

# Automatically Plotting & Identifying ICMEs, Stream Interaction Regions, & High Speed Streams

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# Purpose & Objectives

## Purpose:

- Quickly identify solar wind structure in *in situ* observations enabling multi-spacecraft studies of events.

## Caveats:

- Starting out with simple criteria, combine those to make initial event lists.
- Later, we can have a “human in the loop” certified versions, or the autogenerated lists may become good enough.

## Additional Objectives:

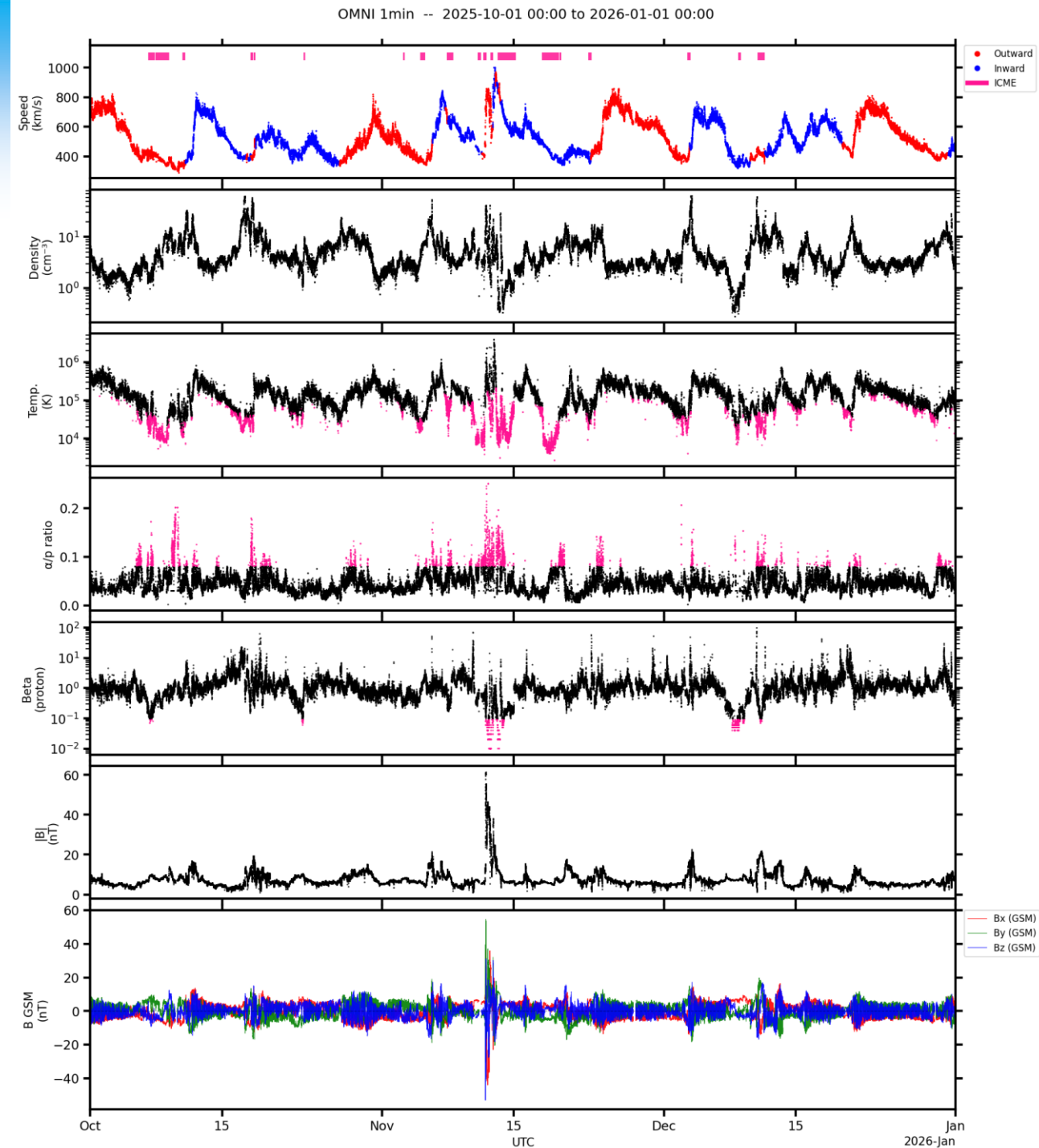
- Starting over in Python to be PUNCH compatible and for ease of scripting and automating Python code.
- Autogenerate event lists and plots.
- Produce tools that make it easier to coordinate pulling in observations from a variety of spacecraft and instrumentation.

# ICME Criteria

- Anomalously Low Proton Temperature
  - $T/T_{ex} < 0.5$  where  $T_{ex} = 636.7 \times V - 1.756 \times 10^5$  K
- Low proton beta
  - $\beta_p \leq 0.1$
- High alpha to proton density ratio
  - $N_\alpha/N_p \geq 0.08$
- Required low temperature plus one of the other criteria to be satisfied within the time range of the low temperature.
- Used the timing from the low temperature intervals to set the time range.
- Removed intervals  $< 3$  hours since most lists do not include those
- Worked fairly well when compared with Richardson and Cane ICME list (no ICMEs  $< 3$  hours).

