STEREO Science Highlight

The Width of Magnetic Ejecta Measured near 1 AU: Lessons from STEREO-A Measurements in 2021–2022

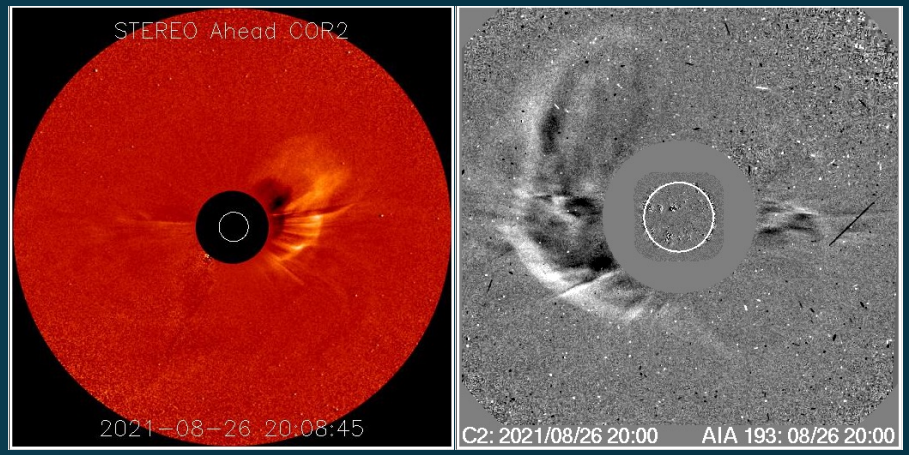
Lugaz, N.; Zhuang, B.; Scolini, C et al. *ApJ*, (2024) **962**, 193,. doi: 10.3847/1538-4357/ad17b9

Background

- Coronal mass ejections (CMEs) are the main drivers of intense space weather; the magnetic ejecta portion of CMEs are the low-density, high magnetic field cores of the ejection and cause most intense geomagnetic storms.
- Over 40 years of in situ measurements of CMEs have revealed many of their “typical” properties, including their average radial size, speed and magnetic field strength.
- However, since over 90% of CMEs are measured in situ by only one spacecraft, little is known directly about their angular extent when they reach Earth.
- Remote observations show CMEs extending 60±10° in angle in the corona. It has been assumed that the CME angular size remains constant as they propagate from the corona to the near-Earth environment.

Analysis

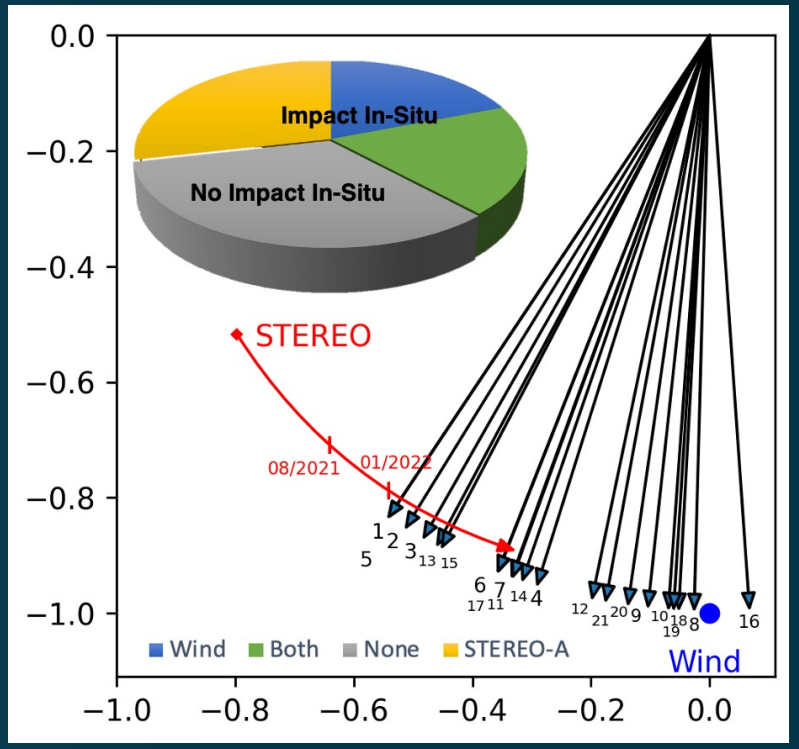
- The study reported by Lugaz et al. (2024) takes advantage of the fact that STEREO-A after 16 years in orbit, returned to the vicinity of Earth in 2022-2023.
  - Remote imaging observations by STEREO/COR2 and by SoHO/LASCO/C2 were used to identify CMEs propagating towards STEREO-A and towards Earth. These observations were analyzed with the graduated cylindrical shell (GCS) model of Thernisien (2011) to determine the CME direction.
  - In situ measurements by STEREO-A/PLASTIC and IMPACT are combined with measurements from Wind/3DP, SWE and MFI to determine which CMEs impact both spacecraft, either or none.
- This work was led by the University of New Hampshire with collaborators from the Austrian Space Weather Office and the Solar-Terrestrial Centre of Excellence in Belgium.



