LESIA l'Observatoire de Paris | PSL

Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

PSP FIELDS

RPW

Solar wind radial evolution with Parker Solar Probe and Solar Orbiter

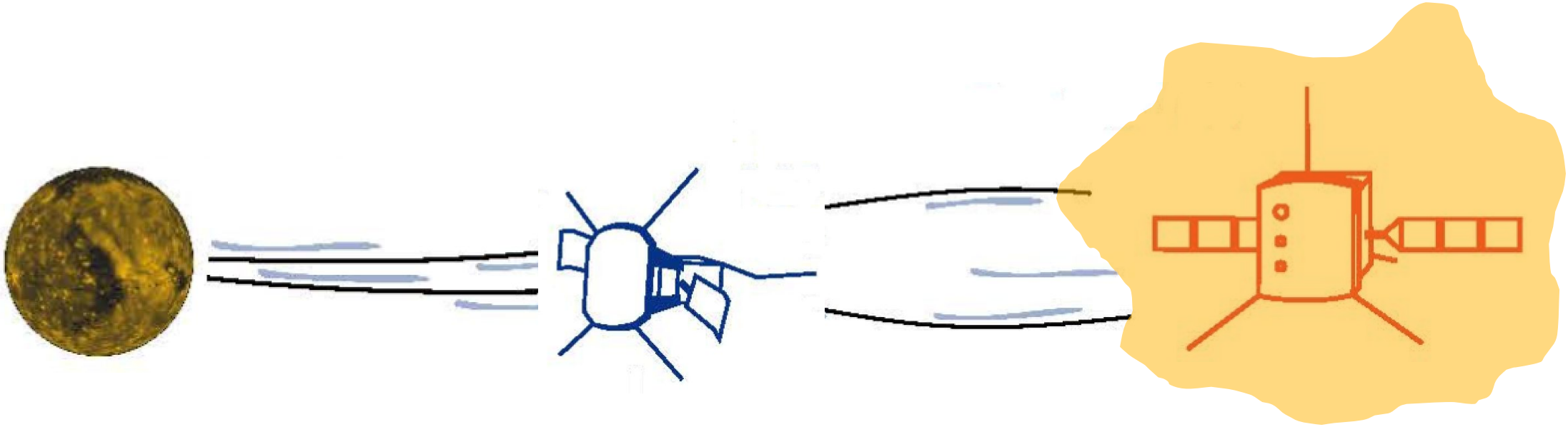




Joint SolO/RPW & PSP/FIELDS workshop

Etienne Berriot, Olga Alexandrova, Pascal Démoulin,
Arnaud Zaslavsky, Milan Maksimovic, Georgios Nicolaou

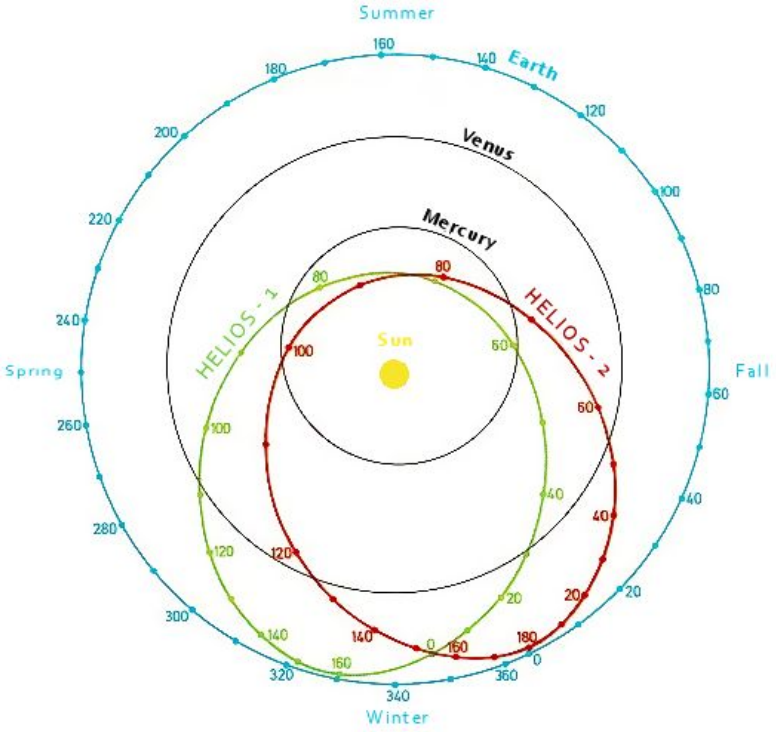
Goal : detect and study the same parcel of solar wind at different distances from the Sun (plasma line-up)

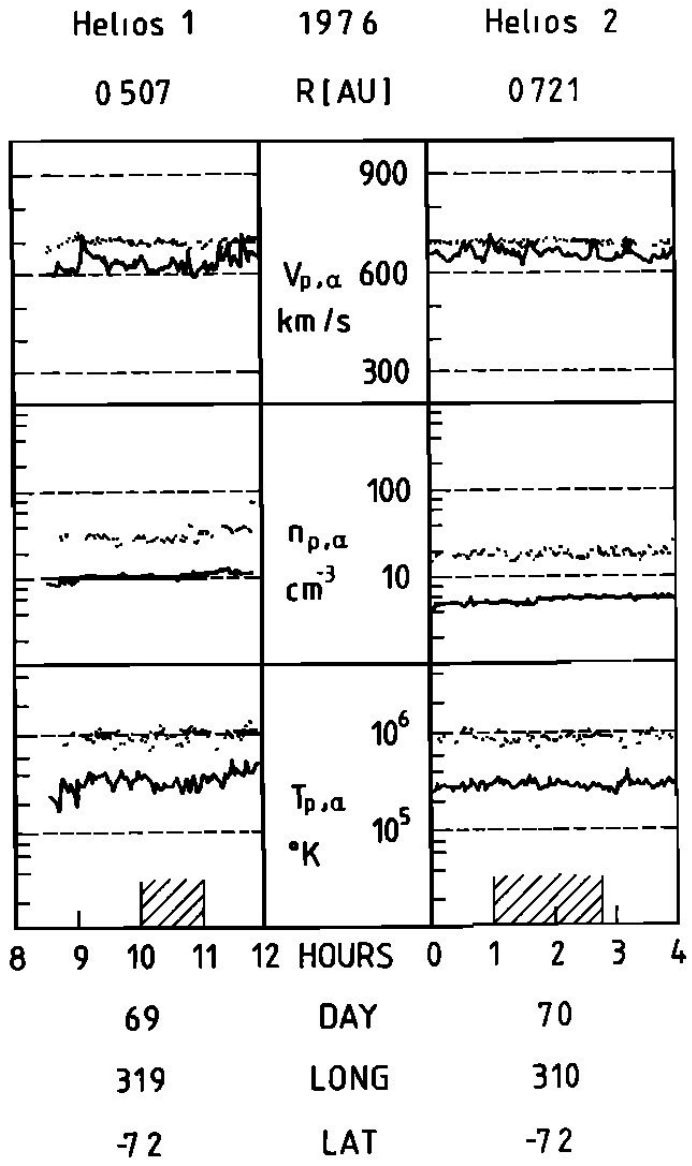


Sun Parker Solar Probe Solar Orbiter

Caracterisation of the solar wind radial evolution !

