Kinetic-scale current sheets in the solar wind:

Do they result from turbulence cascade development?

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Nonlinear Dynamics 12/21/2021

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MHD vs. hydrodynamics turbulence

$$\boldsymbol{\delta B} \Leftrightarrow \boldsymbol{\delta v}$$

$$\boldsymbol{j} = rot\, \boldsymbol{\delta B} \Leftrightarrow \boldsymbol{\omega} = rot\, \boldsymbol{\delta v}$$

current sheets $\Leftrightarrow$ high-vorticity structures

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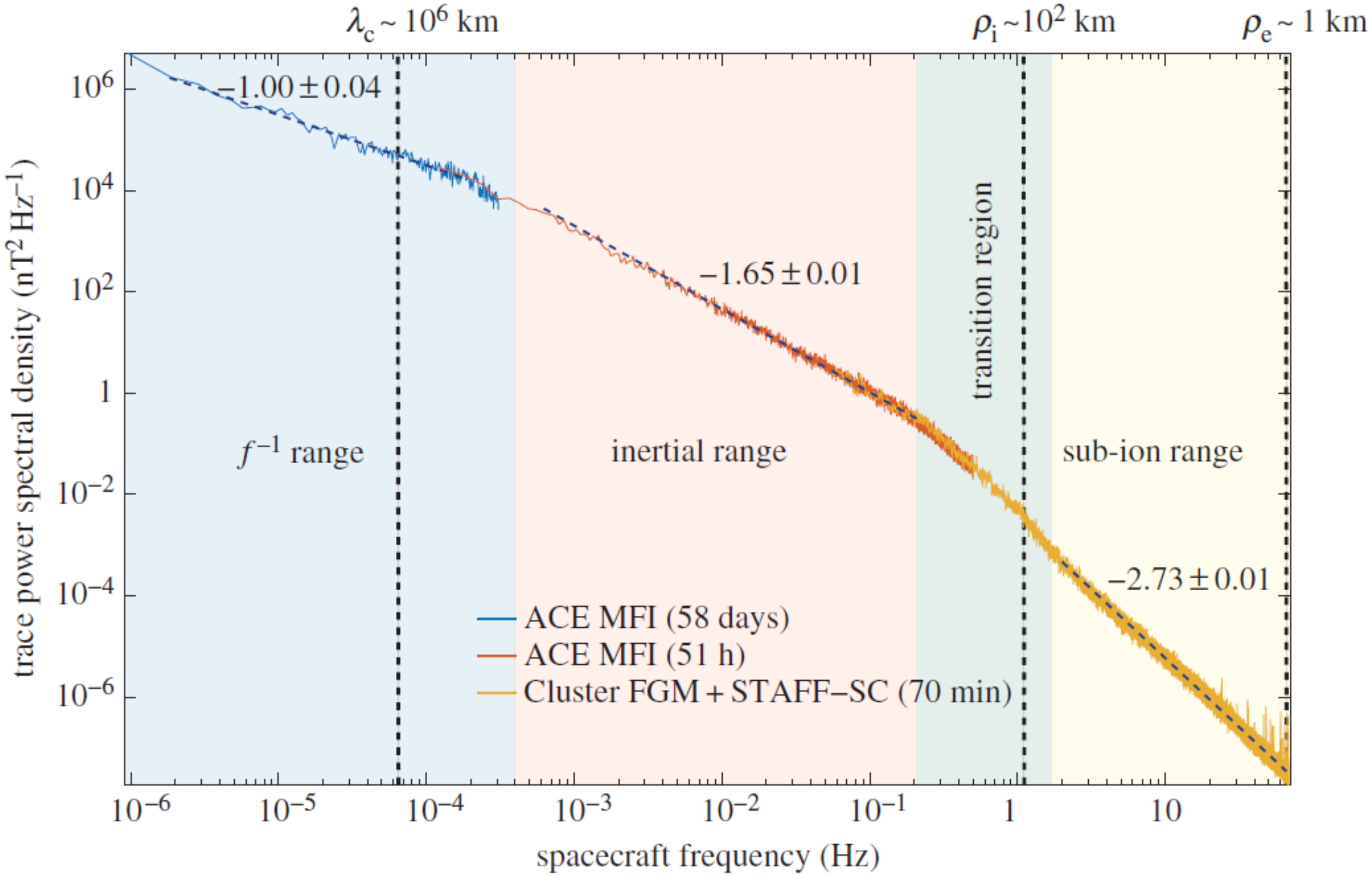
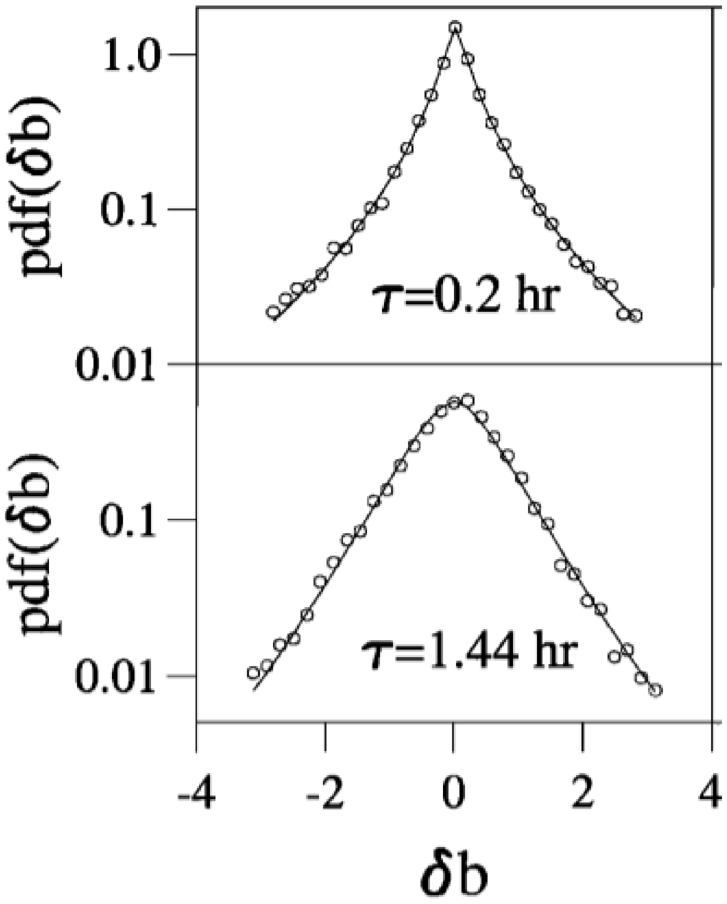
Turbulence & coherent structures in the solar wind

