Weak turbulence in two-dimensional magnetohydrodynamics.

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While the differences in behaviour between the two-dimensional (2D) and three-dimensional (3D) hydrodynamical turbulence of neutral fluids are accepted to be important, those of the MHD system in both cases are conventionally believed to be non-significant [1]. This is mostly due to the fact that the cascades of the ideal quadratic invariants (energy, cross-helicity and magnetic helicity (3D)/ anastrophy (2D)) in both cases have the same direction.

When the magnetic field perturbations are small compare to a uniform background magnetic field, the 2D MHD equations are sometimes used to model turbulence. Such a situation is particularly relevant for solar coronal loops [2].

Moreover, the 2D MHD models allow one to reach better resolution of numerical simulations permitting study of higher kinetic and magnetic Reynolds number flows. The 2D MHD models are often implemented, for instance, in order to test new numerical techniques and in the same time, they are employed to provide estimations of magnetic reconnection.

We consider 2D MHD in the presence of a strong background magnetic field which implies the realization of the weak turbulence regime. One of the main advantages of this regime is the fact that it allows one to derive accurate analytical results for the spectrum. We derive and analyze the kinetic equation describing the three-wave interactions of pseudo-Alfven waves. Our analysis is greatly helped by the fortunate fact that in 2D the wave-kinetic equation is integrable. We explicitly compare turbulence behaviour between weak turbulence regimes in 2D and in 3D; the latter was analyzed rigorously in [3]. The first conclusion is that in contrast with the three-dimensional case, in 2D the wave interactions are nonlocal, i.e. there is no energy transfer between scales. It means that the turbulent diffusion is suppressed at small scales, what also indicates suppression of small-scales magnetic reconnection. Another distinct feature is that strong derivatives of spectra tend to appear in the region of small parallel (i.e., along the uniform magnetic field direction) wave numbers leading to a breakdown of the weak turbulence description in this region. We develop a qualitative theory beyond weak turbulence describing subsequent evolution and formation of a steady state. The details of this investigation can be found in [4].

References

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