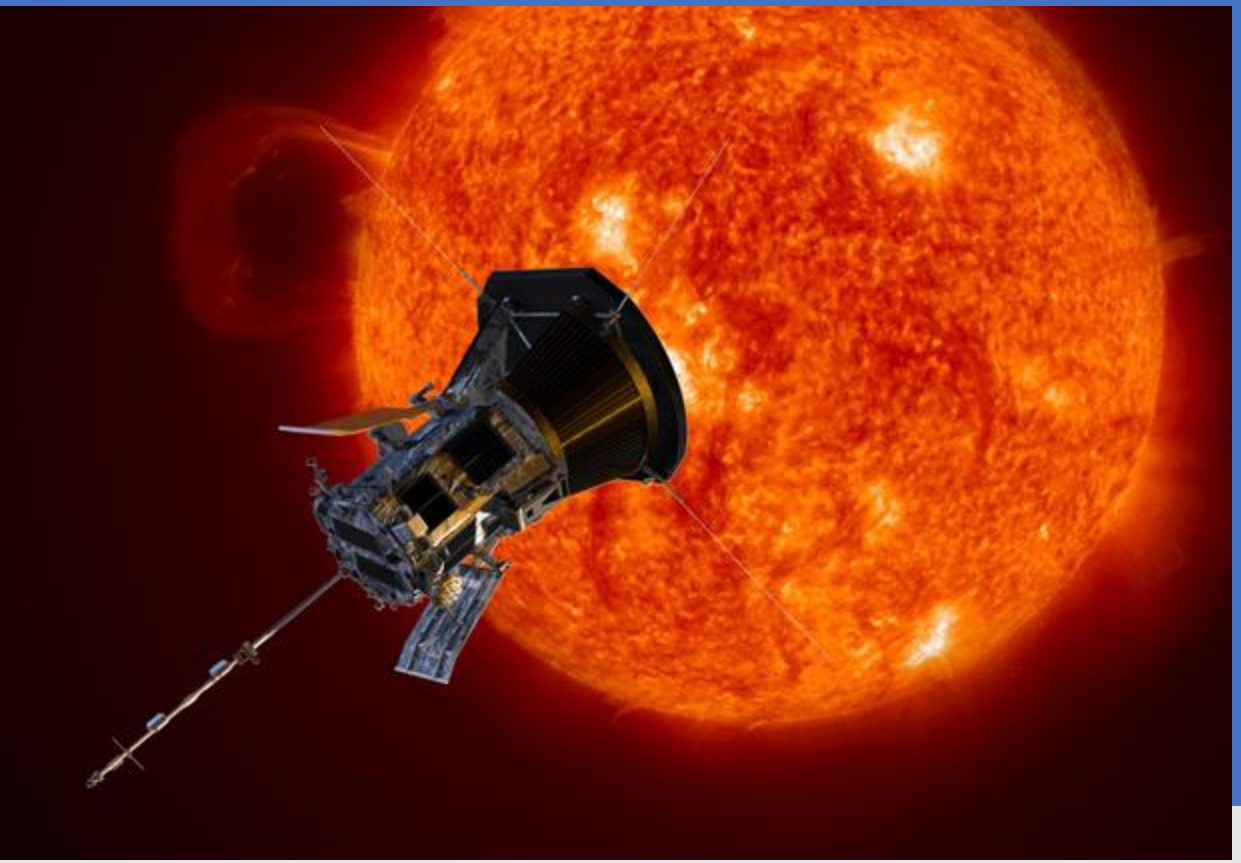
KU LEUVEN

ROYAL OBSERVATORY OF BELGIUM



Solar wind observed by Parker Solar Probe and modelled by EUHFORIA

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About solar wind (SW):

What we know about solar wind?

- *Fast SW:*

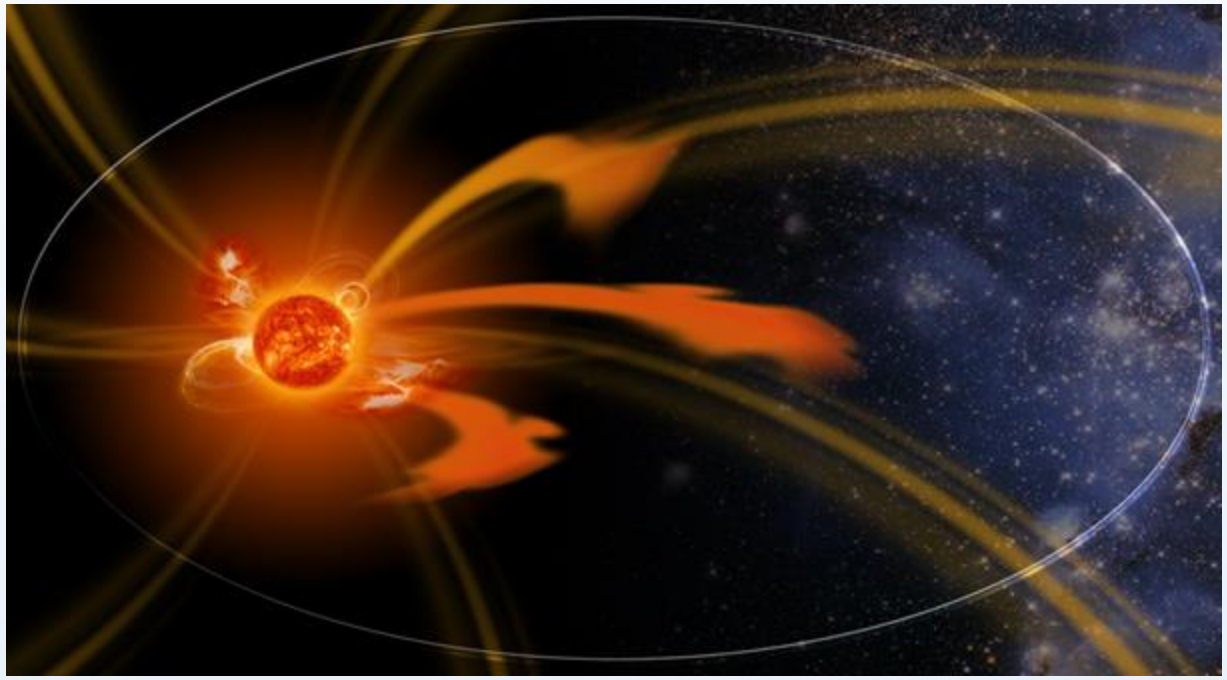
High speed: 500 – 800 km/s
Low density: 3 – 4 particles/cm^3

