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Ensemble modeling of the 30 August 2025 CME in the inner heliosphere and comparison with multi-spacecraft observations

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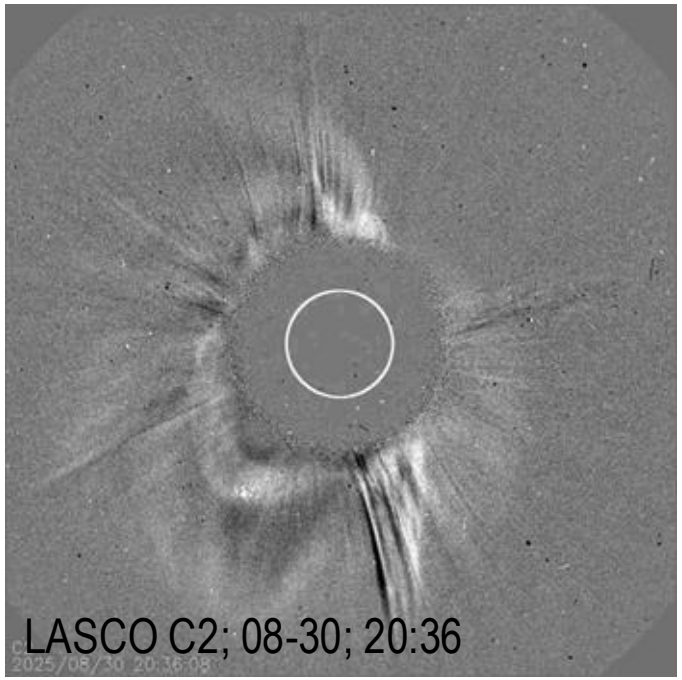
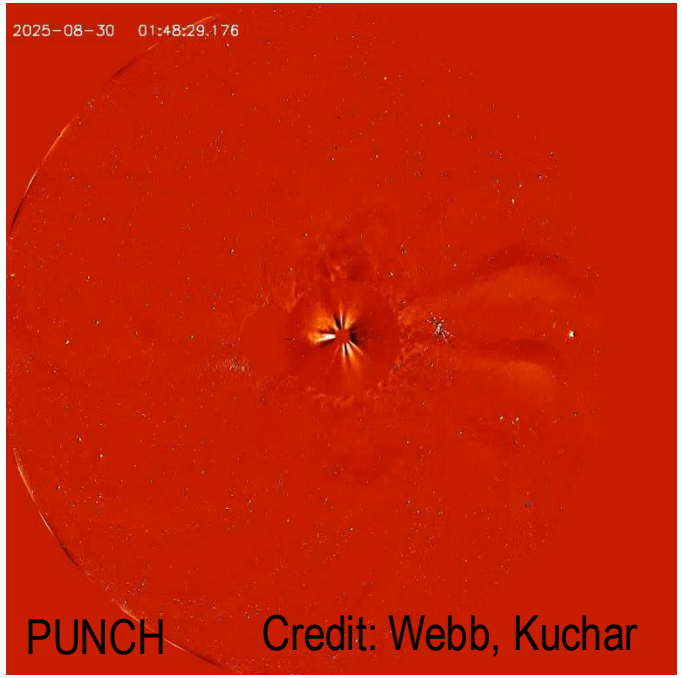
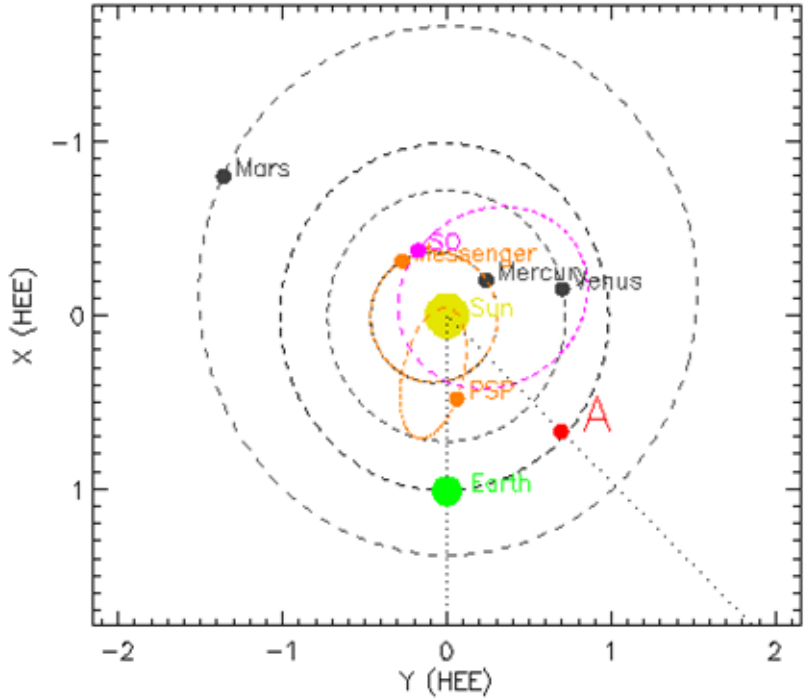
Halo CME Aug 30, 2025





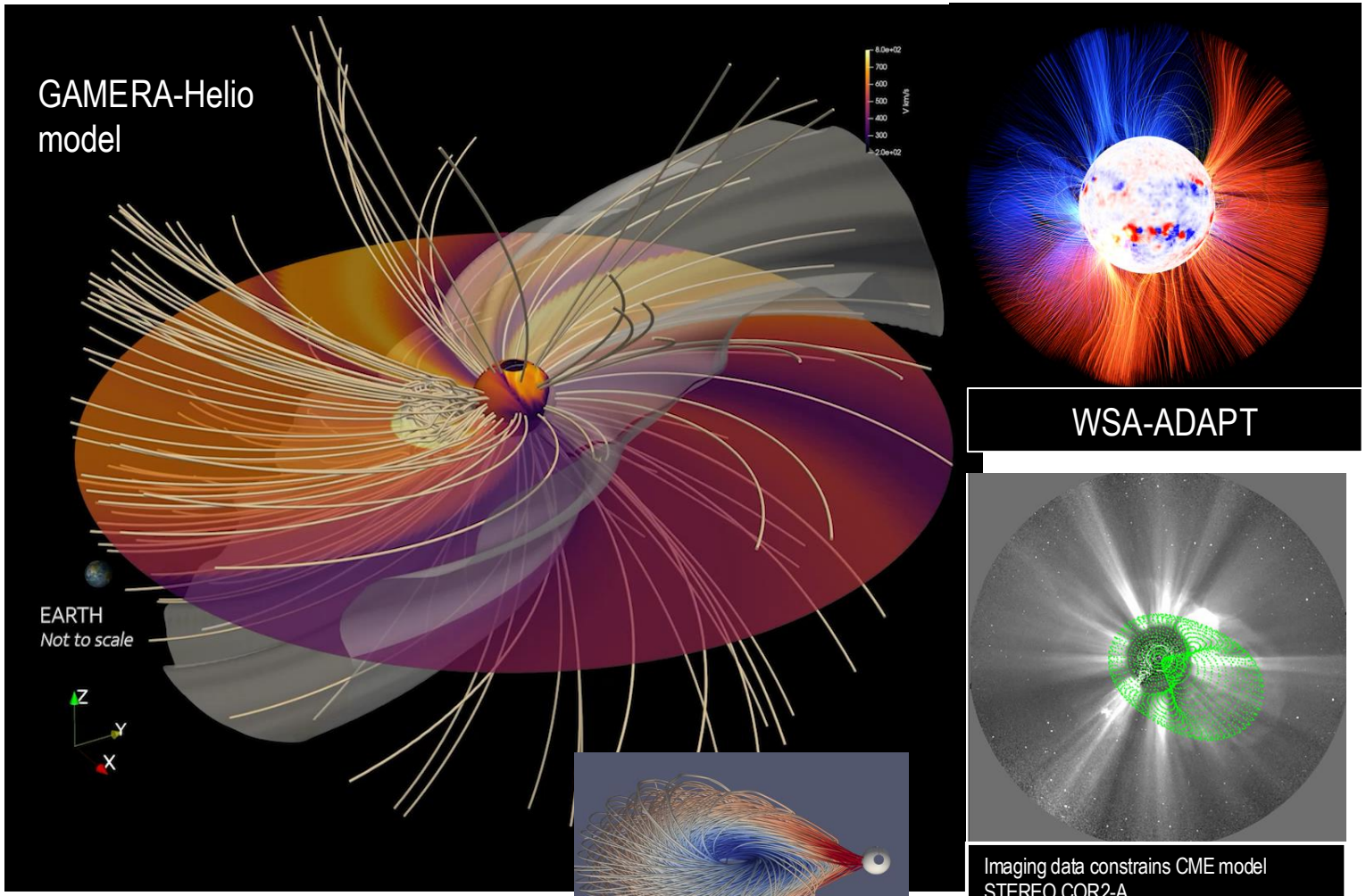


We model the propagation of this CME in the inner heliosphere with GAMERA+Gibson-Low model assuming different magnetic topologies and compare with

- Parker Solar Probe (in-situ)
- ACE and Wind at Earth
- and synthesize PUNCH images in 90° FOV

1) Which CME topology is more consistent with in-situ observations?
2) How do interactions between the CME and background solar wind structures appear in PUNCH-like images?

