# Preliminary results of Small-scale localized structures in sub-alfvenic regions of solar wind

R. Abdulmajed, A. Vaivads, L. Soriso-Valvo, T.Karlsson

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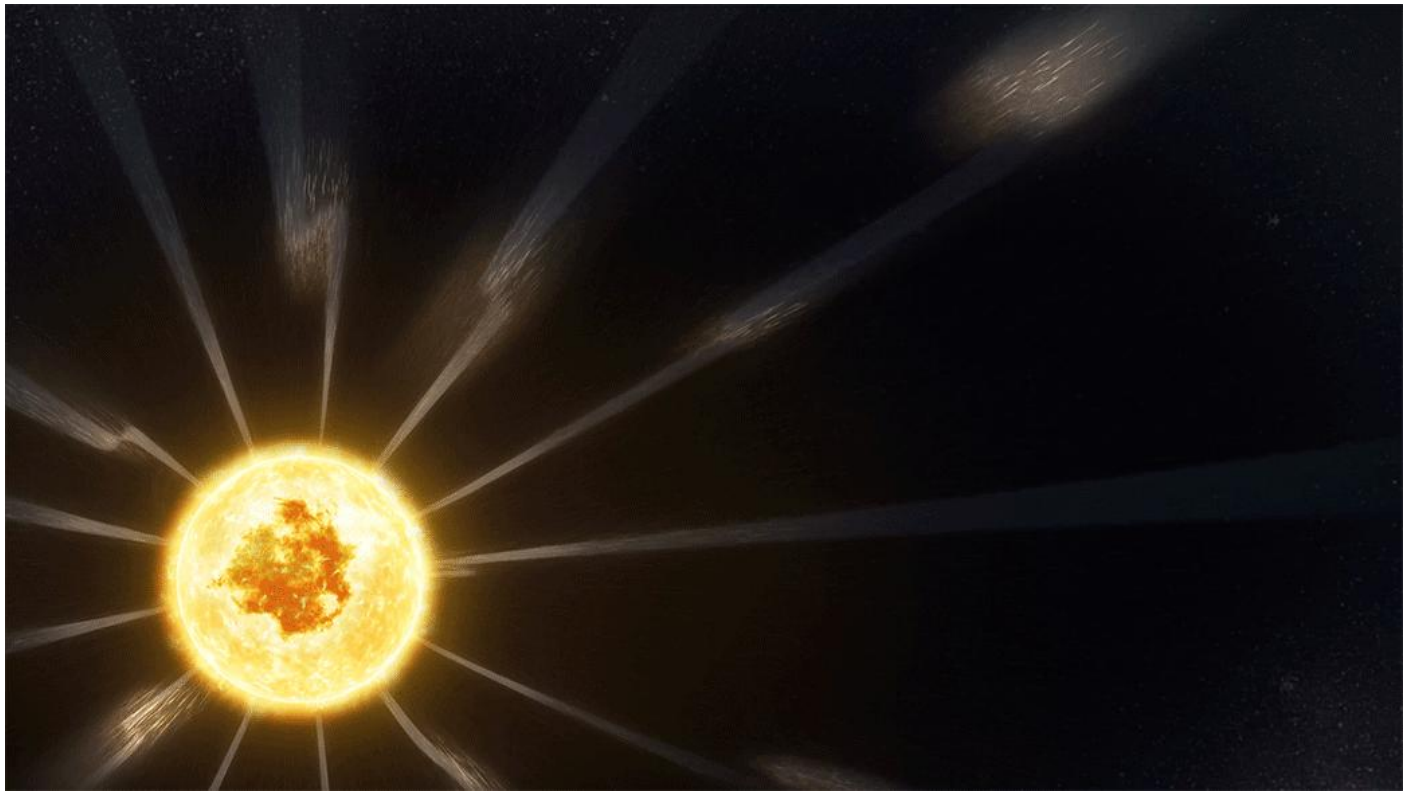
rehaba@kth.se