- *Slow SW:*

Low speed: 250 – 400 km/s
High density: 10.7 particles/cm^3

- *Intermediate SW?!*

Originating from the coronal holes (CHs), but its velocity at 1 au is lower than 500 km/s
(e.g. Schwenn, 2006; Cranmer, Gibson, and Riley, 2017; D'Amicis et al, 2021).



Solar wind observations:

- along 1D spacecraft trajectory:

velocity distributions, particle compositions, derived SW plasma characteristics, magnetic field

- remote sensing – observables integrated along the line of sight

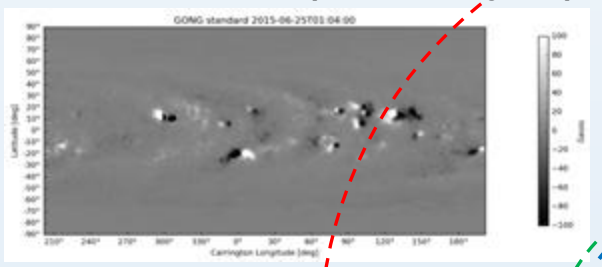
➢ Modelling of the SW can provide us information about its 3D structure!

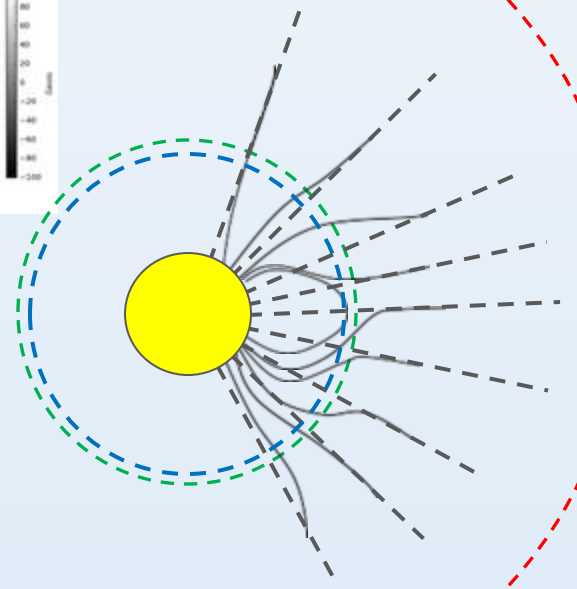
EUHFORIA

Most widely used 3D MHD models of SW are EUHFORIA (Pomoell & Poedts, 2018) & ENLIL (Odstrcil & Pizzo, 1999).

Coronal model:

Main model input are synoptic magnetograms.





Default set up:

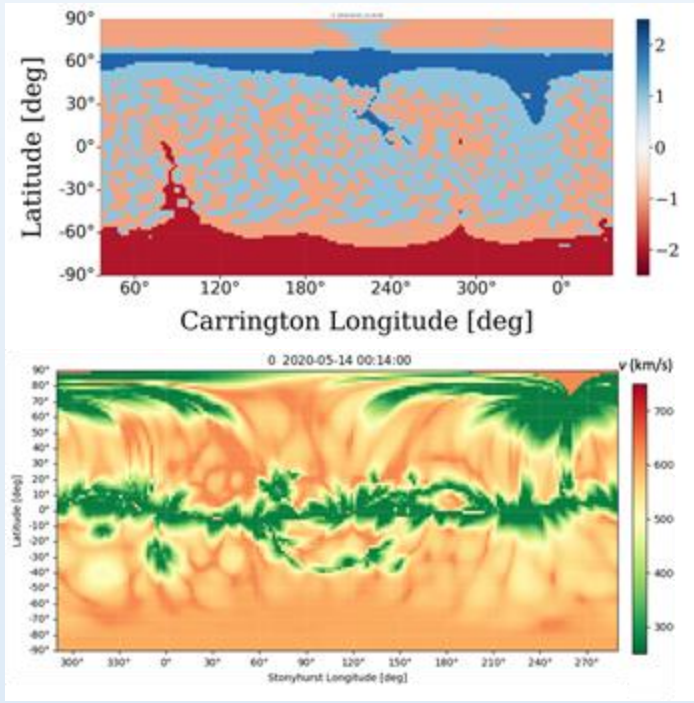
- PFSS model

(1 - 2.6 Rs)

- SCS model

(2.3 Rsun - 0.1 AU)

