WP6: Initialising advanced numerical models based on the kinetic properties of STEREO/HI CMEs and CIRs

- J-maps (HI vs. synthetic)
- Catalogues of solar wind simulations

HELCATS

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WP6 primary goals

Catalogues of CMEs and CIRs observed by HI (from WP2/3 and WP5)

Build advanced catalogues of simulations of CIRs and CMEs

Provide the community with a set of simulations results calibrated by assimilating direct images of the solar wind (wind acceleration + ENLIL)

Outcomes

Enhance forefront research on “background” solar wind (fast and slow solar wind) and on the spatial and temporal **evolution of CIRs and CME shocks**.

Provide unique **material to study and interpret particle radiation** measurements in the inner heliosphere.

Assess the potential role of HI images for space-weather predictions and to prepare future missions (e.g. ESA’s Solar Orbiter).

T6.1- Assimilating HI images

[UPS, del. month 24]

D6.1:

J-maps derived from HI and movies ↔ Synthetic J-maps and movies (ENLIL)

Two classes of events:

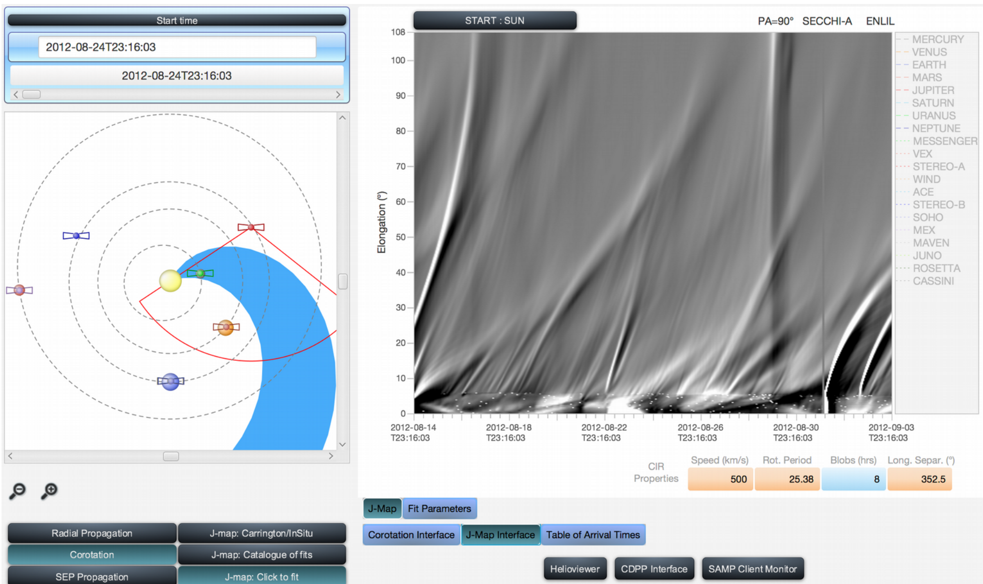
Class 1 – good correspondence immediately obtained.
Class 2 – significant differences.

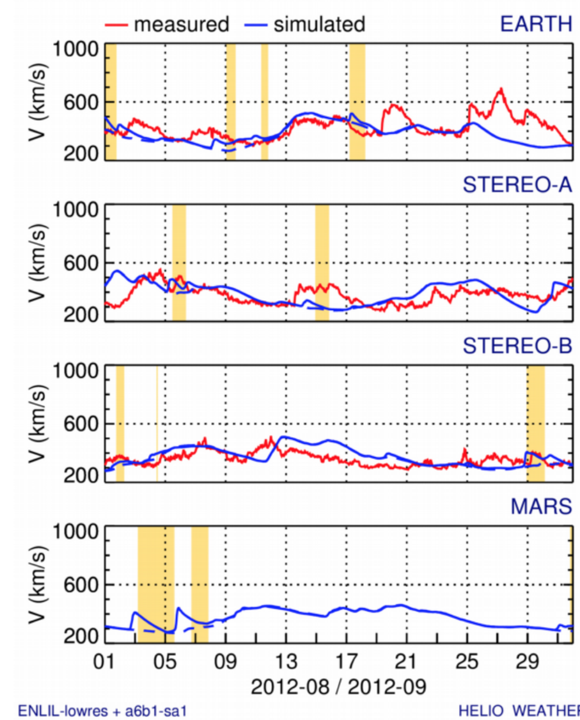
Compare how well ENLIL predicts the in-situ measurements of CIRs for these two classes of events separately **(DONE)**.

Modify the coronal input of ENLIL of class 2 events until synthetic and observed J-maps are in good agreement **(WORK-IN-PROGRESS)**.

T6.1- Assimilating HI images

[UPS, del. month 24]





May 2015: Production of ENLIL J-maps (Dusan) using WSA-cone model (DONKI)

Oct 2015: Integration of ENLIL WSA-cone model Jmaps in Propagation Tool (Alexis)

May 2016: Delivery of first analysis comparing real Jmaps with ENLIL (D6.1, Alexis, Illya, Eduardo)

August 2016: Planned delivery of modification of coronal input (Rui)

T6.1- Assimilating HI images

[UPS, del. month 24]

Comparison of synthetic and real J-maps:

- We carried the analysis on 2012 and 2013 data,
- The ENLIL simulations do not include yet HELCATS catalogues (left for year 3)
- Instead CMEs are defined from the DONKI catalogue
- The solar wind is specified by Wang-Sheeley Arge
- We compare simulations with the in-situ measurements at L1 (space weather driven study)

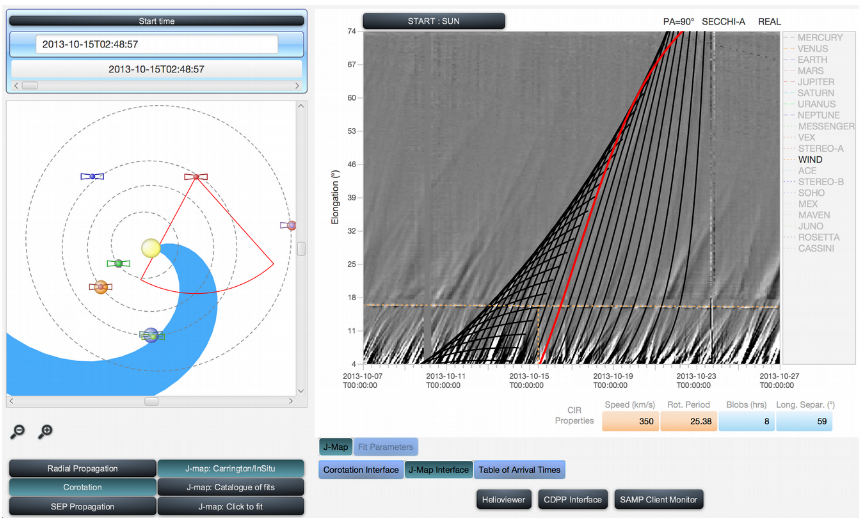
Results of the analysis shows that:

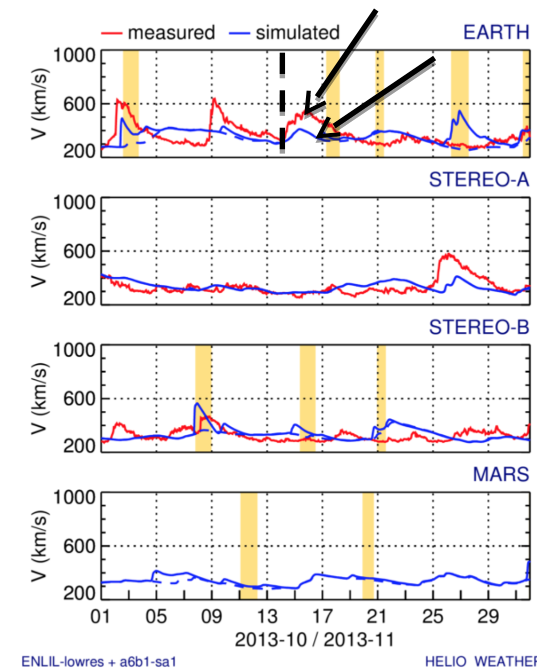
Remember HI detection of CIR is biased to the slow solar wind part (blobs), ENLIL is not!

