# SDO 2025

# Program and Abstract Book

## A GATHERING OF THE HELIO HIVE

# Welcome to the SDO 2025 Science Workshop: A Gathering of the Helio-hive!

Since the launch of SDO, there have been thousands of research papers describing a wide range of science results from this mission. Join us during the maximum of Solar Cycle 25 to discuss what we have learned about the Sun and compare the new cycle and those in the past. The goal of the meeting is to share and discuss recent discoveries, theories and results obtained with new solar observatories and improve communication and synergies throughout the research community. To accommodate the interest in multiple research topics, SDO 2025 will feature plenary sessions, parallel sessions on focused topics, and a series of "mini-workshops" on the final day.

The SDO 2025 Science Workshop is being held 17-21 February 2025 in Boulder, Colorado. It is organized into 7 sessions that span the breadth and depth of SDO Science. Invited speakers will introduce 7 themed plenary sessions spanning SDO's wide range of research topics:

## Solar Internal Dynamics and Structure

SDO observations have significantly advanced our understanding of the plasma motion below the solar surface and its connection with the various phenomena occurring above the surface. These have led to many new discoveries by expanding our knowledge of the solar interior, for example, the identification of Rossby and inertial waves. However, several intriguing problems remain unsolved that require a better understanding of both observational and theoretical aspects. These include the characterization of local flows, at what depth and where the return of meridional flows happens, how helioseismology can provide new insights into solar activity forecasting.

## From Creation to Emergence: Magnetic Fields of the Sun

The creation of magnetic flux in the solar interior along with its subsequent transport and emergence into the solar atmosphere plays an important role in the Sun. SDO's continual full-disk coverage has provided a wealth of information about the solar magnetic field. This session will focus on multiple aspects of the solar magnetic field including dynamo processes, flux emergence and transport, active region evolution, helicity flux, and polar field dynamics. It is intended to connect the convection zone, surface, and the layers above. Theory, numerical simulations, and observations will be compared in order to determine what processes are empirically validated and where gaps in our understanding exist. We particularly welcome statistical analyses, studies on long-term variability, coordination between SDO and other instruments, and comparisons of observation and modeling.

## Coronal Dynamics: Unveiling the Origins of the Solar Wind

This session delves into the intricate relationship between solar corona processes, such as coronal heating, waves, and jets, and the formation of the solar wind. We will explore how observations of coronal dynamics by the SDO enhance our understanding of the solar wind's origin and its significant impact on space weather and Earth's environment.

## Energetic Outbursts: Deciphering Solar Flares, CMEs, and SEPs

Our Sun is the source of the largest instances of energy release in our solar system. Detection of these energy releases can be measured through a large range of instruments and at many wavelengths. Join us at the energetic outbursts session where we focus on a range of phenomena including solar eruptive events, including flares, coronal mass ejections (CMEs), and solar energetic particles (SEPs), as well as discussing the challenges of forecasting these events.

## Impacts of Solar Variability on Earth, Other Planets, and Space Weather

Since it first launched, SDO has been fundamental in providing observations for studying the Sun's area of influence, the heliosphere. This session aims to discuss the ways SDO continually provides vital information for monitoring the effects of the Sun on Earth, other planets, and the Space Weather. In particular, this session hopes to highlight how SDO products and observations feed models in operational environments, drive Research-to-Operations (R2O) solutions, and inform future operation-focused missions.

## Next Horizon: The Future Solar and Heliophysics Missions

SDO's long continuous baseline of solar observations has set the stage for the next generation of instruments, missions, and software. New instruments and investigations are being developed due to SDO's role in mission-enabling technology and broadened understanding of solar processes. The next generation includes new instrumentation, platforms, vantage points, data processing strategies, and even onboard autonomy and data compression. This session will focus on efforts to establish the new era of SDO science.

## Stellar insights from the SDO Observations

The Sun, our closest star and the only one we can observe with spatial resolution, serves as a paradigm for understanding stellar phenomena. By exploring the parallels between the solar and stellar phenomena, from magnetic activities to energetic events, this session will showcase how SDO data bridges solar physics with broader astrophysical insights and enhances our knowledge of stellar dynamics across the universe.

Research that falls outside these topics is also welcome at the Workshop.

As is usual in an SDO Science Workshop, we offer mini-workshops on the final day of the workshop. This time we emphasize combining other data with SDO. An all-day meeting of the EUV Calibration Workshop team will also happen on Friday.

The workshop is being held at the Hotel Boulderado, a historic gem nestled in the heart of Boulder, Colorado. Boulder has a large and active solar research community, providing many opportunities to interact with members of that community.

We hope you enjoy the meeting, including the reception on Monday and dinner on Wednesday. A special treat will be offered at lunch on Monday, a screening of archival solar films produced at the High Altitude Observatory, and the Sacramento Peak Observatory in the 1940s-50s. An excellent comparison of the images used to study the Sun in Solar Cycles 18 and 19 with those we expect to be available today. The Boulder Pearl Street Mall is close at hand to explore the food and night life of Colorado's premier Front Range city.

## Helpful Information:

If you are giving a talk:
Please use the Google Form Submission:
https://forms.gle/N39HGEa2cqbyzUsPA to upload your presentation.
Before uploading, please rename your presentation to Lastname_Firstname_SDO2025.(file type suffix). For example, my talk would be "Pesnell_Dean_SDO2025.pptx".

Due to the large number of registrations, we have decided to split the posters into two groups, Monday & Tuesday and Wednesday & Thursday. Please check the Abstract Book at https://sdo2025.sdo-workshops.org/Abstract_Book_for_SDO_2025_V2.pdf to see which days your poster should be displayed. (This book will be updated to V3 soon.)

Posters:
Posters are assigned a number in the Abstract Book. Please hang your poster on the poster board with that number.

Please remember to put up your poster before the meeting begins on your first assigned day and to remove it before the end of the meeting on the second.

We are organizing a Topical Issue of Solar Physics to bring together the research of SDO. More details will be available at the Workshop.

One final note: We have far more registrants than we expected. Although the conference rooms at the Boulderado Hotel are fine for a smaller group, the total number of registrants exceeds the allowed count. As a result, we will be streaming the talks to participants over Zoom so that people can watch the proceedings from another spot in the hotel. We will send that information in a separate email.

# Welcome to Boulder and Welcome to the SDO 2025 Science Workshop: A Gathering of the Helio-hive!

The program of the workshop is listed below, with the oral presentations first by day, followed by the poster presentations, also organized by day.

## Monday, 17 February 2025

Monday 8:30:00 AM-9:15:00 AM, Ballroom

### SDO at Fifteen (SDO Mission Status)

W. Dean Pesnell
NASA, Goddard Space Flight Center

The Solar Dynamics Observatory has been producing science and science data since May 2010. I will describe some highlights of SDO results, including filament eruptions, flares, and comets. The status of the observatory hardware will also be discussed. The future of SDO will be a series of extended missions, each lasting three years. Our fourth extended mission started October 1, 2024, our first as an infrastructure mission. NASA reviews and evaluates operating missions every three years. The next Senior Review proposal will be written this year!

---

## *Energetic Outbursts: Deciphering Solar Flares, CMEs, and SEPs*

### In Memoriam: Karel Schrijver (1958-2024)

We dedicate this session of the SDO 2025 workshop to the memory of Dr. Karel Schrijver, a distinguished solar physicist whose contributions have profoundly shaped our understanding of the Sun and its dynamic influence on the heliosphere. As a pioneering scientist and former Principal Investigator of the Atmospheric Imaging Assembly (AIA) on NASA's Solar Dynamics Observatory (SDO), Karel's work illuminated the intricate connections between solar activity, space weather, and their broader implications for stellar and exo-planetary environments. Beyond his scientific achievements, he was a generous mentor, collaborator, and leader, whose insights and passion inspired many. This session will honor his enduring legacy and celebrate his remarkable impact on solar physics.

Monday 9:15:00 AM-9:45:00 AM, Ballroom

### Solar Energetic Events: Recent Results and Forecasting Challenges (Invited Review)

Stephanie Yardley
Department of Mathematics, Physics and Electrical Engineering, Northumbria University

Over the last 15 years and now across two solar cycles the Solar Dynamics Observatory has provided continuous coverage of the eruptive Sun in a multitude of wavelengths. SDO has allowed us to analyse solar energetic events (flares, CMEs and SEPs) both on a case-by-case and a statistical basis. I will highlight key and recent results only made possible thanks to SDO's continuous coverage and multiple instruments along with the outstanding challenges that we still face in terms of forecasting space weather.

---

Monday 9:45:00 AM-10:00:00 AM, Ballroom

## Understanding and Predicting Solar Flares in the Solar Dynamics Observatory Era: where has "Big Data" gotten us? And where do we go now?

KD Leka

NorthWest Research Associates (NWRA) and Nagoya University / ISEE

Petabytes of data, "all the [Earth-facing] Sun, all the time", more than 10,000 Active Region Patches and 1.5 Solar Cycles' worth of energetic activity have been accumulated from this mission and its instrument suite, which have performed way beyond proposed expectations. One driving science case has been that this wealth of data (measured by information content as well as just #bytes) would solve the challenge of predicting solar energetic events. Well, has it? (Spoiler alert: not yet.) In this talk I'll argue that, in fact, we are just starting to be able to tackle the relevant questions. I will review progress that has developed from applying SDO data to the topic of solar event forecasting, and some insights now being gained. The latter will include a "tough love" review of the role that Machine Learning has played thus far, and some thoughts on how it may be deployed more effectively in the future. Finally, I'll suggest some tools and infrastructure needed to make progress, now that we are in the era of what I call "finally, almost maybe sufficient data!".

---

Monday 10:30:00 AM-10:45:00 AM, Ballroom

## The evolution of coronal dimmings and their relationship to CMEs

Larisza Krista

University of Colorado/CIRES, NOAA/NCEI

Understanding the evolution of coronal mass ejections (CME) is particularly important as they are major drivers of severe space weather. The low-corona segment of the CME structure is known as the coronal dimming: an area dominated by transient open magnetic field that grows and decays as the magnetic field is dragged out into interplanetary space. To understand CME evolution as a whole, we study the evolution of dimmings in conjunction with the CME morphology and its physical properties from the solar corona all the way to Earth. In this study we focus on the dimming-CME event of January 25, 2011. Our observations showed that the dimming was of predominantly positive polarity, and it occurred near the positive polarity of the active region. An increased magnetic flux imbalance and higher magnetic field strength was observed at the initial phase of the dimming evolution, followed by a decrease in both properties as the dimming slowly decayed. The observations are indicative of a change in the magnetic footpoint distribution in the region: we hypothesize that as the CME eruption occurred in the active region (AR11149), the positive (and temporarily "open") magnetic field lines were displaced through interchange reconnection into the area that was observed as the dimming region. The open field lines allowed plasma depletion, making the region gradually dim. As the CME propagated further into the

heliosphere, the CME plasmoid disconnected, reversing the process. This hypothesis is supported by the CME models and observations: the orientation of the active region loop structures seen in the PFSS model, the CME observed in the STEREO-A/COR2 observation, and the GCS croissant model fitted to the CME were all consistent with the observed morphology and dimming evolution process. Our future goal is to identify and analyze coronal dimmings and their characteristics for an early insight into CME evolution.

---

Monday 10:45:00 AM-11:00:00 AM, Ballroom

## Flaring together: A preferred angular separation between sympathetic solar flares

Louis-Simon Guité [1], Antoine Strugarek [2], Paul Charbonneau [1]
[1] Department of Physics, University of Montreal, Canada; [2] CEA Paris-Saclay, Paris, France

Solar eruptions are classified as sympathetic when they are triggered nearly synchronously but originate from distinct regions on the solar surface, likely due to physical interactions between them. Since the initial investigation of this phenomenon by Richardson et al. (1951), various studies have sought to systematically identify these sympathetic flares from a statistical perspective, but their clear statistical existence on the Sun has yet to be firmly established.
In this presentation, we report on a recent statistical analysis of sympathetic flares, utilizing data from multiple instruments (SDO/AIA, RHESSI, and Solar Orbiter/STIX) that collectively span from the peak of solar cycle 23 to the present. Our analysis reveals a significant overabundance of hemispheric pairs of flares with short waiting times ($w \leq 1.5$ hours) that are separated by approximately 30 degrees in longitude. At these spatial and temporal scales, a physical interaction occurring on the solar surface would imply a characteristic velocity of at least 100 km/s. The occurrence rate of sympathetic flares is estimated to be around 5% across the three instruments. Additionally, we observe a deficit of consecutive transequatorial events separated by 25-30 degrees in latitude and less than 5 degrees in longitude, which we designate as unsympathetic flares. Finally, we propose an interpretation of the observed angular scale of the sympathetic phenomenon based on the separation between magnetic field line footpoints derived from potential field source surface extrapolations.

---

Monday 11:00:00 AM-11:15:00 AM, Ballroom

## A Statistical Analysis of Magnetic Field Changes in the Photosphere during Solar Flares Using High-cadence Vector Magnetograms and Their Association with Flare Ribbons

Rahul Yadav [1], Maria Kazachenko [2]
[1] LASP/CU, Boulder; [2] LASP, NSO, APS/CU, Boulder

We analyze high-cadence vector magnetograms (135 s) and flare-ribbon observations of 37 flares from the Solar Dynamics Observatory to understand the spatial and temporal properties of changes in the photospheric vector magnetic field and their relationship to footpoints of reconnected fields. Confirming

previous studies, we find that the largest permanent changes in the horizontal field component lie near the polarity inversion line, whereas changes in the vertical field are less pronounced and are distributed throughout the active region. We find that pixels swept up by ribbons do not always exhibit permanent changes in the field. However, when they do, ribbon emission typically occurs several minutes before the start time of field changes. The changes in the properties of the field show no relation to the size of active regions, but are strongly related to the flare-ribbon properties such as ribbon magnetic flux and ribbon area. For the first time, we find that the duration of permanent changes in the field is strongly coupled with the duration of the flare, lasting on average 29% of the duration of the GOES flare. Our results suggest that changes in photospheric magnetic fields are caused by a combination of two scenarios: contraction of flare loops driven by magnetic reconnection and coronal implosion.

---

Monday 11:15:00 AM-11:30:00 AM, Ballroom

## Unveiling the Global Magnetic Topology with Physics-Informed Neural Networks

Robert Jarolim [1], Astrid, M. Veronig [2], Julia, K. Thalmann [2], Matthias Rempel [1]

[1] High Altitude Observatory, NSF NCAR, Boulder USA; [2] University of Graz

The 3D coronal magnetic field is the decisive component to understand the formation and eruption of flux ropes in the solar corona. Non-linear force-free magnetic field extrapolations are a frequently applied method to provide a realistic estimate of the coronal magnetic field from photospheric vector magnetograms but are typically limited to small simulation volumes.

We present a novel approach based on Physics-Informed Neural Networks, to perform force-free magnetic field extrapolations of the global solar magnetic field. Our method uses full-disk vector magnetograms from SDO/HMI, and directly models highly twisted quiet-Sun filaments, coronal holes, and complex active region fields, that are in agreement with observations from SDO/AIA in extreme ultraviolet.

We use our method to study the eruption of a trans-equatorial filament on February 5th 2016 and its connection to a quiet-Sun filament eruption. The global extrapolation reveals the magnetic connectivity across the solar equator and interaction with an open-flux region. Furthermore, our model shows the large-scale connectivity that could link to a sympathetic filament eruption. These findings highlight the importance of the global magnetic topology, both for small scale reconnection and large topological reconfigurations. We conclude with an outlook, where we apply this approach to estimate the open magnetic flux and show that highly twisted field configurations play a significant role for the formation of open flux regions.

---

Monday 11:30:00 AM-11:45:00 AM, Ballroom

## Remarkable Magnetic Field Evolution Preceding the May 2024 Gannon Superstorm

Xudong Sun [1], A. A. Norton [2], S. Toriumi [3], P. W. Schuck [4], J. Zhang [5]

[1] Institute for Astronomy, University of Hawaii, Honolulu, USA; [2] Hansen Experimental Physics

Laboratory, Stanford University, Stanford, CA, USA; [3] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Kanagawa, Japan; [4] Heliophysics Science Division, NASA Goddard Space Flight Center, Greenbelt, MD, USA; [5] Department of Physics and Astronomy, George Mason University, Fairfax, VA, USA

In May 2024, NOAA Active Regions (ARs) 13664 and 13668 produced a series of major eruptions that led to the extreme geomagnetic disturbances known as the "Gannon Superstorm." Here, we report on the remarkable magnetic field evolution of this AR complex leading up to the event using SDO/HMI observations. Starting on May 6, multiple pairs of bipoles with drastically different morphology emerged to form AR 13668, west to the pre-existing AR 13664. Various flux components underwent significant collision and shearing, forming a complex δ-type sunspot group. Two groups of filament channels developed at these collision sites with opposite magnetic helicity, but only the southern, positive-helicity filament channel was responsible for the Gannon storm. The magnetic flux started to rapidly increase on May 7, one day before the major eruptions. Several proxies of magnetic non-potentiality increased drastically alongside the magnetic flux, but the rate plateaued on May 9. The estimated peak flux emergence rate (1.8E21 Mx/hr) and the magnetic free energy (over 1E33 erg and 30% of potential-field energy) are both among the highest in the SDO era. We discuss the possible subsurface magnetic configuration, and argue that time-dependent AR properties, e.g., the flux emergence and cancellation rate, are good indicators for impending solar eruptions.

---

Monday 12:15:00 PM-1:00:00 PM, Ballroom

## Projecting the Past: Films from the Vault

Hanna Rose Shell [1]

[1] Division of Arts & Humanities, College of Arts and Sciences, CU Boulder

A screening of archival solar films produced at the High Altitude Observatory, and the Sacramento Peak Observatory in the 1940s-50s, with discussion.

---

Monday 1:00:00 PM-1:30:00 PM, Ballroom

## HMI and JSOC Status

J. Todd Hoeksema

W. W. Hansen Experimental Physics Laboratory, Stanford University, California USA

---

# *From Creation to Emergence: Magnetic Fields of the Sun*

Monday 1:30:00 PM-2:00:00 PM, Ballroom

## Shifting the Paradigm of Active Region Emergence on the Sun (Invited Review)

Hannah Schunker

University of Newcastle (Australia)

SDO/HMI was the first mission to systematically capture the early stages of magnetic active region emergence on the Sun. By providing simultaneous full-disk observations of the magnetic field and Doppler velocity, this solar-monitoring mission enabled a comprehensive analysis of the interaction between emerging magnetic flux and convective flows for a statistical sample of active regions. Quantitative numerical simulations have been crucial in interpreting the observational results, highlighting the role convection plays in the emergence process and leading to a paradigm shift in our understanding of flux emergence. Building on this foundation, our findings suggest that supergranulation-scale flows are particularly important, facilitating the rise of magnetic flux from the Sun's interior to its surface. Additionally, we found that on average Joy's law develops during the emergence process, and can be explained by the Coriolis force acting on near-surface flows which displaces the polarities away from an east-west orientation. These insights have important implications for the dynamo mechanism, suggesting that surface flows transform the Sun's global toroidal magnetic field into poloidal field during the emergence process, closing the solar cycle loop.

---

Monday 2:00:00 PM-2:15:00 PM, Ballroom

## Sunspot simulations: Dependence of penumbra properties on numerical resolution

Matthias Rempel [1], Hideyuki Hotta [2]
[1] HAO/NSF NCAR, USA; [2] Nagoya University, Japan

Sunspot simulations conducted more than a decade ago did demonstrate the formation of a sunspot penumbra and Evershed flow as consequence of overturning convection in an inclined magnetic field. However, many of those simulations were only able to form a penumbra in numerical setups that artificially increased the magnetic field inclination at the top boundary. Specifically numerical setups with a potential field boundary condition failed to produce extended penumbrae. In this study we present a series of new sunspot simulations that use higher numerical resolution with grid spacings as small as 6km. We find that a penumbra can be maintained in the presence of a potential field if the grid spacing is at least in the 6-12 km range. Furthermore, we found that depending on the resolution two solutions can exist – a penumbral solution with Evershed flow and a solution with strong converging flows towards a "naked" umbra that is similar to what is found around pores. For low resolution (~48 km grid spacing) only this anti-Evershed solution exists, for intermediate resolution (12-24 km grid spacing) both solutions exist with significant hysteresis, i.e., depending on how the simulation is set up either one or the other solutions is established, with occasional transitions. For higher resolution (6-12 km grid spacing) the preference moves towards the Evershed flow solution. We discuss the properties of these solutions and causes of the resolution dependence.

---

Monday 2:15:00 PM-2:30:00 PM, Ballroom

## The role of current helicity in driving solar dynamo

Mei Zhang [1], Yuhong Fan [2]
[1] National Astronomical Observatories, China; [2] HAO/NCAR, USA

In the traditional picture of alpha-omega dynamo, the alpha effect is regarded as responsible for producing large-scale poloidal magnetic field and its magnitude is estimated from the calculation of kinetic helicity. However, in a strong MHD helical turbulence, the alpha coefficient is determined by the difference between a purely kinetic and a purely magnetic helical term, according to Pouquet et al. (1976). Here in this talk we present a series of numerical simulations of convective dynamo, with varying grid resolution, with or without explicit magnetic diffusivity and viscosity. We show that in our simulations, with the increase of Reynolds number, the magnitude of current helicity increases dramatically, whereas the variation of kinetic helicity keeps moderate. The competition between the kinetic helicity and current helicity results in an interesting behavior of large-scale magnetic field that resembles the ``dynamo-disappear-and-recover" phenomena reported by Hotta et al. (2016). Our simulation and analysis suggest that, the role of current helicity first functions to suppress the dynamo, as the convectional $\alpha$-quenching concept states, but then functions to drive the dynamo, instead of quenching it, after a critical Reynolds number has been exceeded.

---

Monday 4:00:00 PM-4:30:00 PM, Ballroom

## SDO's Extreme-ultraviolet Variability Experiment (EVE): Instrument Status and Key Flare Results with EVE Data during the 14-year SDO Mission

Thomas Woods

University of Colorado / LASP

NASA's Solar Dynamics Observatory (SDO) Extreme-ultraviolet Variability Experiment (EVE) has been making solar extreme-ultraviolet (EUV) spectral measurements for more than 14 years. EVE's Multiple EUV Grating Spectrograph (MEGS) makes full-disk spectral measurement with 0.1 nm spectral resolution and 10-60 sec cadence. The MEGS-A channel measures between 6 nm and 37 nm, but a capacitor short in its CCD camera has limited the MEGS-A observations between May 2010 and June 2014. The MEGS-B channel measures between 32 nm and 106 nm with 0.1 nm spectral resolution and 10-60 sec cadence. MEGS-B has had more degradation than originally anticipated, so MEGS-B is operated now with 3-hour daily observations to reduce solar exposure. To optimize MEGS-B flare measurements, EVE's flight software has been updated to autonomously start 3-hour flare campaigns for the MEGS-B channel whenever the solar X-ray radiation goes above a M1 flare level. The other key EVE channel is the EUV SpectroPhotometer (ESP). ESP has five EUV channels between 1 nm and 40 nm, each having a spectral passband of about 4 nm and measuring at a higher cadence of 4 Hz. The ESP 1-7 nm band channel uses a quadrant photodiode and thus provides flare location as well as the solar SXR irradiance.

EVE's observations have been a treasure trove for solar EUV flare spectra, which are valuable for most solar physics flare studies. For example, EVE flare spectra have been used to study flare phases (including the discovery of the EUV Late Phase flare class), flare energetics (plasma temperature variations), corona heating (plasma abundance changes support nano-flare heating mechanism), flare dynamics (downwelling and upwelling velocities during flares from Doppler shifts), and coronal mass ejections (CME) energetics (CME mass and velocity derived from coronal dimming in some EUV lines). With over 10,000 flares detected in the EVE observations, there is still much to study and to learn about solar flare physics.

## *Impacts of Solar Variability on Earth, Other Planets, and Space Weather*

Monday 4:30:00 PM-5:00:00 PM, Ballroom

### SDO: A Mission Essential for Space Weather Science and Predictions (Invited Review)

Yari Collado-Vega
NOAA Office of Space Weather Observations

The Solar Dynamics Observatory has been essential in enabling ground-breaking advancements across the space weather discipline. The reliable, fast, and high-resolution images SDO provides of the Sun has transformed the space weather field both in science and in forecasting.The observations provided by the Advanced Imaging Assembly (AIA), the Helioseismic and Magnetic Imager (HMI) and the Extreme Ultraviolet Variability Experiment (EVE) Instrument, led to a more complete understanding of solar dynamics and the drivers of geomagnetic storms. The role of the mission was to understand the solar variations that influence the Earth's environment, but the amazing science also extended to the study of the Sun's interaction with other planets including those in the outer parts of our solar system. This talk will demonstrate some of SDO's influence on the field of space weather and how these observations continue to provide critical information for the future of exploration and forecasting.

---

Monday 5:00:00 PM-5:30:00 PM, Ballroom

### On the farside of solar cycle 25: Observations of a high-speed space weather event at Mars (Metcalf Travel Award)

Rebecca Jolitz, K. G. Hanley, M. Nauth, R. Ramstad, J. Halekas, E. Thiemann, C. O. Lee, M. Lemmon, S. Xu, M. Pinto, B. Sánchez-Cano, S. Howard, J. Cessna, S. Jain, J. Deighan, A. Hughes, N. Schneider, K. Chirakkil, C. Bertucci, C. Fowler, D. Mitchell, J. Luhmann, X. Fang, Y. Ma, L. Andersson, C. F. Dong, C. Mazelle, P. Garnier, H. Madanian, T. Hara, Y. Dong, J. McFadden, R. Lillis, A. Rahmati, N. Schnepf, H. Shen, A. Chasapis, M. Felici, G. Poh, S. Shuvalov, Y. Lee, S. Evans, C. Zhang, G. DiBraccio, and S. M. Curry
Space Sciences Lab, University of California, Berkeley CA

If the current solar cycle could be described in one word, it would be "extreme". Present solar activity has far exceeded prior predictions of a mild cycle, with numerous flares and coronal mass ejections (CMEs). This inclement space weather has affected planets across the solar system. Unlike Earth, Mars has an induced magnetosphere controlled by ambient interplanetary plasma conditions. A sufficiently fast CME can compress the induced magnetosphere and drain the reservoir of planetary ions into space. In a near-decade of operation at Mars, the Mars Volatile Evolution (MAVEN) mission has witnessed many such events. However, these events are typically followed by a slow return to nominal solar wind conditions. This talk will discuss an unusual event in December 2023 where a fast CME merged with a high speed solar wind stream interface and impacted Mars. Although Mars was on the solar farside relative to Earth, we present inferred solar context from SDO HMI farside holography, forward-propagated SDO AIA, and

Mars rover sunspot images alongside in situ plasma observations near the Sun (BepiColombo) and Mars (MAVEN, Mars Express). We synthesize the observations to interpret the event as a leading edge of a CME merged with an SIR. We show the effects of the event at Mars, including multiple kinds of aurora, extreme magnetic disturbance, and ion energization. This event exemplifies the unique physics that can take place in an induced magnetosphere during solar maximum.

---

# Tuesday, 18 February 2025

## *Solar Internal Dynamics and Structure*

Tuesday 8:30:00 AM-9:00:00 AM, Ballroom

### Numerical modelling of solar inertial modes (Invited Review)

Yuto Bekki, Robert Cameron, Laurent Gizon

Max Planck Institute for Solar System Research

Conventionally, acoustic modes of oscillation have been used to probe the Sun’s internal structure and large-scale flows. Thanks to SDO/HMI data, low-frequency modes of inertial oscillations have been observed on the Sun. These modes can also be used as probes of the interior of the Sun. In this talk, we review recent advances in modelling the solar inertial modes, using both a linear eigenmode analysis of the differentially-rotating convection zone and using fully nonlinear numerical MHD simulations of the Sun. One remarkable result is that the high-latitude inertial modes interact dynamically with the Sun’s differential rotation and the magnetic field.

---

Tuesday 9:00:00 AM-9:30:00 AM, Ballroom

### Recovering the amplitudes of solar quake waves using the showerglass effect (Metcalf Travel Award)

Angel Martinez Cifuentes, Alina Donea

School of Mathematics, Monash University

Solar flares, the most energetic and impulsive events in the solar atmosphere, generate seismic waves within the Sun's interior, commonly referred to as "sunquakes." By examining the patterns of surface ripples, we gain insights into the structure and dynamics of their seismic sources and their interaction with the surrounding environment. However, in active regions, magnetic fields influence the propagation of these waves, adding complexity to the analysis of their characteristics.

In this study, we propose a refined approach of the showerglass effect (Lindsey & Braun 2004, “The Acoustic Showerglass. I. Photospheric Magnetic Fields") designed to assess the influence of magnetic field structures on seismic wave observations. Our method quantifies the impact of magnetic fields by analyzing correlations between the surface Doppler field and both the ingression and egression of waves in the Solar Standard Model. By applying this correction method, we achieve a more accurate determination of the seismic properties of the sources driving solar seismicity.

We validate the effectiveness of our pipeline by analyzing two distinct Active Regions using data from the Solar Dynamics Observatory. Our findings demonstrate that this correction technique enables the generation of more precise maps of seismic sources. This improvement advances the detection and characterization of solar flare activity.

---

Tuesday 9:30:00 AM-9:45:00 AM, Ballroom

## An in-depth exploration of the solar tachocline

Sarbani Basu [1], Sylvain G. Korzennik [2]

[1] Department of Astronomy, Yale University, New Haven, CT USA; [2] Center for Astrophysics, Harvard & Smithsonian, Cambridge, MA, USA

By analyzing helioseismic mode parameters derived from long time series, we have investigated the shape of the tachocline, the thin boundary between the differentially rotating convection zone and the interior that rotates like a solid body. Additionally, we examined shorter time series data sets corresponding to solar cycles 23, 24, and the rising phase of cycle 25 to determine if there are any temporal variations in the properties of the tachocline. Our findings indicate that the location of the tachocline, identified as the midpoint of rotational change, exhibited significant variation during solar cycle 24. Conversely, the width of the tachocline showed notable changes during cycle 23, but not later. The variations in the tachocline become more apparent when examining its upper and lower limits. We observed that during periods around solar maxima and minima, the extent of the tachocline initially decreases before expanding again. We have also confirmed earlier results  that the change in rotation across the tachocline shows significant temporal variation, we have extended the result beyond the 2020 solar minimum. Interestingly, the changes observed during the ascending phase of solar cycle 25 almost mirror those in the descending phase of cycle 24, leading us to speculate that the tachocline might have a longer periodicity than both the sunspot and magnetic cycles. Continued global helioseismic observations in the forthcoming years should help clarify this trend. Our results underscore the importance of sustained helioseismic monitoring of the Sun to deepen our understanding of solar activity and its evolution.

---

Tuesday 9:45:00 AM-10:00:00 AM, Ballroom

## Modeling HMI helioseismic observables

Nadiia Kostogryz, D. Fournier, L. Gizon

Max Planck Institute for Solar System Research

Helioseismic analyses are strongly affected by center-to-limb systematic variations which are attributed - in part- to a geometrical effect: the formation height of radiation depends on the position on the solar disk, with radiation forming higher in the atmosphere closer to the limb. Moreover, the formation height is also affected by convection with differences between granules and intergranular lanes.

We develop a framework to compute helioseismic HMI observables, such as continuum intensity and Doppler velocity, by solving the radiative transfer equation in the perturbed solar atmosphere due to acoustic oscillations. Including radiative transfer modeling in the analysis allows us to properly account for the effect of formation heights of solar radiation at different disk positions. Doppler velocity is

computed from the shift of the spectral line at various positions on the disk. Solar convection also affects the spectral line profile, causing a convective blue shift and line asymmetry. To properly simulate convection, we employ the state-of-the-art 3D MHD MuRAM code and extract separate granule and intergranule background models. We perturb the models and synthesize spectral lines at various disk positions, from disk center to the limb. We demonstrate the effects of both radiative transfer modeling and convection on the HMI observables.

---

Tuesday 10:30:00 AM-10:45:00 AM, Ballroom A

## Modeling the signature of acoustic oscillations in HMI observables

Damien Fournier, Nadiia Kostogryz, Laurent Gizon

Max Planck Institute for Solar System Research, Göttingen, Germany

The inference of the Sun's meridional circulation is of fundamental importance for understanding the solar dynamo and has been the focus of several helioseismic studies. This inference often relies on measurements of North-South travel times. To better characterize the center-to-limb variations in the travel times, we propose to incorporate the effects of radiative transfer on the waves and accounting for the details of the measurement procedure. We solve the equations of stellar oscillations and derive the relationship between the velocity measured by HMI and the solution to these equations. This approach involves calculating the emergent intensity as a function of wavelength, convolving these intensities with the HMI filter profiles, and applying the HMI velocity algorithm. We present the effects of radiative transfer and background velocities (e.g., solar rotation and satellite motion) on the measured travel times and compare these results to HMI observations.

---

Tuesday 10:45:00 AM-11:00:00 AM, Ballroom A

## Characterizing Solar High-Latitude Inertial Waves Using Time-Distance Helioseismic Subsurface Flow Maps

Boyang Ding [1], Junwei Zhao [2], Matthias Weidele [2]

[1] Department of Physics, Stanford University; [2] HEPL, Stanford University

High-latitude inertial waves are characterized as low azimuthal modes with strong amplitudes above 50° latitude and retrograde motions. In this study, we use SDO/HMI time-distance subsurface flow fields, which extend up to 82° latitude, to examine these high-latitude waves. Drawing on 14 years of observations, we investigate variations in wave parameters such as power, zonal phase speed, and meridional phase speed, and explore their potential connections to the solar cycle. Our analysis shows that wave power increases during the solar minimum. The zonal phase speed is retrograde while the meridional phase speed is directed equatorward, and both speeds change over time. We also analyze the waves separately in the northern and southern hemispheres to explore their differences. In the northern hemisphere, the waves exhibit double peaks in the spectrum and display greater power compared to the southern hemisphere. Additionally, the wave phases in each hemisphere show temporal variations. These findings suggest that the Sun's magnetic field influences the wave parameters of high-latitude waves.

---

Tuesday 11:00:00 AM-11:15:00 AM, Ballroom A

## Observing solar inertial modes using local correlation tracking

Neelanchal Joshi, Zhi-Chao Liang, Damien Fournier, Laurent Gizon
Max Planck Institute for Solar System Research, Göttingen, Germany

The quasi-toroidal inertial modes of the Sun have properties that allow for the probing of the deep solar convection zone. The synodic frequencies of these modes are on the order of the solar rotation rate, and unambiguous identification and characterization of these modes require long-term, continuous observations of the sun. In this work, we obtain time series of horizontal flow maps from local correlation tracking (LCT) of granulation and small-scale magnetic network features, using 12 years of SDO/HMI intensity images and magnetograms. We compute the temporal and spatial power spectra of these flows, as well as their radial vorticity and horizontal divergence. We identify peaks of excess power in frequency-latitude space at individual azimuthal wavenumbers, within the inertial frequency range. The associated latitudinal eigenfunctions are extracted and compared to previous measurements obtained from ring-diagram analysis. Both approaches yield consistent results, and LCT has better spatial coverage at high latitudes. We also report the existence of an inertial mode with non-zero horizontal divergence, which had not been reported before.

