CESPM2025Abstracts

Patrick Antolin: Disambiguation of cool and hot emission in IRIS/Slit-Jaw Imager and AIA channels

Accurate temperature diagnostics of the solar corona are necessary for detecting the heating and cooling processes, and better understanding the conversion of the magnetic energy into thermal energy. A major obstacle in this enterprise is the multi-temperature emission contained in Ultra Violet (UV) and Extreme UV (EUV) passbands such as those of the Atmospheric Imaging Assembly (AIA) of the Solar Dynamics Observatory (SDO) and the Slit-Jaw Imager (SJI) of the Interface Region Imaging Spectrograph (IRIS). In this work we extend the Response Fitting (RFit) method to disambiguate between cool, warm and hot emission in the SDO/AIA and IRIS/SJI passbands. We improve previous results for AIA 304 Å and find very good cool/hot decomposition for AIA 94 Å allowing to improve previous empirical disambiguation methods for this passband. The good hot temperature coverage of AIA allows RFit to be applied across instruments, leading to very good results for SJI 1330 Å and SJI 1400 Å. We also find ways to constrain to some degree of accuracy the hot emission in AIA 211 Å, and the very hot (flaring) emission in AIA 131 Å and AIA 193 Å. We apply RFit to an AIA-IRIS co-observation that includes a flare, and calculate the average relative contribution for the cool-hot emission to find 30/70, 14/86, 80/23, 76/33, respectively, for AIA 304 Å, AIA 94 Å, SJI 1330 Å and SJI 1400 Å. We obtain a more coherent picture of the hot temperature evolution in the log T = 6.8-7.15 temperature range and its spatial localisation during the flare. We further accurately detect and quantify the cool plasma from coronal rain, which is observed to increase ten-fold due to the flare-driven cooling.

Arunv Awasthi: Probing seed electron characteristics through nonthermal emission and solar energetic electrons (SEEs): STIX and EPD observations

Solar flares are energetic and dynamic phenomena in the solar system, emitting radiation impulsively and solar energetic electrons (SEEs). To examine the characteristics and energetics of seed electron population that is responsible for hard X-ray (HXR) emission and SEEs, we investigate 4 flares (3 B and 1 C1.6 intensity class; SOL2021-09-26T11:41, SOL2021-09-27T11:40, SOL2021-09-28T01:42, SOL2021-09-28T06:26) during 26-28 September 2021, originated from AR12871, and associated (in time) with SEE enhancements recorded using EPD suite onboard Solar Orbiter mission. We conducted spectral analysis of hard X-ray emission observed by STIX and in situ electrons. Our analysed events exhibited a breadth of diversity in terms of - dynamic nature at the source, disparate thermal-nonthermal emission partition, and different spectral types of in-situ electrons. For example, a clear SEE association with the weak B3-class enhancement (SOL2021-09-26T11:41) with remarkably hard HXR emission (nonthermal electron (NTEs) spectral index (δ) ~ 6) despite a SEE-less C3 flare (SOL2021-09-26T11:24) occurring in the same active region with a maximum just 17 minutes ago. On the other hand, despite exhibiting very weak HXR emission, the investigated C1.6 flare (SOL2021-09-28T06:26) is found to be associated with SEEs with a hard spectrum and exhibiting an associated DH type-II burst.

Therefore, the investigation of such a diverse group of flares with associated electron events aims to enrich our knowledge of the energetics of the seed electron population and the effect of further acceleration of SEEs.

Xianyong Bai: The Solar Upper Transition Region Imager (SUTRI) Onboard the SATech-01 satellite

The Solar Upper Transition Region Imager (SUTRI) onboard the Space Advanced Technology demonstration satellite (SATech-01), which was launched to a Sun-synchronous orbit at a height of ~500 km in 2022 July, aims to test the on-orbit performance of our newly developed Sc/Si multi-layer reflecting mirror and the 2k×2k EUV CMOS imaging camera and to take full-disk solar images at the Ne VII 46.5 nm spectral line with a filter width of ~3 nm. SUTRI employs a Ritchey-Chrétien optical system with an aperture of 18 cm. The on-orbit observations show that SUTRI images have a field of view of ~ 41.'6 × 41.'6 and a moderate spatial resolution of ~8″ without an image stabilization system. The normal cadence of SUTRI images is 30 s and the solar observation time is about 16 hr each day because the earth eclipse time accounts for about 1/3 of SATech-01's orbit period. Approximately 15 GB data is acquired each day and made available online after processing. SUTRI images are valuable as the Ne VII 46.5 nm line is formed at a temperature regime of ~0.5 MK in the solar atmosphere, which has rarely been sampled by existing solar imagers. SUTRI observations will establish connections between structures in the lower solar atmosphere and corona, and advance our understanding of various types of solar activity such as flares, filament eruptions, coronal jets and coronal mass ejections.

Yi Bi: Observational Evidence for Fast-Mode Magnetoacoustic Waves in the Chromosphere During X-Class Solar Flares

Fast-mode magnetoacoustic waves serve as a crucial energy transport mechanism in the solar atmosphere and are commonly observed as extreme ultraviolet (EUV) waves in the corona. However, direct observational evidence of these waves in the chromosphere remains limited. This study investigates high-resolution observations of an X-class solar flare to identify potential signatures of chromospheric fast-mode magnetoacoustic waves. We conducted multi-wavelength observations of an X-class solar flare using the New Vacuum Solar Telescope (NVST), Onset, and the Solar Dynamics Observatory (SDO). Our analysis focused on simultaneous brightening phenomena spanning from 3600 Å to EUV wavelengths, with quantitative characterization of their propagation properties. /// The observed brightening structures exhibit characteristic temperatures of approximately 1 MK and propagate primarily perpendicular to the local magnetic field direction with an average speed of ~20 km/s. This propagation velocity is in excellent agreement with theoretical predictions for fast-mode magnetoacoustic wave speeds in the chromosphere. /// Based on comprehensive analysis of the propagation direction, velocity characteristics, and temperature distribution, we conclude that these propagating brightening features represent direct observational evidence of fast-mode magnetoacoustic waves in the chromosphere. These findings provide important insights into wave propagation mechanisms and energy transport processes in the lower solar atmosphere during major flare events.

Harry Birch: Towards a robust algorithm for prominence detection: Optimising the YOLOv5 object detection network for 304 Å SDO/AIA observations.

Solar prominences are tenuous clouds of plasma suspended in the solar atmosphere, appearing as bright structures when observed on or above the solar limb. They exhibit a broad morphological variety and dynamical behaviour, and are intimately linked to other solar phenomena including flares and coronal mass ejections. Consequently, detecting and classifying such structures is an important task, but not trivial. Missions such as the Atmospheric Imaging Assembly (AIA; Lemen et al. 2012) onboard the Solar Dynamics Observatory (SDO; Pesnell et al. 2012) have provided an enormous wealth of observational data on prominences during its over 15-year lifetime. Whilst existing databases of prominences have utilised and benefited from these data, accurate automated detection of prominences remains challenging, more so than other solar features. The advent and availability of machine learning techniques presents an attractive solution to deal with the large amounts of data, aiding the construction of a more robust detection and classification system for prominences. \\\ Previous machine learning based studies of solar prominences have struggled with poor detection, largely due to the challenging nature of the 304 Å channel, in which diffuse material from the hotter Si XI emission often obscures prominence observations off-limb. We show here a renewed effort to incorporate machine learning for prominence detection, using the YOLOv5 object detection model (ULTRALYTICS 2020). We utilise the labelled SDO/AIA prominence dataset of Baek et al. (2021) and carry out a series of detailed tests to investigate different model constraints. In particular, we show the power of transfer learning (using pre-training weights from a different model), dataset augmentation, and hyperparameter tuning for model optimisation. We explore how image processing using the WOW technique (Auchere et al. 2023) can alleviate some of the challenges of the 304-channel data to enhance prominences, and how this effects our model performance. Our prominence models achieve higher performance than previous efforts, with mAP50 (mean average precision at intersection over union threshold of 50) values of 0.85, demonstrating their ability to accurately detect and classify solar features with a high degree of precision and robustness.

Joerg Buechner: Kinetic turbulence and reconnection in the solar atmosphere: from electrons to heavy ion acceleration

This talk addresses two problems: the role of the electrons in the energization of the turbulent solar wind and the acceleration of heavy ions during solar flares, both related to magnetic reconnection processes. \\\ Recently two main hypotheses about the heating of the solar wind are discussed: the dissipation of high-frequency ion-cyclotron waves and that of the low-frequency ‘Alfvénic ’turbulence which now is ubiquitously in situ observed starting from the „base of the solar corona“ by the Parker Solar Probe and throughout the solar system. While long-wavelength (large scale) energy transport properties and spectra of the turbulence are well understood, its small- (sub-ion-, sub-electron-, kinetic) - scale physics is not, yet: how can the long wavelength ‘Alfvénic ’turbulence heat the collisionless solar wind plasma? And what role does reconnection play in this process? Reconnection is also supposed to play a role in flare eruptions. But can it explain the energization of different-mass heavy ions? \\\ Since the underlying acceleration and dissipation / heating processes are essentially non-linear, only kinetic numerical simulations are able to describe the energization processes. \\\ We present results about the formation of small – (electron-) scale structures in the turbulent solar wind plasma and their consequent destruction / dissipation via magnetic reconnection as well as the acceleration of heavy ions during solar flares.

Daniele Calchetti: Recent progress with PHI on board Solar Orbiter

Solar Orbiter is a joint ESA-NASA mission launched in 2020 on a strongly eccentric orbit around the Sun, with closest perihelia at 0.28 AU. The Polarimetric and Helioseismic Imager (SO/PHI) is the vector magnetograph onboard Solar Orbiter. It is composed of the Full-Disc Telescope (FDT), which images the entire solar disk, and of the High-Resolution Telescope (HRT), which observes a smaller part of the solar disk at high resolution. \\\With an orbital period of approximately six months around the Sun, SO/PHI is the first magnetograph to provide maps of the photospheric vector magnetic field from viewpoints away from the Sun-Earth line, including from the far side of the Sun. This opens new scientific opportunities and novel boundary conditions for data-driven and data-inspired numerical simulations, such as following active regions for much longer periods of time, building faster synoptic maps, the stereoscopic resolution of the 180-degree ambiguity, and the stereoscopic measurement of horizontal flows. \\\ Starting in spring 2025, Solar Orbiter began to rise significantly above the ecliptic, providing full spectropolarimetric observations of the solar poles for the very first time. This data will be crucial for the quantitative constraint of the magnetic field in dynamo and heliospheric models.

Jinrui Chang: Studying the Interaction between a Solar Filament and Overlying Magnetic Field with Opposite Helicity Using NVST and SDO Data

We present a case study of a solar flare that commenced on 2024 March 28 at 06:16 UT. The event was observed by both the New Vacuum Solar Telescope (NVST) and the Solar Dynamics Observatory (SDO). Beginning at approximately 06:22 UT, spot-like brightenings accompanied by signatures of magnetic reconnection appeared at the western end of the filament in SDO/AIA 131 Å observations. Subsequently, material was ejected transversely to the filament's axis from this site. The ejected material underwent magnetic reconnection, producing multi-wavelength brightenings indicative of heated material falling back to the chromosphere. Following this, large-scale coronal loops became visible in high-temperature AIA passbands. The footpoints of these loops coincided spatially with chromospheric brightenings observed by NVST, signifying chromospheric evaporation and confirming this as a failed eruption event. Nonlinear force-free field (NLFFF) extrapolations combined with magnetic helicity calculations throughout the eruption reveal that the overall magnetic configuration comprised two distinct domains with opposite helicity above and below the filament. Notably, magnetic field lines possessing helicity opposite to that of the filament enveloped its periphery. The helicity content in the region overlying the filament exhibited depletion concurrent with the eruption. These collective observations suggest that the event was likely triggered by reconnection between these two sets of magnetic flux systems with opposing helicity.

Liang Chang: Chinese Giant Solar Telescope (CGST)

We are proposing to build a solar telescope of the largest aperture over the world, the Chinese Giant Solar Telescope, or CGST for short. This is an advanced ground-based multi-function solar telescope with aperture of 8 m, it will be able to observe the Sun with high space resolution (0.01 arcsec) and time cadence (1 s), as well as high accuracy in measuring the polarization (10^-4). Success in building CGST will in no doubt promoting an innovating development in the new and high-tech fields of optics, techniques of accurate control, AI, and infrared detectors. The kernel sciences of CGST include seeking and identifying the fundamental magnetic structures (about 10 km in scale) in the solar atmosphere, probing weak magnetic field (about 10 G) in the photosphere. It is characterized with high space resolution and time cadence, high accuracy in measuring the polarization and high sensitivity in detection. The purpose is to reveal the physical property of the photospheric convection and dynamo process, to seek the source of disastrous space weather, and help understand the physics of magnetic activities occurring on the other stars.

Changxue Chen: Intense Hard X-ray Emissions in C-class Flares: A Statistical Study with ASO-S/HXI Data

In the standard model of solar eruptive events, coronal mass ejections (CMEs) and flares are associated with each other through magnetic reconnection initiated by erupting flux ropes. Observations also reveal an increasing association ratio between flares and CMEs with flare intensity. However, the fundamental relationship between flares and CMEs, and that between thermal and nonthermal processes, remains unknown. Here we investigate energetic C-class flares (ECFs) -- Geostationary Operational Environmental Satellite (GOES) C-class flares with hard X-ray (HXR) emissions above 30 keV -- using observations from Advanced Space-based Solar Observatory/Hard X-ray Imager (HXI), Solar Dynamic Observatory, and GOES. Among 1331 C-class flares detected by HXI, 127 ECFs (9.5%) were identified for statistical analysis of their properties and associations with CMEs and other flare-related features. Our statistical results reveal that ECFs have relatively shorter durations and harder spectra (the mean electron power-law index is 4.65), with no significant correlation between soft X-ray flux and nonthermal parameters (e.g., HXR peak flux). Among the 127 events, 53 (42%) were associated with type III bursts, 38 (30%) with jets, at least 13 (~11%) with 360 nm brightenings, and only 5 (~4%) with CMEs. Crucially, all five CME events were narrow CMEs associated with jets. The surprising correlation between these ECFs and CMEs suggests that noneruptive or confined magnetic field configurations in these flares may favor electron acceleration, resulting in harder X-ray spectra. We discuss the potential formation mechanisms and efficient electron acceleration processes in these atypical flares, providing valuable insights into nonstandard flare behavior.

Hechao Chen: Minifilament Eruptions as the Last Straw to Break the Equilibrium of a Giant Solar Filament

Filament eruptions are magnetically driven violent explosions commonly observed on the Sun and late-type stars, sometimes leading to monster coronal mass ejections that directly affect the nearby planets ’environments. More than a century of research on solar filaments suggests that the slow evolution of photospheric magnetic fields plays a decisive role in initiating filament eruptions, but the underlying mechanism remains unclear. Using high- resolution observations from the Chinese Hα Solar Explorer, the Solar Upper Transition Region Imager, and the Solar Dynamics Observatory, we present direct evidence that a giant solar filament eruption is triggered by a series of minifilament eruptions occurring beneath it. These minifilaments, which are homologous to the giant filament but on a smaller tempo-spatial scale, sequently form and erupt due to extremely weak mutual flux disappearance of opposite-polarity photospheric magnetic fields. Through multifold magnetic interactions, these erupting minifilaments act as the last straw to break the force balance of the overlying giant filament and initiate its ultimate eruption. The results unveil a possible novel pathway for small-scale magnetic activities near the stellar surface to initiate spectacular filament eruptions, and provide new insight into the magnetic coupling of filament eruptions across different tempo-spatial scales.

Huanxin Chen: Numerical simulation and statistical research: Supergranulations as the cause of solar prominence structures

Solar prominences usually have a horizontally elongated body with many feet extending to the solar surface, resembling a multi-arch bridge with many bridge piers. The origin of these unique foot structures remains elusive. By evolving our supergranule-driven prominence formation model via magnetic helicity condensation to a mature stage, we successfully replicate the structures of solar quiescent prominences, namely spine, feet, and bubbles, in a magnetic flux rope. Similarities between the simulated prominences and observed real prominences by the Chinese H_alpha Solar Explorer, the New Vacuum Solar Telescope, and NASA's Solar Dynamics Observatory suggest the high validity of our model. Unlike traditional views, bubbles mainly consist of legs of sheared magnetic loops caused by unbalanced supergranular flows. Prominence feet settle at the bottom of helical field lines piled up from the photosphere to the spine. We find that supergranulations cause the formation of prominence structures, which indicates that solar convections are intimately linked with magnetic activities in solar atmospheres.

Jie Chen: Small-Scale Eruptions on the Sun

Small-scale jet-like structures are an important component of small-scale activities on the Sun, exhibiting a magnetohydrodynamic evolution process. They primarily include spicules, giant spicules, and jets. Their formation and origins (or driving forces) are believed to be related to magnetic reconnection, Alfvén waves, (magnetic) acoustic waves, etc. Their dynamic evolution processes are linked to coronal heating and the origins and acceleration of the solar wind. In the presentation, we will introduce the formation mechanism of the jet and dynamic evolution of jets.

Jun Chen: Parametric Study of Torus Instability Threshold

A parametric numerical study of the torus instability threshold is carried out, employing the force-free Titov-D\'emoulin equilibrium of a line-tied partial toroidal current channel and flux rope. This addresses the scatter of the critical decay index of the equilibrium external poloidal field (the so-called strapping field) at the position of the current channel about its nominal value, $n_\mathrm{cr}=3/2$. Values scattering in the range $n_\mathrm{cr}\approx$\,1--2 are typically found in numerical and observational studies of flux rope eruptions on the Sun. For zero external toroidal (guide, or shear) field and approximately semicircular geometry (corresponding to minim\bk{al} line-tying), we find the threshold to lie in the theoretically expected range of $\approx$\,1--1.5. An external toroidal field introduces a strong stabilizing effect on the instability, raising the threshold up to $\sim$\,2.5, which can explain observational and numerical results above the nominal value. The threshold also rises above 1.5 due to line-tying in the large footprint regions of flat and thick current channels (normalized footpoint distance $\Df\gtrsim1.5$ and minor radius $a\gtrsim0.75$). We also consider the approximate threshold based on the potential field and find a very good agreement with the exact numerical value, provided the Green function is used to compute the field and the horizontal component perpendicular to the flux rope axis is used to approximate the external poloidal field.

Yajie Chen: Mass supply to solar wind through magnetic reconnection

The solar wind originates from regions of open magnetic fields on the Sun, but the relevant processes remain unsolved. We present a self-consistent numerical model of the source region of the wind, in which jets similar to those observed on the Sun naturally emerge due to magnetic reconnection between closed and open magnetic fields. In this process material is transferred from closed to open field lines and fed into the solar wind. We quantify the mass flux through the magnetic field connected to the heliosphere and find that it greatly exceeds the amount required to sustain the wind. This confirms a decades-old suspicion based on spectroscopic observations and shows that magnetic reconnection in the low solar atmosphere can sustain the solar wind.

Guanchong Cheng: Inertial-range Turbulence Anisotropy of the Young Solar Wind from Different Source Regions

Ellerman bombs (EBs) and ultraviolet (UV) bursts are two of the smallest observed solar activities triggered by magnetic reconnection in the lower solar atmosphere, typically associated with flux emergence regions. Joint observations from the Interface Region Imaging Spectrograph (IRIS) satellite and ground-based solar telescopes reveal that approximately 20% of hot UV bursts are temporally and spatially connected with the cooler EBs. Using 3D radiation magnetohydrodynamic (RMHD) simulations with the MURaM code, we investigated the spontaneous emergence of a magnetic flux sheet, leading to complex magnetic field structures and diverse high-temperature activities due to magnetic reconnection. The simulations show that opposite-polarity magnetic fields converge in the lower solar atmosphere, forming thin current sheets and triggering plasmoid instability, which results in small twisted magnetic flux ropes and highly nonuniform plasma density and temperature. Hot plasmas (>20,000 K) emitting strong UV radiation coexist with cooler plasmas (<10,000 K) showing Hα wing emissions, with the former located ~700 km above the solar surface and the latter above them. Synthesized images and spectral line profiles exhibit characteristics of both EBs and UV bursts, demonstrating that turbulent reconnection mediated by plasmoid instability can occur in small-scale reconnection events in the partially ionized lower solar atmosphere. This model explains the formation mechanisms of UV bursts connected with EBs and indicates that UV bursts can form in atmospheric layers extending from the lower chromosphere to the transition region.

Wenshuai Cheng: <u>The solar atmosphere from the solar surface into the interplanetary space: heating, cooling, dynamics, turbulence</u>

We investigate the wavevector and variance anisotropies in the inertial range of the young solar wind observed by the Parker Solar Probe (PSP). Using the first 19 encounters of PSP measurements, we identify the young solar wind from different source regions: coronal hole (CH) interiors, streamers, and low Mach-number boundary layers (LMBLs), i.e., the peripheral region inside CHs. We assess the wavevector anisotropy with the 2D and slab turbulence model for the CH wind and the streamer wind, and the nearly incompressible (NI) MHD turbulence model for the LMBL wind where Taylor's hypothesis becomes questionable. Our results show that the CH wind has a stronger slab component compared with the streamer wind. In addition, for the CH wind and the streamer wind, the power fraction of 2D fluctuations is smaller than the ~80% typically reported at 1 au. As a representation of the LMBL wind, similarly, the oblique sub-Alfvenic intervals and the near-subsonic intervals are characterized by the dominance of slab fluctuations. All the results suggest that slab fluctuations are more abundant in the young solar wind below 0.3 au than at 1 au. Furthermore, we find a dependence of the variance anisotropy in the inertial range on proton plasma beta β_p. The variance anisotropy is the strongest in the LMBL wind with the lowest β_p, and the weakest in the streamer wind with the highest β_p. This contrast can be interpreted as the remnant of fluctuations from the coronal sources.

Xin Cheng: <u>Toward Understanding Coronal Mass Ejection Initiation</u>

Coronal mass ejections (CMEs) are the most energetic explosive phenomenon in our solar system and can release a large quantity of plasma and magnetic flux into the interplanetary space, probably affecting the safety of human high-tech activities in the outer space. To predict CMEs-caused space weather effects, we need to elucidate some fundamental but still puzzled questions, one of which concerns how CMEs are initiated. In this talk, I will present some new observations about the slow-rise precursor and pre-flare activities that can be used to constrain CME initiation models.

Daniel Clarkson: Tracing the heliospheric magnetic field via anisotropic radio-wave scattering

Solar radio bursts are produced by electrons travelling along magnetic field lines from the Sun through the heliosphere. We demonstrate that the magnetic field not only guides the emitting electrons, but also directs radio waves via anisotropic scattering from density irregularities in the magnetised plasma. Using type III burst observations from spacecraft at multiple vantage points, combined with anisotropic radio wave propagation simulations, we show that the interplanetary field structure is encoded in the observed radio emission directivity, and that large-scale turbulent channelling of radio waves is present over large distances, even for relatively weak anisotropy in the embedded density fluctuations. Tracing the radio emission at many frequencies (distances), we show that the apparent angular location derived from intensity fitting is shifted by ~30 degrees at 200 kHz. Disentangling this effect from the electron motion along the interplanetary magnetic field constrains the angular location of the intrinsic radio source. Our analysis suggests that magnetic field structures within turbulent media could be reconstructed using radio observations, offering a novel method for remotely diagnosing the large-scale field structure in the heliosphere and other astrophysical plasmas.

Jun Dai: End-view Observations of Large-amplitude Longitudinal Oscillations of a Quiescent Prominence

Prominence seismology on the large-amplitude longitudinal oscillation is applied to diagnose the geometry and strength of the magnetic fields inside the prominence indirectly. Combining the imaging and spectroscopic data, we present the end-view observations of large-amplitude longitudinal oscillations of a quiescent prominence at northwest limb on 2023 December 04. Particularly, the prominence oscillation involved Doppler velocities derived from the spectroscopic data and horizontal motions in extreme-ultraviolet (EUV) images. Originally, the prominence oscillation was triggered by the collision and heating of the adjoining hot structure associated with the two coronal jets. The horizontal motions involved two groups of oscillation signals with similar oscillatory parameters, an initial amplitude of $\sim$21.5 Mm and a velocity amplitude of $\sim$27 km s^{-1}, each lasting for $\sim$4 cycles with a period of $\sim$77 minutes. Combining the Doppler velocities derived from the spectroscopic data provided by the Chinese Hα Solar Explorer/Hα Imaging Spectrograph, the three-dimensional (3D) oscillatory initial amplitude and velocity amplitude are determined to be ∼40 Mm and ∼48 km s−1, while the angle between the direction of 3D velocities and the prominence axis is estimated to be ranging from 10◦–30◦. The curvature radius evolution of magnetic dips supporting the prominence are calculated by integrating the 3D velocities, which increased from ∼30 Mm to ∼210 Mm from the bottom to both sides, and then decreased to ∼20 Mm, with transverse magnetic field strength ≥22 G. From this, the realistic 3D geometry of the prominence magnetic dips are sinusoidal rather than semicircular. To our best knowledge, we present the first accurate calculation for the 3D curvature radius and geometry of the prominence magnetic dips based on the high-resolution observation.

