Polarimeter to Unify the Corona and Heliosphere

QuickPUNCH Data for Space Weather Research & Operations

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Space Weather Impacts on Earth

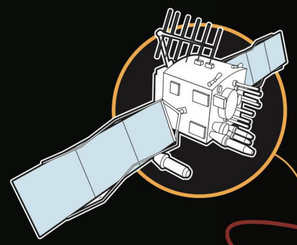
SpWx can influence the performance & reliability of technological systems and endanger life or health.

Global Positioning System

"R, S, G" Scales

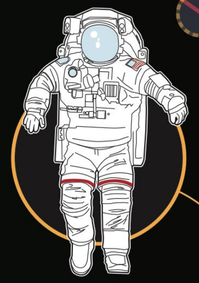
Satellite Operations

"S, G" Scales



Space Operations

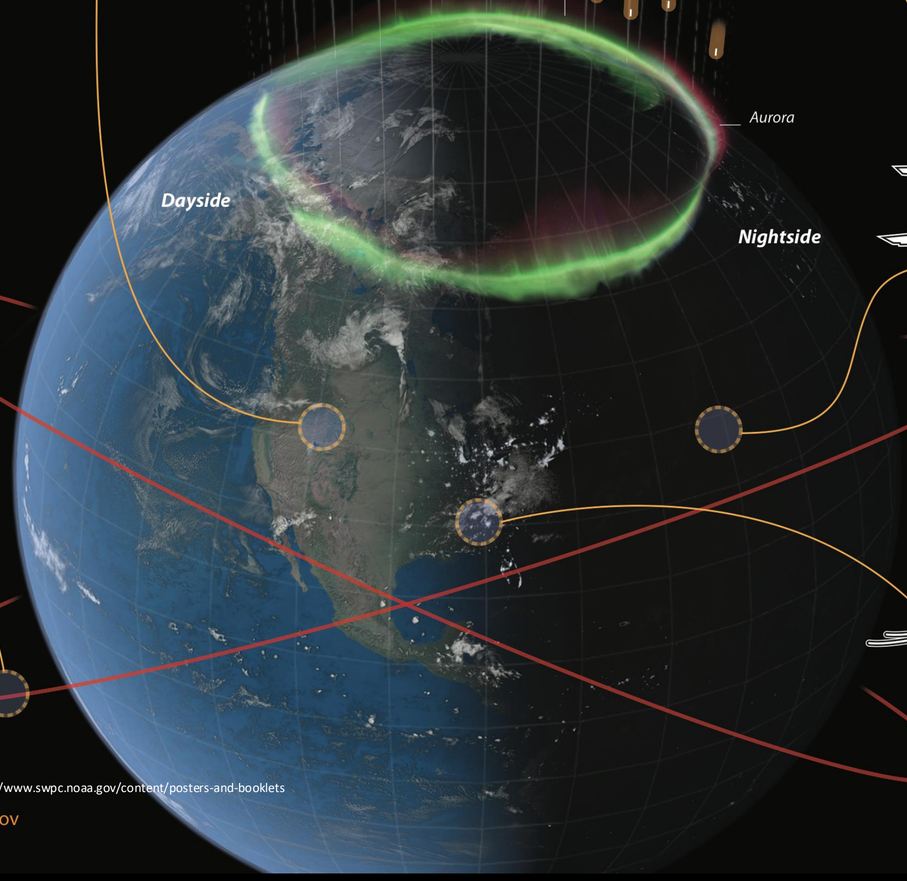
"S, G" Scales



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.



Aurora

THE COLORS OF THE AURORA

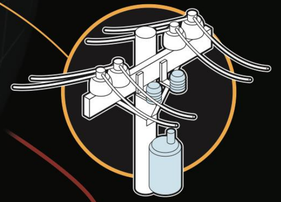
- Deep red from high altitude atomic oxygen
- Magenta from high altitude molecular nitrogen in sunlight
- Greenish yellow from lower altitude atomic oxygen
- Magenta from low altitude molecular nitrogen (not shown in the picture)

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)

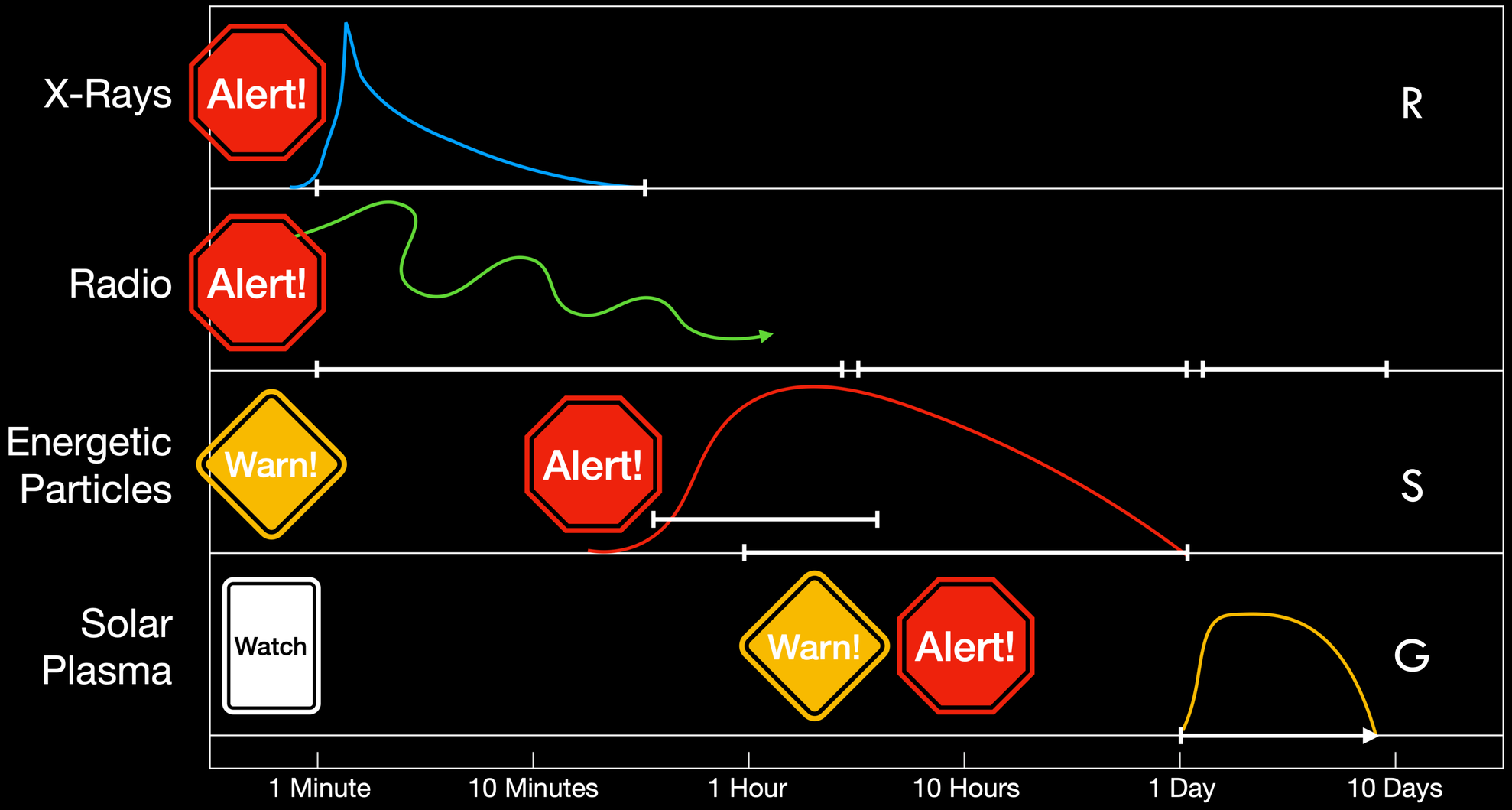
Solar Radiation Storm
(S1 – S5)

