A solar source of Alfvénic magnetic field switchbacks: *in situ* remnants of interchange reconnection on supergranulation scales

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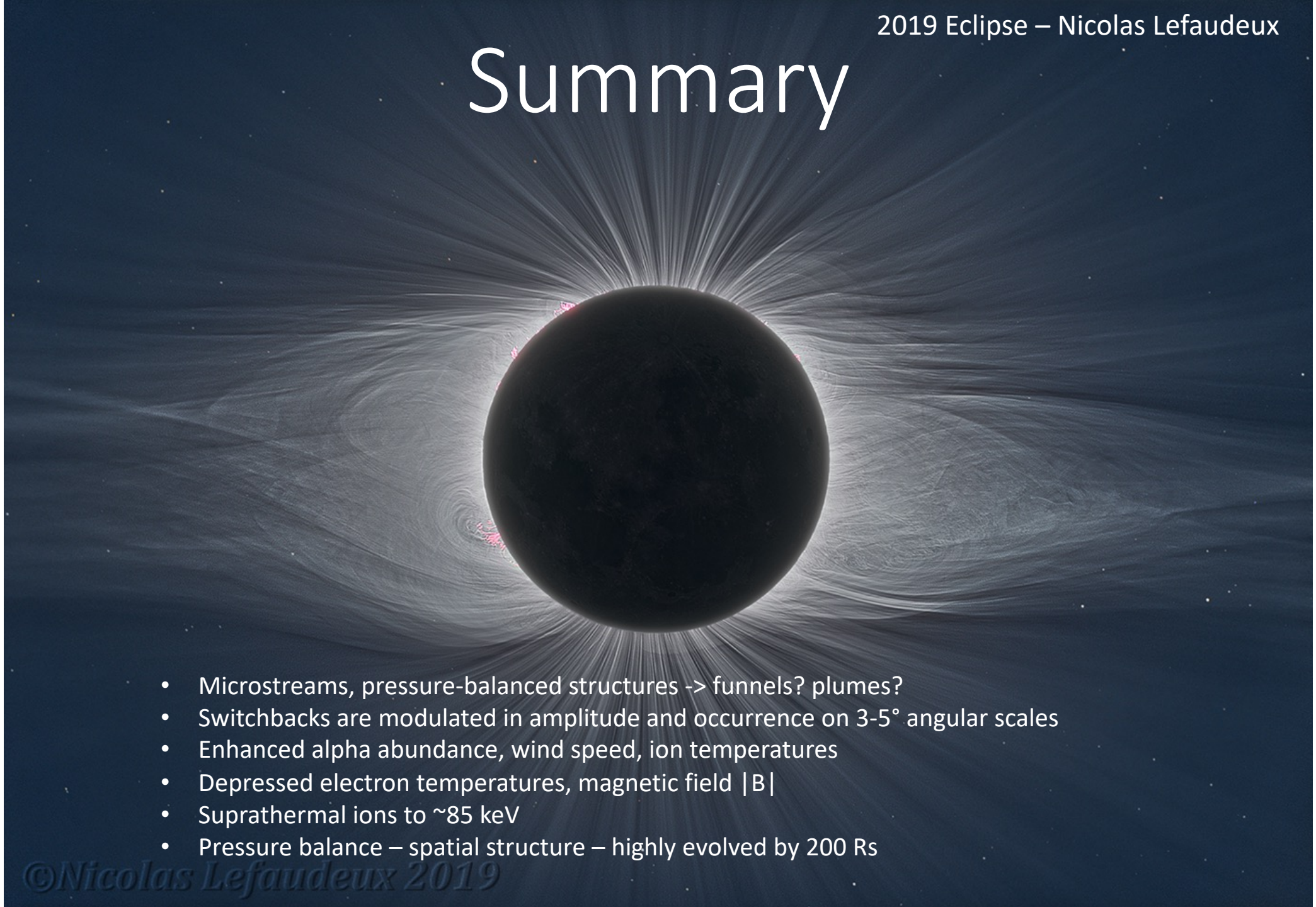
- PFSS Modeling/mapping – Olga Panasenco, Sam Badman, Ronan Laker
- Ballistic mapping and Solar Orbiter analysis – Tim Horbury
- SPAN ion fits – Michael McManus, Lloyd Woodham
- SPAN electron fits – Jasper Halekas
- ISOIS/EPI-Lo measurements – Mihir Desai

