Solar Mass Ejection Imager (SMEI): First results & Future Capabilities

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http://www.vs.afrl.af.mil/Division/VSBX/SMEI.html
http://smei.nso.edu

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Outline

- SMEI Goals re CMEs
  SW Forecasting & Understanding
- How Maps Constructed
- Examples of CMEs:
  Limb, Halo, Multiple
  Solar Origins; Distance-Time plots
- First Statistical Results on CMEs:
  Rates, Brightnesses, Spans, Speeds, Distances
- Future Data Analyses & Collaborations

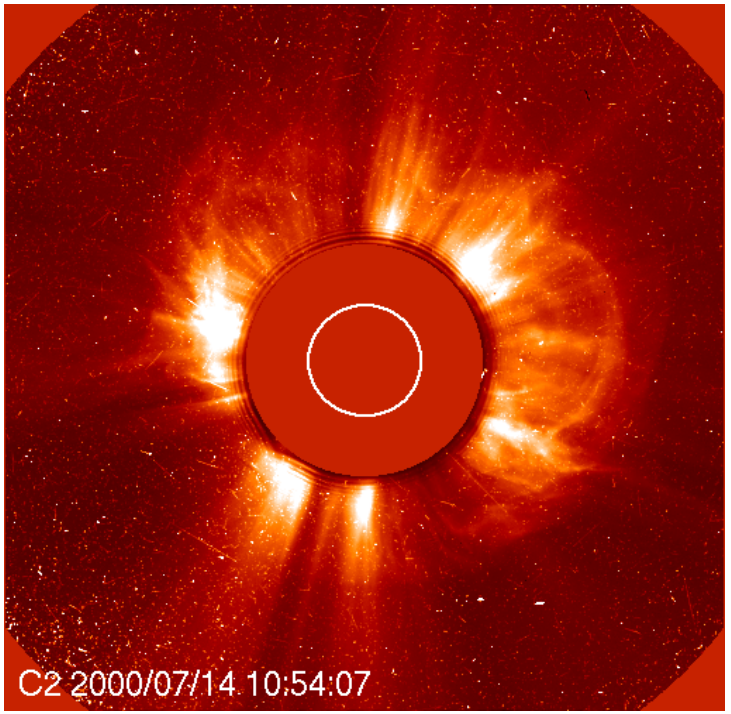
FORECASTING WITH SMEI

CMEs and GEOMAGNETIC STORMS:

CMEs cause all large storms.
Fast CMEs drive IP shocks; Shocks produce SEPs.
Our ability to forecast storms is poor.
Most storms not forecast and most forecasts are false alarms.

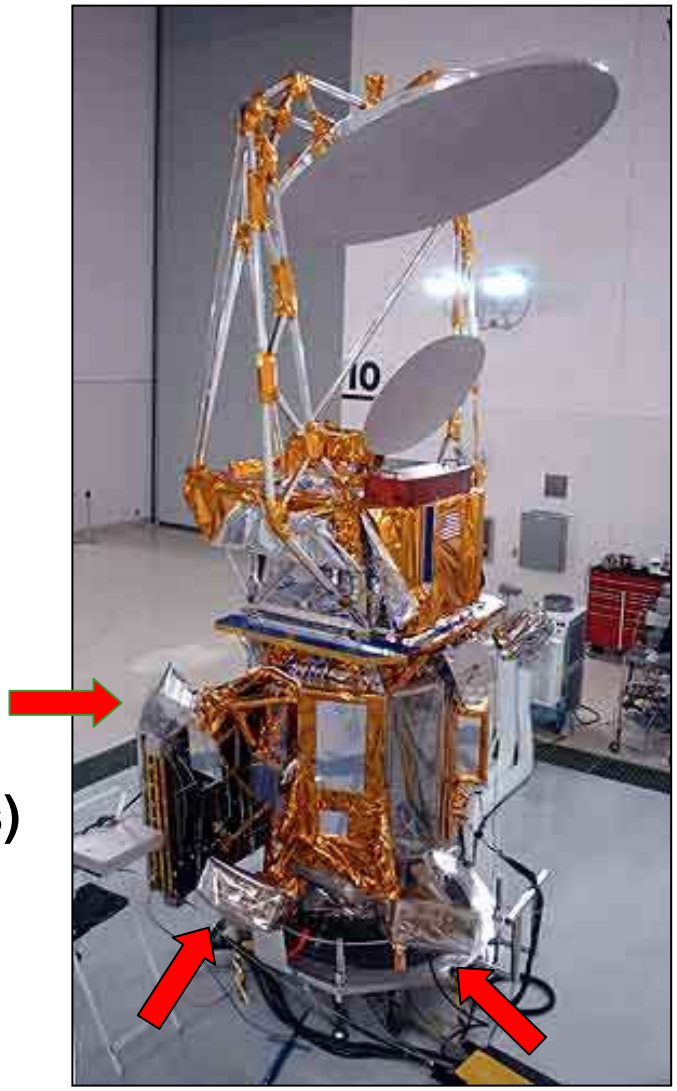
Basic Space Weather problem:

Need trajectory, timing & strength of CME
Will CME hit head-on, graze or miss Earth?
Time of arrival of Shock, dense structures
Predict strength of storm



Solar Mass Ejection Imager (SMEI)

- Proof-of-concept AF experiment
- Launched by AF STP
- Cost: Approx $10M
- Tracking CMEs from Sun to Earth
- First-ever capability
- All-sky view, updated every orbit
- Need to detect signal at 1% of background (zodiacal light & stars)



SMEI on Coriolis Mission

Launched 6 Jan 2003

Vandenberg AFB

Since launch SMEI has observed:

- **68 CMEs, and 3-5 Earth-directed (halo) CMEs**
- **1 comet (Neat)**
- **1 asteroid (Vesta)**
- **Auroral light when Kp>4**

Experiment Schedule

- **YEAR 1 – Calibration, data processing, develop techniques for tracking CMEs & predicting storms**

  Data Latency (photon –> CCD –> AFRL) 24 hours

- **YEAR 2 – Validate forecasting techniques (post hoc and real-time tests)**

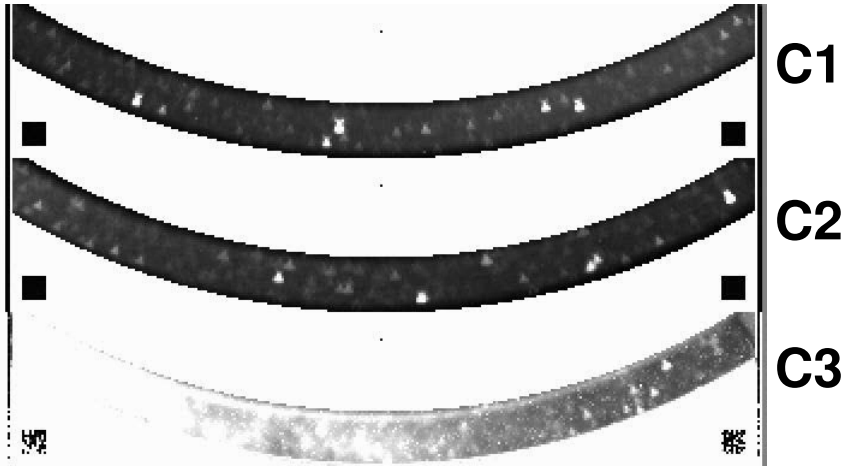
  Data Latency (original) 6 hours in Years 2 - 5

- **YEARS 3 - 5 – Contribute regularly to operational forecasts?**

- Challenges:

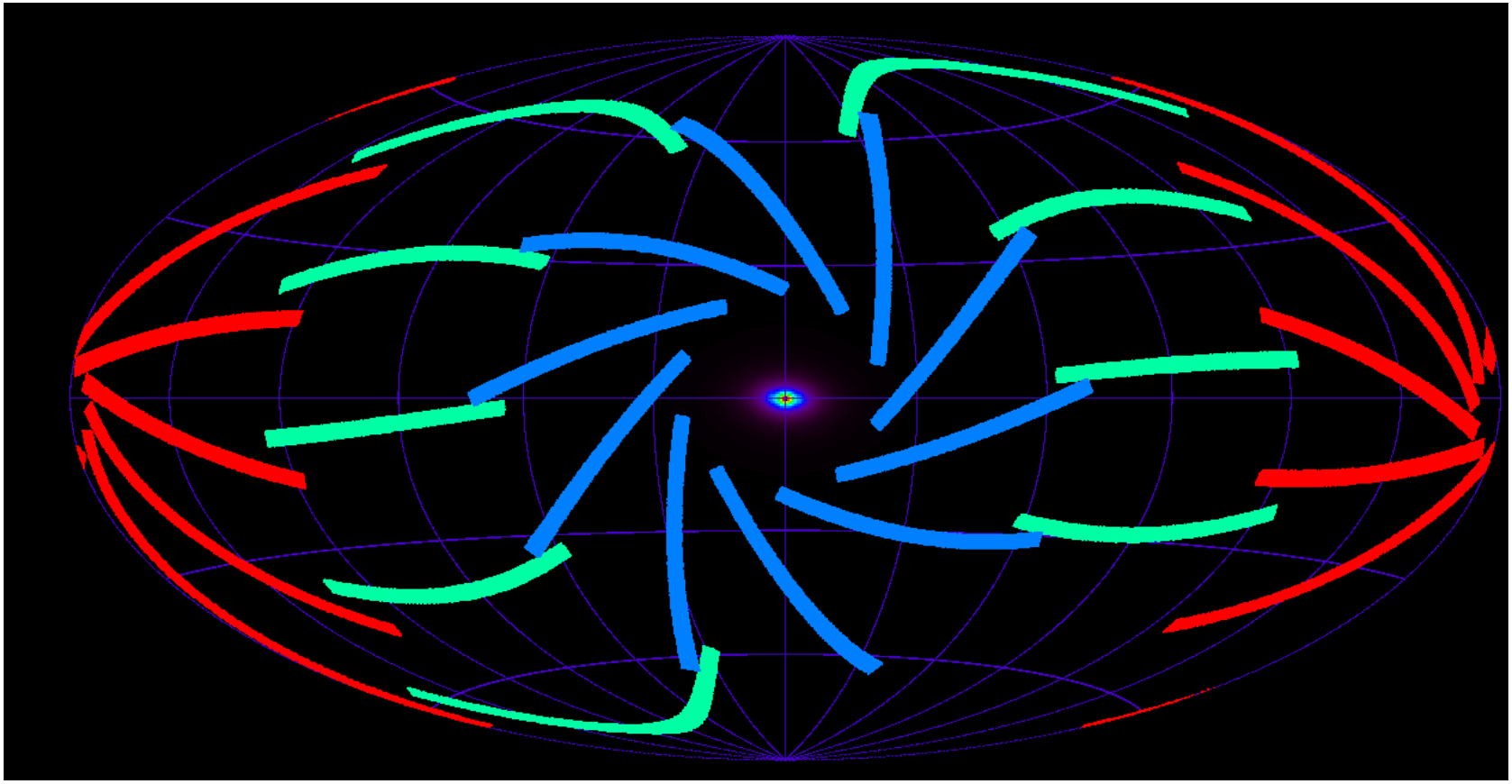
Camera pointing closest to Sun is 20^{o} warmer than expected.
Particle hits obscure large regions of the sky.
Fewer telemetry contacts than required for operational forecasts.