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

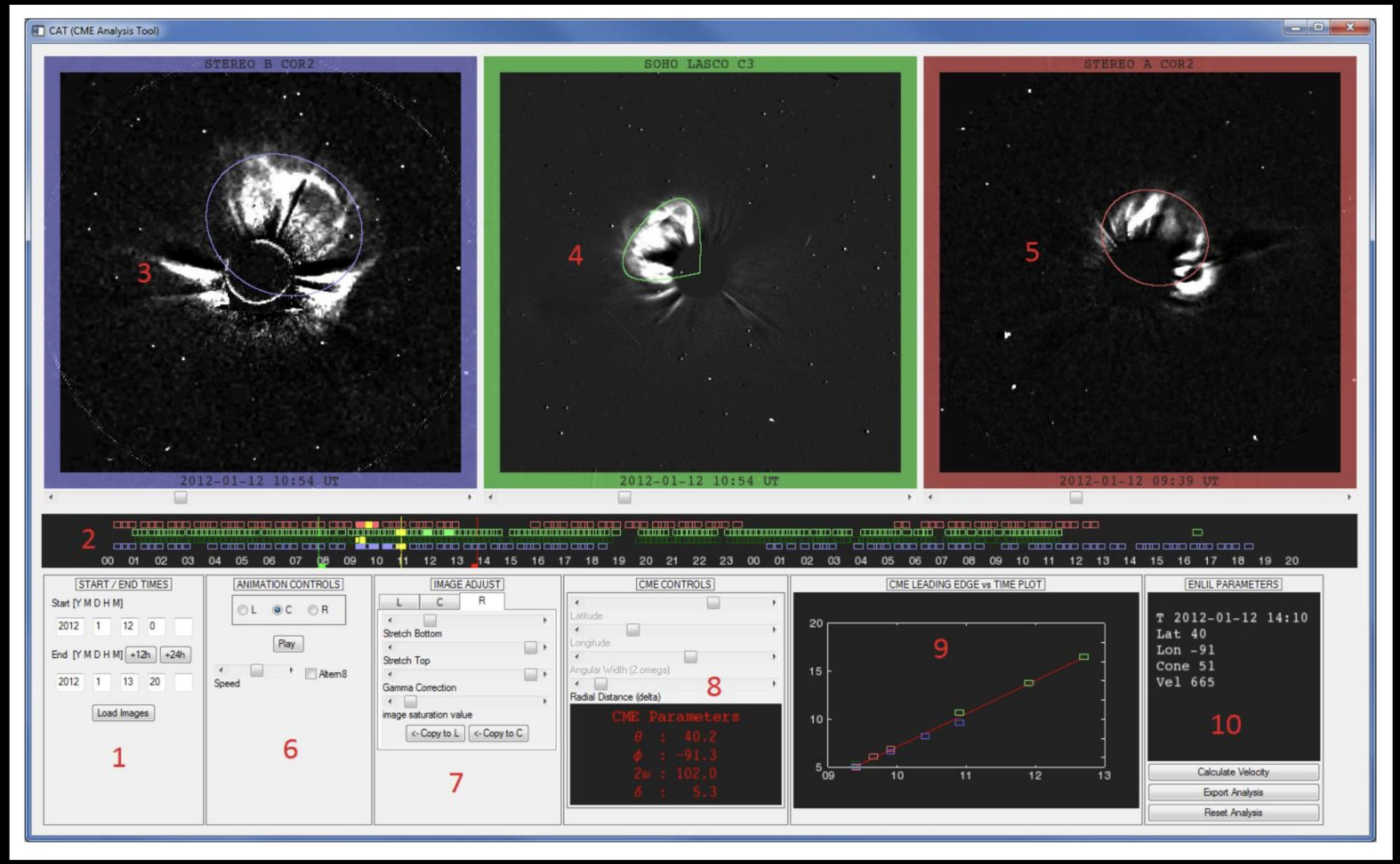


Forecasting Sequence of Events

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

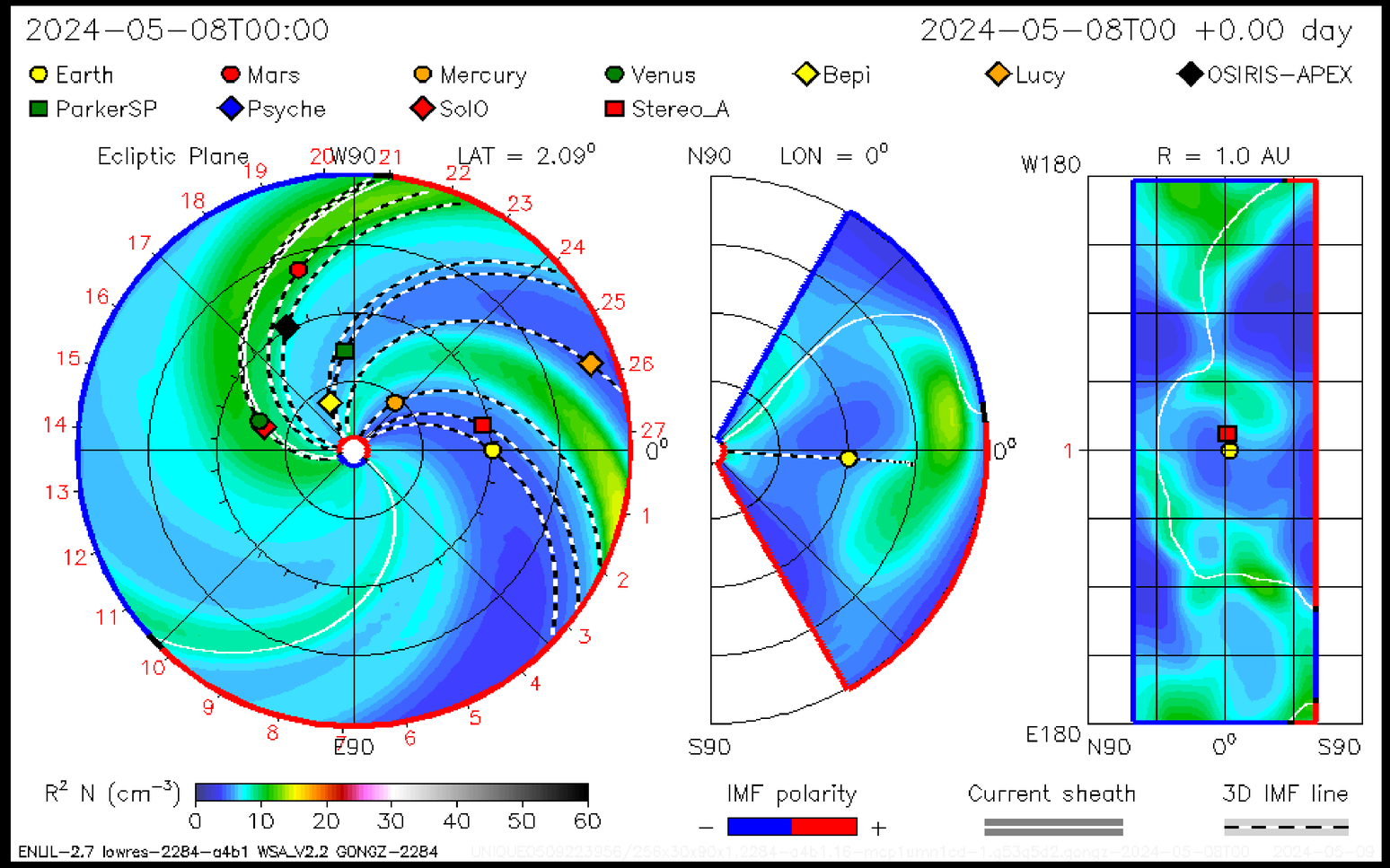
Forecasting Sequence of Events

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

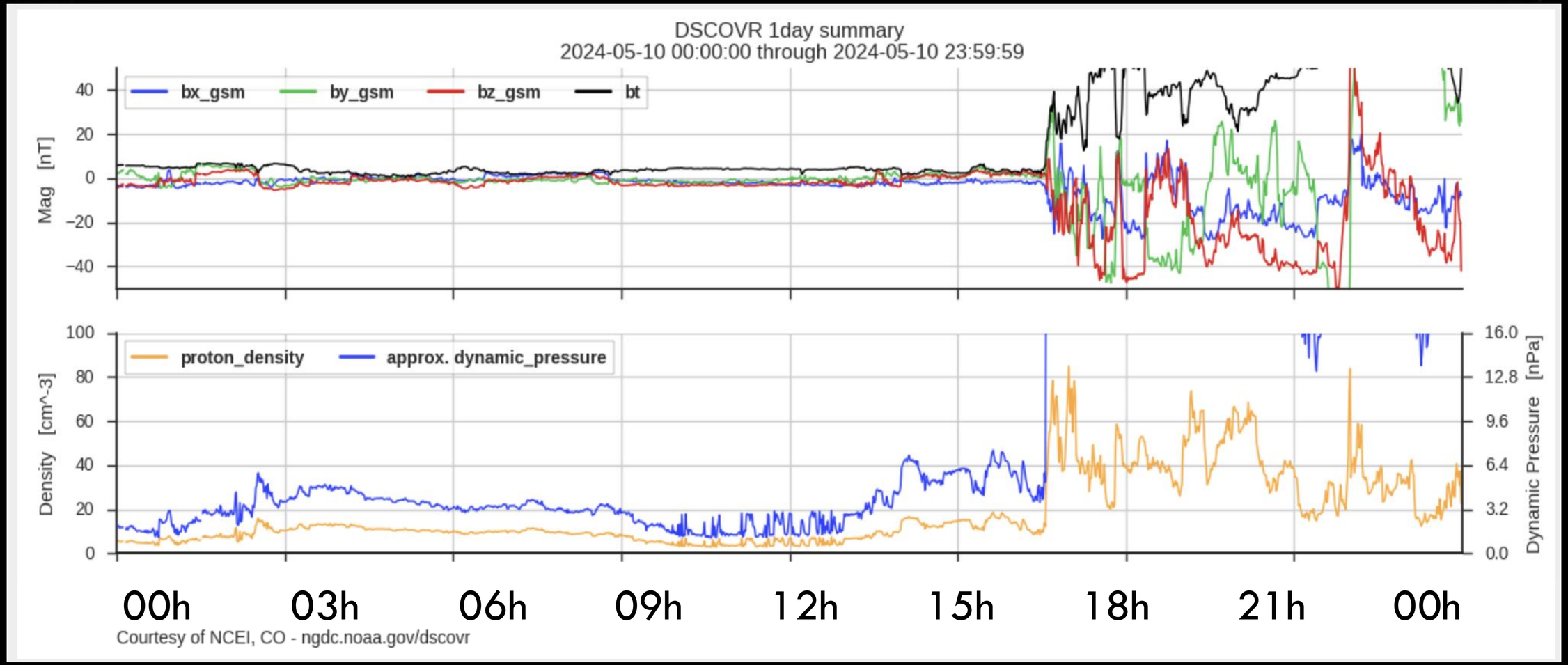


