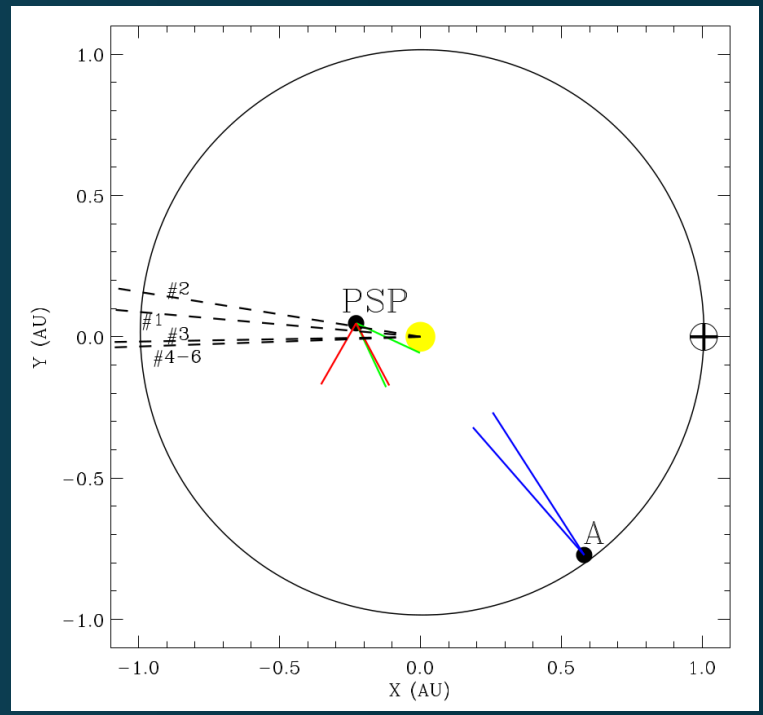
STEREO-A Identifies CMEs that are the First to be Simultaneously Imaged and Probed In-situ by Parker Solar Probe

B. E. Wood, P. Hess, Y. Chen, and Q. Hu (2023), ApJ, 953, 123; doi: 10.3847/1538-4357/ace259

Background

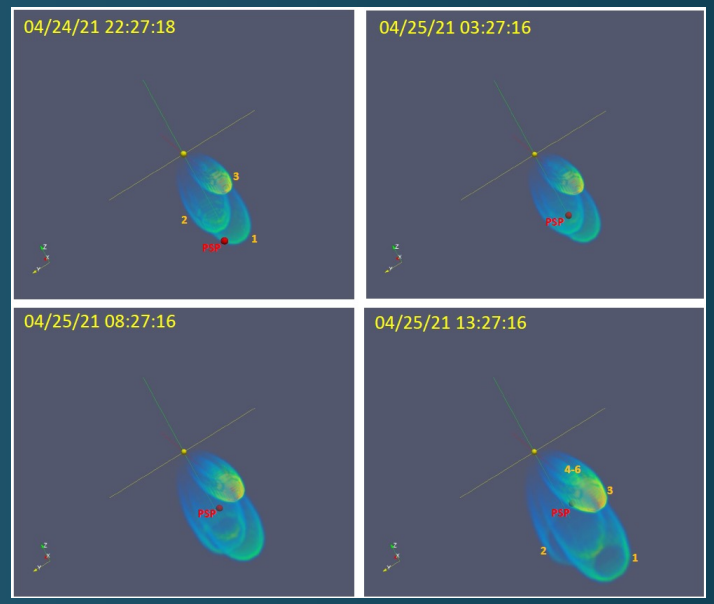
- An important goal of Heliophysics is to ***understand the evolution of coronal mass ejections (CMEs) close to the Sun***. This will ultimately allow us to better predict their behavior and related space weather effects
- Parker Solar Probe (PSP) is currently exploring the solar wind closer to the Sun than any previous spacecraft. Its primary observations are of the plasma and field properties measured in situ. However, it has one remote sensing instrument, the Wide-field Imager for Solar Probe (WISPR), which images white light scattered from solar wind particles ahead of the spacecraft in its orbit around the Sun.
- On 2021 April 24-25, at a distance of about 45 solar radii from the Sun, signatures of a small coronal mass ejection (CME) or series of CMEs were observed by the in situ instruments. This corresponded to a series of white light fronts observed by WISPR. **This is the first clear case of PSP/WISPR imaging a CME while the CME is actually hitting the spacecraft.**
- In a classic case of not being able to see the forest for the trees, it is difficult for PSP to know the nature of what is hitting it without assistance from coronagraphic observations taken from some other distant observatory. This is where STEREO-A comes in. PSP's location almost directly behind the Sun relative to Earth means that observations from observatories operating on or near Earth are of no help. **Only STEREO-A was well placed to observe the series of small CMEs that were directed right at PSP.**



