

Selected CMEs around the Current Solar Minimum and their 3-D Reconstruction: Comparison with STEREO Results

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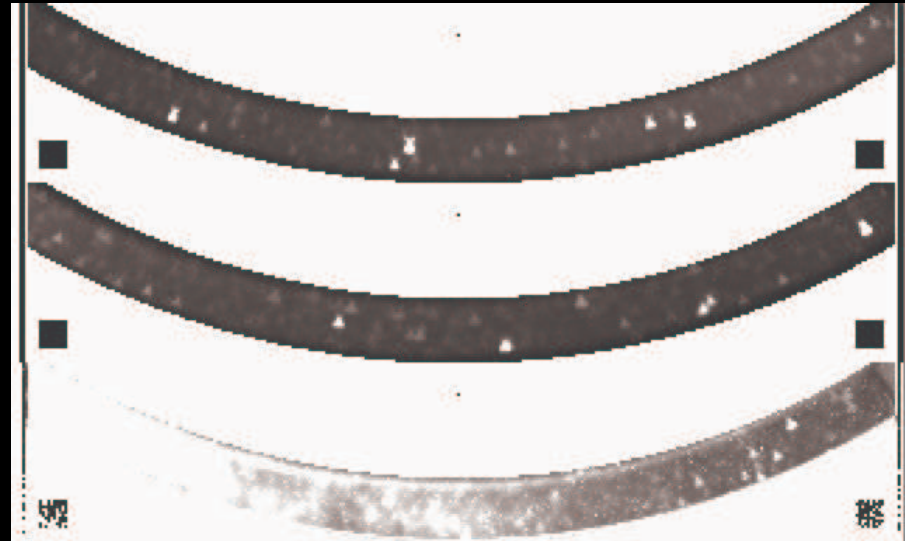
Outline

- ❖ Solar Mass Ejection Imager (SMEI)
 - ❖ Interplanetary Scintillation (IPS)
- ❖ 3-D Reconstructions of Coronal Mass Ejections (CMEs) and their comparison with STEREO results:
 - 26 April 2008 CME (SMEI)
 - 02 June 2008 CME (IPS)
- ❖ Overall Summary and Future Prospects

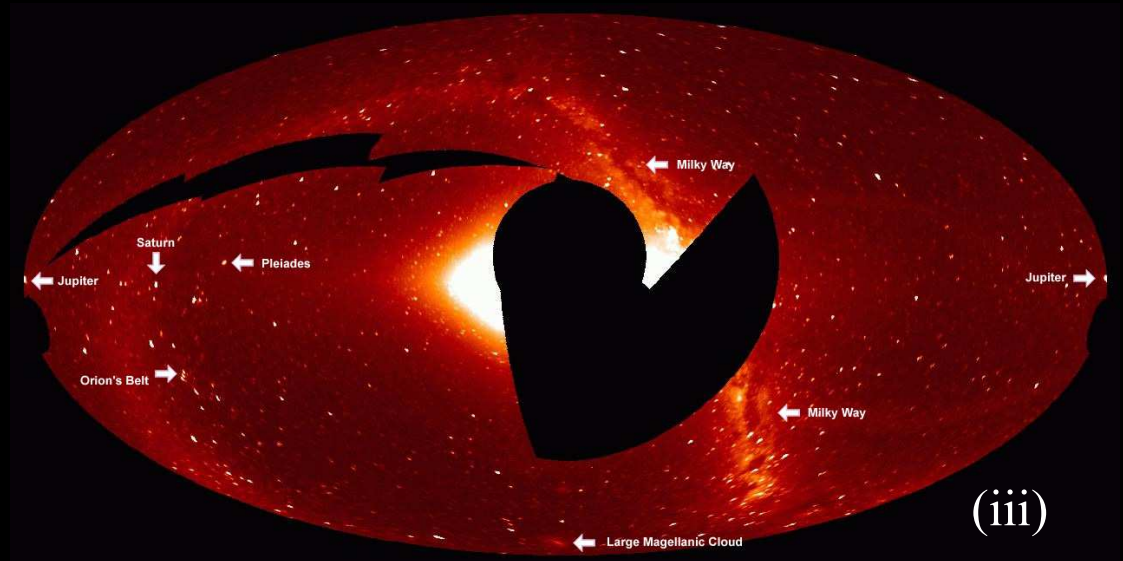
Solar Mass Ejection Imager (SMEI)



(i)



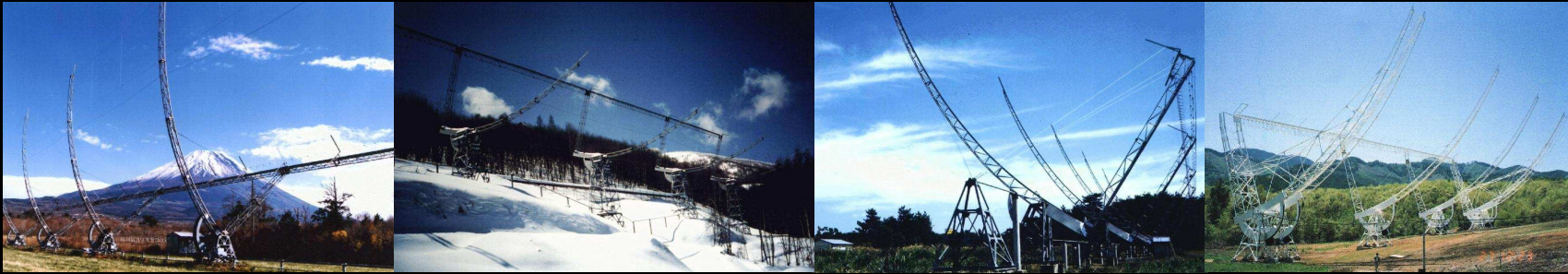
(ii)



(iii)

Launched in a Titan II from Vandenberg AFB on 6 January 2003: (i) Artist impression; (ii) Simultaneous images from the three SMEI cameras; (iii) First-light - composite all-sky map 2 February 2003 from the three SMEI cameras

Interplanetary Scintillation (IPS) System Used



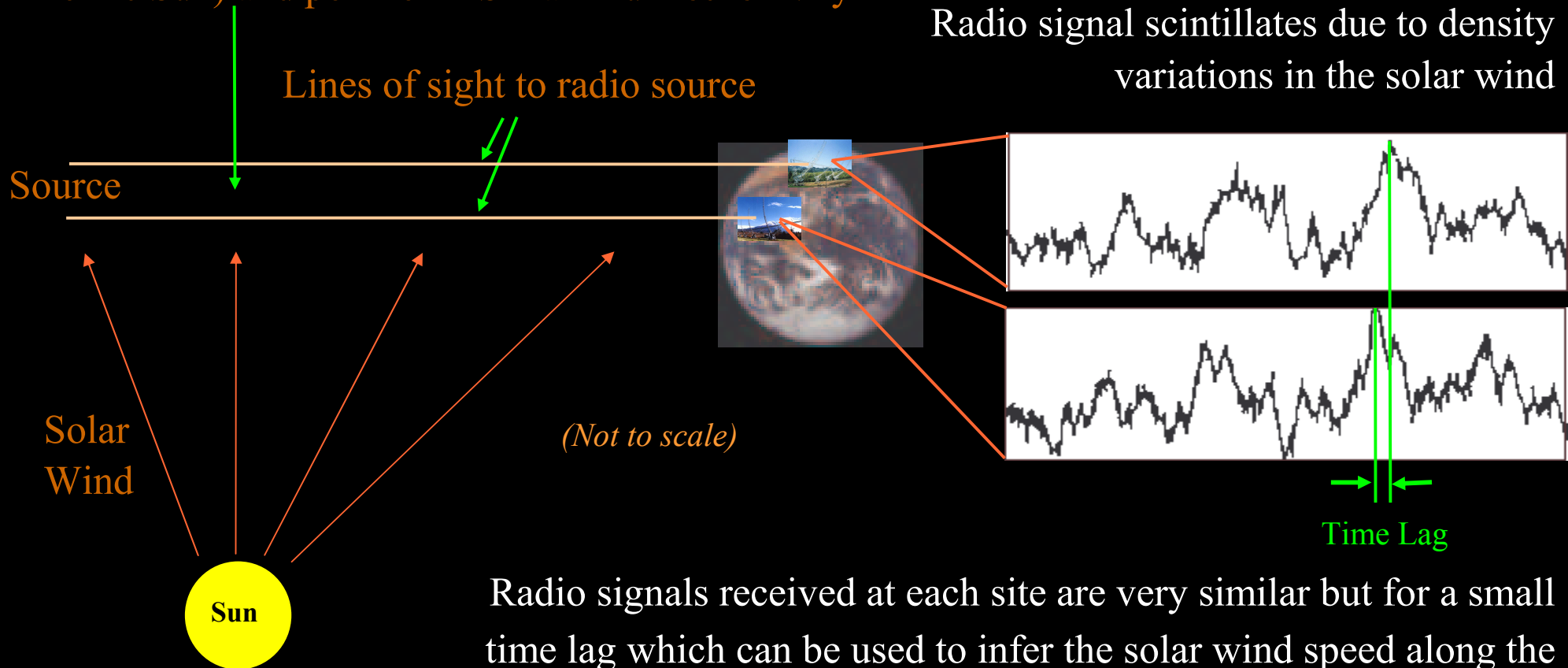
*The STELab antennas from left-to-right: Fuji, Sugadaira, Toyokawa (old), and Kiso.
(Courtesy of http://stesun5.stelab.nagoya-u.ac.jp/uhf_ant-e.html)*



