Proton and alpha particle features linked to switchbacks

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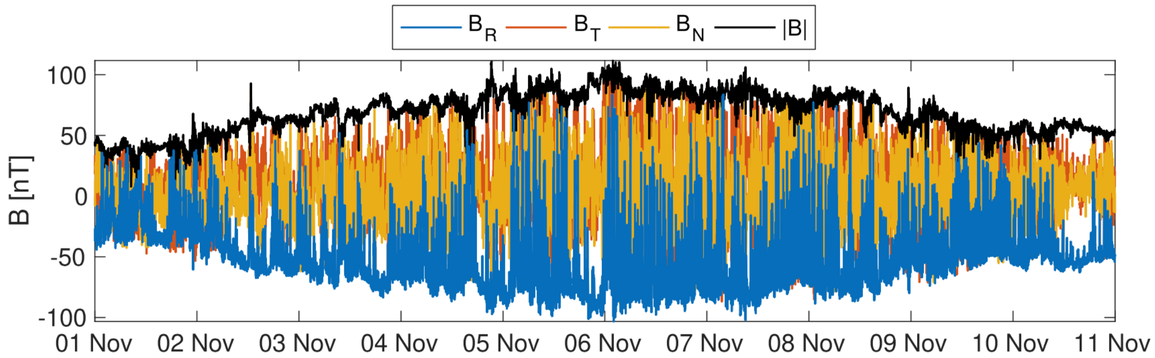
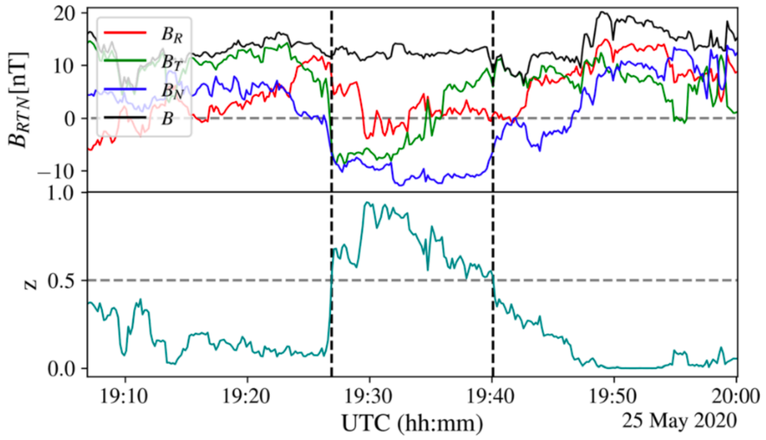
In collaboration with: A. Settino, R. D'Amicis, R. De Marco,
S. Perri, R. Bruno, D.Telloni