GAMERA-Helio with magnetized Gibson-Low CME



WSA-ADAPT

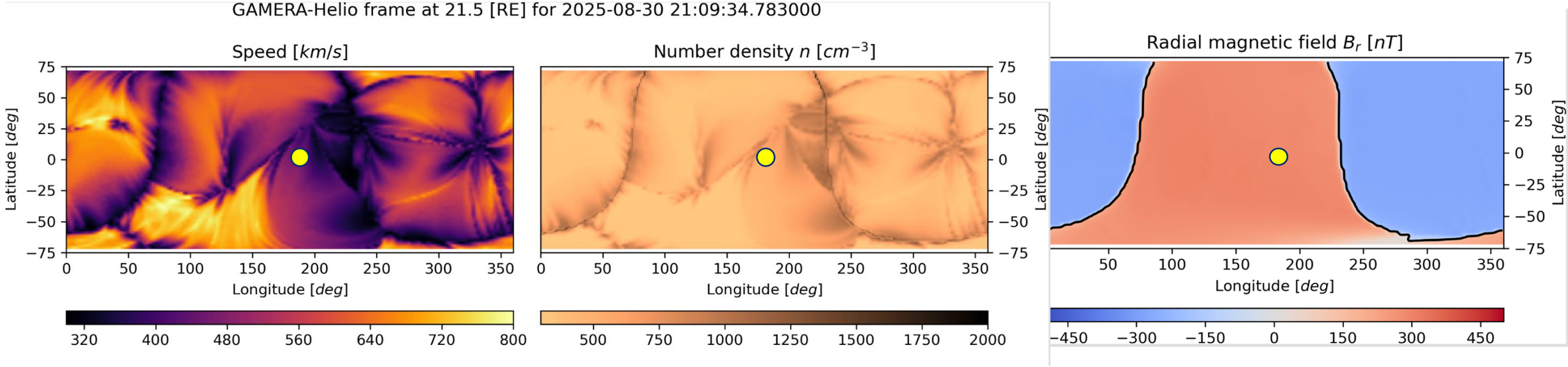
Imaging data constrains CME model
STEREO COR2-A
2023-04-21T19:23UT

Gibson-Low CME model
with internal magnetic field

Model:

- GAMERA-Helio MHD model simulates solar wind and CME propagation in the inner heliosphere *(Provornikova et al. 2024)*
- WSA–ADAPT provides boundary conditions for the solar wind background at 20 Rs *(Arge et al. 2004)*
- CME initialized with the Gibson–Low CME model with magnetic structure *(Gibson&Low 1998)*

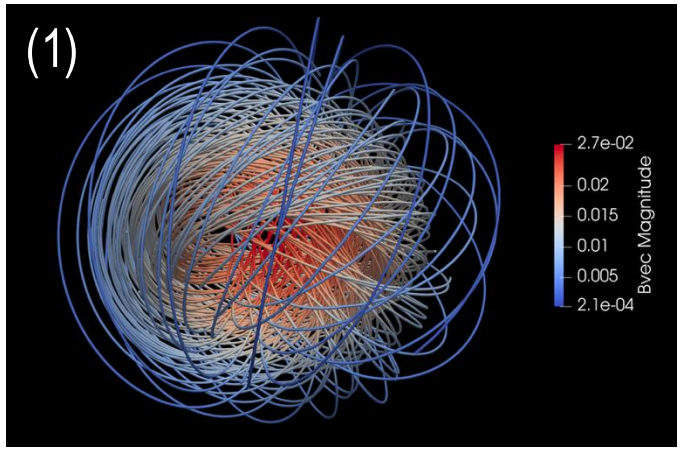
GAMERA inputs: ADAPT-WSA map at 21.5 R_S

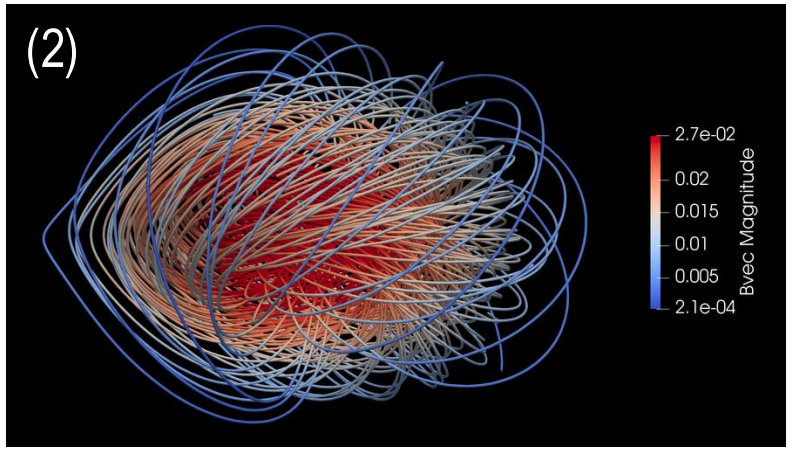


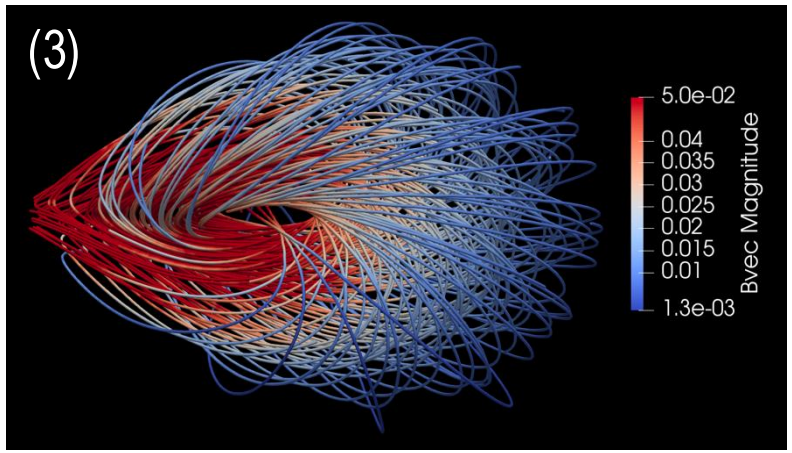
- WSA solution for ADAPT gong magnetogram 2025-08-28-1200 R0
- Yellow dot marks CME propagation direction

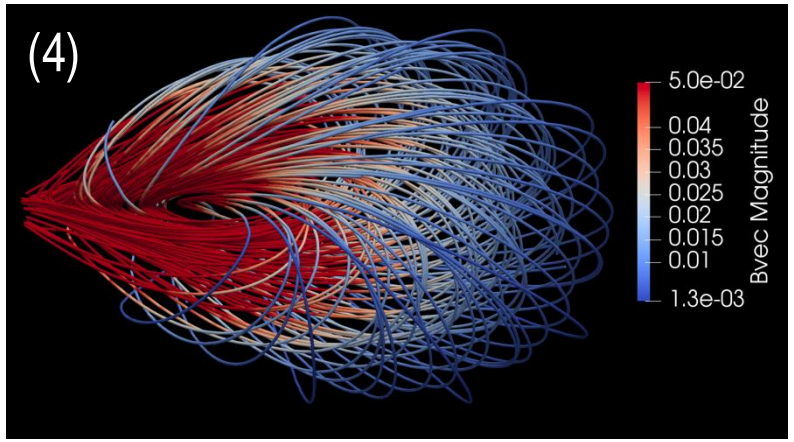
GAMERA inputs: Gibson-Low CME configurations

- Four different magnetic topologies for the CME:
  - spheromak, slightly stretched spheromak, tethered spheromak, flux rope





