Polarimeter to Unify the Corona and Heliosphere

QuickPUNCH Data for Space Weather Operations

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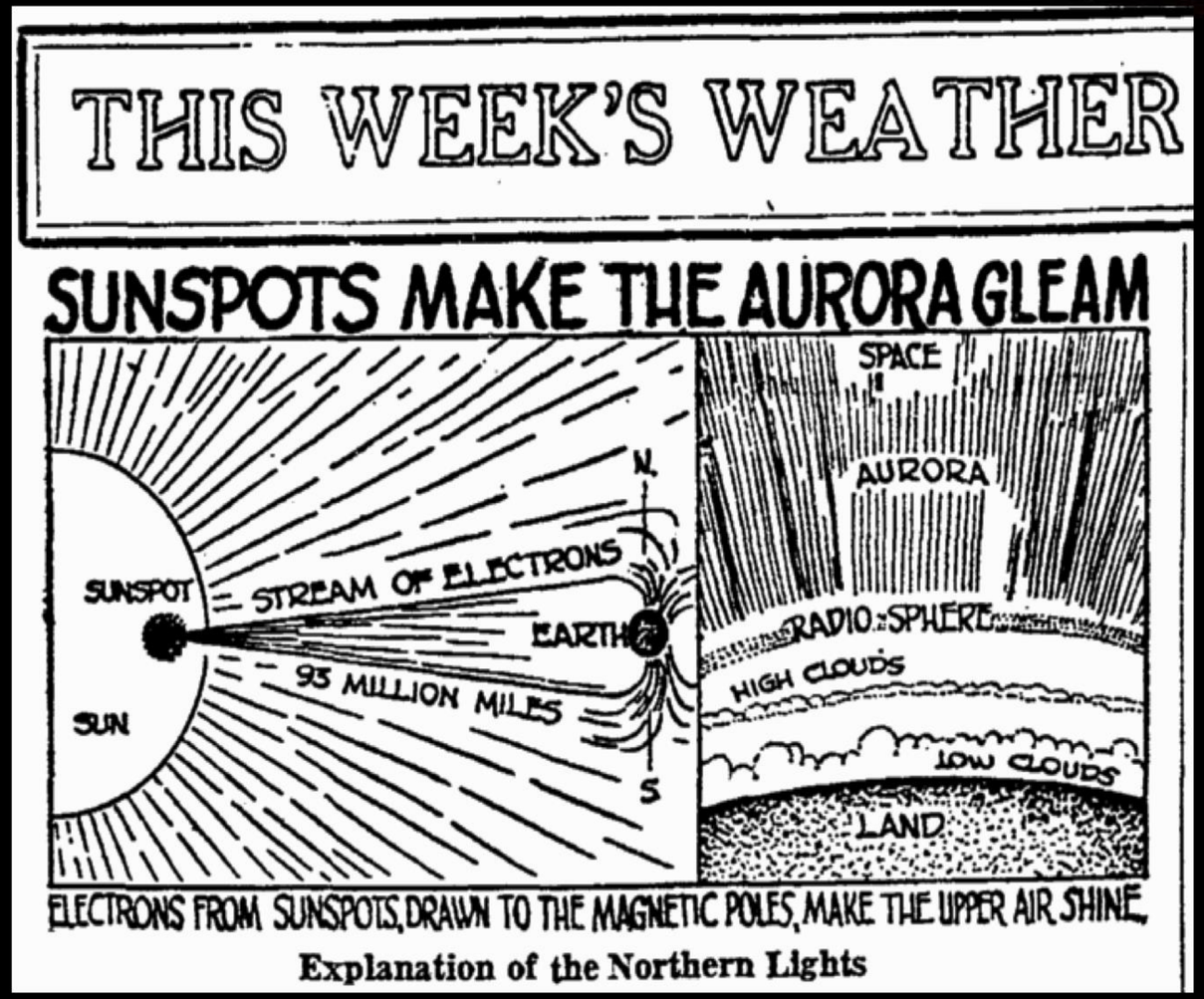
Space Weather & Space Weather Effects

Why should you care?
What can we do about it?

1. Solar Eruptions and Solar Wind
2. Interplanetary Propagation, IMF
3. Geospace
4. Geomagnetic Response
5. Ionosphere Response
6. Technological Impacts

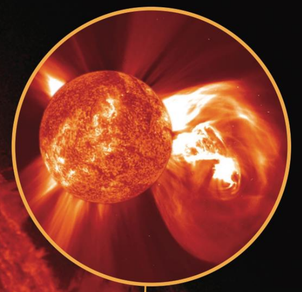


Trenton Times Advisor (September, 1941).

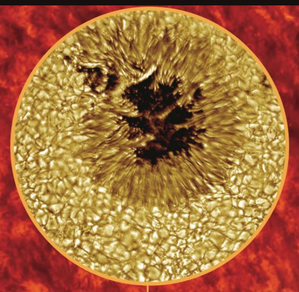
Space Weather

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

Sunspots



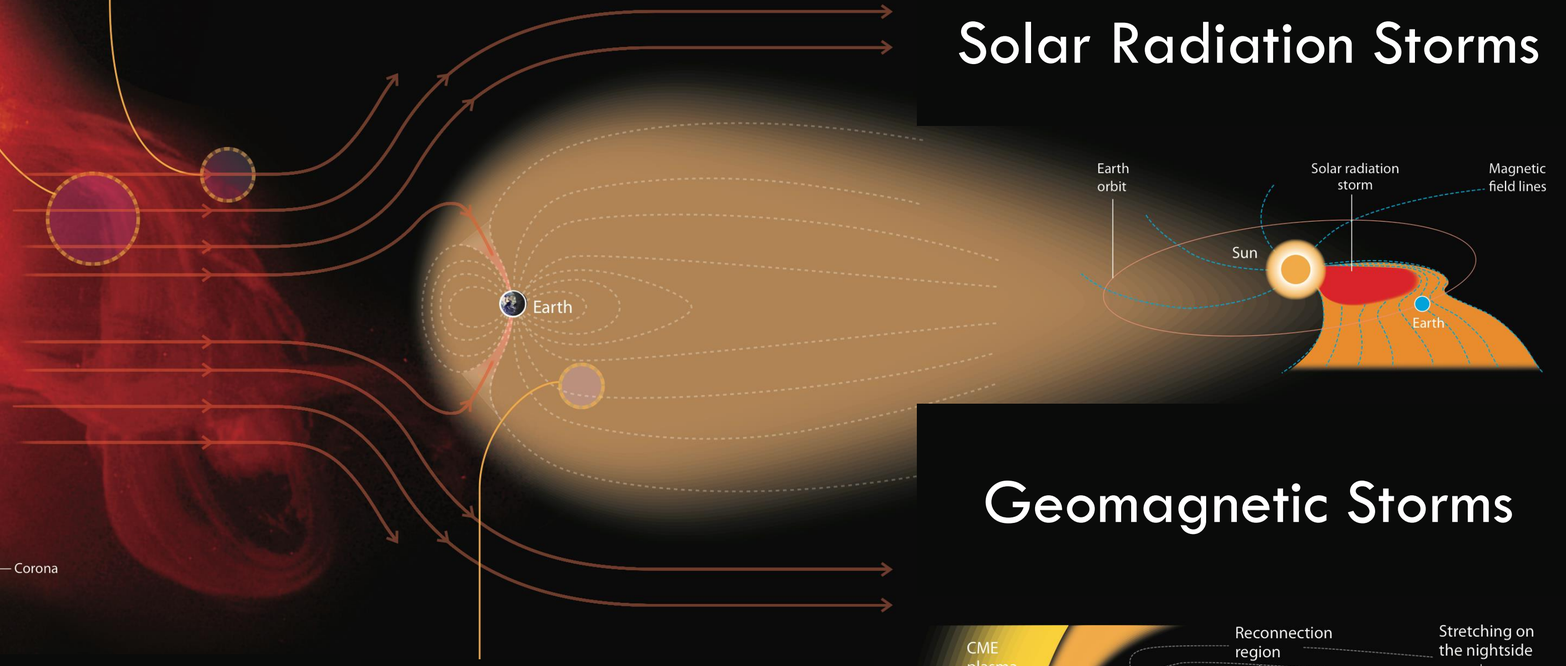
Coronal Mass Ejections (CMES)



Solar Wind

Sun's Magnetic Field

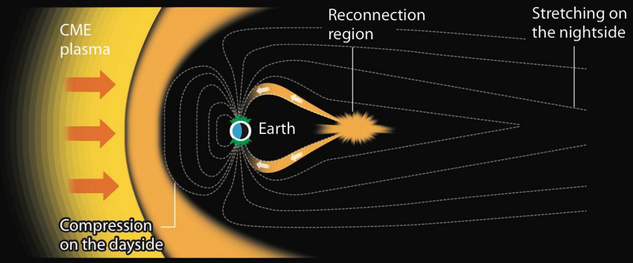
Solar Radiation Storms

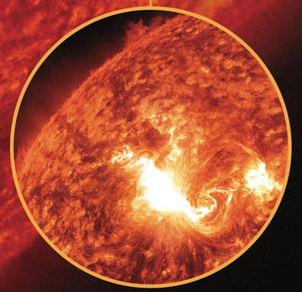


Solar Atmosphere

Corona

Geomagnetic Storms





Solar Flares

Earth's Magnetic Field

NOAA Space Weather Prediction Center – www.spaceweather.gov

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

Source images: NASA, NOAA.

Space Weather Impacts on Earth

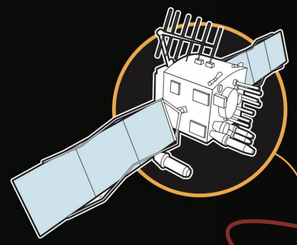
SpWx can influence the performance & reliability of technological systems and endanger life or health.

