Waves and Instabilities in the Solar Atmosphere (WISA)

Monday 22 September 2025 - Saturday 27 September 2025

INAF, Osservatorio Astronomico di Roma

Book of Abstracts

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Invited Talk / 2

Observing the evolution of the Sun's global coronal magnetic field over 8 months

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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.

Travel support needed:

Sessions:

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Inferring the Polarisation of Coronal Standing Kink Oscillations Using CoMP

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Understanding the polarisation state of coronal waves is key to constraining wave displacement and velocity amplitude, improving estimates of wave energy flux and deposition. We present a novel method to infer the polarisation of a standing kink oscillation in a coronal loop from a single viewpoint, using combined spectral and imaging data from the Coronal Multi-channel Polarimeter (CoMP). CoMP's unique capabilities enable simultaneous observation of Doppler velocity, intensity, and line width for the entire corona, allowing us to track the motion of a loop perturbed by an eruption which excites a kink oscillation. Tracking the loop apex, we extract the line-of-sight velocity and plane-of-sky displacement, combining them to construct the loop's phase portrait in velocity space. Our analysis reveals a horizontally polarised kink mode with an oscillation period of 8.9 ± 0.5

minutes, in a plane tilted $-13.6^{+2.9}_{-3.0}$ degrees from the plane of sky. We also detect a periodic enhancement in line width at both the kink period and its harmonic. This double peak feature matches predictions of torsional Alfv\'en waves or shear flow-induced eddies at the loop boundaries, and suggest potential energy dissipation through wave-induced turbulence or resonant coupling. These results highlight the power of combined imaging-spectral analysis for probing wave dynamics and pave the way for deeper insights into energy transport in the solar atmosphere.

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Multi-Height Wave Analysis of Sausage, Kink, and Fluting Modes in a Solar Pore

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Magnetic pores act as conduits for magnetohydrodynamic (MHD) waves, facilitating energy transport through the solar atmosphere. While Grant et al. (2015) identified upwardly propagating sausage-mode oscillations, and Albidah et al. (2020,2023) and Jafarzadeh et al. (2024) demonstrated the power of Proper Orthogonal Decomposition (POD) in analysing wave dynamics, a detailed breakdown of wave energy partitioning across modes as they move upward through the lower solar atmosphere remains unexplored.
In this work, we apply POD to high-cadence, multi-height observations of a solar pore (Continuum 4170, G-band, Na I D, Ca II K, H-alpha) to quantify the relative energy contributions of sausage, kink, and fluting modes at different atmospheric heights.
By analysing the convex hull points of the pore boundary at each height, we isolate spatially coherent oscillatory structures and track their evolution. The mode-dependent partitioning of energy provides insights into wave coupling and dissipation processes, with implications for mode conversion as density and magnetic field strength vary with altitude (Riedl et al. 2021).
Additionally, we investigate the temporal frequencies of these modes, investigating whether the chromospheric 3 mHz signal is driven by direct p-mode leakage or nonlinear mode coupling. We employ the WaLSA tool repository for advanced spectral analysis, demonstrating its utility in characterizing multi-height wave evolution. This study represents a step toward a more complete observational picture of wave propagation, mode conversion, and energy transport in the lower solar atmosphere.

Travel support needed:

Sessions:

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Evolution of the Rayleigh-Taylor Instability in a Slab Model of a Horizontal Magnetic Flux Sheet

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Abstract
The evolution of the magneto-Rayleigh-Taylor instability (MRTI) in a slab model of an isolated horizontal magnetic flux sheet embedded in a two-layer atmosphere with different densities and temperatures is investigated using the 2.5D magneto-hydrodynamic (MHD) code AMRVAC.
In the solar context, this two-layer model serves as a simplified representation of the photosphere/chromosphere interface. The horizontal flux sheet, initially representing a solar prominence anchored between two sunspots, is located in the high-density, low-temperature layer, satisfying the MRTI conditions under a constant gravitational acceleration. The magnetic field is primarily horizontal (Bx = 14 G), which constrains the development of perturbations along this direction. Ideal MHD is assumed. The instability is primarily driven by the buoyancy force, which causes the denser plasma to sink while the lighter plasma rises. As the instability develops, mushroom-shaped descending structures form as heavy plasma slides downward, while buoyant bubbles rise due to the lower density and the restoring magnetic pressure. This process amplifies the deformation of the interface, further enhancing the instability. In the nonlinear regime, the buoyancy-driven sinking magnetic structures reach a velocity of approximately 4 km/s, moving almost vertically until they reach the photosphere. The interaction of these descending flux tubes with the photosphere could influence the formation of penumbral structures by altering the local magnetic field topology and plasma flows.

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3D Wavelet Method for Analysis of Propagating Waves in Solar Prominence

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On 26 September 2022, a quiescent solar prominence was observed using Hα imaging spectroscopy with SDDI on SMART. Previous studies found 4- and 15-minute oscillations with limited spatial coverage. We extend this to the full prominence using 3D wavelet analysis, comparing with SDO/AIA, STEREO-A/EUVI, and Solar Orbiter/EUI data for a tomographic view.
We examine oscillatory power from 3 to 64 minutes across plasma at different temperatures and viewpoints to assess wave propagation.
We analyze SDO/AIA, STEREO-A/EUVI, Solar Orbiter/EUI, and ground-based SDDI/SMART Hα observations, combining Doppler velocities and EUV intensities at 304 Å and 174 Å.
We confirm persistent propagating waves with periods from 4 to 64 minutes, strongest in Hα and 304 Å in the prominence's core. Weak 4-minute and rapid 30-second oscillations occur near the solar surface in Doppler data. Vertical motions, kink waves, and transient short-period oscillations point to complex internal dynamics and possible coupling with photospheric 5-minute oscillations.

Travel support needed:

Sessions:

Seismology of solar and stellar atmospheres

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Kink instability of partially ionized plasma jets in the solar atmosphere

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We analyze the stability of chromospheric jets by investigating the Kelvin-Helmholtz Instability (KHI) in partially ionized plasma. Emphasizing the role of ambipolar diffusion, we explore how stability varies with the degree of ionization and compute KHI growth times for various conditions. A magnetic slab model with linear perturbation theory for incompressible, single-fluid MHD is used to derive a general dispersion equation for non-aligned jets. Partial ionization effects are incorporated through the generalized Ohm's law, introducing ambipolar diffusion via Cowling conductivity. Since ambipolar diffusion is considered only within the jet, the continuity condition for the tangential electric field is omitted, while pressure continuity is modified. Analytical solutions reveal that chromospheric jets can become KH unstable even below the classical velocity threshold when ambipolar diffusion is included.

Travel support needed:

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Equilibrium models of solar prominence thin threads

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Solar prominences are composed of thin threads that outline particular magnetic field lines of the prominence structure. Observations have shown the presence of Alfvénic waves in threads, which are probably driven at the photosphere. Wave dissipation could be a relevant heating mechanism in prominences. In this work, we construct 1D equilibrium models of partially ionized prominence threads that satisfy an energy balance between radiative cooling, thermal conduction and, optionally, Alfven wave heating. The obtained models have a cold region, corresponding to the thread itself, an extremely thin prominence-corona transition region, and a coronal region. The properties of the equilibria are explored by performing a parameter survey. For instance, the thread length decreases with increasing central temperature. When wave heating is included, we find that the thread length increases with the wave energy flux, and no equilibrium is possible when the wave heating rate is larger than radiative losses at the thread core. Additionally, the effects of gravity and the magnetic field geometry are investigated.

Travel support needed:

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Wave generation, energy transport, dissipation and heating

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Probing spectral line asymmetries due to the propagating transverse waves in the solar corona

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Decades-long studies of asymmetric spectral lines observed in the solar corona and the transition region point to mass and energy transport from the lower layers of the solar atmosphere to the corona. Slow magnetoacoustic waves and jets (plasma upflows) are considered to be the two possible drivers for these spectral line asymmetries. However, due to insufficient multiwavelength observations and the low spatial and spectral resolution of the current instruments, spectral line asymmetries due to the propagating transverse MHD waves have yet to be observed. We present evidence of the spectral line asymmetries caused by the transverse MHD waves propagating in the inhomogeneous plasma in the solar corona. We performed 3D MHD simulations and forward modeling for the Fe XIII (1074.9 nm) emission line. We also explored the possibility of observing these line asymmetries using modern ground-based facilities such as DKIST.

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

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Gravity Waves in the Lower Solar Atmosphere: Observational Perspective

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Gravity waves are generated by turbulent subsurface convection overshooting or penetrating locally into a stably stratified medium. While propagating energy upwards, their characteristic negative phase shift over height is a well-recognized observational signature. Since their first detailed observational detection and estimates of energy content, a number of studies have explored their propagation characteristics and interaction with magnetic fields and other wave modes in the solar atmosphere. We investigate the solar atmospheric gravity waves dispersion diagrams utilizing intensity observations that cover photospheric to chromospheric heights over different magnetic configurations of quiet-Sun (magnetic network regions), a plage, and a sunspot as well as velocity observations within the photospheric layer over a quiet and a sunspot region. In order to investigate the propagation characteristics, we construct two–height intensity - intensity and velocity –velocity cross-spectra and study phase and coherence signals in the wavenumber - frequency dispersion diagrams and their association with background magnetic fields. In this talk, I will discuss the impact of magnetic fields on the propagation of gravity waves in the lower solar atmosphere.

