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Lane Dynamics in 2D Pair-ion Plasmas: Effect of Obstacle and Geometric Aspect Ratio

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When driven out of equilibrium, many physical systems spontaneously often exhibit pattern formation, for example, in molecular systems, geology, the animal kingdom, granular systems, colloids, migrating macro ions, in binary plasmas, in systems of self-propelling particles, pedestrian dynamics, and in army ants. Understanding the behaviour of such non- equilibrium systems that form patterns is extremely challenging to predict.

Lane formation [1,2,3] is an important representative of non-equilibrium phase transition phenomena. Here, we focus on a 2-D Pair ion (PI) plasma system and explore the lane formation dynamics using Langevin Dynamics (LD) simulation [1], specifically, both in presence and absence of the external magnetic field the influence of the obstacle and geometric aspect ratio is studied [3]. Lanes are found to form when like particles move along or opposite to the applied field direction. The critical value of the electric field, and hence the location of the phase transition, is observed to affect by the Coulomb coupling parameter value. Lane order parameter, cumulative order parameter and the distribution of the order parameter have been implemented to detect phase transition. Here, specular reflective boundary condition is implemented to mimic an obstacle. We demonstrate that obstacle promotes the merging of lanes for small aspect ratio values (see, Figure 1) and the system transits into a partially mixed state for higher aspect ratio values (Figure 1). Our study also reveals an appearance of void for lower aspect ratio value of the system, which flips on either side of the obstacle in irregular intervals in the presence of an external magnetic field. Furthermore, the study in presence of the external magnetic field promotes acceleration of the phase transition process towards lane mixing phase, it also reveals the existence of the electric field drift in the system [3]. Our simulation results may provide a fundamental understanding of non- equilibrium lane formation in the naturally occurring Pair-ion (PI) plasma [1] systems. Finding has important implications in technology, for example, from determining the uniformity of plasma surface treatments [4], particle separation in microfluidic devices [5] and many more.

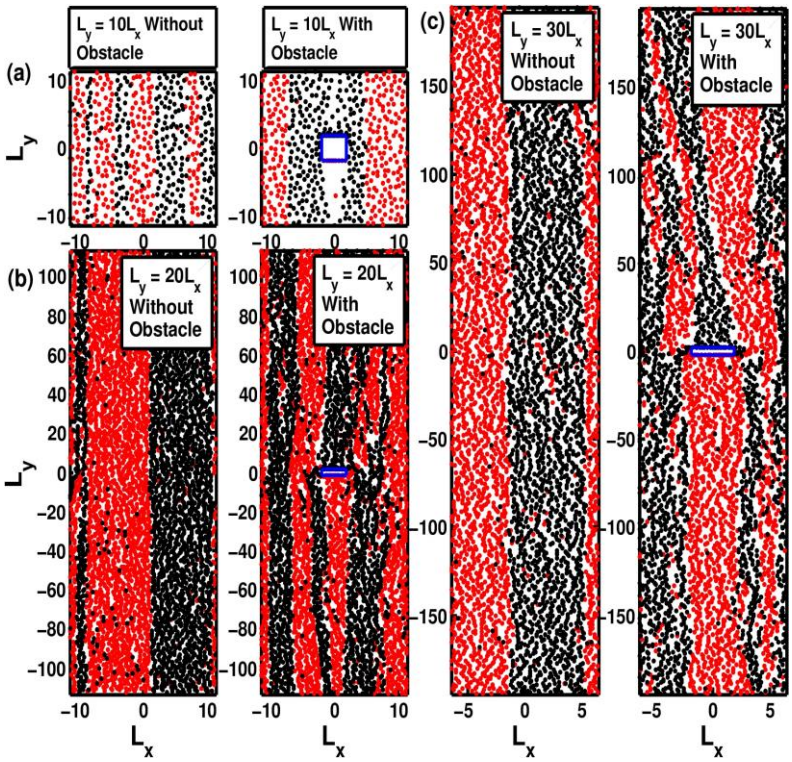

Figure 1: Comparative simulation snapshots of 2D PI plasma system are plotted for different aspect ratio values both in presence and absence of an obstacle.

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