Welcome to CDPP/Propagation Tool

A tutorial

I. Plotnikov, A.P. Rouillard

Article describing the tool:
Rouillard et al, 2017, Planetary and Space Science, Volume 147, p. 61-77
https://doi.org/10.1016/j.pss.2017.07.001

Tool location: http://propagationtool.cdpp.eu/

Mac users:

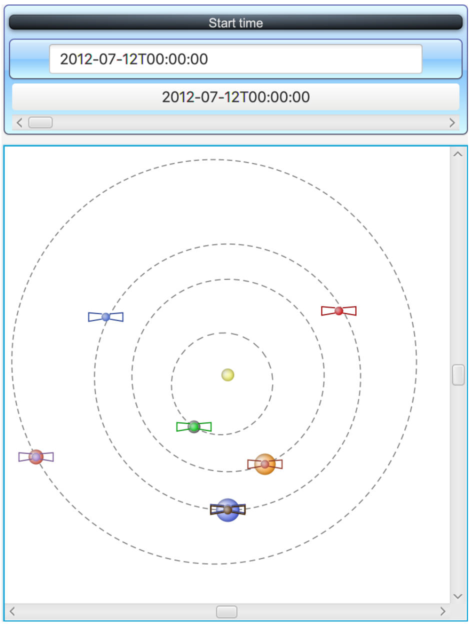
- click on the icon
- download the propagationtool.jlnp file
- right-click on the file and open with java web start
- java may ask you to download the latest version (java 8, version 281), say yes.
- if all went well, you should have the following window appearing:

Case study 1: Radial propagation of a CME

Coronal Mass Ejections (CMEs) are produced by the eruptive solar activity that results in impulsive release of mass and magnetic clouds into the heliosphere. The speed of these structures varies from 400 km/s to above 3000 km/s for strongest events (e.g., 2017-09-10 event). CMEs are commonly observed in Coronagraph white-light images and -- more recently -- in Heliospheric Imagers. The bright structures observed in white-light directly translate into higher local density structures, in virtue of Thomson scattering effect.

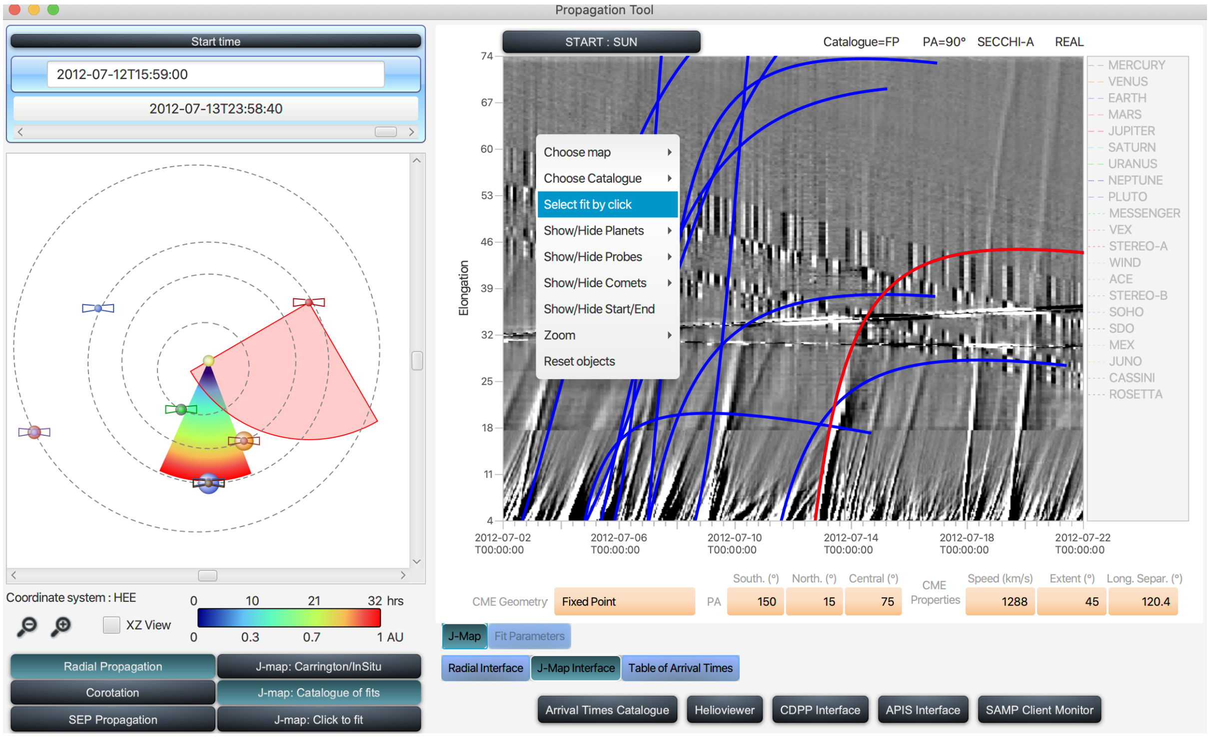
Here we study a CME propagation that followed the 2012-07-12 eruption.

1) Select the date in the Tool interface. After update, planet and different space mission's positions should looks like this:



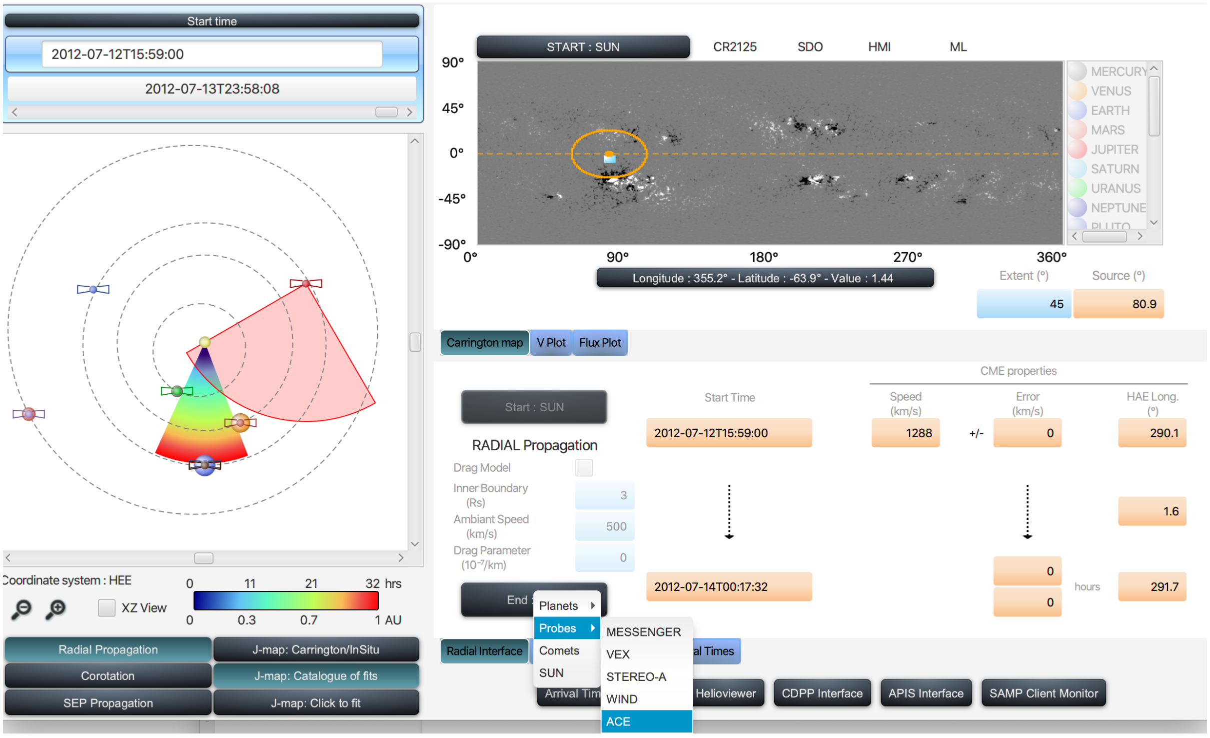
   - Colored circles: Planets
   - Colored symbols with 'wings': space missions
   - Dashed ellipses: orbits of planets

