7th Metis Workshop Program
(11-13 Novembre 2019)

Monday 11 (Archivio Antico Palazzo del Bo)	14:00 – 16:10	Plenary Session	Welcome Prof. Flavio Seno (Director, Dept. Physics and Astronomy) Dr. Luca Poletto (Director, CNR-IFN) Prof. Stefano Debei (Director, CISAS)	15 min
			M. Romoli (UniFi) - Space coronagraphs	20 min
			S. Fineschi (INAF-OATO) - Metis science performance	30 min
			D. Banerjee (IIA) - Aditya L1: India's first dedicated solar space mission (remote connection)	25 min
			H. Li (PMO) - ASO-S sciences and the possible synergies with Metis coronagraph and Solar Orbiter	25 min
	16:10 – 16:30	Coffee break		
	16:30 – 18:30	Plenary Session	**C. de Forest (SWRI)** - PUNCH (remote connection)	20 min
			S. Fineschi (INAF-OATo) – Proba3, UVSC and CODEX	30 min
			G. Valori (MSSL) - Comparing coronal models for the PSP-P1 passage	20 min
			Discussion	20 min
Tuesday 12 (CUP)	09:00 – 10:40	Coordinated Heliophysics Science	**C. Garcia (ESA)** - Solar Orbiter Project Status	20 min
			S. Solanki (MPS) - SO/PHI data products of possible interest to Metis	20 min
			A. Giunta (RAL) - Outflow velocity and composition maps with SPICE: synergy with the other instruments on Solar Orbiter	20 min
			V. Andretta (INAF-OAC), Parenti (IAS) - Synergies between EUI and Metis.	20 min
			P. Massa (UniGe) – The STIX Image Reconstruction Concept	20 min
	10:50 – 11:10	Coffee break (posters)		
	11:10 – 13:00	Coordinated Heliophysics Science	**C. Grimani (UniUrb)** - Time dependence, radial and latitudinal gradients of the galactic cosmic-ray flux in the inner heliosphere for Solar Orbiter	20 min
			G. Cauzzi (NSO) - The Daniel K. Inouye Solar Telescope: Coronal Capabilities and Opportunities for Joint Science with METIS	20 min
			J. Burkepile (HAO) - Ground-based Coronal Observations that Complement and Enhance Metis and Solar Orbiter Science	20 min
			C. Sasso (INAF-OAC) – MADAWG	20 min
			P. Pagano (U.St.Andrews) - MHD Simulations for Metis and Non-equilibrium ionisation effects in CME	20 min
	13:00 – 14:00	Lunch		
	14:00 – 15:50	Science new ideas	**K. Tsinganos (Univ. Athens)** – On recurrent CME-like eruptions	15 min
			G. Zimbardo (UniCal) - Study of shocks in the solar corona with Metis	15 min
			F. Frassati (INAF – OATo) - Analysis of the shock formation due to CME–streamer interaction in the inner corona.	15 min
			D. Del Moro (UniRM2) - Refining the Drag Parameter for Coronal Mass Ejection propagation models	15 min
			W. Mishra (MPS) - Modeling the Thermodynamic Evolution of Coronal Mass Ejections	15 min
			Y. Rivera (U. Michigan) - A comprehensive study to determine spectral lines for CME diagnostics with current and future observatories	15 min
			B. Ying (PMO) - Study of a Coronal Mass Ejection with UV and VL coronagraphs: the need for multi-wavelength observations	15 min
	16.00 – 16:30	Coffee break (posters)		

	16:30 – 18:30	Science new ideas	**A.Verdini (UniFI)** – Acceleration of the solar wind **S. Landi (UniFi) -** Interpreting spacecraft Observations with high resolution fluid and kinetic simulations in Arcetri **P. Lamy (LATMOS) -** Electron density distributions in 1D, 2D, and 3D from inversion of coronal white-light images **S. Giordano (INAF-OATo) -** H I Ly-alpha UVCS Observations through a full solar cycle **S. Guglielmino (UniCt) -** Magnetic flux emergence through the solar atmosphere **E. Papini (UniFi) -** Characterizing fast magnetic reconnection in the solar corona with Hall-MHD and Hybrid-PIC simulations **F. Reale (UniPa) -** Impulsive heating in the solar corona: large scale magnetic rearrangements **P. Romano (INAF-OACt) -** Flux rope formation and evolution Discussion	20 min 15 min 15 min 15 min 15 min 15 min 15 min 15 min
	20:00	Social Dinner		
Wednesday 13 (CUP)	09:00 – 10:40	Science new ideas	**D. Spadaro (INAF-OACt)** – Introduction to Metis science **P. Heinzel (CAS)** - Synergies between Metis and Proba3 Open discussion **(D. Spadaro, M. Romoli)**	20 min 20 min
	10:40 – 11:00	Coffee break		
	11:00 – 13:00	Plenary Session	**L. Sanchez (ESA) –** Solar Orbiter science operations **G. Nicolini - R. Susino (INAF-OATo) -** In-flight calibration and data product (level 3) Open discussion and summary (**M. Romoli)**	25 min 25 min
	13:00	End of the Workshop		

