Project Details

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Topic: Understanding The Onset of Major Solar Eruptions

Project Title:
Physics-based Understanding and Data-constrained Simulations of CME Initiation and Propagation

PI Name: Antonia Stefanova Savcheva
PI Email: asavcheva@cfa.harvard.edu
Affiliation: SAO
Project Member(s):
- Karna, Nishu;Co-I;Smithsonian Institution/Smithsonian Astrophysical Observatory
- Tassev, Svetlin;Co-I;Smithsonian Institution/Smithsonian Astrophysical Observatory
- Kliem, Bernhard;Co-I;Smithsonian Institution/Smithsonian Astrophysical Observatory
- Zhang, Jie;Co-I;George Mason University
- Lugaz, Noe;Co-I;University of New Hampshire, Durham

Summary:
Physics-Based Understanding and Data-constrained Simulations of CME Initiation and Propagation

There are multiple factors that determine the stability of active regions (AR) and how much energy they can store, which on the other hand determines the properties of the eruption. For this purpose we plan physics-based parameter study of Titov-Demoulin (TD) flux rope (FR) equilibria with and without boundary motions in an idealized 3D MHD simulation that will address the following science questions:

1. What are the factors that determine the stability of TD FRs in different topologies?

2. How much energy and helicity is stored in each case and what are the parameters of the eruptions produced from the loss of equilibrium?

3. What factors determine if an eruption is failed, or if successful " its initial parameters?

Based on identifying typical topologies, classes of boundary motions, and equilibrium parameters, we will aim at identifying pre-eruptive configurations that possess similar characteristics based on data from the current fleet of NASA space missions like SDO, Hinode, IRIS, STEREO, and LASCO. We propose to perform data-constrained simulations of CME initiation and propagation starting from a realistic initial condition of these ARs with evidence of a FR that is on the verge of eruption. We can use this suite of state-of-the-art observations together with MHD simulations explore some long-standing science objectives:

1. Describe the CME initiation phase and the early phase of development of the CME.

2. Reproduce the observed three-part structure of CMEs as seen in LASCO and STEREO, and their in situ properties at 1AU by using data-constrained MHD simulations and data from WIND and DISCOVER.

3. Identify features that mark the configurations as ready to erupt and quantify the uncertainties in the location of the initiation site, the time period in which an eruption might happen, and predicted parameters of the ejecta. Estimate the probability that it could be a failed eruption.

To achieve these objectives we will address the following science questions:

1. What is the role of reconnection, instability, FR properties, and ambient field in the CME initiation process, i.e. how is the CME triggered?

2. How are the observed remote heliospheric and in situ characteristics of the CMEs with FRs at 1AU influenced by the initial properties in the corona and the subsequent propagation of the ejecta?

3. What are the predictive capabilities of the method and how can it be implemented for real time operations?

In answering the proposed science questions we will utilize NLFFF models of observed erupting active regions from the FR

insertion method as initial conditions to the Space Weather Modeling Framework global MHD code. We will use this method to initiate and propagate more realistic CMEs to 1AU.

Contribution to the FST Effort

This proposal aims at addressing the LWS topic " Understanding the Onset of Major Solar Eruptions " by focusing specifically on both physics-based understanding and data-constrained simulations of AR eruptions which will shed light on the triggers and drivers of CMEs and their properties. One of our major milestones will consist in devising tools to determine markers of potential imminent eruptive behavior and how close to eruption the AR might be, and the subsequent CME properties with an estimate of the factors that contribute to any uncertainties on the prediction.

We propose to contribute to the team efforts by: (1) providing the results of our analyses of ARs and CMEs with a broad range of parameters and topologies from solar cycle 24; (2) sharing our physics-based understanding of the factors that affect AR stability and CME properties; (3) providing additional analyses of specific events as required by the team effort (e.g, AR QSL maps from our new fast 3D QSL code).

Publication References:

no references