PSP Solar Wind Sources at 13.3 Solar Radii

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Introduction

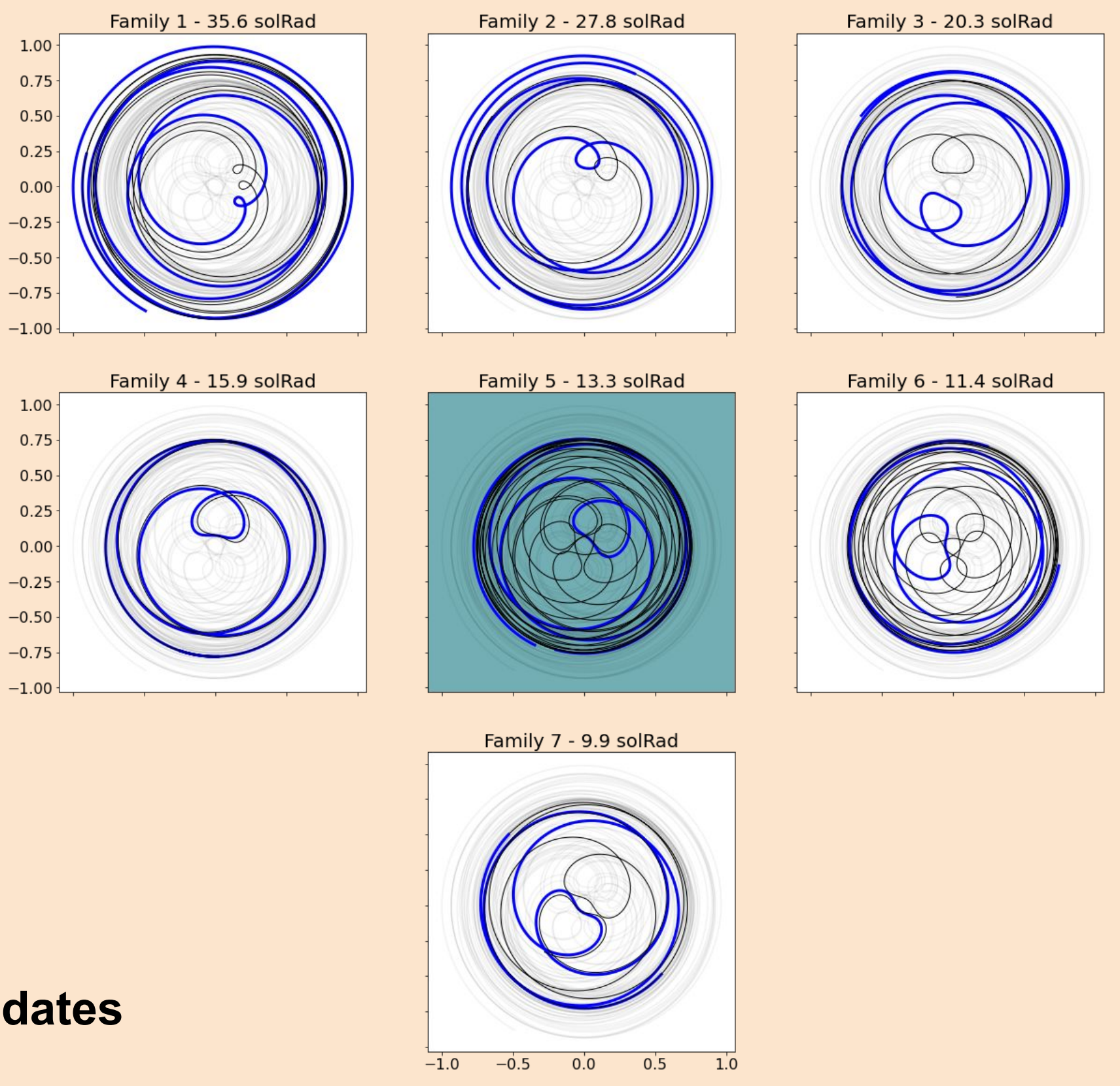
The What….

