Solar Physics High Energy Research (SPHERE) 4 Workshop

Space Sciences Laboratory
UC Berkeley

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Tuesday, August 12

Observatory Highlights

Limb-Occulted Flare Observations with HXI, GBM, and STIX

Observatory Highlights
12 Aug 2025
09:20-09:45

Säm Krucker[1,2]

[1]FHNW [2]University of California, Berkeley

I will show latest results on occulted flare observations with Solar Orbiter/STIX, ASO-S/HXI, and Fermi/GBM.

OVSA: An Integrated Radio Community Facility for Solar and Space Weather Sciences

Observatory Highlights
12 Aug 2025
09:45-10:10

Bin Chen[1]

[1]New Jersey Institute of Technology

I will discuss latest updates of the Owens Valley Solar Arrays (OVSA), which is now operating as an integrated community facility that comprises the Expanded Owens Valley Solar Array (EOVSA) observing in microwaves and the Owens Valley Radio Observatory's Long Wavelength Array (OVRO-LWA) observing in meter-decameter waves.

The Status and Early Results of ASO-S/HXI

Observatory Highlights
12 Aug 2025
10:10-10:35

Yang Su[1]

[1]Purple Mountain Observatory

The Hard X-ray Imager (HXI) aboard the ASO-S provides hard X-ray spectra and images of solar flares in the energy range 10-300 keV, currently the only solar HXR imager from Earth's perspective. Since the launch date of 2022 Oct. 09, it has detected more than 1600 flares, among which there are more than 70 X-class flares. More importantly, HXI and STIX aboard Solar Orbiter provide us, for the first time, both images and spectra of solar X-ray bursts simultaneously from two different viewpoints. These observations are crucial for studying flare X-ray directivity and 3D properties of X-ray sources. In this talk, I will first present the status of HXI instrument, the data processing, data calibration, imaging calibration, HXI analysis software, as well as cross-calibration results of the HXI detectors. Some early results of the studies based on HXI data, including the 3D properties of HXR sources based on imaging with HXI and STIX, will be summarized. Additionally, I will present the work of HXR directivity. With a newly developed thick-target model and a new joint spectral fitting method for both HXI and STIX spectra, we obtained solid evidence of HXR directivity in a GOES X-class flare and the corresponding pitch-angle distribution of energetic electrons. The time evolution of the pitch-angle distribution reveals the nearly beamed pitch-angle distribution during the two impulsive peaks and nearly isotropic pitch-angle distribution after the first peak. These results will help us understand electron acceleration and transport in flares.

Energy Storage and Release

Energy Storage and Release
12 Aug 2025
10:50-11:10

A Unified Perspective on Solar Flares: Spectroscopy and Modeling

Reetika Joshi[1,2]

[1]NASA/GSFC [2]GMU

Solar flares are among the most energetic events associated with solar activity, releasing as much as 1032 ergs. They are detectable across the full electromagnetic spectrum, from X-rays to radio, and frequently manifest as elongated, bright features at chromospheric heights, known as flare ribbons. We will present spectral analysis of flare ribbons and reconnection process along with radiative transfer modeling. We will compare the IRIS, FERMI, and high-resolution ground based observations with RADYN modeling to understand the energy deposition mechanisms into the atmosphere

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Energy Storage and Release
12 Aug 2025
11:10-11:30

Anisotropic Turbulent Flows Observed in Above-the-Loop-top Regions During Solar Flare

Xiaoyan Xie[1]

[1]CfA

Solar flare above-the-loop-top (ALT) regions are vital for understanding solar eruptions and fundamental processes in plasma physics. Recent advances in 3D MHD simulations have revealed unprecedented details on turbulent flows and MHD instabilities in flare ALT regions. Here, for the first time, we examine the observable anisotropic properties of turbulent flows in ALT by applying a flow-tracking algorithm on narrow-band Extreme Ultraviolet (EUV) images that are observed from the face-on viewing perspective. First, the results quantitatively confirm the previous observation that vertical motions dominate and that the anisotropic flows are widely distributed in the entire ALT region with the contribution from both upflows and downflows. Second, the anisotropy shows height-dependent features, with the most substantial anisotropy appearing at a certain middle height in ALT, which agrees well with the MHD modeling results where turbulent flows are caused by Rayleigh–Taylor-type instabilities in the ALT region. Finally, our finding suggests that supra-arcade downflows (SADs), the most prominently visible dynamical structures in ALT regions, are only one aspect of turbulent flows. Among these turbulent flows, we also report the anti-sunward-moving underdense flows that might develop due to MHD instabilities, as suggested by previous three-dimensional flare models. Our results indicate that the entire flare fan displays group behavior of turbulent flows where the observational bright spikes and relatively dark SADs exhibit similar anisotropic characteristics.

Precursors

Hot Onset Precursor Events (HOPEs)

Precursors
12 Aug 2025
11:30-11:45

Hugh Hudson[1,2]

[1]SSL [1]Glasgow

Flare precursor activity takes many forms, but we have found that this invariably involves the appearance of plasma at flare temperatures well prior to the impulsive phase or flare maximum. The HOPEs are thus a prerequisite for flare occurrence but have not yet gotten much theoretical attention or model development. Because all flares have hot onsets, we can use this property to anticipate flare occurrence, sometimes tens of minutes in advance, simply by characterizing the GOES soft X-ray emission properly. The hot onsets precede the hard X-ray emission of the impulsive phase, but there are hints of non-thermal activity that I will discuss.

Exploring the Physics Basis of Hot Onset Flare Precursor Events (HOPE)

Precursors
12 Aug 2025
11:45-12:00

James Drake[1]

[1]University of Maryland, College Park

There is emerging evidence that the onset of hard x-rays in solar flares is preceeded by a period of increasing soft x-rays that correspond to an increasing volume of hot plasma with a temperature of around 10 MK.[1,2] This flare precursor has a duration of around 10 minutes. The physics basis for these observations are explored based on the emerging understanding of the mechanisms for particle heating and acceleration during magnetic reconnection in large scale systems. A key result based on the particle-in-cell (PIC)[3] and more recent kglobal simulations[4,5] is that reconnection with a strong guide field produces strong plasma heating with electron temperature increments of around $0.1 m_i C_A^2$ (with C_A the Alfven speed based on the reconnecting magnetic field) but with essentially no non-thermal particle acceleration. For typical solar parameters this temperature increment is around 10 MK. As is seen in the observations, in reconnection simulations the temperature increment of electrons remains stationary while the number of hot electrons increases in time. In contrast, reconnection with a weak guide field efficiently drives a spectrum of non-thermal electrons and protons that extend many decades in energy.[4,5] Thus, a hypothesis is that the hot onset results from reconnection with a strong guide field that then evolves into reconnection with a weak guide field and the rapid production of non-thermal particles. The evolution from strong to weak guide field is supported by observations of two-ribbon flares and large-scale MHD simulations of flares.[6] Reconnection simulations with the *kglobal* model with a variable upstream guide field have been carried out to test this idea. Consistent with observations, the simulations reveal the formation of a hot thermal plasma with increasing emission measure during the period of strong guide field reconnection with a sudden increase in non-thermal electrons and protons during the onset of weak guide reconnection.

Broadband Emission

Broadband Emission
12 Aug 2025
13:45-14:05

The FOXSI-4 Observation

Kristopher Cooper[1]

[1]University of Minnesota

The Focusing Optics Solar X-ray Imager (FOXSI) sounding rocket missions all utilise direct-focusing optics and have successfully observed the quiet Sun, active region emission, and microflares in soft and hard X-rays (SXR and HXRs) over four flights. Using direct-focusing optics allows for greater image quality achieving higher sensitivity and dynamic range when compared to indirect imaging techniques; therefore, detailed simultaneous measurements become possible between relatively weak and bright sources. Direct imaging HXR telescopes are used regularly to observe astrophysical sources and, even though not solar-optimised, are occasionally able to observe the Sun if conditions are sufficiently quiet (e.g., with NuSTAR). FOXSI is the first solar-optimised direct-focusing HXR instrument capable of observing emission from a range of solar phenomena at different scales. The FOXSI-4 instrument, the fourth sounding rocket mission, incorporated new hardware compared to previous flights with upgrades including improved CMOS soft X-ray detectors, variable-pitch double-sided CdTe HXR strip detectors, a new Timepix detector, high-resolution Wolter-I optics from Nagoya University and Marshall Space Flight Center, and microfabricated pixelated attenuators from Goddard Space Flight Center.

FOXSI-4, flown on 2024 April 17 from Poker Flat in Alaska, took part in NASA's first solar flare campaign with Hi-C Flare where an M1 GOES class flare was near-simultaneously observed by both experiments. FOXSI-4 also observed a weaker flare within its field of view as well as quiescent active region emission. We present an overview of the FOXSI-4 sounding rocket instrumentation and the observation during flight. We show the preliminary investigation into the spatial, temporal, and spectral nature of the observed X-ray emission. We utilise spectral analysis tools along with data from other co-observing sources (e.g., the Solar Dynamics Observatory) to start obtaining an unprecedented view into energy deposition throughout the solar atmosphere and flare particle acceleration via high-resolution images and spectra.