Switchbacks



Dudok de Vit et al., ApJS 2020

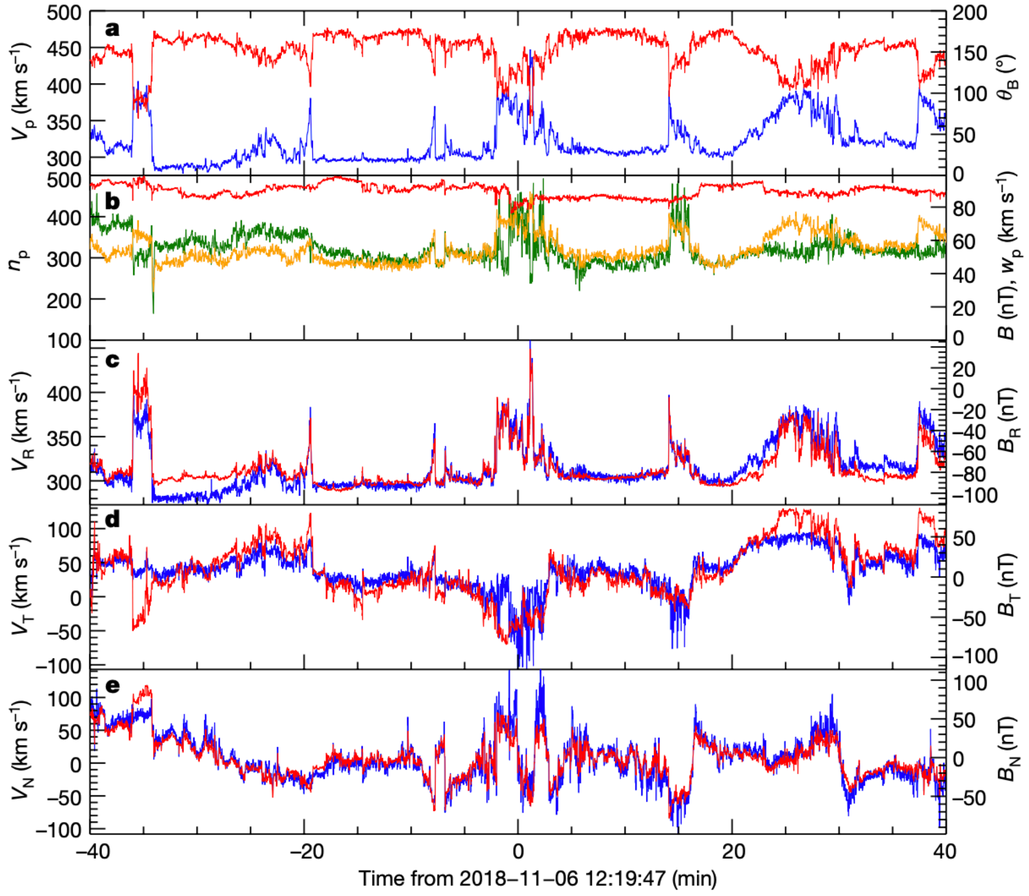


Pecora et al., ApJL 2022

Normalised deflection

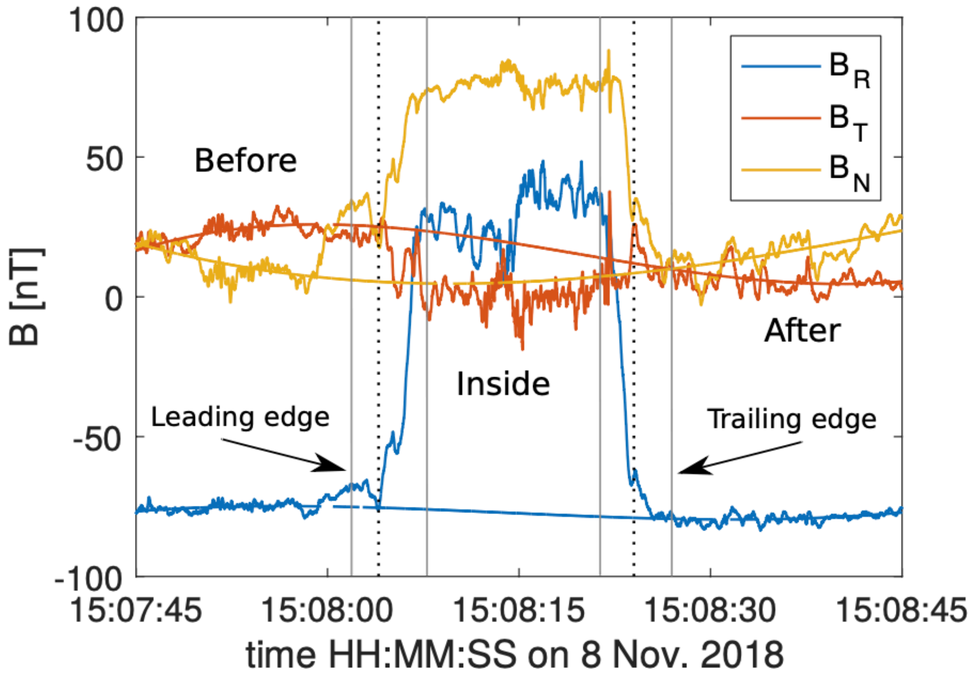
$$z = \frac{1}{2}(1 - \cos\alpha)$$

as a proxy for the magnetic field deflection

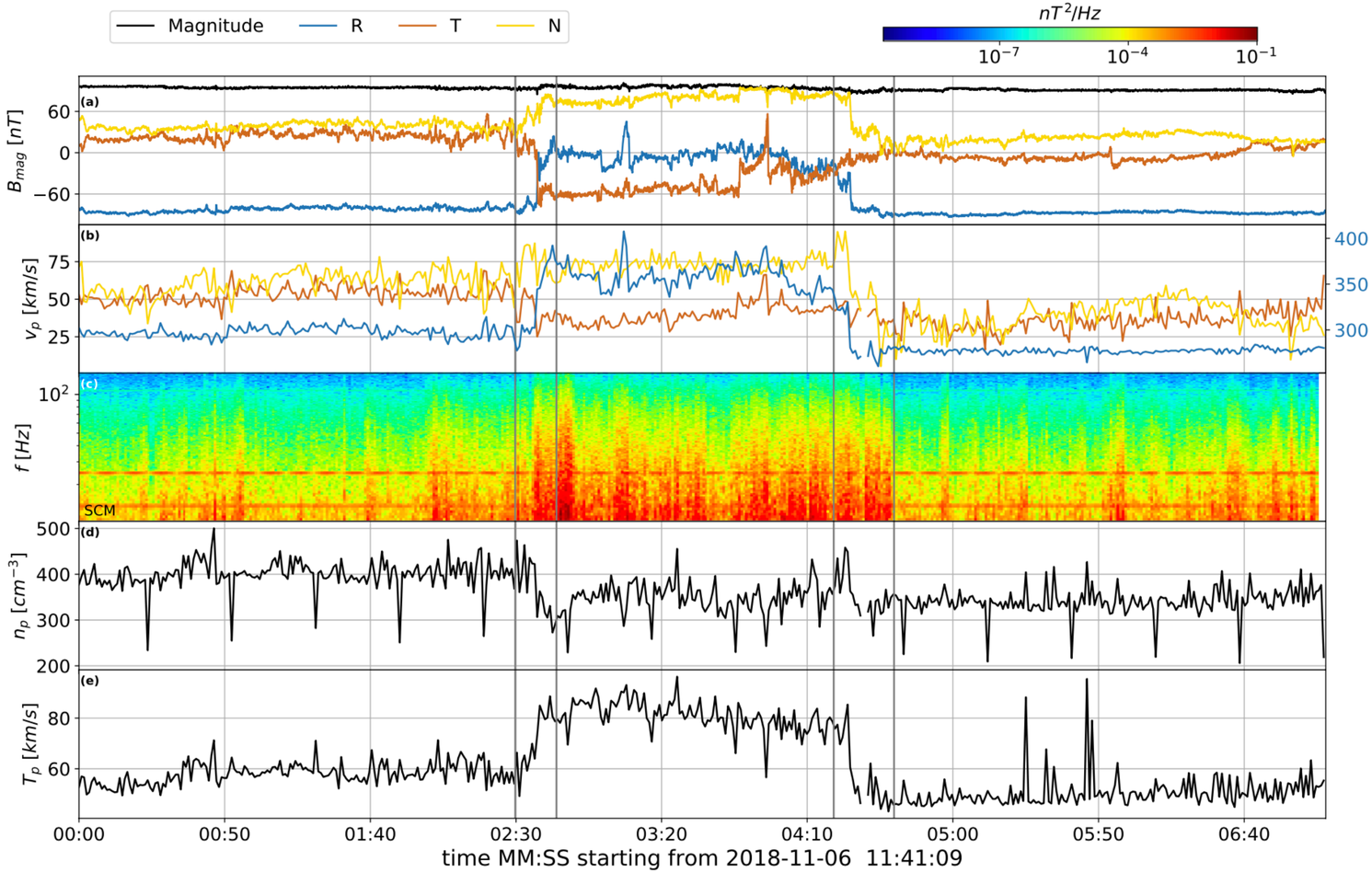


Kasper et al., Nature 2019

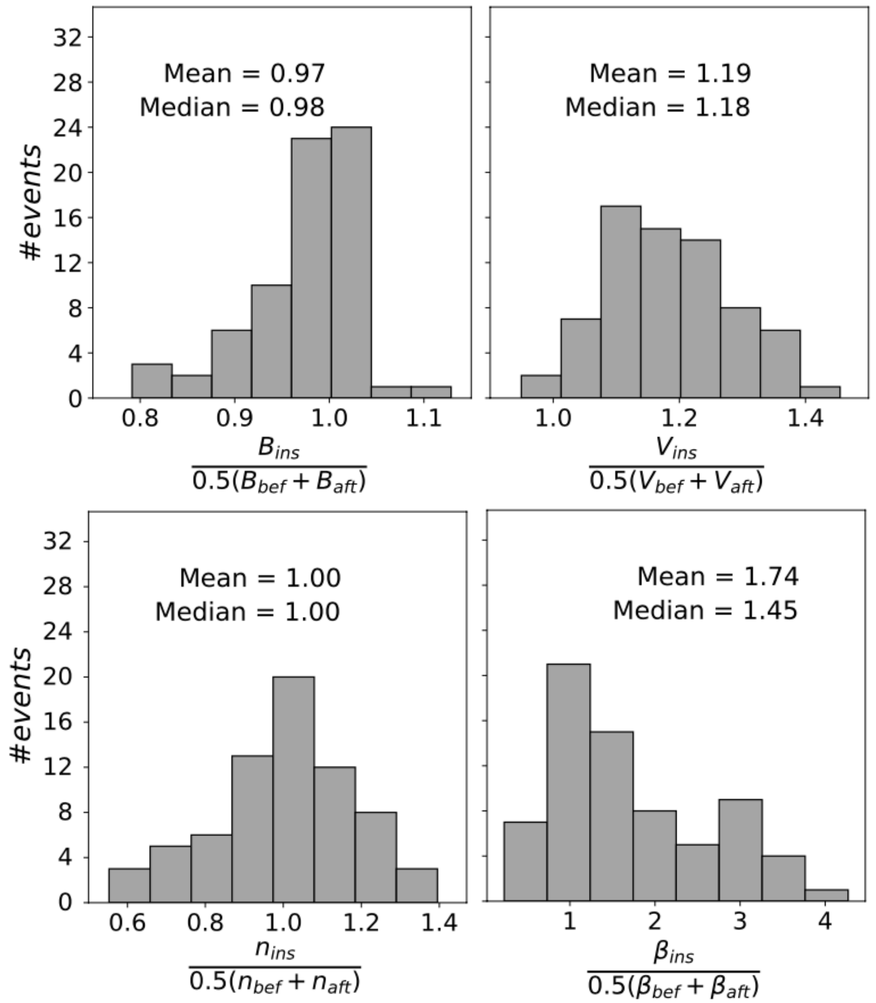
Statistical analysis (PSP)

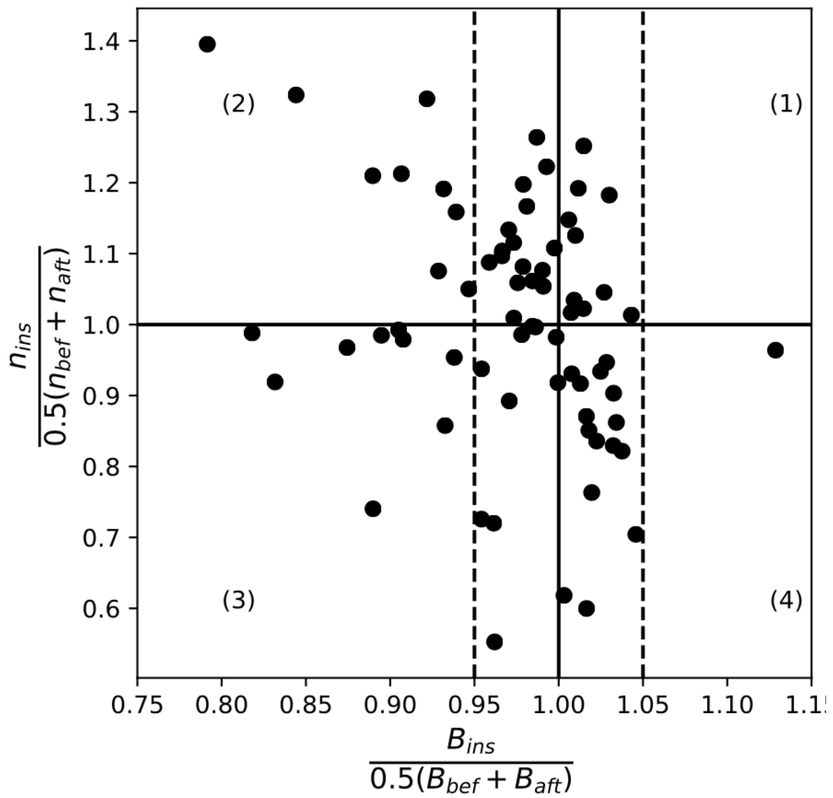


Larosa et al., A&A 2021

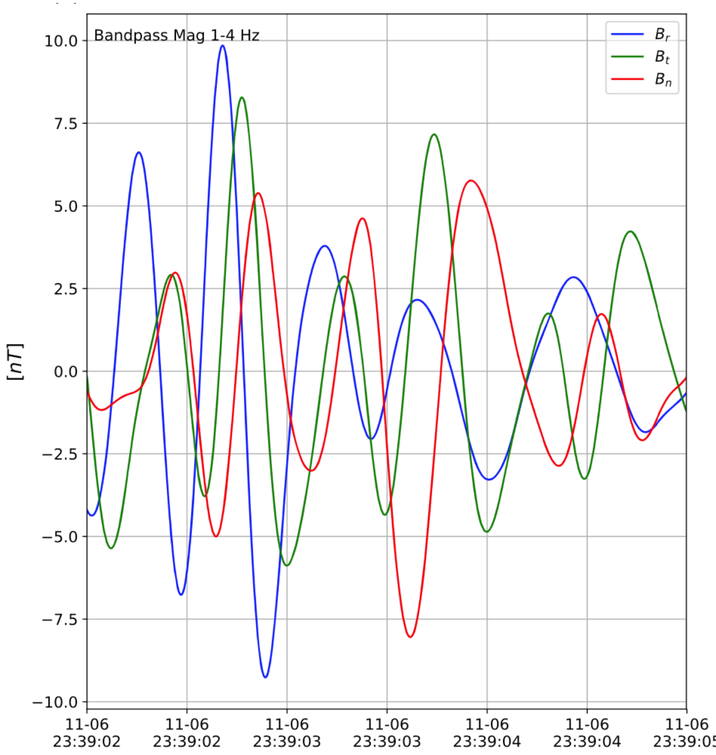


Statistical analysis (PSP)





