Polarization Status of Magnetic Fluctuations at Proton Scales

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in collaboration with

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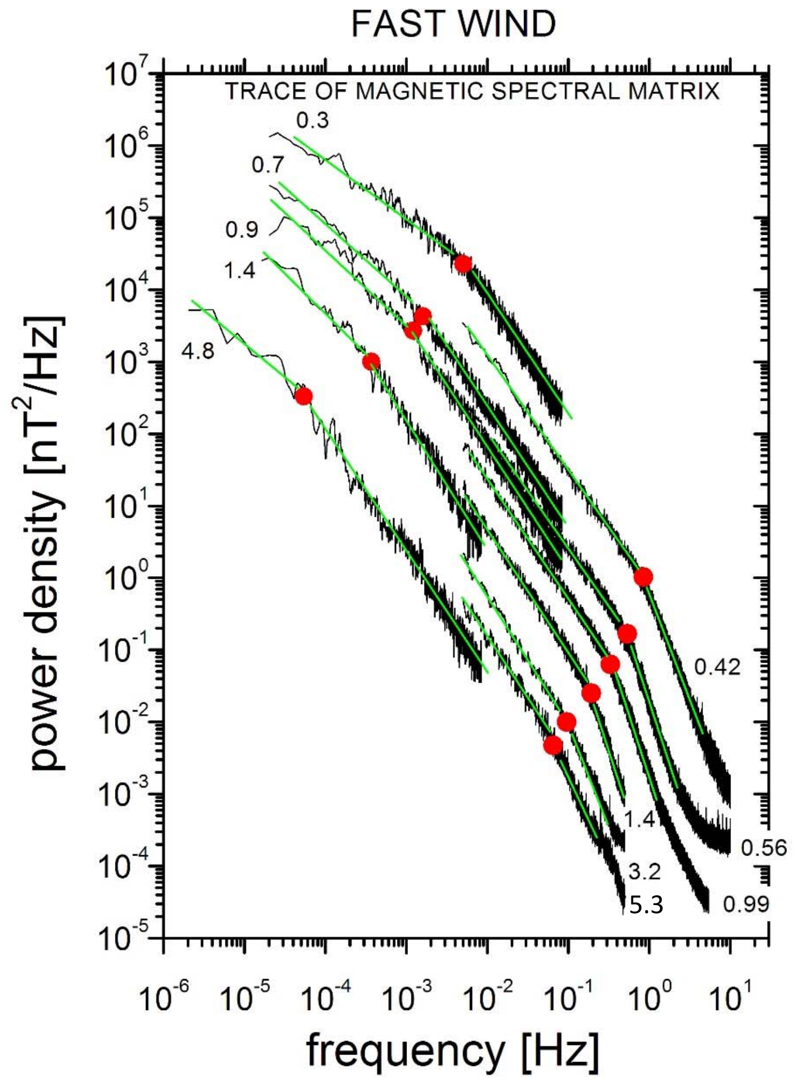
Spectral radial evolution in the inner heliosphere

merging low and high frequency mag field spectra in the ecliptic



[adapted from Telloni et al., 2015]

- ❑ **Low and high frequency breaks move to lower frequencies with increasing radial distance form the Sun**
- ❑ **Low frequency break has a faster radial evolution**

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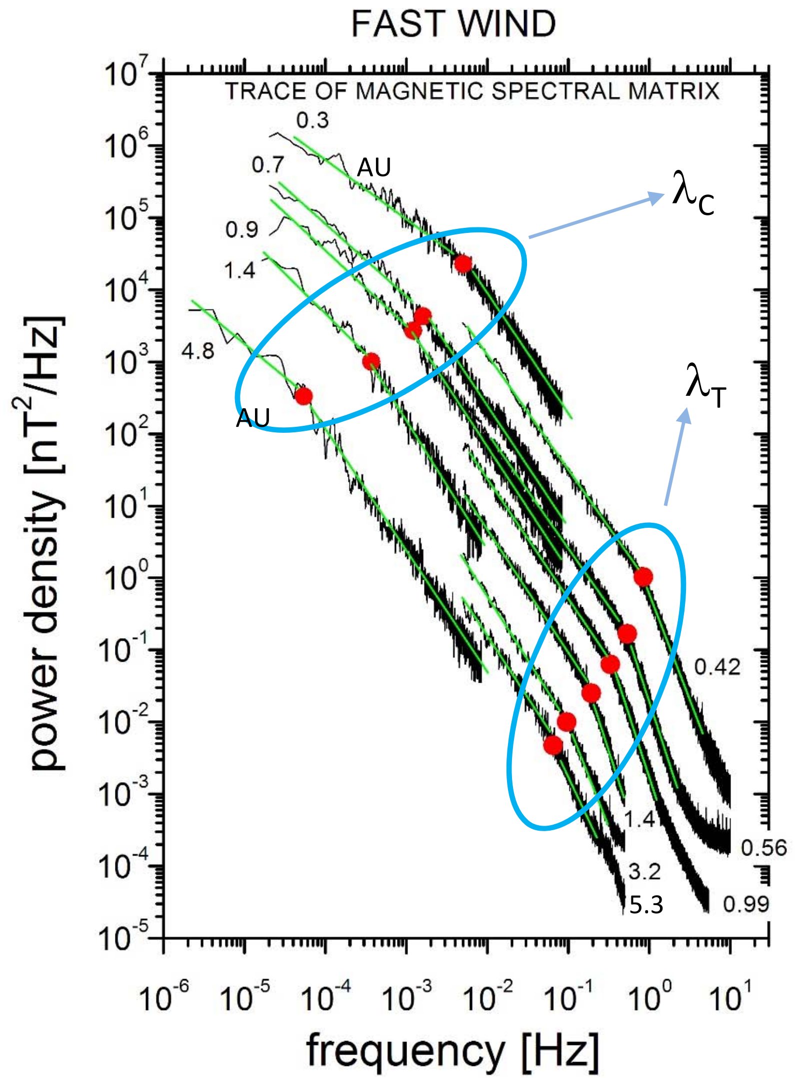

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- ❑ Low and high frequency breaks move to lower frequencies with increasing radial distance form the Sun
- ❑ Low frequency break has a faster radial evolution

Rough estimates:

$\lambda_C \sim R^{-1.5}$

$\lambda_T \sim R^{-1.1}$

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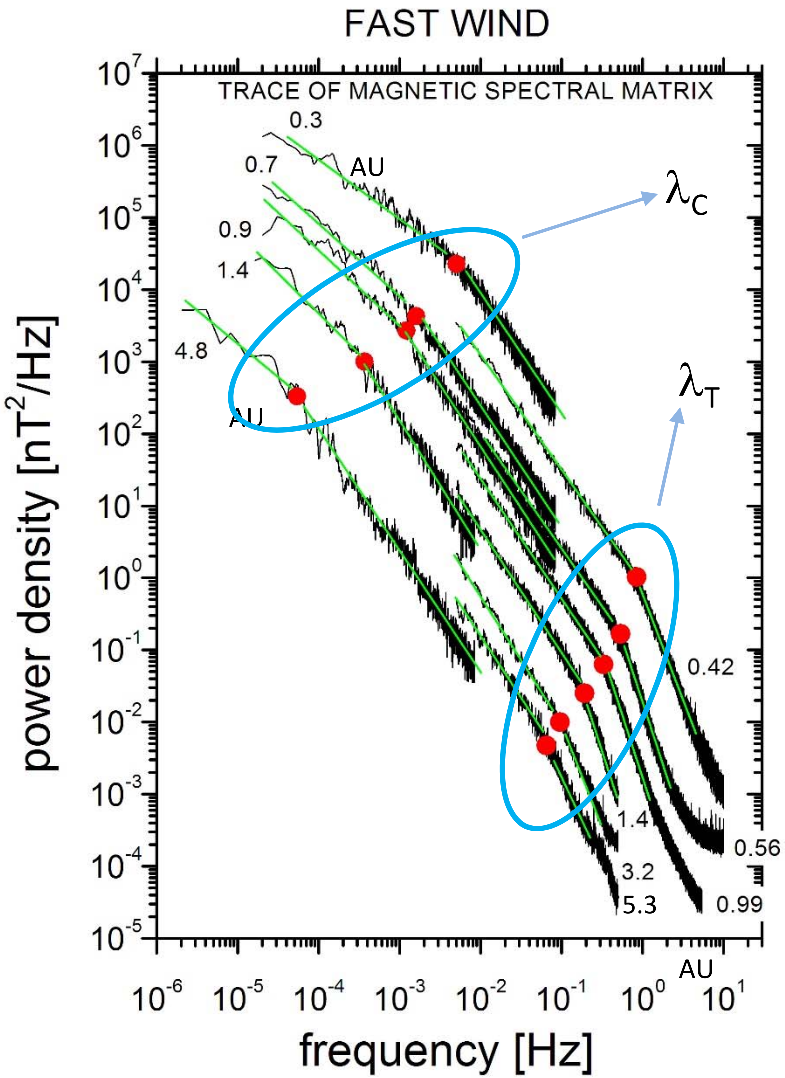

