

Polarimeter to Unify the Corona and Heliosphere

QuickPUNCH Data for Space Weather Research & Operations

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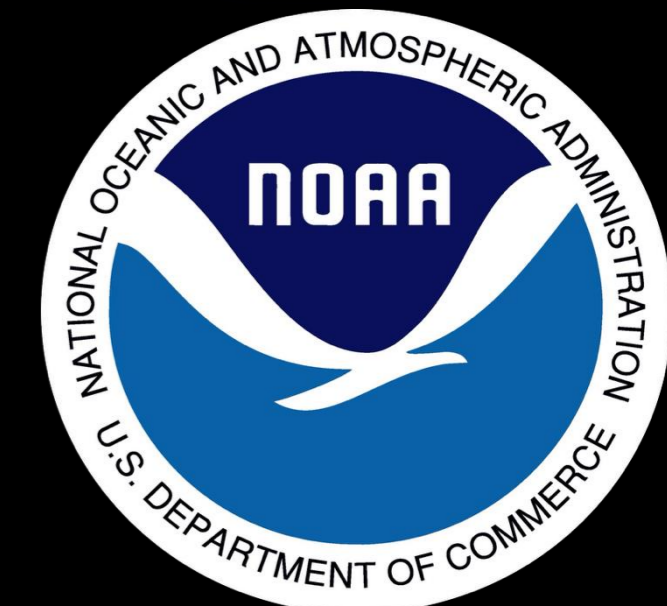
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³CU/CIRES & NOAA SWPC

⁴NOAA Office of Space Weather Observations

⁵NOAA NESDIS Common Cloud Framework

⁶European Space Research and Technology Centre



PUNCH 7, SwRI, Boulder, Colorado – May 14, 2026

Special thanks to Rob Redmon (NOAA NCEI)





Space Weather Impacts on Earth

Global Positioning System

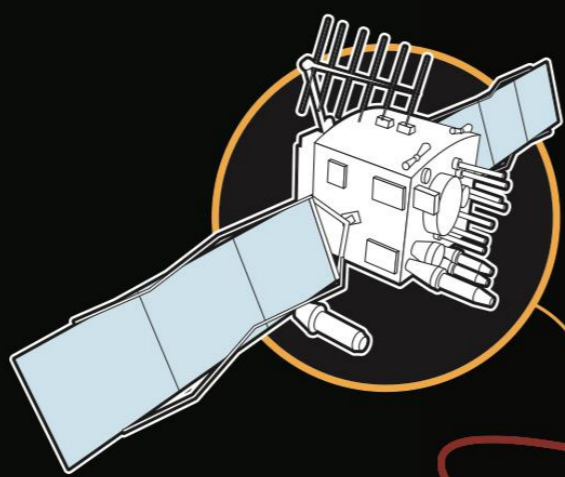
“R, S, G” Scales



SpWx can influence the performance & reliability of technological systems and endanger life or health.

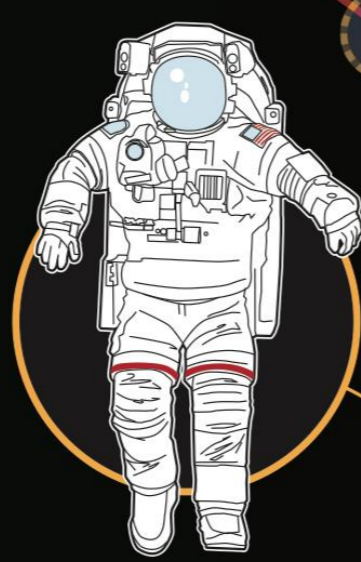
Satellite Operations

“S, G” Scales



Space Operations

“S, G” Scales



Aurora

Electrons accelerated in the tail of the magnetosphere travel down the magnetic field lines.

Electrons collide with the upper atmosphere 50 to 300 miles above Earth.

Electrons exchange energy with the atmosphere exciting the atmospheric atoms and molecules to higher energy levels. When the atoms and molecules relax back to lower energy levels, they release their energy in the form of light.



THE COLORS OF THE AURORA

- Deep red from high altitude atomic oxygen
- Magenta from high altitude molecular nitrogen in sunlight
- Greenish yellow from lower altitude atomic oxygen
- Magenta from low altitude molecular nitrogen (not shown in the picture)

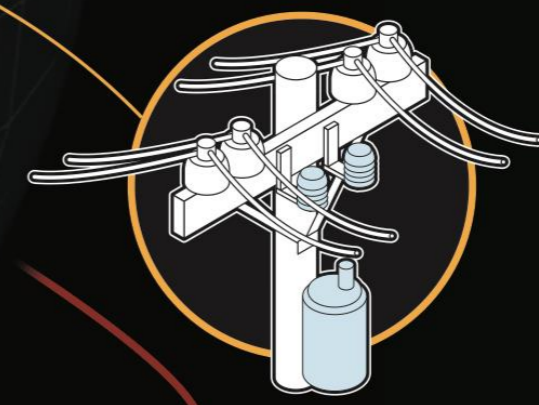
Aviation

“R, S, G” Scales



Power Grids

“G” Scale



NOAA Education www.education.noaa.gov

NOAA Space Weather Prediction Center www.spaceweather.gov

Adapted from: <http://www.swpc.noaa.gov/content/posters-and-booklets>

*Image source: Aurora Borealis taken from the International Space Station in April of 2012.



SWPC Space Weather Scales

**Radio Blackout
(R1 – R5)**

**Solar Radiation Storm
(S1 – S5)**

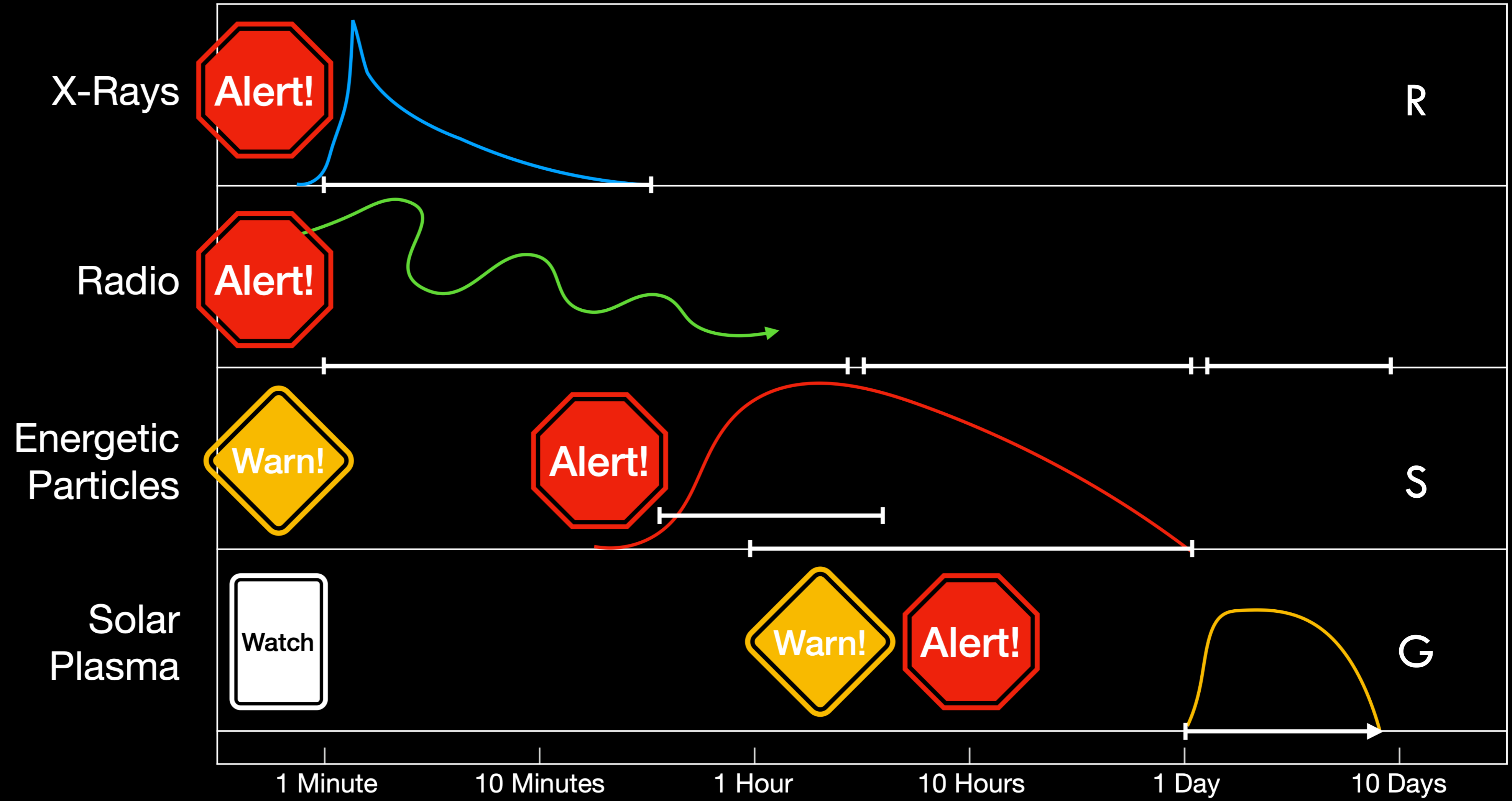
**Geomagnetic Storm
(G1 – G5)**

Scale	Intensity	Physical measure	Average Frequency
G 5	Extreme	Kp = 9	4 per 11-year solar cycle (4 days per cycle)
G 4	Severe	Kp = 8	100 per cycle (60 days)
G 3	Strong	Kp = 7	200 per cycle (130 days)
G 2	Moderate	Kp = 6	600 per cycle (360 days)
G 1	Minor	Kp = 5	1700 per cycle (900 days)