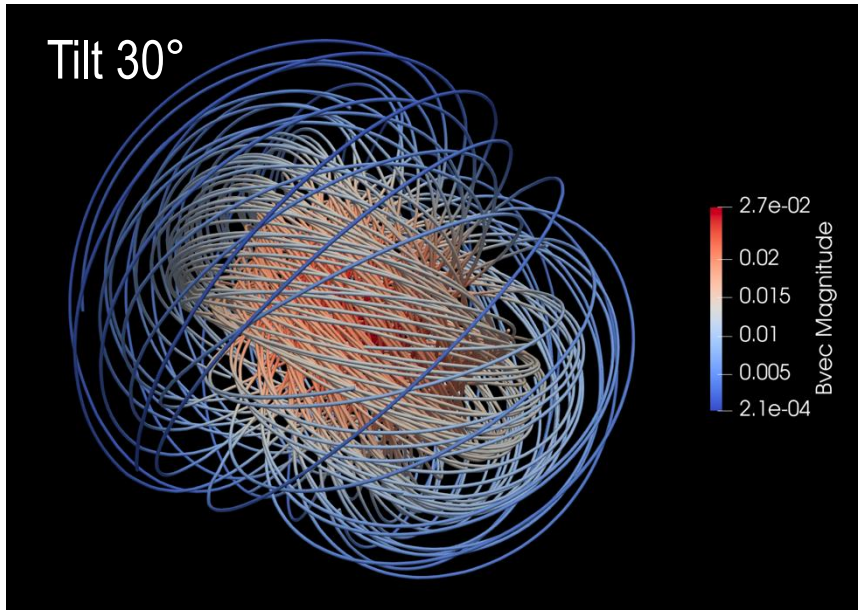




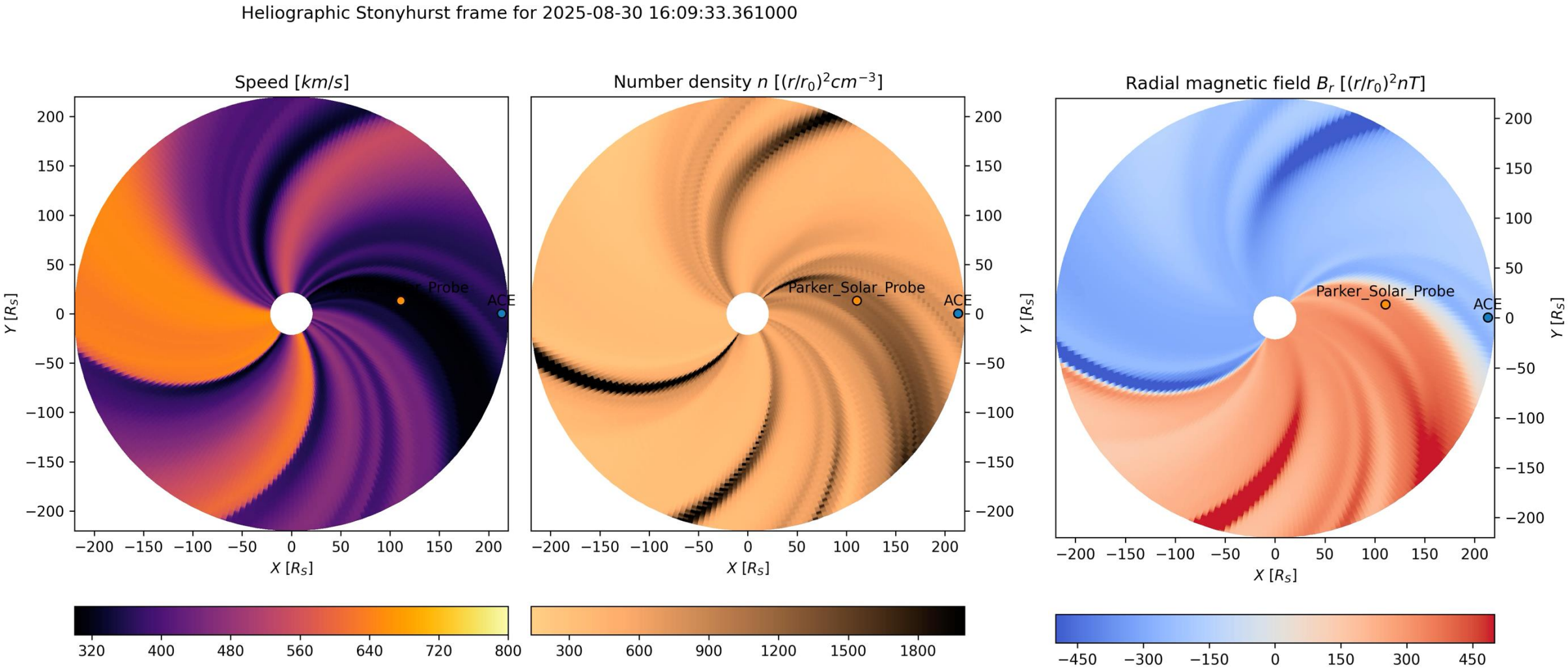
Which CME topology is more consistent with in-situ observations?

GAMERA inputs: Gibson-Low CME parameters

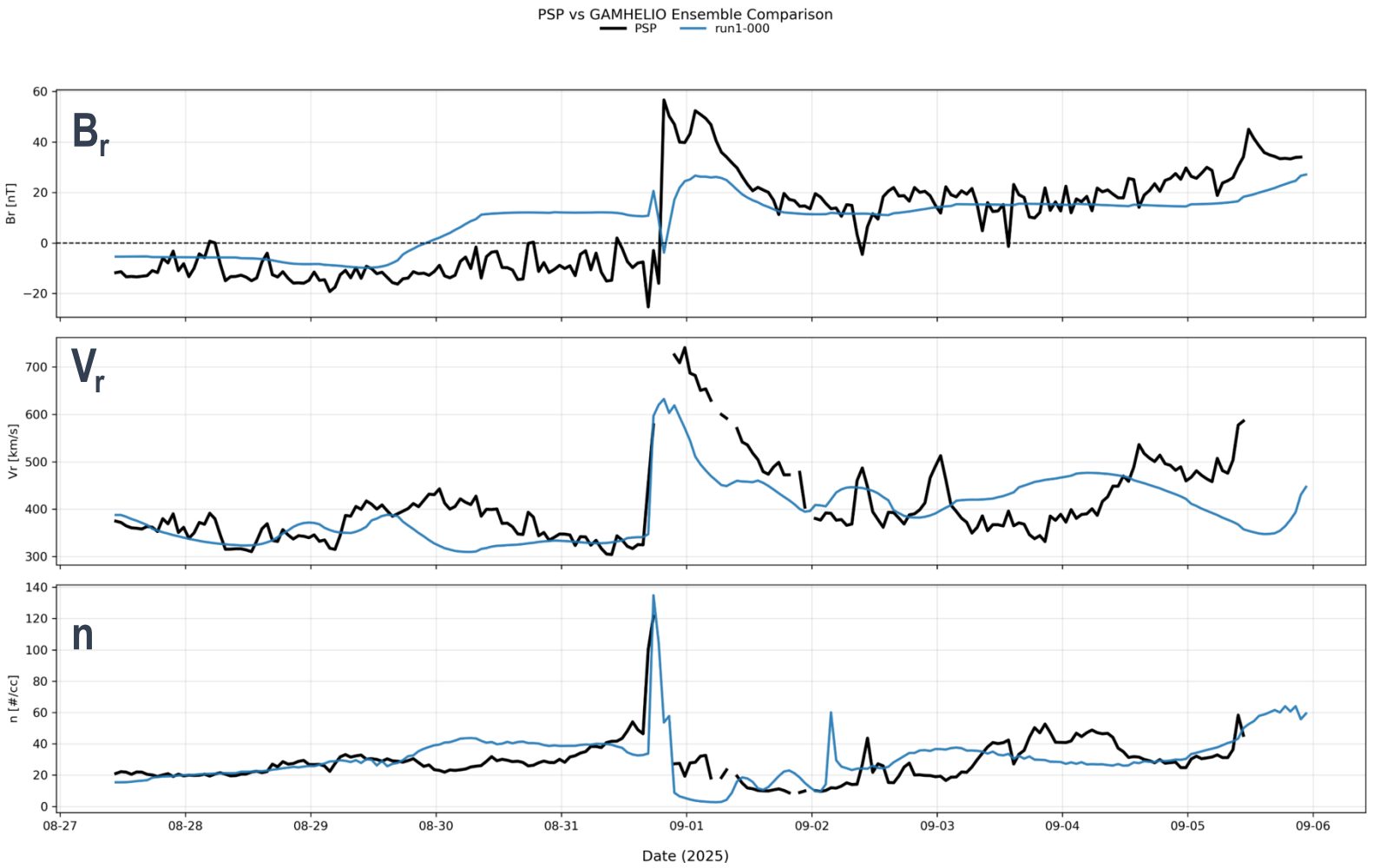
- Tilt = 30° (informed by Weiss et al. reconstruction)
- V_{CME} = 1250 km/s (CCMC DONKI)
- Width = 70° (CCMC DONKI)
- Lat = 5N, Lon = 10 E (CCMC DONKI)
- CME at 21.5 R_S : 2025-08-30 22:40 UT
- B_{max} = 2000 nT
- n_{CME} = 700 cm-3
- T_{CME} = 10^6 K
- 4 different topologies