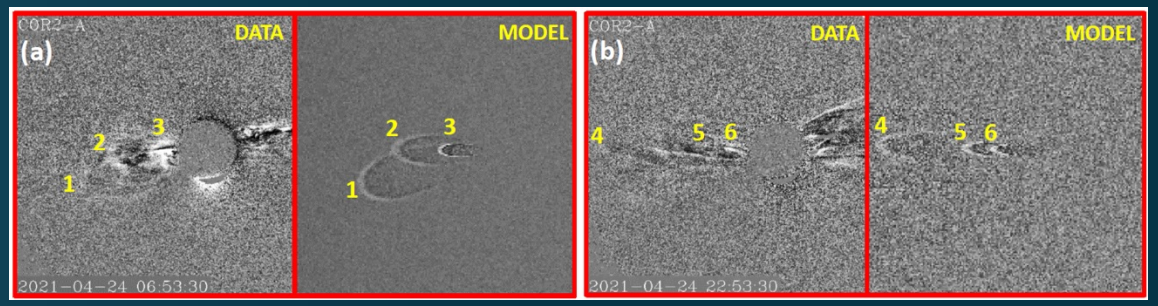
Ecliptic plane map showing the locations of PSP and STEREO-A, relative to the Sun (at center), and Earth (to the right). The green and red lines indicate the fields of view of the WISPR-I and WISPR-O imagers on PSP. The blue lines indicate the field of view of the COR2 coronagraph in STEREO-A. The dashed lines indicate the inferred central trajectories of the 6 small CMEs observed erupting from the Sun by STEREO-A. Wood et. al 2023

Analysis

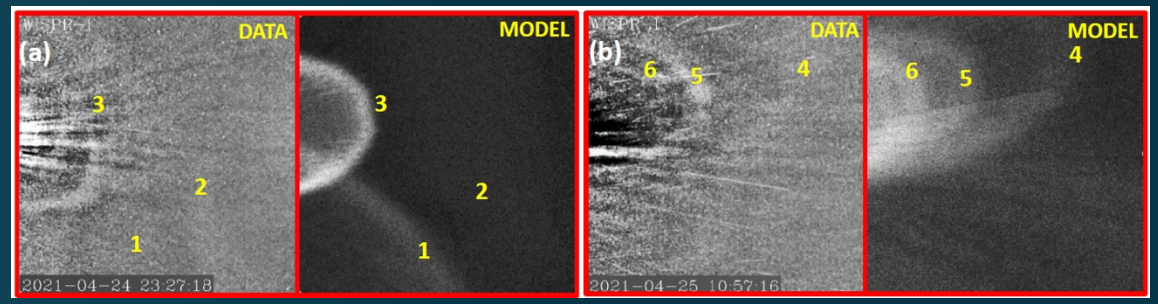
- The COR2 images from STEREO-A reveal a series of 6 small CMEs erupting from the Sun that are responsible for the PSP-observed activity. These CMEs are connected to white light fronts observed by PSP/WISPR.
- The STEREO-A and PSP images are used to reconstruct the basic kinematics and morphology of the 6 CMEs. It is found that the second CME (CME2) is the first to hit PSP, but PSP later encounters CME3 as well.
- Investigators are from the Naval Research Laboratory and the University of Alabama in Huntsville.



