EPSC Abstracts
Vol. 6, EPSC-DPS2011-1822, 2011
EPSC-DPS Joint Meeting 2011

Steps in planet formation: Collisions of mm sized dust aggregates in the cm/s regime

T. Jankowski*, T. Kelling, G. Wurm
Fakultät für Physik, Universität Duisburg-Essen, Germany, *tim.jankowski@uni-due.de

Abstract

In the first phase of planet formation, dust grows to aggregates starting from μm sizes up to planetesimals. The experimental analysis of collisions of dust aggregates with different sizes and velocities is needed for theoretical calculations and modeling. Starting with μm sized grains, growth occures rather rapidly until mm-sizes are reached and the process slows down [1] and might even stopp at a bouncing barrier [2]. With the experiment presented here, it is possible to analyse collisions of mm sized dust aggregates at several cm/s.

1. Experiments

The experiment consists of a vacuum chamber with a heater and illumination inside. A high-speed camera records the collisions (see Fig. 1). The dust aggregates are placed onto a slightly concave surface directly on the heater. The Knudson compressor effect leads to levitation of the dust aggregates and (natural and induced) relative motion to collisions between them [3]. The impacts are analysed determining parameters like particle sizes and shapes, lowest-distance-velocity, center-of-mass-velocity, impact parameters and contact area on collision.

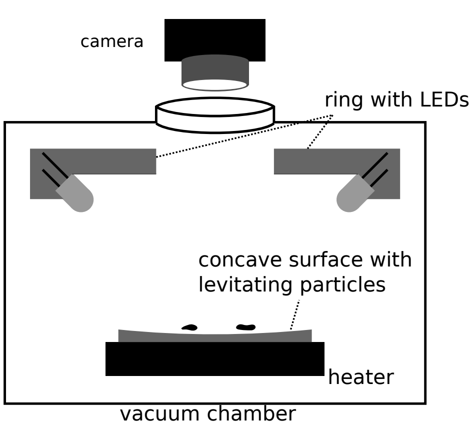

Figure 1: Scheme of the experimental setup.

The Knudsen compressor effect can be understood as follows: If two gas reservoirs at different temperatures T_1 and T_2 were connected via a small tube with a diameter which is small compared to the mean free path, thermal creep can lead to gas flow from the colder to the warmer reservoir and therefore to overpressure (Fig. 2) [4].

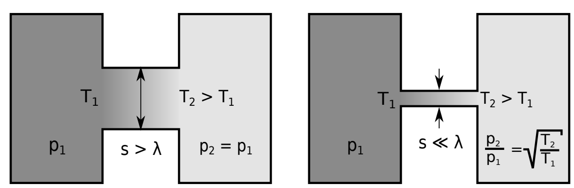

Figure 2: Left: Two gas reservoirs with temperatures T_1 and T_2, connected via a tube with diameter $s > \lambda$, p_1 equals p_2 due to pressure equalisation; Right: $s \ll \lambda$, thermal creep leads to a gas flow from the colder to the warmer reservoir and to an overpressure at the warmer side.

The dust aggregates used in this experiment consist of μm sized dust grains. The pores between these grains act as microchannels inside the particle. These channels are small connection tubes between the top (surrounding) gas reservoir and the bottom. Due to the heating from below, a temperature gradient is induced vertically inside the aggregates. The Knudsen compressor effect then leads to a gas flow and overpressure at the bottom which lifts the aggregate until an equilibrium of gravitational force and the Knudsen force (which is lowered by the sidewards outflowing gas) occurs. Typical levitation heights are in the $\sim$ 100 μm to mm range (Fig. 3).

2. Collisions and Observations

In general, three types of collisions can be observed: bouncing, accretion and fragmentation. For mm-sized dust aggregates made of μm basalt powder, $v_{col} \approx 1.5 - 15$ cm/s, mainly bouncing and accretion are ob-

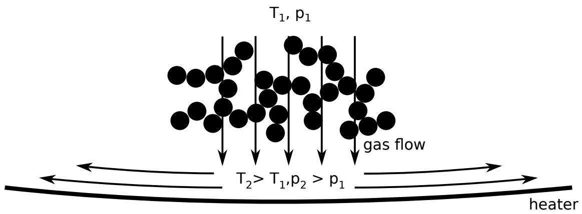

Figure 3: The Knudsen compressor effect leads to an overpressure below the particle, small microchannels (inside the aggregate) act as connection tubes.

served while fragmentation is only possible if former accreted aggregates are hit by a third aggregate. The collisions are analysed, determining aggregate sizes and shapes, velocities (center-of-mass and point of first contact velocity), impact parameters and contact area on collision.
See Fig. 4 - 6 for three typical collisions observed with this setup (accretion, bouncing and fragmentation).

