Parker Solar Probe In situ Measurements of the August 30th, 2025 CME

Orlando Romeo[1] (oromeo@berkeley.edu), Yeimy Rivera[2], Samuel Badman[2], Davin Larson[1], Mike Stevens[2], Roberto Livi[1], Phyllis Whittlesey[1], Ali Rahmati[1], Jia Huang[1], Mingzhe Liu[1], Marc Pulupa[1], Stuart D Bale[1], Nour E. Rawafi[3], & SWEAP/FIELDS Teams

[1]Space Sciences Laboratory, University of California Berkeley, Berkeley, CA [2]Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA [3]Johns Hopkins Applied Physics Laboratory, Laurel, MD

Introduction

- On August 30th, 2025, an Earth-directed **Halo ICME** erupted at ~19:50 UTC and was observed in situ by L1 observatories.
- Parker Solar Probe (**PSP**) was positioned 108 R_S (0.5 AU) from the Sun in **radial alignment with the Earth** in cruise mode.
- PSP's orbital position provides a unique opportunity to help constrain changes in CME morphology and dynamics during its propagation toward Earth for **improving CME arrival time estimates at L1** and enhancing space weather predictions.

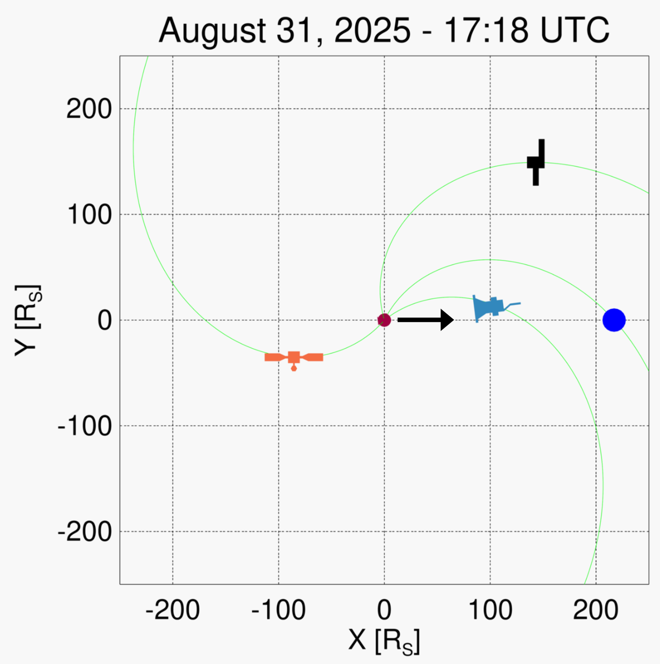


Fig. 1: Orbital positions (HEE frame) of Earth (blue), PSP (cyan), SolO (orange), and STEREO-A (black) with the CME propagation direction (arrow) from the Sun (red) on 08/31/25 at 17:18 UTC.