# Example Auto Identified ICMEs 10/01/2025 to 12/31/2025

- The 3 criteria work well.
- Other potential criteria to add are:
  - Magnetic field smoothness (drop in variability)
  - Magnetic field rotation to flag the magnetic clouds



# High Speed Stream & Stream Interaction Region Criteria

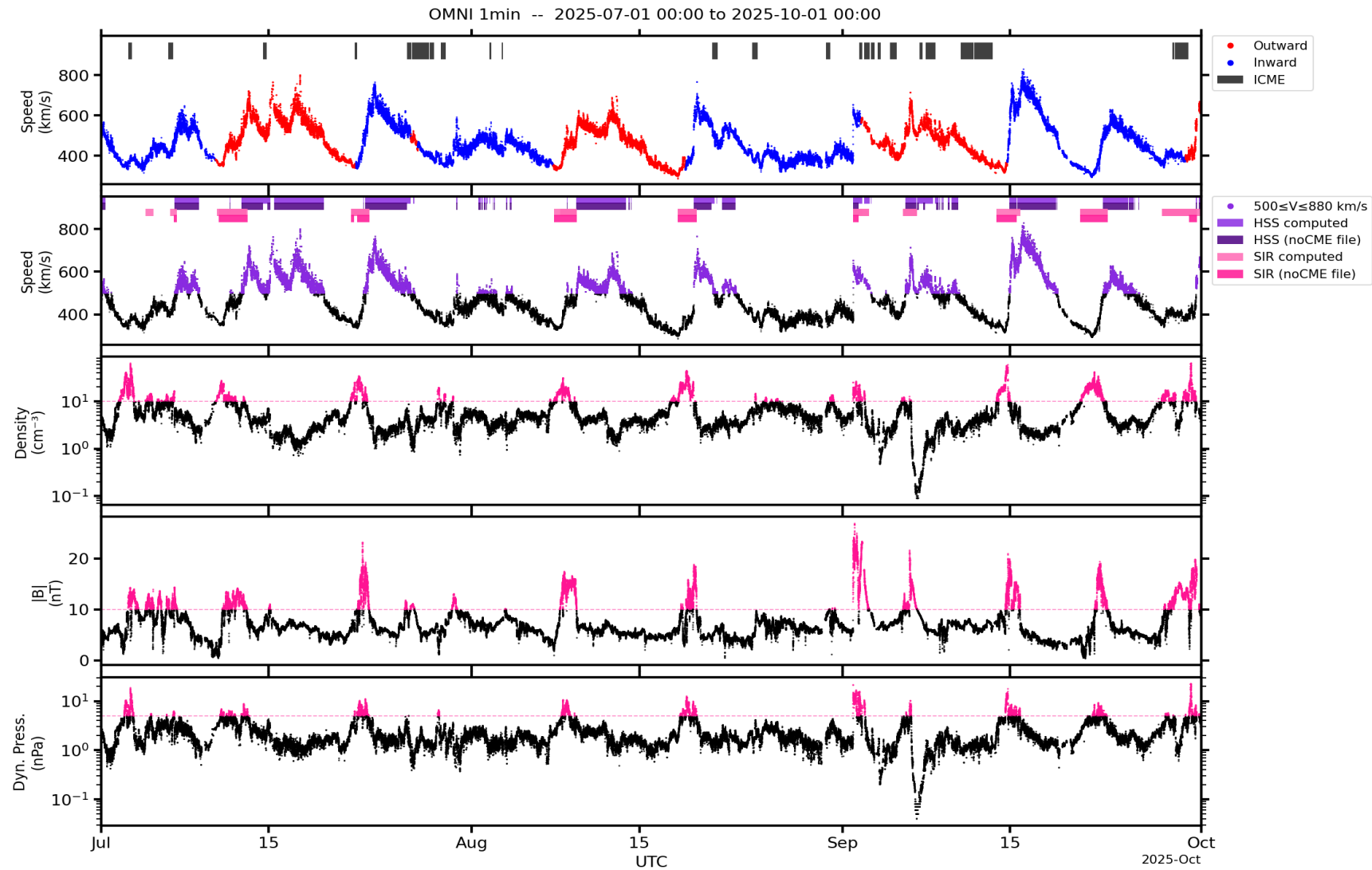
## High Speed Streams:

- $500 \text{ km/s} \leq \text{Speed} \leq 880 \text{ km/s}$  and 95% one polarity/sector

## Stream Interaction Regions:

- High solar wind dynamic pressure
  - $P_{\text{dyn}} > 5 \text{ nPa}$
- High interplanetary magnetic field strength
  - $|B| > 10 \text{ nT}$
- High proton density
  - $N_p > 10 \text{ cm}^{-3}$
- Required all three of the above to be true with in the time range of the high dynamic pressure interval.
- Required the average speed-time slope in the high pressure interval be positive.
  - $\langle dV/dt \rangle > 0$
- Removed all events  $< 3$  hours for HSS and SIRs
- Removed ICMEs for HSS and SIRs

