SWATNet Workshop 3

Solar Activity and Space Weather: Physics Behind the Process

29-30 September 2022 - Athens, Greece

The Abstract Book

Co-organisers of the event

Academy of Athens

University of Ioannina

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Description of the training

This workshop focuses on those physical aspects and physics-/AI-based tools of space plasma physics that are most relevant for the initiation of space weather manifestations. In terms of solar processes, magnetic flux ropes, eruption initiation and plasma /magnetic instabilities, modeling approaches in different domains will be addressed.

Programme

https://swatnet.eu/workshop-3-solar-activity-and-space-weather-physics-behind-the-process/

Format

The school will be primarily in-person, with a capability of virtual participation for students and lecturers. In the abstract book each lecture is marked correspondingly - **[P]** stands for in-person contributions and **[V]** stands for virtual lectures, and **[R]** for recorded lecture.

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29 September 2022 (DAY 1)

Properties of active regions and eruptive activity: recent results and future directions [V]

Ioannis Kontogiannis, Leibniz Institute for Astrophysics Potsdam, Potsdam, Germany

Major flares and coronal mass ejections (CMEs) are produced by active regions with common morphological characteristics, such as δ-spots, filaments, sigmoids, and strongly sheared magnetic polarity inversion lines. These indicate complex magnetic configurations, associated with strong electric currents and huge amounts of free magnetic energy and helicity. Based on this knowledge we calculate appropriate parameters/predictors that quantify the flaring and eruptive potential of active regions. With the regular provision of near real time, uninterrupted, high-quality observations from space, large, statistically significant samples are available. These comprise not only photospheric magnetograms, but also EUV images, spectra, and time series and, thus, our inventory of data sources and feature extraction methods expands. This talk reviews these efforts to parameterize the characteristics of eruptive active regions and discusses ongoing work on developing new parameters suitable for CME prediction and exploiting time series of magnetic properties.

The Birth of Coronal Mass Ejections: Physical Mechanisms, Observables and Challenges [P]

Spiros Patsourakos, Department of Physics, University of Ioannina, Ioannina, Greece

Coronal Mass Ejections (CMEs) represent a major driver of space weather. While there is no doubt about the magnetic origins of CMEs, we are still far from reaching consensus about the specifics of the destabilization and eventual eruption of huge amounts of magnetized plasmas from the solar atmosphere into the interplanetary space. Therefore, understanding how CMEs are born, is of great value not only in terms of solving an important plasma astrophysics problem, but also for eventually enabling their prediction, which will represent a milestone achievement for space weather forecasting. With this talk we provide an account of physical mechanisms behind the formation and eventual eruption of magnetic configurations leading up to CMEs, discuss various observables which are employed to test the realism of these mechanisms, and highlight current challenges in our understanding and possible pathways for improvement.

Coronal observations in pre- and post-eruption evolution [P]

Alexander Nindos, University of Ioannina, Greece

The solar atmosphere exhibits a wealth of dynamic phenomena. The most powerful of them are coronal mass ejections (CMEs) and flares. CMEs are large-scale expulsions of magnetized coronal plasma into the heliosphere. Flares result in the impulsive release of energy in the solar atmosphere, with major events occurring exclusively in active regions where plasma is heated and particles are accelerated to relativistic energies on short timescales. CMEs and flares do not necessarily correlate one-to-one. When they do, the flare is called eruptive, otherwise it is called confined. The flare-CME association likelihood increases with flare magnitude; the largest flares are usually one-to-one associated with CMEs. The combination of multi-wavelength observations (white-light, EUV, soft X-ray, $H_{alpha,}$ and radio data) has shed much-needed light on the configuration and morphology of the structures that erupt. I will review pertinent recent observations and discuss key properties of the

regions that erupt which highlight the magnetic nature of the phenomena. I will also provide an outlook on open issues and challenges regarding the observational study of eruptive events.

Magnetic flux emergence in the Sun [R]

Vasilis Archontis, University of Ioannina, Greece

This lecture will be a recorded presentation.Magnetic flux emergence is a key process in the Sun. Therefore, in this talk, we are going to discuss how the magnetic fields emerge from the solar interior to the surface and into the stratified solar atmosphere. We will focus on numerical simulations and how one can study the multi-scale evolution of the emerging magnetized plasma, towards the onset of small-scale events (e.g. Ellerman bombs) and large-scale phenomenon (e.g. Active Regions).

Space radiation monitor measurements for space weather applications [P]

Ingmar Sandberg, Space Applications & Research Consultancy, Greece

The increasing number of radiation environment sensors at different orbits - covering both Earth's magnetosphere and the inner heliosphere - provide new assets in space weather and environment analysts. The characteristics and the reliability of the associated measurements are crucial for the nowcasting, forecasting and the specification of the space radiation environment as determined by solar energetic protons and trapped energetic particles in Earth’s radiation belts. In this talk, we will review relatively recent datasets and discuss procedures for their analysis that enable us to take full advantage of their characteristics, in terms of both monitoring and forecasting tasks.

