Anisotropy of Solar Wind Turbulence in the Dissipation Range

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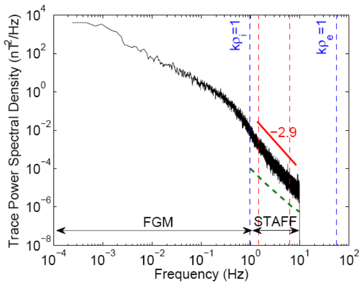
Abstract

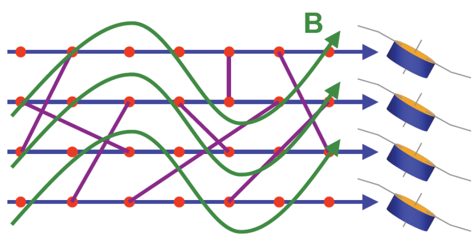
- We measure the anisotropy of turbulence in the fast solar wind between the ion and electron gyroscales
- A multi-spacecraft technique is used to calculate structure functions at different angles to the local magnetic field
- From this we infer the variance anisotropy, power anisotropy and spectral index anisotropy
- The fluctuations are spatially anisotropic ($k_\perp > k_{||}$)
- The spectral index of the perpendicular component varies with angle, suggesting critically balanced whistlers or kinetic Alfven waves
- The spectral index of the parallel component is shallower, which does not match theoretical predictions

Multi-Spacecraft Structure Functions

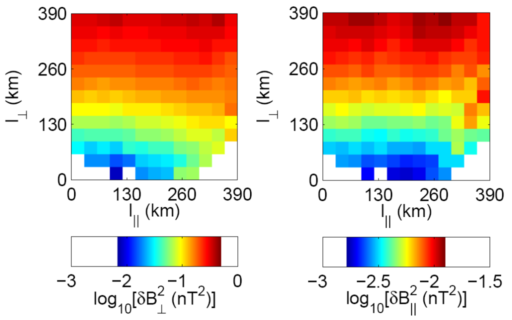
- We combine data from the STAFF and FGM magnetometers to get magnetic field data, B, valid up to 10 Hz
- The steeper dissipation range can be seen in the power spectrum:



- Assuming Taylor's hypothesis, we calculate 2nd order structure functions, $\delta B_i^2(\mathbf{l}) = \langle|B_i(\mathbf{r}+\mathbf{l}) - B_i(\mathbf{r})|^2\rangle$, from pairs of spacecraft measurements (purple lines):



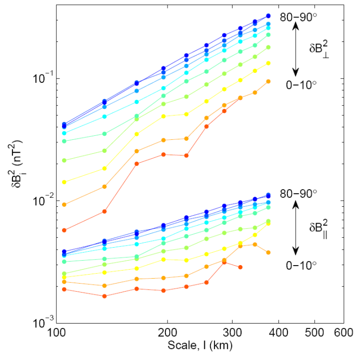
- The structure function values are binned depending on parallel and perpendicular separations to the *local* mean field $[\mathbf{B}(\mathbf{r}+\mathbf{l})+\mathbf{B}(\mathbf{r})]/2$:



- For both field components the contours are elongated in the field parallel direction ⇒ fluctuations are anisotropic

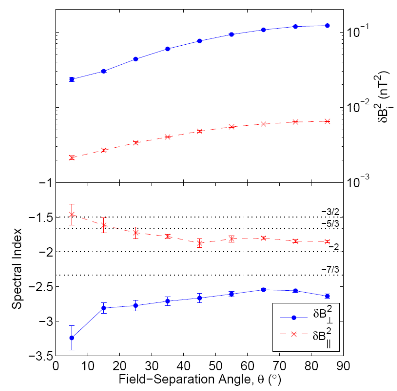
Variance Anisotropy

- The data are also binned in angle/magnitude coordinates
- The overall power in the parallel component is lower than that in the perpendicular component
- $\delta B_{||}^2$ is around 5% of $\delta B_\perp^2$
- This is roughly what is expected from kinetic Alfven wave predictions



Power Anisotropy

- The interpolated structure function value at 200 km is found for each angle
- Both components show power clearly increasing with angle
- Perp component: $S_\perp/S_{||} = 5 \pm 1$
  Par component: $S_\perp/S_{||} > 3$
- This means $k_\perp > k_{||}$, which is an important assumption for many theories



Spectral Index Anisotropy

- Structure function scaling, *g*, is related to spectral index, $-\alpha$, by $\alpha = g + 1$
- Scaling in different directions to the magnetic field is measured from the structure functions and the spectral index is found
- Critically balanced whistler / kinetic Alfven wave predictions are -7/3 at large angles and -5 at small angles
- In the perpendicular component at large angles the spectral index is -2.6, which is slightly steeper than the prediction
- In the perpendicular component at small angles it is -3, but since the steepest possible measurement with this technique is -3, this is consistent with the predictions
- In the parallel component we measure a shallower scaling of -1.9 at large angles, which is not consistent with the kinetic Alfven wave theory

Summary and Conclusions

- We measure three types of anisotropy in the solar wind dissipation range
- Variance anisotropy: power in the parallel component is 5% of power in the perpendicular component
- Power anisotropy: there is larger power at larger angles to the field ⇒ $k_\perp > k_{||}$
- Spectral index anisotropy: for the perpendicular component it steepens at small angles, suggesting a critically balanced cascade; for the parallel component it is shallower, which is not yet understood
- A larger survey is needed to determine whether the behaviour seen here is typical for the solar wind

Acknowledgements

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