PSP observations of the solar wind coherent structures from MHD to sub-ion scales at 0.17 AU

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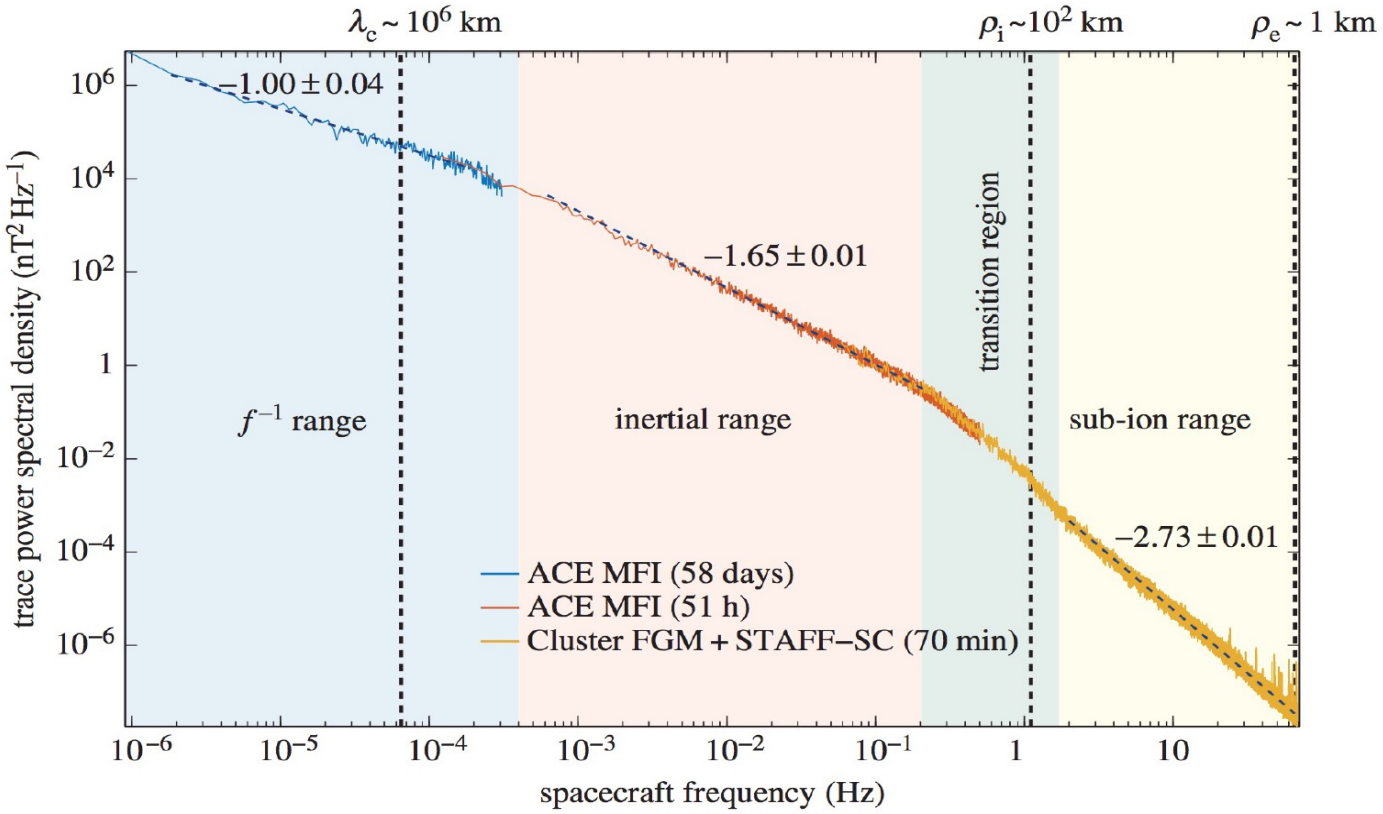
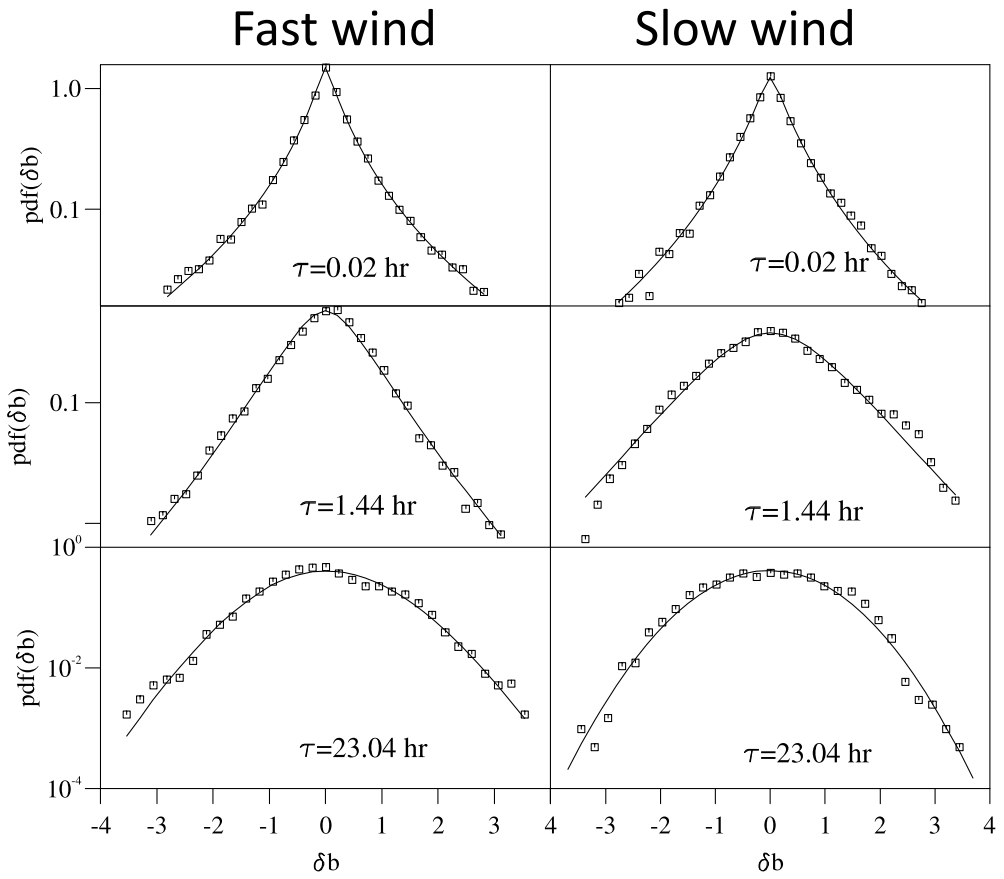
Solar wind turbulence