# What are the Switchbacks!

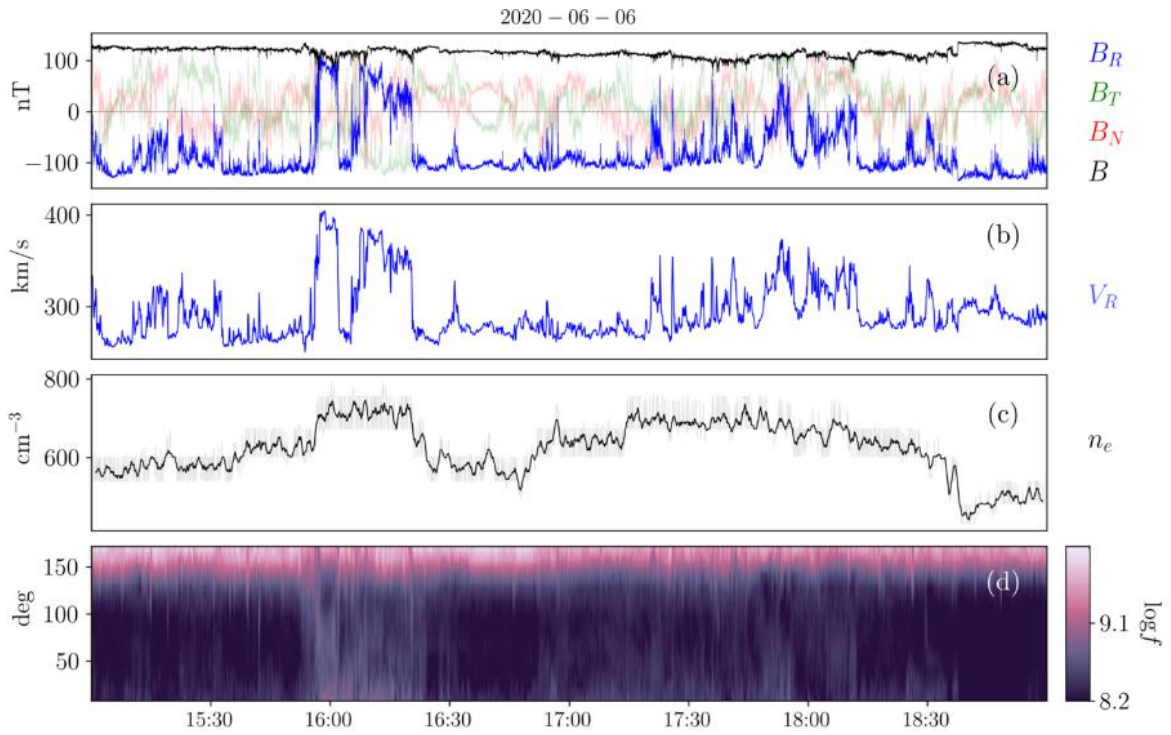
- Large-amplitude, localized deflection of the radial component of the interplanetary magnetic field, that folds back on itself without crossing the heliospheric current sheet.



Credits: NASA’s Goddard Space Flight Center/Conceptual Image Lab/Adriana Manrique Gutierrez

# What are the Switchbacks!

- Rapid reversal of the radial magnetic field (often >90° rotation).
- Velocity enhancement (jets).
- No change in the Pitch Angle Distribution PAD.
- Alfvénic.