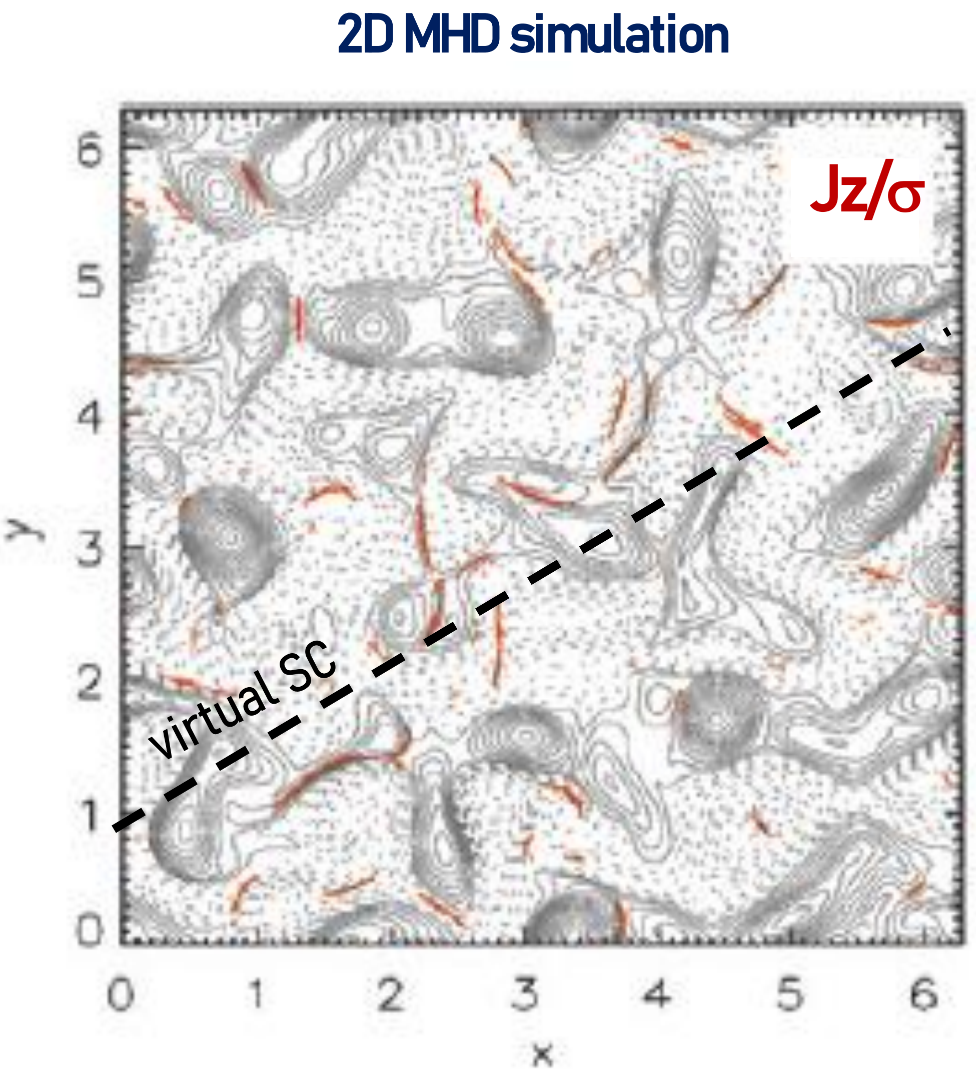


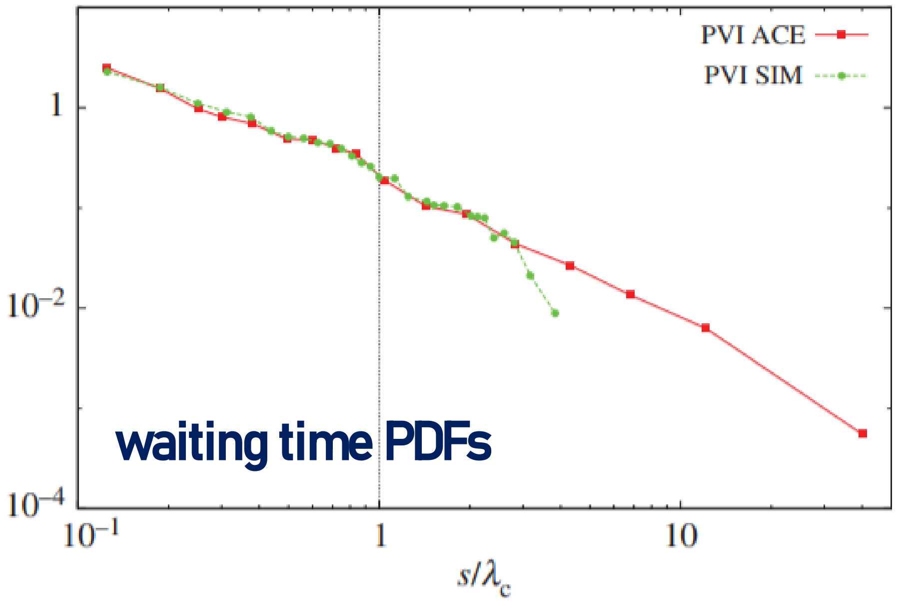


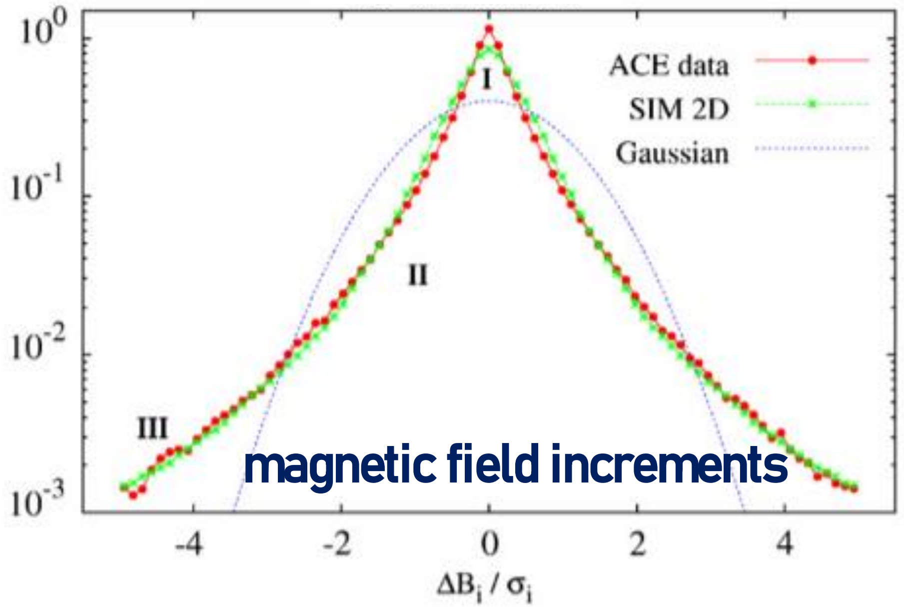
Sorriso-Valvo+,1999; Kiyani+,2015

Non-Gaussian distributions of magnetic field increments in the inertial as well as sub-ion range

Arguments for turbulent origin of current sheets in the solar wind







Greco+, ApJL, 2009

Any other arguments supporting this hypothesis?

$$\boldsymbol{\delta B} \Leftrightarrow \boldsymbol{\delta v}$$

