§12. Zonal Flow Formation in Geodynamo Simulations

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Zonal jets are omnipresent in nature. Examples include atmospheres of gas giants of the solar system, alternating jet streams in the Earth's ocean, and zonal flows in fusion devises. A common feature of them is that they are spontaneously generated in turbulent systems. The Earth's liquid core, whence the geomagnetic field is generated through the MHD dynamo process, is also in a turbulent state. We have shown by computer simulations that a zonal flow can be generated in the core.

It is known that convection motion in rotating spherical shells is basically composed of columnar convection cells that are aligned to the rotation axis. Recently, we have performed geodynamo simulations with the highest spatial resolution ever achieved. The fine resolution has enabled us to study convection motion in the low viscous, high rotation rate frontier, or the lowest Ekman number (Ek) regime of O(10E-7).

One of the most interesting findings in the low Ek simulation is that the convection motion is composed of sheet-like plumes rather than columns [1], that are visualized as spoke-like radial stripes in panel (d) in Fig.1, in which rotation rate and Rayleigh number are increased as it goes from panel (a) to (d). Another interesting finding in our simulation is that the sheet plumes are surrounded by a zonal flow [2,3], that is visualized as the spiral pattern in the panel (d), surrounding the sheet plumes.

The dual convection structure, with the inner sheet plumes and the outer zonal flow, is stable even under self-generated strong magnetic field. Note that the Earth's core is “capped” by a solid boundary or the mantle. The zonal flow is formed under the non-slip velocity boundary condition. Our simulation suggests that the Earth's liquid core might be closer to the atmosphere and ocean than we had expected.

1) A. Kageyama, T. Miyagoshi, and T. Sato, Nature, vol.454, pp.1106-1109 (2008)
2) T. Miyagoshi, A. Kageyama, and T. Sato, Nature, vol.463, pp.793-796 (2010)
3) T. Miyagoshi, A. Kageyama, and T. Sato, submitted to Phys. Rev. E

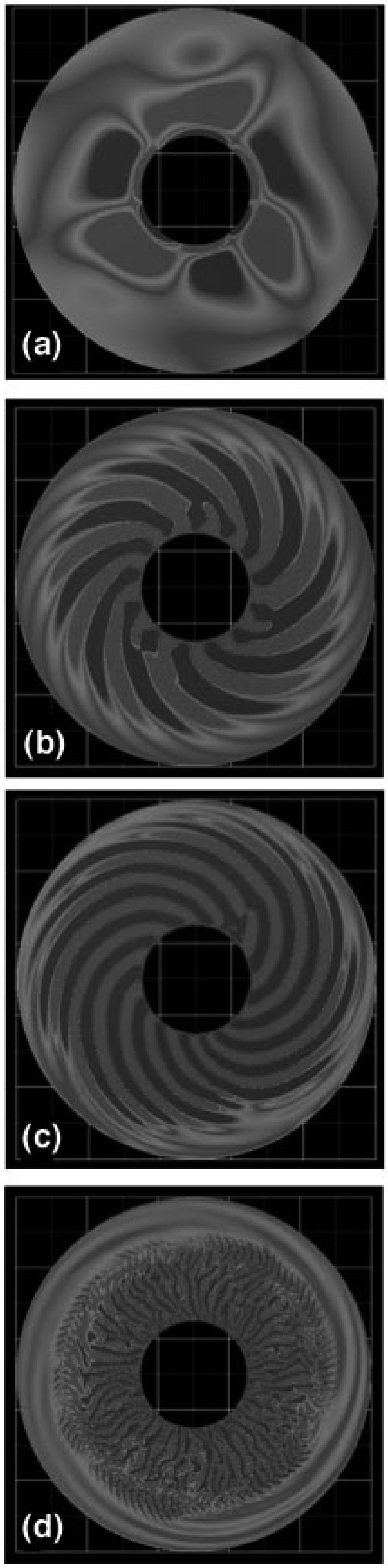

Fig. 1. Equatorial cross sections of the axial component of the vorticity in MHD thermal convection motion in a rapidly rotating spherical shell as a model of geodynamo.