# Example Auto Identified HSS & SIRs 07/01/2025 to 09/30/2025



# Storm Criteria

## Dst/SYM-H

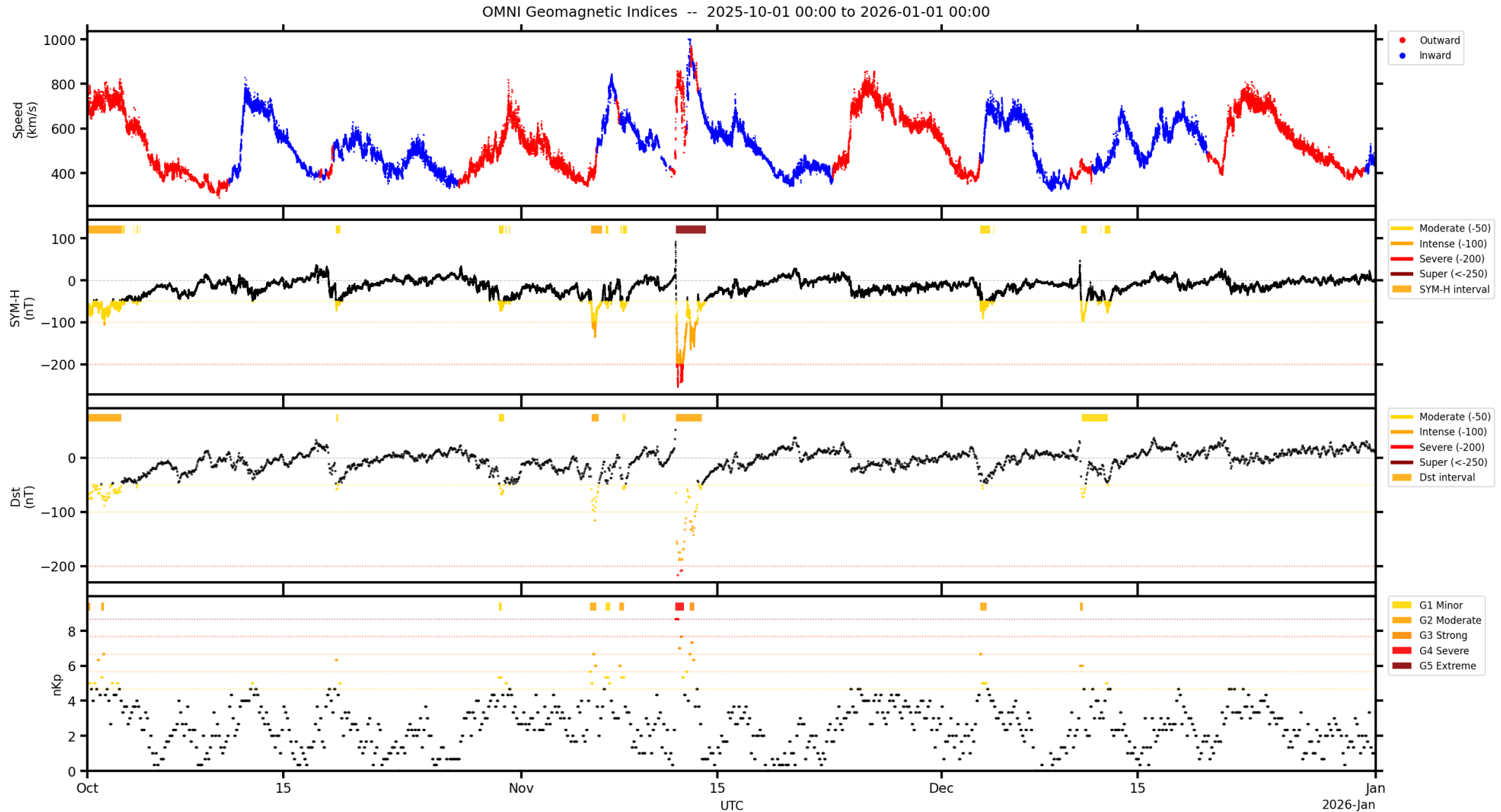
- Find all intervals where index  $\leq -50$  nT
- Find the minimum DST value to assign storm category
  - Moderate: Index  $\leq -50$  nT
  - Intense: Index  $\leq -100$  nT
  - Super Storm Index  $\leq -250$  nT

## Kp Index

- Find all of the intervals where  $K_p \geq 5$
- Find the maximum Kp value to assign storm category
  - G1:  $K_p=5$
  - G2:  $K_p=6$
  - G3:  $K_p=7$
  - G4:  $K_p=8$
  - G5:  $K_p=9$