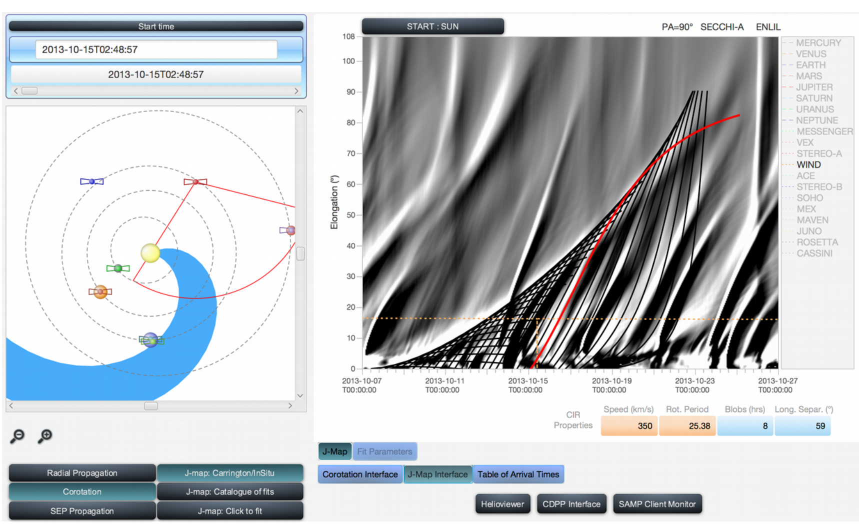
(1) When CIR patterns in ENLIL and STEREO J-maps agree then the arrival of the simulated CIR and the in-situ CIR measurements agree.

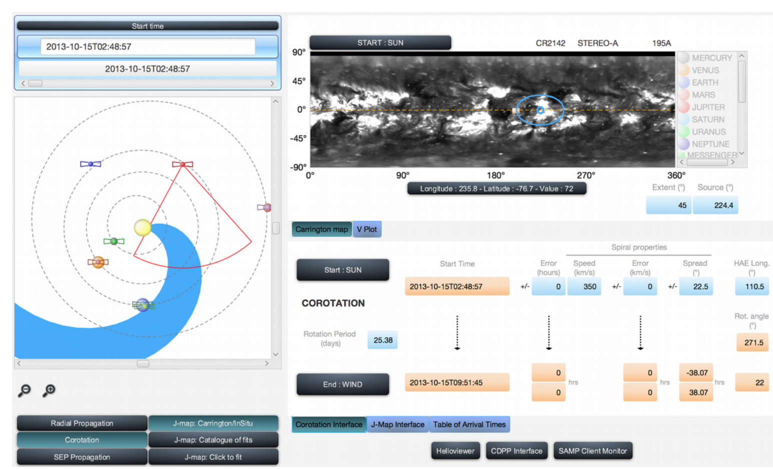
(2) The slope of the CIR pattern gives the speed of the slow solar wind ahead of the CIR (Illya's result), hence the STEREO and ENLIL J-maps may agree on the pattern location but differences occur due to this observational constraint on HI.

(3) The maximum speed of the fast solar wind that follows may be very different for in situ measurements and ENLIL simulations and yet that is not detected as differences between observed and simulations J-maps: hence HI can help for the slow but not the fast solar wind

