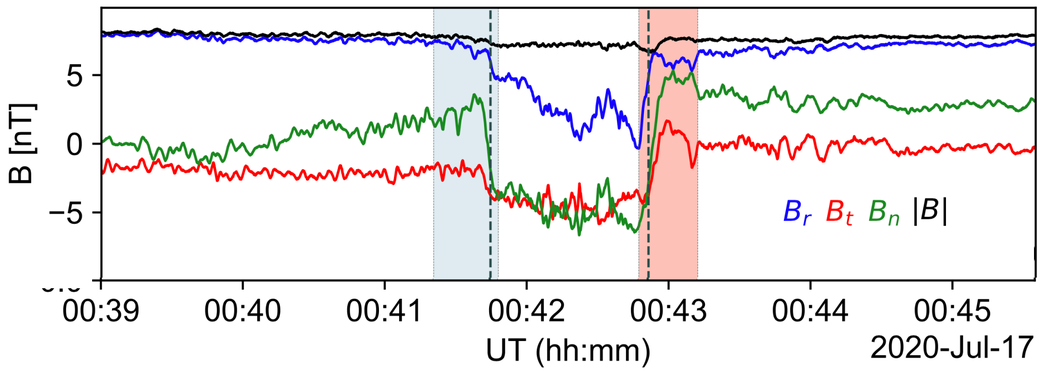
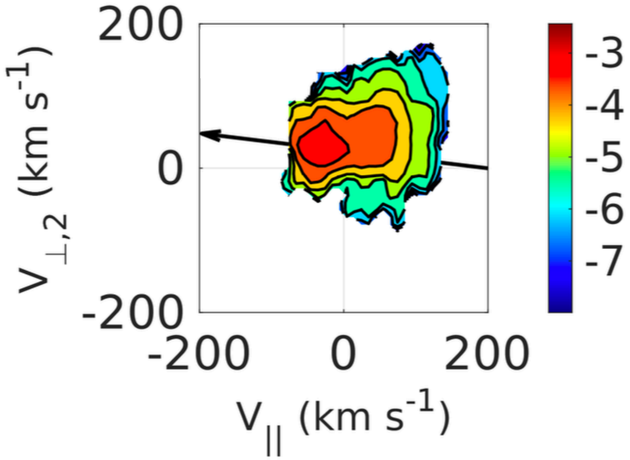
Kinetic effects on ions due to switchbacks
Solar Orbiter observations

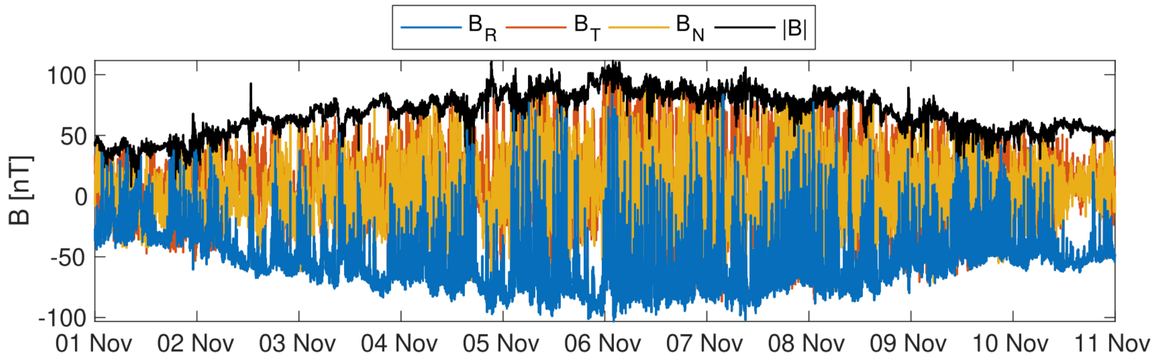
Denise Perrone – denise.perrone@asi.it



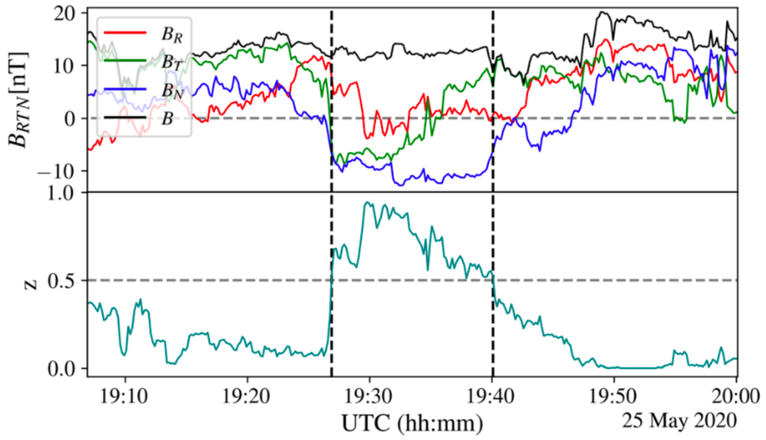


In collaboration with: A. Settino, R. D'Amicis, R. De Marco, S. Perri, R. Bruno, D.Telloni

Switchbacks: *PSP* perspective



Dudok de Wit et al., ApJS 2020

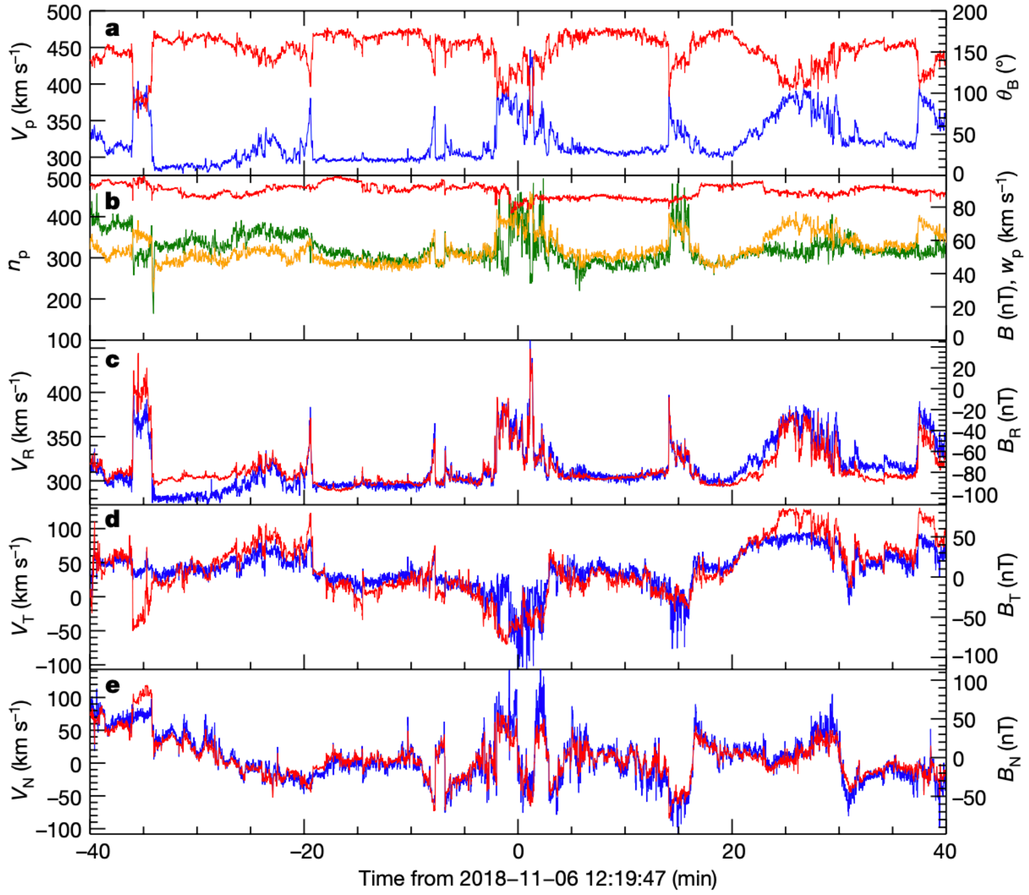


Pecora et al., ApJL 2022

Normalised deflection

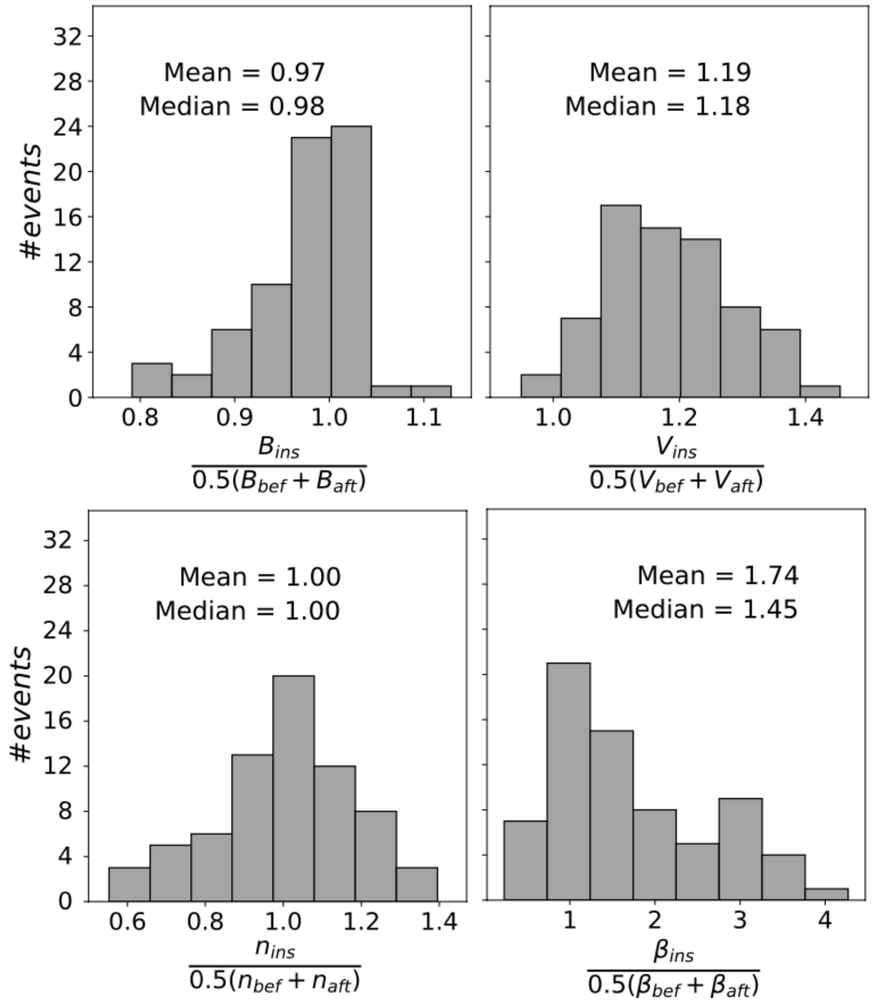
$$z = \frac{1}{2}(1 - \cos\alpha)$$

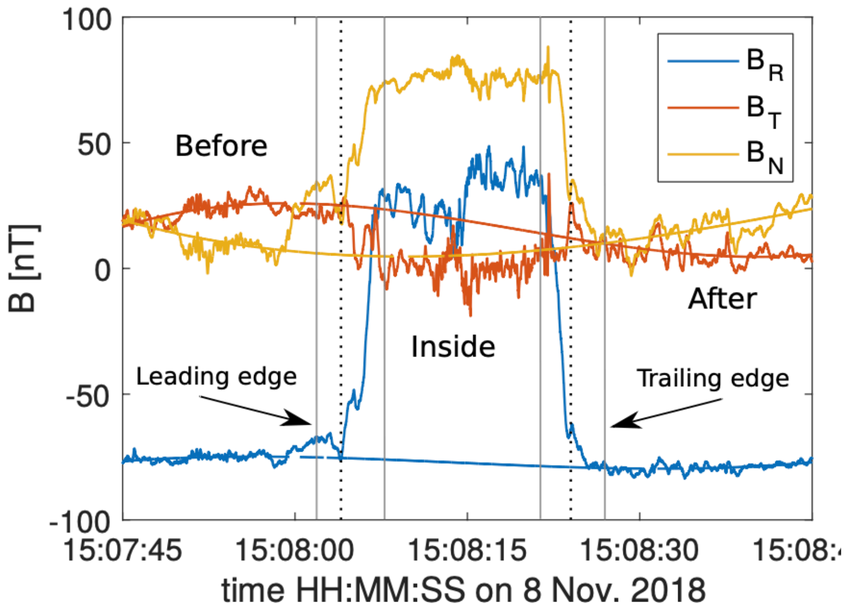
as a proxy for the magnetic field deflection



