Modeling and Data Analysis Tools in support for Solar Orbiter and Parker Solar Probe science

R. Pinto (1), IRAP/CDPP and MADAWG teams

(1) IRAP / CNRS-OMP / U. Paul Sabatier, Toulouse, France

Connectivity Tool

. **past** and **future** spacecraft – solar surface connectivity

. **Solar Orbiter**, **Parker Solar Probe**, etc.

Accurate background solar wind simulations

. physics based modeling, alternative to semi-empirical (WSA)
. data driving, full set of background wind properties (speed, density, etc)
. flexible setup: full 3D, plane-of-sky, orbit, etc.

. a **two step problem:** corona + heliosphere
. **fit into/complement existing SWx tool ecosystem** (cf. swe.ssa.esa.int, CCMC)

. **Interface with ConnectTool, PropagationTool**, **AMDA**, etc.

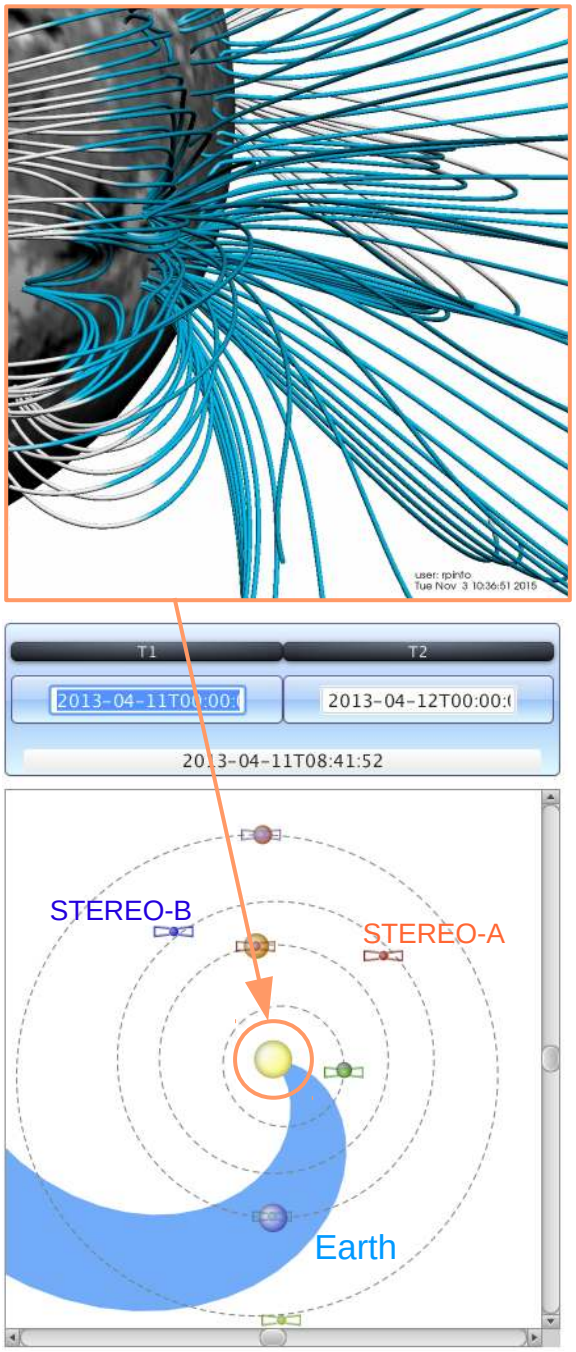
MADAWG (Modeling and Data Analysis WorkGroup)

STORMS (Solar Terrestrial ObseRvations and Modeling Service)

Rui Pinto
(rui.pinto@irap.omp.eu)

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

Connectivity Tool



- **Paths** and **delays** of propagation Sun – spacecraft

  (wind flows, CME, shocks, energetic particles)

- **Use many models:** forecast redundancy

  (but keep it simple!)

- **Planning and management of campaigns**

  exploit synergies between multiple s/c.

- **Scientific exploitation**

  past data: post-event analysis relating in-situ ↔ remote,

Connectivity Tool

Layout of the connectivity tool

1. Chose mode of operation

Post-event analysis **Forecast**

↓

2. Choose date or s/c position

↓

3. Trace down magnetic field-line

i) Parker spiral or heliospheric model

use **measured** wind speed use **estimated** wind speed

ii) Coronal field reconstruction

(PFSS, NLFFF, MHD, . . .)

use **HMI magnetograms** use **ADAPT magnetograms**

↓

4. Find connectivity points at the surface

Take into account propagation delays (wind, particles)

Plot maps at slow/fast wind / SEP launch times + target time

Compare instrument FOV, estimate uncertainties

Connectivity Tool

Home Help Contacts

Prototype webpage http://storms-connectsolo.irap.omp.eu/

Solar Orbiter / Solar Probe Plus Connectivity Tool

Select date/time at spacecraft

Date: 2020-05-01 00:00

Mode: SCIENCE

Select Science/ Forecasting Mode

Select coronal model

Coronal magnetic field: PFSS

Interplanetary magnetic field: PARKER

Select interplanetary model

SEARCH

Time reference | SDOHMI | SDO171

Carrington maps at plasma impact time

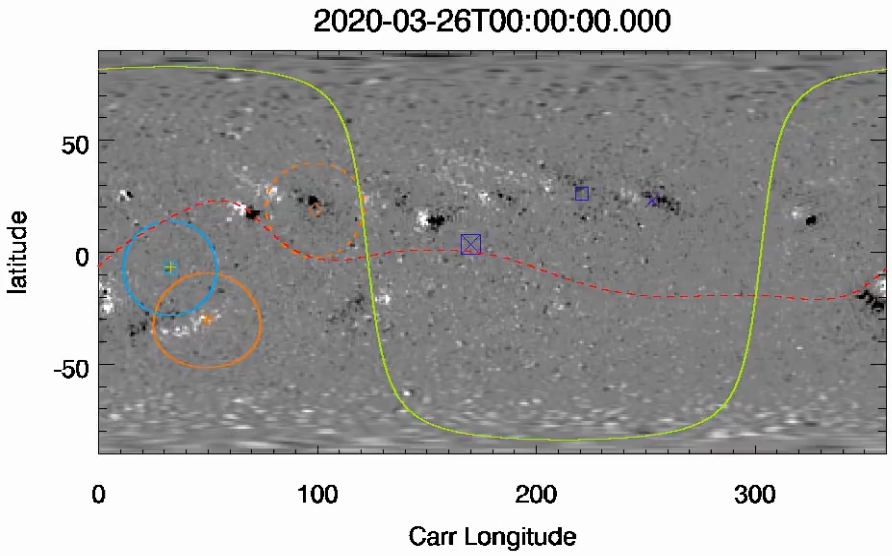
Spacecraft

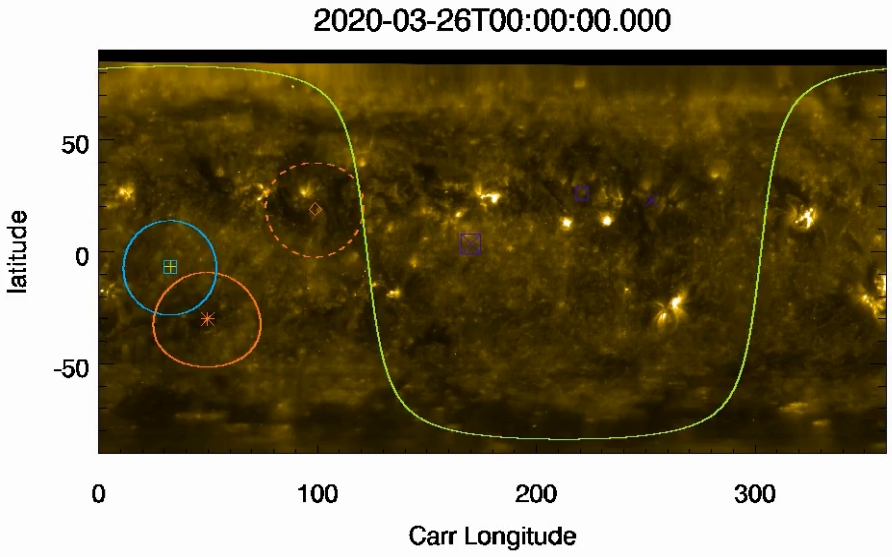
Carrington maps at plasma release time

Sun

IT team : M. Bouchemit, M. Indurain

Solar Orbiter CONNECTIVITY TOOL





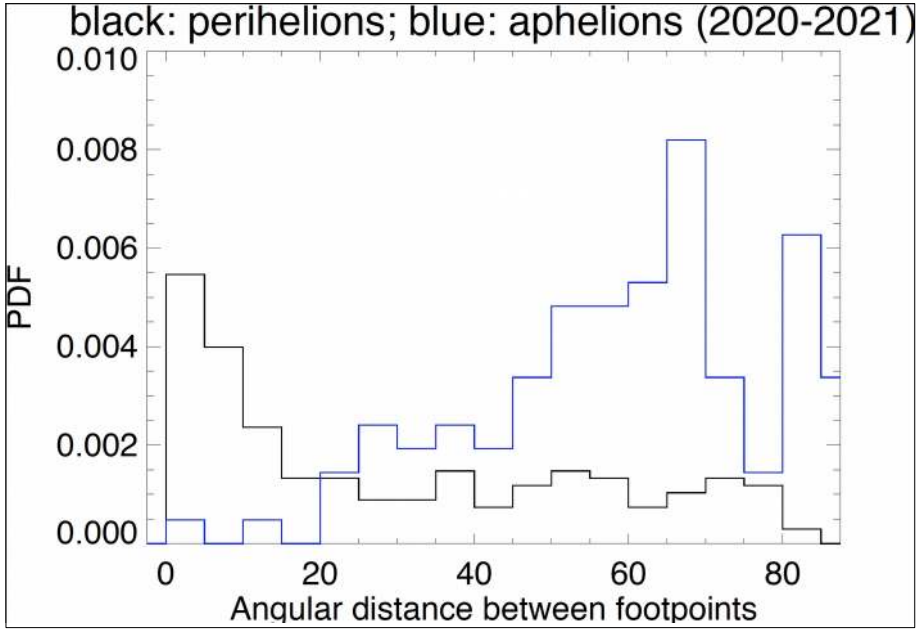
HMI magnetograms (time-evolved)
EIT 171 Å

Limb as seen from Solar Orbiter
Neutral line

EUI FOV centered on Solar Orbiter position
EUI FOV centered on Solar Orbiter footpoints
(slow wind and fast wind)

Position and footpoints of Parker Solar Probe

Solar Orbiter footpoint separation

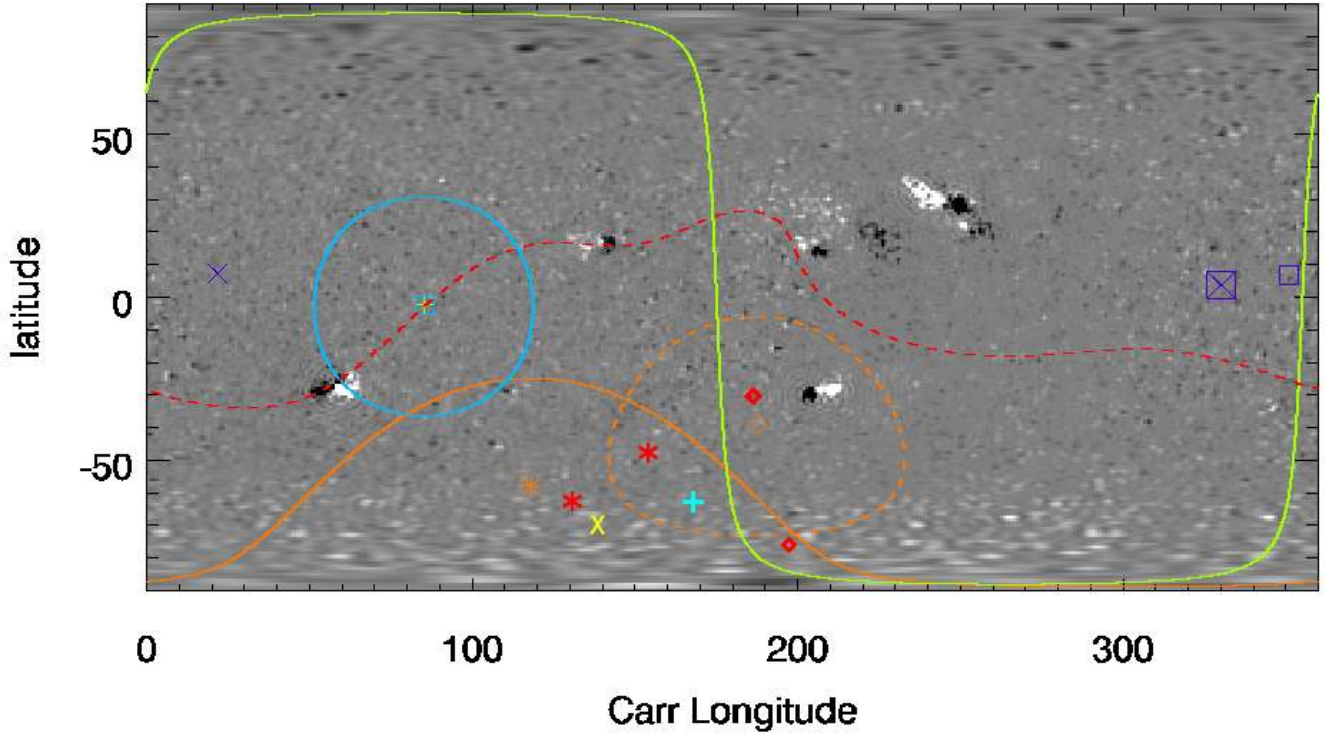


Connectivity maps

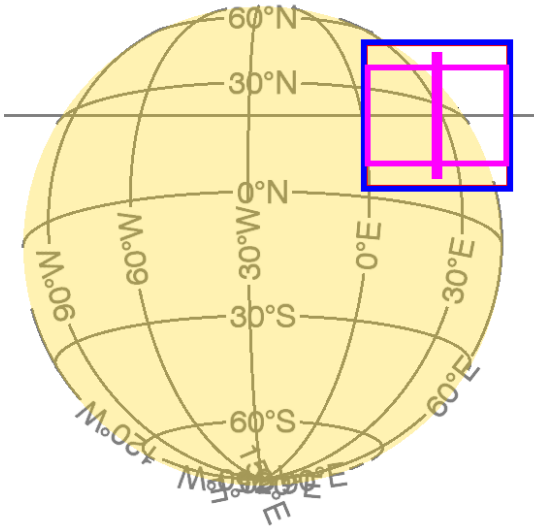
Forecasting: testing different approaches

Corona:
ADAPT+PFSS, ADAPT+NLFFF (maybe)

Heliosphere:
PARKER, EUHFORIA, ENLIL



asterisks/diamonds: fast, slow wind ADAPT; X cross: EUFHORIA; + cross MULTI-VP



End data product:

probability distribution of connectivity
(positions + sizes of distributions vs. FOV)

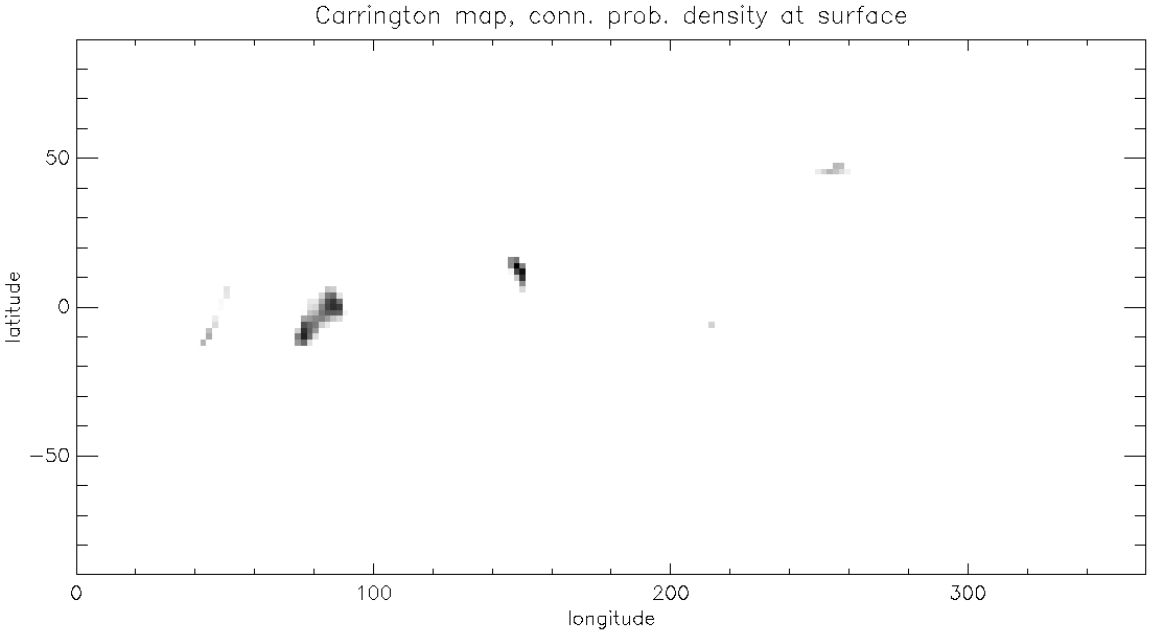
Souces of scatter :

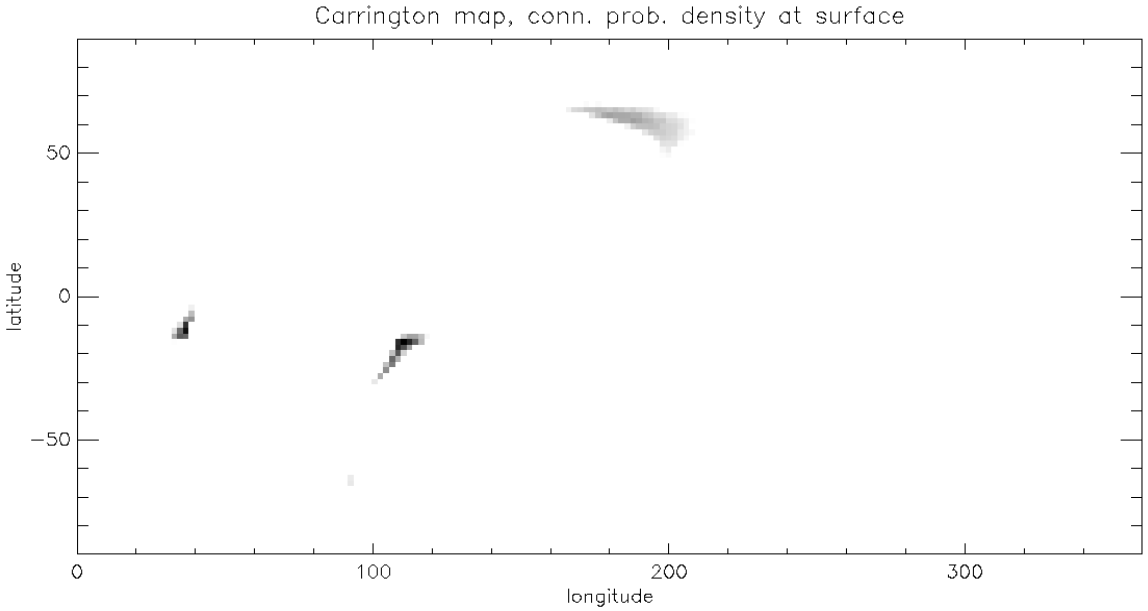
- **different magnetogram sources**
- **magnetic field extrapolation methods**
- **assumed/forecasted wind profile**

Tasks :

- **cross-calibrate different magnetograms**
  (cf. Riley et al, 2014, Linker et al 2017)
- **integrate fresh SolO/PHI data into the modelling**
- **synoptic → synchronic maps** (e.g, Henney, et al)
- **integrate other models from the community**

Connectivity: mapping the uncertainty





Method :

1) run an *ensemble* of connectivity estimations
different models, different parameters

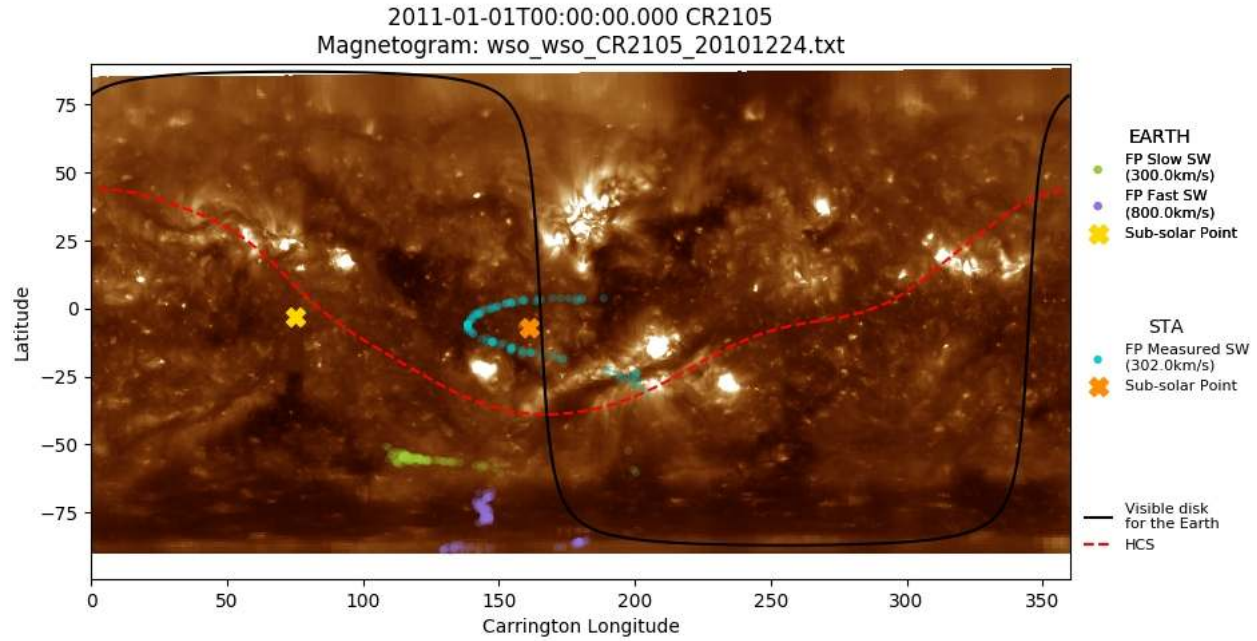
2) assign φ and θ uncertainty at R_{ss} for each estimation
typically, a bi-gaussian with $\sigma_\varphi > \sigma_\theta$; $P^i_{ss}(t,\varphi,\theta)$

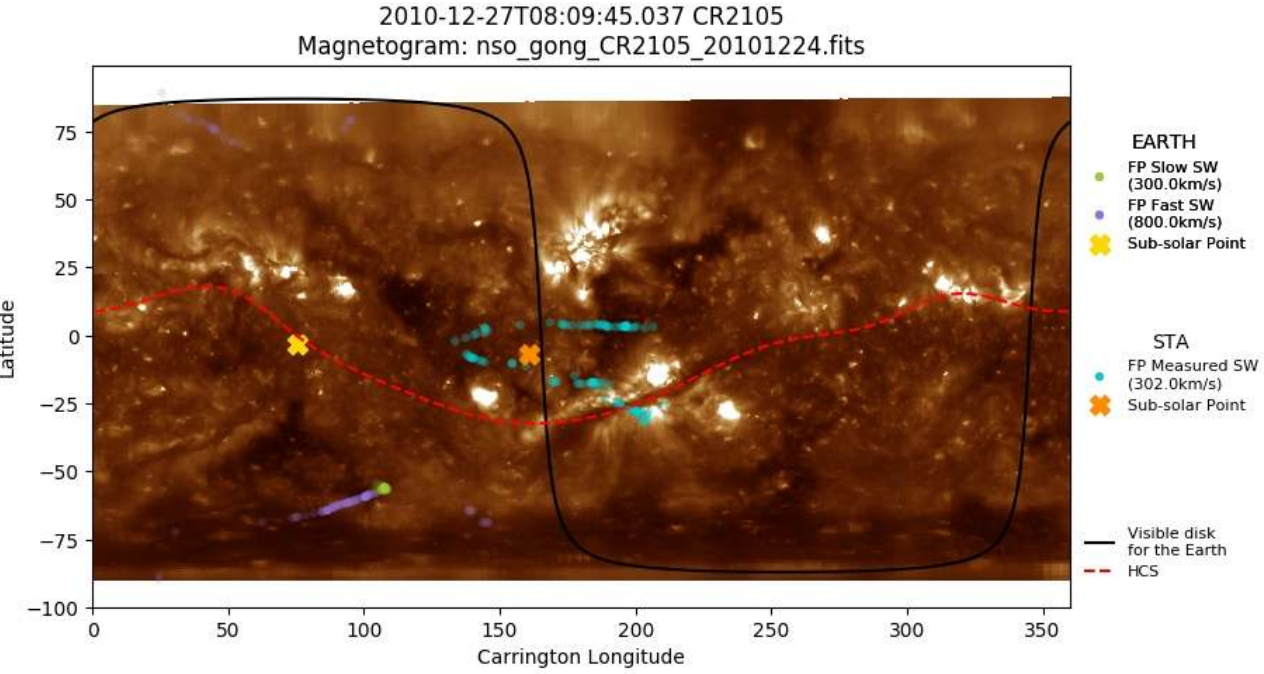
3) map probability density function down to 1 R_s
take mag. field topology into account,
respect magnetic path bifurcations,

4) combine all into one probability density function
keep a minimal amount of discriminant info

5) pick reduced set of coordinates for science ops.

Connectivity: mapping the uncertainty





Method :

1) run an *ensemble* of connectivity estimations
different models, different parameters

2) assign φ and θ uncertainty at R_{ss} for each estimation
typically, a bi-gaussian with $\sigma_{\varphi} > \sigma_{\theta}$; $P^{i}_{ss}(t,\varphi,\theta)$

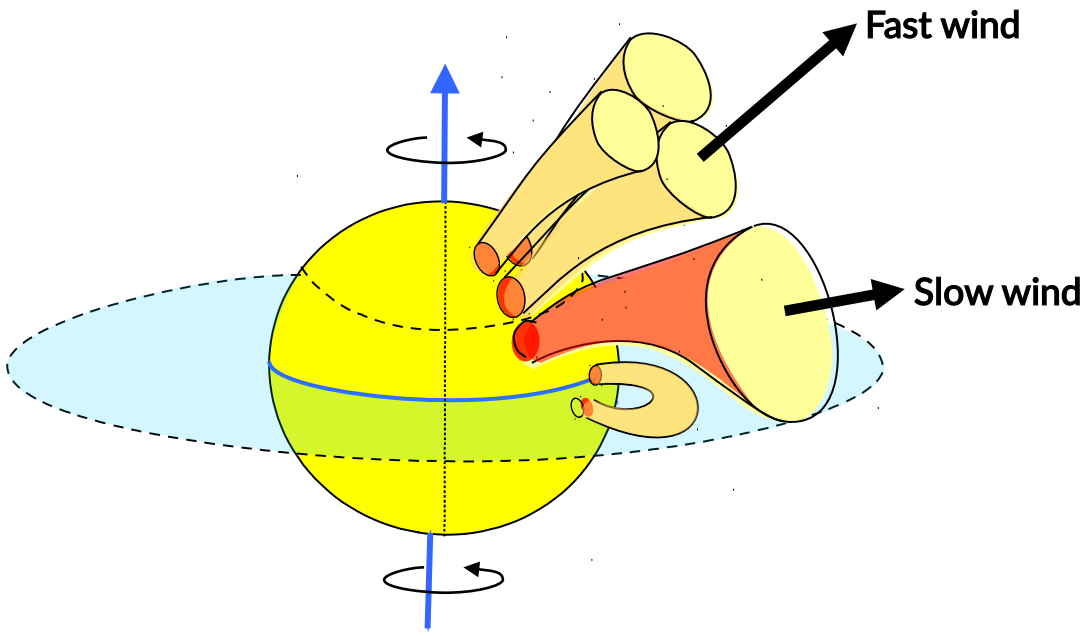
3) map probability density function down to 1 R_s
take mag. field topology into account,
respect magnetic path bifurcations,

4) combine all into one probability density function
keep a minimal amount of discriminant info

5) pick reduced set of coordinates for science ops.

Estimating the solar wind speed distribution

Semi-empirical scaling laws



WSA (Wang-Sheely-Arge)

$$V_{wind} = 265 + \frac{1.5}{(1+f_{ss})^{1/3}} \times \times \left[5.8 - 1.6\exp\left[1 - \frac{{\theta_b}^3}{7.5^3}\right]\right]^{3.5} \text{ km s}^{-1}$$

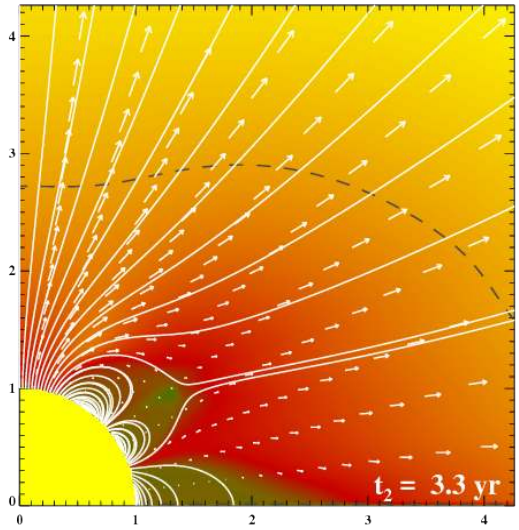
f_{ss}: total flux-tube expansion ratio (Wang, 1995; Velli 2013)
θ_b: distance to coronal hole boundary

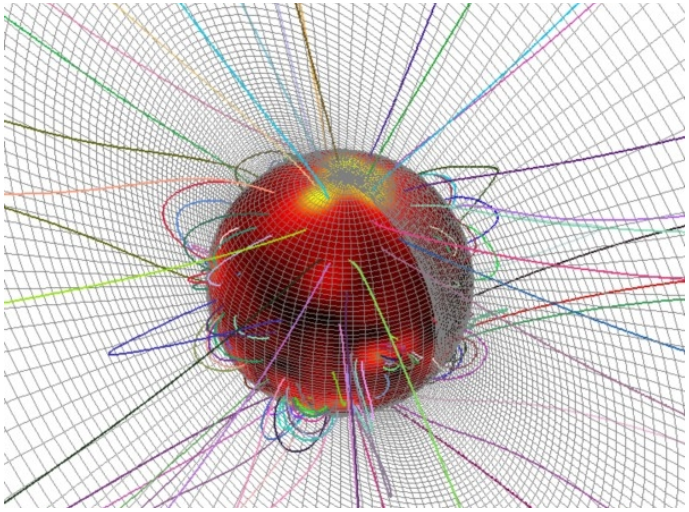
Coronal hole area – wind speed relation

$$V = (80 \pm 2)A + 426 \pm 5.$$

V: wind speed at 1 AU
A: total CH area
(Nolte et al 1976, Vršnak, et al 2007, Tokumaru et al 2016)

Global MHD corona and wind models





More physics, but higher complexity

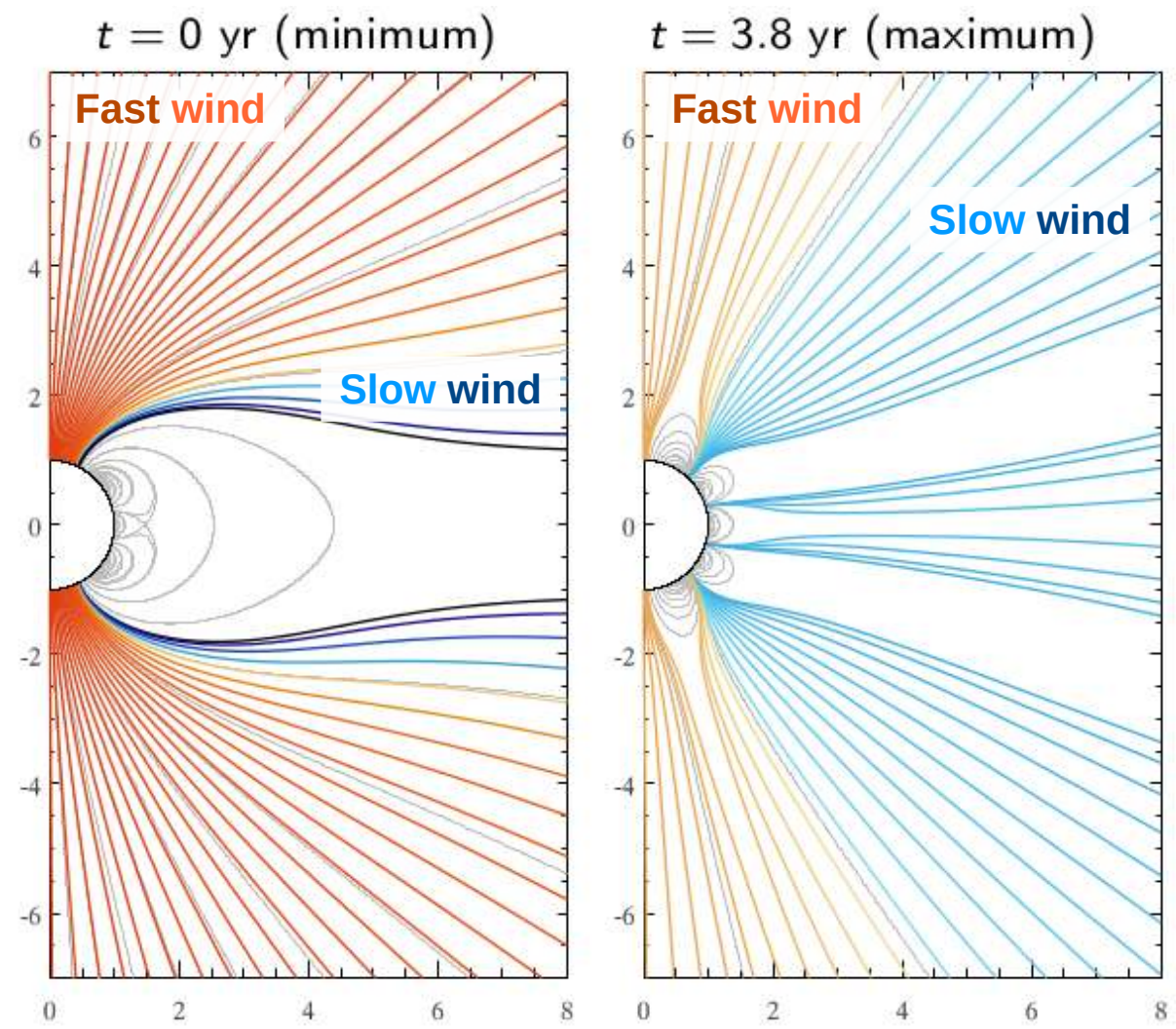
Full magnetic geometry
(but other simplifications)

