Heliospheric Tomography

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and

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http://smei.ucsd.edu/ **http://ips.ucsd.edu/**

Heliospheric Tomography

Introduction:

The Model: Heliospheric Tomography – (actually a fit to data)

(Time-dependent view from a single observer location)

The Data Sets:

IPS (STELab, Ooty, EISCAT), SMEI

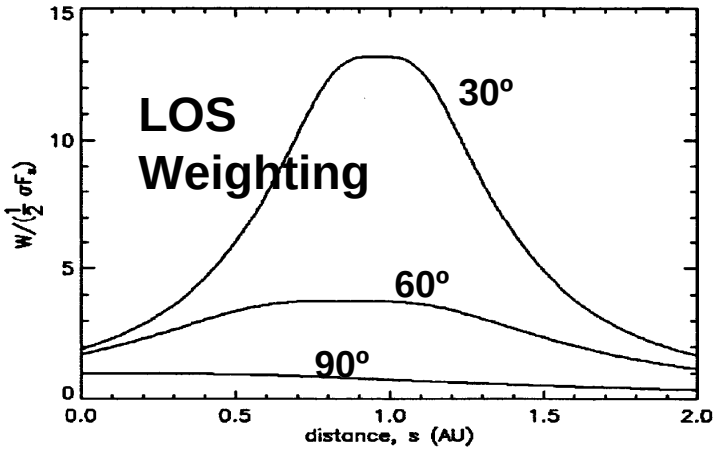
(How the model validates different data sets)

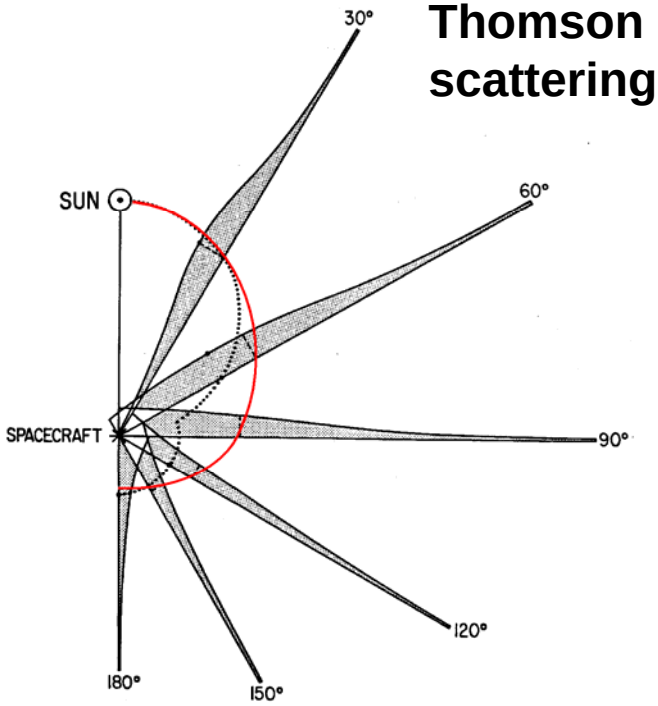
New Projects:

FR inversion
In-situ incorporation into the tomography
Real-time SMEI

Heliospheric Tomography

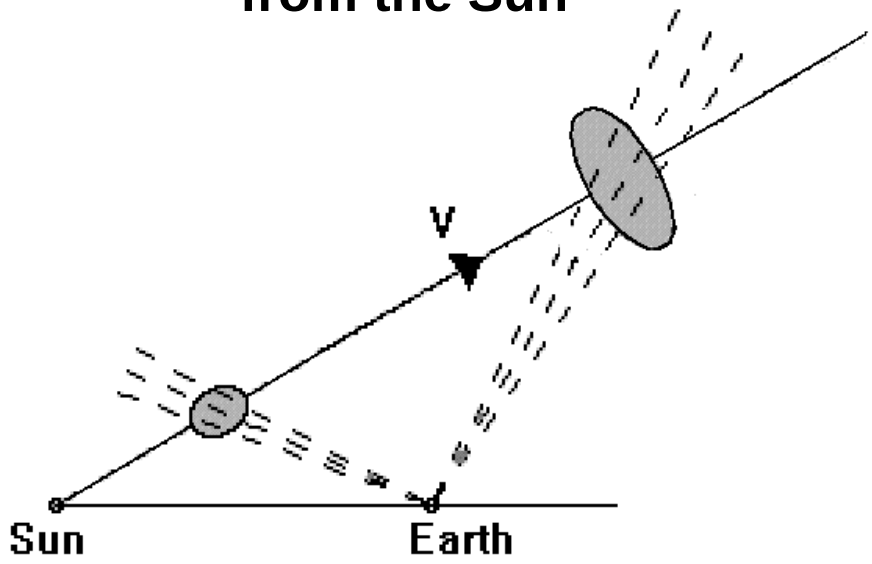
Jackson, B.V., et al., 2009, *Adv. in Geosciences* (in press).





Heliospheric 3D-reconstructions

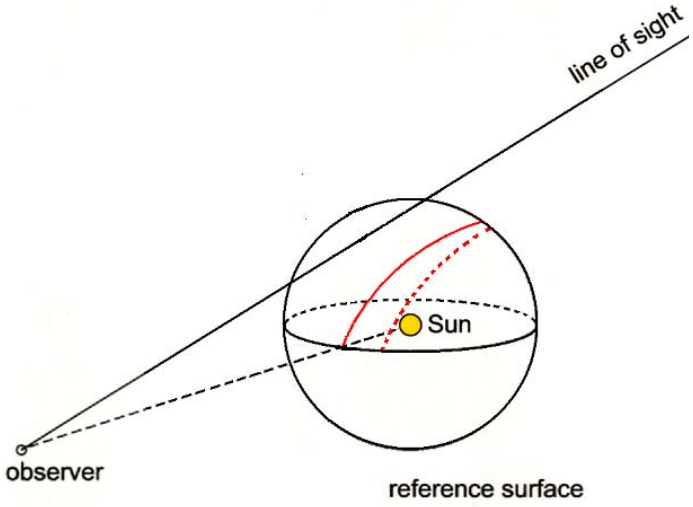
The outward-flowing solar wind structure follows very specific physics as it moves outward from the Sun

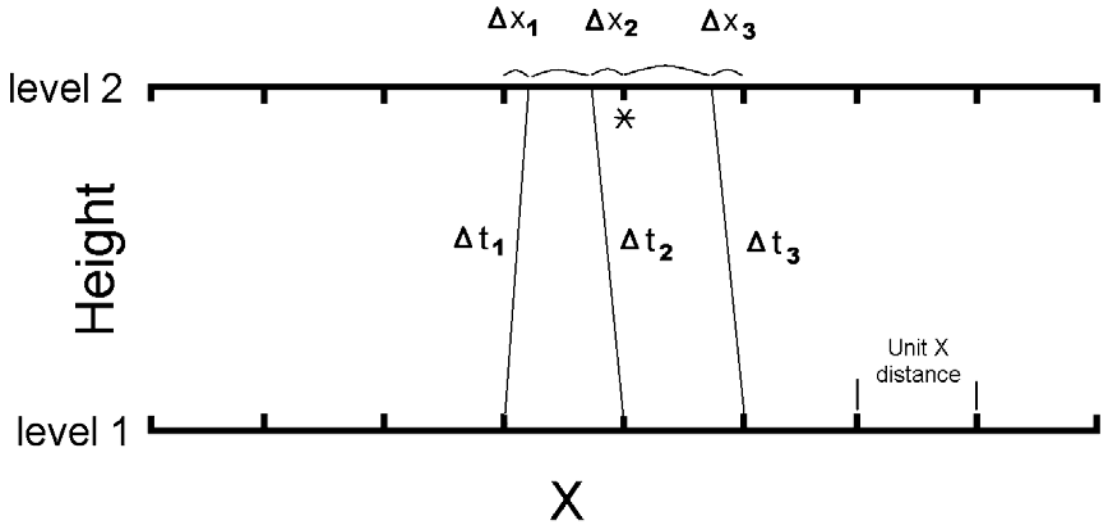


Heliospheric Tomography

Jackson, B.V., et al., 2009, *Adv. in Geosciences* (in press).

The UCSD 3D-reconstruction program





The "traceback matrix" (any model will work)

In the traceback matrix the location of the upper level data point (starred) is an interpolation in x of Δx2 and the unit x distance – Δx3 distance or (1 – Δx3). Similarly, the value of Δt at the starred point is interpolated by the same *spatial* distance. Each 3D traceback matrix contains a regular grid of values ΣΔx, ΣΔy, ΣΔt, ΣΔv, and ΣΔm that locates the origin of each point in the grid at each time and its change in velocity and density from the heliospheric model.

Heliospheric Tomography

DATA

STELab IPS Heliospheric Analyses

STELab IPS array near Fuji

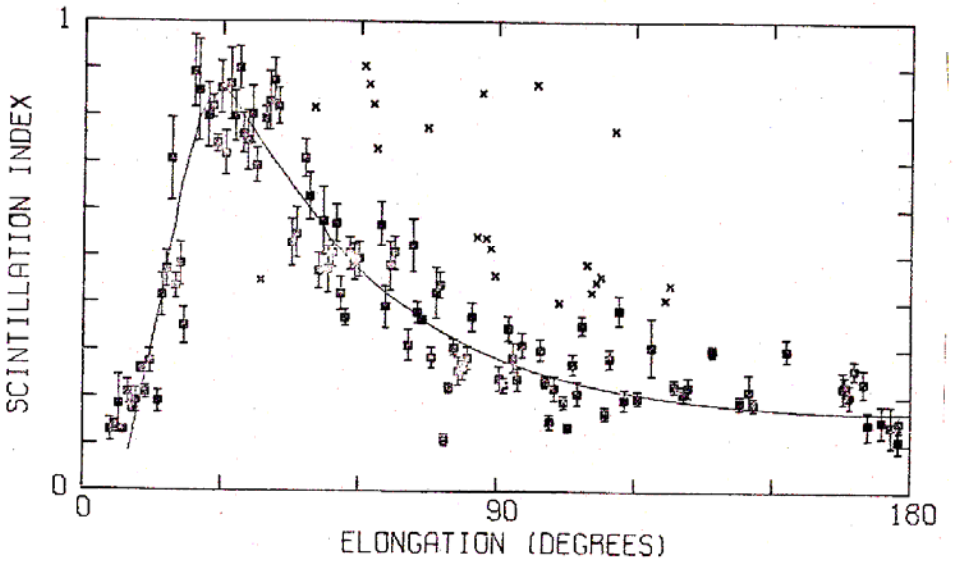
Heliospheric Tomography

DATA

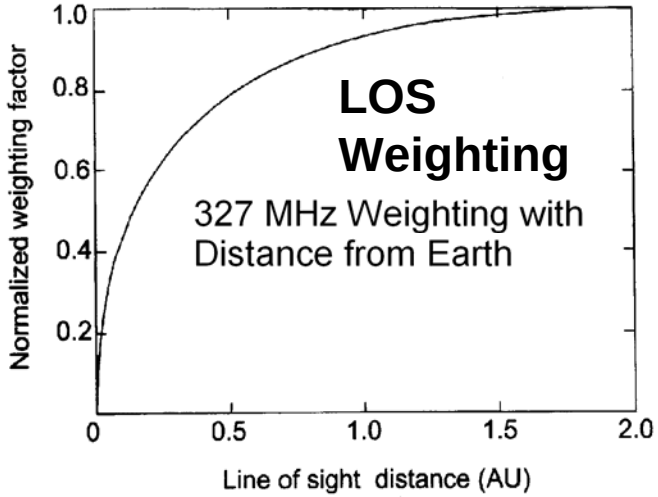
Jackson, B.V., et al., 2009, *Adv. in Geosciences* (in press).

Scintillation Level Heliospheric Analysis

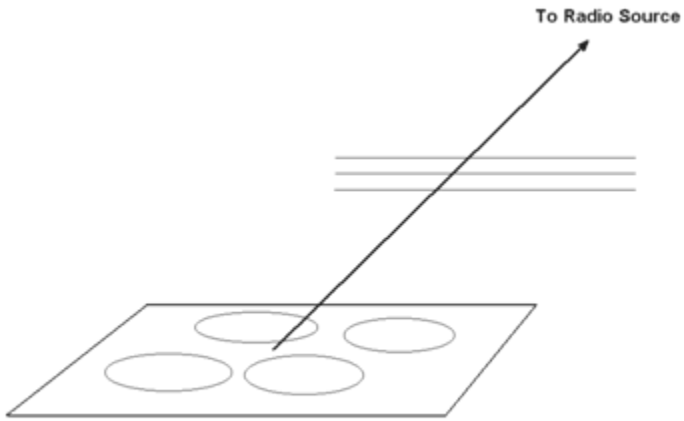
Intensity interplanetary scintillation (IPS) g-levels.



g = m/<m>



STELab IPS



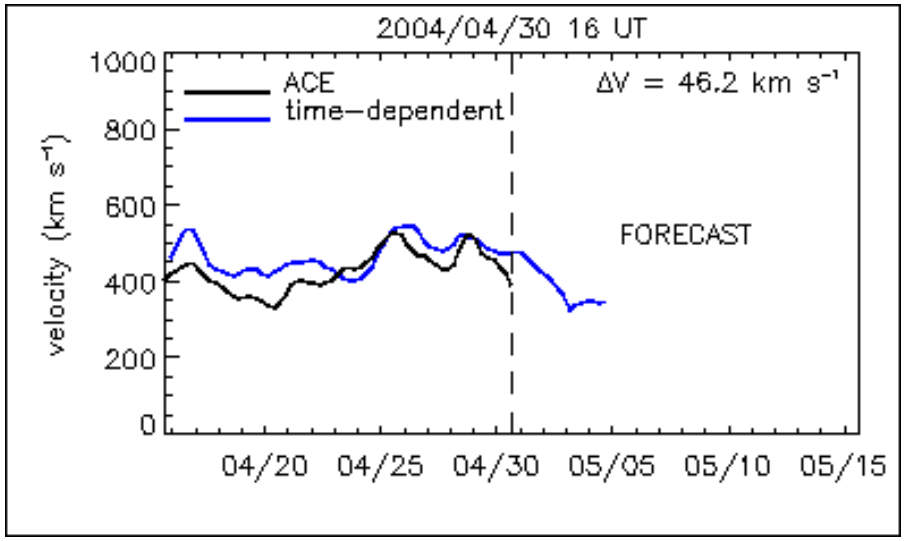
IPS line-of-sight response

Heliospheric Tomography

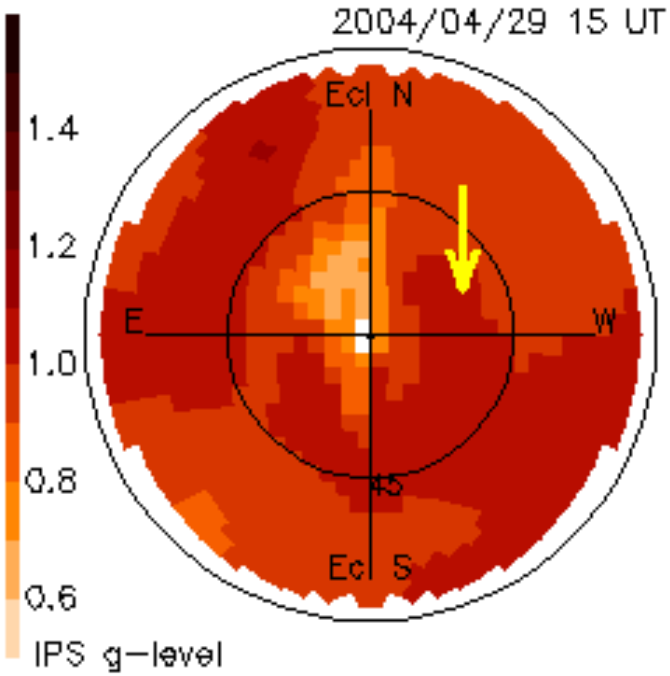
http://ips.ucsd.edu/

UCSD time-dependent IPS WEB model

Velocity model time-series



G-level sky map



Real-time tomographic analysis of the solar wind on April 29-30, 2004 showing a halo CME response in the interplanetary medium.

Web Analysis Runs Automatically Using Linux on a P.C.

