Dynamics of polydisperse charged dust particles

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Compaction of a system of hard small particles is a problem common to a number of applications in physics. According to the domain in science, the context is called : "granular matter" (e.g. sand dune formation), "colloidal particles" (such as ceramic processing), or "regolith" (as for the dynamics of the dust on the surface of the moon or asteroids). Statistical Physics is the general theoretical background, and this makes the theory of such systems always intricate. Consequently, a number of approximations are often used to make the theoretical approach simpler, such as : the particles are all the same, the particles are spherical in shape, etc. Even within these approximations, description of the various behaviors of a system made of many small hard particles under mechanical stress is noticeably incomplete, whatever the physical context. Recently, it appeared unavoidable to revisit the usual approximation considering that all the particles of a given system are of same size. Reasons to do that were either the observation that particles are naturally polydisperse – with polydispersity depending on the formation process –, or the hope that particle polydispersity could induce new effects.

In this presentation, we will review the state-of-the-art results about intriguing behaviors of a system of polydisperse hard charged spheres in a stress field, with focus on the micrometer and sub-micrometer size particles. A central question is about the overall homogeneity of the system : when does the external field induce size segregation in the system? Subsequent questions are many, for example: self-organization and mechanical properties of charged dust sediment, profile of the size-distribution of charged dust particle levitating over a surface due to photoelectric effect, etc.

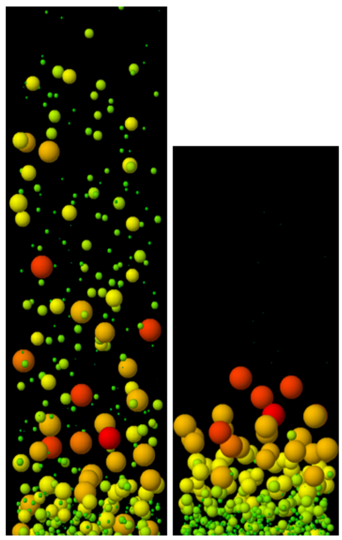

Figure 1: Example of Molecular Dynamics simulation of 3D system of charged spheres with log-normal radius-distribution in a vertical pressure field. Colors are the particle sizes (red = big, green = small). The right-hand figure is the final state (sediment), in which the big particles 'float' over the small ones.

With this in mind, the problem of charged particles in a uniform gravitational field is of particular importance. It was recently shown that in this case, big particles tend to 'float' at the surface of the system. The mechanism is that the particles most repulsive (the biggest ones) tend to form a loose crystal, and the gravitational field pushes the small particles (weakly charged, then less sensitive to the electric repulsions) inside the voids below the big particles. Then, schematically, the big particles levitate on the electric field made of a background of weakly repulsive particles. This behavior has consequences in various domains : in the ceramic processing, it forbids the capability to form compact Apollonian arrangement ; in the context of lunar regolith, it makes light scattering a particular haze-like signature, since the layer of 'big' dust particles (*i.e.* around 1μm diameter) are much interacting with the electromagnetic field.