions.

Primary author: JAROLIM, Robert (University of Graz)

Co-authors: VERONIG, Astrid (University of Graz); THALMANN, Julia (University of Graz); Dr REMPEL, Matthias (High Altitude Observatory, NCAR)

Presenter: JAROLIM, Robert (University of Graz)

Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **302** Type: **Poster**

Combining SDO and Hinode data to simulate a typical Coronal Bright Point in 3D

Understanding the mechanism behind coronal heating remains a fundamental challenge in solar physics. Above small-scale bipolar regions we observe Coronal Bright Points (CBPs) in extreme-UV coronal emission. We analyze 346 CBPs track their lifetimes, shapes, polarities, merging behavior, etc. to select a typical CBP for a 3D MHD simulation.
Most CBPs show magnetic some flux cancellation. The brightest CBPs typically exhibit bipolar fields and longer lifetimes, while weaker polarities produce fainter CBPs. Typical CBPs have lifetimes exceeding 6 hours, supporting the hypothesis that CBP heating primarily occurs through magnetic-energy dissipation, e.g. through relatively steady and gradual reconnection.
We aim to replicate an isolated CBP in a 3D simulation. We need to combine magnetograms from SDO and Hinode. For consistency, photospheric magnetic fields need a sufficiently large fields-of-view, as well as similar resolution. Our overlaying technique enhances the limited Hinode FOV with SDO data with an added high-resolution network.
Later, we may compare MHD simulation results with the really observed CBP. This allows us to improve our understanding of the CBPs heating and to track the coronal plasma dynamics. Coronal Doppler-shifts maps from Hinode/EIS allow us to verify our simulation result.

Primary author: KRAUS, Isabella (University of Graz)

Co-author: Dr BOURDIN, Philippe-A. (University of Graz)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **303** Type: **Poster**

Modeling the Propagation of CMEs with COCONUT: Implementation and application of the RBSL Flux Rope Model

Coronal mass ejections (CMEs) are rapid eruptions of magnetized plasma that occur on the Sun. They are known to be the main drivers of adverse space weather. The accurate tracking of their evolution in the heliosphere in numerical models is of the utmost importance for space weather forecasting. We implement the RBSL flux rope model in COCONUT, a new global coronal MHD modeling, to simulate the propagation of CMEs resulting from the eruptions of the flux rope with a complicated shape from the solar surface to 25 solar radii. Hereafter, we investigate the impacts of the morphology of flux ropes on their resulting CMEs. As such, we can establish a bridge between the CMEs at 20 solar radii and their progenitors in solar source regions.his work demonstrates the potential of the RBSL flux rope model in reproducing CME events that are more consistent with observations. Our findings strongly suggest that magnetic reconnection during the CME propagation plays a critical role in destroying the coherent characteristics of a CME flux rope.

Primary authors: LANI, Andrea (KU Leuven); SCHMIEDER, Brigitte (Observatoire de Paris); GUO, Jinhan (KU Leuven / Nanjing University); LINAN, Luis (CmPA, KU Leuven); Prof. CHEN, Pengfei (Nanjing University); Prof. POEDTS, Stefaan (KU Leuven); Prof. GUO, Yang (Nanjing University); Mr NI, Yiwei (Nanji)

Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **304** Type: **Poster**

Infrared spectropolarimetry of C class solar flare

The influence of solar flares on the dynamics of lower atmospheric plasma is not yet fully understood. We performed full-Stokes spectropolarimetric observations of active region NOAA 3363 on GREGOR Infrared Spectrograph (GRIS) during consecutive C class flares on July 16, 2023. The near-infrared spectral interval covered photospheric Si I 10827˚A and Ca I 10839˚A lines and chromospheric He I 10830˚A triplet line. Besides the enhanced emission of He I 10830˚A triplet, the upper photospheric line Si i 10827˚A also showed a significant intensity increase. The intensity of the Si I line was increased after several minutes of He I enhancement, which indicates slow energy transfer from the chromosphere to the upper photosphere. We speculate that the heat transfer by thermal conduction from the formation height of He I to the formation height of the Si I line is responsible for the observed time delay.

Primary authors: Dr VASHALOMIDZE, Zurab (Astronomical Institute SAS); ZAQARASHVILI, Teimuraz (IGAM, Institute of Physics, University of Graz); BENKO, Martin (Astronomical Institute Slovak Academy of Sciences); Dr KURIDZE, Davit (National Solar Observatory); GÖMÖRY, Peter (Astronomical Institute Slovak Academy of Sciences); RYBAK, Jan (Astronomical Institute, Slovak Academy of Sciences, Tatranska Lomnica, Slovakia); COLLADOS, Manuel (Instituto de Astrofísica de Canarias)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **305** Type: **Poster**

Anticipating solar flares with zero false positives

Solar flares invariably begin with "hot onset" soft X-ray emission. This produces an initial horizontal branch in an [EM,T] diagnostic diagram (Jakimiec), a phase characterized by hot (5-20 MK) soft X-ray emission with continously growing emission measure. As detected by GOES, the hot onset may begin over up to 30 minutes
prior to the flare impulsive phase. This universal property has the practical consequence of anticipating flare occurrence and magnitude. This has practical consequences as a reliable "nowcastng" technique for flare occurrence. Theoretically, this phenomenon must underpin all of the many other aspects of early flare development and termed "precursors". The hot onset may or may not include discrete flare-like events, but also often has a smooth and featureless development suggestiveof a deflagration wave.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **306** Type: **Poster**

Coalignment for a quiet region from two vantage points of SO/PHI and Hinode/SP

In a quiet region, a variety of convection (granulation)-driven phenomena at a tiny spatial scale are observed. For their understanding, it is important to derive the vector of the velocity and magnetic field. One of the effective approaches to study the phenomena is to take advantage of the stereoscopic configuration between Solar Orbiter (SO)/ Polarimetric Helioseismic Imager (PHI) and Hinode/Spectro-Polarimeter (SP), thanks to their high and comparable spatial resolution under the stable observation from the space. Since the spatial scale of the granulation is down to their 1-pixel size, an accurate co-alignment is required. However, several difficulties such as their different pixel sampling, image distortion, different viewing angle, and even different observation instruments (Hinode/SP adopts a slit-based observation while the SO/PHI does a filtergraph) have to be taken in account.

