Long-term fluctuation of convection pattern in liquid metal under uniform magnetic field

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Thermal convection of liquid metal under external magnetic field is important for understanding the dynamics in the Earth's outer core. Theoretical approach is powerful around the critical value of Rayleigh number, and its prediction for the flow pattern has been ensured by laboratory experiments. But turbulent behavior of the flow at higher Rayleigh number is not fully understood, because liquid metal is opaque and it is difficult to visualize the flow. We used the Ultrasonic Velocity Profiler method to measure the fine-scale velocity field, and realized the direct visualization of the flow pattern.

Our setting of the laboratory experiment is for the Rayleigh-Benard convection in liquid gallium, with and without external uniform magnetic field. The geometry of the container is a square one. Under no magnetic field, large-scale flow pattern is clearly observed, and it is interpreted as a kind of organized structure of turbulence. The remarkable feature of this large-scale flow is its fluctuation. It shows clearly regular periodic behavior, whose typical timescale is comparable to the circulation time of the mean flow. When we apply horizontal magnetic field, the large-scale flow is reorganized as two-dimensional roll with its axis to become parallel to the direction of the magnetic field. With the increase of the intensity of the applying magnetic field, the periodic components of the flow weaken remarkably and the mean velocity of the roll-like flow pattern increases. At the same time, fluctuation with much longer timescale is observed, which is characterized by the reversal of the flow direction of the two-dimensional roll. The reversal occurs randomly and it may give an insight to the outer core dynamics. Under much stronger magnetic field, the flow pattern becomes steady two-dimensional roll without any fluctuation. We succeeded in summarizing the behavior of the flow by two parameters, Rayleigh number and Chandrasekhar number.