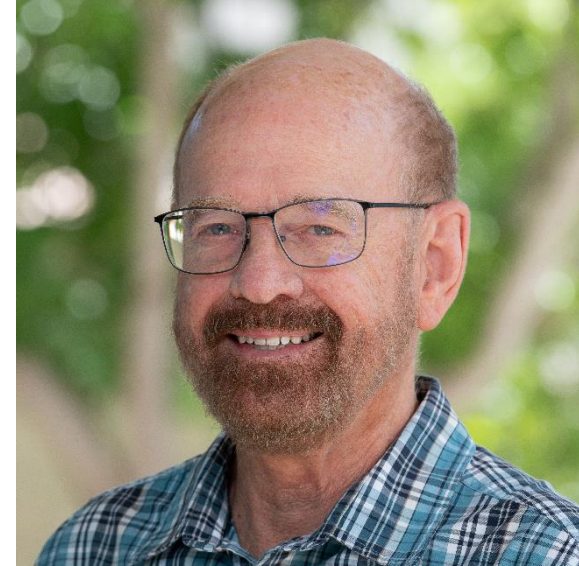


# UCSD Time-Dependent 3-D High-Resolution Reconstructions Using PUNCH Images: What We Have Done To Date

**Bernie Jackson**



**Eric Chen, Sam Nasri, Unity Listiak, Vishwas Tattala**

*Department of Astronomy and Astrophysics, University of California,  
San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0424, USA*

<https://ips.ucsd.edu/>

<https://stereo.ucsd.edu/>

<https://stereo.ucsd.edu/PUNCH>

# 3-D High-Resolution Reconstructions Using PUNCH Images

<https://ips.ucsd.edu>

The screenshot shows a web browser window with two tabs titled "CASS/ISEE IPS Space Weather Forec". The address bar displays "https://ips.ucsd.edu". The page header includes the "A&A" logo, "UCSD Department of Astronomy and Astrophysics", and "Institute for Space-Earth Environmental Research" with the "ISEE" logo. The main content area features a dark space background with the text "Space Weather Forecasting Velocity and Density Plots with Interplanetary Scintillation Data" in yellow. Below this text is a large image of a 3D reconstruction of a solar wind structure, showing a central yellow and orange region with a blue dot and a red dot, surrounded by pinkish-red plasma. A left sidebar contains a clock showing "01:03:41 UTC" and "07-Apr-2024", a small image of the solar wind structure, and a list of navigation links: "High Resolution Predictions", "IPS-Driven ENLIL", "ENLIL Predictions", "Archival 3D Imagery", "Experimental Forecasts", "Additional Information", and "STEREO".

# 3-D High-Resolution Reconstructions Using PUNCH Images

03:55:10 UTC

04-May-2026



[Home](#)

[Predictions D, V](#)

[Predictions MAG](#)

[Bz, V Forecasts](#)

[Planet, S/C D, V](#)

[Planet, S/C Br, Bt](#)

[Real-Time Archive](#)



UCSD Department of Astronomy and Astrophysics  
Institute for Space-Earth Environmental Research

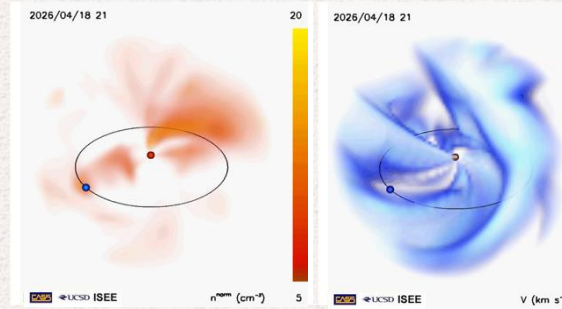


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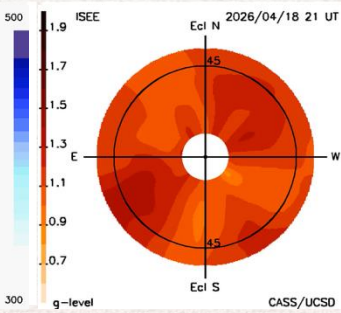
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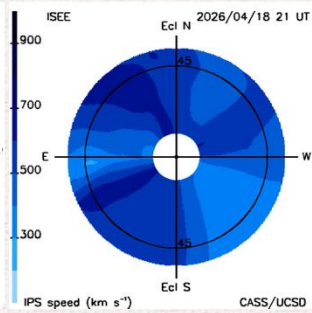
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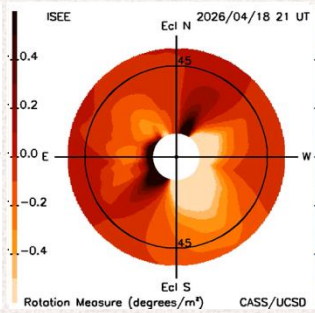
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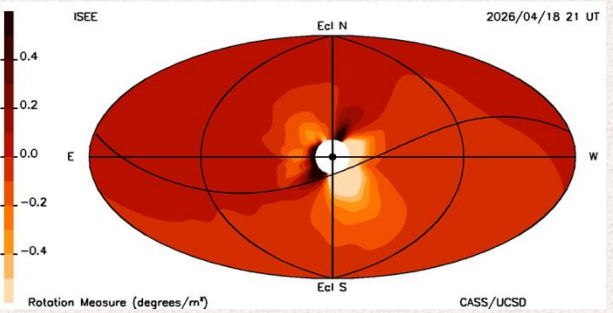
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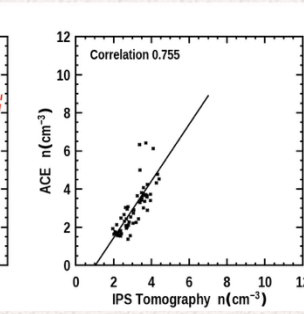
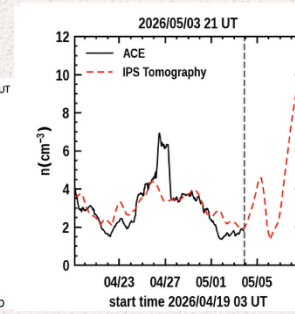
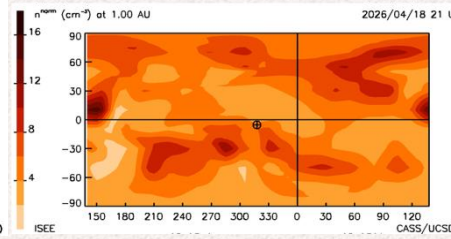
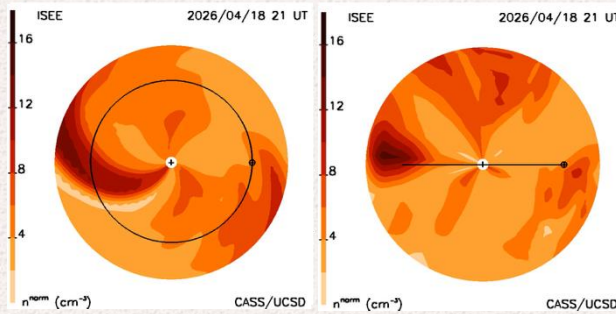
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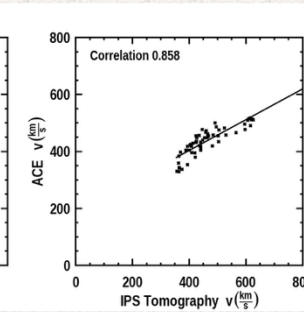
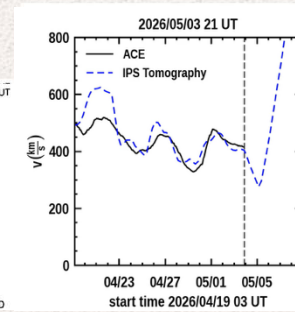
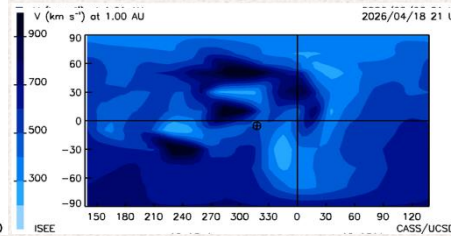
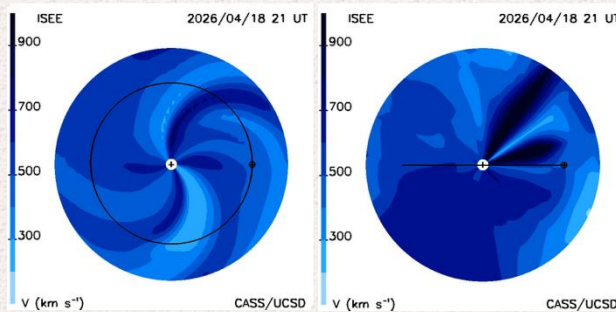
Hammer-Aitoff Rotation Measure



Density



Radial Velocity



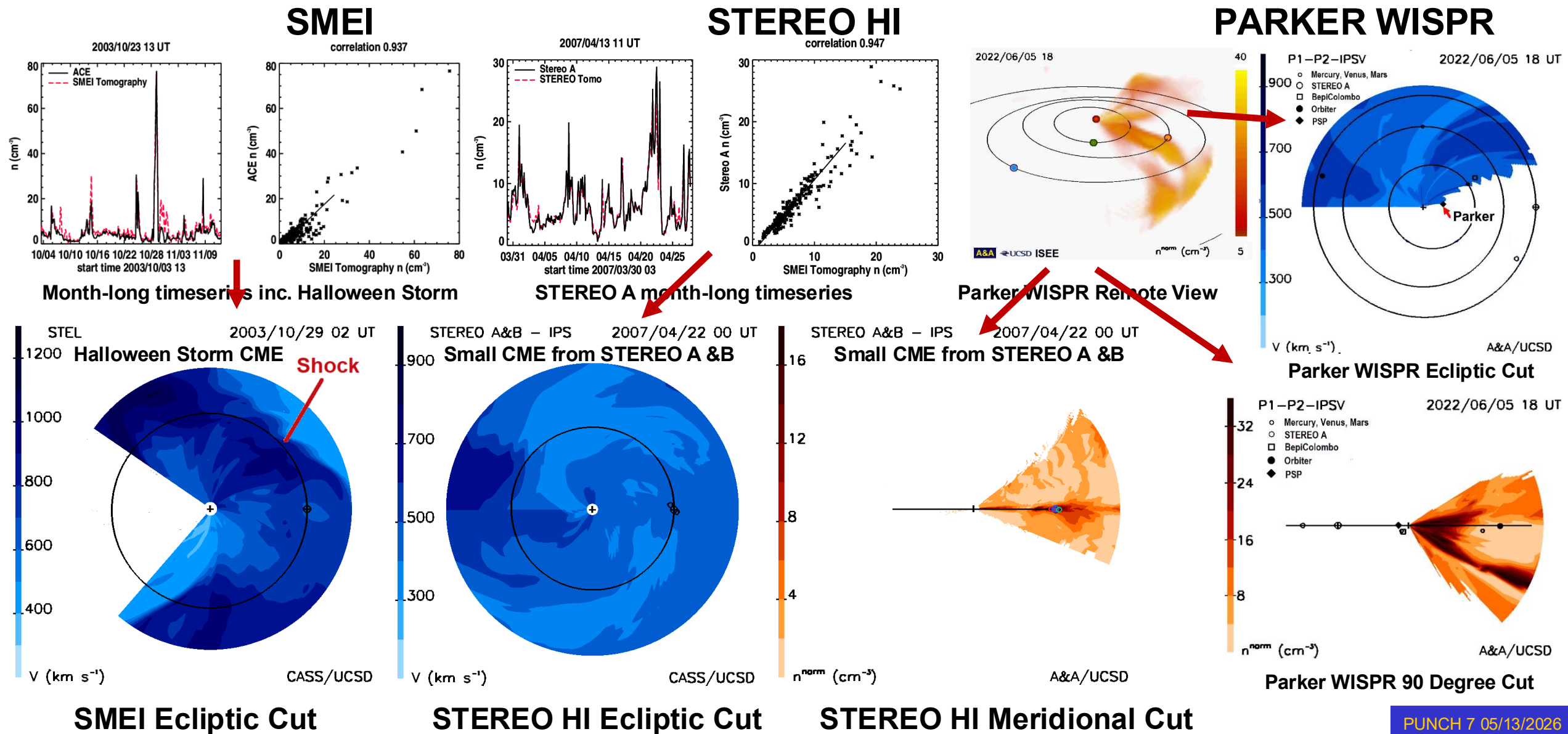
# 3-D High-Resolution Reconstructions Using PUNCH Images

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**Thomson Scattering  
B Analyses and IPS**