The target region, taken on 10th April 2023, is off disk-center for both instruments with heliocentric angles of 0.79-0.92 for Hinode and Solar Orbiter, respectively, and a separation angle of 63 degrees between the Sun-Hinode and the Sun-SO lines. In the coalignment process, the scaling and offsets in the X- and Y-directions are chosen to find the best correlation. The resulting coaligned-map with spatial size 34"x 76"reaches a correlation coefficient of 0.91. In this presentation, we will discuss the usability of this coaligned-dataset for the purpose of stereoscopical diagnosis of the vector fields of physical quantities in the convection-driven phenomena. In addition, we will discuss the physical origin of the still remained discrepancies seen in this coaligned-map.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **307** Type: **Poster**

On the thermal and magnetic properties of an active region anemone jet

Abstract: Recurrent jets are regarded as one of the crucial processes for the periodic release of magnetic free energy through intermittent magnetic reconnections. In this talk, we will present a detailed analysis of the dynamic, thermal, and magnetic characteristics and evolution of a typical anemone jet amid a series of recurrent eruptions at the edge of the active region 13102. This jet demonstrates a multi-thermal nature, encompassing plasma with temperatures ranging from the chromosphere to the transition region and the corona. NLFFF extrapolations reveal a highly twisted flux rope (with a twist number of ~2.06) featuring a bald patch structure at the jet's footpoint, which facilitates magnetic reconnections. This indicates that even small-scale reconnections associated with coronal jets might be linked to highly complex magnetic configurations. Moreover, this jet has also been found to have a close relationship with local magnetic cancellation in a local quadrupolar region, which has seldom been reported in the literature.
Keywords：solar jets, magnetic reconnection ; solar magnetic fields ; solar activity

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **308** Type: **Talk**

Parametrization of SHARP Vector Magnetic Field Using Disentangled Representation Learning

Thursday 12 September 2024 12:20 (15 minutes)

Contemporary solar physics deals with the increasing amount of high-dimensional data, making it an excellent case for the application of machine learning (ML) algorithms. Synoptic full-disk observations with the Solar Dynamics Observatory (SDO) are one example, allowing us to follow the solar magnetic activity over more than one solar activity cycle and to study its local and global facets. The Space-weather HMI Active Region Patches (SHARP) vector magnetic field (VMF) maps and parameters, based on Helioseismic and Magnetic Imager (HMI) full-disk observations, are developed for studying the magnetic evolution of individual active regions and flare triggering mechanisms. We present a method for active region parametrization by combining empirical parameters and ML-extracted features based on SHARP maps. Time series of SHARP VMF maps are used as input for Disentangled Variational Autoencoder (VAE), a Disentangled Representation Learning (DRL) algorithm, which facilitates the extraction of low-dimensional feature representation. The power of the VAE model lies in its ability to encode generalized information about nonlinear dynamical systems, in this case a solar active region, where each feature represents a particular aspect of the input data. We demonstrate how the VAE-based features can be used to identify and study the stages of the magnetic patches evolution in combination with the SHARP empirical parameters, relating empirical and learned features. Furthermore, empirical dataset enhanced with ML features can be used to analyze the development of individual active regions and searching for eruption precursors.

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Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **309** Type: **Poster**

Heliospheric Space Weather Centre tools for space weather monitoring

The Heliospheric Space Weather Centre (HSWC) is an ALTEC, INAF –OATo, and UniGe joint project aimed at providing and supporting services related to the heliosphere. It currently hosts two tools developed by ALTEC and INAF: the Geo Magnetic Effectiveness (H103d) and the CME propagation prediction (H103e). The tools are part of the SWESNET project, within the ESA Space Weather programme. The algorithms, developed by INAF, are integrated into ALTEC's infrastructure, which handles data retrieval, scientific product generation, storage, and web interface.
The H103d tool uses data from the DSCOVR instrument to compute magnetic helicity, used to identify geo-effective events. It analyzes near real-time measurements and generates 7-day plots of magnetic field, solar wind speed, proton density, proton temperature, DST index, magnetic helicity spectrogram, and integrated magnetic helicity.
The H103e tool employs data from DSCOVR/FC and LASCO/C2-C3. Its algorithms detect halo CMEs, identify CME features, model solar wind, and model CME propagation. The pipeline computes 48 solar wind and proton density maps daily from DSCOVR/FC data over the previous 28 days, and identifies earthward CMEs, calculates their parameters and arrival time.
ALTEC infrastructure is being upgraded to host AI support tools. In the next future, AI-based modules will be added to both the H103d, in the context of AIxtreme-I project, and H103e tools; a third tool dedicated to predict the occurrence of intense solar flares within next 24 hours is currently in the integration phase.
The presentation will cover the pipelines, components, and working mechanisms of current and future tools.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **310** Type: **Poster**

Deciphering magnetic reconnection dynamics in the large and small-scale explosions on the Sun

Flares and jets are explosive phenomena driven by magnetic reconnection in the solar atmosphere. We present a comprehensive study combining observational analysis and numerical simulations to elucidate the intricate structures and processes underlying these events. Utilizing SDO/HMI vector magnetogram data, we performed a data-constrained simulation of a C1.3 class flare observed in an active region NOAA 12734 with the EULAG code. Our analysis reveals a complex magnetic configuration involving a magnetic flux rope with overlying envelope of quasi-separatrix layers (QSLs), augmented by the presence of a 3D null and null-line contributing to the flare ribbon brightening (spanning over 100 Mm x 50 Mm spatial scale). Inclusion of the Hall effect in our simulation leads to faster reconnection dynamics, along with the signatures of observed swirling motions absent in the traditional MHD simulation. On the lower end of the energy spectrum, jet activity that could potentially contribute to the solar wind is observed in coronal hole plumes at spatial scales of less than 1000 km. To probe the dynamics of these small-scale jets and their correlation with magnetic field evolution, we conducted a self-consistent 3D MHD simulation of a coronal hole plume using the MURaM code. Similar to the large-scale flare, we found that QSLs play an important role in structuring the flows along the boundaries of plumes. These findings highlight the role of magnetic structures in shaping solar eruptive events and flows around plumes, shedding light on their complex yet unified behavior.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **311** Type: **Poster**

MOF: the Ground Support to Metis Data and Operations

METIS is the coronagraph of the scientific payload of Solar Orbiter, a joint ESA-NASA mission aiming at studying the Sun poles and the circumsolar region. METIS operations are handled via the Metis Operations Facility (MOF), which is built, run, and maintained by ALTEC in close collaboration with INAF. MOF empowers the scientific analysis and exploitation of data acquired by METIS in different ways:

• Data retrieval and processing: the METIS raw telemetry is fetched on a daily basis from Mission Operation Center (MOC) and transformed up to L2 data products;
• Data archival: METIS data products are indexed and preserved with the aim of enabling exploitations of METIS data in space weather and solar science applications;
• Data exploration: the scientific team has the capability to explore the MOF archive by searching for METIS data products exploiting a wide set of scientific keywords;
• Data analysis and validation: reports about METIS data products are generated in order to allow the scientific team to detect observed solar events of interest like Coronal Mass Ejections (CMEs) and flares. Validated data is eventually published to the ESA Solar Orbiter Archive (SOAR);
• TM/TC Monitoring: METIS telemetry stored in MOF can be exploited to perform further analysis about the instrument and spacecraft status.

