EP 6: Sun and Heliosphere III

Time: Tuesday 16:15–18:15 Location: ZHG101

Invited Talk EP 6.1 Tue 16:15 ZHG101

Decoding coronal loops: Structure and dynamics — •Sudip Mandal — Max Planck Institute for Solar System Research, Göttingen, Germany

Coronal loops, distinguished by their bright, curved, tube-like appearance, are among the most recognizable features of the solar corona. These loops are fundamental building blocks of the solar corona, making it essential to understand their properties in order to unravel the dynamics of the upper solar atmosphere. Despite several years of research, some of the key fundamental properties of these structures remain a mystery. For example, are these loops truly tube-like or sheet-like structures? If they are tube-like, are their cross-sections circular or elliptical? How do loops maintain their shape over several pressure scale heights, contrary to theoretical predictions? In this talk, I will provide key insights into these questions within the context of ESA's Solar Orbiter mission. Additionally, I will discuss the dynamics of these structures, particularly how coronal loops act as excellent waveguides that allow magnetohydrodynamic (MHD) waves to propagate and dissipate their energy at coronal heights, thereby contributing to the ongoing effort to solve the long-standing coronal heating problem.

EP 6.2 Tue 16:45 ZHG101

Robust yet rare coronal loops observed by EUI on board solar orbiter — •Vasantharaju Naganna and Hardi Peter — Max Planck Institute for Solar System Research, Göttingen, Germany

Coronal loops are the most common intensity features in the coronal filtergrams. However, their true nature and morphology are still debatable. By studying variations of cross-sectional properties along the loop and in time, we can understand the structure and heating of these loops. In this study, we investigated the cross-sectional intensity profiles, both spatially and temporally, of two unique coronal loops, observed in the periphery of two distinct active regions by the Extreme Ultraviolet Imager (EUI) on board Solar Orbiter. The main results of this study are 1. The lifetimes of these two loops (L1 > 120 min & L2 > 45 min) are longer than the typical coronal cooling timescales. 2. The loops exhibited an almost constant width, both spatially and temporally (width for L1 about 2.1 Mm, and for L2 about 1.3 Mm), indicating that the loops are stable cylindrical structures. 3. The loop widths are greater than 6-8 pixels of EUI, indicating that the loop cross-section is uniformly filled on well-resolvable scales. 4. We present observational evidence that the loops are not braided, which strongly suggests that the non-expanding nature of these loops with height cannot be attributed to the twist of the magnetic field lines. We conclude that these coronal loops are steady cylindrical structures of uniform cross section that exist for an unusually long time in the corona, which raises questions on which processes ensure the remarkable stability of these loops and our understanding of the coronal magnetic field structure.

EP 6.3 Tue 17:00 ZHG101

Rapid Coronal Variability — •Abhas Pradhan[1], Lakshmi Pradeep Chitta[1], and Hardi Peter[1,2] — [1]Max Planck Institute for Solar System Research, Goettingen, Germany — [2]Institut für Sonnenphysik (KIS) , Freiburg , Germany

Solar coronal loops are heated to temperatures exceeding 1 MK, despite the photosphere being only ∼5700K. The mechanisms sustaining such extreme temperatures in the corona remain unclear. One hypothesis is that nanoflares, small-scale transient magnetic reconnection events, heat the corona. These nanoflares are thought to create rapid UV/EUV variability at the footpoints of coronal loops. High-resolution observations are required to quantify this variability, which in turn will inform us the occurence and energy contribution of nanoflares to coronal heating. Solar Orbiter's EUI offers higher-resolution coronal observations over several hours, complemented by PHI magnetograms providing photospheric magnetic field data at matching resolution. We analyzed high-resolution EUI 174 Å images (180km/pixel, 5s cadence) of an active region core, along with bright points and the diffuse corona, to detect these rapidly varying events. We find frequent occurrences of such rapid events in moss regions and bright points, typically every 3 to 5 minutes, while diffuse regions show almost no rapid activity. The lifetimes and wait-times of rapid events in bright points and moss show similar patterns, remaining consistent despite changes in the underlying magnetic topology. Our study offers better insights to constrain nanoflare-based heating models and processes responsible for mass and energy injection into the hot loops.

