Dynamical Magnetic Fields of Planets - From the Macro-Spin Model -

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Irregular reversals of the geomagnetic polarity and the regular short-period reversal of the solar magnetic field have been observed. They also show fluctuations of all the time scales. However, the trigger of the polarity reversal has not yet been elucidated so far. Although the full MHD numerical study is now popular to find the trigger mechanism of the polarity reversal, due to the limitations of the computer power, unrealistic parameter values are forced to be used in the calculations, and even in this case, the number of the reversal is limited. Therefore, it is highly necessary to develop a different approach to extract the physical essence of the magnetic polarity reversals and to clarify their trigger. In our previous paper (Nakamichi, et al., 2012, Mon. Not. R. Astron. Soc., 423, 2977; Mori, et. Al., 2013, Phys. Rev. E 87, 012108), we proposed a simple model in which the magnetic fields are represented by a set of macro-spins which are local dynamo elements, as shown in figure 1: Arrows indicate N macro spins in the dynamo region of the outer core. These spins are synchronized to form global magnetic fields. This macro-spin model was successful in describing the dynamics of the geomagnetism as well as the solar magnetic fields, reproducing several observational properties. Furthermore, we have succeeded to generalize this model in the realistic three-dimensional space in the paper (Kunitomo, Nakamichi, Hara, in preparation).

In this contribution, we applied this general macro-spin model to the variety of magnetic fields of many planets. In the case of Jupiter, a strongly non-dipole type magnetic field with another pole near the equator is observed by the spacecraft JUNO. In our spin model, this exotic field configuration can be identified as the transient stage in the process of the polarity reversal, as shown in figure 2: Time evolution of Jupiter's magnetic poles represented our macro-spin model. Over time, a pole appears near the equator, and the magnetic poles eventually reverse. In the case of Mercury, the north-south-asymmetric field is measured by the MESSENGER spacecraft. In our spin model, this extreme field configuration can be a typical snapshot of the dynamically evolving magnetic field.

Moreover, we further extended the model to include the heat flow and dissipation inside the planet. We demonstrated that the unusual magnetic fields of Jupiter and Mercury could be reproduced even in this case. Thus, planets are generally considered to have strongly dynamical magnetic fields. Therefore the origin of the magnetic reversal and the activity in the wide range of time scales is identified as the spontaneous synchronization of the macro-spins in the energy flow.

If time allows, we describe our attempt to classify all the magnetic fields of the planets by a single parameter, the ratio of the dynamo-active region, and the radius of the planet.

Keywords: magnetic reversal, macro-spin model, magnetic field of Jupiter , magnetic field of Mercury

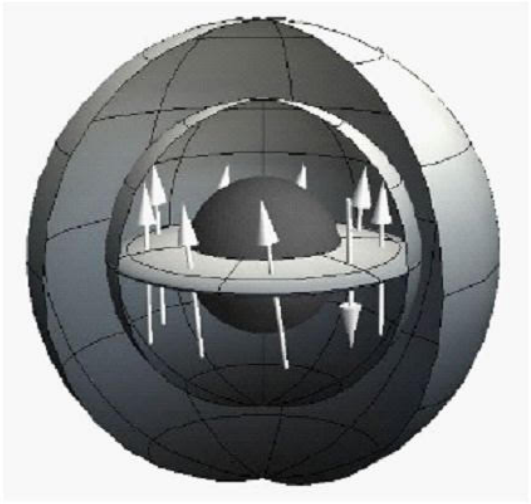

Fig.1

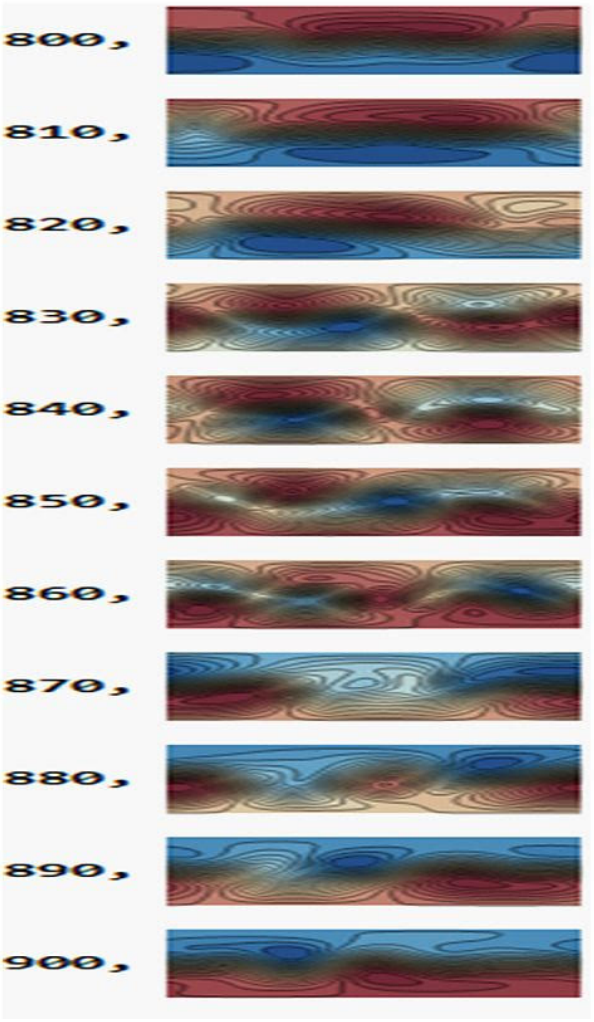

Fig.2