In the talk, MOF capabilities and the current state and nominal functioning will be presented. Moreover, future plans and perspectives to further exploit METIS data in space weather and big data and AI related applications will be discussed.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **312** Type: **Poster**

3D recostruction of a CME with polarimetric technique

On October 3, 2023, around 12:45 UT, a prominence erupted from the active region located at 18°N, 20°W, as observed by the Full Sun Imager/Extreme Ultraviolet Imager (FSI/EUI) on board the Solar Orbiter. This eruption was followed by a partial halo coronal mass ejection (CME) and a CME-driven shock, confirmed by the detection of a Type II radio burst by . In order to estimate the CME plasma electron density and to infer the 3D structure of the CME by using a single point of view, we applied the polarization-ratio technique to the Metis white light data (polarized and total brightness). Additional constraints to the 3D reconstruction were provided by observations from other LASCO-C2 on SOHO and COR1 and COR2 on STEREO-A. By using UV data from Metis and considering the radiative and/or collisional excitation, also the CME electron temperature can be estimated. This work thus provides new information on the thermodynamic evolution of CMEs in the inner corona

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **313** Type: **Invited**

The fine scales of solar flares

Thursday 12 September 2024 09:00 (25 minutes)

The quest for ever higher spatial and temporal resolution in solar physics can sometimes be thwarted by photon flux. However, in solar flares the greatly increased output across most of the electromagnetic spectrum means that we can often take advantage of high spatial and temporal resolution simultaneously. The rapid evolutionary timescales of flares certainly merit this effort. This talk will review some recent results in which observations at fine spatial and temporal scales are used to explore the properties of solar flare magnetic energy release and energy transport. The emphasis will be on chromospheric and transition region observations of flare footpoints and ribbons. Topics will include ribbon fine structure and what it reveals about coronal processes, and footpoint timing measurements and the chromospheric source heights, both of which help constrain energy transport models.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **314** Type: **Poster**

A catalog of CME-ICME lineup events

An accurate assessment of our current space weather modeling is necessary due to progress in space weather research. Any validation framework needs suitable qualitative data for consistent validation procedures. The qualitative data also contributes to the refinement of the model and hence better forecasting ability. In alignment with this objective specifically for CME events, we present a newly prepared dataset of CME-ICME lineup events. This dataset includes in-situ observations from various spacecraft like Messenger, Venus Express, Maven, Stereo-A/B, Solar Orbiter, Bepi Colombo, Parker Solar Probe, Wind, etc, with detailed CME analysis performed by Space Weather Database of Notifications, Knowledge, Information (DONKI) developed at the Community Coordinated Modeling Center (CCMC). Apart from CME-ICME information, the dataset also possesses the necessary information about Probabilistic Drag Based Model (P-DBM) quantities. The dataset is publicly available to provide a valuable resource for model validation and to compare the performance with other available CME propagation models.
Our work offers a unique opportunity to refine CME propagation models, as ICMEs have been observed at multiple targets across a wide range of heliocentric distances. By utilizing this dataset, researchers can better understand the dynamics of CME propagation and improve the forecasting methods.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **315** Type: **Poster**

Sun cubE onE (SEE): a CubeSat Mission for High-Energy Solar Observations

The SunsCube One (SEE) mission, currently in the early design stages, is being built by a team led by the University of Roma Tor Vergata. This mission is one of several small satellites planned by the Italian Space Agency (ASI) under ALCOR program. SEE proposes a 12U CubeSat to investigate gamma-ray, X-ray, and ultraviolet (UV) solar emissions. SEE aims to improve our understanding of space weather and Sun-Earth interaction from Low Earth Orbit (LEO). SEE's scientific payload is specifically designed for two key investigations. First, X and Gamma SEE's scientific payload is designed to investigate the energy spectrum of solar flares from the soft X-rays to the high-energy gamma rays. Importantly, the instrument will achieve this with a high time sampling rate, allowing for a detailed analysis of the rapid fluctuations that occur during a flare event. Second, the mission will monitor solar activity by capturing full-disk images of the Sun in the specific wavelength of the Magnesium II (Mg II) doublet at 280 nm, utilizing a dedicated full-disk imager. This is valuable because UV radiation heavily influences both Earth's upper atmosphere, impacting space weather, and the lifespan of orbiting debris. SEE will leverage data from existing space and ground-based observatories, including those focusing on solar features (Solar Orbiter, IRIS, SDO, Aditya-L1, TSST), high-energy particles (GOES, CSES), and Earth's magnetic field (geomagnetic data). This multi-instrument, multi-wavelength, and multi-messenger approach will provide a comprehensive picture of solar activity and its impact on Earth.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **316** Type: **Talk**

First comparison of MSDP spectroscopic observation of the C1.6 solar flare with FLARIX NLTE simulations

Thursday 12 September 2024 10:10 (15 minutes)

For the first time we present comparison of advanced FLARIX NLTE time-dependent numerical simulations of flaring emission with spectral observations of a compact C1.6 GOES-class flare recorded with MSDP (Multichannel Subtractive Double Pass) imaging spectrograph installed at the Białków Observatory. The high time resolution (50 ms) MSDP spectral data, enabled comprehensive analysis of H-alpha line profiles and light curves measured within the chromospheric flaring sources. For FLARIX simulation an initial atmospheric model similar to VAL-C, but with a modified temperature in the upper chromosphere, was applied. We also used, as an input parameters, increased to sub-second time resolution non-thermal electron (NTE) beam's parameters obtained from RHESSI satellite. To achieve it the basic 4-sec resolution data were modulated using the de-modulated (to 250 ms) hard X-ray (HXR) RHESSI flux. Synthetic H-alpha line profiles obtained from FLARIX were compared with the observed spectra. During the impulsive phase of the flare, the general evolution of the observed and synthetic H-alpha line intensity were in good agreement, but some differences were observed in intensities in various parts of the H-alpha line profile. Variations of the energy flux of NTEs was in strong correlation with H-alpha emission during the analysed HXR pulse. Considering various effects, such as the filling factor FF = 0.20 influenced on observed emissions, relatively good agreement between theoretical and observed lines was achieved.