Mikhail Demidov: ON PREDICTION OF SOLAR WIND LARGE-SCALE STRUCTURES ON THE BASIS OF NEW CHINESE ASTRONOMICAL FACILITIES

There are two world-important events in experimental solar physics that has happened recently due to China: the first one is a launch of the Advanced Space-based Solar Observatory (ASO-S), where one of the three payloads is the Full-disk Vector MagnetoGraph (FMG). The second one is a creation in the framework of International Meridian Circle Program (IMCP) of the new ground-based telescope - the Solar Full-disk Multi-layer Magnetograph (SFMM), installed at Gan Yu Solar Station (GYSS). In this study as a necessary intermediate step we evaluate the robustness of the original SFMM measurements by means of cross-comparison of the full-disk magnetograms with ones from other observatories. For an example of the WSO-SFMM case it was found that the correlation coefficient is high enough (≈0.70), but there is a significant difference in magnetic field strengths (regression coefficients is R≈5.0), what most probably caused by using different spectral lines. A detailed discussion of such differences from physical point of view will be a subject of future investigations. \\\The most important final objective of these two new solar facilities (as well as of the old one — the SMAT telescope at the Huairou Solar Observing Station, HSOS) is to provide reliable information about distribution of magnetic fields across the solar surface for construction of synoptic maps, which are necessary for prediction of some space weather (SW) parameters, since namely such maps are actually the low boundary conditions for corresponding numerical simulations. To do such calculations (using PFSS model in our case) on the example of SFMM synoptic maps for some Carrington rotations is the main aim of this study. The possibilities of the obtained results for SW issues are demonstrated and discussed.

Sahel Dey: Global Scale MHD Modelling of the Slow Solar Wind in light of In-Situ Observations

The solar wind is a continuous stream of charged particles emanating from the Sun that fills the entire heliosphere. With rapidly fluctuating characteristics, it is the primary driver of space weather and, therefore, maintains the Sun-Earth connection. Space-based observations reveal that there exist two different categories of solar wind, distinguished by their outflow speed, dynamic nature, and composition. The properties of the fast solar wind are well explained by established theory, but by contrast, the Slow Solar Wind (SSW) and its origin, composition, and high degree of variability remain a mystery. The Earth and other solar system planets are embedded in the highly fluctuating SSW for almost half of the 11-year solar cycle period. Hence, deciphering the origin of the slow solar wind is extremely crucial for understanding and predicting space weather near the Earth. \\\ The aim of this scientific exploration is to test one of the leading hypotheses, the role of the Interchange Magnetic reconnection (IMR) process in the formation of SSW. Here, we present a series of state-of-the-art 2.5 and 3-dimensional computational modelling using the MPI-AMRVAC code. The setup includes several layers of the solar atmosphere, starting from the cool chromosphere region to the million Kelvin hot solar corona extending to 30 solar radius. A realistic magnetic field configuration of Helmet streamer and Pseudostreamer structures is imposed. First, we evolve the model to achieve a quasi-static phase of the solar wind while considering several critical components of plasma thermodynamics, e.g., volumetric coronal heating, anisotropic heat conduction and optically thin radiative cooling. In the next step, we introduce shearing motions at one of the legs of both streamers, mimicking the supergranulation motion. As a result, IMR is induced between the closed and open field of the Pseudostreamer and the reconnection rate is modified at the current sheet of the Helmet streamer. Next, we discuss the synthetic solar wind characteristics and emphasize the role of the interchange magnetic reconnection in the formation of the Slow Solar Wind. We finally present the coronal plasma properties from our model in the context of the recent in-situ observations of the Parker Solar Probe.

WeHost Team: The 2.5-Meter Wide-field High-resolution Solar Telescope (WeHoST)

This talk briefly introduces a new-generation solar telescope in China, the 2.5-meter wide-field high-resolution solar telescope (WeHoST), which is dedicated to observations of solar active regions and eruptive events. WeHoST is an on-axis Gregorian telescope, which can perform imaging or spectral observations at a number of continuum and line windows: 3600 Å, 4305 Å, TiO 7058 Å, Hα 6563 Å, Ca II 8542 Å and He I 10830 Å, and spectro-polarimetric observations at Fe I 6173 Å (photosphere) and Mg I 5173 Å (chromosphere). With the aid of GLAO, WeHoST can acquire data with a field of view 5×5 arcmin^2 and a spatial resolution of better than 0.3 arcsec. WeHoST can also be switched to wide-band spectral observations at night used for time-domain astronomy. WeHoST will be installed at Mt Wumingshan (altitude of 4700 m), Daocheng, Sichuan in Western China and is expected to attain its first light in 2027. This project is led by Nanjing University, in collaboration with Yunnan Observatory and Nanjing Institute of Astronomical Optics and Technology.

Tao Ding: The Giant Eruption in Solar Cycle 25

On 2024 October 3, solar active region (AR) 13842 produced an X9.0 flare, which is the largest one in solar cycle 25 so far. Our study is to answer the question of what process caused this flare. Based on the magnetic field observations from the Solar Dynamics Observatory (SDO), we find that the nonconjugated sunspots of opposite polarities of the

AR core region underwent a persistent collision process with strong shearing motions. Moreover, flux cancellation was observed at the collision region, e.g. 10^21 Mx of unsigned flux canceled at the local area within 2 hours, suggesting the occurrence of collisional shearing. Meanwhile, a collisional polarity inversion line (PIL) was produced in the AR core region, as a result of collision of the nonconjugated polarities during flux emergence. The SDO/Atmospheric Imaging Assembly extreme ultraviolet observations show that two flux ropes formed above the PIL. Due to the photospheric magnetic field evolution, the two flux ropes destabilized, and then erupted simultaneously. Using nonlinear force-free field modeling, we notice that there were three flux ropes at the PIL, including the two ropes mentioned above and another unobserved one. We suggest that the formation of flux ropes that carry massive accumulated free energy by the collisional shearing process and the eruption of the flux rope system are responsible for the giant flare in solar cycle 25.

Tom Van Doorsselaere: MHD waves and heating in the solar corona

In the last decade, it has become clear that the corona is filled with MHD waves. I will discuss highlights of recent observational results, in particular with DKIST and Solar Orbiter. These form the observational motivation to reconsider wave heating models of the solar corona. I will review wave heating mechanisms and modern implementations of them.

Xiyao Duan: A global multi-scale feature of photospheric magnetic fields observed through Hilbert spectral analysis

The photospheric magnetic power spectrum is a key diagnostic of solar-surface dynamics. Traditional Fourier techniques, while widely used, struggle with the intrinsic non-stationarity and embedded structures of magnetogram data. In this study we employ Hilbert spectral analysis on line-of-sight magnetograms recorded by the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO). Using co-temporal 193 Å images from SDO/AIA, we classify each pixel as belonging to an active region, quiet-Sun area, or open-field environment, and analyse the three categories separately. Hilbert spectra for every category reveal distinct energy “bumps” whose characteristic scales follow an exponential progression with common ratio e. After separating a broadband power-law background from these bumps, we find remarkably similar behaviour across all three environments: the background exhibits a slope close to −1, while the dominant bump, centred near 20 Mm, accounts for roughly 60 % of the total spectral energy. These results shed new light on how magnetic structures originate and interact in the photosphere.

Xuchun Duan: A Statistical Analysis of Magnetic Parameters in Solar Source Regions of Halo CMEs with and without SEPs

Large solar energetic particles (SEPs) can cause adverse space weather hazards to human technology, and such events are especially associated with halo coronal mass ejections (CMEs). But in turn, a significant portion of halo CMEs are not associated with large SEPs. The objective of this study is to gain an understanding of the source region distinctions between halo CMEs in SEP and non-SEP events. Among the 176 halo CMEs observed from 2010 to 2024, we screen out 45 large SEP events and 131 non-SEP events from this data set. It is revealed that CME speed is a good discriminator between SEP and non-SEP events. Through classifying the source regions of all the halo CMEs, we find that 53% of SEP events originate from "single AR (active region)," and 47% from "multiple ARs" or "outside of ARs." The corresponding proportion for non-SEP events is 70% and 30%. This suggests that SEP source regions are more likely to originate from large-scale sources. We have also calculated the relevant magnetic parameters of the source regions and found that SEP source regions have higher magnetic free energy and reconnection flux compared to non-SEP source regions. However, SEP source regions are smaller in terms of the intensive magnetic parameters such as mean characteristic magnetic twist α and mean shear angles. Our statistical results can provide new potential variables for forecasting SEPs.

Malcolm Druett+: Chromospheric evaporation by particle beams in multi-dimensional flare models, and the formation of flare ribbons

Since the 1970s, one-dimensional models of solar flares have been able to generate hot dense upflows of plasma from the lower atmosphere called "chromospheric evaporation", via energy transported to the lower atmosphere in energetic particle beams. The beam energy fluxes are injected at the tops of the models and justified using Hard X-ray observations. Until now, 2D and 3D magnetohydrodynamic (MHD) flare models only produced evaporation as a result of other processes. We use hybrid MHD-beam particle models to generate the first chromospheric evaporation in multi-dimensional simulations that is driven by energetic electrons. We also provide a new schematic of the evolution of the lower atmospheres in flares using our state-of-the-art simulations, paired with high-resolution and cadence observations of flares using instrumentation such as IRIS and the SST to inspect the formation and fine structure of flare ribbons. \\\ This investigation provides a platform for future investigations of NLTE ionisation, pairing kinetic and MHD modelling of particle acceleration, and testing affordable Machine Learning approaches. Opportunities for joint observation and simulation investigations can be driven by the latest simulation suites, computational facilities, and instrumentation being developed in Europe, China, and beyond.

Changliang Gao: The Impact of Solar Activity on Earth's Weather and Climate

Earth's weather and climate are closely related to human survival and production. They are influenced by natural factors such as solar activity, high-energy cosmic rays, and volcanic eruptions, as well as human production activities. Whether Earth's weather and climate are dominated or severely affected by solar activity has long been an important and controversial issue. With the accumulation of massive amounts of solar observation data, we now have the opportunity to conduct in-depth research and reveal the relationship between solar activity and Earth's weather and climate. \\\ Over the past decade, extreme weather events have become increasingly frequent, severely impacting human production and daily life, and even threatening human survival. A research report released in July by the Grantham Institute at Imperial College London noted that climate change has doubled the mortality rate from heatwaves. In June and July, severe heatwaves in 12 European cities, including London, caused 2,300 deaths, nearly tripling the previous rate. Moreover, the frequency of such extreme weather events continues to rise. Early studies on the relationship between solar activity and Earth's climate often faced challenges such as poor correlation between the two and short data time scales, leading to the conclusion that solar activity has a relatively minor impact on climate change. However, research has shown that the correlation between solar activity and Earth's climate is influenced by observational time and space. These temporal and spatial differences result in a weaker correlation between solar activity and Earth's climate(Herman and Goldberg, 1978), thereby significantly underestimating the impact of solar activity on Earth's climate. Currently, we are in the peak year of the 25th solar cycle, with frequent intense solar activity. Many new solar observation devices have been put into use, combined with historical massive solar observation data and Earth meteorological data, providing an important opportunity to clarify the relationship between solar activity and Earth's magnetosphere, ionosphere, middle and upper atmosphere, and Earth's weather and climate, as well as to predict the possibility of future extreme weather and climate events. \\\ In this study, we compiled statistics on M-class and above solar flares since 1975, as well as high-energy cosmic rays and daily monthly sunspot numbers, and other solar data. We also combined geomagnetic index Dst data with meteorological data such as ground-level 2m temperature, sea surface temperature, Earth's surface longwave radiation, and ground-level 10m zonal wind. By leveraging interdisciplinary research between solar physics and meteorology, we qualitatively or quantitatively revealed the relationship between solar activity and Earth's weather and climate changes. The analysis results preliminarily indicate that the geomagnetic index Dst, like sunspot numbers, exhibits an average 11-year variation pattern, but there is a time lag between their peak times. The intensity of the geomagnetic index Dst is consistent with the occurrence of large flares; high-energy cosmic rays reaching Earth are significantly modulated by solar activity, particularly large flares and their accompanying coronal mass ejections (CMEs), which have a significant blocking effect on high-energy cosmic rays. The peak timing of DST and the high-frequency occurrence of strong solar flares are consistent; the peak of cosmic rays corresponds to the trough of Dst. The trend-adjusted changes in ground-level 2m temperature show consistency with the occurrence of solar flares. Additionally, an approximate 11-year solar cycle has been detected in both ground-level 2m temperature and sea surface temperature data. We preliminarily conclude that solar activity has a positive correlation with ground-level 2m temperature, while sea surface temperature and longwave radiation exhibit an inverse correlation and show a trend influenced by solar activity. Further analyses are underway, including comparisons of the common characteristics and differences between solar flares at different locations and CMEs, as well as studies on the influence of solar activity on temperature after accounting for carbon dioxide effects. \\\ In this work, we will further integrate solar observations to identify the solar-driven causes of Earth's weather and climate changes. We anticipate revealing the effects of solar activity at different timescales on Earth's weather and climate, as well as the underlying physical processes, thereby providing a research foundation for effectively predicting Earth's extreme climate events.

Yuhang Gao: Observation and modeling of propagating kink waves in the solar polar region

In the solar polar regions, numerous transverse waves propagate along coronal plumes, typically interpreted as kink or Alfvénic waves. These waves have been widely recognized for their potential roles in coronal heating, solar wind acceleration, and in providing seismological diagnostics of plasma parameters. In this study, we construct a 3D MHD model of a gravitationally stratified open magnetic flux tube, where a velocity driver at the lower boundary excites propagating kink waves. Our results show that both resonant absorption and density stratification significantly influence the wave amplitude. In particular, when using velocity amplitude to infer the density profile, it is crucial to account for resonant damping to avoid overestimations. We also find that phase mixing of Alfvénic motions near the tube boundary generates small-scale structures, facilitating partial energy dissipation and producing a modest temperature increase, especially at higher altitudes. To connect theory with observations, we perform forward modeling to synthesize observational signatures, demonstrating the strong potential of future instruments such as the Multi-slit Solar Explorer in detecting wave-induced features. Additionally, we conduct an observational study using Solar Orbiter/EUI data, which offers extreme ultraviolet imaging at unprecedented spatial and temporal resolutions. Our statistical analysis reveals the presence of a previously underexplored frequency regime around 10 mHz, which appears to carry substantial energy and may contribute to plasma heating in the lower corona.

Yuhang Gao: Reconnection Nanojets in an Erupting Solar Filament with Unprecedented High Speeds

Solar nanojets are small-scale jets generated by component magnetic reconnection, characterized by collimated plasma motion perpendicular to the reconnecting magnetic field lines. As an indicator of nanoflare events, they are believed to play a significant role in coronal heating. Using high-resolution extreme-ultraviolet imaging observations from the Extreme Ultraviolet Imager on board the Solar Orbiter mission, we identified 27 nanojets in an erupting filament on 2024 September 30. They are potentially associated with the untwisting of magnetic field lines of the filament. Most nanojets exhibit velocities around 450 km/s, with the fastest reaching approximately 800 km/s, significantly higher than previously reported but comparable to the typical coronal Alfvén speed. To our knowledge, these are the highest speeds ever reported for small-scale jets (less than ∼1 Mm wide) in the solar atmosphere. Our findings suggest that these nanoflare-type phenomena can be more dynamic than previously recognized and may contribute to the energy release process of solar eruptions and the heating of coronal active regions.

Hanlin Guan: Formation of δ-Sunspots: Numerical Simulation of Flux Tube Emergence

δ-sunspots, recognized as one of the most complex magnetic structures in solar active regions, are characterized by tightly interwoven opposite polarities, strong magnetic shear, and high flare productivity. They are formally defined as two sunspots of opposite polarity sharing a common penumbra. \\\ Through numerical simulations, we modeled a magnetic flux tube with dual buoyant segments residing in the shallow convection zone. Driven by density perturbations in these segments, the tube emerged through the photosphere to form two distinct bipolar magnetic systems. The leading polarity of one active region converged toward the trailing polarity of the other system. Their subsequent collision produced a complex δ-configuration featuring a shared common penumbral structure. \\\ This represents the prevailing model for δ-sunspot formation. Statistical analysis of 221 δ-configuration sunspot groups from Solar Cycle 22 confirms that virtually all observed cases align with this mechanism.

Jingnan Guo: The new phenomenon of delayed arrival of faster solar energetic particles seen by Solar Orbiter

The particle acceleration and transport process during solar eruptions is one of the critical and long-standing problems in space plasma physics. Through decades of research, it is well accepted that particles with higher energies released during a solar eruption arrive at observers earlier than the particles with lower energies, forming a well-known structure in the energy spectrum called particle velocity dispersion (VD), as frequently observed by space missions. However, this picture is challenged by new observations from NASA's Parker PSP and ESA's SO which show an unexpected inverse velocity dispersion (IVD) phenomenon, where particles with higher-energies arrive later at the observer. Facing on the challenge, we here first report the discovery of such IVD structures with 10 solar energetic proton events observed by Solar Orbiter, and then analyze the mechanisms causing this unusual phenomenon. We suggest that shock diffusive acceleration, with respect to magnetic reconnection, is probably a dominant mechanism to accelerate protons to tens of MeV in such events where particles need longer time to reach higher energies. We determine, innovatively, the physical conditions and time scales during the actual shock acceleration process that cannot be observed directly.

Jingnan Guo: Radial dependence of solar energetic particle peak fluxes and fluences

We present a list of solar energetic particle (SEP) events detected by instruments on board the Solar and Heliospheric SOHO, Parker Solar Probe (PSP), and Solar Orbiter (SO) between 2021 and 2023. The investigation focuses on identifying the peak flux and the fluence of

SEP events in four energy ranges from 10.5 to 40 MeV, as observed by PSP or Solar Orbiter at heliospheric distances shorter than 1 AU and by SOHO at the Sun-Earth L1 Lagrangian point. Based on the data from these events, we conduct a statistical analysis to study the radial dependence of the SEP proton peak flux and fluence at di erent energies. We identified 42 SEP events with enhanced proton flux that were observed simultaneously by at least two out of three spacecraft (SOHO, PSP, and SO). These events were further selected based on a criterion of a difference smaller than a 30 difference in longitudinal separation between the magnetic footpoints of the two spacecraft. For the selected events, we used a linear interpolation method to compute the proton peak flux and fluence in four energy ranges and quantified their radial dependence as a function of R^(-α), where R is the radial distance of the observer from the Sun. The peak flux and fluence of the SEP events display the following radial dependence: The average values of α across all energies range between about 3.7 and 2 for the peak fluxes and between 2.7 and 1.4 for the fluences. We also obtained the energy dependence of α, which decreases with increasing energy. Additionally, based on theoretical functions, we find that the SEP source and transport parameters may have a significant impact on α(E), and the measurement-derived α(E) values and their distribution fall within the range of theoretical predictions.\\\ Despite the uncertainties arising from the low statistics and the longitudinal influence, the radial dependence of the peak flux agrees with the upper limit R^(-3) predicted by previous studies. The radial dependence on the fluence R^(-2) tends to be weaker than the radial decay of the peak flux. As the proton energy increases, the proton mean free path increases, and the adiabatic cooling effect modifies the proton energy. As a result, the peak flux and fluence decay more significantly with increasing radial distance for lower-energy particles.

Jinhan Guo: The Birth of a Major Coronal Mass Ejection with Intricate Magnetic Structure from Multiple Active Regions

Coronal mass ejections (CMEs) are the eruptions of magnetized plasma from the Sun and are considered the main driver of adverse space weather events. Hence, understanding their formation process, particularly the magnetic topology, is critical for accurate space weather prediction. Here, based on imaging observations and three- dimensional (3D) data-constrained thermodynamic magnetohydrodynamic (MHD) simulation in spherical coordinates, we exhibit the birth of a CME with intricate magnetic structure from multiple active regions (ARs) due to 3D magnetic reconnection. It is observed as a coronal jet between ARs, accompanied by the back-flowing of filament materials along the jet spine after the passage of the eruptive filament. This jet connects two dimming regions within different ARs. This is an observational proxy of 3D magnetic reconnection between the CME flux rope and the null-point magnetic field lines crossing ARs. Hereafter, the thermodynamic data-constrained MHD simulation successfully reproduces the observed jet and the reconnection process that flux ropes partake in, leading to a CME flux rope with a complex magnetic structure distinct from its progenitor. The generality of this scenario is then validated by data-inspired MHD simulations in a simple multipolar magnetic configuration. This work demonstrates the role of multiple ARs in forming CMEs with intricate magnetic structures. On the one hand, a noncoherent flux rope where not all twisted magnetic field lines wind around one common axis is naturally formed. On the other hand, our findings suggest that the topology of a real CME flux rope may not be solely determined by a single AR, particularly during periods of solar maximum.

Mingzhe Guo: MHD waves and their applications in coronal seismology

MHD waves and oscillations are now widely accepted as ubiquitous phenomena in the solar corona. They carry information about their waveguides, enabling us to infer parameters that are otherwise difficult to measure directly in the corona, such as the coronal magnetic field and spatial characteristics of magnetic structures. This principle forms the foundation of coronal seismology. In this talk, I will present our progress in the field of coronal seismology. We have investigated the properties of MHD eigenmodes in various magnetic structures and developed a series of seismological schemes to constrain coronal parameters. These results may shed light on future studies in coronal seismology.

Yang Guo: Magnetic Field Observation and Modelling: Pre-research for SMT aboard LAVSO

Nanjing University, Shanghai Academy of Spaceflight Technology, and other collaborative institutes are leading a Lagrange-V Solar Observatory (LAVSO), which aims to study solar magnetic fields, solar eruptions, and space weather effects. The Spectral Magnetic Telescope (SMT), designed and manufactured by Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), is one of the five payloads planned to be carried. Here, we introduce the scientific goals and technical indicators of SMT. We also discuss how the magnetic field measurement accuracy can be improved by multi-perspective observations, how the Stokes profile inversion can be improved by neural networks. Once highly accurate magnetic fields are observed, they can be served as the key ingredients for data-driven and data-constrained magnetic field modelling and magnetohydrodynamic (MHD) simulations. The simulated results can be synthesized into multi-wavelength radiation, such as the white light, extreme-ultraviolet (EUV), and radio wavebands, which will be compared with observations obtained by other instruments aboard LAVSO, and other missions.

Qi Hao: Long-term variations of solar activities and active region features detected via machine learning

Solar active regions (ARs) are areas on the Sun with very strong magnetic fields where various activities take place. Prominences, also known as filaments, are one of the most common features in the solar atmosphere. Their eruptions often lead to solar flares and coronal mass ejections (CMEs). Therefore, studying their morphological features and relationships is useful for predicting eruptive events and understanding the long-term evolution of solar activity. A large amount of data has been collected from various ground-based telescopes and satellites. This massive amount of data makes human inspection difficult. To address this issue, we developed a series of automated detection methods for solar activities and ARs based on machine learning techniques. We applied these methods to process data from recent solar cycles. In addition to butterfly diagrams and the latitudinal migration of prominences, filaments, flares, and ARs, we analyzed the variations in their morphological features and N-S asymmetries over calendar years and latitude bands. Most of the statistical results obtained using our methods align with previous studies, which validates our methods. We also analyzed the tilt angle of the dipole, flare ribbons, and filament chirality.

Qi Hao: Developing Automated Detection, Tracking and Analysis Methods for Solar Activities via Machine Learning

Solar active regions (ARs) host the majority of solar activity, including flares and filaments. Studying the evolution and morphological features of ARs and solar activities is significant for understanding the physical mechanisms of solar eruptions and beneficial for forecasting hazardous space weather. A substantial amount of data has been collected from various ground-based telescopes and satellites. However, the sheer volume of data makes human inspection difficult. To address this challenge, we have developed automated detection, tracking, and analysis methods for filaments, flares, and ARs using machine learning techniques. These methods have been validated through rigorous testing, and their application to recent solar cycles has produced statistically significant, consistent results with previous studies, demonstrating their reliability and validity.

