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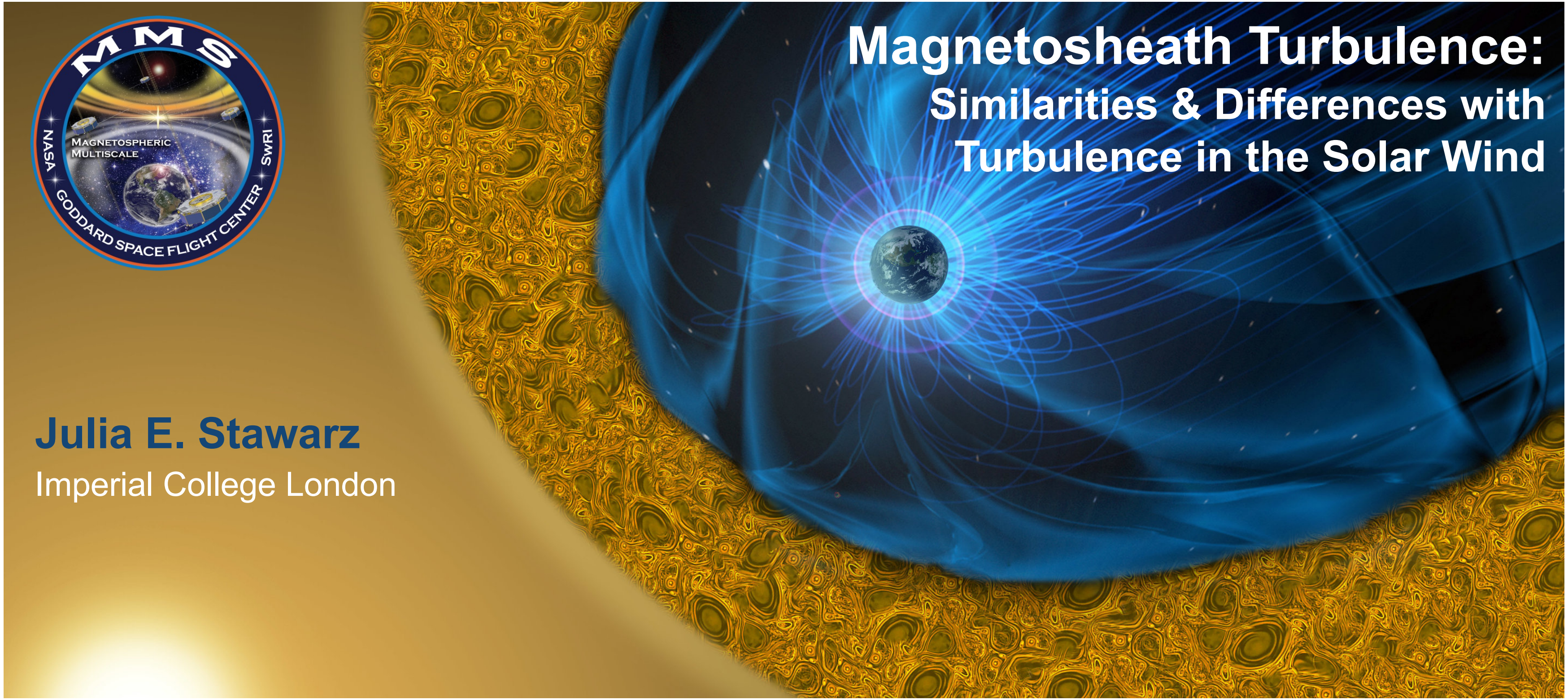
THE ROYAL SOCIETY

MMS Science Working Team Meeting
4-6 October 2022



Magnetosheath Turbulence:
Similarities & Differences with Turbulence in the Solar Wind

