Abstracts

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Plenaries, Invited Talks, and Scene-Setting Talks:

George Ho

Johns Hopkins University Applied Physics Laboratory

Topic 3.2: Energetic and Suprathermal Particle Measurement at the Inner Heliosphere

Particles that have energies of a few times the solar wind plasma energy up to 100s of keV/q are called suprathermal particles. Recent studies have revealed that these particles may a significant role as seed particles for further acceleration to higher energies. This may occur either close to the Sun in solar energetic particle (SEP) events, but also locally at 1 AU in energetic storm particle events, or even outside 1 AU as ions accelerated in Corotating Interaction Regions. The origin of these suprathermal particles is largely unknown at this time. It is therefore important to make high-time resolution measurements of the composition and spectra of this particle population in the inner heliosphere to better characterize its origins and role as a seed population in particle acceleration processes. Because of the vastly different mass-per-charge ratios of the various possible origins of suprathermal ions, we expect to see distinct difference and radial dependencies in their abundances in low-energy accelerated particles in the inner heliosphere. Here we describe the measurements that we are making on both Solar Orbiter and Parker Solar Probe that will make significant contributions to the understanding of the particle population in this largely unexplored energy range.

Hamish Reid

Mullard Space Science Laboratory, University College London, UK

Topic 3.1: Accelerated Electrons Escaping the Sun

Electrons accelerated during solar flares can escape the confines of the coronal magnetic field and propagate through the interplanetary medium. We can detect these escaping electron beams in situ in the solar wind with spacecraft. The transport of these electron beams, travelling near the speed of light, can also result in radio emission being produced via nonlinear plasma processes. The subsequent impulsive radio bursts (known as type IIIs) can be used to diagnose properties of electron beams that we are unable to measure directly. Moreover, we can also compare escaping electron beam properties with those of confined electron beams inferred from hard X-rays. I will start the talk by providing an introduction into in situ and radio diagnostics of escaping electron beams from flares. I will then review some recent observational results and theoretical developments that have been advancing this area of research, including the simultaneous study with solar hard X-rays. I will then conclude with some of the big questions that we have not yet answered regarding escaping solar energetic electrons.

Jiong Qiu

Montana State University

Topic 1.2: Observing magnetic reconnection before, during, and after solar eruptions

[Abstract to come]

Spiro Antiochos

University of Michigan

Topic 1.1: Models for energy storage and explosive release

[Abstract to come]

Vanessa Polito

(1) Bay Area Environmental Research Institute, (2) Lockheed Martin Solar and Astrophysics Lab

Topic 4.1: UV spectroscopy and models of solar flares

Recent observations with UV spectrometers and imagers have provided new insights into the understanding of the physical mechanisms at play during solar flares. In this scene-setting talk, I will discuss how the comparison between spectroscopic observations and models can help us constrain and understand solar high-energy processes.

New Mission Lightning Talks:

Still to come…

Early-Career Talks:

Anna Volpara

Volpara A. (1), Massa P. (1), Battaglia A. F. (2,3), Perracchione E. (4), Garbarino S. (1), Benvenuto F. (1), Massone A. M. (1,5), Hurford G. J. (2), Krucker S. (2,6) and Piana M. (1,5)

(1) MIDA, Dipartimento di Matematica, Università degli Studi di Genova, Via Dodecaneso 35, 16146 Genova, Italy
(2) University of Applied Sciences and Arts Northwestern Switzerland, Bahnhofstrasse 6, 5210 Windisch, Switzerland
(3) ETH Zürich, Rämistrasse 101, 8092 Zürich, Switzerland
(4) Dipartimento di Scienze Matematiche "Giuseppe Luigi Lagrange", Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy
(5) CNR-SPIN, Via Dodecaneso 33, 16146 Genova, Italy
(6) Space Sciences Laboratory, University of California, 7 Gauss Way, 94720 Berkeley, USA

Parametric imaging for STIX: global search methods

The STIX imaging problem consists in reconstructing hard X-ray flaring sources from samples of the Fourier transform of the incoming flux, named visibilities. This issue is more challenging than in the case of RHESSI, since STIX visibilities are one order of magnitude less than the ones typically provided by RHESSI. The objective of this talk is twofold. First, we show that, due to this significantly more sparse coverage of the spatial frequency domain, standard simplex-based optimization does not work for parametric imaging in STIX. Second, we prove that global search techniques like Simulated Annealing, Evolutionary Algorithm, and Particle Swarm Optimization (PSO) represent a natural solution to this issue. More specifically, using experimental visibilities measured by both RHESSI and STIX, and STIX synthetic visibilities, we show that PSO represents the best trade-off between reconstruction accuracy and computational effectiveness and can therefore be considered as the method of choice for parametric imaging in STIX.

Bennet Schwab

Schwab, Bennet D. (1), Sewell, Robert H. A. (1), Woods, Thomas N. (1)

(1) Laboratory for Atmospheric and Space Physics

Modeling Abundance Evolution During Solar Flares with Soft X-ray Spectra

Coronal heating via chromospheric evaporation due to magnetic reconnection is investigated by looking at deviations from coronal abundances during flaring events. A single temperature, single emission measure model with separate abundance factors (AF) for Mg, Si, and Fe is fit to solar Soft X-ray (SXR) spectra covering three separate flaring events observed by the Miniature X-ray Solar Spectrometer (MinXSS-1) CubeSat. The evolution of the AF, a scaling factor multiplied by the Feldman Standard Extended Coronal (FSEC) quiescent abundance values, shows decreasing AF in the beginning of the gradual phase of each flare. A minimum AF value then occurs around 3 minutes prior to each flare's intensity peak before relaxing back towards preflare values in the remainder of the gradual phase. This is strong supportive evidence of magnetic reconnection heating the corona through chromospheric evaporation. The evolution of temperature shows that the chromospheric plasma is hottest 3 minutes before the majority of the energy is emitted through SXR radiation. Maximum temperature values reached by the SXR emitting plasma is greater for higher magnitude flares, which implies that higher intensity flares provide more heating to the corona than lower intensity flares. Additional flare modeling is done with the increased spectral resolution data taken from the Dual Aperture X-ray Solar Spectrometer (DAXSS).

Cole Tamburri

Tamburri, Cole (1), Kazachenko, Maria (1,2,3), Kowalski, Adam (1,2,3)

(1) University of Colorado Boulder, (2) Laboratory for Atmospheric and Space Physics, (3) National Solar Observatory

Case study analysis of solar flare development patterns with impulsiveness, ribbon morphology, and simulation

The physical drivers of solar and stellar flare development during the rise phase remain poorly understood, due, for example, to the observed rapid development of brightenings, which have yet to be reconciled with the longer-duration of the flare rise phase. Variation in flare ribbon geometry, magnetic field structure, and overall flare development complicate the search for a comprehensive theory of flare energetics. A new classification of solar flares using the impulsiveness index provides a framework to better understand the mechanism driving the rapid development of the rise phase in solar and stellar flares. These datasets are used to perform detailed spatial analysis of physical properties in six flares corresponding to a range of impulsiveness values. We determine the parallel and perpendicular stages of flare ribbon motion and corresponding reconnection fluxes and rates and compare these to the chromospheric light curves. We verify that the end of the flare rise phase corresponds to the end of the ribbons' parallel motion, while perpendicular motion persists afterwards. In addition, we use the relative positions of newly-brightened flare ribbon pixels to determine magnetic shear. Previous work suggests that magnetic shear may be related to rates of particle precipitation. The relationship between magnetic shear and impulsiveness is investigated, providing unique insight into the origin of light curve shapes in stellar flares. These empirical results are combined to guide modeling efforts for reconciling the observed long-duration rise times in white-light stellar flares and short timescale particle injection events.

Crisel Suarez

Crisel Suarez (1, 2) , Christopher S. Moore (2), MinXSS Team

(1) Vanderbilt University, (2) Harvard|Smithsonian Center for Astrophysics

Solar Flare elemental abundance deviations obtained by the MinXSS-1 CubeSat mission

The solar corona is composed of plasma that is over 1 MK. Solar flares accelerate particles on timescales of minutes, converting magnetic energy to thermal, radiative and kinetic energy through magnetic reconnections. As a result, local plasma can be heated to temperatures in excess of 20 MK. These flares emit high energy electromagnetic radiation, such as soft X-rays (sxr). The elemental abundance of low first-ionization potential (FIP) elements are typically observed to be depleted during solar flares. The Miniature X-ray Solar Spectrometer CubeSat-1 (MinXSS-1) provides disk-integrated solar spectra in the 1-12 keV energy range with a nominal 0.15 keV full-width at half-maximum (FWHM) resolution at 5.9 keV and a cadence of 10 seconds. During the year-long mission of MinXSS-1, between May 2016 - May 2017, ~20 flares were observed ranging from C to M class. We examine the time evolution of temperature, emission measure, and elemental abundances of Fe, Ca, Si, and S with CHIANTI spectral models and MinXSS-1 data. We present that the abundances of Fe, Ca, Si, and S, show an abundance of near photospheric values during the peak of the flare. This corroborates that during a solar flare, the lower atmospheric plasma fills the coronal loops due to chromospheric evaporation.

Devojyoti Kansabanik

Kansabanik, Devojyoti (1), Oberoi, Divya (1), Mondal, Surajit (2), Bhunia, Shilpi (3), Dey, Soham (1)

(1) National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Pune, India, (2) New Jersey Institute of Technology, USA, (3) Trinity College Dublin, Ireland

New prospects of combined space weather research with high fidelity low-frequency spectro-polarimetric imaging and Aditya-L1 mission

The solar corona is composed of plasma that is over 1 MK. Solar flares accelerate particles on timescales of minutes, converting magnetic energy to thermal, radiative and kinetic energy through magnetic reconnections. As a result, local plasma can be heated to temperatures in excess of 20 MK. These flares emit high energy electromagnetic radiation, such as soft X-rays (sxr). The elemental abundance of low first-ionization potential (FIP) elements are typically observed to be depleted during solar flares. The Miniature X-ray Solar Spectrometer CubeSat-1 (MinXSS-1) provides disk-integrated solar spectra in the 1-12 keV energy range with a nominal 0.15 keV full-width at half-maximum (FWHM) resolution at 5.9 keV and a cadence of 10 seconds. During the year-long mission of MinXSS-1, between May 2016 - May 2017, ~20 flares were observed ranging from C to M class. We examine the time evolution of temperature, emission measure, and elemental abundances of Fe, Ca, Si, and S with CHIANTI spectral models and MinXSS-1 data. We present that the abundances of Fe, Ca, Si, and S, show an abundance of near photospheric values during the peak of the flare. This corroborates that during a solar flare, the lower atmospheric plasma fills the coronal loops due to chromospheric evaporation.