Zhenyong Hou: Numerous bidirectionally propagating plasma blobs near the reconnection site of a solar eruption

current sheet is a common structure involved in solar eruptions. However, it is observed in a minority of the events, and the physical properties of its fine structures during a solar eruption are rarely investigated. Here, we report an on-disk observation that displays 108 compact, circular, or elliptic bright structures, presumably plasma blobs, propagating bidirectionally along a flare current sheet during a period of ~24 min. Using extreme ultraviolet images, we investigated the temporal variation of the blob number around the flare's peak time. The current sheet connects the flare loops and the erupting filament. The width, duration, projected velocity, temperature, and density of these blobs are ∼1.7 ±0.5 Mm, ~79 ±57 s, ∼191 ±81 km s-1, ~106.4±0.1 K, and ∼1010.1±0.3 cm-3, respectively. The reconnection site rises with a velocity of ≤69 km s-1. The observational results suggest that plasmoid instability plays an important role in the energy-release process of solar eruptions.

Zhenyong Hou: Radio dimming associated with filament eruptions in the meter and decimeter wavebands

Filament eruptions are considered to be a common phenomenon on the Sun and other stars, yet they are rarely directly imaged in the meter and decimeter wavebands. Using imaging data from the DAocheng solar Radio Telescope (DART) in the 150−450 MHz frequency range, we present two eruptive filaments that manifest as radio dimmings (i.e., emission depressions). Simultaneously, portions of these eruptive filaments are discernible as dark features in the chromospheric images. The sun-as-a-star flux curves of brightness temperature, derived from the DART images, exhibit obvious radio dimmings. The dimming depths range from 1.5% to 8% of the background level and show a negative correlation with radio frequencies and a positive correlation with filament areas. Our investigation suggests that radio dimming is caused by free-free absorption during filament eruptions obscuring the solar corona. This may provide a new method for detecting stellar filament eruptions.

Huidong Hu: Lateral Deformation of Coronal Mass Ejections in Non-radial to Radial Propagation

A substantial fraction of CMEs exhibit a transition from non-radial to radial propagation in the low corona, which determines their propagation direction and affects their space weather impacts. However, the characteristics of CMEs during this directional transition remain poorly understood and insufficiently studied. Using multi-wavelength imaging observations of the solar disk and corona, we investigate the evolution of two CMEs originating from the same active region, both transitioning from non-radial to radial propagation in the low corona. The potential field source surface method is employed to obtain the magnetic field configuration and decay index surrounding the eruption site. \\\ The two CMEs display similar early-stage evolution. After eruption, the CME initially propagates nearly horizontally. Subsequently, the upper portion of the CME structure bulges and deforms laterally, leading to radial propagation at a latitude offset of ~25 degrees from the eruption site. The CMEs erupt beneath a system of overlying loops, whose magnetic fields are roughly aligned with the CME flux rope. Although the decay index above the eruption site reaches the critical value of 1.5 at a low altitude (~20 Mm), the CME does not rise radially above the eruption site. This is probably because the overlying loops impose strong magnetic pressure and constrain the CME's radial expansion directly above the eruption site. \\\During the non-radial propagation phase, the CME moves beneath the loops like a bullet in a gun barrel until it leaves the loop system and expands laterally. In the radial propagation stage, the flank of the expanding CME interacts with the loops, resembling the plucking of musical instrument strings. After the directional transition, the previously bulged flank in the non-radial phase becomes the leading edge (nose) of the radially propagating CME. This study presents a detailed picture of how a CME transitions from non-radial to radial propagation through lateral deformation.

Jialiang Hu: QFP waves produced in the solar eruptions

We propose a mechanism for the excitation of large-scale quasi periodic fast-propagating magnetoacoustic (QFP) waves observed on both sides of the coronal mass ejection.Through a series of numerical experiments, we successfully simulated the quasi-static evolution of the equilibrium locations of the magnetic flux rope in response to the change of the background magnetic field, as well as the consequent loss of the equilibrium that eventually gives rise to the eruption.During the eruption, we identified QFP waves propagating radially outward of the flux rope, and tracing their origin reveals that they result from the disturbance within the flux rope. Acting as an imperfect wave guide,the flux rope allows the internal disturbance to escape to the outside successively viaits surface, invoking the observed QFP waves. Furthermore, we synthesized the images of QFP waves on the basis of the data given by our simulations and found consistency with observations. This indicates that the leakage of the disturbance outside the flux rope could bear reasonable mechanism fo rQFP waves.

Ruifei Huang: A study of quasi-periodic pulsations event and its physical origin
There are many proposed mechanisms and models for quasi-periodic pulsations (QPPs), but no general consensus. Here we investigate the flare SOL2024-05-15T08:37X3.5 to study the origin of QPPs in the microwave and hard X-ray (HXR) emissions during the main phase, and further diagnose associated properties of high-energy particles. The microwave and HXR fluxes share the same period of approximately 20 and 40 seconds, microwave and HXR sources are located in the flare loop top and footpoint, respectively. During the QPP, HXR flux exhibits a general decline, while microwave flux shows an increasing trend. The turnover frequencies of the microwave spectrum exceed 15 GHz, and the microwave flux peak times are temporally delayed relative to those in HXR. HXR spectra display a “soft–hard–soft” pattern, but the hardening of microwave spectral index gradually lags behind, exhibiting a “soft-hard-harder” feature, and the spectral slope in optically thin regime is flatter throughout the eruption. Combined with observations of a CME and the evolution of coronal loops in EUV, we suggest that the sequential magnetic reconnection, quasi-periodic particle acceleration and injection induce the observed QPPs. The temporal delays in microwave emissions are attributed to the accumulation of trapped mildly relativistic electrons at the flare loop top, and the high turnover frequency is caused by the self-absorption effect. These results shed new light on the origin of QPPs and the acceleration of energetic electrons.

Xing Hu: Estimation of Day-time Seeing Changes at Observatory Sites Based on Neural Networks
Seeing, also know as the Fried parameter, is a key factor affecting the image quality of astronomical observations. Currently, day-time seeing is typically obtained using the Solar Differential Image Motion Monitor (SDIMM) or spectral ratio method. In this work, We propose a neural network model for estimating daytime seeing. The experimental results of the training set and the test set show that this model can currently estimate seeing with an accuracy exceeding 99%. Using this model to estimate the seeing of Huairou Solar Observing Station(HSOS) in 22 consecutive years from 1989 to 2010. The medianseeing of HSOS in 22 consecutive years was around 2.5 cm, and the best seeing was in April and September of one year. This result confirmed the long-term stability of seeing conditions.

In addition, we conducted an error analysis comparing the seeing measured by SDIMM and the results obtained by the spectral ratio method both under domeless and domed conditions. The results indicate a significant correlation between the SDIMM results and the spectral ratio method results, with first-order fitting coefficients of 2.2 and 2.9, respectively.

Rekha Jain: Recent advances in Helioseismology

Over the years, Helioseismology has been very successful in providing information about the solar interior structure and dynamics. Recently, there have been many advances including the discovery of various types of inertial waves in the Sun. In this talk, I will present an overview of some of these advances.

Hyun-Jin Jeong: Prediction of Time-evolving Magnetic Fields on the Solar Surface Using Deep Learning

We develop two AI-based models (Models A and B) to predict time-evolving photospheric magnetic fields with an adjustable time step, ranging up to one solar rotation ahead. Model A predicts future magnetic field data using three consecutive radial magnetic field maps, each 12 hours apart. Model B reconstructs evolving magnetic fields using two sets of three consecutive maps: one from a given date and the other from 27 days ahead, also spaced 12 hours apart. To train and evaluate the models, we adopt a Pix2PixCC-based architecture and use radial magnetic field data from SDO/HMI during the solar maximum periods of 2012–2016 and 2021–2023. Both models successfully generate magnetic field maps corresponding to the specified prediction time step. Based on quantitative comparisons, Model A outperforms the persistence model and performs comparably to the classical surface flux transport model. Model B shows improved performance over both. We also compare predictions for NOAA active regions 12673 and 13664, which rapidly emerged and produced powerful solar flares. Notably, both Models A and B can predict increases in total unsigned magnetic fluxes several days in advance if their evolution is already captured in the input data. Model B also reconstructs radial magnetic fluxes that smoothly overlap between the input and predicted data. These results demonstrate the capability of our models to generate time-evolving magnetic field maps flexibly and to capture emerging magnetic fluxes, which are essential for heliophysics research and space weather forecasting. Finally, we present preliminary results and discuss the application of our deep learning models to improving time-evolving MHD simulations of the solar corona and supporting space weather forecasts.

Chunyu Ji: Northern-Southern Hemispheric Differences and Evolution of Coronal Jets in cycle 24

The Sun's ~11-year activity cycle is famously manifest in the butterfly diagram of sunspots and active regions and in the pronounced north–south asymmetries of sunspot and flare occurrence. In this work, we ask whether small-scale off-limb coronal jets are similarly modulated by the solar cycle and exhibit hemispheric asymmetry. We apply a semi-automated detection algorithm by Liu et al. to compile a catalog of Solar Cycle 24 off-limb jets, manually remove false positives (e.g., dark lanes and coronal rays), and delineate each jet's full spatial extent. Using the differential emission measure (DEM) inversion code of Su et al., we derive for each jet its total emission measure (EM), EM-weighted mean temperature, and total thermal energy (from the sum of thermal kinetic energy). We find that the AIA 304 Å intensity and thermal energy of jets follow nearly identical cycle-long trends, peaking near solar maximum and exhibiting a strong linear correlation (CC = 0.84). During the rising phase, jets migrate from high to low latitudes in a butterfly-diagram pattern, and their thermal energy and average temperature decrease poleward. From the poles to the equator, jet heat flux, EM, and AIA 304 Å intensity increase systematically, reflecting stronger magnetic activity in the activity belts; equatorial jets exhibit higher and more narrowly distributed temperatures, whereas polar jets show larger temperature variability. Equatorial parameter distributions are less skewed with sharper peaks, while polar and global distributions display pronounced high-value tails or bimodality. These results demonstrate that off-limb coronal jets are governed by the solar activity cycle and exhibit clear hemispheric asymmetries in both their statistical distributions and physical properties.

Haisheng Ji: <u>Magneto-acoustic oscillations observed by HMI and the associated MHD solution</u>

With a plage region, we show following observational facts observed by HMI: 1) For the stronger and weaker magnetic field, the perturbations are always anti-phased. 2) Magnetic perturbations lag behind a quarter of cycle in phase with respect to the p-mode Doppler velocity. 3) The amplitudes of the magnetic perturbations are found to be proportional to magnetic field strength. We further show that the relationships can be well explained with an MHD solution for the magneto-acoustic oscillations in high-β plasma.

Jie Jiang: <u>Minimal Roles of Solar Subsurface Meridional Flow in the Distributed Babcock-Leighton Dynamo</u>

The subsurface meridional flow has long been recognized as a critical factor in modulating the solar cycle.Specifically, the equatorward return flow in the tachocline is widely believed to drive the formation of the sunspot butterfly diagram and determine the solar cycle period within the framework of flux transport dynamo (FTD) models. We aim to investigate whether the subsurface meridional flow also plays a significant role in the recently developed distributed Babcock-Leighton (BL) dynamo model, which operates within the convection zone, rather than the tachocline. Various meridional flow configurations, including a deep single cell, a shallow single cell, and double cells, are applied in the distributed BL dynamo model to explore the mechanisms driving the butterfly diagram and variations in the cycle period. Subsurface meridional flow plays a minimal role in the distributed dynamo. A solar-like butterfly diagram can be generated even with a double-cell meridional flow. The diagram arises from the time- and latitude-dependent regeneration of the toroidal field, governed by latitude-dependent latitudinal differential rotation and the evolution of surface magnetic fields. The cycle period is determined by the surface flux source and transport process responsible for polar field generation, which corresponds to the α-effect in the BL-type dynamo. The cycle period may exhibit varying dependence on the amplitude of the subsurface flow. The distributed BL dynamo differs fundamentally from the FTD dynamo, as it does not rely on the subsurface flux transport. This distinction aligns the distributed BL dynamo more closely with the original BL dynamo and the conventional $\alpha-\Omega$ dynamo.

Chunlan Jin: Local dynamo process in the solar atmosphere

The 11-year solar activity cycle, recognized as nature's third cycle, is characterized by the rise and fall in the sunspot number. In nature, the solar cycle is magnetic and driven by the global dynamo within the Sun. Babcock-Leighton dynamo mechanism provides a theoretical framework for explaining the generation of magnetic field in active regions and polar regions. However, advancements in solar observational technologies have revealed an abundance of small-scale magnetic fields. These small-scale magnetic fields contribute magnetic flux far beyond the ARs, posing significant challenges to global dynamo theories. In this report, we will review the cyclic variations of small-scale magnetic fields, and discuss their sources.

Pengyu Jin: Periodic Behavior of Symmetric and Antisymmetric Magnetic Fields and Their Impacts on North-South Asymmetry Local dynamo process in the solar atmosphere

Hemispheric asymmetry of solar activity can be interpreted as the superposition of antisymmetric (dipolar) and symmetric (quadrupolar) magnetic fields. In this study, we investigate the periodic behavior of these components and their impact on north-south asymmetry based on spherical harmonic decomposition of synoptic solar magnetograms (Stanford/WSO, NSO/KPVT, NSO/SOLIS, UCLA/MWO). Our results confirm the presence of the well-known ~22-year magnetic cycle in the axial dipole component, while the quadrupolar component reveals additional sub-periodicities in the range of 11–14 years. The sum period and beat period resulting from the superposition of dipolar and quadrupolar fields align with reported periodicities of hemispheric asymmetry. However, the period values of antisymmetric and symmetric fields vary significantly with different spherical harmonic degrees, leading to diverse resultant periods through superposition. This variation may account for discrepancies in observed periodicities of hemispheric asymmetry derived from different types of solar activity data. Furthermore, we also quantify the temporal evolution of hemispheric asymmetry based on the decomposed dipolar/quadrupolar fields or anti-symmetric/symmetric fields. It is found that quadrupolar fields dominate during solar maximum, while dipolar fields prevail at minimum. Additionally, the energy difference between the antisymmetric field and the symmetric field gradually decreases with increasing harmonic degree, resulting in an increase in hemispheric asymmetry. These findings offer new insights into the mechanisms governing the solar cycle and its hemispheric asymmetry.

Larisa Kashapova: The role of a coherent emission source in the energy release of the 09 October 2024 flare

It is assumed that microwave flare emission at frequencies up to 1 GHz is usually formed by an incoherent gyrosynchrotron mechanism. Thus, rare events where we observe emission of coherent nature at low microwave frequencies attract special attention as markers of peculiarities in flare topology or energy release scenarios. We present preliminary results of analysis of the 09 October 2024 flare. The combination of observations by the Mingantu Spectral Radioheliograph (MUSER) and the Siberian Radiohelograph revealed fine structure in quasiperiodic pulses with a frequency range of about 1-3.5 GHz, which is not typical for gyrosynchrotron emission. Spectral analysis confirmed the plasma mechanism of the observed QPPs, and that their source was located near a powerful sunspot. We discuss the role of QPP sources in the initiation and development of flares and possible reasons for the coherent nature of QPPs observed in the microwave range.

Rony Keppens: Mathematics for coronal rain: the hydrodynamic thermal continuum

The solar corona is structured in myriads of magnetic loops and contains rarified plasma at million degrees Kelvin. However, observations reveal how spontaneous in-situ condensations show up nearly everywhere. In the strong coronal magnetic field, these cold (10000 K) and dense blobs are then guided to rain down curved loops, such that an essentially hydrodynamic evolution along a 1D loop suffices to explain the physics. These coronal rain condensations are manifestations of an energy exchange between the plasma and the radiation field, where optically thin radiative losses preferentially act as a sink for internal energy. This makes the loop plasma liable to a runaway linear thermal instability, originally postulated by the late Eugene Parker [ApJ 117, 431, 1953]. In this talk, I will present an overview of state-of-the-art numerical simulations that have progressed from 1D hydrodynamic loop models to full 3D radiative magnetohydrodynamic setups, which rival in resolution with our observations. All these confirm the essential role played by thermal instability to instigate rain formation. A rigorous mathematical analysis of the linearized non-adiabatic hydrodynamic equations reveals the presence of a thermal continuum in the essential spectrum of eigenmodes of a stratified loop. We will show the intricate links with spectral theory in stratified atmospheres, where p- and g-modes get modified by radiative losses, and where the entropy mode turns into a continuous range of eigenfrequencies with ultra-localized (singular) eigenfunctions. This insight connects and clarifies findings on thermal non-equilibrium states, waves affected by thermal misbalance, and the present confusion on the role of isochoric versus isobaric thermal instabilities.

Ankit Kumar: Modeling of High-Frequency MHD Waves and Oscillations in Coronal Loops: Implications for Coronal Heating and Magneto-seismological Applications

Fast magnetoacoustic oscillations, particularly the sausage and kink modes, are frequently observed in solar coronal loops and are considered important for both energy transport and plasma diagnostics in the upper solar atmosphere. In the present work, we examine the damping behaviour of these oscillations by modelling the coronal loop as a straight, cylindrically symmetric magnetic flux tube with radial variation in plasma density. Our focus lies in the regime where wave energy is not fully confined within the loop but is allowed to leak into the surrounding corona, providing a possible mechanism for energy dissipation. To make the model more representative of coronal conditions, we incorporate the effect of shear viscosity into the linearized MHD equations, thereby going beyond the ideal approximation. A general dispersion relation for fast MHD modes is derived under the low-β assumption, and the eigenvalue problem is solved by prescribing the axial wavenumber. This enables us to investigate the complex frequency spectrum associated with damped wave modes. The analysis shows that, in the long-wavelength regime, the oscillation period is primarily governed by the loop radius, whereas in the short-wavelength regime, both the radius and length of the loop significantly influence the wave period. Furthermore, the presence of viscosity leads to a marked increase in damping, as reflected by the imaginary part of the complex frequency, which controls the temporal decay of wave amplitude. These results provide a better understanding of how wave leakage, loop geometry, and viscous dissipation together affect the dynamics of MHD waves in coronal structures. They also enhance the potential of using damped wave signatures for solar magneto-seismology and support the role of MHD wave damping as a contributing factor in coronal heating.

Alexey Kuznetsov: Multiwavelength observations of the 2024-02-16 solar flare: implications for the electron acceleration processes

Solar flares produce electromagnetic emission in a broad range of wavelengths. We analyze the X2.5 class flare that occurred on 2024-02-16 in the active region 13576 near the solar limb. The flare was observed by the Siberian Radioheliograph, Chashan Broadband Solar millimeter spectrometer, and Nobeyama Radiopolarimeters in the microwave range, by the Advanced Space-based Solar Observatory and Konus-Wind spectrometer in the hard X-ray range, and by the Solar Dynamic Observatory in the extreme ultraviolet range. We demonstrate that in the considered event the magnetic reconnection occurred at large heights (and likely was triggered by filament eruptions); the corresponding particle acceleration and plasma heating resulted in microwave and EUV brightenings that appeared simultaneously both in the core of the active region and as far as ~100 Mm from it. The bulk of the microwave emission originated from energetic electrons trapped in several relatively compact flaring loops; spectral fitting has allowed us to estimate the electron parameters. The hard X-ray observations revealed the presence of extremely high-energy electrons (with the energies of up to ~10 MeV). We demonstrate that those electrons were initially injected at large pitch-angles within the flaring loops, and their subsequent evolution was affected mostly by the Coulomb collisions. We discuss the particle acceleration mechanisms that could be responsible for the observed phenomena.

Jorrit Leenaarts: Results from recent instrument upgrades at the Swedish 1-m Solar Telescope

The Swedish 1-m Solar Telescope (SST) has been in operation since 2002 and routinely delivers diffraction-limited data owing to its high optical quality, its AO system, and MOMFBD image restoration. The SST instrumentation has been continuously upgraded since then.
\\\ In 2023 the HeSP instrument produced its first science data. HeSP is a microlens-based integral-field spectropolarimeter for He I 10830 with a FOV of 8x8 arcsec. \\\ In April 2025 the CHROMIS dual Fabry-Perot instrument was upgraded with new cameras and polarimetric capabilities were added. It now delivers diffraction limited data with a FOV of 80x80 arcsec in the wavelength range 390-500 nm and can take full Stokes polarimetry in the Ca II H&K lines. \\\ The CRISP2 dual Fabry-Perot imaging spectropolarimeter will be installed in July 2025. It is a replacement of the current CRISP instrument, with as primary improvement a much increased FOV: 120 arcsec circular instead of 78 arcsec circular. It takes spectropolarimetric data in a variety of spectral lines in the range 500-900 nm. \\\ I will present the first data taken with these new instruments, discuss some scientific results as well as their future potential.

Binghang Li: Revaluating the role of the surface magnetic field in the solar dynamo

The surface magnetic field plays a crucial role in the solar dynamo. On one hand, the polar magnetic field during the solar minima has been demonstrated to exhibit a strong correlation with the strength of the next solar cycle, which was once considered to be a compelling observational evidence supporting the Babcock-Leighton dynamo model. However, some mean-field dynamo models can also reproduce this correlation remarkably well. On the other hand, there has been a study showed that the surface magnetic field integral can estimate the hemispheric net toroidal flux in the interior under the soalr differential rotation profile. This method has also proven highly applicable to Sun-like stars. Nevertheless, a recent study suggest that the strong radial shear in the internal tachocline may also contribute to the toroidal flux at a comparable magnitude to the surface integral in mean-field models. To address these disagreement, we analyze the influence of magnetic field configuration on the toroidal flux under a constant magnetic flux and demonstrate that the surface integral method remains valid for estimating the hemispheric net toroidal flux. Furthermore, through different model analysis, we show that the key factor underlying the correlation between the polar field at the solar minima and the strength of the next solar cycle is the magnetic field configuration rather than the poloidal field generation mechanism. In fact, any dynamo model capable of reproducing the observed magnetic features of the Sun can yield a strong correlation between the polar field at solar minimum and the strength of the subsequent solar cycle.

Chuan Li: From CHASE to LAVSO – a Deep-space Mission for Solar Physics and Space Weather

As the first solar space mission of China National Space Administration (CNSA), the Chinese Hα Solar Explorer (CHASE), also known as "Xihe" (羲和), was successfully launched on 2021 October 14. The CHASE has been performing exceptionally well in orbit. Based on its high-quality full-disk spectroscopic observations, more than 60 peer-reviewed papers have been published. The CNSA's successive solar mission, "Xihe II" (羲和 II) – the LAgrange-V Solar Observatory (LAVSO), scheduled for launch in 2028. LAVSO aims to address two fundamental questions in solar physics and space weather, i.e., "the evolution of solar active-region magnetic fields and their connection to the solar eruptions" and "the propagation of solar eruptions and their relationship with hazardous space weather". Here we summarize the key scientific findings from the CHASE mission and present the scientific objectives, payloads, and mission design of LAVSO.

Dong Li: Localizing Flare QPPs in HXR, Microwave, Lyα, and White-light Emissions

We investigated the origin of quasi-periodic pulsations (QPPs) at two periods in multiple wavelengths of an X6.4 flare on 2024 February 22, which occurred at the edge of a sunspot group. A short period at about 3 minutes is simultaneously observed in wavebands of HXR, microwave, and Lyα during the flare impulsive phase. The onset of flare QPPs is almost simultaneous with the start of magnetic cancellation between positive and negative fields, indicating that it is most likely triggered by accelerated electrons that are associated with periodic magnetic reconnections. A long period at about 8.5 minutes is only detected in the white-light emission, suggesting the presence of cutoff frequency. The similar periods of 3 and 8.5 minutes are measured at the umbra and penumbra in the adjacent sunspot. Moreover, the NLFFF extrapolation results suggest that the flare area and sunspots are connected by the magnetic field lines. Our observations support the scenario that the short-period QPP is modulated by the slow magnetoacoustic wave originating from the sunspot umbra, while the long-period QPP is probably modulated by the slow-mode magnetoacoustic gravity wave leaking from the sunspot penumbra.

Haitang Li: The Formation of a Multifilament System Driven by Photospheric Converging Motions in a Bipolar Sunspot

Solar filaments are believed to be a clump of cold plasma accumulated in the magnetic dips. However, the magnetic configuration of filaments and the key factors for their formation remains elusive. In this Letter, we present a detailed study of the formation and eruption of a multifilament system with observations and simulations. Before the filament appeared visible, the chromospheric fibrils gradually gathered together, evolving from a diffuse distribution into threadlike structures that were nearly parallel to the polarity inversion lines. On 2022 March 20, an arch filament first appeared showing high dynamics, and subsequently two reserved S-shaped filaments were visibly observed. These two filament segments further reconnected, forming a long coherent filament and resulting in a double-decker configuration. In addition, continuous converging motion and magnetic flux cancellation were found in the photosphere during the evolution. Simultaneously, more bald patch structures appeared at the polarities' collision position. Through a data-driven numerical simulation, we further reconstructed the coronal magnetic field, which is composed of two twisted magnetic flux ropes (MFRs) with their bottom touching the photosphere, along with a group of sheared arcades forming an X-shaped configuration. These findings suggest that the magnetic configuration of the filament is in a highly dynamic state, evolving from a hybrid to a coherent MFR. Moreover, we propose that the formation and eruption of the multifilament system are closely related to magnetic reconnection taking place on the photosphere and in the lower corona, respectively, both mainly driven by the photospheric converging motion.