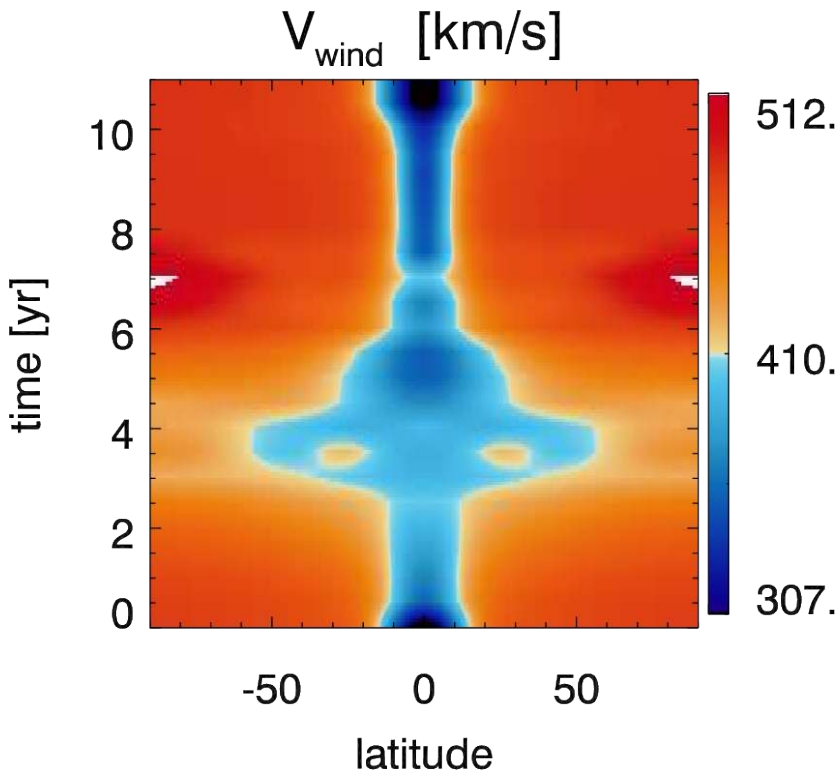
CPU-heavy
(especially in the corona)

Mikić et al (2011), Gressl et al (2014),
Pinto et al (2011,2013),
van der Holst et al (2015), +

Solar wind speed and flux-tube geometry

Global MHD simulations of the solar dynamo, corona and solar wind (11 yr cycle)





Wind speed distribution

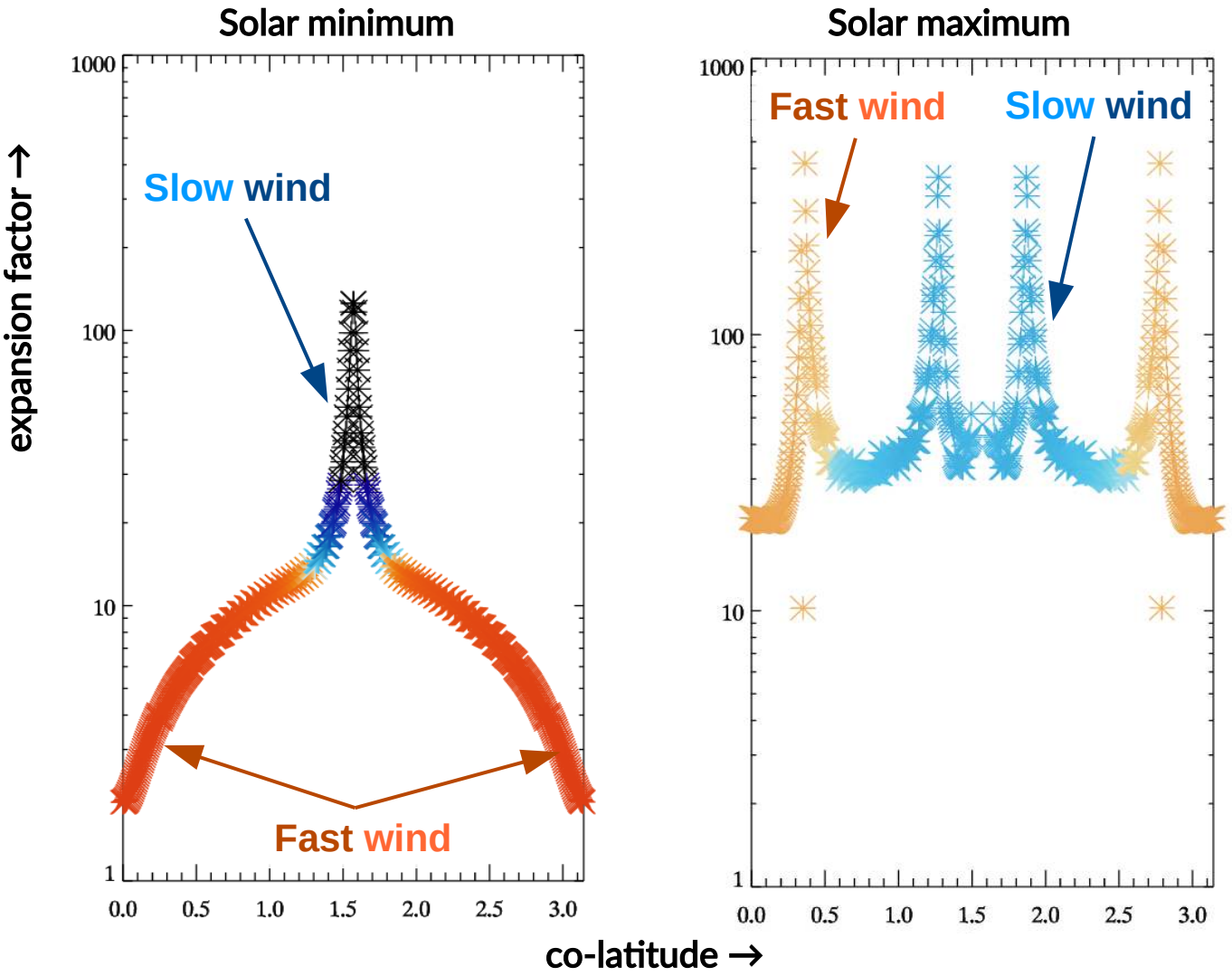
↕

Magnetic geometry

Pinto, et al (2011)
Pinto, Brun, Rouillard (2016)

Solar wind speed and flux-tube geometry

Expansion factor and wind speed



Flux-tube geometry:

- expansion profiles
- fieldline inclination

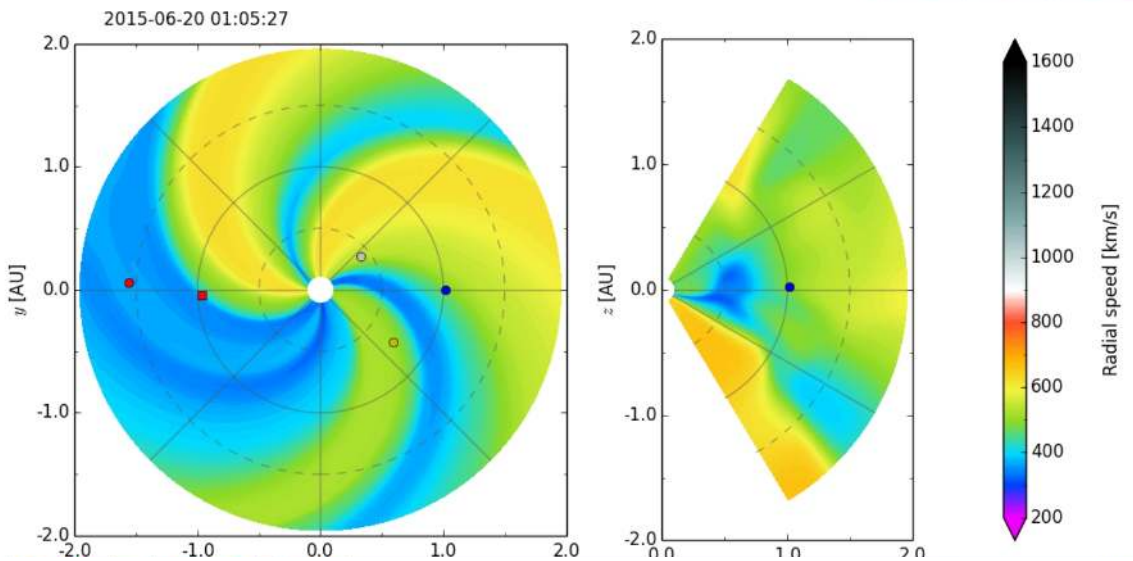
$$\partial_s v = \frac{v}{1-M^2}\left[\frac{GM_\odot m_p}{2r^2 k_b T}\cos(\alpha) - \frac{1}{A}\partial_s A\right]$$

α: inclination angle
A: flux-tube cross-section

Pinto, Brun, Rouillard (2016)
Li, et al (2011)
Peleikis, et al (2016)

Solar wind throughout the heliosphere

VSWMC - EUHFORIA



(credits: J. Pomoell, http://spaceweather.hpc.kuleuven.be/)

1) Semi-empirical model of the corona
- PFSS/SCS: geometry of B
- WSA: map of V_{wind} at 21.5 R_{sun} (=0.1 AU)
- Empirical scalings n-V_{wind} and T-n

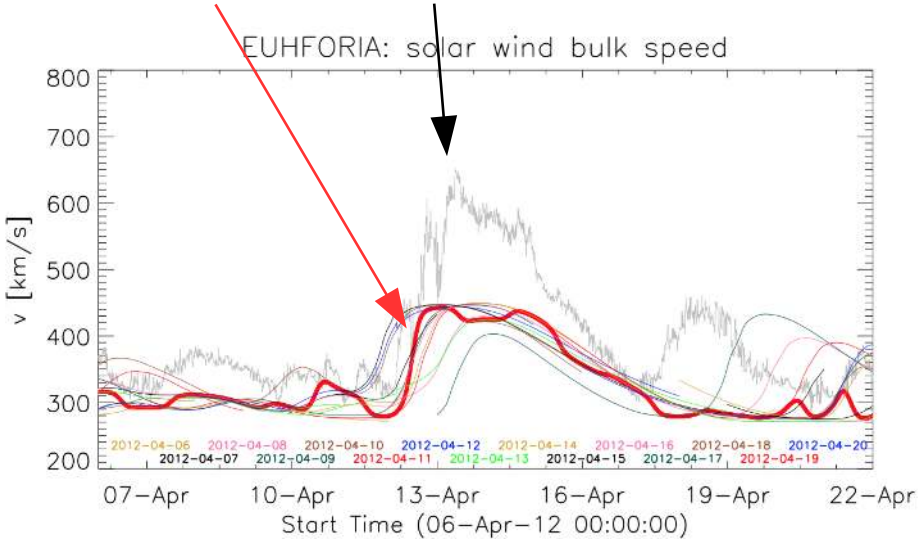
$$\rho = \rho_{fsw}(v_{fsw}/v)^2$$
$$T = T_{fsw}(\rho_{fsw}/\rho)$$

→ but there is now an alternative!

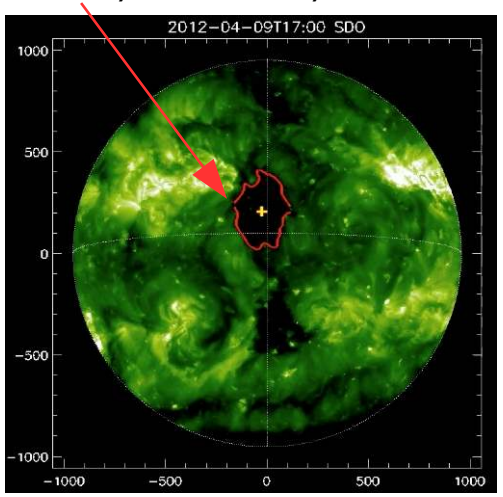
2) Physical (MHD) heliosphere
- EUHFORIA

propagate super-critical wind into IP medium
rotation: formation of SIR

EUHFORIA vs. ACE (forecasting of a HSS)



Boundary of most likely source CH



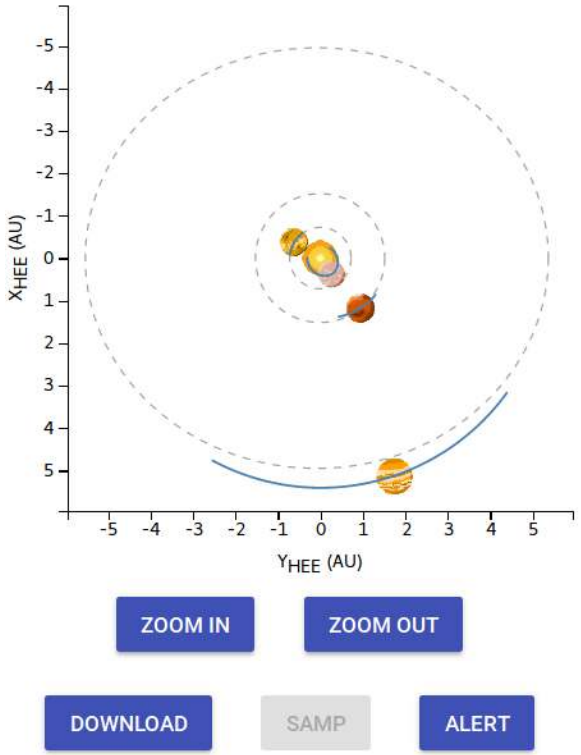
Heliospheric propagation of solar wind data

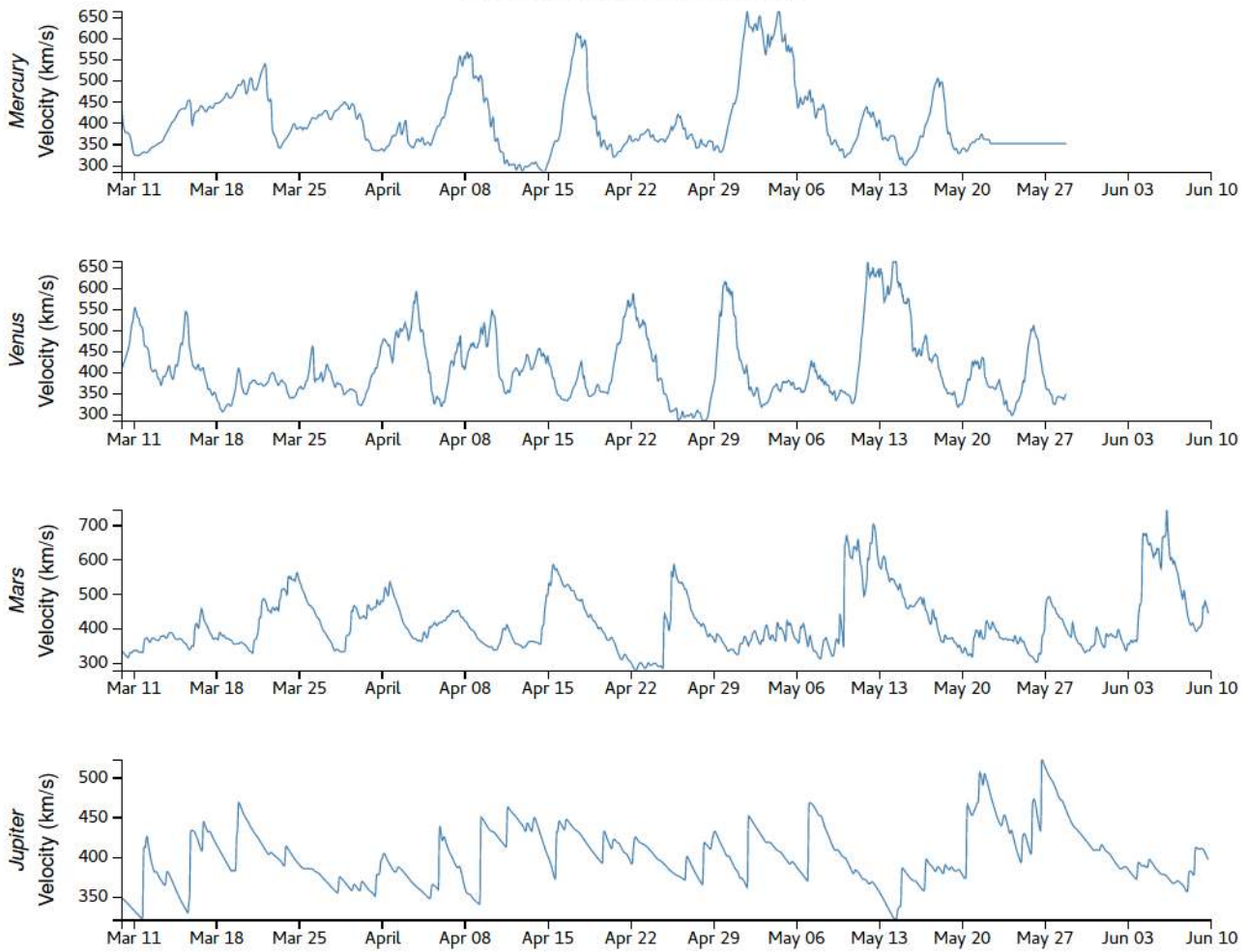
HELIOPROPA (heliopropa.irap.omp.eu)

Forward + backward propagation of in-situ data
(to planets / other bodies at the ecliptic)

SW1D model
1D MHD heliospheric propagation model (Tao et al 2005)

Short-term forecast window (for outer planets)





Solar wind modeling challenges

What we need now

- **Global physics-based** modeling
- **Other quantities**
  (density, dyn pressure, phase speeds)
- **Diagnostics**
  (synthetic imagery and in-situ)
- **Full surface to heliosphere**
  (propagation to 1 AU, Earth, planets, multiple s/c positions)
- Add **minimal amount of complexity**
  (robustness, quick computation)
- **Real-time** modeling
  (current full 3D MHD models are very CPU intensive)

SWiFT / MULTI-VP Data-driven solar wind model

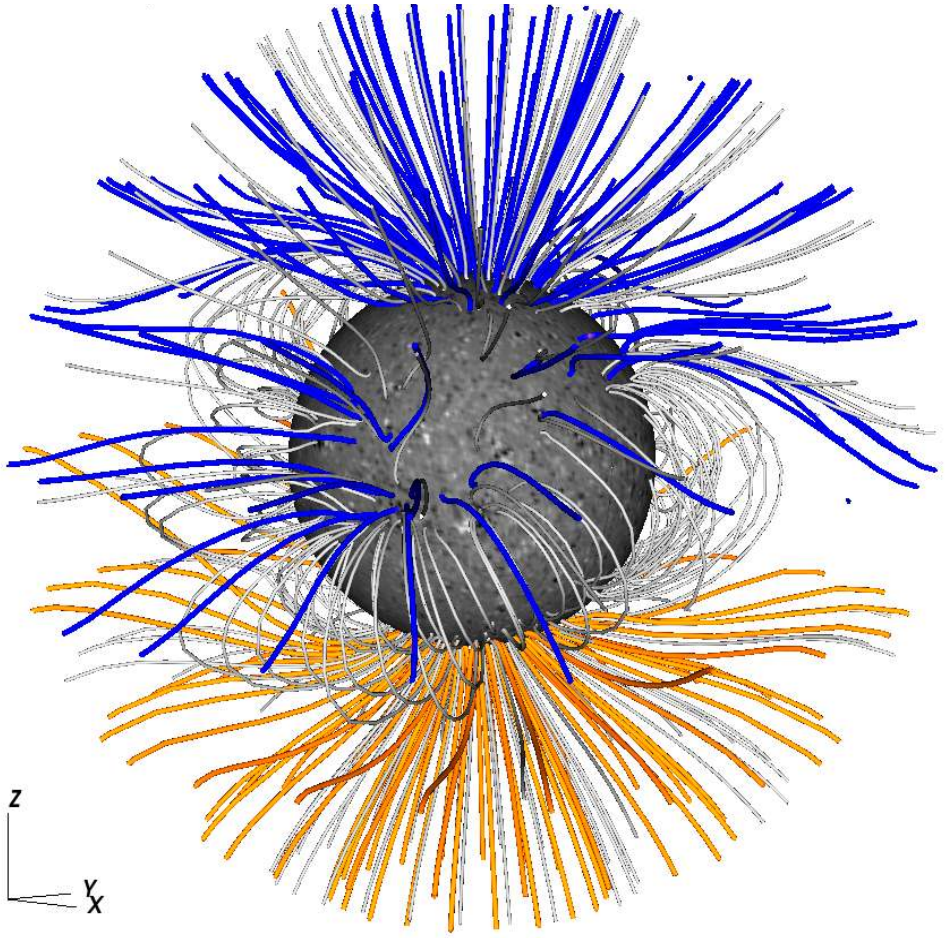
Sun / surface observations
(magnetograms: HMI, WSO, ADAPT)

Coronal field reconstruction
(PFSS, NLFFF, etc)

MULTI-VP

Heliospheric propagation
(ENLIL, EUHFORIA)

Earth / interplanetary medium
(S/C data, heliospheric imaging)



PFSS field lines: positive / negative polarity

SWiFT / MULTI-VP Data-driven solar wind model

Sun / surface observations
(magnetograms: HMI, WSO, ADAPT)

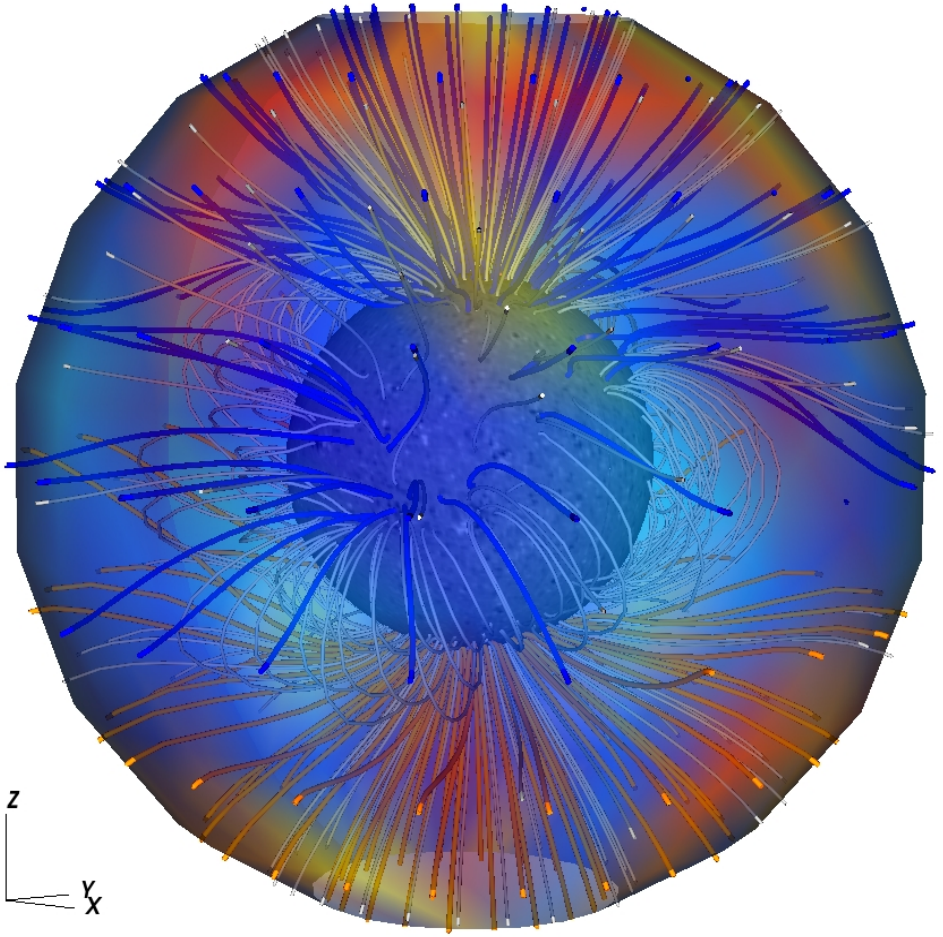
Coronal field reconstruction
(PFSS, NLFFF, etc)

MULTI-VP

Heliospheric propagation
(ENLIL, EUHFORIA, SW1D)

Earth / interplanetary medium
(S/C data, heliospheric imaging)

SWiFT framework pipeline

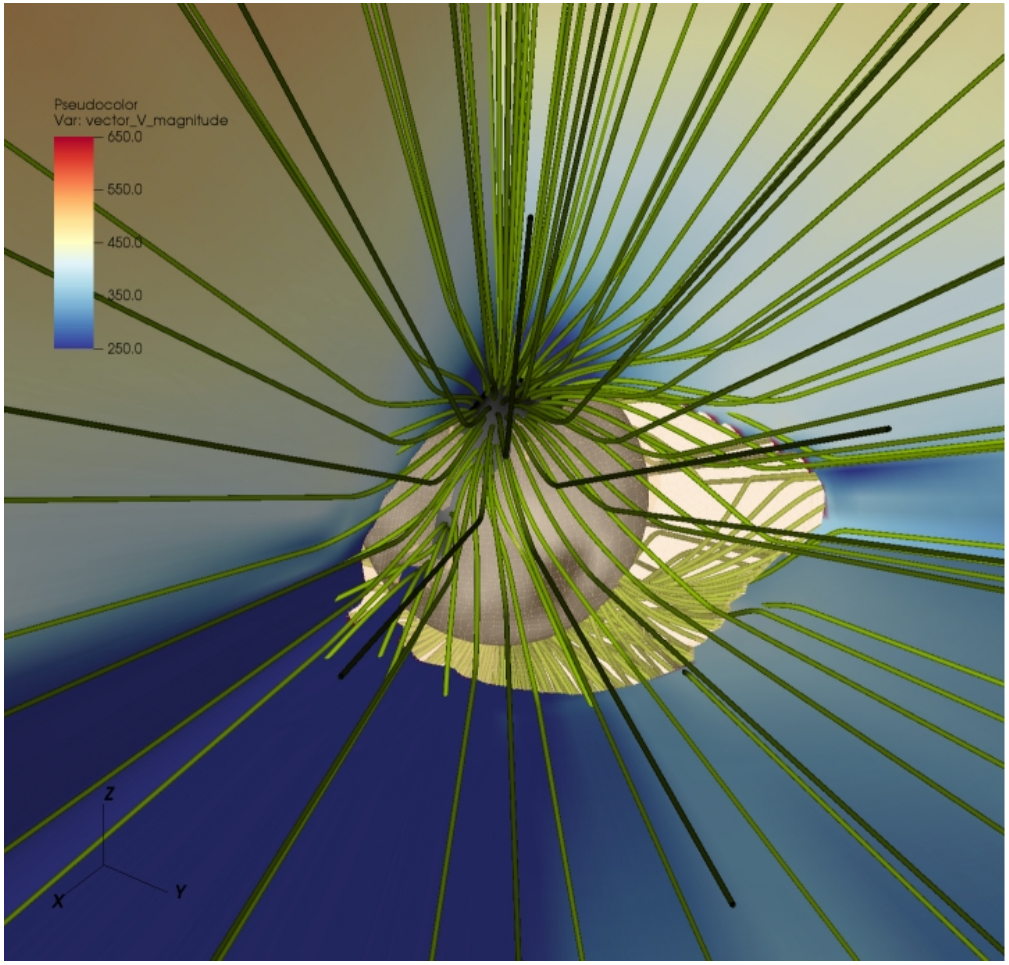


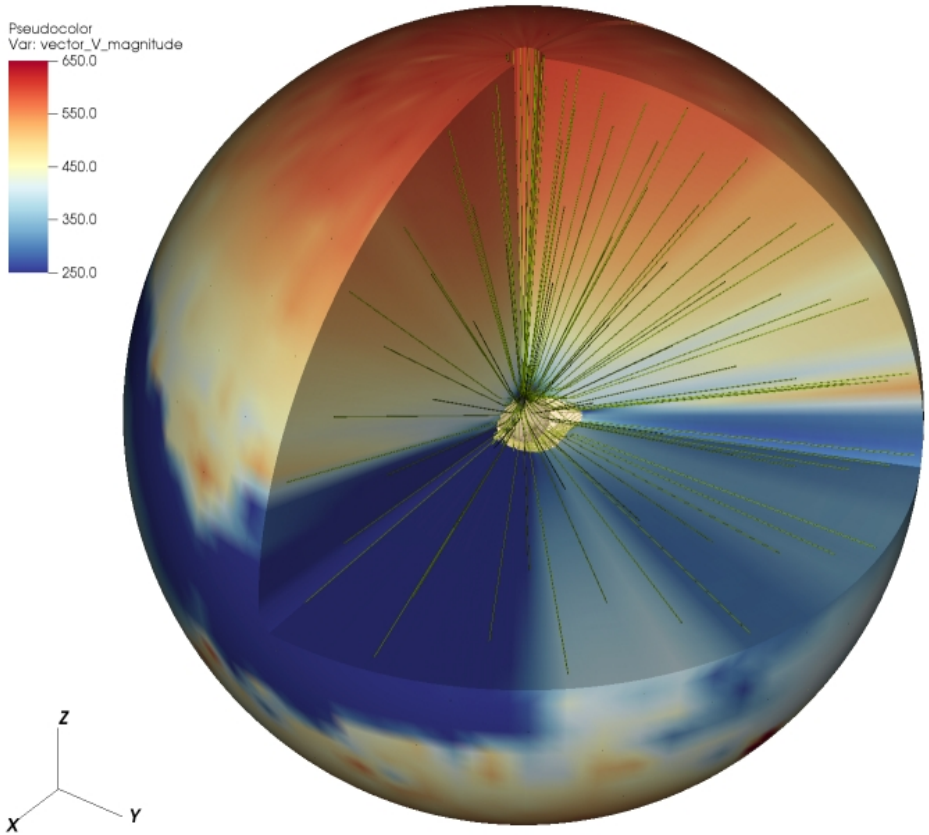
PFSS field lines: positive / negative polarity
Wind speed: 300 / 700 km/s

MULTI-VP Data-driven solar wind model

CR 2055

Solar wind speed





Low corona (close-up view)

High corona (1 – 15 R_{sun})

Open magnetic fieldlines ("coronal holes")
Streamer / coronal hole boundaries

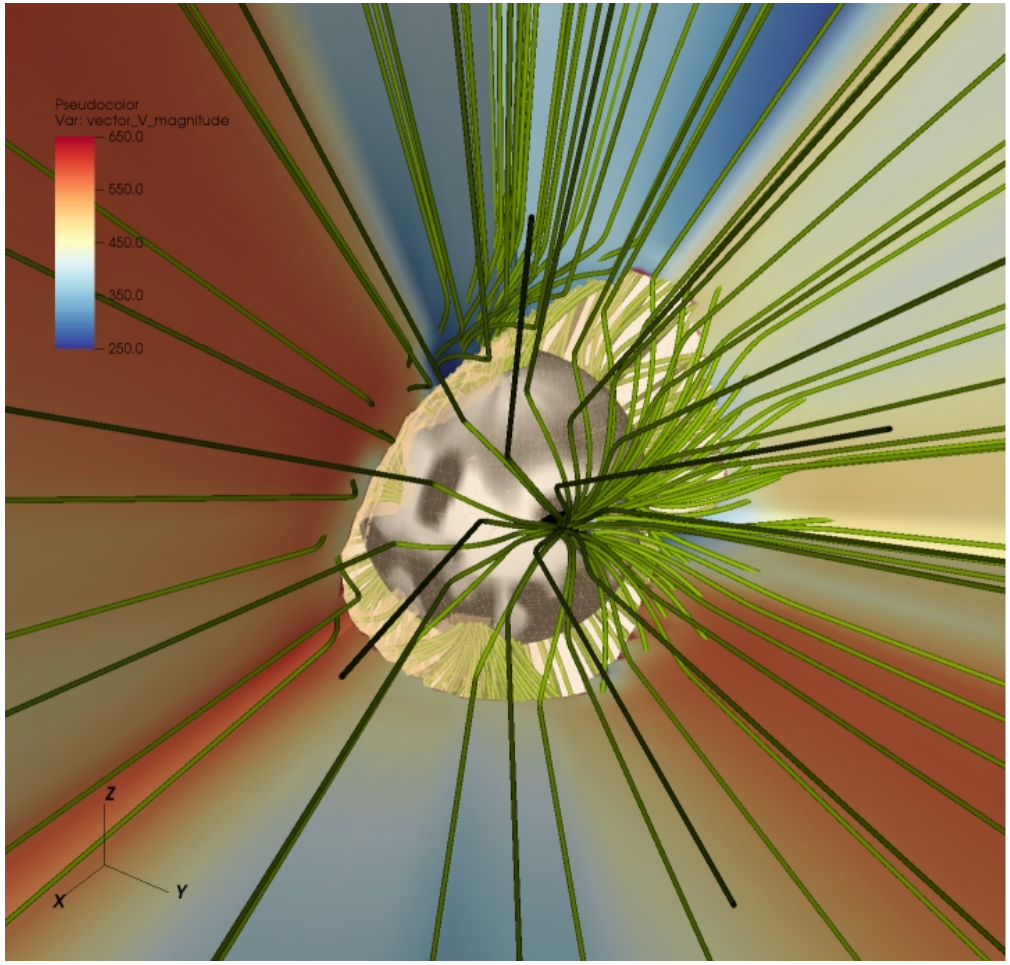
Fast wind
Slow wind

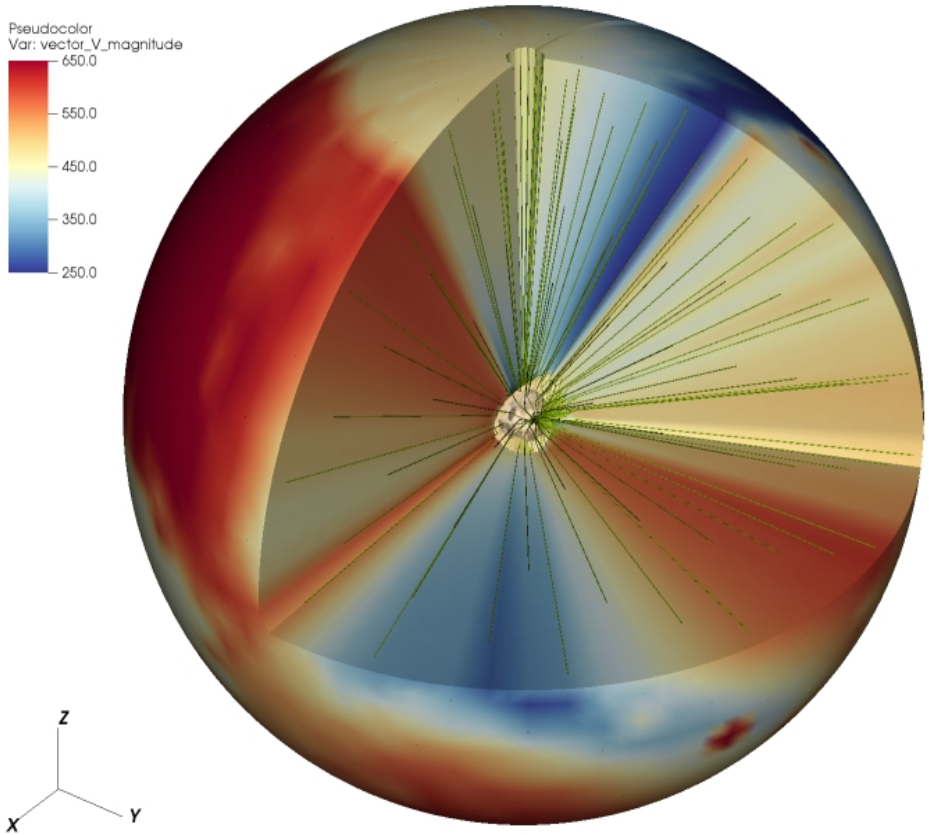
Pinto, Rouillard, ApJ (2017)