Forecasting Sequence of Events

Watch for Solar Events



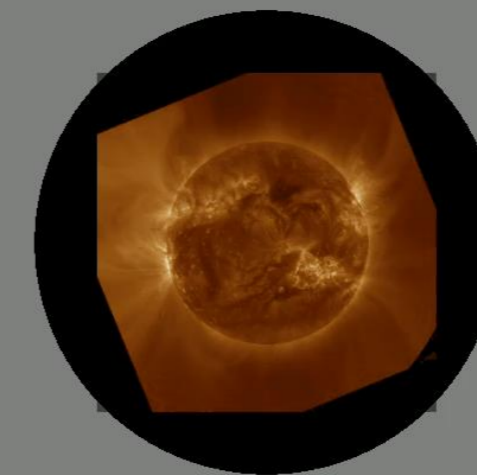
(t = 0 is 8 minutes after eruption onset)

Time (Log Scale)



Forecasting Sequence of Events

Forecasting CME arrival starts with EUV and coronagraph imagery of events near the Sun



2024-05-10T00:00:08.540



Forecasting Sequence of Events

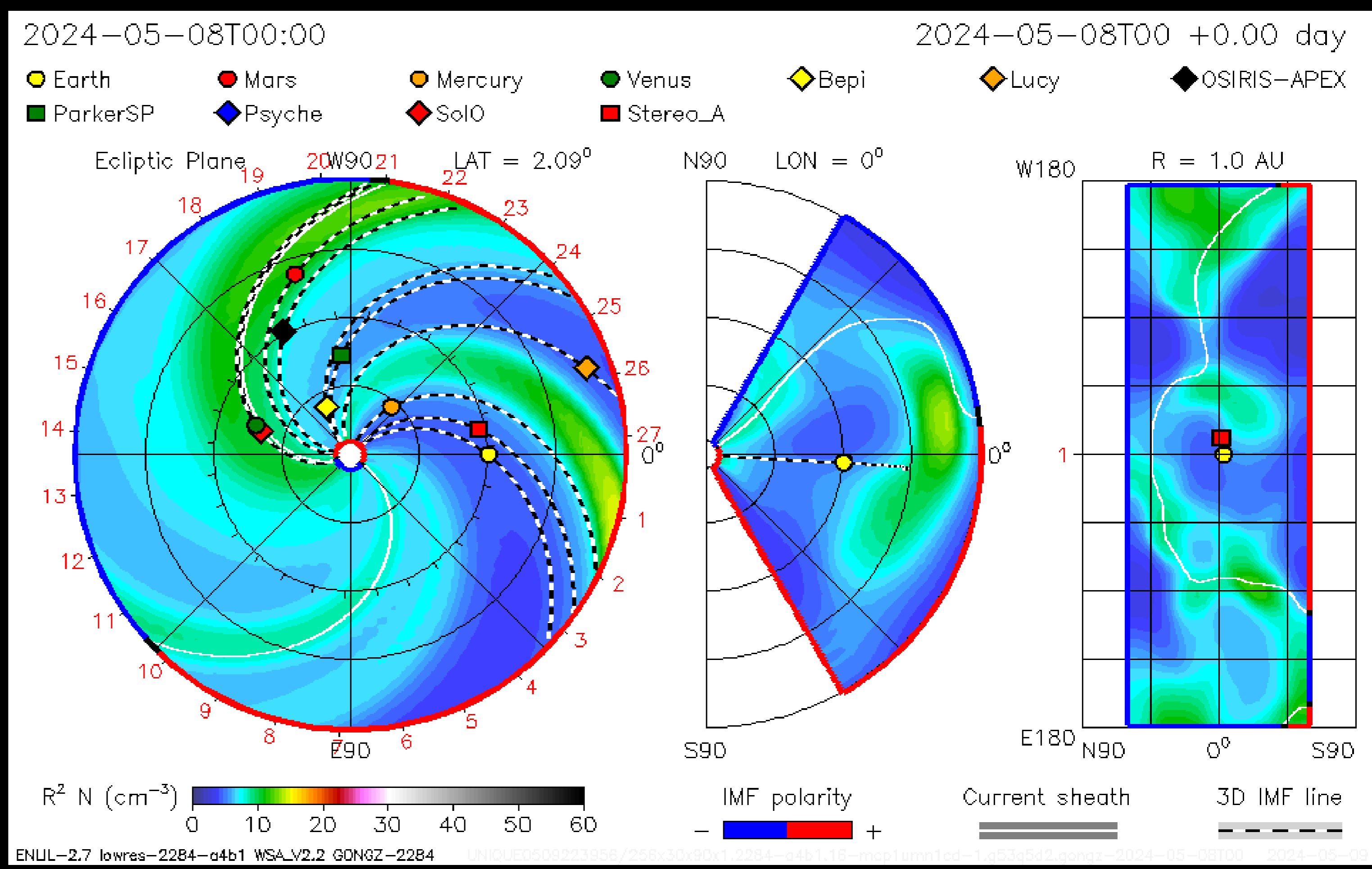
SWPC's CME Analysis Tool (CAT) used to create 3D reconstruction and classification of CME parameters.

The screenshot displays the CAT (CME Analysis Tool) interface. At the top, three coronagraph images are shown: STEREO B COR2 (left, labeled 3), SOHO LASCO C3 (middle, labeled 4), and STEREO A COR2 (right, labeled 5). Below these images is a timeline bar (labeled 2) showing event activity from 00 to 20 hours. The control panel at the bottom is divided into several sections: 1. START/END TIMES: Start [Y M D H M] 2012 1 12 0, End [Y M D H M] 2012 1 13 20. 2. ANIMATION CONTROLS: L, C, R radio buttons, Play button, Speed slider, and Alt8 checkbox. 3. IMAGE ADJUST: L, C, R radio buttons, Stretch Bottom, Stretch Top, Gamma Correction, and image saturation value sliders. 4. CME CONTROLS: Latitude, Longitude, Angular Width (2.omega), and Radial Distance (delta) sliders. 5. CME LEADING EDGE vs TIME PLOT: A graph showing the leading edge position over time, labeled 9. 6. ENLIL PARAMETERS: T 2012-01-12 14:10, Lat 40, Lon -91, Cone 51, Vel 665, labeled 10. A central CME Parameters table is also visible, showing: θ : 40.2, ϕ : -91.3, 2ω : 102.0, δ : 5.3. Buttons for Calculate Velocity, Export Analysis, and Reset Analysis are located at the bottom right.



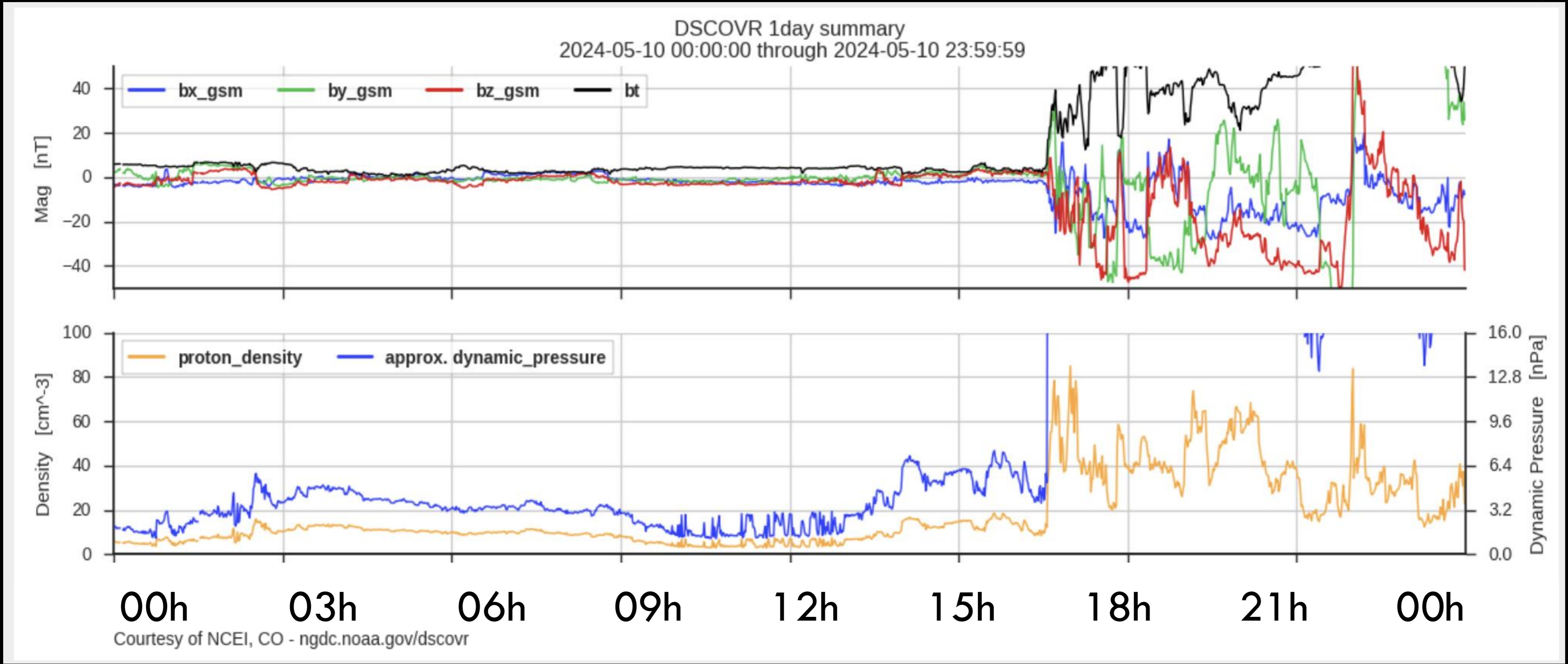
Forecasting Sequence of Events

Manually inputting CME parameters into WSA-Enlil model gives initial arrival time estimate





