Project Details

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Topic: Understanding The Onset of Major Solar Eruptions

Project Title:
Observationally guided simulations of coronal mass ejections (CMEs)

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Summary:
We propose to perform magnetohydrodynamic (MHD) simulations of coronal mass ejections (CMEs) in the corona using observations of the photospheric magnetic fields as input. The goal is to determine the coronal magnetic field evolution of the CME events from the quasi-static build-up to the dynamic eruption, and to ascertain the properties of the eruption, such as acceleration, speed, and direction through the lower solar corona into the solar wind. The validity of the simulated magnetic field evolution will be examined by comparing with coronal multi-wavelength observations of selected events observed by SDO/AIA, SOHO/LASCO, STEREO, and Mauna Loa Solar Observatory (MLSO). The main scientific questions we want to address are: (1) What are the observational signatures that are indicative of the build-up of a magnetic flux rope and readiness for eruption? (2) What are the conditions that lead to confined vs. ejective eruptions and what are the crucial factors that determine the acceleration, terminal speed and orientation of the magnetic field in the out-going CMEs? (3) What are the conditions that can lead to the development of homologous and cannibalistic CMEs, and how do their interactions affect the CME speed, shocks and magnetic field structures.

We will use the Magnetic Flux Eruption (MFE) MHD code (Fan 2012, 2016, 2017) to carry out the simulations of CME initiation in the large-scale corona driven by an imposed flux transport at the base of the corona. For the imposed flux transport, we will first experiment with prescribing the emergence of idealized twisted magnetic flux ropes whose properties are guided by the observed flux emergence patterns (e.g. Fan 2016), and then we will use the electric field directly inferred from time sequences of vector magnetograms from SDO/HMI (Kazachenko et al. 2014, 2015). The MFE code solves the semi-relativistic MHD equations in a spherical domain with the thermodynamics taking into account the essential non adiabatic effects of the corona and transition region, including an empirical coronal heating, optically thin radiative cooling, and field-aligned thermal conduction (Fan 2017). We will construct synthetic EUV and X-Ray images as well as coronagraph white light images from our simulations of the CME source regions and eruptions, and compare them with SDO/AIA, SOHO/LASCO, STEREO, and MLSO/KCor observations of the simulated events.

The proposed study will directly contribute to the goals of the Focused Science Team Effort on the Focused Science Topics of "Understanding the Onset of Major Solar Eruptions". Our project integrates numerical simulations with observational synthesis to interpret observations of CME events for both the build-up phase and the dynamic eruption phase. Our observationally guided MHD simulations to determine the realistic coronal magnetic field evolutions of the CME events will (1) improve our understanding of the conditions for the readiness for eruption and identify their observational signatures; (2) quantify the build-up of free magnetic energy and determine the coronal magnetic field evolution of CME source regions given photospheric magnetic field observations; (3) improve our ability to determine the velocity and magnetic field structure of the outgoing CMEs needed to improve space weather forecasts. Metrics and milestones for determining the successful progress and outcome of the research include refereed publications on results of simulations that provide physical understanding and interpretation of the observed signatures of the CME events. The ability for our observationally guided simulations to reproduce the observed eruptive behavior first qualitatively and then quantitatively (e.g. the speed, direction and morphology of the CMEs) will be the milestones and measure of success of our project.

Publication References:

no references