Coulomb Clusters: Stability and Spectrum of Energy States

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Coulomb cluster is a phenomenon in classical physics which is under substantial amount of attention. These clusters are characterized by the strong electrostatic interaction of highly charged particle trapped within an external confining potential. Examples of such systems include ion traps and quantum dots. Investigation in this area had been further encouraged in the past few decades with the discovery of complex (dusty) plasmas and the increase in the computer simulation of complex plasma experiments. In discharge complex plasma system, micron-sized dust particles which are highly negatively charged (~10^4e) repel each other under strong coulomb forces to arrange themselves into well ordered structures. Such structures with limited number of particles are referred as Coulomb clusters in dusty plasma.

In this study, stability of dust clusters with different numbers (2 to 12) of micron-sized particles levitated in a horizontal plane was investigated 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. It was found that the fluctuating motion of the particles was dominated by its azimuthal component which was 2-12 times larger than radial component. 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

The experiments where complemented by numerical study and dynamic of coulomb cluster systems are simulated on a computer for various particle numbers. The system is modelled using electrostatic confinement from a potential well, classical coulomb repulsion, friction force and a stochastic force. Classical force equations are used to simulate the behaviour of highly charged dust particles in such a field. Our model allowed us to predict the structural configuration of the dust cluster under particular experimental conditions and the results are symmetrical clusters with concentric shells with multiple stable (metastable) states (referred to as packing sequences). It was shown that configuration of Coulomb clusters depends on friction force (pressure). A simple explanation based on limited-time metastable states approach was proposed. Spectrum of energy states of dust Coulomb clusters corresponding to various packing sequences was obtained. The broadening of the spectrum due to inter-shell rotation was discovered.