Charging and Transport of Dusty in Plasma: beyond the basics

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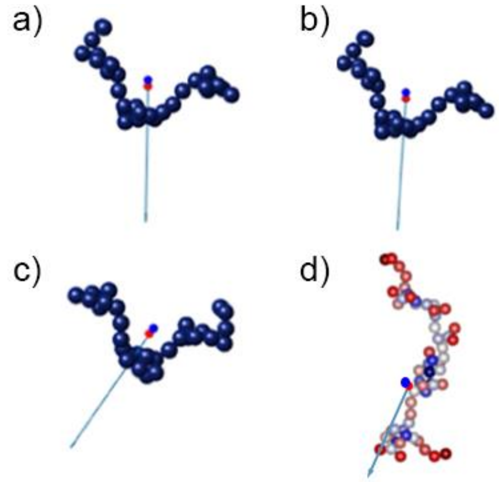
Dust is a common component in plasma environments. It can be a contaminant in fusion and plasma processing, a dangerous hazard on airless bodies like the Moon, or an essential component of astrophysical systems and basic complex plasma experiments. Dust grains collect ions and electrons from the plasma environment and become charged. The simplest theory of dust charging assumes that dust grains are isolated spheres in an isotropic, homogeneous plasma. The greater mobility of the electrons, compared to more massive ions, means that surfaces exposed to plasma become negatively charged. However, experimental and theoretical studies reveal that the charge collected by a dust grain depends on many factors such as the shape and material of the grain, plasma flow, and the presence of magnetic fields.

The charge collected by asymmetric, irregular grains is distributed unevenly over the grain surface. The greater surface area of an irregular aggregate allows the grain to collect more charge than a spherical grain [1-2]. This leads to stronger interaction with electric or magnetic fields in the plasma environment. The uneven charge distribution on an irregular grain also gives rise to an electric dipole moment. The electrostatic torques acting on the grain change the dynamics of the system, which can alter subsequent grain growth, the coupling to the gas in the environment, and grain transport [3-5].

As plasma particles stream past a grain, the trajectories of positive ions are deflected and build up in a region downstream of the grain, called the plasma wake. The positively charged wake leads to anisotropic plasma shielding, creating directional variations in energy transport and coupling. Molecular dynamics and Particle-in-Cell simulations of the plasma particles reveal the dynamic wakes present in various dust systems [6-7]. Recent work has been aimed at finding more accurate models which allow ion wakes to be incorporated into kinetic models as an effective dust potential [8-9].

Magnetic fields also change the charging and transport of dust in a plasma. Magnetization of the electrons results in a directional electron charging current which alters the magnitude charge [10-11]. A magnetic field can significantly alter the ion drag and the ion wake. The helical motion of ions deflected by charged dust particles can result in a region of ion depletion downstream from the dust referred to as an ion shadow [12]. Competing torques induced by an electric field, magnetic field, and gas drag can cause dust to align along a specific orientation with respect to the magnetic field, affecting dust grain charging and transport [13-14].

This talk will give an overview of dust charging and the recent advances in predicting and measuring the charge on irregular grains or granular surfaces.



Orientation of an aggregate in the sheath of an rf plasma showing the effects of competing torques: (a) dipole moment of the aggregate (arrow) aligned with the electric field, (b) electrostatic torque plus ion drag, (c) addition of weak thermophoretic force, (d) addition of strong thermophoretic force. The center of mass and center of charge of the aggregate are indicated by the blue and red dots, respectively. In (d) the color of each monomer indicates the charge on the monomer.

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