# §32. Simulation Study of Dynamo Process Driven by Magnetorotational Instability

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Recently, in relation to the angular momentum transport problem in astrophysical accretion disks, the magnetorotational instability (MRI) has been investigated intensively. The MRI, which arises in a magnetized fluid disk rotating with outwardly decreasing angular velocity, has a comparable growth time to the rotation period, and is believed to play a key role for the generation of turbulent viscosity in accretion disks. Another important effect of the MRI is the dynamo process, in which the magnetic energy can be sustained against the resistive decay. However, the detail mechanism whereby the MRI amplifies the magnetic field has not yet been well understood. Aiming to reveal the physical processes of the energy conversion in the turbulence driven by the MRI, we developed a new numerical model, and performed the three dimensional simulation studies.

The simulation box corresponds to a small piece of the disk co-rotating with the angular velocity at a fiducial radius (Fig.1). The calculation is carried out using the Arbitrary Lagrangian Eulerian (ALE) method, in which the coordinate system and the numerical grids are fixed on the background rotating motion. The ALE method improves the numerical accuracy, because it can totally prevents the numerical noise, which arose from the interpolation at the radial boundaries in the conventional shearing box model. The size of the simulation box is 1 x 2π x 1, in which 102 x 82 x 42 grid points are uniformly collocated.

The velocity is divided into the mean rotation $V_0$ and the turbulence $v$, and the dynamo action of each velocity component is evaluated by the energy conversion rates,

$$\dot{E}_{V_0} = -\int V_0 \cdot (J \times B) dV ,$$

and

$$\dot{E}_v = -\int v \cdot (J \times B) dV ,$$

respectively.

As a result of the analyses, it was found that the turbulence plays a role to convert the magnetic energy to the kinetic energy, if the shear parameter $q$ defined by $-\mathrm{d} \ln \Omega / \mathrm{d} \ln R$ is less than 2.3 as shown in Fig.2, where Ω and R are the angular velocity and the disk radius, respectively. It means that amplification of the magnetic energy in the MRI is mainly due to the twisting effect of the differential rotation rather than a result of the turbulent dynamo action. When $q$ is larger than 2.5, the energy conversion rate from the kinetic energy to the magnetic energy is switched to positive, because low modes, which are destabilized by the Rayleigh instability, can work for the turbulent dynamo. Three dimensional structure of the velocity component contributing the dynamo action is represented in Fig.3 for the low and high $q$ cases, respectively. On the other hand, it is also revealed that, the α-dynamo effect exists at least for $q>0.75$, although the amplification effect of the large scale magnetic field is very weak.

From these results, it can be concluded that, even though the MRI is able to amplify the magnetic energy, the turbulence due to the MRI is less effective as a driver of the conventional dynamo process, unless the Rayleigh instability arises.

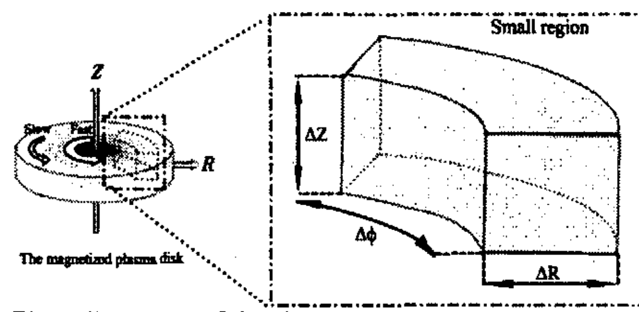


Fig.1 Illustration of the simulation box, which corresponds to a small piece of the rotating disk.

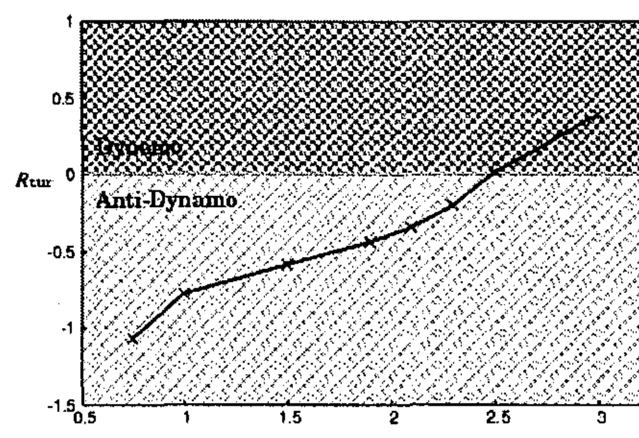


Fig.2 Fraction of the magnetic energy generated by the turbulent dynamo action $R_{tur}$ vs. the shear parameter $q$. Negative and positive $R_{tur}$ indicates that the turbulence plays as the anti-dynamo and the dynamo, respectively.

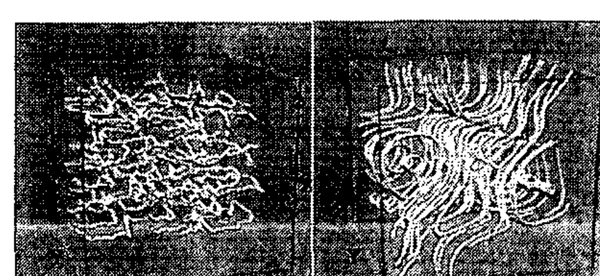

Fig. 3. Streamlines of the velocity components, which are effective to the dynamo action for $q$=1.5 (*left*) and $q$=3.0 (*right*), respectively.

Reference

1) Nakahara, J., Miyoshi, T., and Kusano,K.: Journal of the Physical Society of Japan **73** (2004) 94.