'UK Solar Physics Open Session (UKSolar)' Abstracts

Talks

Evaluating Quasi-Periodic Pulsations with STIX Observations

Authors

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Abstract

Solar flares are among the most energetic events in the solar system, releasing vast amounts of energy and driving significant space weather effects at Earth. While magnetic reconnection is widely accepted as the primary driver, the detailed physical processes governing energy release, particle acceleration, and their temporal variability remain poorly understood.
Recent X-ray and extreme ultraviolet observations have revealed quasi periodic pulsations (QPPs) in flare emission on timescales of tens of seconds to minutes, offering a potential diagnostic of the underlying energy release and modulation processes. However, establishing the significance of these signals is challenging due to the inherently stochastic nature of flare light curves. In this work using STIX X-ray observations from Solar Orbiter, we perform a rigorous statistical analysis of X-ray light curves to assess the significance and physical plausibility of these QPP signatures. Our approach incorporates the stochastic nature of flare time series, including appropriate coloured noise models and underlying probability distributions. We present several compelling examples of statistically significant QPPs from our analysis, which can shed light on flare models and inform future observations.

Vortices as Waveguides:Quantifying Vortex-Driven Inter-Layer Coupling in the Solar Atmosphere via SPOD and Granger Causality

Authors

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Abstract

Vortices are ubiquitous throughout the solar atmosphere and can form channels connecting different atmospheric layers. As they interact with magnetic fields, they can excite magnetohydrodynamic disturbances and facilitate energy transport. We investigate whether solar vortical tubes act as coherent waveguides and determine the nature of the waves and energy transport they sustain in the lower atmosphere.

Nonlocal thermal transport in solar flares

Authors

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Abstract

During solar flares, very large temperature gradients are formed, which in combination with the low density found within the solar corona, can lead to the temperature length scale becoming comparable to the mean free path within the plasma. Thus the local thermal conduction approximation can become invalid and the heat flux becomes suppressed and non-local. Using a non-local thermal transport model first derived in the context of laser plasmas, 2.5D MHD solar flare simulations are carried out to investigate the extent to which these effects change the evolution.

Non-local thermal transport influence on coronal loops with TNE

Authors

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Abstract

Thermal non-equilibrium (TNE) manifests itself as evaporation-condensation cycles in coronal loops. To locally trigger a condensation, the size of the perturbation should be comparable with the Field length, depending on the interplay between thermal conduction and net cooling in a coronal part of the loop. The effectiveness of classical Spitzer-H\"{a}rm (SH) thermal conduction makes the Field length comparable with the loop lengths for typical coronal parameters. However, under coronal conditions, the mean-free-path of electrons can no longer be assumed to be small in comparison to the temperature length scales. In this case, the thermal transport is non-local, and the (SH) approximation is violated. In this study, we compare the TNE cycles in coronal loops modelled with local and non-local thermal transport. To model non-local transport, we utilise the Schurtz-Nicolai-Busquet (SNB) model, which is widely used in laser-plasma studies and has been demonstrated to be the most accurate non-local model applicable on fluid timescales. Our results demonstrate that non-local transport leads to longer-period TNE cycles and the formation of smaller coronal rain clumps. In addition, the evolutionary trajectories in density-temperature phase space differ significantly between the SH and SNB models. These findings suggest that non-local thermal transport plays an important role in shaping the evolution of coronal loops undergoing TNE.

Solar activity and exoplanet hunting: how SDO data helps us understand stellar variability

Authors

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Abstract

As the precision and stability of our instruments improve, the intrinsic variability of host stars now represents the greatest barrier for the detection of small exoplanets and possible ExoEarths. Magnetic activity on the surface of stars generates signals in the radial velocities (RVs) that can mimic or hide the periodic signature of a planet. Solar data have proven to be invaluable in developing targeted mitigation techniques for Extreme Precision Radial Velocity (EPRV) surveys, offering both unparalleled cadence and baselines, and the opportunity to directly link spatially resolved solar phenomena to the variability they imprint in the RVs. In this context, I will present how data from the Solar Dynamics Observatory (SDO) has become one of the cornerstones of EPRV solar activity analysis. I will explain how the exoplanet community uses the SolAster pipeline to transform SDO resolved-Sun images into time series comparable to Sun-as-a-star ground spectrographs. I will also introduce a new method to study how solar magnetism affects disk-integrated line profiles, by generating disk-integrated Stokes profiles. This work provides a crucial benchmark for quantifying how different magnetic features shape spectral lines and impact extracted RVs.