---

Tuesday 11:15:00 AM-11:30:00 AM, Ballroom A

## Amplitude variations of the m=1 high-latitude inertial mode

Zhi-Chao Liang, Laurent Gizon
Max Planck Institute for Solar System Research, Göttingen, Germany

We study the long-term amplitude variations of the m=1 high-latitude inertial mode, as observed in direct Doppler data. We used Dopplergrams from the Mount Wilson Observatory, GONG, and HMI, covering five solar cycles from 1967. The deprojected velocity amplitude of the mode varies significantly throughout this time period in the range from 5 to 20 m/s. The amplitude peaks at the start of solar cycles 21, 22, and 25, and during the rising phases of cycles 23 and 24. Overall, the amplitude is anticorrelated with the sunspot number and the solar rotation rate at 60 deg latitude. We find a decrease of the mode frequency during 1990-2020 at the approximate rate of 0.25 nHz/year, consistent with the decrease in the surface rotation rate at 60 deg latitude during the same period. The results are described in full at https://arxiv.org/abs/2409.06896.

---

Tuesday 11:30:00 AM-11:45:00 AM, Ballroom A

## Sensitivity of solar inertial modes to rotation at high-latitudes

Prithwitosh Dey, Yuto Bekki, Laurent Gizon
Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany

The inference of solar internal rotation is one of the triumphs of p-mode helioseismology. However, little is known about the rotation profile at high latitudes (above approximately 75 deg) or in the deep interior (within 20 percent of the solar radius). Solar inertial modes present a promising means to probe the Sun's

interior. Among these inertial modes, the m=1 high-latitude mode is the higher-amplitude mode. It has been seen in data from multiple observatories, using various observational techniques.
Here we use an eigenvalue solver to compute the normal modes of oscillation in the inertial frequency range of the solar convection zone, and find that the m=1 mode frequency differs from the observations by approximately 20 nHz, while the uncertainties in the observed frequency are of the order of 5 nHz. Furthermore, we find that the latitudinal differential rotation at high latitudes plays a crucial role in determining the frequency of the computed mode. We find that the mode frequency is strongly dependent on the rotation profile near 80 deg in the middle of the convection zone, where the p-mode estimates are not reliable.

---

Tuesday 10:30:00 AM-10:45:00 AM, Ballroom B

## Investigating the Uniqueness and Causal Relationship of Precursor Activity to Solar Energetic Events

Karin Dissauer, Graham Barnes [1], K. D. Leka [1,2], Eric L. Wagner [1]

[1] NorthWest Research Associates, Boulder USA; [2] Institute for Space-Earth Environmental Research, Nagoya University, Nagoya Japan

The physical role played by small-scale activity that occurs before the sudden onset of solar energetic events (SEEs, i.e., solar flares and coronal mass ejections) remains in question, in particular as related to SEE initiation and early evolution. It is still unclear whether such precursor activity, often interpreted as plasma heating, particle acceleration, or early filament activation, is indicative of a pre-event phase or simply on-going background activity.
In this contribution we investigate the uniqueness and causal connection between precursors and SEEs using paired activity-quiet epochs. We focus on transient brightenings (TBs) and present analysis regimes to study their role as precursors, including imaging of the solar atmosphere, magnetic field, and topology analysis using archive data from the Atmospheric Imaging Assembly and the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory.
Applying these methods qualitatively to three cases, we find that prior to solar flares, TBs 1) tend to occur in one large cluster close to the future flare location and below the separatrix surface of a coronal null point, 2) are co-spatial with reconnection signatures in the lower solar atmosphere, such as bald patches and null point fan traces and 3) cluster in the vicinity of strong-gradient polarity inversion lines and regions of increased excess magnetic energy density.
TBs are also observed during quiet epochs (i.e., no SEE activity) of the same active regions, but they appear in smaller clusters not following a clear spatial pattern, although sometimes associated with short, spatially-intermittent bald patches and fan traces, but predominantly away from strong gradient polarity inversion lines in areas with little excess energy density.

---

Tuesday 10:45:00 AM-11:00:00 AM, Ballroom B

## Statistical Investigation of Solar Flare Onsets: Physical Properties and Short-term Flare Forecasting Potential

Anant Telikicherla, Thomas N. Woods, Bennet Schwab, Robert Sewell

Laboratory for Atmospheric and Space Physics, University of Colorado Boulder

The solar flare Hot Onset Precursor Event (HOPE) phenomena, characterized by elevated plasma temperatures (in the range of 10-15 million Kelvin) prior to the impulsive phase of solar flares, has been the focus of many recent studies (see for example, Hudson et al., 2021; Battaglia et al., 2023) and remains an open investigation in the solar physics community. In this study, we present the analysis of Solar Soft X-ray spectra of all flares observed by the Dual-zone Aperture X-ray Solar Spectrometer (DAXSS) to show statistical trends in the flaring plasma parameters during the flare onset period. We present a method that utilizes the trends in the plasma temperature and emission measure during the flare onset phase to generate alerts in-advance of the main flare peak. We test this methodology on ~1000 flares observed by the Geostationary Operational Environmental Satellite (GOES) X-ray Sensor (XRS) to estimate the performance metrics for the short-term flare prediction algorithm. Additionally, we analyze extreme ultraviolet (EUV) images from the 193 Å channel of the Atmospheric Imaging Assembly (AIA) on-board the Solar Dynamics Observatory (SDO) to study plasma morphology and movement during the flare onset period. Results indicate that Hot Onset Precursor Event phenomena is common in many flares and has a promising potential for generating flare alerts in-advance of the main flare peak (with timescales in the range of 5-30 minutes).

---

Tuesday 11:00:00 AM-11:15:00 AM, Ballroom B

## Introducing Deep Survival Analysis to Solar Flare Forecasting

Moritz Meyer zu Westram, J. Zbinden, L. Kleint

Astronomical Institute, University of Bern, Bern, Switzerland

Solar flares and accompanying coronal mass ejections are drivers of intense space weather, which can have major impacts on e.g., satellite communication, navigation, and power-grid integrity. Despite the large interest in solar flares, prediction models are still not fully able to make adequate forecasts due to the complexity of the underlying physical processes.

We aim to improve the quality and flexibility of forecasting models by introducing the time-to-event approach of deep survival analysis, a method traditionally used in medicine and economics. This allows us to not only model the likelihood of a flare happening within the next few days but also its timing. A support vector machine (SVM) is employed to find decision boundaries for warning systems after the main time-to-event model has been trained.

This study demonstrates the capabilities of deep survival neural networks based on multivariate time series extracted from solar photospheric vector magnetograms in Spaceweather HMI Active Region Patch (SHARP) series.

Our model is able to follow the evolution of an active region and to distinguish flaring vs. non-flaring active regions with a true skill statistic (TSS) of 0.88. Introducing an artificial 24-hour warning boundary with the SVM, we reach TSS scores of 0.73.

---

Tuesday 11:15:00 AM-11:30:00 AM, Ballroom B

## Low Coronal Disturbances Linked to Coronal Mass Ejections

Nariaki Nitta, Meng Jin, Marc DeRosa
Lockheed Martin Advanced Technology Center

Coronal mass ejections (CMEs) are centrally responsible for various space weather hazards. It is extremely important to advance our understanding of how they start and evolve in the corona, a key to making space weather forecasts useful to mankind. This may be partially achieved by studying the signatures that CMEs may leave in the low corona as identified in extreme ultraviolet (EUV) images before they emerge in coronagraph images. Among them, coronal dimmings may be the most reliable indicator for CMEs. Dimmings are often accompanied by large-scale coronal propagating fronts, or EUV waves, which may be a more commonly used term. We present an ensemble study of EUV waves based on images from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory and from the Extreme-Ultraviolet Imager (EUVI) on board the Solar-Terrestrial Relation Observatory (STEREO). We characterize the waves more extensively than the previous work that concentrated on the maximum propagation speed per event. The main objective of this study is to better understand the relation of EUV waves with CMEs, as observed by coronagraphs on SOHO and STEREO. We discuss the relative magnitude of EUV waves, dimmings and CMEs during the whole SDO period that encompasses one solar minimum and two solar maxima. The involvement of EUV waves in CMEs may depend on the height at which the CME starts to accelerate and on the large-scale magnetic field surrounding the eruption. We also discuss other phenomena possibly related to EUV waves, including widespread solar energetic particle events, quasi-periodic fast-mode propagating wave trains, metric type II bursts.

---

Tuesday 1:00:00 PM-1:15:00 PM, Ballroom A

## A new perspective on the solar internal rotation from fitting long and very long time-series.

Sylvain Korzennik [1], Antonio Eff-Darwich [2]
[1] Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA 02138, USA; [2] Universidad de La Laguna , Tenerife, 38204, Spain & Instituto de Astrofísica de Canarias, Tenerife, 38206, Spain

With some 14, 15 and 29 years of HMI, MDI and GONG observations, respectively, we have reached a new milestone in acquiring almost three decades of nearly continuous helioseismic observations. Moreover, an alternative fitting methodology to the respective projects global helioseismic pipeline has produced tables of individual mode frequencies based on long and very long time-series, namely from 3.2 to 12.6 year long time-series for all 3 instruments to even a 25.2 year long one for GONG observations. Having fitted such long time-series results in having very precise individual mode frequencies and individual rotational splittings. Hence we ought to revisit our traditional rotation inversion techniques and methodology to derive the best estimate of the solar internal rotation.
To achieve this, we have reassessed some of our preconceived conceptions, like the density of the model grid used for inversions, but also developed a new iterative technique to complement the classical regularized least square one.
We present new results from inverting rotational frequency splittings derived from these long and very long time-series, with an emphasis on optimizing the resolution near the tachocline. We show how we validated our inferences using simulations and, of course, recognize that our inferences correspond to the

mean rotation rate over the extent of the fitted time-series.

---

Tuesday 1:15:00 PM-1:30:00 PM, Ballroom A

## Anomalous Phase Shifts between GONG and SDO/HMI Dopplergrams

Junwei Zhao [1], Ruizhu Chen [1], Paul Rajaguru [2],
Shukur Kholikov [3]

[1] W. W. Hansen Experimental Physics Laboratory, Stanford University; [2] - Indian Institute of Astrophysics, India; [3] NSO

Several studies have reported that the meridional circulation measured from SDO/HMI Dopplergrams and from GONG Dopplergrams differ from each other, with the former showing stronger southward flows across most latitudes. The causes of this discrepancy and methods to reconcile these measurements have been the subject of investigation in recent years. In this study, we analyzed Dopplergrams obtained simultaneously from both instruments and measured their relative phase shifts across all disk locations. Our analysis revealed that, in addition to the known factors such as differences in data acquisition timing and systematic center-to-limb effects, an anomalous region was identified around 10° west longitude and 25° north latitude in the relative phase map. Within this region, the SDO/HMI phases lagged the GONG phases by approximately 0.005 radians, equivalent to a delay of about 0.25 seconds. Since this represents a relative phase difference between the two instruments, it is not immediately clear which instrument exhibits the phase anomaly or how it should be corrected. Further investigation is required to determine the source of this discrepancy, and a robust correction method needs to be developed.

---

Tuesday 1:30:00 PM-1:45:00 PM, Ballroom A

## Comparing Helioseismic Measurements of Solar Meridional Circulation from SDO/HMI and GONG Observations

Ruizhu Chen [1], Junwei Zhao [1], Paul Rajaguru [2], Shukirjon Kholikov [3]

[1] W. W. Hansen Experimental Physics Laboratory, Stanford University; [2] - Indian Institute of Astrophysics, India; [3] NSO

The Sun's meridional circulation is crucial to understanding the solar dynamo and interior dynamics. However, helioseismic determination of the deep solar meridional flows is complicated by multiple systematic effects, leading to inconsistent results in previous studies. To find the cause of the discrepancies, we collect measurement codes from multiple previous studies and analyze over 14 years of simultaneous HMI and GONG data. We conduct a comprehensive comparison across different methods, data sources, and data preparation procedures, and analyze the multiple systematic effects in measurements obtained using HMI and GONG data. A systematic GONG-HMI offset in the North-South direction is confirmed. For most acoustic wave travel distances, no discrepancies are found among independent measurements by multiple authors, and the meridional-flow signals are consistent between GONG and HMI after correcting for the known systematic effects. However, discrepancies for shorter travel distances are found and the cause of the discrepancies is being investigated.

---

Tuesday 1:45:00 PM-2:00:00 PM, Ballroom A

## Solar-Cycle Variation of Large-Scale Flows in the NSSL from SC 23 to SC 26

Rudolf Komm [1], Rachel Howe [2]

[1] National Solar Observatory, Boulder CO, USA; [2] University of Birmingham, Birmingham, UK

The zonal and meridional flow vary with the solar cycle throughout the near-surface shear layer (NSSL). The solar torsional oscillation has been tracked by global helioseismology for nearly 30 years using GONG, MDI, and HMI Dopplergrams and nearly as long with ring-diagram analysis (RDA) covering Solar Cycles 23 to 25. With high-resolution HMI data, we can more reliably explore subsurface flows at mid- to high latitudes. For example, the zonal- and meridional-flow patterns during the maximum phase of a solar cycle close to 50 degree appear to be associated with the activity pattern of the following solar cycle. We show that the flow patterns near the maximum of Solar Cycle 24 (2012 to 2013) close to 50 degree have reached latitudes close to the equator by now, which is near the maximum of Solar Cycle 25. The beginning of Solar Cycle 26 was noticed in the most recent global helioseismology data around 45 to 50 degree latitude (Howe et al., 2024). The zonal and meridional flows derived with RDA show the same behavior in their flow patterns. We will derive large-scale flows throughout the NSSL using RDA with different tile sizes and present the latest results.

---

Tuesday 2:00:00 PM-2:15:00 PM, Ballroom A

## Unraveling the Dynamics of the Upper Regions of the Solar Near-Surface Shear Layer

M. Cristina Rabello Soares [1], Sarbani Basu [2], Rick Bogart [1]

[1] Stanford University; [2] Yale University

The near-surface shear layer (NSSL) of the Sun, characterized by a rapid decrease in rotation rate towards the surface, is crucial for advancing our knowledge of solar dynamics and the associated dynamo processes. We present a detailed analysis of the dynamics of the NSSL and also its temporal variations using helioseismic data. Our study reveals three distinct regions within the NSSL: a deeper region with small shear that steepens towards the surface; a narrow middle layer (sometimes called the leptocline) with strong shear; and a surface layer where the gradient is close to zero but varies towards the surface. We find that the middle layer's depth varies with latitude, ranging from 2.4 Mm near the equator to 2.8 Mm at 60 degrees latitude. Using an improved ring-diagram analysis of data obtained by the Helioseismic and Magnetic Imager we investigate the temporal variations of the NSSL structure and its correlation with the known zonal flow pattern. Our improvements include the use of power spectra averaged over a rotation period and the use of two different inversion techniques: OLA and RLS inversions. We focus on variations in location, gradient amplitude, and width of both the narrow middle layer and the near-surface layer. This comprehensive study of the NSSL's fine structure and its temporal evolution contributes to our understanding of solar interior dynamics and its connection to surface activity.

---

Tuesday 2:15:00 PM-2:30:00 PM, Ballroom A

## Plasma Flow Dynamics of Active Regions During the May 2024 Solar Storm

Lekshmi Biji, Sushanta Tripathy, Jain Kiran, Alexei Pevtsov
National Solar Observatory, Boulder, Colorado, USA

In May 2024, one of the most intense solar storms since November 2003 was observed, driven by the merging of active regions 13664 and 13668 in the southern hemisphere. This interaction led to a series of powerful X- and M-class flares, starting on May 7. Notably, this active region displayed an extended lifetime, remaining visible on the solar disk after one full rotation and continuing to produce flares. Additionally, active region 13663 in the northern hemisphere also contributed to multiple X- and M-class flares in early May. In this study, we analyse the evolution of subphotospheric plasma flow parameters within these active regions during their transit across the solar disk. Plasma flow velocities are measured using ring-diagram analysis of Dopplergrams from SDO/HMI. Key flow parameters, including divergence, curl, and kinetic helicity, are investigated at depths ranging from the surface to ~20 Mm. Furthermore, we examine the relationship between these flow parameters and the magnetic properties of these active regions. Our findings aim to enhance the understanding of the connection between sub-surface flow dynamics, surface magnetic properties and the generation of high-intensity solar flares.

---

Tuesday 1:00:00 PM-1:15:00 PM, Ballroom B

## Imaging a Failed Solar Eruption During an Intense Confined Flare

Tingyu Gou [1], Kathy Reeves [1], Peter Young [2], Astrid Veronig [3]
[1] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA; [2] NASA Goddard Space Flight Center, USA; [3] University of Graz, Austria

We present observations of an intense and long-duration but confined flare that occurred on the solar west limb. SDO/AIA takes images of a solar prominence that rises behind the limb at the flare onset, but it finally fails to escape from the Sun. A magnetic flux rope structure that rises together with the prominence contains high-temperature plasmas as is evident in AIA hot channel images. The photospheric magnetogram taken from SDO/HMI shows a multipolar magnetic field configuration in the active region associated with this flare. The event was also observed simultaneously by multiple other instruments including IRIS, XRT and EIS onboard Hinode, and by EUI and STIX on Solar Orbiter from a different point of view. Coordinated observation from different instruments and stereoscopic observation from Earth and Solar Orbiter reveal the details of dynamics involved in this event.

---

Tuesday 1:15:00 PM-1:30:00 PM, Ballroom B

## Various Features of the X-class White-light Flares in Super Active Region NOAA 13664

Ying Li, Liu, X.F., Jing, Z.C., Chen, W., Li, Q., Su, Y., Song, D.C. et. al.
Purple Mountain Observatory, Nanjing, China;

Super active region NOAA 13664 produced 12 X-class flares (including the largest one so far, an occulted X8.7 flare, in solar cycle 25) during 2024 May 8–15, and 11 of them are identified as white-light

flares. Here we present various features of these X-class white-light flares observed by the White-light Solar Telescope (WST) on board the Advanced Space-based Solar Observatory and the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory. It is found that both the white-light emissions at WST 3600 Å (Balmer continuum) and HMI 6173 Å (Paschen continuum) show up in different regions of the sunspot group in these flares, including outside the sunspots and within the penumbra and umbra of the sunspots. They exhibit a point-, ribbon-, loop-, or ejecta-like shape, which can come from flare ribbons (or footpoints), flare loops, and plasma ejecta depending on the perspective view. The white-light duration and relative enhancement are measured and both parameters for 3600 Å emission have greater values than those for 6173 Å emission. It is also found that these white-light emissions are cospatial well with the hard X-ray (HXR) sources in the on-disk flares but have some offsets with the HXR emissions in the off-limb flares. In addition, it is interesting that the 3600 and 6173 Å emissions show different correlations with the peak HXR fluxes, with the former one more sensitive to the HXR emission. All these greatly help us understand the white-light flares of a large magnitude from a super active region on the Sun and also provide important insights into superflares on Sun-like stars.

---

Tuesday 1:30:00 PM-1:45:00 PM, Ballroom B

## Using AIA Emission Measure Inversion Failures to Track Interesting Flare Physics

Amy Winebarger, L. Mallett [2], P. S. Athiray [3]

[1] NASA MSFC; [2] Harvey Mudd College; [3] University of Alabama in Huntsville

EUV channels of the AIA instrument have long been used to characterize the temperature of the plasma, particularly through emission measure inversions. During a solar flare, the instrument can suffer several instrumental artifacts that complicates the analysis. We have performed an analysis of the evolution of two X class flares and find regions where the inversion fails that cannot be easily explained by instrumental artifacts. These failures tend to occur at the top of the flare loop arcade where energy is thought to be released and several non-equilibrium processes may be contributing to the emission of the plasma. In this presentation, I will establish the regions of the emission measure failures and discuss the potential instrumental and physical explanations for these failures.

---

Tuesday 1:45:00 PM-2:00:00 PM, Ballroom B

## Solar Flare Ribbon Morphology from Coronal Magnetic Null Point and Separator Reconnection

Graham Barnes, Karin Dissauer

NorthWest Research Associates

Solar flare ribbons are believed to trace out the chromospheric footpoint of magnetic field lines that are reconnecting higher in the solar atmosphere. These field lines lie in a separatrix or quasi-separatrix layer that separates domains of different magnetic connectivity. When the separatrix surface is associated with a single magnetic null point in the corona, its intersection with the chromosphere typically forms a closed contour, which would produce a circular flare ribbon. When two null points of opposite type are present in the corona and connected by a separator, we show that the typical intersection with the photosphere of

the separatrix from each null point is an open segment that naturally results in two flare ribbons. The presence of additional null points connected by separators to one of the original two nulls can result in additional disjoint segments at the chromosphere and hence more complex flare ribbons. Thus we argue that almost any flare ribbon morphology can be explained by null point or separator reconnection.

---

Tuesday 2:00:00 PM-2:15:00 PM, Ballroom B

## Self-Organized Criticality Systems in the SDO Era

Markus Aschwanden [1], Ersin Gogus [2]

[1] Lockheed Martin Solar and Astrophysics Laboratory, Palo Alto, USA ; [2] Sabanci University, Faculty of Engineering and Natural Sciences, Istanbul, Turkey

In this study we are testing whether the power law slopes (a_F, a_E) of fluxes (F) and fluxes or energies (E) are universal in their size distributions, N(F) ~ F{-a_F} and N(E) ~ E^-{-a_E}, in various astrophysical observations. This is a test of fundamental importance for self-organized criticality (SOC) systems. The test decides whether (i) power laws are a natural consequence of the scale-freeness and inherent universality of SOC systems, or (ii) if they depend on more complex physical scaling laws. The former criterion allows quantitative predictions of the power law-like size distributions, while the later criterion requires individual physical modeling for each SOC variable and data set. Our statistical test, carried out with 61 published data sets, yields strong support for the former option, which implies that observed power laws can simply be derived from the scale-freeness and do not require specific physical models to understand their statistical distributions. The observations show a mean and standard deviation of a_F=1.78+/-0.29 for SOC fluxes, and a_E=1.66+/-0.22 for SOC fluences, and thus are consistent with the prediction of the fractal-diffusive SOC model, with a_F=1.80 and a_E=1.67. The observed astrophysical data cover solar flares, CMEs, SEPs, and other energetic phenomena observed with SD.

---

Tuesday 2:15:00 PM-2:30:00 PM, Ballroom B

## Assessing the energy budget of a long-lasting active region with NLFFF extrapolations

Alexis Blaise [1], Adam Finley [1], Antoine Strugarek [1], Buchlin Eric [2], Janvier Miho [2]

[1] Departement of Astrophysics, IRFU, CEA-Saclay; [2] Institut d'Astrophysique Spatial, CNRS, Orsay FRANCE

As solar activity increases during the solar cycle, magnetic flux emerges to the Sun's surface creating large, complex and long-lasting active regions. These active regions are the source of energetic processes like solar flares and sometimes their accompanying coronal mass ejections. The main energy reservoir for these impulsive events is the free magnetic energy that can be used to reconfigure the coronal magnetic topology. The release of this magnetic energy is mediated by reconnection.

We used a physics informed neural network (PINN), called neural network force-free magnetic field extrapolation NF2 [1], to efficiently reconstruct the coronal magnetic field. NF2's inputs are the SDO/HMI SHARP data with vector magnetograms and their error maps at the solar surface. Using the 3D

reconstructed magnetic field from NF2, we monitored the evolution of the total and the free magnetic energies in the solar atmosphere, with a twelve minute cadence (corresponding to the SHARP data availability).

We used this method to estimate the amount of magnetic energy released and to locate flare sites during impulsive events. As we performed extrapolations, the evolution of the coronal magnetic field was primarily a consequence of changes at the photosphere. We collected statistics on multiple quantities in solar active regions in order to verify the performance of the NLFFF extrapolations. We correlated flare sites with the location of free magnetic energy build-up and release using GOES observations and in the near future with STIX observations.

[1] : Jarolim, R., Thalmann, J.K., Veronig, A.M. et al. Probing the solar coronal magnetic field with physics-informed neural networks. Nat Astron 7, 1171–1179 (2023)

---

Tuesday 4:00:00 PM-4:30:00 PM, Ballroom

### Current Status and Future Outlook of SDO/AIA

Meng Jin

Lockheed Martin Solar & Astrophysics Lab, Palo Alto, CA, USA

The Solar Dynamics Observatory (SDO) has been our primary eye on the Sun since its launch in 2010, delivering unprecedented insights into solar dynamics and their impact on space weather. Among its suite of instruments, the Atmospheric Imaging Assembly (AIA) has been pivotal in monitoring the Sun in UV/EUV wavebands, capturing over 300 million images over its 15 years of operation. These observations have profoundly advanced our understanding of the Sun, its influence on the solar system, and its connection to broader astrophysical phenomena. This talk, presented on behalf of the SDO/AIA team, will provide an update on the current status of the AIA instrument, including ongoing operational activities, science-supporting initiatives, and the development of new tools to enhance data usability. Additionally, I will highlight key scientific discoveries from the global heliophysics community made possible by AIA and SDO's extensive dataset. Finally, I will extend the discussion to future plans and strategies for AIA as we embark on the fourth extended SDO mission, with a focus on continuing to deliver high-quality scientific data and fostering cutting-edge heliophysics research.

---

## *Next Horizon: the Future Solar and Heliophysics Missions*

Tuesday 4:30:00 PM-5:00:00 PM, Ballroom

### The Future May Be as Blindingly Bright as The Sun Itself: The Abundance of New Tools to Address SDO Science (Invited Review)

James Mason

JHU/APL

The Solar Dynamics Observatory (SDO) has been at the forefront of big data science in heliophysics, producing 4K+ imaging so detailed that even today only the highest-end displays (8K) can showcase its

full resolution. These vast data volumes challenge even state-of-the-art machine learning models. Over the last decade or so, the SDO community has begun to bridge the gap between AI tools and our observations, setting the stage for the future of heliophysics science and space weather forecasting.
The future of virtually all science, as I see it, will increasingly leverage AI tools to get the most out of our measurements and models and to free us from the minutia of programming -- transforming us from data scientists into information scientists. Heliophysics data is likely to become even more disparate than it already is with an increasing number of smaller missions, many new vantage points, increased collaboration with planetary and astrophysics stellar missions, and upcoming technologies that will enable new types measurements. In this talk, I will share why I am so excited about the future of heliophysics based on numerous threads that may seem disparate now, but that I see weaving together into a stunning tapestry in the coming years. From the SpaceX Starship to customized large language models to instrument miniaturization to satellite constellation technology to complementary interdisciplinary science to whatever the Decadal Survey recommended (not available at the time of writing!): it's a good time to be a heliophysicist!

---

Tuesday 5:00:00 PM-5:15:00 PM, Ballroom

## Joint science with SDO, PUNCH, and NASA's HSO

Craig DeForest, Sarah E. Gibson [2], Ronnie Killough [1], William Wells [1], the PUNCH Mission Team
[1] Southwest Research Institute; [2] University Corporation for Atmospheric Research, Boulder, CO

The Polarimeter to Unify the Corona and Heliosphere (PUNCH) is scheduled to launch imminently, to image the outer reaches of the solar corona and the inner heliosphere. PUNCH is a constellation mission that implements a "virtual coronagraph", imaging the K corona and solar wind with full linear polarimetry, from 6 Rs to 45° from the Sun at 4 minute cadence. Compared to legacy instruments such as LASCO C-3 and STEREO/HI, PUNCH implements 2x-5x improved optical resolution and 30x improved SNR. PUNCH operates similarly to SDO, in a single full-field synoptic sequence with no campaigns; data are reduced to Level 3 (background-subtracted) and released to the public under an open-source data policy, via NASA's SDAC and the VSO. Together with SDO/AIA and SDO/HMI, and new coronagraph assets such as CCOR and CODEX, PUNCH offers a new era of Sun-to-Earth science via direct continuous observation of outflowing phenomena from the photosphere to 1 AU. We will discuss PUNCH mission capabilities, status, and data and science-team access; and joint science potential with existing assets including SDO, CCOR, CODEX, SoLO, and PSP.

---

Tuesday 5:15:00 PM-5:30:00 PM, Ballroom

## NOAA’s Solar Observatories

Laurel Rachmeler, Pacini, Alessandra - NOAA/NCEI,
and the entire NCEI NOAA SWx team.
NOAA/NCEI

The future of solar observations lies in the Integrated HelioSystems Laboratory (HSL), as described in the recent Decadal Survey of the National Academy of Sciences. A key component of the HSL are the NOAA Space Weather Observations. These observations have been designed and crafted for an

Operational user, but they are also relevant and important to scientific users. We discuss the similarities and differences between the NASA and NOAA similar observations (AIA <-> SUVI; EVE <-> EXIS; LASCO <-> CCOR). We will also present a preview of the NOAA NCEI mini-workshop about how to use NOAA GOES data and why you might be interested in learning more.

---

# Wednesday, 19 February 2025

## *Coronal Dynamics: Unveiling the Origins of the Solar Wind*

Wednesday 8:30:00 AM-9:00:00 AM, Ballroom

### Unveiling the Origins and Formation of the Solar Wind with SDO (Invited Talk)

Samantha Wallace

Embry-Riddle Aeronautical University

For fifteen years, the Solar Dynamics Observatory (SDO) has provided unprecedented, high resolution observations of the solar atmosphere in time and space. These observations are fundamental for investigating time-dependent coronal processes, and their role in the heating and release of the solar wind. In this talk, I will review how SDO has revolutionized our understanding of the origins of the solar wind, and the coronal dynamics involved in its formation. This includes how SDO has laid the foundation for, and contributed to, the novel results of Parker Solar Probe and Solar Orbiter which sample the pristine solar wind in situ. I will also discuss how SDO has enabled my own work, in which we investigate the origins and formation of the solar wind. This work heavily utilizes the Wang-Sheeley-Arge (WSA) model to derive the coronal magnetic field and the magnetic connectivity of in situ solar wind measurements to their sources at the Sun observed remotely. I present results that use SDO observations in conjunction with WSA to address outstanding questions in solar wind physics, such as the "open flux problem". Lastly, I will show results from aggregate work from our group of how we have used SDO observations to constrain coronal and solar wind forecasting models.

---

Wednesday 9:00:00 AM-9:15:00 AM, Ballroom

### How Small-scale Jet-like Solar Events from Miniature Flux Rope Eruptions Might Produce the Solar Wind

Alphonse Sterling [1], Navdeep Panesar [2], Ronald Moore [3]

[1] NASA/MSFC; [2] Baeri; [3] UAH

We consider how small-scale jet-like events might make the solar wind, as has been suggested in recent studies. We show that the events referred to as "coronal jets" and as "jetlets" both fall on a power-law distribution that also includes large-scale eruptions and spicule-sized features; all of the jet-like events could contribute to the solar wind. Based on imaging and magnetic field data, it is plausible that many or most of these events might form by the same mechanism, in this manner: Magnetic flux cancelation produces small- scale flux ropes, often containing a cool-material minifilament; this minifilament/flux rope then erupts and reconnects with adjacent open coronal field, along which "plasma jets" flow and

contribute to the solar wind. The erupting flux ropes can contain twist that is transferred to the open field and plausibly
become Alfvénic pulses that form magnetic switchbacks, providing an intrinsic connection between switchbacks and the production of the solar wind.

---

Wednesday 9:15:00 AM-9:30:00 AM, Ballroom

## Quantification of Bursty and Steady Heating of the 4--8 MK Coronal Plasma in a Solar Active Region using Minimum, Maximum, and Average Brightness Maps

Sanjiv Tiwari [1, 2], Lucy A. Wilkerson [3], Navdeep K. Panesar [1, 2], Ronald L. Moore [4, 5], Amy R. Winebarger [4]

[1] Lockheed Martin Solar and Astrophysics Laboratory; [2] Bay Area Environmental Research Institute, Palo Alto, CA, USA; [3] University of Maryland, College Park, MD 20742, USA; [4] NASA Marshall Space Flight Center; [5] Center for Space and Aeronomic Research, The University of Alabama in Huntsville, Huntsville, AL 35805, USA

We present a method of quantifying coronal heating's bursty and background components, applying it to \FeXVIII\ (hot94) emission of an active region (AR) observed by SDO/AIA. The maximum, minimum, and average brightness values for each pixel, over a 24 hour period, yield a maximum-brightness map, a minimum-brightness map, and an average-brightness map of the AR. Running sets of such three maps come from repeating this process for each time step of running windows of 20, 16, 12, 8, 5, 3, 1 and 0.5 hours. From each running window's set of three maps, we obtain the AR's three corresponding luminosity light curves. We find that the time-averaged ratio of minimum-brightness-map luminosity to average-brightness-map luminosity increases as the time window decreases, and the time-averaged ratio of maximum-brightness-map luminosity to average-brightness-map luminosity decreases as the window decreases. For the 24-hour window, the minimum-brightness map's luminosity is 5\% of the average-brightness map's luminosity, indicating that at most 5\% of the AR's hot94 luminosity is from heating that is steady for 24 hours. This upper limit on the fraction of the hot94 luminosity from steady heating increases to 33\% for the 30-minute running window. This suggests that the heating of the 4--8 MK plasma in this AR is mostly in bursts lasting less than 30 minutes. At most a third of the heating is in the background for 30 minutes.

---

Wednesday 9:30:00 AM-9:45:00 AM, Ballroom

## Quantifying eruptivity in global coronal models

Anthony Yeates

Durham University

I will show results on quantifying “eruptivity” in global coronal models driven by SDO/SHARPs magnetograms. With the recent move toward time-evolving coronal magnetic models in the community, we need new approaches for comparing non-potential aspects not captured in traditional static models. One important aspect is eruptions such as streamer blowouts and/or coronal mass ejections. I will

highlight two possible measures that avoid the need to define and identify individual eruptions. Within the context of the magneto-frictional model, I have used these measures to study the pattern of eruptivity over the solar cycle, as well as the relation between eruptivity and magnetic helicity or free energy.

---

Wednesday 9:45:00 AM-10:00:00 AM, Ballroom

## Observations of the 2024 April 8 total solar eclipse with CATE 2024, SAMI on NASA's WB-57, GOES/SUVI, and SDO/AIA

Amir Caspi [1], Dan Seaton [1], Sarah Kovac [1], Ritesh Patel [1], Derek Lamb [1], Will Ashfield [1], Cooper Downs [2]

[1] Southwest Research Institute, Boulder, CO; [2] Predictive Science Inc., San Diego, CA

The total solar eclipse on 2024 April 8 offered a fortuitous opportunity for high-resolution, high-fidelity, multi-wavelength observations of prominences & magnetic structures in the inner & middle corona from terrestrial (ground-based & airborne) instruments together with space-borne telescopes, providing a rich data set for joint analysis.

CATE 2024 deployed 43 observing stations along the eclipse path from Mazatlan, Mexico to Houlton, Maine, with totality data available from 35 sites covering over an hour. CATE measured 4 polarization angles (0°, 45°, 90°, 135°) with a horizontal FOV of ±3 Rsun & platescale of 1.43"/pix, using an 8-image logarithmically-scaled exposure sequence to achieve a high dynamic range (HDR) & full Stokes I, Q, & U values at every pixel with cadence of ~2 sec.