Fanxiaoyu Xia (presented by Zhentong Li)

Xia, Fanxiaoyu(1,2); Su, Yang(1,2); Wang, Wen(3); Wang, Linghua(3); Warmuth, Alexander(4); Gan, Weiqun(1); Li, Youping(1)

(1) Purple Mountain Observatory, Chinese Academy of Sciences, China; (2) University of Science and Technology of China, China (3) Peking University, China; (4) Leibniz-Institut für Astrophysik Potsdam (AIP), Germany

Evidence of energy cutoffs in flare-accelerated electrons

Flares are violent explosions and natural particle accelerators in solar atmosphere. The accelerated particles play an essential role in flare energy release and distribution. High and low energy cutoffs define the upper and lower limits of accelerated electrons. They are important parameters in understanding particle acceleration and energy distribution. However, the existence of acceleration-related low-energy cutoff is still a question, and the high-energy cutoff has been rarely studied and discussed. We present a recent study using X-ray and SEP (solar energetic particles) observations and report on the evidence of low and high energy cutoffs that are related to acceleration process in flares, including the full spectral signatures. The result provides new clues and constraint for understanding high energy spectra, electron acceleration, and transportation. In the talk, I will also present the status of data processing and software development for the HXI payload onboard the ASO-S mission.

Kristopher Cooper

Cooper, Kristopher (1), Hannah, Iain (2), Grefenstette, Brian (3), Glesener, Lindsay (4), Krucker, Sam (5), Hudson, Hugh (6), White, Stephen (7), Smith, David (8), Duncan, Jessie (9)

(1,2,6) University of Glasgow, (3) California Institute of Technology, (4,9) University of Minnesota Twin Cities, (5) University of Applied Sciences and Arts Northwestern Switzerland, (5,6) University of California, Berkeley, (7) Air Force Research Laboratory, (8) University of California, Santa Cruz

NuSTAR observations of a repeatedly microflaring active region

The Nuclear Spectroscopic Telescope Array (NuSTAR) is an astrophysical X-ray telescope capable of observing the Sun with direct imaging spectroscopy providing a unique sensitivity >2.2 keV. We use NuSTAR to investigate highly frequent and weak flares thought to contribute to heating the Sun's atmosphere particularly in active regions. I will present several X-ray microflares from an active region, AR12721, that were observed on 2018 September 9-10 with NuSTAR. In combination with SDO/AIA, I describe the temporal, spatial, and spectral evolution of these GOES sub-A class microflares that reach temperatures >5 MK; i.e., above those of the surrounding active region. Using SDO/HMI, I also present evidence of photospheric magnetic flux cancellation/emergence at the footpoints in 8 of the NuSTAR microflares (Cooper et al. 2021 MNRAS 507 3).

One of the microflares presented is the faintest non-thermal microflare thus far observed with NuSTAR providing a non-thermal power of 7e24 erg/s by estimating the non-thermal contribution with a photon broken power-law. This microflare is further investigated utilising a new Python spectral fitting software optimised for high energy solar data, directly modelling properties non-thermal electron distributions. This continued research corroborates previous non-thermal results via fitting and MCMC. The new Python software also allows more powerful analysis techniques to be easily applied to spectral data, such as nested sampling when performing model comparisons.

Malte Broese

Broese, Malte (1)(6), Warmuth, Alexander (1), Sakao, Taro (2)(3), Su, Yang (4)(5)

(1) Leibniz Institut für Astrophysik Potsdam (AIP); (2) Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan; (3) Department of Space and Astronautical Science, School of Physical Sciences, SOKENDAI, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan; (4) Key Laboratory of Dark Matter and Space Astronomy, Purple Mountain Observatory, Chinese Academy of Sciences, 10 Yuanhua Road, Nanjing 210023, PR China; (5) School of Astronomy and Space Science, University of Science and Technology of China, 96 Jinzhai Road, Hefei 230026, PR China; (6) Zentrum für Astronomie und Astrophysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Temperature and differential emission measure evolution of a limb flare on 13 January 2015

Spatially unresolved observations show that the cooling phase in solar flares can be much longer than theoretical models predict. It has not yet been determined whether this is also the case for different subregions within the flare structure. We aim to investigate whether or not the cooling times, which are observed separately in coronal loops and the supra-arcade fan (SAF), are in accordance with the existing cooling models, and whether the temperature and emission measure of supra-arcade downflows (SADs) are different from their surroundings. We analysed the M5.6 limb flare on 13 January 2015 using SDO/AIA observations. We applied a differential emission measure (DEM) reconstruction code to derive spatially resolved temperature and emission measure maps, and used the output to investigate the thermal evolution of coronal loops, the SAF, and the SADs. In the event of 13 January 2015, the observed cooling times of the loop arcade and the SAF are significantly longer than predicted by the Cargill model, even with suppressed plasma heat conduction. The observed SADs show different temperature characteristics, and in all cases a lower density than their surroundings. In the limb flare event studied here, continuous heating likely occurs in both loops and SAF during the gradual flare phase and leads to an extended cooling phase.

Meriem Alaoui

Alaoui, Meriem(1,2); Holman, Gordon(2); Allred, Joel(2); Drake, James(1); Swisdak, Marc(1); Dennis, Brian; (2); Tolbert, Kim (2)

(1) IREAP/UMD; (2) NASA/GSFC

Limiting regimes of the solar flare accelerated electron beam/return current system: Toward a self-consistent model of electron propagation

Energetic electrons are thought to be accelerated during solar flares by conversion of magnetic energy into kinetic energy. These electrons are accelerated in the corona and stream both toward the interplanetary medium and toward lower (and denser) layers of the solar atmosphere. They constitute a current on the order of 10^{17} Amperes, which must be neutralized by a co-spatial and oppositely-directed return current. We show how the beam/return-current system propagates between the corona and the chromosphere, and how this modifies the assumptions of the standard collisional thick-target model for various flares observed by RHESSI. The results are based on the 1D beam/return current model which accounts self-consistently for runaway electron acceleration out of the ambient (return current) electrons (RunRC, Alaoui et. al 2021). We also show that for a few large flares an adequate beam/return-current model is still unavailable.

Michalina Litwicka

Michalina Litwicka (1), Tomasz Mrozek (1), Arun Kumar Awasthi (1)

(1) Space Research Centre Polish Academy of Sciences, Wrocław, Poland

How precisely we can determine the thermal energy of weak flares based on STIX images?

During 20-21 September 2021 STIX observed many weak flares of GOES class B and below. Using MARLIN imaging algorithm for collimators 3-10, we reconstructed images of X-ray sources for each flare with and we estimated sizes of sources with errors. Additionally, we made

images using forward-fit algorithm, which also enables us to estimate errors and compare results of both algorithms. Obtained parameters highly depend on registered background as we reconstructed images for very weak events. We found that standard approach, i.e. pre-flare background subtraction, may cause significant decrease of a quality of image reconstruction. Therefore, we applied a method which accounts for background inside iteration performed by MARLIN. Analysis of source size during iteration process let us to determine some reliable range of values for this parameter and in the next step enable us to estimate range of source volumes. With estimated volume and with physical parameters, such as temperature and emission measure, derived from OSPEX package, we were able to determine thermal energy range for each flare. Differences between obtained energies for each flare proves that careful imaging is crucial for determination of physical properties of flare, especially for weaker events.

Milo Buitrago-Casas

Juan Buitrago-Casas (1), Savannah Perez-Piel (1), Anton Tremsin (1), Juan Carlos Martinez Oliveros (1)

(1) Space Sciences Laboratory - University of California Berkeley

The Quad-Timepix/Timepix3 Detector: A novel solution for coming solar high energy space experiments

TimePix3 is a cutting-edge high-energy chip developed by CERN, NIKHEF, and Bonn University that offers a superior time resolution (1.56ns with an almost zero dead time performance). It acquires time and charge information in pixels with a 55-micron pitch. The original chip design comprises a 256 x 256-pixel array with a 1.4cm x 1.4cm active area. We developed an updated design of the TimePix3 solution, consisting of a quad-sensor system integrated with 2 x 2 Timepix ASICs and a CdTe substrate array. Two Interface Boards and a (Reconfigurable Open Architecture Computing Hardware) ROACH board serve as (Field Programmable Gate Arrays) FPGAs to process data and allow the user to access the data via PC. Each Interface Board serves two ASICs and is connected to the ASIC board by 100-pin connectors. We present this assembly of detectors as a viable option for imaging spectral analysis applications in solar physics, expandable to other applications in space sciences. In particular, we present the TimePix3 quad-sensor as one of the detectors that will be part of the Focusing Optics X-ray Solar Imager (FOXSI) fourth-sounding rocket flight, funded to launch from Poker Flat in 2024 in the first-ever solar flare campaign. TimePix3 will also be part of the solar PolArization and Directivity X-Ray Experiment (PADRE) payload to explore electron distributions' polarization and directionality during solar flares. We demonstrate the quad detector's design and energy and spectral characterization, including power resolution, gain, and power consumption. We also remark on future work, including the miniaturization of the ROACH board FPGA to a flight-ready module.

Mithun N. P. S.

Mithun N. P. S. (1), Santosh V. Vadawale (1), Biswajit Mondal (1), Aveek Sarkar (1), P. Janardhan (1), Bhuwan Joshi (1), Anil Bhardwaj (1), Giulio Del Zanna (2), Helen E Mason (2), Yamini Rao (2)

(1) Physical Research Laboratory, Ahmedabad, India, (2) DAMTP, University of Cambridge, UK

Soft X-ray spectroscopy of sub-A class to X class flares with Chandrayaan-2 XSM

We present observations of sub-A class microflares to large X-class flare with the Solar X-ray Monitor (XSM) instrument on-board Chandrayaan-2 mission. XSM observes the Sun as a star and measures the soft X-ray spectrum in the energy range of 1 – 15 keV with high spectral resolution at a cadence of one second. Since the beginning of observations in late 2019 during solar minimum, XSM has observed several weak sub-A class microflares which are identified to be occurring outside active regions. This provided a unique opportunity to investigate the frequency distribution of small scale X-ray events in the corona which provide insights into their contribution towards coronal heating. With the increasing solar activity over the last couple of years, XSM has also observed several larger flares including couple of X-class flares. We use these observations to investigate the evolution of elemental abundances during the course of solar flares. We also investigate the temperature structure of the flaring loops by modeling the X-ray spectra. Here we discuss some of the interesting results from these studies using XSM observations of solar flares and their implications.