- Low and high frequency breaks move to lower frequencies with increasing radial distance form the Sun
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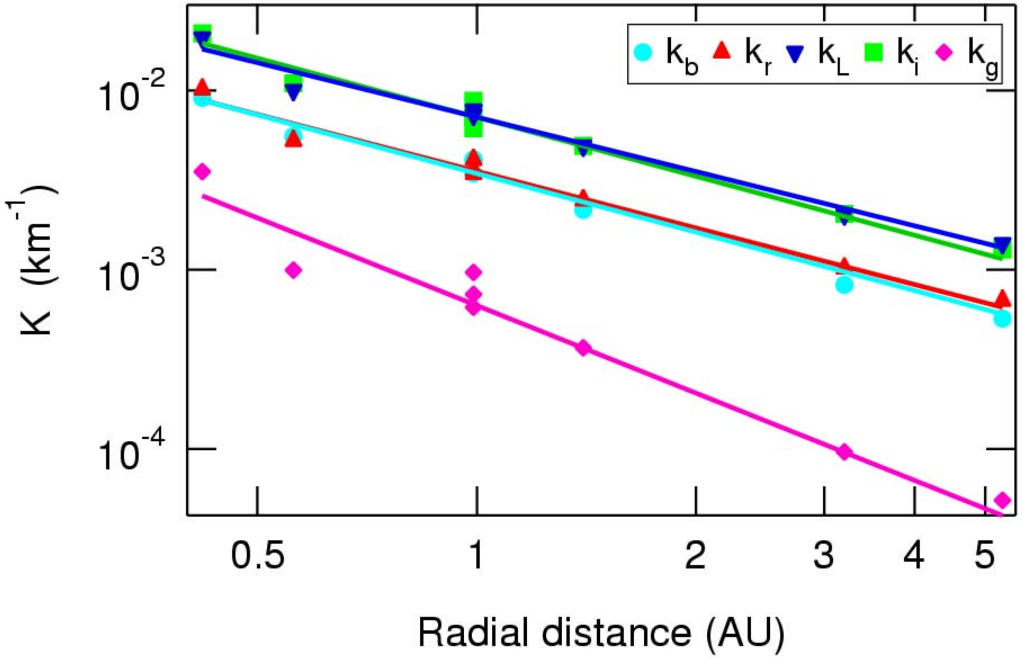
$$Re_m^{eff} = \left(\frac{\lambda_C}{\lambda_T}\right)^2$$

Effective Reynolds number
(rough estimate from breaks locations)

(0.85/0.005)^2 = ...3E4		.3-.4 AU
(0.53/0.0015)^2 = ...1.1E5		.6-.7 AU
(0.38/0.001)^2 = ...1.5E5		.9-1 AU
(0.192/0.00034)^2 = ...3.2E5		1.4AU
(0.065/0.00005)^2 =..... 1.7E6		4.8-5.3AU

[Matthaeus et al., 2005: 2.3E5 1.AU]

Looking for the radial dependence of the high frequency break



Bruno & Trenchi, ApJL, 2014

$\lambda_i \rightarrow$ $k_i = \omega_p / c$

$\lambda_L \rightarrow$ $k_L = \Omega_p / v_{th}$

$f_b \rightarrow$ $k_b = 2\pi f_b / v_{sw}$

$f_{ic} \rightarrow$ $k_g = \Omega_p / v_{sw}$

Ion-cyclotron resonance $k_r = \Omega_p / (v_A + v_{th})$

$$k_b = (3.4 \pm 0.2) \cdot 10^{-3} R^{(-1.08 \pm 0.08)}$$

$$k_i = (7.0 \pm 0.5) \cdot 10^{-3} R^{(-1.10 \pm 0.10)}$$

$$k_L = (7.0 \pm 0.4) \cdot 10^{-3} R^{(-1.02 \pm 0.10)}$$

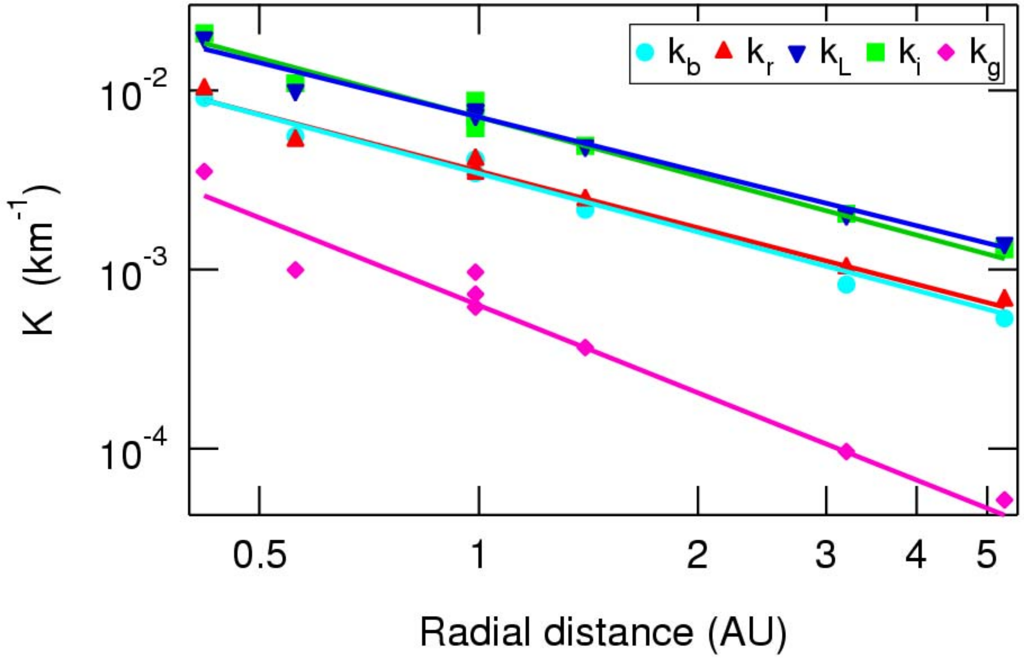
$$k_g = (6.3 \pm 1.2) \cdot 10^{-4} R^{(-1.62 \pm 0.31)}$$

$$k_r = (3.5 \pm 0.2) \cdot 10^{-3} R^{(-1.06 \pm 0.10)}$$

best agreement: ion-cyclotron resonance, primary role of $K_{//}$

Results between 0.42 and 1.4 AU based on radial alignments Messenger-WIND and WIND-Ulysses

Looking for the radial dependence of the high frequency break



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best agreement: ion-cyclotron resonance, primary role of $K_{//}$

quite unexpected, given that turbulence proceedes for $K_{\perp}$

Results between 0.42 and 1.4 AU based on radial alignments Messenger-WIND and WIND-Ulysses

Looking for the radial dependence of the high frequency break

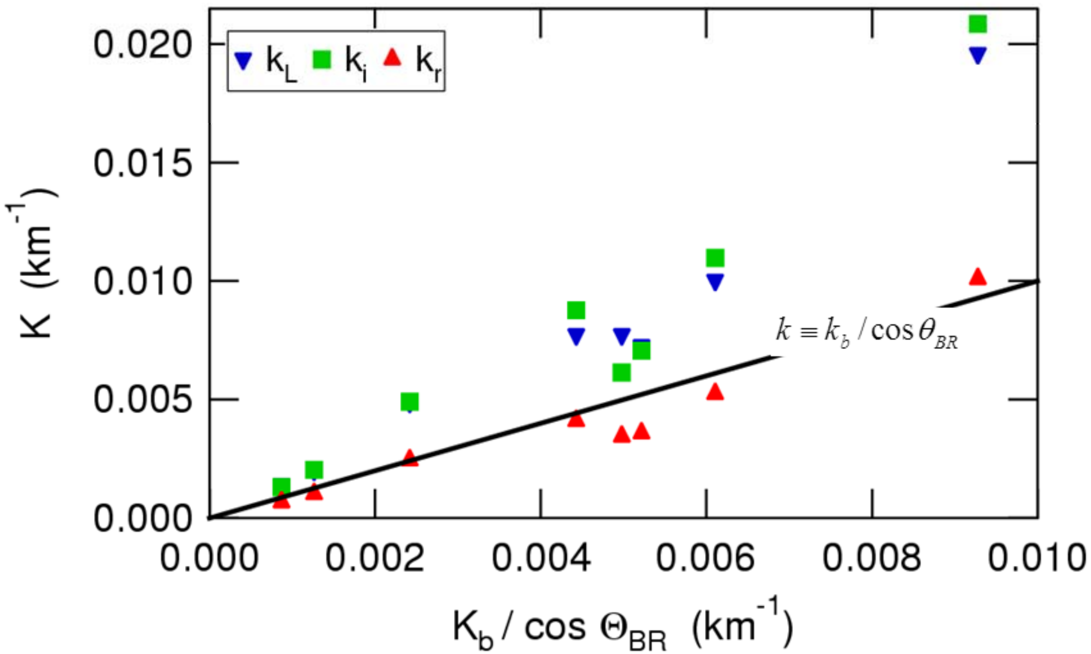
Considering that:

- we are sampling along the radial direction at an angle θ_{BR} (see table)
- $\underline{\kappa}$ is along the mean field

$$\kappa_b \rightarrow \kappa_b / \cos\theta_{BR}$$

(where K_b corresponds to the observed break)

Interval	s/c	$R(AU)$	$\theta_{BR}[°]$
2011, 100.87-101.03	MESS	0.42	11.8
2010, 182.04-182.65	MESS	0.56	24.7
2010, 182.83-183.95	WIND	0.99	46.3
2011, 102.65-102.78	WIND	0.99	20.7
2007, 239.12-240.24	WIND	0.99	38.7
2007, 241.77-243.29	ULYSS	1.4	27.0
2000, 192.96-193.34	ULYSS	3.2	49.0
1992, 235.92-236.30	ULYSS	5.3	52.2

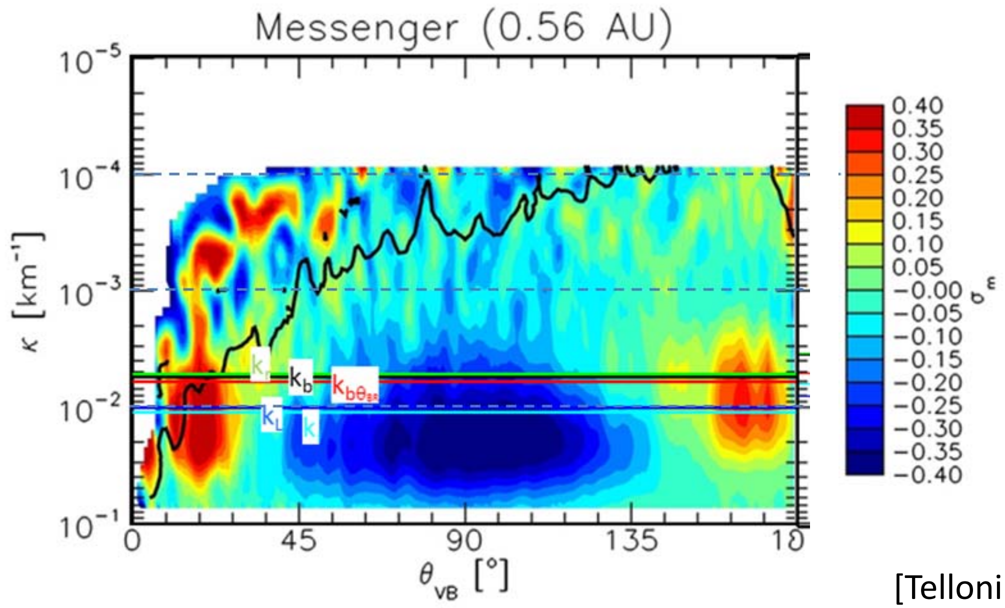


Bruno & Trenchi, ApJL, 2014

Best agreement shown by the wavenumber k_r associated to the resonant condition

Results between 0.42 and 1.4 AU based on radial alignments Messenger-WIND and WIND-Ulysses

Normalized reduced magnetic helicity to study the nature of the fluctuations right beyond the frequency break



[Telloni et al., 2015]

$$k_i = \omega_p / c$$

$$k_L = \Omega_p / v_{th}$$

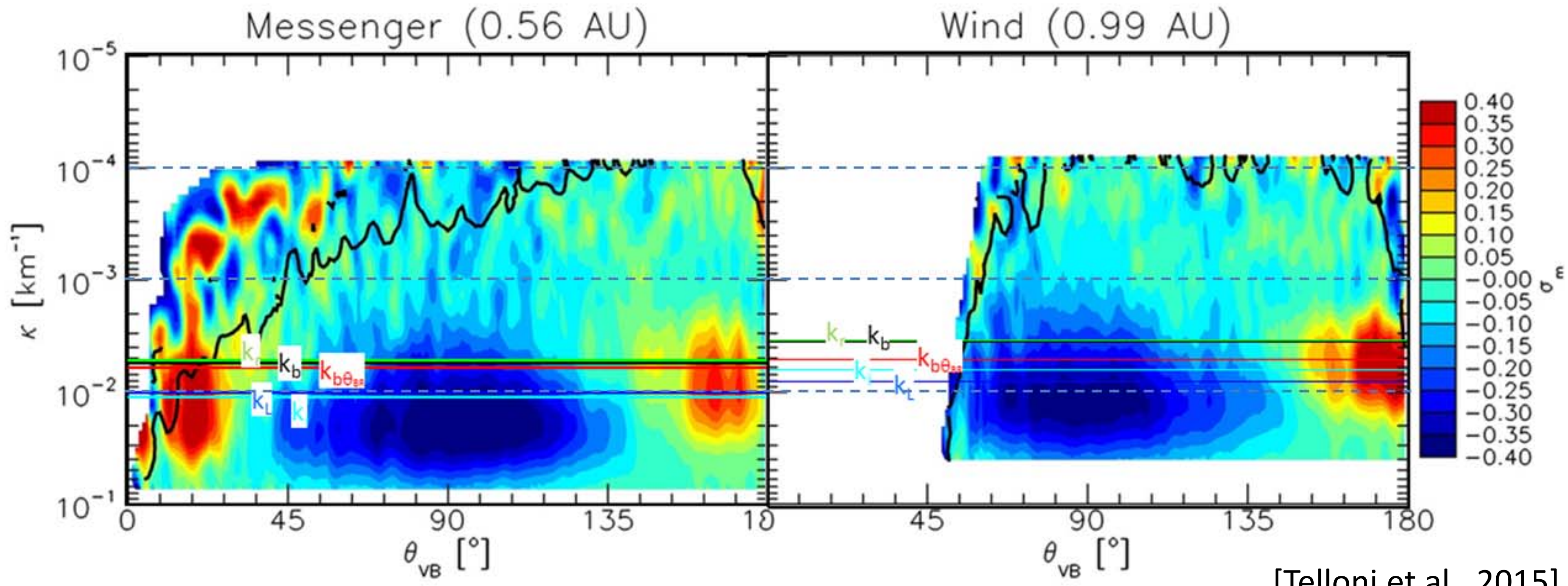
$$k_b = 2\pi f_b / v_{sw}$$

$$k_r = \Omega_p / (v_A + v_{th})$$

- Large scale background magnetic field inward oriented
- local magnetic field direction scale by scale
- left-handed Alfvén-cyclotron waves with positive magnetic helicity propagating antiparallel to B
- right-handed KAW waves with negative magnetic helicity propagating at large angles wrt B
- results similar to He et al., 2011 and Podesta & Gary, 2011

Normalized reduced magnetic helicity to study the nature of the fluctuations right beyond the frequency break

Messenger & Wind radial alignment [0.56-0.99AU]



[Telloni et al., 2015]

- Clear shift in *k* for the two populations towards smaller *k's* with increasing distance confirming that they are related to the frequency break

