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Ice particle collisions

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Granular interactions of ice occur in a range of geophysical, astrophysical and industrial applications. For example, Saturn's Rings are composed of icy particles from micrometers to kilometres in size - inertial and yet too small to interact gravitationally. In clouds, ice crystals are smashed to pieces before they re-aggregate to for snow floccules in a process that is very much open to interpretation.

In a granular flow of ice particles, the energy spent in collisions can lead to localized surface changes and wetting, which in turn can promote aggregation. To understand the induced wetting and its effects, we present two novel experimental methods which provide snippets of insight into the collisional behaviour of macroscopic ice particles.

Experiment 1: Microgravity experiments provide minute details of the contact between the ice particles during the collision. A diamagnetic levitation technique, as alternative to the parabolic flight or falling tower experiments, was used to understand the collisional behaviour of individual macroscopic icy bodies. A refrigerated cylinder, that can control ambient conditions, was inserted into the bore of an 18 Tesla superconducting magnet and cooled to -10ºC. Initial binary collisions were created, where one $\sim$4 mm ice particle was levitated in the magnet bore whilst another particle was dropped vertically from the top of the bore. The trajectories of both particles were captured by high speed video to provide the three-dimensional particle velocities and track the collision outcome. Introducing complexity, multiple particles were levitated in the bore and an azimuthal turbulent air flow introduced, allowing the particles to collide with other particles within a coherent fluid structure (mimicking Saturn's rings, or an eddy in a cloud). In these experiments, a sequence of collisions occur, each one different to the previous one due to the changes in surface characteristics created by the collisions themselves. Aggregation becomes more likely when the particles are new and rough, but also after they have been through many collisions.

Experiment 2: To create an even higher collision density and to understand the collective behaviour of these ice particles, a sample of them were placed to cover the tray of an electromagnetic shaker, mounted in an environment controlled chamber at -2ºC. Continuous shaking of this system permitted observation of a spontaneous transition from dry granular behaviour to that of wetted granules. Vibrating with a fixed acceleration, image sequences were recorded every 10 min to show that at early stage (<15min) the particles adopted the dry granular flow (particles are free to bounce on the vibrating plate). After circa 40 min 90% particles became spontaneously immobile in an approximately hexagonally packed 2 dimensional sheet.