

Finding Hidden Conjunctions in the Solar Wind



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CORONA

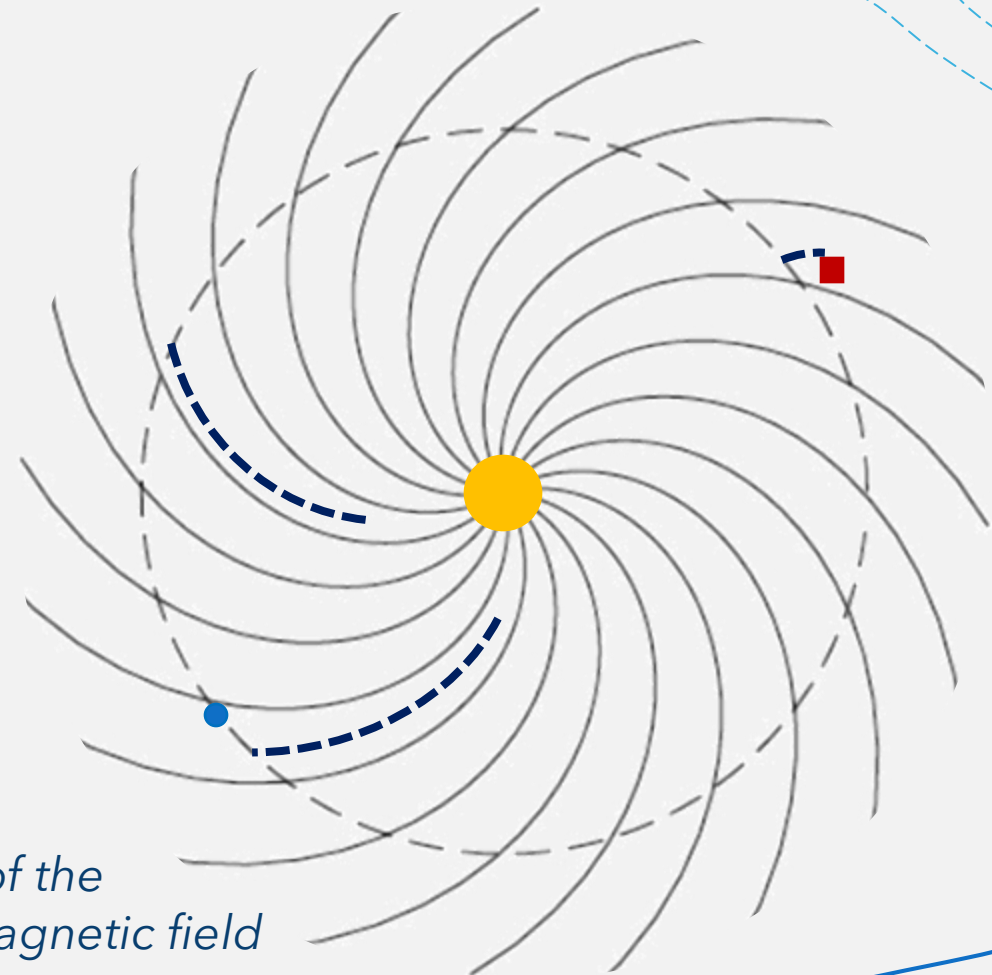
The Solar Wind

Credit: Goddard Space Flight Center, Lisa Poje

What is a conjunction?

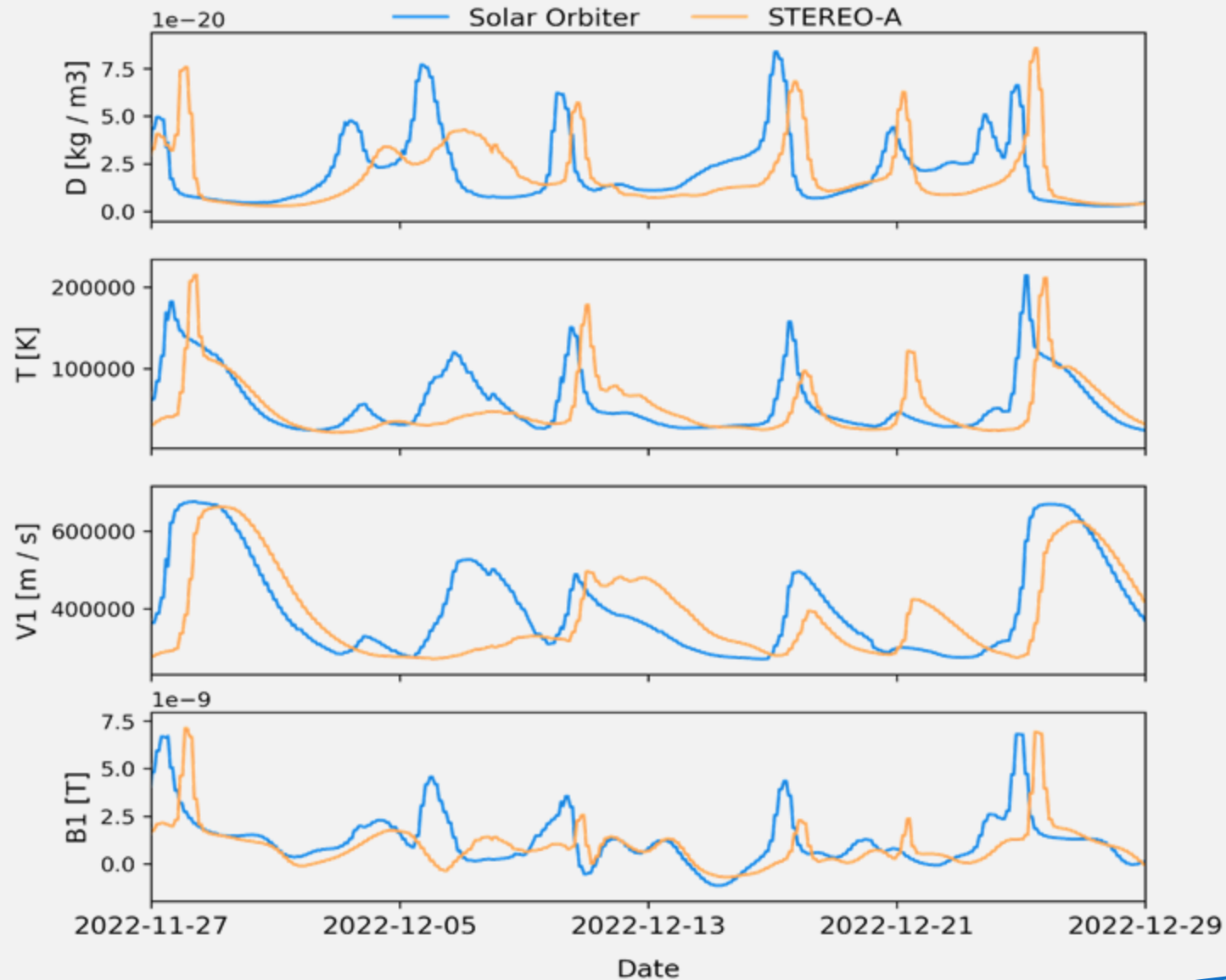
- + Two spacecraft are in conjunction where they are sampling the same volume of plasma
- + This allows us to characterize the expansion of the solar wind