2019 Eclipse – Nicolas Lefaudeux

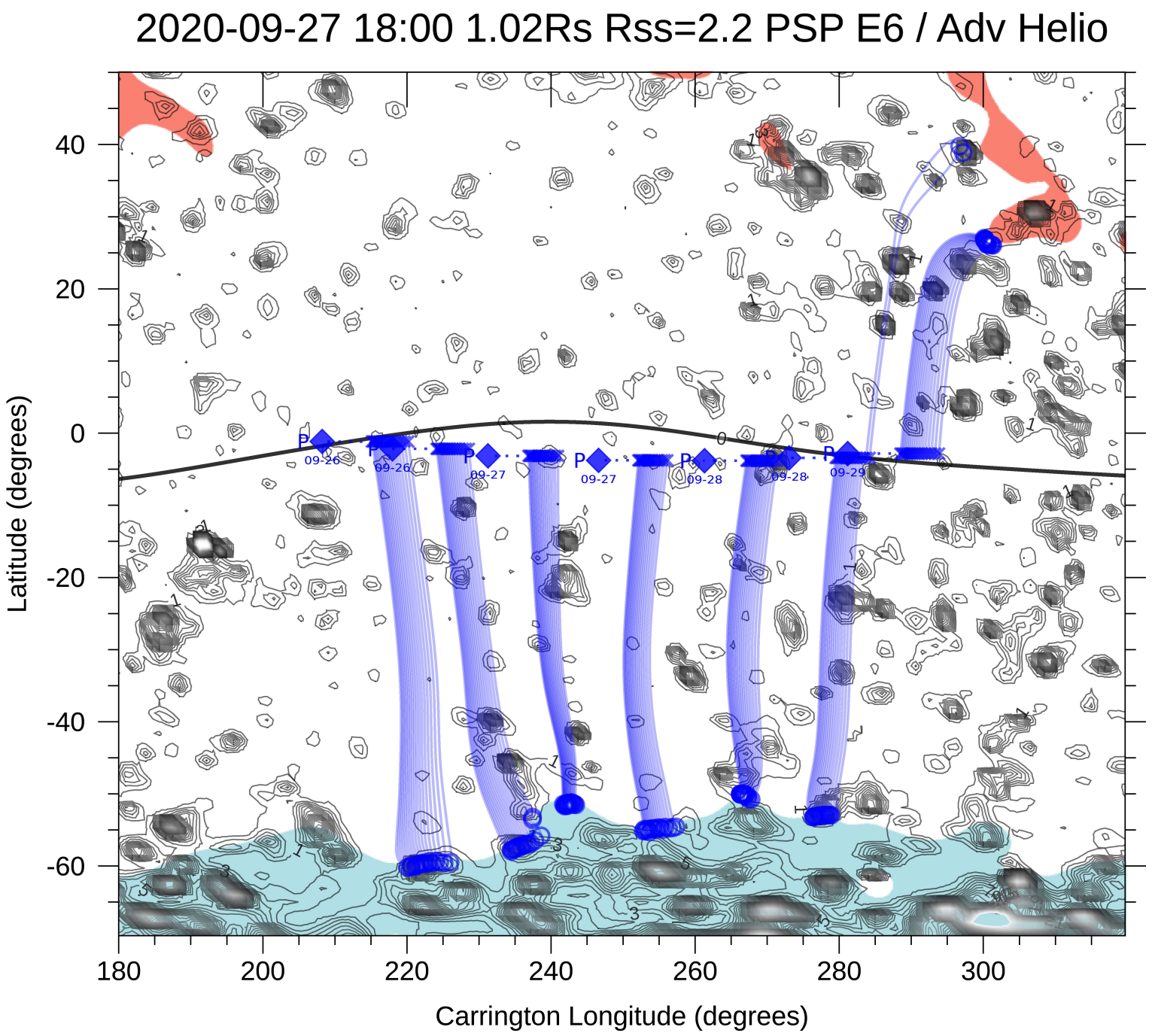
Summary



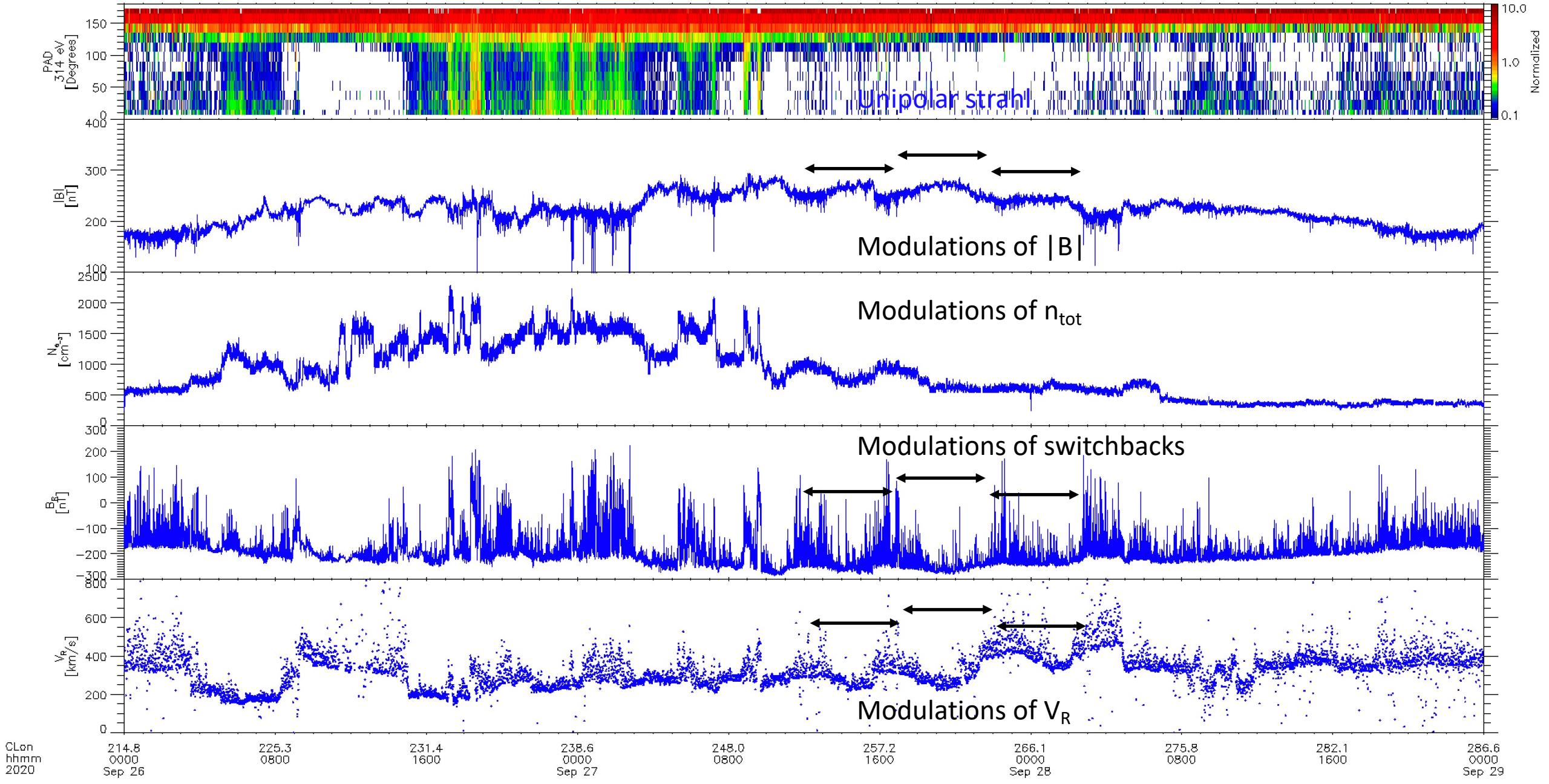
- Microstreams, pressure-balanced structures -> funnels? plumes?
- Switchbacks are modulated in amplitude and occurrence on 3-5° angular scales
- Enhanced alpha abundance, wind speed, ion temperatures
- Depressed electron temperatures, magnetic field |B|
- Suprathermal ions to ~85 keV
- Pressure balance – spatial structure – highly evolved by 200 Rs