Forecasting Sequence of Events

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



Forecasting Sequence of Events



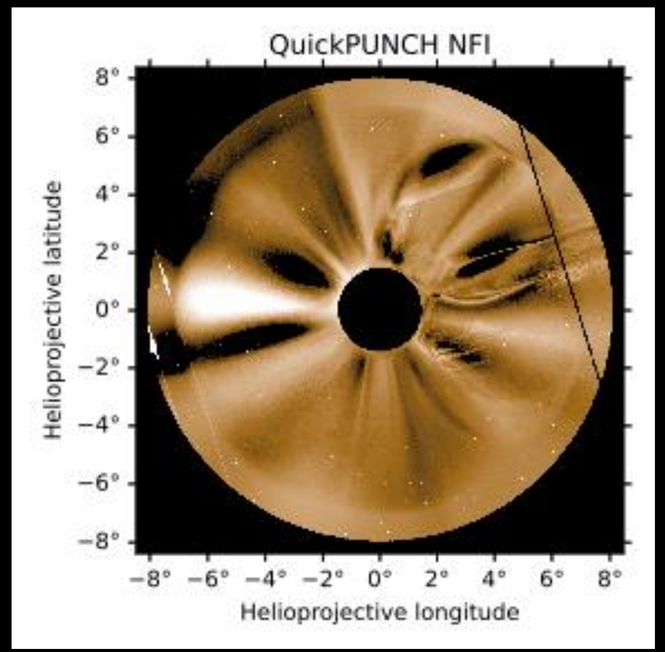
SOLAR-1 solar wind monitors at L1 provide real-time alerts

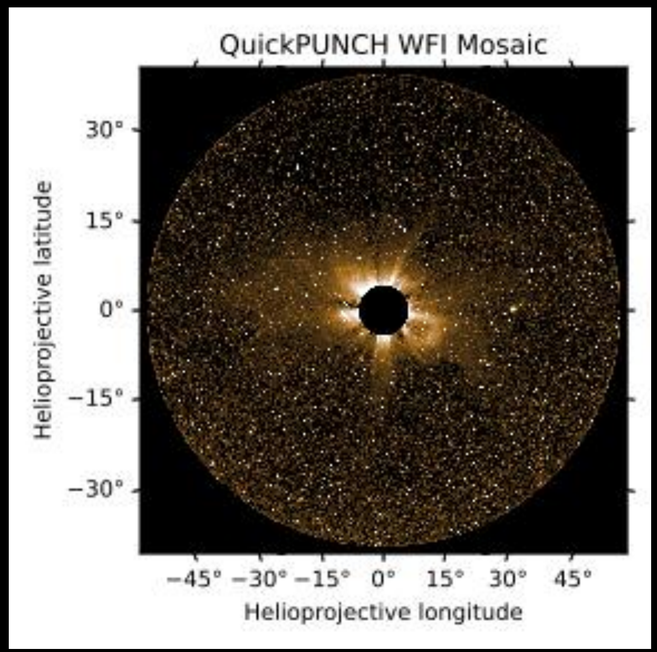
Polarimeter to Unify the Corona and Heliosphere

