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Vortex formation in a phase-separated binary complex plasma under microgravity

Cheng-Ran Du[1], Sheng Pan[1], Andrey Lipaev[2], Andrey Zobnin[2], Markus Thoma[3], Wei Yang[1]
[1] College of physics, Donghua University, [2] Joint Institute for High Temperatures, RAS, [3] Institute of Experimental Physics I, Justus Liebig University Giessen
e-mail: chengran.du@dhu.edu.cn

Complex plasma is composed of a weakly ionized gas and mesoscopic particles. The particles are negatively charged due to the higher thermal velocity of the electrons and interact with each other via screened Coulomb interactions. As the motions of individual particles can be easily recorded by video microscopy, generic processes in liquids and solids can be studied in complex plasmas at kinetic level.

The formation of vortex is a ubiquitous phenomenon in nature. In two-dimensional complex plasmas, vortexes are observed as particles flow past an obstacle or a dust void. In three-dimensional complex plasmas, vortex motions can be induced by the ion drag force from the gradient of ion density and ambipolar velocity or the thermal creep from the gradient of the wall temperature. Here we present a new type of vortex formation driven by a particle flow at the interface of a phase separated binary complex plasma under microgravity condition.

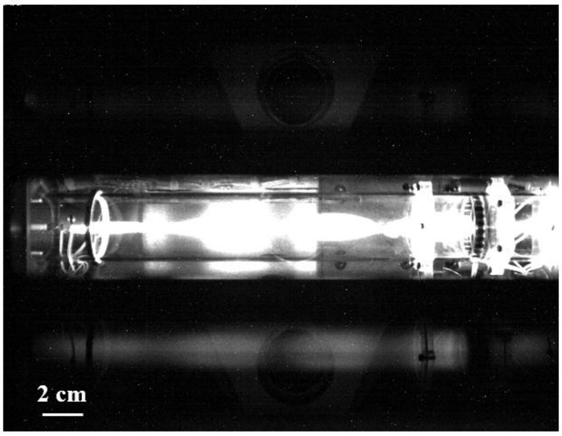

Figure 1 Plasma discharge, illuminated microparticles, and manipulation laser recorded by the PGO camera in the PK-4 laboratory on board the ISS.

The experiments were performed in the PK-4 laboratory on board the International Space Station (ISS)[1]. An argon plasma was ignited in a glass tube by the dc discharge at a gas pressure of 40 Pa, as shown in Fig.1. Small and big particles were consecutively injected in the tube with a time interval of 2 s. After the particles were transported in the center of the tube, polarity switch with a frequency of 500 Hz was switched on by the cosmonaut such that the particles were confined instantaneously. In the experiment, phase separation occurred instantaneously, presumably due to the unbalance of the electrostatic force and ion drag force in the plasma, forming an ellipsoidal interface (highlighted by the red curves in Fig.2) between the small (left) and big (right) particles[2]. A manipulation laser was switched on and the particles along the central axis were driven by the optical pressure provided by the laser beam with a diameter of 1.5 mm.

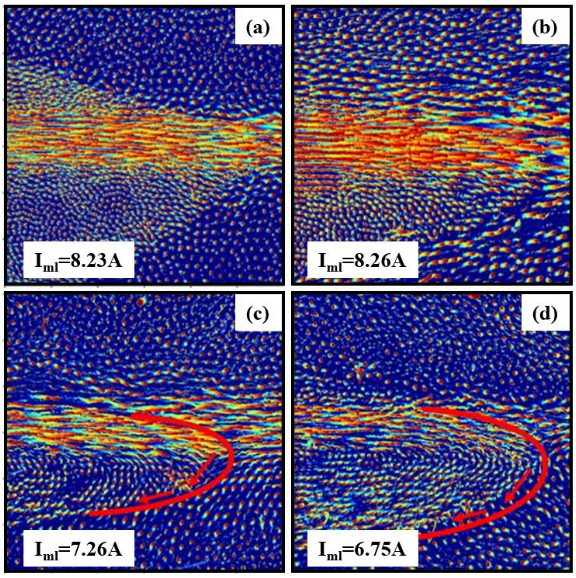

Figure 2 Overlay of particle positions (color coded from blue to red) at the interface with different manipulation laser currents I_{ml}.

Here, we focus on the motions of the small particle in the vicinity of the interface, as shown in Fig.2. When the manipulation laser current is low and the flow velocity is relatively small, a significant portion of the small particles driven by the optical pressure were hindered by the big particles at the interface by the Yukawa repulsions. Those particles reverse their direction of motion, move along the ellipsoidal interface and form a vortex on the side (highlighted by the red arrows in Fig.2). On the contrary, when the flow velocity is much bigger, most of the small particles can penetrate through the interface, mix with the big particles. As result, the small particle motion on the side of the flow does not demonstrate any sign of vortex. This transition is experimentally identified[3]. Our results demonstrate a new type of vortex formation, which is associated with the interface of a phase-separated binary complex plasma.

References
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