Broadband Emission
12 Aug 2025
14:05-14:25

Microwave Observations of a Non-thermal Above-the-Loop-top Source Associated with Supra-Arcade Downflows in an Eruptive Solar Flare

Sijie Yu[1]

[1]NJIT

Nonthermal emissions from the above-the-looptop (ALT) region in solar flares offer important diagnostics of particle acceleration driven by magnetic reconnection in the corona. We present preliminary results from a study of a nonthermal ALT source observed in microwave by the Expanded Owens Valley Solar Array (EOVSA) during an eruptive solar flare on 2022 January 18. Simultaneous EUV observations by SDO/AIA reveal supra-arcade downflows (SADs) in the same region, which are believed to be signatures of ongoing magnetic reconnection. We find a one-to-one correspondence between the arrival of SADs and the onset of nonthermal microwave emission in the ALT region, with the sources appearing co-spatial. The event was also observed by the STIX instrument onboard Solar Orbiter, providing complementary imaging of the thermal looptop and nonthermal footpoint sources. The hard X-ray emission from the footpoints appears to lag behind the onset of nonthermal microwave emission in the ALT region. We will discuss the implications of these findings for understanding particle acceleration and energy release in solar flares.

Energy-Containing Electrons in Solar Flares: Improving Hard X-ray and EUV Diagnostics

Broadband Emission
12 Aug 2025
14:25-14:45

Yingjie Luo[1]

[1]University of Glasgow

Solar flares effectively accelerate particles to non-thermal energies. These accelerated electrons are responsible for energy transport and subsequent emissions in hard X-rays (HXR), radio waves, and ultraviolet/extreme ultraviolet (UV/EUV) radiation. Due to the steeply decreasing spectrum of energetic electrons, the electron population and consequently the overall flare energetics, are predominantly influenced by low-energy non-thermal electrons. However, deducing the electron distribution in this energy-containing range remains a significant challenge. In this study, we apply the warm-target HXR emission model with kappa-form injected electrons to two well-observed GOES M-class limb flares. Moreover, we utilize EUV observations to constrain the flaring plasma properties, which enables us to unambiguously determine the characteristics of accelerated electrons across a range from a few keV to tens of keV, thereby obtaining the flare energetics. We demonstrate that the warm-target model reliably constrains the properties of flare-associated electrons, even accounting for the uncertainties that had previously been unaddressed. The application of a kappa distribution for the accelerated electrons allows for meaningful comparisons with electron distributions inferred from EUV observations, specifically for energy ranges below the detection threshold of RHESSI. Our results indicate that the accelerated electrons constitute only a small fraction of the total electron population within the flaring region. Moreover, the physical parameters, such as electron escape time and acceleration time scale, inferred from both the warm-target model and the EUV observations further support the scenario in which electrons undergo thermalization within the corona. This study highlights the effectiveness of integrating the warm-target model with EUV observations to accurately characterize energy-containing electrons and their associated acceleration and transport processes.

Wednesday, August 13

DKIST Invited Talk

DKIST Invited Talk

Invited Talk
13 Aug 2025
09:00-09:50

Gianna Cauzzi[1]

[1]National Solar Observatory

Abstract forthcoming.

Dynamic Magnetic Field

Dynamic Magnetic Field
13 Aug 2025
09:50-10:10

Detection of Rapid Coronal-Hole Boundary Reconfigurations Triggered by Reconnection-Driven Plasma Eruptions Using Correlation-Dimension Mapping

Eduardo Flandez[1]

[1]Universidad de Chile

Coronal jets are transient solar phenomena linked to energy release processes, with magnetic reconnection widely regarded as their likely origin. However, the precise timing and location of reconnection events remain uncertain. Furthermore, the geometric complexity of coronal hole (CH) boundaries, where these jets commonly arise, indicates a highly dynamic and spatially structured environment.

To investigate these issues, we combined AIA/SDO observations with the Correlation Dimension Mapping (CDM) technique. CDM quantifies geometric irregularities by calculating the correlation dimension along the CH boundaries, providing spatially resolved insight into their structural complexity.

We applied CDM to AIA image sequences taken between 22:00 and 23:59 UT, normalizing images by their maximum intensity for cross-channel comparability. Edge detection was performed using 8-point median smoothing with a threshold of 100 DN. Fractal dimensions were computed across several spatial scales, and the 6–25 pixel range was selected for its lower statistical uncertainty and greater physical relevance.

The resulting maps revealed non-uniform boundary complexity: highly structured regions were spatially localized, temporally variable, and correlated with jet activity. A comparison with intensity profiles from the 193 Å channel showed a temporal correlation between jet brightening and increases in the correlation dimension, suggesting that CDM may capture the local conditions favorable for reconnection.

To explore this further, we generated a CDM–time map by calculating the correlation dimension at each AIA time step (12-second cadence over two hours). This produced a time-resolved view of structural changes, where high-complexity regions appeared as distinct, trackable features. By retrieving and mapping the coordinates of these regions back onto the CH boundary, we identified several coronal jets.

These results indicate that CDM not only quantifies magnetic complexity but may also be useful for detecting the onset and location of coronal jets. Overall, this approach provides a novel, data-driven tool for probing small-scale dynamics at coronal hole boundaries and offers new insight into the mechanisms underlying solar jet formation.

Dynamic Magnetic Field
13 Aug 2025
10:10-10:30

Detection of High-Frequency Oscillation Power in the Magnetic-Field Polarity-Inversion Lines of Flaring Active Regions

Arman Manookian[1,2]

[1]New Jersey Institute of Technology, Newark, NJ, U.S.A [2]NASA Ames Research Center, Mountain View, CA, U.S.A.

Quasi-periodic oscillations are frequently recorded in the microwave and X-ray emissions during solar flares. Possible mechanisms include modulation of radiation emission by magnetohydrodynamic (MHD) waves and spontaneous quasi-periodic energy release. Using the Doppler velocity and magnetic field data from the SDO HMI instrument, we investigate the oscillation power maps in flaring active regions, including emerging active regions 13663 and 13664, which produced a series of strong flares in May 2024. These maps showed that the oscillation power is suppressed in magnetic field regions. However, it is enhanced along the polarity inversion lines (PIL) at low frequencies below 1 mHz and high frequencies at 6–11 mHz. This result suggests that enhanced photospheric magnetoconvection in the PILs excites high-frequency MHD oscillations that can propagate into the higher solar atmosphere and modulate the flare emissions. We discuss the temporal and spatial variations of the high-frequency oscillation power during the emergence and evolution of active regions and periods of strong solar flares.

High Cadence

Recent Results in High-Cadence Flare-Optimised X-ray and EUV Imaging and Spectroscopy

High Cadence
13 Aug 2025 10:50-11:05

Daniel Ryan[1]

[1]UCL/MSSL

X-ray and EUV emission from non-thermally accelerated particles and locally heated plasma are among the earliest observable signatures of magnetic reconnection and particle acceleration in solar eruptive events. Modelling over recent decades suggests that these processes occur on timescales of 0.1-1s. However, while high-frequency variations in spatially integrated X-ray flare emission have long been known, discerning between current models of reconnection and particle acceleration requires high-cadence imaging and spectroscopy of the X-ray and EUV sources. In this talk, we discuss some of the latest observational results in this area. These include the first flare-optimised, high-cadence (2s) EUV imaging taken with EUI/HRI as part of Solar Orbiter's recent flare campaigns, as well as the first 1s-cadence HXR spectroscopic imaging, taken with Solar Orbiter/STIX of the estimated X-16.5 GOES class flare of 2024-05-20. We also discuss implications of these achievements for future mission concepts that aim to elucidate the magnetic reconnection and particle acceleration in solar eruptive events.

Flare-Associated Fast-Mode Coronal Wave Trains: Observational and Modeling Advances

High Cadence
13 Aug 2025 11:05-11:20

Wei Liu[1,2]

[1]Bay Area Environmental Research Institute [1]Lockheed Martin Solar and Astrophysics Laboratory

Quasi-periodic, Fast-mode Propagating wave trains (QFPs) are one of the new observational phenomena discovered by the SDO/AIA instrument by direct imaging in extreme ultraviolet (EUV). They are fast-mode magnetosonic waves closely related to Quasi-Periodic Pulsations (QPPs) in solar flare emissions, ranging from radio to X-ray wavelengths, that have been observed for decades yet with little to no imaging information. The significance of QFPs lies in their diagnostic potential, by providing the critical imaging linkage to QPPs and thus clues to flare energy release, and by serving as new tools for coronal seismology to probe the physical conditions of the solar atmosphere. We report here recent advances in observing and modeling QFPs. Specifically, we performed a statistical survey of QFP events over the 15-year long SDO mission. We found that a large fraction of global EUV waves (the so-called EIT waves), on the order of ¿100 events, have QFPs present. There is also a preferential association of QFPs with eruptive flares (e.g., those associated with CMEs) rather than confined flares (those without CMEs). In addition, we performed data-constrained 3D MHD simulations of selected QFP events. We constructed waveguides by increasing the plasma density and thus reducing the local Alfven speed in fan loops (where QFPs are observed) in the flaring active region, and applied localized periodic perturbations to excite QFPs. We found that QFPs are present throughout the local and ambient corona, but their detectability and morphology vary significantly with the spatial distribution of the Alfven and thus fast-mode speeds, the observer's viewing angle (thus LOS integration), and the observing wavelength channel (thus the temperature of the emitting plasma). This can potentially explain the long-standing puzzle of two morphologically distinct types of QFPs: those seen in the 171A channel within funnel-shaped fan loops, and those seen in the 193A channel traveling along the solar limb to further distances. We will discuss the implications of these results and the potential roles played by QFPs in coronal heating, energy transport, and solar eruptions in general.

