§1. Dipole Field Generation by an MHD Dynamo

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Computer simulation of a magnetohydrodynamic dynamo is performed. It is found that strong dipole field is self-consistently and preferentially excited by thermal convection of an electrically conducting fluid in a rapidly rotating spherical shell. Thus, the long standing puzzle of the origin of the earth's dipole field is finally resolved. It is also found that radial components of the generated magnetic field are accumulated, with equal intensity and polarity, in all cyclonic convection columns near the outer spherical boundary. This is the reason that the dipole moment becomes dominant over other moments. Therefore, we can conclude that the preferential excitation of the dipole field is a natural consequence of well-organized convection columns.

Our simulation model is a rotating sphere with a constant angular velocity. The sphere consists of an inner spherical core that has a heat source to keep its surface ($r = r_i$) at a high temperature (T_h), an outer heat absorbing spherical boundary surface ($r = r_o$) which is kept at a low temperature (T_ℓ), and an intermediate conductive fluid medium sandwiched by the two spherical boundaries ($r = r_i$ and r_o) with different temperatures (T_h and T_ℓ). The conductive medium is represented by a set of compressible, resistive magnetohydrodynamic equations with gravity force. The medium is implemented on a spherical coordinate (r, ϑ, φ) grid point system. The parameters used in this simulation are as follows: $r_i = 0.3$, $r_o = 1.0$, $R = 1 \times 10^4$, $Rm = 3.33 \times 10^2$, $T = 5.88 \times 10^6$, $Pr = 1$, $Pr_m = 9.43$, where R, Rm, T, Pr, Pr_m are Raleigh number, Magnetic Reynolds number, Taylor number, Prandtl number, Magnetic Prandtl number, respectively.

A thermal convection instability, with no magnetic field, grows when a weak random noise is superimposed upon the initial temperature profile. Well-organized anti-cyclonic and cyclonic columnar cells, or, anti-cyclonic and cyclonic convection columns, whose axes are beautifully aligned along the rotation axis, are formed in an alternating fashion so as to encircle the rotation axis. After the convection columns have reached to a steady state, we superimpose a seed of random magnetic field components upon it.

Fig. 1 and 2 show longitudinally averaged profile of the magnetic field on a meridian plane. The poloidal field component are shown by magnetic field lines in the right half plane and the toroidal field component is shown by contour lines in the left. Magnetic field lines outside of the sphere are also drawn supposing that it is a potential field. Fig. 1 shows the magnetic field in the linear growing phase and Fig. 2 shows the field after saturation of the dynamo process.

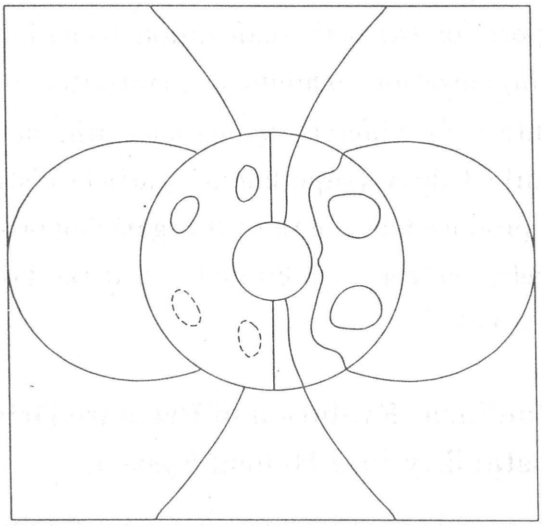

Fig 1

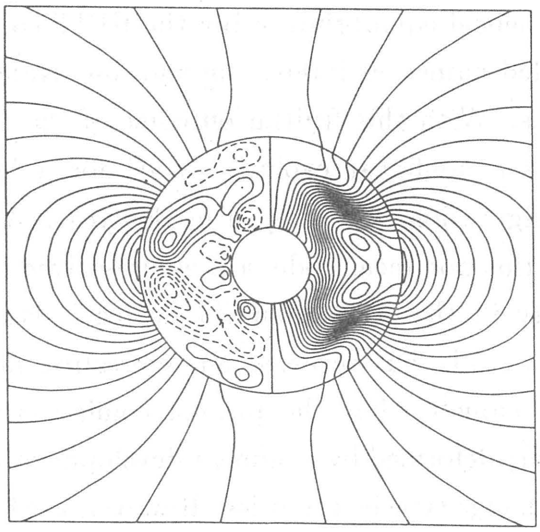

Fig. 2