Investigating the link between Active Region photospheric characteristics and its eruptive potential

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Forecasting the probability of a solar Active Region (AR) to flare is a challenging and pursued topic in the Space Weather field. The R value, developed by Schrijver (2007) on MDI data, is among the most used descriptors of the photospheric magnetic field in ARs for flare forecasting applications. We propose a modified computation for the R value to exploit the higher spatial resolution of HMI (cross-calibrated with MDI data to maintain compatibility) and verify its functionality on the full set of cycle 24th solar flares. Furthermore, we propose a new parameter D, based on the automatic recognition of magnetic polarity-inversion lines in the identified AR, to parametrize the AR magnetic topological complexity. We use both R and D parameters to train a logistic regression method to predict the occurrence of X- or M- class flares in a given solar active region during the following 24 hours period.

The results of our statistical analysis show that both parameters are good descriptors of the flaring proneness of an AR and possible tools for flare forecasting. D parameter will be included in the flare forecasting product of the Space WEeatherR TOr vergata university (SWERTO), presently based on the R value. SWERTO is an operational Space Weather service operated on regional scale (Regione Lazio) based on data from space-based and ground-based instruments. Also, we investigate the extension of this approach towards the prediction of Coronal Mass Ejection.

Interpreting and predicting spacecraft observations of plasma turbulence with high-resolution hybrid simulations

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Abstract: We present results from high-resolution hybrid (kinetic ions, fluid electrons) simulations of plasma turbulence, exploring realistic physical conditions encountered by spacecraft missions during specific events in different regions of the inner heliosphere. In particular, we reproduce and interpret observations by NASA Magnetospheric Multiscale (MMS) of turbulence generated by a Kelvin-Helmholtz event in the magnetosheath on September 8th 2015 and by NASA Parker Solar Probe (PSP) during its first perihelion at 35.7 solar radii on November 5th 2018. In both cases, we follow the development of the turbulent energy cascade from magnetohydrodynamic scales down to sub-ion scales. For the MMS event, our numerical results exhibit an unprecedented quantitative agreement for what concerns the spectral and intermittency properties, allowing us to investigate the nature of fluctuations at kinetic scales and the importance of the interplay between turbulence and magnetic reconnection. For the PSP event, our preliminary results show a qualitative agreement with observational data. In this case, the magnetic field spectrum is much steeper than previously shown by hybrid simulations in the literature and by spacecraft observations of the solar wind and of the near-Earth environment. By varying the plasma conditions, we investigate the possible mechanism(s) behind such change of regime. We discuss our results in the framework of theoretical models which predict the behaviour of the nonlinear interaction of dispersive wave modes and reconnection in low-beta plasmas. Our results confirm the ability of our hybrid simulations to reproduce and predict spacecraft observations in different plasma conditions, which is a necessary condition for interpreting in-situ data from instruments onboard Solar Orbiter. Our future predictions of the plasma dynamics extremely close to the Sun, in regions not accessible to in-situ measurements, will also provide a strong support in the interpretation of METIS remote sensing observations.

Three-dimensional reconstruction of the expanding shock associated with the 21st June 2013 solar energetic particle event

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Abstract:

Early on 21st June 2013 an eruptive prominence occurred along with an M2.9 class flare. The eruption resulted in a fast partial halo coronal mass ejection (CME) producing a Type II radio burst which yielded a clear signature of shock propagation, also observed in white light (WL) coronagraphic images. The concomitant emission of solar energetic particles (SEPs) produced a significant increase in the proton fluxes measured by LET and HET aboard STEREO-B, in the energy range 4 – 100 MeV. On the other hand, only small enhancements at much lower energies were observed at STEREO-A (ST-A) location and GOES-15 at the Earth.

We reconstructed the 3D shape of the expanding shock front by processing the STEREO/SECCHI and SOHO/LASCO simultaneous coronagraphic observations and by assuming a spheroidal shock model. We found that the shock front was expanding in the south-west and south-east direction on the plane-of-sky of the ST-B and LASCO respectively, while it was a backside event as seen by ST-A.

By projecting the 3D shock locations at different times on the ecliptic plane we obtained that during the expansion the region located between the nose and the eastern flank of the shock was magnetically connected with ST-B in agreement with the significant SEP flux measured on-board this spacecraft. On the other hand, the shock was only marginally connected with ST-A and GOES-15. These results were used to interpret the different SEP flux behavior at ST-B, ST-A, and GOES-15 locations, and discussed in the framework of particle acceleration by CME-driven shocks.

Exploring the solar corona through observations of sungrazing comets with Solar Orbiter/Metis

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Abstract: Observations of comets with space instruments, such as coronagraphs and heliospheric imagers, reveal highly dynamic tails, which exhibit disconnections, wave-like motion, and respond to the solar wind flows and to the passage of coronal mass ejections (Vourlidas et al., *ApJ*, **668**, L79, 2007; DeForest et al., *ApJ*, *812*, 108, 2015). Recently, Nisticò et al., *A&A*, **615**, A143 (2018) proposed that the observed transverse oscillations of comet tails are attributed to the formation of a Kármán vortex street, whose properties depend upon the characteristics of the comet itself and the local medium. Furthermore, during the 25 years of the SoHO space mission, the LASCO coronagraphs have observed more than 3500 sungrazing comets plunging in the solar atmosphere (Battams & Knight, *Phil. Trans. R. Soc. A*, **375**, 20160257, 2017). Such comets can be exploited as probes of the corona and the near-Sun environment (Jones et al., *SSR*, **214**, 20, 2018). The coronagraph Metis aboard the Solar Orbiter spacecraft will certainly provide observations of sungrazing comets with unprecedented spatial and temporal resolutions, and from very advantageous positions (minimum distance below 0.3 AU), both in the visible and UV wavelengths. Metis will accurately image the interaction of the comet tails with the local medium, observe how cometary ions are channelled along the local magnetic field lines, and allow diagnostics of the coronal plasma encountered by the sungrazing comets, e.g., by spectroscopy in the hydrogen Lyman-α line (Bemporad et al., *ApJ*, **620**, 1, 2005). We present simulations of trajectories for some groups of sungrazing comets in the METIS field-of-view during the different phases of the Solar Orbiter mission, in order to demonstrate plausible observational scenarios in connection with the further Solar Orbiter instruments (e.g., Solo-HI) and other space missions (e.g., Parker Solar Probe, Proba-3).

Diagnostics of coronal mass ejections with Solar Orbiter/Metis

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Abstract: The analysis of the coronal emission observed at different wavelengths during the propagation of coronal mass ejection and associated phenomena, such as erupting prominences and shocks, can provide unique information on the main geometrical, kinetical, and thermodynamical properties of these major manifestations of the solar activity.

We discuss recent results obtained from different diagnostic techniques applied to visible-light and UV coronagraphic data, providing physical properties of the plasma such as the density, temperature, and magnetic field distribution, in the perspective of the possible applications to future Solar Orbiter/Metis data.

The 3D geometry of the solar magnetic structures

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Most of the physical processes in the outer solar atmosphere (e.g. CMEs) depend on the complex dynamics and evolution of the magnetic field and plasma at different heights in the solar atmosphere. In this regard, reconstructing the 3D structure of the solar magnetic regions, as well as estimating the key physical parameters of the plasma (gas pressure, density, velocity) and their variation in the inner solar atmosphere, can offer important inputs for the understanding of the dynamical processes observed in the outer atmosphere.

Here, we show how results from multi-height spectropolarimetric measurements from the photosphere to the upper chromosphere can be effectively combined in order to produce data which are useful for the interpretation and study of the coronal processes.