Encounter 06
Perihelion at 20 Rs
PFSS Connectivity on Sept 27, 2020

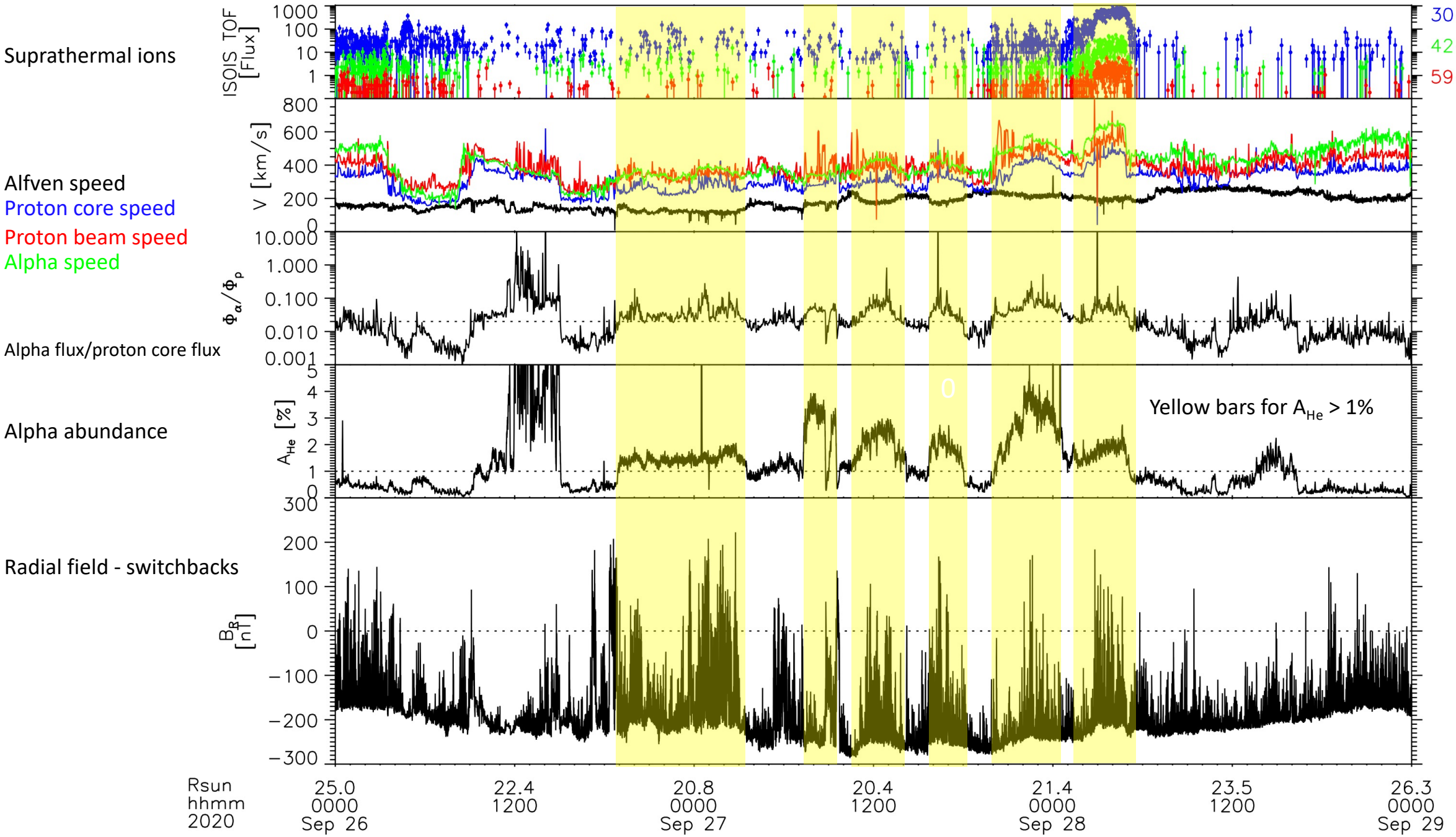
- Rss = 2.2 Rs
- PSP is connected to a southern coronal hole (CH) at around -60°
- Black contours are magnetic pressure at 14 Mm altitude
- Network magnetic field