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Conditions for Solar Prominence Formation Triggered by Single Localized Heating

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We performed numerical simulations to study mechanisms of solar prominence formation triggered by a single heating event. In the widely accepted "chromospheric-evaporation condensation"model, localized heating at footpoints of a coronal loop drives plasma evaporation and eventually triggers

condensation through the development of thermal instability. The occurrence of condensation is strongly influenced by the characteristics of the heating. Various theoretical studies have been conducted along one-dimensional field lines with quasi-steady localized heating. The quasi-steady heating is regarded as the collection of multiple heating events among multiple strands constituting a coronal loop. However, it is reasonable to consider a single heating event along a single strand as an elemental unit to investigate the onset of thermal instability in isolation.
We investigated the condensation phenomenon triggered by a single heating event using 1.5-dimensional magnetohydrodynamic simulations. By varying the magnitude of the manually imposed localized heating rate, we explored the conditions necessary for condensation. We found that, when a heating rate approximately $\sim 10^4$ times greater than that of steady heating was applied, condensation occurred. Condensation was observed when the thermal conduction efficiency in the loop became lower than the cooling efficiency, with the cooling rate significantly exceeding the heating rate. Using the loop length L and the Field length λ_F, the condition for condensation is expressed as $\lambda_F < L/2$ under conditions where cooling exceeds heating. We extended the analytically derived condition for thermal nonequilibrium to a formulation based on heating amount.

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Coronal Density Fluctuations in the Middle Corona Observed by Metis

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The Metis coronagraph on board Solar Orbiter allows observations of the middle solar corona at spatial resolutions that can rival or surpass those attained by other operating coronagraphs over a field of view going from 1.6 to 3.4 degrees, corresponding to the range 1.7 - 3.6 solar radii at perihelion. The instrument is also capable to observe the corona at high temporal cadences - down to 20 s - for extended observing runs, or down to 1 s for a few minutes.
Since the beginning of the mission nominal science phase in 2022, these capabilities have been utilized to obtain observations that are opening a new window on the dynamics of the solar corona in a range of previously unexplored parameters. I present and discuss, in particular, the detection of density fluctuations in the corona above 2 solar radii with characteristic periods in the range 3-5 minutes.

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Sessions:

Wave generation, energy transport, dissipation and heating

Invited Talk / 13

Baroclinic instabilities in Alfvénic modes

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The nonlinear evolution of Alfvénic modes (torsional, kink, or fluting modes) in magnetic flux tubes is strongly affected by the Kelvin-Helmholtz (KH) instability, which arises from shear flows at the tube boundary. In this study, we show that baroclinic instabilities of Rayleigh-Taylor (RT) type can also emerge at locations in the boundary where the plasma acceleration is directed normal to the boundary. This mechanism plays a significant role in the evolution of fluting modes, leading to the formation of RT-like arrowhead structures alongside the KH-induced vortices and rolls. The concurrent growth of both instabilities is marked by the oscillating nature of the shear flows and the normal acceleration. The interplay between these instabilities introduces complex turbulent dynamics, which may influence the efficiency of resonant damping.

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Uniturbulence and Alfven wave solar heating model (UAWSOM)

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The coronal heating problem and the generation of the solar wind remain central challenges in solar physics, both of which require a detailed understanding of wave-based heating mechanisms. In this study, we investigate the turbulent cascade of kink and Alfv\'en wave energy and its role in heating the solar atmosphere and driving the solar wind, through a newly implemented physics module in MPI-AMRVAC called UAWSOM. We assess the heating efficiency of kink waves in comparison to traditional Alfv\'en waves which necessitate an anomalous background heating function for numerical stability. We demonstrate that kink wave driven (UAWSOM) models forgo this requirement by demonstrating that a stable coronal atmosphere can be maintained using only kink waves.

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Automatic detection of oscillations on Solar Orbiter EUV images using spectral techniques: Preliminary results

Author: Guillem Castelló i Barceló[1]

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Spectral (periodogram) analysis has proved effective for identifying oscillatory behavior in Hα solar filament observations. In this preliminary study, we apply recent periodogram-based frameworks—those of Luna et al. (2022) and Castelló et al. (2025)—to extreme-ultraviolet (EUV) image sequences from the Solar Orbiter mission. Adopting a Bayesian inference approach with a red-noise background model, we will evaluate whether periodic signals can be robustly detected across the full field of view. Our primary goal is to determine the feasibility of these techniques for automatic oscillation detection and spatial characterization in EUV time sequences, thereby eliminating the need for manually placed analysis slits. The outcomes will inform the development of a systematic, data-driven pipeline for mapping solar oscillations in high-resolution EUV datasets.

Travel support needed:

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Fast-to-Alfvén wave transformation in partially ionized plasmas with shear flows

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We theoretically investigate the interplay between magnetohydrodynamic (MHD) waves and shear flows in a partially ionized solar plasma, focusing on the energy exchange mediated by the flow and the transformation between wave modes. We consider a simple model composed of a uniform partially ionized plasma with a straight magnetic field. A shear flow is present in the direction of the magnetic field with a velocity that varies linearly across the magnetic field. The linearized MHD equations in the single-fluid approximation are used, which include the ambipolar diffusion term due to ion-neutral collisions. A nonmodal approach is adopted, in order to convert the flow spatial inhomogeneity into a temporal one, adding a temporal dependence into the component of the wavevector in the direction of the flow inhomogeneity. A system of three ordinary differential equations is derived, which generally governs the temporal evolution of the coupled MHD waves, their interaction with the shear flow, and their ambipolar damping. Numerical solutions are computed to study the coupling and mutual transformation between the fast magnetosonic wave and the Alfvén wave. A detailed parameter study is conducted, demonstrating how the energy transfer and mode transformation are affected. The role of ambipolar diffusion is investigated by comparing the results of the ideal case with those obtained when ambipolar diffusion is included. It is found that ambipolar diffusion can significantly affect the efficiency of the energy exchange between modes and introduces a new coupling mechanism. Additionally, a specific application to solar prominence threads is included, showing that wave coupling and energy exchange can occur within these and other similar structures in the solar atmosphere.

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Diagnosis of MHD Waves in the Solar Plages

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The plages are strong magnetic field regions, and they frequently appear as bright intensity patches (in the chromosphere) around sunspots. The high-resolution spectroscopic observations are used from the Interface Region Imaging Spectrograph (IRIS), and magnetic field observations from Helioseismic and Magnetic Imager (HMI) are used to diagnose the waves in an active-region (AR) plage. We have deduced the Doppler velocity time-series from some spectral lines (e.g., Fe I, Mn I, Mg II k2r, Mg II k2v, Mg II k3), and these lines are forming at different heights from the photosphere to the chromosphere. The wavelet analysis is applied to the deduced doppler velocity time series to estimate global wavelet power (GWP) from each spatial location of the solar plage. Further, we exclude those periods from GWS that have the wave power less than the 95% significance level, and then, the first and last periods of the GWS spectrum are termed as the minimum and maximum periods, respectively. Next, we estimate the dominant (first peak) period of the GWS spectrum, i.e., a period corresponding to the maximum power peak. Note that around half of the spatial locations of the solar plage have one more peak, therefore, we estimate the period corresponding to the second peak in GWS, i.e., the second peak period. We estimate the minimum period, maximum period, first peak period, and second peak period from each location of solar plage, and produced histograms for each category of these periods. Through this methodology, we estimate the mean period and standard error for each category of periods. It is found that the mean of the minimum, first peak, and second peak periods are decreasing linearly with height. While the mean of the maximum period does not show any correlation with the atmospheric height. We further investigated the relationship of these periods with the strength of the magnetic field, and it was found that these periods increase with the strength of the magnetic field.

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Is Thermal Instability Instrumental to Coronal Rain Formation?

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The state of coronal loops essentially depends on the complex interplay between plasma flows, gravity, heating, radiative cooling and conduction. Numerical simulations show that, under the influence of a steady or quasi-steady footpoint heating, coronal loops can be in a state of thermal non-equilibrium (TNE), characterised by a localised thermal runaway that leads to the formation of cold and dense condensations. While earlier studies identified thermal instability (TI) as the primary mechanism behind coronal rain formation, its role has been questioned recently, particularly since the advent of TNE-focused studies. The main aim of this study is to identify the importance of TI in the context of coronal rain formation. Through a normal mode analysis (NMA), we investigate the role of thermal instability in driving coronal rain formation, probing for a deeper understanding of this mechanism in the context of the solar corona. After our analysis, it becomes evident that, while TNE functions as a large-scale, global process within coronal loops, TI tends to manifest locally, revealing a nuanced relationship between spatial and temporal dynamics.

