IPS 3D reconstructions and their comparison with STEREO and Wind spacecraft

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New STELab Toyokawa IPS array
(B.V. Jackson, 2006)

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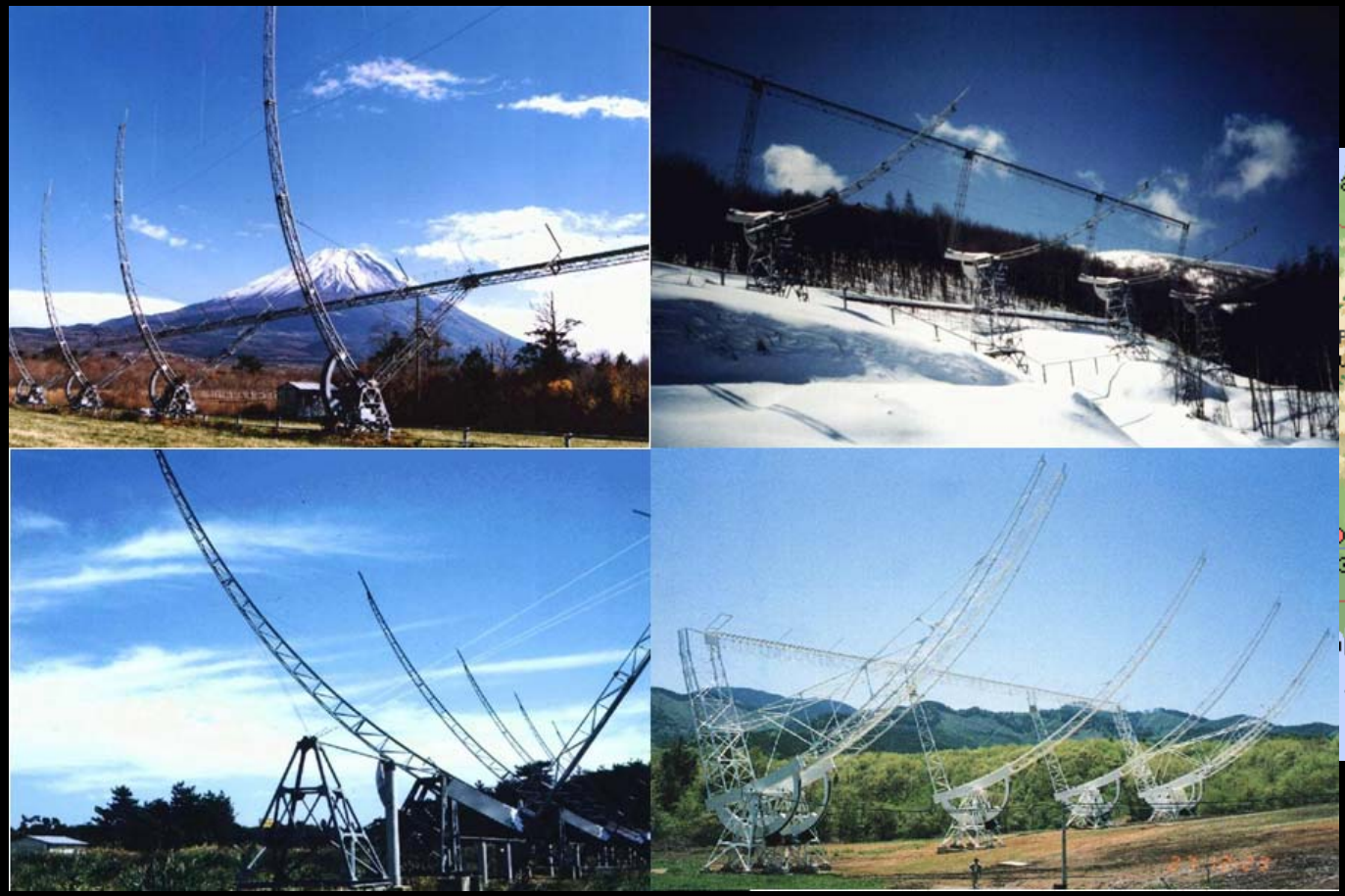
Abstract

We present results from simultaneous Interplanetary Scintillation (IPS) and STEREO measurements/observations using 3D reconstructions from the Solar-Terrestrial Environment Laboratory (STELab) of the Whole Heliosphere Interval (WHI) – Carrington rotation 2068 (CR2068). This is part of the world-wide IPS community's International Heliosphysical Year (IHY) collaboration. We show the structure of the inner heliosphere during this time and how our global reconstructions compare with in-ecliptic deep-space spacecraft measurements such as those taken by Wind and the twin STEREO spacecraft. These 3D tomographic reconstructions of the inner heliosphere have been successfully used for over a decade to visualize and investigate the structure of the solar wind and its various features such as transients and co-rotating regions.

IPS Arrays Used in this Study



The STELab antennas (four images in a square): Fuji (top left), Sugadaira (top right), (old) Toyokawa (bottom left), and Kiso (bottom right); location map (far right)

(Courtesy of http://stesun5.stelab.nagoya-u.ac.jp/uhf_ant-e.html)

Others also include: EISCAT/ESR, northern Scandinavia; MEXART, Mexico; MERLIN, UK; Pushchino, Russia; MWA, Australia; and LOFAR, Netherlands

Interplanetary Scintillation (speed)

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

Lines-of-sight to radio source

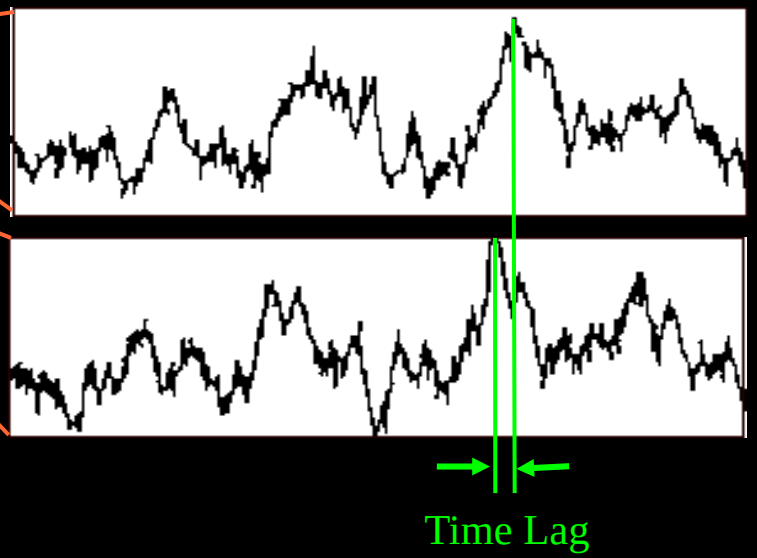
Source

Solar Wind

Sun

(Not to scale)

Radio signal scintillates due to density variations in the solar wind



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

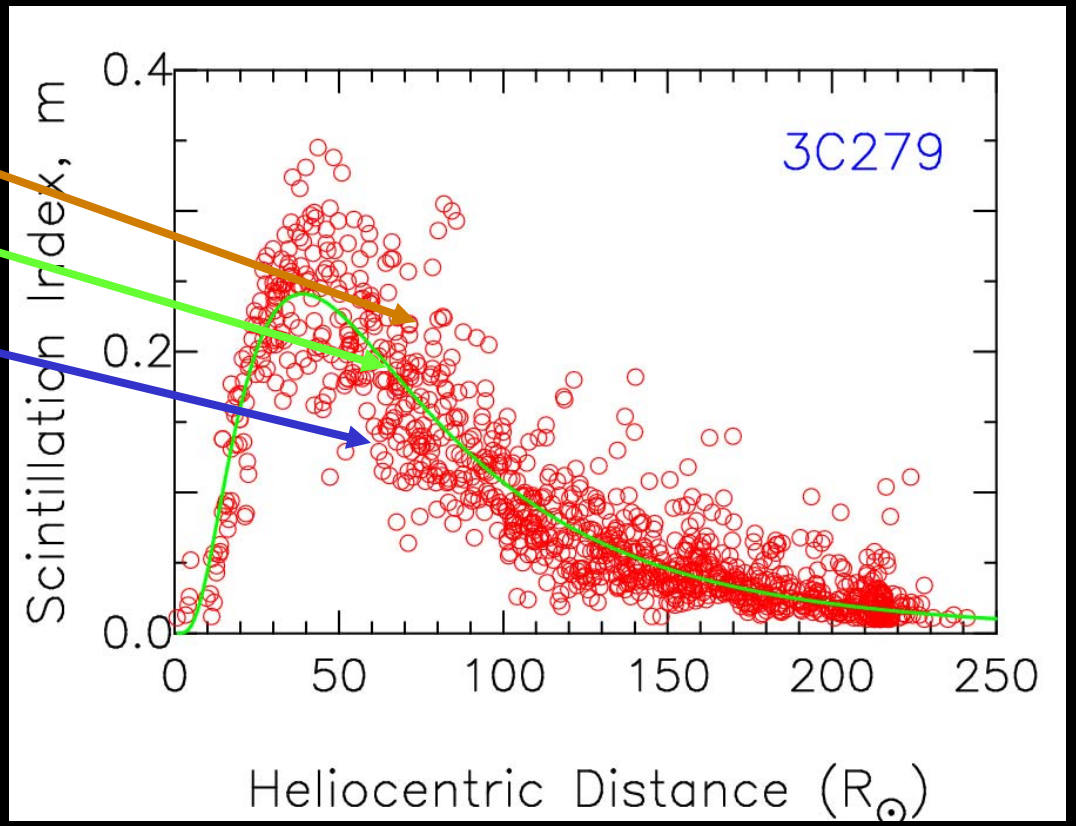
By suitably transforming and calibrating the intensity scintillation time series, the solar wind speed can also be obtained from the spectrum of a single-site IPS observation