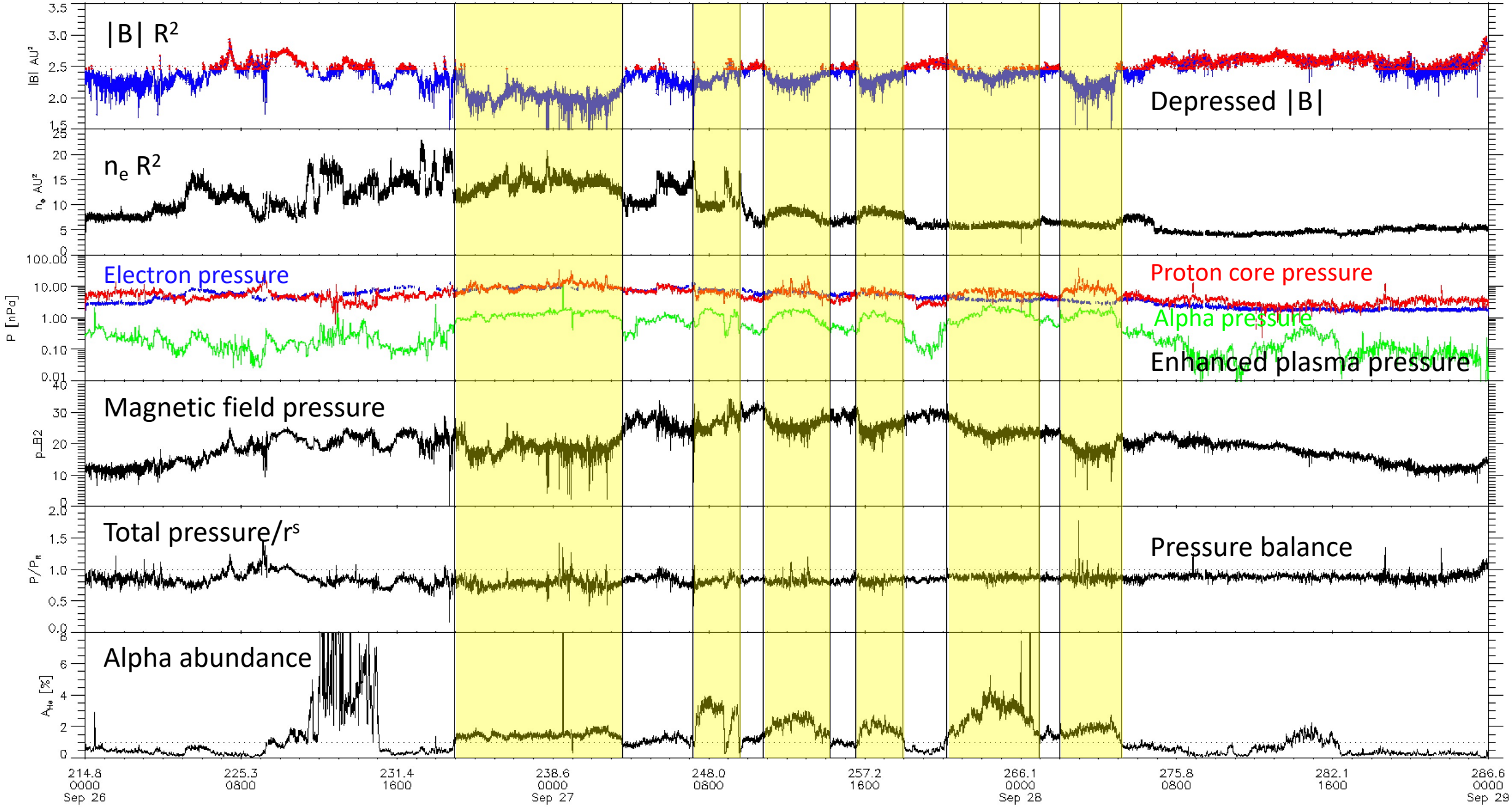
PSP Encounter 06



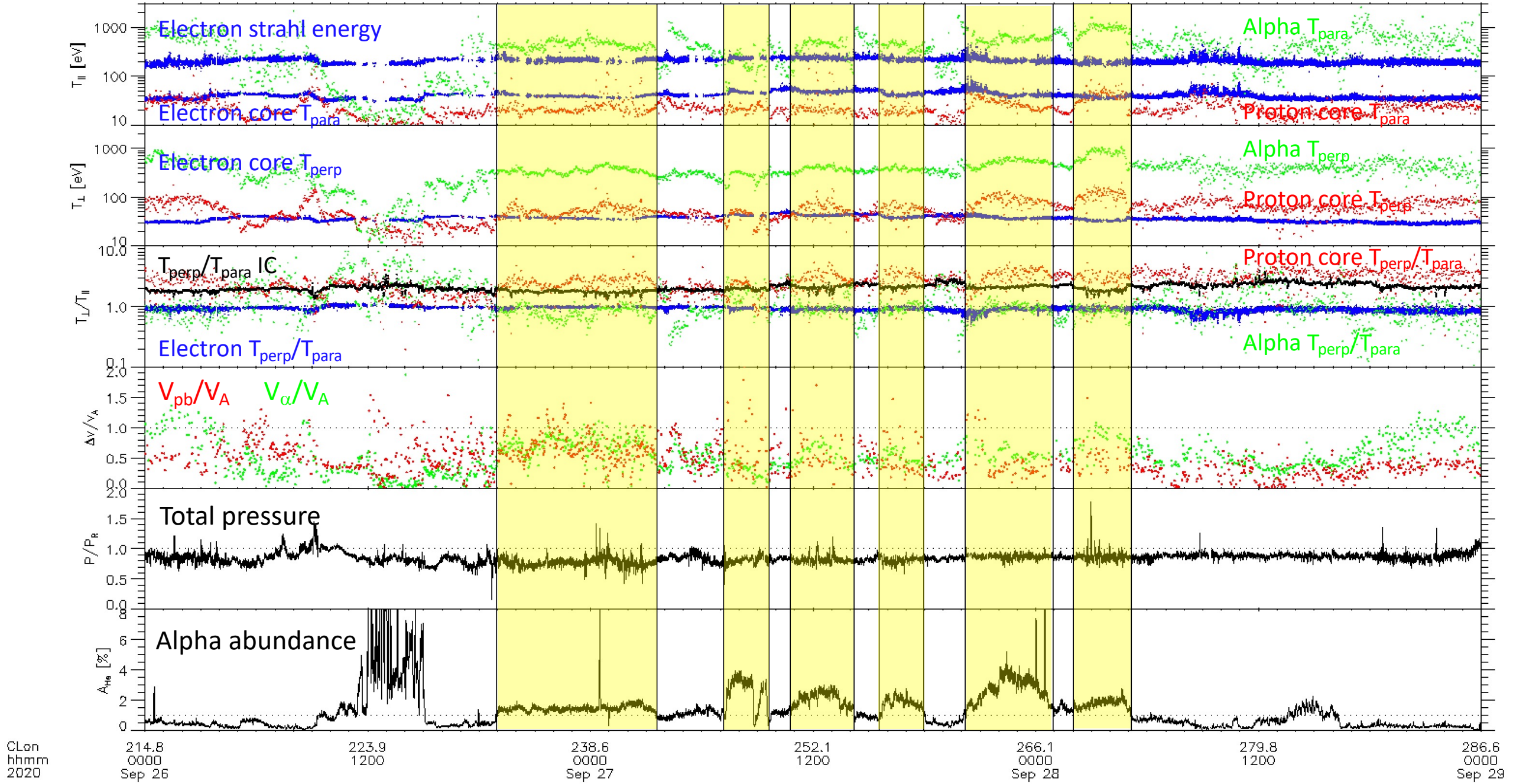
Suprathermals, enhanced A_{He} and higher Mach radial flows