Larosa et al., A&A 2021

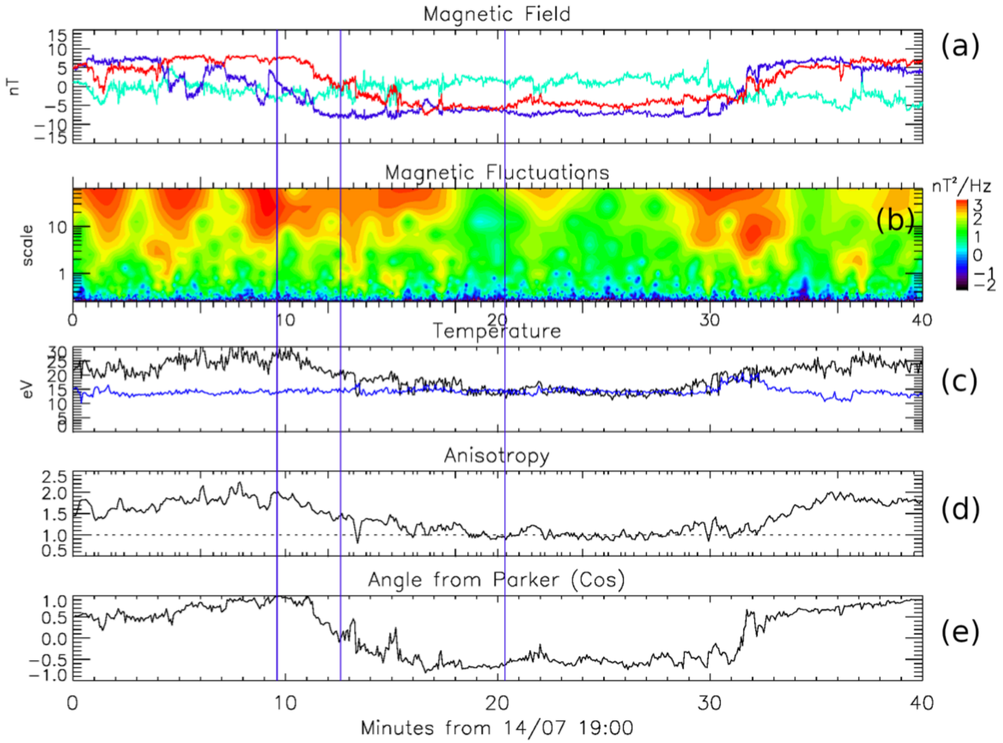


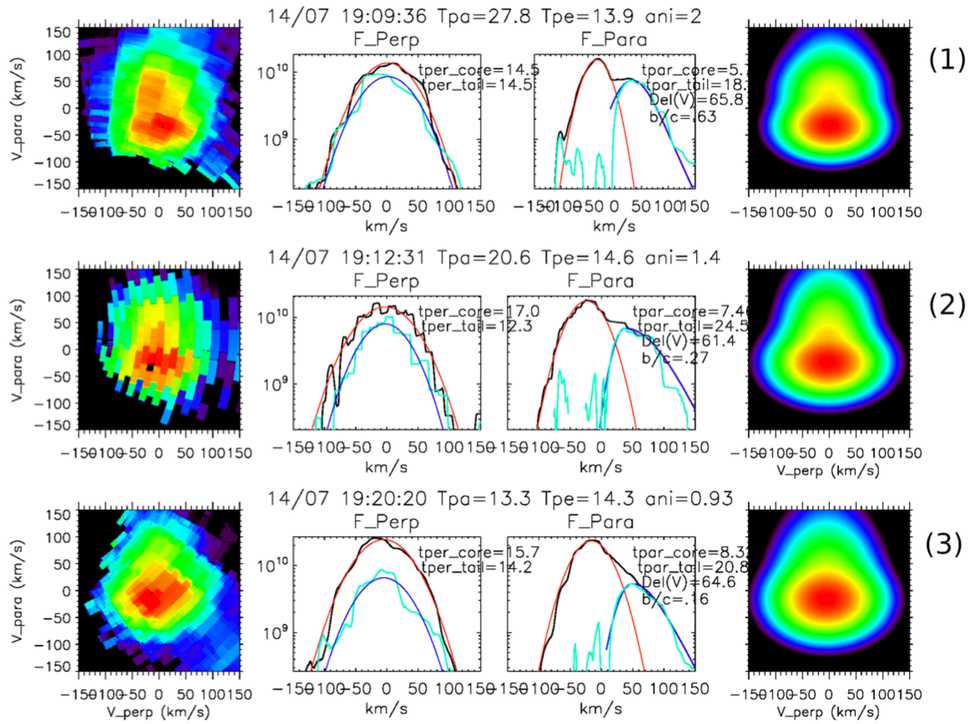
Krasnoselskikh et al., ApJS 2021

Switchbacks by Solar Orbiter

Agenzia Spaziale Italiana

Louarn et al., A&A 2021

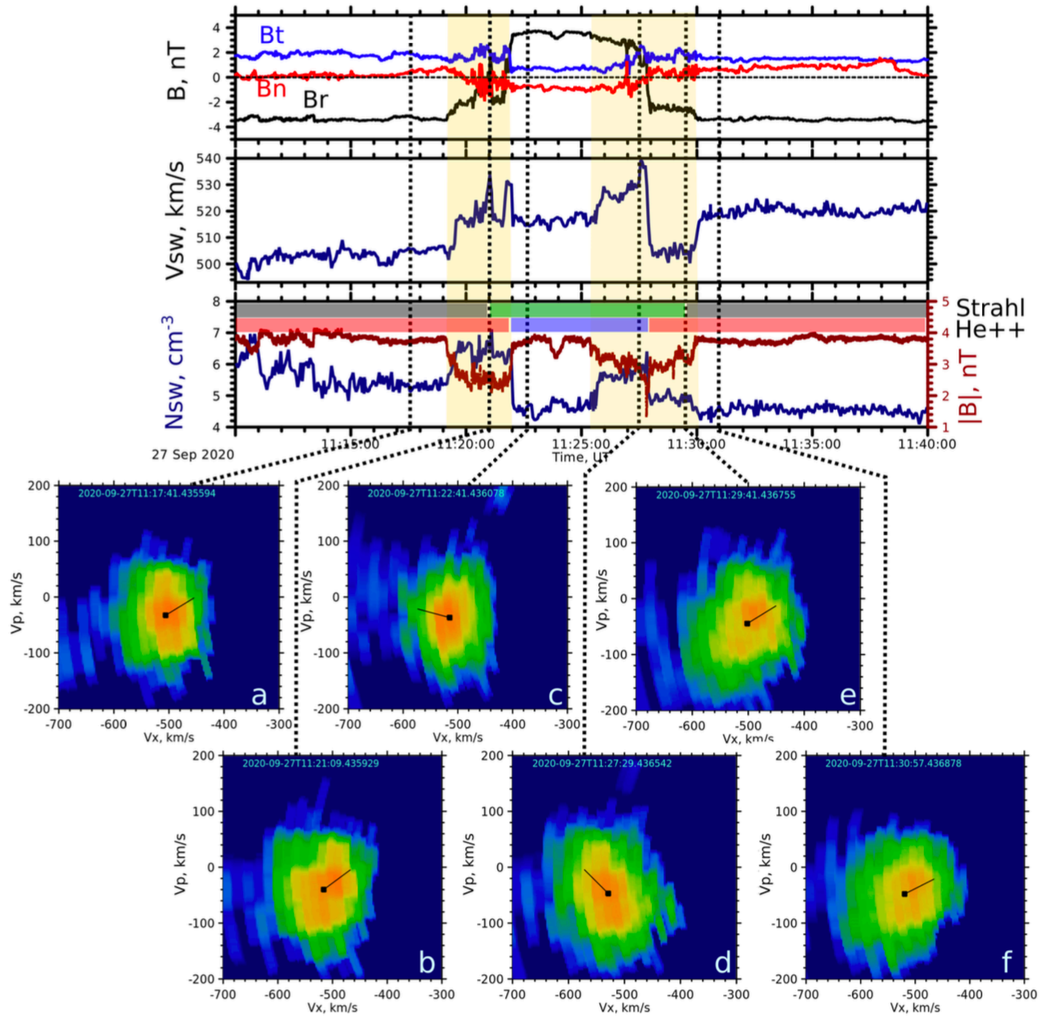




The internal part of the switchback corresponds to a complete relaxation of the total temperature anisotropy.

The transition from external anisotropic to the internal isotropic plasma is mostly associated with a decrease of the beam relative density, by a factor of ~4.

Switchbacks by Solar Orbiter



The embedded switchback observed at 11:25 UT is shown in Fig. 4. The radial magnetic field is reversing for about 6 min without any significant perturbations in the other components. Interestingly, we see boundary layers on both sides of this switchback. Both boundary layers show abrupt increases of the proton bulk velocity as well as anti-correlated profiles of the number density and magnetic field magnitude. The changes in velocity, with jets, combined with decreased magnetic field and increased density, are all consistent with these boundary layers being the result of reconnection (see Gosling et al. 2005). The properties of the proton velocity distribution functions (VDF) are also consistent with reconnection. Before the first boundary layer (Fig. 4, VDF a) we see proton distributions with $T_{\parallel} < T_{\perp}$. As soon as SolO enters the boundary layer, we see the VDF (b), with $T_{\parallel} > T_{\perp}$ and likely containing two populations. Such a VDF is typical for the reconnection exhaust due to the mixing of two solar wind populations from the two sides of the exhaust (see Gosling et al. 2005 and the discussion in Sect. 3). We note that reconnection has been observed at the boundaries of switchbacks with PSP also (Froment et al. 2021). In the center of the switchback, where the magnetic field is positive and radial (VDF c), the VDF again shows $T_{\parallel} < T_{\perp}$. Upon the exit of the switchback, the same features are repeated but in opposite order (distributions d and e). The multi-component nature of the proton VDF is particularly evident in distribution (e). When SolO enters region #4, with negative B_r, the VDF becomes more smooth, but maintaining $T_{\parallel} > T_{\perp}$.

Fedorov et al., A&A 2021

Solar Orbiter at 0.64 au

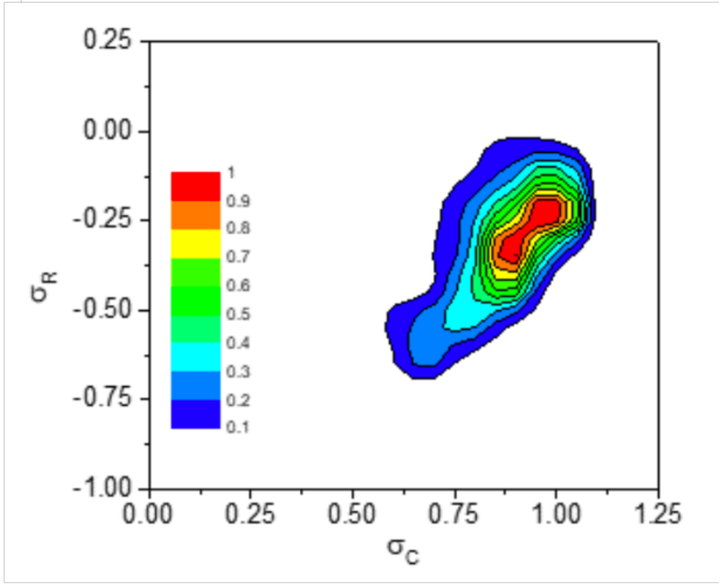
A&A 656, A21 (2021)
https://doi.org/10.1051/0004-6361/202140938

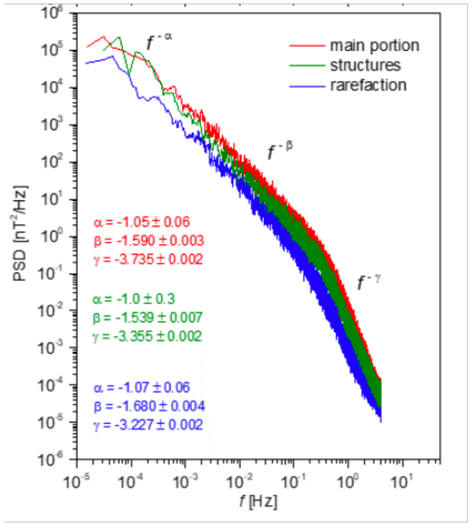
Solar Orbiter First Results (Cruise Phase)

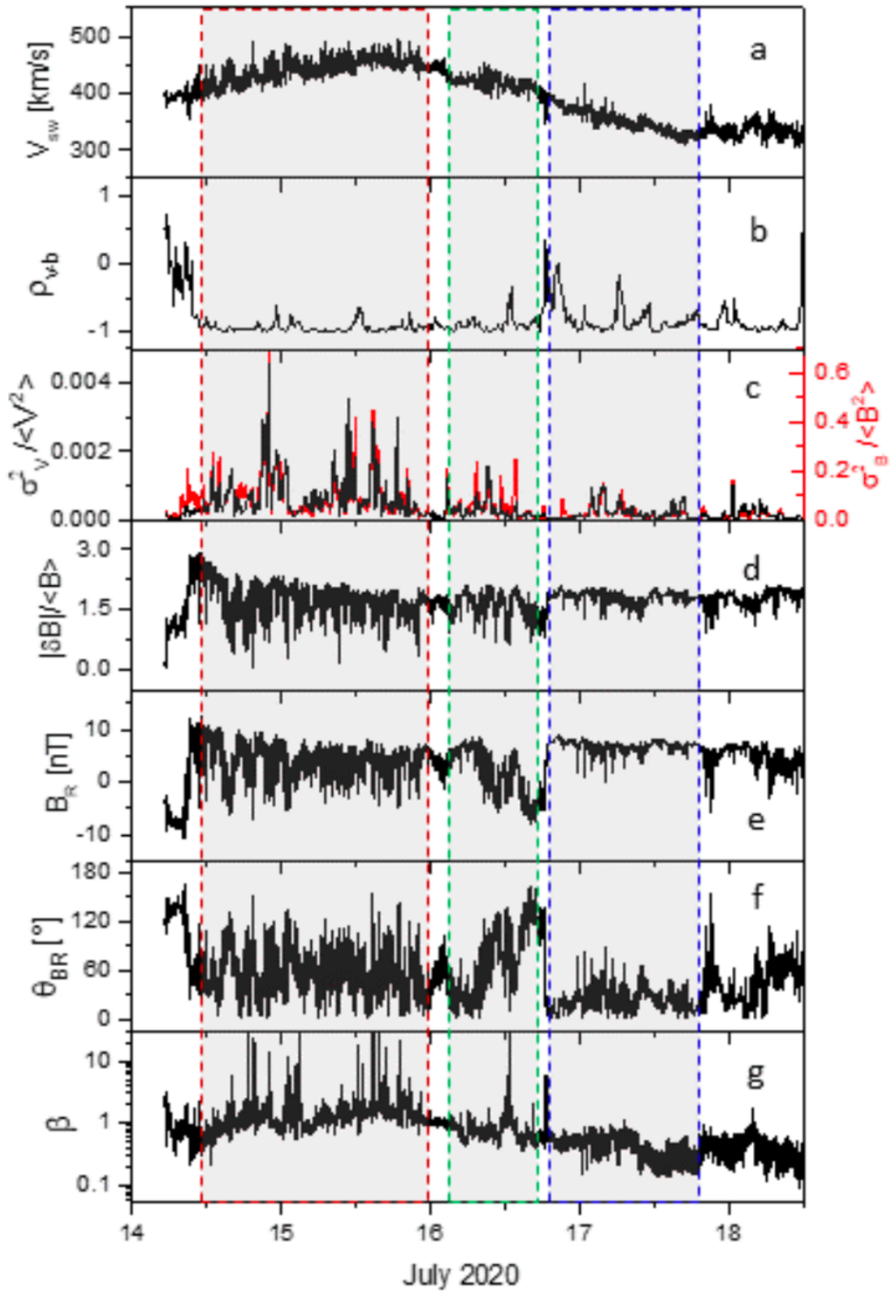
Astronomy & Astrophysics
Special issue

First Solar Orbiter observation of the Alfvénic slow wind and identification of its solar source