Samuel T. Badman et al., 2026

Samuel T. Badmanet al. 2026
Peter Wyper et al. 2026

# History!

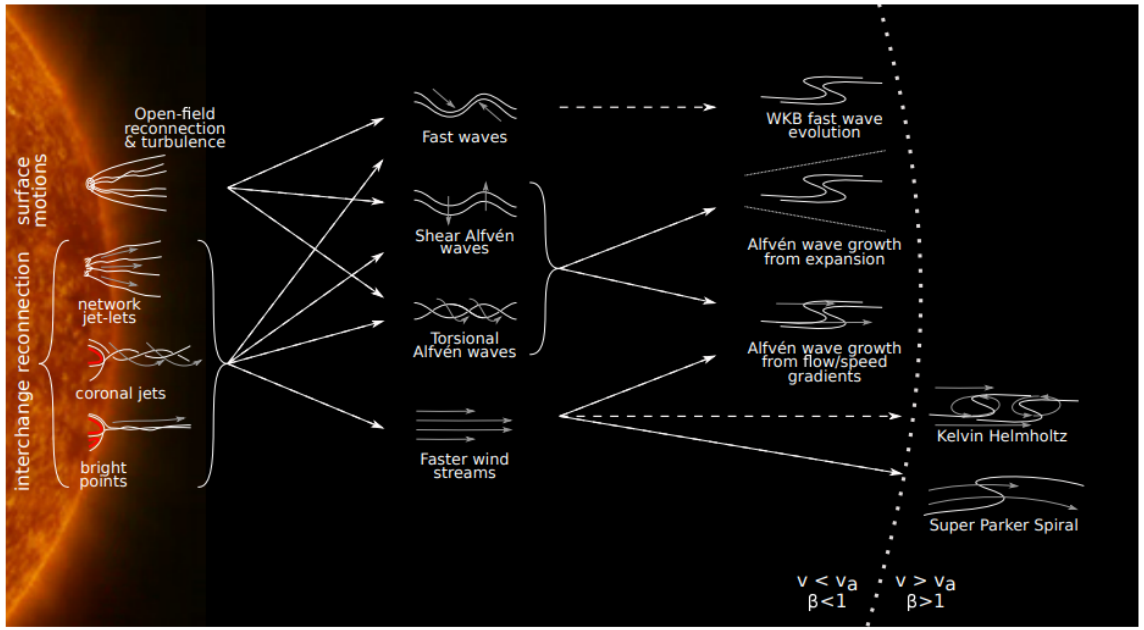
- They were first detected by Ulysses as ‘polarity inversions’ (Balogh et al. 1999).
- large-scale magnetic field inversions at sector boundaries observation using WIND (Crooker et al. 2004).
- Using Ulysses data, first used terminology ‘switchbacks’, Yamauchi et al. (2004).

# How they are formed!

- **In Lower Corona:** Switchbacks originate near the Sun through magnetic reconnection or photospheric processes; they propagate outward as pre-formed structures.

- **In Situ:** Switchbacks are generated locally in the expanding solar wind through plasma instabilities, turbulence, or expansion effects

- Neither paradigm alone is sufficient.