1st case study of plasma line-up with Helios 1 & 2 : Schwartz & Marsch, 1983

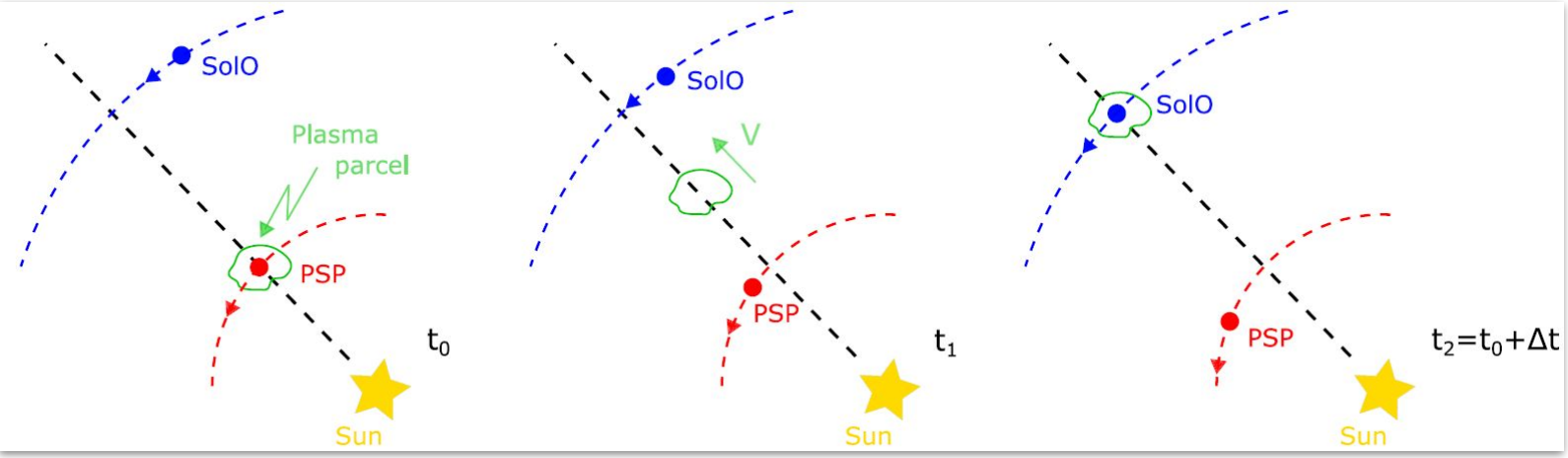




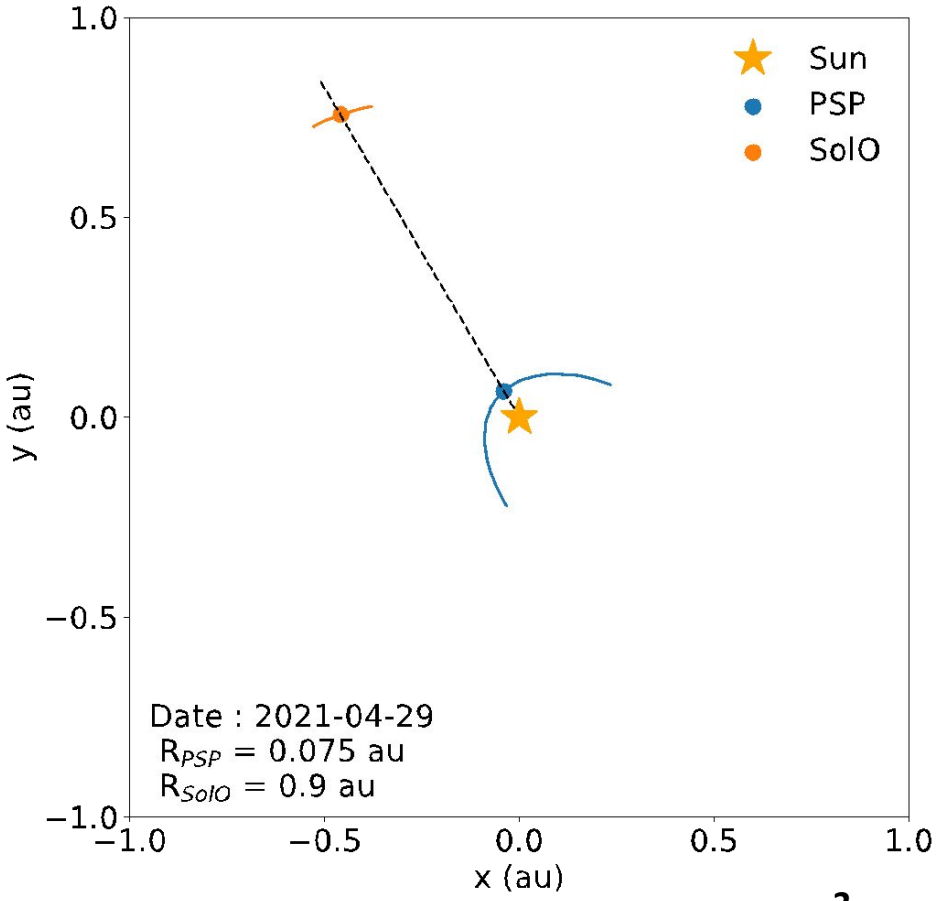
- Fast solar wind
- Prediction assuming a constant and radial propagation velocity.
- Solar wind's expansion taken into account.
- Helios era : few studies, not very concluding (large error bars, data gaps)

PSP, SolO : new opportunity to study solar wind radial alignments

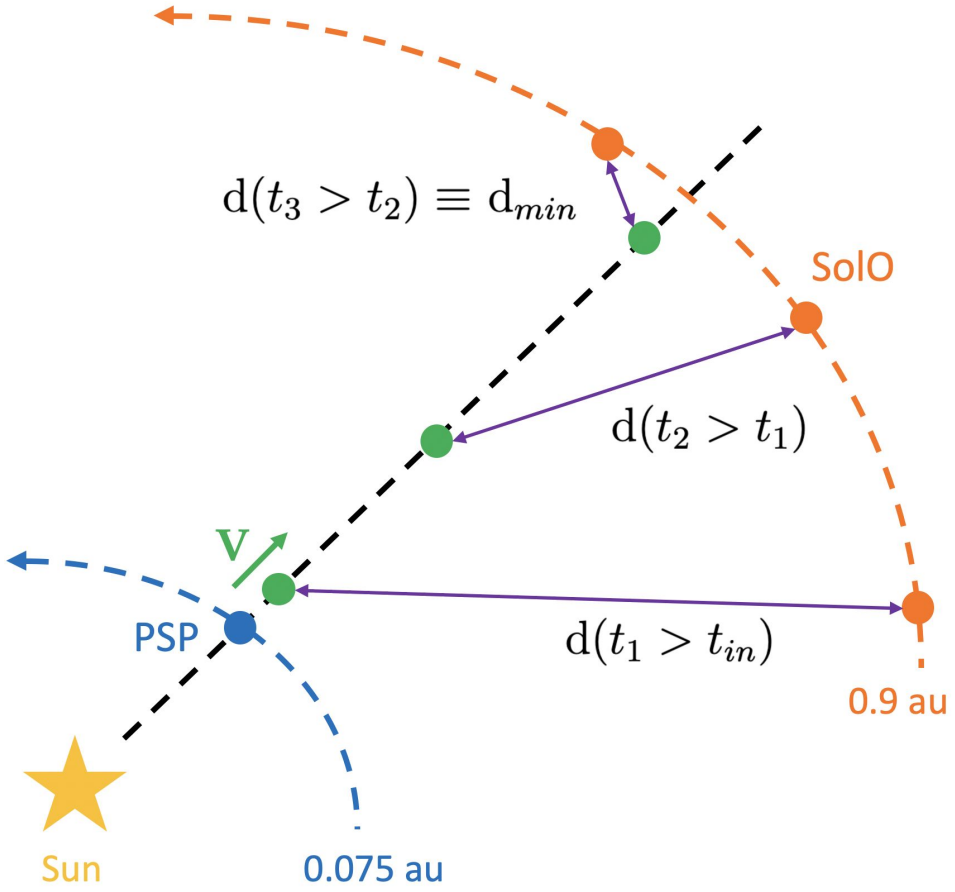
Schematic: Telloni et al. [2021]