MULTI-VP Data-driven solar wind model

CR 2132

Solar wind speed





Low corona (close-up view)

High corona (1 – 15 R_{sun})

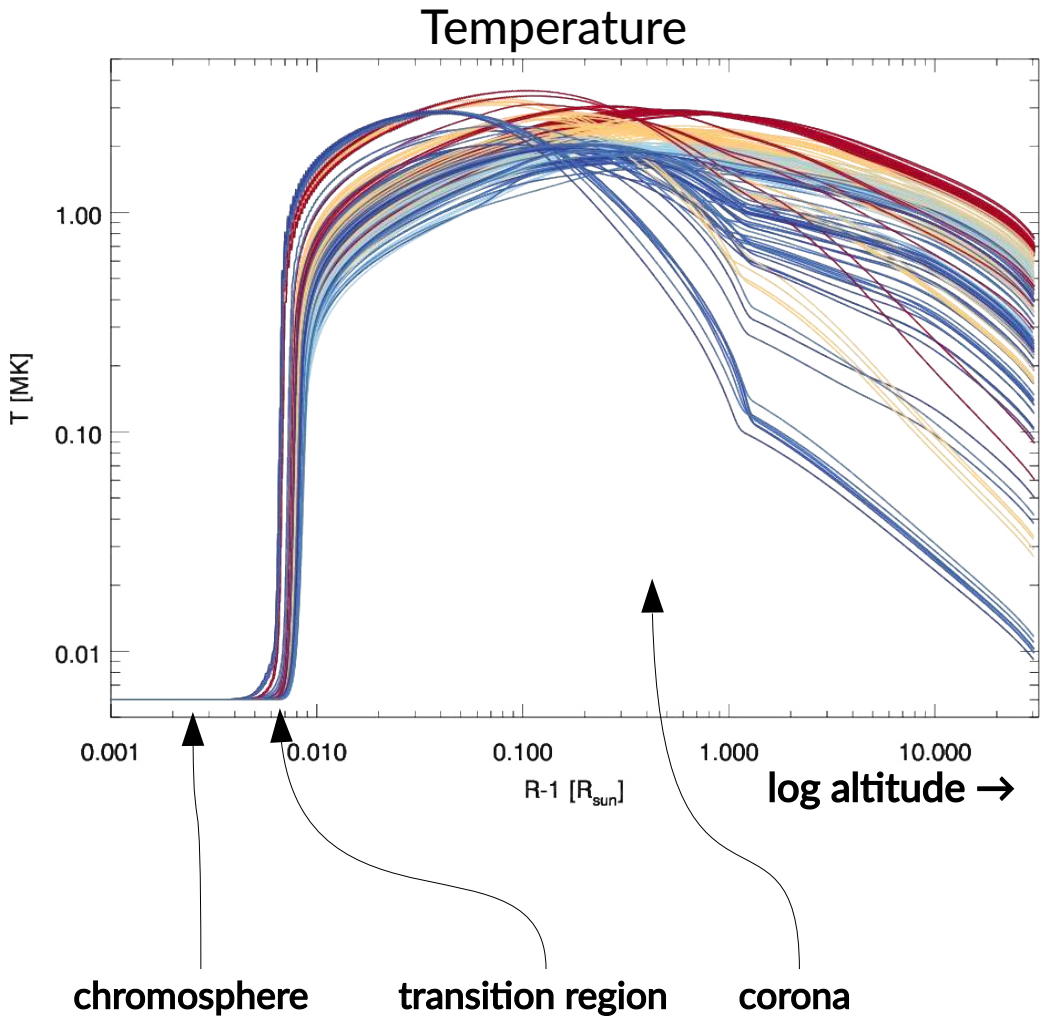
Open magnetic fieldlines ("coronal holes")
Streamer / coronal hole boundaries

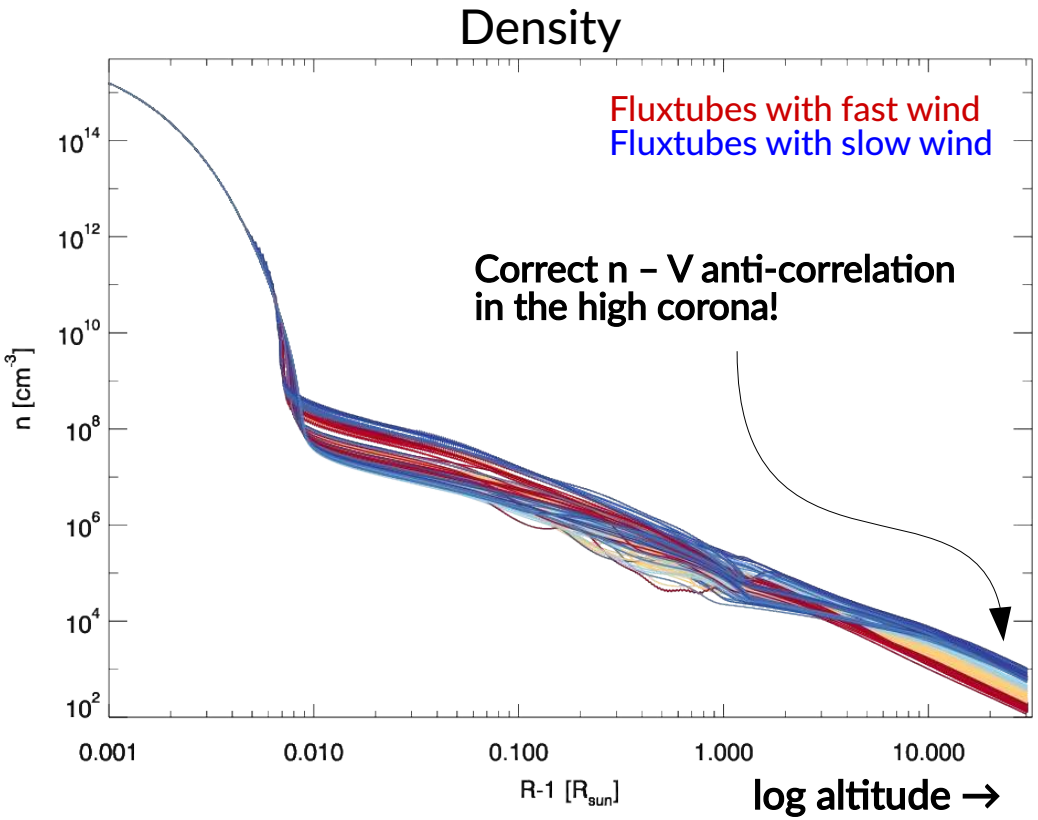
Fast wind
Slow wind

Pinto, Rouillard, ApJ (2017)

MULTI-VP Data-driven solar wind model

From the surface to the corona

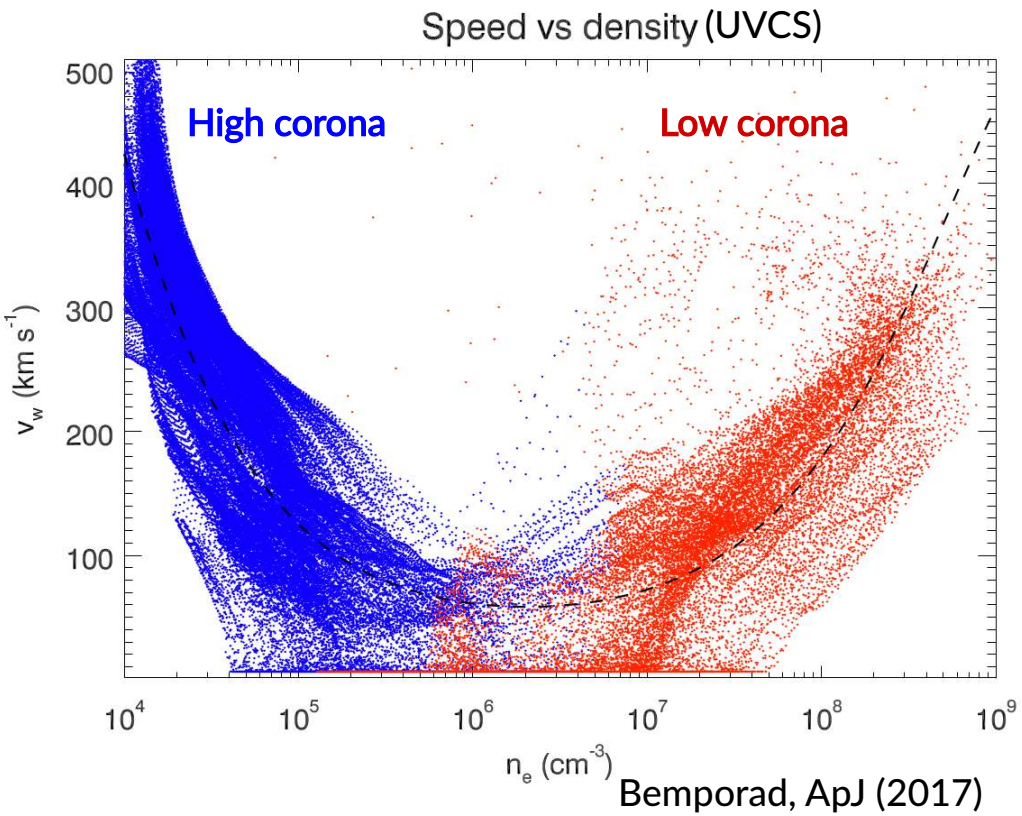




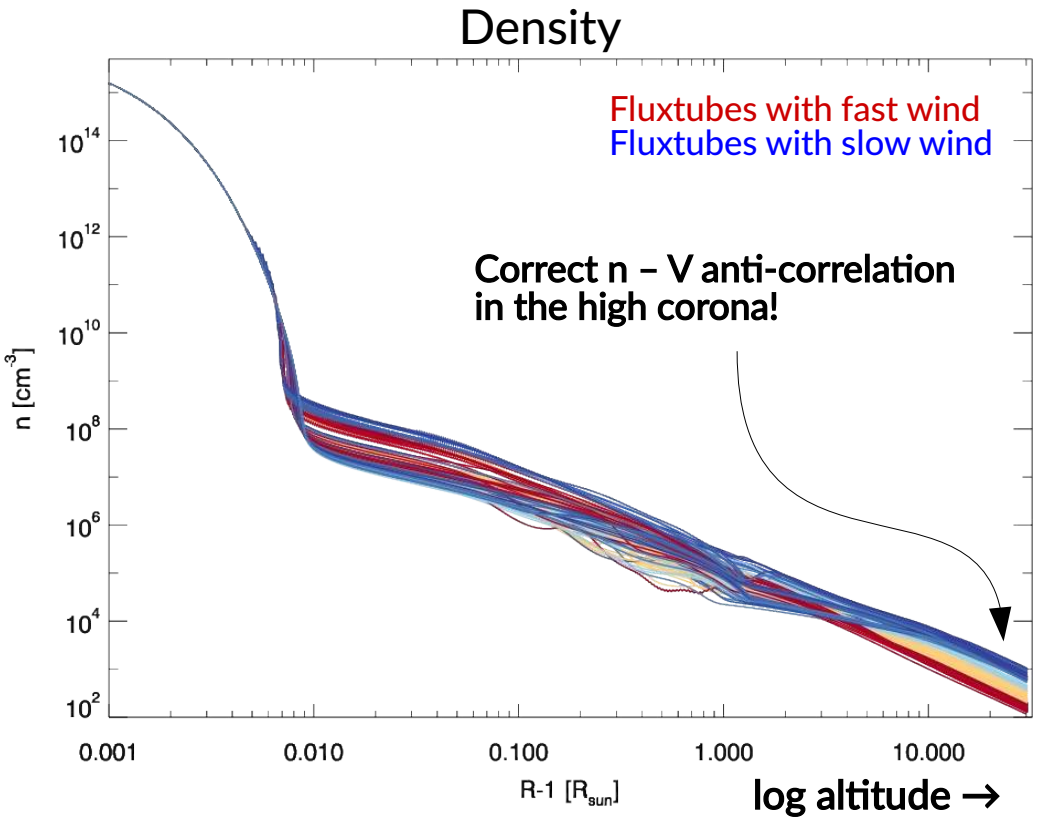
Pinto, Rouillard, ApJ (2017)

MULTI-VP Data-driven solar wind model

From the surface to the corona



Bemporad, ApJ (2017)



Pinto, Rouillard, ApJ (2017)

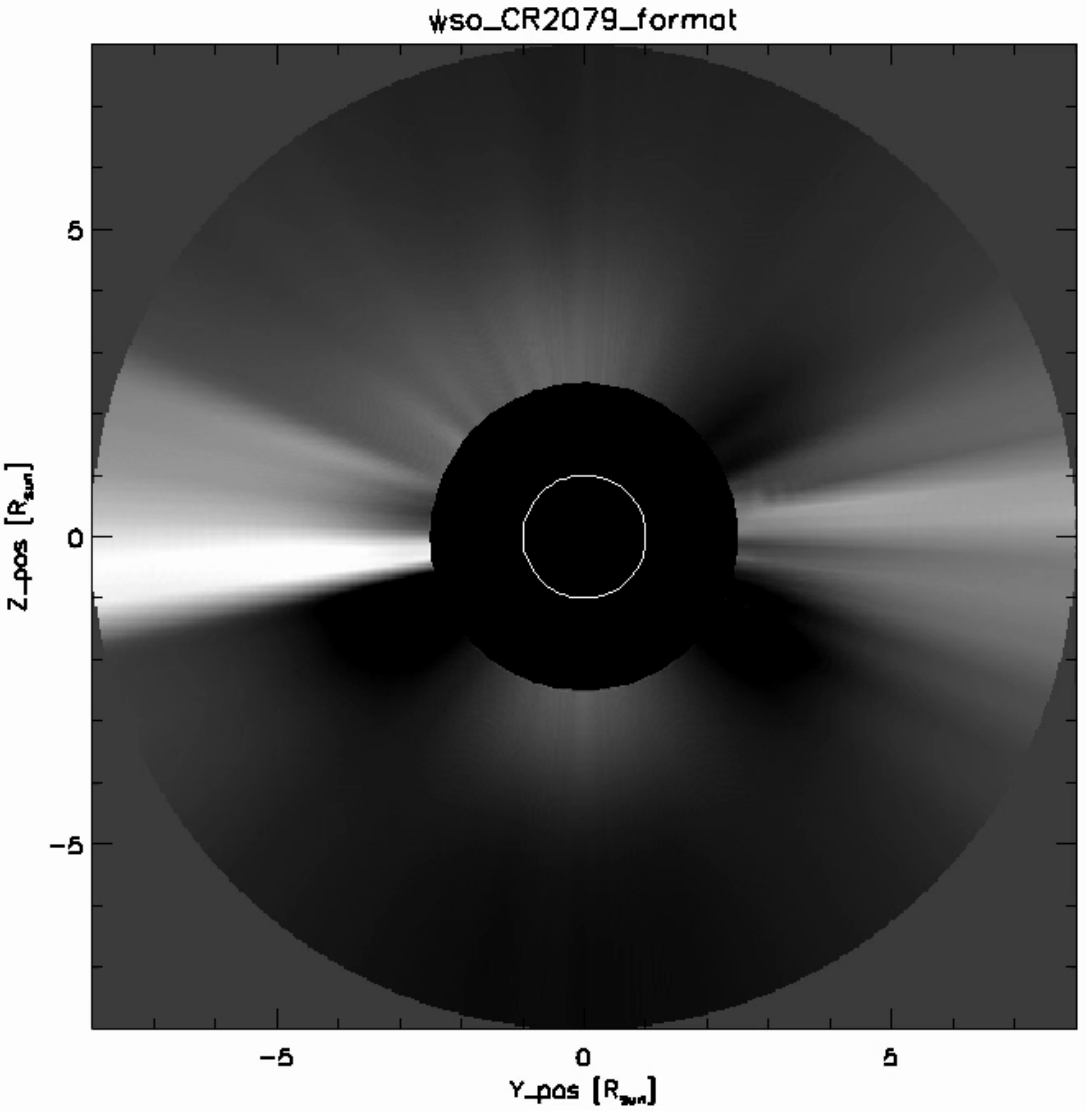
MULTI-VP Data-driven solar wind model

Synthetic images of the corona

CR 2079 – 2080

MULTI-VP + FORWARD

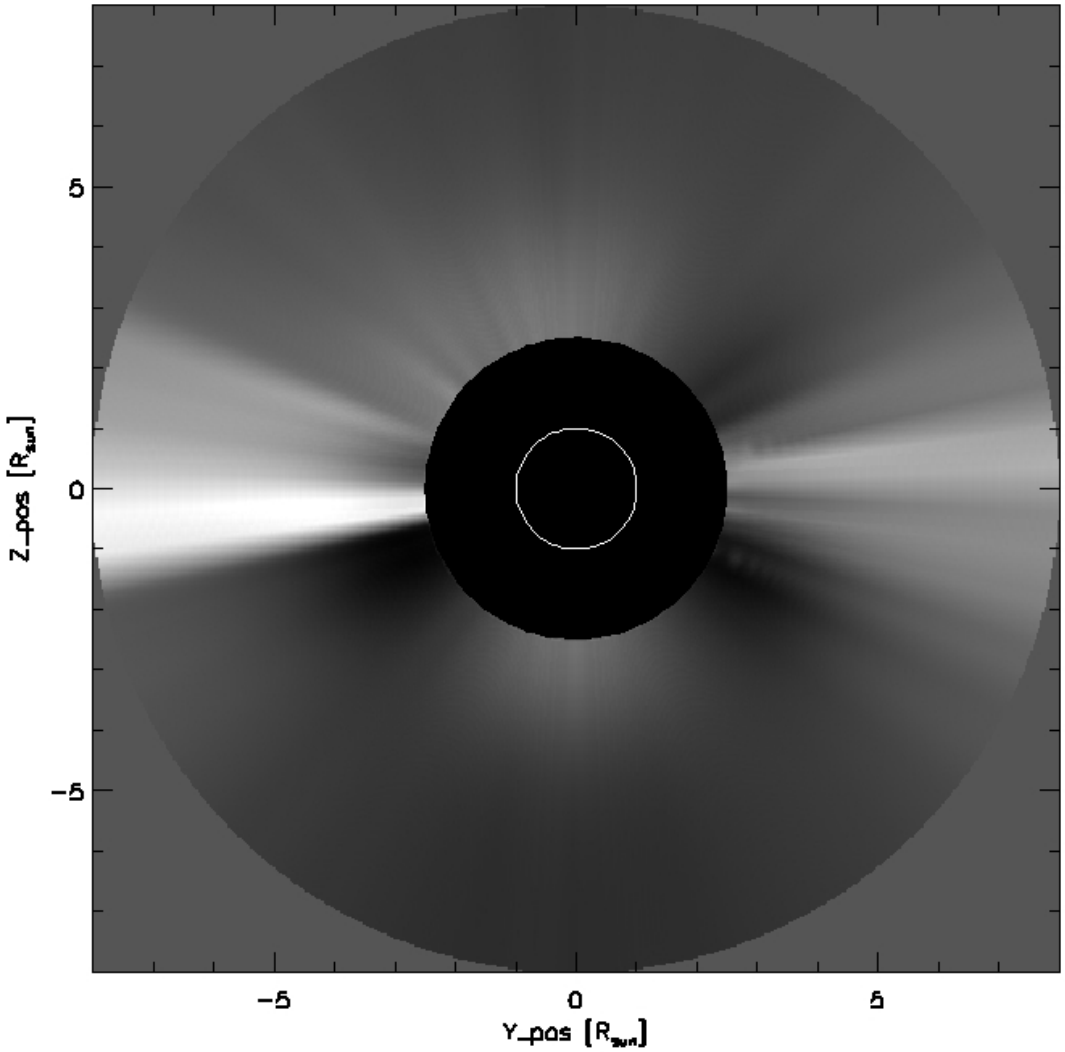
(NRGF-filtered, ~C2 FoV)



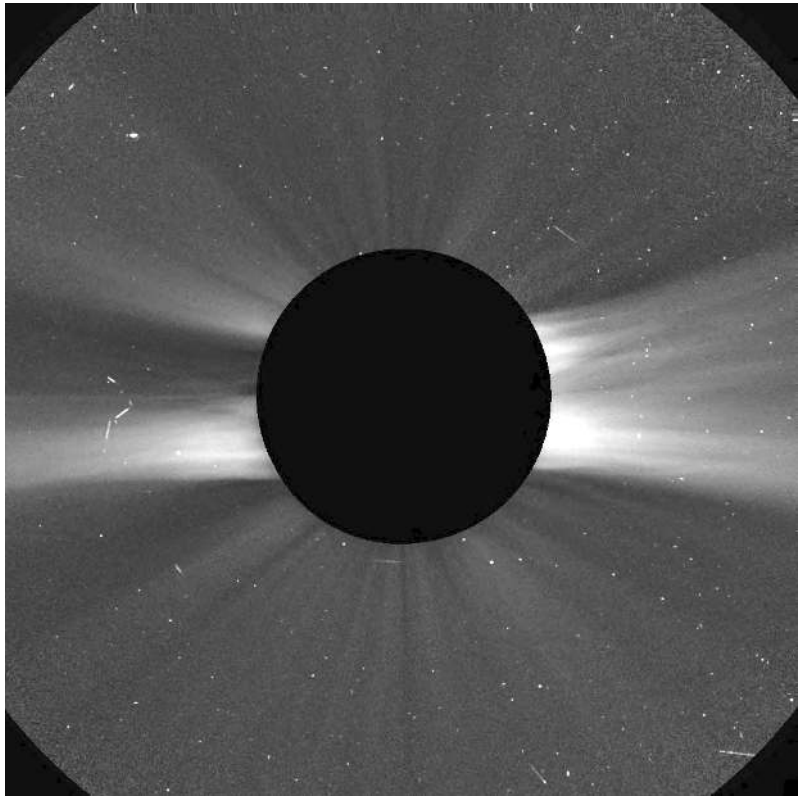
MULTI-VP Data-driven solar wind model

Synthetic images of the corona

CR 2079 (Earth, mid-CR, MULTI-VP NRGF-filtered)



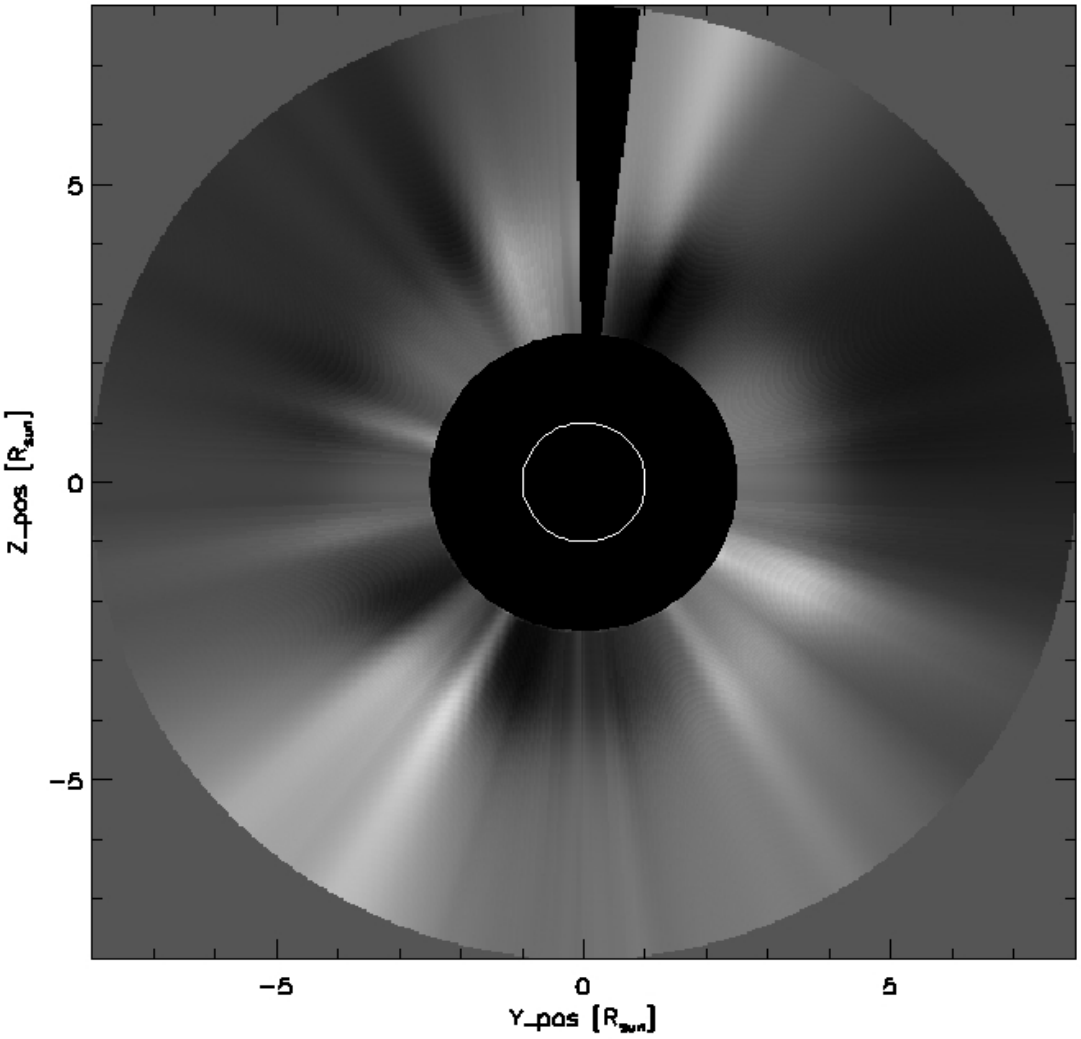
CR 2079 (L1, mid-CR, LASCO C2)



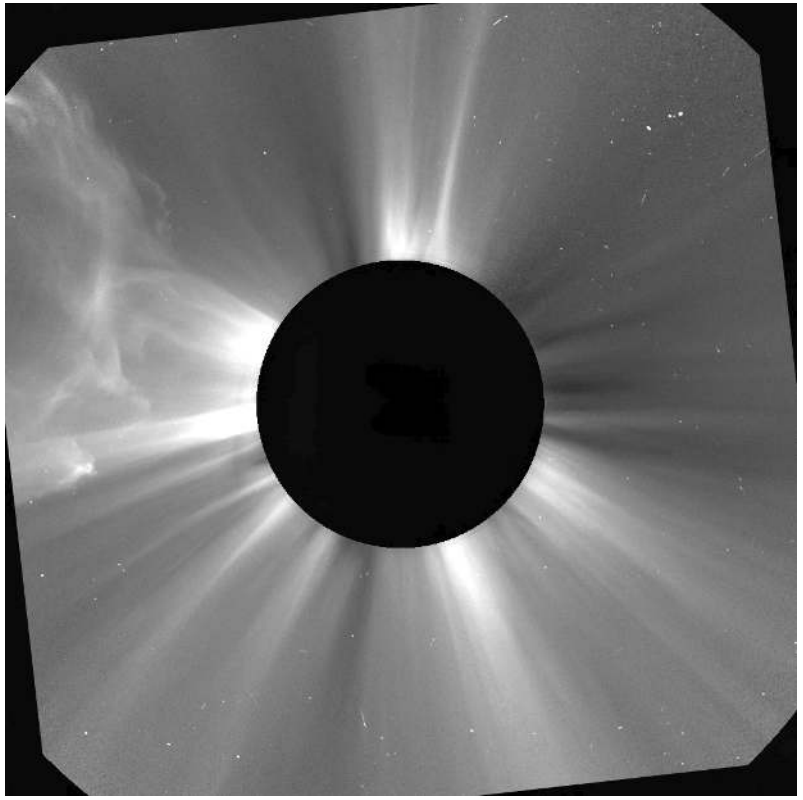
MULTI-VP Data-driven solar wind model

Synthetic images of the corona

CR 2136 (Earth, mid-CR, MULTI-VP NRGF-filtered)



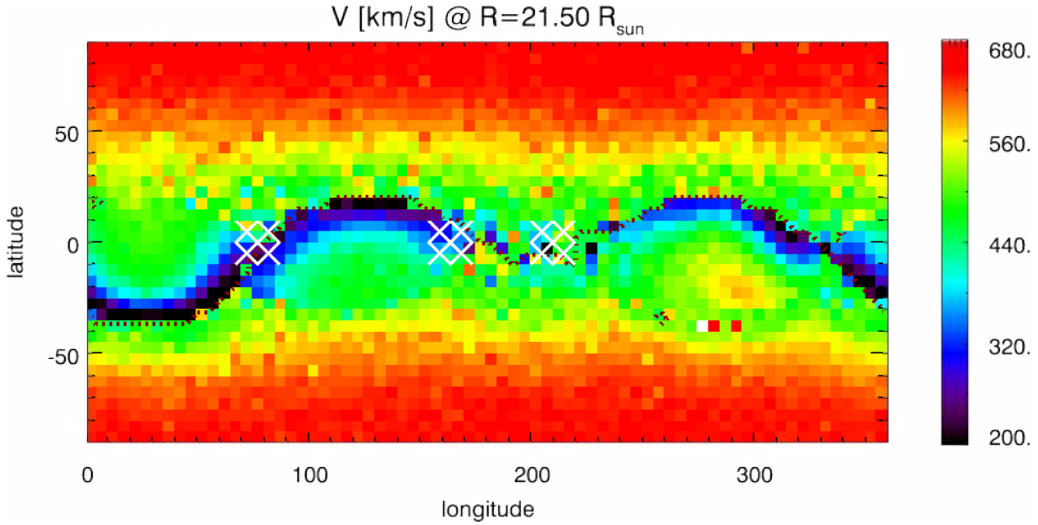
CR 2136 (L1, mid-CR, LASCO C2)

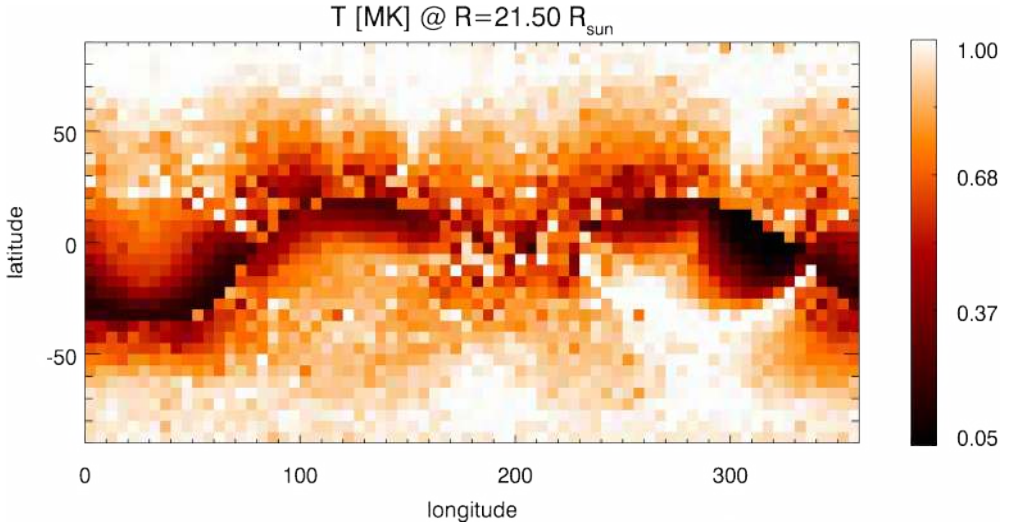


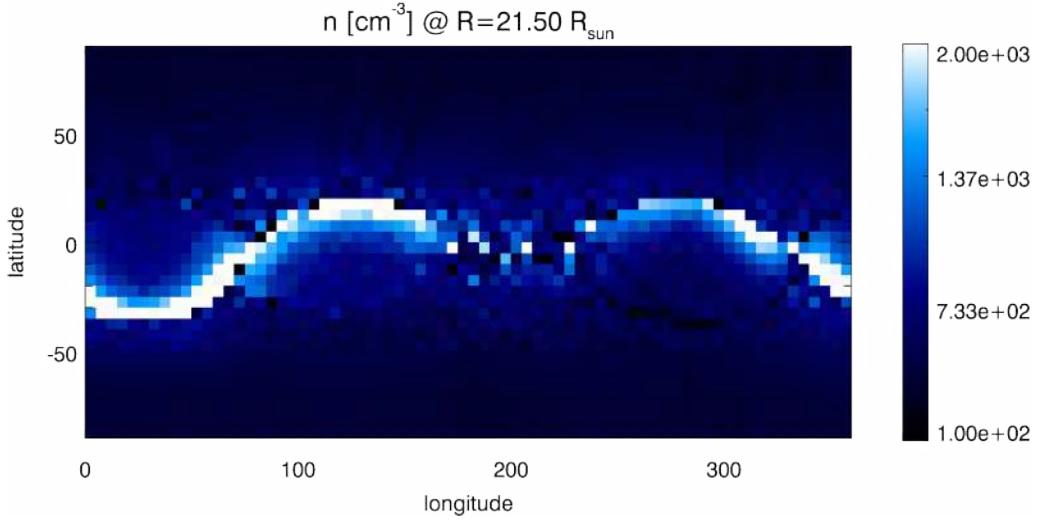
MULTI-VP Data-driven solar wind model

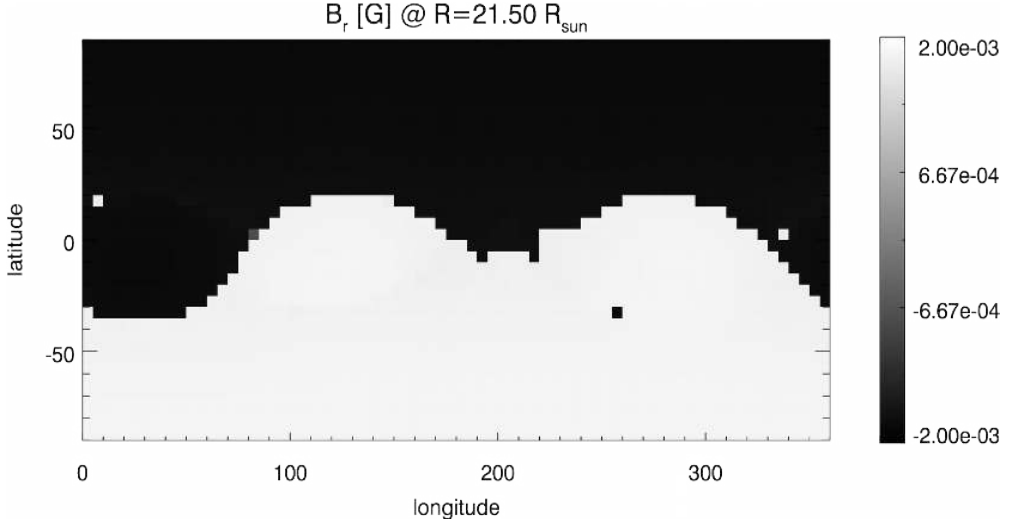
Solar wind maps

CR 2056 (2008, minimum)









