PUNCH observations of CME Shocks & Associated Particle Acceleration

Mihir Desai, Heather Elliott, Maher Dayeh, Felix Minta

Southwest Research Institute, San Antonio TX

Science Motivation: CME shocks & SEPs?

Solar Energetic Particles (SEPs)

Ions accelerated to MeV/nuc energies by CME-driven shocks are a primary space weather hazard for astronauts, satellites, and aviation.

The Remote-Sensing Gap

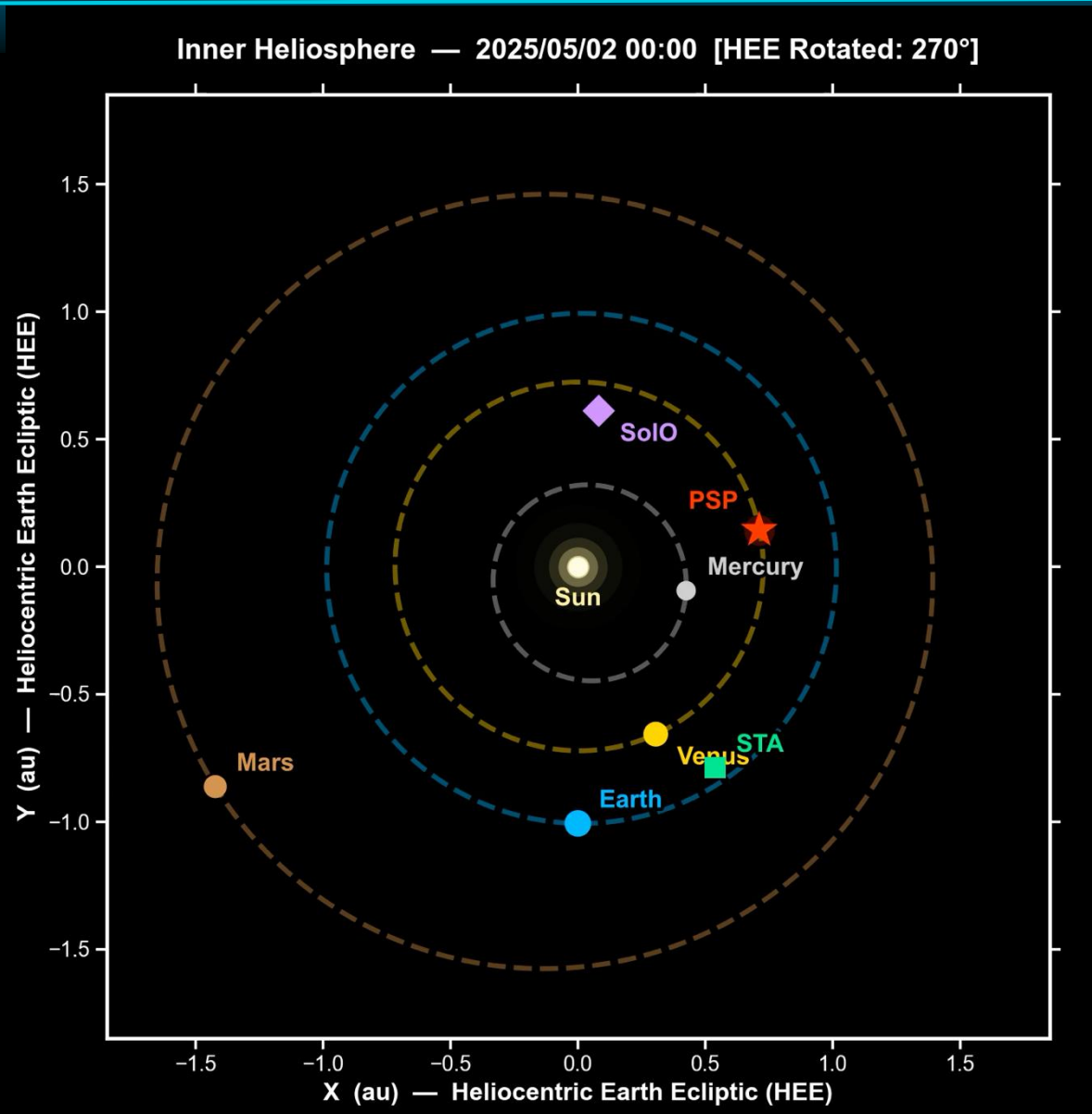
Before PUNCH, there was no way to continuously image CME shocks as they propagated from the corona (a few R⊙) out to 1 AU. PUNCH's Wide Field Imagers (WFI) fill this gap.

Multi-Spacecraft Context

Combining PUNCH imaging with in-situ data from Solar Orbiter, Parker Solar Probe, ACE, Wind, and STEREO-A allows us to link remote observations with the in-situ data

Some Key Open Questions

Where do CME shocks first become supercritical? When do they begin accelerating SEPs? How does shock efficiency evolve with distance? Does turbulence play any role?



CME / ICME/SEP Observations

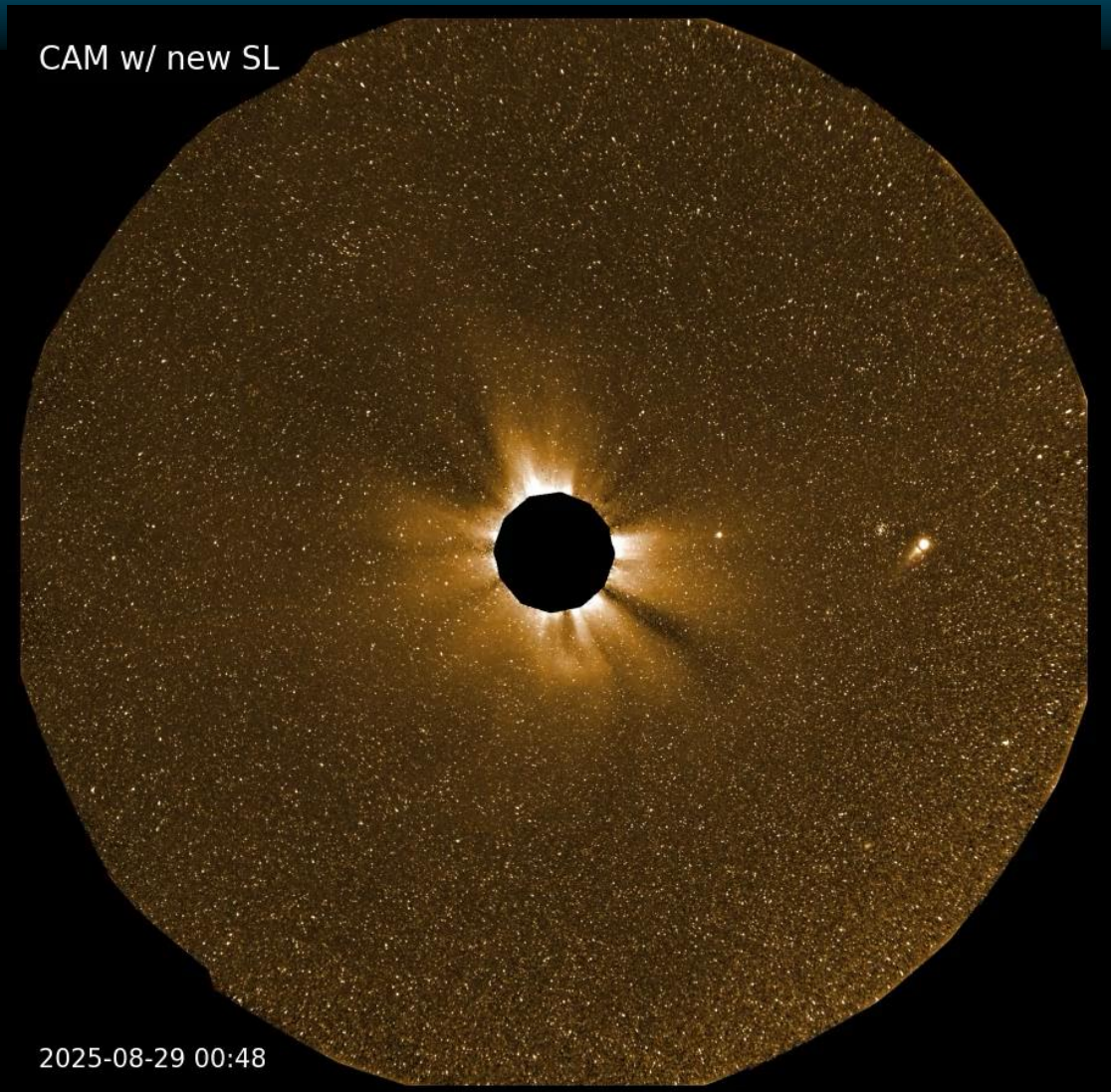
PUNCH WFI
Remotely images CME shocks steepening in the Wide-Field Imager FOV as they propagate outward from the Sun

Solar Orbiter
In-situ magnetic field, plasma & energetic ion (SEP) measurements; ICMEs detected at 0.44 – 0.74 AU

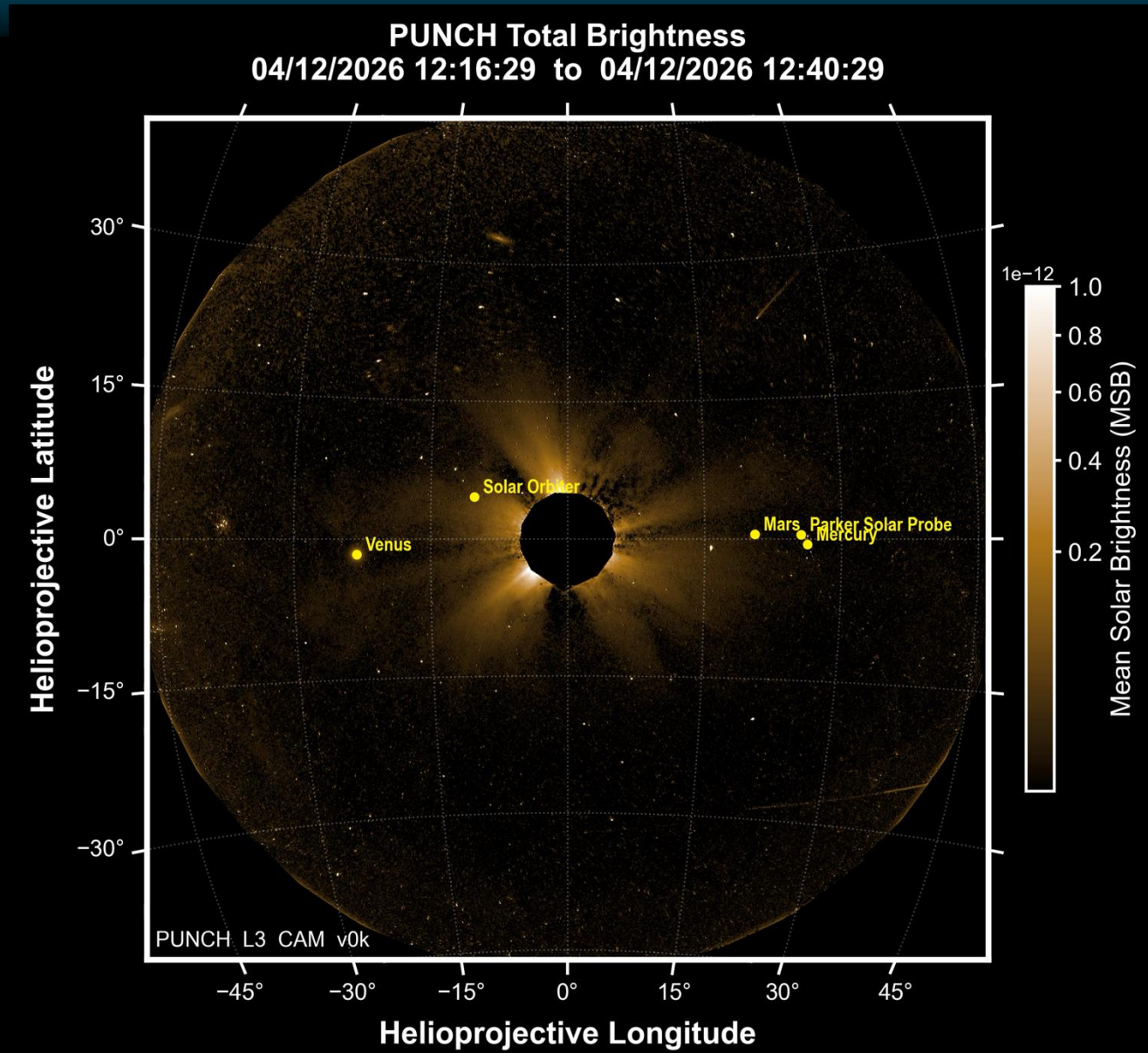
SEP Onset
Ion intensities rise to several MeV/nuc well before the shock arrives – shock acceleration already underway

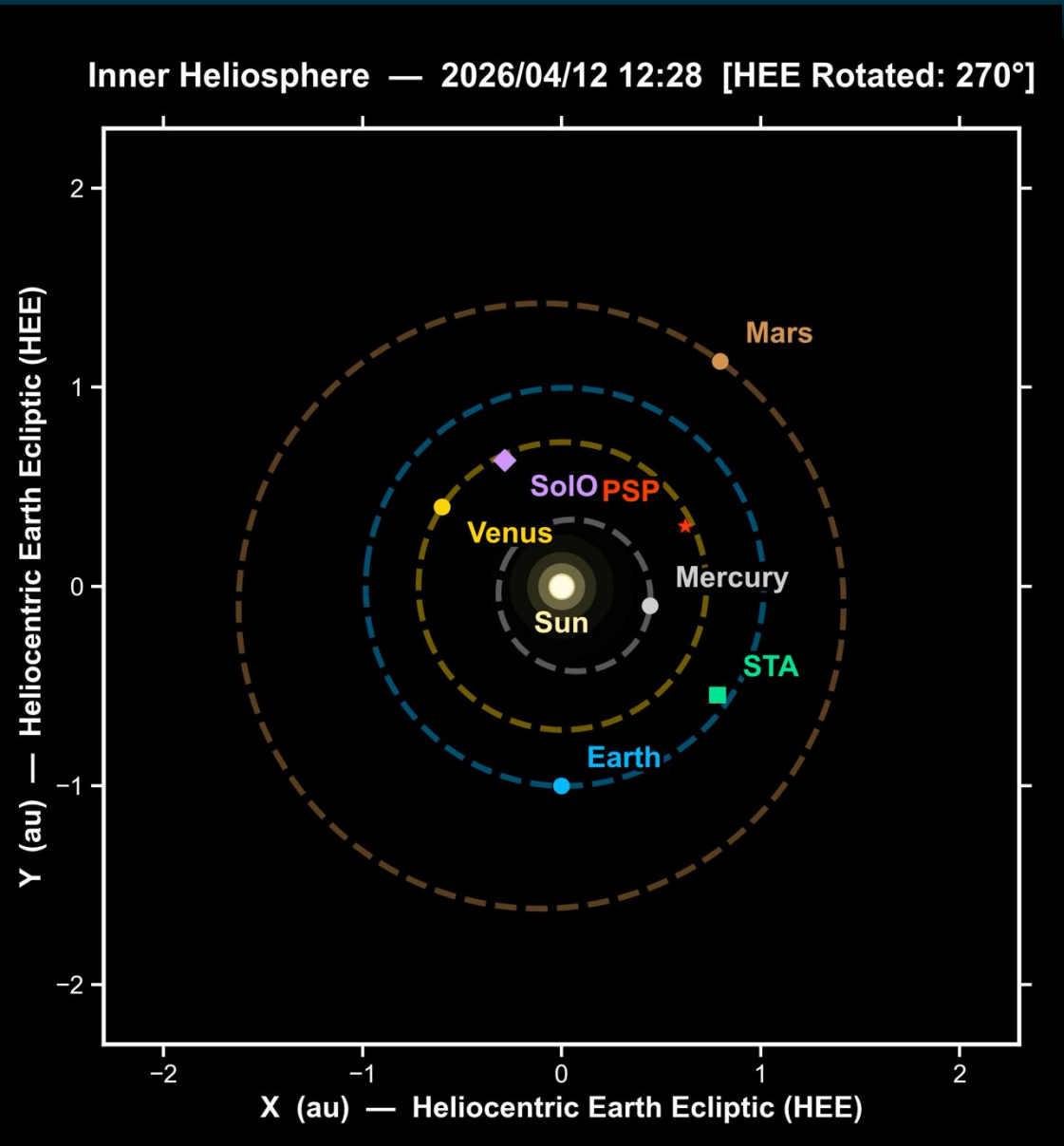
Multi-Spacecraft
ACE, Wind (L1), STEREO-A, Parker Solar Probe provide radial & longitudinal coverage