■ *Spacecraft A*
● *Spacecraft B*

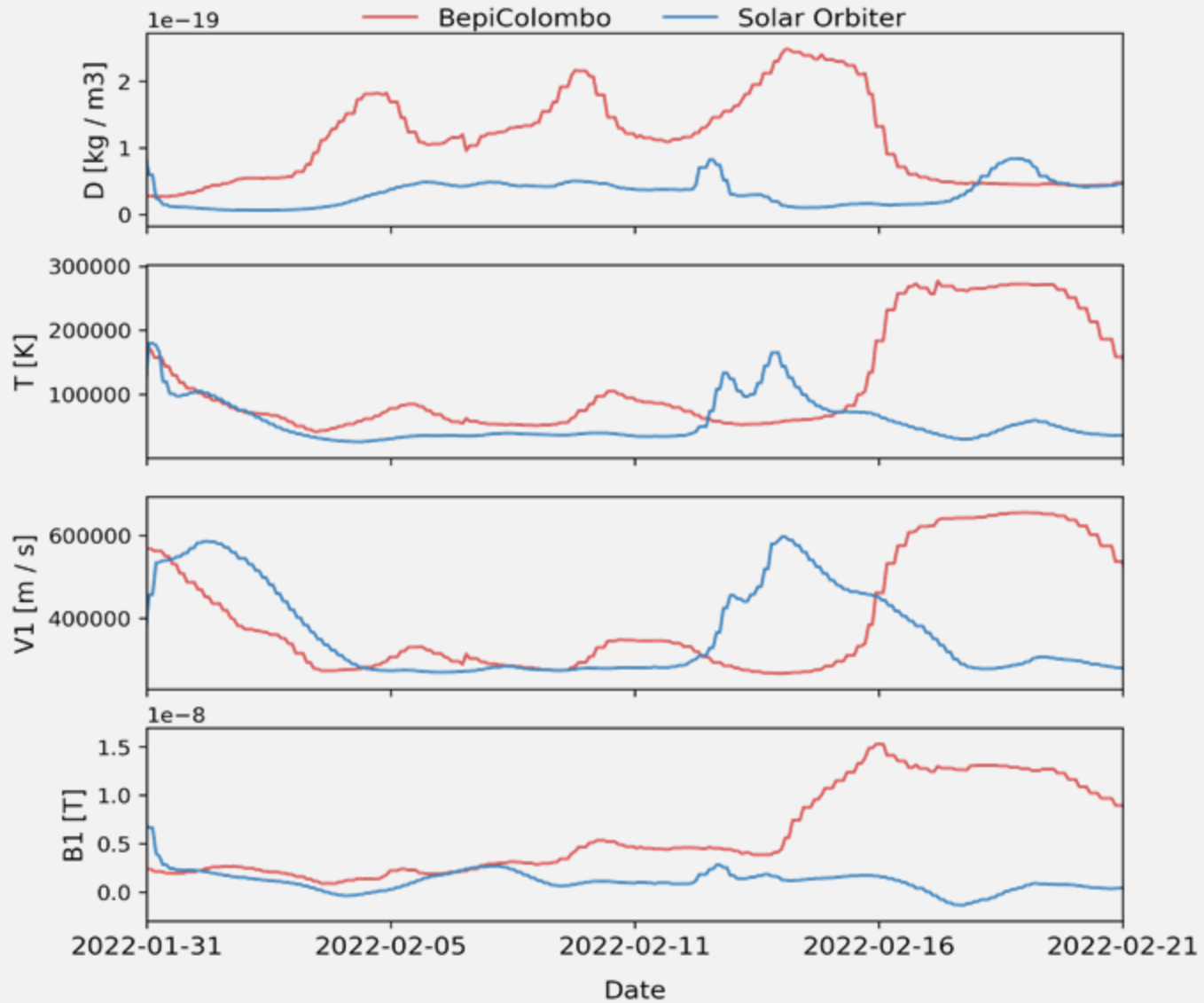


Simplified view of the interplanetary magnetic field in the ecliptic plane

What does a conjunction look like?