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



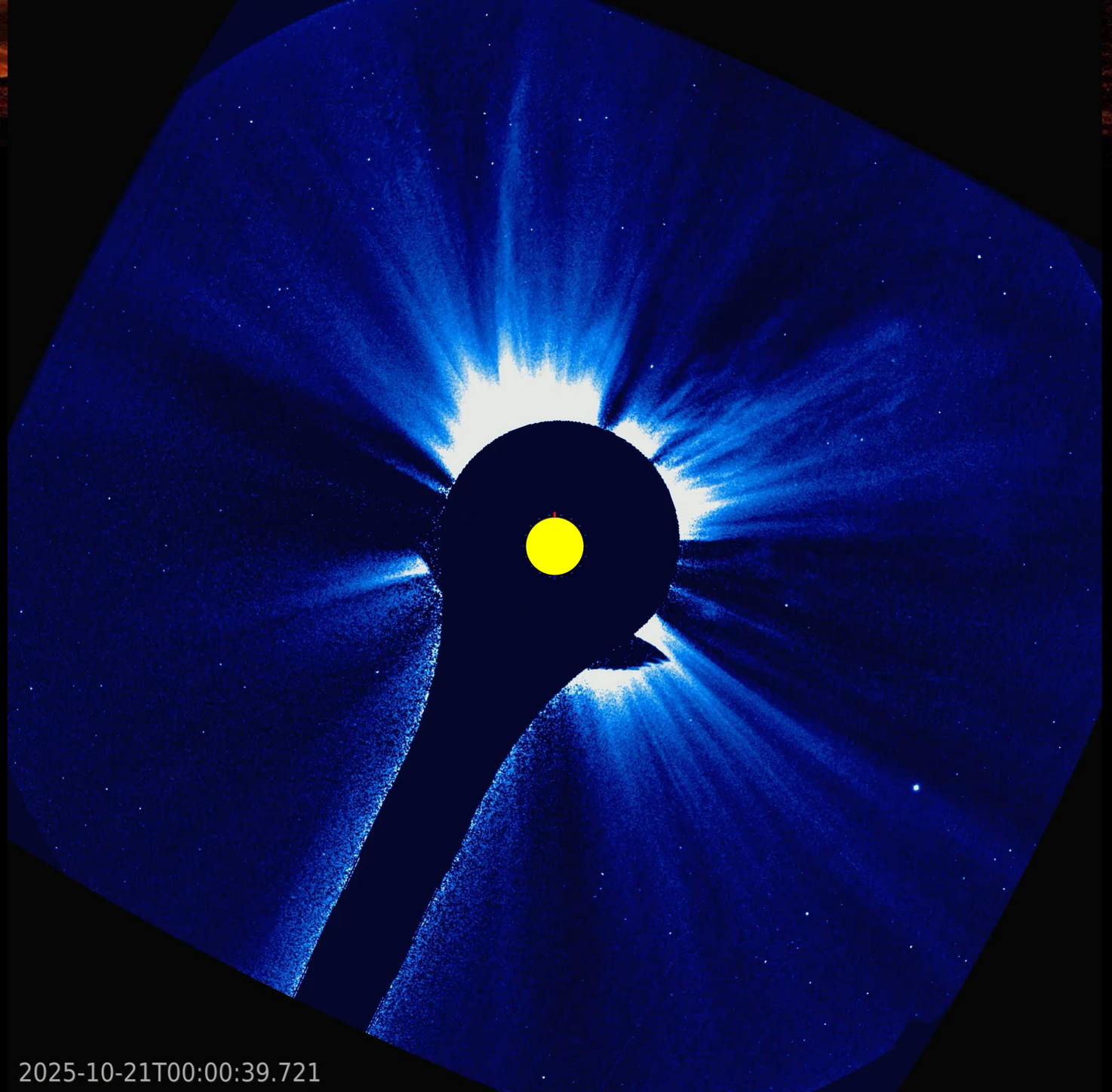


QuickPUNCH Project Status

- 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

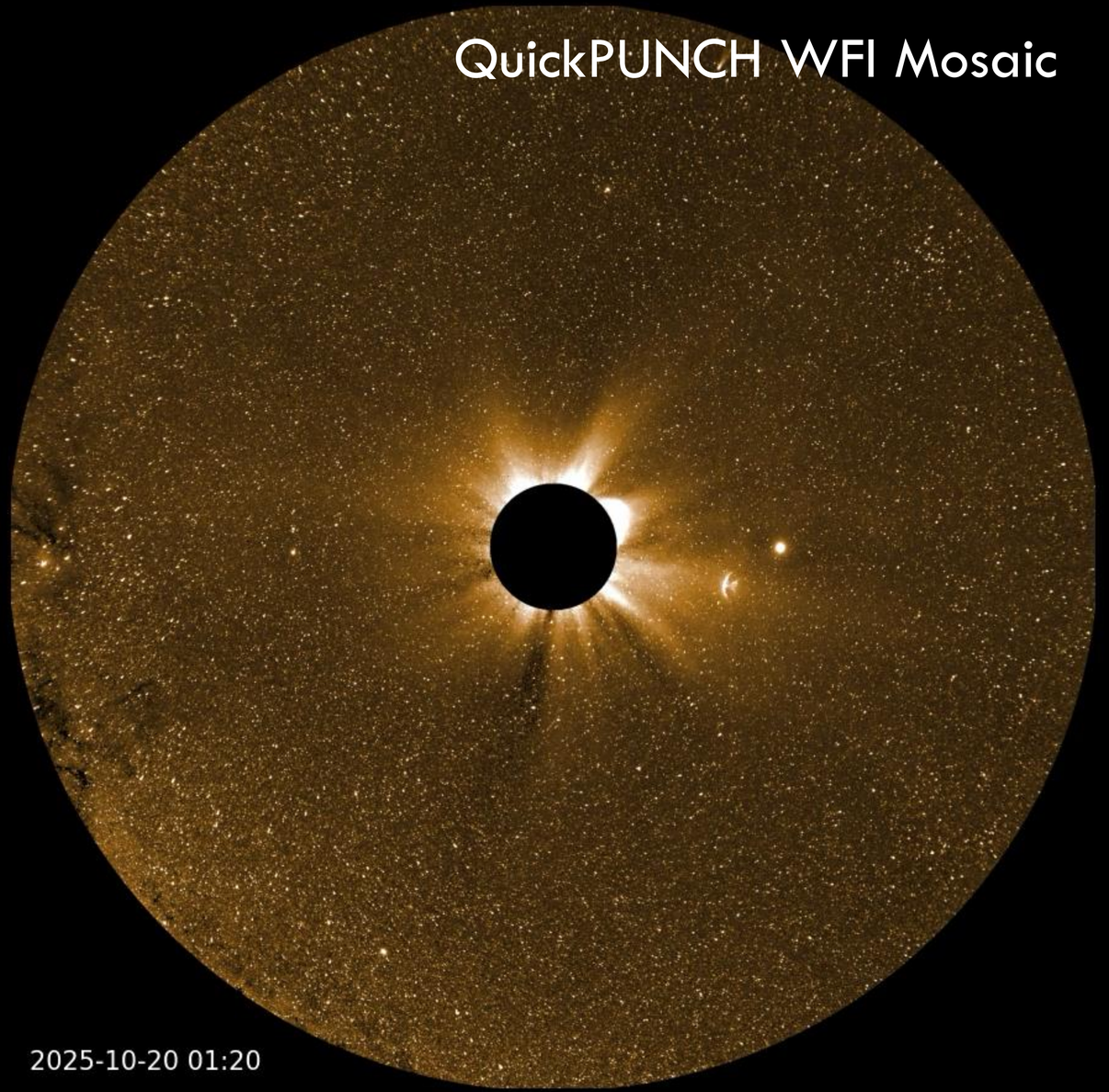
NOAA CCOR images

CCOR FOV:
3.7 $R_\odot$ – 17 $R_\odot$



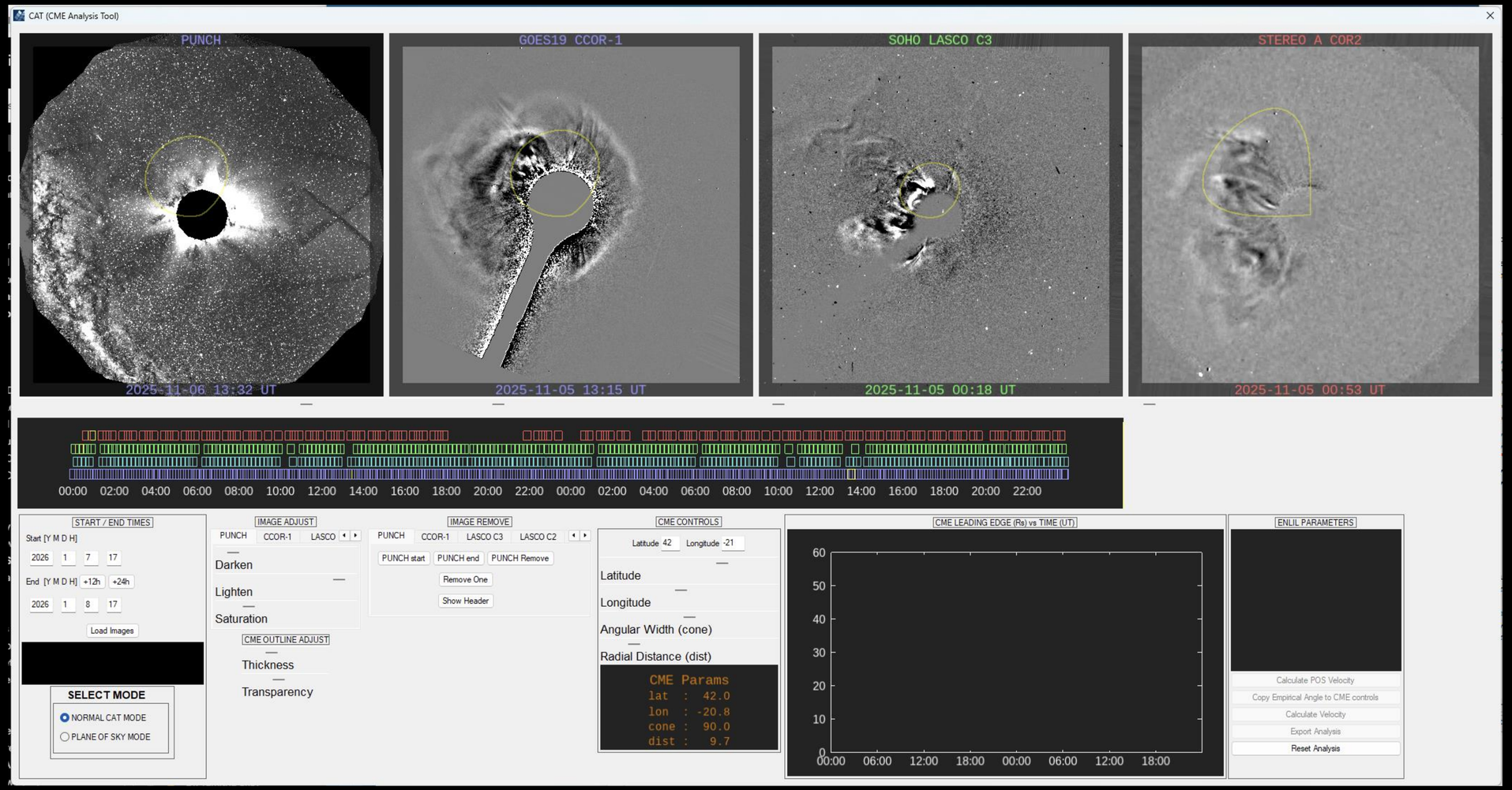
- QuickPUNCH Mosaics provide opportunities to refine CME tracking measurements