Interplanetary Scintillation (*g*-level/density)

Density Turbulence

- Scintillation index, m, is a measure of level of turbulence
- Normalized Scintillation index, g = m(R) / <m(R)>

- **g > 1 → enhancement in δNe**
- **g ≈ 1 → ambient level of δNe**
- **g < 1 → rarefaction in δNe**



(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

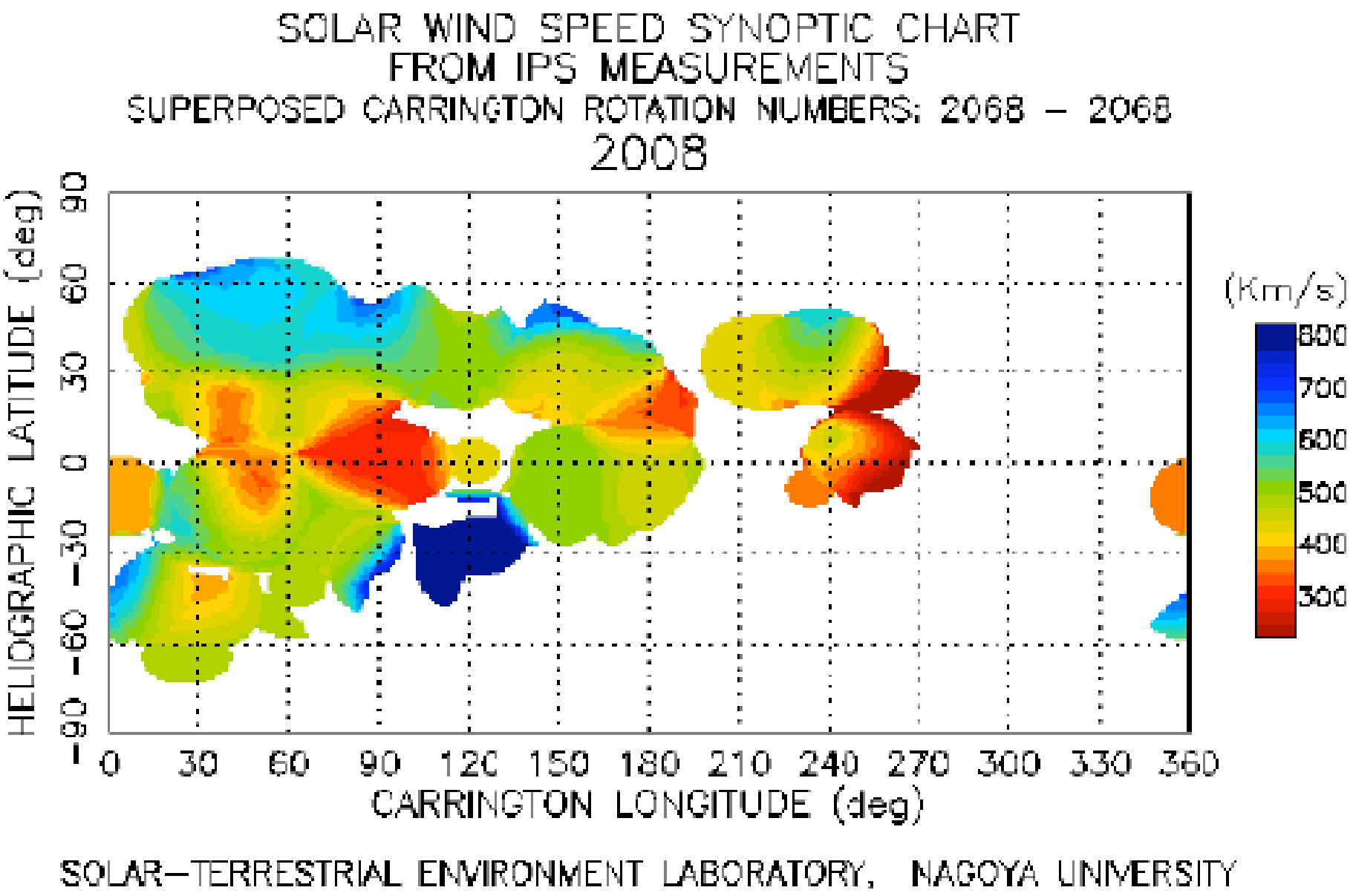
Time Period Discussed Here

Whole Heliospheric Interval (CR2068)
2008/03/20-2008/04/16

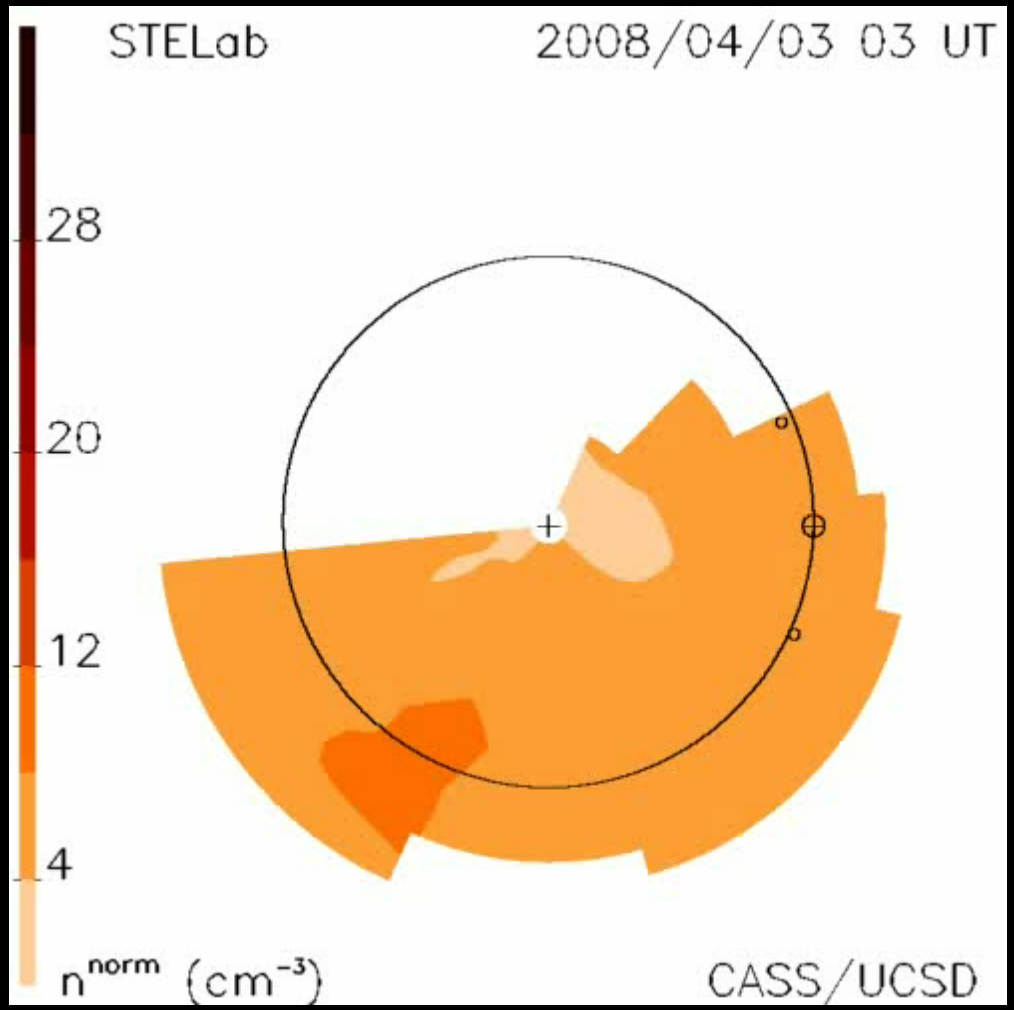
STELab IPS observations commenced 2008/04/03 and were interrupted again for some time from 2008/04/22