Aditya L1: India's first dedicated solar space mission

D. Banerjee[1],

[1]*Indian Institute of Astrophysics, Koramangala, Bangalore, India*

ADITYA-L1 is the first Indian mission that is dedicated to study solar atmosphere with unprecedented spatial and temporal resolution. The satellite will carry seven payloads and is expected to be launched in 2020-21 by PSLV-XL from Sriharikota. The main payload is the Visible Emission Line Coronagraph (VELC), an internally occulted solar coronagraph capable of simultaneous imaging, spectroscopy and spectro-polarimetry close to the solar limb, with 3 visible and 1 Infra-Red channels. Solar Ultraviolet Imaging Telescope (SUIT) will image the Photosphere and Chromosphere in near Ultraviolet (200-400 nm) and measure solar irradiance variations. Solar Low Energy X-ray Spectrometer (SoLEXS) will monitor the X-ray flares for studying the heating mechanism of the solar corona and High Energy L1 Orbiting X-ray Spectrometer (HEL1OS) will focus on the dynamic events in the solar corona and provide an estimate of the energy used to accelerate the particles during the eruptive events. In addition ADITYA will have two particle detectors and a magnetometer on board for the Solar wind studies. In this talk I will focus on the capabilities of VELC and emphasize the need for coordinated observations with METIS.

ASO-S sciences and the possible synergies with Metis coronagraph and Solar Orbiter

Hui Li, Weiqun Gan, Li Feng & ASO-S team
Purple Mountain Observatory, CAS, 10 Yuanhua Road, Nanjing 210033, China

The Advanced Space-based Solar Observatory (ASO-S) in proposed to be launched in early 2022 and is currently in its phase-C development. ASO-S consists of three payloads: the Full-disk vector MagnetoGraph (FMG), the Lyman-alpha Solar Telescope (LST) and the solar Hard X-ray Imager (HXI). With such a payload combination, ASO-S aims at addressing scientific questions related the solar magnetic field, solar flares and coronal mass ejections (CMEs). The LST payload is composed of a Solar Disk Imager (SDI), a Solar Coronal Imager (SCI), a White-light Solar Telescope (WST) and a Guide Telescope (GT). Of these instruments, SCI is similar to the Metis coronagraph for the Solar Orbiter mission, which enables possible synergies with these payloads. In the presentation, I will talk about ASO-S sciences and the possible synergies with payloads on both the ASO-S mission and the Solar Orbiter mission, with emphasis on that with the LST and the Metis payloads.

Comparing coronal models for the PSP-P1 passage

G.Valori(1),R.Pinto(2), A.Rouillard(2), M.Indurain(2) A.Kouloumvakos(2) and the MADAWG Team

(1) University College London - Mullard Space Science Institute (UK)

(2) Research Institute in Astrophysics and Planetology (F)

Presenting author: *Gherardo Valori*

Abstract: The modeling of the magnetic environment that will be experienced by Solar Orbiter and its connection to the Sun will be key to the success of both the in-flight operations as well as to the mission's scientific goal. This is a challenging task, however, as it requires a reliable model of the entire corona from the photosphere up to satellite position. Using the opportunity offered by the Parker Solar Probe to simulate operational conditions for Solar Orbiter, a number of models have been used estimate its connectivity. Such coronal models employ different techniques and boundary data, and have been produced different photoelectric locations for the connectivity. I will present a first analysis of the models that aims at understanding their differences and building the tools for their validation.

Solar Orbiter Project Status

C. Garcia .[1] for the Solar Orbiter Project Science Team

[1] ESA, ESTEC, The Netherlands

Abstract: Solar Orbiter is getting closer to its 2020-02-06 launch date!

Solar Orbiter is a mission dedicated to solar and heliospheric physics. It was selected as the first medium-class mission of ESA's Cosmic Vision 2015-2025 Program. The mission will provide close-up, high-latitude observations of the Sun, and it will have a highly elliptic orbit – between 1.01AU at aphelion and 0.28AU at perihelion. It will reach its operational orbit just under two years after launch by using gravity assist maneuvers (GAMs) at Earth and Venus. Subsequent GAMs at Venus will increase its inclination to the solar equator over time, reaching up to 24° at the end of the nominal mission (approximately 7 years after launch) and up to 33° in the extended mission phase.

The payload consists of both remote sensing and in situ instruments, which will work together to connect the Sun and heliosphere by addressing four top-level science questions: (1) What drives the solar wind and where does the coronal magnetic field originate from?; (2) How do solar transients drive heliospheric variability?; (3) How do solar eruptions produce energetic particle radiation that fills the heliosphere?; and (4) How does the solar dynamo work and drive connections between the Sun and the heliosphere?

The payload and spacecraft assembly, integration, and testing are complete. By the time of the Metis-7 meeting, it will have shipped from Europe to the U.S. for a launch on a NASA-provided Atlas V-411 rocket from Cape Canaveral Air Force Station in Florida.

https://sci.esa.int/web/solar-orbiter

SO/PHI data products of possible interest to Metis

S.K. Solanki[(1)], J. Hirzberger[(1)], T. Wiegelmann[(1)], J. Woch[(1)] and the SO/PHI Team

[(1)]Max Planck Institute for Solar System Research, Göttingen, Germany

Presenting author: *Sami K. Solanki*

Abstract: SO/PHI is the magnetograph onboard the Solar Orbiter that also provides data for helioseismology. Of its two telescopes, the FDT (Full Disc Telescope) is the one likely of greater relevance for Metis science. PHI will allow a number of unique perspectives and will provide data products, such as synoptic charts, or global magnetic field extrapolations with PFSS and non-potential models such as NLFFF, magnetostatics and MHD that may usefully complement Metis data.

