Science & Technology Facilities Council

RAL Space

HELCATS WP7: Assessing the complementary nature of radio measurements of solar wind transients – Interplanetary Scintillation (IPS) (T7.1) – UPDATES…

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Outline

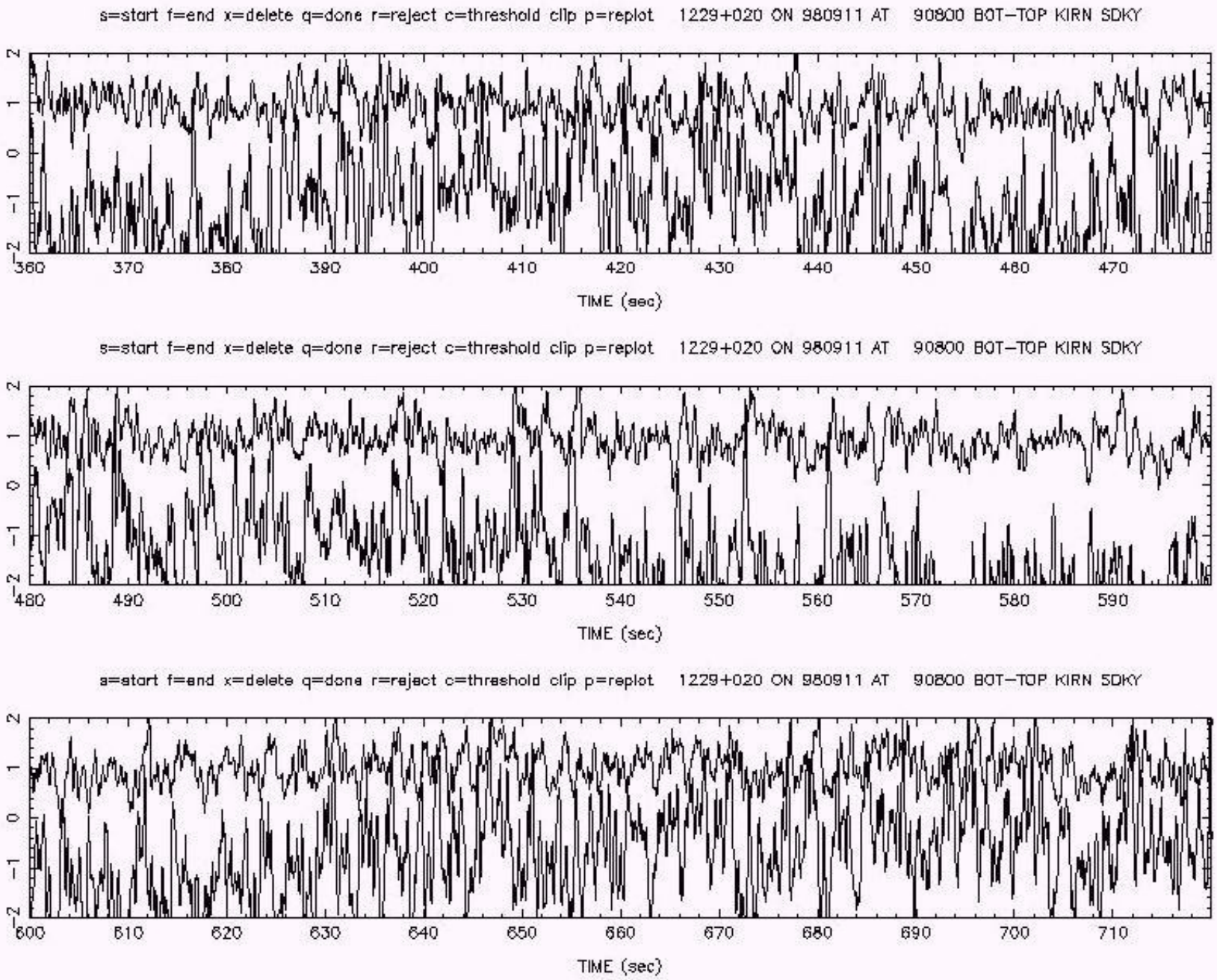
- Task 7.1 Overall Purpose.
- Reminder of Interplanetary Scintillation (IPS).
- Reminder of the University of California, San Diego (UCSD) Three-Dimensional (3-D) Time-Dependent Tomography.
- Some Example Work that we are Building On (Primary Only).
- Development of Feature-Finding Tools for finding the CME/SIR/CIR Signature in the IPS Data
- A Brief Overview of the IPS Work Plan Progress to Date (Task 7.1).

Task 7.1 Overall Purpose

- Started at month 10 (February 2015) for 19.5 months equivalent effort by month 36 – only a fraction used to date – largely delayed due to ongoing analysis-program issues now (hopefully) resolved.
- Development of a catalogue of CMEs observed using IPS during the STEREO mission time line and comparison with white-/visible-light observations where geometry allows.
- As above but for SIRs/CIRs.
- Requires a way of finding the relevant features in the IPS data.
- Primary aspect: EISCAT/ESR and LOFAR individual observations used primarily in conjunction with the HI catalogues.
- Secondary aspect: where time allows and other IPS data are available *(e.g.* from ISEE in Japan), use UCSD tomography and IPS-driven ENLIL on a case-by-case basis for a fuller comparison.

