E113-008 **Room: 301B** **Time: May 19 15:45-16:00**

Magnetic field variations of short timescales in a numerical geodynamo model

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Advances of performance of supercomputers have gradually made it possible to use realistic parameters in simulating generation processes of the geomagnetic field in the Earth's core. I have carried out Earth-type dynamo simulations (Sakuraba and Roberts, submitted) in which the Ekman number is 5 x 10^{-7} and the magnetic Prandtl number is 0.2, by which viscous effects of the working fluid can be suppressed in the equation of motion. The ratio between the mean magnetic and convective kinetic energy densities inside the core is about 5, which means magnetic effects dominate in the force balance like in the Earth's core. A strong, quasi-stable axial dipole is sustained by large-scale convective flows. Strong toroidal fields are also seen just beneath the low-latitudes of the core surface. Use of small Ekman and magnetic Prandtl numbers raises a possibility that magnetic and velocity variations of short timescales can be analyzed. Here I focus on such phenomena as westward drift of magnetic flux patches, magnetic jerks and torsional oscillations.

The flux patches at the core-mantle boundary are generally categorized into normal and reversed flux patches, the radial component of the former being the same as that of the main dipole field and vice versa. At the Earth's core surface, it is indicated that there are several normal patches under the equatorial region from Africa to the Indian Ocean that slowly move westward (Finlay and Jackson, 2003). In most of previous geodynamo models, the westward drift was well simulated but it was common that reversed flux patches appeared near the core equator contrary to the observations. In the present numerical solutions, the low-latitude flux patches are largely normal and drift westward. The westward motion is confined within a low-latitude belt as has been suggested by geomagnetic observations. The flux-patch motion seems to be caused by advection due to a westward zonal flow beneath the core equator. I discuss how the normal flux patches are created in the low-latitudes and sustained against magnetic diffusion.

The geomagnetic jerks are known as abrupt changes of secular variations, but the origin is poorly understood. A possibility is suggested that jerks have relation to time variations of zonal flows inside the core (Courtillot and Le Mouel, 1984). In particular, torsional oscillations of the core, which are rotational oscillations of imaginary coaxial cylinders about the Taylor state in which the axial torque acting on the cylinder is zero, are most convincing (Bloxham et al., 2002). In the present numerical model, magnetic secular variations at virtual observatories occasionally show zigzag curves, which are very similar to geomagnetic jerks although the signatures are seen not only in the Y component but in all three components. I also made a wave analysis on torsional oscillations and found wave-like propagations of zonal motion of cylinders. The timescales of the two phenomena were nearly the same, suggesting some links between them. However, this does not necessarily mean that torsional oscillations are the cause of jerks. It is possible that there is a cause elsewhere and it produces jerks on the Earth's surface and oscillatory zonal motion in the fluid core. A preliminary analysis shows that tiny reversed patches, of which the size is about 100 km, appear in the mid-latitude, move equatorward and vanish in a short time. The creation mechanism of these tiny patches is still under investigation but dynamics of such a short-timescale phenomenon may give an insight into research of geomagnetic secular variations.