# 3-D High-Resolution Reconstructions Using PUNCH Images

## Mesoscale Structure ( $1^\circ \times 1^\circ$ latitude, longitude, 0.02 AU, 1 Hr cadence)



# 3-D High-Resolution Reconstructions Using PUNCH Images

**What About PUNCH?**

# 3-D High-Resolution Reconstructions Using PUNCH Images

**ISEE and LOFAR  
(UK Chilbolton)  
IPS Combined**

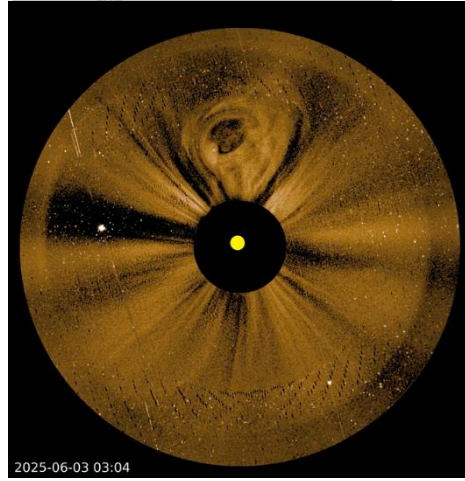
Bernard V. Jackson<sup>1#</sup>, Kazumasa Iwai<sup>2</sup>, Ken'ichi Fujiki<sup>2</sup>, Mario M. Bisi<sup>3</sup>, Richard Fallows<sup>3</sup>, Jackie Davies<sup>3</sup>, David Barnes<sup>3</sup>, and Oyuki Chang<sup>3</sup>

<sup>1</sup>Department of Astronomy and Astrophysics, University of California, San Diego 9500 Gilman Drive #0424, La Jolla, CA 92093

<sup>2</sup>Institute for Space-Earth Environmental Research, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

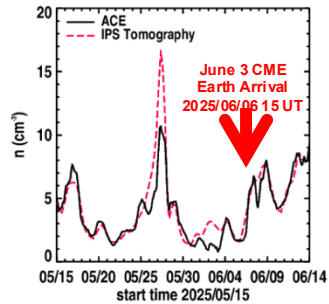
<sup>3</sup>United Kingdom Research and Innovation – Science & Technology Facilities Council - Rutherford Appleton Laboratory, RAL Space, Harwell Campus, Oxfordshire, OX11 0QX, United Kingdom

#Corresponding author: [bjackson@ucsd.edu](mailto:bjackson@ucsd.edu) Presenter Tel: 858 442-9532

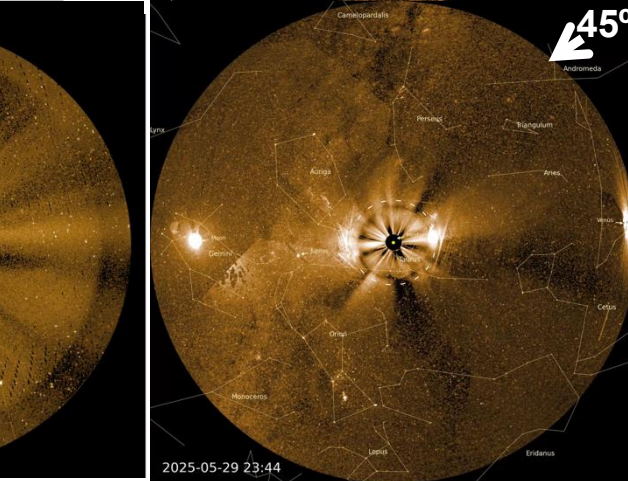


PUNCH NFI 2025 06 03 03:04

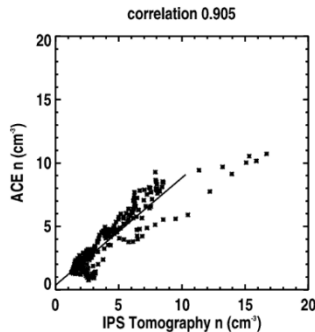
Skymap 2025/05/30 00 UT



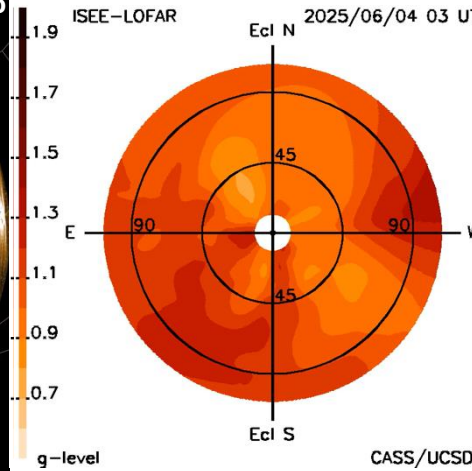
ISEE-LOFAR time series with CME



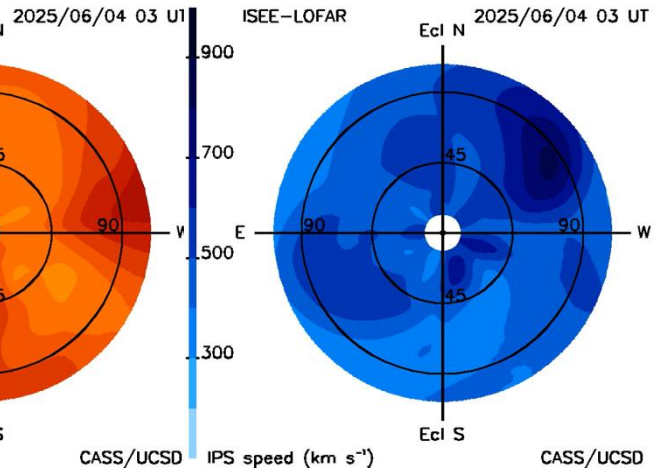
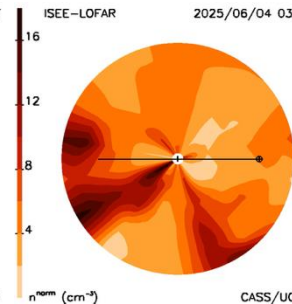
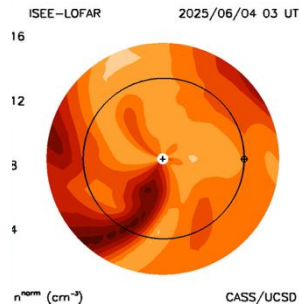
PUNCH WFI 2025 06 03 15:44



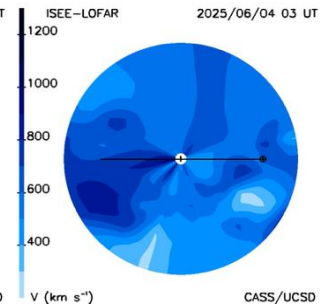
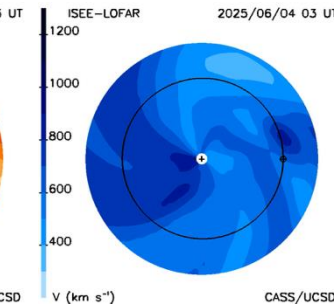
WIPSS Np ecliptic & meridional cuts



ISEE-LOFAR G-level Skymap



ISEE-LOFAR Velocity



WIPSS V ecliptic & meridional cuts

PUNCH NFI and WFI both see a CME as does the WIPSS IPS analysis from ISEE and LOFAR (UK Chilbolton) IPS analysis

# 3-D High-Resolution Reconstructions Using PUNCH Images

**ISEE and LOFAR  
(UK Chilbolton)  
IPS Combined**

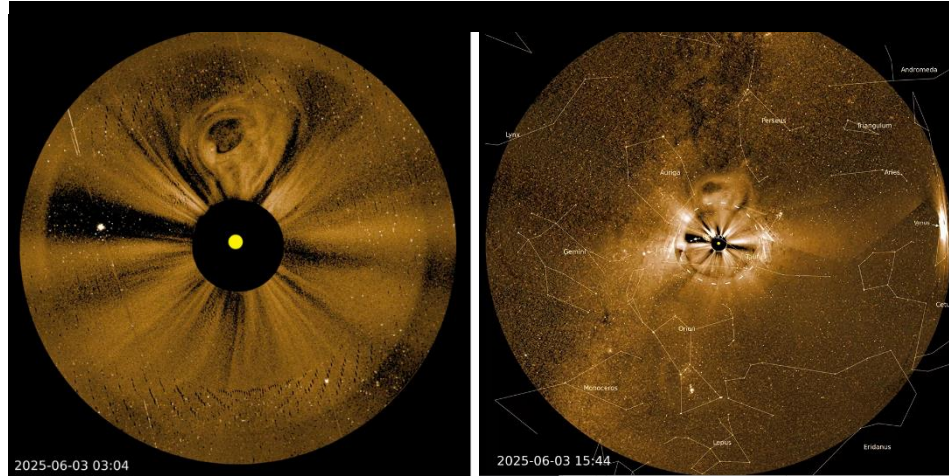
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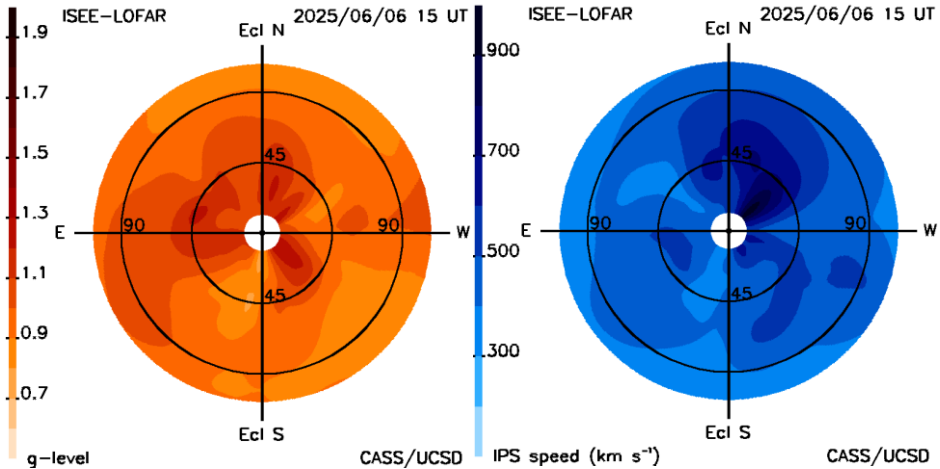
<sup>3</sup>UK Space and Technology Research and Innovation – Science & Technology Facilities Council - Rutherford Appleton Laboratory, RAL Space, Harwell Campus, Oxfordshire, OX11 0QX, United Kingdom

#Corresponding author: [bjackson@ucsd.edu](mailto:bjackson@ucsd.edu) Presenter Tel: 858 442-9532



PUNCH NFI 2025 06 03 03:04

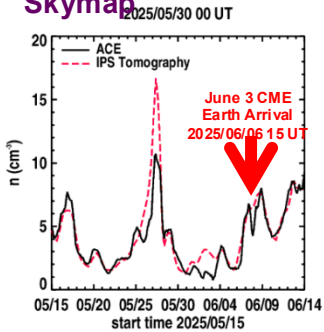
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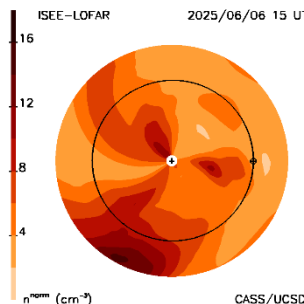
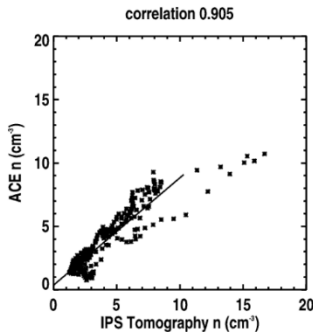
ISEE-LOFAR G-level Skymap

