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Novel equilibrium states for charged micro-particle systems in plasma medium

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Dusty plasma medium is an ideal test bed to study the static and dynamic properties of a strongly coupled system. The study of strongly coupled systems is an interesting research topic in various fields of physics and applications concerning their particle ordering, crystallization[1-3], cluster formation[4,5] and other complex behaviors.[6,7] Dusty plasma is essentially a multicomponent system where nano/micrometer sized dust particles are immersed in a typical electron-ion plasma. In the plasma environment, these dust particles will become highly charged because of the constant bombardment of plasma electrons and ions. A very high value of charge on the dust surfaces often leads them to be in the strongly coupled state. Thus, experimentally, they can be easily prepared in the strongly coupled regime without any stringent criteria on temperature and density.

In the present study, two-dimensional (2-D) and three dimensional (3-D) Molecular Dynamics (MD) simulations have been carried out to investigate the structures and equilibrium dynamical features of such a strongly coupled charged micro-particle system in the plasma environment. In particular, layered crystal structure formation has been depicted in the 3-D studies[8] where in addition to the Yukawa pair interactions amidst dust grains, a combined gravitational and external electric field force has been applied externally in the vertical direction. The externally applied vertical electric field mimics the sheath electric field in experiments. The multilayer structures are formed due to the combined effect of the external confining force parameterized by α and repulsive pair interaction amidst them represented by κ, as have been shown Fig. 1.

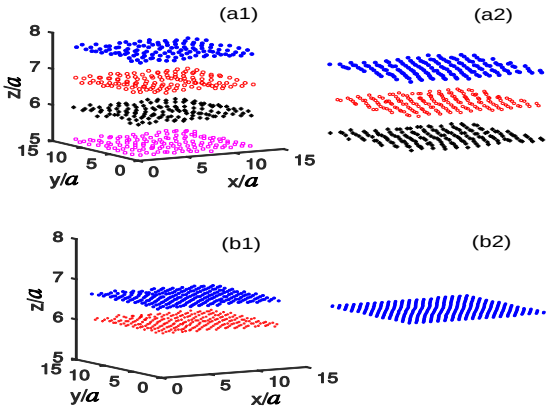

Fig. 1. Layer formation for different κ and α values. Subplots (a1) and (a2) are for κ = 1.0 and 1.5 with a fixed α = 1.0, respectively. Subplots (b1) and (b2) are for α = 2.5 and 15 with fixed κ = 2.5, respectively.

The conditions for the formation of layered structures and the form of the crystalline patterns are identified.

The relaxation states of 2-D dusty plasma systems have also been investigated in our MD study[9] where beside the pair interaction amongst particles, they have been confined in x-y plane by an external 2-D parabolic potential. It is shown that in equilibrium, particles arrange themselves in the form of cluster optimizing the effective potential energy associated with the pair interactions and external confining field.

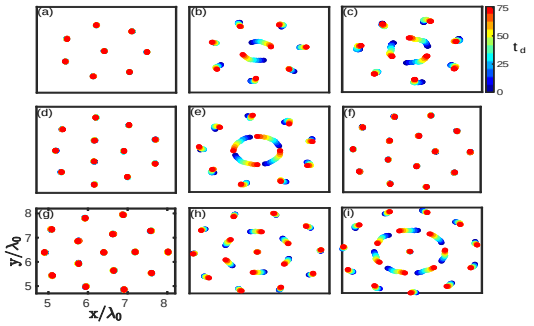

Fig. 2. Particle trajectories over a time duration t_d for different cluster configurations consisting of total number of particles (a) Np = 8, (b) 9, (c) 10, (d) 12, (e) 13, (f) 15, (g) 16 (h) 17, and (i) 19.

It is observed that for small N_p values both the static and dynamic equilibrium configurations exhibiting inter-shell rotations, radial oscillations can be achieved, as have been shown in Fig. 2. For clusters consisting of higher N_p values, a novel equilibrium state with coherent rigid angular oscillation of the entire cluster is observed. These unique dynamical states of finite clusters have been characterized over a wide range of system parameters viz., total number of particles, screening parameter, etc.

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