SMEI Fields of View



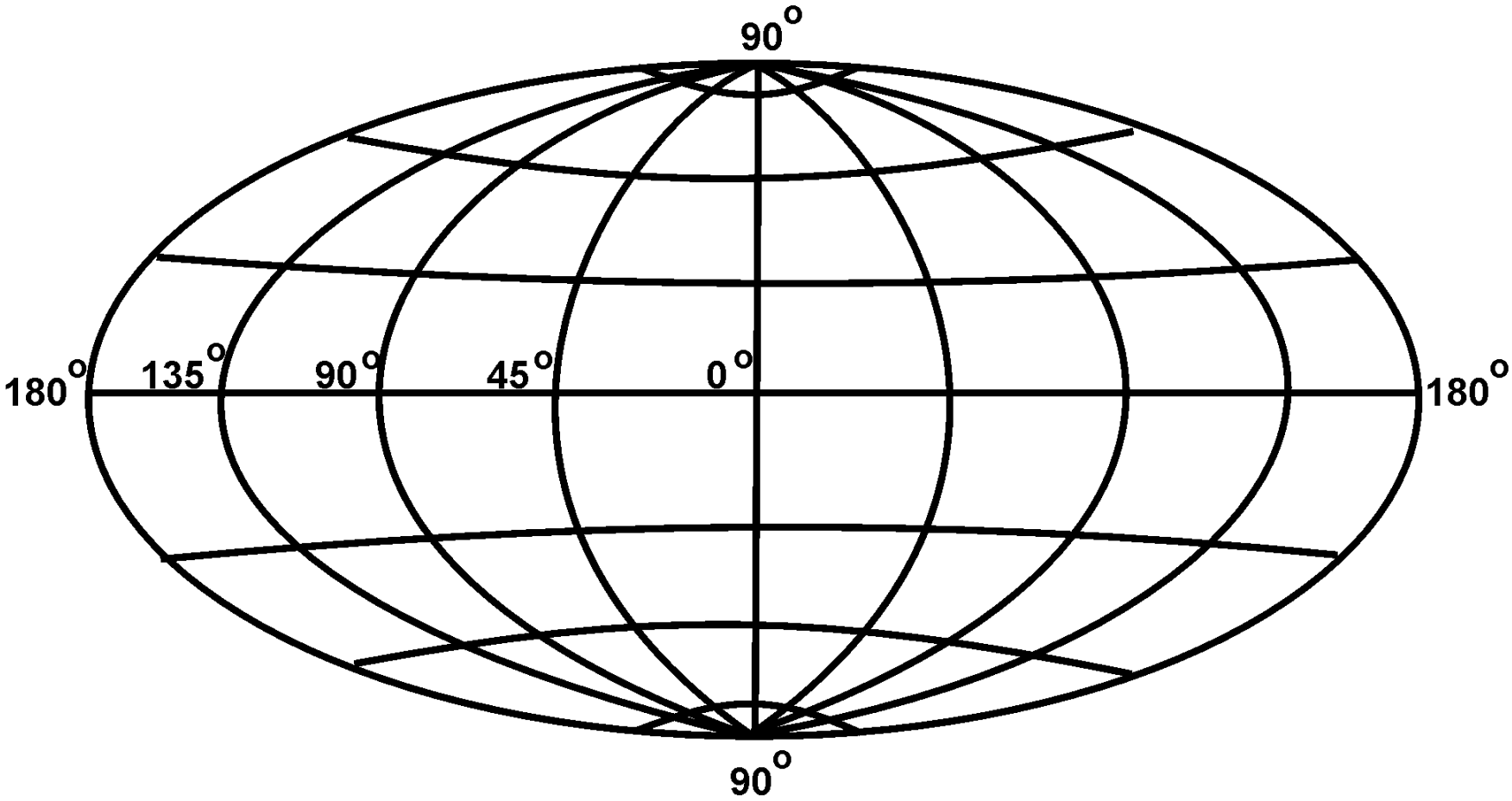
Frame Composite for Aitoff Map

***Blue** = Cam3; **Green** = Cam2; **Red** = Cam1*

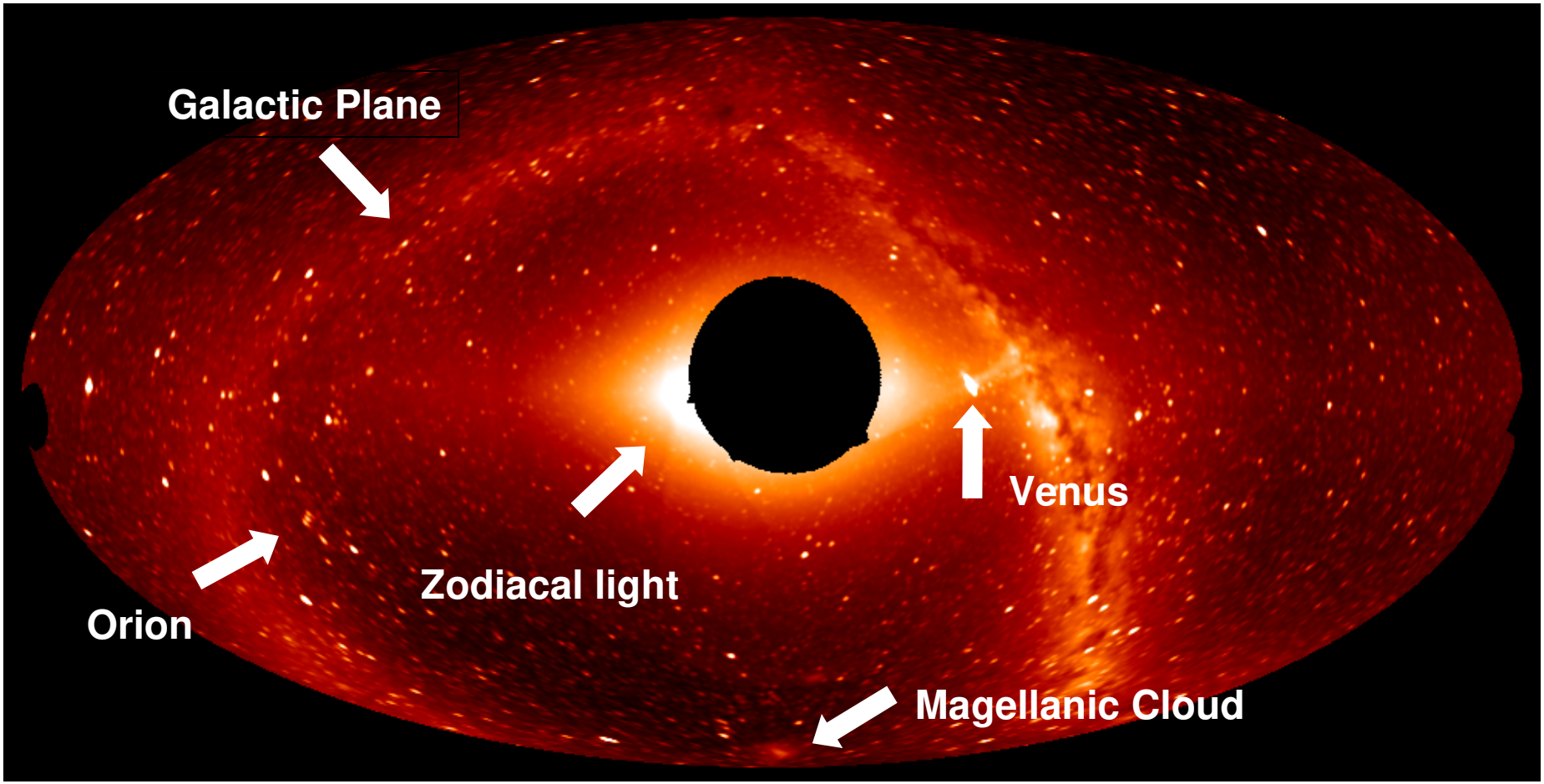


D290; 17 October 2003

Hammer-Aitoff Projection: "Standard" SMEI View

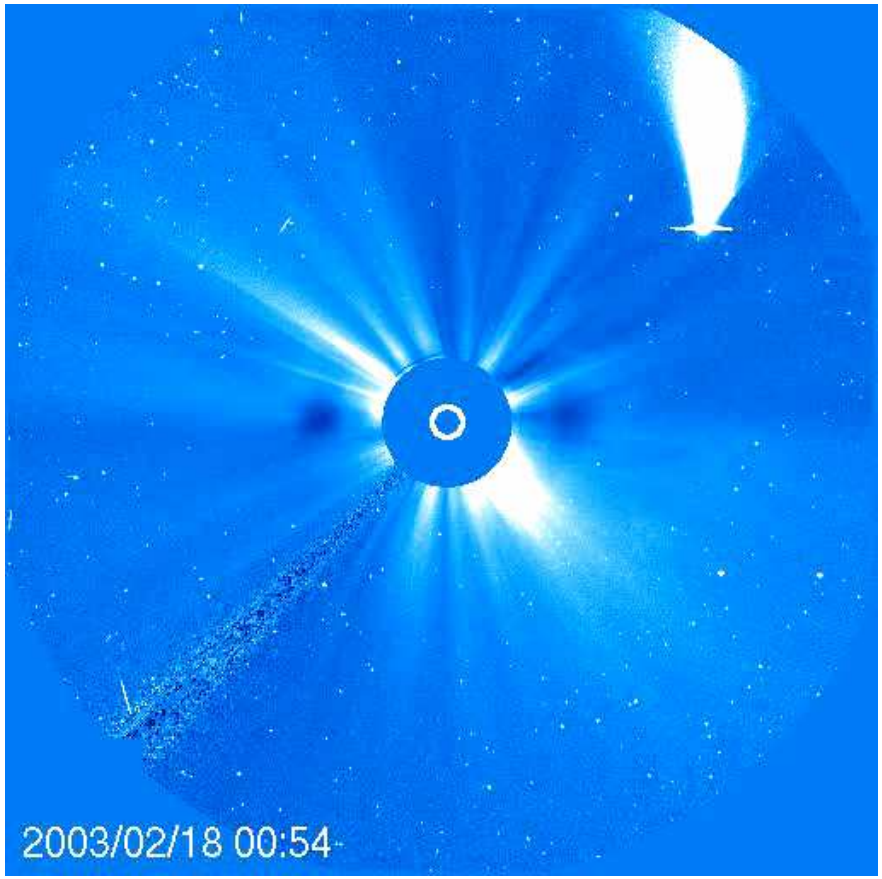


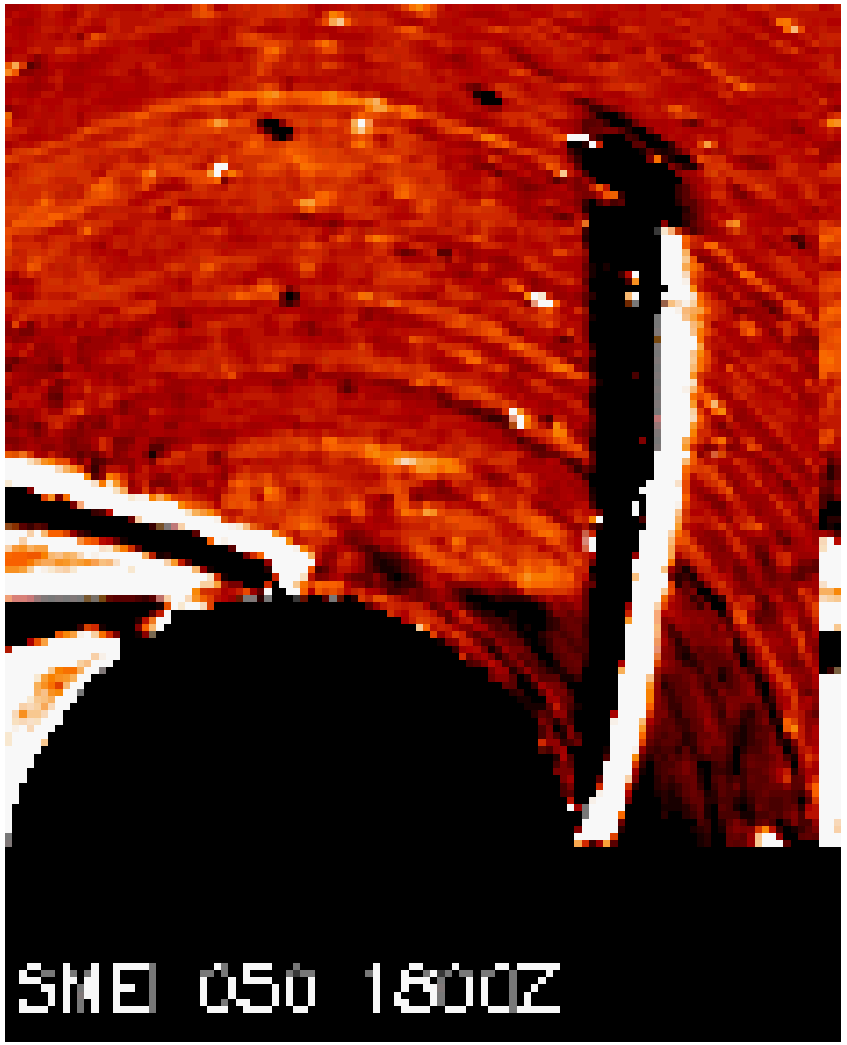
SMEI Composite All-Sky Image



