# Multi-point observations of the dynamics at an ICME sheath-ejecta boundary

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## Interplanetary coronal mass ejections

- Interplanetary coronal mass ejections (ICMEs) often drive a shock and sheath region in front of them.
- Magnetic reconnection at the ICME sheath-ejecta boundary mixes sheath and ejecta plasmas.
- Fig. 1: We present observations at the boundary of the ICME on 20 August 2020 at the Earth's orbit.
- Fig. 2: We study observations from MMS and Cluster which were in the solar wind.

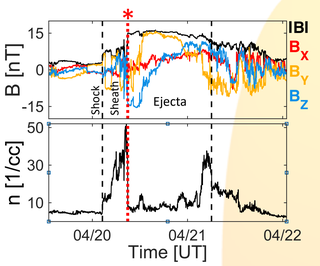



**Figure 1.** OMNI data in Aug 2020.

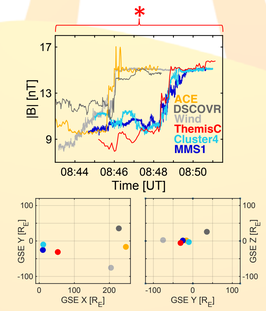



**Figure 2.** MMS and Cluster observe the ICME sheath-ejecta boundary in the solar wind.

## Two-sided reconnection jets at the boundary imply multiple (patchy) reconnection sites

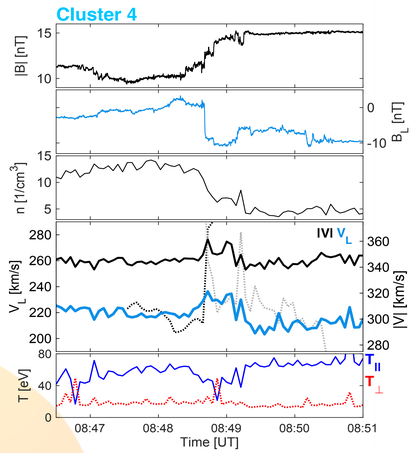
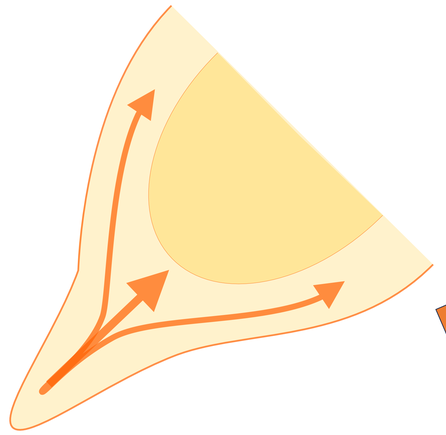



**Figure 3.** Cluster 4 measurements



- Across the boundary, local dips of |B| and a multi-step $B_L$ -rotation occurred. Lower-resolution plasma measurements cannot resolve if the dips were generated by diamagnetic currents.
- **Two-sided jets develop in a multiple or patchy reconnection exhaust when the reconnection outflow interacts with the preceding slower exhaust plasma.**
- Reconnection was also observed by Themis C which however did not show a multi-step rotation of $B_L$ or a two-sided jet.

## Multi-spacecraft observations reveal local structures at the boundary

- Localized structures occurred at the boundary (Cluster inter-spacecraft separations were < 2 $R_E$)
- Plasma measurements only available from Cluster 4 cannot resolve the dynamics driving the local dynamics
- Four $B_L$ rotations occurred across the boundary (pale shadings)

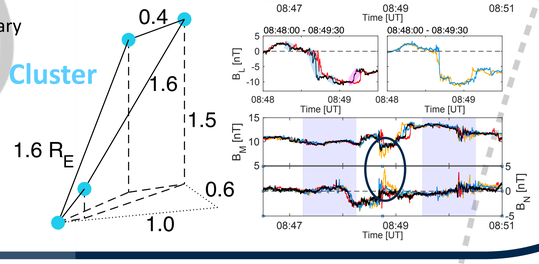


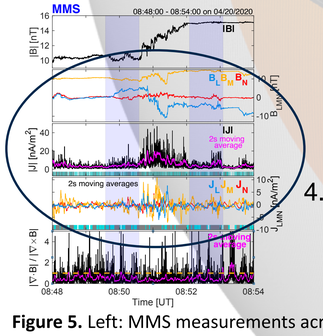




**Figure 5.** Left: The Cluster constellation. Right: Cluster 1-4 field measurements across the ICME sheath-ejecta boundary.

## Filamentary currents at the boundary

SMALL SCALES



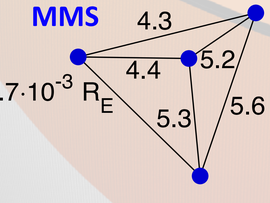
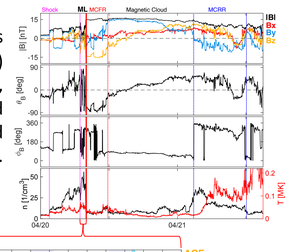




**Figure 5.** Left: MMS measurements across the ICME sheath-ejecta boundary. Right: The MMS constellation and inter-spacecraft separations during the crossings.

- The crossing MMS observed a more gradual boundary (see Figure 2).
- Boundary included a bifurcated current sheet which was followed by an opposite $B_L$ –rotation.
- The boundary hosted filamentary currents estimated with the curlometer technique.
- High time-resolution plasma measurements are required for further investigation.

## 1 hour of localized southward magnetic field at 1 AU

**Figure 6.** The ICME ejecta was preceded by a mixing layer (ML) characterized by dip of |B|, highly rotating field and relatively high density and temperature.




BIG SCALES

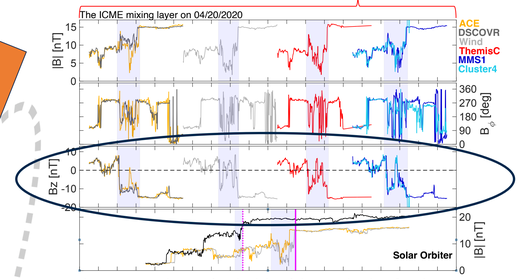



**Figure 7.** The mixing layer (pale blue) has a lack of coherence across radial (transverse) spacecraft separations of 240 $R_E$ (110 $R_E$) at 1 AU. Especially DSCOVR and Wind show very different time series of $B_z$.

## Solar Wind Investigation Frontier (SWIFT)

- The unique MMS and Cluster measurements demonstrate the need for continuous multi-point measurements (at 1 AU) that can address the spatio-temporal structure of ICMEs.
- The Space Weather Investigation Frontier (SWIFT) is a multi-spacecraft mission concept dedicated to addressing these questions including the ICME three-dimensional structure and dynamics.
- The mission aims to provide continuous measurements along the Sun-Earth line beyond the Lagrange L1 point (sub-L1), doubling the current forecasting lead-times.

**Follow the Solar Wind Investigation Frontier (Akhavan-Tafti et al. 2023)**

## References and Acknowledgements

- Akhavan-Tafti M., Johnson L., Sood R., Slavin J. A., Pulkkinen T. I., Lepri S., Kilpua E., Fontaine D., Szabo A., Wilson L., Le G., Atilaw T. Y., Ala-Lahti M., Soni S. L., Biesecker D., Jian L. K. and Lario D. (2023), Space weather investigation Frontier (SWIFT). Front. Astron. Space Sci. 10:1185603. doi: 10.3389/fspas.2023.1185603

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