# Example Auto Identified Storms

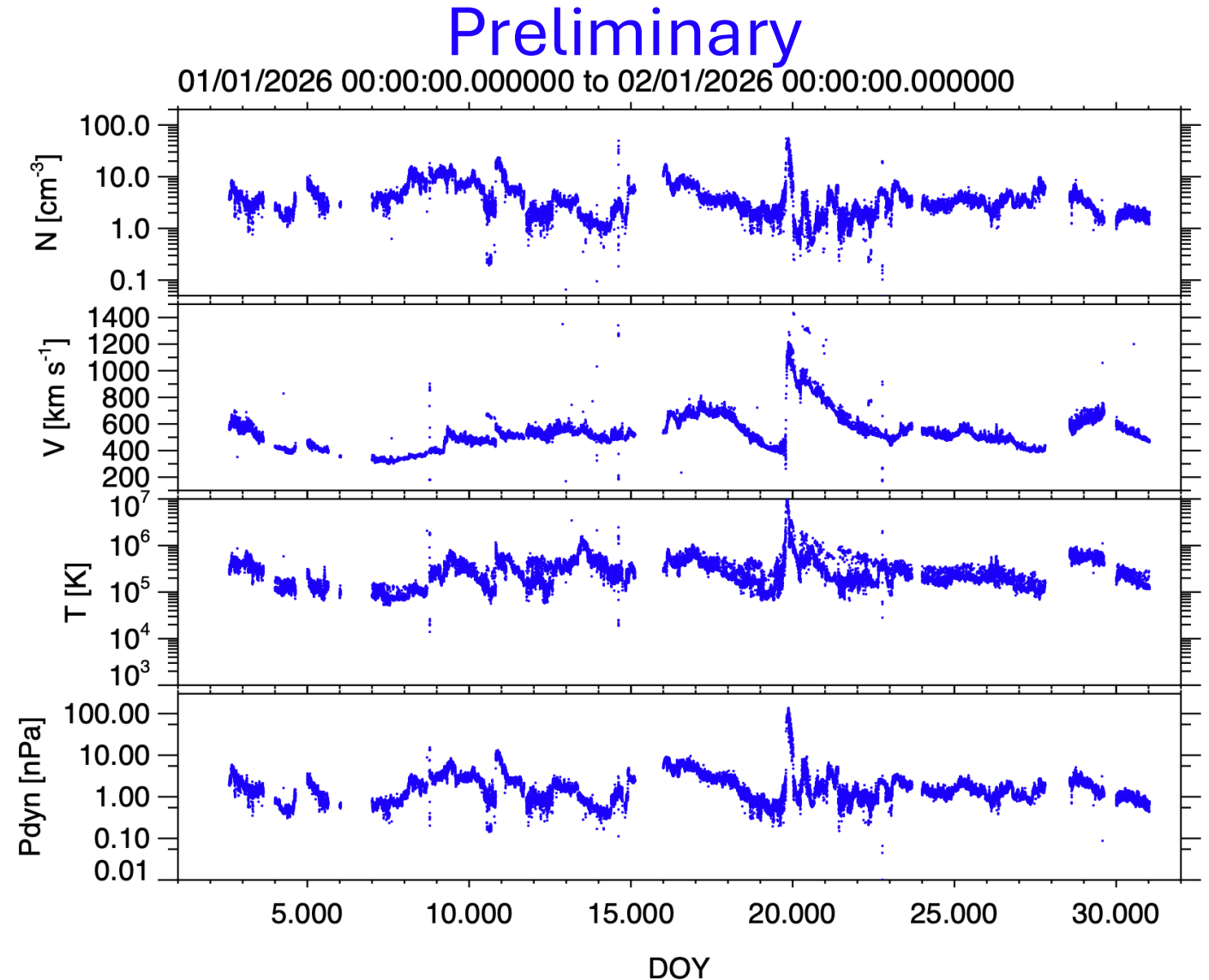
## 10/01/2025-12/31/2025



# **Connecting with Other Observations**

# SWiPS on NOAA's Solar-1

- SWiPS on Solar -1 will provide full 3-D solar wind distributions
- 60 second cadence in realtime
- $N_p$ ,  $T_p$ ,  $V_p$ ,  $P_{dyn}$
- Velocity vector in GSE an GSM.
- Robust collected measurements through out January 19-20, 2026 ICME with peak speed of 1200 km/s