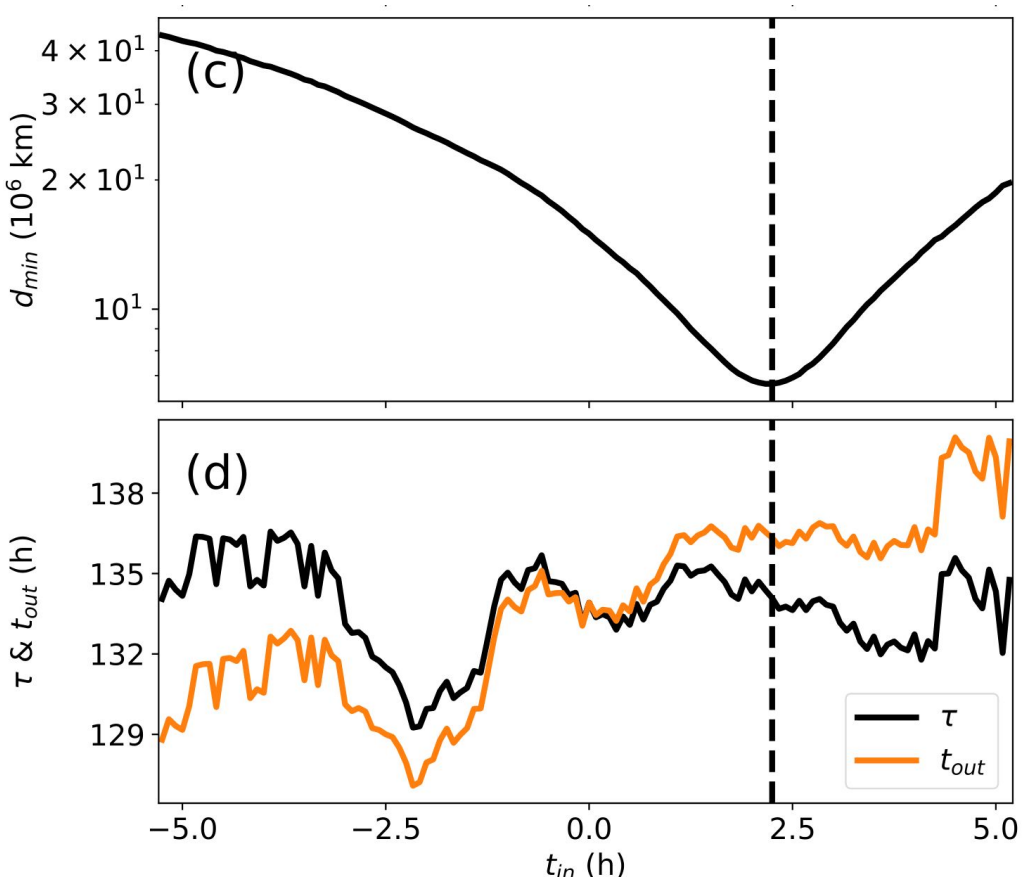
1. Find an approximate alignment between the two spacecraft.
2. Establish a propagation model using the inner spacecraft measurements.
3. Identify the same plasma on both spacecraft.



Plasma propagation method



$$\mathrm{d}(t, t_{in}) = |\mathbf{R}_{out}(t) - \mathbf{R}_{parcel}(t, t_{in})|$$



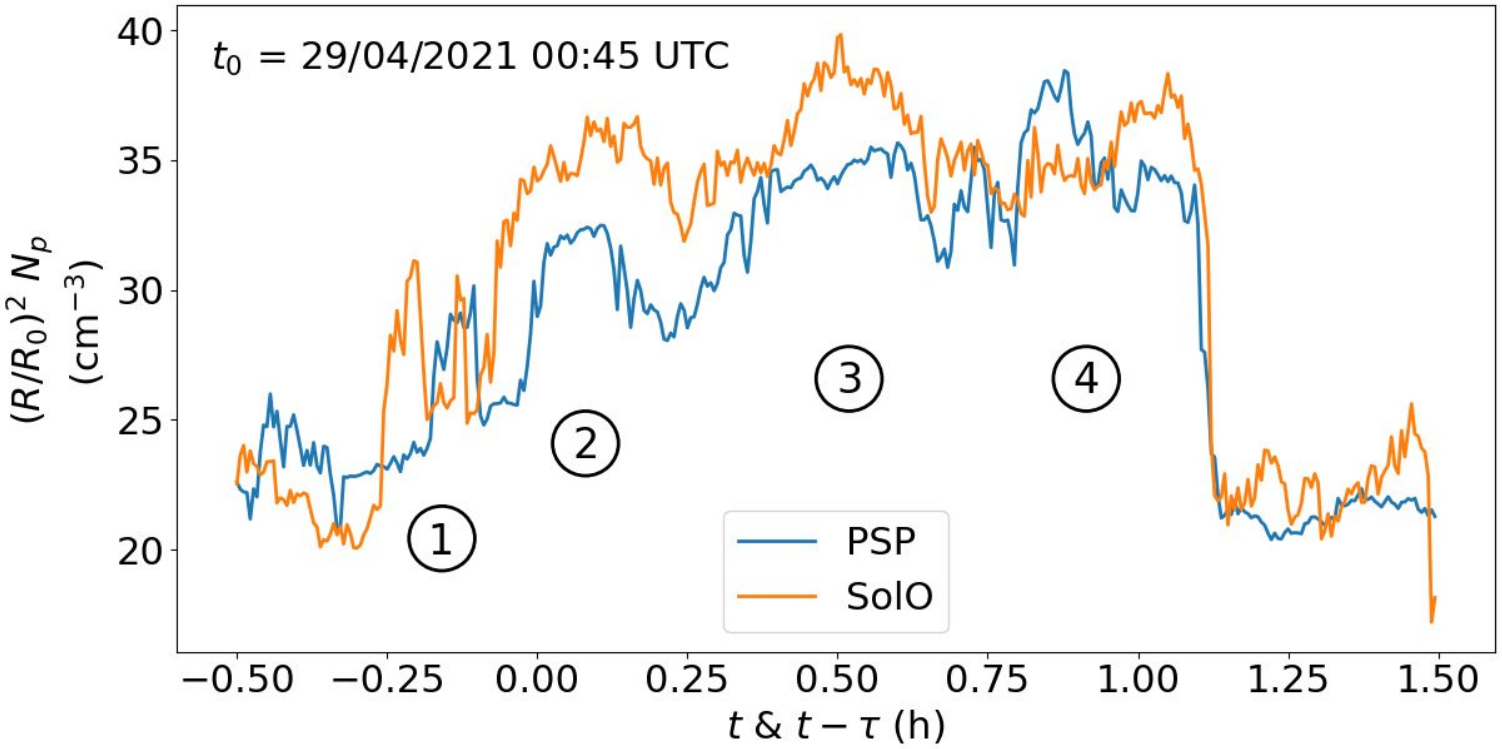
➡ propagation time (~134 h).

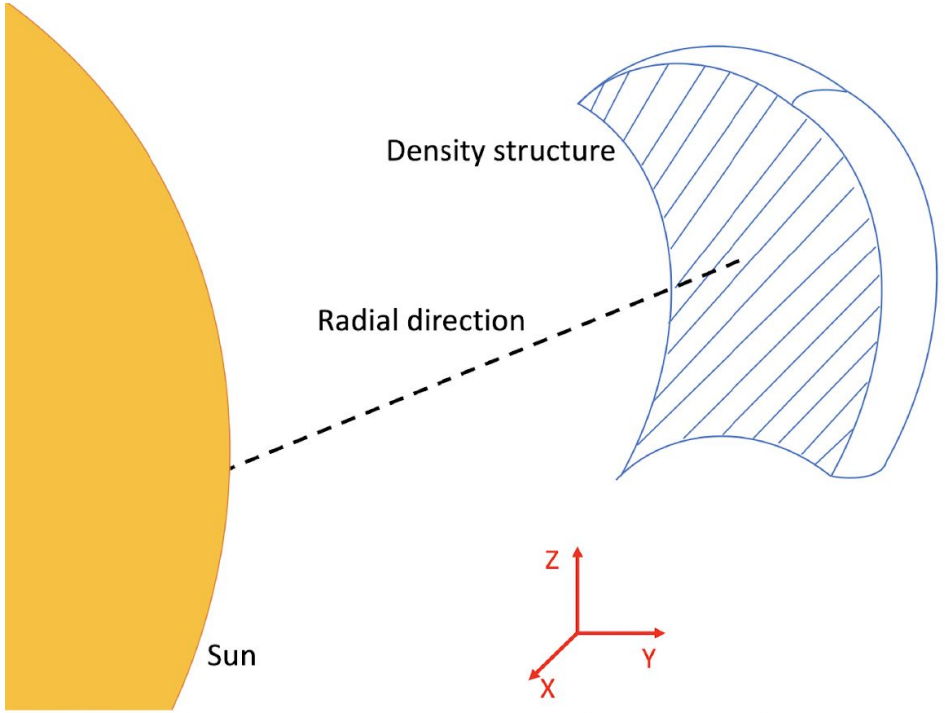
Refinements :