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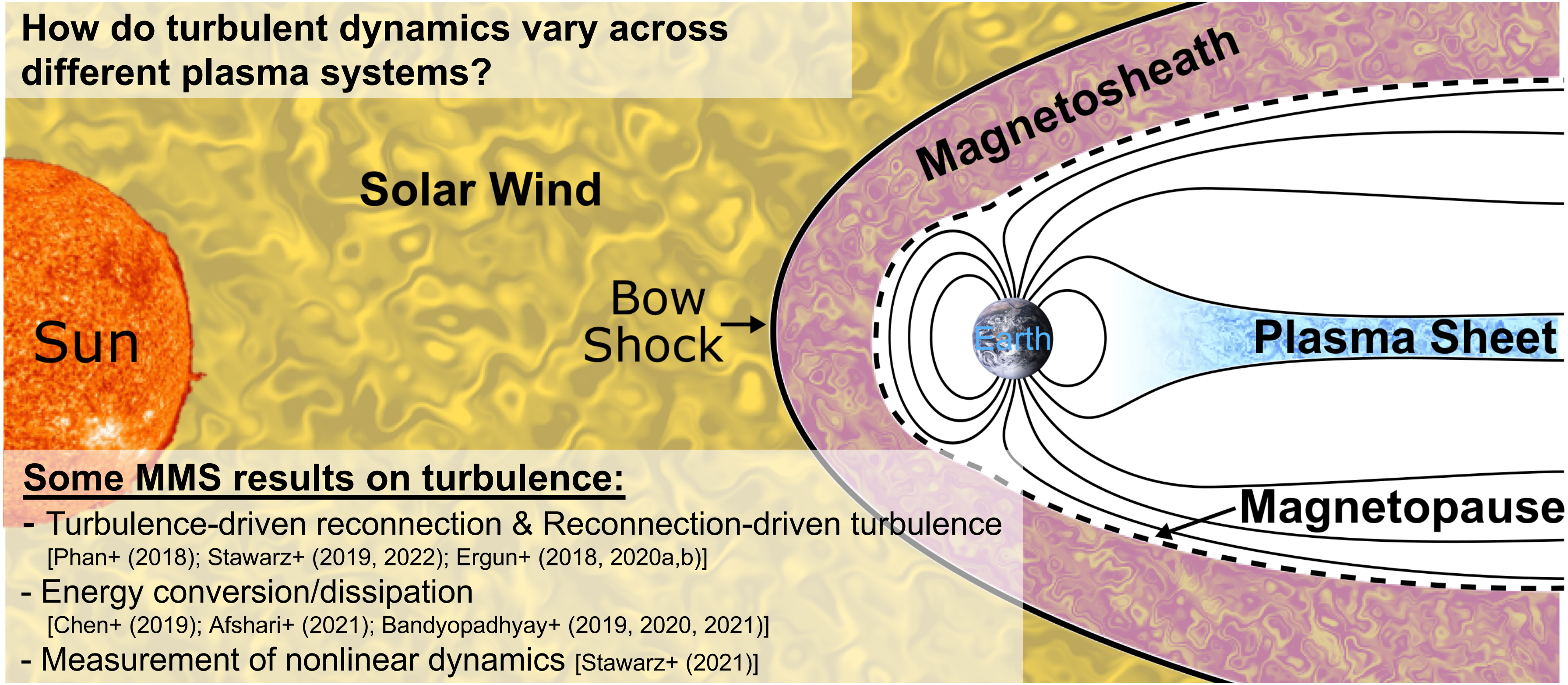
Turbulence In Near-Earth Space

How do turbulent dynamics vary across different plasma systems?



Some MMS results on turbulence:

- Turbulence-driven reconnection & Reconnection-driven turbulence
  [Phan+ (2018); Stawarz+ (2019, 2022); Ergun+ (2018, 2020a,b)]
- Energy conversion/dissipation
  [Chen+ (2019); Afshari+ (2021); Bandyopadhyay+ (2019, 2020, 2021)]
- Measurement of nonlinear dynamics [Stawarz+ (2021)]

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Overview

Taylor Hypothesis in the Magnetosheath

Correlation Lengths

Bulk Alignment Properties

Cross Helicity & Residual Energy

Intermittency & Small-Scale Structures

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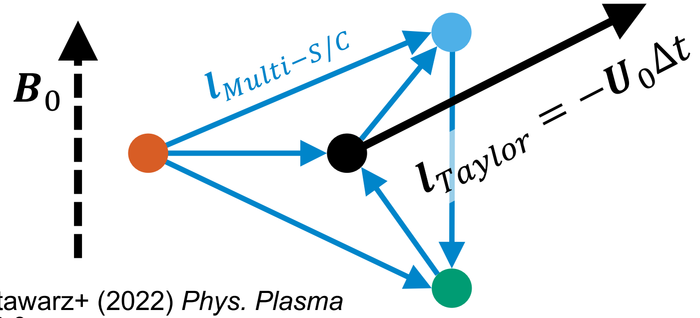
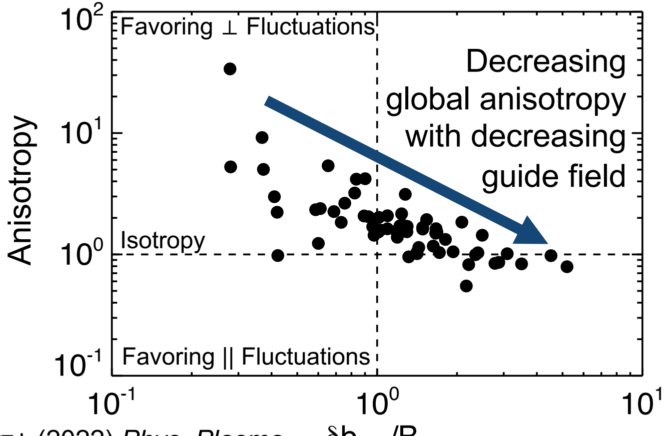
Taylor Hypothesis in the Magnetosheath