2) Go to Radial Propagation module + J-map: Catalogue of fits
3) Select J-map interface, on the right-side. Right-click -> Select Fit by click. Click on the latest fit. The results should look like



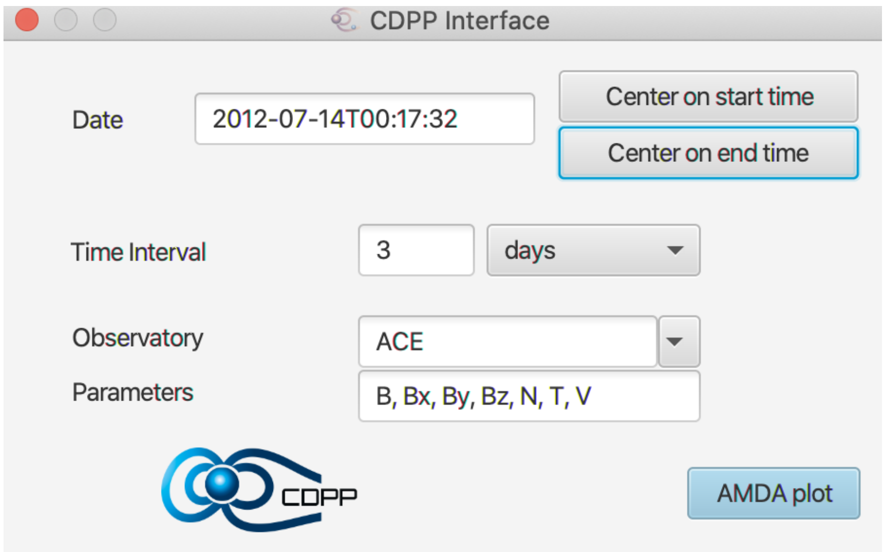
Note on the meaning of what is a J-map: To track individual density features as they propagate through the fields of view of the heliospheric imagers, maps of brightness variation are often created by extracting bands of pixels along a constant position angle (PA), corresponding to a fixed solar radial, and displaying them as a function of elongation (Y-axis) and time (X-axis). Such time–elongation maps are often referred to as J-maps (Sheeley et al., 1999, 2008a,b; Davies et al., 2009). This is what is displayed in the Propagation Tool.

The speed of the CME from this fit is 1288 km/s. And it is directed towards Earth. We will now compare the fit from white-light with predicted in-situ measurements.
Go to “Radial Interface” and click on End -> Probes -> ACE

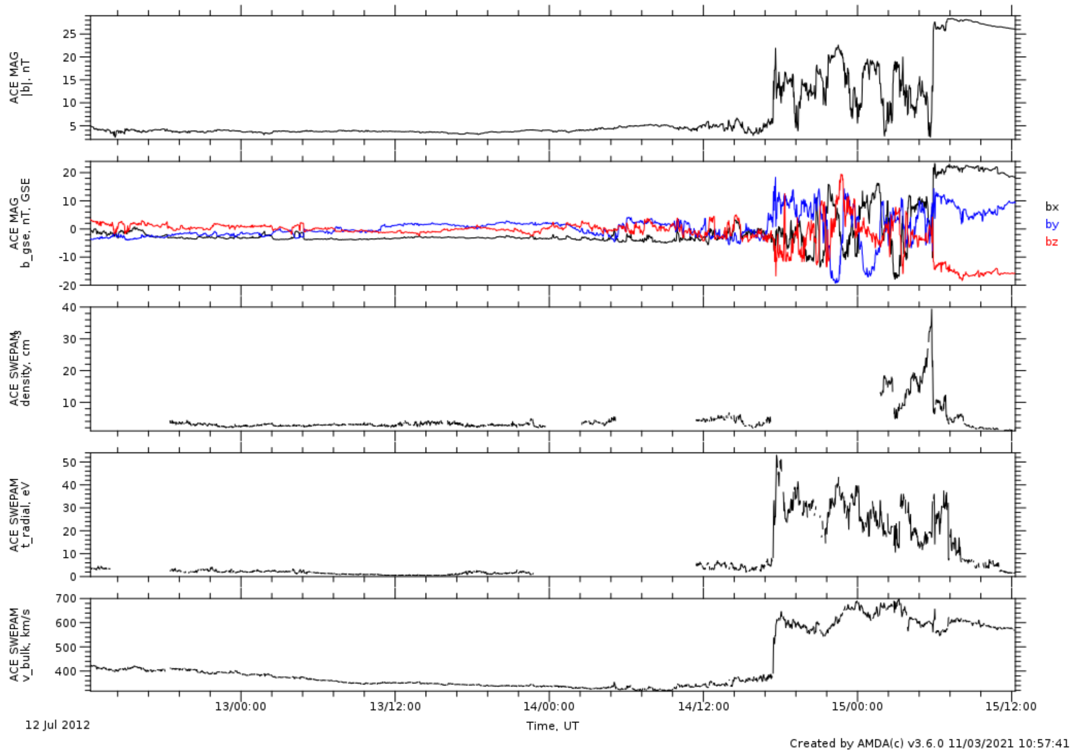


This should predict the CME impact time on ACE at 2012-07-14 00:17.

4) Click on ‘CDPP interface’ that pops up a new window:
Select: Center on end time, Time interval = 3 days, select ACE



Then click on ‘AMDA plot’.
This opens the internet navigator and interrogates the CDPP database.
Following plot may be obtained:



The measured CME impact time is around 17:00, that is 17h later than predicted from white-light fit.
The CME speed at ACE is around 600 km/s that is smaller than used.

Exercise (1) : Try to improve the fit by-hand (use 'J-map: click to fit' interface) in order to get better agreement with in-situ arrival time.

Exercise (2): increase the time window in CDPP interface to >5 days in order to display the full flux rope of the CME.

Exercise (3): check the consistency of the start time of the erupted CME by looking at the GOES X-ray data in 'Flux Plot' interface:

The cursor on the plot helps to read the flare start (or peak) time.

Case study 2: Corotating Interaction Regions

Definition by Alves et al 2006, JGR: "Corotating interaction regions (CIRs) are structures formed when high‐speed solar wind streams overtake slow solar wind streams as they propagate outward. These structures produce regions of enhanced density and magnetic field strength in the solar wind near the ecliptic plane". In Heliospheric Images the density blobs inside the CIR can appear as converging tracks and exhibiting a 'locus of enhanced visibility' if the Sun rotates toward the spacecraft field-of-view, and as diverging tracks if the Sun rotates outward the field-of-view of the spacecraft's camera (more detailed discussion in Sheeley & Rouillard 2010, ApJ).

Good review on CIRs: Richardson (2018), Living Reviews in Solar Physics, 15, article id. 1, 95 pp

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Possibilities of case studies:
2007-July-11 (Davies et al 2009)
2007-Sept-11 (Rouillard et al 2008)
2008-Feb - Mars (Plotnikov et al 2016, Fig. 5)
2008-Aug-06 (Plotnikov et al 2016, Fig 1)

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Here we chose the 2008-Aug-06 CIR.

