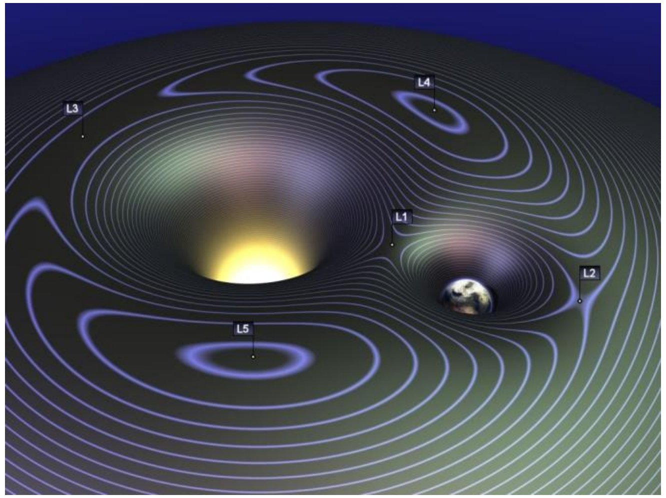

L4 Measurements

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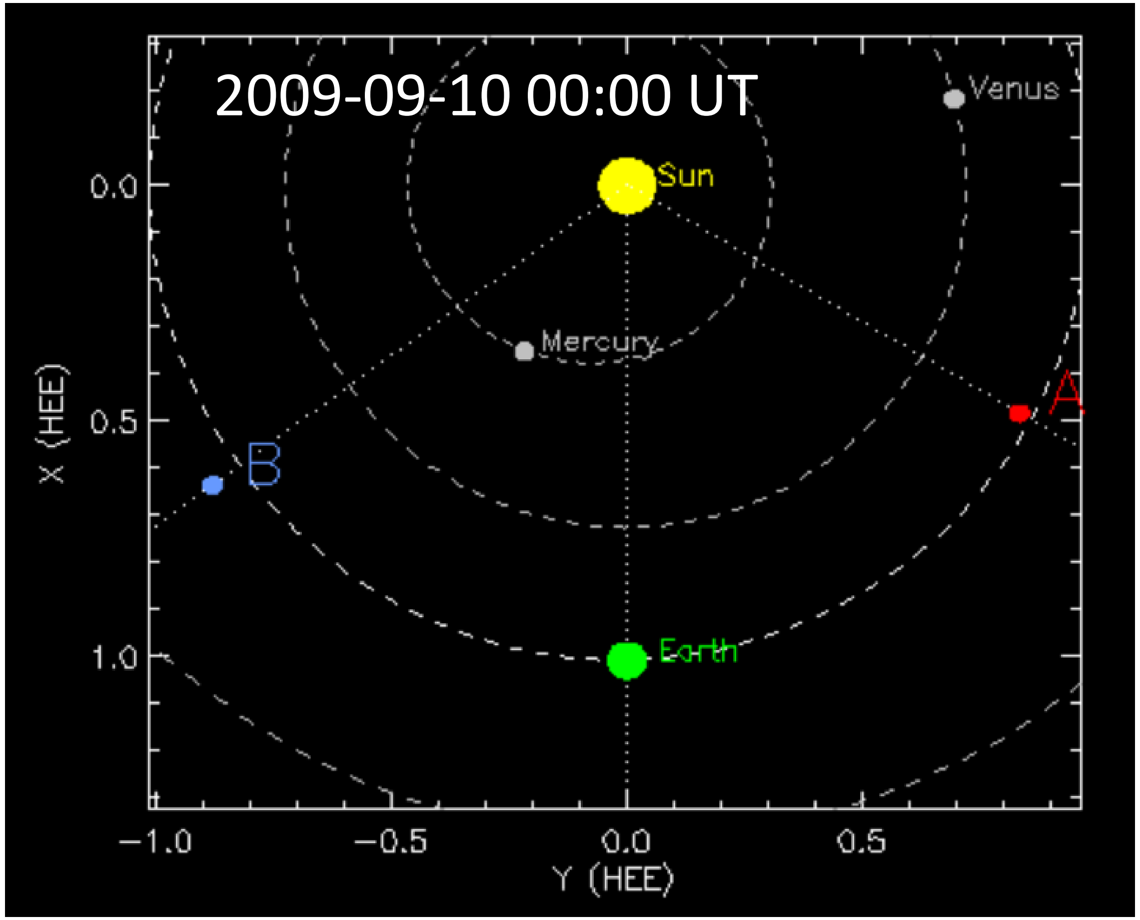
NASA Goddard Space Flight Center

Space Weather Operations and Research Infrastructure: Workshop Part I
June 16-17, 2020

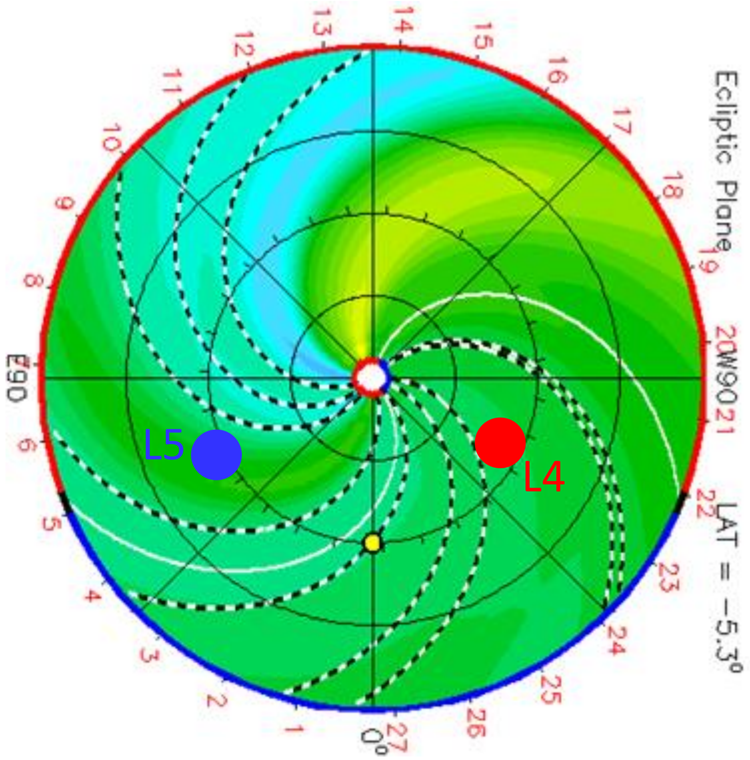
Measurements: Photosphere, corona, heliosphere

- Magnetograph (STEREO did not have it!): CME sources (AR, Filament region), global field for solar wind modeling, RC flux (coronal flux rope).
- EUV Imager: PEA (for RC flux), Core dimming (FR toroidal flux), Flare evolution (CME acceleration), Early phase of CMEs, EUV waves, eruptive prominences, SEP arrival (snowstorm), coronal holes (CME deflection).
- Soft X-ray detector (flare light curve, CME acceleration, flare size).
- WL coronagraph: CME kinematics, coronal flux rope size (+RC flux → flux rope field), shock standoff distance (ambient field).
- Low frequency radio telescope: shock detection near the Sun. All large SEP events have associated type II bursts.
- Energetic particle detector (connectivity).
- Heliospheric Imager (adjusting CME arrival forecasting, solar wind properties, shock calibration from radio).