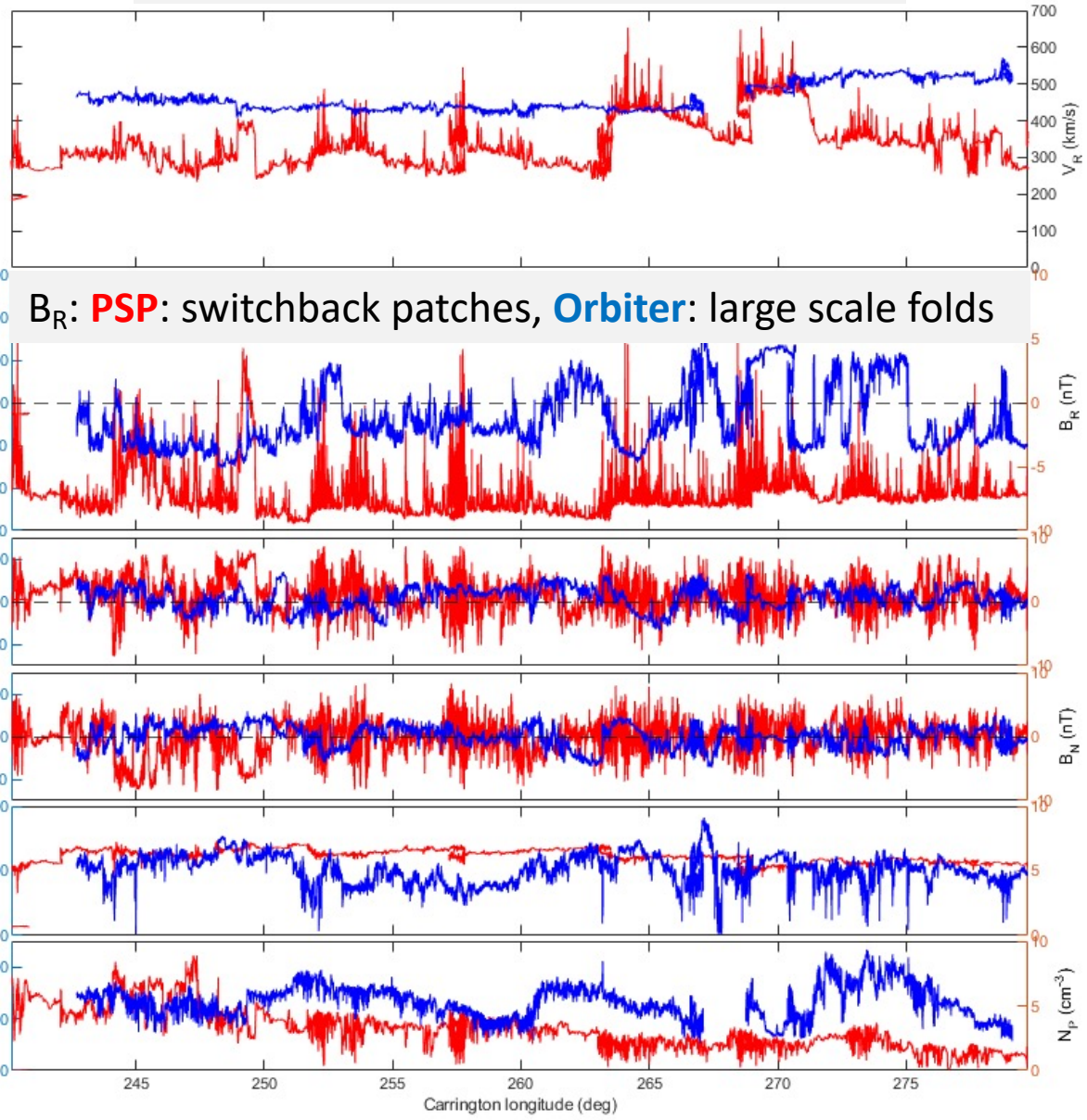
Structures are pressure-balanced



Ion temperatures are elevated, electron temperatures are depressed



Speed: **PSP**: structured, **Orbiter**: smooth

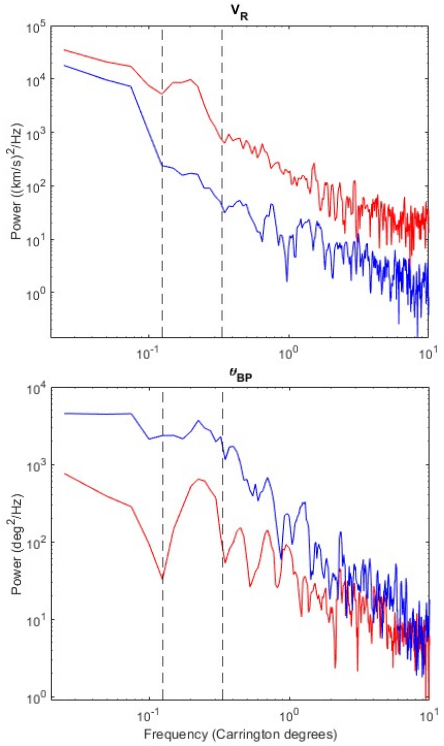


B_R: **PSP**: switchback patches, **Orbiter**: large scale folds

How do switchback patches evolve with distance?

- Encounter 6: PSP at 20 R_S, Orbiter at 208 R_S
  Both at similar latitude, cover same longitude range
- Ballistic map to 2.5R_S using measured solar wind speed
- Takes into account spacecraft motion; assumes corotating structures

Spectra of speed and magnetic field variations with respect to source surface longitude



Speed: **PSP** microstreams (plumes?) smooth out by 1 AU at **Orbiter**

Magnetic field (angle to Parker spiral): peak at **PSP** (switchback patches) becomes large scale field variations: break in spectrum at **Orbiter**