- We model the source regions for encounters 10 and 11 which are the first PSP [1] orbits with perihelia at 13.3 Rs.
- Model predictions from various modelers are combined for each encounter to establish a consensus blind prediction for solar observers.
- We compare the predictions to in situ data after the fact, and find the extreme and rapid variation in spatial position leads to new and robust in situ-model comparisons. We highlight the importance of viewing the datasets in terms of spacecraft position

…and the Why

- Establishing the source region which results in given measurements at PSP allows important contextualization of the data in one direction and model validation/improvement in the other.
- PSP's orbit will continue to become more extreme and so tracking the implications of its changing orbit in source localization is important.

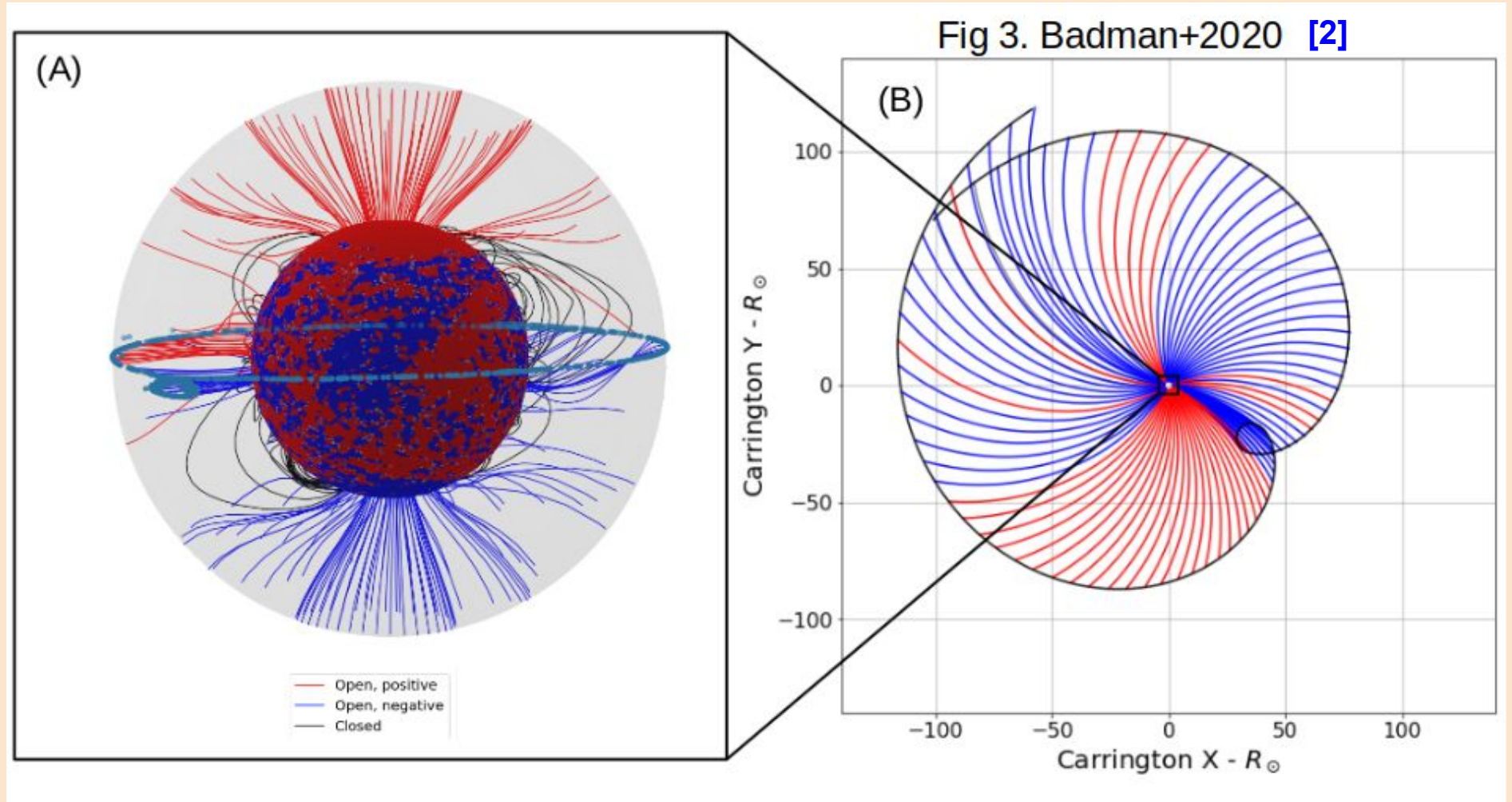
The 13.3 Rs orbit family: Carrington Frame