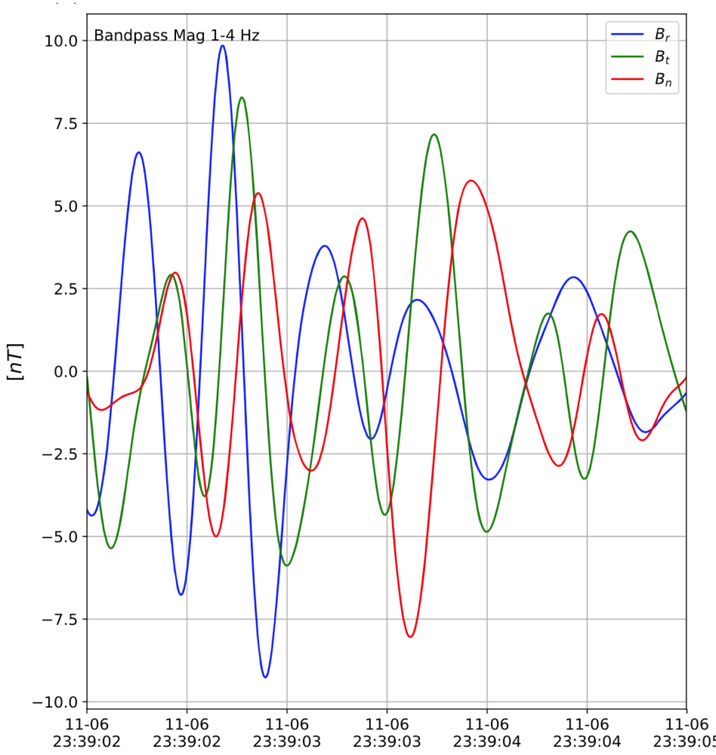
Kasper et al., Nature 2019

Statistical analysis (PSP)





Larosa et al., A&A 2021

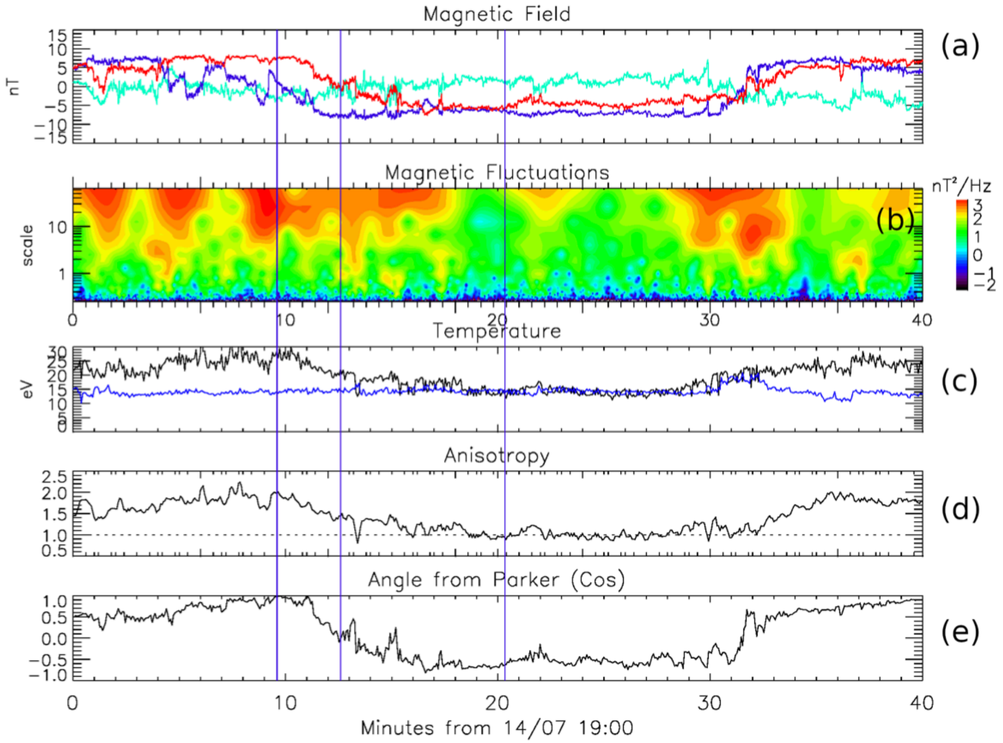


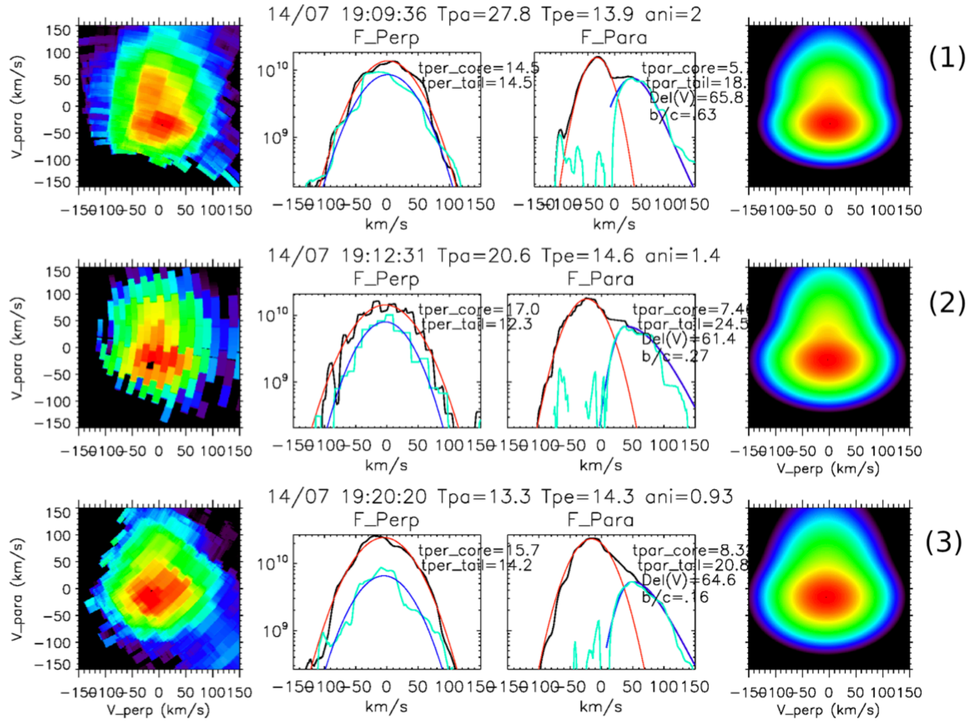
Krasnoselskikh et al., ApJS 2021

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.

Solar Orbiter at 0.64 au

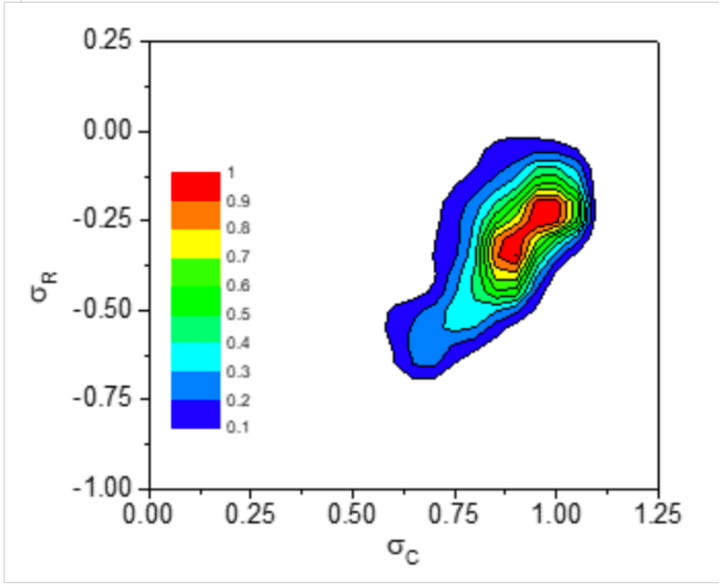
A&A 656, A21 (2021)
https://doi.org/10.1051/0004-6361/202140938
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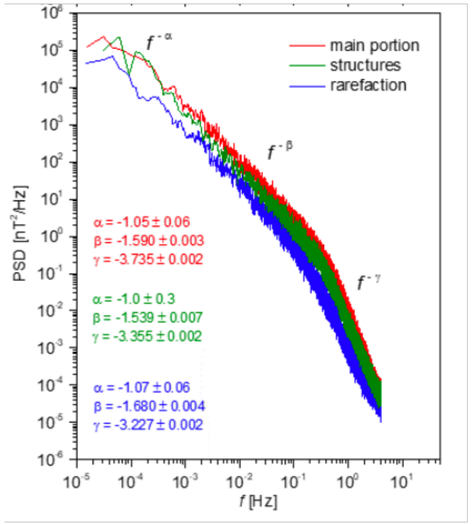
Astronomy & Astrophysics
Special issue