Morgan Stores

Stores, Morgan (1), Jeffrey, Natasha (1), Mclaughlin, James (1)

(1) Northumbria University

X-ray Diagnostics of Spatially Extended Turbulent Electron Acceleration and Transport in Solar Flares

Solar flares are effective particle accelerators, with as much as 10-50% of the <10^33 ergs of energy released from magnetic reconnection contributing to accelerating particles to energies greater than 20 keV. However, the properties and location of the acceleration region is largely unknown with competing theories of the acceleration mechanism, including acceleration by turbulence. The imaging spectroscopy abilities of RHESSI, and now STIX onboard Solar Orbiter (SolO), have provided spatially resolved X-ray spectra from bremsstrahlung-emitting electrons accelerated during flares. Thus, hard X-ray emission has been a vital tool in determining the properties of flare accelerated electrons at the Sun. In order to constrain the properties of the acceleration region itself, a time independent Fokker-Planck equation is used to describe the transport of energetic electrons through a coronal plasma of finite temperature, accounting for collisions as electrons are transported along the guiding magnetic field. Furthermore, an extended turbulent acceleration region is incorporated into the model, driven by recent non-thermal line broadening observations (Hinode EIS) suggesting extended regions of turbulence, and possibly acceleration in the loop apex and loop itself. To determine how different acceleration environments (i.e. varying acceleration timescale, spatial extent of the acceleration region, spatial distribution of turbulence) change observed accelerated electron properties we produce outputs for the density weighted electron spectrum modelled in energy, pitch angle and space from the corona to chromosphere. Using our simulation results, I will discuss several useful X-ray spectral and imaging diagnostics which can be compared directly to archived RHESSI and new STIX observational data, helping to constrain the properties of solar flare acceleration in individual flares.

Sabrina Guastavino

Guastavino (1), Marchetti (2), Benvenuto (1), Campi (1), Piana (1)

(1) Dipartimento di Matematica, Università di Genova, (2) Dipartimento di Matematica, Università di Padova

A video-based CNN for flare forecasting

We first introduce a general paradigm for generating independent and well-balanced training, validation, and test sets for use in supervised machine/deep learning flare forecasting. Then, we use this implementation paradigm in the case of a deep neural network, which takes as input videos of magnetograms recorded by the Helioseismic and Magnetic Imager on-board the Solar Dynamics Observatory (SDO/HMI). We finally discuss the results of this analysis, showing that the way the training and validation sets are prepared for network optimization has a significant impact on the prediction performances; and that deep learning is able to realize flare videos classification with prediction performances that are in line with the ones obtained by machine learning approaches applied to features a priori extracted from HMI magnetograms.

Sarah Paterson

Paterson, Sarah (1), Hannah, Iain (1), Grefenstette, Brian (2), Hudson, Hugh (1,3), Krucker, Säm (3,4), Glesener, Lindsay (5), White, Stephen (6), Smith, David (7)

(1) University of Glasgow, (2) California Institute of Technology, (3) UC Berkeley, (4) FHNW Switzerland, (5) University of Minnesota, (6) Air Force Research Laboratory, (7) UC Santa Cruz

NuSTAR Observations of Small-Scale Phenomena in the Quiet Sun

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a sensitive hard X-ray (HXR) focusing telescope capable of observing the faint emission from small-scale phenomena in the quiet Sun. During the recent solar minimum, NuSTAR observed the quiet Sun several times, providing the unique opportunity to perform imaging spectroscopy on very faint solar HXR sources. We present analysis on several small features from the NuSTAR 28 September 2018 full disk solar mosaics, including X-ray/coronal bright points, a jet, and an emerging flux region that later went on to become an active region. This is the first time these features have been observed with an HXR imaging spectrometer. To investigate the contribution of these quiet Sun sources to heating the solar atmosphere, we determine their thermal properties from their X-ray spectra, and calculate upper limits on the possible non-thermal emission. We combine X-ray data from NuSTAR with EUV data from SDO/AIA and soft X-ray data from Hinode/XRT to reconstruct their differential emission measures (DEMs) in order to investigate the multithermal temperature evolution of these small-scale phenomena.

Savannah Perez-Piel

Savannah Perez-Piel (1), Juan Camilo Buitrago Casas (1), Juan Carlos Martínez Oliveros (1), Charles Lindsey (2)

(1) Space Sciences Laboratory - University of California, Berkeley • (2) NorthWest Research Associates

Submerged Acoustic Sources: The SOL20140207T10:28 Study Case

We present a study of SOL20140207T10:28, finding evidence of a submerged source of acoustic power some three thousand km beneath the photosphere. By creating depth-time maps of the transient emission at 4, 6, 8, and 10 mHz, we can visualize this compact source and determine that the flaring event is not correlated with the seismic observation. We suggest that some non-trivial amounts of sunquakes may be triggered at a noticeable depth by a mechanism associated with photospheric activity but not directly triggering the observed helioseismic activity.

Sherry Chhabra

Sherry Chhabra (1), Jeffrey Reep (2), Harry Warren (2), N.P.S. Mithun (3)

(1) George Mason University, Fairfax, VA, (2) Naval Research Laboratory, Washington DC, (3) Physical Research Laboratory, Ahmedabad, India

Probing the Solar SXR Background Emission with Chandrayaan-2 XSM

A majority of radiative losses from the million-degree hot solar corona are in the form of X-rays and EUV radiation which plays a vital role in driving our space weather. The solar soft X-ray (SXR) emission has been used to obtain unique diagnostics of hot plasma, primarily during flares. However, attempts to characterize the SXR non-flaring (background) emission from the Sun have been sparsely performed in the past. The problem is rooted in the lack of spectrally resolved observations over the energy range of 0.5-10 keV, limited sensitivity for low solar flux levels, and limited imaging capabilities. Recently, missions such as MinXSS CubeSat and CORONAS/SPhinX have provided such observations, exhibiting much higher sensitivity for quiescent emission, but they are limited by their short mission-lengths.

The Solar X-ray Monitor (XSM) onboard Chandrayaan-2 observes the solar spectra between 1-15 keV at a spectral resolution of 0.18 keV (at 5.9 keV) with a cadence of 1 s. The mission began in Sept. 2019 and continues to collect solar spectra to date, making it the only high-resolution instrument that has observed an absolute solar minimum and the rise of the solar cycle, thus providing ideal measurements to characterize the background emission. In this study, we use XSM data to constrain active region and quiet Sun temperatures by performing 2-Temperature (2T) fits to the spectra. We examine their variability with time and correlation with proxies for magnetic activity on the Sun, such as F10.7 index and the Mg II index. We also use this method to constrain the evolution of elemental abundances of trace elements as an active region emerges on a quiescent disk. The results are then used to validate the findings from MinXSS, and SPhinX studies mentioned above. This work significantly aids in quantifying the temperature and

emission measure variations with solar activity and will be used to improve a solar spectral irradiance model.

Yixian Zhang

Zhang, Yixian (1), Musset, Sophie (2), Glesener, Lindsay(1), Panesar, Navdeep (3), Fleishman, Gregory(4)

(1) University of Minnesota, (2) European Space Agency, (3) LMSAL/BAERI, (4) New Jersey Institute of Technology

Observations of magnetic reconnection and particle acceleration locations in solar coronal jets

We present a multi-wavelength analysis of two flare-related jets on November 13, 2014, using data from SDO/AIA, RHESSI, Hinode/XRT, and IRIS. Unlike most coronal jets where hard X-ray (HXR) emissions are usually observed near the jet base, in these two events HXR emissions are found at several locations, including in the corona. We carry out the first differential emission measure (DEM) analysis that combines both AIA (and XRT when available) bandpass filter data and HXR measurements from RHESSI for coronal jets, and obtain self-consistent results across a wide temperature range and into non-thermal energies. In both events, hot (>10 MK) plasma first appeared at the base of the jet, but as the base plasma gradually cooled, hot plasma also appeared near the top of the jet. Moreover, non-thermal electrons, while only mildly energetic, are found in multiple HXR locations and contain a large amount of total energy. The non-thermal electron distributions have spectral indices around 10 and extend down to ~9 keV. Particularly, the energetic electrons that produced the HXR sources at the top of the jet were accelerated near the location of those top sources, rather than traveling from a reconnection site at the jet base. This means that there was more than one particle acceleration site in each event. Jet velocities are consistent with previous studies, including major upward and downward velocities around ~200 km/s and ~100 km/s respectively, and fast outflows of 400-700 km/s only visible in the 131 A filter. We also examine the partition of various energy components in the later event, and find that the non-thermal energy in accelerated electrons is most significant compared to other energy forms considered. Combining all the observational results, we discuss the interpretations and provide constraints on mechanisms for coronal jet formation.

Zhentong Li

Zhentong, Li (1)(2), Yang Su (1)(2), Astrid M. Veronig(3), Wenhui Yu (1)(2), Weiqun Gan (1)(2), Wei Chen (1)(2)

(1) Purple Mountain Observatory, China, (2) University of Science and Technology of China, China, (3) University of Graz, Austria

Detailed energy release in a microflare and the status of ASO-S/HXI payload

In this talk, I will first present a comprehensive, quantitative analysis of energy release and plasma heating processes in the microflare first reported by Glesener+2020, which shows the existence of a nonthermal component down to 6.5 keV in the X-ray spectrum. Using careful

differential emission measure (DEM) analysis and the calculated multithermal X-ray component, we confirm the existence of the nonthermal component in the observed X-ray spectrum. We also report the first imaging evidence for low-energy cutoff of energetic electrons in EM maps of >10 MK plasma, which first appeared as two coronal sources significantly above the chromospheric footpoints. This study reveals the important role of electron thermalization and low-energy cutoffs in the physical processes of microflares. On the other hand, I will present the status of the HXI payload onboard the ASO-S and a new index we recently developed for evaluating the quality of image reconstruction for ASO-S/HXI and other modulation-based X-ray imagers. Initial tests show that it can help in PSF design and assessment of imaging algorithms.

Posters:

Alexander Kosovichev

Kosovichev, Alexander (1,2), Sadykov, Viacheslav (3), Stejko, Andrey (1), Stefan, John (1), Allred, Joel (4), Kowalski, Adam (5,6,7), Asmah, Nana (1)

(1) Physics Department, New Jersey Institute of Technology, Newark, NJ 07102, USA, (2) NASA Ames Research Center, Moffett Field, CA 94035, USA, (3) Physics & Astronomy Department, Georgia State University, Atlanta, GA 30303, USA, (4) NASA Goddard Space Flight Center, Solar Physics Laboratory, Code 671, Greenbelt, MD 20771, USA, (5) National Solar Observatory, 3665 Discovery Drive, Boulder, CO 80303, USA, (6) Department of Astrophysical and Planetary Sciences, University of Colorado Boulder, 2000, Colorado Ave, CO 80305, USA, (7) Laboratory for Atmospheric and Space Physics, University of Colorado Boulder, 3665 Discovery Drive, Boulder, CO 80303, USA.

Can Proton Beams Explain White-Light Flares and Sunquakes?