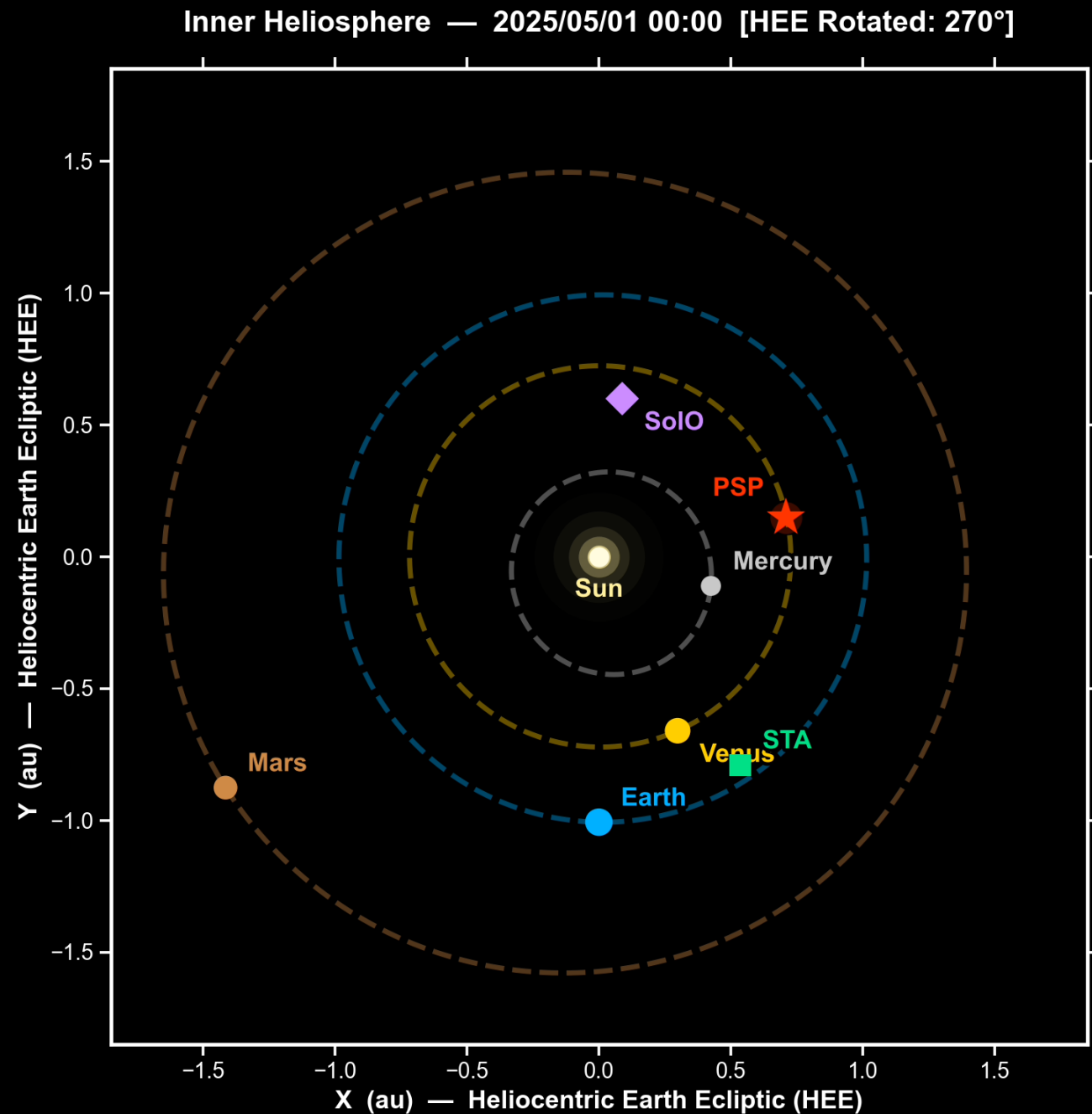


# IMAP Realtime Stream Products

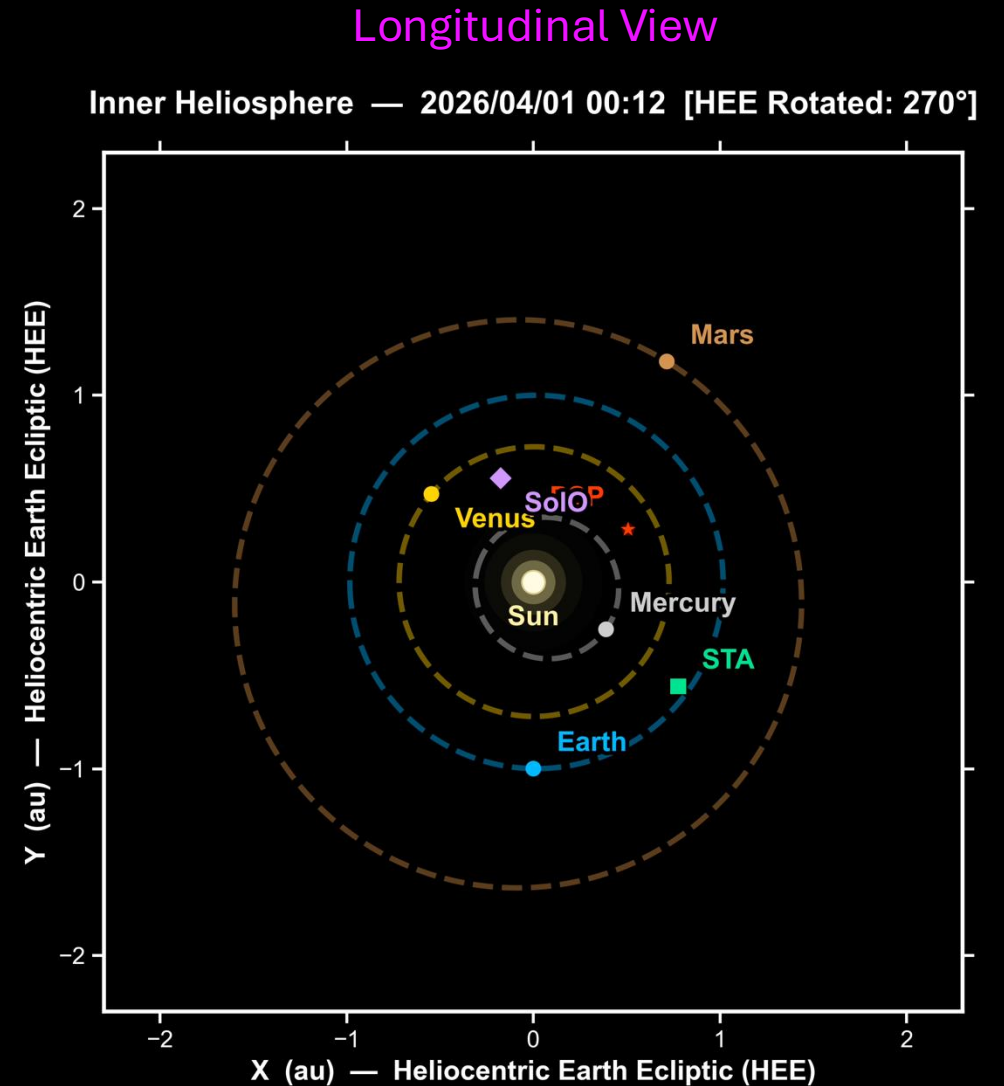
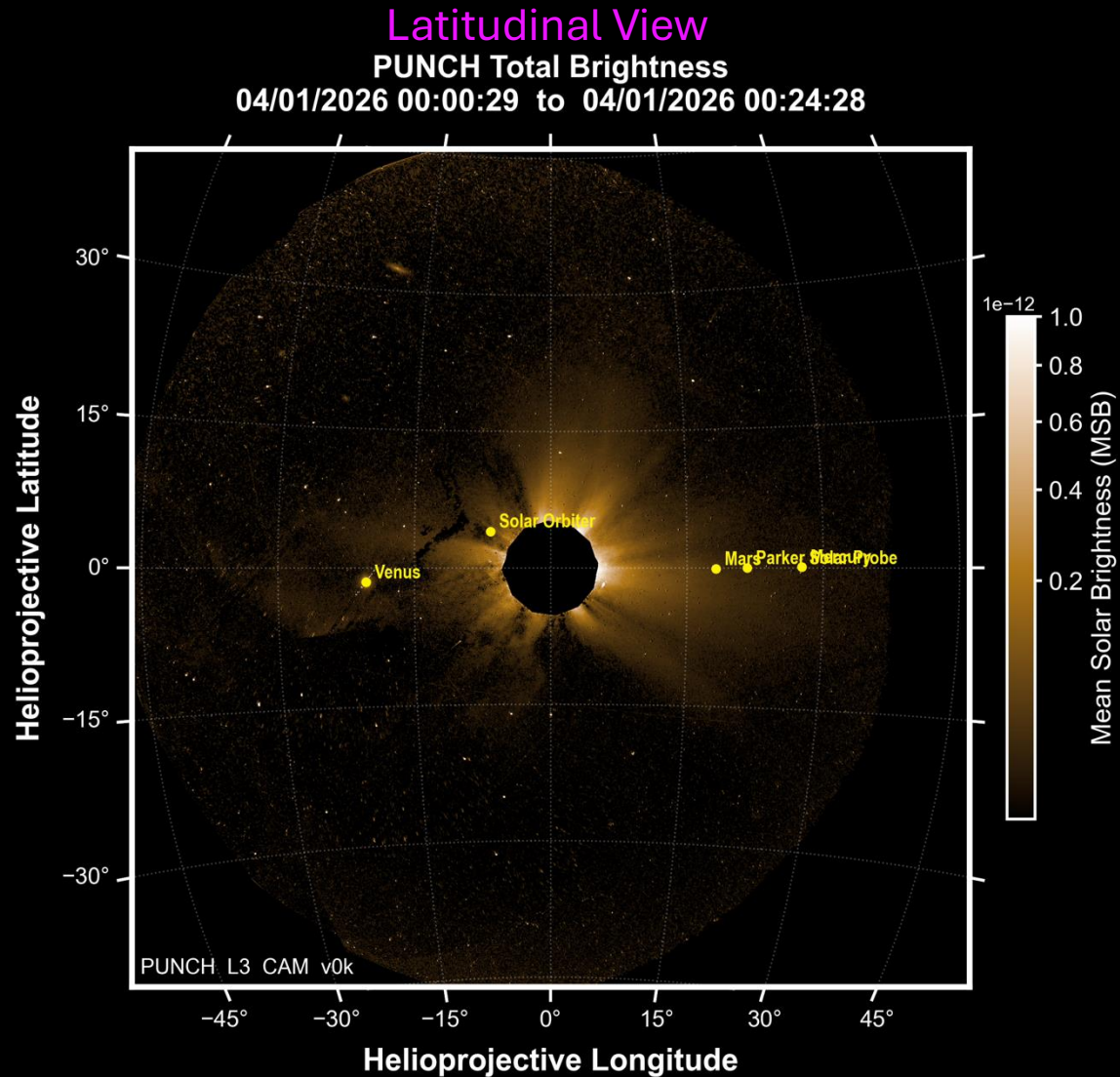
Mission	Instrument	Native Cadence	Solar Wind Parameters
NASA-IMAP	SWAPI	12 sec	Pseudo $V_p$ , $n_p$ , and $T_p$
NASA-IMAP	MAG	4 sec	$ B $ , vector B-field in GSE, GSM, and RTN, field angles in GSE and GSM
NASA-IMAP	CoDICE-Lo	4 min	C to O abundance, Mg to O abundance, Fe to O abundance, C+6 to C+5 ratio, O+7 to O+6 ratio, Low Fe to High Fe Charge States
NASA-IMAP	CoDICE-Hi	4 min	H+ proton energy fluxes (15 energy ranges)
NOAA-Solar-1	SWIPS	60 sec	3-D distribution functions, $V_p$ , $V_x$ , $V_y$ , $V_z$ in GSE and GSM, $T_p$ , dynamic pressure (protons and alphas)
NOAA-Solar-1	MAG	4 sec	$ B $ , vector B-field in GSE, GSM, and RTN, field angles in GSE and GSM