*New STELab
Toyokawa
IPS array –
now partially
operational...*

Interplanetary Scintillation (1)

P-Point (point of closest-approach of the line-of-sight raypath to the Sun) and point of IPS maximum sensitivity



Radio signals received at each site are very similar but for a small time lag which can be used to infer the solar wind speed along the lines of sight for multi-site IPS observations

IPS is only sensitive to the component of flow that is perpendicular to the line-of-sight

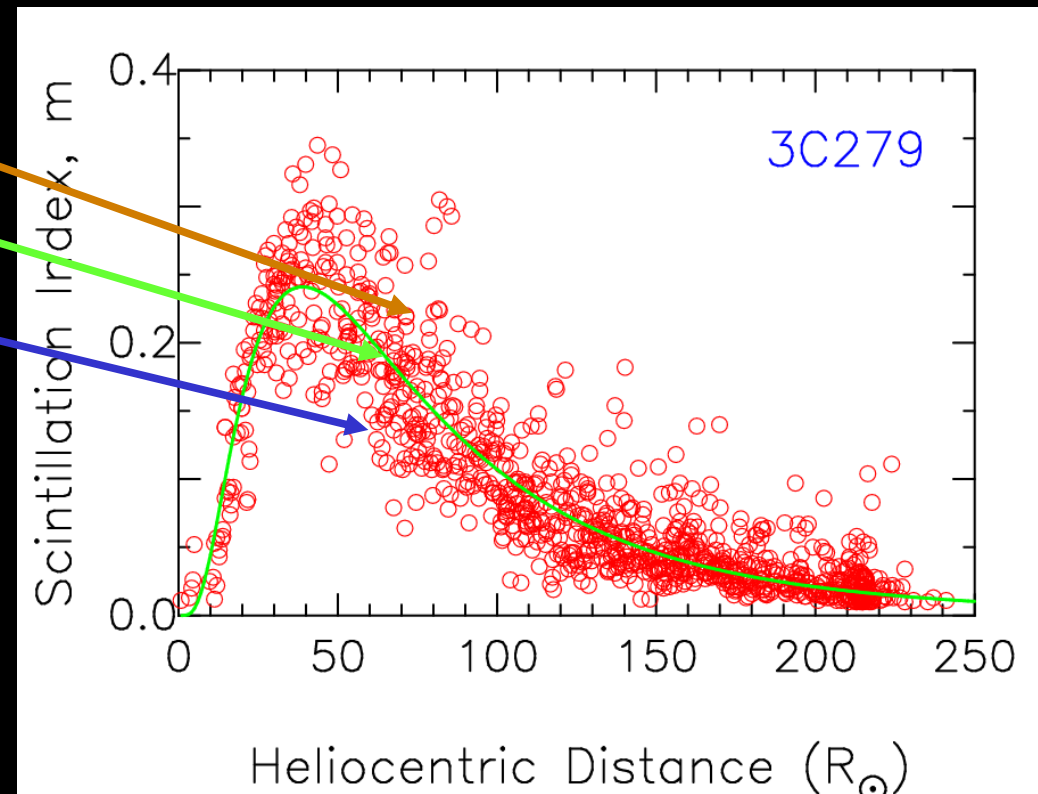
By suitably transforming and calibrating the intensity scintillation time series, the solar wind speed can also be obtained from the spectrum of a single-site IPS observation

Interplanetary Scintillation (2)

Density Turbulence

- ❖ Scintillation index, m , is a measure of level of turbulence
- ❖ Normalised Scintillation index, $g = m(R) / \langle m(R) \rangle$

- $g > 1 \rightarrow$ enhancement in δN_e
- $g \approx 1 \rightarrow$ ambient level of δN_e
- $g < 1 \rightarrow$ rarefaction in δN_e

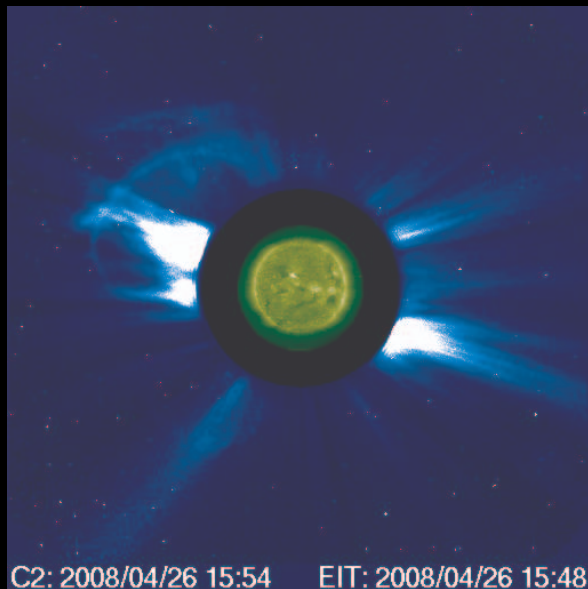


(Courtesy of
P.K. Manoharan)

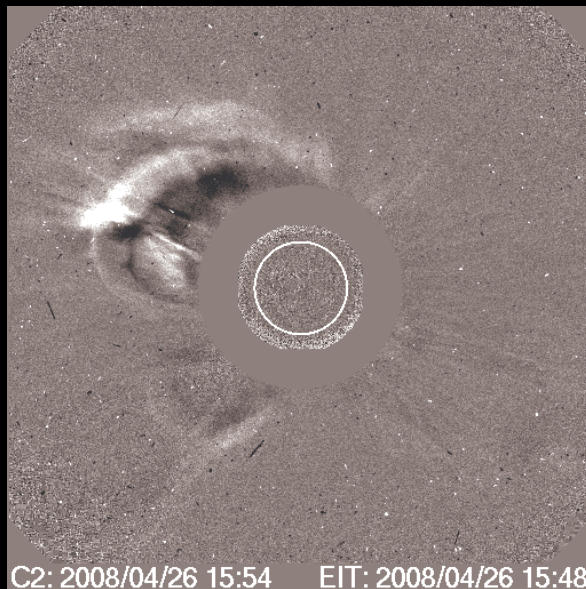
Scintillation enhancement with respect to the ambient wind identifies the presence of a region of increased turbulence/density and possible CME along the line of sight to the radio source