$$\boldsymbol{j} = rot\,\boldsymbol{\delta B} \Leftrightarrow \boldsymbol{\omega} = rot\,\boldsymbol{\delta v}$$

$$\boldsymbol{j}\ vs\ \boldsymbol{\lambda} \Leftrightarrow \boldsymbol{\omega}\ vs.\ \boldsymbol{\lambda}$$

current sheets $\Leftrightarrow$ high-vorticity structures

current sheets	high-vorticity structures
?	$\delta v \propto \lambda^{1/3}$ $\omega \propto \lambda^{-2/3}$

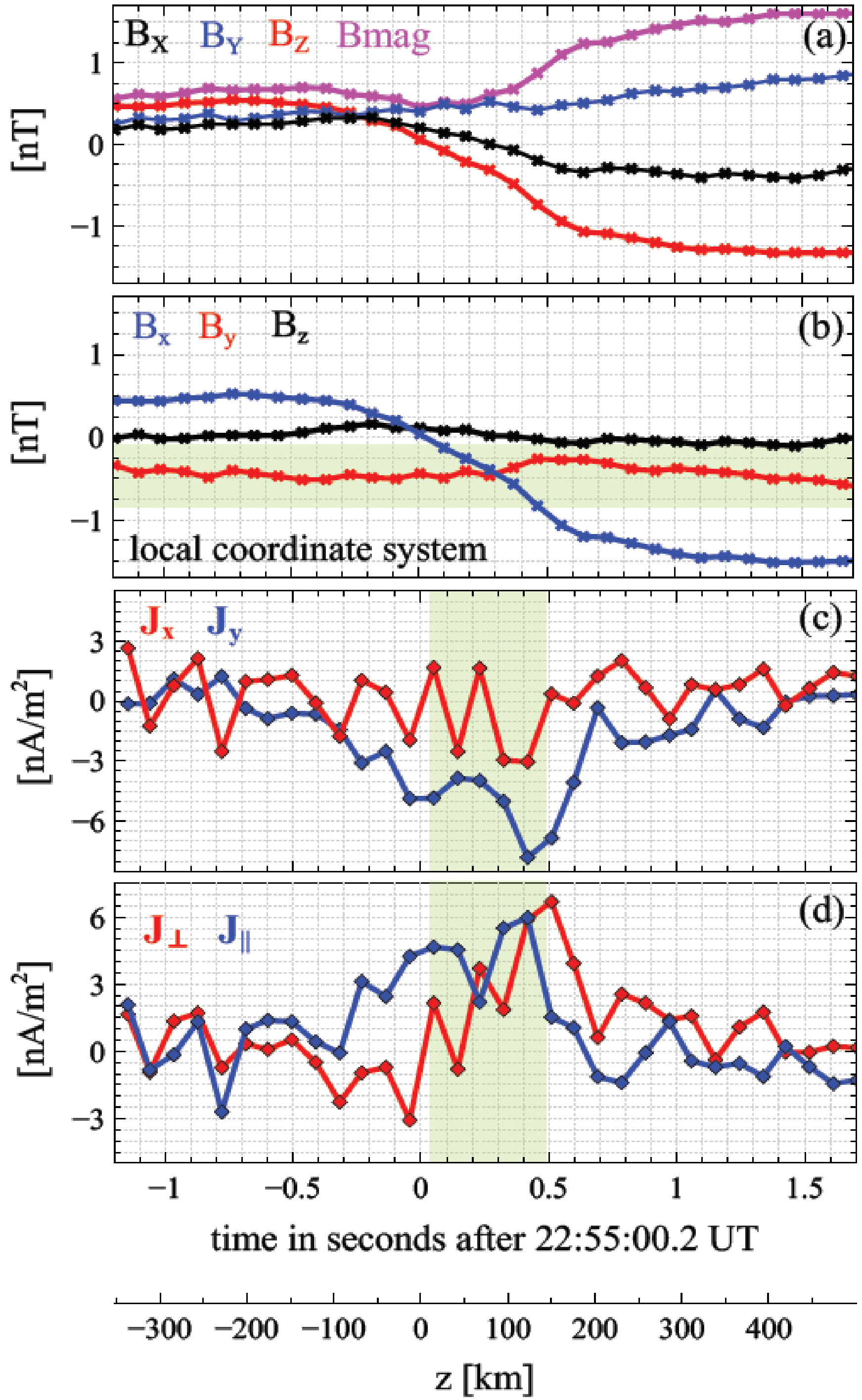
e.g., Agafontsev, Kuznetsov & Mailybaev, 2015,2017