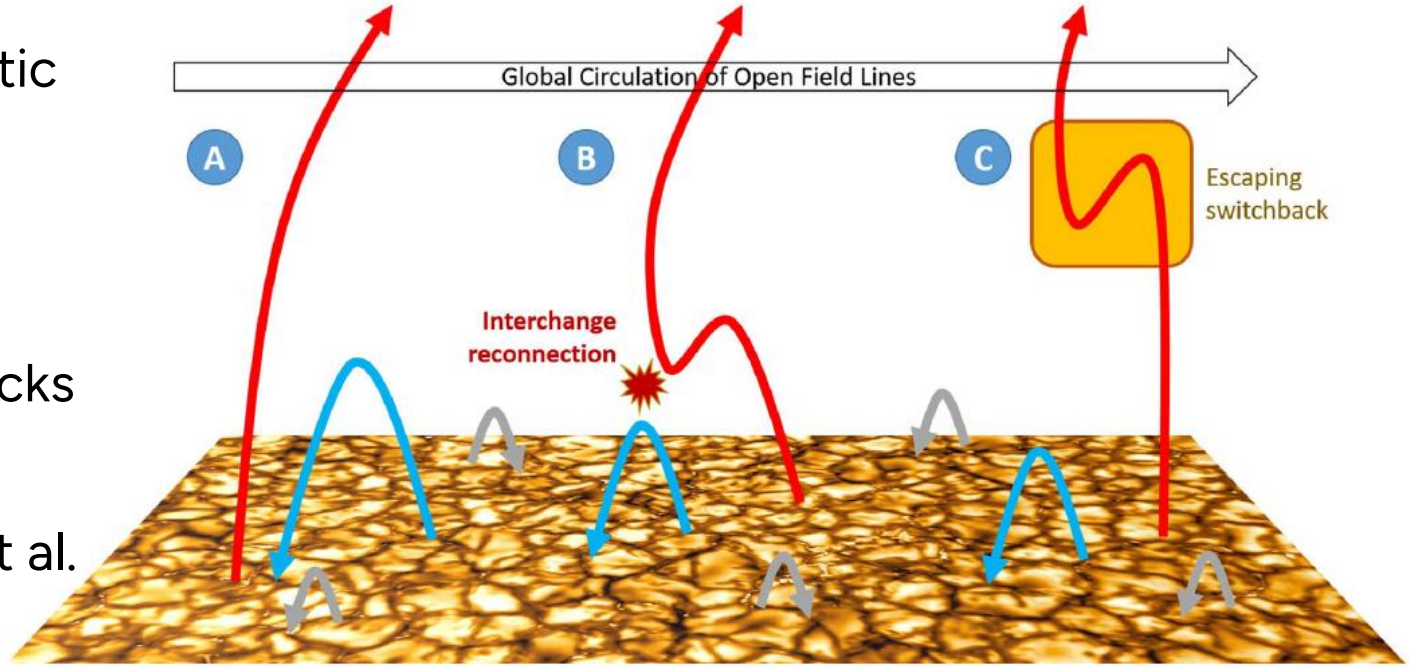



Peter Wyper et al. 2026

# Interchange Reconnection

- Open magnetic field lines reconnect with closed coronal loops near the solar surface
- This process launches kinked magnetic field lines and plasma jets into the heliosphere
- Interchange reconnection can eject helical flux ropes into the solar wind, which may be identified as switchbacks

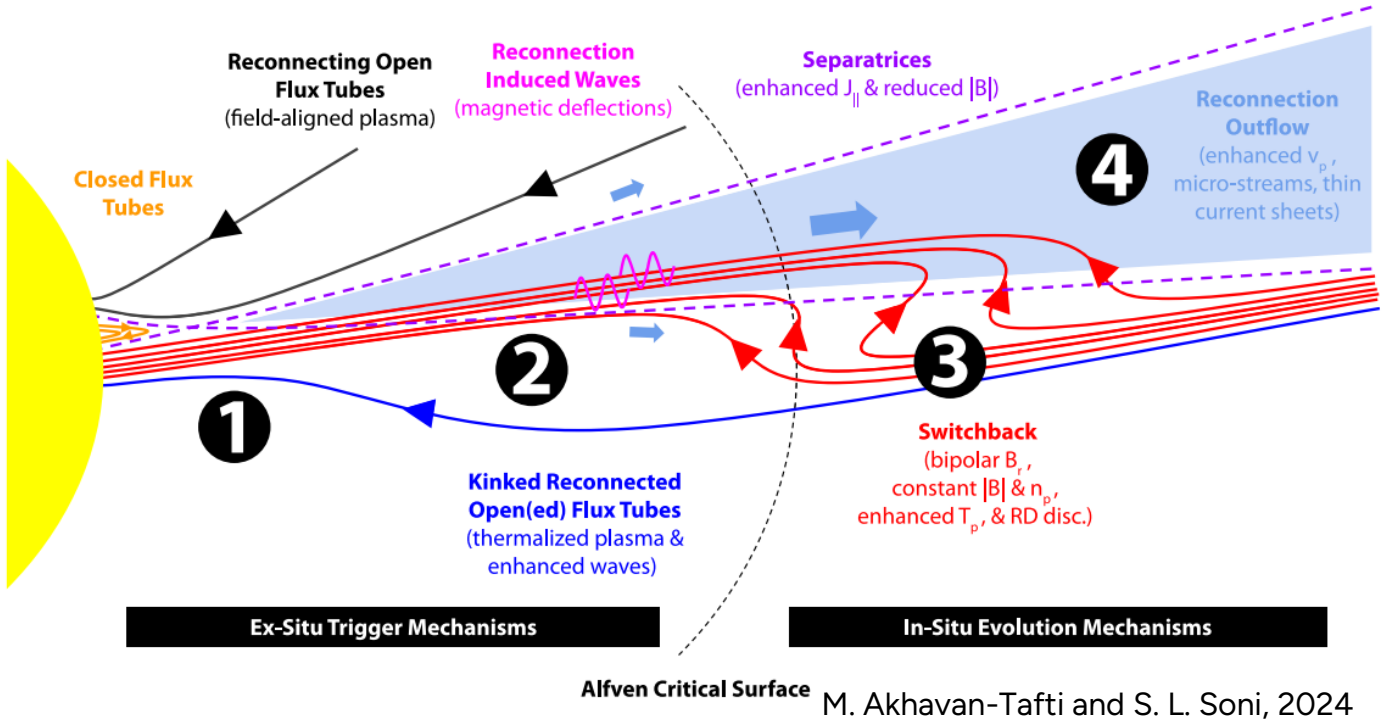
(Fisk 2005, Fisk & kasper 2020, Zank et al. 2020, Bale et al. 2021)