R. D'Amicis[1], R. Bruno[1], O. Panasenco[2], D. Telloni[3], D. Perrone[4], M. F. Marcucci[1], L. Woodham[5], M. Velli[6], R. De Marco[1], V. Jagarlamudi[1], I. Coco[7], C. Owen[8], P. Louarn[9], S. Livi[10], T. Horbury[5], N. André[9], V. Angelini[5], V. Evans[5], A. Fedorov[9], V. Genot[9], B. Lavraud[11,9], L. Matteini[5], D. Müller[12], H. O'Brien[5], O. Pezzi[13,14,15], A. P. Rouillard[9], L. Sorriso-Valvo[15,16], A. Tenerani[17], D. Verscharen[8,18], and I. Zouganelis[19]







Coherent structures

frontiers

1

Ion kinetic effects linked to magnetic field discontinuities in the slow Alfvénic wind observed by *Solar Orbiter* in the inner heliosphere

Denise Perrone [1,*], **Adriana Settino** [2], **Rossana De Marco** [3], **Raffaella D'Amicis** [3] **and Silvia Perri** [4]

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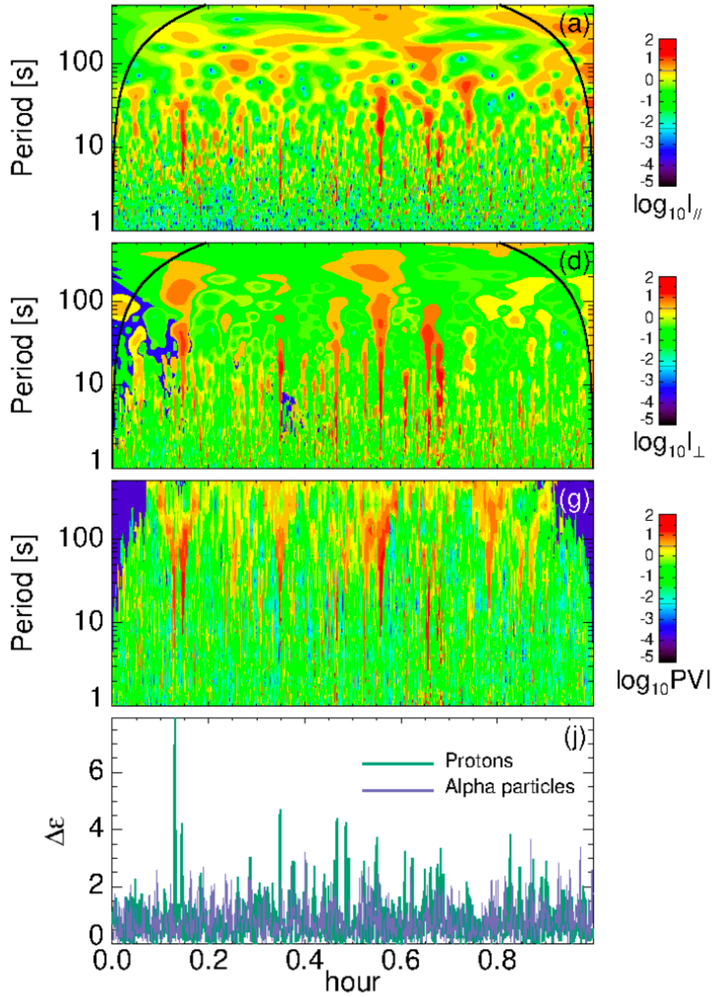
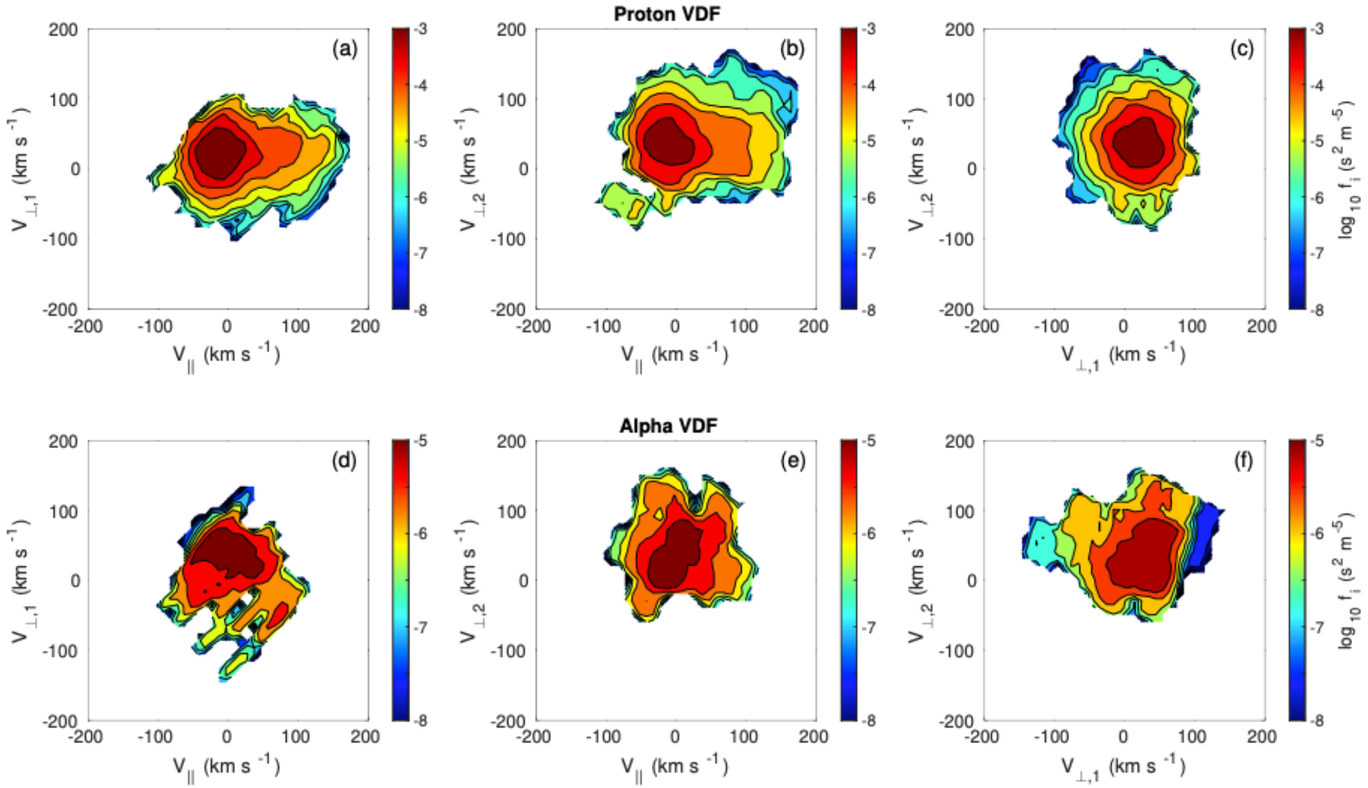
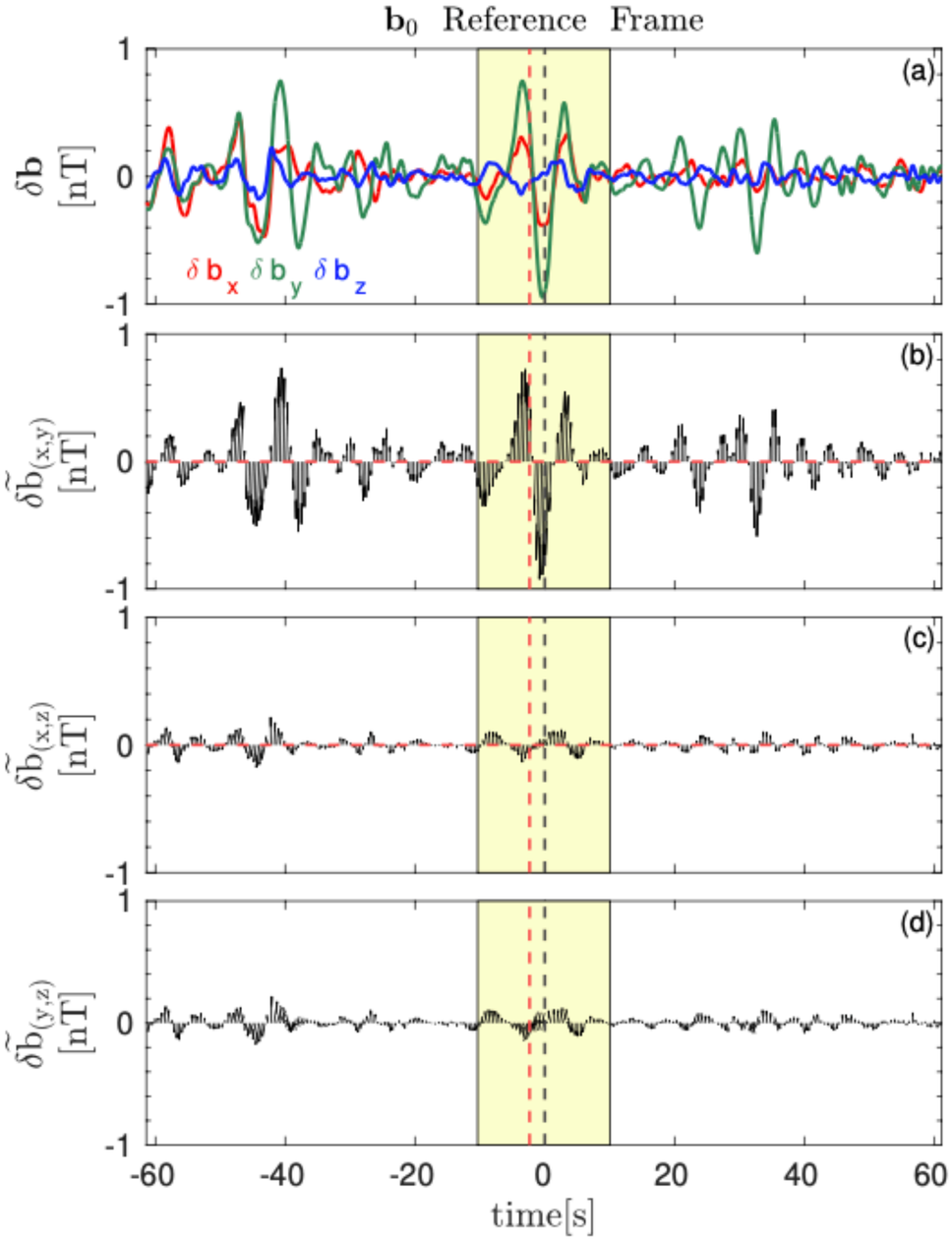
Adriana's Presentation (yesterday)