B_T, B_N in upper panel
V_T, V_N in lower panel

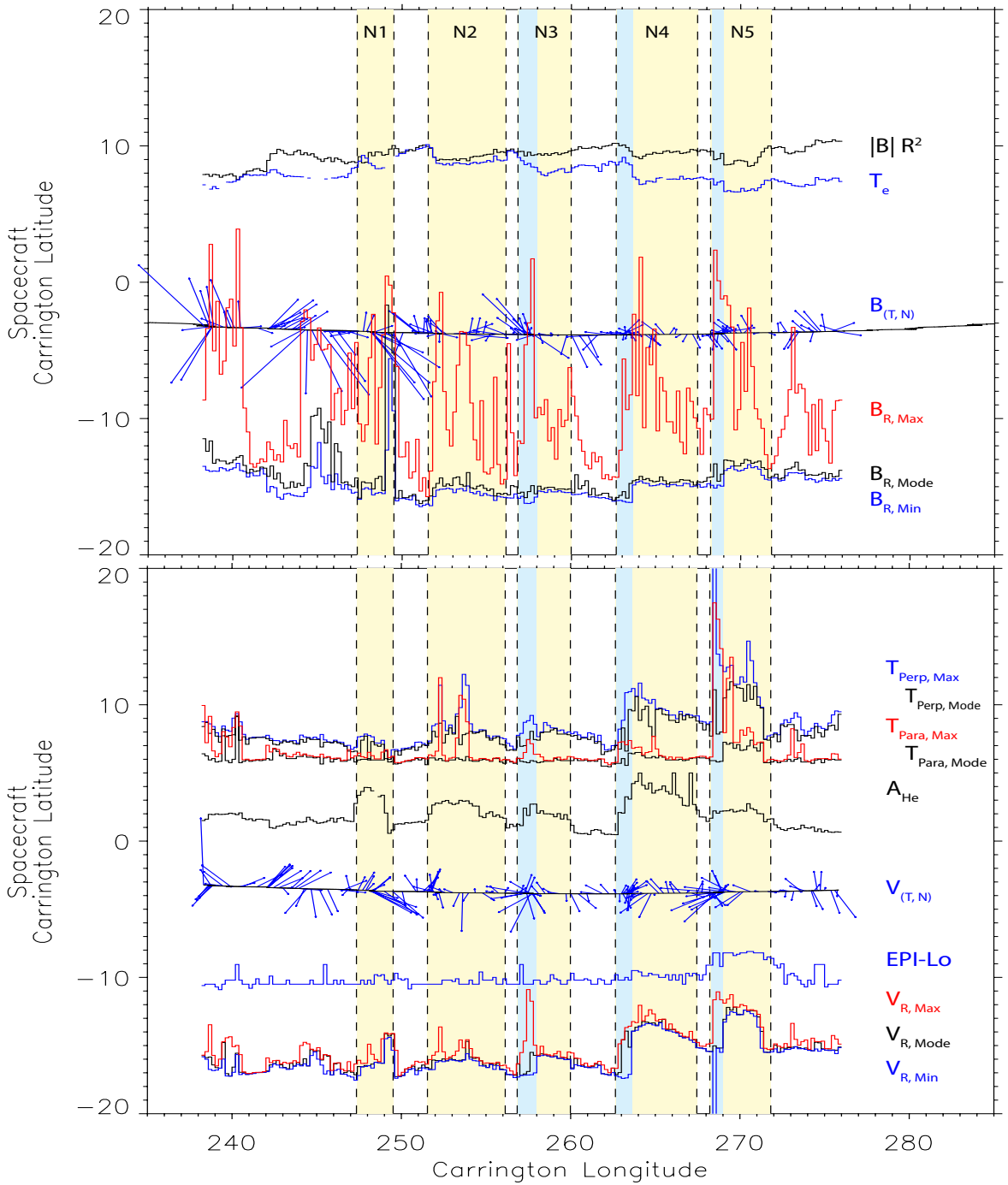
|B| in upper panel
B_R in upper panel

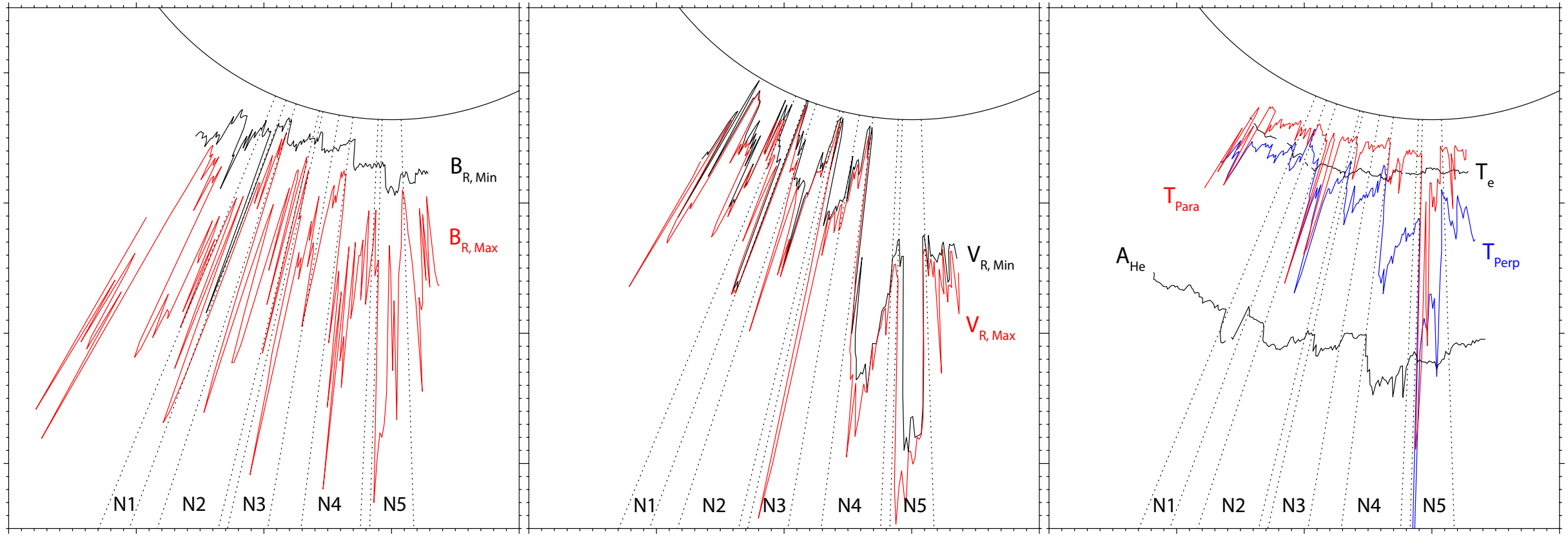
A_{He} in lower panel
V_R in lower panel
