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Flows, Waves and Turbulence in Laboratory Plasma

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The self-organized structures of flows, waves and turbulence in plasma is important for space weather report, development of magnetic fusion and also various industrial applications. We are struggling for establishment of an advanced view of plasma physics thus have promoted the development of magnetized plasma research by a laboratory plasma experiment. Laboratory plasma is very useful to study the flow, wave and turbulence, because it has excellent reproducibility and controllability and allows multi-point simultaneous measurement.

Non-linear interactions between turbulent fluctuations form radially localized azimuthal flow (zonal flow) and radially elongated convective cells (streamer) [1]. The streamer is identified in a linear magnetized plasma device, LMD-U [2]. While the zonal flow doesn't drive particle and energy transport, the streamer enhances cross-field transport. Actually, the radially elongated fluctuating structure in streamer is found to drive cross-field particle flux [3]. Streamer and zonal flow are excited by turbulence through the secondary instabilities [1]. Competition between them, i.e. rule of energy partition, is thus important to understand the transport, which determine the stable structure of plasma.

Flow shear plays a crucial role on interaction between flow and turbulence. While the drift waves are suppressed by a strong flow shear, the D'Angelo mode is excited by a parallel flow shear. The co-existence of D'Angelo mode and drift waves is often observed in the PANTA (successor to the LMD-U) [4]. The D'Angelo mode can drive an inward radial particle flux [5], which enhances a density gradient, and thus it can affect the drift waves which are excited by density gradient in the PANTA. On the other hand, the drift waves can enhance the parallel flow shear through the Reynolds stress. The co-existence of different instabilities and interplay between them are key mechanisms to form the self-organized structure in plasma.

For more comprehensive understanding of structure formation mechanism, multi-scale physics of plasma, i.e. not only ion-scale waves but also electron-scale waves should be studied. The electron temperature gradient (ETG) mode at ~ 0.4 MHz is found to be excited in the Qt-upgrade machine by the ETG formed using a novel method involving the superimposition of high- and low-temperature electrons in the linear magnetized plasmas [5]. The ETG mode co-exists with a low-frequency collision-less drift wave at ~ 7 kHz and a distant-scale interaction, i.e. the energy transfer from the ETG mode to the drift wave, is clarified. In addition, it is found that a sufficiently large radial electric field can suppress the ETG mode regardless of its signs [6]. This suggests important role of the zonal flow on the electron-scale waves.

In summary, laboratory plasma experiments exhibited a picture of magnetized plasma in which the co-existence of multi-scale instabilities, flows and transports will form self-organized structure through non-linear interactions between them.

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