Coulomb Clusters in Dusty Plasmas: Rotation and Stability

F.M. Cheung, C. Brunner, A.A. Samarian, B.W. James
School of Physics, The University of Sydney, NSW 2006, Australia

Coulomb Clusters are well ordered structures formed from highly charged particles trapped in a potential well. These structures are formed because the particles undergo strong electromagnetic interactions from forces such as coulomb repulsion and electrostatic confinement, hence their name. These clusters contain small amounts of particles (N<100) whose shape is governed by the nature of the potential well. For a radial parabolic well, the cluster consists of concentric shells given enough particles in the system. Due to their discrete structure, the dynamics of coulomb clusters are relatively easy to analyse using various analytical and numerical methods. This combined with their unique physical properties due to their small size, have made coulomb clusters a popular research topic of late. Examples of cluster systems include quantum wells and ion traps. One area where coulomb clusters have been of particular interest is in dusty plasmas (or complex plasmas).

Rotation and stability of dust clusters with different numbers (2 to 12) of micron-sized particles levitated in a horizontal plane was studied experimentally in inductively coupled magnetised dusty plasma. When the magnetic field was absent, the clusters exhibited small random fluctuation but always remained around their equilibrium position. And when an axial magnetic field with strength up to 90G was applied normal to the cluster plane, the dust cluster was observed to undergo rotational motion as a rigid body. At such low magnetic field strength, the electrons were fully magnetized, the ions were partially magnetized, and the dusts were unmagnetized. Since the direction of the rotation was in the left-handed direction with respect to the magnetic field, so presumably, the cluster rotation was mainly due to the collisional drag from the azimuthal component of the ion flow. Here we offer an alternative interpretation of the experimental results by comparison with the different theoretical models. Moreover, we give an alternative explanation of the angular velocity saturation observed in cluster rotation.

It was also found that the fluctuating motion of the particles was dominated by its azimuthal component which was 2-12 times larger than radial component (see Fig.1). It was also observed that the number of particles in a cluster strongly influenced the cluster instability. The reason behind certain cluster structures being more unstable than others was likely to be due to their number of possible metastable states. It was observed that the stability of individual particles within the clusters increased with increasing axial magnetic field.

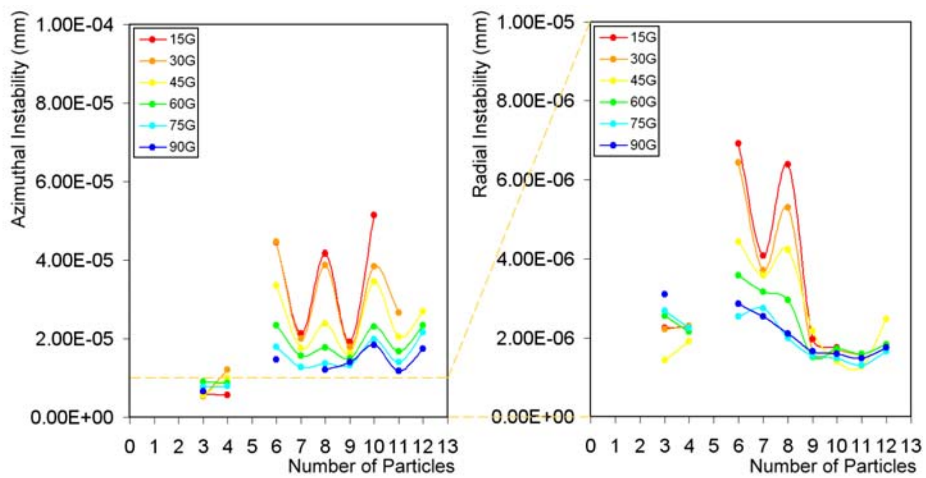

Fig. 1. The relative instability coefficients (reduced rms displacements) of azimuthal and radial fluctuations plotted as a function of the number of particles.