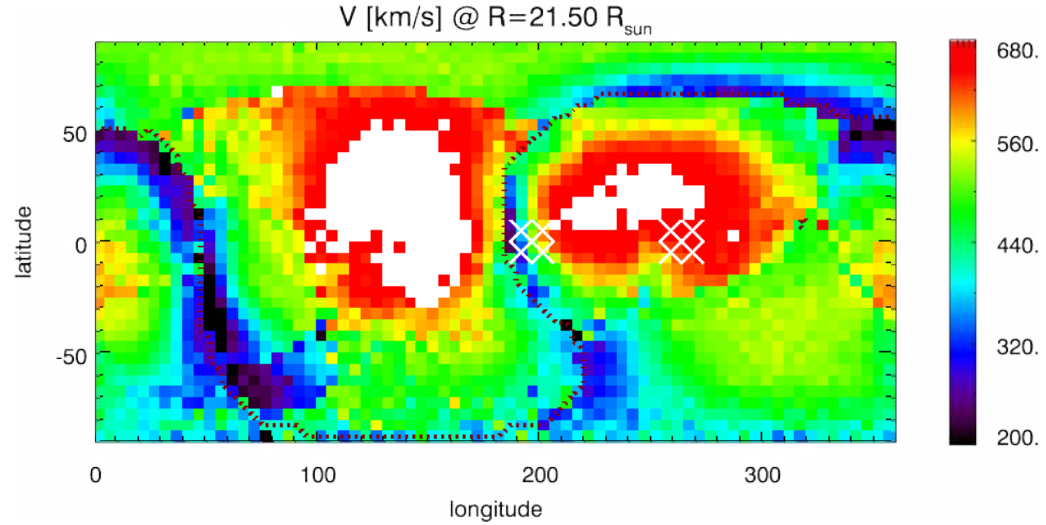
HELCATS catalogue: https://stormsweb.irap.omp.eu/doku.php?id=windmaptable

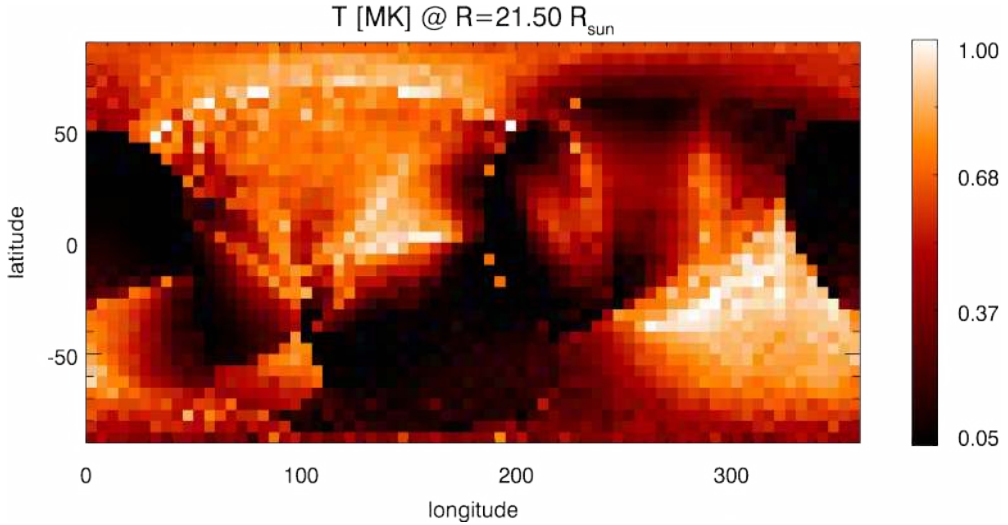
Source positions of CIR from CIRCAT

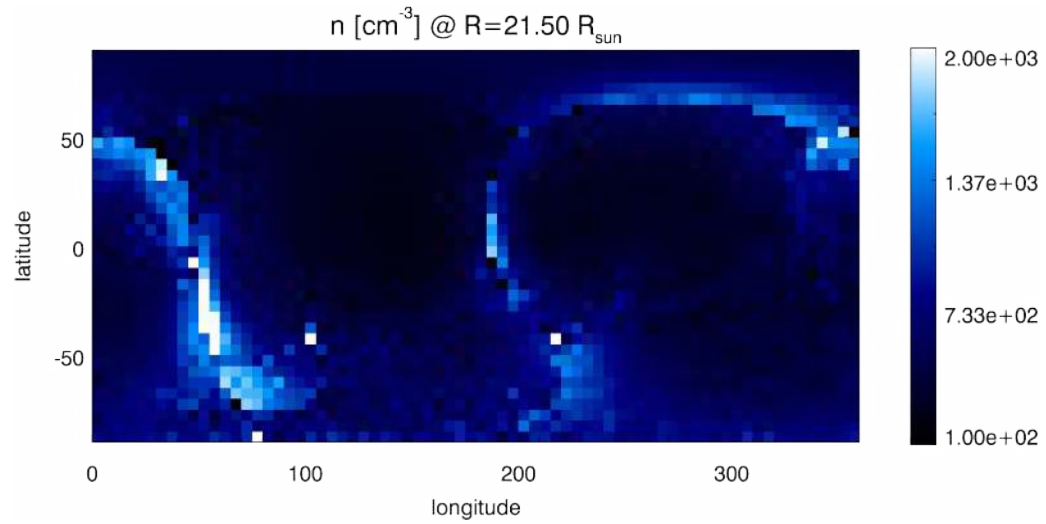
MULTI-VP Data-driven solar wind model

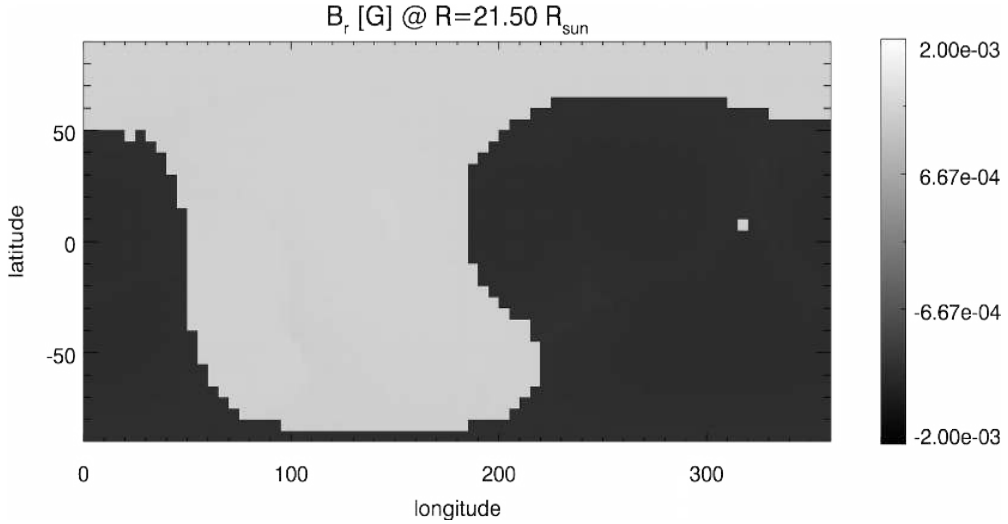
Solar wind maps

CR 2136 (2013, maximum)









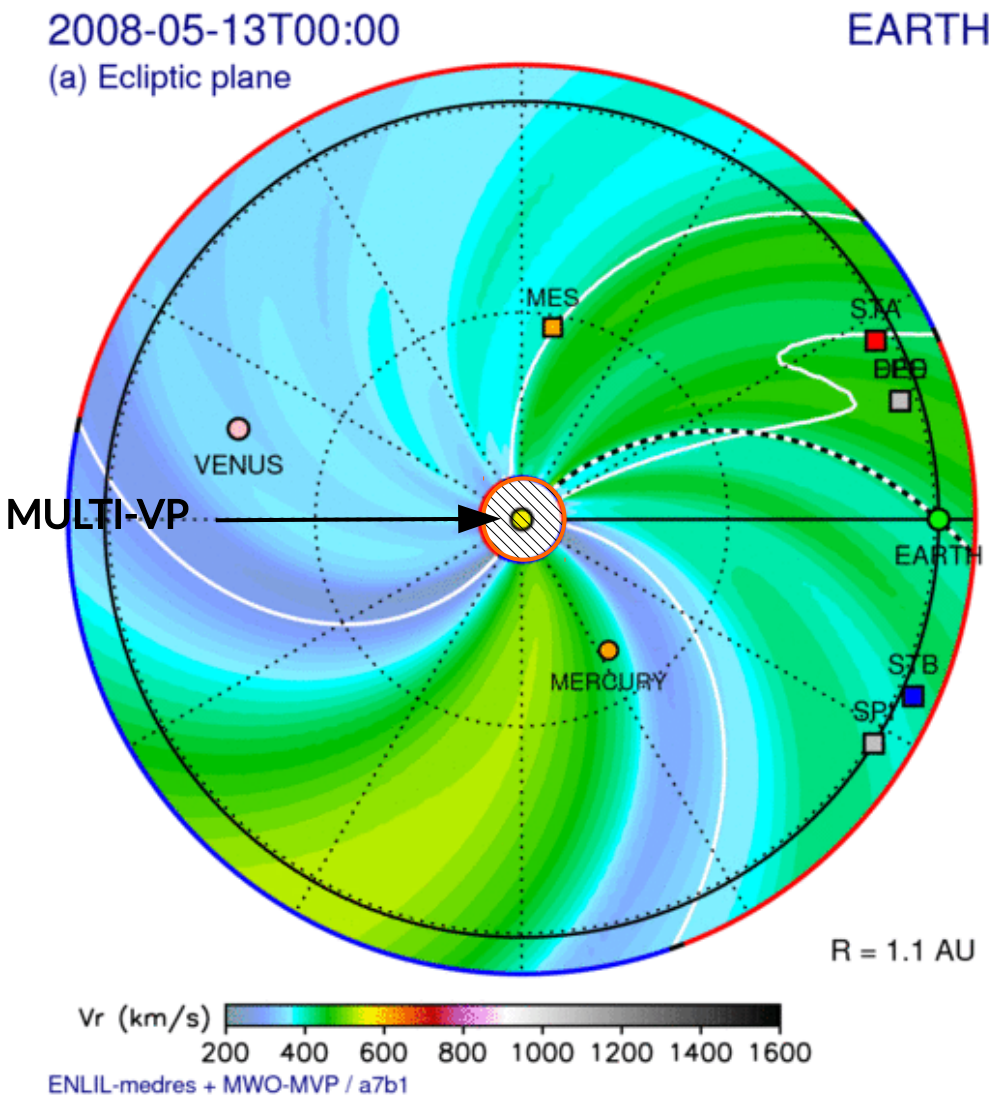
HELCATS catalogue: https://stormsweb.irap.omp.eu/doku.php?id=windmaptable

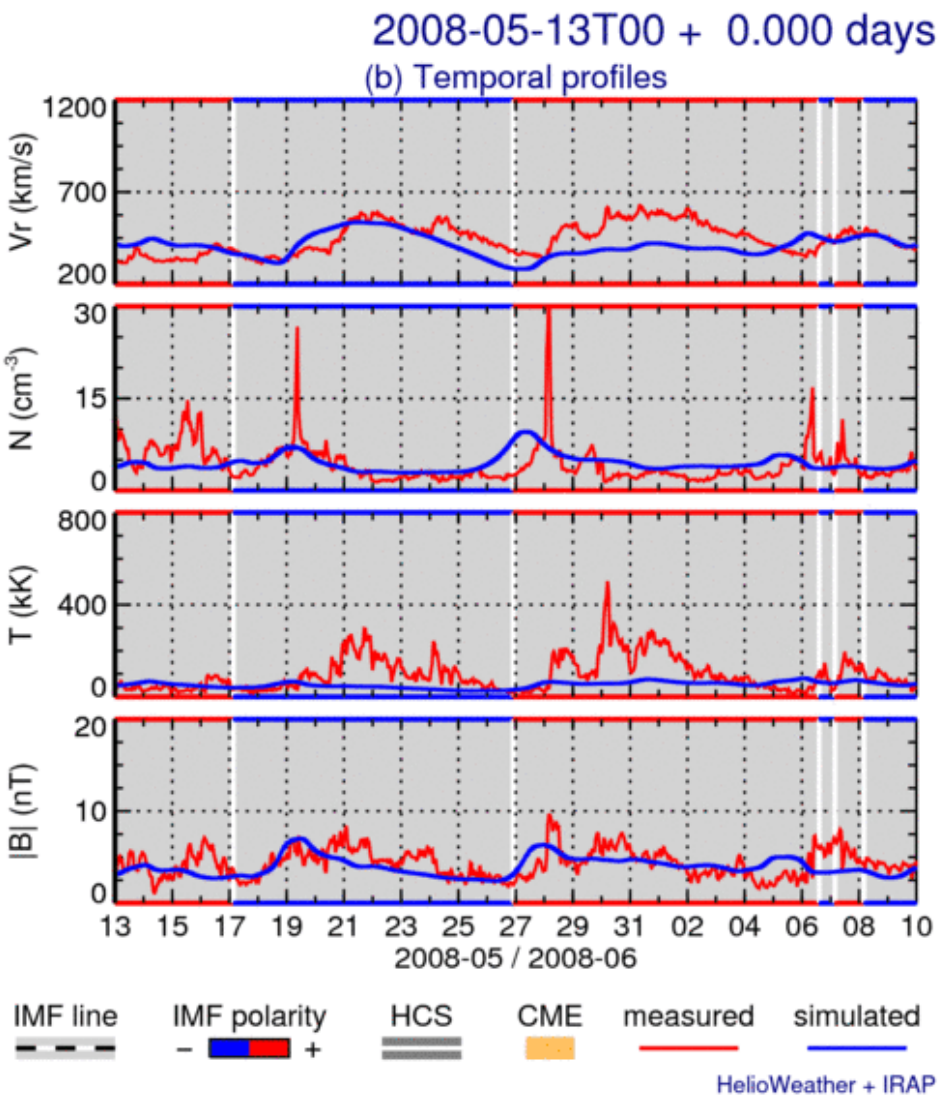
Source positions of CIR from CIRCAT

Predicting the solar wind conditions at 1 AU

Interplanetary medium, in-situ data

MULTI-VP maps at 21.5 Rsun → ENLIL



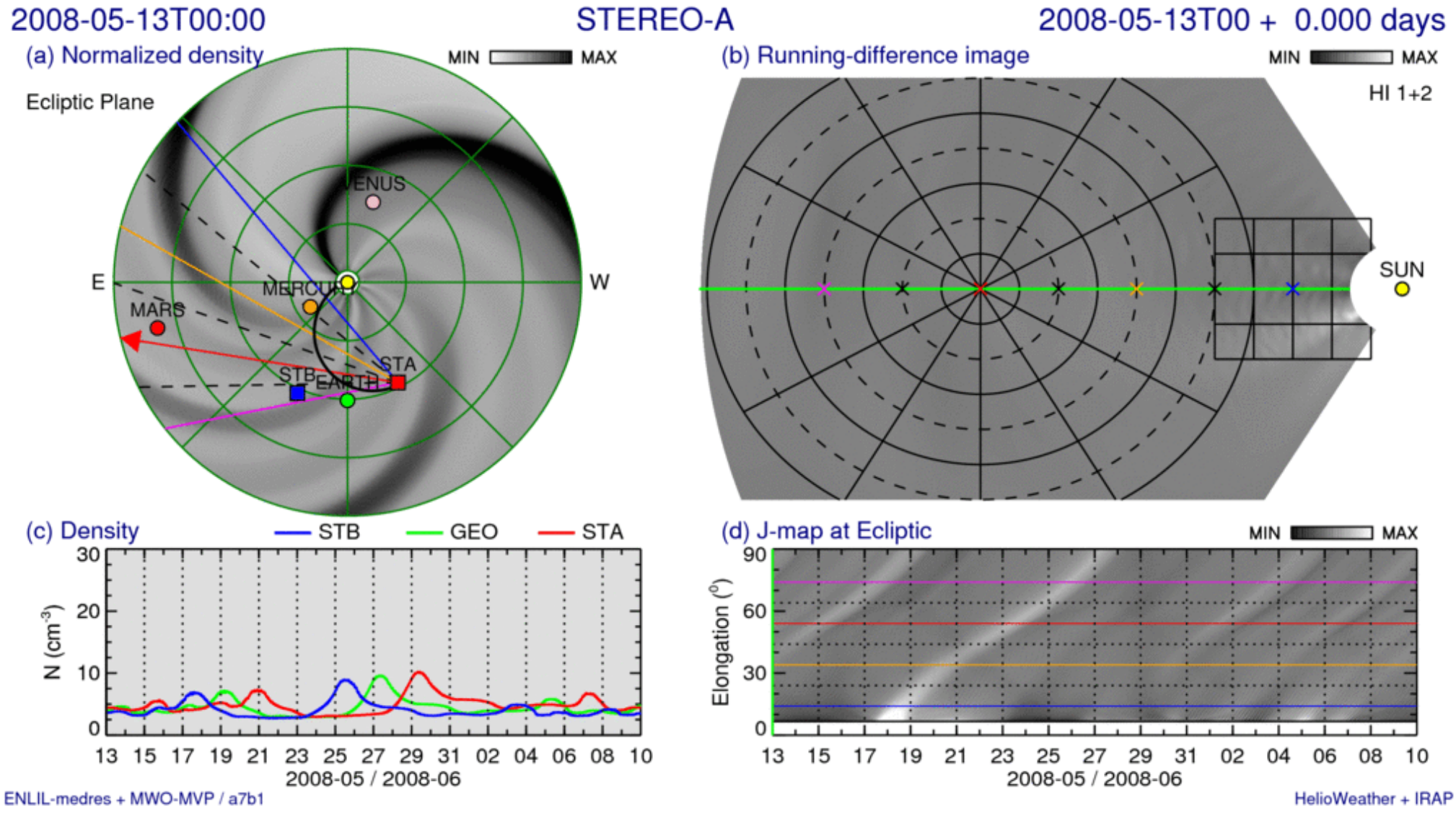


(Pinto, Rouillard, Odsctrill, Mays, in prep)

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

HELCATS catalogue: https://stormsweb.irap.omp.eu/doku.php?id=windmaptable

Predicting the solar wind conditions: J-maps

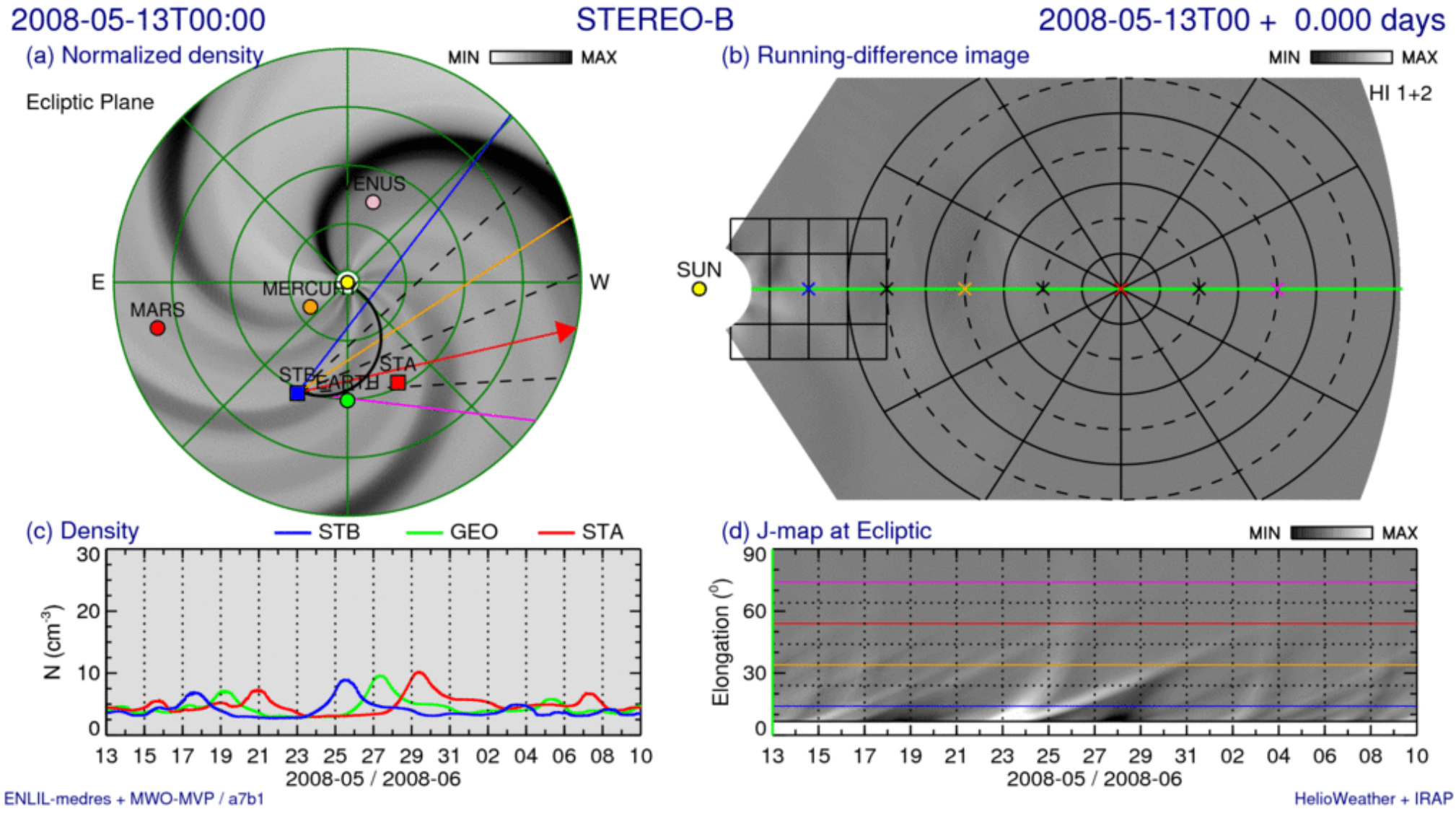


(Pinto, Rouillard, Odsctrill, Mays, et al)

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

HELCATS catalogue: https://stormsweb.irap.omp.eu/doku.php?id=windmaptable

Predicting the solar wind conditions: J-maps



(Pinto, Rouillard, Odsctrill, Mays, et al)

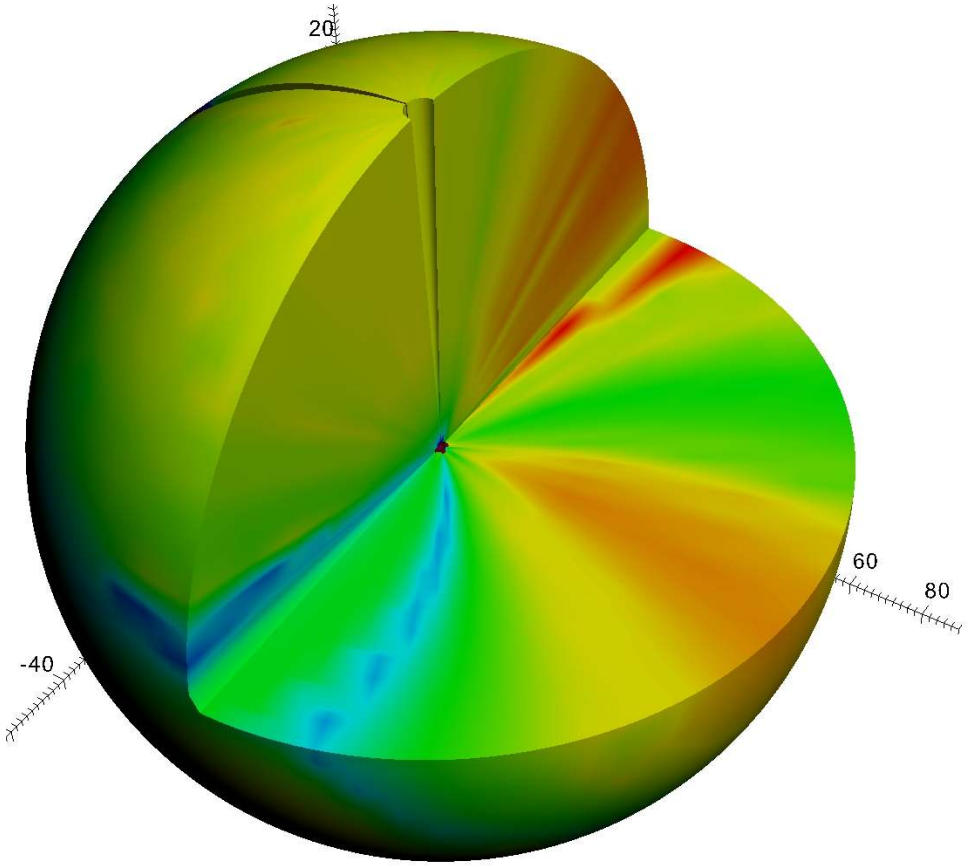
http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

HELCATS catalogue: https://stormsweb.irap.omp.eu/doku.php?id=windmaptable

WIP: SWiFT with 1D heliospheric propagation

1D Heliospheric SW propagation

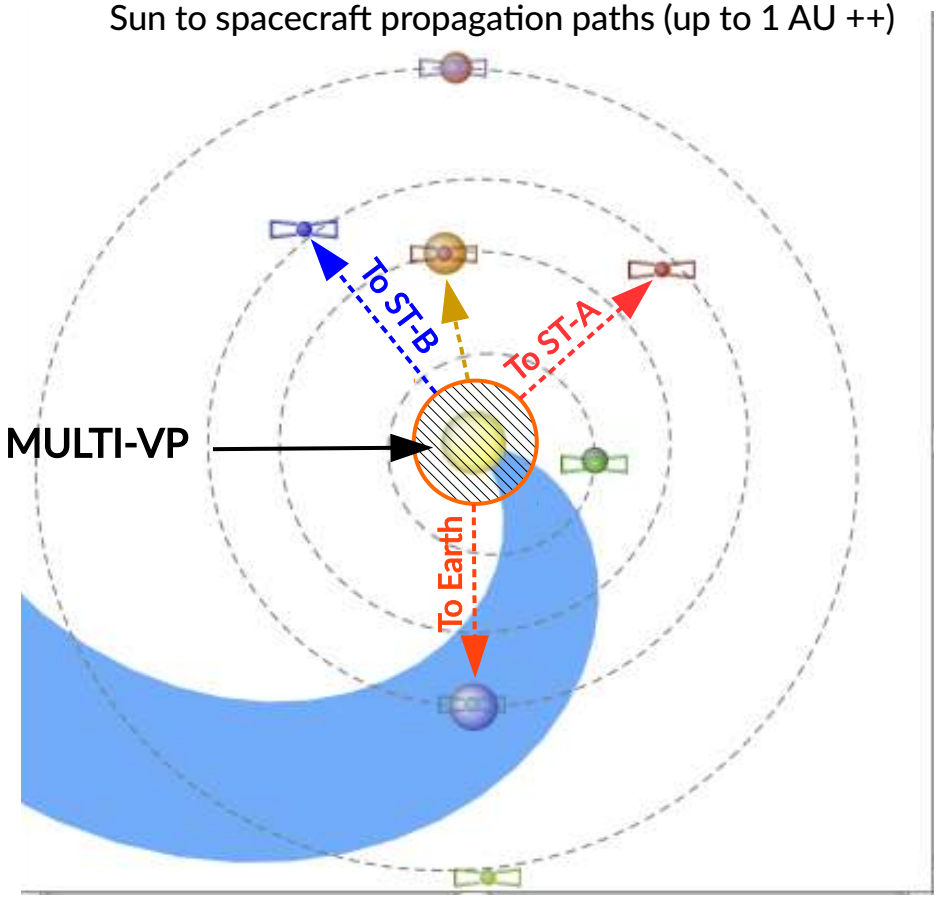
Multiple wind propagation paths, global view **1 to 90 R_{sun}**



Parker Solar Probe

perihelions: ~36 to 9 R_{sun}
radial scan regions (quasi-corotation) covered

Sun to spacecraft propagation paths (up to 1 AU ++)



propagationtool.cdpp.eu
(propagation method from Tao et al, 2005)

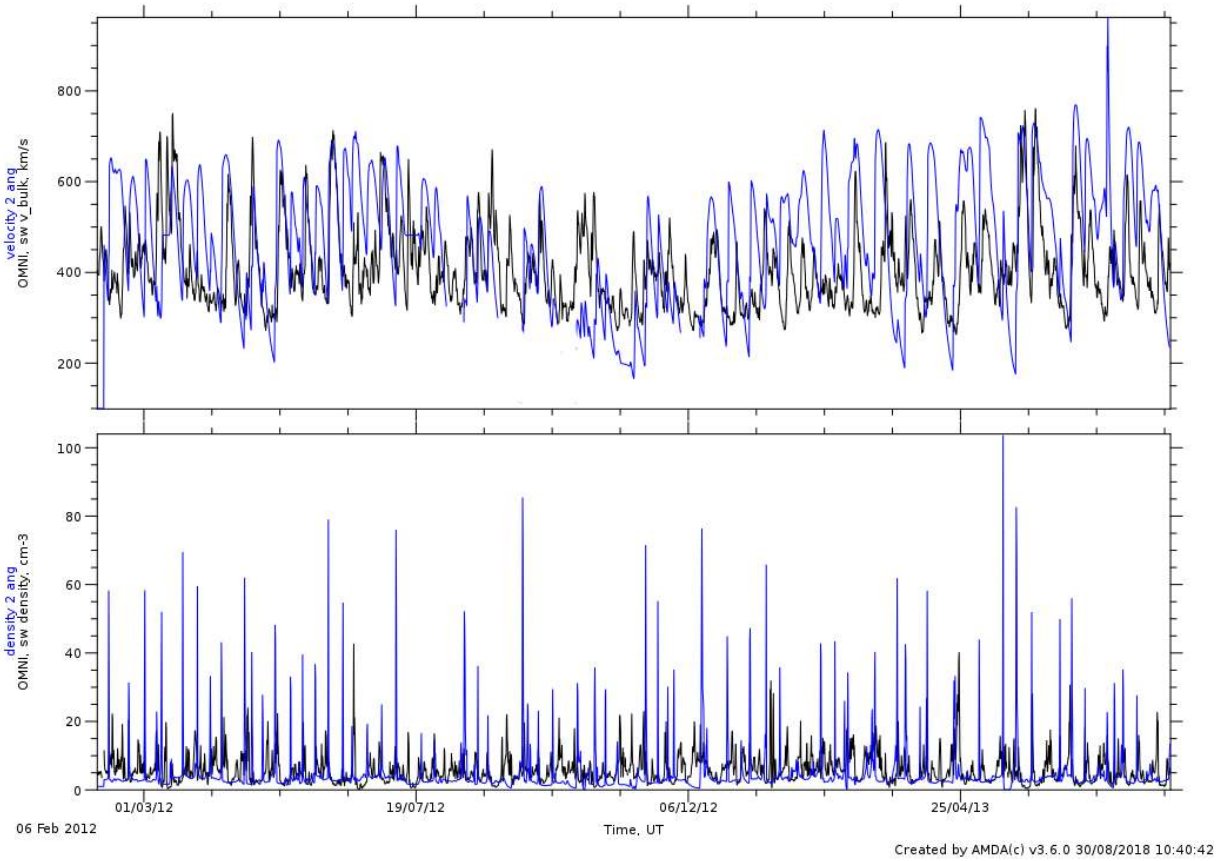
Forward propagation from output of MULTI-VP
(arbitrary radial paths, any latitude or longitude)

Multiple time-series, at **different orbital positions**,
rotation + background field evolution

