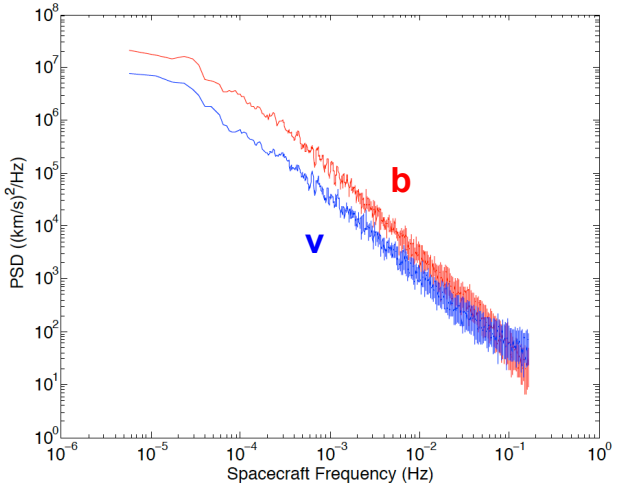
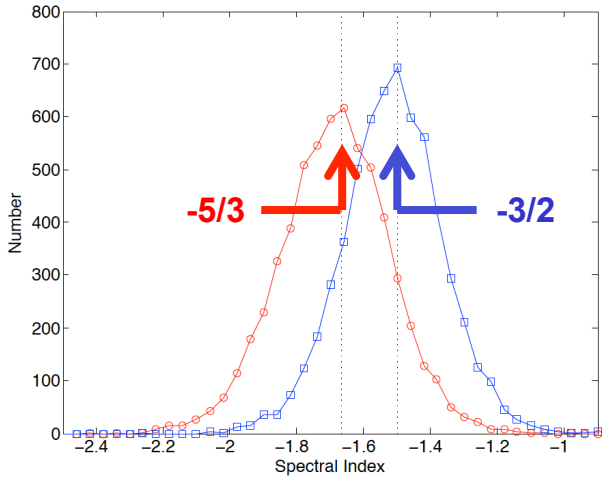
Inertial Range Scaling

- Typical spectra of b and v, b is steeper
- This is true on average, as seen many times (Grappin et al. 1991 AnGeo, Mangeney et al. 2001, Podesta et al. 2006 JGR, Podesta et al. 2007 ApJ, Salem et al. 2009 ApJ, Tessein et al. 2009 ApJ, Podesta & Borovsky 2010 PoP, Chen et al. 2011 ApJL, Boldyrev et al. 2011 ApJL, Borovsky 2012 JGR, Chen et al. 2013 ApJ)
- What about E?
- Is difference real or due to instrumental noise?
- Can measure E spectrum directly





Electric Field Spectrum

- E spectrum in s/c and solar wind frames

$$\mathbf{E}_{\mathrm{sw}} = \mathbf{E}_{\mathrm{sc}} + \mathbf{v}_{\mathrm{sw}} \times \mathbf{B}$$