Key Result
PUNCH enables early detection & tracking of SEP-producing CME shocks across the inner heliosphere

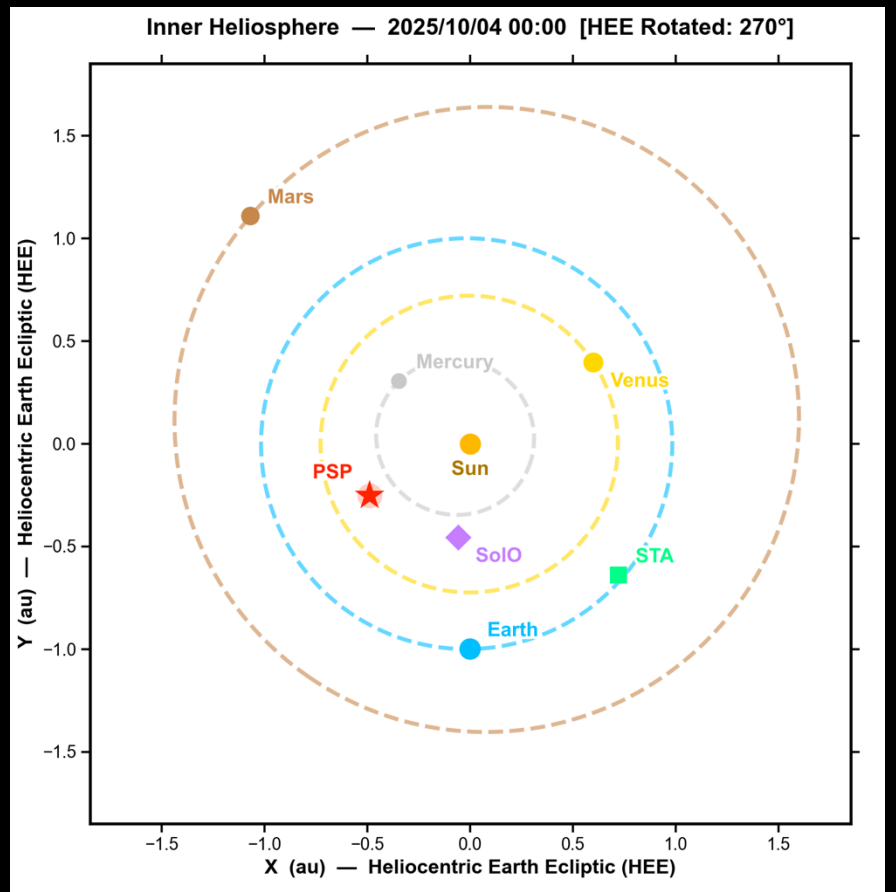


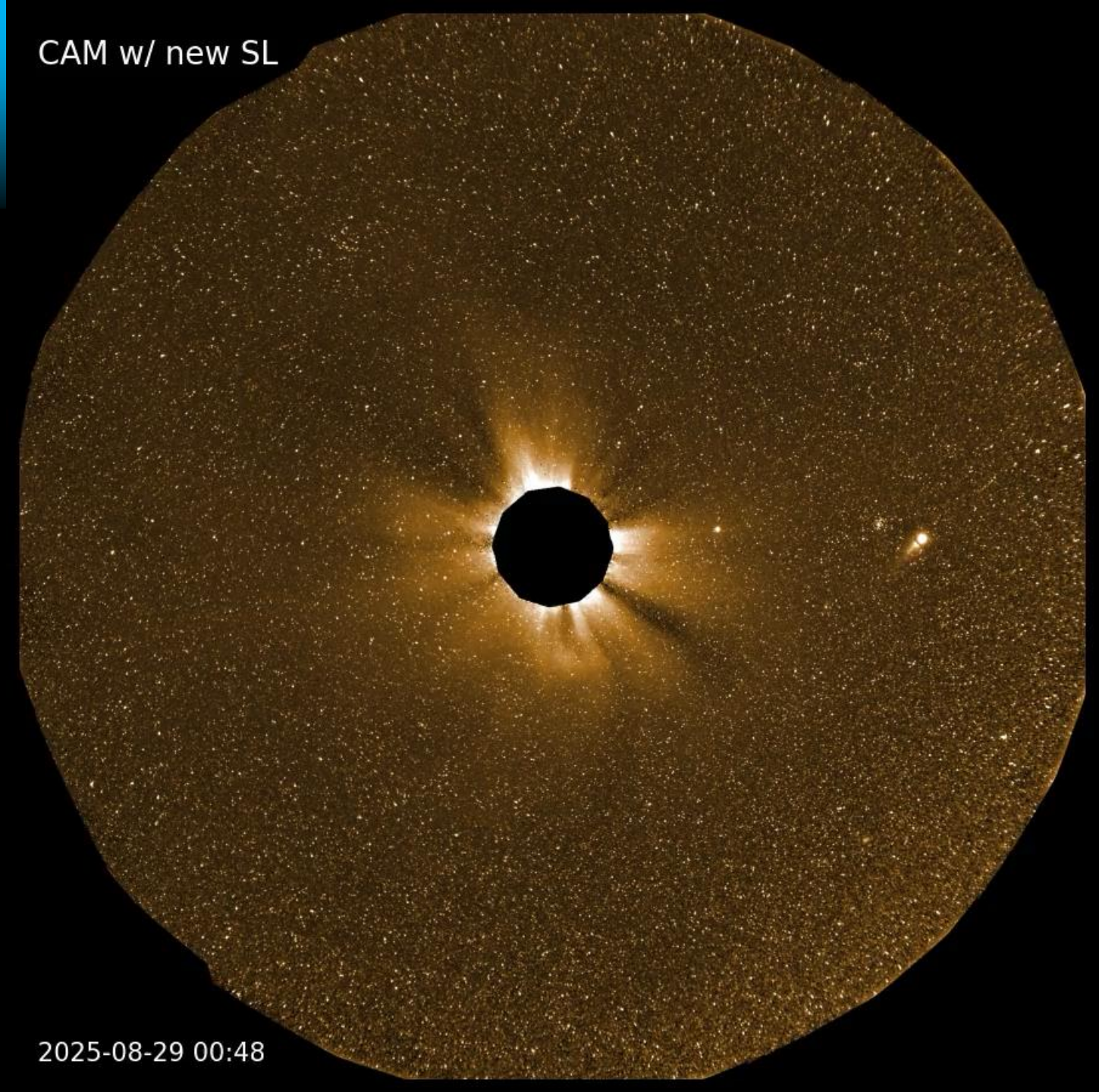
Spacecraft Alignments: Looking Down on Ecliptic





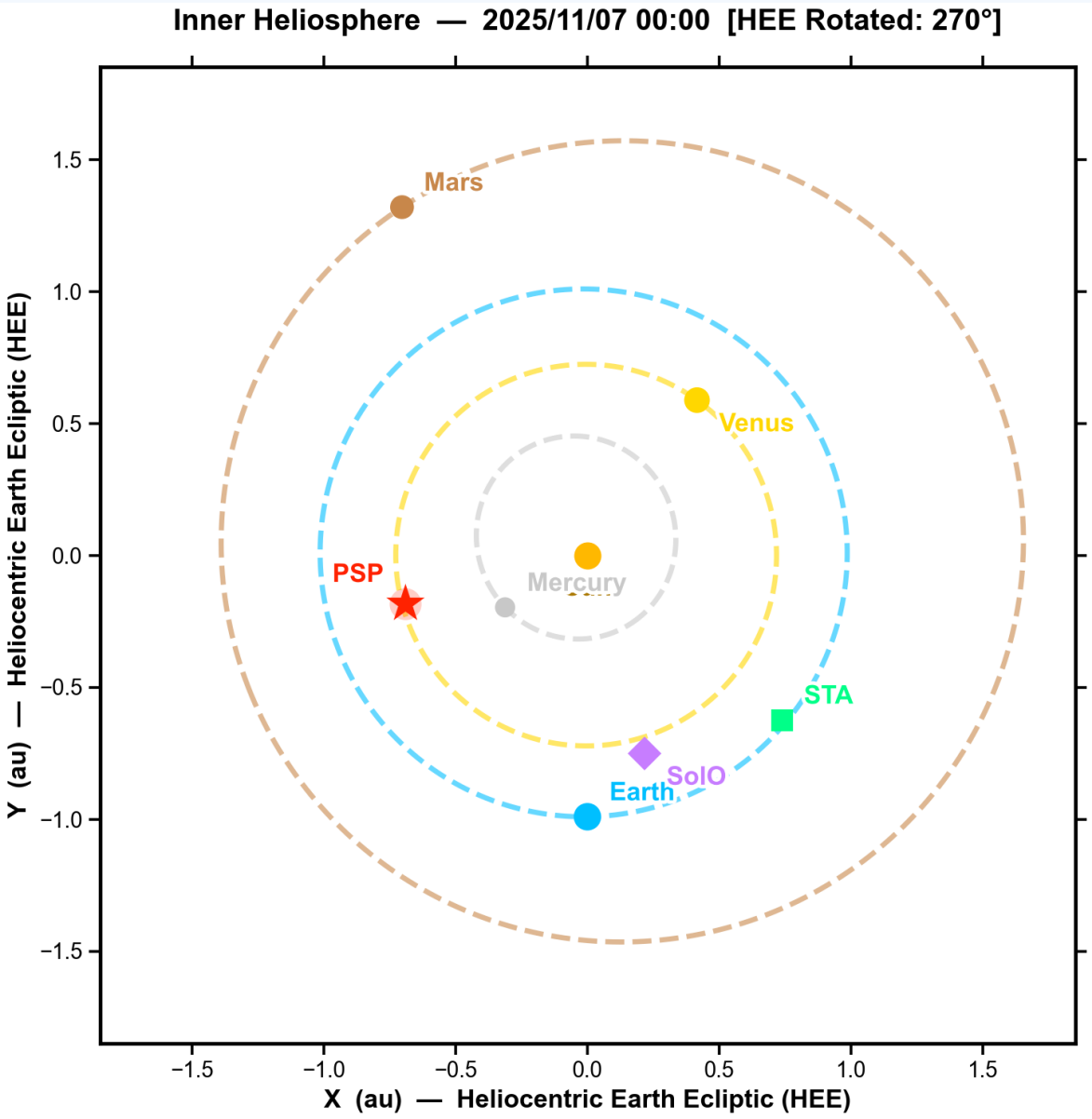
October 2025 Solar Orbiter & Earth Aligned

