Geophysical Research Abstracts
Vol. 17, EGU2015-3457, 2015
EGU General Assembly 2015

Three-dimensional Iroshnikov-Kraichnan Turbulence in a Mean Magnetic Field

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We present a new cascade scenario motivated by the three-dimensional energy spectrum observed in numerical simulations of incompressible MHD turbulence in a strong mean field. It is shown that the energy distribution is not in accord with standard critical balance and the associated scale anisotropy. This is not surprising as the present setup with isotropic large-scale forcing predominantly yields fluctuations in the weak-turbulence regime.In spite of this, a measurable anisotropy of structure-function scaling exists independent of taking spatial increments with respect to the mean or local direction of the magnetic field.

We, thus, propose a combination of weak Iroshnikov-Kraichnan dynamics governing energy transfer in the field-perpendicular plane and the ricochet process distributing energy quasi-resonantly along all other directions. This turbulence properties are consistent with the main numerical findings, in particular, regarding the energy spectrum: (i) an inertial-range power law exponent independent of direction, (ii) a direction-dependent power-law spectral-range extent $\sim b_{rms}/B_0$. This spectral transfer process asymptotically approaches the 2D IK-cascade as B_0 increases.

The new transfer mechanism is at variance with the commonly accepted resonant weak-turbulence cascade as well as with the critically balanced strong turbulence cascade, both resulting in strictly perpendicular energy transfer. This is necessary to explain the significant field-parallel extent of the observed energy distribution, The findings also disagree with the small-scale dynamic-alignment phenomenology.

It is shown that the non-universal spectral dynamics are determined by the large-scale ratio of kinetic and magnetic energy.