Outflow velocity and composition maps with SPICE: synergy with the other instruments on Solar Orbiter

A. Giunta[(1)], A. Fludra[(1)], M. Caldwell[(1)], T. Grundy[(1)] , S. Guest[(1)], S. Sidher[(1)] and the SPICE team

[(1)] RAL Space, STFC Rutherford Appleton Laboratory, Harwell, Didcot, OX11 0QX, UK

Presenting author: *Alessandra Giunta*

Abstract:

The Spectral Imaging of the Coronal Environment (SPICE) is a high resolution spectrometer observing at extreme ultraviolet wavelengths.

SPICE wavelength bands include emission lines from a wide range of ionized atoms of H, C, O, N, Ne, S, Mg, Si, and Fe. These ions are formed at temperatures from 10,000 to 10 million K, covering different layers of the solar atmosphere, from the chromosphere up to the corona.

SPICE will study the source regions of outflows and ejection processes which link the solar surface and corona to the heliosphere, providing a quantitative knowledge of the physical state and composition of the plasma in the solar atmosphere.

The ability of SPICE to derive abundance ratios of low and high First Ionisation Potential (FIP) elements and build up composition maps as well as velocity maps is discussed. SPICE will identify the sources of the fast solar wind inside the polar coronal holes, connecting them to solar wind structures observed by in-situ instruments.

The synergy with several other instruments on Solar Orbiter is also investigated, focusing on the METIS coronagraph and the Heavy Ion Sensor (HIS), which is part of the Solar Wind Analyzer (SWA).

Time dependence, radial and latitudinal gradients of the galactic cosmic-ray flux in the inner heliosphere for Solar Orbiter

C. Grimani(1,2), M. Fabi(1,2)

(1)University of Urbino "Carlo Bo", Urbino (PU), Italy; (2)INFN, Florence; Italy

Presenting author: *Catia Grimani*

Abstract:

We will report about a compilation of experimental data providing precious clues on galactic cosmic-ray (GCR) flux variations with time, radial distance from the Sun and latitude for Solar Orbiter instrument performance estimates. The possibility of normalising the cosmic-ray flux predictions and observations carried out on board Solar Orbiter (EPD instrument) with the AMS-02 magnetic spectrometer experiment data gathered on the Space Station will be discussed accordingly.

The Daniel K. Inouye Solar Telescope:

Coronal Capabilities and Opportunities for Joint Science with METIS

G. Cauzzi(1,2), V. Martinez Pillet(1), V. Andretta(3), D. Spadaro(4)

(1) National Solar Observatory, Boulder CO (USA); (2) INAF-OAA, Firenze (Italy); (3) INAF-OAC, Napoli (Italy); (2) INAF-OACt, Catania, Italy

Presenting author: *Gianna Cauzzi*

Abstract: The National Science Foundation Daniel K. Inouye Solar Telescope (DKIST) is a solar four-meter, optical / near-IR telescope under construction in Maui, Hawai'i. Start of operation is foreseen for the second half of 2020.

One of the primary scientific goals of DKIST is that of investigating the solar corona at high resolution. In particular, the Cryo-NIRSP instrument is planned to routinely obtain polarimetric observations in near-IR coronal lines like the FeXIII 1074 and 1079 nm. To this end, beside being equipped with a disk occulter, the telescope sports an off-axis optical design and a highly polished primary mirror, both necessary to minimize the locally scattered light. Combined with cutting edge polarimetric capabilities, and the very dark sky conditions on Haleakala (especially in the near-IR), the DKIST is expected to measure solar coronal magnetic fields with unprecedented cadence, resolution, and accuracy.

These unique capabilities offer novel opportunities for joint science with space-based facilities such as Solar Orbiter and METIS, including, e.g., studies on the Helium abundance in the corona; the relationship of magnetic field strength and topology with solar wind parameters; etc. I will present some of these possible synergies, along the lines of the discussion initiated in 2018 during a dedicated DKIST "Critical Science Plan workshop".

Ground-based Coronal Observations that Complement and Enhance Metis and Solar Orbiter Science

J. Burkepile[(1)], G. deToma[(1)], S. Gibson[(1)], S. McIntosh[(1)], S. Tomczyk[(1)], E. Landi[(2)], M. Galloy[(1)]

[(1)]National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colorado USA, [(2)]Department of Climate, Space Sciences and Engineering, University of Michigan, Ann Arbor, Michigan, USA