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Session Classification: Multi-scale energy release, flares and coronal mass ejections

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **317** Type: **Poster**

Temporal evolution of a coronal bright point in the transition region and corona

Coronal bright points are systems of loops that connect small bipoles in the magnetic network of the quiet Sun.
While a bright point as a whole might persist for several hours, individual loops within it evolve on timescales of minutes.
Capturing their atmospheric signatures, that span from the ultraviolet to X-rays, requires simultaneous observations over a broad range of plasma temperatures from the low transition region to the corona.
We present a unique observation of a coronal bright point evolution, with Solar Orbiter at 0.29 AU from the Sun.
During more than 2 hours, the EUI imager captured the bright point near 1 MK with great detail, at a spatial resolution of about 200 km and cadence down to 3 s.
For 45 minutes, the bright point was also covered with the spectrograph SPICE through consecutive narrow, six-step raster-maps with 72 s cadence, capturing simultaneously plasma from just below 0.1 MK to 1 MK.
The surface magnetic footpoints were (partially) covered with magnetograms from PHI, showing flux emergence, and ceaseless interaction between the main polarities of the bright point and the surrounding smaller magnetic features.
The EUI images reveal complex loops, that first appear twisted and overlapping, and relax to a more parallel state.
Our preliminary analysis of a loop bundle, that appear as one elongated feature in SPICE data, shows evidence for a time delay in thermal response of about 60 s from the lower transition region plasma (below 0.1 MK) to the upper transition region (above 0.1 MK).

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **319** Type: **Poster**

COCOMAG: color-coded magnetograms as probes of active region evolution and complexity

We are proposing a visualization of vector magnetograms whereby the three components of the photospheric magnetic field vector are combined into RGB colored maps, creating color-coded magnetograms (COCOMAGs). In this configuration the primary and secondary colors represent magnetic field with different orientation. The areas occupied by different color hues are extracted, creating appropriate time series (color curves). The resulting colored maps and color curves are used as proxies of the active region evolution and its complexity. The morphology exhibited in COCOMAGs is associated to typical features of active regions, such as sunspots, plages, and sheared polarity inversion lines. In complex regions, extended, twisted flux systems appear as continuous, color processions, while abrupt color changes signify sheared polarity inversion lines. Active regions in their decay phase are dominated by rather vertical magnetic field (pixels with green color), indicating a gradual relaxation of the magnetic field configuration. The color curves, which represent the area coverage of magnetic field with different orientation, exhibit varying degree of correlation with active region complexity. Particularly the red and magenta color curves, which represent strong, purely horizontal magnetic field, seem to be good indicators of future flaring activity. The proposed visualization can be adapted to different color tables, it facilitates a comprehensive view of the evolution of active regions and their complexity and offers a framework for pattern recognition, feature extraction and flare prediction schemes.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **320** Type: **Poster**

Upflows with different morphologies at active region boundaries observed by Hinode and Solar Orbiter

Plasma upflows with a Doppler shift exceeding 20 km/s at active region (AR) boundaries are considered potential sources of nascent slow solar wind. These upflows are often located at the footpoints of large-scale fan-like loops, showing temperature-dependent Doppler shifts from the transition region to the lower corona. In this study, we identified two upflow regions in the vicinity of an active region by analyzing the Doppler shift of the Fe XII 195 line observed by Hinode/EIS. Context images for the two regions are obtained by the High Resolution Imager (HRI) telescope of the Extreme Ultraviolet Imager (EUI) onboard Solar Orbiter. The region to the west of the AR appears as typical fan-like loops, while the eastern upflow region is near AR moss, revealing small-scale dynamic fibril structures. Carefully addressing the point spread function issue with the SPectral Imaging of the Coronal Environment (SPICE), we derive the Doppler shifts of Ne VIII, emitted by cooler plasma compared to Fe XII, in these two regions. The fan-like loops in the west show downflows (redshifts) of approximately 20 km/s, whereas the eastern region shows upflows (blueshifts) from 20 to 30 km/s. Further studies compare the density and thermal structures of the two regions. The different morphologies and plasma properties of the two upflow regions reveal the diversity in AR upflows, implying potentially different driving mechanisms.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **321** Type: **Poster**

Solar Cycle Variation of the Distribution of Photospheric Magnetic Flux Features Using SDO/HMI

We use statistical tools to analyse data from the Solar Dynamics Observatory Helioseismic and Magnetic Imager to determine the distribution of the magnetic flux of photospheric magnetic features and its variation over a full solar cycle.

We use statistical figures of merit to test how well different types of probability distribution function represent the magnetic flux distribution inferred from the data and how their shape changes over the solar cycle.

Our analysis indicates that a double power law provides the best representation of the data over the full solar cycle and we discuss the variation of the power law exponents with the phase of the solar cycle.

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Session Classification: Coffee break and poster session 1

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **322** Type: **Talk**

Waves in coronal structures up to 1 Rsun?

Tuesday 10 September 2024 09:55 (15 minutes)

At Solar Orbiter's perihelion, the FSI telescope of the EUI instrument images the EUV corona up to 1 Rsun above the limb with a plate-scale better than 1000 km on the Sun. Here we report on exceptional FSI image sequences in the 17.4nm bandpass with deep exposures and a 30s cadence during the so-called "Density Fluctuations"and "Probe Quadrature"Solar Orbiter Observing Plans (SOOPs).

These data, with unique high S/N in the high EUV corona, reveal ubiquitous intensity fluctuations propagating outward along open magnetic field-lines up to 1 Rsun above the limb, well beyond the FOV of traditional EUV imagers. Difference movies suggest these propagating intensity fluctuations have both a longitudinal as well as a transversal "swaying"component.

We will discuss the relation of these high-altitude fluctuations with similar features reported before in the low solar corona (eg COMP & AIA data), as well as higher up in simultaneous Metis data. Implications for the energisation of the solar wind will be discussed.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **323** Type: **Talk**

Restructuring of magnetic fields at the periphery of granules

Monday 9 September 2024 17:00 (15 minutes)

Plasma flows in the near-surface region are thought to play an important role in replenishing the quiet Sun magnetic field. The interaction of magnetic fields with the complex flow structure causes these fields to reorganize at sub-granular scales. Horizontally aligned vortex flows near the edge of solar granules can grab magnetic fields from beneath and bring them to the visible surface. However, it is still unclear if these magnetic fields are amplified during their motion through such a turbulent environment. Here, we present results from a recent high-resolution radiative magnetohydrodynamic simulation carried out using the CO5BOLD code, focusing specifically on the periphery of granules. We investigate the formation and evolution of coherent vortex structures in these regions to determine if they contribute to amplifying the magnetic field to levels observable on the quiet Sun.

Primary authors: VIGEESH, G.; Dr RIVA, Fabio (Istituto Ricerche Solari Locarno (IRSOL), Università della Svizzera italiana (USI), CH-6605 Locarno-Monti, Switzerland.); STEINER, Oskar (Istituto ricerche solari Aldo e Cele Daccò)

Presenter: VIGEESH, G.

Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **324** Type: **Poster**

CHROMOSPHERIC ORIGIN OF CORONAL HEATING: OBSERVABLE TIMESCALES?

Using a simplified kinetic plasma model, we show that a transition region and a million-Kelvin corona can form thanks to fast, short-lived temperature fluctuations in the chromosphere. The proposed mechanism works if such activity occurs on sub-second timescales, which however are unresolved in current observations.

We briefly outline the model and then discuss two scenarios in which chromospheric features vary on longer (and therefore possibly accessible to observations) timescales, being nonetheless sufficient to form the solar corona: one in which fluctuations are due to changes of field lines connectivity and another where slower chromospheric fluctuations lead to different temperatures for protons and electrons.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **325** Type: **Poster**

Investigating the relation between the measured solar wind speed and the extrapolated magnetic field configuration in the solar corona

Our understanding of the physics behind the origin and the evolution of the solar wind in the low/middle corona depends on our capability of gathering information on the characteristics of the solar wind and on its interaction with the magnetic field within this region. Despite the possibility of acquiring in situ measurements closer to the Sun provided by the Parker Solar Probe and the Solar Orbiter missions, the region below 10 solar radii remains still impenetrable. Our knowledge of this portion of the solar corona relies on the acquisition of remote sensing instruments and on models. This work aims at deriving new insights on the relationship between the configuration of the coronal magnetic field and the measured solar wind speed. We combined solar wind speed measurements obtained by exploiting the Doppler dimming technique using SOHO/UVCS and SOHO/LASCO-C2 data, with the configuration of the magnetic field lines derived by using the Wang-Sheeley-Arge (WSA) model starting from photospheric magnetic field measured. This statistical analysis has been done for different Carrington Rotations. In this work, we provide a detailed description of the used method and of the obtained results explaining how the same technique can be used on data acquired by other remote sensing instruments capable of measuring the outflow speed of the solar wind in corona such as Metis on-board Solar Orbiter and CODEX.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **326** Type: **Poster**

State-of-the-art Image Slicer developments to Enable 2D Extreme Ultraviolet Imaging Spectroscopy in Seconds.

Observations in the Extreme Ultraviolet (EUV) are crucial for understanding the dynamics of the solar corona. The current EUV observing method utilises an entrance slit and scans over a field of view to build up 2D imaging spectroscopy. This scanning results in low-cadence images on the order of minutes which misses fundamental processes that occur on faster timescales. The application of image slicers for EUV integral field spectrographs is therefore revolutionary as they will enable observations of EUV spectra from an entire 2D field of view in seconds. However, the current technology limits their use, with future image slicer developments focussing mainly in two key parameters: the reduction of the slicer mirror width and the improvement of the surface roughness. We present results from a recent study that allows higher resolution better surface roughness to reduce stray light, and innovative ideas when using these slicers for highly efficient Integral Field Spectrographs. We show the thinnest metal image slicers that have been produced in the world to date. These improvements in image slicer technology are one big step towards implementing the Spectral Imaging of the Solar Atmosphere (SISA) instrument proposal for observing important spectroscopic diagnostics for characterization of solar coronal and flare plasmas.

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Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **327** Type: **Poster**

Coronal Loops are not one-dimensional

Closed magnetic loops make up a large part of the magnetically closed corona of the Sun and other stars.
Coronal loops come in different shapes and sizes.
Loop length, magnetoconvection at the footpoints and numerical resolution influence loop properties such as temperature, density and velocities.
These parameters in turn influence observable quantities such as emission intensity and the profile of spectral lines.
We model coronal loops as straightened magnetic flux tubes in a Cartesian box including a realistic convection zone at each end. This setup simplifies controlling loop parameters such as the loop length.
On stars other than the Sun, the small-scale structure of the corona cannot directly be observed. Instead, we rely on scaling laws to interpret observations.
Analytical scaling laws relate properties such as maximum temperature, loop length and pressure. These scaling laws, however, assume one-dimensional loops in equilibrium.
We conduct a parameter study of coronal loops in full 3D, varying loop length and the convection pattern at the footpoints.
We review coronal loop scaling laws for a variety of 3D MHD loop simulations with different parameters with respect to modelling stellar coronal loops.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **328** Type: **Poster**

Correlation approach to nanoflare heating diagnostics

The solar corona is hypothesized to be heated via small-scale random impulsive events, i.e., nanoflares. Recent DEM analysis results indicate that nanoflare generation frequency may be noticeably higher than the characteristic cooling rate of coronal plasma. Hence, individual nanoflare lightcurves are hardly distinguishable from the seemingly uniform background, complicating standard event-based statistical methods to study these phenomena. We believe that process-based techniques may be more effective. We propose a new model-based correlation approach to probe the main parameters of nanoflares, such as their frequency and duration. The latter is directly associated with the energy release time crucial for physical interpretation. We present and discuss the results of applying the algorithm to a range of synthetic data and observations provided by the latest space-bourne solar observatories.

Primary author: ULYANOV, Artem (Max Planck Institute for Solar System Research)

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **329** Type: **Poster**

Kinetic Models of Solar Wind Current Sheets

In-situ measurements of kinetic-scale collisionless current sheets in the solar wind have shown that such current sheets are often approximately force-free despite having a plasma beta of the order of one. Statistical analyses have found that the plasma density and temperature can vary across a current sheet in an anti-correlated manner such that the plasma pressure remains essentially uniform across the sheet.

Kinetic models of force-free collisionless current sheets have been developed which allow for asymmetric plasma density and temperature profiles. The earliest of these models introduced the required asymmetry by adding an additional term to both the ion and electron distribution functions. Recent models instead try to introduce the required asymmetries by modifying only the electron distribution function. However, the resulting equilibrium problem is non-linear in nature. An approximate solution was found under the assumption that the magnetic field is unchanged.

We present an improved approximate solution which drops this assumption and allows for changes in the magnetic field. We also present the results of a full numerical solution to the non-linear equilibrium problem. It is shown that, for the given forms of the electron and ion distribution functions, it does not seem possible to model the observed electron density and temperature asymmetries correctly when only the electron distribution function is modified.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **330** Type: **Invited**

Radiation Properties of Cool Coronal Condensations

Monday 9 September 2024 14:35 (25 minutes)

Cool plasma condensations in the corona manifest themselves as various types of prominences, loop structures, flare loops, coronal rain etc. They can be highly dynamical, exhibiting fine structures down to resolution of current instruments. Nowadays they are modeled using multidimensional MHD simulations. But to compare with observations, a non-LTE radiative-transfer spectral synthesis is needed.
We will review current approaches to synthesize the spectra and monochromatic images from up-to-date MHD models. The methods are based on multispecies-multilevel non-LTE modeling which provides the overall excitation-ionization structure.
An important ingredient is the illumination from the surrounding solar atmosphere.
As a result one can determine the partial ionization of the plasma and optically-thick radiative losses through the whole volume, both being critical for realistic MHD simulations. We will review the modern approaches and discuss future prospects.