Reminder of Interplanetary Scintillation (IPS)

IPS (1)


s=start f=end x=delete q=done r=reject c=threshold clip p=replot 1229+020 ON 980911 AT 90800 BOT-TOP KIRN SDKY
2
1
0
-1
-2
360 370 380 390 400 410 420 430 440 450 460 470
TIME (sec)
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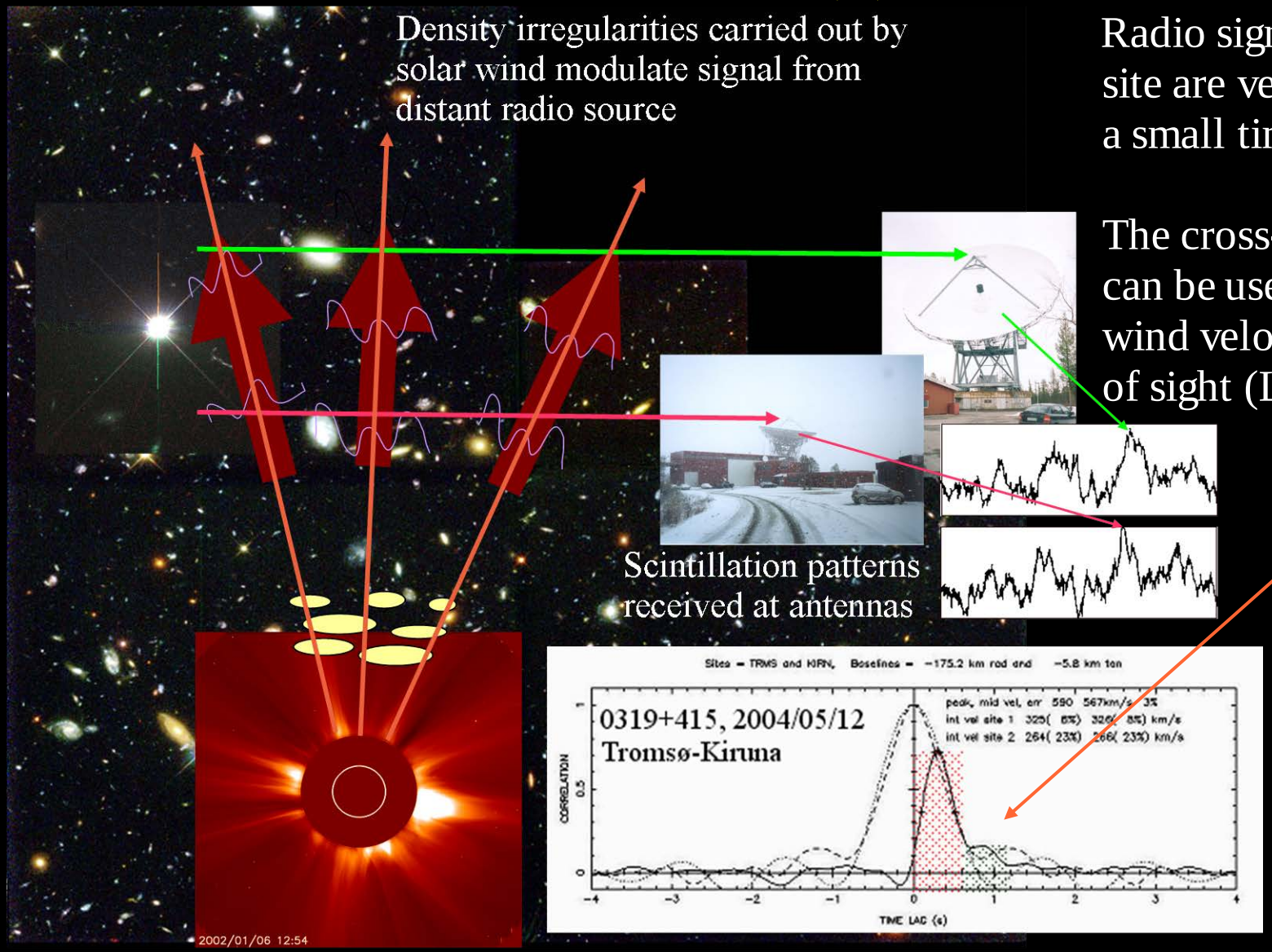
2
1
0
-1
-2
480 490 500 510 520 530 540 550 560 570 580 590
TIME (sec)
s=start f=end x=delete q=done r=reject c=threshold clip p=replot 1229+020 ON 980911 AT 90800 BOT-TOP KIRN SDKY
2
1
0
-1
-2
600 610 620 630 640 650 660 670 680 690 700 710
TIME (sec)

IPS (2)



Hubble Deep Field – HST (WFPC2) 15/01/96 – Courtesy of R. Williams and the HDF Team and NASA

Radio signals received at each site are very similar except for a small time-lag.

The cross-correlation function can be used to infer the solar wind velocity(s) across the line of sight (LOS).