Remote Sensing Observations

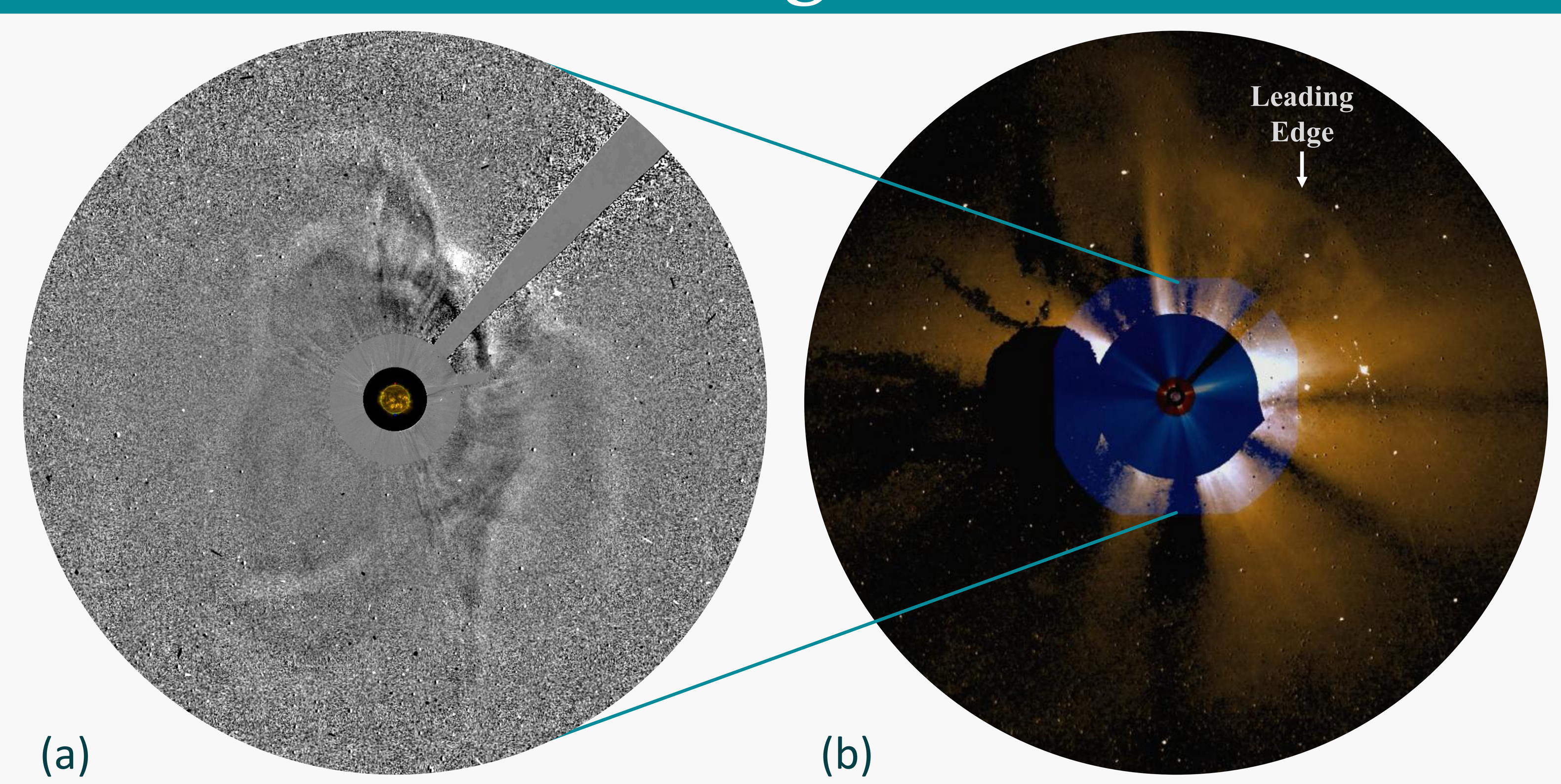


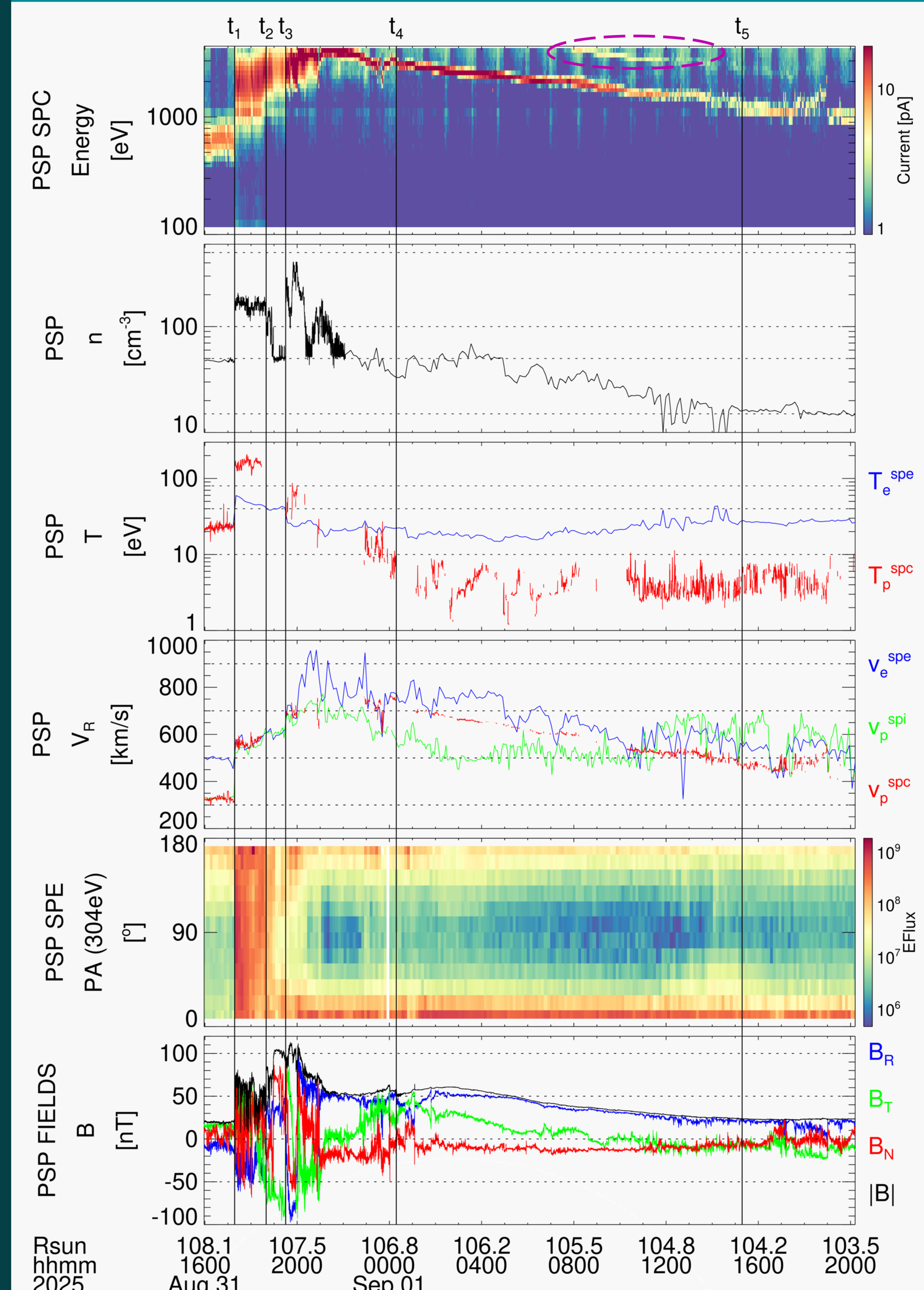
Fig. 2: Remote sensing observations on 08/31/2025 with SDO/AIA 171 Å solar disk images. **(a)** Running difference composite of SOHO LASCO C2 and C3 at ~00:15 UTC. **(b)** Composite image at ~22:30 UTC combining LASCO C2 and C3 with the PUNCH Wide Field Imager (WFI) mosaic.

- ICME was observed by SOHO, SDO, STEREO-A, PUNCH, and PSP/WISPR
- Asymmetric Halo CME with an initial estimated speed of **1200 – 1300 km/s**

In Situ Measurements

- **PSP cruise phase** ($r \gtrsim 0.25$ AU) considerations during the ICME event:
  - Time cadences of the Solar Probe ANalyzers[1] for ions (SPAN-I) and electrons[2] (SPAN-E) were reduced to 3.7 and 7.5 minutes, respectively.
  - The proton velocity distribution function (VDF) was primarily measured outside of SPAN-I's FOV – *inaccurate density/velocity component estimates*.
  - The Solar Probe Cup (SPC) was operational as PSP was far from perihelion, providing proton and alpha particle measurements and fits.
  - Quasi-Thermal Noise (QTN) electron densities are reliable for $n_e \gtrsim 60$ cm^{-3}.
- We perform **electron VDF fit/moment calculations** to obtain plasma bulk properties such as electron density, temperature, velocity[3] to compare with SPC.
- We create a combined dataset of plasma density from SPAN-E, QTN, and SPC, along with temperature and velocity measurements from SPAN-E and SPC.