Forecasting Sequence of Events



SOLAR-1 solar wind monitors at L1 provide real-time alerts

Polarimeter to Unify the Corona and Heliosphere

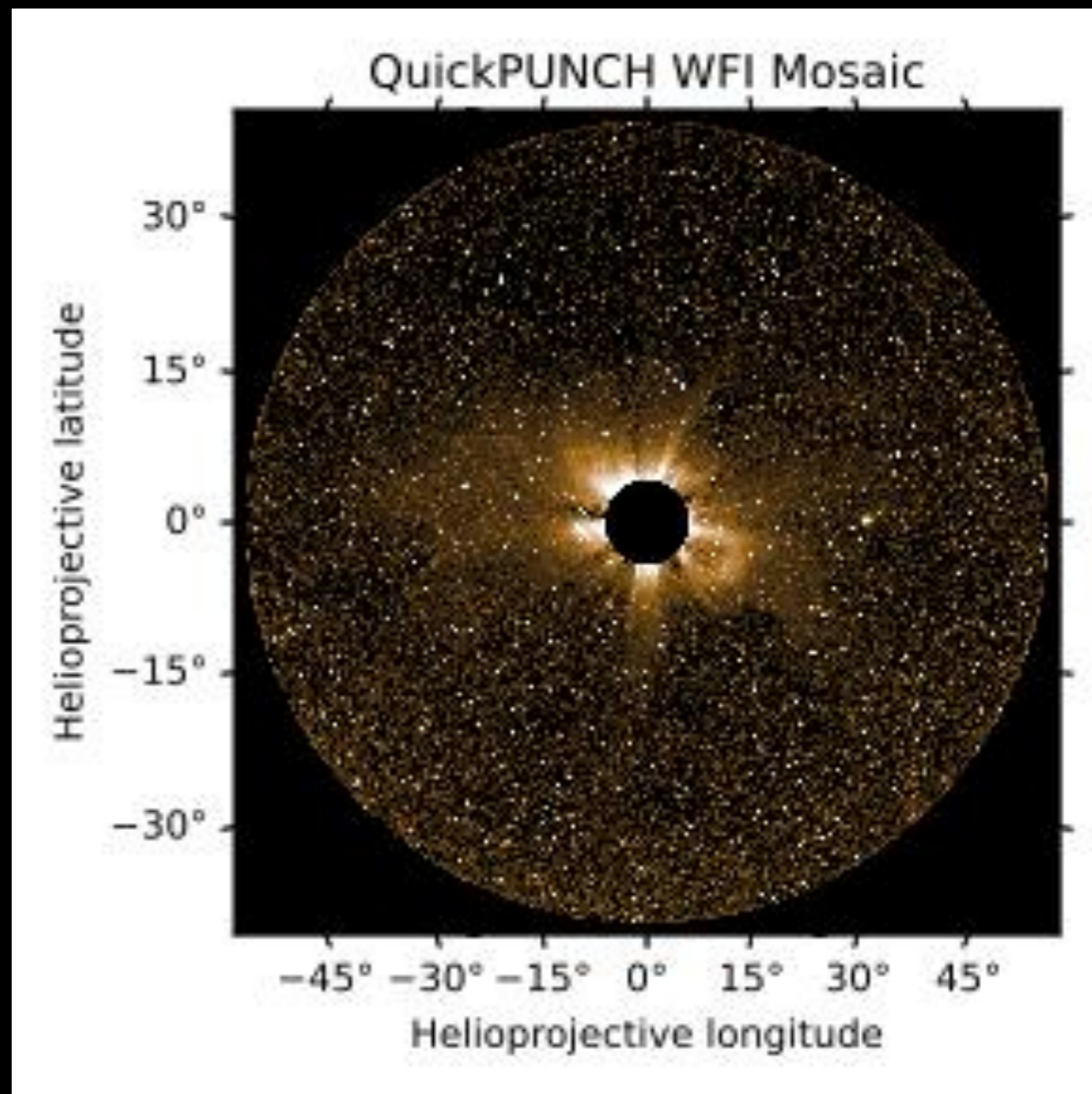
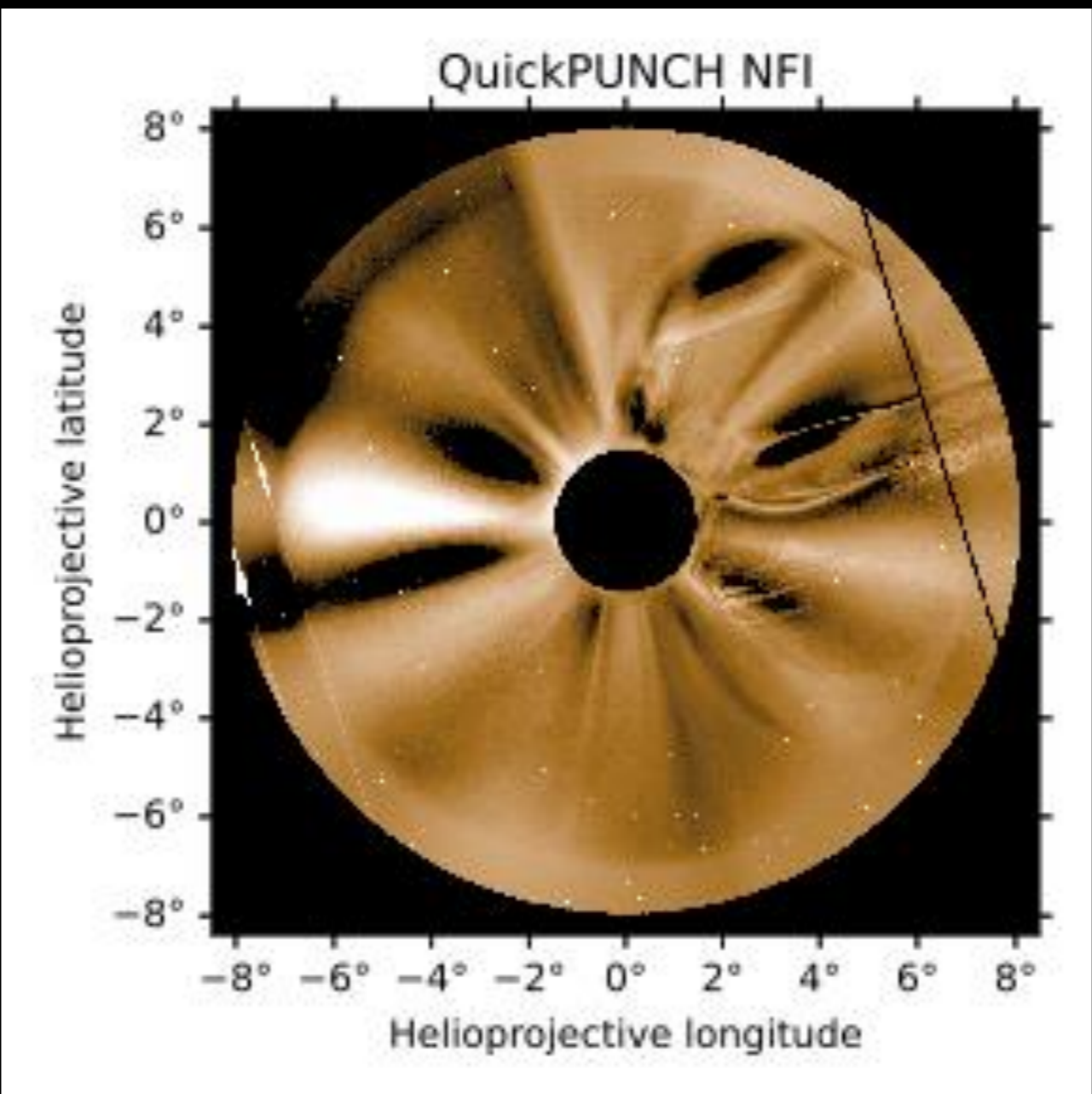


QuickPUNCH helps fill the gap between Sun
and Earth



What is QuickPUNCH?