Proton temperatures in lower panel
EPI-Lo ions in lower panel

Mapped ballistically into Carrington longitude

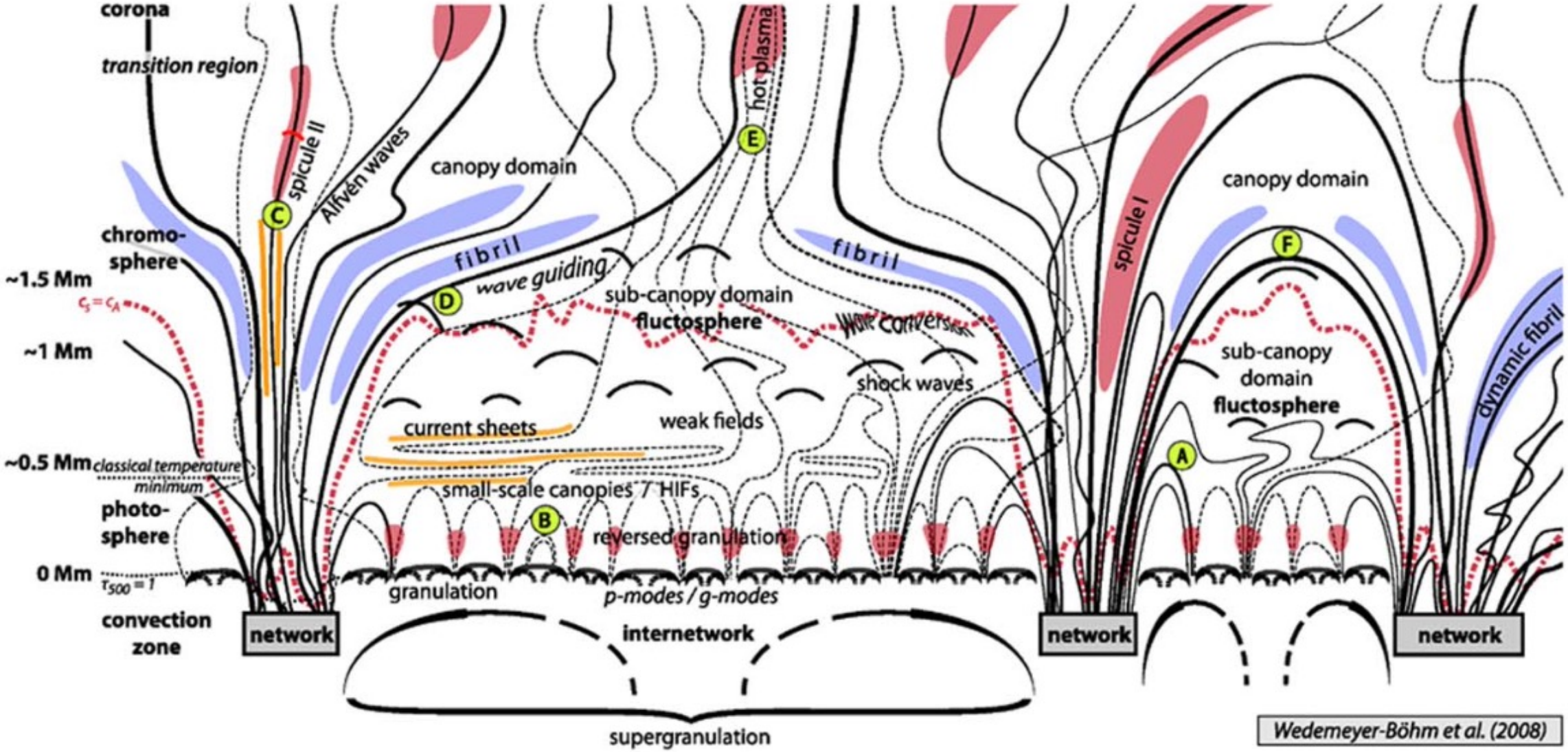
Yellow bars are enhanced A_{he}
Blue bars are hotter leading edge