Fisk & Kasper 2020

# In situ mechanisms

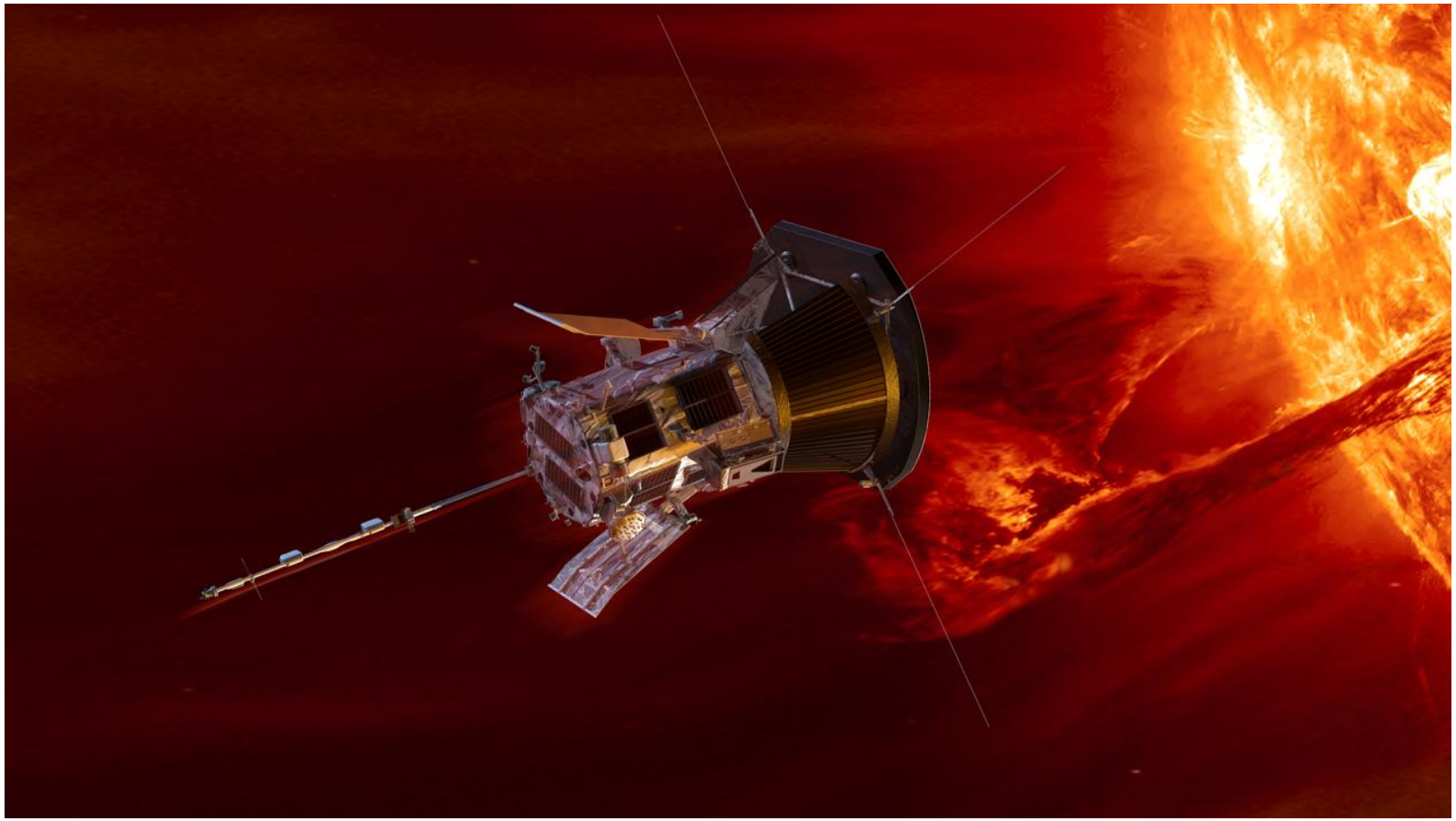
- Alfvénic turbulence in the expanding solar wind can spontaneously generate magnetic reversals.
- Flow shear across reconnection outflow boundaries can trigger instabilities that grow magnetic deflections
- Kelvin-Helmholtz instability at switchback boundaries may play a role in their evolution