- Semi-Empirical WSA



Inner boundary magnetic field & speed synoptic maps

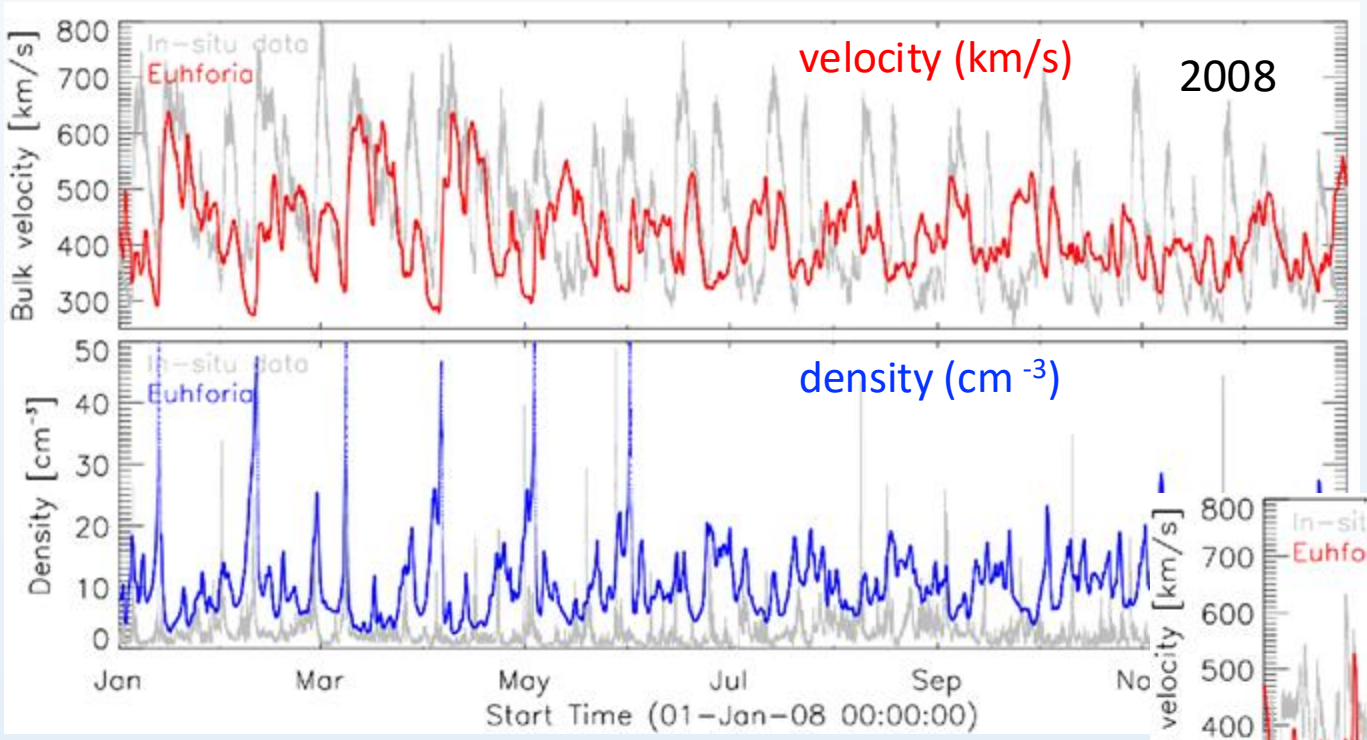
CME insertion at 0.1 au

0.1 au

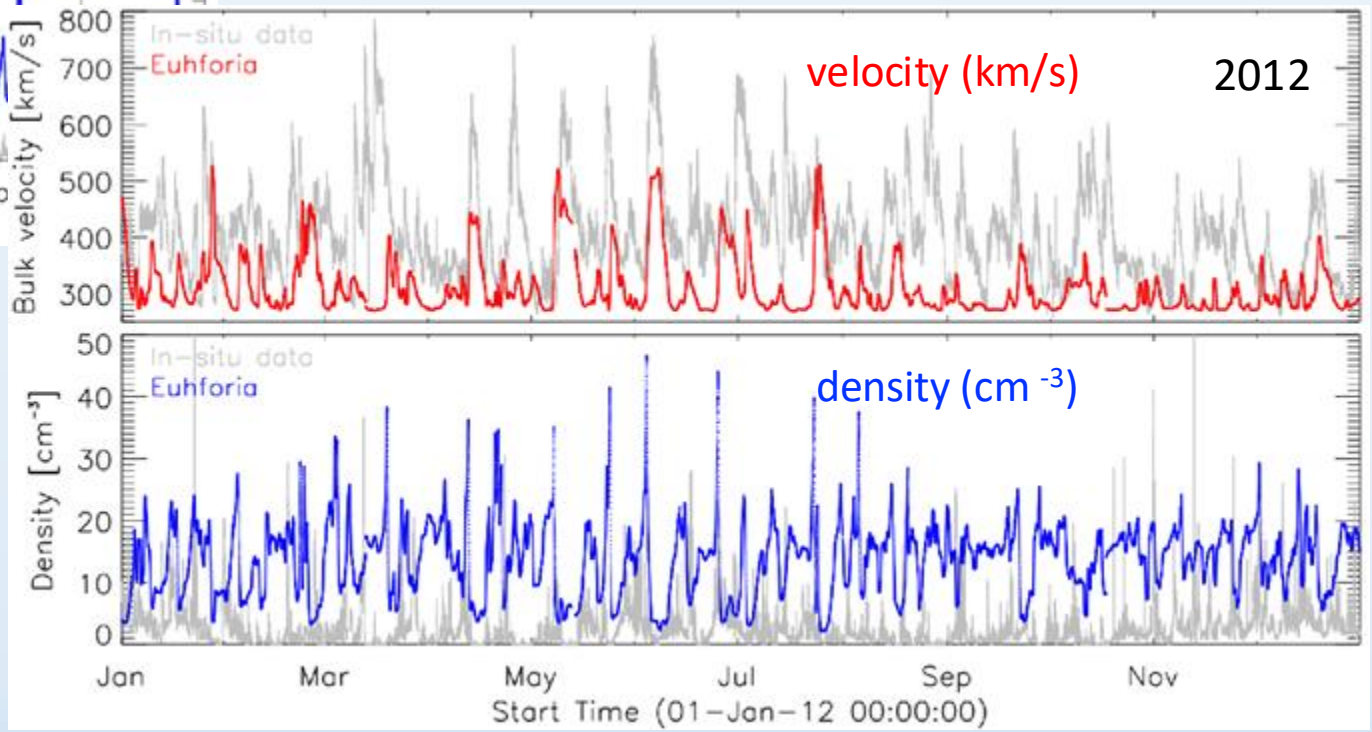
Heliospheric model

3D
2D &
1D output
at up to 2 au.