Haiyu Li: Helioseismic Survey of Acoustic Waves Travel-time in Sunspots

It is known that when acoustic waves propagate into and out from a sunspot, their travel time would be shifted; and the measured travel times of these waves into and out from sunspots are also different by as much as tens of seconds. We studied a sunspot in AR NOAA 11312 using helioseismology method, making measurements of waves traveling into and out from the sunspot, but with different traveling directions, with different angles relative to the sunspot's radial directions. We also performed forward modeling for travel times using ray-tracing method. We found that both ingoing and outgoing waves travel faster than the waves in quiet region by as much as 40 seconds, and this time shift reaches its maximum when waves travel along radial direction with small skip distance. The travel times of ingoing waves are mostly smaller than that of outgoing waves, the amplitude of time difference can be more than 1 minute, also reaches its maximum at radial direction and small skip distance. The overall time shift is mainly caused by the sunspot's magnetic field and sound speed perturbation, and the difference between ingoing and outgoing waves is mainly caused by the subsurface flow. However, understandably, the travel times estimated from the model do not fully agree with our measurements in many other aspects.

Hongrui Li: Observational Analysis of Counter-streaming Flows in a Forming Filament and Their Relationship with Local Heating at Filament Footpoints

Utilizing high-resolution imaging and spectroscopic observations from the New Vacuum Solar Telescope (NVST), the Interface Region Imaging Spectrograph (IRIS), and the Solar Dynamics Observatory, we investigated the nature and origin of counter-streaming flows within a forming active region filament. The ever-present counter-streaming flows observed within the filament are identified as interleaved bidirectional mass flows occurring in neighboring filament threads. IRIS and NVST observations corroborate the multi-thermal nature of these counter-streaming flows, with the cool Hα component exhibiting velocities of approximately 10−20 km s−1 and the warm ultraviolet component displaying typical velocities of around 40−70 km s−1. Spectral diagnostics of the IRIS Si iv 1400 A line reveal a substantial line width of 40 km s−1 in the counter-streaming flow regions. Flows emanate from brightenings at the two ends of the filament, where network jets are occurring. A series of small-scale jets continuously injects cool and warm plasma with chromospheric and transition region temperatures into the filament's channel. At the jet bases, footpoint brightenings exhibit pronounced intensity enhancements and line broadening in IRIS Si iv and C ii spectral lines, indicative of significant chromospheric local heating. Below the jet bases, numerous small-scale photospheric magnetic elements with opposing polarities undergo flux emergence and/or cancellation, exhibiting a typical magnitude of 101 Mx. These dynamic magnetic interactions likely indicate unresolved magnetic reconnection events occurring at small scales. Such reconnection events may trigger the observed small-scale jets and contribute to localized heating in the region. This work elucidates the multi-thermal origin of counter-streaming flows within a forming filament and provides evidence of localized chromospheric heating at the filament footpoints.

Leping Li: Coronal condensation and magnetic reconnection

The condensation of cool plasma out of the hot corona is a widely observed phenomenon. It is an important part of the mass cycle of solar atmosphere. One widely investigated concept for this process is based on the thermal properties of the plasma alone. It is independent of the (evolution of the) coronal magnetic field, and only the loss of equilibrium between heating input, heat conduction, and radiative losses causes the plasma to cool catastrophically. In this talk, we report the coronal condensation facilitated by interchange magnetic reconnection between open and closed magnetic structures. The curved higher-lying open structures move down toward the surface, and reconnect with the lower-lying closed loops, resulting in the formation of a magnetic dip in the former. The newly reconnected open and closed structures then appear, and retract away from the reconnection region. The coronal plasma surrounding the dip of higher-lying open structures converges into the dip, leading to the enhancement of plasma density in the dip. Triggered by the density enhancement, thermal instability occurs, and cooling and condensation of hot coronal plasma take place in the dip. A coronal cloud prominence then forms, and then facilitates a speedup of the reconnection. Due to the successive reconnection, the condensation falls to the surface, under the effect of gravity, along the legs of newly reconnected closed loops and higher-lying open structures as coronal rain. Interchange reconnection thus plays an active role in the mass cycle of coronal plasma because it can initiate the catastrophic cooling and condensation. This underlines that the magnetic and thermal evolution has to be treated together and cannot be separated, even in the case of catastrophic cooling.

Shihan Li: Enhanced Peak and Extended Cooling of the Extreme-ultraviolet Late Phase in a Confined Solar Flare

We present observations and analysis of an X1.8 non-eruptive solar flare on 2012 October 23, which is characterized by an extremely large late-phase peak seen in the warm coronal extreme-ultraviolet (EUV) emissions, with the peak intensity over 1.4 times that of main flare peak. The flare is driven by a failed eruption of a magnetic flux rope (MFR), whose strong squeeze force acting on the overlying magnetic structures gives rise to an intense early heating of the late-phase loops. Based on differential emission measure (DEM) analysis, it is found that the late-phase loops experience a "longer-than-expected" cooling without the presence of any obvious additional heating, and meanwhile, their volume emission measure (EM) maintains a plateau level for a long time before turning into an evident decay. Without the need for an additional heating, we propose that the special thermodynamic evolution of the late-phase loops revealed in this flare might arise from loop cross-sectional expansions with height, which are evidenced by both direct measurements from EUV images and by magnetic field extrapolation. By blocking the losses of both heat flux and mass from the corona, such an upward cross-sectional expansion not only elongates the loop cooling time, but also more effectively sustains the loop density, therefore leading to a later-than-expected occurrence of the warm coronal late phase in combination with a sufficiently high late-phase peak. We further verify such a scenario by analytically solving the cooling process of a late-phase loop characterized by a variable cross section. Hereafter, the data-constrained MHD simulation reproduces the 3D magnetic-field evolution of this confined flare, revealing the magnetic origins of late-phase flare loops.

Shuyue Li: Extreme Ultraviolet Wave and Quasi-periodic Pulsations during an M-class Flare on 2011 February 24

In this poster, we report multiwavelength and multiview observations of the prominence eruption from active region 11163, which is associated M3.5 class flare as well as fast coronal mass ejection (CME) on 2011 February 24. The rising prominence propagates nonradially in the southeast direction. Using the revised cone model, three-dimensional reconstructions of the prominence reveal that the latitudinal inclination angle decreases from ∼60° at 07:25 UT to ∼37° at 08:48 UT, suggesting that the prominence tends to propagate radially. The longitudinal inclination angle almost keeps constant (-6◦). The angular width of the icecream-like prominence is between 13° and 21°. The highly inclined prominence eruption and the related CME drives an extreme ultraviolet wave moving southward at a speed of 445±2 km/s observed in 304 and 193 Å. The flare shows quasi-periodic pulsations in soft X-ray, hard X-ray, EUV, and radio wavelengths with periods of 51−120 s. A thin current sheet and multiple plasmoids are generated beneath the eruptive prominence, which are basically cotemporal with the flare QPPs. Combining with the appearance of drifting pulsation structure, the QPPs are most probably created by quasiperiodic magnetic reconnections and particle acceleration as a result of magnetic islands in the flare current sheet.

Ting Li: Observations of 3D magnetic reconnections

The 3D evolution and eruptive character of solar flares is one of the most important unsolved problems in solar and space physics. A better understanding of this problem can improve the accuracy of space weather prediction and reduce the risks of our high-tech activities. Magnetic reconnection is a fundamental physical process in plasmas whereby stored magnetic energy is converted into heat and kinetic energy of charged particles. Its nature in two dimensions is much better understood than that in 3D, where its characteristics have not been revealed due to the lack of observational evidences. By using IRIS high-cadence observations, we found quasi-periodic super-Alfvénic slipping motions in ribbon kernels during solar flares. The super-Alfvénic slippage with a speed of up to ~1688 km/s is directly observed and the calculated period of the apparent super-Alfvénic slippage is about 10 s. It greatly updates our understanding of 3D evolution of solar flares, and provides observational evidences for 3D reconnection models.

Wenxian Li: Solar and Stellar Magnetic Field Diagnostics from X-ray and EUV Spectra

The magnetic fields of the solar and stellar coronae play a crucial role in triggering explosive phenomena such as flares and coronal mass ejections, as well as in driving solar winds. However, it remains highly challenging to measure them from the conventional spectropolarimetric observations due to the faint signals of coronal plasma. We proposed an exotic transition, namely magnetic-field-induced transition, which is caused by the quantum interaction between the magnetic field and atoms/ions. I will use the X-ray and EUV spectral lines in Ne-like ions and Fe X as examples to illustrate its principle and potential for solar and stellar magnetic field diagnostics.

Xiaohong Li: 3D structures of the base of small-scale recurrent jets revealed by Solar orbiter

Solar jets, characterized by small-scale plasma ejections along open magnetic field lines or the legs of large-scale coronal loops, play a crucial role in the dynamics of the solar atmosphere. They are often associated with other solar active phenomena, 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 studied in detail due to the limitations in the spatial resolution of observations. Solar Orbiter enables us to investigate the structure of solar jets with much higher spatial and temporal resolutions and from a different angle than from Earth. By combining observations made by instruments onboard Solar Orbiter with data from the Solar Dynamics Observatory, we analyzed recurrent solar jets originating in a mixed-polarity region near an active region. Additionally, we employed potential field and magneto-hydro-static extrapolation techniques to determine the magnetic field topology associated with the jets. We observed "fireworks" structures in the EUV observations, which are the dynamic manifestations of the jet base. This bright structure is located above the magnetic inversion line. Numerous flows spread out from the reconnection point to the surrounding area at speeds exceeding 100 km/s. By analyzing the evolution of the magnetic field, we identified a clear flux cancellation process at the footpoint of the jet. The jets display a fan-spine structure indifferently to the extrapolation method applied. The base flows are confined within the fan structure, with the highest flow speed near the null point. Additionally, we studied the thermal structure of the jet base, and temperature peaks near the null-point, proving that persistent magnetic reconnection at the null-point drives the recurrent jets.

Hao Liang: Thermal MHD simulation of eruptive MFR driven by collisional shearing

Solar hot channel is a rope-like channel filled with extremely hot plasma with a temperature of 10 MK, first observed by the Atmospheric Imaging Assembly (AIA) telescope on board the Solar Dynamics Observatory (SDO). It appears in the initiation stage of a solar eruption and erupts as the core of a coronal mass ejection leaving behind a solar flare. Based on the appearances of the hot channel such as a twisted axis, internal helical threads, a circular cross section and writhing to a reverse Y shape during eruption, the researchers conjectured that the hot channel is a hot magnetic flux rope (MFR), in which helical magnetic field lines wind around a common axis at least one circle to form a rope-like structure. In the two-dimensional theoretical CSHKP and Lin-Forbes solar flare models, the pre-existing MFR rises due to the catastrophic loss of equilibrium and induces magnetic reconnection behind in an elongating electric current sheet producing flare loops. In this work, we reveal the relationship between MFR and hot channel, and the whole evolution of hot channel in simulation.

Jiaben Lin: Introduction to the Solar Polar-orbit Observatory (SPO) Mission

Solar magnetic fields and related solar magnetic activities dominate the heliospheric environments from the near-Earth space to the interplanetary space, and up to the interstellar boundary. The polar magnetic fields of the Sun and its dynamic processes are especially vital in the aspects of manifesting the internal dynamo of the Sun, and shaping magnetic fields in the heliosphere. But so far, high quality observations of solar polar region is quite limited, especially the accurate polarization and Doppler imaging. The Chinese spacecraft of Solar Polar-orbit Observatory (SPO) has been designed to directly image the solar polar regions in an unprecedented way by traveling in a large solar inclination angle (larger than 80 degree) and a small ellipticity. Based on multi-band remote-sensing and in-situ measurements, the SPO will focus on: the origin of solar magnetic activity cycle and high-speed solar wind, and providing the necessary, complete, and self-consistent initial and boundary conditions for creating a data-driven global heliospheric numerical model that serves as the foundation for space weather prediction. In this presentation, we will give an overview of SPO, such as its scientific objectives, satellite, payloads, and mission plan.

Jiaben Lin: Application of Multimodal Large Language Model in Solar Physics

Frontier AI technologies, represented by Large Language Models (LLMs), are revolutionizing scientific research methods and have achieved breakthrough results in fields such as biochemistry. This raises the question: Can Multimodal LLMs be applied to solar physics? If so, how? This report explores the essential foundations and application methods of LLMs in solar physics, taking the JinWu Solar Large Model as a case study.

Jun Lin: The Solar Close Observations and Proximity Experiments (SCOPE) mission

The Solar Close Observations and Proximity Experiments (SCOPE) mission will send a spacecraft into the solar atmosphere at a low altitude of just 5 $R_\odot$ from the solar center. It aims to elucidate the mechanisms behind solar eruptions and coronal heating, and to directly measure the coronal magnetic field. The mission will perform in situ measurements of the current sheet between coronal mass ejections and their associated solar flares, and energetic particles produced by either reconnection or fast-mode shocks driven by coronal mass ejections. This will help to resolve the nature of reconnections in current sheets, and energetic particle acceleration regions. To investigate coronal heating, the mission will observe nano-flares on scales smaller than 70 km in the solar corona and regions smaller than 40 km in the photosphere, where magnetohydrodynamic waves originate. To study solar wind acceleration mechanisms, the mission will also track the process of ion charge-state freezing in the solar wind. A key achievement will be the observation of the coronal magnetic field at unprecedented proximity to the solar photosphere. The polar regions will also be observed at close range, and the inner edge of the solar system dust disk may be identified for the first time. This work presents the detailed background, science, and mission concept of SCOPE and discusses how we aim to address the questions mentioned above.

Jiajia Liu: Coronal Jets in Solar Cycle 24

Coronal jets are one of the most commonly observed phenomena in the solar atmosphere; their initiation and evolution often represent the violent and gradual release of free magnetic energy. In this talk, I will briefly introduce our work over the past few years on the (semi-) automated detection using computer vision and machine learning techniques of coronal jets observed off the solar limb in solar cycle 24. Using these algorithms, we have identified over 2,000 coronal jet events during solar cycle 24. Statistical analysis reveals that the energy of these jets follows a power-law distribution similar to those of solar flares and coronal mass ejections, suggesting that these solar eruptive phenomena across different scales might share similar underlying physical mechanisms. I will also present a few other findings together with the first butterfly diagram of coronal jets, demonstrating that coronal jets-like large-scale eruptive events such as flares and coronal mass ejections—are also modulated by the solar activity cycle.

Jiayi Liu: Towards a Robust Estimate of the Solar Photospheric Poynting Flux and Helicity Flux

The observed solar photospheric magnetic fields and Doppler velocities are frequently used to quantify the Poynting flux and helicity flux. Multiple methods have been developed for this purpose, but their estimates of the Poynting flux and helicity flux often differ from one another. Here we study the performance of three widely used methods on NOAA active region 12673: "PTD-Doppler-FLCT Ideal" (PDFI), "Differential Affine Velocity Estimator for Vector Magnetograms" (DAVE4VM), and an extension of the latter with Doppler velocity constraint (DAVE4VMwDV). We find that the values of the accumulated energy and helicity differ significantly between the three methods, even in signs. Using the Helmholtz-Hodge decomposition, we show that Doppler velocity can contribute significantly to the Poynting flux and helicity flux through the non-inductive (curl-free) electric field. The different, ad hoc treatments of the Doppler and transverse velocities in three methods are directly responsible for the discrepancies. We discuss the desired future observations that can better constraint these methods.

Junyan Liu: Automatic Identification and Statistical Analysis of the Coronal Holes

Coronal holes(CHs) are the darkest regions of the sun, which is usually associated with the open magnetic field and fast solar wind. Accurate delineation of CH boundaries is crucial for analyzing physical properties, such as solar wind acceleration. In this work, we have developed the DEtection and Tracking Algorithm for Coronal Holes (DETACH). DETACH significantly reduces the misidentification of filaments as coronal holes compared to previous methods, achieving higher accuracy across comprehensive evaluation metrics. Using DETACH, we successfully detected and tracked the coronal hole region of extreme ultraviolet(EUV) 195-angstrom wavelength from the Solar Dynamics Observatory satellite (SDO) Atmospheric Imaging Assembly instrument (AIA). Afterward, a catalog of the Coronal Holes during the period from 2010 to 2024 was established. This catalog, with a 12-hour temporal resolution, details the evolution of the physical parameters for different individual coronal holes. Based on this catalog, we found that the zonal coronal hole rotation rates are different from the differential rotation rates observed from the photosphere. The amplitudes of the coronal hole rotation rates at different latitudes are extremely smaller than that of the photosphere. However, the meridional velocities of coronal holes are in good agreement with the solar meridional circulation. Besides, we also noticed a north-south asymmetry in the distribution, area, intensity, flux, and magnetic field of the coronal holes. Moreover, the coronal hole distribution is also not fully asymmetric for different longitudes, especially in the solar maxima period. These asymmetries can be partly explained by some solar dynamo models and may possibly offer potential insights into CH formation mechanisms.

Lijuan Liu: ON THE CME PRODUCTIVITY OF SOLAR ACTIVE REGION 13664/8

In May 2024, NOAA AR 13664/8 emerged as an exceptionally productive region of the current solar cycle. It produced 12 X-class flares and over 20 CMEs, triggering the strongest geomagnetic storm since 2003. \\\ Why is the AR complex so productive, particularly in CMEs? We examine the photospheric magnetic evolution, eruption sources, and eruption waiting times to address this. Initially, the region contained only AR 13664 and remained relatively inactive until AR 13668 emerged on May 4. This rapid, complex flux emergence increased the region's area, magnetic flux, and non-potentiality, as reflected in the photospheric parameters. It also enhanced the region's complexity, with clustered major eruptions occurring concurrently. Comparison with five other ARs reveals parameter thresholds identifying the ARs' productivity: total excess magnetic energy density (5.85×10^{23} erg cm^{-1}) and total current helicity (2700 G^2 m^{-1}) distinguish flare-rich ARs, while mean current helicity (0.01 G^2 m^{-1}) further identifies CME-rich regions. The region's complexity is manifested by at least 10 emerged bipoles and collision at 7 non-conjugated polarity interfaces, where significant shearing occurred, serving as primary eruption sources. Decay index distributions reveal lower critical heights for torus instability above CME sources, with a threshold of 50 Mm distinguishing CMEs from confined flares. Double peaks in CME waiting time distribution support that high complexity enhances CME productivity by increasing both recurrent CMEs from same location and disturbance-triggered CMEs from nearby locations. \\\ These highlight that in addition to sufficient non-potentiality and rapid background field decay, high complexity is crucial in determining the region's CME productivity.

Tao Liu: The Data-Driven Simulation on the Formation of Active Region Filaments

The formation of active region filaments is closely linked to the accumulation of magnetic free energy and helicity, reflecting the energy storage process preceding solar eruptions. Understanding this mechanism is a key scientific challenge in solar eruption research, making the study of filament formation in active regions essential. Although previous studies have significantly advanced our knowledge of active region filament formation, many questions remain unanswered. To address this, we conduct data-driven magnetofriction simulations to reveal the magnetic field evolution during filament formation in emerging active regions for few days. Our numerical models show excellent agreement with observational data, matching the magnetic flux ropes with filaments. We quantify magnetic helicity, relative helicity flux through photosphere, and free magnetic energy in models and find local mixed polarity helicity signatures with an overall negative magnetic helicity. Meanwhile, free magnetic energy showed a steady increase during the filament formation.

Yang Liu: Untwisting motion and bidirectional outflows of a filament

Filament consists of cold and dense plasma that is suspended in the corona. Observations with a high spatial resolution indicate that its fine structure is highly dynamic during its evolution and eruption. We wish to understand the mechanism that produces twisting motions and bidirectional outflows in filaments by combining observation and simulation. The filament evolution was observed in multiple wavelengths by the New Vacuum Solar Telescope (NVST), the Solar Upper Transition Region Imager (SUTRI), the Chinese H Solar Explorer (CHASE), the Atmospheric Imaging Assembly (AIA), and the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamic Observatory (SDO). A data-constrained magnetohydrodynamic (MHD) 3D simulation was performed to explain the physical phenomena behind the observations. We report untwisting motions in a filament and its bidirectional outflows before and after a B8.4 X-ray flare. Before the flare, magnetic reconnection between threads occurred in the middle part of the filament, which resulted in the rise and oscillations of the filament. Brightenings in AIA 304 Å and AIA 171 Å in the interaction region were registered. After about 40 minutes, the right branch of the filament showed untwisting motions and bidirectional outflows in H as measured by time-distance diagrams and Dopplergrams of NVST. the MHD simulations showed that during the rising phase of the right branch of the flux rope (FR), magnetic reconnection of the sheared arcades below the flux rope occured that increased the FR twist. Magnetic reconnection induced bidirectional outflows and increased the plasma density in the FR by levitation. The 3D data-based MHD simulations confirmed that the bidirectional outflows observed in the NVST H filament were caused by magnetic reconnection. During the reconnection, plasma is injected, which leads to the dense observed filament with a high opacity in CHASE observations.

Yukun Luo: simulation of solar surface flux transport constrained by magnetic power spectra

The multiscale surface magnetic field is important for investigating the solar interior and external dynamic processes. The surface flux transport (SFT) model is a useful tool for studying the evolution of solar surface magnetic flux and successfully reproduces magnetic patterns such as the butterfly diagram and polar field. However, the simulated field has never been proven to be able to reproduce the observed magnetic field multiscale features, which can be examined through magnetic power spectra. In this study, we aim to investigate the performance of the SFT model and the influence of parameters on different-scale magnetic structures by comparing observed and simulated power spectra. For the first time, we obtain the simulated large-scale magnetic power spectra that are consistent with the observation. Our comparisons show that the simulated magnetic power spectra at spherical harmonic degrees $l>60$ are gradually divergent from observations, which might be caused by the widely used diffusion approximation for supergranulation. We further analyze simulations with varying transport parameters and meridional flow profiles. The results indicate that simulations yield similar outcomes when the ratio of meridional flow speed to diffusion coefficient, represented by the dynamo effectivity range λR, remains constant. This study provides a new perspective for constraining key ingredients in SFT models by magnetic power spectra and helps us understand the surface magnetic flux transport process.

Suli Ma: First Observation and Interpretation of Spike-like Repeating Burst Pairs

Solar radio bursts are observed at a variety of time scales and frequency bandwidths and often provide unique insights into the physical processes in the solar corona. Sub-second radio observations unveil intricate fine structures within solar radio burst emissions. Here, we report a new type of solar radio burst--a spike-like repeating burst pair. These bursts consist of two short-lived (0.1--2s), narrow bandwidth structures (tens of kilohertz) that occur in temporal succession, separated by ~4s with a consistent central frequency in the range 30--50MHz. Statistical analysis of spatial, frequency, and time-resolved 613 repeating burst pairs (with 308 used for imaging) characterizes the delayed burst duration, frequency bandwidth, frequency drift rate, peak flux density, and centroid position of each component. Imaging analysis using the LOw Frequency ARray (LOFAR) shows that the burst sources are closely linked to an active region, with the delayed components appearing spatially separated and with a reduced drift rate compared to the earlier components. Possible mechanisms to explain the observations are proposed. The formation of the delayed component as a turbulent echo of harmonic emission in the anisotropic turbulent plasma of the solar corona is quantitatively modeled.

Victor Melnikov: Dynamics of microwave flare emission: Influence of scattering, energy losses, and acceleration of nonthermal electrons

Over the past two years, regular observations have commenced at the Siberian multi-frequency radioheliograph (SRH, 3–6 GHz, 6–12 GHz, 12–24 GHz). This opens up exceptional opportunities for diagnosing the physical conditions in flare plasma based on the spatial, spectral, and polarimetric characteristics of the continuum (gyrosynchrotron) microwave flare emission. \\\ Based on observation of microwave (SRH and CBS) and HXR (ASO-S, Konus-Wind, and Solar Orbiter/STIX), this report pays particular attention to flare features of the spatial distribution of microwave (MW) emission, the time delays between MW and hard X-ray (HXR) emissions, as well as the differences in the slopes of the electron energy spectra derived from MW and HXR data. On the example of flares detected with SRH (2023-05-09, 2024-05-14, 2024-05-15), we demonstrate what can be learned about: 1) the dynamics of the parameters of the energy and pitch-angle distributions of non-thermal electrons in a flare loop; 2) the place of electron acceleration in the specific flare loops; 3) the interaction of energetic electrons with plasma turbulence.