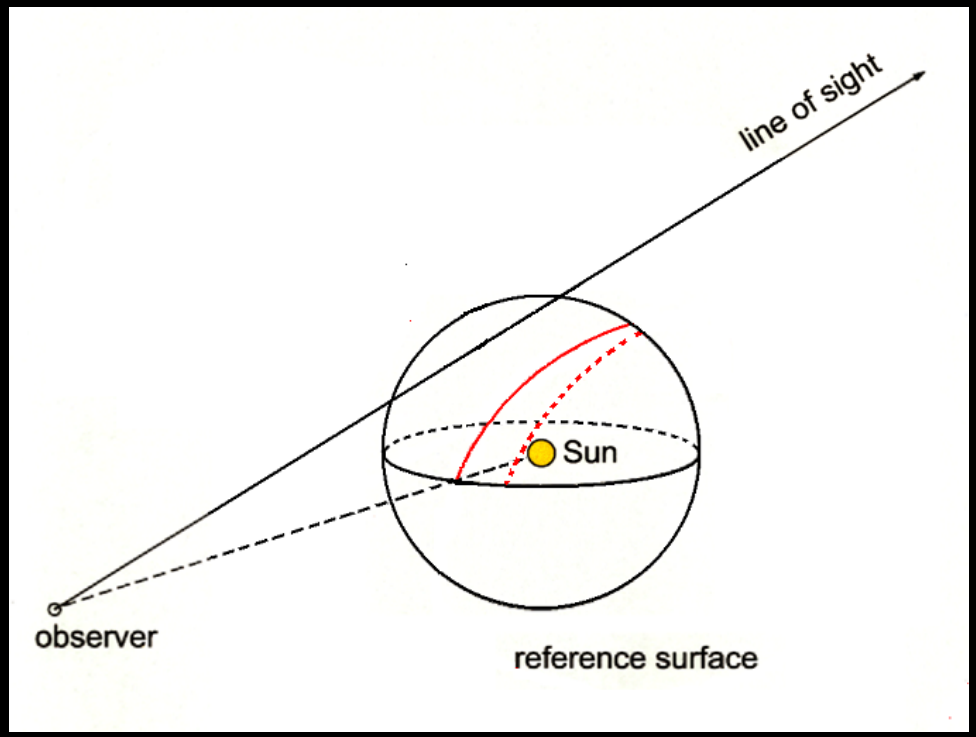
(Not to scale)

IPS is most-sensitive at and around the P-Point of the LOS to the Sun and is only sensitive to the component of flow that is perpendicular to the LOS; it is variation in intensity of astronomical radio sources on timescales of ~0.1s to ~10s that is observed.

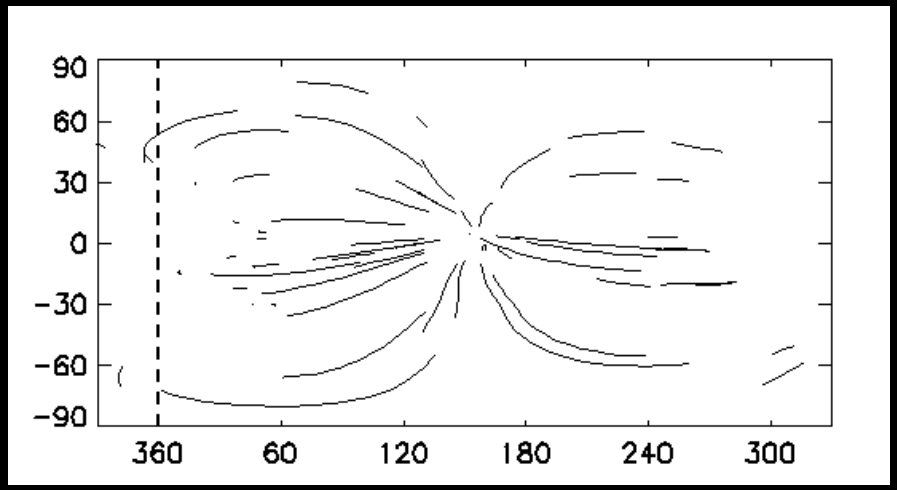
Reminder of the University of California, San Diego (UCSD) Three-Dimensional (3-D) Time-Dependent Tomography

UCSD 3-D Tomography

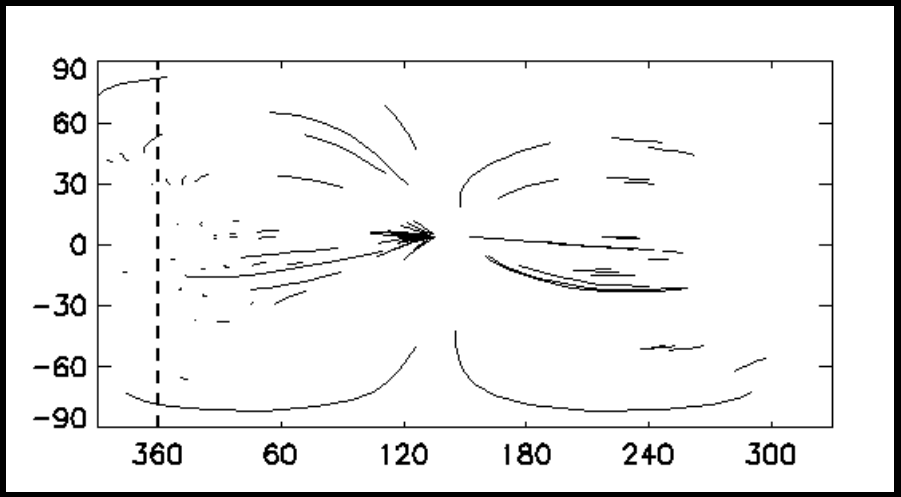
Heliospheric C.A.T. Analyses: example line-of-sight distribution for each sky location to form the source surface of the 3D reconstruction.