Not a conjunction



Project aim

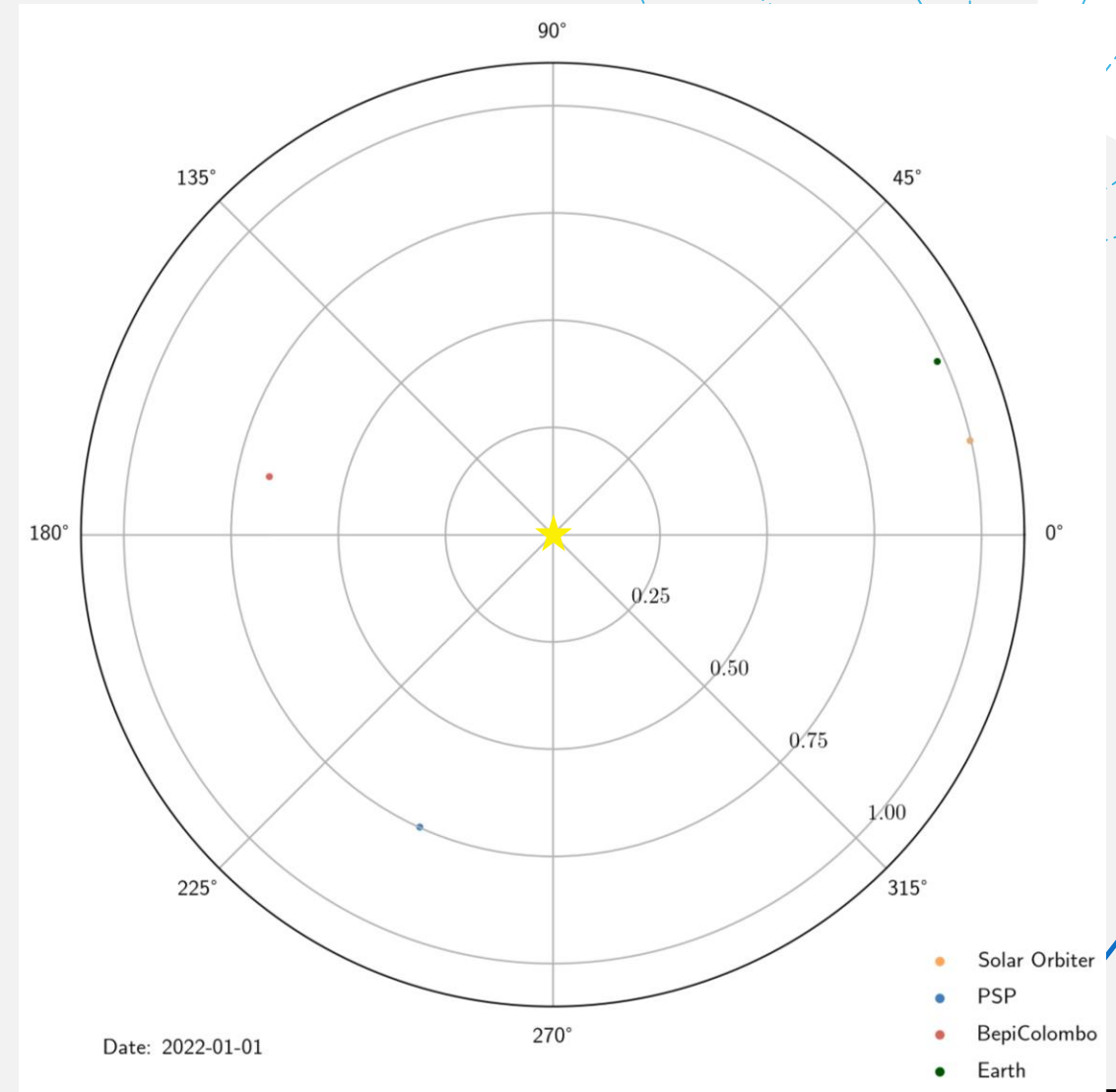
Identify hidden conjunctions between

- + Solar Orbiter
 - + Parker Solar Probe
 - + STEREO-A
 - + BepiColombo
 - + Near-Earth spacecraft
- to maximize the scientific return
of heliophysics missions



What makes a conjunction “hidden”?

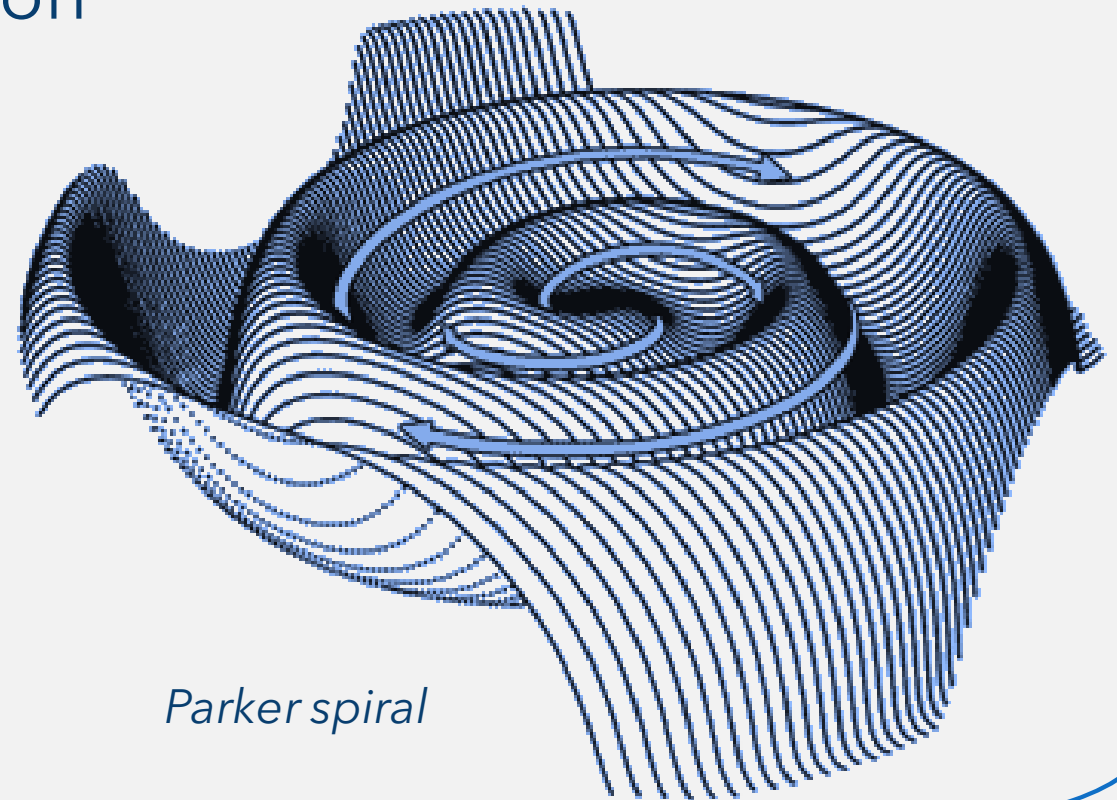
- + There are different models for how the solar wind propagates
- + From these, we can predict when spacecraft will be in conjunction
- + Hidden conjunctions are found outside of these predicted alignments



How are conjunctions identified?