M. Akhavan-Tafti and S. L. Soni, 2024

# PSP…. Finally!

- observations within 0.3 AU showed:
- Switchbacks occur in both slow and fast solar wind streams
- prevalence decreases with heliocentric distance
- no characteristic magnitude or duration



Credits: NASA/APL

# PSP …. Unfortunately!

- The rate of occurrence falls off sharply approaching the Sun near 0.2 au (40 Re) and rises gently from 0.2 au outward.

(Pecora et al. 2022)

- enhanced magnetic fluctuations (θB <=90°).
- A clear absence of radial field reversals (θB >= 90°) in the sub-Alfvénic corona.

(M. Akhavan-Tafti and S. L. Soni, 2024)

**Table 1**
List of PSP $R_A$ Crossings and $B_r$ Reversal Statistics

| Encounter # | $R_A$ crossings (count) | Duration (s) (min) | $B_r$ reversals (count) |
|---|---|---|---|
| 1 | 0 | 0 | 663 |
| 2 | 0 | 0 | 413 |
| 3 | 0 | 0 | ... |
| 4 | 0 | 0 | 449 |
| 5 | 0 | 0 | 420 |
| 6 | 0 | 0 | 512 |
| 7 | 0 | 0 | 286 |
| 8 | 2 | 140, 90 | 370 |
| 9 | 1 | 176 | 305 |
| 10 | ... | ... | 329 |
| 11 | 0 | 0 | 295 |
| 12 | 3 | 100, 50, 40 | 199 |
| 13 | 4 | 35, 40, 250, 15 | 246 |
| 14 | 0 | 0 | 314 |

M. Akhavan-Tafti and S. L. Soni, 2024

More than 4800 Br reversal events were identified, about 10% of which were further characterized as switchbacks.