- Extends tracking time for a 750 km/s CME from 8 hours to **40+ hours**
- SWPC has demonstrated in CAT, undergoing validation now

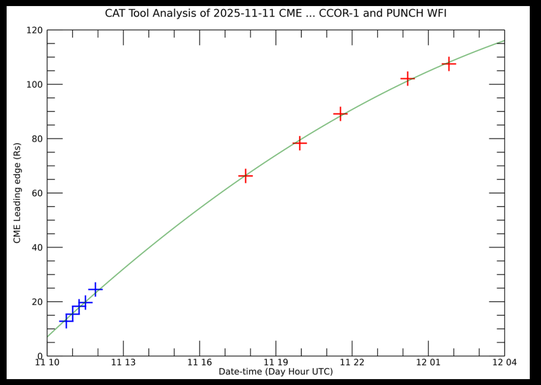
QuickPUNCH WFI Mosaic



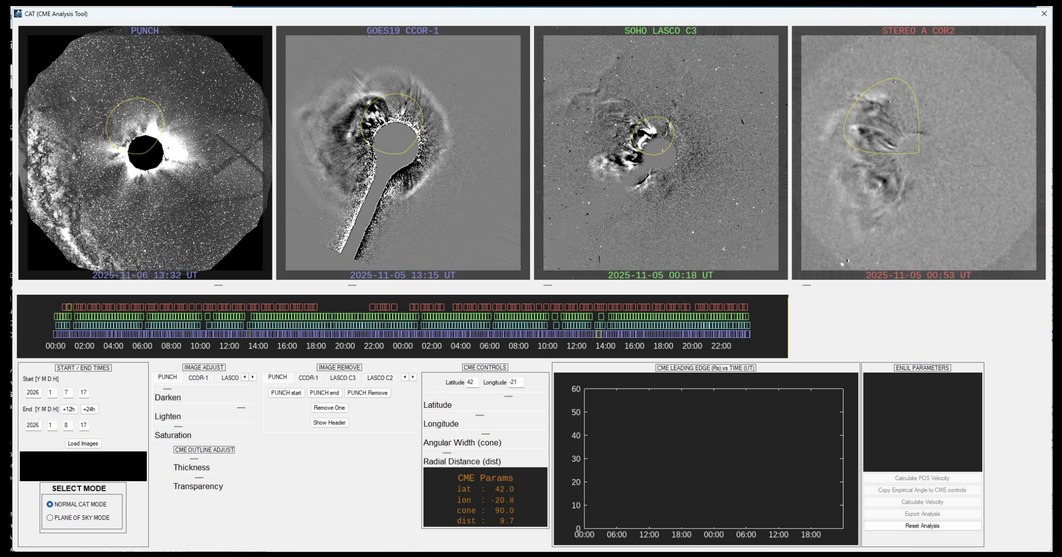
QuickPUNCH in CAT

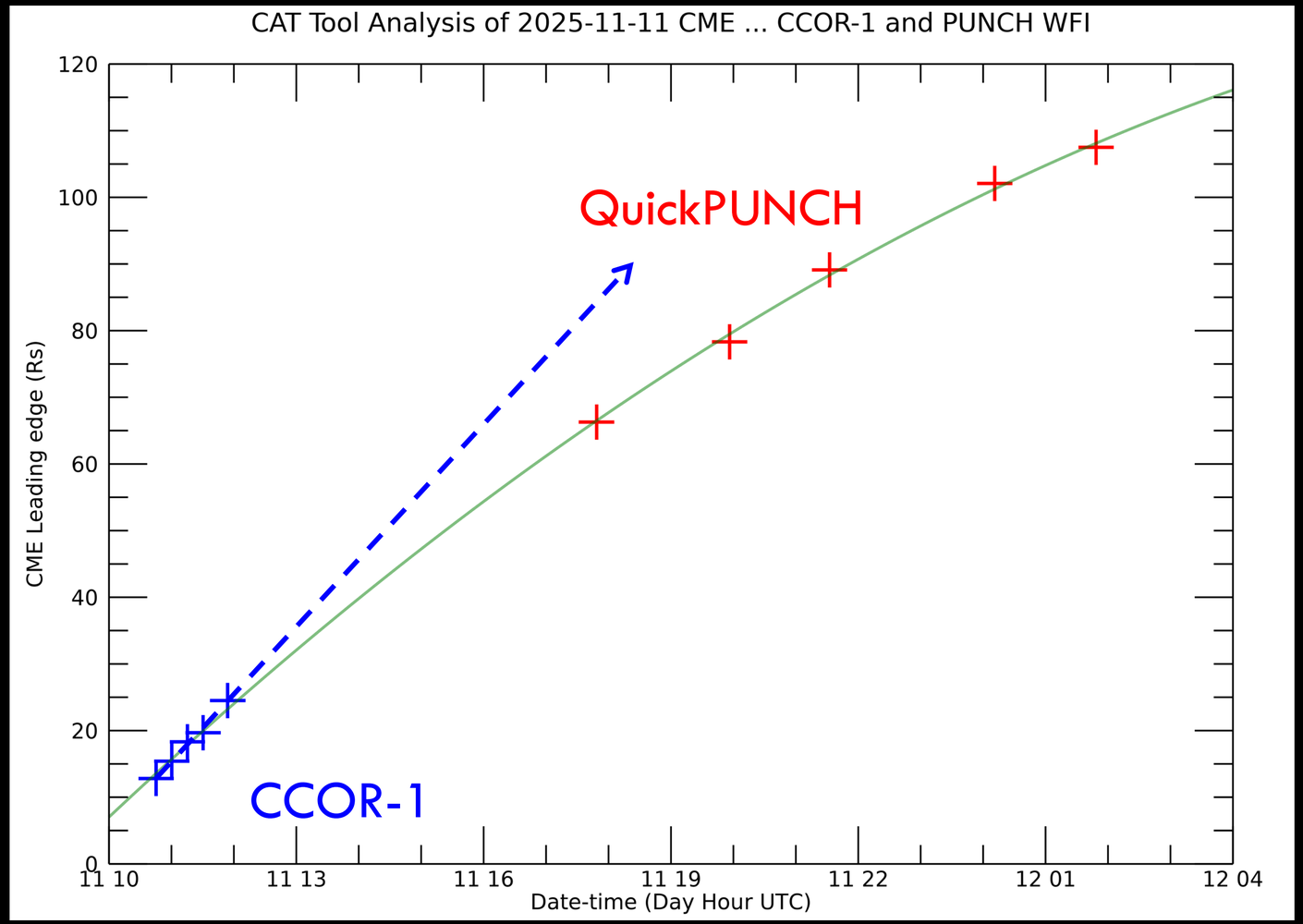
QuickPUNCH CCOR-1 LASCO C3 STEREO A COR2