An overview of this event is presented in the Figure below (J-maps (a-b), ecliptic plane (c), EUVI Carrington Map (d)) :

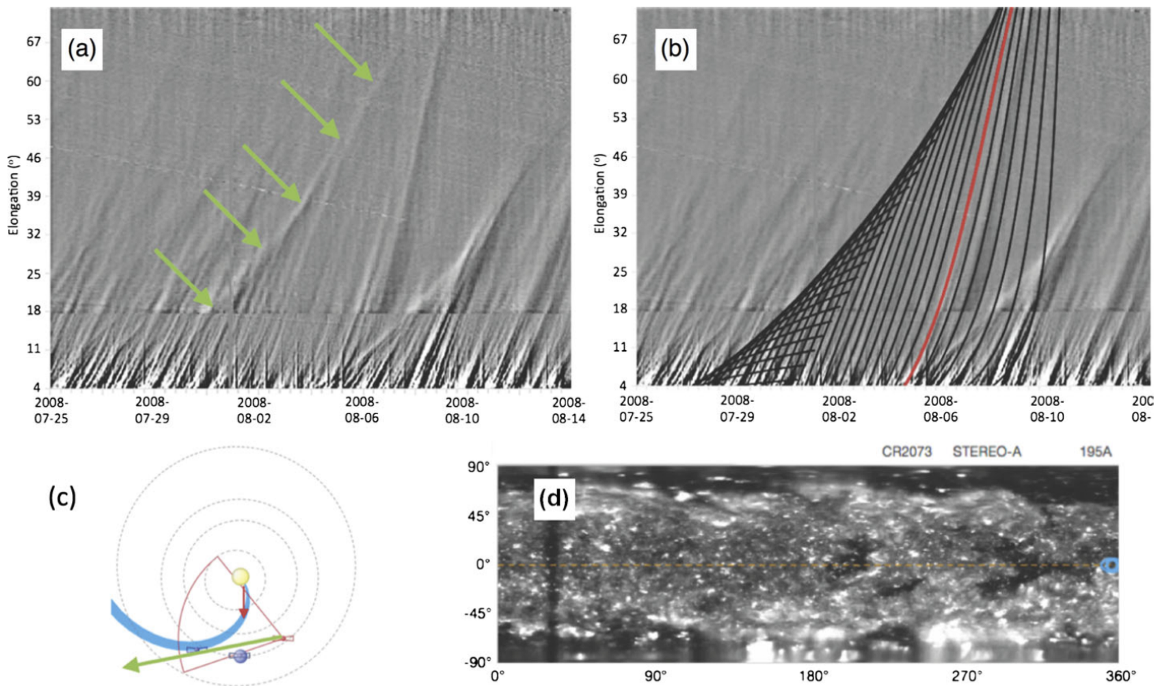
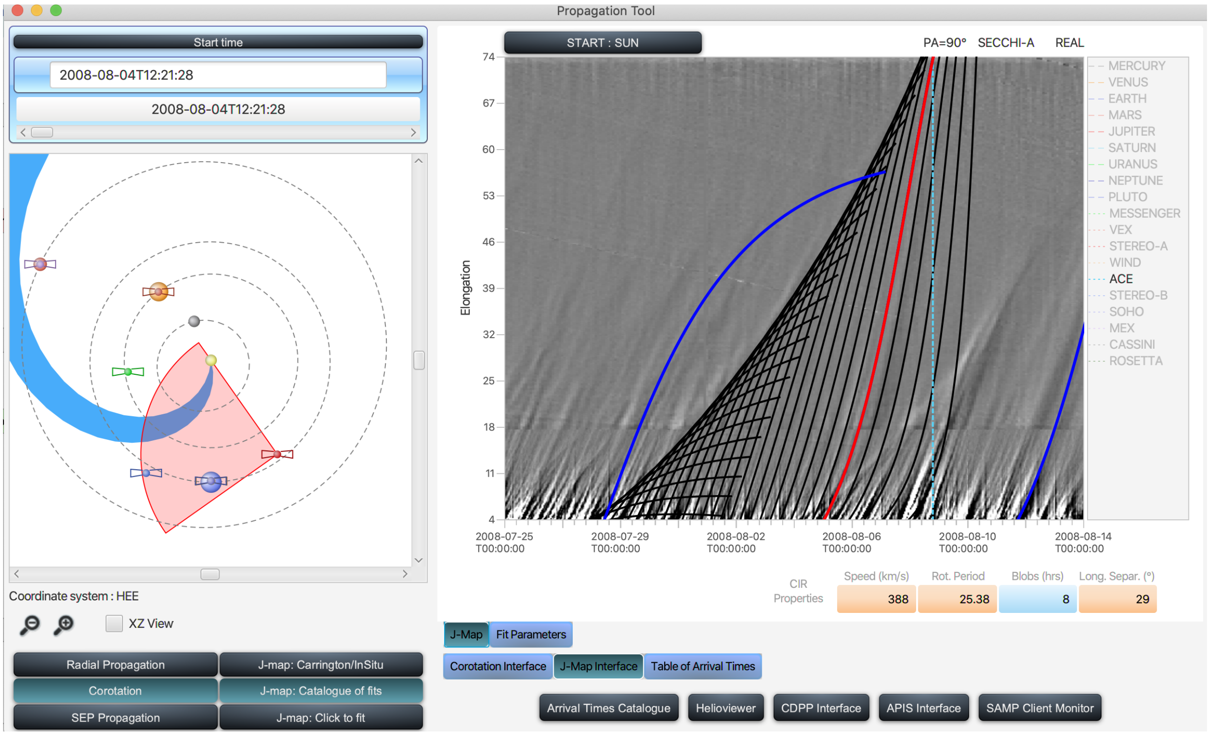


Figure 1 (a) Example of a J-map extending from 25 July to 14 August 2008. (b) The same J-map but overlaid with time–elongation profiles corresponding to a series of individual blobs that comprise a CDS. The red curve is the actual fit to one well-observed CDS blob (emission time 2008-08-03T21:36:26 UT, $V_b = 358 \pm 10\ \mathrm{km\,s^{-1}}$, and $\phi = 34^\circ \pm 3^\circ$). The black curves, reconstructed using this speed, simulate the elongation variations of a series of such blobs emitted at 8-hour intervals from the same region on the Sun. (c) The orbital configuration at the emission date (see detailed comments in text). (d) The coronal map for the Carrington rotation 2073 at a wavelength of 195 Å, derived from ST-A/EUVI images.

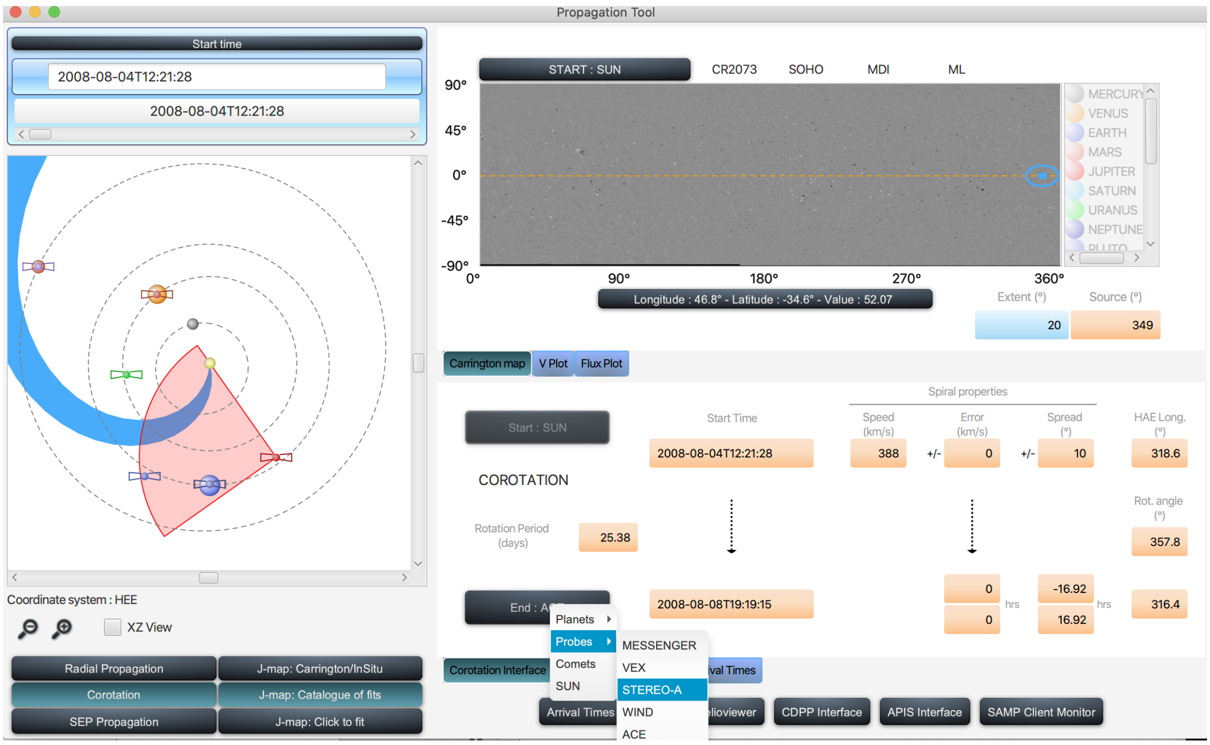
Now, in Propagation Tool, select the date of 2008-08-04.
Select ‘Corotation + Jmap: catalogue of fits’ mode

