Measurements of velocity field for Rayleigh-Benard convection in liquid metal and the characteristic of the flow pattern

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The Earth's outer core consists of molten iron whose viscosity is low and thermal diffusivity is large. That is, the Prandtl number of the outer core material is much lower than unity. Hence, it is very important to make up the image of thermal convection with low Prandtl number fluids for understanding the dynamics of the Earth's outer core. The convective flow in the outer core is supposed to be extremely turbulent, because its spatial scale is very large and the estimated Rayleigh number is extremely high. It is essential for the outer core dynamics that the flow behaves turbulent under the influence of rotation and magnetic field. But it is very difficult to directly simulate the convection in the outer core numerically in MHD calculation. In the simulation for the Earth's dynamo, eddy viscosity or hyper-diffusivity is introduced for the calculation because of the limitation of computer recourses. The laboratory experiment is a useful way to understand such highly turbulent thermal convection at low Prandtl number.

We succeeded in the direct measurement of velocity profile for the Rayleigh-Benard convection at low Prandtl number with Rayleigh number up to 10ˆ6. Liquid gallium is used for the analogue material of the molten iron. Gallium is the most suitable metal because its melting temperature is around room temperature and easy to handle. We adopt the UVP (Ultrasound Velocity Profiler) method to measure the flow occurring in the liquid metal. Measuring the horizontal velocity at several sites in the container (size: 50mm∗200mm∗50mm) with the UVP, many fluctuations are observed, that reflect turbulent behaviors of the flow. When we see the long-term tendency, we can reconstruct two-dimensional roll-like pattern. This roll-like pattern is supposed to be a kind of mean-flow, that is the organized structure in the turbulence, and the small fluctuations may show the behavior of small plumes. The roll-like pattern shows clearly regular periodic behavior. This means that the roll structure gets longer and shorter laterally and periodically. Its typical time scale is around 25 seconds for Ra˜10ˆ6 in this container. With the increase of Rayleigh number, the velocity of the mean-flow becomes higher. At the same time, the oscillation timescale of the mean-flow becomes shorter. The periodic behavior of the roll-like structure is very important, because it shows the interaction between the small plumes and the mean-flow.