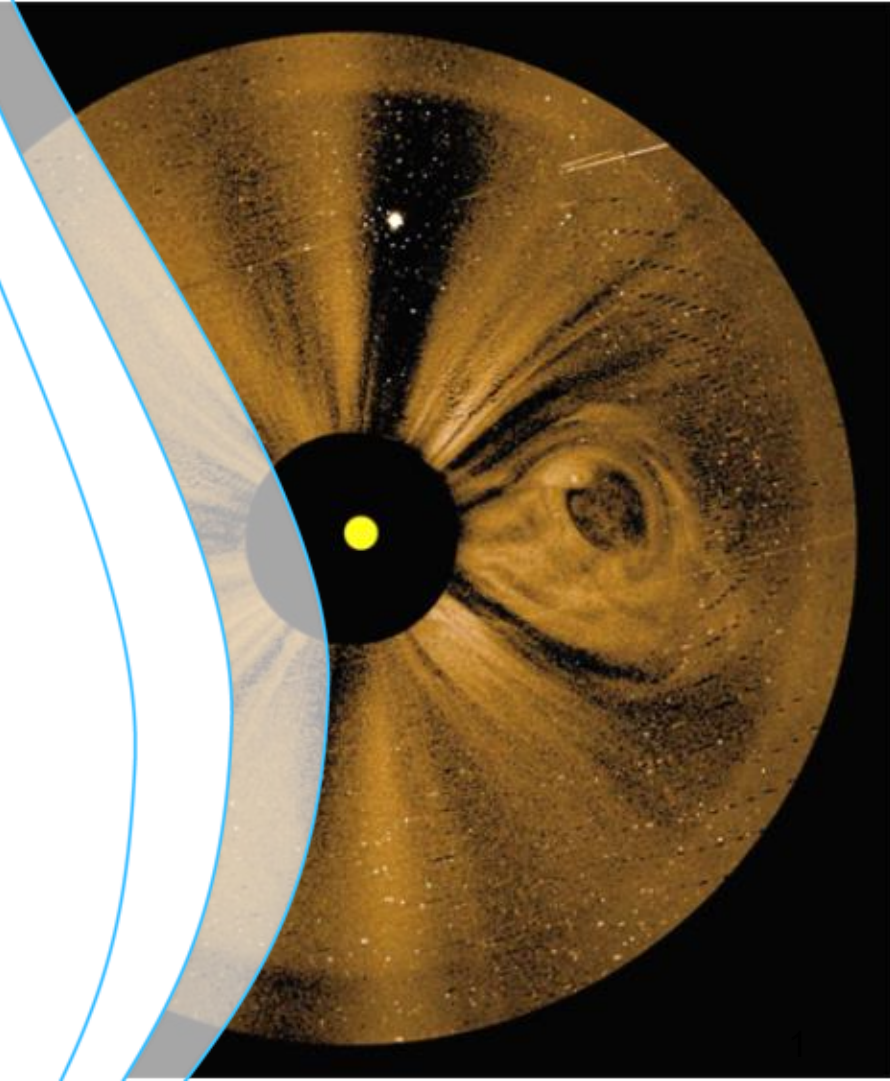
February 11, 2026

The PUNCH Mission: Synergies with Metis

Sarah Gibson, Craig DeForest, and the PUNCH Team

This material is based upon work supported by NASA's Heliophysics U.S. Participating Investigator program, involving U.S. CoIs of PROBA-3 ASPIICS



PUNCH: Global Context

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GOAL: To understand how the Sun's corona gives rise to the heliosphere and solar wind

Track CMEs and SIRs: Sun to Earth in 3D

Measure solar wind: globally in near-real time

DATA: polarized visible-light images, 90° FOV

STRUCTURE:
- four smallsats act as one "virtual imager"
- 650km sun-synchronous polar orbit

LAUNCHED: March 11, 2025.

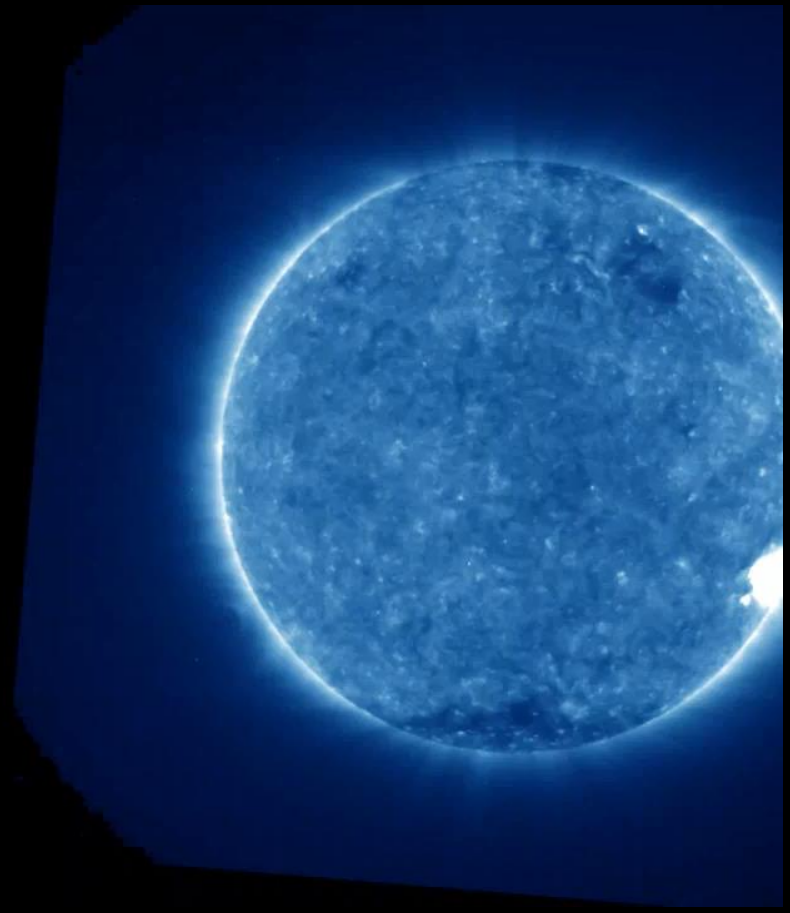
SCIENCE OPERATIONS: started early June (L+90d)

NOMINAL CONSTELLATION: early August (L+140)

Status:
Operational!
All four spacecraft nominal!
Data are flowing!

(Data are preliminary)
(NFI: issue with stray light)

THE SOLAR CORONA DOESN’T REALLY END…



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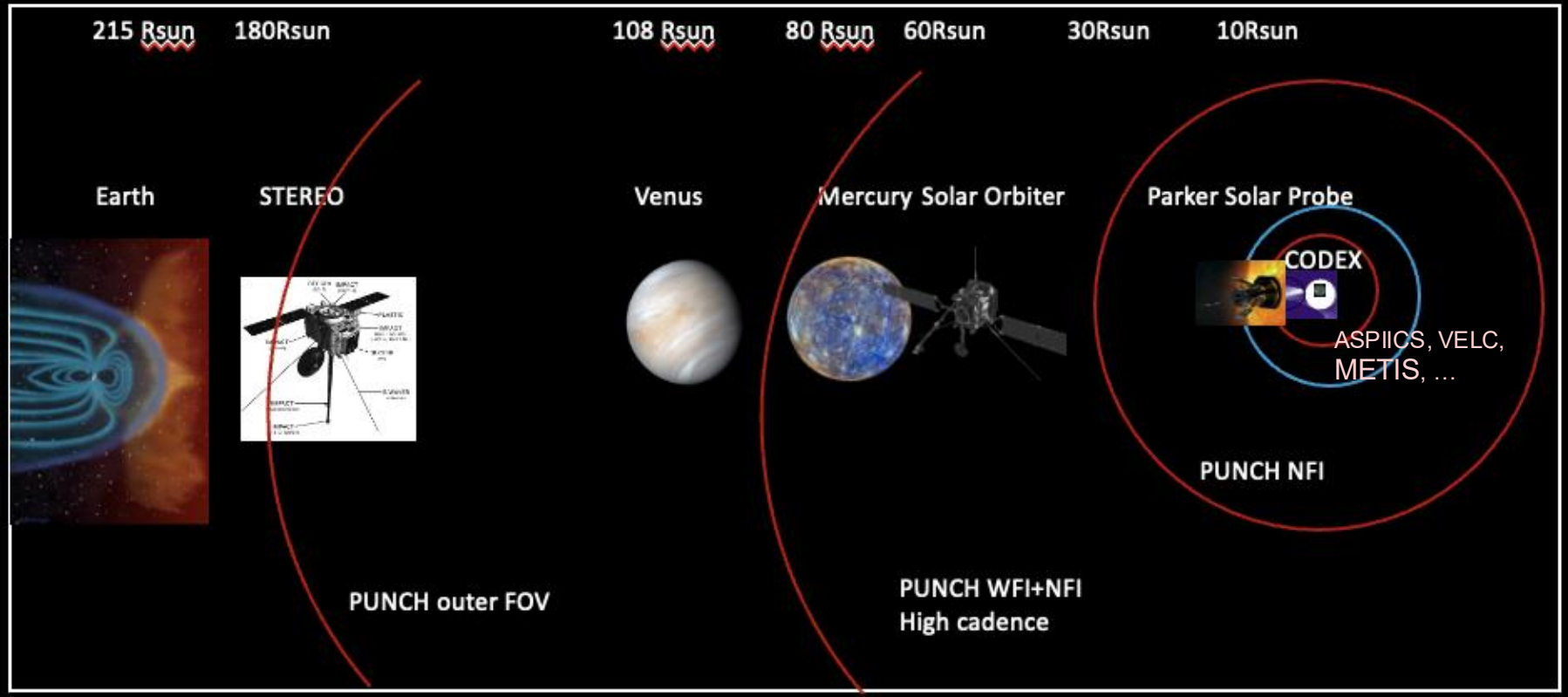
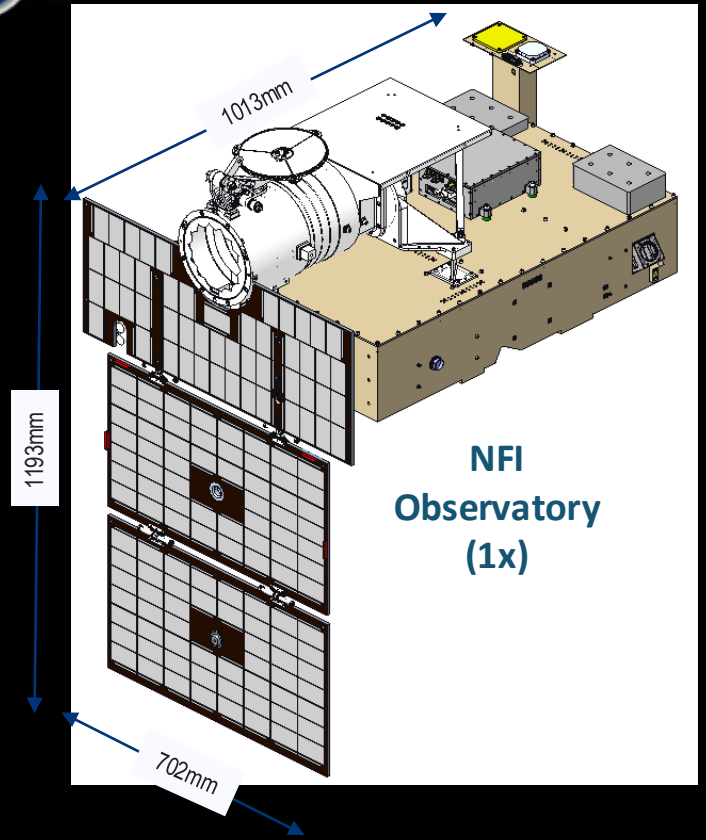
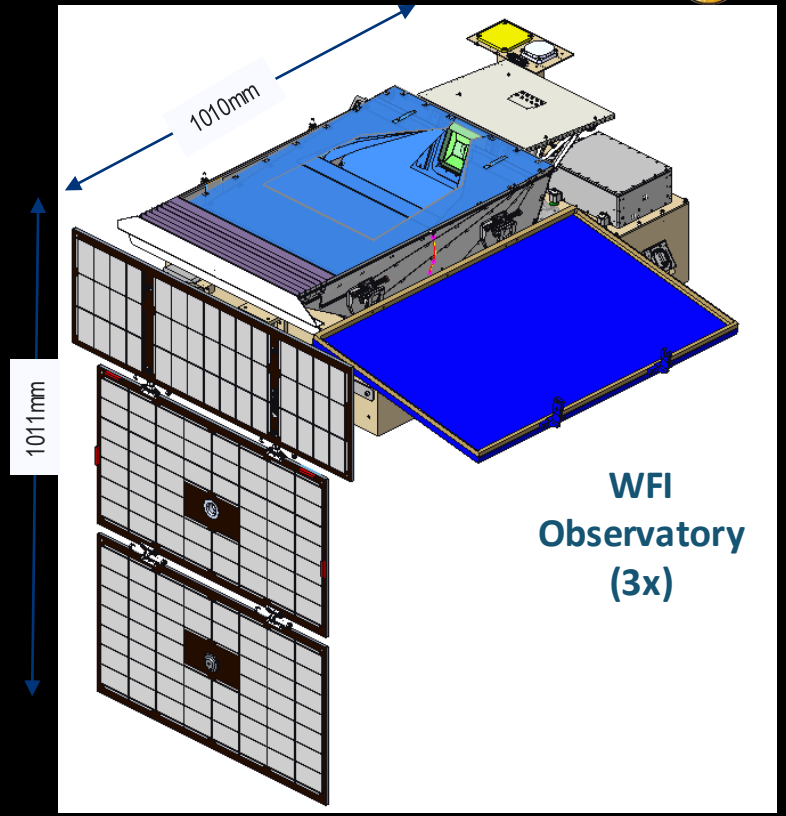


PUNCH: Mission and Instruments

PUNCH Observatories



NFI Observatory (1x)



WFI Observatory (3x)

Each PUNCH spacecraft carries one primary instrument; the spacecraft are interchangeable.