Global Positioning System

"R, S, G" Scales

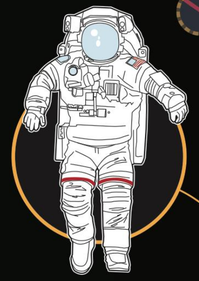
Satellite Operations

"S, G" Scales



Space Operations

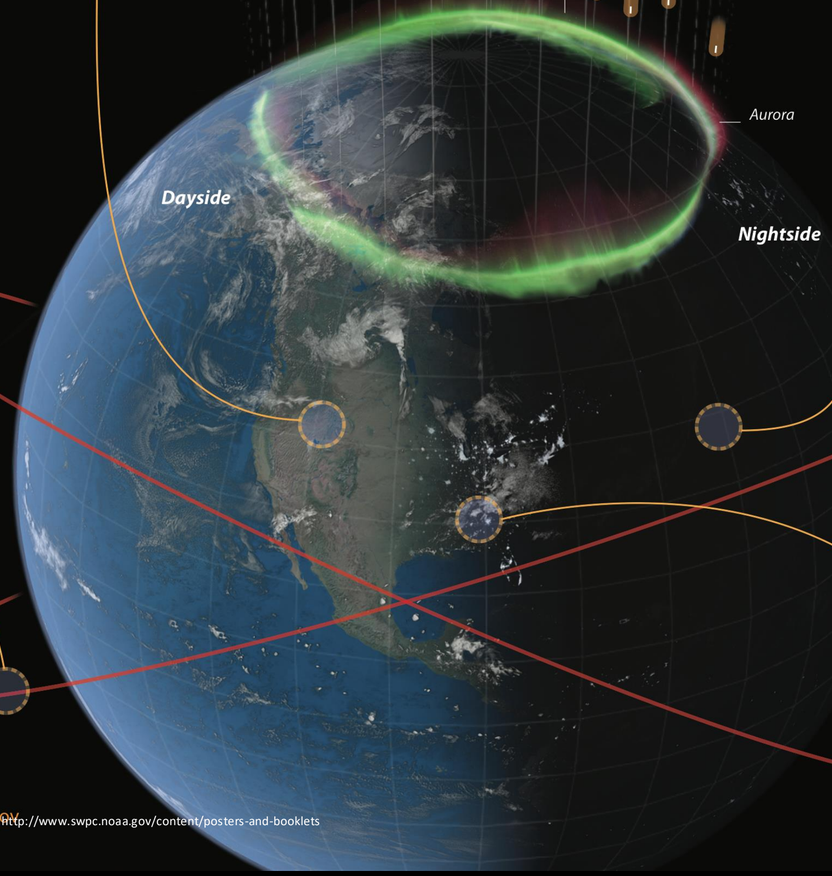
"S, G" Scales



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

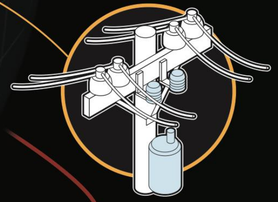
- Deep red from high altitude atomic oxygen
- Magenta from high altitude molecular nitrogen in sunlight
- Greenish yellow from lower altitude atomic oxygen
- Magenta from low altitude molecular nitrogen (not shown in the picture)

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.

Radio Blackout Scale

Scale	Intensity	Effect	Physical measure	Average Frequency
R 5	Extreme	Complete HF blackout to sunlit side of Earth	X20	Less than 1 per 11-year solar cycle
R 4	Severe	Several hours of interruption of HF communications on sunlit side of Earth	X10	8 per cycle
R 3	Strong	Wide area of HF blackout, some impacts to navigation	X1	175 per cycle
R 2	Moderate	Limited blackout and degradation to navigation systems	M5	350 per cycle
R 1	Minor	Minor degradation of HF communications	M1	2000 per cycle

Adapted from http://www.swpc.noaa.gov/noaa-scales-explanation

Solar Radiation Storm Scale

Scale	Intensity	Effect	Physical measure	Average Frequency
S 5	Extreme	Serious health hazards to astronauts, potentially fatal satellite failures, complete blackout of HF communications	10^5 (Flux level of >10 MeV particles)	<1 per 11-year solar cycle
S 4	Severe	Major health hazards to astronauts, significant satellite failures, complete blackout of HF communications	10^4	3 per cycle
S 3	Strong	Some health hazards to astronauts, infrequent but significant satellite problems, degraded HF communications	10^3	10 per cycle
S 2	Moderate	Impacts to human spaceflight-related technology, infrequent satellite single event upsets, HF interference on polar routes	10^2	25 per cycle
S 1	Minor	Minor interference to HF communications	10	50 per cycle

Adapted from http://www.swpc.noaa.gov/noaa-scales-explanation

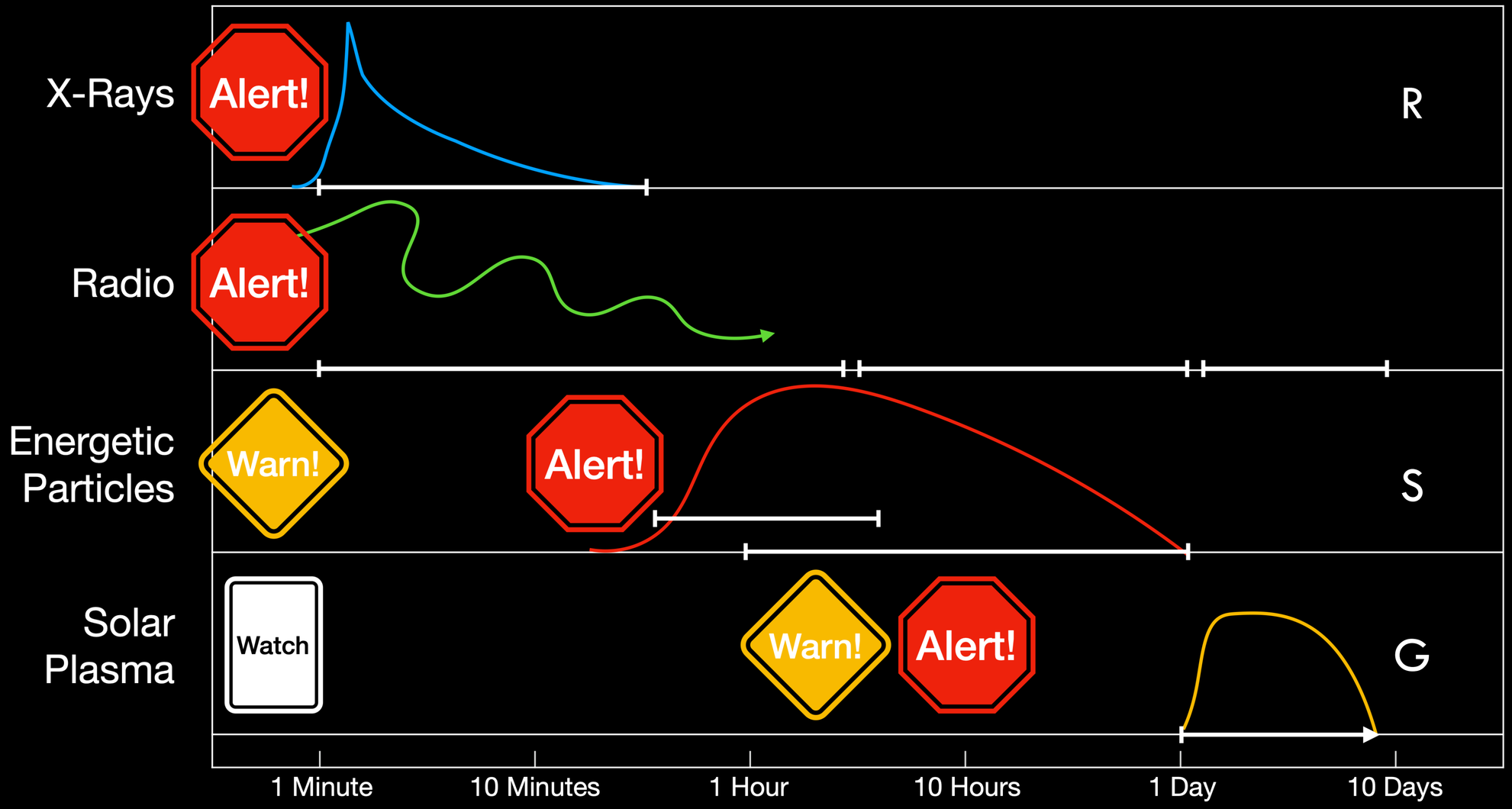
Geomagnetic Storm Scale

Scale	Intensity	Effect	Physical measure	Average Frequency
G 5	Extreme	Potential power grid collapse, major impacts to satellite function and communication, aurora widespread	Kp = 9	4 per 11-year solar cycle (4 days per cycle)
G 4	Severe	Widespread power grid impacts, surface charging on spacecraft, major impacts to satellite navigation, aurora visible in California and Alabama	Kp = 8	100 per cycle (60 days)
G 3	Strong	Power grid mitigations required, communications interruptions, aurora visible in Illinois or Oregon	Kp = 7	200 per cycle (130 days)
G 2	Moderate	Transformer impacts, minor spacecraft effects, aurora visible in northern New York and Idaho	Kp = 6	600 per cycle (360 days)
G 1	Minor	Minor issues in power grids, affects on migratory animals	Kp = 5	1700 per cycle (900 days)

Adapted from http://www.swpc.noaa.gov/noaa-scales-explanation

Forecasting Sequence of Events

Watch for Solar Events



(t = 0 is 8 minutes after eruption onset)

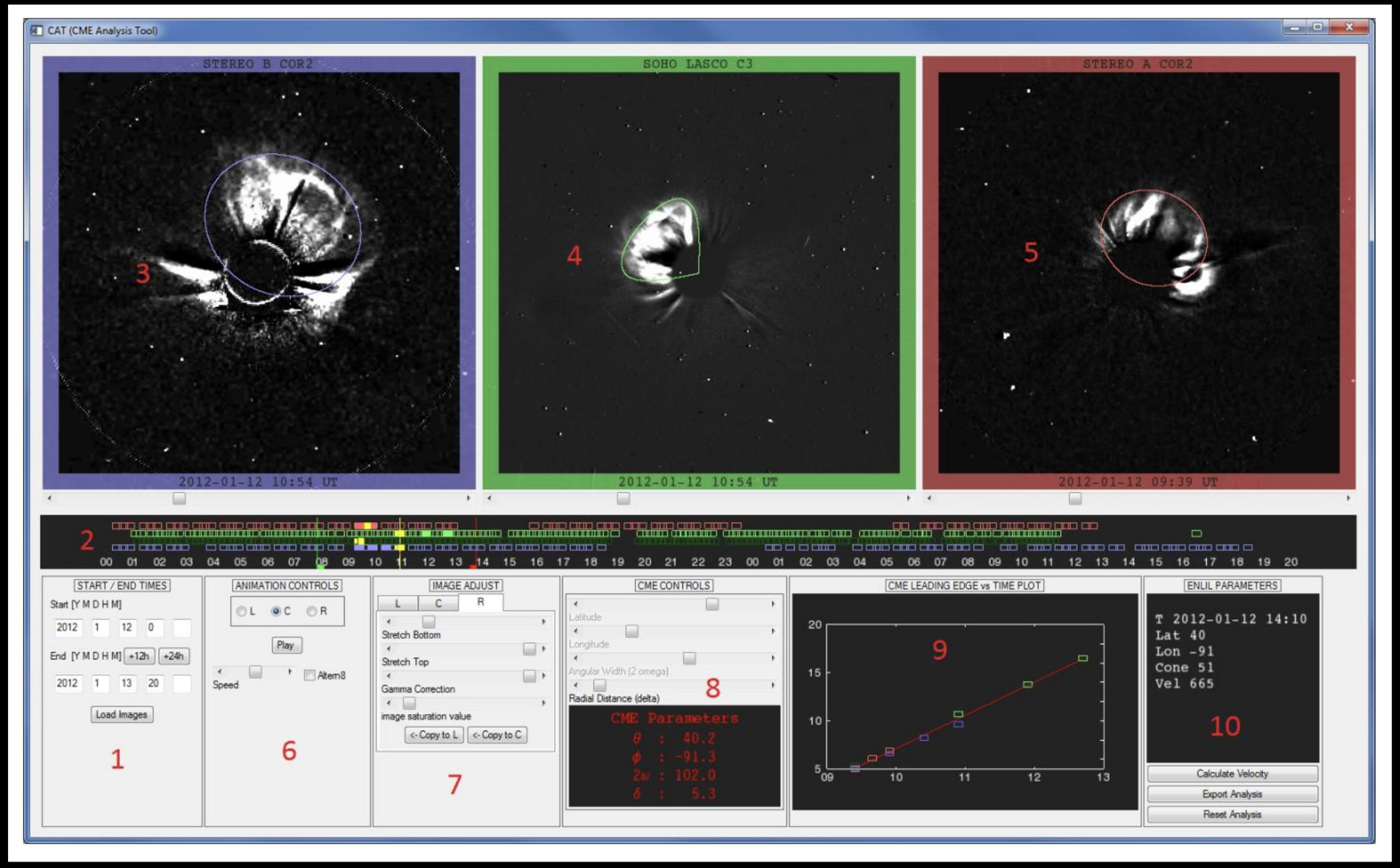
Time (Log Scale)