ISEE-LOFAR Velocity

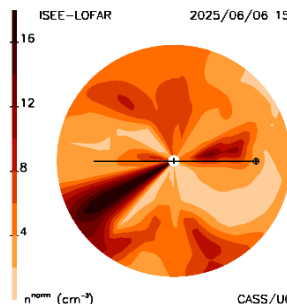
Skymap



ISEE-LOFAR time series with CME



WIPSS Np ecliptic & meridional cuts

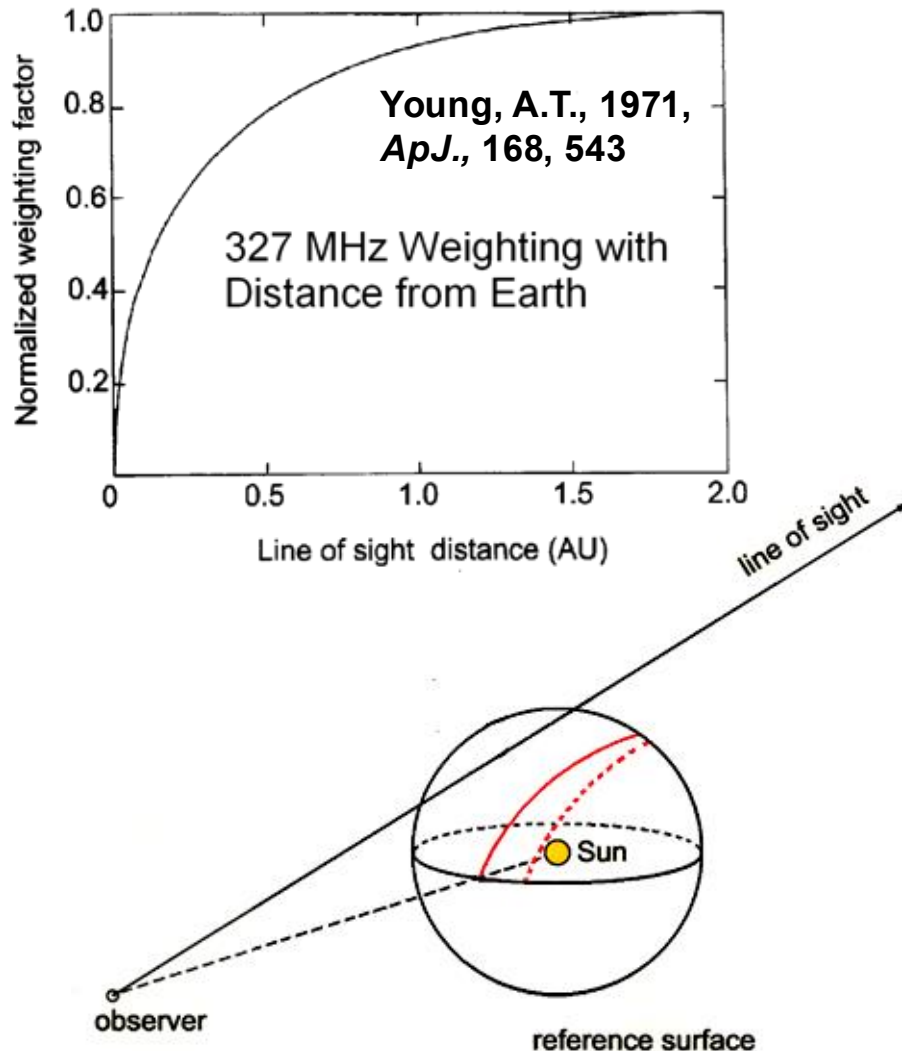


WIPSS V ecliptic & meridional cuts

PUNCH NFI and WFI both see a CME as does the WIPSS IPS analysis from ISEE and LOFAR (UK Chilbolton) IPS analysis

# 3-D High-Resolution Reconstructions Using PUNCH Images

## Interplanetary Scintillation Line-of-Sight Response

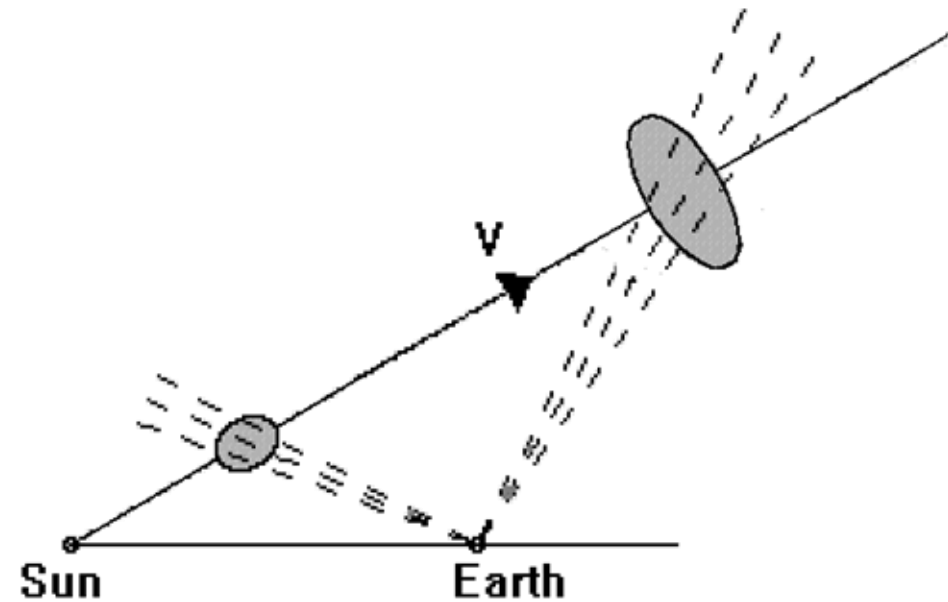


Jackson, B.V., et al., 2008, *Adv. in Geosciences* 21, 339

Jackson et al., 2020, *Frontiers in Astronomy and Space Sci.*, doi: 10.3389/fspas.2020.568429

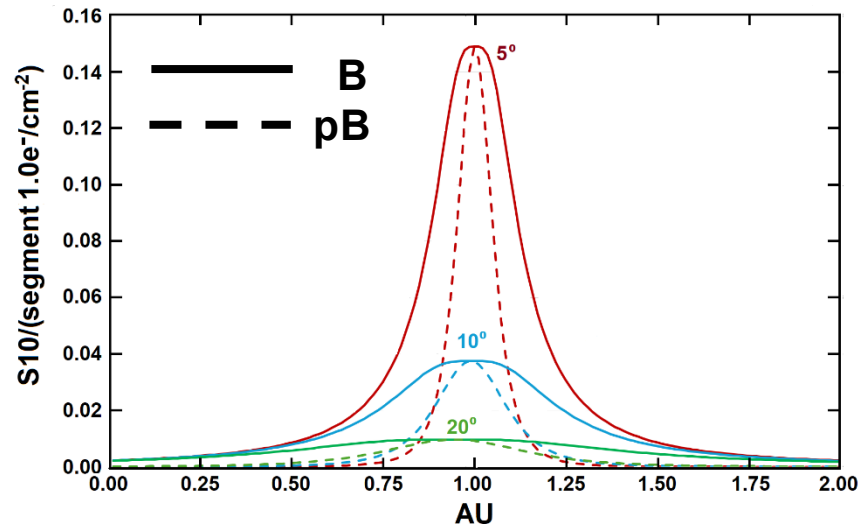
## ISEE DATA

Heliospheric C.A.T. analyses: example line-of-sight distribution for each sky location to form the source surface weighting of the 3-D reconstruction.

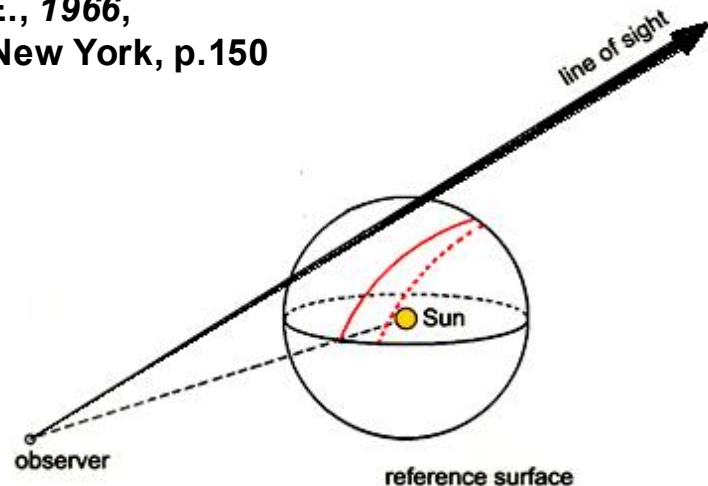


# 3-D High-Resolution Reconstructions Using PUNCH Images

## Thomson-Scattering B & pB Line-of-Sight Response



Billings, D.E., 1966,  
*Academic*, New York, p.150

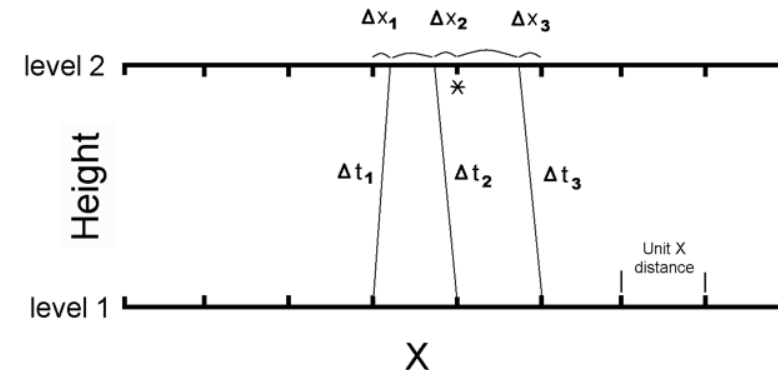


Jackson, B.V., *et al.*, 2008, *Adv. in Geosciences* 21, 339

Jackson *et al.*, 2020, *Frontiers in Astronomy and Space Sci.*, doi: 10.3389/fspas.2020.568429

Heliospheric C.A.T. analyses:

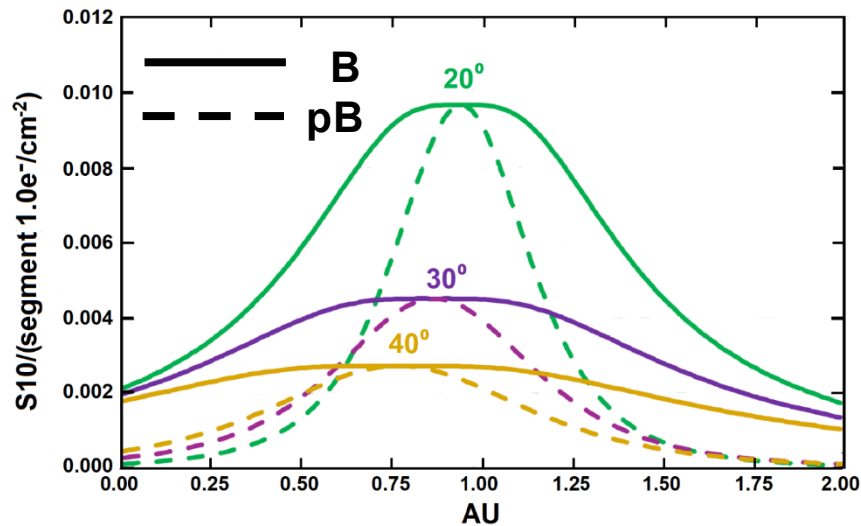
## “Traceback” Matrix Concept



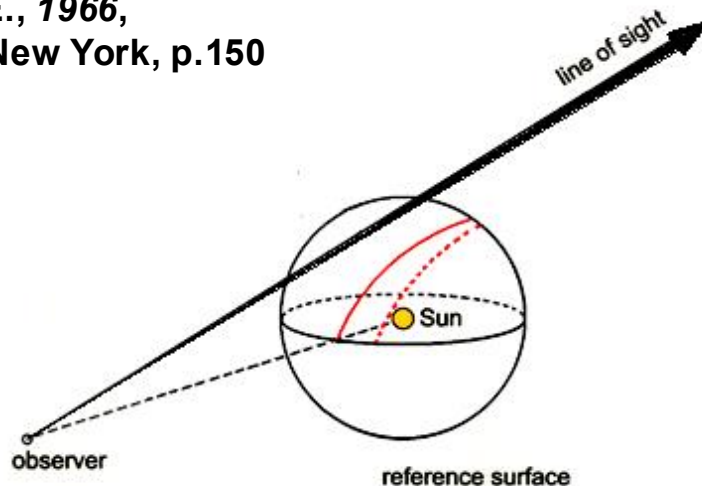
In a recent innovation, all heliospheric image “cones-of-sight” (cones) and IPS line-of-sight (LoS) segments have now been set to lengths that assume radial flow of the solar wind and are set to a value that is commensurate with the heliospheric resolution requested. The effect of this provides segments closer together near the Sun and farther apart distant from it. The cones or LoS extend the distance to the outer heliospheric boundary that is generally chosen to be 3.0 AU. The result is a more efficient 3-D reconstruction analysis that takes fewer computer resources especially when the tomographic spherical resolution are set to  $1^\circ \times 1^\circ$  or less.

