Magnetic Reconnection in the Solar Atmosphere: Future Plans for Solar Observations

Shinsuke Imada[1], International SOLAR-C Team
[1] Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo
e-mail (speaker):imada@eps.s.u-tokyo.ac.jp

As a fundamental step towards answering how the plasma universe is created and evolves, and how the Sun influences the Earth and other planets in our solar system, the proposed mission is designed to comprehensively understand how mass and energy are transferred throughout the solar atmosphere. Understanding the solar atmosphere, which connects to the heliosphere via radiation, the solar wind and coronal mass ejections, and energetic particles, is pivotal for establishing the conditions for life and habitability in the solar system.

SOLAR-C is a mission designed to provide a conclusive answer to the most fundamental question in solar physics: how does the interplay of magnetic fields and plasma drive solar activity? The most significant examples of this interplay are atmospheric heating and explosive energy release, such as flares and coronal mass ejections (CMEs). Thus, the two primary science objectives for SOLAR-C are:

I. Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind.
II. Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions.

In order to advance our understanding of the mysterious Sun, especially of the origin of the hot solar atmosphere and the occurrence of the solar flares, the SOLAR-C mission concept tackles the scientific objectives by taking the following unique approaches:

A. To seamlessly observe all the temperature regimes of the atmosphere from the chromosphere to the corona simultaneously,
B. To resolve elemental structures of the solar atmosphere and track their changes with sufficient cadence, and,
C. To obtain spectroscopic information on dynamics of elementary processes taking place in the solar atmosphere.

Magnetic reconnection is one of the fundamental processes for converting magnetic energy into the thermal and kinetic energy of the plasma. This process occurs much faster than is predicted by classical theory. SOLAR-C will observe the dynamics of magnetic structures to understand the mechanisms that lead to fast magnetic reconnection in partially or fully ionized plasmas. SOLAR-C will test reconnection models (e.g., Sweet-Parker, Petschek, or plasmoid-unstable type reconnection) by observing the velocity, temperature, density, ionization rate in and around the shocks, and magnetic islands of the reconnection region. The high spatial and temporal resolution by spectrometer, assisted by slit-jaw context imaging of the chromosphere, will allow us to study chromospheric evaporation produced by reconnection not only at coronal temperatures but also at low temperatures deep in the transition region and chromosphere. This will determine how much energy is released through magnetic reconnection. The observation of magnetic reconnection in the chromosphere by SOLAR-C will clarify the role of the fast reconnection process in partially ionized plasma.

To date, many observations have been made on the solar corona to confirm the presence of high-temperature and high-speed plasma flows produced by magnetic reconnection above flare arcades. In this talk, We will introduce the study on plasma heating considers the time-dependent ionization process during a large solar flare on 2017 September 10, observed by Hinode/EUV Imaging Spectrometer (EIS). The observed Fe XXIV/Fe XXIII ratios increase downstream of the reconnection outflow, and they are consistent with the time-dependent ionization effect at a constant electron temperature Te = 25 MK. Moreover, this study also shows that the nonthermal velocity, which can be related to the turbulent velocity, reduces significantly along the downstream of the reconnection outflow, even when considering the time-dependent ionization process[1]. The number of high-temperature lines observed by Hinode/EIS is limited, so it is difficult to make a sufficient diagnosis of the reconnection region. Recently, the next generation solar observation satellite SOLAR-C has been discussed intensively. An ultraviolet imaging spectrometer with dramatically improved spatial and temporal resolution is planned for this satellite. In the SOLAR-C era, thermal nonequilibrium plasma will be extensively discussed. We expect that SOLAR-C (EUVST) will reveal the reconnection region in detail.

References

[1] Imada, S., "Nonequilibrium Ionization Plasma during a Large Solar Limb Flare Observed by Hinode/EIS", The Astrophysical Journal Letters, Volume 914, Issue 2, id.L28