Shuyi Meng: Statistically Preferential Acceleration of Protons than Heavy Ions in the Solar Wind Measured by PSP, Solar Orbiter, and WIND

The heavy ions have been reported to be preferentially accelerated in the solar corona by Alfven waves. However, the protons being slower and faster than the heavy ions are both measured in situ in the solar wind. So far, the preferential acceleration mechanism is still under debate. This work aims to study the variation of speed of protons, alpha particles, and O6+ along the solar radial distance by statistics using the measurements from Parker Solar Probe, Solar Orbiter, and WIND spacecrafts during the ascending phase of solar cycle 25. The results show that the slope of speed increase of protons along solar radial distance is obviously larger than that of the alpha particles and of O6+. In the solar wind stream from the same origin measured jointly by PSP, SolO, and WIND, the proton speed measured by PSP is significantly slower than that measured by WIND and SolO. The latter two are rather similar, though the proton speed measured by SolO is slightly slower than that of WIND. However, the speed of alpha particles and that of O6+ show quite similar values in the measurements of the three spacecrafts at different solar radial distances. The ratio between alpha particle speed and proton speed along solar radial distance shows two branches according to the slopes. It supports that the alpha particles may not be preferentially accelerated in the solar corona in a type of stream. There is a critical position around 0.3 au where the ratio decreases to about 1. The results suggest that protons are preferentially accelerated in the solar wind than heavy ions statistically. The preferred acceleration of heavy ions mostly happens in the solar corona. Even in the solar corona, quite some heavy ions are not preferentially accelerated in the years near solar minimum.

Dibya Mishra: Plage Identification in Historic Suncharts via Neural Network Imaging Techniques

The Kodaikanal Solar Observatory (KoSO) maintains one of the longest archives of solar observations, spanning more than a century and encompassing multi-wavelength data, including white-light, Ca II K, and Hα images. Among its rich holdings are hand-drawn suncharts (1904–2022), which systematically document solar features such as sunspots, plages, filaments, and prominences using the Stonyhurst grid and distinct color codes. These historical records have recently been digitized at high resolution (6k × 6k) and stored in .tif format. In this study, we report the first fully automated identification of solar plages in KoSO's suncharts covering the period 1909–2007, corresponding to ten solar cycles. A supervised machine learning framework employing a Convolutional Neural Network (CNN) was developed for this purpose. The model was trained using manually annotated plage masks from one solar cycle and was further adapted to identify the solar disk boundary, enabling accurate extraction of disk center, radius, and position angle (P-angle) parameters. Plage area measurements derived from the CNN-based segmentation were validated against those obtained from Ca II K full-disk photographic observations. Our findings help to resolve historical data gaps in KoSO's plage records and provide the foundation for constructing long-term synoptic maps of solar activity from 1904 to 2007.

Mirabbos Mirkamalov: Probing Hard X-Ray Footpoint Asymmetry in Solar Flares

Hard X-ray (HXR) emission, produced by non-thermal electrons precipitating into the lower atmosphere, serves as a critical diagnostic of particle acceleration, transport, and energy deposition. In this study, we conduct a statistical investigation of the asymmetry between conjugate HXR footpoints (FPs) in double-ribbon flares and examine their connection to the photospheric magnetic fields and electric currents. We combine magnetograms from the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) with HXR images from the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). UV/EUV images from the Atmospheric Imaging Assembly (AIA) onboard SDO are also used to verify the spatial correspondence between HXR sources and flare ribbons, ensuring the inclusion of only two-ribbon events that possess a local bipolar configuration consistent with the standard flare model. To minimize projection effects, the analysis is restricted to X- and M-class flares that occurred within 45° of the solar disk center. Our results demonstrate that the asymmetry in HXR FP emission is significantly influenced by the preexisting strong magnetic fields and electric currents. Specifically, the asymmetry as defined by the ratio between stronger and weaker HXR source is positively correlated with the ratio of not only the unsigned magnetic field flux but also the unsigned electric current through the same sources, which is contrary to what the magnetic mirroring or electric field effect is expected. These findings provide new insights into how pre-flare conditions modulate the interaction of flare-accelerated electrons with the lower solar atmosphere.

Mahdi Najafi-Ziyazi: Multifluid Moldeing of the Solar Chromosphere

Unaccounted solar storms travelling towards the Earth can cause disturbances for the orbiting satellites and ground-based infrastructures. These threats prompted the development of a system to be able to predict these phenomena well in advance to mitigate their impact. Most available computational models are predominantly single-fluid; multifluid variants exist, and their speed depends on the numerical schemes. In this work, we use the COCONUT (COolfluid COronal UnsTructured) code that is developed to model the solar corona using a time-implicit Finite Volume (FV) solver that performs faster than its time-explicit counterparts. In this work, we extend the model to include the lower layers of the atmosphere, particularly the chromosphere, to capture ion-neutral interactions for more accurate predictions. \\\ To this end, we implement the multi-fluid formulation of the MHD governing equations in COCONUT, where we treat the ions and neutral atoms separately. This formalism is necessary because the lower temperatures in the chromosphere result in partial ionisation and neutral populations. We present the numerical implementation and discuss the expected improvements in modelling the chromosphere and its coupling to the corona.

Smitha Narayanamurthy: Sunrise III flight and early science highlights

In July 2024, Sunrise III flew from Sweden to Canada at stratospheric heights capturing high resolution diffraction-limited images of the Sun for 6.5 days. The telescope carried three scientific instruments each complementing the other by observing in different parts of the solar spectrum from the near-ultraviolet by SUSI (309 nm - 417 nm), the visible by TuMag (517 nm - 525 nm) to the near infrared by SCIP (765 nm - 855 nm). During its flight, Sunrise III observed a wide variety of features on the Sun including the quiet region, sunspots, plages, filaments, spicules, flux emergence, and also flares. By combining the data from the three instruments, it is possible to infer and understand various properties of the solar atmosphere from the photosphere to the upper chromosphere. In this talk, I will walk you through the Sunrise III journey, the science planning, present observational highlights and provide a glimpse into some of the exciting ongoing scientific analysis from the Sunrise III data.

Benxu Niu: Origin of Sunspot Group Tilt Angles: Convection Zone or Solar Surface?

The line connecting the two polarities of a sunspot group typically forms a specific angle with the solar equator, known as the tilt angle, and its distribution follows Joy's Law. The angle is a necessary prerequisite for Babcock-Leighton type solar dynamos. However, the mechanism behind the tilt angle's formation remains unclear. Traditional theory posits that as magnetic flux tubes emerge through the convection zone, they are continuously influenced by the Coriolis force. Thus sunspots possess an inherent tilt angle at the time of their appearance at the surface. Recent relevant research has cast doubt on this view. \\\ To clarify the physical origin of the tilt angle, this study uses the DPD sunspot dataset, and by categorizing sunspot groups into four evolutionary stages—initial emergence, emergence, stabilization, and decay phases—systematically investigates the evolutionary characteristics of sunspot tilt angles. Our results indicate that, in the initial emergence phase, the overall distribution of sunspot tilt angles is highly dispersed with a mean value close to zero. It is only after sunspots enter the emergence phase that tilt angles clearly exhibit a dependence on latitude, suggesting that the systematic characteristics of tilt angles are formed after their emergence onto the photosphere. Among sunspots exhibiting an anti-Joy tilt angle during the initial emergence phase, smaller sunspots tend to experience a more significant change in tilt angle and are more likely to reverse their direction during evolution, converging toward Joy's Law. Our findings contradict classical magnetic flux emergence theory and offer new perspectives on magnetic flux emergence processes.

Daniel Nóbrega-Siverio: Deciphering solar coronal heating: 3D reconnection in Coronal Bright Points

Coronal Bright Points (CBPs) are fundamental building blocks of the solar atmosphere. These ubiquitous brightenings, typically spanning 5–40 Mm, consist of compact, hot loops that shine in X-rays and EUV for hours to days. CBPs are also known sources of dynamic events such as coronal jets and small-scale filament eruptions. In this talk, we present a novel 3D radiative-MHD model that successfully reproduces the main observational characteristics of CBPs, including their sustained heating. We perform an in-depth analysis of three-dimensional magnetic reconnection processes within the CBP, focusing on braiding-induced reconnection at loop footpoints, interchange reconnection associated with the null point, and slipping reconnection along quasi-separatrix layers. In addition, we link these reconnection modes with their expected observational signatures, providing synthetic EUV diagnostics to facilitate direct comparisons with instruments such as SDO/AIA, Solar Orbiter/EUI, and the upcoming MUSE and Solar-C missions.

Jacob Oloketuyi: Temporal Behavior and Latitudinal Relationships Between Key Solar Parameters and Green-Line Emissions in the Solar Corona

Understanding the link between solar parameters and their influence on greenline emissions would help unravel the complexities of eruptive phenomena within the solar corona. This study explores the intricate relationship between greenline emissions and various solar indicators, including flares, F10.7cm flux, and sunspot numbers. Utilizing data from both ground-based and space-based sources spanning from 1996 to 2024, covering solar cycles 23 to 25, the investigation employs the multitaper and cross-correlation analyses. The study reveals distinct behaviors and contributions to greenline emissions at low-and-high latitudes. The F10.7cm radio flux exhibits zero lag with green line emissions, indicating that both are contemporaneously influenced by solar activity, as shown by their correlation with sunspot numbers. In contrast, B-, M-, and X-class flares typically act as precursors or aftermaths of such activity. C-class flares exhibit a pronounced positive correlation with greenline, causally linked to plasma dynamics, particularly at low latitudes. Sunspots, on the other hand, act as a leading and significant indicator of greenline with positive lag, preceding the emissions. The emissions are found to be an excellent indicator of solar activity, with immediate response to the F10.7cm flux and a delayed response to sunspot emergence. The differences in observed impacts could be attributed to the behavior of confined plasma within magnetic loops, influenced by factors such as solar magnetic configurations, differential rotation, and dynamo mechanisms. These factors collectively impact the global coronal structure and influence greenline across latitudes.

Valerii Pipin: Helicity Fluxes of Active Regions Emerging from the Convection Zone Dynamo

Using a 3D non-linear mean-field solar dynamo model, we investigate the magnetic helicity flux and magnetic twist, and tilt parameters of bipolar magnetic regions (BMRs) emerging from the solar convection zone due to the magnetic buoyancy instability. The twist and tilt of the BMR magnetic field are modeled as a result of an effective electromotive force along the rising part of the toroidal magnetic field. This force generates the poloidal field that tilts the whole magnetic configuration. We find that variations of BMR's twist and tilt determine the magnitude and the sign of the magnetic helicity flux on the solar surface. The model shows that the helicity flux associated with the BMR's tilt/twist is the dominant contribution to the BMR helicity at the beginning of the BMR's evolution, while the effect of differential rotation is the main source of the helicity flux at the final stage of the BMR's evolution. We discuss the implications of these effects on the basic properties and variations of the hemispheric helicity rule of active regions on the solar surface.

Stefaan Poedts: Coupled, dynamic models for CME evolution in the solar atmosphere and the heliospheric wind and the gradual SEPs they cause

"Space weather" is the term used to describe how activity on the Sun, such as solar flares and eruptions of charged particles, affects the space around Earth. Just as storms on Earth can disrupt power lines and transportation, space weather "storms" can impact satellites, GPS navigation, radio communications, power grids, and oil and gas pipelines, resulting in a range of socio-economic losses. Solar Coronal Mass Ejections (CMEs) are large-scale eruptive events in which large amounts of plasma (up to 1013-1016 g) and magnetic field are expelled into interplanetary space at very high velocities (typically 450 km/s, but up to 3000 km/s). They are considered the major drivers of space weather and the associated geomagnetic activity. To mitigate these effects or at least reduce their impact, numerical physics-based models are developed to unravel the underlying physics behind these phenomena and predict their effects several days in advance.To predict the impact of a CME, its so-called geo-effectiveness, it is essential to consider the internal magnetic structure of the CMEs, as the sign of the magnetic field component perpendicular to the equatorial plane upon arrival at Earth is a key parameter. I will first present the challenges in modelling the solar wind and the evolution of CMEs. Then I will delve deeper into the latest results on magnetic flux-rope models for CMEs, as implemented in EUHFORIA and ICARUS, our heliospheric wind and CME evolution models (Pomoell & Poedts, 2018; Verbeke et al., 2022). I will also present our novel global MHD corona model, COCONUT (Perri, Leitner et al., 2022), as well as our particle acceleration and transport model, PARADISE. These models are all dynamically coupled, meaning that the photospheric magnetograms, used as boundary conditions for COCONUT, can be evolved in time to get a dynamic global corona, which is coupled to Icarus (and EUHFORIA) to get a time-dependent background heliospheric wind. We can superpose magnetic flux-rope CMEs on this and use this dynamic background wind with evolving CMEs as input for PARADISE.

David Pontin: Interchange magnetic reconnection: mass and energy transport between closed and open field in the corona

Interchange magnetic reconnection operating on a range of scales facilitates the exchange of plasma between open and closed magnetic flux in the Sun's atmosphere. The release of hot, dense plasma from closed field regions has been proposed as an explanation for compositions in certain solar wind streams, and a source of energy to explain observed temperatures in the open field. In this talk I will present some results of theoretical and computational modelling of interchange reconnection, and its contribution to energising the corona. I will also discuss new results on the geometry of the open-closed flux boundary, and implications for understanding the origin on the slow solar wind.

Youqian Qi: The Evolution of Granules and Intergranular Lanes with the Emergence of Hα Jets

We investigate the relationship between granular patterns development and Hα jets evolution with the ground-based 1-m New Vacuum Solar Telescope (NVST). The observations are carried out the Hα ± 0.8\,\AA~passbands and TiO 7058\,\AA~passband. \\\ The Fourier Local Correlation Tracking (FLCT) algorithm is applied to derive the horizontal velocities of the granules. \\\ Analysis of 85 ascending Hα jets revealed that their basal average horizontal velocity is 1.50 ± 0.64\,\kms, which are higher than typical granular horizontal velocity. And the higher velocity of granules might motivate the swirls and contribute to the formation of dynamic jet-like features. \\\ We detect 1431 swirls in the intergranular lanes using the Automated Swirl Detection Algorithm (ASDA), among which the occurrence rate of swirls associated with Hα jets is 2.0 *10^{-5}Mm^{-2} s^{-1}, while the occurrence rate of swirls non-associated with Hα jets is 1.4* 10^{-5} Mm^{-2} s^{-1}. The radii of these swirls range from 150 to 550 km. For the swirls associated with Hα jets, the number of expanding/contracting swirls is 61.2% and 38.8%; In contrast, for the swirls not associated with Hα jets, the number of expanding/contracting swirls is 47.5% and 52.5%. The number of expanding swirls corresponding to Hα jets is greater than the number of expanding swirls that do not correspond to Hα jets. We conducted a statistical analysis of the area variation rate of intergranular lanes before and during the rise of 85 Hα jets. Despite the presence of two outliers, the majority of intergranular lanes exhibited expansion as the Hα jets rose. The expansion rates were predominantly in the range of 50% to 100%. The sizes of the expanding intergranular lanes varied from 158 to 750 km. Both the intergranular lanes and the associated swirls showed expansion and had similar widths. This suggests that the expanding swirls may contribute to the increase in the area of the intergranular lanes and could potentially trigger \alfven pulses, which may carry a significant amount of energy to drive the formation of Hα jets.

Fangfang Qiao: Origin and Fine Structure of sunspot bipolar light bridges in AR 13663

Bipolar Light Bridges (BLBs), which appear as bright structures between umbrae of opposite magnetic polarity, are significantly different from ordinary light bridges. These structures have been found to harbor superstrong magnetic fields. Previous studies, through statistical analysis of numerous BLB samples, have confirmed the ubiquitous presence of strong magnetic fields within BLBs. Magnetohydrodynamic (MHD) simulations of δ-type sunspot groups further suggest that the magnetic field strength in highly sheared BLB regions can exceed 6 kG. Although earlier studies have suggested that BLBs may originate from the coalescence of opposite-polarity sunspots, their formation mechanisms, evolutionary processes, and fine-scale structures remain poorly understood. \\\ This study analyzes a well-defined case of a bipolar light bridge (BLB) observed in AR13663 on 3 May 2024, utilizing high-resolution BBSO/GST observations and long-term data from SDO/HMI. The observations reveal a BLB characterized by finely structured, penumbra-like fibrils with alternating brightness, and a stable Doppler velocity pattern showing persistent redshift–blueshift alternation. Based on long-term HMI observations, we propose a possible formation scenario in which the bipolar light bridge arises from the interaction between two emerging bipole pairs. The convergence of opposite polarities (N2 and P1) leads to the interleaving and compression of their penumbrae, while sunspot rotation likely contributes to the formation of an elongated, horizontally aligned structure. The observed alternating redshift and blueshift patterns in the velocity field may reflect the line-of-sight projection of penumbral Evershed flows. The convergence of oppositely directed vertical magnetic fields above the umbrae may trigger magnetic reconnection in the upper atmosphere, resulting in post-flare loops that overarch and stabilize the BLB. These results provide new insights into the dynamic evolution of the solar magneto-convective system and its connection to solar activity.

Axel Raboonik: Exact Nonlinear Decomposition of Ideal-MHD Waves Using Eigenenergies

Precise tracking and measurement of the energy carried by the individual magnetohydrodynamic (MHD) modes has important implications and utility in both astrophysical and laboratory plasmas. Previously, this was only achievable in limited linear MHD cases in the $\beta \ll 1$ or $\beta \gg 1$ regimes. In this talk, I willl introduce the Eigenenergy Decomposition Method (or EEDM) and derive exact analytical expressions for the modal energy components—called eigenenergies—of nonlinear 3D disturbances governed by the inhomogeneous ideal MHD equations. I will also provide detailed guidelines for applying the decomposition scheme to any general inhomogeneous quasi-linear partial differential equations that possess a globally conserved quantity, beyond the realm of MHD. Furthermore, it is shown that the eigenenergies can be used to locate and measure nonlinear mode conversions, which is an additional feature of the method. Finally, well-categorized context for the application of the method to simulation and a discussion on possible numerical inaccuracies that may inevitably arise owing to discretization will be provided.

Stephane Regnier: A statistical study of potential field energy in solar active regions

In the solar atmosphere, active regions are dominated by the magnetic field, its complex topology and evolution. To understand the divers nature of active regions, we study a large sample of 3D magnetic field configurations to derive general properties relating magnetic flux, magnetic energy and magnetic field scale-height. We compute the magnetic fields under the potential field assumption for about 900 snapshots of active regions observed by

SDO/HMI (CEA SHARP series) during solar cycle 24. We found that the magnetic energy follows a power law of the total unsigned photospheric flux with an index of about 1.5. In addition, we estimate the free magnetic energy that active regions can reach during the solar cycle. We provide a statistical distribution of the height decay of the active region magnetic field strength provided by the magnetic scale-height depending on the properties. We also provide the upper-bound of magnetic energy setting up a limit on the amount of magnetic energy that can be injected in the solar atmosphere. We thus analyse the connectivity of active regions: especially focusing on the umbrae/umbrae magnetic flux connection. We discuss the implications for modelling active region magnetic fields and the requirements for advanced models.

Hamish Reid: Using Type III Radio Bursts to Diagnose Electron Kinetics

The brightest radio sources in the night sky, solar type III radio bursts have been observed since the 1940's. They are an indirect signature of electrons streaming through the solar and heliospheric plasma close to the speed of light. Advanced radio interferometers like MUSER, LOFAR and the MWA can track energetic electron kinetics and bulk plasma properties in the solar corona using imaging spectroscopy of type III bursts at frequencies detected above the ionospheric cutoff around 10 MHz. Moving into space, we utilize our fleet of international spacecraft to detect the frequency evolution of type III bursts and triangulate the movements of energetic electrons travelling through the solar system. I will discuss diagnostics of energetic electrons that use recent observational results of type III bursts detected by ground-based and space-based instruments. I will also discuss how we can interpret these results using numerical simulations of type III bursts and the associated plasma emission mechanism that drives them.

Guiping Ruan: Magnetic reconnection or waves as trigger of jets in solar atmosphere.

Based on the high spatial and temporal resolution of the instruments on the ground with SST, THEMIS, and the Goode telescope (GST), and in space with the high quality of the spectra of the Interface Region Imaging Spectrograph (IRIS). \\\ I will report on bidirectional coronal magnetic reconnection outflows reaching ±200 km/s as observed in an active region with the Si IV and C II spectra of IRIS. The evolution of the active region is followed by SDO with an emerging flux and a jet. The reconnection occurs continuously in the corona between quasi parallel magnetic field lines, which is possible in a 3D magnetic configuration. \\\ The second example concerns magnetic reconnection in a light bridge of sunspot observed with the Goode telescope. The reconnection is very low in the photosphere and the signature are a fan jet with diverging beams, and Ellerman bombs at the footpoints. Co-temporally, EUV brightenings developed at the front of the dark material jet indicating possible compression. \\\ The third example concerns the jet which continued for up to 4 h. The time-distance diagram shows that the peak of the jet has clear periodic-eruption characteristics (5 min) during 18:00 UT–18:50 UT. We also found a periodic brightening phenomenon (5 min) during the jet bursts in the observed bands in the transition region (1400 Å and 2796 Å), which may be a response to intermittent jets in the upper solar atmosphere. The time lag is 3 min. The multiwavelength analysis indicates that the events we studied were triggered by magnetic reconnection that was caused by mixed-polarity magnetic fields. We suggest that the horizontal motion of the granulation in the photosphere drives the magnetic reconnection, which is modulated by p-mode oscillations.

Guiping Ruan: Transport of the magnetic flux away from a decaying sunspot via convective motions

We report the decay of a sunspot observed by the 1.6 m Goode Solar Telescope (GST) with the TiO Broadband Filter Imager (BFI) and the Near-InfraRed Imaging Spectropolarimeter (NIRIS). The analysis was aided by the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamic Observatory (SDO). In the first step, we followed the decay of the sunspot with HMI data over three days by constructing its evolving area and total magnetic flux. In the second step, the high spatial and temporal resolution of the GST instruments allowed us to analyze the causes of the decay of the sunspot. Afterward, we followed the emergence of granules in the moat region around the sunspot over six hours. The evolution of the trees of fragmenting granules (TFGs) was derived based on their relationship with the horizontal surface flows. We find that the area and total magnetic flux display an exponential decrease over the course of the sunspot decay. We identified 22 moving magnetic features (MMFs) in the moats of pores, which is a signature of sunspot decay through diffusion. We note that the MMFs were constrained to follow the borders of TFGs during their journey away from the sunspot. The TFGs and their development contribute to the diffusion of the magnetic field outside the sunspot. The conclusion of our analysis shows the important role of the TFGs in sunspot decay. Finally, the family of granules evacuates the magnetic field.

Brigitte Schmieder: THEMIS new generation: Dynamics and MHD simulations of filaments

In 2022 THEMIS new generation is operating in the Canary Islands. The concept of the telescope has been changed that allows us to have an adaptive system. The telescope is still free of polarization. The telescope is equipped by spectrographs and a polarimeter. Different modes of observations are proposed. Imagery of granulation and sunspot with a resolution of 0.06 arc sec have been achieved. The CCD cameras are CMOS 2kx2k. The mode MTR in spectroscopy is used simultaneously with 4 cameras. A mask is designed for each obseerver according to his/her objectives; in 2023 we obtained 7 days of observations combined with IRIS observations. We observe mainly filaments. \\\ I will show the high capabilities of THEMIS concerning the high spatial resolution imaging, Dynamics of filaments has been studied with spectra with pixel size =0.06 arcsec. Spectra in Halpha discovered bilateral flows of more than 100 km/s during a magnetic reconnection between a filament and a jet. Very large counter-streaming flows were detected in a disturbed filament and were finally interpret by waves. NLFFF extrapolations show that this quiescent filament was changing with a time scale of intra-network evolution. The helicity is conserved but there is bifurcation in the spine due to mini-null points. \\\ Forward Modeling of Magnetic Energy Release Diagnosis during Solar Flares Based on the Magnetic-field-induced Transition Effect

Feiyang Sha: Mapping ground-based coronagraphic images to Helioprojective-Cartesian coordinates system by image registration

A few ground-based solar coronagraphs have been installed in western China for observing the low-layer corona in recent years. However, determining the Helioprojective Coordinates for the coronagraphic data with high precision is an important but challenging step for further research with other multi-wavelength data. In this paper, we propose an automatic coronal image registration method that combines local statistical correlation and feature point matching to achieve accurate registration between ground-based coronal green-line images and space-based 211 Å images. Then, the accurate field of view information of the coronal green-line images can be derived, allowing the images to be mapped to the Helioprojective Descartes Coordinates with an accuracy of no less than 0.1''. This method has been extensively validated using a substantial volume of coronal data, demonstrating its broad applicability to ground-based coronagraphs equipped with green-line observations. It significantly enhances the scientific value of ground-based coronal data, enabling comprehensive studies of coronal transient activities and facilitating the joint analysis of data from multiple instruments. Additionally, it holds potential for future applications in improving the pointing accuracy of coronagraphs.