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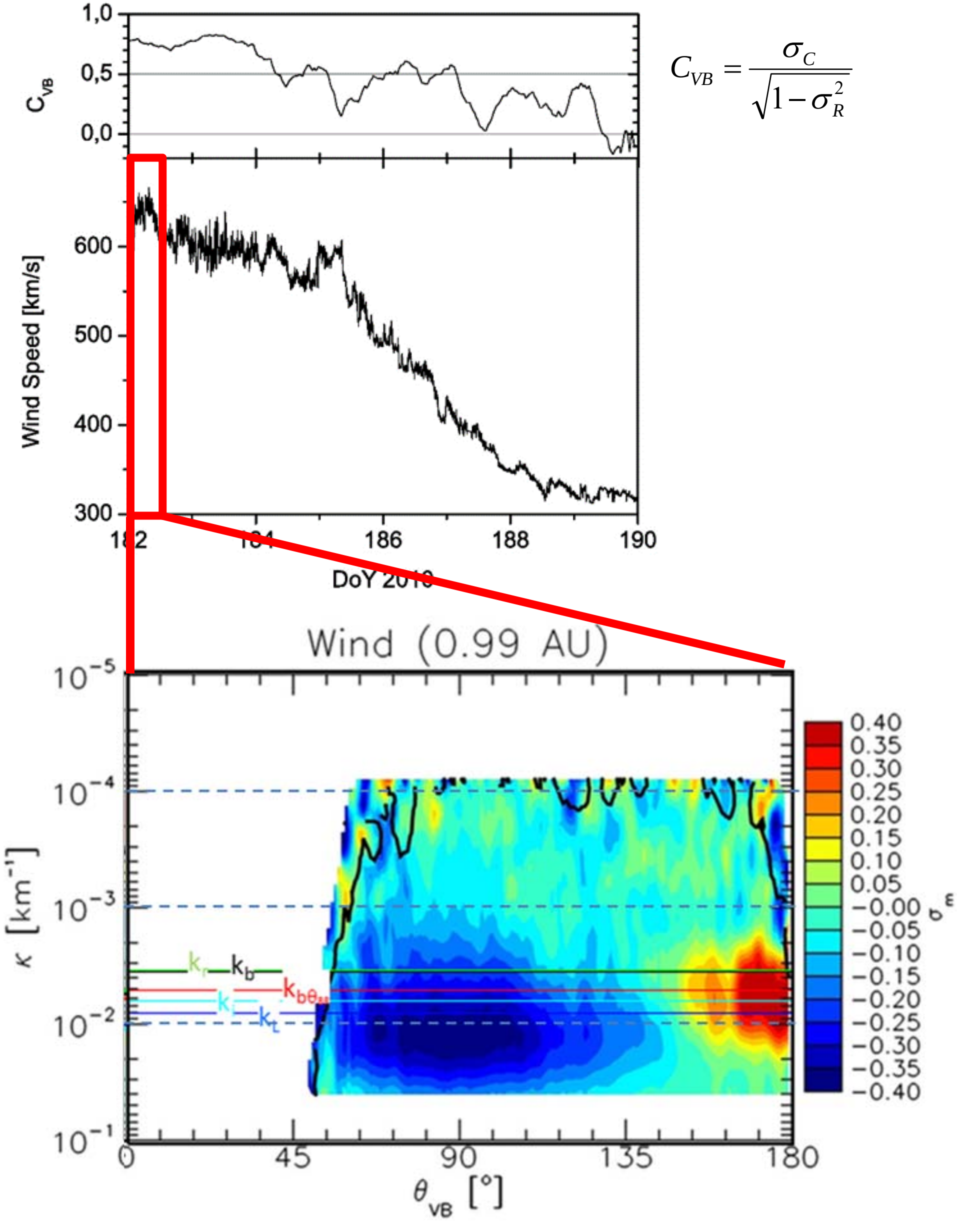
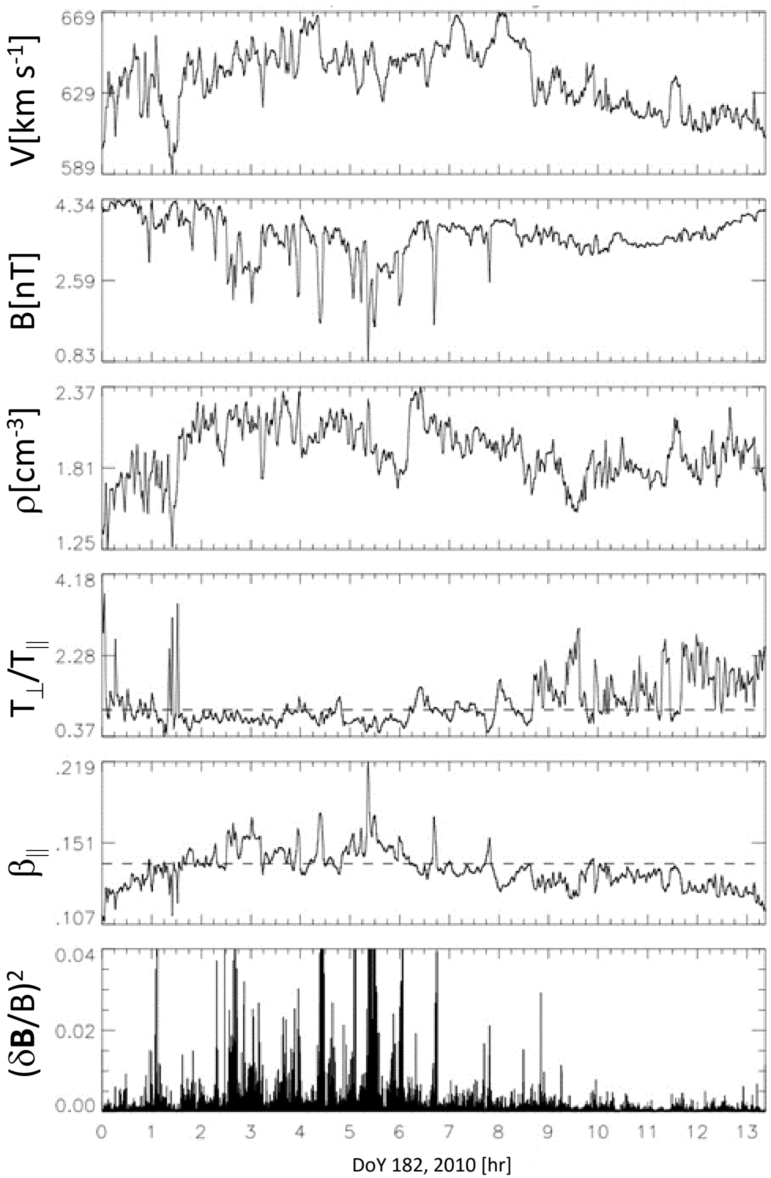
Further details on fluctuations



$$C_{VB} = \frac{\sigma_C}{\sqrt{1-\sigma_R^2}}$$



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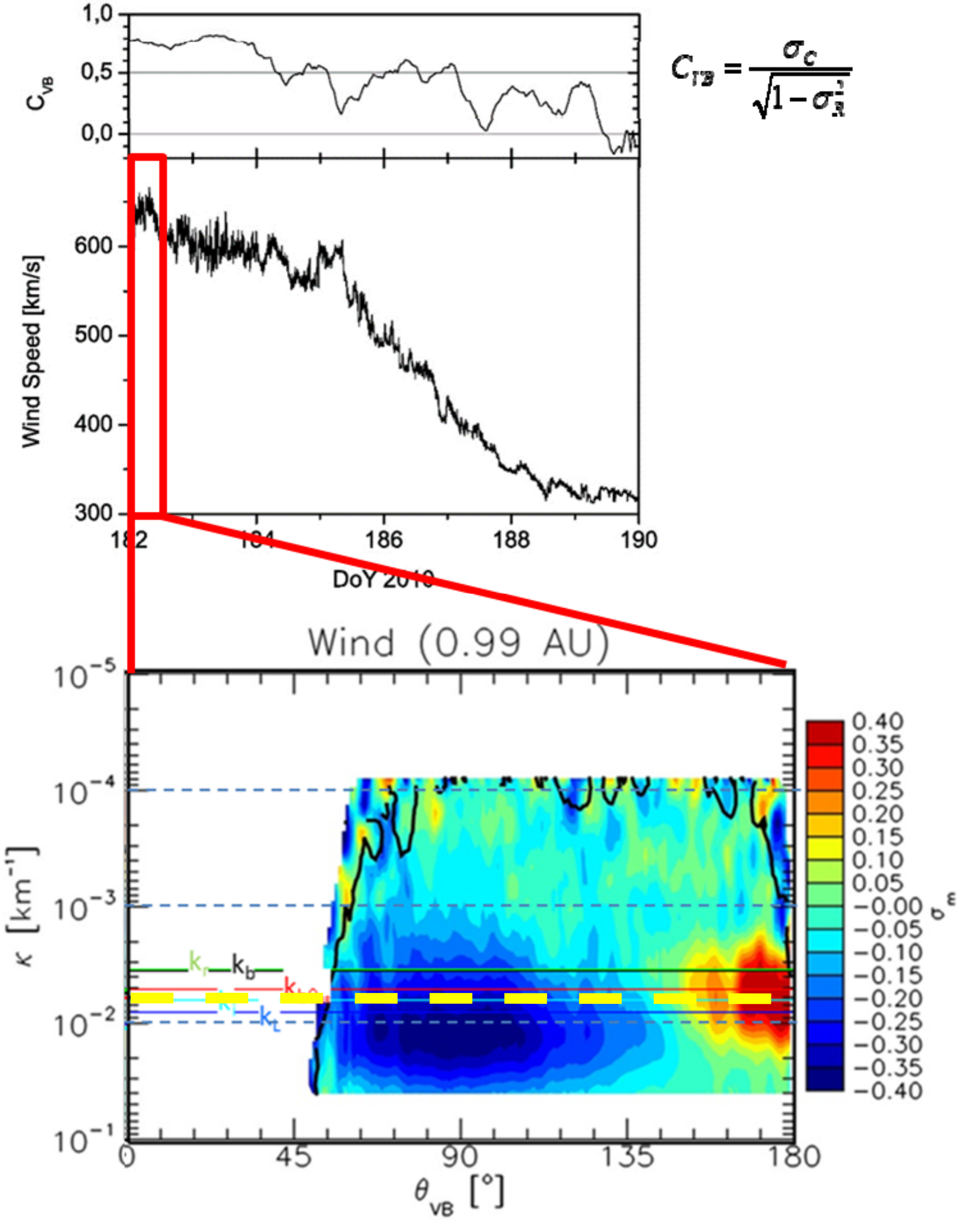