# Spacecraft Alignment Movie Looking Down on Ecliptic

- Variety of configurations in the ecliptic.
- Many intervals where L1/Earth are longitudinally aligned with Solar Orbiter and and Solar Probe
- STEREO-A is moving away from Earth towards quadrature.



# Combined Body Overlay on PUNCH FOV with Ecliptic View Earth



# Tracking Coverage of Specific PUNCH Products

- Purpose: To enable comparisons with other data sets
- Wrote a Python code to customize making a calendar and csv files of the inventory of specific PUNCH data products
- Coverage Calendars
  - Makes a pdf and html calendars
  - Shows the number of files of a given kind of data product
  - Links to the location on the NASA-SDAC.
- Plan is to add to the PUNCH examples.

# Example Calendar

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file:///Users/helliott/projects/punch\_inventory/punch\_data\_calendar\_20

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Health care Writing Writing Secure Access SSL VPN2 Creating PNG Plots in IDL Marriott Find ...vation Details Welcome: SWAP Welcome: SWAP

🌟 Main plot ICME timeseries visualization - Cl...
📅 April 2026 Movies (Big comet) - OneDrive

PUNCH Data Calendar — October 2025

## PUNCH Data Availability — October 2025

Sun	Mon	Tue	Wed	Thu	Fri	Sat
<b>28 (271)</b>	<b>29 (272)</b>	<b>30 (273)</b>	<b>1 (274)</b>	<b>2 (275)</b>	<b>3 (276)</b>	<b>4 (277)</b>
L3CAMv0j L3CAMv0k L3PAMv0j L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k
<b>5 (278)</b>	<b>6 (279)</b>	<b>7 (280)</b>	<b>8 (281)</b>	<b>9 (282)</b>	<b>10 (283)</b>	<b>11 (284)</b>
L3CAMv0j L3CAMv0k L3PAMv0j L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k
<b>12 (285)</b>	<b>13 (286)</b>	<b>14 (287)</b>	<b>15 (288)</b>	<b>16 (289)</b>	<b>17 (290)</b>	<b>18 (291)</b>
L3CAMv0j L3CAMv0k L3PAMv0j L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k
<b>19 (292)</b>	<b>20 (293)</b>	<b>21 (294)</b>	<b>22 (295)</b>	<b>23 (296)</b>	<b>24 (297)</b>	<b>25 (298)</b>
L3CAMv0j L3CAMv0k L3PAMv0j L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	41 L3CAMv0j 41 L3CAMv0k 41 L3PAMv0j 41 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 44 L3PAMv0j 44 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k
<b>26 (299)</b>	<b>27 (300)</b>	<b>28 (301)</b>	<b>29 (302)</b>	<b>30 (303)</b>	<b>31 (304)</b>	<b>1 (305)</b>
L3CAMv0j L3CAMv0k L3PAMv0j L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	45 L3CAMv0j 45 L3CAMv0k 45 L3PAMv0j 45 L3PAMv0k	38 L3CAMv0j 38 L3CAMv0k 22 L3PAMv0j 22 L3PAMv0k

