§10. Vortex Dynamics Experiments with Electron Plasma

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We experimentally examine the time evolution of vortex dynamics of a strongly magnetized pure electron plasma in a two-dimensional plane transverse to a homogeneous external magnetic field. The guiding centers of the electrons form an incompressible fluid with infinitely large Reynolds number. In the limit of small Larmoir radii and axial homogeneity, the density of the electron plasma is proportional to the vorticity of the $E \times B$ flows. In other words, the vorticity is equivalent to the space charge density, and the circulation corresponds to the total electric charge. For clear examinations of the vortex dynamics we introduce thin strings of electrons (*1/e* diameter < 1mm and 230mm long) up to a number of 19 into a Malmberg trap and let them execute collective interactions for > 1s (>> the vortex time-scale of < 100μs) in an isolated environment. [1-3]

We have observed the formation of "crystal states" of vortices after passing through stochastic phase of the vortex-string dynamics. [4] In the relaxation process from the initial 19 discrete vortices, increasing numbers of them are filamented to be partially rolled up by others with the rest remaining to form a rugged distribution of low level vortices. The fine structure of the background vortices strongly affects the dynamics of coherent vortices which decrease successively in number after periods of ordered states in quasi-equilibrium. [4,5] Some examples of the ordered states are shown in Fig.1.

The fundamental processes in the relaxation toward the ordered states are examined in more simplified configurations with less numbers of vortex strings immersed in a variable level of background vortex. A single vortex string either moves along the gradient of the background vortex strongly modifying the background distribution [2] or generates a ring hole around it [6] In the former case patched holes are generated through reconnections in the spiral wake generated behind the vortex string. The sluggish motion of the holes slows down the merging between coherent vortices (peaks in the vorticity distribution).

Two vortex strings are subject to opposite actions of the background vortex. Generally the background accelerates the approaching motion of the two strings. [1] The upper panels in Fig.2 illustrate this type of dynamics. But after the two come close within a distance of a few diameters of the strings, the strings either merge quickly or remain separated as in a form of binary vortices as depicted in the lower panels in Fig.2. The apparently contradictory evolutions in the vortex dynamics may be attributed to subtle differences in the structure of vorticity distribution generated around the vortex strings. The role of the modified background distribution is further strengthened by the observation that three vortex strings, initially unbalanced, are led to form a regular triangle dressed in different sizes of ring holes only in the presence of the background vortex.

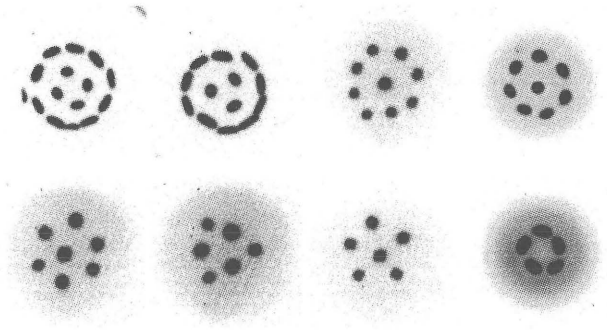

Fig.1

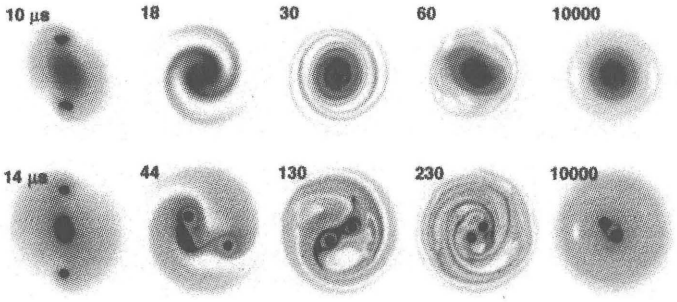

Fig.2

References

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