Comparing extrapolations of the coronal magnetic field structure at 2.5 $R_\odot$ with multi-viewpoint coronagraphic observations

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Goals

- **to demonstrate the feasibility of using SolO instruments (PHI, EUI, Metis, …) to derive the magnetic connectivity along the SolO orbits**

- **To forecast the magnetic field configuration far from the Sun starting from known photospheric field**

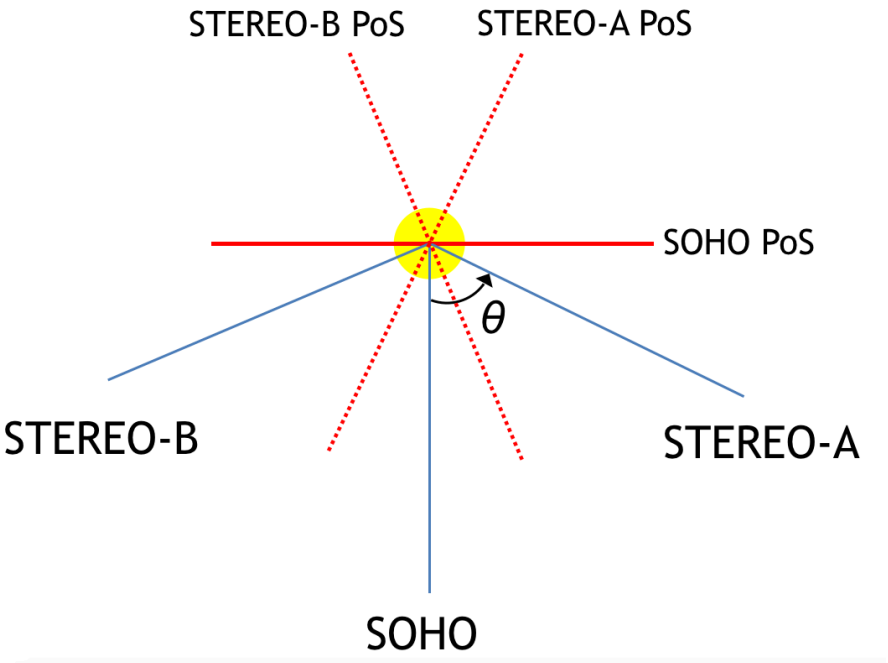
We use WL Carrington maps to easily constrain the solutions of the extrapolations by comparing the position of the streamers with the position of the neutral line

Our aim is to verify if this comparison could be a fast method to check systematically the reliability of the many methods available to reconstruct the coronal magnetic field.

The dates selected for this extrapolation are defined in respect to the orbit of SolO (based on launch late 2018): 2020-01-01
In order to match existing observed data, we subtracted 10 years to these values —> CR 2091 (12/2009-1/2010)

In the literature, we find this kind of comparison but they all assume a “static” corona over a CR.

The idea: to combine SOHO/LASCO-C2 and STEREO –A and –B/COR1 Carrington maps at given altitude to have an almost «instantaneous» picture of coronal structures → compare locations of streamers with extrapolated location of magnetic neutral line at the same altitude.

