液体金属の磁気対流に見られる準周期的な流れ場の逆転

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Quasi-periodic flow reversals observed in a magnetoconvection of liquid metal

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Rayleigh-Benard convection in liquid metals under the influence of an external magnetic field is a basic problem in considering the flow of the outer core. Especially, to clarify the relation between a large-scale flow structure and turbulence under magnetic fields is important. The flow of liquid iron in the outer core of the Earth may be turbulent because of its very large size, and the characteristics of the turbulence may be controlled by the geomagnetic field.

We carried out laboratory experiments of thermal convection in a liquid gallium layer with various intensities of uniform horizontal magnetic fields. The gallium layer was in a square vessel with a 5:5:1 length ratio (1 is the height), where the horizontal magnetic field is applied in the direction normal to the vertical wall. An ultrasonic velocity profiling method was used to visualize the spatio-temporal variations in the flow pattern, and the temperature fluctuations in the gallium layer were also monitored.

The observed flow pattern without a magnetic field shows fluctuating structure of large-scale flow and the time averaged flow pattern is isotropic. The typical time scale of the fluctuation is comparable to the circulation time of the flow. The fluctuating motion of the flow pattern was suppressed when increasing the applied horizontal magnetic field, and a roll-like structure with its axis parallel to the direction of the magnetic field emerged with a drastic reduction of the flow velocity in the direction of the magnetic field. At the same time, fluctuations with much longer timescale are observed; those are characterized by quasi-periodic reversals of the flow direction of the roll. Under much stronger magnetic field, the flow pattern becomes steady two-dimensional roll without any fluctuation. The same features are observed with increases in Rayleigh number under a fixed intensity of the magnetic field, and can be classified into three regimes as follows: (1) a steady two-dimensional roll structure with its axis aligned to the direction of the magnetic field, (2) emergence of periodic oscillation of the roll structure, (3) increase of the velocity component parallel to the magnetic field and emergence of quasi-periodic flow reversals, and (4) fluctuating isotropic flow structure independent of the magnetic field direction. These transitions may be explained as a result of an increase in the dominance of Lorentz forces over inertia. The flow in regime (3) shows a stimulating behavior in relation to the outer core dynamics, and we investigated the details of the flow structure with long time experiments.