SDO/HMI observations reveal a class of solar flares with substantial energy and momentum impacts in the photosphere, resulting in white-light emission and helioseismic response (sunquakes). Previous radiative hydrodynamic modeling using the RADYN code showed that such impacts could not be explained in the framework of the standard flare model with electron beam heating. One of the possibilities to explain the observed white-light emission and sunquakes is to consider additional heating mechanisms involved in solar flares, for example, Alfvén wave heating and heating by the proton beams. In this work, we analyze the single-loop RADYN proton beam simulations for a wide set of beam parameters. Using the output of the RADYN models, we calculate synthetic HMI-line Stokes profiles and line-of-sight (LOS) observables as well as the 3D helioseismic response and compare them with the corresponding observed characteristics. The initial results show that the RADYN models with proton beam heating are substantially closer to the HMI observations than the standard electron-beam thick-target models.

Alexander Warmuth

Warmuth, Alexander (1), Mann, Gottfried (1), Schuller, Frederic (1)

(1) Leibniz Institute for Astrophysics Potsdam (AIP)

Energy partition in solar flares: first results from new observations and new models

Solar eruptive events are characterized by a complex interplay of energy release, transport, and conversion processes. Over the past two decades, the energetics of both the thermal plasma and the accelerated nonthermal electrons have been studied extensively using RHESSI data and the cold thick-target model. Here, we report on first results using two novel approaches: (1) HXR spectroscopy using STIX data, which have the advantage of a very stable background, and (2) applying the warm-target model, which can provide upper estimates of the nonthermal electron energetics.

Alexei Struminsky

Alexei Struminsky (1), Irina Grigorieva (2), Andrei Sadovski (1)

(1) Space Research Institute, (2) Pulkovo Observatory

Velocities of SXR source expansion and CME

We calculate from the SXR observations. X1. 1 flare on July. 6, 2012 an expansion rate of the. SXR source assuming different densities. The expansion rate reach supersonic and super-Alfven velocities if the plasma frequency in the source were less than 245 MHz. The expansion rate corresponds to the expected velocities of the CME with its uniform acceleration from 1.1-1.25Rs.

Andrea Francesco Battaglia

Battaglia, Andrea Francesco (1,2), Wang, Wen (1,3), Saqri, Jonas (4), Podladchikova, Tatiana (5), Veronig, Astrid (4), Collier, Hannah (1,2), Warmuth, Alexander (6), Krucker, Säm (1,7)

(1) FHNW, Windisch, Switzerland; (2) ETHZ, Zürich, Switzerland; (3) SESS, Beijing, China; (4) UniGraz, Graz, Austria; (5) Skoltech, Moscow, Russia; (6) AIP, Potsdam, Germany; (7) UC, Berkeley, USA

Solar Orbiter/STIX flare observations associated with coronal jets

Understanding the mechanisms of the acceleration of electrons in the lower solar corona and their subsequent access to the interplanetary space are outstanding and unsolved questions in science. Coronal jets, that are defined as collimated plasma jets in the corona, are of particular interest since they are believed to be at the origin of the solar winds. Despite coronal jets are widely observed, their formation mechanism is still debated.

In this work, we report on the study of coronal jets that are associated with Hard X-ray (HXR) observation of flares performed with the Spectrometer/Telescope for Imaging X-ras (STIX) aboard Solar Orbiter. EUV/UV and optical observations confirm the nature of the eruption and type III radio measurements indicate the presence of propagating nonthermal electron beams toward interplanetary space. Detailed STIX imaging and spectroscopic analysis allowed us to investigate thermal and nonthermal emissions for two case studies.

Arun Kumar Awasthi

Awasthi, A.K.(1), Mrozek, T. (1), Litwicka, M. (1), Stęślicki, M. (1), Kołomański, S. (2), Kułaga, K. (2)

(1) Space Research Centre, Polish Academy of Sciences, Bartycka 18A, 00-716 Warsaw, Poland, (2) Astronomical Institute, University of Wrocław, Kopernika 11, 51-622 Wrocław, Poland

Relative productivity of X-ray and E/UV emission in weak flares observed during STIX-STEREO Conjunction

Standard model of energy release during solar flares enables deriving the relative productivity of the Soft X-ray (SXR) and Hard X-ray (HXR) fluxes during flares through the Neupert effect [Neupert, 1968]. A generalization of the Neupert effect is further attempted by associating UV emission during flares discretely with the flare heating [Qiu, 2021]. Since weak flares (GOES class ≤B) are often found to produce strong non-thermal emissions [Inglis and Christe, 2014, Warmuth and Mann, 2020], it is imperative to investigate the thermal and nonthermal nature of the flare plasma in the framework of Neupert effect to infer the underlying energy release mechanism. The observing line-of-sight of Spectrometer Telescope for Imaging X-rays (STIX) (at ~0.5 AU) and STEREO-A (at ~0.95 AU) satellites remained in close vicinity during September 2021, thus offering a unique opportunity for a detailed multi-instrument investigation. More than 50 weak flares have been identified during September 20-21, 2021, originating from Two ARs, located on different hemispheres. SXR (4-10 keV) and HXR (>10 keV) fluxes have been investigated for timing association and relative productivity. UV emission in 1600˚A & 1700˚A during flares have been further convolved with an exponentially decaying cooling function to qualitatively mimic the temporal evolution of soft X-ray emission. Next, X-ray images in 6-10 keV at flare maximum have been synthesized to deduce geometrical properties of X-ray sources. A correlation of geometrical parameters of X-ray and EUV sources are being processed to associate it with flare cooling. With such a multi-wavelength analysis of weak flares, we aim to probe energy release mechanism and evaluate the same in the framework of standard model of solar flares.

Daniel Clarkson

Daniel L. Clarkson (1), Eduard P. Kontar (1), Nicole Vilmer (2), Mykola Gordovskyy (3), Xingyao Chen (1)

(1) University of Glasgow, (2) LESIA, Paris Observatory, (3) University of Manchester

Radio-wave Scattering Effects on Observations of Solar Radio Spikes and Type IIIb Striae Within a Closed Loop System

Radio bursts frequently manifest within the corona due to non-thermal electrons accelerated from the release of magnetic energy and are strongly affected via propagation through a turbulent medium. Solar radio spikes are very short duration bursts that are indicative of sub-second small-scale energy release in the corona, yet their origin is not understood. We present a statistical analysis of spatially, frequency, and time resolved imaging of individual solar radio spikes between 30-45 MHz within a coronal loop using the LOw Frequency ARray (LOFAR) and compare with fine frequency structures of type III emission (striae). We show that spikes and striae are co-spatial, emitted within a finite region, and subject to significant centroid displacement with comparable and frequency dependent trajectories over time at fixed frequencies. The spike centroid velocities are often superluminal, independent of frequency, and consistent with radio-wave scattering simulations with strong anisotropy of the density fluctuation spectrum. The similarity between the bandwidth ratio distributions of each burst implies the emission passes through density inhomogeneities with comparative spatial scales. The observed emission properties are consistent with the interpretation of radio-wave scattering in an anisotropic turbulent medium, that likely extends to decimeter spike observations due to a consistent trend in decreasing decay time and source size. Estimations show that the intrinsic source size could be less than 1 arcsec, and comparable to sizes in the decimeter range. The dominance of scattering on the observed time profile and brightness temperature suggests that the energy release responsible for electron acceleration is more intense, and occurs over a shorter time than previously assumed, reducing the characteristic emission timescale to tens of milliseconds at decameter wavelengths.

David Tsiklauri

Tsiklauri, David (1)

(1) University of Georgia, School of Science and Technology, Tbilisi, Georgia

Particle-in-cell simulation of sub-ion cyclotron frequency spectrum of circularly polarized dispersive Alfven waves in inhomogeneous solar flaring plasmas

The observed soft X-ray flux during solar flares is produced by electron bremsstrahlung, when accelerated electrons that move from magnetic loop top to the footpoints slow down by dense layers of the sun. In order to explain the observed soft X-ray flux during solar flares, if electron acceleration happens at loop top, nearly 100% electrons need to be accelerated. No acceleration mechanism is known with such high efficiency. This problem can potentially be solved by postulating [Fletcher & Hudson, Astrophys. J. 675, 1645 (2008)] that flare at loop top creates dispersive Alfven waves (DAWs) which then propagate towards the footpoints, and as they move in progressively denser parts of the loop (due to natural gravitational stratification) the aforementioned high percentage is no longer needed. It has been known that, in homogeneous plasma, when perpendicular wavelength of Alfven wave (AW) approaches kinetic scales such as e.g. ion-inertial length, it acquires magnetic-field-aligned (parallel) electric field, which can efficiently accelerate electrons [Stasiewicz et al Space Sci. Rev. 92, 423 (2000)]. Further, Tsiklauri, Sakai, & Saito, Astron. Astrophys. 435, 1105 (2005) have shown that if DAW propagates in plasma with transverse (with respect to external magnetic field) density inhomogeneity, the generated parallel electric field is orders of magnitude higher than (i) homogeneous plasma case and (ii) Dreicer electric field (one that triggers electron run-away acceleration). Subsequently Tsiklauri Phys. Plasmas 19, 082903 (2012) has revisited the problem with full 3D particle-in-cell approach. Ofman JGR 115, A04108 (2010) considered similar set up as in Tsiklauri, Sakai, Saito (2005) but instead of considering one DAW harmonic with 0.3 \omega_{ci} he considered f^(-1) AW cascade and added He++ ions and used Hybrid simulation model. Note that our approach uses PIC code so it can resolve electron-scale physics

contrary to Ofman who used Hybrid code, which can resolve only ion-scale physics. Now in the present work we essentially revisit Ofman's set up run it for two cases
1. when transverse density gradient is ~c/\omega_{ci} (as in Tsiklauri, Sakai, Saito (2005) and Tsiklauri (2012)), i.e. on "electron"-scale;
2. when the gradient is on ion scale circa 40 c/\omega_{ci} (as in Ofman (2010)) i.e. on "ion"-scale; In this presentation novel numerical simulation results will be presented. Including the scaling of the magnetic fluctuations power spectrum steepening in the higher-density regions, and the heating channelled to these regions from the surrounding lower-density plasma due to wave refraction, as originally found by Ofman (2010).

Fan Guo

Fan Guo (1), Xiaocan Li (2), Xiangliang Kong (3), Bin Chen (4), Chengcai Shen (5), Lindsay Glesener (6), Sijie Yu (7), Jing Ye (8), Joe Giacalone (9)

(1) Los Alamos National Laboratory, (2) Dartmouth College, (3) Shandong University, (4) NJIT, (5) HAO, (6) University of Minnesota, (7) NJIT, (8) Yunnan Observatory, (9) University of Arizona

Numerical Modeling of Particle Acceleration and Emissions during Solar Eruptions in the Imaging Spectroscopy Era

Multi-wavelength imaging spectroscopy has provided unprecedented opportunities to study high-energy processes in solar flares in detail. We briefly introduce recent progress on numerical modeling on nonthermal particle acceleration driven by magnetic reconnection. We introduce a framework for studying nonthermal acceleration, transport, and radiation by combining magnetohydrodynamic simulations, particle transport, and radiation models. This is designed to compare in concord with observations and deepen our understanding to high-energy processes in solar flares. This model has been applied to reproduce several features of nonthermal emissions in solar flares, such as energetic particles in the loop-top region, double coronal sources, and the broad current sheet region. Although preliminary, these first results have shown a great potential for understanding the roles of flare configuration, magnetic reconnection and shocks in energetic electron production and distributions.

