STEREO Science Highlights

Imaging and Radio Signatures of Shock–Plasmoid Interaction

P. Kumar, J.T. Karpen, P.K. Manoharan, N.Gopalswamy, ApJ Letters, 991, 1, L3 (2025).

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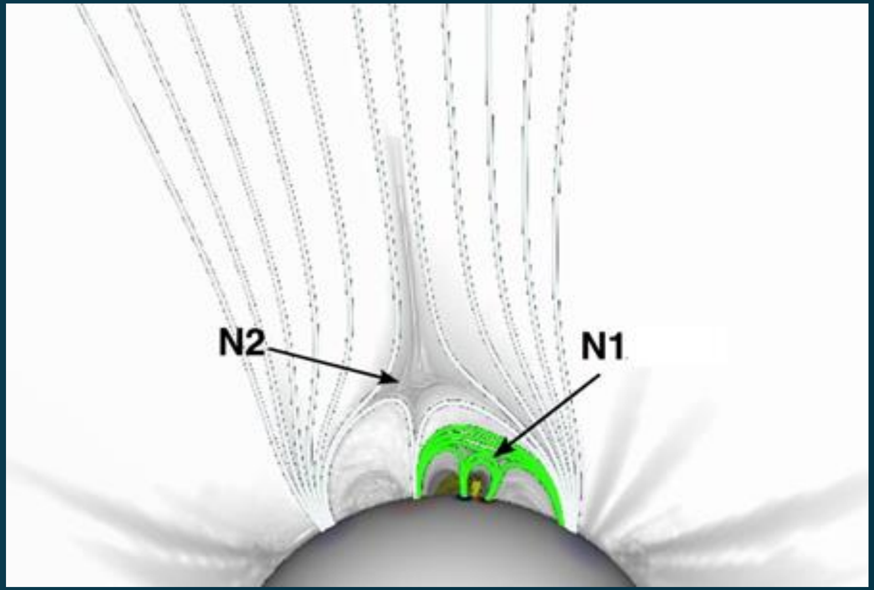
Background

- Plasmoids (blobs) formed by magnetic reconnection are frequently observed in coronal and heliospheric current sheets, but their interaction with shocks has not been explored observationally.
- Prior studies focused mainly on CME–CME interactions; direct shock–plasmoid interactions have not been identified before.

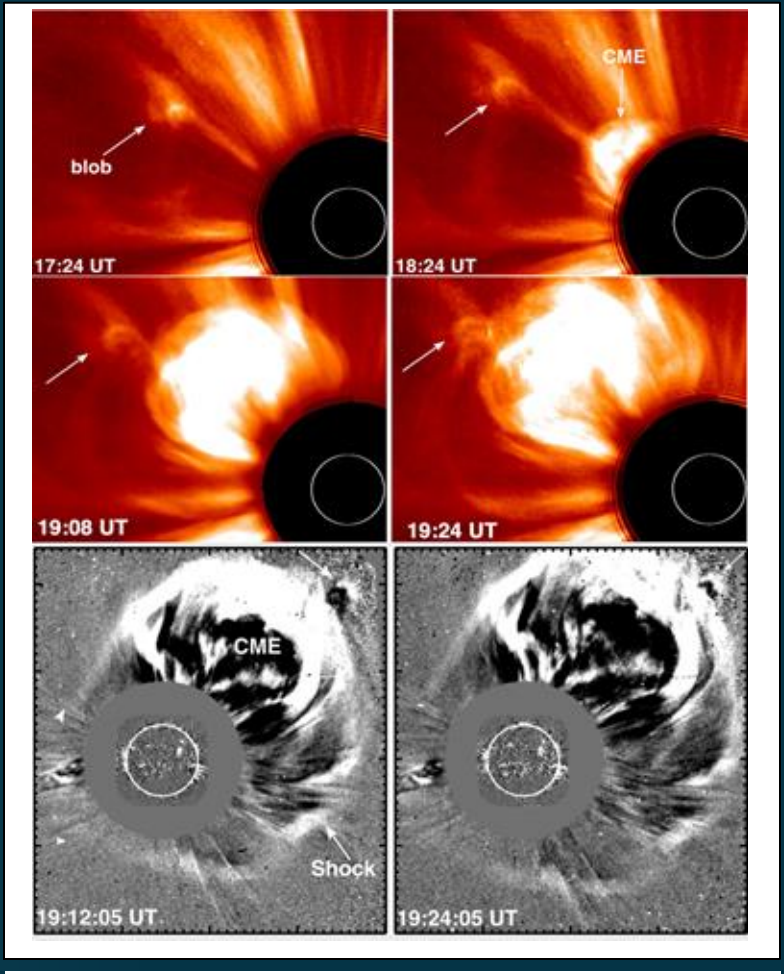
- CME-driven shocks are key drivers of particle acceleration that commonly produce type II radio bursts, while type III bursts indicate escaping electron beams.
- This study investigates a unique event where a CME-driven shock interacts with a slowly moving plasmoid, using coordinated white-light and radio observations from *STEREO-A*, *SOHO*, and *Wind*.
- The CME was associated with an X1.7 flare that occurred on 2014 March 29 in a nested null-point topology (Kumar et al. 2025b).