Updates

- Closest approach to Sun so far
- 110 degrees longitude swept out between corotation intervals

Making a Connection



Coronal Part

- Field ine tracing through numerical grid

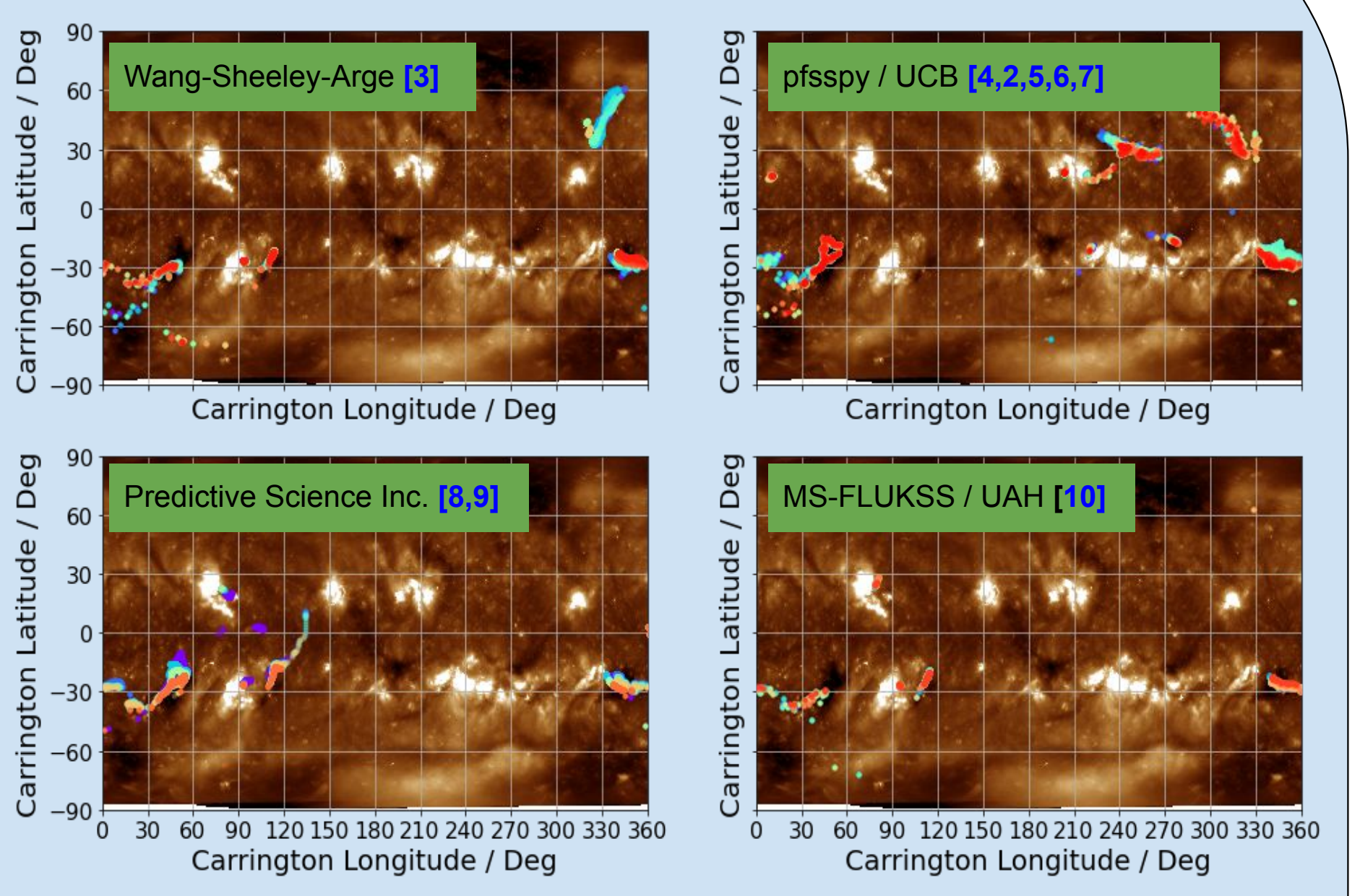
Heliospheric Part

- Analytic assumption of Parker spiral (Vsw as input)

Result : A continuous fieldline described by 3d coordinates in the Carrington frame, for each spacecraft position grid point, from spacecraft position, down to the photosphere.