High Cadence
13 Aug 2025
11:20-11:35

Emission and Dynamics of Hard X-ray Footpoints and Flare-Ribbon Kernels: Insights from STIX and IRIS Observations

Juraj Lorincik[1]

[1]BAERI/LMSAL

Solar flare ribbons and hard X-ray (HXR) footpoint sources are valuable probes of magnetic reconnection, the driver of solar flares. Their dynamics, inferred from direct imaging and source reconstruction, respectively, can however appear inconsistent. Our study is focused on high-cadence IRIS and STIX observations of an M9.6-class flare from March 31 2022. Non-thermal emission observed by STIX exhibited quasi-periodic pulsations (QPPs) with dominant footpoint sources in the brightest central region of the flare with minimal dynamics. Most of the STIX QPPs are correlated with intensity response captured by the Slit Jaw Imager (SJI) of IRIS in ribbon segments corresponding to the HXR footpoint sources. SJI, however, also observed apparent motions of flare kernels driven by slipping reconnection which are difficult to associate with the STIX QPPs. This is because the earliest signatures of the slipping motions set on several minutes before the STIX QPPs, occurring in a ribbon subregion outside of the strongest HXR footpoint sources. Our observations suggest a weaker non-thermal energy deposition rate (per area and time) by the apparently-slipping flare kernels, in contrast to stronger deposition to brighter, more stationary ribbon segments where the dominant sources of the STIX non-thermal emission were located. Spatial distribution of the squashing factor was analyzed to study potential correlation between the location of the strongest HXR footpoint sources and connectivity gradients within the flaring region. We found that the dominant sources, and hence the strongest deposition, occurred near the reconnection site at the intersection of quasi-separatrix layers. In contrast, the kernel slippage occurred further away from the reconnection site and directed away from it.

Atmospheric Response

Atmospheric Response
13 Aug 2025
10:50-11:05

Spectro-Polarimetric Properties of White-Light Flare Kernels and Sunquake Sources

Alexander Kosovichev[1]

[1]New Jersey Institute of Technology

The white-light flare kernels observed during the flare impulsive phase are often associated with substantial photospheric impacts producing helioseismic waves ('sunquakes'). The current beam-heating flare models do not currently explain such impacts. To gain insight into the properties of white-light kernels and sunquakes, we conduct a detailed analysis of the Stokes profiles of the Fe I 6173 Å line, reconstructed from the HMI linear and circularly polarized filtergrams. The results show rapid variations in continuum emission, with a fast growth and slower decay lasting a few minutes, coinciding in time with the hard X-ray impulses. The variations in the line core appeared slightly ahead of the variations in the line wings, showing that the heating started in the higher atmospheric layers and propagated downward. The most significant feature of the line profile variations is the transient emission in the line core, indicating intense, impulsive heating in the lower chromosphere and photosphere. In addition, the observed variations of the Stokes profiles reflect transient and permanent changes in the magnetic field strength and geometry in the white-light flare kernels and sunquake sources.

Modeling

Spatial Variation of Energy-Transport Mechanisms in Solar Flares

Modeling
13 Aug 2025
13:30-13:50

Graham Kerr[1]

[1]Catholic University of America [1]NASA GSFC

Solar flares release a tremendous amount of magnetic energy that subsequently manifests in several forms, the bulk of which is transported through the Sun's atmosphere where it explosively heats the chromosphere. While hard X-ray observations have pointed to flare accelerated non-thermal energetic electrons as a primary means by which energy is transported following flares, other processes likely play a role. To shed light on this we analysed flare-optimised, high-cadence Solar Orbiter observations. Footpoints from two flare ribbons were observed, including by the SPICE instrument, who's slit crossed a footpoint from each ribbon. Curiously, they exhibited rather different behaviour: one had short-lived yet strong decreases of the Ly beta to Ly gamma intensity ratio whereas the other exhibited more prolonged, moderate dip of that ratio. These behaviours were interpreted via radiation hydrodynamic simulations of flares driven by non-thermal electrons, non-thermal protons, and by thermal conduction alone. Synthetic Ly beta to Ly gamma ratios demonstrated that the stronger source was consistent with energetic particle precipitation, whereas the weaker source was more consistent with an enhanced heat flux. This study demonstrates that energy transport along solar flare ribbons is neither uniform nor dominated by a single process.

Energy Conversion and Particle Acceleration and Transport in 3D Simulations of Solar Flares

Modeling
13 Aug 2025
13:50-14:10

Xiaocan Li[1]

[1]Los Alamos National Laboratory

Recent observations and simulations indicate that solar flares undergo complex 3D evolution, making 3D particle transport models essential for understanding particle acceleration and interpreting flare emissions. We address this challenge by coupling energetic-particle transport equations with 3D MHD simulations of flares. Our analysis of energy conversion within the 3D system clarifies the contributions of key acceleration sites: the reconnection current sheet (CS), the termination shock (TS), and supra-arcade downflows (SADs). We find that large-amplitude turbulent fluctuations are generated and sustained in the 3D system. The particle modeling results demonstrate that a significant number of particles (both electrons and protons) are accelerated to high energies, forming power-law energy spectra. These energetic particles are widely distributed, with concentrations at the TS and in the flare looptop region, consistent with results derived from recent HXR and MW observations. By selectively turning particle acceleration on or off in specific regions, we find that the CS and SADs effectively accelerate electrons to several hundred keV, while the TS enables further acceleration to MeV. However, no single mechanism can independently account for the significant number of energetic electrons observed. Instead, the mechanisms work synergistically to produce a large population of accelerated electrons. Our model provides spatially and temporally resolved electron distributions in the whole flare region and at the flare footpoints, enabling synthetic HXR and MW emission modeling for comparison with observations. These results offer important insights into particles acceleration and transport in 3D solar flare regions.

Modeling
13 Aug
2025
14:10-14:30

Two-Zone Fokker–Planck Approach for Modeling the Time Evolution of Non-thermal Emissions in Solar Flares

Shunsaku Nagasawa[1]

[1]SSL/UC Berkeley

The time evolution of non-thermal emissions in solar flares provides critical insights into the underlying particle acceleration and transport mechanisms. In particular, a Soft-Hard-Soft (SHS) spectral variation in hard X-rays, where the power-law index hardens as the flux increases toward the peak, then softens as the flux decreases, has been frequently observed in solar flares. This behavior is believed to reflect underlying particle acceleration or energy losses, but the detailed description of these processes is still missing. During the impulsive phase of the M7.6-class flare on July 23, 2016, we identified a characteristic pattern seen in the plane X-ray flux – spectral index. The spectrum is harder during the rising phase than during the decay phase characterized by the same flux level, thus with time the flare parameter follow a clockwise trajectory in this plane. Similar asymmetric temporal evolution has also been reported not only in other solar flares (Grigis+2004) but also in blazar-type sources (Takahashi+1996), providing new constraints on the acceleration and transport processes of non-thermal electrons in broader high-energy astrophysical environments. In this study, we develop a time-dependent two-zone model to investigate the mechanisms responsible for this spectral evolution. The model consists of two distinct regions: zone-1, representing the flare loop-top where non-thermal electrons are injected and undergo energy losses via Coulomb collisions, bremsstrahlung, or synchrotron radiation; and zone-2, representing the flare footpoints where electrons accumulate after escaping from zone-1 and emit bremsstrahlung photons. The energy-dependent escape timescales from zone-1 to zone-2 include scenarios such as direct propagation and pitch-angle deflection. Using numerical approach based on the Fokker-Planck equation, we perform a systematic analysis of the time evolution of electron distributions and synthetic hard X-ray spectra for various loss and escape conditions. While the two-zone model captures key aspects of electron transport and cooling, we find that it alone cannot reproduce the observed clockwise pattern under the assumption of fixed injected spectrum of accelerated electrons. This suggests that dynamic changes in the properties of the injected electron population, specifically simultaneous variations in both spectral slope and flux, are crucial for reproducing the observed clockwise behavior, which is likely a signature of changes in the acceleration process itself rather than solely due to cooling and transport effects. This work provides a framework for interpreting future high-sensitivity, spatially resolved hard X-ray observations and contributes to a deeper understanding of flare-associated particle acceleration.