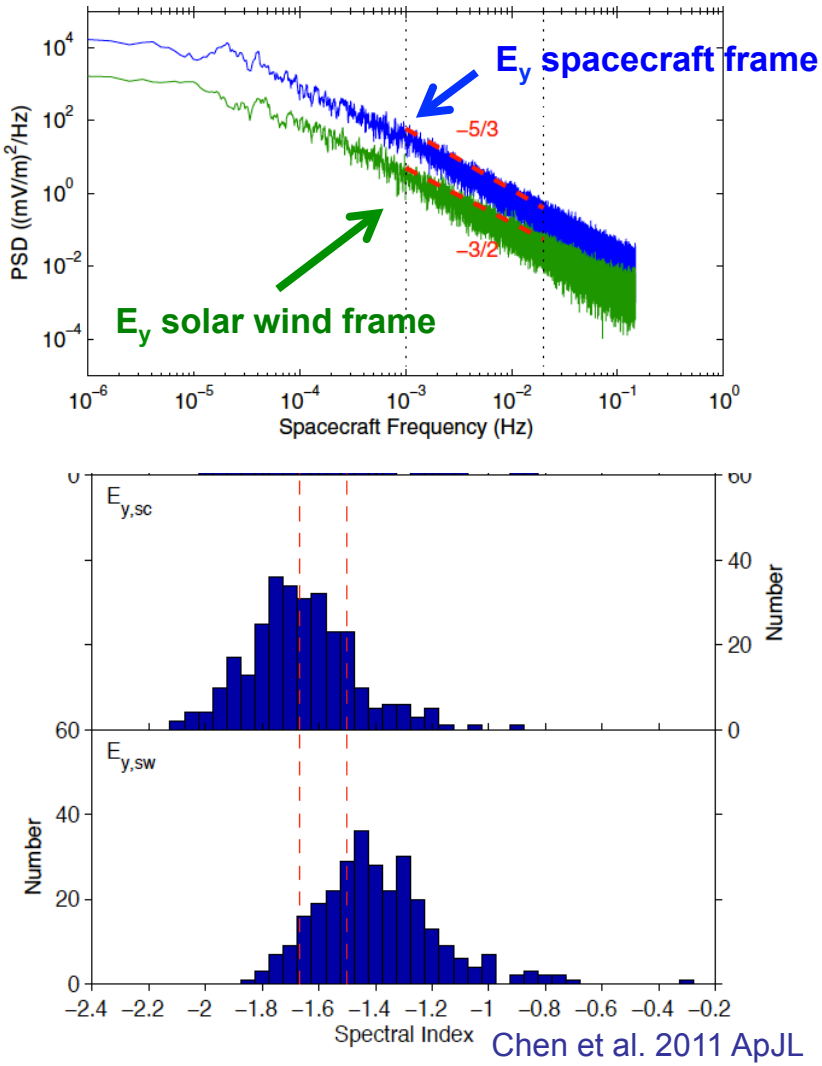
- E in the spacecraft frame matches B (Bale et al. 2005)

$$\mathbf{E}_{sc} = -\left(\mathbf{v}_{sw} + \delta\mathbf{v}\right) \times \mathbf{B}$$

- E in the solar wind frame matches v

$$\mathbf{E}_{sw} = -\delta\mathbf{v} \times \left(\mathbf{B}_0 + \delta\mathbf{B}\right)$$

- Independent confirmation of v/b difference
- So why are v and b different?