Wave Generation via Oscillatory Reconnection at a Three-dimensional Magnetic Null Point

Authors

Luiz A. C. A. Schiavo (1), Gert J. J. Botha (1), James A. McLaughlin (1)

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Abstract

This work conducts a three-dimensional (3D), nonlinear magnetohydrodynamic (MHD) simulation to investigate wave-generating, time-dependent reconnection around a magnetic null point. A nonperiodic perturbation (in the xz-plane) triggers oscillatory reconnection (OR) at the 3D null, resulting in a self-sustained oscillation with a constant period P. We investigate the response of the system using three distinct wave proxies (compressible parallel, compressible transverse, and incompressible parallel) as well as spectral proper orthogonal decomposition for decoupling and analyzing the resultant MHD wave behavior. We find that OR generates a slow magnetoacoustic wave of period P that propagates outward in all directions along the spine and fan plane of the 3D null point. We also find the generation of a propagating Alfvén wave of period P, exclusively along the y-axis in the fan plane, i.e., in the direction perpendicular to the spine motion. These findings provide new insights into waves generated from a 3D null point and their implications for coronal seismology.

INSPEX: in situ electron spectral analysis for solar flare science

Authors

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Abstract

Solar flares are efficient particle accelerators, but the mechanisms driving this acceleration remain poorly constrained. Electrons escaping into the heliosphere following a flare carry signatures of their origin in their energy spectra, providing a counterpart to the population producing hard X-rays at the chromosphere. Comparative analysis of these two populations offers new constraints on where and how electrons are accelerated, but until now no in situ equivalent to the widely-used OSPEX X-ray spectral analysis software has existed for this purpose.

INSPEX (https://github.com/SamuelCarter42/INSPEX) is a new open-source Python tool that fills this gap, providing a graphical user interface for downloading, calibrating, and spectrally fitting in situ electron data. It currently loads data from Solar Orbiter SWA/EAS and EPD/STEP, combining them into a continuous spectrum spanning 0.5-78 keV, a range covering both the thermal and non-thermal electron regimes, and includes a cross-calibration factor to ensure a seamless join.

Applying this to the 09/10/2021 solar flare, we recover a two-component thermal distribution with temperatures of ~2.5 MK and 17-25 MK, consistent with corona/active region and flaring plasma temperatures observed by X-ray remote sensing (Carter et al. 2026, under review). This suggests the detected electrons may have passed through the hot flare region, providing a potential link between in situ and X-ray-emitting populations which previously was not established. This allows insight into whether the populations originate in the same region of the flare.

Beyond solar flares, INSPEX supports user-supplied spectra, making it adaptable across a range of heliospheric applications. We invite the community to engage with the tool, contribute instrument expertise, and help shape its development, expanding its reach to enable future multi-spacecraft studies of electron transport across the heliosphere.

Considering the Effects of Optically Thick Radiation on Cool Coronal Condensations

Authors
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Abstract
The formation of cool coronal condensations, such as prominences and coronal rain, in coronal loop structures through different processes (including thermal non-equilibrium cycles), has been studied at length. Whilst the trade-off between optically thin radiative losses (at high temperatures), and thermal conduction are key to forming these structures, as they cool below ~30 kK partial ionisation and optical depth effects become important. The former of these significantly reduces the pressure for a given mass density and temperature over what is predicted by the ideal gas law, whilst the latter can dramatically increase the radiative losses whilst out of equilibrium but also provide an energy source term potentially helping to stabilize structures.

Recent work has shown that in static radiative models, including the effects of non-equilibrium ionisation and optically thick losses in the cooling of these structures temporarily produces temperatures much cooler than those predicted by an instantaneous relaxation to ionisation equilibrium, before a slow reheating phase towards radiative equilibrium state. Here, we present initial 1D radiation hydrodynamic and 2.5D radiation magnetohydrodynamic models of cool coronal condensations considering detailed optically thick radiative losses and non-equilibrium ionisation. We discuss some implications for the stability of these structures as well as considerations for spectroscopic diagnostics.

Matching Solar Differential Rotation with Dynamo Models (Invited)

Authors

Valentin Aslanyan (1), Radostin Simitev (1), David MacTaggart (1)

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Abstract

Helioseismic inversions show homogeneous rotation in the radiative core of the sun and strongly varying differential rotation in its convection zone. Models of the solar dynamo, which self-consistently reproduce phenomena such as the sunspot cycle achieve varying success in also reproducing the differential rotation profile. We present metrics to evaluate the accuracy of a given model in this respect, and apply them to recent studies. We present parameter scans which optimize the differential rotation in an anelastic magnetohydrodynamic model.