In Situ



Time	ICME Feature
t_1	17:18 UT (08/31) *Shock Arrival*
t_2	18:39 UT (08/31) *End of Sheath*
t_3	19:30 UT (08/31) *Large B rotation* *Higher n*
t_4	00:18 UT (09/01) *Magnetic Cloud* *Lower T_p* *He^{++} Abundance*
t_5	15:18 UT (09/01) *Event End* *Lower n & V_r*

	Peak Value
n_e	407 cm^{-3}
T_e	60 eV
T_p	160 eV
V_R	760 km/s

Fig. 3: Time series of PSP data during the August 30th ICME. **(a)** SPC energy spectra with He^{++} stripe circled in purple. **(b)** Combined plasma density from SPAN-E, QTN, and SPC. **(c)** Electron (blue) and proton (red) temperatures from SPAN-E and SPC. **(d)** Electron (blue) and proton (green and red) radial velocities from SPAN-E, SPAN-I, and SPC. **(e)** SPAN-E PADs for 304 eV electrons. **(f)** Magnetic field in RTN from FIELDS. Specific times are denoted by vertical black lines with labels $t_1 - t_5$.

PSP Shock Estimation (RH Equations) of Fast-Forward Shock

Shock Speed V_{sh}	668 km/s ± 6 km/s
Normal Angle θ_{Bn}	63° ± 3.5° (*quasi-perpendicular*)
Density (Magnetic) Compression Ratio	3.54 ± 0.05 (3.03 ± 0.10)
Alfvén Mach Number	5.85 ± 0.1