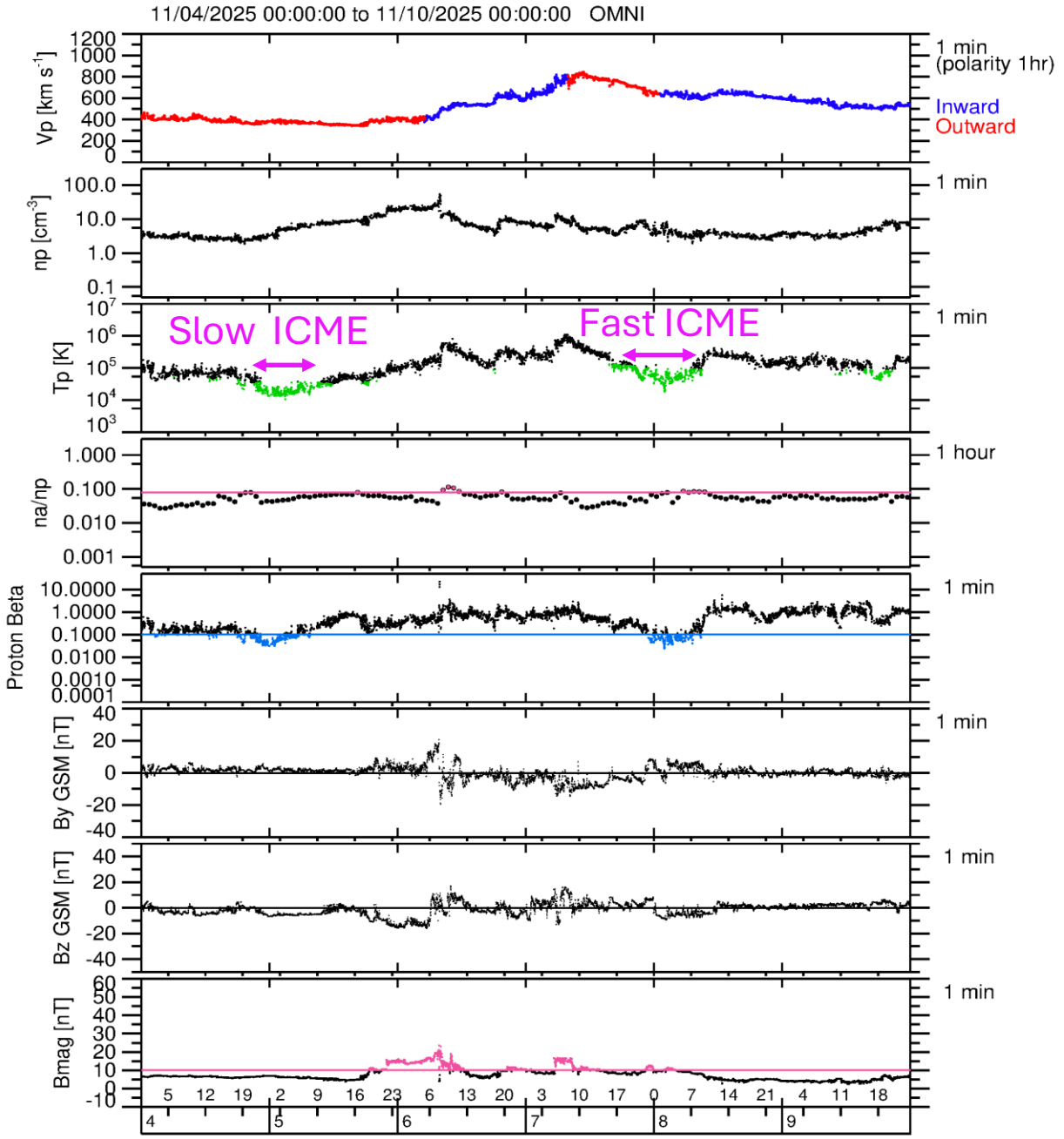




Early November 2025

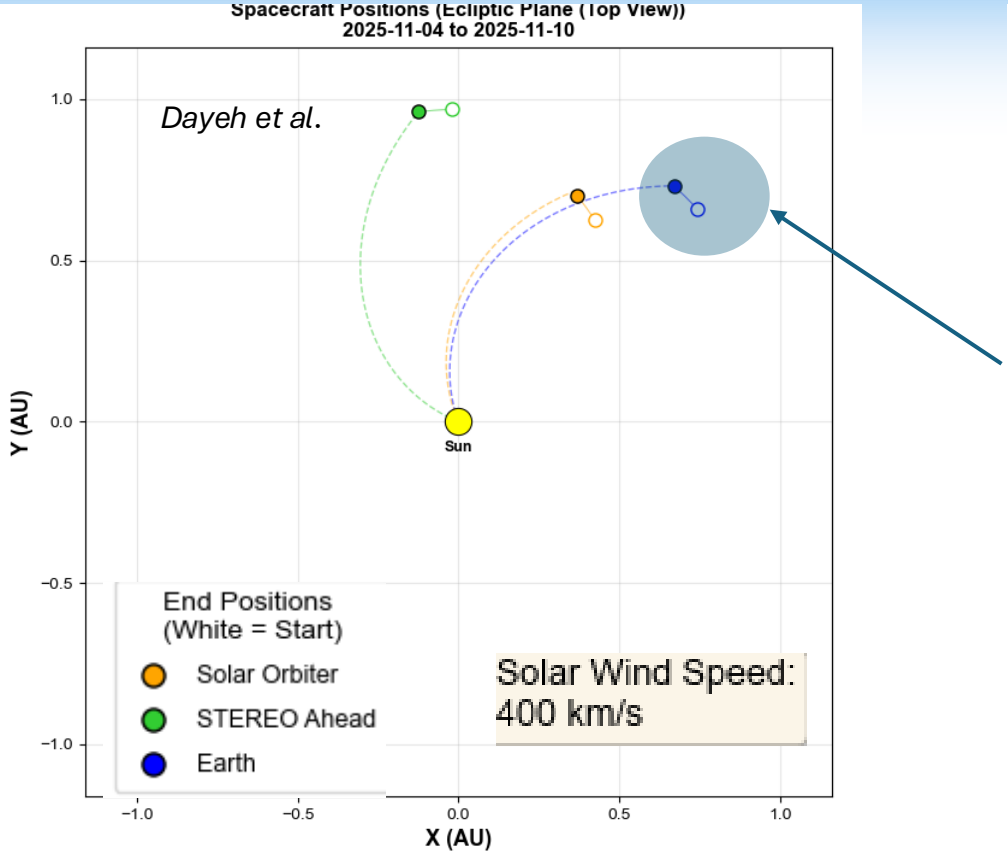
2 ICMEs one Fast one Slow
OMNI 11/04/2025 -11/08/2025

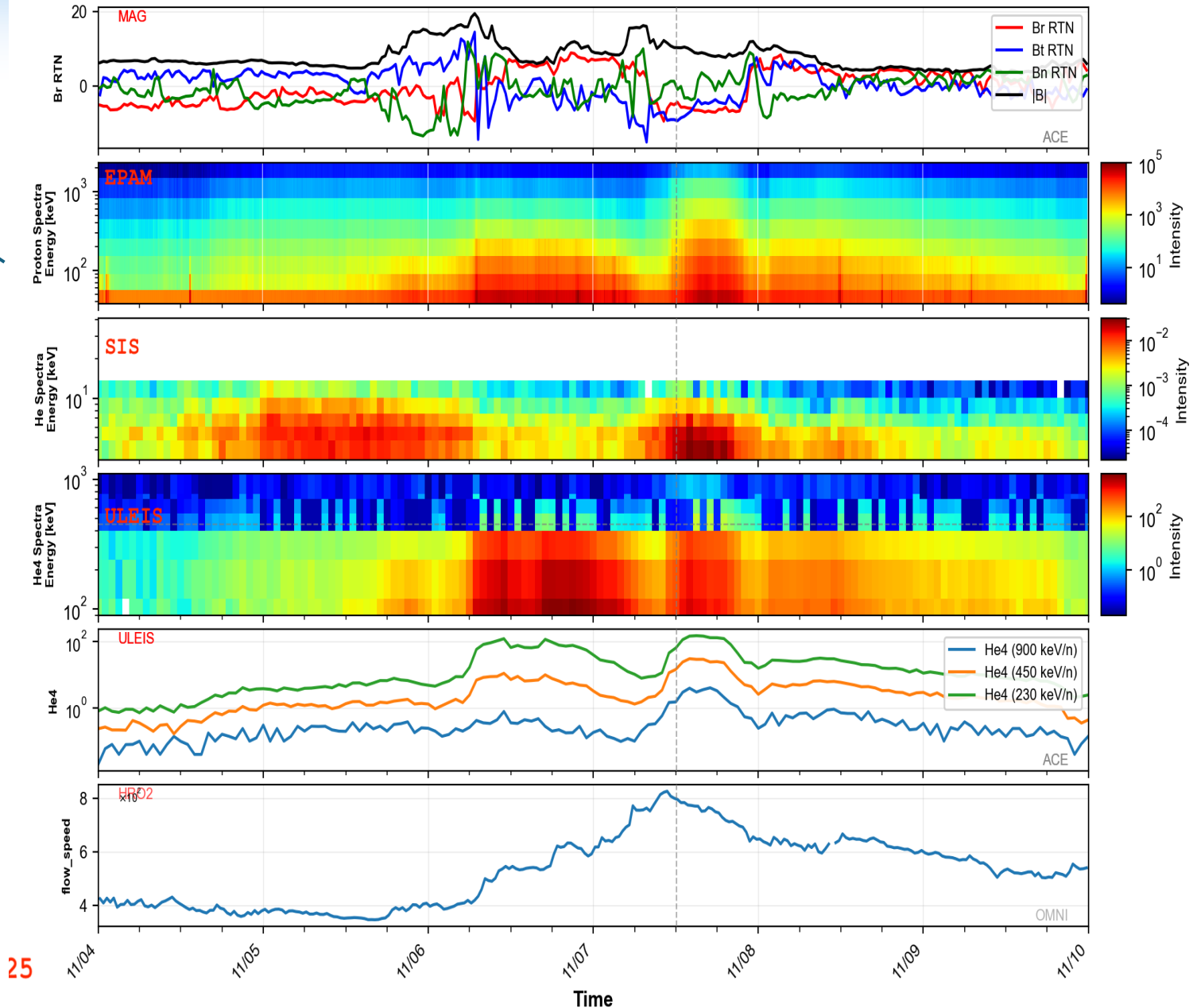




Elliott et al.

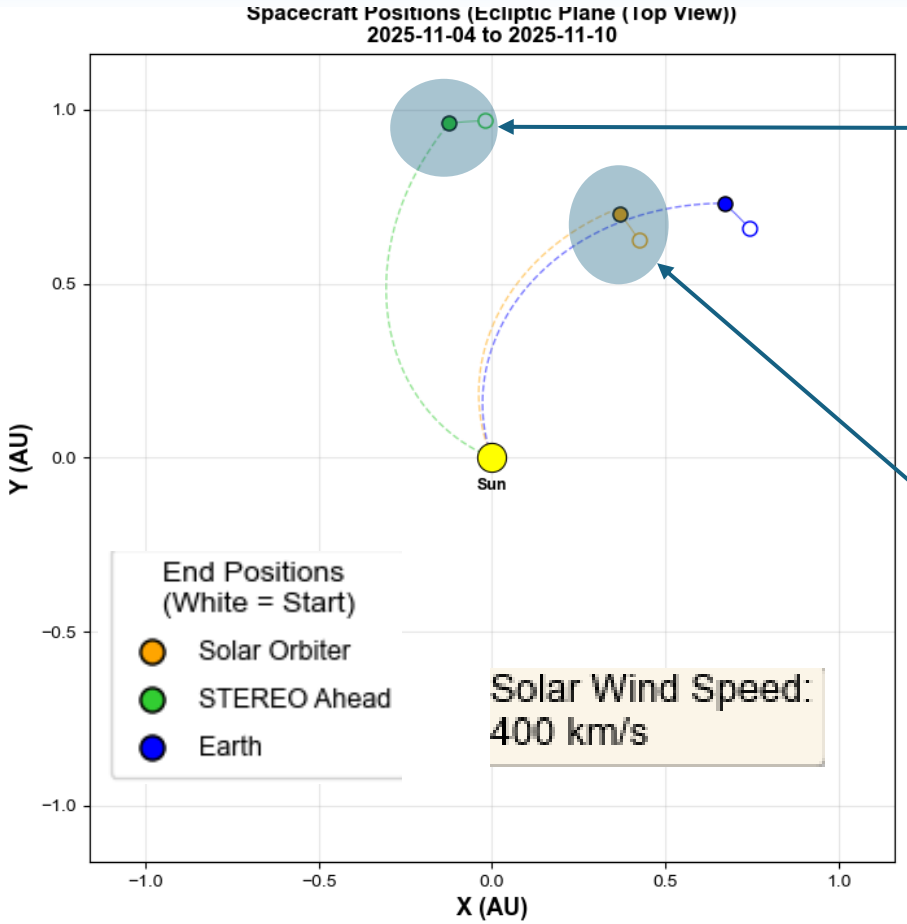
ACE 11/04/2025 -11/10/2025

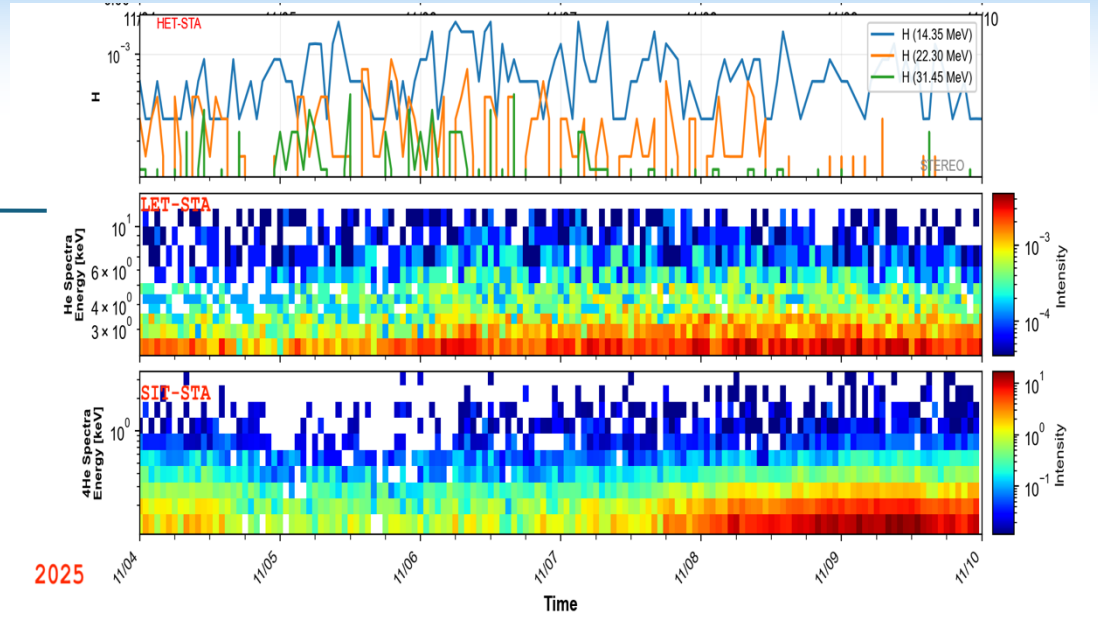


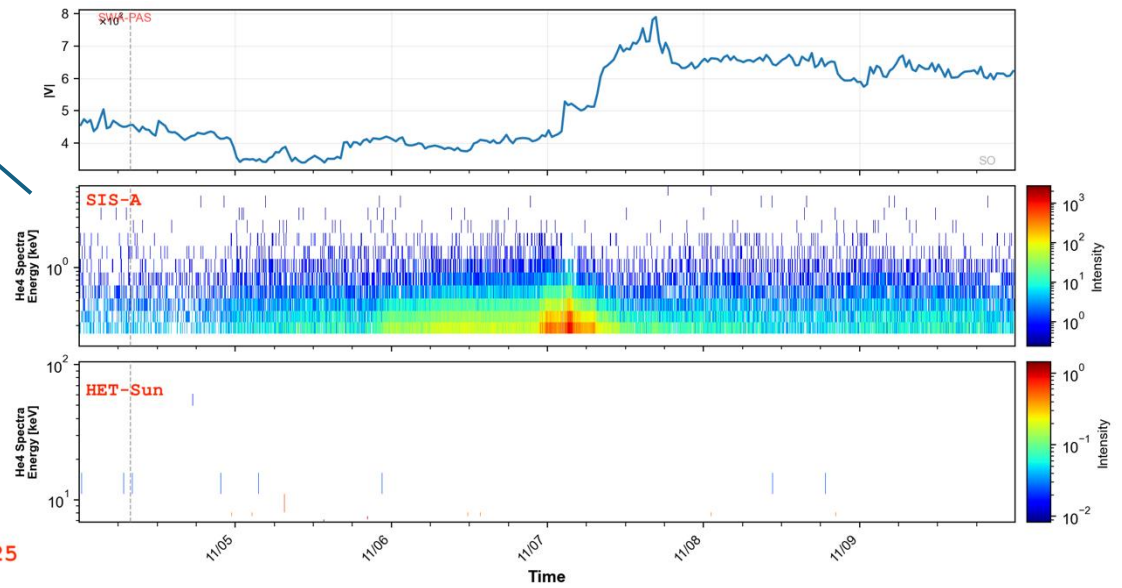


Fast ICME ~800 km/s, accompanied by proton and He solar energetic particle (SEP) events;