[Kiyani et al. 2015]

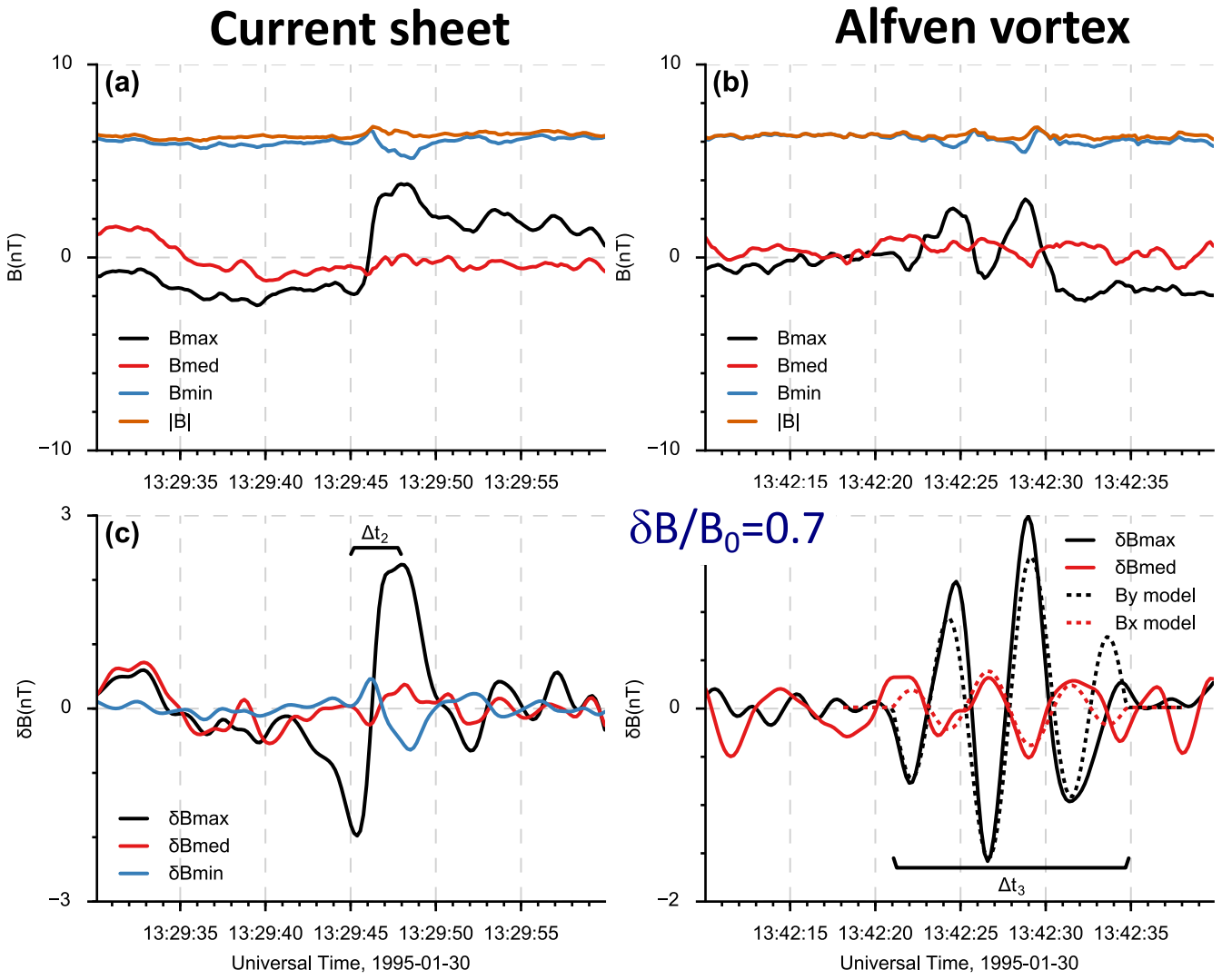


[Sorriso-Valvo et al. 1999]



$$\left|\Delta \mathbf{b}\right| = \left|\mathbf{b}(s+\Delta s) - \mathbf{b}(s)\right|$$

