§10. Transport Characteristics in Well-controlled Turbulence Driven by Electrohydrodynamic Convection

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Turbulent transport is a key issues in a wide area of scientific research fields such as hydrodynamics, astrophysics, plasma physics and so on. Based on similarity between rotating fluids and magnetized plasmas, a collaboration between astrophysics and laboratory plasma physics was proposed and workshop was held at NIFS since 2010. A unique experiment have been started using well-controlled turbulence driven by electrohydrodynamic convection (EHC) to investigate the effect of coupling between rotation and turbulence on turbulence transport property.

As a first stage of this experiment, turbulent transport in a planar convection cell was investigated in a static system, using particle tracing technique. Figure 1 shows the orbit of tracer particle that is a glass sphere with the almost same mass density with fluids (liquid crystal) and with the size of 8 times smaller than the height of the cell. The traveling distance during a period δt was statistically analyzed, and a power law ($< l^2 > \propto \delta t^{2H}$, where H is Hurst index.) was observed, which is shown in Figs. 2 and 3. The transport property can be classified by the Hurst index; subdiffusive for $H < 0.5$, super-diffusive for $H > 0.5$ and diffusive for $H = 0.5$. The Hurst index evaluated by this experiment is $H \sim 0.5$ in the well-developed turbulent state ($(V/V_{\mathrm{C}})^2 > 10^2$, where V and V_{C} are voltage based between two planar plates and critical voltage to start convection motion, respectively), and the particle transport is characterized by random walk process (Brown motion). The effective diffusion coefficient can be estimated by $D_{\mathrm{eff}} =< l^2 > /\delta t$, which is shown in Fig. 4. The diffusivity increases with a power of 0.85 of $(V/V_{\mathrm{C}})^2$ which is a index proportional to Rayleigh number/Reynolds number. Therefore, it is concluded that the turbulent diffusivity of particle transport increases with $R_{\mathrm{a}}^{0.85}$. On the other hand, in the weak turbulent state with $(V/V_{\mathrm{C}})^2 < 30$, super-diffusive nature was observed. The reason of super-diffusive transport is speculated that a fundamental convection structure remains in the turbulence and particle trapping by the large convection motion affects the particle transport property.

Next step of this study is identification of effect of rotation on turbulence property and on turbulence transport. A rotary stage and a diagnostic system in a rotating frame are being developed. In near future, we will start the experiment in the range of $R_{\mathrm{o}} > 0.1$, where R_{o} is a Rossby number.

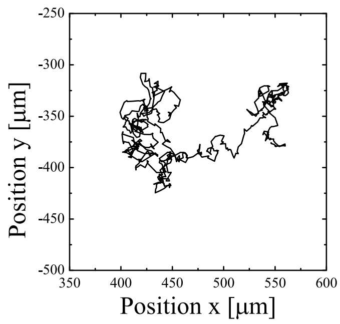

Fig. 1: Orbit of tracer particle in an EHC turbulence.

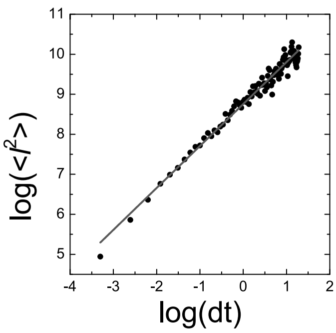

Fig. 2: Traveling distance as a function of periods.

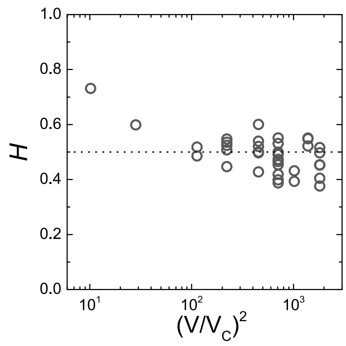

Fig. 3: Experimentally evaluated Hurst number.

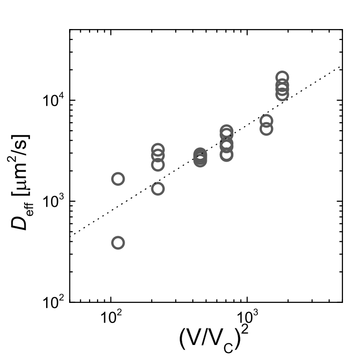

Fig. 4: Effective diffusivity as a function of biased voltage.