- QuickPUNCH is an enhancement to nominal PUNCH data streams to support NOAA space weather forecasting
- QuickPUNCH reduces latency of key PUNCH products for space weather from days or weeks to hours
- Two Products:
 - tB NFI Images
 - tB WFI mosaics
- Both FITS & JPEG2000 products available for different use cases





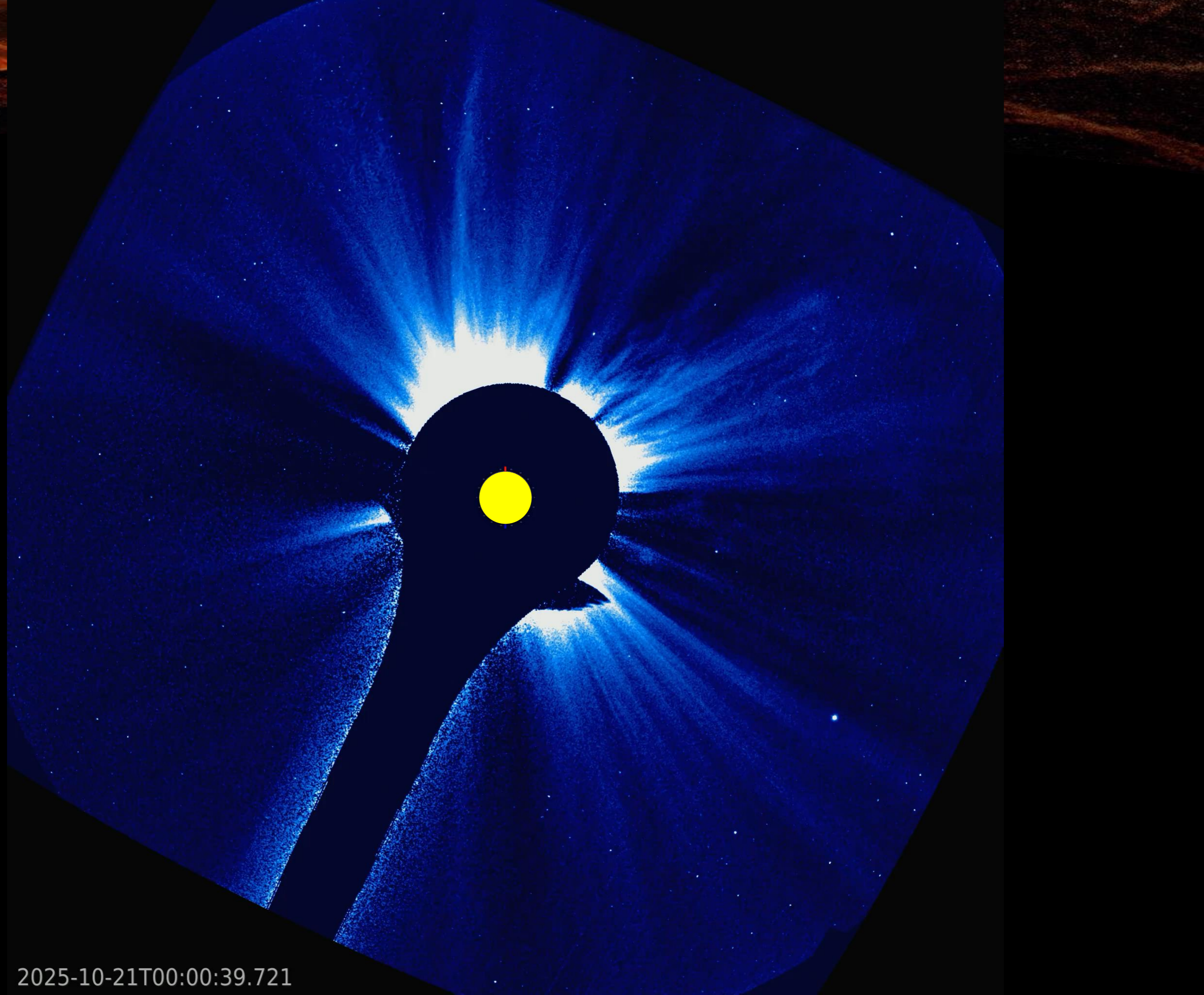
QuickPUNCH Project Status

- Interface from SOC to NOAA via NESDIS Common Cloud Framework (NCCF) has been demonstrated for real-time operations
- Interface from NCCF to SWPC is fully functional
- QuickPUNCH WFI Mosaics available for space weather operations testing and validation now
- QuickPUNCH NFI Images (PCA-processed) provide tertiary capability for space weather operations



NOAA CCOR images

CCOR FOV:
 $3.7 R_{\odot} - 17 R_{\odot}$

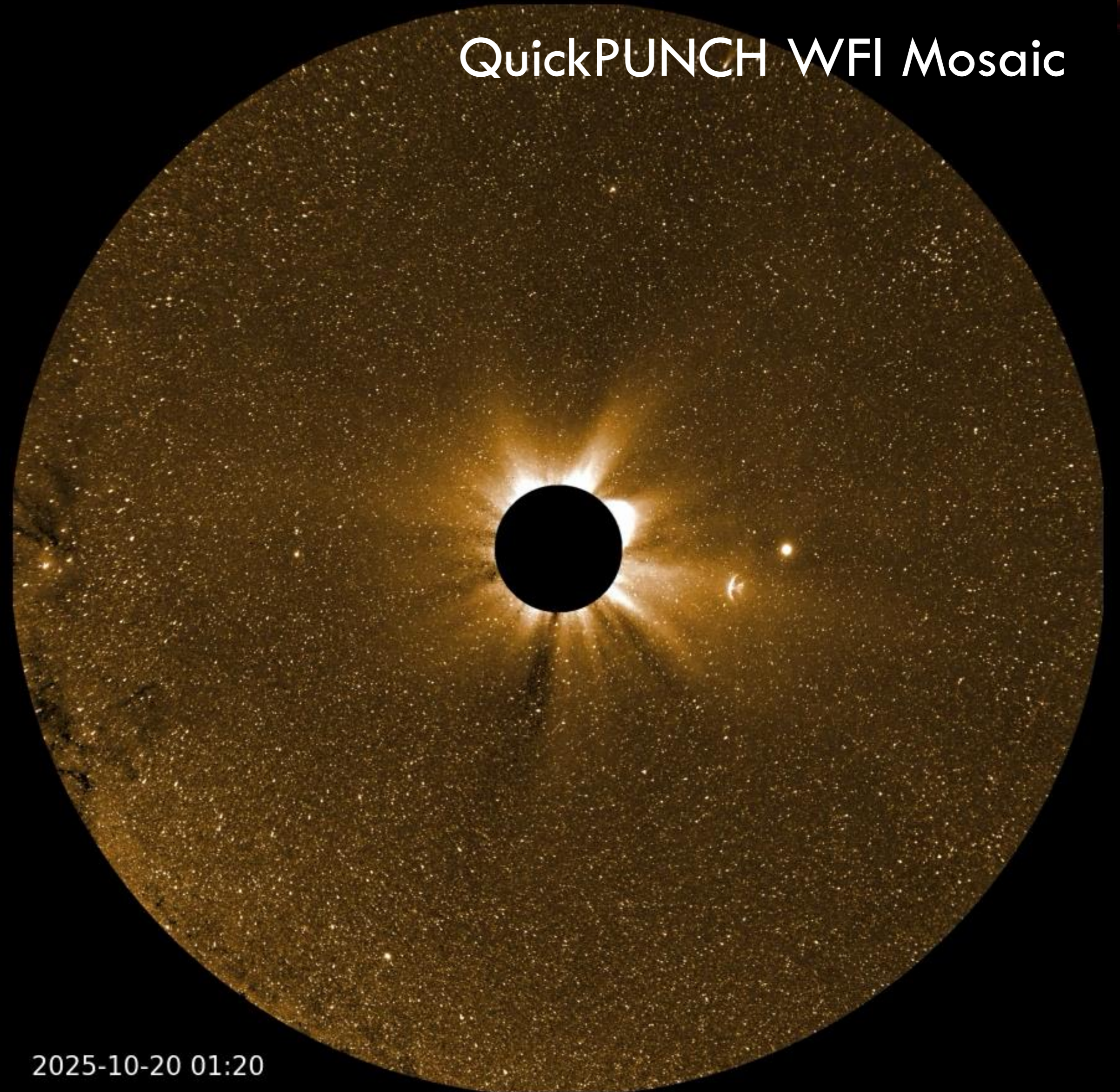


2025-10-21T00:00:39.721



QuickPUNCH WFI Mosaic

- QuickPUNCH Mosaics provide opportunities to refine CME tracking measurements
- Extends tracking time for a 750 km/s CME from 8 hours to 40+ hours
- SWPC has demonstrated in CAT, undergoing validation now





QuickPUNCH in CAT

QuickPUNCH

CCOR-1

LASCO C3

STEREO A COR2

CAT (CME Analysis Tool)

2025-11-06 13:32 UT 2025-11-05 13:15 UT 2025-11-05 00:18 UT 2025-11-05 00:53 UT

00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

START/END TIMES
Start [Y M D H]: 2026 1 7 17
End [Y M D H]: 2026 1 8 17
Load Images