Wavelet detection of ion-scale coherent structures (1 AU)



[Lion, Alexandrova & Zaslavskiy, 2016, APJ, Perrone et al 2016, 2017, Roberts et al 2016]

Role of coherent structures in heating:

- Observations (ACE,WIND): Coherent structures correlate with enhancements in (Q_e,T_e,T_i). [Osman 2011]
- Kinetic simulation [Karimabadi 2013] -> reconnection-like heating

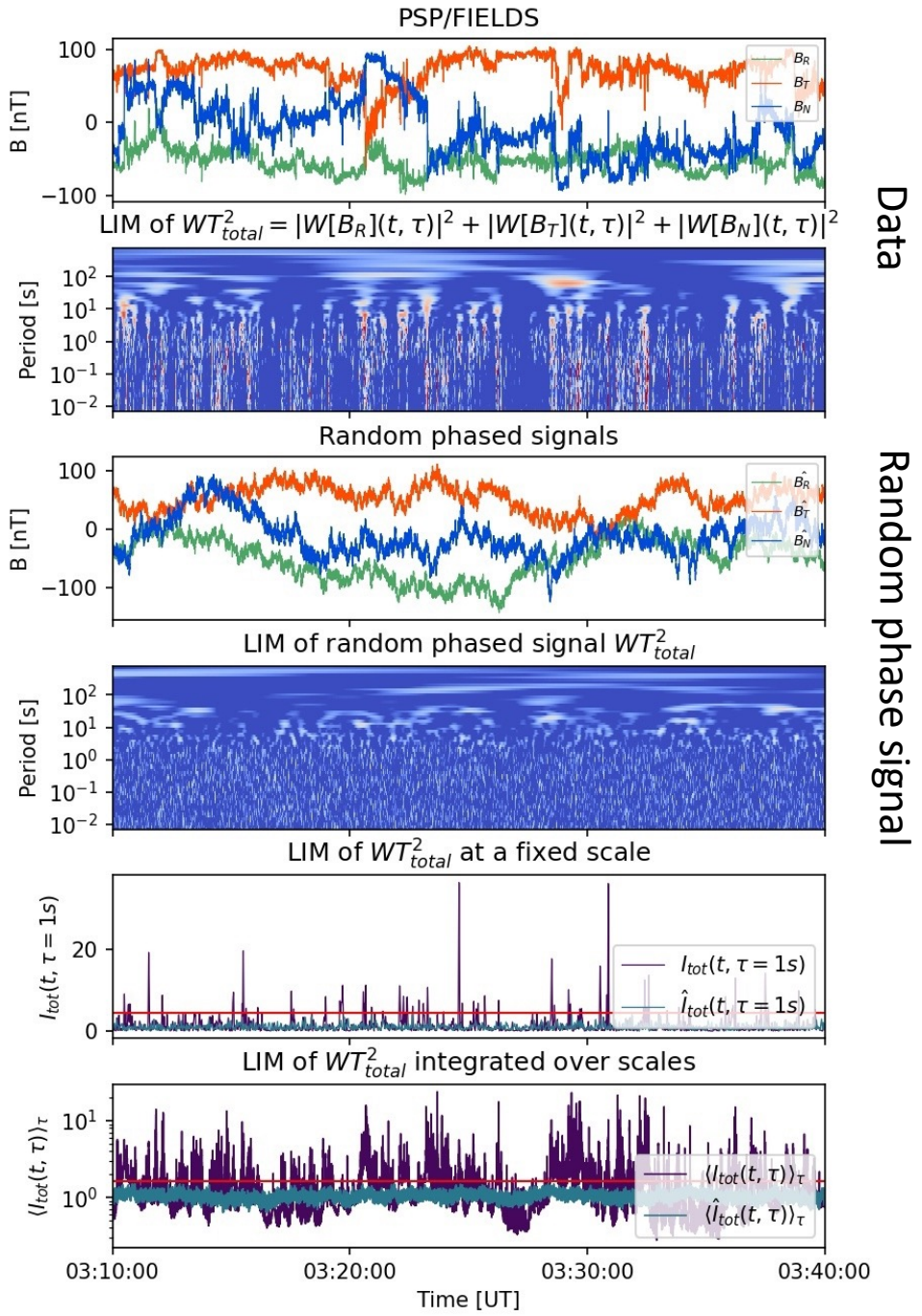
We investigate coherent structures **from MHD to sub-ion scales**