Taylor hypothesis tested by comparing single and multi-spacecraft 2nd-order structure functions

$$S_2(\boldsymbol{l}) = \langle |\boldsymbol{B}(\boldsymbol{x}+\boldsymbol{l}) - \boldsymbol{B}(\boldsymbol{x})|^2 \rangle$$

$$R_{Taylor}(\theta) = S_2(\boldsymbol{l}_{Taylor}) / S_2(\boldsymbol{l}_{Multi-S/C})$$



Stawarz+ (2022) *Phys. Plasma*

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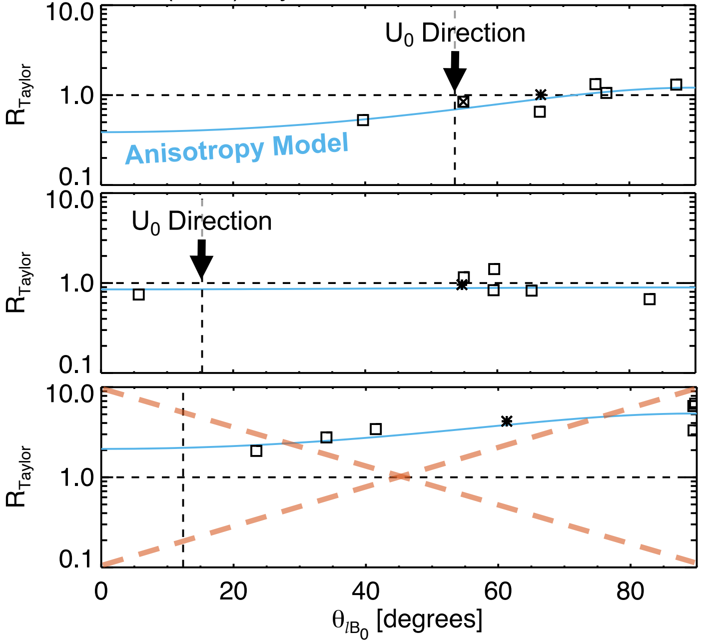

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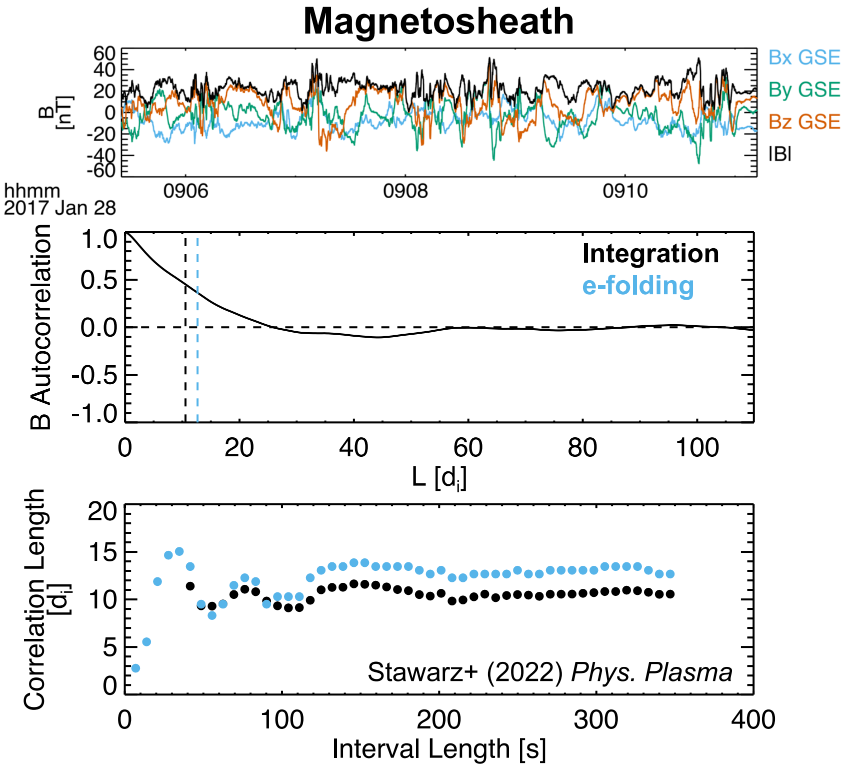
Turbulence Correlation Length

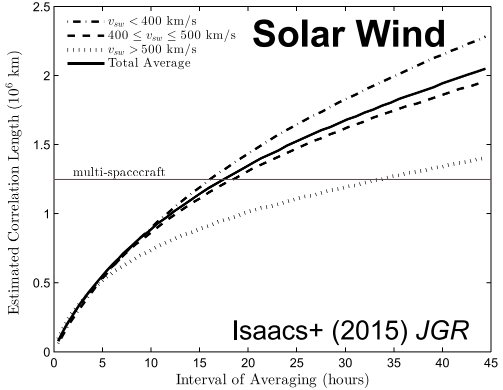


Correlation length defined as:

$$\lambda_C(\theta) = \int_0^{\infty} A(\boldsymbol{l})dl$$

$$\text{with } A(\boldsymbol{l}) = \frac{\langle \delta\boldsymbol{b}(\boldsymbol{x}+\boldsymbol{l})\cdot\delta\boldsymbol{b}(\boldsymbol{x})\rangle}{\langle|\delta\boldsymbol{b}(\boldsymbol{x})|^2\rangle}$$