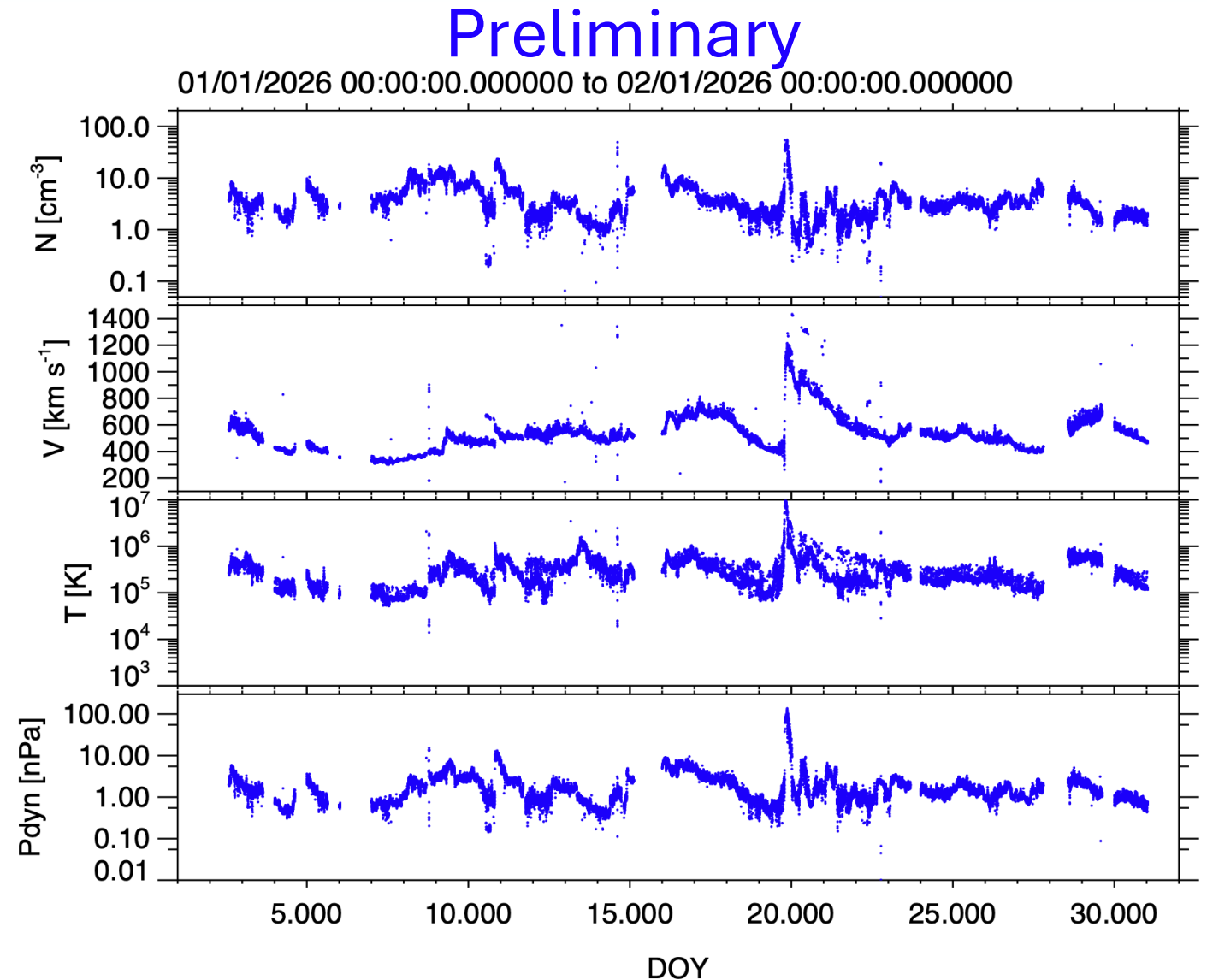
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**Integrating with New Observations:  
Shift to Near Realtime Identifications**

