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Free Collisions at Low Velocities

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1 Motivation

In order to understand the growth mechanisms of planetary bodies, one has to study collisions between small particles. Usually the relevant collision velocities depend on the particle size, smaller particles collide with smaller velocities than big ones. The initially (sub-) micrometer sized grains that are the building blocks of the bigger aggregates can be manipulated by gas jets that allow for a survey of a broad variety of velocities. Large aggregates collide with typical velocities of centimeters to meters per second or more, which can be achieved in the laboratory by using pendulums or monitoring two particles in free fall that have a relative velocity to each other.

The growth of millimeter-sized dust aggregates is mainly determined by their behavior in collisions with velocities of a few millimeters per second. Due to gravity these velocities are nearly impossible to achieve in the laboratory. Therefore, we developed a microgravity setup that allows us to study collisions of about millimeter-sized particles at these low velocities.

It is based on experiments by Heißelmann et al. (2010), who have conducted experiments where an ensemble of glass beads was injected into a flat chamber under microgravity conditions. Due to inelastic collisions among the glass beads the average velocity decreased over time (collisional cooling). As the coefficient of restitution, the ratio of the velocity of two colliding particles after and before a collision, is even lower for dust aggregates than for glass beads (Heißelmann et al., 2007), we expected this concept to work for dust as well.

2 Experiment setup

Our experimental setup (see Fig. 1) consists of a vacuum chamber with a height of 50 mm and a diameter of 25 mm made of glass. The bottom flange is made of aluminum and can include a device enabling us to accelerate a solid particle into the chamber. The top flange is permeable to air, but not to our particles

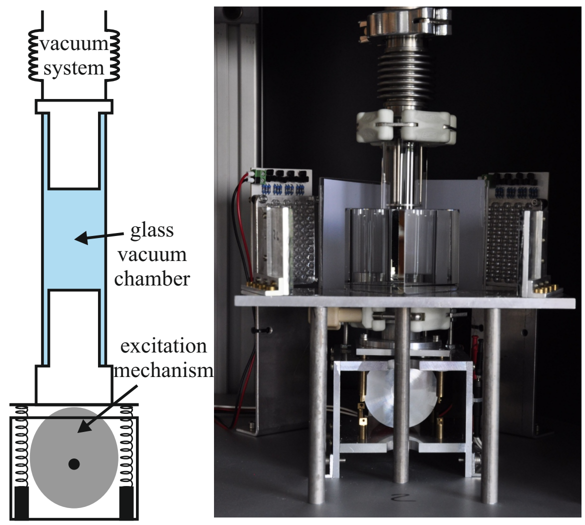

Figure 1: *Left*: Sketch of the glass vacuum chamber atop the excitation mechanism. *Right*: Experiment setup as seen from the camera. In front of the chamber the 3D optics is placed, in the background LED arrays and diffusors can be seen.

and connected to the vacuum system. The vacuum system can connect several setups, and using a turbo-molecular pump we can evacuate the system down to about 0.1 Pa.

The chamber is mounted on an excitation mechanism, consisting of a DC motor driving a wheel with a slightly off-centered horizontal axis. This causes a nearly sinusoidal up- and down-motion of the wheel upon which the chamber is resting. Springs ensure the contact of chamber and wheel even in microgravity, causing the chamber to follow the wheel's vertical movement. The excitation is used to keep the particle density homogeneous by moving particles at the flanges back into the chamber and, thus, compensating for drift or residual accelerations in the vertical direction.

To examine the experiment we observe the vacuum chamber with a high-speed camera with 500 frames per second. Between the camera and the chamber a

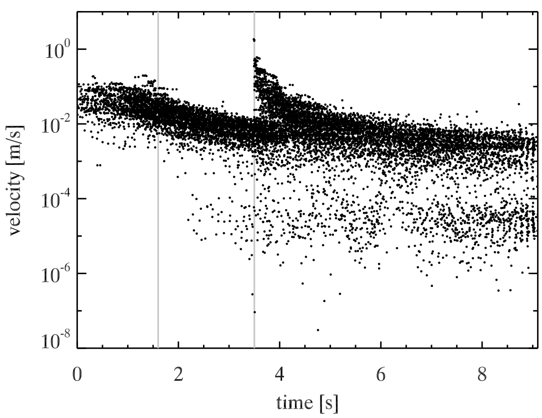

Figure 2: The dots show the absolute velocity of the dust aggregates during the experiment. The vertical lines denote the shutdown of the excitation and the injection of a fast-moving object, respectively (from Weidling et al., 2011).

3D optics consisting of a 90°-mirror and two plane mirrors is placed, which allows us to get two views from different perspectives separated by 90° with just one camera. In a recent setup the optical system was replaced by a single prism, where the two views are separated by only 30°. The experiment is backlit with LED arrays.

So far, we have conducted three Drop Tower campaigns in Bremen with more than 100 single experiments in total. We have studied collisions of dust aggregates of different sizes, materials and number densities as well as of chondrule analogues and different solid particles. Parts of the setup, e.g. the 3D optics, have been improved between the measurement campaigns to gain even better results.

3 Collisional cooling

Figure 2 (Weidling et al., 2011) shows the absolute velocity of all 0.5 to 1.5 mm diameter dust aggregates over time in one drop tower experiment. At first, the particle velocity is constant at around 1 to 10 cm s^{-1}, until the excitation mechanism is turned off (first vertical line). After this, the average velocity is decreasing due to inelastic collisions down to a few mm s^{-1}, while some particles are even slower than that. The second line denotes the injection of a fast, solid particle into the chamber which collides with some few particles and accelerates them, but most of the particles are slowed down further by collisions with each other.

4 Scientific application

The setup can be used to study the collisional properties of different materials at low velocities. Until now we have examined experiments with submillimeter sized dust aggregates (see abstract by Kothe et al.), millimeter-sized aggregates (see other abstract by Weidling et al.) and chondrule analogues (see abstract by Beitz et al.). We have also conducted experiments with glass beads, steel and ceramic balls of different sizes, but analysis of these collisions is still in progress.

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