# 3-D High-Resolution Reconstructions Using PUNCH Images

## Thomson-Scattering B & pB Line-of-Sight Response



Billings, D.E., 1966,  
*Academic*, New York, p.150

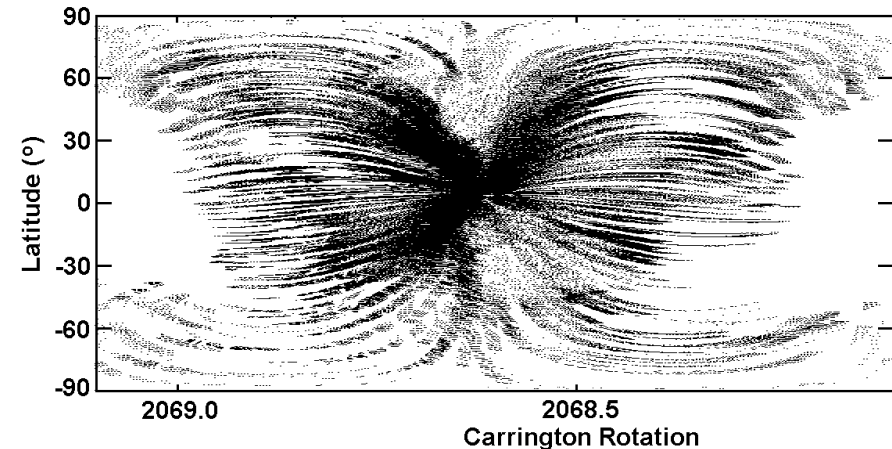


Jackson, B.V., et al., 2008, *Adv. in Geosciences* 21, 339

Jackson et al., 2020, *Frontiers in Astronomy and Space Sci.*, doi: 10.3389/fspas.2020.568429

Heliospheric C.A.T. analyses:  
example line-of-sight distribution  
for each sky location to form the  
source surface weighting of the  
3-D reconstruction.

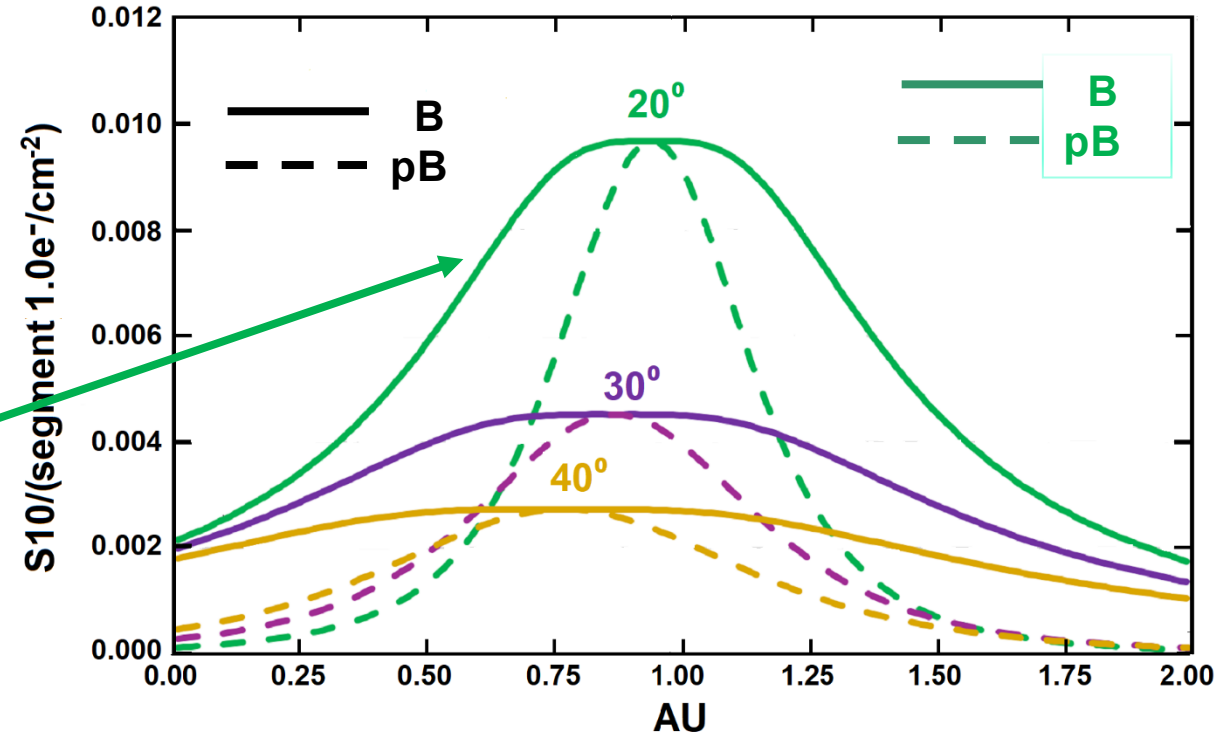
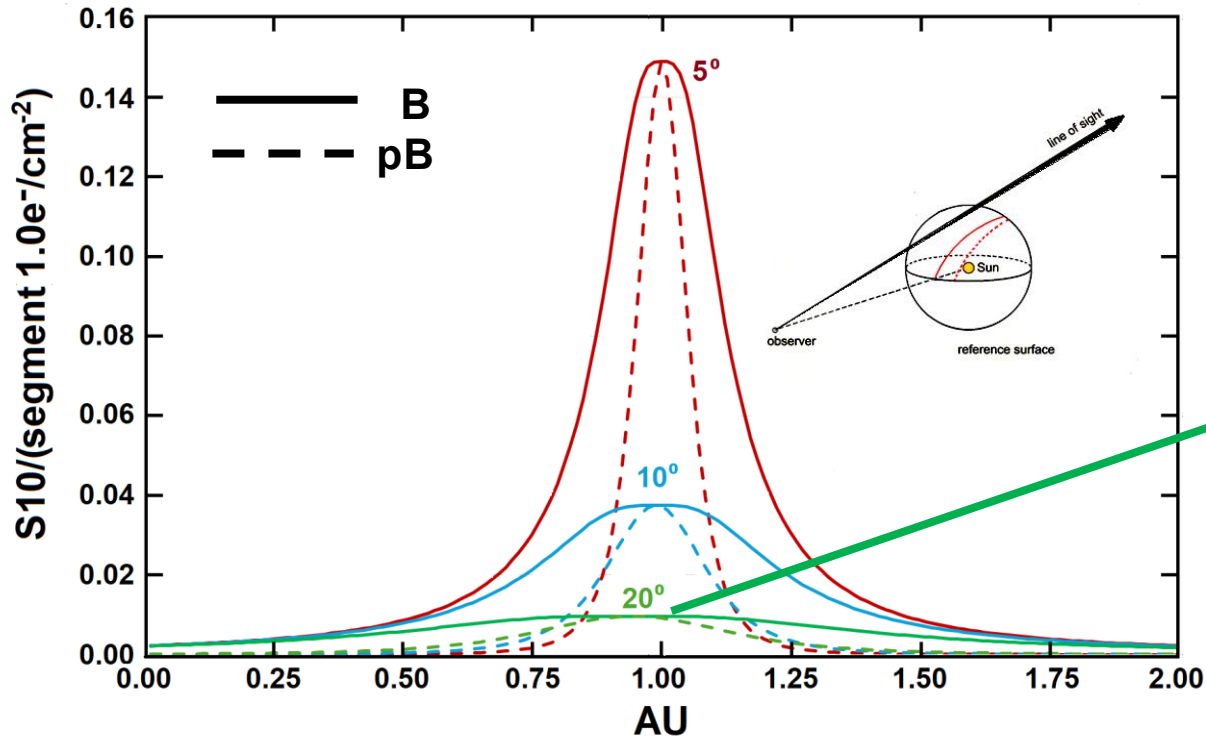
## Thomson Scattering CAT Analysis



From SMEI (6 hr difference- 1/25 # of LOS)  
3-5 Million LoS in a one-month interval

# 3-D High-Resolution Reconstructions Using PUNCH Images

## A Robust Method to Determine B or pB 3-D Heliospheric Structures



LoS weighting to 2 AU at elongations  $5^\circ - 20^\circ$

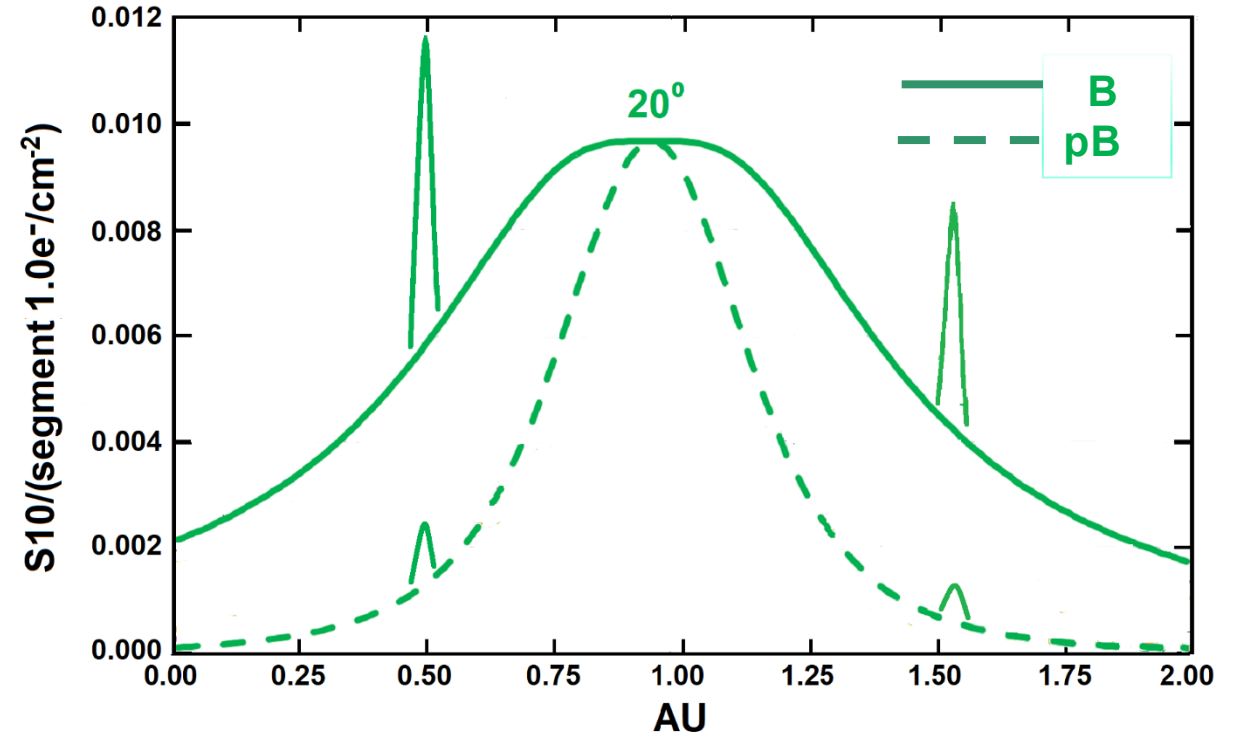
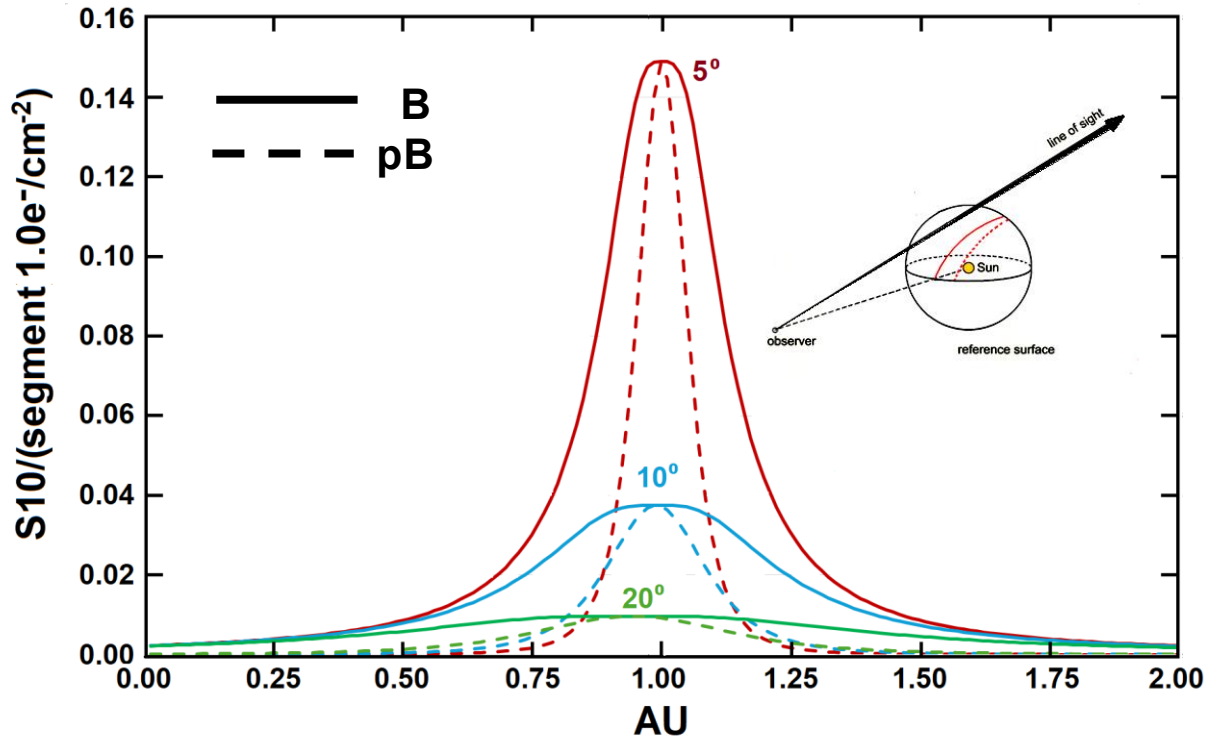
LoS weighting to 2 AU at elongations  $20^\circ - 40^\circ$

The key to the way to determine a robust *ITERATIVE* 3-D reconstruction using degree of polarization (pB/B) is shown in the next slide by LoS weighting given above. There are a couple things to notice first:

1. The electron scattering is very peaked for LoS that go close to the Sun.
2. Near Earth, the  $5^\circ$  pB signal is over 2 orders of magnitude less than the B signal.