Heliospheric Tomography

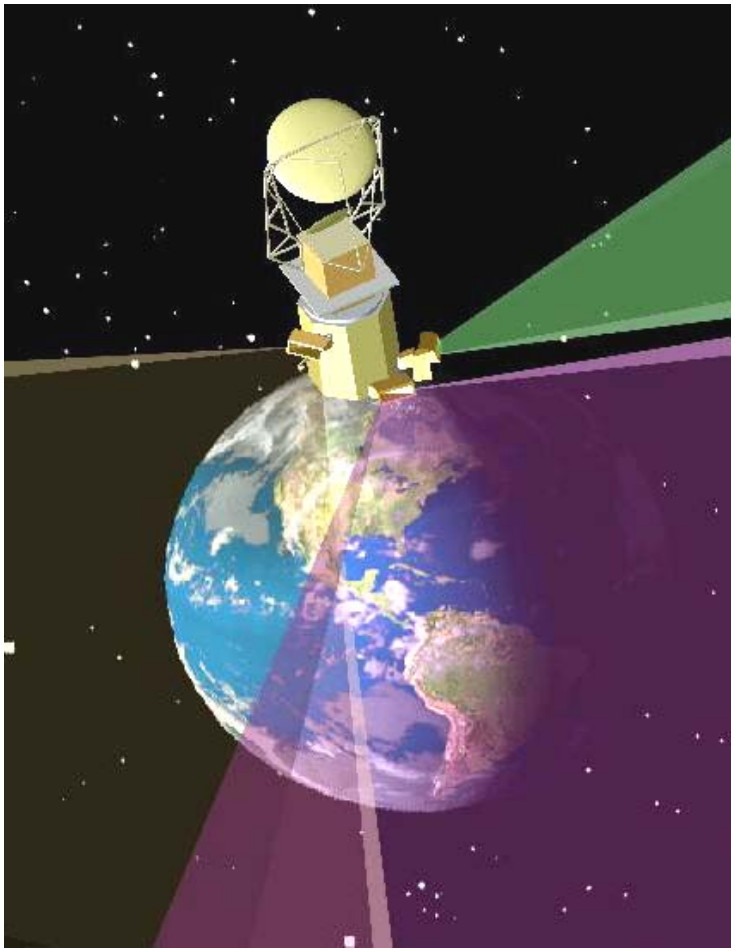
DATA

SMEI

Jackson, B.V., et al., 2006, *J. Geophys. Res.*, 111, A4, A04S91

Launch 6 January 2003

1 gigabyte/day; now ~3 terabytes



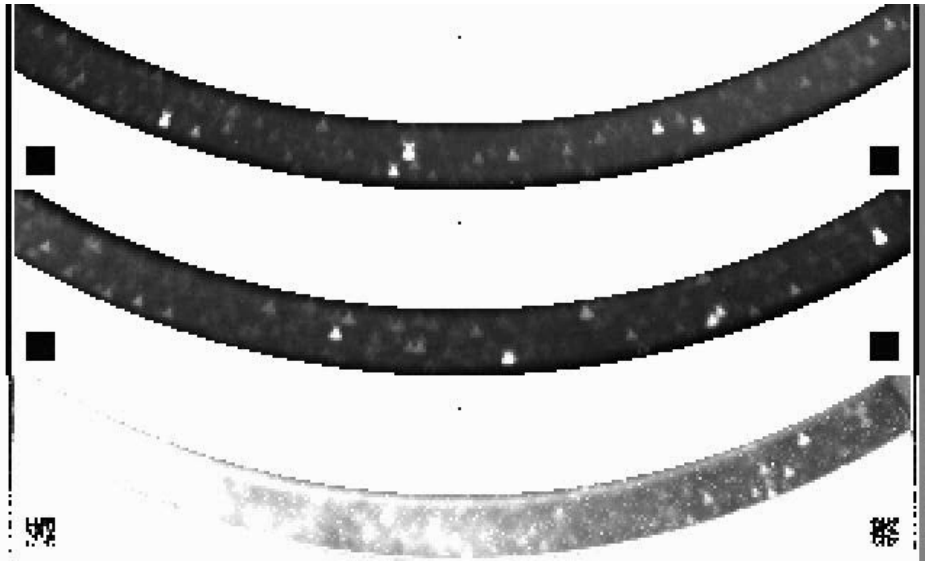
← Sun

C1

C2

C3

Sun ↓



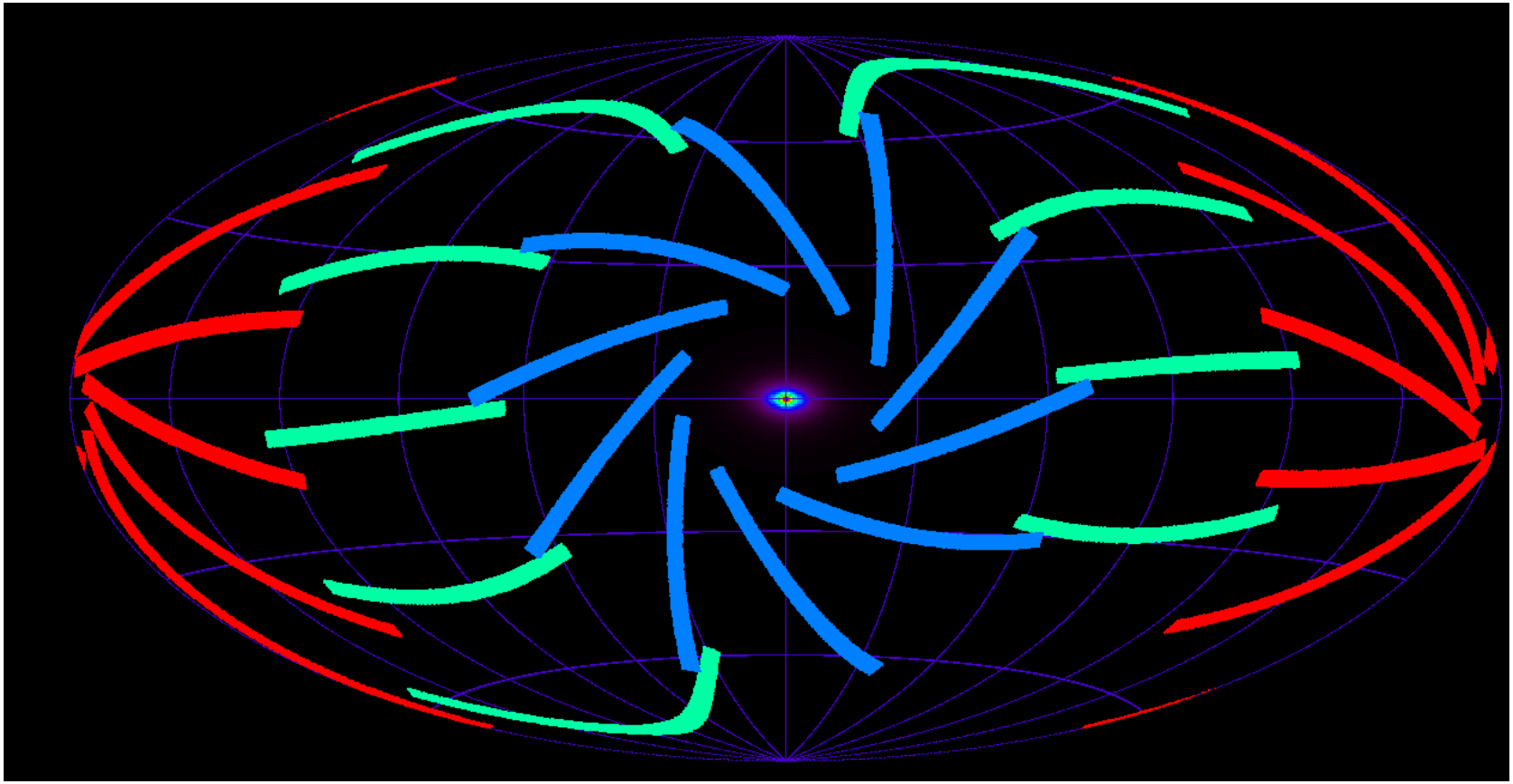
Simultaneous images from the three SMEI cameras.

Heliospheric Tomography

DATA

Frame Composite for Aitoff Map

Blue = Cam3; Green = Cam2; Red = Cam1



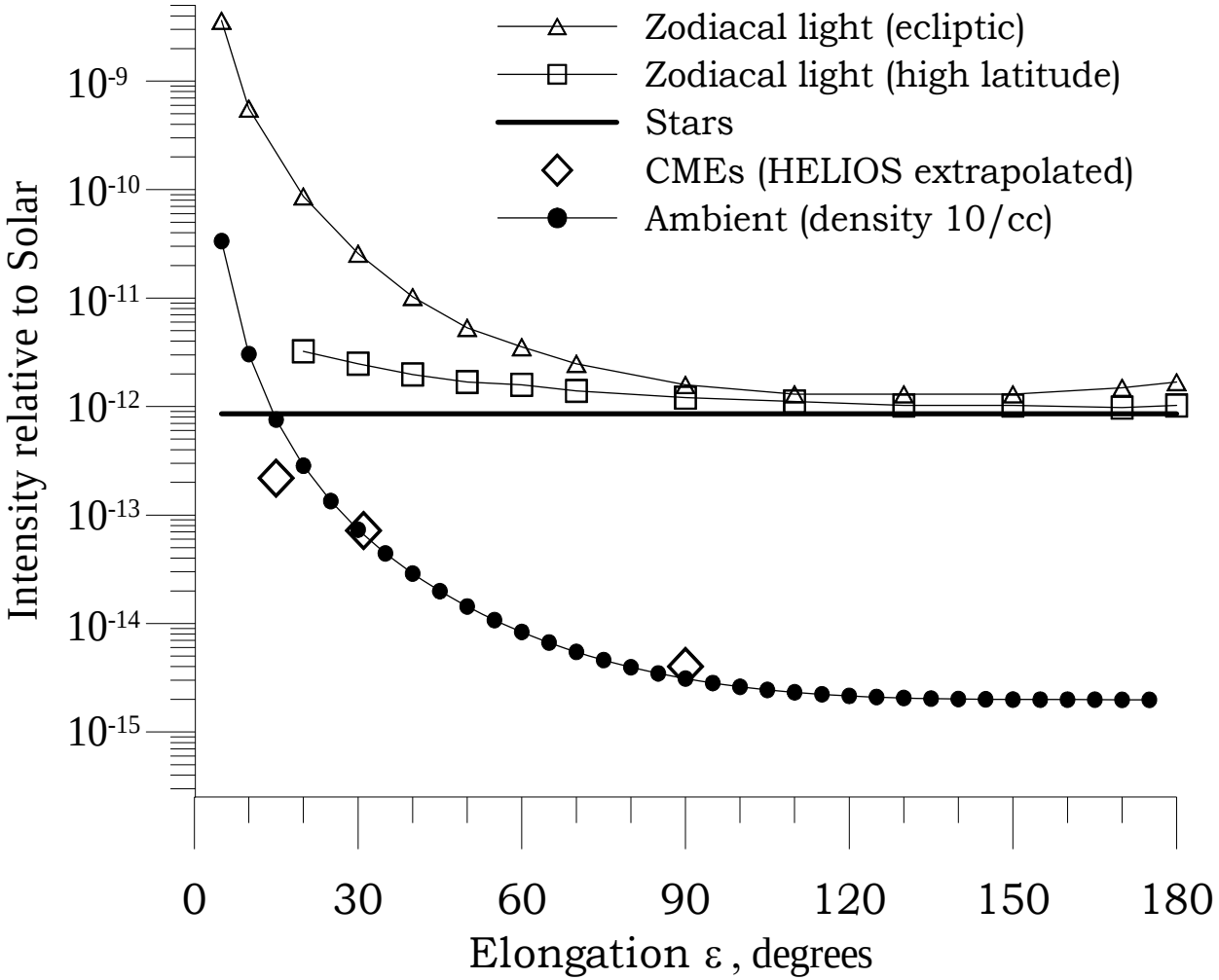
D290; 17 October 2003

DATA

Heliospheric Tomography

Jackson, B.V., et al., 2009, *Solar Phys*. (in press).

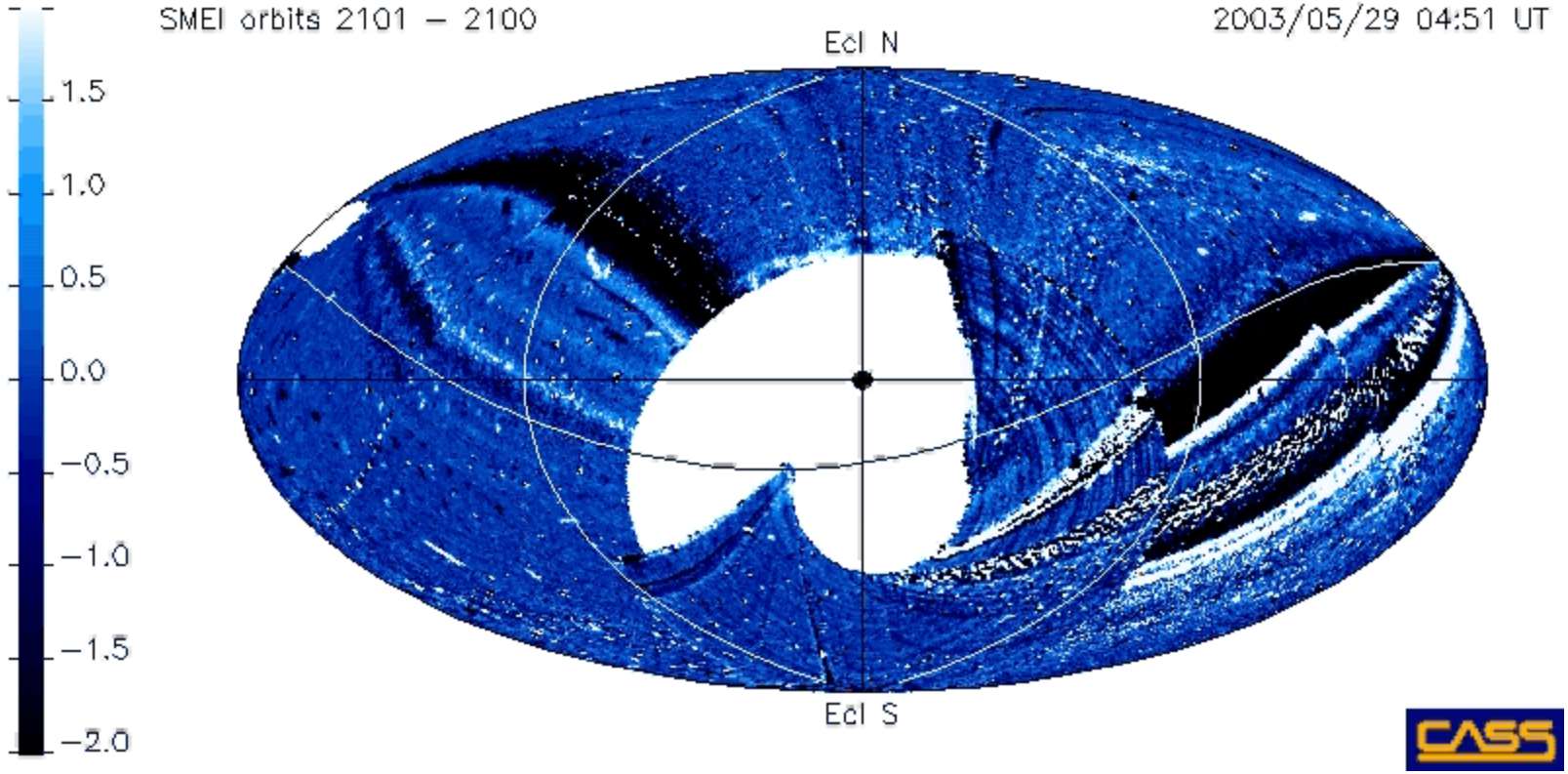
Brightness fall-off with distance



DATA

Heliospheric Tomography

Heliospheric direct images (differenced)



Heliospheric Tomography

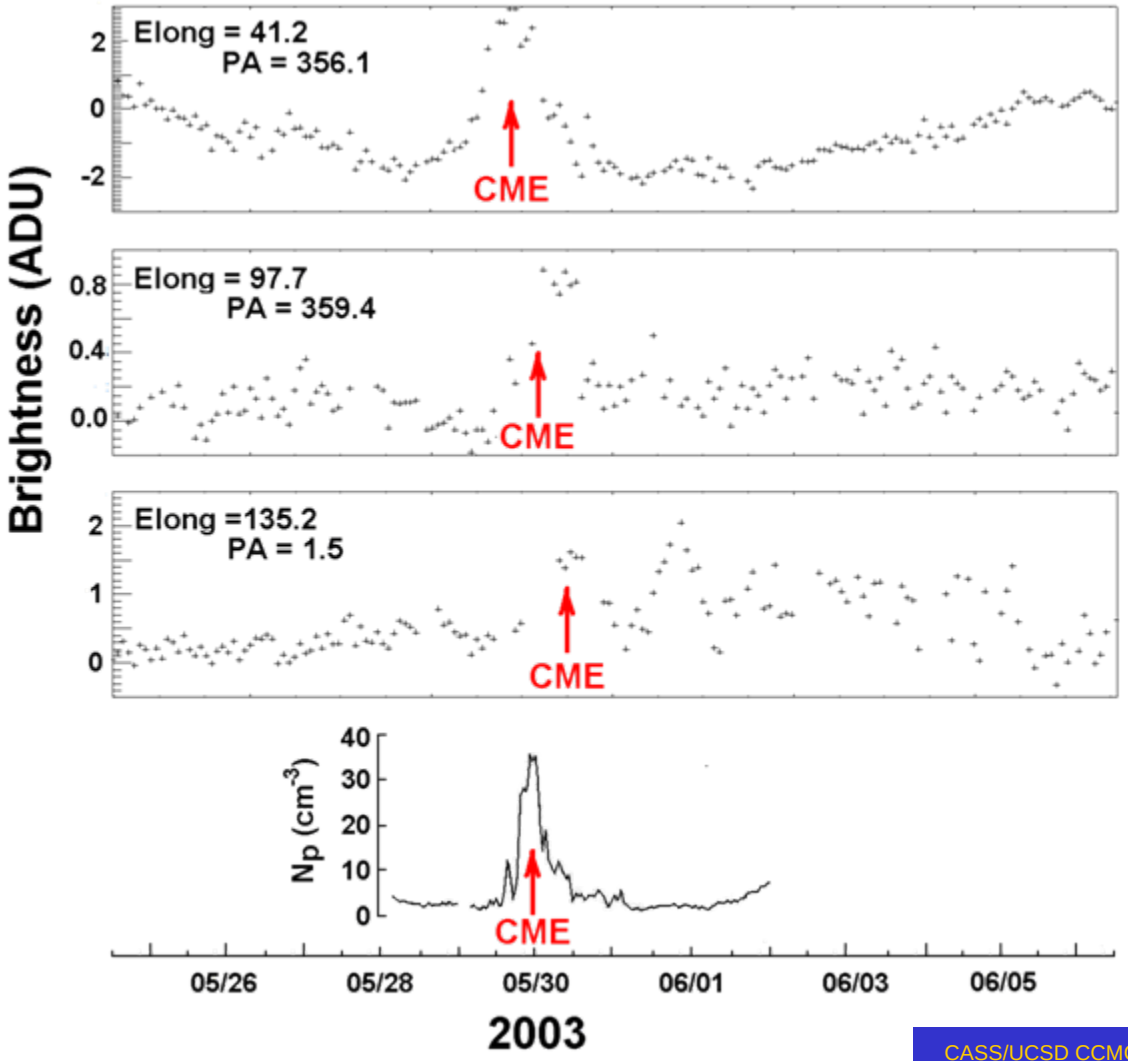
Jackson, B.V., et al., 2008, *J. Geophys Res.*, 113, A00A15, doi:10.1029/2008JA013224

27-28 May 2003 CME events brightness time series for select sky sidereal locations

SMEI Brightness with a long-term (~30 day) base removed.

(1 S10 = 0.46 ± 0.02 ADU)

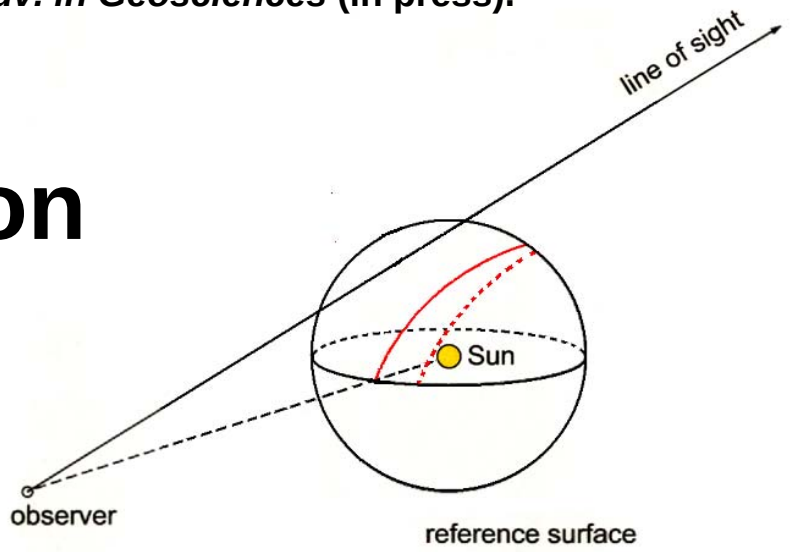
DATA



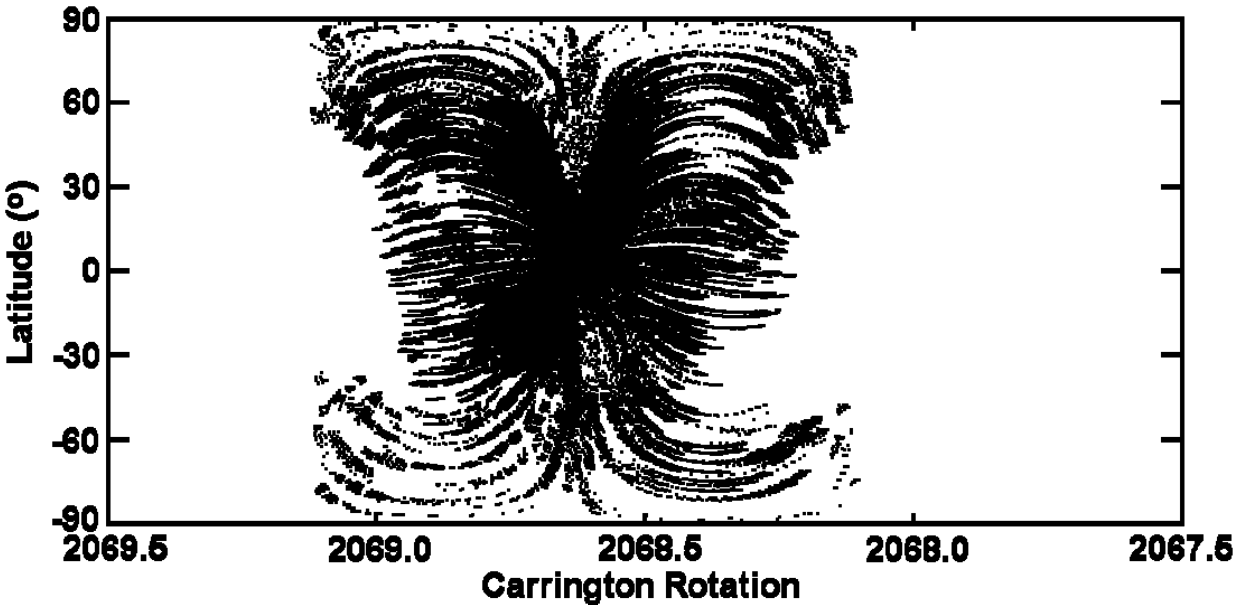
Heliospheric Tomography

Jackson, B.V., et al., 2009, *Adv. in Geosciences* (in press).