Modeling
13 Aug
2025
13:30-13:50

3D Radiative MHD Modeling of Particle-Beam Heating in the Impulsive Phase of Solar Flares

Samuel Granovsky[1,2]

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While solar flares are, in general, most associated with enhanced UV and X-ray emission, certain flares are accompanied by significant increases in continuum visible light emission. Accordingly, these flares are referred to as white-light flares (WLFs). Despite advances in observational capabilities, the precise mechanisms responsible for the compact, short-lived brightening in WLF kernels remain uncertain. Spectroscopic and photometric studies suggest that the observed white-light emission originates from localized heating of the lower chromosphere and upper photosphere. However, traditional thick-target models of solar flares, which rely on energy deposition by electron beams, struggle to explain WLFs. According to these models, most of the energy carried by these beams is deposited in the upper chromosphere as

the precipitating electrons do not carry enough power to produce meaningful effects in the photosphere at realistic beam energies. This has led to growing interest in high-energy protons as an alternative or complementary mechanism for energy transport. We investigate the mechanism for photospheric heating through the development of realistic 3D radiative MHD simulations of precipitating electron and proton beams using using the Stellarbox code. The computational domain encompasses the solar subsurface and atmosphere, extending from z = -10 Mm to +15 Mm at various magnetic field strengths. After computing the corresponding hydrogen populations and electron densities, we then use the RH 1.5D code to compute Stokes parameters for the HMI 6173 Å line for comparison with HMI observations of WLFs. In addition, we compare these 3D Stellarbox models and corresponding Stokes parameters with results from previous 1D RADYN models.

Thursday, August 14

A Novel Electron Fermi-Acceleration Mechanism in Magnetic Reconnection Across a Broad-Range Guide Field

Energization
14 Aug 2025
09:00-09:15

Haihong Che[1]

[1]University of Alabama in Huntsville

Over the past five years, my group has developed a unified and efficient electron Fermi-acceleration mechanism in magnetic reconnection, applicable across a broad range of guide field strengths relevant to solar flare observations. In low guide field regimes (Bg/B0 < 2.5), electrons are accelerated by expanding vortices generated by the electron Kelvin-Helmholtz instability. Our work reveals that these vortices can also excite a new Alfvénic electron Fermi-acceleration process in high guide field regimes (Bg/B0 > 2.5), enabling a stransition in acceleration as the guide field strength increases in solar flares.

This mechanism exhibits several distinctive features:

1. It can reproduce key observational signatures of solar energetic electrons within the short timescales needed to overcome collisional energy losses (e.g., power-law energy spectra within ¡1 s).

2. It explains the two-stage evolution of electron energy spectra observed in solar flare events.

3. As the guide field increases, the transition from vortical to Alfvénic acceleration corresponds to a shift from two-stage to single-stage spectral evolution—a novel and testable feature in solar energetic electron production.

Despite its relevance, this work has not yet gained broad recognition within the solar physics community. I would therefore like to present a plenary talk at the workshop to introduce this new mechanism and receive feedback from colleagues. I am also seeking new collaborations to further develop and expand this model.

This work is supported by NSF CAREER and NASA Heliophysics ECIP program.

Energization
14 Aug 2025
09:15-09:30

A Universal Scaling Law for Particle Energization in Plasmas

Mitsuo Oka[1]

[1]University of California, Berkeley

Particles are energized — heated and accelerated to nonthermal energies — in laboratory, space, solar, and astrophysical plasma environments. While it is well established that fundamental plasma processes such as shocks and magnetic reconnection play crucial roles in particle energization, the precise mechanisms of energization and associated partitioning of energy between ions and electrons remain unclear. Here we show, based on coupled theoretical and observational scaling analyses, that a simple formula $\Delta\varepsilon = qVBL$ can universally explain plasma energization, where $\Delta\varepsilon$ is the particle energy gain, q is the particle charge, V is the bulk flow speed, B is the magnetic field strength, and L is a characteristic spatial scale. A key point here is that different choices of L yield predictions for different observables. For example, taking L as the system size predicts maximum particle energies, whereas using a kinetic scale leads to predictions for heating (temperature increase ΔT) in shocks and magnetic reconnection regions, for both ions and electrons. Our preliminary results suggest that this scaling law is applicable across a wide range of environments, from solar flares to supernova remnants and planetary magnetospheres, although some assumptions and outliers introduce limitations.

High Energies

High Energies
14 Aug 2025
09:30-09:45

Probing the Puzzle of the Fermi-LAT Long-Duration Solar Flares: A CME-Shock View

Meng Jin[1]

[1]Lockheed Martin Solar & Astrophysics Lab

The growing number of long-duration, ¿100 MeV gamma-ray flares detected by Fermi/LAT presents a challenge to our understanding of particle acceleration and transport in solar eruptive events. Particularly puzzling are behind-the-limb events, where the gamma-ray emission originates tens of degrees away from the flare site, and flares in which the emission centroid migrates across the solar disk for hours after the impulsive phase. In this study, we investigate the CME-driven shock scenario, where particles are accelerated at CME-driven shocks and then propagate back to the solar surface to produce gamma-rays. We focus on several well-observed long-duration Fermi events and employ the data-driven global magnetohydrodynamic Alfven Wave Solar Model (AWSoM) to simulate the evolving global coronal magnetic field during each eruption. This allows us to assess the magnetic connectivity between the CME-driven shock and the gamma-ray emission regions observed by Fermi. To understand particle transport, we calculate the proton scattering mean free path in the downstream of the shock and estimate the energy-dependent escape times of protons traveling back to the solar surface, using outputs from the MHD simulations. Our results indicate that the CME-driven shock and its interaction with the large-scale coronal magnetic field play a critical role in sustaining long-duration gamma-ray emission. This supports the hypothesis that high-energy particles responsible for these events are not confined to the flare site, but instead are accelerated and redistributed through large-scale coronal processes associated with CME shocks. These findings offer new insight into the origins of long-duration gamma-ray flares and suggest a potential shift of paradigm on particle acceleration in solar eruptive events.

Over-the-Pole Shock Propagation and Precipitation of High-Energy Protons to Produce Sustained Gamma-Ray Emission on 14 February 2024

High Energies
14 Aug 2025
09:45-10:00

Nat Gopalswamy[1]

[1]NASA Goddard Space Flight Center

On 2024 February 14, the Large Area Telescope (LAT) onboard the Fermi mission observed a sustained gamma-ray emission (SGRE) from the Sun in association with a backside eruption originating from S36W160. Among the handful of behind-the-limb eruptions that resulted in a Fermi/LAT SGRE event, the 2024 February 14 event has the farthest central meridian distance (160^{o}). We identified the source location by tracking NOAA AR 13575, which produced the previous SGRE event on 2024 February 9 when it was at the west limb. In longitude, this event is farthest from the west limb (70^{o}). However, the source latitude is at S36, which means, the south limb is only 54^{o} away. This suggests that the protons are precipitating to the frontside over the south pole. The eruption was frontsided for Parker Solar Probe, so it observed a large solar energetic particle (SEP) event and an intense interplanetary type II radio burst in association with an ultrafast (2200 km/s) backside SOHO/STEREO halo coronal mass ejection (CME). An IP type III lasted for 35 min indicating the presence of a long-duration flare. The early life of the CME was revealed by SDO's Atmospheric Imaging Assembly and GOES/SUVI images followed by an EUV wave that appeared on the frontside over the poles around the time of the SGRE event (04:00-04:36 UT). These observations provide a complete set of characteristics of an SGRE-associated eruption that is consistent with shock accelerated protons back-propagating to the Sun resulting in gamma-rays.

Transport of High Energy Particle in Turbulent Plasma with Strong Guiding field: Application to CME-shock Environments and Fermi Gamma-ray Observations

High Energies
14 Aug 2025
10:00-10:15

Vahe Petrosian[1]

[1]Stanford University

Fermi-Large Area Telescope (LAT) has detected long-duration gamma-rays from flares associated with fast CMEs, several of which originated behind the limb (BTL) of the Sun. We investigate the scenario for these events, whereby protons accelerated at the coronal mass ejection (CME) shock are transported from the downstream of the shock to the photosphere. We use results from the global MHD modeling of the CME of 2014-Sep-1 BTL flare, by the Alfvén Wave Solar Model (AWSoM), to obtain the characteristics of the downstream plasma, such as magnetic field geometry, Alfvén speed, and energy density of turbulence, that are required to treat the transport of the particles. This allows us to evaluate the variations of the proton scattering mean free path with energy and distance from the CME. Using an approximate analytic relation between the relevant time scales of the transport, we determine the energy dependence of the residence time at (or escape time from) different distances above the photosphere, and determine the evolution of the proton spectrum from the acceleration site to the photosphere. These results can be used to obtain the spectrum of the observed gamma-rays. Inversely, the spectrum of protons at the photosphere, obtained from the observed gamma-rays, can be "de-evolved" back to the CME using the same algorithm. Comparison of these spectra with the in-situ observations of Solar Energetic Particles (SEPs) can also shed light on their transport from the CME to the Earth.

Small Events

Small Events
14 Aug 2025
10:40-10:55

Revisiting the Original RHESSI "Wee" Hard Microflare

Iain Hannah[1]

[1]University of Glasgow

RHESSI observed 10,000s of microflares (GOES A,B class events) demonstrating particle acceleration and heating like larger events (Christe et al. 2008, Hannah et al. 2008). But one microflare proved to be very "intriguing" as it had a photon power-law spectrum of index -2.4 to remarkably high energies (¿50 keV), even though it was a low A-class microflare (Hannah et al. 2007). Recently dozens of these "hard microflares" have been found with Solar Orbiter on STIX (Battaglia et al. 2024), showing similar efficiency at accelerating electrons to high energies, as well as a possible magnetic setting for this behaviour. Here we present a reanalysis of the original RHESSI wee hard microflare, not only in the context of the STIX work, but also using more advanced approaches than the 2007 paper – particularly in terms of the X-ray spectral fitting to determine the properties of this non-thermal energy release. This will then be used to investigate how the solar atmosphere responds to such an energy input through RADYN simulations, helping to understand the energy transport and deposition.

