§5. Local Structures of Hall MHD Turbulence

Miura, H., Araki, K. (Okayama Univ. Sci.)

Hall term represents effects of the ion skin depth in the magnetic induction equation. In the single-fluid MHD equations, the Hall term is neglected as the consequence of the ordering. However, as the numerical resolution of simulations is increased, the ion skin depth comes in the numerical resolution. For example in our fully three-dimensional MHD simulations of MHD[1), the ion skin depth is about 5cm for a plasma of beta=5%, Ti=0.5keV and B=0.5T, while a typical azimuthal wavelength of a moderate-wave-number unstable ballooning mode is comparable to the ion skin depth. For the purpose of studying dynamics of the ballooning modes correctly, the ion skin depth should be taken into account. However, the inclusion of the Hall term brings about high-frequency dispersive waves in numerical simulations and restricts the time step width of numerical simulations.

In order to overcome the difficulty, we consider adopting an approach so called as the large eddy simulation (LES). In an LES, governing equations are operated by a low-pass filter, and the scales smaller than the cut-off wave number (sub-grid-scale, SGS) are replaced by an appropriate numerical model. However, a SGS model for the LES of the Hall MHD model is not established yet. We have studied the small-scale natures in Hall MHD turbulence in order to provide some insight to construct a SGS model. Some statistical data as well as local structures in Hall MHD turbulence are obtained by the direct numerical simulations of homogeneous and isotropic Hall MHD turbulence. Local structures in Hall MHD simulations are studied to clarify the most dominant motions or magnetic field structures in the turbulent field. We operate a low-pass filer of the cut-off wave number k_c to the simulation data. In Fig.1(a) (Fig.1(b)), isosurfaces of the enstrophy density (dark surfaces) and the current density (isosurfaces in a blight color) operated by the k_c =128 (k_c =64) low-pass filter are shown. While the sheet-like structures are dominant both in the enstrophy density and the current density when the cut-off wave number is high, tubular structures becomes dominant as the cut-off wave number becomes lower, although the current field structures are not changed by the change of the cut-off wave number significantly. It suggests that dominant motions in Hall MHD turbulence can be different among scales. It can be interesting because we do not observe such a scale-dependency of the structures in the single-fluid MHD turbulence. We consider our SGS model should be constructed based on these observations.

These numerical results were reported in the 13th European Turbulence Conference (September 2011, Warsaw)[2), and also in the 18th International Stellarator/ Heliotron Workshop & 10th Asia Pacific Plasma theory Conference (January 2012, 2012, Canberra).

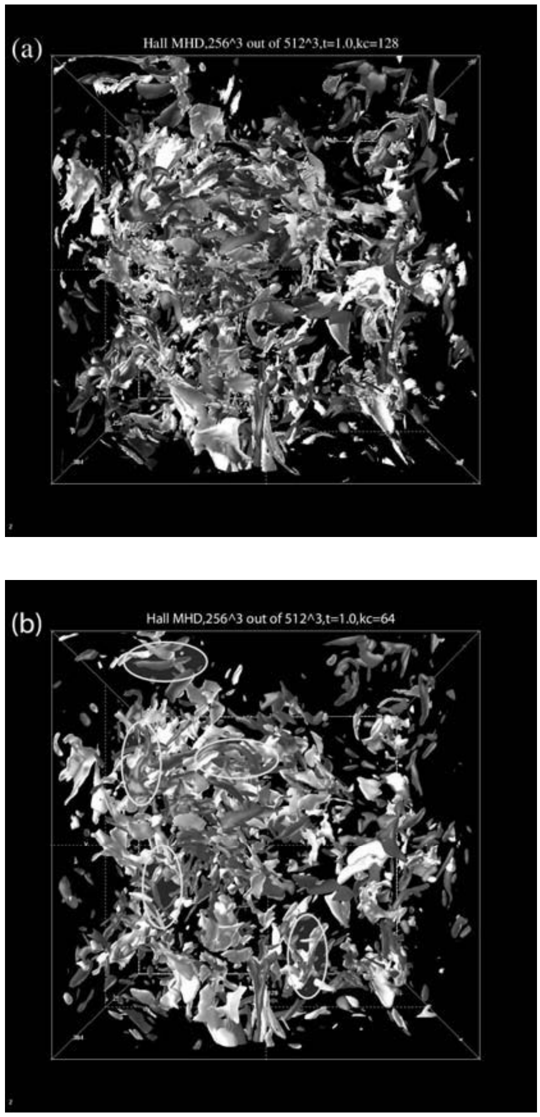

Fig.1: Isosurfaces of the enstrophy density (dark) and the current density (blight) in (a) single-fluid MHD and (b) Hall-MHD turbulence. A region of number of grid points 256^3 is displayed while the numerical simulation is carried out by 512^3 grid points.

1) H. Miura and N. Nakajima, Nuclear Fusion 50 (2010) 054006.
2) H. Miura and K. Araki, J. Phys. Conf. Ser. 318 (2011) 07032.

.