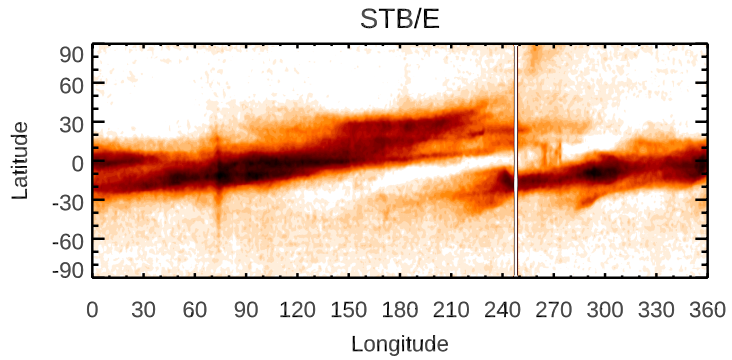


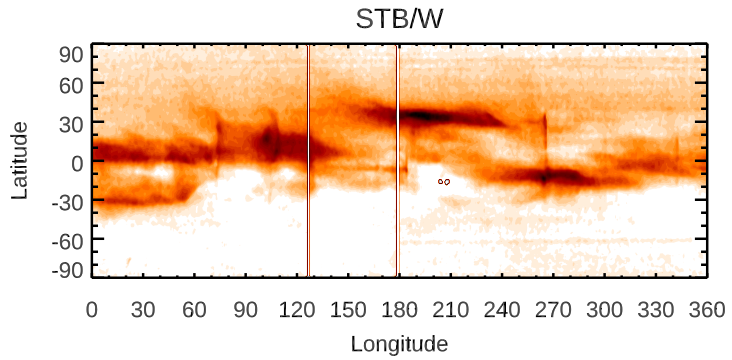
For CR2091 the STEREO-SOHO separation angles were 64° (ST-A) and -67° (ST-B) on 20 December 2009 at 20:20 UT.

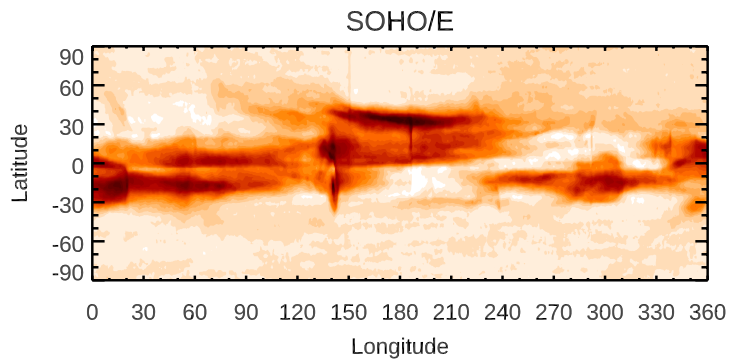
After ~ 5 days the same structures seen by SOHO start to be observed by STEREO-A and were observed 5 days before by STEREO-B → combining the 3 spacecraft and both limbs we need only ~ 5 days (instead of 27 days) of data to see one full coronal rotation.