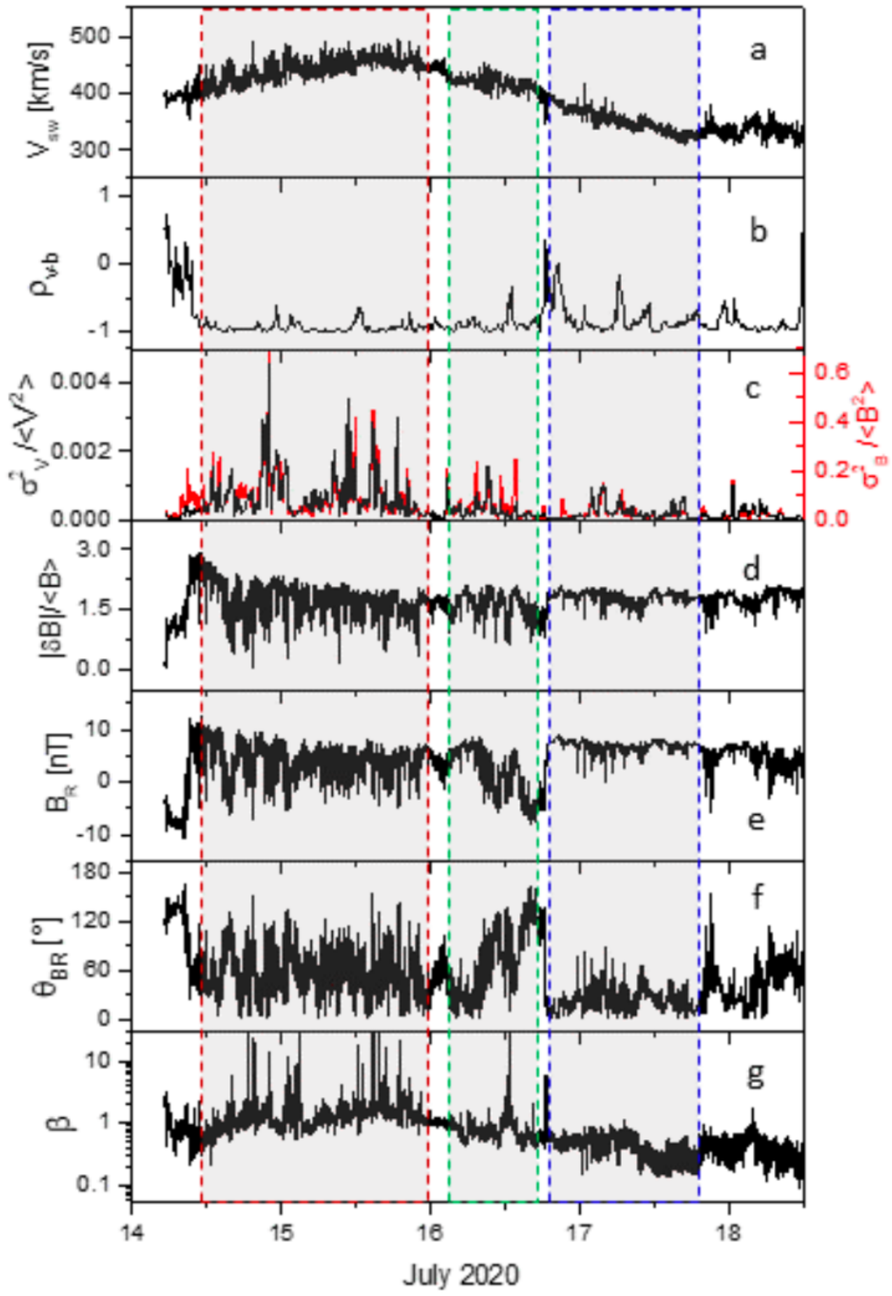
Solar Orbiter First Results (Cruise Phase)

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]







Solar Orbiter at 0.64 au

frontiers | Frontiers in Astronomy and Space Sciences

TYPE Original Research
PUBLISHED 06 November 2023
DOI 10.3389/fspas.2023.1250219

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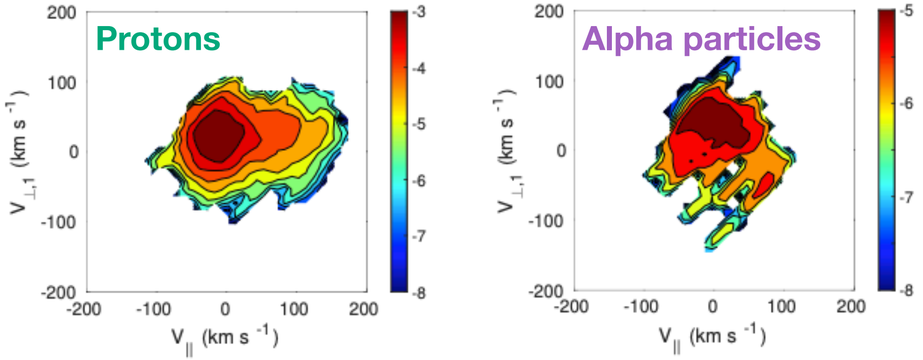
*CORRESPONDENCE
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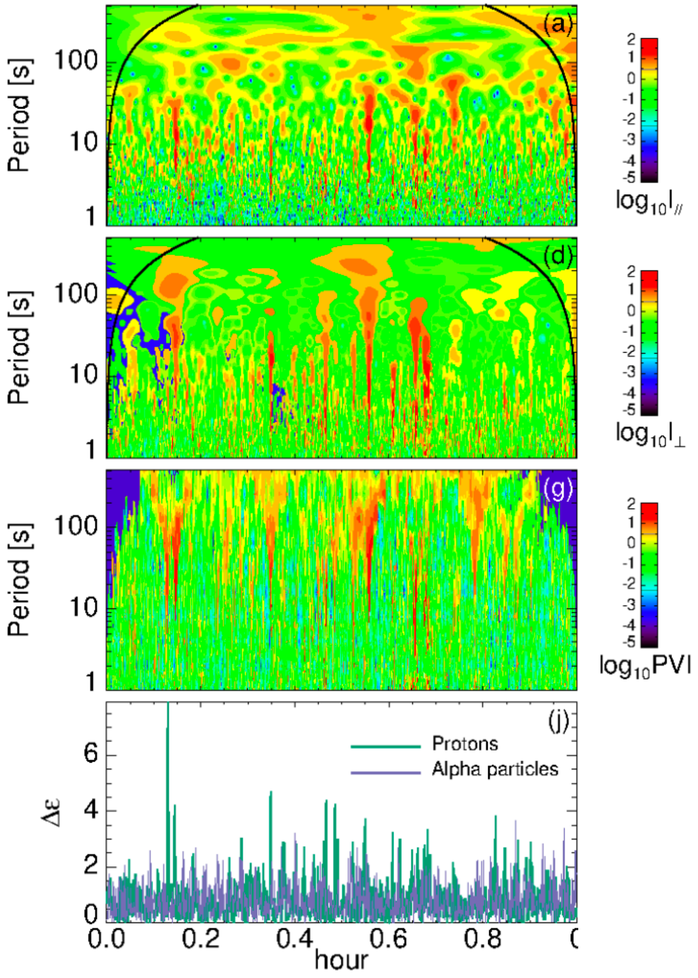
RECEIVED 29 June 2023
ACCEPTED 19 September 2023
PUBLISHED 06 November 2023

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]

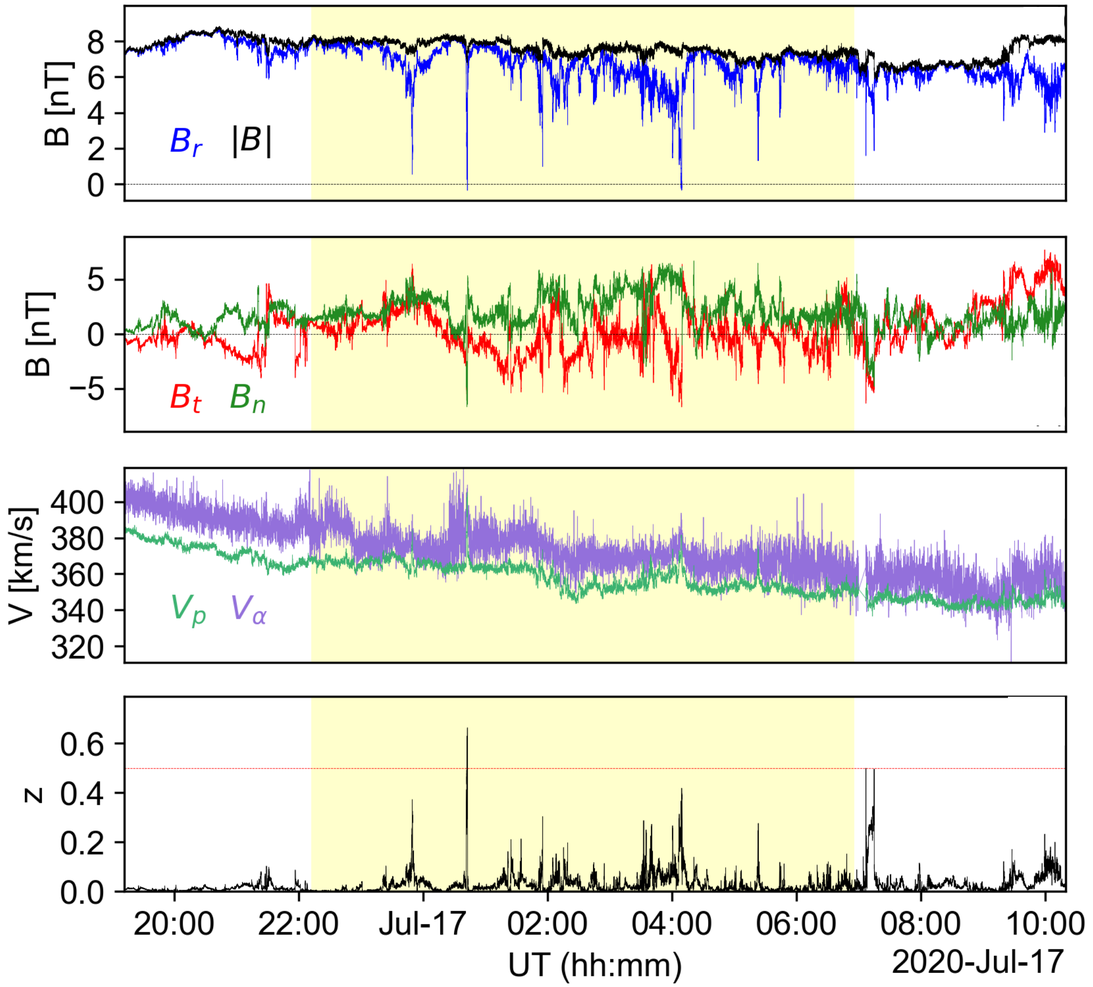
[1]ASI—Italian Space Agency, Rome, Italy, [2]Space Research Institute, Austrian Academy of Sciences, Graz, Austria, [3]National Institute for Astrophysics, Institute for Space Astrophysics and Planetology, Rome, Italy, [4]Dipartimento di Fisica, Università Della Calabria, Rende, Italy





Solar Orbiter Nugget #26

Within the rarefaction region



Protons and **alpha particles** have been separated by using an innovative technique based on the statistical technique of clustering directly to the full 3D VDFs measured by PAS which separates the core and beam for both ion populations