Heliospheric 3-D Reconstruction



Line of sight "crossed" components on a reference surface. Projections on the reference surface are shown. These weighted components are inverted to provide the time-dependent tomographic reconstruction.

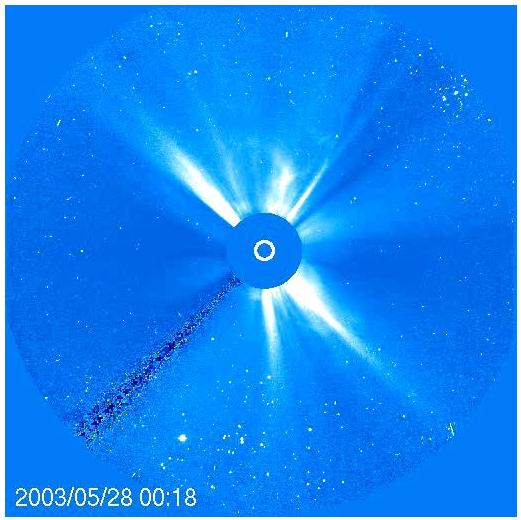


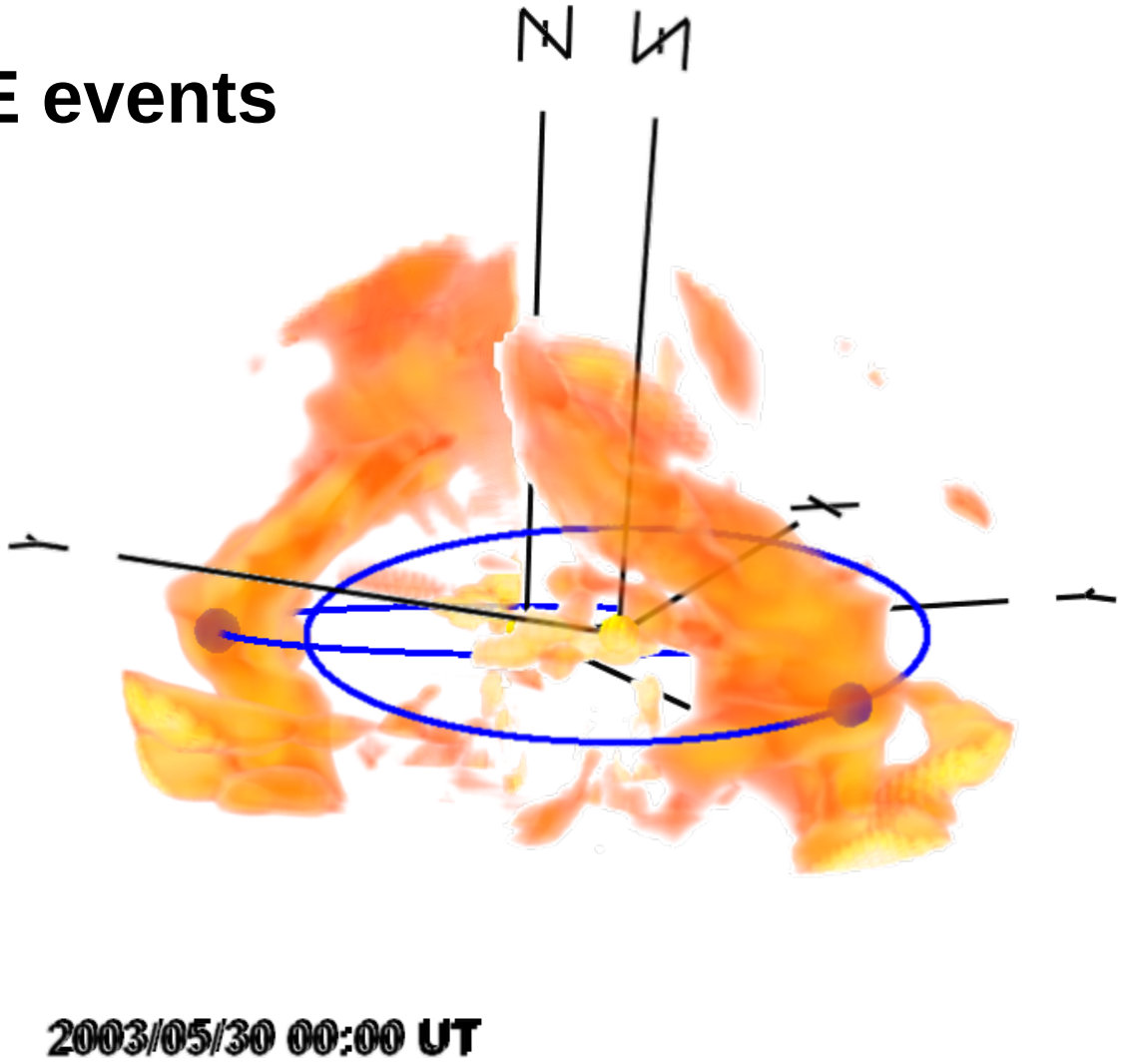
Heliospheric Tomography

Jackson, B.V., et al., 2008, *J. Geophys Res*., 113, A00A15, doi:10.1029/2008JA013224

2003 May 27-28 CME events

SMEI density 3D reconstruction of the 28 May 2003 halo CME as viewed from 15º above the ecliptic plane about 30º east of the Sun-Earth line.





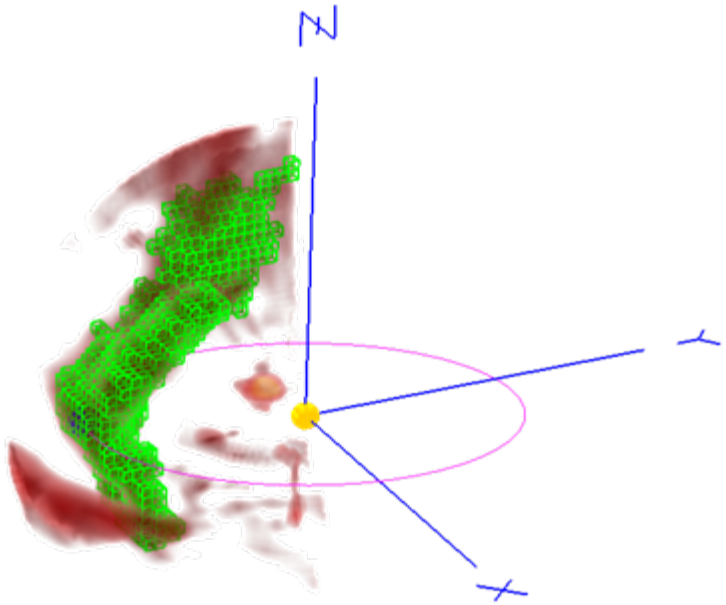
SMEI density (remote observer view) of the 28 May 2003 halo CME

Heliospheric Tomography

Jackson, B.V., et al., 2008, *J. Geophys Res*., 113, A00A15, doi:10.1029/2008JA013224

2003 May 27-28 CME events

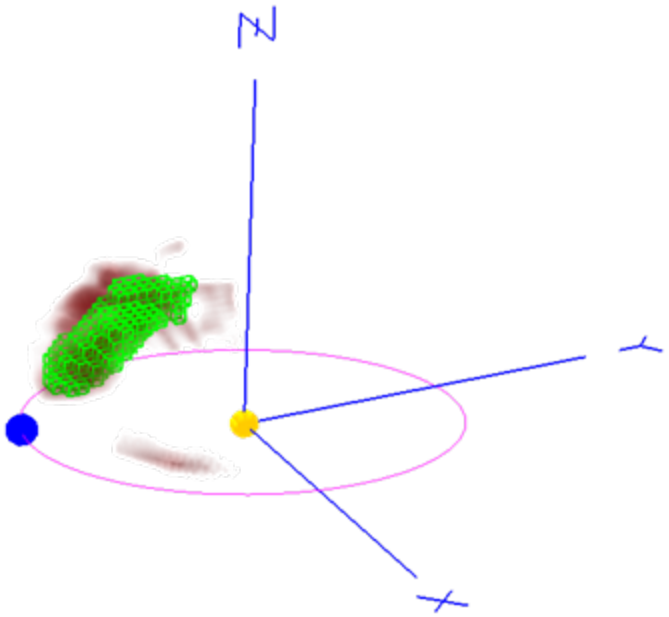
CME masses



Excess Mass(g): 1.844E+016
Total Mass(g): 2.491E+016
Ambient (g): 6.470E+015
Energy (ergs): 3.448E+031

Volume: 0.144 AU^3

2003/05/30 00:00 UT



Excess Mass(g): 5.117E+015
Total Mass(g): 6.921E+015
Ambient (g): 1.804 E+015
Energy (ergs): 8.759 E+030

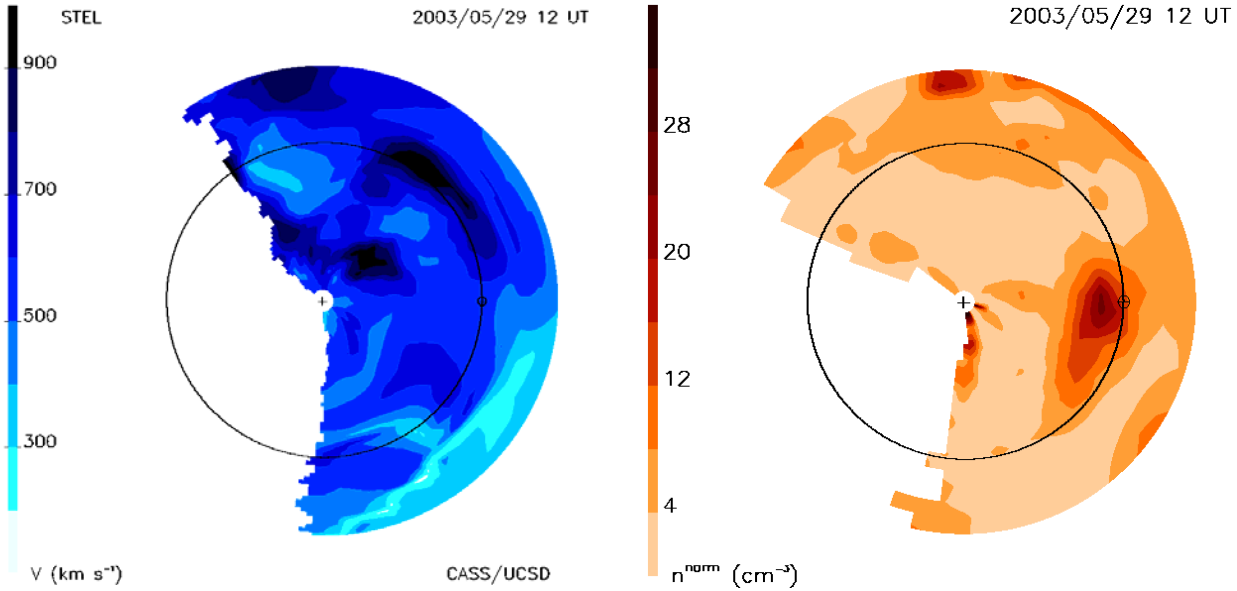
Volume: 0.030 AU^3

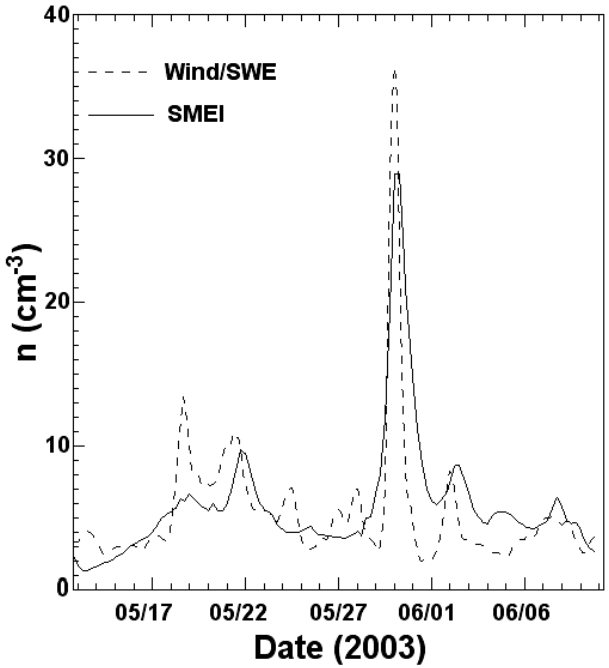
2003/05/30 00:00 UT

Heliospheric Tomography

Jackson, B.V., et al., 2008, *J. Geophys Res*., 113, A00A15, doi:10.1029/2008JA013224

27-28 May 2003 CME event period





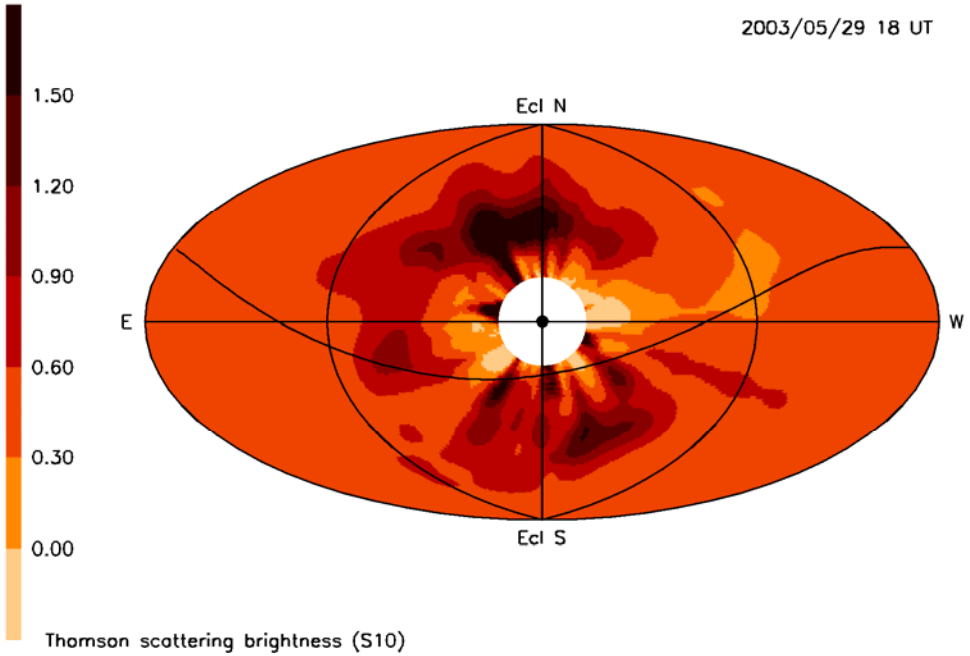
IPS Velocity and SMEI proton density reconstruction of the 27-28 May 2003 halo CME sequence. Reconstructed and Wind *in-situ* densities are compared with over one Carrington rotation.

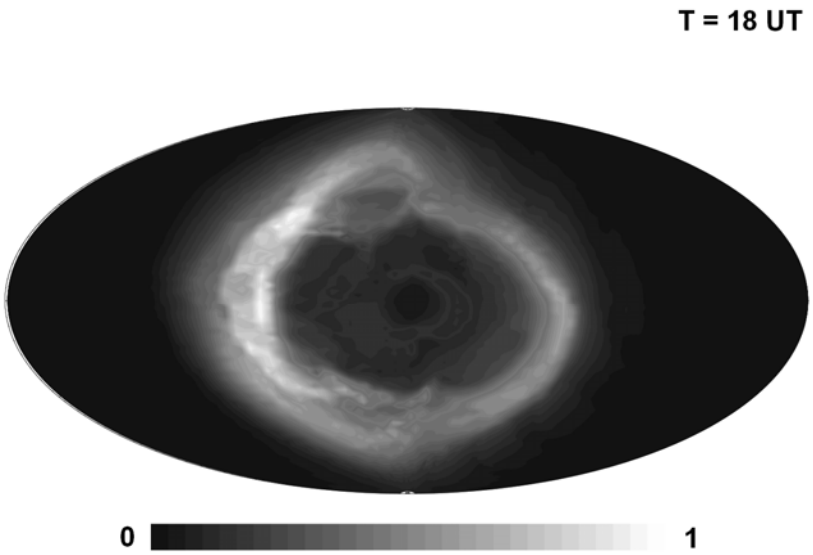
Heliospheric Tomography

Jackson, B.V., et al., 2008, *J. Geophys Res*., 113, A00A15, doi:10.1029/2008JA013224

2003 May 27-28 CME events

HAF Model Comparison



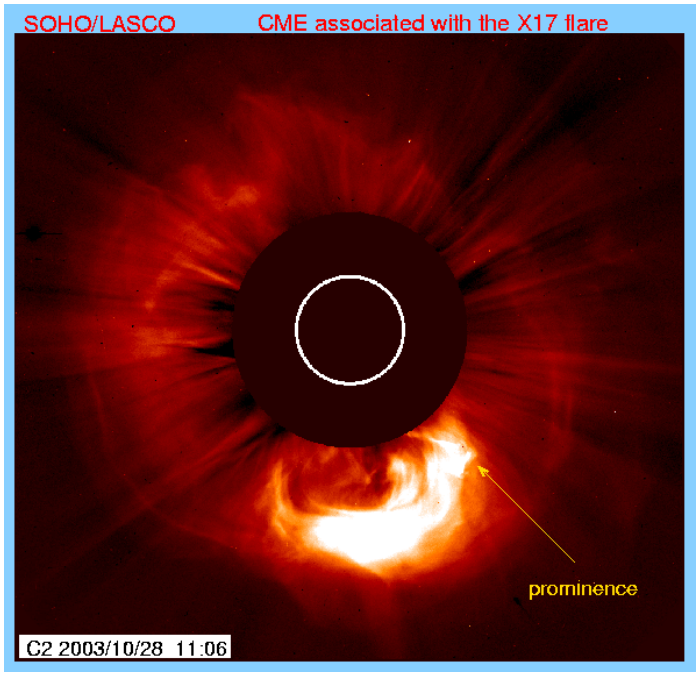


Brightness from the 28 May 2003 halo CME 3D reconstruction (left) and HAF model (right).

