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Experimental Study on Turbulent Transport using ElectroHydroDynamics Convection Turbulence

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Turbulent transport is a very general subject in a wide area of physics research. The phenomena that we are interested in are very complex ones associated with structure formations in turbulence. It is well known that the Kolmogorov scaling appears in three-dimensional isotropic turbulence. However, it is less interested because nothing happens. In many cases of our interest, some structures appear in turbulence due to symmetry breaking such as temperature gradient, density gradient, intensity gradient of turbulence, rotation, velocity shear, magnetic field, etc. We have proposed a new experimental approach to turbulent transport using ElectroHydrodynamic Convection (EHC).

The EHC is a convection motion driven by the electric field in a liquid crystal, where the gravity and the temperature gradient in a Rayleigh Bernard convection (RBC) system can be replaced by the electric field alone. When the electric field is increased, the EHC becomes turbulent, which is the same feature as RBC with stronger buoyant force. Non-dimensional parameters characterizing EHC turbulence can be easily controlled with the biased voltage. The Rayleigh number is proportional to voltage squared and the Prandtl number is inversely proportional to the frequency of biased ac voltage, respectively. When the EHC turbulence experiment on a rotating table becomes possible in future, the Rossby number can be also controllable.

In the first step of the EHC turbulence experiment, particle transport in homogeneous EHC turbulence without rotation (symmetric case) was evaluated with a particle tracing technique. The small particles put in the liquid crystal can visualize local flow velocity in the EHC turbulence and the particle transport can be evaluated by the orbit tracing of particles. The diffusive nature (random walk process, the Hurst number ~0.5) of particle transport was observed in the EHC turbulence. The effective diffusivity increases with the Rayleigh number with the power index of ~0.85. These results are very similar to turbulent transport properties in viscos fluids (Navier-Stokes system).

The details of EHC turbulence experiment in laboratory frame without symmetry breaking and three experimental plans will be discussed. One is an investigation of non-uniformity effects on turbulent transport with inhomogeneity of turbulence intensity (spatial gradient of the Rayleigh number). Second one is an investigation of rotation effect on turbulent transport. These experiments on turbulent transport may reveal some general effects of symmetry breaking of scalar field and vector field, respectively. The last one is a laboratory simulation of the convection zone in stars and/or planet atmosphere with three-dimensional geometry identical to the real geometry (rotating spherical shell with radially driven convection). The radially-driven turbulence in rotating spherical shell have never realized in laboratory. Using ECH turbulence, turbulence can be driven in the radial direction with radial electric field. The convective zone in the Sun is the first target because of relatively large Rossby number~0.1-1.

Keywords: turbulent transport experiment, symmetry breaking, EHC, liquid crystal