STEREO-Ahead at Sun-Earth L4



- Not many space weather events occurred during STEREO-A's passage through L5
- No indication of trojan asteroids lurking at L4/L5



Difference between L5 and L4 views caused by
Solar rotation direction (AR, CIR)
Parker spiral (SEPs)

Overview

- An L4 mission can satisfy most of the baseline SWx observational needs
- Measurements related to CMEs and their source region

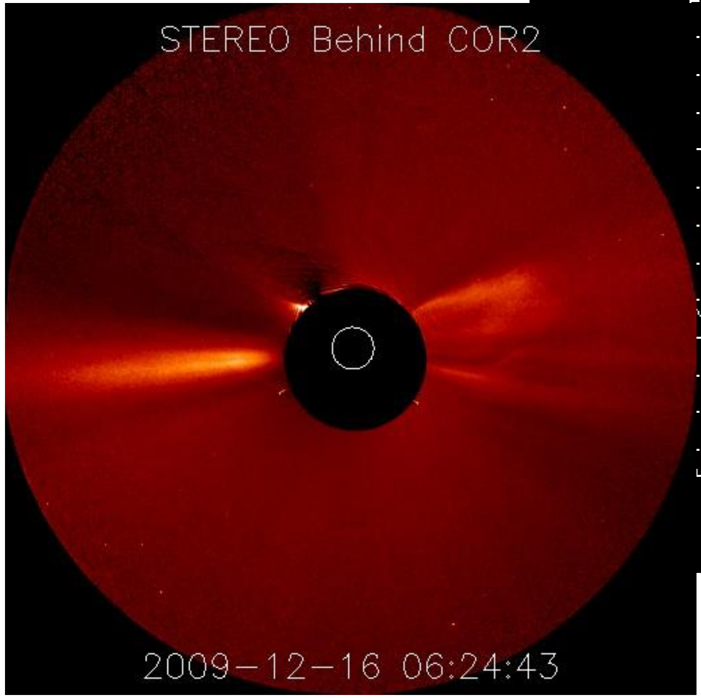
- Geomagnetic storms: Bz prediction based on reconnected flux (PEA & magnetogram), sheath?

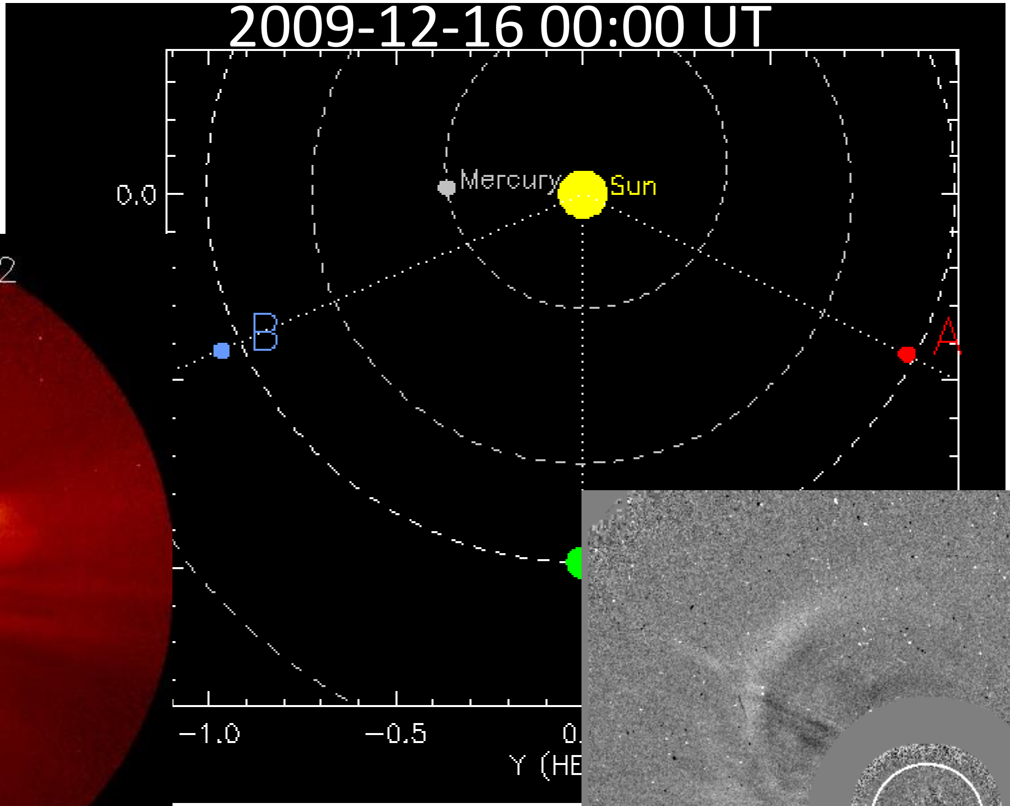
- SEP events: spectra & intensity. Wide-ranging impact: radbelt, ionosphere (PCA), and atmosphere (ozone), other destinations (e.g., Mars)
- Shock structure of Earth-directed CMEs

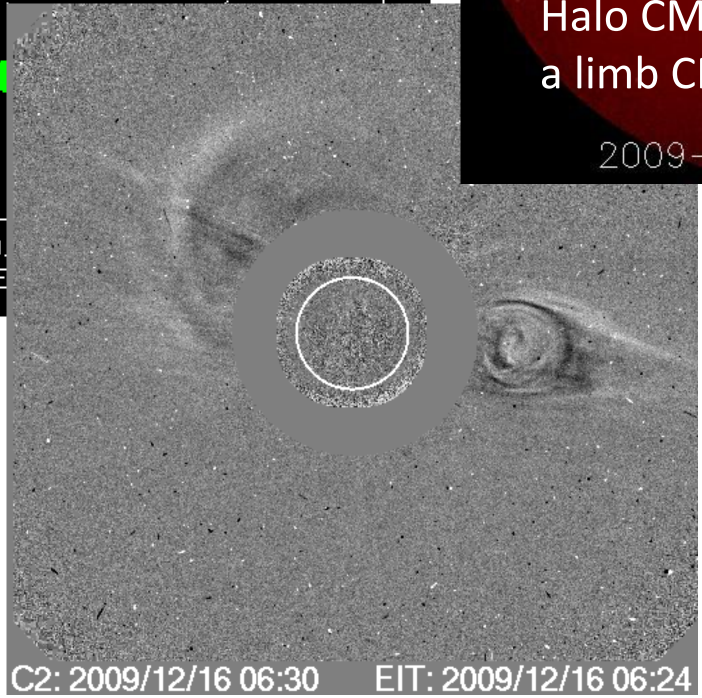
- Measurements related to the background solar wind: all magnetic features on the Sun

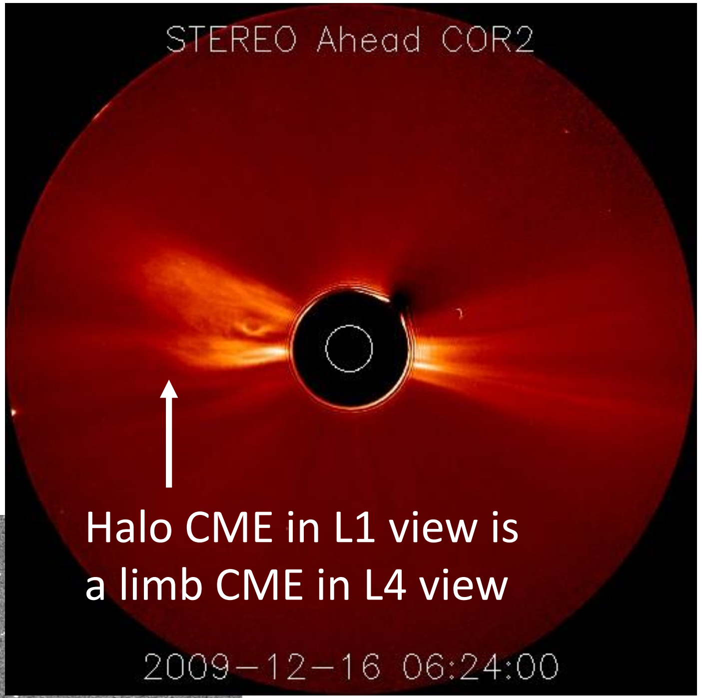
- Solar wind modeling needs global magnetic field as input; important for CME propagation (drag, field line paths for SEPs)