Detection of coherent structures at 0.17 AU

- Total local intermittency measure $I(t,\tau)_{tot}$ shows the relative total energy of fluctuations at a given moment in time at a given scale τ

$$I(t,\tau)_{tot} = \frac{\sum_{i=R,T,N} |W[B_i](t,\tau)|^2}{\langle \sum_{i=R,T,N} |W[B_i](t,\tau)|^2 \rangle_{t \in T'}}$$

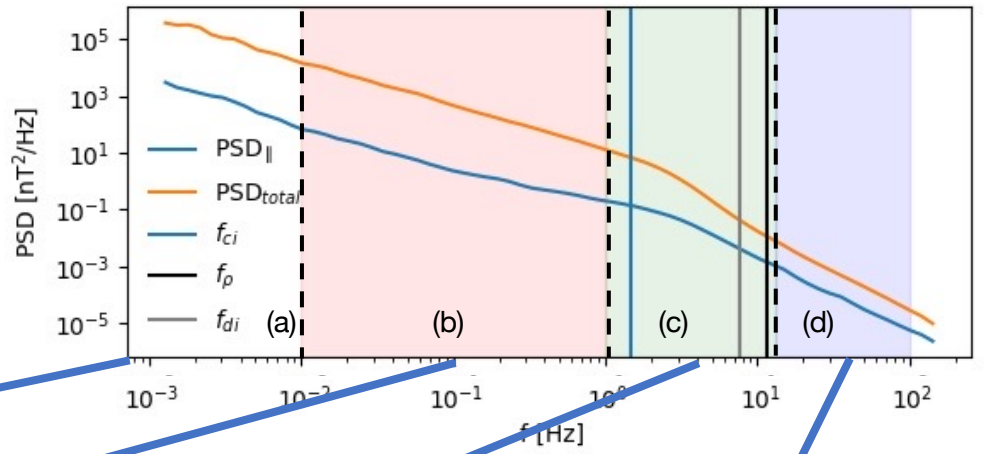
- To detect the structures we compare magnetic field measurements with an random-phased signal
- **Vertical lines: coupled phases across scales -> Coherent structures**

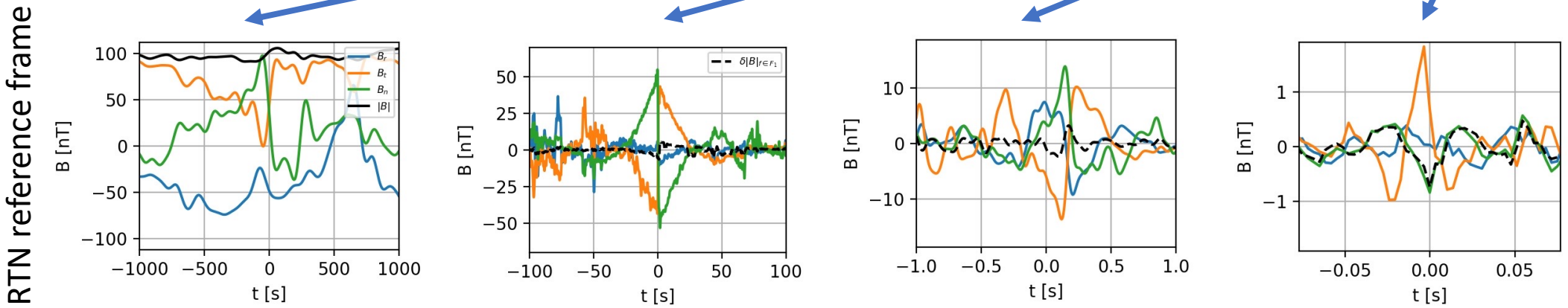


1. Discontinuity

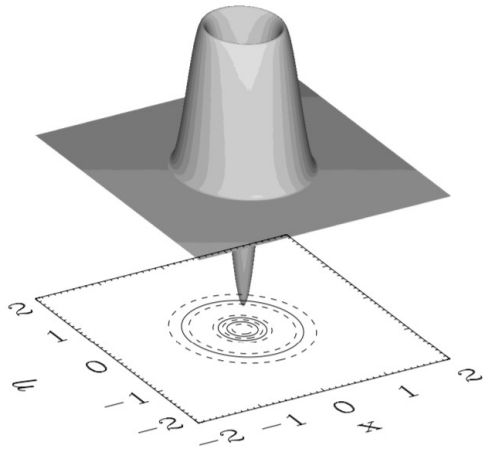
- Current sheet at MHD scales
- Interesting sub-ion scale vortex-like structure
- Is it possible that sub-ion structure has been formed as a result of current sheet instability/ reconnection?