Small Events
14 Aug 2025
10:55-11:15

A Statistical Survey of Faint Solar X-ray Transients Observed by NuSTAR

Reed Masek[1]

[1]University of Minnesota

X-rays are closely linked to the initial energy release and immediate heating of flares, making them invaluable in understanding their driving processes. Transient events weaker than GOES B-class, such as microflares, are understudied in X-rays relative to more energetic flares due to sensitivity limitations of solar-dedicated instrumentation. NuSTAR is the first direct focusing, hard X-ray observatory to have observed the Sun, offering a unique opportunity to search for and characterize X-ray events from within and external to active regions that would be otherwise unobservable.

We present the first statistical survey of NuSTAR solar observations, characterizing weakly energetic X-ray transients down to $10^2$6 erg, currently making this the most comprehensive analysis of the faintest-observable X-rays transients. Using an automated identification algorithm, we have cataloged 110 solar transients observed by NuSTAR using X-rays in the 2.5 - 12 keV range across over 200 hours of observations of active and quiet Sun conditions. The thermal and possible nonthermal properties of each transient were characterized through spectral fitting, and we compared the properties of transients found within active regions to those found under quiescent conditions. We also compared the frequency distributions of our transients to those found by other instruments, showing excellent agreement with RHESSI before quickly turning over due to suspected instrumental or methodological sensitivity limitations. Relative to RHESSI microflares, our NuSTAR transients are generally cooler, dimmer, and have slightly steeper spectra as a consequence of their lower thermal energy content. However, thermal energy content of the transient appears to be independent of the volume of emitting plasma for transients produced by active regions. This is in contrast to those from the quiet corona, which on average have lower energy content, smaller emission volumes, and appear cool but bright rather than hot but dim, suggesting a break in trends from traditional microflares.

Quiescent active regions

Temperatures, Emission Measures, and Elemental Abundances of the Quiescent Sun Using DAXSS Data

Quiescent active regions
14 Aug 2025 11:15-11:35

Bennet Schwab[1]

[1]UC Berkeley/SSL

The physical properties of the quiet sun have long been studied, but are often outshined by the brighter active regions on the solar disc. These DAXSS data analyzed are not perfectly "quiet" but are quiet-like, or quiescent, and peer into what the steady state of the non-flaring sun looks like. Non-flaring conditions are important since they are the baseline for change during solar activity. We can then see how events such as solar flares and active region evolution deviate from the background of the quiescent sun. These analyses of temperature, emission measure, and elemental abundances using DAXSS data were conducted using the quietest periods of the downlinked DAXSS data so far. Three temperatures, Three emission measures, and elemental abundances of Mg, Si, S, and Fe are investigated in this solar spectral fitting model.

Discovery of a New Hot Component in a Giant Arcade Formed in a Quiet Region Using FOXSI-3 Soft X-ray Focusing Imaging Spectroscopic Observation

Quiescent active regions
14 Aug 2025 11:15-11:35

Tadashi Hirose[1]

[1]Graduate University for Advanced Studies / NAOJ

The third flight of the Focusing Optics Solar Imager (FOXSI-3) is a sounding rocket experiment for focusing-imaging spectroscopy of the Sun in X-rays. It was launched on September 7, 2018, and observed the entire solar disk through several pointings over approximately six minutes. The CMOS detector onboard FOXSI-3 achieved the first focusing imaging spectroscopic observation in soft X-rays (0.8-5keV). Although the hard X-ray detector onboard FOXSI-3 did not detect high-energy photons of above 5keV (Butrago-Casas et al. 2022), the CMOS detector recorded approximately ten million soft X-ray photons and observed entire solar disk including a large arcade structure known as a Giant Arcade. This Giant Arcade is approximately 200 Mm in length and formed in association with a filament eruption in a quiet region that occurred approximately 6 hours prior to the FOXSI-3 observation. Giant Arcades are large arcade structures often visible in soft X-rays (SXR) after filament eruptions. Their observations were actively conducted using Yohkoh/Soft X-ray Telescope (SXT) in the 1990s (e.g., McAllister et al. 1992). Yamamoto et al. (2002) reported that their peak temperatures are between $1.8 - 4.4$ MK and the density is about $10^8 cm^{-3}$. That is, the temperature is higher than the quiet corona, and the density is comparable to the quiet corona. We analyzed the temperature and density of a Giant Arcade using SXR imaging spectroscopic data from FOXSI-3 and identified three distinct temperature components: an approximately 2.5 MK component, a background component, and a newly discovered hot component. The first and second components are consistent with previous results by Yohkoh/SXT. In addition to these components, we discovered a new hot component with a temperature exceeding 7MK and density about one order of magnitude lower than that of the surrounding corona. This discovery clearly demonstrates the advantage of SXR imaging spectroscopy. In contrast, this hot component could not be detected by the Hinode/X-Ray Telescope, which employs broadband SXR filters similar to those used in Yohkoh/SXT, likely due to the low density of the hot component. An investigation of the spatial distribution of this hot component showed that it is predominantly located near the apex of the arcade. Based on its spatial distribution and high temperature, we consider that the hot component was heated by the reconnection outflow. This can be the crucial evidence that the Giant Arcade is generated by the magnetic reconnection. In this presentation, we report these findings in detail.

Coronal Electrons

Coronal Electrons
14 Aug 2025
13:30-13:45

Solar Flares Host MeV-Peaked Electrons in a Coronal Source

Gregory Fleishman[1]

[1]NJIT

Solar flares promptly release large amounts of free magnetic energy in the solar corona to produce substantial populations of high-energy charged particles, both ions and electrons. These particles are detected when they radiate microwaves in solar magnetic fields and X- and γ-rays when they encounter matter. Analysis of γ-rays in solar flares has revealed a distinct population of electrons peaking at energies of a few MeV, which is spectrally, temporally, and directionally distinct from the well-studied flare-accelerated electrons with steeply falling energy spectra. The origin and precise spatial location and extent of this mysterious MeV component have been unknown up to now. Here we report a joint study of this MeV-peaked electron population in the 2017-Sep-10 solar flare with *Fermi* MeV γ-ray data and EOVSA spatially resolved microwave imaging spectroscopy data. We demonstrate that the microwave spectrum from the peaked MeV distribution has a distinctly different shape from that produced by the well-known population of electrons with falling energy spectrum. We inspected microwave maps of the flare and identified an evolving area where the measured microwave spectra matched the theoretically expected one for the MeV-peaked population, thus pinpointing the site where this MeV component resides in the flare. The locations are in a coronal volume adjacent to the region where prominent release of magnetic energy and bulk electron acceleration were detected, which implies that transport effects play a key role in forming this population.

Coronal Electrons
14 Aug 2025
13:45-14:05

Observations and Modeling of Solar-Flare Energetic Electrons in Hard X-ray, Radio, and In-Situ Near 1 AU

Yuankun Kou[1]

[1]Nanjing University

Magnetic turbulence in the interplanetary space effectively influences the transport of energetic electrons. However, there lacks a systematic investigation on the electron-energy dependence of the turbulent scattering. In this work, we collect in-situ energetic electron events ($27 - 310$ keV) over the years from 2002 to 2024, and present the statistical energy relationships of the rise and decay time of their flux profiles as well as the time delay of their traveling relative to the free-flying time. We find that the observed rise, decay, and delay time are in the range of 100-600 s, 100-3000 s, and 200-2000 s, respectively; both the rise and delay time are lower at the higher electron energy, showing the power-law trends with the index of -0.45 and -0.12, respectively. But the decay time does not show monotonic relationships with the electron energy. From modeling and numerical simulations, we find that the turbulent scattering is dependent on both the distance from the Sun and the electron energy, with the diffusion coefficient $D_{\mu\mu} \sim z^{-1}E^{0.6}$; the scattering mean free path near the Earth lies in the range of 0.6 to 11 AU.

Heliospheric connection

On the Parker Solar Probe's Discovery of New Populations of Accelerated Ions in Impulsive Solar Flares

Heliospheric connection
14 Aug 2025
14:05-14:25

Samer Alnussirat[1]

[1]SSL / UC Berkeley

Recent observations conducted by Parker Solar Probe (PSP) have provided new insights into particle acceleration and transport during impulsive solar flare events. In this talk, I will present the PSP discovery of a new set of ion populations, specifically accelerated protons, alphas, and heavy ions, originating from impulsive solar flares at energies less than 30 keV/nuc. These newly measured populations of accelerated particles cannot be observed in the X- or gamma-ray energy bands. Moreover, this discovery will enable, for the first time, the constraining of the low-energy cutoff and the estimation of the total energy carried by accelerated ions.

Properties of Energetic Particles in the Sub-Alfvénic Solar-Wind Flow Observed by Parker Solar Probe

Heliospheric connection
14 Aug 2025
14:25-14:45

Prachi Pathare[1]

[1]UTSA-SwRI

Coronal Mass Ejections (CMEs) can drive shock waves that accelerate particles to near-relativistic energies. Suprathermal (ST) ions could serve as candidate seed populations for CME-driven shocks that produce large gradual solar energetic particle events.