The Physics of Sun-to-Heliosphere Transport [V]

Emilia Kilpua, University of Helsinki, Finland

This lecture will focus on processes and phenomena that happens between the Sun and the Earth. The propagation, evolution and interaction of solar wind transients and stream interaction regions forms a critical step in understanding and forecasting space weather and its consequences. In a case of a coronal mass ejections (CMEs) its structure and expected impact can dramatically change due to various and complex physical process in interplanetary space, such as erosion of flux due to magnetic reconnection, interaction between two CMEs and propagation of an interplanetary shock past a preceding CME. As a consequence, CMEs rotate, deflect, deform, change their propagation speed and can even completely lose their characteristic signatures.

Unveiling Current Challenges in Predicting Solar Energetic Particle (SEP) Events [P]

Anastasios Anastasiadis, Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Greece

Space Weather effects of Solar Energetic Particle (SEP) events range from the direct radiation hazard that those impose to crews and equipment primarily in the interplanetary space to ramifications within the Earth's magnetosphere and atmosphere. Hence, SEP events are of particular importance for the near future planned manned missions to the Moon and Mars, as well as, for the un-obstacle daily

living. We will discuss how the parameters of the parent solar events (i.e. solar flares and coronal mass ejections - CMEs) are related to the probability of occurrence and critical characteristics (i.e. peak proton flux, fluence) of SEP events in the near-Earth environment. The modeling efforts of SEP events that are geared towards operational prediction will be outlined. Finally, future challenges that need to be addressed by the scientific community are put forth and discussed.

Physics-based modelling of solar eruptions: Paving a pathway for space-weather forecasting [P]

Ranadeep Sarkar, University of Helsinki, Finland

One of the major challenges in space weather forecasting is to reliably predict the arrival time and the north-south magnetic field component (Bz) of interplanetary coronal mass ejections (ICMEs) at near-Earth space. Since magnetic field cannot be measured reliably remotely in solar eruptions, and direct continuous measurements of the Earth-impacting solar transients are available only very close to our planet, modelling of solar eruptions is paramount. Comparing the remote-sensing and in-situ observations of solar wind data, the empirical models derive a functional relationship between the near-Sun CME kinematics and the variables related to CME arrival at 1AU. Although these empirical relations can be used as arrival time prediction of a CME, those cannot incorporate the internal magnetic structure of a CME and its continuous evolution from Sun to Earth.
Based on the principles of CME evolution and a magneto hydrodynamic (MHD) approach, the physics-based models simulate the CME magnetic field as well as the associated plasma parameters all the way from near-Sun to Earth. Therefore, the physics-based models are capable of estimating both the time of arrival as well as the internal magnetic configuration of a CME when it reaches Earth. In this talk, I will highlight how the physics-based models work to simulate the heliospheric evolution of a CME and how the input parameters of the model can be constrained from remote sensing observations. The application of the models to few CME events will be discussed to showcase their current prediction capability and the factors that affect the model performance. A future roadmap on building an operational modelling tool will also be discussed from the perspective of space-weather forecasting.

30 September 2022 (DAY 2)

AI-based Modeling of Solar Eruptions: Machine- and Deep-Learning in solar flare forecasting [V]

Sabrina Guastavino, University of Geneva, Switzerland

Solar flares are the most explosive phenomena in the heliosphere, releasing a huge amount of electromagnetic radiation at all wavelengths and, in this way, triggering the whole space weather connection. Solar flares originate from magnetically active regions (ARs) on the Sun. However, not all active regions give rise to solar flares and the nature of the prediction is intrinsically probabilistic. In the last decade machine and deep learning approaches have been obtaining an increasing interest in flare forecasting, thanks to flexible algorithms that may take as input point-in-time feature sets extracted from magnetograms, time series of features, point-in-time images of ARs, and videos of magnetograms of ARs. The prediction performances of these supervised approaches are

characterized by a notable degree of heterogeneity, which is probably related to significant differences in the way datasets are generated for training and validation.
In this talk we discuss some crucial aspects for the forecasting effectiveness of machine/deep learning for flare prediction: (1) the optimization of the network weights which depends on an appropriate choice of the loss function in the training phase; (2) the validation strategy for the prediction method and (3) the assessment of the prediction power of the method. Finally, we show a validation strategy based on the generation of well-balanced training and validation sets and we discuss its performances by means of a video-based deep learning approach.

EUV coronal spectroscopy and its use as a possible flare precursor [P]

Costis Gontikakis, Academy of Athens, Greece

The solar upper atmospheric emission in the ultraviolet is rich in spectral lines and provides critical information on the composition and dynamics of the solar coronal plasma. We will present elements of the solar UV spectrum, some measurements that can be carried out and subsequent diagnostics. Moreover, we will present findings of potential solar flare precursors (i.e., flare-related features at relatively short times prior to the flare onset) that can be derived from UV spectral measurements. Potentially promising future research directions may be drawn from these findings.