Effect of a collisional heliospheric environment on simulated in-situ electron spectra

Authors

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Abstract

High-energy particles responsible for solar weather events at the Earth are known to be non-thermally accelerated in the solar corona, established through both remote hard X-ray (HXR) observations and in-situ measurements of high-energy particles. However, the plasma conditions and turbulent properties within the acceleration region(s) remain poorly constrained. One approach is to use in-situ energy spectra to provide diagnostics, as these spectra include signatures of collisional processes in the acceleration region as well as non-collisional transport effects throughout the heliosphere.

Most solar energetic particle (SEP) transport models neglect collisional scattering in the extended corona and heliosphere, citing the comparatively low plasma densities and the computational cost of including such effects. As a result, the degree to which collisions within the heliospheric shape in-situ observations is not fully understood.

In this work, we implement a continuous plasma environment extending from the base of a coronal acceleration region to 1 AU to establish the role of collisional transport beyond the corona. We show how these collisional effects modify the resulting in-situ energy spectra and assess the implications for using such spectra to infer source-region plasma properties, turbulence characteristics, and acceleration region locations.

Resonant cavity effects on slow wave spectra in the sunspot corona

Authors

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Abstract

Chromospheric resonances above sunspot umbrae have been measured in observational and numerical studies. The coronal power spectra of slow magnetoacoustic waves above sunspots have been attributed to the acoustic cut-off frequency, the chromospheric resonance cavity bounded above by the transition region, or a combination of both. It is well established that wave reflections with height in the lower sunspot atmosphere facilitate the formation of the resonant cavities. However, the connection between the wave driver, the cut-off frequency, and the resonant cavities remains unclear. We perform 2.5D magnetohydrodynamic numerical simulations on different slices of the same sunspot configuration to investigate the response of the systems to different monochromatic acoustic drivers as well as a single-pulse driver. The resonant cavity is identified to be in the upper chromosphere of the sunspot simulation setup. Single-pulse driving shows that the chromospheric resonance cavity excites a broadband of frequencies rather than a single dominant mode. In the case of monochromatic driving, the dominant resonant frequency is influenced by the driving frequency due to tunnelling effects. Continuous driving imposes an additional dominant frequency on top of the natural resonance, which is reflected in the overall shape of the coronal power spectra of slow waves. A two-dimensional investigation of the radial dependence between magnetic field lines in sunspot umbrae reveals cross-field communication between magnetic field lines within the resonance cavity.

Oscillatory reconnection and resonant response to wave excitation in 2D coronal null points

Authors
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Abstract
Magnetic null points are known sites of magnetic reconnection and wave generation in the solar atmosphere, and are associated with highly energetic phenomena, such as flares. In this work, we numerically explore the connection between the properties of oscillatory reconnection at coronal null points and the latter's nature as resonant cavities for waves. By perturbing null points located in the corona through simple propagating velocity pulses, we see the excitation of both periodic reconnection events and wave refraction around each null point. We find that each null point imposes frequencies on the reconnection matching those of the waves generated from the individual resonant cavity. These frequencies also differ from those excited by the low-frequency driving of the propagating pulses reaching the null points, with the driving frequencies lying outside the 95% confidence interval. As such, excited periodic reconnection can be characterised as oscillatory reconnection, i.e. with properties intrinsic to the null points. Finally, the generated waves at the null propagate across the domain, reminiscent of the observed quasi-periodic fast-propagating waves. The propagating waves generated at the resonant cavity can therefore provide us with a diagnostic tool for the reconnection process at the null point and the background coronal plasma conditions.

Automatic detection of Ellerman bombs in the Hα line

Authors

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Abstract

Ellerman Bombs (EBs) are small and short-lived magnetic reconnection events in the lower solar atmosphere most commonly reported in the line wing of the H-alpha line. These events are thought to play a role in heating the solar chromosphere and corona, but their size, short lifetime, and similarity to other brightenings make them difficult to detect. To remedy this problem, we developed a code that automatically detects these events using star-finding algorithms so that their properties can be studied in statistically significant numbers. Our code was used on ten high-resolution H-alpha datasets from the Swedish 1-m Solar Telescope (SST). This code identifies and follows EBs temporally while separating them from visually similar pseudo-EBs. It returns key parameters such as size, contrast, lifetime, and occurrence rates for over 2000 EBs, which are composed of nearly thirty thousand individual detections. In this presentation I will discuss this code, the statistics derived from the detections, and how they compare to previous manual studies.