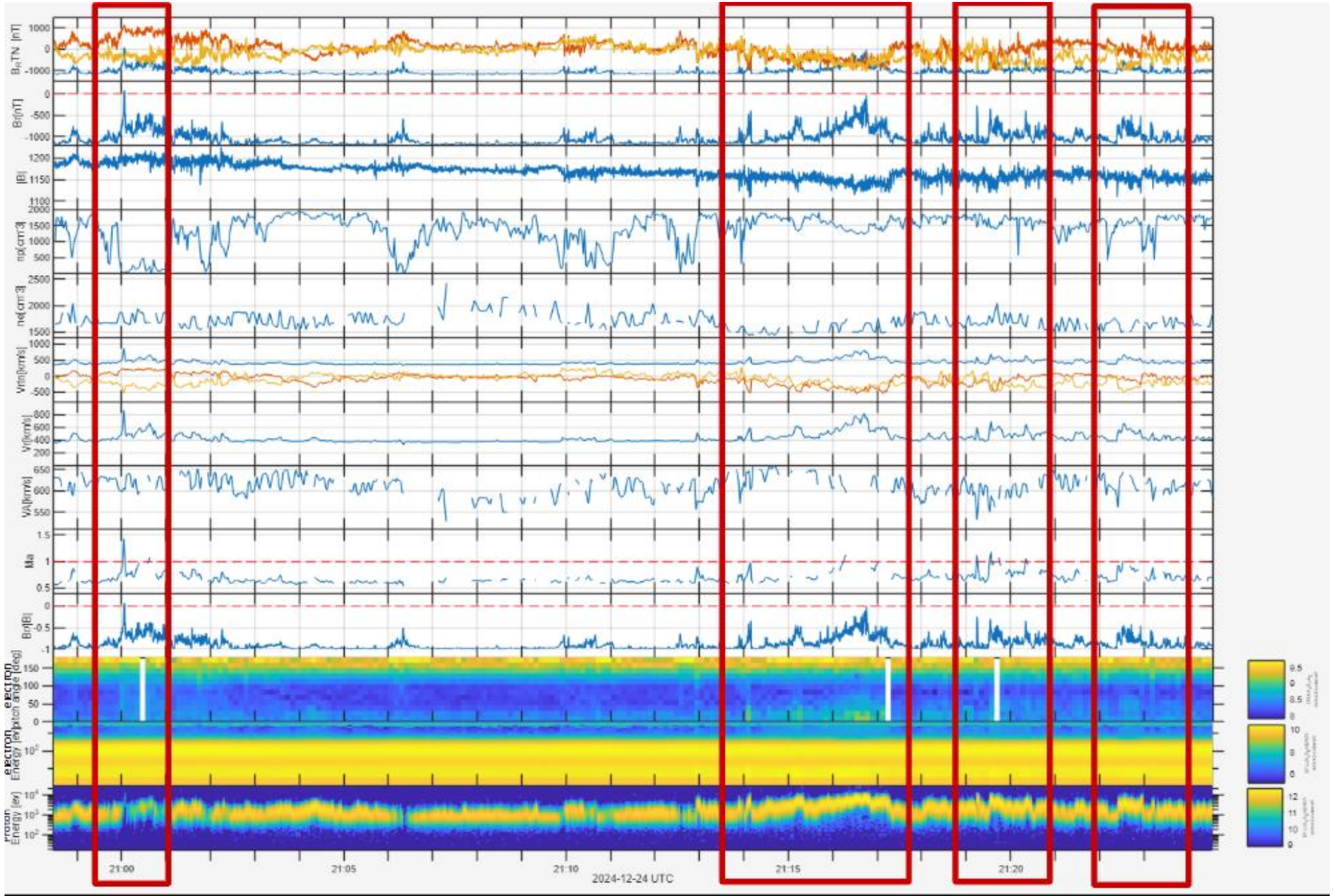
# Why Switchbacks!