Taken from: Bisi, M.M., B.V. Jackson, A. Buffington, J.M. Clover, P.P. Hick, and M. Tokumaru, "Low-Resolution STELab IPS 3D Reconstructions of the Whole Heliospheric Interval and Comparison with in-Ecliptic Solar Wind Measurements from STEREO and Wind Instrumentation", *Solar Physics (undergoing minor referee-suggested changes)*, 2009

STELab IPS Synoptic Coverage of Velocity

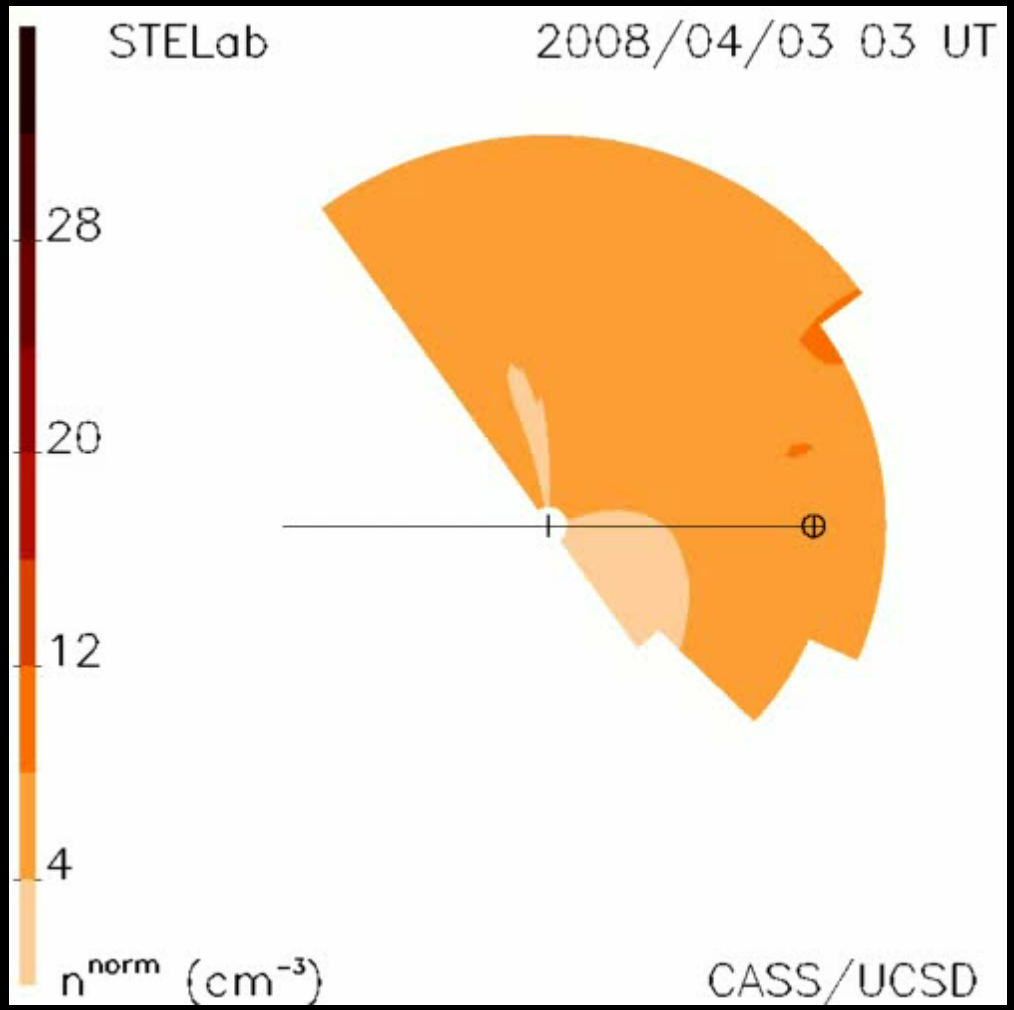


STELab IPS WHI Density Reconstruction (1)



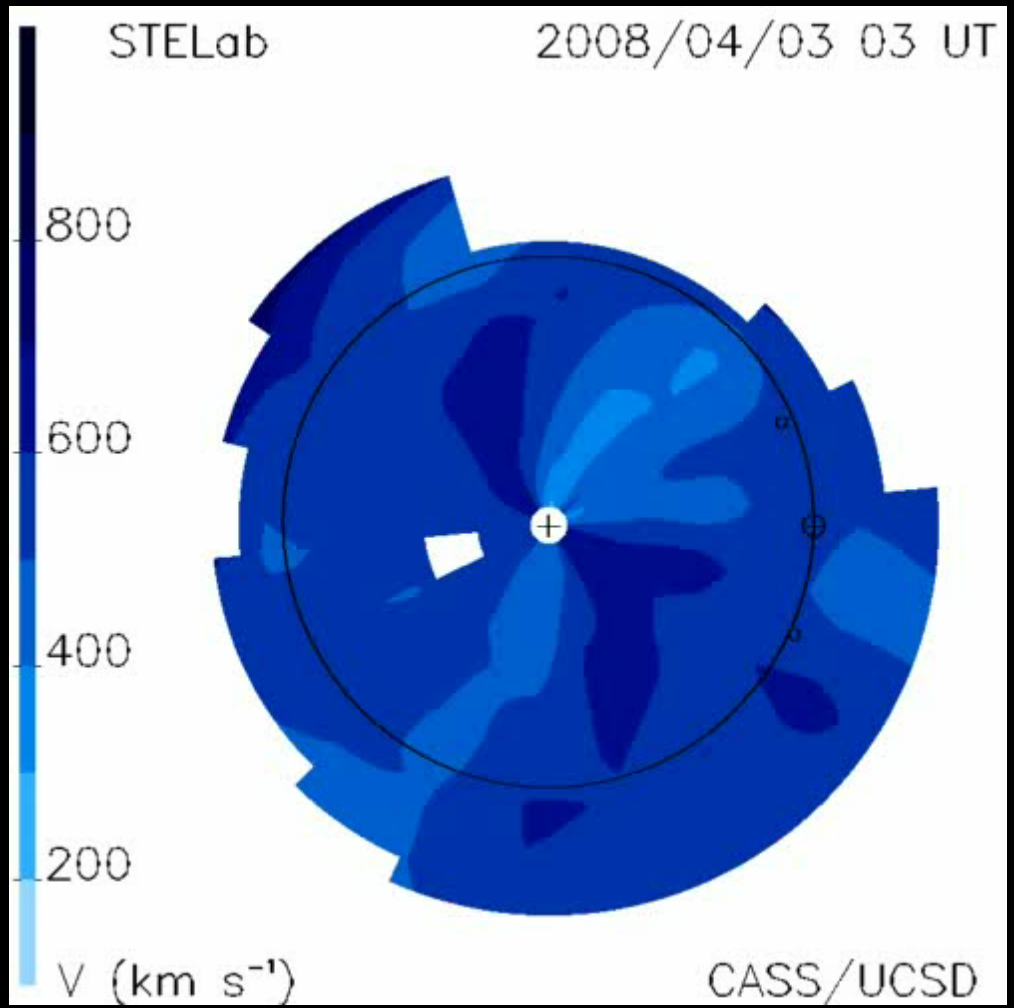
STELab IPS density reconstruction as seen in the ecliptic plane for CR2068 when data were available showing Earth and the two STEREO spacecraft

STELab IPS WHI Density Reconstruction (2)