**SMEI – LASCO – SECCHI:
26 April 2008 CME –
First seen by SOHO|LASCO C2
at around 14:30 UT**

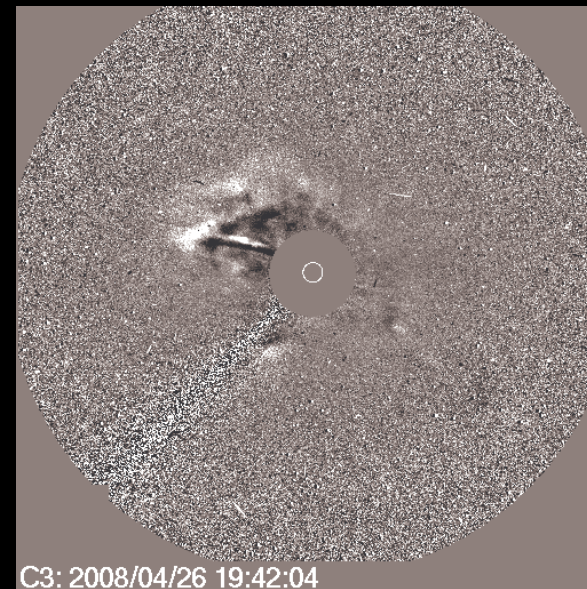
SOHO EIT and LASCO Images



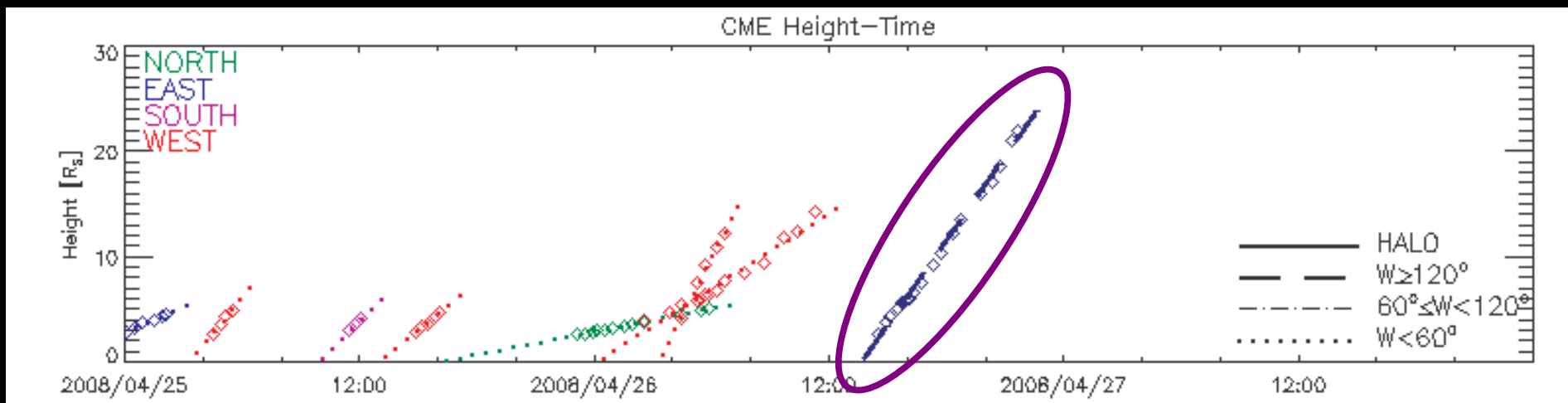
SOHO|EIT/LASCO C2
Composite Images



SOHO|LASCO C2
Difference Image

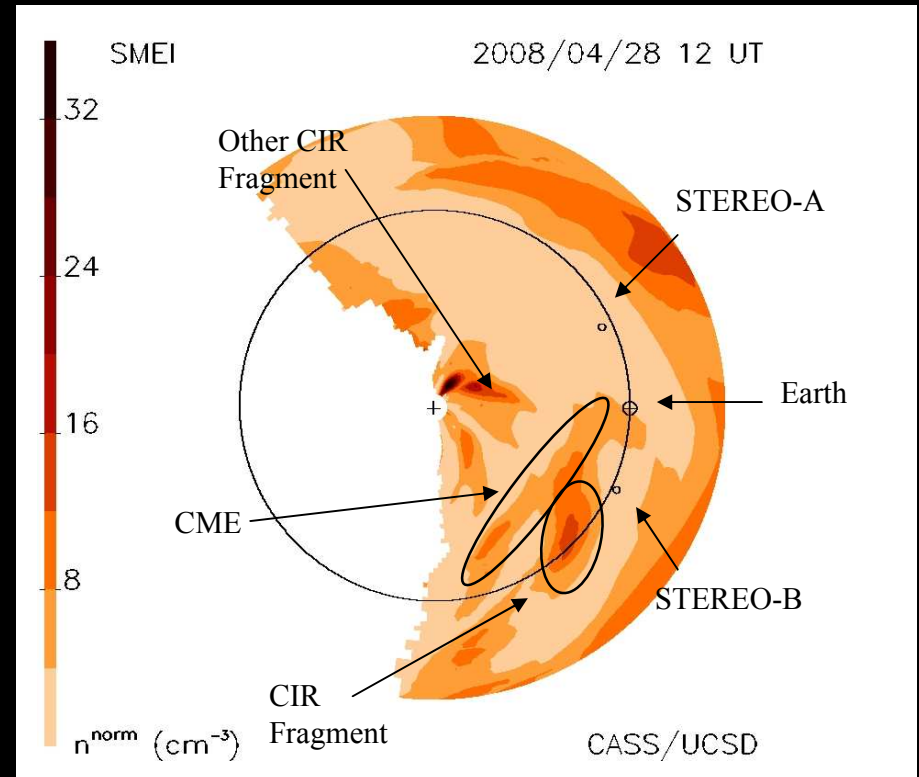
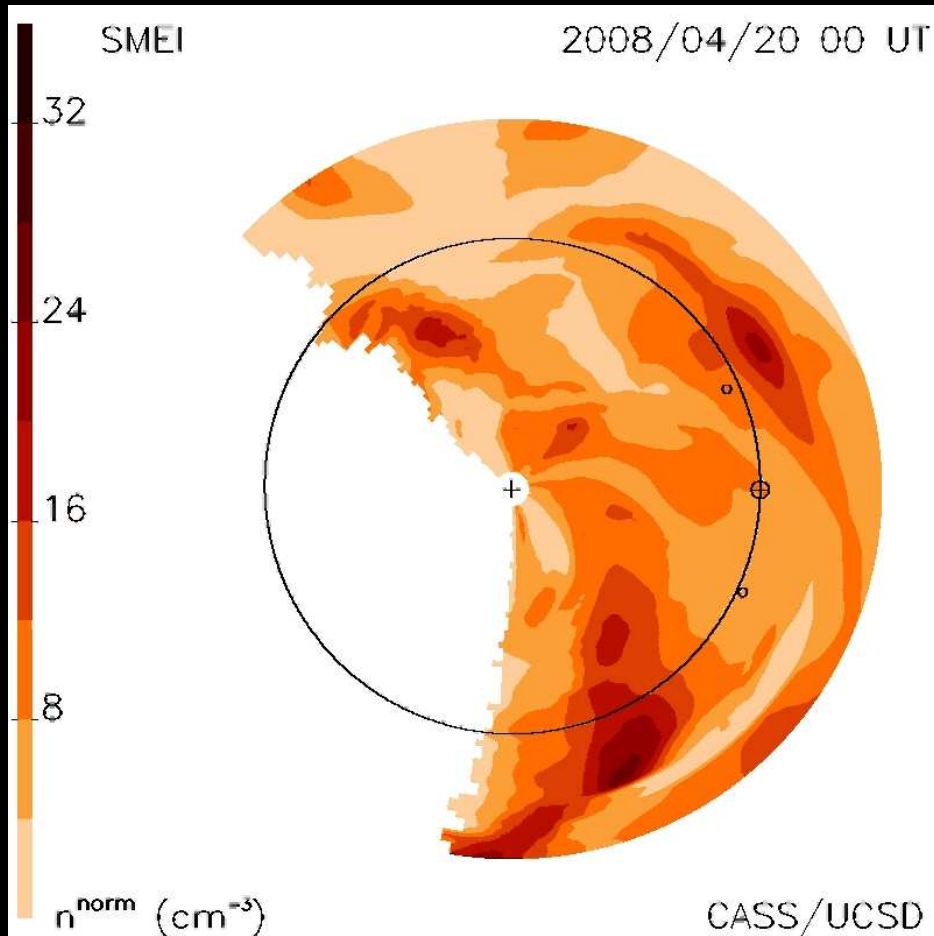