Characteristic size of largest turbulent structures – set by driving scale or inverse cascade



While λ_C converges to a value in magnetosheath, it continues to grow with interval length in solar wind

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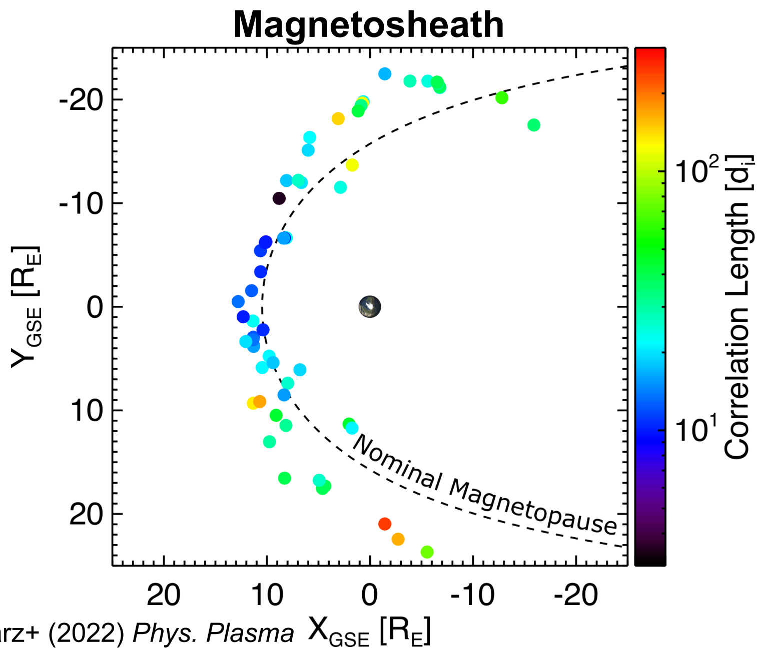
Turbulence Correlation Length



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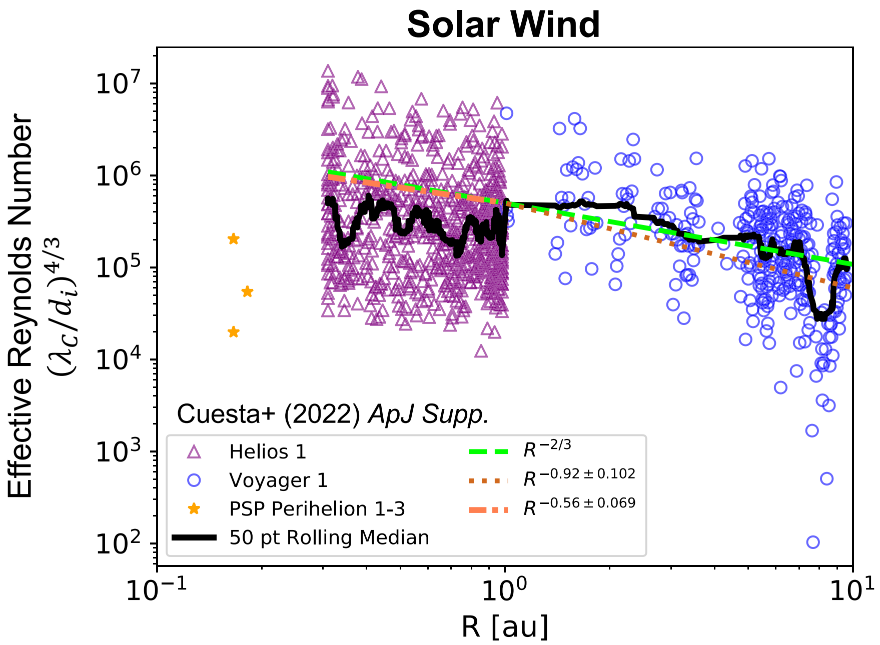