The SCIFLI Multispectral Airborne Imager (SAMI) flew onboard a NASA WB-57 high-altitude jet to observe the eclipse at 50,000-foot altitude over Mazatlan, Mexico for over 6 minutes using 4 scientific cameras covering 9 spectral bands: VIS (blue, green, red), NIR, SWIR, & 4 bands of MWIR. Each camera operated at 20 Hz & was co-boresighted with platescales ranging from 0.8"/pix to 1.6"/pix, for measurements out to ~2.5 Rsun over each of the East & West limbs for ~3 min per limb.

Together, CATE 2024 & SAMI enable multispectral & broadband polarization studies of prominences & coronal structures, as well as dynamics within these on timescales as short as a few seconds to as long as a few tens of minutes.

We compare & contrast the CATE 2024 visible-light and SAMI visible & IR observations with simultaneous EUV measurements from SDO/AIA and a GOES/SUVI off-point campaign to capture extended structures in the middle corona. We compare these with the PSI/MAS forward-model of the eclipsed corona. We discuss joint co-analysis to characterize the nature of emission processes in coronal structures & prominences, structural connectivity into & within the middle corona, & dynamic evolution.

---

Wednesday 10:30:00 AM-10:45:00 AM, Ballroom

## Solving the Solar Oxygen Problem with Atomic Physics?

Regner Trampedach [1], Werner Däppen [2]

[1] Space Science Institute, Boulder, CO, USA; [2] Dept. of Physics and Astronomy, USC, LA, CA, USA

The previous century saw a nice convergence of our solar models towards both classic and seismic observations. That was upended by homogeneous solar abundances analyses based on deep, 3D,

radiation-coupled Hydrodynamic simulations of the convective solar atmosphere. We seek to solve the conflict with improved atomic physics, in particular the interior opacities and the equation of state (EOS) they are based on. We present our EOS work here, which includes many features not available in other stellar EOS, and highlight changes that will impact opacity calculations. The new EOS will also impact seismic abundance analysis of the noble gasses He and Ne, as well as a seismic validation of the spectroscopic metallicity. Progress on the accompanying opacity calculations by Pradhan & Nahar will be reviewed.

---

Wednesday 10:45:00 AM-11:00:00 AM, Ballroom

## Rossby Wave Cavities in the Solar Interior

Catherine Blume [1], Bradley W. Hindman [2]

[1] Department of Astrophysical and Planetary Sciences, University of Colorado Boulder, Boulder, USA; [2] JILA, Department of Astrophysical and Planetary Sciences, and Department of Applied Mathematics, University of Colorado Boulder, Boulder, USA

Although classical Rossby waves have been extensively studied in quasi-2D thin shells, there is a gap in understanding how these waves propagate radially in thick shells such as the solar interior. Here, we explore such radial behavior. Using the beta-plane approximation, we derive a local dispersion relation that describes the radial propagation of Rossby waves in a stratified fluid. From this dispersion relation, we can identify the wave cavities and propagation frequencies in various atmospheres. We present a propagation diagram for Model S, which reveals two separate families of Rossby waves living in two separate cavities: one in the radiative interior, and the other in the convection zone. Additionally, we solve for solutions in a toy model consisting of an isothermal atmosphere coupled to an unstable polytropic one.

---

Wednesday 11:00:00 AM-11:15:00 AM, Ballroom

## Numerical studies of solar inertial modes using Dedalus

Suprabha Mukhopadhyay, Yuto Bekki, Xiaojue Zhu, Laurent Gizon

Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany

The Sun undergoes oscillations with which we can probe deep into its interior. Inertial modes are low-frequency oscillations restored by the Coriolis force (Gizon et al. 2021). In this work, we use a flexible spectral code, Dedalus (Burns et al., 2020), to compute the eigenmodes of the differentially rotating convection zone, employing several simplifying assumptions. This framework helps us to examine the sensitivity of the modes to different model assumptions, including the incompressible and the anelastic approximations. These approximate modes are compared with the compressible modes, as well as with the observed modes at the Sun’s surface. We find that the anelastic approximation is acceptable, while the assumption of incompressibility is not justified. Furthermore, we show that the inertial modes are almost decoupled from the radiative interior.

---

Wednesday 11:15:00 AM-11:30:00 AM, Ballroom

## Nonlinear saturation mechanism of high-latitude inertial modes on a differentially rotating sphere

Muneeb Mushtaq, Damien Fournier, Laurent Gizon

Max-Planck Institute for Solar System Research, Göttingen, Germany

At high latitudes the solar rotation rate drops fast with increasing latitude and is linearly unstable. In this presentation we discuss the nonlinear saturation mechanism, which controls the amplitude of the $m=1$ high-latitude inertial mode. Using nonlinear numerical simulations of purely toroidal modes on the sphere, we show that the bifurcation is supercritical. This justifies the use of the weakly nonlinear theory to model the development of the disturbance amplitude and to determine to what value it saturates. We find a simple relationship between the mode amplitude and the linear growth rate of the mode.

---

Wednesday 11:30:00 AM-11:45:00 AM, Ballroom

## Atypical eigenfunction of m=3 Rossby wave

Yash Mandowara [1], Yuto Bekki [1], Damien Fournier [1], Zhi-Chao Liang [1], Suprabha Mukhopadhyay [1], Laurent Gizon [1], Rick S. Bogart [2]

[1] Max Planck Institute for Solar System Research, Göttingen, Germany; [2] Stanford University, California USA

A rich spectrum of inertial modes has been conclusively observed on the Sun. Studying the properties of these low-frequency modes can provide further insight into the internal structure and dynamics of the Sun. The present study uses the horizontal flow maps derived from HMI Dopplergrams using the Stanford ring-diagram pipeline (5 deg tiles) to measure the surface eigenfunction of the m=3 Rossby mode and highlight its substantial deviations from that of the classical equatorial Rossby mode. The observed mode shares properties with the high-latitude modes, a conclusion which is also reached using computed eigenfunctions.

---

Wednesday 10:30:00 AM-10:45:00 AM, Ballroom

## Estimating the Poynting flux of Alfv\'enic waves in polar coronal holes across Solar Cycle 24

Richard Morton [1], James McLaughlin [1], Micah Weberg [2], Nikita Balodhi [1]

[1] Northumbria University UK; [2] US Naval Research Laboratory, USA

Alfvénic waves are known to be prevalent throughout the corona and solar wind. Determining the Poynting flux supplied by the waves is required for constraining their role in plasma heating and acceleration, as well as providing a constraint for Alfvén wave driven models that aim to predict coronal and solar wind properties. Previous studies of the Alfvénic waves in polar coronal holes have been able to provide a measure of energy flux for arbitrary case studies. Here we build upon previous work and take a more systematic approach, examining if there is evidence for any variation in Poynting flux over the course of the solar cycle. We use imaging data from SDO/AIA to measure the displacements of the fine-

scale structure present in coronal holes. It is found that the measure for Poynting flux is broadly similar over the solar cycle, implying a consistent contribution from waves to the energy budget of the solar wind. There is variation in energy flux across the measurements (around 30\%), but this is suggested to be due to differences in the individual coronal holes rather than a feature of the solar cycle.

---

Wednesday 10:45:00 AM-11:00:00 AM, Ballroom

## Modeling the Excitation, Propagation and Dissipation of MHD Waves in Coronal Magnetic Structures Motivated by SDO/AIA Observations

Leon Ofman [1, 2], Tongjiang Wang [1,2], Xudong Sun [3] , Wei Liu [4], Meng Jin [5]

[1] Catholic University of America, USA; [2] NASA GSFC, Greenbelt, MD, USA; [3] U. Hawaii, Maui, USA; [4] BAERI/LMSAL, Palo Alto, USA, [5] LMSAL, Palo Alto, USA

The role of MHD waves in the solar corona in the heating of coronal loops and active regions, as well as in producing the solar wind is still debated. Since the launch of the SDO spacecraft more than a decade ago, ample evidence of MHD waves in EUV was obtained by SDO/AIA. Fast magnetosonic waves associated with flares and coronal mass ejections (CMEs) were detected in the lower corona, providing information on flare pulsations as well as on the magnetic field magnitude through coronal seismology. It is evident that MHD waves can transport significant energy flux in active regions and coronal loops. Here, we present models of MHD waves such as the observed quasi-periodic propagating (QFPs) fast magnetosonic waves using realistic active region structures thus improving the accuracy of coronal seismology, as well as providing better estimate on the energy flux that can be transported by the waves. Here, we extend previous models by including in our 3D MHD model the effects of enhanced viscous and resistive dissipation in realistic magnetic configuration of observed active regions based on force-free field (FFF) extrapolation with more realistic density and temperature structures. We investigate various forms of excitation and dissipation of the MHD waves and compare qualitatively to SDO/AIA observations. We produce synthetic emission measure (EM) maps from the 3D MHD modeling output to facilitate comparison to EUV observations. We find that the present more realistic models provide better agreement with observations and are necessary steps for improving coronal seismology, coronal wave heating and solar wind acceleration models.

---

Wednesday 11:00:00 AM-11:15:00 AM, Ballroom

## AWSoM MHD Simulation of a Solar Active Region: Realistic Spectral Synthesis, and Statistical Analysis of Alfven Wave Dissipation and Reflection, Scaling Laws, and Energy Budget on Coronal Loops

Tong Shi [1], Ward Manchester IV [2], Enrico Landi [2], Bart van der Holst [2], Judit Szente [2], Yuxi Chen [3], Gabor Toth [2], Luca Bertello [4], Alexander Pevtsov [4]

[1] SETI Institute; [2] University of Michigan; [3] Boston University; [4] National Solar Observatory

The coronal heating problem has been a major challenge in solar physics, and tremendous amount of effort has been made over the past several decades to solve it. Here, we aim at answering how the

physical processes behind the Alfven wave turbulent heating adopted in the Alfven Wave Solar atmosphere Model (AWSoM) unfold in individual plasma loops in an active region (AR). We perform comprehensive investigations in a statistical manner on the wave dissipation and reflection, temperature distribution, heating scaling laws, and energy balance along the loops, providing in-depth insights into the energy allocation in the lower solar atmosphere. We demonstrate that our 3D global model with a physics-based phenomenological formulation for the Alfven wave turbulent heating yields a heating rate exponentially decreasing from loop footpoints to top, which had been empirically assumed in the past literature. A detailed differential emission measure (DEM) analysis of the AR is also performed, and the simulation compares favorably with DEM curves obtained from Hinode/EIS observations. This is the first work to examine the detailed AR energetics of our AWSoM model with high numerical resolution and further demonstrates the capabilities of low-frequency Alfven wave turbulent heating in producing realistic plasma properties and energetics in an AR.

---

Wednesday 11:15:00 AM-11:30:00 AM, Ballroom

## Synoptic Maps of Solar Magnetic Field and Open Magnetic Flux

Yang Liu [1], C. Nick Arge [2], Shaela I. Jones [2,3], Andrew Leisner [4]

[1] Stanford University, USA; [2] NASA Goddard Space Flight Center, USA; [3] Catholic University of America; [4] George Mason University, USA

It has been reported that the interplanetary magnetic field (IMF) measured near the Earth can differ from that derived from coronal models by as much as a factor of two, especially near solar maximum. In this work, we investigate this discrepancy by modeling the IMF using a potential field source surface model driven by synoptic maps of the photospheric magnetic field. We choose various types of radial field synoptic maps from the data taken by the Solar Dynamics Observatory's Helioseismic and Magnetic Imager from May 2010 to April 2024. Four types of radial field synoptic maps are used in this work: the Br synoptic maps from vector magnetic field data, the Mr synoptic maps that are computed from the line-of-sight field data, the rescaled Mr synoptic maps that are rescaled from the Mr maps by a center-to-limb distance dependent rescaling factor of $B_r/M_r$, and the composite synoptic maps that combine strong-field pixels from Br maps and rest from Mr maps.

The IMF is modeled using a Potential Field Source Surface (PFSS) model using the above-mentioned synoptic maps as its input. The modeled IMFs from all four types of synoptic maps agree with each other well during solar maximum phase while they are up to 2 times smaller than in situ measurement. The IMF values calculated from the $B_r$ and composite synoptic maps match well with in situ observation at 1 AU during solar minimum from 2017 to 2022. The IMFs modeled from $M_r$ and rescaled $M_r$ synoptic maps are still significantly smaller during this time interval though the rescaled $M_r$ synoptic maps minimize this discrepancy greatly. This suggests that (1) the $B_r$ represents radial field better than the $M_r$ computed from the line-of-sight field assuming the field is radial; (2) the PFSS model is appropriate to model the heliospheric magnetic field in solar minimum but has limitation in use in solar maximum.

---

Wednesday 1:00:00 PM-1:15:00 PM, Ballroom

## Measuring the solar differential rotation with iterative helioseismic holography

Björn Müller [1], Laurent Gizon [1], Damien Fournier [1], Thorsten Hohage [2]

[1] Max-Planck-Institute for Solar System Research, Göttingen, Germany; [2] Institut für Numerische und Angewandte Mathematik, Göttingen, Germany

The primary data in helioseismology consists of highly noisy, five-dimensional cross-correlations (with two spatial dimensions and one temporal dimension) of line-of-sight velocities observed at the solar surface. Due to the vast amount of data, traditional techniques like time-distance helioseismology often rely on subsets of this seismic information. Helioseismic holography, by contrast, uses a more comprehensive and physically motivated averaging technique, wherein solar wave disturbances are back-propagated to infer proper ties of the solar interior. Through this method, all seismic information is used indirectly to generate feature maps. Despite its success in certain applications, such as farside imaging, helioseismic holography lacks a quantitative regularization framework, and the exact choice of wave propagator remains somewhat ambiguous. In this work, we interpret traditional helioseismic holography as an adjoint method, where the holograms form the first step in an iterative imaging approach.
This reformulation transforms traditional helioseismic holography into a fully quantitative imaging technique, capable of addressing nonlinear inversion problems, such as subsurface flow reconstruction. Iterative helioseismic holography stands out as the only method that fully uses the entire cross-correlation dataset without the need to explicitly compute it, while also handling nonlinear problems. In this talk, we present synthetic test cases that demonstrate the potential of this improved holographic approach. Furthermore, we apply iterative helioseismic holography to study the North-South-antisymmetry of solar differential rotation.

---

Wednesday 1:15:00 PM-1:30:00 PM, Ballroom

## Direct tests of SDO/HMI far-side helioseismology using SO/PHI magnetograms

Dan Yang

Max Planck Institute for Solar System Research, Göttingen, Germany

Helioseismology can image and monitor magnetic activity on the Sun's far side using acoustic waves observed on the Sun's Earth side. This technique is known as helioseismic far-side imaging, which allows detection of active regions days before they appear on the Earth's side of view. In this talk, I will briefly explain how far-side helioseismology works, and then validate and calibrate SDO/HMI far-side helioseismology using magnetograms of the far side obtained by SO/PHI.

---

Wednesday 1:30:00 PM-1:45:00 PM, Ballroom

## A New Perspective on Solar Convection: The Ball-tracked Carousel of Polar Faculae

Raphael Attie [1, 2], Julia Clark [1, 3], Sarah Okome [1], Dean Pesnell [1], Karin Muglach [1, 4]

[1] NASA GSFC; [2] GMU; [3] Montana State State University; [4] CUA

The Sun’s surface flows have been routinely studied for over a century. Since the 1980s, automated

tracking techniques, such as feature tracking and helioseismology, have provided increasingly detailed estimates of solar plasma velocity fields. However, high-latitude surface flows (above ~60° latitude) remain poorly understood. This limitation arises from the reduced accuracy of helioseismic inversions at high latitudes and the foreshortening effects that diminish the visibility of standard tracers, such as granules in continuum images and moving magnetic features (MMFs) in magnetograms.
Consequently, accurate flow maps near the poles are lacking, leaving critical gaps in our understanding of the interactions between polar magnetic fields and polar flows. To address this, we present a novel approach that leverages polar faculae (PFe) as tracers of high-latitude flows. Using an improved version of the "Magnetic Balltracking" algorithm, tailored specifically for PFe, we analyze data from SDO/HMI white-light images and vector magnetograms. PFe are bright, small-scale features associated with concentrated magnetic flux that appear above 60° latitude near the Sun's poles. Their prevalence varies with the solar cycle, being more frequent during solar minimum and less so as solar maximum approaches.
By tracking PFe with sizes of at least a few pixels in HMI white-light images, we uncover an increased randomness in their motions compared to MMFs at lower latitudes where they are more strongly influenced by structured flows such as supergranulation, differential rotation, and meridional flows. These findings reveal distinct characteristics of polar flows, setting them apart from the rest of the quiet Sun. Understanding these unique dynamics provides critical insights for refining models of global magnetic flux transport and the solar dynamo.

---

Wednesday 1:45:00 PM-2:00:00 PM, Ballroom

## On the Solar Convective Conundrum: a path theory to study global solar convection

Allan Sacha Brun

Dept of Astrophysics, CEA Paris-Saclay

Helioseismic inversions of the solar convective power distribution done with HMI onboard SDO confirms that there is a disagreement on the amplitude of the large scale convection motions between different observational techniques as well as with numerical simulations of global solar convection. This tension is known as the solar Convective Conundrum. In this talk, we will present a recent study based on high resolution numerical simulations of global solar convection with the ASH code, that characterizes how the power is distributed among the convection scales depending on input parameters. By following a theory path in parameter space that respects key identified force balances via a control of the Nusselt number at fixed Rossby but increasing Reynolds number, we are able to build a global turbulent model of the solar convection that is in better agreement with the various observational constraints (large scale convective power, polar Rossby mode, superadiabaticity degree). We discuss the properties of this new solar model and the way forward.

---

Wednesday 2:00:00 PM-2:15:00 PM, Ballroom

## Understanding the solar tachocline in terms of the dynamo's magnetic field

## penetrating deep into the radiative interior

Loren Matilsky, Brummell, Nicholas H. - Department of Applied Mathematics, University of California, Santa Cruz
Korre, Lydia - Department of Applied Mathematics, University of Colorado Boulder
Department of Applied Mathematics, University of California, Santa Cruz

In the solar interior, strong latitudinal differential rotation persists throughout most of the convection zone (CZ). At the base of the CZ, this differential rotation transitions across a narrow layer, known as the "tachocline", to rigid rotation in the radiative zone (RZ) below. This rigidity persists as far down as helioseismology can reliably probe. A basic dynamical understanding of the simultaneous confinement of the tachocline to a thin layer and the rigidification of the whole RZ has proven elusive, despite the potentially profound consequences for the solar dynamo, spin-down, and the Sun's observed lithium depletion. We recently explored three-dimensional magnetohydrodynamic simulations of a solar-like CZ-RZ system, in which the nonaxisymmetric magnetic field from a quasiperiodic convective dynamo was able to spread into the RZ via a magnetic skin effect. This field forced the RZ into rigid rotation and confined a tachocline via magnetic torque, both against viscous spread and radiative spread (where the latter is dominant in the Sun). Furthermore, the steady-state angular momentum profiles in our simulations indicate that the CZ (as a whole) rotates very slightly faster than the RZ, a fact which remarkably appears to be true for the helioseismic inversion data as well. We thus argue that the solar dynamo, via its skin effect, could be a source of magnetic field, even deep within the radiative interior, which forces the whole Sun to have a nearly constant angular-momentum-weighted rotation rate.

---

Wednesday 2:15:00 PM-2:30:00 PM, Ballroom

## Investigating the Role of Radially Varying Diffusivities in Stellar Convection Modeling

Brandon Lazard [1], Nicholas Featherstone [2], Jonathan Aurnou [1]
[1] Department of Earth, Planetary and Space Sciences, University of California, Los Angeles; [2] Department of Solar and Heliospheric Research, Southwest Research Institute, Boulder, CO

Convection is ubiquitous in stellar and planetary interiors and is integral to the generation of their respective dynamos. These interiors remain hidden to direct observation. As a result, our understanding of interior convective phenomena largely comes from computational and theoretical models. In these models, radially varying forms of the viscous ($\nu$) and thermal ($\kappa$) diffusivity are routinely utilized as an ad-hoc representation of the effects of subgrid scale motion. However, the values of even these diffusivities are constrained to unphysically high values due to computational limitations. Moreover, the different choices for the different functional forms of these diffusion coefficients can lead to very different behaviors in the fluid. To date, no systematic studies exist that compare the radially varying diffusivities and their effect on the dynamics within global convection zone simulations. We present results for a series of non-rotating solar-like convection models with varying radial functions for the diffusivities and differing boundary conditions. We show that alternative formulations for the diffusivity lead to different distributions of turbulence within the shell and that the kinetic energy scales similarly regardless of diffusivity. In contrast, the heat transfer is dependent on the functional form of the diffusivity and changes proportionately with the boundary conditions.

Wednesday 1:00:00 PM-1:15:00 PM, Ballroom

## Deciphering solar wind source regions using interpretable deep learning

Vishal Upendran [1, 2, 3], Mark Cheung [4]; Shravan Hanasoge [5], Ganapathy Krishnamurthi [6]

[1] Bay Area Environmental Research Institute; [2] Lockheed Martin Solar and Astrophysics Laboratory; [3] Inter University Centre for Astronomy and Astrophysics, Pune; [4] CSIRO; [5] TIFR; IIT Madras

Emanating from the base of the Sun's corona, the solar wind fills the interplanetary medium with a magnetized stream of charged particles whose interaction with the Earth's magnetosphere has space weather consequences such as geomagnetic storms. Accurately predicting the solar wind through measurements of the spatiotemporally evolving conditions in the solar atmosphere is important but remains an unsolved problem in heliophysics and space weather research. In this work, we use deep learning for prediction of solar wind (SW) properties. We use extreme ultraviolet images of the solar corona from space-based observations to predict the SW speed from the National Aeronautics and Space Administration (NASA) OMNIWEB data set, measured at Lagragian Point 1. We evaluate our model against autoregressive and naive models and find that our model outperforms the benchmark models, obtaining a best fit correlation of $0.55 \pm 0.03$ with the observed data. Upon visualization and investigation of how the model uses data to make predictions, we find higher activation at the coronal holes for fast wind prediction ($\approx$3 to 4 days prior to prediction), and at the active regions for slow wind prediction. These trends bear an uncanny similarity to the influence of regions potentially being the sources of fast and slow wind, as reported in literature. This suggests that our model was able to learn some of the salient associations between coronal and solar wind structure without built-in physics knowledge. Such an approach may help us discover hitherto unknown relationships in heliophysics data sets.

---

Wednesday 1:15:00 PM-1:30:00 PM, Ballroom

## Testing Theories of Coronal Heating: A New Generation of 4D Forward Models Compared with SDO and Hinode/XRT Data

Steven Cranmer, Daniel I. Mendoza

University of Colorado Boulder

Many different processes have been suggested to explain the origin of the corona and solar wind, but we still have not conclusively identified the detailed pathways of energy transfer from convection and magnetic fields to plasma heating. There has been substantial progress in producing 3D simulations that reproduce many observed properties of the corona, but these tools are often limited by either (1) coarse spatial and time resolution that does not resolve granulation-scale magnetic field dynamics, or (2) including only a single proposed heating mechanism, such as MHD turbulence. We will present preliminary results from an attempt to build a more "theory-agnostic" proving ground, which takes the form of a forward-modeling framework that includes as many of the proposed processes as possible, all on equal footing. Our primary product will be line-of-sight integrated synthetic images of EUV/X-ray emission for the low corona, computed at different times over the solar cycle. These will include arbitrary combinations of AC, DC, turbulence, and Taylor-relaxation mechanisms, as well as heat-flux gradients

with ambipolar diffusion and DEM broadening from nanoflare-like heating intermittency. Direct comparisons of these forward models with observed images will sample three orders of magnitude of temperature and will provide newly tightened constraints on the actual contributions of the proposed theories. We will also present results of a comparison between multiple field-line extrapolation models (e.g., PFSS vs more sophisticated methods), and with total eclipse data, which will help refine what kinds of magnetic extrapolation are best suited for testing coronal heating models.

---

Wednesday 1:30:00 PM-1:45:00 PM, Ballroom

## Effective Off-Limb Data Visualization: A Review of Common Techniques

Chris "Gilly" Gilbert [1], S. Cranmer [2]

[1] Southwest Research Institute; [2] APS, CU, Boulder, Colorado USA

Off-limb data from the Atmospheric Imaging Assembly (AIA) contains a wealth of information that often exceeds what can be effectively visualized using standard display technology and human vision. To address this challenge, the community has developed several families of algorithms designed to reduce the dynamic range of this imagery, allowing it to be presented in a single frame. This talk will review common techniques such as Histogram Equalization, Radial Graded Filters, and Multiscale Methods, highlighting their respective strengths and limitations. Attendees will gain insights into selecting the most appropriate method for various scenarios, thus optimizing the visualization and interpretation of off-limb data.

---

Wednesday 1:45:00 PM-2:00:00 PM, Ballroom

## Quantifying how surface complexity influences properties of the solar corona and solar wind

Caroline Evans [1], Cooper Downs [2], Don Schmit [3]

[1] Department of Astrophysical and Planetary Sciences, University of Colorado Boulder, Boulder USA; [2] Predictive Science, Inc., San Diego USA; [3] Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder, Boulder USA

The Sun's magnetic field is a key driver of the mechanisms of coronal heating and consequently solar wind acceleration. To better encapsulate these processes, we seek to quantify how the structures of the photosphere affect the low corona and evolve into the middle corona. We analyze three simulations of the 3D global solar corona that vary the resolution of the surface boundary condition, derived from SDO/HMI, while keeping the same parameterization of a thermodynamic, wave-turbulence-driven magnetohydrodynamic model. We quantify structural differences endemic to each simulation using spherical harmonic decomposition and associated statistics. We demonstrate that small-scale photospheric magnetic flux augments the amount of heating across spatial regimes throughout the low and middle corona. We calculate 40% more heating in our best resolution simulation and describe a one-to-one correlation between the structure of the magnetic field and heating in the low corona across resolutions. In principle, these results can enable more efficient subgrid modeling in future low-resolution simulations.

---

Wednesday 2:00:00 PM-2:15:00 PM, Ballroom

## Coronal Holes of Solar Cycle 24 in McIntosh style synoptic maps

Ian Hewins [1], Barbara Emery [1], Thomas Kuchar [2]

[1] HAO/NCAR; [2] Boston College

The original McIntosh Archive of solar synoptic maps covers solar cycles 20 – 23 (1964 – 2008). It utilizes H Alpha images for filaments, sunspots and plage, magnetograms for polarity and polarity inversion lines and beginning in 1974 Helium 10830 Å images for coronal holes. We are now making maps of solar cycle 24 (2008 – 2020) using SDO AIA 193 data (instead of Helium 10830 Å), continuing the McIntosh Archive. We are working with a team of machine learning experts who are utilizing every step of our map making process with the intention of reproducing the techniques and making more solar cycles of maps. Although the tools used to make maps today are more modern than those used in the exact method used 1964, the approach is the same. The archive is a unique tool that allows us to look at both open and closed field regions in the context that they exist on the sun at a given time as well as how features evolve over multiple rotations and solar cycles. We present on the cartographic process used as well as some preliminary results of analysis, specifically coronal hole lifetimes. In previous research (Hewins et. al. 2020) we looked at coronal hole lifetimes with the McIntosh Archive from the years 1974 – 2008 and found approximately 32% of non-polar or low-latitude coronal holes had lifetimes of at least 2 Carrington Rotations and the longest lifetimes were over 30 rotations. We are now looking at coronal hole lifetimes in solar cycle 24. Improvements in our techniques allow us to continue tracking the lifetimes of low-latitude coronal holes that attach to the polar coronal holes as polar coronal hole extensions.

---

Wednesday 2:15:00 PM-2:30:00 PM, Ballroom

## Coronal Cooling and Condensation near Magnetic Null Points: Feeding the Return Flow of the Chromosphere-Corona Mass Cycle

Wei Liu [1, 2], Patrick Antolin [3], Xudong Sun [4], Sijie Yu [5], Manuel Luna Bennasar [6], Cooper Downs [7], Viacheslav S. Titov [7]

[1] LMSAL; [2] BAERI; [3] Northumbria Univ; [4] Univ. Hawaii; [5] NJIT; [6] Universidad de Las Islas Baleares; [7] PSI

Coronal heating and cooling are the two sides of the same coin, which are equally important to the fundamental process of mass transport in the solar atmosphere and the chromosphere-corona mass cycle. The cool, dense chromosphere is the source of mass that is heated and transported upward to the hot, tenuous corona. Meanwhile, the corona, under favorable conditions, can undergo a process called thermal non-equilibrium (TNE) via radiative cooling and condense into cold material in the forms of coronal rain and prominences, which, if not ejected with solar eruptions, generally return to the chromosphere eventually. Where, when, and how such cooling condensations take place is not well understood. We report imaging and spectroscopic observations from SDO/AIA/HMI and IRIS that can shed light on this question. Specifically, it is well known that coronal rain is common in active region loops because of strong heating, high densities, and thus strong radiative cooling there. However, on the quiet Sun away

from active regions, such condensations do not appear randomly, but follow a pattern to preferentially occur at the dips of coronal loops or funnels. They are located at/near magnetic "topological singularities", such as null points and quasi-separatrix layers (QSLs), which are regions characterized by high values of the squashing factor. Some of such structures appear at high latitudes and are long-lived, lasting for almost a year during certain phases of the solar cycle. We identified evidence of magnetic reconnection at such locations, which can produce favorable conditions, e.g., density enhancement by compression and/or mass trapping in plasmoids, that can trigger run-away radiative cooling. We present MHD simulations that demonstrate the role of reconnection in transporting cooled mass from overlying, long loops to underlying, short loops where it slides down as coronal rain. We discuss the significance of these results and their broad implications.

---

Wednesday 4:00:00 PM-4:15:00 PM, Ballroom

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

Daniele Calchetti [1], Gherardo Valori [1], Hanna Strecker [2], Julian Blanco [3], Johann Hirzberger [1], David Orozco Suarez [2], Sami Solanki [1]

[1] Max Planck Institute for Solar System Research; [2] IAA; [3] University of Valencia

Since its launch in February 2020, Solar Orbiter has been providing high-quality data from the many layers of the solar atmosphere. The Polarimetric and Helioseismic Imager onboard Solar Orbiter (SO/PHI) is a spectropolarimeter scanning the Fe I line at 617 nm, the same line sampled by SDO/HMI and many other on-ground instruments providing data of the solar photosphere. A first comparison of the magnetic field vector obtained by SO/PHI and SDO/HMI has already been discussed in Sinjan et al. 2023 and Moreno Vacas et al. 2024.

Here, we compare the line-of-sight velocity measured by the High Resolution Telescope (HRT) of SO/PHI and SDO/HMI. The goal of this comparison is multi-purpose: Firstly, reliable measurements of up- and down-flows from SO/PHI-HRT are crucial and unique when Solar Orbiter is facing the far side of the Sun. Secondly, a good cross-calibration is mandatory to achieve stereoscopic measurements of horizontal flows from two vantage points. For this purpose, we compare the line-of-sight velocity measured by SO/PHI-HRT and SDO/HMI on 29 March 2023, when Solar Orbiter was crossing the Sun-Earth line at 0.39 au from the Sun. This configuration offered an uncommon opportunity to directly compare data products from both telescopes. The results show very good agreement and correlation between the two different instruments when instrumental effects and large-scale velocities on the Sun are also considered. A deeper investigation is needed to carefully treat and understand the deviation between the two instruments.

---

Wednesday 4:15:00 PM-4:30:00 PM, Ballroom

## The Propagation of Atmospheric Gravity Waves in the Magnetized Lower Solar Atmosphere

Oana Vesa [1], Jason Jackiewicz [2], Julio Morales [2]

[1] W.W. Hansen Experimental Physics Laboratory, Stanford University, Stanford, CA USA; [2] Department of Astronomy, New Mexico State University, Las Cruces, NM

Atmospheric Gravity Waves (AGWs) are low-frequency, buoyancy-driven waves generated abundantly by turbulent convection and overshoot on the Sun. In addition to their role in energy transport and coupling atmospheric layers, the propagation of AGWs is sensitive to the magnetic field topology: highlighting their potential as novel diagnostics for the magnetic field in the lower solar atmosphere. Using multi-height IBIS/DST and HMI/SDO observations, we investigate the characteristics of AGWs throughout the lower solar atmosphere in different magnetic field configurations and disk positions. Employing Fourier analysis and local helioseismology techniques, we detect propagating AGWs carrying energy upward at the expected temporal and spatial scales consistent with quiet-Sun independent observations, theory, and numerical simulations. By using HMI's line-of-sight magnetogram and SHARP data, we disentangle the effects of the magnetic field on their behavior, such as their suppression at locations of high magnetic flux. This work aims to create a comprehensive characterization of AGWs and unravel their diagnostic potential.

---

Wednesday 4:30:00 PM-4:45:00 PM, Ballroom

## A Machine Learning Approach to Investigate the Evolution of Sunspots

Janis Kjell Witmer [1], Lucia Kleint [1], Jonas Zbinden [1], Brandon Panos [2]

[1] Astronomical Institute, University of Bern, Bern Switzerland; [2] FHNW University of Applied Sciences and Arts Northwestern Switzerland, Windisch Switzerland

Sunspots are key indicators of solar activity. They can appear and decay within hours to weeks. However, the mechanisms underlying the evolution of sunspots remain largely unknown. We aim to better understand the driving mechanisms in sunspot formation in active regions. Our overall vision is to have a machine learning model for the Sun, which can predict its appearance in the future. Our first goal is determining whether an active region will evolve into a sunspot and identify precursors of sunspot formation.

We propose an advanced hybrid deep learning model that integrates the image classification capabilities of Convolutional Neural Networks (CNNs) with the contextual sequence processing strengths of Transformers. This model is designed to classify sequences of continuum intensity, line-of-sight (LOS) magnetograms, vector magnetic fields, and LOS Dopplergram images acquired by the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO), based on their potential to develop into sunspots.

Our model successfully predicts the evolution of active regions into sunspots hours before the event happens. Prediction accuracies tend to increase, the closer our sequences are to the sunspot formation event, reaching True Skill Statistic (TSS) scores of 0.88 (1 perfect prediction, 0 random, -1 adverse predictions). Our results show that LOS Dopplergram data are the best indicator of sunspot formation for short timescales $t<9.2$ h. For longer timescales $t>9.2$h vector magnetic field data are most indicative. We propose that the likelihood of sunspot formation is primarily governed by the initial configuration of the magnetic field. When the magnetic field structure is suited to sunspot formation, plasma flows become the critical factor driving the process. This hypothesis explains why vector magnetic field data are the most reliable predictors over longer timescales, while LOS Dopplergram data provide the strongest indicators on shorter timescales.

Wednesday 4:45:00 PM-5:00:00 PM, Ballroom

## Utilizing far-side active regions detected by helioseismology as input to magnetograms for 360° synchronic solar wind forecasting.