Modeled solar wind at Earth & in situ data

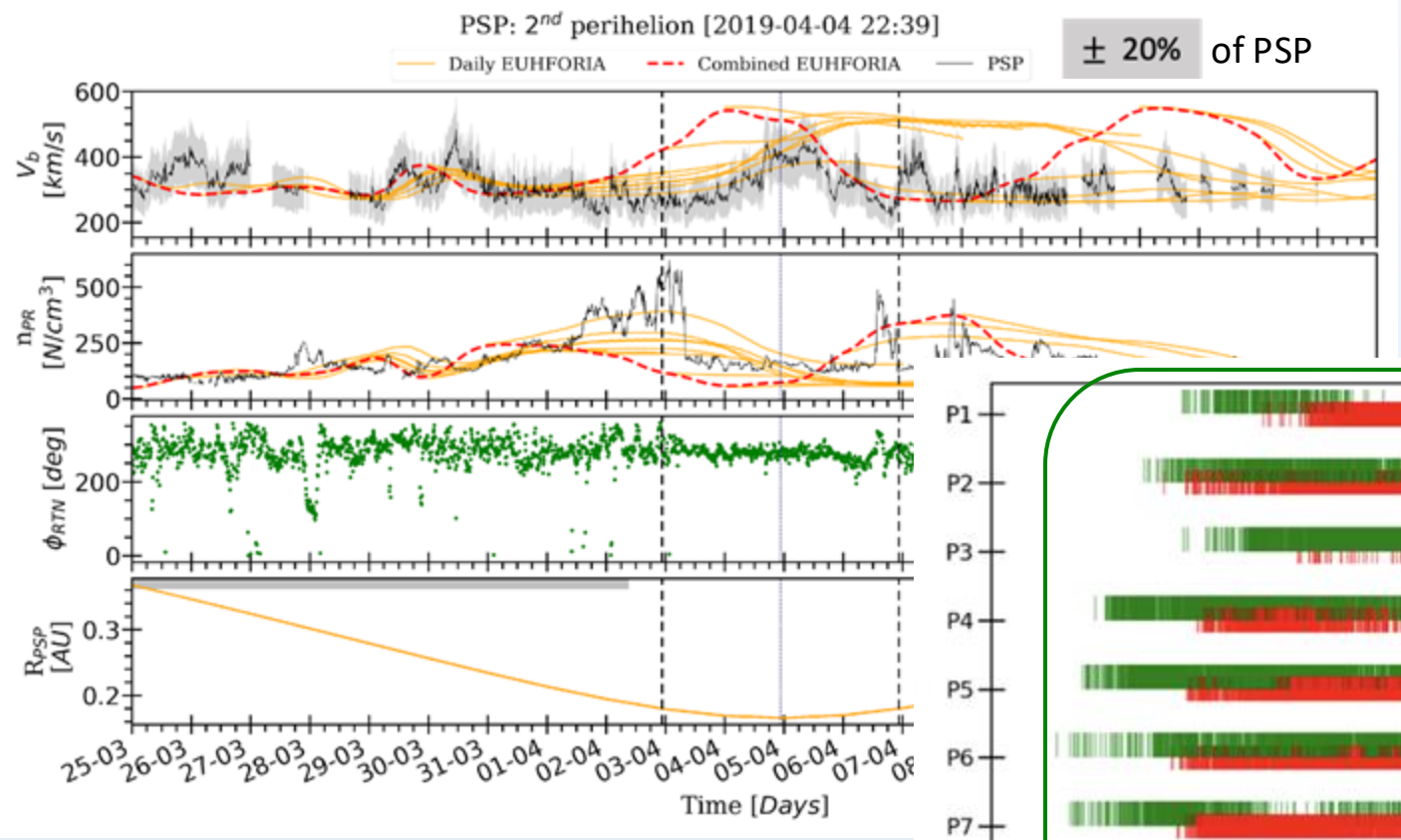


- Modelling of SW at 1 AU with **EUHFORIA** (Hinterreiter et al., 2019).
- The default set-up of EUHFORIA & the GONG synoptic magnetograms.