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Infrared spectropolarimetry of a C-class solar flare footpoint plasma

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We performed full Stokes spectropolarimetric observations of loop footpoints in the active region NOAA 13363 during a C-class flare with the GREGOR Infrared Spectrograph (GRIS) on 2023 July 16. The observed spectral region included the photospheric Si I 10 827 A and Ca I 10 839 A lines and the chromospheric He I 10 830 A triplet. Simultaneously, high-cadence and high-resolution imaging observations were carried out with the improved High-resolution Fast Imager (HiFI+) in the Ca ii H line and TiO bands. The observations were conducted under excellent seeing conditions, as confirmed

by the Fried-parameter measurements. Speckle-restored HiFI+ Ca II H images revealed thin flare-related filaments and diffuse haze-like emissions, further confirmed by background-subtracted solar activity maps (BaSAMs), which localized chromospheric variability near the sunspot. The He I triplet showed enhanced emission during the flare events and developed intense red- and blueshifted components, with the decisive shift of 90 km s−1, suggesting the significant energy release and plasma motion triggered by the flare. Simultaneously, a delayed increase in the Si I line wing intensity was observed approximately 6 minutes after the He I emission, suggesting that the upper photosphere experienced secondary heating, possibly due to thermal conduction rather than energetic particles. This time delay and spatial correlation support a scenario where dynamic flare processes influence chromospheric and upper photospheric layers.
Our results demonstrate a temporal and spatial coupling between chromospheric and upper photospheric regions, and the time delay rules out direct heating by flare accelerated electrons, so we propose thermal conduction or ionization effects as possible mechanisms.

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Wave generation, energy transport, dissipation and heating

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Magnetohydrodynamic Wave Modelling in the Solar Wind and their Observational Consequences

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Magnetohydrodynamic (MHD) waves are ubiquitous in the solar atmosphere and are key in many models for seismological or energy conversion processes. With the help of modern coronagraphs on board missions such as Solar Orbiter, Aditya-L1 and PROBA-3, it is now possible to study wave dynamics in the extended solar atmosphere in unprecedented detail. In our work, we aim to provide context to such observations using MHD modelling of waves in an extended solar atmosphere, studying their propagation in open and closed-field regions such as coronal holes and helmet streamers, respectively. Our model includes important physics such as spherical expansion, gravitational stratification, thermal conduction, radiative cooling, and a background wind that transitions from being sub-Alfvénic to super-Alfvénic. MHD wave energy can be dissipated via processes such as phase mixing. Together with ponderomotive forcing, this can perturb the local density and temperature. Additionally, our modelling provides estimates about how much of the wave energy can be trapped between density inhomogeneities. Such a large-scale model allows us to track wave dynamics, the formation of small scales and energy dissipation rates as wave fronts propagate from the Sun out into the solar wind.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

21

Uncommon frequencies in the lower solar atmosphere

Author: Michele Berretti[1]

Co-authors: Marco Stangalini [2]; Gary Verth ; Viktor Fedun [3]; Shahin Jafarzadeh [4]; David Jess [5]; S. D. T. Grant ; Timothy Duckenfield [5]; Francesco Berrilli [6]

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The general understanding of oscillations in the Sun's atmosphere is that the photosphere is dominated by the global resonant modes of the entire stellar structure at 3mHz, while, moving upwards to the chromosphere, the dominant period shifts to 5mHz. However, the availability of stable and seeing-free coverage of the Sun for more than 15 years thanks to NASA's Solar Dynamics Observatory (SDO) allowed us to carry out the largest statistical studies of the dynamics of magnetic structures in the photosphere. In our work, we tracked the horizontal perturbations of more than 1 million "small-scale"magnetic concentrations in the photosphere spanning a whole solar cycle and found a dominant frequency of 5mHz, unexpected at such heights. Furthermore, the analysis of the line-of-sight velocity of nearly 1 thousand sunspots highlighted the presence of statistically significant power in the 4-6mHz band. Understanding the origin of these frequencies, more commonly associated with chromospheric heights, is a challenging task that will require joint observation from multiple observatories, the help of numerical simulations and novel tools capable of working with the large datasets available. Our findings provide a timely avenue for future exploration of the magnetic connectivity between sub-photospheric, photospheric, and chromospheric layers of the Sun's dynamic atmosphere.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

Invited Talk / **22**

Shining light on the formation process of cool plasma

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Prominences are cold and dense structures in the hot and tenuous solar corona and are ubiquitous on the Sun. They possess thermodynamic conditions that vary from chromospheric internally to those of the corona that surrounds them. Even though predominantly in the corona, they connect all the layers in the solar atmosphere and play an important role in the energy transfer between the different layers. There are multiple theories explaining how prominences form [1], and capturing evidence of each of these processes in observations has been notoriously difficult. In this study we focus on the formation via the so-called evaporation-condensation process. This implies heating, localised at the footpoints of the magnetic loop, which leads to an increase in density in the loop and then to radiative cooling. We investigate this process using a new technique to calculate synthetic spectra based on state of the art MHD simulations. We perform a numerical simulation using an open-source, MHD code, MPI-AMRVAC [2,3,4] whose details are described in [5] and where we showed the effects of various localised heating profiles on the characteristics of the newly formed condensation. Now, we create synthetic spectra of the particular moment of plasma condensation - hot, tenuous plasma turning into cold and dense prominence plasma. At the same time, we look at an IRIS observation that shows condensations that appear to be forming in a similar manner to those in the simulation. Using the synthetic spectra created with the non-LTE spectral framework Lightweaver [6] we compare the properties of the spectra we find in the simulation with those from the observation.

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[5] Jercic, V., Jenkins, J. M. , Keppens, R., 2024, A&A, 688, A145
[6] Osborne, C. M. J. & Milić, I., 2021., ApJ, 917(1), 14

Travel support needed:

Sessions:

Instabilities

23

Joint action of phase mixing and nonlinear effects in MHD waves propagating in coronal loops

Authors: Claudio Meringolo[None]; Fabio Feraco[None]; Fabio Reale[None]; Francesco Malara[1]; Francesco Pucci[None]; Gabriele Cozzo[None]; Giuseppe Nisticò[None]; Paolo Pagano[None]; Tom Van Doorsselaere[None]

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The evolution of Alfvén waves in coronal loops can be affected by phase mixing and turbulent cascade. Both processes contribute to the dissipation of the bulk energy of the waves through the generation of small spatial scales. Different regimes can be envisaged according to how timescales of the two processes are related and to the typical dissipative timescale. We investigate the interplay of phase mixing and the nonlinear turbulent cascade in the evolution and dissipation of Alfvén waves using compressible magnetohydrodynamic numerical simulations. We consider perturbations in the form of torsional waves, both propagating and standing, or turbulent fluctuations, or a combination of the two. The main purpose is to study how phase mixing and nonlinear couplings jointly work to produce small scales in different regimes. We find that phase mixing takes place for moderate amplitudes of the turbulent component even in a distorted, nonaxisymmetric configuration, building small scales that are locally transverse to the density gradient. The dissipative time decreases with increasing the percentage of the turbulent component, both for propagating and standing waves. Even in the fully turbulent case, a mechanism qualitatively similar to phase mixing occurs, which generates small scales together with the nonlinear cascade, thus providing the shortest dissipative time. General considerations are given to identify this regime in the parameter space. The turbulent perturbation also distorts the background density, locally increasing the Alfvén velocity gradient and further contributing to accelerating the formation of small scales.

Momenta of the line-of-sight velocity component are calculated from simulation results,corresponding to emission from the spectral line Fe IX at 171 Å. 2D maps perpendicular to the assumed line of sight are calculated for the emission intensity, the Doppler shift and the non-thermal broadening, for several values of the model parameters. The presence of transverse oscillations is clearly visible in Doppler shift maps, in particular the effect of phase mixing at the loop borders. Non-thermal broadening is mainly located at the loop boundary. Spectra of momenta are also calculated and compared with spectra of density and velocity fluctuations derived from simulations. Results are discussed in the perspective of a forward modeling of observations of fluctuation dynamics in coronal loops, in particular by MUSE spacecraft.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

24

Thermal instability and the thermal continuum in coronal configurations

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Despite its extremely high temperature, the Solar corona features many cooler structures, like prominences and coronal rain. The root cause of the formation of cool and dense plasma is a thermal runaway effect, in which the plasma density increases in response to a decrease in temperature due to radiative cooling, in turn enhancing the radiative cooling effect again. This thermal instability can be triggered when a combination of radiative cooling, heating, and thermal conduction modifies the stable entropy mode into an unstable thermal continuum of highly localised modes. Performing a linear stability analysis, we show how the thermal continuum arises in a stratified atmosphere and 1D coronal loops, as well as how it is replaced with a quasi-continuum in a resistive medium and interacts with tearing instabilities in a current sheet. For the latter configuration, we simulate how the coupled tearing-thermal evolution behaves non-linearly.

Travel support needed:

Sessions:

Instabilities

25

Using Solar Pore Shapes to Extract Horizontal Velocity Profiles

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Solar pores unlike Sunspots are difficult to analyse, due to being much smaller in size, the absence of a penumbra and its shape evolution appearing more unstable, giving no fixed boundary of the pore. By using shape analysis tool Deformetrica created by Bone et al (2018), we can fix grid points over the shape of the pore and track the changes as it evolves over time. By doing this, we can extract the horizontal velocity profile of the pore, which we can use for various different analysis, such as combining with magnetic field and line of sight (los) velocity of the same dataset around the pore to derive the poynting flux, or potentially applying Proper Orthogonal Decomposition (POD) to verify any oscillatory behaviour.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

27

Observation of Alfven Wave Reflection in the Solar Chromosphere: Ponderomotive Force and the First Ionization Potential Effect

Authors: Mariarita Murabito[1]; Martin Laming[2]

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We investigate the propagation of Alfven waves in the solar chromosphere, distinguishing between upward and downward propagating waves. We find clear evidence for the reflection of waves in the chromosphere and differences in propagation between waves interpreted to be resonant or nonresonant with the overlying coronal structures. This establishes the wave connection to coronal element abundance anomalies through the action of the wave ponderomotive force on the chromospheric plasma, which interacts with chromospheric ions but not neutrals, thereby providing a novel mechanism of ion-neutral separation. This is seen as a "First Ionization Potential Effect" when this plasma is lifted into the corona, with implications elsewhere on the Sun for the origin of the slow speed solar wind and its elemental composition.