Dataset

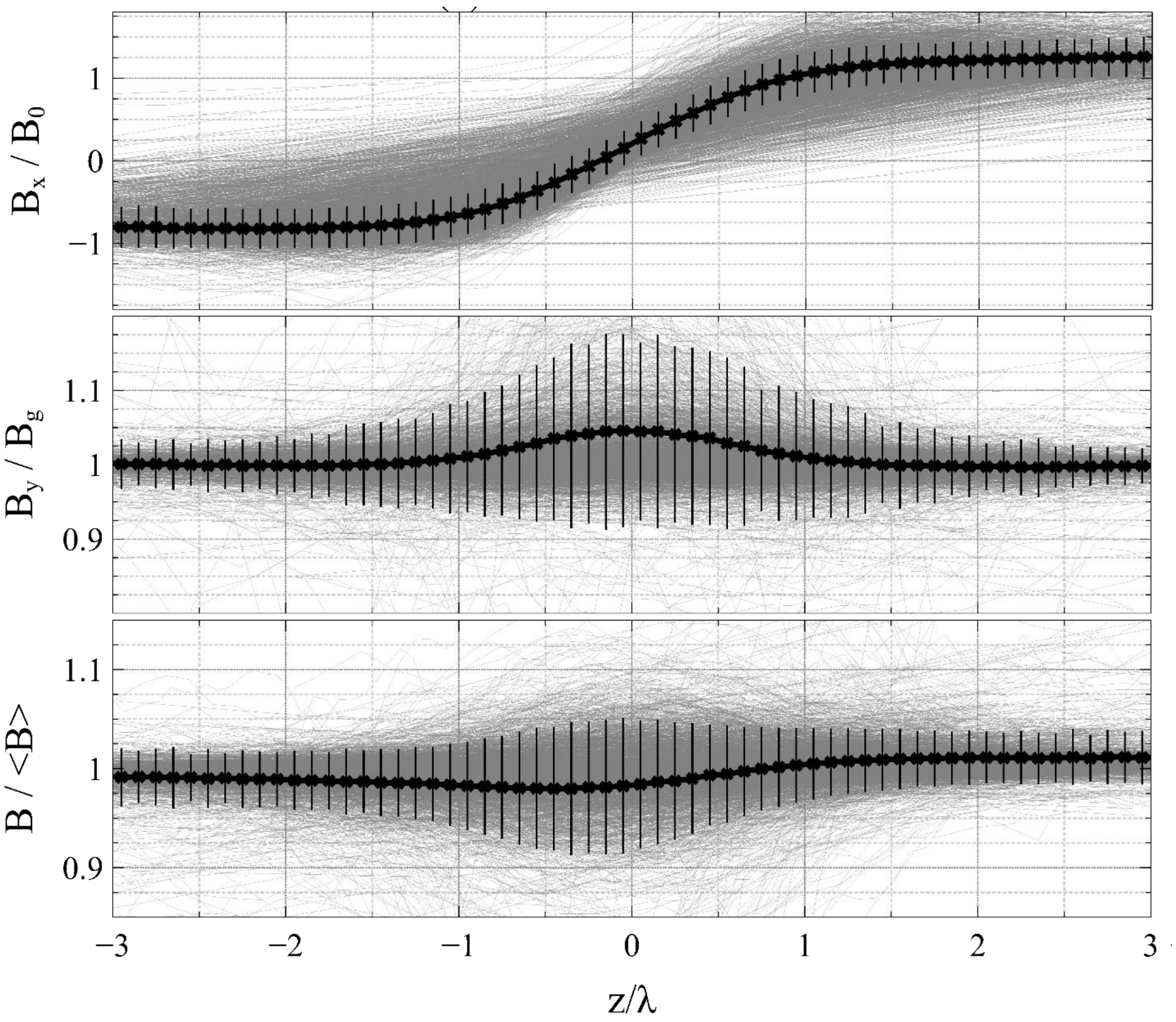
- 124 days of Wind spacecraft (11 S/s B-field, 3s protons, 9s electrons)
- 18785 CSs / ~150 CSs per day
- PVI method (τ=1/11 s and σ computed over 2h intervals), CS selected among PVI>5 events