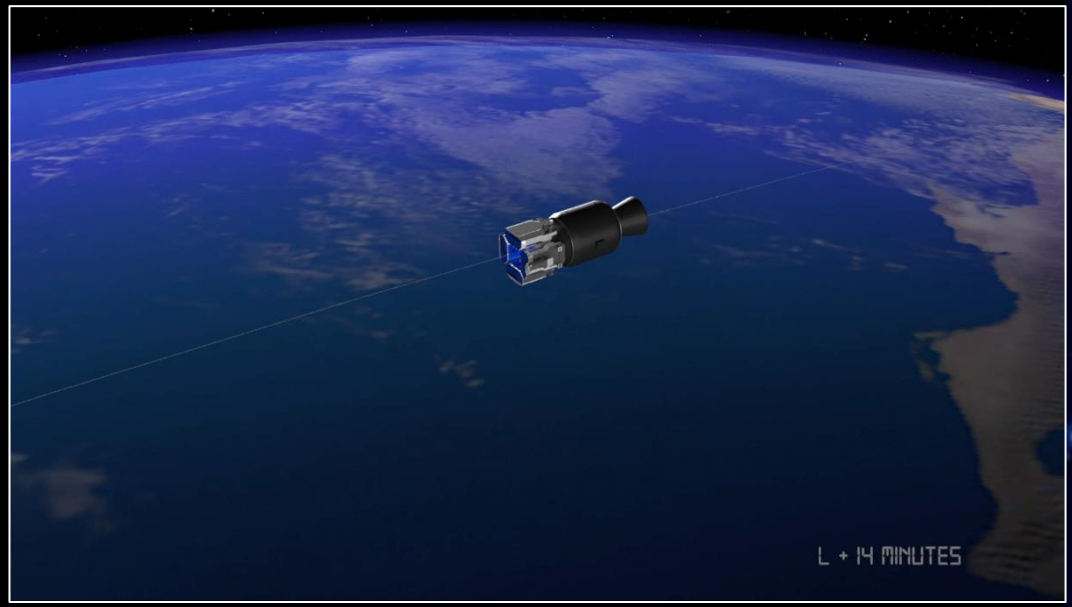
PUNCH Observatories at VSFB

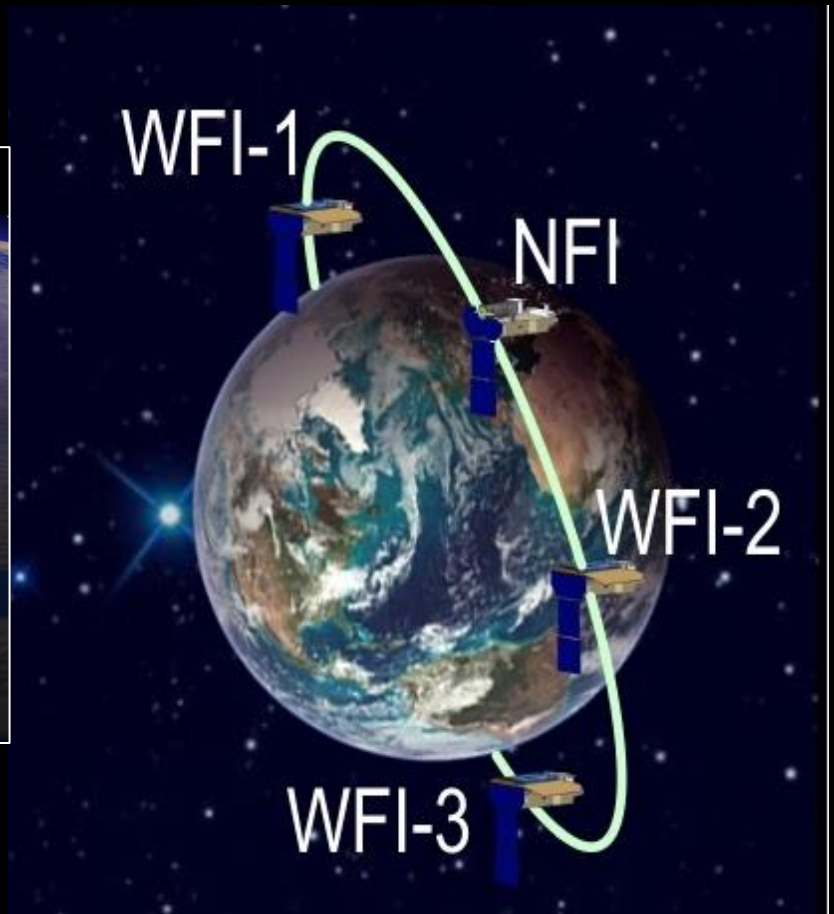
Late February 2025

PUNCH Observatories over Africa

March 11, 2025

PUNCH is now on station!

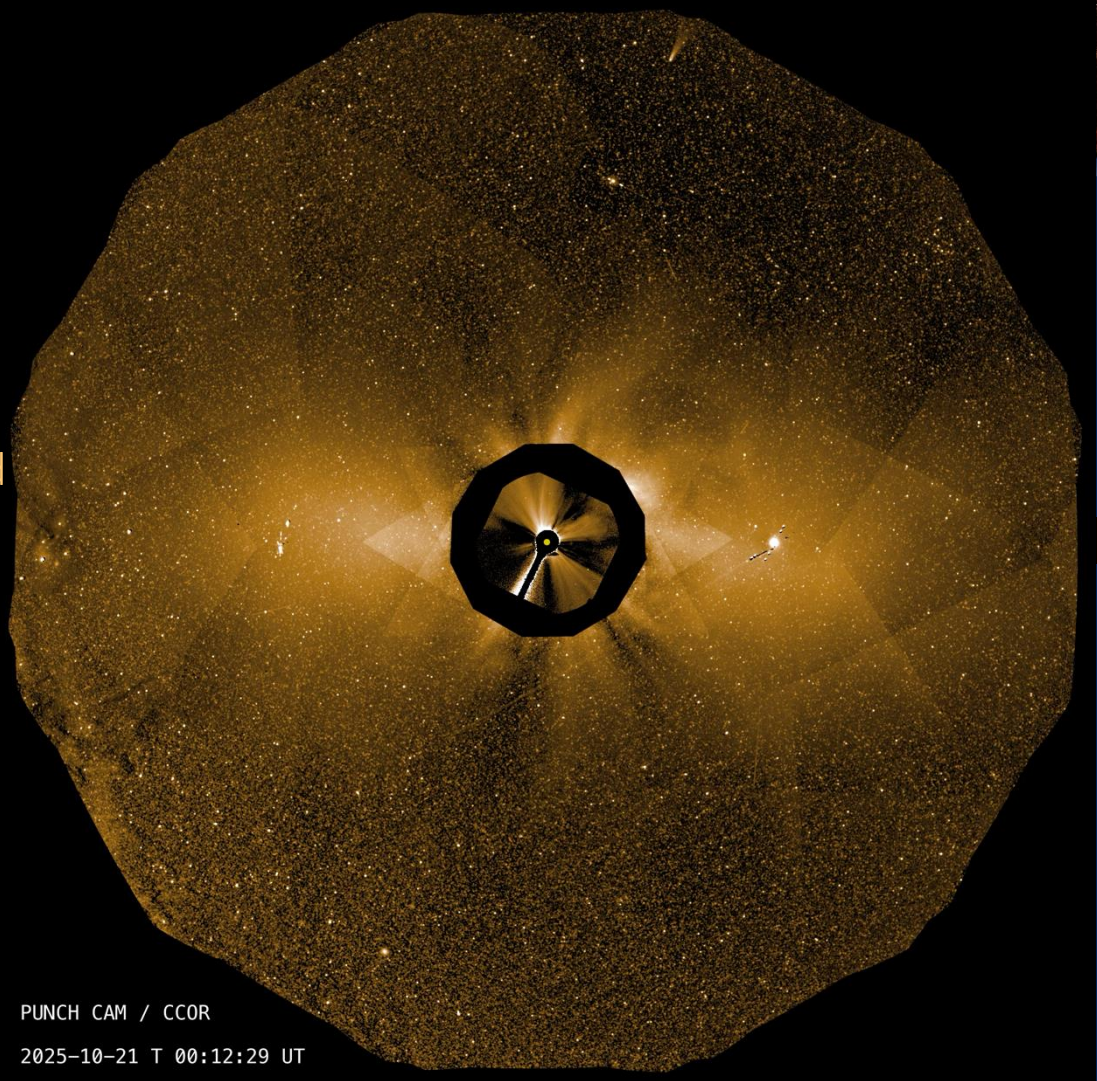




PUNCH Data

PUNCH data show the Sun in context.

- 90° field of view
- This movie: NOAA's CCOR in inner field
- Solar wind streams visible to ~100 Rs
- CMEs visible to 45° from Sun



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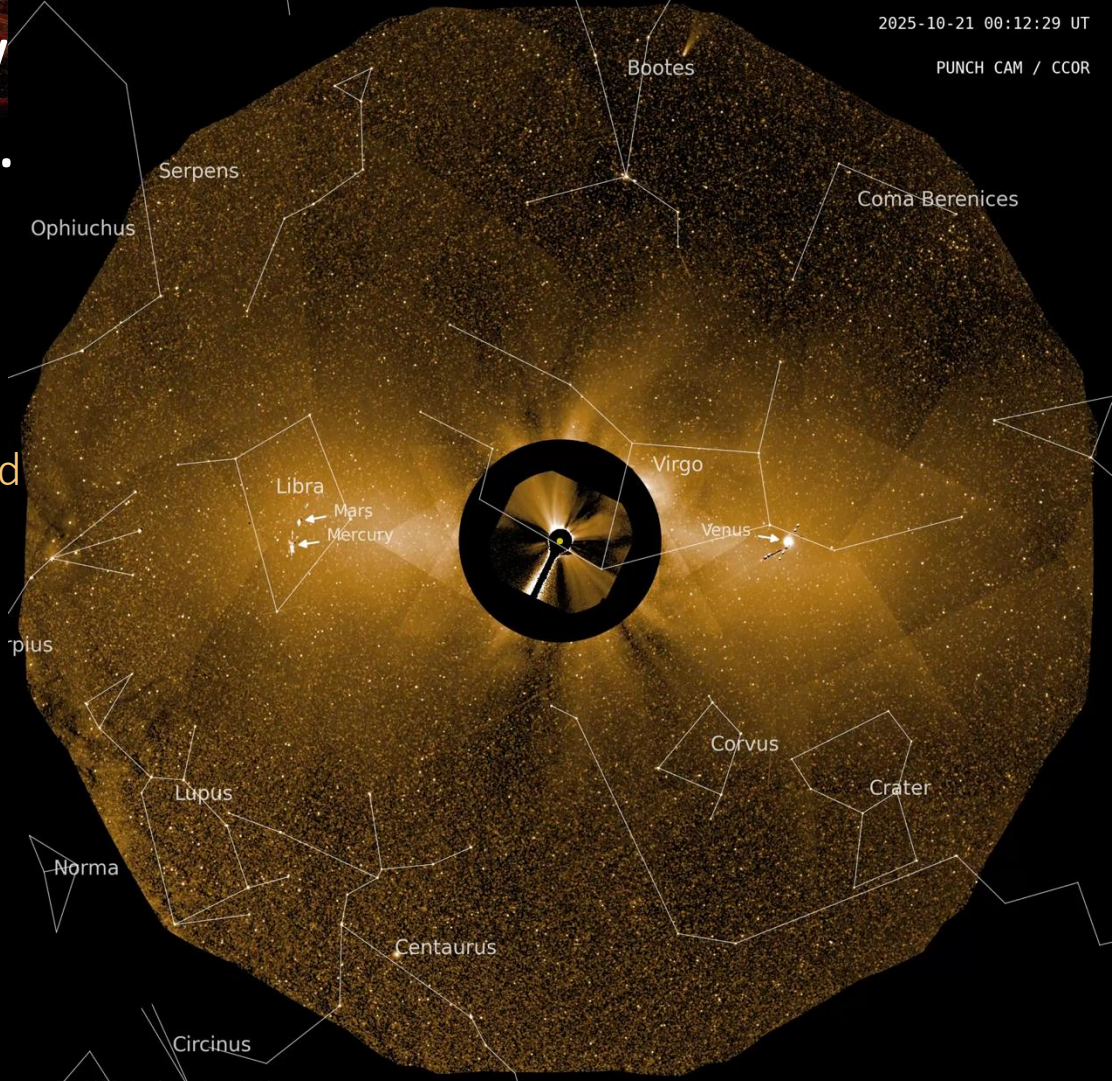
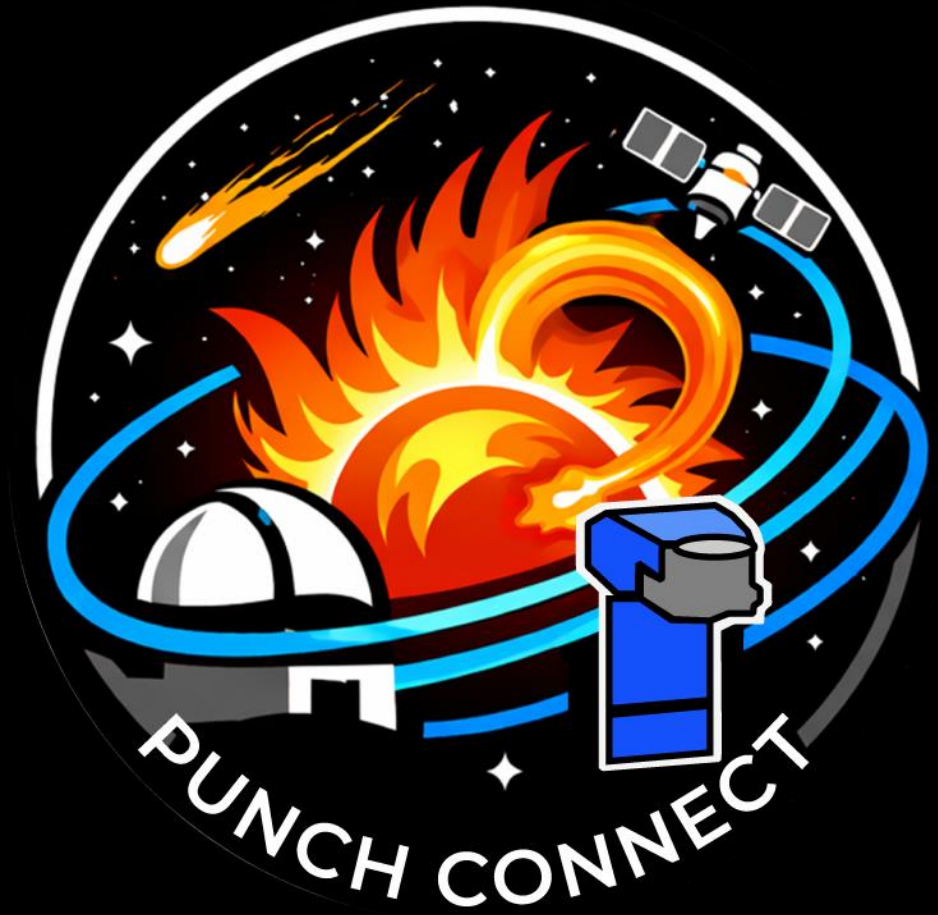