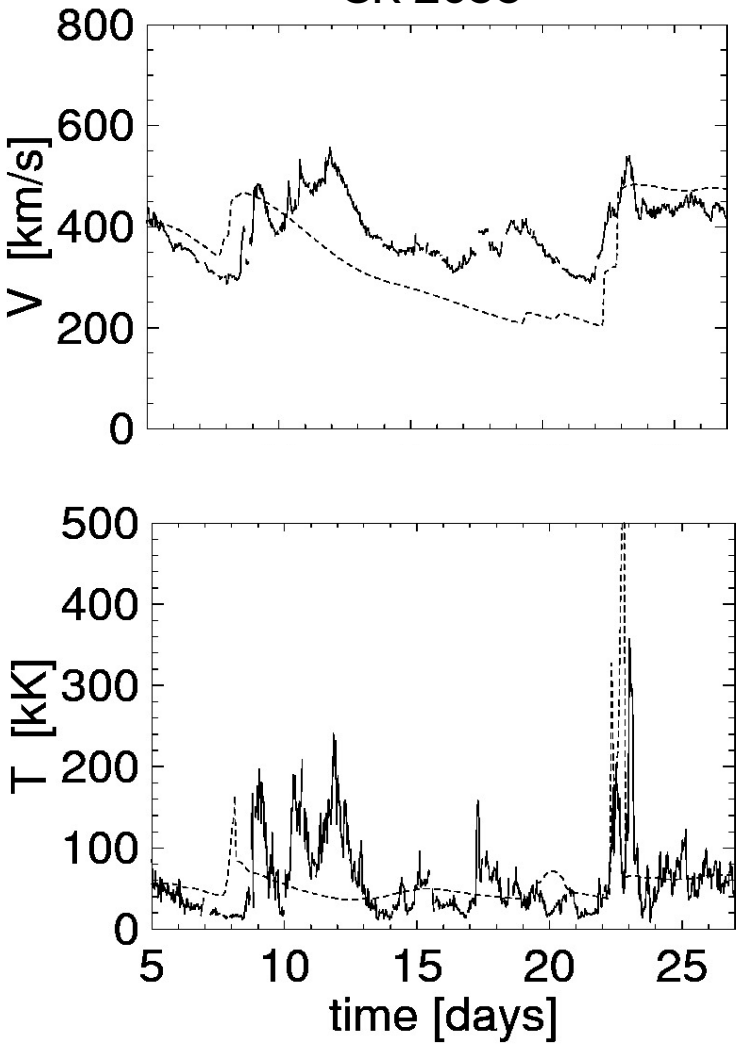
WIP: SWiFT with 1D propagation

Simulations vs. OMNI

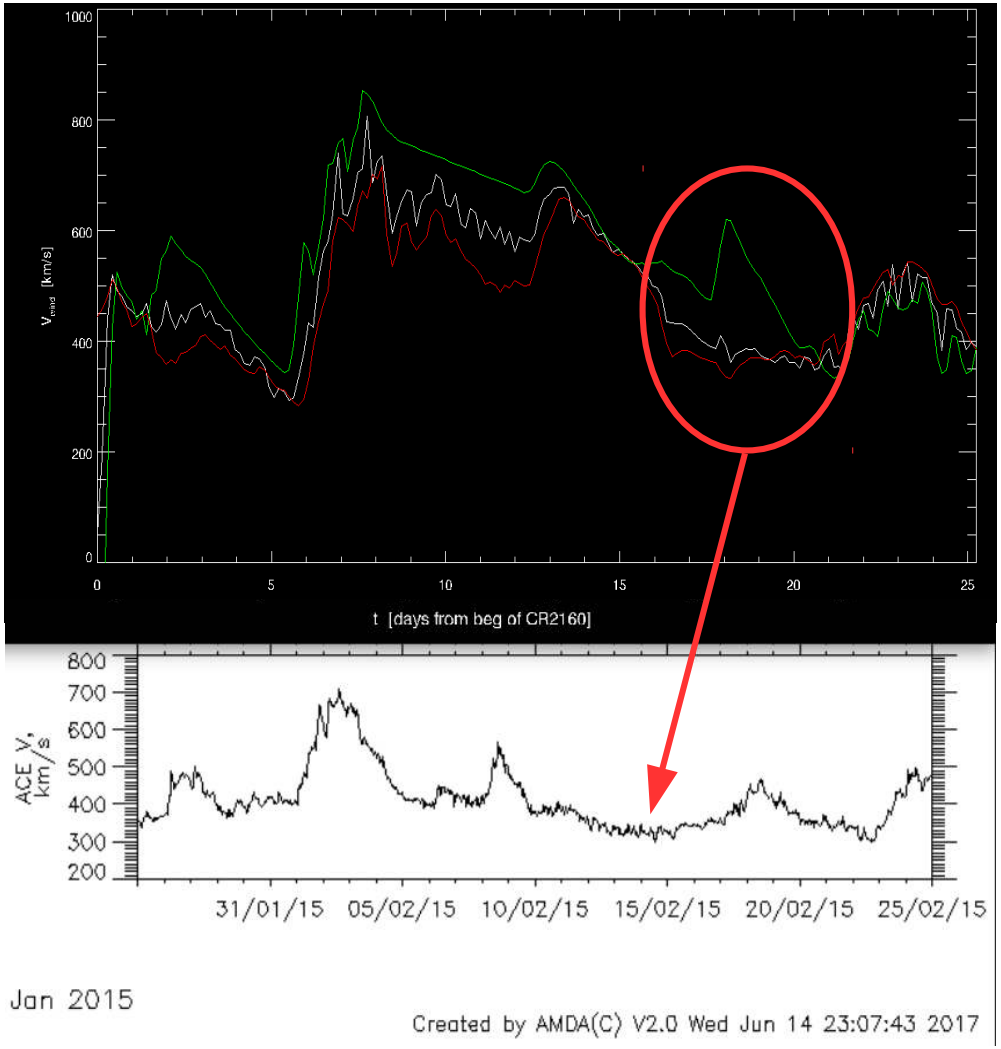
~20 CRs



CR 2055



SWiFT with 1D propagation: some issues



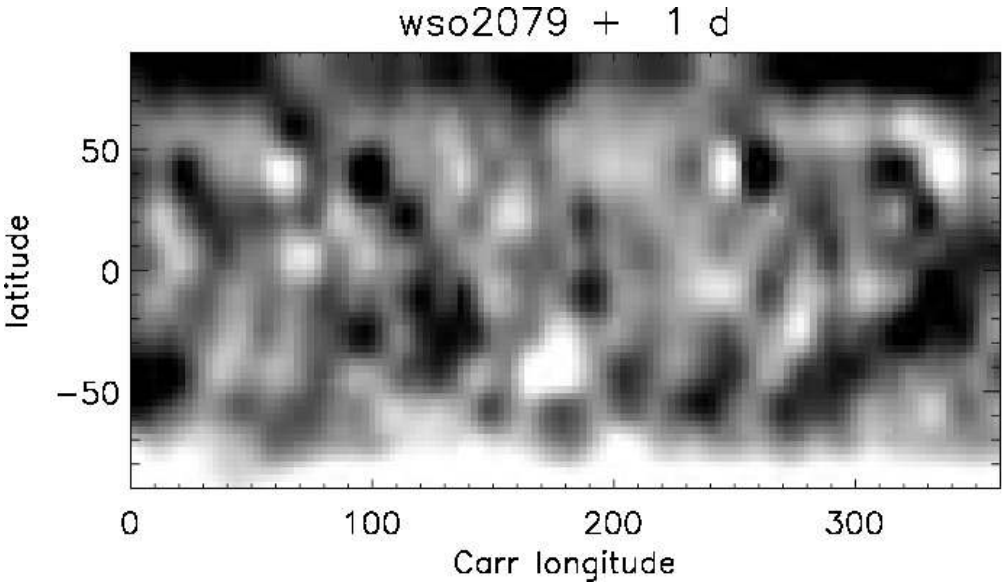
- **Hits and misses i.r.t. in-situ data**
  due, e.g, to errors in latitude of wind streams
- **Dependence on mag. field reconstruction**
  background field evolution, **B**-map cross-calibration
- **No impulsive perturbations**
  but rotation, intermittent heating, small δv waves OK

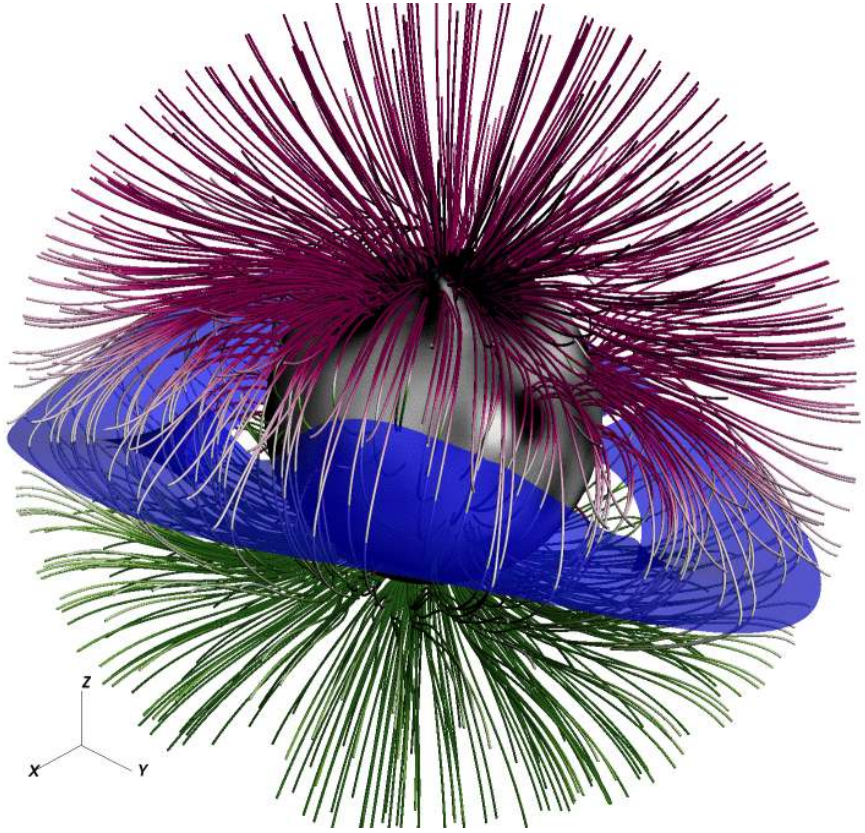
wind streams measured at
higher latitude / lower latitude

Synchronic magnetograms

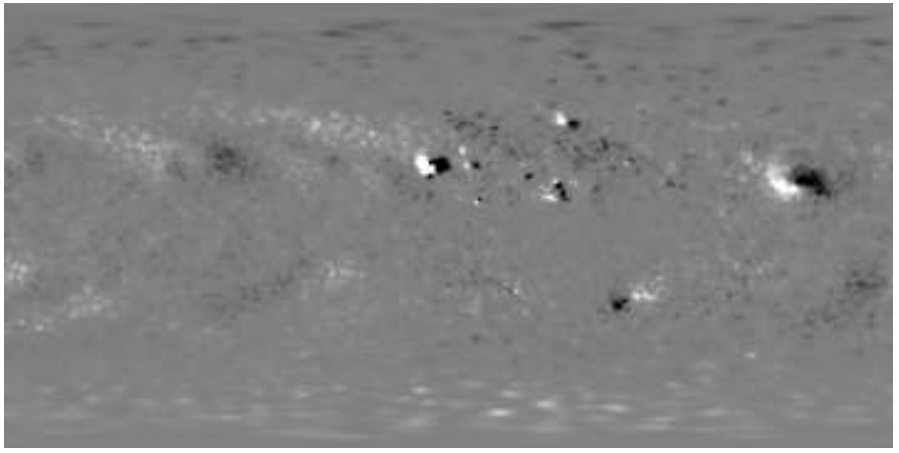
Surface flux-transport methods to evolve magnetograms (full disk)

Simple large-scale shear+diffusion (cf. Wang et al)





ADAPT ensemble maps (Henney, Arge, et al)



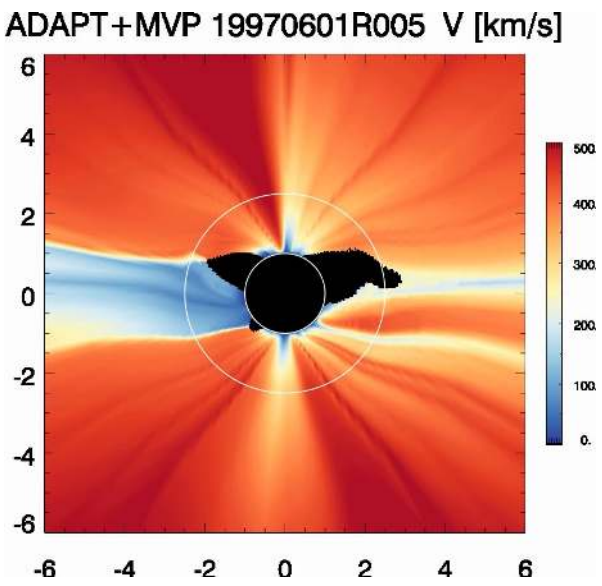
Rui Pinto (rui.pinto@irap.omp.eu)
Alexis Rouillard

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

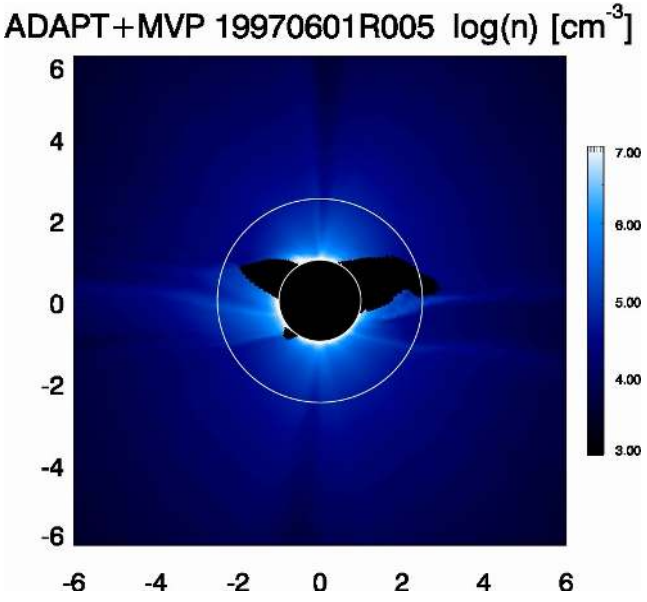
Synchronic wind runs (ADAPT + PFSS-SCS + MULTI-VP)

MULTI-VP (plane-of-sky only) **1 – 30 June 1997**
ADAPT / KPVT maps, PFSS + SCS coronal field reconstruction

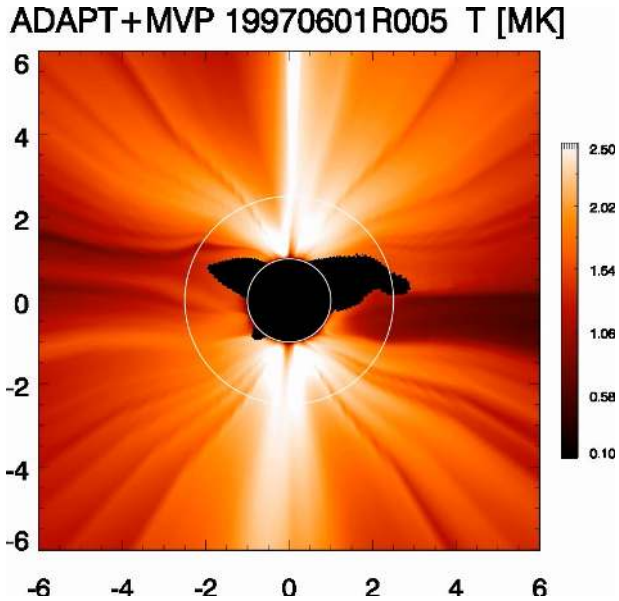
Speed



Density

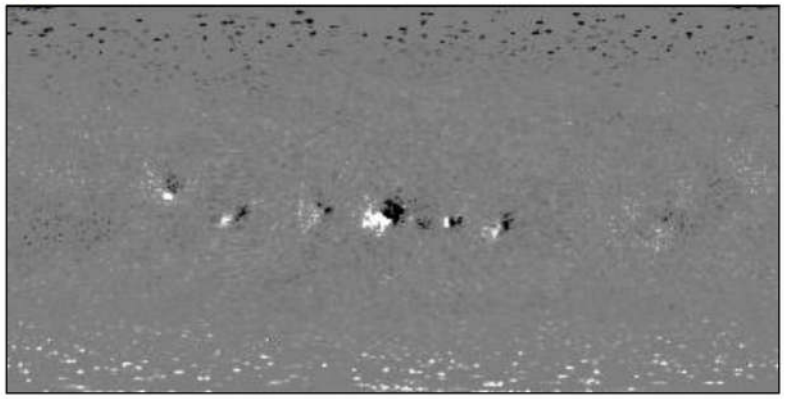


Temperature



dark patches: streamers, data gaps
white lines: surface, source-surface

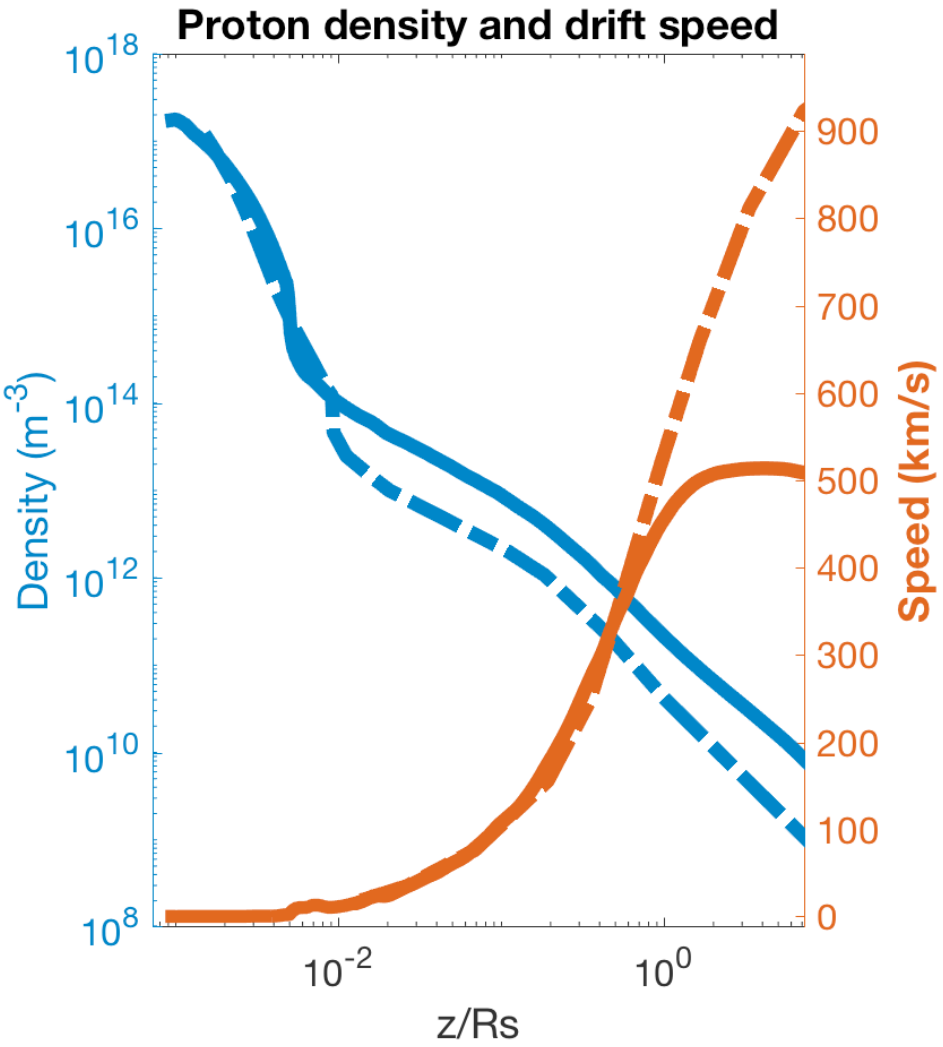
(Pinto, Bemporad, Arge, *in prep*)

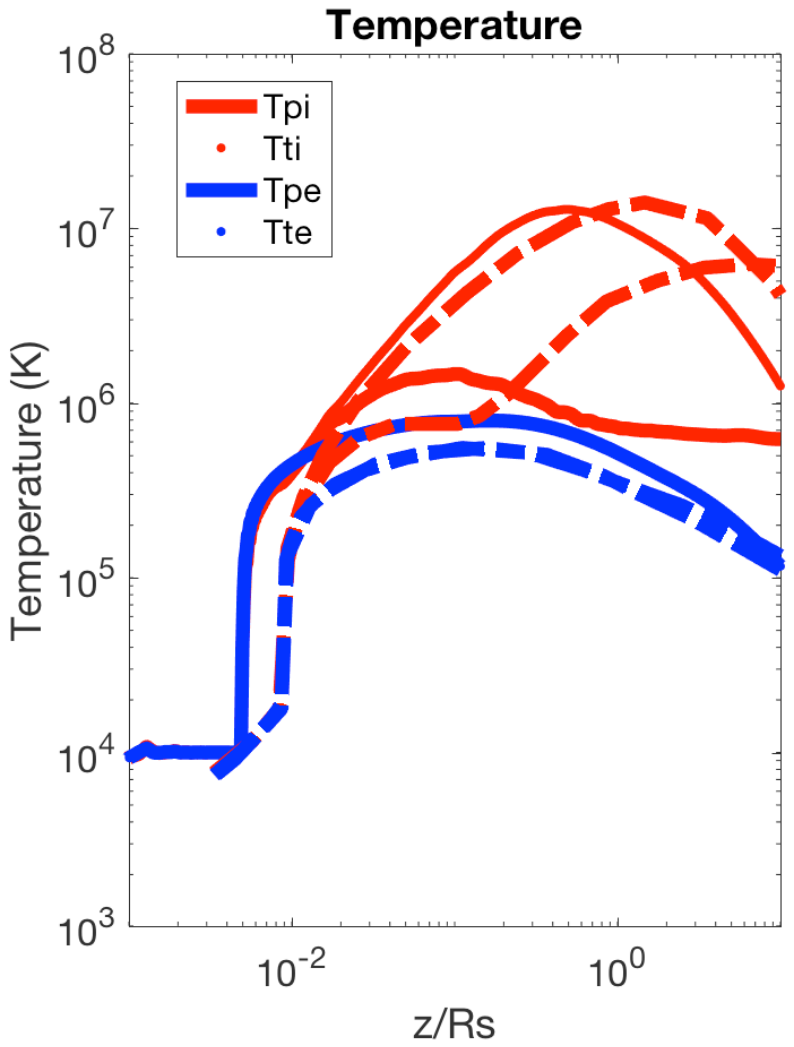


ADAPT magnetogram (Henney, Arge, et al)

- **ADAPT-WSA vs. MULTI-VP vs. UVCS data**
- synchronic magnetic maps are required
- preparation for **Solar Orbiter/METIS**

Multi-fluid and kinetic fluid solar wind





- better insight into **heating mechanisms**
- solar wind **ion composition**
- solar wind sources

(Lavarra, et al, *in prep*)

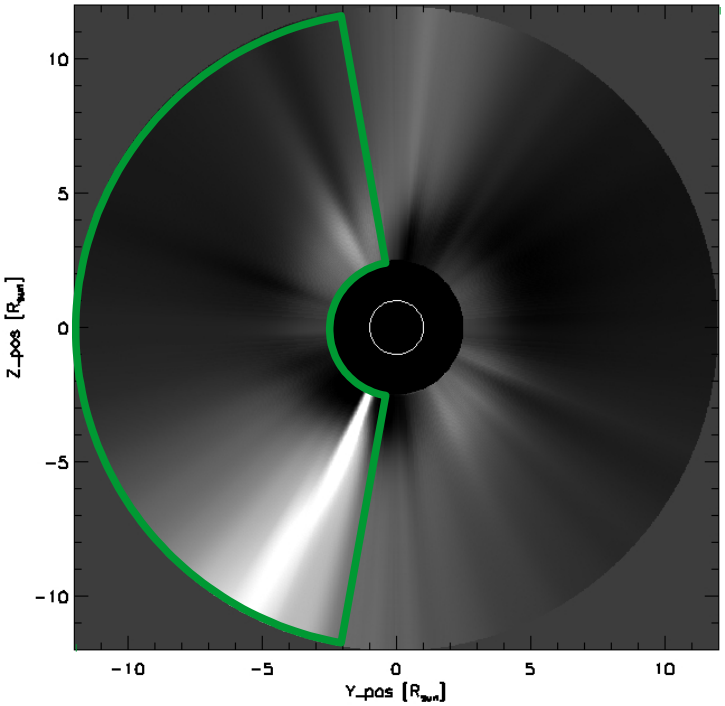
WIP: Continuous solar wind forecast (7-10 days ahead)

1. Early-on magnetogram data

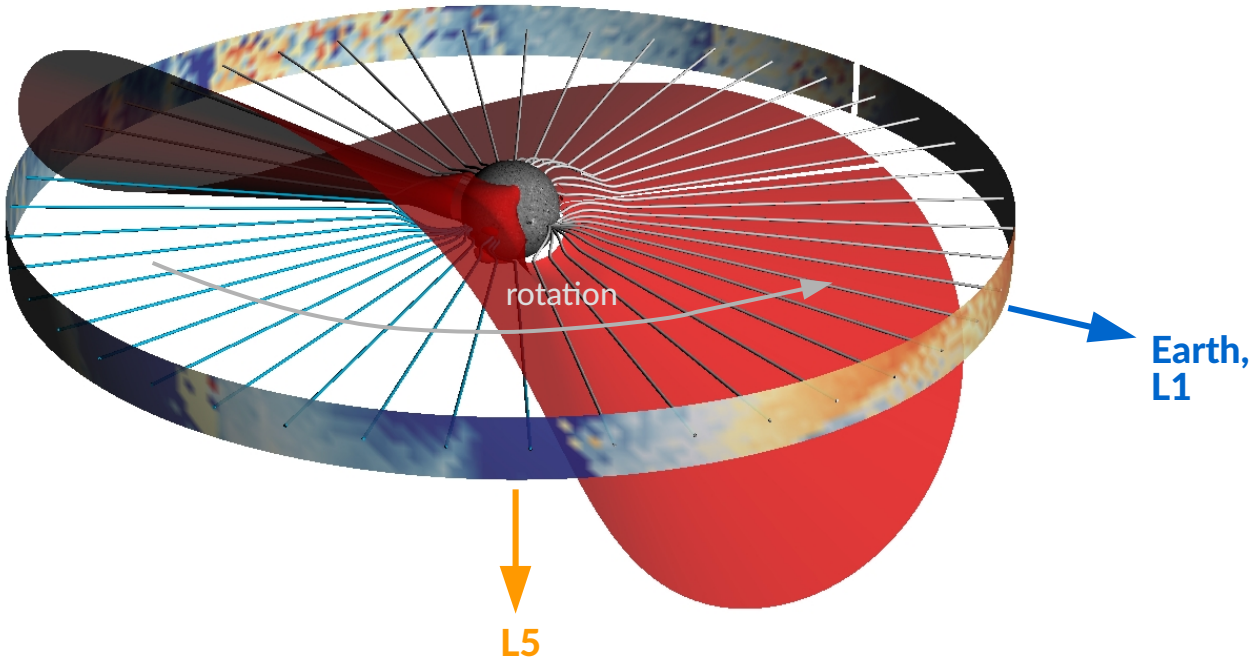
2. East-limb nowcast
synthetic vs. real coronographic imagery
calibration, re-iteration, forecast quality flags

3. L5 in-situ cross-check
verify and (re-)flag propagated wind solutions

4. Sun-Earth path on west limb
real-time monitoring, Cor/HI imaging



East limb nowcast
(synthetic coron. imaging)



SWiFT pipeline

Rui Pinto (rui.pinto@irap.omp.eu)
Alexis Rouillard

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

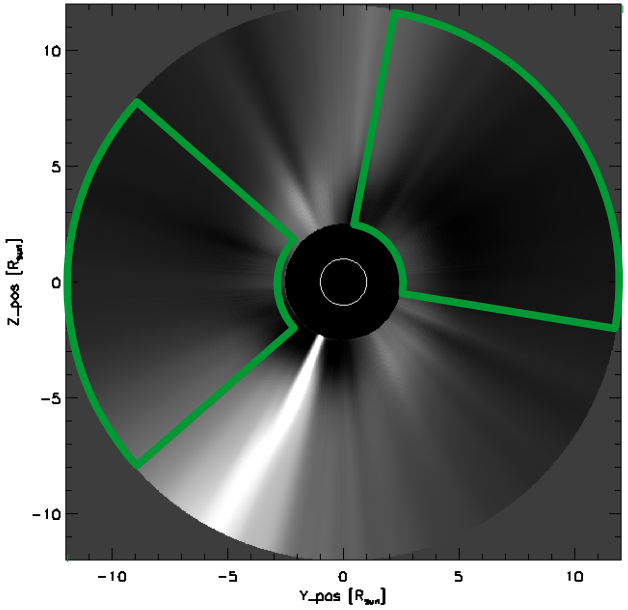
WIP: Continuous solar wind monitoring and forecasting

1. Early-on/forecast magnetogram data

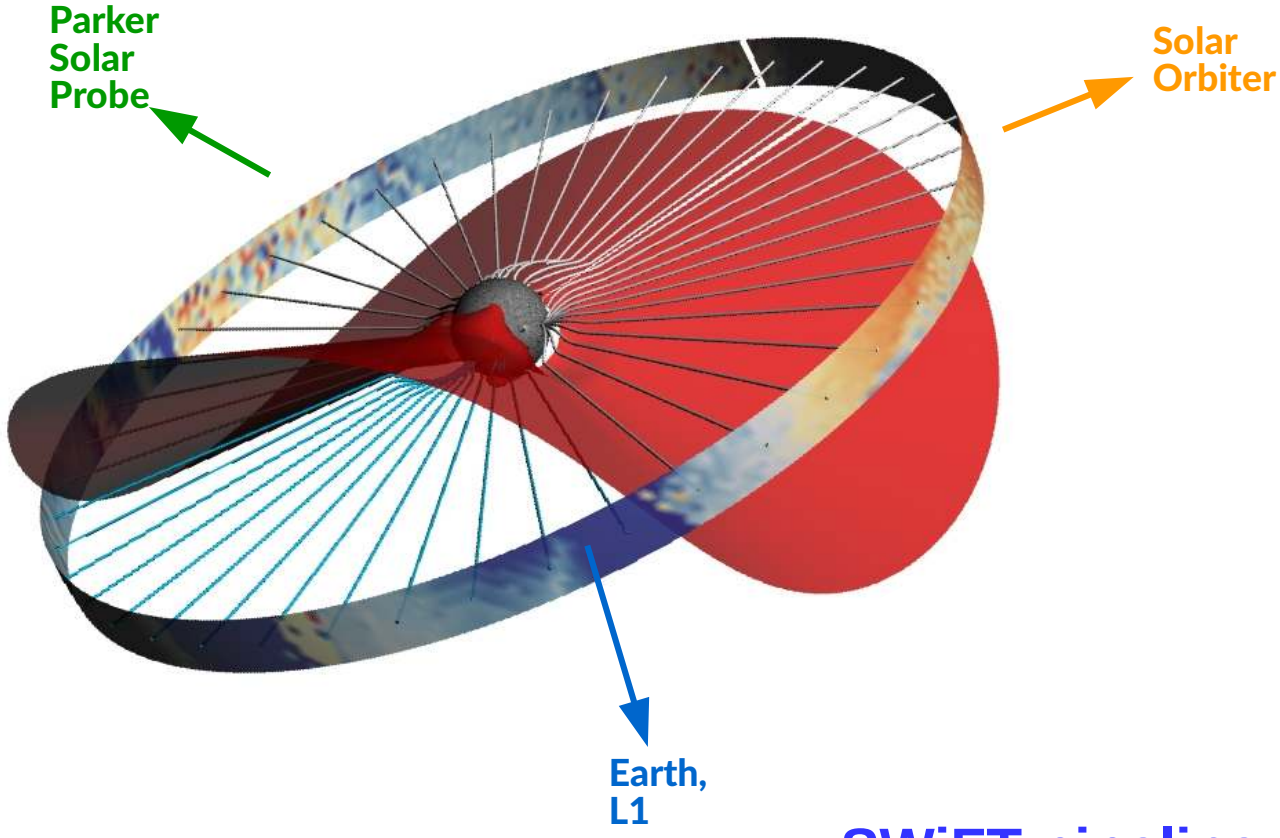
2. East/west limb WL nowcast
synthetic vs. real coronographic imagery
calibration, re-iteration, forecast quality flags

3. Intermediary in-situ cross-check
verify and (re-)flag propagated wind solutions

4. Sun-spacecraft path on Cor/HI fov
real-time monitoring



East/west limb nowcast
(synthetic coron. imaging)



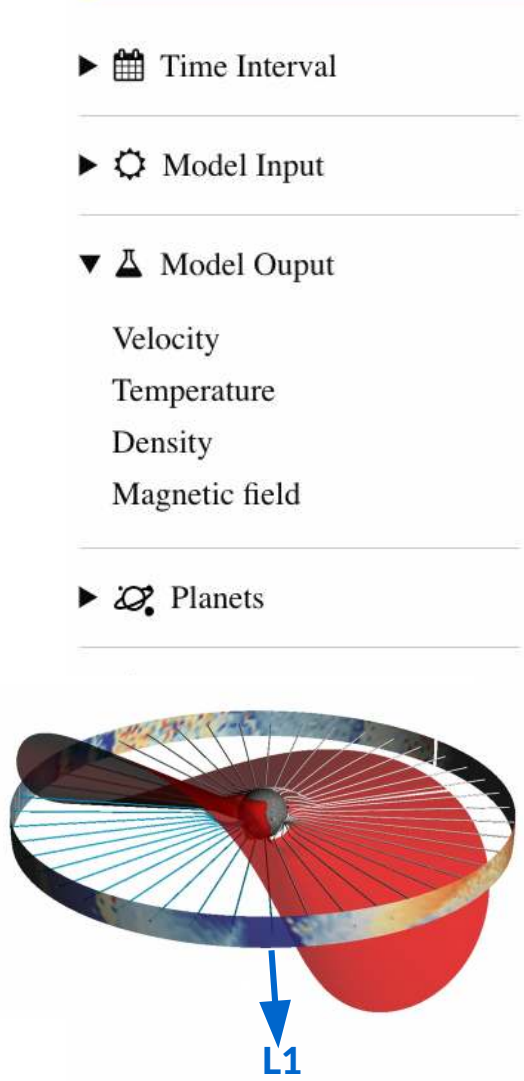
SWiFT pipeline

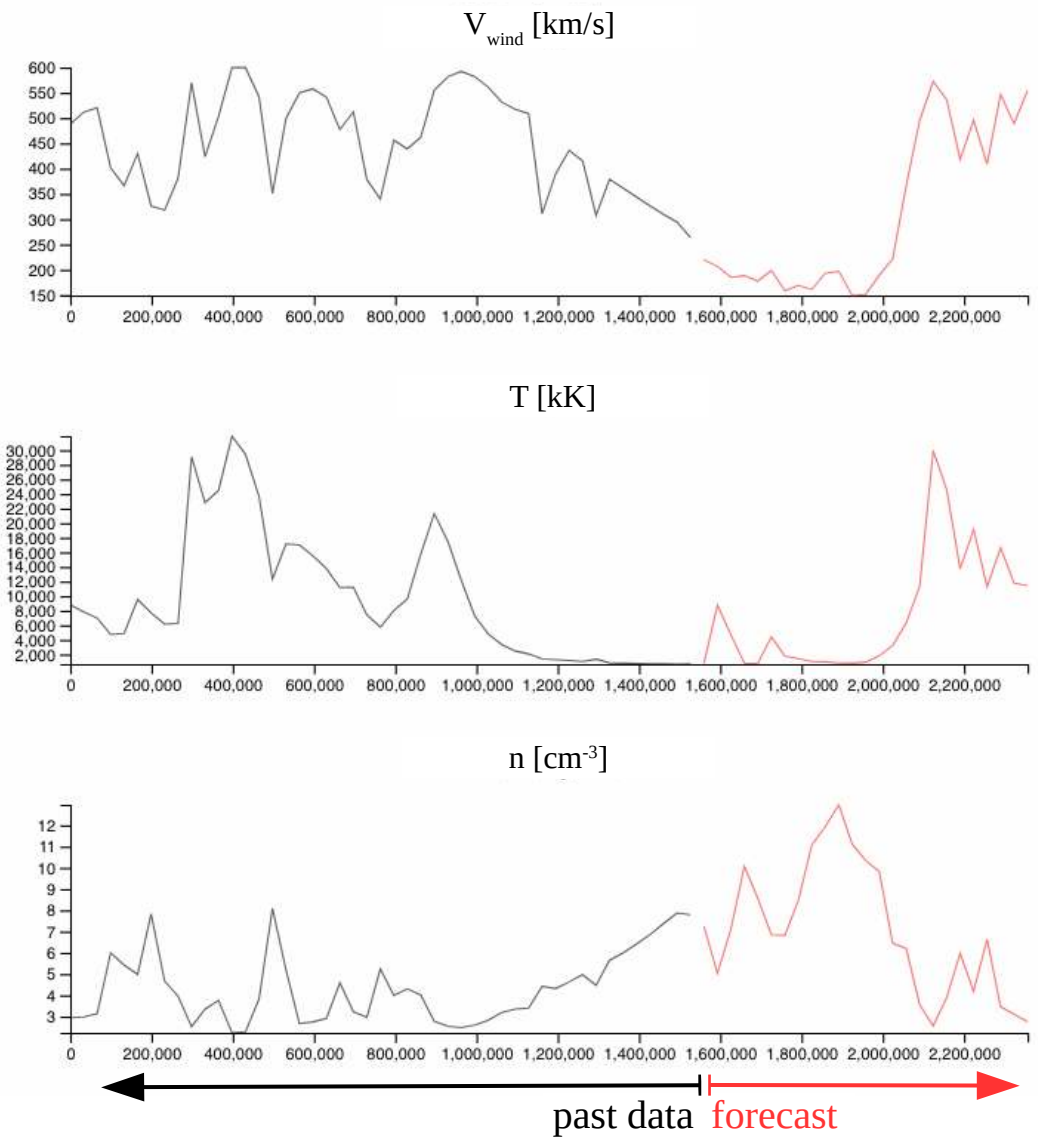
Rui Pinto (rui.pinto@irap.omp.eu)
Alexis Rouillard