Presenting author: *Joan Burkepile*

Abstract: The Mauna Loa Solar Observatory (MLSO) provides coronal observations designed to advance our understanding of the processes behind the Sun's continuous flow and dynamic release of magnetized plasma and energy. MLSO operates the COSMO K-Coronagraph (K-Cor) that provides calibrated polarization brightness images of the corona over a full field-of-view from 1.05 to 3 solar radii. K-Cor operates at a cadence of 15 seconds and has a pixel size of 5.6 arcseconds. A second coronagraph, the Upgraded Coronal Multi-Channel Polarimeter (UCoMP), will be deployed in early 2020 and will provide intensity and linear polarization from nine coronal and chromospheric emission lines in wavelengths from 530.3 nm to 1083.0 nm that span temperatures from 100,000 to 3 million degrees K. The UCoMP instrument has a field of view from 1.05 to 2.0 solar radii and a pixel size of 1.8 arcseconds. The K-Cor observations provide high cadence images of the low corona that can be used to track CME basic properties such as location, speed, acceleration, expansion, and line-of-sight density and mass from the very low corona into the Metis field-of-view. In addition, K-Cor observations of radial density profiles in open and closed structures in the very low corona can be combined with Metis observations to track variations in coronal densities down into the first coronal scale height. UCoMP observations will provide information on coronal topology from linear polarization and Doppler information from emission line intensity scans that has been used to identify and study coronal Alfven waves. UCoMP will provide observations of magneto-thermal properties of the low corona that complement Metis observations. A description of the K-Cor and UCoMP instruments are provided. We present science results from K-Cor and CoMP observations and discuss their complementarity with Metis coronagraph and Solar Orbiter observations and science goals.

MHD Simulations for Metis and Non-equilibrium ionisation effects in CME

P. Pagano[(1)], A. Bemporad[(2)], S. L. Yardley[(1)], D. H. Mackay[(1)]
[(1)]University of St Andrews; [(2)]INAF – Osservatorio Astrofisico di Torino

Presenting author: *Paolo Pagano*

Abstract: Metis is a new generation coronagraph that will study Coronal Masse Ejections (CMEs) and its strength is to use multichannel observations where visible light and UV observations will provide new diagnostic possibilities. However, ground-breaking observations from Metis will need to be interpreted and so now is the time to develop state-of-the-art diagnostic techniques. In this talk we will address how data-driven coupled magnetofrictional and MHD simulations provide a useful asset for the achievement of Metis scientific goals.

We will touch on a new diagnostic technique that can unveil the eruptive nature of active regions, helping Solar Orbiter and Metis in selecting target and then we will discuss how MHD simulations provide a unique framework to synthesise realistic Metis observations and provide tools to interpret the data.

We will largely focus on the derivation of the coronal plasma temperature and how this is affected by the number of neutral Hydrogen atoms along the line of sight. Our aim is to measure if the non-equilibrium ionisation effects are relevant in CMEs and more in particular when and in which regions of the CME the plasma can be assumed in ionisation equilibrium.

We use a magnetohydrodynamic simulation of a magnetic flux rope ejection that generates a CME and we then reconstruct the ionisation state of Hydrogen atoms in the CME by evaluating both the advection of neutral and ionised Hydrogen atoms and the ionisation and recombination rates in the MHD simulation.

We find that the equilibrium ionisation assumption holds in the core of the CMEs that are here represented by the magnetic flux rope, whereas non-equilibrium ionisation effects are significant at CME fronts, where we find about 100 times more neutral Hydrogen atoms than prescribed by ionisation equilibrium conditions.

On recurrent CME-like eruptions

Kanaris Tsinganos[(1)], Petros Syntelis[(2)], Vasilis Archontis[(2)]

[(1)]University of Athens Athens, Greece; [(2)]University of St. Andrews, St. Andrews, UK

Presenting author: Kanaris Tsinganos

Abstract: Results of 3-D MHD simulations of recurrent eruptions in emerging magnetic flux regions will be presented. Using large numerical domains, we show the initial stage of reconnection of sheared field lines, along the polarity inversion line of an emerging bipolar region. This leads to the formation of a new magnetic structure, which adopts the shape of a magnetic flux rope (FR) during its buoyant rising motion through the solar interior to the solar atmosphere. Initially, the FR undergoes a slow-rise phase and, eventually, it experiences a fast-rise phase and ejective eruption toward the outer solar atmosphere. In total, four eruptions occur during the evolution of the system. For the first eruption, our analysis indicates that the torus instability initiates the eruption and that tether-cutting reconnection of the field lines, which envelop the FR, triggers the rapid acceleration of the eruptive field. For the following eruptions, it is the interplay between tether-cutting reconnection and torus instability that causes the onset of the various phases. The plasma density and temperature distribution, together with the rising speeds, energies, and size of the erupting fields, indicate that they may account for small-scale (mini) coronal mass ejections. The kinetic energy of the produced ejective eruptions in the emerging flux region ranges from 10^{26} to 10^{28} erg, reaching up to the energies of small coronal mass ejections. The kinetic and magnetic energies of the eruptions scale linearly with the magnetic flux in a logarithmic plot.