SOHO|LASCO C3
Difference Image

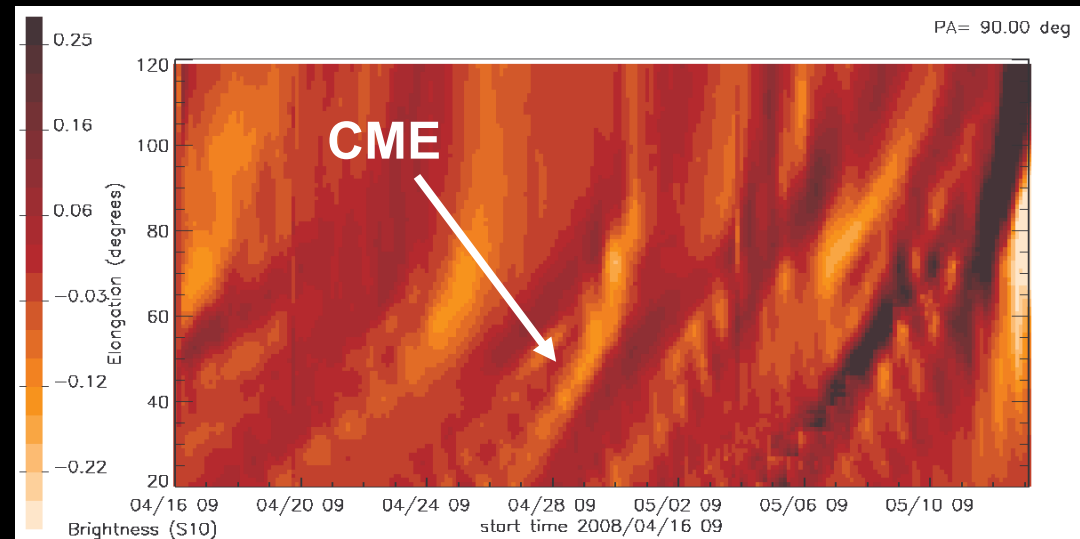


SOHO|LASCO Height-Time Plot (bottom) – All images Courtesy of CDAW CME Catalogue

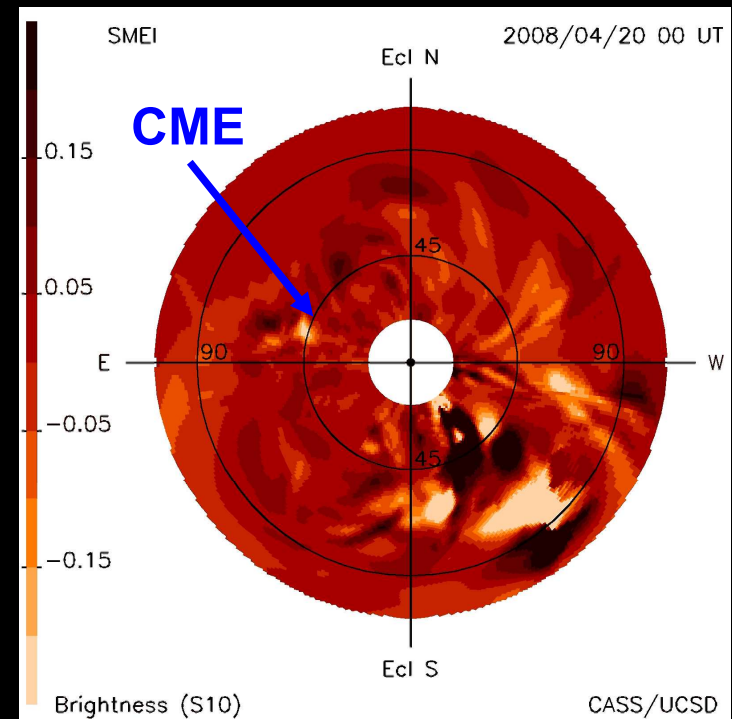
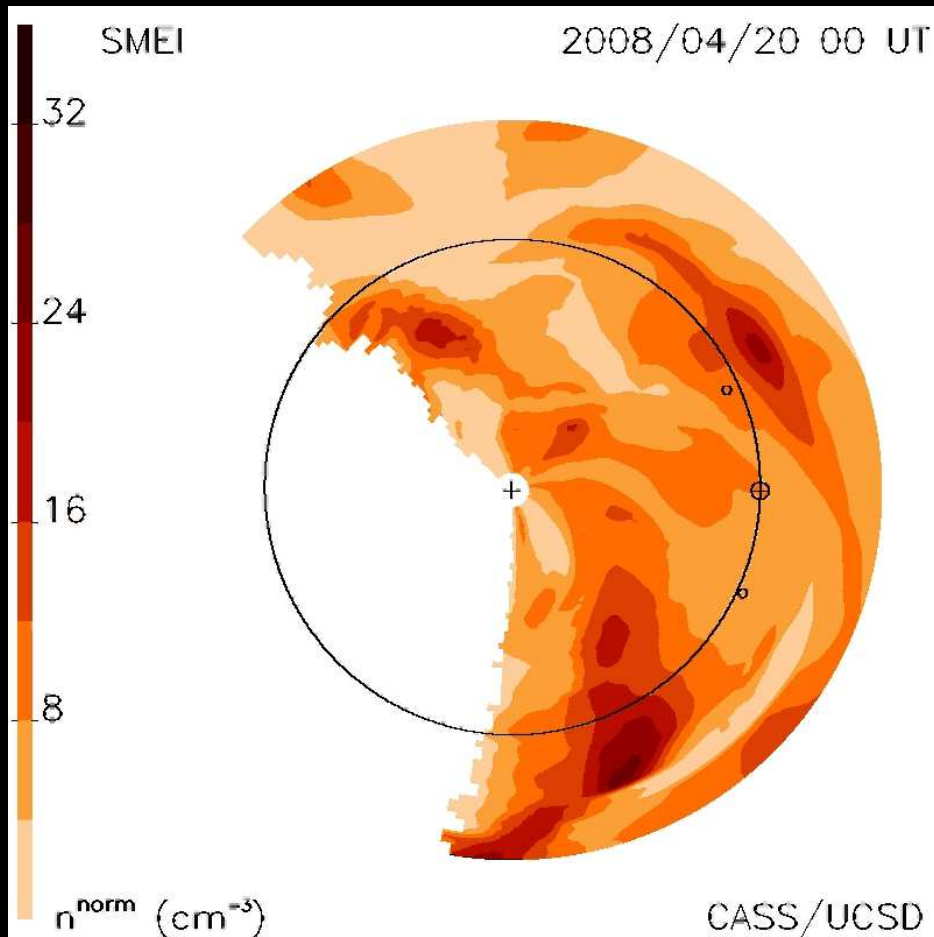
SMEI 3-D Reconstruction (1)



SMEI 3-D reconstructions:
ecliptic-cut movie (above);
ecliptic-cut snapshot (above
right);
and 12-hour differenced
90° PA J-map (right).