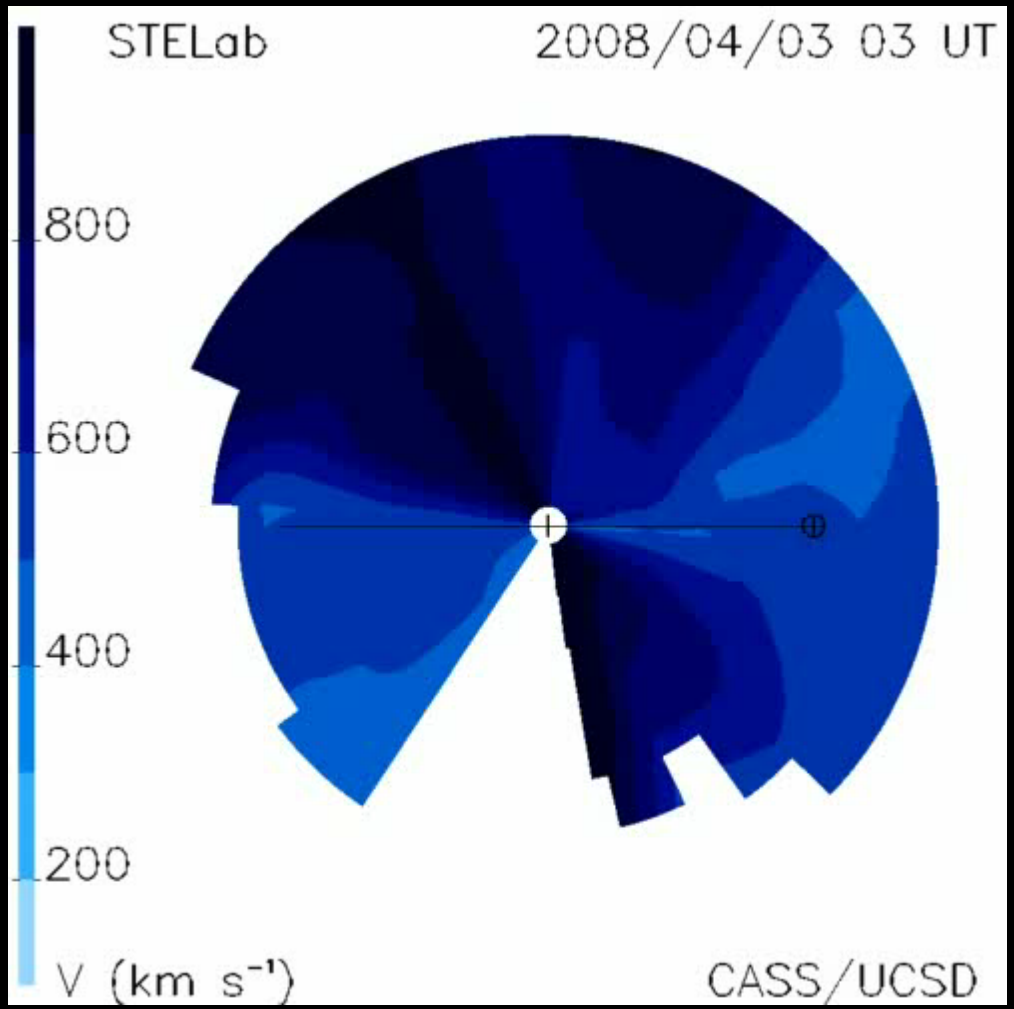
STELab IPS density reconstruction as seen in the meridional plane for CR2068 when data were available showing Earth and its orbit across the ecliptic

STELab IPS WHI Speed Reconstruction (1)



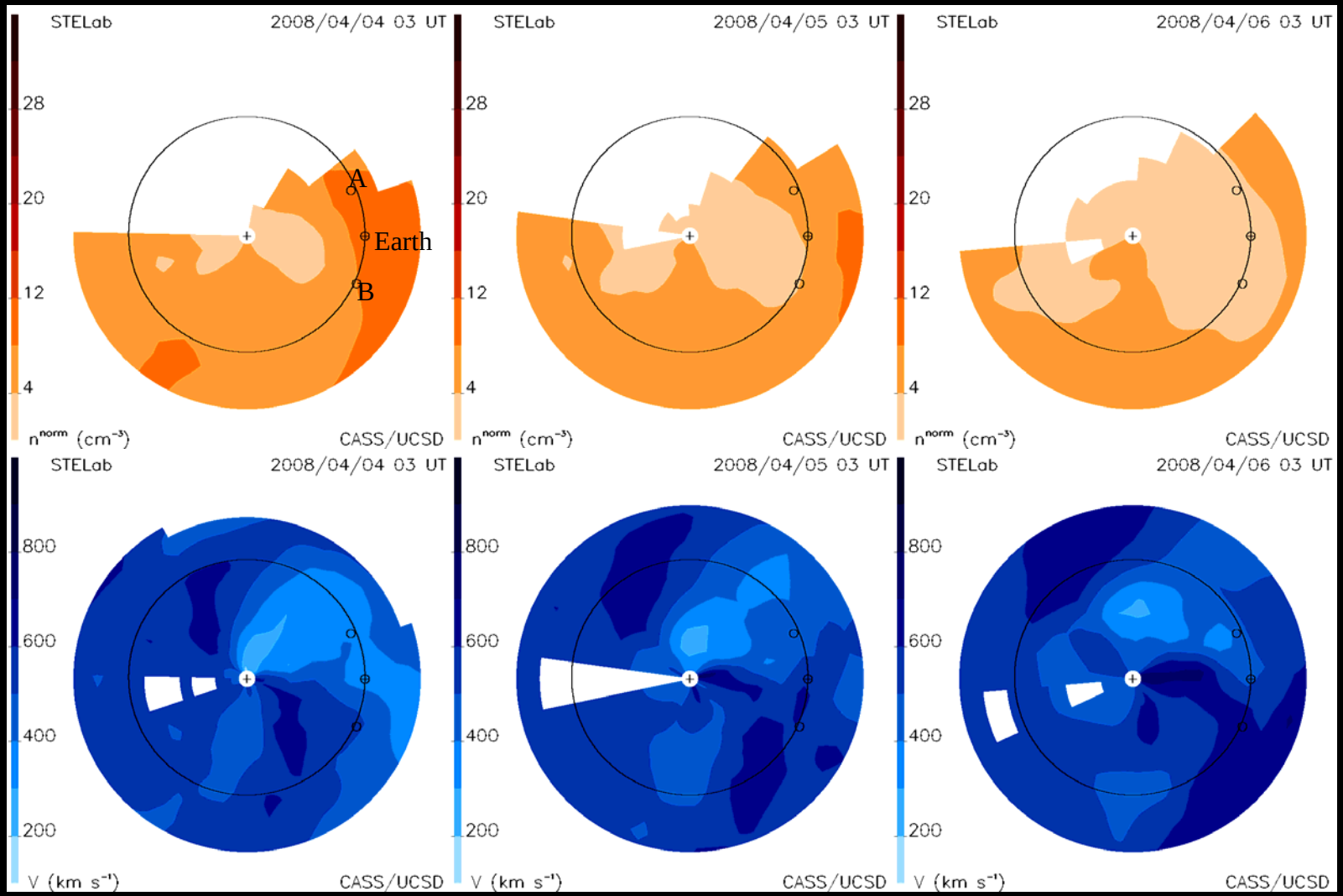
STELab IPS speed reconstruction as seen in the ecliptic plane for CR2068 when data were available showing Earth and the two STEREO spacecraft

STELab IPS WHI Speed Reconstruction (2)



STELab IPS speed reconstruction as seen in the meridional plane for CR2068 when data were available showing Earth and its orbit across the ecliptic

