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Instability and Turbulence Generation through Non-uniform Toroidal Magnetic Field in Accretion Disks

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Plentiful dynamics observed in accretion disks, e.g. disk winds, jets, and outflows, are believed as the results of angular momentum transport highly enhanced by magnetohydrodynamic turbulence. The magneto-rotational instability (MRI) is one of the most successful mechanisms to drive the required turbulent state, and generates a large toroidal magnetic field in the nonlinear evolution. In this study, we investigate the local stability of accretion disks especially focusing on the stage when the toroidal field is dominant, which is important to understand the dynamics and the nature of turbulence in well-developed disks, and suggest another possible path leading to the turbulent generation.

It is known that the differentially rotating plasmas threaded by the uniform toroidal field are unstable essentially for the perturbation with a vertical wavevector. Our linear analysis, however, shows that if the initial toroidal field has non-uniformity, the unstable modes confined within the equatorial plane, or with no vertical wavenumber, appear. Furthermore, a series of two-dimensional nonlinear simulations reveal that when the plasma beta is not so low (roughly $\beta>1$), this unstable mode can grow as far as the background field configuration breaks down. As another possible situation, we study the stability of the toroidal field with wavy structure. The simulations show that after the above unstable modes grow enough to interact with neighboring modes, they couple, marge, and eventually evolve to very turbulent state. In the saturated stage, the alpha parameter describing the efficiency of the angular momentum transport reaches to the same level with the previous studies of a toroidal MRI. This instability plays an important role in plasma transport since it may couple with magnetic reconnection occurring in an equatorial plane and then contribute to the saturation mechanism of MRI.