Stephan G. Heinemann [1], Dan Yang [2], Jens Pomoell [1], Shaela Jones [3], Carl Henney [4], Eleanna Asvestari [1], Nick Arge [3]

[1] Department of Physics, University of Helsinki, 00014 Helsinki, Finland; [2] Max Planck Institute for Solar System Research, 37077 Göttingen, Germany; [3] Heliophysics Science Division, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, USA; [4] Air Force Research Laboratory, Space Vehicles Directorate, KAFB, NM, USA

Synoptic magnetic field data typically serve as the boundary condition for simulations of the global magnetic field. However, these data are subject to "aging effects," as a full 360° longitudinal view can only be obtained over the course of one solar rotation. To mitigate this limitation, we employ the “combined surface flux transport and helioseismic Far-side Active Region Model” (FARM) to integrate near-side HMI/SDO magnetograms and far-side helioseismic active regions into a surface flux transport model. This approach enhances the accuracy of far-side magnetic field modeling, leading to a more precise representation of the global magnetic field and improved solar wind forecasting. We utilize potential field source surface (PFSS) modeling along with the EUropean Heliospheric FORecasting Information Asset (EUHFORIA) to derive the coronal magnetic field configuration and heliospheric structure. Additionally, we assess the impact of incorporating far-side active regions into magnetic field maps using the WSA solar wind model. The modeled solar wind results show good agreement with far-side in-situ measurements obtained from various instruments. Our findings underscore the importance of including both the near-side and far-side of the Sun to accurately model the heliosphere and the propagation of solar transients.

Wednesday 5:00:00 PM-5:15:00 PM, Ballroom

## A Practitioners Perspective on SDO

Robert Steenburgh

NOAA/Space Weather Prediction Center

The launch of SDO 15 years ago transmogrified the practice of operational space weather forecasting. The low latency, high resolution data provided an unprecedented ability to monitor the evolution of active regions and the eruption of coronal mass ejections. The imagery simplified the production of the solar synoptic drawing, enhanced the ability to attribute flares to the correct regions, to differentiate between near and far side CMEs, and to diagnose solar wind changes attributable to coronal holes. These capabilities were built on the foundations laid by SOHO EIT and MDI instrument success decades earlier. SDO not only influenced the operational landscape immediately after data started flowing. It rapidly made the case for including multi-wavelength ultraviolet imagers on future operational spacecraft. In some respects, GOES SUVI is the sincerest form of flattery.

However, there were and still remain some unrealized opportunities at SWPC. Most of these dreams

deferred came in the last stages of the research-to-operations process. One example is the calculation of solar active region area and length, quantities determined manually by solar analysts of the United States Air Force. Another example is the failure of SHARPs, Space-Weather HMI Active Region Patches, to result in operational products to aid with flare and CME forecasting. Finally, the absence of training aimed at operations personnel meant they were occasionally bamboozled by artifacts in the data. The launch of SWPCs Space Weather Testbed will provide an ecosystem where conversations among researchers, forecasters, and stakeholders mean missed opportunities like the ones described above will be less likely. SDO is a revolutionary vehicle serving the purposes of both research and operations, and continued close community collaboration means future missions will build on this success.

---

Wednesday 5:15:00 PM-5:30:00 PM, Ballroom

### Quasi-Periodic Pulsations in TEC Measurements Synchronised with Solar Flare EUV Emission

Aisling O'Hare [1], Susanna Bekker [1], Laura A. Hayes [2], Ryan O. Milligan [1]

[1] Astrophysics Research Centre, Queen's University Belfast, UK; [2] European Space Research and Technology Centre, European Space Agency, The Netherlands

The extreme ultraviolet (EUV) and X-ray radiation emitted during solar flares has been shown to cause considerable increases in the electron density of the Earth's ionosphere. During flares, quasi-periodic pulsations (QPPs) in X-ray flux originating in the corona have previously been linked to subsequent pulsations in the Earth's ionospheric D-region. Similar pulsations have been detected in chromospheric EUV emission, although their impact on the Earth's ionosphere had not previously been investigated. Here, for the first time, synchronous pulsations were detected in solar EUV emission and ionospheric Total Electron Content (TEC) measurements. We present the detection of QPPs with periods on the order of 85 seconds in chromospheric EUV emission lines (304Å, 972Å and 977Å) during the impulsive phase of an X5.4 flare on 7 March 2012 using SDO/EVE. These lines contribute to the ionisation in the ionospheric E- and F-regions, resulting in subsequent variations of electron density, which was detected in TEC measurements. This work demonstrates that these layers of the Earth's ionosphere are responsive to very small fluctuations in EUV emission during flares, with time delays found on the order of 30 seconds. This may have applications in atmospheric modelling and solar-terrestrial studies, including the calculation of ionospheric recombination rates.

---

# Thursday, 20 February 2025

## *Stellar Insights from SDO Observations*

Thursday 8:30:00 AM-9:00:00 AM, Ballroom

### SDO's Contributions to the Study of Solar-stellar Connections (Invited Talk)

Shin Toriumi

Institute of Space and Astronautical Science and Japan Aerospace Exploration Agency, Sagamihara, Japan

Even with the modern large telescopes, it is still difficult to spatially resolve solar-type stars to diagnose the structures of starspots they host, how they produce flares, and how they affect the orbiting exoplanets. One possible way to overcome this problem is to observe the Sun as if it were a distant star, i.e., without spatially resolving it, and compare its properties with those of the stars. SDO's full-disk, multi-wavelength, long-term observations of the Sun have contributed significantly to this effort. For example, AIA and EVE data indicate that the detection of coronal dimming is probably one of the most promising ways to probe CMEs associated with the stellar flares, which led to the survey of X-ray dimming associated with stellar superflares. By analyzing SDO data to reproduce the Sun-as-a-star light curves in the visible and UV/EUV wavebands when an active region passes through the solar disk, it has been suggested that it may be possible to estimate the spatial extent and magnetic and thermal structures of stellar active regions from the measurement of stellar light curves at multiple wavelengths. Furthermore, by comparing a variety of Sun-as-a-star observables including the SDO data, it has been found that the magnetic flux and the irradiance of the Sun and Sun-like stars follow the common power-law relationships in different temperature ranges, suggesting that the atmospheric heating mechanism is universal among these stars.

---

Thursday 9:00:00 AM-9:15:00 AM, Ballroom

## The Relationships among Solar Flare Impulsiveness, Energy Release, and Ribbon Development

Cole Tamburri [1, 2], Maria D. Kazachenko [1, 2, 3], Adam F. Kowalski [1, 2, 3]

[1] University of Colorado Boulder, Boulder, CO, USA; [2] National Solar Observatory, Boulder, CO, USA; [3] Laboratory for Atmospheric and Space Physics, Boulder, CO, USA

We develop the impulsiveness index, a new classification system for solar flares using the Solar Dynamics Observatory/Extreme Ultraviolet Experiment 304 Å Sun-as-a-star light curves. Impulsiveness classifies events based on the duration and intensity of the initial high-energy deposition of energy into the chromosphere. In stellar flare U-band light curves, Kowalski et al. found that impulsiveness is related to quantities such as a proxy for the Balmer jump ratio. However, the lack of direct spatial resolution in stellar flares limits our ability to explain this phenomenon. We calculate impulsiveness for 1368 solar flares between 2010 April and 2014 May. We divide events into categories of low, mid, and high impulsiveness. We find, in a sample of 480 flares, that events with high maximum reconnection rate tend to also have high impulsiveness. For six case studies, we compare impulsiveness to magnetic shear, ribbon evolution, and energy release. We find that the end of the 304 Å light-curve rise phase in these case studies corresponds to the cessation of polarity inversion line (PIL)-parallel ribbon motion, while PIL-perpendicular motion persists afterward in most cases. The measured guide-field ratio for low- and mid-impulsiveness case-study flares decreases about an order of magnitude during the impulsive flare phase. Finally, we find that, in four of the six case studies, flares with higher, more persistent shear tend to have low impulsiveness. Our study suggests that impulsiveness may be related to other properties of the impulsive phase, though more work is needed to verify this relationship and apply our findings to stellar flare physics.

---

Thursday 9:15:00 AM-9:30:00 AM, Ballroom

## Inferring stellar butterfly diagram using the autocorrelation of acoustic oscillations

Samarth Ganesh Kashyap, Laurent Gizon, Jesper Schou

Department of Solar and Stellar Interiors, Max Planck Institute for Solar System Research, Germany

The eleven-year solar activity cycle is known to affect solar p-modes; p-mode frequencies are correlated with magnetic activity, while their lifetimes are anti-correlated with activity. Activity related frequency shifts have also been observed in other stars, but are difficult to measure mode by mode. Measurements of seismic travel times from the p-mode autocorrelation function provide an alternate approach which is robust to noise. In this work we use a simple forward model to interpret such measurements. We derive kernels that capture the sensitivity of travel-time measurements to surface activity at different latitudes. We perform linear inversions for the active latitudes using both synthetic data and solar data (VIRGO) using a regularized least squares technique. This technique is promising for inferring stellar butterfly diagrams.

---

Thursday 9:30:00 AM-9:45:00 AM, Ballroom

## Scaling Relations for Sun-as-a-Star XUV Spectra and Magnetic Flux: Predicting Radiative Environments of Exoplanets around Young, Active Sun-like Stars

Kosuke Namekata [1], Shin Toriumi [2], Vladimir Airapetian [1], Mumehito Shoda [3], Kyoko Watanabe [4], Yuta Notsu [5]

[1] NASA Goddard Space Flight Center, Maryland USA;[2] JAXA/ISAS, Kanagawa, Japan; [3] The University of Tokyo, Tokyo, Japan; [4] National Defense Academy of Japan, Kanagawa, Japan; [5] University of Colorado, Colorado USA

Recent observations unveiled that Sun-like stars frequently host exoplanets. They suggest that young exoplanets are subject to high X-ray and extreme-ultraviolet (EUV) radiation fluxes that may cause changes in their atmospheric dynamics and chemistry. While X-ray fluxes are directly observable, EUV fluxes are challenging to detect due to strong absorption by the interstellar medium. Here, we present a new solar empirical method to estimate the full stellar XUV (X-ray + EUV) and FUV spectral bands based on stellar unsigned magnetic flux (Namekata et al., 2023, ApJ, 945, 147). Using a decade-long Sun-as-a-star dataset from SDO/EVE, TIMED/SEE, and SORCE/XPS, we derive power-law relationships between the solar XUV and FUV spectra (0.1–180 nm) and the total unsigned magnetic flux with spectral resolutions of 0.1–1 nm. Applying these relations to active young Sun-like stars shows that observed stellar XUV/FUV spectra generally align with the derived solar power-law relations within an order of magnitude. Our scaling relations reliably estimate the XUV flux in the vicinity of the missing EUV band, suggesting that the SDO/EVE-based empirical model can also be used to approximate the flux within the missing stellar EUV band. Additionally, we identify discrepancies between solar and stellar observations in the 2–30 nm EUV range, emphasizing the need for simultaneous measurements of stellar magnetic fields and XUV/FUV fluxes for further validation. The critical role of SDO/EVE in providing precise, long-term solar spectral data has been essential in developing and verifying our model. Future missions

like SOLAR-C and MUSE will refine our empirical method by improving understanding of how EUV spectra depend on magnetic flux, spatial distribution, and coronal abundances, advancing the characterization of solar and stellar atmospheres and their impact on exoplanets.

---

Thursday 9:45:00 AM-10:00:00 AM, Ballroom

## High-time resolution observations of optical / near-ultraviolet / X-ray emission from two recent M-dwarf multi-wavelength observation campaigns

Yuta Notsu [1], Adam Kowalski [1, 2], Rachel Osten [3], Isaiah Tristan [1], Alexander Brown [1], Shun Inoue [4], Teruaki Enoto [4], and the AUMic campaign & Fulcrum campaign teams

[1] Laboratory for Atmospheric and Space Physics, University of Colorado Boulder, Boulder, CO, USA; [2] National Solar Observatory, Boulder, United States; [3] Space Telescope Science Institute, Baltimore, United States; [4] (Kyoto University, Kyoto, Japan

Many high-energy M-dwarf flares exhibit a strong response in the X-ray and near-ultraviolet (NUV), which is in line with the Neupert effect and the standard heating scenario for less energetic solar flares. However, there are also flares that do not follow the Neupert effect. Our fundamental understanding of stellar flares and particle acceleration beyond the Sun has been hampered by the lack of multi-wavelength observational data that can robustly constrain the physics in state-of-the-art models. We then recently conducted two multi-wavelength observation campaigns to investigate the X-ray, NUV, and optical behavior of high-energy flares: (1) 7-day XMM-Newton campaign of early M-dwarf AU Mic with NUV photometry + X-ray spectroscopy + optical H-alpha high-dispersion spectroscopy. (2) HST Treasury Program of early/mid M-dwarfs CR Dra and GJ 1243 with HST NUV spectroscopy, TESS optical photometry, and NICER X-ray spectroscopy. The initial results of campaigns have reported higher fraction of non-Neupert flares than solar flares (Tristan et al. 2023 ApJ), and hot temperature NUV emissions (Kowalski et al. 2024 ApJ in press). In this presentation, we introduce the ongoing summary results of these two campaigns, and discuss how bright and hot thermal emission of such flares can be linked to the time-evolution of non-thermal optical/NUV emission and chromospheric line profiles. This simultaneous X-ray information is very important to develop an unified model describing the flare heating mechanism producing the optical/NUV emission of high-energy stellar flares. We also discuss perspectives where investigations of solar flares (e.g., with SDO) can help the understanding of these stellar flares.

---

Thursday 10:30:00 AM-10:45:00 AM, Ballroom

## SDO constraints on the Babcock-Leighton dynamo processes

Robert Cameron

Max Planck Institute for Solar System Research

Flux emergence, obeying Joy's law, is a crucial component of the solar dynamo. It is the step by which poloidal flux first appears at the solar surface. The amount of poloidal field at the surface is crucial for understanding the subsequent generation of toroidal field in the Sun's interior. In this talk we will focus on constraints on these key processes, and in particular how combining SDO observations, simulations,

and theory illuminates them.

---

Thursday 10:45:00 AM-11:00:00 AM, Ballroom

## SDO/HMI Magnetogram Analysis to Derive Active Regions' Global and Local Dynamics Before, During and After Big Solar Storms

Mausumi Dikpati [1], Marianna Korsos [2], Aimee A. Norton [3], Breno Raphaldini [1], Andre S. W. Teruya [4], Kiran Jain [5], Scott W. McIntosh [6],
Nour Raouafi [7]

[1] High Altitude Observatory, NSF-NCAR, Boulder, Colorado, USA; [2] Sheffield University, Sheffield, UK; [3] Stanford University, California, USA; [4] Sao Paulo University, Sao Paulo, Brazil; [5] NSO, Colorado, USA; [6] Lynker Space, Colorado, USA; [7] JHU/APL, Maryland, USA

Active regions are observed to be predominantly stringed in tight-fit toroid patterns, which manifest as a combination of global modes with low longitudinal wavenumbers. By analyzing the active regions' (ARs) global patterns during cycle 23 Halloween storms, cycle 24 peak-phase storms as well as some of the storms during the late rising phase of cycle 25 storms, it has been shown that complex ARs, appearing at the locations in the North and/or South toroids that are locally "tipped-away" with respect to each other, are most-prone to erupting the form of CMEs or X-class flares. While this global pattern may be an indicator of upcoming big solar storms, study of local dynamics of active regions reveals that magnetic helicity exceeding a certain value can lead to big flare activity from those active regions. We will present the pre-storm features of local and global dynamics of several flare-prolific ARs during cycles 24 and 25 and show how the combined local and global dynamics could offer a few weeks of lead time to prepare for upcoming space weather hazards.

---

Thursday 11:00:00 AM-11:15:00 AM, Ballroom

## Towards a Robust Estimate of the Solar Photospheric Poynting Flux and Helicity Flux

Jiayi Liu [1], Xudong Sun [1], Peter W. Schuck, [2]

[1] Institute for Astronomy, University of Hawaii at Manoa, Hawaii USA; [2] Heliophysics Science Division, NASA Goddard Space Flight Center, Maryland USA

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

for the discrepancies. To address this, we propose two post-processing procedures for the DAVE4VMwDV output that can reduce the discrepancies. We discuss the desired future observations that can better constraint these methods, and the implications on data-driven simulations

---

Thursday 11:15:00 AM-11:30:00 AM, Ballroom

## Magnetic Helicity Signs in Filaments and Sigmoids and Active-Region Flaring Propensity

Aparna V. [1, 2], Manolis Georgoulis [3], Petrus Martens [4]

[1] LMSAL; [2] BAERI; [3] JHU/APL; [4] GSU

Sigmoids produce strong eruptive events. Earlier studies have shown that the ICME axial magnetic field Bz can be predicted with some credibility by observing the corresponding filament or the polarity inversion line in the region of eruption and deriving the magnetic field direction from that. Sigmoids are coronal structures often associated with filaments in the sigmoidal region. In this study, we compare filament chirality with sigmoid handedness to observe their correlation. Second, we perform nonlinear force-free approximations of the coronal magnetic connectivity using photospheric vector magnetograms underneath sigmoids to obtain a weighted-average value of the force-free parameter and to correlate it with filament chirality and the observed coronal sigmoid handedness. Importantly, we find that the sigmoids and their filament counterparts do not always have the same helicity signs. Production of eruptive events by regions that do not have the same signs of helicities is ~3.5 times higher than when they do. A case study of magnetic energy/ helicity evolution in NOAA AR 12473 will be presented.

---

Thursday 11:30:00 AM-11:45:00 AM, Ballroom

## Acoustic ringing around an  unbreakable sunspot rushing on the solar surface

Alina Donea [1], Suzana S. A. Silva [2], Matthew Lennard [2], Istvan Ballai [2], Gary Verth [2], Viktor Fedun [2]

[1] Monash University; [2] Plasma Dynamics Group, School of Electrical and Electronic Engineering, University of Sheffield

This study on the active region AR12135 explores the unique behavior of two fast-evolving sunspots, providing new insights into sunspot dynamics and the factors influencing their preservation and disintegration. Specifically, AR12135 exhibits a leading sunspot that moves unusually quickly across the solar surface without breaking apart, and a secondary sunspot that remains stationary but rapidly disintegrates within five days.

To uncover why AR12135 behaves differently from other active regions, the research focuses on detailed acoustic and magnetic mappings during its transit across the solar disk. The study examines the morphological and kinetic properties of the active region and, for the first time, demonstrates that flow barriers around sunspots can maintain the sunspot's shape and acoustic characteristics, even during rapid movement.

These findings are crucial for understanding the mechanisms behind flux emergence and the conditions that preserve or destabilize sunspots. The preservation of sunspot shape and acoustic properties by flow

barriers could represent a significant advancement in solar physics, offering a novel perspective on sunspot evolution and stability.

---

Thursday 10:30:00 AM-10:45:00 AM, Ballroom

## SuperSynthIA: Magnetograms from HMI, Hinode, and Machine Learning

David Fouhey [1], Ruoyu Wang [1], Richard Higgins [2], Spiro Antiochos [2], Graham Barnes [3], J. Todd Hoeksema [4], K.D. Leka [3], Yang Liu [4], Peter W. Schuck [5], Tamas I. Gombosi [2]

[1] Computer Science and Electrical Engineering, New York University, New York, USA; [2] University of Michigan; [3] NWRA; [4] Stanford; [5] NASA GSFC

Vector magnetograms of the Sun's photosphere are cornerstones for much of solar physics research. These data are often produced by data-analysis pipelines combining per-pixel Stokes polarization vector inversion with a disambiguation resolving an intrinsic 180° ambiguity. We introduce a learning-based method, SuperSynthIA, that produces full-disk vector magnetograms from Stokes vector observations. As input, SuperSynthIA uses Stokes polarization images [I,Q,U,V] from Solar Dynamics Observatory (SDO) Helioseismic and Magnetic Imager (HMI). As output, SuperSynthIA simultaneously emulates the inversion and disambiguation outputs from the Hinode/Solar Optical Telescope-Spectro-Polarimeter (SOT-SP) pipeline.

SuperSynthIA provides a new tool for improved magnetic fields from full-disk SDO/HMI observations using information derived from the enhanced capabilities of Hinode/SOT-SP. Compared to our previous method, SuperSynthIA provides physics-ready vector magnetograms and mitigates many unphysical artifacts. SuperSynthIA data show improved temporal consistency as well as a noise reduction in low-signal areas (resulting in less center-to-limb bias outside strong-signal areas). The data also track the long-term trends of the HMI-recorded evolution of the magnetic field.

In addition to showing results, we will discuss limitations, new analyses, as well as applications of the system to enhancing line-of-sight data (including historic data).

---

Thursday 10:45:00 AM-11:00:00 AM, Ballroom

## Instrumental Discrepancies in Lyman-alpha Observations of Solar Flares

Harry Greatorex [1], Ryan O. Milligan [1], Ingolf, E. Dammasch [2]

[1] School of Mathematics and Physics, Queen's University Belfast, Belfast, UK; [2] Solar Influences Data Analysis Center, Royal Observatory of Belgium, Brussels, Belgium

Advances in instrumental capabilities and a shift in focus over previous solar cycles mean it is now routinely possible to take regular co-observations of Lyman-alpha (LyÎ±; 1216 ËšA) emission in solar flares. Thus, it is valuable to investigate how different instruments may influence the analysis of flare observations. We compare LyÎ± measurements from three M-class flares observed by GOES-14/EUVS-E, GOES-15/EUVS-E, or GOES-16/EXIS-EUVS-B, alongside data from PROBA2/LYRA, MAVEN/EUVM, ASO-S/LST-SDI, and SDO/EVE-MEGS-P. While relative flux measurements showed minimal discrepancies, contrasts, excess fluxes, and energetics varied significantly, sometimes by a factor of five. These differences can affect multi-instrument studies of solar flare emission variability. This work provides guidance for analysing LyÎ± emission from both current and future instruments, including those

on Solar-C and GOES-R.

---

Thursday 11:00:00 AM-11:15:00 AM, Ballroom

## Revised Point-Spread Functions for SDO/AIA

Stefan Hofmeister, Michael Hahn, Daniel Wolf Savin

Columbia University

We present revised point-spread functions (PSFs) for AIA that account for long-distance diffuse scattered light. Using lunar occultation data, we accurately measured the PSF wings and tails. Our analysis reveals that diffuse scattered light contributes 10–35%, depending on the AIA channel, while the total amount of scattered and diffracted light reaches approximately 40–60%. These high levels of contamination reduce the dynamic range of AIA images and impact subsequent DEM analyses. For example, when correcting for these effects by a PSF deconvolution, bright regions like active regions appear up to 30% brighter, dark regions such as coronal holes appear up to 90% darker, and the DEM peak of flares increases by about 50%. We recommend that future instruments, particularly those observing the middle, off-limb corona, carefully account for long-distance scattered light during the design phase and aim to minimize it.

---

Thursday 11:15:00 AM-11:30:00 AM, Ballroom

## The Origins and Impacts of Scattered Light in EUV Images

Dan Seaton [1], Phillip C. Chamberlin [2], Stefan Hofmeister [3], Alan Hoskins [1], Andrew Jones [1], James P. Mason [4]

[1] Southwest Research Institute, Boulder, CO, USA; [2] Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, USA ; [3] Columbia University, New York, NY, USA; [4] Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA

Until fairly recently, scattered light was not a primary concern for designers of extreme ultraviolet imagers, but a series of recent reports have underscored the importance of understanding and managing this important noise source for a variety of EUV imaging applications. Scattered light originates from several sources: diffraction due to the wire mesh that supports thin foil filters, scattering from microroughness of multi-layer mirrors, and potentially even dust and internal reflections within instruments. Although scattered light generally does not significantly impact signal-to-noise ratio for EUV observations near the solar disk, such as from AIA, it can contaminate results when analyzing data, for example by introducing spurious temperature contributions into differential emission measure analyses. For off-disk observations, particularly of the middle corona between 1.5–6 Rsun, scattered light becomes even more important. Compared to faint EUV emission at larger heights, scattered light could appear to be a significant source of noise; but it can be effectively mitigated by instrument design and can be removed with dedicated deconvolution techniques.

Here we discuss the ways in which scattered light can originate in EUV images, how it can be modeled, and how it can be managed by specific instrument optimizations. We discuss how analysis of on-orbit data can be used to characterize scattered light and how it can be removed via deconvolution. We use two case studies – AIA and the planned SunCET wide field-of-view EUV imaging CubeSat – to highlight the importance of careful characterization and mitigation of scattered light contributions to EUV data.

Thursday 11:30:00 AM-11:45:00 AM, Ballroom

## Characterizing Emission in the Middle Corona with AIA During an EVE Cruciform Maneuver

Ritesh Patel, Dan Seaton, SwRI Boulder, CO, USA
Matt West, ESTEC, Noordwijk, Netherlands
Amir Caspi, SwRI Boulder, CO, USA
Cooper Downs, Predictive Science Inc. San Diego, CA, USA
James Mason, Johns Hopkins University APL, Laurel, MD, USA
Joe Plowman, SwRI Boulder, CO, USA

SwRI, Boulder

The Solar Dynamics Observatory (SDO) undergoes periodic cruciform maneuvers to calibrate the Extreme ultraviolet Variability Experiment (EVE). While making this maneuver, the Atmospheric Imaging Assembly (AIA) runs at a cadence of 12 s, scans up and down, then side to side, over six hours, as if drawing a massive plus sign in space. Using AIA data from such a maneuver on 2014-11-12, we generated a composite mosaic of the corona extending up to 6 Rsun, providing a unique characterization of EUV emission in the middle corona. The overlapping regions in successive off-points are useful to estimate instrumental scattered light and allow better estimation of the coronal emission. We plan to extend this analysis to multiple passbands of AIA over the solar cycle and improve our understanding of the variability of coronal emission over the course of time. We will also compare the measurements with overlapping observations from Solar Orbiter Full Sun Imager for the respective passbands.

---

Thursday 1:00:00 PM-1:15:00 PM, Ballroom

## Onset of Joy's Law as a Function of Latitude

Asha Lakshmi KIZHAKKEKUNNATHARA VENU, Hannah Schunker

School of Information and Physical Sciences, University of Newcastle, Australia

In some solar dynamo models the tilt of the polarity pair in magnetic active regions away from an east-west alignment (known as Joy's Law) is a critical component of the solar cycle. It is thought that the Coriolis force is responsible for Joy's Law, due to the average tilt angle being proportional to the sine of the latitude, but it is not clear what flows the Coriolis force is acting on to cause the tilt. On average, active regions emerge with an east-west orientation and Joy's Law sets in during the flux emergence process for which convective flows are also thought to be important. By studying a statistical sample of 123 active regions included in the Solar Dynamics Observatory Helioseismic Emerging Active Region (SDO/HEAR) survey, we tracked the location of each of the polarities in the line-of-sight magnetic field maps during emergence. We found that on average the active regions emerge east-west aligned independent of latitude and that the latitudinal dependence of Joy's Law is robust in the following polarity.

Thursday 1:15:00 PM-1:30:00 PM, Ballroom

## Magnetic flux evolution of active regions over more than one solar rotation

Hanna Strecker [1, 2], D. Orozco Suárez [1,2], G. Valori [3], A. Feller [3], J. Hirzberger [3], Blanco Rodríguez, J., [4, 2], D. Calchetti [3], del Toro Iniesta, J.C., [1, 2], Sami Solanki [3], Joachim Woch [3]

[1] Instituto de Astrofísica de Andalucía (IAA-CSIC); [2] Spanish Space Solar Physics Consortium, Granada, Spain; [3] Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany; [4] Universitat de València and Spanish Space Solar Physics Consortium, Valencia, Spain

For almost 15 years the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) has delivered continuous observations of the full solar disk providing information of the photospheric magnetic field. This has allowed tracking and analysing the evolution of active regions while they move across the solar disk as seen from Earth. However, the studies were restricted by the length of time over which the regions were visible from Earth which is often much shorter than the lifetimes of the regions. Attempts had been made to connect regions appearing at the east limb with regions which had rotated out two weeks earlier. Nevertheless, the full evolution and history of the magnetic field of the active regions while they pass over the solar far side remained unknown. The launch of Solar Orbiter with the Full Disk Telescope (FDT) of the Polarimetric and Helioseismic Imager (SO/PHI) changed that situation in 2020.

The unique, heliocentric and highly elliptical orbit of Solar Orbiter allows the spacecraft to spend around five months each year at a longitudinal separation angle of more than 130º from the Sun-Earth line. During these times the synoptics campaign run with the SO/PHI-FDT provides information about the magnetic field on the photospheric solar far side. The combination of these data with observations by SDO/HMI from the near-Earth side finally allows an almost uninterrupted study of the evolution of the magnetic field of active regions. Exploiting this novel possibility, we have followed active regions over several rotations and studied their characteristics, e.g., magnetic flux, almost uninterruptedly. In this contribution we present results for some of the active regions and show the special combination of data of the SDO/HMI and SO/PHI-FDT.

---

Thursday 1:30:00 PM-1:45:00 PM, Ballroom

## Advancing the capability of Advective Flux Transport (AFT) Model by incorporating HMI Far-Side Active Regions

Bibhuti Kumar Jha [1], Lisa Upton [1], Ruizhu Chen [2], Shea Hess Webber [2], K D Leka [3]

[1] SwRI, Boulder, CO; [2] Stanford University, Stanford, CA, USA; [3] NWRA, Boulder, CO, USA

The Advective Flux Transport (AFT) model, which uses data assimilation of the near-side, has been exceptionally successful in modelling the global solar magnetic field, as well as the evolution of Active Regions (ARs) over their lifetime. One of the pitfalls of the AFT model is that it can not predict the emergence of ARs in the farside, which impact models that rely on the global magnetic field for, e.g., calculating the global coronal and heliospheric magnetic field, the inferred structure of the heliospheric current sheet, and our knowledge of active regions appearing at the East solar limb, some of which may give rise to limb flares. These limb flares can have severe space weather impacts and significantly affect our satellites and communication systems. In this study, we address this limitation by incorporating far-

side unsigned magnetic flux maps derived from time distance helioseismic acoustic data. These maps are derived from the Doppler measurements of the Helioseismic and Magnetic Imager (HMI) and are transformed into magnetic representations through a machine learning algorithm. Despite their innovative approach, these generated acoustic maps present notable challenges, such as significant uncertainties and the potential for false AR detections. To mitigate these issues, our work introduces an automated detection and tracking algorithm for ARs on the far-side, allowing us to evaluate their accuracy. The algorithm assigns properties such as tilt and flux to the far-side ARs, using information from their near-side manifestations if they rotate into view at the eastern limb. Subsequently, these characterized ARs are integrated into the AFT model. We will discuss preliminary findings showing the effectiveness of incorporating far-side magnetic field data into the AFT model, an approach that could also be applied to other Surface Flux Transport (SFT) models.

---

Thursday 1:45:00 PM-2:00:00 PM, Ballroom

## Using SDO/HMI and SO/PHI data to study facular contrast from two vantage points

Kinga Albert, Johann Hirzberger, Natalie A. Krivova, X. Li , Sami K. Solanki, D. Calchetti, G. Valori, and the SO/PHI Team

Max Planck Institute for Solar System Research, Göttingen, Germany

Investigating the brightness of magnetic features as a function of their observation angle greatly benefits from full-disc imaging. Such studies are essential for understanding faculae, as these features — formed by relatively small concentrations of magnetic field — appear vastly different at varying observation angles.

The continuous full-disc observations of SDO/HMI provide a good opportunity for such studies. Taking a step further, we complement SHO/HMI data with a second point of view, provided by the Solar Orbiter spacecraft, to characterise facular continuum intensity contrast in relation to the associated magnetic flux density and the observation angle. Specifically, we use data from the Polarimetric and Helioseismic Imager instrument (SO/PHI) from a time when Solar Orbiter was close to quadrature with Earth. At this time SO/PHI observed features appearing at the limb in SDO/HMI, much closer to the disc centre from its second perspective.

This work builds on our previous study, where we used the Full Disk Telescope of SO/PHI, which we are now extending to observations by its High Resolution Telescope. We use the corresponding magnetic field measurements of facular features from disc centre provided by SO/PHI-HRT to overcome the observational limitations concerning the magnetic field at large viewing angles, close to the limb. This second vantage point allows a more accurate estimation of the magnetic field associated with the studied features. As a result, we derive facular contrast in relation to both the viewing angle and the associated magnetic field strength extending all the way to the extreme limb. This relationship is instrumental in modelling total solar irradiance, studying the structure and physics of small magnetic field concentrations, and constraining magnetohydrodynamic simulations.

---

Thursday 2:00:00 PM-2:15:00 PM, Ballroom

## The Open-source Flux Transport Model: Opening the Door to Surface Flux Transport Modeling

Lisa Upton [1], Ron Caplan [2], Raphel Attie [3], James Turtle [2], Bibhuti Jha [1], Jon Linker [2], Cooper Downs [2], Nick Arge [3], Shaela Jones [3], Carl Henney [4]

[1] Southwest Research Institute; [2] Predictive Science; [3] NASA GSFC; [4] AFRL / Space Force

Surface Flux Transport (SFT) models simulate the evolution of the magnetic field over the entire surface of the Sun. Available observations and current knowledge of the physical processes of the surface dynamics are used to produce maps of the magnetic flux distribution over the entire surface of the Sun. These maps fill in the gaps where observations are not available, such as the far-side of the Sun, and enable predictions of the future evolution, for instance for coronal structure during an eclipse or for the polar fields that will produce the next cycle. Typically, SFT models have only been available to the modelers that create them. Here, we introduce the Open-source Flux Transport (OFT) package, an open-source SFT modeling package that can be configured and run as needed by anyone in the community (e.g., see the abstract by Jon Linker et al.). OFT was specifically designed for parallel processing, allowing multiple realizations to be run quickly and efficiently. OFT includes three core components: MagMap for acquiring, processing, and remapping HMI magnetogram data, Conflow for generating time-evolving convective flow field, and HipFT for solving the induction equation for the photospheric magnetic field evolution. This presentation will provide an introduction to the OFT package and each of these three components.

---

Thursday 2:15:00 PM-2:30:00 PM, Ballroom

## A magnetic pressure difference rule on moving bipolar pores

Chia-Hsien Lin, Mendoza, M. Merlin

Department of Space Science and Engineering, National Central University, Taiwan

Solar pores are short-lived dark spots with concentrated magnetic fields on the photosphere. They resemble a sunspot umbra without a penumbra. Their appearance, disappearance and movement are closely related to the emergence, concentration, dissipation, and transportation of magnetic fields. Their movement has been found to be correlated with the magnetic pressure differences at their opposite ends. The objective of this work is to investigate possible reasons for this correlation. The results of analyzing 19 pairs of bipolar pores identified from Spaceweather HMI Active Region Patches (SHARP) indicate that (1) the signs of the differences between the magnetic pressures at the front and back sides of the pores in a same pair are opposite; and (2) the directions of the maximum positive difference between the magnetic pressures at the opposite ends for the pores in a same pair are both pointing toward either left or right and toward higher latitudes. The results indicate that the solar global magnetic fields play a non-negligible role in the properties and dynamics of bipolar pores.