Observations at 2.5 Run

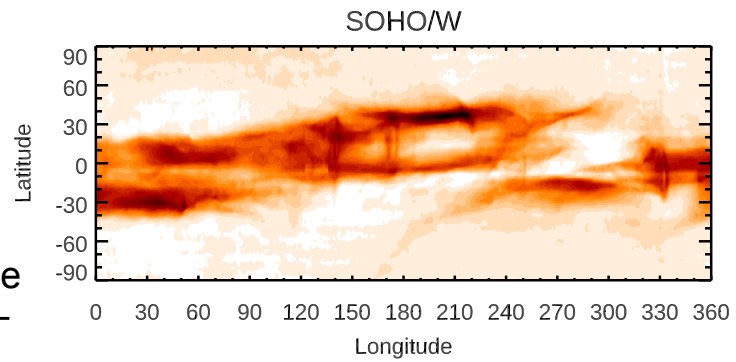
+ 5 days

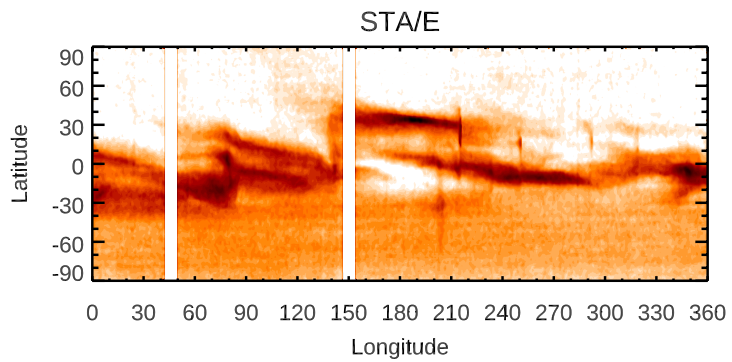


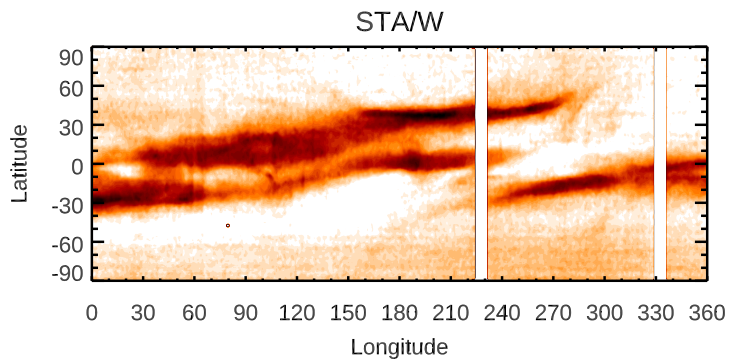




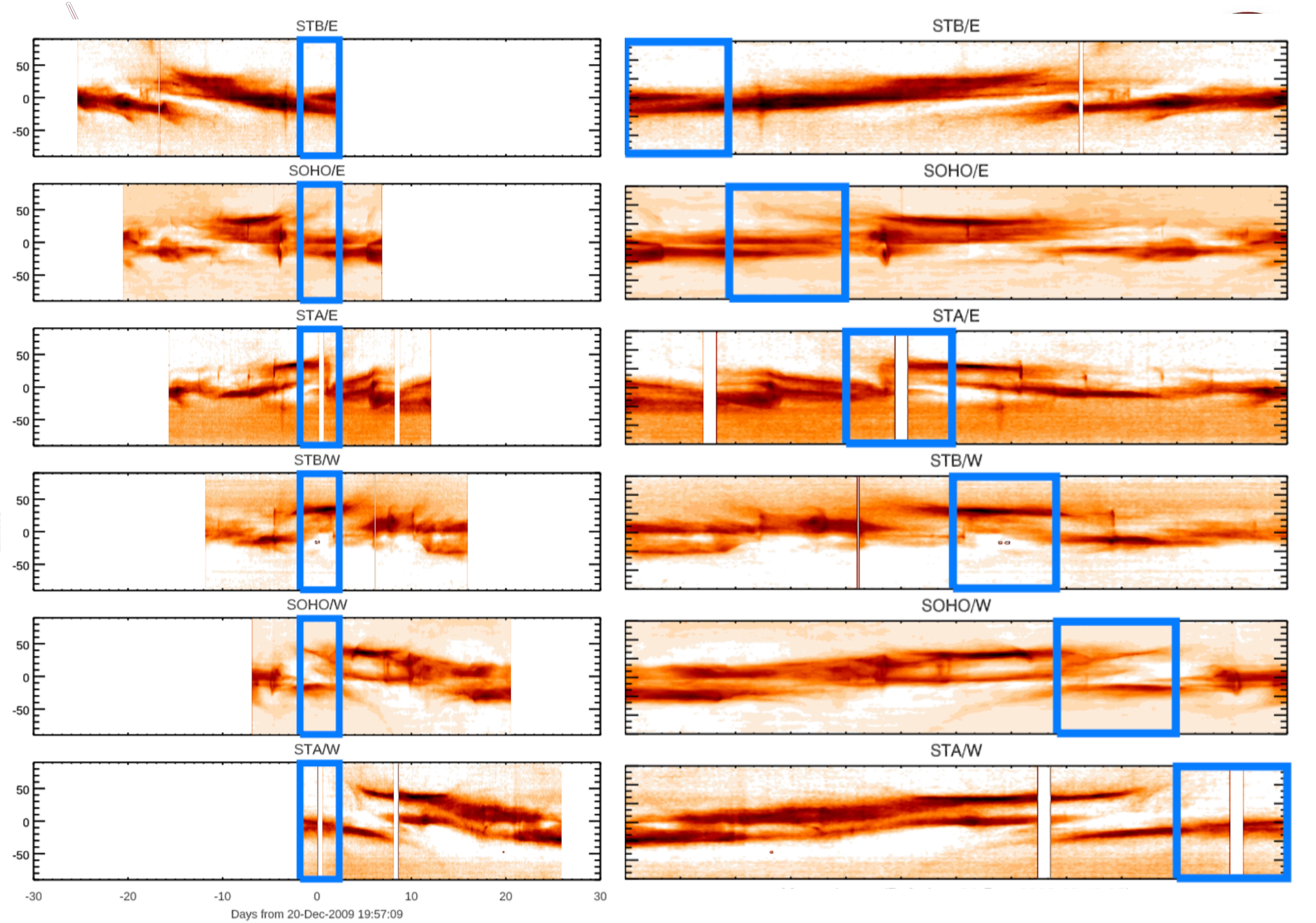
Time
<—



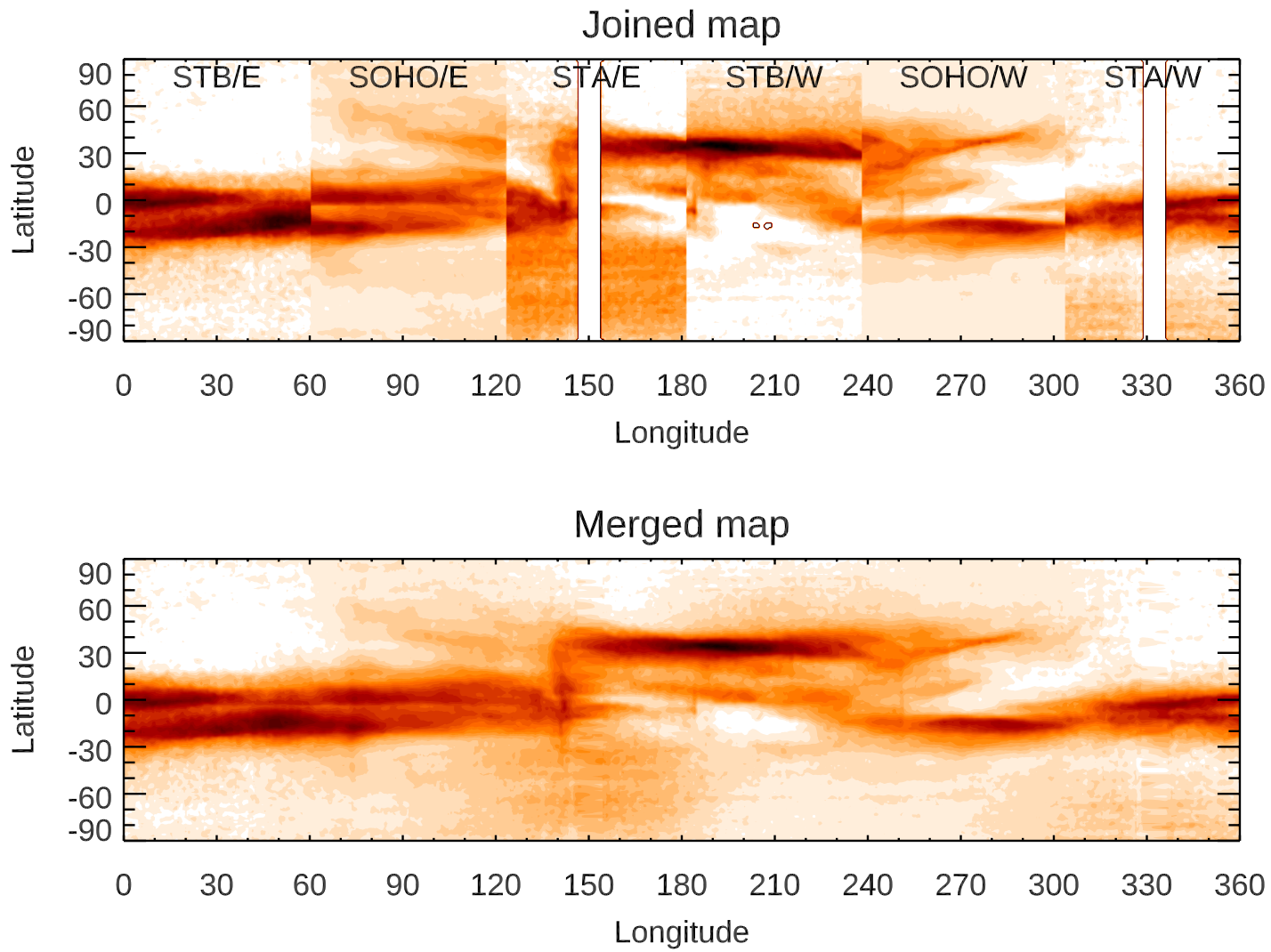




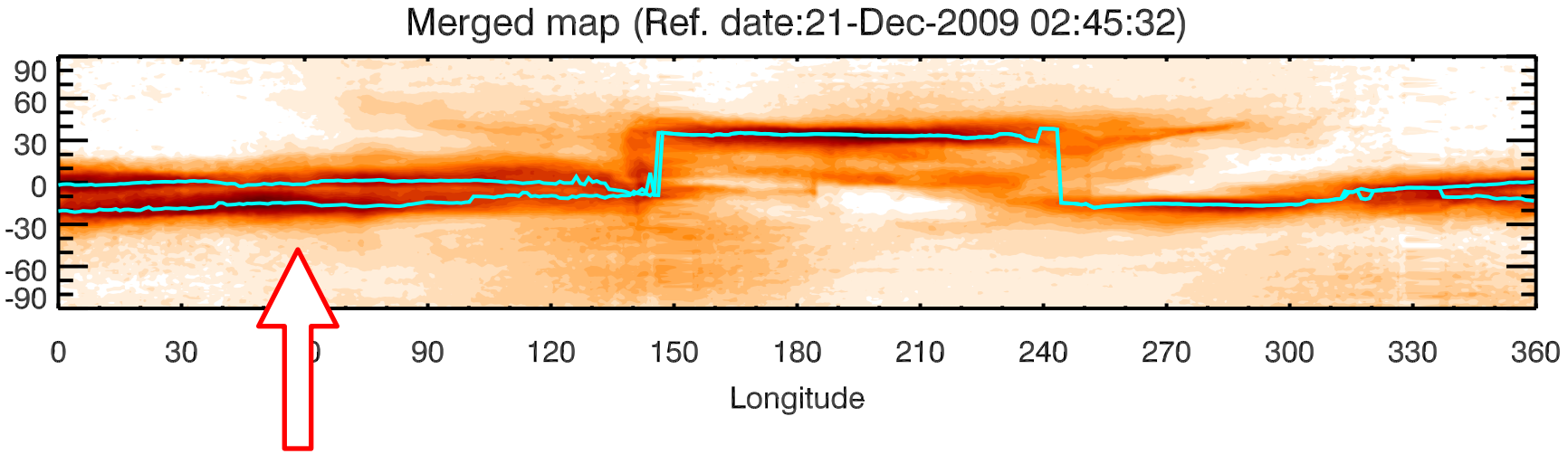
- 5 days


STB/E
SOHO/E
STA/E
STB/W
SOHO/W
STA/W
50
0
-50
-30
-20
-10
0
10
20
30
Days from 20-Dec-2009 19:57:09

STEREO-B + SOHO + STEREO-A combination guarantees the minimum amount of temporal evolution in the maps as possible.



— The position of the streamers is a good proxy of the position of the magnetic neutral line at 2.5 $R_\odot$.
— We decide to compare the magnetic neutral line obtained from the observed Carrington maps by taking the peaks of maximum intensity at each date, with the extrapolated neutral lines.



Observationally, at least for CR2091, we can not distinguish between streamers and pseudostreamers but we can still derive useful information on the reliability of the extrapolations

Extrapolations

We selected magnetogram sources and mature extrapolations methods used by the community and thoroughly in the literature. Furthermore, we tried to select 4 methods that are representative of the different types of techniques (e.g, low and high resolution magnetograms, synoptic and synchronic maps). But the approach used in this work for testing the extrapolations can of course be applied to any other method and magnetogram dataset.