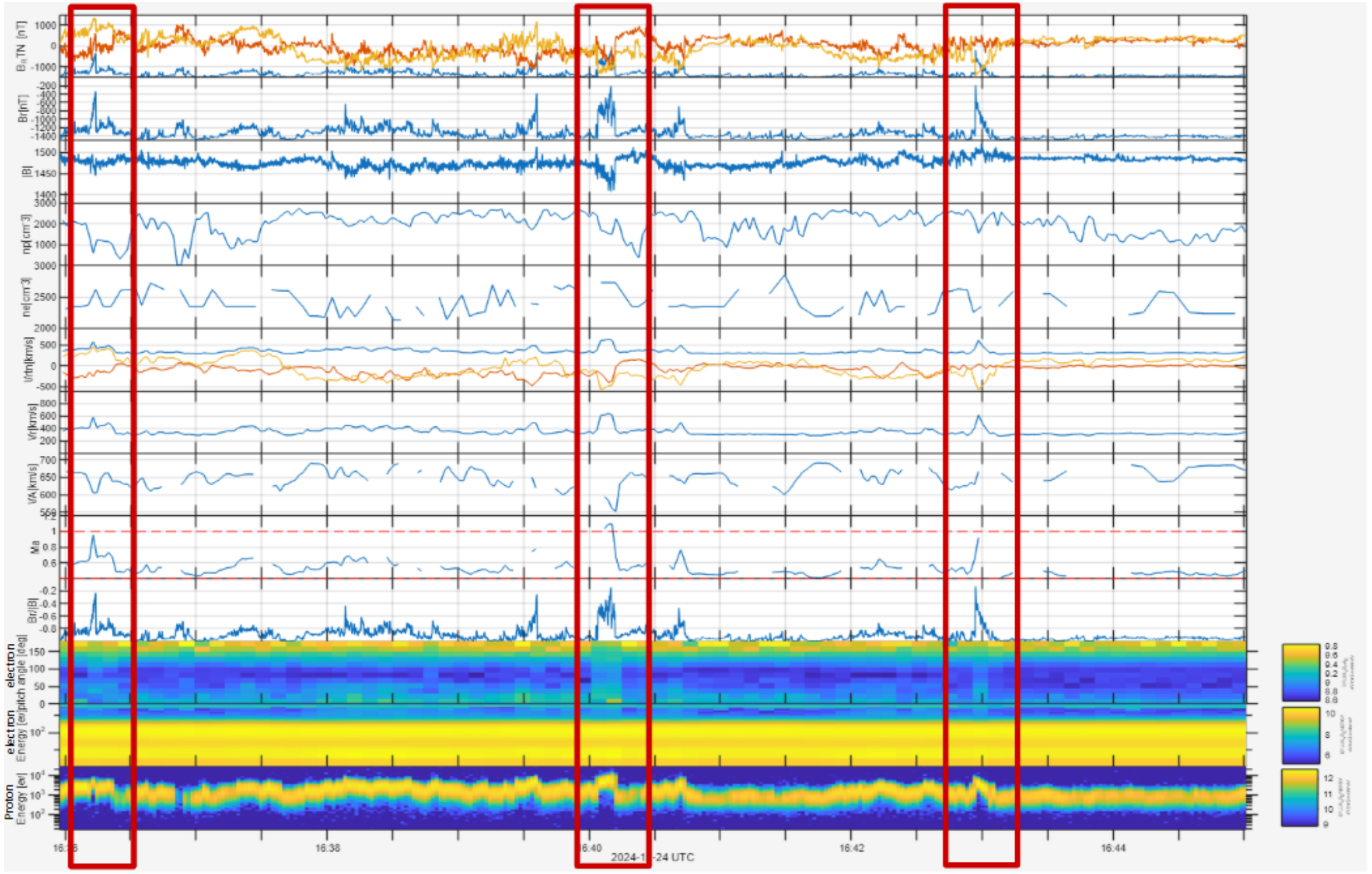
- Unsolved structure with a lot of open questions

- Where do they form? (Solar surface vs. in situ)
- How do they evolve with radial distance?
- Do they contribute to solar wind acceleration?

# Synergies!

# Preliminary Result from PSP E22


B_RTN [nT]
Br[nT]
|B|
np[cm^3]
nα[cm^3]
Vrtn[km/s]
Vr[km/s]
vA[km/s]
Ma
Br/|B|
electron
Energy [eV]
electron
pitch angle [deg]
Proton
Energy [eV]
21:00
21:05
21:10
2024-12-24 UTC
21:15
21:20


$B_{RTN}$ [nT]
Br[nT]
|B|
np[cm^3]
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Vrtn[km/s]
Vr[km/s]
VA[km/s]
Ma
Br/|B|
electron
Energy [ev]/pitch angle [deg]
electron
Energy [ev]
Proton
Energy [ev]
16.38
16.40
16.42
16.44
2024-1 -24 UTC


KTH
VETENSKAP
OCH KONST
Thank you!