- Constant acceleration constrained by measurements
- Non-radial propagation

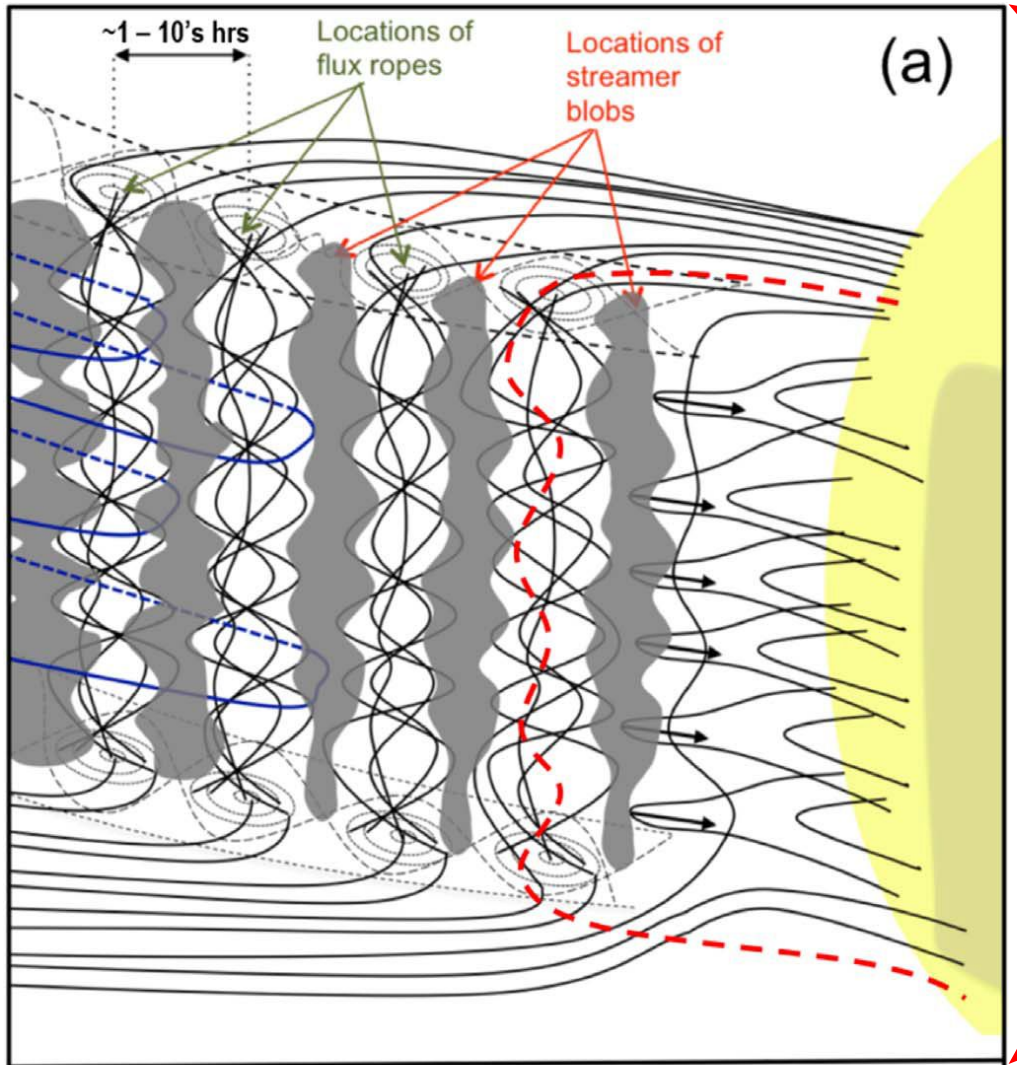
Same structure identification

Matching density structures

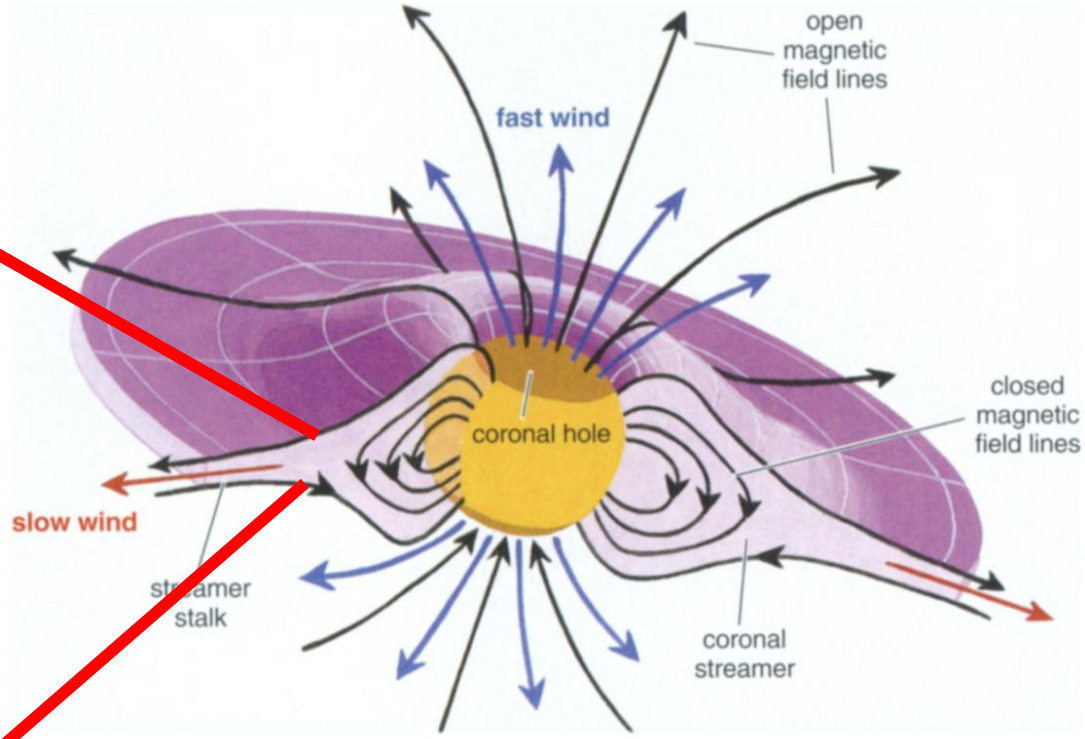




Heliospheric Current and Plasma Sheets (HCS/HPS) substructures



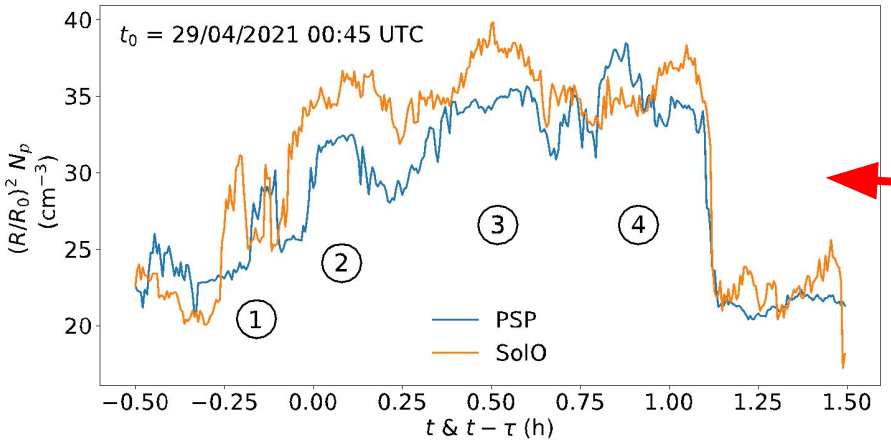
Schematic of the HCS/HPS close to the Sun.
Lavraud et al. 2020