To define fluctuations within a frequency range, we apply a band-pass filter $f \in F_j$





2. Alfven vortex

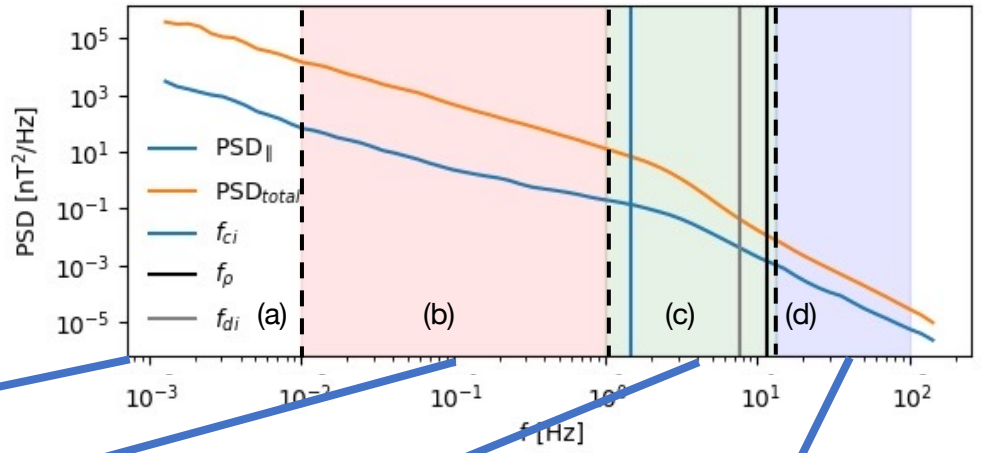


Incompressible MHD vortex [Petviashvilli & Pokhotelov 1992]

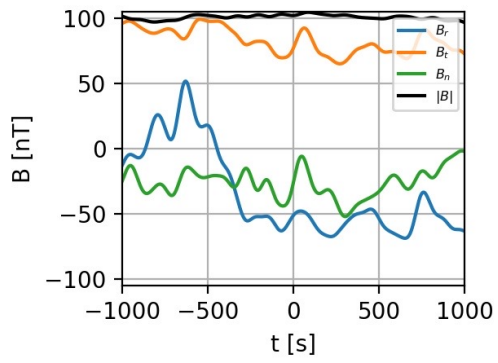
Compressible MHD + Ion-scales vortex model: Jovanovic et al. 2020;

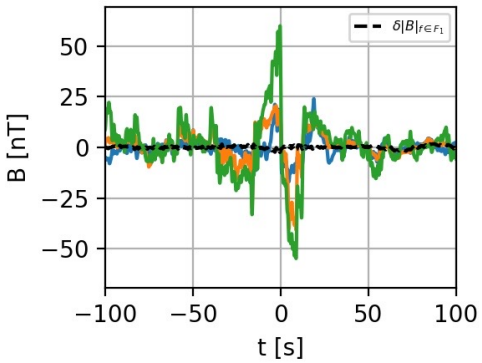
Figure from Alexandrova 2008.

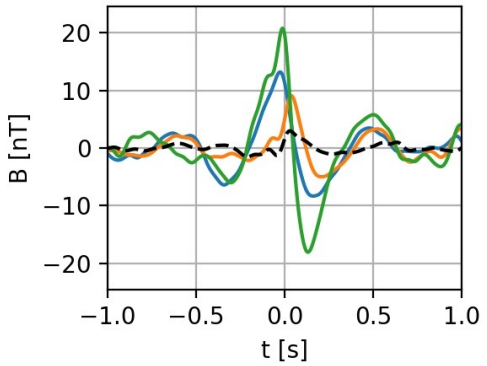
To define fluctuations within a frequency range, we apply a band-pass filter $f \in F_j$

