Inverse cascade of kinetic energy in two-dimensional β-Plane magnetohydrodynamic turbulence

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Numerical studies of two-dimensional β-plane homogeneous magnetohydrodynamic turbulence are presented. The study of the fundamental properties of such turbulence allows understanding the evolution of various astrophysical objects from the Sun and stars to planetary systems, galaxies, and galaxy clusters. Energy spectra and cascade process in two-dimensional β-plane MHD are studied.

In this work the equations of two-dimensional magnetohydrodynamics with the Coriolis force in the β-plane approximation are used for the qualitative analysis and numerical simulation of processes in plasma astrophysics. The equations are solved on a square box of edge size $2\pi$ with periodic boundary conditions applying a the pseudospectral method using the 2/3 rule for dealiasing. The results of numerical simulation of two-dimensional β-plane MHD turbulence with a spatial resolution of $1024 \times 1024$ and $4096 \times 4096$ with different Rossby parameters $\beta$ and different Reynolds numbers are presented.

It is found that only unsteady zonal flows with complex temporal dynamics are formed in two-dimensional β-plane magnetohydrodynamic turbulence. It is shown that flow nonstationarity is due to the appearance of isotropic magnetic islands caused by the Lorentz force in the system. The formation of Iroshnikov–Kraichnan spectrum is shown in the early stages of evolution of two-dimensional β-plane magnetohydrodynamic turbulence. The self-similarity of the decay of Iroshnikov–Kraichnan spectrum is studied. On long time scale violation of self-similarity of the decay and formation of Kolmogorov spectrum is discovered. The inverse cascade of kinetic energy, which is characteristic of the detected Kolmogorov spectrum, provides the formation of zonal flows.

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