Jinhua Shen: Rapid spatio-temporal evolution of vertical electric currents during an X-class flare

In this paper, we present a detailed analysis to the spatio-temporal evolution of photospheric vertical electric currents (VECs) during an X1.1 flare (SOL2013-11-10T05:08). The VEC on solar surface is calculated using the 135 seconds high temporal resolution vector magnetograms obtained from the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamic Observatory (SDO). In the region, a highly sheared magnetic channel that is also a polarity inversion line (PIL) divides the region into two parts. The spatial configuration of VEC ribbons is always conjugate footprints and it takes the form of a sigmoid along two sides of the PIL at the beginning of the flare. The temporal evolution of the VECs shows a rapid enhancement associated with the impulsive phase of the flare, and mean horizontal fields in this region show the similar temporal behavior. The most prominent enhancement of VECs not only shows up along the two sides of the enhancement B_{h}, but also spreads outward along the PILs. The VECs in positive and negative fields have an initial separation motion and followed by an apparent approaching motion. In contrast, the flaring loops and white-light flare ribbons have an initial contraction and later expansion motion. Our results show that the rapid change of magnetic fields related to flares has a predominant role in affecting spatio-temporal evolution of the VECs.

Fanpeng Shi: Spatially Resolved Oscillations of a Flare Looptop X-Ray Source

We report novel details of a flare looptop X-ray source using the STIX onboard the Solar Orbiter. The looptop source exhibits an oscillation in height that is statistically anticorrelated with the X-ray intensity, in which the variation in intensity slightly precedes the height. Two oscillation periods are found, i.e., a period of ∼2 minutes with a large amplitude and a relatively weak period of ∼1 minute. The nonthermal electron spectral index and flux deduced from X-ray spectra, and the intensity of flare ribbons/footpoints seen in EUV/UV images all show similar oscillations. In addition, the repeated downward contracting loops/plasmoids from the reconnection current sheet are observed. These observations strongly support a physical scenario where repeated reconnection outflows impinge on the flare looptop, while concurrently accelerated electrons are also quasiperiodically injected into it. These energy inputs (bulk flow and electron beams) subsequently produce oscillations in the looptop X-ray source, and cause brightness fluctuations in the flare ribbons/footpoints in the lower atmosphere.

Guanglu Shi: The Role of Far-side Magnetic Structures in Modeling 2024 Solar Eclipse

The corona is a crucial region that connects the solar surface to the solar wind and serves as the primary site of solar activity. The 2024 total solar eclipse (TSE) provides a unique opportunity to investigate the large-scale coronal structure. Combined with TSE observations, we study the impact of the magnetic structure of the far-side active region, located in the eastern hemisphere of the Sun that has not yet rotated into the Earth Field-of-View, on a global Magnetohydrodynamic simulation. To address the limitation of single-view measurements in the routine synoptic map, we correct the magnetic field in the far-side region by incorporating full-disk magnetograms measured several days after the TSE, allowing us to capture the temporal evolution of the photospheric magnetic field in near real-time. Simulation results demonstrate that the local magnetic field in the far-side active region can significantly influence a global coronal structure by altering the position of the heliospheric current sheet, and further affect a global distribution of plasma parameters, even in polar regions. A comparison between the white-light TSE observation and synthetic images derived from simulations reveals that the composite synoptic map significantly improves the accuracy of coronal modeling. This work provides robust support for advancing our understanding of coronal evolution, as well as deepens the link between the photosphere and large-scale coronal structure. Furthermore, it establishes a theoretical foundation for the future development of multi-view, stereoscopic measurements of the photospheric magnetic field.

Viktoriia Smirnova: Multi-wavelength analysis of SOL2024-06-01T08:45 solar flare: electron acceleration and plasma heating

According to the "standard" model of solar flares, the millimeter (mm) radiation can be generated in the chromosphere as a result of its heating by accelerated electrons. As a result, the time profile of mm flare radiation should correlate with hard X-ray and microwave emissions. But in some cases the maximum of mm radiation is delayed by several minutes with respect to the hard X-ray flare maximum and the mm time profile correlates relatively well with soft X-ray and EUV emission. This suggests a close relationship between the mm radiation source and hot coronal loops [1] and contradicts to the previous conclusions about the insignificant contribution of plasma of hot coronal loops to the sub-THz radiation of solar flares [2]. \\\ In the present work, the SOL01.06.2024T08:45 solar flare of the GOES class X1.4 is analyzed on the base of multi-wavelength observations in order to identify the nature of the mm emission source. We used radio data from Siberian Radioheliograph (SRH, 3 - 24 GHz), Chashan Broadband Solar millimeter spectrometer (CBS, 35 - 40 GHz), sub-THz telescope (RT-7.5, 93 GHz), hard X-ray data from Advanced Space-based Solar Observatory (ASO-S) and Konus-Wind, as well as EUV data from AIA/SDO and other complementary data. \\\Our analysis of the flare's time profiles, images, and spectra has shown that the enhanced mm emission source at the post-impulsive flare phase cannot be associated with the plasma of hot coronal loops ("Neupert effect"). Most likely the mm source originates from the dense chromospheric plasma in the flare loop footpoints. Our model estimations demonstrate that the number of non-thermal electrons derived from HXR emission spectra in the impulsive phase of the flare is not enough to heat the chromospheric plasma and to produce the long-term (10 min) mm burst at the post-impulsive flare phase. The enhanced mm emission can be caused by the "gentle" thermal energy release process, i.e. chromospheric heating not accompanied by the acceleration of energetic electrons.

Hongqiang Song: A new explanation on the nature of the three-part strucutre of CMEs

CMEs often exhibit the archetypical three-part structure in coronagraphs, including the bright core, dark cavity, and bright front. In the popular explanation, the bright core corresponds to the cold and dense filament, which locates at the dip of MFR. The dark cavity is the MFR with relatively lower density due to the enhanced magnetic pressure. The bright front originates from the pileup of background plasma along the MFR boundary. For many years, there has been no controversy over this traditional opinion. Based on a series of studies (Song et al. 2017, 2019a, 2019b, 2022, 2023a, 2023b, 2025a, 2025b), we completed a new explanation on the nature of the three-part structure of CMEs. The new explanation suggests that the MFR is responsible for the bright core, the plasma pileup along the overlying coronal loops corresponds to the bright front, and the low-density zone between them appears as the dark cavity in the early eruption stage. The new explanation predicts that almost 100% of normal CMEs have the three-part structure in the inner corona, which is supported by observations (Song et al. 2023b, ApJL).

Yongliang Song: Detection and Analysis of White-light Emission in Solar Flares through Light Curve Diagnostics

White-light flares (WLFs) that showing obviously enhancement of visible continuum emission are crucial for understanding the energy transport and heating processes in lower solar atmosphere. Systematic study of WLFs is highly necessary. However, most WLFs have very weak continuum emissions and are difficult to be detected. To address this, we propose a more reliable, accurate, and scientifically rigorous detection method based on light curve analysis. Through the observations of Atmospheric Imaging Assembly (AIA) and Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO), the light curve of each pixel in the flaring region can be obtained. By subtracting the slowly varying quasi-periodic background, we obtain a series of rapidly varying radiative pulses. Pixels where radiative pulses during flares significantly exceed those occurring before and after the flare are identified as WL emission regions. We applied and validated our method to the detection of the X2.2 flare on September 6, 2017. We find that the WL emission in this flare exhibits two phases. And different regions show distinct WL emission properties. We also detected the WL emission in all the flares (1 X-class, 2 M-class, and 20 C-class) occurred in NOAA Active Region 12887. It is found that 15 of the 23 flares are WLFs (1 X-class, 2 M-class, and 12 C-class). The occurrence rate of WLFs in this active region is $\sim$ 65%. And surprisingly, the occurrence rate of WLFs in C-class flares even reach up to 60%. It should be noted that most of these C-class WLFs are below C5.0. And a C1.0 WLF is identified which is the lowest GOES-class event with confirmed WL emission to date. These results demonstrate that WL emission is ubiquitous in most flares, even down to C-class events.

Rodion Stepanov: Synchronization Effects in a Nonlinear Solar Dynamo Model

The solar dynamo remains one of the most fundamental processes underlying the generation and maintenance of the Sun's large-scale magnetic field. This process is crucial for understanding the entire spectrum of solar activity phenomena, including sunspots, solar flares, coronal mass ejections, and solar wind variability. Despite substantial progress in both theoretical and numerical modeling, the inherently nonlinear nature of the solar dynamo, particularly its sensitivity to internal dynamic processes in the solar convection zone, continues to pose open questions. Among these, the potential synchronization of the 11-year solar cycle with external periodic forces remains a subject of ongoing debate and scientific interest. \\\ Observational data reveal significant variability in the amplitude and duration of solar activity cycles, producing a broad fluctuation spectrum with a prominent maximum near the 11-year period. However, it is not yet clear whether the phase of these cycles remains coherent over long timescales. The existence of phase synchronization with an external “clock” — such as weak tidal forces from planetary configurations (e.g., Jupiter, Venus, and Earth) — has been proposed as a possible mechanism. Recent studies have shown that the phase of solar cycles does not follow pure random-walk statistics. Due to the limited reliability and duration of observational datasets, the statistical significance of phase coherence remains low. Furthermore, a plausible theoretical framework that can account for such synchronization in the context of a realistic solar dynamo model is still lacking. \\\ In this work, we investigate the possibility of synchronization in a fundamentally nonlinear mean-field dynamo model that includes a dynamically evolving magnetic α-effect. Unlike previous studies, which primarily rely on algebraic quenching of the α-effect, we employ a dynamic formulation based on the evolution of magnetic helicity. This model incorporates a periodic component in the hydrodynamic part of the α-effect, simulating a weak external periodic forcing. The central question addressed in this study is whether such periodic modulation can synchronize the inherently chaotic or quasi-periodic dynamics of the solar dynamo. \\\ To assess synchronization, we analyze the phase relationship between the dynamo cycle and the imposed periodic modulation. We apply wavelet-based phase diagnostics and histogram-based statistics of phase deviations relative to the external forcing. The primary observable extracted from the model is the total magnetic energy of the axisymmetric mean field. The maxima of this quantity serve as proxies for the timing of solar activity maxima, allowing us to compute the distribution of phase deviations across thousands of simulated cycles. \\\ Our results demonstrate a clear manifestation of synchronization when the amplitude of the periodic modulation is sufficiently large and its period closely matches the natural period of the dynamo wave. In the absence of modulation, the phase of the dynamo cycle exhibits random drifts across the full 2π range, indicative of chaotic or stochastic dynamics. As the amplitude of the periodic α-effect increases, the phase distribution becomes sharply peaked, signaling synchronization. When the period of the external forcing differs significantly (e.g., by a factor of two), the effect becomes weak or vanishes altogether, indicating a high sensitivity to resonance conditions. \\\ Interestingly, our numerical simulations reveal a mixed character of the dynamo signal. On short timescales (up to 8 cycles), the signal exhibits features consistent with stochastic wandering, while on longer timescales, phase coherence emerges, consistent with weak synchronization. These findings are in qualitative agreement with wavelet spectra derived from observational data and suggest that real solar activity may also be governed by such a mixed dynamical regime. \\\ The results presented here provide the first evidence of synchronization in a dynamical magnetic α-effect model with realistic nonlinear feedbacks, as opposed to artificially injected noise. This supports the idea that external periodicities, if they are present, could in principle modulate the solar cycle even in the presence of nonlinear turbulent dynamics.

Wei Su: The Impact of Solar -- Terrestrial Plasma and Magnetic Field on the Detection of Space-borne Gravitational Wave Detections

Space-borne gravitational wave detections raise new questions for heliophysics: how the Sun-Terrestrial space environment affect gravitational wave detection, and to what extent?

Space-borne gravitational wave detectors use laser interferometry to measure displacement variations between two free test masses caused by gravitational waves. Space-borne gravitational wave detectors require extremely high measurement accuracy, making it necessary to take into account the effects of space plasma and magnetic field. On one hand, laser propagation through space plasma can induce optical path difference noise, affecting distance measurement accuracy. On the other hand, interactions between space magnetic field and the test masses can generate acceleration noise. This review introduces studies on laser propagation noise and space magnetic acceleration noise in space gravitational wave detection. And this review presents a method, time-delay interferometry, to suppress laser propagation noise.

Yang Su: ASO-S Mission: Status, Results, and Future Plans

The Advanced Space-based Solar Observatory (ASO-S), launched in October 2022, is the first comprehensive solar observatory of China. Its main scientific objectives are solar magnetic field, flares, coronal mass ejections (CMEs), and their relationships. Three scientific payloads (FMG, LST, and HXI) are deployed aboard the ASO-S to simultaneously observe solar magnetic field, hard X-ray bursts, Lyman-α images up to 2.5 solar radii, and full disk images at 360 nm. ASO-S has observed over a thousand solar flares, including over 70 X-class flares, and released data products and analysis software in April 2023. A brief introduction to the mission, the status of the instruments, and the early results will be presented in this talk. These include the new findings of the origin of flare quasi-periodic pulsations, the statistical study of energetic C-class flares, the discovery of Lyman-α waves, the 360 nm brightenings, the 3-dimentional study of hard X-ray sources, and the first solid evidence of X-ray directivity in a solar flare, etc.

Yingna Su: Unexpected major geomagnetic storm caused by faint eruption of a solar transequatorial flux rope

Some geomagnetic storms' solar origins are ambiguous, making them hard topredict. On March 23, 2023, a severe geomagnetic storm occurred, however,forecasts based on remote-sensing observations failed to predict it. Here, weshow clear evidence that this storm originates from the eruption of a transequatorial, longitudinal and low-density magnetic flux rope (FR) with weaker coronal emission and no chromospheric signs. The FR's gentle eruption results in a faint full-halo coronal mass ejection (CME), which is missed by forecasters and not included in CME catalogs. Combining magnetic field modeling and in situ measurements, we reveal the FR's southward axial magnetic field as the main cause of the geomagnetic storm. This CME is the stealthiest one reported causing a severe geomagnetic storm. Our study highlights that erupting transequatorial FRs can generate major geomagnetic storms in a stealthy way. Characteristic observational signatures of similar eruptions are proposed to help in future forecasts.

Yingzi Sun: The First Solar Full - disk Vector Magnetograph Observing Network without Sunset

The project aims to develop a high-resolution, fully automated full disk magnetic solar telescope. This telescope is planned to be located in South America which is approximately 12 hours behind China in time. An observing network will be established by combining this telescope with Solar Full-disk Multi-layer Magnetograph (SFMM) and the Solar Magnetism and Activity Telescope (SMAT) both supported by the Chinese Meridian Project II. This project will extend observing time for solar ground-based observation and form the first full disk vector magnetographs observing network without sunset thereby enhancing the capability of space environment monitoring.

Zhenxuan Sun: Connectivity between Solar Wind Variability and Source Regions during Parker Solar Probe Encounter

The properties of solar wind are closely related to its source region in the solar atmosphere. Here we investigate the variability of solar wind measured by Parker Solar Probe (Parker) during Encounter 7 (E7) and connect it to spatio-temporal changes in magnetic connectivity to multiple sources in the solar atmosphere. Using Parker's in situ data, we identify Alfvénic slow solar wind (ASSW) and magnetic-velocity alignment structure (MVAS; with high magnitude of the magnetic field and velocity correlation factor Cvb and moderately negative normalized residual energy σr). We trace back to the solar atmosphere by applying PFSS and ballistic backmapping and find they belong to three distinct regions. Combining these results with EUV observations from SDO/AIA and Hinode/EIS, and the modeled magnetic field from the photosphere to the source surface, we find that magnetic footpoints in the first region (R1) oscillate between the center and boundary of a coronal hole (CH), corresponding to variable solar wind containing fast solar wind (FSW) and MVAS. In the second region (R2), footpoints are located in the western side of NOAA active region (AR) 12796, evidenced by open field lines, the strong intensity on AIA map and outflow shown by the blueshifted Doppler velocity. This indicates that the ASSW may originate from the AR. Footpoints in the third region (R3) are primarily located in a quiet sun (QS) region, a possible MVAS source region. These findings highlight the complex and dynamic nature of solar wind variability and their connection to different source regions.

Baolin Tan: Heating Mechanisms and Radio Response from the Solar Chromosphere to Corona

Heating mechanism in the solar atmosphere (from chromosphere to corona) is one of the top-challenges in modern astronomy. The classic mechanisms can be divided into two categories: wave heating (W) and magnetic reconnection heating (X). Both of them still face some problems currently difficult to overcome. Recently, we proposed a new mechanism, called magnetic-gradient pumping heating (MGP, or P) which seems to overcome those difficulties, but still lacks sufficient observational evidence. Which one really explained the physics of hot corona exactly? How can observations be used to identify and verify the heating mechanism? Since different heating mechanism will generate non-thermal particles from different accelerations and experience different propagations, they will have different response on the broadband spectral radio observations. Among them, the non-thermal electrons from W mechanisms are closely related to shock-wave acceleration, and their radio response should be group of spike bursts with random distribution of drifting rates; the non-thermal electrons from X mechanisms are accelerated by reconnecting electric field with bidirectional flow, and their radio response should be type III pairs or spike pairs; P mechanism will produce energetic particle upflows, and their radio response should be unidirectional fiber bursts with moderate negative drifting rates. Therefore, the heating mechanism can be identified and verified from the the broadband dynamic spectral radio observations. Additionally, using high-resolution radioheliographs and spectral-imaging observations, the heating mechanisms in different regions can be identified and verified separately, thereby demonstrating the physical essence of hot corona.

Chengming Tan: MUSER Observation and superfine solar radio bursts

MUSER (MingantU SpEctral Radioheliograph) in China is composed of three arrays, with MUSER-L covers 30-400 MHz with 224 LPDAs, MUSER-I covers 0.4-2.0 GHz with 40 mesh antennas and MUSER-H covers 2–15 GHz with 60 dish antennas. They have observed hundreds of radio burst events. The totally datasize are more than 8 Petabyte. This presentation will report the observation results, data processing, and spectral imaging results of some typical and specific events. Small scale superfine solar radio bursts have high brightness temperature and rich characteristics. They are known as type III bursts (or pairs), quasi periodic pulsations, spiky bursts, zebra stripes, etc., and are driving phenomena for studying energy release and high-energy particle acceleration. The high resolution of solar radio imaging observations will provide clues for studying the physical evolution of coronal heating and help us understand the origin of space weather.

Song Tan: SJET: An Interactive Solar Jet Extraction Tool for CoSEE-Cat Applications

Solar jets are fundamental manifestations of magnetic reconnection processes crucial for understanding coronal heating and solar wind acceleration. We develop SJET (Solar Jet Extraction Tool), an innovative Python-based platform that semi-automatically extracts and analyzes solar jet geometric parameters from solar EUV observations. We have applied SJET to analyze hundreds of jet events from the Comprehensive Solar Energetic Electron event Catalogue (CoSEE-Cat) and will present preliminary results. The tool's automated parameter extraction capabilities enable comprehensive jet population analysis in large-scale statistical studies. This application provide systematic correlation between jet properties and energetic particle events, advancing our understanding of particle acceleration mechanisms.

Kyriakos Tapinou: Data-driven flux emergence with Athena++: comparison of boundary driving strategies

Despite the large quantity of observational data available, the Sun’s magnetic field dynamics remain a mystery. Solar flares and eruptions, which result from the field evolution, can have significant impacts on Earth and our space environment. Data-driven modelling of the solar magnetic field uses photospheric observations as boundary conditions to drive a simulation of the field above the photosphere with the goal of recreating flux emergence and eruptive events. Different strategies for characterising the driven boundary exist in the literature, but there is no consensus on the most effective method. We restrict our focus to treatment of the boundary driving and exclude the considerations associated with augmenting the data itself (e.g. initial field inversions, post processing to improve consistency with Maxwell's equations etc). We consider driving using (i) the magnetic field (**B**) or (ii) the electric field (**E**) data. We present simulation results with different choices of data-driving method but under identical problem conditions and with the same numerical tool (Athena++). Previous comparisons in the literature have used different simulation conditions and numerical tools. We compare the results qualitatively (field structures) and quantitatively (magnetic helicity, magnetic energy injection, total energy, and magnetic flux) with results indicating that electric field driving is favorable, numerically speaking.

Hui Tian: Mapping the global coronal magnetic field through 2D coronal seismology

Coronal seismology, a technique of magnetic field diagnostics based on observations of magnetohydrodynamic (MHD) waves, has been widely used to estimate the field strengths of oscillating structures in the solar corona. However, previously coronal seismology was mostly applied to occasionally occurring oscillation events, providing an estimate of only the average field strength or one-dimensional distribution of field strength along an oscillating structure. This restriction could be eliminated if we apply coronal seismology to the pervasive propagating transverse MHD waves discovered with the Coronal Multi-channel Polarimeter (CoMP). Using several CoMP observations of the Fe xiii 1074.7 nm and 1079.8 nm spectral lines, we obtained maps of the plasma density and wave phase speed in the global corona, which allow us to map both the strength and direction of the coronal magnetic field in the plane of sky. More recently, using nearly continuous observations of these transverse waves with the Upgraded CoMP (UCoMP), we have managed to obtain magnetic field maps of the global corona on a daily basis. Such routine coronal magnetic field measurements could provide critical information to advance our understanding of the evolution of the Sun's magnetism and the magnetic coupling of the whole solar atmosphere.

Hui Tian: Sun-as-a-star Spectroscopic Observations of mass ejections

Coronal mass ejections (CMEs) are one of the most energetic eruptive phenomena in the atmospheres of other late-type stars. However, the detection of CMEs on stars beyond the solar system is challenging. To explore the feasibility of using Sun-as-a-star spectra for solar CME detections and applying the similar technique to stellar observations, we searched the spectroscopic signatures of mass ejections in the Sun-as-a-star spectra. We identified the blue-shifted secondary components caused by mass ejections in EUV line profiles and estimated their line-of-sight velocities accordingly. We also found obscuration dimming related to filament eruptions in Sun-as-a-star flux of He II 304 Å and established a relationship between dimming and filament properties. These studies provide new insights for stellar CME and filament detections.

Yuriy Tsap: Acceleration of quasi-thermal electrons and pre-flare plasma heating

The relationship between pre-flare plasma heating to high temperature (~ 10 MK) and the electron acceleration in the impulsive phase of solar flares is considered. The important role of Coulomb collisions of quasi-thermal electrons in the course of acceleration by electric field is highlighted. Based on the Spitzer approximation for Coulomb collisions, we show that the efficiency of the acceleration of quasi-thermal electrons increases significantly with increasing temperature. The reason for this is a decrease of energy losses of quasi-thermal electrons and broadening of the Maxwell distribution tails leading to a significant (by orders of magnitude) increase in the number of fast particles which can overcome the Coulomb barrier of energy losses under the action of the electric field in the flare region. Consequences of these effects for the solar and stellar flares are discussed.

Elias Roland Udnaes: Using extensive NLTE spectral analyses in time and space to estimate chromospheric heating

The solar chromosphere is a thin layer situated between the photosphere and the corona, that is intimately tied to both the solar wind and heating of the corona. Therefore, understanding the energy transfer through the solar chromosphere is a prerequisite to solving long-standing problems in solar physics. Our work combines a comprehensive large-scale analysis of two 3D rMHD simulations, spanning the entirety of the simulations for several solar hours to study the energy dissipation in the solar chromosphere. In particular, we focus on the dissipation of acoustic wave energy through the chromosphere. We found a close correlation between viscous dissipation and the decrease of acoustic wave energy in quiet Sun regions, and calculated the frequencies and scales where acoustic wave energy dissipates. We also performed extensive NLTE calculations from hundreds of snapshots of the two simulations to do spectral analyses in time and space of the Ca II H&K, Ca II 8542 Å, and Mg II h&k lines. Our approach involved unsupervised machine learning techniques to estimate energy dissipation by using information from the chromospheric spectral lines. For quiet Sun chromospheric conditions, we were able to estimate chromospheric heating from the spectral data, where we saw that spatial and temporal information gave important context to decipher heating processes. The spectral signatures that reveal chromospheric heating can be used to estimate energy dissipation from observations.