SoLO/STEREO-A 11/04/2025 -11/10/2025



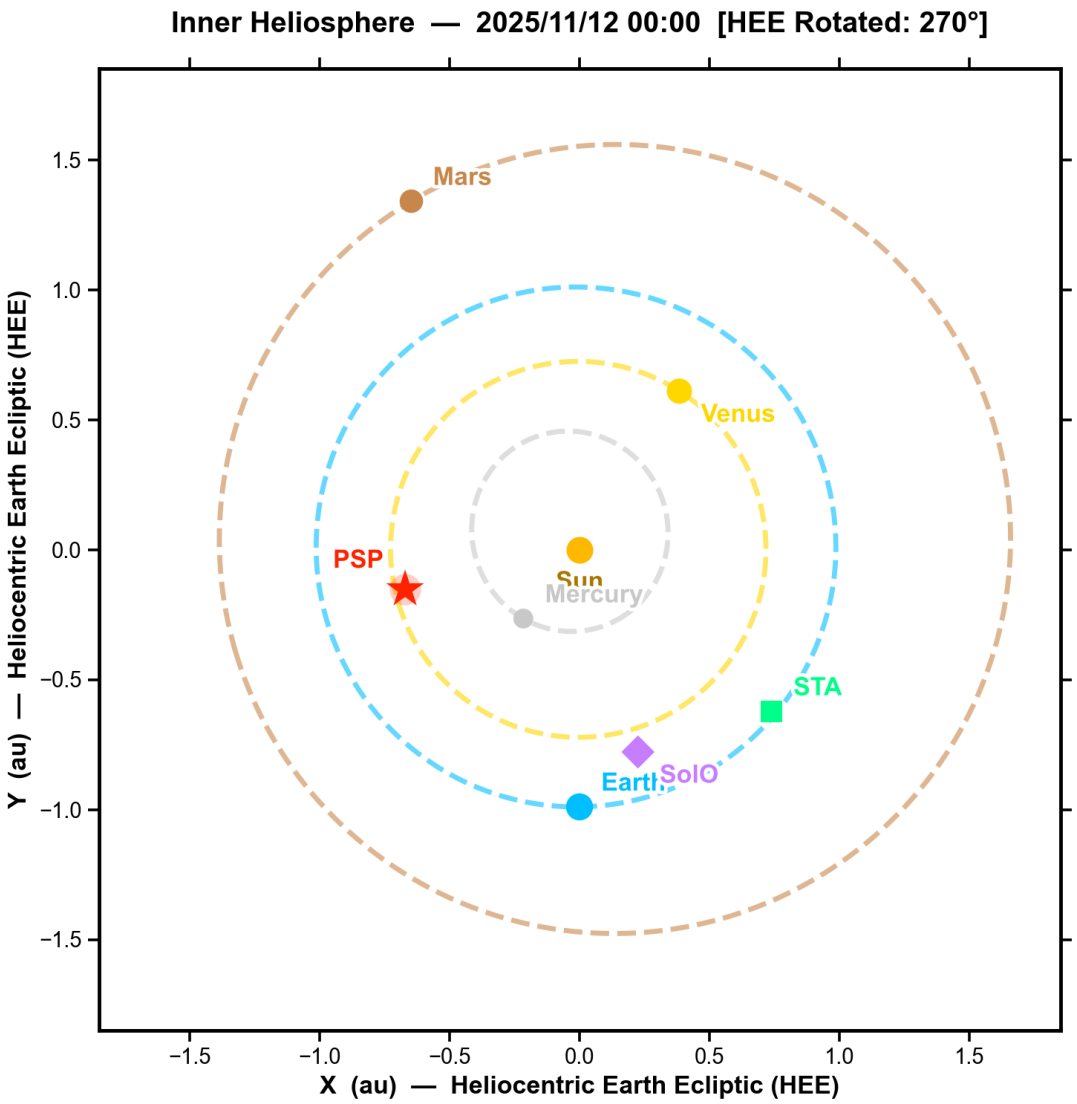


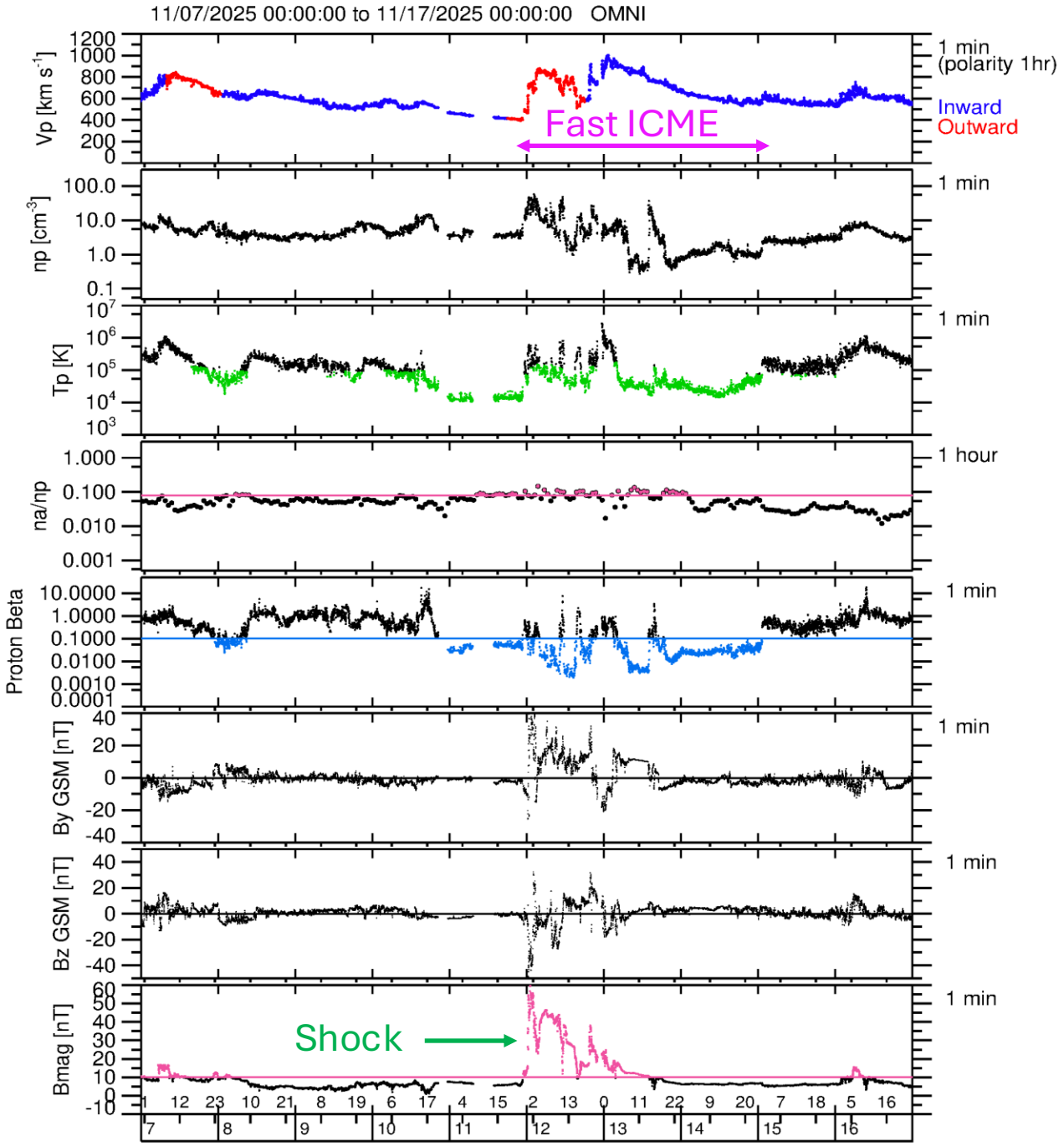


Dayeh et al.

Mid November 2025

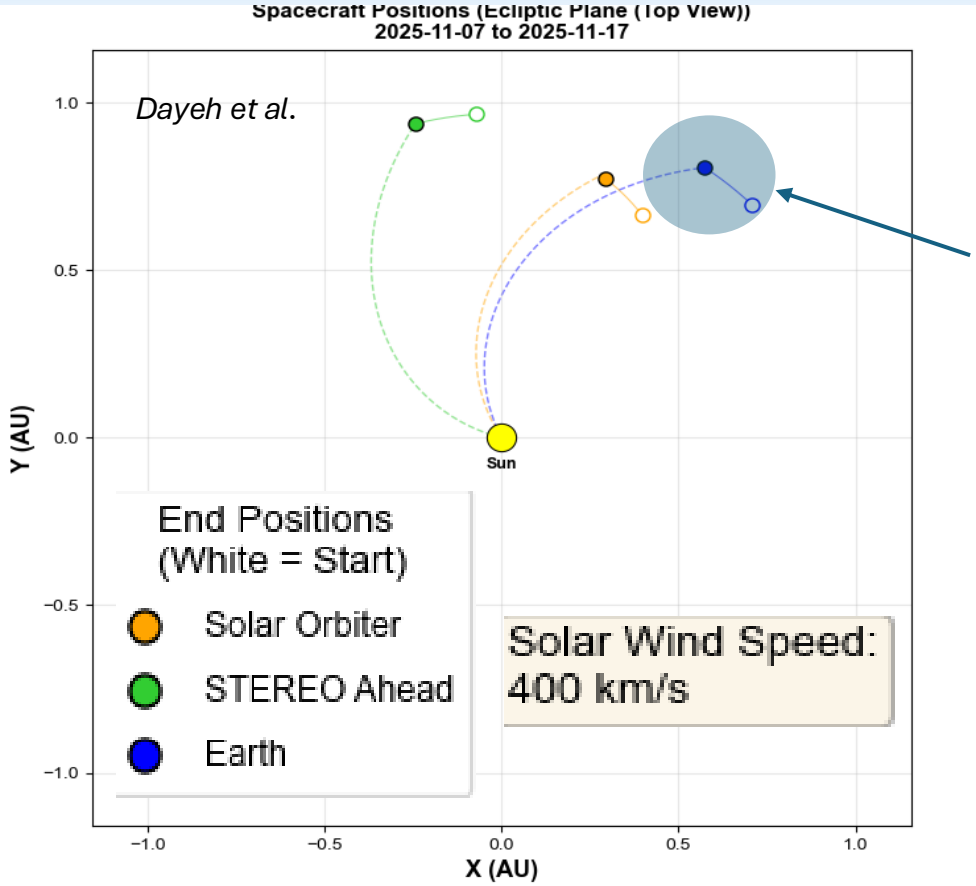
Very Fast ICME with Strong Shock: OMNI Nov 11-14, 2025

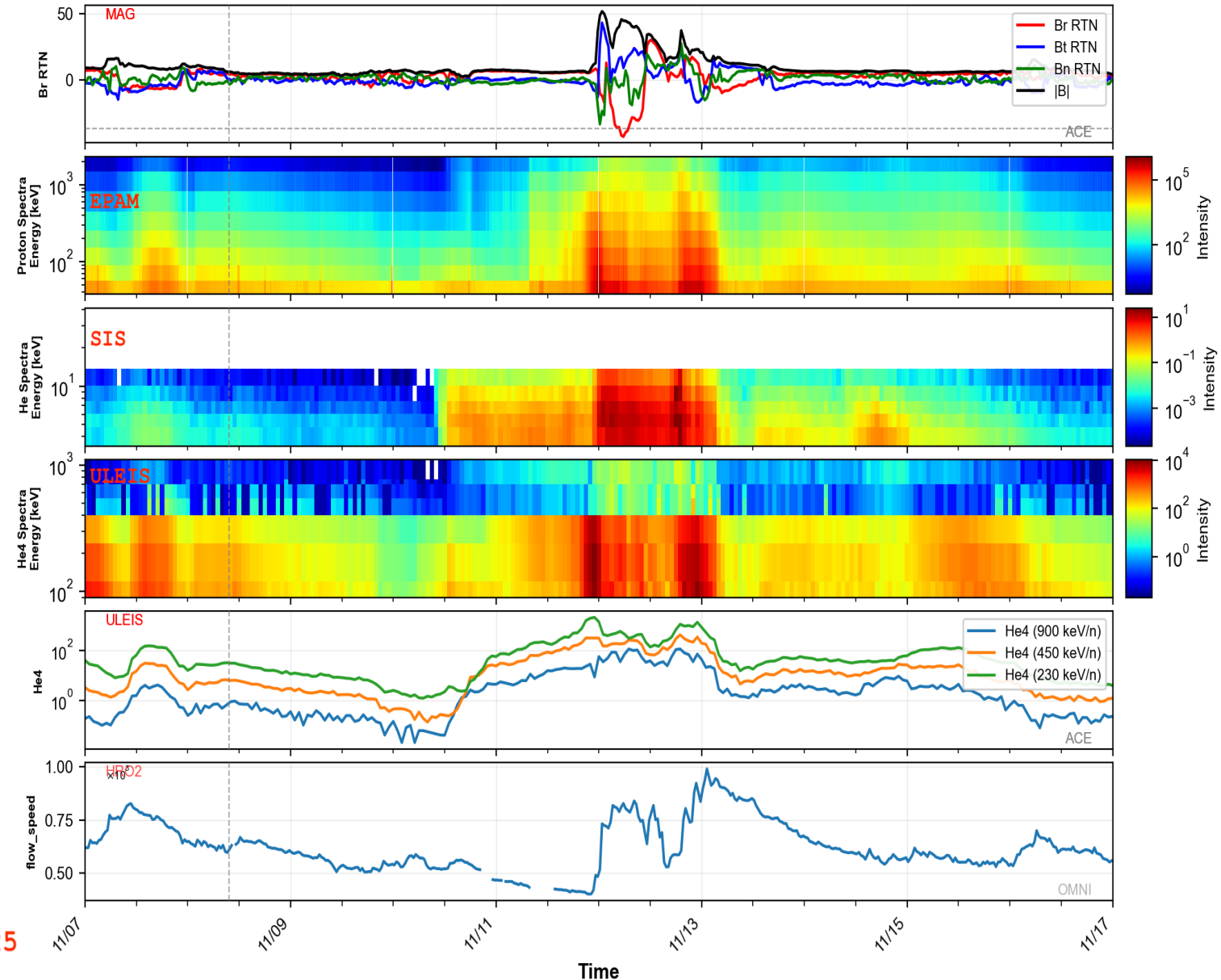




Elliott et al.