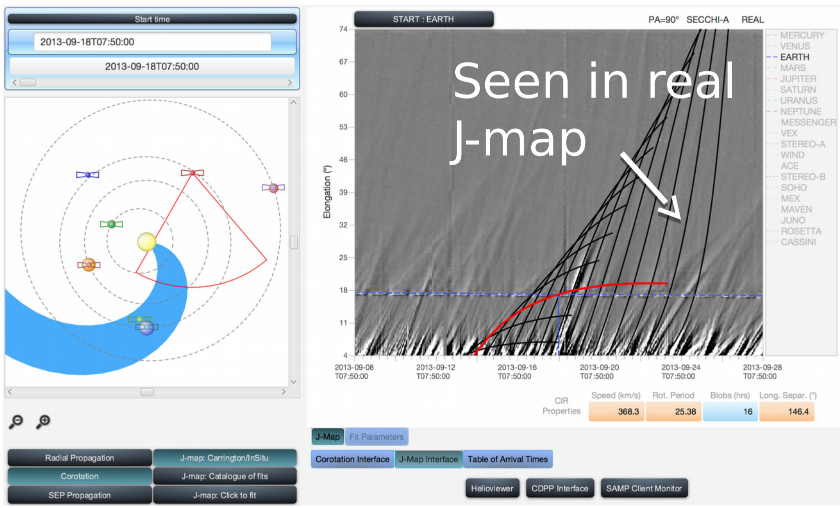


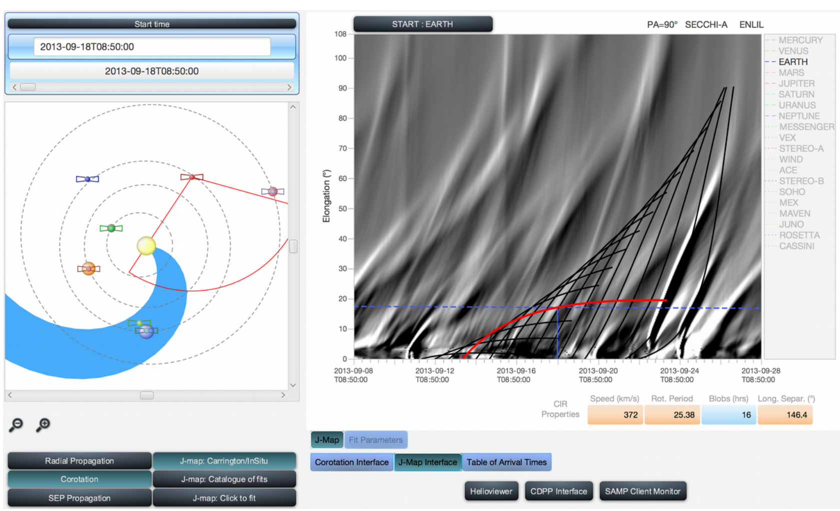


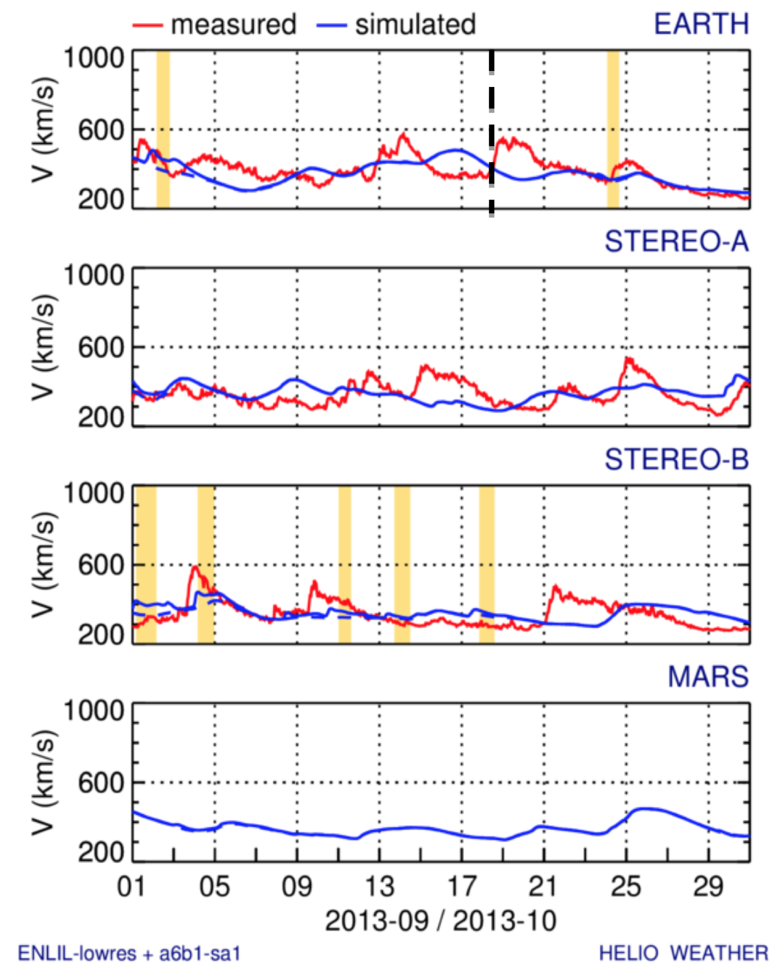




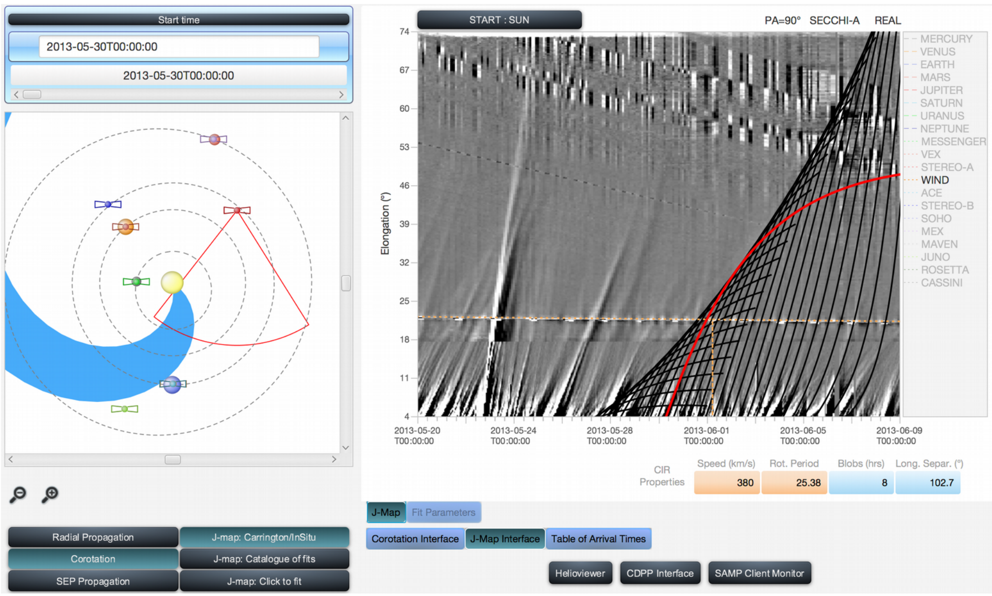
(4) Interestingly there are cases (we found about 5 for the period analysed) where ENLIL misplaces a CIR completely both in the J-map and in situ, but HI detects the CIR clearly in the J-map:

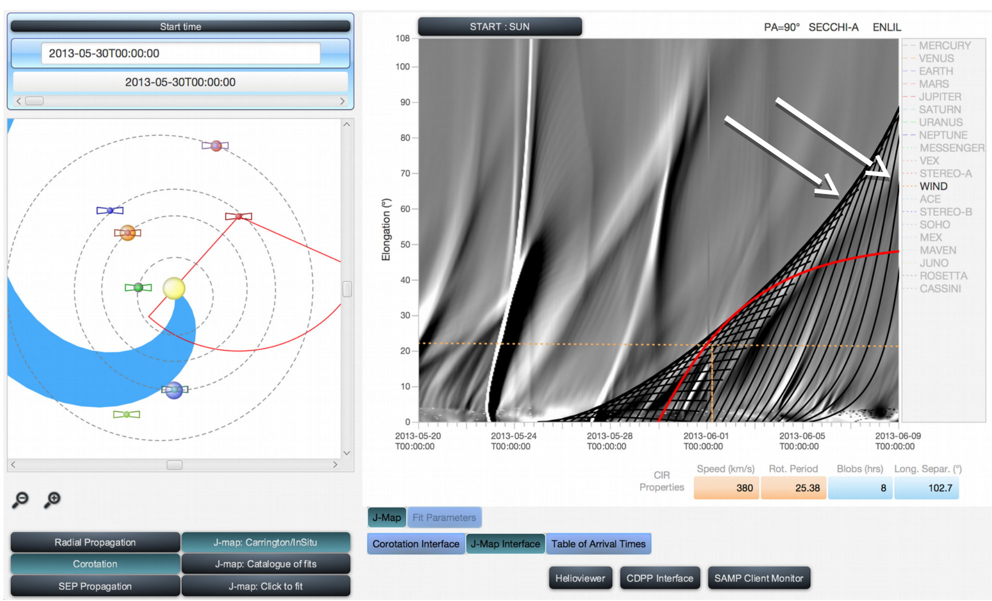


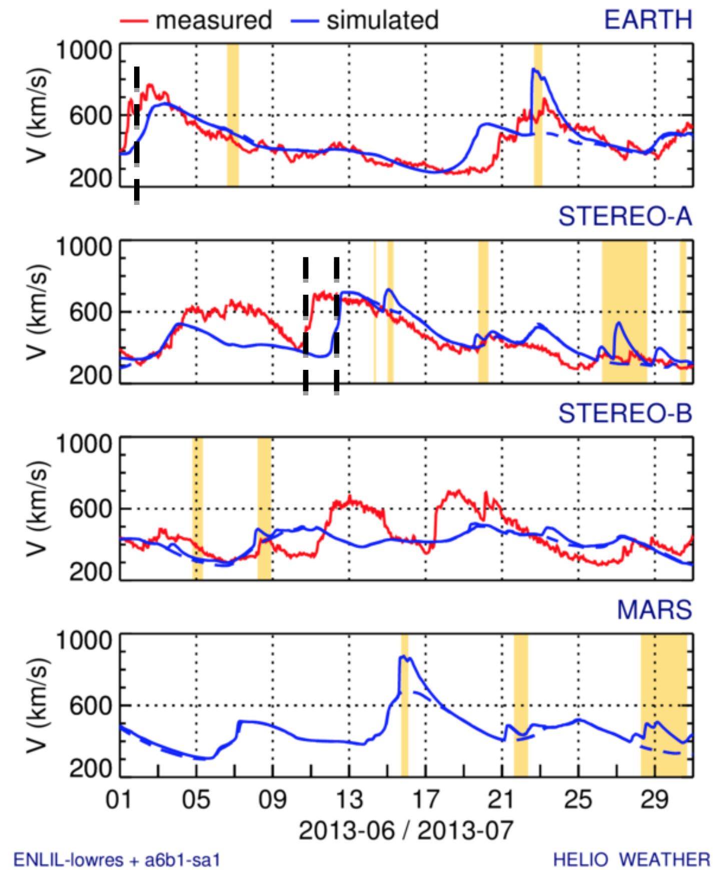


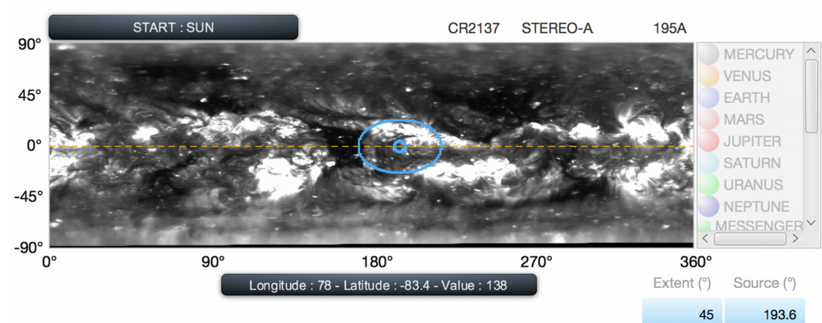


(5) The HI J-map can also detect if the corotation is too slow in ENLIL, this is the CIR associated with Eduardo's blob analysis, the CIR in ENLIL corotates too slowly (likely because coronal hole expands).