A CME observed from L1, L4 & L5 by STEREO & SOHO



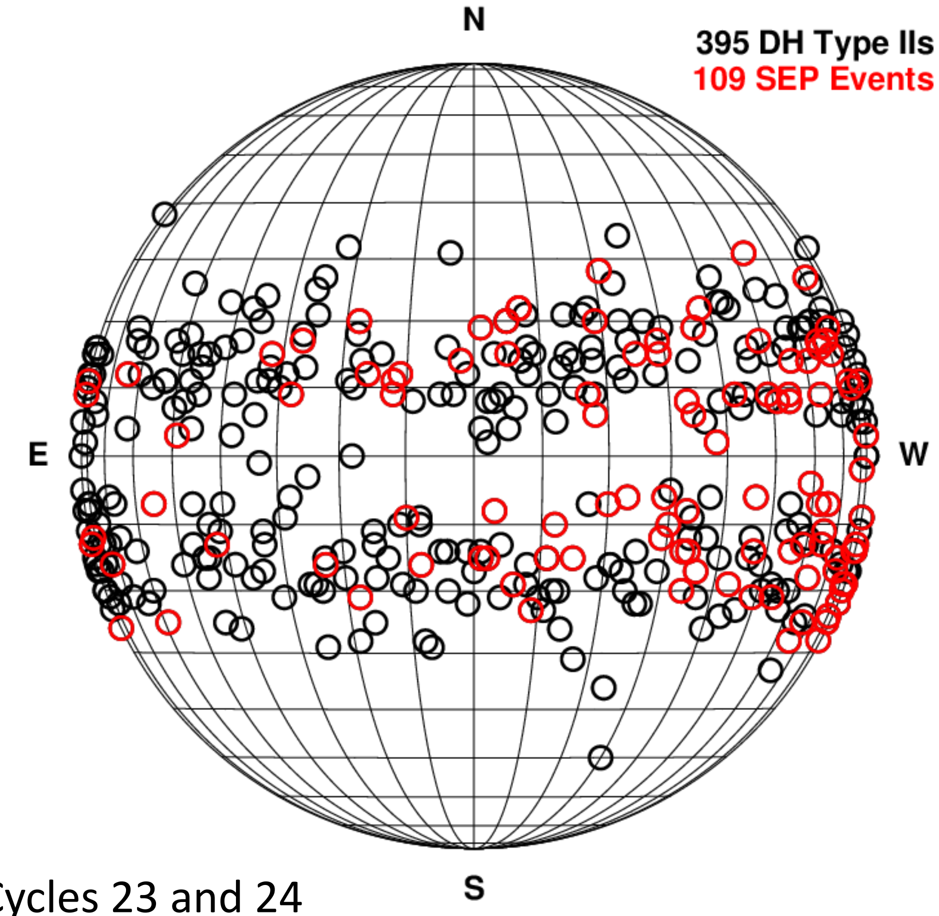






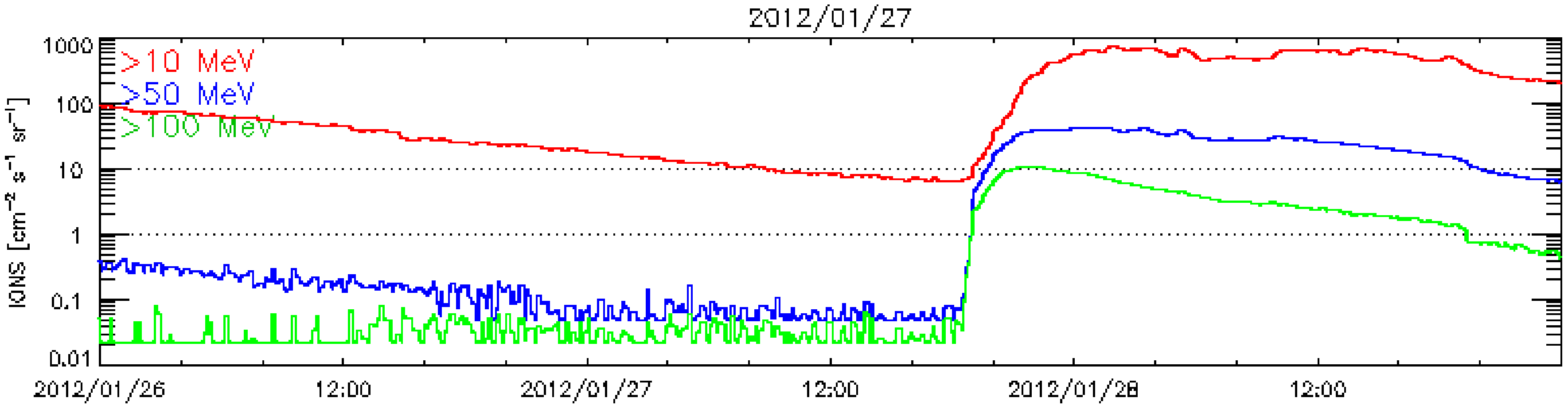
For Earth-directed CMEs
L4 and L5 views provide
similar information
L5 subject to snowstorm

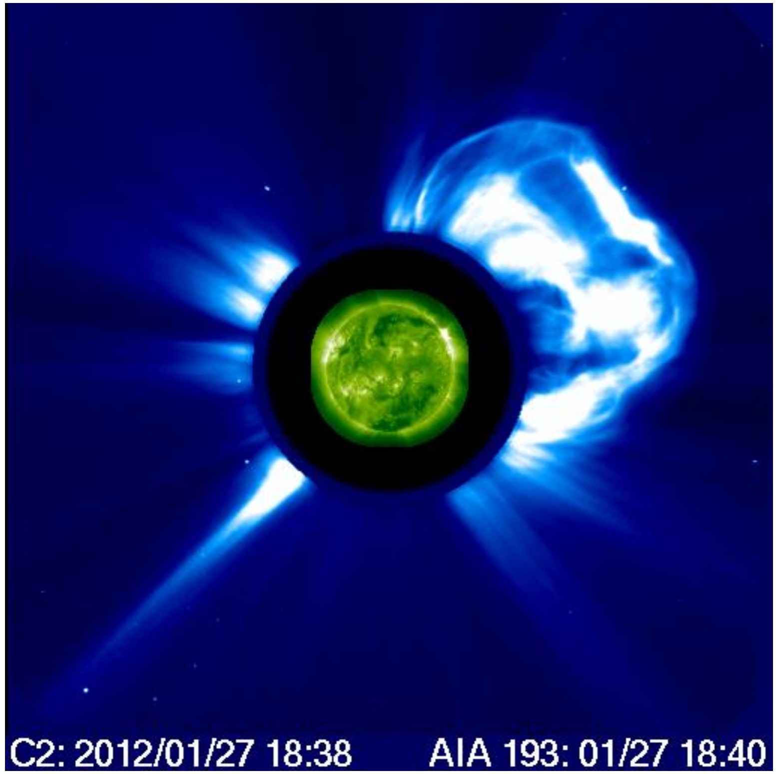
CMEs Associated with Large SEP Events (>10 MeV proton flux ≥10 pfu) at Earth