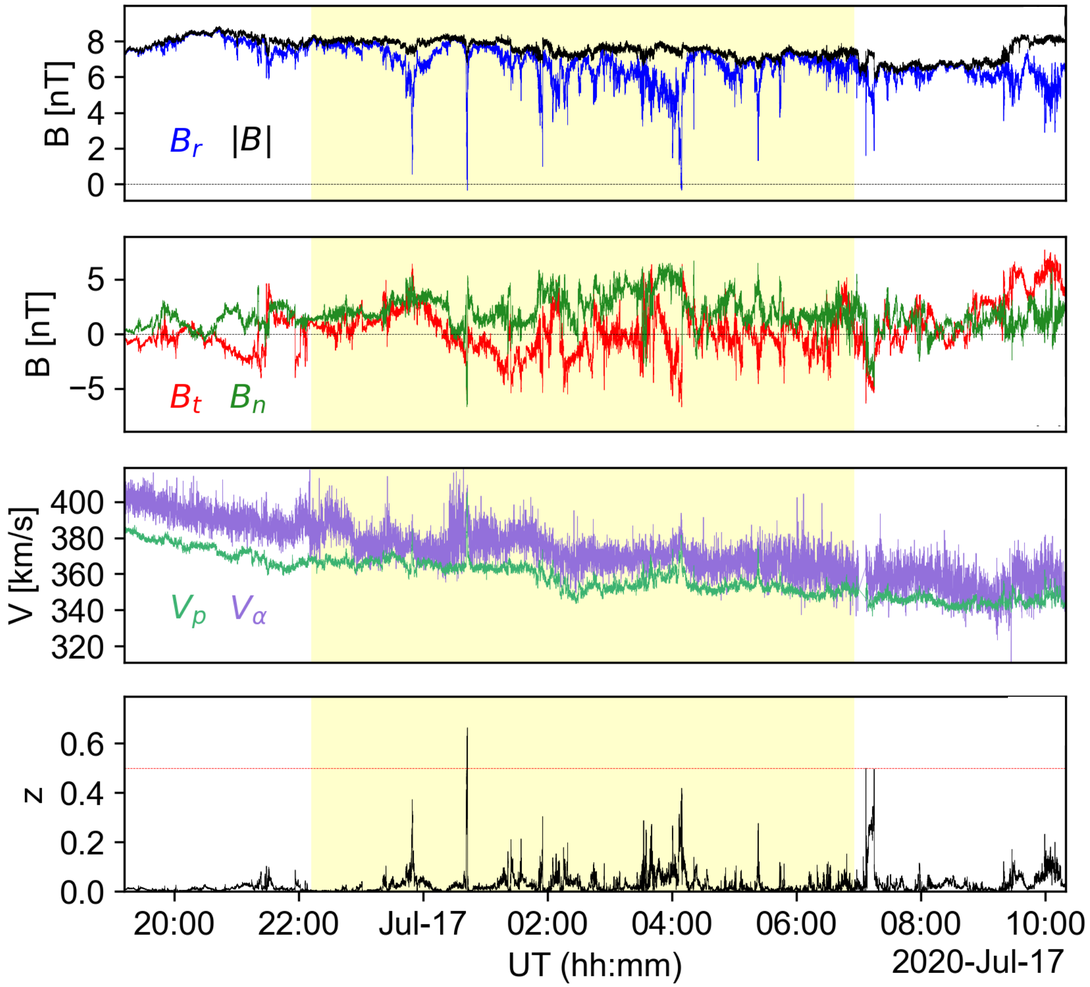
De Marco et al., 2023
Bruno et al., 2024

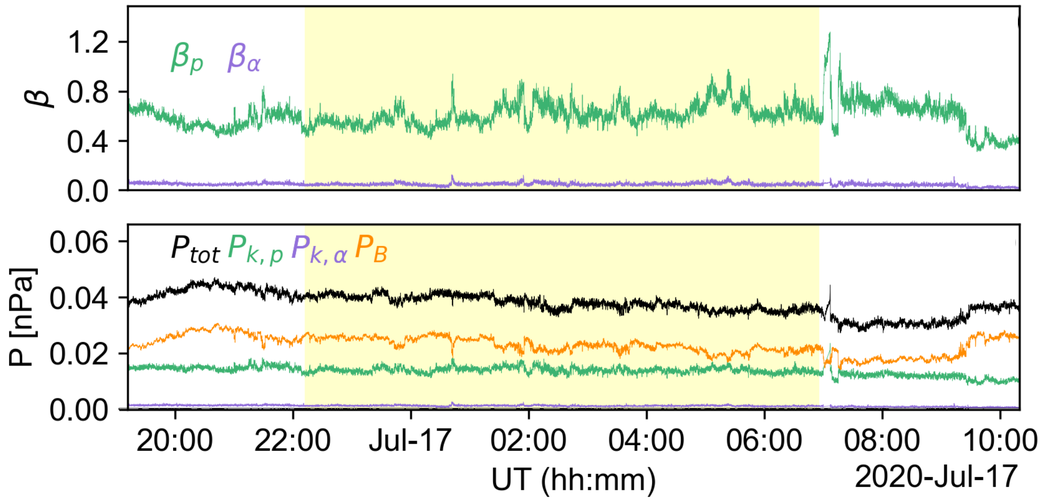
$$z = \frac{1}{2}(1 - \cos\alpha)$$

where α is the angle between the point wise magnetic field ***B*** and a local average <***B***> evaluated over the considered 6 hr

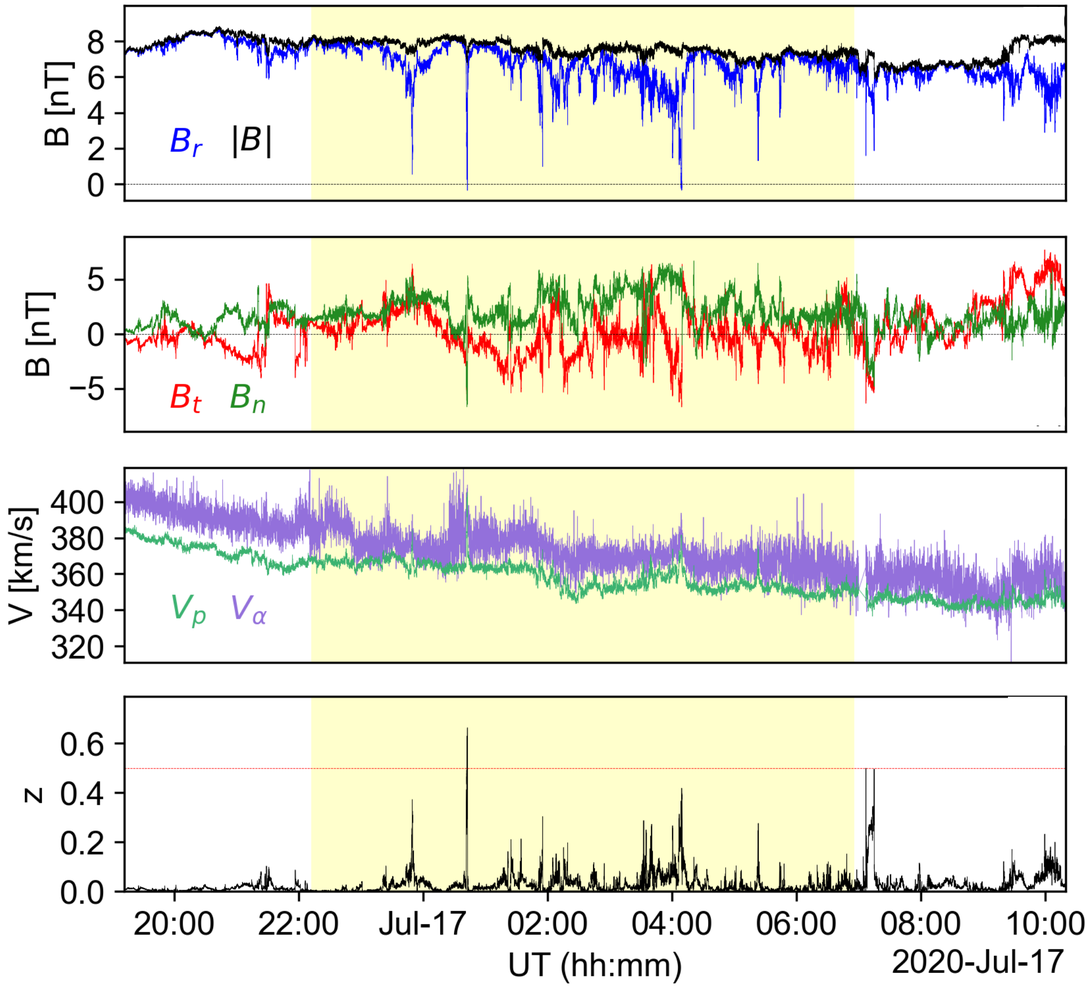
$z \geqslant 0.5$, corresponding to magnetic field deflections larger than 90° with respect to the local average