Frederic Schuller

Schuller, Frederic (1), Warmuth, Alexander (1), Mann, Gottfried (1), Hurford, Gordon (2, 3), Krucker, Säm (2, 3)

(1) Leibniz-Institut für Astrophysik Potsdam (AIP), Germany; (2) University of Applied Sciences and Arts Northwestern Switzerland; (3) Space Sciences Laboratory, University of California, Berkeley, USA

The STIX Aspect System and Solar Orbiter's pointing stability

The Spectrometer/Telescope for Imaging X-rays (STIX) has been delivering images in thermal and non-thermal X-ray emission since April 2020. Because only flaring regions are visible in hard X-rays, no other solar features that are conventionally used for co-alignment (e.g. the solar limb) can be used to assess the pointing. Moreover, thermoelastic deformation of the spacecraft

or STIX mechanical structures can change the relative direction of the STIX optical axis in the spacecraft reference frame, so that relying on the spacecraft aspect solution alone does not provide the required accuracy to place STIX images in the context of data acquired at other wavelengths. Therefore, a dedicated optical system, the STIX Aspect System (SAS), was specifically designed to measure the pointing direction of STIX with respect to the Sun. Here we provide a description of the system and an overview of the results obtained so far, which demonstrate how the SAS measurements can help improving the pointing stability of Solar Orbiter over the course of the mission.

Gabriela Galarraga

Galarraga, Gabriela (1)(2); Azuma, Jeffery (1)(2); Dhindsa, Ajay (1)(2); Fitzgerald, Alex (1)(2); Pickens, Aaron (1)(2); Sandiford, Carson (1)(2)

(1) Colorado Space Grant Consortium, (2) University of Colorado Boulder

Student Thermal Energetic Activity Module (STEAM): X-Ray Spectrometers Investigating Solar Plasma Heating Mechanisms

The Student Thermal Energetic Activity Module (STEAM) will explore how solar coronal plasmas are heated in flares and active regions by measuring the abundances of elements with low first ionization potential (FIP) using soft (0.5-10 keV) and hard (5-30 keV) X-rays to distinguish signatures of magnetic reconnection-based heating mechanisms.

Typically, coronal abundances of low-FIP elements (e.g. Mg, Si, Fe, Ca) are enhanced by a factor of ~4 above chromospheric values. Measuring the abundances of low-FIP elements for various species at different temperatures provides insight into the coronal or chromospheric origins of the heated plasma. X-ray emissions, including spectral lines and continuum, provide the most direct diagnostic signatures of hot coronal plasma.

STEAM will use a pair of hard and soft X-ray spectrometers to measure incident photons and their energies emitted from solar flares and active regions. Combined, the detectors will capture a broad range of X-ray emissions from 0.5 to 30 keV, with spectral resolutions of <0.3 & <1 keV FWHM in soft and hard X-rays respectively, providing a comprehensive look at thermal plasma evolution. STEAM will utilize forward modeling with bremsstrahlung and atomic emission databases to fit physical parameters such as temperature and elemental abundance to observed spectral data. These elemental abundances allow STEAM to infer the origin of plasma for flares and active regions.

STEAM is a student payload hosted on one of the PUNCH Small Explorer spacecraft with an expected launch in mid-2025 and 2-year prime mission. STEAM's spectral observations of solar flares and active regions in soft and hard X-rays during the maximum of solar cycle 25 will measure a wide range of activity to help constrain potential heating mechanisms for coronal plasma. STEAM has completed Critical Design Review and is currently building and testing the engineering model. We will present the STEAM science motivation, design, current progress, and future outlook.

Graham Kerr

Kerr, Graham (1)(2), Polito, Vanessa (3)(4), Yan Xu (5)

(1) Catholic Univeristy of America,; (2) NASA Goddard Space Flight Center, ; (3) Bay Area Environmental Research Institute, ; (4) Lockheed Martin Solar and Astrophysics Laboratory; (5) New Jersey Institute of Technology

Flare ribbon fronts: the chromosphere's window on magnetic reconnection

Recent observations at high spatial resolution have revealed that the very narrow, fainter, leading edge of flare ribbons (ribbon fronts) exhibit different properties than the brighter trailing portions. The IR He I 10830 line has been seen to dim, producing negative ribbons, for ~1-3 minutes before brightening. Near-UV Mg II spectra have unique characteristics at the ribbon fronts (including slightly blueshifted line core, very broad wings, a deeper central reversal, and strong subordinate line emission), lasting for a similar duration. Similarly, UV imaging has shown a 1-3 min period between activation and the peak of emission in ribbon front sources. Modelling work by us has revealed that in order to produce the He I 10830 negative flare ribbons non-thermal electrons must be present in those locations, with weaker electron fluxes with harder energy spectra producing a longer period of dimming. Similarly, the simulations that are better able to produce He I 10830 dimming produce Mg II spectra that are more consistent with ribbon front profiles than simulations with higher energy fluxes. However, the duration of both was very short, only a few seconds compared to the dozens of seconds in observations. The only way that we are able to reproduce the observed timing of ribbon front behaviour is to have to have two phases of energy deposition into each location in lower atmosphere: an initial extended period of weak heating to produce ribbon fronts, followed by much stronger heating to produce the bright portion of the ribbons. The ribbon front profiles persist for as long as we have weak heating, suggesting that in some locations we have 1-3 minutes of weak heating preceding the bulk of energy injection into that same location. These results illustrate that the lower atmosphere carries important information about the magnetic reconnection and particle acceleration processes in the corona, and that by studying the chromosphere at high spatial and temporal resolution we can potentially place constraints upon them.

Haihong Che

H. Che (1), G.P. Zank(1), A. O. Benz (2), B. Tang (1) and C. Crawford(1)

1. University of Alabama in Huntsville 2. University of Applied Sciences and Arts Northwestern Switzerland

The Formation of Electron Outflow Jets with Power-law Energy Distribution in Guide-field Magnetic Reconnection

Observationally, electron beams with power-law energy spectra are commonly associated with solar flares. Previous studies have found that during magnetic reconnection (MR) with a guide field B g larger than 0.1 times the asymptotic field B0, electron beams are unable to develop due to the strong deflection caused by the guide field. Using particle-in-cell simulations we show that in force-free reconnection, the development of an electron Kelvin– Helmholtz instability (EKHI) can suppress the Hall effect and produce a flute-like outflow exhaust, in which both electrons and ions are nearly frozen-in with the magnetic field. The coupling of a continuously growing electron velocity shear and E × B drift drive the electrons out of magnetic vortices and results in collimated jets with a power-law energy spectrum in the elongated exhaust. The spatial density of electron jets is comparable to the background and is highly inhomogeneous, signifying on asymmetric density structure in guide field reconnection.

Hannah Collier

Hannah Collier (1,2), Laura Hayes (3), Andrea F. Battaglia (1,2), Louise Harra (2,4), Säm Krucker(1,5)

(1) Fachhochschule Nordwestschweiz, Windisch, Switzerland; (2) ETH, Zürich, Switzerland; (3) ESA ESTEC, Noordwijk, Netherlands; (4) PMOD/WRC, Davos, Switzerland; (5) UC Berkeley, CA, USA

Decomposition of the hard X-ray emission of solar flares into individual Gaussian pulses

The Spectrometer Telescope for Imaging X-rays (STIX) onboard Solar Orbiter consists of 32 energy channels which detect X-ray emission from solar flares of energies in the range of 4-150 keV. With STIX, it is possible to perform imaging spectroscopy for solar flares with a 1 keV energy resolution at an unprecedented high time cadence (0.5 s), in the hard X-ray range. This work exploits the novel capability of STIX by focusing on the investigation of fast time, oscillatory variations in the hard X-ray emission of flares. Gaining an understanding of the mechanism behind such fast time variations is pertinent for revealing the fundamental processes involved in the acceleration of electrons and ultimately for the generation of a unified solar flare model. In this work a new approach to HXR time series analysis is developed involving Gaussian process regression (GPR) for signal smoothing. The smoothed HXR time profiles are then fitted with a linear combination of Gaussians, from which key characteristics such as the time between peaks, FWHM, height and periodicity are derived. This method provides important timing information which can be used to spatially resolve sources and to perform time dependent spectral analysis of the individual peaks. This analysis is based on several M and X class flares observed by STIX since September 2021.

Hugh Hudson

Hudson, Hugh (1,2), Hannah, Iain (2)

(1) SSL, UC Berkeley, (2) University of Glasgow

Hot Onsets and Precursors

The identification of flare or CME precursor activity has generated extensive literature; we count 662 ADS ``flare + precursor" entries (qualified to exclude non-solar cases, such as "volcanoes") and another 229 for "CME + precursor". These articles cover a wide range of phenomena, and anecdotally we recall the Skylab astronauts' use of H-alpha filament agitation to anticipate eruption. The recent recognition of the "hot onset" property observed in Sun-as-a-star soft X-rays appears in the great majority of flare/CME events of all types.

The identifying property is the sudden appearance of high isothermal temperatures (typically 10-15 MK) at emission measures of order 10^(46)-10^(48) cm^(-3) during the precursor increase. The hot onset clearly precedes the impulsive-phase hard X-ray emission and has a characteristic pattern in the diagnostic diagram correlating temperature and emission measure, in which the emission measure increases almost linearly at roughly constant temperature. Many cases exist, however, in which hints of non-thermal activity accompany the hot onset (e.g. SOL2001-09-24T10:38 (X2.6), as described in the Yohkoh era by Farnik et al., 2003. We provide a hot-onset analysis of this very extended precursor (tens of minutes) and point out further examples in the RHESSI era.

Ilan Roth

Ilan Roth (1)

(1) University of California, Berkeley, CA 94720 USA

Coronal Braids – Oscillations, Reconfigurations, Stability: manifested by physics, controlled by mathematics

Relaxation of magnetized plasma from initial non-equilibrium state to its final state is a fundamental process for laboratory and space/astrophysical analysis and prediction of the path to the equilibrium plasma state has been a topic of major effort in theory and experiment. The geometrical and topological modifications in the structure of the magnetic field may shed light on the intricate quantities, which determine the evolution of the system. In the present attempt we deal with the evolution of entangled magnetic braids, which were observed or presumed in the solar corona, as mathematical entities, i.e. Artin Braids. These braids, a set of n disjoint strings in 3-space attached to two (horizontal) bars at the top and at the bottom with elementary crossings of strands, in many aspects are similar to the solar magnetic braids observed in high resolution. The interplay between physical and magnetic knots allows us to predict observable oscillations and impose bounds on the stability of active coronal.