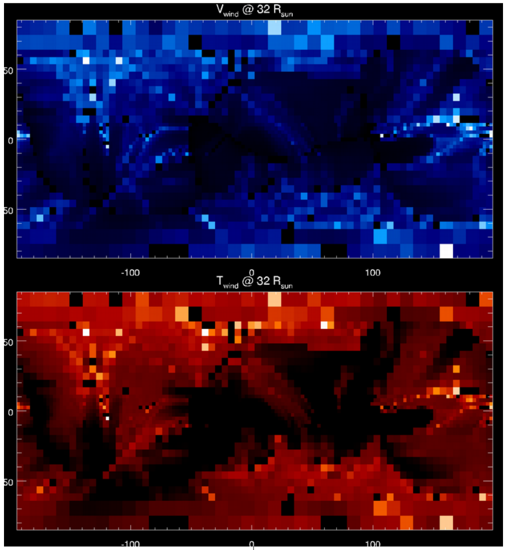


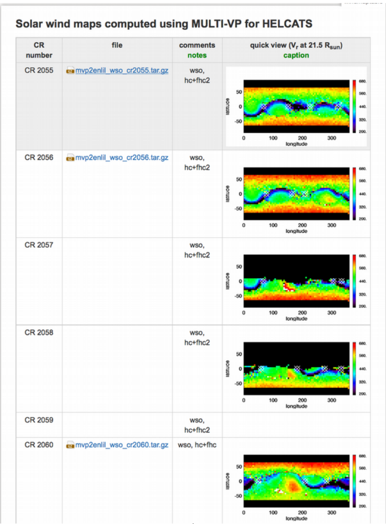
T6.2- H Imaging, background wind

[UPS, del. months 7-36]

D6.2:

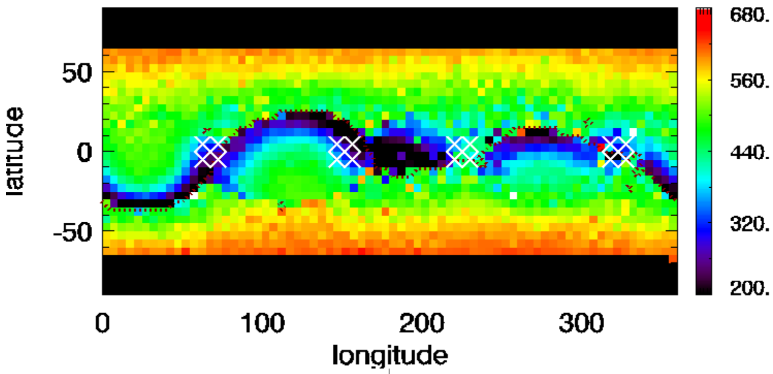
Catalogue of the most accurate simulations of the background solar wind
Uses: initialise other simulations, direct scientific exploitation **(nearly done)**





Solar wind maps computed using MULTI-VP for HELCATS

CR number	file	comments notes	quick view (V_r at 21.5 R_{sun}) caption
CR 2055	mvp2enlil_wso_cr2055.tar.gz	wso, hc+fhc2	
CR 2056	mvp2enlil_wso_cr2056.tar.gz	wso, hc+fhc2	
CR 2057		wso, hc+fhc2	
CR 2058		wso, hc+fhc2	
CR 2059		wso, hc+fhc2	
CR 2060	mvp2enlil_wso_cr2060.tar.gz	wso, hc+fhc	



May 2015: New approach to model solar wind input with PFSS (R Pinto)

March 2016: Delivery of the first catalogue of simulations (with correct densities!).

May 2016: Delivery of the first comparisons ENLIL ↔ HELCATS CIR (Dusan, Alexis).

August 2016: Planned delivery of comparison with J-maps

Data-driven solar wind model

Sun / surface observations
(magnetograms)

↓

Coronal B-field reconstruction

↓

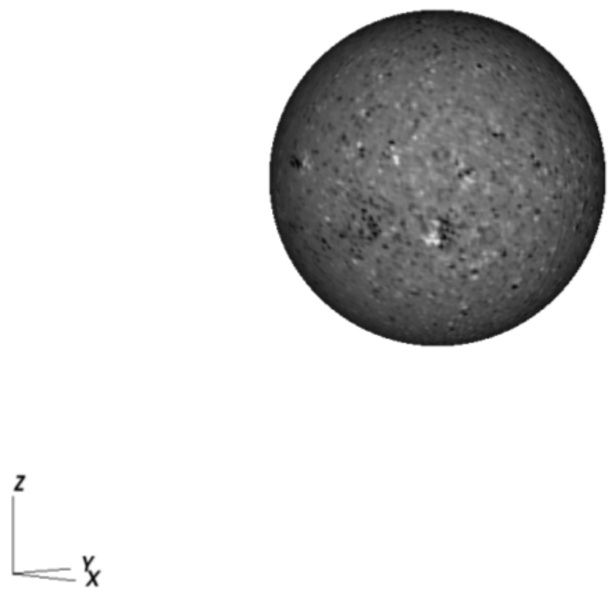
MULTI-VP

↓

Heliospheric propagation models
(ENLIL)

↓

Earth / interplanetary medium
In-situ data, heliospheric imaging



Surface magnetic field B_r (±30 G)
PFSS field lines positive/negative polarity

Data-driven solar wind model

Sun / surface observations
(magnetograms)
↓

Coronal B-field reconstruction
(PFSS HMI, WSO, ADAPT)

↓
MULTI-VP
↓

Heliospheric propagation models
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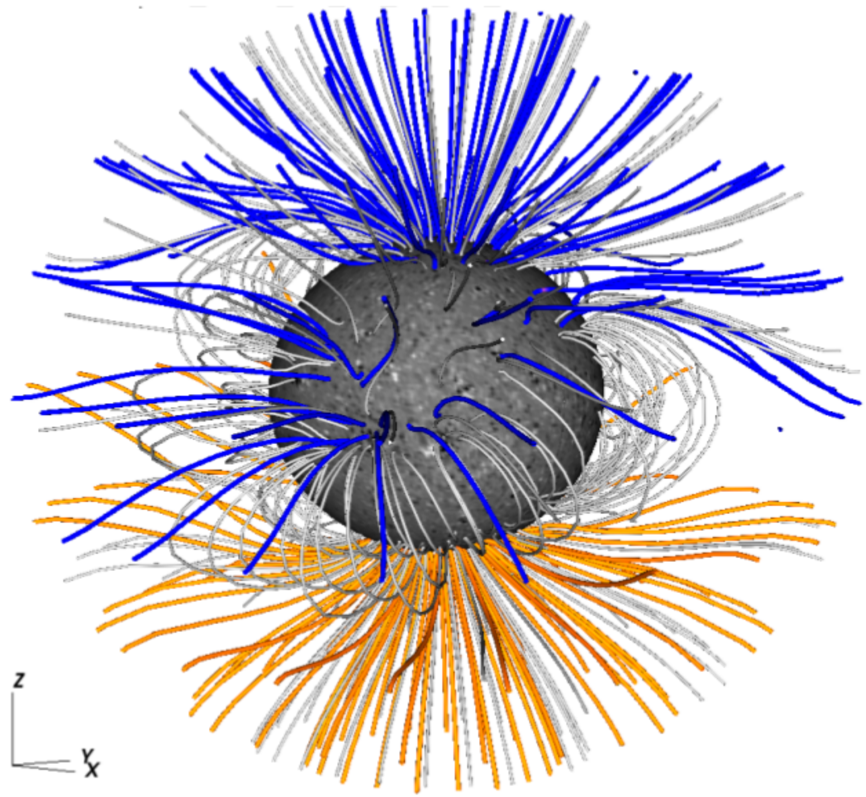

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MULTI-VP

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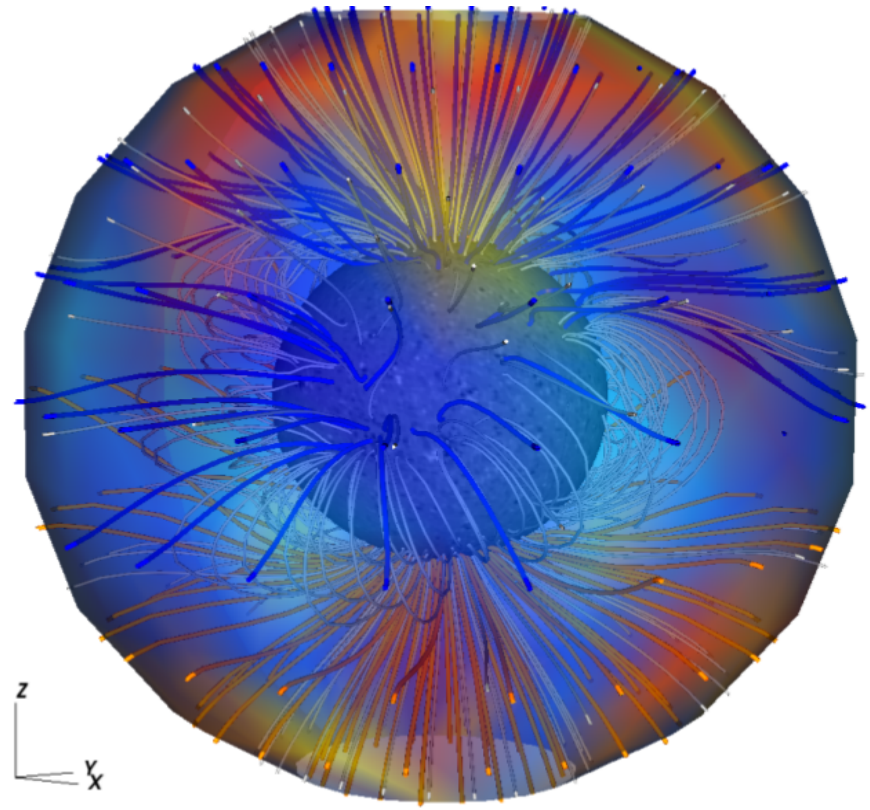