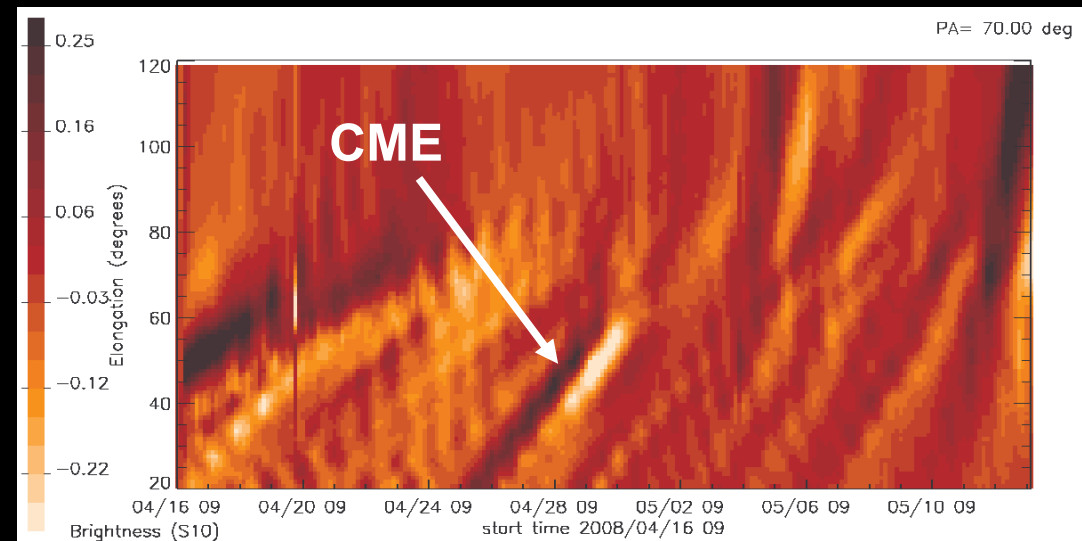


SMEI 3-D Reconstruction (2)



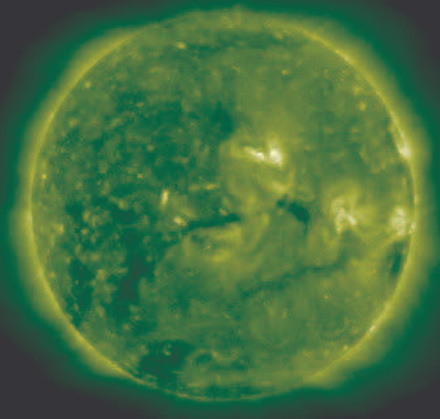
Now a 12-hour differenced 70° PA
J-map (right) which shows the
CME "track" more clearly.

Timing consistent with *in-situ*
signatures at STEREO-B



STEREO SECCHI Movies

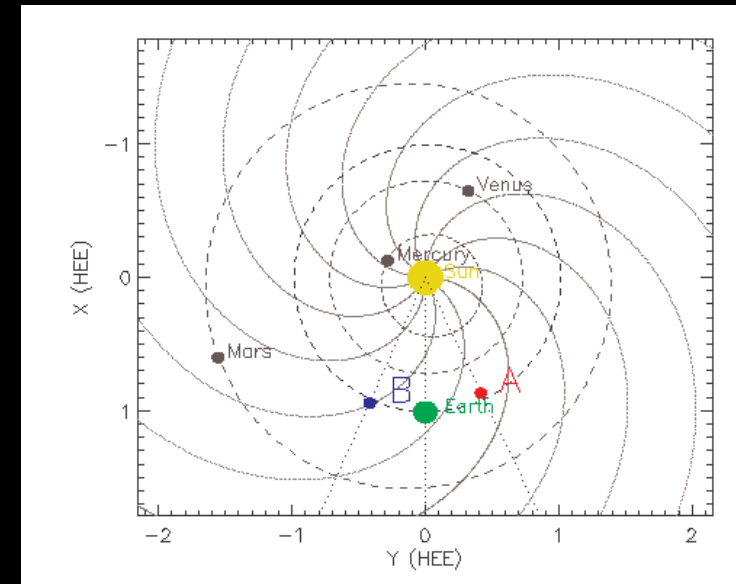
STEREO Behind EUVI 195



2008-04-26 10:06:03

- Arcade, dimming, EIT wave, Type-II burst, faint halo CME from STEREO-B.

- Near Sun-center for STEREO-B & the Earth.

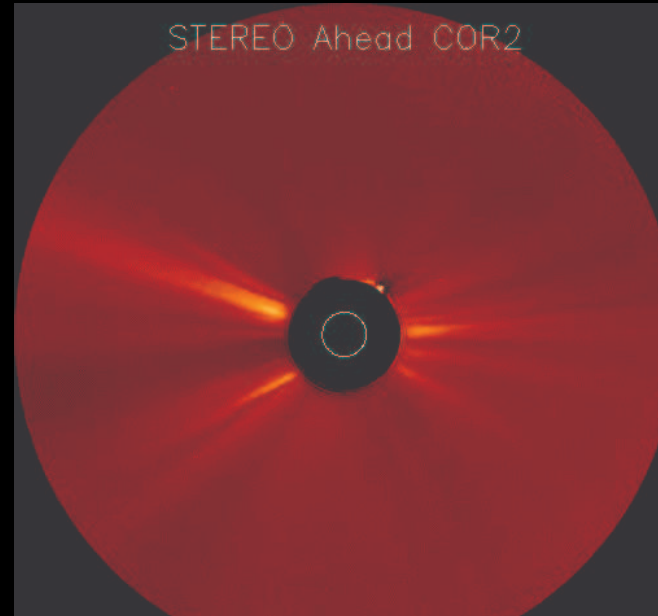


STEREO Behind COR2



2008-04-26 09:38:27

STEREO Ahead COR2

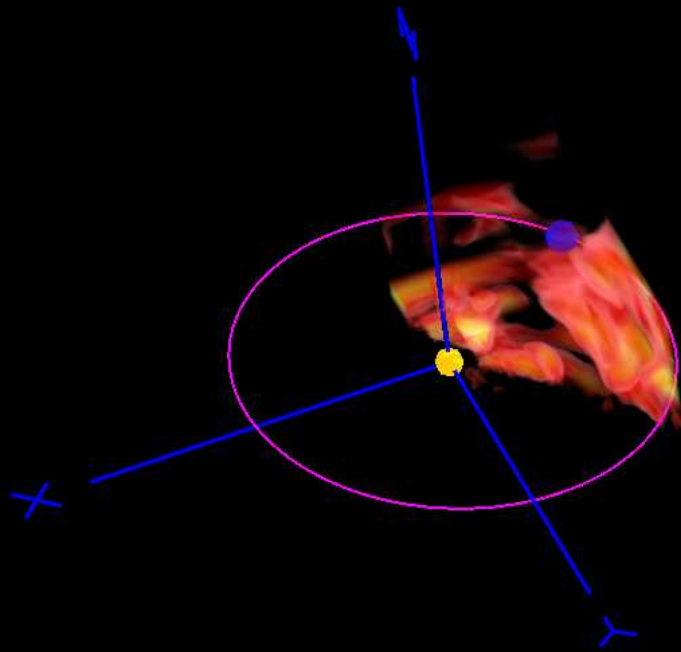


2008-04-26 10:07:54

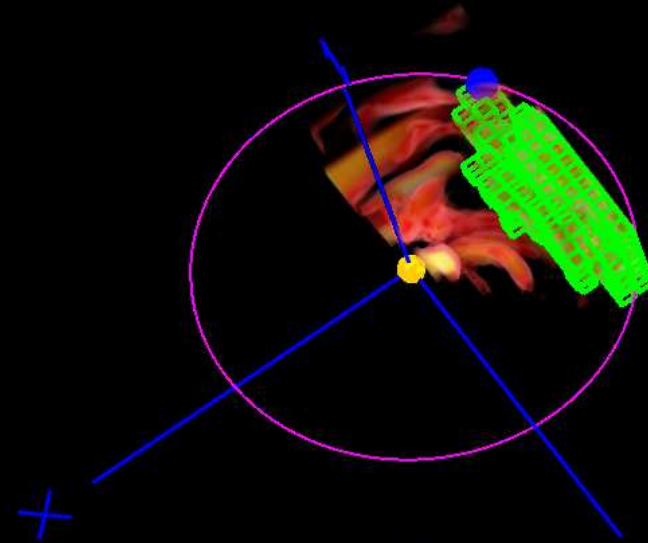
- Majority of mass seen in STEREO-A is in the ecliptic and just North of the ecliptic (as with the SMEI density reconstruction).

Movies are courtesy of Dave Webb.