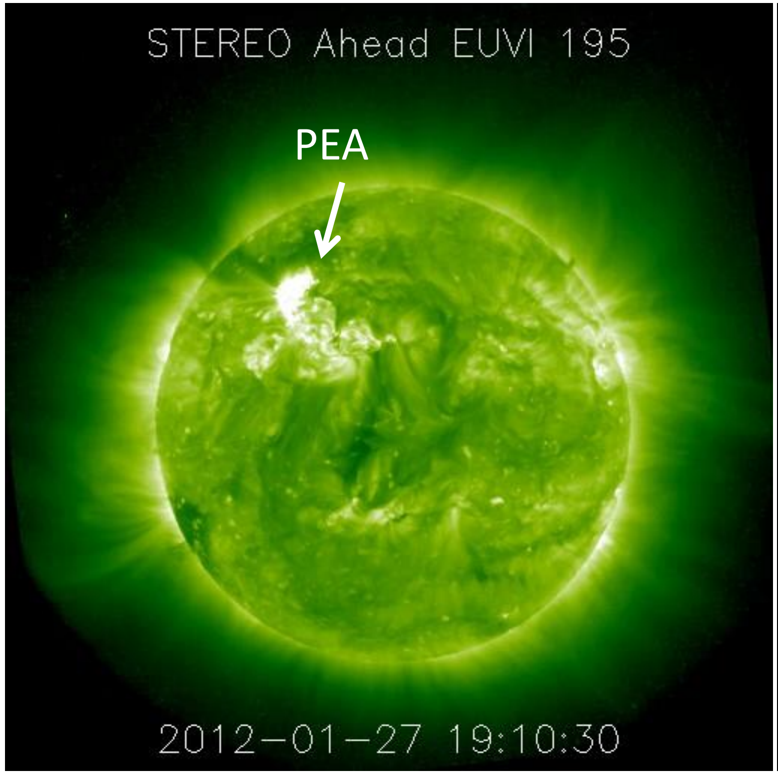


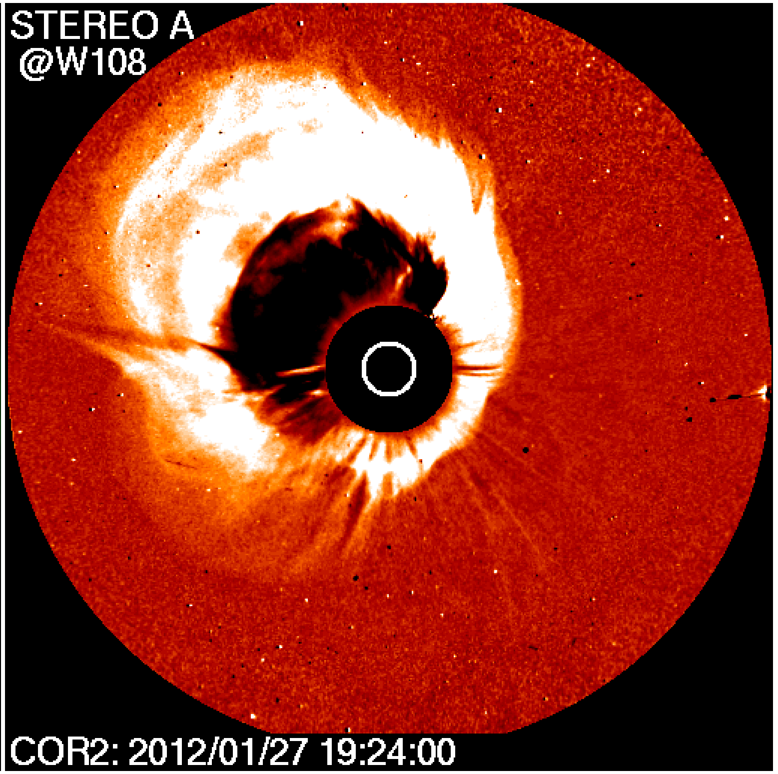
Cycles 23 and 24
Circles: CME sources with type II burst
Red circles: with type II burst and LSEP event

- SEP events have wide-ranging impact in the heliosphere
- Two well known Mars missions affected by SEP events
- SEP events well connected to Earth cause severe space weather in geospace: ozone depletion, radiation belt intensification, PCA events, and radiation exposure to air travelers.
- ~80% of SEP events originate from the western hemisphere
- Sources well connected to Earth are close to central meridian in L4 view, while it is backsided in L5 view
- L4 can observe such CMEs without snowstorm
- L4 can also observe the source region (mag, EUV)
- Low frequency type II bursts are good indicators of shocks that accelerate particles throughout the inner heliosphere
- Shocks also lead to ESP events, GIC onset, magnetospheric particle acceleration, SSC