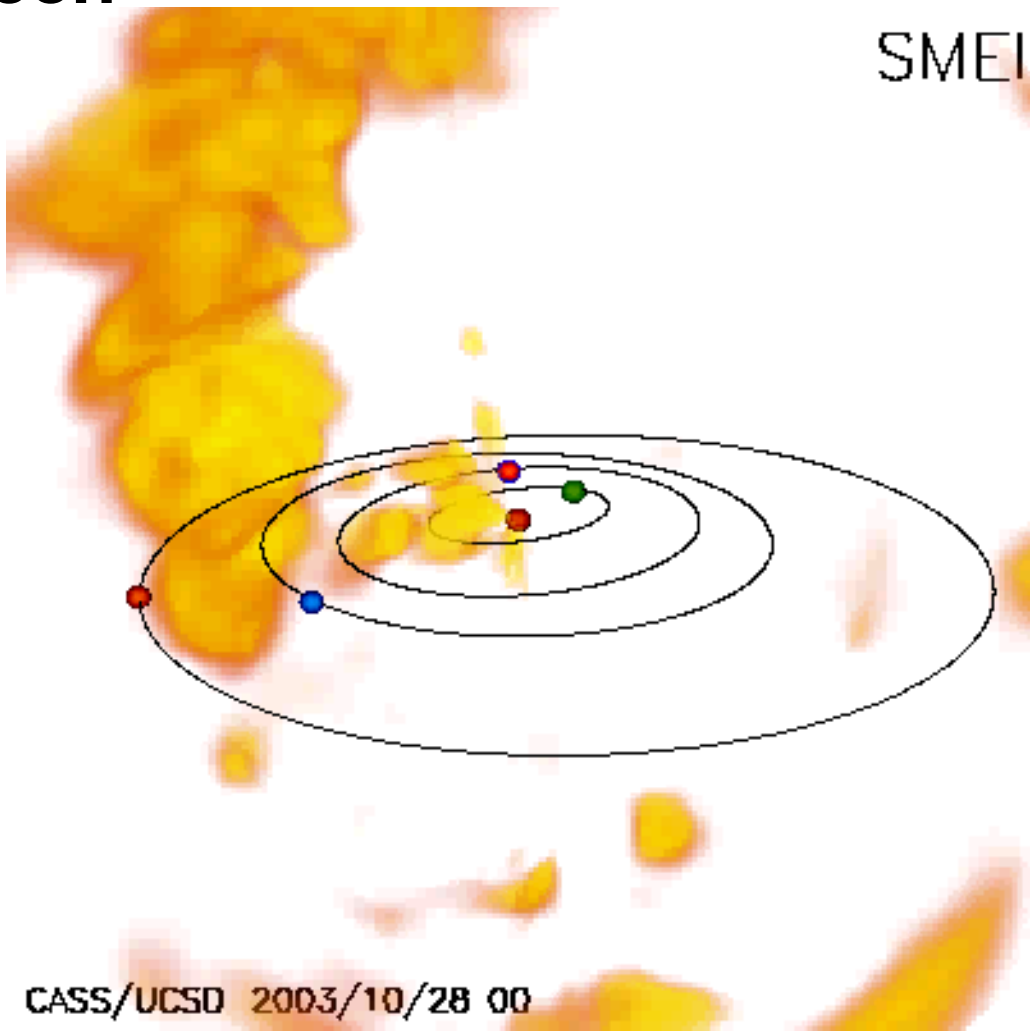
Heliospheric Tomography

Jackson, B.V., et al., 2006, *J. Geophys. Res.*, 111, A4, A04S91

SMEI 3D reconstruction of the 28 October (Halloween Storm) 2003 CME.



LASCO C2 coronagraph image.

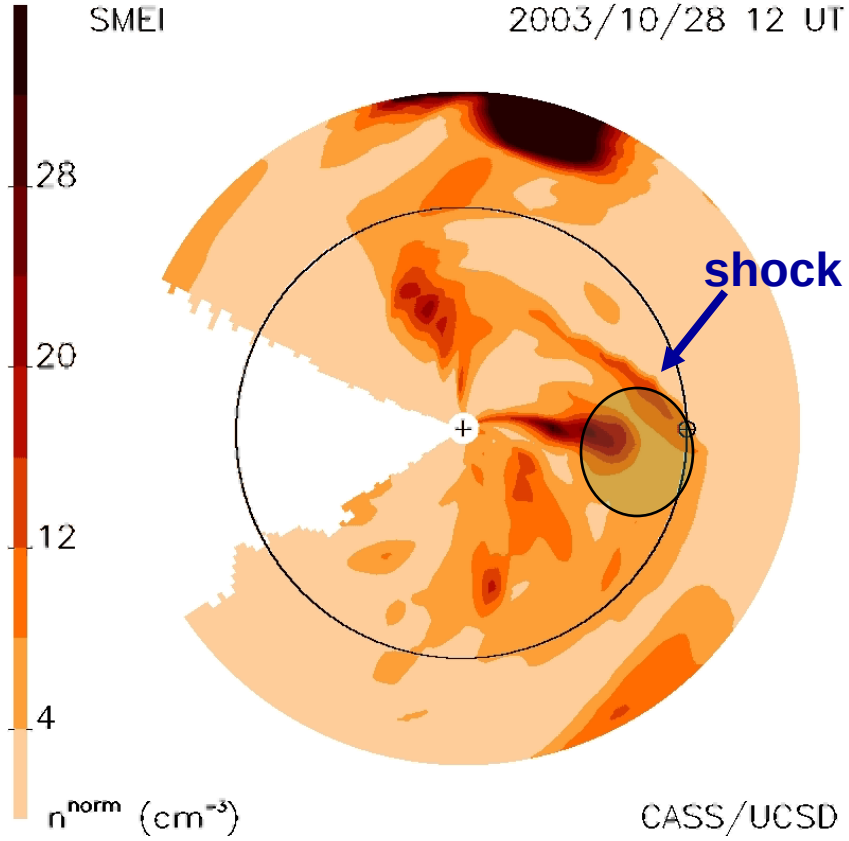


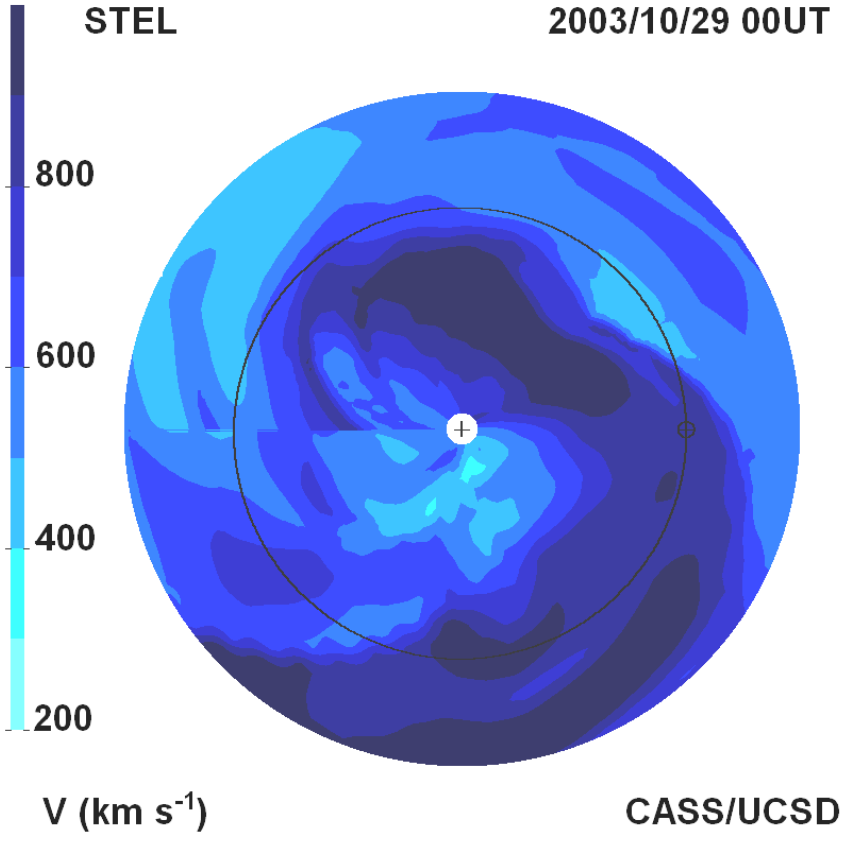
SMEI 3D-reconstruction.

Heliospheric Tomography

Recent higher-resolution SMEI PC 3D reconstructions show the CME sheath region as well as the central dense core

28 October 2003 CME “Halloween storm” ICME

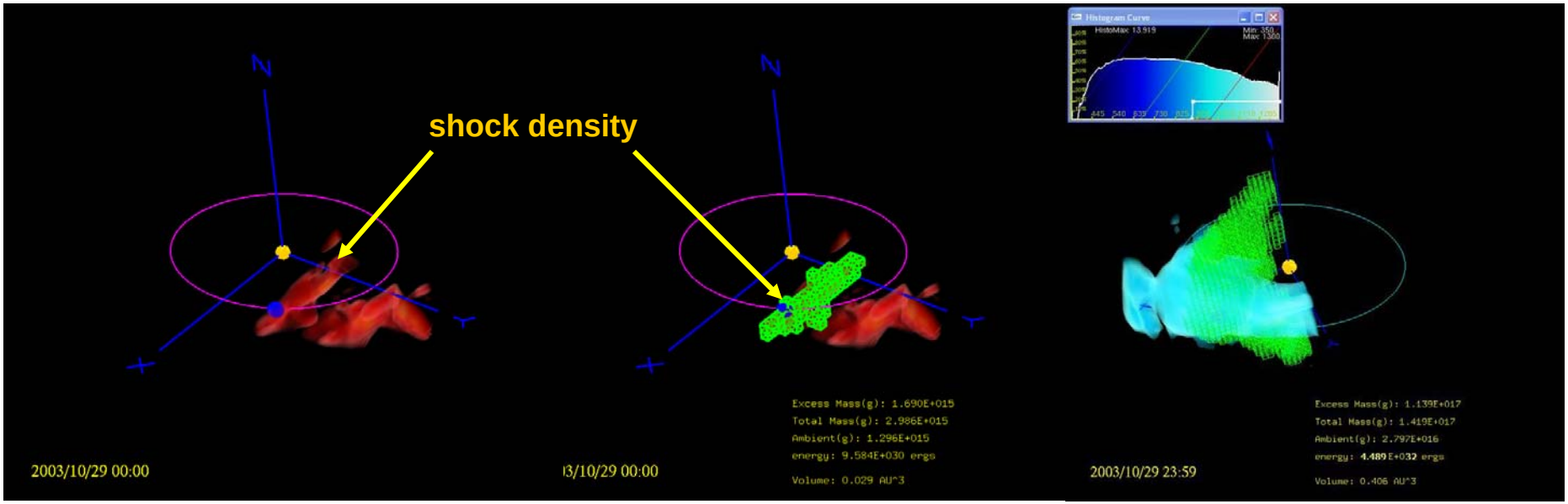




Ecliptic cuts

Heliospheric Tomography

28 October 2003 CME/ICME



Volumetric mass density

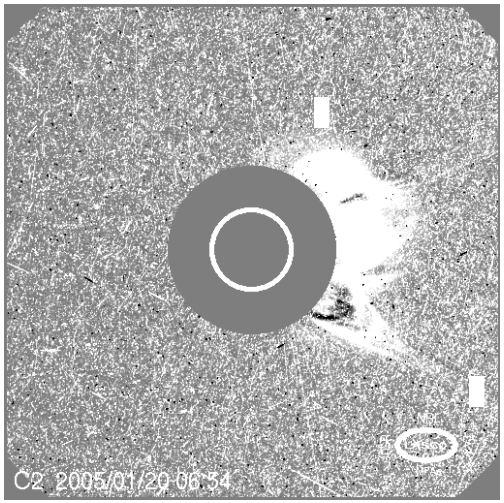
Meridional cuts

Shock density enhancement volumetric mass

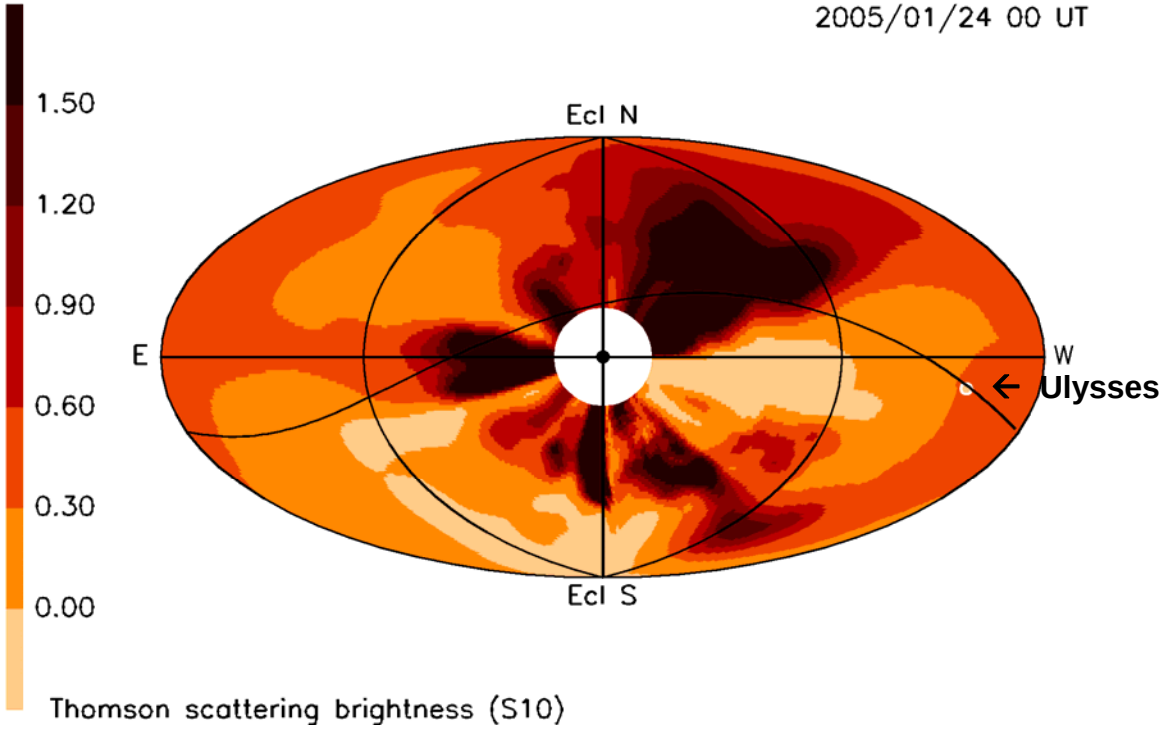
The major portion of the shock density enhancement for the 28 October 2003 ICME is present over only a tiny portion of the heliosphere!

Heliospheric Tomography

20 January 2005 CME shock



LASCO C2 coronagraph difference image.



SMEI Hammer-Aitoff image of the whole sky

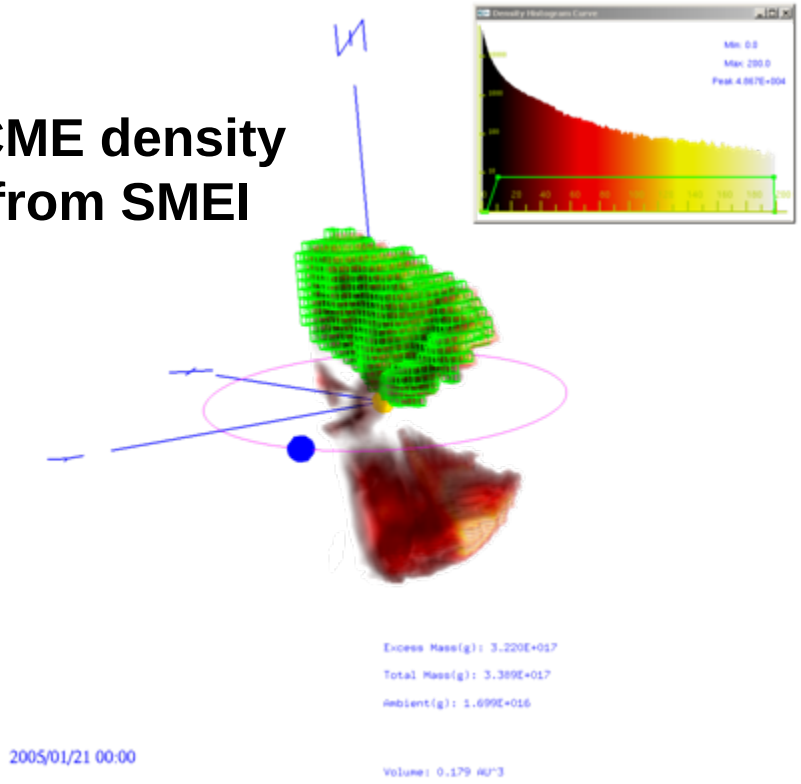
The 20 January 2005 flare/ CME is associated with a very energetic (and prompt) SEP.

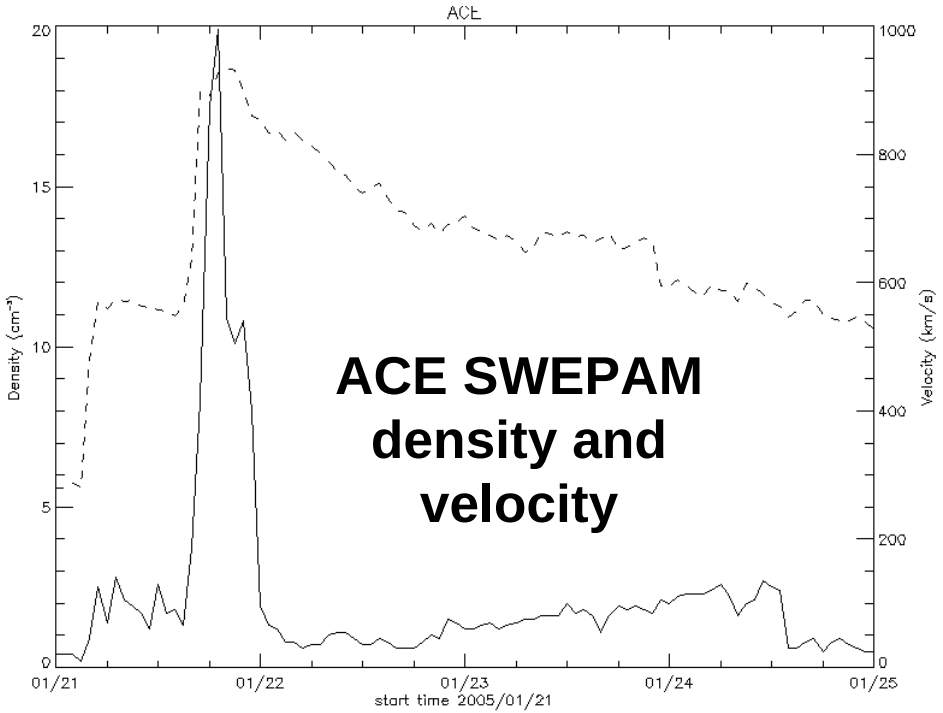
Heliospheric Tomography

20 January 2005 CME shock

Jackson, B.V., et al., 2009, *AIP* (in press)

ICME density from SMEI



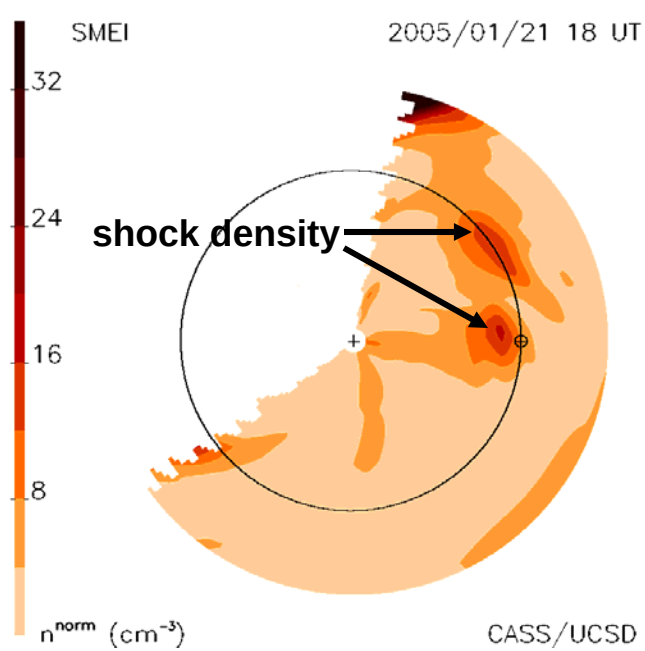


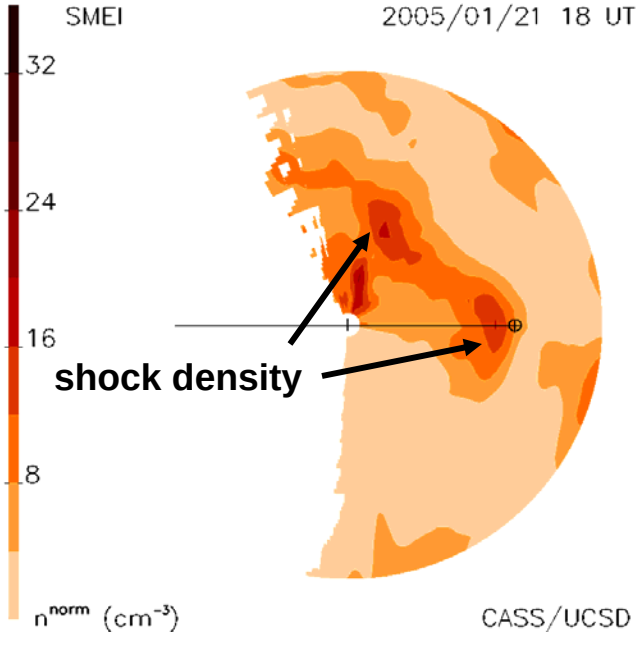
The bulk of the ICME mass of 3 x 10^{17} g reached 1 AU in about one day indicating an average speed for this mass of approximately 1600 km s^{-1}, or a total kinetic energy for the CME of ~2 x 10^{33} ergs. A large shock was observed at Earth a day and a half following the CME onset at about 08:00 UT 20 January, 2005.