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu

Very soon: continuous solar wind monitoring and forecasting

SWiFT-WINDCAST (IRAP / CDPP / STORMS)





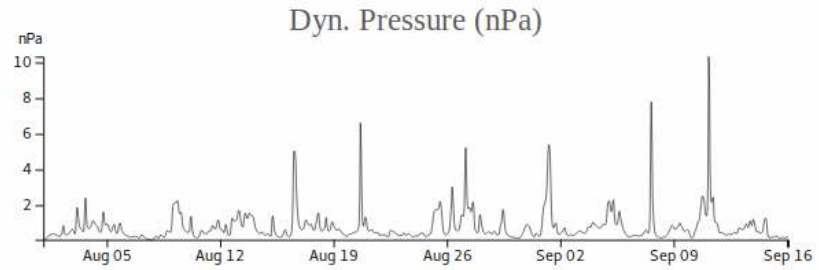
Rui Pinto (rui.pinto@irap.omp.eu)
Alexis Rouillard

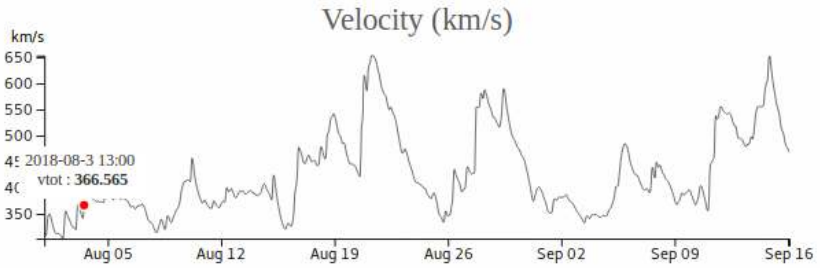
Many thanks to M. Alexandre, E. Budnik

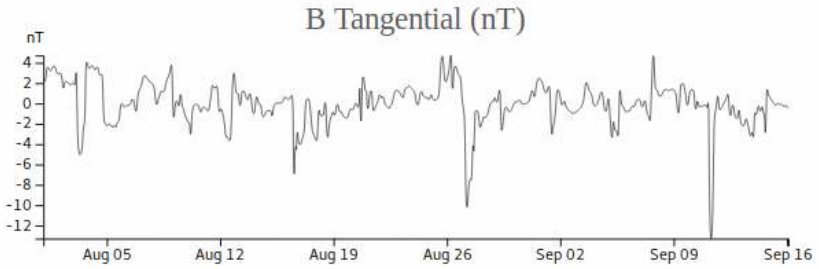
STORMS/SWiFT

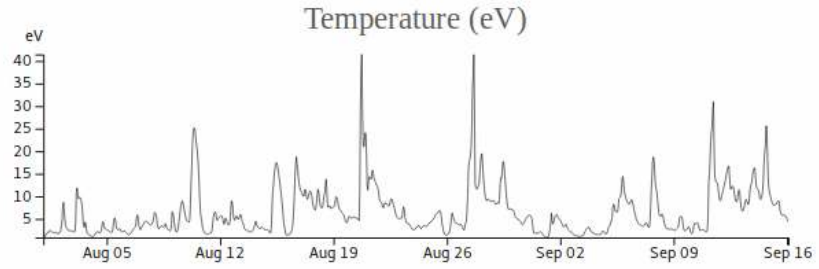
Simulation of the solar wind, using STORMS/SWiFT models

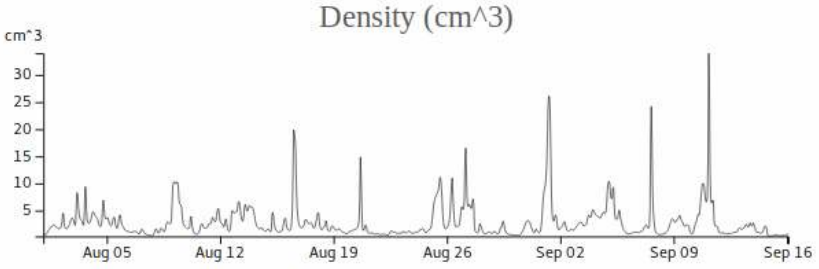
- Time Interval
- Model Input
- Model Ouput
  - Dyn. Pressure
  - Velocity
  - B Tangential
  - Temperature
  - Density
  - Angle T-S-E
- Planets
- Pics of Magnetic Fields





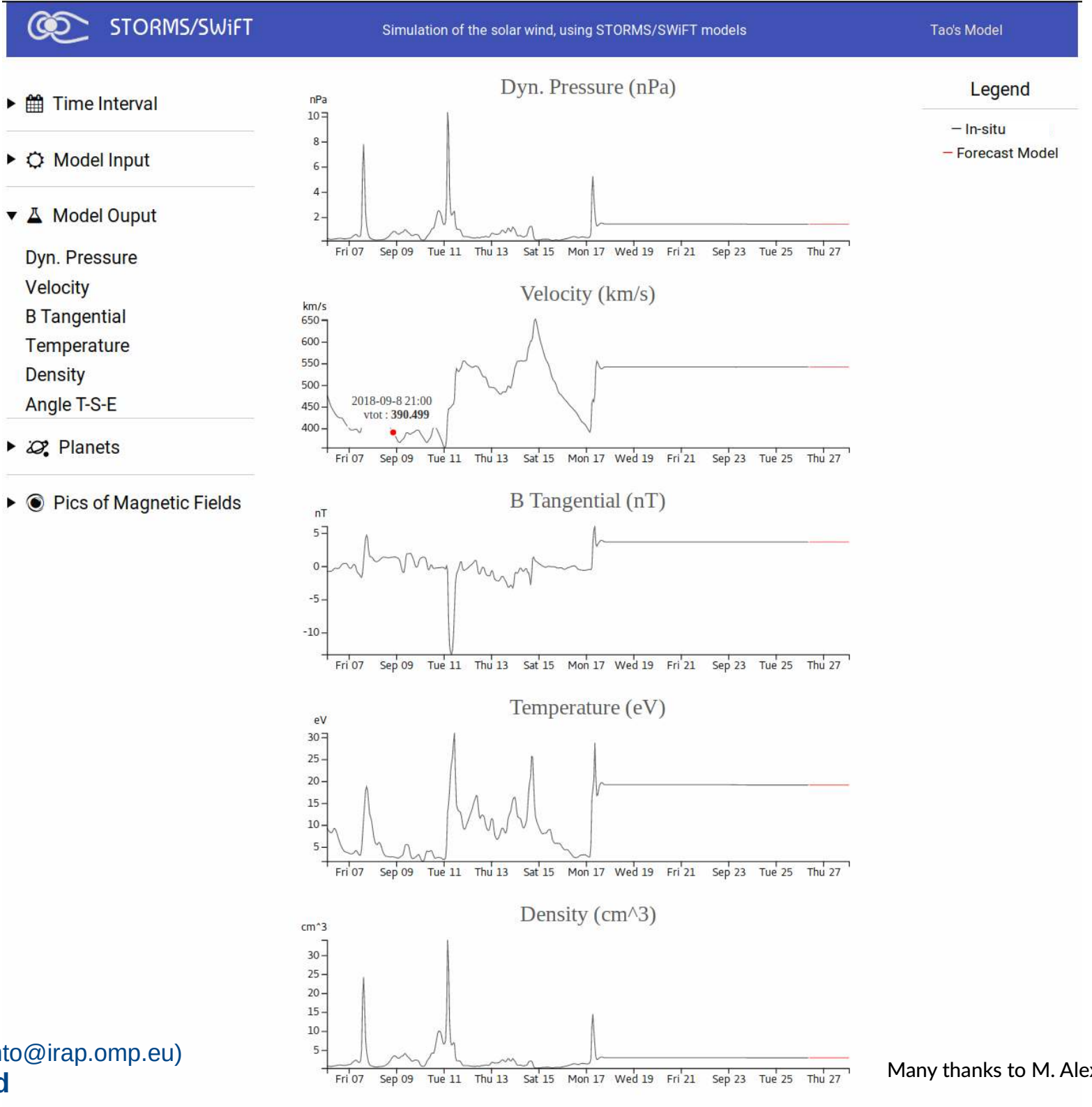






Rui Pinto (rui.pinto@irap
Alexis Rouillard

nks to M. Alexandre, E. Budnik



Rui Pinto (rui.pinto@irap.omp.eu)
Alexis Rouillard

Many thanks to M. Alexandre, E. Budnik

The IRAP and the CDPP

CDPP – Data centre for plasma physics

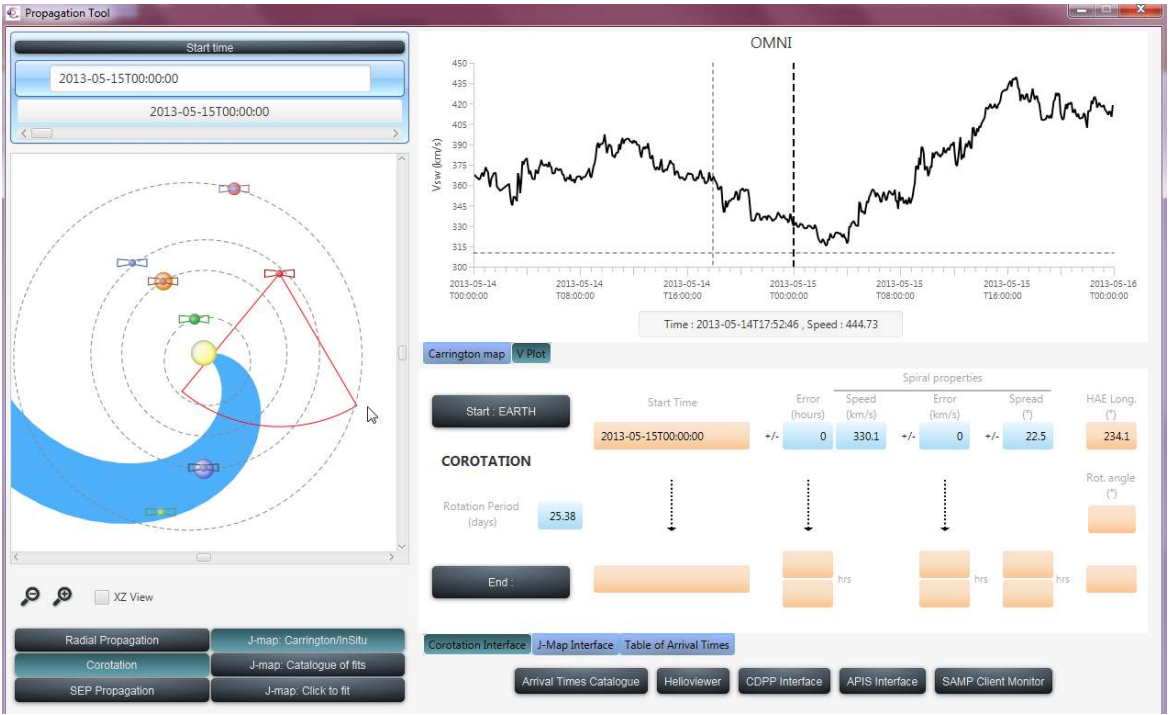
- **European space mission data**
- **Tools for data analysis**
- **Services (public and community)**

Connectivity Tool
http://storms-connectsolo.irap.omp.eu

Sun to s/c connectivity

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

Propagates solar perturbations : CME, SIR and SEP



SWiFT-WINDCAST (SOON!)
http://swiftwindcast.irap.omp.eu

Solar wind forecasts at Earth or s/c

HELIOPROPA
http://heliopropa.irap.omp.eu/

Solar wind propag. in-situ to s/c and planets

AMDA
http://amda.cdp.eu/

Object-oriented data analysis (space plasmas)

3DView
http://3dview.cdpp.eu/

Orbitography, num. simulations, space data

STORMS
http://stormsweb.irap.omp.eu/

Solar-Terrestrial ObseRvation and Modelling Service

Conclusions

Connect Tool: Determine surface – s/c connectivity, multiple methods
Testing with SolO orbit, SDO data with 10 yrs offset
Issues: quantify uncertainties, criteria for forecast quality

SWiFT/ MULTI-VP: global wind model (1 - 32 R_{sun}), fast computation,
alternative to semi-empirical (WSA) and to full 3D MHD models

Full set of background solar wind properties,
at all latitudes and azimuths, coronal rotation

Diagnostics (e.g white-light, EUV, in-situ; pre/intermediate/final checkpoints)

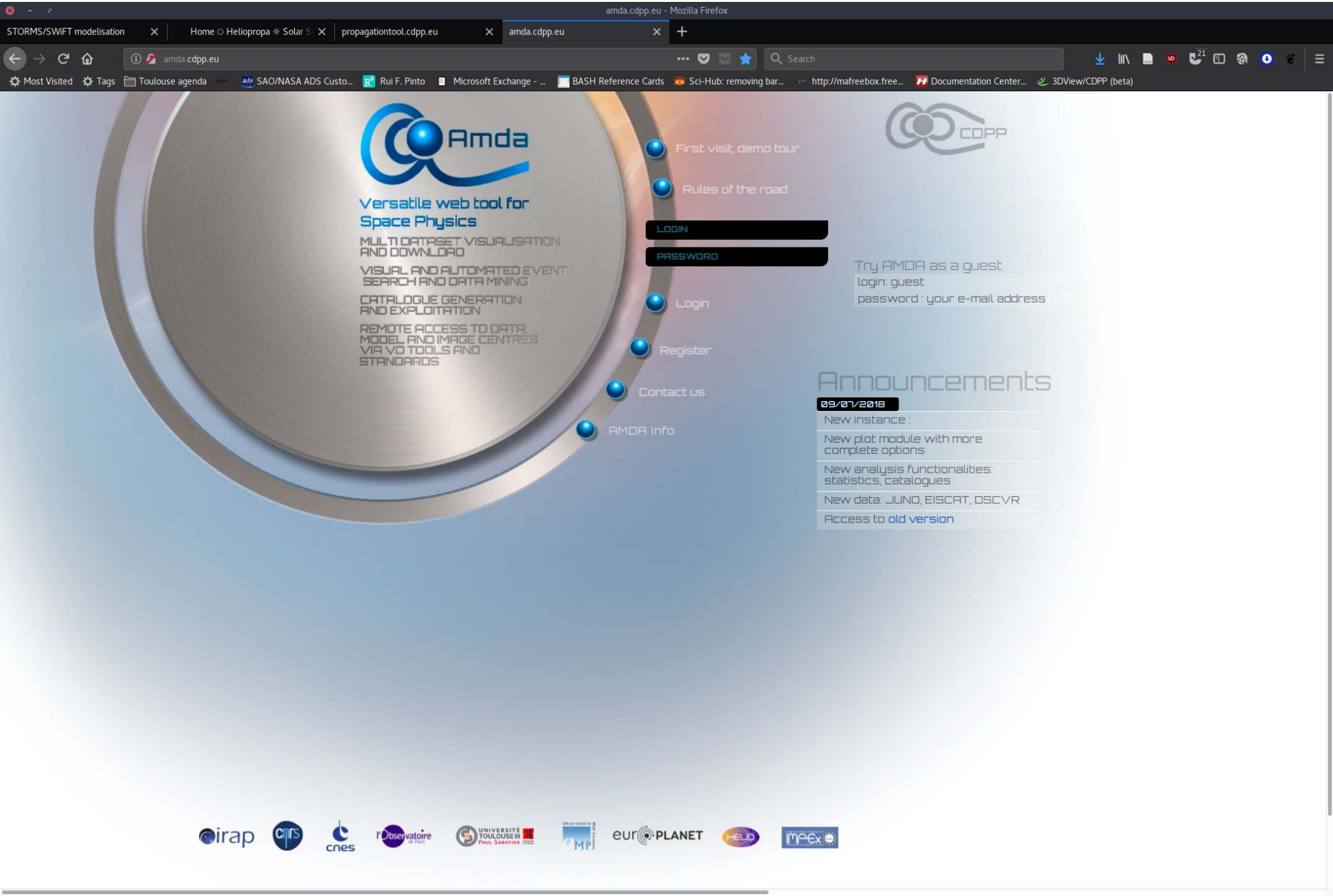
Corona to Heliosphere (ENLIL, EUFHORIA, SW1D)

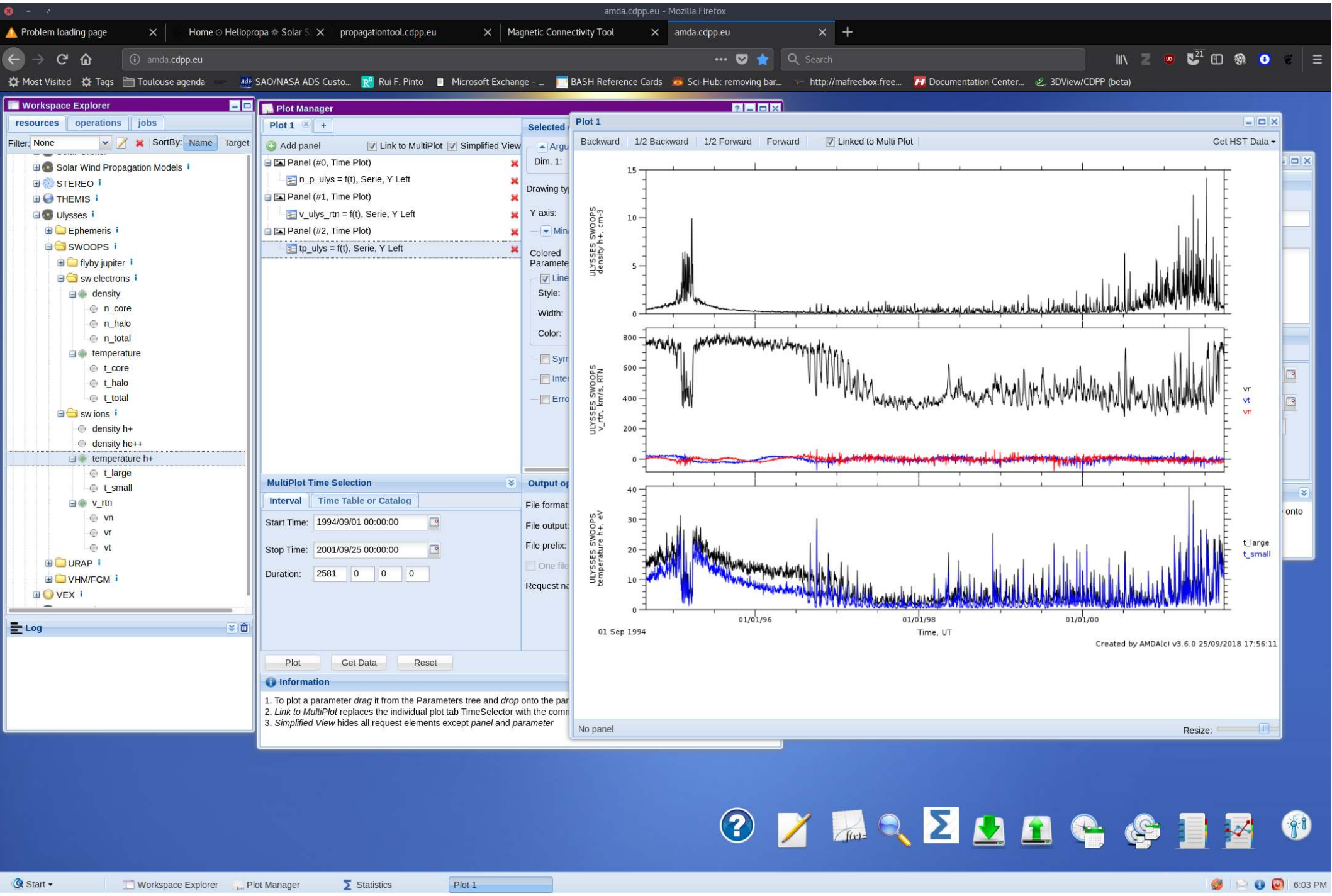
Work-in-progress:

Adding other models: contributions from the community are welcome
Data-driving: synoptic to synchronic magnetic maps, adding local mag maps
Forecast mode: continuous few-days forecast at s/c position

Rui Pinto (rui.pinto@irap.omp.eu)

http://www.helcats-fp7.eu/
http://stormsweb.irap.omp.eu


amda.cdpp.eu - Mozilla Firefox
STORMS/SWIFT modelisation
Home ⊙ Heliopropa ✳ Solar S
propagationtool.cdpp.eu
amda.cdpp.eu
amda.cdpp.eu
Search
Most Visited
Tags
Toulouse agenda
SAO/NASA ADS Custo...
Rui F. Pinto
Microsoft Exchange - ...
BASH Reference Cards
Sci-Hub: removing bar...
http://mafreebox.free...
Documentation Center...
3DView/CDPP (beta)
Amda
Versatile web tool for
Space Physics
MULTI DATASET VISUALISATION AND DOWNLOAD
VISUAL AND AUTOMATED EVENT SEARCH AND DATA MINING
CATALOGUE GENERATION AND EXPLOITATION
REMOTE ACCESS TO DATA, MODEL AND IMAGE CENTRES VIA VO TOOLS AND STANDARDS
First visit, demo tour
Rules of the road
LOGIN
PASSWORD
Login
Register
Contact us
AMDA Info
CDPP
Try AMDA as a guest
login: guest
password : your e-mail address
Announcements
09/07/2018
New instance :
New plot module with more complete options
New analysis functionalities: statistics, catalogues
New data: JUNO, EISCAT, DSCVR
Access to old version
irap
cnrs
cnes
l'Observatoire de Paris
Université Toulouse III Paul Sabatier
OMP
eurPLANET
HELIO
IMPEX


amda.cdpp.eu - Mozilla Firefox
Problem loading page
Home ○ Heliopropa ✳ Solar S
propagationtool.cdpp.eu
Magnetic Connectivity Tool
amda.cdpp.eu
amda.cdpp.eu
Search
Most Visited
Tags
Toulouse agenda
SAO/NASA ADS Custo...
Rui F. Pinto
Microsoft Exchange - ...
BASH Reference Cards
Sci-Hub: removing bar...
http://mafreebox.free...
Documentation Center...
3DView/CDPP (beta)
Workspace Explorer
resources
operations
jobs
Filter: None
SortBy: Name
Target
Solar Wind Propagation Models
STEREO
THEMIS
Ulysses
Ephemeris
SWOOPS
flyby jupiter
sw electrons
density
n_core
n_halo
n_total
temperature
t_core
t_halo
t_total
sw ions
density h+
density he++
temperature h+
t_large
t_small
v_rtn
vn
vr
vt
URAP
VHM/FGM
VEX
Log
Plot Manager
Plot 1
Add panel
Link to MultiPlot
Simplified View
Panel (#0, Time Plot)
n_p_ulys = f(t), Serie, Y Left
Panel (#1, Time Plot)
v_ulys_rtn = f(t), Serie, Y Left
Panel (#2, Time Plot)
tp_ulys = f(t), Serie, Y Left
Selected
Dim. 1:
Drawing ty
Y axis:
Colored
Paramete
Style:
Width:
Color:
MultiPlot Time Selection
Interval
Time Table or Catalog
Start Time: 1994/09/01 00:00:00
Stop Time: 2001/09/25 00:00:00
Duration: 2581 0 0 0
Output op
File format
File output:
File prefix:
Request na
Plot
Get Data
Reset
Information
1. To plot a parameter drag it from the Parameters tree and drop onto the par
2. Link to MultiPlot replaces the individual plot tab TimeSelector with the comn
3. Simplified View hides all request elements except panel and parameter
Plot 1
Backward
1/2 Backward
1/2 Forward
Forward
Linked to Multi Plot
Get HST Data
ULYSSES SWOOPS density h+, cm-3
ULYSSES SWOOPS v_rtn, km/s, RTN
vr
vt
vn
ULYSSES SWOOPS temperature h+, eV
t_large
t_small
01 Sep 1994
01/01/96
01/01/98
01/01/00
Time, UT
Created by AMDA(c) v3.6.0 25/09/2018 17:56:11
No panel
Resize:
Start
Workspace Explorer
Plot Manager
Statistics
Plot 1
6:03 PM

Propagation Tool

Welcome to CDPP/Propagation Tool

Tutorials : video (mov files)

- Introduction to the CDPP Propagation Tool (13M)
- Description of the propagation tool main interface (8M)
- Case 1: Using the tool in the Jmap Carrington/In situ mode (radial) (37M)
- Case 2: Using the tool in the Jmap tool click mode (radial) (39M)

Tutorials : video (mpeg files)

- Introduction to the CDPP Propagation Tool (46M)
- Description of the propagation tool main interface (47M)
- Case 1: Using the tool in the Jmap Carrington/In situ mode (radial) (176M)
- Case 2: Using the tool in the Jmap tool click mode (radial) (184M)

Table of available data

- Flare Data, Carrington Maps, J-Maps, Solar Wind Speed

Supported set up

- Java requirements
- Get Java 8
- Linux troubleshoot

What's new ?

Launch the Propagation Tool

java 8: Mac users: please use Firefox or Safari

A new interactive tool accessible to the solar, heliospheric and planetary science communities to track solar storms, streams and energetic particles in the heliosphere.This tool was defined and developed by *IRAP* and *IAS* staff through a subcontract with *GFI informatique* and *CNES* financial support. It follows on from and is complementary to the propagation tool developed by the FP7 HELIO project.

Main functionalities are described in the reference paper recently published in Planetary and Space Science.

The propagation tool allows users:

- to propagate solar eruptions (CMEs) radially sunward or anti-sunward (**Radial Propagation**),
- to propagate corotating structures (CIRs) in the heliosphere (**Corotation**),
- to propagate solar energetic particles along magnetic fields lines sunward or anti-sunward (**SEP Propagation**),

The START and END points can be the Sun, planets or probes situated in the interplanetary medium. The times of propagation between the START and END points are based on simple analytic calculations.

The added values of the tool are an easy access to unique datasets and a fast interoperability :

- it integrates the **orbital elements** (using SPICE) of probes and planets. This allows you to determine via simple clicks the position/orientations of imagers that you would like to consider,
- it offers **web-service** access to summary plots of in-situ data stored at the CDPP as well as movies of solar images stored at MEDOC,
- it provides access to a wide range of **Carrington maps** of the solar surface to visualize the location of active regions, coronal holes and solar flares on the Sun

The great novelty of the tool is the immediate visualisation and basic manipulation of maps of solar wind mass flows tracked continuously from the Sun to 1AU. These maps are called J-maps and are generated by extracting bands of pixels in coronal and heliospheric images along the ecliptic planes and stacking them vertically (along the ordinate) with time (along the abscissae). The maps are produced from teraoctets of imagery data that are impossible to manipulate if you are not an expert in the field. The tool was designed to be user friendly and accessible to any scientist interested in locating CMEs/CIRs and particle fluxes in the ecliptic plane.

With the tool you can use these maps to:

- cross check your ballistic calculation of CME/CIR propagations,
- carry out your own calculations of CME/CIR trajectories in the ecliptic plane via a few clicks on the map (simple use),
- use pre-calculated CME trajectories to check if a transient emerged from the Sun and impacted a planet or probe