Solar wind propagation prediction

+ Parker spiral model

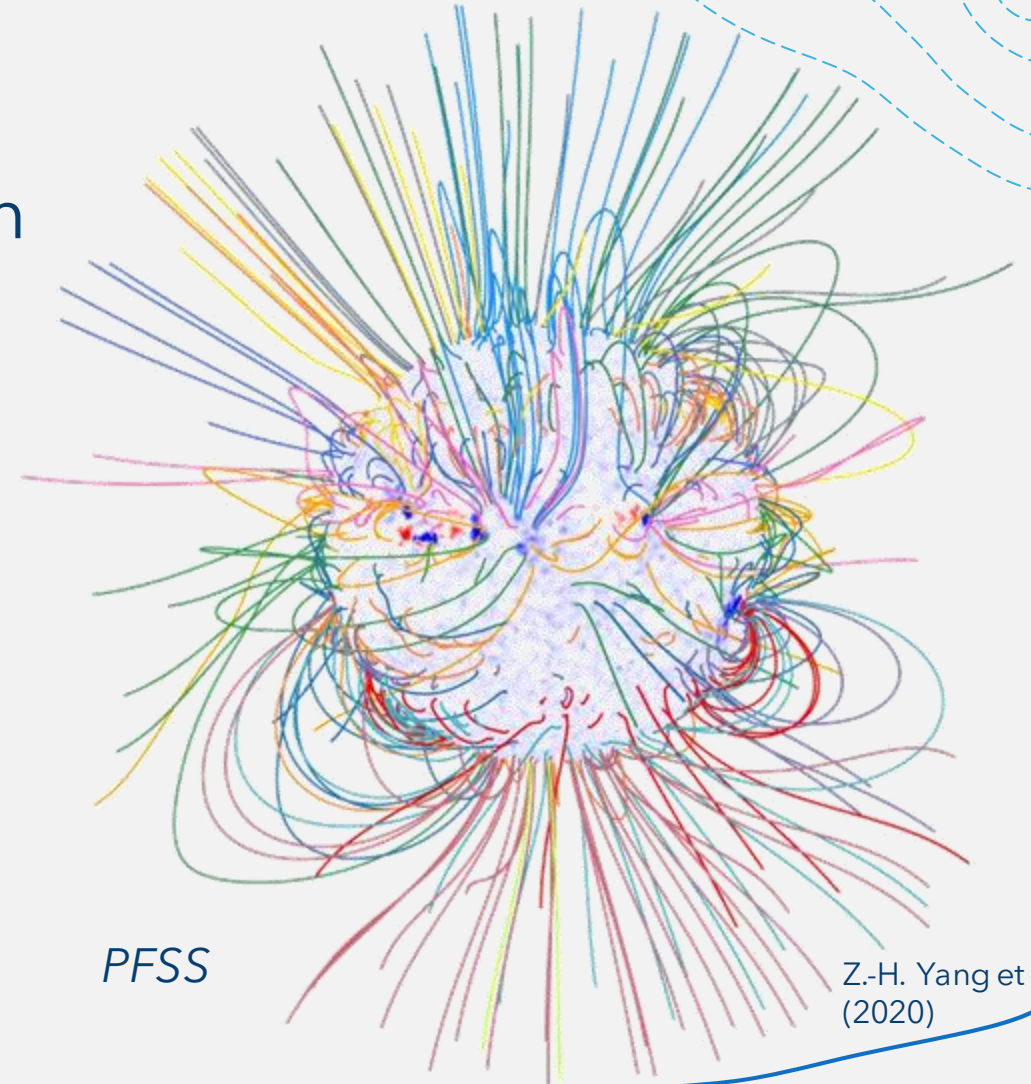


Parker spiral

How are conjunctions identified?

Solar wind propagation prediction

- + Parker spiral model
- + Potential-Field Source-Surface (PFSS) model



PFSS

Z.-H. Yang et al. (2020)

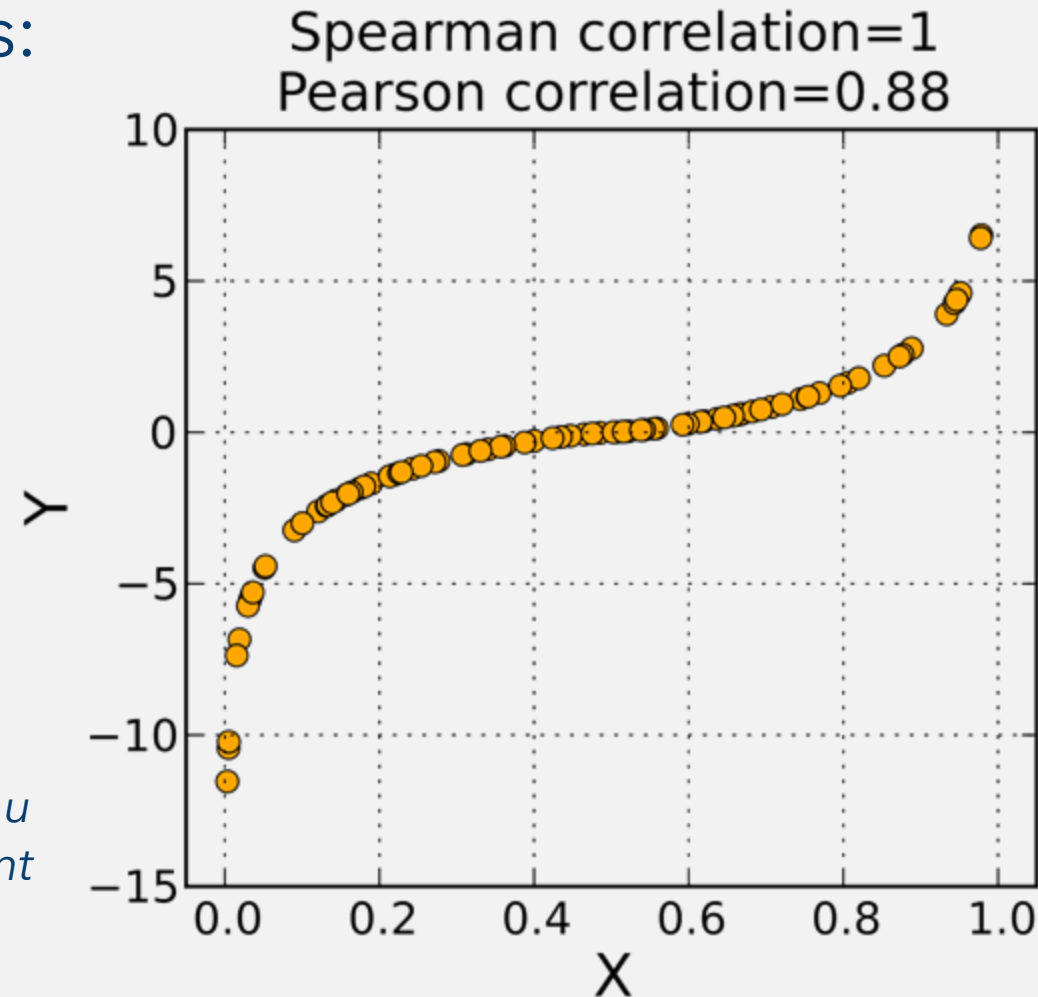
How are conjunctions identified?