Estimating Posterior Distributions of Solar Magnetic Field Strength via Bayesian Inference

Authors

Lewis J Dean (1), Stéphane Régnier (1), Maryam Garba (1), Gert Botha (1)

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Abstract

The magnetic field in the photosphere is observed by using data from the Solar Dynamics Observatory (SDO) via its Helioseismic and Magnetic Imager (HMI) magnetograph. These measurements are accompanied by instrumental noise including inversion process, leading to inaccuracy. Therefore, we aim to employ Bayesian inference to approximate this uncertainty onto pixels of the magnetogram to obtain an accurate measurement of the magnetic field. Bayesian inference is a statistical technique for estimating parameters given a chosen prior, likelihood and observational data/evidence. It then uses a Markov Chain Monte Carlo (MCMC) method, using a random walk until the parameter value convergences, to obtain a posterior distribution as the output. In this study, we analyse different types of likelihoods (given by different distributions) to determine the optimal distribution for representing the true magnetic field in solar active regions, including a comparison between the umbra, penumbra, plages and quiet-Sun regions. We then compare our findings to research with no approximation for instrument uncertainty, by comparing the inferred magnetic field strength posterior distributions, and the Solar characteristics (flux, field gradient, signal to noise ratio, structural entropy etc) to validate if higher accuracy has been achieved. We also analyse the Bayesian characteristics (Z-scores, residual heteroscedasticity, calibration, log-predictive density etc). Finally, we apply the inferred results, as a boundary condition, to 3D Cartesian potential field extrapolations.

Solar Flare Ion Temperatures

Authors

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Abstract

This talk argues that the ion temperature is several times the local electron temperature in the hot onset phase and in the above-the-loop region of solar flares. The talk considers:
(1) the evidence of spectral line Doppler widths ("nonthermal" broadening);
(2) evidence for "universal" ion and electron temperature increase scaling relations for magnetic reconnection in the solar wind, Earth's magnetopause, Earth's magnetotail, and numerical simulations; and
(3) thermal equilibration times for onset and above-the-loop densities, which are much longer than previous estimates based on soft X-ray flare loops.
We conclude that the ion temperature is likely to reach 60 MK or greater and that it may represent a substantial part of spectral line widths, significantly contributing to solving the long-standing issue of the excess nonthermal broadening in flare lines.

The signs of modern grand solar minimum (2020-2053) and its impact on terrestrial environment

Authors

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Abstract

The two Principle Components (eigen vectors) derived with Principle Component Analysis from the solar background magnetic field defining two largest magnetic waves of the poloidal field of the Sun are shown to be generated in two layers by the solar dynamo with the dipole magnetic sources. The two magnetic waves revealed a noticeable phase shift between them resulting in the variations of 11-year cycle amplitudes in the summary curve modulated by the envelope curve with a period of 330-380 years defined by the usual wave interference with a small phase shift. This envelope curve defines the grand solar cycles separated by grand solar minima (GSMs), similar to those observed in the past: Maunder, Wolf, Oort and other grand minima. There are the two modern GSMs approach-ing: GSM1 (2020-2053) and GSM2 (2375-2410). During a GSM a reduction of solar irra-diance is expected by about 3 W/m2 from the modern level that causes a decrease of the average terrestrial temperature by about 1.0C. This temperature reduction is already ob-served for the GSM1 clearly in the Northern hemisphere from the West to East signaling the arrival of Little Ice Age for GSM1.

Posters

Magnetic connectivity and photospheric flows associated with a C-class solar flare

Authors
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Abstract
A multi-layer analysis of a C-class flare observed on 1 July 2012 is presented using high-resolution Swedish 1-m Solar Telescope (SST) observations, SDO/HMI SHARP data, SDO/AIA imaging, and potential field extrapolations. The chromospheric structure, flare ribbon positions, polarity inversion line (PIL), photospheric velocity flows and rate-of-strain tensor are strongly co-spatial. They indicate that the flare occurred within a well-defined area of photospheric deformation. The extrapolated magnetic field lines are rooted across the PIL, with opposite footpoints embedded in distinct flow streams with different local strain environments. These field lines are spatially consistent with the chromospheric and ultraviolet flare ribbons observed in SST H-alpha and AIA 1700 A, linking the photospheric deformation to the overlying flare geometry. The combined observations strongly suggest that localised strain and shear flows around the PIL contribute to the magnetic field evolution before and after the flare. This event provides a compelling example of how fine-scale photospheric deformation can organise flare-relevant magnetic connectivity from the photosphere into the chromosphere and lower corona.