- Structure is clustered near boundaries
- Switchbacks are clustered near leading edge





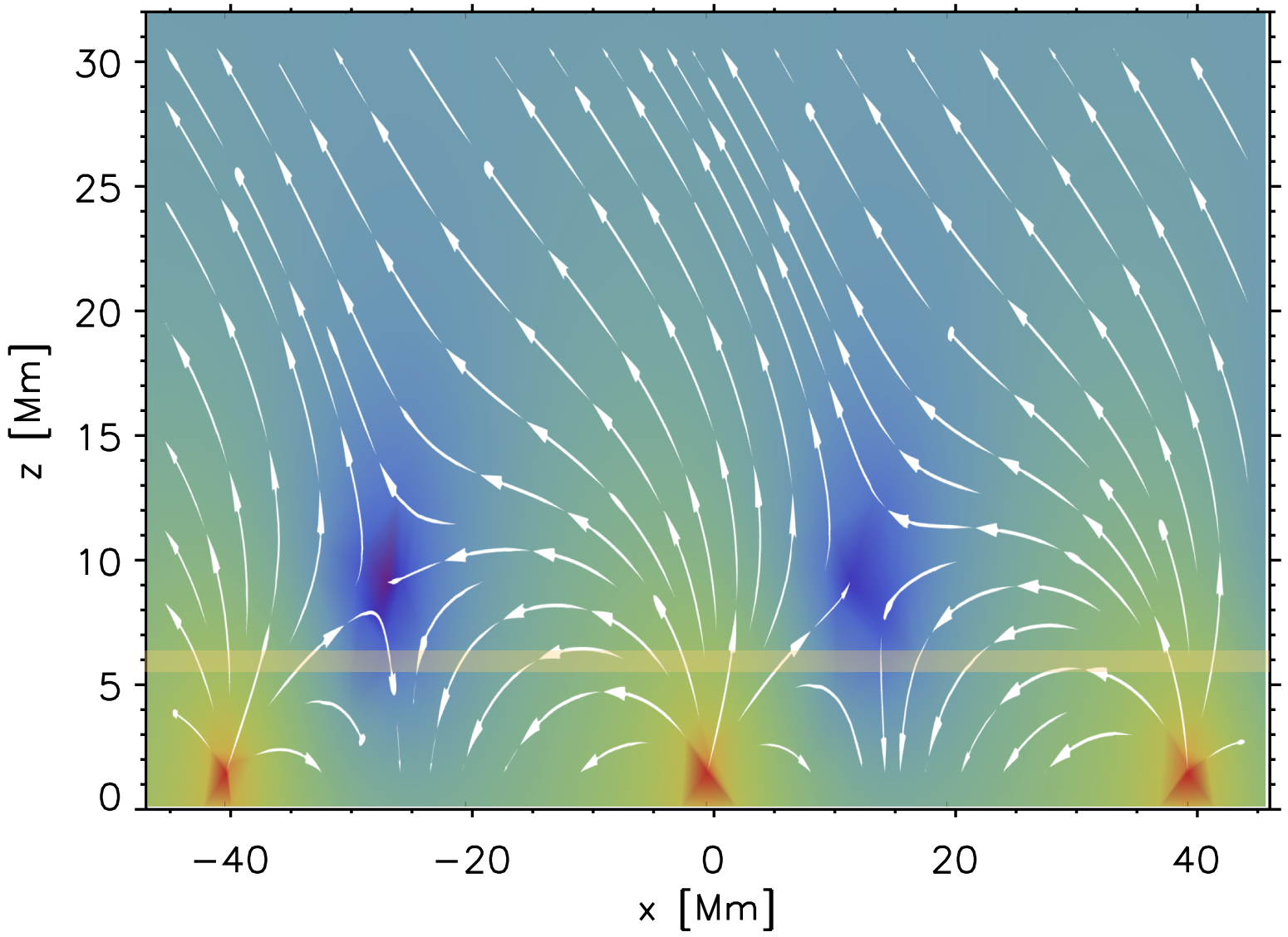
Polar representation



Wedemeyer-Böhm et al. (2008)

Superradial expansion gives |B| depression in center

- $B_R \sim 1/r^2$
- $B_{(T,N)} \sim 1/r$



Potential field solution – (a la Hackenberg and Mann, 2000)

Observations

- Switchbacks are modulated on supergranulation angular scales
- Photospheric field has B^2 modulations on similar scales
- Pressure balanced – spatial structure at 20 Rs
- Structure is evolved out by 200 Rs
- Fast wind-like (higher) A_{He} and lower strahl energy – frozen-in from source, associated with open magnetic field
- Higher β and flow speed within structures
- Suprathermal ions to 85 ~keV
- Depressed |B| – overexpansion of magnetic field below PSP – funnels

Conclusions?

- These are the solar wind remnants of coronal plumes/funnels and switchback occurrence and amplitude peaks within them
- This tells us something about the switchback source
  - Funnels at supergranulation boundaries
  - Network magnetic field
- This maybe tells us something about the switchback generation mechanism
  - Interchange reconnection at funnel/loop boundaries?
  - Alfven waves in overexpanding funnels?
- This maybe tells us something fundamental about coronal heating