Dynamo process in the Earth and terrestrial planets

Masaru Kono[1]

[1] ISEI, Okayama University

www.misasa.okayama-u.ac.jp

Since the Kageyama and Sato (1995) and Glatzmaier and Roberts (1995) papers, a number of groups reported the results of three dimensional, fully nonlinear dynamo simulation. We made a complihensive review of these studies and the result is now published (Kono and Roberts, Rev. Geophys., 40, (4) 4-1 -- 4-53, 2002). It appears from that study that we are now in the stage in which some of the characteristics of the Earth and planetary magnetic fields obtained by observations may be understood from the physical mechanism of the dynamo process.

First, I will list some of the conclusions we reached ealier which are most relevant to the present discussion.

(1) For various Ekman numbers studied so far, dynamo process seem to take place rather easily if there is convection; i.e., the Rayleigh number necessary to generate dynamo is not so big compared to the critical Rayleigh number at which convection takes place.

(2) In terrestrial planets, the source of energy for convection and dynamo process is rather limited. In the case of the Earth, no significant amount of radiogenic heat source is present in the core, and convection is primarily driven by secular cooling and composition difference between the inner and outer core. This may also explain why there is or is not the intrinsic magnetic field when two planets (e.g., Earth and Venus) are very similar in many ways.

(3) Reversals of the dipole moment occurs in many dynamo models. The mode of occurrence and morphology of the reversals seem to be strongly controlled by the heat flow boundary condition at the core-mantle boundary.

I would argue that these properties of the terrestrial dynamos are the main reasons for the characteristic properties of the magnetic field of the terrestrial planets, particularly that of the Earth as observed by paleomagnetism. Some of the important conclusions are listed below.

(1) Unlike some conjectures, the Rayleigh number of the Earth's core is not too large compared to the critical Rayleigh number. This follows from the paucity of energy source in the core. The temperature gradient is very close to adiabatic (T-Tad ? 10-1 K). This will lead to the dipole dominated dynamo. (Kutzner and Christensen (2002) report that nondipole/dipole ratio systematically increases with the Rayleigh number).

(2) Reversals can occur, but are rare events. This is because the dipole feature is the preferred mode of operation of the dynamo in this parameter range. With much more energy, many reversals occur and the distinction between N and R become obscure. In the case of the Earth, departure from dipole structure is not so common (hence the bimodal distribution of virtual dipole moments).

(3) In this respect, it is permissible to consider that reversal period is a mode of the magnetic field different from the normal times when dipole dominates (which is a common practice in paleomagnetic studies).

(4) Gauss coefficients other than g10 change chaotically with time, which results in unimodal distribution for these coefficients.