# 3-D High-Resolution Reconstructions Using PUNCH Images

## A Method to Determine B or pB 3-D Heliospheric Structures



LoS weighting to 2 AU at elongations 5° - 20°

LoS weighting to 2 AU at elongations 20° - 40°

All an image shows is the total of the LoS values. The electrons in the single blip shown doubles the pB value, but the same number of electrons also doubles the B value on those line segments. Another set of electrons. As these structures move outward from the Sun to larger elongations they move farther away from 1.0 AU, but usually on different LoS. When the theoretical total deg. of polarization matches the observed at some elongation you have a solution to 3-D structure.

# 3-D High-Resolution Reconstructions Using PUNCH Images

13:38:15 UTC

14-Feb-2025



[STEREO D.V](#)

[STEREO Br.Bt.Bz](#)

[PUNCH](#)

[PARKER](#)

[Mesoscale](#)

[IPS UCSD](#)

**A&A** UCSD Department of Astronomy and Astrophysics  
 Institute for Space-Earth Environmental Research **ISEE**



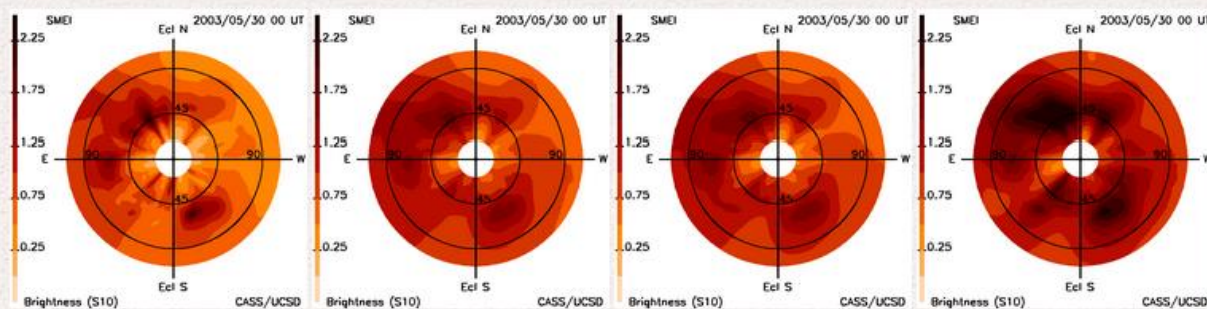
Polarimeter to Unify the Corona and Heliosphere (PUNCH)

Artists impression of the four PUNCH spacecraft. Credit: Southwest Research Institute

<https://stereo.ucsd.edu/PUNCH>

**May 30, 2003**

Brightness from PUNCH Solar Mass Ejection Imager (SMEI) Analysis



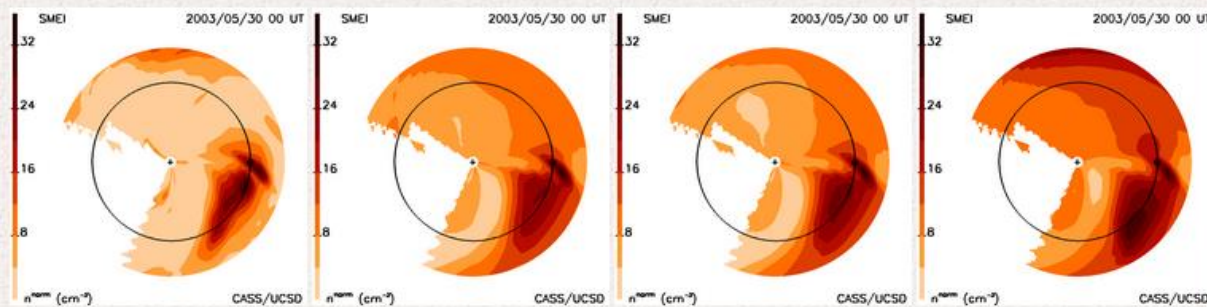
Direct brightness (B)

Pseudo brightness (B)

Pseudo polarized brightness (pB)

Pseudo pB/B pseudo degree of polarization

Density & Time Series

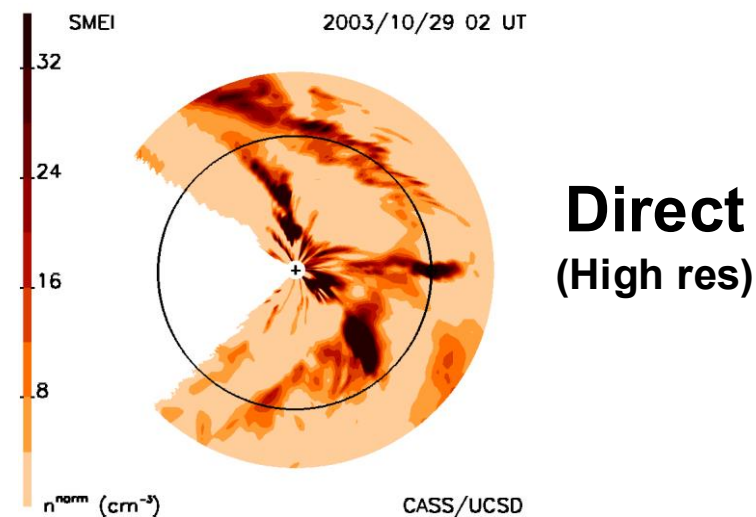


Direct density

Density from pseudo B

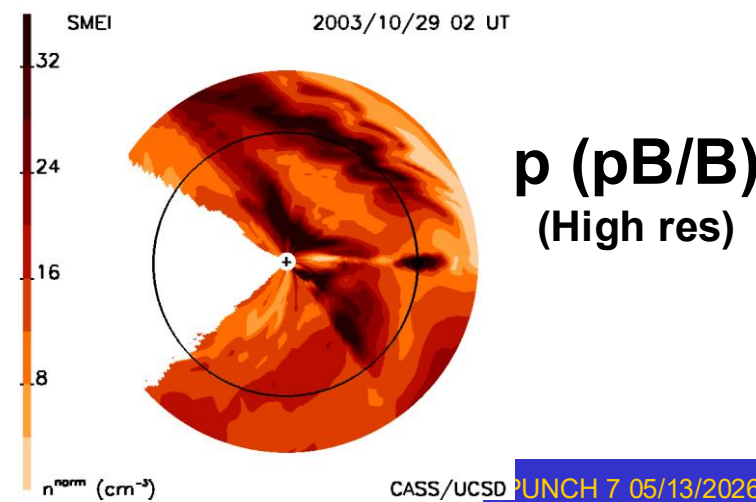
Density from pseudo pB

Density from pseudo degree of polarization



**Direct  
(High res)**

CASS/UCSD  
**October 29, 2003**



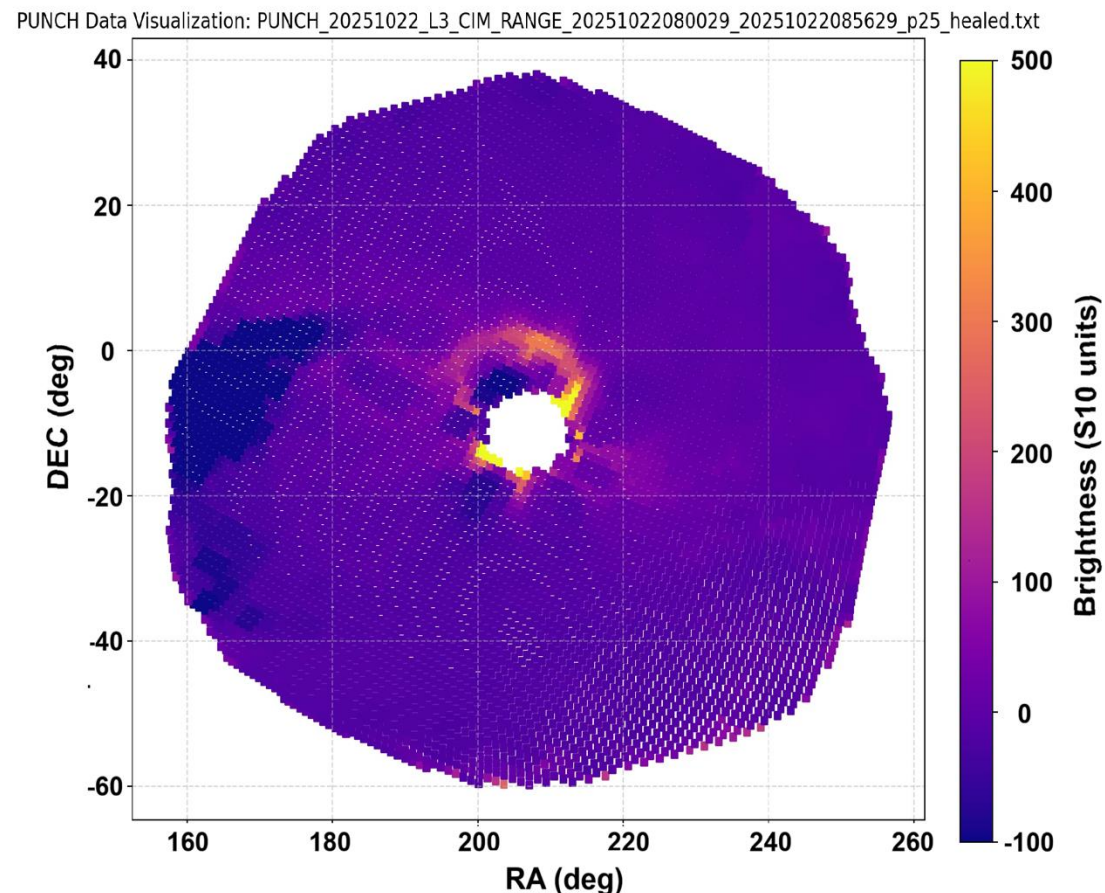
**p (pB/B)  
(High res)**

# 3-D High-Resolution Reconstructions Using PUNCH Images

## PUNCH Data Preconditioning

The UCSD 3-D reconstruction program needs input data that includes RA, Dec., a brightness value in S10 units, and the time of the observation; great if they can be gotten to one minute. The SWRI SOC provides a pixel value conversion to RA and Dec., UCSD converts the brightness to S10 and then; to provide our inputs we bin many pixels together and median filter them over the many image pixels to remove the stars. With these binned pixels we make a composite minimum map to remove the stray light from the image edges and elsewhere.