SELECT MODE
 NORMAL CAT MODE
 PLANE OF SKY MODE

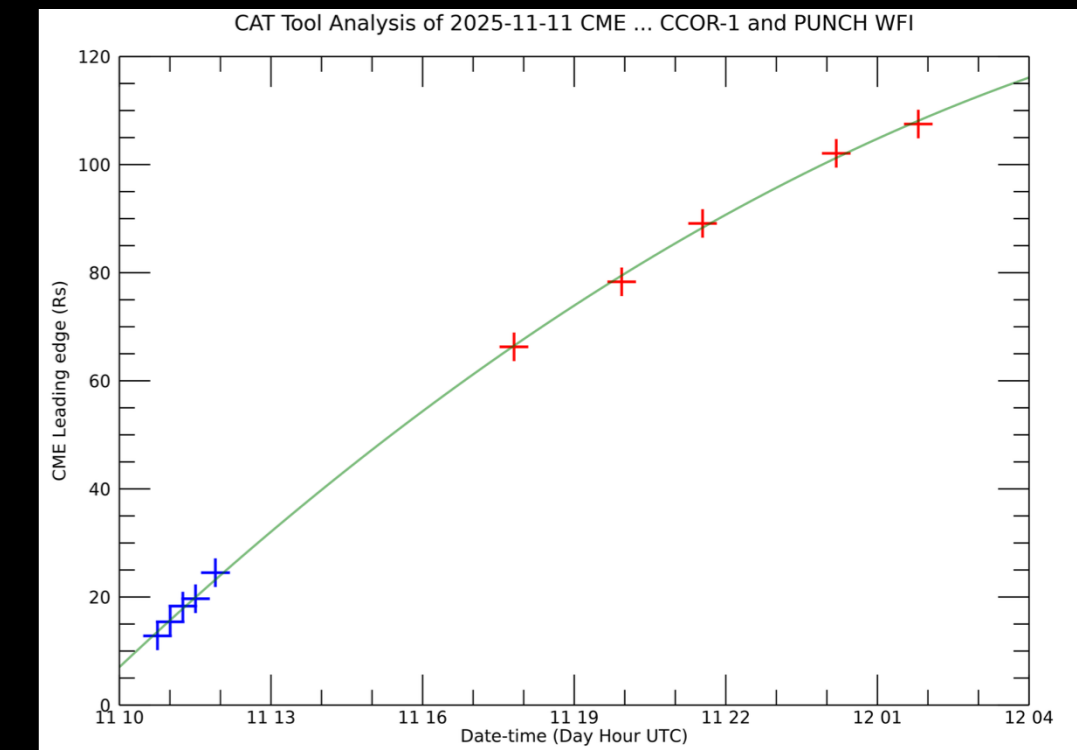
IMAGE ADJUST
PUNCH CCOR-1 LASCO
Darken
Lighten
Saturation
CME OUTLINE ADJUST
Thickness
Transparency

IMAGE REMOVE
PUNCH CCOR-1 LASCO C3 LASCO C2
PUNCH start PUNCH end PUNCH Remove
Remove One
Show Header

CME CONTROLS
Latitude 42 Longitude -21
Latitude
Longitude
Angular Width (cone)
Radial Distance (dist)
CME Params
lat : 42.0
lon : -20.8
cone : 90.0
dist : 9.7

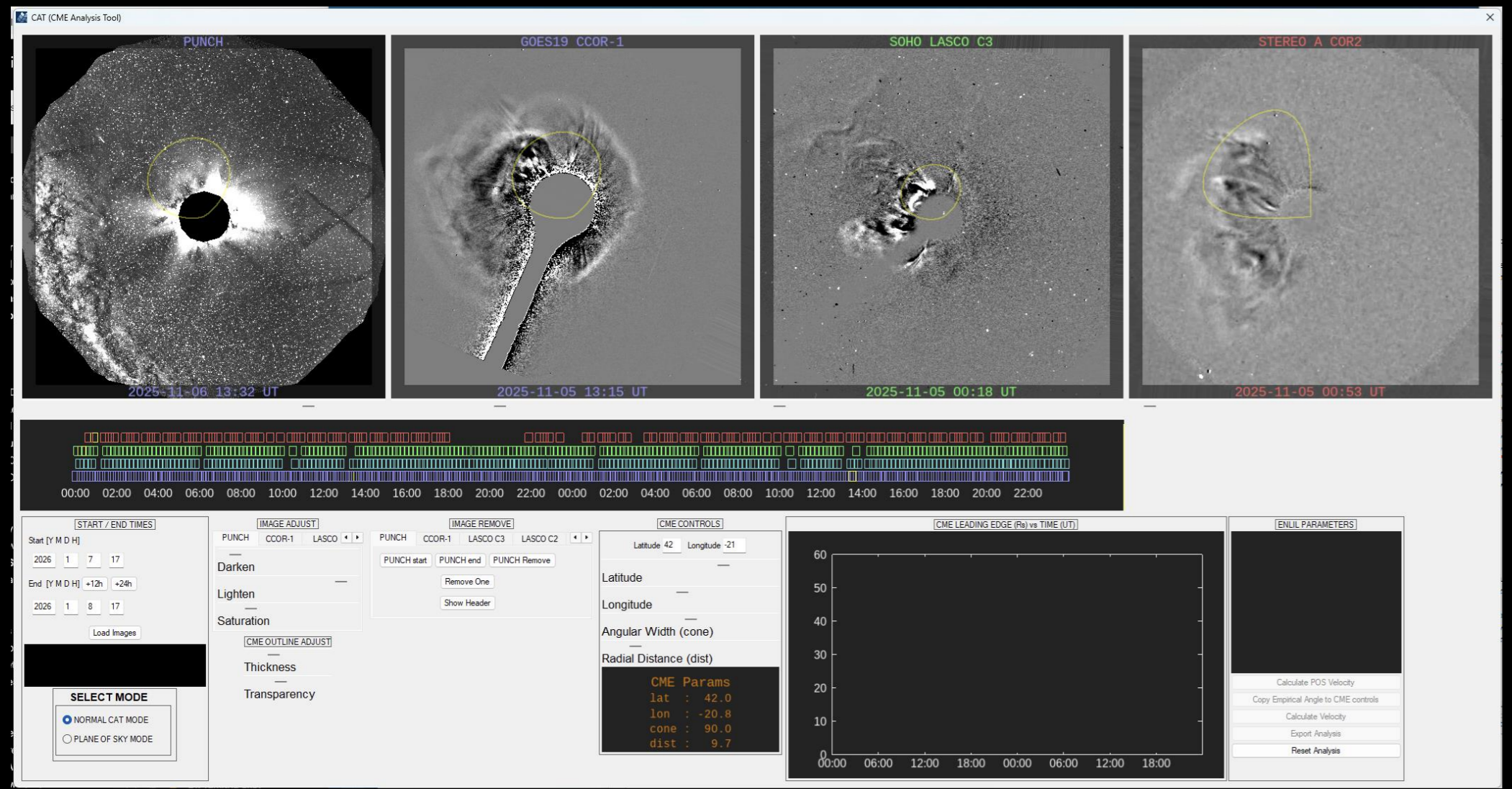
CME LEADING EDGE (Rs) vs TIME (UT)
60
50
40
30
20
10
0
00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00

ENLIL PARAMETERS
Calculate POS Velocity
Copy Empirical Angle to CME controls
Calculate Velocity
Export Analysis
Reset Analysis

