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Nonlinear evolution of magnetorotational instability in protoplanetary disks

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MHD turbulence driven by magnetorotational instability (MRI) in accretion disks is investigated using the local shearing box calculations. Magnetorotational instability (MRI) is the most promising source of angular momentum transport in accretion disks (Balbus & Hawley 1998). Local and global simulations of magnetized accretion disks have revealed that the Maxwell stress in MHD turbulence driven by the MRI can transport angular momentum significantly (Hawley et al. 1995; Hawley 2000). However the nonlinear

saturation mechanism of the MRI have not been understood yet, so that what determines the saturation amplitude of the stress, or the size of the alpha parameter of Shakura & Sunyaev, is still unclear. It is important to investigate throughly the nature of MHD turbulence in accretion disks to understand the saturation processes of the MRI.

We focus on the nonlinear evolution of channel flow in MRI driven turbulence. The channel flow is an unstable mode of axisymmetric MRI whose wavevector is parallel to the rotation axis. The channel mode is important because it is the equal fastest-growing of all linear MRI modes, even including those with non-zero radial and azimuthal wavenumbers. The eigenfunctions of this mode satisfy not only the linearized MHD equations but also the nonlinear equations in the incompressible limit (Goodman & Xu 1994). Thus the amplitude of channel flow can grow exponentially even in the nonlinear regime. The nonlinear growth of channel modes is the most efficient mechanism of field amplification in the disks.

We found that the growth of many short-wavelength channel flows in the spatial distribution of the current density during the turbulent phase. These small channel flows can be regarded as a unit structure of MRI driven turbulence. Nonlinear evolution of the channel flow affects the saturation amplitude and time variability of the Maxwell stress. Exponential growth of a channel mode is stopped by the Kelvin-Helmholtz type instability which triggers the subsequent magnetic reconnection. The characteristics of the magnetic reconnection are consistent with the Sweet-Parker model. These studies of the nonlinear evolution of the channel flow are required to understand the saturation mechanism of the MRI.