Being one of the first observational signatures of solar eruptions, solar flares not only enable probing the plasma processes at play in the million-kelvin environment but also improve our capability of predicting the magnitude and timing of the impact of solar eruptions on the Earth and beyond. Solar flares and accompanying events are by far the most energetic dynamic phenomena in the Solar System emitting a substantial amount of energy in the X-ray and Extreme Ultraviolet (EUV) range. Particles are accelerated in the highest layer of the solar atmosphere (solar corona) to very high energies. Particles escaping from the acceleration region may reach interplanetary space where they are recorded as Solar Energetic Particles (SEPs). The remaining particles propagate along closed magnetic structures to the chromosphere where they lose their energy by colliding with ambient charged particles. This causes abrupt heating of encountered plasma to temperatures above 10 MK. Plasma heated due to high-energy particle beams fills coronal magnetic structures which are observed in the X-rays as flares. Therefore, a solar flare emits both radiation as well as particles. While the high-energy radiation and particles emitted during solar flares are mostly deflected away from the Earth, thanks to the magnetic cocoon around us. However, navigation satellites, space stations, Astronomers, and commercial flights are at risk of getting impacted by flare-related emissions.

Observations and analysis of the activities occurring in the solar atmosphere and their influence on the state of the heliosphere are the main aims of various dedicated science missions to the Sun, e.g., ESA’s key solar mission: Solar Orbiter (SO), and ADITYA-L1 mission: India’s first dedicated solar observatory in space. With the wealth of observations recorded by these space- and ground-based missions, the aim of the solar scientific community is to provide answers to the fundamental questions concerning solar physics, the physics of the heliosphere, and the physics of the Solar System. Advancements in technologies enabled observing the emission from the Sun with high spatial resolution will be made from a distance 3 times closer compared to past missions. This enables witnessing the unexplored territory of plasma, charged particles, and magnetic field environment. Therefore, our proposal exploits this capability in a unique manner by associating different kinds of radiation emitted during solar flares with associated electron events. While the multi-wavelength emission and acceleration of charged particles in the solar corona is due to magnetic reconnection, the attempt to systematically combine the remote and in-situ observations has only been made possible very recently, which is the primary aim of the proposal.

Aided by multi-wavelength analysis and hydrodynamical simulations, the proposed work aims to understand a few of the long-standing problems in astrophysics, for example, if X-class (extreme intensity class) flares are the most energetic or the strongest contributor in affecting the space weather as well, or what is the physics of proportionating the free (excess) magnetic energy in thermal and nonthermal processes during flares? To answer these outstanding issues, we aim to probe the long-term plasma and magnetic field properties of the active region that lead to flare events releasing strong emissions and energetic particles (termed to be energetically-rich flares). From the analysis of multi-wavelength observations, we aim to trace the plasma properties during magnetic reconnection that exhibit a direct association with the energetically rich flares. We plan to undertake the analysis of the entire period of observations available from the STIX mission (from 2021-ongoing) that includes flare observations of more than 30000 flares and in-situ observations from EPD, both instruments onboard Solar Orbiter. A natural outcome of this analysis will be the identification of a list of outstanding strong flares in terms of X-ray emission as well as associated electrons. These events will be further analyzed by employing multi-wavelength observation and hydrodynamical modeling. Working in close collaboration with the STIX team for the last 1.5 years, thanks to the ongoing MSCA funding, gives an advantage to quickly obtain the results according to the proposed plan. In addition, while the applicant is already equipped with the experience related to conducting hydrodynamical simulations, the application of machine learning will be acquired in the course of the implementation of the proposed work. We anticipate producing several publications and an online catalog containing the flares of space weather importance.