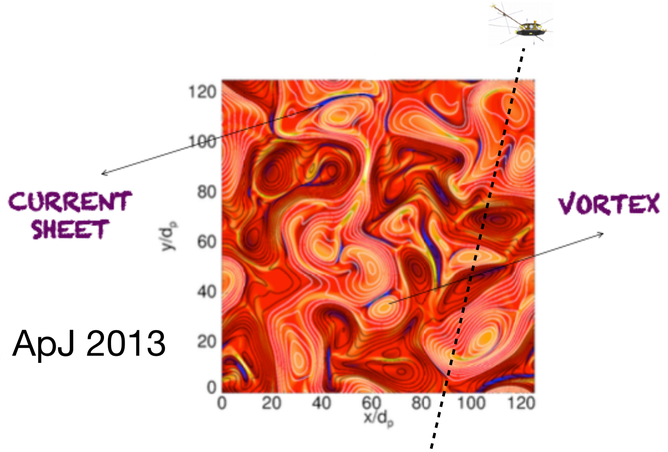


Vortex chain

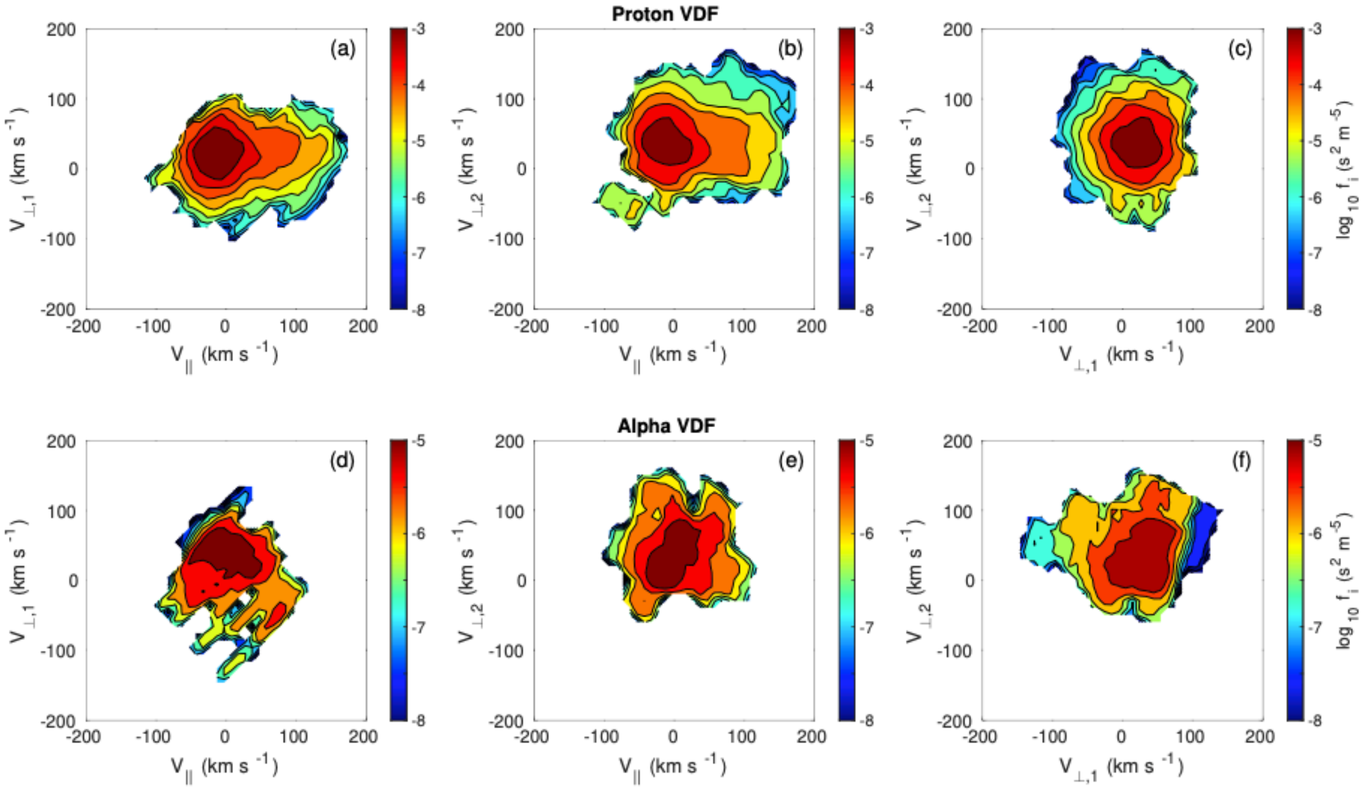


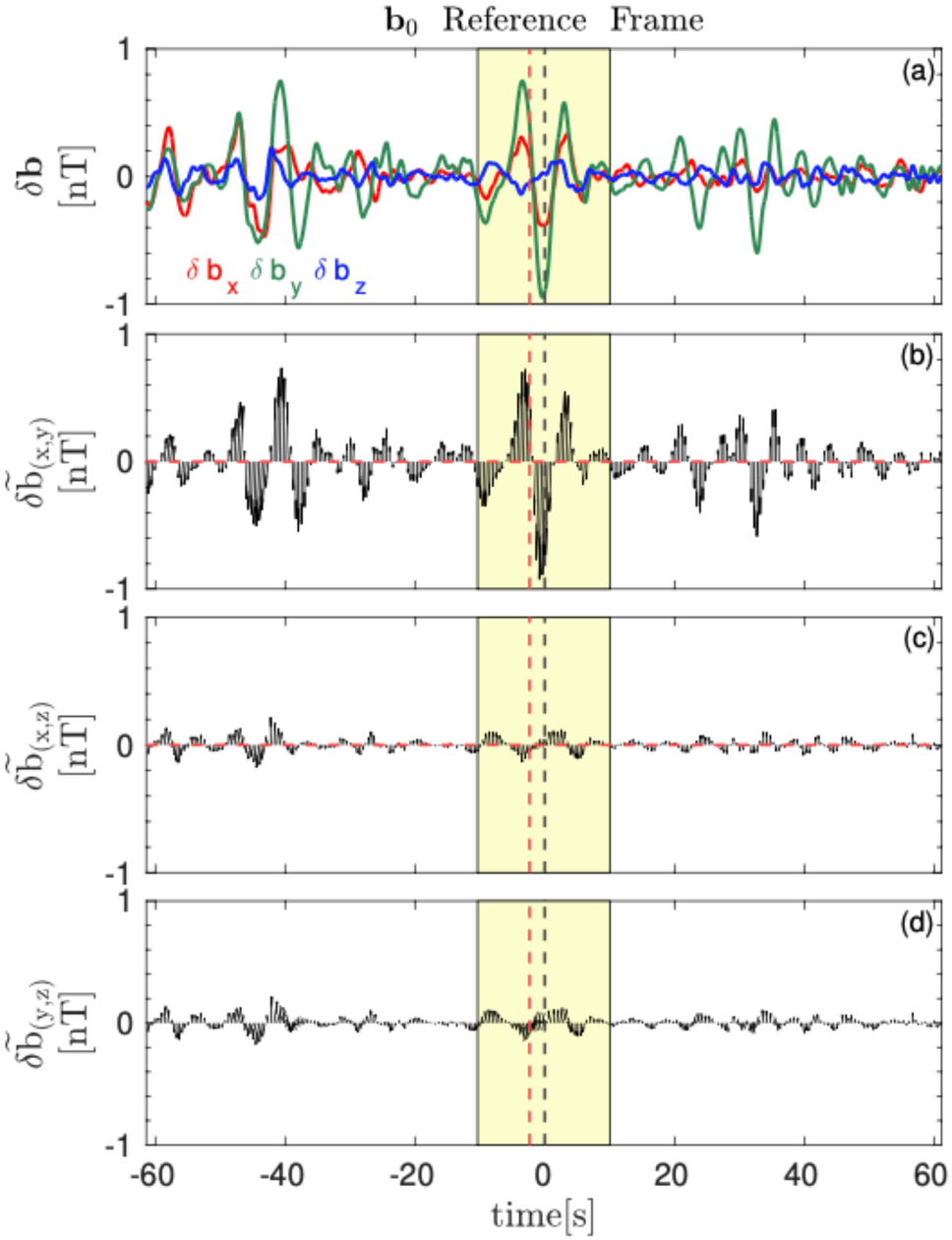


Vortex chain

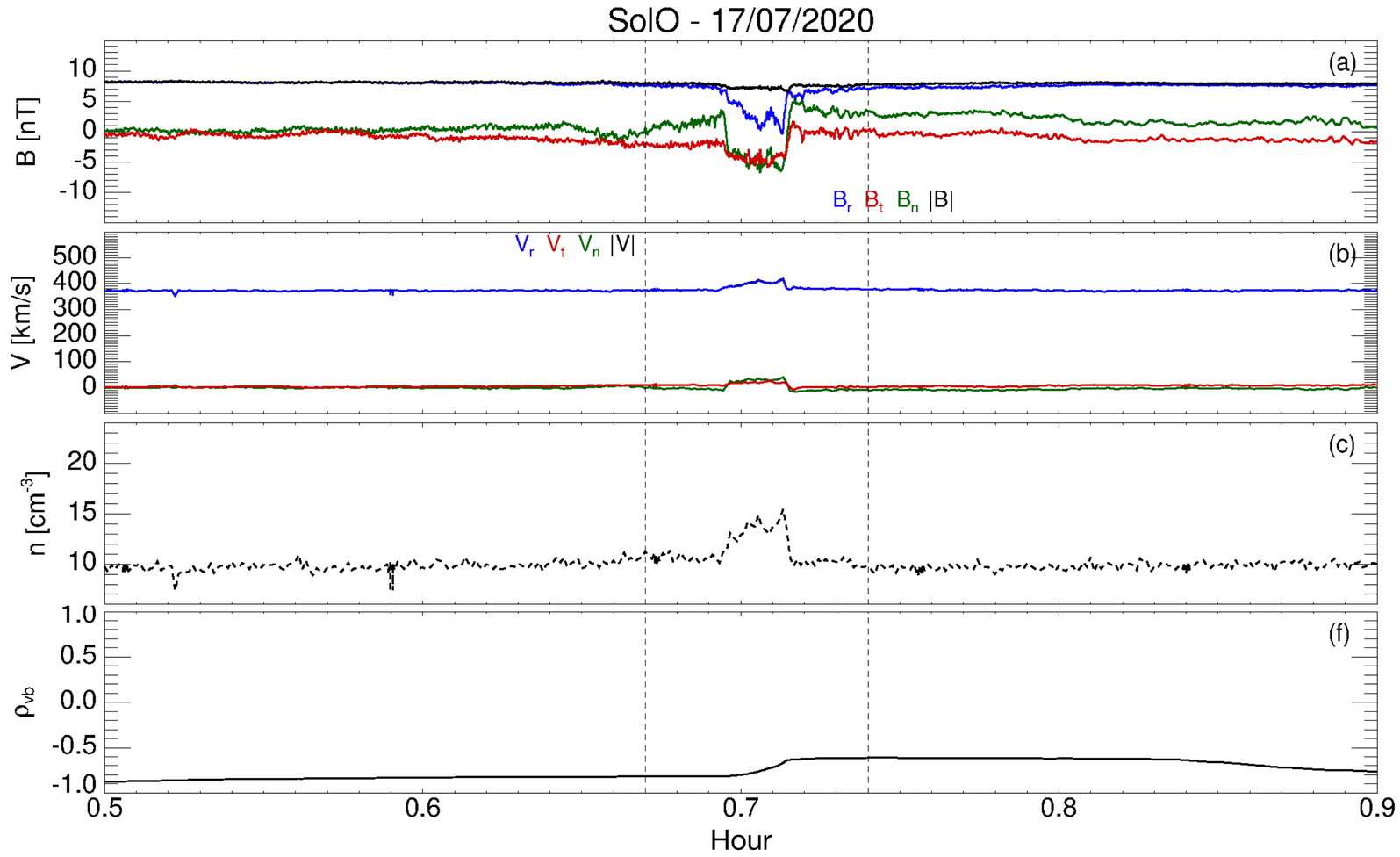


Perrone et al., ApJ 2013

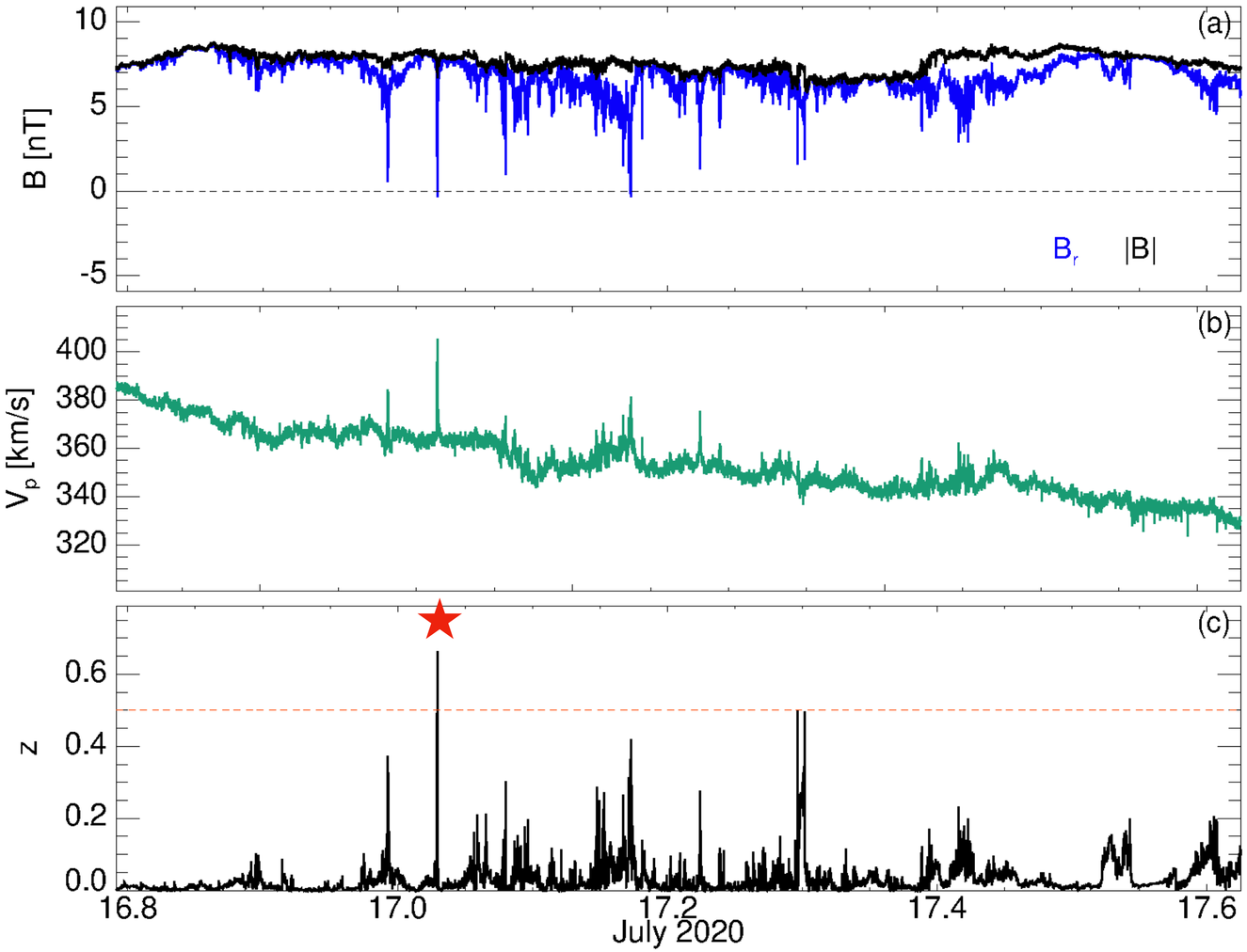




Isolated large-scale structure



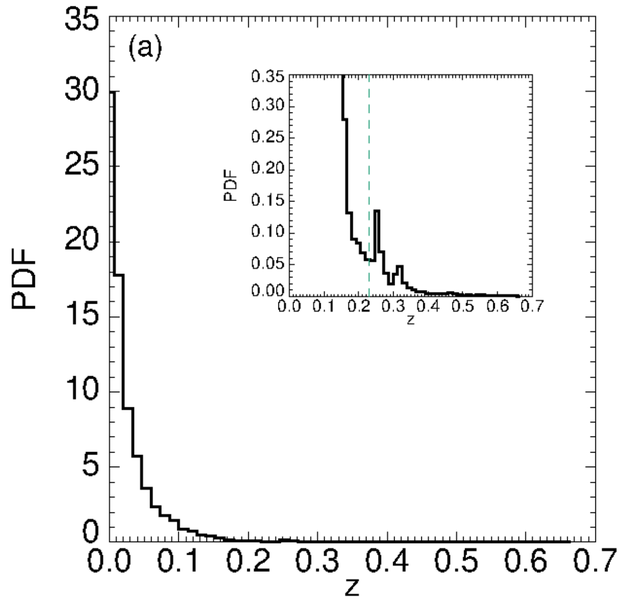
Switchbacks identification



