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The influence of the initial magnetic field configuration on the nonlinear state of MRI

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The magneto - rotational instability (MRI) is one of the MHD instabilities evolving in differentially rotating plasma, like accretion disks. MRI amplifies magnetic field perturbations and makes the system in a magnetic turbulent state. Previous studies have suggested that MRI and resultant magnetic turbulence play important roles in some phenomena occurring in accretion disks, such as mass accretion, mass loading, and planet formation.

A lot of three-dimensional simulation studies have been performed to clarify the dependence of MRI turbulence and amplitude of turbulent stress on initial settings such as the density profile, plasma beta, etc. They have revealed that initial settings of the background magnetic field have significant influence on the saturation states of MRI turbulence. Hawley et al. (1995) showed that the turbulent stress and plasma beta in saturation states are two orders greater for poloidal field situations than those for toroidal field situations in an unstratified disk model, in which the density and pressure are assumed to be constant.

On the other hand, most of the recent simulation studies using a stratified disk model, in which density and pressure profiles have a gradient in the poloidal direction due to gravitational acceleration by central objects, have considered only the situations of purely toroidal or poloidal magnetic field whose profile is sinusoidal, therefore averaged poloidal component is zero. However, the formation process of accretion disks is thought that interstellar gas rotation is spun up due to the gravitational acceleration by central objects, after moving along magnetic field lines and gathering on the same surface perpendicular to magnetic field lines. Therefore the initial magnetic field having a perpendicular component to a disk surface is plausible and need to be investigated in a stratified disk model.

In the present study, using an originally developed three-dimensional MHD code, we perform numerical experiments of MRI in a stratified disk model under the situation where the spatially averaged perpendicular component of initial magnetic field is non-zero. As results, we find that in the early stage of the simulation magnetic field energy is increased with the time scale consistent with the linear growth rate of MRI, while the magnetic field turbulence is gradually amplified by MRI after the transition to the nonlinear stage. In addition, before the saturation state is set up, we find a higher level of turbulent stress than expected from observations and an accretion flow around the equatorial plane of the disk. We also find that the density profile observed in the simulation results is significantly modified by the turbulent magnetic field during several rotation periods and that the assumption of the Keplerian rotation required from the local shearing model used in our simulation is eventually disrupted. In this presentation, we show details of these simulation results and discuss the effects of the turbulent stress and the magnetic field amplification by MRI on the dynamics of the disk gas. In the formation process of the disk, the situation where the initial magnetic field has both perpendicular and parallel components to the disk surface is possible to occur. We also treat such situations and discuss the dependence of the nonlinear stage of the MRI turbulence on the initial magnetic field configuration.

Keywords: MHD, accretion disk, magneto - rotational instability