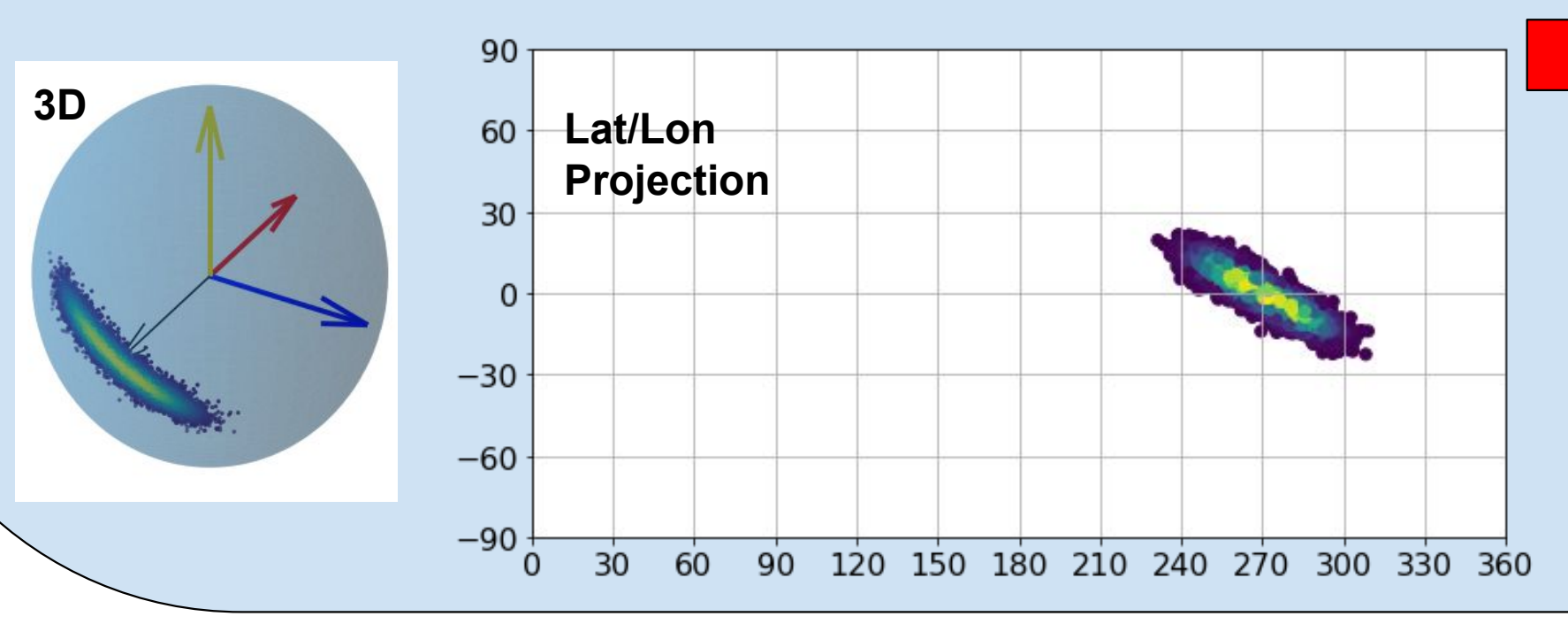
Predictions and Consensus Building

(1) Gather Model Predictions
Individual modelers provide footpoint longitude, latitude and timestamp, projecfed forward in time with the most recent magnetogram.



(2) Establish consensus

- Form ensemble from multiple model predictions
- Fit ensemble with a Kent distribution
- Results in consenus centroid and error region (FWHM ellipse)
- Sanity check : is the distribution unimodal and well clustered? Is the consenus footpoint located in a likely source (coronal hole, active region, …) according to EUV data