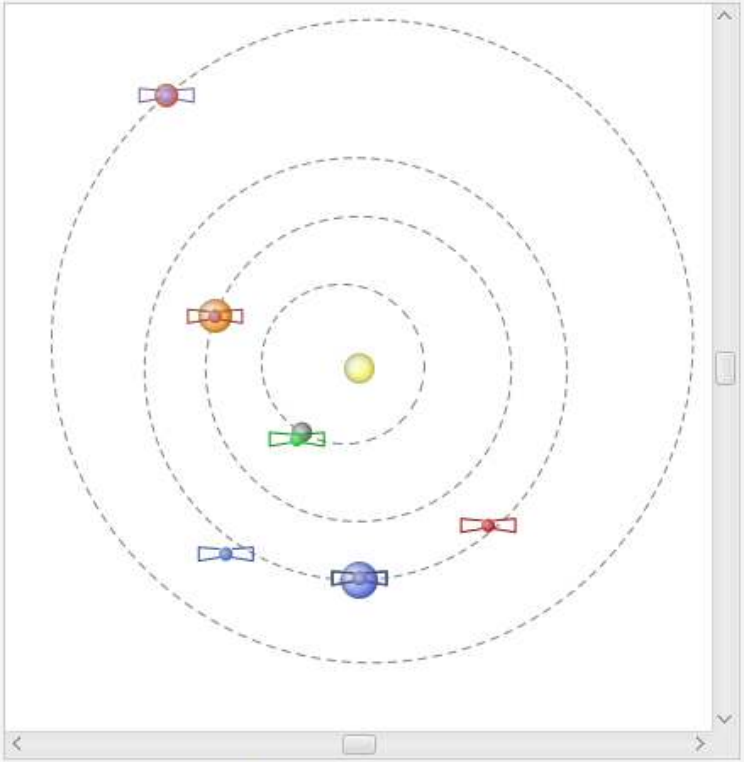
Contact

Propagation Tool

Start time

2008-09-24T12:00:00

2008-09-24T12:00:00



Coordinate system : HEE

XZ View

Radial Propagation

Corotation

SEP Propagation

J-map: Carrington/InSitu

J-map: Catalogue of fits

J-map: Click to fit

CDPP

irap

Propagation Tool

Release 2.2.4 - 12/07/2018

cnes

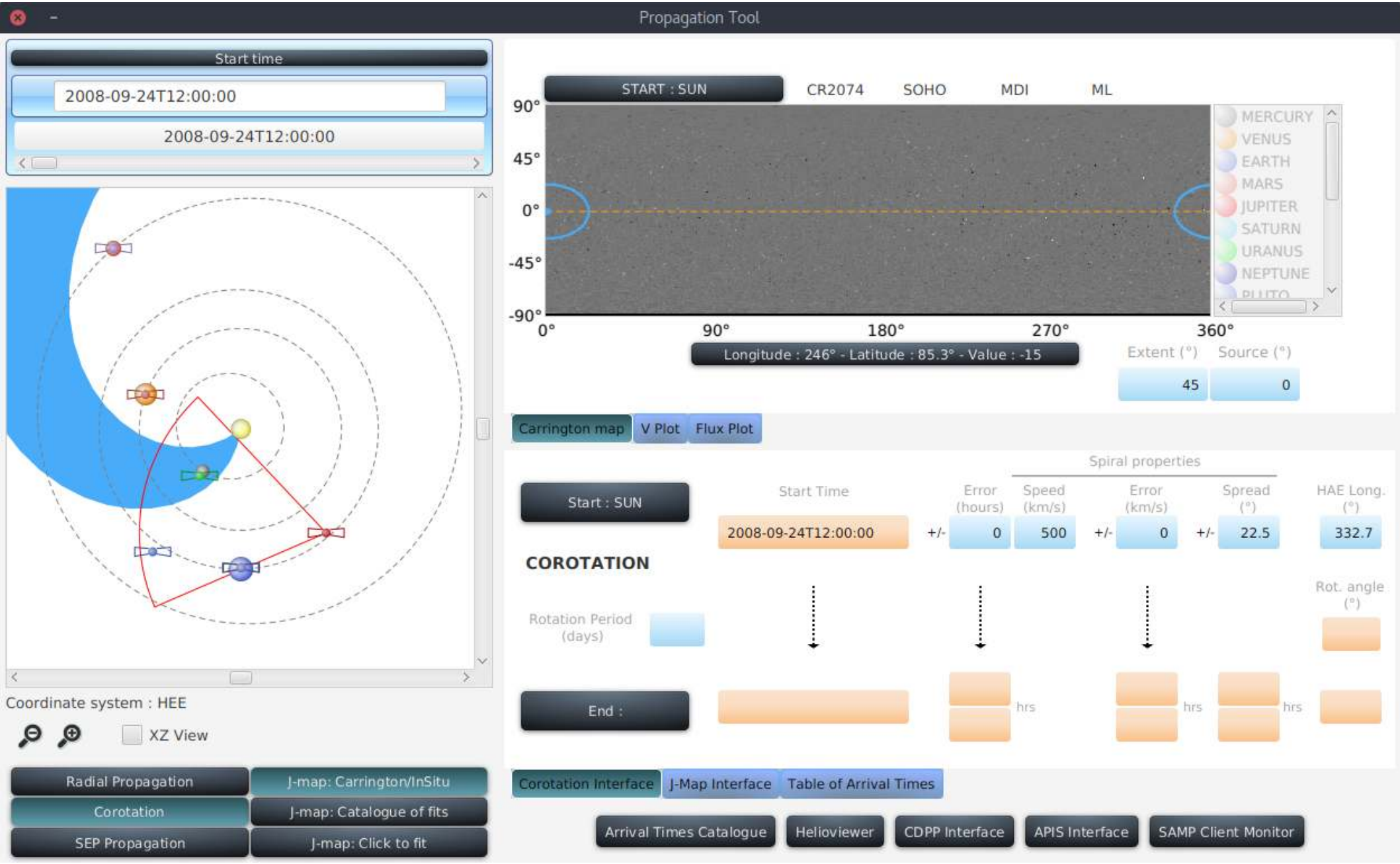
cnrs

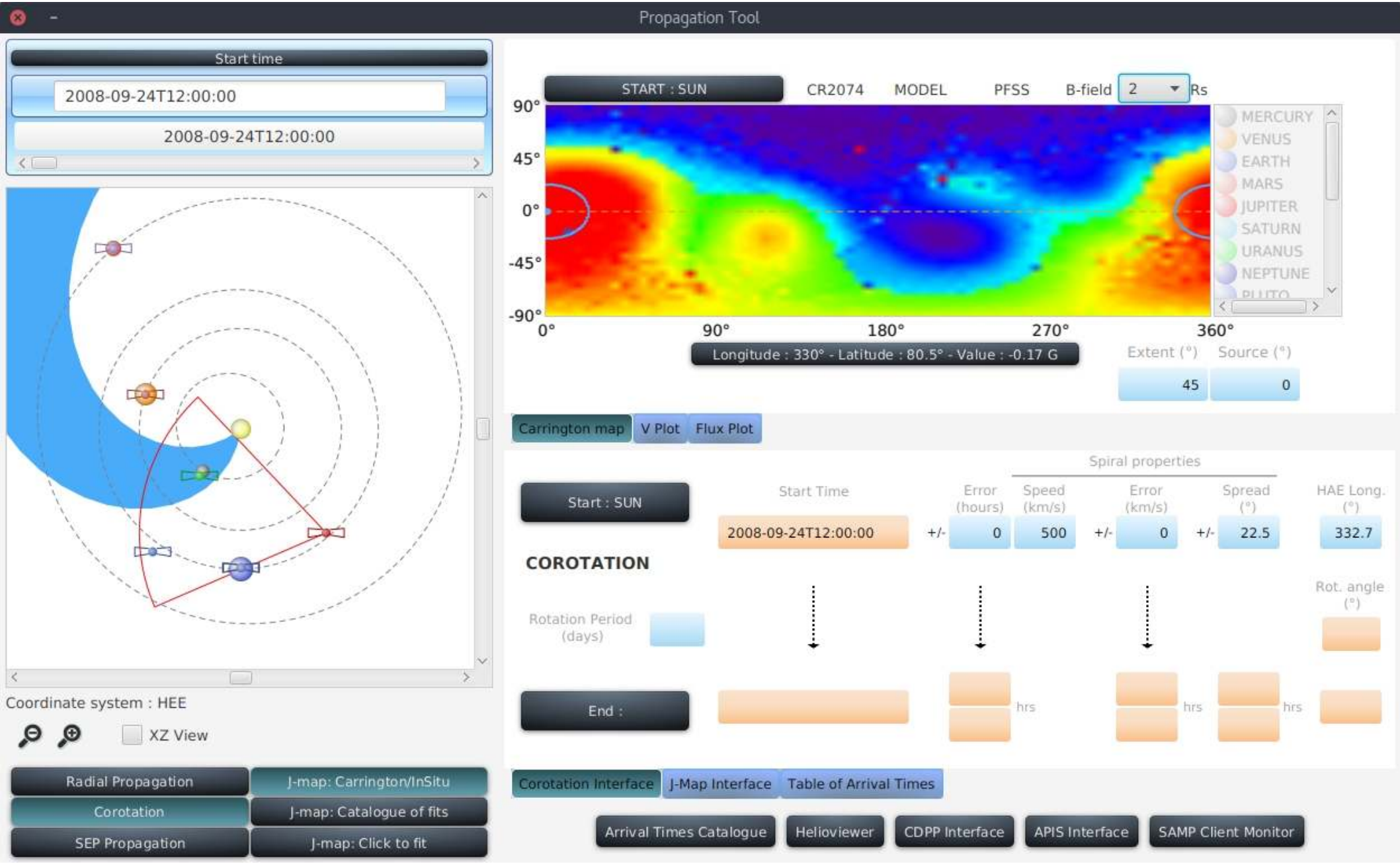
Université Toulouse III Paul Sabatier

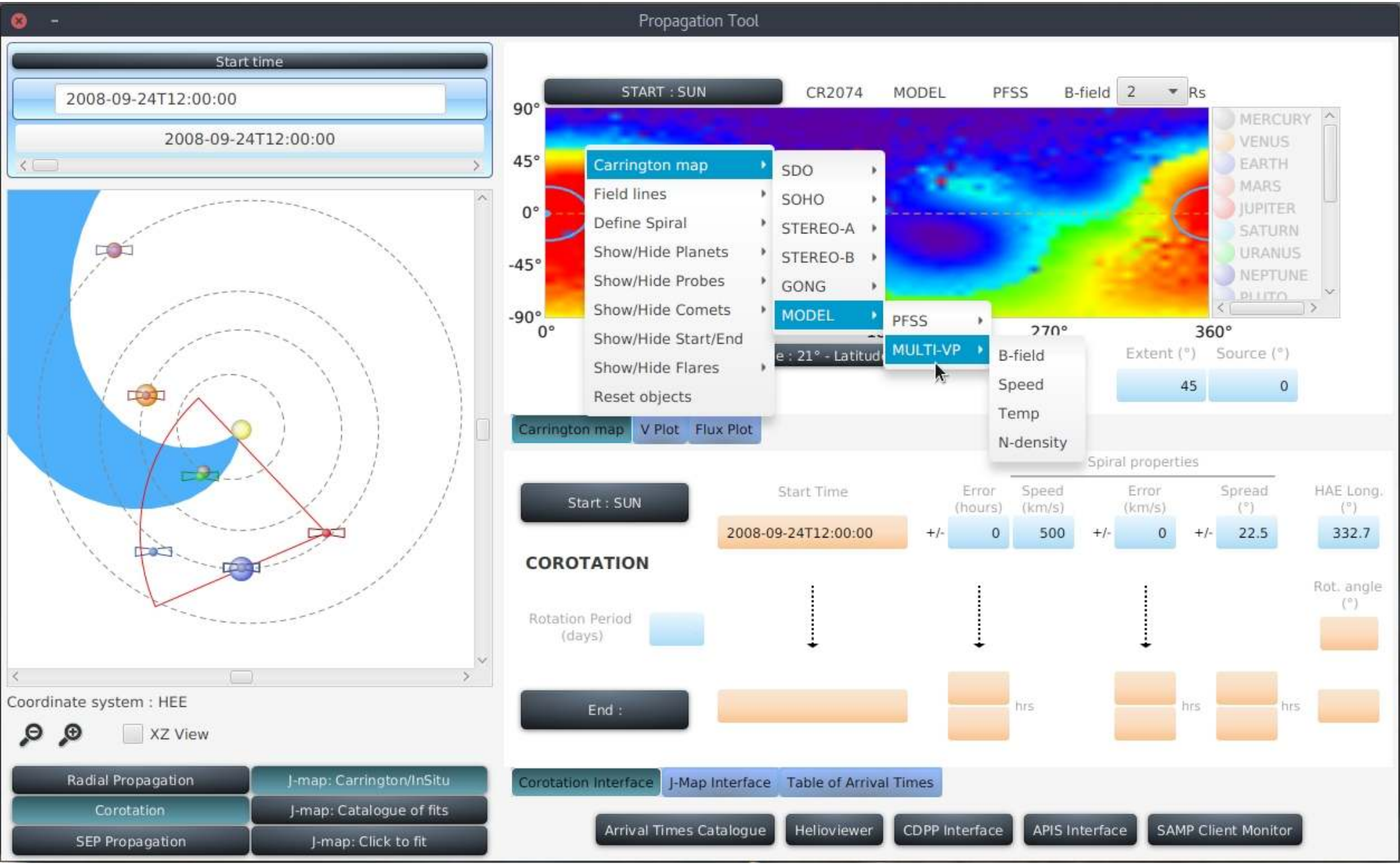
l'Observatoire de Paris

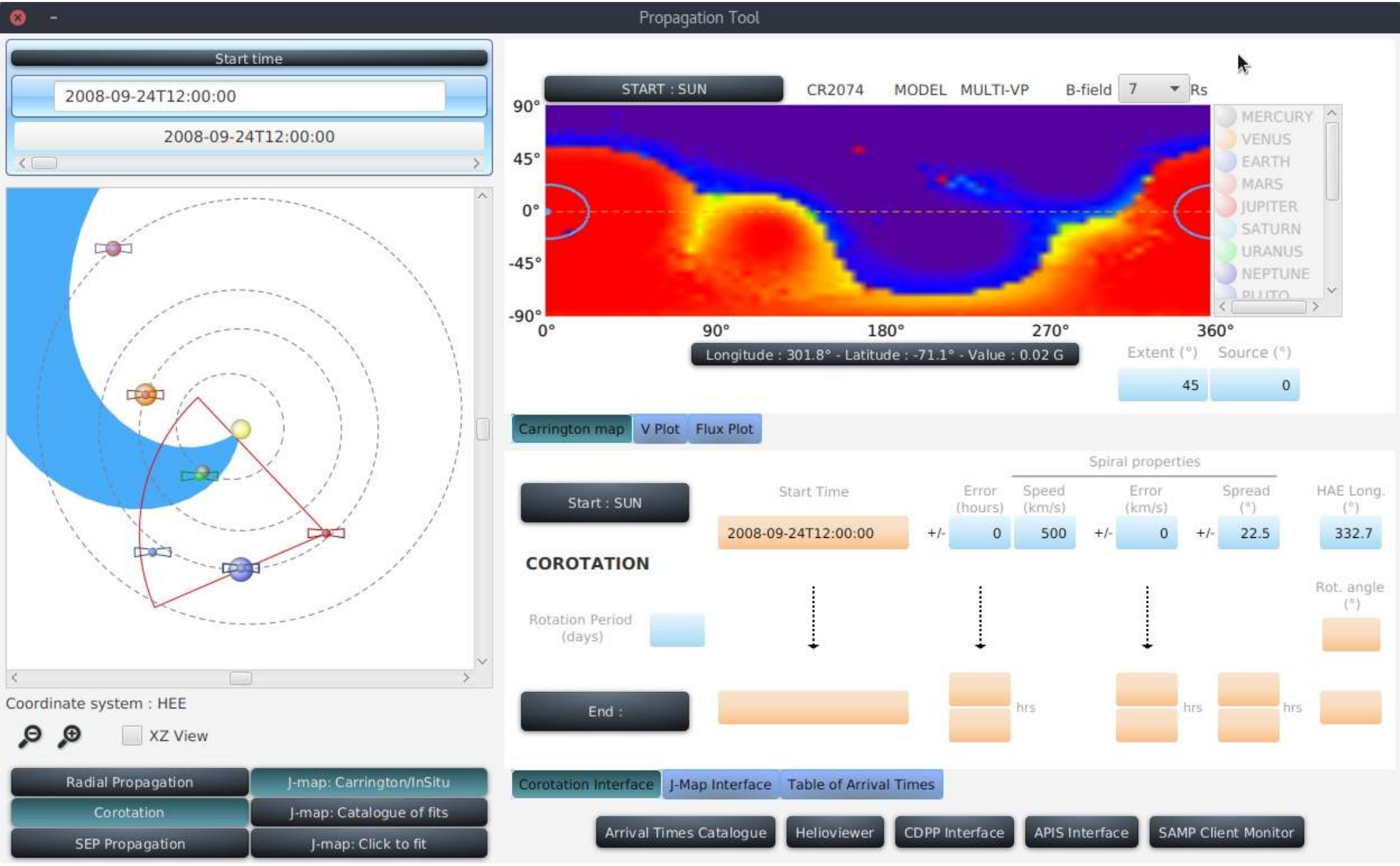
gfi

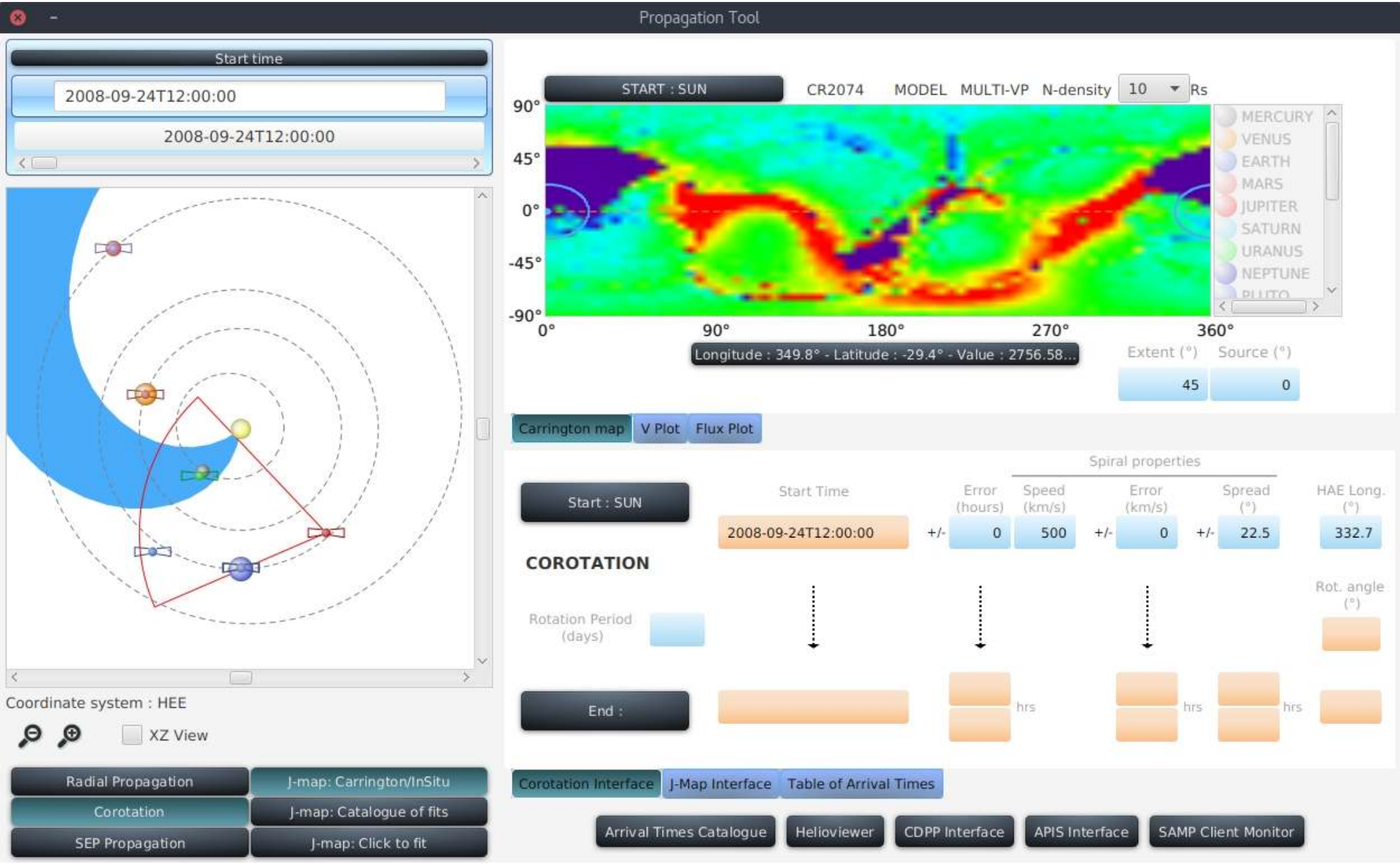
EUROPLANET


Propagation Tool
Start time
2008-09-24T12:00:00
2008-09-24T12:00:00
START : SUN
CR2074
SOHO
MDI
ML
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Longitude : 246° - Latitude : 85.3° - Value : -15
Extent (°)
Source (°)
45
0
Carrington map
V Plot
Flux Plot
Spiral properties
Start : SUN
Start Time
Error (hours)
Speed (km/s)
Error (km/s)
Spread (°)
HAE Long. (°)
2008-09-24T12:00:00
+/-
0
500
+/-
0
+/-
22.5
332.7
COROTATION
Rot. angle (°)
Rotation Period (days)
End :
hrs
hrs
hrs
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T12:00:00
2008-09-24T12:00:00
START : SUN
CR2074
MODEL
PFSS
B-field
2
Rs
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Longitude : 330° - Latitude : 80.5° - Value : -0.17 G
Extent (°)
Source (°)
45
0
Carrington map
V Plot
Flux Plot
Spiral properties
Start : SUN
Start Time
Error (hours)
Speed (km/s)
Error (km/s)
Spread (°)
HAE Long. (°)
2008-09-24T12:00:00
+/-
0
500
+/-
0
+/-
22.5
332.7
COROTATION
Rot. angle (°)
Rotation Period (days)
End :
hrs
hrs
hrs
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T12:00:00
2008-09-24T12:00:00
START : SUN
CR2074
MODEL
PFSS
B-field
2
Rs
90°
45°
0°
-45°
-90°
0°
270°
360°
Carrington map
Field lines
Define Spiral
Show/Hide Planets
Show/Hide Probes
Show/Hide Comets
Show/Hide Start/End
Show/Hide Flares
Reset objects
SDO
SOHO
STEREO-A
STEREO-B
GONG
MODEL
PFSS
MULTI-VP
B-field
Speed
Temp
N-density
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Extent (°)
Source (°)
45
0
Carrington map
V Plot
Flux Plot
Spiral properties
Start : SUN
Start Time
2008-09-24T12:00:00
Error (hours)
Speed (km/s)
Error (km/s)
Spread (°)
HAE Long. (°)
+/-
0
500
0
22.5
332.7
COROTATION
Rot. angle (°)
Rotation Period (days)
End :
hrs
Coordinate system : HEE
XZ View
Radial Propagation
Corotation
SEP Propagation
J-map: Carrington/InSitu
J-map: Catalogue of fits
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T12:00:00
2008-09-24T12:00:00
START : SUN
CR2074
MODEL
MULTI-VP
B-field
7
Rs
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Longitude : 301.8° - Latitude : -71.1° - Value : 0.02 G
Extent (°)
Source (°)
45
0
Carrington map
V Plot
Flux Plot
Spiral properties
Start : SUN
Start Time
Error (hours)
Speed (km/s)
Error (km/s)
Spread (°)
HAE Long. (°)
2008-09-24T12:00:00
+/-
0
500
+/-
0
+/-
22.5
332.7
COROTATION
Rot. angle (°)
Rotation Period (days)
End :
hrs
hrs
hrs
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor

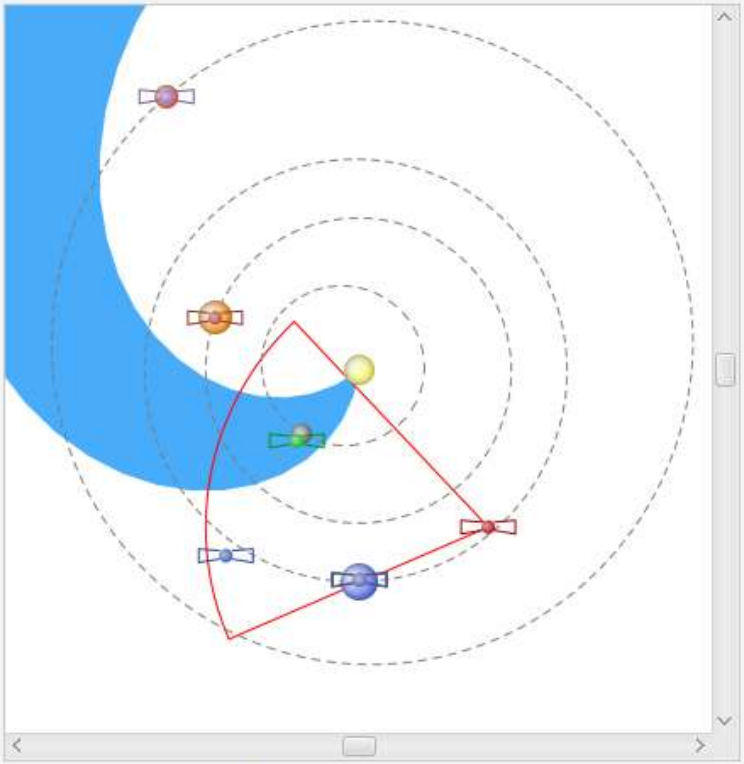

Propagation Tool
Start time
2008-09-24T12:00:00
2008-09-24T12:00:00
START : SUN
CR2074
MODEL
MULTI-VP
N-density
10
Rs
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Longitude : 349.8° - Latitude : -29.4° - Value : 2756.58...
Extent (°)
Source (°)
45
0
Carrington map
V Plot
Flux Plot
Spiral properties
Start : SUN
Start Time
Error (hours)
Speed (km/s)
Error (km/s)
Spread (°)
HAE Long. (°)
2008-09-24T12:00:00
+/-
0
500
+/-
0
+/-
22.5
332.7
COROTATION
Rot. angle (°)
Rotation Period (days)
End :
hrs
hrs
hrs
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor

Propagation Tool

Start time

2008-09-24T12:00:00

2008-09-24T12:00:00



Coordinate system : HEE

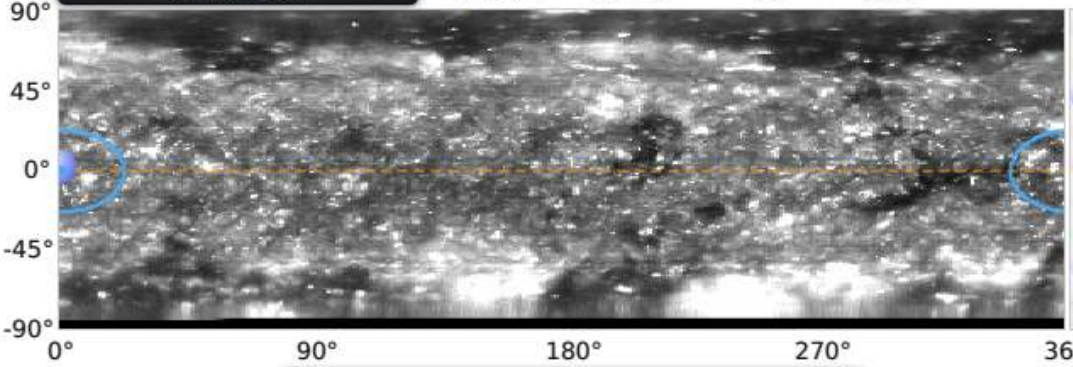
XZ View

Radial Propagation | J-map: Carrington/InSitu

Corotation | J-map: Catalogue of fits

SEP Propagation | J-map: Click to fit

START : SUN CR2074 SOHO EIT 195A



Longitude : 319.8° - Latitude : 79.6° - Value : 20.8

Extent (°) 45 Source (°) 0

Carrington map | V Plot | Flux Plot

Spiral properties

	Start Time	Error (hours)	Speed (km/s)	Error (km/s)	Spread (°)	HAE Long. (°)
Start : SUN	2008-09-24T12:00:00	+/- 0	500	+/- 0	+/- 22.5	332.7

COROTATION

Rotation Period (days)

Rot. angle (°) 34.7

End : EARTH	2008-09-30T09:05:09	0 / 0 hrs		0 / 0 hrs	-38.07 / 38.07 hrs	7.5

Corotation Interface | J-Map Interface | Table of Arrival Times

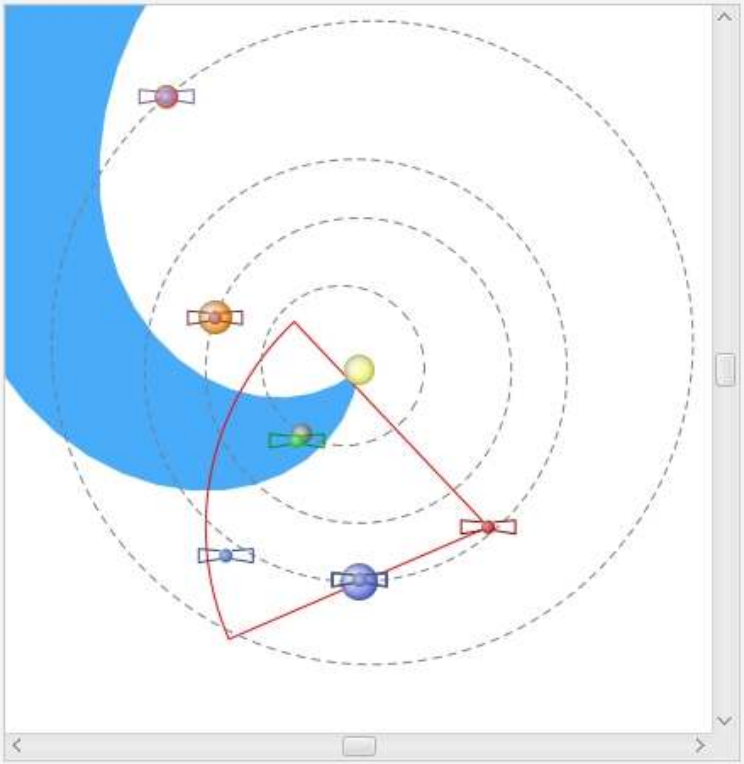
Arrival Times Catalogue | Helioviewer | CDPP Interface | APIS Interface | SAMP Client Monitor

Propagation Tool

Start time

2008-09-24T12:00:00

2008-09-24T12:00:00



Coordinate system : HEE

XZ View

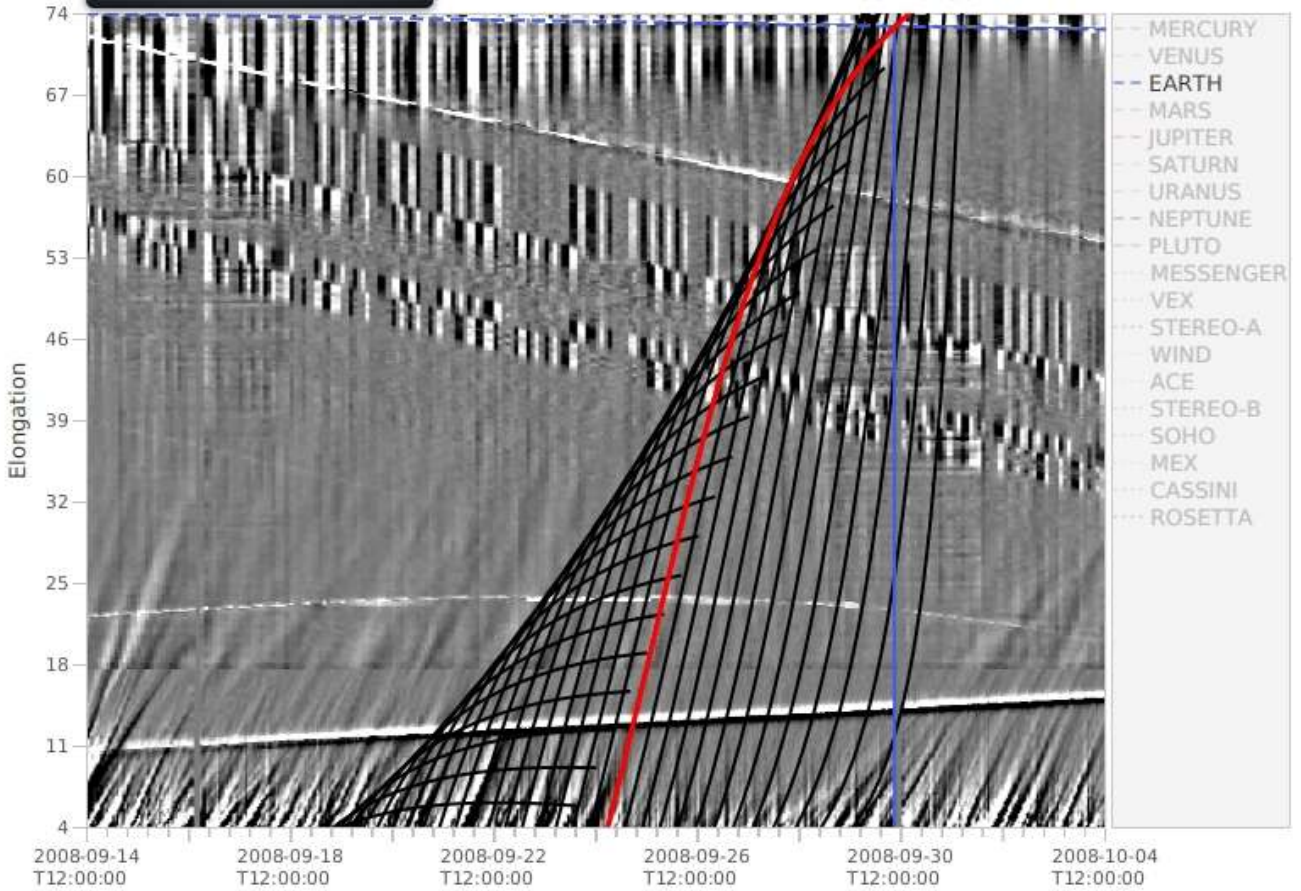
Radial Propagation | J-map: Carrington/InSitu

Corotation | J-map: Catalogue of fits

SEP Propagation | J-map: Click to fit

START : SUN

PA=90° SECCHI-A REAL



CIR Properties	Speed (km/s)	Rot. Period	Blobs (hrs)	Long. Separ.
	500	25.38	8	68.3

J-Map | Fit Parameters

Corotation Interface | J-Map Interface | Table of Arrival Times

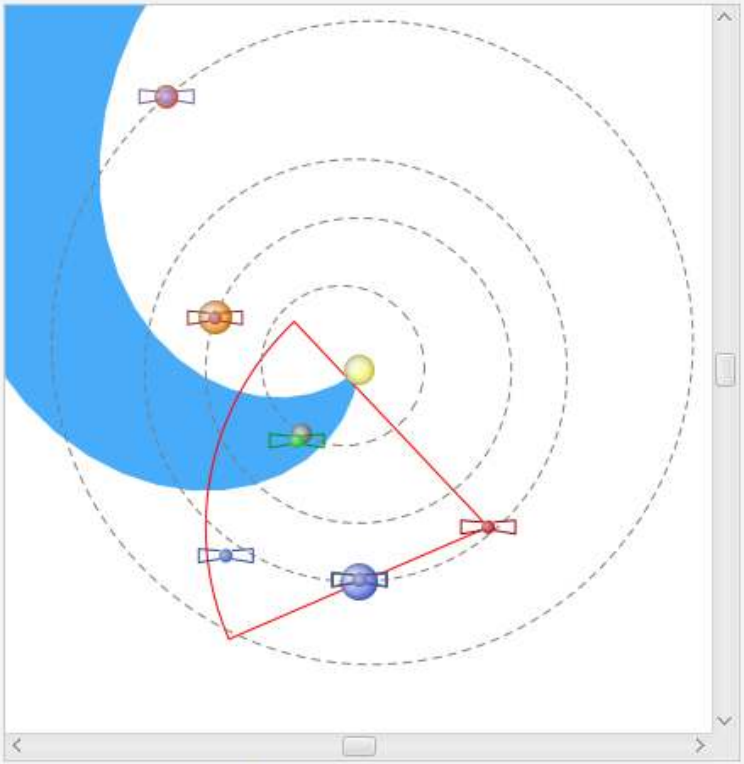
Arrival Times Catalogue | Helioviewer | CDPP Interface | APIS Interface | SAMP Client Monitor

Propagation Tool

Start time

2008-09-24T12:00:00

2008-09-24T12:00:00



Coordinate system : HEE

XZ View

Radial Propagation | J-map: Carrington/InSitu

Corotation | J-map: Catalogue of fits

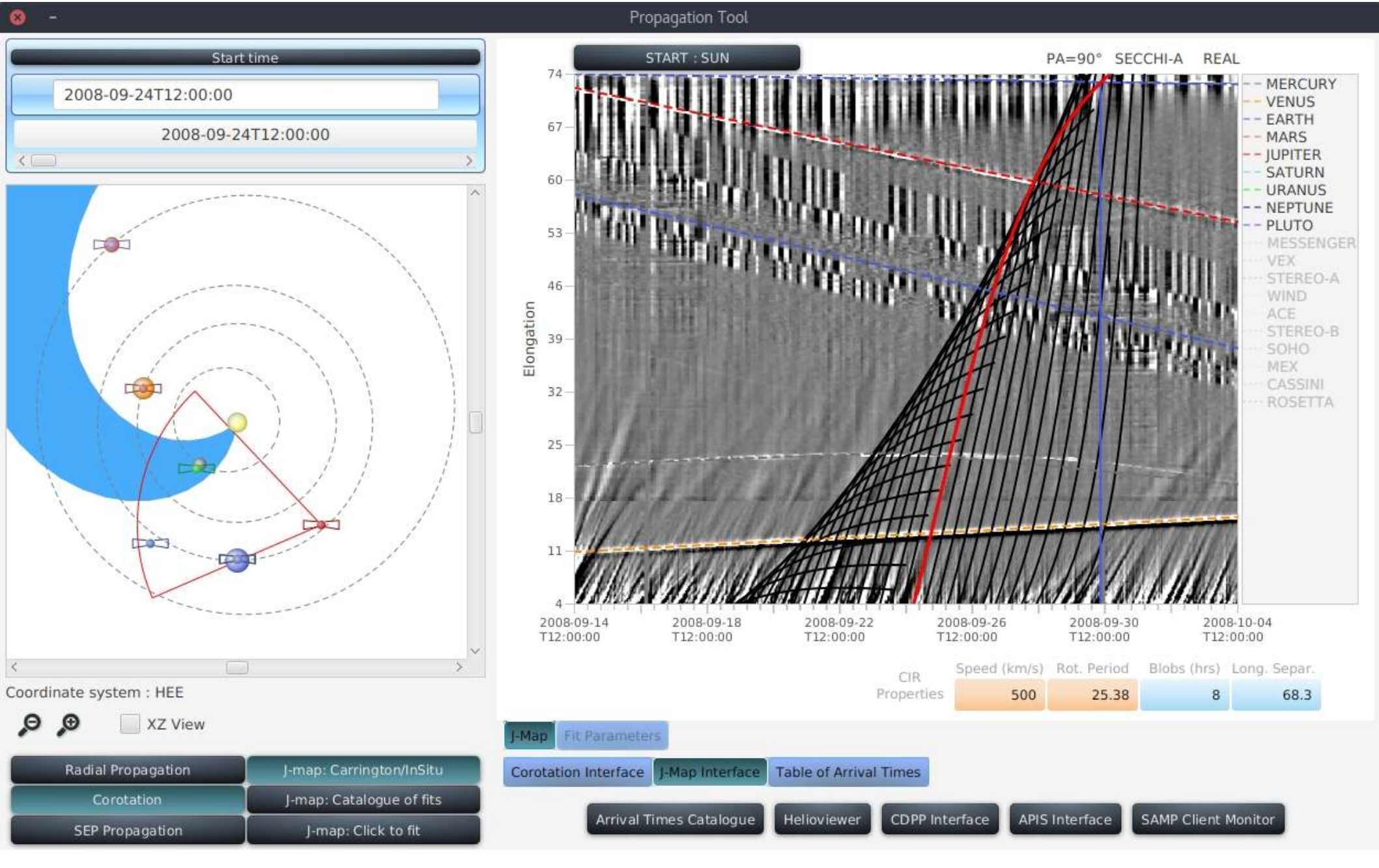
SEP Propagation | J-map: Click to fit

Target	t'	t'min(Δt)	t'max(Δt)	t'min(ΔV)	t'max(ΔV)	t'min(Δφ)	t'max(Δφ)	φEnd(t'...
		(hrs)	(hrs)	(hrs)	(hrs)	(hrs)	(hrs)	(°)
SUN	2008-09-24T12:00:00	0	0	0	0	-38.07	38.07	0
Probes								
MESSEN...	2008-09-25T07:54:00	0	0	0	0	-38.07	38.07	350.38
VEX	2008-10-19T03:38:48	0	0	0	0	-38.07	38.07	318.16
STEREO-A	2008-10-03T05:33:18	0	0	0	0	-38.07	38.07	77.44
WIND	2008-09-30T08:03:39	0	0	0	0	-38.07	38.07	34.53
ACE	2008-09-30T08:08:57	0	0	0	0	-38.07	38.07	34.68
STEREO-B	2008-09-27T22:56:18	0	0	0	0	-38.07	38.07	356.24
SOHO	2008-09-30T08:40:44	0	0	0	0	-38.07	38.07	34.96
MEX	2008-10-17T23:10:42	0	0	0	0	-38.07	38.07	255.74
CASSINI	2008-10-14T20:53:48	0	0	0	0	-38.07	38.07	190.48
ROSETTA	2008-09-26T13:45:31	0	0	0	0	-38.07	38.07	282.63
Planets								
MERCURY	2008-09-25T03:50:59	0	0	0	0	-38.07	38.07	349.99
VENUS	2008-10-19T03:38:18	0	0	0	0	-38.07	38.07	318.16
EARTH	2008-09-30T09:05:09	0	0	0	0	-38.07	38.07	34.72
MARS	2008-10-17T23:10:32	0	0	0	0	-38.07	38.07	255.74
JUPITER	2008-10-09T15:57:17	0	0	0	0	-38.07	38.07	322.4
SATURN	2008-10-14T20:57:26	0	0	0	0	-38.07	38.07	190.49
URANUS	2008-10-14T14:26:50	0	0	0	0	-38.07	38.07	18.14
NEPTUNE	2008-09-26T06:56:13	0	0	0	0	-38.07	38.07	350.24
PLUTO	2008-09-27T17:39:58	0	0	0	0	-38.07	38.07	297.55
Comets								