SMEI 3-D Reconstruction (3)



2008/04/28 12:00



2008/04/28 12:00

Excess Mass(g): 3.122E+015
Total Mass(g): 9.019E+015
Ambient(g): 5.897E+015
energy: 2.691E+030 ergs
Volume: 0.103 AU³

SMEI reconstructed volume (left) and SMEI reconstructed isolated CME portion (right)

Mass of CME from CDAW CME List (LASCO) = 3.4×10^{15} g (CDAW)

Mass of CME from the SMEI 3-D reconstruction = 3.122×10^{15} g

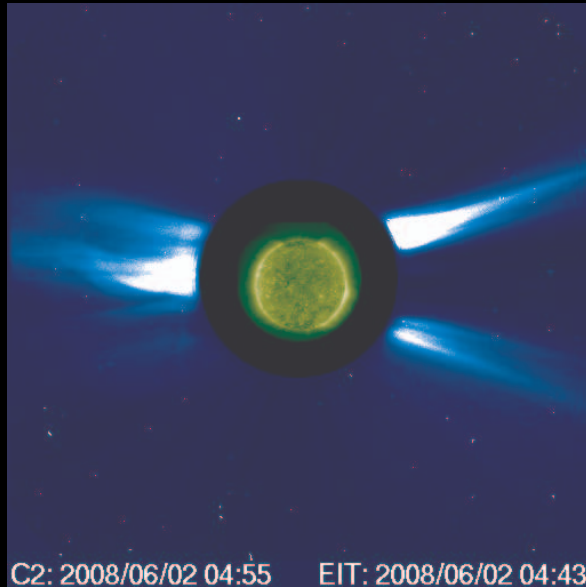
The excess mass above the ambient is what is being shown as the CME mass

**STELab – LASCO - CORs:
02 June 2008 CME –
First seen by SOHO|LASCO C3
at around 04:17 UT**

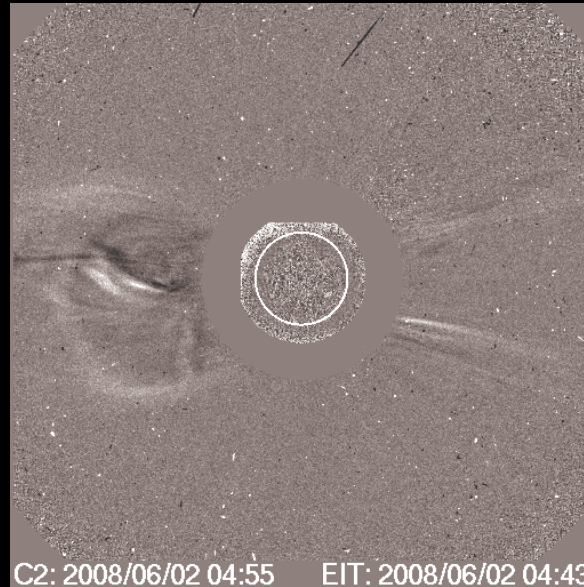
Bisi *et al.*, Solar Wind 12 Proceedings, AIP Publishing, 2009