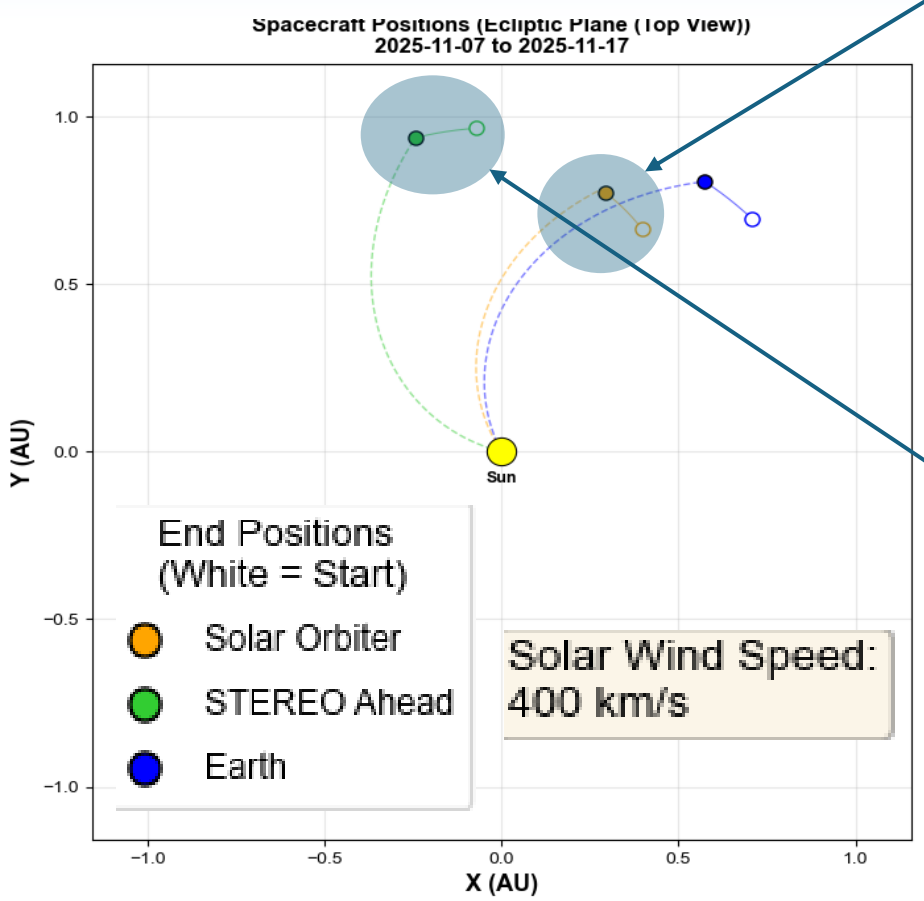
ACE 11/07/2025 – 11/17/2025

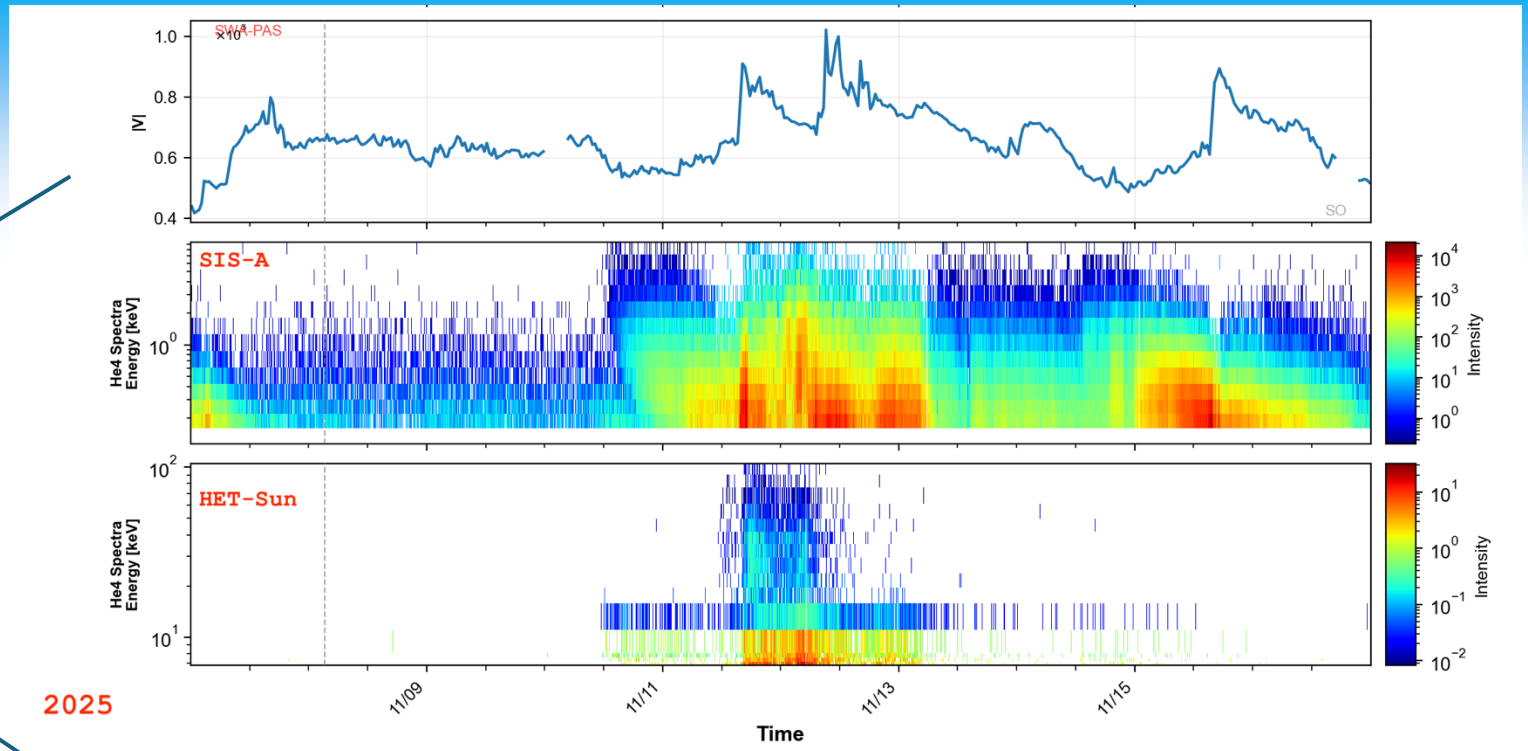


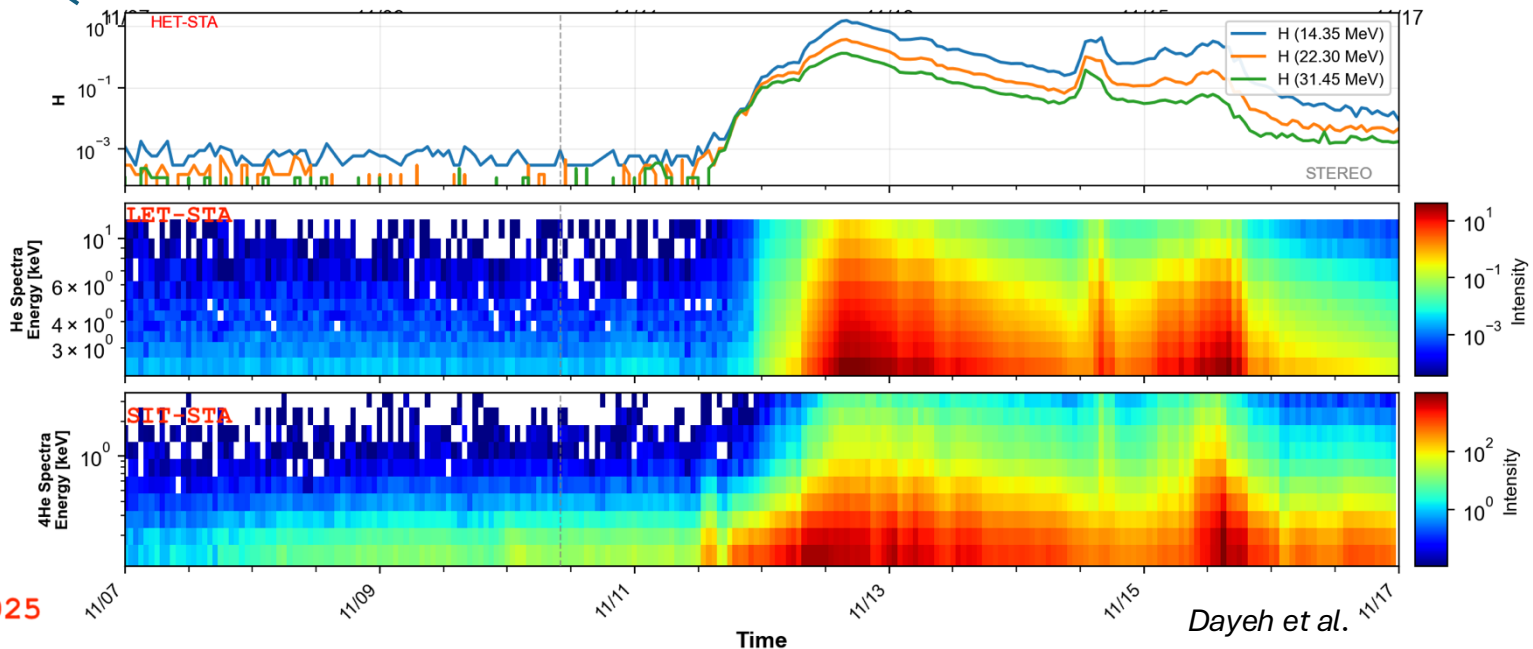


Two IP shocks, accompanied by strong proton and He4 energetic storm particle (ESP) events;

STA, SoLO Nov 7-17 2025



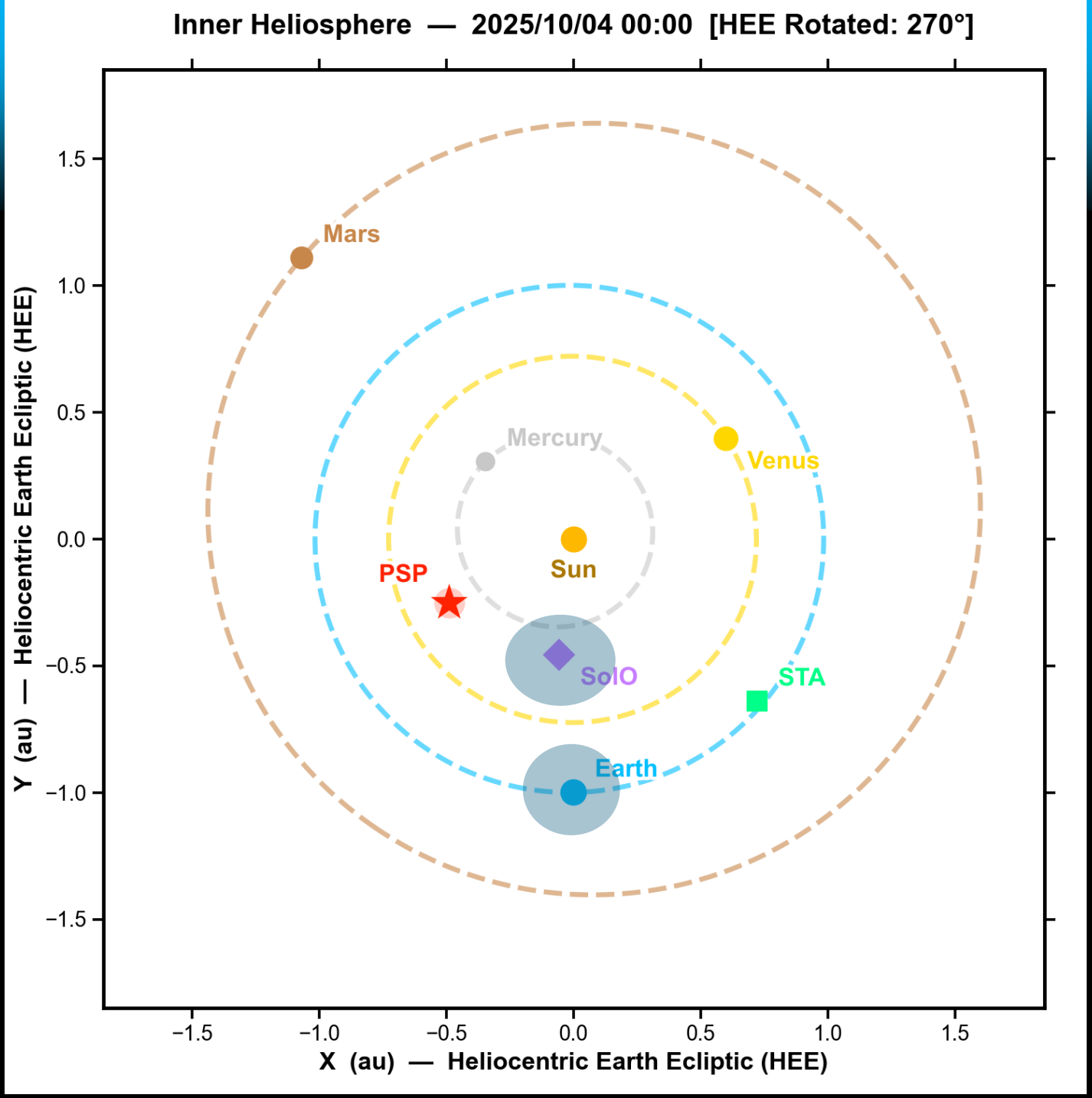




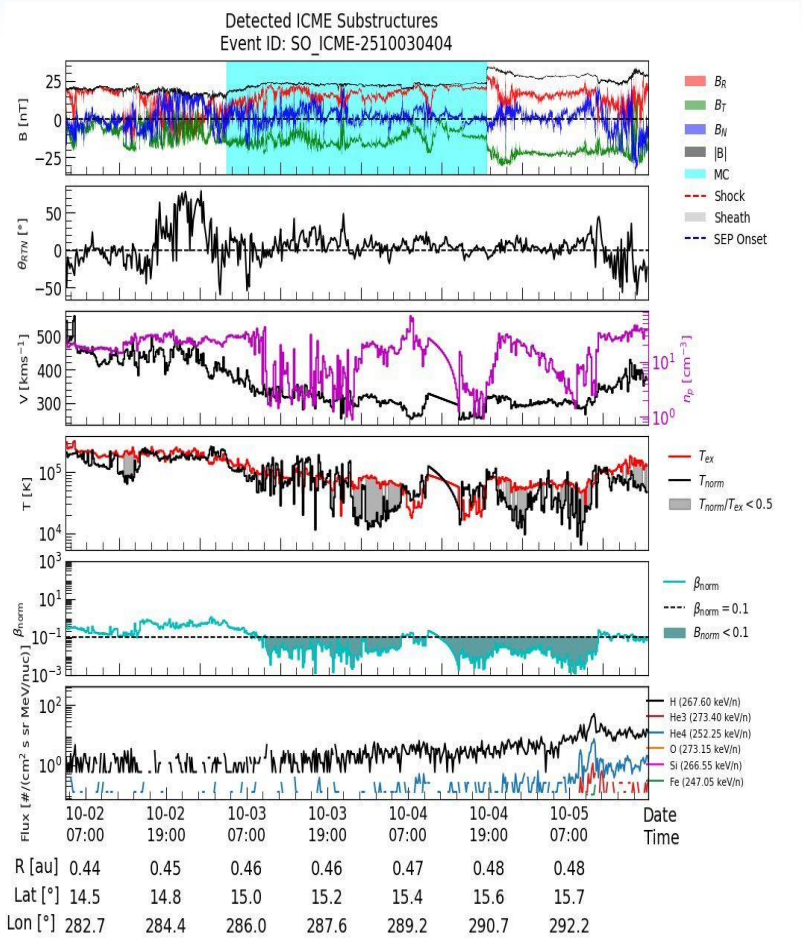
Dayeh et al.

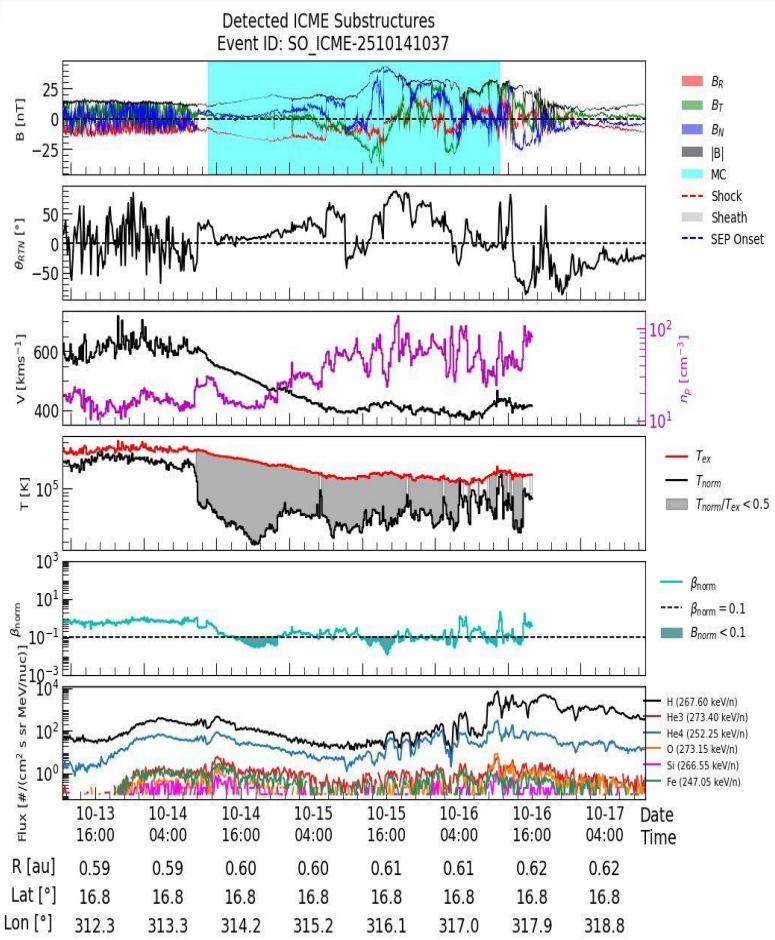
Dayeh et al.