Forecasting Sequence of Events

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

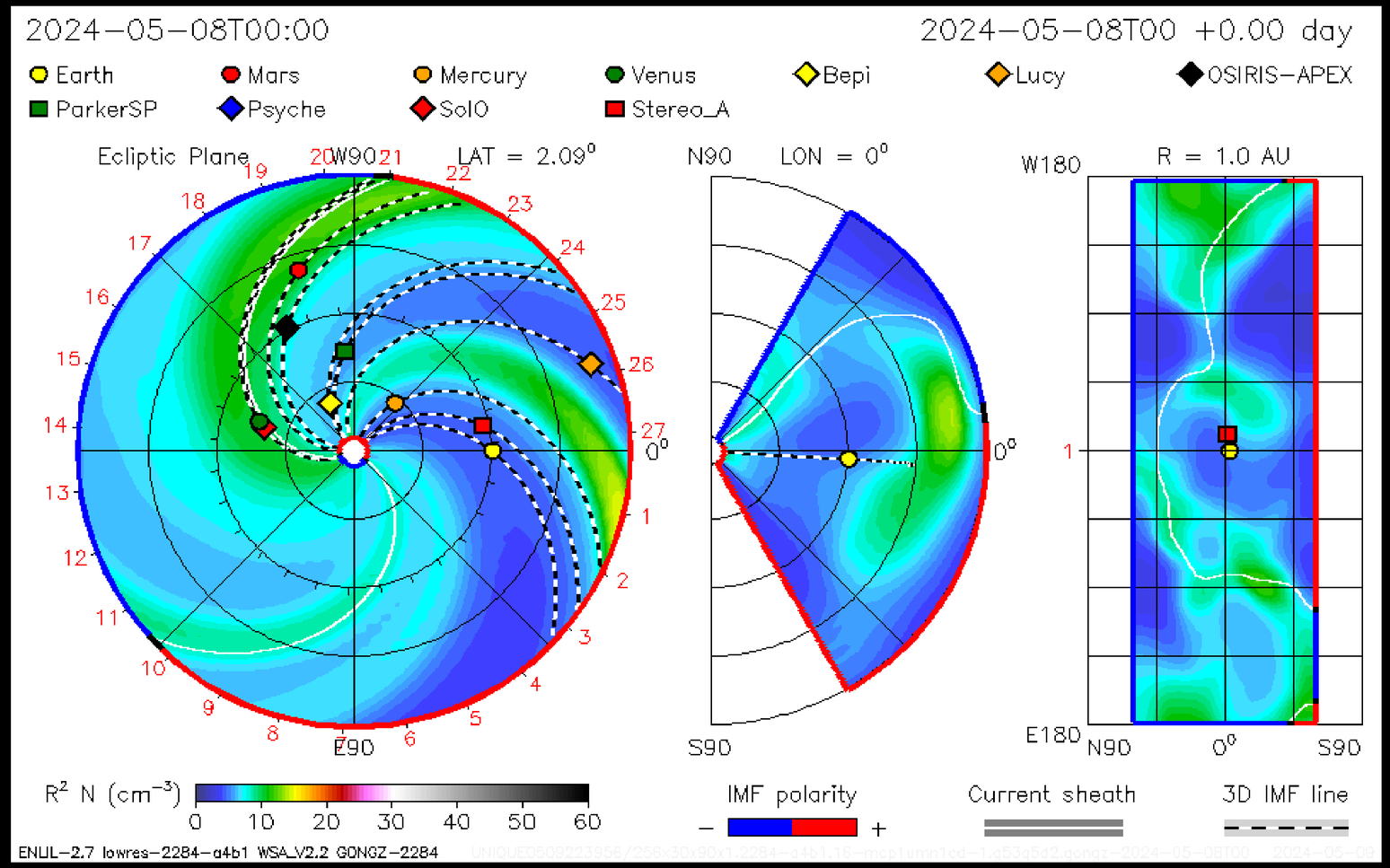
Forecasting Sequence of Events

SWPC CAT tool facilitates 3D reconstruction and classification of CME parameters.



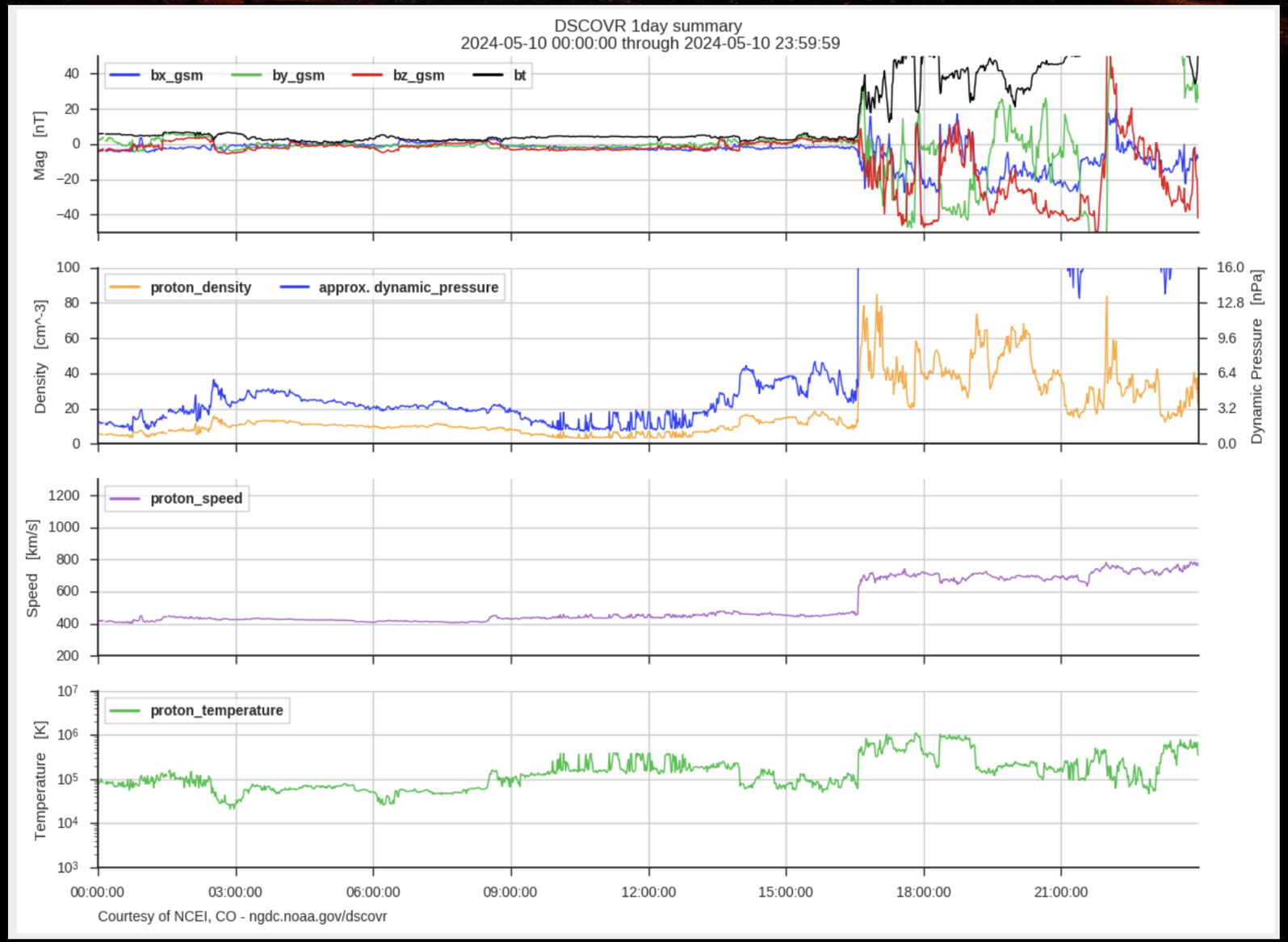
Forecasting Sequence of Events

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



Forecasting Sequence of Events

Solar wind monitors at L1 from DSCOVR provide real-time alerts



Forecasting Sequence of Events

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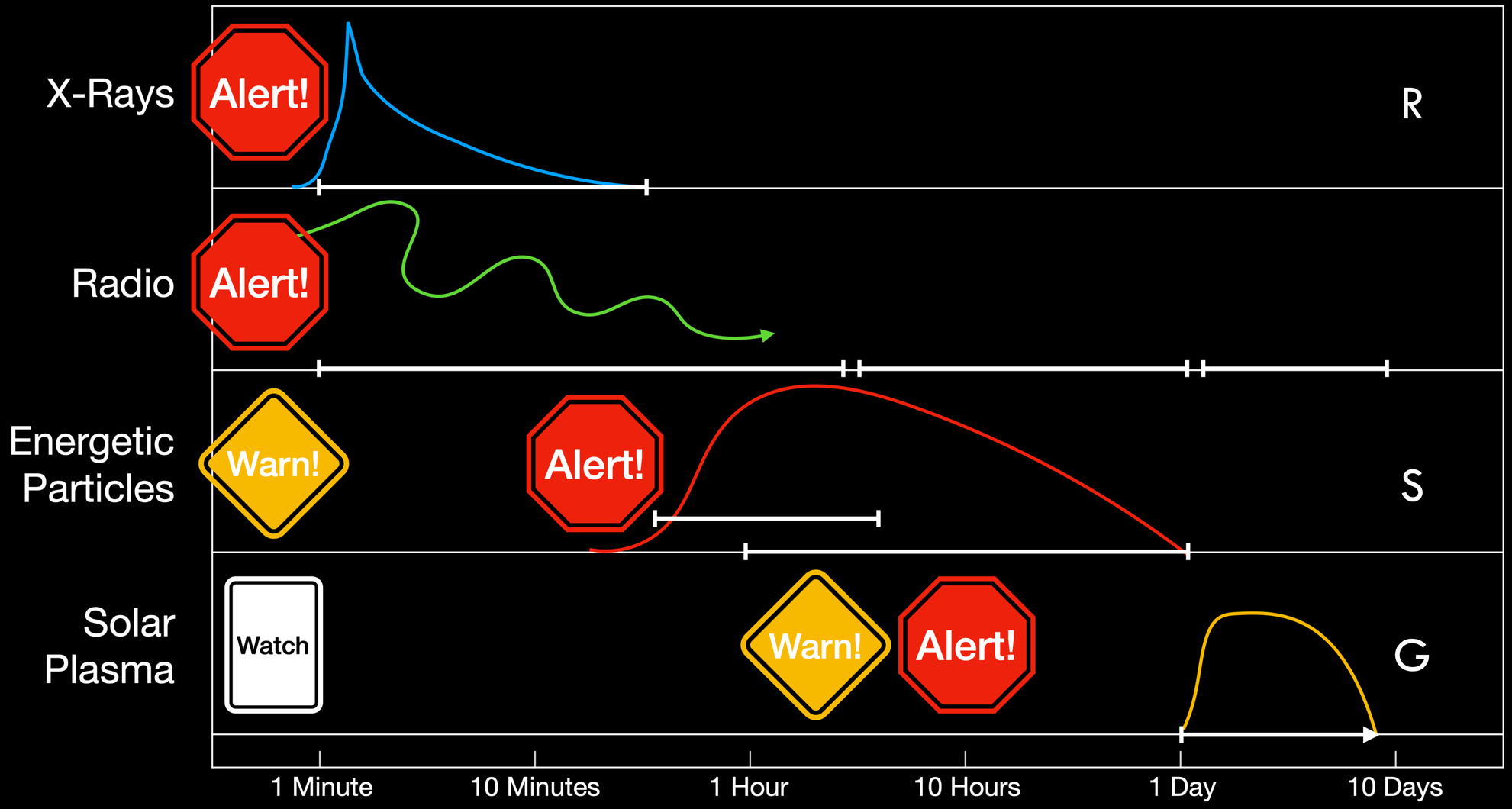