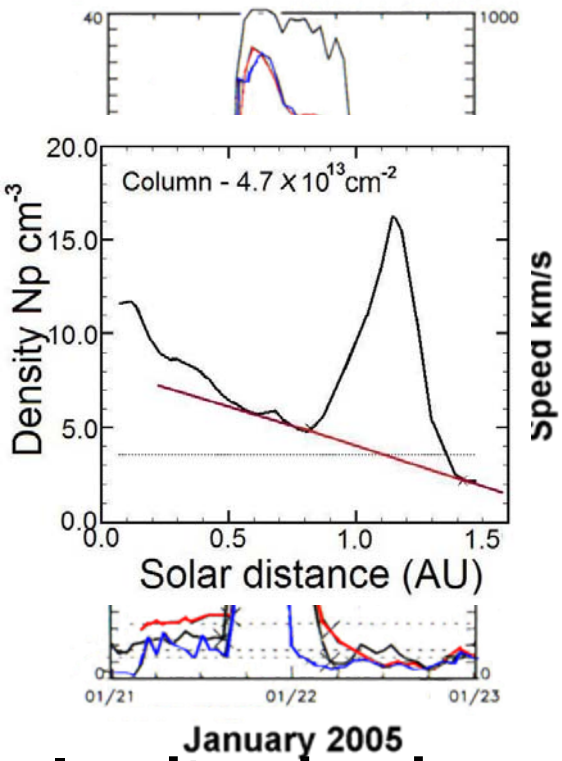
Heliospheric Tomography

20 January 2005 CME shock

Jackson, B.V., et al., 2009, *AIP* (in press)







Ecliptic cut **Meridional cut** **In-situ shock**

From volumetric data determine mass flow past the spacecraft by measuring the density along the radial from Sun to Earth. **SMEI = 4.7×10^{13}cm^{-2}**

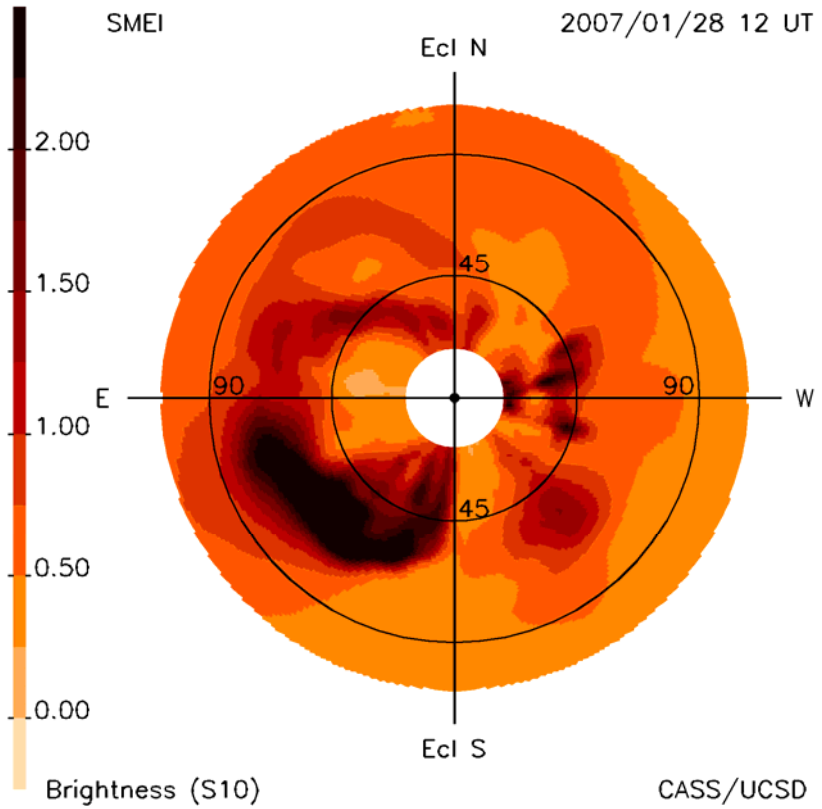
From *in situ* data determine mass flow past the spacecraft by measuring the flux of material that has passed the spacecraft over time.

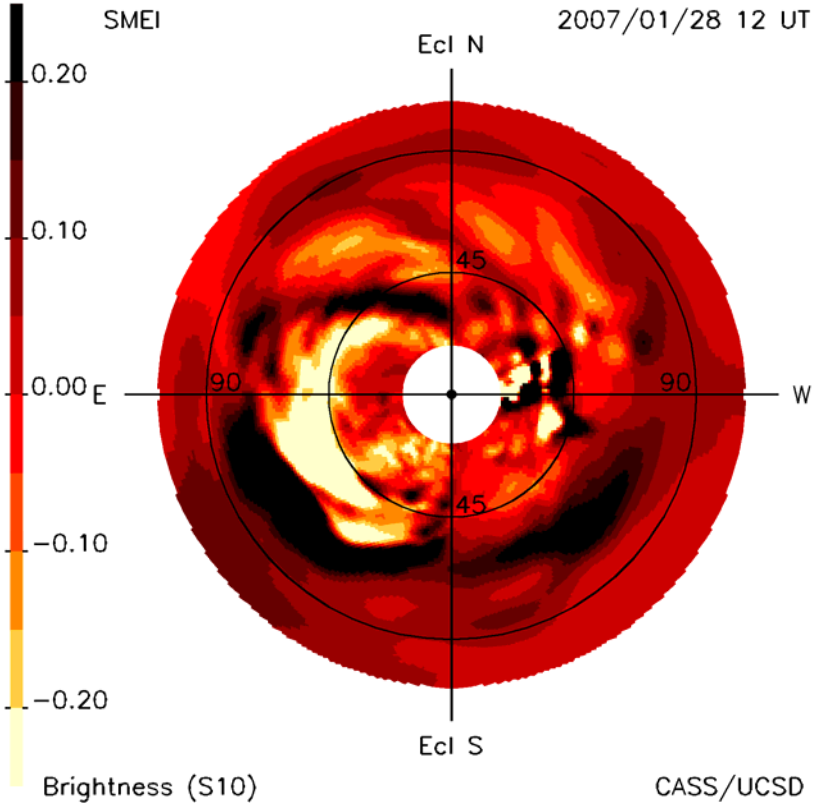
Wind SWE = 4.54×10^{13}, SOHO CELIAS = 6.55×10^{13}, ACE SWEPAM L0 = 2.57×10^{13}

Heliospheric Tomography

Heliospheric difference images

Jackson, B.V., et al., 2009, *Annales Geophysicae*, 27, 4097.

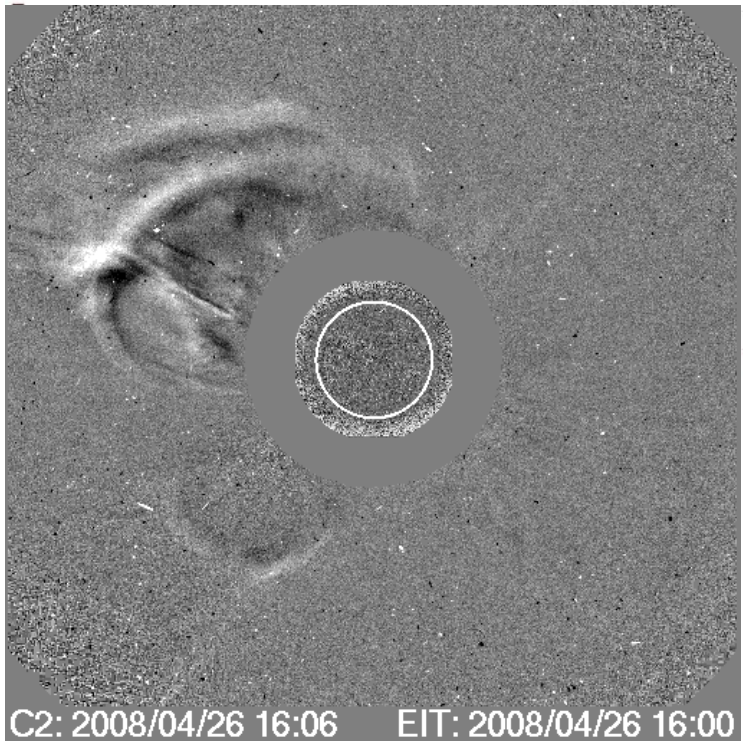


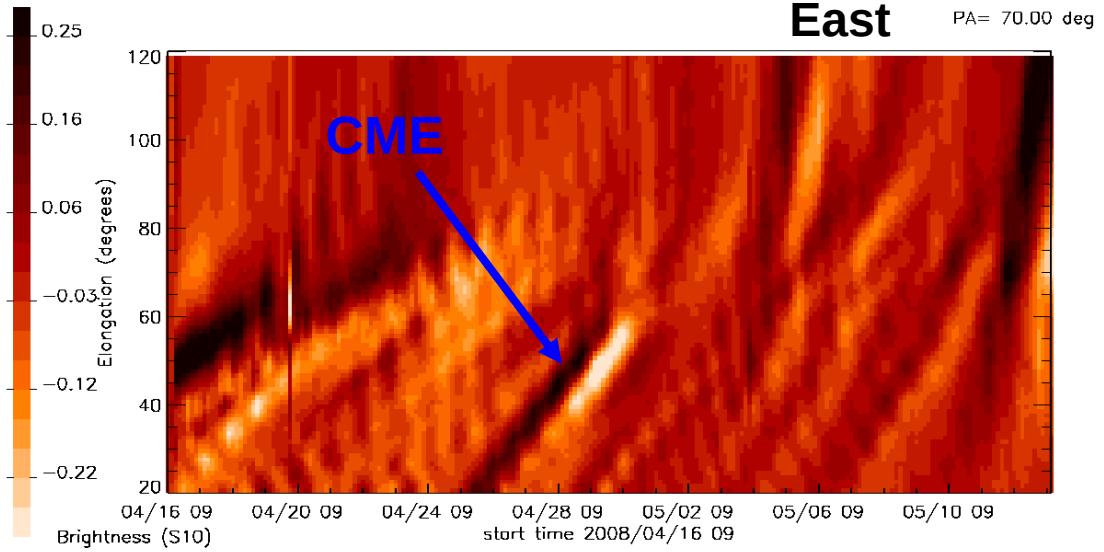


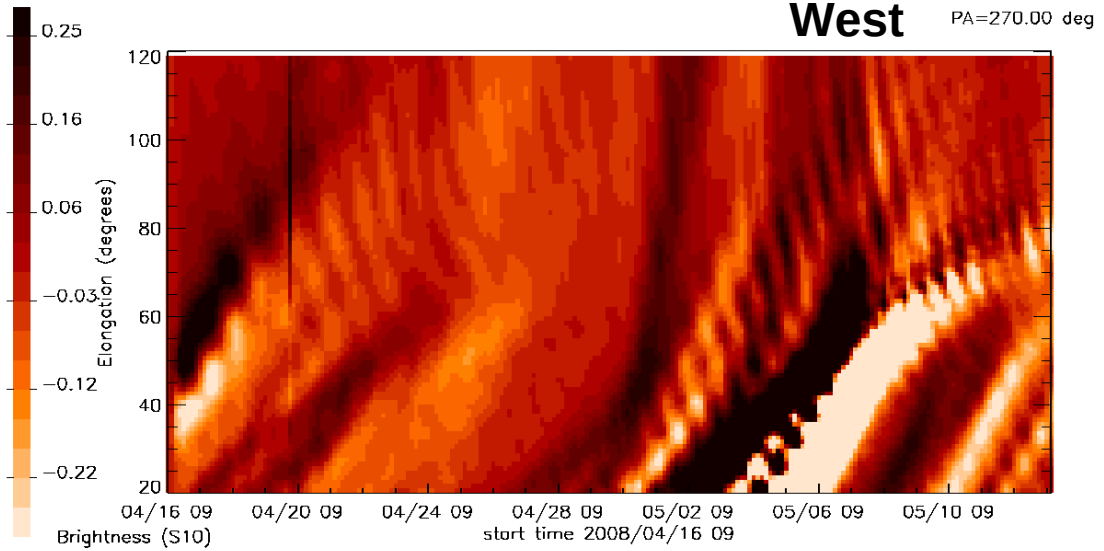
SMEI 3-D reconstructed difference images

Heliospheric Tomography

Post-WHI April 2008 analysis (26 April CME)

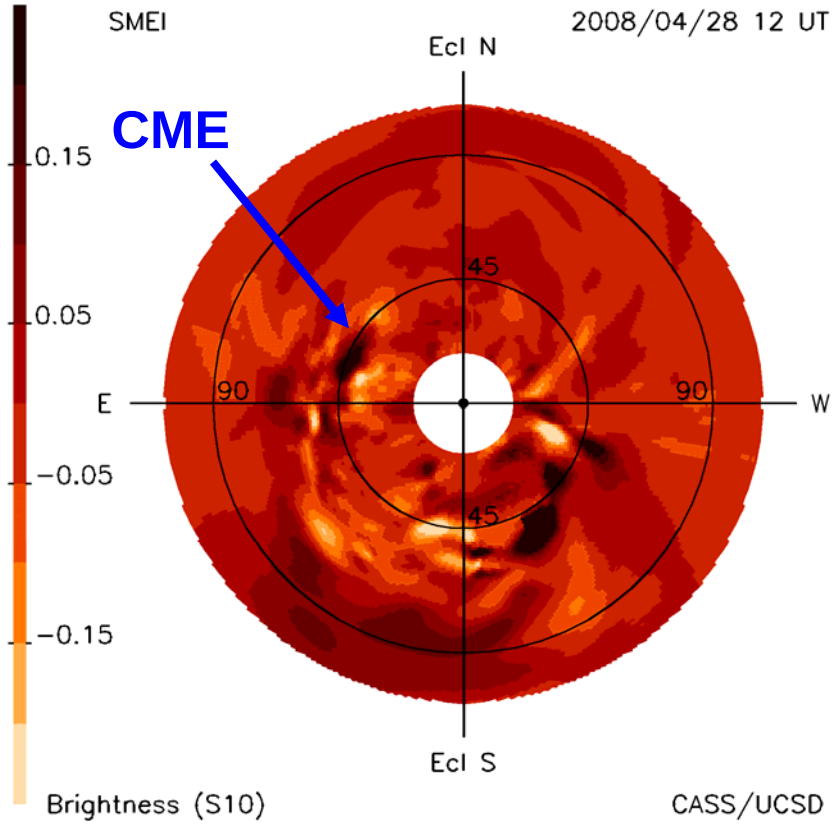


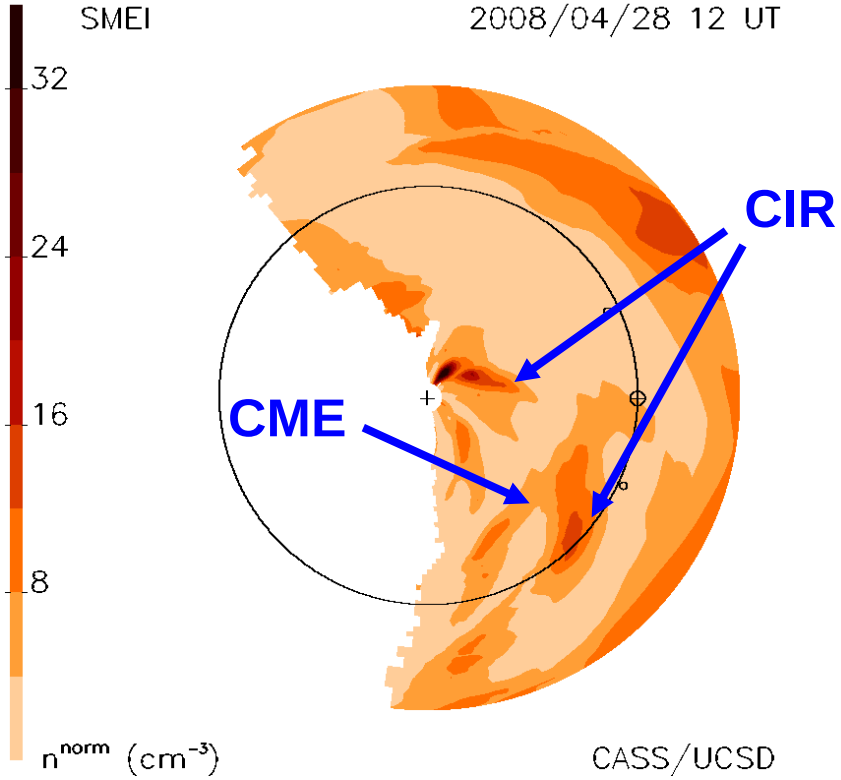




Heliospheric Tomography

Post-WHI April 2008 analysis (26 April CME)