COmmunity Nexus for Noteworthy Event Context and Tracking



COmmunity Nexus for Noteworthy Event Context and Tracking

PUNCH Bimonthly "Sandbox" with 85 attendees, Oct 30, 2025

Halo CME originating **Aug 30, 2025**. Presentations included:

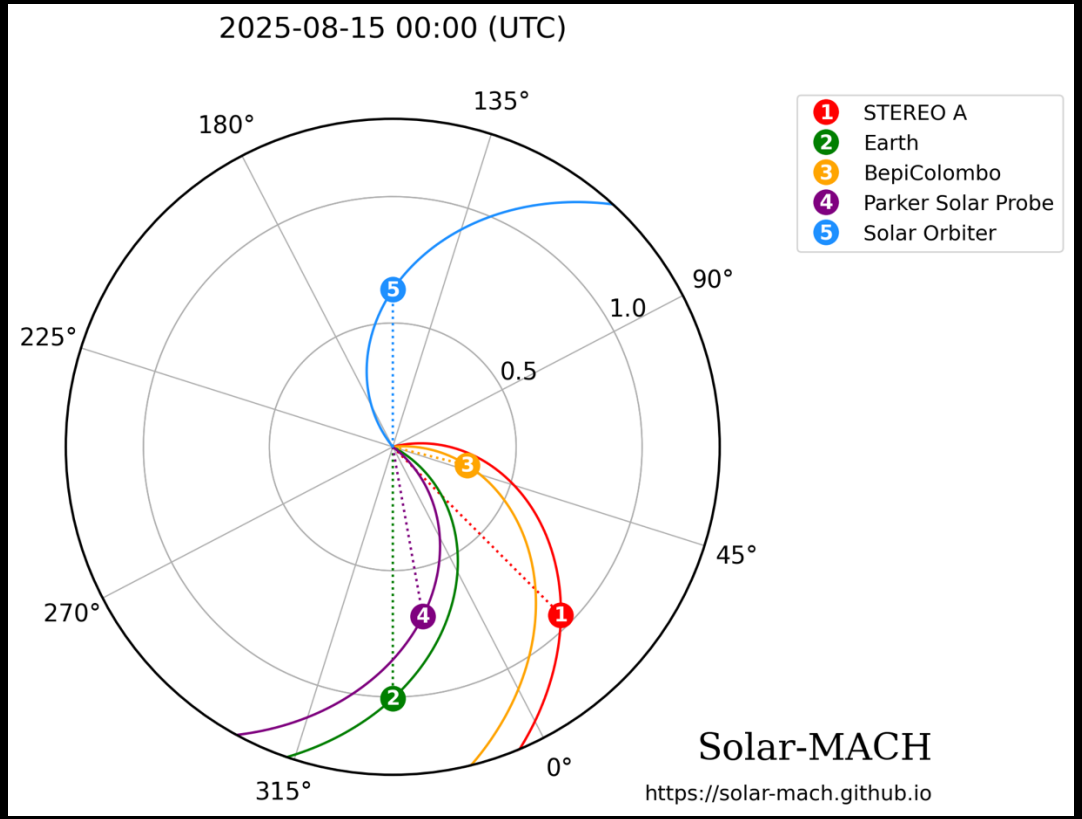
Remote-sensing: SDO, OVRO-LWA, LASCO, STEREO-A, PSP WISPR

In-situ: PSP, STEREO-A, L1-DSCOVR; GFZ Potsdam

Models: GONG-PFSS, CCMC Enlil, ELEvo, 3DCORE (flux rope fitting),

ICME shock analysis, tomographic prediction

PUNCH + ASPIICS + METIS + CODEX: August 15 2025



15 August 2025

Solar Orbiter – Earth : superior conjunction

SolO @0.63 au, 7° from the ecliptic

Metis FOV: 3.8-6.9 Rsun

Metis Observing Programs : Synoptic (1 pB + 1 UV; cadence 1800 s; binning 4x4) + Synoptic (1 pB + 1 UV; cadence 120 s; binning 2x2)

ASPIICS Observing Program : CME Watch, WBF every 30s (3 exposures) + all filters every 5 min

Courtesy N. Viall

Abundant Candidate Events

15 August 2025: ASPIICS/Metis/PUNCH/CODEX
30 August -1 September 2025: Multiple missions
21-22 September 2025: ASPIICS/Metis/PUNCH
31 October - 11 November 2025: *****?
January 10; 18-24 2026: ASPIICS/Metis/PUNCH

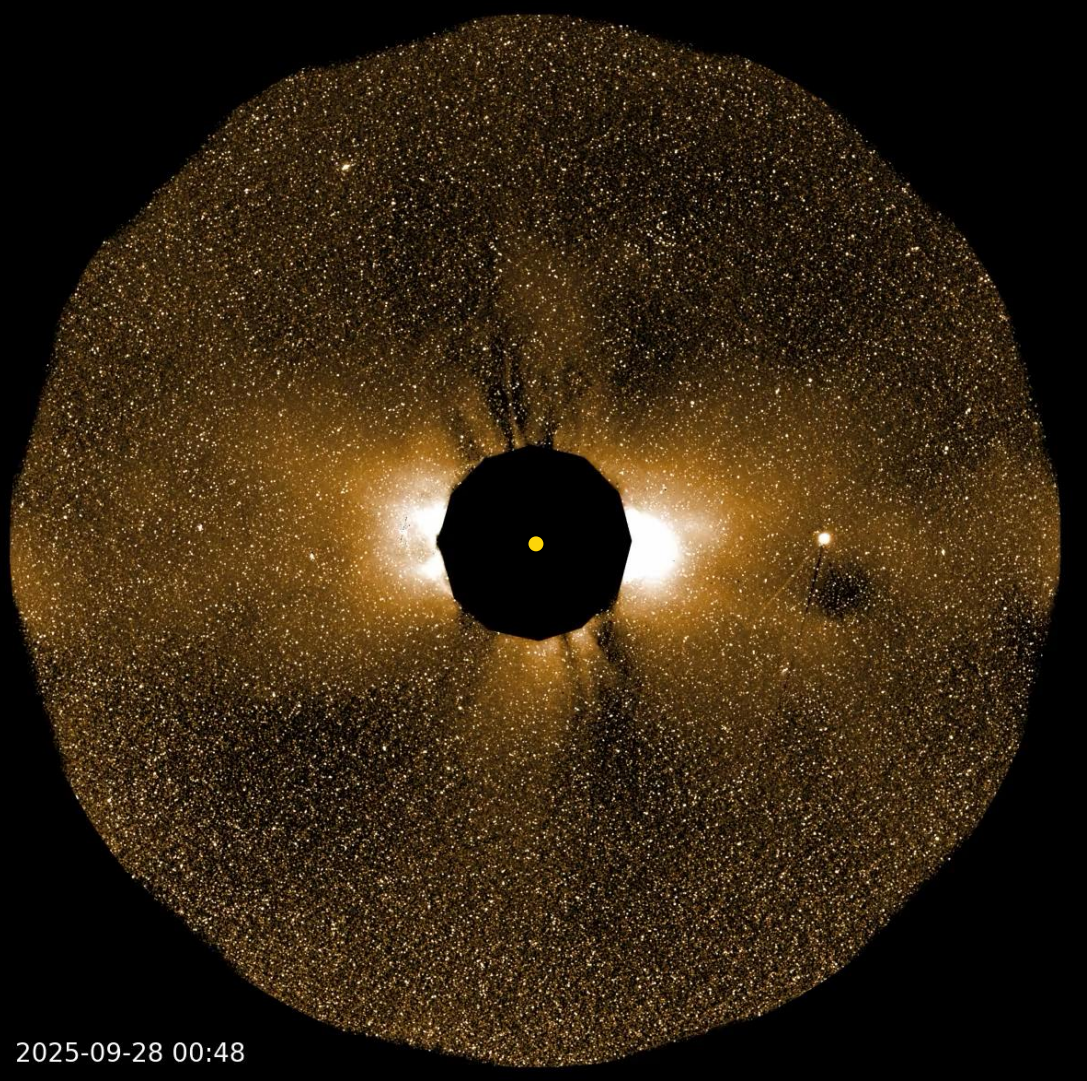
How do I join PUNCH Connect?

Indicate interest via Google form: https://forms.gle/QmLy83GdMQPpYt1C7
(can find link to form on our web page)

Juliet is the Sun…

- Latest update: **“v0j” shipped to NASA SDAC**
  - Directly downloadable and on NASA/VSO
  - Refinement in progress
  - v0k expected March 2026 will include NFI
  - v1 data expected April-May 2026

- **https://punch.space.swri.edu**
  - Tutorials & reference guides
  - Presentations & publications
  - Data links

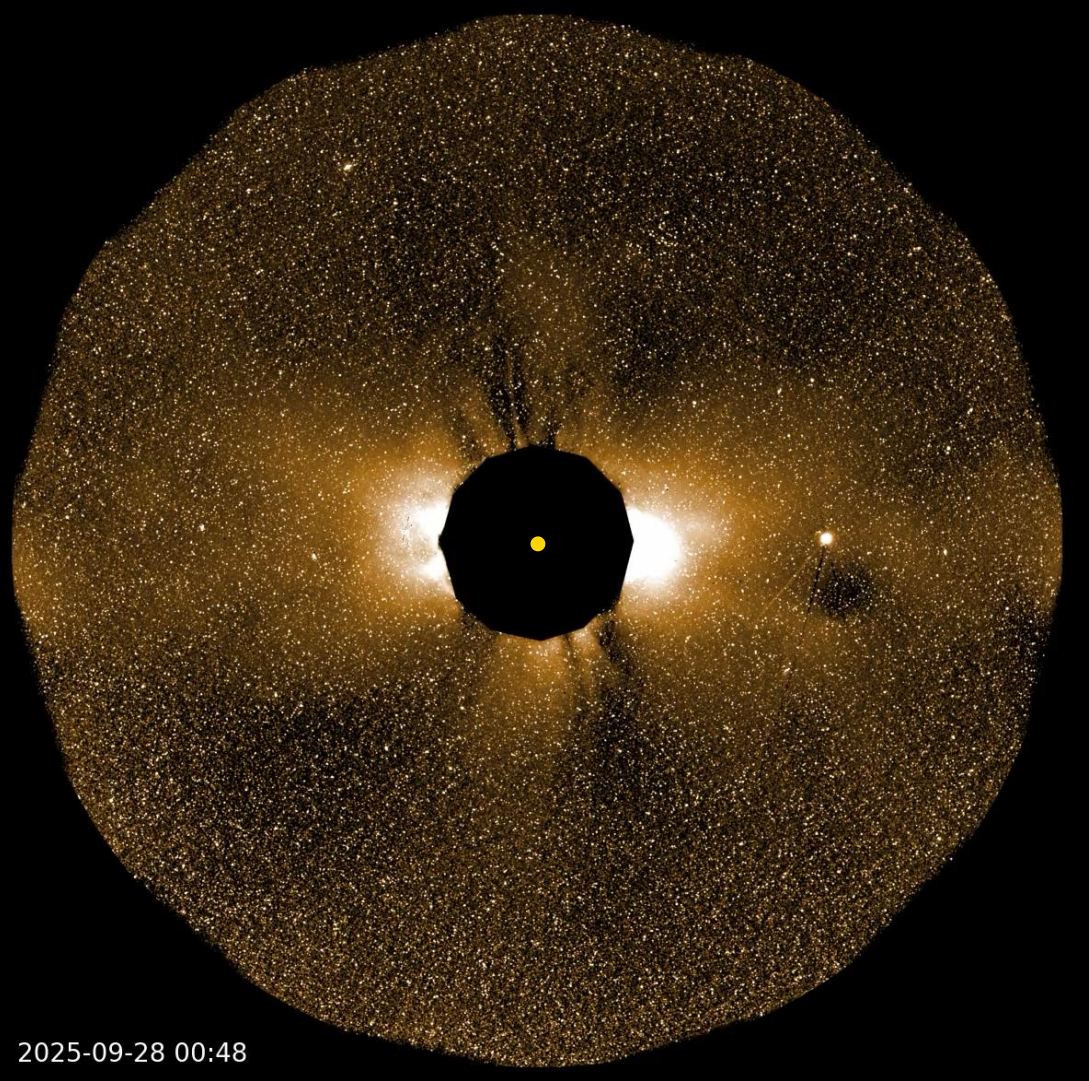


Get Involved!