Study of shocks in the solar corona with METIS

G. Zimbardo [(1)], G. Nisticò [(2)], and S. Perri [(1)]

[(1)]Dipartimento di Fisica, Universita' della Calabria, 87036 Rende CS, Italy;

[(2)]Institut für Astrophysik, Georg-August-Universität, Göttingen, 37077, Germany

Presenting author: *Gaetano Zimbardo*

Abstract: Shock waves in the solar corona convert direct flow energy into heat and particle kinetic energy, thus contributing to the energy budget of the solar corona as well as to the generation of Type II solar radio bursts. However, many details of such conversion processes are not clear. Shock waves formed in association with large flares and coronal mass ejections have been observed by SoHO - UVCS since a few years, see, e.g., Mancuso et al., A&A, 383, 267 (2002) and Bemporad and Mancuso, ApJ, 720, 130 (2010). Moreover, smaller scale shocks can be associated with coronal hole polar jets, as shown by numerical simulations of magnetic reconnection in the low corona (Yokoyama and Shibata, PASJ, 48, 353 (1996)). Periodic radio bursts, which are a signature of shocks, have been also observed in associations with propagating fast wave trains (Goddard et al., A&A, 594, A96, 2016). The Solar Orbiter mission, with the imaging capabilities of the METIS instrument, is ideally suited to investigate such phenomena, also in the lower corona where reconnection processes and the onset of shock waves actually occurr. For strong shocks, a direct comparison between the shock parameters determined by METIS and the observed radio bursts could be carried out, thus giving a quantitative estimation of the shocks' evolution as well as of their capability to accelerate electrons. This would also be of fundamental importance for improving particle acceleration models. In this presentation, a possible observational strategy will be discussed in connection with spacecraft like Parker Solar Probe and ground-based instrumentation like LOFAR.

Analsys of the shock formation due to CME–streamer interaction in the inner corona.

S. Mancuso[1], F. Frassati[1], A. Bemporad[1], and D. Barghini[1,2]

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[2]*Università degli Studi di Torino – Dipartimento di Fisica, via Pietro Giuria 1, Torino, TO, Italy*

Presenting author: *Federica Frassati*

Abstract:

On 2014 October 30 a coronal mass ejection (CME) occurred over the southeast limb of the Sun. The event, observed by the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamic Observatory (SDO), was associated with a band-splitted type ii radio burst, clear signature of a shock wave.

We investigated the dynamics of the EUV wave front and the physical properties of the plasma compressed and heated by the accompanying shock wave, in combination with the analysis of simultaneous images obtained with the Nançay Radioheliograph (NRH). The geometry of the CME/shock event was recovered through 3D modeling, given the absence of concomitant stereoscopic observations, and by assuming that the band-splitted type ii burst was emitted at the intersection of the shock surface with two adjacent low-Alfvén speed coronal streamers.

Our analysis shows that the fast expansion in all directions of the plasma front acted as a piston and drove a spherical shock, clearly detected in the EUV channels centered at 193 A and 211 A, ahead of it. The EUV density compression ratio of the shock is in agreement with values obtained with radio data in the metric range. The modest compression ratio and temperature jump derived from the EUV analysis at the shock passage characterize this event as a weak shock. Moreover, from the derived spatio-temporal evolution of the standoff distance between shock and CME leading edge, we were finally able to infer the magnetic field strength B in the inner corona.

Refining the Drag Parameter for Coronal Mass Ejection propagation models

D. Del Moro[(1)], F. Berrilli[(1)], R. Foldes[(1)], L. Giovannelli[(1)], G. Napoletano[(2)], E. Pietropaolo[(2)]
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***Presenting author**: D. Del Moro*

Abstract: ICME (Interplanetary Coronal Mass Ejection) are violent phenomena of solar activity that affect the whole heliosphere and the prediction of their impact on different solar system bodies is one of the primary goals of the planetary space weather forecasting. The travel time of ICME from the Sun to the Earth can be computed through Drag Based Model (DBM) approach, which is based on a simple equation of motion for the ICME that defines the acceleration as $a=-\Gamma(v-w)|v-w|$, where a and v are the CME acceleration and speed, w is the ambient solar-wind speed and Γ is the so-called drag parameter (Vršnak et al., 2013). In this framework, Γ depends on the ICME mass and cross-section, on the solar-wind density and, to a lesser degree, on other parameters. The typical working hypothesis for DBM implies that both Γ and w are constant far from the Sun. To run the codes, forecasters use empirical input values for Γ and w. In the 'Ensemble' approaches (Dumbovich et al., 2018; Napoletano et al. 2018), the uncertainty about the actual values of such inputs are rendered by Probability Distribution Functions (PDFs), accounting for the values variability and our lack of knowledge. Among those PDFs, that of Γ is poorly defined due to the relatively scarce statistics of recorded values.

Taking advantage of the large data-set of ICMEs registered by Richardson & Cane (2010), we computed how the Γ is depending on SW velocity, and found evidence of a variation in the Γ PDFs if the SW is accelerating or braking the propagation. By using a set of simulations of an ICME structure into the SW fluid, we link this change to the structure of the ICME.

This is a pioneering work in the exploration on how Γ depends on the physical parameters of the ICME, to verify and extend the work by Vršnak et al. (2010). This would lead to a more robust definition of the PDF of the drag parameter Γ that could be used in the various DBM approaches to real-time ICME travel time forecasting, e.g the one currently operated within the Ionosphere Prediction Service (IPS).