$$\mathrm{PVI}(t,\tau) = |\Delta \mathrm{B}(t,\tau)|/\sigma,$$

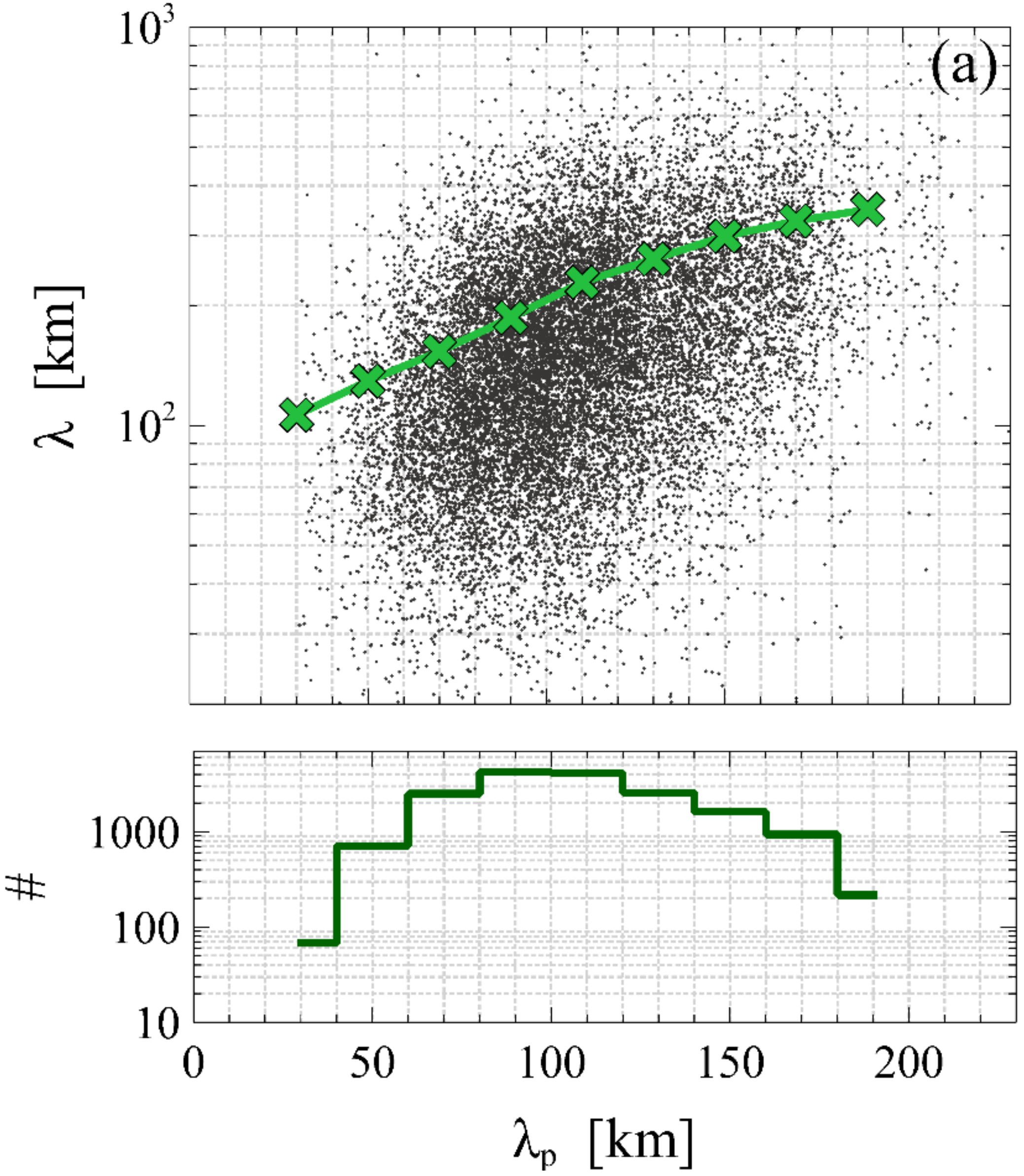
$$\Delta \mathrm{B}(t,\tau) = \mathrm{B}(t+\tau) - \mathrm{B}(t)$$



