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Three dimensional structure of magnetohydrodynamic turbulence in the solar wind

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Knowledge of the three dimensional power spectrum of solar wind MHD turbulence is important for predicting the propagation of energetic particles, as well as understanding the nature of the turbulence itself. However, spacecraft measurements are taken only along the solar wind flow direction, resulting in a so-called ‘‘reduced’’ spectrum, and making the determination of the full spectrum very difficult. We present a new analysis of Ulysses magnetic field data taken in high speed polar solar wind, using a novel wavelet method, which results in a detailed estimate of the reduced spectrum. We demonstrate for the first time that fluctuations with wave vectors parallel (‘‘slab’’) and perpendicular (‘‘2D’’) to the magnetic field have different spectral indices, in agreement with some recent theories of MHD turbulence; and that the fraction of power in slab fluctuations is only a few percent, with important consequences for energetic particle propagation. Finally, we discuss deviations of the data from the slab/2D model and the consequences for our understanding of the turbulent cascade in collisionless plasmas.