EP 6.4 Tue 17:15 ZHG101

1D hydrodynamics simulations of impulsively heated short loops to explain the origin of EUV brightenings in the quiet Sun. — •Antoine Dolliou[1,2], James Klimchuk[3], Susanna Parenti[2], and Karine Bocchialini[2] — [1]Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany — [2]Université Paris-Saclay, CNRS, Institut d'Astrophysique Spatiale, 91405 Orsay, France — [3]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD 20771 USA

The Sun upper atmosphere, the corona, is maintained to more than 1 MK, through processes that are still not fully understood. One of the main theories of the coronal formation suggests that the energy is dissipated through small scales (< 1E24 erg) and impulsive processes (Parker et al., ApJ, 1988). On 2020 May 30, the High Resolution Imager EUV (HRIEUV), onboard Solar Orbiter, was used to detect small (400 to 4000 km), short lived (10 to 100 s) EUV brightenings in the quiet Sun. Their contribution to coronal heating and their physical origin is actively studied. The aim of this work is to understand their physical origin. To do so, we simulate impulsively heated short loop, using the 1D hydrodynamics code HYDRAD (Bradshaw et al., A&A, 2003). We use two types of loops with distinct thermal behavior: cool (T < 0.1 MK) and hot (T > 0.1 MK) loops. The synthetic light curves of HRIEUV, SDO/AIA and Solar Orbiter/SPICE are computed and compared with those obtained from observations. The results showed that cool loops are good candidates to explain the physical origin of EUV brightenings, contrary to most hot loops models.

EP 6.5 Tue 17:30 ZHG101

A blowout jet in a self-consistent model of a solar coronal hole region — •Yajie Chen[1], Hardi Peter[1,2], Damien Przybylski[1], Lakshmi Pradeep Chitta[1], and Sudip Mandal[1] — [1]Max-Planck Institute for Solar System Research, 37077 Goettingen, Germany — [2]Institut für Sonnenphysik (KIS), 79110 Freiburg, Germany

Solar blowout jets are a distinct subclass of ubiquitous EUV and X-ray coronal jets. Most existing numerical models of blowout jets rely on prescribed initial magnetic field configurations or manual modifications of the magnetic field in the photosphere to trigger the jets. In this study, we first construct a comprehensive self-consistent 3D radiation MHD model of a solar coronal hole region, extending from the upper convection zone to the lower corona. Subsequently, we synthesize emissions in several EUV and X-ray passbands and identify a blowout jet self-consistently created in the model. The jet initially appears as a standard jet but later evolves into a blowout jet. The jet has a width of ~10 Mm and a lifetime of ~10 minutes. The plasma speeds within the jet reach approximately 180 km/s, and we also find a faint component in the synthesized X-ray images propagating at Alfvén speeds of ~500 km/s, which can be attributed to heating fronts. The corresponding magnetograms in the modeled photosphere show signatures of flux emergence and cancellation. These characteristics match well with those observed in blowout jets. By examining the magnetic field lines in and around the jet base, we validate the scenario that the jet is triggered by magnetic reconnection between the newly emerged twisted closed loops and the pre-existing open field lines.

EP 6.6 Tue 17:45 ZHG101

Comprehensive simulations of solar prominences — •Lisa-Marie Zessner, Robert Cameron, Sami K. Solanki, and Damien Przybylski — Max Planck Institute for Solar System Research, Göttingen, Germany

Solar prominences are cool and dense plasma clouds suspended in the hot solar corona. The heavy prominence plasma is supported against gravity by the magnetic field. Solar prominences are common features in the solar atmosphere, with diverse properties: they can have very different sizes, lifetimes, dynamics, and fine structures. If they become unstable, they can erupt and form the core of coronal mass ejections. Many aspects of their physics are still unknown, including their formation mechanism. We use the radiative magnetohydrodynamic code MURaM to simulate the formation and dynamics of a prominence in the solar atmosphere. MURaM includes the relevant physical processes to simulate the solar photosphere, chromosphere, and corona.

We create a stable, dipped magnetic arcade configuration in a 3D simulation box and let it evolve. In the course of the simulation, a solar prominence forms self-consistently. First, a dense plasma seed ejected from the chromosphere randomly settles into a magnetic dip of the field configuration and gets cooled by radiative losses. The resulting pressure drop then drives a strong inflow of hot plasma that condenses onto the feature. In this way, a dynamic, cool, and dense structure is built up in the solar corona. In this contribution, I will present the formation mechanism and properties of the simulated prominence for different setups of our configuration.

EP 6.7 Tue 18:00 ZHG101

Ubiquitous magnetic reconnection in filament eruptions revealed by Solar Orbiter at perihelion — •Song Tan[1,2], Alexander Warmuth[1], and Frédéric Schuller[1] — [1]Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16 14482 Potsdam, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany

Using unprecedented high-resolution observations (105 km/pixel) of Solar Orbiter Extreme Ultraviolet Imager, we reveal ubiquitous magnetic reconnection events in a failed filament eruption. Magnetic reconnection occurs between the filament and the surrounding magnetic field structures, with frequency and type far exceeding previous observations. These ubiquitous reconnections significantly affect the stability and eruption dynamics of the filament, leading to simultaneous coronal jets and failed eruptions. We propose a "magnetic erosion effect" concept, emphasizing the importance of frequent, fine-scale magnetic reconnection during the filament evolution.