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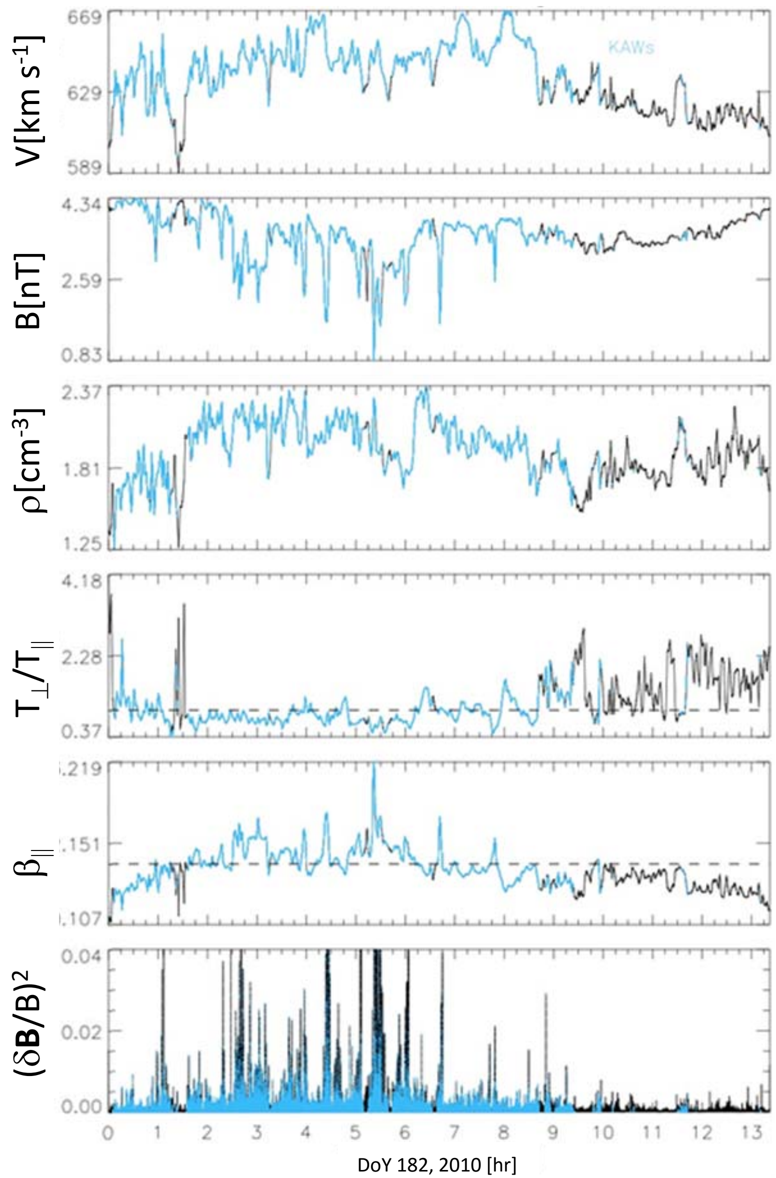

arbitrary cut at 7E-3 km^{-1}

blue color for KAW

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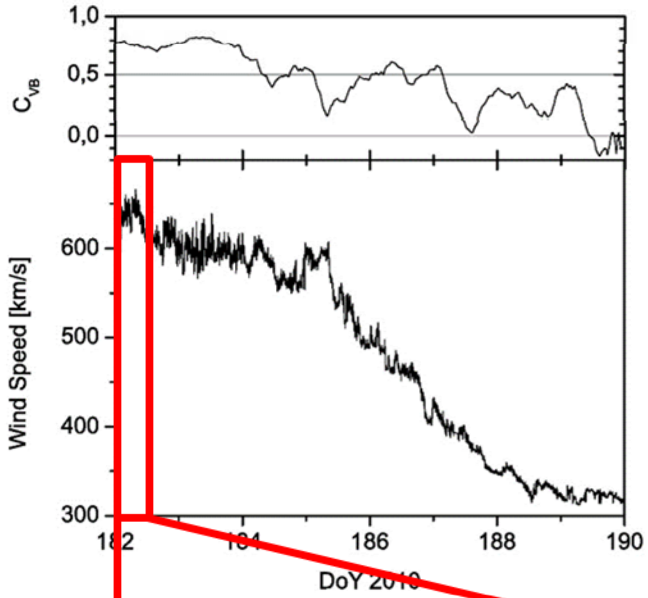

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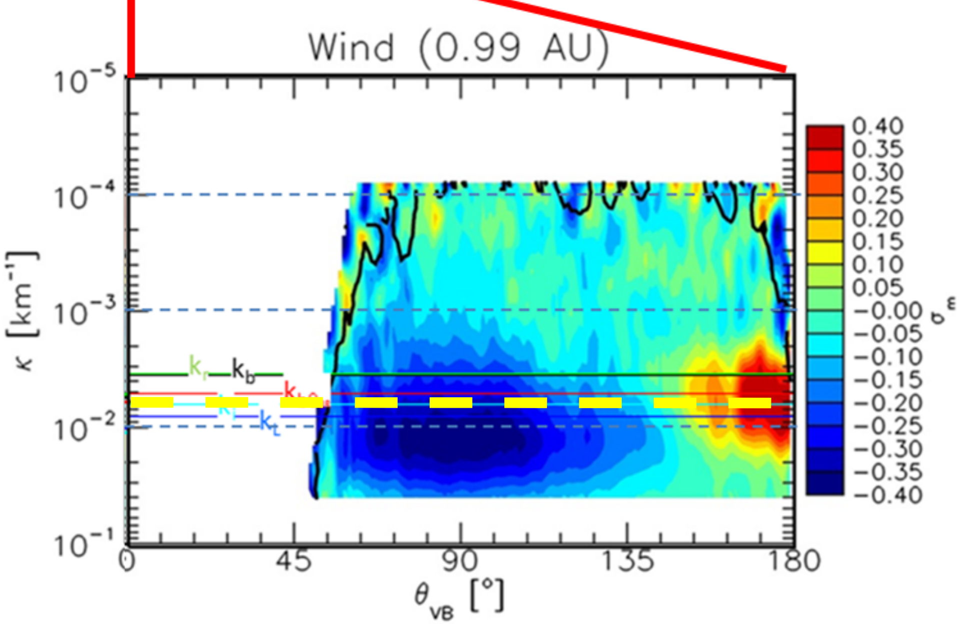

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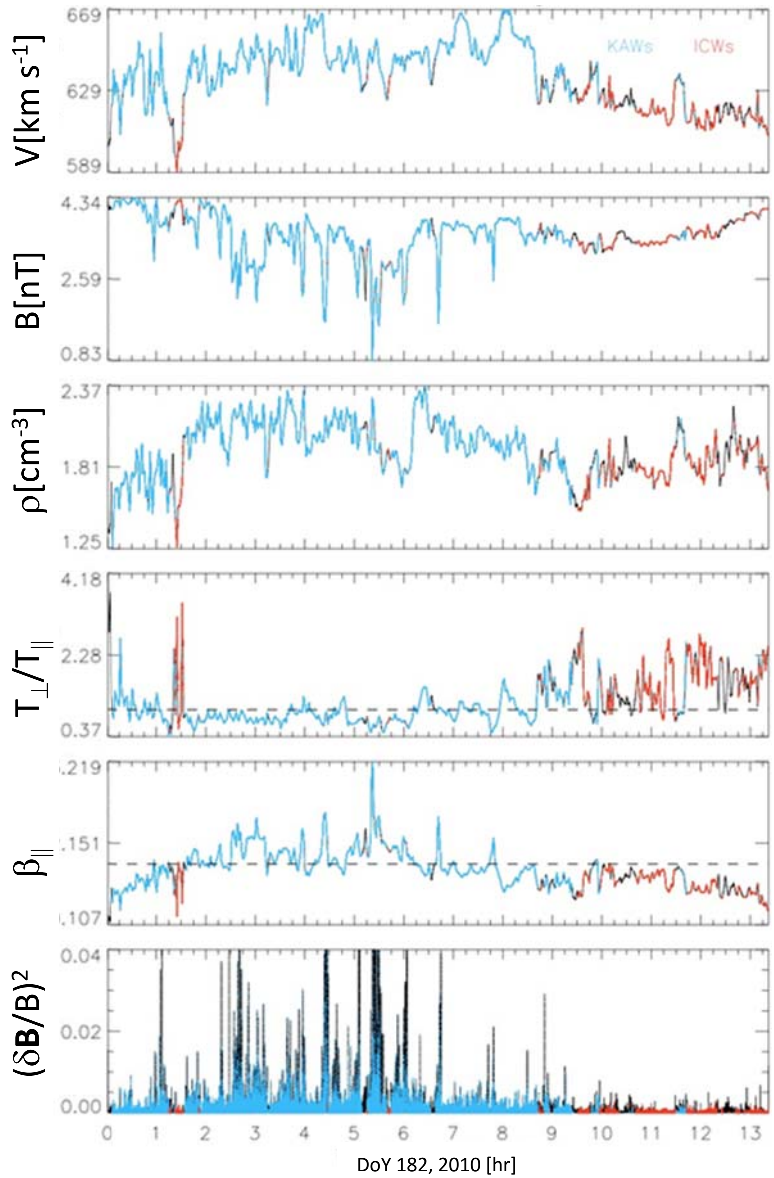