For "hidden" conjunctions:

looking at *in-situ* data

+ Correlations

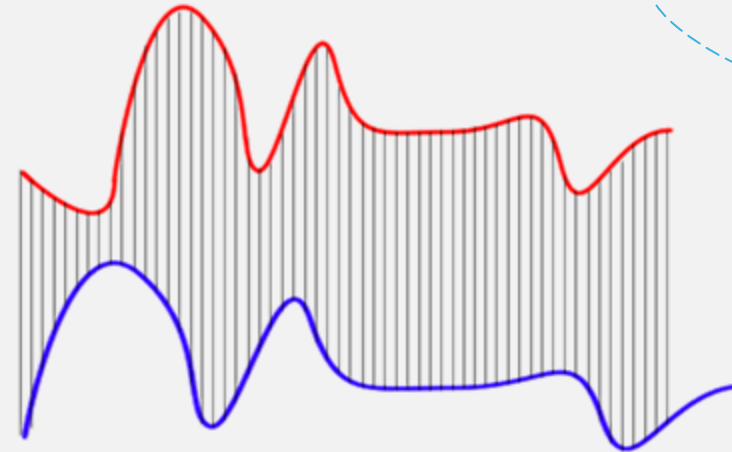
Pearson's vs. Spearman's tau correlation coefficient



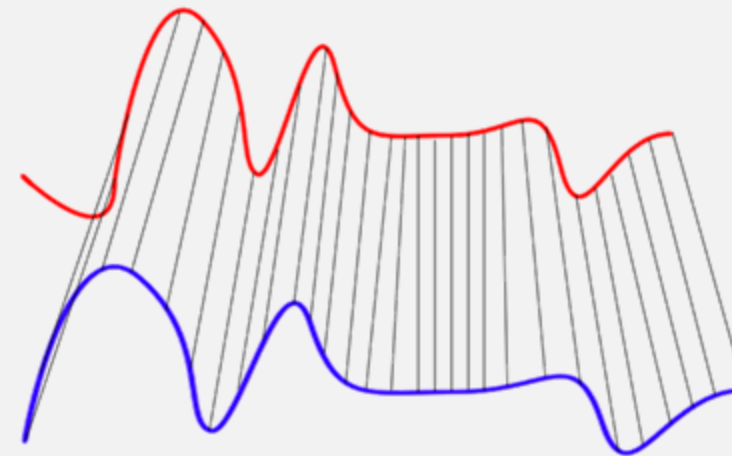
How are conjunctions identified?

For “hidden” conjunctions:
looking at *in-situ* data

- + Correlations
- + Dynamic Time Warping
 - + A similarity metric that allows unsynchronized timeseries to vary in speed



Euclidean Matching

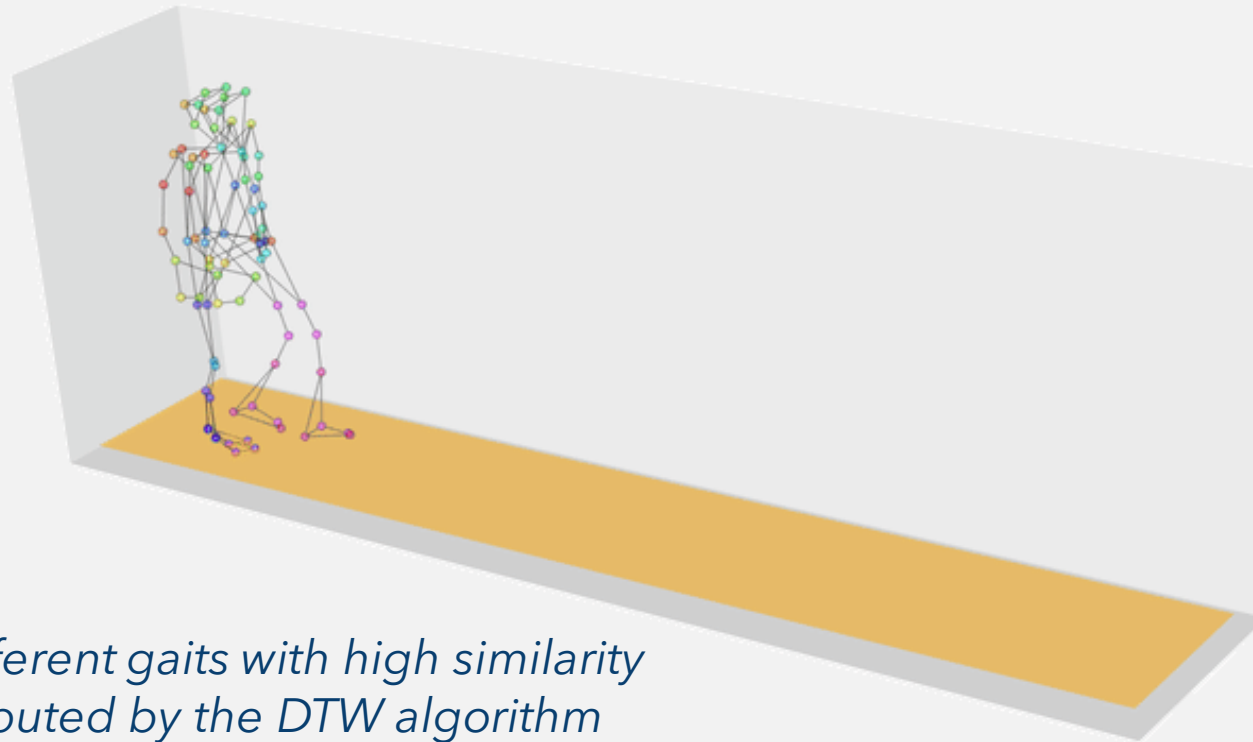


Dynamic Time Warping Matching

Credit: XantaCross

Dynamic Time Warping

- + This is useful to identify common (or slightly varying) features observed at different speeds



