Study of the orientation of erupting magnetic fluxropes from the solar corona to 1AU

Ying Wang [1] Yan Xu [1] Yu Chen [2] Haimin Wang [1]

[1]New Jersey Institute of Technology [2]The University of Alabama in Huntsville

Abstract

Eruptive events are the major sources of solar wind and bring magnetic fields and energetic particles from the solar surface to the near Earth environment and cause geomagnetic storms. Previous studies suggested that the south-ward magnetic fields play an important role in generating magnetic cancellation and hence the violent variation of Earth's magnetosphere. In this study on the correlation between the orientation of the interplanetary magnetic field (IMF, the counterpart of CME and ICME at 1AU) and the orientation of eruptive filaments and flux ropes (**FR**s) near the solar surface.The results help to determine the magnetic orientation of IMF, and eventually forecast the geomagnetic storms. This poster focuses on three events, one shows obvious rotation, one does not show much rotation and the other one is in between. For each event, we determine the orientation of magnetic flux ropes by the observation of AIA 171Å and HMI magnetograms. The orientation of the CME upto 32 solar radii (LASCO C2) is estimated by applying the Graduated Cylindrical Shell (GCS) simulation. The rotation of CME, if exists, can be obtained by comparing the MFR axis from the GCS modeling results with the MFR orientation of flux ropes/filament. In addition, the Grad–Shafranov (GS) model is used to reconstruct the flux-rope structure from *in-situ* measurements at 1AU to get the flux axis direction. Our case studies demonstrate that the orientation of the ICME's Bz component is significantly influenced by both the rotation of the flux rope axis and the orientation of the filament or flux rope on the solar surface.

Methodology

- **The determination of ICME orientation** According to the research by *K. Martinic et al (2022)*, CMEs with their central axis roughly parallel to the ecliptic plane are referred to as "low-inclination FRs." In these cases, the Bz component, which represents the helical field, changes sign as the FR is crossed. On the other hand, CMEs with their central axis roughly perpendicular to the ecliptic plane are known as "high-inclination FRs." In such cases, the Bz component represents the axial field, and its sign remains unchanged as the FR is crossed (as observed in *Palmerio et al., 2018)*.

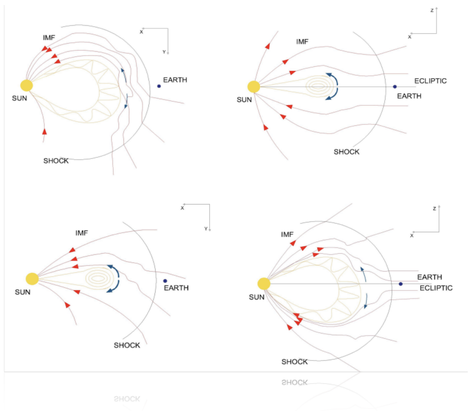
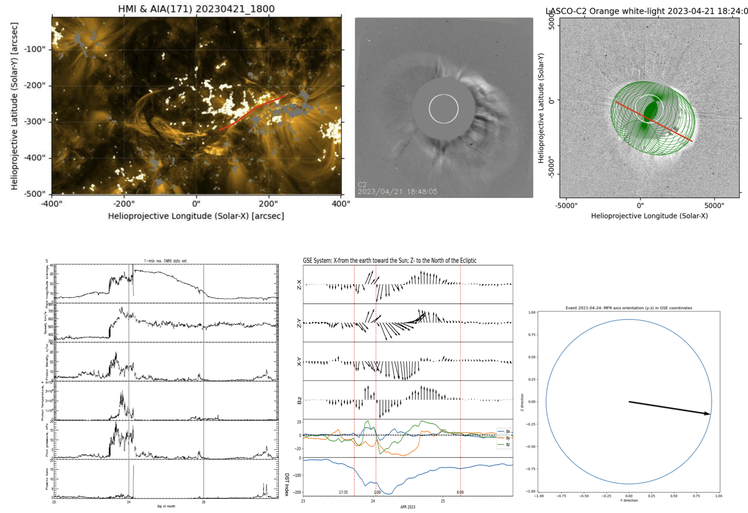