Nicole Vilmer: Connecting Energetic Electrons at the Sun and in the Heliosphere through X-ray and Radio Diagnostics

One of the main objective of the Solar Orbiter mission is concerned with the production of energetic particles in the heliosphere, in particular with understanding how particles are released from their acceleration sources and distributed in space and time in the heliosphere. For energetic electrons, part of this question can be addressed by combining X-ray and radio observations. Indeed, while downward moving electrons produce X-rays in the chromosphere, upward moving electrons may generate coherent radio emissions when propagating through the corona, such as radio type III bursts. The launch of the Solar Orbiter in early 2020 marked a significant milestone, as it is equipped with the capability to simultaneously capture both types of emission. In this contribution, we shall present some of the results that we derived recently from the comparison of X-ray flares observed by STIX in the 4-150 keV range on Solar Orbiter with radio type III bursts detected by RPW below 10 MHz on Solar Orbiter. The first work had focused on 15 Interplanetary Type III radio bursts (IT3s) associated with HXR emission peaks, observed during the second commissioning phase of the STIX from November 17 to 21, 2020. Changes in the X-ray source morphology are systematically found coinciding with the occurrence of IT3 emissions confirming the role of interchange reconnection in the access of flare-accelerated electrons to open magnetic field lines. In the second part of the presentation we will review some statistical studies previously achieved on the link between the properties of X-ray bursts and associated type III emissions and present some results from a recent study combining RPW and STIX observations on the link between the energy density of the X-ray emitting electrons and the charateristics of the radio burst.

Can Wang: <u>Quantitative Analysis of the Formation of Magnetic Flux Rope in MURaM Simulation</u>

Magnetic flux rope (MFR) is the key magnetic structure in solar eruptions, whose formation mechanism can be divided into two categories: (1) emergence of flux tube from the convection zone; (2) flux cancellation related to photospheric motion and magnetic reconnection. Based on a radiative magnetohydrodynamic (RMHD) simulation conducted with the MURaM code, we analyze the roles of these two mechanisms quantitatively by calculating the advection term and shear term of helicity flux. The shear term, which is related to horizontal motions, is mainly located at edges of sunspots, while the advection term that comes from the emerging or submerging horizontal magnetic field is concentrated near the PIL region. When integrating the helicity flux within the footprints of the flux rope on photosphere, we find that both shear and advection terms develop quickly before the eruption. Moreover, we recognize that the shear term dominates the helicity flux at most of the time. We also measure the helicity injected into the flux rope through different heights, which indicates that as height increases, the shear term gradually transforms to advection term as a result of magnetic reconnection. Our work suggests that both the direct flux emergence process and the ‘shear and reconnection ’process can contribute to the flux rope formation, while the latter, which originates naturally during the active region evolution, is of higher efficiency.

Haopeng Wang: Efficient and Quasi-realistic Magnetohydrodynamic Modeling of Dynamic Corona and Coronal Mass Ejections

Coronal mass ejections (CME), the expulsion of magnetic plasma from the corona into the interplanetary medium, are among the primary drivers of space weather. However, quasi-realistic and computationally efficient models of coronal evolution and CME propagation, especially within the sub-Alfvénic corona, is still lacking. We are developing novel MHD models to address these challenges. \\\ Based on previous research efforts in China and Europe, we have recently developed two implicit time-evolving global MHD coronal models driven by a series of time-varying magnetograms. One is time-evolving COCONUT, developed at KU Leuven; the other is SIP-IFVM, developed at NSSC and KU Leuven. Both models have flexibility in selecting large time steps and enable faster-than-real-time coronal evolution simulations using only a few dozen CPU cores on grids exceeding one million cells, significantly outperforming explicit models in terms of computational efficiency. Moreover, the numerical stability challenges in simulating time-evolving low-β problems are effectively alleviated by the extended magnetic field decomposition algorithm proposed in these works. Based on these capabilities, we have achieved faster-than-real-time CME simulations suitable for practical applications, including one observation-based realistic CME event simulation. \\\\Currently, we are developing simpler algorithms, but comparable in performance to the extended magnetic field decomposition approach, to further improve numerical stability of time-evolving COCONUT. We are also using AI-generated synchronize magnetograms to improve simulation fidelity and implementing local mesh refinement to better resolve active-region evolutions. Also, we are trying to cover the whole solar-terrestrial space by extending our coronal model to 1 AU or coupling it with an inner heliosphere model, thereby enable faster-than-real-time CME simulations from solar surface to 1 AU.

Hongyi Wang: Large numbers of Small Flux Ropes generated by interchange reconnection from coronal holes measured by Parker Solar Probe

The origin of small flux ropes is unclear. Simulations has shown that the small flux ropes could be formed by interchange reconnection and wrapped in the magnetic switchbacks in the solar wind. This work aims to identify the small flux ropes formed by interchange reconnection in the solar wind measured by Parker Solar Probe during its encounters. We apply a normalized time scale on the studied small flux ropes having durations less than 7.6 hours. The normalized temporal profiles of the small flux ropes are superposed together. All the studied microstreams are traced back to their source confirming that they are from coronal holes. The results show that when the proton temperature reaches the top at the center of the small flux ropes, the radial component of the proton velocity gets to the maximum and shows significant correlation to the Alfven speed. There is a dip at one edge of the small flux rope. The fraction of the small flux ropes having longer duration and larger radial size increases with the solar radial distance. Compared to the small flux ropes from non-microstream, the most obvious signature of the small flux ropes formed by interchange reconnection in the microstream in a coronal hole is the dip at the edge of the flux ropes. This work supports that large numbers of small flux ropes having duration less than 7.6 hours are formed by interchange reconnection in microstream from coronal holes. They are going to merge into larger flux ropes and are accelerated by Alfven waves. The magnetic dip at the edge may be a distinct feature for interchange reconnection compared to closed-flux reconnection.

Jiasheng Wang: Non-LTE Inversion of the Hβ 4861Å Line for Chromospheric Magnetic Field measurement

The chromosphere is a complex solar atmosphere that hosts variety of dynamic transients and transports a critical amount of free energy to heat the corona, with mechanisms such as magnetoacoustic wave heating and small-scale transients (nano-flares and spicules) proposed by observational evidence. However, due to the limited sensitivity of polarization measurement and the influence of spectral line broadening, the basic magnetic field configuration in chromosphere has not yet been fully revealed to correspond with the observed phenomena. In this work, we investigated the validity and application of the magnetic field inversion method for the H-beta 4861 Å spectral line with non-local thermodynamic equilibrium (NLTE) approximations. The formation height of H-beta line in the chromosphere is 1200 km, with a stratification of 200 km. We generated synthetic spectra by incorporating magnetic fields into semi-empirical VAL models for quiet Sun and sunpots, and then performed inversions to obtain the magnetic fields, which were then compared with the magnetic fields in the models. In addition, we evaluated the accuracy of the magnetic fields obtained using the weak-field approximation (WFA) and the impact of using these WFA results as the initial guess model for NLTE inversion on the final results. Our work validates the effectiveness of the inversion method applied to the measurement of line-of-sight magnetic field components in both weak-field (0-1200 Gauss) and strong-field (>2000 Gauss) regions, while maintaining accuracy of WFA in the field range of 1000-2000G. This demonstrates that the inversion techniques we employed are capable of resolving Zeeman-sensitive spectral lines in the chromosphere, which can be applied to the H-beta observational data from the Solar Magnetism and Activity Telescope at the Huairou Solar Observing Station to provide full-disk chromospheric magnetic field information. \\\
Three dimensional magnetic reconnection mediated with plasmoids and the resulted multi-thermal emissions in the cool atmosphere of the Sun

Jincheng Wang: The formation and material supply mechanisms of Solar filaments

Our study focuses on the formation and material supply of solar filaments. We present observations of over 100 events where filaments formed gradually. Using high-resolution data from NVST, CHASE, GONG, and SDO, we investigate the detailed formation process.

Ruihui Wang: Solar Surface Magnetic Field Simulation from 2010 to 2024 and Anomalous Southern Poleward Flux Transport in Cycle 24

The solar surface magnetic field is fundamental for modeling the coronal magnetic field, studying the solar dynamo, and predicting solar cycle strength. We perform a continuous simulation of the surface magnetic field from 2010 to 2024, covering solar cycle 24 and the ongoing cycle 25, using the surface flux transport model with assimilated observed active regions (ARs) as the source. The simulation reproduces the evolution of the axial dipole strength, polar field reversal timing, and magnetic butterfly diagram in good agreement with SDO/HMI observations. Notably, these results are achieved without incorporating radial diffusion or cyclic variations in meridional flow speed, suggesting their limited impact. Poleward surges of the following polarity typically dominate throughout the cycle, but in the southern hemisphere during cycle 24, they are limited to a short period from 2011 to 2016. This anomalous pattern arises from intermittent AR emergence, with about 46% of total unsigned flux contributed by ARs emerging during Carrington Rotations 2141-2160 (September 2013 - February 2015). After 2016, poleward migrations of leading-polarity flux become dominant, despite most ARs following Joy's and Hale's laws. This reversal is likely due to prolonged intervals between AR emergences, which allow leading-polarity flux to distribute across a broad latitude range before cancellation by subsequent ARs. These findings highlight the importance of the temporal interval of AR emergence in driving the flux transport pattern.

Quan Wang: Change Ratios of Magnetic Helicity and Magnetic Free Energy During Major Solar Flares

Magnetic helicity is an important concept in solar physics, with a number of theoretical statements pointing out the important role of magnetic helicity in solar flares and coronal mass ejections (CMEs). Here we construct a sample of 47 solar flares, which contains 18 no-CME-associated confined flares and 29 CME-associated eruptive flares. We calculate the change ratios of magnetic helicity and magnetic free energy before and after these 47 flares. Our calculations show that the change ratios of magnetic helicity and magnetic free energy show distinct different distributions in confined flares and eruptive flares. The median value of the change ratios of magnetic helicity in confined flares is −0.8%, while this number is −14.5% for eruptive flares. For the magnetic free energy, the median value of the change ratios is −4.3% for confined flares, whereas this number is −14.6% for eruptive flares. This statistical result, using observational data, is well consistent with the theoretical understandings that magnetic helicity is approximately conserved in the magnetic reconnection, as shown by confined flares, and the CMEs take away magnetic helicity and energy from the corona, as shown by eruptive flares.

Wei Wang: Research progress on MUSER and IPS telescope for space weather

The Mingantu Spectral Radioheliograph (MUSER), initially named the Chinese Spectral Radioheliograph (CSRH), was developed from 2009 - 2016. Located at the Mingantu Observing Station in Inner Mongolia, it covers the 400 MHz to 15 GHz frequency range. Currently, it consists of two arrays: MUSER - I (400 MHz to 2.0 GHz with 40 4.5 m mesh antennas) and MUSER - II (2 to 15 GHz with 60 2 m dish antennas). Under the Meridian - II Project, it has been expanded with MUSER - L (30 to 400 MHz using 224 Log - Periodic Dipole Antennas). MUSER's mission is to provide solar radio images for monitoring solar bursts from the solar surface to interplanetary space. So far, MUSER has observed dozens of solar radio burst events, which have provided valuable data for solar physics and space weather research. Now, MUSER's upgrade on frequency resolution and polarization is carrying out. \\\ The Interplanetary Scintillation (IPS) telescope, a significant facility of the Meridian Project, has been successfully completed last year. Focused on space weather research, this telescope plays a crucial role in enhancing our understanding of the space environment. The telescope has three 140 m by 40 m cylinder antennas at the MUSER site, and two 30 m dish antennas about 200 km away in nearby counties. The cylinder antennas operate at 327 MHz and 654 MHz with dual - linear polarizations, a 40MHz adjustable bandwidth, and a sky zenith angle of 60 degrees, enabling observation of thousands of radio sources. The 30 m dish antennas work at 327MHz, 654MHz, and 1.4GHz with dual - line polarization and can scan the entire sky. The IPS telescope has already carried out daily observations and can observe the speed of the solar wind. Relevant observational examples will be presented in this paper as well. \\\ Both MUSER and IPS telescopes will play important roles in solar and space weather research. This paper aims to detail their hardware, construction process, and present preliminary observation results, along with the observed events of these two advanced telescopes.

Wensi Wang: Quantitative study of solar erupting magnetic flux ropes in solar cycle 24

We have developed a novel automated algorithm to detect footpoints of erupting magnetic flux ropes (MFRs), based on theoretical concepts and observational characteristics of MFRs. This method has been improved upon our previous detection method of coronal dimmings (see Wang et al. 2017, 2019, 2023). Now we applied this method to a sample comprising 427 eruptive flares of GOES class C5.0 and larger within 45 deg from the central meridian observed by the SDO/AIA from 2010 May to 2019 December. Only 84 of these eruptive events exhibited observational signatures of MFR's feet. Our method successfully identified the footpoints of these MFRs, estimated the magnetic flux and vertical electric current through footpoints, and inferred magnetic twist.

Yikang Wang: Three-dimensional numerical simulations and spectra synthesis of the quiet-Sun chromosphere

The solar chromosphere serves as a channel for mass and energy between the photosphere and the corona. It is highly dynamic and permeated by MHD waves of various modes. In this study, we reproduce the dynamic structure of the quiet Sun from the photosphere to the corona using three-dimensional numerical simulations. We then synthesize the Hα spectral line with Multi3D and present the results of both the simulation and the line synthesis. We further demonstrate that the ubiquitous MHD waves have a significant impact on the synthesized spectra at both local and global scales.

Yulei Wang: Basic Pattern of Three-dimensional Magnetic Reconnection within Strongly Turbulent Current Sheets

Magnetic reconnection is a fundamental mechanism of driving eruptive phenomena of different scales and may be coupled with turbulence as suggested by recent remote-sensing and in situ observations. However, the specific physics behind the complex three-dimensional (3D) turbulent reconnection remains mysterious. Here, we develop a novel methodology to identify and analyze multitudes of multiscale reconnection fragments within a strongly turbulent current sheet (CS) and apply it to a state-of-the-art numerical simulation of turbulent reconnection for solar flares. It is determined that the reconnection fragments tend to appear as quasi-2D sheets forming along local magnetic flux surfaces, and, due to strong turbulence, their reconnection flow velocities and reconnection rates are significantly broadened statistically but are scale independent. Each reconnection fragment is found to be surrounded by strongly fluctuated in/outflows and has a widely distributed reconnection rate, mainly in the range of 0.01–0.1. The results, for the first time, provide quantitative measurements of 3D magnetic reconnection in strongly turbulent flare CSs, offering insights into the cascading laws of 3D reconnection in other turbulent plasmas.

Zi-Fan Wang: The power spectra of simulated emerging magnetic field at ephemeral region scale

Magnetic flux emergence on the Sun at varied spatial scales is generally complex as it usually consists of several emerging regions and smaller secondary emergence. The power spectra of the photospheric magnetic field have been a key diagnostic to evaluate the evolution of magnetic field at different scales during flux emergence. The application of this diagnostic to the analysis of realistic magnetohydrodynamical simulations of flux emergence is expected to reveal new insights. Here we provide a series of simulations of rising horizontal magnetic flux tubes with different amounts of twist carrying the flux of typical ephemeral regions. The power spectra of the emerging fields follow power laws with increasing steepness as the total amount of flux increases, with the steepest having a non-Kolmogorov index -0.79. When the photospheric magnetic field is convolved with an Airy disk corresponding to the HMI magnetograph on the SDO mission, the power law indices obtained from observational inertial range experience a noticeable difference, though the range 2.7Mm<L<10Mm is of larger scales than the resolution. Our results suggest that the power spectra at the scale we consider are non-Kolmogorov as the size and spatial distribution of magnetic features is not in equilibrium during flux emergence.

Alexander Warmuth: CoSEE-Cat: constraining the acceleration and propagation of solar energetic electrons with Solar Orbiter

We present a comprehensive study of solar energetic electron (SEE) events, derived from joint observations by remote-sensing and in-situ instruments aboard ESA's Solar Orbiter spacecraft. The Energetic Particle Detector (EPD) is used to characterise the properties of energetic electrons in situ and to estimate their injection times at the Sun. The timing, location, and intensity of associated X-ray flares is obtained using the Spectrometer/Telescope for Imaging X-rays (STIX), while the Extreme Ultraviolet Imager (EUI) provides complementary observations of the flare evolution and eruptive phenomena. The Solar Orbiter coronagraph (Metis) and heliospheric imager (SoloHI) are employed to characterise potential associated coronal mass ejections. Type III radio bursts detected by the Radio and Plasma Waves (RPW) instrument are used to connect the eruptive solar events to the SEE events observed in situ. The conditions of the solar wind and interplanetary magnetic field are monitored with the Solar Wind Analyzer (SWA) and the Solar Orbiter magnetometer (MAG). All results are made available for the community in the form of the Comprehensive Solar Energetic Electron event Catalogue (CoSEE-Cat). Using this unprecedented wealth of data, we find new results on the particle acceleration and transport processes on the Sun and in the heliosphere.

Yidian Wu: Witnessing a Transition from Coronal Rain to Prominence Condensation

How the dense and cold prominences are formed and suspended in the hot and tenuous corona is still under debate. Here we provide direct imaging observations of how two groups of intersecting coronal loops, along which coronal rain is continually ongoing, transform into a funnel-like structure hosting prominence material. The event takes place above the east limb, observed by the Atmospheric Imagining Assembly on board Solar Dynamics Observatory from 2024 September 9 to 12. The two group of coronal loops are consistent with the magnetic field configuration derived from the potential field source surface model. The transformation into the funnel-like structure is associated with mass flows, loop oscillation, and plasma heating, as evidenced by differential emission measure analysis. Plasma condensation suddenly appears at the U-shaped bottom of the funnel and extends downward, eventually giving the appearance of a hedgerow prominence consisting of vertical threads. The observations suggest that magnetic reconnection may play an import role in transforming intersecting loops into a funnel with magnetic dips at the bottom, within which thermal instability sets in to produce plasma condensation, and eventually the hedgerow prominence.

Yuchuan Wu: Non-LTE synthesis and inversion of the Mg I 12.32 μm line

Magnetic field is one of the most important physical quantities in solar physics. Mg I 12.32 μm line is very sensitive to magnetic field, thus is suitable for measuring solar magnetic field. We employed the radiative transfer code RH 1.5D to synthesize the spectra of Mg I 12.32 μm line based on a model atmosphere computed with the magnetohydrodynamic numerical code MURaM. We analysed Mg I 12.32 μm line's features at various locations and the relationships between these features and physical parameters in model atmosphere. We also use an inversion code STiC to inverse synthesized spectra of Mg I 12.32 μm line and get physical parameters of the atmosphere.

Zhao Wu: An Extremely Strong millimeter Burst Induced by Two Successive Flares

Abstract: We report an extreme microwave burst (EMB, >10,000 SFU at millimeter wavelengths) exclusively generated during an X1.7-class flare (Flare II) observed by SRH and CBSmm. Observations reveals that a preceding M2.6 flare (Flare I) and subsequent interaction with coronal loops (Loops2) produced super-hot plasma (≈40 MK). During Flare II, these electrons severed as seed particles, and underwent three-stage acceleration via reconnection-driven processes, forming a dense nonthermal electron population with an exceptionally hard energy spectrum. We conclude that the two eruptive flares accelerate electrons successively, and ultimately generate the extreme microwave burst.

Ziqi Wu: Modeling Multiscale Transient Processes from Coronal Streamers to the Heliosphere

The heliospheric current sheet (HCS) is the largest structure imposed by the Sun, shaping the heliosphere and hosting multiple dynamic processes, including magnetic reconnection. The HCS is rooted in coronal helmet streamers, which are characterized by elongated, dynamical bright structures extending from the solar surface. A dense heliospheric plasma sheet (HPS) envelops the HCS, which is also considered the source of the slow solar wind during solar minimum. In-situ measurements and remote observations by spacecraft such as the Parker Solar Probe reveal that the HCS hosts multi-scale magnetic reconnections, which periodically release dense plasma transients and contribute to the heating and acceleration of slow solar winds. Using advanced 2.5D magnetohydrodynamic (MHD) simulations based on MPI-AMRVAC, we examine different triggering mechanisms of multiple reconnections in the HCS and reproduce the formation and ejection of transients. We also investigate the radial evolution of fast wind–slow wind patterns in the HCS-HPS system to bridge the gap between near-Sun and 1 AU observations and analyze their impact on planetary environments. This study provides a comprehensive picture of the morphology and dynamics of the HCS-HPS system and enhances our understanding of solar wind acceleration and associated space weather phenomena.

Quan Xie: New Progress in Small-scale Photospheric Vortices

Using the Automated Swirl Detection Algorithm(ASDA), recently, we obtained some distribution characteristics of small-scale vortices in the photosphere and found that there may be a larger distribution scale - inter-mesogranular lanes. Moreover, in a recent study, we improved the Automated Swirl Detection Algorithm to more accurately recognize small-scale vortices, resulting in some more accurate results.

Chen Xing: Initiation Route of Coronal Mass Ejections

The initiation of coronal mass ejections (CMEs) refers to the transition process from the quasi-static evolution of pre-eruptive structures to the erupting state of CMEs. In kinematics, the CME initiation is characterized by a slow rise of the pre-eruptive structures (e.g., hot channels and filaments) shortly before the impulsive eruption. A full understanding of the mechanisms of CME initiation is the key to forecasting solar eruptions and induced disastrous space weather, but it remains elusive so far. In this talk, I will present our recent advancements in determining the complete CME initiation routes through the state-of-the-art magnetohydrodynamics simulations. Our findings show that the moderate hyperbolic flux tube (HFT) reconnection occurring below the pre-eruptive structures and the drainage of the filament mass within the pre-eruptive structures play an important role in triggering and driving the slow rise (CME initiation). Consequently, we propose that the enhanced drainage of filament mass and various phenomena related to the HFT reconnection, such as, the split of pre-eruptive structures and the pre-flare loops and X-ray emissions, can serve as the precursors of CME initiation in observations, which will be useful for better forecasting the solar eruptions.

Ming Xiong: Data Calibration Of One New Giant IPS Radio Telescope Array Within The Meridian-II Space Weather Monitoring Project In China

Interplanetary scintillation (IPS) refers to random fluctuations in radio intensity of distant small-diameter celestial object, over time periods of the order of 1 second. The scattering and scintillation of emergent radio waves are ascribed to turbulent density irregularities transported by the ubiquitous solar wind streams. The spatial correlation length of density irregularities and the Fresnel radius of radio diffraction are two key parameters in determining the scintillation pattern. Such a scintillation pattern can be measured and correlated between multi-station radio telescopes on the Earth. Using the phase-changing screen scenario based on the Born approximation, the bulk-flow speed and turbulent spectrum of the solar wind streams can be extracted from the single-station power spectra fitting and the multi-station cross-correlation analysis. Moreover, a numerical computer-assisted tomography model, iteratively fit to a large number of IPS measurements over one Carrington rotation, can be used to reconstruct the global velocity and density structures in the inner heliosphere for the purpose of space weather modelling and prediction. A brand-new three-site IPS-dedicated facility in northern China was constructed in late 2024 within the Meridian-II Space Weather Monitoring Project. In this talk, we will present the initial results of raw data calibration during the commission phase of our new facility, and emphasize the potential benefits from international cooperation within the Worldwide IPS Stations (WIPSS) network.

Haiqing Xu: Solar cycle variation of current helicity inferred from vector magnetograms obtained by HSOS/SMFT

We study the hemispheric sign rule of current helicity and its long-term variation using vector magnetograms obtained from Solar Magnetic Field Telescope (SMFT) at Huairou

Solar Observing Station (HSOS). The data covered the period of 1988–2019, from solar cycle 22 to 24. Our dataset comprises 12281 vector magnetograms of 1484 active regions. Although the hemispheric sign rule of helicity generally holds, we also found significant time variations in the yearly values of helicity during the observation period. The helicity generally follows the hemispheric sign rule during solar maximum, but exhibits sign reversal tendencies at both the beginning and end of the solar cycle. In particular, during solar cycle 24, the helicity sign reversal became more pronounced in the northern hemisphere.

Dan Yang: FARM: A Combined Surface Flux Transport and Helioseismic Far-Side Active Region Model

Helioseismology can produce maps of the Sun's far side using acoustic waves observed on the Sun's partially visible surface (near side). This enables the detection of active regions days before they rotate into Earth's view, offering significant potential for improving space-weather forecasting models. In this talk, I will briefly introduce the basic principles of this method. I will then focus on our work, "Combined Surface Flux Transport and Helioseismic Far-Side Active Region Model (FARM)", published in Solar Physics (299, 161). We propose a novel approach to estimate the magnetic fields of active regions on the Sun's far side using helioseismic measurements; the modeled active-region magnetic field is then incorporated into a surface flux transport model. Comparisons between FARM-modeled open-field areas and EUV observations show a substantial improvement in agreement when far-side active regions are included. This proof-of-concept study demonstrates FARM's potential to improve space-weather modeling. Finally, I will discuss the potential to use far-side magnetograms from SO/PHI to validate and calibrate FARM.