March 2003

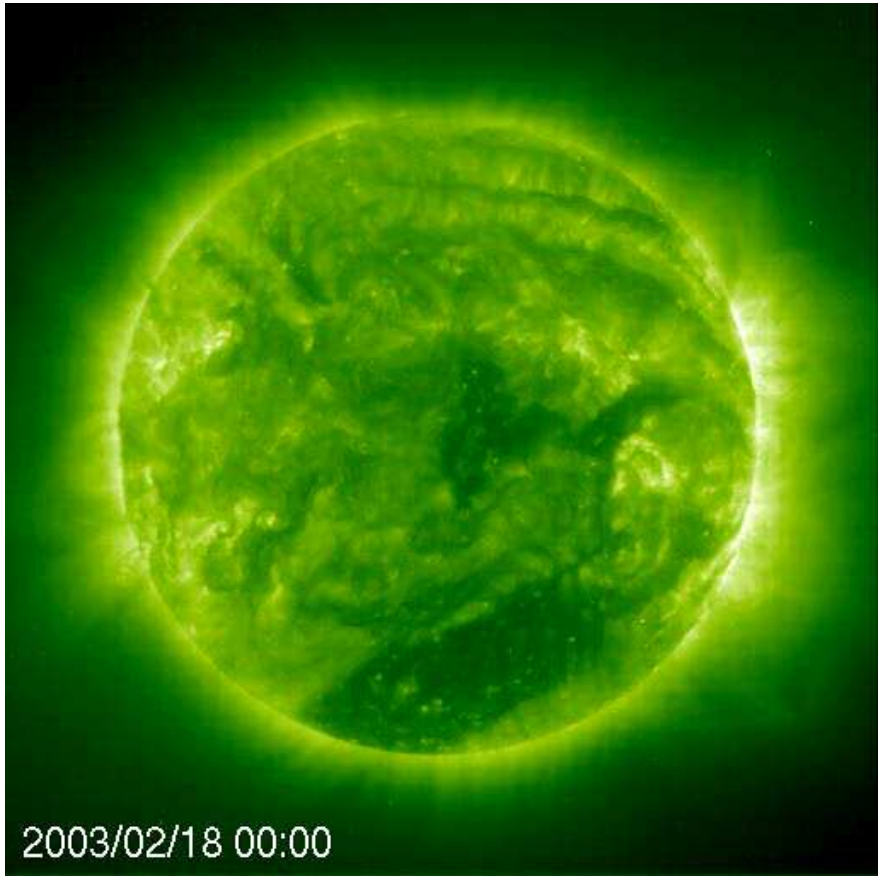
The First SMEI CME!

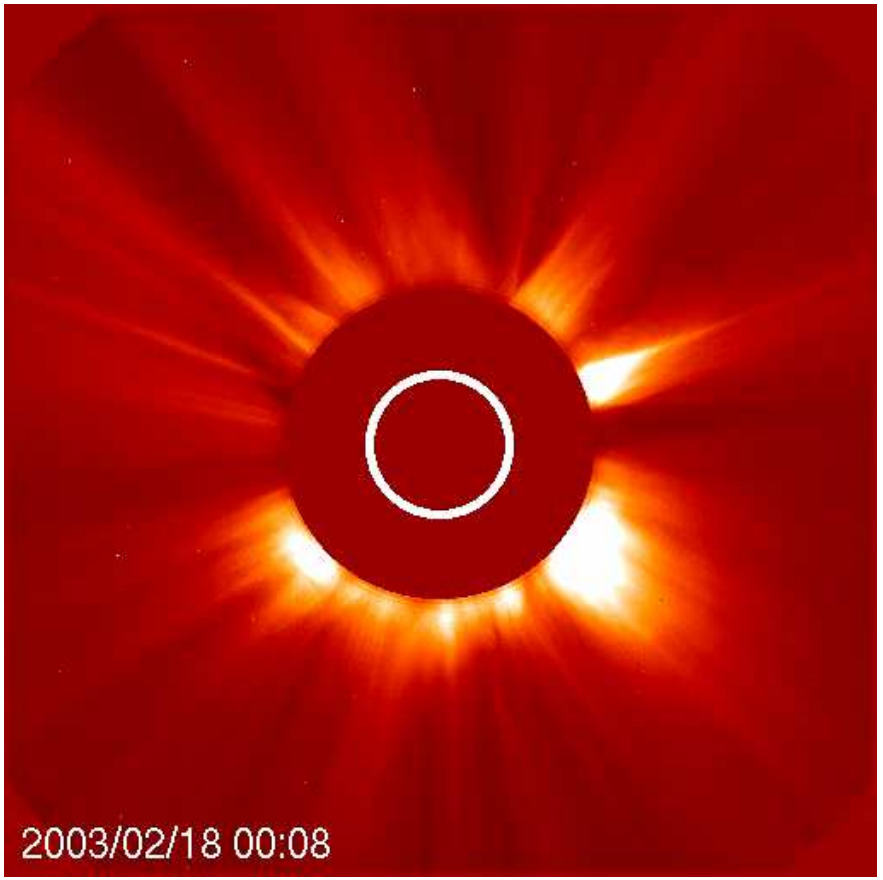




18-19 February 2003

An Amazing, Long Prominence Eruption!

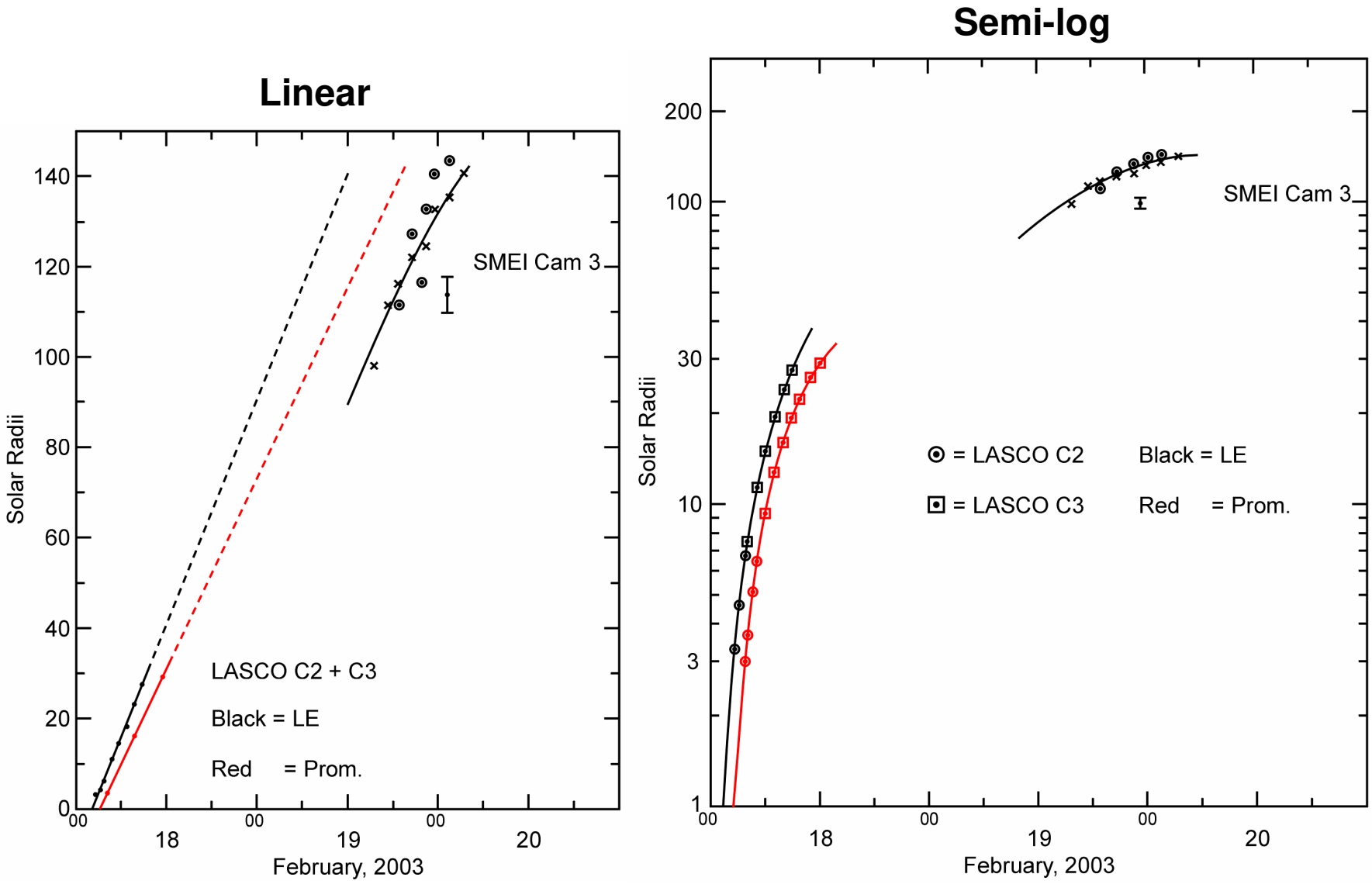




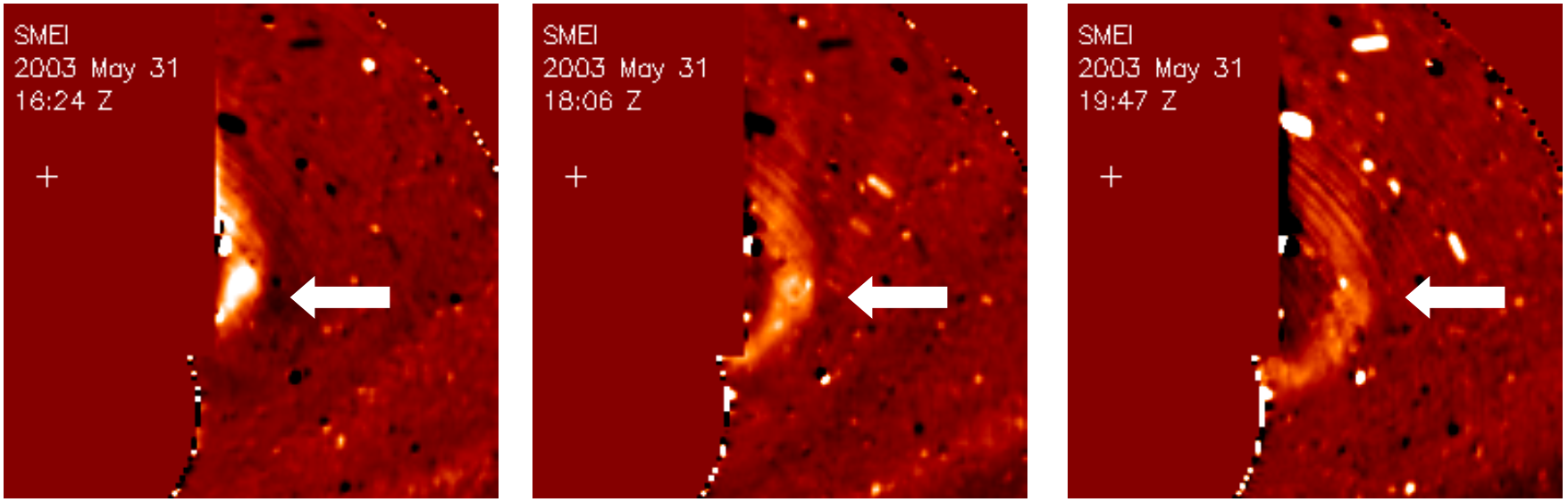
SOHO EIT 195A ***SOHO LASCO C2***

Event discussed in earlier talk in SH21C-04 by Hill et al.