The CME shock acceleration process begins as low as 2 Rs, understanding the properties of the ST ion populations within the Alfvén surface (¡10 Rs) is key to understanding the physics of the CME shock acceleration process in the near-Sun magnetically dominated environment. Since Perihelion 8, Parker Solar Probe (PSP) has repeatedly entered the sub-Alfvénic solar wind regime (Sub-Alfvénic solar wind, characterized by solar wind speed slower than the Alfvén speed), providing in situ observations of ST ions in this near-sun magnetically dominated environment.

In this study, we survey ST ions properties such as intensity-time profiles, velocity dispersion and pitch-angle distributions during the time intervals when PSP sampled the sub-Alfvénic solar wind flow. We initiated this study by identifying time periods where the Alfvén speed exceeds the solar wind speed during each PSP perihelion (from 8-21). Subsequently, we analyze the spectral properties of energetic particles during these time intervals and their phase space densities (PSDs). This comprehensive approach could provide insights into the pre-acceleration conditions relevant for gradual SEP events and space weather forecasting.

Mission Enabling

Mission Enabling
14 Aug 2025
15:10-15:30

Analysing STIX Data with sunkit_spex, a Python Package for Solar X-ray Spectroscopy

Jake Mitchell[1]

[1]Leibniz Institute for Astrophysics (AIP)

Sunkit-spex is a Python based package for solar X-ray spectroscopy that is currently under development. The main aim is to produce an open development, open source, python-first package that is able to provide the necessary framework and solar specific models to fit the current needs of the high-energy solar physics community whilst remaining flexible enough to support use cases presented by future missions. High energy spectroscopic analysis requires the use of instrument specific non diagonal response matrices to convert physical models from photon spectra to instrument modelled count spectra that can then, through forward fitting and other methods, be fit to observed data. This requires the use of a dedicated software package, several of which already exist (e.g., OSPEX or XSPEC) and are widely used by the community. However, none of these packages allow for simultaneous fitting of multiple datasets, provide necessary solar specific models, support time resolved spectroscopy and solar specific data products and have an easy installation procedure. Sunkit-spex has the capability to address all of these requirements and more. Through the creation of a generic data container, based on NDcube, Sunkit-spex aims to remain agnostic to a wide range of data products from existing and future missions whilst also aligning with the Astropy and Scipy modelling APIs allowing for user friendly yet flexible forward fitting methodologies. Sunkit-spex can also facilitate the usage of custom analytical tools and techniques such as MCMC and other Bayesian methods or integration with existing machine learning libraries. Here I will present some initial results obtained with Sunkit-spex focused specifically on the analysis of STIX data.

Mission Enabling
14 Aug 2025
15:30-15:50

Real-Time Early-Flare Alert System for Sounding-Rocket Solar-Flare Campaigns

Julia Vievering[1]

[1]Johns Hopkins Applied Physics Laboratory

Understanding when and where a solar flare will occur continues to be an important goal for the heliophysics community, relevant to fundamental research, coordinated flare observations, and space weather applications. Flare forecasting products have typically included long-term probabilistic forecasts (e.g., probability that a flare of a given size will occur over a given time period) and flare alerts (e.g., notification when the flare flux has already reached a high level). For a wide variety of research and operational purposes, there is an additional need for an early flare alert system to anticipate large and long-lasting flares that is more actionable than long-term forecasts and provides earlier notice than current flare alerts. Such a tool would enable triggered observations of the early stages of solar flares, a crucial capability for demonstrating novel instrumentation optimized for solar flares via sounding rockets and other observing campaigns targeting flares. With this goal in mind, a collection of tools was developed and implemented for the first sounding rocket solar flare campaign in April 2024, which featured a suite of novel solar X-ray and EUV instruments onboard the FOXSI-4 and Hi-C Flare experiments. These tools leveraged near-real-time solar imaging and irradiance measurements from SDO/AIA, GOES/XRS, SDO/EVE/ESP, and EOVSA to determine when to launch to observe a large solar flare (¿C5 class). Here we present on the real-time early flare alert system which supported these sounding rocket teams through a successful solar-flare-triggered sounding rocket launch and plans for continued development of these tools for upcoming campaigns.

Machine-Learning-Driven Solar-Flare Nowcasting for the FOXSI-5 Sounding-Rocket Campaign

Mission Enabling
14 Aug 2025
15:50-16:10

Marianne Peterson[1]

[1]University of Minnesota

In April 2024, NASA's solar flare sounding rocket campaign successfully observed the decay phase of an M1.6-class flare with the Focusing Optics X-ray Solar Imager (FOXSI)-4 and the High Resolution Coronal Imager (Hi-C) Flare telescopes. The two rockets performed a triggered launch within a 4-hour daily window over two weeks, targeting large flares (¿C5) using a custom-built suite of flare nowcasting tools. These tools identify optimal launch conditions for high success rates, and enable real-time flare location tracking and duration prediction. Central to deciding when to start the launch countdown was a statistically derived flare trigger based on GOES XRS data, designed to identify launch conditions most likely to yield successful observations for both payloads, taking into account the inherent timing of the launch. Building on this success, FOXSI-5 is set to launch winter 2025/2026 in a second solar flare sounding rocket campaign, providing the opportunity to improve upon the existing flare trigger, specifically with the goals of increasing precision and enabling more impulsive-phase observations.

We present an expansion of the flare trigger work, integrating machine learning (ML) to predict GOES XRS magnitudes within a timeframe actionable for sounding rocket observations. Using the same dataset of ∼12,000 GOES XRS flares, we trained gradient-boosted tree models with engineered features derived from the previous flare trigger statistical study. The models predict maximum GOES XRSB flux levels 8-14 minutes into the future, with both binary (>C5) and multi-class (<C5, C5-M1, M-class, X-class) predictions. Optimized for precision, the models often outperform the original flare trigger in terms of early warning, while achieving comparable precision scores. Unlike the flare trigger, which occurs at any point once its conditions are met, our ML framework consists of a model for each minute of the flare, centered around the GOES start time. This structure enables analysis across different stages of flare evolution—from pre-flare to early impulsive and peak phases. Analysis of how feature importance evolves over time is currently underway, aiming to connect the ML models' predictive decisions to underlying physical processes. We present the ML model design, training methodology and performance metrics, as well as initial interpretations of the results in the context of their relevance to early-flare physics. We also demonstrate the integration of these models into a real-time interface, to be used as an additional tool in the FOXSI-5 launch campaign

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Friday, August 15

Missions

Missions
15 Aug
2025
09:00-09:15

High-Resolution ALMA Observations of Solar Flares

Stephen White[1]

[1]AFRL

ALMA offered the first opportunity for circular polarization measurements of solar emission at millimeter wavelengths in 2024, and observations of active regions were obtained in May. Serendipitously, several flares were observed in the course of these observations: with a resolution of 1 arcsec and superb image quality, these are among the best radio images of flares ever obtained. While the observations were not designed with flares in mind and therefore are not ideal for detailed study, the data still provide remarkable results. This talk will briefly discuss the data for an M2 flare on May 5 and an X1 flare on May 9, exhibiting quite different behaviors.

Missions
15 Aug
2025
09:15-09:30

Observing Flares at Mid-IR

Guillermo Giménez de Castro[1]

[1]UCentro de Rádio Astronomia e Astrofisica Mackenzie (CRAAM), Sao Paulo, Brazil

The mid-infrared (mid-IR) range, spanning from 10 THz (30 μm) to 60 THz (5 μm), has recently become accessible for solar flare observations. Under quiet Sun conditions, mid-IR continuum emission is primarily thermal bremsstrahlung originating from below the temperature minimum region. If the same mechanism applies to flares, studies suggest that the emission may also originate from the lower chromosphere at approximately 1100 km. Therefore, mid-IR observations are crucial for understanding energy transport from the upper atmospheric layers, where magnetic energy is released, to the lower layers, and are a direct diagnostic of local plasma temperature.

Since 2011, the Mackenzie Center for Radio Astronomy and Astrophysics (CRAAM) has been monitoring the Sun using small-aperture telescopes and commercial room-temperature detectors at (10 ± 2.5) µm. Currently, it operates two telescopes: SP30T in São Paulo, Brazil, and AR30T in Argentina. Both telescopes have detected multiple solar flares, ranging from GOES B to X class. When data are available, the light curves show a strong correlation with white-light emissions and the continuum at 160/170 nm. Accelerated particles have been shown as the primary energy transport mechanism during X-class flares. However, for weak B- and C-class flares, when no evidence of accelerated particles is present, heat conduction appears to be a good mechanism. Additionally, other energy transport mechanisms, like Alfvén waves, should be considered for the chromospheric heating.

In this work, we present a summary of the observations and analysis from a dozen events, and future perspectives. These include the new full sun photometer for 20 μm (15 THz) HATS which is in commissioning since April this year, and quantum sensors for the mid-IR, that were used to observe the sun with the McMath-Pierce telescope at Kitt Peak and now are installed in the Goode Solar Telescope (GST) at Big Bear Solar Observatory.