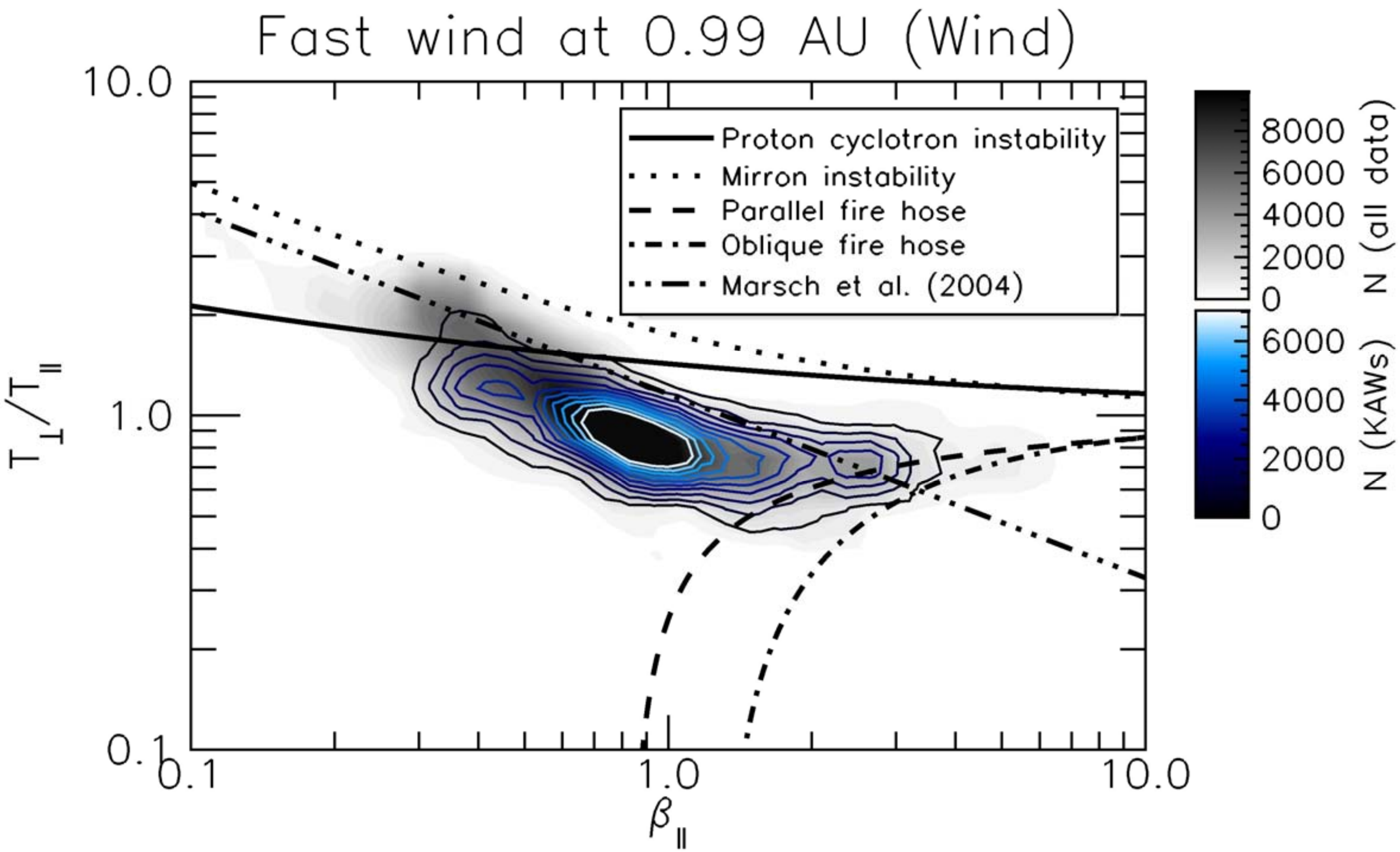
blue color for KAW

red color for ICW

EGU General Assembly, Vienna, Austria
17-22 April, 2016

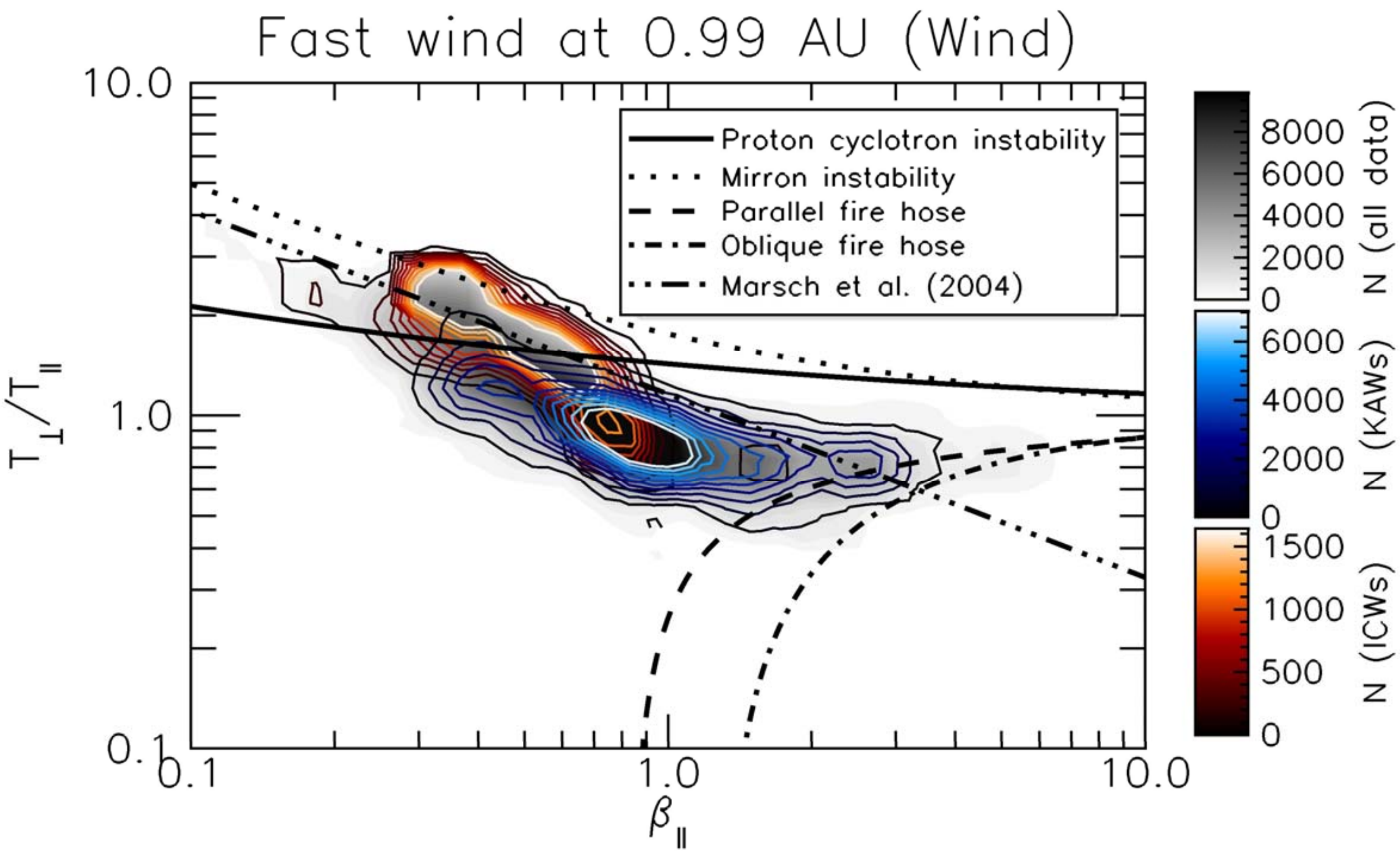
Instabilities plot

Selecting fluctuations with σ_m<0



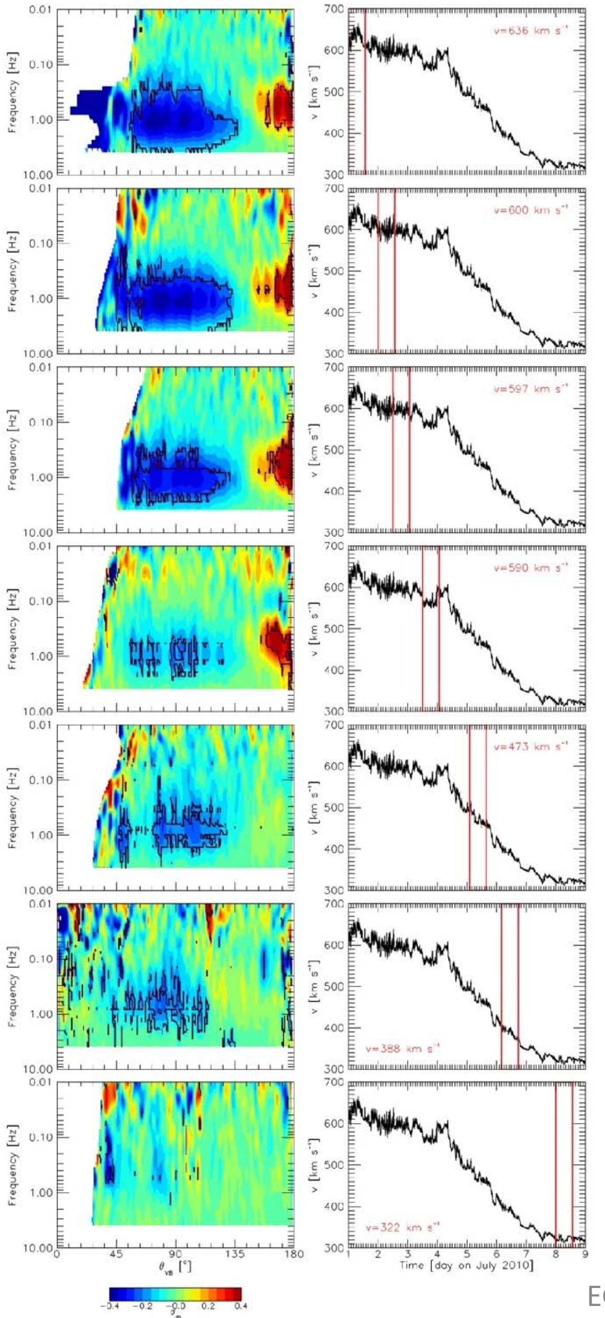
Instabilities plot

Selecting fluctuations with σ_m<0 and σ_m>0

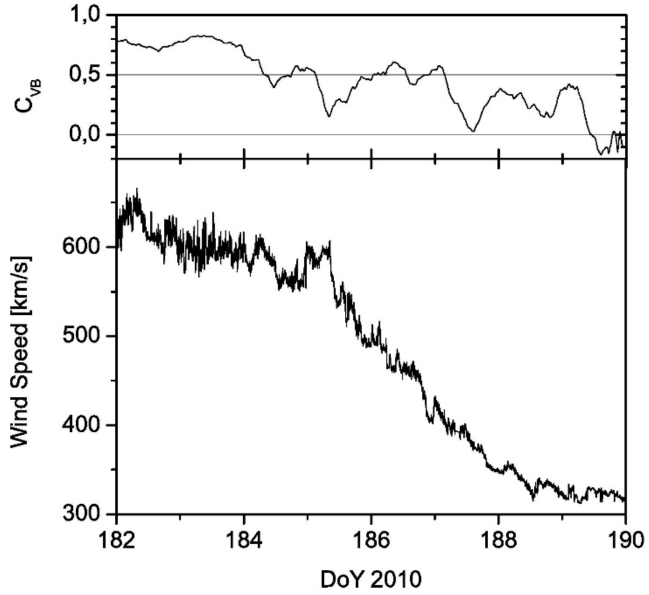