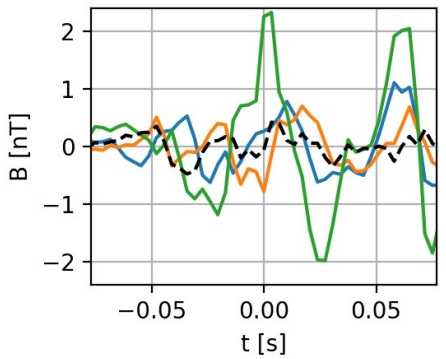


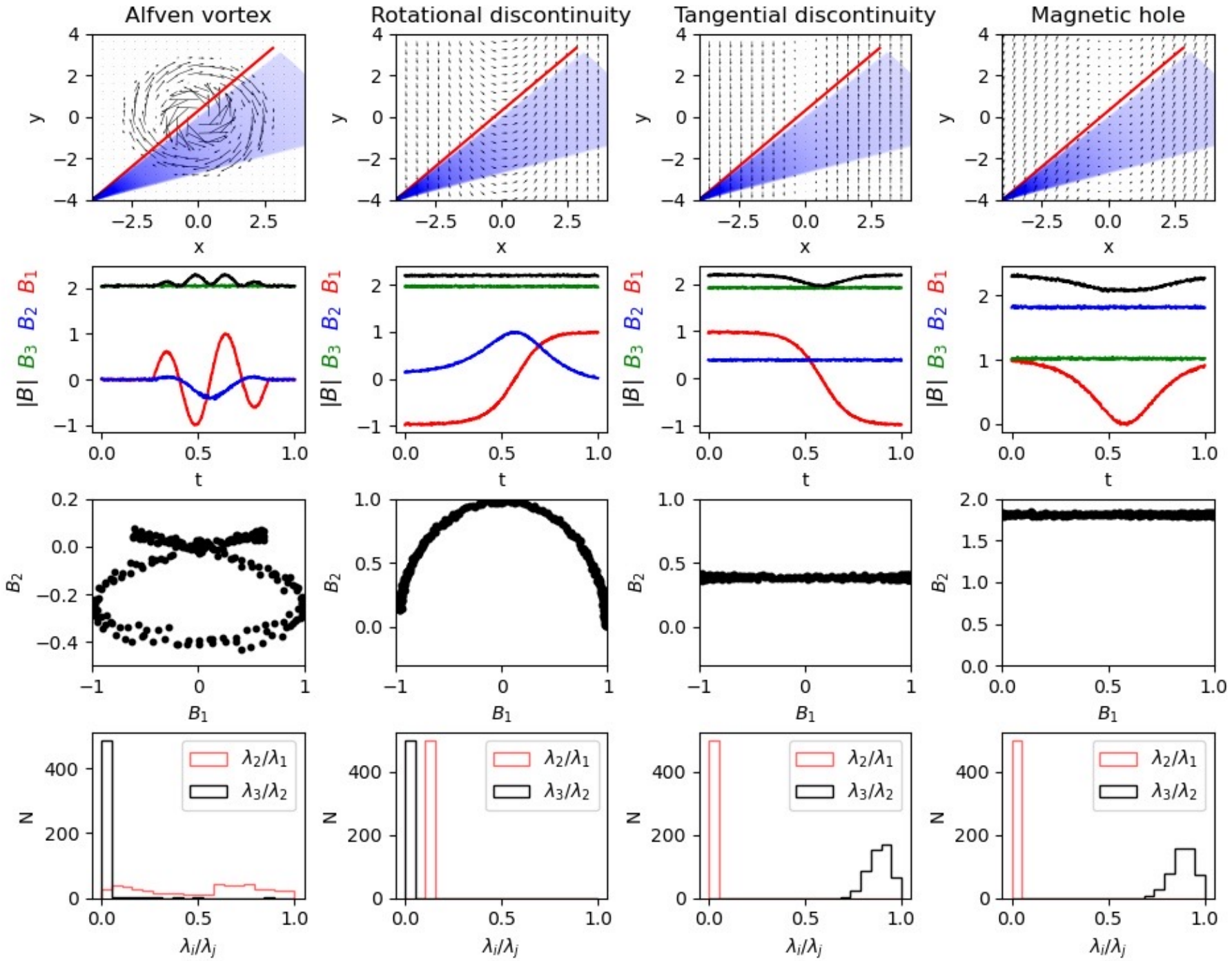
RTN reference frame











Simulation of coherent structures crossings

λ_1– maximum variation

λ_2– intermediate variation

λ_3– minimum variation

Statistics: 600 structures

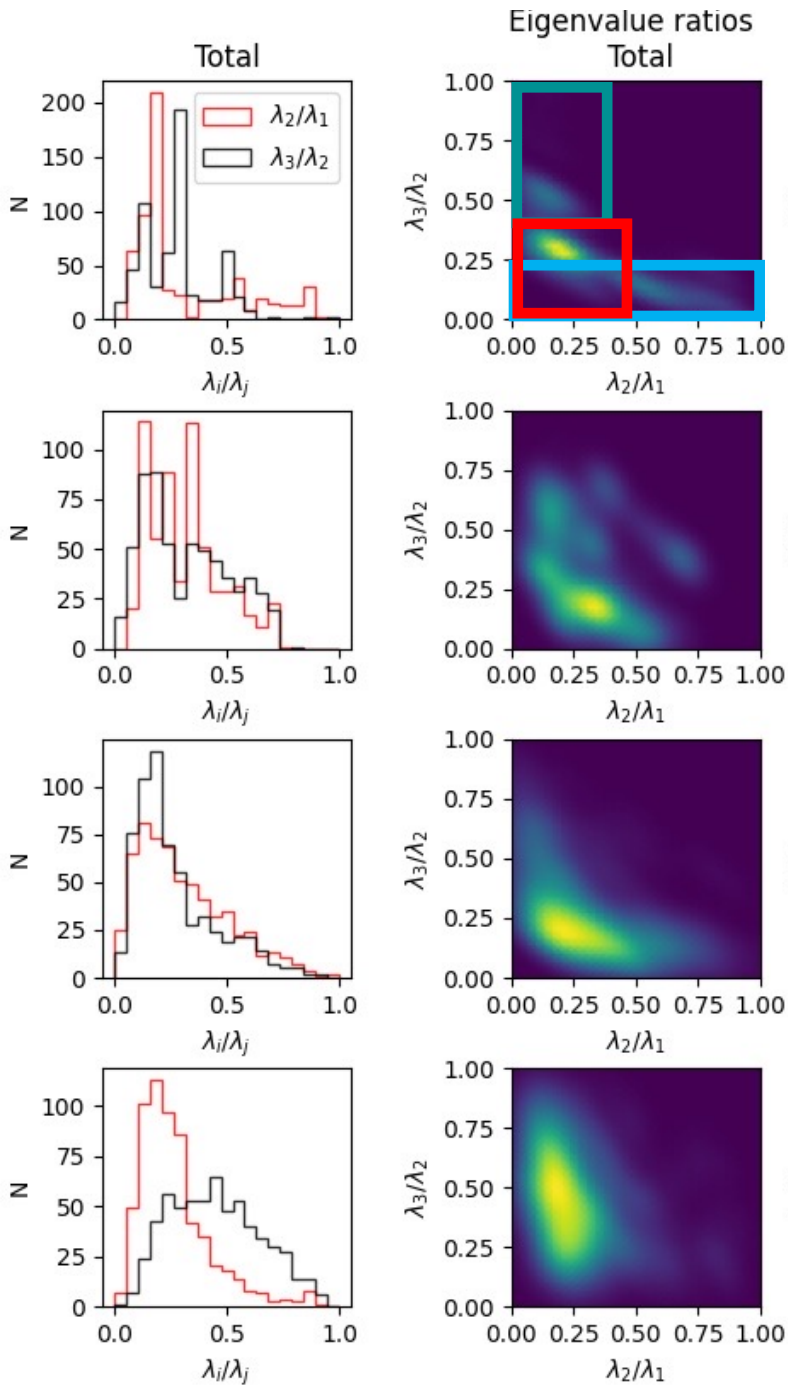
- Upper left area – tangential discontinuities/magnetic holes
- Lower elongated rectangle – Alfven vortices
- Area at the zero vicinity – rotational discontinuities