The SHARP Instrument on the PADRE Mission

Missions
15 Aug 2025
09:30-09:45

Pascal Saint-Hilaire[1]

[1]UC Berkeley Space Sciences Lab

PADRE, the PolArization and DiRectivity Experiment, is a 12U cubesat launched on a Sun-Synchronous Orbit on June 23, 2025. It carries two instruments: the Solar HArd X-Ray Polarimeter (SHARP) and the Measuring Directivity to Determine Electron Anisotropy (MeDDEA). The former will measure flare hard X-ray polarization, while the latter, in conjunction with Solar Orbiter's STIX, flare hard X-ray directivity (radiation pattern). Both are markers of electron anisotropies, a possible signature of flare electron acceleration and transport. The commissioning of SHARP will commence in a few weeks. We shall review SHARP's science goals, its expected performance, and, hopefully, present first light results.

The Measuring Directivity to Determine Electron Anisotropy (MeDDEA) Instrument on the PADRE CubeSat

Missions
15 Aug 2025
09:45-10:00

Steven Christe[1]

[1]NASA GSFC

The Measuring Directivity to Determine Electron Anisotropy (MeDDEA) instrument on the PolArization and Directivity X-Ray Experiment (PADRE) CubeSat observatory will investigate the acceleration mechanism in solar flares. In coordination with Solar Orbiter STIX, it will observe the Sun from 5 to 100 keV with cross-calibrated detectors to make the first measurements of x-ray directivity from solar flares to constrain the associated electron angular distributions.

SoLEXS on Aditya-L1: Initial Results and Capabilities

Missions
15 Aug 2025
10:00-10:20

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SoLEXS on Aditya-L1: Initial Results and Capabilities

POSTERS

Dual-Vantage Observations of a Partially Occulted Nonthermal Above-the-Looptop Source in an Eruptive Solar Flare

Bin Chen (New Jersey Institute of Technology)

In solar flares, nonthermal emissions from the region above the flare arcade – known as the above-the-looptop (ALT) region – offer key diagnostics of particle acceleration driven by coronal magnetic reconnection. Partially occulted flares, where the footpoints of the flare arcade are hidden behind the solar limb, provide an excellent opportunity to isolate and study the coronal particle acceleration region without the contamination from bright footpoint hard X-ray (HXR) emission. Here we present a study of a partially occulted nonthermal ALT source from an eruptive flare on 2022 August 30, observed jointly by EOVSA in microwaves and Fermi/GBM in HXRs. Fortuitously, this event was also captured by the STIX instrument onboard Solar Orbiter from a complementary vantage point, enabling a stereoscopic view of the flare. We find that the partially occulted ALT microwave and HXR emissions, observed by EOVSA and Fermi/GBM, lag behind the unocculted coronal HXR emission from STIX's view. We discuss the implications for the development of particle acceleration in this flare.

New analysis of RHESSI and Fermi/GBM X-ray and gamma-ray observations of the 10 September 2017 Flare

Brian Dennis (Self)

RHESSI imaging spectroscopy and GBM spectroscopy results will be presented for the full duration of the limb flare on 10 September 2017. Only RHESSI front-segment data are available for four detectors (1, 3, 6, and 8) and pulse pileup limits the accuracy of the results during the time of peak emission. Nevertheless, reliable spectra have been obtained of the partially occulted footpoint emission during the impulsive phase and the rising HXR coronal source(s) visible into the decay phase. GBM spectroscopic observations from both the NaI and BGO detectors have also been analyzed over a similar time range. The NaI observations also suffer from pulse pileup but are consistent with RHESSI spectra. Basically, the following five X-ray and gamma-ray spectral components have been identified that dominate in different energy ranges and that evolve differently in time: (1) the thermal emission that dominates below 20 keV is primarily form the corona, (2) a power-law component from the one visible footpoint dominates below 100 keV, is soft on the rise of the impulsive phase, becomes harder at the peak, and softer again on the decay (SHS spectral evolution), (3) a power-law component primarily from the corona that dominates at energies above 100 keV that has a SHH spectral evolution, (4) a flatter power-law component that extends to energies above 1 MeV with an exponential rollover at higher energies (PLexp component), and (5) a nuclear gamma-ray component with a time history consistent with that of the HXR footpoint emission suggesting that it is from the same partially occulted footpoint. The PLexp component is the same as that discussed in our recent paper (Share et al. ApJ. 981:11,2025). Similar spectral evolution has been seen in other large flares.

Searching for rapid pulsations in solar flare X-ray data

Andrew Inglis (The Catholic University of America / NASA Goddard Space Flight Center)

Most studies of quasiperiodic pulsations (QPPs) in solar flares have identified characteristic periods in the 5–300 s range. Due to observational limitations, there have been few attempts to probe the ¡5 s period regime and understand the prevalence of such short-period QPPs. However, the Fermi Gamma-ray Burst Monitor (GBM) has observed approximately 1500 solar flares to date in high-cadence 16Hz burst mode, providing us with an opportunity to study short-period QPPs at X-ray energies. We systematically analyze every solar flare observed by Fermi/GBM in burst mode, estimating the prevalence of QPPs in multiple X-ray energy bands. To better understand these results, we complement this with an analysis of synthetic solar flare lightcurves, both with and without oscillatory signals present. Using these synthetic lightcurves, we can understand the likely false-alarm and true-positive rates in the real solar GBM data. We do not find strong evidence for widespread short-period QPPs, indicating either a low base occurrence rate of such signatures or that their typical signal-to-noise ratios must be low – less than 1 – in Fermi/GBM data. Finally, we present a selection of the most interesting potential QPP events that were identified in the GBM solar X-ray data.

The Parallel and Perpendicular Diffusion Coefficient of Energetic Charged Particles in the Inner Heliosphere from the Turbulent Magnetic fields Measured by Parker Solar Probe

Nibuna Madam Subashchandar (The University of Alabama in Huntsville)

This study investigates the diffusion of energetic particles in the inner heliosphere, focusing on both parallel ($\kappa_{\parallel}$) and perpendicular ($\kappa_{\perp}$) transport relative to the mean magnetic field. By integrating advanced theoretical models—Second-Order Quasi-Linear Theory (SOQLT) and Unified Non-Linear Transport (UNLT)—with in-situ observations from NASA's Parker Solar Probe (PSP), we explore how solar wind turbulence governs particle motion between 0.07 and 0.27 AU. A key element of this work is the use of wavelet-based analyses to extract turbulent power spectra from high-resolution magnetic field data. These spectra allow us to characterize turbulence geometries—specifically, distinguishing slab from 2D components—and assess their radial evolution. We pay particular attention to the Alfvén Mach number (M_A), fluctuation amplitude ($\delta B/B_0$), and turbulence anisotropy, which critically influence diffusion behavior. By coupling the observed spectra with SOQLT and UNLT, we derive energy- and radial-dependent diffusion coefficients: $\kappa_{\|}(E, r)$ describes motion along the field, and $\kappa_{\perp}(E, r)$ captures cross-field scattering caused by transverse structures as well as energy- and $\delta B/B_0$-dependent diffusion coefficients. Our preliminary results show that $\kappa_{\|}$ follows a strong energy dependence at sub-GeV to GeV energies. Meanwhile, $\kappa_{\perp}$ typically ranges from 0.1–1% of $\kappa_{\|}$ but can be enhanced by more than an order of magnitude in regions dominated by strong 2D turbulence. This suggests that small-scale transverse structures in the solar wind can significantly amplify cross-field transport, a factor often underestimated in conventional models. To validate these theoretical predictions, we examine time-intensity profile from selected solar energetic particle (SEP) events. By fitting observed SEP profiles, we obtain observationally derived $\kappa_{\|}$ values for comparison with theoretical estimates.

Solar Flare Abundance calculations with MinXSS and RHESSI

James McTiernan (University of California)

In this work we use MinXSS and RHESSI data to obtain estimates of the Differential Emission Measure for solar flares, with the goal of determining abundances for elements with prominent lines in the X-ray energy range of 1 to 10 keV.

The DEM is modeled as a set of gaussian functions of Log(T). In contrast to our previous work with EVE and RHESSI (2019ApJ...881..161M), where Fe abundance was fixed at 'coronal' or 'photospheric' the relative abundances of 7 elements (Mg, Si, S, Ar, Ca, Fe, Ni) are free parameters in the calculation.

Using a sample of approximately 150 time intervals from six solar flares observed by MinXSS and RHESSI in 2016 and 2017, we calculate the abundances using MinXSS alone and MinXSS plus RHESSI. We also use MinXSS data to obtain abundance estimates for pre-flare and non-flare time intervals, and look at abundance variation with respect to GOES emission level.

An upcoming balloon-borne solar X-ray instrument pushes the limits of scintillation detectors

William Setterberg (University of Minnesota)

We give an overview of an upcoming solar X-ray balloon piggyback mission, with some focus on detector and related hardware updates.

The Integrating Miniature Piggyback for Impulsive Solar Hard X-rays (IMPISH) is a low-cost solar spectrometer that will piggyback on the second flight of the Gamma Ray Imager/Polarimeter for Solar flares balloon (GRIPS-2). IMPISH is a collaboration between University of Minnesota, Montana State University, Space Sciences Laboratory, and Southwest Research Institute. Our spectrometer is optimized to measure fast variations in nonthermal X-rays from solar flares. Sub-second spikes in the X-ray flux offer a probe into particle acceleration mechanisms in solar flares through their (a)periodicity, duration, and timing differences across energy bands.