 [Telloni and Bruno, 2016]

The polarization status changes from fast to slow wind



[Bruno and Telloni, 2015]



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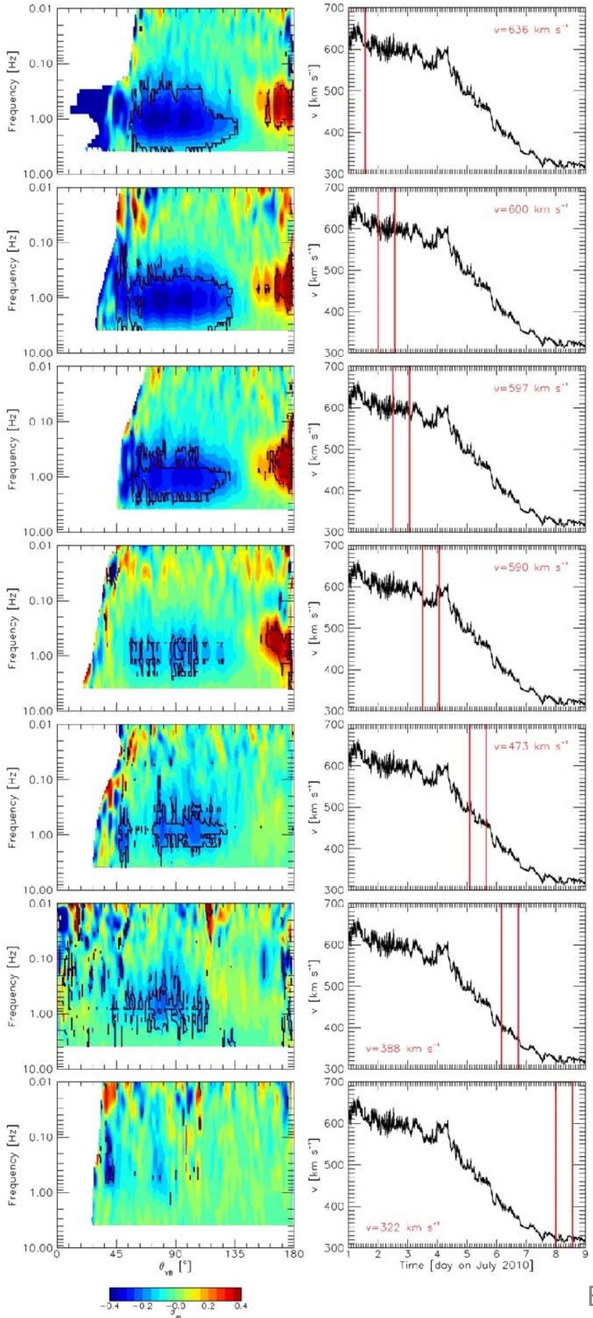

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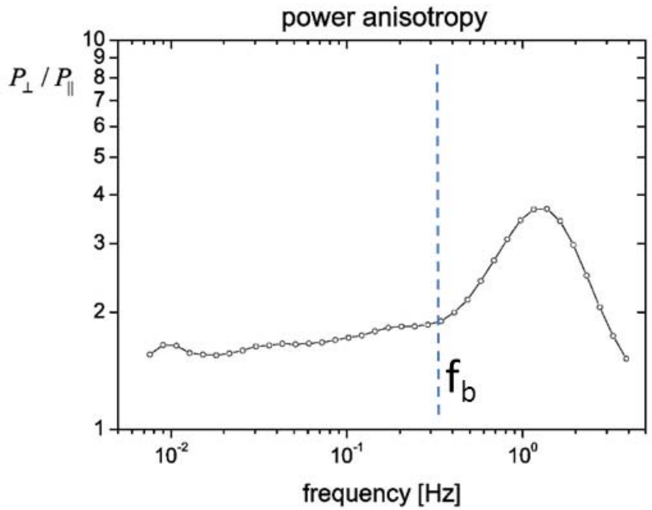
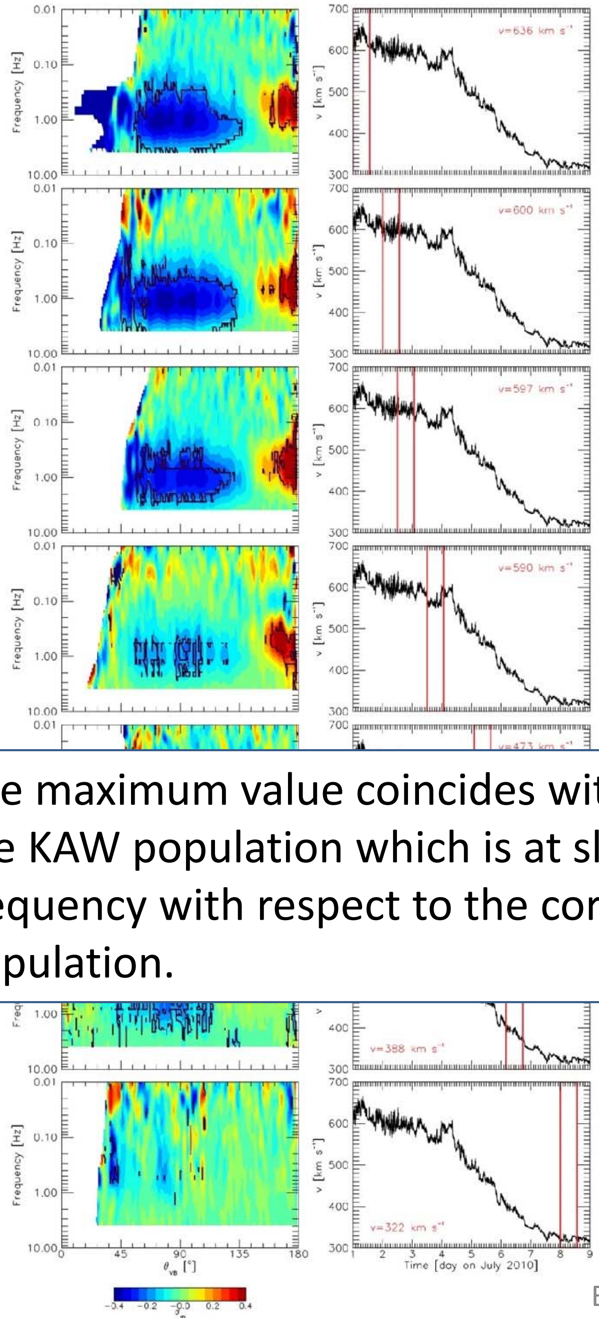
Power anisotropy