GAMERA solution for a spheromak CME



Comparison with Parker Solar Probe: GAMERA with spheromak CME



- PSP at 0.5 au
- CME arrives at PSP on August 31 17:18 UTC
- Model arrival time agrees

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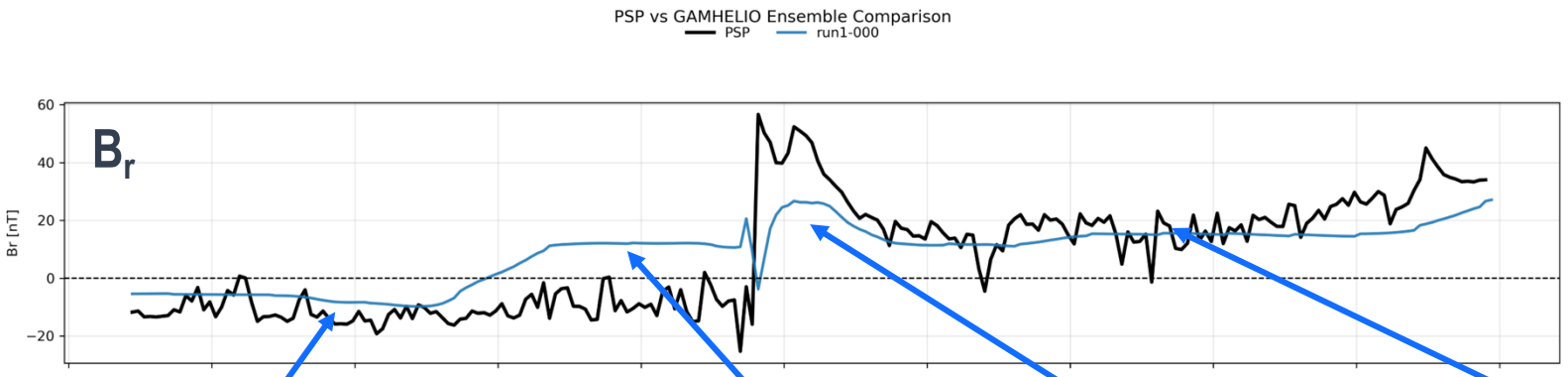

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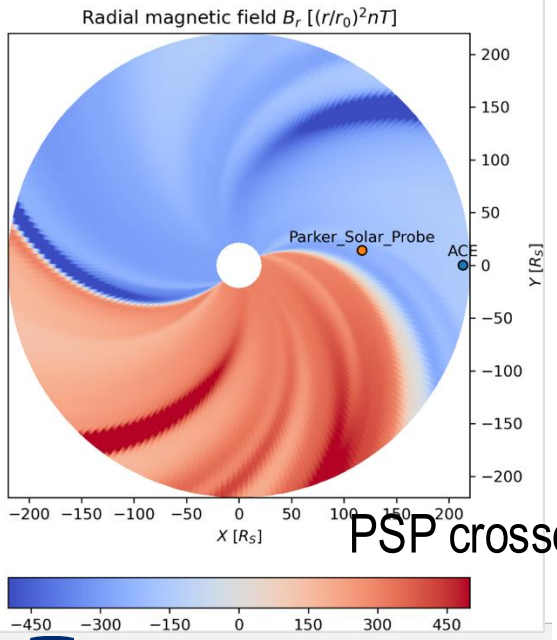
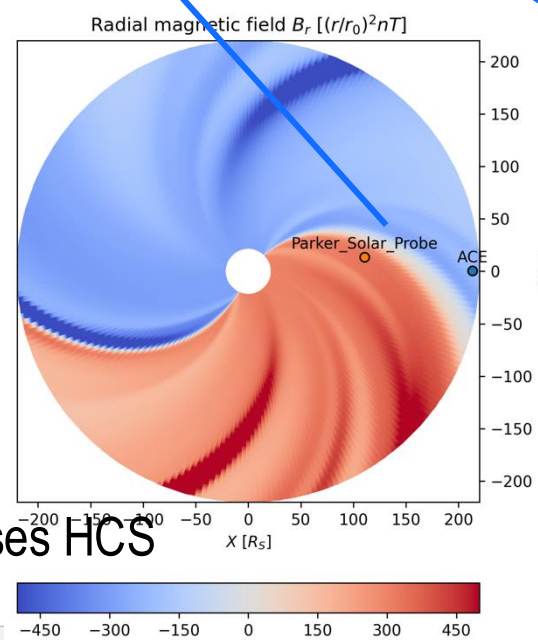
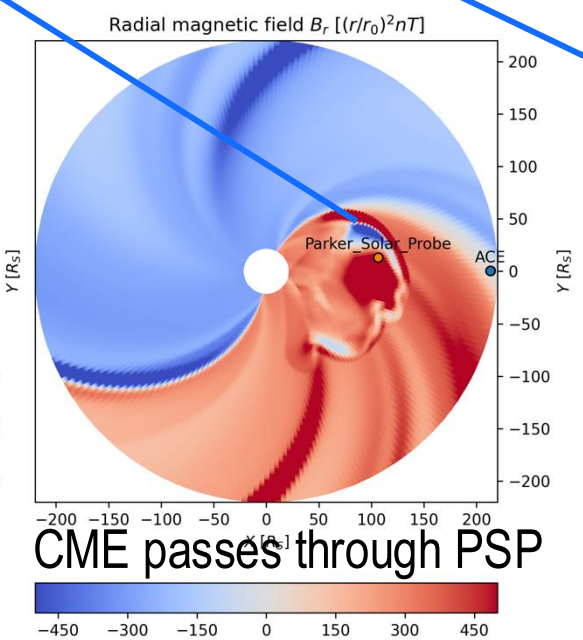
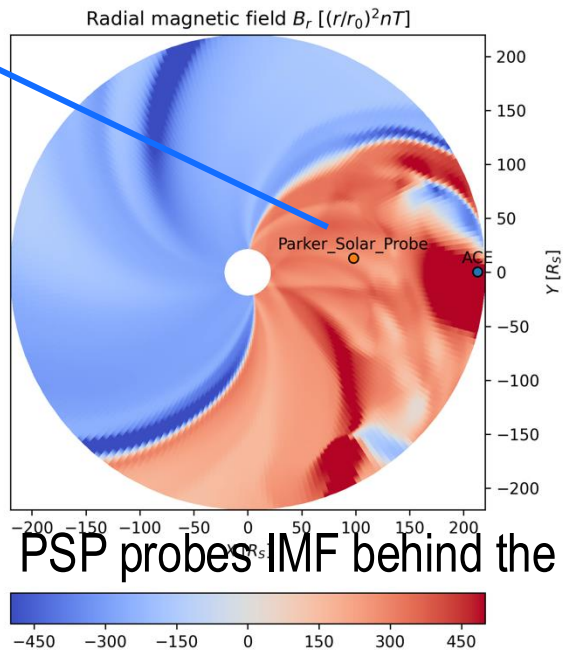


