Turbulence and structure formation associated with vortex dynamics in a non-neutral plasma flow

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We discuss generation processes of two distinct structures, ordered arrays of clumps (sharply-peaked density distributions) and single-peaked macro structures, as visually observed in isolated relaxation processes of strongly magnetized pure electron plasmas starting from non-equilibrium initial distributions. The two-dimensional (2D) dynamics of the electron system transverse to the magnetic field macroscopically shows equivalence between the distributions of electron density and the vorticity distribution in the ***E***x***B*** flow of guiding centers of the particles.

Observations have revealed critical contributions of fluctuating electric fields originating from the ambient (or background) electron distribution in assisting the formation of ordered arrays of clumps and their destruction that is successively followed by the next stage of ordered structures with decreased number of clumps. Observed logarithmic dependence of the formation time of the successive ordered configurations suggests common features shared among various matters in a quasi-crystallized state beyond plasmas[1].

If the distributions of density blobs are not sharp enough, as generated in the non-linear stage of shear-driven Kelvin-Helmholtz instability, successive mergers proceed with power dependence on time eventually to form a single-peaked moderate distribution. The fluctuating (turbulent) components extracted from the whole electron system via wavelet analyses exhibit characteristic features in ***k***-space dynamics as predicted on ideal 2D turbulence model. While the vorticity strength (enstrophy) is transported upward in the wave-number space, the energy density cascades down in k to form a global structure bounded by the system size[2], suggesting a feature common to the formation of zonal flows.

Such dynamics that is interpreted mainly in terms of idealized 2D fluid, however, actually stands for dynamism of many-electron system in terms of redistributions of the electrostatic potential energy and the electromagnetic angular momentum[3]. One of unique features of 2D electron vortex dynamics may be attributed to the contribution of axial dynamics of resonant electrons which convey externally applied EM field to the bulk particles supporting the 2D vortex system as a source of energy and momentum through Landau-damping[3,4].

These new features as observed in pure electron plasmas suggest that there are abundant physics issues in plasma science that remain unnoticed but, if once noticed, they may prepare attractive arenas for far-reaching physics discussion beyond plasma boundaries.

[1] Y. Kiwamoto, N. Hashizume, Y. Soga, J. Aoki, and Y. Kawai, Phys. Rev. Lett. Vol.99 (2007) 115002-1-4.

[2] Y. Kawai and Y. Kiwamoto, Phys. Rev. E Vol.78 (2008) 036401-1-8.

[3] Y. Kiwamoto, Y. Soga and J. Aoki, Phys. Plasmas Vol.12 (2005) 094501-1-4.

[4] Y. Soga, Y. Kiwamoto and N. Hashizume, Phys. Plasmas Vol.13 (2006) 052105-1-7.

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