Right-click on the Jmap (right-side panel) -> Select fit by click -> Click on the middle blue line that starts on 2008-08-04. You should see appear the following pattern on the Jmap:



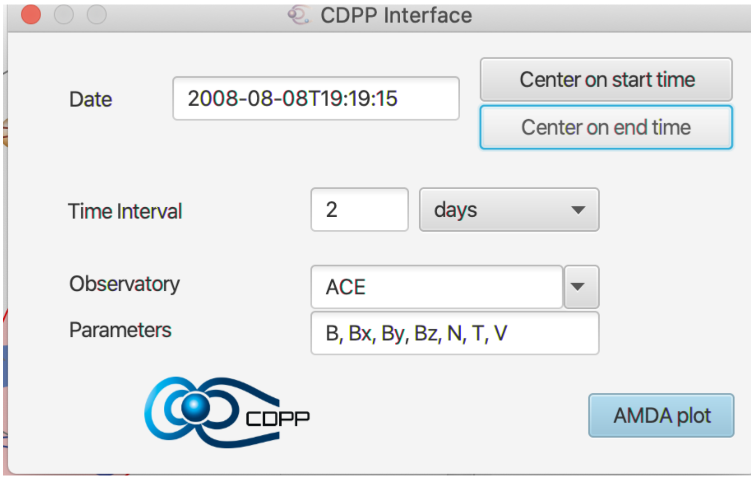
This pattern reconstructs the tacks of density blobs released at 8h intervals from the same region on the Sun and propagating radially outwards.
The red line corresponds to the reference track that was used in the saved fitting.

Now, go to the ‘Corotation Interface’ (left blue button at the bottom). Click on the END -> Probes -> ACE, as shown below:

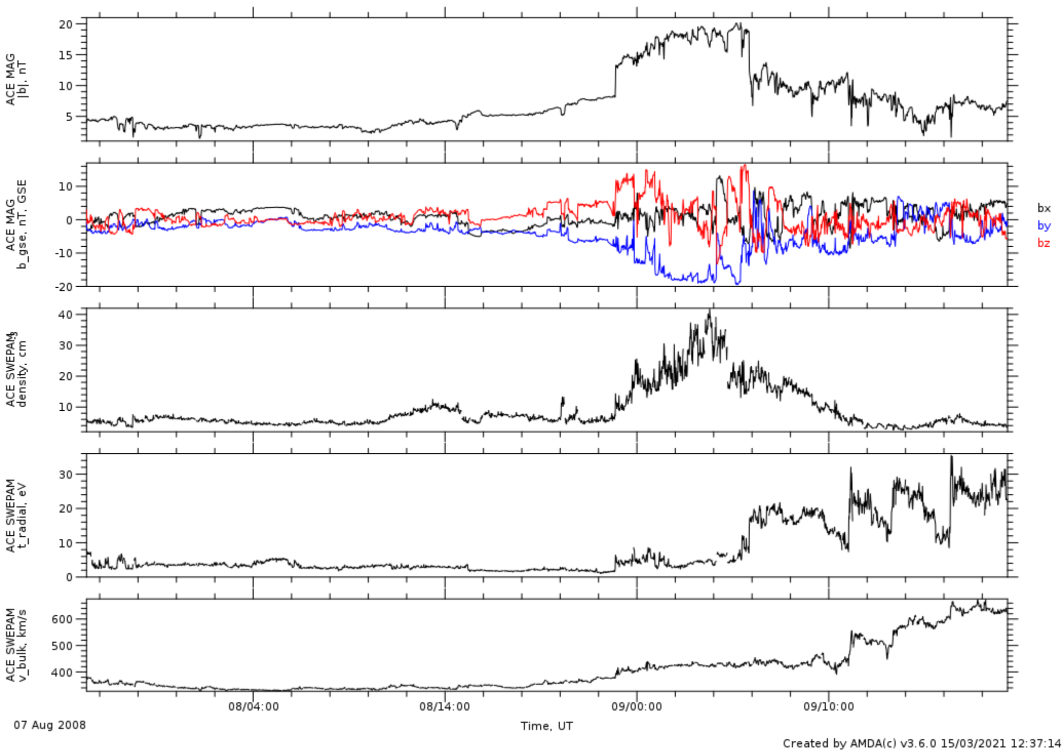


This will calculate the impact time of the fitted CIR structure at the position of ACE spacecraft on 2008-08-08 at 19:19.

Then go to the CDPP interface -> Click on ‘Center at end time’ -> Select ‘Time Interval’ at 2 days. Select ‘Observatory’ = ACE -> B, Bx,By,Bz,N,T,V:



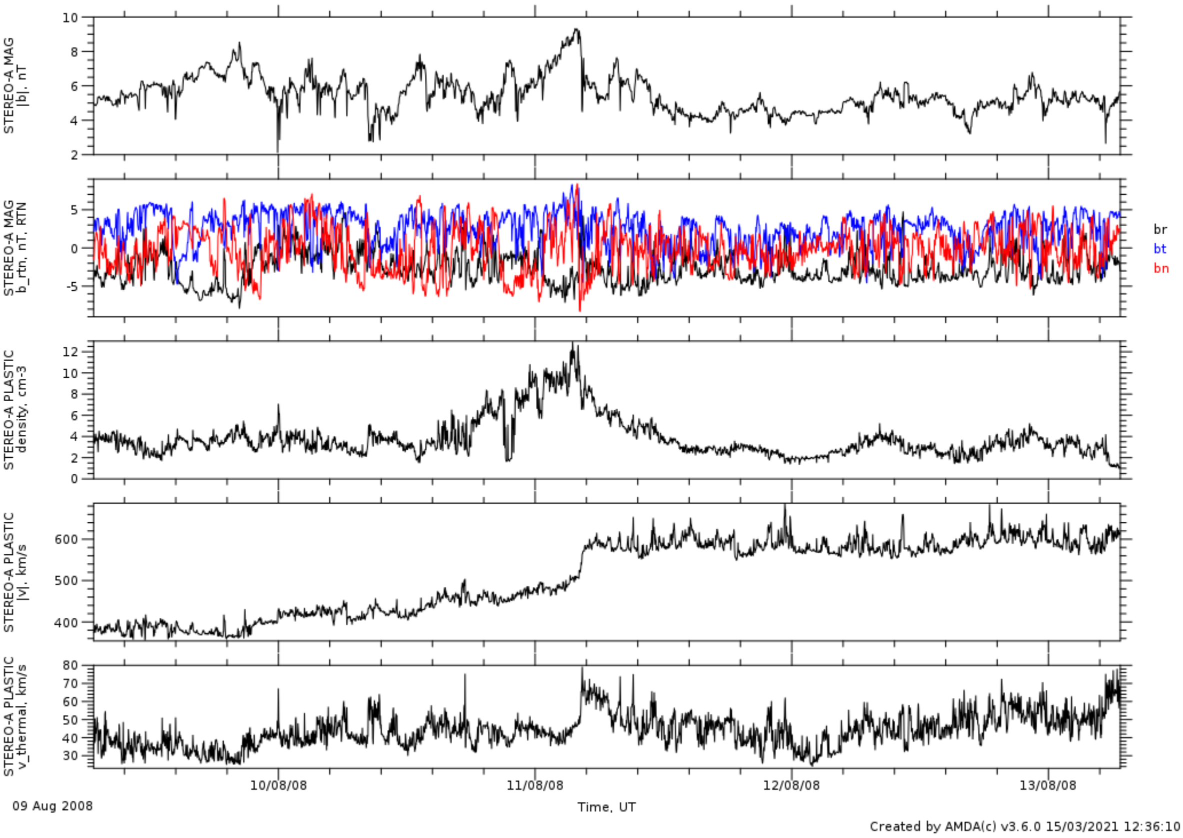
By clicking on ‘AMDA plot’ you will open a web browser that will call AMDA database. You should see appearing the following plot (2 day window of ACE in-situ data centered on the selected end time):