CIM “0i” PUNCH data composite minimum map

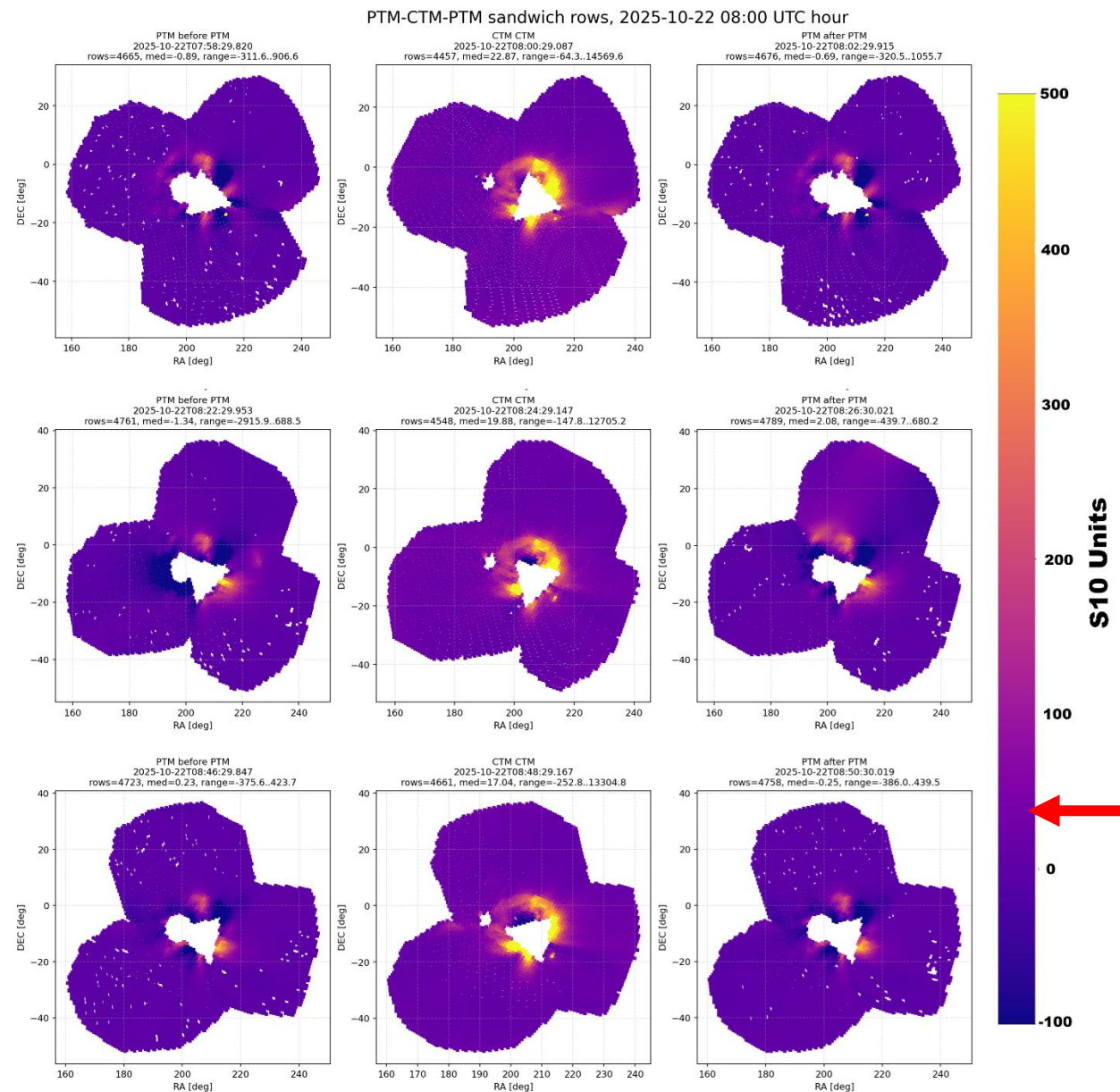
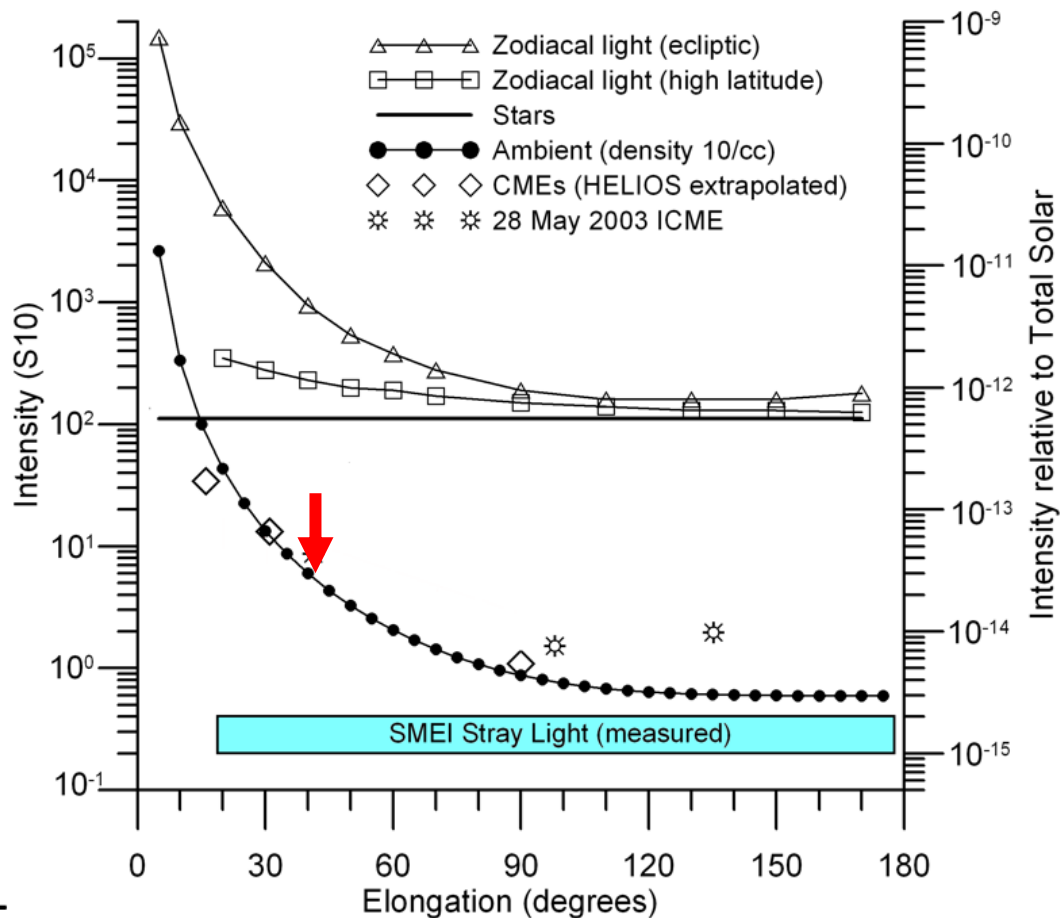


