Solar Flux Rope Formation and Eruption: MHD Simulation and Forward Modeling

Xiaozhou Zhao[1], Rony Keppens[1]

[1] *CmPA, KU Leuven, Leuven, Belgium*

We study the flux rope (FR) formation and eruption process driven by photospheric converging motion, which occurs frequently in the solar atmosphere.

A two-and-a-half-dimensional magnetohydrodynamic (MHD) simulation is conducted in a chromosphere-transition-corona setup [1]. The initial arcade-like linear force-free magnetic field is driven by an imposed slow motion converging toward the magnetic inversion line at the bottom boundary. The convergence brings opposite-polarity magnetic flux to the polarity inversion, giving rise to the formation of an FR with an embedded prominence by reconnection. The FR rises, and a current sheet (CS) forms below it. The CS evolution during the FR formation and eruption process in the MHD simulation can be divided into four stages. The first stage shows the CS forming and gradually lengthening. Resistive instabilities that disrupt the CS mark the beginning of the second stage. Magnetic islands disappear in the third stage and reappear in the fourth stage. The FR undergoes a series of quasi-static equilibrium states in the first stage, and the impulsive acceleration starts from the beginning of the second stage.

We conduct forward-modeling analysis based on the MHD simulation [2]. Synthetic images and light curves of the seven Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) channels, i.e., 9.4 nm, 13.1 nm, 17.1 nm, 19.3 nm, 21.1 nm, 30.4 nm, and 33.5 nm, and the $3-25$ keV thermal X-ray are obtained with forward-modeling analysis. The loop-top source and the coronal sources of the soft X-ray are reproduced in forward modeling. The light curves of the seven SDO/AIA channels start to rise once resistive instabilities develop. The light curve of the $3-25$ keV thermal X-ray starts to go up when the reconnection rate reaches one of its peaks. Quasi-periodic pulsations (QPPs) appear twice in the SDO/AIA 17.1 nm, 21.1 nm, and 30.4 nm channels, corresponding to the period of chaotic (re)-appearance and CS-guided displacements of the magnetic islands. QPPs appear once in the SDO/AIA 9.4 nm and 33.5 nm channels after the disruption of the CS by resistive instabilities and in the 19.3 nm channel when the chaotic motion of the magnetic islands reappears. We also study the physical properties and dynamics of magnetic islands.

References

[1] Zhao, X., Xia, C., Keppens, R., & Gan, W., ApJ, **841**, 106 (2017)

[2] Zhao, X., Xia, C., Van Doorsselaere, T., Keppens, R., & Gan, W., ApJ, **872**, 190 (2019)