By inspecting the plots, you can see the magnetic field and density increase around 2008-08-08 at 22:00, which is slightly later than predicted from the Jmap fit.
The CIR nature of the in-situ data is confirmed by solar wind velocity increase from 360 km/s prior to the density blob (slow wind), to 630 km/s after the density blob (fast

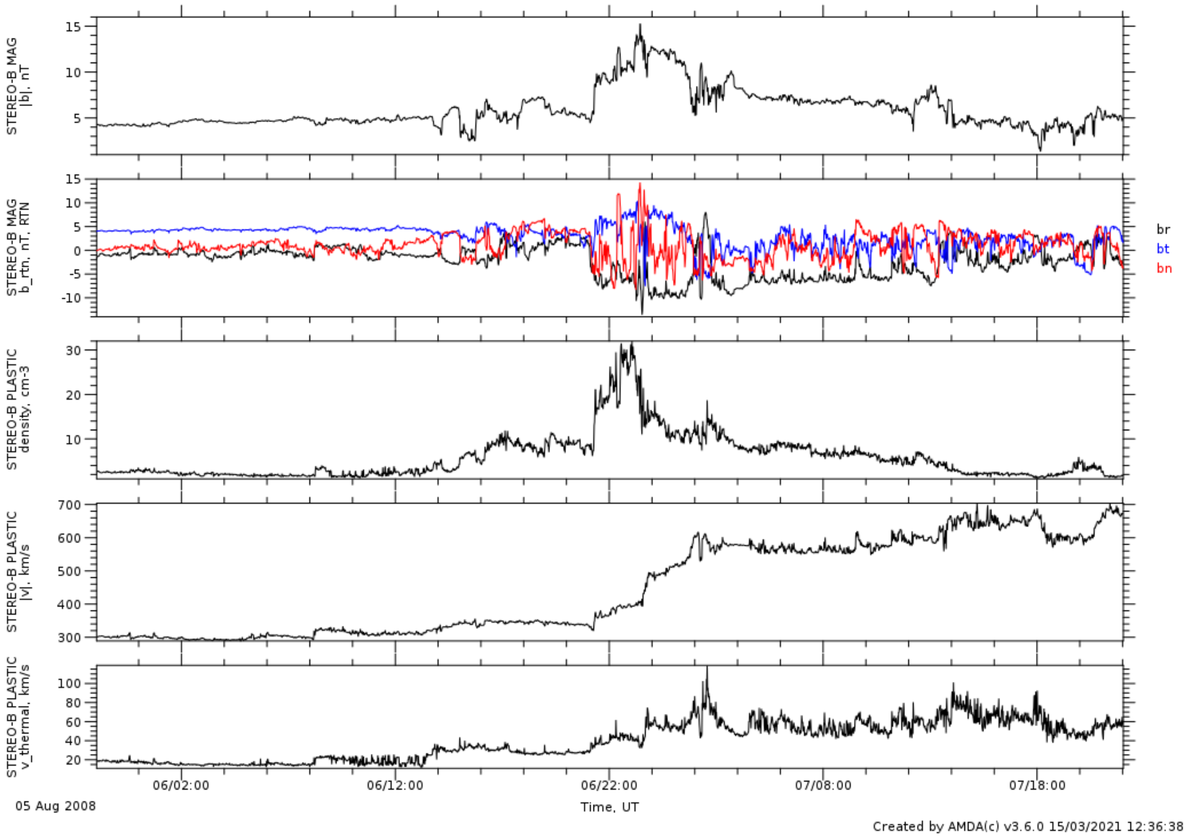
wind). The peak of the density structure corresponds to the so-called ‘stream interface’.

Now, you can repeat the procedure for STEREO-A: select END: STEREO-A -> Go to ‘CDPP interface’, center on end time / 2 days / STEREO-A -> ‘B, Bx,By,Bz,N,T,V’:



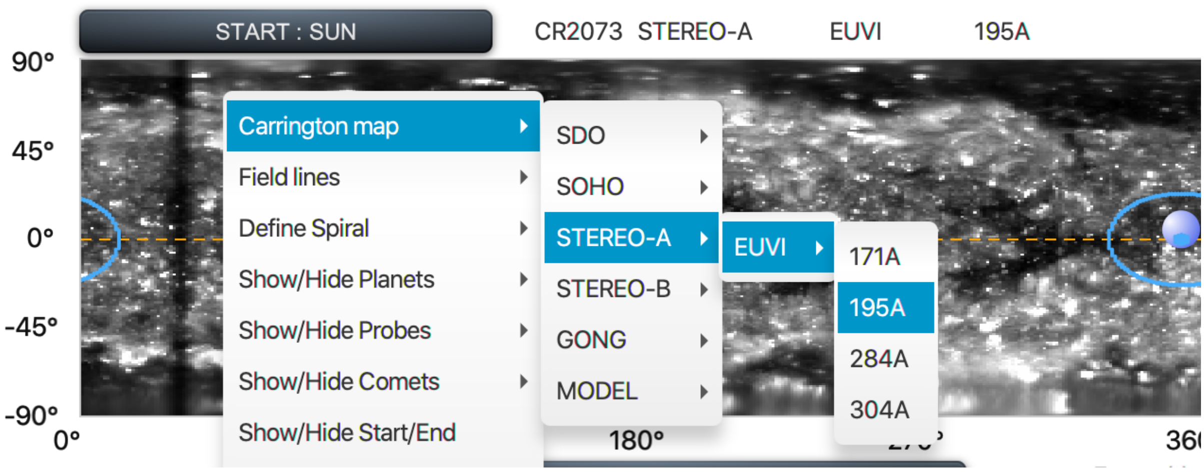
Here, the stream interface is less clear but we still clearly see the transition from slow to fast wind.

And the same procedure for STEREO-B gives:

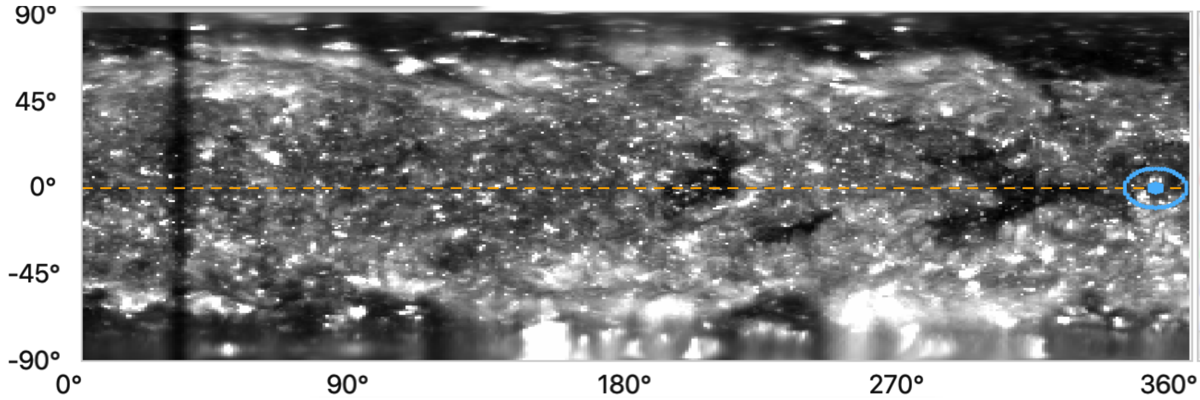


Here the prediction of impact time is the most accurate, as the stream interface is close to the middle of the plot.