STELab IPS



13 July 2000



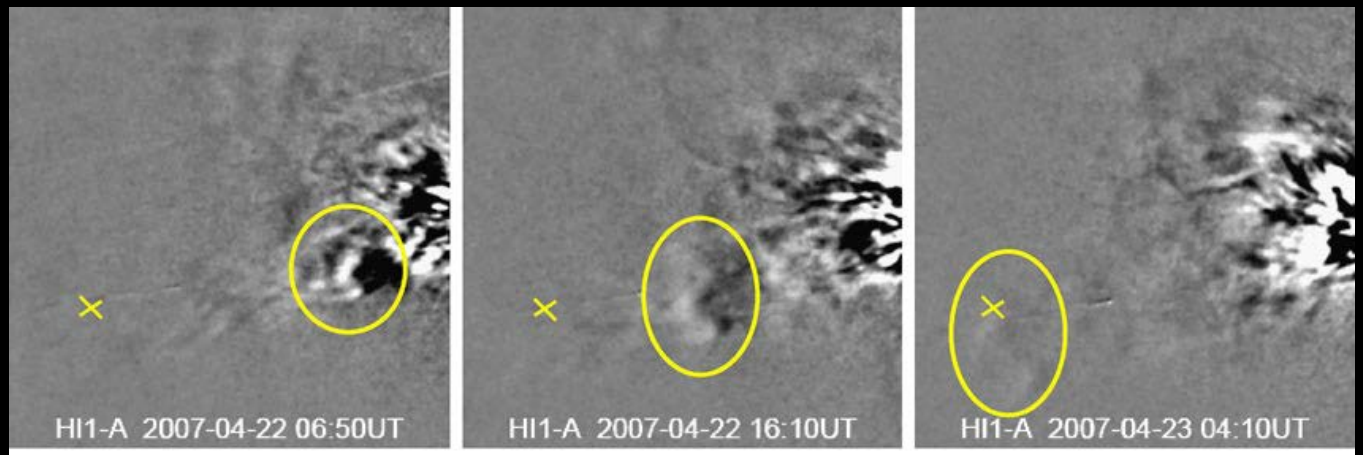
14 July 2000

Some Example Work that we are Building On (Primary Only)

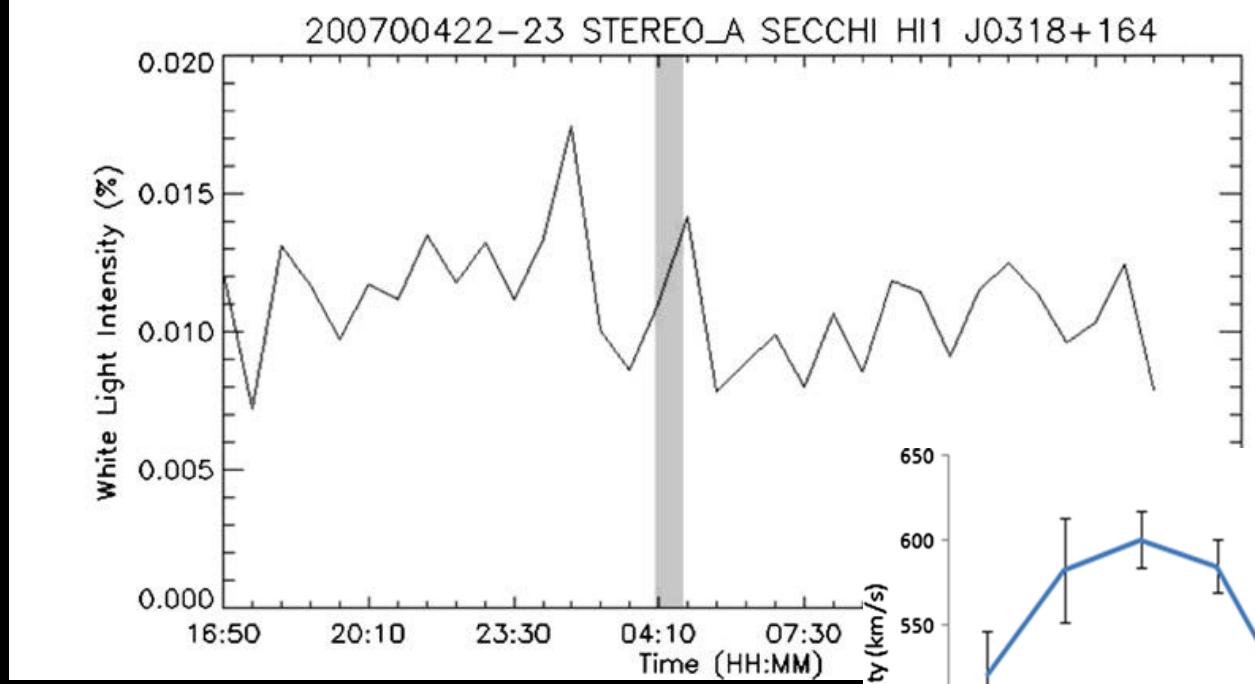
Comparison Between IPS and STEREO HIs (Primary)

- S.A. Hardwick, M.M. Bisi, J.A. Davies, A.R. Breen, R.A. Fallows, R.A. Harrison, and C.J. Davis, "Observations of Rapid Velocity Variations in the Slow Solar Wind", Solar Physics "Observations and Modelling of the Inner Heliosphere" Topical Issue (Guest Editors M.M. Bisi, R.A. Harrison, and N. Lugaz), 285 (1-2), 111-126, 2013.