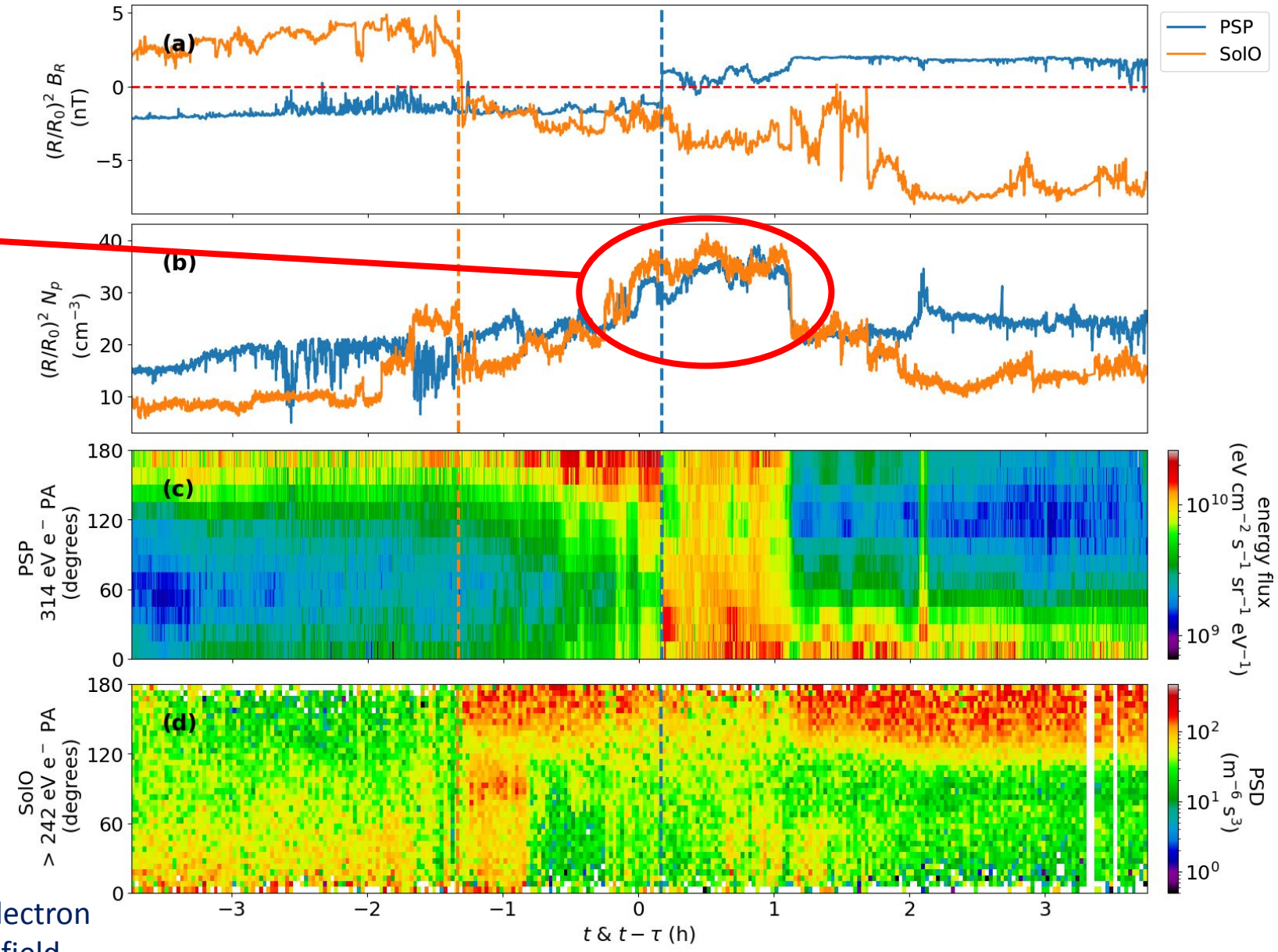
Schematic of the heliospheric magnetic field and solar wind sources.
Woo and Habbal 2002

- The Heliospheric Plasma Sheet has a complex topology and is formed of several substructures.

Comparison PSP-SolO (zoom out)

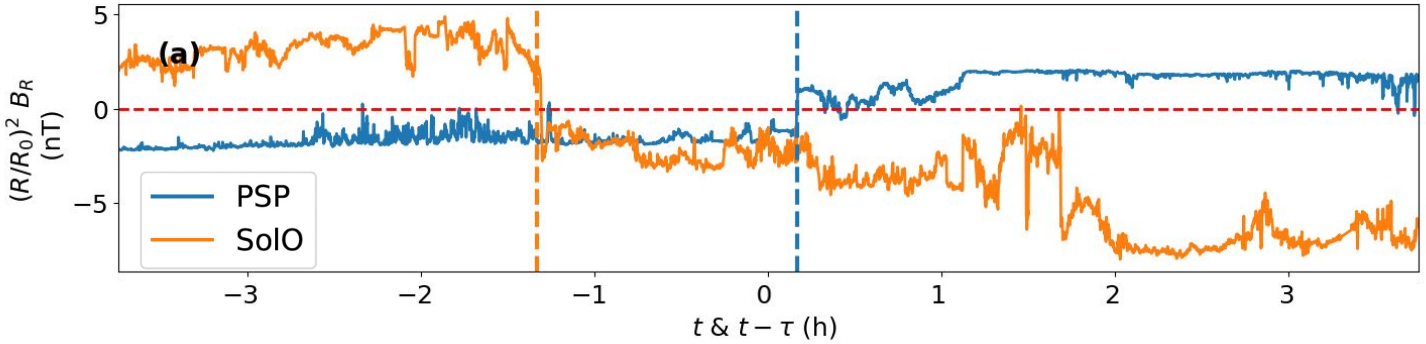


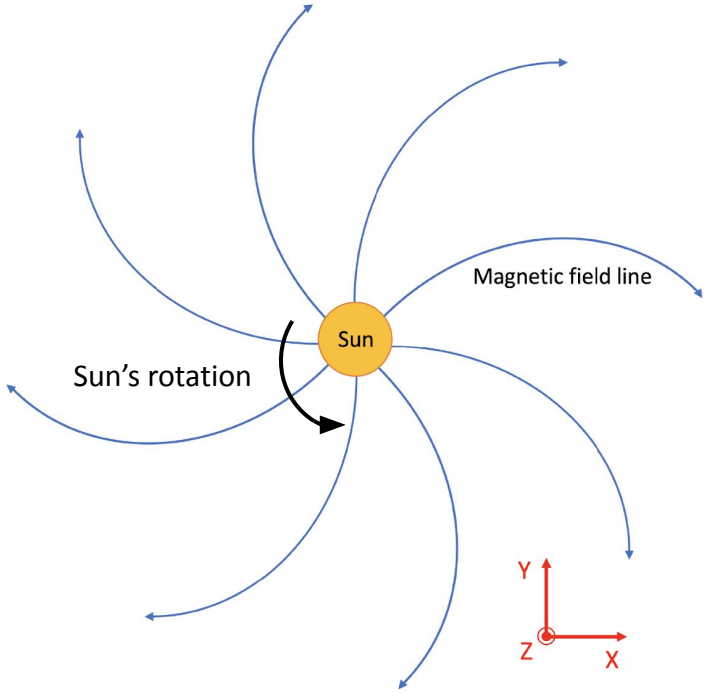
- Physical parameters indicate crossings of the HCS/HPS on both PSP and SolO.
- B-data ⇒ PSP & SolO go through the HCS in opposite directions.