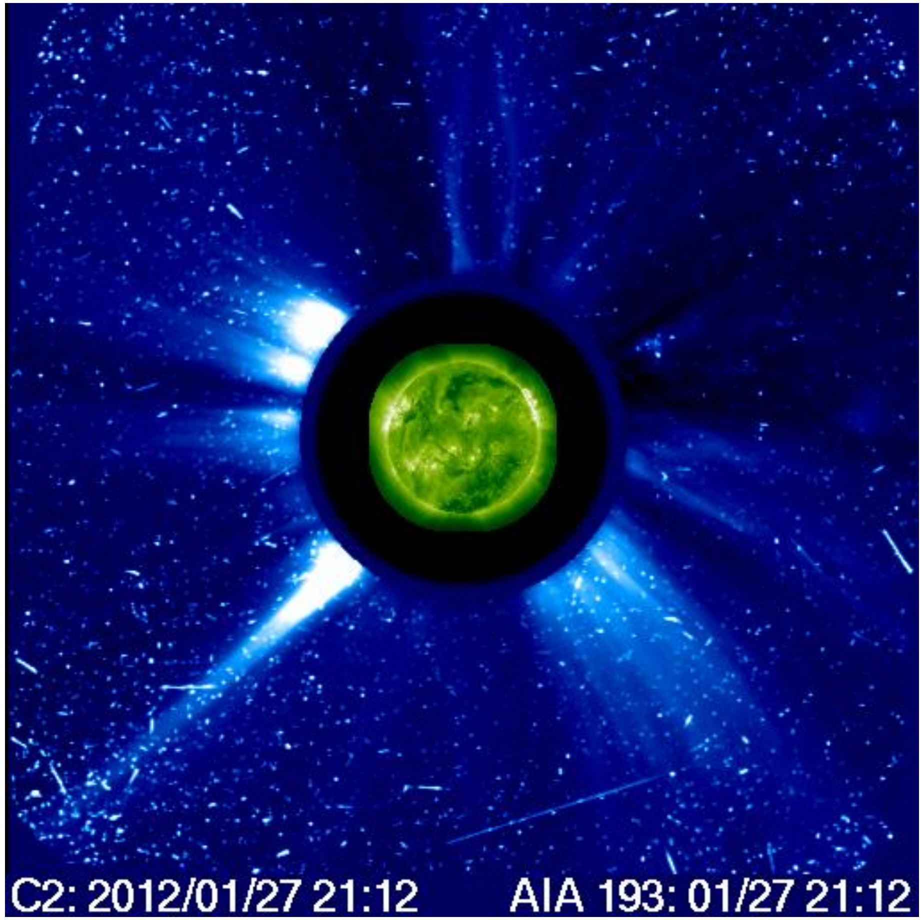


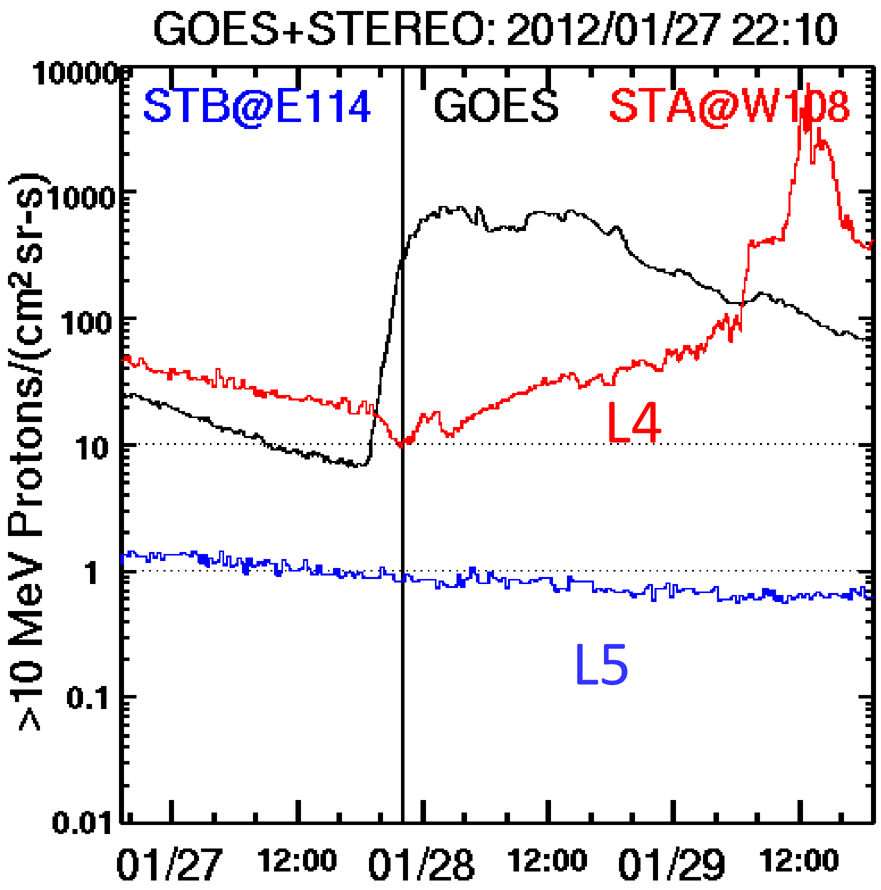
Earth view: N27W71
Source not well observed

Add magnetograph → RC Flux
FR size (WL/EUV) + RC flux → FR field vector

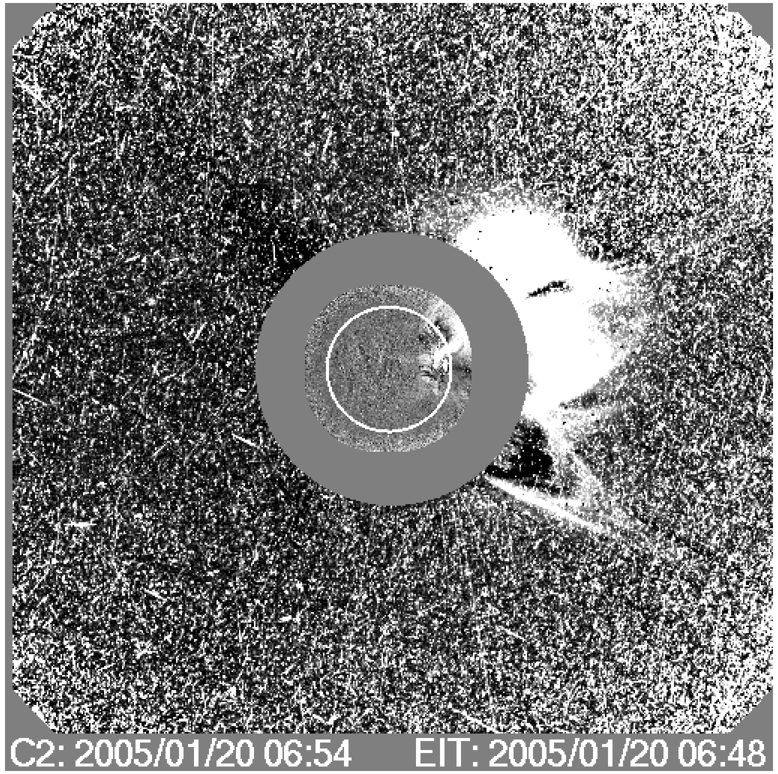
STEREO-A view: N27E27
Source well observed, halo

