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The angular momentum transport in protoplanetary disks by magnetohydrodynamical turbulence

Shu-ichiro Inutsuka[1], Takayoshi Sano[2]

[1] Physics Dept.

Kyoto Univ., [2] Astronomy, Univ of Maryland

http://aoi.scphys.kyoto-u.ac.jp/~inutsuka/

The gaseous astrophysical disk around central star with sufficient ionization degree (that allows ideal MHD approximation) becomes almost unconditionally unstable and develops into a turbulent state. Numerical simulations have shown that the instability grows exponentially from very small amplitude, and saturates when the magnetic pressure becomes comparable to the thermal pressure. In this talk, we discuss physical mechanism in the saturation processes by showing the result of three-dimensional numerical simulation which include non-ideal MHD effects.

Recent observations by radio and infrared have revealed the ubiquitous existence of circumstellar disks around young stellar objects. Observations also show that those disks are composed of gaseous material and dust grains. These disks are called "protoplanetary disks" because our planetary system is supposed to have the origin in the hypothetical solar nebula similar to these disks. Observations suggest that the typical mass of a protoplanetary disk depends on the evolutional stage, and on average decreases with time. Thus it is important to study the accretion process of the disk material onto the central star. Among the processes of the angular momentum transport that enables the disk accretion, the magnetohydrodynamical (MHD) turbulence is believed to be a crucial and unique mechanism.

The linear stability analysis and non-linear numerical simulation have clearly shown that the gaseous disk with sufficient ionization degree (that allows ideal MHD approximation) becomes almost unconditionally unstable and develops into a turbulent state. This is a general conclusion because the magnetic field with initially infinitesimal strength enables this dynamo activity. Numerical simulations have shown that the instability grows exponentially from very small amplitude, and saturates when the magnetic pressure becomes comparable to the thermal pressure. Although the reconnections of magnetic field lines are supposed to play an important role in this saturation processes, its mechanism is not yet fully understood theoretically. In this talk, we discuss physical mechanism in the saturation processes by showing the result of three-dimensional numerical simulation which include non-ideal MHD effects.

In actual protoplanetary disks, the non-ideal effects such as Ohmic dissipation are important even in the state of laminar flow. Therefore it is imperative to study the ionization degree in real protoplanetary disks. Detailed calculations of ionization degree show the protoplanetary disk is stable inside 20 AU and the accretion is possible only outside of 20 AU if we adopt the standard solar nebula model.