https://punch.space.swri.edu

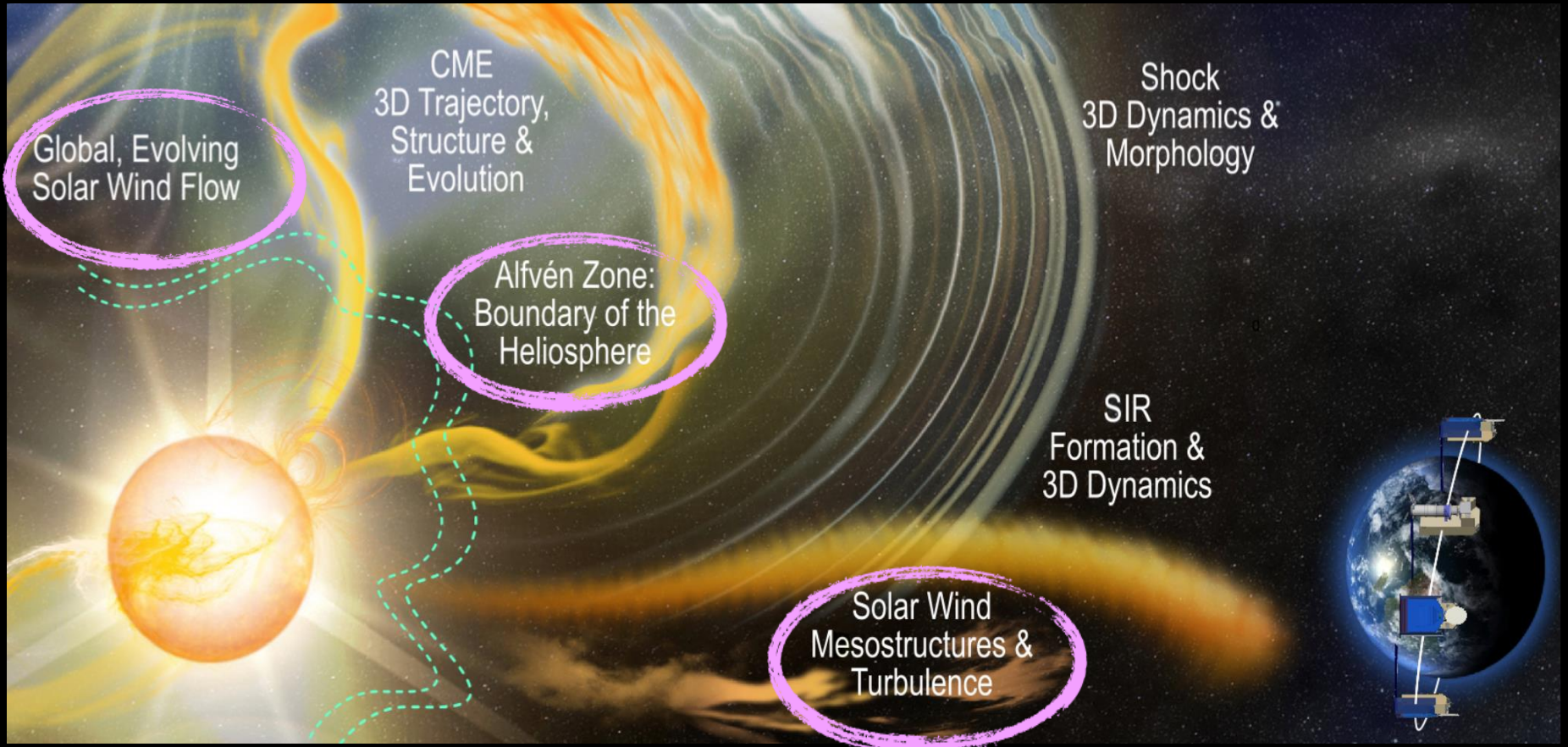
punch-science mailing list
(contact punch-help@mailman.boulder.edu)

- Sign up for bimonthly science telecons
- PUNCH CONNECT
- PUNCH 7 in Boulder, May 12-14 2026

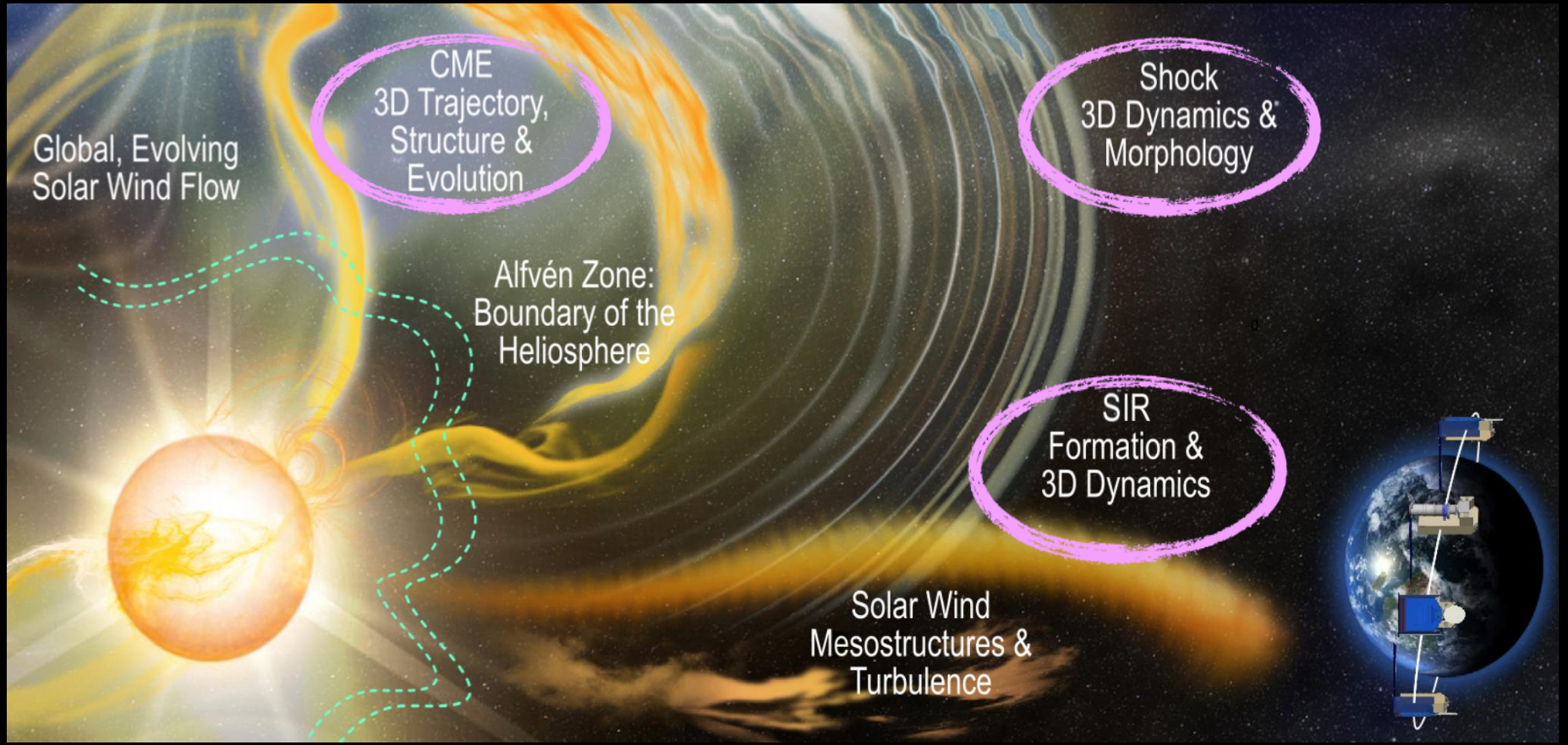


PUNCH Science

The Big Picture on the Young Solar Wind



The Big Picture on the Young Solar Wind



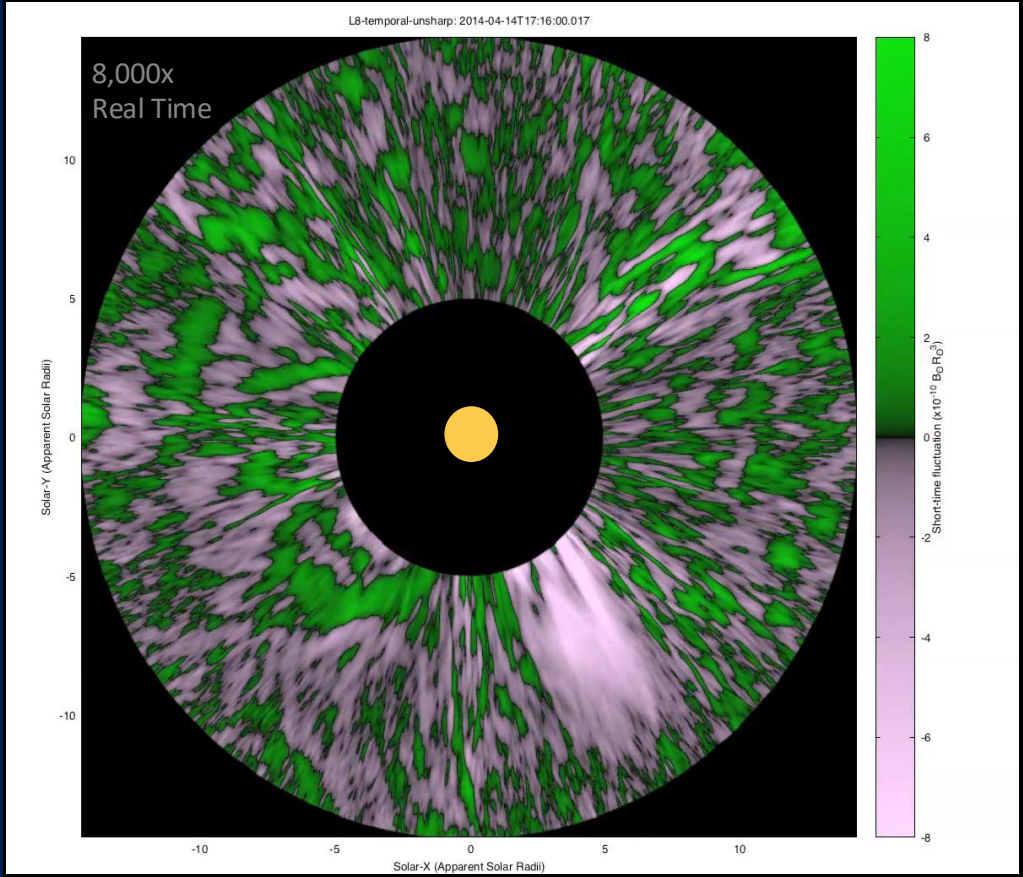
PUNCH Science Data: Flow Maps

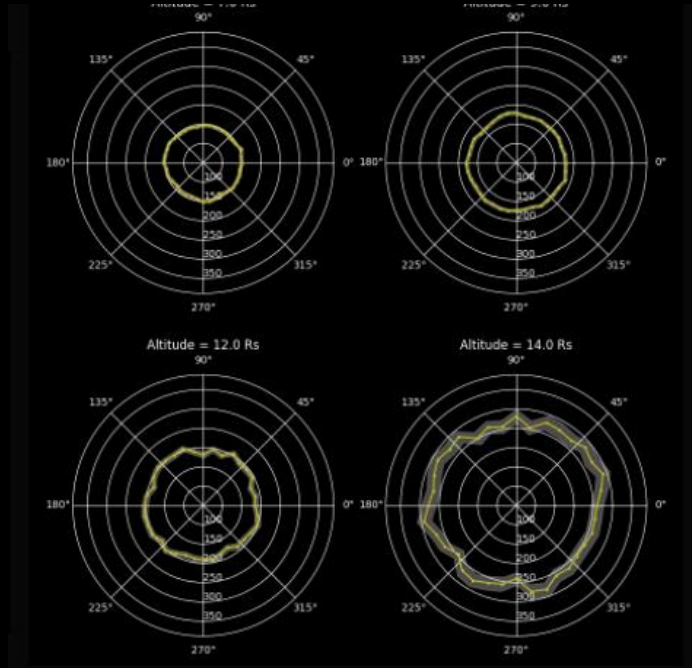
How much and what types of mesoscale structures are solar in origin, and how much and what types develops en route?

What is the global context of the interface between corona and heliosphere, the frothy Alfven zone that Parker is flying through?

How do SIRs and CMEs move and evolve in the solar wind?