An important topological connection between braids and knots/links was established through the Alexander theorem stating that any knot may be obtained from a closure of some braid, joining orderly through simple arcs the endpoints at the upper loose ends of a braid with the lower ones. Since knots posses, beside helicity, set of knot invariants based on the three Reidemeister diagrammatic moves, the Artin Braid Group moves allow stable braid oscillations which are therefore predicted in high resolution observation of physical braids. Additionally, Markov moves allow a large number of new magnetic braids interchange with existing braids to undergo significant modifications and still converge by closure to the same knot. Therefore, one may impose conditions on stable heating process which increase macroscopically the active region, while processes which do not conserve the equivalent knot invariant are candidates for disruption of this region. This approach may add significantly to the understanding of coronal oscillations and its stability.

Ivan Zimovets

Zimovets, Ivan (1), Nechaeva, Alena (1), Sharykin, Ivan (1), Nizamov, Bulat (2)

(1) Space Research Institute of the Russian Academy of Sciences, (2) Moscow State University, Sternberg Astronomical Institute

Sources of Long-Period X-Ray Pulsations before the Onset of Solar Flares

According to [Tan et al., 2016], long-period (with a period P~1.9–47.3 min and a duration of 1–2 h) pulsations are observed in soft X-rays before a significant fraction (26–46%) of "isolated" solar flares. It was obtained from the GOES/XRS data without spatial resolution. Using RHESSI images we found that such events can be divided into two types. In type I events, the sources of all pulsations and the main flare are located in the same active region (AR) on the Sun, while in type II events the sources of at least part of the pulsations are located in different AR(s) than the flare AR. A more detailed analysis of two type I events and three type II events using RHESSI X-ray and SDO/AIA ultraviolet images shows that the sources of pulsations in one AR are located in different places (within ~20 Mm from each other and from the main flare) and their appearance corresponds to the appearance of new loop-shaped ultraviolet sources. We present observational arguments, which are not in favor of the mechanisms suggested in [Tan et al., 2016] based on oscillations of coronal loops as LRC electric circuits or MHD oscillations of loops. Observations show that pre-flare pulsations are rather the result of successive episodes of energy release due to magnetic reconnection associated with the dynamics of the magnetic field in AR. For example, in a type I event on February 17, 2013, preflare pulsations are accompanied by a pronounced shear motion (with an average velocity of about 0.5 km/s) of one more compact sunspot relative to another one of an opposite magnetic polarity. For this event, we present the results of a detailed analysis and comparison of the energy release during preflare pulsations and during the main flare. It is also interesting to note that in type I events, successive episodes of energy release occur in one AR, while in type II events they occur in several separated (up to ~2 solar radii) ARs, at least some of which are unlikely to be connected by coronal loops. To explain such type II events one needs to assume the coherence of the subphotospheric emergence of magnetic fluxes in different parts of the Sun. This assumption requires further verification.

Ivica Skokić

Skokić, Ivica (1), Benz, Arnold O. (2,3), Brajša, Roman (1), Sudar, Davor (1), Matković, Filip (1), Bárta, Miroslav (4)

(1) Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia, (2) University of Applied Sciences and Arts Northwestern Switzerland, Windisch, Switzerland, (3) Institute for Particle Physics and Astrophysics, ETH Zürich, Switzerland, (4) Astronomical Institute of the Czech Academy of Sciences, Ondřejov, Czech Republic

Flares detected in ALMA single-dish images of the Sun

We report the first solar flares observed by ALMA with complete spatial coverage. We searched for millimeter flares during the times of ALMA single-dish imaging in times reported by a solar flare catalog. The temporal and spatial evolution of five selected flares is analyzed by comparing ALMA measurements with EUV and H-alpha filtergrams and GOES X-ray fluxes. Significant

millimeter radiation of up to 600 K above normal level was found as well as a surprising variety of associations with spatial features related to both hot and cold plasma, from H-alpha filaments to hot loop tops and footpoints. Although the millimeter emission process is probably thermal free-free emission, it seems that the previous scenario of a chromospheric hot spot heated by a precipitating electron beam is too simplistic.

James McTiernan

McTiernan, James (1), Caspi, Amir (2), Warren, Harry(3), Laming, J.Martin (3)

(1) Space Sciences Laboratory, University of California, Berkeley, CA (2) Southwest Research Institute, Boulder, CO (3) Naval Research Laboratory, Washington, DC

Solar Flare Abundance calculations with MinXSS and RHESSI

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), the relative abundances of 5 elements (Si, S, Ca, Fe, Ni) are free parameters in the calculation.

Using a sample of approximately 150 time intervals from nine solar flares observed by MinXSS and RHESSI in 2016 and 2017, we calculate the abundances using MinXSS alone and MinXSS plus RHESSI, and compare with previous results.

Jana Kašparová

Kasparova, J., Karlicky M., Farnik, F.

Astronomical Institute of the CAS, Ondrejov, Czech Republic

Radio and HXR emission of two M-class flares

We present our attempt to analyse two GOES M-class events observed by radiotelescopes in Ondrejov and STIX which show radio pulsation in the impulsive phases. One event, on 9 Oct 2021, is seen as on disk from the Earth and Solar Orbiter, the second, on 28 Mar 2022, is seen on limb from Solar Orbiter while on disk from the Earth.

Janusz Sylwester

Janusz Sylwester (1), Barbara Sylwester (1), Kenneth J.H. Phillips (2), Arun Kumar Awasthi (1)

(1) Space Research Centre, Polish Academy of Sciences, Solar Physics Division, (2) Natural History Museum, Earth Sciences Department, London

On a possibility to determine Iron absolute plasma abundance from STIX spectra

The X-ray spectral range covered by STIX on The Solar Orbiter (ESA/NASA heliocentric orbit probe) includes a group of strong Fe II-XXVI lines in its 6-7 keV (3rd) energy channel during flares. These iron lines have been observed superposed on the continuum which is due to bremsstrahlung (ff) and recombination (fb) radiation. The contribution of iron line emission to the continuum (L/c) in this channel depends on ionization conditions in the flaring plasma (or temperature if in equilibrium) and the abundance of iron. For quasi-equilibrium plasma conditions the L/c temperature dependence can be calculated for the 3rd (iron) and neighboring STIX energy channels in the fixed lower energy ranges 4-5-6-7-8-9 keV (used by STIX early in the mission). For this purpose the CHIANTI atomic code has been used to generate input spectra and the detector response matrix, DRM. The resulting synthetic spectra have been calculated over a wide range of plasma temperatures (3-100 MK) and for various plasma compositions (including elements whose abundances depend strongly on first ionization potential, FIP). It was found that the ratio of the flux observed in the 3rd to the average flux in the 2nd and 4th channels (we call this factor LFe/C) shows a characteristic dependence on plasma temperature and on the absolute abundance of Fe. In this contribution we will present the theoretical dependence and discuss our expected flare iron abundance determinations. We give as an example (preliminary analysis) the observed evolutionary path on a diagram of LFe/C vs. temperature for a flare in 2021 (M3.9 SOL2021-05-07T19:04 UT), showing the Fe abundance variations in the course of the flare evolution.

Jiong Qiu

Jiong Qiu (1)

(1) Montana State University

The Neupert Effect of Flare Ultraviolet and Soft X-Ray Emissions

We model the Neupert effect that relates flare heating energy with the observed soft X-ray (SXR) emission. The traditional form of the Neupert effect refers to the correlation between the time-integrated hard X-ray or microwave light curve and the SXR light curve. In this study, we instead use, as the proxy for heating energy, spatially resolved ultraviolet (UV) emission at the foot-points of flare loops and modify the model of the Neupert effect by taking into account the discrete nature of flare heating, as well as cooling. The Neupert effect is studied using two methods, a modified empirical formula of the Neupert effect and the UV Foot-point Calorimeter (UFC) technique (Qiu 2021). The experiments have produced the flare total SXR emission in agreement with observations, and provided a good estimate of heating rates in flare loops continuously formed by magnetic reconnection throughout the flare evolution.

Jonas Saqri

Saqri,J.(1), Veronig,A.M.(1), Dickson,E.C.M.(1,2), Podlachikova,T.(3), Battaglia,A.F(2,4)., Warmuth,A.(5), Krucker,S.(2,6)

(1)Institute of Physics, University of Graz, (2)University of Applied Sciences and Arts Northwestern Switzerland, (3)Skolkovo Institute of Science and Technology, (4)ETH Zürich, (5)Leibniz-Institut für Astrophysik Potsdam (AIP), (6)Space Sciences Laboratory, University of California

Energy and impulsive CME dynamics in an eruptive C7 flare

Solar flares are the impulsive release of magnetic energy giving rise to a wide range of phenomena that influence the heliosphere and in some cases even conditions of earth. Part of this liberated energy is used for particle acceleration and to heat up the solar plasma. The heated solar plasma rising up into the corona is usually observed in soft (<10keV) X-rays and EUV, while the flare accelerated particles hitting the lower atmosphere produce signatures in the hard X-ray band.

On April 17th, 2021, the Spectrometer Telescope for Imaging X-rays (STIX) onboard the Solar Orbiter spacecraft observed a flare that was partially occulted from Earth view. The flare was estimated to be of GOES class C7 and shows several episodes of nonthermal hard X-ray bursts over a total duration of about an hour. This event was also associated with a fast CME and is particularly interesting due to spacecraft positions on April 17th. For Solar Orbiter and STEREO-A, the flare occurred on disc, enabling us to study the response of the lower solar atmosphere to the flare particle acceleration and energy deposition using STIX X-ray imaging, spectral fitting and EUV images from STEREO EUVI. For earth-orbiting spacecraft like SDO which were separated by 98 degrees from Solar Orbiter, the flare occurred just behind the eastern limb. With the bright flare footpoints occulted, this allows us to study the flare related changes in the corona from a side on view and to put them into context of the STIX and STEREO on disc observations.

We find several instances of plasma motions such as detaching plasmoids, flare-related reconnection outflows and super arcade downflows observed by SDO AIA. Some of these plasma flows occur simultaneously with individual HXR bursts observed by STIX. The most distinct instance is the ejection of a hot plasmoid at the beginning of the impulsive flare phase where the acceleration coincides with a peak in the HXR lightcurve. We analyze the dynamics and thermal properties of the flare-related plasma flows and the flaring arcade, the energy releases and particle acceleration as diagnosed by STIX as well as the relation of the ejected plasmoid to the associated CME. Combining different vantage points and instruments allows us to perform a detailed study of the flare and the related eruption over a wide range of atmospheric heights.