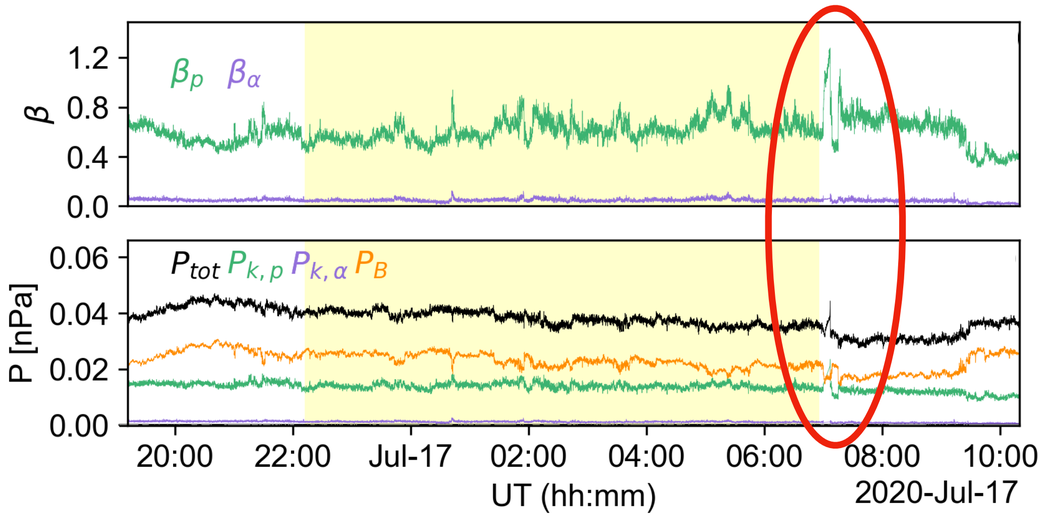
Within the rarefaction region



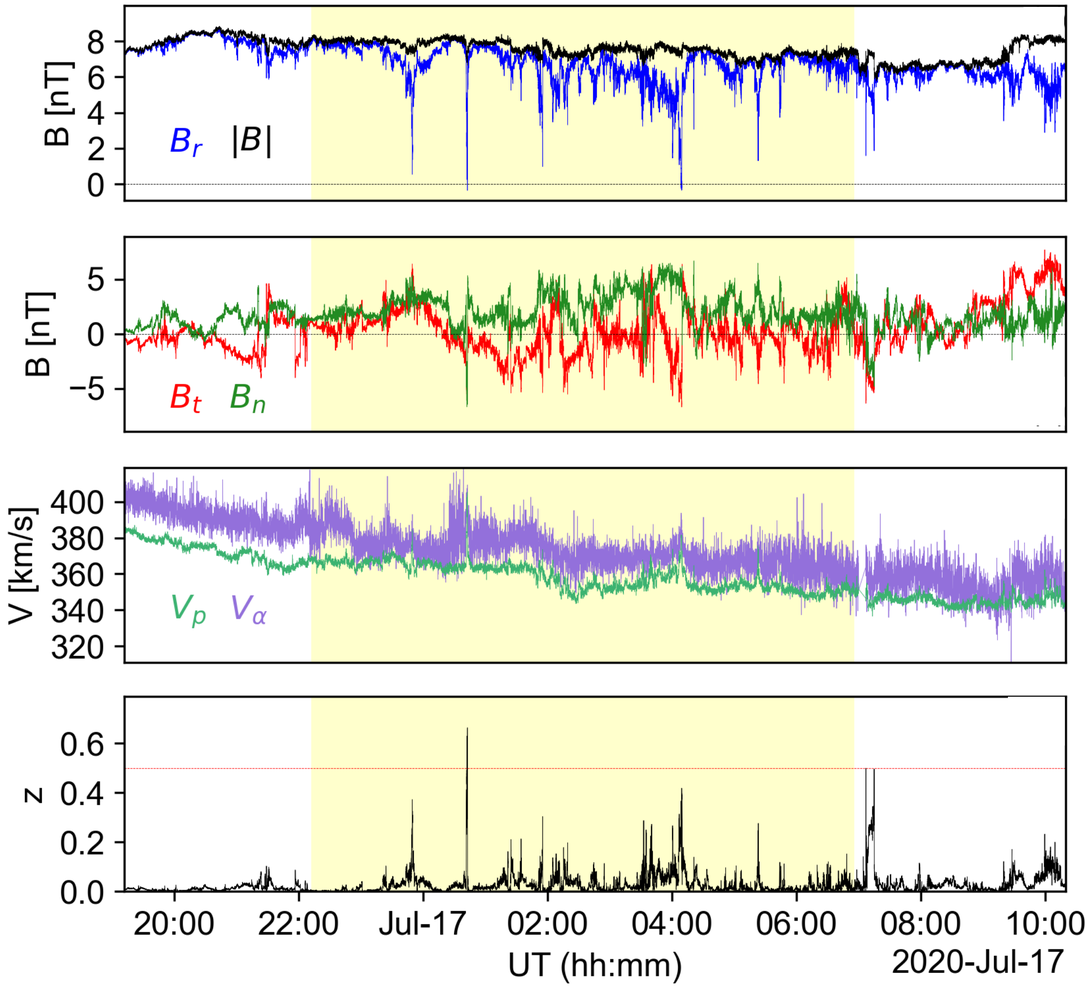


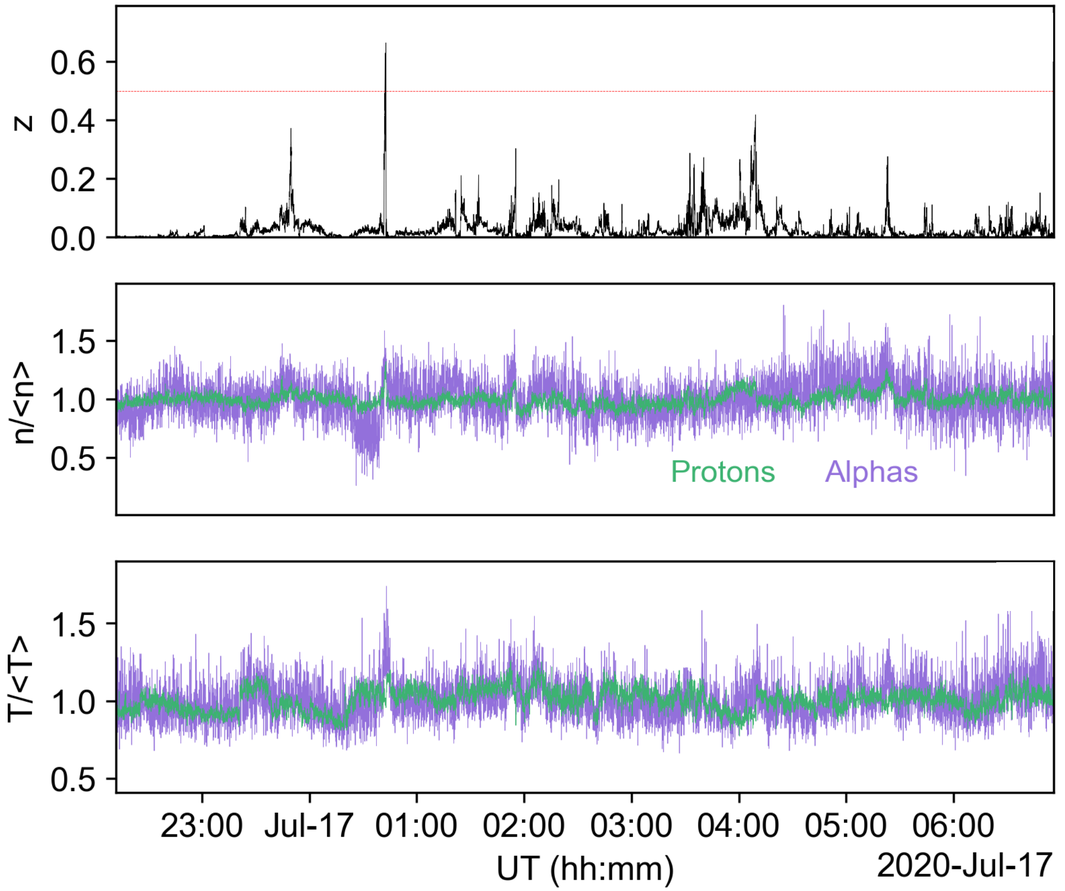
Within the rarefaction region



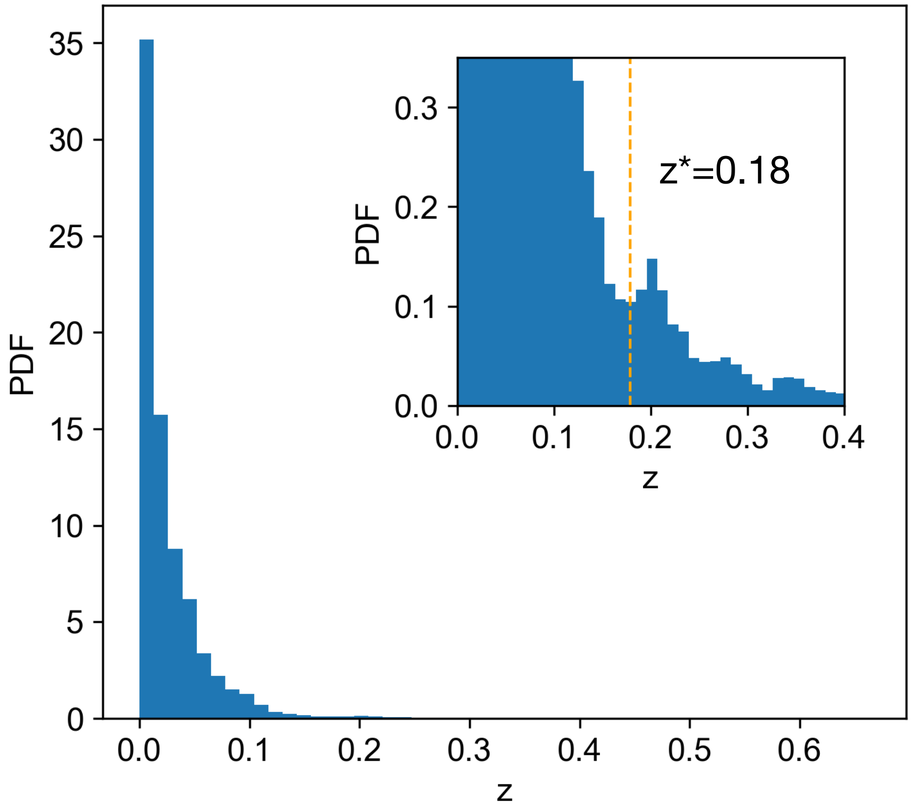


Within the rarefaction region

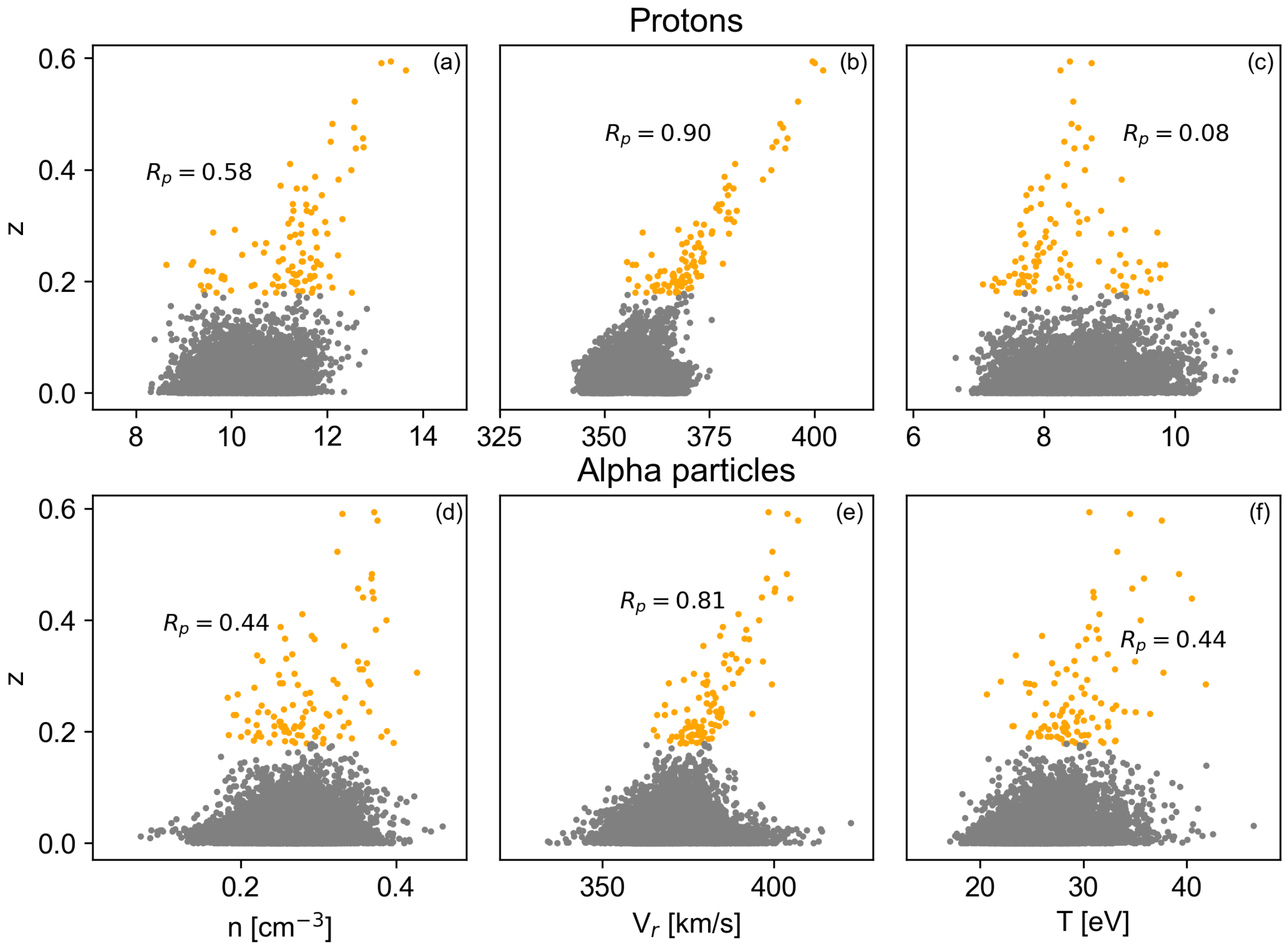




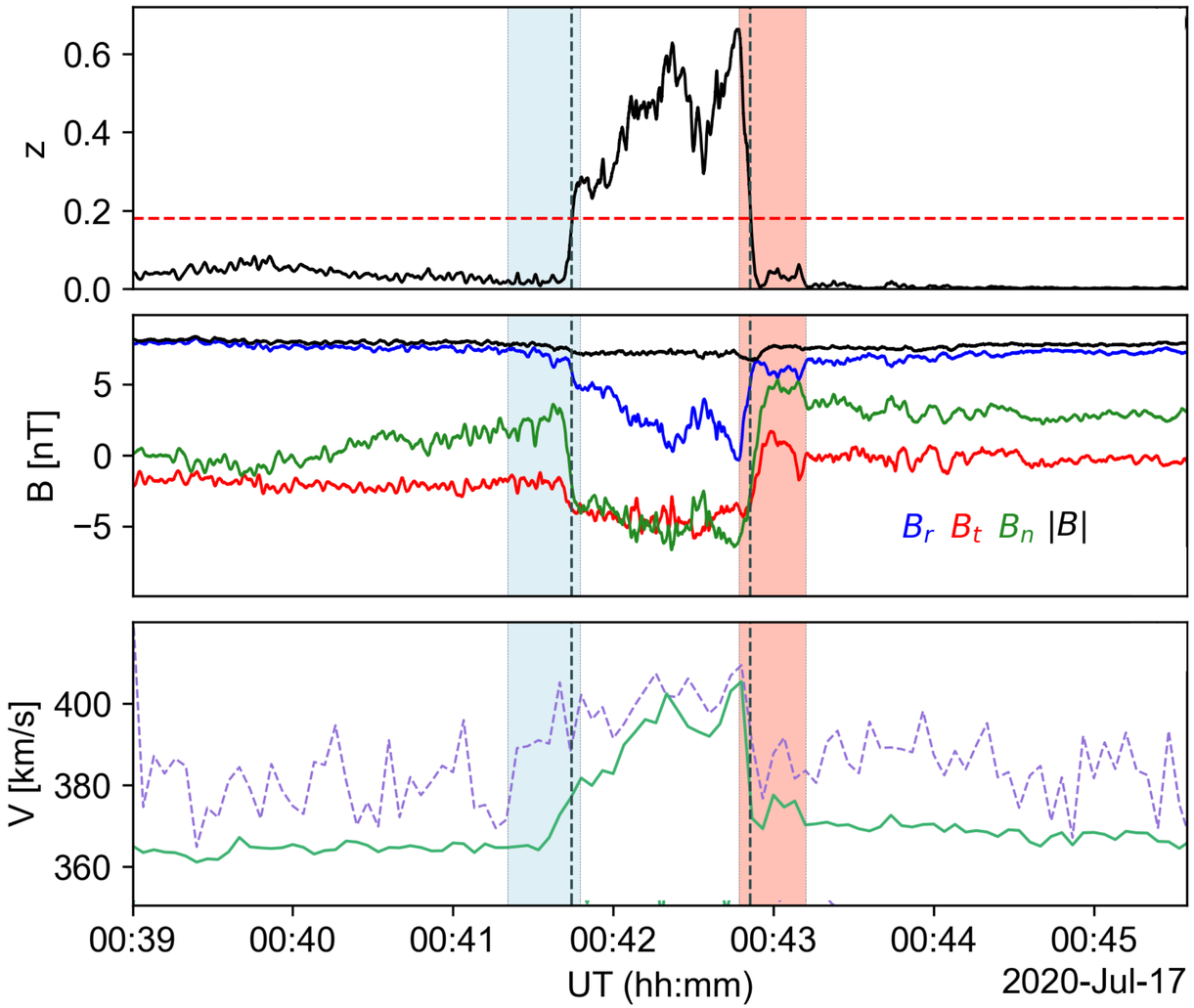
Switchback identification