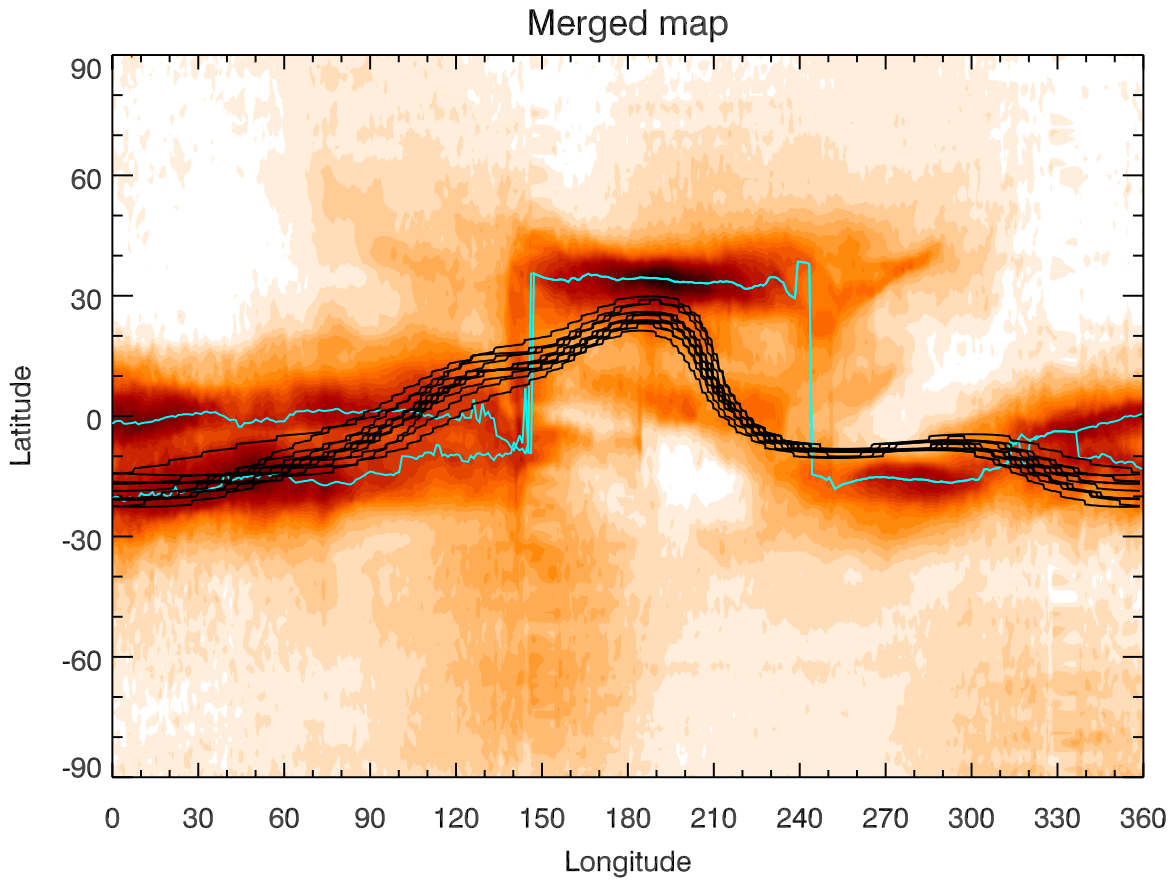
1. **Method 1**
   Potential Field Source-Surface (PFSS) extrapolation from the Wilcox Solar Observatory (WSO) synoptic maps. The result of this extrapolation is a source surface synoptic chart, available on the WSO web site: **1 neutral line**

2. **Method 2**
   PFSS extrapolations from the WSO photospheric synoptic maps but we use a PFSS extrapolation method following Wang et al. —> The result of this extrapolation is a source surface synoptic chart: **1 neutral line**

3. **Method 3**
   PFSS extrapolation from MDI observations. This method comprises the application of a flux transport model to the photospheric data as described by Schrijver & De Rosa, 2003.
   The result of this extrapolation is a unique Carrington map each 6 hours, and we choose three days of the CR 2091 to have results to compare with the observations: 07/12/2009, 20/12/2009, and 03/01/2010.
   We have **1 neutral line for each chosen day**