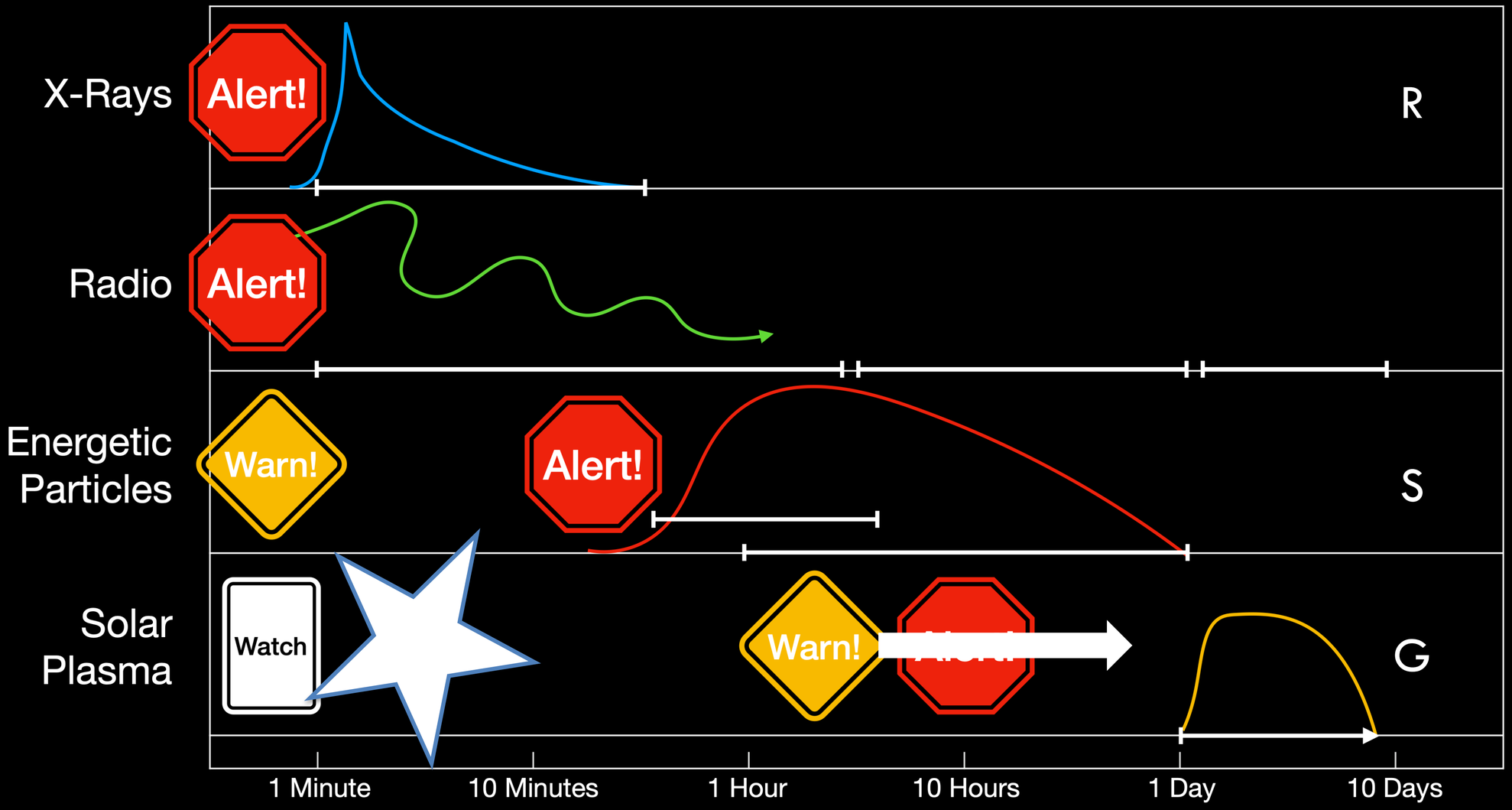
QuickPUNCH in CAT





Forecasting Sequence of Events

Watch for Solar Events



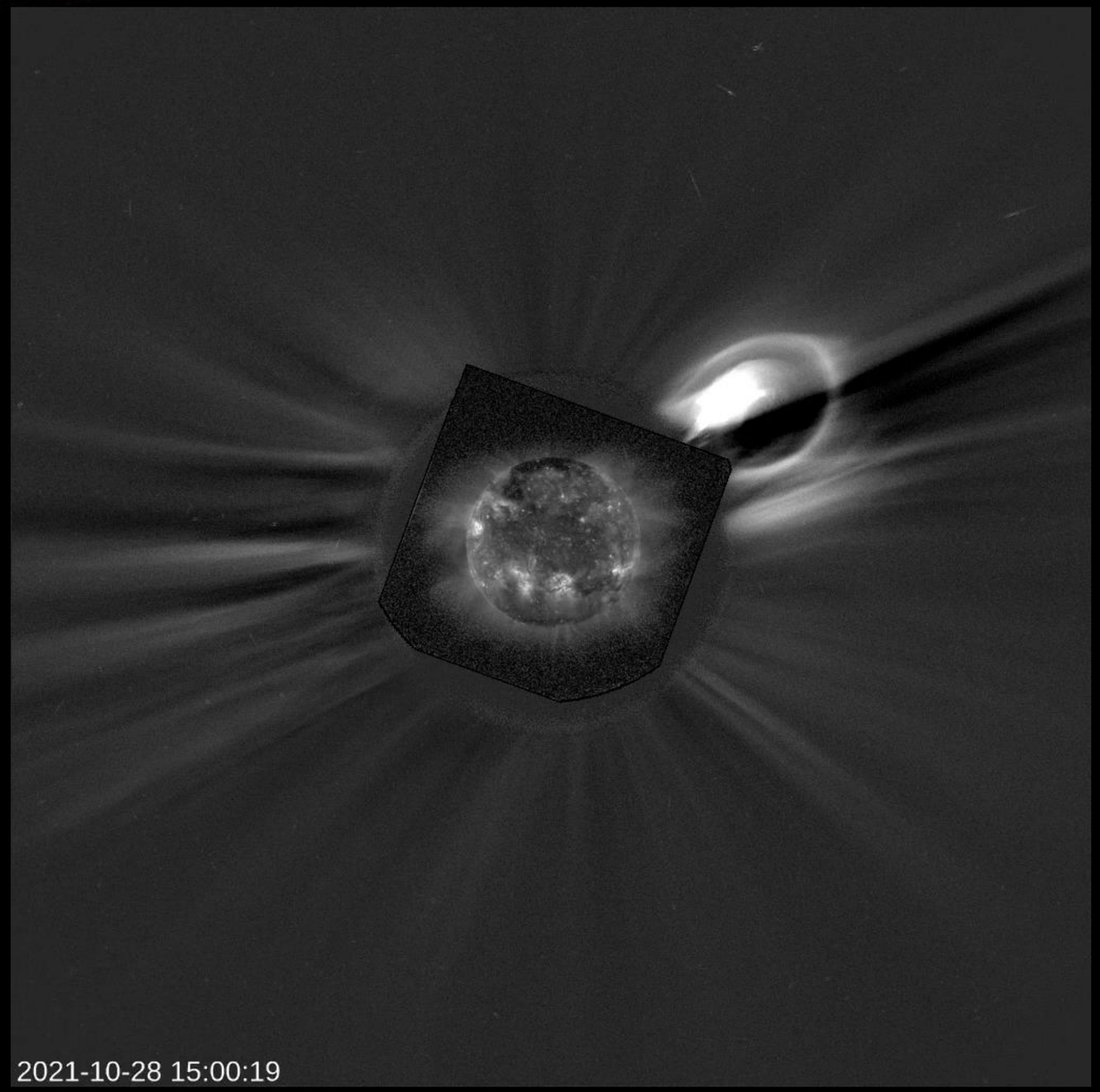
(t = 0 is 8 minutes after eruption onset)

