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Experimental Study on Turbulent Transport in a Rotating Fluid
回転流体中の乱流輸送の基礎実験

Kenichi Nagaoka, Shinji Yoshimura, Yoshiki Hidaka[a], Kenichiro Terasaka[b], Tatsuya Kobayashi, Nobumitsu Yokoi[c], Yohei Masada[d], Hideaki Miura, Masahito Kubo[e], Ryoko Ishikawa[e],
永岡賢一、吉村信次、日高芳樹、寺坂健一郎、小林達哉，横井喜充、政田洋平、三浦英昭、久保雅仁、石川遼子、

National Institute for Fusion Science, Toki, 509-5292, Japan
[a]Kyushu Univ., Fukuoka 819-0395, Japan
[b]Kyushu Univ. Kasuga, 816-8580, Japan
[c]Univ. Tokyo, Tokyo 153-8505, Japan
[d]Kobe University, Kobe 657-8501, Japan
[e]National Astronomical Observatory of Japan, Mitake 181-0015, Japan
核融合科学研究所、509-5292 岐阜県土岐市
[a]九州大学、819-0395 福岡県福岡市
[b]九州大学、816-8580 福岡県春日市
[c]東京大学、153-8505 東京都
[d]神戸大学、657-8501 兵庫県神戸市
[e]国立天文台、181-0015 東京都三鷹市

A new experimental approach to understanding of turbulent transport has been progressed using a turbulence driven in a liquid crystal cell (ElectroHydroDynamics (EHC) turbulence). The turbulent transport properties in EHC turbulence is dominated by the diffusive process driven by the turbulence, which agrees with that in normal fluids (Navier-Stokes systems) within the acculacy in the experiment. In the case with rotation, a nonlinear coupling appears in low wave-number regime. The preliminary results and future plans are presented.

1. Introduction

Turbulent transport is a very general subject in a wide area of physics researches. Most of phenomena that we are interested in are very complex ones associated with structure formations in turbulence. In the cases torus plasma experiments, some structures appear in turbulence due to “symmetry breaking” such as gravity, temperature gradient, density gradient, intensity gradient of turbulence, rotation, velocity shear, magnetic field, etc [1].

In this paper, the turbulent transport using ElectroHydrodynamic Convection (EHC) is presented. The preliminary results and future plan are discussed.

2. Experimental setup

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 as shown in Fig. 1, which is the same feature as RBC with stronger buoyant force. The Rayleigh number and the Prandtl number can be controllable independently in this experiment.

The size of liquid crystal cell used in this experiment is 10 mm x 10 mm, and the thickness of the cell is 50 μm. The diagnostic is 2 dimensional microscope image. The transparency pattern represents the velocity field perpendicular to the cell. The flow dynamics in the EHC turbulence is captured by a CCD camera. The spatial resolution is 1024 x 768, and the frame rate is 30 fps.

The EHC cell and the diagnostic system can be rotated with a rotary stage. The rotation speed is continuously controlled from 0 rpm to 180 rpm. Therefore the Rossby number is also controllable independently.

3. Results

Here we discuss about the experimental results of turbulent transport with symmetry and without symmetry. In order to evaluate turbulent transport properties in laboratory frame, small particles (6μm in diameter) with the mass density identical to the liquid crystal are mixed in the liquid crystal. The particle tracing technique were applied to the movie. Figure 2 shows the particle orbit in the EHC turbulence. The particle was observed to move randomly depending on the turbulence. In order to