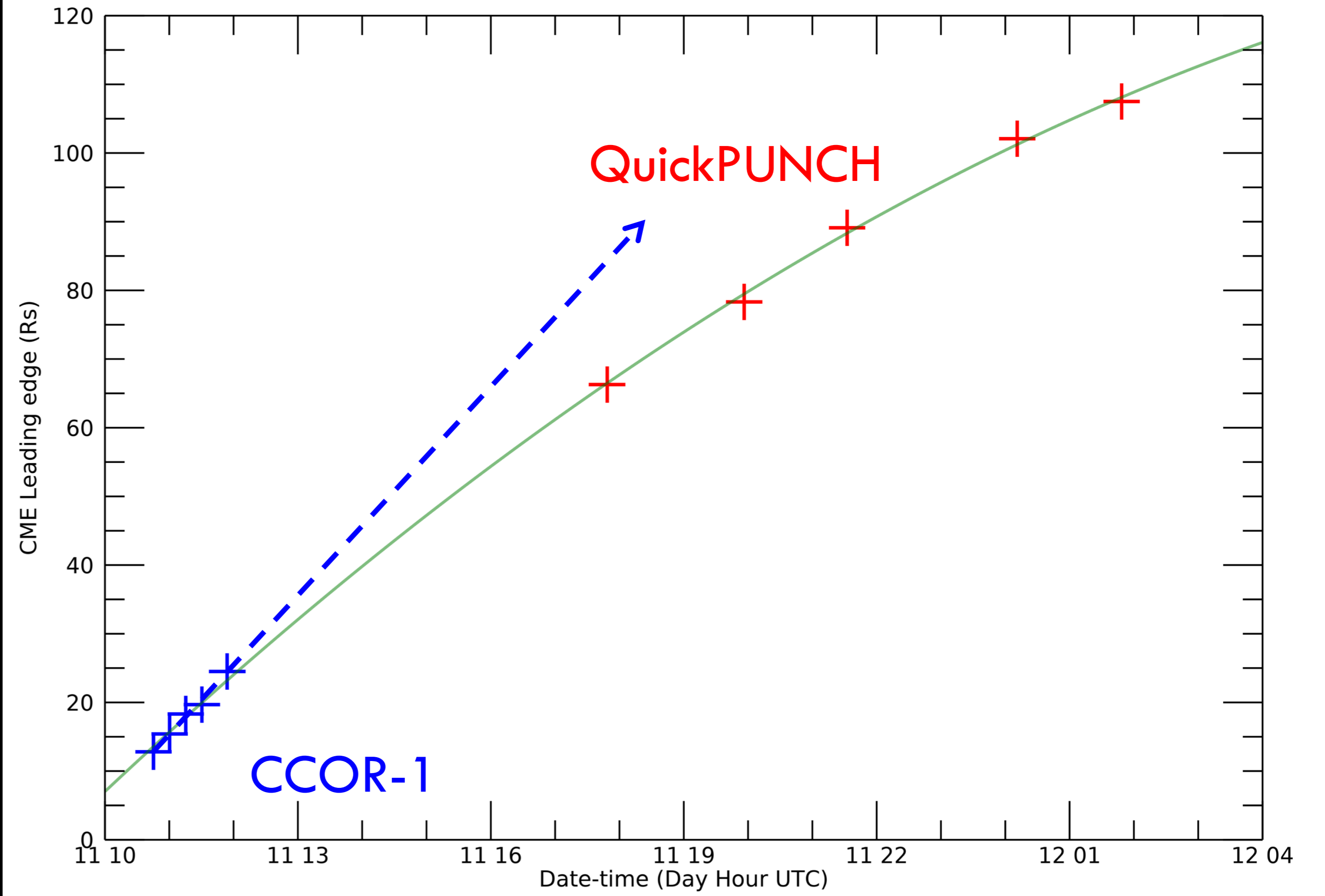




QuickPUNCH in CAT



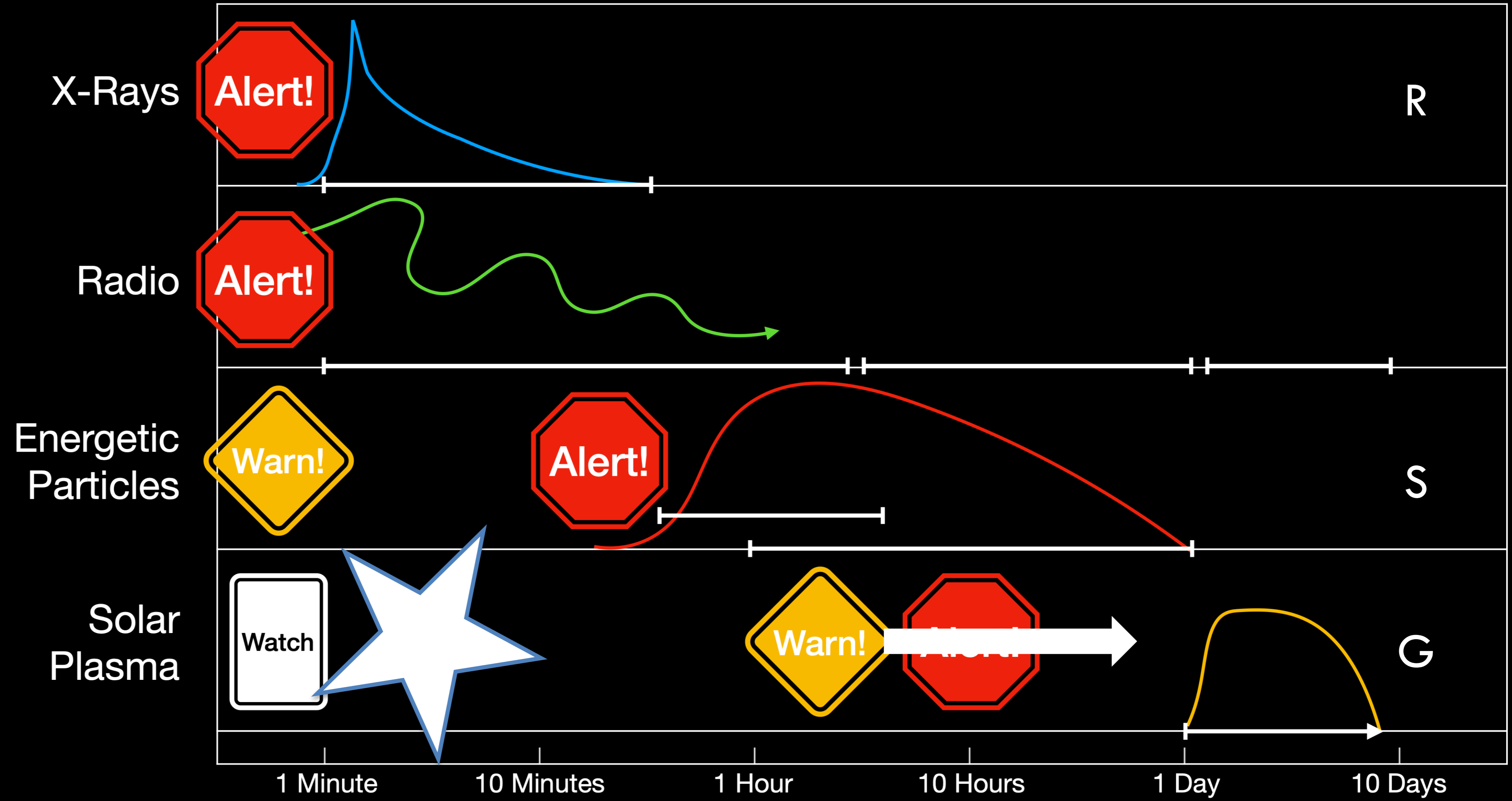
CAT Tool Analysis of 2025-11-11 CME ... CCOR-1 and PUNCH WFI





Forecasting Sequence of Events

Watch for Solar Events



(t = 0 is 8 minutes after eruption onset)

Time (Log Scale)

Polarimeter to Unify the Corona and Heliosphere

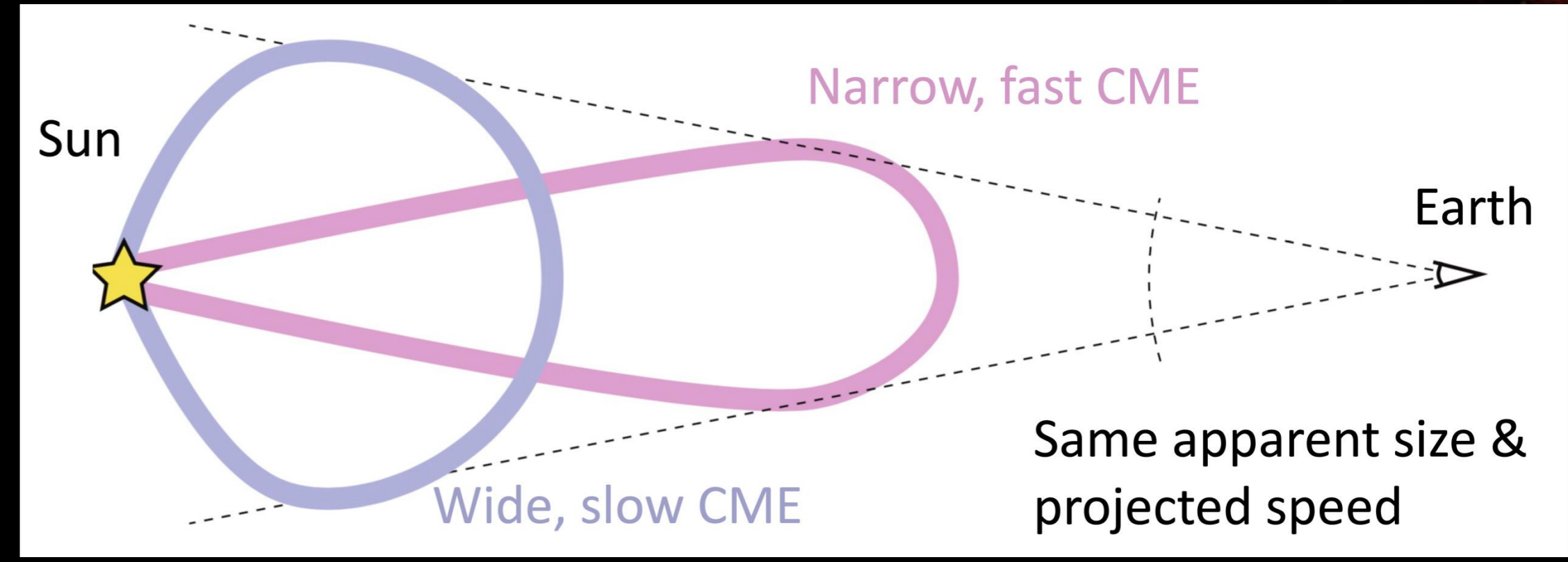
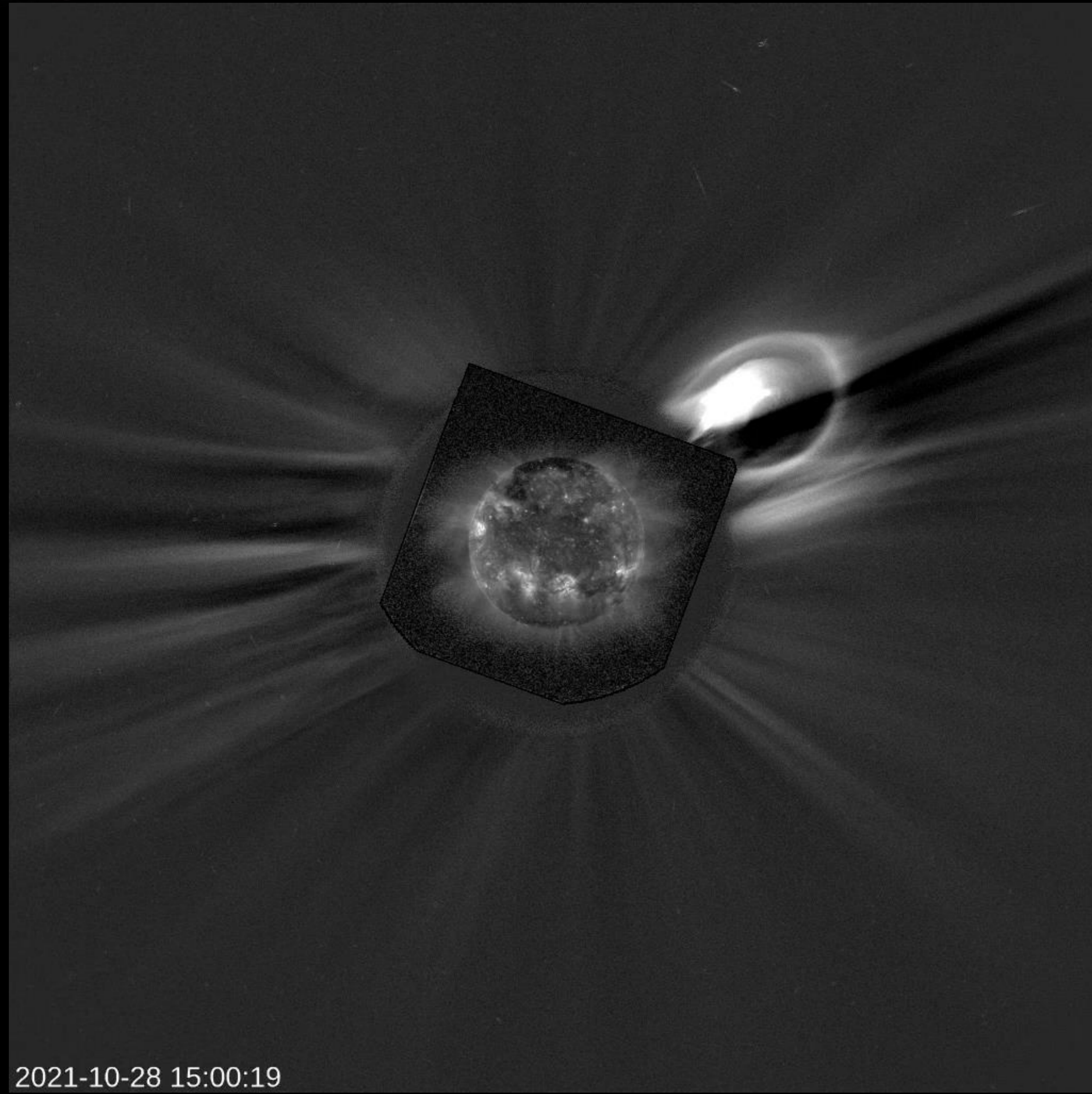