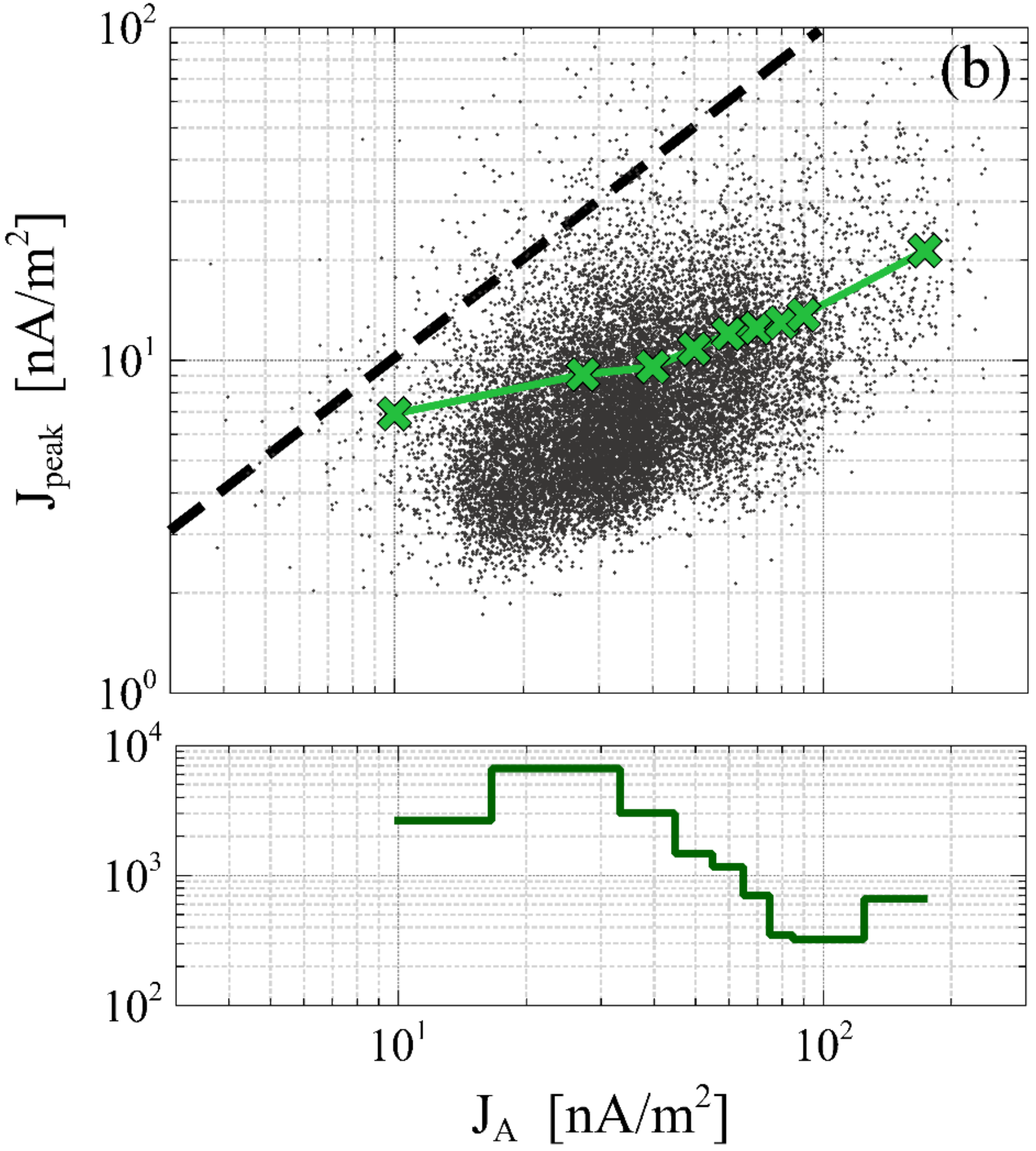
Averaged current sheet structure



CS thickness vs proton inertial length

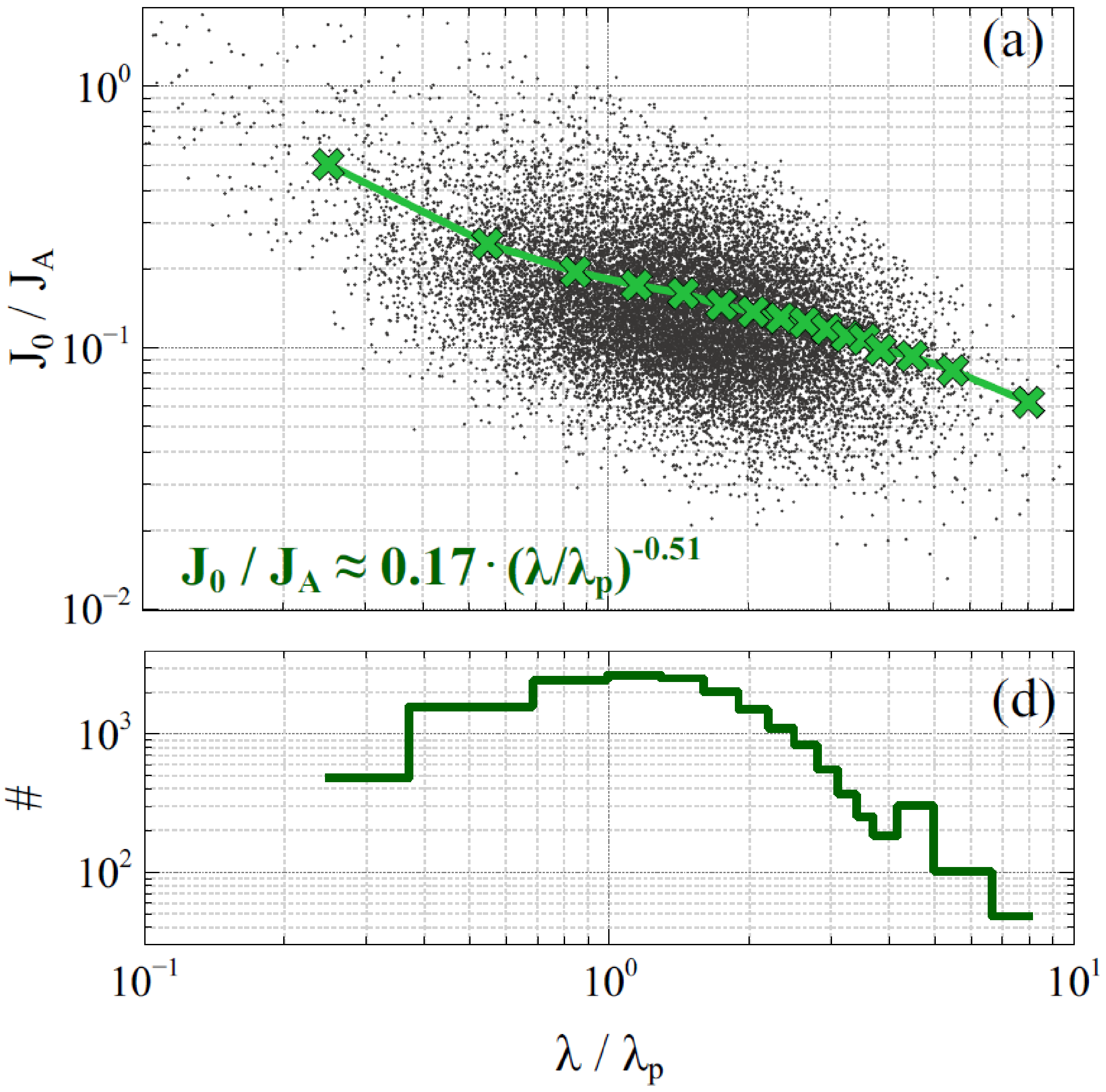


current density vs. Alfven current density



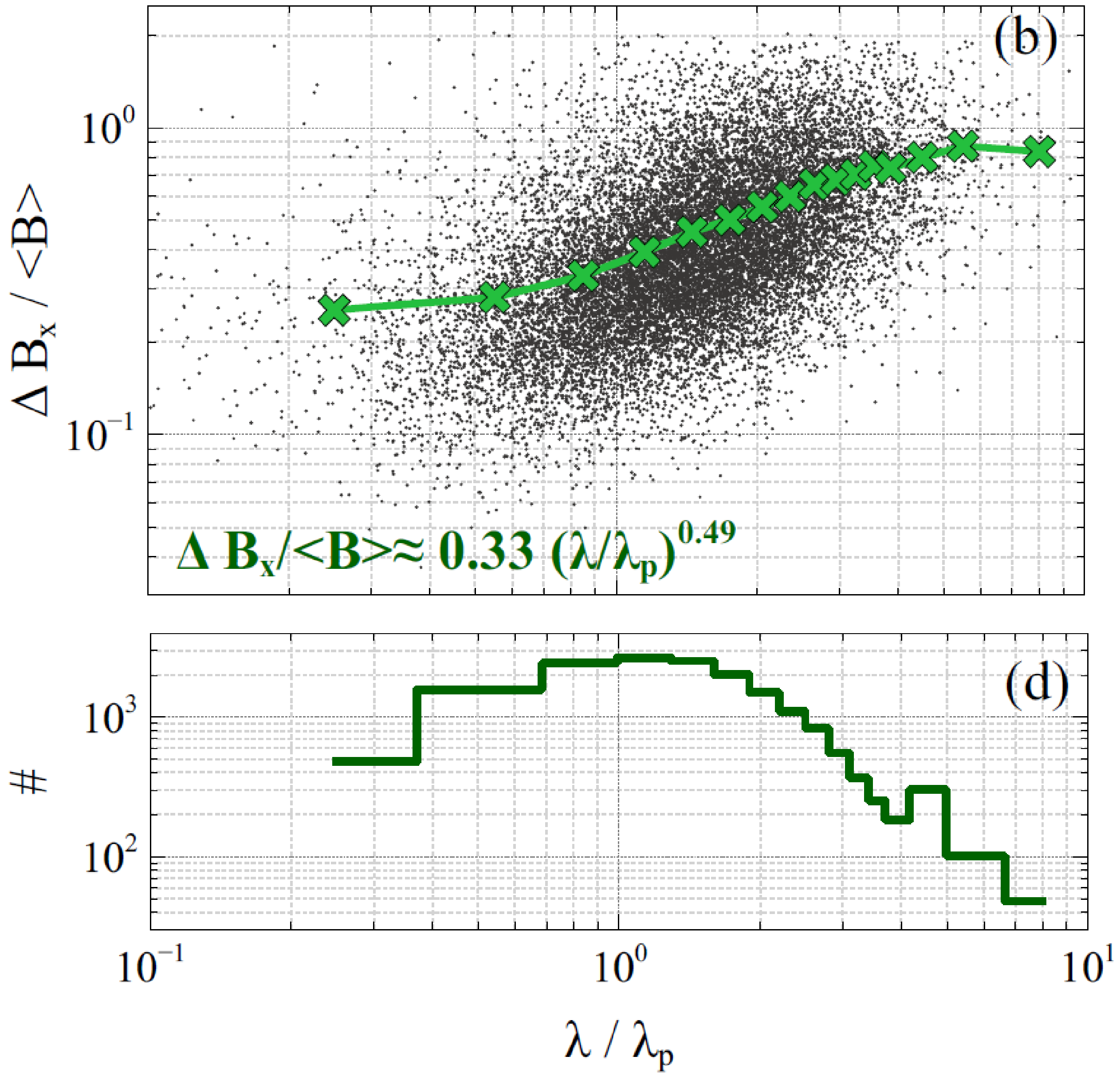
Scale-dependent current density

$$J_0/J_A = 0.17 \cdot (\lambda/\lambda_p)^{-0.51}$$



Scale-dependent amplitude

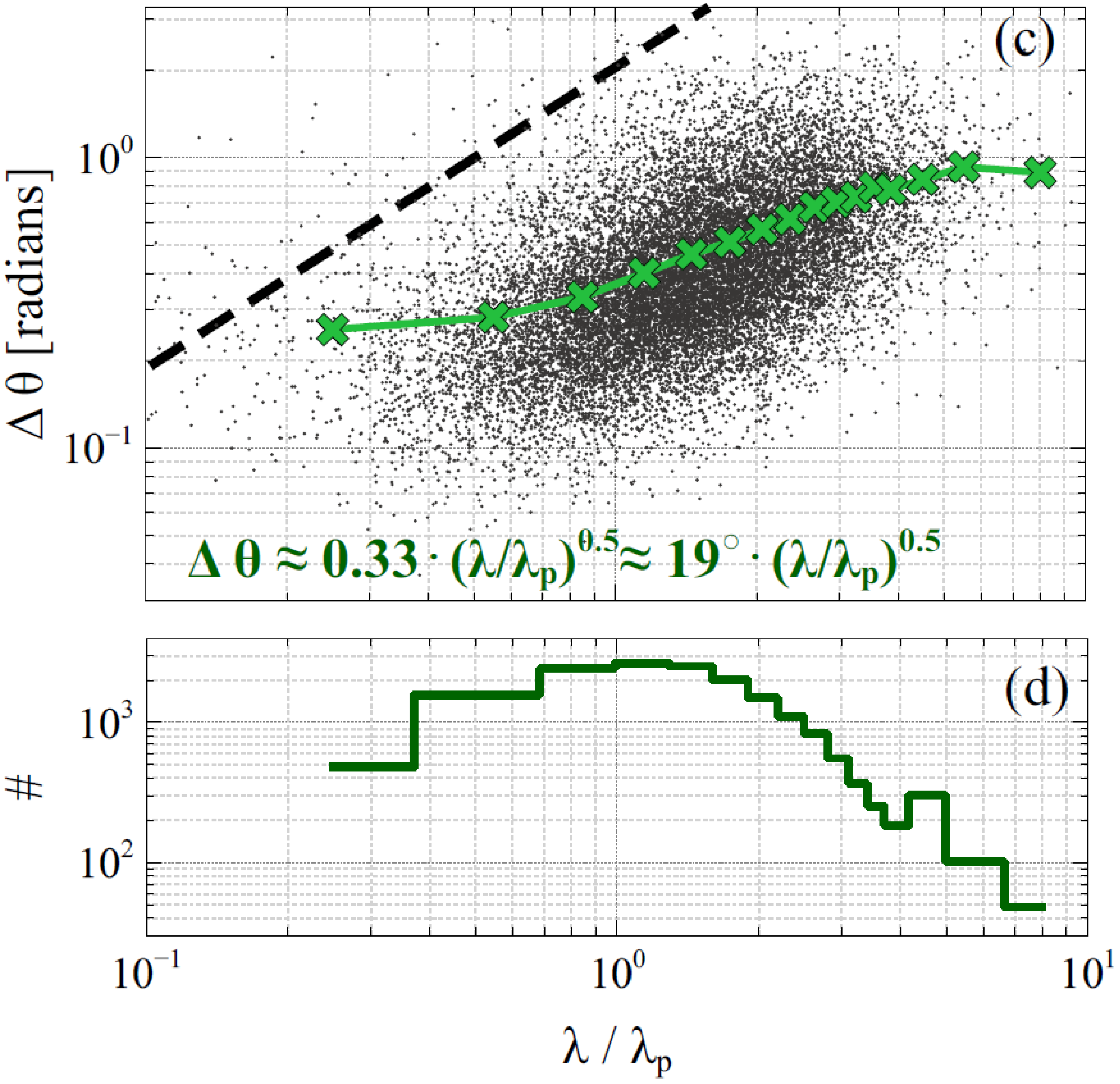
$$\Delta B_x / \langle B \rangle = 0.33 \cdot (\lambda/\lambda_p)^{0.49}$$



Scale-dependent shear angle

$$\Delta\theta \approx 0.33 \cdot (\lambda/\lambda_p)^{0.5}$$

$$\Delta\theta \approx 19^\circ \cdot (\lambda/\lambda_p)^{0.5}$$



Scaling properties: turbulence vs. current sheets