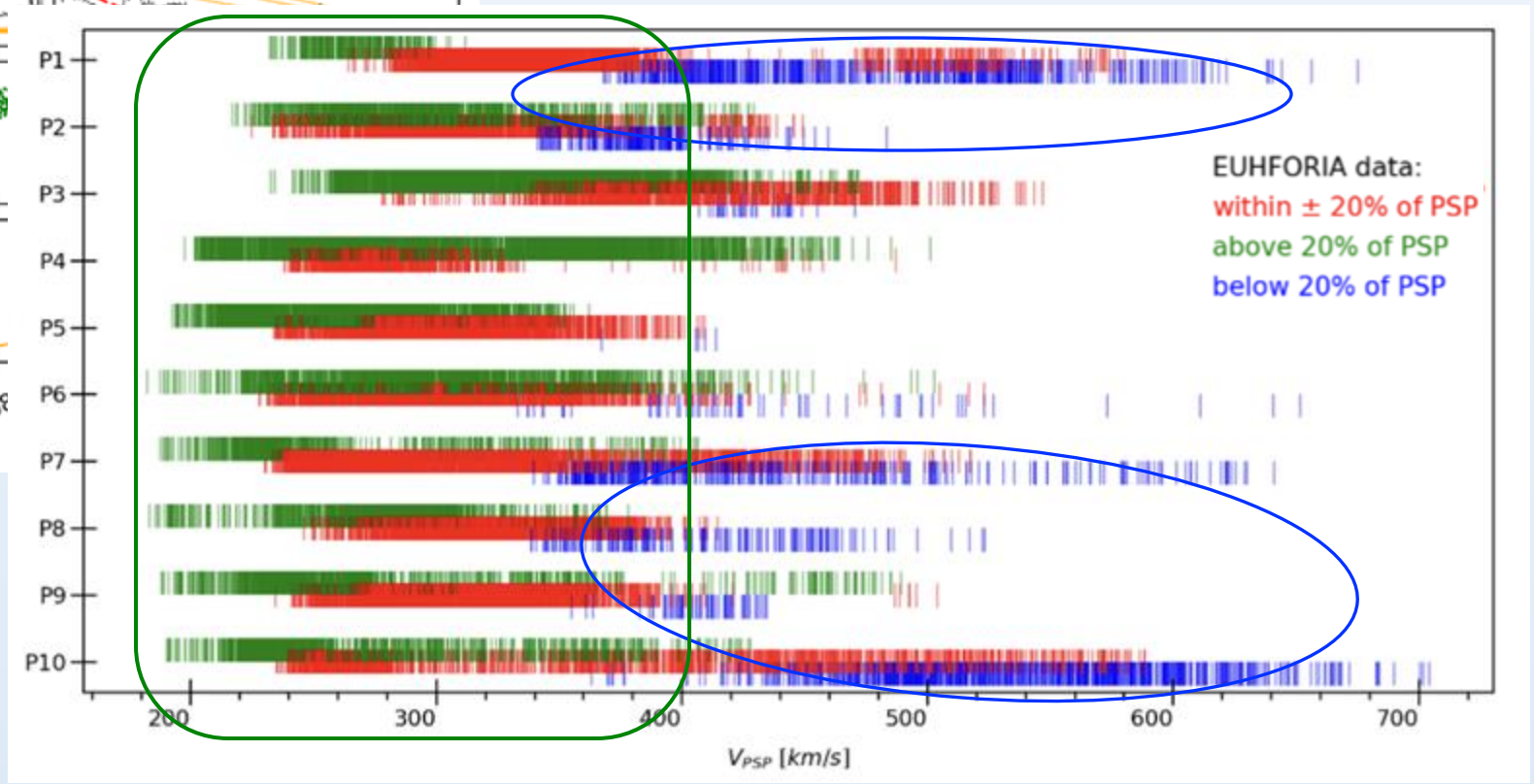


- SW velocity modeled by EUHFORIA is at 1 AU mostly underestimated (Hinterreiter et al., 2019; Samara et al., 2021)

Modeled solar wind at the PSP positions & in situ data



- The modeled SW at PSP distances (first 10 close encounters) shows generally overestimated SW velocity (Senthamizh, et al., to be submitted).



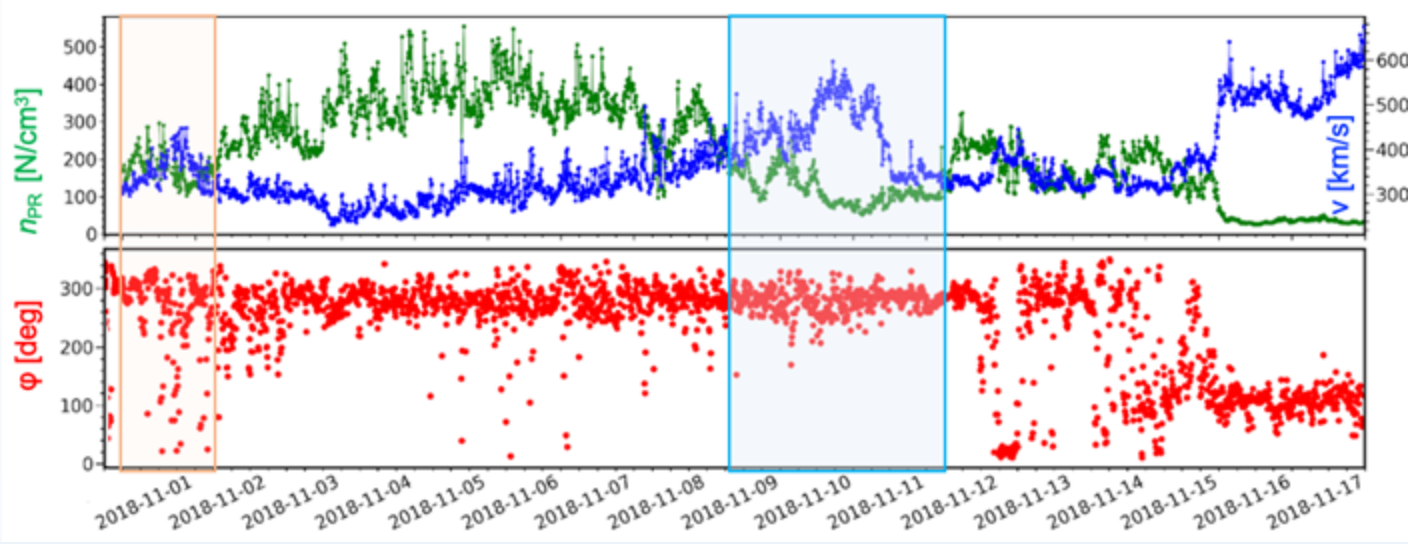
- Over-expansion in EUHFORIA, should we aim to fine-tune ‘free parameters’ in the model?
  (e.g. Samara et al, 2024)