Height-Time Plots of NW EPL/CME



A Fast Limb CME

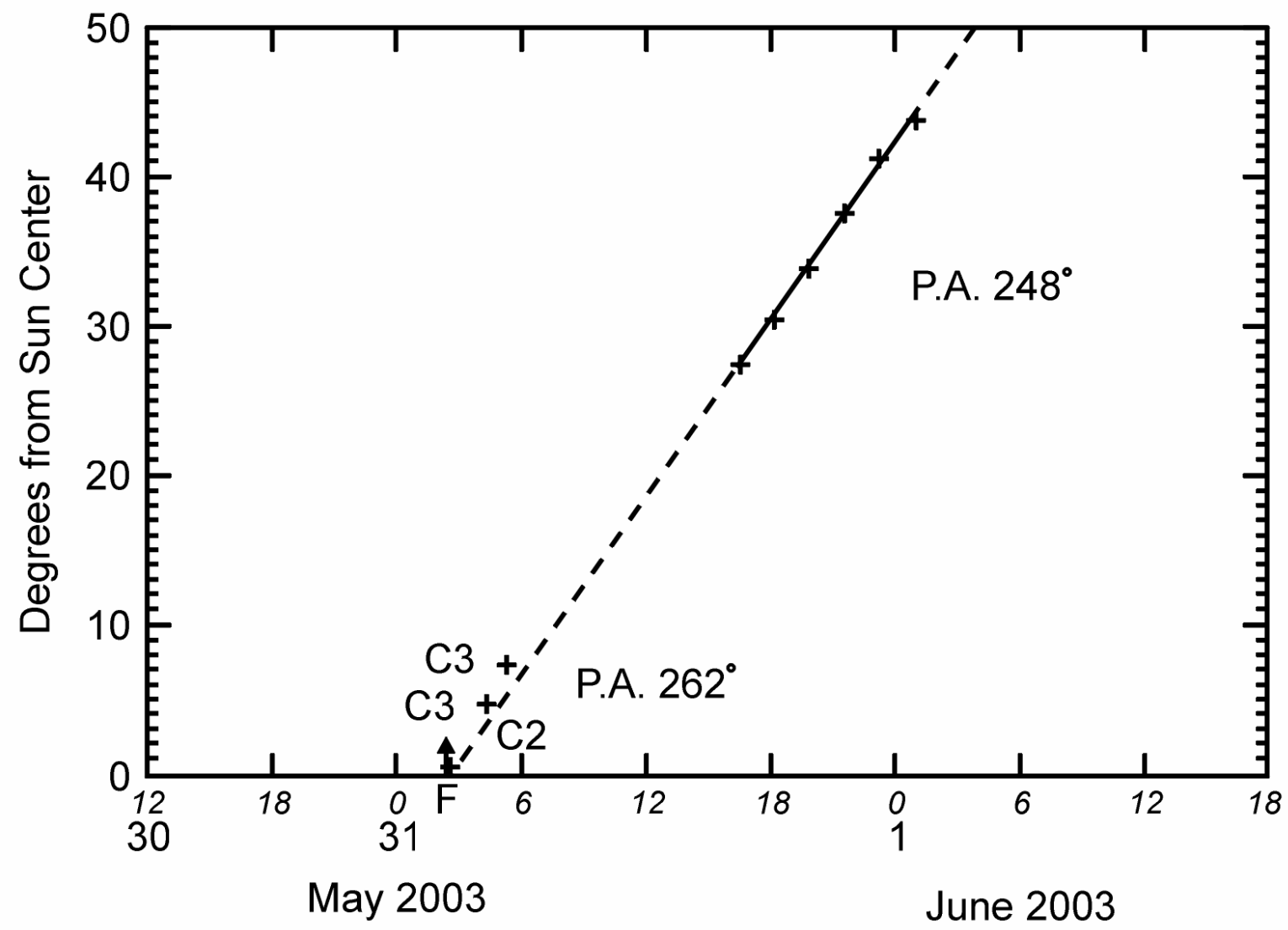


31 May 2003

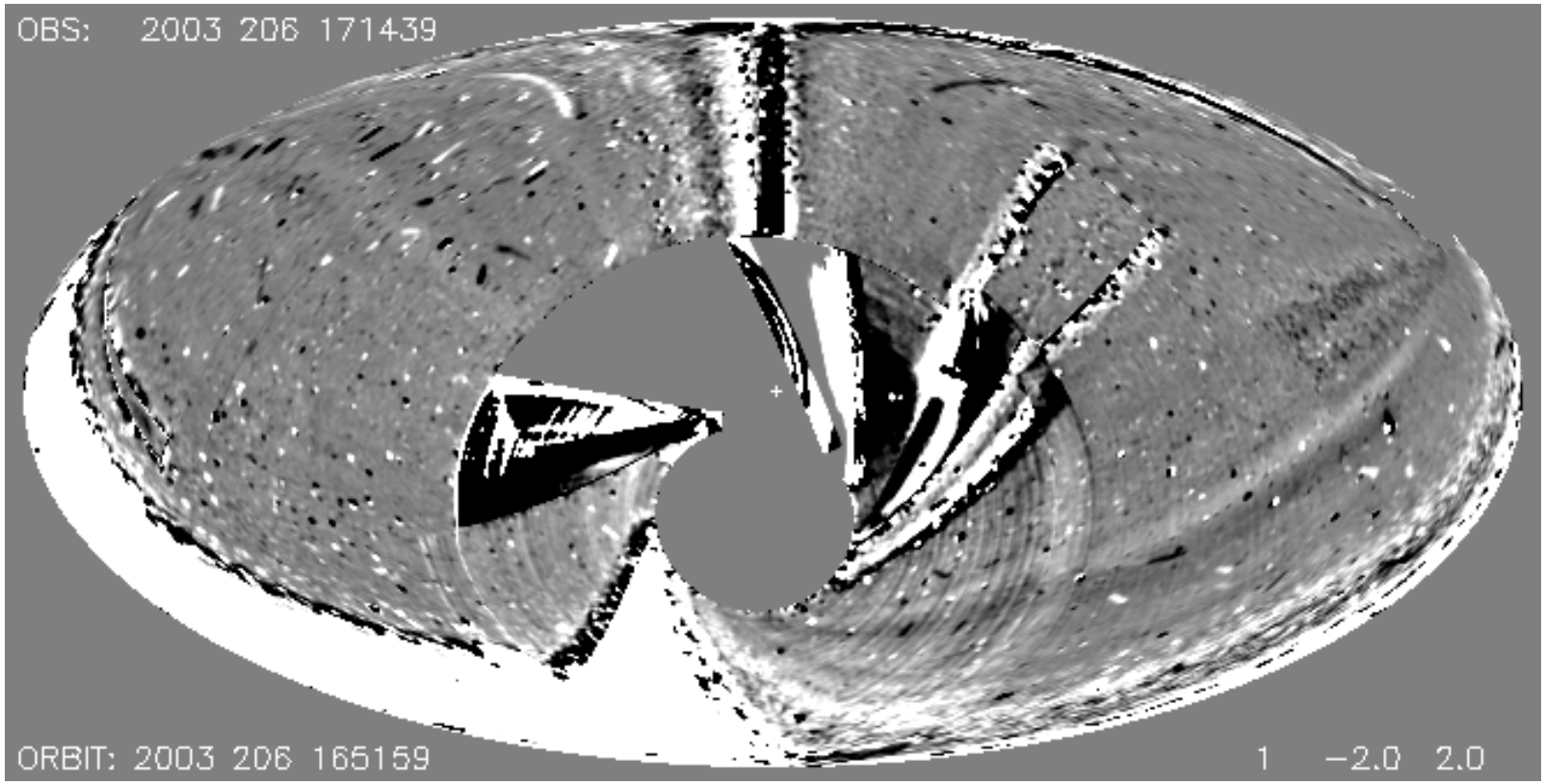
Speed: LASCO C3 1765 km/sec.
SMEI 1450 km/sec.

CME speeds range from 100 - 2500 km/sec.

Distance-Time Plot of 31 May Limb CME



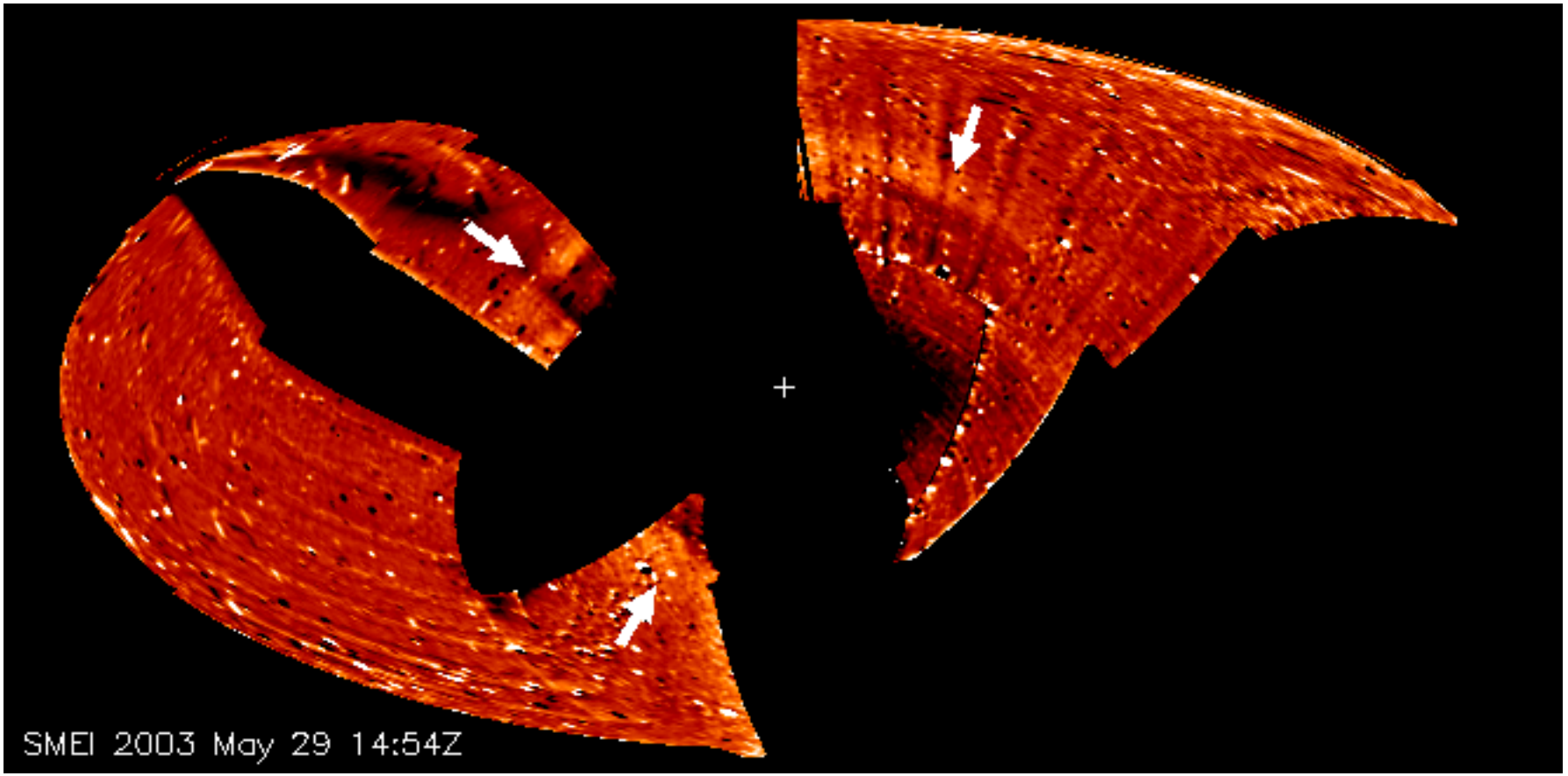
Example Movie of SMEI CMEs



At least 4 separate CMEs!