PSP crosses HCS



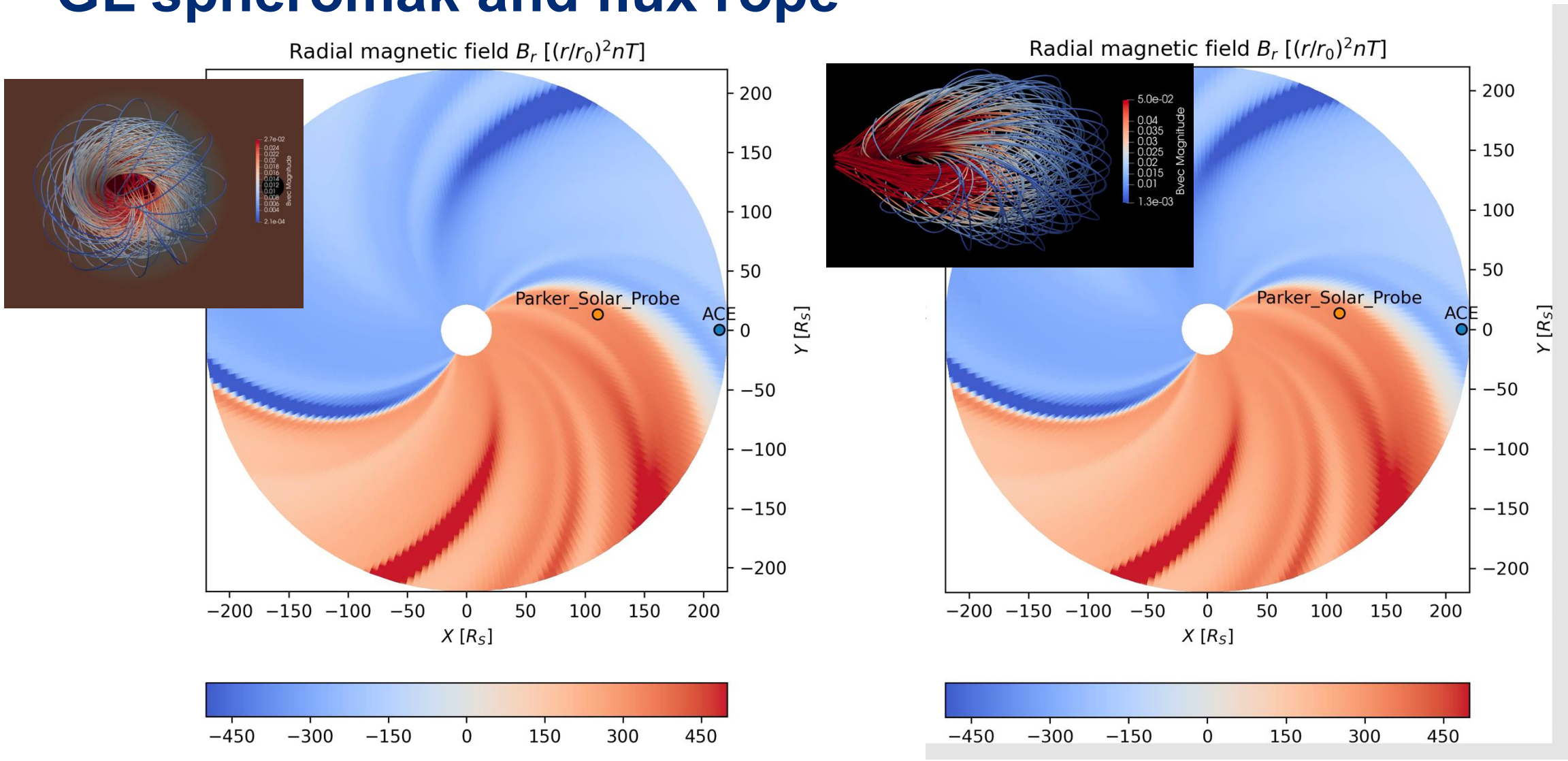


CME passes through PSP

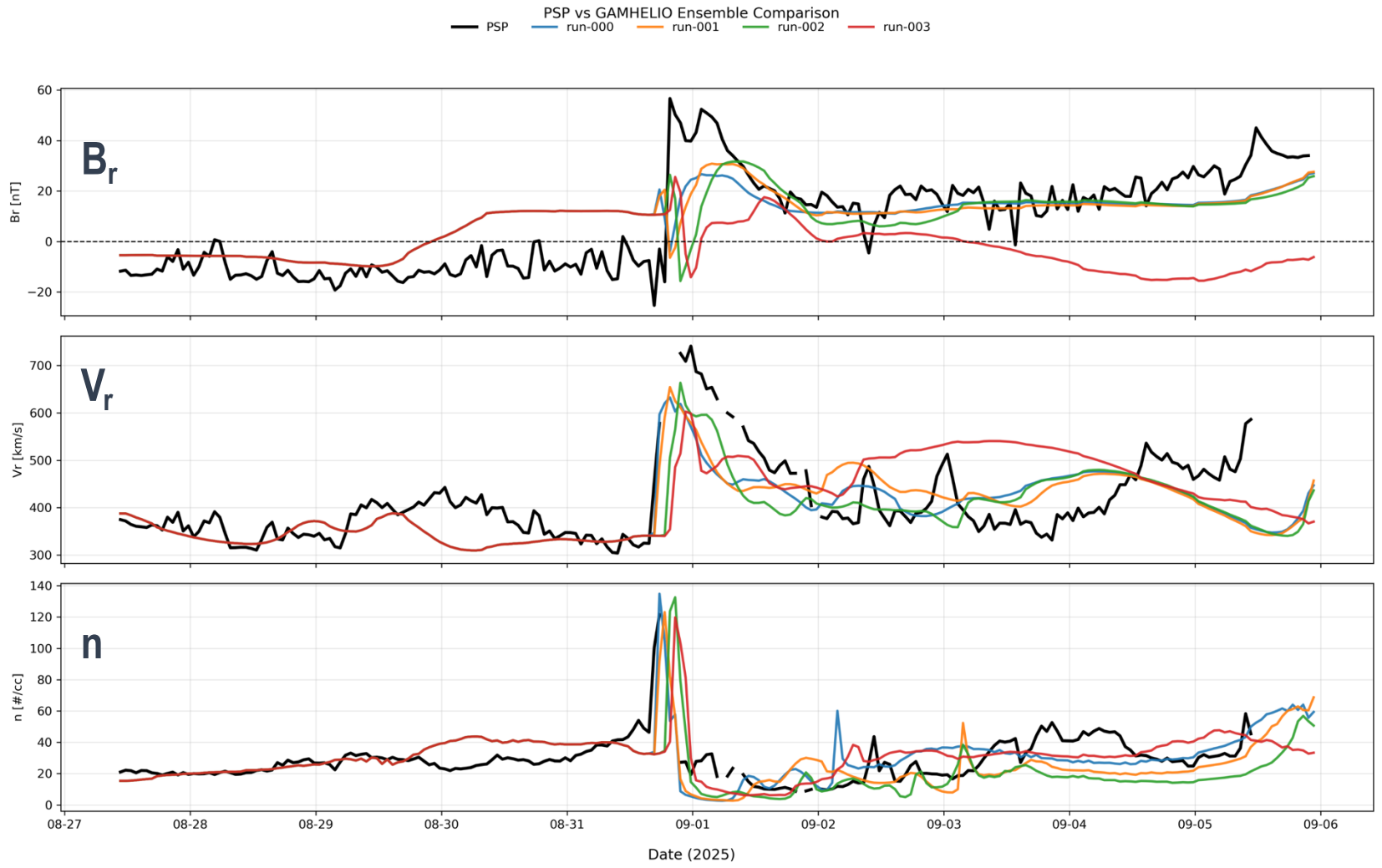


PSP probes IMF behind the CME

Two different CME structures: Heliospheric evolution of GL spheromak and flux rope



Comparison with Parker Solar Probe: GAMERA ensemble with four different Gibson-Low CME structures



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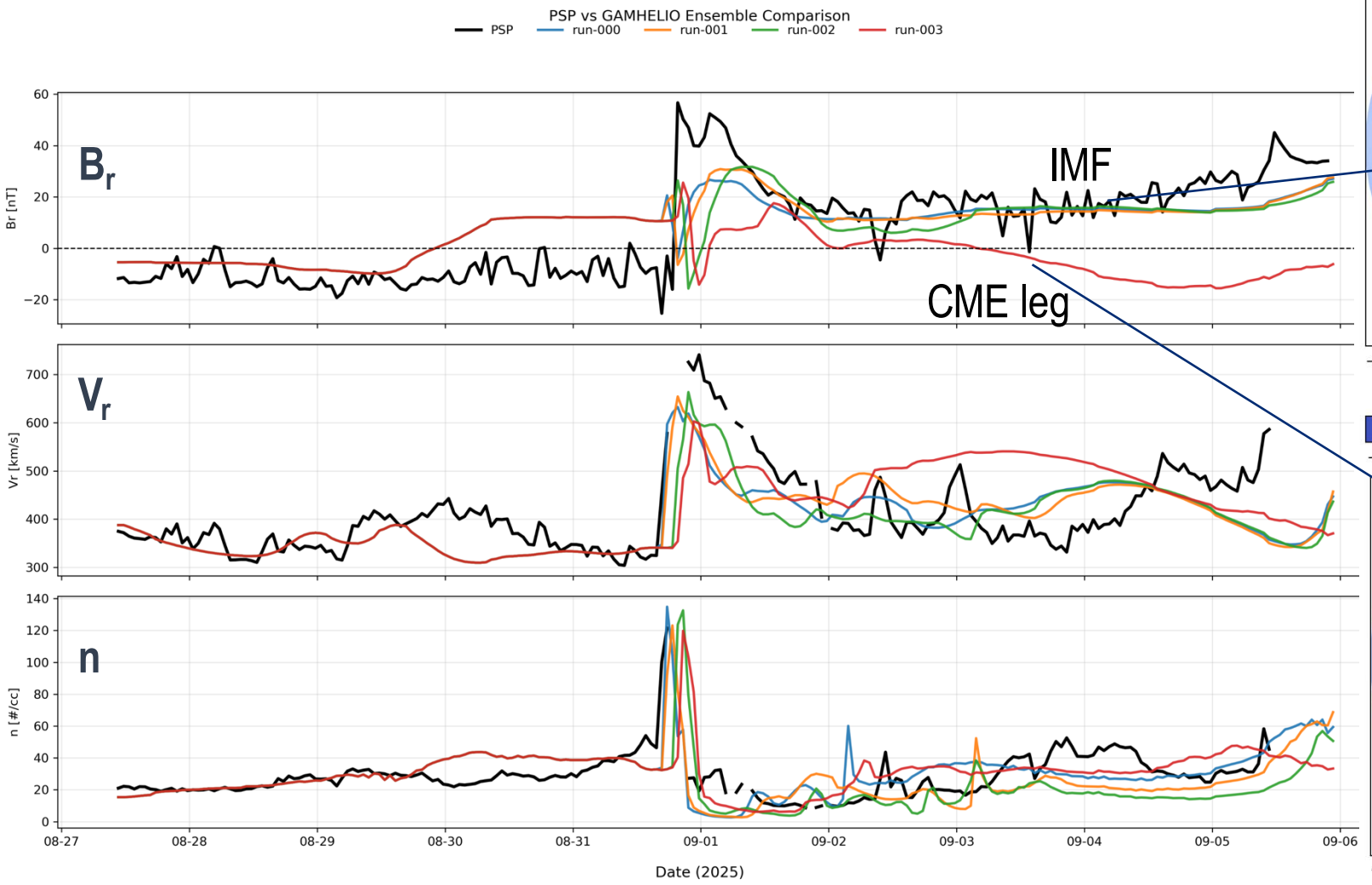