PUNCH Solar Wind Speed Maps

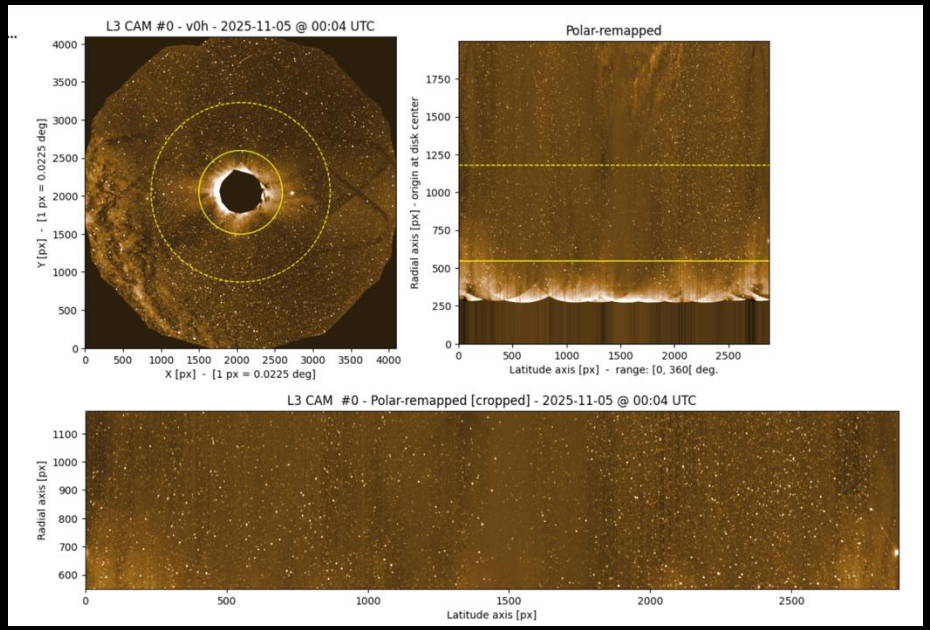


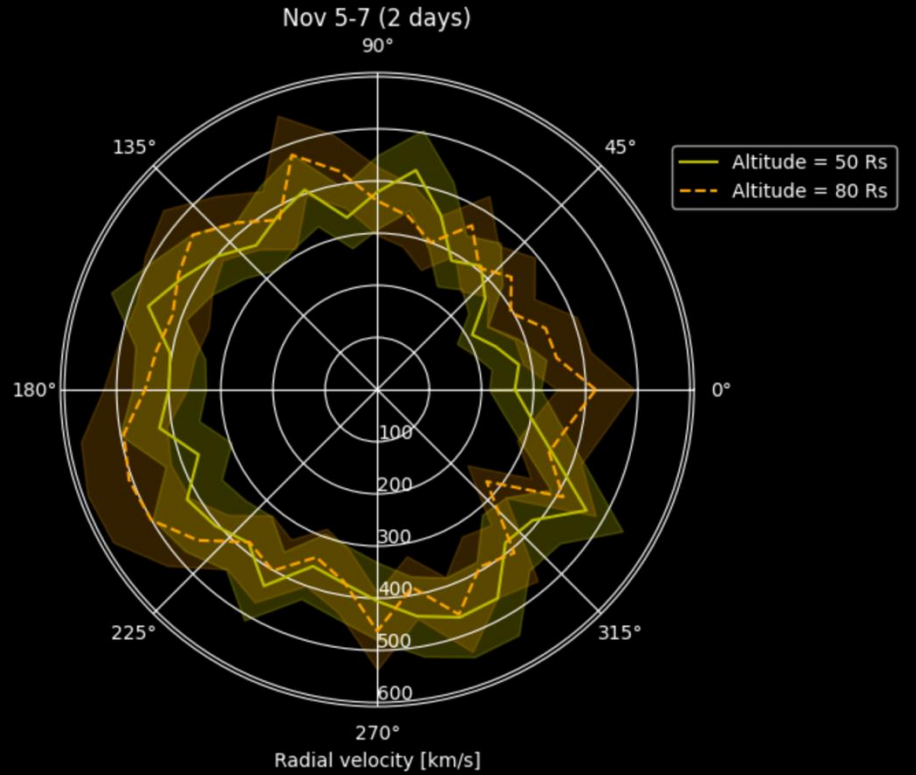


- Correlation-based radial flows:
  - @SOC: Ring-Average radial speed of the ambient solar wind over at least 4 different radial bins between 5 to 80 Rs, 6-hr cadence, over 1440 latitudinal bins.

R. Attie

PUNCH Solar Wind Speed Maps





R. Attie

PUNCH Science Data: Polarization

What are CME 3D trajectories/arrival times at Earth?

What is the 3D structure (and substructure) of CMEs and SIRs?

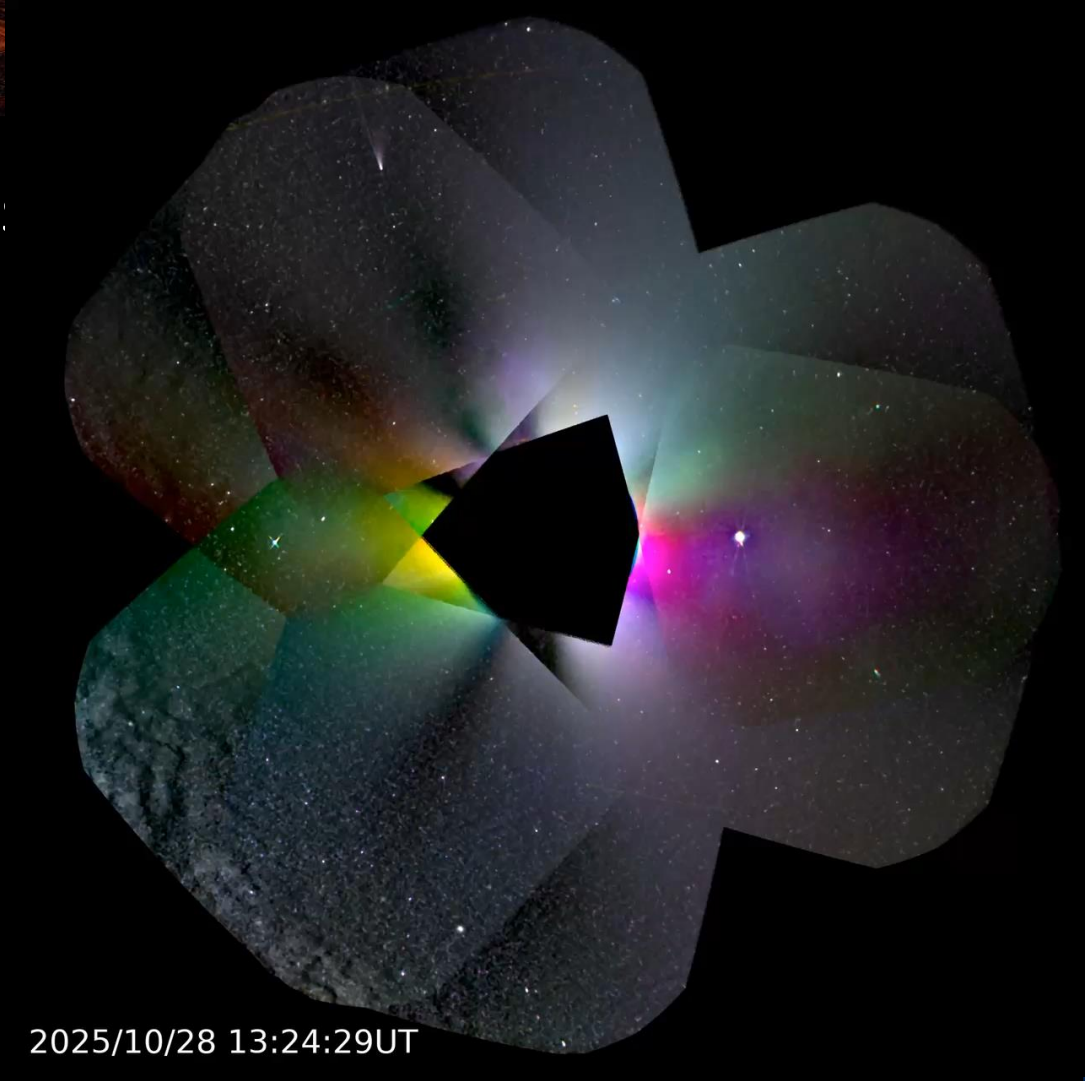
How does solar wind dimensionality vary?

PUNCH preliminary polarimetry reveals CME

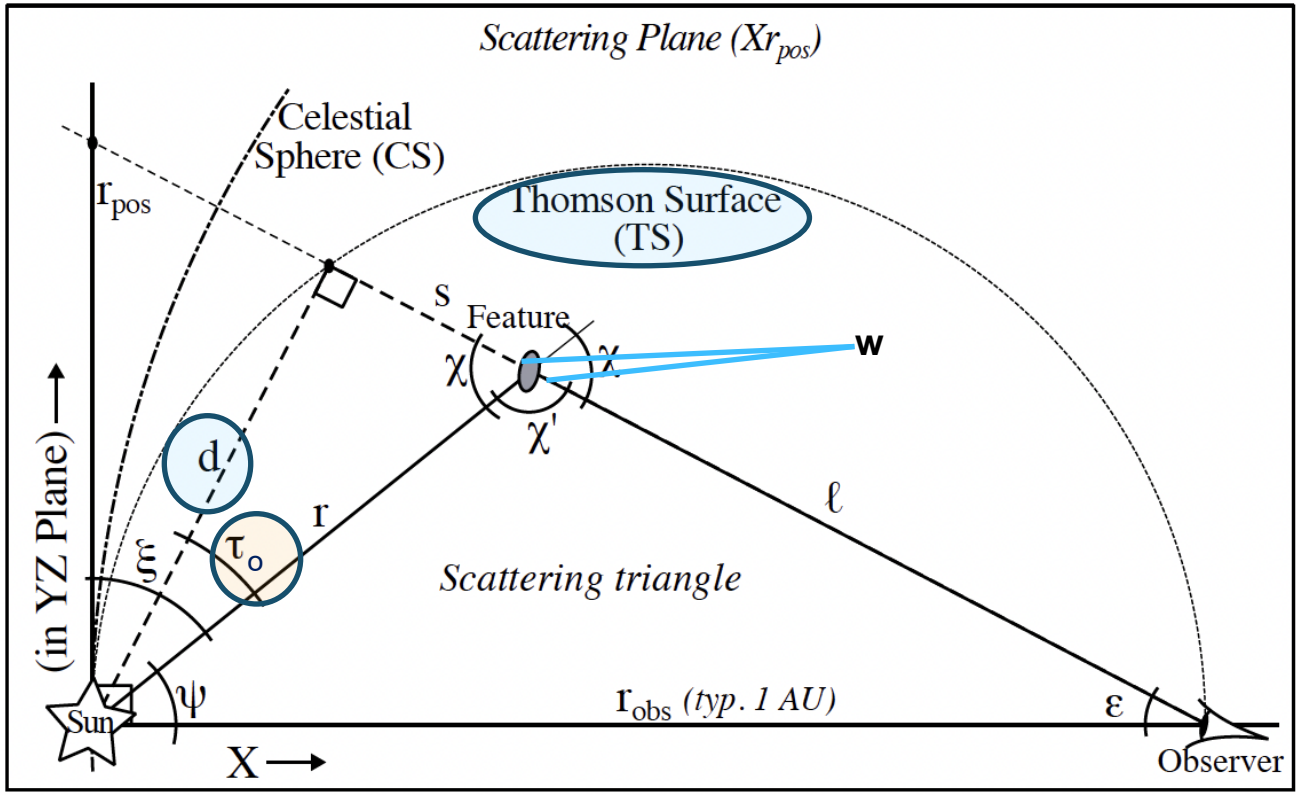
- Preliminary product uses HSL encoding

- Hue: direction of polarization
- Saturation: degree of polarization
- Lightness: brightness

- CME is visible and strongly polarized



Polarimetry: The P in PUNCH



$$PR = \frac{tB - pB}{tB + pB} = \frac{1 - p}{1 + p}$$

$$\tau_{pol} = \text{asin}(\sqrt{PR}) = |\tau_o|$$

- Angular distance along LOS for localized feature
- Unsigned – could be in front/behind TS

