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Formation and dynamics of structures in strongly coupled medium driven by electrostatic interactions

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The formation of classical bound structures and their dynamics in electron-ion ultracold neutral plasma (UCP) [1] is studied in two and three dimensions using an open source classical Molecular Dynamics (MD) simulation software LAMMPS [2]. The charged particles are interacting through the long-range pair Coulomb potential. In order to avoid the blowing up of simulation due to attractive Coulomb interaction between opposite signed charged particles a short-range Lennard-Jones (LJ) repulsive potential is also added. The chosen LJ parameters 'sigma and epsilon' provides a minima in the interaction potential of electrons and ions.

The electrons and ions get trapped in the minima of interaction potential and leads to the formation of different variety of 2D bound structures specially in strongly coupled medium. These bound structures are observed to move freely in the medium. The 3D bound structures are not observed to be formed in the plasma medium. In the absence of plasma medium they appear as stable structures, however, as soon as they are immersed in the plasma medium they are observed to re-organize and turn into 2-D clusters.

When the medium is disturbed by adding external highly charged particle (which can be seen to mimic an applied potential) Debye like shielding is observed. However the potential profile is observed to deviate from the exact Debye form and gets decided by the Debye scale length and the parameter sigma [3] of the LJ potential determining its minima. The medium being strongly coupled oppositely charged particles gather around it in a typical hexagonal structure in 2-D which is typical of a one component strongly coupled plasma.

In 3-D the particles arrange in spheres of distinct radii. The spatial properties of these crystalline structures have been analysed through the Radial Distribution Function (RDF) and Voronoi diagram in 2D and 3D simulations.

The stability of these structures has also been studied under the action of an external oscillatory electric field.

References
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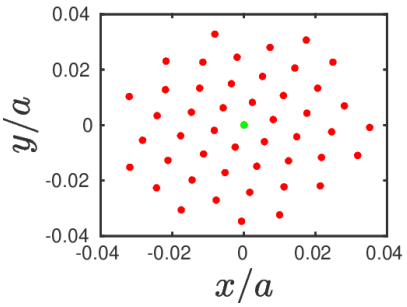

Figure 1: Crystalline structure near the external perturbation in 2D simulations.

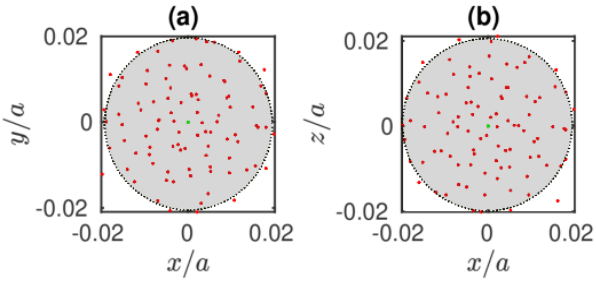

Figure 2: Crystalline structure near the external perturbation in 3D simulations.