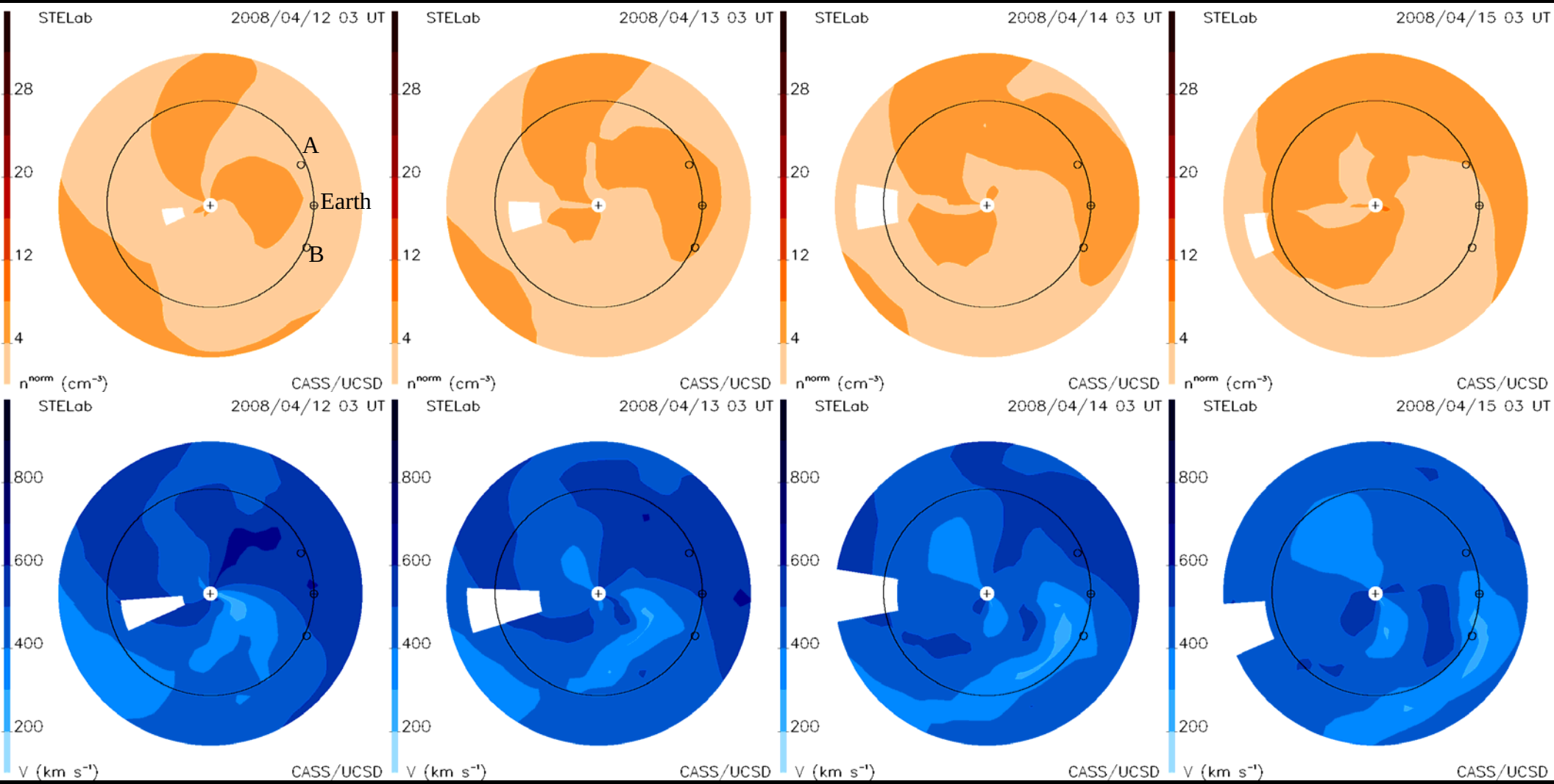
CIR: 04-06 April 2008



Ecliptic cut extractions from the 3D tomography: looking down from North of the ecliptic in both density (top) and velocity (bottom)

A period of three days is shown here, centred on 03:00UT for each of the days

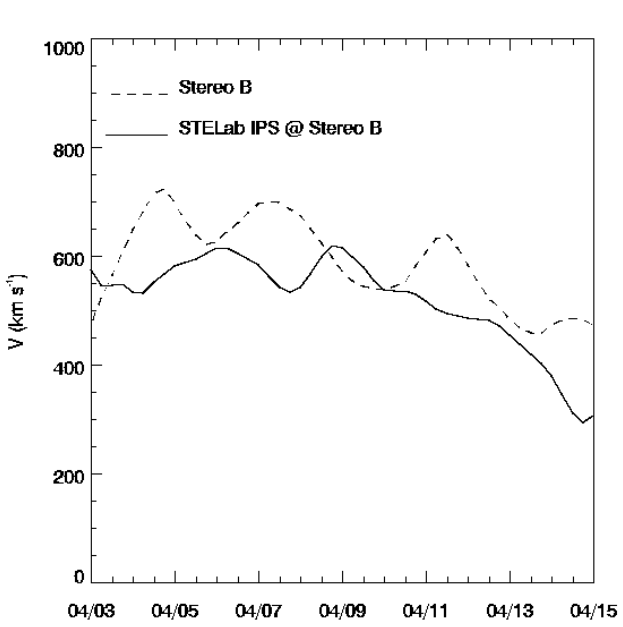
CME: 12-15 April 2008

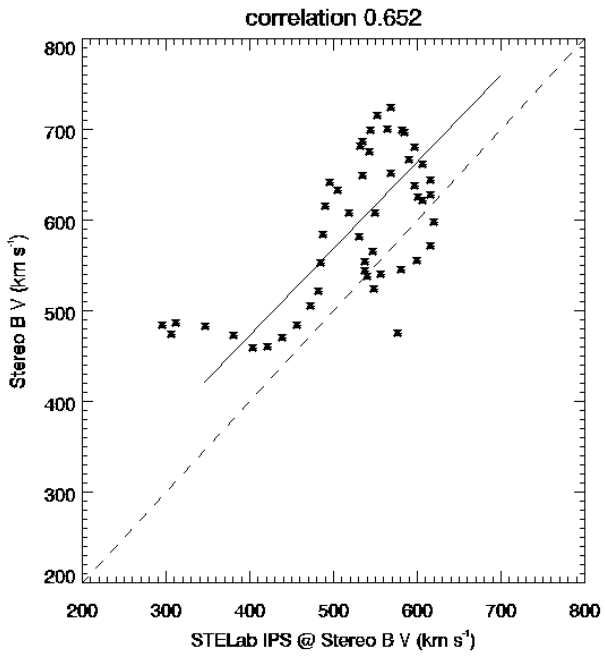


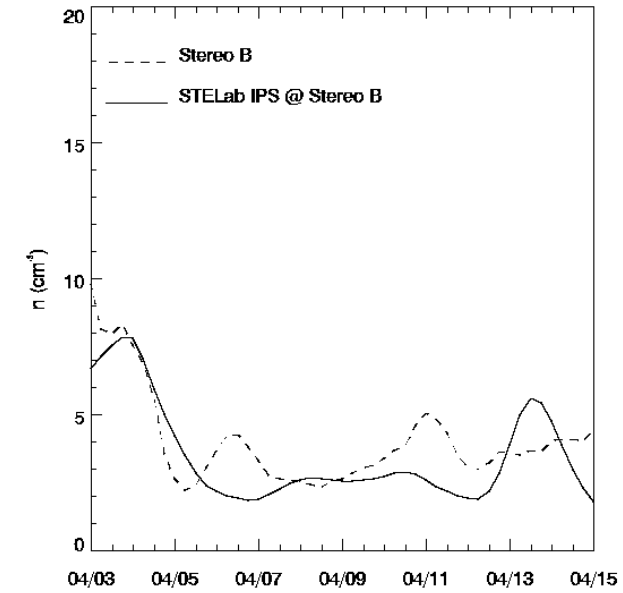
Ecliptic cut extractions from the 3D tomography: looking down from North of the ecliptic in both density (top) and velocity (bottom)

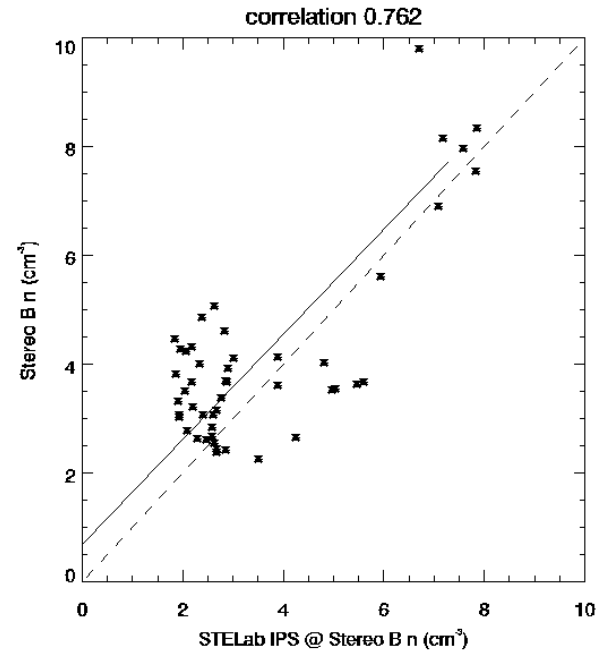
A period of four days is shown here, centred on 03:00UT for each of the days