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

Invited Talk / 28

Coronal kink oscillations and photospheric driving

Author: Nicolas Poirier[1]

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Transverse kink oscillations have long been observed in the corona and in closed magnetic loops especially. Although their properties are quite well-known now it is still rather unclear how they manage to sustain themselves over quite a long duration, with open questions regarding their driver and excitation mechanism. In this talk I will give an overview over the different ideas/theories that discuss the role of photospheric driving in the generation of kink oscillations. Unique observation datasets are exploited, coordinated between the Solar Orbiter (SolO) mission and the Swedish 1-m Solar Telescope (SST), providing high-cadence and high-resolution diagnostics in the photosphere, chromosphere and corona. A quantification of the photospheric dynamics is made at the footpoint of oscillating coronal loops using SST/CRISP data. A link is then made with the properties of the coronal loop oscillations detected in SolO/EUI/HRI images. Finally, I will discuss the implications of this work on the driving and excitation mechanism of kink oscillations, and future perspectives.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

29

Propagation of MHD waves in inhomogeneous media at the solar atmosphere.

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The dynamic behavior of the solar atmosphere remains one of the most relevant open problems in solar physics, especially regarding energy transport and dissipation. For this reason, the propagation of magnetohydrodynamic (MHD) waves has been used to describe phenomena such as the heating of the solar corona. However, most studies have focused on homogeneous media, even though the solar plasma presents significant inhomogeneities in density, pressure, and magnetic field.

This work proposes to study how these inhomogeneities affect the propagation of linear MHD waves, both in free media and in magnetic flux tubes. The analysis will focus on variations in the wave morphology, their efficiency in energy transport, and the redistribution of energy into kinetic energy, enthalpy, and Poynting flux. The methodology includes the selection of realistic inhomogeneity profiles and the solution of the linearized MHD equations through numerical simulations using the MAGNUS code. Different oscillation modes and boundary conditions will be evaluated to represent typical solar scenarios. This study will help to understand how plasma gradients influence the observable properties of MHD waves, contributing to the improvement of existing theoretical models and facilitating the interpretation of data obtained by high-resolution solar missions.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

30

Atmospheric Gravity Waves in the Magnetized Lower Solar Atmosphere

Author: Oana Vesa[1]

Co-authors: Julio Morales [2]; Jason Jackiewicz [2]; Gangadharan Vigeesh [3]; Kevin Reardon [4]

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Atmospheric gravity waves (AGWs) are low-frequency, buoyancy-driven waves generated by turbulent convection in the lower solar atmosphere. In addition to their role as energy agents and coupling atmospheric layers, simulations showcase their sensitivity to the average magnetic field topology. Using multi-height IBIS/DST and HMI/SDO velocity and magnetic field 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 independent observations, theory, and COBOLD numerical simulations. Using the data derived from HMI SHARP vector magnetograms and moving away from the traditional k-ω diagnostic diagram, we disentangle the effects of the magnetic field on their behavior. We show that AGWs are suppressed and/or reflected in regions of vertically inclined intermediate to large magnetic fields ($|B| > 30$ G) in the upper photosphere. At the same time, they propagate unhindered in quiet-Sun transverse fields, in line with COBOLD numerical simulations. This highlights their potential as novel diagnostics for probing the upper photospheric magnetic field.

Travel support needed:

Sessions:

Seismology of solar and stellar atmospheres

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Apparent and actual damping of 3-min slow waves along individual umbral fan loops

Author: Girjesh R Gupta[1]

Co-author: Ananya Rawat

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Coronal fan loops rooted in sunspot umbra constantly show a 3-min period propagating slow magnetoacoustic waves (SMAWs) in the corona (upper solar atmosphere). Using the recently devised technique of Rawat & Gupta (2023), we trace these loops along with their cross-sectional area with height from the photosphere to the corona via the transition region and chromosphere (lower solar atmosphere). We estimated the relative amplitude and energy flux of propagating 3-min SMAWs in the lower and upper solar atmosphere along the fan loops. We obtained their damping length of 208 km and 4.3 Mm in the lower and upper atmosphere, respectively. We further investigated the role of the area expansion of these loops on the damping of these SMAWs. We deduced the decay of total wave energy content within the loop cross-sectional area with height and estimated the damping length to be 303 km in the lower atmosphere. Henceforth, we present the first report on the actual damping of SMAWs after incorporating the geometric effect of area expansion of the loops. Findings reveal that the area expansion of loops with height plays an important role in the damping of these waves in the lower atmosphere, while the effect is negligible in the upper atmosphere. These actual damping lengths can be utilized to investigate the dominant damping mechanisms in the lower (photosphere to corona) and upper solar atmosphere (corona).

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Dynamics of Vortical Networks and it's Evolution: from Photosphere to Corona

Author: Lauren McClure[1]

Co-authors: Suzana S. A. Silva [1]; Gary Verth [2]; Istvan Ballai [2]; Viktor Fedun [1]

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Vortices are ubiquitous in the turbulent upper solar atmosphere, acting as key drivers of energy, mass, and momentum transport from the photosphere through the chromosphere and into the corona. By examining how vortices influence each other rather than treating them as isolated phenomena, we find that highly interconnected "vortex communities"can arise. With their degree of interconnectedness defined by the velocity one vortex induces on another.

In this presentation, we focus on these community centroids, their evolution in time, and the overall induced velocity field at the centroids —comparing it directly with the velocity field. The total induced velocity field offers valuable insight into the effects of the vortices on the system, providing tangible understanding of the way in which vortices may effect the velocity field of the turbulent intergranular lanes. We also identify particularly influential vortices within these communities and discuss how their properties differ from others in the system.

Finally, we explore the merging and splitting of vortex communities, shedding new light on the broader solar plasma dynamics and offering us a foundation to investigate the merging and splitting of vortex tubes. Specifically, we consider how these communities evolve as we move up through the upper solar atmosphere. Understanding the merging of vortex tubes as they ascend through the chromosphere provides insight into their persistence and potential contribution to coronal heating. This approach may also help predict which vortices remain coherent through different atmospheric layers and contribute to the global velocity field evolution.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

34

Probing the magnetic field and plasma-β along individual umbral fan loops using 3-min slow waves

Author: Ananya Rawat[1]

Co-authors: Girjesh R Gupta [2]; Krishna Prasad Sayamanthula [3]; Tom Van Doorsselaere [3]; robertus erdelyi [4]

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Coronal fan loops rooted in sunspot umbra constantly show 3-min period propagating slow magnetoacoustic waves (SMAWs) in the corona. However, the origin of these waves in the lower solar atmosphere is still unclear. Here, we present the results of our study of these waves along a clean fan loop system using multi-wavelength imaging observations from IRIS and SDO. We demonstrate a novel observational technique to trace the origin of these waves at the photosphere by utilizing amplitude and frequency modulations of 3-min waves from the corona to the photosphere via the transition region and chromosphere. These modulation periods are in the range of 20–35 min at all the heights. Tracing of these loops also provides observational evidence of cross-sectional area expansion of the loops from the photosphere to the corona. We utilized this information to estimate the magnetic field strength and plasma-β along isolated individual loops emanating from the sunspot umbra. We find the RMS magnetic field strengths in the range 1596-2269 G at the photospheric footpoints of the fan loops decrease rapidly to 158-236 G at the coronal footpoints. We estimated the plasma-β at the photospheric and coronal footpoints in the range 0.2-0.5 and 0.0001-0.001, respectively. We found plasma-β 1 along the whole loop, whereas the plasma-$\beta \approx 1$ layer is found to be at sub-photospheric heights. We compared our findings for isolated individual fan loops with a previously established model for active regions and found an almost similar pattern in variations with height, but with different plasma-β values. Our results demonstrate the seismological potential of 3-min slow waves omnipresent in the umbral sunspot atmosphere to probe and map isolated loops along with their cross-sectional area and determine the magnetic field and plasma-β along these loops.

Travel support needed:

Sessions:

Seismology of solar and stellar atmospheres

Invited Review Talk / 35

Wave theories and modelling in the lower solar atmosphere

Author: Gary Verth[1]

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In this talk I will review recent progress and the remaining challenges in both modelling and analysing observed magnetohydrodynamic (MHD) waves in the lower solar atmosphere. To model waves in sunspot umbrae, we have had to go beyond the standard cylindrical flux tube model due to the irregular shapes of the MHD waveguides. For sunspots the umbra/penumbra boundary shape is reasonably static over the time scales of oscillations of interest. This makes solving the eigenvalue problem for MHD wave modes in sunspots tractable because of the assumption of time independent boundary shape conditions. However, the same cannot be said about pores that have highly dynamic boundary shape changes. I will highlight recent progress that has been made in this very challenging area of research.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

36

Coronal Wave–Prominence Interaction and Induced Prominence Dynamics

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In this talk, we present results from 2.5D MHD simulations of a solar eruption, the propagation of coronal waves through a non-uniformly magnetized solar corona, and their interaction with remote flux rope prominences, leading to induced prominence dynamics. The initial atmosphere is a non-adiabatic, gravitationally stratified corona permeated by a magnetic field composed of two main components: (1) a 2.5D catastrophe field responsible for triggering the eruption and coronal wave, and (2) a dipolar field used for the subsequent formation of flux rope prominences. Our simulations reveal the formation of a secondary front when the wave produced by the eruption encounters the equipartition layer. The main front steepens into a shock as the wave propagates farther from the eruption site. When reaching the prominence region, the wave generates reflected and transmitted fronts. The wave impact excites complex prominence oscillations, both along the magnetic field and in the vertical direction. Furthermore, the downward push from the wave front triggers magnetic reconnection beneath the prominence flux rope. To improve the comparability of our results with real observations, we generated synthetic images in the 131 Å, 193 Å, and 304 Å SDO/AIA channels.