- Features may considered localized if:

$$\frac{w}{d}\cos^2(\tau_o) << 1$$

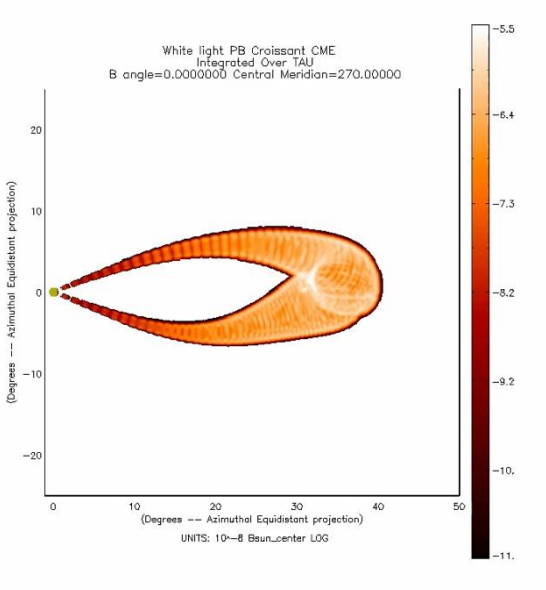
Gibson et al., SP, 2026

Polarimetry: The P in PUNCH

Finding 3D location of CME edge

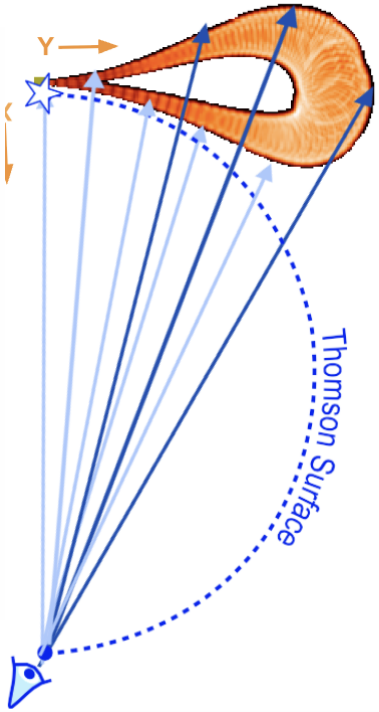
Twisted croissant model

Thernisien 2011; Hutton & Morgan 2015; 2017

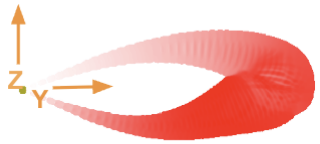


Gibson et al., SP, 2026

View from North Pole

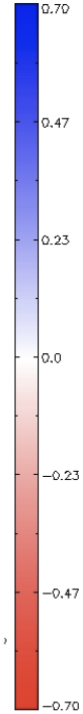


View from Observer



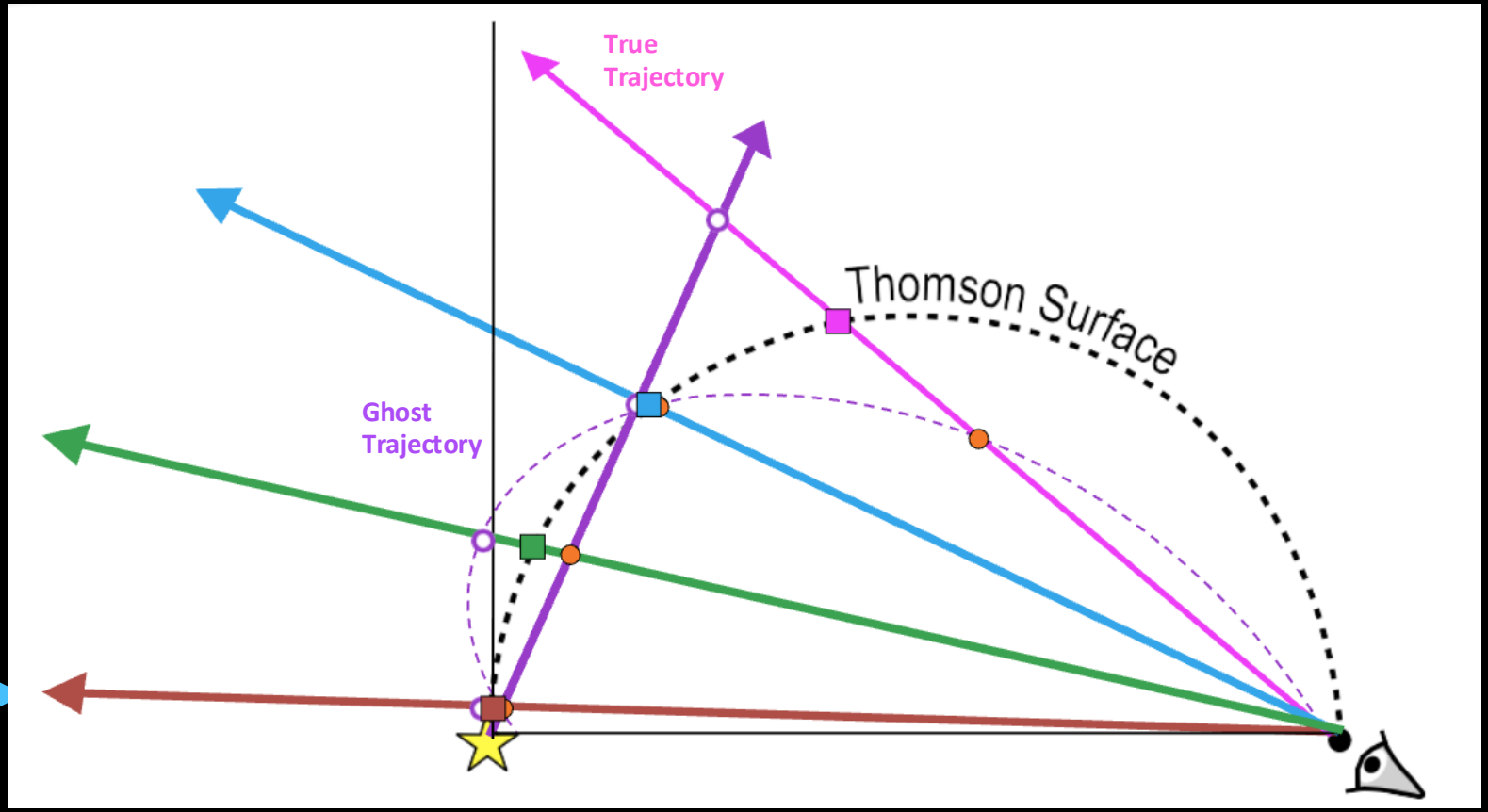
Ground truth τ position along line of sight

Unsigned τ position along line of sight inferred from polarization ratio (shown in same negative color table as τ_{COM})



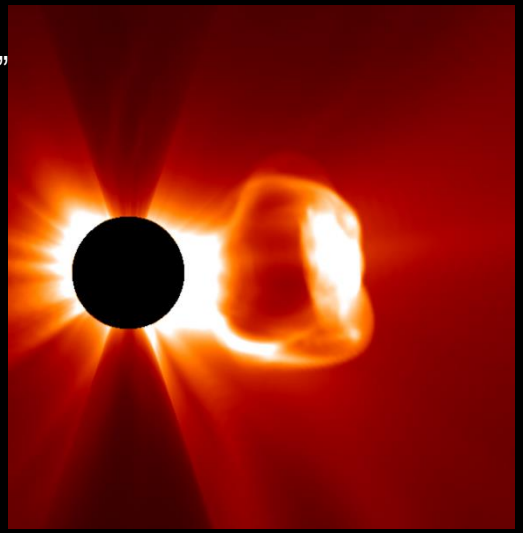
(distance from Thomson Sphere in radians)

Ghostbusting!



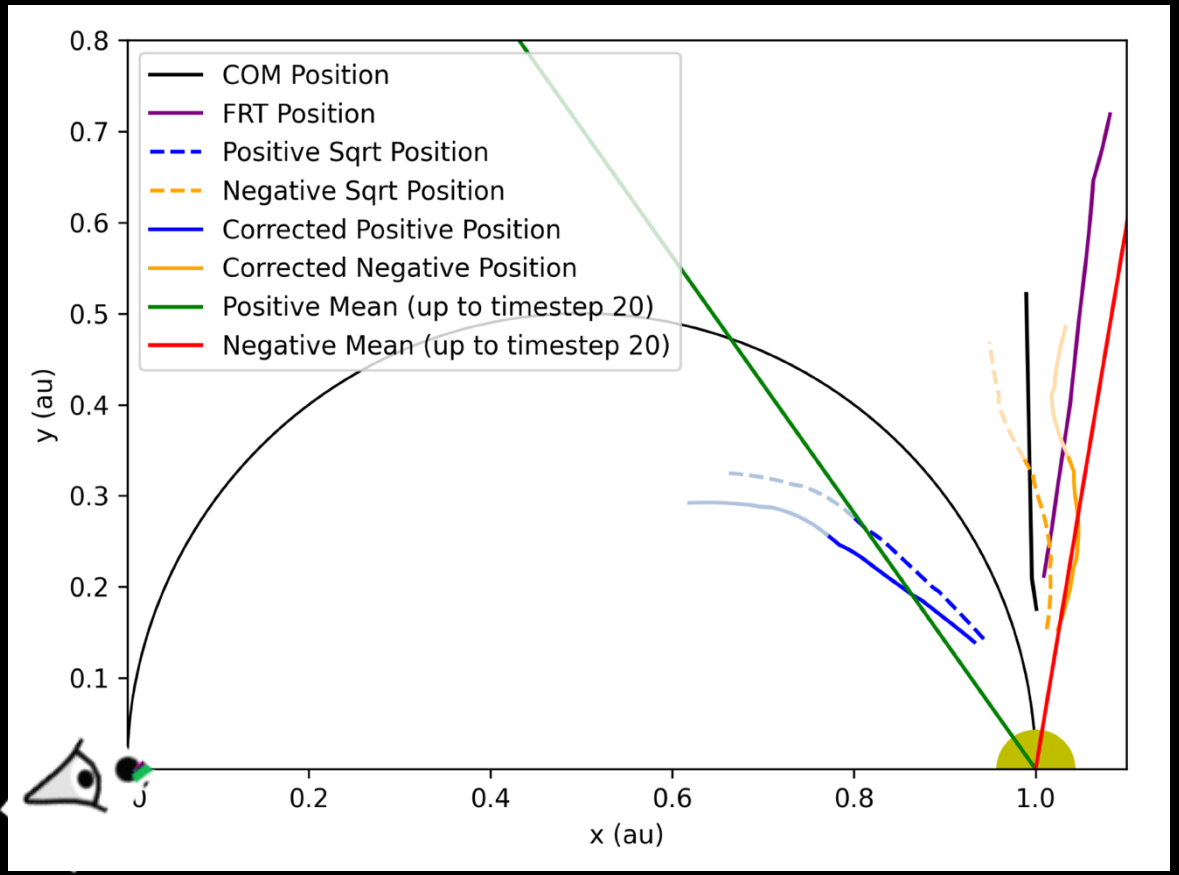
Polarization Diagnosing CME Trajectory

lenge”



- “Ground truth”: purple / black
- Blue: “Ghost solutions” (ruled out: non-radial)
- Yellow: best estimate location from inversion

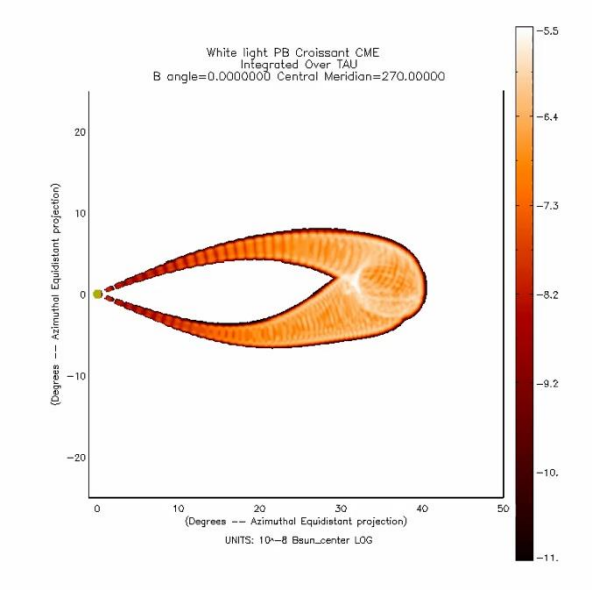
(N. Laurent, 2024)



Polarimetry: The P in PUNCH

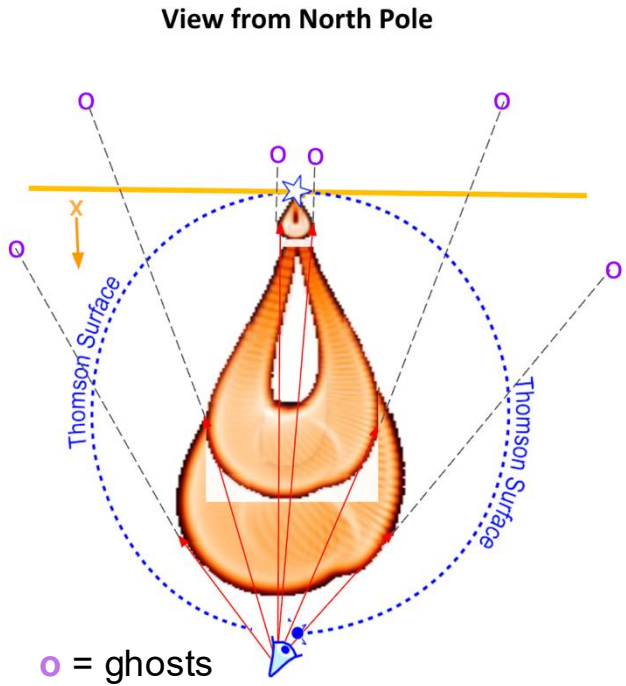
Twisted croissant model

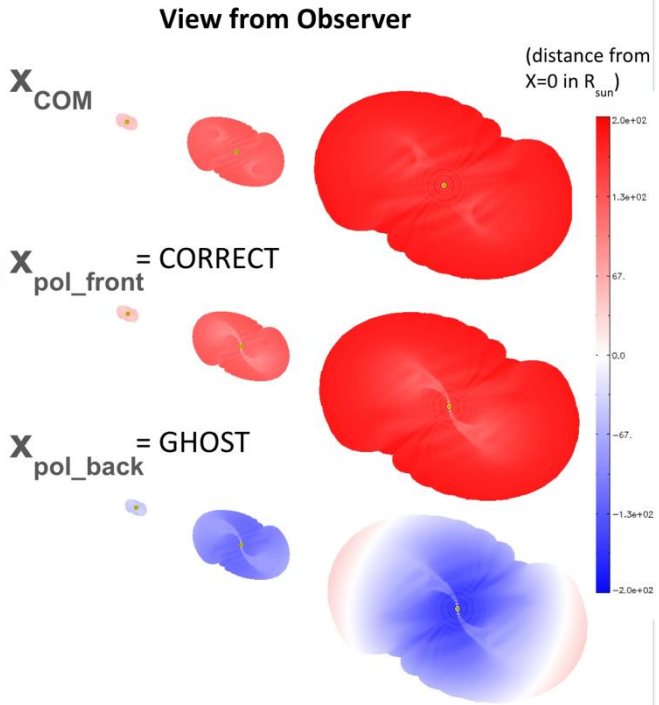
Thernisien 2011; Hutton & Morgan 2015; 2017