Kazi Abul Firoz

Kazi Abul Firoz (1), Wei-qun Gan (1), Y. P. Li (1), J. Rodriguez-Pacheco (2)

(1) Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, China, (2) Universidad de Alcalá de Henares, Madrid, Spain

On the Possible Mechanism of 14 July 2000 High Energy Particle Event

We have studied the solar energetic particle (SEP) and ground level enhancement (GLE) event occurred during the 14 July 2000 Bastille Day and interpreted the results with those obtained by some other researchers in order to comprehend the possible mechanism of the event. It is observed that the rise phase of the soft X-ray (SXR) flare component was associated with a group of fast-drifting solar radio type III bursts and then with coronal shock manifested in m-type radio II burst, thereby specifying that the flare acceleration phase was the most important energy release episode associated with the rise phases of SEP and GLE. The SEP rise phase was characterized by an impulsive evolution and then by a gradual evolution, which was associated with the coronal shock manifested in DH-type II radio burst that lasted far beyond the flare end. Both the impulsive and gradual components of the SEP rise phase coincided with the rise phases of electromagnetic radiation components of different wavelengths exhibiting different episodes of energy releases from lower to higher corona, thereby explaining the roles of the flare and shock acceleration on the SEP rise phase. Analysis of the spatial evolution showed that the flare eruption occurred in two stages, with the first eruption existing in the western part of the flare ribbons over the SXR impulsive rise phase, and the second eruption triggering at the eastern part over the SXR decay phase.

Marek Stęślicki

Marek Stęślicki (1)

(1) Space Research Centre, Polish Academy of Sciences

Elementary flare profiles fitted to the STIX light curves using differential evolution algorithm.

After the launch of the Spectrometer Telescope for Imaging X-rays (STIX) onboard Solar Orbiter on 10 February 2020, it is recording solar X-rays almost uninterruptedly since January 2021 covering the rising phase of solar cycle 25. STIX registers many number of flares. We present a methodology is given to determine basic parameters of flares from their X-ray light curves. One is a semiautomatic flare detection procedure that gives start, peak, and end times for single ("elementary") flare events under the assumption that the light curve is a simple convolution of a Gaussian and exponential decay functions. More complex flares with multiple peaks can generally be described by a sum of such elementary flares. The flare time profiles are hard to fit automatically using standard methods. I will present a method based on differential evolution used to fit elementary flare profiles to the STIX light curves.

Maria Kazachenko

Kazachenko, Maria (1,2)

(1) University of Colorado, Boulder, (2) National Solar Observatory, Boulder.

Eruptive vs. confined solar flares: statistical comparison of their solar source properties

What is the difference between confined and eruptive flares in terms of their physical properties at the Sun? We analyze 294 largest flares (154 eruptive and 140 confined) from 2010 until 2017 located within 45 degrees from the disk center observed by the Solar Dynamics Observatory (SDO). We compare GOES X-ray thermal flare properties, including temperature and emission measure, active-region and flare-ribbon magnetic field properties, including peak rates of reconnected magnetic flux, between confined and eruptive flare groups. We summarize statistical similarities (e.g. in reconnection fluxes, temperatures etc.) and differences (e.g. in reconnection flux rates, mean photospheric magnetic fields etc.) between these groups. We discuss how these results advance our understanding of the physical mechanisms responsible for eruptive and confined solar flares.

Marianne Peterson

Marianne Peterson (1), Lindsay Glesener (1), Vanessa Polito (2), Paola Testa (3), Sijie Yu (4), Jessie Duncan (1)

(1) University of Minnesota, (2) Bay Area Environmental Research Institute, (3) Harvard-Smithsonian Center for Astrophysics, (4) New Jersey Institute of Technology

NuSTAR and IRIS Co-observation of Microflare-Accelerated Electrons

The Nuclear Spectroscopic Telescope ARray (NuSTAR) uses direct-focusing Hard X-Ray (HXR) telescopes to study astrophysical sources, and is capable of performing solar observations. NuSTAR's direct-focusing optics provide high sensitivity to observe transient brightenings of microflares below GOES class B. The HXR regime is particularly useful for measuring nonthermal electron distributions and flare-heated plasma on the order of 5-10 MK, both via bremsstrahlung radiation (Grefenstette 2016). Investigation of nonthermal emission in these microflares, made possible by NuSTAR's sensitivity, expands our understanding of particle acceleration to fainter flares, and gives important insight on similarities in the energy makeup between large and small flares.

In conjunction with the increasingly organized multi-instrument campaigns centered around Parker Solar Probe's (PSP) perihelia, NuSTAR observed the Sun on April 29th, 2021, along with the Interface Region Imaging Spectrograph (IRIS) and the radio observatory the Very Large Array (VLA). This co-observation presents powerful opportunities for the joint study of flare-accelerated electrons and how these high-energy electrons affect the local plasma. During this observation, the IRIS slit that is capable of spectroscopy was aligned atop the same flaring region contained in NuSTAR's FOV. Doppler blueshifting of the Silicon IV emission line is indicative of nonthermal activity with IRIS (Testa 2014), and was seen in initial IRIS analysis for this observation. Initial NuSTAR investigation also suggests the possibility of flare-accelerated particles present in at least 1 flare. A full spectral, spatial and temporal characterization of the flares that show possible nonthermal signatures within this NuSTAR observation will be presented. This joint analysis presents potential for the observation of both nonthermal emission signatures in the transition region with IRIS, and direct observation of the accelerated electron distribution at the flare source with NuSTAR. By combining the available analysis methods, greater knowledge of nonthermal emission within microflares may be achieved than with previous independent observations.

Meredith Wieber

Wieber, Meredith (1), Saint-Hilaire, Pascal (1), Shih, Albert (2), Al Nussirat, Samer (1) and the GRIPS team

(1) Space Sciences Laboratory, Berkeley, CA, (2) NASA Goddard Space Flight Center, Greenbelt, MA

Preparations for the second flight of the Gamma Ray Imager/Polarimeter for Solar Flares (GRIPS)

The GRIPS (Gamma Ray Imager/Polarimeter for Solar Flares) high-altitude balloon is scheduled for its second long duration balloon flight from Antarctica in 2024. It will study gamma rays and hard X-rays from solar flares in the 20 keV to 10 MeV range with high resolution imaging, spectroscopy, and polarimetry. The GRIPS spectrometer/polarimeter consists of 12 high-purity Germanium (HPGe) strip detectors with 3D-position sensitivity and an energy resolution of a few keV FWHM and spatial resolution of ~0.1mm3. Imaging is achieved through the use of the Multi-pitch rotating modulator (MPRM), a single 2.5-cm thick tungsten alloy slit/slat grid with pitches that range quasi-continuously from 1 to 13 mm. With the MPRM placed 8 m from the spectrometer and rotating at ~10 rpm, GRIPS is able to image gamma-rays from solar flares with 12.5’’ resolution. As no accurate CAD model of the MPRM currently exists, efforts have been recently made to digitize this coded aperture. Images taken with a Canon DSLR camera prior to the 2016 flight were processed into grayscale and black-and-white versions, then averaged and analyzed for rotation and/or tilt angles to produce a list of widths, positions, and orientations for each slat. These are known to within a pixel and allow the precise reconstruction of solar flare images. Flare observations collected with GRIPS will be used to address several outstanding questions in solar science, such as whether electrons and ions in flares share a common acceleration process, and whether this is related to the spatial separation in emission between the two, as well as how anisotropic relativistic electrons emitted from flares are and how they and the energetic ions propagate through the solar environment.

Muriel Stiefel

Stiefel, Muriel (1), Battaglia, Andrea (2), Collier, Hannah (2), Barczynski, Krzysztof (3), Schwanitz, Conrad (3), Harra, Louise (3), Krucker, Säm (2)

(1) ETH Zürich, (2) Fachhochschule Nordwestschweiz, (3) Physikalisch-Meteorologisches Observatorium Davos

Hard X-ray signatures from flare accelerated electrons away from the main flare loop

SOL2021-09-23UT15:28M1.8 is one of the strongest solar flares observed by SolO/STIX in 2021. It has a prominent impulsive phase that lasts for about 5 minutes with counts well above 50 keV. As well as observation by STIX, there is also excellent coverage available from Hinode/EIS, Hinode/XRT, SDO/AIA and IRIS. Contrary to the general flare picture, from which we expect to observe two main hard X-ray sources located at the footpoints of the flaring loop, SOL2021-09-23UT15:28 clearly reveals four hard X-ray sources in the non-thermal energy range (18-28 keV). The two inner sources correspond to the ‘classic’ footpoints of the flaring loops while there are two additional outer sources. These are symmetrically located to the east and west of the main flare loop. The outer sources are slightly fainter than the two main sources

and are only seen for about ~2 minutes at the onset of the flare. Afterwards only the inner two sources remain. Measurements of an up flow at the outer sources and the dimming regions of the CME suggest that the outer sources are at the anchor points of an erupting filament, where flare-accelerated electrons within the filament precipitate into the chromosphere. As the available observations do not allow us to cleanly identify the erupting filament, our interpretation remains inconclusive.

Olena Podladchikova

O. Podladchikova (1), L. Harra (2,3), A. Warmuth (1), S. Parenti(4), F. Auchère(4), P. Antolin(5), A.M. Veronig(6), M. Georgoulis (7), S. J. Hofmeister (1), C. Verbeeck(9), L. Dolla (9), M. Mierla(9), D. M. Long(10), N. Engler(3,4) A. N. Zhukov(9), H. Safari (11), U. Schühle (12), L.Teriaca(12), A. F. Battaglia(13), É. Buchlin,(4). E. Soubrié(4), R. Aznar Cuadrado(12), K. Barczynski (3,4), D. Berghmans(9), V. Büchel (14), L. P. Chitta (12) , S. Gissot (9), A. De Groof (15), M. Gyo (3), M. Haberreiter(3), J. P. Halain(16,17), B. Inhester(12), E. Kraaikamp (9), D. Müller (16), D. Pfiffner (14), T. Podladchikova(18), S. Purkhart(6), L. Rodriguez(9), P. Rochus(17), F. Schuller(1), P.J. Smith (10), W. Schmutz(3,4), K. Stegen(9), W. T. Thompson(19), Y. Zouganelis (15)

(1) Leibniz Institute for Astrophysics Potsdam, (2) Physikalisch-Meteorologisches Observatorium Davos, (3) ETH-Zürich, (4), Institut d'Astrophysique Spatiale, - Orsay, (5) Northumbria University, (7) University of Graz, (8) Athens Academy, (9) Royal Observatory of Belgium, (10) MSSL, (11) University of Zanjan, (12) MPS, (13) University of Applied Sciences, Windisch, (14) Davos Instruments, (15) EZA Spain, (16) EZA Netherlands, (17) Center Spatial de Liege, (18) Skoltech, (19) NASA Goddard

Picoflares in the Solar EUV Corona

The X-ray monitoring of the Sun inspired E. Parker to describe the elementary unit of energy release in the corona as nanoflare. He estimated the energy of the nanoflare as the dissipation of all currents in a single loop of the active region with a loop length >10000 km, resulting in an energy ~10^(24) erg. He predicted the observation of even smaller heating events with more sensitive instruments. At present, it has not been possible to observe such small heating events. Moreover, EUV imaging in recent decades has set the rigorous limit for the smallest solar flares at the nanoflare level.