Modeling the Thermodynamic Evolution of Coronal Mass Ejections

Wageesh Mishra[(1)], Luca Teriaca[(1)], Yuming Wang[(2)], Yutian Chi[(2)], and Jie Zhang[(3)]

[(1)]Max Planck Institute for Solar System Research, Goettingen, Germany;

[(2)]University of Science and Technology of China, Hefei, China;

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Presenting author: *Wageesh Mishra*

Abstract: Several earlier studies, using remote sensing and in situ observations, have attempted to estimate the thermodynamic properties of Coronal Mass Ejections (CMEs) either very close to the Sun or at 1 AU. In our study, we attempt to understand the evolution of the internal state of CMEs during their heliospheric propagation. For this purpose, we use the flux rope internal state (FRIS) model which is constrained by the kinematics of the CMEs. The kinematics of the CME is estimated using the STEREO/SECCHI observations in combination with drag based model (DBM) of CME propagation. In our analysis, we have selected a few Earth-directed CMEs which are launched with different speeds into different solar wind conditions. We also attempt to compare the estimated thermodynamic properties of the CMEs from the FRIS model with the in situ observations of the CMEs taken at 1 AU. We focus on estimating the polytropic index of the CME plasma, heating/cooling rate, entropy changing rate, Lorentz force and thermal pressure force acting inside the CME. We outline the approximations made in our study of probing the internal state of the CME during its heliospheric evolution and discuss the possible causes of the observed discrepancies.

A comprehensive study to determine spectral lines for CME diagnostics with current and future observatories

Yeimy Rivera[(1)], Enrico Landi[(1)], Susan Lepri[(1)]

[(1)]University of Michigan, Ann Arbor, Michigan, USA

Presenting author: *Yeimy Rivera*

Abstract:

Our recent modeling work reconstructed the thermodynamic evolution of several plasma structures (prominence, prominence-coronal transition region, and coronal-like plasma) within the radial expansion of a coronal mass ejection (CME) by examining heliopsheric ion composition within the ejecta. This study suggested that the components experienced rapid, continuous, and non-uniform heating as they travelled away from the Sun. The work indicated that comprehensive CME studies require multi-wavelength plasma observations along with a wide off-limb field of view. However, the dynamic nature of the eruption makes it difficult to capture the plasma's temporal and spatial evolution with a single narrowband imager or high resolution spectrometer.

In anticipation of the multi-messenger era of solar activity observations in the upcoming solar cycle, our work has identified useful spectral lines for CME diagnostics designed for complementary observations with present and planned observatories. We have investigated the diagnostic potential of several spectral lines spanning the extreme ultraviolet to near-Infrared, 100-14400Å, ranging between chromospheric and sub-flare temperatures to examine the eruption. We use our previously simulated CME properties to compute synthetic intensities between the plasma's release and 2Rsun, taking into account the departures from ionization equilibrium experienced by each CME plasma component. We find several of the most observable lines are within the planned observations of future solar telescopes; DKIST, and UCoMP, and instruments on Solar Orbiter (e.g. SPICE, METIS). We envision the recommended lines will facilitate the planning of coordinated efforts with instruments on the ground and in space.

Study of a Coronal Mass Ejection with UV and VL coronagraphs: the need for multi-wavelength observations

B. Ying [(1)], A. Bemporad [(2)], L. Feng [(1)]

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Presenting author: *Beili Ying*

Abstract: Many previous studies have revealed that corona mass ejections (CMEs) often appear different features in different pass-bands. We can only obtain the sufficient information of physical parameters of the CMEs with the aid of the multi-wavelength observations. Several works, including observations (Susino et al. 2016) and magnetohydrodynamic (MHD) simulations (Bemporad et al. 2018), have provided a diagnostic method, which will be applied to the future two-channel coronagraph missions (including the Metis instrument on board the next ESA-Solar Orbiter mission and the LST on board the Chinese Advanced Space-based Solar Observatory mission), to derive electron temperatures in the CMEs' bodies by combining the visible-light (VL) and ultraviolet (UV, H I Lyα 1216 Å) lines. Based on these works, we studied a fast (1100 km/s) CME with a driven shock with the combination of lower-cadence (20 min) VL images acquired by SOHO/LASCO coronagraph, and the higher-cadence (10 min) intensity profiles measured with SOHO/UVCS both in the UV (H I Lyα line) and in the VL channels. In this work, we have estimated the plasma electron and effective temperatures of the CME core and void, and showed their time evolution. The occurrence of the decrease of the electron temperature, when the core of CME transit through the UVCS FOV, might imply the cold plasma coming from the erupting prominence embedded in the CME core. The largest difference between the derived electron temperature ($10^{5.0}$-$10^{5.5}$ K) and the effective temperature ($10^{5.8}$-$10^{6.4}$ K) of the CME core even reaches up to an order of magnitude. This might imply that in the CME core the possibly lower kinetic temperatures are counter-balanced by higher non-thermal plasma motions, related with prominence fragmentation during the CME expansion phase. According to the formation mechanism of the H I Lyα 1216 Å line, the Doppler dimming factor plays a vital role in this diagnostic method, and is directly affected by the radial velocity distributions of the CMEs. For the high-cadence observations from Metis and LST, in order to improve the accuracy of this technique, we have developed a method to derive the two-dimensional (2D) velocity maps within the CME bodies with cross-correlation analysis. Given the low cadence of available images for this event, we showed an alternative simple geometrical technique that can be applied in case the cadence of future data will be not sufficient to apply cross-correlation analysis.

Acceleration of the Solar Wind

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Presenting author: Andrea Verdini

Abstract:

The most developed paradigm for the acceleration of the solar wind implies the damping of Alfvénic fluctuations in the low corona via turbulent dissipation.However, one-dimensional models indicate that for an input energy consistent with photospheric motion, the turbulent heating is too small to be able to produce a fast solar wind.

