Seminar

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Institute for Plasma Research

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Title: Structure, dynamics and phase transition of finite dust clusters in complex plasmas : A Molecular Dynamics study

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Date: 29th August 2025 (Friday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

Abstract

In this presentation, I will talk about our recent work on finite clusters formed by charged dust particles under harmonic confinement in complex plasmas using Molecular Dynamics simulation. Finite systems formed by charged particles are of interest to physicists as they appear in diverse physical systems, like ions in Paul or Penning traps, in quantum dots, electrons above the liquid He surface, and in colloidal clusters, etc. In complex plasmas, finite dust clusters can be formed both in 2D and 3D. We have found that a 3D dust cluster undergoes a first-order phase transition between an ordered rotational phase and a disordered rotational phase as a function of the Coulomb coupling parameter and magnetic field strength, and the phase boundary corresponding to the phase transition in the magnetic field - temperature plane obeys a power law. The phase boundary can be viewed as dividing the magnetic field-temperature plane into two different timescale regimes, and the phase transition occurs when one timescale dominates over another timescale [1]. The competition between different time scales within the cluster was further explored in the system while studying the collective and single-particle dynamics in a 2D dust cluster in the presence of a transverse external magnetic field using Langevin Dynamics simulations. It was observed that the phonon spectra of the cluster split up into two distinct branches with the higher frequency branch approaching cyclotron frequency once the cyclotron time scale (Tc) approaches the dust-dust interaction time scale (Tint) defined by the dust plasma frequency. Moreover, the cluster exhibits a transition from a normal diffusion to superdiffusion once the cyclotron time scale becomes smaller than the harmonic time scale (Th) [2]. The analysis of the static structure and dynamics of a 3D dust cluster using both frictionless Molecular Dynamics (fMD) and Langevin Dynamics (LD) elucidates the effects of dust neutral collision on the dynamics and structure of this finite system. The static properties were found to remain largely unaffected, whereas the dynamics of the cluster showed strong dependence on the dust-neutral collision. The relaxation of the interparticle distance in fMD was found to be extremely slow, whereas the same in LD was much quicker, leading to the vanishing of a persistent rotation of the particles in the cluster about a common axis with the introduction of dust-neutral collision in the dynamics [3].

References

[1] H. Sarma, R. Sarmah, and N. Das, Physical Review E 107, 035206 (2023).
[2] H. Sarma and N. Das, Physics of Plasmas 31 (2024).
[3] H. Sarma and N. Das, arXiv preprint arXiv:2506.18820 (2025).