# SWiPS on NOAA's Solar-1

- SWiPS on Solar -1 will provide full 3-D solar wind distributions
- 60 second cadence in realtime
- Scaler:  $N_p$ ,  $T_p$ ,  $V_p$ ,  $P_{dyn}$ ,
- Velocity vector in GSE an GSM.
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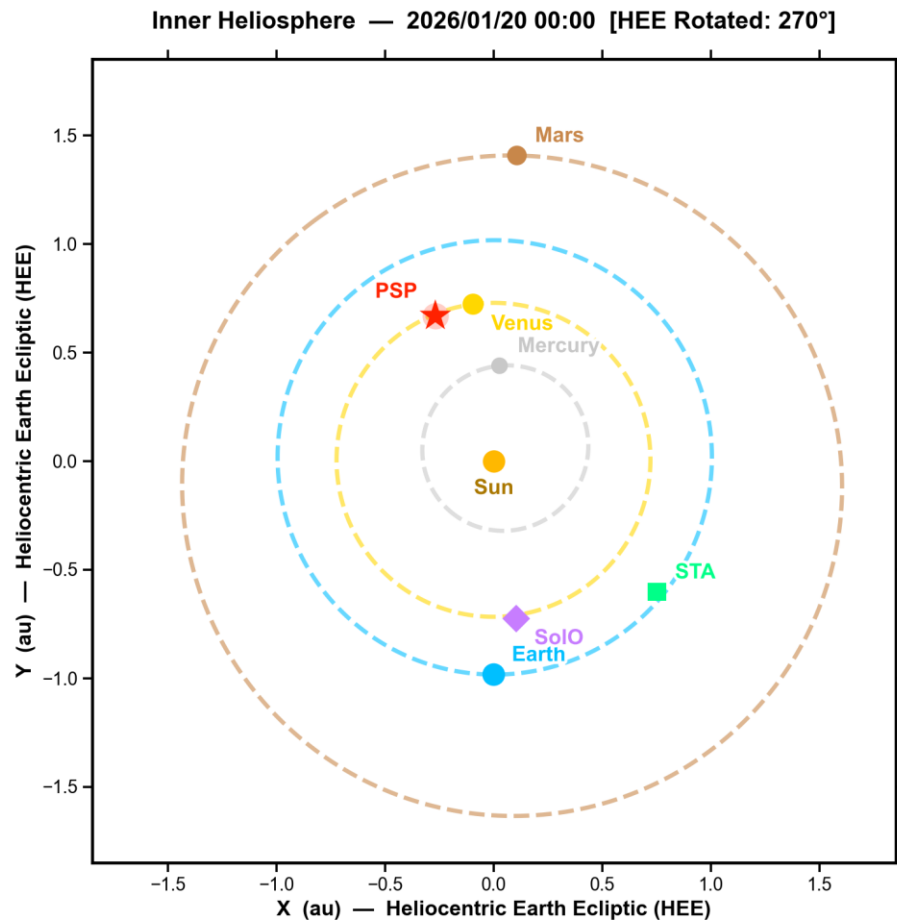
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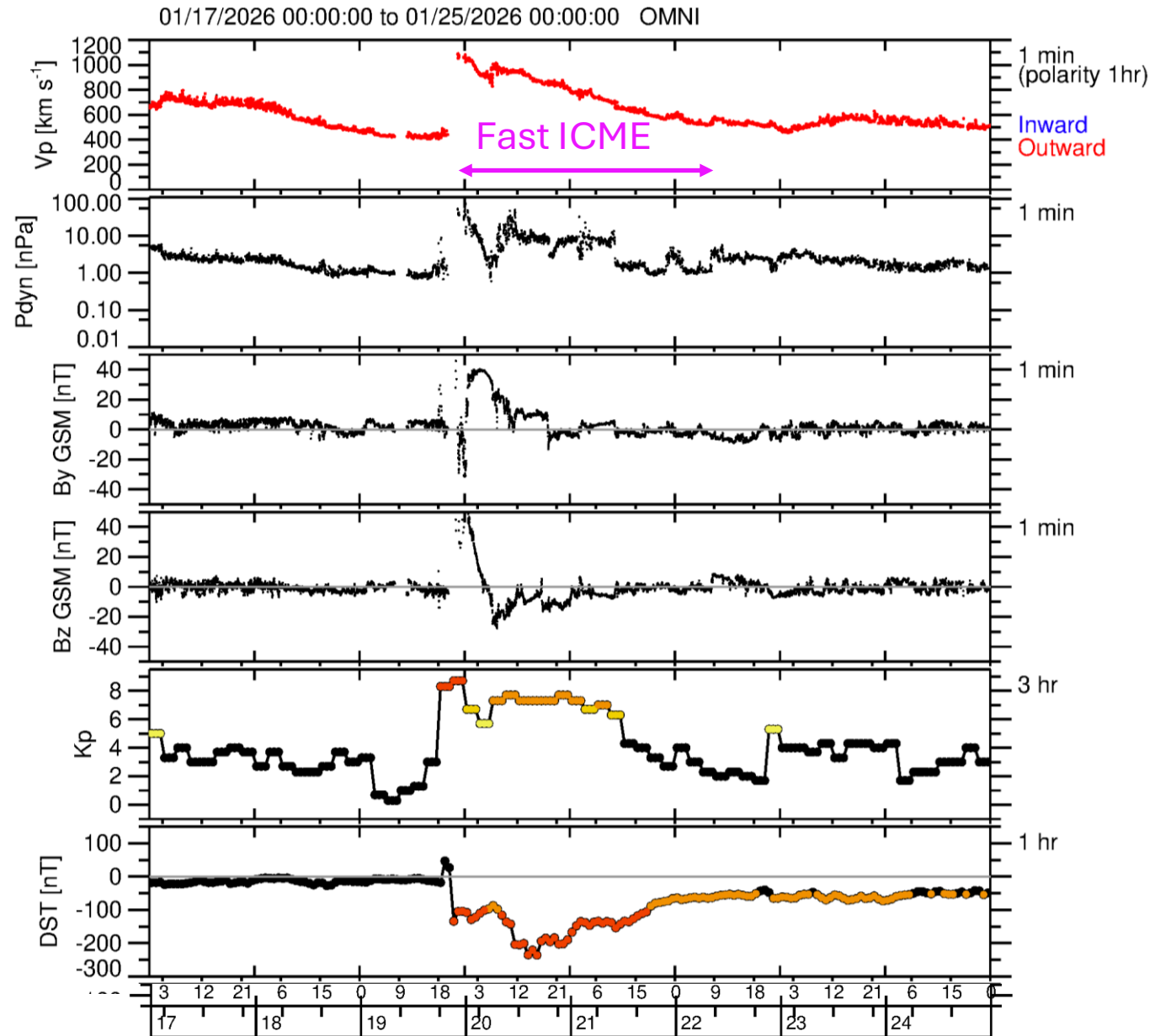
# Summary and Conclusions

- We started with OMNI because it is commonly used by the wider Heliophysics community and new mission data (e.g. Solar-1 & IMAP) will be integrated into OMNI.
- The long timespan of OMNI is ideal for testing methods.
- We chose simple algorithms that could easily be adapted to work in near real-time with Solar-1 and IMAP.
- We may need to have a human in the loop to produce validated lists, but the plots and automatic lists will make it easier for the human.
- The simple algorithms have good potential.
- IMAP CoDICE solar wind composition data can be added to improve the automatic lists.
- **In the PUNCH era we have many ICMEs and series of CIRs and lots of data from a lot of spacecraft!**

# Highly Geoeffective ICME 01/19/2026 to 01/22/2026



Elliott et al.



Elliott et al.