Travel support needed:

Sessions:

Seismology of solar and stellar atmospheres

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A unified picture of swirl-driven coronal heating: magnetic energy supply and dissipation

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The outermost layer of the solar atmosphere is referred to as corona, of which temperature is hundred times hotter than the surface while the ultimate heat source locates at the inner core. The solar coronal heating problem is one of the most critical challenges in solar physics. Recent advancements in observational accuracy have revealed numerous facts that cannot be explained by the conventional classical model of solar coronal heating. Among these, small-scale swirls, whose diameters are comparable to the current instrumental limits, are observed at the top of the convection zone. They have been highlighted as a potential new source of magnetic energy supply to the corona. However, the overall contribution of swirls to the total magnetic energy supply to the corona remains uncertain. Additionally, theoretical model capable of deriving the magnetic energy dissipation caused by swirls has yet to be established. To address this, we conducted statistical analyses using radiative magnetohydrodynamic simulations that consistently solve the system from the convection zone to the corona. We investigated the statistical properties of magnetic energy supply and dissipation caused by swirls in a unified framework. Our results reveal that swirls account for approximately half of the total magnetic energy supplied to the corona and can trigger magnetic reconnection, achieving magnetic energy dissipation consistent with observed heating signatures.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

Poster Viewing / 38

GATES: A New Network for Synoptic Space Weather Observations

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We can deduce the activity and dynamic status of the Sun and its possible dependence on the magnetic cycle using continuous, multi-height observations of the solar atmosphere. Furthermore, multi-height observations allow us to probe the propagation of magneto-acoustic-gravity waves through the solar atmosphere, potentially providing insight into other solar phenomena, such as the heating of the upper chromosphere/corona and space weather events such as flares. To investigate these phenomena, we describe the design and construction of a multi-nodal synoptic telescope network (GATES: Global Automatic Telescopes Exploring the Sun) to continuously observe the entire disk of the Sun. This network currently comprises two instruments: the Tor Vergata Solar Synoptic Telescope (TSST), undergoing testing at Università degli Studi di Roma Tor Vergata, to be mounted in La Palma, Canary Islands, Spain, and the Mojave Solar Observatory (MSO) located in Apple Valley, California. These telescopes are based off of previous Magneto-Optical Filter (MOF)-based telescopes such as the Magneto-Optical filter at Two Heights (MOTH) which performed multiple successful observing campaigns. TSST consists of a dual-channel full disk telescope, a lab-tested K MOF channel and an Hα channel for flare detection and localization. MSO houses a dual Na and K channel magneto-optical filter (MOF)-based telescope currently able to observe on-sky. We show that this network consists of low-cost, robotic facilities able to achieve the necessary data for the study of space weather events and investigate the propagation of magneto-acoustic gravity waves. We present preliminary data obtained using the GATES'nodes, technical specifications for the future operation of the network, and potential science questions the GATES data aims to investigate.

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

40

Merging plasmoids and nanojet-like ejections in a coronal current sheet

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Forced magnetic reconnection is triggered by external perturbations, which plays a crucial role in the energy release during solar transient events, that are often associated with the disintigration of electric current sheets (CSs) through tearing instability. The instability in the CS is triggered by imposing impulsive velocity perturbations concentrated at different locations in the upper half along the CS plane. This leads to the formation of plasmoids and their later coalescence. We demonstrate that a transition from purely 2D reconnection to 2.5D reconnection with guide field takes place at the interface between the plasmoids as the latter evolve from the pre-merger to the merged state. The small-scale, short-lived, and collimated outflows during the merging process share various physical properties with nanojets. The subsequent thermodynamic change within and outside the merged plasmoid region is governed by the combined effect of Ohmic heating, thermal conduction, and expansion/contraction of the plasma.

Travel support needed:

Sessions:

Invited Review Talk / 41

Shocks and instabilities in the partially ionised solar atmosphere

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Observations of the Sun reveal a rich array of dynamics throughout all levels of the solar atmosphere. In many cases. the observed dynamic motions are driven by the magnetic field. However, the lower solar atmosphere, i.e. the photosphere and chromosphere, is a partially ionised plasma, with most of the species being neutral. This means that the driver of the fluid motions cannot directly influence the fluid itself, this only happens through the interaction of neutral and charged species. In this talk I will look at an important areas of research into partially ionised plasma dynamics, relating to MHD shocks and instabilities, which are of particular relevance to our understanding of the dynamic solar atmosphere. For shocks, the neutral fluids decouples from the magnetic field in the shock front, creating a broad shock transition that contains substructure in which multi-fluid effects manifest. For instabilities, partial ionisation is found to change the growth rate and the effects of non-linear transport. These two ideas can come together with partial ionisation changing how the stability properties of non-linear waves. To date studies using two fluid models are often highly idealised, but progress is being made to look at more realistic settings. I will review some of the recent advances.

Travel support needed:

Sessions:

Invited Review Talk / 42

From the Core to the Solar Atmosphere: Advances and Frontiers in Helioseismology

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Helioseismology has revolutionised our understanding of the Sun's internal structure and dynamics, offering unparalleled insights into processes hidden beneath the solar surface. In this review, I will summarise key developments in global and local helioseismology, including recent advances in determining large-scale flows in the solar interior. I will highlight the current status of refining solar models due to revised elemental abundances, and recent advances in time-distance and ring-diagram methods for mapping subsurface magnetism, providing context for active region formation. I will also discuss the emerging frontiers in helioseismology, such as connecting seismic signatures to solar activity and space weather, or the study of Rossby Waves. Finally, I will outline how new missions and observations promise to extend the diagnostic power of helioseismology and address outstanding challenges at the interface of waves, instabilities, and magnetic fields in the solar atmosphere.

Travel support needed:

Sessions:

Seismology of solar and stellar atmospheres

43

Introducing IBIS2.0: Updates to the Interferometric BIdimensional Spectrometer

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IBIS2.0 is the updated edition of the Interferometric BIdimensional Spectrometer(operated at the Dunn Solar Telescope of the National Solar Observatory from 2003 to 2019). The enhancements include a new optomechanical design, an upgraded polarimetric unit, and a new array of high-performance cameras, all aimed at improving the instrument's capability to capture high-resolution spectropolarimetric data of the solar atmosphere in the 580-860 nm spectral range. While the instrument's core remains the same, with two tunable Fabry-Perot interferometers working in tandem with a set of narrowband interference filters and the polarimetric unit to acquire high-resolution spectropolarimetric data of the solar atmosphere, a new control software is being developed to automate and remotely operate the instrument. With the manufacturing in the pipeline and the testing underway, we look forward to starting the installation of IBIS 2.0 at the Teide Observatory in 2025 based on the signed MOU. We report the current status of the project and the observation possibilities that the upgraded instrument will offer.

Travel support needed:

Sessions:

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Importance of non-local thermal transport for coronal plasma physics

Author: Sergey Belov[1]

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Under coronal conditions, especially in flaring loops, 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 classical Spitzer–Härm (SH) approximation is violated. Here, we consider two scenarios in which the effects of non-local thermal transport are important. The first scenario is the solar atmosphere's response to a localised heating event, and the second one is an evolution of standing slow waves, which are commonly observed in post-flaring loops. To model non-local transport, we utilise the Schurtz–Nicolaï–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 time-scales. In the first scenario, we simulate a 1D flare-heated loop and find that the SNB model yields a markedly different density–temperature evolution than the SH model. Specifically,

the SNB model leads to higher apex temperatures and lower densities, with a more localised and intense temperature peak during energy deposition. In the SNB case, the heat flux suppression reduces chromospheric evaporation, resulting in lower post-flare densities. In the second scenario, using 1D models of standing slow waves, we show that non-local thermal conduction modifies wave damping by suppressing the isothermal regime. Depending on loop parameters, this can lead to damping times that differ by up to 80% from classical predictions. In conclusion, our results indicate the importance of non-local conduction in various solar phenomena. The SNB model has the potential to improve the realism of coronal simulations.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

45

Propagating slow magnetoacoustic waves as probes of magnetic field geometry in the solar corona

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Propagating slow magnetoacoustic waves, observed as intensity disturbances in coronal extreme ultraviolet (EUV) emission, are powerful tools for magnetohydrodynamic (MHD) seismology. Their dispersive properties, phase speeds, and damping behaviour enable diagnostics of coronal plasma conditions, including magnetic field geometry. Using quasi-stereoscopic data from the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) and the High Resolution Imager in EUV (HRIEUV) onboard Solar Orbiter, we investigate how projected propagation speeds can constrain the local direction of magnetic field lines within several feathers of a plasma fan in a coronal active region. This dual-instrument approach allows us to capture the same coronal structures from two vantage points, expanding our 2D projected view into a 3D understanding of slow wave-hosting waveguides. By determining slow wave parameters across neighbouring fan structures, we aim to characterise fine-scale variations in wave properties and relate them to the underlying magnetic topology. This study highlights the potential of combining fine-scale seismology with multi-viewpoint imaging to infer the three-dimensional structure of the solar corona, constraining and validating other magnetic field estimation methods such as potential field extrapolation.

