Predicting Corotating Interaction Regions (CIR) arrival times at Rosetta by means of the « Propagation Tool » catalogue.

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INTRODUCTION

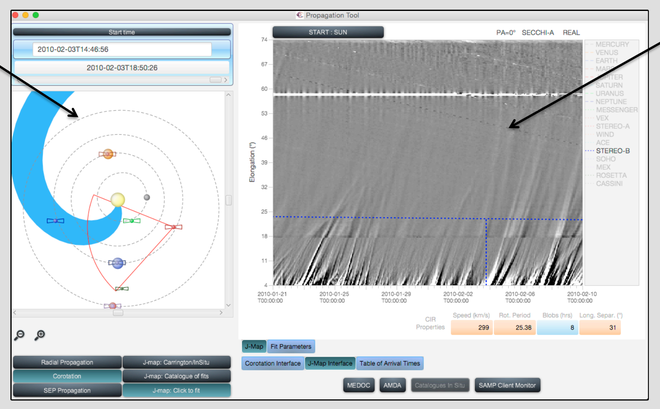
We present the 'propagation tool' that allows users to track the propagation of Coronal Mass Ejections (CMEs) and Corotating Interaction Regions (CIRs, [1]) to several AUs. This tool provides access to maps of solar wind outflows from the Sun and offers different ways to estimate the location and speed of CMEs and CIRs with time. It also provides access to catalogues of CIRs and CMEs that have been derived by the HELCATS project.

The CIR catalogue is derived using white-light images from the HI instruments on STEREO and is here compared with in-situ measurements. We compare the predicted arrival time and speed of the density structures embedded in CIRs with the in-situ arrival of density peaks and the stream interfaces located in the CIR compression regions. This procedure apears to give a very reasonable agreemment between the imager prediction and the in-situ detection.

PROPAGATION TOOL

Real time calculation of different objects position in the Sloar System

J-maps of running difference Heliospheric images, Carrington Maps



Modules of CMEs, Corotation and Solar Energetic Particles display, fitting and propagation.

Link to the AMDA database and To the Helioviewer at relevant date times.

- User friendly tool developped by Alexis Rouillard and a team of software engineers at IRAP and CNES.
- Takes account of the orbital motion of the sattelite.
- Fits one track and reproduces the whole CIR signature with periodically emitted structures (emission time, velocity, solar origin point…)

COROTATING INTERACTION REGIONS

A series of structures from the same solar region but at different times, moving radially outward with the same speed. As seen from Stereo A HI field of view.

J-map view [2]:

- Visual signature of a SIR
- Reasonable unique speed estimation for all tracks
- Does not give value of the density (running difference images)

In-situ view of a CIR

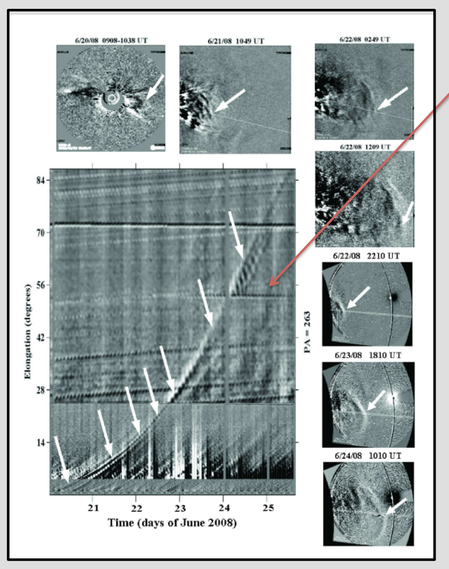
Figure 5. A sketch of a CIR in the vicinity of 1 AU. Standard view in the reference frame of the Sun in RTN coordinates. The reference frame emphasizes the westward-eastward flow deflection (arrows) in the CIR (brown shading).

Borovsky & Denton JGR, 115, A10101, 2010

1. Radial component of the solar wind speed: transition from slow wind to the fast wind (500-700 km/s)
2. Transverse velocity: clearly seen deflection of the flow around the stream interface.
3. Local peak value in Temperature, magnetic field magnitude, plasma density.
4. Enhancement in caracteristic speeds value: sound, alfvenic, magnetosonic.
5. Ion specific entropy (T_i/ n^(2/3)) appears to be relevant to loacalise the stream interface.

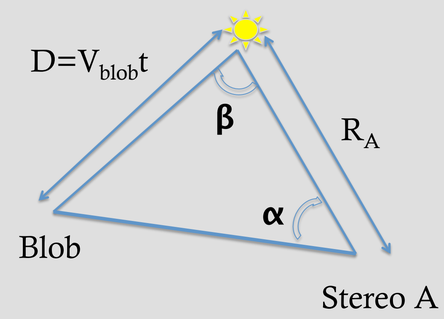
HELIOSPHERIC IMAGERS AND ARRIVAL TIME PREDICTION

Construct a J-map from Heliospheric images



Sheeley and Rouillard (2010)

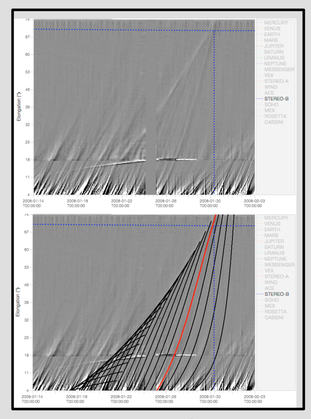
In-ecliptic pixels band extracted from a time sequence of images.