We fix the threshold value, $z \geq z^*$, which corresponds to magnetic field deflections larger than 50° with respect to the local average

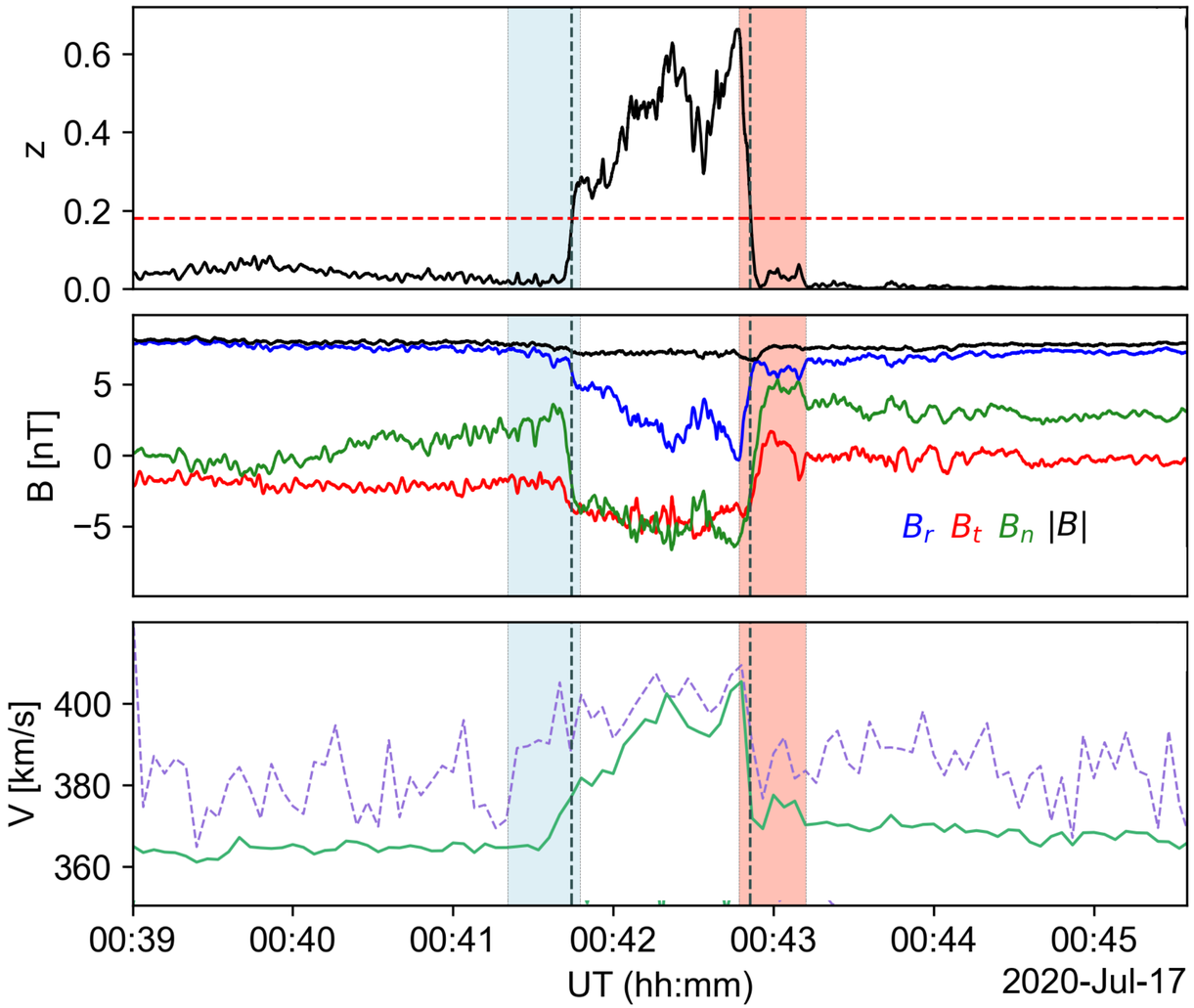


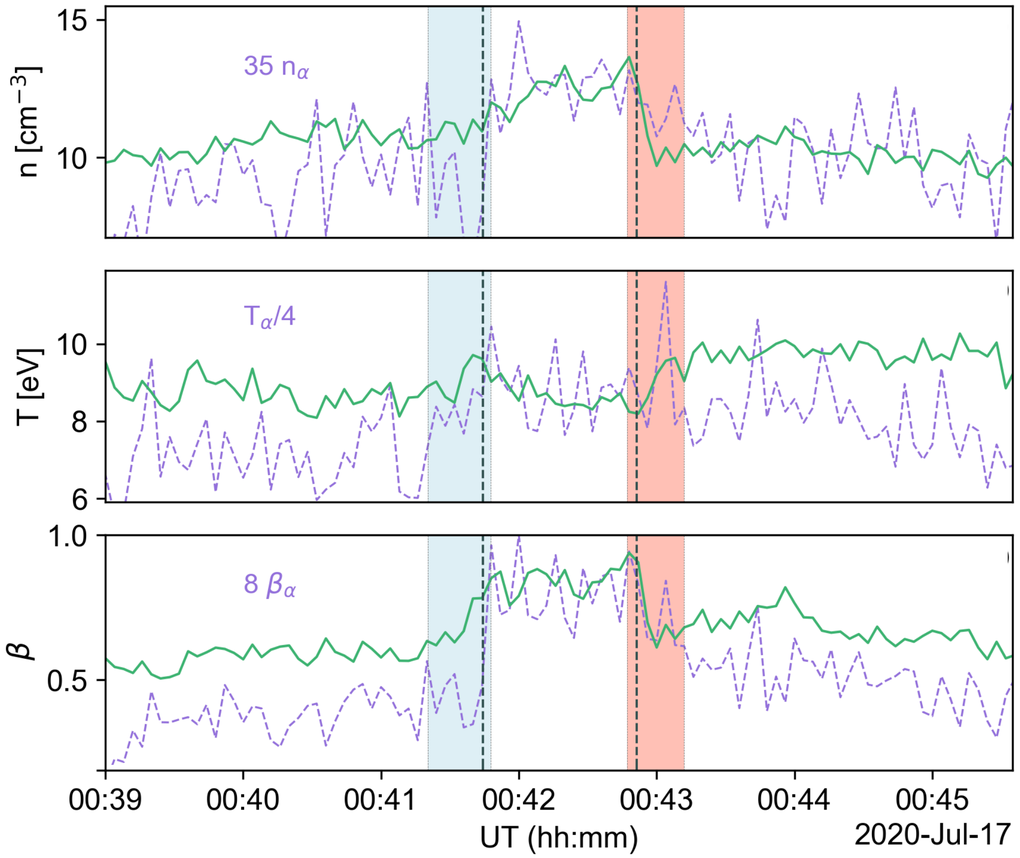
Isolated large-scale switchback



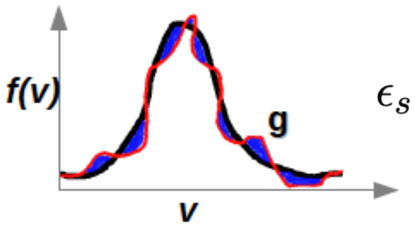
Regions	Start [UT]	End [UT]
Switchback	00:41:44.4	00:42:51.2
Leading	00:41:20.4	00:41:47.7
Trailing	00:42:47.1	00:43:12.0
Left-side background	00:39:03.8	00:41:20.4
Right-side background	00:43:12.0	00:45:34.8