RA, Dec quick-look composite map of a bright “backside” CME on Oct. 22, 2025

# 3-D High-Resolution Reconstructions Using PUNCH Images

## PUNCH Data Preconditioning

### PTM – CTM – PTM Sandwich (RA-Dec, S10 Units)

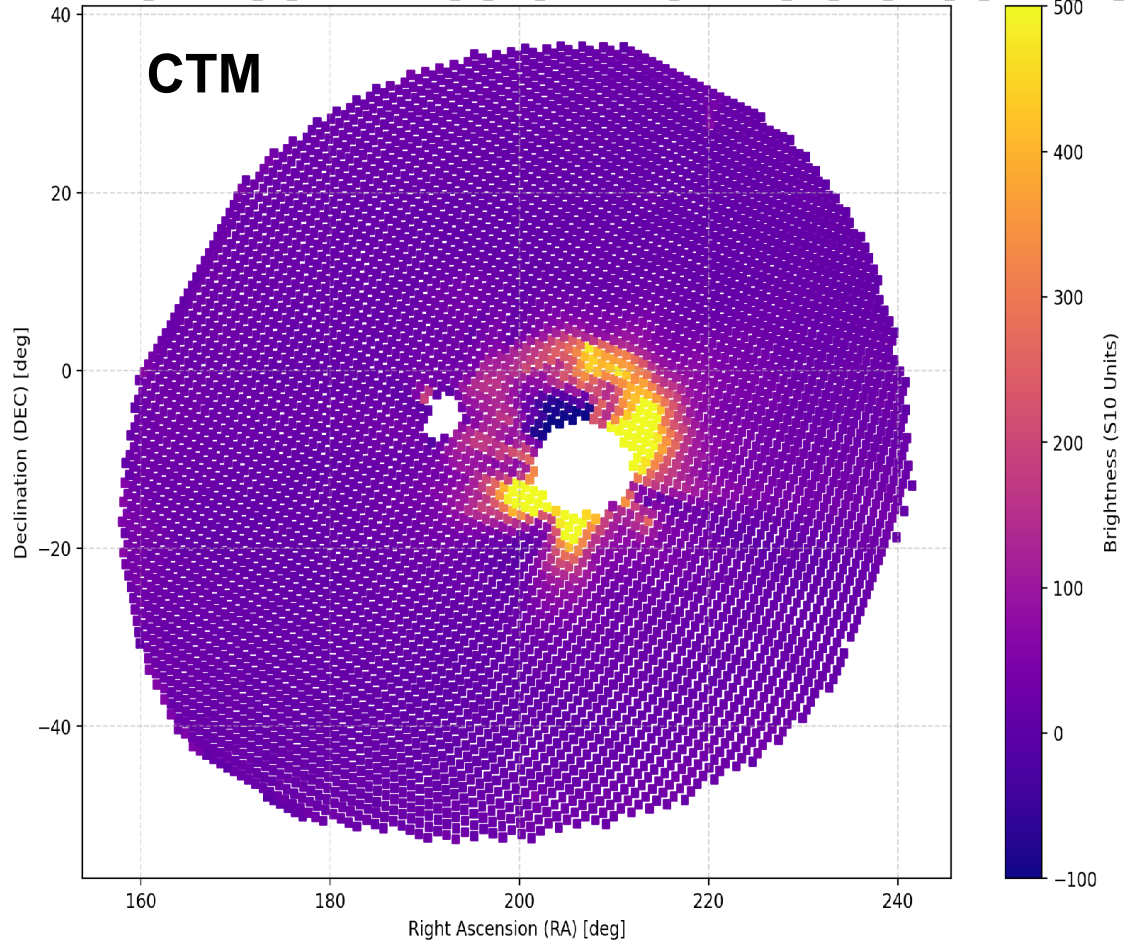


# 3-D High-Resolution Reconstructions Using PUNCH Images

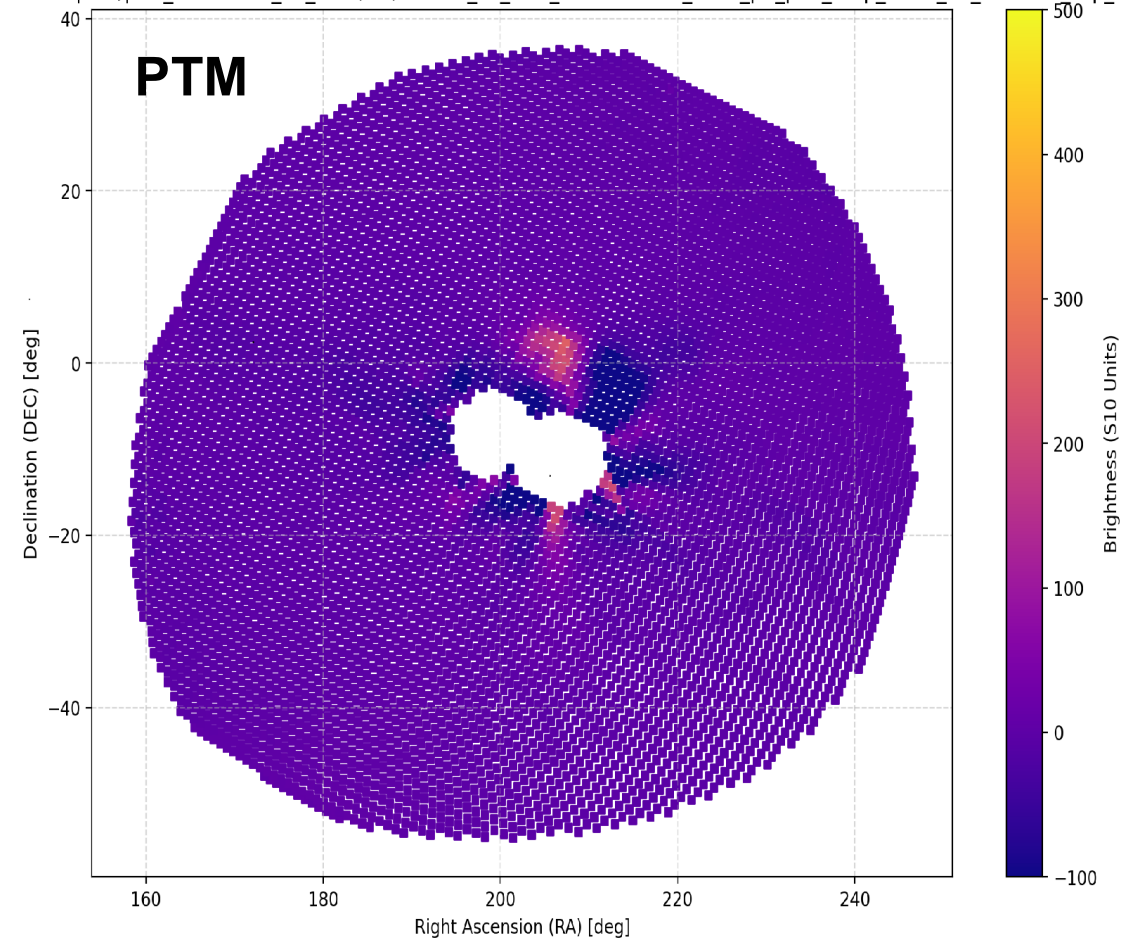
## PUNCH Data Preconditioning

### CTM – PTM Composite images in (RA-Dec, S10 Units)

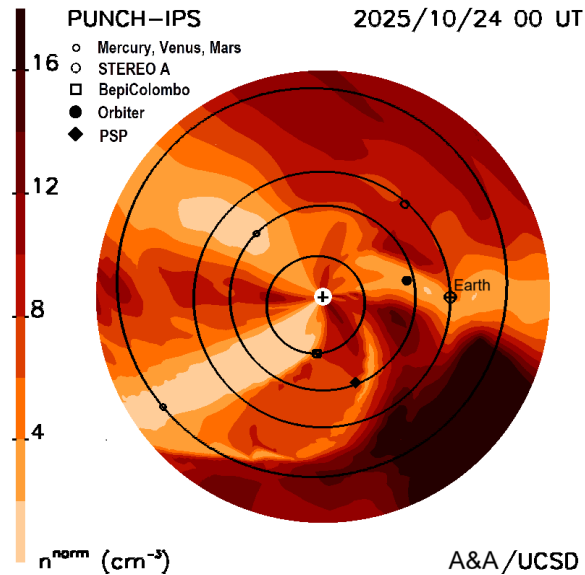
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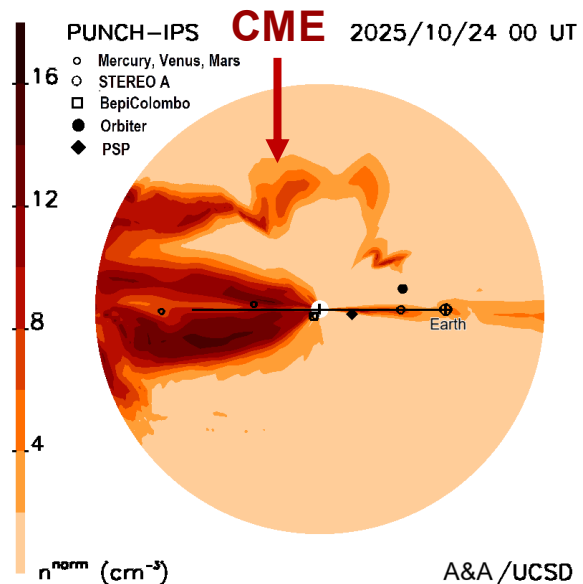
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# 3-D High-Resolution Reconstructions Using PUNCH Images



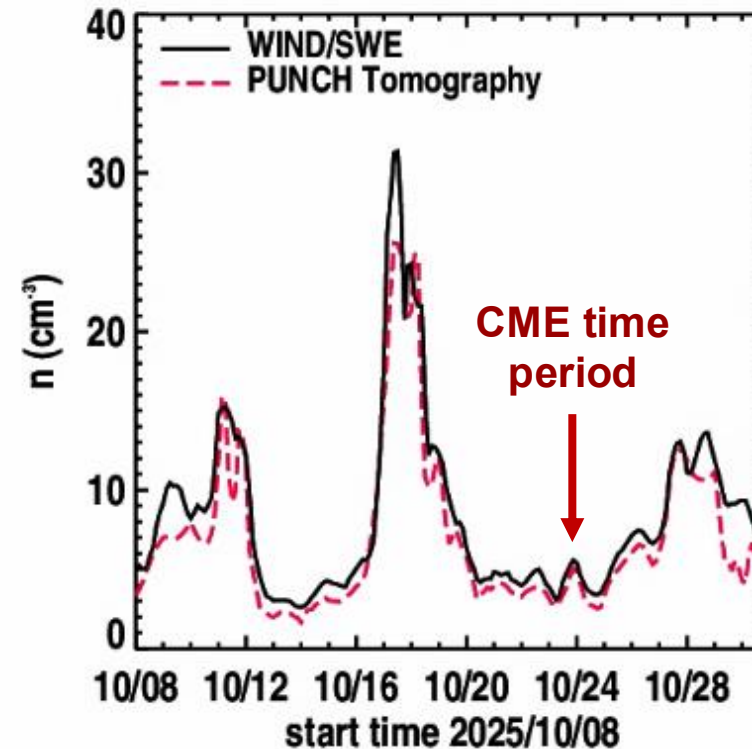
Ecliptic Cut



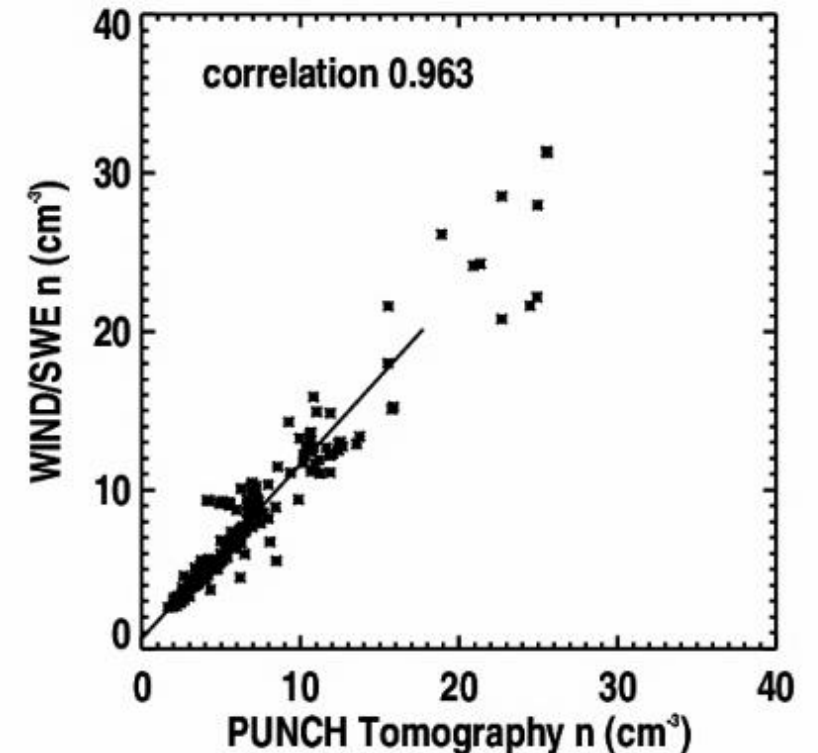
Meridional Cut Through Earth

## CME Time period on October 22, 2025

Low resolution, preliminary result only from heliospheric brightness



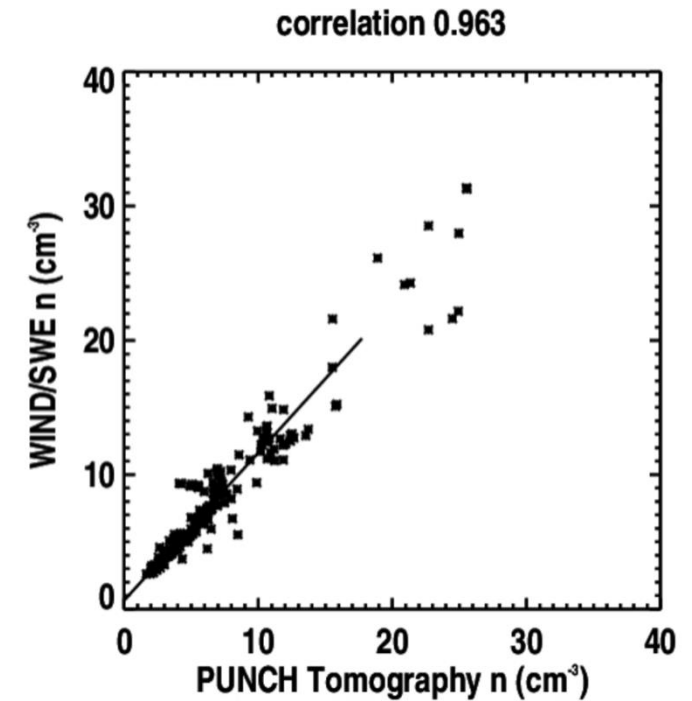
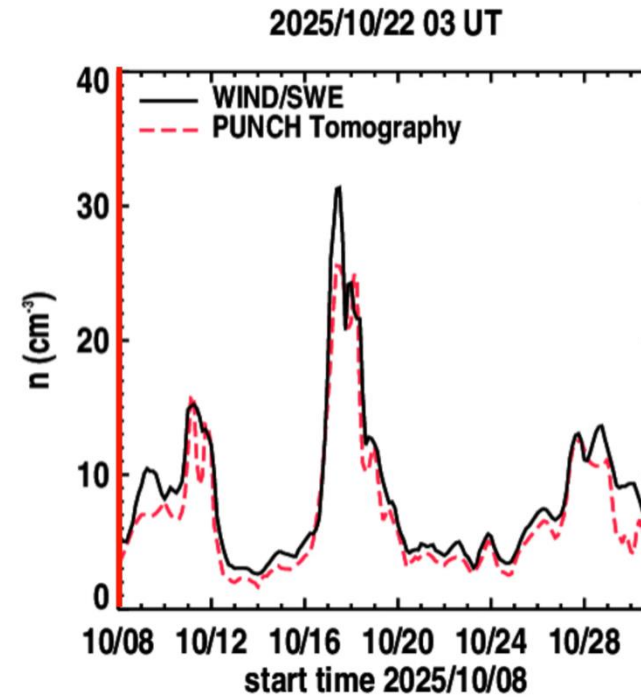
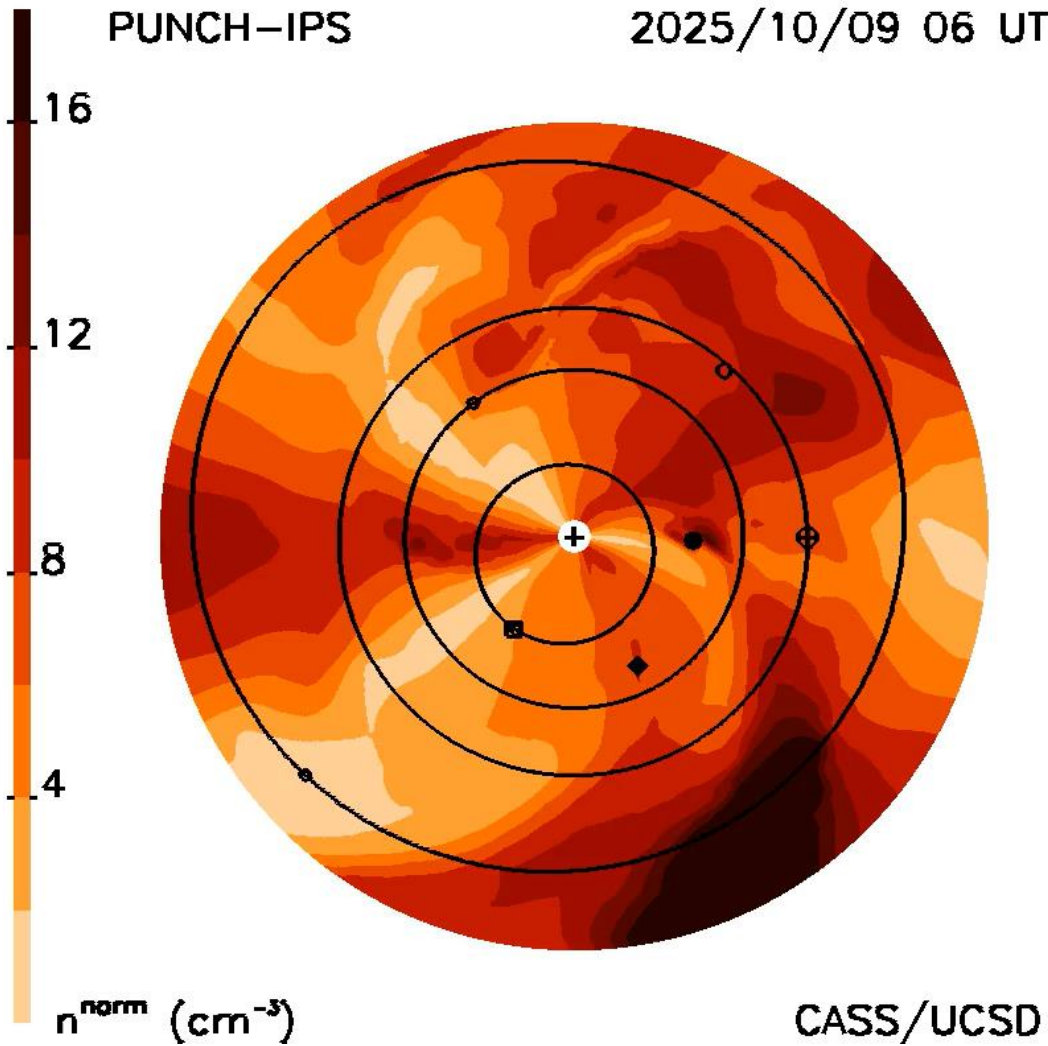
Density Time Series