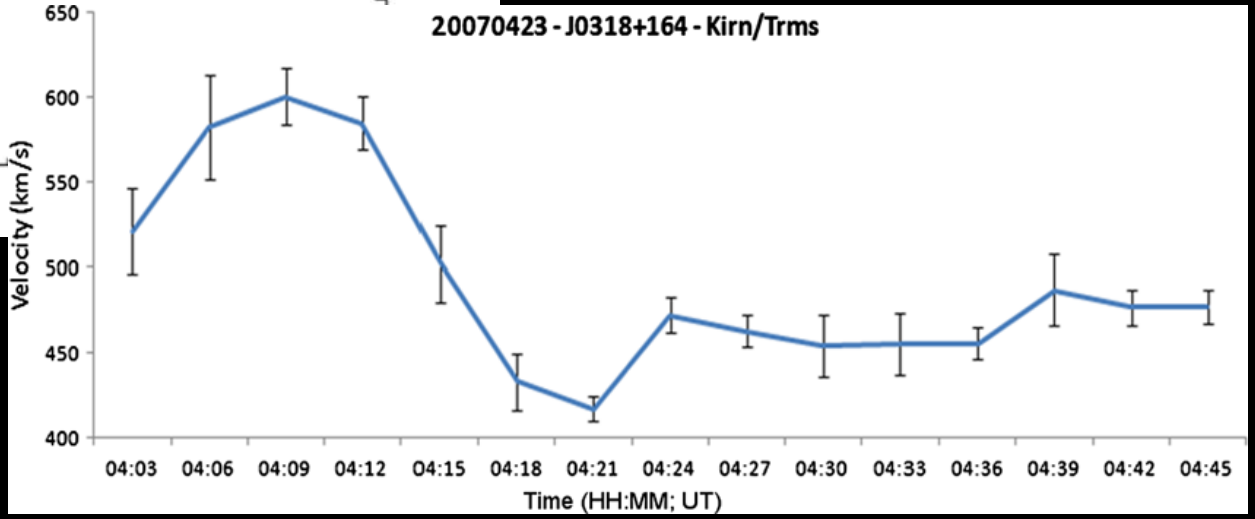
EISCAT IPS and STEREO HI1-A Comparisons



- Sequence of STEREO HI1-A images of a CME with the IPS P-Point superimposed; the grey area on the intensity plot represents the overlap in time with the IPS.



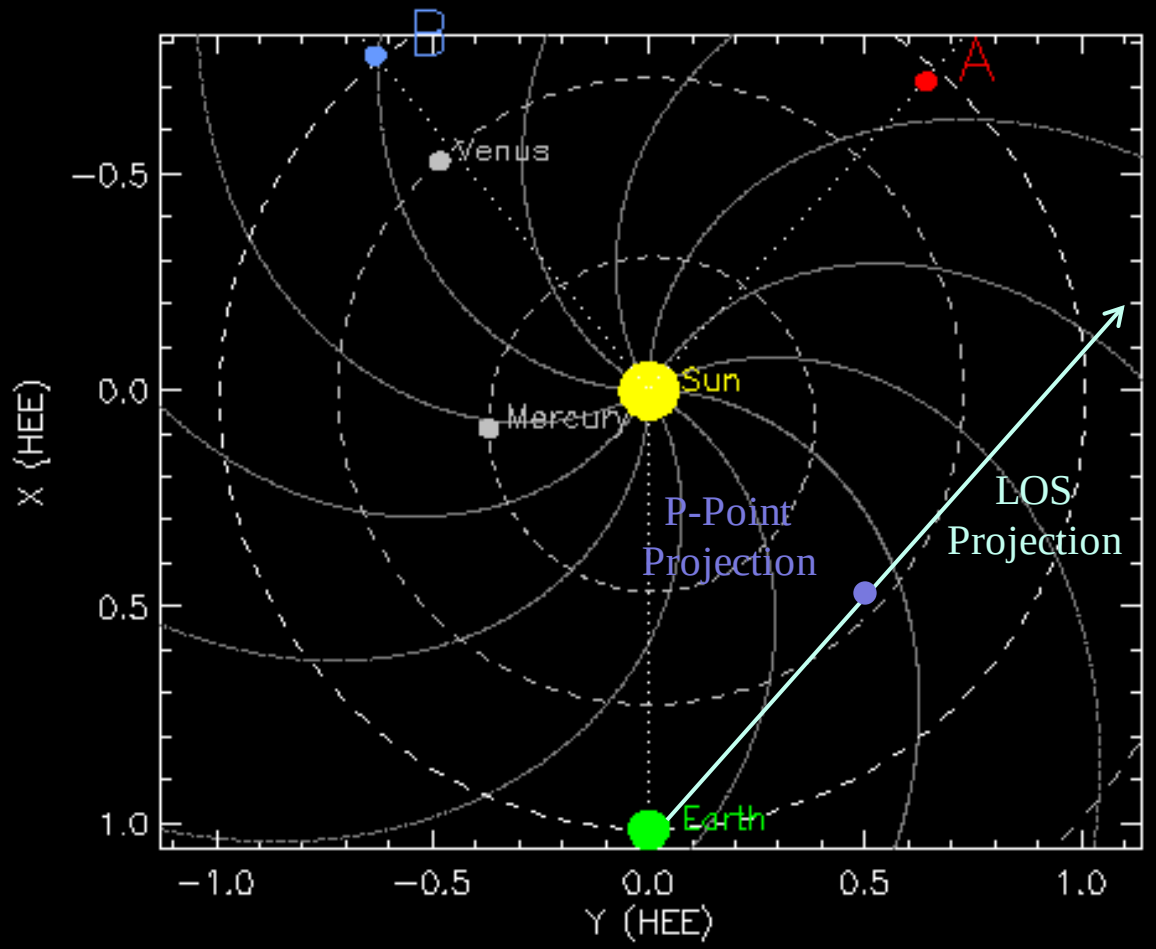
- Variation in velocity as determined from the IPS.