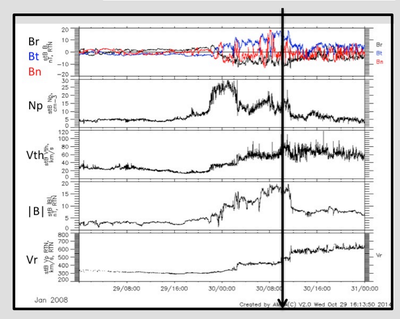
A blob having a constant speed seen from a satellite (Fixed phi approx.):

$$\alpha = \arctan\left[\frac{V_{blob}\,t\,\sin\beta}{R_A(t) - V_{blob}\,t\,\cos\beta}\right]$$

- Fit of the one density enhancement blob.
- Reconstruct all traces and the envelope (locus of enhanced visibility)
- Backproagate to the Sun (CH in proximity?)
- Propagate to different probes (Stereo A-B, ACE, Wind, Rosetta…)

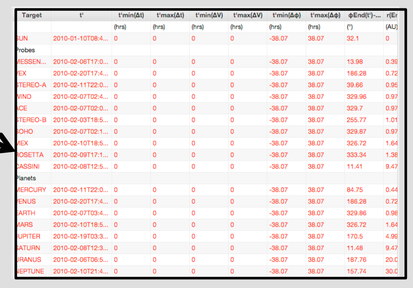


Example of Stereo B in situ data and the predicted arrival time inside the transition region between the slow wind to the fast wind (black arrow).



The catalogue includes:

- A list of events from 2007 up to 2014
- Subset of arrival times at different probes.
- Included into the Propagation Tool (CIR fits database).
- About to be included into AMDA database (arrival times at different probes).



Target	t*	t*min(Δt) (hrs)	t*max(Δt) (hrs)	t*min(ΔV) (hrs)	t*max(ΔV) (hrs)	t*min(Δφ) (hrs)	t*max(Δφ) (hrs)	φEnd(t*)-... (°)	r(Er (AU)
SUN	2010-01-10T08:4...	0	0	0	0	-38.07	38.07	32.1	0
Probes									
MESSEN...	2010-02-06T17:0...	0	0	0	0	-38.07	38.07	13.98	0.39
VEX	2010-02-20T17:4...	0	0	0	0	-38.07	38.07	186.28	0.72
STEREO-A	2010-02-11T22:0...	0	0	0	0	-38.07	38.07	39.66	0.96
WIND	2010-02-07T02:4...	0	0	0	0	-38.07	38.07	329.96	0.97
ACE	2010-02-07T02:0...	0	0	0	0	-38.07	38.07	329.7	0.97
STEREO-B	2010-02-03T18:5...	0	0	0	0	-38.07	38.07	255.77	1.01
SOHO	2010-02-07T02:1...	0	0	0	0	-38.07	38.07	329.87	0.97
MEX	2010-02-10T18:5...	0	0	0	0	-38.07	38.07	326.72	1.64
ROSETTA	2010-02-09T17:1...	0	0	0	0	-38.07	38.07	333.34	1.36
CASSINI	2010-02-08T12:5...	0	0	0	0	-38.07	38.07	11.41	9.47
Planets									
MERCURY	2010-02-11T22:0...	0	0	0	0	-38.07	38.07	84.75	0.44
VENUS	2010-02-20T17:4...	0	0	0	0	-38.07	38.07	186.28	0.72
EARTH	2010-02-07T03:4...	0	0	0	0	-38.07	38.07	329.86	0.98
MARS	2010-02-10T18:5...	0	0	0	0	-38.07	38.07	326.72	1.64
JUPITER	2010-02-19T03:3...	0	0	0	0	-38.07	38.07	170.5	4.99
SATURN	2010-02-08T12:3...	0	0	0	0	-38.07	38.07	11.48	9.47
URANUS	2010-02-08T06:5...	0	0	0	0	-38.07	38.07	187.76	20.0
NEPTUNE	2010-02-10T21:4...	0	0	0	0	-38.07	38.07	157.74	30.0

CONCLUSION

- Predicted arrival time to Rosetta is avialable for each CIR in the catalogue.
- When CIRs are well identified in heliospheric images, their arrival time at 1 AU is predicted with +12 hours accuracy. The precision at 2-3 AU (Rosetta) will be several hours worst.
- Average CIRs velocity is found to be 312 km/s from Heliospheric J-map fits. About 100 km/s less then the velocity on the density peak at the stream interface locally measured at 1 AU. The model of constant solar wind velocity above 20 Solar radii needs to be reexamined in this case. The compressed density interface should naturally accelerate in route from 0.1 to several AUs.

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REFERENCES

[1] V. Sarabhai, “Some consequences of Nonuniformity of Solar Wind Velocity”, 1963, JGR, 68, 1555

[2] A. Rouillard et al., “First imaging of corotating interaction regions using the STEREO spacecraft”, 2008, GeoRL, 35, L10110

[3] J.E. Borovsky, M.H. Denton, “Solar wind turbulence and shear: A superposed-epoch analysis of corotating interaction regions at 1 AU », 2010, JGR, 115, A10101

[4] N. R. Sheeley Jr, & A. Rouillard, “Tracking Streamer Blobs into the Heliosphere”, ApJ, 715, 300