Research to Operations for PUNCH

Potential Future Uses of Polarized Data



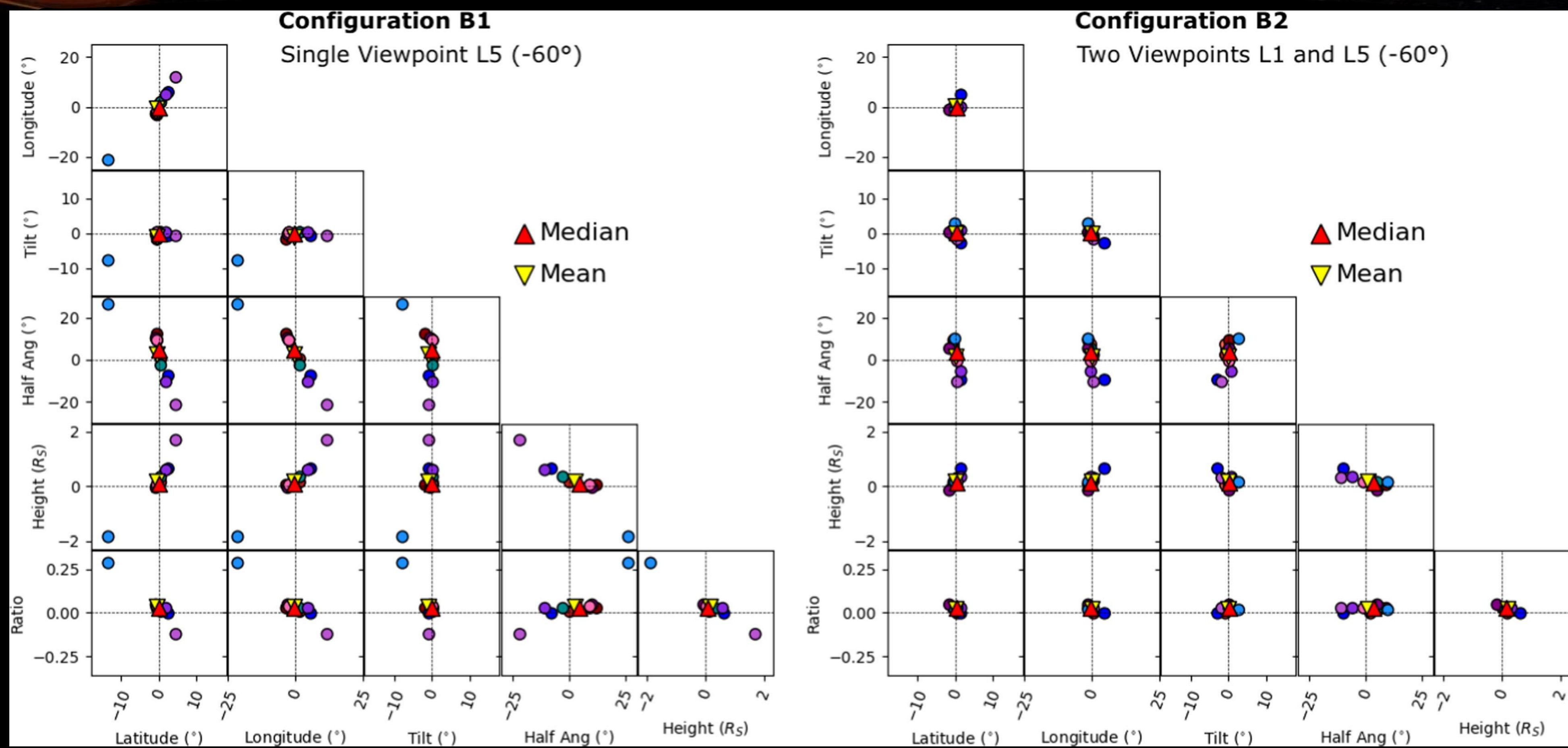
Tracking CMEs in 3D without Polarization



Halo CMEs are subject to ambiguity between size and speed



Tracking CMEs in 3D without Polarization



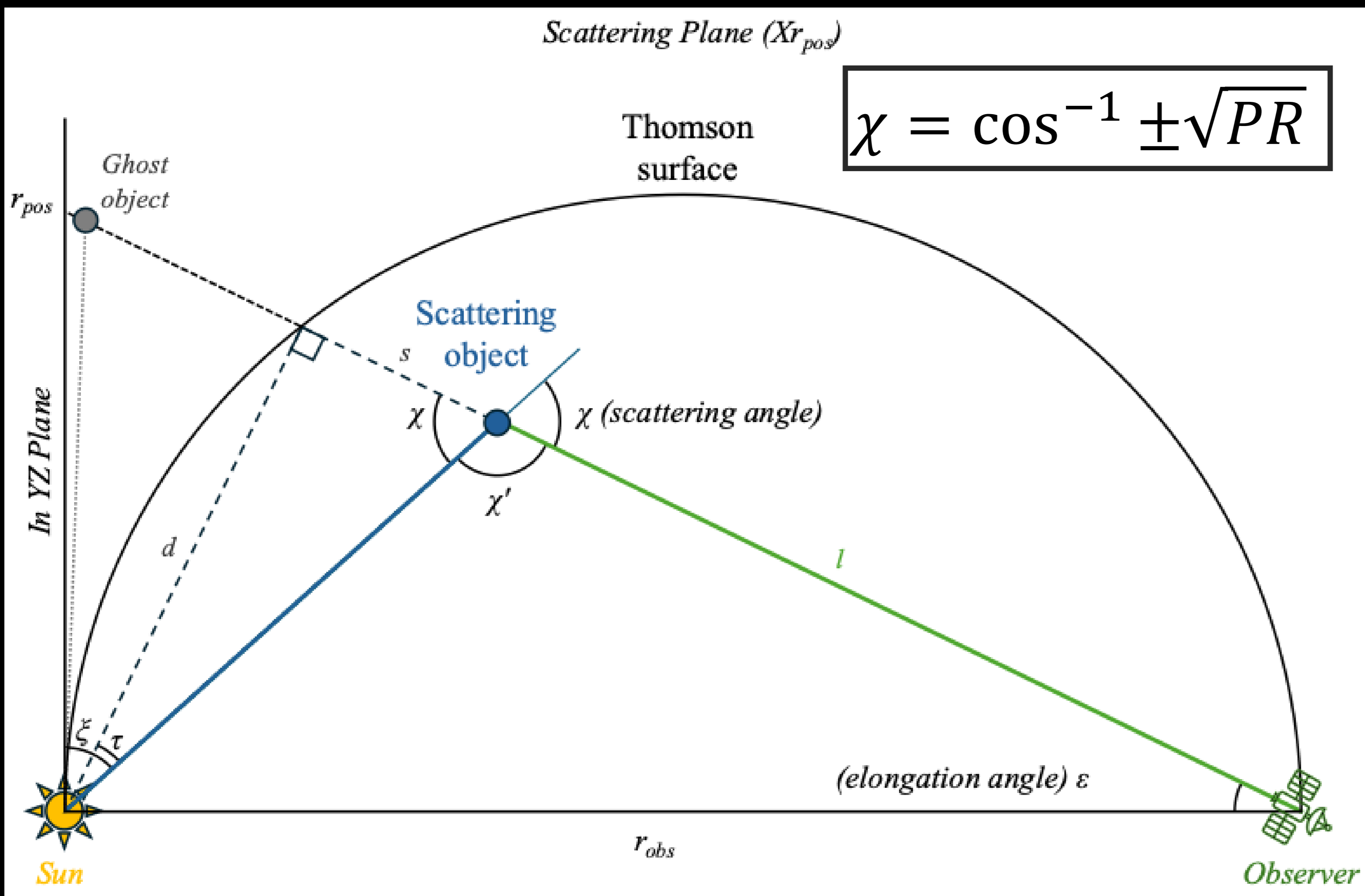
Verbeke+ (2023)