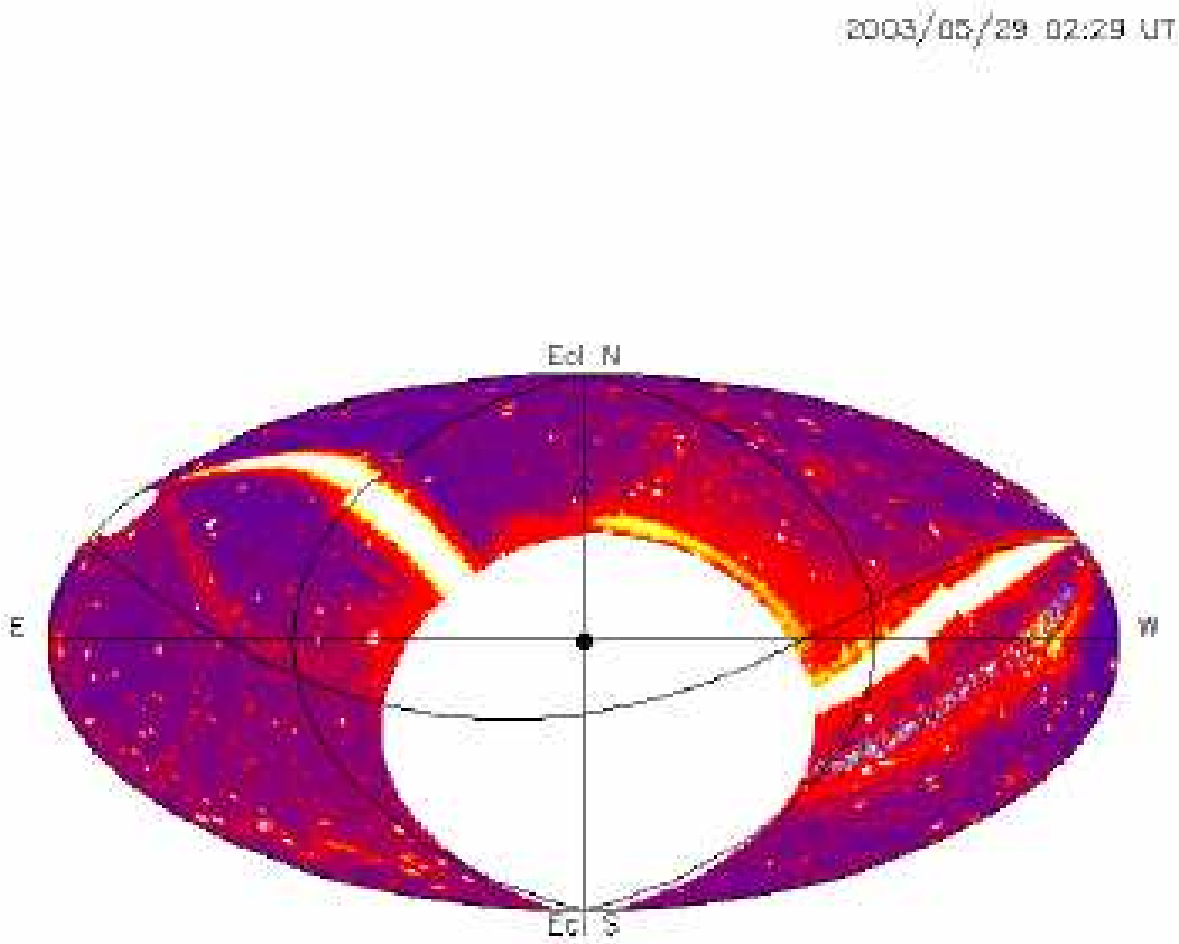
Slow, bright, bent arc to NW (Cam 3 into 2; lasts 2 days!)
Faint, wide arc over NP
2 wide arcs to E & NW (NOT Halos! Cam 2 into 1)