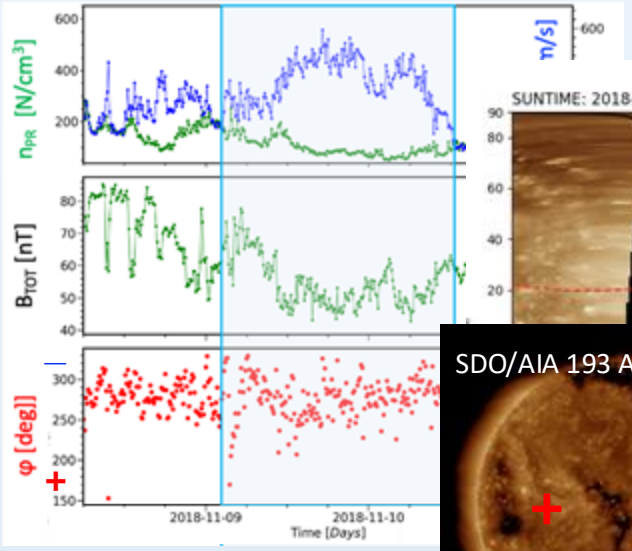
Small flows in the PSP data

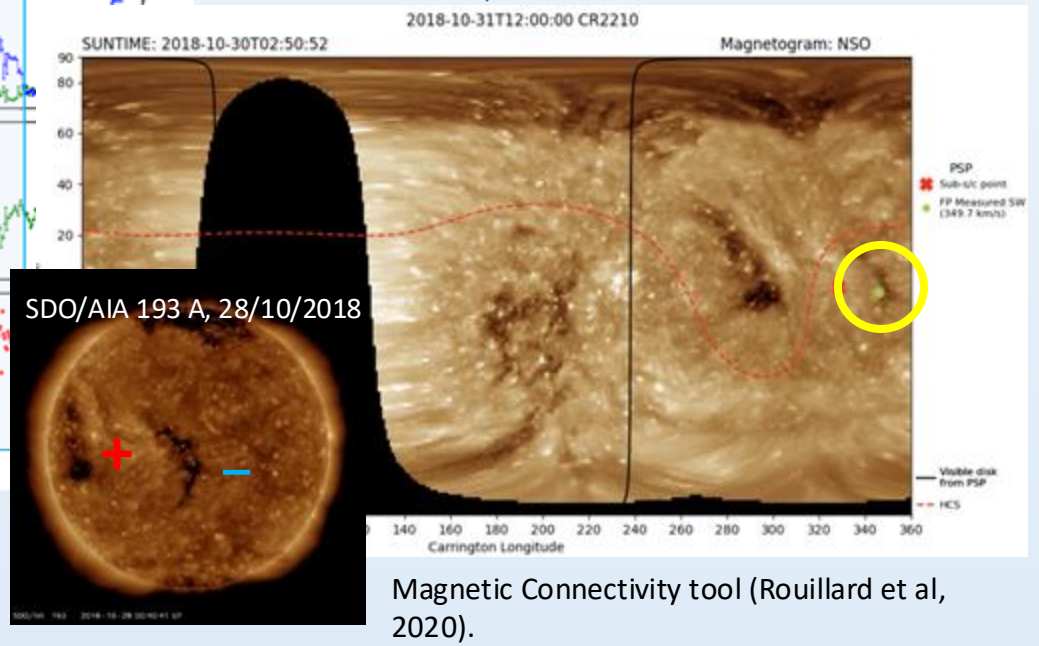
- The SW bulk velocity *v*, proton density n_{PR}, & the interplanetary magnetic field longitudinal φ-angle.

- In the first 8 PSP close encounters we found 35 intervals of enhanced SW flows

confine to the criteria of SW originating from the CHs (e.g. Jian et al., 2006).





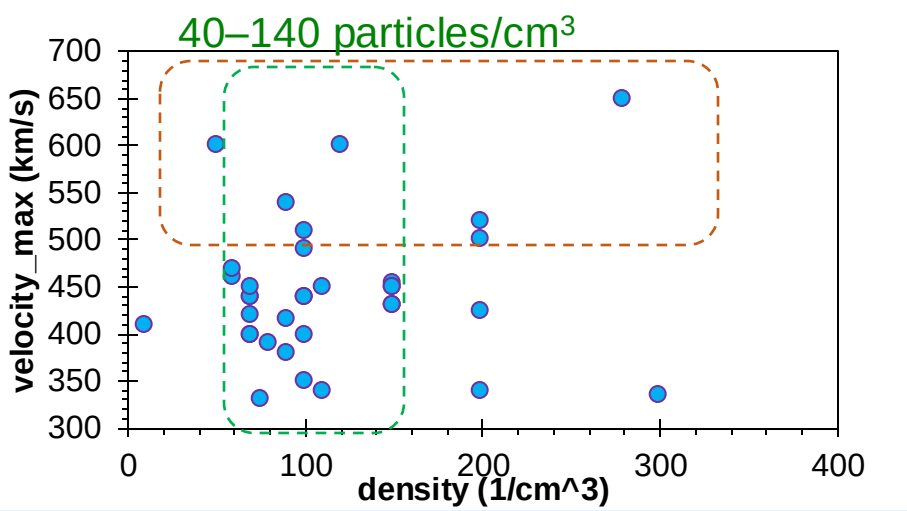


Magnetic Connectivity tool (Rouillard et al, 2020).

- Using a magnetic connectivity tool developed by ESA's MADAWG group (Rouillard et al., 2020) we confirmed that flows mostly originate mostly from small CHs

- The source of the two studied SW flows was a small, narrow, elongated negative polarity CH ? not at all modeled by EUHFORIA.