---

Thursday 1:00:00 PM-1:15:00 PM, Ballroom

## The CubeSat Imaging X-ray Solar Spectrometer (CubIXSS): a new 16U mission to understand heating of coronal plasma in solar flares and active regions

Amir Caspi [1], P.S. Athiray [2], Will Barnes [3,4], Mark Cheung [5], Sherry Chhabra [6], Craig DeForest [1], Szymon Gburek [7], Mary Hanson [1], J. Marcus Hughes [1], Viliam Klein [1], James Klimchuk [4], Mirosław Kowaliński [7], Derek Lamb [1], Glenn Laurent [1], James P. Mason [8], Biswajit Mondal [9], Tomasz Mrozek [7], Scott Palo [10], Jacob Parker [4], Bennet Schwab [10], Mark Schattenburg [11], Daniel Ścisłowski [7], Daniel B. Seaton [1], Albert Y. Shih [4], Marek Stęślicki [7], Janusz Sylwester [7], Harry Warren [6], Thomas Woods [10], and the CubIXSS Team

[1] Southwest Research Institute, Boulder, CO; [2] Univ. of Alabama, Huntsville, AL; [3] American Univ., Washington, DC; [4] NASA Goddard Space Flight Center, Greenbelt, MD; [5] CSIRO, Marsfield, Australia; [6] Naval Research Lab., Washington, DC; [7] PAN/CBK, Wrocław, Poland; [8] Johns Hopkins Univ. / Applied Physics Laboratory, Laurel, MD; [9] NASA Marshall Space Flight Center, Huntsville, AL; [10] Univ. of Colorado Boulder, Boulder, CO; [11] MIT Lincoln Labs, Cambridge, MA

The CubeSat Imaging X-ray Solar Spectrometer (CubIXSS) is a 16U CubeSat funded under NASA H-FORT to address a compelling overarching science question: what are the origins of hot plasma in solar flares & active regions? CubIXSS will make sensitive, precise measurements of abundances of key trace ion species – a unique diagnostic of how mass & energy flow into & within the corona, whose spectral signatures thus reveal the chromospheric or coronal origins of heated plasma at temperatures of ~1 to >30 MK.

CubIXSS comprises two co-optimized & cross-calibrated instruments that fill a critical observational gap: * MOXSI, a novel diffractive spectral imager using a pinhole camera & X-ray transmission diffraction grating for spectroscopy of flares & active regions over an unprecedented spectral range of 1 to >70 Å; and * SASS, a suite of four spatially-integrated off-the-shelf spectrometers for high-cadence, high-sensitivity X-ray spectra of lines & continuum from 0.5 to >30 keV. CubIXSS is currently in Phase C/D (implementation) & will launch in late 2025 to observe intense solar flares & active regions during the peak of solar cycle 25. Its 1-year prime mission is well timed with the extended mission of SDO, with perihelia of Parker Solar Probe and Solar Orbiter, & with the launches of complementary missions such as SunCET, PADRE, & PUNCH. CubIXSS is a pathfinder for the next generation of Explorer-class missions with improved capabilities for SXR imaging spectroscopy. We present the CubIXSS motivating science background, its suite of instruments & expected performances, and current updates on implementation status & projected outlook for the mission, as well as additional planned developments including novel analysis techniques to fully exploit the rich data set of CubIXSS spectral observations.

---

Thursday 1:15:00 PM-1:30:00 PM, Ballroom

## Beyond AIA: The EUV CME and Coronal Connectivity Observatory (ECCCO)

Kathy Reeves [1], Katharine Reeves [1], Daniel Seaton [2], P. S. Athiray [3], Peter Cheimets [1], Craig E. DeForest [2], Edward DeLuca [1], Giulio Del Zanna [4], Cooper Downs [5], Leon Golub [1], Nishu Karna [1], Wei Liu [6], Chad Allen Madsen [1], Christopher Samuel Moore [1], Yeimy Rivera [1], Joseph Plowman [2], Jenna Samra [1], Paola Testa [1], Matthew John West2 and Amy R Winebarger [7]

[1] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States; [2] Southwest Research Institute, Boulder, CO, United States; [3] University of Alabama in Huntsville, Huntsville, AL, United States; [4] University of Cambridge, DAMTP, Cambridge, United Kingdom; [5] Predictive Science Inc., San Diego, CA, United States; [6] Lockheed Martin Solar and Astrophysics Lab, Palo Alto, United States; [7] NASA Marshall Space Flight Center, Huntsville, AL, United States

The Atmospheric Imaging Assembly on SDO has been a breakthrough instrument for studying the solar corona in great detail. Using heritage from the AIA telescopes, the EUV CME and Coronal Connectivity Observatory will take EUV observations to the next level, providing for the first time dedicated, global spectral and imaging measurements of the Middle Corona (1.5–3 Rs), a previously underexplored part of the solar atmosphere that links the flow-dominated outer corona with the complex magnetic environment of the inner corona. ECCCO's science objectives will uncover the slow-evolving connections between the low coronal magnetic structures and the outflow that gives rise to the solar wind, and they will characterize the birth, evolution, and effects of solar eruptions that disrupt the Sun-Earth system and dominate space weather. Three Science Enhancement Options extend ECCCO's impact by leveraging complementary observations from the Heliophysics System Observatory: developing comprehensive EUV spectroscopy with MUSE & EUVST, producing multi-viewpoint 3D reconstructions of the corona, and providing gap-closing low-latency observations for space weather forecasts. The groundbreaking science enabled by this instrument, together with a proven spacecraft and an experienced team, create a low-cost, low-risk mission that will address multiple Heliophysics Decadal Priority Science Goals.

---

Thursday 1:30:00 PM-1:45:00 PM, Ballroom

## New Secondary Science Instrument on Rocket EVE

Bennet Schwab, Thomas, N. Woods, Robert Sewell, Anant Telikicherla, Dave Crotser
CU/LASP, Boulder, CO, USA

The SDO EVE sounding rocket program provides underflight calibration measurements for the on-orbit SDO EVE satellite instruments. Additionally, the EVE sounding rocket enables the development and flight of secondary science instruments to piggyback alongside the primary payload. One new instrument is currently being designed and built to be flown on the next rocket launch in July 2025. This instrument will utilize a grating and six pinholes that will direct the Sun's light onto a CMOS detector. The result will be six Soft X-Ray (SXR) images of the sun at three different bandpasses on the top half of the detector, and many spectral lines in the ExtremeUltra Violet (EUV) on the bottom half of the detector. Each pixel on the detector will be able to derive two temperatures and two emission measures, resulting in a temperature and emission measure map of pixels across the solar disc. The EUV spectra will be taken alongside an SXR spectrometer and the data from both EUV and SXR regimes can then be compared with one another.

---

Thursday 1:45:00 PM-2:00:00 PM, Ballroom

## Near-continuous monitoring of active region nests using the current fleet of heliospheric observers

Adam Finley, Sacha Brun, Antoine Strugarek
CEA Paris-Saclay

Active region nests -- areas on the Sun with recurring flux emergence -- are often attributed to non-axisymmetries in the generation and storage of the Sun's dynamo magnetic field. Understanding their behaviour is vital for reliable space weather forecasting as they create complex structures in the coronal

magnetic field that can trigger some of the largest solar eruptions. Active region nests have also been observed on other Sun-like stars, hinting that their formation might be universal for dynamo-driven magnetic fields. However, our ability to study the long-term evolution and flare occurrence rates of solar active regions is limited by their visibility from Earth alone. Now with ESA's Solar Orbiter, observations are periodically available for the Sun's far-side (akin to the STEREO-AB era), facilitating coordinated studies of active regions that span several solar rotations. We present joint-observations of long-lived active region nests, persisting for several solar rotations, that were identified during the rising phase of sunspot cycle 25. We evaluate the contribution of these active region nests to the Sun's global flaring activity, as well as the influence they have on the coronal magnetic field above. In future, short to medium-term space weather forecasting will benefit from the improved identification and monitoring of active region nests.

---

Thursday 2:00:00 PM-2:15:00 PM, Ballroom

## The SOSPIM Radiometer, onboard the future Solar C mission from JAXA

Marie Dominique [1], Krzysztof Barczynski [2], Hirohisa Hara [3], Louise K Harra [2], Shinsuke Imada [4], Nils Janitzek [2], Andri Morandi [2], Toshifumi Shimizu [5], Kyoko Watanabe [6], Dana Talpeanu [1]

[1] Royal Observatory of Belgium/STCE; [2] Physikalisch-Meteorologische Observatorium Davos/World Radiation Center, Davos, Switzerland; [3] NAOJ, Tokyo, Japan; [4] Nagoya University, Nagoya, Japan; [5] JAXA Japan Aerospace Exploration Agency, Sagamihara, Japan; [6] National Defense Academy of Japan, Yokosuka, Japan

The Spectral Solar Irradiance Monitor (SOSPIM) is one of the two instruments of the JAXA SOLAR-C mission, scheduled for launch in 2028. SOSPIM is designed to complement the measurements of the EUVST spectrograph by observing the full-disk integrated chromosphere and corona at high cadence in the Lyman-alpha and EUV spectral ranges. This presentation introduces the instrument and outlines its primary scientific objectives, which closely align with the research themes explored by SDO/EVE. Opportunities for follow-up and collaborative studies are also discussed.

---

Thursday 2:15:00 PM-2:30:00 PM, Ballroom

## Next-Generation Solar Observations: Advancing Space Weather Research from the Solar Surface through the Middle Corona

Matthew West [1], Daniel Seaton [2]

[1] European Space Agency; [2] Southwest Research Institute

Understanding the origins of space weather, from the solar surface through the middle corona, is critical for advancing forecasting capabilities and research. This region defines model boundary conditions, offering early indicators of solar activity that can lead to space weather events. The middle corona, in particular, is a key yet under-explored region, linking the dynamic processes of the inner corona to the heliosphere. It encompasses the critical physical transitions and processes that govern the evolution of solar wind, eruptions, and flows, while modulating inflows from above that influence the inner corona.

Additionally, it is a site of high-energy particle generation and plays a pivotal role in shaping heliospheric conditions.

This presentation highlights the next generation of solar observational instruments designed to address these challenges, including several key instruments on the Vigil mission, alongside observations from the next generation of L1-oriented inner and middle corona observing instruments, such as ECCCO and SUNCET. Vigil's unique vantage point, off the Sun-Earth line, provides unparalleled opportunities for the early detection of solar activity, complementing Earth-directed observations. By integrating L5 and L1 observations, we can significantly refine space weather science, models and forecasting accuracy.

---

Thursday 4:00:00 PM-4:30:00 PM, Ballroom

## The active region magnetic field at different vantage points: an analysis with SO/PHI-HRT and SDO/HMI (Metcalf Travel Award)

Jonas Sinjan [1], Johann Hirzberger [1], Daniele Calchetti [1], Sami K. Solanki [1], Gherardo Valori [1], Xiaohong Li [1], David Orozco Suárez [2], Hanna Strecker [2], Julian Blanco Rodríguez [3]

[1] Max Planck Institute for Solar System Research, Göttingen Germany; [2] Instituto de Astrofísica de Andalucía, Granada Spain; [3] Universitat de València, Valencia Spain

The open flux problem is currently an unsolved mystery, representing a 2-3 factor mismatch between the open flux measured at 1 AU and that via remote sensing of the solar atmosphere and extrapolated to 1 AU. One explanation is that the open flux at the photosphere is underestimated, in particular in the polar regions. Until now it was impossible to test this with observations: the Polarimetric and Helioseismic Imager (PHI) on board Solar Orbiter has made this a reality such that in combination with Earth-based assets, such as SDO/HMI, stereoscopy can be employed.
First the impact of the viewing angle on the inferred magnetic field, open or closed, can be evaluated. From 12 - 17th October 2023 Solar Orbiter observed an active region (NOAA 13465), separated from Earth by an angle of 60-80 degrees, which was just visible inside the East limb as seen by Earth at the start of the campaign. This dataset provides a broad range of different viewing angles ($\mu=\cos(\theta)$) between SO/PHI-HRT and SDO/HMI, such that the $\mu$-correction (which assumes the field to be radial) can be directly tested with observations for the first time. A comparison will be shown of the evolution and magnitude of the magnetic field inferred by SO/PHI-HRT with that from SDO/HMI at these different vantage points.

---

Thursday 4:30:00 PM-4:45:00 PM, Ballroom

## Magnetic Structure of Coronal Dark Halos

Jonathan Noelke, Sami Solanki, Johann Hirzberger, Hardi Peter, Pradeep Chitta

Max Planck Institute for Solar System Research, Göttingen Germany

At low coronal temperatures around 1 MK, distinct regions exhibit emission levels significantly below those of the quiet Sun. A prominent example are dark halos surrounding active regions, which are sometimes misidentified as coronal holes. Although several models have been proposed, the mechanism

responsible for the formation of dark halos remains unclear.
On 5 November 2021, Solar Orbiter and SDO observed several dark halo patches surrounding an active region. One of these patches overlaps with an adjacent coronal hole, providing a unique opportunity to directly compare the two phenomena.
The dark halo patches exhibit slightly reduced mean unsigned magnetic fields compared to the quiet Sun. However, the difference in magnetic field strength between the inner and outer boundaries of the dark halo patches is more pronounced. At the outer boundary, the unsigned magnetic field decreases by approximately 25%, making it 10%–20% weaker than the surrounding area.
SDO/AIA observations enabled us to analyse emission across different coronal temperatures. In the cooler 171˚A channel, the emission within the dark halos is reduced and relatively homogeneous. In contrast, hotter channels (≥ 1.6 MK) reveal enhanced emission and a strong gradient away from the active region.
At these higher temperatures, the coronal hole appears distinctly as dips in emission. Using a PFSS model, we further demonstrated that the dark halo patches are magnetically closed, whereas the coronal hole within the structure is characterised by open magnetic field lines.
Our combined EUV and magnetic field observations suggest that dark halos result from reduced heating, while the hotter corona above the dark halos connects to the large-scale magnetic field of the active region.

---

Thursday 4:45:00 PM-5:00:00 PM, Ballroom

## Coronal Bright Points statistics from SDO images and preparation for 3D MHD model to be compared with Hinode-EIS data

Isabella Kraus, Philippe, A. Bourdin
Institute of Physics, University of Graz, Austria

Understanding the precise mechanism behind coronal heating remains a fundamental challenge in solar physics. Above small-scale bipolar regions we observe Coronal Bright Points (CBPs) in extreme-UV emission from the coronal plasma in the SDO-AIA 171 channel. Our statistical study comprises 346 CBPs using a continuous dataset of Solar Dynamics Observatory (SDO) observations. We track the CBP lifetimes, shapes, polarities, merging behavior, flux emergence, magnetic evolution. Most CBPs show mixed polarities with magnetic flux cancellation. The brightest CBPs typically exhibit bipolar fields with loop-like shapes and longer lifetimes, while weaker polarities produce fainter CBPs. Typical CBPs have lifetimes exceeding 6 hours, supporting the hypothesis that CBP heating primarily occurs through magnetic-energy dissipation, e.g. through relatively steady and gradual reconnection. As a next step we select a typical CBP for a 3D MHD simulation run using the Pencil Code. To this end, we combine magnetograms from SDO and Hinode with different FOV. For consistency, photospheric magnetic fields require a similar resolution and therefore we develop an overlaying technique that combines the higher resolution within the Hinode FOV with the larger network visible in SDO-HMI data. Finally, we may compare the MHD simulation result with Hinode-EIS data in the Fe-XII line. This allows us to improve our understanding of the heating and magnetic configuration that forms a CBP. We may track the coronal plasma dynamics and compare with observed Doppler-shifts maps, which allows us to verify our simulation result.

# Posters Displayed on Monday and Tuesday

Please remember to put up your poster before the meeting begins and to remove it before 5:00 pm MT on Tuesday. Posters are assigned a number in the Abstract Book. Please hang your poster on the poster board with that number.

Monday and Tuesday Poster #1

## Finding Global Eigenmodes using Spectral Methods: Magneto-inertial Waves and the MRI

Kyle Augustson

Southwest Research Institute, Boulder, USA

The Sun hosts myriad modes of waves and instabilities, creating order in its observed cacophony. Arising from nonlinear excitation, these modes exhibit the relative influence of various restoring forces when filtered over a range of time scales. Here we explore how to numerically extract the 2D global structure of eigenmodes from a variety of wave equations with radial and latitudinal coupling using sparse spectral methods and self-correcting Arnoldi eigensolvers.

---

Monday and Tuesday Poster #2

## Comparing NSSL Flows Inferred from Ring-diagram Analyses of GONG and HMI

Richard Bogart [1], Charles S. Baldner [1], Sarbani Basu [2], Rachel Howe [3], Kiran Jain (4]; Maria Cristina Rabello Soares [1], Sushant Tripathy [4]

[1] Stanford University, USA; [2] Yale University, USA; [3] University of Birmingham, UK; [4] National Solar Observatory, USA

Both GONG and HMI have been concurrently gathering data and running ring-diagram analysis pipelines since May 2010, with additional GONG data extending back to summer 2001 and overlapping with MDI. The ring-diagram pipelines produce comparable estimates of subsurface flow velocities in approximately coaligned regions sampled over nearly identical time periods 24 times per Carrington rotation. In order to identify and understand systematic differences between the inferred flows, we have undertaken a program of comparing results when data from each source are independently processed through each program's pipeline. Interruption of the functioning of the JSOC has interfered with the delivery of HMI data to the GONG pipeline and the processing of GONG data by the HMI pipeline. Nevertheless we are able to present some preliminary initial results, while describing in detail the differences in the analysis pipelines and their effects on the final products, along with the plans for the full comparison.

---

Monday and Tuesday Poster #3

## Bayesian modeling of the averaged supergranule from HMI observations

Doug Braun [1], A. Herczeg [2], J. Jackiewicz [2]

[1] NorthWest Research Associates, Boulder, USA; [2] New Mexico State University, USA

We employ Bayesian modeling methods to infer the subsurface flows of the "averaged" supergranule. A comprehensive set of travel-time difference measurements, obtained using helioseismic holography and applied to a 32-day timeseries of HMI/SDO Dopplergrams, were performed and averaged over an ensemble of more than 60,000 supergranules. A Bayesian approach to the modeling is carried out by forward modeling hundreds of thousands of potential flow profiles and compiling a complete probability distribution function of the model parameters. We tentatively find that supergranular flows extend down to approximately 8 Mm below the photosphere, reaching peak horizontal speeds of about 350 m/s at a depth of around 3 Mm, and vertical speeds of 250 m/s at a depth of 5 Mm. Comparisons with other recent supergranular inferences are presented.

This work is supported by the NASA HGI program (grant 80NSSC22K0754) and in part by the COFFIES DSC Cooperative Agreement 80NSSC22M0162.

---

Monday and Tuesday Poster #4

## Holography Measurements with Large-box Active Region Simulations

Doug Braun [1], M. Rempel [2]

[1] NorthWest Research Associates, Boulder, USA; [2] High Altitude Observatory/NCAR, Boulder, USA

Using publicly available active-region (AR) scale simulations developed for helioseismic modeling, we show sample validation measurements of surface and subsurface flows obtained with helioseismic holography. The simulations are derived using HMI magnetograms of actual large ARs (specifically ARs 11944 and 12187) and fill the domain through upward and downward extrapolations. Multiple simulations exist of each AR with and without forcing terms designed to produce target flows resembling active-region inflows as well as a subsurface shear flow resembling the near-surface shear layer. Using holography, we compare the agreement between measurements of the flows present in the simulations with expectations from the known flows. Deviations between measurements and expectations from the Born approximation, using sensitivity functions convolved with the true flows, are mapped over the domain. These show the presence of magnetic artifacts which are spatially correlated with surface flux but extend a few tens of Mm below the largest sunspots.

The data are publicly available through the globus.org portal for general use. Support from NASA was provided under the Living With a Star program (grant 80NSSC18K0066), the Heliophysics Guest Investigator program (grant 80NSSC22K0754) and by the COFFIES DSC (grant 80NSSC22M0162).

---

Monday and Tuesday Poster #5

## Helioseismic signature of fragmentation of magnetic flux beneath sunspot photosphere?

Elena Broock [1], Alina Donea [2], Angel Martinez Cifuentes [2], Charles Lindsey [3]

[1] Instituto de Astrofisica de Canarias, Spain; [2] Monash University, Australia; [3] NorthWest Research Associates, Boulder, USA

A crucial element of the stability of sunspots was the apparent need for the umbral magnetic flux, monolithically dense in the photosphere, to separate into thin magnetic strands a few hundred km beneath

its photosphere (Eugene Parker, 1979). The submerged medium separating the magnetic strands bears a crucial relationship to umbral dots, which admit most of the thermal energy flux that penetrates into the umbral photosphere. Subjacent-vantage phase-correlation acoustic holography by Brooke et al. (2025) shows signatures of "strong acoustic scatterers" in the extreme outer convection zone beneath the sunspot photosphere. They propose that these features are a signature of Parker's proposed fragmentation of the magnetic flux in the shallow sunspot sub photosphere. An understanding of the implications of these helioseismic signatures could help us penetrate a diverse array of outstanding fundamental problems in sunspot structure and dynamics. It may lead us, for example, to a recognition of the reservoir into which the convective flux blocked by inhibited convection is diverted by a sunspot during its sometimes weeks-long life cycle.

---

Monday and Tuesday Poster #6

## Possible Role of Strong Acoustic Scatterers in Disposing of Radiative Flux Blocked by Sunspots

Elena Broock [1], Alina Donea [2], Angel Martinez Cifuentes [2], Charles Lindsey [3]

[1] Instituto de Astrofisica de Canarias, Spain; [2] Monash University, Australia; [3] NorthWest Research Associates, Boulder, USA

Phase-correlation helioseismic holography of large sunspot in the 2.5--4.5-mHz p-mode spectrum, by Broock, Donea, Martinez & Lindsey show a signature that could be explained by fragmentation of magnetic flux into thin strands within the top few hundred km of sunspot subphotospheres. If so, this reinforces a hypothesis by Parker that such a fragmentation of magnetic flux in this layer is crucial to sunspot stability. The thermal structure of the medium separating the magnetic strands would become overstable to vertical oscillations that would momentarily penetrate the overlying magnetic monolith manifesting bright, transient umbral dots, known to be the primary source of the heavily diminished thermal flux that penetrates into the sunspot photosphere. Parker suggested, at length, that the remainder of the blocked flux was sequestered into oscillatory waves. In the case of downwardly propagating Alfven or slow-mode waves would disappear from the global solar radiative flux and would be invisible in the p-mode spectrum. How this energy eventually is disposed of sometime after the magnetic flux had been ejected, is among the open questions. We ask whether, alternatively, the overstable oscillations in question could inject the blocked energy flux into the solar interior in the for of p-modes in the 0.1--1.0-mHz spectrum. Such waves that would inhabit the solar interior for days while their photospheric signatures, distributed over a relative continuum, would be practically invisible to familiar helioseismic diagnostics. Could "strong acoustic scatterers" of p-modes in the helioseismic signatures, discovered by Broock et al. (2023), be a local manifestation of these hypothetical low-frequency acoustic emitters? The lower limit of the foregoing spectrum is in line with the approximate lifetime of the "strong acoustic scatterers" we have sampled to date.

---

Monday and Tuesday Poster #7

## The Solar Internal Rotation Project I: Data sets

Rafael A. García [1], S. Basu [2], S.N. Breton [3], A.M. Broomhall [4], Jørgen Christensen-Dalsgaard [5] P. Dey [6], A. Eff-Darwich [7,8], P. Dey [9], R. Howe [9], K. Jain [10], S. Korzennik [11], A. Kosovichev [12], T. P. Larson [13], K. Mandal [12], S. Mathur [5,6], D. Salabert [14], J. Schou [7], S.C. Tripathy [10], R.K. Ulrich [15], S.V. Vorontsov [16, 17] and the Solar Internal Rotation Team

[1] Universite Paris-Saclay, Université Paris Cité, CEA, CNRS, AIM, 91191, Gif-sur-Yvette, France, [2] Dept. of Astronomy, Yale University, USA; [3] INAF – Osservatorio Astrofisico di Catania, Italy; [4] Centre for Fusion, Space and Astrophysics, Physics Department, University of Warwick, UK; [5] Department of Physics and Astronomy, Aarhus University, Denmark; [6] Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany; [7] Universidad de La Laguna (ULL), Departamento de Astrofísica, Tenerife, Spain; [8] Instituto de Astrofísica de Canarias (IAC), Tenerife, Spain; [9] School of Physics and Astronomy, University of Birmingham, UK; [10] National Solar Observatory, Boulder, USA; [11] Center for Astrophysics, Harvard & Smithsonian, Cambridge, USA; [12] New Jersey Institute of Technology, USA; [13] Formerly at Stanford University, Stanford, USA; [14] Universitée Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, France; [15] Dept. of Phys. and Astro., University of California, Los Angeles, USA; [16] Astronomy Unit, School of Physical and Chemical Sciences, Queen Mary University, London, UK; [17] Institute of Physics of the Earth, Moscow, Russia

Helioseismology is a powerful tool to probe the internal structure and dynamics of the Sun. However, it requires long uninterrupted datasets to extract the rotational splittings with the highest precision. Two types of facilities were developed. On the one hand, ground-based telescopes such as the Birmingham Solar Oscillation Network (BiSON) and the Global Oscillation Network Group (GONG). On the other hand, the space-based instruments such as Global Oscillations at Low Frequency (GOLF) and Solar Oscillation Imager/Michelson Doppler Imager (SOI/MDI) on board the Solar and Heliospheric Observatory (SoHO), and the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO). In this work, we present the different datasets obtained, the methods used to extract the rotational splittings, and we study how to create a combined dataset of low- and medium-degree modes for inferring the solar rotation from the core to the surface.

---

Monday and Tuesday Poster #8

## The Solar Internal Rotation Project II. Analysis of Inversion Techniques.

Jørgen Christensen-Dalsgaard [1], S. Basu [2], S. N. Breton [3]. A. M. Broomhall [4 ], P. Dey [5], A. Eff-Darwich [6,7] , R. A. García [8], R. Howe [9], K. Jain [10], S. Korzennik [11], A. Kosovichev [12], T. P. Larson [13], K. Mandal [12] , S. Mathur [6,7], D. Salabert [14], J. Schou [5], S. C. Tripathy [10], R. K. Ulrich [15], S. V. Vorontsov [16,17] and the Solar Internal Rotation Team

[1] Department of Physics and Astronomy, Aarhus University, Denmark; [2] Dept. of Astronomy, Yale University, USA; [3] INAF – Osservatorio Astrofisico di Catania, Italy; [4] Centre for Fusion, Space and Astrophysics, Physics Department, University of Warwick, UK; [5] Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany; [6] Universidad de La Laguna (ULL), Departamento de Astrofísica, Tenerife, Spain; [7] Instituto de Astrofísica de Canarias (IAC), Tenerife, Spain; [8] Universite Paris-Saclay, Université Paris Cité, CEA, CNRS, Gif-sur-Yvette, France, [9] School of Physics and Astronomy, University of Birmingham, UK; [10] National Solar Observatory, Boulder, USA; [11] Center for Astrophysics, Harvard & Smithsonian, Cambridge, USA; [12] New Jersey Institute of

Technology, USA; [13] Formerly at Stanford University, Stanford,  USA; [14] Universitée Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, France; [15] Dept. of Phys. and Astro., University of California, Los Angeles, USA; [16] Astronomy Unit, School of Physical and Chemical Sciences, Queen Mary University, London, UK; [17] Institute of Physics of the Earth, Moscow, Russia

Many techniques have been developed to analyse observations of solar rotational splittings to infer properties of the solar internal rotation rate. In preparation for the analysis of the extensive sets of data now available, we carry out tests and comparisons of a variety of inversion techniques, characterized by their resolution and error properties. Our ability to infer specific features in solar rotation is investigated through analysis of artificial data based on prescribed internal solar rotation rates.

---

Monday and Tuesday Poster #9

## Exploring the Role of Density Stratification and Convective Rossby Number on Convective Length-scale and Amplitude

Nick Featherstone [1], Catherine Blume [2] , Maria Camisassa [3], Rafael Fuentes [2], Bradley Hindman [2],  Lydia Korre [2], Loren Matilsky [4]

[1] Department of Solar and Heliospheric Physics, Southwest Research Institute, Boulder, USA; [2] University of Colorado, Boulder, USA; [3]  Universitat Politecnica de Catalunya, Spain; [4] University of California, Santa Cruz, USA

Models of the solar convection zone that are at once turbulent and differentially rotating in a manner analogous to the Sun have been surprisingly difficult to construct. The typical state of differential rotation achieved is one in which rapidly-rotating poles are accompanied by a slowly-rotating equator. This situation, sometimes referred to as the convective conundrum, arises naturally from the nonphysical link between model diffusivities and the thermal content of down-flowing plumes. We present results from a new survey of 3-D simulations designed to disentangle these two aspects of the convection, allowing solar-like differential rotation to be reliably achieved even in regimes of extreme turbulence. In particular, we describe how the properties of mean flows and convective structure vary with respect to a singular control parameter, the convective Rossby number, in systems characterized by high degrees of turbulence and density stratification.

---

Monday and Tuesday Poster #10

## Overview of MPS results on solar inertial modes

Laurent Gizon, MPS Team

Max Planck Institute for Solar System Research, Göttingen, Germany

This poster presents an overview of the observational and theoretical techniques developed by the MPS team to study global solar oscillations in the inertial frequency range. Mode properties are measured using horizontal flow maps constructed with multiple methods, including p-mode helioseismology and correlation tracking of granulation and magnetic features. Some inertial modes are directly visible in Dopplergrams from SDO/HMI, GONG, and Mount Wilson, spanning five solar cycles.
Modeling efforts include linear eigenvalue solvers to classify modes (e.g., Rossby modes, high-latitude

modes) and assess their sensitivity to differential rotation, entropy gradients, superadiabaticity, and viscosity. Semi-analytic models explore mode excitation by turbulent convection, while nonlinear simulations in 2D and 3D reveal the evolution of unstable modes, their saturation mechanisms, and type of bifurcation.
By combining diverse observational techniques with modeling tools, we highlight the diagnostic power of inertial modes and their importance in advancing our understanding of solar convection and rotation.

---

Monday and Tuesday Poster #11

## Using the Morphology and Temporal Evolution of the Sun's High-Latitude Convection as a Probe of its Dynamo State

Bradley Hindman [1], Catherine Blume [1], Maria Camisassa [2], Nicholas Featherstone [3], Rafael Fuentes [1], Lydia Korre[1], Bhishek Manek [1], Loren Matilsky [4]

[1] University of Colorado Boulder, USA; [2] Polytechnic University of Catalonia in Barcelona, Spain; [3] Southwest Research Institute, Boulder, USA; [4] University of California, Santa Cruz, USA

We present the morphology, evolution, and large-scale motion of the convection cells that are likely to manifest in the Sun's polar regions and thus be observable by a future polar overflight mission. Numerical simulations of the Sun's convection zone reveal that the large-scale convection at high-latitudes can take on the form of either an ordered lattice of anticyclonic cells or a more disorganized and evolving network of cyclonic plumes. Which form prevails depends on the Rossby number of the convective motions. This suggests that the morphology, size, and handedness of the primary large-scale convective structures could be used as a diagnostic of the Rossby number of the Sun's deep convection, and subsequently help ascertain the dynamical regime and dynamo in which the Sun is operating. Through a suite of simulations spanning a significant range of Rossby number, we explore how the size, shape, motion, handedness, and lifetime of the convective vortices change as a function of latitude and Rossby number.

---

Monday and Tuesday Poster #12

## Far-side helioseismology with global mode frequencies from Sun-as-a-star and resolved observations

Rachel Howe [1], Sushant Tripathy [2], W. J. Chaplin [1], Y. Elsworth [1], S. J. Hale [1], M. Nielsen [1]

[1] School of Physics and Astronomy, University of Birmingham, UK; [2] National Solar Observatory, Boulder, USA

The frequencies of helioseismic modes vary with activity at a wide range of spatial and temporal scales. For global modes, we would expect the frequencies to be sensitive to activity at all longitudes, not just the visible ones, while most activity proxies include only activity on the Earth-facing side of the Sun. We present results from fitting p-mode spectra derived from 7-d segments of Sun-as-a-star helioseismic observations from the Birmingham Solar Oscillations Network covering 32 yr, and from 9-d segments of

resolved-Sun observations from the Global Oscillations Network Group (GONG) covering 29 yr. The results show a clear dependence of the mode frequencies on solar activity, and the frequency dependence of the sensitivity to activity can also be seen. Because we use data segments that cover less than half of a solar rotation, we are able to test for the effect of activity on the solar far side. By fitting with a model that takes into account activity on the far side of the Sun, we show that the frequency shifts are indeed sensitive to activity from the whole Sun, not just the side facing the observer. We hope to extend this analysis to data from HMI and MDI when they become available.

---

Monday and Tuesday Poster #13

## What Have We Learned from Sun's Acoustic Mode Frequencies over Three Decades?

Kiran Jain [1], Sushant Tripathy [1], Partha Chowdhury [2], Mausumi Dikpati [3], Rafael A. Garcia [4], Rachel Howe [5], Sylvain Brenton [6], W. J. Chaplin [5], Yvonne Elsworth [5], Steven J. Hale [5], Martin B. Nielsen [5], Eva Panetier [7]

[1] National Solar Observatory, Boulder USA; [2] University of Calcutta, Kolkata, India; [3] NCAR/High Altitude Observatory, Boulder, USA; [4] Université Paris-Saclay, Université Paris Cité, CEA, CNRS, Gif-sur-Yvette, France; [5] School of Physics and Astronomy, University of Birmingham, UK; [6] INAF – Osservatorio Astrofisico di Catania, Italy; [7] Université Paris Cité, Université Paris-Saclay, CEA, CNRS, Gif-sur-Yvette, France

The Sun's magnetic field varies in multiple timescales as evidenced by the emergence and decay of sunspots on the solar surface. Among these timescales, the 11-yr cyclic pattern, commonly known as Solar Activity Cycle, is the most prominent period. The acoustic oscillations observed at the surface of the Sun are known to correlate with the variations in solar magnetic activity. Availability of continuous helioseismic observations spanning over almost three decades from the ground and space suggest dynamical changes occurring in the solar interior. The long time series has allowed us to uncover several new features in helioseismic data that were inaccessible otherwise. Here we will present results on the temporal variability and various periodicities present in the oscillation frequencies. We will also discuss the spatiotemporal evolution of acoustic mode frequencies and the surface magnetic activity over the course of multiple solar cycles, to improve our understanding of the connection between the solar interior and atmosphere.

---

Monday and Tuesday Poster #14

## Assessing GONG and SDO/HMI Far side Active Region Detection Pipelines with Direct Far side Observations from SO/PHI

Kiran Jain [1], Hanna Strecker [2], David Orozco Suarez [2], Charles Lindsey [3], Mitchell Creelman [1], Amr Hamada [1], Niles Oien [1], Alexei Pevtsov [1], Sushant Tripathy [1], Thomas M. Wentzel [1]

[1] National Solar Observatory, Boulder USA; [2] Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain; [3] NorthWest Research Associates, Boulder, USA

Knowledge of the magnetic flux configuration of the whole Sun, including both front- and far-

hemispheres, is important for developing data-driven global magnetic field models, which are crucial for space weather forecasting applications. The frontside regions of high magnetic flux concentration (known as active regions) can be directly observed, while for far side active regions, we presently rely mostly on indirect helioseismic detection and mapping. The far side pipelines of the Global Oscillation Network Group (GONG) and Solar Dynamic Observatory/Helioseismic and Magnetic Images (SDO/HMI) produce Carrington maps of the strong active regions shown by its seismic signatures. These maps are computed using the technique of helioseismic holography applied to Doppler observations of the Sun's front hemisphere. This technique is primarily based on phase shifts between waves entering and exiting a region of concentrated magnetic flux. When direct observations of the far side are not available, it is difficult to assess the reliability of the helioseismic signatures. The availability of direct observations by Solar Orbiter (SO) from different vantages onto the far side provides a unique opportunity to test the reliability of seismically predicted active regions. Here, we compare SO/Polarimetric and Helioseismic Imager (PHI) observations of the far side to predictions of GONG and HMI far side pipelines and verify the locations and areas of selected active regions. We find that all large active regions are predicted successfully by these pipelines, however the helioseismic signatures fail for a few small active regions, apparently due to their seismic signatures falling below the realization-noise threshold of helioseismic holography.