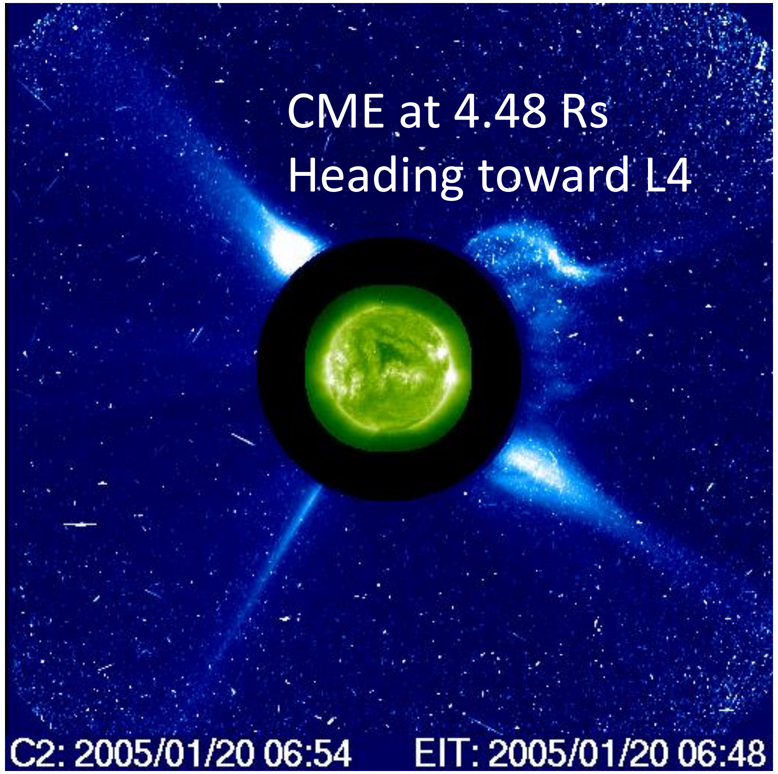
Snowstorm at L1, Not at L4

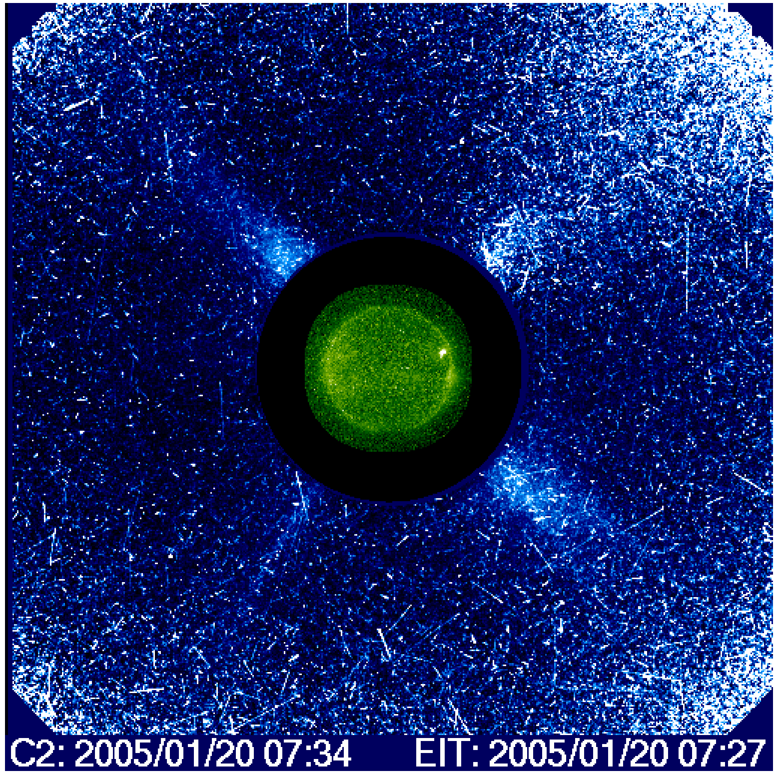




The 2005 January 20 GLE Event: CME could not be characterized due to snowstorm





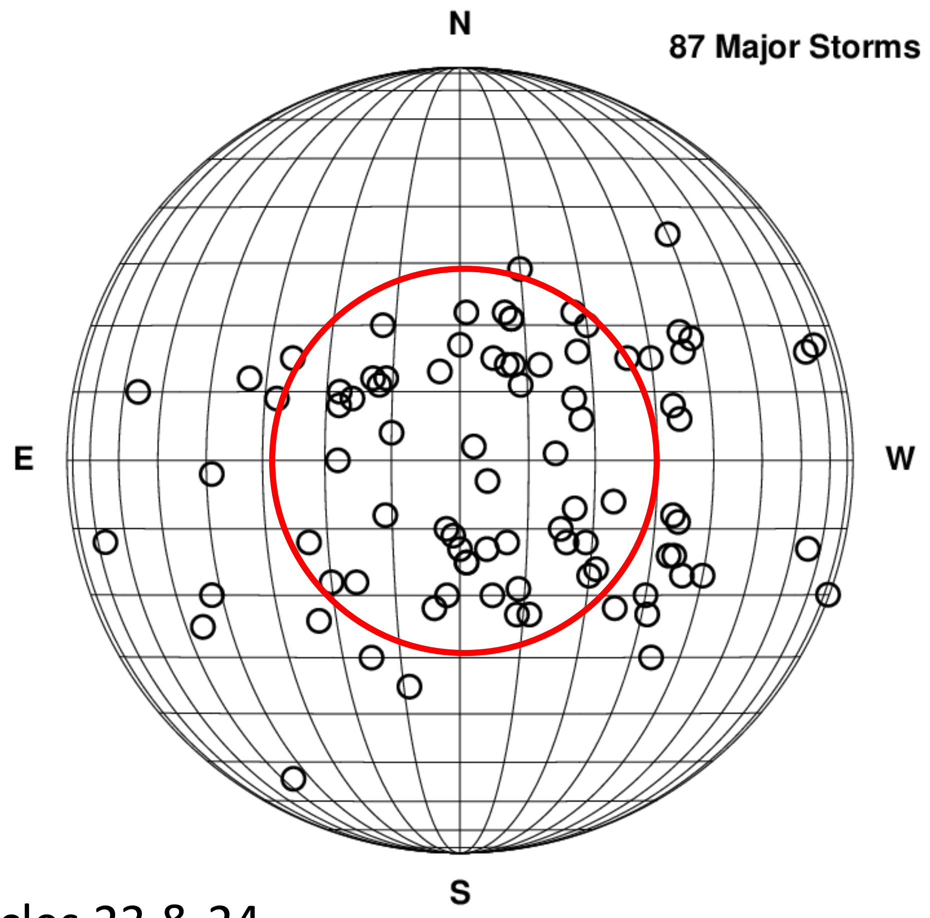


Extended field EUV imager (e.g., SWAP) to capture CME early life including initial acceleration that determines the SEP spectrum

Estimated speed ~3500 km/s from Flare onset: 06:39 UT (~2 km s^{-2}) LASCO/C2: 4.48 Rs at 06:54

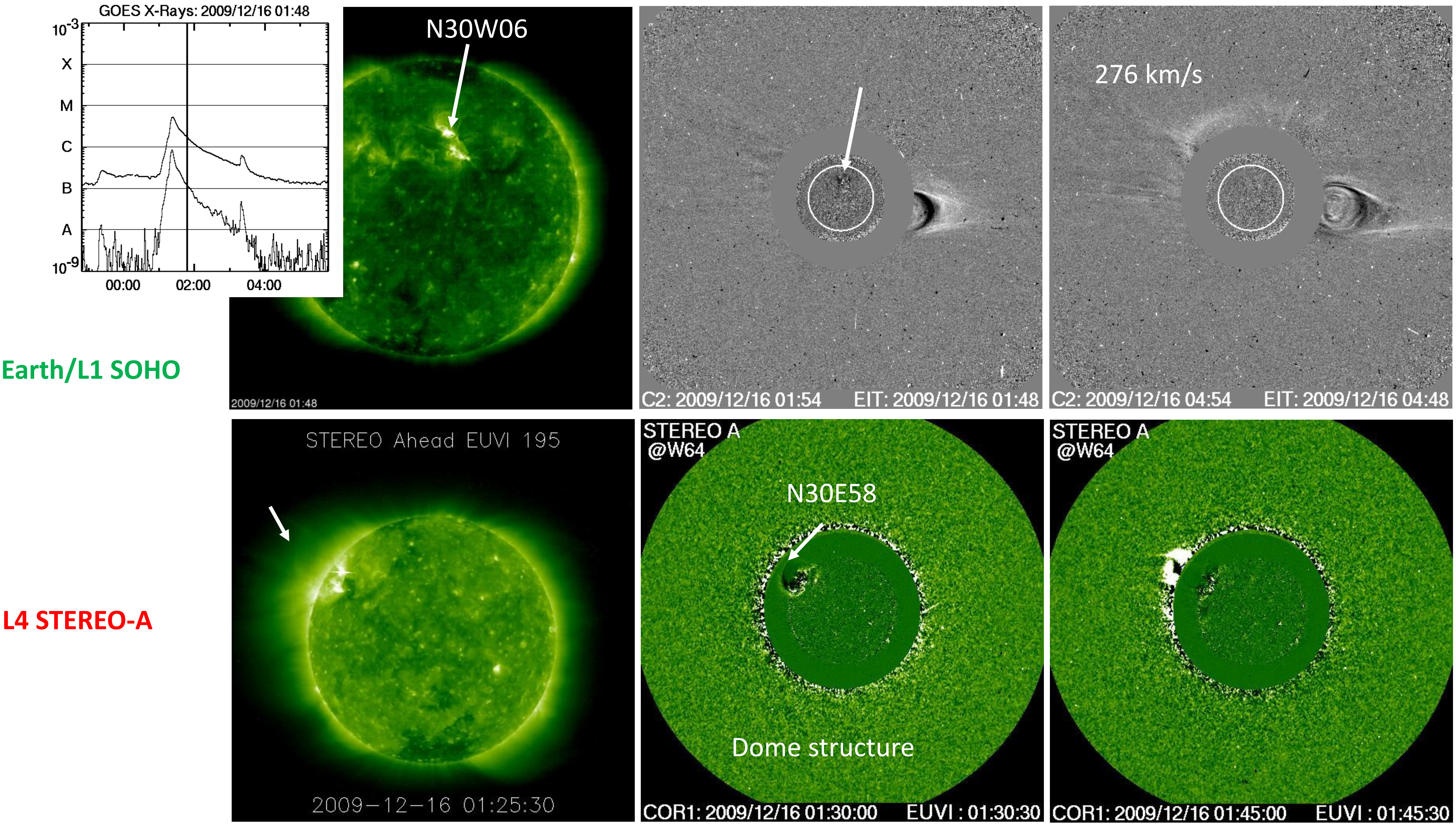
The GLE was the largest in cycle 23 with intensity 277% above background