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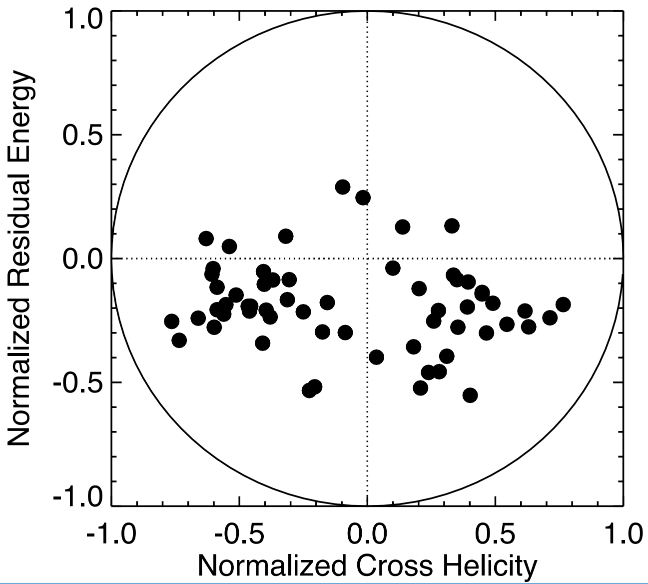
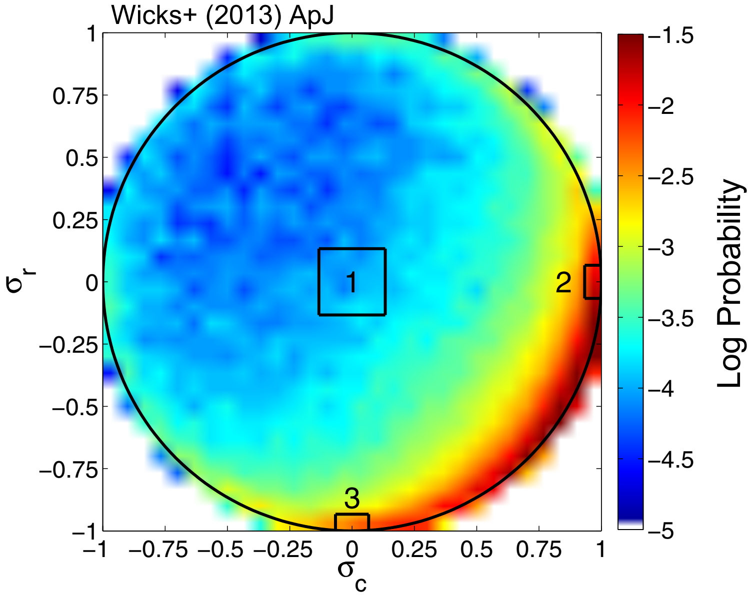
Cross Helicity & Residual Energy

$$\sigma_C = \frac{2\langle \delta\boldsymbol{u} \cdot \delta\boldsymbol{b} \rangle}{\langle |\delta\boldsymbol{u}|^2 + |\delta\boldsymbol{b}|^2 \rangle} \qquad \sigma_R = \frac{\langle |\delta\boldsymbol{u}|^2 - |\delta\boldsymbol{b}|^2 \rangle}{\langle |\delta\boldsymbol{u}|^2 + |\delta\boldsymbol{b}|^2 \rangle}$$