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Presenter: HEINZEL, Petr (Czech Academy of Sciences)

Session Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **331** Type: **Poster**

Estimating the helicity and electromotive force with SolarOrbiter in-situ data of an iCME

During inter-planetary coronal mass ejections we expect faster solar wind to push into slower ambient wind, leading to the formation of super-sonic shocks. This may trigger turbulence to amplify magnetic fields stronger than expected by pure compressional effects, known as turbulent dynamo action. The turbulent nature of iCME fronts can be uncovered by computing the electromotive force. Peaks in the electromotive force reveal the arrival time of such fronts and their following sheath regions at the spacecraft. Since the magnetic helicity is conserved, we expect the same handedness as in the coronal source region of the outbreak. From an asymmetric double peak in the electromotive force, we can find this helicity handedness in an event observed by the MAG and SWA-PAS instruments around November 4, 2021. We compare this particular event with a series of previously recorded events from the Helios missions observed in the inner heliosphere. A scaling law on the magnitude of the electromotive force shows how these events are expected to decay while propagating to 1 au. This knowledge allows to automatically identify iCME shocks in heliospheric mission data with simple means. Future missions may use this technique to automatically switch the instrument observing modes to higher cadence, in order to fully capture dynamic events.

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Session Classification: Coffee break and poster session 2

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **332** Type: **Talk**

The Tunable-Imaging Spectropolarimeters/Fixed-Band Imagers for the European Solar Telescope

Thursday 12 September 2024 15:10 (15 minutes)

The European Solar Telescope (EST) will be equipped with a comprehensive suite of state-of-the-art intruments designed to observe the solar atmosphere at high spatial and temporal resolution and with high polarimetric sensitivity. Among them are three Tunable-Imaging Spectropolarimeters and Fixed-Band Imagers (TIS/FBIs) that will provide diffraction-limited measurements of photospheric and chromospheric magnetic fields over large fields of view. Each of these instruments consists of a narrow-band imaging spectropolarimeter and a broad-band imager. The spectropolarimeter is based on a dual Fabry-Perot interferometer and a polarimeter incorporating two nematic liquid crystal variable retarders. The imager will provide context information at the fastest cadence and will allow for reconstruction of the narrow-band images. The three TIS/FBIs will be operated in parallel for high cadence monitoring of the lower solar atmosphere in three or more spectral lines simultaneously, greatly improving the capabilities of existing filtergraphs that measure individual lines sequentially. The TIS/FBIs will provide unprecedented polarimetric sensitivity due to their optimized design and the large photon collecting area of the 4.2 m primary mirror of the telescope.

In this talk we will present the science goals of the EST TIS/FBI instruments. We will also review the current status of the TIS/FBIs, focusing on the main design drivers and the technological solutions adopted in this development phase. The TIS/FBIs are expected to go through a conceptual design review by the end of 2024, together with the other instruments of the EST Instrument Suite.

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Presenter: BELLOT RUBIO, Luis (Instituto de Astrofisica de Andalucia (IAA-CSIC))

Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **333** Type: **Poster**

Changes in chromospheric structure with magnetic field strength

A detailed understanding the structure and dynamics of the chromosphere is important to understand the heating of the solar atmosphere. The local magnetic field couples the turbulent convection zone to the atmosphere and provides the energy flux which heats the atmosphere. The study of the chromosphere is complicated by it's highly dynamic nature, additionally the radiative processes must be treated in NLTE. Utilising the chromospheric extension of the MURaM code we study the chromosphere formed in a set of simulations. The mean vertical magnetic field strength is varied from 5 to 500 Gauss to represent regions from weak fields, such as internetwork and coronal holes, to stronger network fields and plage. We study the dynamics and structure of the chromosphere and investigate the impact on the spectral lines formed in the chromosphere.

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Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **334** Type: **Poster**

Assessing the eruption scenario triggered by flux emergence in a non-zero beta environment

Along with the increase in high-performance computing resources, the ability to conduct 3D simulations has made a difference to unveiling the topology of the magnetic structures during the eruption. Flux emergence has been proposed as a main trigger mechanism of CMEs Feynman & Martin(1995). The emergence of magnetic flux can reconnect with an existing, current-carrying flux rope and lead to an unbalanced configuration which can trigger CMEs.
Török(2023) have studied this scenario on a pre-existing stable twisted flux rope coming from a model called TDm . Several trigger mechanisms have been identified, such as the interaction between emerging magnetic flux and the overarching confining magnetic field or the flux-rope itself causing a magnetic reconnection restructuring the magnetic topology. These results have been obtained in a zero-beta environment that did not take into account thermal and kinetic effects. We will show simulations following the same approach but with a stratified atmosphere and a non-zero plasma beta. Some parameters influencing the eruption or non-eruption of the pre-existing TDm are explored, such as duration of the emergence, strength of magnetic dipole, orientation and distance to TDm. For each of them, we characterise their ability to trigger the eruption, and, how they affect the speed of the ejection.
We will add synthetic emission thanks to the non zero beta environment and test particles to characterise non-thermal emission due to accelerated particles. These observations will be compared to solar flares signature of the EUV spectrum and X-ray Spectrum using the data provided by Solar Orbiter.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **335** Type: **Invited**

Numerical Modeling of Prominence Dynamics, Eruption and Coronal Waves Propagation Using MPI-AMRVAC

Tuesday 10 September 2024 11:50 (25 minutes)

Solar prominences are the birthplaces of coronal mass ejections, making studies of their pre-eruptive dynamics crucial for space weather. In this talk, I will review our most recent numerical studies of prominence dynamics with MPI-AMRVAC code.
Our investigation extends to the eruption evolution and the generation of coronal waves, which propagate over considerable distances through a magnetized medium and interact with flux rope prominence. This study relies on a numerical experiment performed with the MPI-AMRVAC code, using a gravitationally stratified corona and accounting for nonadiabatic effects. The initial magnetic field configuration consists of a dipole and a pre-existing flux rope in the low corona that suddenly erupts due to a 2.5D catastrophe.
The eruption gives rise to multiple energetic waves propagating throughout the magnetized corona. These waves ultimately reach distant prominences, evidently perturbing it. We generated synthetic images to increase our findings' comparability with SDO/AIA observations of similar events.
We analyzed and compared two scenarios with and without a uniform background magnetic field component aligned with the invariant direction. These scenarios result in different beta regimes and overall distinct evolutions of the eruption, variations in tearing instability within the current sheet, and differences in the propagation of coronal waves.

