Project Details

ROSES ID: NNH14ZDA001N
Selection Year: 2014
Program Element: Focused Science Topic

Topic: Prediction of the Interplanetary Magnetic Field Vector Bz at 1AU

Project Title:
Understanding the Longitudinal Extent and Timing of the SEP Onset

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Summary:
This investigation will focus on large SEP events with energies above 25 MeV that have been observed by both STEREO and near-Earth spacecraft. Recently, Richardson et al. (2014) compiled a catalog of 209 individual greater than 25 MeV solar proton events in cycle 24 and found that there were 25 events observed at all three spacecraft [STEREO and a near-Earth platform] from December 2009 December 2013 when the STEREO spacecraft were separated by greater than ~60 degrees in heliolongitude from Earth. We will combine remote-sensing multi-point observations with forward-modeling using an oblate spheroid shock model to (1) study the longitudinal extent and angular width of the expanding CME-shock and EUV wave for the 25 three-spacecraft SEP events; (2) study the acceleration profiles of the CME-shock and EUV wave in its early evolution, including both radial expansion and lateral expansion; 3) develop the relations between the shock front speed and the shock leading edge speed and the expansion speeds at semi-major and semi-minor axes. By using a full 3D forward-modeling, we can accurately determine the true speed, heliographic distance, angular width, and the location where the magnetic connectivity occurs. Based on the above results, we will study the correlation between the proton peak intensities, the shock speeds and angular widths and derive a formula predicting the SEP intensity. The main objective of this proposal is to investigate whether the wide spread SEP events are in fact a result of the expanding shock and to gain sufficient scientific understanding that will lead to a predictive capability. This proposal is highly relevant to the scientific objectives of the Focused Topic: 3.1.2 Physics-based methods to predict connectivity of SEP sources to points in the inner heliosphere, tested by location, timing, and longitudinal separation of SEPs since the proposed work will focus on models & observations that provide a better understanding of the initial phases of CMEs and how that couples into longitudinal extent and timing for the SEPs. We will contribute data analysis expertise, as well as modeling capabilities that are directly relevant to team objectives. By the end of Year Four we will also provide a three-spacecraft event list with accurate heliographic distances, space speeds, and angular widths of the CME-shock at SEP onset times at each spacecraft. The extensive list developed as part of the proposed investigation will be made available to the modeling efforts and theoretical studies through the CDAW website.

Publication References:

Summary: This study compared the electron release times using the time-shifting analysis (TSA) method for events with high anisotropy values and proton release times with the velocity dispersion analysis (VDA) method. The paper advanced our understanding of the relation between particle direct acceleration and their scattering effects.

Reference: Xie H.; Makela P.; Gopalswamy N.; St. Cyr O. C.; (2016). Energy dependence of SEP electron and proton onset times. Journal of Geophysical Research (Space Physics), 121, 6168-6183, doi: 10.1002/2015JA021422

- **Investigation Type:** Data Analysis
- **Data Sources:** SOHO:ERNE STEREO A:EUVI STEREO A:COR1 STEREO A:COR2 STEREO B:EUVI STEREO B:COR1 STEREO B:COR2 ACE:EPAM WIND:3DP

Summary: The study performed three case studies using the forward flux-rope and shock model to determine the angular extent of the shock and the shock speeds at connecting to observer (COB) points for each spacecraft. It advanced the investigation on whether the CME-shock spatial extension can explain the wide longitudinal spread of large SEP events.

Reference: Xie H.; Makela P.; St. Cyr O. C.; Gopalswamy N.; (2017). Comparison of the coronal mass ejection shock

acceleration of three widespread SEP events during solar cycle 24. Journal of Geophysical Research (Space Physics), 122, 7021-7041, doi: 10.1002/2017JA024218

- **Investigation Type:** Data Model Comparison
- **Names of models being tested or validated:** GCS flux-rope model plus oblate spheroid shock model
- **Datasources:** SOHO:LASCO STEREO A:EUVI STEREO A:COR1 STEREO A:COR2 STEREO B:EUVI STEREO B:COR1 STEREO B:COR2

Summary: The study suggested that both good longitudinal and latitudinal connectivity are required for the highest-energy particles to be accelerated in the nose part of shocks, while the lower energy particles are accelerated at all parts. There were also well-connected fast CMEs, which did not seem to have accelerated high-energy particles due to possible unfavorable ambient conditions (high Alfven speed, overall reduction in acceleration efficiency in cycle 24).

Reference: Gopalswamy N.; Xie H.; Akiyama S.; Makela P. A.; Yashiro S.; (2014). Major solar eruptions and high-energy particle events during solar cycle 24. Earth, Planets, and Space, 66, 104, doi: 10.1186/1880-5981-66-104

- **Investigation Type:** Data Analysis
- **Data Sources:** SOHO:LASCO STEREO A:EUVI STEREO A:COR1 STEREO A:COR2 STEREO A:HI STEREO B:EUVI STEREO B:COR1 STEREO B:COR2 STEREO B:HI

Summary: The study present preliminary results for improving the prediction of proton intensity by taking into account the effects of CME widths and their source locations.

Reference: Xie H.; St. Cyr O. C.; Makela P.; Gopalswamy N.; (2018). Relationship between SEP peak intensity and shock speed, CME width and acceleration; no. , 112

- **Investigation Type:** Other Investigations
- Performed study on how CME energies and its source locations affect the correlation between SEP intensities and shock speeds, CME widths and accelerations in order to develop a formula for predicting the SEP intensity as function of shock speed, width and connection angles.