Now, you can browse the EUVI Carrington map from STEREO-A, by going to ‘Carrington interface’ -> ‘Carrington map’. Right-click on map and choose ‘Carrington Map/STEREO-A/EUVI/195A:

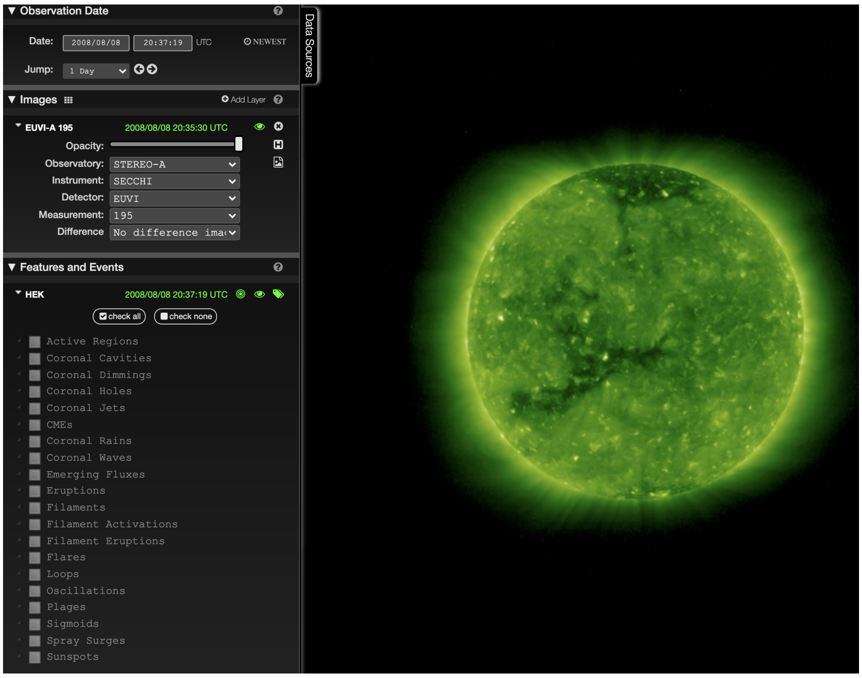


Remark the equatorial Coronal Hole (low-luminosity feature) at equator (latitude close to 0 deg) and longitude 300 degrees, here appearing as V-shaped form:



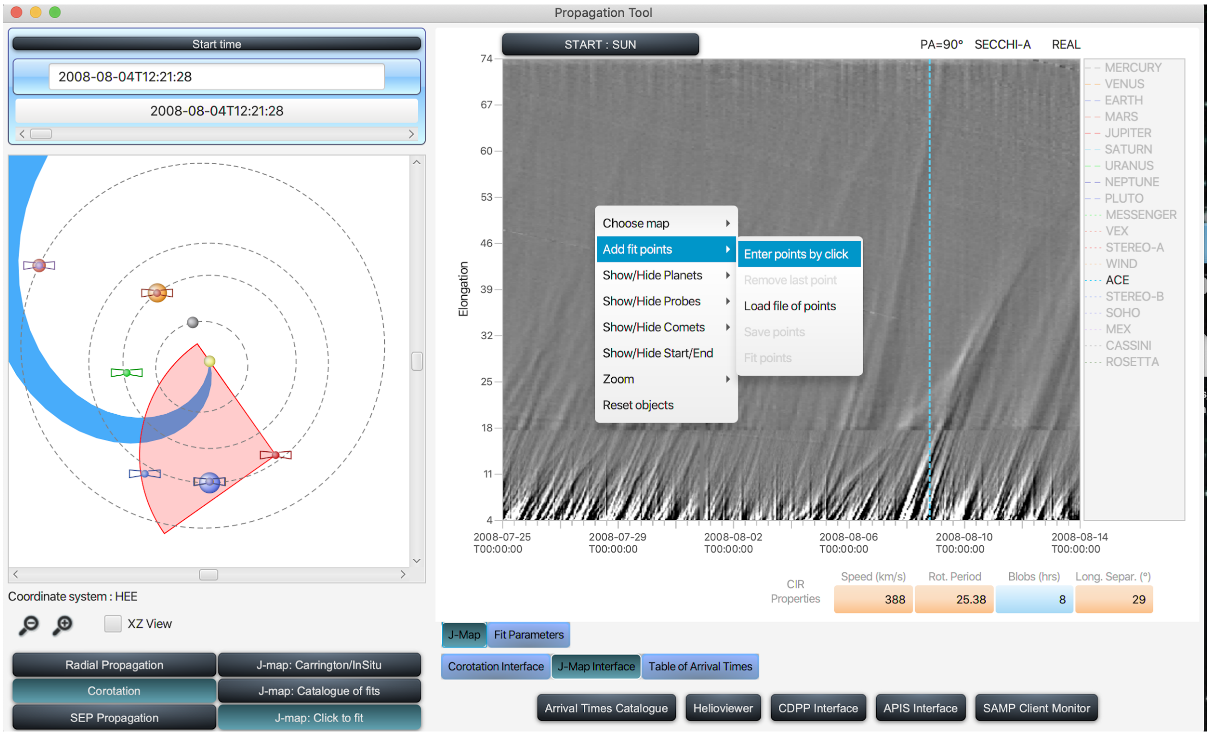
The interface between this coronal hole (source of fast solar wind) and source of slow wind at larger longitudes produces, at large heliospheric distances, the observed CIR.

Alternatively, you can also view the solar disc observations in different wavelengths through the call to Helioviewer (button in the lower panel of the Propagation Tool)
Click on ‘Helioviewer’.
Select the date 2008-08-08T00:00:00.
Observatory: STEREO-A/EUVI/195A.
Click on ‘via Http’.
This will open the web browser and display the following image:

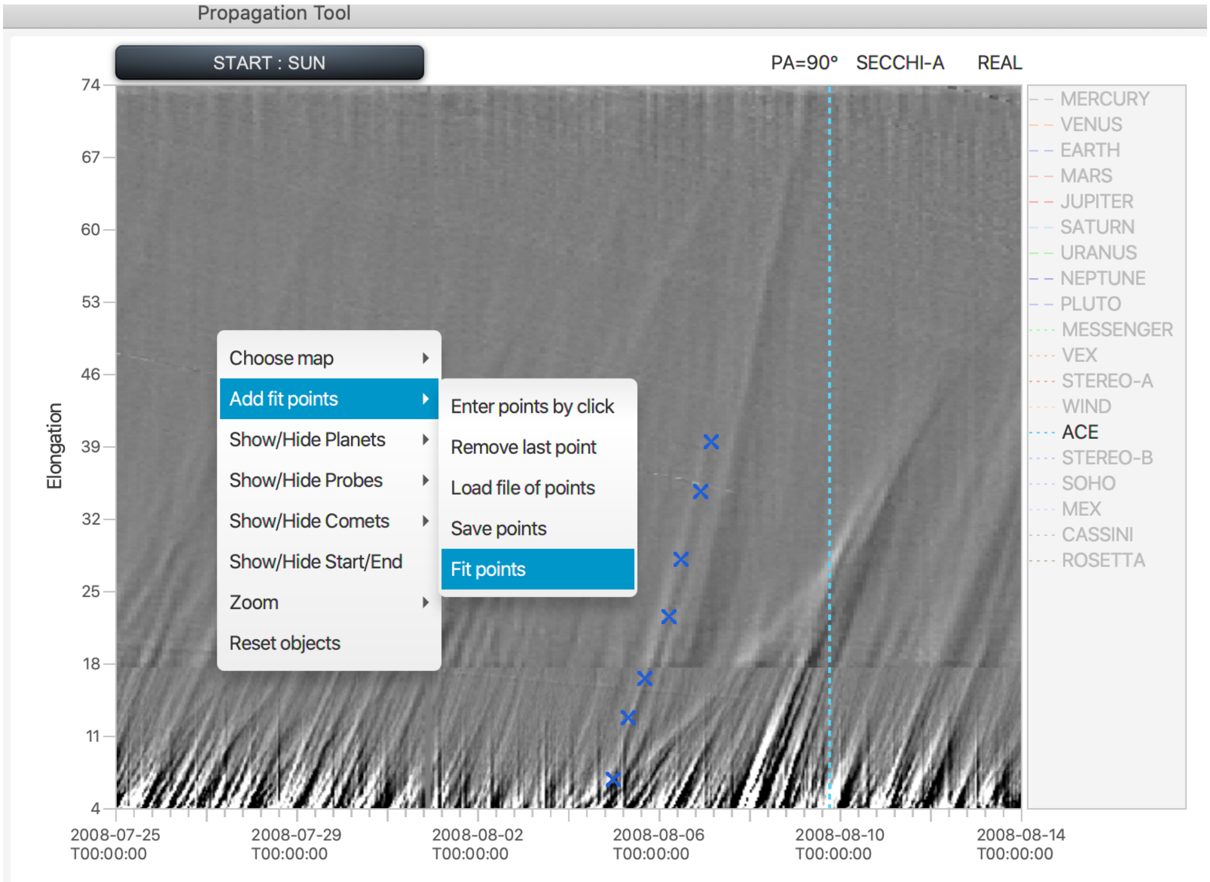


The coronal hole is clearly seen around the solar equator.
You can, of course, explore other display capabilities of the Heliviewer.

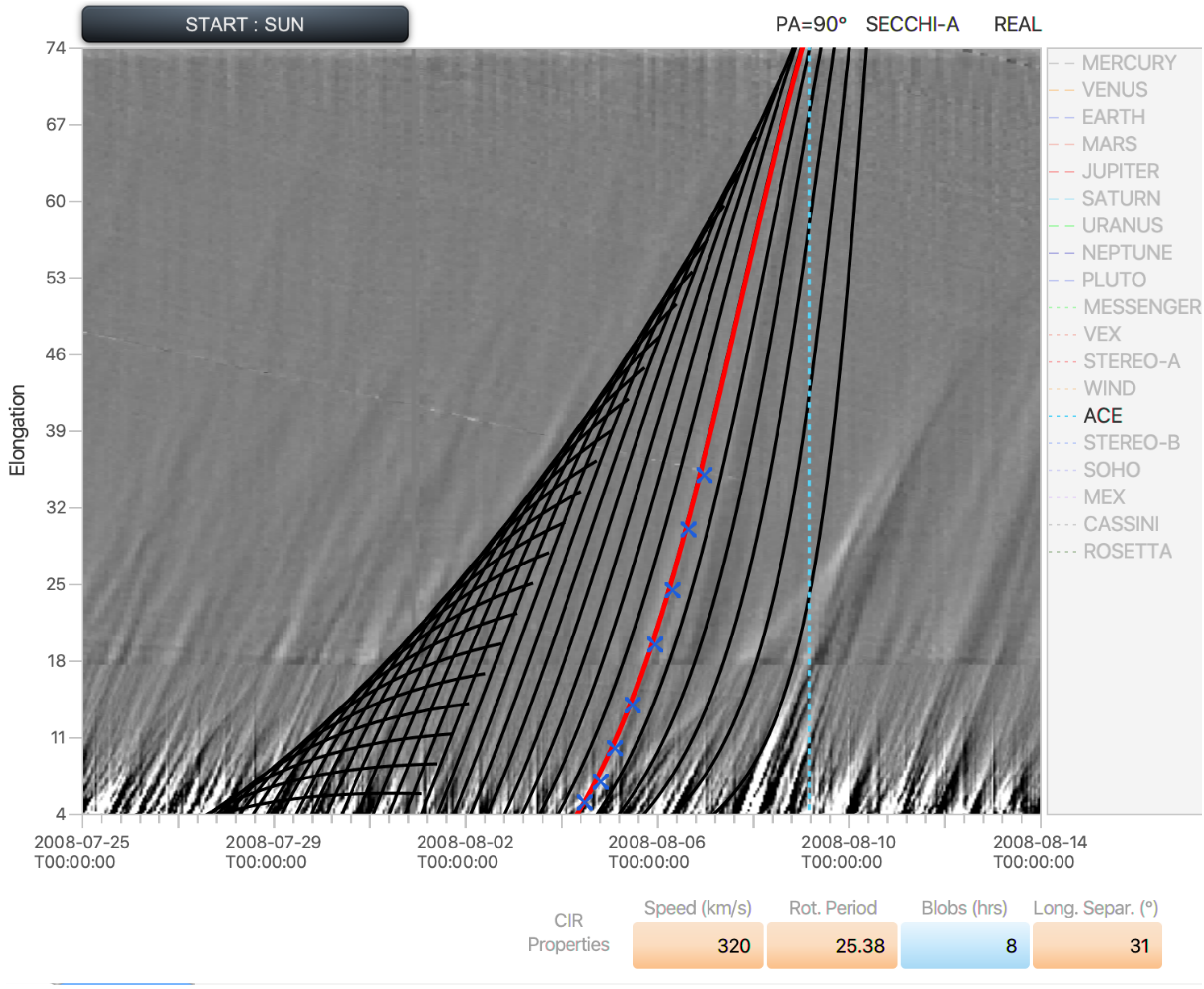
Alternatively, instead of using the catalogue of fits, you can make the fits by yourself. Below we present the procedure.
Select ‘Corotation / Jmap: click to fit’ mode.
Go to Jmap interface.
Right-click on the Jmap, select ‘Add fit points/ Enter points by click’, as in the figure below:



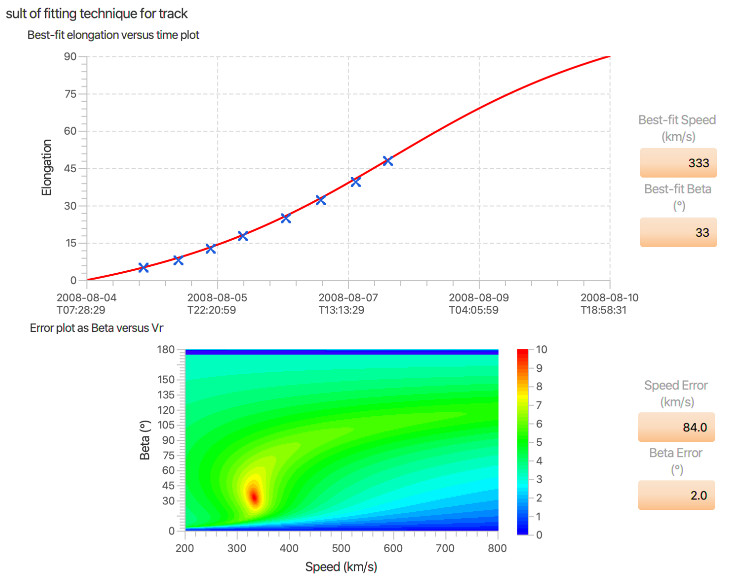
Add points by left-click on a given bright track (example below):



Once you added some points, do a right-click: Add fit points -> Fit points. This will produce a series of reconstructed tracks. An example is shown below:



Sometimes, it is necessary to do several tries to make a good fit of the 'reference' density blob AND of the common envelope of all tracks (locus of enhanced visibility). By clicking on 'Fit parameters' you can see the quality of the fit:



You can now calculate the impact times as in the previous example.

Exercise: do the same analysis for the 2007-Sept-11 CIR.