Isolated large-scale switchback





Effects on particles



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

Greco et al., 2012
Valentini et al., 2016
Servidio et al., 2017

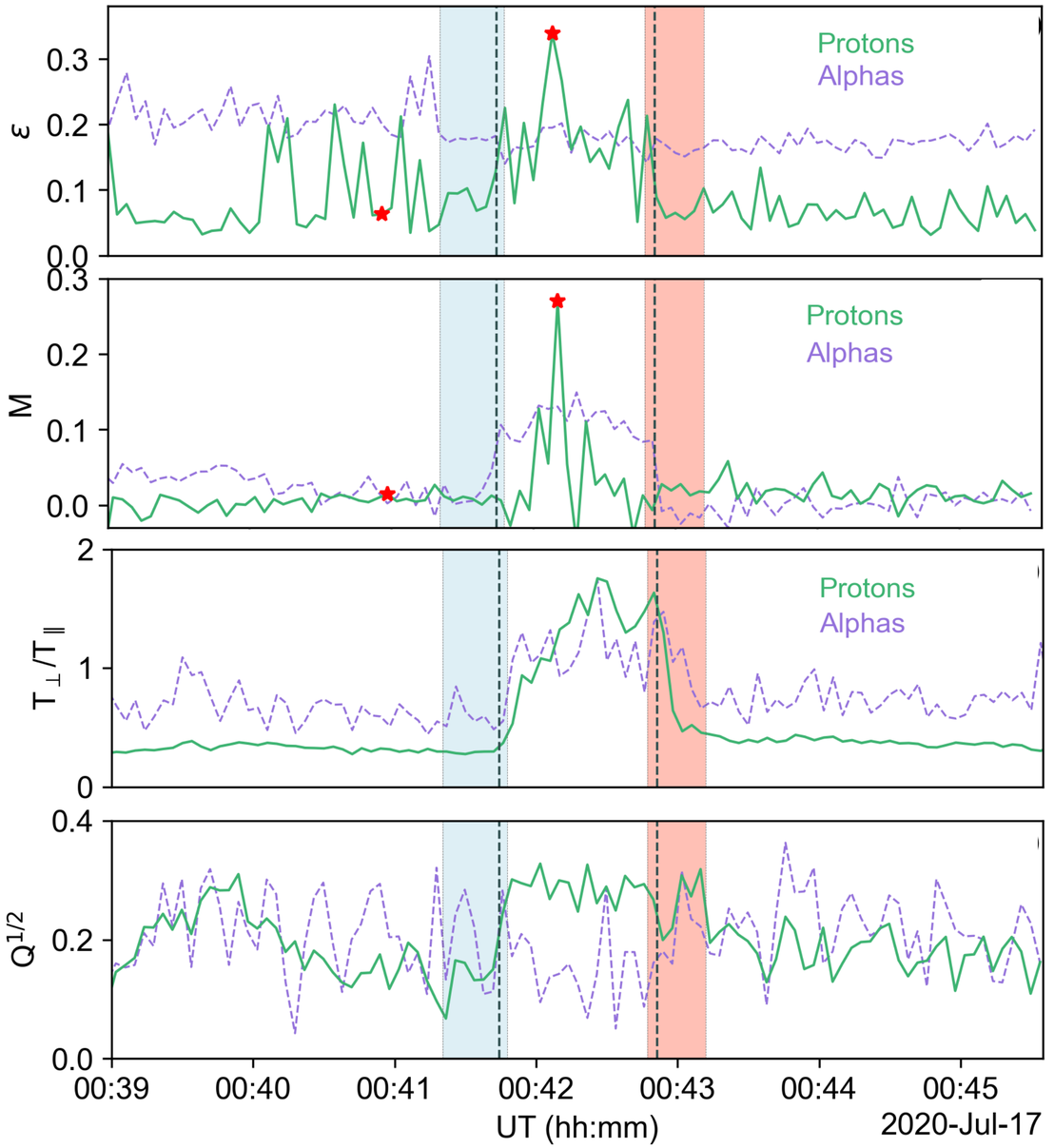
$$M_{\mathrm{KP},\alpha}(\boldsymbol{r},t) = \frac{s_{\mathrm{M},\alpha}(\boldsymbol{r},t) - s_\alpha(\boldsymbol{r},t)}{(3/2)k_B n_\alpha(\boldsymbol{r},t)}$$

Pezzi et al., 2021

$$Q = \frac{P_{xy}^2 + P_{xz}^2 + P_{yz}^2}{P_\perp^2 + 2P_\perp P_\parallel}$$

Swisdak, 2016

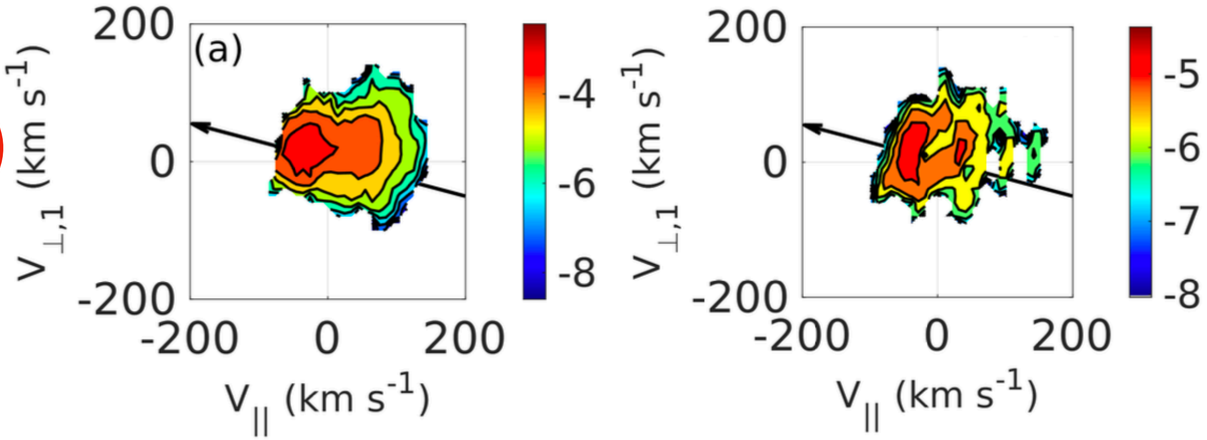
where P_{ij} are the components of the ion (**protons** and **alpha particles**) pressure tensor in the reference frame in which one of the axes is along the direction of the background magnetic field and the two perpendicular pressures are the same.



