Highlights of Astronomy, Volume 15
XXVIIth IAU General Assembly, August 2009
Ian F. Corbett, ed.

doi:10.1017/S1743921310010331

A Summary of 3-D Reconstructions of the Whole Heliosphere Interval and Comparison with in-Ecliptic Solar Wind Measurements from STEREO, ACE, and Wind Instrumentation

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Abstract. We present a summary of results from simultaneous Solar-Terrestrial Environment Laboratory (STELab) Interplanetary Scintillation (IPS), STEREO, ACE, and Wind observations using three-dimensional reconstructions of the Whole Heliosphere Interval – Carrington rotation 2068. This is part of the world-wide IPS community's International Heliosphysical Year (IHY) collaboration. We show the global structure of the inner heliosphere and how our 3-D reconstructions compare with in-ecliptic spacecraft measurements.

Keywords. (Sun:) solar wind, (Sun:) solar-terrestrial relations

1. Introduction

Interplanetary Scintillation (IPS) is the rapid variation in radio signal from a compact distant natural source produced by turbulence/variations in density of the solar wind (e.g., Hewish, Scott, & Wills 1964). Observations of IPS allow the solar wind velocity (and an inferred value of density) to be determined over a large range of heliographic latitudes and solar elongations. Multi-antenna observations of IPS at 327 MHz used in this paper are from simultaneous recordings of the same radio source by up to four antennas separated by baselines of up to ∼200 km. These allow solar wind velocity to be measured to a high degree of accuracy. Density values for the solar wind can be inferred from the "normalised scintillation level" (g-level) of IPS observations.

IPS observations using the Solar-Terrestrial Environment Laboratory (STELab) arrays, Nagoya University, Japan (Kojima & Kakinuma 1987), are used routinely for the time-dependent three-dimensional (3-D) tomographic reconstructions. These have a one-day cadence and 20° × 20° digital resolution for current STELab IPS data, but are smoothed by a Gaussian filter that interpolates temporally and spatially over regions with few data points (e.g., Jackson & Hick 2005). The resolution is predicated by the number of lines of sight available for the reconstructions. During the Whole Heliosphere Interval (WHI), there are few lines of sight (particularly those contributing to the density reconstruction); thus, there was sometimes incomplete coverage for individual days

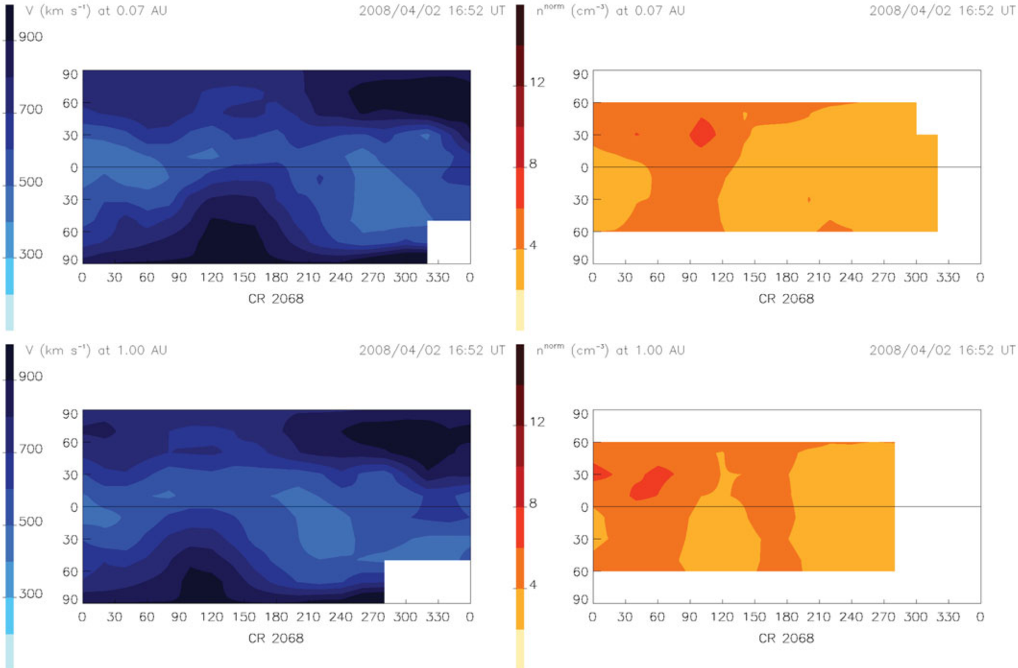

Figure 1. CR-averaged synoptic plots from the 3-D reconstructions at the "source surface" (15 $R_\odot$) (top) and at 1 AU (bottom) for velocity (left) and density (right). The "evolution" of structure can be seen from near the Sun to Earth's distance. From these, an *in situ* comparison is made with solar-wind measurements near 1 AU (Figure 2).

reconstructed. For the details of the 3-D reconstruction methods, see Bisi *et al.* (2009) and references therein.

In this paper, we summarise our 3-D reconstructions of the WHI Carrington rotation (CR) 2068 using the STELab IPS data and expand on the Bisi *et al.* (2009) paper. We concentrate on global average CR structure (through the summing and then averaging of all the available days reconstructed) and comparison with multi-point in-ecliptic *in situ* measurements.