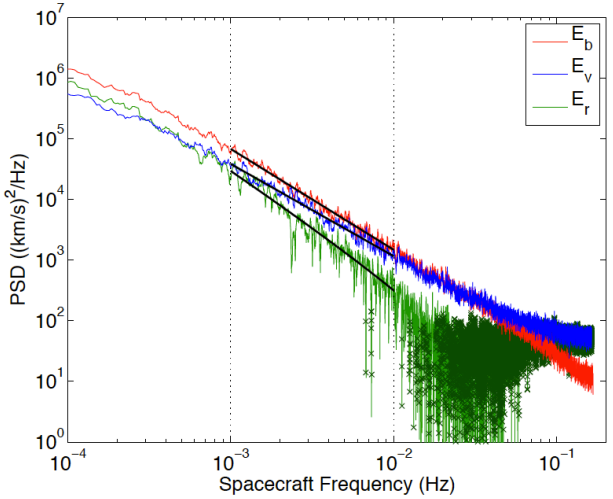
Chen et al. 2011 ApJL

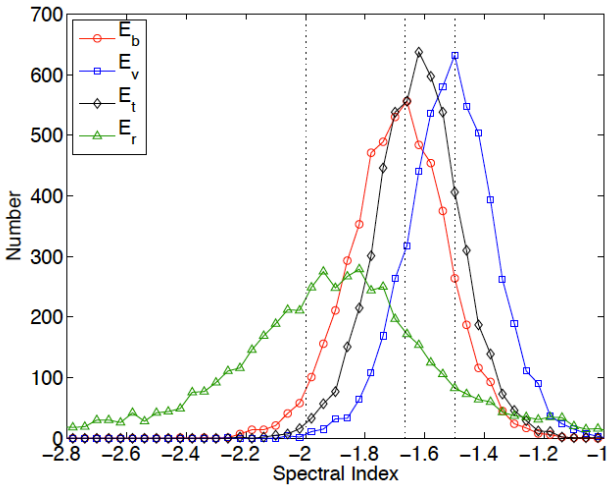
Residual Energy Spectrum

- Difference has been explained by residual energy theories: Alfvénic turbulence generates excess δb (Grappin et al. 1983 A&A, Muller & Grappin 2004 PPCF, 2005 PRL, Boldyrev & Perez 2009 PRL, Wang et al. 2001 ApJL, Boldyrev et al. 2012, Gogoberidze et al. 2012 PoP, Schekochihin et al. 2012 PRE)
- 5 years of *Wind* data show average spectrum of -1.9 similar to theory and simulations (Boldyrev et al. 2011, 2012)
- Note we included anisotropy / drift corrections in Alfvén speed

$$\delta\mathbf{b} = \frac{\delta\mathbf{B}}{\sqrt{\mu_0\rho}}\left[1+\frac{\mu_0}{B_0^2}\left(p_\perp - p_\parallel - \sum_s m_s n_s (\Delta\mathbf{v}_s)^2\right)\right]^{\frac{1}{2}};$$

- Other theories are available…

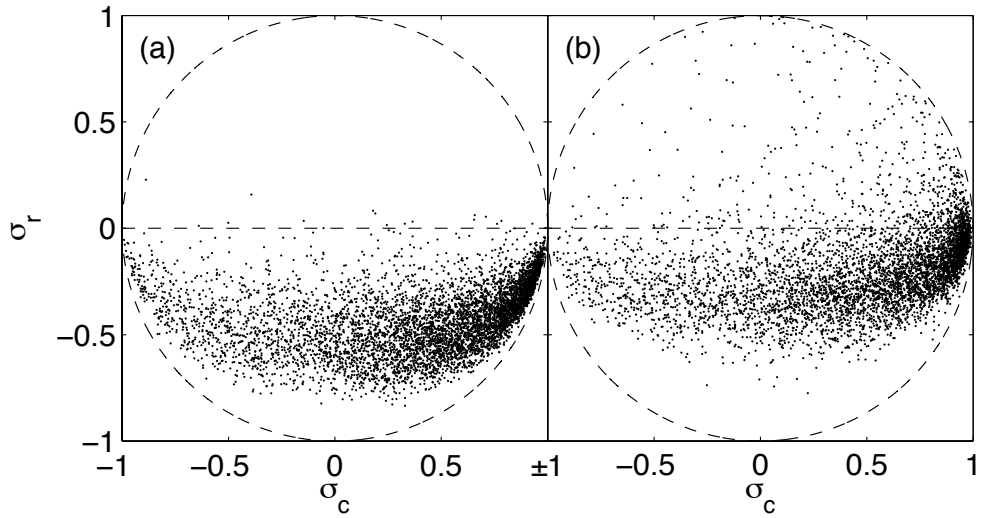




Chen et al. 2013 ApJ

MHD vs Kinetic Normalization

$$\delta\mathbf{b} = \frac{\delta\mathbf{B}}{\sqrt{\mu_0\rho}} \qquad \delta\mathbf{b} = \frac{\delta\mathbf{B}}{\sqrt{\mu_0\rho}}\left[1 + \frac{\mu_0}{B_0^2}\left(p_\perp - p_\parallel - \sum_s m_s n_s (\Delta\mathbf{v}_s)^2\right)\right]^{\frac{1}{2}}$$



residual energy

imbalance

Chen et al. 2013 ApJ

Table 1
Mean Values in the MHD and Kinetic Normalizations

Parameter	MHD	Kinetic
σ_r	−0.43	−0.19
σ_c	0.40	0.46
r_A	0.40	0.71
r_E	3.37	4.45

- Using kinetic normalization more appropriate to the solar wind there is less residual energy but it is still, on average, negative