§9. Generation and Reversal of Magnetic Dipole Field in a Rotating Spherical Shell

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The results on convective magnetohydrodynamic (MHD) dynamo simulation in a rotating spherical shell are presented. The motivation for this research is to understand how the dominant dipole magnetic field observed in planets and stars like the Earth and the Sun can be generated and sustained by the velocity fields in the convective zone. It is also known from observations that this field can reverse its polarity. This simulation consists of solving the full set of MHD equations in a self-consistent way using finite difference method. The time integration is based on the fourth-order Runge-Kutta scheme. Generation of magnetic dipole field in a rotating spherical shell was successfully demonstrated in our previous work [1]. The generation mechanism was revealed as a combination of α and ω-dynamos in the mid-portion of the spherical shell.

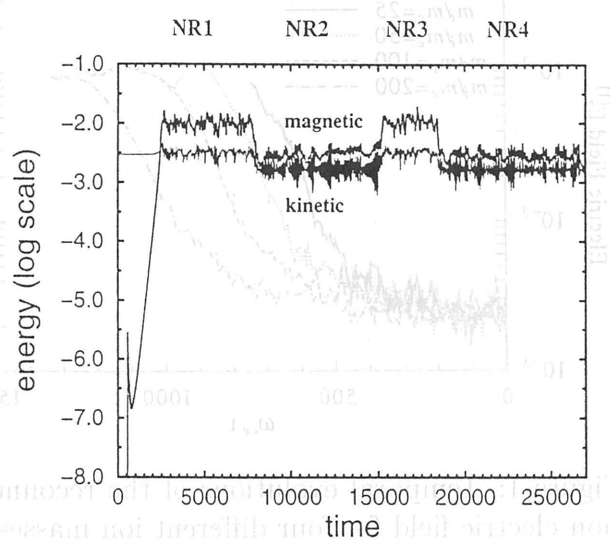

Fig.1. It shows the time evolution of the kinetic and magnetic energies.

In the present work the parameters are $T = 5.88 \times 10^6$, $Ra = 3.36 \times 10^4$, $Pr = 1$, and $Pr_m = 10.6$. Different regimes are observed in the nonlinear phase (see Fig.1). This is a new observation in this kind of simulation. The dipole component of the magnetic field remains as the main mode, while the octapole component is the second symmetric mode. The dipole contribution to the total energy can be as high as 60 per cent. The non-symmetric components contribution is small compared to the dipole contribution. The reversal of the dipole is observed to accompany the transition from NR1 to NR2 regimes, as it is shown in Fig.2.

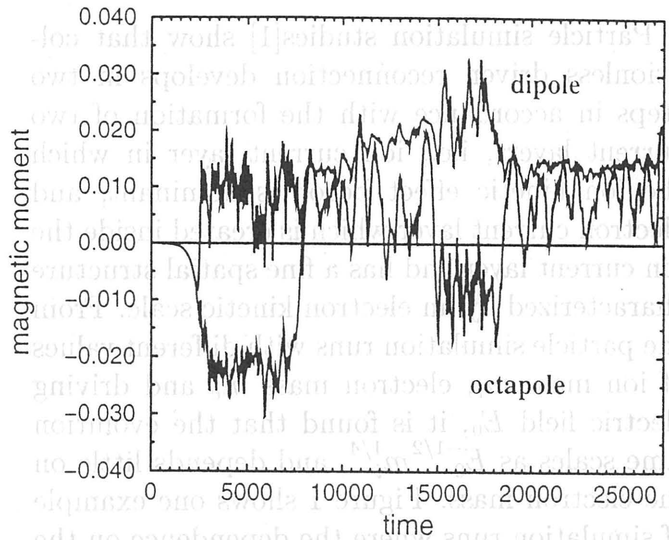

Fig.2. It shows the magnetic dipole and octapole moments versus time. These curves are obtained from the spherical harmonics expansion on the outer boundary of the shell. They are the main symmetric modes.

In the beginning of the dipole reversal process, the convection pattern consists of six straight cyclonic and anticyclonic vortex column pairs aligned to the rotation axis. In the intermediate stage, the magnetic energy decreases and the magnetic field is observed to change direction in some regions, accompanied by reorganization of the vortex columns. In the final stage, the field is completely reversed, the number of convection columns is increased and the magnetic energy is lower than in the second stage.

Although a simple picture is adopted to study the convective MHD dynamo, the dipole field generation and its reversal are successfully observed. This suggests that the intermittent dipole reversal of the Earth's magnetic field is part of the intrinsic nature of an MHD open system. Specific physical conditions were not required to observe the dipole reversal in the present model.

Reference

1) Kageyama and Sato, *Phys. Rev. E* 55, 4617 (1997)