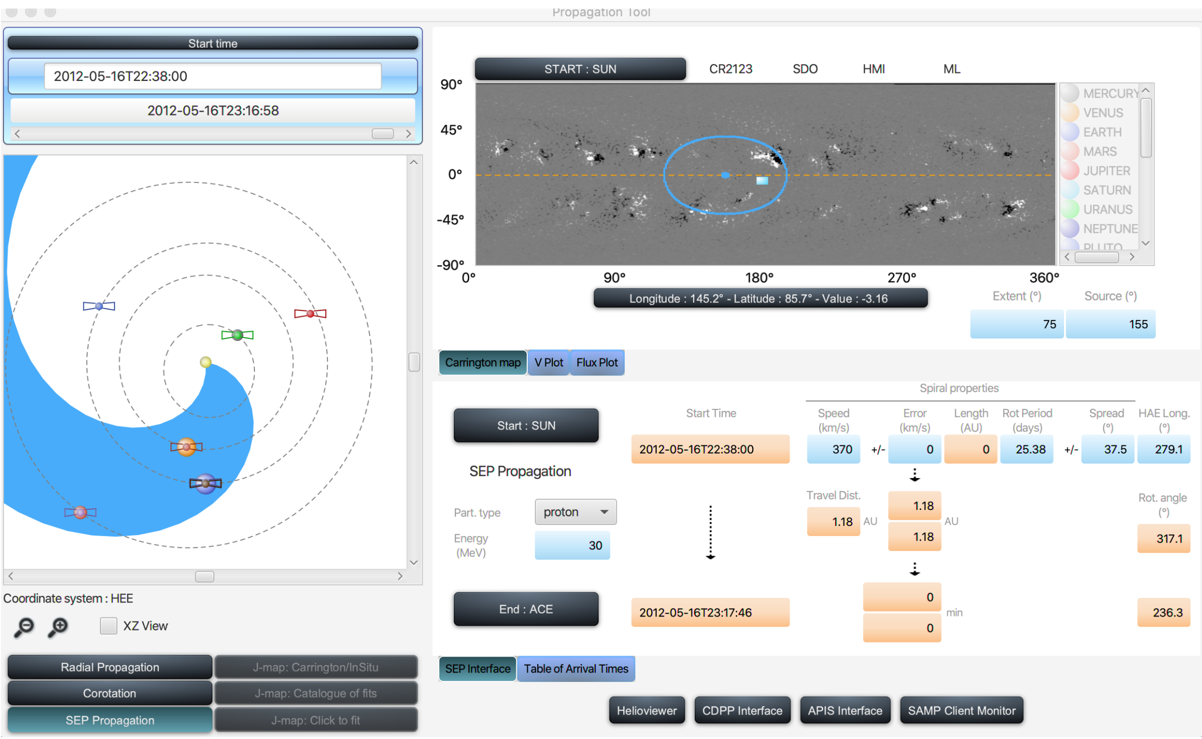
Case study 3: SEPs

Solar Energetic Particle (SEP) events are sudden enhancements of non-thermal particle flux measured in-situ by space-based missions (e.g., ACE, Wind, STEREO, Solar Orbiter). For large SEP events, these particles are accelerated in nearly collisionless plasma of the solar corona and beyond (by, e.g., flaring magnetic loops and CMEs). SEP events can be impulsive or gradual depending on their duration (from hours to several days). Being charged, these energetic particles follow magnetic field lines from solar corona to the observer. In the interplanetary space, the structure of the field is usually assumed to follow a Parker Spiral.

Here, we propose a case study of ballistic propagation of SEPs for one solar event.

Select the third mode of the Tool that deals with SEPs: ‘SEP propagation’.

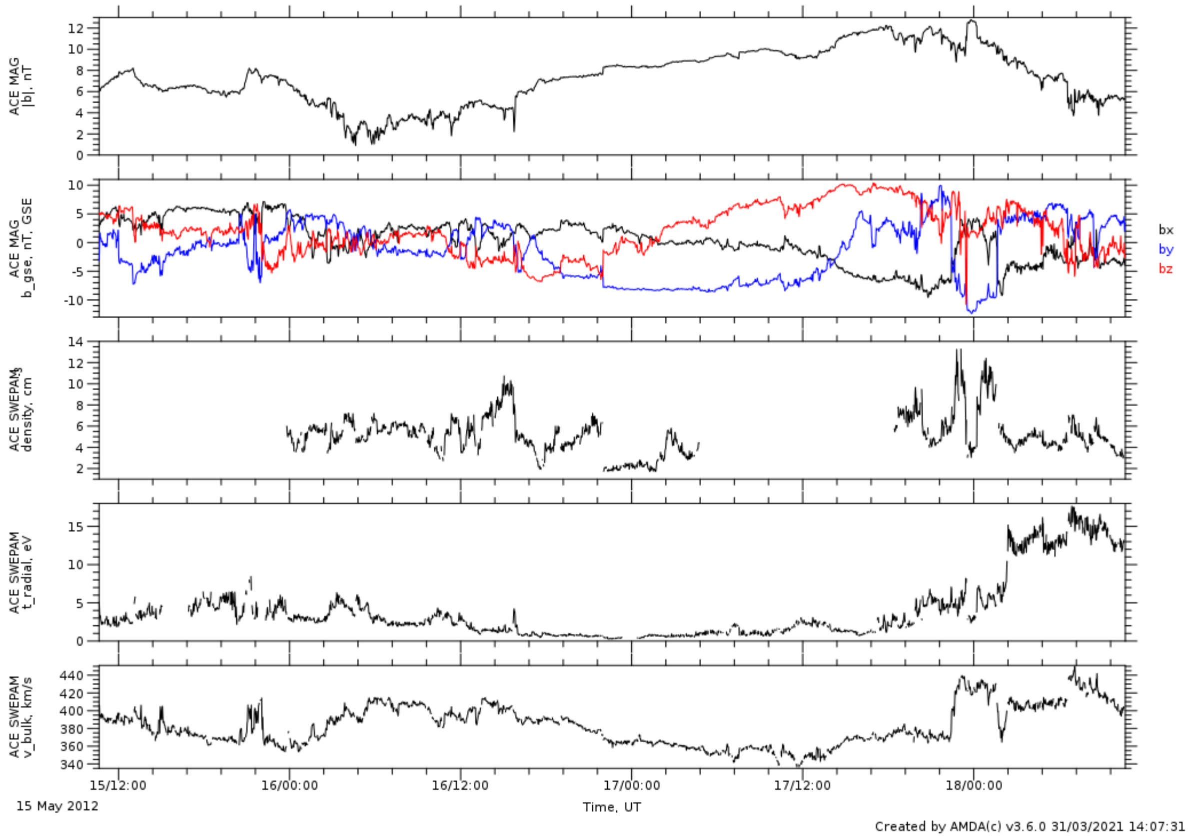
- Select the date on 2012-05-16T22:38:00
- Upper right side: define source longitude in ‘Source’ box at **155 degrees**, ‘Extent’ on **75** degrees, and ‘Spiral Properties’ / speed on **370 km/s**.
- You should obtain the following screen:



Now, you can play with ‘SEP propagation’ box by selecting protons and electrons of different energies and deriving the expected SEP arrival time on ACE (or other near-Earth satellites). This time can be compared with in-situ energetic particle flux measurements (not yet available within Propagation Tool).

What you can also do to check the consistency of chosen date, source position, spiral speed:

1) Find start time of the CME in Jmap, using ‘Radial Propagation / Catalogue of Fits’ mode.
2) Go to Vplot bloc, select Start: Probes / ACE. Read the solar wind speed at the start time, as measured by ACE. Is it close to Parker Spiral speed selected?
3) Try different speed for the Parker Spiral. See how the ‘Travel Dist’ of particles changes (path length on the Parker Spiral from source to the observer).
4) Using the start time and selecting different probes (e.g., ACE, Wind) plot in-situ B-field and solar wind using CDPP interface. Below we show for ACE:



It illustrates that the CME erupted on the Sun, when the Earth environment was inside a Magnetic Cloud connected to the erupting region. This probably played an important role for this event to be the first GLE of the last solar sycle.

5) NOT AVAILABLE YET: plot in-situ energetic particle flux using CDPP interface
6) Display the soft X-ray from GOES (‘Flux Plot’ bloc) and find the flare start time.