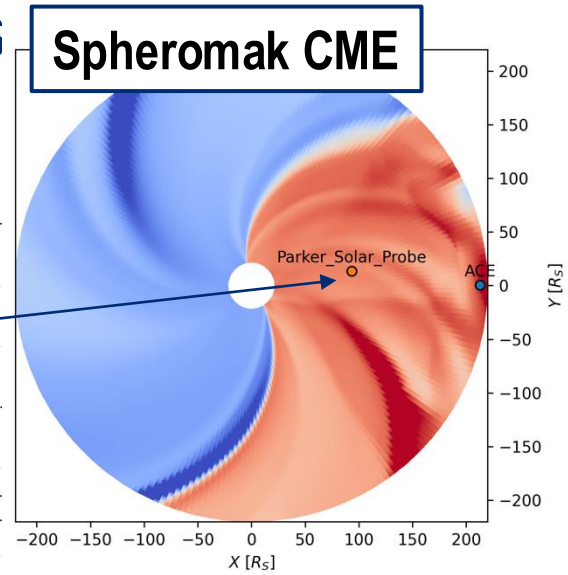

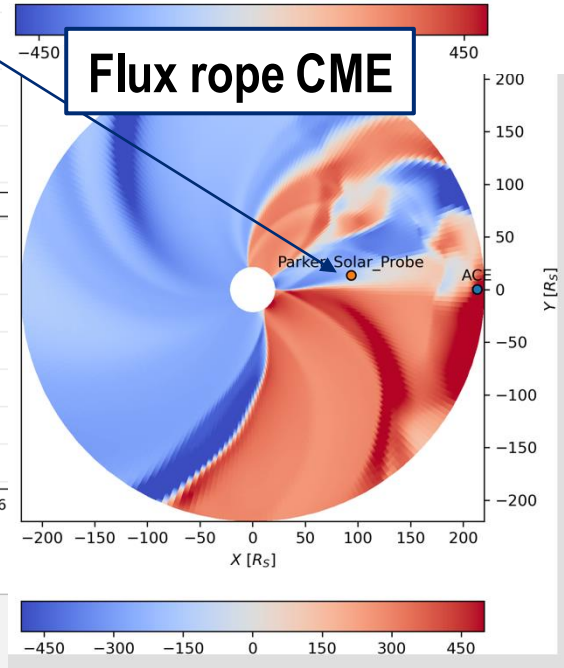

Spheromak CME is a better match to Parker measurements

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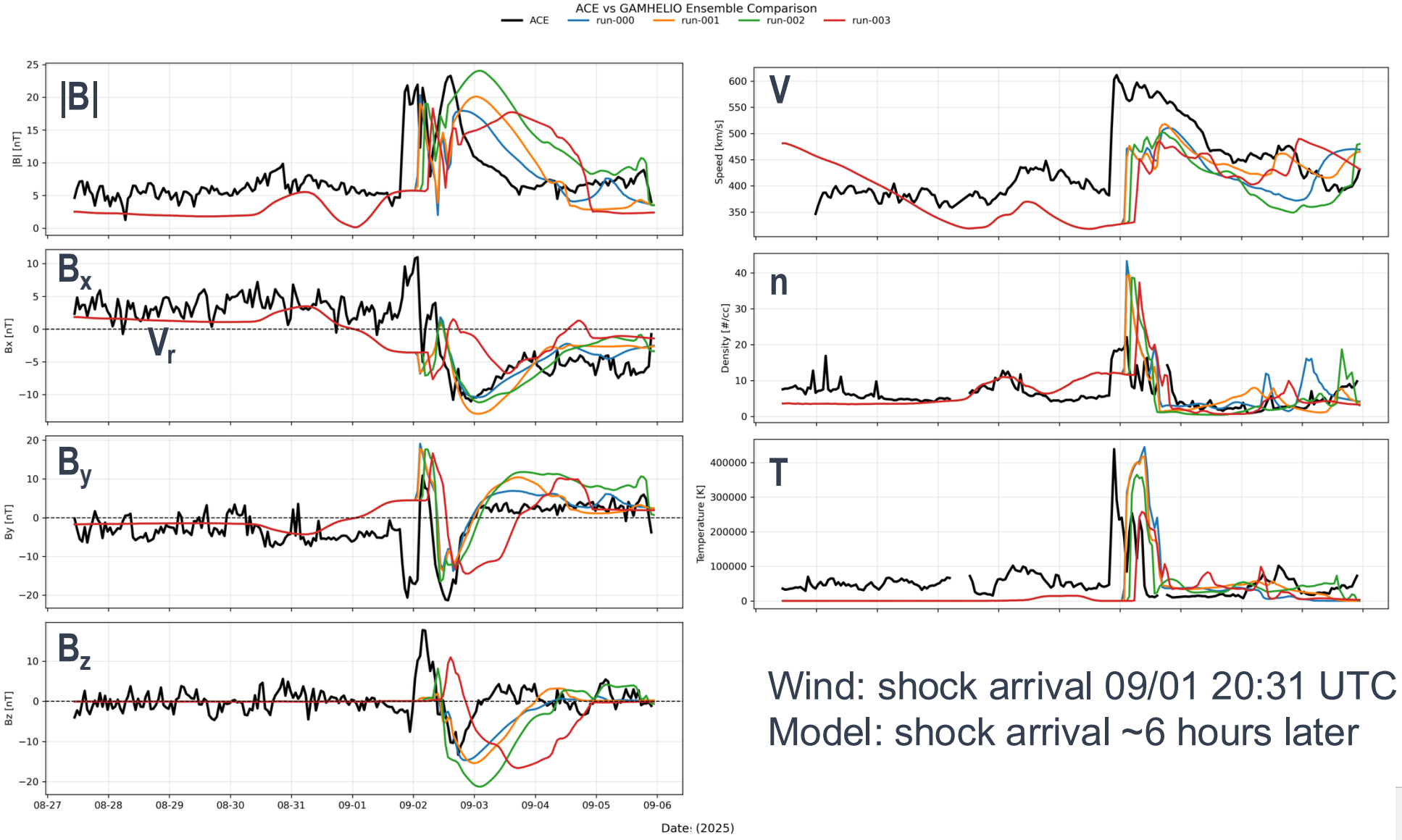
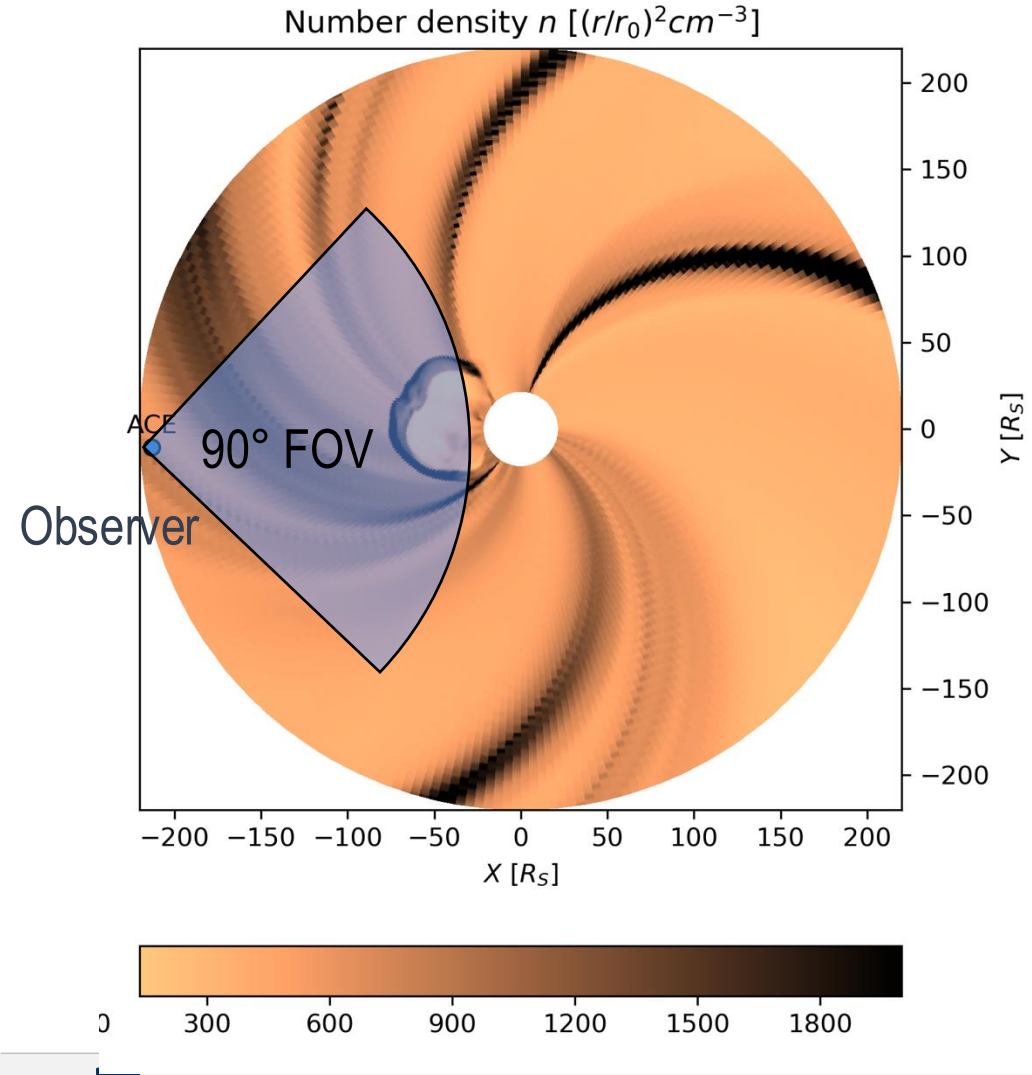
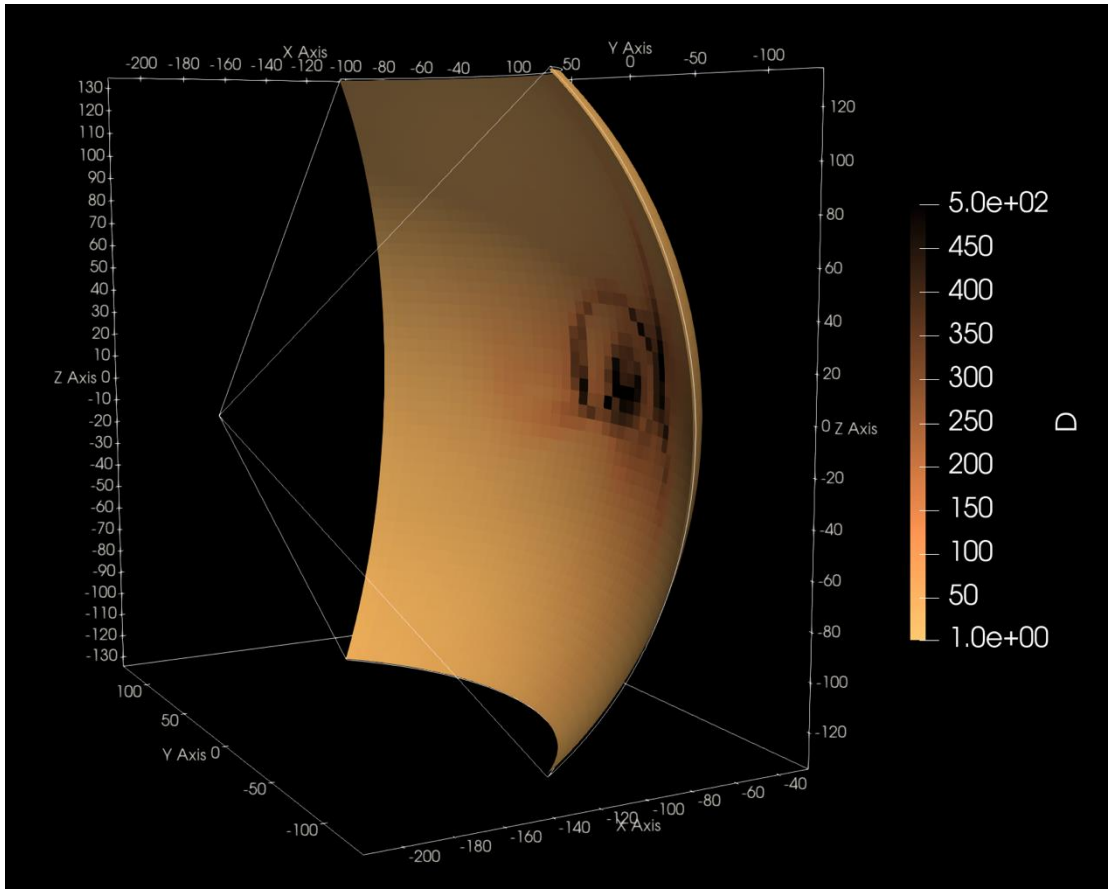
Comparison with ACE and Wind at L1: GAMERA ensemble with different Gibson-Low CME structures