STEREO-B *in situ* Comparison

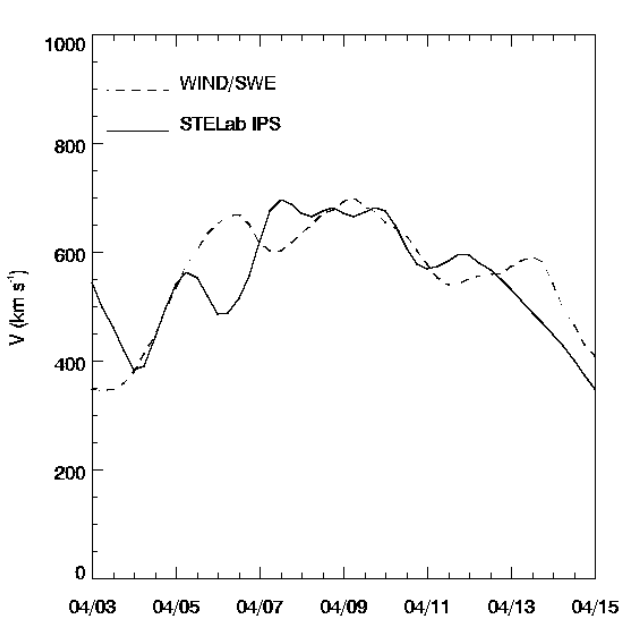


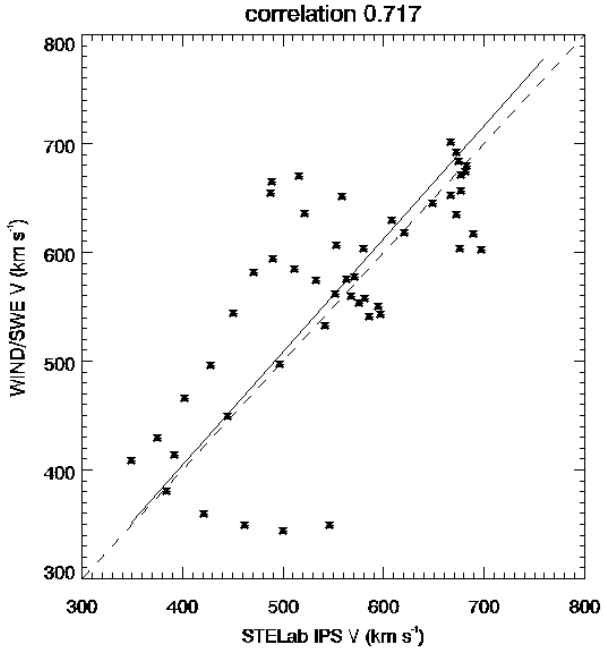


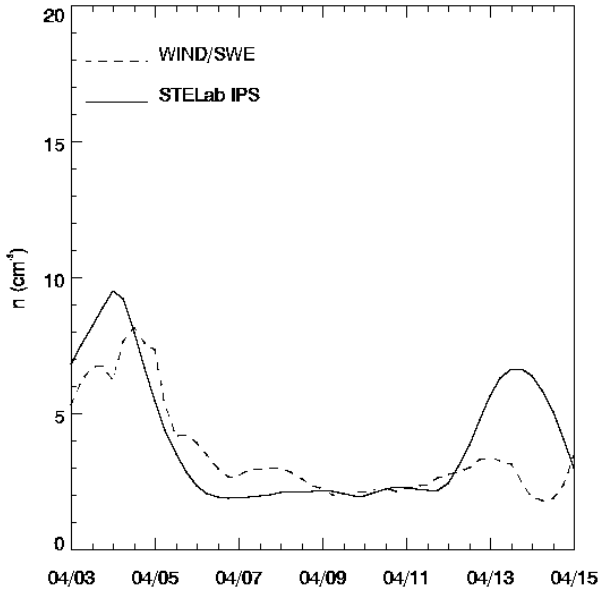


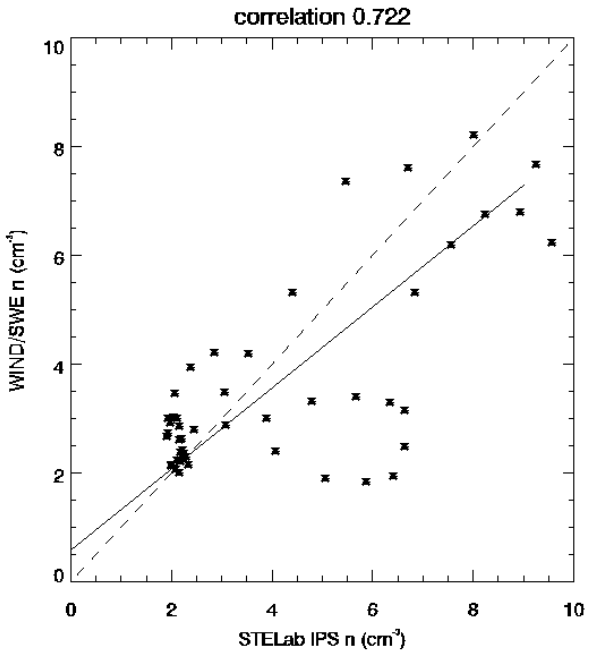


Wind *in situ* Comparison

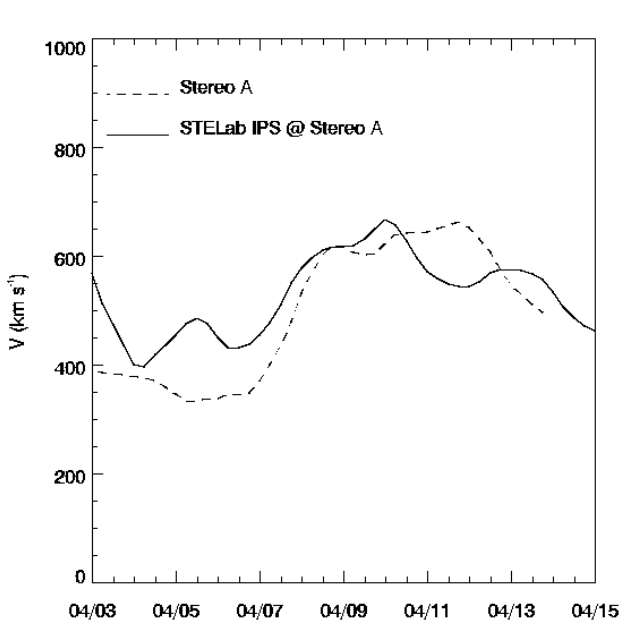


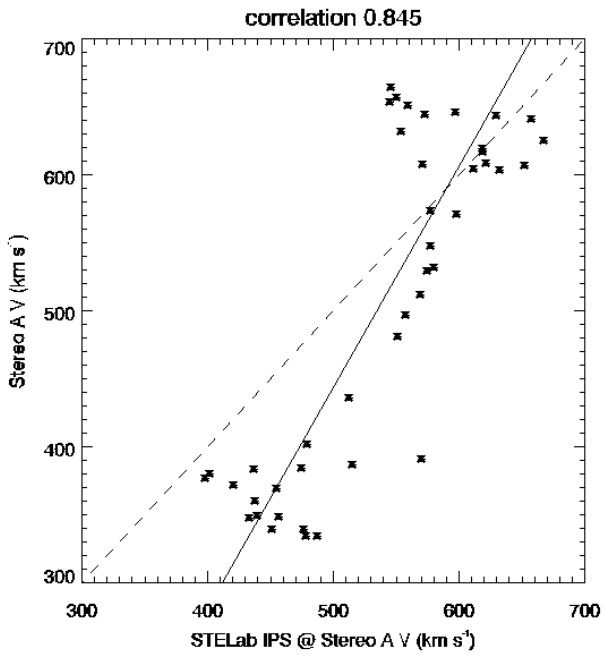


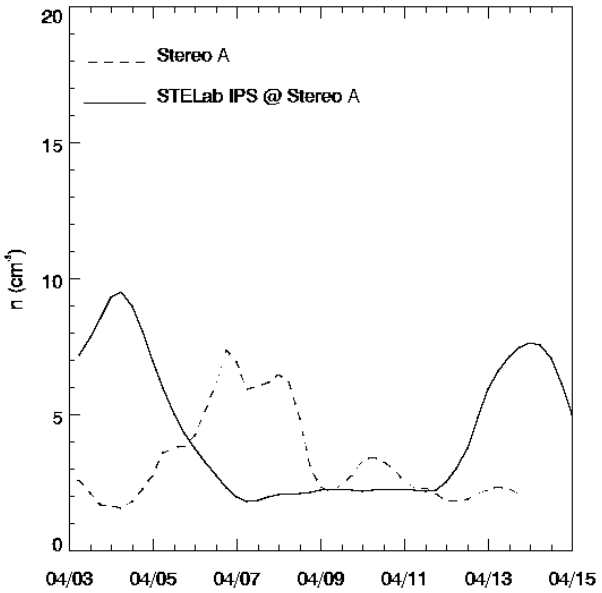


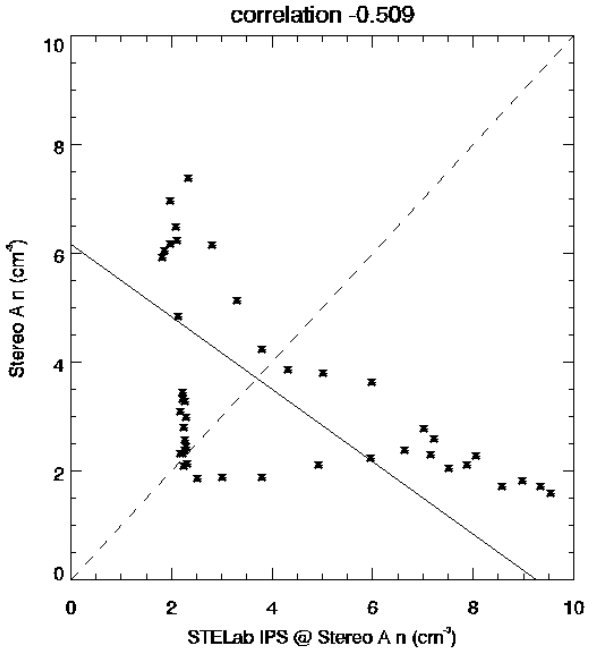