(t = 0 is 8 minutes after eruption onset)

Time (Log Scale)

Polarimeter to Unify the Corona and Heliosphere

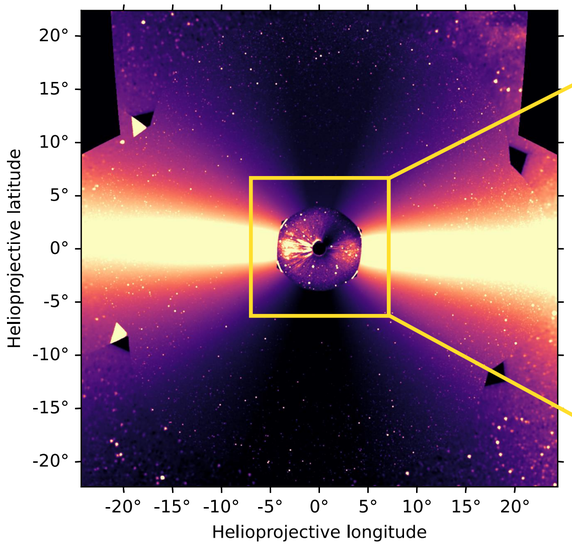
QuickPUNCH helps fill the gap between Sun and Earth

What is QuickPUNCH?

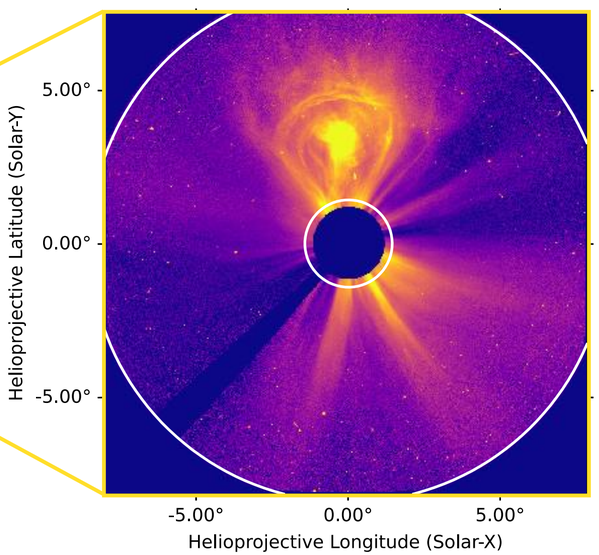
- QuickPUNCH is an enhancement to nominal PUNCH data streams to support NOAA space weather forecasting
- QuickPUNCH reduces latency of key PUNCH products for space weather from days or weeks to hours
- Initial demonstration of service immediately following commissioning
- All data will be accessible to whole community via SDAC and Virtual Solar Observatory alongside regular PUNCH products

QuickPUNCH Data Products at Low Latency

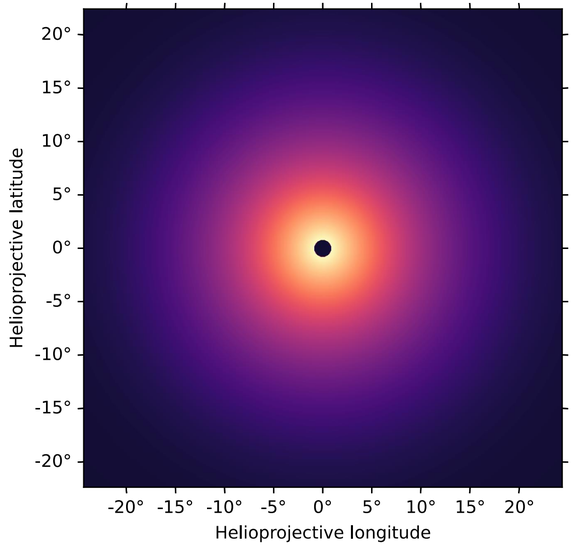
Planned QuickPUNCH Low-Latency Data Products



Low-Latency WFI Mosaics
5–80 $R_\odot$
Every 4 Minutes
1024×1024 pixels
~3 arcmin resolution



Low-Latency NFI Images
5.4–32 $R_\odot$
Every 4 Minutes
1024×1024 pixels
~1 arcmin resolution



WFI & NFI F-Corona Background
Every 12 Hours
Derived from preceding 1 month of data

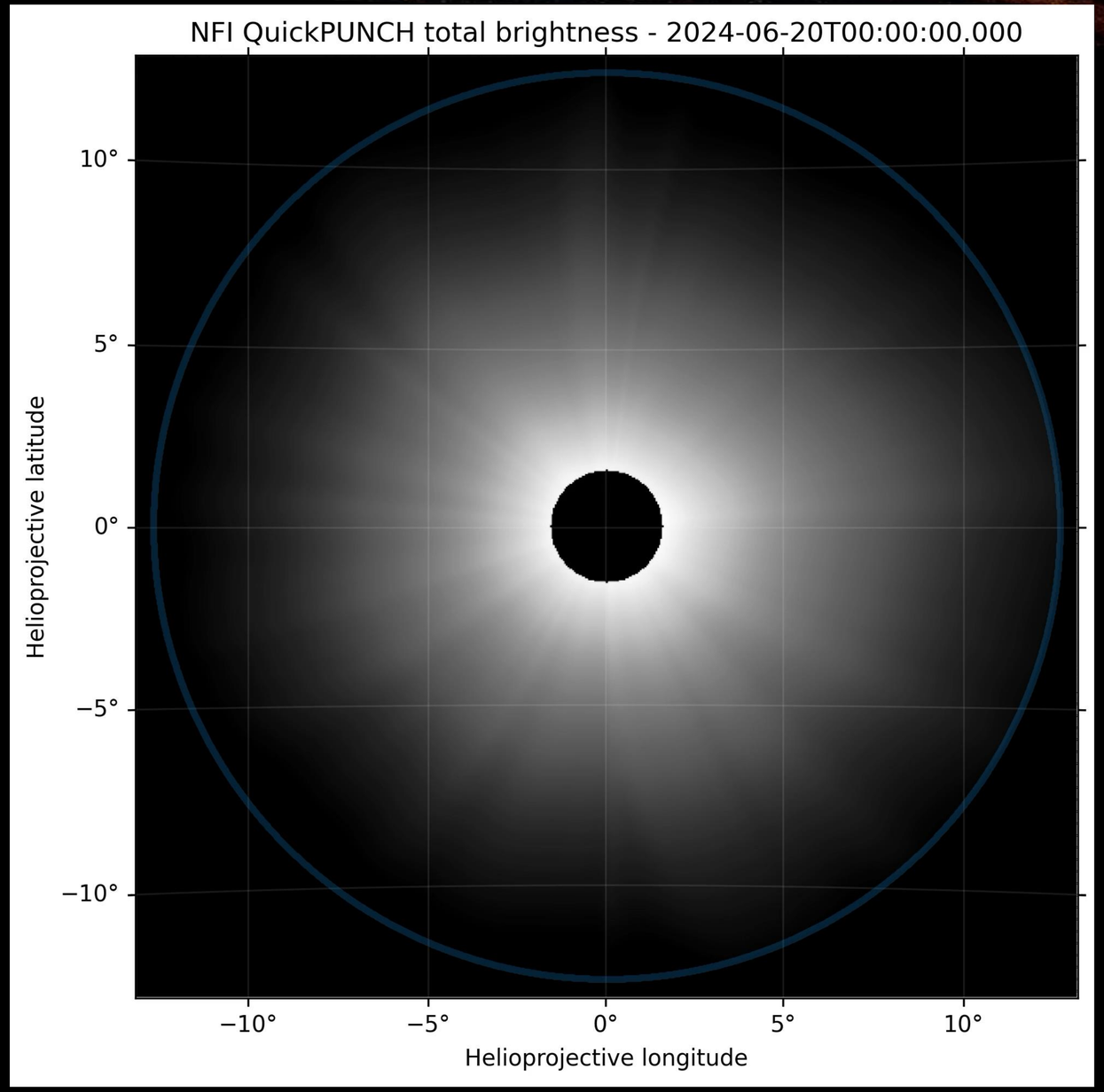
Dedicated Python software generates running difference & F-corona-subtracted images on the fly.

Analysis products are FITS format. Quicklook in JPEG & Helioviewer-compatible JPEG2000.

Data available via PUNCH website as soon as generated.