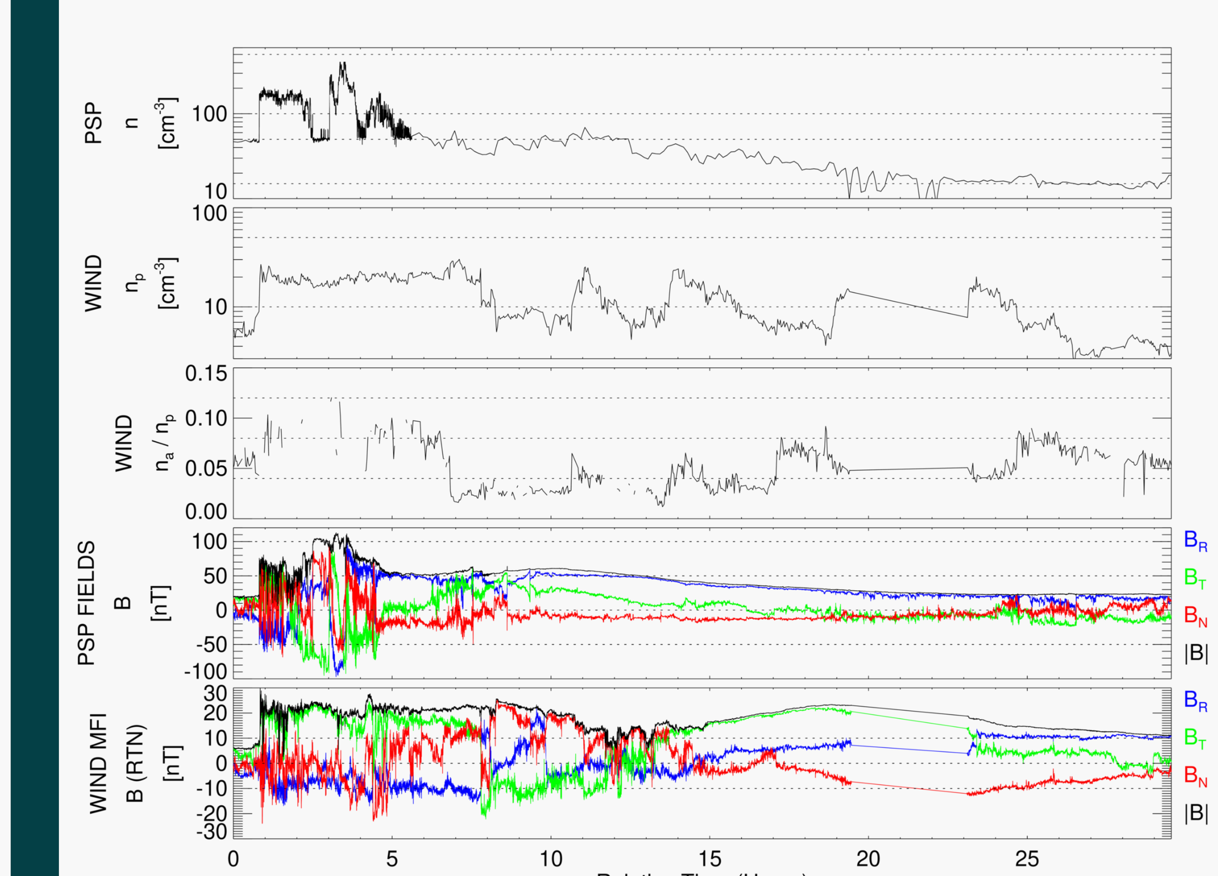


Fig. 4: Shifted time series to align shock arrival times of PSP (08/31 at 17:18 UTC) and Wind (09/01 at 20:31 UTC), with a time shift of Δt = 27.2 hours. Based on the radial velocity measured at PSP, Wind was expected to observe the shock ~29.2 hours after PSP, assuming constant speed. From top to bottom, **(a)** PSP plasma density, **(b)** Wind proton density, **(c)** Wind alpha to proton density ratio, **(d)** PSP magnetic field, and **(e)** Wind magnetic field in RTN.

Results

- Another ICME erupted on 08/31/25 at 12:48 UTC and was observed by PSP with a B rotation and high He^{++} abundance, along with increased n_p intervals.
- A slow-forward shock is observed with a decrease in B at the beginning of the event, and an increase in n, T, and v measured by SPC and SPAN-E.
- Wind also observed this ICME based on the increase in He^{++} abundance and change in proton density and temperature (*not shown*).
- The ICME arrival time at WIND is expected to be ~43 hours after PSP arrival.