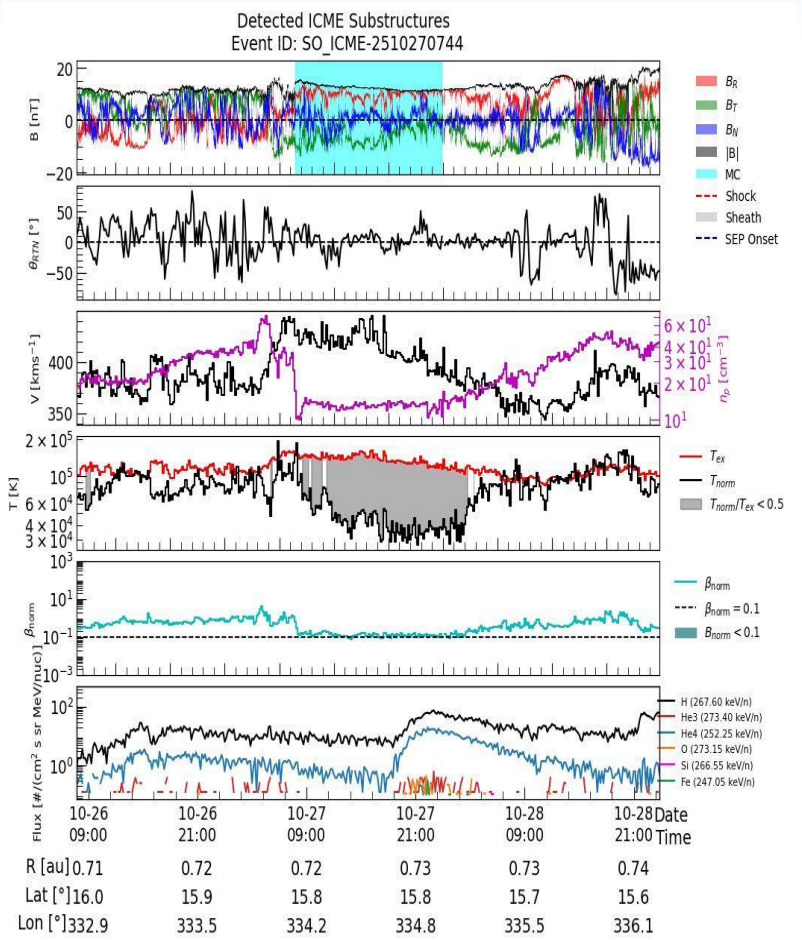
October 2025 Solar Orbiter & Earth Aligned



Three Solar Orbiter ICME Events — Oct 2025 Summary







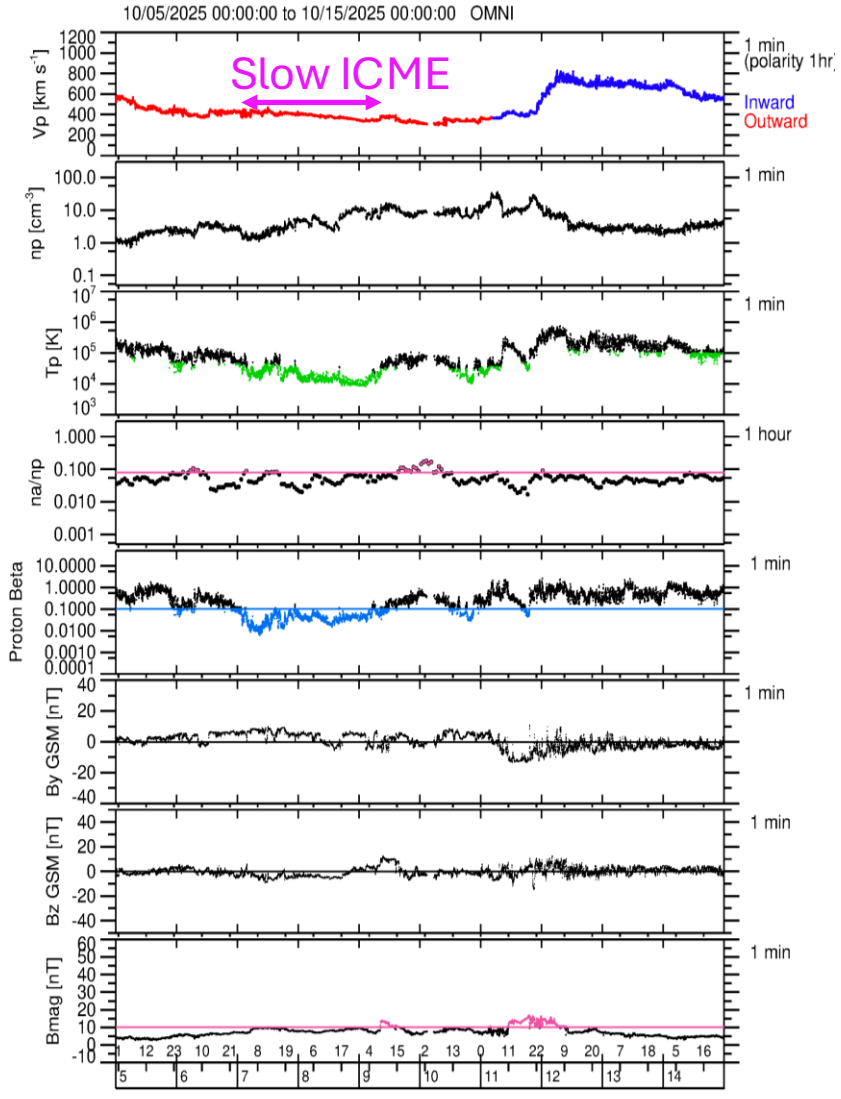
Event 1: Oct 2–5
0.44–0.48 au

Event 2: Oct 13–17
0.59–0.62 au

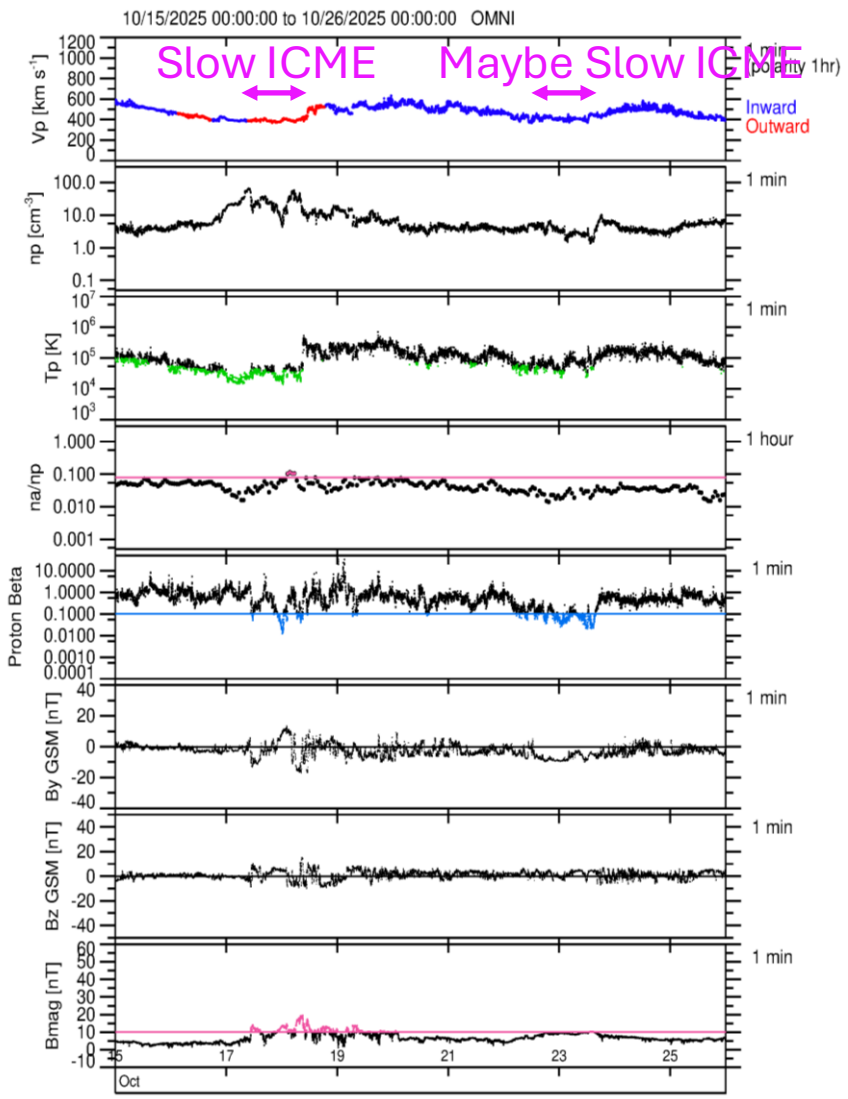
Event 3: Oct 26–28
0.71–0.74 au

Elliott et al. | Minta et al.