QuickPUNCH Data Products at Low Latency

- QuickPUNCH NFI Images provide backup for NOAA's Compact Coronagraphs in GOES-U & SWFO-L1
- NFI images provide additional intercalibration opportunities across multiple coronagraphs



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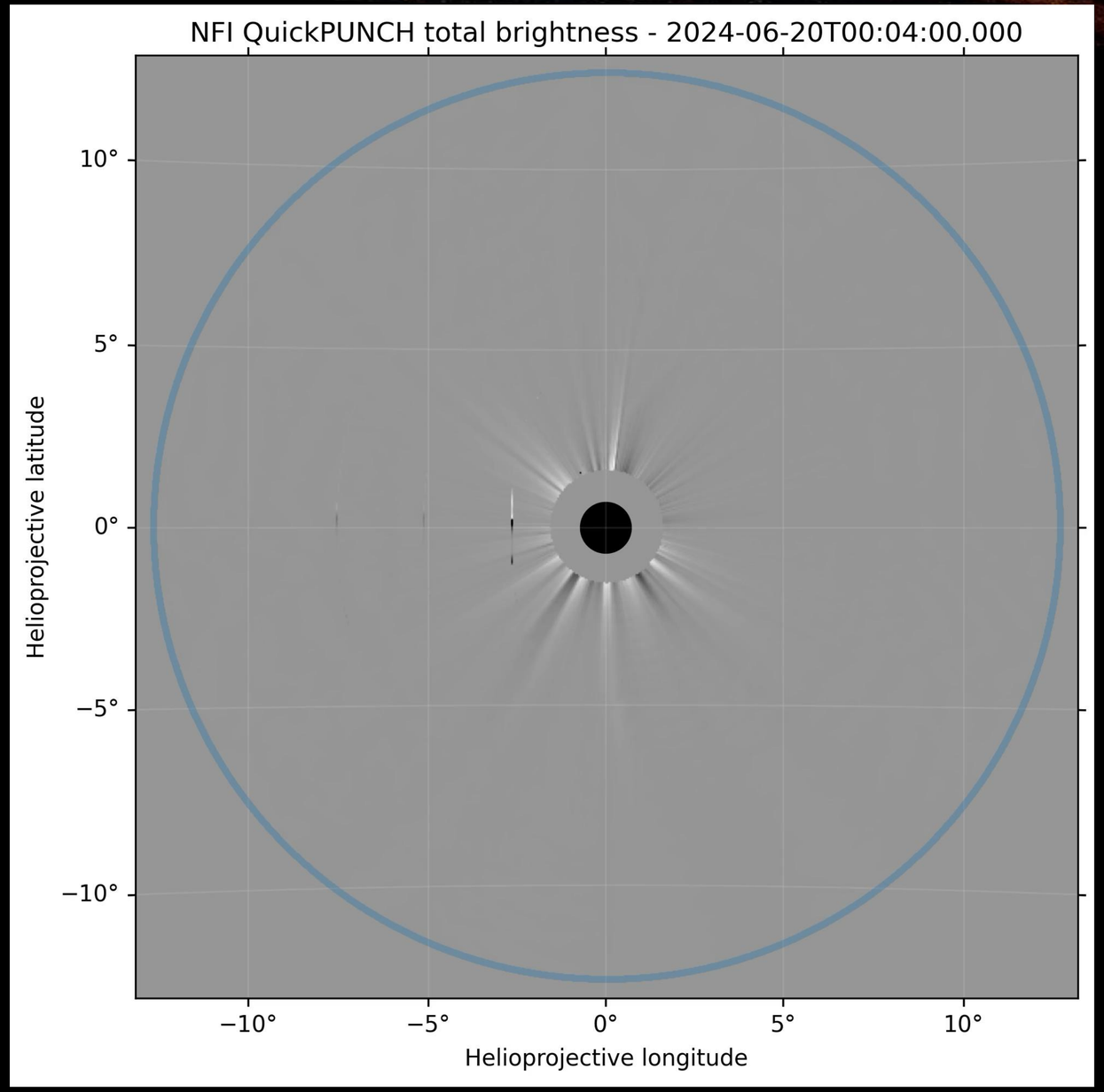
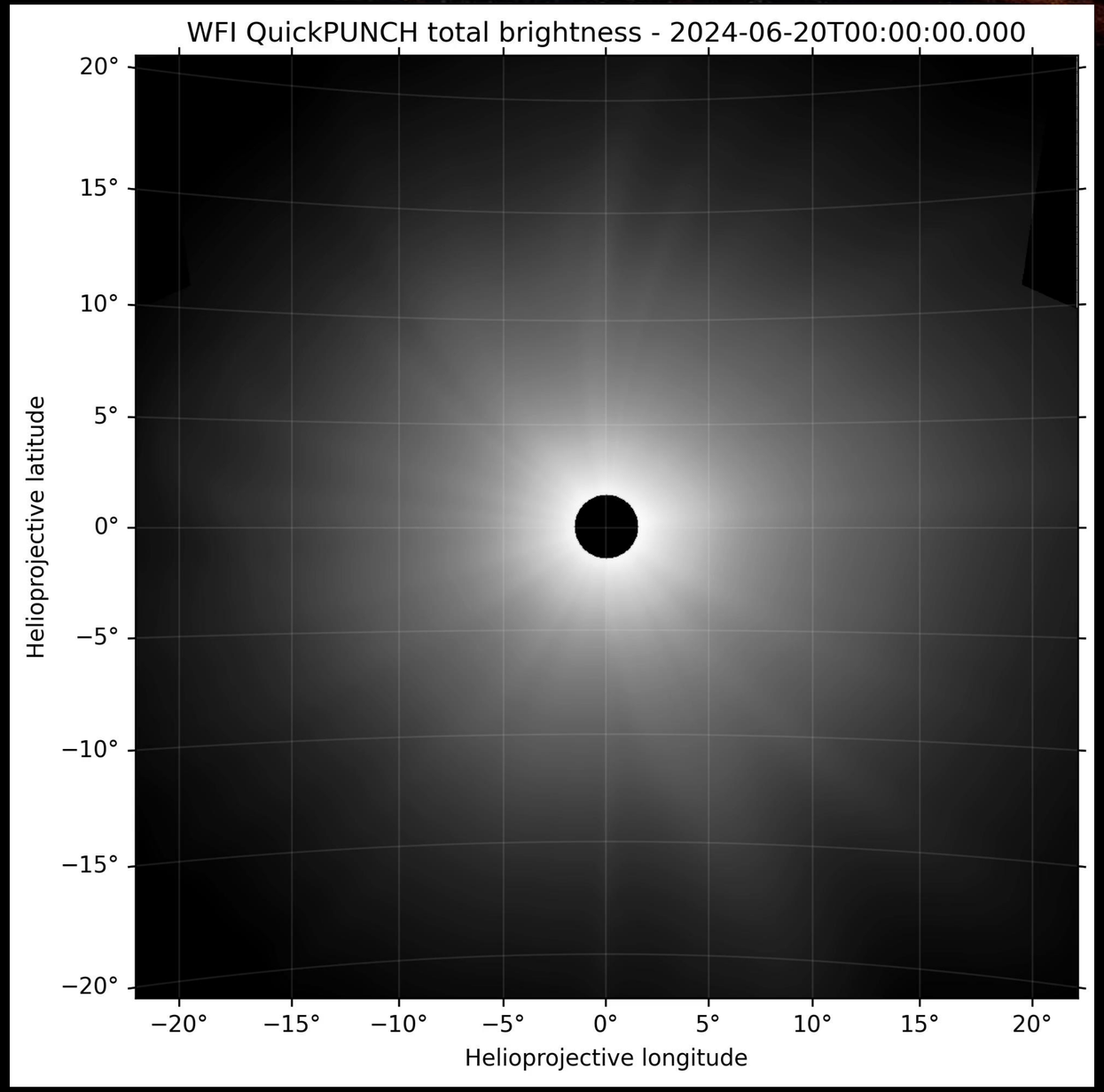


QuickPUNCH Data Products at Low Latency

- QuickPUNCH Mosaics provide opportunities to refine CME tracking measurements
- Extends tracking time for a 750 km/s CME from 8 hours to **20+ hours**



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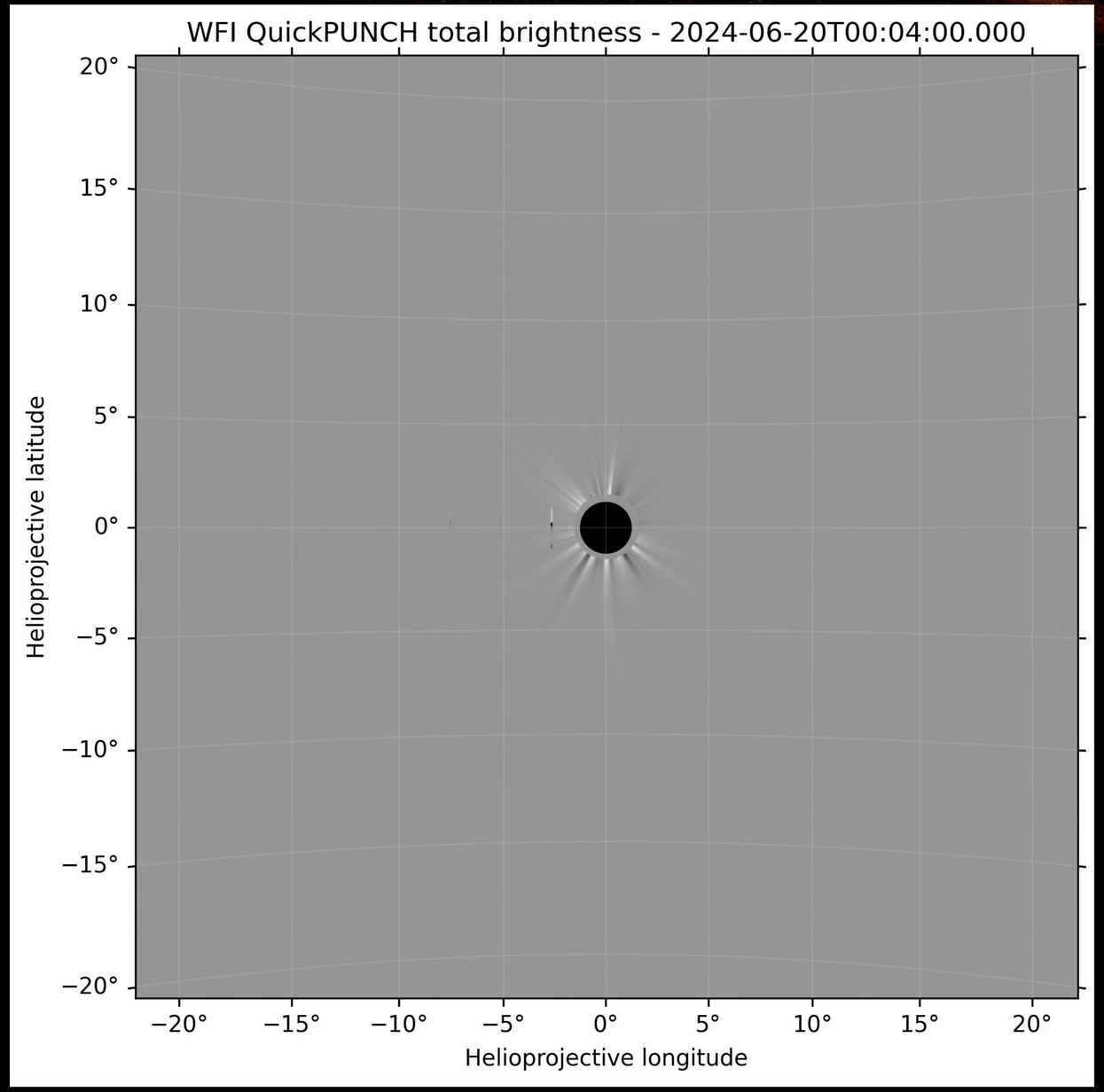