Magnetosheath



Solar Wind



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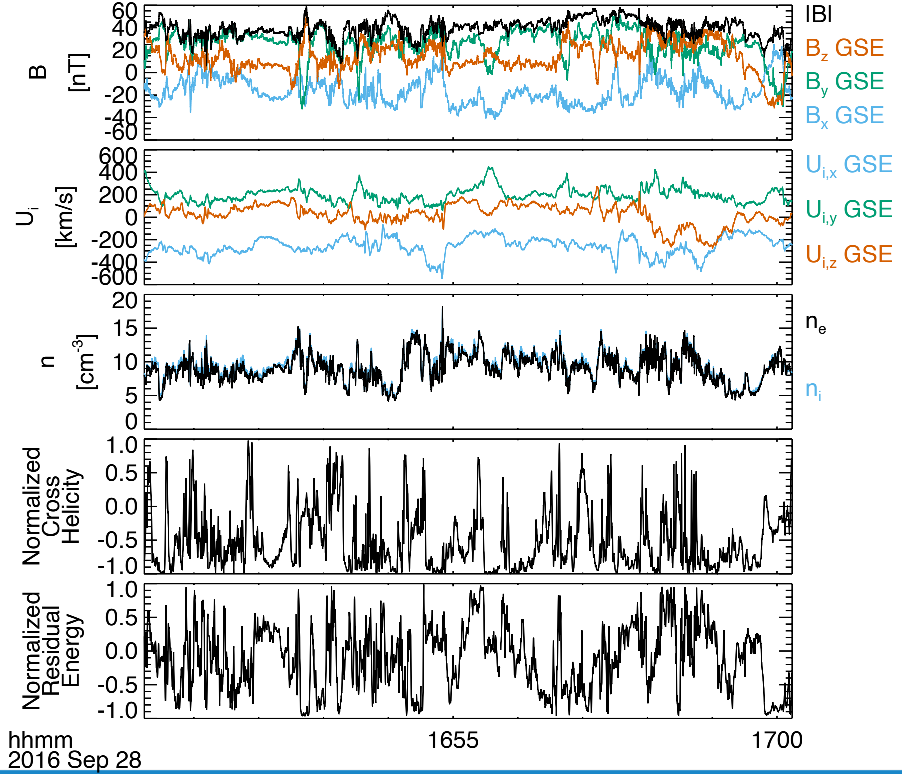
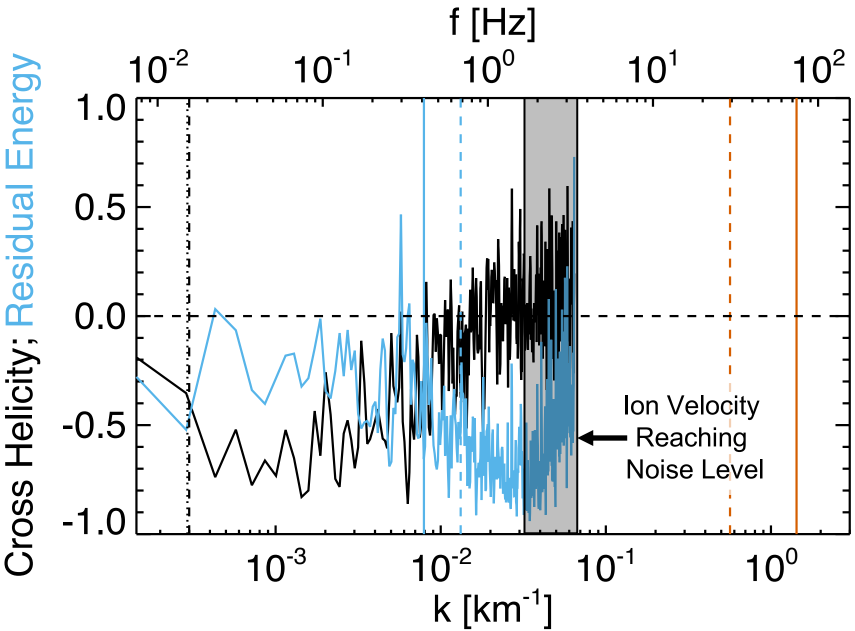
Cross Helicity & Residual Energy



σ_C and σ_R are 'patchy' in space and vary as a function of scale



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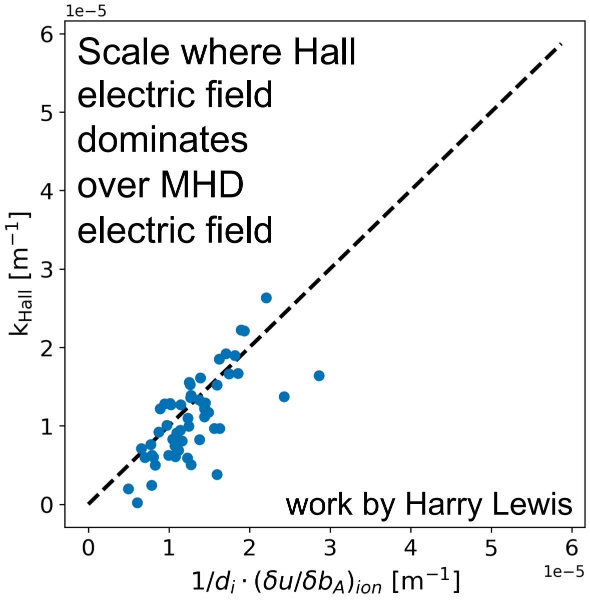
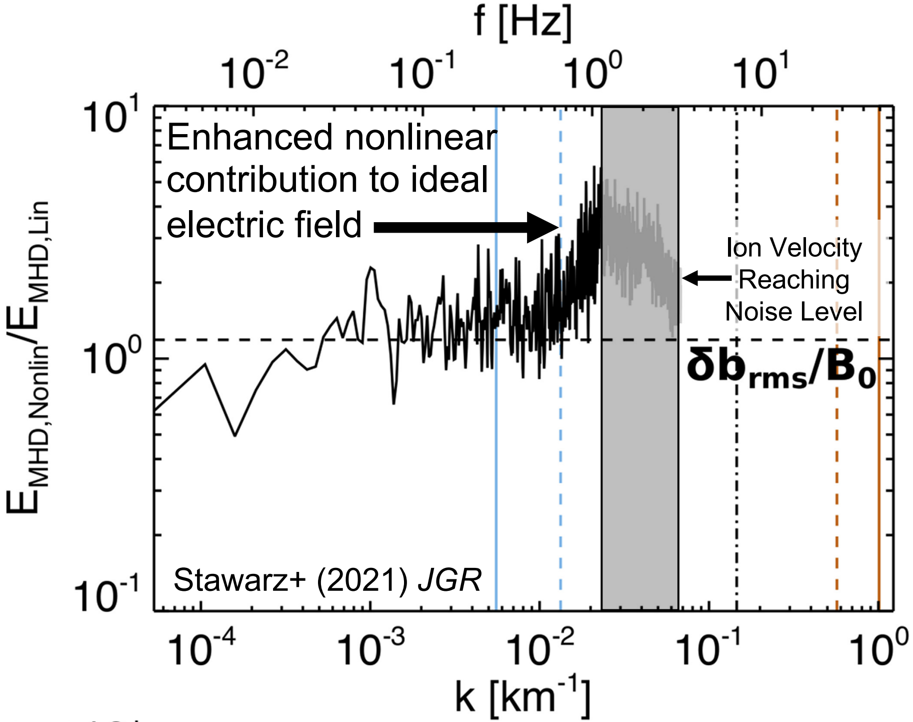
Cross Helicity & Residual Energy