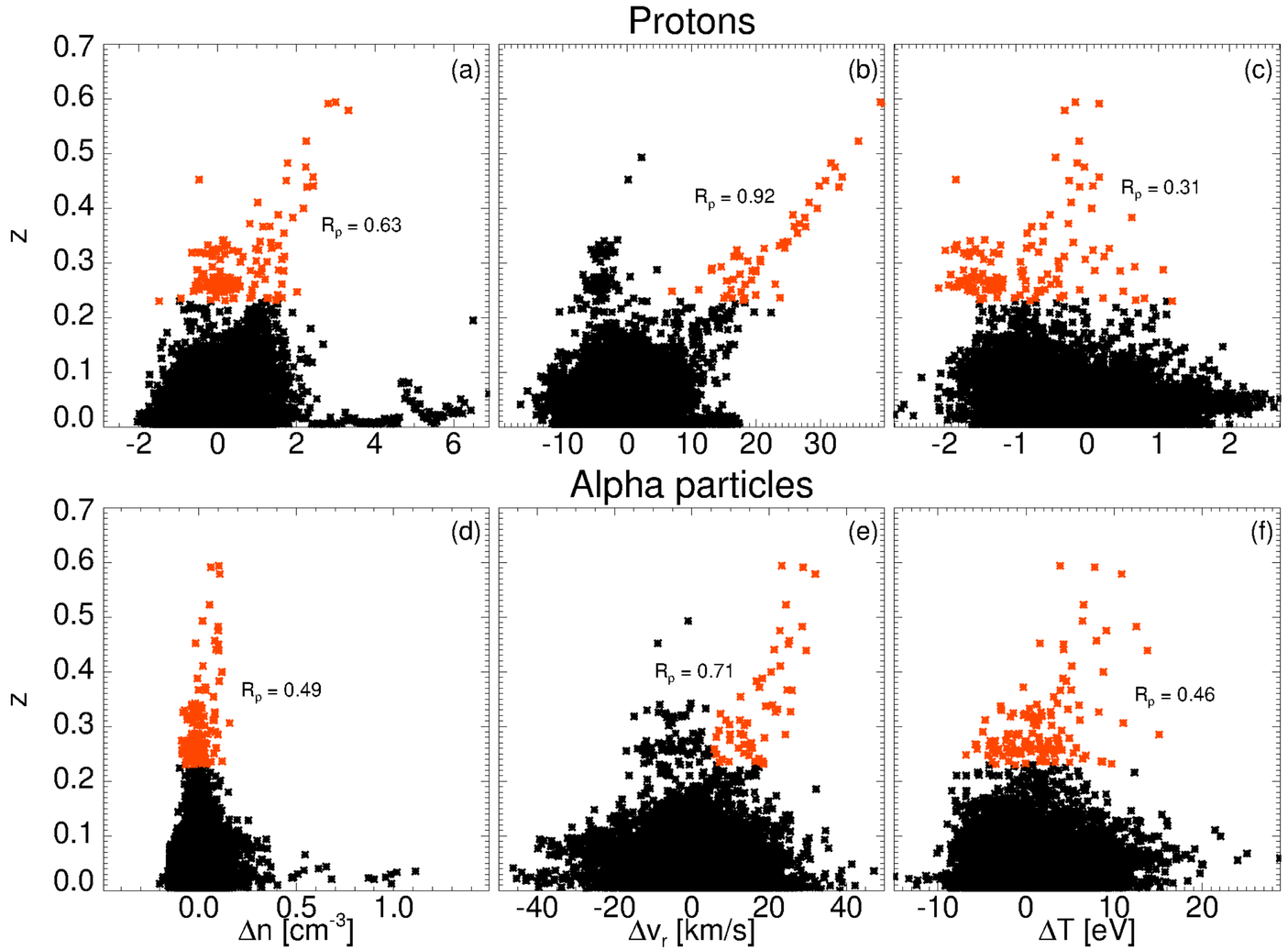
$$z = \frac{1}{2}(1 - \cos\alpha)$$

where α is the angle between the pointwise magnetic field $\boldsymbol{B}$ and a local average $\langle \boldsymbol{B} \rangle$ evaluated over the considered 6 hr.

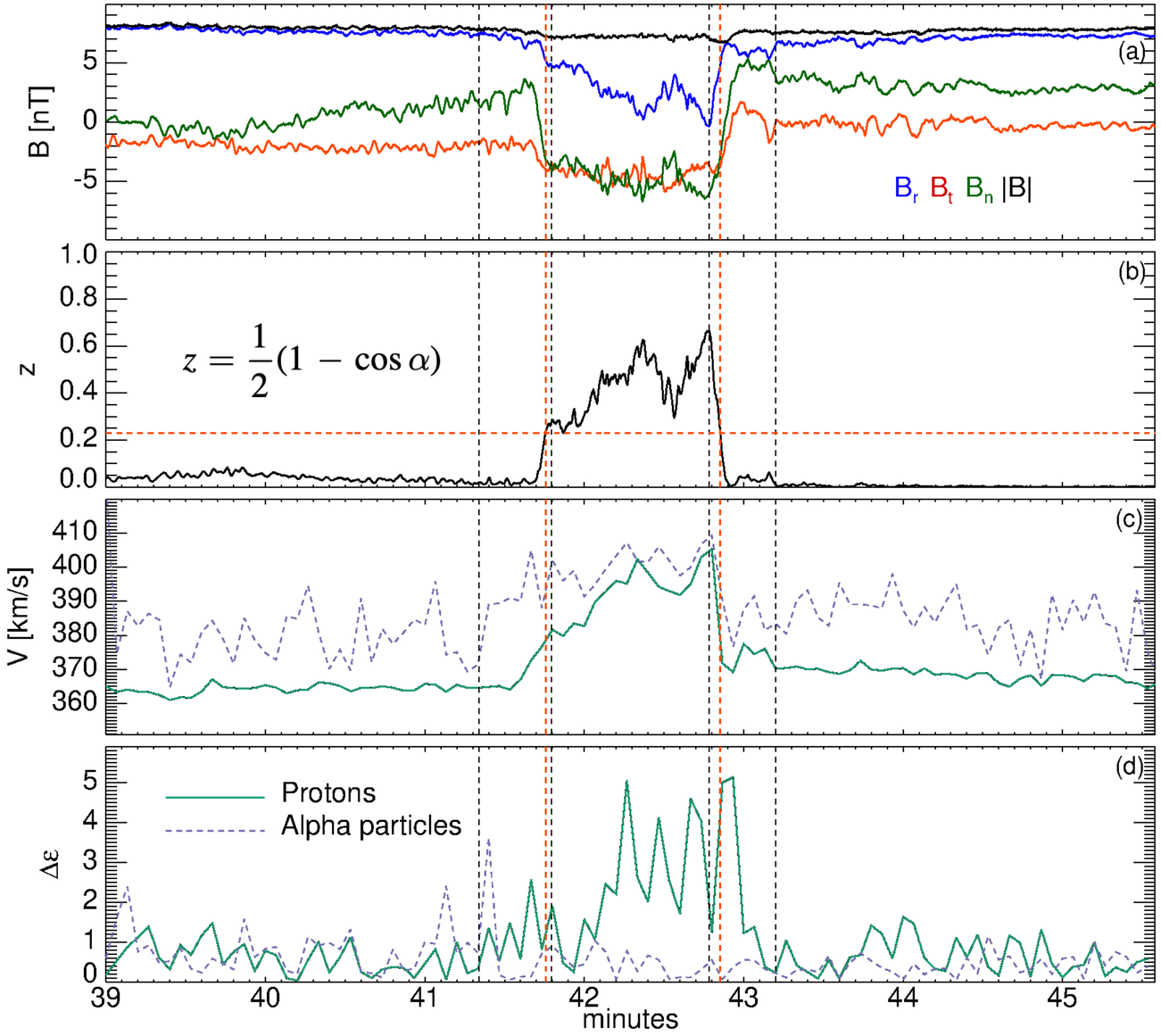
$z \geqslant 0.5$, corresponding to magnetic field deflections larger than 90° with respect to the local average.