First Earth-Directed CME Seen by SMEI
29-30 May 2003



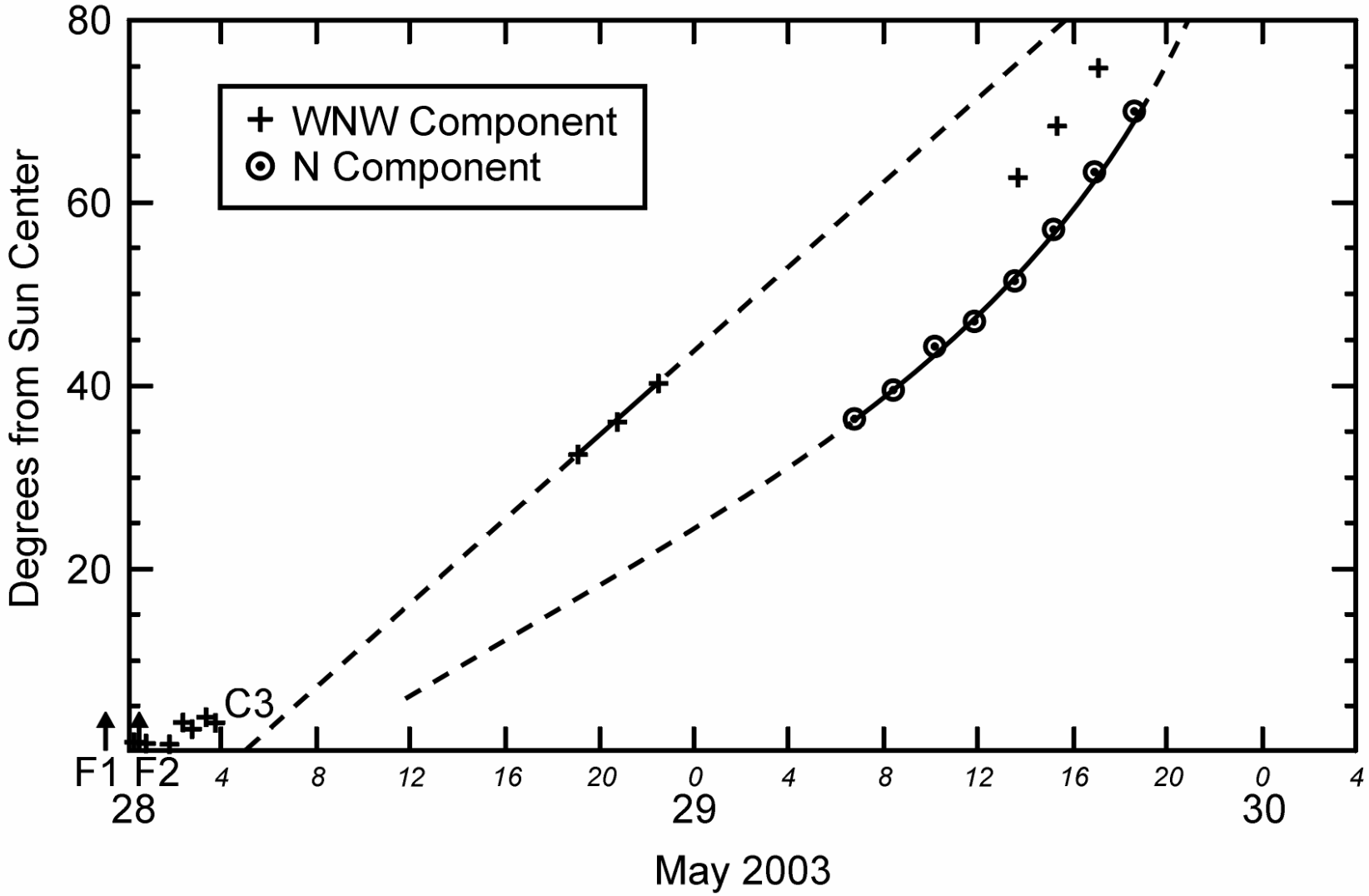
Tappin et al., GRL, in press, 2003

Movie of Late May Halo CME: SMEI Cams 2 + 1

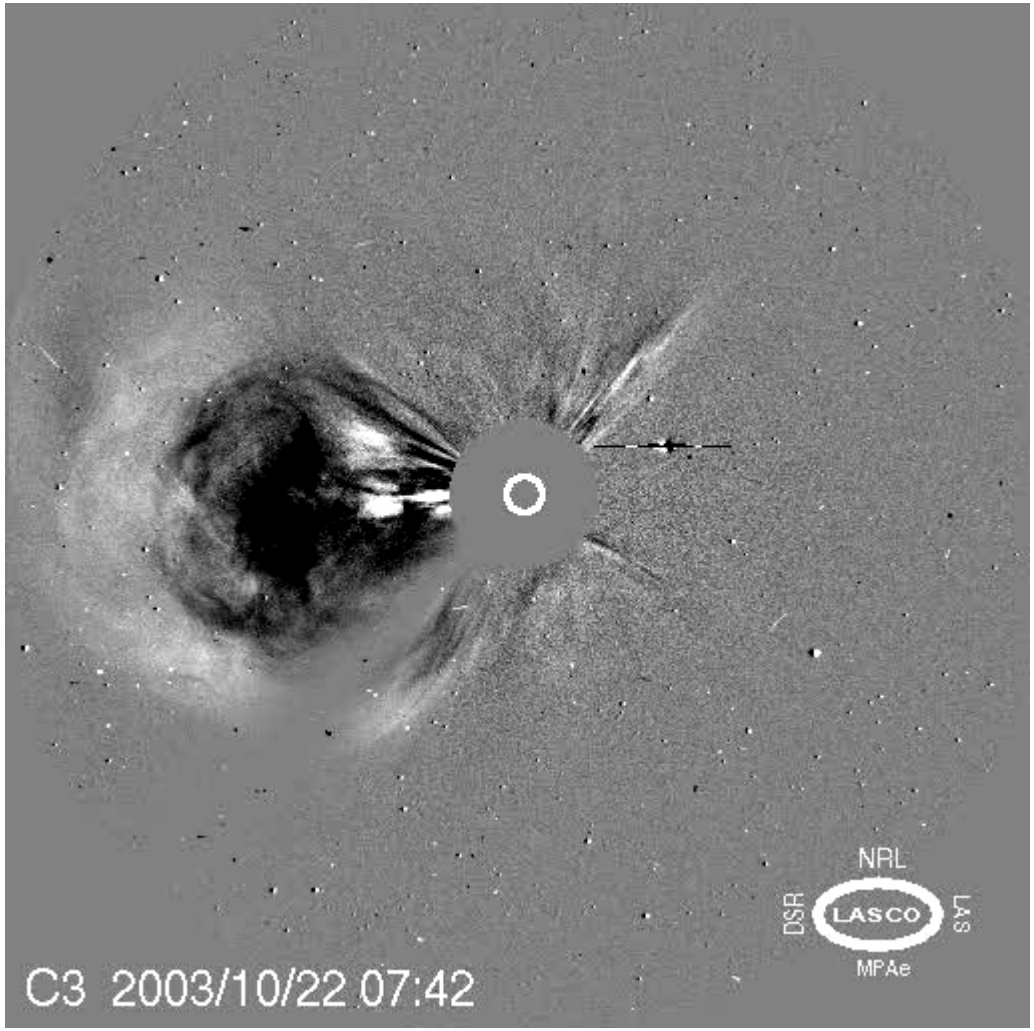


Courtesy: B. Jackson & A. Buffington, UCSD

Distance-Time Plot of May Halo CME



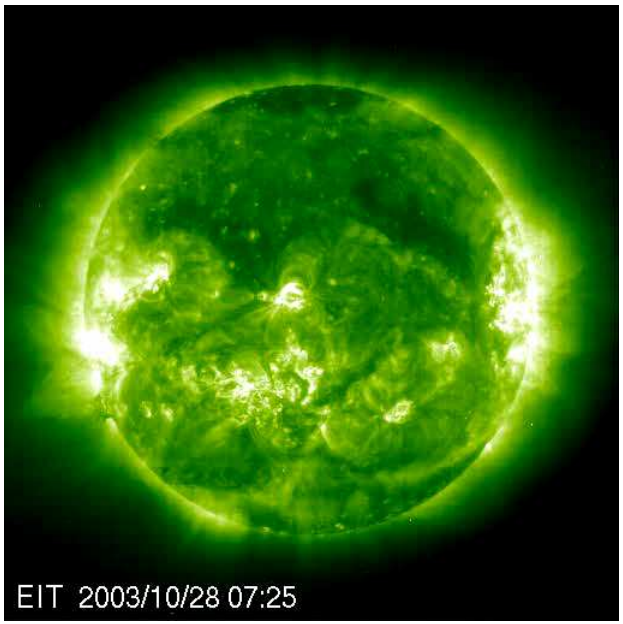
1st of Recent Halo CMEs

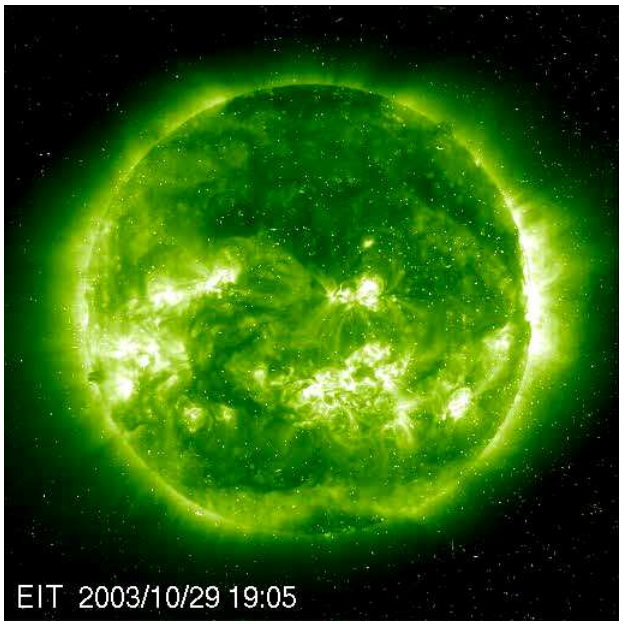


SOHO LASCO C3: Oct. 22

X17 Flare/CMEs X10

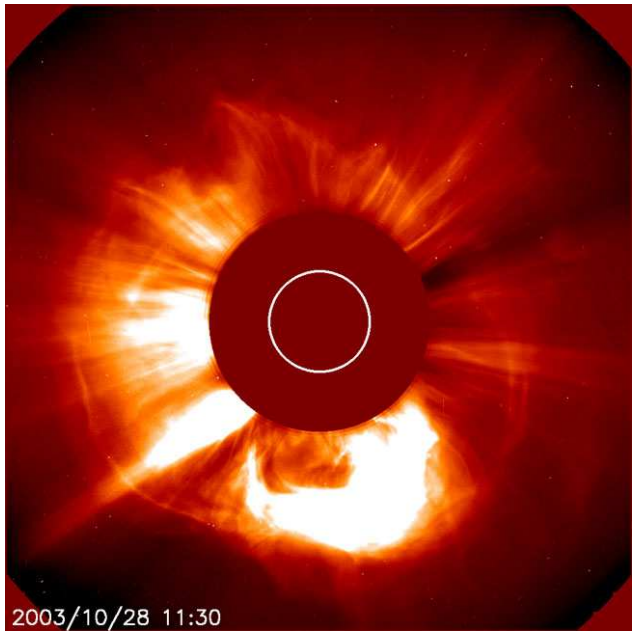
Oct. 28
EIT 195A

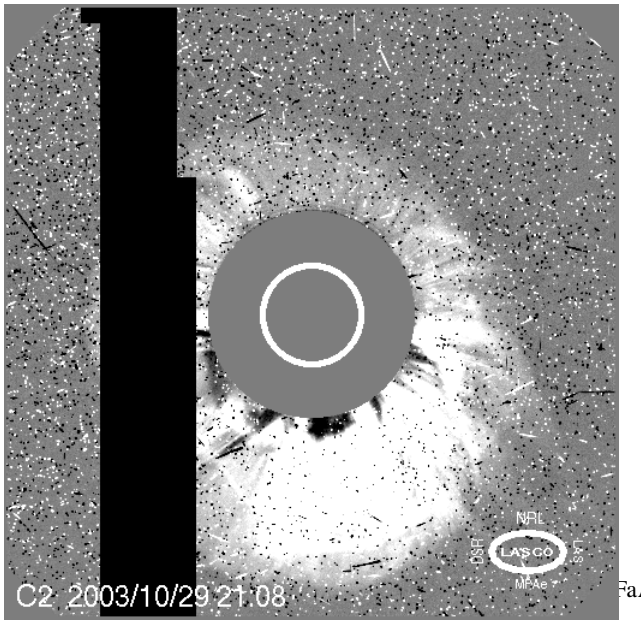




Oct. 29
EIT 195A

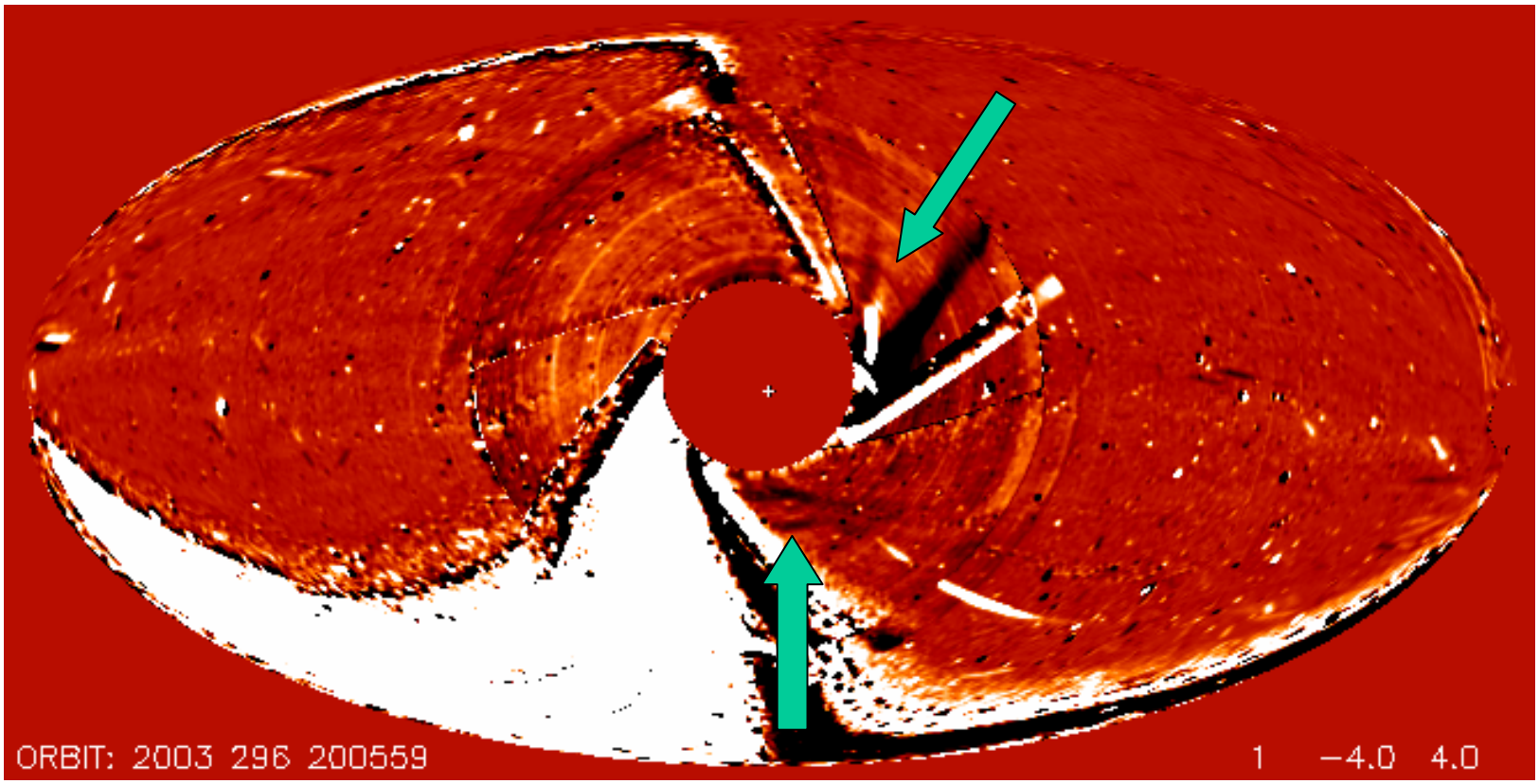
Oct. 28
LASCO
C2



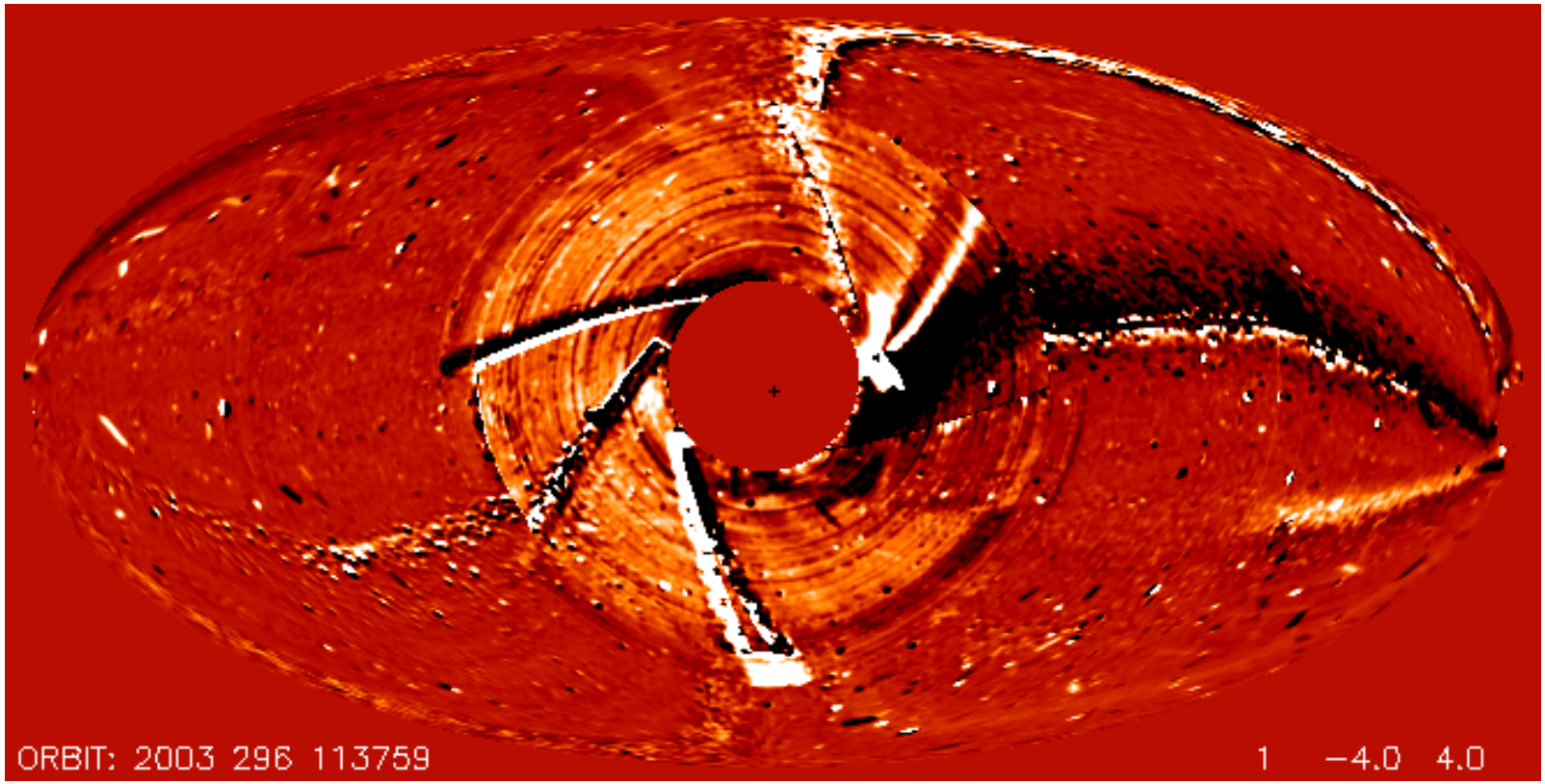


Oct. 29
LASCO
C2
(Diff.)