σ_C and σ_R can impact the nonlinear turbulent dynamics





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Solar Wind Intermittency

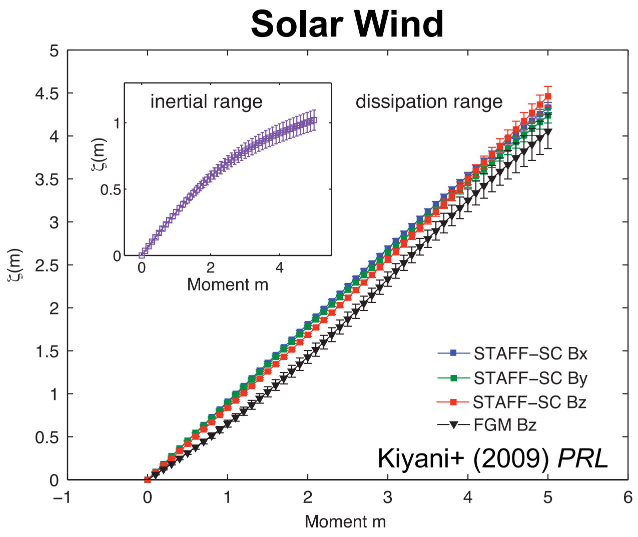
Scaling of structure functions

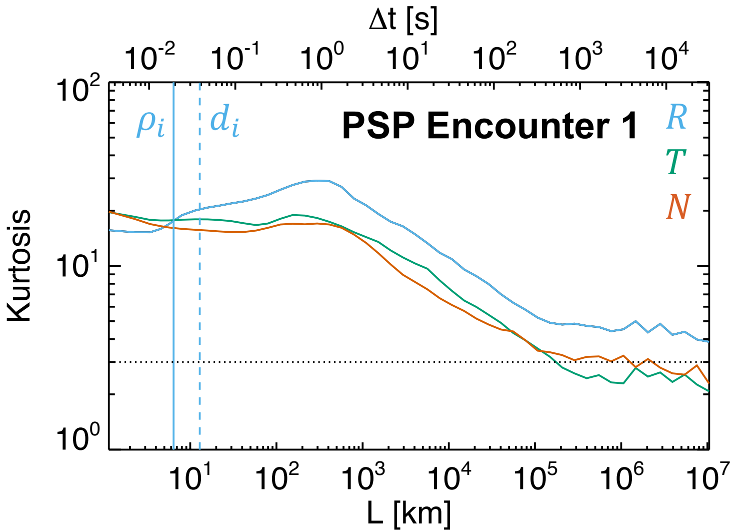
$$S_m(\ell) = \left\langle \left(B_i(x+\ell) - B_i(x)\right)^m \right\rangle \sim \ell^{\zeta(m)}$$

Scale-dependent kurtosis

$$\frac{S_{4,i}(\ell)}{\left[S_{2,i}(\ell)\right]^2} = \frac{\langle [B_i(x+\ell) - B_i(x)]^4 \rangle}{\langle [B_i(x+\ell) - B_i(x)]^2 \rangle^2}$$

Previous studies show sub-proton scale fluctuations become less intermittent in solar wind