Single perspective \rightarrow up to 5 \times error in arrival time vs. two viewpoints

Arrival prediction is significantly worse for fast CMEs



Tracking CMEs in 3D with Polarization



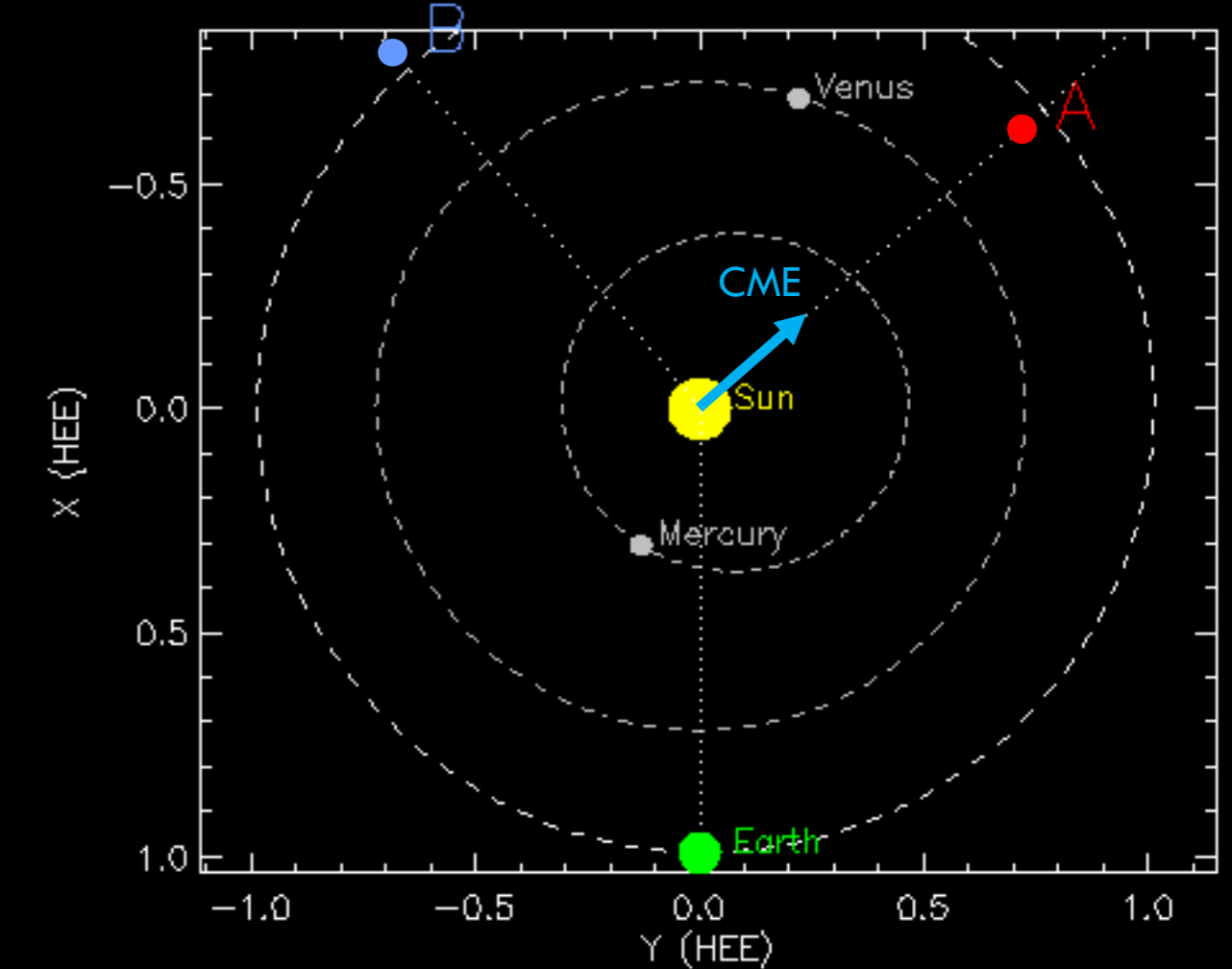
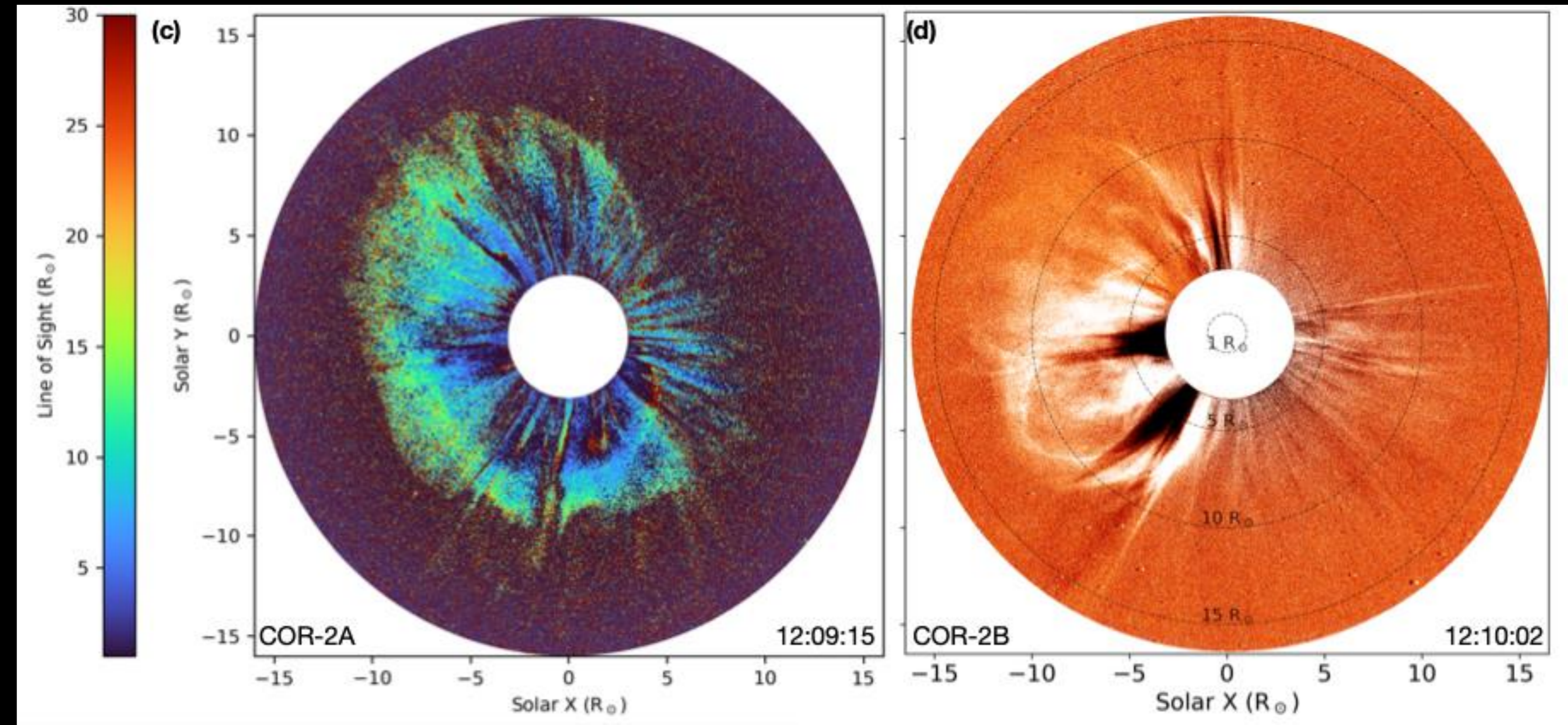
$$p = pB/tB$$

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

Polarization yields a simple relationship to find location of an object between Earth and Sun



Tracking CMEs in 3D with Polarization



STEREO A/B
Quadrature
2013 Feb 26

Figure Courtesy R. Patel/M. West

CME reconstruction demonstration using VAPOR Python Package, currently available in the PUNCH-Mission GitHub Organization



Key Takeaways

- Current CME forecasts lack constraints between remote sensing at a few 10s of R_{\odot} and in situ at L1
- QuickPUNCH augments NOAA data streams by potentially adding backup capability (NFI) and extending region of remote sensing (WFI)
- Research-to-operations capability development uses polarization to improve CME tracking in 3D