Forecasting Sequence of Events

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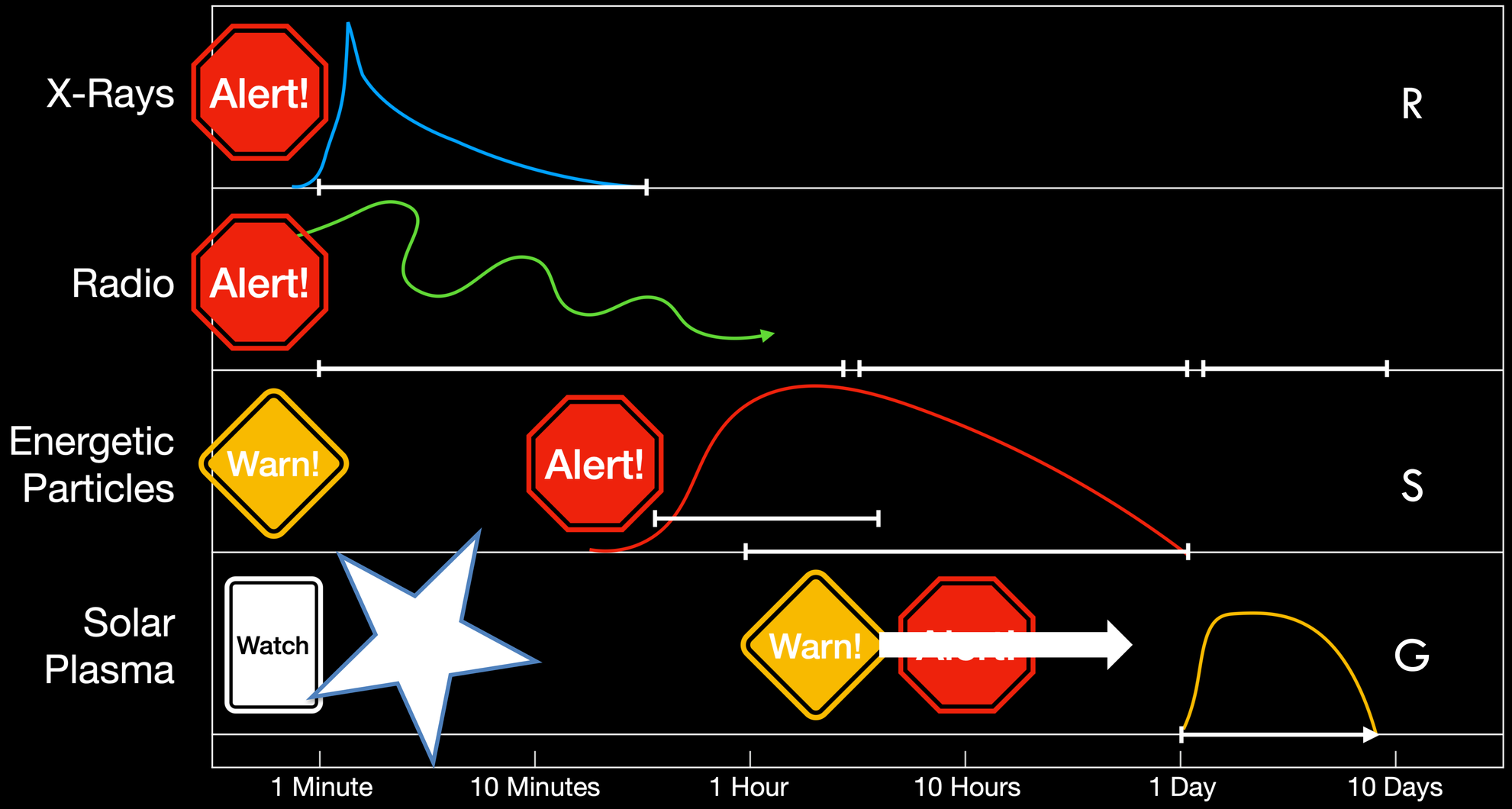


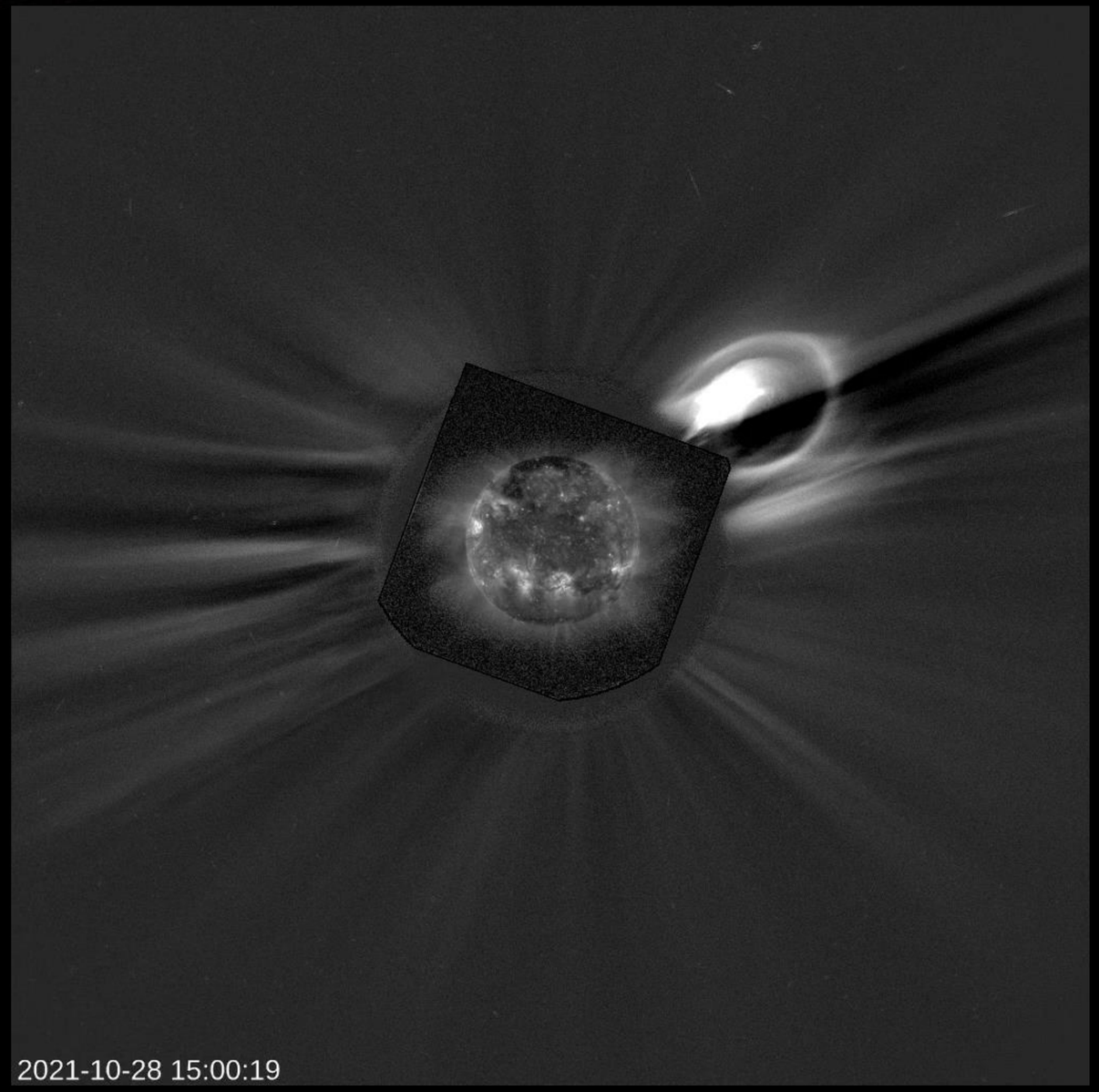
(t = 0 is 8 minutes after eruption onset)

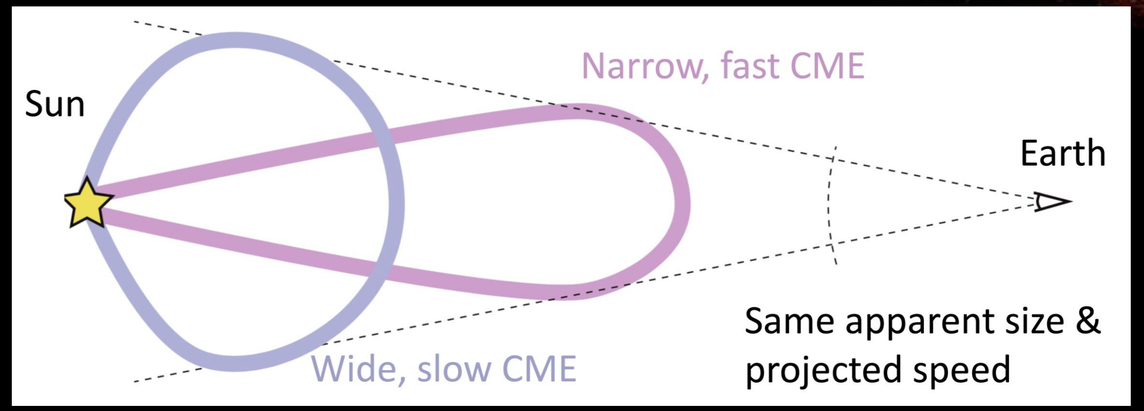
Time (Log Scale)