Characteristics of the small SW flows observed by the PSP

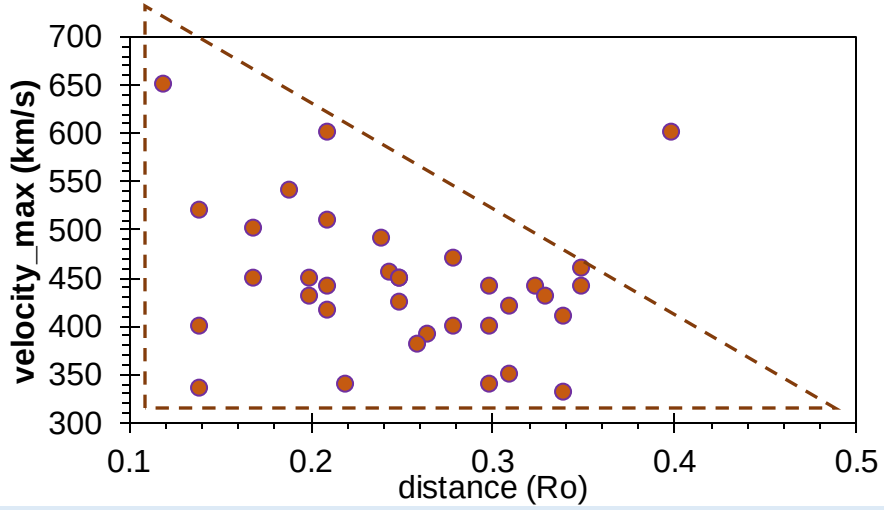


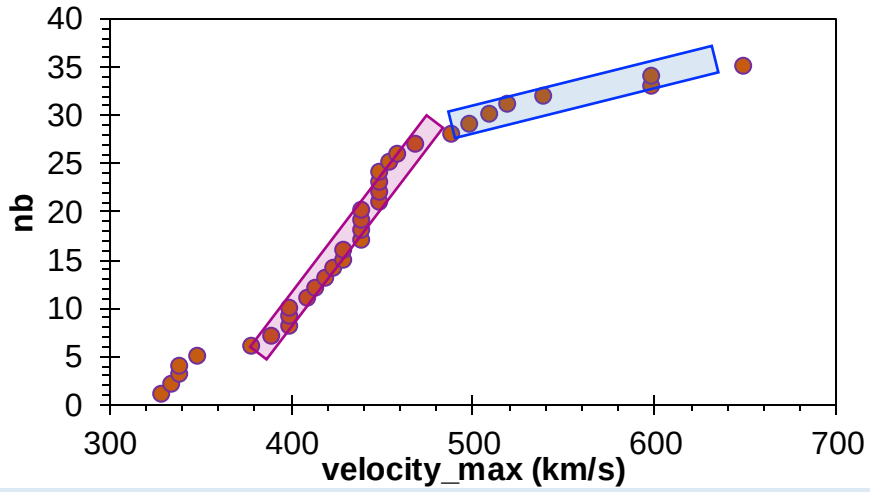
- 20% of flows have velocity ≥ 500 km/s.
- Only 4 (11%) have source in large CHs!

- The flows originating from the small CHs might contribute to **slow** OR **fast** SW at 1 au!

  ➡ None of them was modelled by EUHFORIA.

- Can we 'trace' these small flows?
- Can time-dependent modelling help? ☐ The first results show fragmented structure of the fast SW – to be further studied!