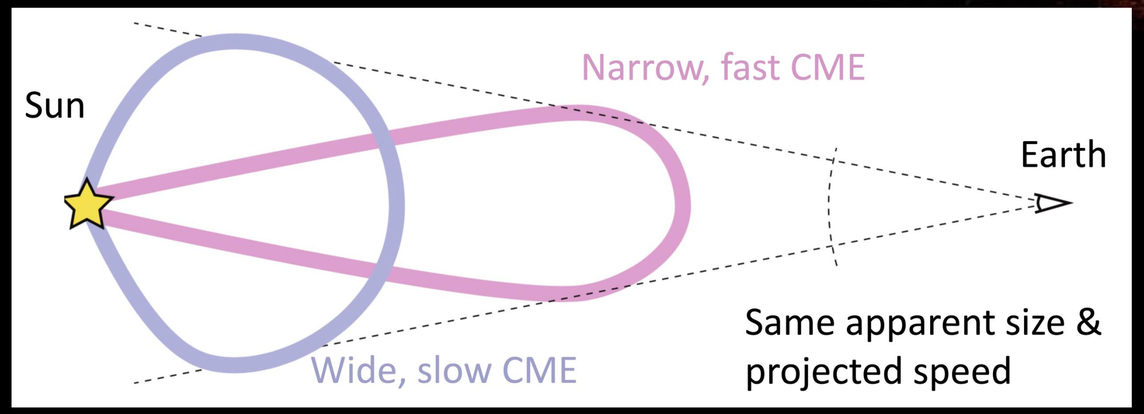
Polarimeter to Unify the Corona and Heliosphere

Research to Operations for PUNCH

Potential Future Uses of Polarized Data

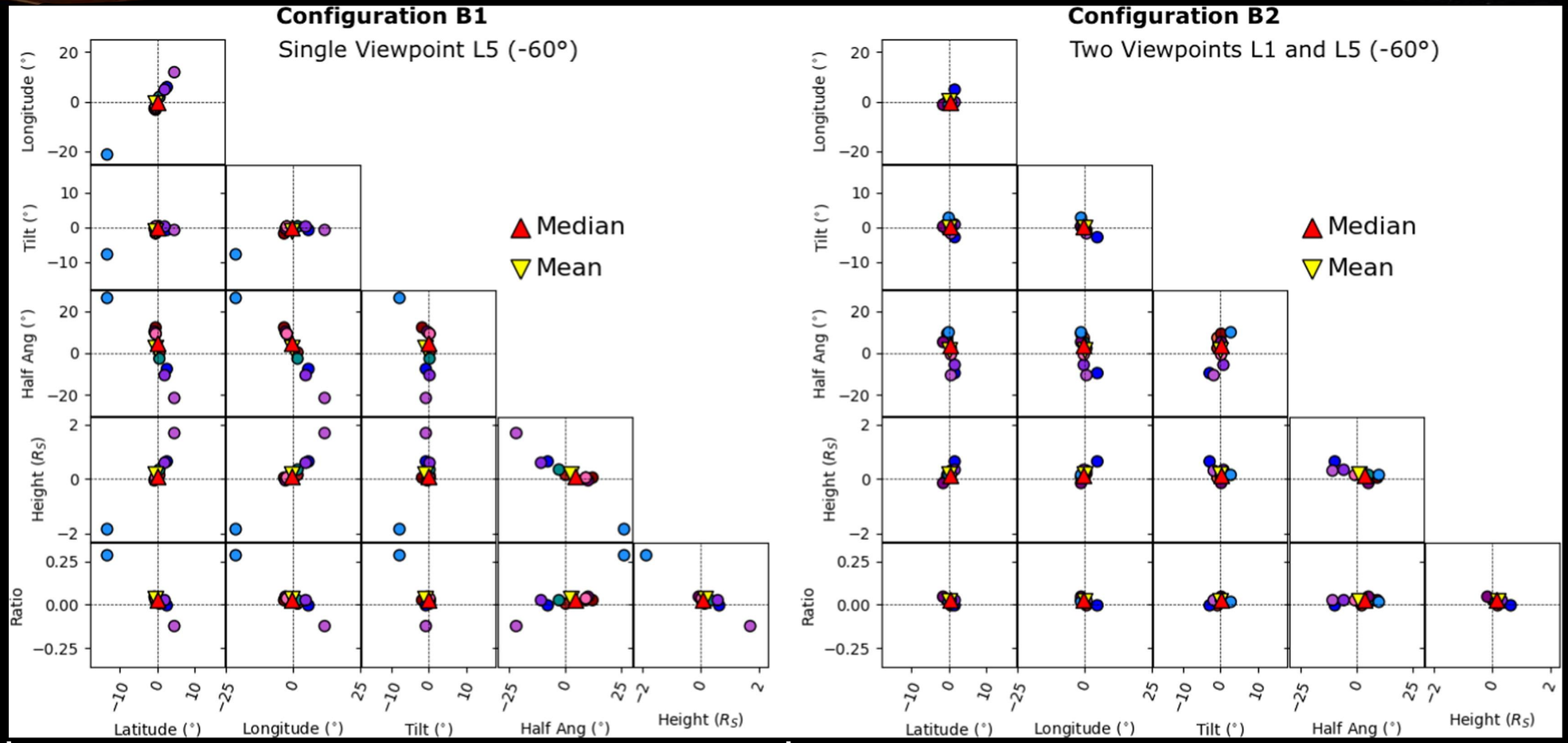
Tracking CMEs in 3D without Polarization