Our Second Coronal Mass Ejection (CME) with LOFAR… (Primary)

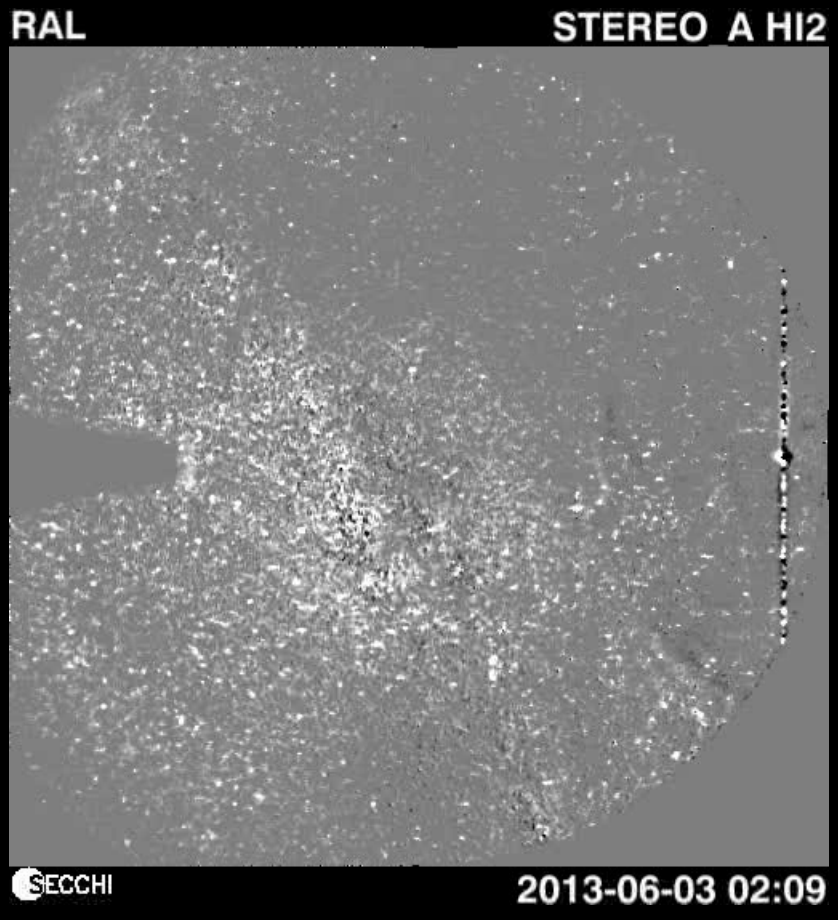
- Investigations are ongoing.

Initial CME Identification



(Above) In-ecliptic positions and/or projections at the time of the LOFAR CME observation in IPS (http://stereo-ssc.nascom.nasa.gov/cgi-bin/make_where_gif).

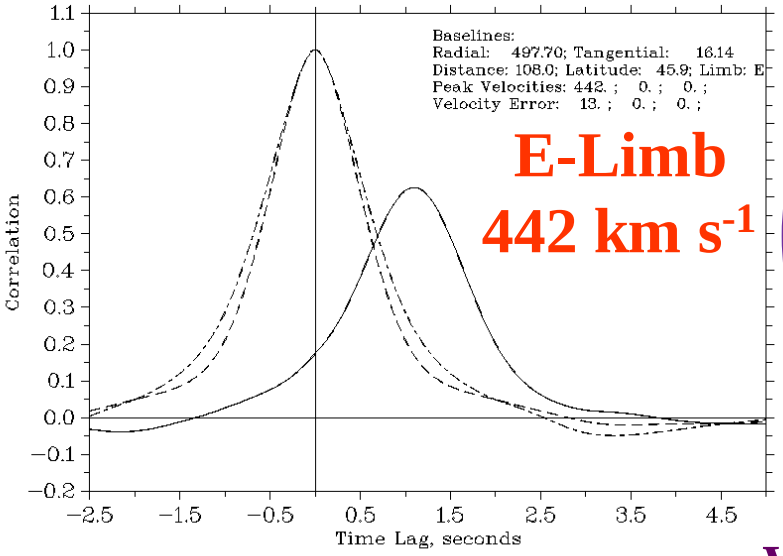
(Below) An HI-2A smoothed difference movie of 03 June 2013 – part of CME just seen beyond the Earth on the right-hand side.