Remote observations by STEREO-A/COR2 (left) and LASCO/C2 (right) of a coronal mass ejection on 2021 August 26 when STEREO-A was 42° away from the Sun-Earth line. The CME is found to propagate exactly in-between the two spacecraft (*adapted from Lugaz et al., 2024*).

Findings

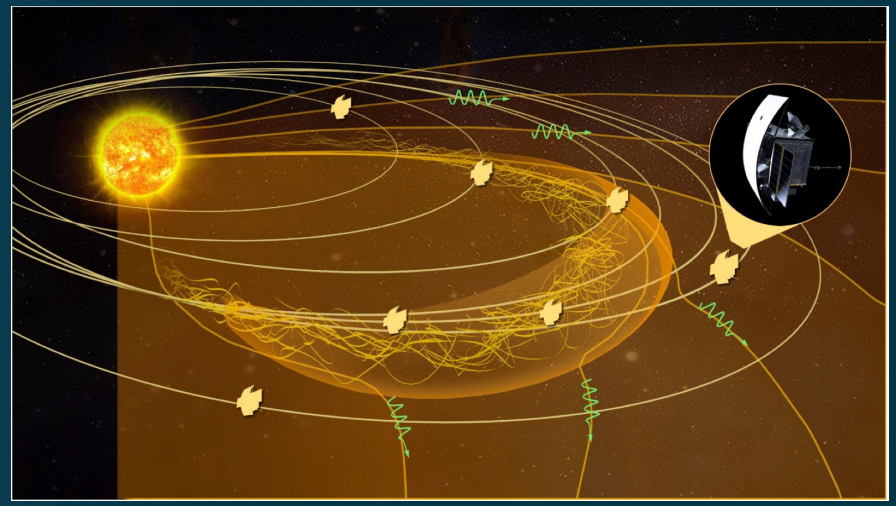
- Out of the 21 CMEs propagating in-between STEREO-A and Wind when the spacecraft were separated by 20°-60°, only 4 magnetic ejecta were measured in situ by both spacecraft.
- Magnetic ejecta are therefore typically only 20°–30° in angular extent at Earth, much less than the angular size of 45°–60° deduced from remote imaging observations in the corona.
- Even for these four CMEs measured by the two spacecraft, the measurements were very different.



Direction of propagation in the ecliptic of the 21 CMEs studied propagating between STEREO-A and Wind in 2020-2022. Location of STEREO at the beginning and end of the time period studied shown by red curve. Location of Wind by blue dot. Only CMEs 2, 5, 12, 21 impacted both spacecraft (adapted from Lugaz et al., 2024).

Impacts

- This study highlights that we do not understand even a simple property of CMEs such as their angular size. This is critical to develop realistic models of these eruptions.
- Numerous mission concepts have been proposed over the past 25 years to provide multi-spacecraft in-situ measurements of CMEs. This study has a direct impact on the orbital configurations of such missions, with spacecraft needed to be < 20° apart to maximize multi-point measurements.
- Future space weather missions will go closer to the Sun to measure CMEs before they impact Earth and increase the lead time of any forecast, allowing for mitigation. This study highlights that, even at moderate separations of 10°-20°, such measurements may have significant differences with what is measured at Earth.



Living With A Star Focused Mission Topic (FMT)-2 with 7-9 spacecraft within 60°–90°. Such mission may need to target smaller total separations. (*from Living With a Star Architecture Committee Report for the NASA Heliophysics Division, 2022*).

References

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Publication Information

"The Width of Magnetic Ejecta Measured near 1 au: Lessons from STEREO-A Measurements in 2021–2022"

Noé Lugaz[1] , Bin Zhuang[1] , Camilla Scolini[1,2] , Nada Al-Haddad[1] , Charles J. Farrugia[1] , Réka M. Winslow[1] ,Florian Regnault[1] , Christian Möstl[3] , Emma E. Davies[3] , and Antoinette B. Galvin[1]

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[1] University of New Hampshire

[2] Royal Observatory of Belgium

[3] Austrian Space Weather Office