Halo CMEs are subject to ambiguity between size and speed

Tracking CMEs in 3D without Polarization

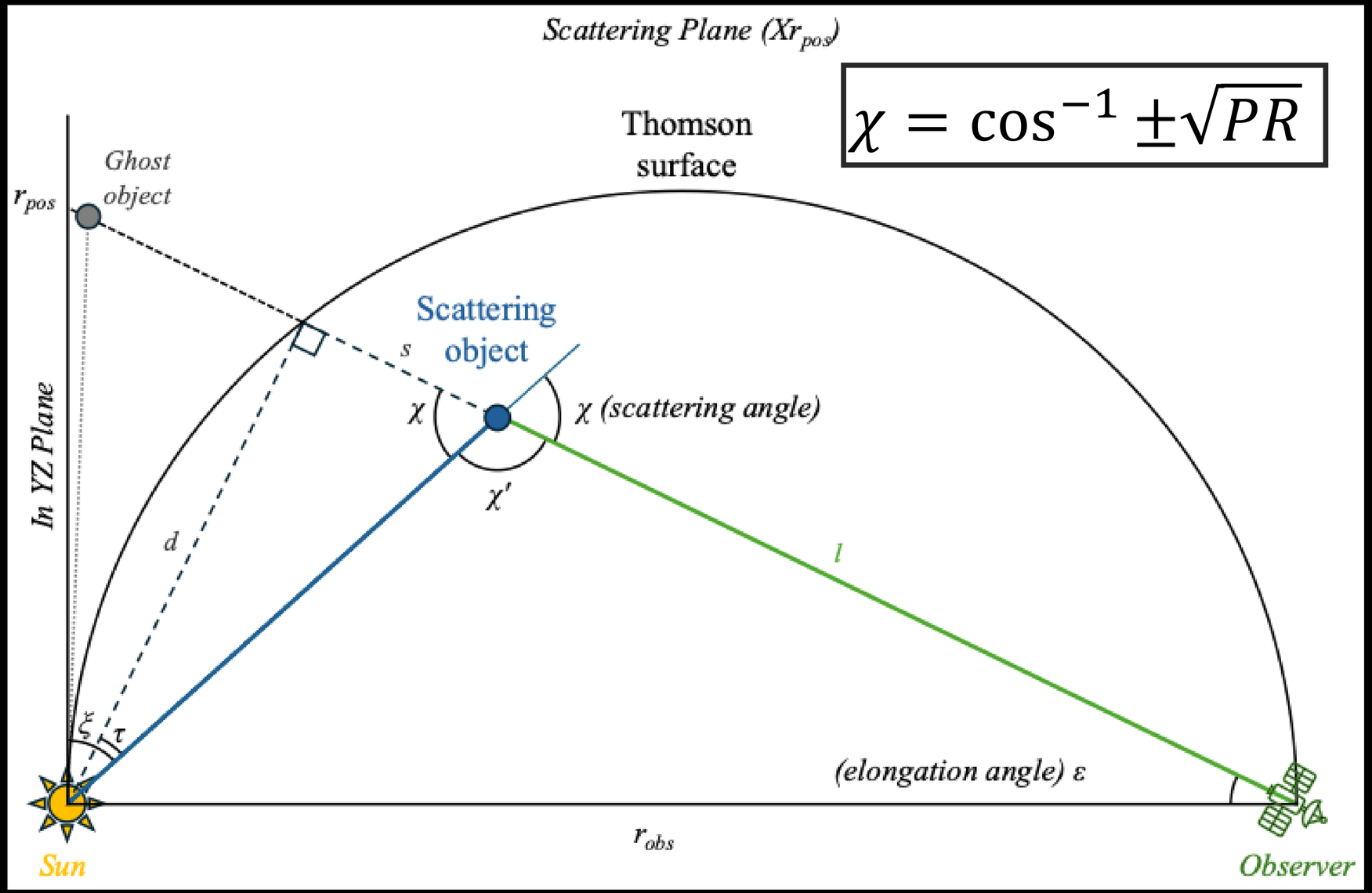


Verbeke+ (2023)

Single perspective → up to 5× error in arrival time vs. two viewpoints

Arrival prediction is significantly worse for fast CMEs

Tracking CMEs in 3D *with* Polarization

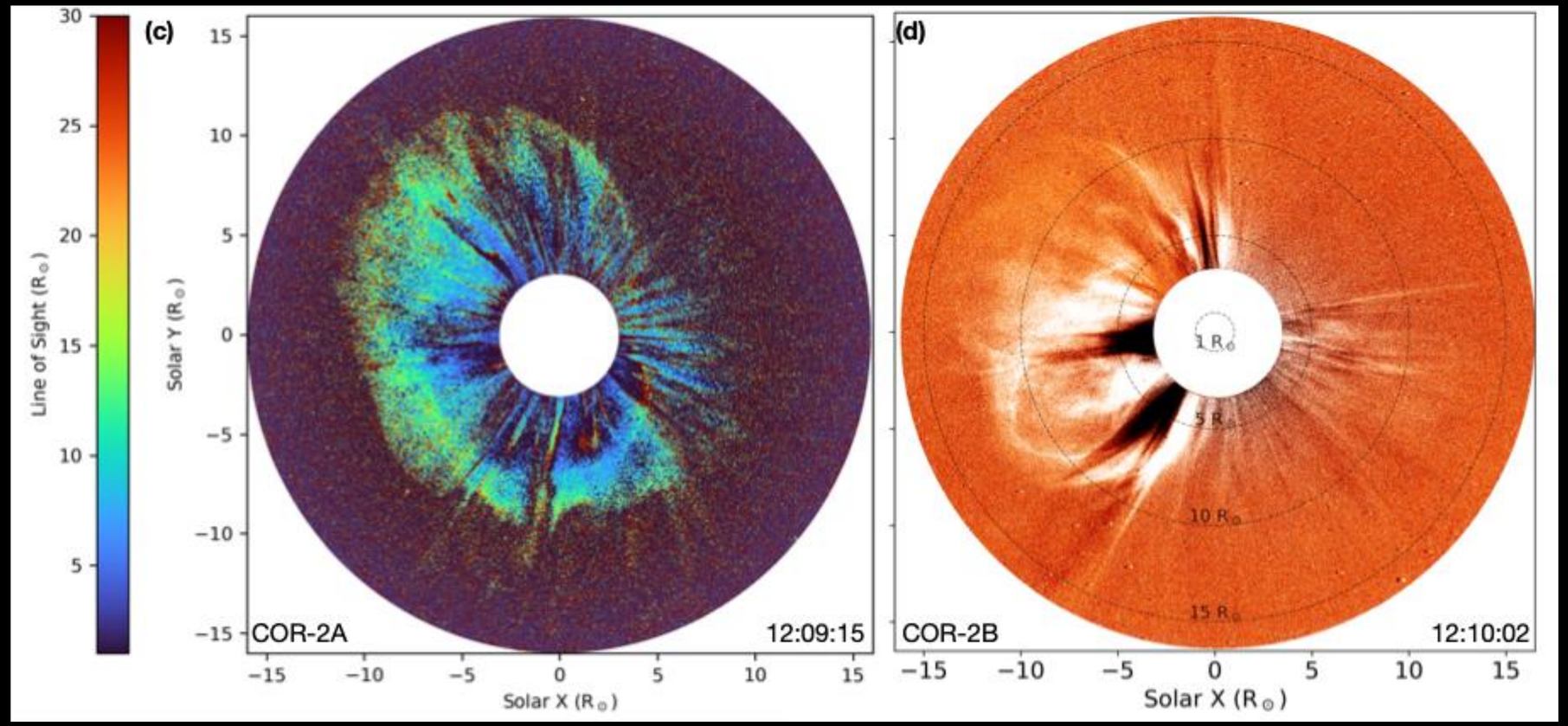


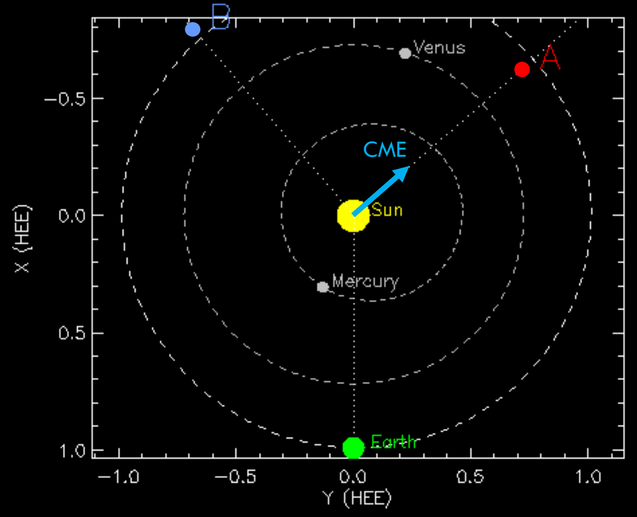
$$p = pB/tB$$

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

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