Two different gaits with high similarity as computed by the DTW algorithm

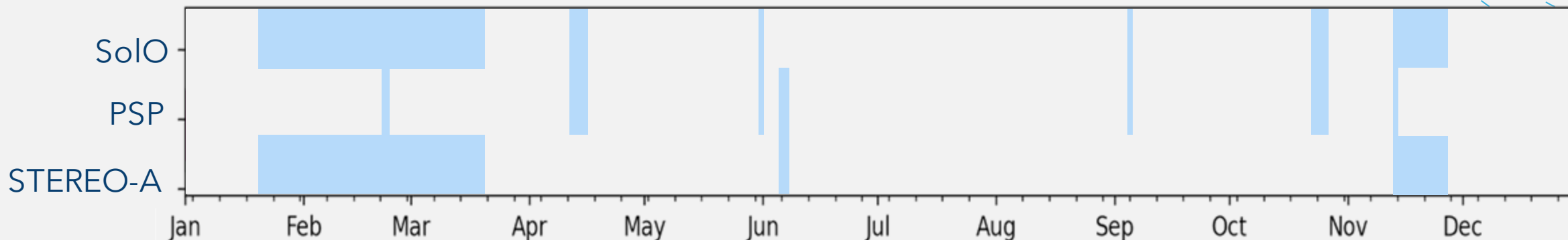
Credit: Lars Lau Raket

Preliminary Results for 2022

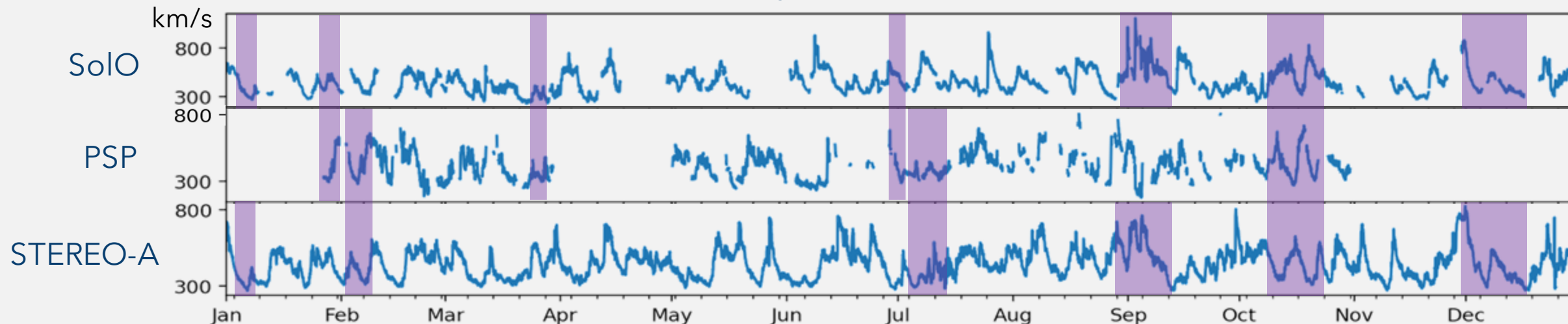
(Solar Orbiter, Parker Solar Probe and STEREO-A only)