The maximum value coincides with the core of the KAW population which is at slightly higher frequency with respect to the core of the ICW population. (see also Podesta 2009)

Power anisotropy



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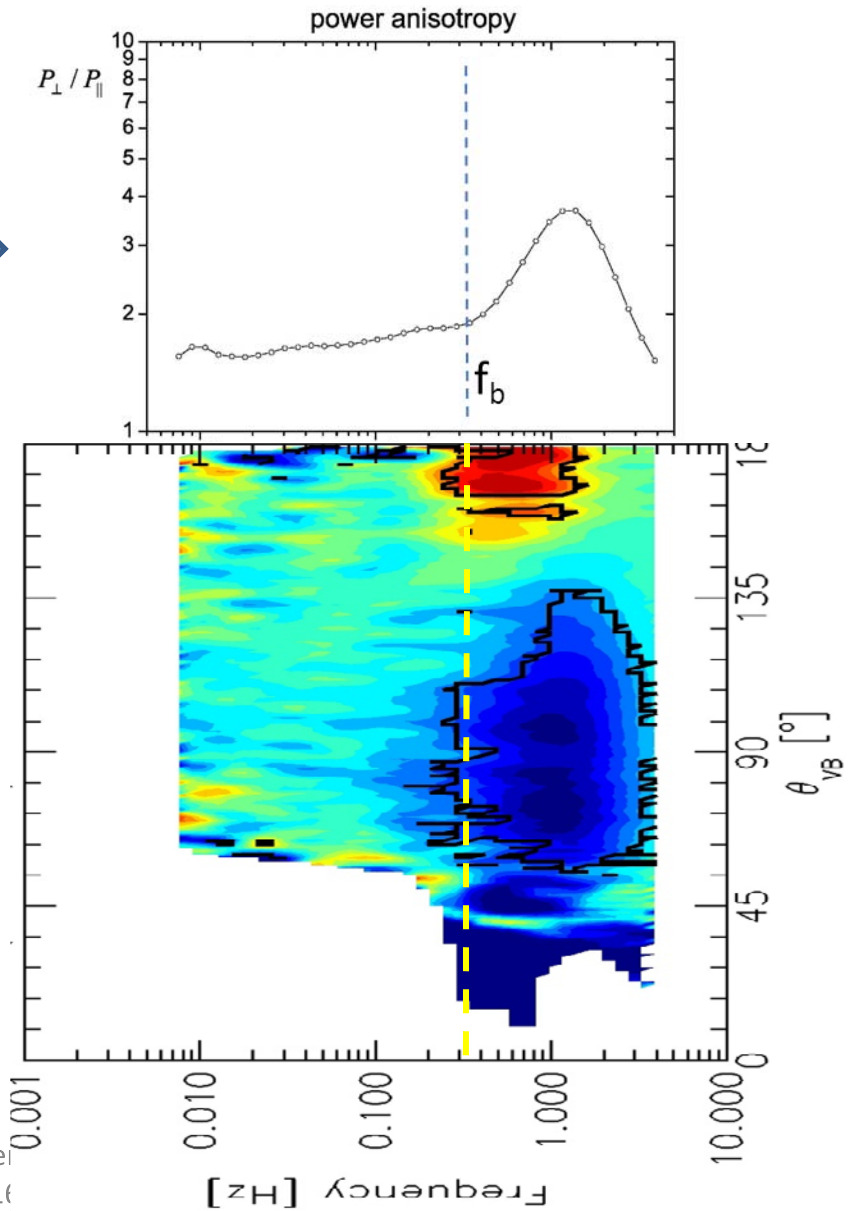

[Bruno and Telloni, 2015]

Summary and conclusions

- Proton cyclotron-resonant mechanism for parallel propagating Alfvén waves strongly related to the frequency break. We need to understand why since we know that turbulence proceedes for $K_{\perp}$

- KAWs and ICWs occupy different areas in the instability plot.

- Inverse correlation between temp anisotropy and $\beta_{//}$ confirmed for left_handed ICWs. We need to understand why proton cyclotron instability curve goes through the ion-cyclotron population. Including other effects might move this curve upwards [Hellinger et al., 2006].

- We need to understand the link between the turbulence status in the inertial range and the different populations observed in the ''dissipation'' range.

- We need to understand why fluctuations polarization is depleted moving from fast to slow wind.

- We do need a better description of plasma kinetics

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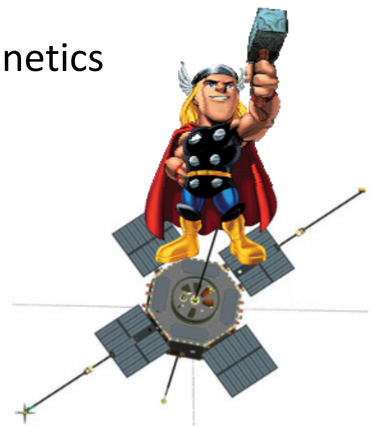
We do need THOR!



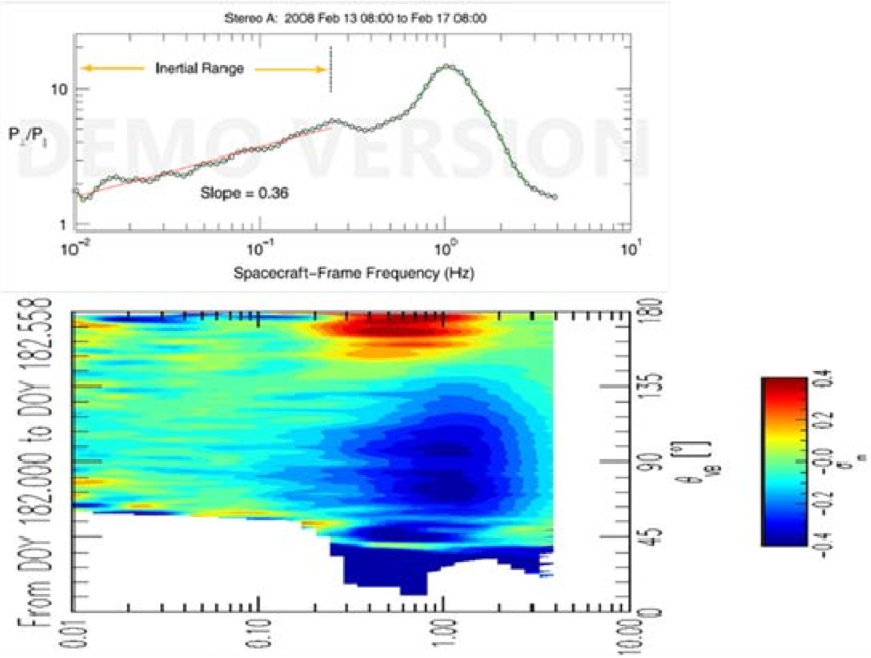
Thank you

Power anisotropy and intermittency

(work in progress)

Anisotropy

(fluxgate data)



intermittency

(searchcoil Cluster observations)