磁気回転不安定性の非線形段階でパラサイト不安定性が駆動する乱流の波数スペクトルの異方性について

Anisotropic wave number spectra of turbulence driven by parasitic instability in the nonlinear stage of MRI

*平井 研一郎[1]、加藤 雄人[1]、寺田 直樹[1]、河合 宗司[2]
*Kenichiro Hirai[1], Yuto Katoh[1], Naoki Terada[1], Soshi Kawai[2]

1.東北大学大学院理学研究科地球物理学専攻、2.東北大学大学院工学研究科航空宇宙工学専攻
1.Department of Geophysics, Graduate School of Science, Tohoku University, 2.Department of Aerospace Engineering, Graduate School of Engineering, Tohoku University

The magneto-rotational instability (MRI) (Balbus & Hawley, 1991) is one of the most important phenomena in accretion disks and causes turbulence driving the mass accretion in the disks. Goodman & Xu (1994) suggested that the magnetic field structure cased by the MRI cascades into turbulence through the evolution of the parasitic instability, which is related to the Kelvin-Helmholtz instability and magnetic reconnection. Pessah (2010) suggested the wave vector and growth rate of parasitic instability are strongly related to both magnetic diffusivity and fluid viscosity. These facts indicate that the artificial diffusivity, which is necessary in an MHD simulation scheme for treating the discontinuity and shock, should be as low as possible in the ideal MHD simulation of MRI-driven turbulence.
We have originally developed the MHD simulation code by employing the MHD scheme suggested by Kawai (2013). This scheme focuses on resolving the turbulence much accurately, and treats the discontinuity by adding the artificial diffusivity only to the vicinity of discontinuity (Localized Artificial Diffusivity method). We carry out the three-dimensional ideal MHD simulation by the developed code with net vertical magnetic field in the local shearing box disk model. We use 256x256x128 grids in the simulation system. We analyze the simulation results for the evolution of the MRI and the simultaneous enhancement of the parasitic instability.
Simulation results in the present study show that the MRI grows in the time scale of a few orbital periods and saturates at 2.8 orbital period. We find that a channel flow is formed through the evolution MRI and that the parasitic instability grows concurrent with the MRI, resulting in the turbulence spectra of both magnetic field and velocity in the simulation system. We confirm the strong enhancement of the parasitic instability at the timing of the saturation of the MRI and its anisotropic wave number spectra of turbulence appeared when the first channel flow is broken down. The anisotropic wave number spectra observed in the simulation result are consistent to the previous analytical studies. Additionally, we reveal that the magnetic field and velocity vectors enhanced by the MRI do not change in time from the same specific angle in the horizontal plane, but the waves enhanced by the parasitic instability in the subsequent channel break down does not show such a clear anisotropic wave number spectra as we find in the first channel flow. It could be because the turbulent flow breaks the laminar channel flow in the subsequent channels as Latter et al. (2009) suggested. We study the formation process of the anisotropic turbulence by analyzing the simulation results in detail.

キーワード：磁気回転不安定性、パラサイト不安定性、MHDシミュレーション
Keywords: Magneto-rotational instability, Parasitic instability, MHD simulation