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Coulomb crystallization in classical and quantum systems[1]

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Coulomb crystallization occurs in one-component plasmas when the average interaction energy exceeds the kinetic energy by about two orders of magnitude. A simple road to reach such strong coupling consists in using external confinement potentials the strength of which controls the density. This has been succsessfully realized with ions in traps and storage rings and also in dusty plasma. Recently a three-dimensional spherical confinement could be created [1] which allows to produce spherical dust crystals containing concentric shells. I will give an overview on our recent results for these "Yukawa balls" and compare them to experiments. The shell structure of these systems can be very well explained by using an isotropic statically screened pair interaction. Further, the thermodynamic properties of these systems, such as the radial density distribution are discussed based on an analytical theory [3]. I then will discuss Coulomb crystallization in trapped quantum systems, such as mesoscopic electron and electron hole plasmas in coupled layers [4,5]. These systems show a very rich correlation behavior, including liquid and solid like states and bound states (excitons, biexcitons) and their crystals. On the other hand, also collective quantum and spin effects are observed, including Bose-Einstein condensation and superfluidity of bound electron-hole pairs [4]. Finally, I consider Coulomb crystallization in two-component neutral plasmas in three dimensions. I discuss the necessary conditions for crystals of heavy charges to exist in the presence of a light component which typically is in the Fermi gas or liquid state. It can be shown that their exists a critical ratio of the masses of the species of the order of 80 [5] which is confirmed by Quantum Monte Carlo simulations [6]. Familiar examples are crystals of nuclei in the core of White dwarf stars, but the results also suggest the existence of other crystals, including proton or α-particle crystals in dense matter and of hole crystals in semiconductors.

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