Travel support needed:

Sessions:

Seismology of solar and stellar atmospheres

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On the reliability of Local Correlation Tracking for inferring photospheric vortex flows in high-resolution observations

Author: Shivdev Turkay[1]

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Vortex flows in the solar photosphere are ubiquitous and are thought to channel energy into the upper solar atmosphere in the form of Poynting flux and excitation of Alfv\'{e}n waves. However, observing photospheric intensity vortices is challenging due to their small size and the fact that the flow field is primarily parallel to the plane-of-sky. Despite this, a large number of photospheric intensity vortices have been observed by applying Fourier Local Correlation Tracking (FLCT) to high-resolution observations. Validating these detections raises two questions: i) Are changes in photospheric intensity a suitable proxy for tracking the plasma velocity field? ii) Are the statistics on the observed properties of photospheric vortices accurate, given a significant number of vortices are considered to remain unresolved by most instruments? To address these questions, we compare observations from the Daniel K. Inouye Solar Telescope (DKIST) with a synthetic observation produced by a radiative magnetohydrodynamic MURaM simulation. We employ FLCT to infer the velocity field from the observations and use the Γ-functions method to identify and track the properties of vortices therein. We find a discrepancy between the number of vortices identified in the DKIST observation, the synthetic observation, and the plasma properties derived from the simulation. Here, we compare the simulated and inferred velocity fields and outline the potential implications of the validity of FLCT. This research draws important conclusions on the photospheric intensity vortices with further consequences on the expected energy transfer to the upper solar atmosphere.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Investigating Chromospheric Waves and Flows in a Giant Spiral Structure using SST CRISP

Author: Yash Saneshwar[1]

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Twisted magnetic fields in the solar chromosphere are thought to give rise to a plethora of MHD waves and flows, enabling mass and energy channelling from the photosphere to the corona. Here we report on the statistical properties of observations of waves and flows in an apparently stable but relatively large-scale spiral structure (herein referred to as a "giant spiral"), close to disk centre, in H-alpha 656.3nm line core images, from the Swedish 1-m Solar Telescope (SST) CRisp Imaging SpectroPolarimeter (CRISP) instrument. The observations are analysed using CRISPEX in conjunction with a loop tracing algorithm called OCCULT2, allowing us to trace 100s of magnetic loops forming the giant spiral. Extracted magnetic loops are then read into a new edge detection code to investigate the true nature of field aligned flows and waves. We are interested in the relation between loop curvature and the properties of the waves and flows. We report on the correspondence between hot signatures in the (E)UV images of the lower corona and high frequency waves

and flows in curved loops in the chromosphere, using co-spatial and co-temporal observations in the (E)UV with observations taken from the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA).

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

Invited Talk / 48

Tracing the Flow of Energy in Coronal Hole Solar Wind

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The 2024 total solar eclipse over North America provided a multi-perspective view of the Sun and solar wind through combined ground (DKIST, Mauna Loa Solar Observatory UCoMP and K-Cor) and space (Parker Solar Probe, Solar Orbiter, LASCO/C2, Hinode/EIS) -based remote and in situ observations. Through a multi-mission coordinated effort, we examine near-contemporaneous and multi-wavelength observations of the corona to derive detailed plasma conditions and magnetic field properties used to compute an energy budget of an equatorial coronal hole. The remote properties of nascent coronal hole wind are connected to its heliospheric counterpart sampled by Parker Solar Probe and Solar Orbiter during a fortuitous spacecraft alignment. Together, the Alfvén wave, enthalpy, kinetic, and gravitational energy fluxes of a single high speed solar wind stream can be traced from deep in the corona (subsonic regime), across the Alfvén surface to its super-Alfvénic state, providing critical constraints to the mass and energy flow in the atmosphere of our star.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

50

Explaining the Observed-Theoretical Mismatch in AGW Diagnostics via Inclined Magnetic Field Effects

Author: Julio Morales[1]

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Atmospheric gravity waves (AGWs) are buoyancy-driven waves generated by overshooting turbulent convection in the vertically stratified solar atmosphere. These waves are of particular interest

due to their potential role in mediating the energy balance of the chromosphere. AGWs are typically analyzed through k-ω diagnostic diagrams, which are interpreted by comparison with theoretical models accounting for stratification and radiative damping. However, a longstanding discrepancy exists: observed diagnostic diagrams often deviate significantly from predictions using these over-simplistic models. Previous theoretical work has shown that in the presence of inclined magnetic fields, AGWs can exhibit a range of consequential behaviors, including reflection, non-linear wave breaking, and mode conversion into Alfvén waves and fast/slow magnetoacoustic modes. In this study, we derive solutions to the full 3D MHD dispersion relation in order to qualitatively and quantitatively reproduce observed k-ω diagnostic diagrams of AGWs. We then use these magnetic dispersion solutions to infer average field strength and inclinations in the lower chromosphere, over the spatial and temporal scales corresponding to the observations of AGWs. These inferred field parameters are compared with co-temporal and co-spatial Helioseismic and Magnetic Imager (HMI) magnetograms. This work provides a compelling explanation for the longstanding mismatch between AGW observations and theory and offers a novel method for indirectly probing chromospheric magnetic field properties via wave diagnostics.

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

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Exploring the Link Between Wave Activity in the Photospheric Velocity Driver and the FIP Bias in the Solar Corona

Author: Andrea Mesoraca[1]

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This work investigates wave activity on the Solar Photosphere in the presence of active regions, aiming to explore a possible connection with a phenomenon observed in the Solar Corona: the First Ionization Potential (FIP) effect. This effect refers to a chemical inhomogeneity in the solar atmosphere, where elements with low first ionization potential are preferentially transported to higher atmospheric layers. It is often associated with the reflection of magnetohydrodynamic waves (Laming [2017]). Building on previous studies by Murabito, M. et al. [2021] and Baker et al. [2021], which focused on a single active region over a short period, this study extends the analysis by following the evolution of active regions during their entire transit across the solar disk. This approach provides a broader temporal perspective, rarely addressed in this context. We analyze the propagation of high-frequency waves in the photospheric velocity field, with particular attention to active region 12665, observed for six consecutive days in July 2017. During the same period, sixteen FIP bias maps are available from the EIS instrument aboard the Hinode satellite. By monitoring active regions throughout their disk passage, we aim to better understand the temporal evolution of their wave dynamics and how these may contribute to elemental fractionation in the upper solar atmosphere. The results may offer new insights into the mechanisms behind the FIP effect and the role of photospheric activity in shaping coronal properties.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

Poster Viewing / 52

The application of artificial neural networks to identify oscillations in the solar corona

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The explosive increase in observational data from ground- and space-based instruments highlights the need for automated detection techniques capable of detecting the phenomena of interest in a large amount of data for a reasonable time. Nowadays, Artificial Neural Networks (ANN) demonstrate such a capability. In this study, we demonstrate how artificial neural networks can be used to detect oscillatory phenomena in time series and imaging data. First, we trained the Fully Convolution Network (FCN) to detect exponentially decaying harmonic Quasi-Periodic Pulsations (QPP) in flare lightcurves. For this purpose, we generated 90,000 synthetic flare lightcurves with and without QPP. After training, the FCN showed an accuracy of 87.2% on the synthetic test data and did not experience overfitting. Then, the FCN was tested on real data, including the Kepler flare catalogue, comprised of 2274 events. The latter resulted in a 7% QPP detection rate with a probability above 95%. Next, we implemented a CNN–LSTM hybrid model to detect transverse (kink) oscillations in coronal loops using imaging data. The model demonstrated ~95% accuracy on synthetic loop datasets. The model's performance is being tested on real solar observations to ensure its robustness. These results highlight the potential of ANN-based tools for automated preprocessing and initial classification of solar oscillatory events, enabling faster and more scalable analysis of large observational archives.