Gibson et al., SP, 2026

Disambiguating Halo CMEs: Front-back *x_pol*





If both front and back are positive anywhere, must be Earth-approaching

Polarimetry: The P in PUNCH

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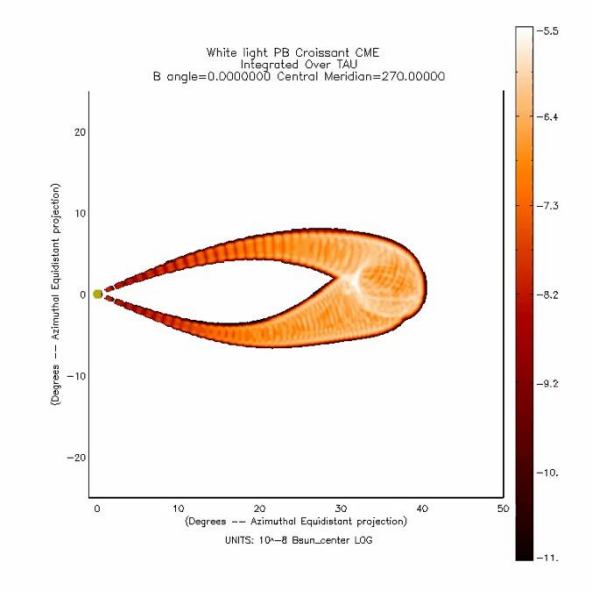
Thernisien 2011; Hutton & Morgan 2015; 2017



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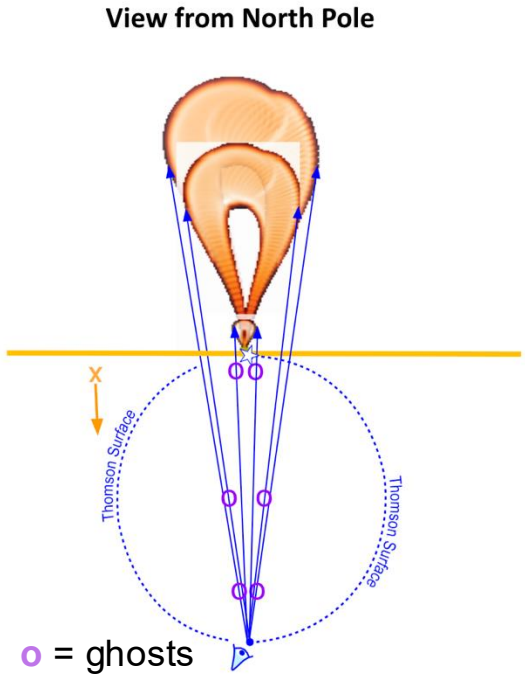
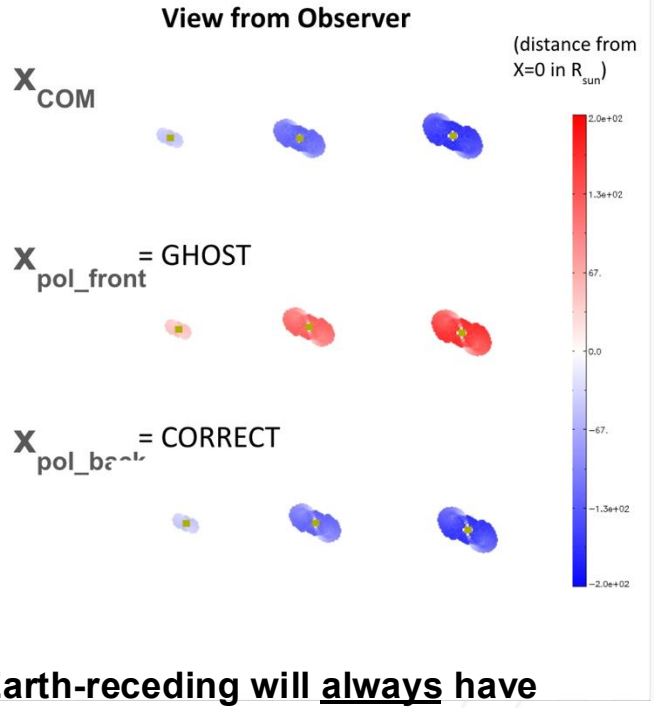


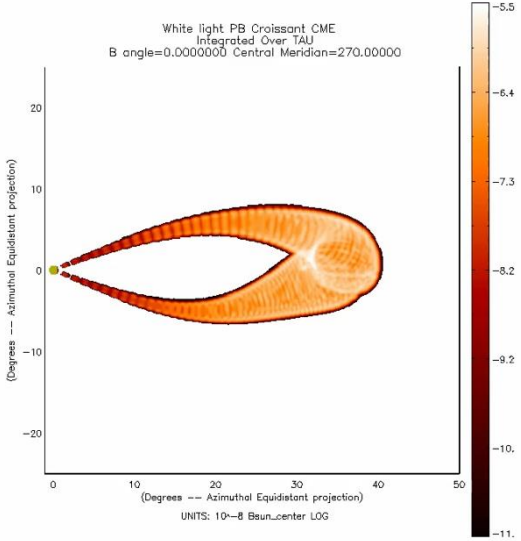


Earth-receding will always have front/back x_pol solutions opposite sign

Polarimetry: The P in PUNCH

Twisted croissant model

Thernisien 2011; Hutton & Morgan 2015; 2017

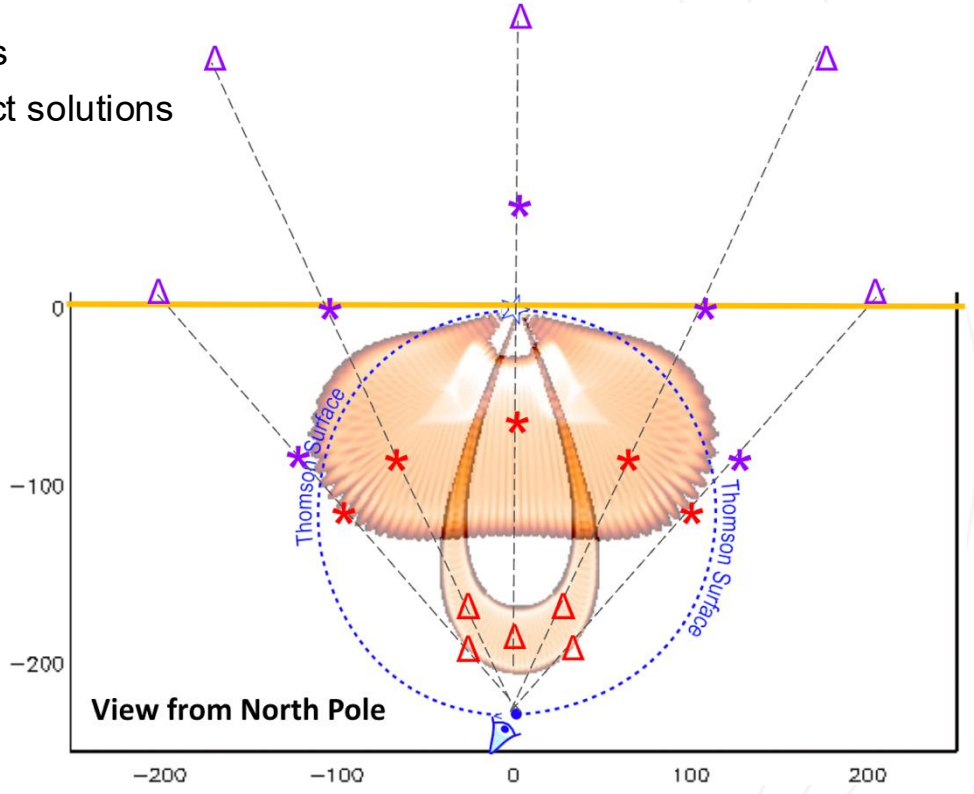


Gibson et al., SP, 2026

Disambiguating Halo CMEs: Wide-Narrow *x pol*

Δ * = ghosts

Δ * = correct solutions



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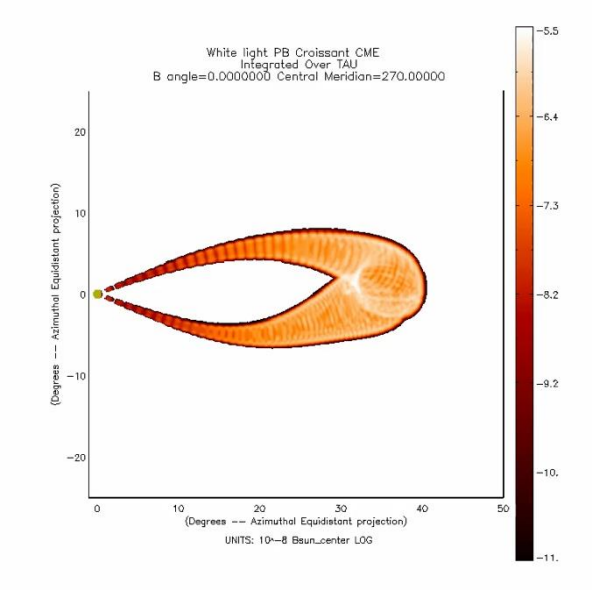
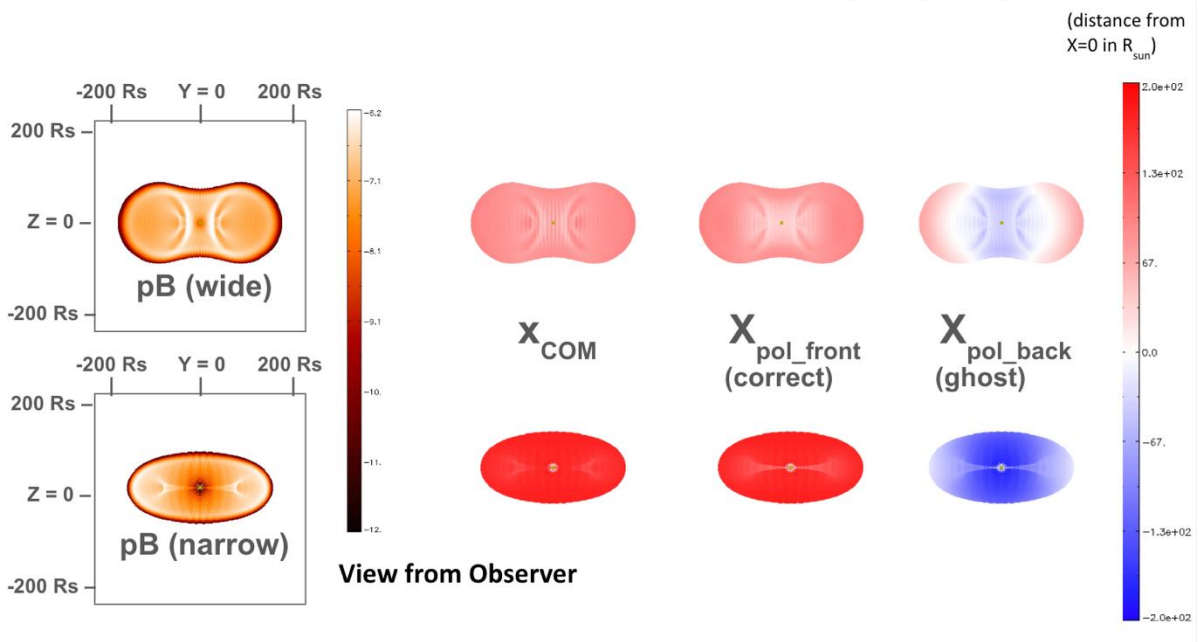


Gibson et al., SP, 2026

Disambiguating Halo CMEs: Wide-Narrow *x_pol*



If both front and back are positive anywhere, must be Earth-approaching

Polarimetry: Challenges close to the Sun

- Close to the Sun, the Sun is not a point source

$$PR = \frac{tB - pB}{tB + pB} = \frac{1-p}{1+p} = 1 - \frac{\mathcal{G}_2(r(\varepsilon,\tau_o))}{\mathcal{G}_1'(r(\varepsilon,\tau_o))} \cdot \cos^2(\tau_o)$$

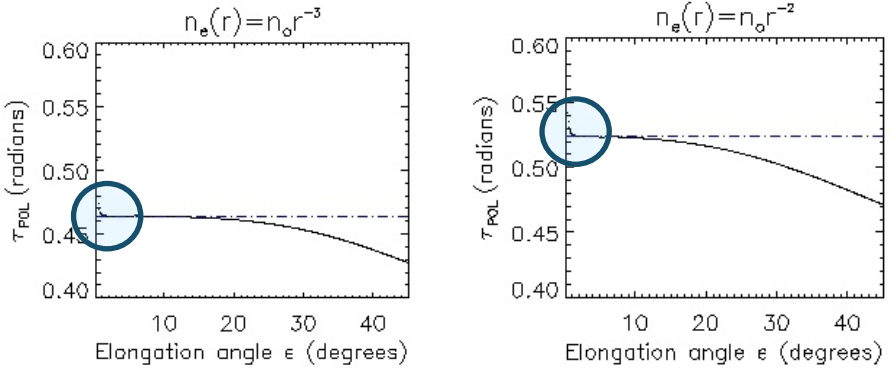
Can be explicitly taken into account

- Close to the Sun, CME front/back ambiguity can't be resolved (because TS is ~ X=0 plane)

