Direct Observation of Particle Interactions and Clustering in Charged Granular Streams

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***Abstract*— Clustering of fine particles is important in many circumstances ranging from the early stages of planet formation to industrial powders and airborne pollutants. Models of such clustering typically focus on inelastic deformation and short-range sticking forces. On the other hand, even in charge-neutral particle systems comprised of grains of the same dielectric material, tribocharging can generate large amounts of net positive or negative charge on individual particles, resulting in long-range electrostatic forces. The effects of such forces on cluster formation are not well understood and have so far not been studied in situ. By observing freely falling grains in vacuum with a co-falling high-speed camera, we track the relative positions of individual particles with high spatial and temporal precision and eliminate the effect of gravity and air drag. We observe individual collide-and-capture events between pairs of charged sub-millimeter particles, including Keplerlike orbits, and particle-by-particle aggregation into clusters, which provide direct experimental evidence of the profound effect electrostatic forces have on collisional clustering. Furthermore, since particles of different net charge and size are seen to aggregate into characteristic spatial configurations, our results suggest new possibilities for the formation of chargestabilized "granular molecules". We can reproduce the observed molecule configurations by taking many-body, dielectric polarization effects into account.**