Wind: shock arrival 09/01 20:31 UTC
Model: shock arrival ~6 hours later

Synthetic images of white-light brightness: integrating Thomson scattered light intensity





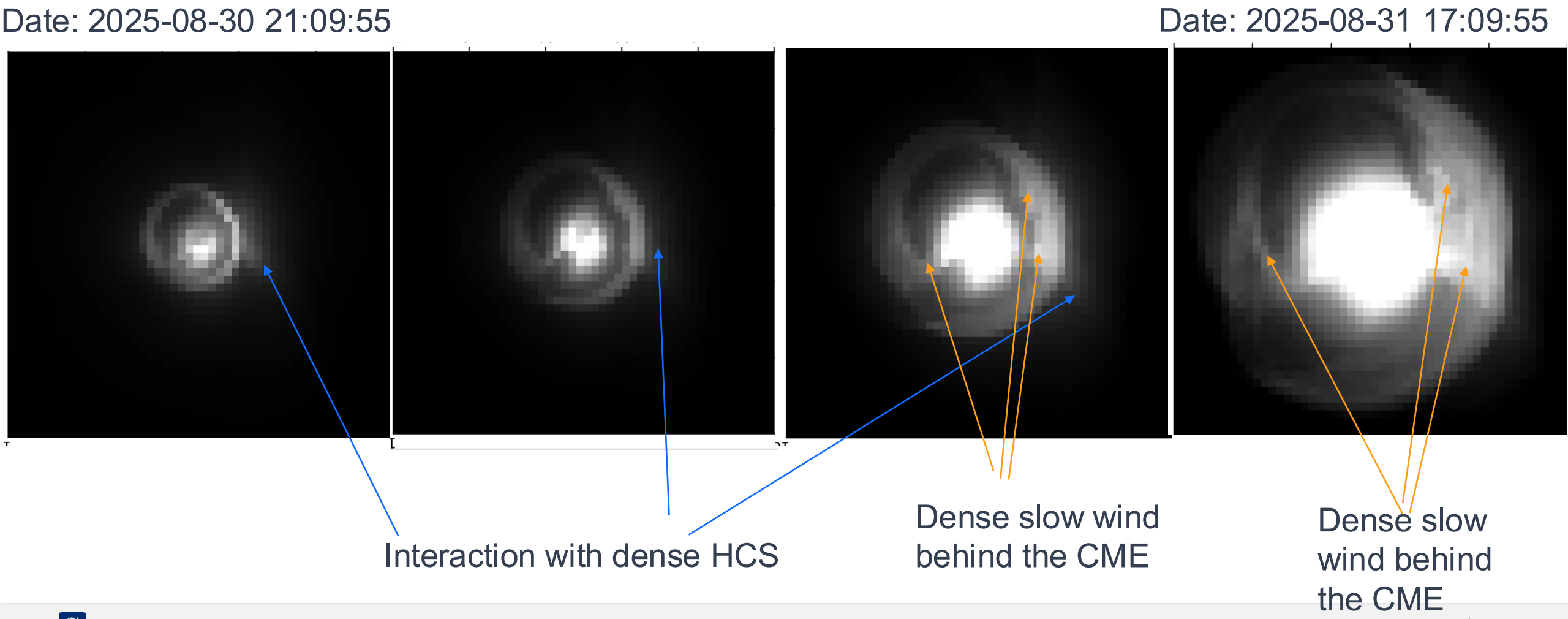
Grid 50x50x100, 90° FOV

Integrating Thomson scattered light brightness along the line-of-sight (Howard and Tappin 2009)