Major Geomagnetic Storms: caused by CME flux ropes and/or shock sheaths



Cycles 23 & 24
CMEs that caused Dst < -100 nT

- L4 and L5 are equally good in measuring Earth-directed CMEs
- L4/L5 view can provide shock information
- Earth directed CMEs sources are well-connected to L5 – may affect WL coronagraph images at L5



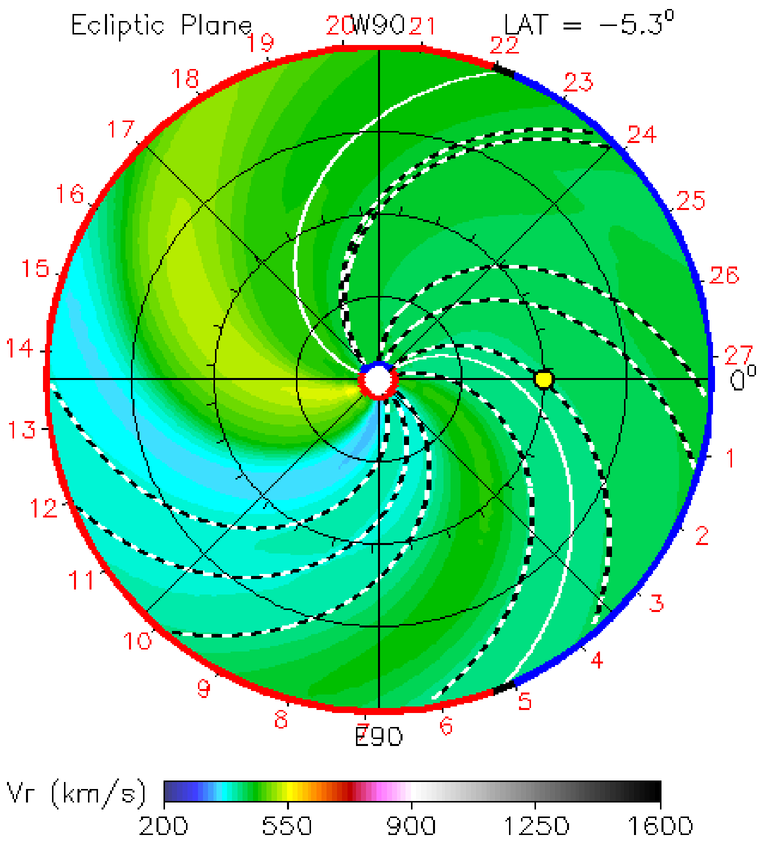
GOES X-Rays: 2009/12/16 01:48
10^-3
X
M
C
B
A
10^-9
00:00
02:00
04:00
N30W06
2009/12/16 01:48
276 km/s
C2: 2009/12/16 01:54
EIT: 2009/12/16 01:48
C2: 2009/12/16 04:54
EIT: 2009/12/16 04:48
Earth/L1 SOHO
STEREO Ahead EUVI 195
2009-12-16 01:25:30
STEREO A
@W64
N30E58
Dome structure
COR1: 2009/12/16 01:30:00
EUVI : 01:30:30
STEREO A
@W64
COR1: 2009/12/16 01:45:00
EUVI : 01:45:30
L4 STEREO-A

Solar Wind Modeling from Photospheric Field

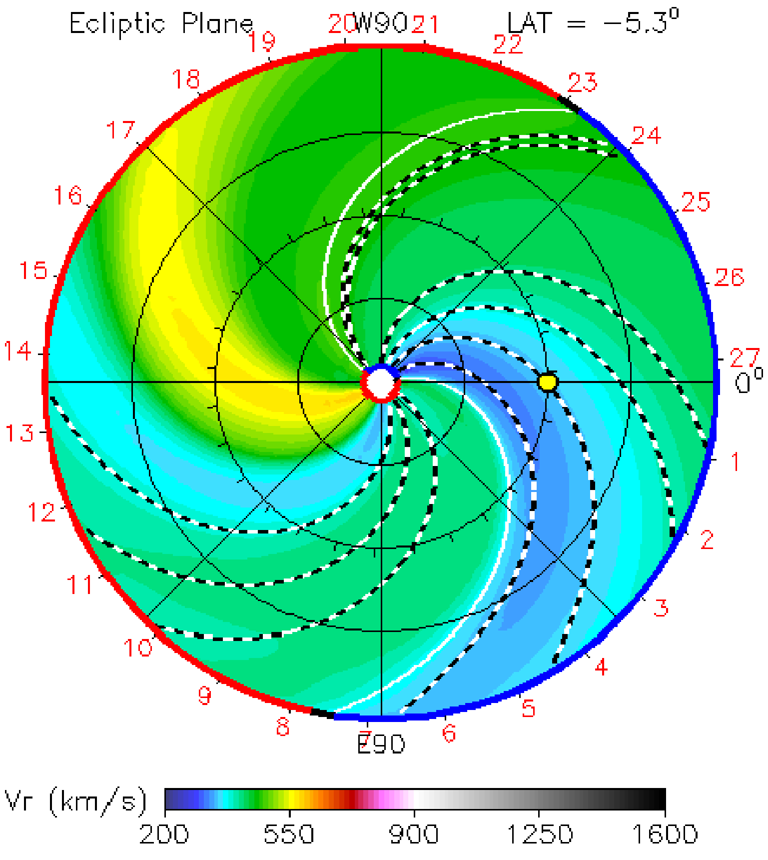
Schrijver's (2001) synthetic Sun observed in different views