3-D visualizations of the six reconstructed CMEs erupting from the Sun, with CME2 being the first to hit PSP shortly before the time of the second frame. PSP is encountering CME3 in the final frame. All images from Wood et al. 2023



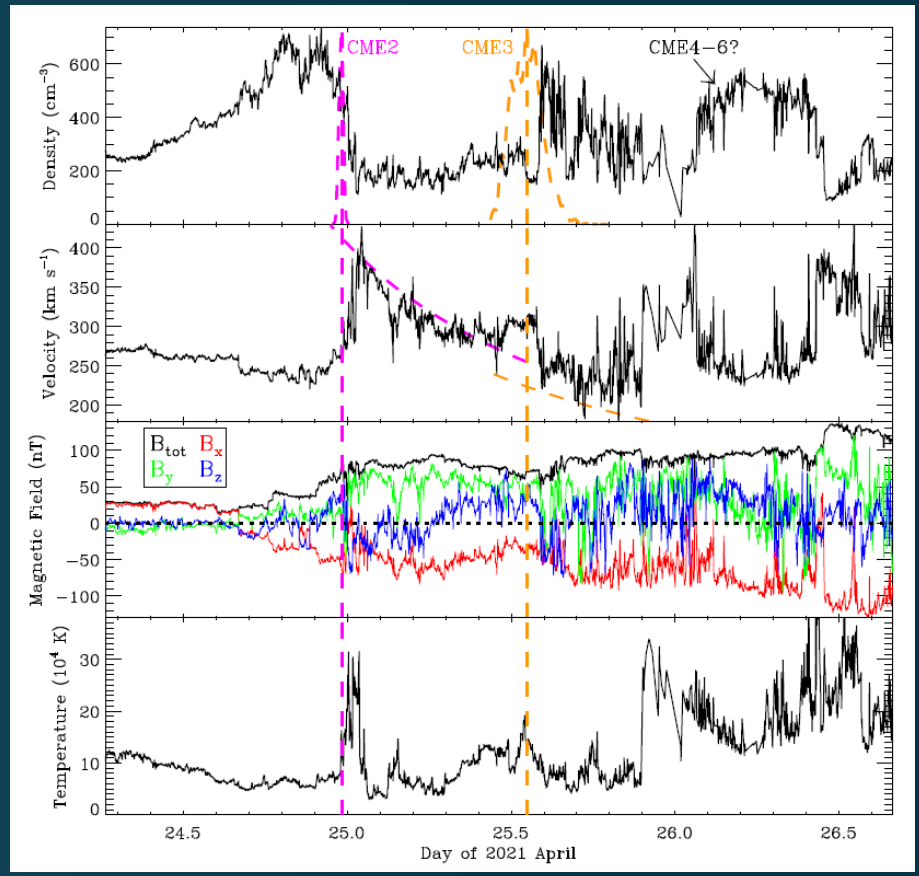
(a) On the left is a STEREO-A/COR2 image of a series of 3 small CMEs, (CME1, CME2, and CME3) compared on right with a synthetic image based on a 3-D reconstruction of these CMEs. (b) Similar to (a), but for CMEs numbered 4-6.



(a) On the left is a PSP/WISPR image of the fronts corresponding to CMEs #1-#3 observed by STEREO-A, compared on right with a synthetic image based on a 3-D reconstruction of these CMEs. (b) Similar to (a), but for CMEs numbered 4-6.

Findings & Impacts

- The complex 3-D reconstruction of the sequence of six CMEs observed by STEREO-A and PSP/WISPR allows for a proper interpretation of the in situ plasma and field PSP data, with CME2 and CME3 having clear signatures in the in situ data, and with a broad density peak possibly being due to the collective influence of the last 3 CMEs (CME4-6).
- Sequential eruptions of small CMEs may be indicative of macroscopic magnetic reconnection processes, analogous to smaller scale reconnection that may be responsible for solar wind acceleration more broadly.
- This study demonstrates the importance of coronagraphic monitoring from spacecraft like STEREO-A for maximizing the science from PSP. This monitoring provides the context for the variable solar wind through which PSP is traveling.
- The ability to understanding how CMEs evolve and accelerate as they move out of the corona and into the heliosphere is important in predicting their effects on other parts of the solar system, including at Earth



In situ plasma and field measurements from PSP, during the passage of the 2021 April 24 CMEs over the spacecraft. The top two panels are proton density and velocity. The third panel shows magnetic field components, and the fourth panel shows plasma temperature. Vertical dashed lines indicate the predicted arrival times of CME2 and CME3 based on the image-based 3-D reconstruction, and there are in situ signatures of these events. The broad density increase early on April 26 may be due to the last three CMEs (CME4-6). Wood et al. 2023

Publication Information

"Sequential Small Coronal Mass Ejections Observed In Situ and in White-Light Images by Parker Solar Probe"

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