2. Carrington-Rotation-Averaged 3-D Reconstruction Summary

Full details on the reconstructions for this period can be found in Bisi *et al.* (2009). Using the same data and time-dependent tomography here, the 3-D reconstructions for each day were averaged over the entire rotation (CR 2068). Data coverage, and thus reconstruction, was far greater in velocity than it was in *g*-level (density proxy) and so the CR-averaged density reconstruction has larger gaps in coverage.

Figure 1 shows the CR-averaged synoptic maps in both velocity and density at 0.07 AU (15 $R_\odot$) and 1 AU. A fairly-well defined and "tilted" streamer belt can be seen as a lower velocity region, and some small structures are visible in density. The lower velocities follow the heliospheric current sheet (HCS) mapped near the solar surface at this time. Note how structure changes from near the Sun to near the Earth, and that the time shift in solar-wind velocity structures is clearly seen as a result of the ~radial propagation out to 1 AU. The density plots in our analysis show no dominant density structure that

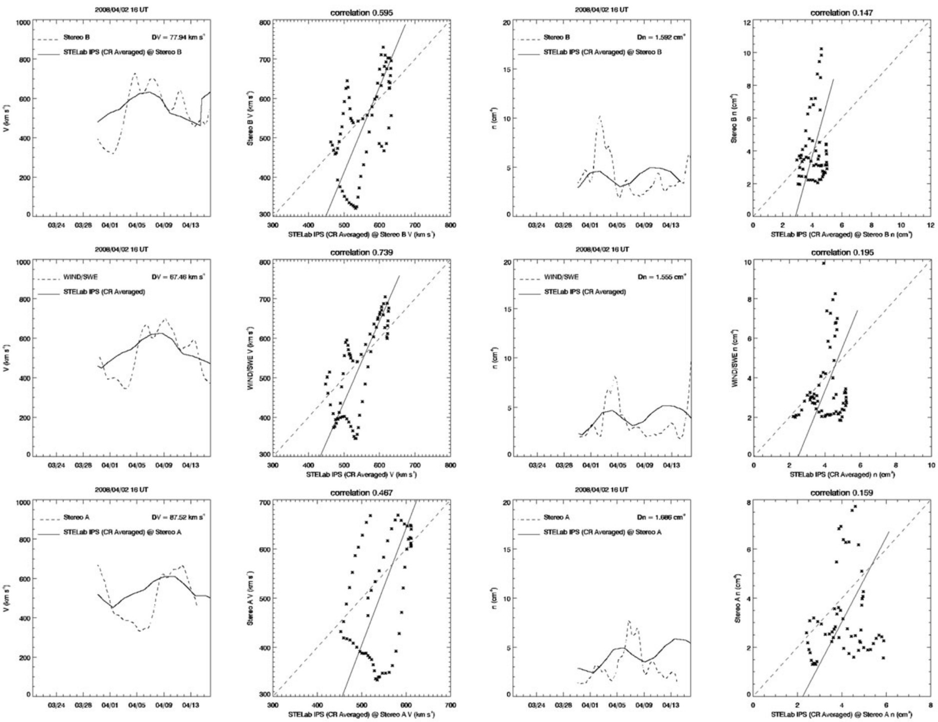

Figure 2. The lefthand plots for each of the six pairs shown compare the CR-averaged reconstructed solar wind velocity (left) and density (right) at STEREO-B, Wind, and STEREO-A (top-to-bottom – solid line), and those measured by each respective spacecraft (dashed line). The spacecraft data, originally hour-averaged, have been averaged over a day to match that of the IPS time-dependent reconstruction. On the right of each pair are plots of the correlation of the two data sets in each case; the dashed lines represent a 100% correlation and the solid lines represent the best fit.

follows the HCS during this period, even though the results of our composite of transient features match the density enhancements observed at 1 AU.

Figure 2 shows an extraction from the CR-averaged synoptic maps displayed in Figure 1 at 1 AU with solar wind measurements taken from STEREO and Wind instruments. Overall, the CR-averaged velocity compares well with these measurements; density compares well sometimes (with disagreement likely due to a limited number of observations going into the 3-D reconstruction). For unknown reasons, the ACE density data are very different from Wind, and the SOHO|CELIAS data seem more similar to Wind than ACE. The extraction from the tomography agrees better with Wind density than with ACE density.

3. Conclusions

The CR-averaged synoptic maps show good velocity structure both at the source surface and near Earth, with some structure visible in the density maps (but to a lesser extent). The overall comparison of these CR-averaged data are good with the "ground truth" *in situ* data, especially for velocity. Although the comparison is not as good as those obtained with the individual day time-dependent extractions shown by Bisi *et al.* (2009), it does verify our tomographic technique showing that we can reproduce the synoptic velocity (and density) structure throughout a large portion of WHI with these available STELab IPS data.

Acknowledgements

UCSD authors acknowledge NASA (grant NNX08AJ116), the NSF (grants ATM 0331513, ATM0852246, ATM0925023), and AFOSR (grant FA9550-06-1-0107) for funding for these analyses. The IPS observations were carried out under the solar wind program of the Solar-Terrestrial Environment Laboratory (STEL) of Nagoya University. We also thank the Wind|SWE, SOHO|CELIAS, ACE|SWEPAM, and STEREO|PLASTIC Groups for making their data freely available on the internet.

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