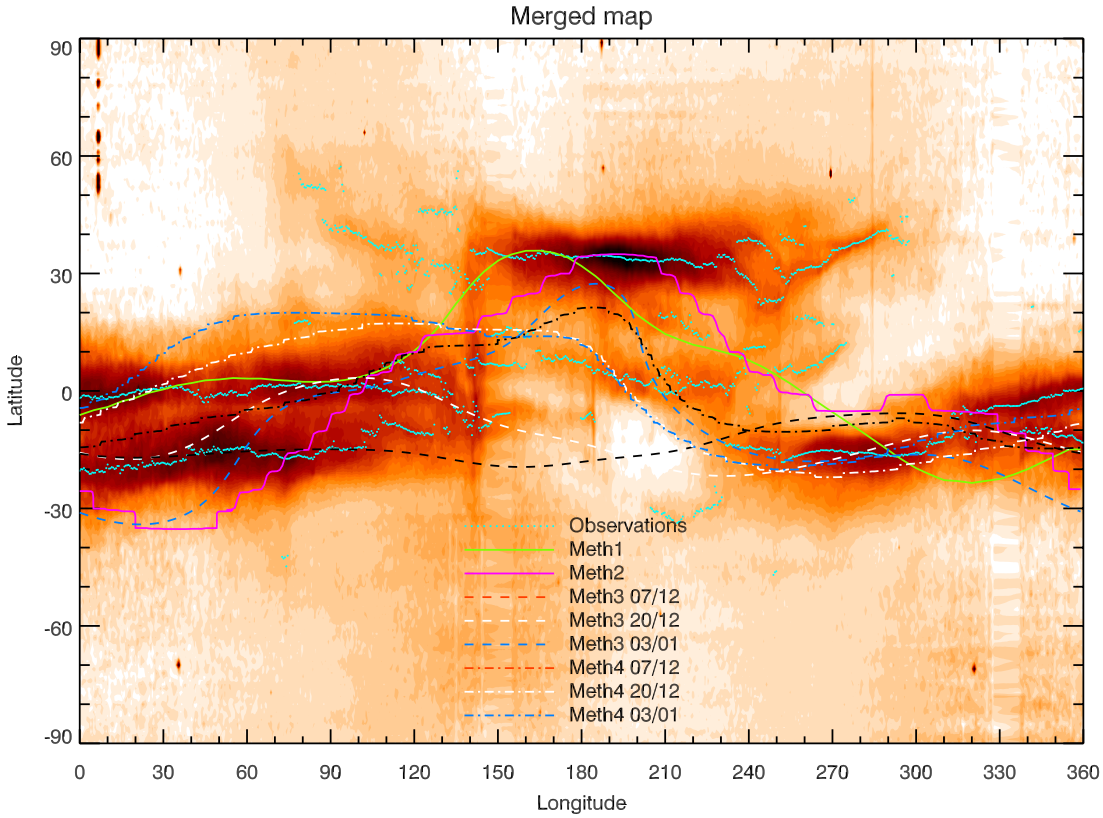
4. **Method 4**
   PFSS extrapolation from NSO/GONG observations.
   ADAPT (Air Force Data Assimilative Photospheric Flux Transport) generates global solar photospheric magnetic field maps using flux transport providing synchronic solutions at the time cadence we want
   The result of this extrapolation are 12 Carrington maps for each predicted time. We have **12 neutral lines for each chosen day**

Results for Method4: we are not able to constrain the solutions



Method4 produces twelve neutral lines for each day.
We find that the differences among the ADAPT neutral lines are too small to let us distinguish among them through a comparison with the observations. We do not need such a high resolution in the extrapolations for this kind of analysis.

Comparison observations versus extrapolations



Qualitatevely, for Method3 and Method4: we find that the neutral lines obtained from three different days during the Carrington rotation can be very different. This is because the photospheric field data may change in a day

METRIC: Absolute value of the latitudinal difference between the extrapolated neutral lines and the two streamer axes, as function of the longitude.

We find a good agreement for Method1, Method2, and Method4 (performed on 20 Dec 2009).
All three methods start from photospheric maps of the magnetic field (synoptic or synchronic) built with data observed around the same days of the coronagraphic observations of the streamers.

It is important to reduce the time needed to scan the corona by, for example, combining images from instruments looking at the Sun from different viewing angles.

Conclusions

Aim

- to use WL Carrington maps to easily constrain the solutions of the extrapolations by comparing the position of the streamers with the position of the neutral line

- to verify if this comparison could be a fast method to check systematically the reliability of the many methods available to reconstruct the coronal magnetic field to forecast it starting from photospheric observations.

The current set of extrapolations are not useful beyond a top-level comparison w/ coronagraphs (i.e., streamer exists or not at a given position angle). They lack robust information on the field to go beyond that (e.g. compare position angle of a streamer against extrapolation).

Future plans

We plan to re-do the multi-viewpoint analysis with other CR maps to cover one solar cycle and other extrapolations.
We also plan to identify in the white-light maps further visible structures (for example, the position of the coronal holes) to compare them with the results of the extrapolations.