Bisi *et al.*, Ap.J.Lett. (submitted), 2009

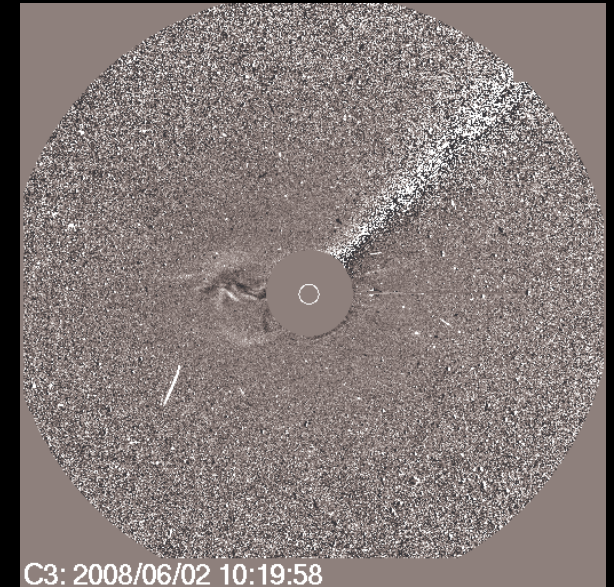
SOHO EIT and LASCO Images



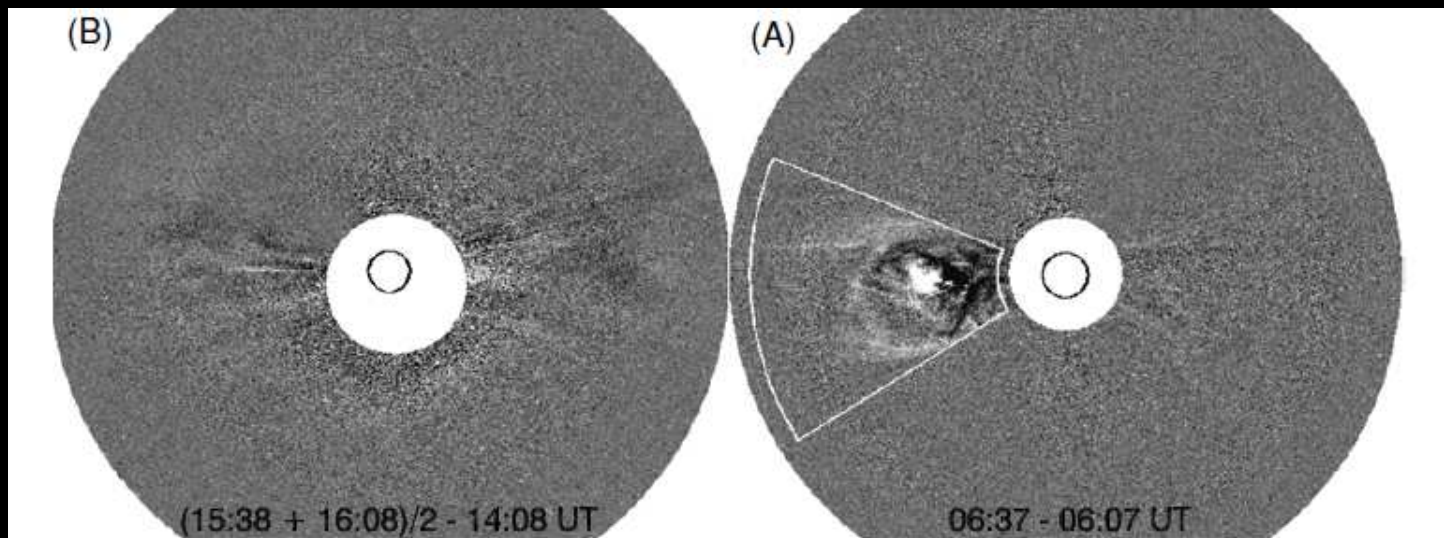
SOHO|EIT/LASCO C2
Composite Images



SOHO|LASCO C2
Difference Image



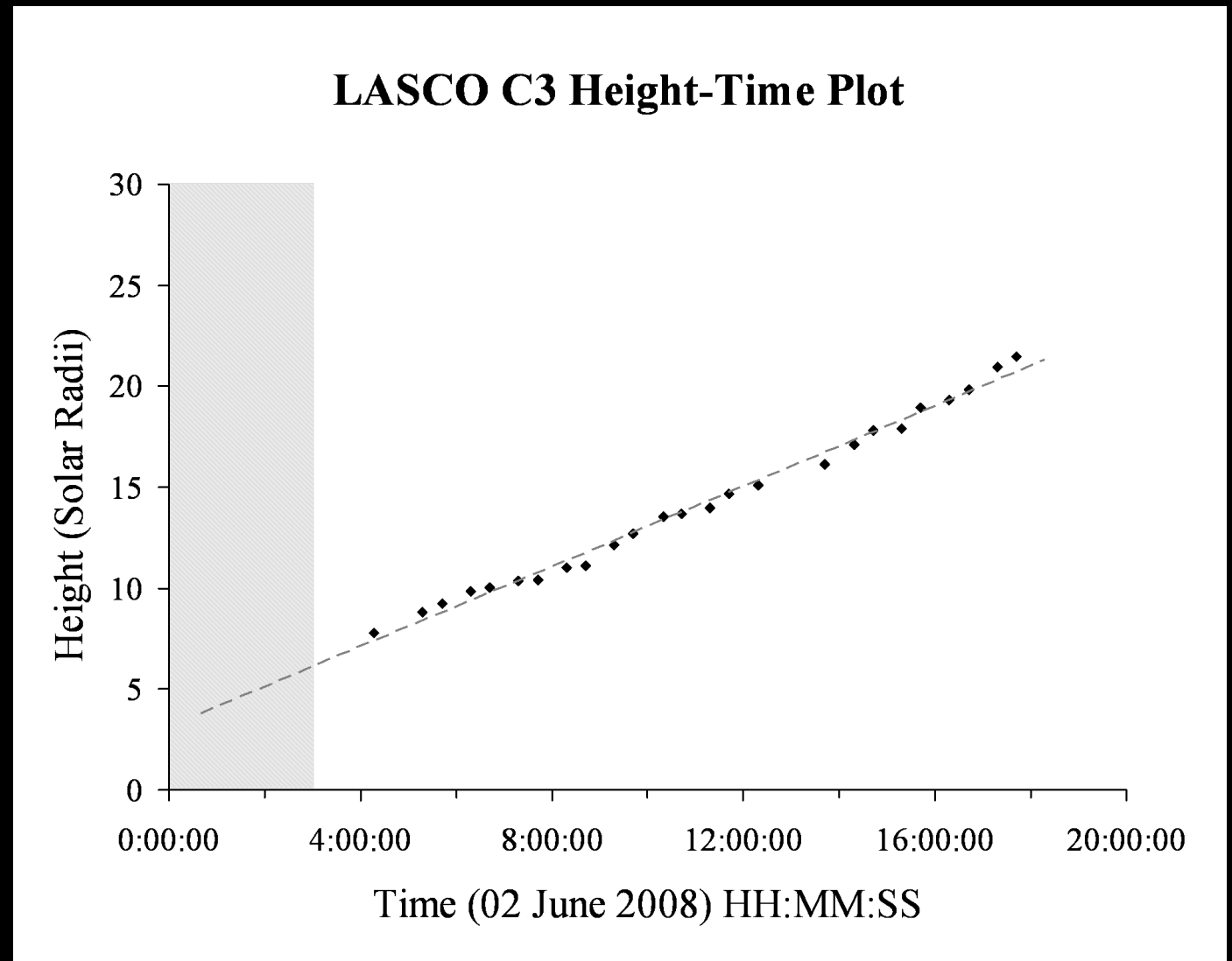
SOHO|LASCO C3
Difference Image



STEREO (B and A) COR2 difference images (from Robbrecht *et al.*, *Ap.J.*, 2009)

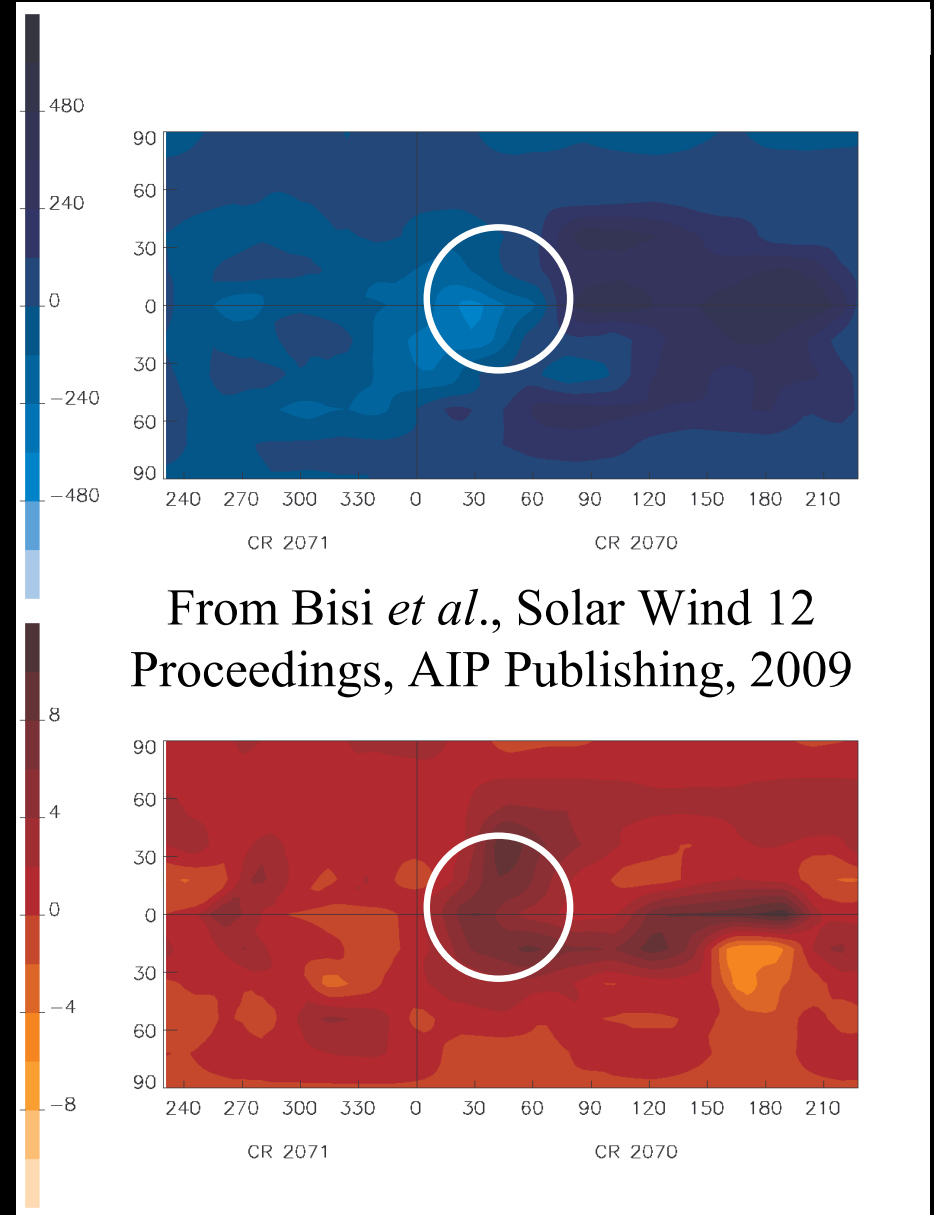
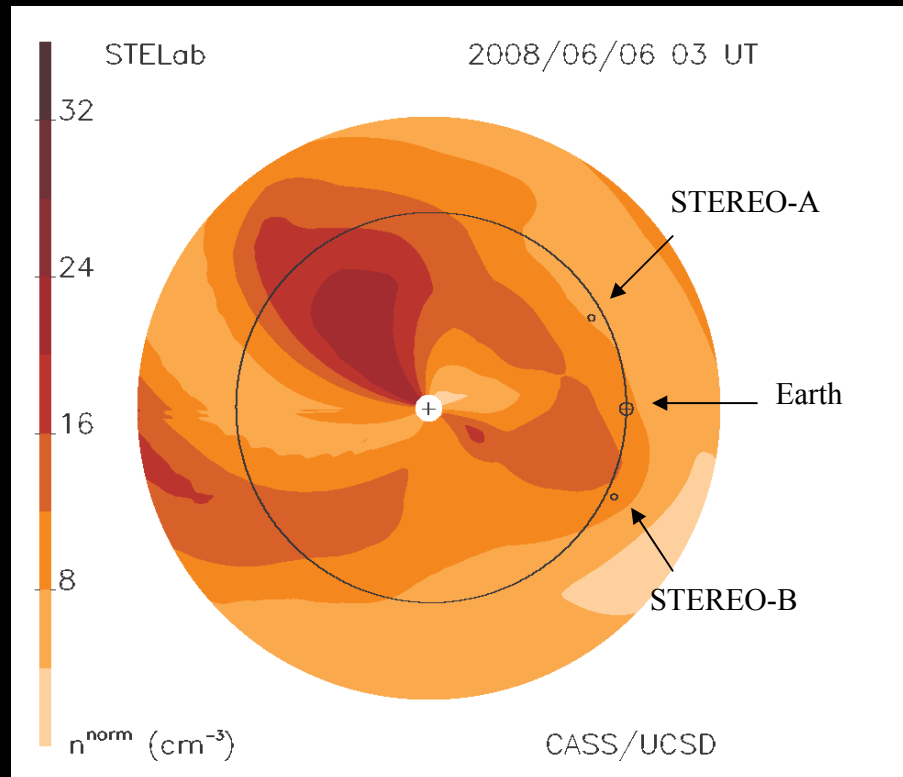
LASCO Height-Time Plot

The LASCO C3 height-time (elongation-time) plot of the 02 June 2008 CME using data taken from the CDAW CME catalog. The diagonal-hashed/grey area represents the time when LASCO was down until early on 02 June 2008; thus measurements of the CME within the C3 field of view were only taken from a height of around $8R_{\odot}$.