Given defined width, targets in red are impacted by Spiral

Corotation Interface | J-Map Interface | Table of Arrival Times

Arrival Times Catalogue | Helioviewer | CDPP Interface | APIS Interface | SAMP Client Monitor

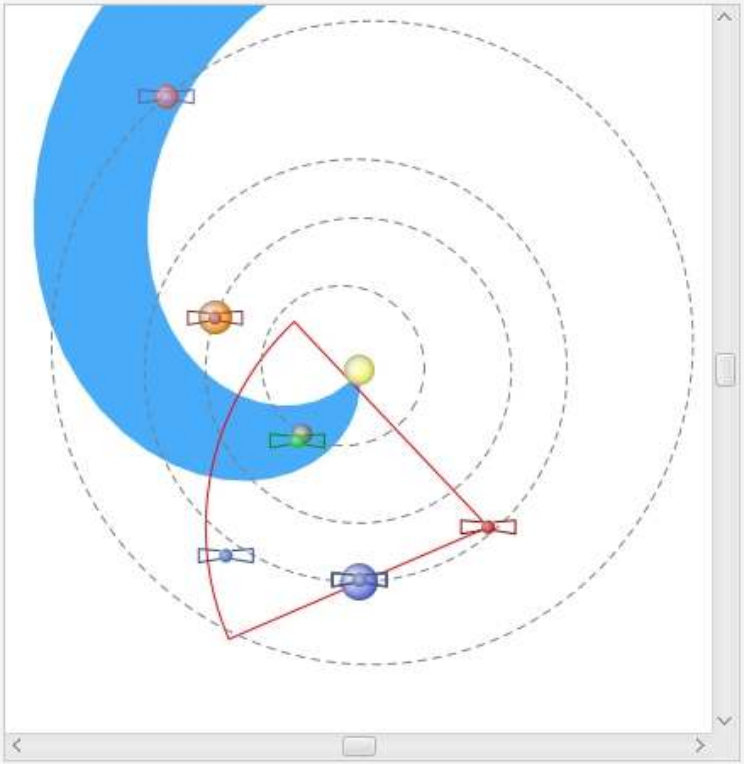

Propagation Tool
Start time
2008-09-24T12:00:00
2008-09-24T12:00:00
START : SUN
PA=90° SECCHI-A REAL
Elongation
74
67
60
53
46
39
32
25
18
11
4
2008-09-14 T12:00:00
2008-09-18 T12:00:00
2008-09-22 T12:00:00
2008-09-26 T12:00:00
2008-09-30 T12:00:00
2008-10-04 T12:00:00
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
MESSENGER
VEX
STEREO-A
WIND
ACE
STEREO-B
SOHO
MEX
CASSINI
ROSETTA
CIR Properties
Speed (km/s)
Rot. Period
Blobs (hrs)
Long. Separ.
500
25.38
8
68.3
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
J-Map
Fit Parameters
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor

Propagation Tool

Start time

2008-09-24T13:14:27

2008-09-24T13:14:27



Coordinate system : HEE

XZ View

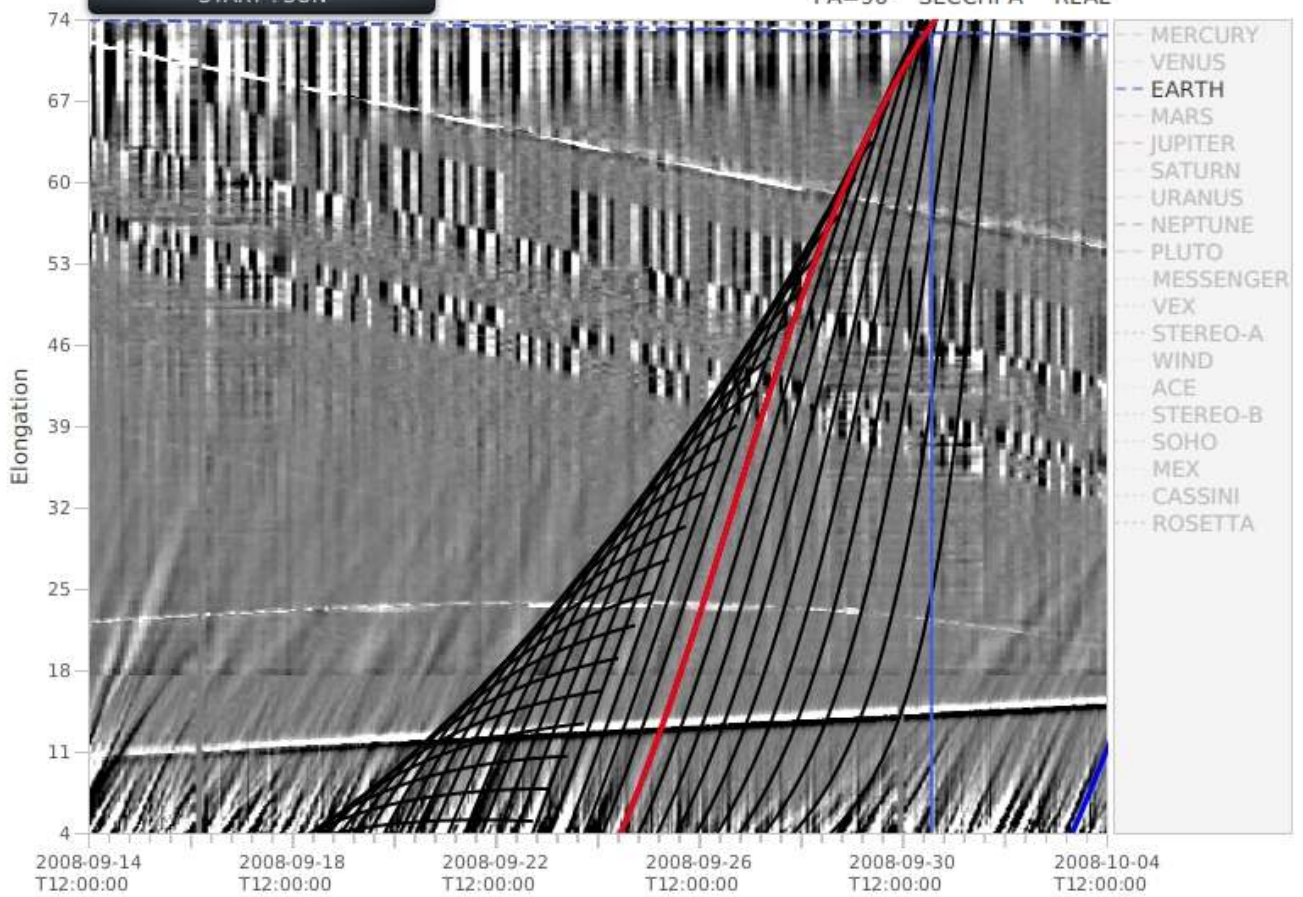
Radial Propagation | J-map: Carrington/InSitu

Corotation | J-map: Catalogue of fits

SEP Propagation | J-map: Click to fit

START : SUN

PA=90° SECCHI-A REAL

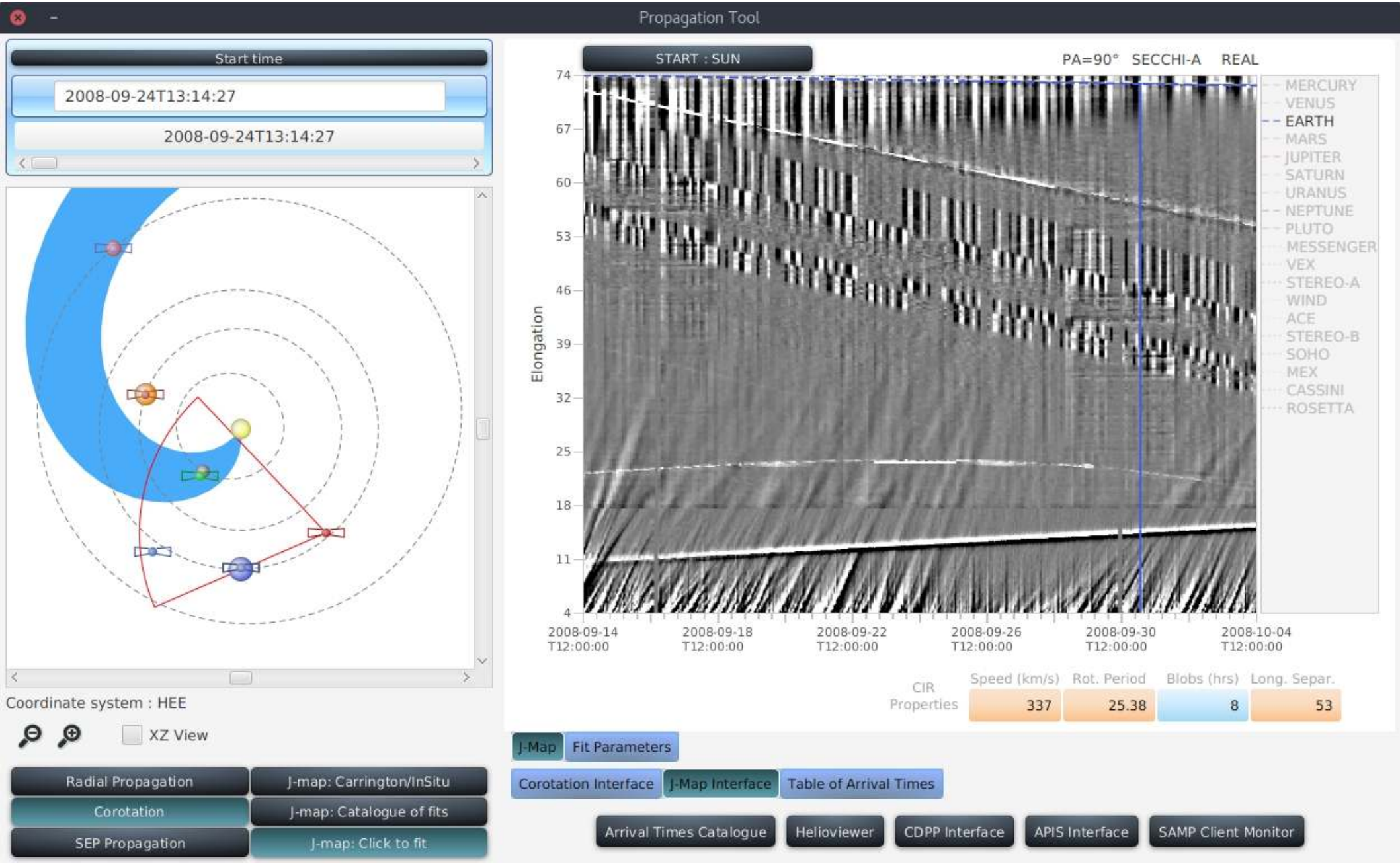


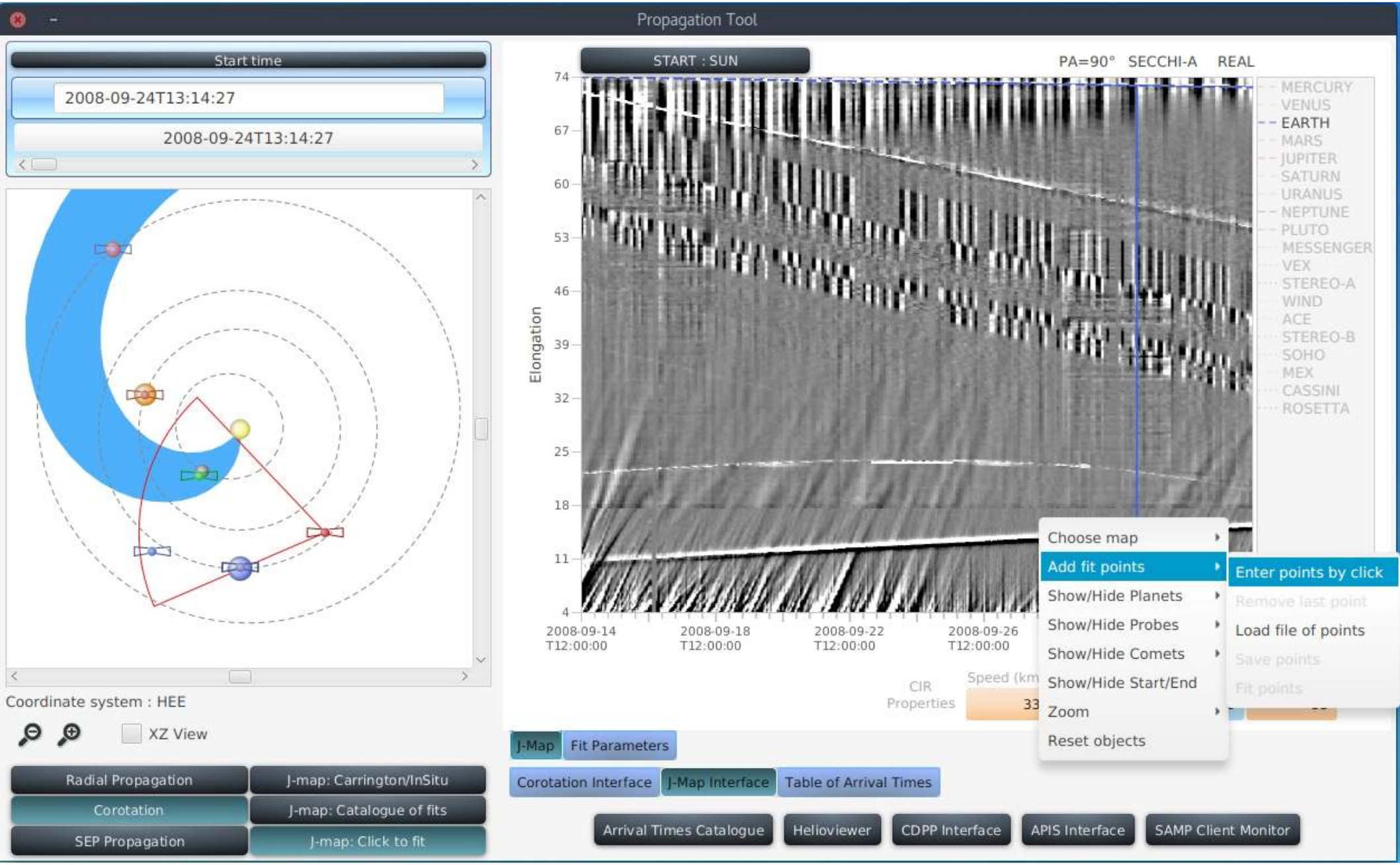
CIR Properties	Speed (km/s)	Rot. Period	Blobs (hrs)	Long. Separ.
	337	25.38	8	53

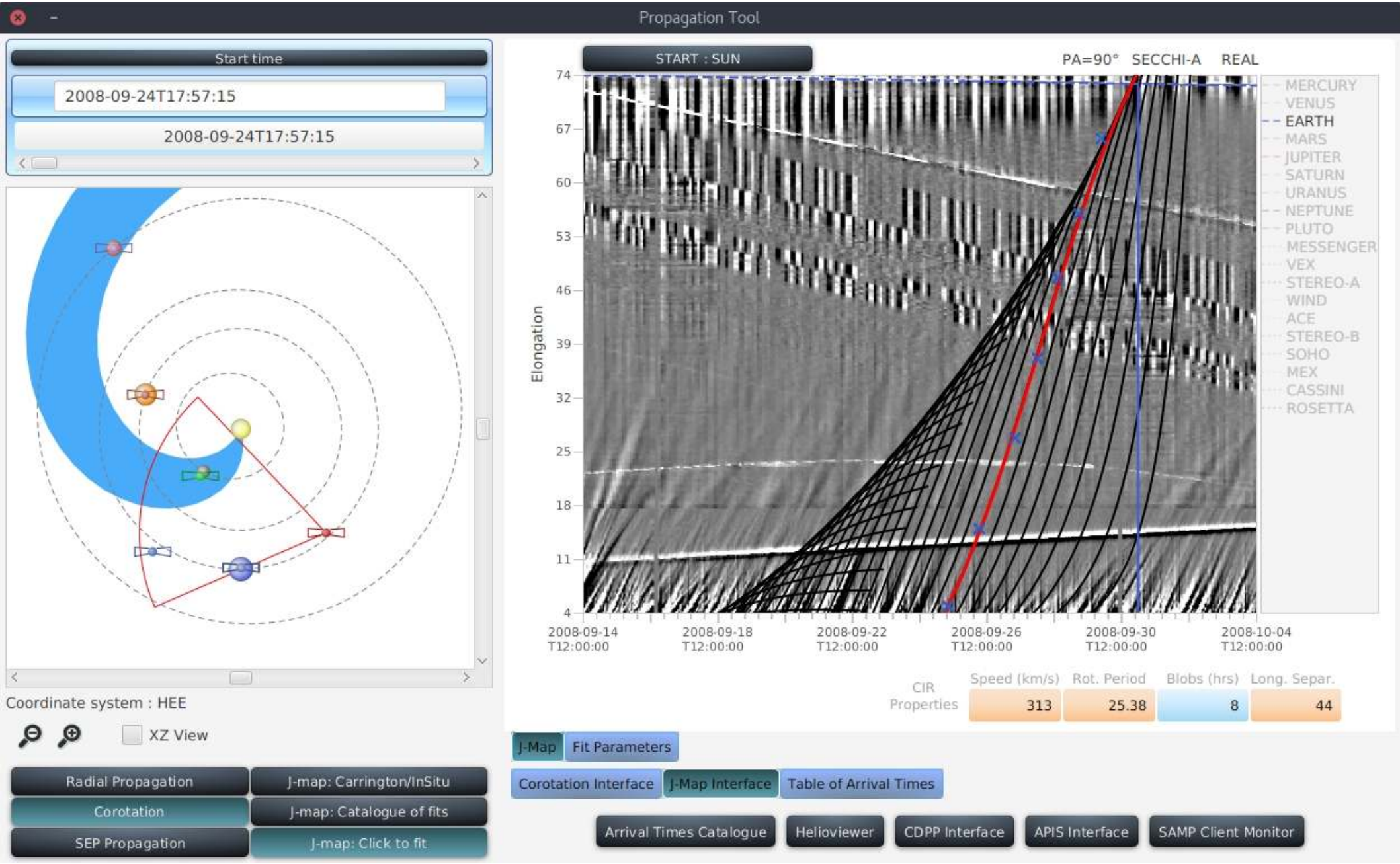
J-Map | Fit Parameters

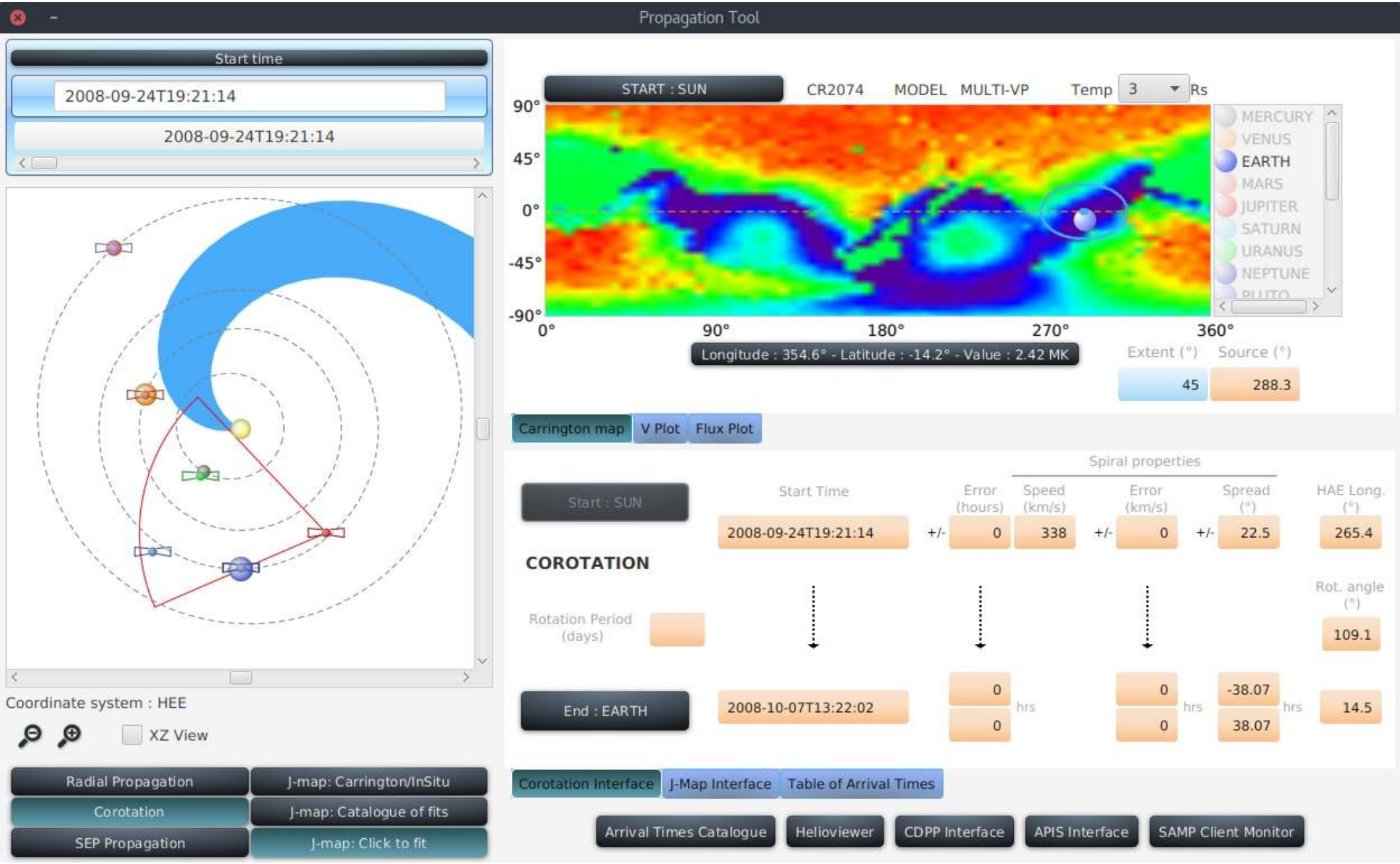
Corotation Interface | J-Map Interface | Table of Arrival Times

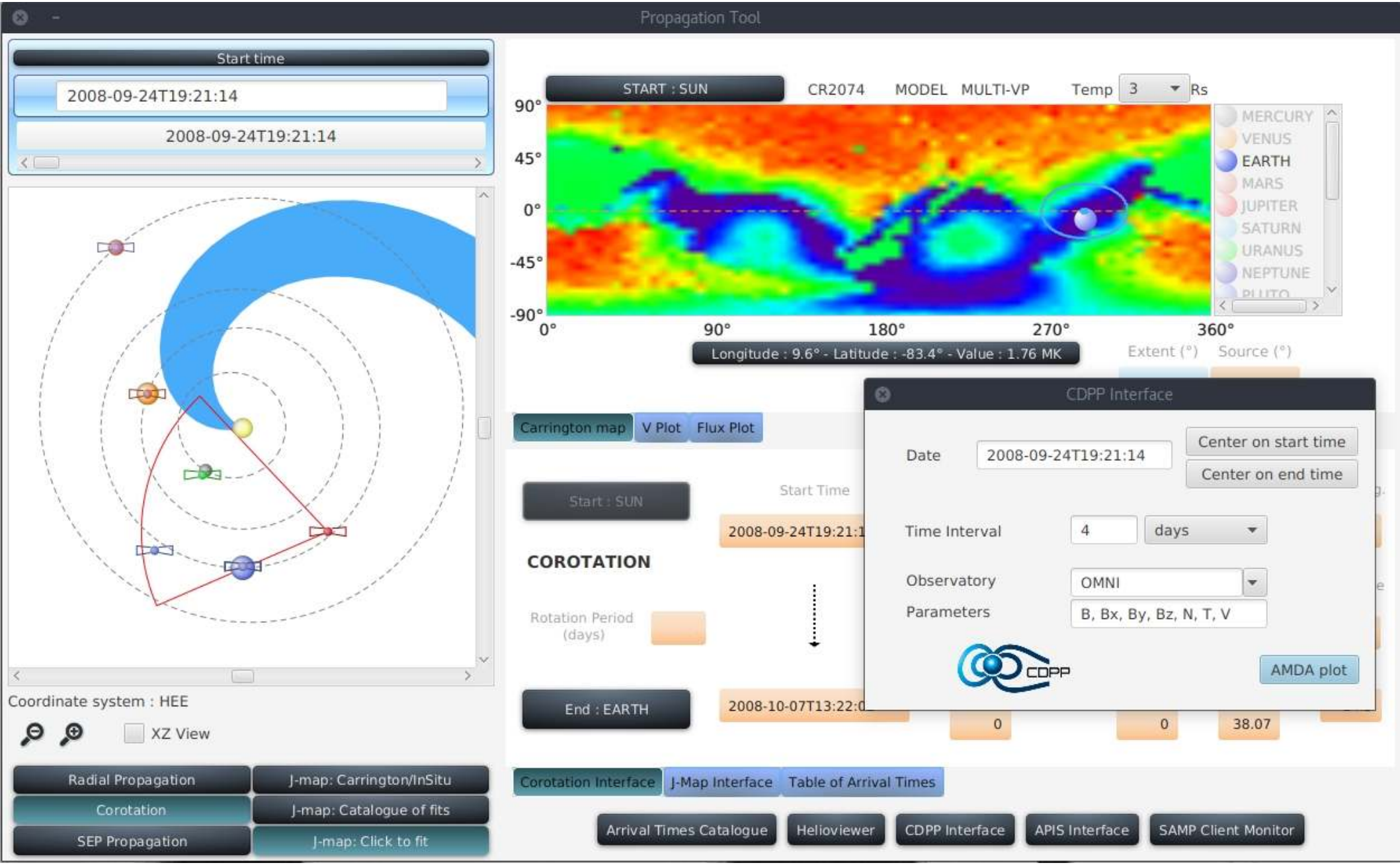
Arrival Times Catalogue | Helioviewer | CDPP Interface | APIS Interface | SAMP Client Monitor

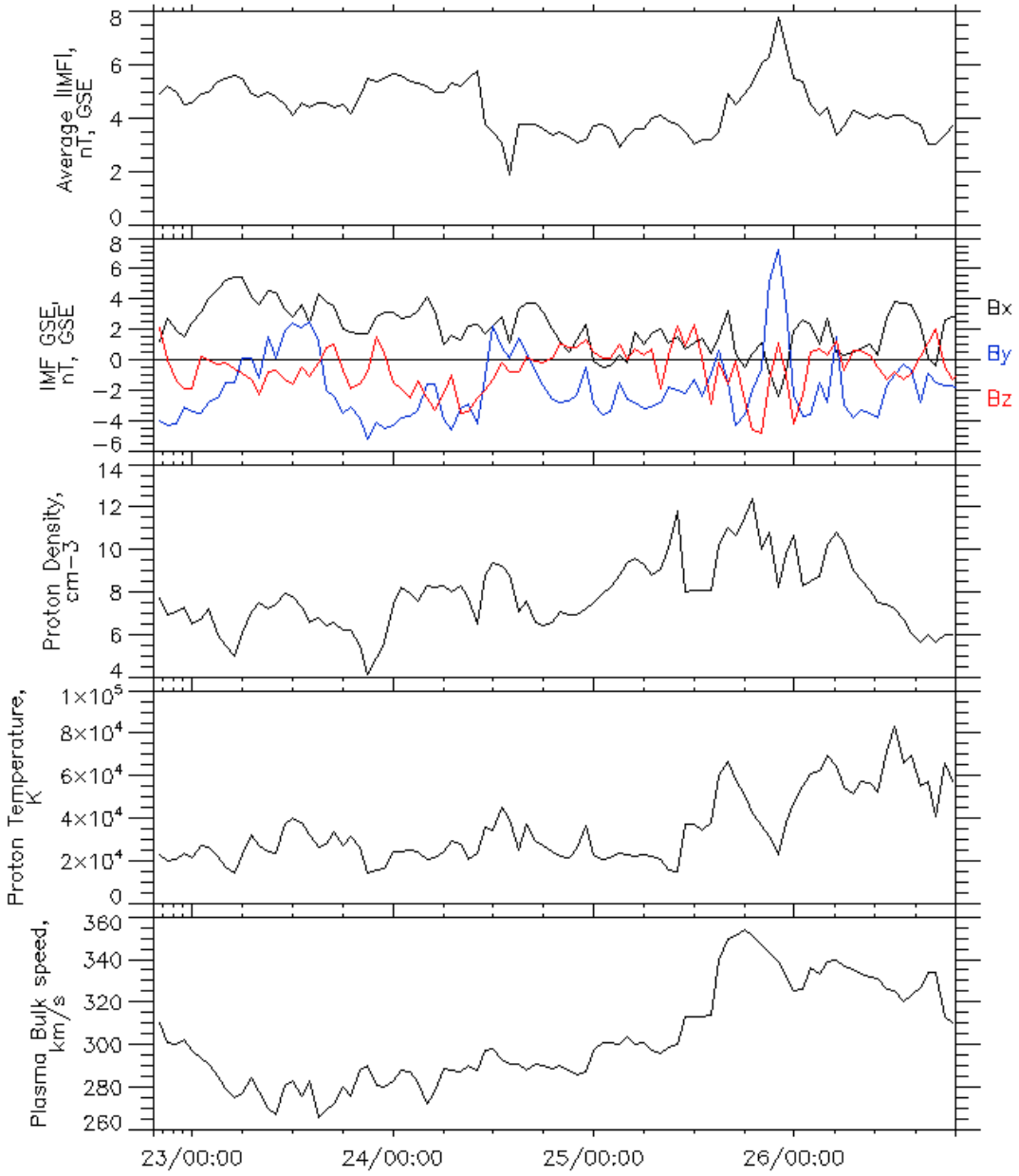

Propagation Tool
Start time
2008-09-24T13:14:27
2008-09-24T13:14:27
START : SUN
PA=90° SECCHI-A REAL
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
MESSENGER
VEX
STEREO-A
WIND
ACE
STEREO-B
SOHO
MEX
CASSINI
ROSETTA
Elongation
74
67
60
53
46
39
32
25
18
11
4
2008-09-14 T12:00:00
2008-09-18 T12:00:00
2008-09-22 T12:00:00
2008-09-26 T12:00:00
2008-09-30 T12:00:00
2008-10-04 T12:00:00
CIR Properties
Speed (km/s)
Rot. Period
Blobs (hrs)
Long. Separ.
337
25.38
8
53
Coordinate system : HEE
XZ View
J-Map
Fit Parameters
Corotation Interface
J-Map Interface
Table of Arrival Times
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T13:14:27
2008-09-24T13:14:27
START : SUN
PA=90° SECCHI-A REAL
Elongation
74
67
60
53
46
39
32
25
18
11
4
2008-09-14 T12:00:00
2008-09-18 T12:00:00
2008-09-22 T12:00:00
2008-09-26 T12:00:00
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
MESSENGER
VEX
STEREO-A
WIND
ACE
STEREO-B
SOHO
MEX
CASSINI
ROSETTA
Choose map
Add fit points
Show/Hide Planets
Show/Hide Probes
Show/Hide Comets
Show/Hide Start/End
Zoom
Reset objects
Enter points by click
Remove last point
Load file of points
Save points
Fit points
CIR Properties
Speed (km
Coordinate system : HEE
XZ View
J-Map
Fit Parameters
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T17:57:15
2008-09-24T17:57:15
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
START : SUN
PA=90° SECCHI-A REAL
Elongation
74
67
60
53
46
39
32
25
18
11
4
2008-09-14 T12:00:00
2008-09-18 T12:00:00
2008-09-22 T12:00:00
2008-09-26 T12:00:00
2008-09-30 T12:00:00
2008-10-04 T12:00:00
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
MESSENGER
VEX
STEREO-A
WIND
ACE
STEREO-B
SOHO
MEX
CASSINI
ROSETTA
CIR Properties
Speed (km/s)
Rot. Period
Blobs (hrs)
Long. Separ.
313
25.38
8
44
J-Map
Fit Parameters
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T19:21:14
2008-09-24T19:21:14
START : SUN
CR2074
MODEL
MULTI-VP
Temp
3
Rs
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Longitude : 354.6° - Latitude : -14.2° - Value : 2.42 MK
Extent (°)
Source (°)
45
288.3
Carrington map
V Plot
Flux Plot
Spiral properties
Start : SUN
Start Time
Error (hours)
Speed (km/s)
Error (km/s)
Spread (°)
HAE Long. (°)
2008-09-24T19:21:14
+/-
0
338
+/-
0
+/-
22.5
265.4
COROTATION
Rot. angle (°)
Rotation Period (days)
109.1
End : EARTH
2008-10-07T13:22:02
0
0
hrs
0
0
hrs
-38.07
38.07
hrs
14.5
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor


Propagation Tool
Start time
2008-09-24T19:21:14
2008-09-24T19:21:14
START : SUN
CR2074
MODEL
MULTI-VP
Temp
3
Rs
90°
45°
0°
-45°
-90°
0°
90°
180°
270°
360°
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
Longitude : 9.6° - Latitude : -83.4° - Value : 1.76 MK
Extent (°)
Source (°)
CDPP Interface
Carrington map
V Plot
Flux Plot
Date
2008-09-24T19:21:14
Center on start time
Center on end time
Start : SUN
Start Time
2008-09-24T19:21:1
Time Interval
4
days
COROTATION
Observatory
OMNI
Parameters
B, Bx, By, Bz, N, T, V
Rotation Period (days)
CDPP
AMDA plot
End : EARTH
2008-10-07T13:22:0
0
0
38.07
Coordinate system : HEE
XZ View
Radial Propagation
J-map: Carrington/InSitu
Corotation
J-map: Catalogue of fits
SEP Propagation
J-map: Click to fit
Corotation Interface
J-Map Interface
Table of Arrival Times
Arrival Times Catalogue
Helioviewer
CDPP Interface
APIS Interface
SAMP Client Monitor



Sep 2008

Created by AMDA(C) V2.0 Wed Sep 26 00:16:59 2018