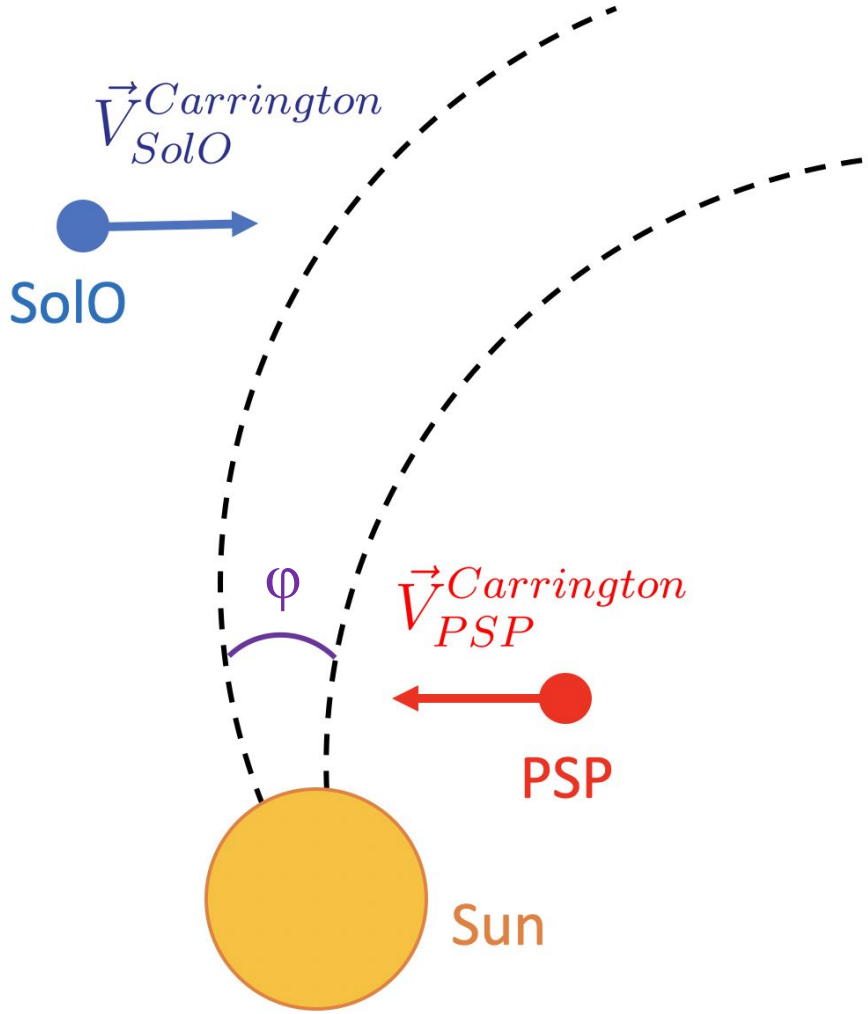


Pitch Angle (PA) = angle between electron energy flux and local magnetic field

Taking into account the Sun's rotation



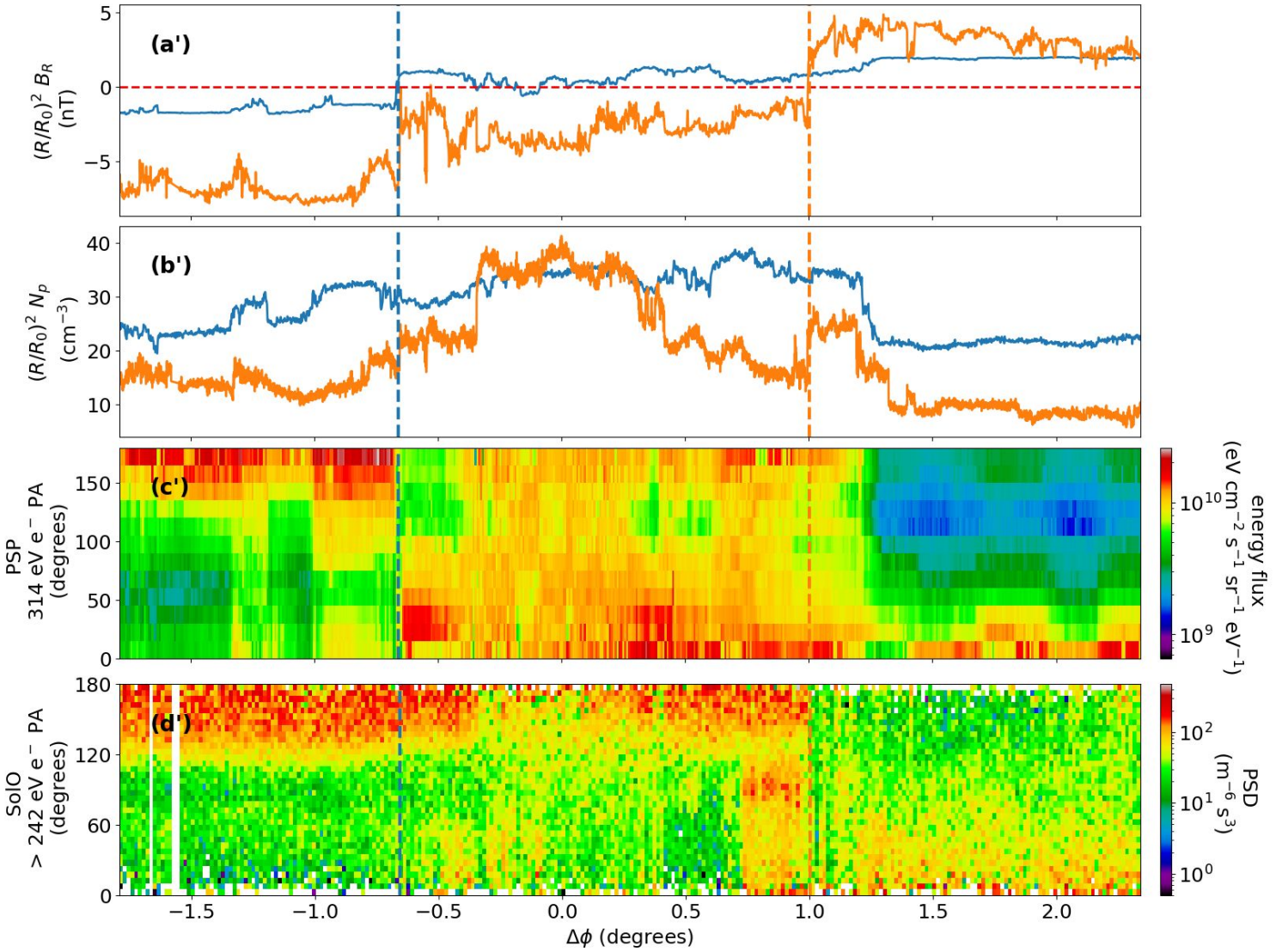


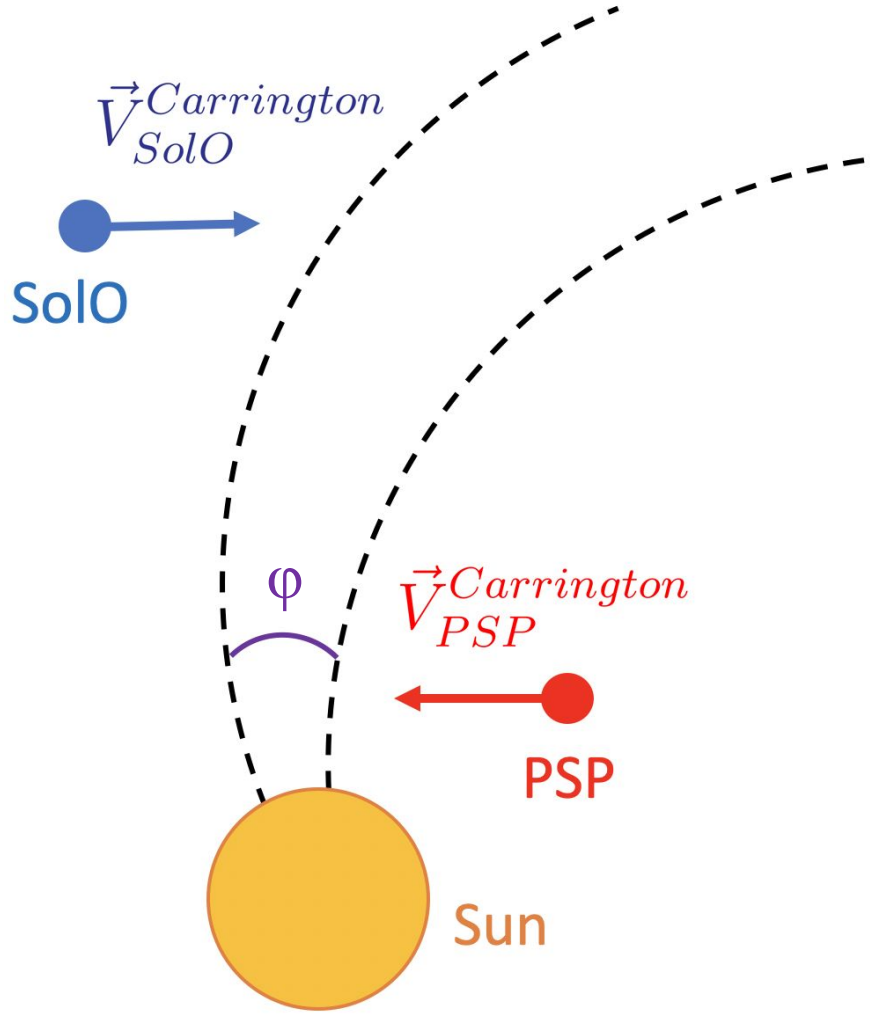


- We take into account the solar and spacecraft rotations:

$$\Delta\phi = (\omega_{inner} - \omega_{Sun})\Delta t_{inner}$$
$$\Delta\phi = (\omega_{outer} - \omega_{Sun})\Delta t_{outer}$$

