2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Wave, flow and vortex: the third structure in drift wave turbulence

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Turbulence play important roles on structure formation not only neutral fluids but also in plasmas. There is a profound analogy between Rossby wave turbulence in geophysical fluids and drift wave turbulence in magnetized plasmas. Rossby wave or drift wave turbulence excite azimuthally symmetric band-like shear flows, so called zonal flows [1]. Moreover, in planetary fluids, e.g., the Jovian atmosphere, vortex of various scales are also organized/damped in zonal flow-Rossby wave system [2]. Thus, the mutual-interactions among flow, wave and vortex in plasmas give basic insights into the understanding of structural formation by turbulence.

We performed the turbulence excitation experiment in a linear magnetized plasma. The regime of plasma parameters for the onset of zonal flow, streamer [3] and strongly-deformed drift waves are surveyed [4]. Then, the dynamics of strongly-deformed drift waves, (which coexists with the zonal flow) is investigated in an experimental condition (900 G axial magnetic field strength and 5 mTorr argon gas pressure) [5]. Here, we discovered a solitary vortex, which is nonlinearly driven by drift wave and zonal flow [6]. Typical plasma parameters in this condition are $\sim 6 \times 10^{18}\,\mathrm{m}^{-3}$ of center plasma density and ~2.5 eV electron temperature.

The azimuthal cross-section image of drift wave and solitary vortex is reconstructed with the 64-channel azimuthal Langmuir probe array (radial position of r = 4 cm) and a radially movable Langmuir probe. The values of ion saturation current and floating potential on radially movable prove are conditionally averaged at each excitation of solitary vortex with the azimuthal probe array. Here, the time at the peak of the density dump on solitary vortex is used as reference. The reconstructed structure is shown in Fig.1. The filled contour shows the fluctuation component of ion saturation current. The contour black lines indicate the floating potential fluctuation. The purple solid line indicates the position of the vortex excitation. The other side of the vortex shows the density peak of the drift wave.

The spatio-temporal structure of the solitary vortex is closely related to that of the quasi-periodic evolution of the zonal flow (~0.4 kHz). The solitary vortex is organized around an inner antinode of the zonal flow. The solitary vortex lives during accelerated phase where the azimuthal flow is toward the electron diamagnetic direction.

The solitary vortex governs the dynamics of zonal flow. The evaluation of Reynolds force by floating potential measurement indicates the vortex accelerates zonal flow during its excitation. Moreover, the Reynolds force driven by the vortex has the same order of magnitude as that driven by the drift wave. The solitary vortex has substantial impact on excitation and saturation process of zonal flow. This finding gives a new insight into the system of drift wave turbulence, in which the third member plays a substantial nonlinear influence on waves and zonal flow.

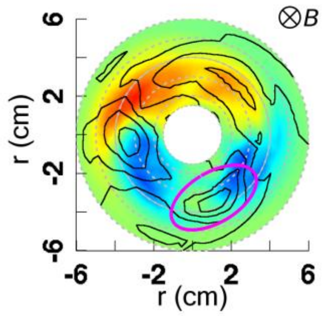

Fig.1 Two-dimensional filled contour structure of the ion saturation fluctuation. The contour black lines indicate the floating potential fluctuation. The purple solid line indicates the position of the vortex excitation.

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