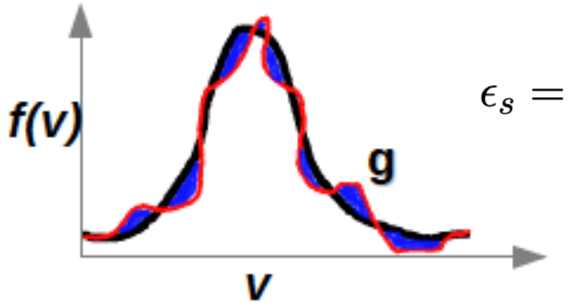
Correlation



Example of switchback



Non-Maxwellianity



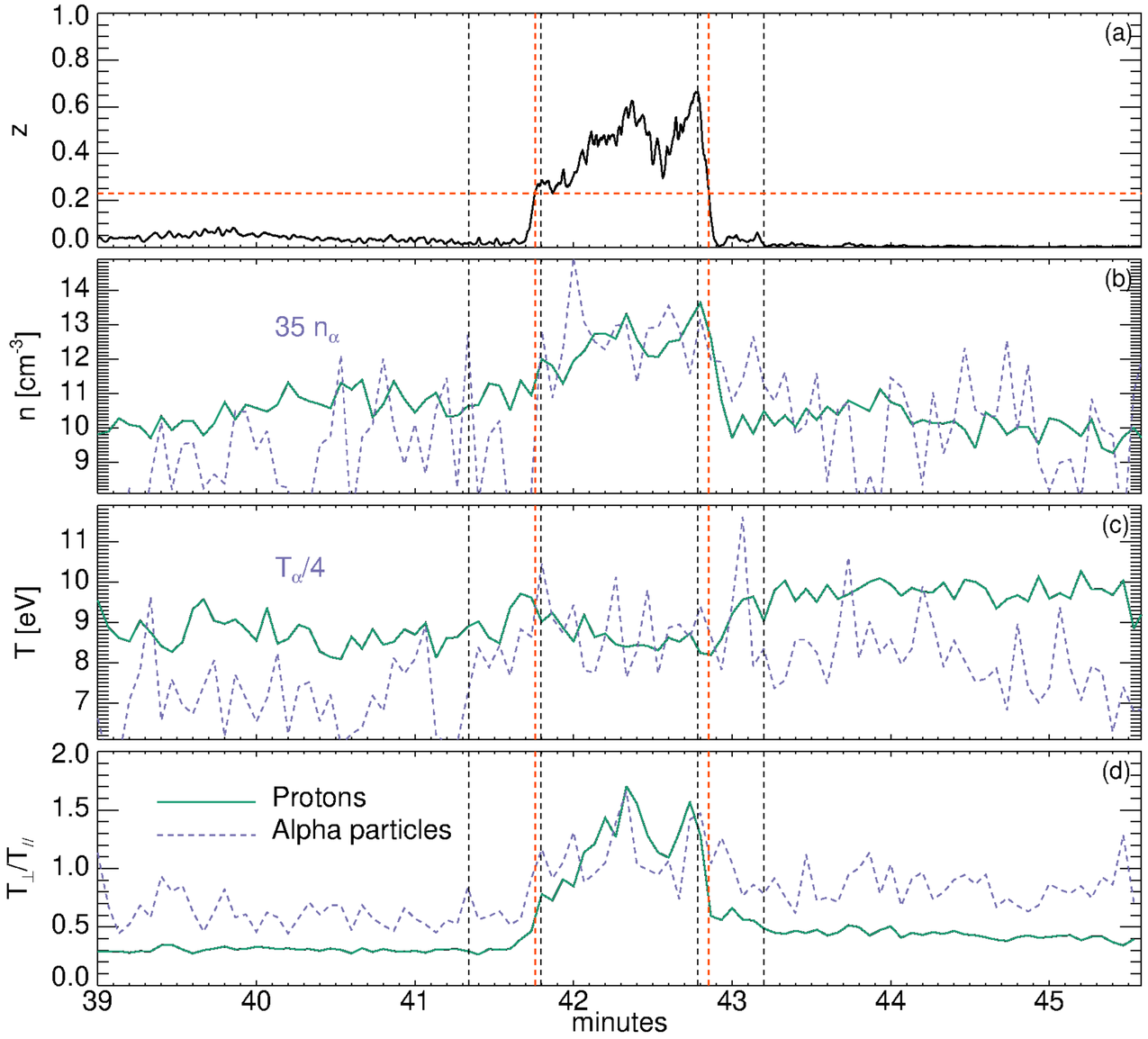
$$\epsilon_s = \frac{1}{n_s}\sqrt{\int (f_s - g_s)^2 d^3v}$$

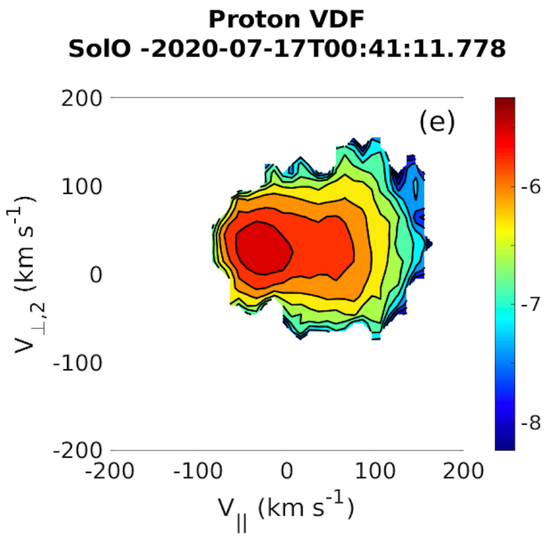
where n_s is the density for a species s, f_s is the measured VDF and g_s is the associated Maxwellian distribution with the same density, temperature and velocity as the observed one.

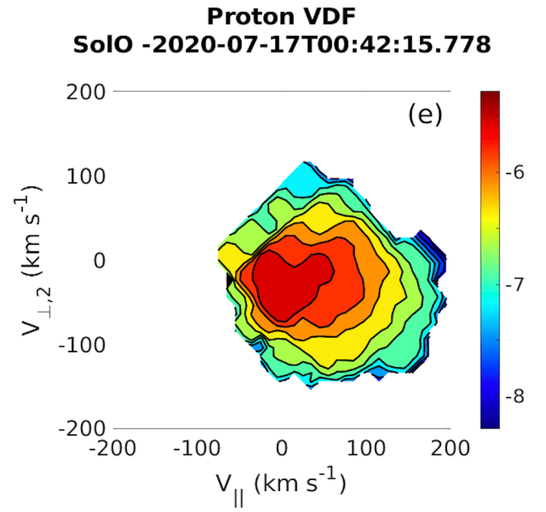
$\Delta\epsilon$ increments of non-Maxwellianity