LOFAR Observations of IPS on 03 June 2013

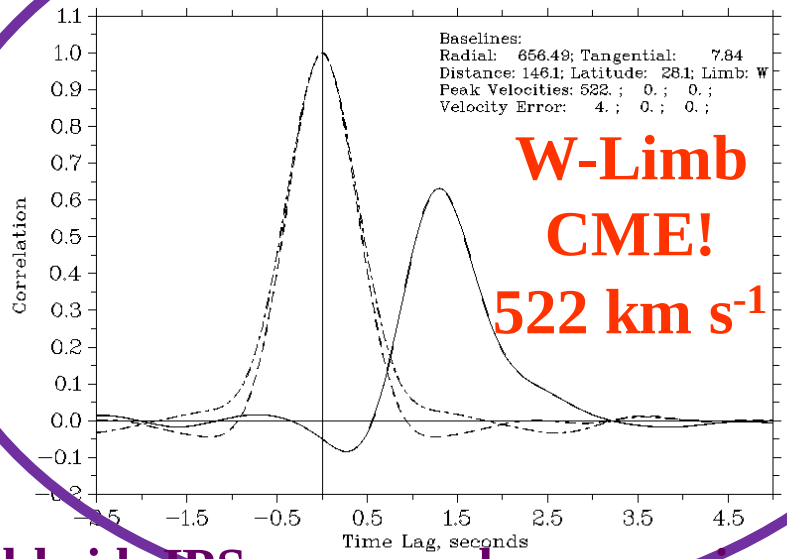
20130603 : 07:50:00 : 3C147 : F606−U608

108.0 R_S at 45.9° Lat.



20130603 : 06:45:00 : 3C48 : D602−F606

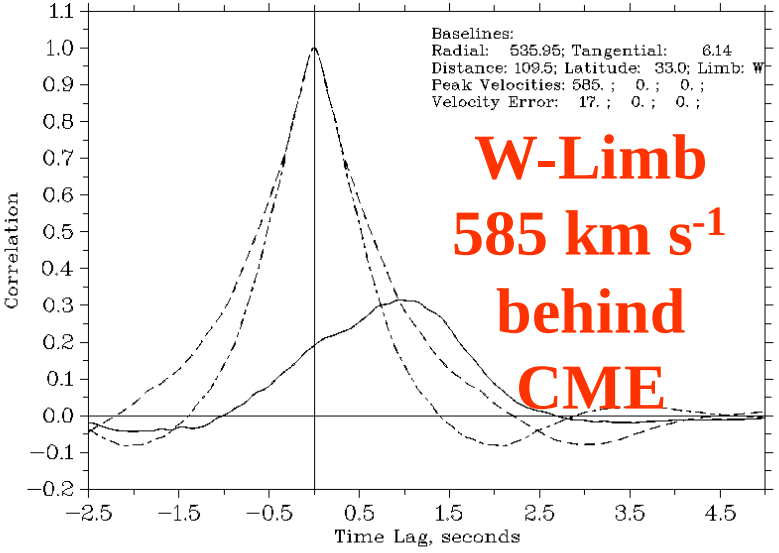
146.1 R_S at 28.1° Lat.



Worldwide IPS cross-analyses exercise…

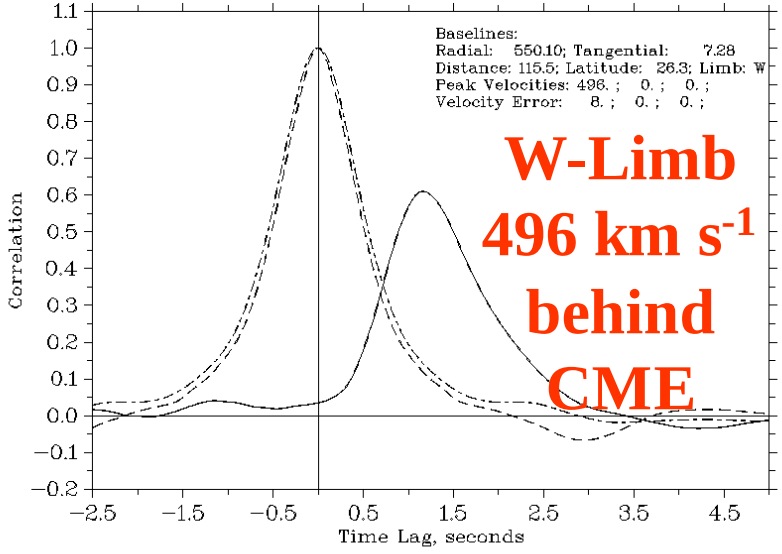
20130603 : 08:40:00 : 3C68.2 : D605−U608

109.5 R_S at 33.0° Lat.



20130603 : 09:26:00 : 3C67 : D605−U608

115.5 R_S at 26.3° Lat.



Development of Feature-Finding Tools for finding the CME/SIR/CIR Signature in the IPS Data

IPS CCF Feature Finding (1)

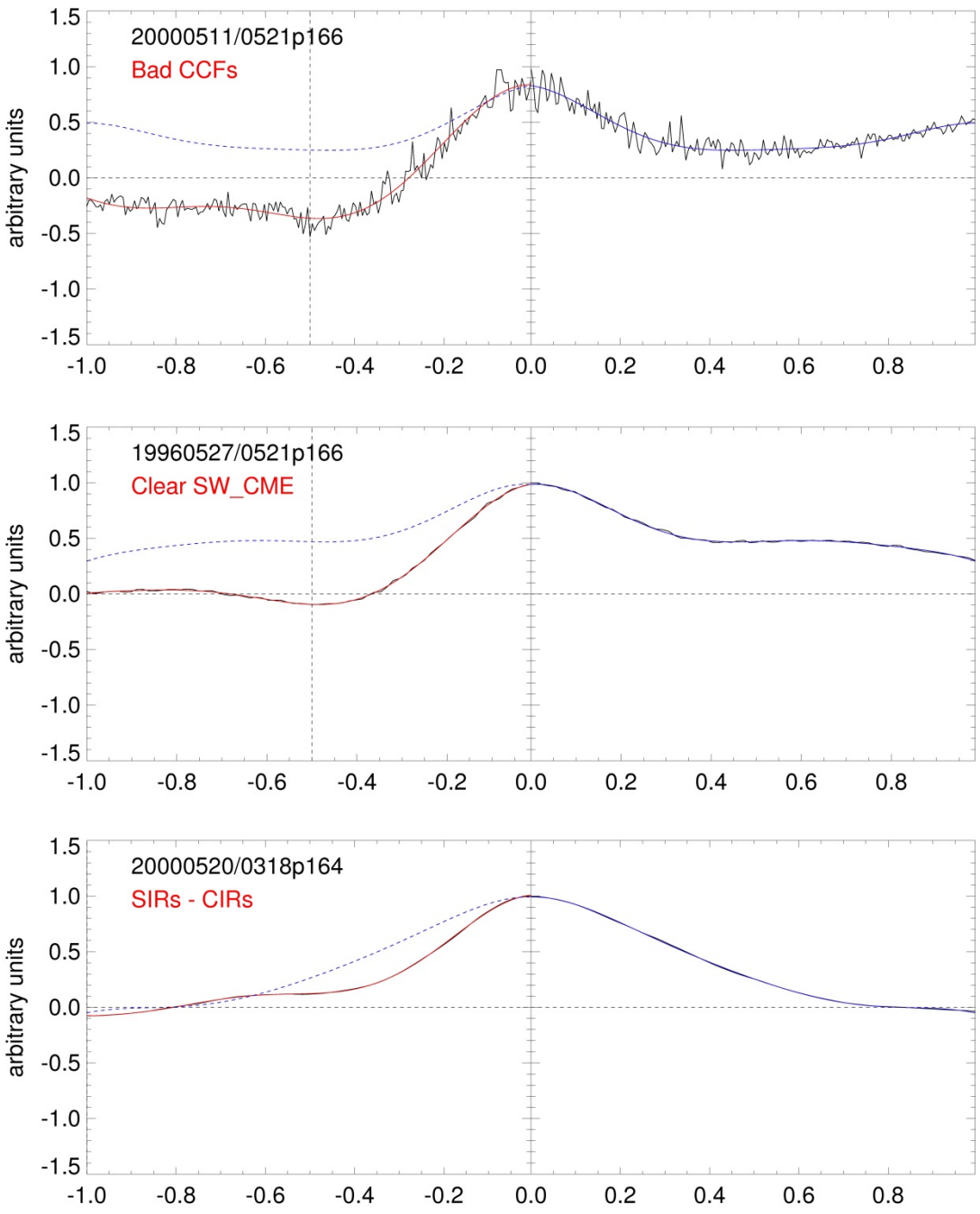
- In order to efficiently make up the catalogues of both the CME detections and the SIR/CIR detections from the EISCAT IPS data, we first need to be able to develop an automatic way of finding their respective features in the cross-correlation functions (CCFs): negative lobe at (or near to) zero time lag and strong asymmetry in the CCF where there is a non-clear second peak "amalgamated" into the primary peak.