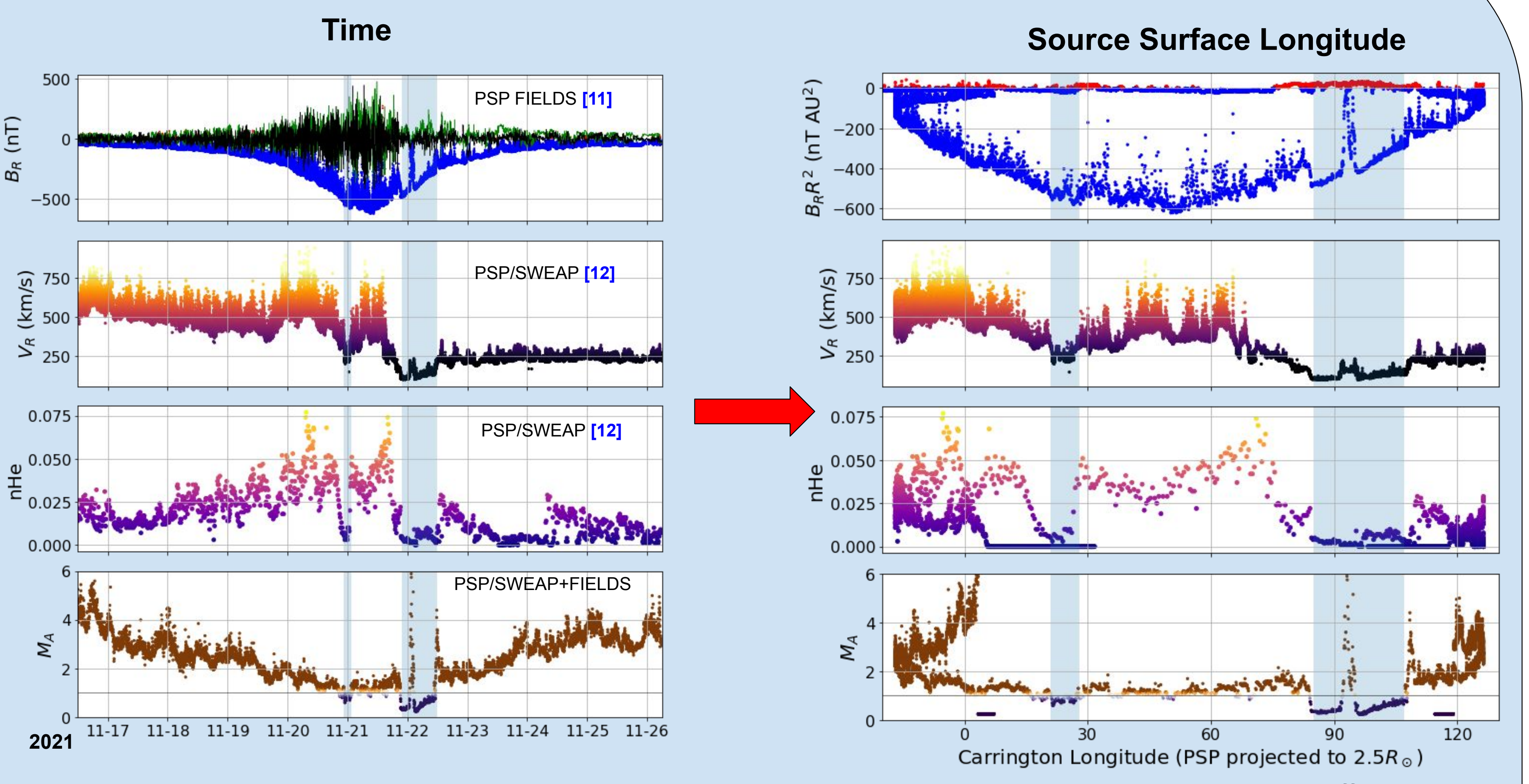


(3) Iterate in time and publish to web : Footpoint prediction data, summary plots and narrative forward in time from date of prediction.

For encounter 10, prediction was 3 distinct coronal holes sequentially one after the other.