Polarimeter to Unify the Corona and Heliosphere

Research to Operations for PUNCH

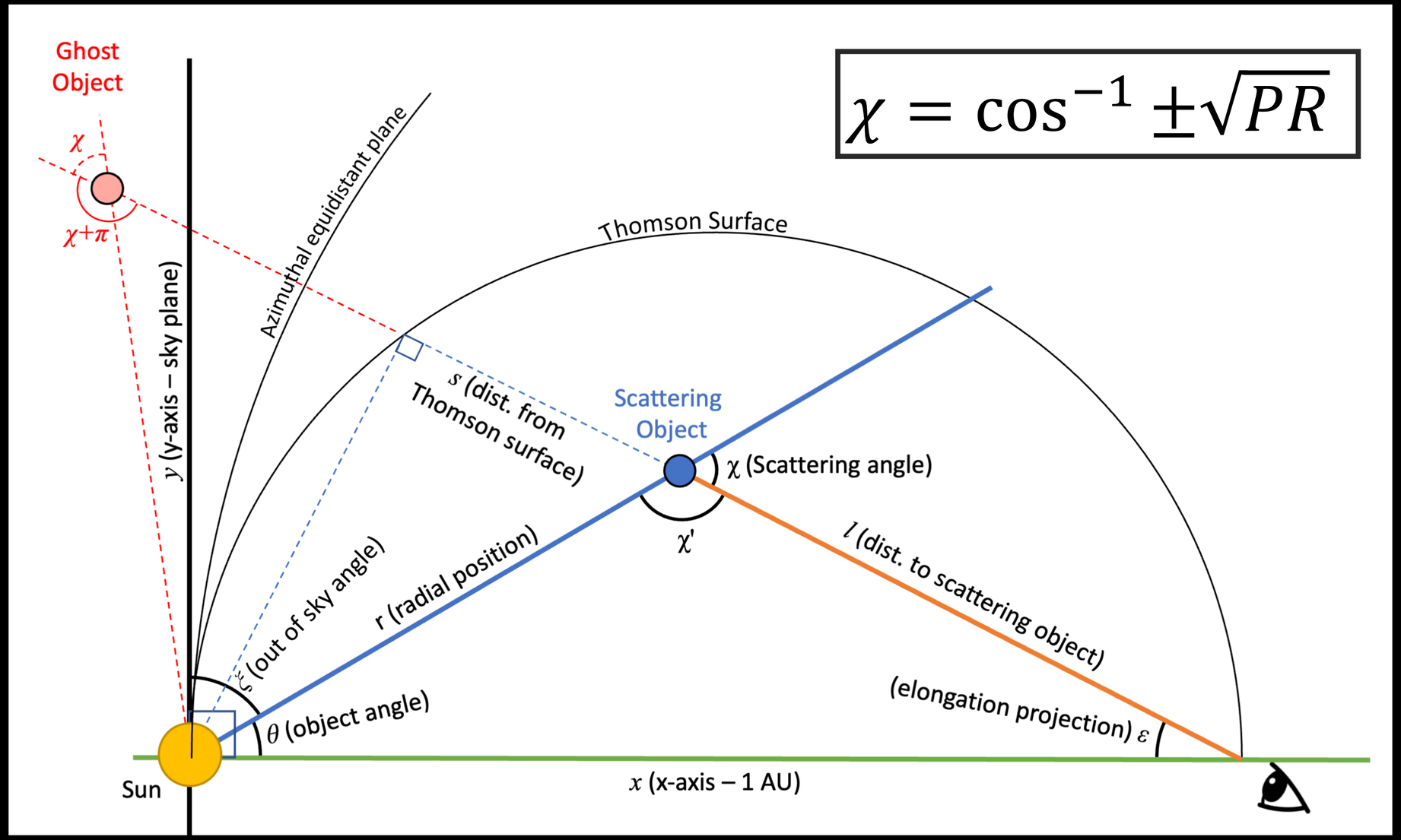
Tracking CMEs in 3D without Polarization





Halo CMEs are subject to ambiguity between size and speed

Tracking CMEs in 3D *with* Polarization



$$\chi = \cos^{-1} \pm\sqrt{PR}$$

$$p = pB/B$$

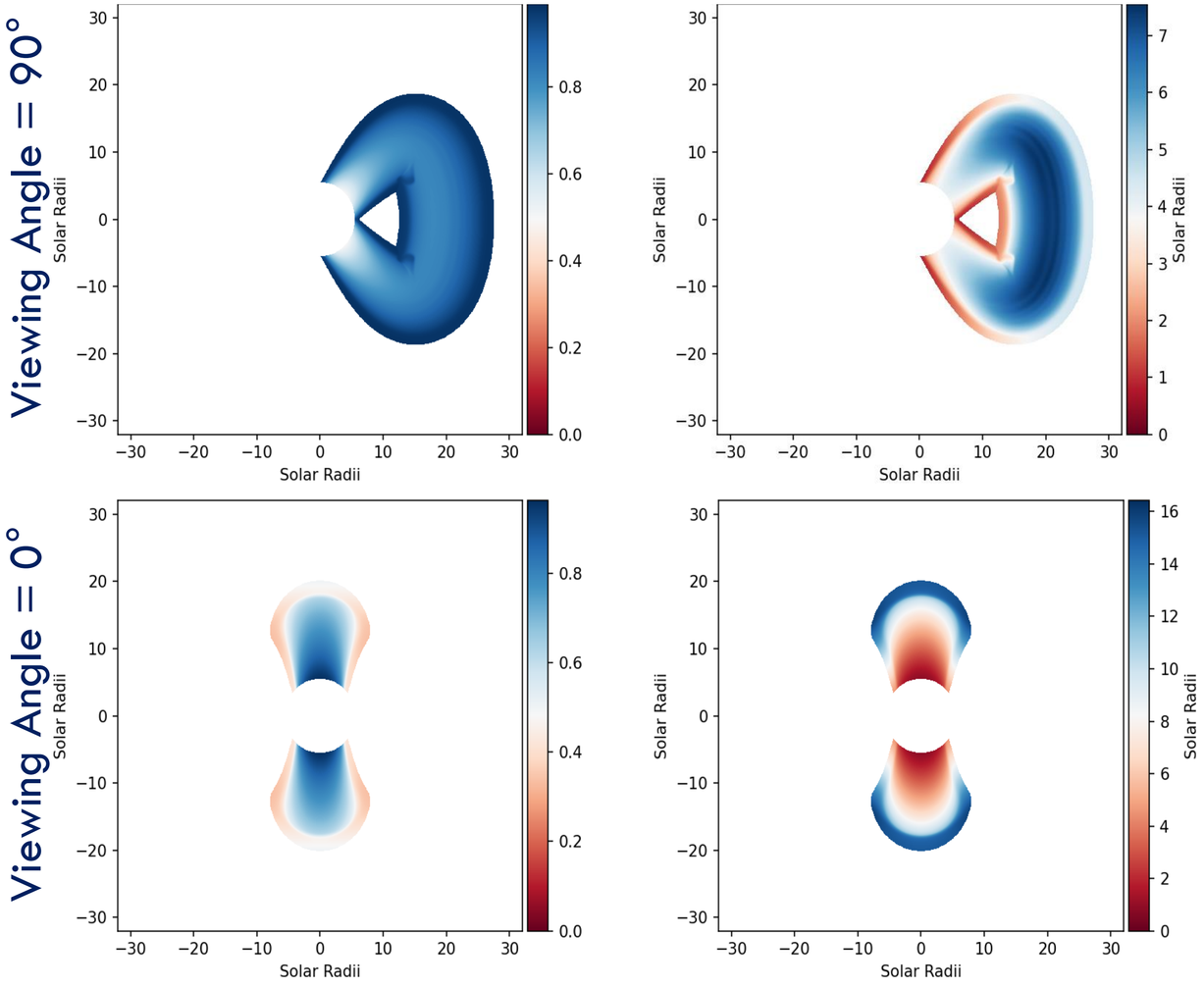
$$PR = \frac{1-p}{1+p}$$

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

Polarimeter to Unify the Corona and Heliosphere

Velocity and POsition Reconstruction Mapping Tool (VAPOR)

