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Charge moderated preplanetary growth from single grains to giant aggregates

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In early phases of planet formation, bouncing and fragmentation barriers still represent major obstacles. Beginning at micrometer, dust can readily grow to sub-millimeter size in collisions due to cohesion before bouncing prevails. Later, streaming instabilities trigger further growth which might finally results into planetesimal formation by gravitational collapse. However, for streaming instabilities sub-millimeter grains might be too small, therefore there is gap of at least 1 order of magnitude in size which needs to be bridged.

Here, we present our ongoing work how to bridge this gap by charge moderated aggregation [1]. When two (dielectric) grains collide they charge. This tribocharging or collisional charging is omnipresent in nature. We designed drop tower experiments in which we generated charges on glass and basalt grains by collisions in a shaker. In microgravity, the particle trajectories and collisions were observed, and charges were measured by applying an electric field.

In early work, we analyzed millimeter-sized glass grain collisions with a copper plate. The coefficient of restitution increased with the charge on a single grain due to mirror charge forces. That means highly charged grains tend to stick more easily to surfaces than uncharged grains. The velocity where sticking is possible was increased by a factor of 100 up to several dm/s [2].

More recently, we used half millimeter basalt spheres and observed sticking events at several cm/s among grains themselves [3]. This is also way higher than predicted by adhesion. In a number of cases, we could observe the sequential formation of aggregates of up to ten single grains. During approach the grains are accelerated due to net charge Coulomb forces but likely also due to higher order charges on the surfaces in agreement to earlier measurements of strong permanent dipole moments [4]. Attraction increases collision cross-sections and the growth is sped up. Growth only stopped by the end of microgravity [3].

To observe the formation of still larger aggregates we developed a new setup, in which a dense cloud of 150 µm diameter basalt grains was continuously agitated slightly under microgravity and in vacuum. Here, the growth of a giant aggregate of centimeter size was observed collecting nearly all material in one cluster [5].

To conclude, in experiments under various conditions, we see strong evidence that electrostatic charges on grains are able to conquer the bouncing barrier. We observed the bottom-up growth tracking individual particles, stable clusters emerging from dense regions and the formation of giant clusters during agitation. These are all bricks in the wall giving evidence that collisional charging might play a crucial role in planet formation.

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