Wind speed: red = 650 km/s; blue = 350 km/s

Data-driven solar wind model

Sun / surface observations
(magnetograms)

↓

Coronal B-field reconstruction
(PFSS HMI, WSO, ADAPT)

↓

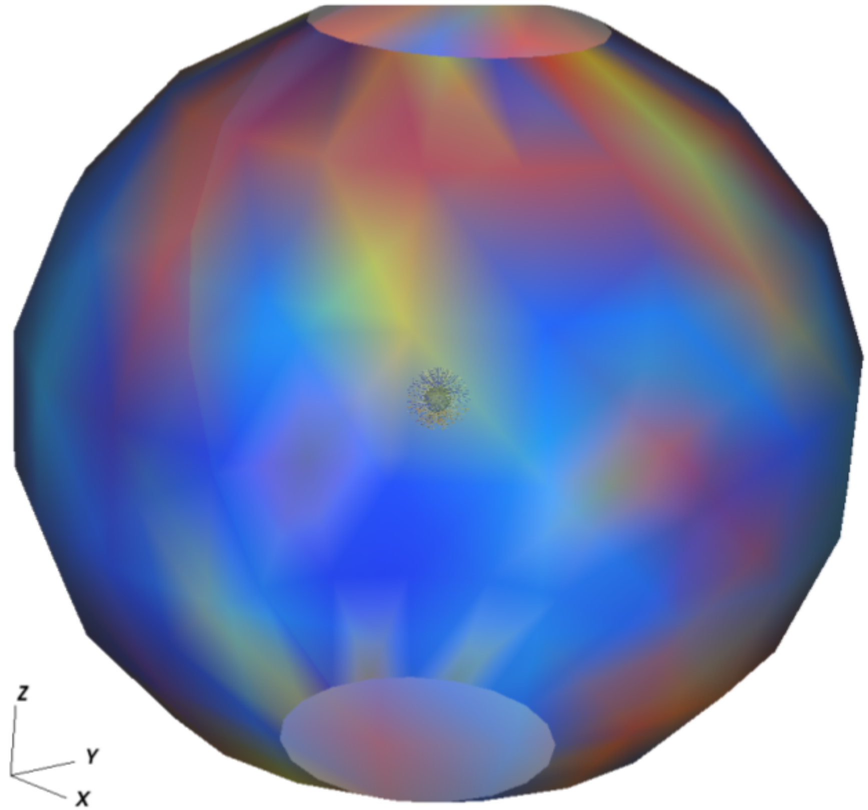
MULTI-VP

↓

Heliospheric propagation models
(ENLIL)

↓

Earth / interplanetary medium
In-situ data, heliospheric imaging



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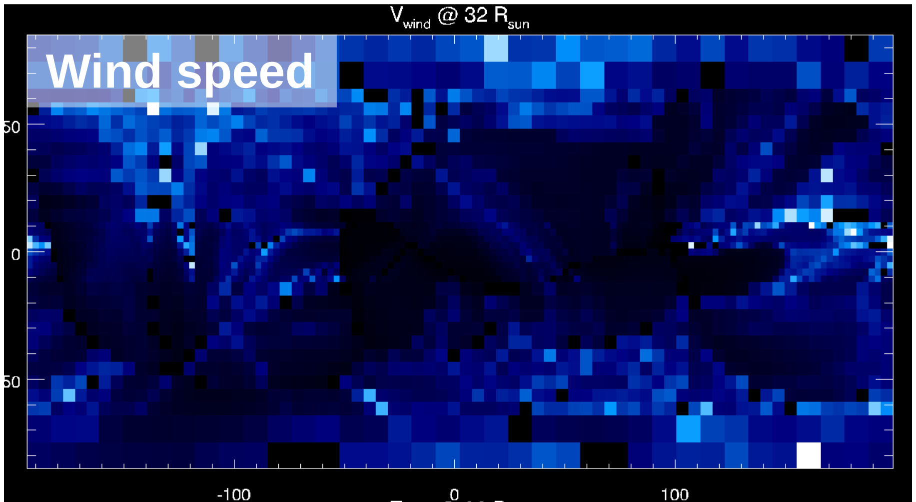
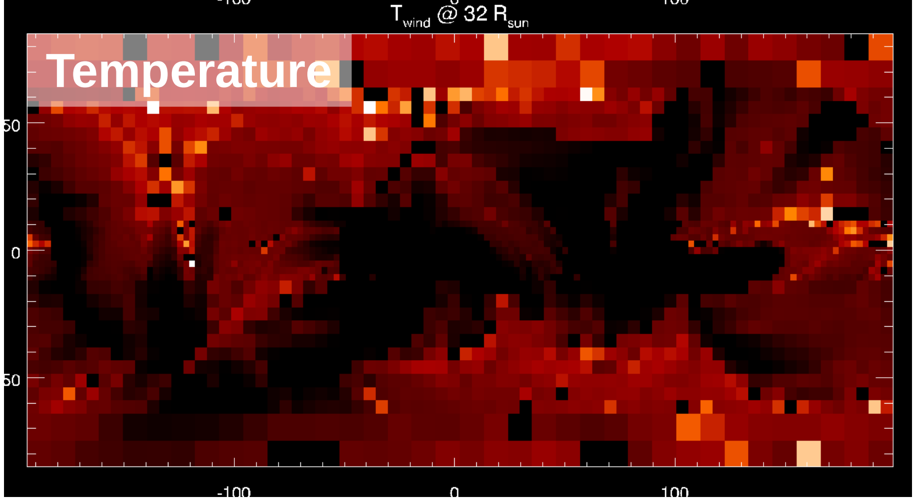
T6.2- H Imaging, background wind

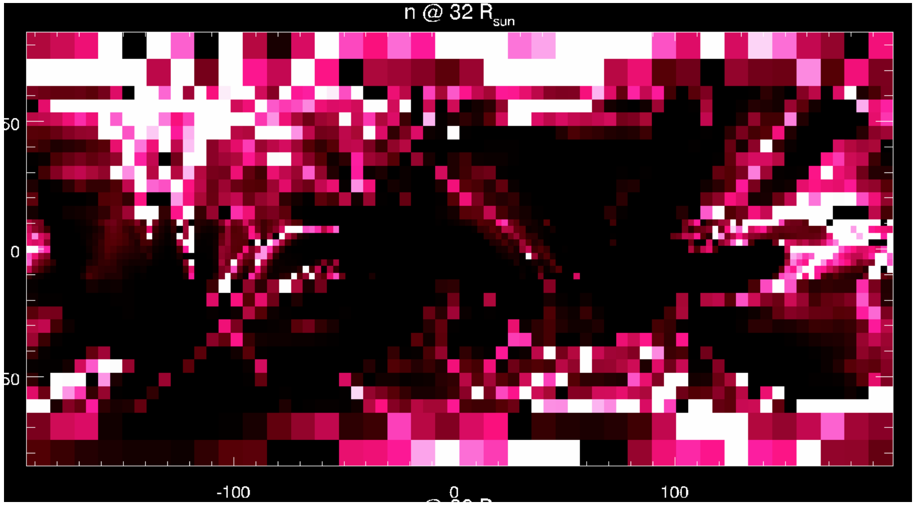
[Issues with wind modelling (as of May 2015)]