Taking into account the Sun's rotation

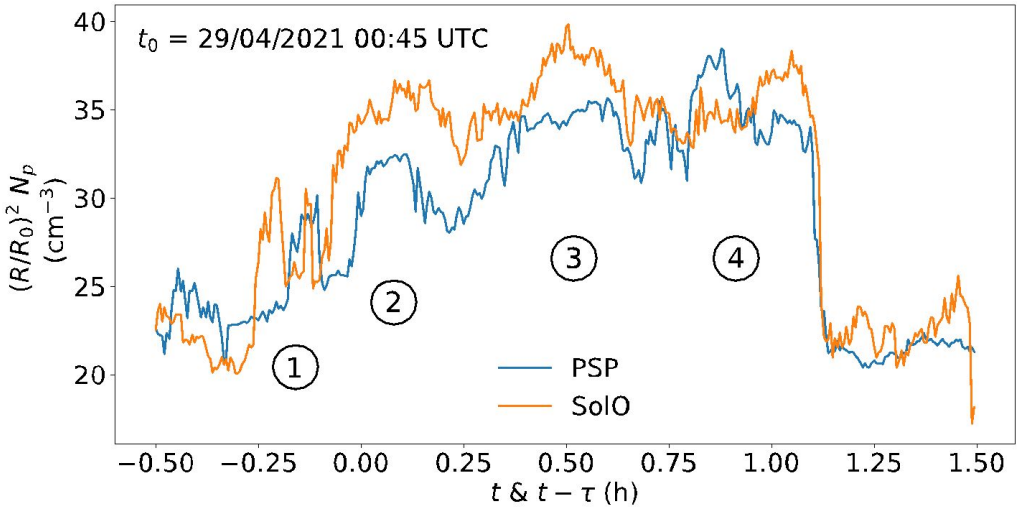




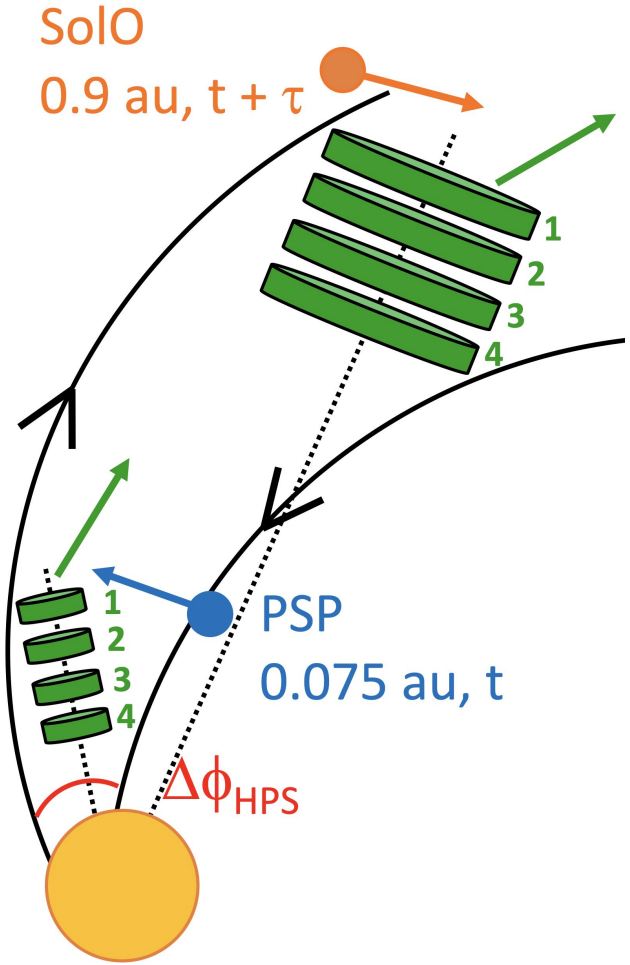
- We take into account the solar and spacecraft rotations:

$$\Delta\phi = (\omega_{inner} - \omega_{Sun})\Delta t_{inner}$$
$$\Delta\phi = (\omega_{outer} - \omega_{Sun})\Delta t_{outer}$$

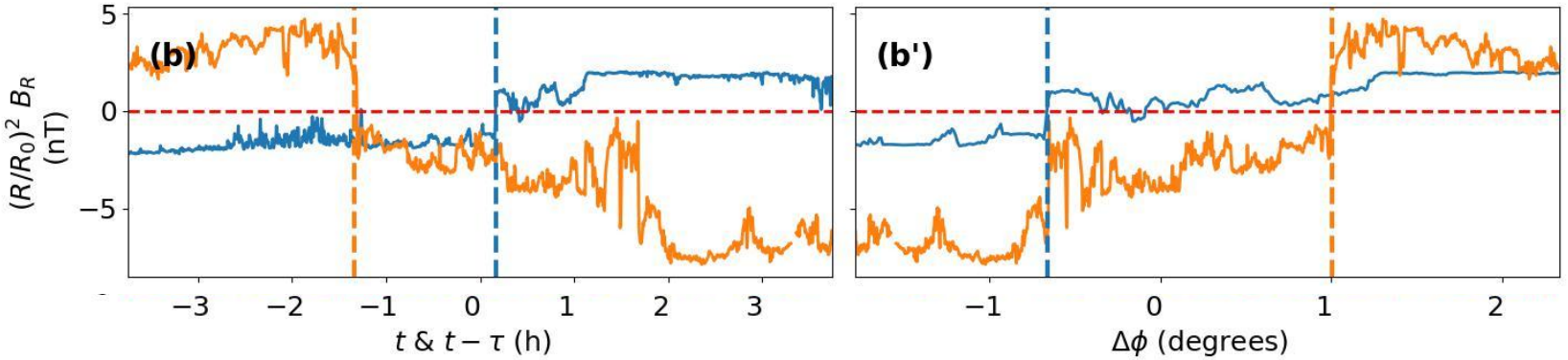
Interpretation



Density structure advected by the solar wind ⇒ radial gradients



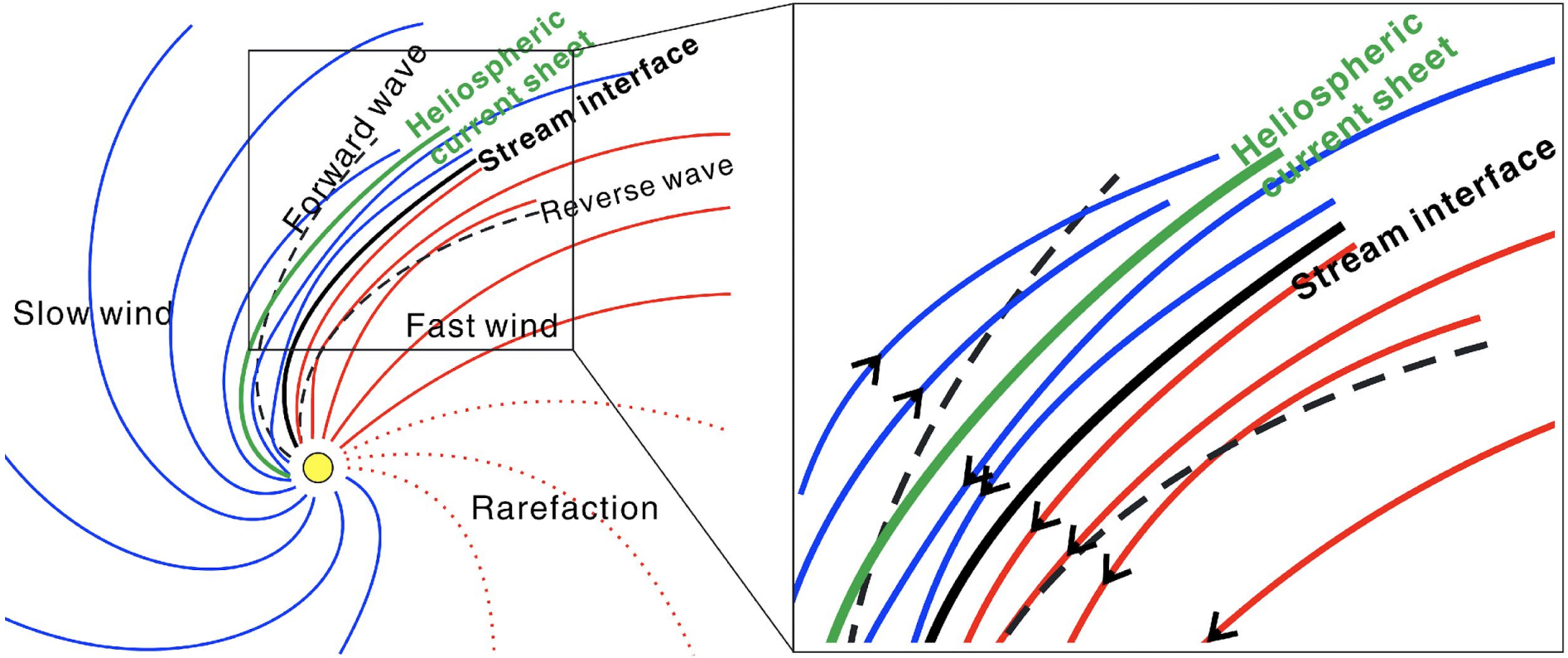
Magnetic inversion linked with the solar wind sources ⇒ longitudinal gradients



