Numerical modeling of a lunar dynamo and its long-term evolution

*Fumi Hyodo[1], Futoshi Takahashi[2], Satoshi Kaneshima[2], Hisayoshi Shimizu[3], Hideo Tsunakawa[4]

1. Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2. Department of Earth and Planetary Sciences, Kyushu University, 3. Earthquake Research Institute, University of Tokyo, 4. Deparment of Earth and Planetary Sciences, Tokyo Institute of Technology

Now the Moon has no global magnetic field unlike the Earth, and there are only local crustal fields which are of approximately several hundred nT on the lunar surface [Tsunakawa et al., 2015]. However, lunar paleomagnetic studies indicate evidence for ancient lunar dynamo, and that the Moon had a global magnetic field of about 70 μT on the lunar surface at least between 4.2 and 3.56 Ga [e.g., Garrick-Bethell et al. 2009; Shea et al., 2012; Suavet et al., 2013]. In this study, we assume that the lunar dynamo is powered by compositional buoyancy due to inner core growth, which enabled the dynamo to work for such a long time interval. Based on the assumption, we perform a series of numerical simulations of MHD dynamo by varying the ratio of the inner core and outer core radii $\chi = r_i/r_o$ from *0.1* to 0.7 like Heimpel et al. [2005], where r_i and r_o are the inner core radius and the outer core radius, respectively. Long-term variations of the Rayleigh number *Ra* and the Ekman number *E*, which are key dimensionless parameters controlling the dynamo action, used in the dynamo simulations are calculated as functions of χ from a thermal history model of the lunar core. Then a relative core evolution curve is drawn, along which we perform a suite of dynamo runs with a given value of χ and with the values of *Ra* and *E* that are calibrated by scales of $Ra_0=4000$, 8000 and 10000, and $E_0=O(10^{-4})$. We investigate features of lunar dynamo evolution in scenarios with different values of Ra_0. In summary, we find three types of dynamo regimes during the evolution of lunar core: self-sustaining regime, failing-dynamo regime with convection, and failing-dynamo regime without convection. From the results of the simulations, we find that dynamos cease under a low magnetic Reynolds number that causes the termination of convection because of slow inner core growth in a late phase. We also find that it is difficult to drive convection in the cases of thin shell ($\chi=0.6$ and 0.7) even with the highest Ra_0. This result might suggest a possible scenario in which the lunar dynamo driven by compositional convection shuts off.

Keywords: Lunar dynamo , Magnetic field of the Moon, Evolution of the Moon, Thermal history, Inner core growth, Compositional convection