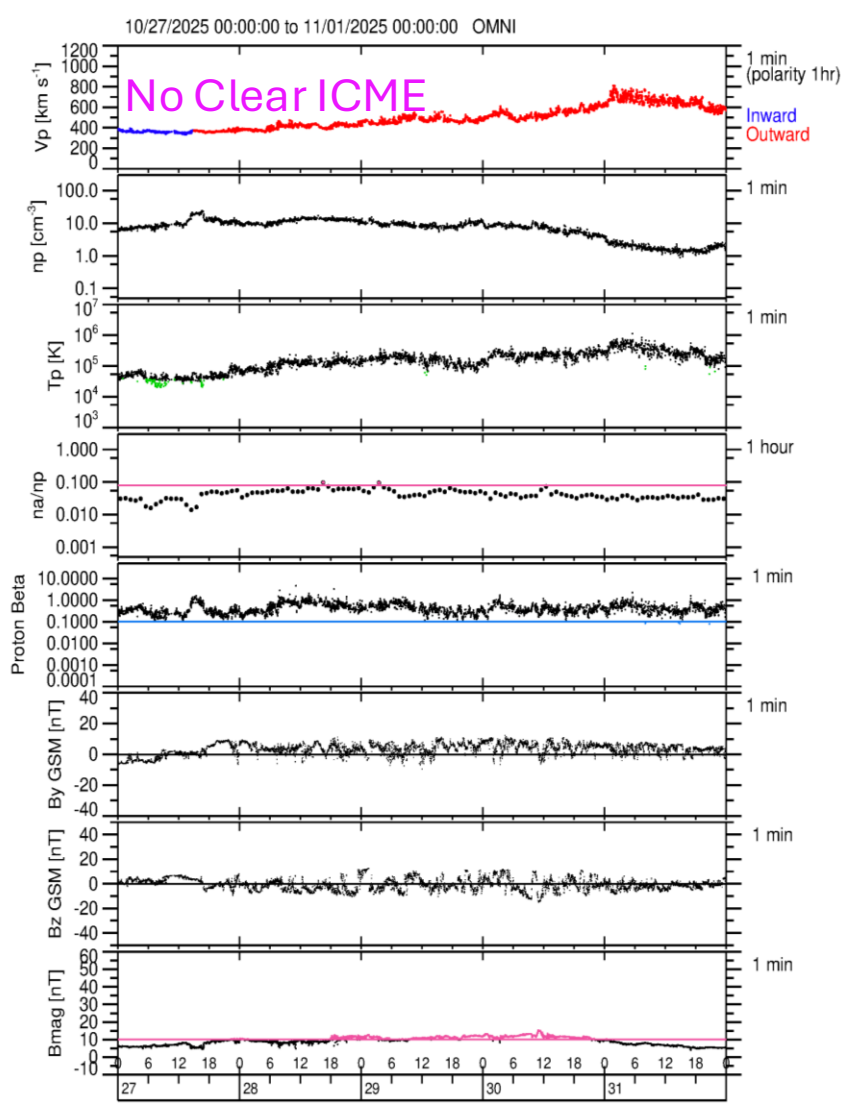
Three 1 au events — Oct 2025 Summary



Event 1: Oct 5–15



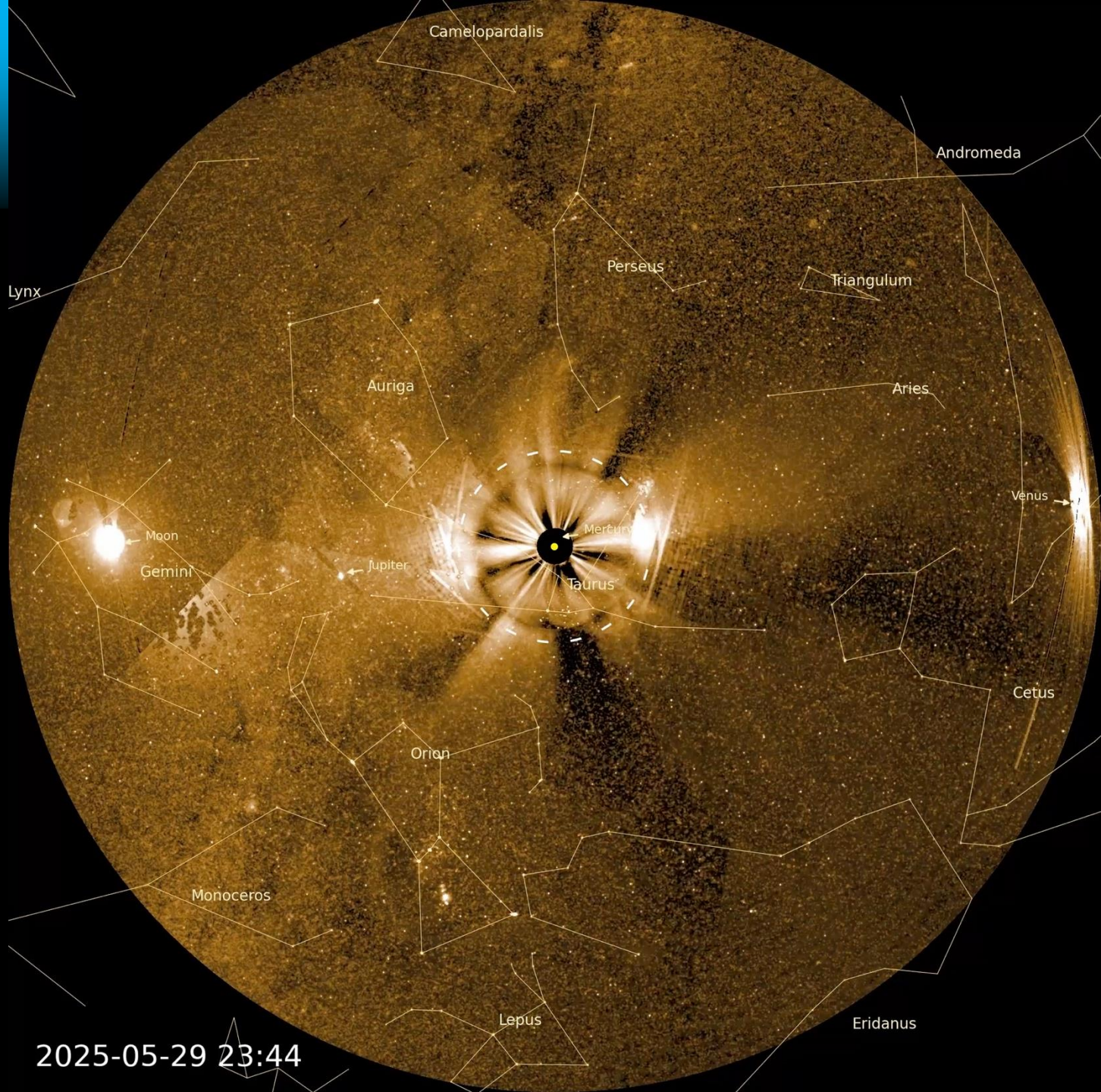
Event 2: Oct 15–27



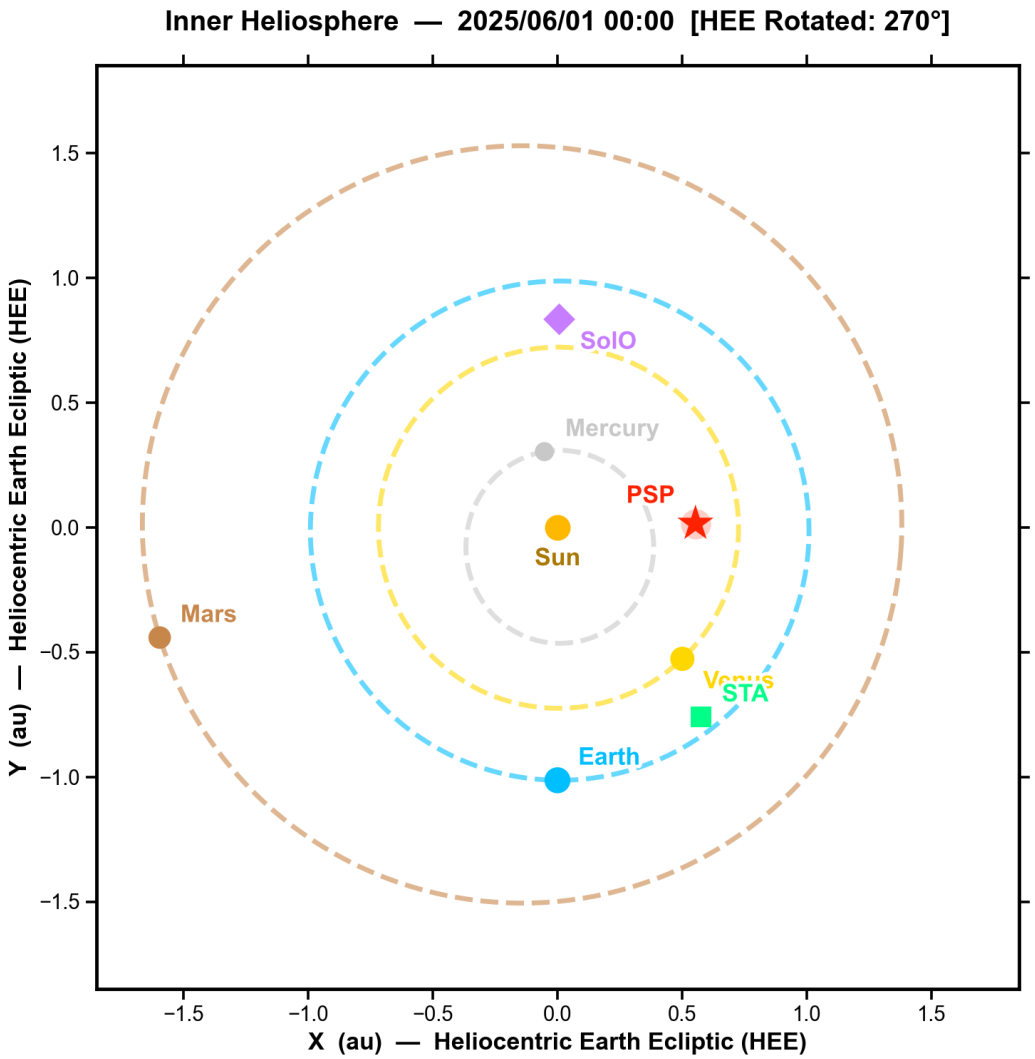
Event 3: Oct 27–Nov 1

May-June 2025

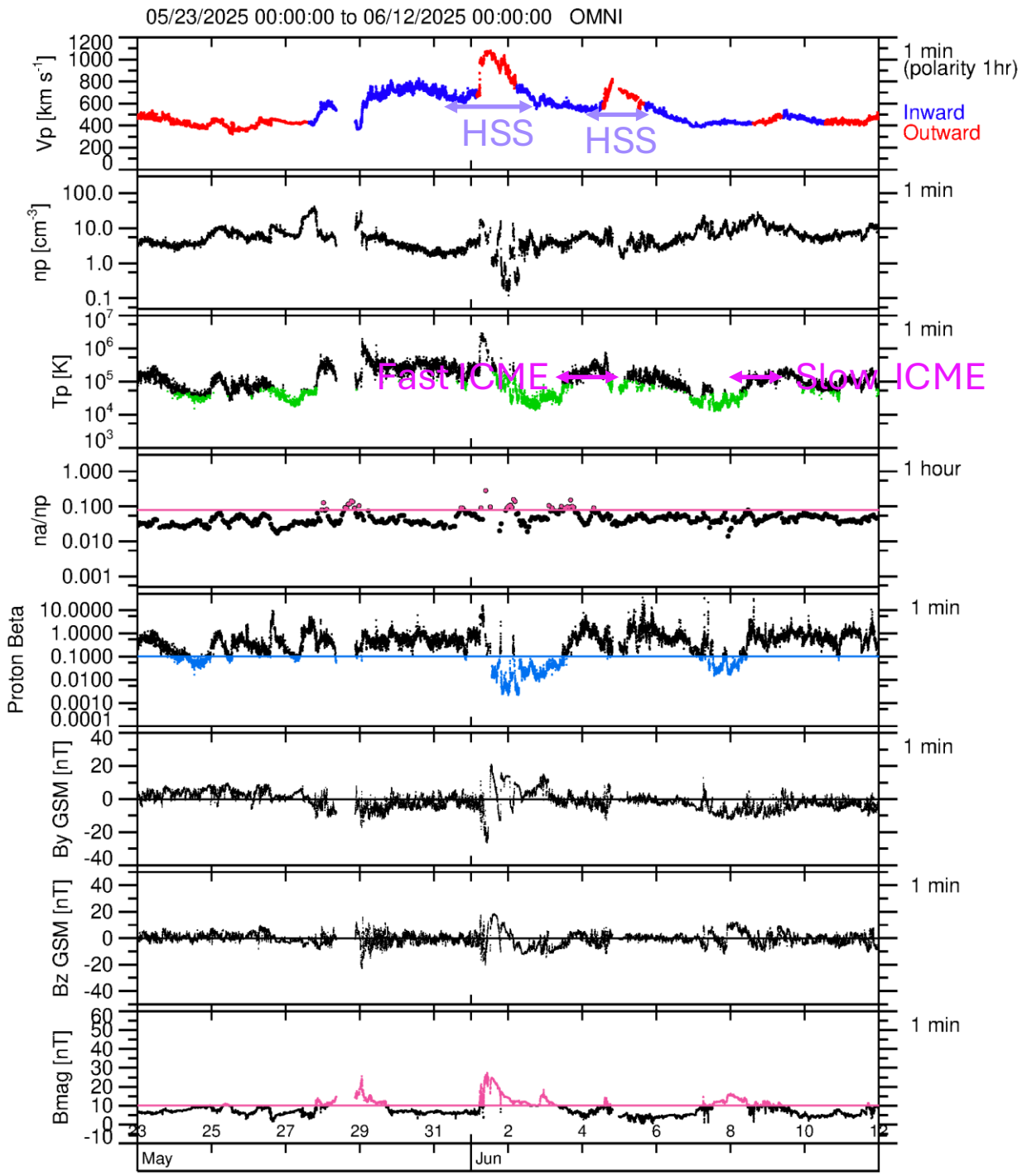
ICME running into high-speed stream



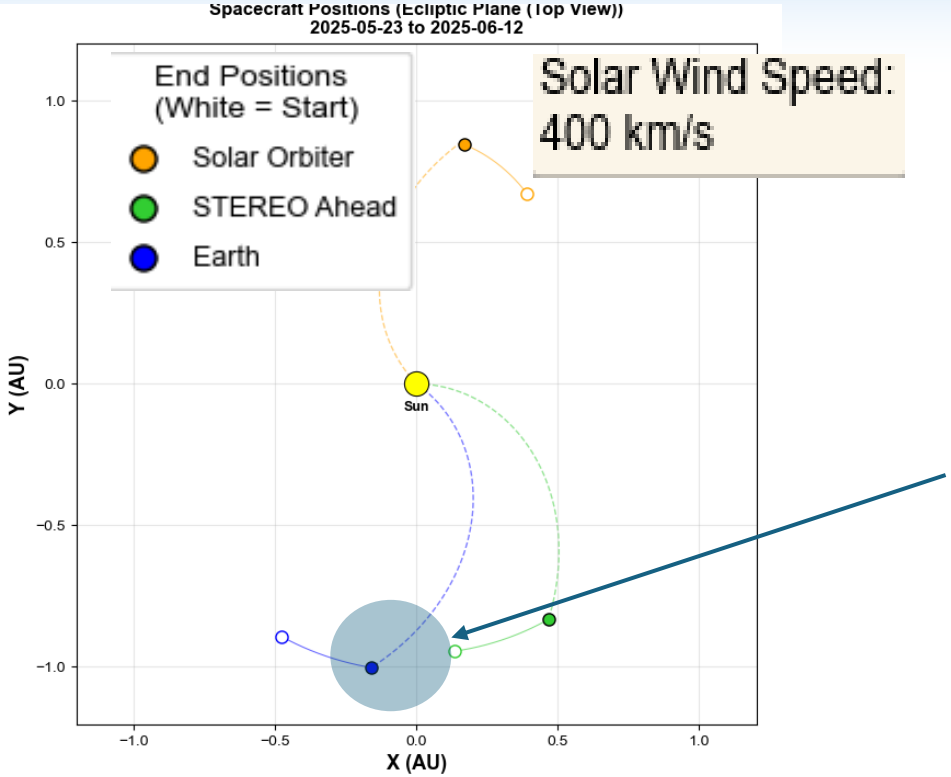
Fast ICME Runs Into High Speed Stream: OMNI June 1-2, 2025



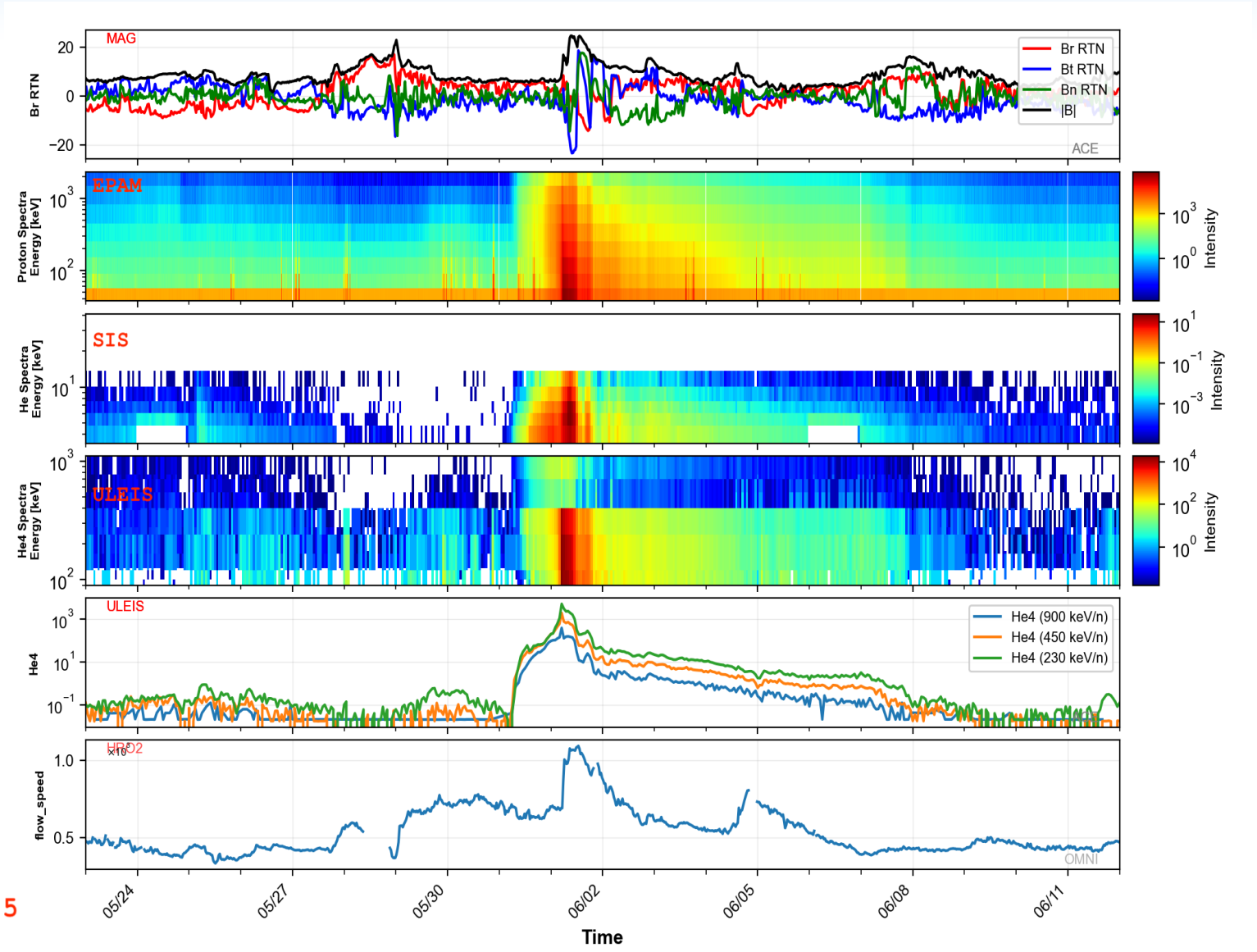
Elliott et al.