STEREO-A *in situ* Comparison









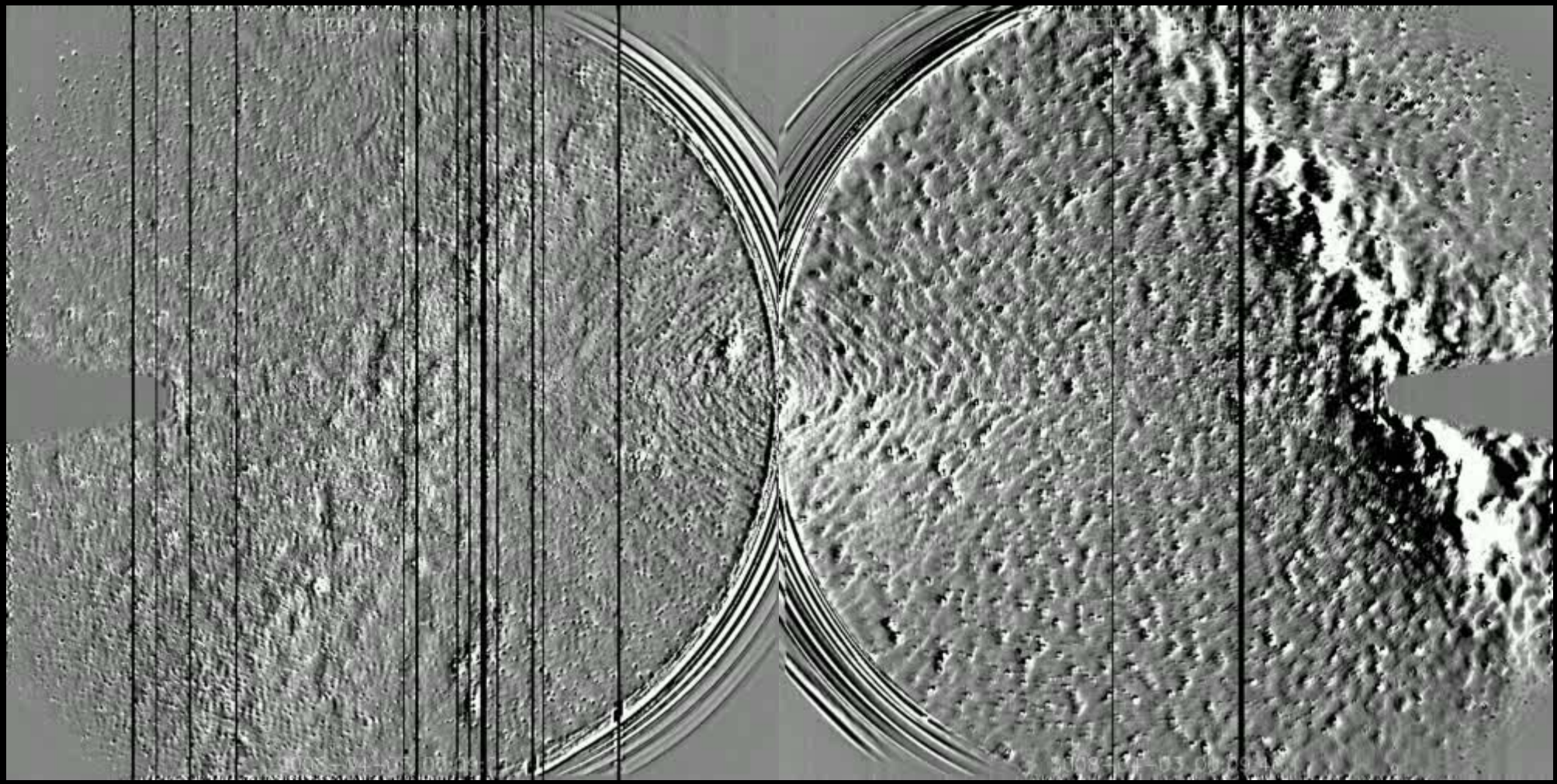
Time Period Discussed Here Summary

CIR and CME features simultaneously???

CIR in speed and CME in density from the *in situ* measurements and the 3D reconstructions tend to agree (but *g*-level observations are few to the West, *i.e.* in the direction of STEREO-A…)

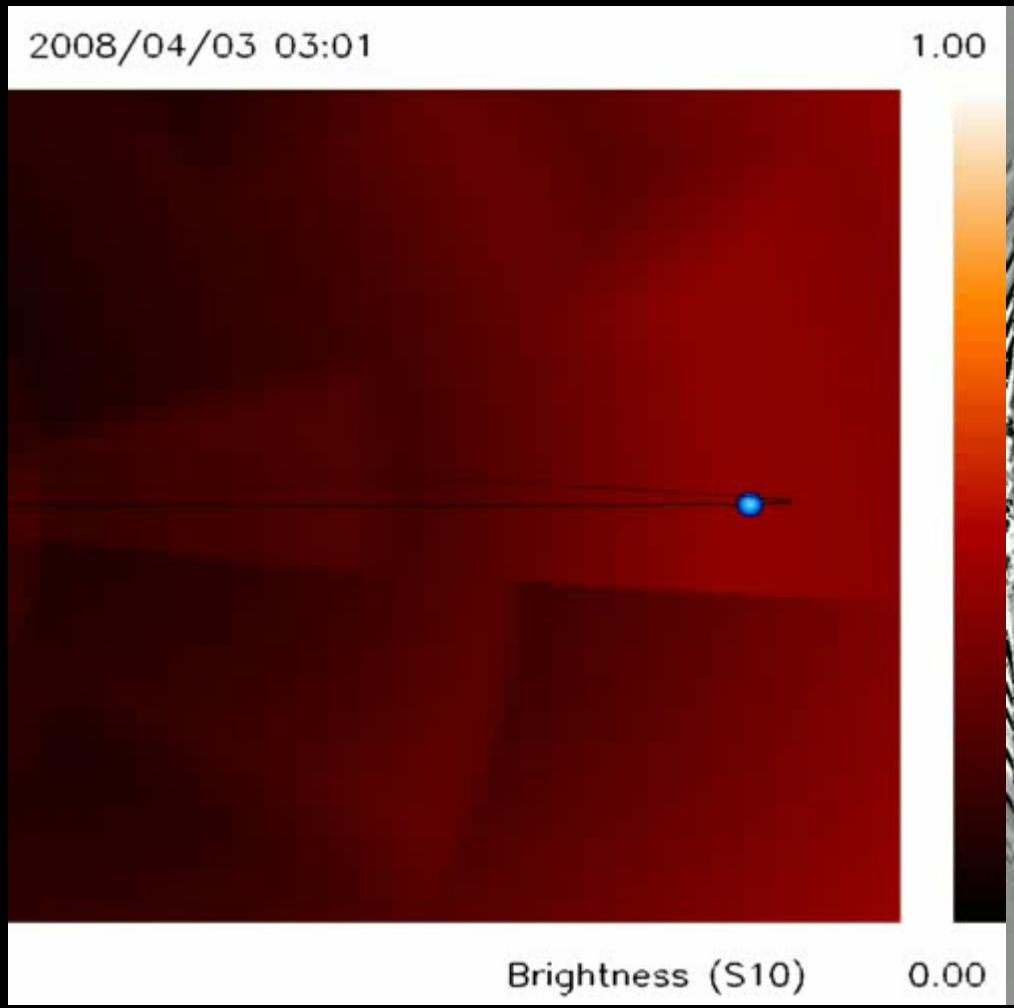
What about seen as brightness?

