EPSC Abstracts
Vol. 6, EPSC-DPS2011-217, 2011
EPSC-DPS Joint Meeting 2011

Collisions of Protoplanetary Dust Aggregates and the Influence of their Volume Filling Factors

T. Meisner , J. Teiser and G. Wurm
Faculty of Physics, University Duisburg-Essen, Duisburg, Germany, (thorsten.meisner@uni-due.de / Fax:+49-203-3791965)

Abstract

In laboratory experiments we investigate the growth of dust agglomerates by coagulation. To understand the mechanisms leading to mass accretion, collisions between cm-sized dust agglomerates are studied in dependence on porosity at velocities around the fragmentation threshold. Further collision experiments are performed to study the porosities of protoplanetary dust agglomerates more exactly. With respect to the approximated masses and coupling times of dust aggregates in dusty disks, these investigations are very important for the understanding of coagulation processes.

1. Introduction

It is widely accepted that planets form around stars in so-called protoplanetary disks (PPD‘s). While the final phase of planet formation in those disks can be explained by collisions of km-sized planetesimals driven by gravitational force, the formation of planetesimals forming via coagulation of small dust aggregates is not clearly understood so far. Once particles are compact agglomerates, compaction and erosion accur [2] and drift velocities become large and particle growth stops [4]. One possible scenario to explain further growth is the growth of planetesimals by coagulation of dust agglomerates starting with micrometer sized particles. Relative velocities of colliding dust agglomerates depend on the aggregate sizes and can reach values of 60 m/s or more for m-sized bodies. Collisions of dust aggregates leading to mass accretion are investigated with two experimental setups. Using a special experimental setup, free collisions between cm-sized dust agglomerates can be realised. Here, we observed the effect of partial fragmentation and mass transfer in more detail. The variation of the filling factor has consequences for models of planetesimal formation. In addition we are able to measure the accretion efficiency by recovering the dust samples after the collisions. Using a further experimental setup we are able to observe the formation of dust aggregates by multiple collisions. With this method the effect on volume filling factors of dusty solids produced by the dynamic pressure can be studied more exactly.

2. Experimental setups

Collisions of dust agglomerates of different filling factors are accomplished by accelerating a prepared dust cylinder vertically upwards against another one like it is illustrated in Fig. 1 [1]. The chosen setup consists of a solenoid on which a small platform is mounted. On this platform the dust aggregate (m $\approx$ 13g) with higher porosity, which is used as projectile, is placed. A dust cylinder with nearly the same mass but lower porosity is used as target. It is affixed with a thin thread and an elastic band a few cm above the dust projectile. The collisions are filmed with a high speed camera (500 frames/s) and collision velocities between 0.5 m/s and 1.5 m/s can be achieved. The mass of the target is always measured before and after the collisions. The whole assembly is installed in a vacuum chamber at pressures of about 10^{-3} mbar. Since we want to investigate cm-sized dust aggregates concerning the volume filling as an important property and its changing by dynamical pressure, we use the same drop-tube setup like it is described in [3]. Sieves with different mesh sizes are used. Due to gravity the dust grains hit the bottom of a cup in a velocity range of 1 m/s to 7 m/s and build up fluffy dust samples. In addition high porous dust targets are also placed at the bottom of this tube. Dust particles of different sizes and with different velocities can be dropped onto the dust agglomerates with very low filling factors.

3. Results

By analysing the movies of the reproducible free collisions (Fig. 1) of dust agglomerates we always observe the effect of partial fragmentation and mass transfer. The gained mass is roughly conically shaped. The accretion efficiency is on the order of a few percent of the particle‘s mass. At collision velocities between 0.5

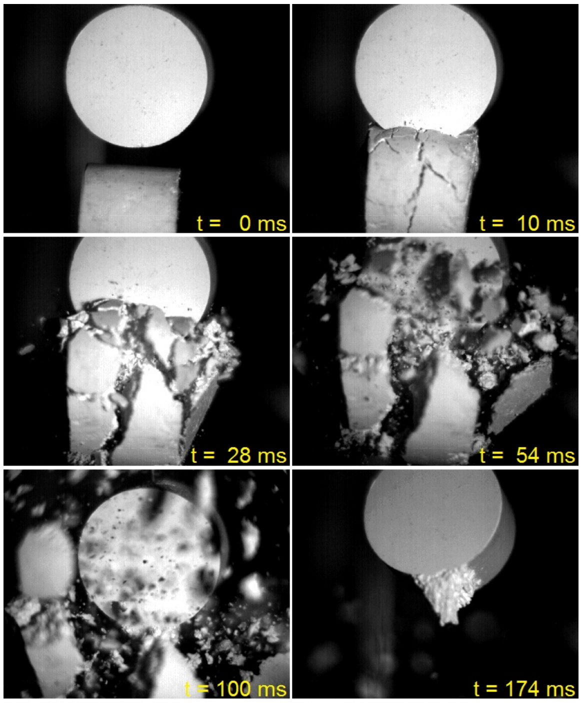

Figure 1: This movie extract illustrates colliding cm-sized dust-aggregates with different filling factors and collision velocity around $1\,\mathrm{m\,s^{-1}}$ [1]

m/s and 1.5 m/s and constant held porosity differences the analysis shows that the accretion efficiency clearly depends on the impact velocity. At larger velocities we observe an increase in accretion efficiency. The accretion efficiency clearly depends also on the sample porosity. We determine that accretion efficiency increases at larger differences in porosities if collision velocity is held constant.

Dust aggregates are produced with the same mechanism and in the same velocity range (1.5 m/s to 7 m/s) like it is described by [3]. In contrast to that work the dust agglomerates are produced in a cup and a sieve with a mesh size of 4 mm is used instead of $250\,\mu$m. With increasing collision velocities the volume filling of the produced dust aggregates grows from 0.24 to 0.31. The same saturation level and the same increasing volume filling is observed, as in [3], although the colliding particles are 16 times larger than those in [3].

In an additional experiment series highly porous dust agglomerates (volume filling of 0.2) are hit by large numbers of small ($125\,\mu$m and 4 mm) agglomerates. The targets within the analyzed size range ($125\,\mu$m - 4 mm) are not affected by these multiple collisions. A compaction due to impacts mainly influences the outer shell of a highly porous dust agglomerate, whereas the inner parts remain unchanged. This behaviour does not depend on the particle size.

4. Conclusions

Our investigations show evidence for eventually too large estimated masses and coupling times of dust aggregates in PPD‘s. Large inner parts of such aggregates are highly porous. Nevertheless they are stable enough to withstand high dynamical pressure of colliding particles. The porosity differences of colliding dust agglomerates plays also an important role in the formation of planetesimals in PPD‘s.

Acknowledgements

We thank the Deutsche Forschungsgemeinschaft for funding the Forschergruppe 759 "The Formation of Planets: The Critical First Growth Phase" (grants Wu 321/5-2), which fund the impact experiments in the Duisburg laboratory.

References

[1] Beitz, E. et al. 2011: Low-velocity collisions of centimeter-sized dust aggregates, ApJ, accepted.

[2] Güttler, C. et al. 2010: The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals?. I. Mapping the zoo of laboratory collision experiments, A&A, 513, id. A56.

[3] Teiser, J. et al. 2011a: Porosities of Protoplanetary Dust Agglomerates from Collision Experiments, in review.

[4] Weidenschilling, S. J. and Cuzzi, J. 1993: Formation of planetesimals in the solar nebula, In: Protostars and planets III (A93-42937 17-90), p. 1031-1060.