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

Invited Talk / 53

Vortex Flows and associated Waves in the Solar Atmosphere

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Solar vortex flows are rotating plasma structures widely detected in direct solar observations as well as comprehensive numerical simulations. We investigate and compare vortex dynamics in three magnetic regions, viz., Quiet Sun, Weak Plage, and Strong Plage, using realistic three-dimensional simulations from a comprehensive radiation-magnetohydrodynamics (MHD) code, MURaM. We find that the spatial extents and spatial distribution of vortices vary for different setups, even though the photospheric turbulence responsible for generating vortices has similar profiles for all three regions. We investigate kinetic and magnetic swirling strength and find them consistent with the Alfven wave propagation. Using a flux tube expansion model and linear MHD wave theory, we find that

the deviation in kinetic swirling strength from the theoretically expected value is the highest for the Strong Plage, least for the Weak Plage, and intermediate for the Quiet Sun at chromospheric heights. It suggests that Weak Plage is the most favoured region for chromospheric swirls, though they are of smaller spatial extents than in Quiet Sun. We also conjecture that vortex interactions within a single flux tube in Strong Plage lead to an energy cascade from larger to smaller vortices that further result in much lower values of kinetic swirling strength than other regions. These findings indicate the potential of vortex-induced torsional Alfven waves to travel higher in the atmosphere without damping for weaker magnetic regions, such as the Quiet Sun, whereas vortices would result in dissipation and heating due to the vortex interactions in narrow flux tubes for the strongly magnetized regions, such as Strong Plage.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Wave Analysis Tools

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Wave phenomena are key to diagnosing the solar atmosphere, from chromospheric magnetoacoustic oscillations to Alfvénic waves in the corona. Yet, interpreting these complex signals depends critically on choosing the right analysis methods —a non-trivial task given the multi-dimensional, non-stationary nature of solar data and the diversity of available techniques. In this presentation, we highlight insights from our recent *Nature Reviews Methods Primers* article (https://WaLSA.tools/nrmp), which offers a systematic comparison of widely used wave analysis tools and underscores the importance of matching method to data characteristics and science goals. Building on this work, we present **WaLSAtools** (https://WaLSA.tools) —an open-source software library developed by and for the solar community —which implements a range of reproducible, well-tested techniques suited to the unique challenges of solar wave research. Originally motivated by wave dynamics in the lower solar atmosphere, **WaLSAtools** is continually evolving to support both established and emerging methods, with a focus on accessibility, transparency, and cross-disciplinary collaboration. This presentation outlines the toolkit's capabilities, practical examples from solar datasets, and our vision for building a robust, shared platform for wave analysis in solar physics.

Full author list: Shahin Jafarzadeh, David B. Jess, Marco Stangalini, Samuel D. T. Grant, Jonathan E. Higham, Martin E. Pessah, Peter H. Keys, Sergey Belov, Daniele Calchetti, Timothy J. Duckenfield, Viktor Fedun, Bernhard Fleck, Ricardo Gafeira, Stuart M. Jefferies, Elena Khomenko, Richard J. Morton, Aimee A. Norton, S. P. Rajaguru, Luiz A. C. A. Schiavo, Rahul Sharma, Suzana S. A. Silva, Sami K. Solanki, Oskar Steiner, Gary Verth, Gangadharan Vigeesh & Nitin Yadav

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

Invited Review Talk / 55

Novel diagnostic techniques for detecting MHD wave modes in the solar atmosphere

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Over the past few years, multi-line spectropolarimetry has revolutionized diagnostic capabilities, enabling the accurate identification of MHD modes in diverse structures and assessing their contributions to the energy budget of the solar atmosphere. In this presentation, I will illustrate the potential of these diagnostic techniques through the analysis of several illustrative cases. Furthermore, I will explore the synergistic application of these techniques with simplified models. In conclusion, I will outline several potential enhancements that can be driven by next-generation solar instrumentation.

Travel support needed:

Sessions:

Novel diagnostic techniques and forward modelling

Invited Talk / 56

Vortical Dynamics in the Solar Atmosphere: Mechanisms of Wave Generation and Energy Transport

Author: Suzana S. A. Silva[1]

Co-authors: Viktor Fedun [1]; Istvan Ballai [2]; Gary Verth [2]

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The solar atmosphere is a dynamically turbulent and magnetically organised environment, where waves and flows are central to energy transport. Among the features shaping this complexity are solar vortices—localised, rotating structures that span multiple spatial and temporal scales. This talk focuses on how vortices influence wave propagation and energy redistribution, particularly in the upper atmosphere, where they may facilitate magnetohydrodynamic (MHD) wave activity and localised dissipation. Conceptual and methodological challenges in capturing multi-scale, multi-modal wave–plasma interactions in structured magnetic environments will also be discussed.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

Invited Review Talk / 57

Wave observations in the solar atmosphere

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Within the last decade, solar physics has moved into a golden era of discovery. A diverse assortment of ground- and space-based facilities have helped make rapid progress in the detection, identification, characterisation and understanding of dynamic oscillatory motions spanning the entire solar atmosphere. Combined modelling efforts have resulted in a number of outstanding science questions that can only be addressed with more advanced instrumentation and/or larger aperture telescopes. Here, I will outline some of the recent discoveries linked to observations of wave activity in the solar atmosphere that have only been made possible using high-resolution instrumentation. I will bridge these newfound results into overarching science questions in solar physics, before highlighting how current facilities and next-generation instruments can shine light on these challenging problems.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Tracking waves in the solar atmosphere using a next-generation integral field unit

Author: Glen Chambers[1]

Co-authors: David Jess [2]; Marco Stangalini [3]; Michele Berretti [4]; Shahin Jafarzadeh [5]

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In the ever-evolving field of instrumentation for solar physics, the need for high cadence simultaneous observations at high resolutions in both the spatial and spectral domains is undeniable. To successfully achieve such measurements requires the implementation of contemporary technology, with integral field units (IFUs) offering a clear path. Here, we present a novel fibre-fed variation of an IFU, FRANCIS, that offers insights beyond the typical wavelength range of typical solar physics IFUs, extending from the near-ultraviolet to mid-optical regions, covering 390 −700 nm. Key spectral lines that can be extracted from this region include Ca II H/K, Na I D1/D2, H-beta and Sr II. The benefit of using a fibre-fed IFU can be found in its remapping of a two-dimensional cross-section fibre array to a one-dimensional array, fed into a Czerny-Turner spectrograph for spectral measurements of up to 20 per second. Such a construction provides the opportunity for observers to obtain hyperspectral images of the Sun at high temporal cadences. We present fully processed data from recent active region observations using both the FRANCIS IFU and the ROSA imaging system at the Dunn Solar Telescope covering the Ca II H/K and Na I D1/D2 Fraunhofer lines. By carrying out wave analysis on this data, with the assistance of WaLSA.tools, we will showcase wave propagation and the variation of energy fluxes across the upper photosphere and chromosphere within the vicinity of a sunspot umbra.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Delta-Function-like Condensation Modes in Thermal Instability – A New Paradigm for Fine Structure Formation in Solar Prominences

Author: Minseon Lee[1]

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Solar prominences, composed of ribbon-like structures with fine thread-like substructures, are widely believed to form via thermal instability (TI) leading to the cooling and condensation of hot coronal plasma. Motivated by the ubiquitous presence of sub-Alfvenic counter-streaming flows along magnetic field lines in prominences, we revisit TI in magnetized plasmas under the influence of shear flows. Surprisingly, despite the wealth of literature on thermal instability, the role of sub-Alfvenic shear flows has received little attention.

In this work, we conduct a linear stability analysis that incorporates radiative cooling, coronal heating, and anisotropic thermal conduction, fully accounting for the presence of shear. Our analysis uncovers a striking and previously unreported result: the eigenfunctions of condensation modes are singular, exhibiting delta-function-like behavior. This singular behavior does not occur in the absence of shear flows and emerges even for flows exceeding merely 10^{−4} times the Alfven speed. From the eight coupled linearized MHD equations, we derive a single second-order ordinary differential equation for one variable, and find that those delta-function-like peaks in TI eigenfunctions occur precisely at the zeros of the coefficient of the second order derivative term in the single equation. Furthermore, our study underscores the crucial role of sub-Alfvenic shear flows by demonstrating that super-Alfvenic flows generate isentropic Kelvin-Helmholtz instability instead of isobaric TI, and suppress thermal condensation.

Our findings strongly suggest that the formation of the observed fine, thread-like substructures in solar prominences is an inherent consequence of TI in magnetized plasmas permeated by sub-Alfvenic shear flows.

Travel support needed:

Sessions:

Instabilities

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Fast magnetoacoustic wave behaviour within magnetically-inhomogenous, gravitationally-stratified media

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The nature of MHD waves within inhomogeneous media is fundamental to understanding and interpreting wave behaviour in the solar atmosphere. We investigate fast magnetoacoustic wave behaviour within magnetically-inhomogenous, gravitationally-stratified media, by studying various magnetic environments, including a simple X-type null point and also a topology created by two dipoles. We find that the addition of gravitational stratification fundamentally changes the nature of the system, including breaking the symmetry, and that that there are two main competing effects: the stratified-density profile acts in opposition to the strong magnetic field close to the dipoles, creating a system replete with refraction. The system is investigated using both numerical simulation and a semi-analytical WKB solution (via Charpit's method and a fourth-order Runge-Kutta solver) and we find strong agreement between both. The results show a fundamental difference between the stratification-free and stratified cases, with significant unexpected behaviour, and we explain how these results fit into the pantheon of MagnetoAcousticGravity waves.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Periodic MHD wave generation arising from time-dependent reconnection at a three-dimensional null point

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Magnetic null points are natural 'weaknesses'in the magnetic topology of the solar atmosphere. When perturbed, they facilitate time-dependent magnetic reconnection, leading to the reconfiguration of magnetic field lines and plasma heating. This work employs advanced three-dimensional, nonlinear magnetohydrodynamic (MHD) simulations to investigate wave-generating, time-dependent reconnection around a magnetic null point. The system is initialized in a stable equilibrium before being perturbed by a localized magnetoacoustic pulse. This perturbation triggers oscillatory reconnection at the null, producing self-sustained oscillations propagating throughout the spine and fan plane. We analyze the system's response, tracking three distinct types of wave (slow, fast and Alfven) as well as the associated energy propagation. Our results include the generation of slow magnetoacoustic waves that propagate along the spine, the excitation of fast magnetoacoustic waves propagating away from the null point, and Alfvén disturbances in the fan plane. We demonstrate that 3D null points can act as natural wave sources, generating periodic oscillations even when driven by non-periodic perturbations. These findings provide new insights into wave dynamics in the solar atmosphere and their implications for energy transport and dissipation.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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What can we learn from stereoscopic photospheric wave analysis?

