Subcritical Turbulence in 2D MHD Plane Shear Flows -- Self-sustenance via Interplay of Linear Transient Growth and Nonlinear Transverse Cascade

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We found and investigated via numerical simulations [1] self-sustained two-dimensional turbulence in a magnetohydrodynamic flow with maximally simple configuration: plane, noninflectional (constant shear of velocity) and threaded by a parallel uniform background magnetic field. This flow is spectrally stable, so the turbulence is subcritical by nature and hence it can be energetically supported just by transient growth mechanism due to shear flow nonnormality. This mechanism appears to be essentially anisotropic in spectral (wavenumber) plane and operates mainly for spatial Fourier harmonics with streamwise wavenumbers less than a ratio of flow shear to the Alfven speed, (i.e., the Alfven frequency is smaller than the shear rate). To understand the sustaining mechanism of the turbulence, we Fourier transformed basic MHD equations and derived evolution equations for the perturbed kinetic and magnetic spectral energies in wavenumber plane. In these spectral equations, using the simulation results, we calculated individual terms, which are divided into two types -- terms of linear and nonlinear origin. The terms of linear origin -- the Maxwell and Reynolds stresses -- are responsible for energy exchange between the turbulence and the mean flow through transient amplification of perturbation harmonics due to shear. However, only positive Maxwell stress appears to be a dominant (magnetic) energy injector for the turbulence; it is much larger than negative Reynolds stress, which does not contribute to turbulent energy gain. The nonlinear terms do not directly draw the mean flow energy and act to redistribute this energy in spectral plane, continually repopulating perturbation harmonics that can undergo transient growth.

Thus, we demonstrated that in spectrally stable shear flows, the subcritical MHD turbulence is sustained by interplay of linear and nonlinear processes -- the first supplies energy for turbulence via shear-induced transient growth mechanism of magnetic field perturbations and the second plays an important role of providing a positive feedback that makes this transient growth process recur over long times and compensate viscous and resistive dissipation. This picture is consistent with the well-known bypass scenario of subcritical turbulence in spectrally stable shear flows. Our study, being concerned with a new type of the energy-injecting process for turbulence -- the transient growth, represents an alternative to the main trends of MHD turbulence research. The essence of the analyzed nonlinear MHD processes appears a transverse redistribution of kinetic and magnetic spectral energies in wavenumber plane and differs fundamentally from the existing concepts of cascade processes in MHD shear flows.

[1] G. R. Mamatsashvili et al., *Phys. Rev. E (2014)*, in press