§17. Experimental Simulation of Convective Zone of the Sun

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Recently, flow structure in the convective zone in the sun was determiend by helioseismology and the conical structure of differential rotation and the very slow meridional flow toward the poles were identified. The meridional flow have a time scale of 22 years, which is the same with the time scale of magnetic activity in the sun (butterfly diagram). The differential rotation and meridional flow are considered as a key to understand dynamo mechanism in the sun, which is not solved yet.

These physical issues on self-generated (turbulence-driven) flow in the sun were reviewed in the first collaborative workshop between laboratory plasma group in the NIFS and Hinode project team in the National Astronomical Observatory of Japan (NAOJ), which was held at September 2010 at NIFS.

The target of the workshop is to explore common underlying physics on the flow pattern generation between in the sun and in magnetically confined fusion plasmas. The common nature is coupling of turbulence with vector field such as rotation and magnetic field. This collaboration was trrigered at the Space plasma simposium co-sponsored by Division of Plasma Physics in Physical Society of Japan, Division of Plasma Electronic in the Japanese Society of Applied Physics and Society of Geomagnetism and Earth, Planetary and Space Sciences. In the second collaborative workshop held at March 2011, we proposed a laboratory simulation of convective zone of the sun utilizing electrohydrodynamics (EHD) turbulence, which is a new and original idea.

In the fiscal year of 2011, we have started the new laboratory experiment to simulate the convective zone in the sun. The EHD convection is produced in the liquid crystal by applying voltage. There are two advantages to use EHD turbulence in this experiment. One is the replacement of gravity and temperature gradient by electric field, which enables us to produce a radial convection in the spherical cell. Previous laboratory experiment used centrifugal force and temperature gradient to produce convection in spherical cell, in which the drive force of turbulence couples with Coriolis force, thus the dependence on non-dimensional parameters such as Rossby number become different from the real system. Second advantage is much better controllability of turbulence. The turbulence in the EHD system is controlled by only bias voltage. Two non-dimensional parameters, Reynold number/Rayleigh number and Prandtl number are directory connected to the amplitude of bias voltage and frequency, respectively. In this experiment, the EHD turbulence is produced in a rotating system, therefore, Rossby number is also controllable independently.

This experiment has been prepared at 3rd room in Research and Development laboratory at NIFS. A wide range of zoom scope and polarization scope were prepared for this experiment. The zoom scope enable us to see easily the pattern formation in the EHD turbulence. The polarization scope is necessary to see orientation of the liquid crystal. A planer cell with homeotropic orientation of director of liquid crystal was successfully made in our laboratory in the collaboration with Kai laboratory in Kyushu university. The homeotropic orientation have a symmetry in the direction parallel to the planar electrode, because the director is perpendicular to the electrode.

The EHD convection and turbulence are produced with low and high bias voltage, respectively, which are shown in Fig. 1. Many local rolls were seen in Fig.1(a), while they are not seen in Fig.1(b). The convective cell become smaller as increase with bias voltage, and turbulence develops with higher bias voltage. The flow measurement using tracer particles is planed in next fiscal year.

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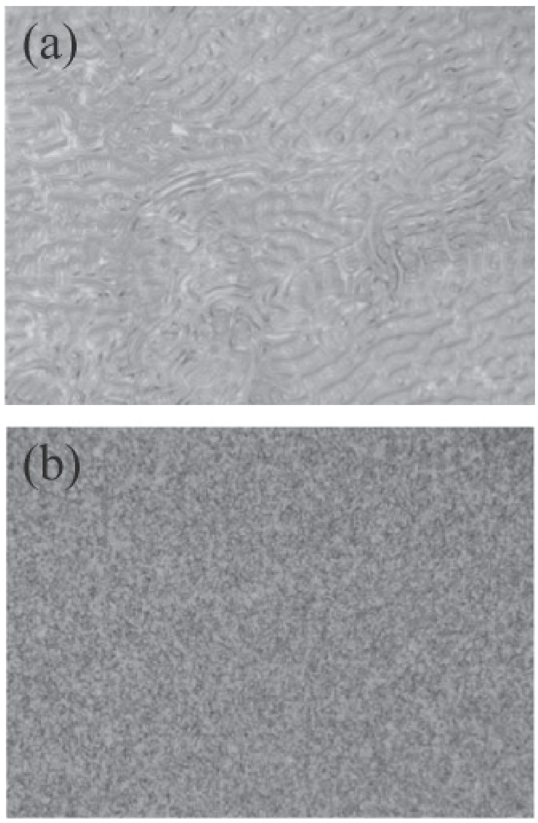

Fig. 1: (a) The snap shot image of EHD convection with low DC voltage and (b) turbulence with high DC voltage.