J167-022 **Room: 303** **Time: May 20 16:15-16:30**

Numerical simulations of liquid gallium thermal convection

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Convection in the Earth's core and the ensuing dynamo action are important components in the Earth system, the understanding of which is essential in exploring structures and histories not only of the Earth but of other planets. It is generally recognized that three-dimensional numerical simulations since the 1990s have unveiled the dynamics of the core to some extent, but there still remain unknowns. The problem is that viscosity and angular velocity in previous numerical models never correspond to the realistic values of the core at the same time; the results were only obtained of sticky fluids or in the case of a planet rotating no more than once a year. There is no adequate grounds that the simulation results can be directly applied to hydrodynamic and electromagnetic phenomena in the core. Convection in the core is believed to be highly turbulent due to low viscosity. One of the current research interests is to explain the connection between small-scale turbulent structures and large-scale magnetic signals observed at the Earth's surface.

We have performed laboratory experiments of thermal convection of liquid gallium in order to obtain fundamental data of turbulence applicable to the Earth's core (Yanagisawa et al., JGU Meeting 2007). The physical properties of liquid gallium are similar to those of iron. It is distinctive that Prandtl number is less than unity because of low viscosity, making it tractable to study the nature of turbulence. The electrical conductivity is high enough to investigate interaction between fluid motions and electromagnetic fields. We can obtain velocity, temperature and magnetic field data in the experiments, but they are restrictive due to technical reasons. It is generally desirable to compare the experimental data and the numerical ones that are computed under similar physical conditions.

We report some numerical results of thermal convection of liquid gallium for comparison to the experimental data. A preliminary result reproduces oscillatory convection patterns as observed in the experiments. The numerical code is still under construction for improving performance. We will also report some technical issues on incorporation of magnetic fields in the numerical code.