Understanding filament eruptions, and coronal mass ejections with data-driven MHD numerical simulations

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Filament eruptions, coronal mass ejections are physical phenomena which require the formation of magnetic flux ropes carrying electric current. It is not only the key structure for solar eruptions, but also the major drivers of geomagnetic storms. As such, a numerical model that can capture the whole process of a flux rope from its birth to its death or eruption is certainly crucial for predicting adverse space weather events.

The observations from space or ground instruments reveal the existence of such flux ropes by the presence of sigmoids in active regions. After proposing cartoons in 2D, potential, linear, and NLFFF extrapolations, numerical simulations were developed, theoretically in a first attempt and further on based data-driven magnetohydrodynamic modeling using high resolution observed vector magnetograms (HMI).

We consider two solar events: event 1 on October 28 2021 [1,2], event 2 on September 2017 [3]. We develop a new data-driven model composed of time-dependent magneto-frictional method and radiation magnetohydrodynamic model, which successfully reproduces the formation and eruption of the observed flux rope. For the formation stage, we find that the photosphere shearing and converging plasma flows play a critical role in flux rope formation. The CME with its three-part structures is well fitted with the numerical simulation in event 1.

References
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