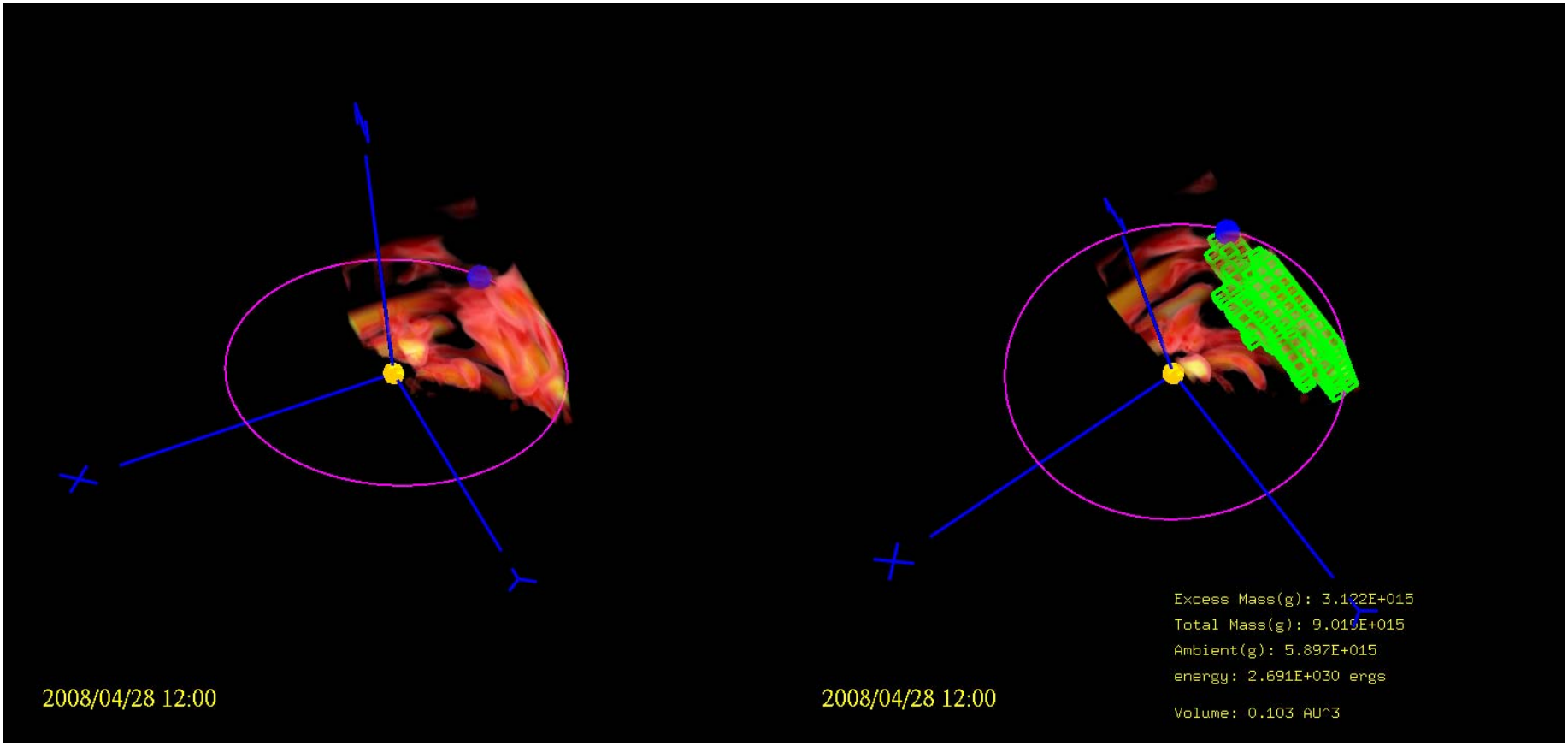




The outward-flowing solar wind structure follows very specific physics as it moves outward from the Sun

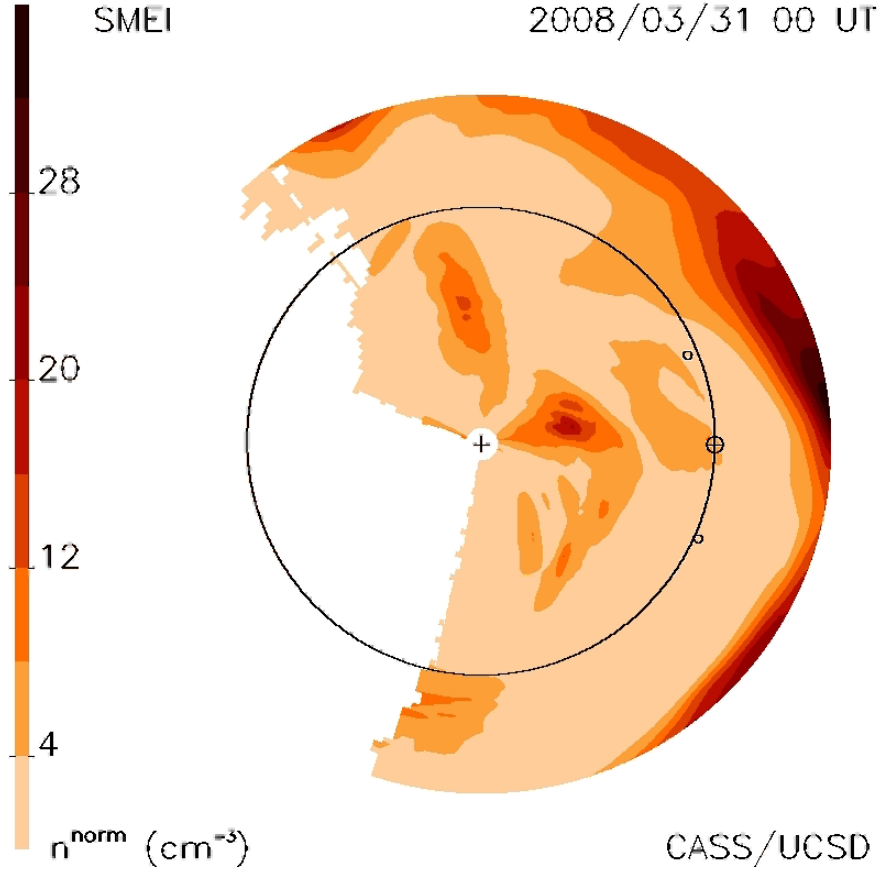
Heliospheric Tomography

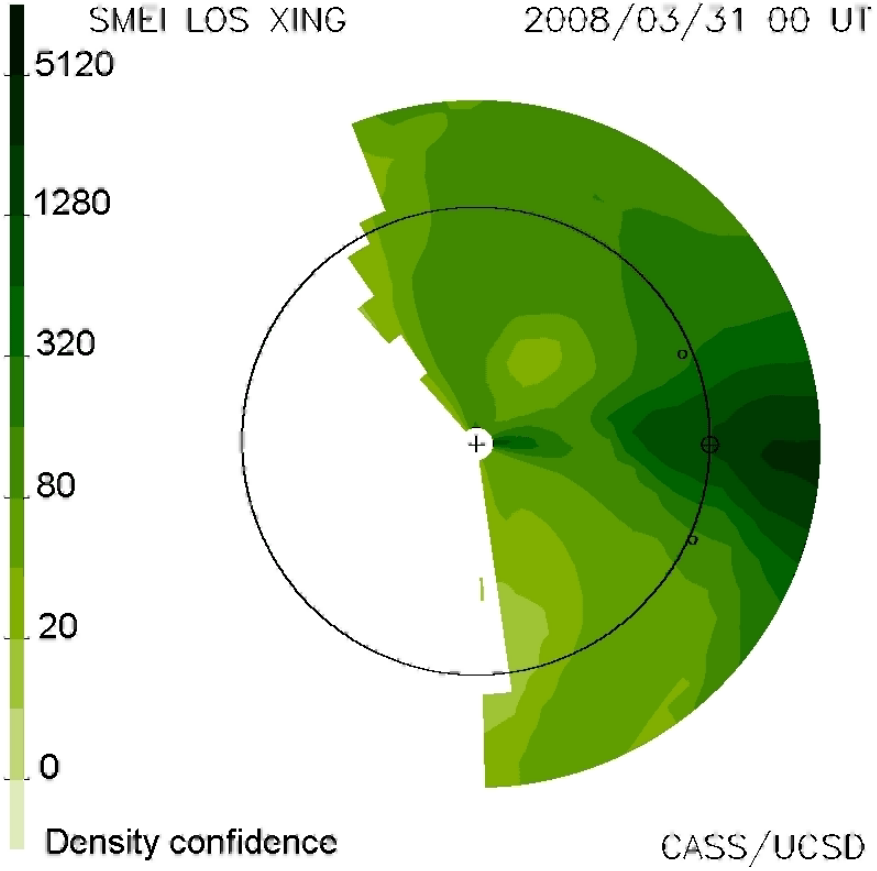
Post-WHI April 2008 analysis (26 April CME)



Heliospheric Tomography

Line of sight crossing error example- the WHI period





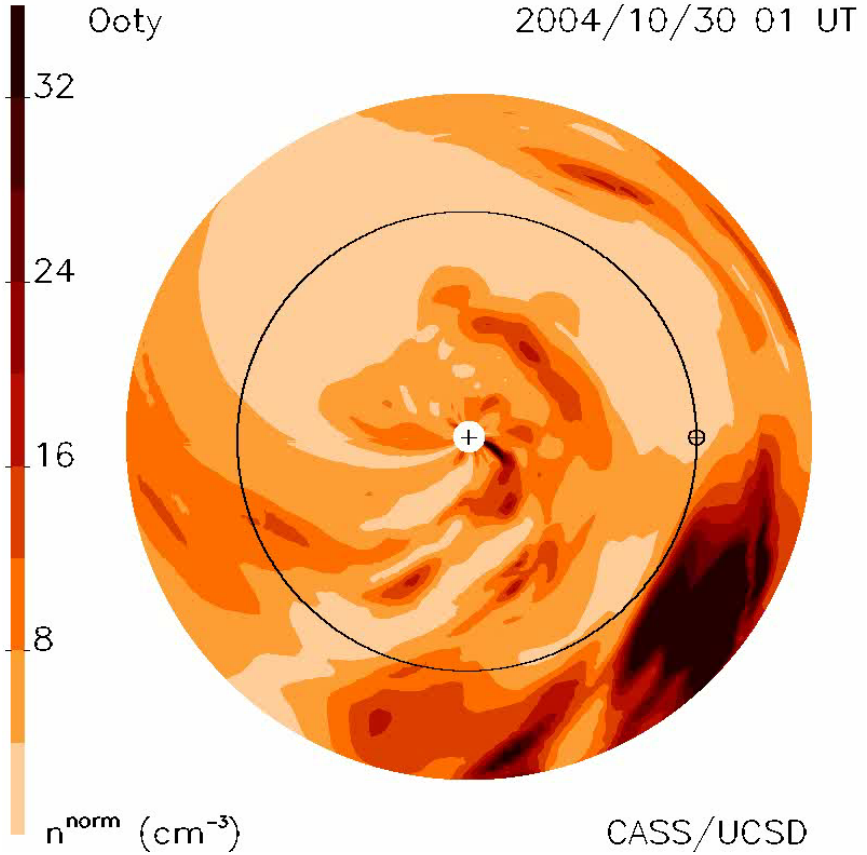
SMEI data analysis

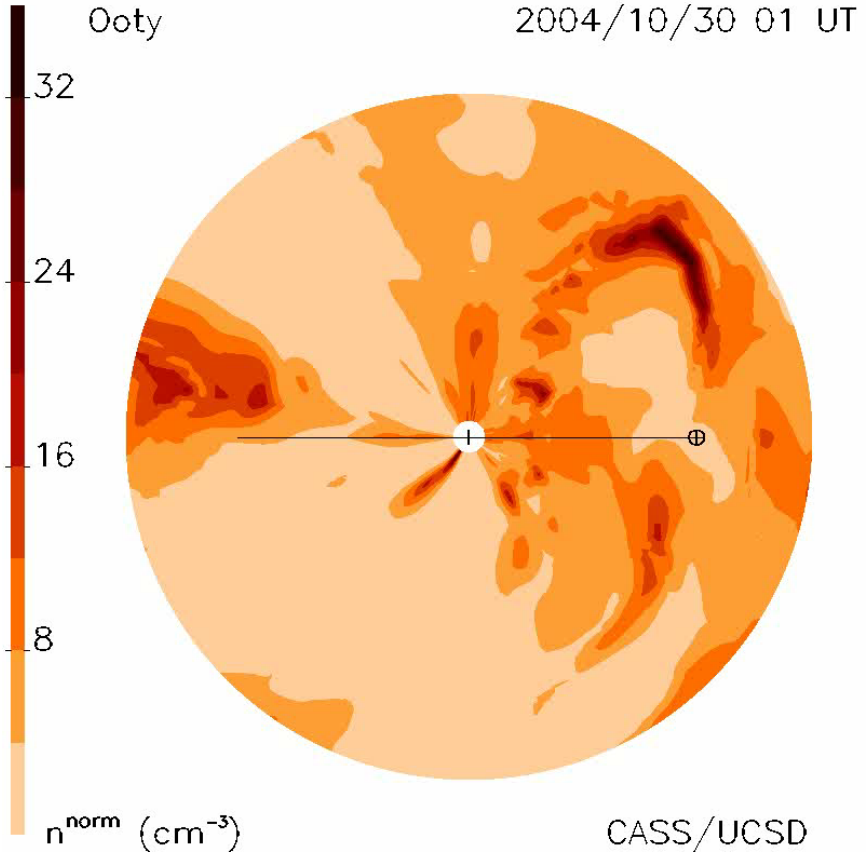
Other Heliospheric Tomography

Ooty Density 3-D Reconstruction

4-7 November 2004

Bisi, M.M., et al., 2009, *Annales Geophysicae,* 27, 4479.





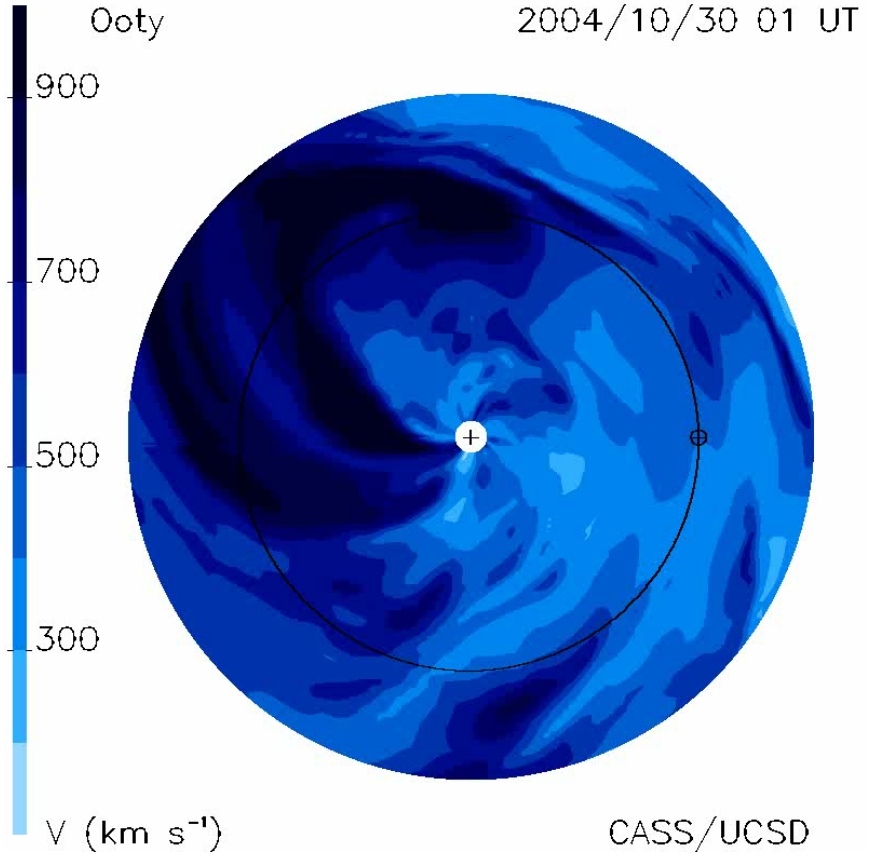
The left shows an ecliptic cut through the 3D Ooty IPS density reconstruction and the right shows a meridional cut (from East of the Sun-Earth line) of the same; both with the Earth on the right-hand side and it's orbit are shown.

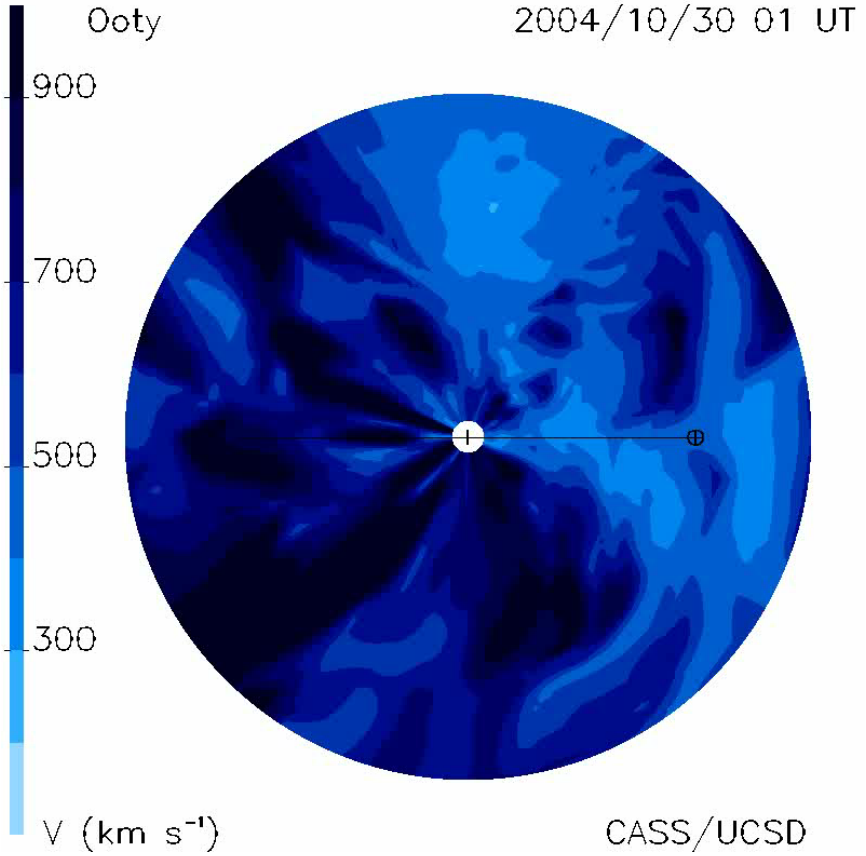
Other Heliospheric Tomography

Ooty Velocity 3-D Reconstruction

4-7 November 2004

Bisi, M.M., et al., 2009, *Annales Geophysicae,* 27, 4479.





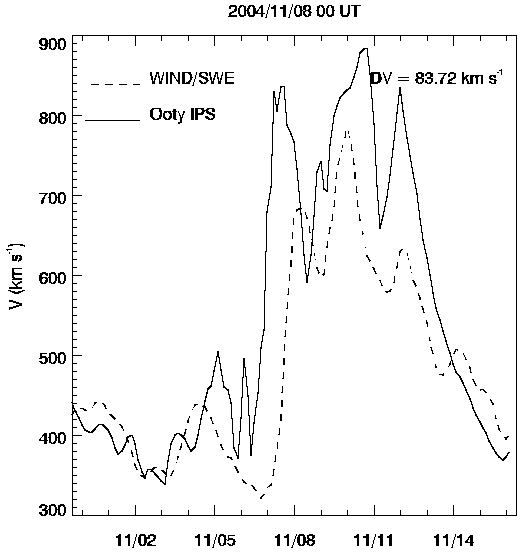
The left shows an ecliptic cut through the 3D Ooty IPS speed reconstruction and the right shows a meridional cut (from East of the Sun-Earth line) of the same; both with the Earth on the right-hand side and it's orbit are shown.