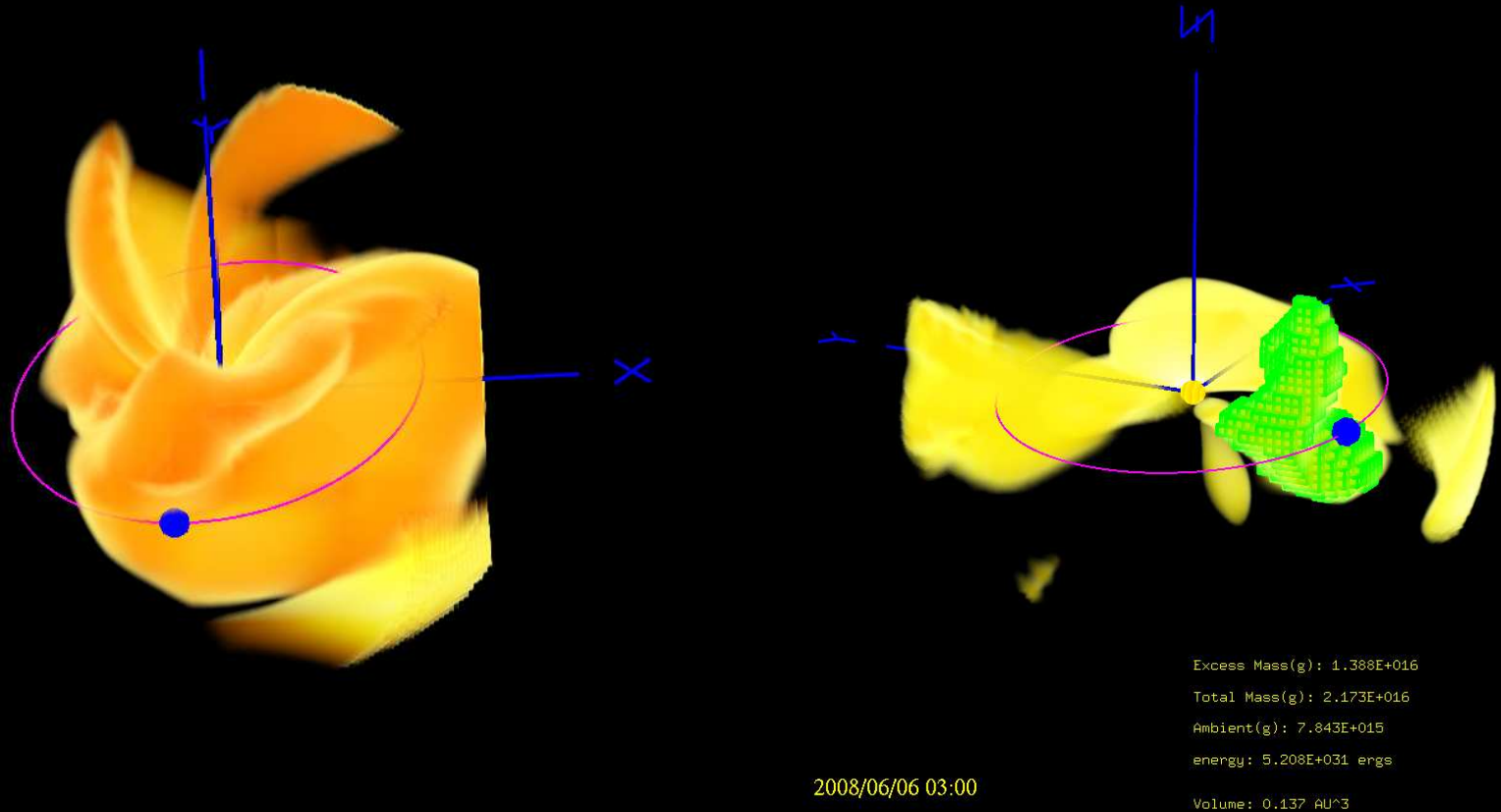
STELab IPS 3-D Reconstruction (1)

The slow CME (LASCO plane-of-sky speed of 192 km s^{-1}) from C3 measurements



STELab reconstructed ecliptic cut (left) – STELab reconstructed CR map differences (right)

STELab IPS 3-D Reconstruction (2)



STELab reconstructed volume (left) and STELab reconstructed isolated CME portion (right)

Source:	Excess Mass/CME Mass:	Reference:
CDAW CME Catalog (LASCO C3)	4.7×10^{14} g	CDAW CME Catalog
STEREO COR1-A	7.5×10^{14} g	Robbrecht et al. (2009)
STEREO COR2-A	3.5×10^{15} g	Robbrecht et al. (2009)
STELab IPS	1.4×10^{16} g	Our 3D Reconstruction

The excess mass above the ambient is what is being shown as the CME mass – taken from Bisi *et al.*, Ap.J.Lett. (submitted), 2009

Summary and Conclusions

- ❖ The mass for the 26 April 2008 CME from the SMEI 3-D reconstructions matches well to the SOHO/LASCO mass obtained from the CDAW CME List; difficult to isolate in the 3-D reconstruction due to the presence of the CIR.
- ❖ 02 June 2008 preliminary use of differenced Carrington maps shows the CME signature at 1 AU which compares with SOHO/LASCO images plus an ecliptic cut in density shows weak interaction with STEREO-B.
- ❖ The masses for the 02 June 2008 are somewhat different from each instrument/technique; larger masses further out from the Sun may reflect mass load behind the slow-moving CME or possibly highlights differences of the two observation types.

Future Prospects and References

- ❖ There are a wealth of “tools” to understand and analyse the reconstructed observations, and to ascertain how well the IPS and SMEI 3-D reconstructions work; of primary importance here is the comparison with further spacecraft measurements and observations.
 - Bisi, M.M., B.V. Jackson, P.P. Hick, J.M. Clover, S. Hamilton, M. Tokumaru, and K. Fujiki, “Large-Scale Heliospheric Structure during Solar-Minimum Conditions using a 3D Time-Dependent Reconstruction Solar-Wind Model and STELab IPS Observations”, Solar Wind 12 Proceedings, AIP Publishing, 2009
 - Bisi, M. M., B. V. Jackson, P. P. Hick, A. Buffington, J. M. Clover, M. Tokumaru, and K. Fujiki, “Three-Dimensional Reconstructions and Mass Determination of the 02 June 2008 LASCO Coronal Mass Ejection using STELab IPS Observations”, The Astrophysical Journal Letters (Submitted), 2009
 - Robbrecht, E., S. Patsourakos, and A. Vourlidas, “No Trace Left Behind: STEREO Observations of a Coronal Mass Ejection Without Low Coronal Signatures”, The Astrophysical Journal, 701:283–291, 2009

http://stesun5.stelab.nagoya-u.ac.jp/uhf_ant-e.html

http://cdaw.gsfc.nasa.gov/CME_list/

Final Acknowledgements

Thanks to CDAW for making their data available on the web: “This CME catalog is generated and maintained at the CDAW Data Center by NASA and The Catholic University of America in cooperation with the Naval Research Laboratory. SOHO is a project of international cooperation between ESA and NASA”.

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Further Info...

IPS: <http://ips.ucsd.edu/>

SMEI: <http://smei.ucsd.edu/>

Thanks for listening!