Experimental analysis of the antisymmetric vorticity during convective vortex merging in electron plasma

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Two co-rotating vortices with (almost) parallel axes merge into a single vortex when they are within a critical distance of each other[1]. The vortex merging is a fundamental ingredient of fluid motion, found to play a key role in the dynamics of shear layers and two-dimensional turbulence.

A symmetric vortex pair, each with equal circulation Γ and a core radius a, separated by a distance b, initially rotates about each other due to the mutually induced velocity and merges when the aspect ratio a/b exceeds the critical threshold $(a/b)_c$ [2]. In viscous fluids, the merging process, which leads to $b = 0$, consists of three phases. In the first diffusive phase, the vortices remain separated by their initial distance b_0 while their cores expand due to viscous diffusion of vorticity. In the convective phase, when the aspect ratio a/b_0 reaches the critical threshold, the vortices rapidly deform due to vorticity advection, significantly reducing b. In the second diffusive phase, b diminishes slowly, and two vorticity maxima are eventually reduced through viscous diffusion.

The vorticity advection in the convective phase generates antisymmetric vorticity. A previous study experimentally demonstrated that the velocity field induced by antisymmetric vorticity causes the vortices to move toward each other[3]. Recently, a numerical study reported that the antisymmetric part of vorticity also causes oscillations in b during the second diffusive phase[4].

We investigated the role of antisymmetric vorticity during convective vortex merging using a collisionless, magnetized, pure electron plasma confined in the BX-U linear trap[5]. The electron plasma in the BX-U was characterized by the Drift-Poisson equations, which describe the E × B drift motion averaged along the magnetic field[6]. These equations are isomorphic to the vorticity equation for a two-dimensional ideal fluid. In this condition, two-dimensional electron density is proportional to vorticity.

In this talk, we show the experimental results of convective vortex merging observed in electron plasma. First, the structure of the antisymmetric vorticity (electron density) and its induced velocity field are analyzed in detail (**Figure 1**). Second, the reduction rate of b induced by the antisymmetric vorticity is calculated by the Biot-Savart law. The computed separation values b_c are compared to the directly measured values (**Figure 2**).

References
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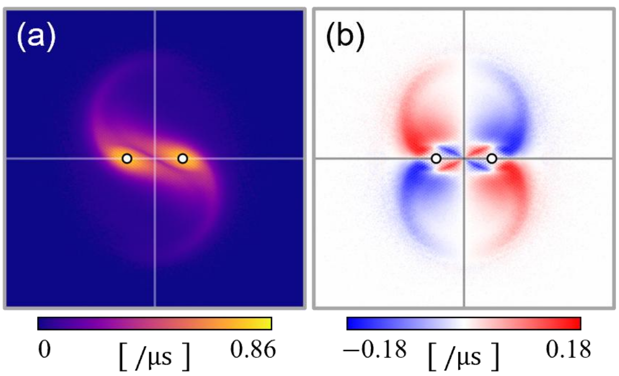

Figure 1. A Snapshot capturing the merging of two equal vortices in electron plasma. The white dots are the calculated vortex centers. (a) Total vorticity (b) Antisymmetric vorticity

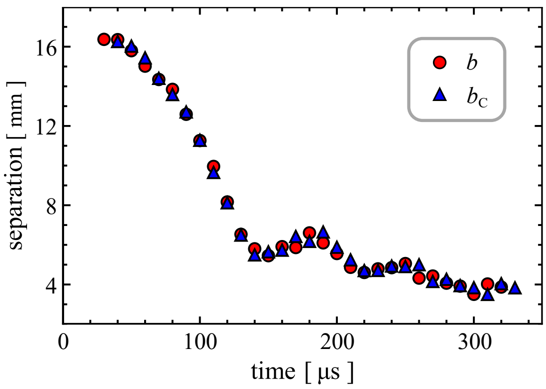

Figure 2. Comparison of the directly measured separation distance b and the expected distance b_c calculated from the antisymmetric vorticity[6].