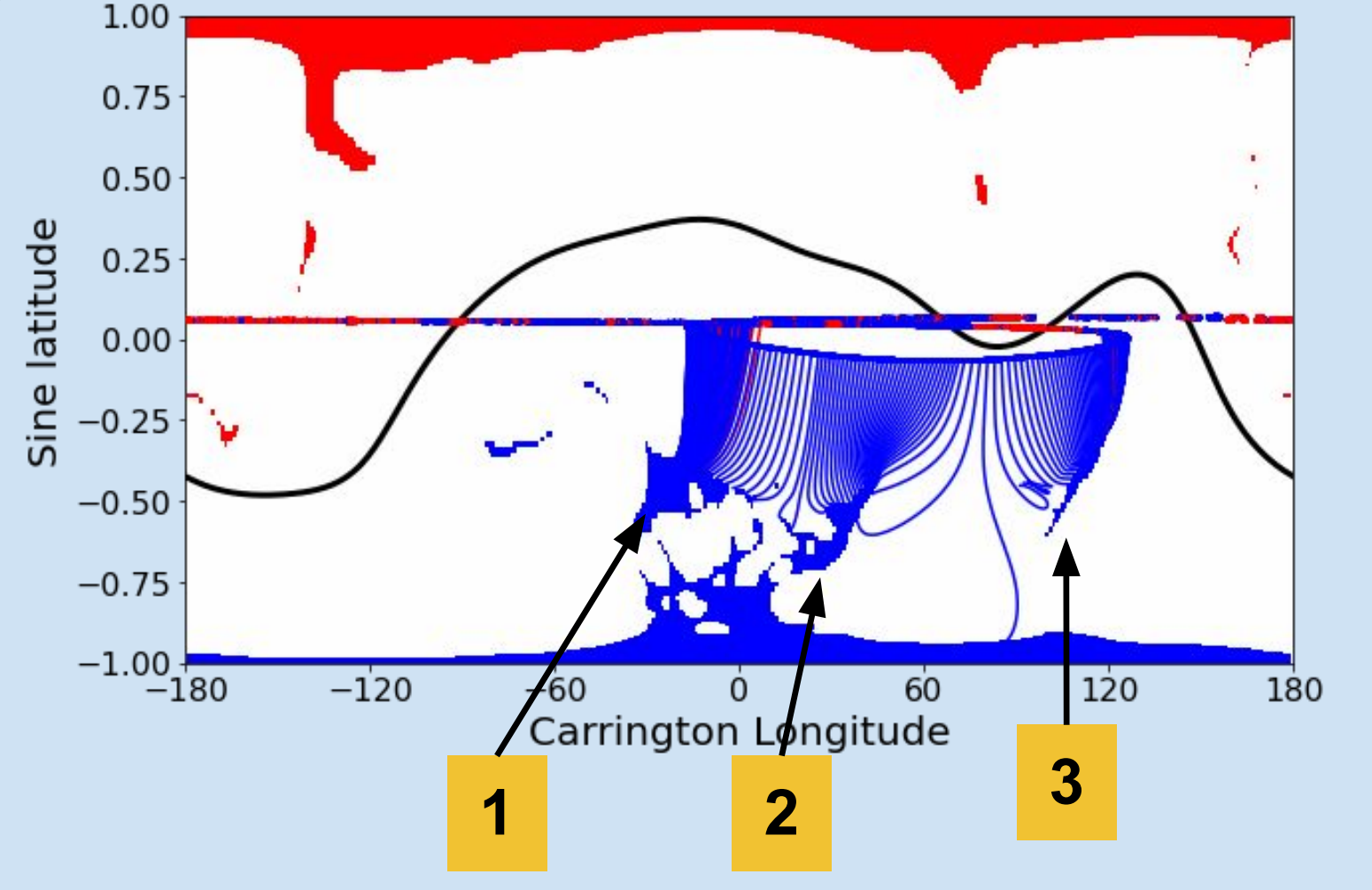
See : https://sppgway.jhuapl.edu/encounters (all encounters) and https://whpi.hao.ucar.edu/whpi_campaigns.php (perihelion on disk encounters)

Encounter 10 Data : Temporal vs Spatial



- Extreme change in relative angular velocity means structures in time and space look very different.
- We see the entire time series from 11/17 to 11/21 is the same fast wind stream being explored in one direction than the other
- For encounter 10, we see spatial structure of 3 clear solar wind streams, **separated by sub-alfvenic intervals** (vertical shading). [C.f. recent studies of PSP crossing the Alfven Surface [13,14]]