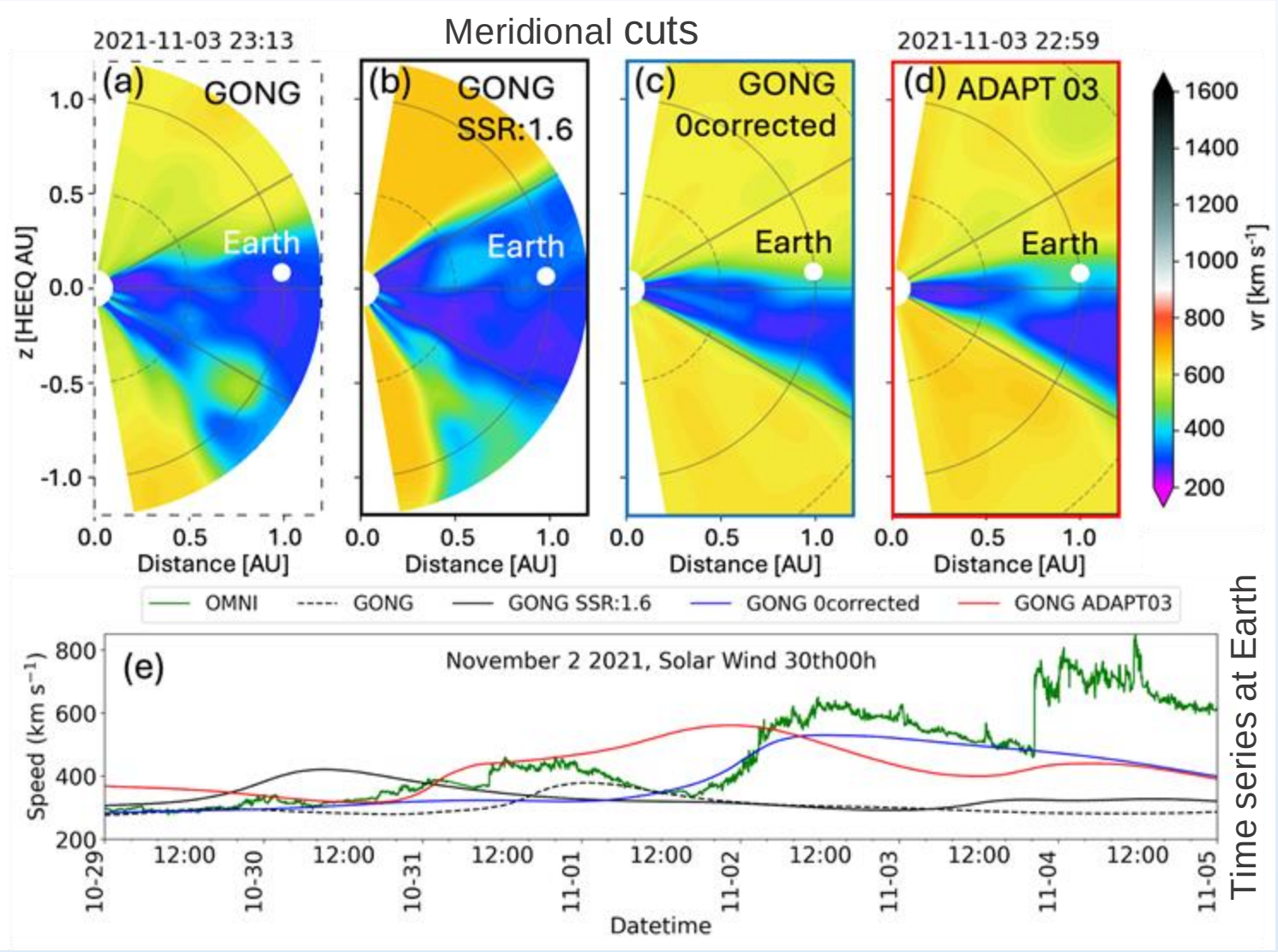




- As we go away from the Sun SW velocity is decreasing.
- Cumulative distribution shows at least two different types of SW.

(Magdalenic, et al., in preparation).

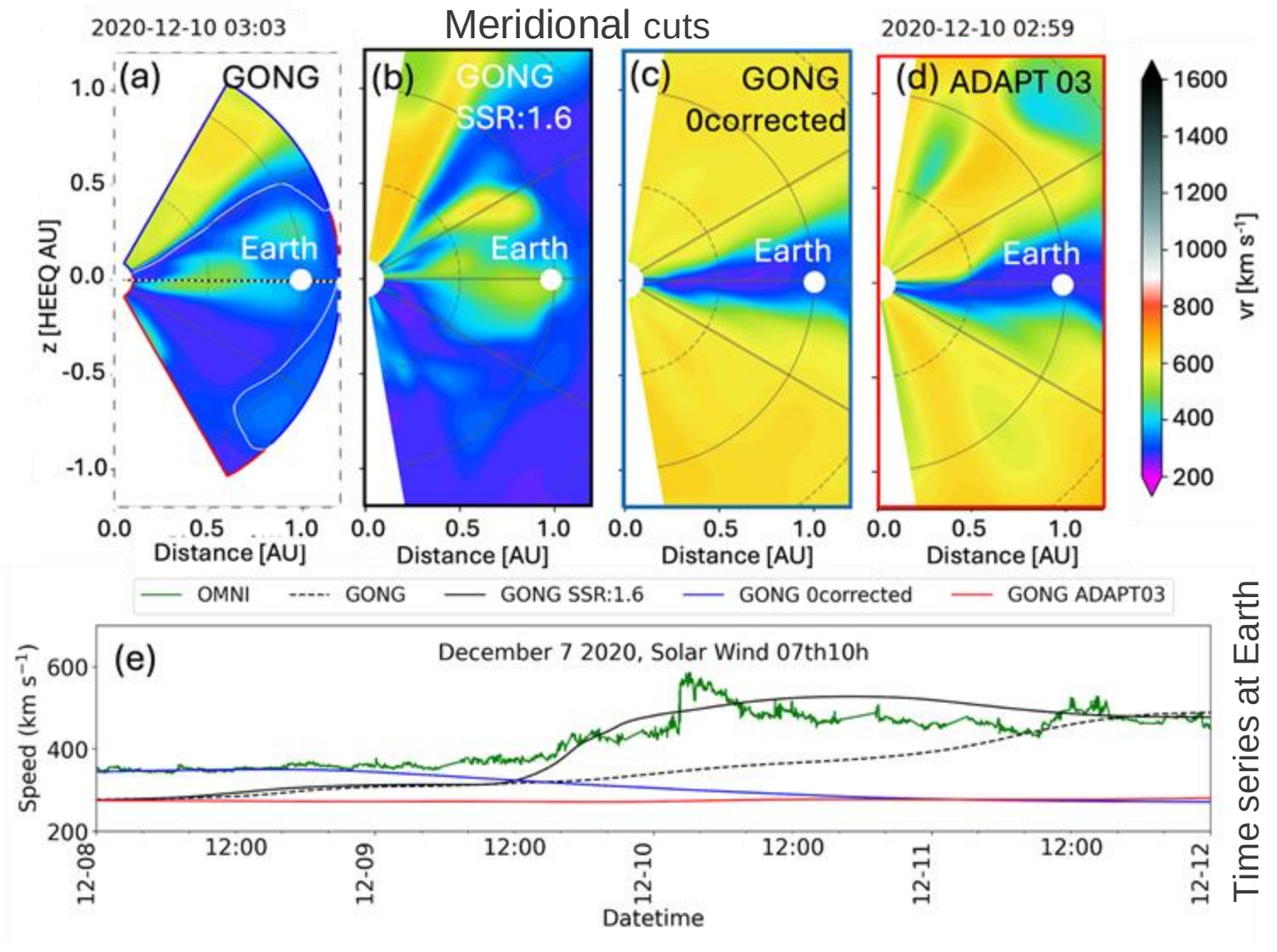
Importance of assessing the 2D & 3D characteristics of solar wind



- The 2D & 3D characteristic of the SW should be considered simultaneously with the 1D time series
  - before adjusting free parameters in the model!

(Valentino & Magdalenic, to be submitted).

Summary



- The small flows might significantly contribute to **slow** and/or **fast** SW at 1 au.
- We are not able to model them with EUHFORIA.
- We should ‘trace’ the small flows & try to quantify their contribution to slow/fast SW at 1 au.
- Validate time-dependent modelling.
- Always inspect the 2D structure of the SW before model adjustments.

Thank you for your attention!