The turbulence in the solar wind is dominated by magnetic field fluctuations highly oblique to mean magnetic field, with a power law spectrum $E_{k_\perp} \propto k_\perp^{-\nu}$, where $\nu \approx 5/3$ in the inertial range, $k_\perp \lambda_p \lesssim 1$, and $\nu \approx 8/3$ at $k_\perp \lambda_p \gtrsim 1$ (e.g., Alexandrova et al. 2013; Chen 2016).

$$\delta b_\lambda \propto (E_{k_\perp} \Delta k_\perp)^{1/2} \propto \lambda^{(\nu-1)/2}$$

$$\Delta k_\perp \propto k_\perp \propto \lambda^{-1}$$

$k_\perp \lambda_p \lesssim 1$ → $\delta b_\lambda \propto \lambda^{1/3}, \quad j_\lambda \propto \lambda^{-2/3}$

$k_\perp \lambda_p \gtrsim 1$ → $\delta b_\lambda \propto \lambda^{5/6}, \quad j_\lambda \propto \lambda^{-1/6}$

current sheet scale-dependencies

$$J_0/J_A = 0.17 \cdot (\lambda/\lambda_p)^{-0.51}$$

$$\Delta\theta \approx 0.33 \cdot (\lambda/\lambda_p)^{0.5}$$

$$\Delta B_x/\langle B \rangle = 0.33 \cdot (\lambda/\lambda_p)^{0.49}$$

Conclusions

- Scale-dependent properties of kinetic-scale current sheets are revealed

- Kinetic-scale current sheets in the solar wind are produced by turbulence

Vasko, Alimov, Phan et al., Kinetic-scale current sheets at 1 AU: scale-dependent properties and critical current density, *The Astrophysical Journal Letters*, under review

Vasko, Alimov, Phan et al. (2021), Kinetic-scale current sheets at 1 AU: properties and reconnection onset, *The Astrophysical Journal Letters*, https://doi.org/10.3847/2041-8213/ac3f30

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