---

Monday and Tuesday Poster #15

## Supergranulation Pattern Size Derived from Helioseismic Noise

Shukur Kholikov, Alexei Pevtsov

National Solar Observatory, Boulder, CO

The size of solar supergranular cells and their potential correlation with the solar cycle phase have been widely studied, yet findings vary significantly due to differences in observational data and measurement techniques. This study introduces a novel method to directly measure supergranular cell sizes using spherical harmonic time series . A key aspect of this approach is the focus on signals below 0.5 mHz, a frequency range typically excluded in standard helioseismic analyses as the helioseismic noise. To investigate long-term temporal variations, the analysis leverages a comprehensive dataset spanning over 25 years, integrating observations from the Helioseismic and Magnetic Imager (HMI), Michelson Doppler Imager (MDI) and the Global Oscillation Network Group (GONG). The findings aim to reconcile existing discrepancies and offer deeper insights into the dynamics of solar supergranulation.

---

Monday and Tuesday Poster #16

## Improvements to Spherical Harmonic Timeseries

Tim Larson [1], Jesper Schou [2]

[1] Formerly at Stanford University, Stanford, USA; [2] Max Planck Institute for Solar System Research, Göttingen, Germany

It has been noticed that our previous rotational inversions of data from the Michelson Doppler Imager (MDI) contain an artifact beginning in late 2003 and continuing through most of 2004. Investigation has revealed that a certain gap structure prevalent during that time was improperly filled by the algorithm we

had previously employed. Here we describe different modifications to the gapfilling algorithm that are capable of removing the artifact. We also investigate a different interpolation algorithm for performing the spherical harmonic decomposition of vector-weighted data from MDI, which takes account of the correlation between pixels introduced by the gaussian smoothing.

---

Monday and Tuesday Poster #17

## Temporal variations of solar inertial mode parameters during sunspot cycles 23 and 24

Lekshmi Biji [1], Zhi-Chao Liang [1], Kiran Jain [2], Laurent Gizon [1]

[1] Max Planck Institute for Solar System Research, Göttingen, Germany; [2] National Solar Observatory, Boulder, USA

We study the evolution of solar inertial modes using nearly 20 years of GONG++ and HMI helioseismic data, focusing on the $m=1$ high-latitude inertial mode and equatorial Rossby modes with $3 \leq m \leq 16$. Horizontal flow maps near the solar surface are derived from the GONG and HMI ring-diagram pipelines at a daily cadence. Mode parameters are extracted from time series divided into overlapping four-year windows with six-month shifts. We find that the power of the $m=3$ Rossby mode is anti-correlated with the sunspot number, while most other Rossby modes show positive correlations. The $m=1$ high-latitude inertial mode power is maximally anti-correlated with sunspot number when delayed by 2.5 years. Frequencies of most Rossby modes are anti-correlated with the sunspot number, whereas the high-latitude mode frequency is positively correlated.

---

Monday and Tuesday Poster #18

## What Can Local Helioseismology Tell Us about Submerged Magnetic Flux?

Charles Lindsey [1], Alina-Catalina Donea [2]

[1] NorthWest Research Associates, Boulder, USA; [2] School of Mathematical Sciences, Monash University, Melbourne, Australia

One of the major quests of local helioseismology is a diagnostic that can reveal submerged magnetic flux some distance beneath the Sun's near photosphere. This utility could prospectively lend us a resource for forecasting the emergence of magnetic flux capable of impacting space weather at Earth longer before it does so than we presently can. One approach to this quest, we will call it the "temporal approach," is to look into records of various helioseismic signatures of a region into which magnetic flux has emerged at various times before the emergence became evident. These efforts have been tried at some length, and the results of them have not been entirely disappointing. However, there have long been tantalizing indications of a "spatial" counterpart to the temporal that might give us some guidance: Helioseismic signatures in the neighborhoods of strong magnetic flux in the photosphere that themselves are not conspicuously magnetic. An example is halos of enhanced acoustic emission from magnetic neutral lines separating strong magnetic poles of opposing polarity. Gauss's law for magnetic flux makes it highly prospective that these are regions of submerged magnetic flux connecting the poles we see at the surface. If this is so, then an understanding of the mechanism of this emission, if this is what it is, might lead us to

some useful insight into what p-mode emission from submerged sources in the quiet Sun can tell us about magnetic flux that is about to intrude into it from beneath it some time sooner before it becomes a space-weather imposition in the Earth and near-Earth environment than it presently does.

---

Monday and Tuesday Poster #19

## Sub-surface Flows Around Active Regions with HMI Time-distance Helioseismic Measurements

Sushant S. Mahajan [1], Junwei Zhao [1], Xudong Sun [2], Yang Liu [1]

[1] W. W. Hansen Experimental Physics Laboratory, Stanford University, USA; [2] Institute for Astronomy, University of Hawaii, USA

Analyzing inflows surrounding solar active regions are crucial for understanding the dynamics of the Sun's interior and the evolution of magnetic activity. In this study, we build upon our previous work (Mahajan, Sun & Zhao 2023) to extend the analysis of inflows around active regions and their influence on modulation of large scale flows. Specifically, we investigate flows in the meridional and zonal direction in the vicinity of active regions, probing depths up to 13 Mm beneath the solar photosphere. This work focuses on characterizing the depth-dependent structure and variations of subsurface flows associated with active regions, providing new insights into their interactions with large-scale solar dynamics. By employing advanced helioseismic techniques and leveraging high-resolution data, we aim to refine the parameterization of inflows and improve our understanding of their role in the modulation of solar activity. The outcomes of this research are expected to contribute to a more comprehensive model of subsurface flow dynamics and their impact on the solar magnetic cycle.

---

Monday and Tuesday Poster #20

## The Role of Aliasing in Ultratransient Helioseismology

Savannah Perez-Piel [1], Alina-Catalina Donea [2], Charles Lindsey [3]

[1] Space Sciences Laboratory, University of California, Berkeley, USA; [2] School of Mathematical Sciences, Monash University, Melbourne, Australia; [3] NorthWest Research Associates, Boulder, USA

Local helioseismology of acoustic transients has told us a lot about the sources of acoustic transients from flares. It has also told us a great deal about the diagnostics we have used to probe this phenomenon. Generally, the higher in the frequency spectrum we apply our diagnostic, the finer the spatial discrimination we enjoy. This turns out to be crucial for acoustic sources excited by flares, as these appear to show the finest spatial structure we can discriminate out to the 11.1-mHz Nyquist frequency of SDO/HMI observations. The HMI Doppler observations are assimilated from sequential snapshots of the Sun in various spectral bands, hence are subject to aliasing in certain conditions. Aliasing is not a serious concern at, say, half of the Nyquist frequency, 5.5 mHz, as the spectral power at the lowest frequencies that would be aliased to it, 5.5 mHz + 11.1 mHz = 16.5 mHz, is orders of magnitude less than at 5.5 mHz itself. However, approaching the Nyquist frequency itself, aliasing becomes important. We explore what this means for local helioseismic diagnostics of flare acoustic emission in the ultratransient spectrum.

---

Monday and Tuesday Poster #21

## Improvements to Global Mode Analysis

Jesper Schou [1], tim larson [2]

[1] Max Planck Institute for Solar System Research, Göttingen, Germany; [2] Formerly at Stanford University, Stanford, USA

As discussed by Larson & Schou (2024a,b), a number of problems with the analysis in Larson & Schou (2015,2018) have been identified. In this poster we will discuss the effects of some of these problems and show that an improved fitting method results in smaller systematic errors and an increased number of modes. We will also show the results of a number of other improvements to the fitting method and discuss what may be done to further improve the fitting methodology.

---

Monday and Tuesday Poster #22

## Investigating Thermal Energy Transport in the NSSL

Kinfe Teweldebirhan [1], Rituparna Curt [2], Nicholas Featherstone [3]

[1] Southwest Research Institute, Boulder, USA; [2] Pasteur Labs and ISI; [3] Department of Solar and Heliospheric Physics, Southwest Research Institute, Boulder, CO USA

The maintenance of the solar near-surface shear layer remains mysterious in a number of respects, but it seems likely to result from the interaction of slow, deep-seated convective motions and rapid, near-surface motions which are relatively insensitive to the Coriolis force. Such a two-component model has recently been proposed by Choudhuri and Jha (2023) found that the near-surface shear layer can be well-reproduced if (i) the region is assumed to be in thermal-wind balance and (ii) if latitudinal temperature perturbations established in the bulk convection zone remains unchanged across the near-surface region. Motivated by these results, we use 3-D numerical simulations of rotating convection to examine the response of convective flow to an imposed, latitudinally varying heat flux at the lower boundary. Across this suite of models, we vary the convective Rossby number, which expresses the ratio of a rotation period to the convective freefall time. We find that below a critical Rossby number, thermal flux variations imposed at the lower boundary are largely reproduced at the upper boundary. Beyond a critical value of the convective Rossby number, however, we observe that convective motions mix heat efficiently in latitude, leading to approximately uniform flux in latitude at the upper boundary.

---

Monday and Tuesday Poster #23

## Measurement of Sun's Large-Scale Flows in Near Surface Shear Layer using Global Spherical Harmonic Coefficients from HMI

Sushanta Tripathy, Kiran Jain, Shukur Kholikov, Rudolf Komm, Lekshmi Biji

National Solar Observatory, Boulder, Colorado, USA

Local helioseismic techniques can reliably measure the Sun's subsurface flows up to different depths

depending on the techniques used. Here we present zonal and meridional components of the subsurface flow up to a depth of 30 Mm to provide observational constraints on the temporal as well as latitudinal variations. The measurements are derived from 30 by 30 degree patches that cover the solar disk at multiple locations on a uniformly spaced grid, within 75 degrees in latitude and 52.5 degrees in longitude. Instead of using the direct Dopplergrams, we use global spherical harmonic (SH) coefficients from Helioseismic and Magnetic Imager (HMI) to reconstruct the Dopplergrams which are then processed through the technique of ring-diagram analysis. The most important advantage of using SH time series is that these are corrected for systematic errors and other artifacts. We will present results computed from 11 years of HMI observations and compare them with those measured by standard HMI pipeline.

---

Monday and Tuesday Poster #24

## A scalable 3D Solver for Modeling High-Resolution Solar Oscillations

Damien Fournier [1], F. Faucher [2], H. Pham [2], L. Gizon [1], H. Barucq [2]

[1] Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany; [2] Project-Team Makutu, Inria, University of Pau and Pays de l'Adour, TotalEnergies, CNRS UMR 5142, France

The interpretation of high-resolution data from SDO/HMI demands increasingly accurate forward modeling. We present a 3D solver for solar oscillation equations that accounts for complex scatterers. The solution is computed in the frequency domain using the Hybridizable Discontinuous Galerkin (HDG) method for spatial discretization. This approach combines the high-order accuracy and parallelizability of Discontinuous Galerkin methods while significantly reducing computational costs. We demonstrate preliminary results on the propagation of acoustic waves through a 3D sound-speed perturbation, simulating the reduced sound speed observed in active solar regions.

---

Monday and Tuesday Poster #25

## Magnetic Discontinuity in the Upper Solar Chromosphere Associated with Coronal Loop Brightening Revealed by the CLASP2.1 Observation

Donguk Song [1], Ryohko Ishikawa [2], David E. McKenzie [3], Javier Trujillo Bueno [4], Frédéric Auchère [5], Ryouhei Kano[2], Amy Winebarger [6], Takenori J. Okamoto [2], Laurel A. Rachmeler [7], Ken Kobayashi [6], Genevieve D. Vigil [6], Adam R. Kobelski [6], Christian Bethge [8], Eun-Kyung Lim [1], Luca Belluzzi [9], Ernest Alsina Ballester [4], Tanausú del Pino Alemán [4], Jiří Štěpán [10]

[1] Korea Astronomy and Space Science Institute South Korea; [2] National Astronomical Observatory of Japan Japan; [3] NASA Marshall Space Flight Center, USA; [4] Instituto de Astrofísica de Canarias, Spain; [5] Institut d'Astrophysique Spatiale, France; [6] NASA Marshall Space Flight Center, USA; [7] National Oceanic and Atmospheric Administration, USA; [8] University of Colorado, Boulder, USA; [9] Istituto Ricerche Solari Aldo e Cele Daccò (IRSOL), Switzerland, [10] Astronomical Institute, Academy of Sciences of the Czech Republic, Czech Republic

We have developed an advanced ultraviolet (UV) spectropolarimeter called Chromospheric Layer SpectroPolarimeter (CLASP2), designed to explore the magnetic fields in the upper solar chromosphere. CLASP2 was launched on board a NASA sounding rocket experiment in 2019, and successfully detected the full Stokes vector in an active-region (AR) plage and in the quiet Sun near the limb across the Mg II h and k lines (280 nm) for the first time. After the experiment, CLASP2 was fully recovered and conducted a second experiment in 2021 under the new name CLASP2.1. During this experiment, we scanned the AR NOAA 12882 with a field of view of 28 arcseconds by 196 arcseconds. By analyzing the CLASP2.1 flight data, we have detected for the first time a magnetic discontinuity in the upper solar chromosphere associated with a coronal loop brightening. During 6-minutes flight of CLASP2.1, we find a coronal loop brightening that is intermittently and recurrently heated. The temperature of the brightening plasma is above 2.5 MK, which is higher than the ambient temperature, and no corresponding brightening is detected in the images of the photosphere and lower chromosphere. The notable finding of our study is that the coronal loop brightening of interest is observed along a region where the magnetic field polarity changes abruptly in the upper chromosphere. Our findings provide observational evidence that the heating mechanism of the coronal loop brightening is consistent with magnetic reconnection in the upper solar chromosphere.

---

Monday and Tuesday Poster #26

## Informing the Study of Electrical Currents in the Solar Atmosphere using Analytic Models

Johnathan Stauffer, Kalman Knizhnik, Mark Linton

Naval Research Laboratory

While the magnetic field is often treated as a fluid in the interpretation of solar simulations and observations, its true origin lies in the propagation of electrical currents. A new technique, CICCI, allows for the disentanglement of magnetic fields generated by currents below and above the solar surface, which have different physical interpretations – while the former is indicative of the “emerged field” originating from the solar convection zone, the latter provides an indirect way of studying the presence of currents in the solar corona, which may help drive solar activity such as flares and coronal mass ejections. However, the resulting decomposed field maps can be difficult to interpret, especially in complex active regions where the magnetic field signatures of multiple current structures may overlap. We present CICCI analyses of several simplified analytical models – representative of current structures expected to be seen on the Sun – to build intuitions for their magnetic field signatures. These insights are then applied to MHD simulations of twisted flux-rope emergence.

---

Monday and Tuesday Poster #27

## Wave Reflection in the Solar Atmosphere

Varun Mahendra Chaturmutha [1], Stuart M. Jefferies [1], Bernhard Fleck [2]

[1] Department of Physics and Astronomy, Georgia State University, USA; [2] ESA/NASA Science and Operations Department, USA

We present evidence supporting wave reflection in the lower solar chromosphere based on helioseismic analysis of multi-height Doppler data from the Solar Dynamics Observatory/Helioseismic and Magnetic Imager and the Magneto-Optical filters at Two Heights II instrument. This evidence is derived through a wave propagation model that incorporates both upward- and downward-traveling (reflected) waves. Moreover, we find that the height of the reflecting region varies with magnetic field strengths in a way that suggests a connection with the plasma $\beta \sim 1$ region. We measure an effective reflection coefficient of 13% in a magnetically quiet region of the Sun.

---

Monday and Tuesday Poster #28

## Surface Flux Transport of Photospheric Fields: Influence of Assimilation Choices

Jon Linker [1], Ronald M. Caplan [1], James Turtle {1], Cooper Downs [1], Lisa A. Upton [2], Charles N. Arge [3], Raphael Attie [3], Carl J. Henney [4]

[1] Predictive Science Inc., USA; [2] Southwest Research Institute, Boulder, USA; [3] NASA Goddard Space Flight Center, USA; [4] Air Force Research Laboratory, USA

The Open-source Flux Transport (OFT) model suite is an open-source package for creating full-Sun photospheric magnetic field maps via surface flux transport (SFT) modeling, now available on GitHub (see the abstract by Lisa Upton et al.). The choice of the magnetogram source data for assimilation into an SFT is key discriminator of the resulting maps, as magnetograms from different instruments may be qualitatively similar but have important quantitative differences. Thus far, most SFT models assimilate line-of-sight (LOS) magnetograms, and there has been relatively little exploration of assimilation of vector magnetograms into SFTs. In this paper, we present preliminary comparisons between assimilative SFT maps incorporating HMI vector magnetograms vs LOS magnetograms, as well as how other assimilation choices affect the resulting map properties.
Research supported by NASA and NSF.

---

Monday and Tuesday Poster #29

## SDO/HMI Spectropolarimetric Inversions with Physics Informed Neural Networks

Momchil Molnar [1], Robert Jarolim [2], Rebecca Centeno [2] Matthias Rempel [2]

[1] Southwest Research Institute, Boulder, USA; [2] High Altitude Observatory, NCAR, Boulder, USA

Spectropolarimetric inversions are fundamental for the inference of the solar magnetic fields. A set of assumptions used for inverting photospheric spectral lines is that they form under the Milne-Eddington (ME) conditions, which allow for fast spectropolarimetric inversions, nowadays used routinely in most inversion pipelines. Due to the observational data being limited by the noise and instrumental effects, the success of estimating the solar magnetic fields relies on properly accounting for those drawbacks in our inversions.

We present a novel method for spectropolarimetric inversions of solar data under the ME approximation with Physics Informed Neural Networks (PINNs). Building on synthetic spectral line profiles, we demonstrate that our approach can reliably solve complex magnetic configurations in a computationally

efficient way. Our method intrinsically enables spatial and temporal coupled inversions that can overcome limitations of noise, while directly providing uncertainty estimates of the magnetic field inference.
We apply our method to observations from SDO/HMI and compare our results to the ones from the VFISV pipeline inversions. We show how our approach improves the magnetic field inversions by the implicit spatio-temporal regularization, and we present an outlook for reducing the noise levels in the faster cadence magnetic field data products from HMI. We apply our method to the solar polar regions to study their magnetic properties with the increased sensitivity of our approach. This study provides a first step to utilize PINNs for spectropolarimetric inversions with SDO/HMI and demonstrates the potential to address long standing solar challenges with existing datasets.

---

Monday and Tuesday Poster #30

## A novel approach to the quantification of magnetic complexity in solar active regions

Stephen Bannister, D. Shaun Bloomfield

Department of Mathematics, Physics and Electrical Engineering, Northumbria University, Newcastle upon Tyne, NE1 8ST, United Kingdom

Active regions are distinct, separable regions of the Sun where sub-surface magnetic flux has emerged. The level of magnetic complexity within active regions is well-known to influence the frequency of eruption events which occur in their surrounding plasma volume, such as solar flares and coronal mass ejection events. Therefore, the quantification of active region magnetic complexity is an important consideration to more accurately track their flaring and evolution potential from a space weather standpoint. Currently, the most widely used magnetic classification scheme in space weather is the Mount Wilson system, which is purely categorical therefore insensitive to any fine detail within the broader groups, i.e. two active regions with the same classification can be tremendously different in both magnetic complexity and eruption frequency. We present a novel method to quantify the magnetic complexity of active regions by introducing our Polarity Inversion Measure (PIM), to examine complexity as a continuous quantity. We then compare the evolution of PIM to the evolution of Mount Wilson classifications in a statistical study using data from over 1,400 active regions since the dawn of SDO to demonstrate the utility of using a quantified complexity measure over a human-assigned daily label. Finally, we demonstrate the effectiveness of PIM in predicting the next day's Mount Wilson classification label based on our statistical findings.

---

Monday and Tuesday Poster #31

## An automatic method to identify and track sunspots using the Solar Dynamics Observatory.

Charlotte Proverbs, D.S. Brown

Jeremiah Horrocks Institute, University of Central Lancashire, Preston, UK

It's well understood that the dynamics of sunspots lead to energy being transferred to the solar atmosphere and stored in the coronal magnetic field. This provides a surplus of energy that may be released in solar

eruptions. The driving mechanisms for this energy transfer may include sunspot rotations, both within individual sunspots and between sunspot pairs. Calculation of the rotations of individual sunspots have been carried out by several authors, but studies of the rotation of sunspot pairs has been less systematically investigated.

Calculation of rotations in either case rely on careful tracking of the sunspots from observation to observation. Identification and tracking of sunspots is therefore essential to understanding the energies in play that lead up to solar eruptions. To date, this has predominantly been done manually which has restricted many studies to being a small number of case studies rather than large statistical samples. In order to construct large samples, the careful tracking of sunspots must be automated.

We present a fully automatic method to identify and track sunspots in long sequences of continuum data from the Solar Dynamics Observatory Helioseismic and Magnetic Imager (SDO/HMI) at a high temporal resolution. Including registering the splitting and merging of sunspots, and allocating sunspots to active regions. This information can be fed into algorithms to measure the rotation of individual sunspots or used to calculate the relative motion of sunspots with respect to each other (including co-rotation).

The method is applied to a four-month and a twelve-month data set, alongside case studies of AR13664 and AR13842. From this data, sunspot dynamics such as sunspot rotation are calculated, alongside sunspot pair interactions. Case studies of successfully tracked sunspots will be presented, showing examples of the individual sunspot rotations and some initial results involving sunspot pair interactions with correlations to solar activity.

---

Monday and Tuesday Poster #32

## Investigating Strong Horizontal Magnetic Fields in Solar Active Regions with SDO/HMI

Sarah Jaeggli [1], Trinity Parascandola [2], Lucas A. Tarr [1]

[1] National Solar Observatory, Pukalani, USA; [2] University of Hawaii, Hilo, USA

Solar active regions sometimes exhibit patches of very strong magnetic field (> 2000 G) in the photosphere, oriented in the mostly horizontal direction with respect to the Sun's surface. These strong horizontal field patches have been noted in delta-sunspots, where they correspond to penumbra between the main and parasitic polarities. The presence of these regions is confusing because under basic physical intuition they would tend to be buoyant, however they can last for hours or days. It is not known what magnetic configuration they correspond to, how widespread they are within active regions, or what their relationship to solar activity is. We have begun an investigation to identify these regions and study their properties using the Helioseismic and Magnetic Imager on-board the Solar Dynamics Observatory.

---

Monday and Tuesday Poster #33

## Solar Prominence Instabilities and Evolution Toward Eruptions

Wei Liu [1], Thomas Berger [2], Andrei Afanasev [2], Yuhong Fan [3]

[1] LMSAL/BAERI, USA; [2] University of Colorado, USA; [3] UCAR/HAO, Boulder, USA

Solar prominences are large-scale plasma structures embedded in non-potential magnetic configurations

in the corona. These configurations can have far-reaching space weather consequences, as they typically erupt in the form of Coronal Mass Ejections (CMEs) with the prominence comprising the bulk of the mass. The mechanisms by which non-potential field/prominence systems evolve toward eruptions are not well understood. One theory is that magnetic flux emerging below the prominence gradually inject flux and helicity into the system, eventually driving it to an unstable state. Recent discoveries of Rayleigh-Taylor (RT) and Kelvin-Helmholtz (KH) instabilities in prominences may indicate the interaction of the emerging flux with overlying prominence magnetic fields. Such instabilities are manifested in the so-called prominence bubbles, which are mysterious, dome-shaped, apparently void structures residing in the lower portions of prominences. We present recent observations from SDO/AIA and IRIS of prominence bubbles, together with preliminary MHD simulations of prominence-carrying flux ropes, to support this scenario. We discuss the role of such instabilities in prominence eruptions, as well mass and magnetic flux transport in the solar atmosphere in general. We expect that direct measurements of prominence and coronal magnetic fields, e.g., by DKIST and future instruments, can further shed light on this subject.

---

Monday and Tuesday Poster #34

## Observational Signatures of the Undular Instability in Emerging Active Regions

Aimee Norton [1], Kalman Knizhnik [2]

[1] Stanford University, USA; [2] Naval Research Laboratory, USA

We search for signatures of the undular instability acting on the magnetic field during active region flux emergence that are distinct from the small-scale signatures of granulation and convection. Observing NOAA 13179 using data corrected for scattered light from the Helioseismic and Magnetic Imager (HMI), we analyze time-series of the continuum intensity, Doppler velocity and vector magnetic field values. Dark lanes next to elongated granules are found to host horizontal fields on the order of 400 Mx cm$^{-2}$ and red-shifted plasma that likely correspond to the loop-top of rising $\Omega$-loops. The nearly radial magnetic fields in the growing bipolar footpoints of the region are two to three times stronger than the horizontal field and host downflows. A line of small-scale, reversed-polarity bipoles with horizontal wavelengths of 2$-$3 Mm appear in the center of the flux emerging region; these are likely U-loops containing plasma trapped beneath the photosphere and their spatial distribution is suggestive of the serpentine nature of the field and the undular instability modes that are present. The observed growth rate of the fastest growing undular mode is fit by $B_{z} = b_{0}e^{{\sigma}t}$ with $b_{0}$=61 Mx and $\sigma$=0.037 (27 minutes). We compare observational results to the Lare3d modeling of the undular instability acting on flux tubes. We believe the scattered light corrected data from HMI can be used for small-scale flux emergence events that have been difficult to observe due to high spatial resolution instruments needing to point to capture such emergence.

---

Monday and Tuesday Poster #35

## Observing the evolution of the Sun's global coronal magnetic field

Zihao Yang [1], Hui Tian [2], Steven Tomczyk [3], Xianyu Liu [4], Sarah Gibson [1], Richard Morton [5], Cooper Downs [6]

[1] NCAR/HAO, Boulder, USA; [2] Peking University, China; [3] Solar Scientific LLC, Boulder, USA;

[4] University of Michigan, Ann Arbor, USA; [5] Northumbria University, UK; [6] Predictive Science Inc., San Diego, USA

The magnetic field in the Sun's corona stores energy that can be released to heat plasma and drive solar eruptions. Measurements of the global coronal magnetic field have been limited to several snapshots. In this work, we present observations, using the Upgraded Coronal Multi-channel Polarimeter, that provide 114 magnetograms of the global corona above the solar limb spanning ~8 months. We determined the magnetic field distribution with altitude in the corona and monitored the evolution at different latitudes over multiple solar rotations. The field strength between 1.05 and 1.60 solar radii varies from <1 to ~20 gauss. A signature of active longitudes appears in the coronal magnetic field measurements. Coronal models are generally consistent with our observations, though they have larger discrepancies in high-latitude regions. In this poster, we also present the latest analysis on magnetic field measurement based on the eclipse observations of UCoMP made on April 9, 2024.

---

Monday and Tuesday Poster #36

## The Study of Multi-Scale Structures in the Solar corona

Mahendra Karna [1], Nishu Karna

[1] Janakpur, Nepal; [2] Center for Astrophysics | Harvard & Smithsonian, USA

The sun's electric field arises from the interaction of protons and electrons formed during the fusion process when hydrogen atoms are stripped apart in intense heat. However, measuring electric fields in the solar atmosphere is scant. The three main observed structures of solar plasma are sunspots, prominence, and coronal holes. Sunspots, a concentration of strong magnetic field lines, have cooler temperatures. Prominence, forming over the polarity inversion line, possesses a higher temperature than the Sunspot. Coronal holes are unipolar and have higher temperatures. The density and the speed of the solar wind also depend on the type of the structure. These three solar structures are interlinked and show distinct properties. Here, we discuss observations and comparisons of these three plasma structures, including the electric field measurements.

---

Monday and Tuesday Poster #37

## Characterization of Plasma Parameters at Coronal Hole Boundaries: Insights from Multi-Instrument Observations

Khagendra Katuwal, Juie Shetye

New Mexico State University, Las Cruces, NM, USA

Coronal holes, regions of lower temperature and density in the solar corona, serve as sources of the fast solar wind. However, the exact plasma dynamics and physical parameters at their boundaries remain elusive. This study presents a detailed analysis of coronal hole boundaries using observations from the Solar Dynamics Observatory (SDO) and ground-based data from the Facility Infrared Spectropolarimeter (FIRS) at the Dunn Solar Telescope. Employing multi-wavelength data, we characterize the temperature, density, magnetic field distributions, and plasma flows in and around a coronal hole observed in May 2021. Intensity thresholds in the AIA 193 Å bandpass and skewness analysis of line-of-sight magnetic

fields confirm the unipolarity of the coronal hole region. Spectropolarimetric inversions using the Hazel code provide a multi-height perspective of plasma dynamics at the chromospheric level. Our findings shed light on the role of coronal hole boundaries as potential sources of the slow solar wind and offer improved methodologies for boundary detection, contributing to our understanding of solar wind origins.

---

Monday and Tuesday Poster #38

## Physics-Informed Neural Networks for Active Region Modeling

Nat Mathews [1], Barbara J. Thompson

[1] NASA / UMD; [2] NASA/GSFC, Greenbelt, USA

Extant methods to model solar active regions are typically either resource-intensive, or have difficulty reproducing the complex, nonlinear physics involved in CME formation and evolution. More robust ways are necessary to bridge the gap between simulations meant for scientific inquiry and fast models for operational forecasting. Machine Learning techniques can provide exactly such a bridge. The initial conditions for CMEs is a major crux for method improvement. We present new results on using a Physics-Informed Neural Network to reproduce historic solar active regions viewed by SDO.

---

Monday and Tuesday Poster #39

## Are there small, obscurated coronal holes on the Sun?

Stefan Hofmeister [1], Eleanna Asvestari [2] , Karin Dissauer [3], Michael Hahn [1], Stephan Heinemann [2], Veronika Jercic [4], Alexandros Koukras [1], Kilian Krikova [5] , Jonas Saqri [6], Manuela Temmer [6], Daniel W Savin [1], Dominik Utz [7], Astrid Veronig [6]

[1] Columbia University; [2] University of Helsinki; [3] NorthWest Research Associates; [4] KU Leuven; [5] University of Oslo; [6] University of Graz; [7] Kepler University Hospital Linz

Coronal holes are well-known as the source regions of fast solar wind streams, with their boundary regions potentially contributing to the slow solar wind. However, the formation process of coronal holes has rarely been observed. Why is this the case? Small coronal holes are easily overshined by the brighter surrounding corona in the line-of-sight.

In this study, we investigate the formation of a small coronal hole observed by SDO at the solar disk center in 2014. Following a filament eruption, a region that appeared to be a coronal dimming region emerged at one of the filament footpoints. However, this region migrated approximately 200" from the formation site within a day and settled at locations where magnetic field extrapolations have shown open magnetic field lines already days before. During this movement phase, the coronal hole floated over magnetic elements in the photosphere with magnetic flux remaining roughly conserved, indicating interchange reconnection. The coronal hole began to be overshined by the surrounding corona about 1.5 days later, at a position roughly 20° west from the disk center. Beyond this point, it would not have been identified as a coronal hole in EUV observations. However, knowing its presence, one can track it visually as a subtle darkening against the coronal background as it rotated toward the solar west limb. With a minimum lifetime of six days and its extraordinary movement phase, one can rule out the possibility of this region to be a coronal dimming.

This unique event raises interesting questions: How many of these small, newly formed coronal holes go

undetected on the solar disk at any given time? And what fraction of the Sun's open magnetic flux and slow solar wind arise from these elusive regions? These questions will be difficult to answer, but are important to consider during our search for the source regions of the slow solar wind.

---

Monday and Tuesday Poster #40

## Evolution of the Heliospheric Current Sheet throughout the solar cycle

Lizet Casillas

Earth, Planetary, and Space Sciences, UCLA, Los Angeles, CA, USA

The heliospheric current sheet (HCS) is the boundary between open magnetic field lines of opposite polarity in the solar wind that are also rooted at the sun in regions of opposite polarity. The HCS is often described to be a disk-like sheet that is 10,000 Km thick at 1 AU, warped by the combined effects of the inclination of the magnetic equator on the sun, solar rotation and solar wind expansion. It is usually assumed that the current sheet is unique and somehow continuous, however, this depends, perhaps, on their being a magnetic dipole component dominating the solar surface field. In the presence of a pure quadrupole, one would expect, for example, two separate conical current sheets. Indeed, there has been evidence of more than one current sheet emanating from the corona during solar maximum from LASCO and STEREO observations. How the current sheet forms depends on the energetics of the opening of closed loops by the expanding solar wind in the corona. Parker Solar Probe (PSP) collects magnetic field data as it crosses the HCS intermittently on its orbit. Through each PSP encounter, observations have introduced numerous interpretations of the structure of the HSC. We examine the possible bifurcation of the current sheet and asymmetries with a simple axially symmetric set of simulations using PLUTO code with a superposed dipole and quadrupole. We also investigate how pseudo streamers generated by the combination of quadruple and dipole might lead to greater open flux or greater energization of the current sheet system.

---

Monday and Tuesday Poster #41

## The Magnetic Origin of Solar Coronal Jets and Campfires: SDO and Solar Orbiter Observations

Navdeep Panesar [1], Alphonse C. Sterling [2], Ronald L. Moore [3], Sanjiv K. Tiwari [1], Viggo H. Hansteen [1], David Berghmans [4], Mark Cheung [5], Daniel Müller [6], Frederic Auchere [7], Andrei Zhukov [4]

[1] LMSAL/BAERI; [2] NASAMarshall Space Flight Center, Huntsville, USA; [3] Center for Space Plasma and Aeronomic Research, UAH, Huntsville, USA; [4] Royal Observatory of Belgium, Belgium; [5] CSIRO Space & Astronomy, Australia; [6] European Space Agency, ESTEC, The Netherlands; [7] Universite Paris-Saclay, CNRS, France

Here we present the magnetic origin of different types of campfires and coronal jets, using line-of-sight magnetograms from Solar Dynamics Observatory (SDO)/Helioseismic and Magnetic Imager together with extreme ultraviolet images from Solar Orbiter/ Extreme Ultraviolet Imager and SDO/Atmospheric Imaging Assembly. We find that (i) both campfires and coronal jets reside above neutral lines and they

often appear at sites of magnetic flux cancelation between the majority-polarity magnetic flux patch and a merging minority-polarity flux patch, with a flux cancelation rate of ∼1018 Mx hr−1 (ii) majority of campfires are preceded by a cool-plasma structure, analogous to minifilaments in coronal jets. Our observations suggest that (a) the presence of magnetic flux ropes may be ubiquitous in the solar atmosphere and not limited to coronal jets and larger-scale eruptions that make CMEs, and (b) magnetic flux cancelation, most likely accompanied with magnetic reconnection in the lower solar atmosphere, is the fundamental process for the formation and triggering of most solar campfires and coronal jets. Finally, we compare fine-scale jets with those found in a Bifrost MHD simulation.

