MHD relaxation with flow inside a sphere

*Kohei Yamamoto[1], Akira Kageyama[1]

1. Kobe University

We have studied MHD (magnetohydrodynamics) relaxation processes inside a spherical vessel with a perfectly conducting boundary. According to the classical theory of the MHD relaxation--Woltjer-Taylor theory--the relaxed state is force-free and its magnetic field configuration is called spheromak. The formation and stability of spheromaks were not only confirmed by plasma experiments, but also used in various experiments such as magnetic reconnections. The Woltjer-Taylor theory assumes, however, that the flow energy in the relaxed state is negligibly small. Here in this study, we investigate MHD relaxations with flow in a ball region by computer simulation. We have numerically solved compressible MHD equations in all ball region including the origin ($r=0$) by making use of recently developed Yin-Yang-Zhong grid [Hayashi & Kageyama, JCP, 2016]. Since we can perform high resolution simulations, incorporated viscosity is much lower than those in previous MHD relaxation simulations. Since general spheromak solutions are composed of the spherical bessel function (in the radial direction r) and the spherical harmonics (in the latitude θ and longitude ϕ directions), they are characterized by eigenvalue n (in r) and l and m (in θ and ϕ). As for the initial conditions, we employed higher modes $l,m>1$ with weak perturbations. Pressure and mass density were uniform. The flow velocity is zero. Due to the instability of the spheromaks with higher modes, flows are driven when simulations start. After some transient time, the flows arrives at quasi-stationary states that retain in the dissipation time (i.e., long) scale, because the simulated viscosity is low enough. Although the flow energies E_K in the quasi-steady states are relatively small compared with the magnetic energies E_M ($E_K/E_M=O(10^{-3})$), the existence of the flow is not negligible. We have found, in particular, the quasi-steady states are not force-free; the electric current and the magnetic field are not in parallel.

Keywords: magnetohydrodynamics, plasma relaxation, Yin-Yang-Zhong grid