Tracking CMEs in 3D *with* Polarization

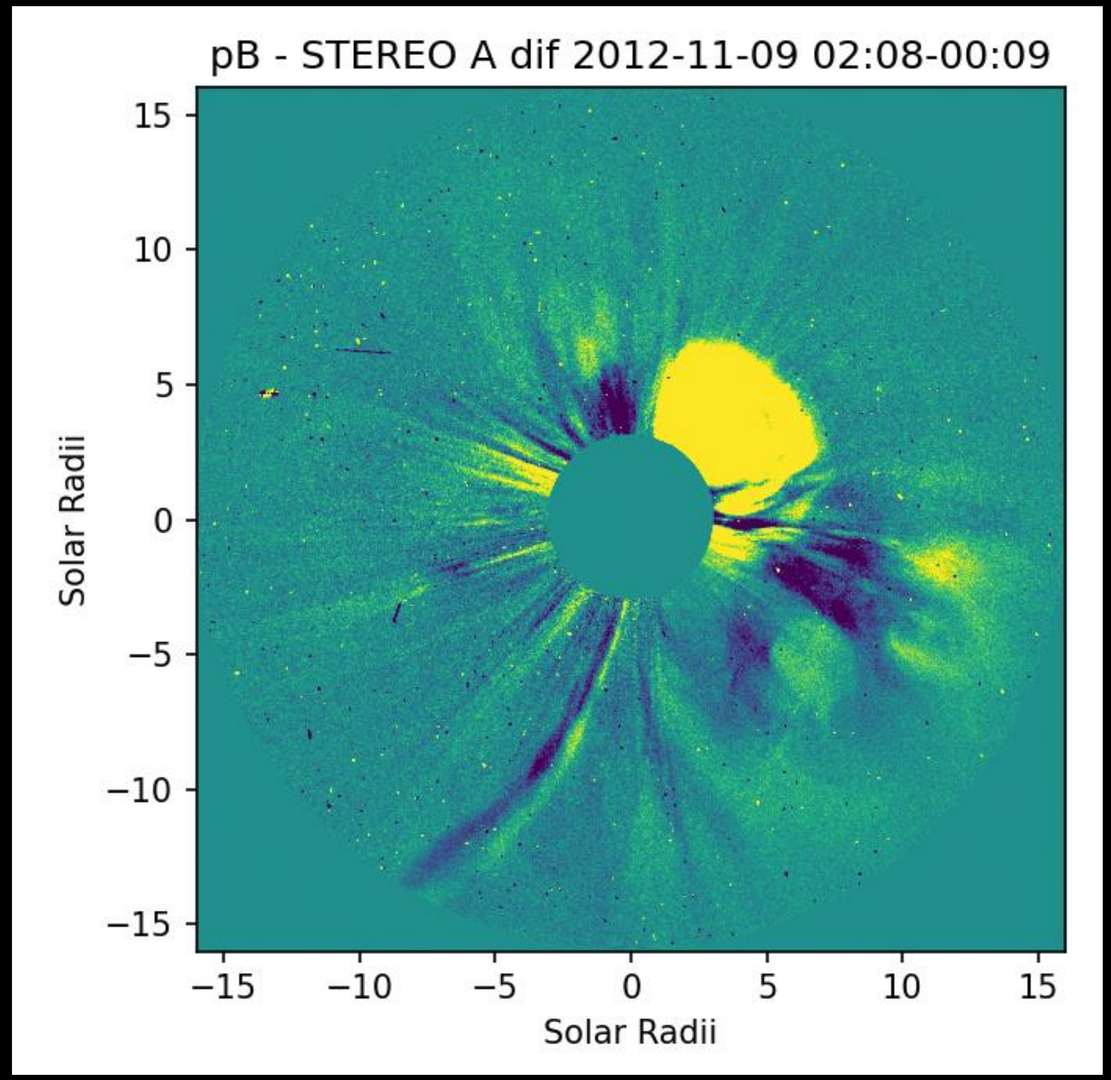


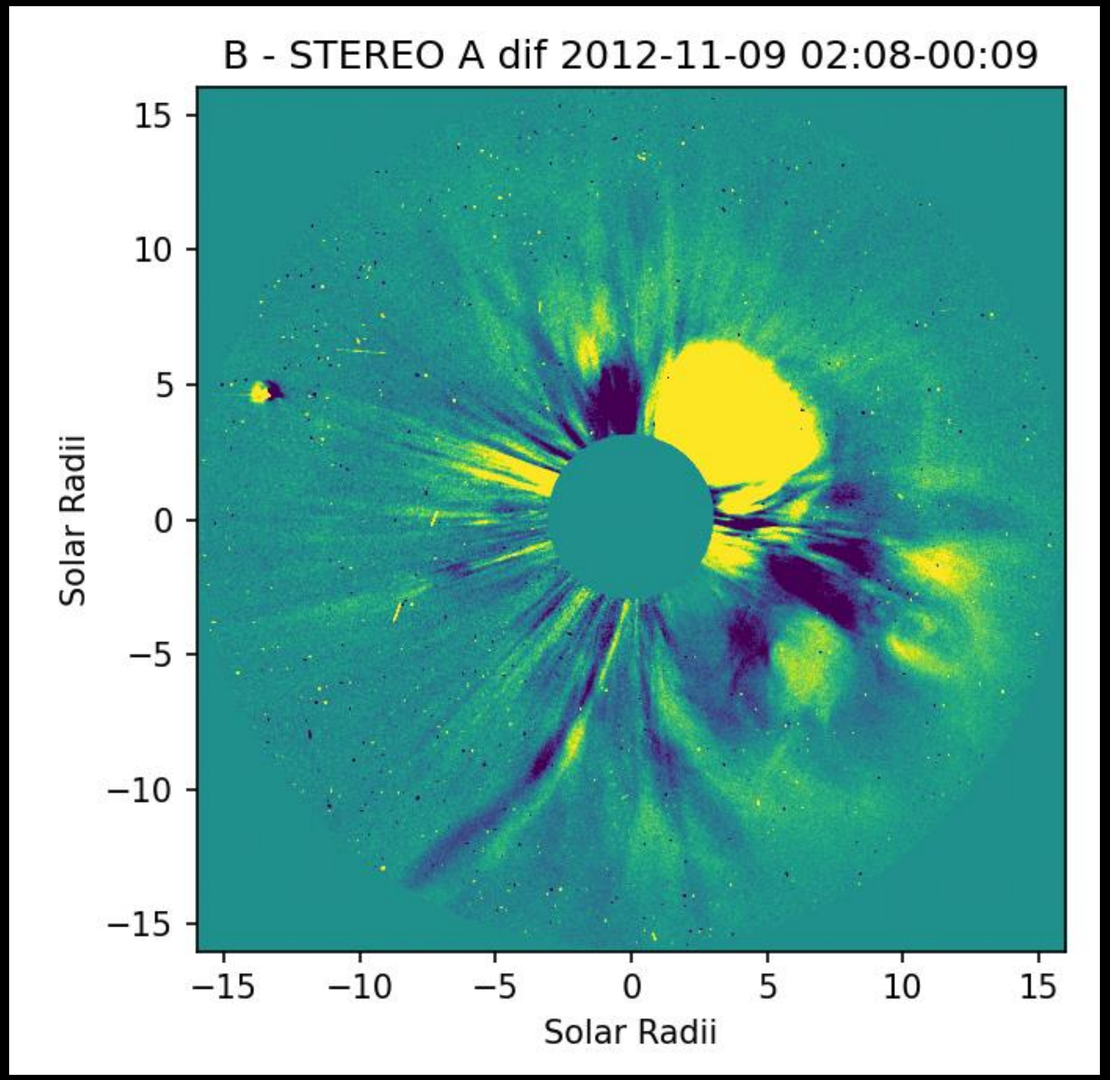
CME in the plane of sky

Halo CME

Tracking CMEs in 3D *with* Polarization

STEREO data provide a good opportunity for a real-world test





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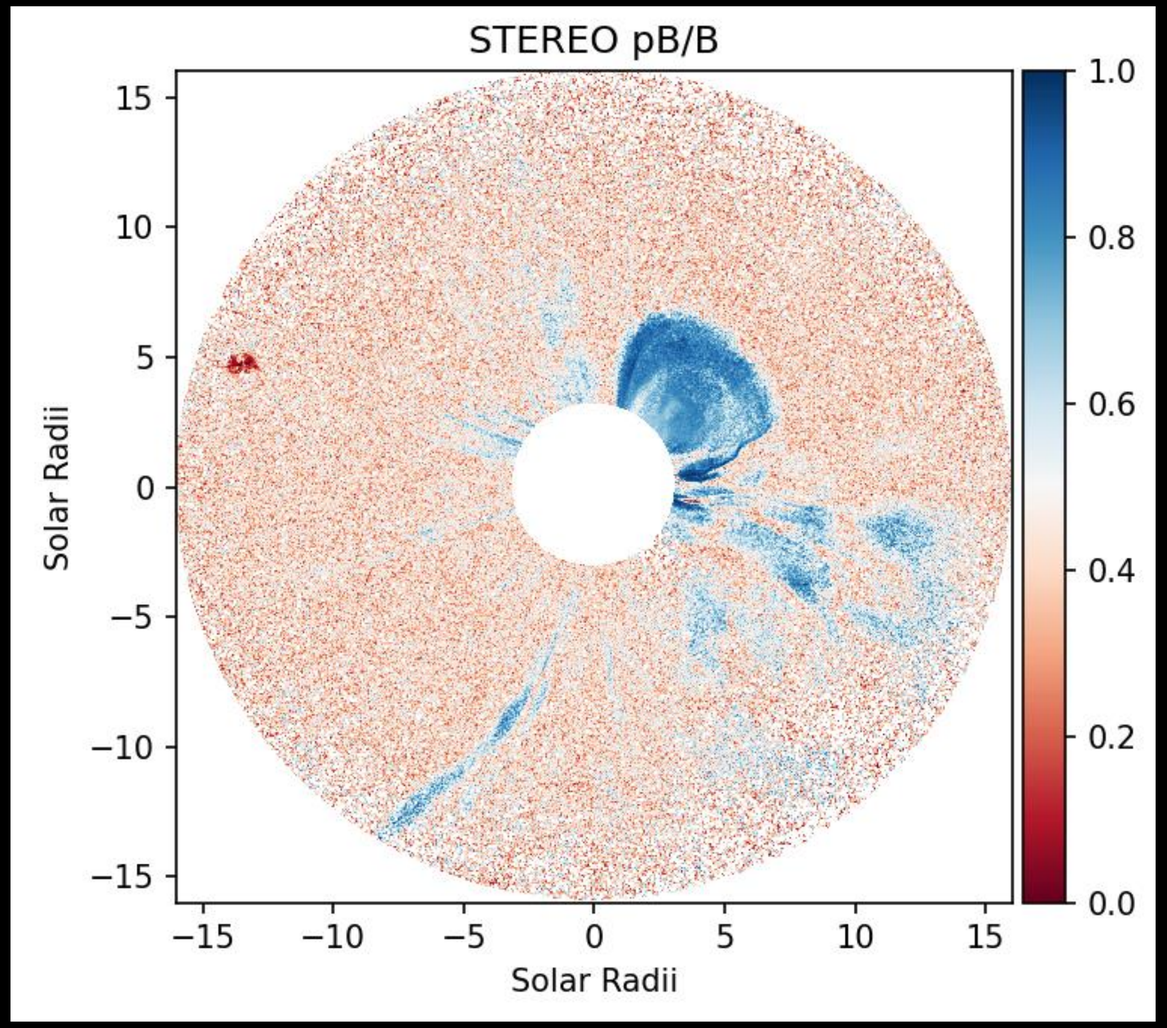

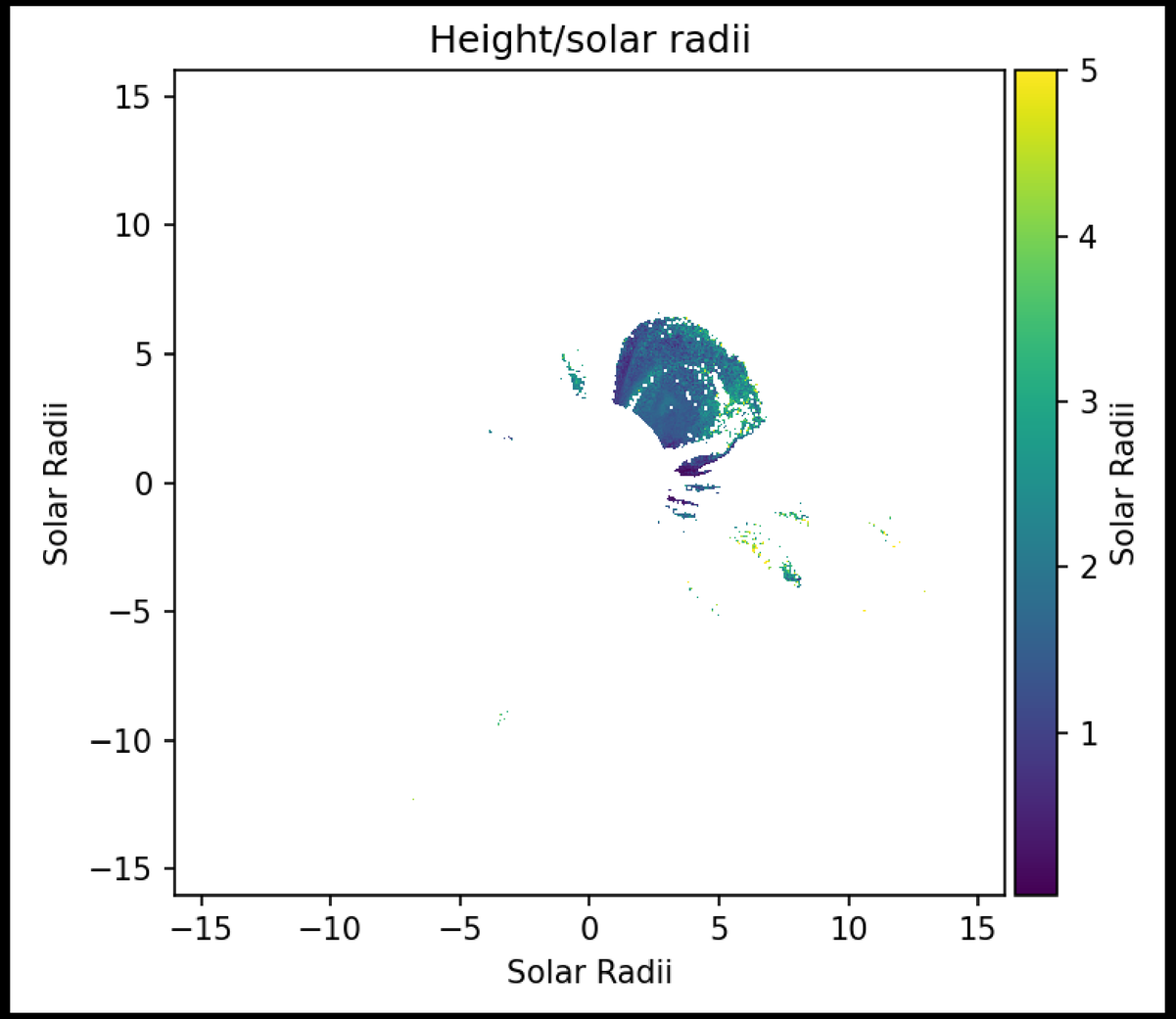

Key Takeaways

- Current CME forecasts lack constraints between remote sensing at a few 10s of R and in situ at L1
- QuickPUNCH will augment NOAA data streams by adding backup capability and extending region of remote sensing
- Research-to-operations capability development uses polarization to improve CME tracking in 3D