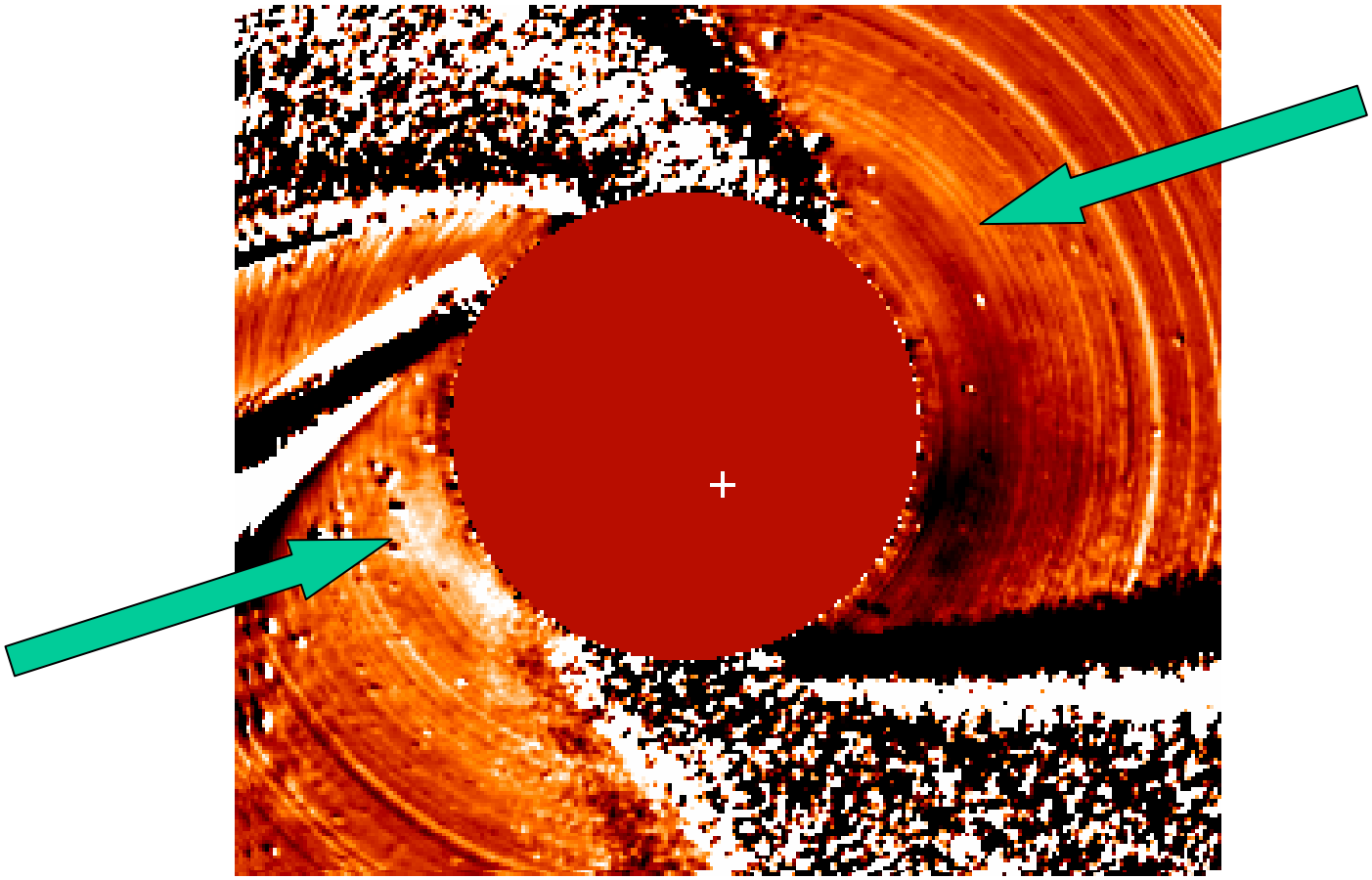
Oct. 22 Halo CME Seen by SMEI



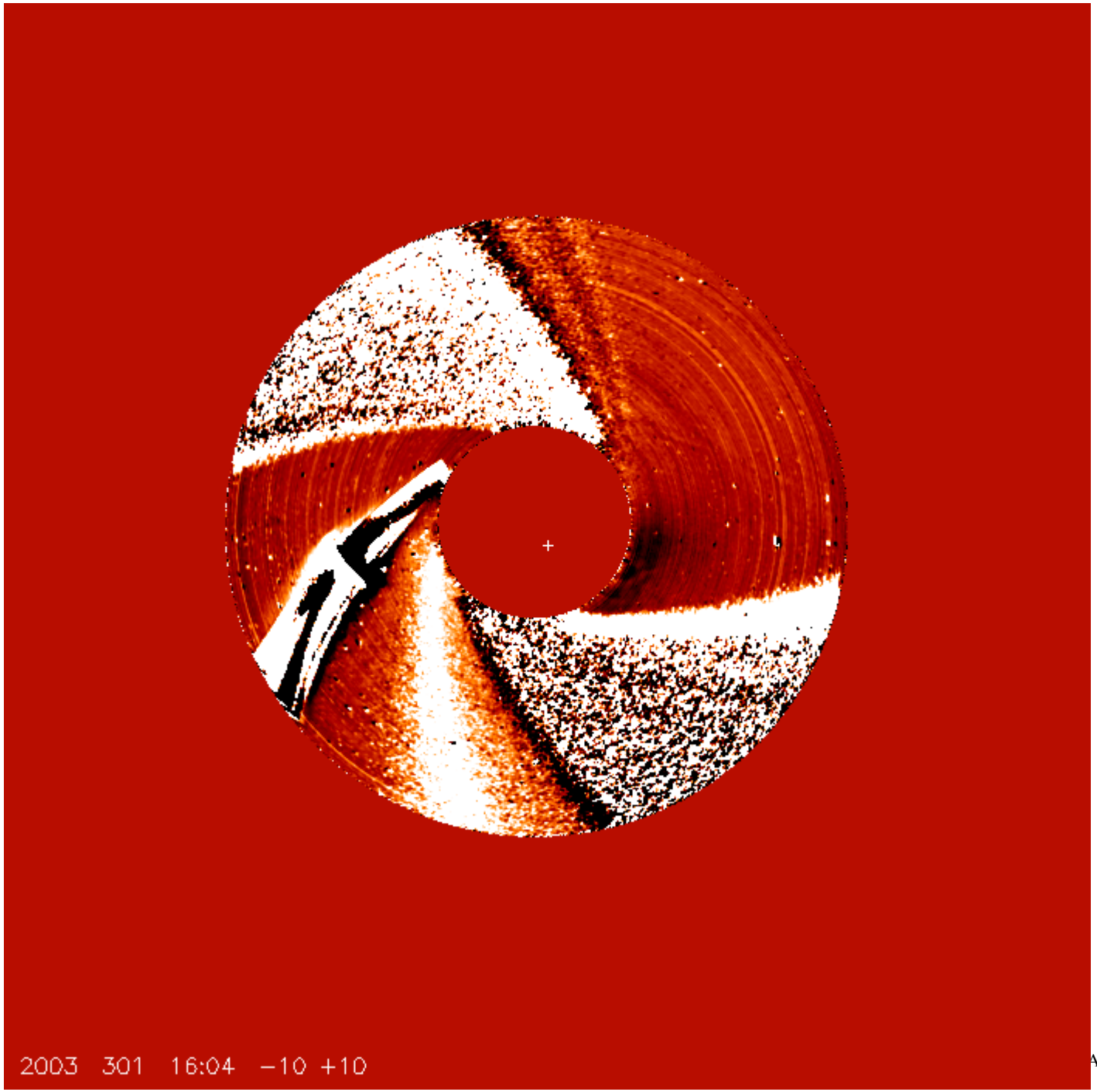
Halo CME Movie



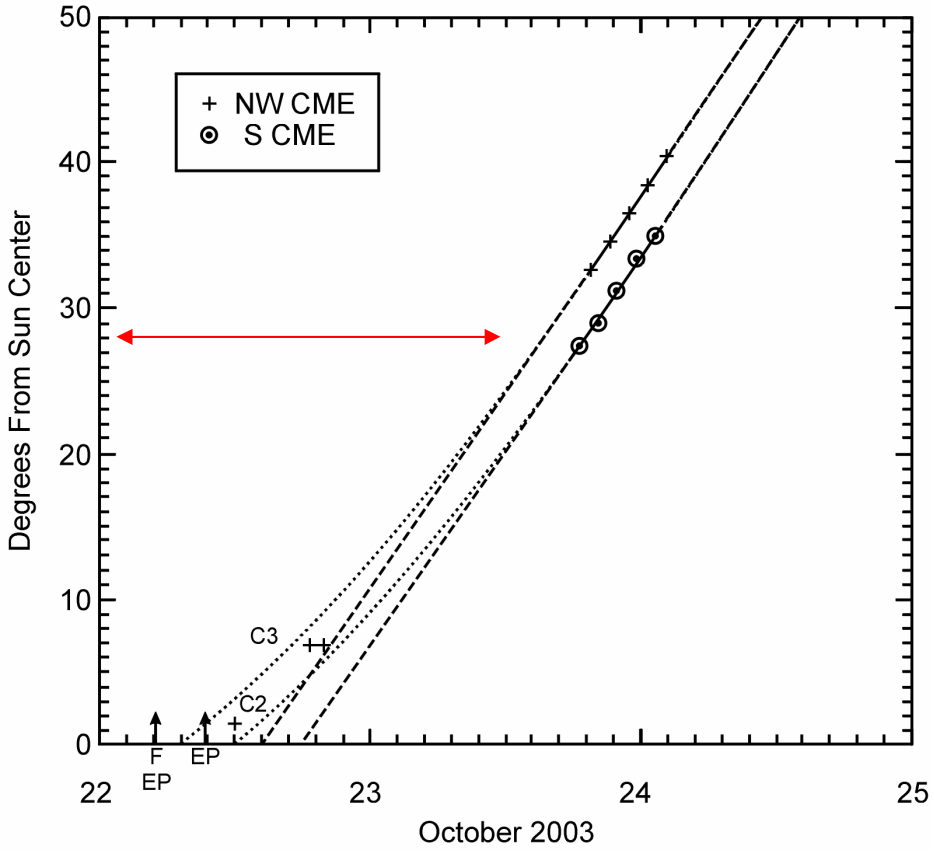
Oct. 28 Fast Halo CME seen by SMEI



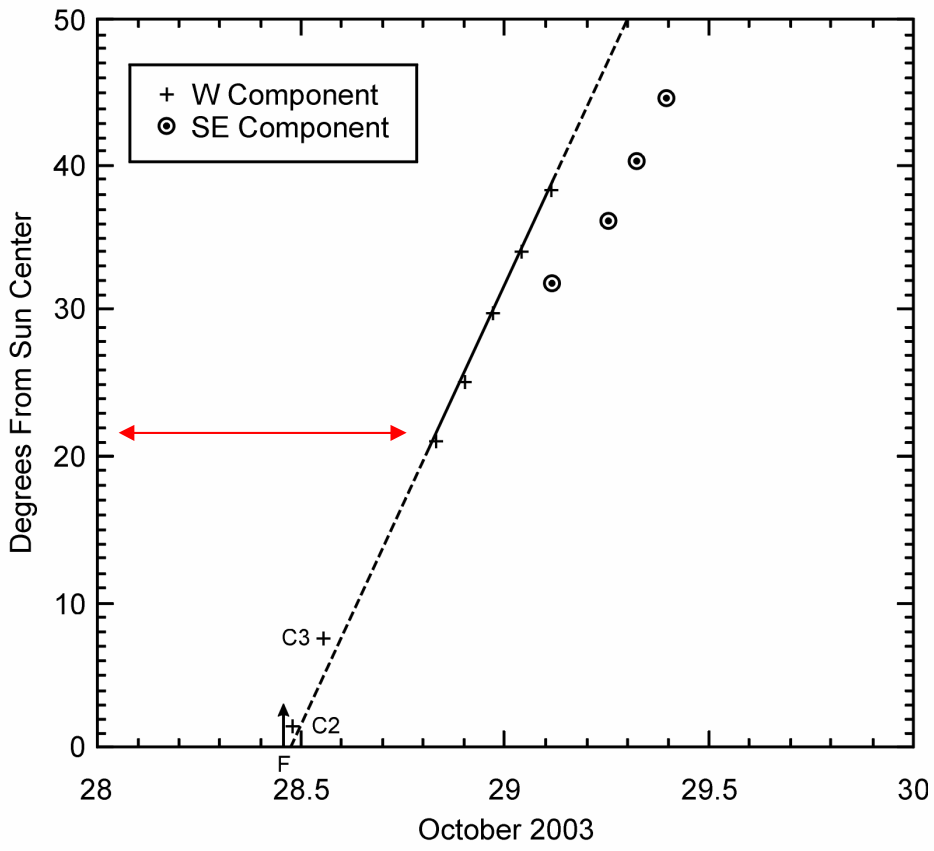
Difference image of 2 parts of halo on Oct. 29, 02:10 UT.


2003 301 16:04 −10 +10

Angular Distance vs Time of Recent Halo CMEs seen by SMEI



Distance vs time plot of 2 parts of Oct. 22-23 CME in SMEI; F= flare onset, EP= erupting prominence, C2 & C3= top of CME in SOHO LASCO coronagraphs.



Distance vs time plot of 2 parts of Oct. 28 CME in SMEI; F, C2 & C3 as before.