On May 30, 2020, the Solar Orbiter High-Resolution Imager (HRIEUV) designed to minimize stray light and being half the distance to the Sun recorded a large number of EUV heating events with smaller spatio-temporal characteristics than nanoflares. Our goal is to classify these heating events according to the physical parameters and to evaluate their individual and collective heat input into the solar corona.

We found that HRIEUV flares emit thermal energy in the {\it picoflare} range of 10^{21}-10^{24}$ ergs, lowering the limit of minimal solar flare energies. They show similar relationship between emission measure and temperature as X-ray flares, but at lower ranges. The most powerful recorded picoflares approaching 10^{24} ergs belong to a GOES class being a factor of 5 smaller than A class flares. These largest events originate in multi-loop flare like configurations and located at 3000-5000 km above the photosphere as was measured stereoscopically for the 1st time in Paper-II. Weaker events of ~10^{21} ergs originate in single loops and located at lower coronal layers of 1000 - 3000 km above the photosphere. The total additional energy of all measured (with > 3 sigma significance) picoflares makes 3 extra previously unaccounted percents to the total power required to sustain the solar corona.

We explain the existence of picoflares as follows. (1) They originate in coronal loops with lengths of 200-10000 km, which is smaller than originally considered by E. Parker. (2) Some picoflares show only a partial energy release along a single loop. (3) Photospheric heights of events belong to the layers where plasma BETA is smaller than 1, especially inside the loops -- which favors the formation of singular field-aligned currents with small dissipative thresholds.

Reed Masek

Masek, Reed (1), Glesener, Lindsay (1), Duncan, Jessie (1), Peterson, Marianne (1), Grefenstette, Brian (2), Smith, David (3), Krucker, Sam (4,5), Hannah, Iain (6), Copper, Kristopher (6)

(1) University of Minnesota, Twin Cities, (2) California Institute of Technology, (3) University of California, Santa Cruz, (4) University of California, Berkeley, (5) University of Applied Sciences and Arts Northwestern Switzerland, (6) University of Glasgow

Constraining the Frequency of Transient Energy Emission through NuSTAR Spectroscopic Analysis

The Nuclear Spectroscopic Telescope ARray (NuSTAR) is a high-energy X-ray telescope orbiting the Earth. NuSTAR's focusing optics and pixel detectors are capable of measuring the time, energy, and position of each measured photon. Each photon is recorded as an individual event, providing high flexibility in the analysis process. While designed as an astrophysical instrument, NuSTAR's increased sensitivity relative to other solar observers offers a unique view of the solar disk, particularly during sub-B-class GOES levels, through direct imaging of hard X-rays greater than 3 keV.

This presentation features work of an automated detection algorithm to identify faint, sometimes unidentifiable by eye, brightenings measured by NuSTAR. Times of heightened count rates are identified from the pixel light curves and grouped based on the temporal and spatial properties of the pixels in order to reconstruct the brightening events. The found events are then put through a first-pass spectroscopic analysis using the XSPEC software to obtain energy estimates and the relative abundance of thermal and non-thermal plasma. We have estimated that NuSTAR has observed hundreds of microflare-scale events, offering a substantial sample size to constrain the flare frequency-versus-energy distribution with energy estimates obtained from the spectral fits. This distribution reveals the significance of small-scale flaring events in providing energy to the solar corona. As instrumentation approaches the observational regime containing the largest nanoflares, refining the flare-frequency distribution becomes increasingly relevant in explaining coronal heating. Lastly, the spectral fits estimate the thermal and non-thermal emission of the event, which is used to characterize the behavior of the microflares relative to their larger counterparts.

Stefan Purkhart

S. Purkhart 1; A. M. Veronig 1; E. C. M. Dickson 1, 2; J. Saqri 1; A. F. Battaglia 2, 3; T. Podladchikova 5; S. Krucker 2, 4; and the EUI team

1 UniGraz, Graz, Austria; 2 FHNW, Windisch, Switzerland; 3 ETHZ, Zurich, Switzerland; 4 UCa, Berkeley, USA; 5 Skolkovo Institute of Science and Technology, Moscow, Russia

A multi-instrument study of the M4-flare on March 28th, 2022

We present results from multi-instrument observations of the M4-class flare on March 28th, 2022, and its associated filament eruption. We focus on remote sensing observations from the Spectrometer Telescope for Imaging X-rays (STIX) and the Extreme-Ultraviolet Imager (EUI) onboard Solar Orbiter and combine them with data from STEREO-A/EUVI+COR2 and SDO/AIA.

Solar Orbiter was close to its first perihelion of the nominal science phase, at a distance of 0.33 AU and at a longitudinal separation of 83.5° from the Earth-Sun line, and observed the Earth-directed event close to the east limb.

Imaging of the STIX hard X-ray observations and comparison with EUI images reveals non-thermal (25-50 keV) emissions from two footpoints and thermal (4-10 keV) emissions from the flare loops. We perform spectral fitting to derive the time evolution of critical parameters of the electron populations.

Emission measure (EM) and temperature derived from the thermal component of the STIX hard X-ray spectrum are compared to results from GOES and Differential Emission Measure (DEM) analysis of extreme ultraviolet (EUV) images from AIA. We find good agreement for the overall time evolution between all three instruments, with exact values varying due to different temperature responses. STIX observed a lower peak EM (0.7*10^49 cm^-3) compared to AIA (1.4*10^49 cm^-3) and GOES (1.6*10^49 cm^-3), while the peak temperature is higher (22 MK) compared to AIA (14 MK) and GOES (16 MK).

We track the erupting filament throughout an EUI 304 Å image series. Observations from STEREO-A/EUVI are used to perform 3D reconstructions of the filament at coinciding timesteps and to fill in the gaps between available EUI images (10 min cadence). We derive speed and acceleration profiles and find a maximum ejection speed of about 580 km/s. Using data from STEREO-A/COR2, we track the CME and its core identified as the ejected filament to a distance of almost 20 solar radii.

Tomasz Mrozek

Mrozek, T. (1), Mikuła, K. (1)

(1) Space Research Centre, Polish Academy of Sciences

Energy-altitude relation in X-ray footpoint sources during solar flares observed by STIX

Solar flares are efficient accelerators of energetic particles, mainly electrons, which transport energy from the reconnection site to the chromosphere. Energetic electrons are thermalized in the denser layers of the solar atmosphere (chromosphere) and produce hard X-ray emissions (HXR; >10 keV) following the thick-target bremsstrahlung mechanism. It further implies that the observed X-ray footpoint sources should follow an energy-altitude relation, i.e., the higher the energy, the lower the altitude of the HXR sources. This is in agreement with previous investigations based on the flares observed with Yohkoh/HXT and RHESSI. Evidently, the energy-altitude relation is an excellent probe of the energy deposition mechanism, properties of the non-thermal electron beam, and the plasma dynamics in flare footpoints. Therefore, we investigated the energy-altitude relation in flare footpoints in a group of strong (>M1.0 GOES class) events recorded by the Spectrometer/Telescope for Imaging X-rays (STIX). STIX is a state-of-the-art HXR experiment that was launched onboard the Solar Orbiter mission and has been recording the X-ray emission from the Sun uninterruptedly since January 2021. We employed the classic Richardson-Lucy algorithm with the MARLIN approach for synthesizing images. Subsequently, obtained relations have been fitted analytically to estimate plasma density in footpoints. Our results of a preliminary search for energy-altitude relation in the STIX images have crucial implications for the thermal-nonthermal energy content in flares.

William Setterberg

Setterberg, William (1), Glesener, Lindsay (1), Gebre Egziabher, Demoz (1), Sample, John (2), Smith, David (3), Caspi, Amir (4), Kozic, Ty (1), Savadogo, Mansour (1), Berger, Christian (1), Clemmer, Lestat (1), Drake, Robert (1), Greathouse, Annsley (1), Ma, Runsheng (1), Nightingale, Mel (1), Walters, Connor (1), Knuth, Trevor (5), Houser, Kyle (1), Meuchel, Rubin (2), Springer, Larry (2)

(1) University of Minnesota, Twin Cities, (2) Montana State University, (3) University of California, Santa Cruz, (4) Southwest Research Institute, (5) NASA Goddard Space Flight Center

The IMpulsive Phase Rapid Energic Solar Spectrometer CubeSat mission

The IMpulsive Phase Rapid Energetic Solar Spectrometer (IMPRESS) is a 3U NSF-Funded CubeSat mission under development by a student-focused team at UMN in collaboration with MSU, UCSC, and SwRI; it will measure X-rays from solar flares at a 30 Hz cadence.

Hard X-ray emission (HXR) from solar flares can be analyzed to explore flare particle acceleration dynamics. Prior studies using Fermi/GBM and RHESSI data have found fast HXR flux variations on timescales of < 10s, but no lower limit to the durations of these limitations has yet been uncovered. The IMpulsive Phase Rapid Energetic Solar Spectrometer (IMPRESS) is designed to observe both soft X-ray (4 to 12 keV) and hard X-ray (10 to 300 keV) emission from solar flares with tens-of-millisecond time resolution to better constrain the timescales of HXR spikes and associated acceleration mechanisms. IMPRESS will measure C1 through X1 GOES class flares with no moving attenuators.

This poster will present an overview of the CubeSat, with an emphasis on its scientific instrumentation. It will also present analytical and Monte Carlo (Geant4) modeling results in the context of our science goals.

Xin Cheng

Y. K. Kou, X. Cheng, Y. L. Wang, S. J. Yu, B. Chen, E. Kontar & M. D. Ding

Nanjing University; New Jersey Institute of Technology; University of Glasgow

Microwave Imaging of Magnetic Reconnection Generating Flare Quasi-periodic Pulsations

Quasi-periodic pulsations (QPPs) are frequently detected in different-scale celestial energy release processes; the responsible physical mechanisms, however, are still to be ascertained. Here, taking advantage of EOVSA and SDO data, we present a clear imaging of magnetic reconnection generating QPPs. The quasi-periodic MW emissions originate from two vertically detached but closely related sources, with the brighter ones located at the flare loops and the weaker ones extending along the stretched reconnection region and even ascending with the decrease of frequency. Although the brightness temperatures of the two MW sources differ greatly, they vary with time synchronously with a prominent period of 30–60 s. The MW spectra, dominated by gyrosynchrotron emission, also present a quasi-periodic soft-hard-soft evolution. The results provide strong evidence for electron acceleration driven by quasi-periodic flare magnetic reconnection, which then generating MW QPPs, likely arising from the modulation of magnetic islands within the reconnection current sheet as validated by 2.5-dimensional magnetohydro-dynamics simulation.