Wind speed and temperature OK at 32 Rsun





But density NOT OK at 32 Rsun (OK only up to 5-6 Rsun)



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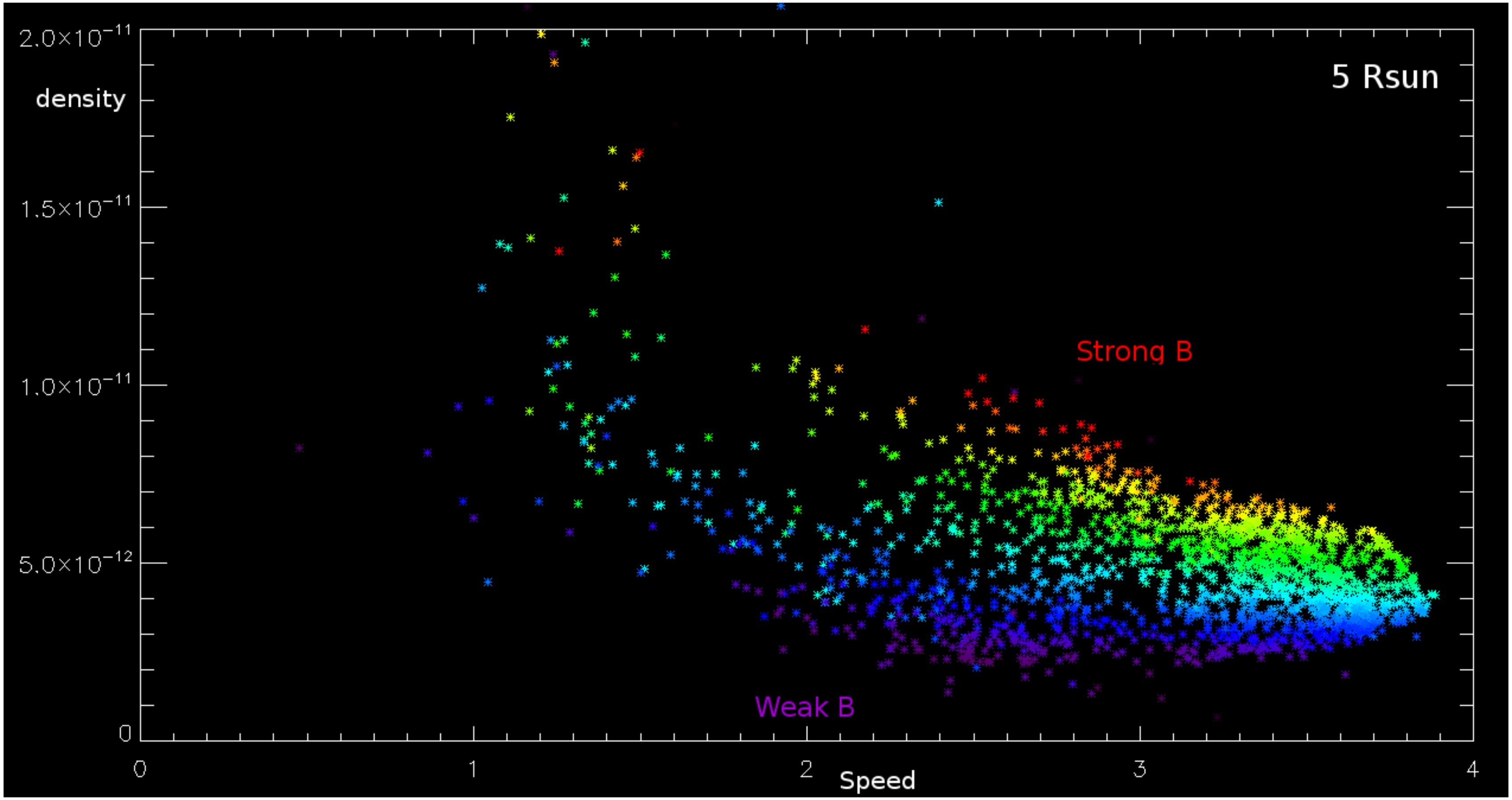

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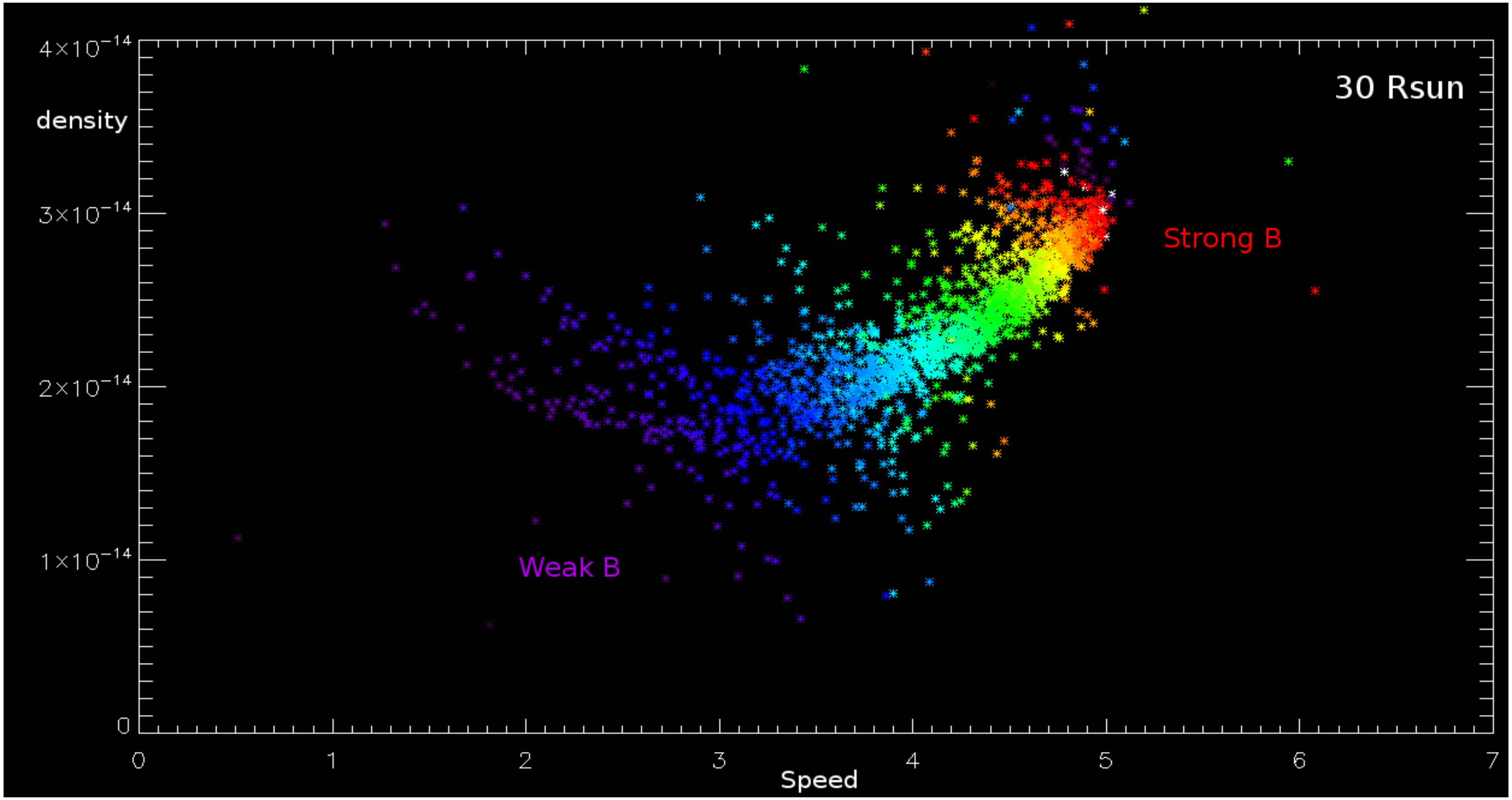