Recently, it has been recognized that turbulent dissipation can be enhanced by density fluctuations or by the shear interaction between different newborn streams at the solar surface.Metis in conjunction with spectroscopic observations and in situ data from both SO and PSP may help in understanding if turbulent dissipation is a viable paradigm for the solar wind acceleration.

Interpreting spacecraft Observations with high resolution fluid and kinetic simulations in Arcetri

S. Landi(1,2), L. Franci(3), E. Papini(1,2), A. Verdini(1,2), P. Hellinger(4), L. Berčič(1,5), L. Del Zanna(1,2). L. Matteini(5,6)

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Presenting author: *Simone Landi*

Abstract:

The interplanetary medium, the solar corona, the planetary magnetospheres are composed by a hot and tenuous ionized gas where collisions between particle's are rare. Moreover they always show a strong dynamic activity over a very large variety of length and time-scales, all of them connected by the strong non-linearity of the physical system. Therefore, the comprehension and interpretation of the fundamental physical mechanisms which drive the dynamical evolution of such systems require the use of high resolution numerical simulations that cover both the large (fluid) and the small (kinetic) scales. In this contribution we will present an overview of the numerical tools that are at disposal of the Arcetri, Space and Astrophysical Plasmas of the Physic and Astronomy Department of the University of Florence and of the results we have obtained. In particular we show a comparison between results obtained by high-resolution numerical simulations using either fluids or kinetic approaches with the data obtained by the last missions both in the solar wind and in the Earth's magnetosphere.

Electron density distributions in 1D, 2D, and 3D from inversion of coronal white-light images

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Presenting author: *P. Lamy*

Abstract: I will review the different techniques to reconstruct the electron density distributions from white-light images starting with the classical 1D inversion pioneered by Van de Hulst (1950) based on the spherically symmetric geometry (spherically symmetric inversion, SSI). It was later generalized to 2D inversion using the spherically symmetric polynomial approximation (SSPA) method independently by Hayes et al. (2001} and Quemerais et al. (2002} and applied to LASCO-C2 *pB* images. The latter authors considered in addition the case of axial symmetry with reference to the axisymmetric model of Saito (1970). The method assumes that the radial variation of the electron density Ne follows a prescribed function of *r* the radial distance to the Sun center, usually a combination of different power laws. The coefficients are determined by forcing the recalculated brightness profile to match the observed one and the procedure is repeated for different position angles to generate a 2D map of the electron density. Wang et al. (2014) showed that the SSPA method could be used to reconstruct the 3D coronal density with a resolution in longitude of approximately 50°. Solar rotational tomography (SRT) is currently the only method that provides 3D results at a global scale without underlying geometrical assumptions unlike the SSPA. Most developments such as those of Morgan et al. (2009) and Kramar et al. (2014, 2016) assume a static corona over half a Carrington rotation, the interval requires to view the corona in full. Time-dependent tomographic reconstructions were achieved by Butala et al. (2010) who implemented a procedure based on Kalman filters and Vibert et al. (2016) who implemented a simpler spatio-temporal regularization. I will then discuss how these different techniques can be applied to the METIS white-light images during the different phases of the Solar Orbiter mission.

H I Ly-alpha UVCS Observations through a full solar cycle

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INAF/Osservatorio Astrofisico di Torino

Presenting author: *Silvio Giordano*

Abstract:

Metis coronagraph for the first time will provide UV images of the solar corona with a field of view from 1.2 to 4 solar radii in the neutral hydrogen Ly-alpha emission. This radiation has been observed only with a rocket observation in 1971 and with a Spartan 201 instrument deployed by the Space Shuttle in 1993, then, since 1996 has been detected spectroscopically for more than a full solar cycle by UVCS instrument abroad SOHO mission with almost daily coverage. UVCS instantaneous field of view is a narrow slit perpendicular to the sunward direction, the slit can be moved along the radial direction and rotated by 360 degrees about an axis pointing to the center of the Sun to observe the entire solar corona between 1.4 and 10 solar radii. UVCS observations have been used to define the requirements and compute the expected performances of Metis instrument; more deep and wide exploitation of these data can be useful for planning Metis observations, in-flight calibration, driving data interpretation and comparison with modeling. In this paper we overview the UVCS observations, which cover the period from 1996 to 2012, we present the tools to access the data, perform the analysis and determine to observed parameters such as the line intensity and line width. The almost daily synoptic observations performed by UVCS allow us to reconstruct the solar corona images in Ly-alpha for more than a solar cycle, here we present the images of the intensity and temperature averaged over throughout each Carrington rotation with analytical approximations as functions of radial distance, latitude and solar phase. These images, with electron density derived from LASCO coronagraph, will provide also maps of the variation of the solar wind speed through a full solar cycle.

Magnetic flux emergence through the solar atmosphere

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Presenting author: *Salvo Guglielmino*

Abstract: High-resolution observations have shown that magnetic flux emergence has a fundamental impact in the upper atmospheric layers. Indeed, magnetic interactions between new and pre-existing fields are thought to be crucial for triggering energy release phenomena, from small-scale reconnection episodes to large-scale events such as flares and CMEs.