Both MVA eigenvalue ratios allow to distinguish between different types of structures.

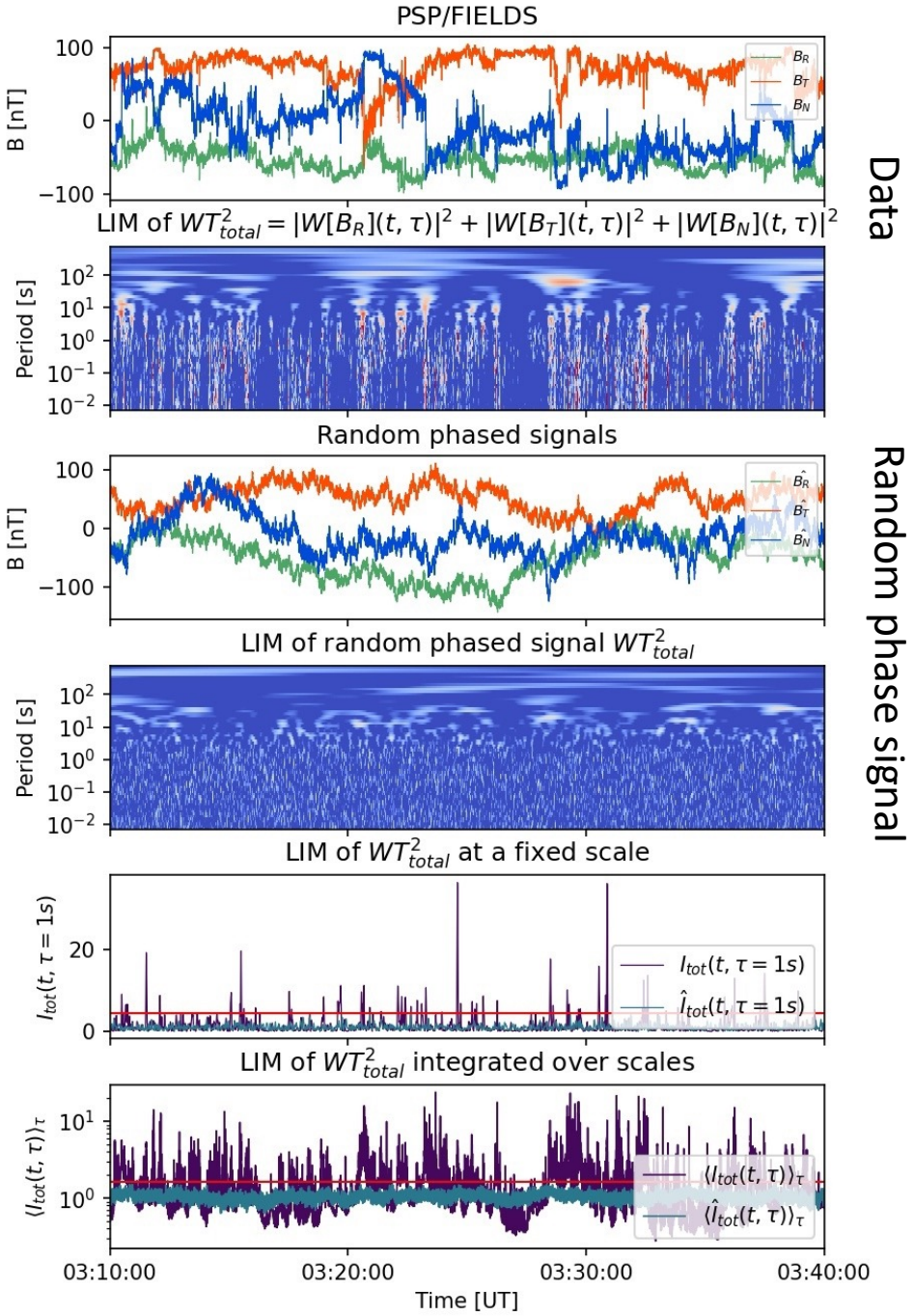
At the largest scales the rotational discontinuities and vortices dominate.

