17th European Solar Physics Meeting ESPM-17

Report of Contributions

POSTER SESSION 1

TOPICS 1, 2, 3

Monday 9, 10:30-11:30
16:00-17:00
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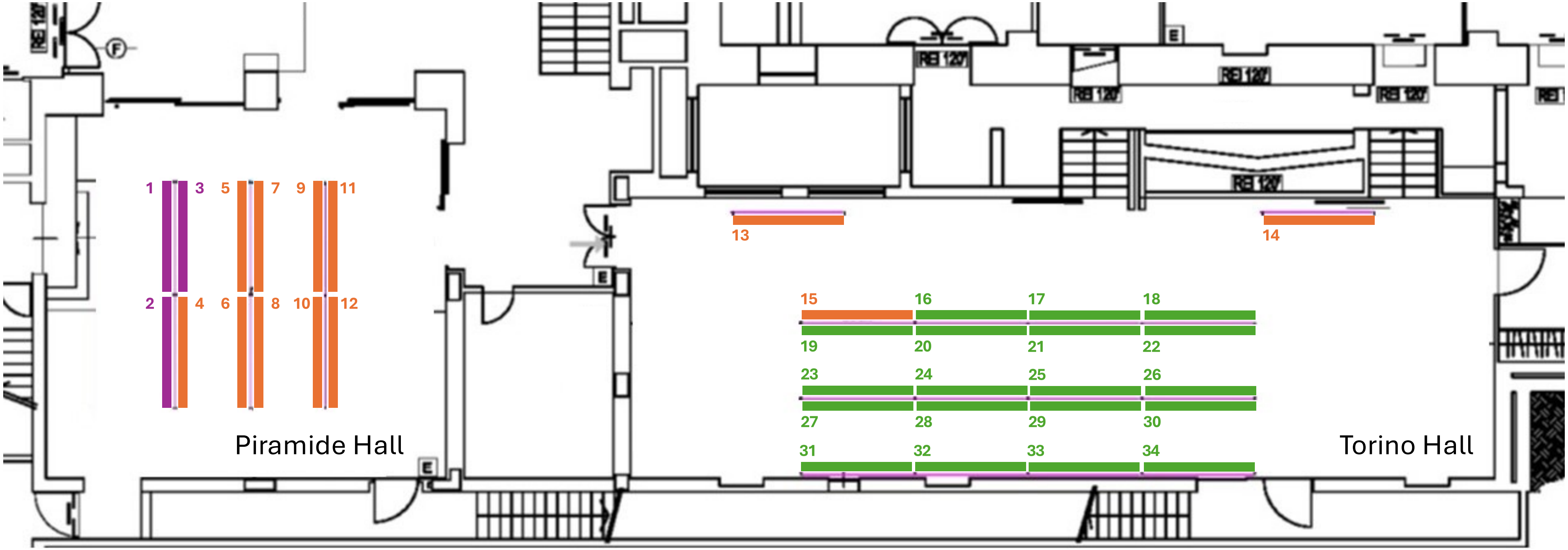
15:55-16:55

Poster Session 1



Topic 1: Solar interior, sub-surface flows and long-term variability

Topic 2: Fundamental mechanisms of solar plasmas: magnetic reconnection, waves, radiation and particle acceleration

Topic 3: Energy and mass transfer throughout the solar atmosphere and structures within

Poster Session 1 (September 9-10)

Topic 1: Solar interior, sub-surface flows and long-term variability

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Topic 3: Energy and mass transfer throughout the solar atmosphere and structures within

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219	Abhas Pradhan	*Observing rapid moss variability in active region cores using Solar Orbiter's EUI and PHI*	27 B
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221	Yoshihiro Naito	*Penetrating waves along spicules to the corona*	28 A
224	Johannes Tschernitz	*Observationally driven 3D MHD simulation of a coronal loop above a sunspot group*	28 B
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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: **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: **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: **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: **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: **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.

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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: **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: **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: **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: **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: **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: **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: **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.

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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: **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 Lyα 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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Session Classification: Coffee break and poster session 1

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

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.

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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: **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.

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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: **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.

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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: **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.

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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: **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.

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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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **152** Type: **Poster**

Inferences under magneto-hydrostatic equilibrium in the chromosphere

One of the major open questions in solar physics is the coronal heating problem, which refers to the fact that the corona has a higher temperature than can be explained by radiation as the main heating process. One of the more popular methods in order to investigate the physical state of the solar plasma is the inference of depth-stratified atmospheric models from spectropolarimetric data using inversion methods. However, most of the methods, with a few exceptions for the photosphere, use the assumption of hydrostatic equilibrium when calculating the gas pressure and density, which leaves out the magnetic forces in the balance. This is especially problematic in the chromosphere, where the magnetic forces start to be larger than the gas pressure.

Evaluating the heating terms requires the electric currents, which depend on the spatial derivatives in geometrical scale. However, these are not very accurate using hydrostatic equilibrium. In this contribution we present the implementation of a solver for the magneto-hydrostatic equilibrium equation into the inversion code STiC in order to account for the magnetic forces in the chromosphere. This will improve the accuracy for estimating the electric currents and therefore the heating terms. We start by investigating this approach by taking all parameters but the gas pressure from a r-MHD simulation to compare the calculated pressure to the simulation. We then limit the input information in density, temperature and magnetic field vector in order to represent more realistic data obtained by modern instruments like CRISP and CHROMIS on the SST.

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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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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: **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.

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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: **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: **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.

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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: **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.

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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: **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.

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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: **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.

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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: **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.

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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: **255** Type: **Poster**

Correlation between photospheric velocity drivers and the FIP effect in solar active regions

The chemical composition of the Sun's atmosphere is not homogeneous. It is known that elements with a low First Ionization Potential tend to be preferentially transported to the outermost layers of the solar atmosphere. This phenomenon, known as the FIP effect, is commonly associated with the refraction of magnetohydrodynamic waves in the chromosphere. In this contribution, we present a study on the FIP effect by exploring the connection between high-frequency waves in the photospheric velocity driver, the FIP bias, and the total magnetic flux of a sample of active regions.
In this work, we aim to correlate the dynamics of the photosphere and lower chromosphere in the presence of active regions with the FIP bias observed in corona.
We conducted our analysis using high temporal resolution images from the HMI instrument aboard the Solar Dynamics Observatory. Specifically, we examined the power spectrum of waves with frequencies between 5.5 and 7.5 mHz (acoustic halos) in the photospheric velocity driver of the active regions, monitoring them for the entire duration of their presence on the solar disk. We then correlated these findings with the FIP bias and the total magnetic flux of the studied regions, including a detailed temporal comparison with FIP bias maps of an active region observed in July 2017. In this research, we have found a clear correlation between the enhancement of high-frequency power and the FIP bias, which contributes to our understanding of the FIP effect and, consequently, to the mechanisms contributing to coronal 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: **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: **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: **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: **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: **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: **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: **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: **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.

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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: **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: **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.

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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: **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: **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: **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: **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: **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: **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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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: **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

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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.

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