Here, we discuss a few case studies relevant to small-scale magnetic structures (size ≈5 Mm, flux ≈10^{19} Mx), highlighting the invaluable contributions expected from Solar Orbiter observations. In this context, we describe the advantage of a synergetic approach between the remote sensing instruments aboard Solar Orbiter (PHI, EUI, SPICE, Metis) to obtain a complete picture of the magnetic flux emergence process from the photosphere to the corona.

Characterizing fast magnetic reconnection in the solar corona with Hall-MHD and Hybrid-PIC simulations.

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Presenting author: *Emanuele Papini*

Abstract: Magnetic reconnection provides the primary source for explosive energy release, plasma heating, and particle acceleration in many astrophysical environments. In the solar corona, reconnection is often invoked as a driver of flares, coronal mass ejections, and transient events generating, e.g., the plasma blobs observed at the cusp of helmet streamers. The last decades witnessed a revival of interest in the tearing instability as a driver for efficient reconnection. It has been established that, provided that the current sheet aspect ratio a/L becomes small enough ($a/L \sim S^{-1/3}$ for a given Lundquist number $S \gg 1$, as it is in the solar corona), reconnection occurs very fast on ideal Alfvén timescales and becomes independent of S. Here we investigate, by means of high-resolution two-dimensional Hall-MHD and Hybrid-kinetic simulations, the ideal tearing instability in the Hall regime, which is appropriate when the width of the diffusion region becomes comparable or smaller than the ion inertial length d_i. Numerical results show that the Hall term greatly affects the nonlinear phase of the tearing instability, where we observe the spontaneous development and reconnection of secondary current sheets, with reconnection rates that can be up to ten times larger than that of the main current sheet. These secondary instabilities naturally lead to an explosive disruption of the whole reconnecting site and to energy release on super-Alfvénic timescales, as required to explain the fast dynamics observed in the solar coronal plasma. Results of this work may guide the interpretation of observations by, e.g., METIS and SoloHI, as well as other instruments onboard Solar Orbiter.

Impulsive heating in the solar corona: large scale magnetic rearrangements

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Presenting author: *Fabio Reale*

Abstract: Multiband observations show clear evidence for large-scale magnetic interaction of coronal loops in active regions. These loops are transiently (~20 min) bright in hot EUV channels (Atmospheric Imaging Assembly on-board Solar Dynamics Observatory, SDO/AIA), with temperatures up to about 10 MK, intersect in the plane of the sky, and their footpoints are hot spots for a short time in transition region UV lines (Interface Region Imaging Spectrograph, IRIS). The UV spectral features can be explained as produced by non-thermal electron beams hitting the transition region and generating a heat pulse of less than 1 minute. This is consistent with periodic pulsations detected in EUV light curves along the interacting loops, produced by sloshing wave fronts driven by short heat pulses. These loop systems represent excellent laboratories for studying impulsive heating mechanisms and allow us to focus physical models for diagnostics. We show preliminary MHD modeling of interacting loops.

Flux rope formation and evolution

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Presenting author: *Paolo Romano*

Abstract: Flux rope (FR) indicates a peculiar topology characterized by a set of magnetic field lines that collectively wrap around a central, axial field line. Such a magnetic configuration is considered crucial in many models of the formation and eruption of solar prominences. When FRs are incorporated in MHD models, the results are in agreement with the observations of the so-called three-part structure of coronal mass ejections, as well as with their precursors.

From the theoretical point of view, the origin of FRs is controversial. Some MHD simulations suggested that rising magnetic flux tubes require a minimum amount of twist to be able to rise cohesively through the convection zone. However, more recent numerical simulations have shown that an FR may not emerge bodily from below the photosphere, but reforms in the corona. Moreover, the question of how the eruption of an FR is initiated and driven is still under debate.

Here, we discuss a few case studies suggesting that the complexity and strength of the photospheric magnetic field is only a partial indicator of the real likelihood of an Active Region to produce the eruption of an FR and a subsequent CME. Therefore, we describe the advantage of coordinated observations by the remote sensing instruments aboard Solar Orbiter (EUI, METIS and PHI) and the new generation ground based telescopes (GST, GREGOR, DIKIST, EST) to obtain a clear comprehension of the mechanisms at the base of the FR formation and evolution at different layers of the solar atmosphere.

Solar Orbiter Science Operations

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Presenting author: *Luis Sánchez*

Abstract:

Solar Orbiter is a mission of the Scientific Programme of the European Space Agency dedicated to solar and heliospheric physics carrying four in-situ and six remote sensing instruments on board.

Its main scientific objectives address how and where the solar wind plasma and magnetic field originate, how solar transients drive heliospheric variability, what are the workings of the solar eruptions that produce energetic particles, and how the solar dynamo works and drives the connection between the Sun and the heliosphere.

In this, Solar Orbiter builds on previous ESA missions like Ulysses and SOHO. However, its trajectory, which takes the spacecraft up to 2 AUs from Earth while tilting its orbit out of the Ecliptic plane to explore the solar poles, poses significant challenges to science operations.

This contribution describes the peculiarities of operating a remote sensing solar physics instrument package together with its in-situ counterparts while far from Earth and responding to a dynamic Sun. The resulting science operations plans may be unfamiliar to the overall solar physics community, as they are quite distinct from those used in previous space missions.