PUNCH can help!

$$\tau_{pol_{symm}} = \text{asin}(\sqrt{PR_{symm}}) = \text{asin}(\sqrt{\frac{1}{c+2}})$$

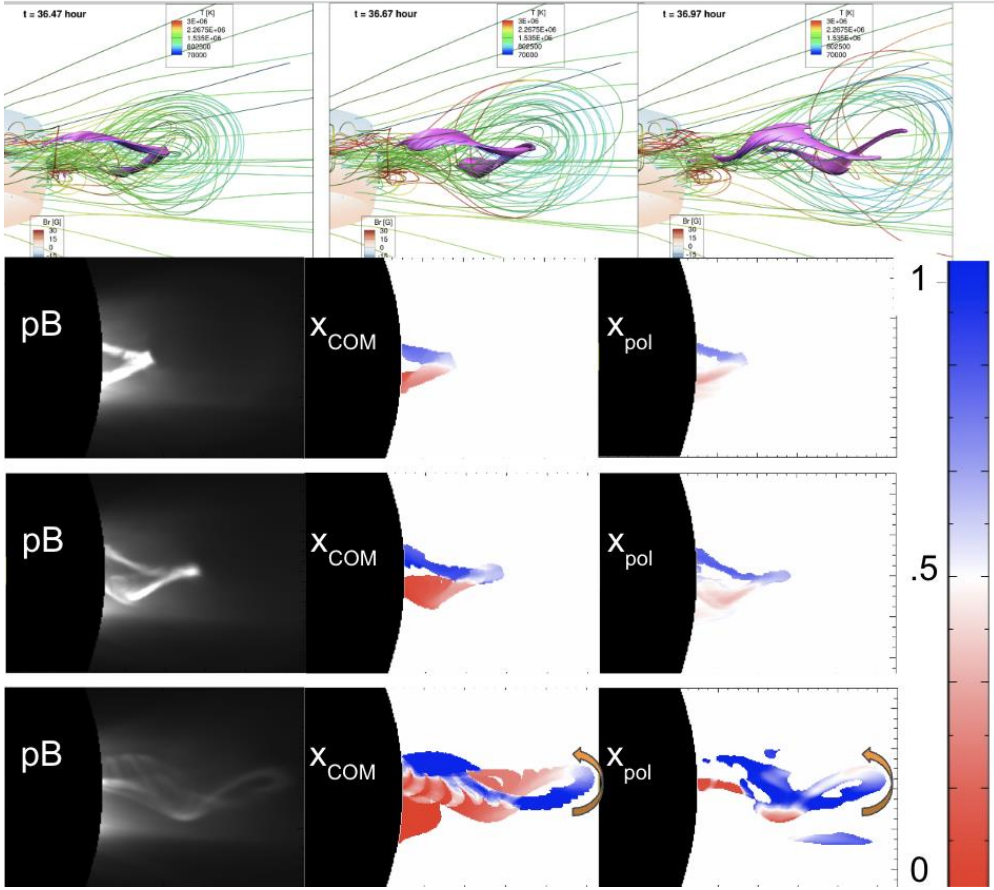
- Structures extended along the line of sight (w large compared to d) result in contribution to polarization that depends on slope.



<u>Localized</u> features may still be isolated from background if they are much brighter, and/or if the background can be subtracted.

Gibson et al., SP, 2026

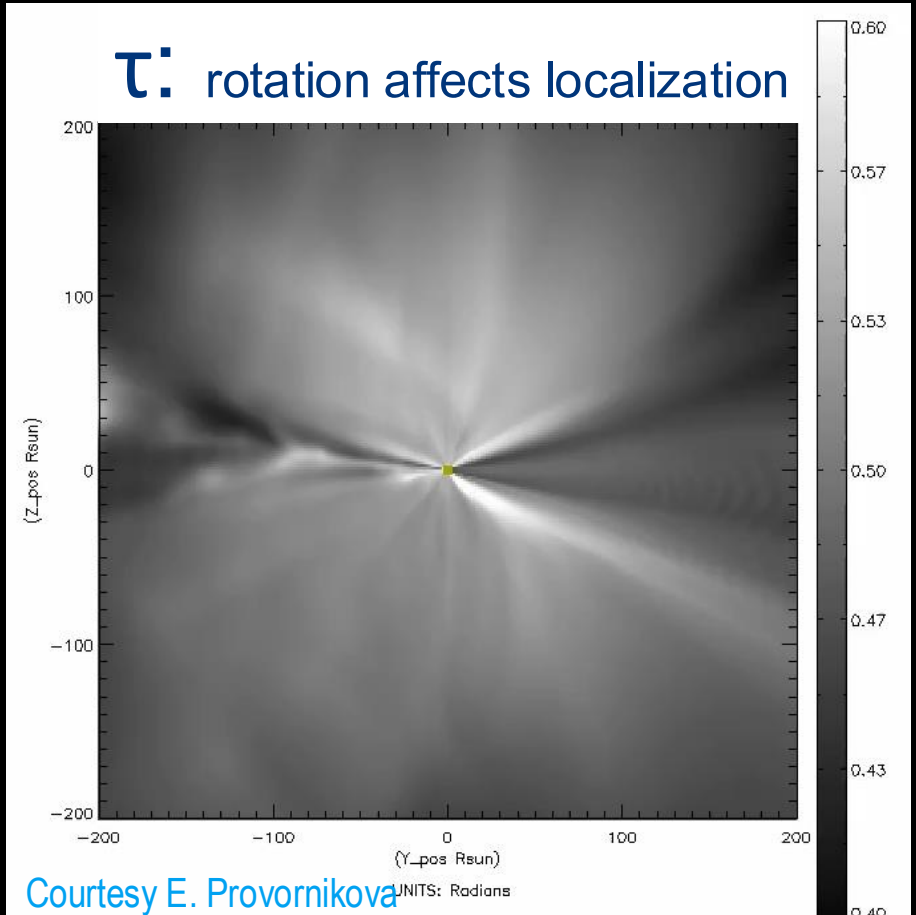
Polarimetry: Challenges close to the Sun

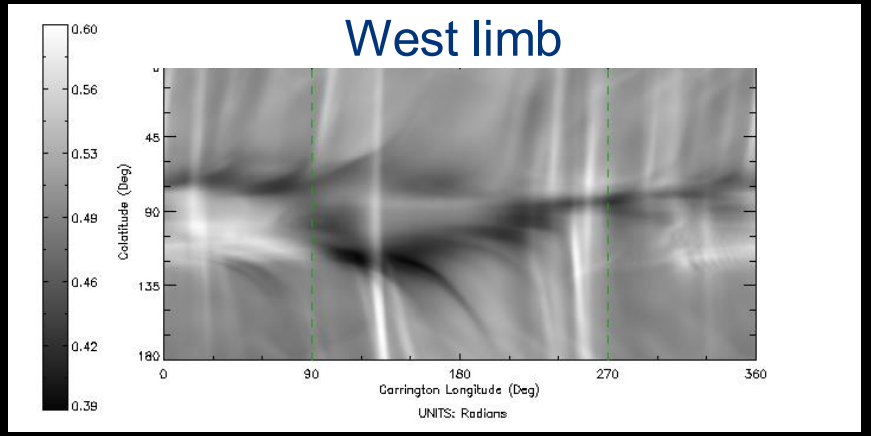


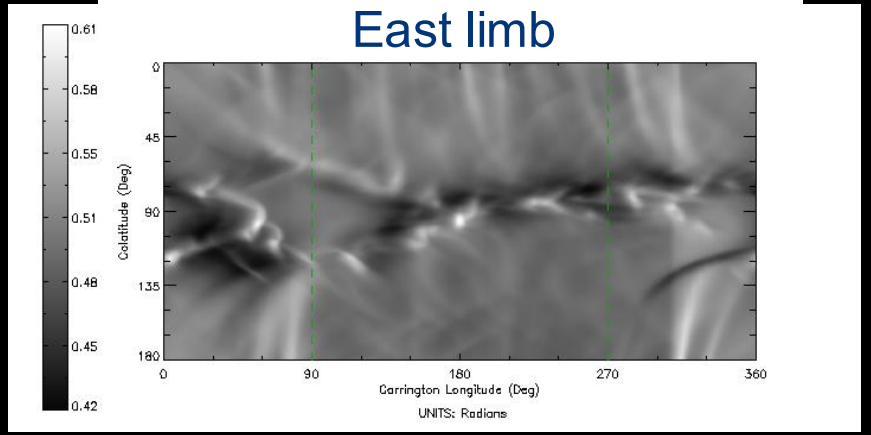
Bright (prominence associated) white-light core isolated by subtracting background; then polarization ratio taken.

Gibson et al., SP, 2026

SIR: Intrinsic East-West Asymmetry







Conclusions

PUNCH's ultra-large FOV and sensitivity will yield flow maps that will probe the origins of turbulence, the global context for Solar Orbiter and Parker, and the frothy Alfven zone

These, in combination with PUNCH polarization, will enable tracking of CME and CIR structure and evolution throughout the inner heliosphere

- Even a single snapshot of a halo CME yields information about whether it is Earth-approaching or Earth-receding and whether it is wide and slow vs narrow and fast. Movies/trajectories will remove all ambiguities.
- To localize a CME substructure, it is first necessary to eliminate the ghost solution, and to subtract the background. After this, a space-time trajectory may be obtained and potentially used to diagnose chirality.

For extended structures along the line of sight, polarization data diagnoses solar wind density radial falloff

- From ε=1.5-15° (PUNCH's lower field of view), the effects of observer asymmetry are predictable and small enough to distinguish between falloff slopes

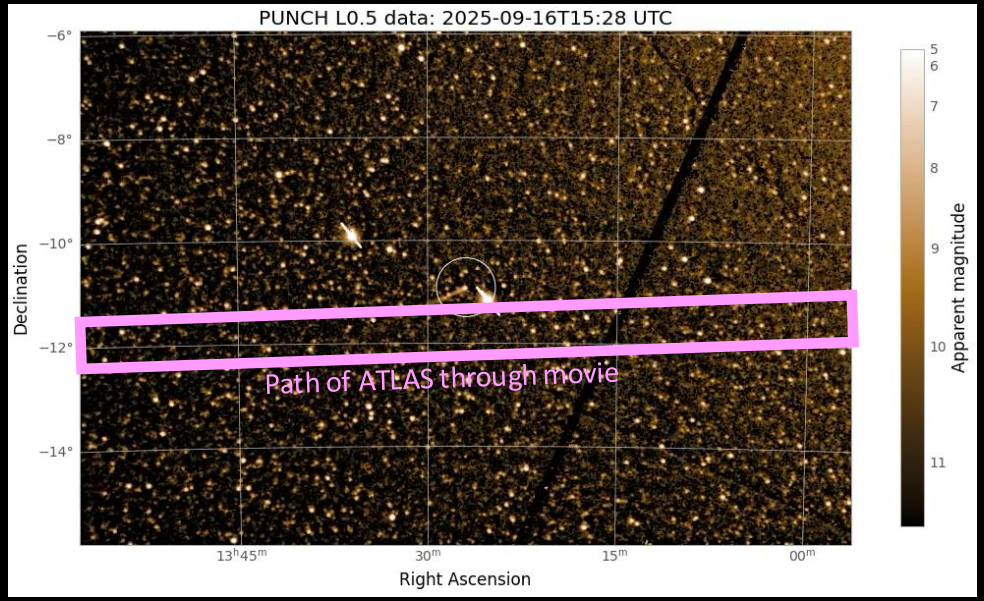
Feature localization depends on LOS linear width w and elongation angle ε, i.e., $w/d \cos^2\tau << 1$.

-A self-similarly expanding structure essentially maintains this critical parameter along its radial trajectory, while a more slowly expanding structure becomes more localized with distance

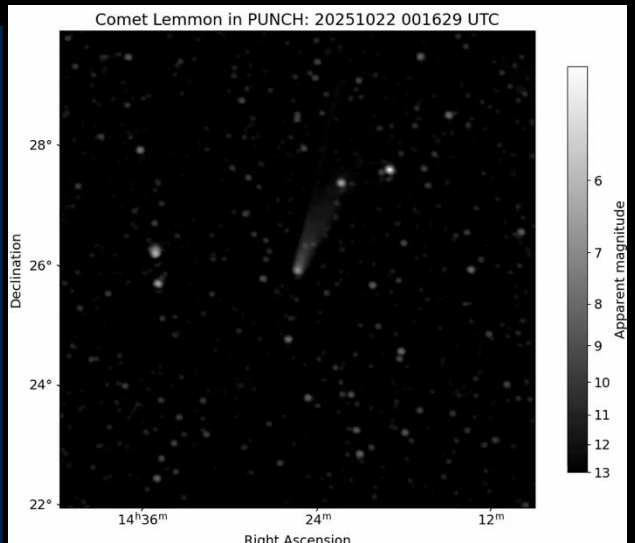
-An East-West asymmetry in localization arises from how solar rotation shapes SIRs.

PUNCH Bonus Science: Comets!

- PUNCH routinely tracks comets and asteroids
- Three novel comets so far this season:
  - SWAN (50+ day track)
  - Atlas (ongoing)
  - Lemmon (ongoing)



Comets SWAN and ATLAS (movie: v0f data)



Comet Lemmon tracked (movie: v0i data)

PUNCH Bonus Science: Comets!