# 3-D High-Resolution Reconstructions Using PUNCH Images

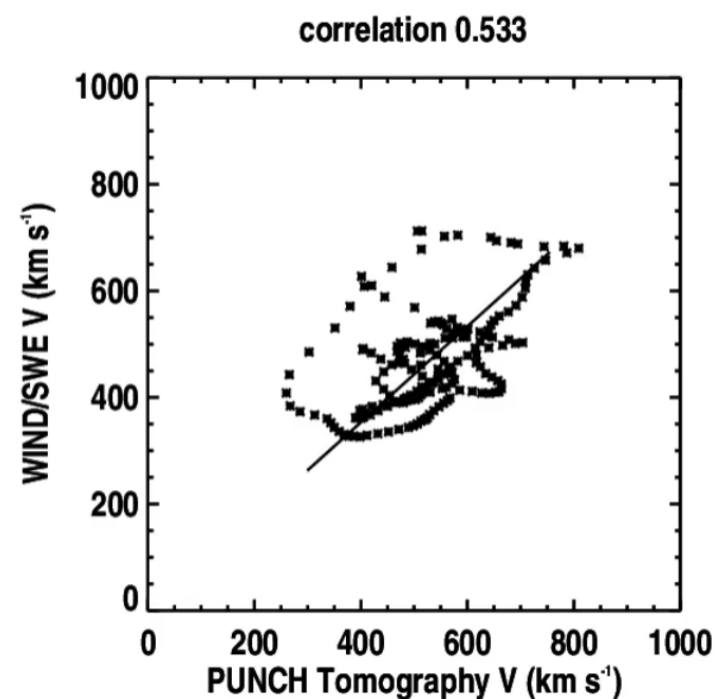
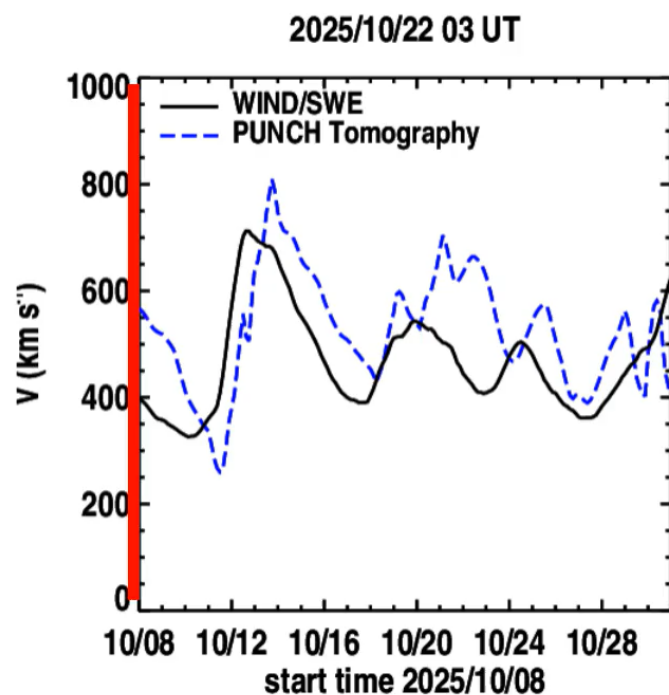
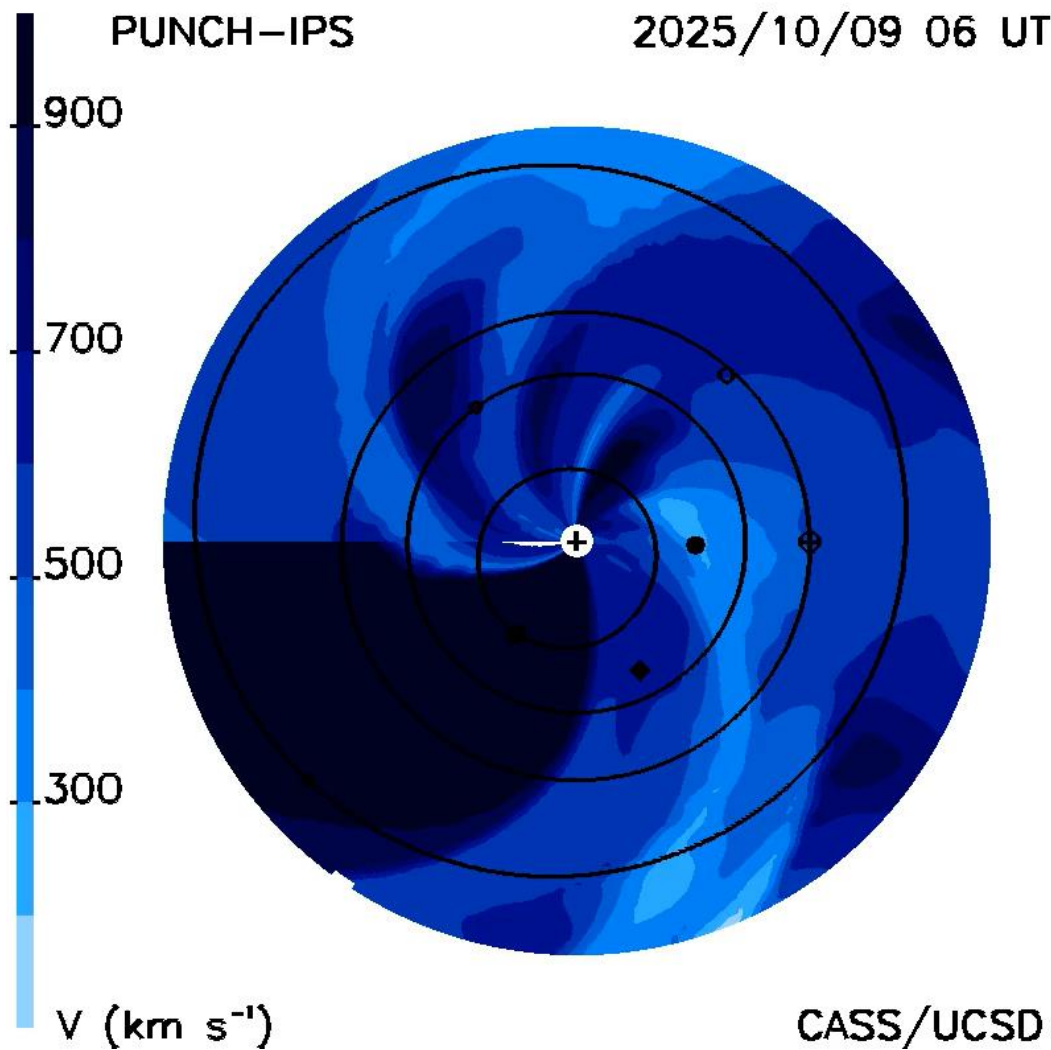
## October 2025 Time Period

## October 2025 Time Period



# 3-D High-Resolution Reconstructions Using PUNCH Images

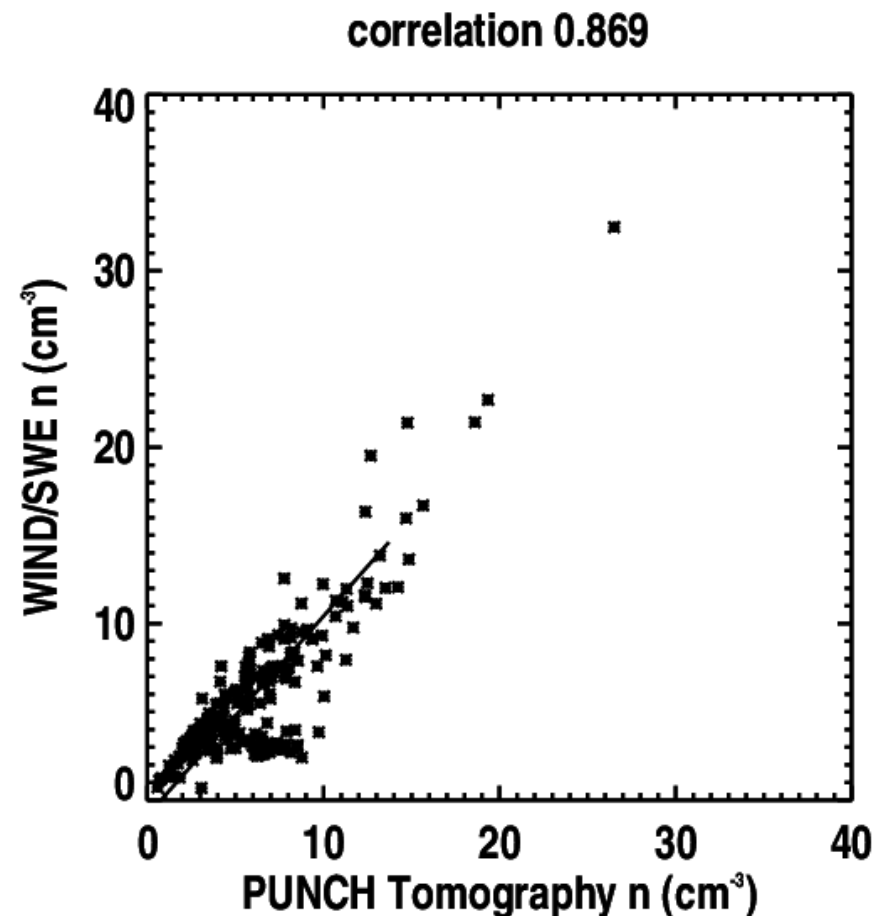
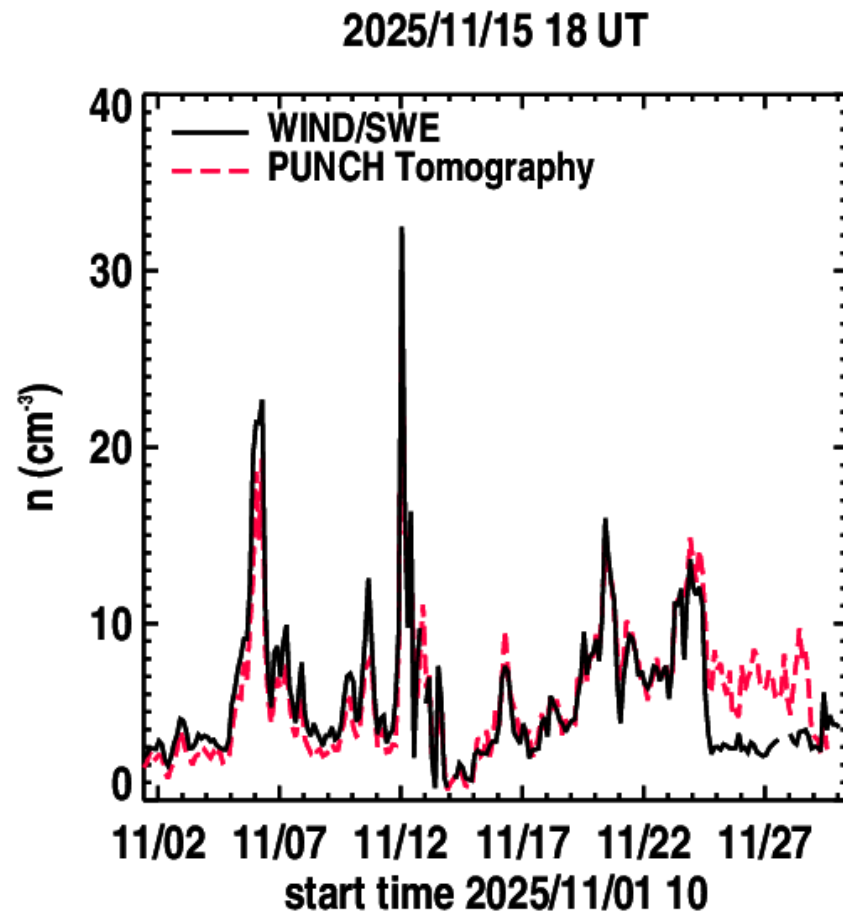
## October 2025 Time Period



# 3-D High-Resolution Reconstructions Using PUNCH Images

Oops, I said **High Resolution** in the abstract

CIM “0i” Data November 2025 Time Period (**2-hour cadence**)



# **3-D High-Resolution Reconstructions Using PUNCH Images**

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## **Summary:**

**PUNCH 3-D iterative time-dependent reconstruction is possible using Helios spacecraft, IPS, SMEI, STEREO HI, and Parker WISPR heritage.**

**This same iterative system can now be accomplished with PUNCH degree of polarization data.**

**In the future these same techniques can be applied in near real time to provide space weather forecasts (“0L” CTM data sets?)**