Streams Interaction Regions (SIR) and HCS

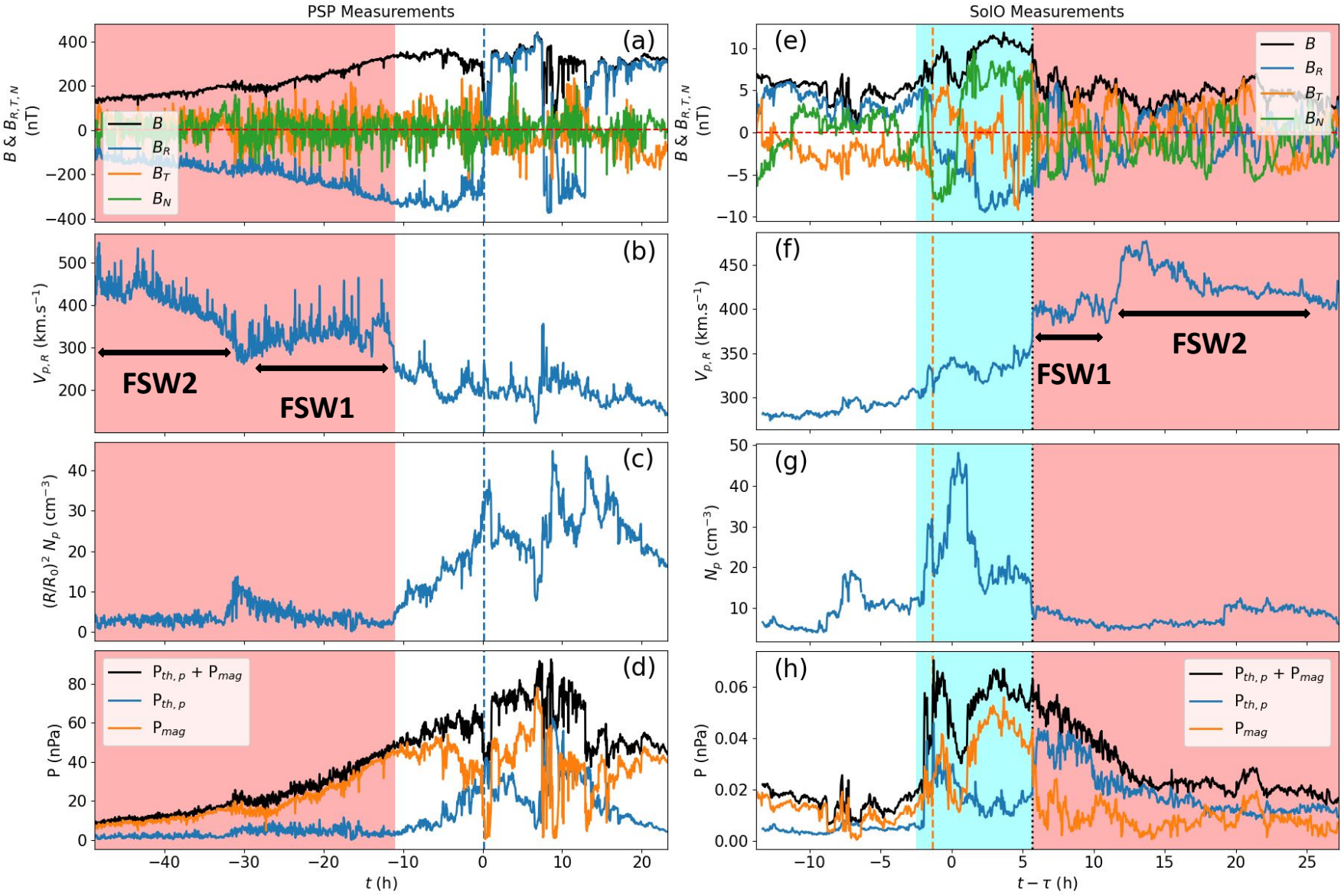
- Due to the Sun's rotation the slow wind can be caught up by a faster wind ⇒ formation of SIR.
  ⇒A pair of propagating shocks can also develop at the edges of the interaction region.

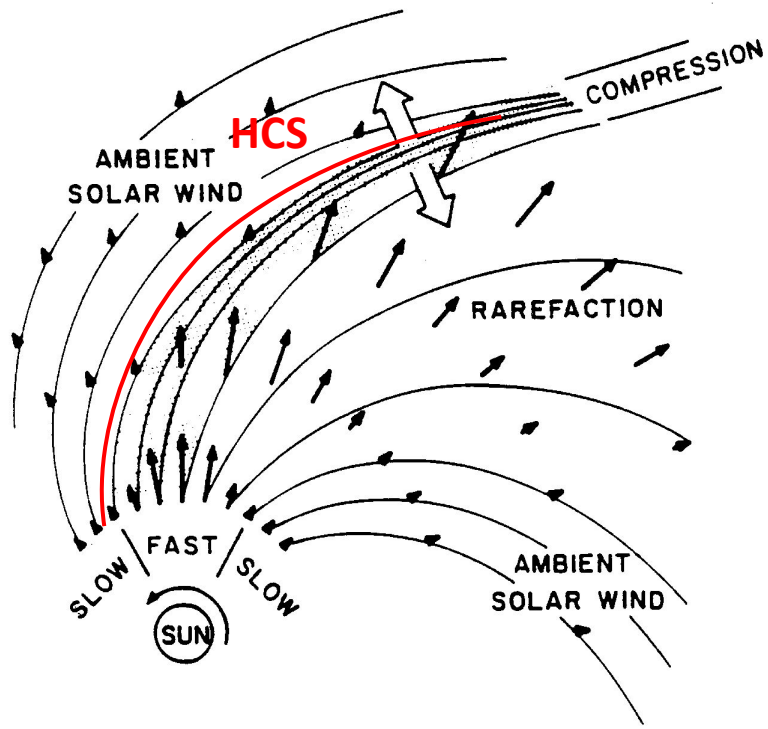
- Depending on the magnetic field topologie SIR can also engulf the HCS and HPS.



Schematic a SIR interacting with the HCS **Huang et al. 2016**

Zoom-out:
Stream Interaction Region (SIR)





Stream Interaction region schematic **Gosling et al. 1999**

Summary

- Propagation Method:
  Constant Velocity ⇒ Constant acceleration ⇒ Non-radial propag.
- Identification of a same density structure.
- Density structure corresponds to a sector boundary substructure.
- Taking into account the Sun's rotation to compare magnetic field data between the 2 spacecraft.
- Observation of Stream Interaction Region forming then engulfing the Heliospheric Current Sheet at SolO.

Futur work

- Characterize and compare the HPS fine scale structure at both spacecraft.