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Session Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **337** Type: **Poster**

Quasi-Periodic Oscillations of Si IV Doppler Velocity During an M-6.5 Class Solar Flare

Quasi-periodic oscillations (QPOs) observed in the solar chromosphere and transition region during flares offer valuable insights into the atmospheric response to sudden energy releases and the evolution of the magnetic field. We have analyzed an M-6.5 class flare observed by the Interface Region Imaging Spectrograph (IRIS) with emphasis on the QPOs in the Doppler velocity measured in the Si IV line at the flare ribbons. Our findings reveal variations in the period of oscillatory signals at different flare phases. Specifically, during the flare's impulsive phase, Doppler velocity oscillations with a period of approximately 5 minutes were observed. Pre-flare oscillations exhibited a maximum power at around 3 minutes. However, during the gradual decay phase of the flare, longer period oscillations (~8 minutes) were detected in and around the flare ribbons. We interpret the change in periodicity to 5 minutes during the impulsive phase as indicative of a change in the formation height of the Si IV to a deeper atmospheric layer, responding to the local acoustic cut-off frequency. Additionally, the longer period oscillations observed during the decay phase may be attributed to a reorientation of the magnetic field, becoming more inclined post-flare.

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Session Classification: Coffee break and poster session 1

Track Classification: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Contribution ID: **338** Type: **Poster**

Probing the substructures of solar flare ribbons

Solar flares are among the most spectacular and energetic phenomena in the solar system, and understanding their driving mechanisms is of paramount importance in solar physics. It is widely accepted that magnetic reconnection is the primary mechanism behind solar flares; allowing for the conversion of magnetic energy into plasma energy, resulting in the acceleration of particles such as electrons and ions. These accelerated particles form electron beams that deposit energy into the coronal plasma locally, and transfer energy globally when they impact the chromosphere, responsible for the characteristic ribbon-shaped emission of Hydrogen 656.3nm (Hα). Using the high-resolution Swedish 1-m Solar Telescope (SST) and CRisp Imaging SpectroPolarimeter (CRISP), we studied the substructures of Hα ribbons in unprecedented temporal and spatial resolution (i.e. 43 km per pixel and a cadence varying in time between 0.2 and 1.2 s). We have identified and analyzed small-scale substructures within the ribbons, referred to as "riblets". We present our definition of riblets and a detailed analysis of their statistical and kinematic properties during an X-class solar flare observed on 10 June 2014. By examining the riblets at this resolution and exploring their evolution in the context of SDO/AIA 304 A and RHESSI contours, we can probe the microphysics of energy deposition in the chromosphere with a high degree of precision. We present our analysis of a new class of rapidly evolving sub-structures with mean lifetimes of 11s that exhibit linear and non-linear dynamics, providing valuable constraints on 1D radiation hydrodynamic models of electron beam physics.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **339** Type: **Poster**

FastQSL: A Fast Computation Method for Quasi-separatrix Layers

Magnetic reconnection preferentially takes place at the intersection of two separatrices or two quasi-separatrix layers, which can be quantified by the squashing factor Q, whose calculation is computationally expensive due to the need to trace as many field lines as possible. FastQSL is developed for obtaining Q and the twist number, with the performance of millions of Q values per second. FastQSL supports both uniformed and stretched grids, the support of spherical coordinates is extended recently.

Primary author: CHEN, Jun (Purple Mountain Observatory, Chinese Academies of Sciences)

Session Classification: Coffee break and poster session 2

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **340** Type: **Poster**

Using Bright-Point Shapes to Constrain Wave-Heating of the Solar Corona: Opportunities for DKIST

Magnetic bright points on the solar photosphere mark the footpoints of kilogauss magnetic flux tubes extending toward the corona. Convective buffeting of these tubes is believed to excite magnetohydrodynamic waves, which can propagate to the corona and there deposit heat. Measuring wave excitation via bright-point motion can thus constrain coronal and heliospheric models, and this has been done extensively with centroid tracking, which can estimate kink-mode wave excitation. DKIST is the first telescope to provide well-resolved observations of bright points, allowing shape and size measurements to probe the excitation of other wave modes that have been difficult, if not impossible, to study to date. In this work, we demonstrate a method of automatic bright-point tracking that robustly identifies the shapes of bright points, and we develop a technique for interpreting measured bright-point shape changes as the driving of a range of thin-tube wave modes. We demonstrate these techniques on a MURaM simulation of DKIST-like resolution. These initial results suggest that modes other than the long-studied kink mode could increase the total available energy budget for wave-heating by 50%. Pending observational verification as well as modeling of the propagation and dissipation of these additional wave modes, this could represent a significant increase in the potency of wave–turbulence heating models. We also present early efforts to apply this tracking and method to DKIST observations.

Primary authors: VAN KOOTEN, Samuel (Southwest Research Institute); Dr CRANMER, Steven (University of Colorado, Boulder)

Session Classification: Coffee break and poster session 1

Track Classification: Energy and mass transfer throughout the solar atmosphere and structures within

Contribution ID: **341** Type: **Talk**

Coronal magnetic field modeling using a non-spherical source surface: implications for the global structuring of the corona

Friday 13 September 2024 12:55 (15 minutes)

Global models of the solar coronal magnetic field are an essential tool for assessing the global-scale magnetic environment of the corona and its connectivity to the heliosphere. In particular, the Potential Field Source Surface (PFSS) model continues to be a frequently and widely adopted tool in the community despite several well-known deficiencies of the model. For instance, regions of open magnetic field provided by the model often only superficially match the observed coronal holes at EUV wavelengths which has been posited as a possible significant source of error contributing to the limited accuracy of many solar wind prediction models. Recently, a different issue has been highlighted through near-Sun solar wind observations by Parker Solar Probe (PSP), as an accurate PFSS modeling of the solar wind magnetic field polarity has only been achieved for source surface radii typically considered to be excessively low.

In this work, we study whether relaxing the fundamental assumption of the PFSS model of a fixed spherical source surface beyond which the magnetic field is purely radial can alleviate the noted deficiencies of the model. To this aim, we employ magnetofrictional modeling to construct magnetic field models where the coronal magnetic field is selectively opened in regions corresponding to those of observed coronal holes. We compare the resulting model results not only to PFSS, global coronal magnetohydrodynamic modeling and imaging observations, but also contrast the results with PSP in-situ observations. Furthermore, we discuss the implications of the results on the unresolved issue of missing open flux.