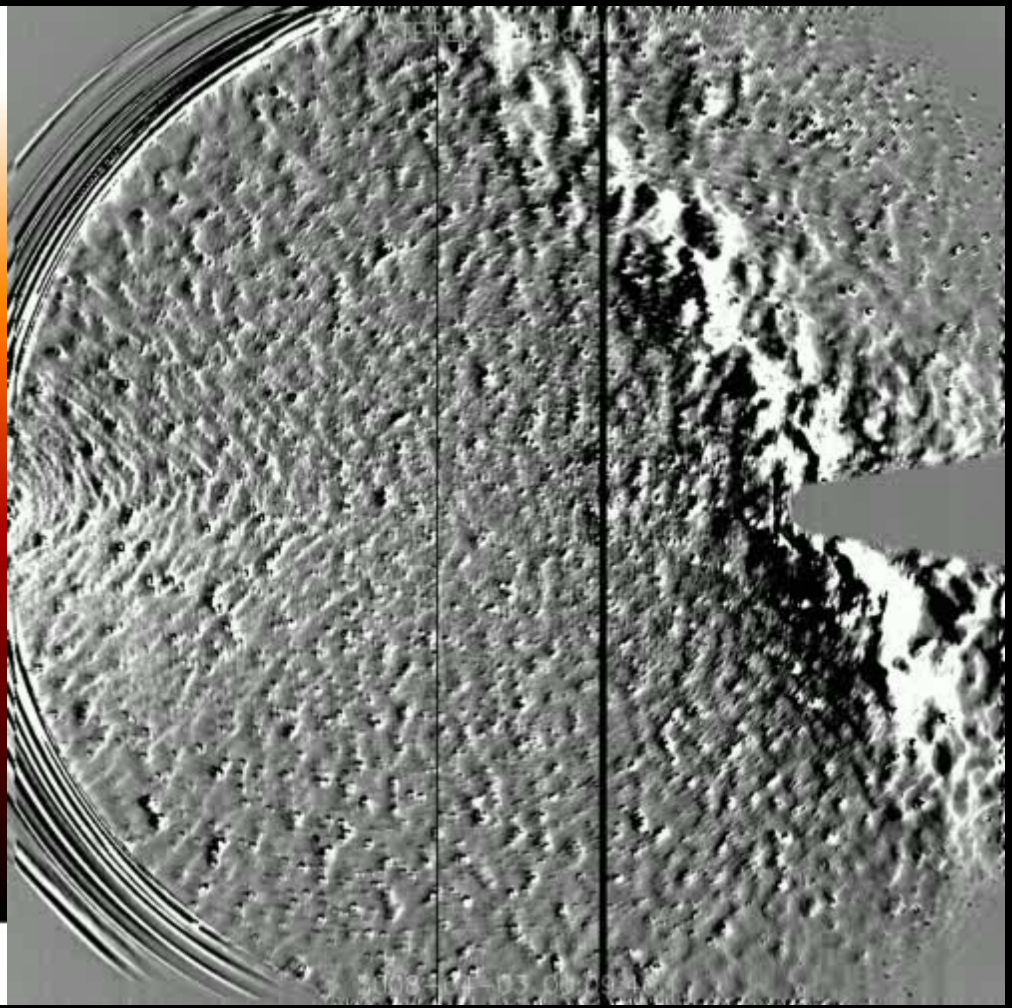
STEREO HI Movies



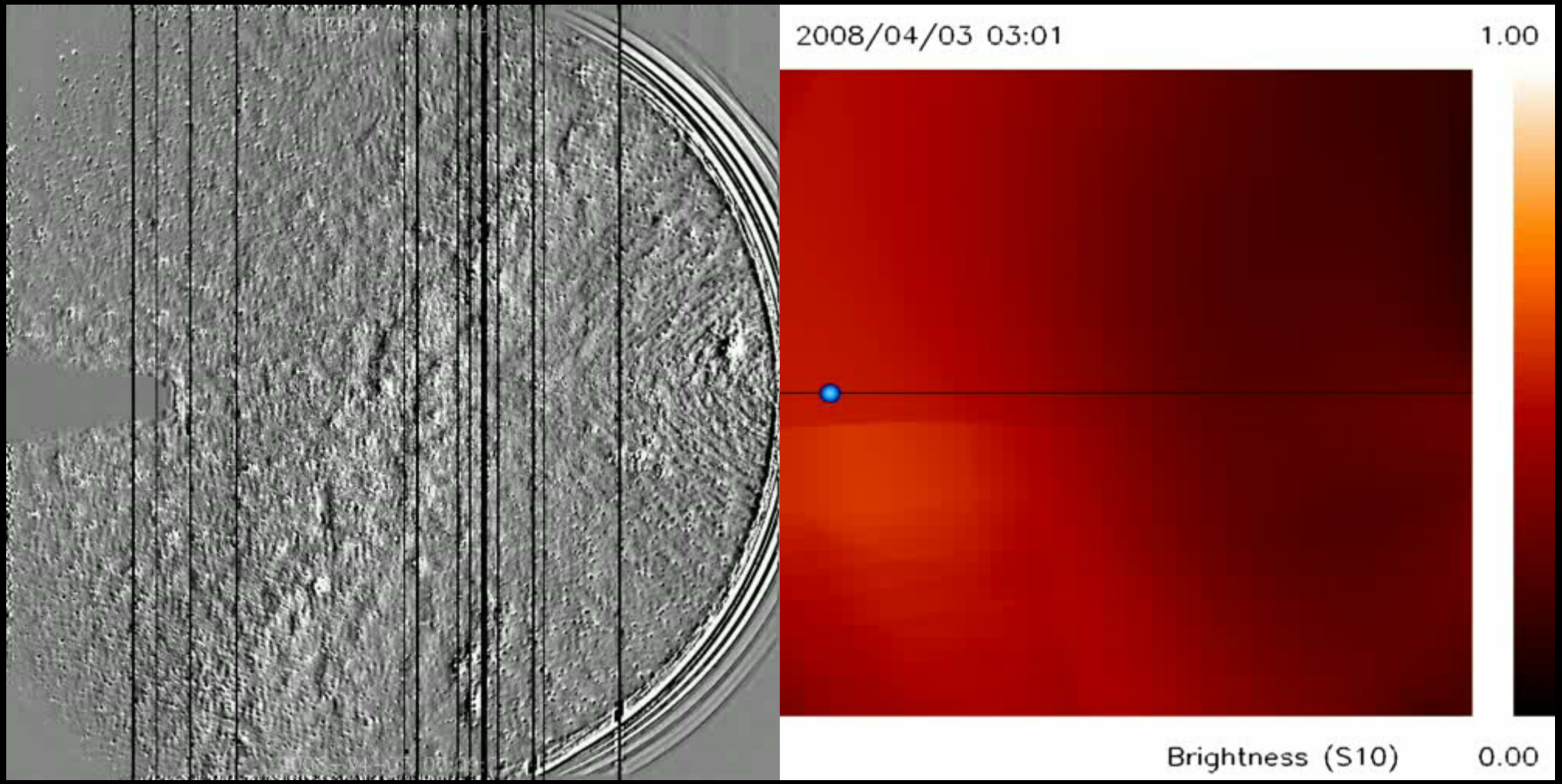
(Original images courtesy of http://stereo-ssc.nascom.nasa.gov/cgi-bin/images)

STEREO-B Brightness Comparison





STEREO-A Brightness Comparison



Summary

- We follow CIR and CME structure from near the solar surface outward until they are observed *in situ* near Earth and at other deep-space spacecraft

- The WHI-period 3D-tomographic reconstructions using STELab IPS data give very good comparison with “ground truth” *in situ* measurements in five out of the six comparisons shown here

- We’re in the process of further *in situ* comparisons with Wind and the twin STEREO spacecraft, and other deep-space spacecraft; particularly where other interesting observations/measurements overlap

Acknowledgements and Primary Reference

Thanks to the Wind|SWE and STEREO|PLASTIC teams for making their *in situ* data available on the Web. Thanks also to the STEREO|SECCHI team for making the HI-2 (A and B) difference images available on the Web.

- Bisi, M.M., B.V. Jackson, A. Buffington, J.M. Clover, P.P. Hick, and M. Tokumaru, "Low-Resolution STELab IPS 3D Reconstructions of the Whole Heliospheric Interval and Comparison with in-Ecliptic Solar Wind Measurements from STEREO and Wind Instrumentation", *Solar Physics (undergoing minor referee-suggested changes)*, 2009

http://stesun5.stelab.nagoya-u.ac.jp/uhf_ant-e.html
http://stereo-ssc.nascom.nasa.gov/cgi-bin/images

WORKSHOP!!!

Remote Sensing of the Inner Heliosphere (IPS/White-light/*in situ*) Workshop, Aberystwyth, Wales (UK), 05-08 May 2009

Follows the STEREO-3/SOHO-22 Workshop in Bournemouth, England (UK)

Details at:

http://heliosphere-2009.dph.aber.ac.uk/

Please E-Mail me (*mmbisi@ucsd.edu*) if you are interested (and haven't already done so)…

Thanks for listening!

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

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