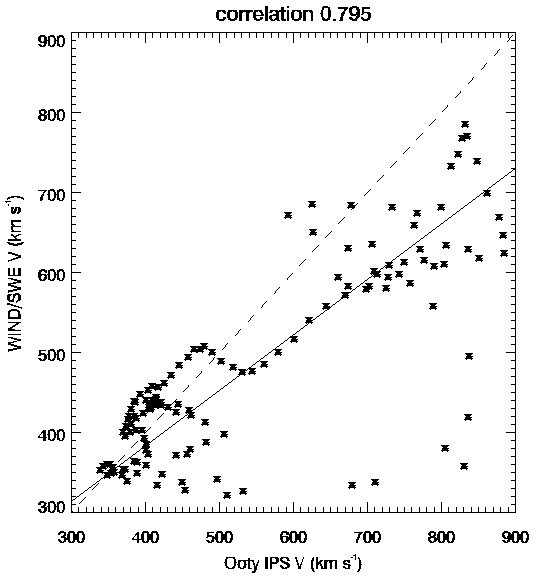
Heliospheric Tomography

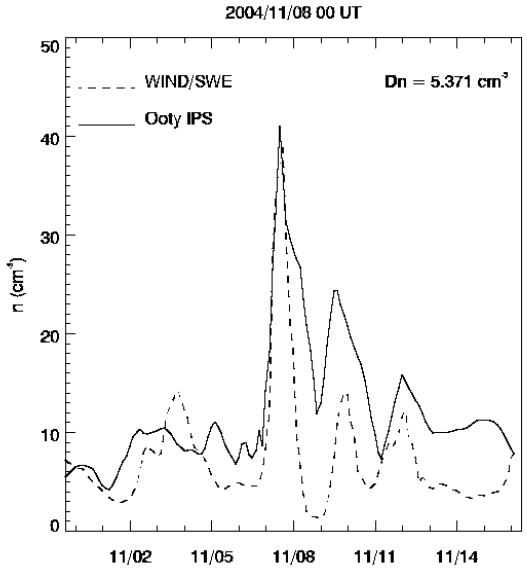
Other

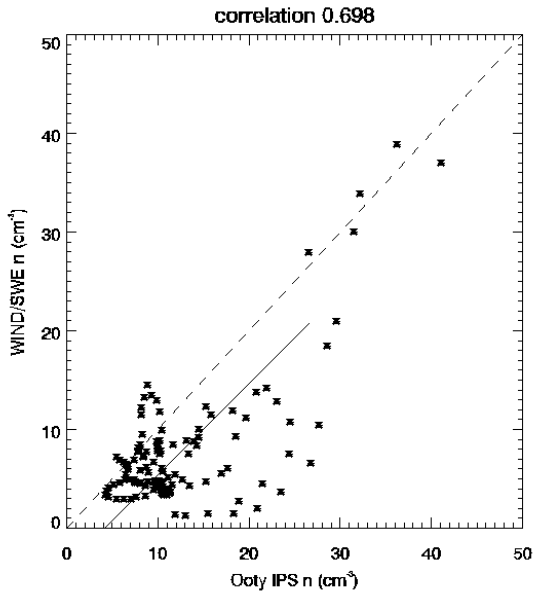
Ooty 3-D Density and Velocity Reconstruction

Bisi, M.M., et al., 2009, *Annales Geophysicae*, 27, 4479.









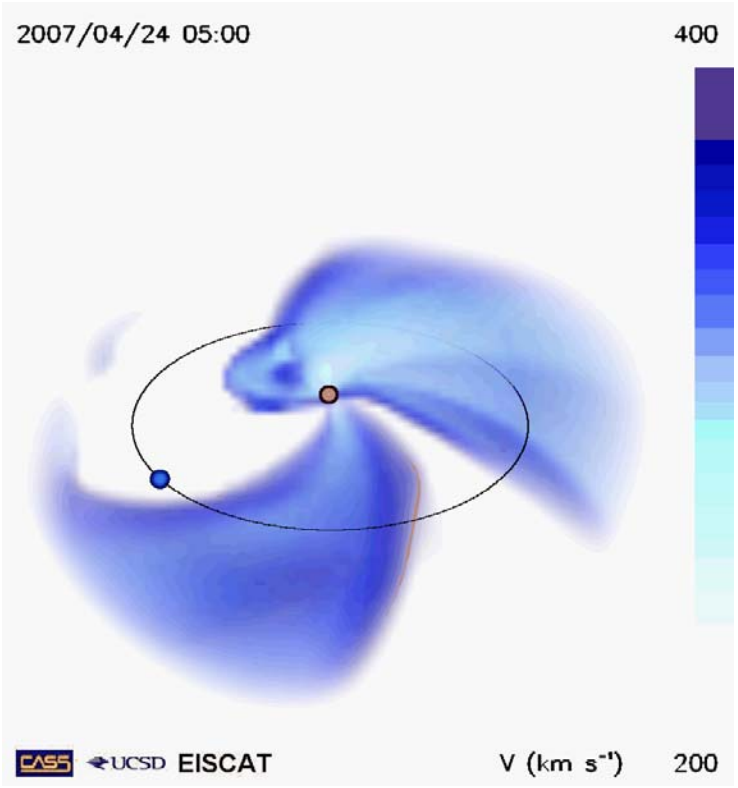
Heliospheric Tomography

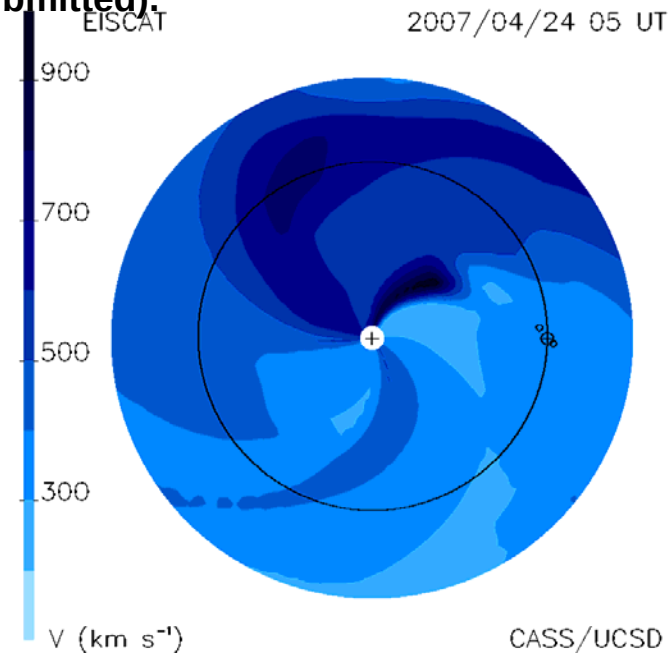
Other

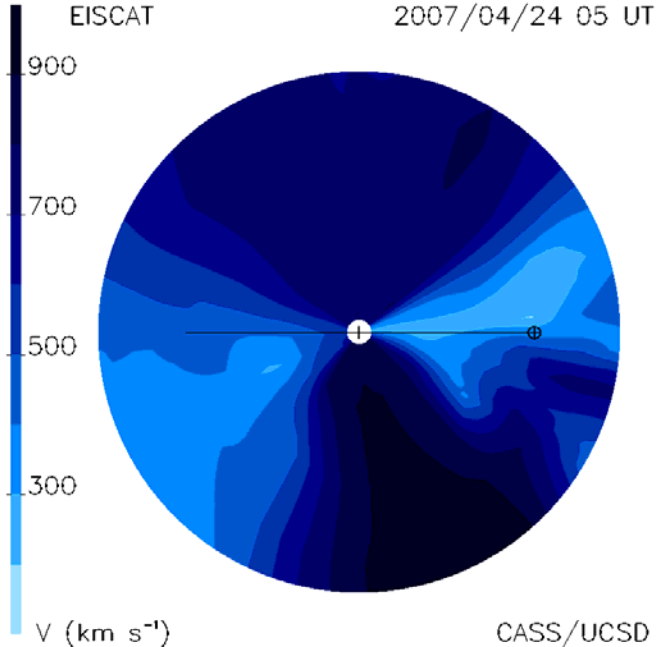
Bisi, M.M., et al., 2010, *Solar Phys*. (submitted).

EISCAT Result

Bisi, M.M., et al., 2010, *Solar Phys.,* (submitted)







It now becomes more important to be absolutely certain of the higher-frequency velocity LOS weighting.

Last Year!! Heliospheric Tomography

•Bisi, M.M., B.V. Jackson, A. Buffington, J.M. Clover, P.P. Hick, and M. Tokumaru, 2009, 'Low-Resolution STELab IPS 3D Reconstructions of the Whole Heliosphere Interval and Comparison with in-Ecliptic Solar Wind Measurements from STEREO and Wind Instrumentation', *Solar Phys*. - STEREO Science Results at Solar Minimum Topical Issue, 256, 201-217, doi:10.1007/s11207-009-9350-9.

•Bisi, M.M., Jackson, B.V., Clover, J.M., Manoharan, P.K., Tokumaru, M., Hick, P.P., and. Buffington, A., 2009, '3D reconstructions of the early-November 2004 CDAW geomagnetic storms: analysis of Ooty IPS speed and density data', *Annales Geophysicae,* 27, 4479.

•Bisi, M.M., Jackson, B.V., Clover, J.M., Tokumaru, M., and Fujiki, K., 2009, 'Large-Scale Heliospheric Structure during Solar-Minimum Conditions using a 3D Time-Dependent Reconstruction Solar-Wind Model and STELab IPS Observations', in-press, *American Institute of Physics* (Solar Wind 12 Proceedings).

•Bisi, M.M., Jackson, B.V., Clover, J.M., Hick, P.P., and Buffington, A., 2009, '3D Reconstructions of the Whole Heliosphere Interval and Comparison with in-Ecliptic Solar Wind Measurements from STEREO, ACE, and Wind Instrumentation: a Brief Summary', XXVIIth IAU General Assembly, August 2009, *Highlights of Astronomy*, 15, 119.

•Bisi, M.M., Jackson, B.V., Breen, A.R., Dorrian, G.D., Fallows, R.A., Clover, J.M., and Hick, P.P., 2009, 'Three-Dimensional (3-D) Reconstructions of EISCAT IPS Velocity Data in the Declining Phase of Solar Cycle 23', *Solar Phys*. (submitted).

•Bisi, M.M., Breen, A.R., Jackson, B.V., Fallows, R.A., Walsh, A.P., Mikic, Z., Riley, P., Owen, C.J., Gonzalez-Esparza, A., Aguilar-Rodriguez, E., Morgan, H., Jensen, E.A., Wood, A.G., Tokumaru, M., Manoharan, P.K., Chashei, I.V., Giunta, A.S., Linker, J.A., Shishov, V.I., Tyul'bashev, S.A., Agalya, , G., Glubokova, S.K., Hamilton, M.S., Fujiki, K., Hick, P.P., Clover, J.M., Pinter, B., 2009, 'From the Sun to the Earth: the 13 May 2005 Coronal Mass Ejection', *Solar Phys*. (submitted).

•Buffington, A., Bisi, M.M., Clover, J.M., Hick, P.P., Jackson, B.V., Kuchar, T.A., and Price, S.D., 2009, 'Measurements of the Gegenschein brightness from the Solar Mass Ejection Imager (SMEI)', *Icarus*, 203, 124, doi:10.1016/j.icarus.2009.04.007.

•Jackson, B.V., Hick, P.P., Buffington, A., Bisi, M.M., and Clover, J.M., 2009, 'SMEI direct, 3D-reconstruction sky maps and volumetric analyses, and their comparison with SOHO and STEREO observations', *Annales Geophysicae*, 27, 4097.

•Jackson, B.V., Hick, P.P., Buffington, A., Bisi, M.M., Clover, J.M., Tokumaru, M., and Fujiki, K., 2009, '3D Reconstruction of Density Enhancements Behind Interplanetary Shocks from Solar Mass Ejection Imager White-Light Observations', *American Institute of Physics* (Solar Wind 12 Proceedings) (in press).

•Jackson, B.V., Hick, P.P., Buffington, A., Bisi, M.M., Clover, J.M., and Tokumaru, M., 2009, 'Solar Mass Ejection Imager (SMEI) and Interplanetary Scintillation (IPS) 3D-Reconstructions of the Inner Heliosphere', *Adv. in Geosciences* (in press).

•Jackson, B.V., Hick, P.P., Bisi, M.M., Clover, J.M., and Buffington, A., 2009, 'Inclusion of in-situ Velocity Measurements in the UCSD Time-Dependent Tomography to Constrain and Better- Forecast Remote-Sensing Observations', *Solar Phys*. (in-press).

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•Webb, D. F., Howard, T. A., Fry, C. D., Kuchar, T. A., Mizuno, D. R., Johnston, J. C., and Jackson, B. V., 2009, 'Studying Geoeffective ICMEs between the Sun and Earth: Space Weather Implications of SMEI Observations', *Space Weather*, 7, S05002, doi:10.1029/2008SW000409.

Next Heliospheric Tomography

UCSD Web Pages

http://smei.ucsd.edu/

	2003 Feb	2003 Mar	2003 Apr	2003 May	2003 Jun	2003 Jul	2003 Aug	2003 Sep	2003 Oct	2003 Nov	2003 Dec
2004 Jan	2004 Feb	2004 Mar	2004 Apr	2004 May	2004 Jun	2004 Jul	2004 Aug	2004 Sep	2004 Oct	2004 Nov	2004 Dec
2005 Jan	2005 Feb	2005 Mar	2005 Apr	2005 May	2005 Jun	2005 Jul	2005 Aug	2005 Sep	2005 Oct	2005 Nov	2005 Dec
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2008 Jan	2008 Feb	2008 Mar	2008 Apr	2008 May	2008 Jun	2008 Jul	2008 Aug	2008 Sep			

SMEI WLS 2003 Jun

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✓ = Science Mode ✓ = Engineering Mode ✗ = No Data

Orbit	Date	DOY	Time	C1	C2	C3			
02142	2003/06/01	152	01:36:32	✓	✓	✓	Full-Sky	Difference	Custom
02143	2003/06/01	152	03:18:08	✓	✓	✓	Full-Sky	Difference	Custom
02144	2003/06/01	152	04:59:45	✓	✓	✓	Full-Sky	Difference	Custom
02145	2003/06/01	152	06:41:21	✓	✓	✓	Full-Sky	Difference	Custom
02146	2003/06/01	152	08:22:57	✓	✓	✓	Full-Sky	Difference	Custom
02147	2003/06/01	152	10:04:34	✓	✓	✓	Full-Sky	Difference	Custom

Fisheye Direct Sky Maps to Fisheye Reconstruction Sky Maps Comparison : May 29, 2003 DOY 149

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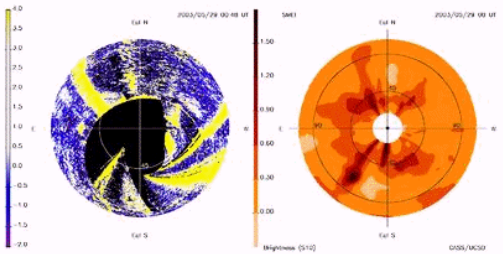
FPS 5

Larger



00:00 UT

UCSD/CASS // Solar Mass Ejection Imager (SMEI)

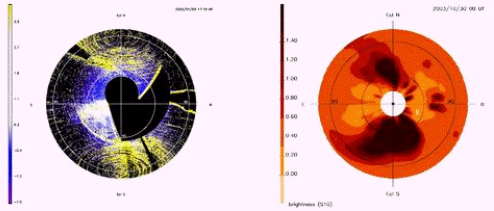
Introduction | Data | Images | Science | Team | Links | Publications | Contact us

To create a custom time series from any of the formats below, click here.
For time series of selected events run with high resolution tomography, click here.
To view side by side comparisions of any two image types, click here.

SMEI Fisheye Sky Maps

Comparisons

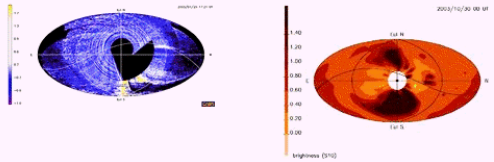
Direct | Difference | Reconstructed



SMEI Hammer-Aitoff Sky Maps

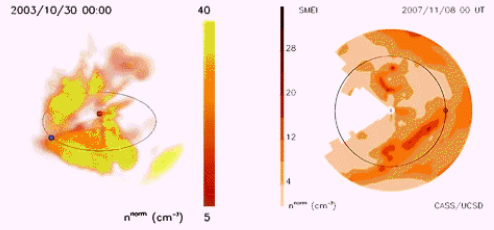
Comparisons

Direct | Difference | Reconstructed



SMEI 3D Reconstructions

45° West of Sun-Earth | Ecliptic Cuts



We will update these data products as time and funding permits. These data are presented in their entirety on the Web both for our use and for colleagues who are interested in specific events present in these data. An attempt has been made to make as consistent a data set as possible from the SMEI analyses in order to search for and analyze possible errors in the processing and in the 3D reconstructions. We are actively analyzing these data sets ourselves, and we will upgrade our analyses as and when newer data analysis techniques or further modifications of current analyses become available; and so these data should be viewed as a "work in progress" rather than a final result.

For more information please Click Here .

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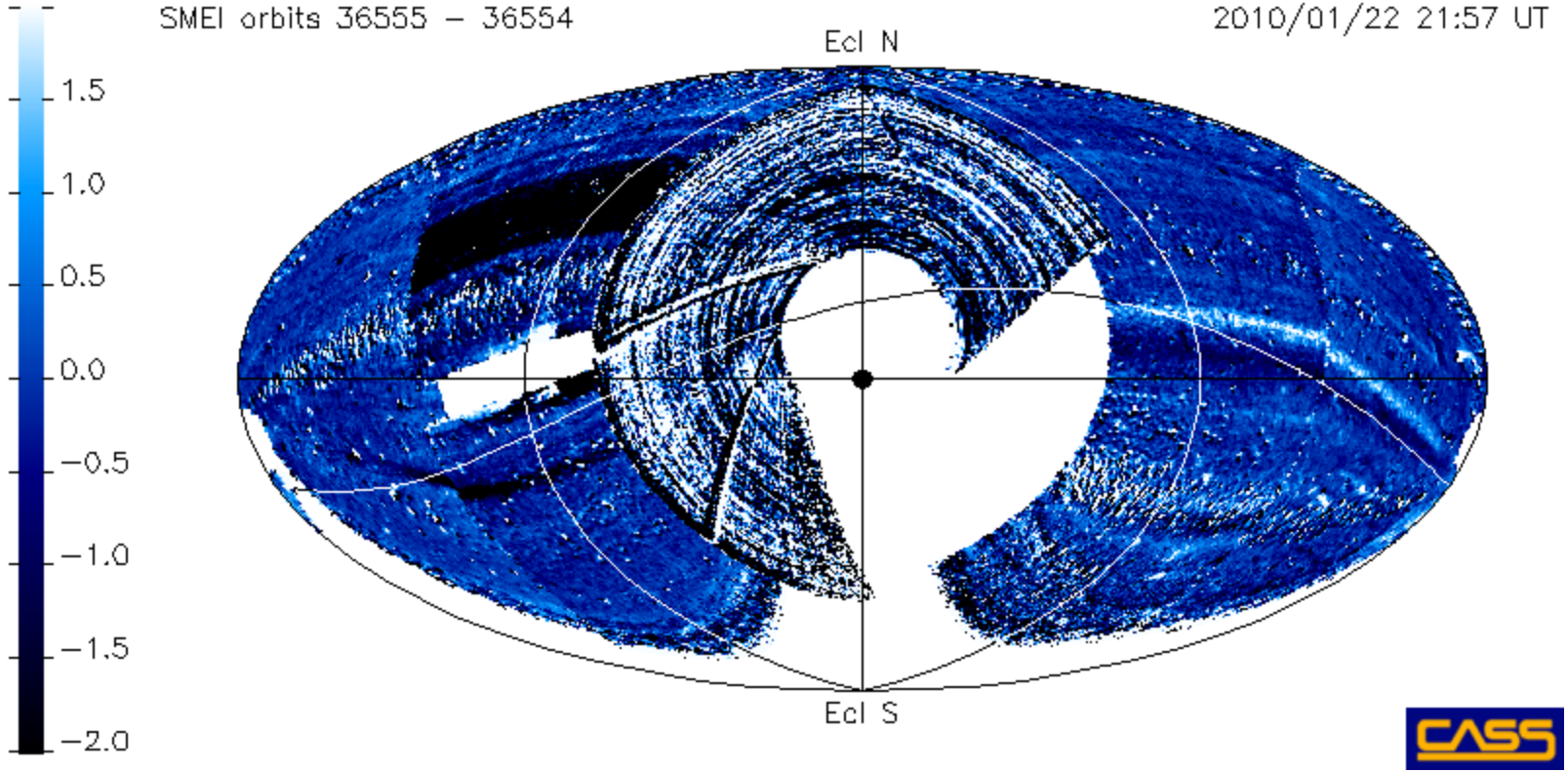
Heliospheric Tomography