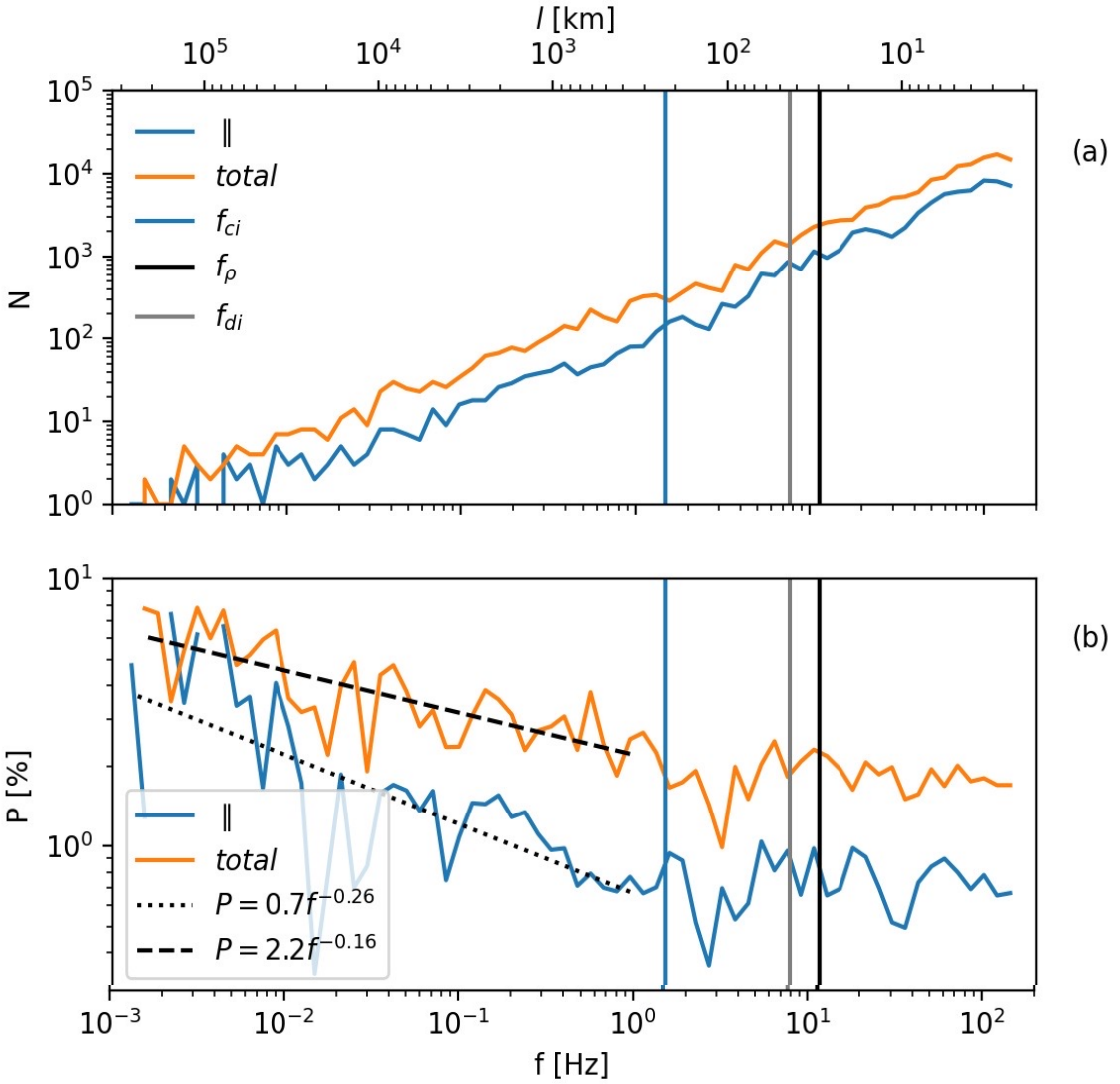
At the ion scales the vortexes are dominant.

The population of tangential discontinuities/ magnetic holes increases towards the smallest scales.



Filling factor of coherent structures





Conclusion

- We observe solar wind coherent structures from MHD to ion kinetic scales and below with numerous embedded structures.
- Comparison of MVA eigenvalue ratios statistics of magnetic fluctuations within coherent structure with the simulation of coherent structures crossing.

Range of scales	Possible dominant type of structures
MHD Inertal range	**Rotational discontinuities**
Ion scales	**Alfven vortexes & rotational discontinuities**
Sub-ion scales	**Tangential discontinuities/ Magnetic holes**

- Intermittent events increase in number towards smaller scales without any significant change at ion kinetic scales.
- The filling factor decrease at MHD inertial range following the power low and saturates at constant value staring from ion scales.