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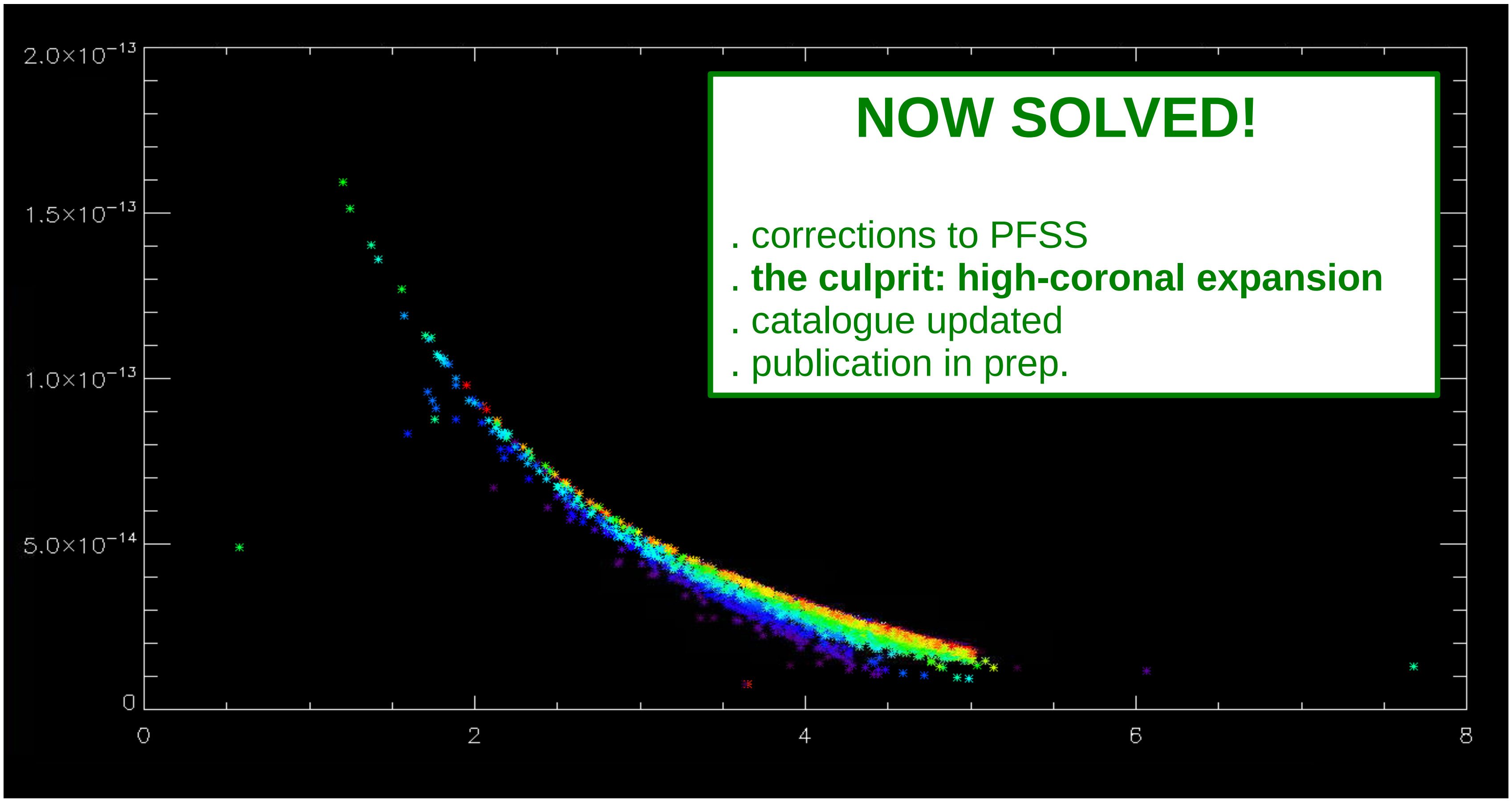
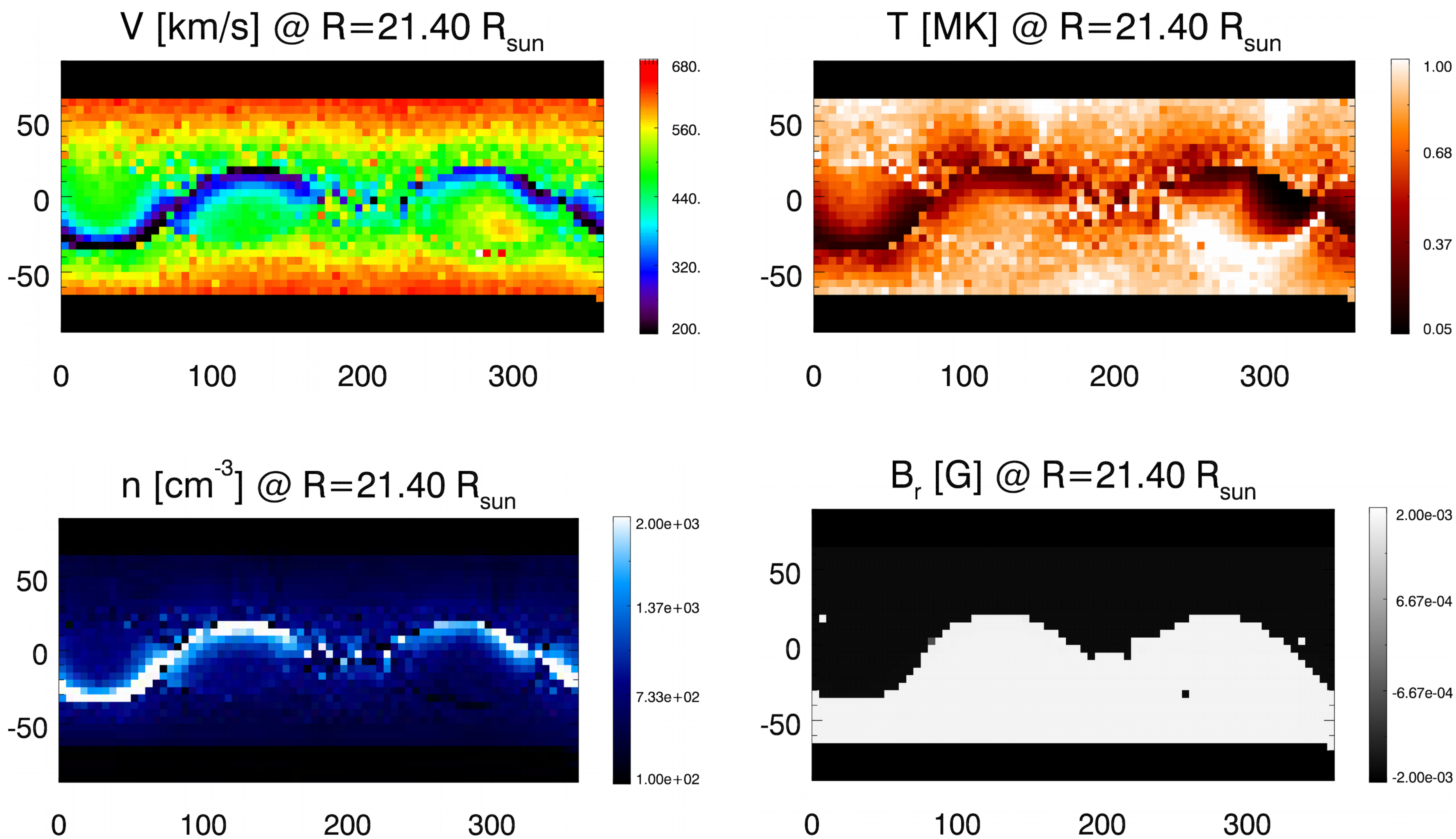


T6.2- H Imaging, background wind

[UPS, del. months 7-36]



T6.2- H Imaging, background wind

[UPS, del. months 7-36]