Travel Times of 3 Geoeff. Halo CMEs

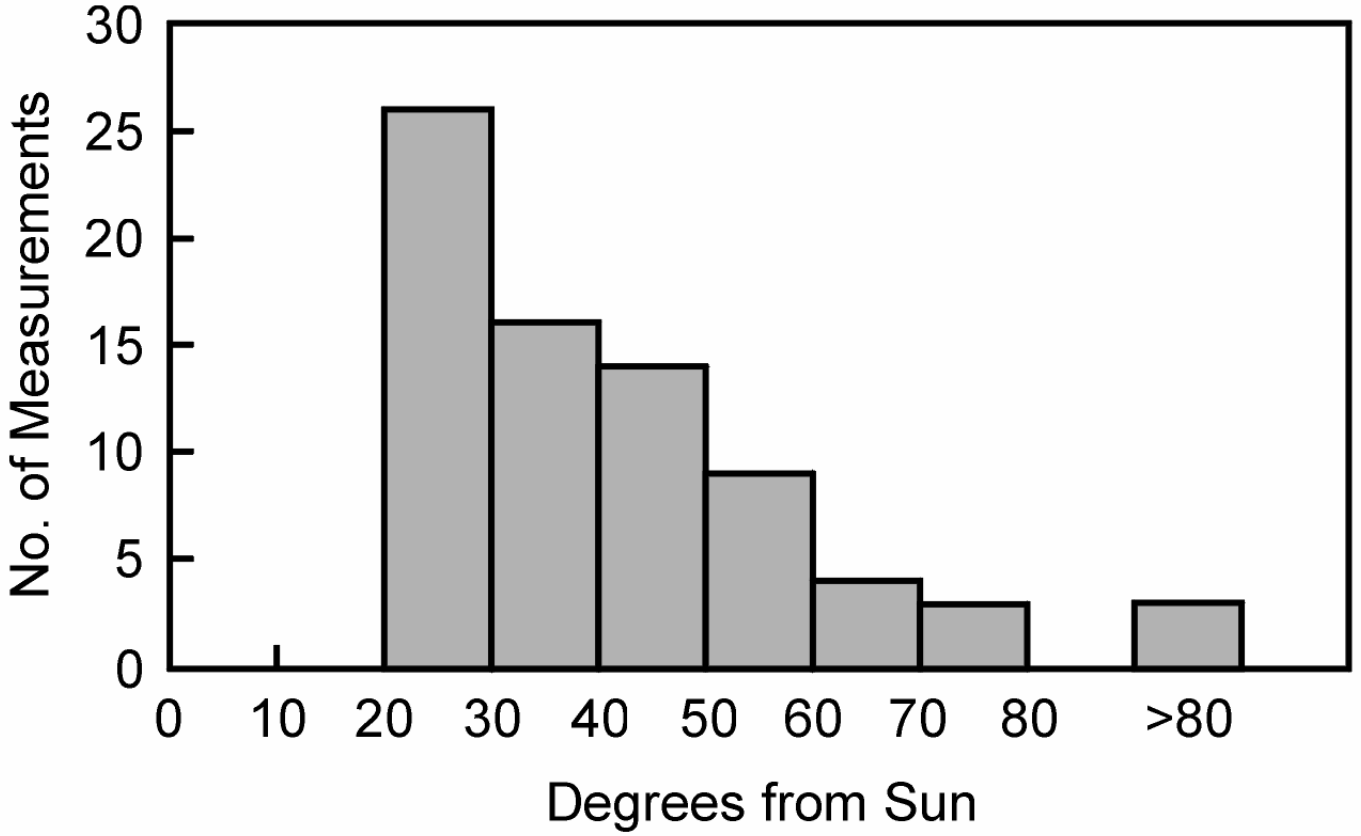
Date/Event 2003	Flare Onset at Sun (UT)	1st SMEI Obs. (hours)	Shock at Earth (hr.)	Shock-SMEI (hr.)
May 27-28 - X1, X4	23, 00	+19,31	+42	+23,+11
Oct. 22 - M4	>05:00	+37	+58	+21
Oct. 28 - X17	11:00	+9	+19	+10
Oct. 29 - X10	21:00	(no data)	+19.5	----

Conclusion: **SMEI first detected 3 Earthward CMEs 10 – 23 hr. before shock arrivals at 1 AU.**

Summary of Early Results: SMEI CMEs

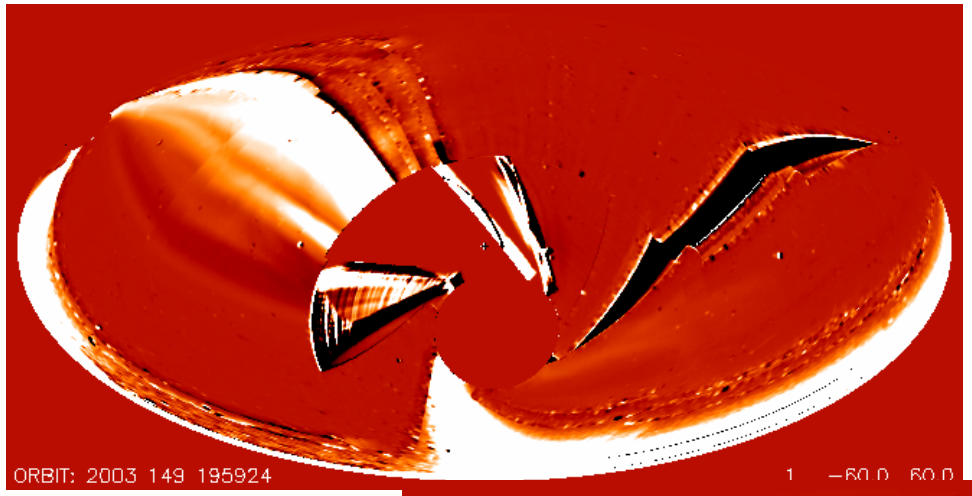
- 68 CMEs Observed; 5 Feb. – 30 Nov. 2003
  298 total d – 53.5 no obs. d = 244.5 obs. Days
  Occurrence rate = 0.28 CMEs/day
- Morphology: More structured nearer Sun (Cam 3) & broad arcs far from Sun (Cams 2, 1)
- SMEI vs LASCO: 36 (of 68) SMEI CMEs compared:
  17 assoc. with LASCO CMEs;
  3 not; 16 ???
- Brightness: Mean = 1.3 adu; Range = 0.2-6.0 adu
  Equiv. to 0.6 S10 units (Range 0.1-3.0 S10)
- Spans (detected): Mean = 43°; Range = 11 – 107°
- Speeds (linear fits projected on skyplane):
  Range = 330 – 3555 km/sec

Angular Distance when CMEs First Detected by SMEI

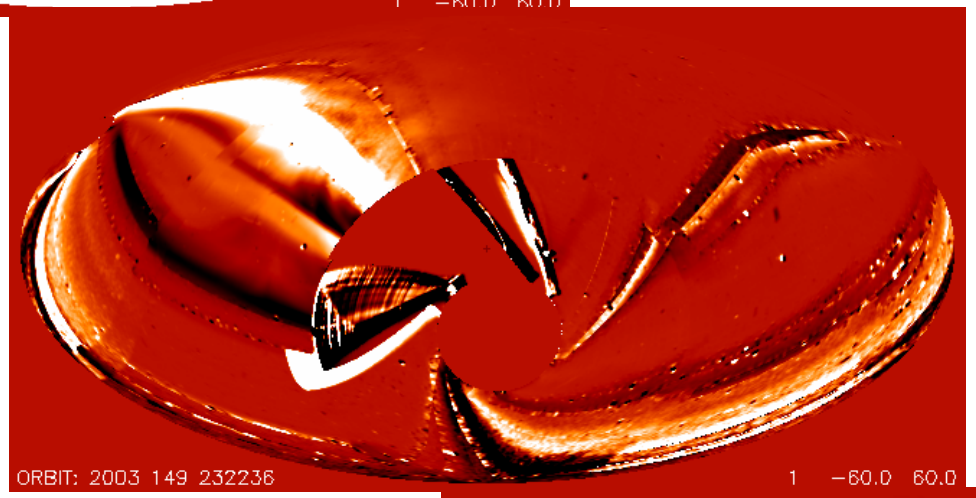


So, most CMEs are first observed 20-60º from Sun.

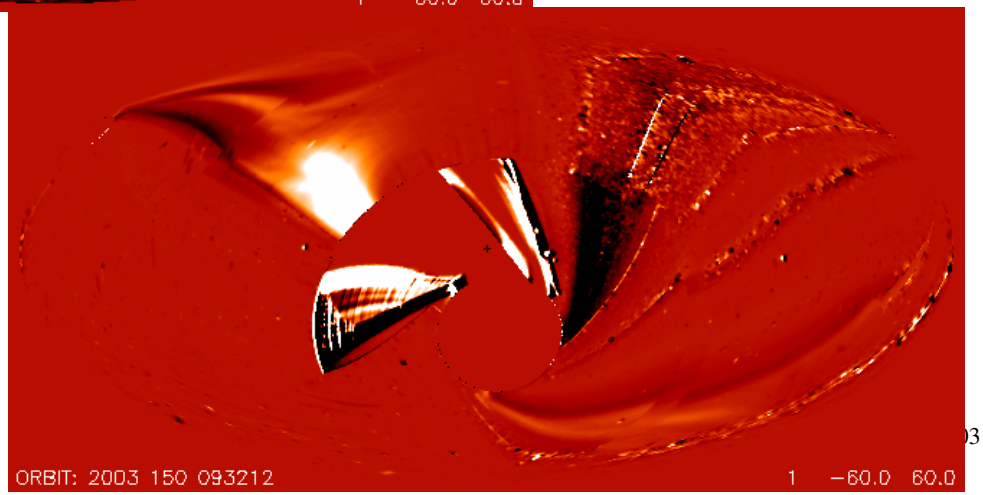
Bright SMEI Aurora: 29-30 May 2003



29, 20:00



29, 23:22



30, 09:32

SMEI Data

Required Processing

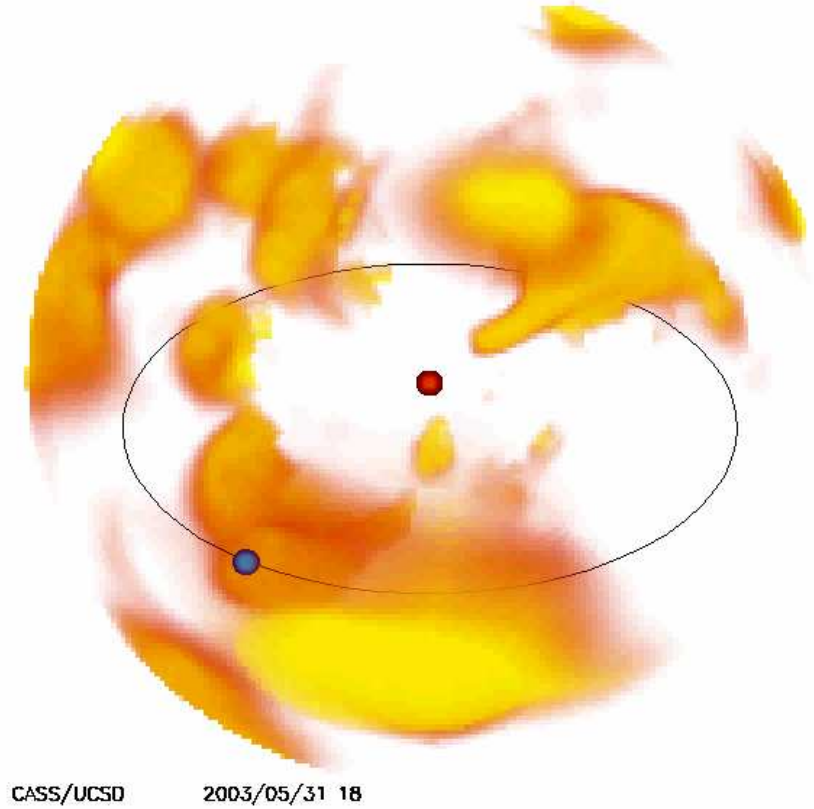
- Remove cosmic rays & hot CCD pixels
- Remove stars: 2 methods being used
- Remove a zodiacal cloud model
- Normalize radial brightness

Final Archives; End Products

- Heliospheric Sky Maps
- 3-D Model Reconstructions
- Zodiacal Cloud
- Stellar Time Series: Novae, Variable stars,
- Planetary transits
- Comets & Near-Earth Objects

CMEs in 3D using Reconstruction

SMEI Thomson-scattering data with model of solar wind kinematics used in a reconstruction inversion to infer 3D structure of CMEs & other regions of enhanced density.



Example of reconstruction using SMEI data in May-June 2003 (B. Jackson, UCSD)

Conclusions

- SMEI has observed 68 CMEs:
  Rate: 0.3/day; Brightness: ~1 S10; Spans: >43º
- CMEs more structured near Sun (like in LASCO);
  broad & arc-like far from Sun.
- SMEI detected 3 geoeffective halo CMEs at ~1/3 of
  Sun to Earth distance.
  - Proof of principal that SMEI can detect even fast Earthward
    CMEs < 1d before arrival.
  - New tool for early warning of storms.
- SMEI also has detected a comet, asteroids & auroral light
- Future Analyses & Collaborations:
  Improved calibrations & Reprocessing
  Tomography of CMEs & Corotating Structures

We Encourage Collaborations! Contact any of us.