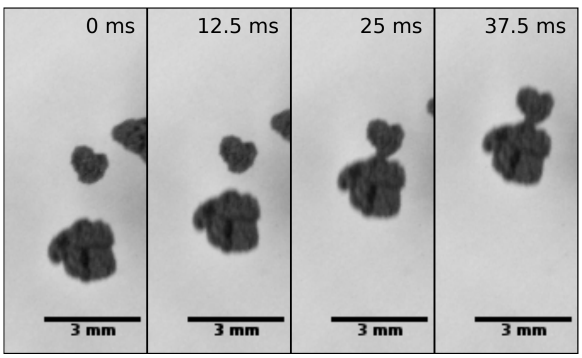

Figure 4: Accretion at 4.9 ± 0.1 cm/s, aggregate sizes are A_1 = 2.8 mm^2 and A_2 = 0.8 mm^2.

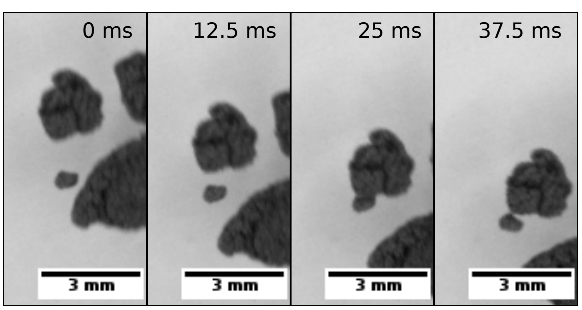

Figure 5: Bouncing at 3.7 ± 0.1 cm/s, aggregate sizes are A_1 = 2.8 mm^2 and A_2 = 0.3 mm^2.

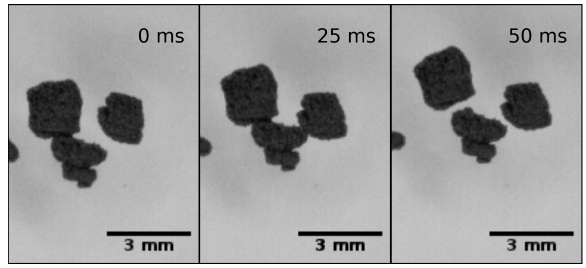

Figure 6: Fragmentation at 1.7 ± 0.3 cm/s, aggregate sizes are A_1 = 5.7 mm^2 and A_2 = 2.3 mm^2 before and A_1' = 3.4 mm^2, A_1" = 2.3 mm^2 and A_2 = 2.3 mm^2 after the collision.

3. Summary and Conclusions

Collisions between two mm-sized particles made of μm grains lead to accretion and bouncing, dependent on many parameters. Furthermore, fragmentation can be observed within a two-body collision with particles consisting of two or more mm-sized particles. With this experiment it is possible to analyse many collisions and provide large statistics for further investigations and simulations. In this contribution first results will be presented.

References

[1] Blum, J. and Wurm, G.: The Growth Mechanisms of Macroscopic Bodies in Protoplanetary Disks, Annual Review of Astronomy and Astrophysics, 46, 21–56, 2008.

[2] Zsom, A. et al.: The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals? II. Introducing the bouncing barrier, Astronomy and Astrophysics, 513, A57, 2010.

[3] Kelling, T. and Wurm, G.: Self-Sustained Levitation of Dust Aggregate Ensembles by Temperature-Gradient-Induced Overpressures, Physical Review Letters, 103, 215502, 2009.

[4] Knudsen, M.: Eine Revision der Gleichgewichtsbedingung der Gase. Thermische Molekularströmung, Annalen der Physik, 336, 633, 1909.