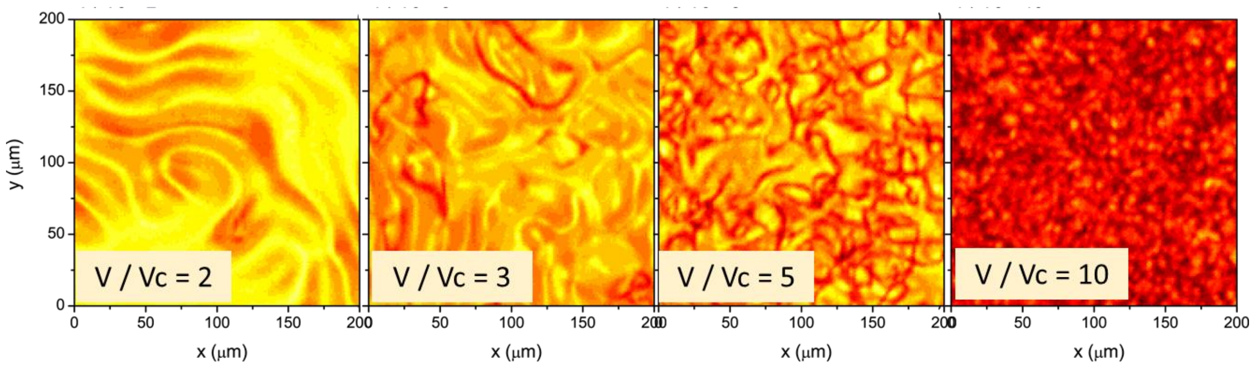

Fig. 1 The snap of EHC turbulence. The color contour indicates the velocity in the Z direction (parallel to the line of sight). The V/Vc is a bias voltage normalized by the critical voltage with which the liquid crystal starts a convection motion.

clarify the transport property, the relation between traveling distance and time duration are statistically compared. It was identified that the particle transport is dominated with diffusive property, in which the $<l>$ is proportional to $t^{0.5}$, in the case of highly developed turbulence (high Rayleigh number regime). The effective diffusivity defined by $D_{\mathrm{eff}} = <l>^2/t$ increases with Rayleigh number $(V/V_c)^2$ with a power of ~0.85. It is noted that the transport characteristics observed in EHC turbulence experiment is identical to the turbulent transport in Rayleigh-Bernald turbulence in the Navier-Stokes systems.

Recently, the experimental study on the turbulent transport in the rotating systems has been started. In order to identify the effects of rotation on the properties of turbulence and the turbulent transport, the turbulence spectra in time and space, nonlinear coupling were examined. In the preliminary experiments, no clear change was observed in the frequency and wave number spectra, and the enhancement of the nonlinear coupling evaluated by the bi-coherence was observed in the low wave number regime.

4. Concluding remarks

In order to extend our understanding on the turbulent transport in complicated systems, the experimental study on the turbulent transport in the rotating frame has been started using the EHC turbulence at NIFS. The common characteristics of turbulent transport between EHC turbulence and normal fluids (Navier-Stokes system) was identified, which indicates the possibility that the experiments using EHC turbulence show general features in turbulent fluids. The nonlinear coupling of the turbulence was observed to be enhanced by the rotation. Systematic investigation of the effects of rotation done in future will reveal many fundamental characteristics of turbulence with symmetry breaking. In the conference of Plasma Conference 2014, the recent results and perspective of this experiment will be discussed.

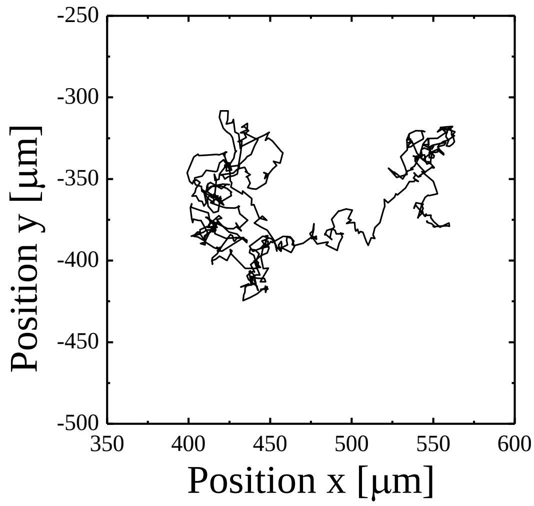

Fig.2. An example of particle orbit moving randomly in the EHC turbulence.

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References

[1] P. Diamond: IAEA Fusion Energy Conference 2008, TH/1-1.