Figure 1. low and high inclination schematic diagram. *K. Martinic et al (2022)*

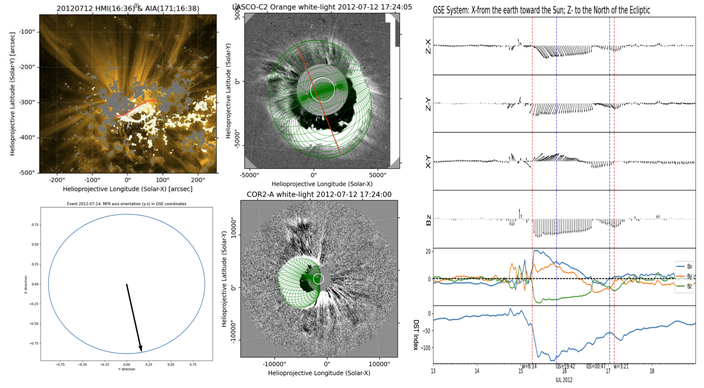
- **The Graduated Cylindrical Shell (GCS)** Use PyThea to parameterize the 3D structure of CME flux-rope
- **The Grad-Shafranov (GS) model** Produce a two-dimensional (2-D) field or flow map of a coherent structure with *in-situ* data.

Event study 1: Low-inclination FR event

This CME occurred at 16:12 on April 21st, 2023. The first picture displays the AIA 171Åand HMI data before the eruption. The middle picture represents the Lasco C2 white light observation. Finally, the right picture illustrates the GCS result based on the GCS model. However, it is important to note that as we only have C2 data, the GCS model's accuracy may be limited due to the lack of comprehensive data.
The ICME Bz component keeps rotating during the period, indicating that the ICME has a low-inclination axis as well, which is aligned with the GS model result. This shows that low-inclination ICMEs exhibit continuous rotations of their Bz component during the transit in the IMF.



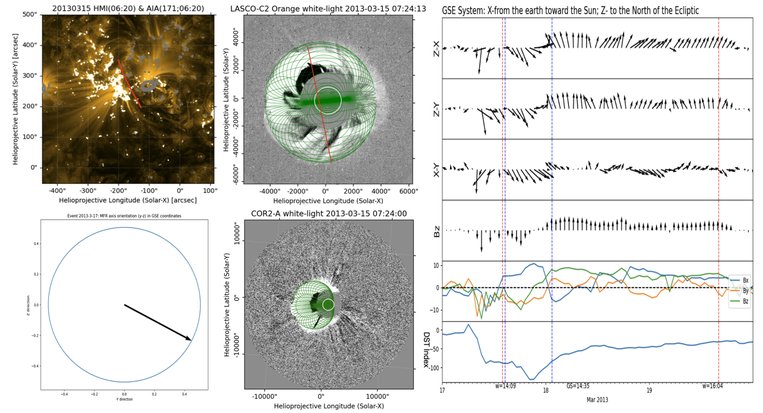
Event study 2: Rotated FR Event



The second CME event occurred at 16:48 on July 12, 2012. For this event, we used LASCO and STEREO data to construct the GSC model for the CME orientation with tilt of -66.5. Additionally, for the in-situ data, we obtained the axis direction from the GS model, as shown in the first picture in the second line. By comparing the different orientations, we observed that the axis of the CME keeps rotating. Specifically, the magnetic field magnitude is initially directed towards the south at the solar surface, but as the CME propagates to 1 AU, it rotates to the northward direction.

Event study 3: High-inclination FR event

The last CME event took place at 7:12 am on March 15, 2013. We took the same approaches in the second case study. Upon comparing the orientation information from AIA data, the GCS model, and GS model results (Tilt= -85.5), we observed a consistent pattern. The IMF axis retained a high inclination from the solar surface to 1 AU. Additionally, the in-situ Bz component of the magnetic field maintained the same direction and exhibited alignment with the filament direction.



Summary

When the axial rotation of a CME occurs, the orientation of the associated ICME becomes difficult to accurately determine. In the cases where the CME axis remains non-rotating, two different scenarios arise:

- If the CME has a significant inclination, the Bz component of the ICME aligns with the filament's direction.
- When the inclination angle is small, the Bz component experiences continuous rotations during its transit through the IMF.

Subsequent research will require further statistical studies to validate the aforementioned hypotheses. By analyzing a larger sample size of CME and ICME events, we can gain a more comprehensive understanding of their behavior and orientations.

Acknowledgements

We thank the NASA SDO team for the AIA and HMI data. We acknowledge use of NASA/GSFC's Space Physics Data Facility's OMNIWeb service, and OMNI data. This research has made use of PyThea v0.7.4, an open-source and free Python package to reconstruct the 3D structure of CMEs and shock waves.The study is supported by NSF grants AGS-2149748 and 2300341.