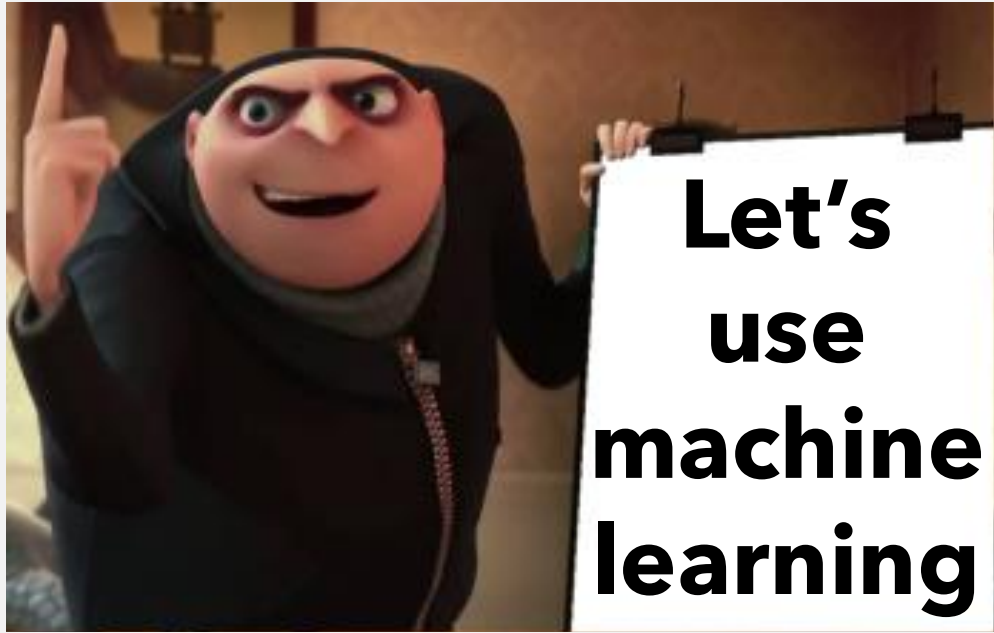


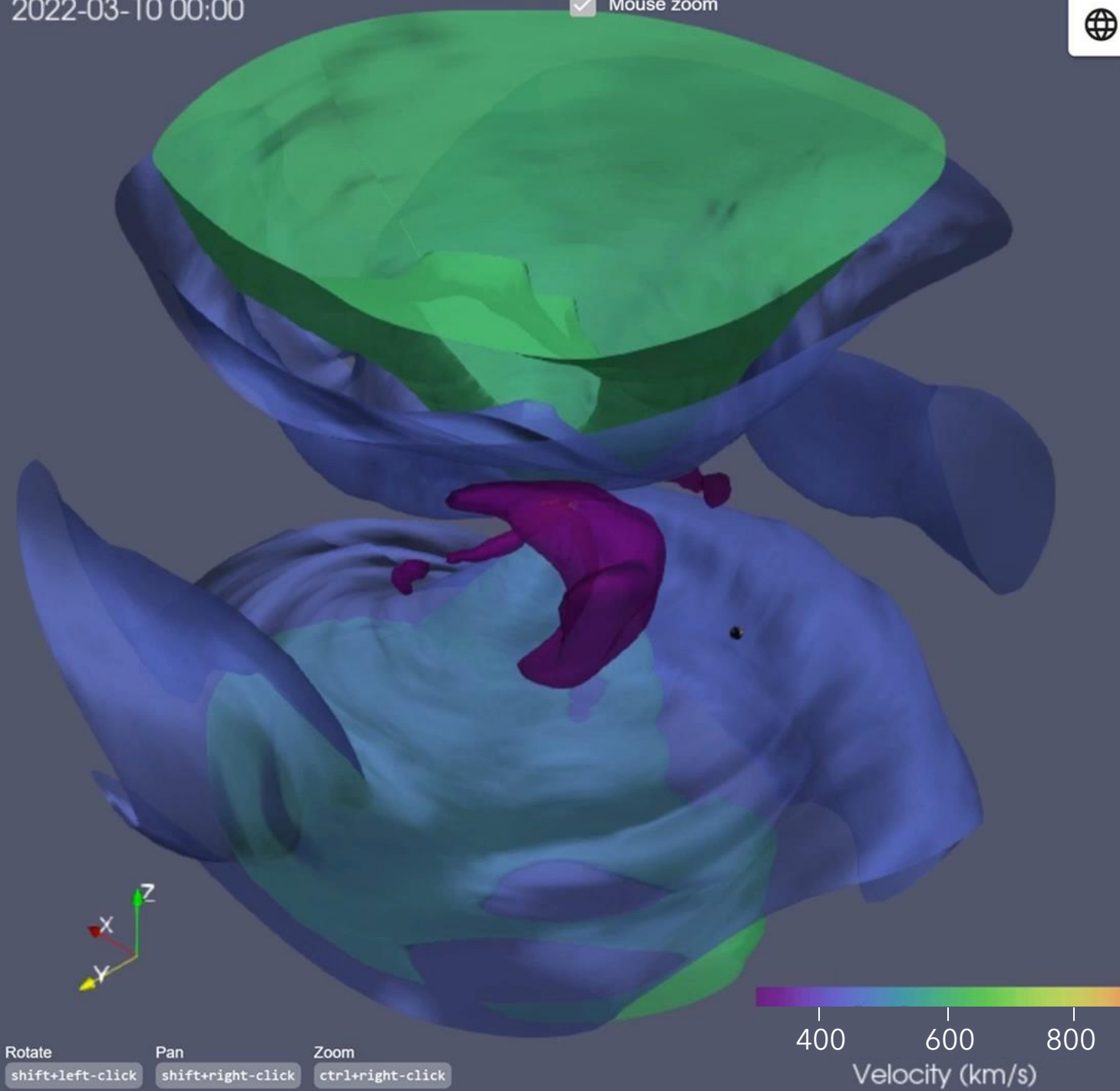
+ Known conjunctions



+ Candidates for 'hidden' conjunctions





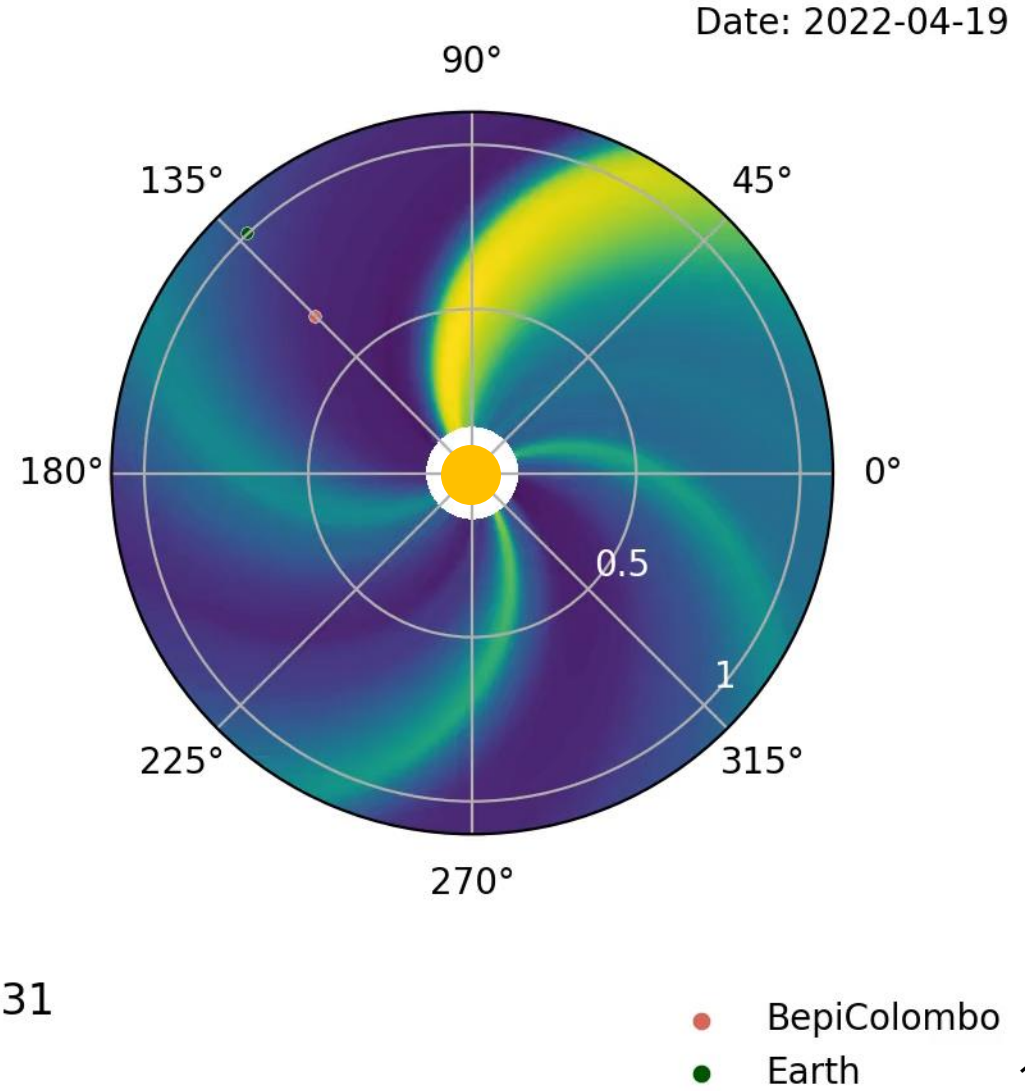
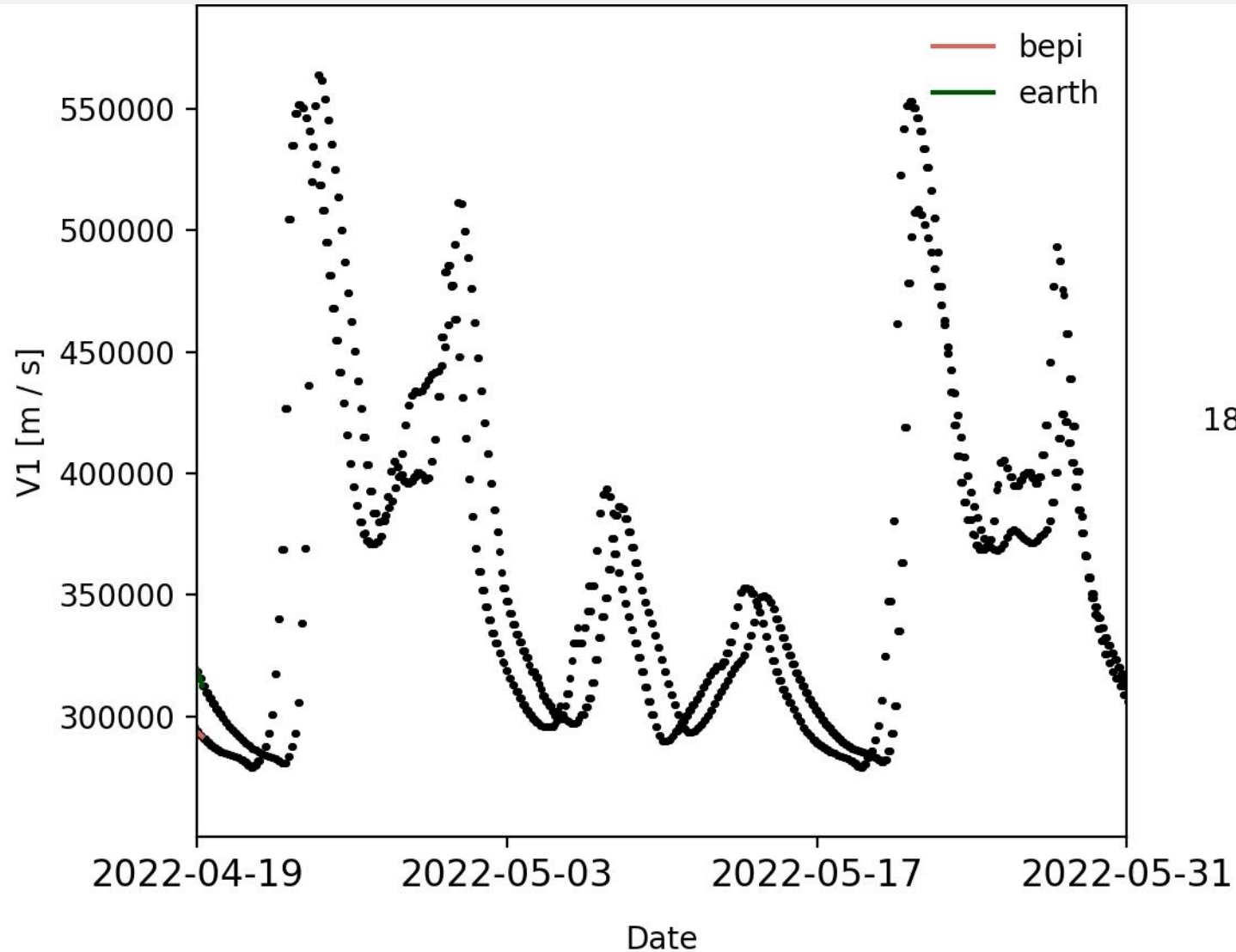


Simulations!

- + Use magneto-hydrodynamic (MHD) simulations to produce synthetic data
- + Identify simulated conjunctions by tracing flow path between spacecraft

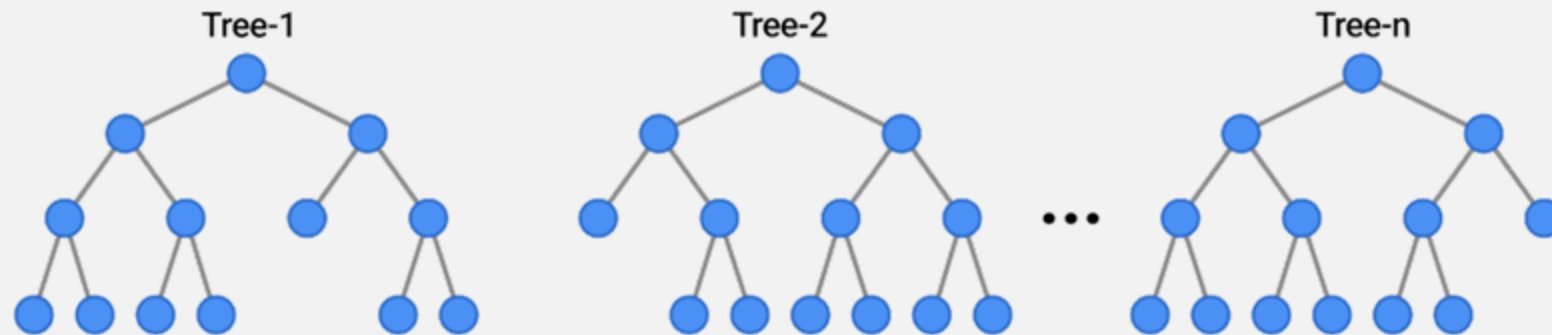
<https://swx-trec.com/h3lioviz/visualizer>
ENLIL run visualized with
H3lioViz

Example of a synthetic Parker spiral conjunction



Next steps

- + Train ML models using simulated timeseries to find candidate conjunctions
- + Hopefully, we find more hidden conjunctions and increase the scientific return of existing and future heliophysics missions!



Random Forest algorithm

Thank you for listening