Case with a spheromak CME

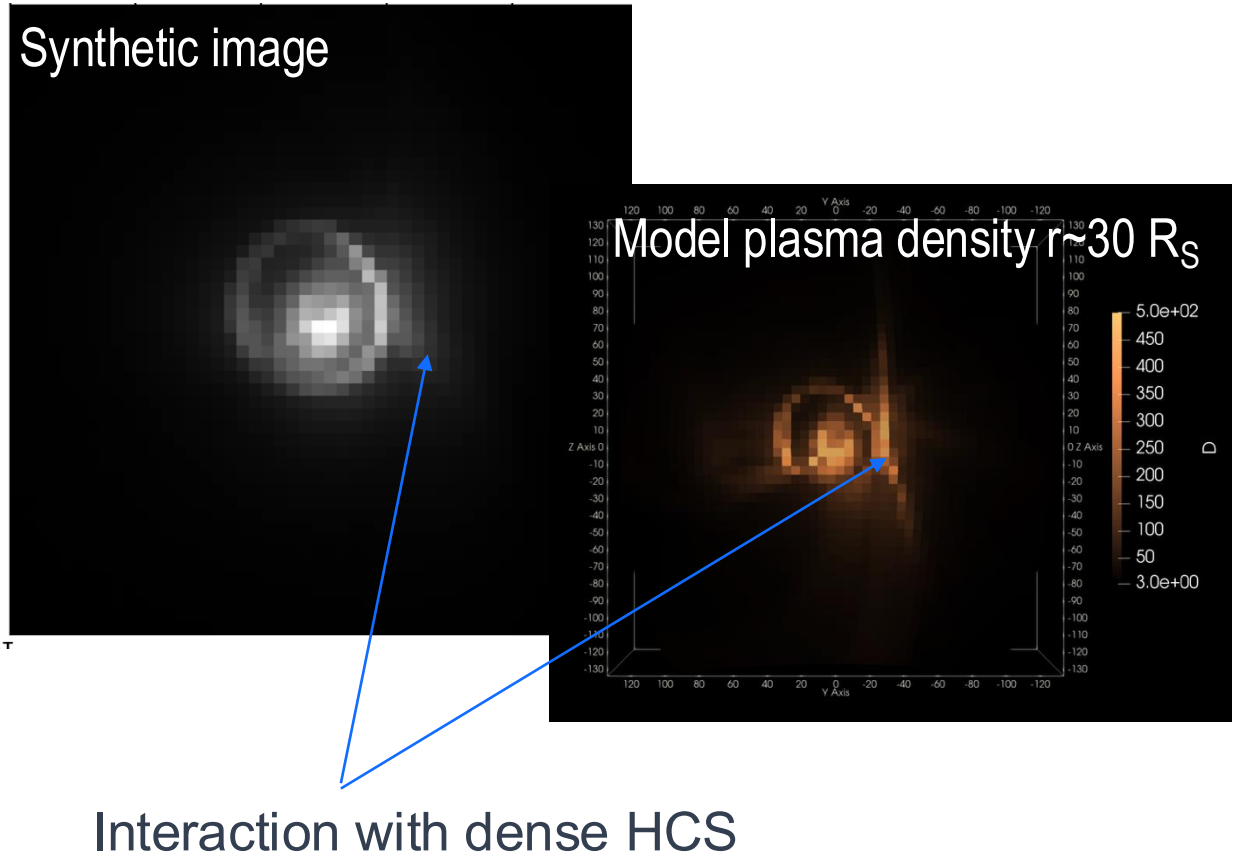
Synthetic white-light images in PUNCH FOV

- FOV 90 deg from Earth location

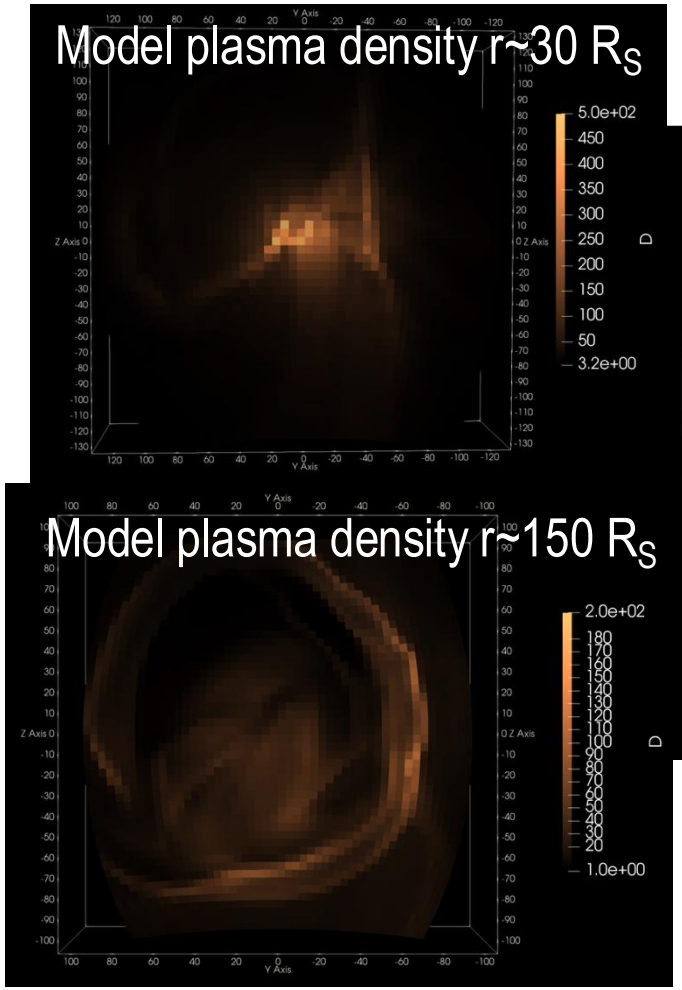


Synthetic white-light images in PUNCH FOV

2025-08-30 21:09:55



Interaction with dense HCS



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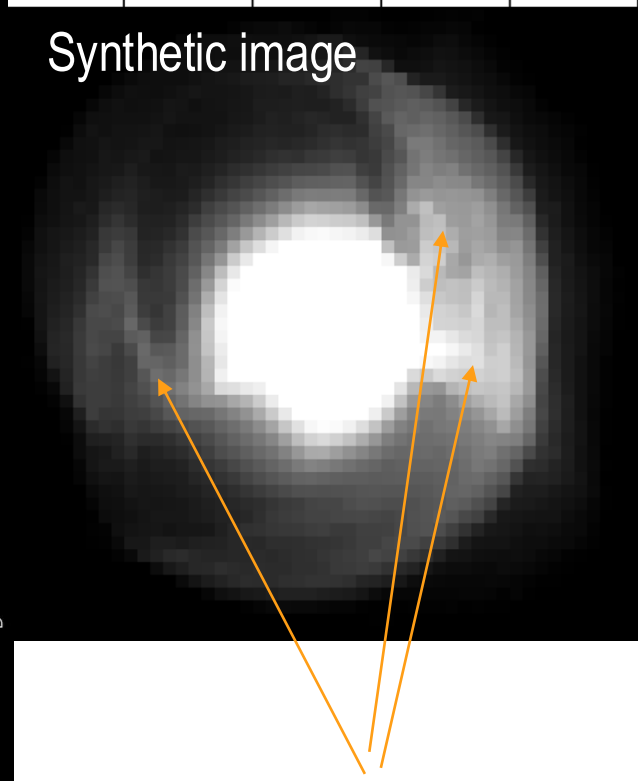

Slow wind behind CME

Next step: comparison of synthetic images with PUNCH data

Summary

- The August 30, 2025 CME event is an excellent PUNCH Connect case study
- Among the four CME magnetic topologies modeled, the spheromak shows significantly better agreement with in-situ observations than the flux-rope
- The CME arrival at both Parker Solar Probe and L1 coincides with spacecraft crossings of the heliospheric current sheet (HCS)
- Synthetic PUNCH imagery captures the interaction between the CME and a strongly inclined HCS on the western side, where the HCS is oriented nearly north–south
- Further refinement of near-Sun CME parameters will help improve agreement between simulations and observations; the modeled magnetic-field profiles during CME passage are particularly sensitive to CME tilt, magnetic topology, propagation direction, and the ambient solar-wind background.

Next steps:

- Comparison with reconstructions from PUNCH and IPS data (👏 Robert and Bernie)
- Collaborate on synthetic white-light generation (👏 Sarah and Anny)