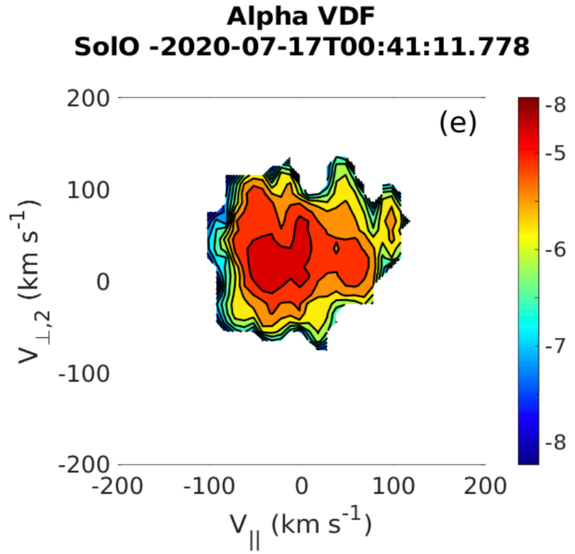
normalised on a time scale of 8 s

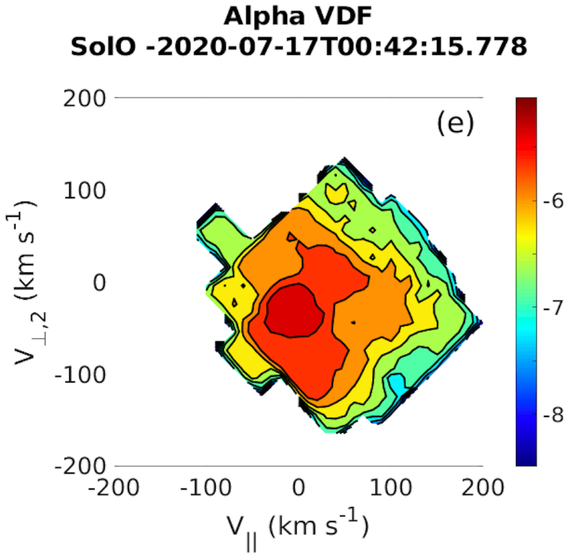
Related effects on particles



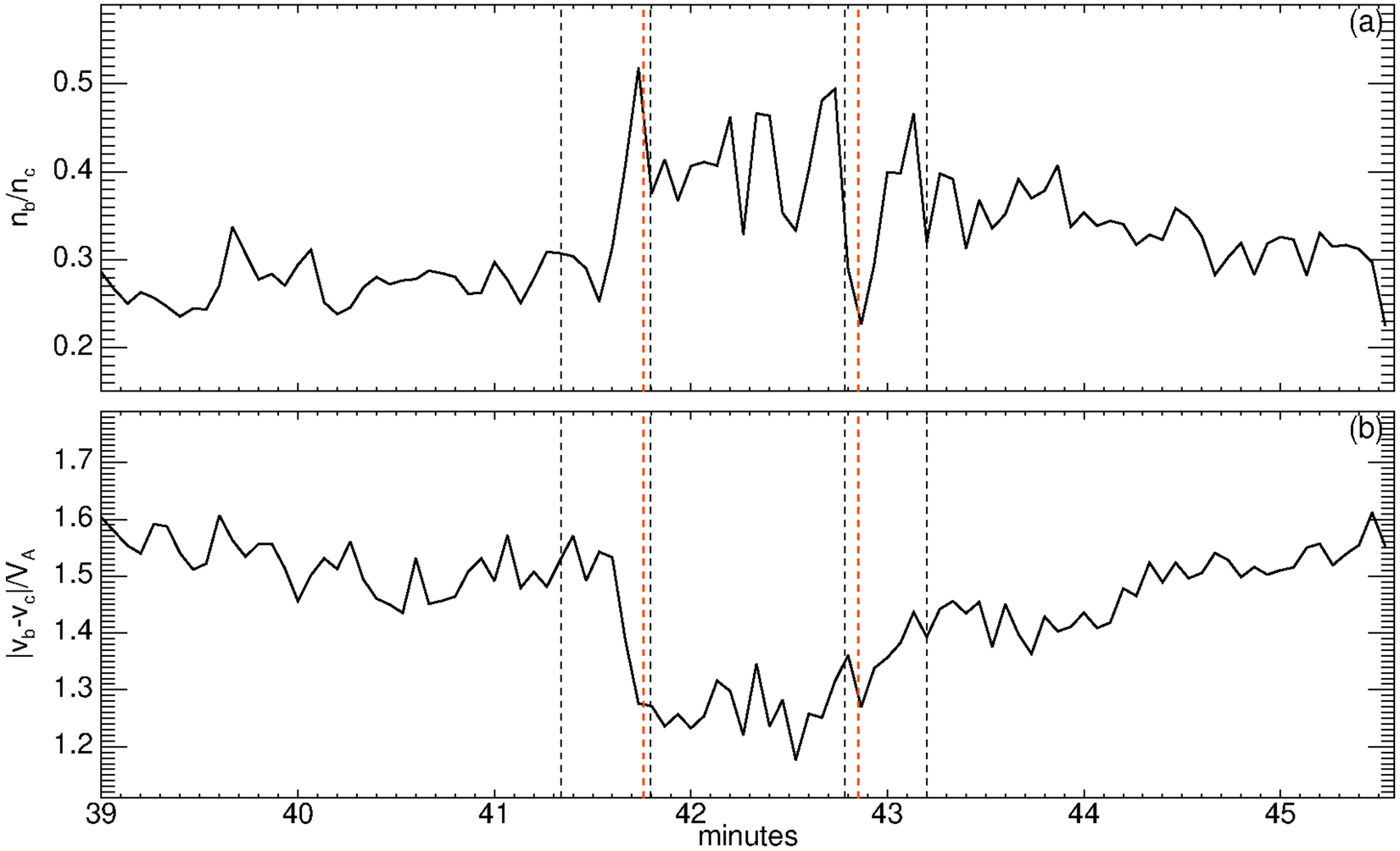








Core vs beam for protons



Summary

Agenzia Spaziale Italiana

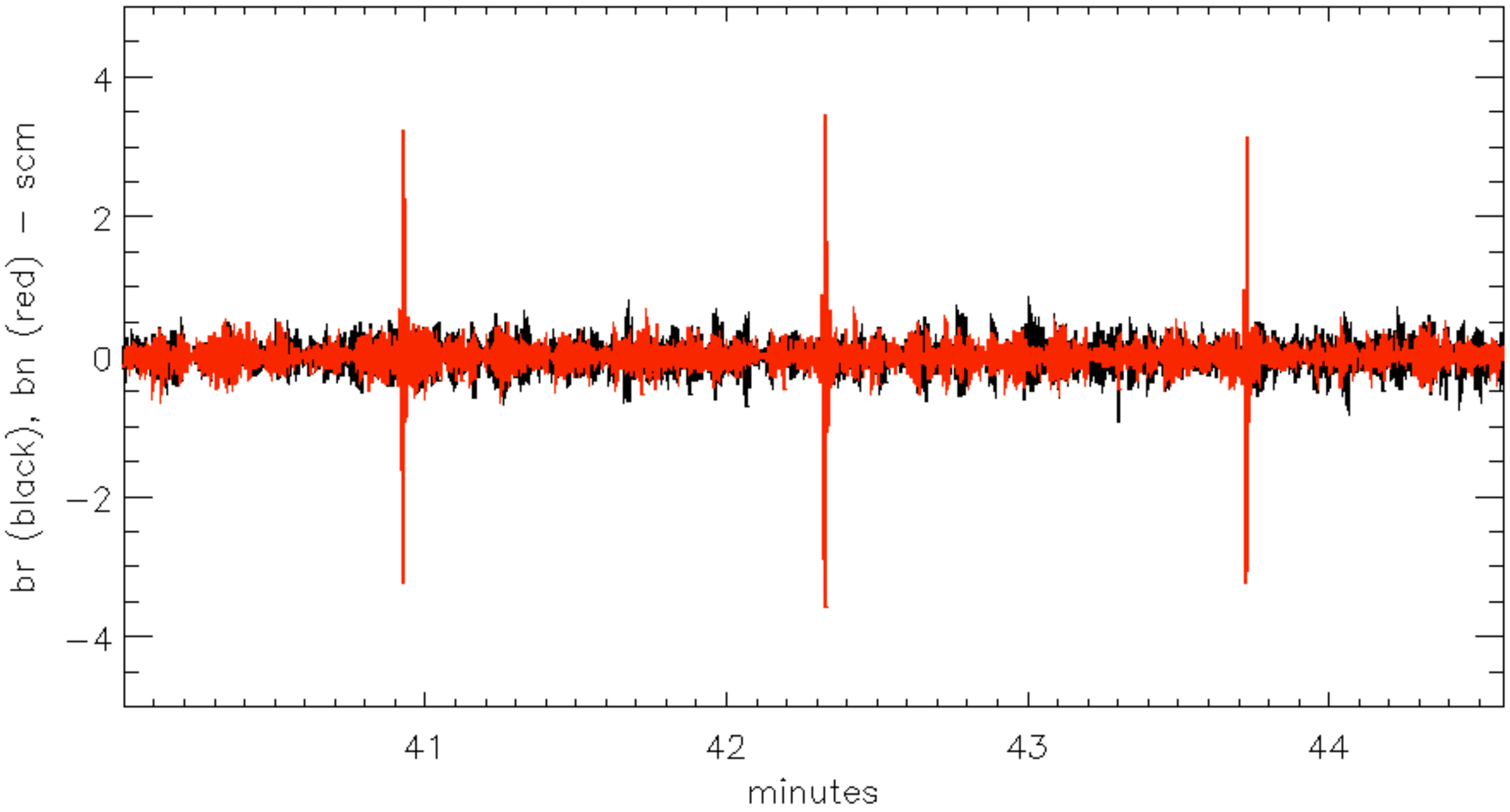
Preliminary results:

- We performed a preliminary statistical analysis on switchback characteristics in the rarefaction region of July 17th, 2020, when Solar Orbiter was at 0.64 au
- There is a linear correlation with ion moments for both protons and alphas
- Strong switchbacks are also associated to strong deformation of the ion distribution function at the boundary and heating inside the structure

Working in progress:

- Study of the wave activity in the leading and trailing edges of the switchbacks. It seems that the electromagnetic activity is stronger in the trailing edge.

RPW data



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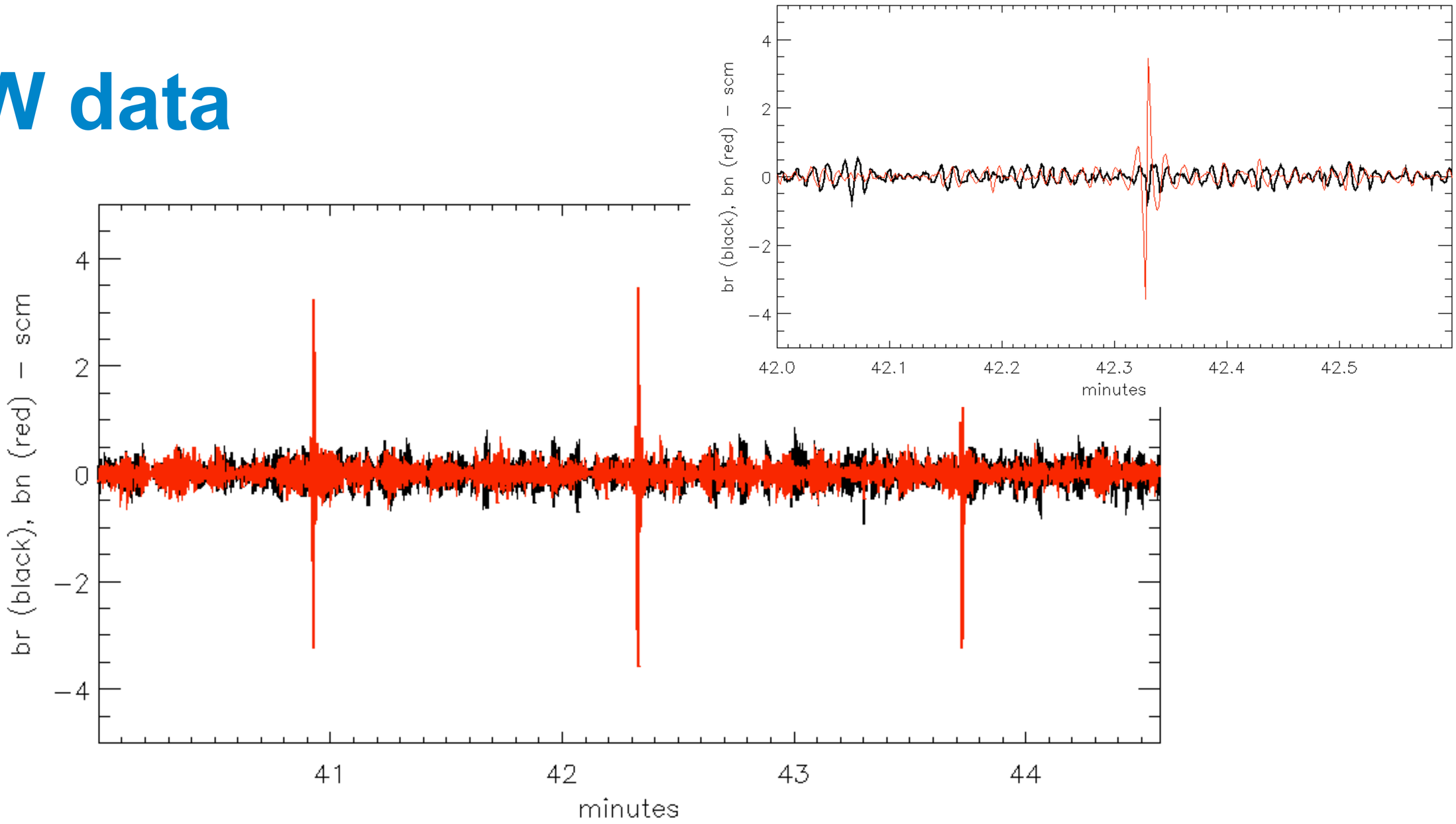
br (black), bn (red) – scm
4
2
0
−2
−4
41
42
43
44
minutes
br (black), bn (red) – scm
4
2
0
−2
−4
42.0
42.1
42.2
42.3
42.4
42.5
minutes