Hanzhao Yang: Photospheric horizontal magnetic field decrease preceding a major solar eruption

Significant photospheric magnetic field changes during major solar eruptions, considered as coronal feedback from eruptions to the photosphere, are well-observed. However, analogous field changes preceding the eruptions, particularly associated with the mild coronal precursors, are rarely reported. In this study, we identify, for the first time, a pre-flare decrease in the photospheric horizontal magnetic field (B_h) associated with an X1.8 class flare using high-cadence vector magnetic field data from SDO/HMI. We find that B_h gradually decreased by approximately −100 Gauss in a structured region along the flaring polarity inversion line (PIL) within 30 minutes prior to the flare, accompanied by a decrease in the force-free parameter α_ω, with no significant flux emergence or cancellation observed. After the flare onset, B_h in different sub-regions exhibited distinct evolutionary patterns: it increased step-wise near the PIL but continued decreasing in farther regions, suggesting that the pre-flare B_h decrease may also have a coronal origin, same as the post-flare B_h decrease. Coronal imaging observations from SDO/AIA reveal that the filament erupted during the flare underwent a slow-rise phase before the flare. The location and timing of this phase correlate well with the pre-flare B_h decrease. We propose that the filament's slow-rise stretched overlying coronal loops, increasing the loops' verticality and thereby reducing B_h at their photospheric footpoints. \\\ To assess whether this feature is a common precursor to large solar eruptions, we conduct a statistical study with 35 major flares. Preliminary results indicate that similar signatures of pre-flare B_h decrease are present in several ARs. A detailed analysis of these events is underway and is expected to reveal a causal link between this photospheric signature and the slow-rise phase of the pre-eruptive filament. If confirmed, it could serve as a forecasting factor.

Shangbin Yang: <u>Solar eruptions - predictions based on modeling and observations of magnetic helicity</u>

It is well known that solar flares and coronal mass ejections (CMEs) are related to the sudden release of stored magnetic Energy. How the corresponding instabilities are triggered has become the central question to understanding the above phenomena. An instability criterion in the magnetohydrodynamics (MHD) with the open boundary of a magnetic field is proposed in recent research. We use a series of linear force-free extrapolation fields, in which the normal part of the magnetic field is fixed, to obtain the linear fitting coefficient called relative alpha by using the cojoined value of magnetic free energy and magnetic flux at the open boundary and the square of relative magnetic helicity. It is found that the fitting coefficient is a good proxy of the criterion to indicate the occurrence of instability after which the magnetic reconnection happens and causes the fast release of magnetic energy both in simulations and observations. This is very helpful to evaluate how far it is from the instability in the MHD and quantitatively estimate the occurrence of solar eruption in the space weather forecast.

Shuhong Yang: <u>Investigation of solar polar magnetic fields</u>

As the primary determinant, the solar polar magnetic fields are deemed to serve as seed fields for the global dynamo producing the solar cycle, and they are important for powering fast solar wind. Based on Hinode's polar observations from 2012 to 2021, we investigate the long-term variation of vector magnetic fields and the pattern of meridional flow near the poles. We find that the magnetic field polarity reversed from about 70 degree latitude to the pole successively at the epoch of solar maximum, reflecting a poleward migration of magnetic flux. After the polarity reversal, the magnetic inclination of the dominant polarity fields decreased, indicating that the stronger the dominant field, the more vertical the field lines. The Hinode observations also show that in each polar cap, during most of the solar cycle except for the period around the polarity reversal, the higher the latitude, the weaker the radial magnetic flux density in general. We employ a surface flux transport model to simulate the global radial magnetic field to explore the meridional flow. For the first time, Hinode's high-resolution vector magnetic field observations in polar caps are used to directly constrain the simulation. The simulation results reveal that when assuming a counter-cell meridional flow from the pole to 70 degree latitude with the maximum amplitude of 3 m/s, the simulation fits the observation well. These results enrich our understanding about the magnetic fields and the meridional flow in the solar polar regions.

Xu Yang: Various of Mid-infrared Sources in an X6.4 Flare

We present a unique observation of the X6.4-class flare SOL2024-02-22T22:34 using the Mid-InfraRed Imager (MIRI) at the Goode Solar Telescope. Three ribbon-like flare sources and one unidentified source were detected in MIRI's two mid-infrared (mid-IR) bands at 5.2 and 8.2 μm. The two stronger ribbons displayed maximum mid-IR enhancements of 21% and 18% above quiet-Sun levels and 10% in HMI continuum intensity (Ic). The weak ribbon and the unidentified source had maximum mid-IR enhancements of 7% but showed HMI/Ic dimmings, instead of excess emissions. Our result suggests that mid-IR emission forms in a higher layer during the flare and is more sensitive to flare heating than HMI/Ic emission. The MIRI observations have high temporal resolution (2.6-s cadence in these observations) and show apparent source motions. One flare ribbon extends along weak vertical magnetic-field channels in the sunspot umbra, light bridge, and penumbra, with an approximately 30 s delay between HMI/Ic and 8.2 μm emissions. Meanwhile, the unidentified source moved at an apparent speed of 130 km/s from a mixed-polarity area to one flare ribbon with a strong HMI/Ic enhancement. We studied the available X-ray/microwave imaging spectroscopy and used nonlinear force-free field extrapolation modeling to identify flare structures. Quantitative analysis strongly suggested the UN source cannot be in the corona. Comparison with the X1.0 flare SOL2022-10-02T20:25 indicates that the total amount of high-energy electron (>60 keV) flux density is a key factor in determining the total brightening area and the maximum intensity enhancement in HMI/Ic emissions.

Mehdi Yousefzadeh: Excited Emissions by Velocity Distribution of Energetic Electrons within Large-Scale Coronal Loop

Particle-in-cell (PIC) simulations are employed to investigate the connection between large-scale coronal loop dynamics and micro-scale kinetic instabilities driven by non-thermal electron velocity distribution functions (EVDFs), with a focus on understanding the generation mechanism of slowly positively drifting bursts (SPDBs). The simulations demonstrate the excitation and emission of different modes depending on the frequency ratios of the surrounding plasma, linking magnetic reconnection events within coronal loops to the formation of accelerated electrons with specific velocity distributions. These distributions drive kinetic instabilities, leading to radio wave emission with a frequency drift consistent with SPDBs. Future work will combine numerical simulations with observational SPDB data, using observed parameters as constraints for the simulations and comparing predicted emission properties with observed characteristics. This integration will enable inferences about the reconnection region and accelerated electron population, contributing to a comprehensive understanding of magnetic reconnection, electron acceleration, kinetic instabilities, and radio wave emission in the solar corona, with broad implications for space physics and astrophysics.

Abdullah Zafar: MHD Simulations of Small-Scale Magnetic Reconnection At Different Altitudes In The Partially Ionized Low Solar Atmosphere

The small-scale reconnection events in multiple wavelengths are frequently observed in the lower solar atmosphere. They play an important role in heating the local atmosphere. However, the fine structures in the reconnection region and the underlying physical mechanisms cannot be clearly understood based on the existing observations. We performed 2.5D single-fluid MHD simulations of magnetic reconnection with different strength of magnetic fields from the solar photosphere to the upper chromosphere. The main emphasis is to identify dominant mechanisms for heating plasmas in the reconnection region under different plasma-β conditions in the partially ionized low solar atmosphere. The numerical results show that more plasmoids are generated in a lower β reconnection event. The frequent coalescence of these plasmoids leads to a significant enhancement of turbulence and compression heating, which becomes the dominant mechanism for heating plasma in a lower plasma-β reconnection process. The average power density of the compression heating (Qcomp) decreases with increasing initial plasma-β as a power function: Qcomp ∼ β^{−a}, where the value a is 1.9 in the photosphere and decreases to about 1.29 in the upper chromosphere. In the photosphere and lower chromosphere, the joule heating contributed by electron-neutral collisions Qen = η_{en}J^{2} eventually dominates over the compression heating when the initial plasma-β is larger than the critical value β0−critical = 8. In the upper chromosphere, the ambipolar diffusion heating and the viscous heating will become equally important as the compression heating when the initial plasma-β is larger than the critical value β0−critical = 0.5. These results indicate that the compression heating caused by turbulent reconnection mediated with plasmoids is likely the major heating mechanism for the small-scale reconnection events with stronger magnetic fields such as active region EBs and UV bursts. However, the heating caused by the partial ionization effects can not be ignored for those reconnection events with weaker magnetic fields such as quiet Sun EBs and cold surges.

Fan Zhang: Multi-fluid-multi-species modeling of magnetohydrodynamics wave propagation in partially ionized plasmas

The solar atmospheric properties change drastically from the photosphere to the corona, where multi-spatial-temporal-scale phenomena take place. In particular, partial ionization effects – including collision, ionization/recombination, etc. – are important for understanding energy transport within these layers, and modeling such effects requires multi-fluid models when collisional timescales are comparable to the timescales of phenomena such as wave propagation, magnetic reconnection. \\\ Therefore, we introduce the multi-fluid-multi-species MHD code Ebysus which allows us to properly describe partial ionization effects in the low solar atmosphere. Specifically, among other advanced features, Ebysus includes various elements heavier than Hydrogen, as these elements contribute a significant portion of the total charged particles and thus significantly affect the dynamics in the low solar atmosphere. In this presentation, we will specifically describe the results of including Hydrogen and several heavier elements in MHD wave models and compare the wave energy deposition with pure hydrogen models. Such models may not only improve the understanding of chromospheric heating, but also contribute to the understanding of solar wind acceleration.

Hongqi Zhang: Solar activities and cycles from observed solar magnetic fields

A large number of observed solar magnetic fields provide important information on the structure and evolution of magnetic fields at different scales in the solar atmosphere, including the fine structures of the magnetic field in the quiet sun, the formation of the magnetic field in the solar active regions and the release of magnetic energy in the solar eruptive process. At the same time, the evolution of the large-scale magnetic fields of the sun relates to solar active cycles. These observations of different scales of magnetic fields on the solar surface offer important external boundary conditions for the formation of the internal magnetic field of the Sun. In this talk, we introduced some advances in the relationship between solar magnetic shear, helicity, and other magnetic non-potential parameters observed by solar photospheric magnetic fields and the relationship with the formation of solar magnetic fields, especially some observations at Huairou Solar Observing Station in the National Astronomical Observatories of China, and existing questions for the research topics in this regard.

Jinge ZHANG: Imaging a Large Coronal Loop Using Type U Solar Radio Burst Interferometry

Solar Type U radio bursts, generated by electron beams travelling along closed magnetic loops in the solar corona, are crucial for probing the solar atmosphere. In particular, low-frequency U-bursts (below 100 MHz) serve as effective tools for investigating large coronal loops that extend into the middle and upper corona. The descending leg of U-bursts—characterised by its drift from low to high frequencies—is typically weaker and more diffuse than the ascending leg (high to low frequencies), and has been less studied due to observational constraints. However, recent advances in radio interferometry, notably with instruments such as the Low-Frequency Array (LOFAR), now enable detailed imaging spectroscopy of U-bursts with improved frequency and temporal resolution. \\\ In this study, we analyse LOFAR interferometric observations of a U-burst recorded on 5 June 2020, which displayed a clear 'U'-shaped structure across the 10–90 MHz range. We derived beam velocities and physical parameters of a large coronal magnetic loop reaching an altitude of nearly 1.3 solar radii—an analysis performed for the first time at this scale. The average electron beam velocity was 0.21 c along the ascending leg and 0.14 c along the descending leg. This apparent deceleration is interpreted as a result of a reduced range of resonant electron energies with Langmuir waves, likely caused by a positive background plasma density gradient along the descending loop leg. At this altitude, the plasma temperature was estimated to be approximately 1.1 MK, the plasma pressure around

0.20 mdyn/cm², and the minimum magnetic field strength about 0.07 G. The similarity in physical parameters inferred from both legs suggests a symmetric loop structure.

Jinge ZHANG: SOLER: Energetic Solar Eruptions – Data and Analysis Tools for the Heliophysics Community

The SOLER (Energetic SOLar ERuptions: Data and Analysis Tools) project is a European collaborative effort uniting five partner institutions across four countries—Finland, Germany, Austria, and France. It investigates the most powerful solar phenomena—flares, coronal mass ejections (CMEs), and solar energetic particle (SEP) events—by combining multi-wavelength electromagnetic observations with in-situ particle measurements. SOLER leverages data from a wide array of missions and observatories, including ESA's Solar Orbiter and SOHO, NASA's Parker Solar Probe, and ground-based facilities such as LOFAR, NenuFAR, and the Nançay Radioheliograph. \\\The project aims to address three key questions in heliophysics: (1) What are the magnetic connections between low-coronal sources and in-situ particle detectors? (2) How are the properties of solar eruptions and energetic particles interrelated? (3) What causes the significant variability observed across SEP events? \\\ Beyond advancing fundamental science, SOLER delivers three major technical outputs: high-level multi-instrument datasets; a suite of user-friendly analysis and visualisation tools (developed in Python and accessible via JupyterHub); and interlinked catalogues of flares, CMEs, and SEPs. These tools are open-source and integrated with ESA archives, promoting reproducibility and cross-disciplinary research. This poster introduces the SOLER project's scientific objectives, methodology, and community-facing tools designed to facilitate next-generation studies of energetic solar eruptions.

Ning Zhang: From Formation to Eruption of Quiescent Solar Prominence Driven by Supergranulations

We obtained supergranular cells on the photosphere by using the Voronoi tessellation method. Driven by the supergranular velocity field, we demonstrated the self-consistent process from the formation to the eruption of a mid-latitude quiescent prominence Magnetic Flux Rope (MFR) through a magnetofriction model and a zero-beta model. We studied the dynamics evolution and magnetic reconnection of the MFR during the eruption using particle tracking technology in the zero-beta model and summarized the magnetic reconnection that occurred during the eruption. We conducted a comparative analysis of the influence of the vortex velocity of supergranules on the accumulation of magnetic free energy and the injection of magnetic helicity during the MFR eruption. The results show that the faster the vortex velocity of supergranules, the faster the accumulation of magnetic free energy and magnetic helicity, and the faster the MFR becomes unstable and erupts. Similarly, we found that there is an upper limit to the accumulation of magnetic helicity and magnetic free energy of the MFR. Once this limit is reached, the MFR becomes unstable and erupts.

Qingmin Zhang: Radio signatures of magnetic reconnection during a solar flare

In this paper, we carry out multiwavelength observations of a solar flare. HXR light curves of the flare show quasi-periodic pulsations (QPPs) with periods of tens of seconds. Radio dynamic spectra shows a clear type III radio burst. Possible signatures of magnetic reconnection within the flare current sheet are provided by radio observations.

Weihang Zhang: Forward Modeling of Magnetic Energy Release Diagnosis during Solar Flares Based on the Magnetic-field-induced Transition Effect

Routine measurements of the magnetic field in the solar corona remain severely limited, constraining our understanding of flare dynamics and the underlying mechanisms of magnetic energy release. The magnetic-field-induced transition (MIT) effect, particularly in the Fe X 257.26 Å emission line in the extreme ultraviolet (EUV), has recently been proposed as a promising diagnostic tool for coronal magnetic fields. \\\ In this study, we perform forward modeling based on a three-dimensional radiation magnetohydrodynamic (RMHD) simulation of a solar flare. Synthetic spectra of the Fe X 257.26 Å line, along with other temperature-sensitive and density-sensitive Fe X transitions, are generated. We apply line profile analysis techniques to invert the plasma temperature, electron density, and magnetic field strength both before and during the flare. Building on this, we estimate the magnetic energy released during the flare using the inverted field strengths derived via the MIT technique, and compare it with the magnetic energy directly computed from the RMHD model. This comparison allows us to evaluate the diagnostic accuracy of MIT-based magnetic field measurements in the context of coronal energy release. \\\ Our results show high consistency between the inverted and model values for temperature and density. However, magnetic field inversion exhibits systematic deviations, primarily due to line-of-sight integration effects, the limited spectral resolution of the instrument, and blended line components within the wavelength range. Despite these limitations, we demonstrate that this method shows strong potential for quantitatively tracking coronal magnetic field evolution and localized energy release during flare processes. \\\ Our work provides a forward-modeling benchmark for the application of the MIT effect to diagnose magnetic energy release in solar flares under high-cadence EUV spectroscopic observations, and offers theoretical guidance for future instrument design in coronal spectrometers.

Xiaofan Zhang: Responses of a Coronal Hole to a Fast Flare-Driven Coronal Wave

Coronal waves, significant solar phenomena, act as diagnostic tools for scientists studying solar atmosphere properties. Here, we present a novel observation detailing how a coronal wave event, associated with an X5.0 class flare, influenced the properties of an adjacent coronal hole (CH) through interaction. The coronal wave was observed in both extreme-ultraviolet (EUV) observations from the Atmospheric Imaging Assembly on board the Solar Dynamics Observatory and Lyα observations from the Solar Disk Imager on board the Advanced Space-based Solar Observatory. Utilizing the method of differential emission measure, we found that as the coronal wave passed through, the adjacent CH experienced an increase in temperature from 1.31 to 1.43 MK and a rise in density from $\sim 1.62 \times 10^8$ to 1.76×10^8 cm^{-3} within the rising period of $\sim$7 minutes. Subsequently, after the wave passed, the entire CH transitioned to a new state with a slight temperature increase and a 14% decrease in density, with more pronounced changes observed at the CH's boundary. Taking into account the impacts of radiative loss and heat conduction, the coronal wave was estimated to provide an average energy of 2.2×10^8 erg cm^{-2} to the CH during the short rising period. This study highlights the identification of the coronal wave in both EUV and Lyα observations, shedding light on the significant energy input, particularly within the CH. These findings provide new insights into better understanding kinematics of fast coronal waves, energy transfer processes open versus closed magnetic topologies, and the possible acceleration of solar winds.

Xiaomeng Zhang: Deflection of filament eruption in competing current channels

On 6 May 2024, Active Region 13663 produced an X4.5-class flare associated with a filament eruption that exhibited remarkable rotation and deflection dynamics. This study aims to investigate two key aspects of this event: the formation mechanisms of the complex flare ribbon structures and the physical drivers behind the observed filament deflection. We conduct data-constrained magnetohydrodynamic simulations under the zero-beta approximation to reconstruct the filament's evolution. Through detailed analysis of quasi-separatrix layers (QSLs) and their comparison with observed flare ribbons, we establish crucial connections between magnetic topology and flare morphology. \\\ First, our simulation successfully reproduces key observational features of the eruption. Then, we connect the flare ribbon morphology with underlying magnetic field configuration. In the end, we find filament deflection results from localized reconnection at the X-point, as evidenced by Lorentz force decomposition. \\\We demonstrate that reconnection above two current channels of opposite helicity governs the eruption dynamics, with magnetic pressure gradients driving flux rope deflection while simultaneously restraining arcade ascent. The event features a "sandwich" magnetic configuration including double parallel polarity inversion lines with strong shear component. We conclude possible eruption behaviors under this configuration. In addition, the evolution of QSLs and flare ribbons provide clear evidence of reconnection between two flux ropes.

Yong Zhang: a real-time prediction system of the intensity of solar energetic proton events based on a solution of the diffusion equation

In this study, based on solar energetic particle (SEP) events classification and a solution of the diffusion equation, we present an efficient system, HITSEP, to predict the intensities in different energy channels (P4 15.0-44.0 MeV, P5 40.0-80.0 MeV, and P6 80.0-165.0 MeV) of energetic proton events observed by GOES spacecraft. The system can predict the rising phase (especially the peak time and peak intensity) of the energetic proton events using only a small amount of data at the beginning of the solar energetic proton events. Among the events that meet the conditions for the use of our prediction system from 2003 to 2017, for P4, P5, and P6 channels, the median Warning Times are 3.70, 2.52, and 1.69 hr; the median Error of the Intensity for events are 0.43, 0.23, 0.34 orders of magnitude; the median Error of the Peak Time for events are 2.53, 0.55, 0.43 hr, respectively. Our system is based on physical mechanisms and has a high accuracy in forecasting the peak intensity with a strict definition of the error. The HITSEP system has huge potential for space weather forecast. The application of the HITSEP system in space weather forecasting is very promising.

Yue Zhang: Waiting time distribution of solar flares in the super active region 13664 during its lifetime

The waiting time distribution (WTD) of solar and stellar flares provide clues for physical mechanisms behind flares. Previous work mainly focused on the WTD of all the flares recorded by a soft X-ray monitor at Earth. In May 2024, the Solar Orbiter was located behind the Sun. Together with the Solar Dynamic Observatory that is orbiting the Earth, a unique opportunity arises to study all the flares originating from one super active region, NOAA AR 13664, over its entire lifetime, including the period when it is on the disk visible to the Earth and the period after it rotates behind the west limb before reappearing on the east limb. The peak times of C1-class-and-above flares that take place within AR 13664 are obtained from the Geosynchronous Operational Environmental Satellite (GOES) flare catalog and from the 4-10 keV SXR lightcurves observed by the Spectrometer Telescope for Imaging X-rays (STIX) on Solar Orbiter. The WTD is calculated as the distribution of intervals between the flare peak times. By using maximum likelihood estimation to fit the distribution and the Kolmogorov-Smirnov test to measure the goodness of fit, we found that the WTD is best fit by a log-normal function, against exponential and power-law functions. Further, the WTDs of all the C1-class-and-above flares taking place on the disk visible to the Earth, and of those throughout the entire lifetime of AR 13664, are best fit by log-normal functions, too. We discuss the implication of the WTDs ’following log-normal rather than exponential and power-law functions.

Qingtong Zhao: Filament Eruption Triggered by Magnetic Flux Emergence at the Footpoint

A typical filament eruption event triggered by emerging magnetic flux (EMF) with clear process and complete observational evidence is reported in this study. In this event, the interaction between the EMF and the filament was extremely significant. The southern footpoint of the filament was anchored to the positive polarity magnetic field of a dipole region, where magnetic flux of opposite polarity emerged. Subsequently, significant brightening was observed in the extreme ultraviolet (EUV) band in this region, indicating effective interaction between the new magnetic system and the background field. As the magnetic flux continued to emerge, the rising magnetic system expanded continuously, causing the structure above the filament footpoint to rise significantly, which ultimately triggered the filament eruption.The observational results strongly suggest that the triggering of filament eruptions is closely associated with the emergence of magnetic flux.

Guiping Zhou: Investigation of the Large-Scale Magnetic Source Topology of Extreme Solar Eruptions in May 2024

As the 25th Solar Cycle enters its peak years, numerous extreme eruptive events have unfolded on the Sun. When these eruptions propagate toward Earth, they may trigger multiple severe geomagnetic storms, threatening the safety of satellite operations, communications, and navigation. They have also led to both rare and frequent occurrence of low-latitude auroral phenomena. Taking the extreme eruptive events in May 2024 as a case study, this work investigates the physical links between the magnetic structures of the eruption source regions and their impacts in near-Earth space. From May 2 to 14, 2024, Active Region (AR) 13664 on the Sun produced nearly 100 flares, accompanied by nearly 20 coronal mass ejections (CMEs) directed toward Earth. Notably, during this period, low-latitude auroral phenomena were visible in the Beijing region, a seldom-seen phenomenon in the historical records of Beijing. This research conducts in-depth analyses of the magnetic field’s evolution, magnetic connectivity, topological characteristics, and physical mechanisms of energy accumulation and release, as well as the propagation and evolution of eruptive structures in AR 13664. The primary aim is to uncover the solar origins of their effects in near-Earth space. Through the examination of interaction processes across multiple scales, structure coupling on various scales, and the formation of global-scale structures, the study aims to outline general eruptive patterns, thereby laying the groundwork for the effective forecasting of space weather conditions.

Xiuhui Zuo: Sequential ejections of plasma blobs due to unbraiding of tangled loops in the solar atmosphere

Nanoflares, which are consequences of braids in tangled magnetic fields, are an important candidate to heat the solar corona to million degrees. However, their observational evidence is sparse and many of their observational characteristics are yet to be discovered. With the high-resolution observations taken by the Extreme Ultraviolet Imager onboard the Solar Orbiter, here we study a series of ejections of plasma blobs resulted from a braided magnetic loops in the upper transition region and reveal some critical characteristics of such processes. The cores of these ejections have a size of about 700 km, a duration less than 1 minute and a speed of about 90 km/s. An important characteristic is that these plasma blobs are apparently constrained by the post-reconnection magnetic loops, along which they show an extension of up to about 2000 km. The propagation of unbraiding nodes along the main axis of the tangled loops has a speed of about 45 km/s. The separation angles between the post-reconnection loops and the main axis of the tangled loops are about 30°. The observations from the Atmospheric Imaging Assembly reveal that the braiding loops are upper transition region structures. Based on these observations, the typical magnetic free energy producing a blob is estimated to be about 3.4×10^{23}erg, well in the nano-flare regime, while the kinematic energy of a blob is about 2.3×10^{23}erg, suggesting that a majority of magnetic free energy in a magnetic braid is likely transferred into kinematic energy.