The IMPISH payload features silicon photomultipliers coupled to LYSO or YAP:Ce scintillators to achieve the desired sub-second (tens of milliseconds) measurements and good energy resolution. The instrument has a 64cm2 geometric area and an energy range of at least 20 to 300 keV.

The Solar Extreme Ultraviolet Spectrograph and High-energy Imager (SEUSHI) Compact Instrument Suite

Robert Sewell (CU Boulder/LASP)

SEUSHI (Solar Extreme Ultraviolet Spectrograph and High-energy Imager) is a compact solar instrument designed to investigate the heating mechanisms of the solar corona and characterize the signature of flare onsets. The mission aims to advance understanding of Hot Onset Precursor Events (HOPEs) that precede solar flares, with the goal of improving flare prediction and space weather monitoring. SEUSHI consists of two complementary channels that share a common CMOS sensor. The Solar Pinhole Imager of Coronal Irradiance with TUNAble-readout (SPICI-TUNA) channel has six pinhole cameras with three pinholes providing full-disk solar soft X-ray (SXR) images at 1.0 arc-minute resolution and with 5 sec cadence and three pinhole cameras imaging at higher cadence of 100 Hz to enable photon-counting spectroscopy for active regions and flares. The three slow-rate, full-disk SXR images are used to generate temperature and emission measure maps at 1.0 arc-minute spatial resolution for the application of the HOPE technique at the pixel level. The other three pinhole cameras provide SXR spectra from 0.5 keV to 3 keV and with 0.1 keV energy resolution to study the evolution of the abundances, which is one indicator of coronal heating. The other SEUSHI channel is an extreme ultraviolet (EUV) spectrograph that uses a spare grating from the Solar Dynamics Observatory (SDO) Multiple Euv Grating Spectrograph A-channel (MEGS-A). This channel is called TEMAKI, or The Euv Megs-A rocKet Instrument. TEMAKI is a grazing-incidence EUV spectrograph that measures the solar EUV spectral irradiance from 17–34 nm with 0.18 nm spectral resolution. The SPICI-TUNA channel is optimized to study the flare onset phase, and TEMAKI is used to characterize the other flare phases: impulsive phase, gradual phase, coronal dimming (CME proxy), and EUV late phase. SEUSHI is scheduled to fly on the upcoming EVE-underflight calibration sounding rocket campaign in April 2026, during which the instrument's hardware and measurement techniques will be validated. SEUSHI's compact design makes it particularly suitable for future CubeSat deployment, supporting both flare studies and space weather monitoring. Here we present SEUSHI's science motivations, detail the instrument suite and expected performance, and outline its current development status.

Modeling Accelerated Electron Pitch-Angle Distributions in Solar Flares

Morgan Stores (University of Minnesota)

Pitch angle distributions (PADs) in solar flares are notoriously difficult to observe, as a result they are rarely studied. In the magnetosphere, PADs can be linked to various electron acceleration mechanisms and thus may provide to be a key diagnostic in understanding how electrons reach the non-thermal energies observed by X-ray instruments in solar flares. Using a time-independent Fokker-Planck equation we study electron PAD changes with the inclusion of turbulent acceleration, turbulent scattering, and various plasma properties (plasma temperature and density). We find energy-integrated electron PADs do not reflect PADs produced by non-thermal electrons, appearing significantly more isotropic. Similarly, spatially-integrated electron PAD does not reflect the electron PAD in the chromospheric footpoints. Electron trapping in the coronal looptop occurs when accelerating electrons out of a thermal distribution, as opposed to injecting electrons in a power law (with a spectral index of 4 from 9 to 80.0 keV), increasing the electron flux perpendicular to the magnetic field. Additionally, studying extreme cases of turbulent scattering timescales demonstrates two ways scattering can trap electrons in the coronal loop top.

Quantifying the Chromospheric Response to Solar Flares with AIA 1600 Å Observations

Danny Sun (UC Berkeley/SSL)

The chromosphere plays a critical role when it comes to understanding the mechanism behind a solar flare's energy deposition and particle acceleration. However, its rapidly evolving and spatially complex response remains challenging to quantify. Ultraviolet observations from the Solar Dynamics Observatory's Atmospheric Imaging Assembly (AIA), particularly in the 1600 Å passband, offer a powerful diagnostic of chromospheric heating in response to flare energy release.

In this study, we use AIA 1600 Å data to characterize the chromospheric response to an M1.6-class solar flare that occurred on April 17, 2024. We identify flare-impacted regions by isolating pixels that brighten to more than three times their quiescent intensity and extract their temporal profiles to assess timing, peak structure, and decay characteristics. Many of these brightenings exhibit multi-peaked impulsive phases followed by two-stage decays, consistent with episodic energy injection and possible signatures of quasi-periodic pulsations.

This analysis aims to evaluate how well AIA 1600 Å emission can be used to constrain the timing and structure of flare energy release in the chromosphere. Ongoing work explores whether patterns in the spatial and temporal evolution of UV brightenings can inform models of impulsive heating and magnetic reconnection. These observations may ultimately help bridge the gap between X-ray diagnostics and lower-atmosphere flare signatures.

A Failed Filament Eruption Involving Breakout Reconnection in the Sextupolar Field

Zhengyuan Tian (Purple Mountain Observatory, Chinese Academy of Sciences)

Solar filament eruptions are key drivers of coronal mass ejections, yet not all eruptions succeed. The mechanisms leading to failed eruptions, particularly in complex multi-polar fields, remain poorly understood. Here, we report a failed filament eruption that involves Breakout reconnection in a sextupolar magnetic configuration, providing new insight into these phenomena. Taking advantage of the opportunity provided by The Spectrometer Telescope for Imaging X-rays (STIX) on board the Solar Orbiter (SolO) for close-range imaging of weak sources, we provide the first complete Hard X-ray (HXR) observational evidence of Breakout reconnection in a multipolar magnetic field, and discover phenomena predicted or not yet confirmed by Breakout model. Our analysis reveals that near-surface reconnection triggered filament destabilization, while Breakout reconnection redistributed flux from the central to side-lobes. Despite strong external magnetic confinement eroded the magnetic flux rope and prevented a successful eruption. Using the nonlinear force-free field (NLFFF) extrapolation and magnetohydrodynamic (MHD) simulations, we first reproduced the complete process of Breakout reconnection in a sextupolar configuration. This unique event bridges the gap in HXR observational evidence of Breakout reconnection and advances our understanding of filament eruption mechanisms in complex magnetic configuration.

Preparing for the FOXSI-5 Launch: Timepix Detector Calibration and Radio Data Analysis Correlated with FOXSI-4 Observations

Anna Tosolini (UC Berkeley/Space Sciences Lab)

The Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket experiment is a crucial component of NASA's Solar Flare Campaign to capitalize on scientific output during the solar maximum. With four successful flights, FOXSI has proven extremely successful at studying particle acceleration and energy release in large solar flares. The FOXSI-4 mission, which launched on April 17, 2024, observed an M1.64 solar flare in both the hard and soft X-ray energy bands. Analysis of a sweep of radio instruments, including STEREO, WIND, eCALLISTO, EOVSA and OVRO-LWA, has shown a Type III Radio Burst peaking 7-14 minutes after the FOXSI-4 X-ray observations, exhibiting a temporal correlation between the X-ray and radio emission. This analysis will include drift rate estimation of the radio bursts, as well as a focus on data analysis from EOVSA and OVRO-LWA. Understanding the multiwavelength behavior of the solar flare will inform us on the nature of particle acceleration and energy transport from the corona through the heliosphere. Additionally, the FOXSI team is preparing for a fifth flight this winter; calibration of the Timepix detector is crucial to a successful launch, as this detector malfunctioned during the FOXSI-4 flight. Discussion of the new calibration results will be presented, including updates and improvements of the Timepix system optimized for the FOXSI-5 flight.

Intermittent Energy Release During Solar Eruptive Events in Active and Quiescent Regions

Juliana Vievering (Johns Hopkins Applied Physics Laboratory)

Hard X-rays (HXRs) provide a key diagnostic for energy release during a solar flare, as HXRs are emitted from flare-accelerated electrons and strongly heated flare plasma. In the case of a solar eruptive event, a flare is associated with the eruption of a coronal mass ejection (CME). Though it is largely understood that reconnection is important for the eventual release of the CME, the triggering mechanism for the eruption and its relationship to flare energy release remains under debate. In this study, we leverage multi-viewpoint observations from STEREO, SDO, and RHESSI to provide simultaneous measurements of CME evolution, magnetic reconnection, and flare energy release for several solar eruptive events, originating from both active and quiescent regions. We examine "bursts" in the HXR, reconnection rate, and CME acceleration profiles, representing distinct episodes of energy release, to explore how intermittent energy release impacts the evolution of the event. We additionally leverage RHESSI observations of partially-occulted flares associated with CMEs to examine faint coronal HXR sources, which provide the most direct signature of flare particle acceleration but have been infrequently observed by previous HXR instruments due to the relatively bright footpoint emission.

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