Heliospheric direct images



SMEI 3-D reconstructed difference images

Current STELab IPS Heliospheric Analyses

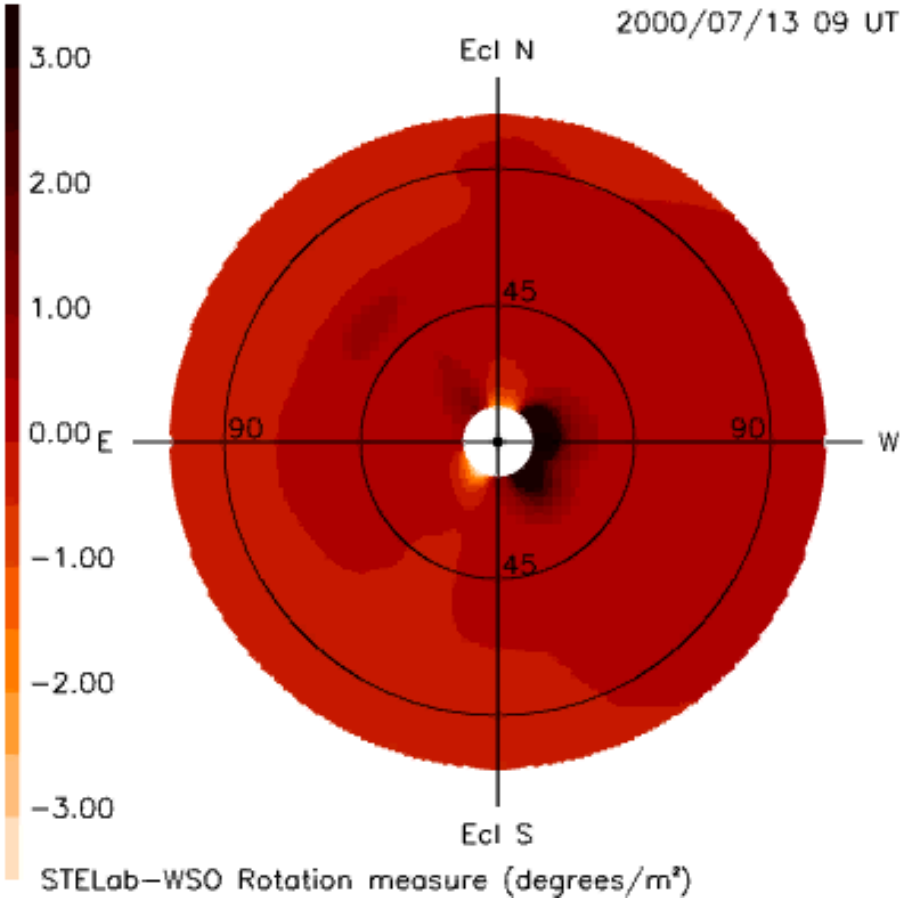
New STELab IPS array at Toyokawa - photo February 17, 2007
(array now operates)

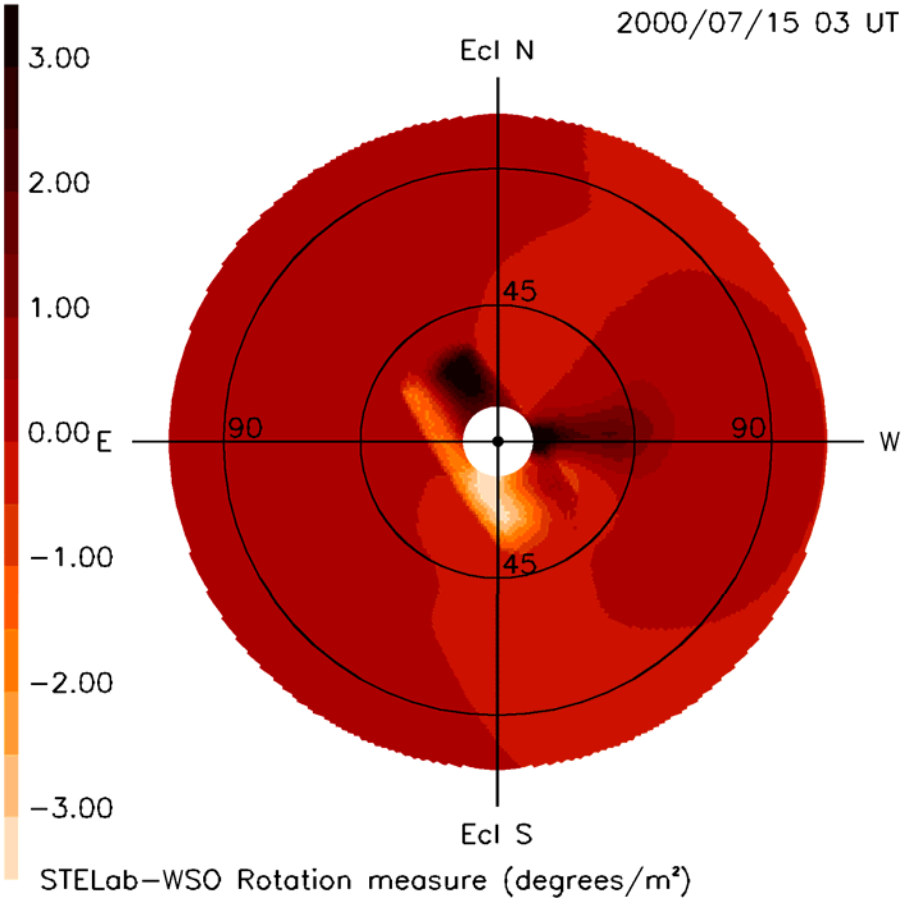
Next

Heliospheric Tomography

Jackson, B.V., et al., 2008, *URAS Workshop*

Faraday rotation tomography





Background Field, 3D UCSD Density

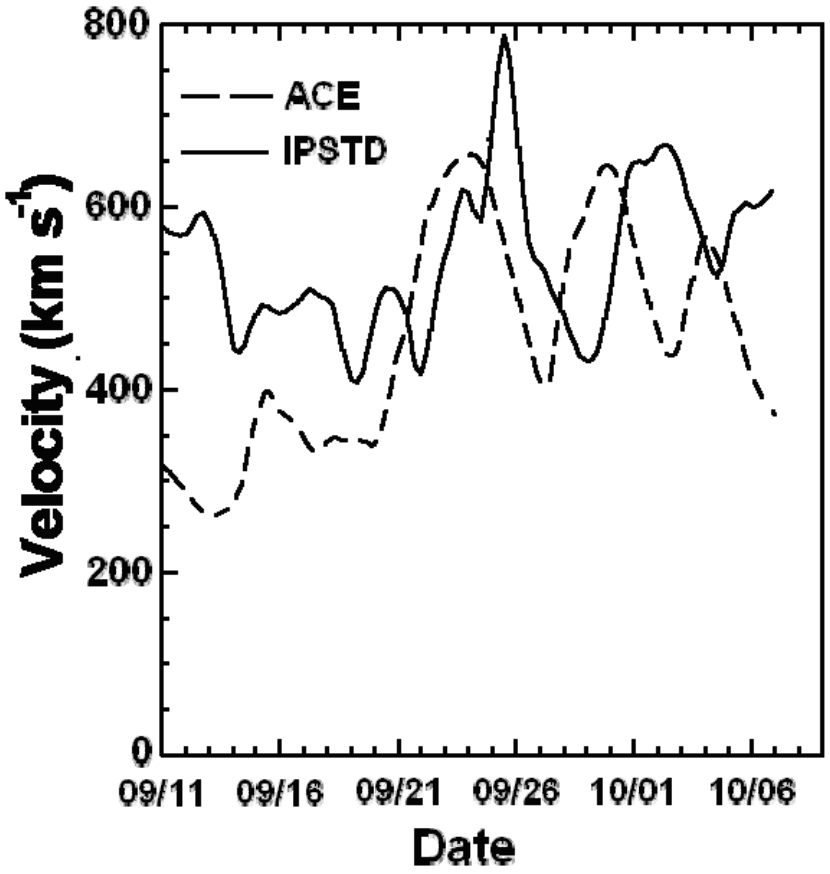
Background Field, 3D UCSD Density, Mulligan “Can”

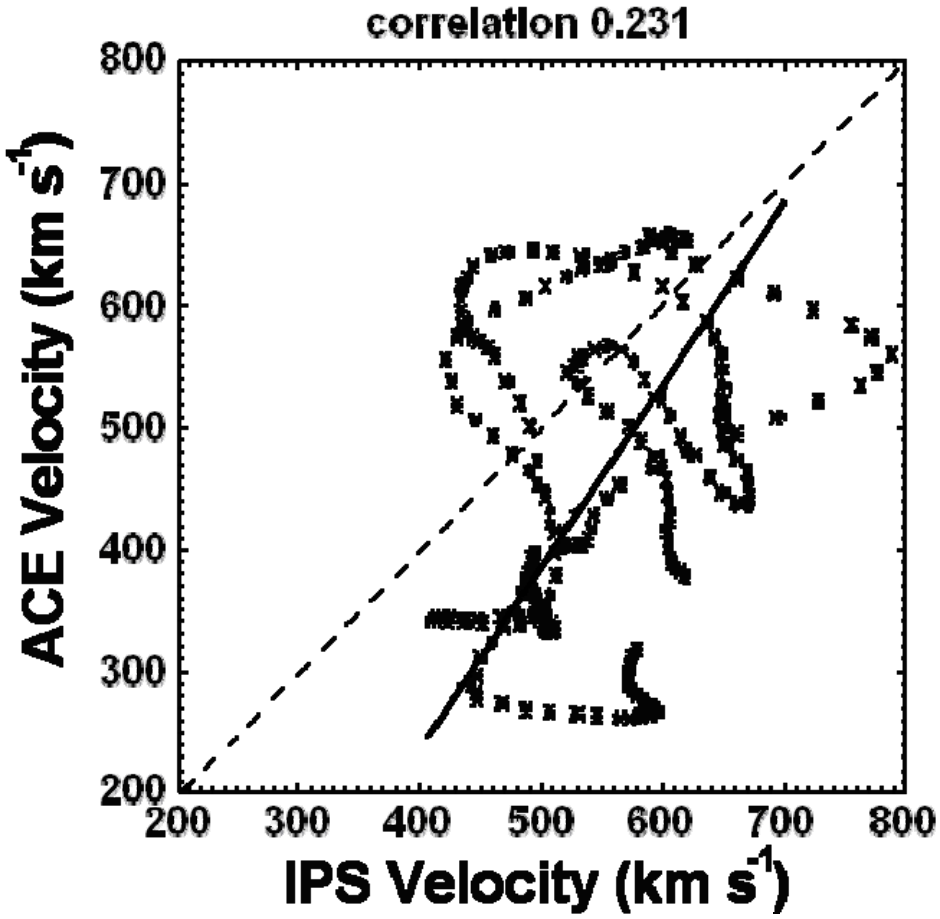
Next

Heliospheric Tomography

Jackson, B.V., et al., 2010, *Solar Phys*. (in press).

Heliospheric 3D-reconstructions





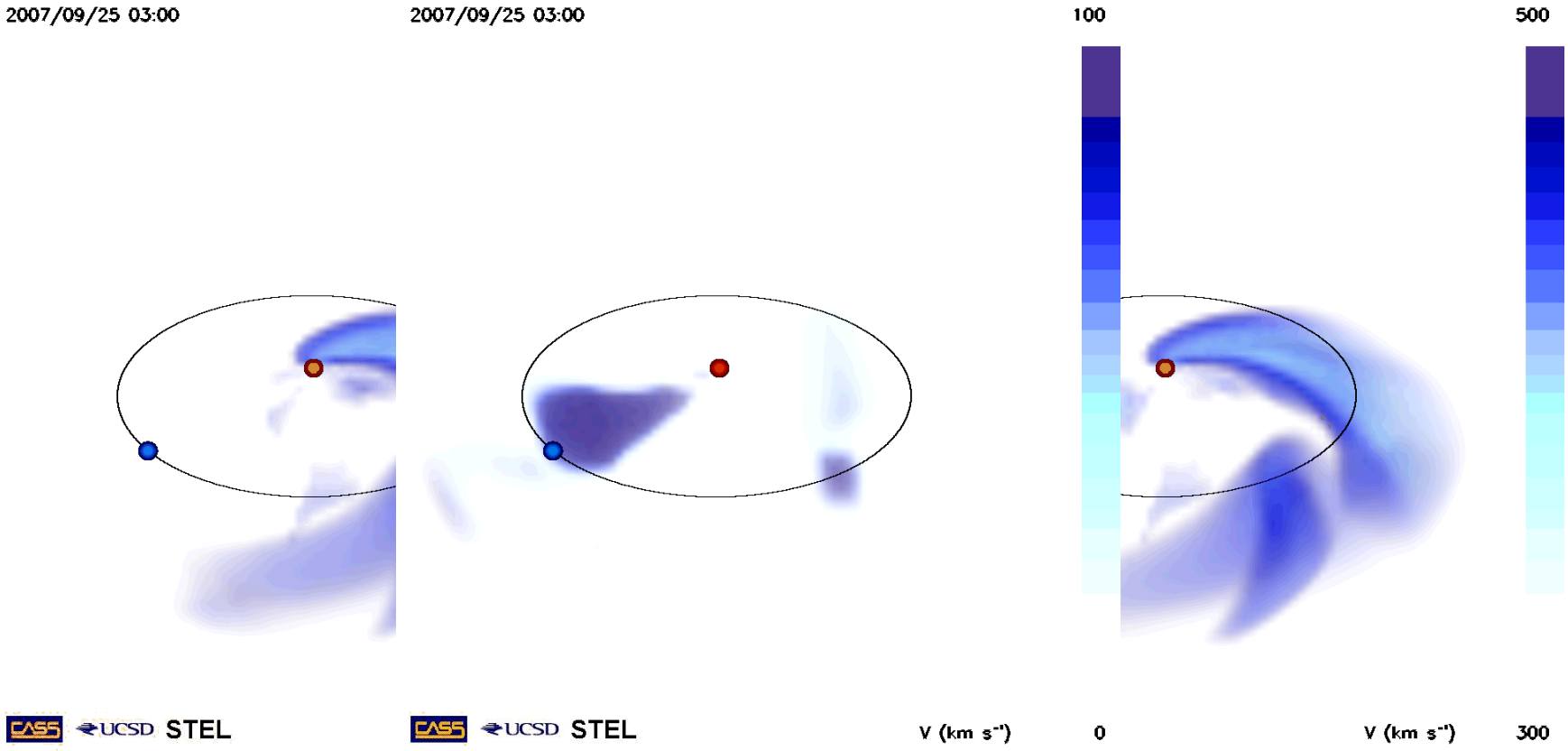
Sometimes the 3-D Reconstruction does not work well

Next

Heliospheric Tomography

Jackson, B.V., et al., 2010, *Solar Phys*. (in press).

Heliospheric 3D-reconstructions



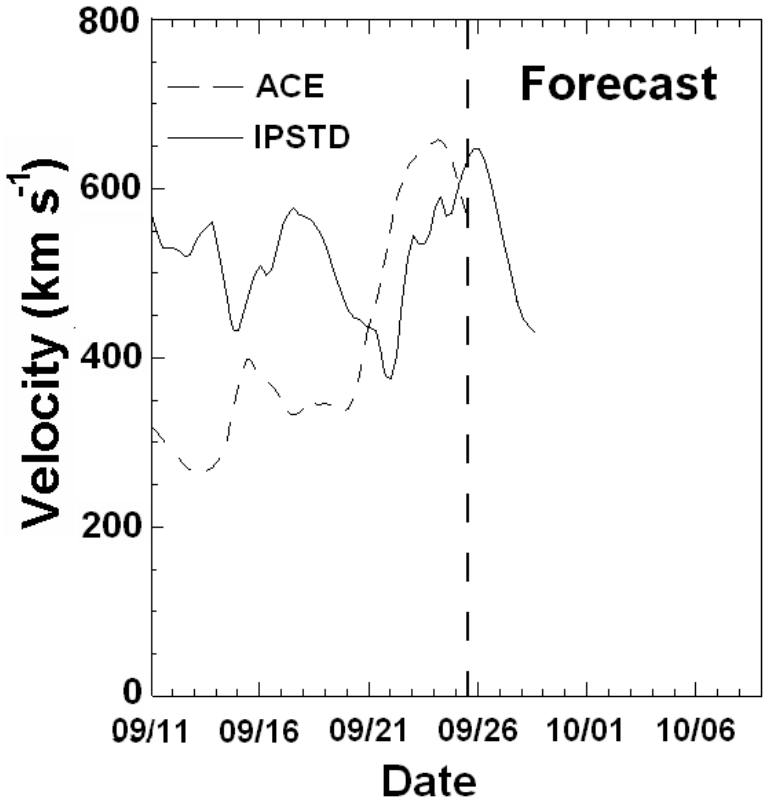
Sometimes the 3-D Reconstruction does not work well

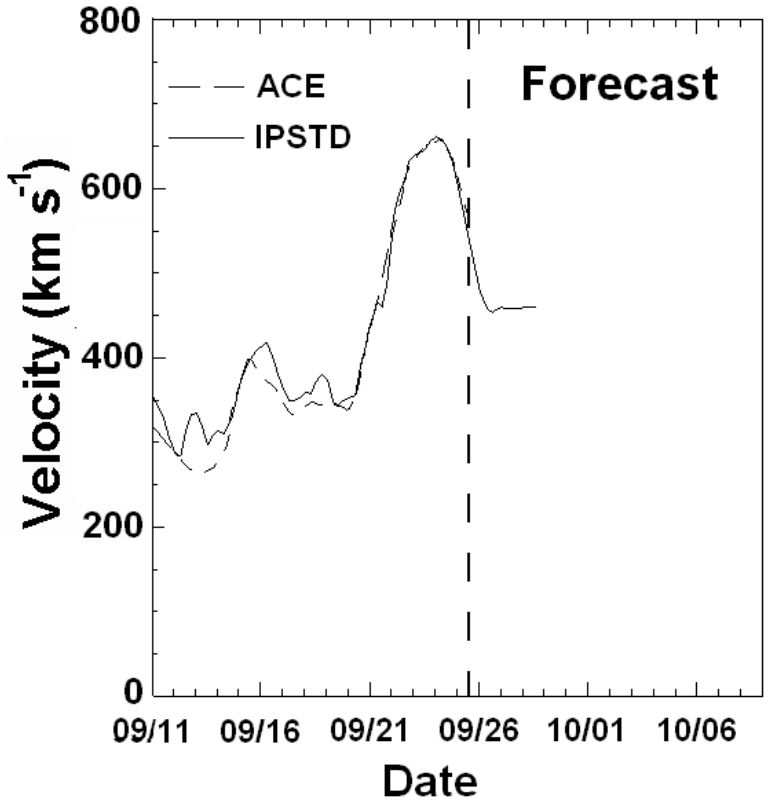
Next

Heliospheric Tomography

Jackson, B.V., et al., 2010, *Solar Phys*. (in press).

Heliospheric 3D-reconstructions





Sometimes the 3-D Reconstruction does not work well

Heliospheric Tomography

Summary:

The Model: (not a model but a fit to data)

- Allows a low-resolution 3-D reconstruction over time of most of the heliosphere.

We've Learned some things:

- How well our data collection system works.
- The extent, shape, 3D mass, and energies of CMEs.
- The latitude-longitude relationship and temporal evolution of velocity structures globally in the heliosphere, and to CMEs.
- In the SMEI highest-resolution tomography, the shock density enhancements analyzed to date do not show a uniform shell-like extent. (?don't know why).

The Future:

- Better research with data sets that now provide a uniform answer.
- Incorporation of the *in-situ* measurements into the tomography.
- Incorporation of 3-D MHD into the tomography code.
- FR inversion to obtain vector fields.