A model of a nested null point topology on the Sun in which one potentially eruptive structure (N1) is positioned under another (N2). Adapted from Kumar et al. 2025b

Analysis

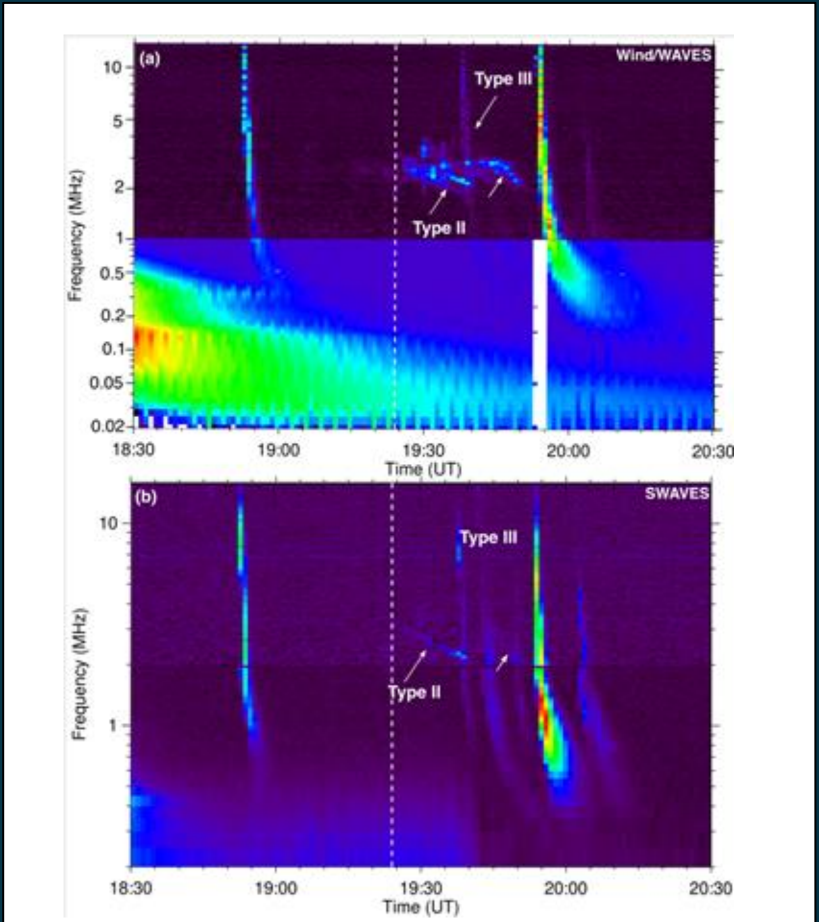
- White-light coronagraph data from *STEREO-A*/COR2 and *SOHO*/LASCO C2 were used to track the plasmoid, CME, and shock fronts.
- Time–distance analysis quantified the kinematics of the blob, CME leading edge, and shock.
- Dynamic radio spectra from *Wind*/WAVES and *STEREO-A*/WAVES were examined to identify shock-related radio signatures.
- The detailed structure of the interplanetary type II burst was used to estimate density compression, Alfvén Mach number, and magnetic field strength in the plasmoid.
- In situ electron measurements from *Wind*/3DP were analyzed to assess associated SEP signatures.
- *STEREO-A*/COR1 images, along with *SDO*/AIA observations, were used to investigate the origin of the blob in the low corona.



STEREO-A/COR2 (intensity; top and middle panels) and *SOHO*/LASCO C2 (running-difference; bottom panels) images showing the CME shock–blob interaction. Credit: Kumar et al. 2025a.