Situation when north-pole visible at Earth

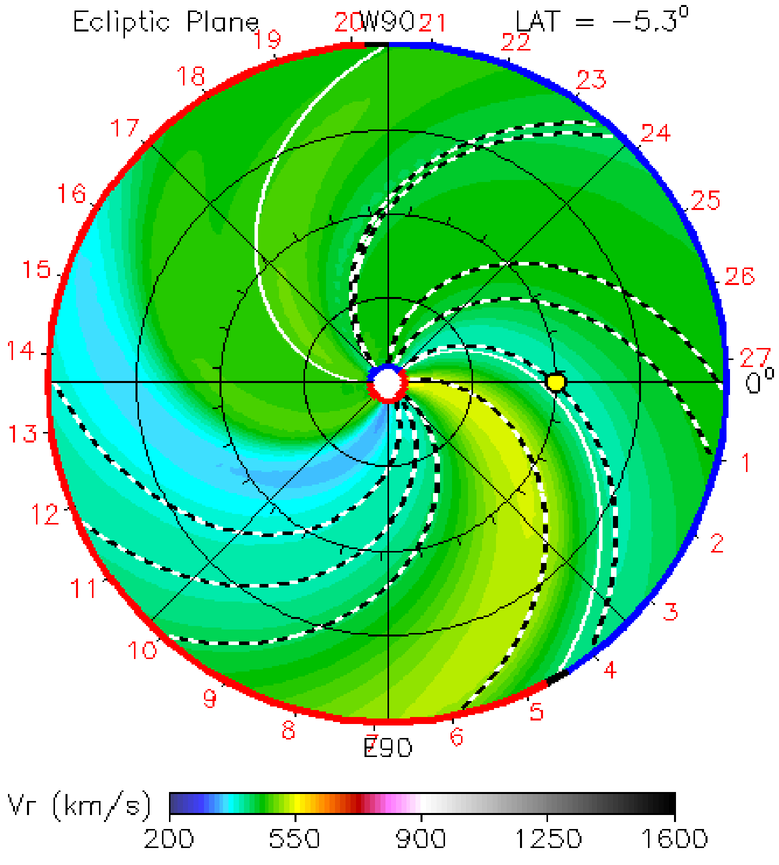
No new emerging flux on the backside



Full

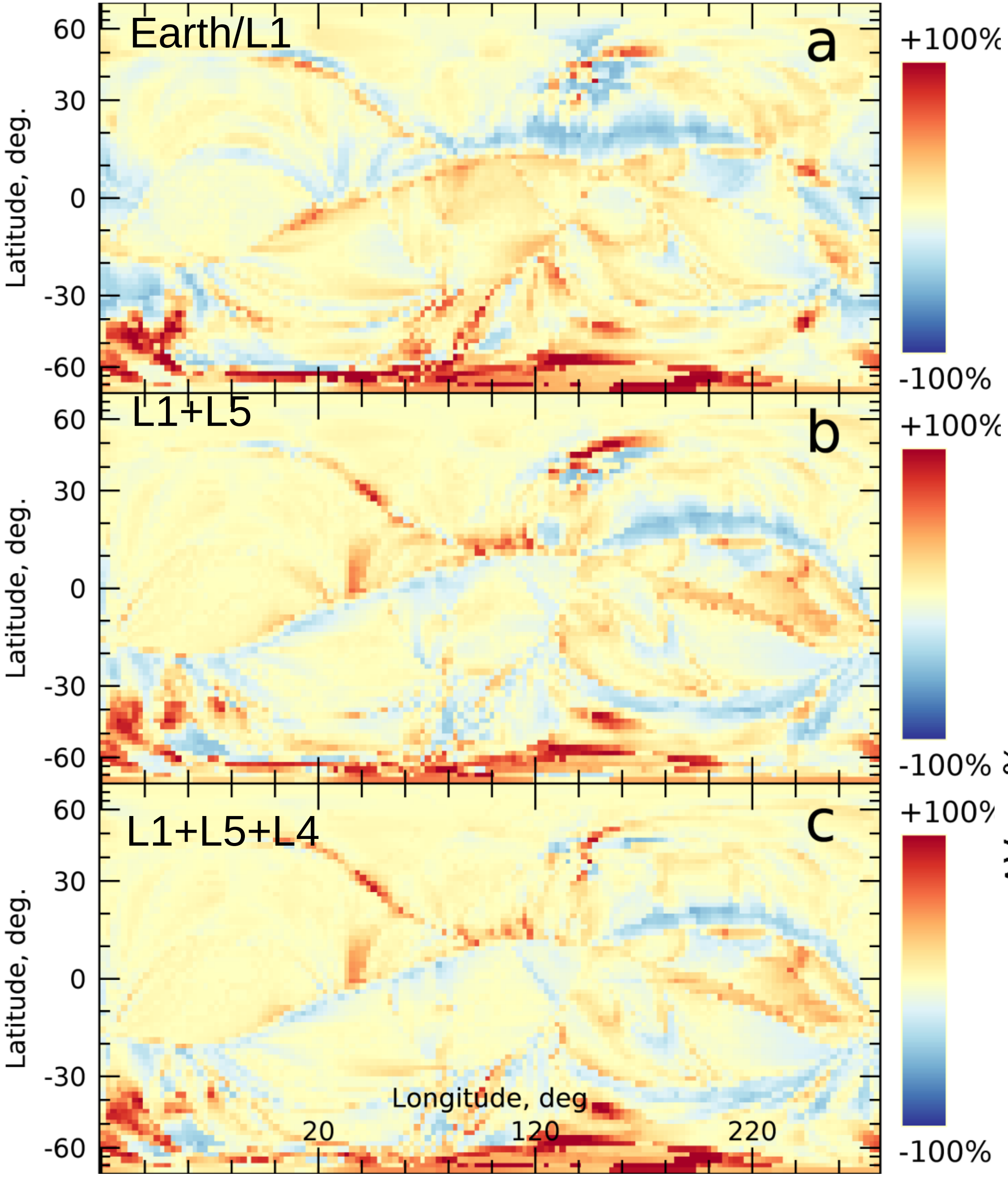


L1



L1 + L5

Pevtsov+ 2020

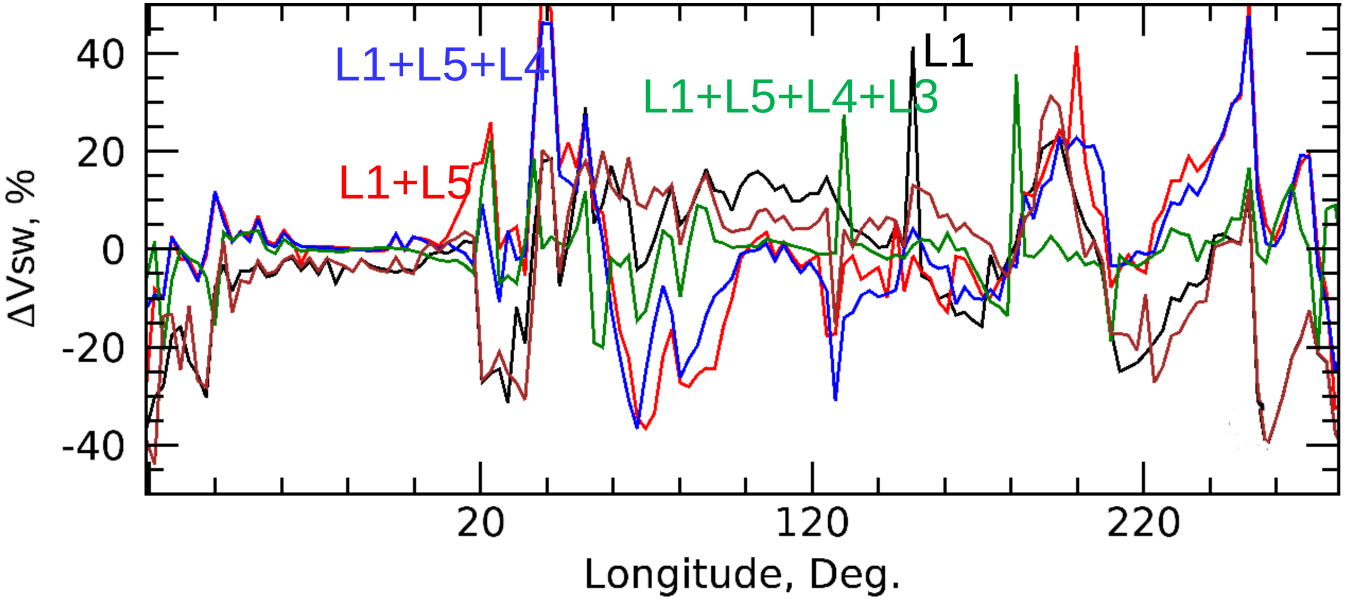


Global solar wind using input from different views compared with that from global magnetic field in WSA+Enlil model

Using L1+L5+L4+L3 is closest to the “true” solar wind speed distribution.

L1+L5+L4 is marginally better than L1+L5

L5 observations update the oldest 2 weeks in the synoptic chart used as input



Pevtsov+ 2020

Final Thoughts

- WL coronagraph: similar to STEREO/COR2, but inner FOV overlapping with EUV imager FOV. Polarization camera reduces a mechanism
- EUV imager with an extended FOV (SUVI, SWAP)
- Low-frequency radio receiver: SEP association increases when type II drifts to frequencies below 15 MHz
- For global solar wind modeling, L5 and L4 input have similar contribution
- L5 has advantage of forecasting AR rotating into Earth view
- L4 view better for observing SEP-producing and storm producing CMEs
- When L5 mission is finalized, instruments may be copied for an L4 mission
- L1+L4+L5 is the best combination for space weather forecasting and science