---

Monday and Tuesday Poster #42

## Post Launch Product Testing for the Compact Coronagraph on GOES-19

Donald Schmit, Gabe Dima, Chris Bethge, Elysia Lucas, Vicente Salinas

University of Colorado/CIRES

The CCOR-1 coronagraph was launched aboard the GOES-U spacecraft in June 2024. The National Centers for Environmental Information (NCEI) is the group within NOAA that is charged with calibrating the CCOR-1 data and producing and distributing retrospective data products. The first six months after the instrument turns on will be dedicated to two distinct phases: Post Launch Testing and Post Launch Product Testing (PLPT). NCEI will lead the PLPT effort. In this presentation, we will describe the 15 aspects of the data that will be calibrated and characterized during PLPT: detector bias, eclipse observing mode, data latency, spatial platescale, attitude knowledge, realtime background calibration, retrospective background calibration, data cadence, SEP removal, earthshine characterization, detector defects, focus, field of view, photometric calibration factor, and vignetting calibration. We will highlight ongoing analysis of these data aspects. The NCEI-produced CCOR-1 data should be available for public download by early March 2025.

---

Monday and Tuesday Poster #43

## Statistical Investigation of Coronal Loop Heating in non-Eruptive Solar Active Regions

Aparna V. [1], Sanjiv Tiwari [1], Navdeep Panesar [1], Ronald Moore [2], Bart De Pontieu [3], Thomas Wiegelmann [4], Brian Welsch [5]

[1] LMSAL/ BAERI; [2] UAH; [3] LMSAL; [4] MPS; [5] UWGB

Based on the results from Tiwari et al. 2017, we investigate the importance of magneto-convection in heating active region (AR) coronal loops. They found via SDO/AIA observations and NLFFF extrapolations based on SDO/HMI vector magnetograms that loops connecting sunspot umbrae are invisible in EUV images and those with one loop footpoint in sunspot umbra or penumbra and the other footpoint in opposite-polarity sunspot penumbra or plage regions, are seen as bright and hot loops. They concluded that a combination of the magnetic field strength and the convective freedom at the loop feet play an important role in determining the amount of heating in a loop. Here, we aim to understand the statistical significance of the above findings. We select a sample of three kinds of ARs -- those having a

pair of sunspots, those with a sunspot in the leading polarity and a plage in the trailing polarity, and those that have no sunspot (only plage) in any polarity. Using AIA images, we select ARs that have not produced flares stronger than a B-class in a duration of 48 hours. We select the instances where bright loops are present and use the nearest SDO/HMI SHARP vector-magnetograms in time to perform NLFFF extrapolations, from which we obtain loop lengths, exact loop-feet location, field strength along loops, etc. We also perform differential emission measure calculations at these times using AIA images to verify the temperature characteristics. Using several ARs we plan to derive a realistic scaling law that includes “invisible” and/or dim coronal loops connecting sunspot umbrae inferred from the extrapolations.

---

Monday and Tuesday Poster #44

## Observations of SEP-Associated CMEs in the low and middle corona from Solar Dynamics Observatory AIA and the Mauna Loa K-Coronagraph

Joan Burkepile [1], O. Chris St. Cyr [2], Ian G. Richardson [3], Giuliana de Toma [1], Barbara Thompson [3], Michael Galloy [1]

[1] National Center for Atmospheric Research, Boulder, USA; [2] NASA Goddard Space Flight Center (retired); [3] NASA Goddard Space Flight Center

The NCAR Mauna Loa Solar Observatory (MLSO) COSMO K-Coronagraph (K-Cor) provides 15 second cadence images of the low and middle corona (1.05 to 3 solar radii) to track the formation and dynamics of coronal mass ejections (CMEs). These observations fill in a gap in space-based coronagraph data and overlap with low coronal observations from AIA.
K-Cor observed 29 CMEs associated with SEP events, based on the most recent catalog of 25 MeV solar proton events from Ian Richardson. Analysis of these CMEs show they are wider and faster than non-SEP events in the low corona. In addition, most of the SEP-associated CMEs show a deformation of the CME front in the K-Cor field-of-view (FOV) at heights at or below 2 solar radii. These deformations are suggestive of shock formation. Some of these CMEs have speeds in the K-Cor FOV that significantly exceed the speed reported in the LASCO catalog, illustrating the need to track CME properties from the low corona, in AIA and K-Cor, to acquire accurate measurements of their properties. These data are needed to understand where and how CME shocks form. We present CME properties of SEP-associated CMEs seen in AIA and K-Cor along with the timing of the SEP events with associated Type II and Type III radio bursts.

---

Monday and Tuesday Poster #45

## Constraining properties of impulsive events in the quiescent corona using simulation-based inference

Vishal Upendran [1, 2, 3], Durgesh Tripathi [3], N.P.S. Mithun [4], Santosh Vadawale [4], Anil Bhardwaj [4]

[1] Bay Area Environmental Research Institute; [2] Lockheed Martin Solar and Astrophysics Laboratory; [3] Inter University Centre for Astronomy and Astrophysics - Pune; [4] Physical Research Laboratory, India

The solar corona consists of a million-degree Kelvin plasma. Quiet Sun regions (QS), which form a background over which large, dynamic events occur, must be studied well to understand the presence of this million-degree plasma. In this work, we study QS regions during the solar maximum and minimum in two ways. In the first analysis, we consider full resolution AIA data in 171, 193, and 211 Å passbands at 12 second cadence, spanning ~8 hours, while in the second analysis we consider the full-disc integrated, absolute flux calibrated soft X-ray data from XSM onboard Chandrayaan - 2 at high cadence. We employ a convolutional neural network based inversion scheme on an empirical, impulsive-event based forward model to infer the occurrence frequency, power law slope and timescales of the impulsive event distribution giving rise to light curves at each pixel of AIA, and the full XSM light curve. We find these events to occur at ~2-3 per minute in AIA, and have time scales of ~10 - 20 minutes, with a dependence on the passband in consideration. In X-ray, the timescales reduce and the events are far more frequent. However, the slope alpha undergoes change from >2 to <2 from 171 Å of AIA to X-ray observations. Finally, we find these events to have amplitudes in 10^21-10^24 erg, with a typical radiative loss of about ≈10^3 erg cm-2 s-1 in the energy range of 1-2.3 keV. These results provide strong constraints on the properties of subpixel impulsive events in maintaining the quiet solar corona.

---

Monday and Tuesday Poster #46

## Current and Future Status of JSOC

Alex Koufos, Art Amezcua, Charles Baldner, Jeneen Sommers, Todd Hoeksema

HEPL, Stanford University, CA

The Joint Solar Observatory Center (JSOC) faced a significant flooding event on November 26, 2024, that impacted our data storage and processing infrastructure. During our recovery efforts, details regarding the incident and the ongoing recovery efforts have been provided on a temporary website. Beyond the recovery efforts, we have been working on other updates at JSOC. To enhance collaboration and version control, JSOC is migrating its codebase from CVS to Git. This transition involves establishing a dedicated GitHub organization, JSOC-SDP, to house our code repositories. Furthermore, JSOC is actively modernizing its web interface using the Flask framework. This shift will provide a more robust and flexible foundation for future development efforts. This poster will detail our recovery efforts, alongside these ongoing modernization initiatives aimed at improving our overall infrastructure at Stanford.

---

# Posters Displayed on Wednesday and Thursday

Please remember to put up your poster before the meeting begins on Wednesday and to remove it before 5:00 pm MT on Thursday. Posters are assigned a number in the Abstract Book. Please hang your poster on the poster board with that number.

Wednesday and Thursday Poster #1

## Particle Measurements from SDO EVE MEGS-B

Don Woodraska, Thomas Woods, Frank Eparvier, Andrew Jones

LASP, University of Colorado, Boulder, CO, USA

The Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE) Multiple EUV Grating Spectrograph B (MEGS-B) channel is a CCD detector designed to measure the solar EUV spectrum from about 33-105 nm. The MEGS-B detector is also sensitive to particles that penetrate the radiation shielding, cosmic rays, as well as secondary radiation effects. The primary science spectrum is dispersed by the gratings across a diagonal strip on the detector, however, most pixels are outside of the spectrum region and receive no light from the gratings. These out-of-band pixels are almost continuously dark, even while observing the sun, providing measurements of the spacecraft environment. These out-of-band pixels are analyzed to quantify the fluxes from all contributing sources, primarily from penetrating particles, across the full range of energies available up to saturation value for almost every MEGS-B image over the mission. The behavior of the particle fluxes can be analyzed over time scales from 10-seconds up to more than a solar cycle with near continuous coverage enabling the study of Solar Energetic Particle (SEP) events, magnetospheric variability, and variation across the entire mission. Initial results for daily means show clear anticorrelation with solar cycle activity, and almost no relationship to solar rotations. High cadence analysis shows daily responses that are consistent with expected contributions from magnetospheric trapped electrons in the outer Van Allen radiation belt. Strong responses to SEP events (protons) are also observed, along with the energy distribution changes throughout the events. This high cadence data enables direct comparisons to other high cadence measurements, and may be useful for studying radiation belt dynamics, cosmic ray variations, and solar energetic particle events. This is the first time this very large, dataset is evaluated.

---

Wednesday and Thursday Poster #2

## Development of solar activity as observed by PROBA2/LYRA

Ingolf Dammasch, Marie Dominique

Royal Observatory of Belgium

The radiometer LYRA has observed solar activity since 2010. For each day, the minimum levels of its two EUV/SXR channels are determined, which correspond to active regions and sunspot numbers. It will be shown how the recent degradation correction improves the correlation, e.g. with GOES values.

---

Wednesday and Thursday Poster #3

## Synergy between MLSO ground-based observations and SDO/AIA

Giuliana de Toma, J. Burkepile
HAO/NCAR, Boulder, C, USA

The two coronagraphs at the Mauna Loa Solar Observatory (MLSO), UCoMP and K-Cor, take daily synoptic observations of the solar corona that overlap in height with SDO/AIA observations. UCoMP observes several coronal emission lines in the visible and IR up to 2 solar radii. In particular, the UCoMP FeXIII line at 1074.7 nm has a formation temperature intermediate between the Fe XII 19.3 nm and FeXIV 21.1 nm lines observed by SDO and, being radiation dominated, falls off more slowly with height. Since UCoMP is an imaging polarimeter that take data at different wavelengths across an emission line, in addition to intensity images, it provides line-of-sight velocity, line width, and linear polarization, which gives information on the plane-of-sky magnetic field. K-Cor is a broadband white-light coronagraph whose field-of-view extends to 3 solar radii, bridging AIA and LASCO. Here, we present examples of quiescent and eruptive magnetic structures observed simultaneously by SDO/AIA and the MLSO instruments and emphasize the synergy and complementarity of the two observatories.

---

Wednesday and Thursday Poster #4

## Improving the Spectral Resolution and Wavelength Scale of SDO/EVE MEGS-A for Flare Doppler Observations

Gabriela Gonzalez [1], Phillip Chamberlin [1], Vicki Herde [2, 3]
[1] Laboratory for Atmospheric and Space Physics/ College of Engineering and Applied Sciences, University of Colorado, Boulder, USA; [2] Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA; [3] Department of Aerospace Engineering Sciences, University of Colorado Boulder, USA

This work uses data from the Extreme ultraviolet Variability Experiment (EVE) instrument onboard the Solar Dynamics Observatory (SDO). Using the â€œAâ€ channel on the Multiple EUV Grating Spectrographs (MEGS-A) on EVE, which measures wavelengths of 5-37 nm, we improve the wavelength scale accuracy and spectral resolution during solar flares. EVE's least processed data product, Level 0B, is used to create updated wavelength scales that are shown to make more precise spectral measurements compared to EVE Level 2 data (Gonzalez et al. 2024). An X2.2 class flare that occurred on 15 February 2011, SOL2011-02-15T0156, was used to derive the pixel-to-wavelength scales. An improvement range of 5.21% to 11.35% was found in the emission line widths. These measurements are used for improved Doppler velocity calculations of the accelerated plasma of various temperatures during solar flares. We use this information to discover which ions are blue- and red-shifted which may tell us at what height the magnetic reconnection of the flare occurs. We aim to do this during the impulsive and gradual phases to determine the flows and how they differ in the two.

---

Wednesday and Thursday Poster #5

## Beyond the SHARP parameters: the Photospheric Magnetic Field Properties of Flaring vs. Flare-Quiet Active Regions

KD Leka [1, 2], Graham Barnes [1], Eric Wagner [1], Sara Petty [1]
[1] NorthWest Research Associates, Boulder, USA; [2] Nagoya University, Japan

The HMI Active Region Patches (HARPs) provide meta-data (the SHARP parameters) that represent a small sample of ways to describe the photospheric magnetic fields in active regions. The SHARP parameters were selected based on decades of research into the question of what drives a solar active region to flare (c.f., Bobra et al 2014 and references therein). We present here an expansive study of additional approaches for characterizing active region magnetic fields in this context, covering much of the SDO mission (c.f. Leka et al 2018). Beyond additional parameterizations of the surface magnetic field as provided by the HMI vector field maps, we examine the ability of a coronal-field model (from the Magnetic Charge Topology analysis, c.f. Barnes and Leka 2006) and parameters derived from them, to distinguish between flare-imminent and flare-quiet epochs -- with the motivation that the solar coronal magnetic field both stores the requisite energy to power energetic events, and is a candidate for trigger mechanisms as well. We perform these analyses of all HARPs, on a daily basis -- and compare the information provided by the short-term evolution to "snapshot" or static parameters. For all, the NWRA Classification Infrastructure (NCI), a facility based on nonparametric discriminant analysis, enables a quantitative evaluation from this large-sample analysis, of which characterizations can best distinguish regions in imminent likelihood of flaring. We present a summary of physical insights from this expanded analysis.

---

Wednesday and Thursday Poster #6

## Beyond the SHARP parameters: Coupling the Photospheric Magnetic Field with the Chromosphere, Transition-Region, and Coronal Properties of Flaring vs. Flare-Quiet Active Regions.

KD Leka [1, 2], Graham Barnes [1], Eric Wagner [1], Sara Petty [1]
[1] NorthWest Research Associates, Boulder, USA; [2] Nagoya University, Japan

Recent work has shown that small-scale short-lived variation in the solar corona is statistically indicative of upcoming flare activity (Leka et al. 2023), even while studies based on static images or low spatial resolution images from the Chromosphere, Transition-Region, and Coronal (CTRC) regime has not yet proven any significant insights to this question. Long-held knowledge of the photospheric magnetic field has thus far guided most efforts into identifying flare-imminent magnetic field configurations, but evidence for the role of the upper atmosphere is both expected (in terms of energy storage, possible trigger mechanisms) and elusive. To that end, we now investigate the question of distinguishing flare-imminent active regions by evaluating both magnetic characteristics from SDO/HMI (beyond the SHARP parameters, see accompanying poster) as compared to, and combined with, the characteristics of the CTRC regime as parameterized using SDO/AIA Active Region Patches (Dissauer et al 2023) covering much of the SDO mission. To gain physical insight from a large-sample analysis, we use the NWRA Classification Infrastructure (NCI), a facility based on nonparametric discriminant analysis, which enables a quantitative evaluation of which descriptions can best distinguish regions in imminent likelihood of flaring. We present a summary of physical insights from this expanded analysis.

---

Wednesday and Thursday Poster #7

## Full-Circle Science: Enabling Large-Sample Physics Investigations with SDO/AIA

KD Leka [1], Karin Dissauer [1], Eric Wagner [1], David Fouhey [3], Meng Jin [4], Jorge Padial Doble [5]

[1] NorthWest Research Associates, Boulder, USA; [2] Nagoya University, Japan; [3] NYU; [4] LMSAL; [5] Vanderbuilt U.

Large-sample physics investigations ensure the realization of the science potential of the Solar Dynamics Observatory, as does sampling different physical regimes such as the photosphere and the chromosphere, transition region, and corona (the 'CTRC') in a coordinated manner.
"Too much of a good thing?" Active-region focused physics questions form a large part of SDO-enabled science, often relying on the "HMI Active Region Patch" (HARPs) extractions and accompanying "SHARP parameters". A similar data product for AIA is needed (c.f., Dissauer et al. 2023), because (1) full disk data are rarely needed for active-region and flare studies, but high spatial and temporal resolution are, (2) easy coordination with the photospheric vector magnetic field data from HMI enables coordinated multi-regime physics, and (3) the AIA images themselves provide limited physical insight.
We have proposed two new AIA data products: 'Region-Targeted AIA Patches' (R-TAPs) for all-filter coverage of HARP-coordinated sub-area extractions, and 'Flare-Targeted AIA Patches' (F-TAPs) extractions before/during/after solar flares for full-cadence exposure-normalized timeseries of all flares GOES C5.0 and above. Both R-TAPs and F-TAPs will be unbiased, full-mission, full-spatial-resolution, ML/AI-ready community-available data products. To further enable physical interpretation, a computer-vision-driven utility (c.f. Wright et al 2019) will solve for Differential Emission Measure for all R-TAPs and F-TAPs. F-TAP targets will be independently characterized by the Automatically Labeled EUV and XRay Incident SolarFlares facility (ALEXIS). Finally, we will include metadata parametrizations that complement the HMI SHARP parameters, guided by e.g. Leka et al 2023.
These new data products will eventually be produced for both the full SDO archive and future mission data. We present here an outline of the proposed methodology and examples of the proposed data products for community feedback.

---

Wednesday and Thursday Poster #8

## Importance of cadence in resolving apparent super-Alfvénic motions of flare kernels

Juraj Lorincik

BAERI/LMSAL

AIA observations have proven invaluable in providing observational verification of predictions imposed by the three-dimensional (3D) extensions of the standard flare model. The 12 s (resp. 24 s) time resolution of AIA has, however, proven insufficient for resolving fast, sometimes super-Alfvénic apparent motions of flare kernels along ribbons. This key signature of slip-running reconnection has been recently discovered via IRIS Slit Jaw Imager (SJI) observations of a confined C4-class flare acquired at a cadence of 2 s. In our study we quantify the importance of the instrument cadence in resolving motions at speeds exceeding thousands of kilometers per second. This was achieved by producing time-distance diagrams

along the same artificial cut, but using data with different time resolution; from SJI 1330, the 304 and 1600 channels of AIA, as well as data degraded to different cadences and spatial resolutions. Signatures of fast kernels were subsequently compared via a computer vision technique of the OpenCV library. Our comparative analysis indicated a progressive decrease of the number of detected kernels in data with lower temporal and spatial resolution. The mean kernel velocities detected in the SJI time-distance diagrams were by 1 and 2 orders of magnitude higher than those resolved in AIA 304 Å and 1600 Å channel data, respectively. The signatures of super-Alfvénic kernels were found to diminish when data were degraded to cadence of 4 s or lower, highlighting the importance of high-cadence observations in studying transient flare phenomena.

---

Wednesday and Thursday Poster #9

## Evolution of Plasmoids in the Current Sheet Following the September 10, 2017 X-8.3 Flare and CME

Ritesh Patel [1], Vaibhav Pant [2], K. Chandrashekhar [3], Dipankar Banerjee [3]

[1] SwRI, Boulder, USA; [2] ARIES, Nainital, India; [3] IIST, India

Coronal mass ejections (CMEs) are frequently associated with flares, current sheets, and plasmoids. In this study, we investigate the properties and evolution of plasmoids observed in the current sheet that formed after the X-8.3 flare and fast CME eruption on September 10, 2017. Using extreme-ultraviolet (EUV) images from the Atmospheric Imaging Assembly (AIA 131 Å) and white-light coronagraph data from K-Cor and LASCO/C2, we manually identified and tracked plasmoids along the current sheet from the inner to the outer corona.

Our analysis reveals bidirectional plasmoid motion: 20 downward-moving and 16 upward-moving plasmoids were observed in the AIA field of view (FOV). The downward-moving plasmoids had an average width of 5.92 Mm, while upward-moving plasmoids had a mean width of 5.65 Mm. Upward-moving plasmoids were further tracked in white-light coronagraphs, where their widths evolved from 64 Mm in K-Cor to 510 Mm in LASCO/C2. The plasmoids exhibited average speeds of ∼272 km $s^{-1}$ (downward) and ∼191 km $s^{-1}$ (upward) in the EUV observations, with speeds increasing to ∼671 km $s^{-1}$ (K-Cor) and ∼1080 km $s^{-1}$ (LASCO/C2), indicating super-Alfvénic propagation in the outer corona. Downward-moving plasmoids displayed accelerations ranging from −11 km $s^{-1}$ to over 8 km $s^{-1}$. The null point of the current sheet was located at ≈1.15 $R_\odot$, where bidirectional plasmoid motion was evident. We find that the plasmoid width distribution follows a power law with an index of −1.12, consistent across small and large scales. The evolution of plasmoid width W and speed V is described by the empirical relation V=115.69 W^0.37. The observed accelerating plasmoids near the neutral point suggest an extended diffusion region, as predicted by MHD models. This work provides new insights into the dynamics of plasmoids during fast magnetic reconnection, contributing to a better understanding of current sheet evolution in flare-associated CME events.

---

Wednesday and Thursday Poster #10

## Flare-associated Fast-mode Coronal Wave Trains: Recent Observational and

## Modeling Advances

Wei Liu [1, 2], Tongjiang Wang [3,4], Xudong Sun [5], Richard Zhang [6], Tong Shi [7], Leon Ofman [3,4], Meng Jin [2]

[1] Bay Area Environmental Research Institute, USA; [2] Lockheed Martin Solar and Astrophysics Laboratory, USA; [3] Catholic University of America, USA; [4] Goddard Space Flight Center, USA; [5] University of Hawaii, USA; [6] Cupertino High School, USA; [7] SETI Institute, Lockheed Martin Solar and Astrophysics Laboratory, USA

Quasi-periodic, Fast-mode Propagating wave trains (QFPs) are one of the new observational phenomena discovered by the SDO/AIA instrument by imaging in extreme ultraviolet (EUV). They are fast-mode magnetosonic waves closely related to Quasi-Periodic Pulsations (QPPs) in solar flare emissions, ranging from radio to X-ray wavelengths, that have been observed for decades yet with little to no imaging information. The significance of QFPs lies in their diagnostic potential, by providing the critical imaging linkage to QPPs and thus clues to flare energy release, and by serving as new tools for coronal seismology to probe the physical conditions of the solar atmosphere. We report here recent advances in observing and modeling QFPs. Specifically, we performed a statistical survey of QFP events over the 15-year long SDO mission, with the assistance of a machine learning tool under development. We found that a large fraction of global EUV waves (the so-called EIT waves), on the order of >100 events, have QFPs present. There is also a preferential association of QFPs with eruptive flares (e.g., those associated with CMEs) rather than confined flares (those without CMEs). We also performed data-constrained 3D MHD simulations of QFP events, e.g., the SOL2015-06-22 M6.5 flare. We found that QFPs are present throughout the local and ambient corona, but their detectability and morphology vary significantly with the spatial distribution of the Alfven and thus fast-mode speeds, the observer's viewing angle (thus LOS integration), and the observing wavelength channel (thus the emitting plasma temperature). This can potentially explain the puzzling distinction between two types of QFPs: those seen in the 171A channel within funnel-shaped fan loops, and those seen in the 193A channel traveling along the solar limb to further distances. We will discuss the implications of these results and the potential roles played by QFPs in energy transport and solar eruptions in general.

---

Wednesday and Thursday Poster #11

## Propagation of untwisting solar jets from the low-beta corona into the super-Alfvénic wind: Testing a solar origin scenario for switchbacks

Louis Seyfritz [1], Jade Touresse [2], Etienne Pariat [3], Clara Froment [4], Valentin Aslanyan [5], Peter F. Wyper [6]

[1] Observatory of Paris master's student, Intern in LASP, CU, Boulder, USA; [2] Institut Polytechnique de Paris, Université Paris Saclay, Observatoire de Paris-PSL, Laboratory of Plasma Physics - LPP; [3] French-Spanish Laboratory for Astrophysics in Canarias, LPP; [4] LPC2E, OSUC, Univ Orléans; [5] School of Mathematics, University of Dundee; [6] Durham University, Department of Mathematical Sciences

The recent discovery of ubiquitous switchbacks, localized magnetic deflections in the nascent solar wind, by the Parker Solar Probe (PSP) has sparked interest in uncovering their origins. A prominent theory suggests these switchbacks originate in the lower corona through magnetic reconnection processes,

closely linked to solar jet phenomena. Jets are impulsive phenomena, observed at various scales in different solar atmosphere layers, associated with the release of magnetic twist and helicity. This leads to the question of whether these helical structures can travel into the inner heliosphere and if there is a direct correlation between specific solar jets and the switchback signatures observed by PSP.
To explore this hypothesis, Touresse et al. (2024) presents parametric simulations using a 3D numerical magnetohydrodynamic (MHD) model of solar-jet-like events. Within the MHD framework, Touresse et al. examined how varying atmospheric plasma beta affects the propagation dynamics of these jets. Employing the ARMS (Adaptively Refined Magnetohydrodynamics Solver) code, we modeled the self-consistent generation of a solar jet based on Pariat et al. (2009). Producing in-situ velocity and magnetic field measurements, akin to those observed by PSP or SolO, Touresse et al. demonstrated that the magnetic wavefront corresponds to an Alfvénic deflection consistent with switchbacks observations. U-loops, prevalent at jet onset, do not persist in the low-beta corona, hindering the formation of full-reversal switchbacks. This may explain the absence of full reversal switchbacks in the sub-Alfvénic wind. Overall, these simulations unveiled the propagation of magnetic deflections through jet-like events, shedding light on possible switchback formation processes. This research is pertinent to SDO's mission as it connects localized coronal dynamics (observable by SDO) with global solar wind phenomena.

---

Wednesday and Thursday Poster #12

## Improved Understanding of Flare Dynamics with New SDO EVE Level 4 Lines Data Product

Tom Woods, Andrew Jones , Theo Stanley, Gabi Gonzalez, Phil Chamberlin, Don Woodraska, Rita Borelli

University of Colorado / LASP, Boulder, CO, USA

NASA's Solar Dynamics Observatory (SDO) Extreme-ultraviolet Variability Experiment (EVE) has been making solar extreme-ultraviolet (EUV: 10-120 nm) spectral measurements for more than 14 years with 0.1 nm spectral resolution and with 10-60 sec cadence. The stability of the EVE instrument temperature and high precision pointing towards the Sun by the SDO spacecraft have enabled the measurements of the Doppler shifts of about 100 emission features in the EVE spectra. There is a new EVE Level 4 Lines data product that provides line profile-fit results for intensity, wavelength shift, and line width for several emission features. These emission features were selected out of 100s of lines in the solar EUV spectrum as being present before and during a flare and with low amount of blending from other emission lines. The solar EUV spectra have many emission lines from the chromosphere, transition region, and corona, and so Doppler measurements of those lines can reveal important plasma dynamical behavior during a flare's impulsive phase and gradual phase. The two most common patterns seen during large flares are that (1) there can be blue shifts of hot coronal emissions during the flare impulsive phase (an indication of plasma upwelling) and (2) there can be red shifts of chromospheric emissions during the flare impulsive phase (an indication of plasma downwelling). There is potential that the blue shifts during the impulsive phase could be an indicator of an eruption (e.g., CME) and its speed, and if so, the Doppler measurements of select emission lines could be a useful tool for future space weather analysis of CMEs, especially if combined with EUV dimming observations of the cooler corona emissions. The EVE Level 4 Lines product will be introduced, along with some of the flare results from the Doppler analysis with this new EVE data product will be presented.

Wednesday and Thursday Poster #13

## MHD Simulation of Prominence-Cavity System

Yuhong Fan [1], Hongyang Luo [2], Jie Zhao [3], Sarah Gibson [1]

[1] HAO/NSF NCAR, Boulder, USA; [2] Hong Kong University; [3] PMO/CAS

We present MHD simulations of a twisted coronal flux rope under a coronal streamer with the formation of prominence condensations, and the development of CME with associated prominence eruption. We find the formation of a prominence-cavity system that qualitatively reproduces several observed features including the cavity, the prominence horns, the central hot core, and the filament barbs, suggesting that the basic underlying magnetic field structure for prominence cavities is consistent with that of a twisted magnetic flux rope with helical field lines. We find that the prominence weight can significantly affect the stability and eruption of the flux rope.

---

Wednesday and Thursday Poster #14

## Statistical study of prominence eruptions in the wide field of view of Solar Orbiter/EUI/FSI

Dana-Camelia Talpeanu [1], Elke D'Huys [1], Luciano Rodriguez [1], Marilena Mierla [1,2], Daria Shukhobodskaia [1], Brenda Daniela Dorsch [1], Matt West [3], David Berghmans [1], Andrei Zhukov [3,4], Cis Verbeeck [1]

[1] Solar-Terrestrial Centre of Excellence - SIDC, Royal Observatory of Belgium, Brussels, Belgium; [2] Institute of Geodynamics of the Romanian Academy, Bucharest, Romania; [3] Southwest Research Institute, Boulder, USA; [4] Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia

In this study we performed a statistical analysis of prominence eruptions recorded by the Extreme Ultraviolet Imager/Full Sun Imager (EUI/FSI) on board Solar Orbiter during the years 2021 and 2022. We start from the comprehensive list of eruptions available at https://www.sidc.be/EUI/solar-eruptions. From this, for a more detailed analysis of their kinematics, we selected events with available data and for which the observed projected height of the prominence exceeded 2 solar radii.

The large field of view (up to 14 solar radii) allows FSI to observe solar eruptions from the solar disc up to heights never before observed in EUV passbands. This makes the instrument uniquely suited for tracing the early phases of eruptions through the middle corona.

The large set of investigated events (230 prominences) offers a wide perspective on the inherent variability within these phenomena. This ongoing statistical analysis aims at deepening our knowledge on the various properties of these eruptions, such as speed, deflection and morphological features. Using observations taken by SDO/AIA, we can analyze their 3D characteristics and their interaction with neighbouring magnetic field structures.

We present here this statistical study with an overview of the observed prominence eruptions and their properties.

---

Wednesday and Thursday Poster #15

## The Role of Remote Small-Scale Magnetic Reconnections in Triggering the X1.3 Flare in the AR NOAA 13777

Eun-Kyung Lim [1], D. Song [1], K. Kusano [2]; V. Yurchyshyn [3]

[1] Korea Astronomy and Space Science Institute, Republic of Korea; [2] Institute for Space-Earth Environmental Research, Nagoya University, Japan; [3] Big Bear Solar Observatory, New Jersey Institute of Technology, USA

We investigate the triggering mechanism of the X1.3-class solar flare in NOAA active region (AR) 13777 by analyzing pre-flare activities using observations from SDO/HMI, AIA, ground-based GONG H-alpha, and high-resolution imaging spectroscopy from FISS/GST. The flare occurred near the leading sunspot, where an arc-shaped filament was anchored with one footpoint inside the sunspot and the other at remote eastern site. Detailed analysis of both space-based and ground-based data reveals that small-scale flux emergence and cancellations at the remote site, approximately an hour before the flare onset, played a pivotal role in altering the filament's magnetic topology. This led to filament-filament reconnection, dynamic filament plasma motion, and eventual eruption. The magnetic topology of the filament was conductive to the double-arc instability, and kappa-scheme analysis further supported the prediction of the X-class flare. Our findings align with the established view that small-scale flux emergence and cancellation are key triggers of flares. Moreover, we emphasize that the location of such flux emergence is critical in determining whether a flare is triggered.

---

Wednesday and Thursday Poster #16

## Modeling homologous eruptions using data-driven simulations

Andrei Afanasev [1], Maria Kazachenko [1], Yuhong Fan [2]

LASP CU, Boulder, USA; [2] HAO NCAR, Boulder, USA

Some of the most energetic solar eruptions are series of repeated eruptions originating from the same active region (AR) and polarity inversion line (PIL). Such consecutive, so-called homologous eruptions likely result from the repeated formation of magnetic flux ropes above the same PIL. We present the results of data-driven simulations of a series of major homologous eruptions, using the SDO-data-driven magnetofrictional approach to model a multi-day evolution of an AR hosting homologous eruptions. We find that the simulations successfully model the observed homologous eruptions. Using the curvature of field lines and the electric current density, we identify the flare onset times in the simulation, and compare them with GOES X-ray flux data.

---

Wednesday and Thursday Poster #17

## Determining Flare Ribbons and Coronal Dimmings in MHD Simulations Using Magnetic Field Line Length Maps

Abdullah Alshaffi [1, 2], Maria Kazachenko [1,2], Yuhong Fan [3], Andrei Afanasev [1,2]

[1] Astrophysical and Planetary Sciences, University of Colorado, Boulder, USA; [2] National Solar Observatory, University of Colorado Boulder, Boulder, USA; [3] High Altitude Observatory, National Center for Atmospheric Research, Boulder, USA

We investigate the evolution of flare ribbons and coronal dimmings in the magnetohydrodynamic (MHD) simulation of an X-class flare and compare these with the observations from SDO/AIA in 1600 Å and 211 Å. We propose a new approach to track the evolution of coronal magnetic field line length as a proxy for flare ribbons and coronal dimmings. We apply this approach to the simulation data to both qualitatively and quantitatively compare it with the observations. Our results yield a good agreement between the morphology of flare ribbons in the observations and simulations. We compare the calculated magnetic reconnection fluxes in observations and simulations and discuss possible sources for discrepancies between them. For the selected threshold, The imbalance between the positive and negative reconnection fluxes is 7% for the simulation and 5% for the observations. Similarly, the coronal dimming morphology between the observation and simulation matches well, but the dimming flux comparison reveals some inconsistencies. The imbalance in the simulated and observed dimming fluxes is 32% for the selected threshold in the simulation and 28% for the observations. We propose possible improvements to estimate magnetic reconnection and dimming fluxes from the simulations and suggest further model comparisons to improve agreement with observations.

---

Wednesday and Thursday Poster #18

## Unveiling Spatiotemporal Properties of the Quasi-periodic Pulsations in the Balmer Continuum at 3600 A in an X-class Solar White-light Flare

De-Chao Song

Key Laboratory of Dark Matter and Space Astronomy, Purple Mountain Observatory, Nanjing, People's Republic of China

Quasi-periodic pulsations (QPPs) in the Balmer continuum of solar white-light flares (WLFs) are rarely reported, and accurately pinpointing the spatial source of flaring QPPs remains a significant challenge. We present spatiotemporal characteristics of QPPs of an X2.8 two-ribbon solar WLF (SOL2023-12-14T17:02), which was well observed by the White-light Solar Telescope (WST) aboard the Advanced Space-based Solar Observatory, with high-cadence imaging (1-2 s) in the Balmer continuum at 3600 A. Combined with additional multi-instrument data, it is found that the enhancement of the WLF in both the Balmer and Paschen continua shows strong spatiotemporal correlation with hard X-ray (HXR) emissions, with the continuum emission peaking about 35 s later than the time derivative of soft X-ray (SXR) 1-8 A emission. Notably, the pulses in the Balmer continuum exhibited a near-zero time lag with most HXR pulses, whereas SXR and extreme ultraviolet emissions showed a lag of 2-3 s. Interestingly, quasi-harmonic QPPs with periods of 6, 11, and 20 s were detected in multiple wavelengths in the rising phase of the white-light continuum. Furthermore, we employed Fourier transform to spatially locate the QPPs around 11 and 20 s, revealing that they primarily originated from the east flare ribbon, which exhibited the most substantial continuum enhancement. More interestingly, we find that the west ribbon contributed significantly to the 11-second QPP but had a weaker contribution to the 20-second QPP. We propose that periodic magnetic reconnection modulated by magnetic islands and the associated excitation of fundamental and harmonic kink modes are the most plausible mechanisms. These observations provide

valuable insights into QPP modeling for solar and stellar flares.