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The launch of Solar Orbiter in 2020 made a multi-view observation of the Sun possible. Since the start of the nominal mission phase, at the end of 2021, the SO/PHI instrument has provided the magnetic field vector and LoS velocity of the solar photosphere. The data taken while Solar Orbiter was in inferior conjunction showed an excellent agreement between magnetic and, more recently, velocity signals measured by the High Resolution telescope of SO/PHI (HRT) and SDO/HMI. This result highlights the possibility of using Dopplergrams from two vantage points of the same region on the solar surface to study 2-D horizontal flows.
Here we present a case study using data acquired on 20 October 2023, while the angular separation between Solar Orbiter and the Earth was ~40 degrees. The observation consists of a 6 hours time series of a sunspot close to disk center for both HRT and HMI. This gives us the possibility to extract 2-D horizontal flow after an accurate alignment of the time series and to study oscillations in such a signal. Moreover, the different angle can be used to detect wave modes in different photospheric features over the considered FoV. We present the preliminary results obtained by this unique configuration.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Response of Alfvén Pulses on Cool Loop Formation Under Energy Imbalance Conditions

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Understanding the formation and dynamics of cool solar loops is essential for unraveling the complex energy transport mechanisms in the solar atmosphere. In this talk, we will focus on the formation of cool loops driven by Alfvén pulses under ideal and non-ideal magnetohydrodynamic (MHD) regimes. Using 2.5D MHD simulations in a gravitationally stratified model solar atmosphere, we demonstrate how multiple transverse pulses that resemble Alfvén pulses, may nonlinearly transfer energy and momentum to field-aligned perturbations via the ponderomotive force. This interaction leads to the generation of magnetoacoustic shocks and the subsequent plasma motions that is responsible for the formation of cool plasma loops along curved magnetic field lines. In the ideal MHD case, the resulting plasma flows exhibit a periodicity of approximately 4 minutes, while the trailing wave signatures show a 2-minute periodicity. We further explore the influence of non-ideal effects, including thermal conduction and radiative cooling, on the thermal structure and evolution of these loops. Our results suggest that impulsive Alfvén pulses may play a significant role in the formation of short, cool loops in the solar atmosphere. These findings offer new insights into wave-driven loop dynamics and have implications for interpreting high-resolution observations from missions such as IRIS. They also contribute to our understanding of localized coronal heating and wave dissipation mechanisms in structured solar atmosphere.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

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Magnetohydrodynamic Wave Mode Conversion in a Pseudostreamer Structure

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Mode conversion of magnetohydrodynamic (MHD) waves at coronal magnetic null points is of intense interest due to its potential roles in coronal heating and oscillatory reconnection. Recently, the first direct imaging of MHD wave conversion was reported in a complex pseudostreamer magnetic topology, accompanied by transverse oscillations. In this study, we perform 2.5D MHD simulations using the adaptive mesh refinement code (FLASH) to investigate the propagation and transformation of such wave behavior. A small-amplitude velocity driver is applied from the side to excite fast magnetoacoustic waves, which undergo strong refraction due to steep Alfvén speed gradients and become wrapped around the magnetic null. When the velocity perturbation is aligned with the background magnetic field, the incoming fast waves split at the β~1 layer, producing four branches of slow magnetoacoustic waves that propagate along the magnetic separatrices. We confirm the total energy carried by the slow waves reaches approximately 72% of the incident fast waves. Additionally, new outward-propagating fast wave components are observed to emerge from the null point. We further explore the efficiency of energy conversion and the effect of the driver's location on the resulting energy redistribution. These findings may offer valuable insights into wave dynamics and energy transport in fan-spine coronal structures.

Travel support needed:

Sessions:

Wave generation, energy transport, dissipation and heating

Invited Talk / 70

Frequency stability of solar acoustic oscillations near the photospheric cut-off

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Acoustic waves below the cut-off frequency reflect at the photosphere, forming standing p-modes in sub-photospheric cavities. Above the cut-off, waves propagate as pseudomodes. Recent observations show pseudomode frequencies vary in anti-phase with the 11-year solar cycle, which is not yet fully explained. Using the Klein-Gordon equation with a piecewise acoustic potential, we study the frequency stability of trapped p-modes and propagating pseudomodes, influenced by the acoustic cut-off and wave source location. P-mode frequencies decrease due to the cut-off effect but are insensitive to source depth. Linking the cut-off to the plasma β parameter, we show that solar cycle modulation of the photospheric magnetic field can explain observed p-mode frequency shifts. Pseudomode frequencies, however, depend on both the cut-off effect and source depth. Our model qualitatively reproduces the observed anti-phase variation of pseudomode frequencies with the solar cycle.

Travel support needed:

Sessions:

Invited Talk / 71

Mixing-induced cooling in the Kelvin–Helmholtz instability

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Abstract: Cool (≈10^4 K), dense material permeates the hot (≈10^6 K), tenuous solar corona in form of coronal condensations, for example prominences and coronal rain. As the solar atmosphere evolves, turbulence can drive mixing between the condensations and the surrounding corona. Whilst both the corona and the condensations are relatively thermally stable, in the sense that radiative losses in these regions act on timescales that are longer than the dynamic timescales, the mixed material (≈10^5 K) is subject to efficient radiative losses that removes thermal energy from the system. The radiative losses far exceed the turbulent heating, thus leading to a net reduction in thermal energy through time. This mixing induced cooling also creates an enhanced emmission in transition region line (e.g., Si IV), which is often interpreted as a sign of heating in observations, however may be a consequence of mixing alone, without requireing heating to occur. Finally, extending the results to 3D reveals that the thermal instability readily forms and further enhances the cooling rate of the Kelvin-Helmholtz instabilty at the corona-condensation interface.

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3D Wavelet Method for Analysis of Propagating Waves in Solar Prominence

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On 26 September 2022, a quiescent solar prominence was observed using Hα imaging spectroscopy with SDDI on SMART. Previous studies found 4- and 15-minute oscillations with limited spatial coverage. We extend this to the full prominence using 3D wavelet analysis, comparing with SDO/AIA, STEREO-A/EUVI, and Solar Orbiter/EUI data for a tomographic view.
We examine oscillatory power from 3 to 64 minutes across plasma at different temperatures and viewpoints to assess wave propagation.
We analyze SDO/AIA, STEREO-A/EUVI, Solar Orbiter/EUI, and ground-based SDDI/SMART Hα observations, combining Doppler velocities and EUV intensities at 304 Å and 174 Å.
We confirm persistent propagating waves with periods from 4 to 64 minutes, strongest in Hα and 304 Å in the prominence's core. Weak 4-minute and rapid 30-second oscillations occur near the solar surface in Doppler data. Vertical motions, kink waves, and transient short-period oscillations point to complex internal dynamics and possible coupling with photospheric 5-minute oscillations.

Travel support needed:

Yes

Sessions:

Seismology of solar and stellar atmospheres

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Koopman Operator Theory and new Data-Driven Approach to Modeling and Signal Processing of Spatiotemporal Data

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We present a method combining ideas from the theory of vector-valued kernels with delay-coordinate embedding techniques in dynamical systems capable of identifying spatiotemporal patterns, without prior knowledge of the state space or the dynamical laws of the system generating the data. The approach is particularly powerful for systems in which characteristic patterns cannot be readily decomposed into temporal and spatial coordinates and are characterized by wide range of scales, potentially coupled with each other.
We show our approach reveals coherent patterns of intermittent character with significantly higher skill than conventional analytical methods based on decomposing signals into separable spatial and temporal patterns. Our approach employs Koopman operator theory and its data-driven approximation with novel machine learning approaches. Extensions of our techniques to nonparameteric predictions, including data-assimilation and subgrid-scale modeling, will be presented as well. Applications in heliophysics and astrophysics will be discussed in the end.

Invited Talk / 75

Revisiting Umbral Flashes: From Chromospheric Resonant Cavities to Intriguing Downflows in a Pore

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Solar active regions are rich in dynamic phenomena driven by wave propagation. Among the most striking are umbral flashes, sudden brightenings observed in the chromospheric core of some spectral lines. Traditionally attributed to upward-propagating shock waves, this interpretation has been recently questioned by observations of downflowing umbral flashes and the identification of resonant cavities above sunspots. In this talk, I will discuss some recent results obtained from observations and modeling of chromospheric waves and umbral flashes. Non-LTE inversions of multi-line SST observations of a sunspot reveal predominantly upflowing plasma during umbral flashes. The fluctuations exhibit signatures of both propagating and standing waves, and evidence of dynamic and spatial changes in the transition region height has been found. In contrast, pore umbral flashes are dominated by downflowing plasma. This finding was explored through numerical simulations incorporating varying radiative cooling times.

Travel support needed:

Sessions:

Invited Talk / 76

Decayless kink oscillations in solar coronal loops

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Coronal waves have been intensively studied due to their potential role in coronal heating and their application in plasma diagnostics. One particularly promising candidate is the recently discovered low-amplitude decayless kink oscillations, which are ubiquitous in the solar corona. Their undamped nature suggests the presence of a continuous energy input counteracts dissipation, although the exact physical mechanism remains debated. This talk will explore the properties and driving mechanisms of decayless kink oscillations based on high-resolution observations and recent insights from numerical simulations. I will also discuss their possible implications for coronal heating.