Rapid distortion theory for homogeneous shear-driven MHD turbulence

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In this report we study statistical properties of astrophysical turbulent plasma flows subjected to large scale velocity shear and an external magnetic field using Rapid Distortion Theory (RDT). The problem of shear-driven turbulence arises in several important physical systems, such as the solar wind and ionized atmospheres of exoplanets. Rapid distortion theory is a linearization method for Reynolds-averaged Navier-Stockes equations. Its main assumption is that the turbulence responds to the external distortion by velocity shear so fast, that inertial forces result in a negligible change in velocity field statistics at small time scales. This allows to linearize equations and to derive equations for second moments of turbulence. We apply RDT approach to incompressible homogeneous MHD turbulence distorted with an external magnetic field and a linear velocity shear in cases of rotating and non-rotating plasma. It is shown that even with a strong nonlinearity many properties of turbulence can be qualitatively studied using a linear theory. A closed system of linear equations is derived for energy, helicity and polarization of velocity and magnetic field correlations. Structural analysis is conducted showing the change of energy distribution between components of spectral tensor of turbulence. Development of initially isotropic turbulence and transition to anisotropy are studied. Model equations for fluid, current and cross helicity are derived. Differences in cases of rotating and non-rotating flows are discussed. This work was supported by the Russian Foundation for Basic Research (project no. 19-02-00016).