§6. Computer Simulation of MHD Dynamo

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We performed a computer simulation of a magnetohydrodynamic (MHD) dynamo in a rotating spherical shell. The physical system considered here is as follows: An electrically conducting fluid is confined in a vessel covered by two concentric spheres (spherical shell). Both the inner and outer spheres rotate with a constant angular velocity. There is a gravity force in the direction of the center of the spheres. Temperatures of both the inner and outer spheres are fixed; hot (inner) and cold (outer). Since the temperature difference is sufficiently large, the convection motion begins when a random temperature perturbation is imposed. At the same time a weak "seed" magnetic field with random spherical harmonic modes is also introduced. Time development of the velocity, magnetic field, density, and pressure are calculated by solving the MHD equations.

When the electrical resistivity of the fluid is sufficiently small, the initial small magnetic field is amplified rapidly by the MHD dynamo mechanism. We found that the total magnetic energy can be more than ten times larger than the total kinetic energy in some cases.

Extensive parameter runs are performed with different resistivities. Some of interesting findings obtained in our simulation are as follows:

1. The total kinetic energy is independent of the amplitude of the generated magnetic field. It is always the same level as that of the neutral convection (without the magnetic field) even in the case when the total magnetic energy is more than ten times larger than the total kinetic energy.

2. The basic characteristics of the convection motion drastically change when the magnetic energy E_M becomes larger than the total kinetic energy E_K. When $E_M < E_K$, the convection motion is laminar and its structure is almost the same as that of the neutral convection. While when $E_M > E_K$, the convection motion becomes turbulent.

3. The growth rate of the magnetic energy (γ) is a linear function of the logarithm of the resistity (η): $\gamma = \alpha \log \eta + \beta$.

4. The generated magnetic field is organized as a set of flux tubes. And some of the flux tubes are confined in columnar convection cells.

Fig. 1 shows time development of the magetic energies with different resistivities. For the comparison, the total kinetic energy of the neutral convection (without the magnetic field) is also shown. We can see that when $\eta \geq 2 \times 10^{-4}$, the initial seed magnetic field is amplified. Fig. 1 also indicates that the smaller the resistivity, the larger the generated magentic field. When $\eta = 1 \times 10^{-5}$, the total magentic energy becomes more than ten times larger than the kinetic energy.
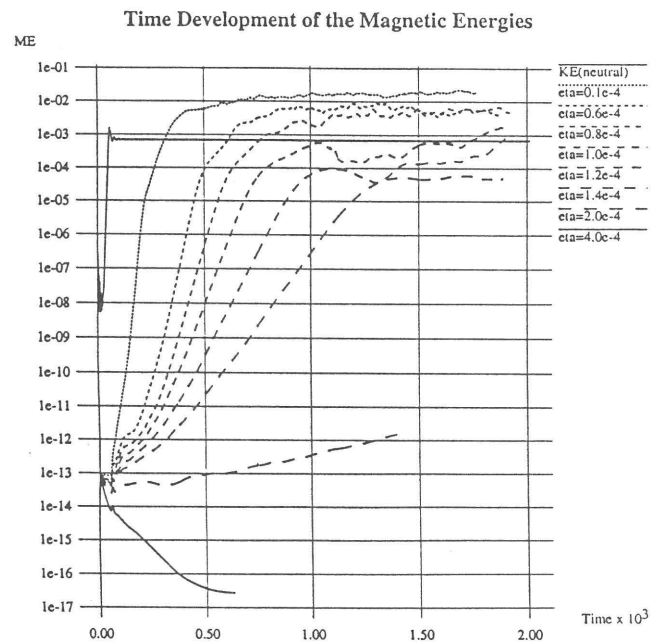

Fig. 1