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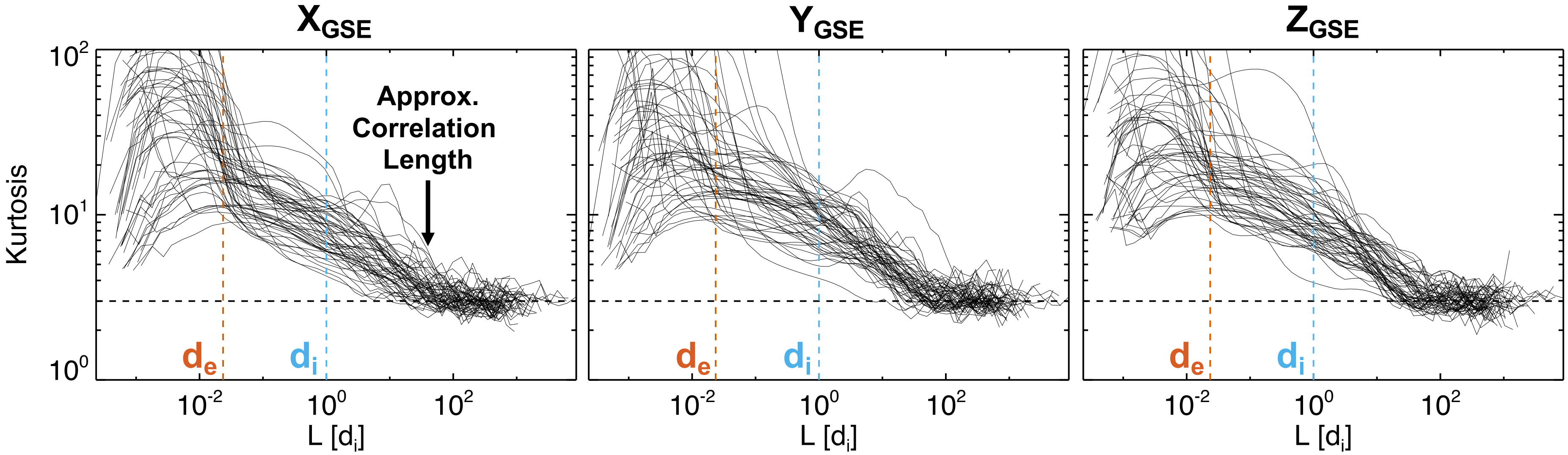
Scale Dependent Kurtosis

In many cases, the magnetosheath shows increasing scale-dependent kurtosis through sub-proton scales

→ Suggests kinetic scale structures may be different solar wind and magnetosheath

[see also Chhiber+ (2018) *JGR* for a case study]



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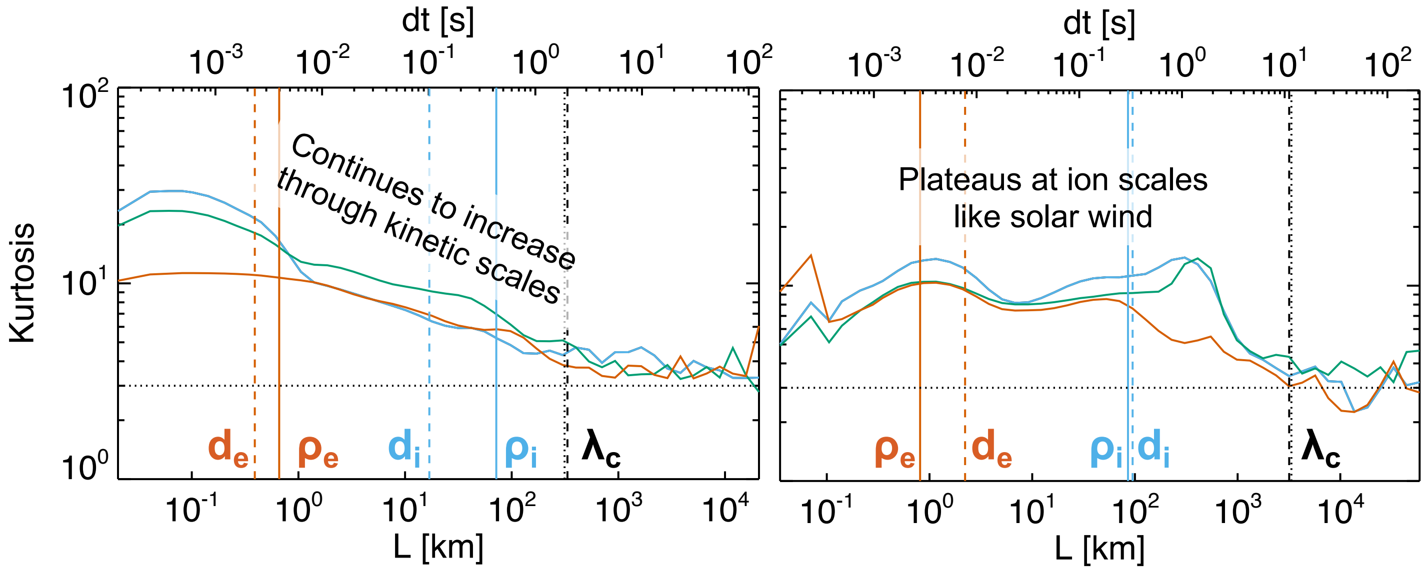

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Summary

We examine several properties of the turbulence in the magnetosheath with an eye toward characterizing the similarities and differences with solar wind turbulence

Taylor Hypothesis reasonable for many (though not all) magnetosheath intervals and signatures of anisotropy/isotropy scaling with $\delta b_{rms}/B_0$ apparent

Correlation Length in magnetosheath much shorter than those in the solar wind

Cross Helicity & Residual Energy place the magnetosheath in a more nonlinear state than many solar wind intervals

Intermittency continues to develop through sub-proton scales in many intervals in contrast to solar wind

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