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

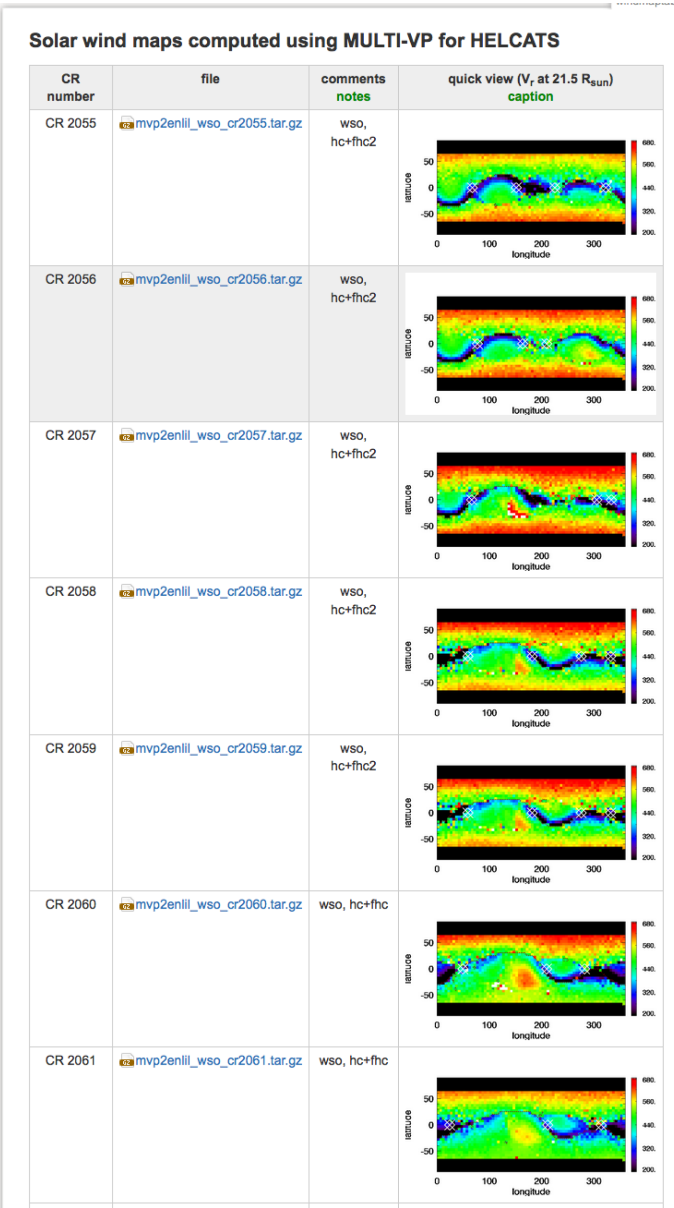
Database of physics-based solar wind simulations (DONE):

. from 1 to 21.5 Rs,
. provides velocity, temperature, magnetic field and density (unlike WSA)

. full field geometry & amplitude
. uniformisation of interplanetary B-field
. correct correlations n-V, V-T, V-B_0
(compared against OMNI and HI data)

(Pinto, Brun, Rouillard, A&A 2016;
Rouillard et al, Sol. Phys. *submitted*)

Initiate ENLIL from these solar wind simulations
(WORK IN PROGRESS)



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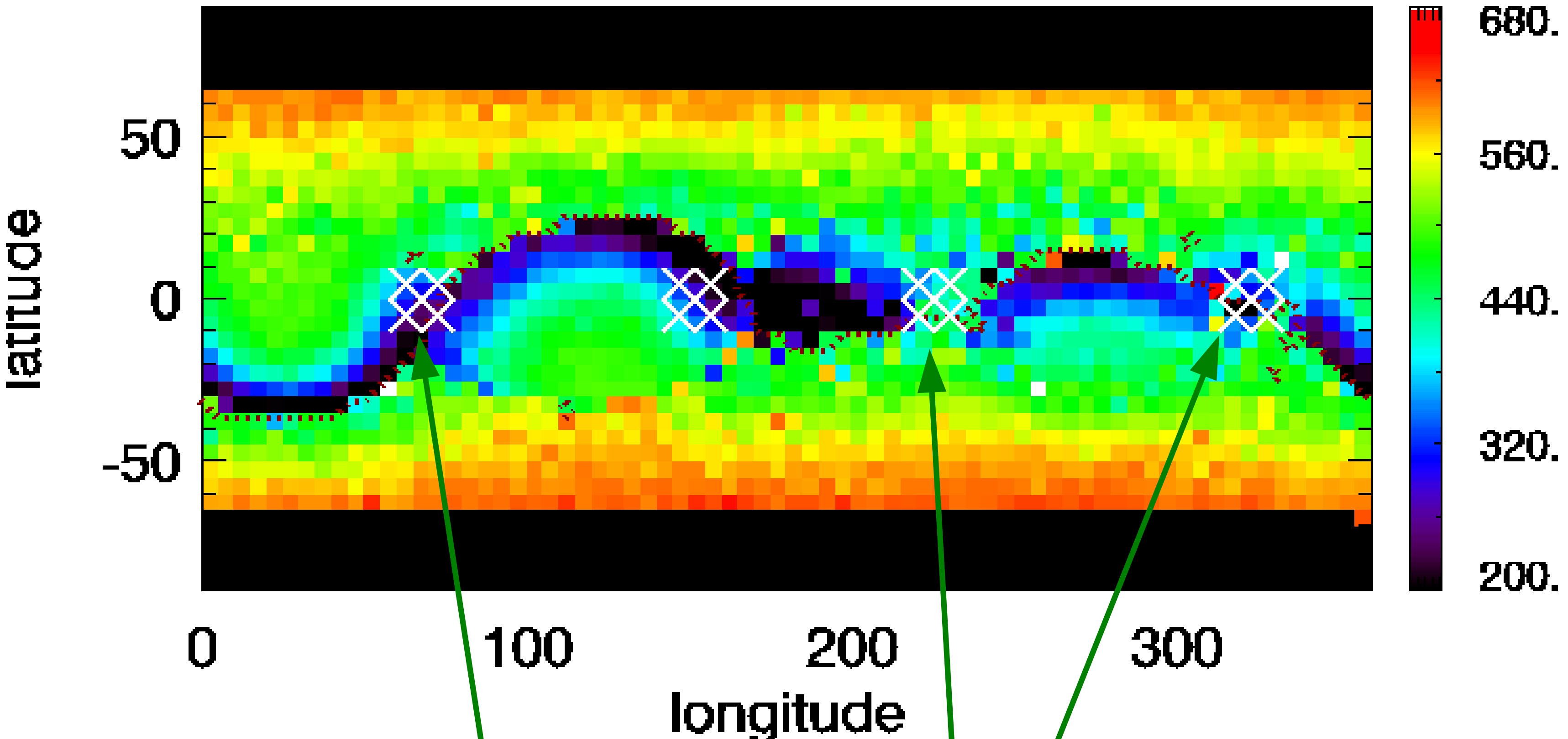
CR 2058	mvp2enlil_wso_cr2058.tar.gz	wso, hc+fhc2	
CR 2059	mvp2enlil_wso_cr2059.tar.gz	wso, hc+fhc2	
CR 2060	mvp2enlil_wso_cr2060.tar.gz	wso, hc+fhc	
CR 2061	mvp2enlil_wso_cr2061.tar.gz	wso, hc+fhc	

T6.2- H Imaging, background wind

[UPS, del. months 7-36]



HELCATS CIRcat → source positions on the wind maps

T6.3 – Assimilation of HI into ENLIL

[UPS, del. month 36]

Continual assimilation of HI data into ENLIL
(not yet done, but preparatory tools already in place)

D6.3 : The results of WP3 and 4 will provide the central axis, volume and speed of CMEs between 10 and 20 solar radii (range of inner boundary for ENLIL). These CMEs will then be injected as hydrodynamic spheres into the most accurate simulations of the background solar wind derived from WP6.1. The arrival time of the leading edge of the CMEs and the properties of the potential shocks driven ahead of them will be compared with in-situ measurements (exploiting the results of WP4.2). A catalogue of these optimised ENLIL simulations of CMEs and their shocks will then be stored for the ecliptic plane. This advanced catalogue will help studies of the origin of solar energetic particle events. **(Not started)**

D6.4 : In Task 6.2, the CME properties are specified once at the inner boundary. The CME position, volume and speed can be updated every 40 minutes for HI-1 and 2 hours for HI-2. Medium resolution ENLIL simulations will be re-launched at every time step such that the CME position and speed remains in agreement with HI images. The results of this set of assimilated simulations will be compared with results of Task 5.2 and in-situ measurements; we will determine whether a continual assimilation of HI images provides a better forecast of CME arrival times at 1 AU. **(Not started)**