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Presenter: Dr POMOELL, Jens (University of Helsinki)

Session Classification: Space weather and the solar-heliospheric connections

Track Classification: Space weather and the solar-heliospheric connections

Contribution ID: **342** Type: **Poster**

Non-Radial and Multiple Interacting CMEs: A Multi-Spacecraft Perspective Combining Coronagraphs and Heliospheric Imagers

An accurate determination of the trajectory of Coronal Mass Ejections (CMEs) is crucial for space weather forecasting and assessing whether or not they will impact Earth. Deviation of CME trajectory from a radial propagation is often observed as a consequence of gradients in the local magnetic pressure or due to CME-CME interactions visible within the coronagraphs' field of view. The combination of coronagraphic and heliospheric observations can provide deeper insights into these phenomena, offering valuable information for future space weather forecasting.

On 2023 September 24, several spacecraft observed four non-radial and interacting CMEs. Our study presents an in-depth analysis of these CMEs for which the 3D trajectories are determined through a Graduated Cylindrical Shell forward-modeling technique combining full-disk imagers and coronagraphs onboard STEREO-A, SOHO, and Solar Orbiter, and making use, for the first time, of both the heliospheric imagers onboard Solar Orbiter and Parker Solar Probe. This multiple-viewpoint approach allowed us to determine eventual deflections in longitude or latitude from the source location.

Our analysis revealed CME-CME interactions in the very low corona. In particular, the second and third CMEs interacted causing a deflection of the second post-CME current sheet and producing a "bouncing effect" that deflected the two CMEs in opposite directions of about 15° in latitude. Additionally, strong magnetic fields near the source regions caused a 25° latitudinal deflection of the fourth CME. Finally, the interaction between the flank of the third CME with the post-CME outflow of the second one showed some interesting macro-scale interaction patterns.

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Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **343** Type: **Poster**

The extremely strong photospheric electric currents of active region NOAA 13664

Active region NOAA 13664 has been so far the most flare-prolific active region of the present solar cycle, producing eight X- and several M- and C-class flares, causing the strongest geomagnetic storm since 2003. In this study, the evolution of the non-neutralized (net) electric currents is examined, along with that of the emerging flux. The net currents were calculated using a method based on image segmentation and error analysis of the photospheric vector magnetograms provided by the Helioseismic and Magnetic Imager (HMI). At its full extent NOAA 13664 became the second largest in area since 2010, second only to NOAA 12192. The region was already an evolving δ-type region when it rotated into view. A series of strong magnetic flux emergence events in its vicinity led to an extremely complex magnetic configuration, with intense shearing motions over almost the entire area of the region. In comparison to the most extended and the most flare prolific regions observed since the beginning of HMI observations, NOAA 13664 had by far the strongest net electric currents. The development of these currents is attributed to a unique case of interaction between a complex δ-type region, which already contained strong net currents, and new highly-deformed flux systems.

Primary author: KONTOGIANNIS, Ioannis (Leibniz-Institute for Astrophysics Potsdam (AIP))

Session Classification: Coffee break and poster session 2

Track Classification: Multi-scale energy release, flares and coronal mass ejections

Contribution ID: **344** Type: **Invited**

Why use real-time operational data in Solar Physics and Space Weather research?

Friday 13 September 2024 09:00 (25 minutes)

The Solar Influences Data Analysis Center (SIDC) at the Royal Observatory of Belgium (ROB) is well known for its advanced solar data analysis methods and comprehensive data catalogues, including CACTUS for automatic CME detection, Solar Demon for EUV flare and dimming detection, SPoCA-suite for the extraction of active regions and coronal holes, etc. Beyond its research initiatives and data processing capabilities, SIDC is also deeply engaged in operational activities related to space weather, ground-based and space-based instrumentation and observations.

This presentation aims to illustrate how real-time operational data collected and analyzed by forecasters serves as a valuable resource for researchers. It will highlight the importance of integrating this data into research workflows and demonstrate how such integration can lead to significant advancements in both solar physics research and space weather forecasting. Finally, from an operational perspective, we will pinpoint areas where real-time models perform poorly, highlighting opportunities for further exploration to improve our knowledge of solar physics and enhance forecasting models.

Primary author: DE PATOUL, Judith (Solar-Terrestrial Centre of Excellence - SIDC, Royal Observatory of Belgium)

Presenter: DE PATOUL, Judith (Solar-Terrestrial Centre of Excellence - SIDC, Royal Observatory of Belgium)

Session Classification: Diagnostic tools and numerical methods in solar physics

Track Classification: Diagnostic tools and numerical methods in solar physics

Contribution ID: **345** Type: **Invited**

EPS Invited Speaker - The role of convection during active region emergence

Monday 9 September 2024 09:50 (25 minutes)

Abstract: The role of convection in forming active regions is controversial. In the thin-flux-tube model, the properties of the active regions are set by the flows in the flux tube during its rise: in the mean-field framework the properties are set by the interaction of the magnetic field with the surrounding turbulent convective motions. Recent observational results point to convection playing an important role in the formation and onset of Joy's Law, challenging the thin flux-tube model. To understand how convective flows are involved in the formation of active regions, we aimed to identify where active regions emerge in the supergranulation flow pattern. We discovered that active regions preferentially emerge at specific locations within these flow patterns: the prograde ends of east-west aligned converging flow lanes. Preceding emergence by 0.5 to 1 day, these regions exhibit a net converging flow of 10-20 m/s, independent of magnetic flux, followed by an increase in outflows. Moreover, we propose that the Coriolis force acting on near-surface flows is responsible for Joy's Law, rather than deep-seated dynamics.

Primary author: SCHUNKER, Hannah (University of Newcastle)

Presenter: SCHUNKER, Hannah (University of Newcastle)

Session Classification: Solar interior, sub-surface flows and long-term variability

Track Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **347** Type: **not specified**

Outreach in Solar Physics

Thursday 12 September 2024 13:25 (1 hour)

Please find the detailed program here:

https://indico.ict.inaf.it/event/2971/timetable/#20240912

Presenters: MASON, Helen (University of Cambridge); HUDSON, Hugh (UC Berkeley / U of Glasgow)

Session Classification: Outreach in Solar Physics

Contribution ID: **348** Type: **Invited**

EPS Invited Speaker

Primary author: SCHUNKER, Hannah (University of Newcastle)

Presenter: SCHUNKER, Hannah (University of Newcastle)

Session Classification: Solar interior, sub-surface flows and long-term variability

Contribution ID: **349** Type: **not specified**

EPS Invited Speaker

Primary author: SCHUNKER, Hannah (University of Newcastle)

Presenter: SCHUNKER, Hannah (University of Newcastle)

Session Classification: Solar interior, sub-surface flows and long-term variability