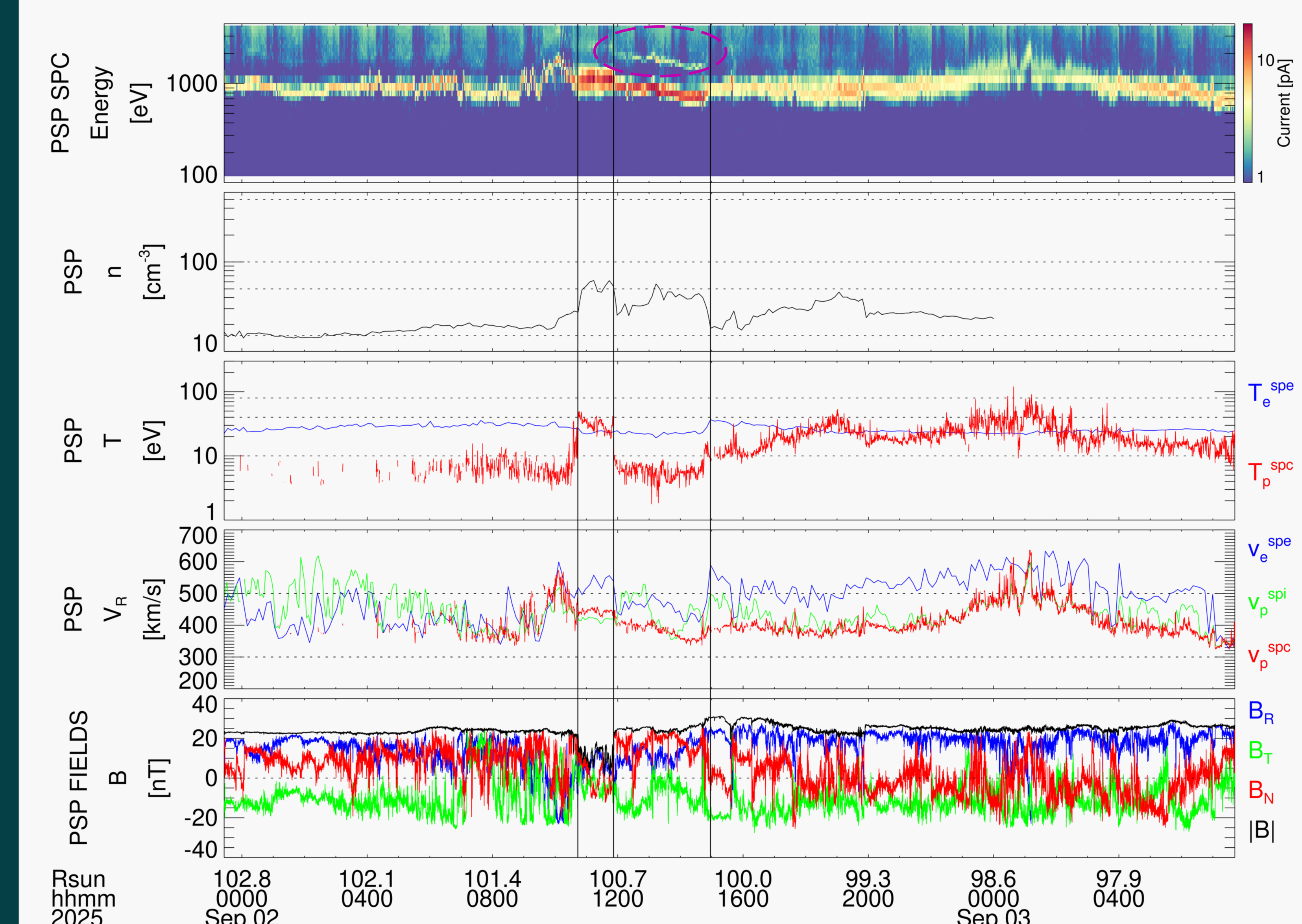


Fig. 5: Time series of PSP data during the August 31st ICME. **(a)** SPC energy spectra with He^{++} stripe circled in purple. **(b)** Combined plasma density from SPAN-E, QTN, and SPC. **(c)** Electron (blue) and proton (red) temperatures from SPAN-E and SPC. **(d)** Electron (blue) and proton (green and red) radial velocities from SPAN-E, SPAN-I, and SPC. **(e)** Magnetic field in RTN from FIELDS.

Conclusions

- PSP provided in situ characterization of the August 30th, 2025 ICME (as well as the August 31st ICME) roughly halfway between the Sun and Earth.
- Created a combined plasma density dataset based on SPAN-E, QTN, & SPC:
  - High-time-resolution SPAN-E data are pending downlink and will enable further analysis of ICME substructure and plasma dynamics at high cadence.
- Identified shock arrival times at PSP and Wind, as well as other CME regions:
  - Computed a fast-forward quasi-perpendicular shock (V_{sh} ~ 668 km/s) at PSP.
  - The shock arrival at Wind was roughly 27.2 hours after PSP arrival.
- For questions regarding SPAN-E / QTN plasma datasets or collaboration opportunities, please contact oromeo@berklely.edu.

References

[1]Kasper, J. C., et al. (2016). Solar wind electrons alphas and protons (SWEAP) investigation: Design of the solar wind and coronal plasma instrument suite for solar probe plus. *Space Science Reviews*, 204, 131-186, doi: 10.1007/s11214-015-0206-3.

[2]Whittlesey, P., et al. (2020), The Solar Probe Analyzers - Electrons on the Parker Solar Probe, *Astrophys. J. Suppl. Ser.*, *246*, 2, doi: 10.3847/1538-4365/ab7370.

[3]Romeo, O. M. (2024). An Interdisciplinary Approach to Novel in Situ Measurements of Solar and Planetary Electrons and Magnetic Fields. *ProQuest Dissertations and Theses*. University of California, Berkeley.