Results

- A fast CME-driven shock (∼640–750 km/s) interacted with the slowly moving plasmoid (∼150–220 km/s) at a heliocentric distance of ~7 $R_\odot$.
- An interplanetary type II radio burst (2–3 MHz) occurred during the shock–plasmoid interaction, directly linking radio emission to the encounter.
- Structure of the type II radio burst implies a moderately strong shock and a plasmoid magnetic field strength of ~60 mG.
- Interplanetary type III bursts were observed during the merging of the plasmoid into the CME, indicating escaping electron beams produced by reconnection.
- The plasmoid intensity (white-light) increased during the interaction, consistent with the compression and energization by the shock.
- The plasmoid was produced by interchange reconnection within the same nested null topology.



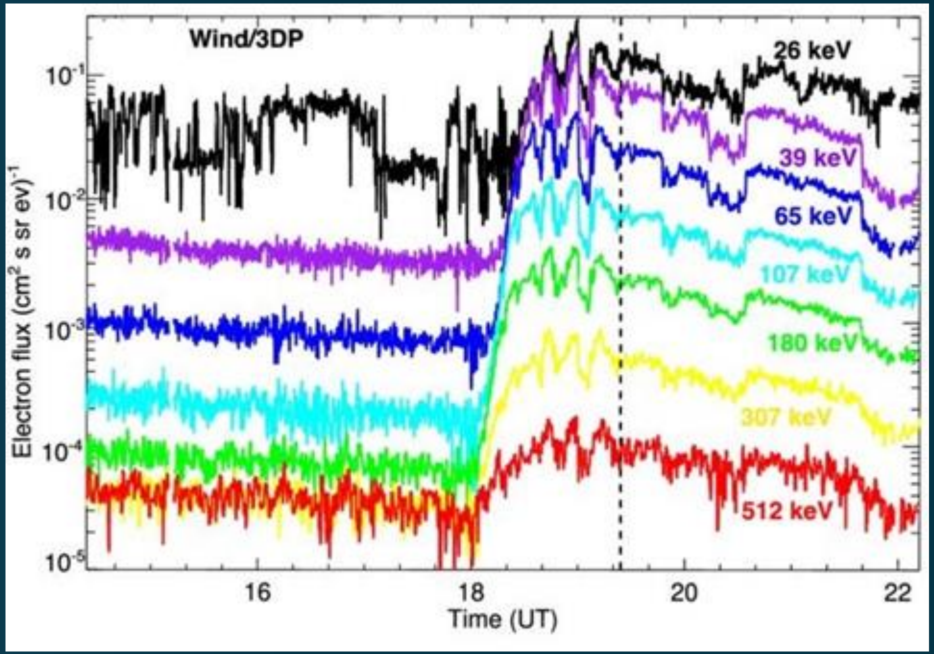
Radio bursts during the CME/shock–blob interaction. (a) and (b) Zoomed view of radio bursts detected during the interaction and the merging of the blob into the CME. Credit Kumar et al 2025a.

Impacts

- Provides the first clear observational evidence that shock–plasmoid interactions can enhance particle acceleration responsible for solar energetic particles (SEPs). SEPs are an important aspect of Space Weather that can lead to hazards to astronauts and spacecraft, especially in the interplanetary space. Understanding their origins is important as we send astronauts to the Moon and Mars.

- Demonstrates that preexisting dense coronal/heliospheric structures (blobs) can modify shock properties and radio signatures.
- Suggests a unifying (hybrid) mechanism applicable to CME shock interactions with streamer blobs, and a possibility of plasmoid–shock interactions in flare current sheets (e.g, Karpen et al. 2012, Nishizuka & Shibata 2013).

- Highlights the importance of multi-spacecraft observations, with strong relevance for current and upcoming missions (e.g., *Solar Orbiter*, *Parker Solar Probe*, *SunRISE*, *PUNCH*, *Aditya L1*, *CODEX*).



The energetic electrons arrive at L1, just upstream from Earth, as observed by the Wind spacecraft. Credit: Kumar et al 2025a

Additional Info

- Publication details:

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- Other References:

Kumar, Karpen, Wyper et al. 2025b, ApJ, 994, 2, 180. doi: 10.3847/1538-4357/ae0e65
Karpen, Antiochos & DeVore 2012, ApJ, 760, 81, doi: 10.1088/0004-637X/760/1/81
Nishizuka & Shibata 2013, Phys. Rev. Lett, doi: 10.1103/PhysRevLett.110.051101