- Various ideas considered.

- Negative lobe easier to find due to its uniqueness.

- Asymmetry (while reducing false positives) is more tricky and required more-robust automated curve-fitting techniques to the CCFs and these were also then applied as checks to finding the negative-lobe signatures…

IPS CCF Feature Finding (2)



- Step 1 – fit function to data (either side of peak)

$$f(x) = \sum_{n=1}^{3} (a_n \cos knx + b_n \sin knx)$$

- Step 2 – identify features

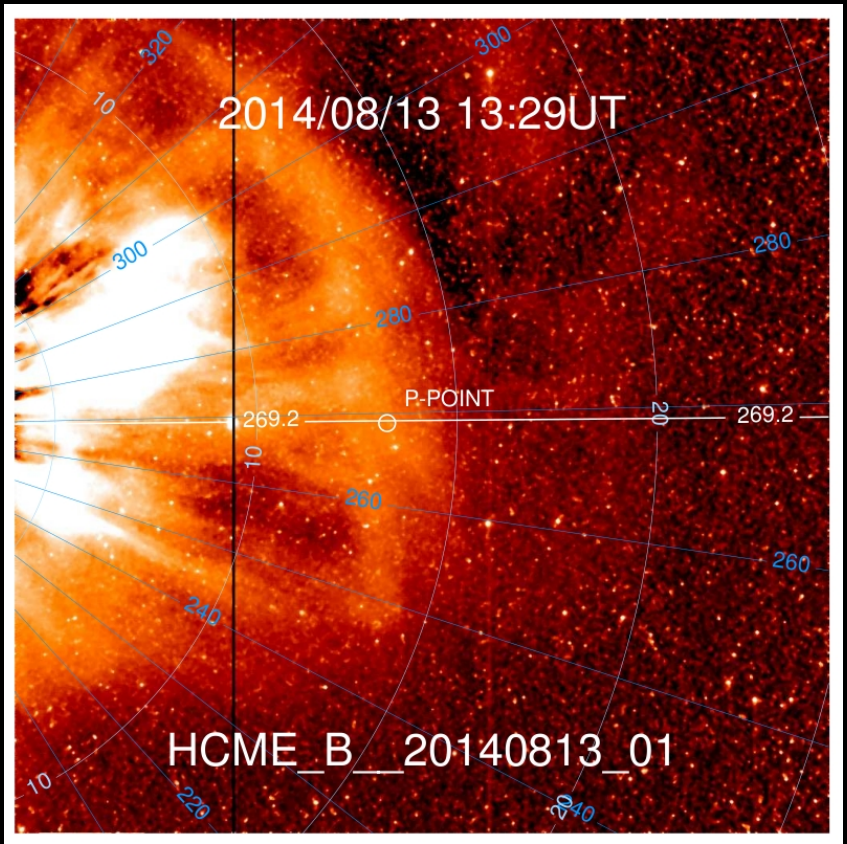
  r = residual

  z = depth of minimum

  a = asymmetry

IPS CCF Feature Finding (3)

- Code has been tested on preliminary CCFs but needs more results
- Probably best for highlighting regions of inetest, rather than automatic detection



- Further code has been developed to identify IPS observations in HI images
- Once IPS analysis is complete we can easily compare IPS and HI catalogues

A Brief Overview of the IPS Work Plan Progress to Date (Task 7.1)

Task 7.1 Progress and Outlook

- Tools for finding the relevant features in the IPS data are undergoing final testing.
- Re-run of the EISCAT dataset relevant to STEREO – underway.
- Development of a catalogue of CMEs observed using IPS – now underway.
- As above but for SIRs/CIRs – not yet started.
- Requires HI catalogues with non-changing event IDs – we have that now.
- Primary aspect is now underway.
- Secondary aspect for a small number of cases remains feasible – but this was always an “optional extra” for HELCATS and does not affect the primary WP7 goals…
- Likely to run to month 33 instead of 30 for initial deliverable, but still be completed overall by month 36 as planned.