Encounter 10 Prediction Validation and Stream Structure

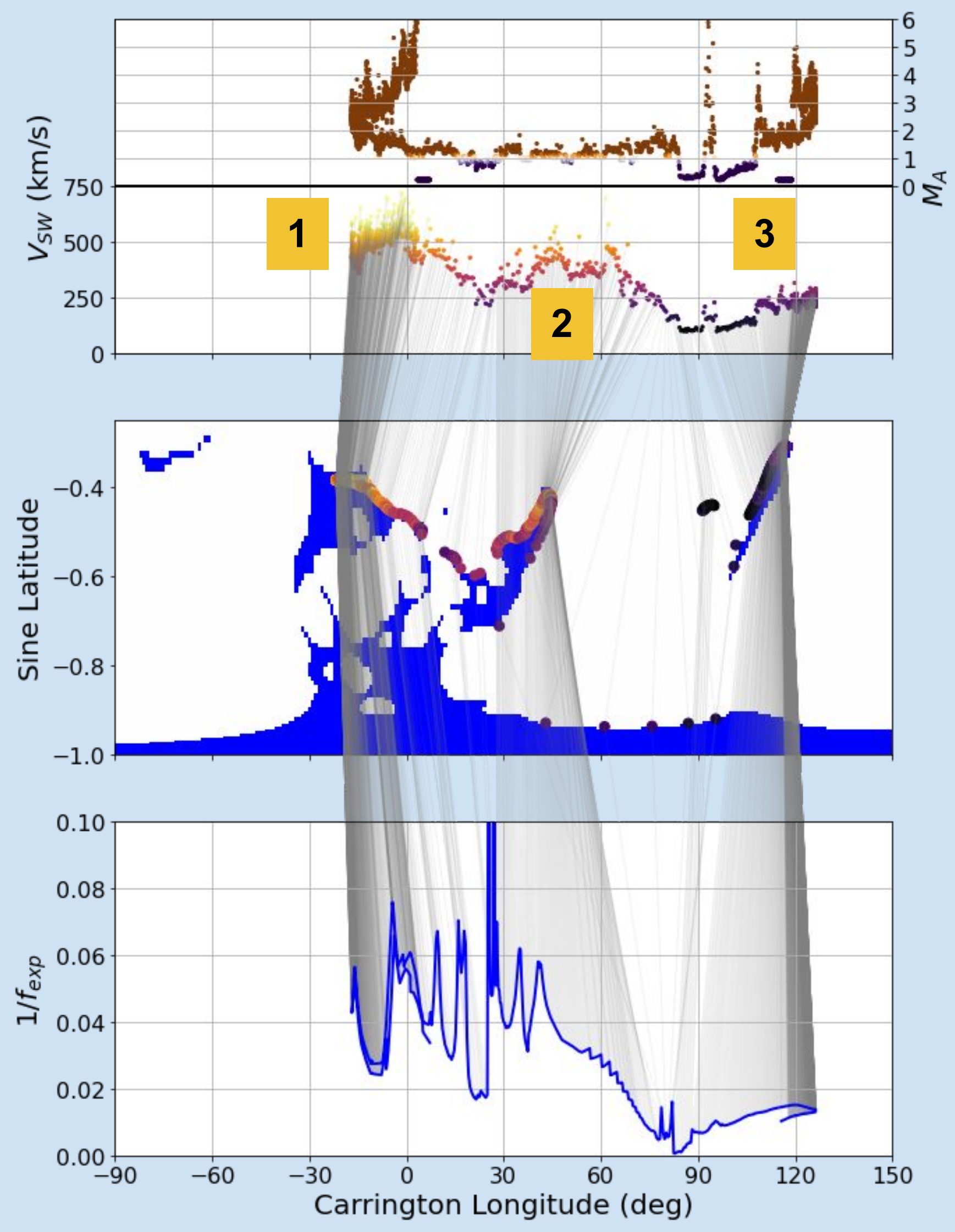


Model Summary

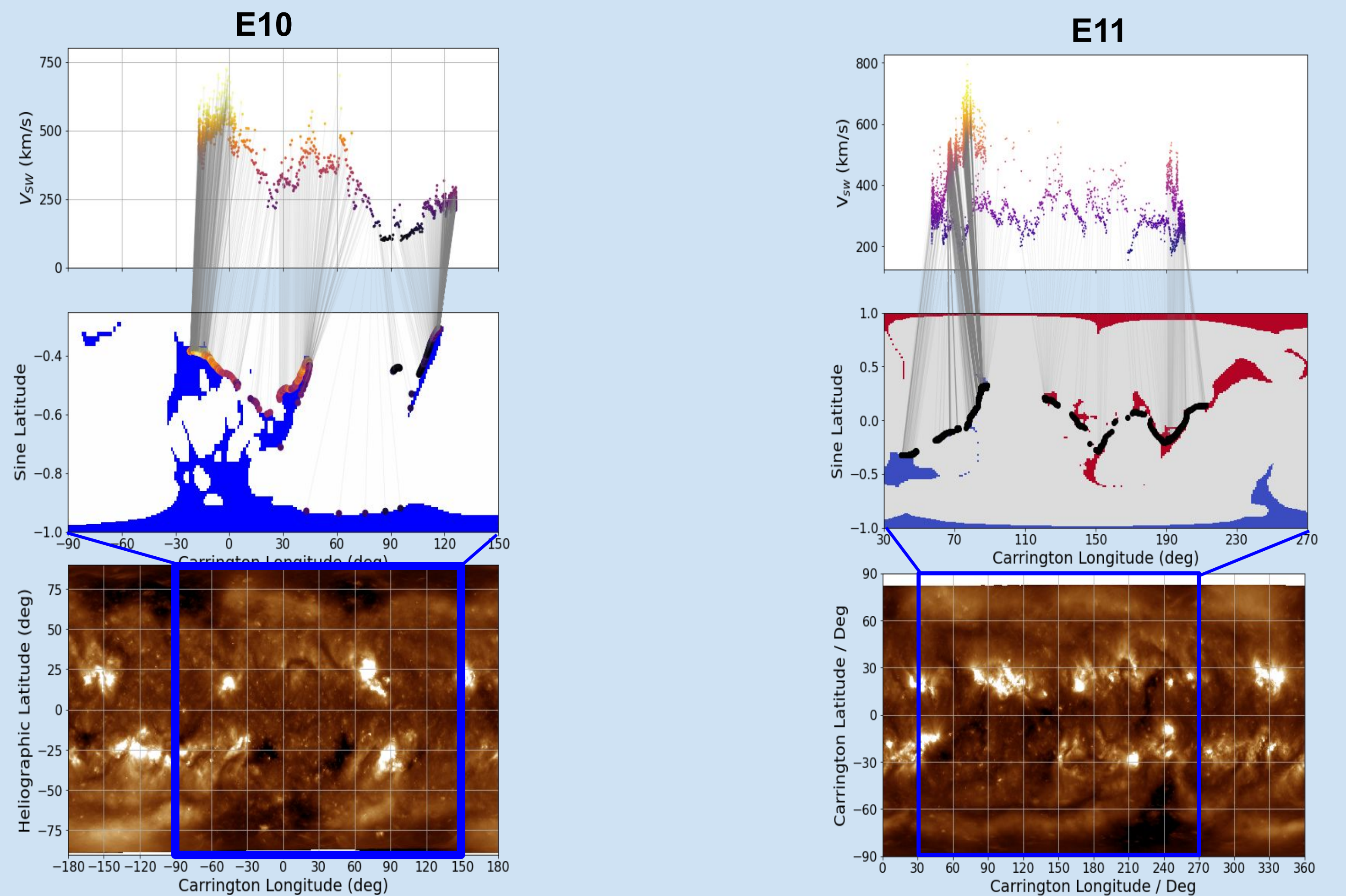
	1	->	2	->	3
Source Type	Large CH	Transition	Large CH	Transition	Small/extended CH
Polarity	-	-	-	-	-
1/f_exp	Large	Small	Large	Small	Small

In Situ Summary

	1	->	2	->	3
Vsw (km/s)	500-700	~250	~400-500	< 200	~250
Polarity	-	-	-	-	-
Alfven Mach #	> 1	< 1	>1	<1	> 1



Comparison of Encounter 10 & 11



Comparison:

- Strong correlation between number of streams measured in situ and number of different coronal hole features sampled in the model.
- Near-Solar max conditions resulting in continuous mid-latitude and equatorial connectivity.
- More than half the Sun sampled in prograde part of orbit.

Conclusions

- Rapid relative motion of PSP in recent orbits with respect to solar rotation leads to significant and important differences in interpreting in situ data in terms of large scale structure and sources. Casting the independent variable from time to spacecraft position is important for accounting for this. This will only become more important as the mission proceeds.
- Encounter 10 is a demonstrative example with clear correspondence between large scale in situ data and distinct (and predictable) modeled solar wind sources.
- 13.3 Rs orbit family is colliding with a real uptick in solar activity, each encounter has been very different in character so far!

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