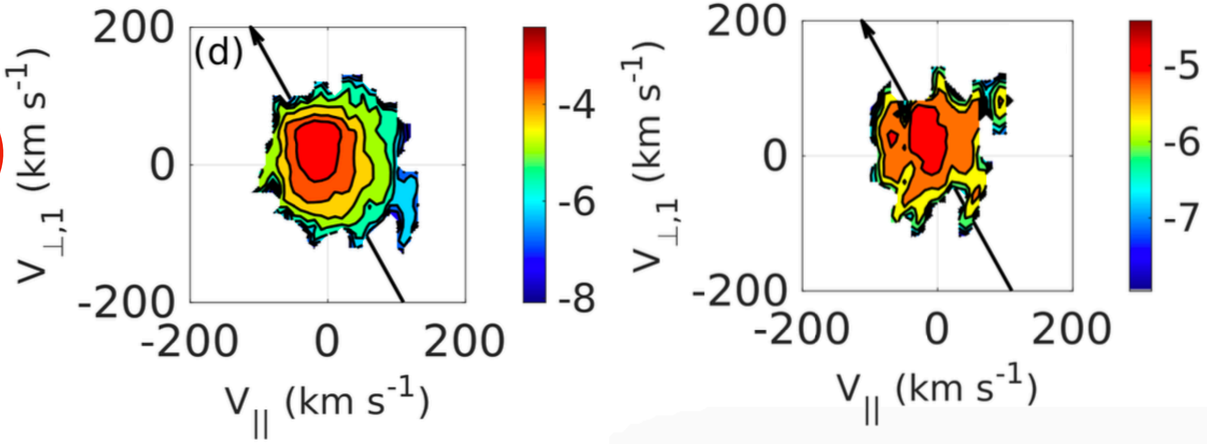
Effects on particles

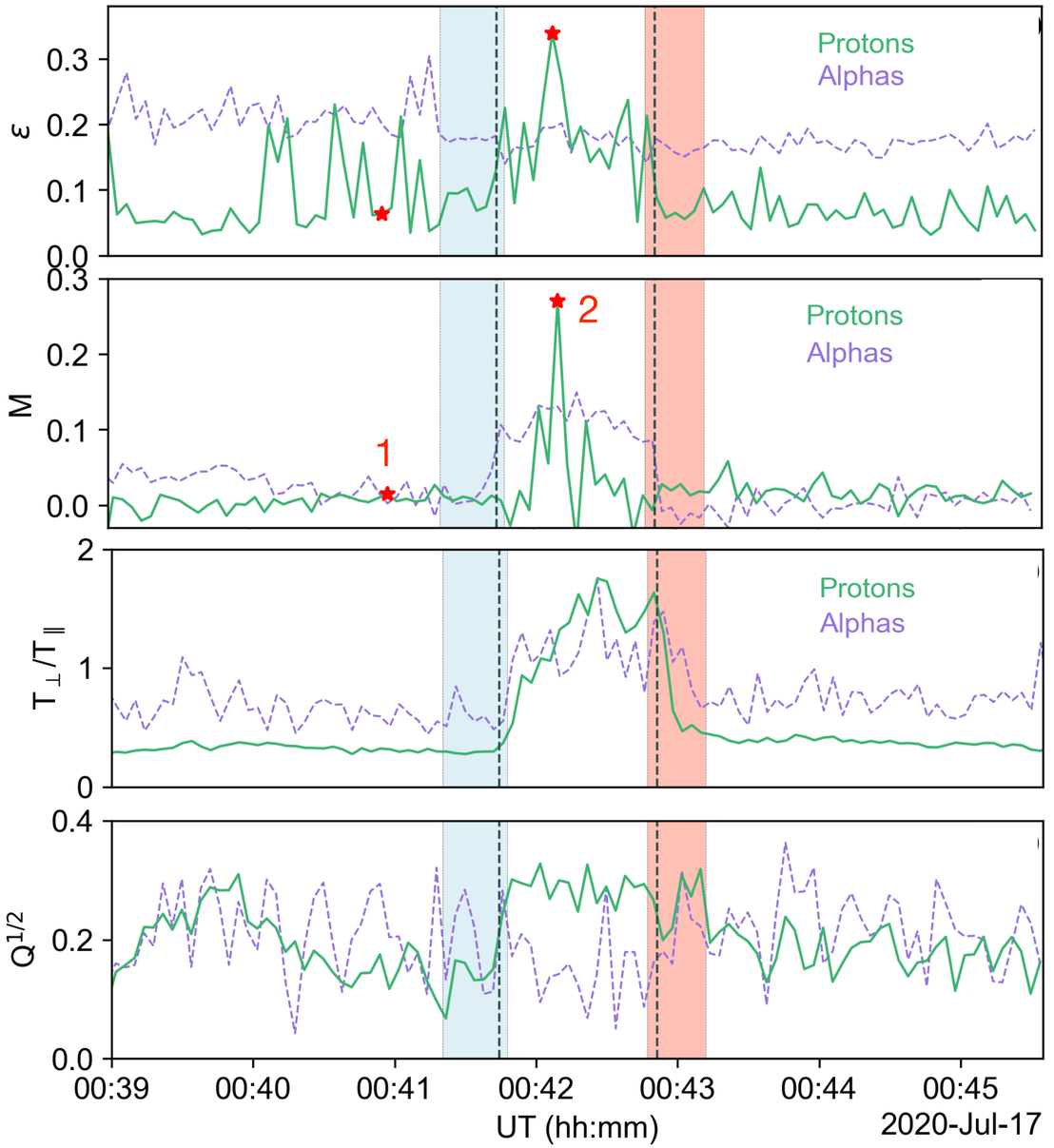
Protons | **Alpha particles**

1



2





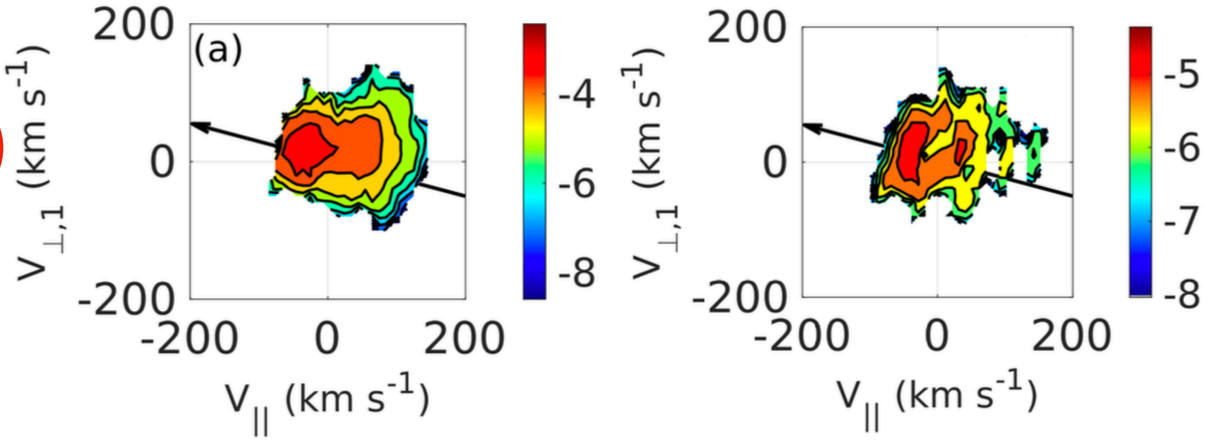
Effects on particles

Agenzia Spaziale Italiana

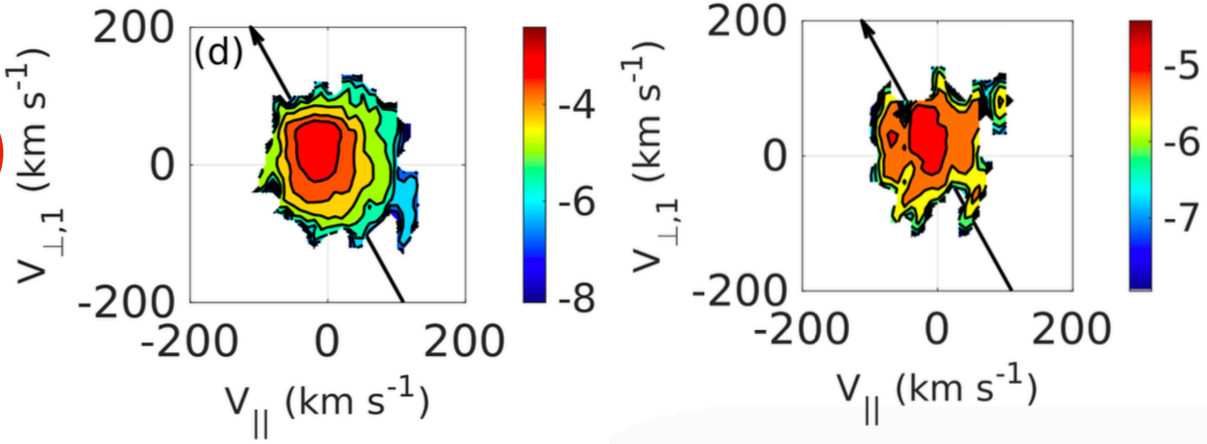
Protons

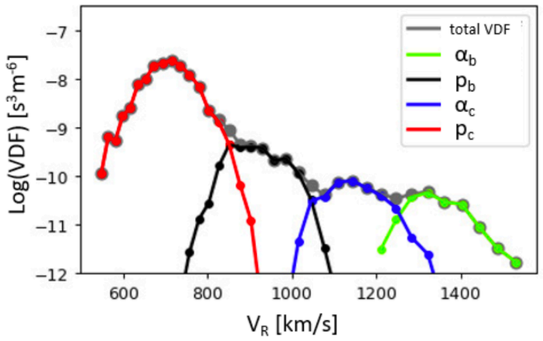
Alpha particles

1

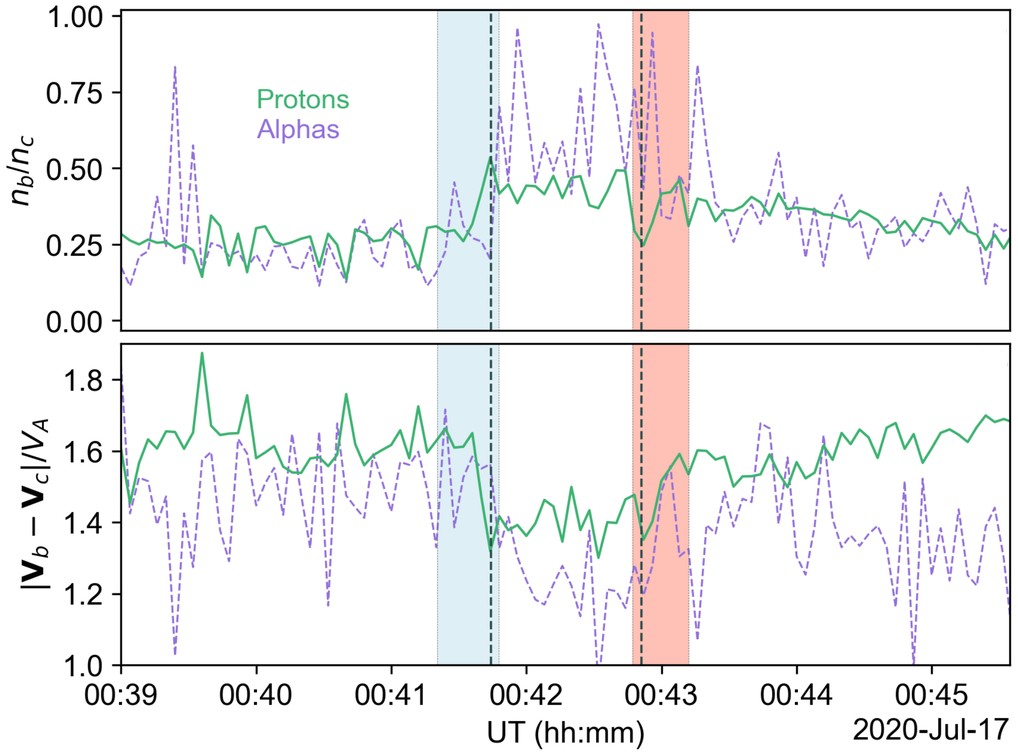


2





De Marco et al., 2023
Bruno et al., 2024



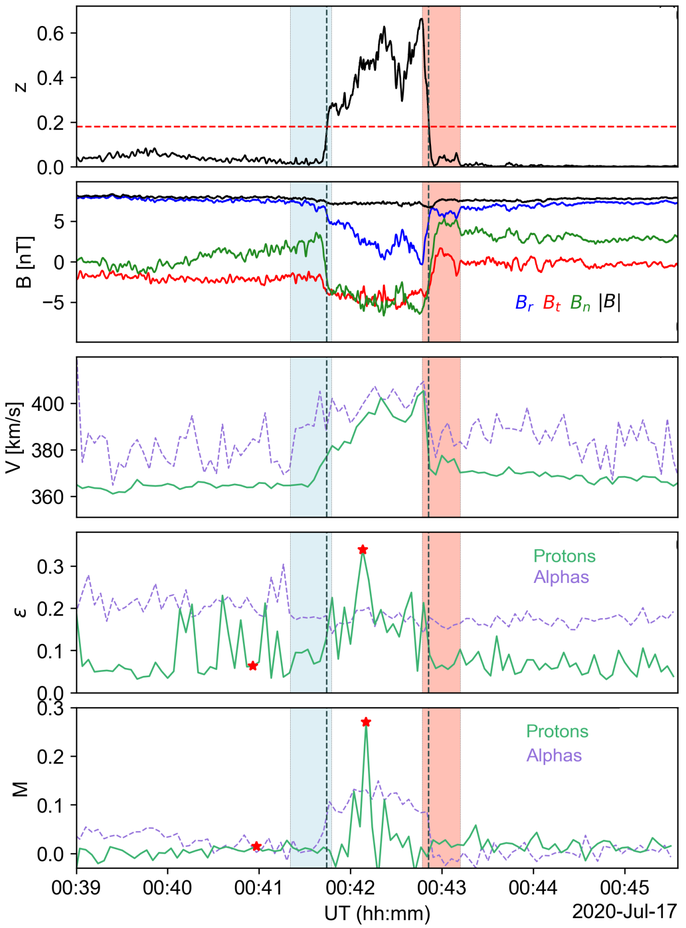
Summary

- We performed a statistical analysis on switchback characteristics in the rarefaction region of July 17th, 2020, when Solar Orbiter was at 0.64 au

- We found a linear correlation between strong deflection of the magnetic field and ion moments for both protons and alphas

- Detailed kinetic analysis has been done and we found that switchbacks are associated to strong deformation of the ion distribution functions.

- Our results suggests that the presence of switchbacks could produce a preferentially heating of alpha particles, while for protons it could play a role in the deformation of the VDF



Perrone et al, ready to be submitted on ApJ