---

Wednesday and Thursday Poster #19

## L-maps: Deriving Coronal Dimming and Flare Ribbon Proxies from Realistic Data-Driven Flare Simulations

Maria Kazachenko [1, 2], Yuhong Fan [3], Andrei Afanasev [1,2]

[1] University of Colorado, Boulder, USA; [2] National Solar Observatory, Boulder, USA; [3] High Altitude Observatory, Boulder, USA

Violent solar flares and coronal mass ejections (CMEs) are magnetic phenomena. Advances in observational techniques have allowed us to derive statistical properties of observed flare ribbons, coronal dimmings and magnetic field changes and use them to constrain some magnetic field properties of 3D eruptive phenomena (see review by Kazachenko et al. 2022). However these studies focus on observed proxies of hard-to-observe coronal magnetic fields using coronal/chromospheric emission and/or photospheric magnetic field maps, not the coronal field directly. Here we complement existing knowledge of these observed proxies by performing an in-depth analysis of simulation data from a data-driven magneto-hydrodynamic simulation of the 2011-02-15 CME event in active region 11158. We analyze the evolution of ribbon and dimming proxies using a method that we call "L-maps" and compare them with 3D magnetic field evolution during the eruption. We discuss how observed dimming and ribbon properties from the SDO could help us constrain realistic magnetic field evolution during solar eruptions and discuss their limitations.

---

Wednesday and Thursday Poster #20

## Probing the substructures of solar flare ribbons

Vishal Singh [1], Gert Botha [2], Eamon Scullion [2], Natasha Jeffrey [2], Malcolm Druett [3]

[1] Department of Mathematics, Physics and Electrical Engineering, Northumbria University; [2] Northumbria University; [3] KU Leuven

Solar flares are among the most spectacular and energetic phenomena in the solar system, and understanding their driving mechanisms is of paramount importance in solar physics. It is widely accepted that magnetic reconnection is the primary mechanism behind solar flares; allowing for the conversion of magnetic energy into plasma energy, resulting in the acceleration of particles such as electrons and ions. These accelerated particles form electron beams that deposit energy into the coronal plasma locally, and transfer energy globally when they impact the chromosphere, responsible for the characteristic ribbon-shaped emission of Hydrogen 656.3nm (Hα). Using the high-resolution Swedish 1-m Solar Telescope (SST) and CRisp Imaging SpectroPolarimeter (CRISP), we studied the substructures of Hα ribbons in unprecedented temporal and spatial resolution (i.e. 43 km per pixel and a cadence varying in time between 0.2 and 1.2 s). We have identified and analyzed small-scale substructures within the ribbons, referred to as "riblets". We present our definition of riblets and a detailed analysis of their statistical and kinematic properties during an X-class solar flare observed on 10 June 2014. By examining

the riblets at this resolution and exploring their evolution in the context of SDO/AIA 304 Å and RHESSI contours, we can probe the microphysics of energy deposition in the chromosphere with a high degree of precision. We present our analysis of a new class of rapidly evolving sub-structures with mean lifetimes of 11s that exhibit linear and non-linear dynamics, providing valuable constraints on 1D radiation hydrodynamic models of electron beam physics.

---

Wednesday and Thursday Poster #21

## Enhanced Three-minutes oscillation above a sunspot during a solar flare

Ya Wang

Purple Mountain Observatory, Chinese Academy of Sciences

Three-minute oscillations are a common phenomenon in the solar chromosphere above a sunspot. Oscillations can be affected by the energy release process related to solar flares. In this paper, we report on an enhanced oscillation in flare event SOL2012-07-05T21:42 with a period of around 3 minutes that occurred at the location of a flare ribbon at a sunspot umbral–penumbral boundary and was observed in both chromospheric and coronal passbands. An analysis of this oscillation was carried out using simultaneous ground-based observations from the Goode Solar Telescope at the Big Bear Solar Observatory and space-based observations from the Solar Dynamics Observatory. A frequency shift was observed before and after the flare, with the running penumbral wave that was present with a period of about 200 s before the flare coexisting with a strengthened oscillation with a period of 180 s at the same locations after the flare. We also found a phase difference between different passbands, with the oscillation occurring from high-temperature to low-temperature passbands. Theoretically, the change in frequency was strongly dependent on the variation of the inclination of the magnetic field and the chromospheric temperature. Following an analysis of the properties of the region, we found the frequency change was caused by a slight decrease of the magnetic inclination angle with respect to the local vertical. In addition, we suggest that the enhanced 3 minute oscillation was related to the additional heating, maybe due to the downflow, during the EUV late phase of the flare.

---

Wednesday and Thursday Poster #22

## Multi-Spacecraft Observations of 2022 February 08 Prominence Cavity Eruption

Nishu Karna, Mari Paz Miralles

Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA, USA

Helmet streamers are common structures that shape the corona at the largest scales, as observed in eclipse and white-light images. Helmet streamers overlie one cavity embedding a prominence and is surrounded by an open field of opposite polarity coronal holes. In this study, we present multi-spacecraft observations of a spectacular prominence-cavity eruption from the southeastern solar limb accompanied by a geoeffective coronal mass ejection, observed by Solar Dynamics Observatory (SDO), Solar Terrestrial Relations Observatory (STEREO), Solar Orbiter (SO), Advanced Composition Explorer (ACE), and Wind. We produce 3D magnetic field configurations before and during the eruption using the flux-rope insertion method and magnetofrictional relaxation that are consistent with the observations. We also compute temperature, density, and study its kinematics using the differential emission measure (DEM)

analysis.

---

Wednesday and Thursday Poster #23

## A Curated Database for Discovering Micro-Events Using AIA Data

Michael Kirk [1], Raphael Attie [1,2], Srija Chakraborty [3]

[1] NASA Goddard Space Flight Center, Greenbelt, USA; [2] George Mason University, USA; [3] Universities Space Research Association, Washington, DC, USA

The analysis of small-scale solar eruptions, or "micro-events," provides critical insights into the dynamics of solar activity. Utilizing data from the Solar Dynamics Observatory’s Atmospheric Imaging Assembly (AIA), we have developed a novel database of such events—compact coronal brightenings, termed "AIA spikes,"—by repurposing energetic particle hits removed in the level 1 processing pipeline. This dataset captures solar-originated photon events that were previously misclassified, presenting an unprecedented opportunity to explore coronal physics at fine spatial and temporal scales. We isolate, classify, and analyze these micro-events across the 10-dimensional data space that includes temporal, spatial, and multi-wavelength features. The resulting curated archive, housed in NASA's Solar Data Analysis Center (SDAC), includes over 10 billion individual entries and provides tools for re-incorporating significant events into AIA images for broader scientific analysis. At SDO 2025, we are excited to debut this searchable archive to the research community. The database offers a comprehensive resource for investigating micro-events through the solar cycle and contributes to an enriched understanding of the Sun’s smallest eruptive behaviors, with potential implications for understanding larger solar phenomena.

---

Wednesday and Thursday Poster #24

## Spectroscopic Observations of Supra-Arcade Downflows

Ryan French [1], Maria D. Kazachenko [1,2], Teodora Mihailescu [3], Katharine K. Reeves [4]

National Solar Observatory, Boulder, USA; [2] University of Colorado Boulder, USA; [3] NASA GSFC, USA; [4] Harvard–Smithsonian Center for Astrophysics, USA

Despite their somewhat-frequent appearance in EUV imaging of off-limb flares, the origins of Supra-Arcade Downflows (SADs) remain a mystery. Appearing as dark, tendril-like downflows above growing flare loop arcades, SADs themselves are yet to be tied into the standard model of solar flares. The uncertainty of their origin is, in part, due to a lack of spectral observations, with the last published SAD spectral observations dating back to the SOHO/SUMER era. In this work, we present new observations of Supra-Arcade Downflows within an M-class solar flare, observed by the Hinode EUV Imaging Spectrometer (EIS) and NASA Solar Dynamics Observatory. We measure Fe XXIV Doppler downflows and non-thermal velocities exceeding those of the surrounding hot flare fan, with evidence of diverging SAD flows above the flare arcade. We compare the LOS Doppler velocities with plane-of-sky velocities measured by AIA, to construct the 3D velocity profile of the SAD geometry.

---

Wednesday and Thursday Poster #25

## Nonthermal Observations of a Flare Loop-top: Implications for Turbulence and Electron Acceleration

W. Ashfield, V. Polito, S. Yu, H. Collier, L. Hayes
Southwest Research Institute, Boulder, CO

The excess broadening of high-temperature spectral lines, long observed near the tops of flare arcades, is widely considered to result from magnetohydrodynamic turbulence. This plasma turbulence is also believed to be a candidate mechanism for particle acceleration during solar flares. However, the degree to which this broadening is connected to the acceleration of nonthermal electrons remains largely unexplored outside of recent work. Using the Interface Region Imaging Spectrometer (IRIS), we present spatially resolved observations of loop-top broadenings using hot (≈11 MK) Fe XXI 1354.1 Å line emission during the 2022 March 30 X1.3 flare. We find nonthermal velocities upward of 65 km/s that decay linearly with time, indicating plasma turbulence's presence and subsequent dissipation. Utilizing simultaneous observations from the Expanded Owens Valley Solar Array (EOVS) and the Spectrometer/Telescope for Imaging X-rays (STIX) on board Solar Orbiter, we found the rate of turbulent energy dissipation to be consistent with the power of nonthermal electrons deposited into the chromosphere, suggesting a direct link between turbulence and electron acceleration. Furthermore, the turbulent activity precedes the formation of bright EUV knots observed by SDO/AIA, where differential emission measure (DEM) analysis reveals the compression of loop-top plasma. These multi-wavelength observations provide compelling evidence for the coupling between turbulence and electron acceleration in solar flare loop-tops, advancing our understanding of energy release mechanisms in solar flares.

---

Wednesday and Thursday Poster #26

## MAVEN at Mars: Providing an additional vantage point for heliospheric observations

Francis Eparvier [1], E.M.B Thiemann [1], C. Lee [2], P. Chamberlin [1], and the MAVEN Team
[1] University of Colorado - LASP, Boulder, USA; [2] University of California - SSL, Berkeley USA

The NASA Mars Volatile Evolution Mission (MAVEN) has a suite of instruments that have been observing the Sun, the space environment at Mars, and the Mars atmosphere for the last decade. MAVEN has been quantifying the space weather inputs to Mars and the response of the planet to variability in those inputs for nearly a full solar cycle. MAVEN provides another vantage point besides those made at Earth or L1 that is key for whole heliosphere space weather determinations. This presentation will give an overview of the MAVEN observations, data products, modeling, and quicklook space weather products.

---

Wednesday and Thursday Poster #27

## FArSide Trained Active Region Recognition (FASTARR): A Machine Learning Approach

Amr Hamada [1], Mitchell Creelman [1] , Kiran Jain [1], Charles Lindsey [2]
[1] National Solar Observatory, Boulder, USA; [2] NorthWest Research Associates, Boulder, USA

Helioseismic holography is used to identify Active Regions (ARs) in the Sun's far hemisphere by analyzing seismic disturbances on the visible hemisphere, caused by acoustic waves traveling through the Sun's interior and reflecting off the far hemisphere. Currently, identification of far-side ARs faces challenges due to limited signal-to-noise, resulting in the reliable detection of only large and strong ARs. We present a fully convolutional FarSide Trained Active Region Recognition (FASTARR) algorithm that aims to enhance AR identification in helioseismic maps. The algorithm is structured as a U-shaped convolutional neural network (UNet), which allows for fast and accurate image segmentation and evaluation of the likelihood that a given helioseismic signature corresponds to a real AR. Our FASTARR algorithm is trained by pairing of phase-shift maps of the Sun's far hemisphere with concurrent far-side AR binary masks derived from the phase-shift measurements and the Extreme Ultraviolet (EUV) observations. The helioseismic phase-shift maps are computed using Dopplergrams observed by the National Solar Observatory's Global Oscillation Network Group's (NSO/GONG). The EUV AR masks are derived from observations by the Solar TErrestrial RElations Observatory/Extreme UltraViolet Imager (STEREO/EUVI). The model has demonstrated its efficacy for space weather forecasting during the ascending and maximum phases of solar cycle 24 (2010 – 2016). The results reveal that FASTARR evaluation achieves greater sensitivity to the presence of AR in the Sun's far hemisphere compared to conventional methods, substantially increasing the number of active regions correctly identified therein. This advancement holds promise for enhancing the role of far-side solar seismology in space weather forecasting, including the integration of Solar Dynamics Observatory/Helioseismic and Magnetic Imager's (SDO/HMI) high-resolution measurements for improved model performance.

---

Wednesday and Thursday Poster #28

## Physics-Informed Hybrid Method for Solar EUV Spectral Irradiance Modeling Using Differential Emission Measures

Courtney Peck [1], Shah M. Bahauddin [1], Daniel B. Seaton [2]

[1] Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA; [2] Southwest Research Institute, Boulder, USA

Variations in the solar extreme ultraviolet (EUV) irradiance are a significant driver of space weather at Earth, causing increased satellite drag, radio communication disruptions, and reduced GPS accuracy. Since solar EUV irradiance measurements are intermittent and inhomogeneous, models attempt to fill spectral and temporal gaps, typically relying on linear correlation methods which can struggle to capture dynamic irradiance variations from the solar corona during flares. In this work, we present a hybrid method for modeling solar EUV irradiance utilizing forward-modeled physics-informed solar differential emission measures to capture the optically-thin coronal emission coupled with traditional correlation methods to capture the chromospheric and continuum emission. We present results from this model using inputs from the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA) and EUV Variability Experiment (EVE) and demonstrate the improvement over traditional correlation-only methods.

---

Wednesday and Thursday Poster #29

## Response of the total electron content in the ionosphere to the impulsive and late phases of X-class solar flares

Susanna Bekker, Ryan Milligan

Astrophysics Research Centre, Queen's University Belfast, Belfast, UK

The Earth's ionosphere is subject to seasonal, daily, and sporadic variations associated with changes in solar and magnetic activity. Variations in X-ray and UV irradiance during solar flares lead to a noticeable increase in the electron concentration in the illuminated part of the Earth's ionosphere. One of the most valuable tools for studying solar-terrestrial connections is Global Navigation Satellite Systems (GNSS). Due to the large amount of experimental data accumulated by GNSS, the total electron content (TEC) response to the impulsive phase of a solar flare has been studied quite well. At the same time, recent studies have shown that approximately 40% of X-class flares have a second strong peak of warm coronal emission (which is called "EUV late phase"), whose influence on the ionization of ionospheric layers is not yet clear. A combined analysis of successive solar emissions and the caused electron concentration changes made it possible to numerically estimate the ionospheric response to the impulsive and late phases of the X2.9 (3 November 2011), X2.4 (23 October 2012), and X2.0 (25 April 2014) solar flares which are characterized by different spectrum and localization on the solar disk. It has been demonstrated that the TEC increment during the EUV late phase of a limb flare can exceed the response to its impulsive phase and reaches 0.6-0.7 TEC units. The TEC response to the relatively weak emissions of the EUV late phase of a disk flare depends on the flare spectrum and is 30–50% of the TEC increase during the impulsive phase. The energy of the EUV late phase of more powerful events than those considered in this work can be much higher, so the obtained result indicates a serious need to consider the late emission of warm coronal lines when modeling and forecasting the ionospheric response to variations in solar radiation.

---

Wednesday and Thursday Poster #30

## Using SDO/HMI Far-side Helioseismology to increase solar irradiance forecast lead-time

Tom Berger [1], Natasha Flyer [2], Shea Hess-Webber [3], Mark Vincent [4], Nate Holland [1]

[1] University of Colorado Boulder, USA; [2] Flyer Research LLC; [3] Stanford University, USA; [4] MAVerick Analysis LLC

Forecasting the solar EUV irradiance over 1--7 day lead times is a key element of thermospheric density modeling used in Low Earth Orbit satellite navigation and collision avoidance planning. Current methods rely only on solar near-side observations or flux transport approximations for far-side estimations of magnetic activity (the underlying cause of EUV irradiance variability). Here we demonstrate that current forecasting methods have low skill and outline our plan for using machine learning (ML) models trained on SDO/HMI far-side helioseismic phase maps along with SDO/AIA EUV images to infer global solar EUV irradiance. This global irradiance approximation can then be virtually rotated to give more accurate 1--7 day forecasts of solar EUV inputs to the thermosphere. We demonstrate that our first stage ML model which regresses SDO/AIA images to the radio F10.7 index that is commonly used in current thermospheric density models is more accurate than multivariate linear regression methods since it

captures the nonlinear relationship between EUV irradiance and the F10.7 index.

---

Wednesday and Thursday Poster #31

## The Next Generation of Flare Irradiance Spectral Models: FISM-3 and FISM-AI

Phillip Chamberlin, S. Bahauddin, B. Schwab, E. Thiemann

LASP, Univ. of Colorado, Boulder, CO, USA

Version 2 of the Flare Irradiance Spectral Model (FISM2; Chamberlin et al., 2020) was released in Dec 2020 to model the solar ultraviolet spectral irradiance over time scales from solar flares (seconds to hours), active region emergence (hours to days), solar rotation (days to weeks), and solar cycle (months to years). FISM-3 will improve the accuracy of solar UV spectral irradiance modeling. Despite the significant improvement from the original FISM to FISM2, discrepancies remain between FISM2 and the measurements for which it is based. The specific objectives of FISM-3 are (1) to incorporate the Lumped Element Thermal Model (LETM; Thiemann et al., 2017) for the delay in flare peak emissions for different wavelengths, (2) adding the additional daily proxies of plasma Temperature and Emissions measures (Schwab, PhD thesis, 2022) (3) incorporate MinXSS-1/2/DAXSS soft X-ray measurements (4) incorporate the new routine measurements that are now available from the GOES/EUVS instrument (5) incorporate the ADAPT full-Sun magnetic field model, as well as relations of the photospheric magnetic field to irradiance, to drive a 'daily average' forecast of the UV solar spectral irradiance.
Additionally, with the maturation of artificial intelligence (AI), deep learning algorithms are becoming more transparent (explainable AI) and are ready to address outstanding issues in Heliophysics, one of which is the development of FISM-AI. The results of FISM-AI will be directly compared to measurements, when available, as well as to the improved FISM-3 model to see which of the different methods employed for FISM-3 and FISM-AI models works best.

---

Wednesday and Thursday Poster #32

## Improving Solar EUV Modeling with Non-Linear and Time-Dependent Techniques

Shah Mohammad Bahauddin [1], G. Keener [2], C. Peck [1], P., Chamberlin [1]

[1] LASP, CU Boulder, USA; [2] Department of Astrophysical and Planetary Sciences, CU Boulder, USA

Solar extreme ultraviolet (EUV) irradiance plays a critical role in driving the dynamics of planetary atmospheres and space weather phenomena. Traditional models often rely on linear assumptions and static proxies, which can oversimplify the intricate physical processes underlying solar EUV emission, such as non-equilibrium ionization during flare events. This talk emphasizes the need to integrate non-linear modeling techniques and temporal evolution to improve the accuracy and reliability of solar EUV irradiance modeling. By utilizing machine learning algorithms, time-dependent proxies, and non-linear parameterizations, we demonstrate methods to capture the complexities of dynamic transient events. Furthermore, the interplay between spectral lines formed in different regions of the solar atmosphere and their mutual contributions to the overall emission is examined. These explainable, physics-informed

machine learning models aim to bridge the gap between observations and predictive tools, enabling more robust forecasting of solar irradiance and its broader impacts on the heliosphere.

---

Wednesday and Thursday Poster #33

## Pi2 pulsation observed in the magnetosphere and on the ground.

omar elsebaei [1], Essam Ghamry [2]

[1] Beni Suef University; [2] National Research Institute of Astronomy and Geophysics, Helwan 11421, Cairo, Egypt

Pi2 pulsations are impulsive oscillations associated with magnetospheric substorm onsets. In this study, we investigate a geomagnetic Pi2 pulsation using the electric field data from the Van Allen Probe satellites (NASA' mission) in the magnetosphere, and on the ground. The Pi2 oscillations in the compressional components are investigated. We noticed a high degree of similarity between the properties of the Pi2 event measured in the magnetosphere and on the ground.

---

Wednesday and Thursday Poster #34

## OzSDO: the first database for the Solar Dynamics Observatory in the Southern hemisphere

Hannah Schunker [1], Simon O'Toole [2], Raymond Burston [1]

[1] University of Newcastle, Australia; [2] Macquarie University

NASA's Solar Dynamics Observatory (SDO), launched in 2010, is a monitoring mission capturing full disk images of the Sun at a number of wavelengths with unprecedented spatial and temporal resolution. The SDO has generated an enormous amount of data over its operational lifetime, making it necessary to store the data in a searchable database for efficient access. We have established the Australian Data Centre for SDO (OzSDO) a NetDRMS installation to archive and distribute data from the AIA and HMI instruments. The OzSDO primarily acts as a mirror for individual data series from the central SDO Joint Science Operations Center repository at Stanford. It currently contains the full meta-data for each of the HMI data series hmi.m_45s, hmi.v_45s, hmi.ic_45s, hmi.sharp_cea_720s, and aia.lev1, as well as the images for selected time periods under analysis. The hardware and infrastructure for the database is hosted at Australian Astronomical Optics Data Central at Macquarie University, and currently consists of a data server with 2 Intel Xeon Gold CPUs (32 cores), 128GB RAM, 20TB RAID5 HDD connected to a 216TB data array and a compute server with two 3.1GHz Intel Xeon Gold CPUs (32 cores total), 512GB memory, and an additional 3.8TB SSD local storage. Access to the OzSDO is available to researchers in the Centre for Solar and Space Physics group at the University of Newcastle (Australia), and externally upon request.

---

Wednesday and Thursday Poster #35

## Helioseismology from L5 with Vigil/PMI

Laurent Gizon, Sami K. Solanki, Jan Staub, and Vigil/PMI Team

Max Planck Institute for Solar System Research, Göttingen, Germany

Vigil is an ambitious mission in ESA's Space Safety program, which will place a spacecraft around the Lagrangian L5 point of the Sun-Earth system. A key instrument onboard Vigil is the Photospheric Magnetic-field Imager (PMI), a full-disc vector magnetograph and Doppler imager, developed with heritage from the Polarimetric and Helioseismic Imager (PHI) instrument on Solar Orbiter.
PMI employs a reflecting off-axis telescope design and samples the photospheric FeI absorption line at 617.3 nm using a solid-state LiNbO3 Fabry-Perot etalon. The polarization of incoming light is modulated by liquid crystal variable retarders and a linear polarizer, and the resulting images are captured by a 2k x 2k CMOS detector synchronized with the modulation. An image stabilization system, based on a limb sensor, ensures precise alignment, achieving a noise level of 0.001 of the continuum intensity, and allowing for the detection of line-of-sight magnetic fields as weak as 5-10 G.
Onboard processing will enable near-real-time inversion of the polarized radiative transfer equation to produce full-disc maps of the photospheric continuum intensity, the three components of the magnetic field vector, and the line-of-sight velocity of photospheric flows. The operational requirements for space weather monitoring demand a temporal cadence of 30 minutes at full spatial resolution with an onboard data latency of about 20 minutes. Additionally, the telemetry budget is expected to permit the transmission of lower resolution line-of-sight velocity images at a 1-minute cadence, for helioseismology applications.

---

Wednesday and Thursday Poster #36

## Getting Ready for the PLATO Mission

Laurent Gizon, Aaron C. Birch, and PLATO PDC Team

Max Planck Institute for Solar System Research, Göttingen, Germany

The PLATO (PLAnetary Transits and Oscillations of stars) mission, part of ESA's Cosmic Vision program, is designed to detect and characterize exoplanets around tens of thousands of bright (Mv < 11) solar-type stars using PLATO's 26 telescopes, with a particular focus on Earth-like planets in the habitable zones of Sun-like stars. A key feature of PLATO is its asteroseismology capability, which will provide tight constraints on stellar radii, masses, and ages. These measurements are critical for accurately determining the properties of exoplanetary systems, as well as for advancing our understanding of the solar-stellar connections.
To achieve these science goals, PLATO relies on an extensive Science Ground Segment (SGS), a distributed network of institutions and infrastructure dedicated to processing and validating mission data. The PLATO Data Center (PDC), a central component of the SGS and the highlight of this poster, is responsible for delivering the science data products, including calibrated light curves, planetary transit parameters, and the asteroseismically determined stellar parameters.The launch of PLATO by an Ariane 6 booster is planned for the end of 2026.

---

Wednesday and Thursday Poster #37

## Updates on capabilities supported by the Solar Data Analysis Center

Jack Ireland [1], Daniel Garcia Briseno [1,2], Alisdair R. Davey [3], Kasim N. Percinel [1,2], Andrew Inglis [1,4], Edmund Mansky [1,2], Paul R. Millard [1,2], Niles Oien [3], Jennifer L. Spencer [1,5], Arthur Amezcua [6], Marc R. Despres [1,2], Kyle Marshall [1,4], Seiji Yashiro [1,4], Michael Moore [1,7], Robert M. Candey [1], Tressa Helvey-Kalsulke [1,8], Lan Jian [1], Brian A. Thomas [1], Kaushal Patel [1,5], Ritika Prasai [1,9], Petrus A. Martens [10]

[1] NASA Goddard Space Flight Center, Greenbelt, USA; [2] ADNET Systems Inc., Greenbelt, USA; [3] National Solar Observatory, Boulder, USA; [4] Catholic University of America, Washington, DC, USA; [5] Telophase Corp., Greenbelt, USA, [6] Stanford University, Palo Alto, USA; [7] Business Integra, Bethesda, USA; [8] ASRC Federal Systems Solutions, Beltsville, USA; [9]KBR, Greenbelt,USA; [10] Georgia State University, USA

The mission of the Solar Data Analysis Center (SDAC) is to support the analysis of solar physics data. This presentation will give progress reports on SDAC-supported services that are being updated to improve the provision and exploration of solar physics data, including SDO data.
The first progress report regards progress being made in rewriting and re-implementing the Virtual Solar Observatory (VSO). The rewrite takes advantage of modern web application frameworks and designs to create an infrastructure that is easier to maintain and develop. Coincident with this, experiments are ongoing on providing search and subsetting capabilities for petabyte-size data volumes when the data is stored as FITS files.
Secondly, this presentation will include a short description of the Helioviewer Project's experimental web application, gl.helioviewer.org. This application allows users to define and interact quickly with three-dimensional animations of the full-disk and coronagraph image data already available via other Helioviewer clients. This introduces a new, mobile-native, three-dimensional and interactive capability that only needs a browser to allow users to visualize and explore the many petabytes of SDO data.
Finally, a short discussion will be given on plans to improve data curation at the SDAC. This includes verification of conformity to FITS standards, data transfer management systems and feedback to mission data providers on their data.

---

Wednesday and Thursday Poster #38

## Future of observations of solar magnetic fields and helioseismology?

Alexei Pevtsov

National Solar Observatory

The importance of helioseismology and solar magnetic field measurements for heliophysics research, modeling, and space weather operations was emphasized in 2024 Decadal Survey “The Next Decade of Discovery in Solar and Space Physics”. However, some of the most important instruments currently in operation are aging rapidly. The Solar Dynamics Observatory (SDO) with HMI on-board was launched about 15 years ago. The NSF’s Global Oscillation Network Group (GONG) stations were in operation for 30 years (since 1995). What would happen if some of these instruments started failing, and what steps should the community be taking now to ensure a continuation of these critical observations? I will briefly review the current state in the fields of observational helioseismology and solar magnetography, outline some outstanding questions, and discuss projects currently under development including ngGONG.

Wednesday and Thursday Poster #39

## Investigating CME-induced coronal dimming using Virtual EVE spectrum recovered from AIA data

Vishal Upendran [1, 2], Meng Jin [2] James Paul Mason [3], Paul Wright [4]

[1] Bay Area Environmental Research Institute; [2] Lockheed Martin Solar and Astrophysics Laboratory; [3] Johns Hopkins University Applied Physics Laboratory; [4] University of Exeter

CMEs leave signatures in the stellar corona as a reduction in coronal intensity, often noted as coronal dimming. Recent studies demonstrate that coronal dimming signatures can be used to infer and put bounds on the properties of stellar CMEs (e.g., Loyd et al. 2022). This inference is driven by learning established from the studies of CME signatures in disc-integrated AIA EUV and EVE data (e.g., Veronig et al. 2021). However, the MEGS-A instrument onboard EVE failed in 2014, disabling statistical studies of CME-induced solar coronal dimming which would inform stellar CME-dimming associations. In this work, we have developed an AIA to full spectrum EVE translation method using vision transformers. We demonstrate the evaluation of this model on a testing set in terms of regular regression metrics and the first 3 moments of each spectral line. We apply this model to generate virtual EVE measurements for dimming events where no EVE data is available, and investigate the possible signatures in the input data captured by the model in terms of explainable AI methods. We shall present the results of these analysis for several dimming events, while also quantifying uncertainties in the predicted spectra. This work serves to demonstrate the application of a virtual spectrum generator for inferring properties in the absence of a working instrument, and helps build large sample dataset to inform stellar CME-induced dimming analysis.

Wednesday and Thursday Poster #40

## Numerical Simulations on Solar and Stellar CMEs: Eruptive vs Confined Events

Tong Shi [1], Meng Jin [2], Xianyu Liu [3]

[1] SETI Institute; [2] Lockheed Martin Solar and Astrophysics Lab; [3] University of Michigan

Coronal mass ejections (CMEs) are powerful eruptions of plasma and magnetic fields that play a significant role in stellar mass loss and influence the habitability of exoplanets. Observations of stellar flares without corresponding CME signatures suggest that a non-negligible fraction of stellar CMEs may be confined, likely due to their inability to escape the star's strong magnetic constraints. Successful stellar CMEs, however, can be extraordinarily energetic, emphasizing the need to differentiate between erupted and confined events and identify their distinct signatures. Here, we investigate the dynamics of successful versus confined CMEs under the Sun-as-a-star framework and extend these insights to stellar cases. We employ the Alfven Wave Solar Model (AWSoM) to perform global magnetohydrodynamic (MHD) simulations using SDO/HMI synoptic magnetograms and initiate CMEs with Titov-Demoulin (TD) flux ropes. Realistic spectral lines are synthesized using the SPECTRUM code to analyze spectral responses. Coronal dimming is used as a diagnostic proxy for CMEs, alongside comparisons of line profiles and differential emission measure (DEM) for erupted and confined cases. To extend this analysis to stellar

environments, we enhance the input magnetic flux and the flux ropes' initial magnetic energies. Preliminary results demonstrate the utility of spectral diagnostics in identifying and characterizing stellar CMEs, potentially providing observers with signatures to distinguish between erupted and confined events.

---

Wednesday and Thursday Poster #41

## Modeling Stellar EUV Irradiance: A Proxy-Based Approach Using FUV Spectral Analysis of Solar Analogs

Md. Soyed Ahmed [1], Shah Mohammad Bahauddin [2]

[1] Department of Electrical and Electronic Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh; [2] Laboratory for Atmospheric and Space Physics, University of Colorado Boulder, USA

The study addresses a fundamental challenge in observational astrophysics: the indirect estimation of stellar Extreme Ultraviolet (EUV) irradiance, which is obscured by interstellar absorption. By clustering stellar catalog data, 89 solar analogs were identified from a sample of 545 stars, further refined to 16 candidates based on spectral quality and relevance. Spectral fitting and baseline corrections were achieved using a Chebyshev Type I filter, offering finer alignment of Far Ultraviolet (FUV) data with established solar irradiance models, such as the Flare Irradiance Spectral Model (FISM). Linear and nonlinear regression techniques were both experimented with to create proxy relationships between FUV and EUV spectra. This systematic framework enables improved estimation of stellar EUV emissions, advancing our understanding of exoplanetary atmospheres and their habitability potential.

---

# Posters Displayed During the EUV Calibration Mini-Workshop on Friday

Please remember to put up your poster before the mini-workshop starts and to remove it before 4:30 pm MT on Friday. Posters can be placed on any open poster board.

EUV Calibration Workshop Poster

## Performance Update of PROBA2/SWAP

Elke D'huys [1], Dana Talpeanu [1] Kyllian Manes [2], Laurence Wauters [1], Marie Dominique, [1], Ingolf Dammasch [1]

[1] Royal Observatory of Belgium/STCE, Brussels, Belgium; [2] ELISA Aerospace School, Saint-Quentin, France

The Sun Watcher using Active Pixel System Detector and Image Processing (SWAP) is a compact EUV telescope aboard the PROBA2 spacecraft, designed to image the solar corona in a bandpass centered at 17.4 nm, corresponding to a temperature of approximately 1 million Kelvin. We have recently conducted a comprehensive reassessment of the instrument's performance. This includes evaluations of dark current, LED signal stability, flat-field evolution, dead-pixel behavior, and other key metrics. This presentation highlights the results of these analyses and their implications for ongoing scientific operations.

---

EUV Calibration Workshop Poster

## Performance Update of PROBA2/LYRA

Marie Dominique [1], Ingolf Dammasch [1], Laurence Wauters [1], Dana Talpeanu [1], Elke D'Huys [1], Kyllian Manes [2]

[1] Royal Observatory of Belgium/STCE, Brussels, Belgium; [2] ELISA Aerospace School, Saint-Quentin, France

The Large Yield Radiometer (LYRA) is a broadband, full-disk solar irradiance instrument that observes the Sun across four UV/EUV channels. Fifteen years post-launch, we have undertaken a comprehensive re-evaluation of the instrument's performance, including analyses of dark current, calibration LEDs, the behavior of its three redundant units, the spectral effects of contamination, cross-calibration, and more. This presentation details the findings of these analyses and explains how they are incorporated into LYRA's calibration procedures to ensure continued accuracy and reliability.

---

EUV Calibration Workshop Poster

## In-flight cross-calibration of HRI/EUI and AIA/SDO

Sergei Shestov [1], Andrei N. Zhukov [1], Frederic Auchere [2], David Berghmans [1], Jerome Loicq [3]

[1] Solar-Terrestrial Centre of Excellence–SIDC, Royal Observatory of Belgium, Brussels, Belgium; [2] Institut d’Astrophysique Spatiale, Université Paris-Saclay, CNRS, Orsay, France; [3] Faculty of Aerospace Engineering, Delft University of Technology, Delft, Netherlands

The extreme ultraviolet High-Resolution Imager (HRI) of the EUI telescope onboard Solar Orbiter observes the solar corona in a ~5A passband near 174A with unprecedented high spatial resolution. We perform radiometric cross-calibration of the HRI and the EUV channels of the Atmospheric Imaging Assembly (AIA) telescope of the SDO in order to allow further mutual analysis of the observational data. We apply differential emission measure analysis using quasi-simultaneous images in 7 spectral channels – HRI and 6 AIA – and compare the real and the simulated images on the per-pixel basis across the mutual field-of-view. The comparison suggests that the real HRI images have a 60-80% larger signal than predicted by the DEM analysis. While the DEM analysis is known to be error-prone, a good re-production of EUI images justifies the approach. The observed difference in real/simulated signal suggests either AIA absolute calibration or EUI absolute calibration is off. We also found that adding the HRI signal to the AIA-based DEM inversion procedure brings information about moderate ~1MK plasma. We discuss how mutual observations can be used to better understand the physics of individual events or structures.