ACE 05/23/2025 -06/12/2025

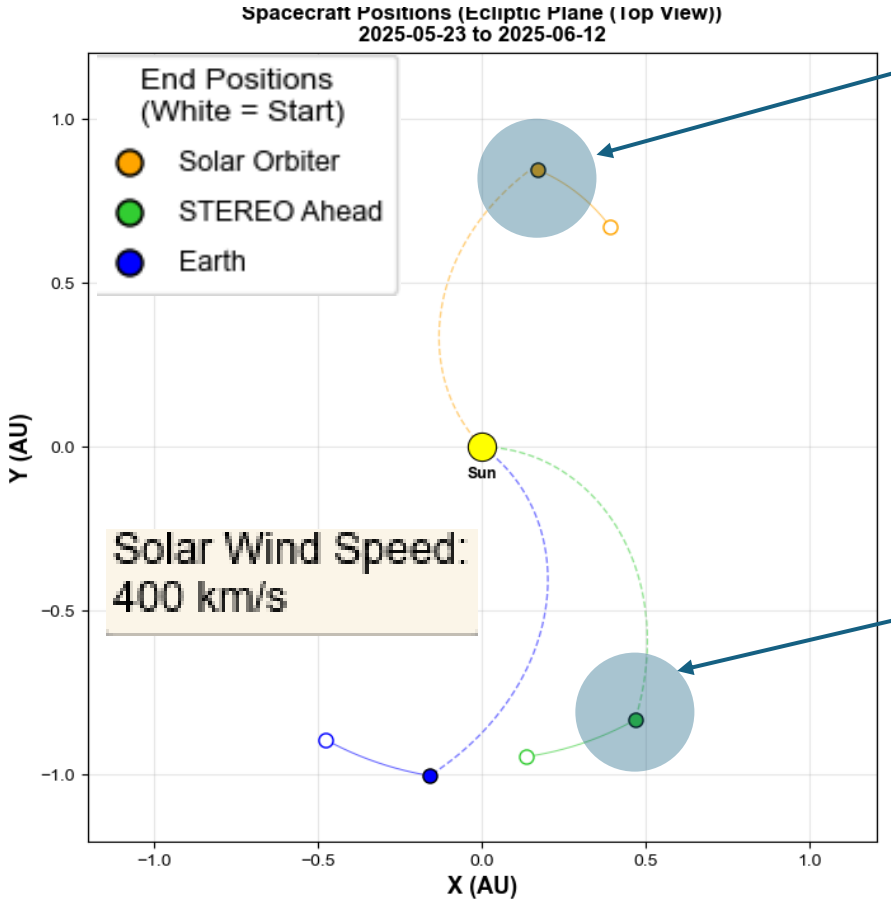


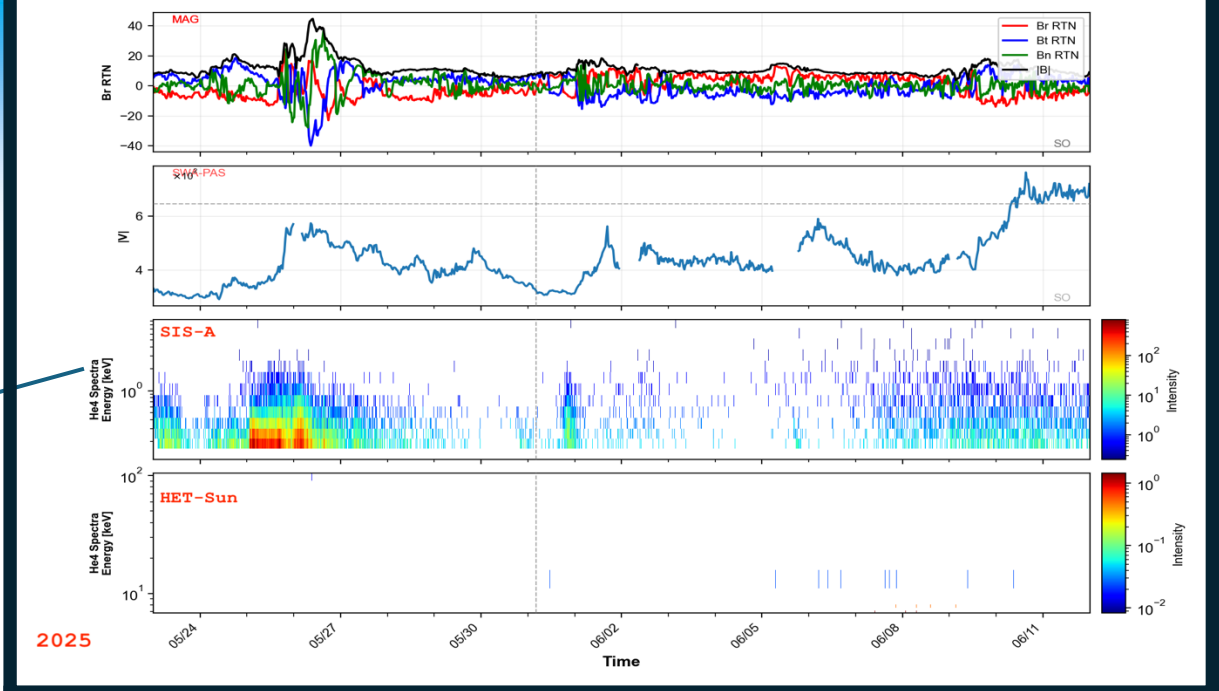
Fast ICME ~1000 km/s, with IP shock on Jun 1 accompanied by a strong proton and He4 energetic storm particle (ESP) event extending to >1 MeV;

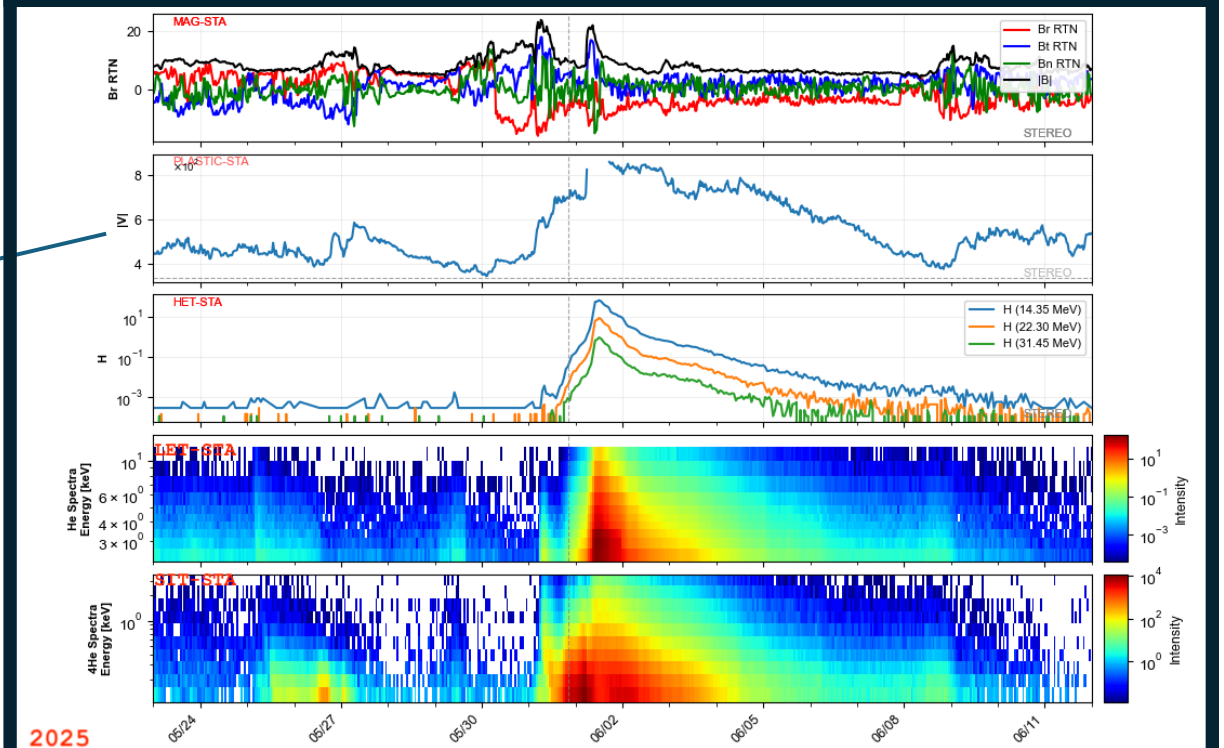


Dayeh et al.

STA, SoLO May 23-June 12 2025



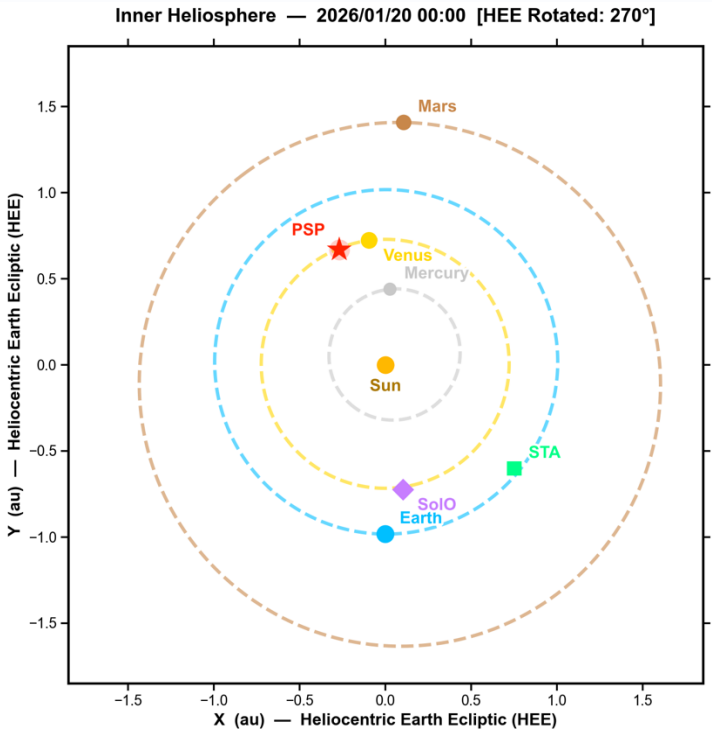


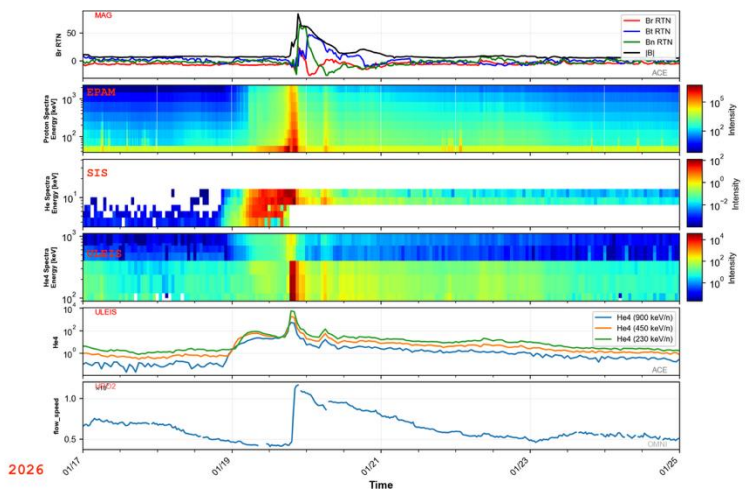


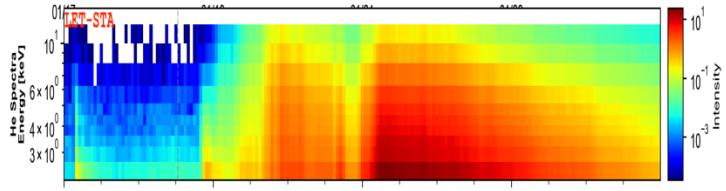
Dayeh et al.

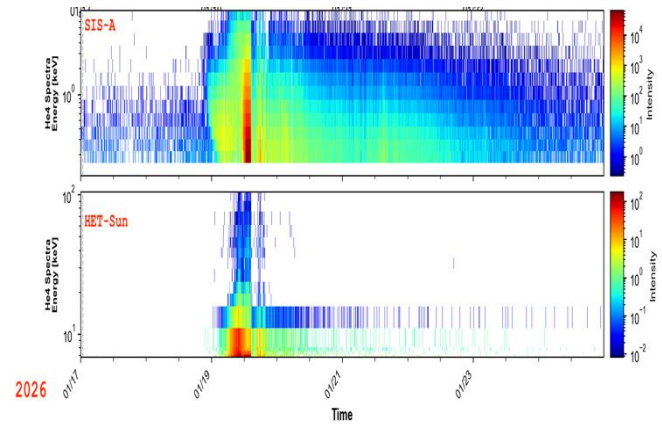
Mid January 2026

Anxiously Awaiting January PUNCH Data
Very Fast ICME OMNI 01/19/2026
01/22/2026



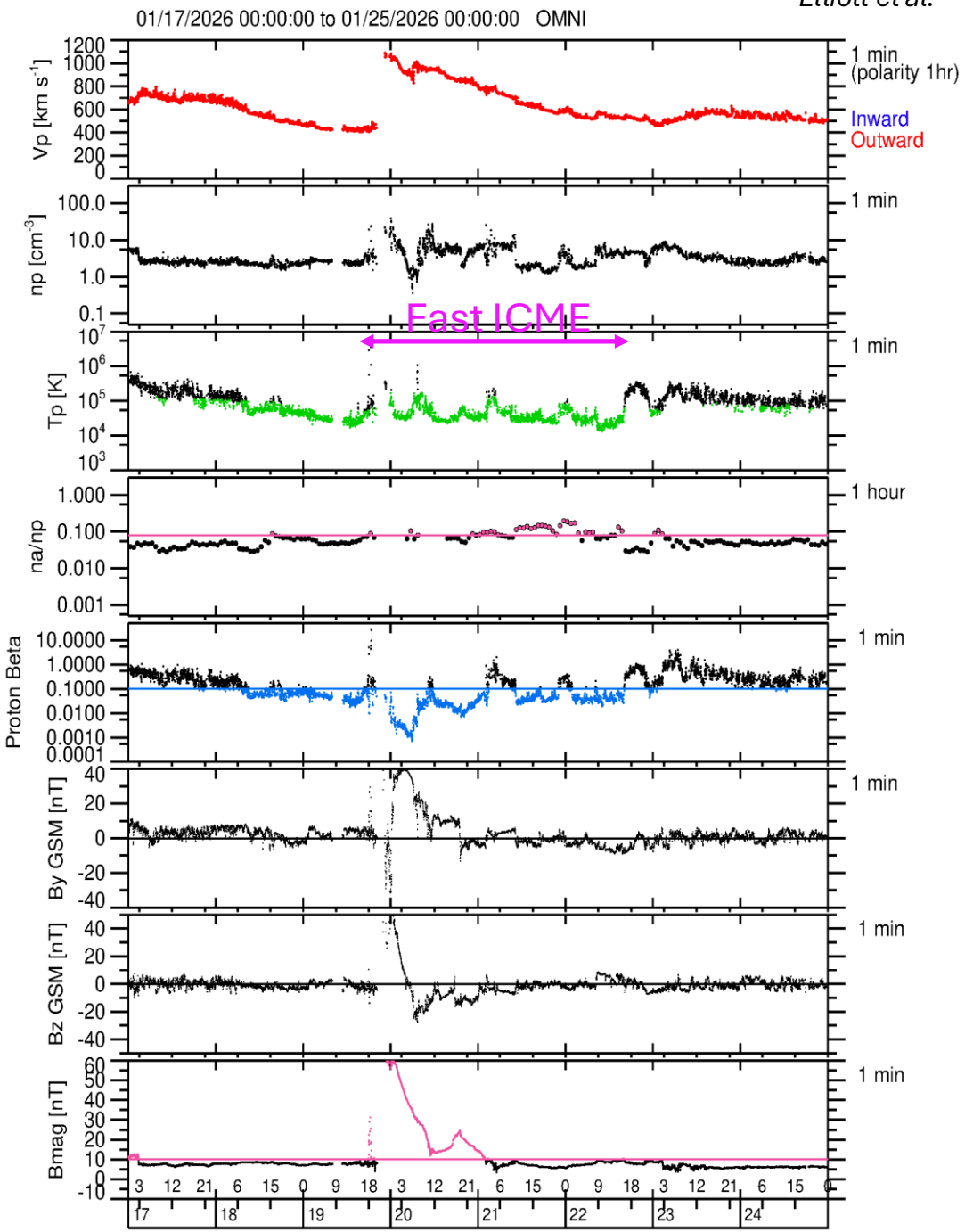






Fast ICME >1200 km/s, with IP shock accompanied by strong SEP and ESP events extending to >1 MeV; DST<-300 nT;

Elliott et al.



Summary & Conclusions

Key Results

- PUNCH WFI imaged CME shocks steepening in the inner heliosphere (Oct–Nov 2025, May-June 2025)
- In situ interplanetary shocks and ICMEs are observed by multiple spacecraft
- SEP and ESP events accelerated by CME-driven shocks are also observed at multiple spacecraft
- Multi-species ions (H, He3, He4, O, Si, Fe) observed up to several MeV/nuc
- Jan 2026 geoeffective ICME highlights PUNCH's real-time forecasting potential

PUNCH Capability

Provides a NEW way to:

- Track CME shock evolution remotely
- Detect SEP-producing shocks before in-situ arrival
- Bridge remote sensing → in-situ gaps

Future Work:

- PSP, SoHO conjunction events
- Wind, ACE, IMAP and SOLAR-1 cross-calibration
- Model SEP spectral and temporal evolution