Mechanical Properties of Dust Aggregates

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1 Introduction and Abstract

Coagulation of submicron sized dust grains is known to have been the first step towards planet formation in the early solar nebula (e.g. [7]). Nevertheless, the physics of this process is still poorly understood. On the experimental side, there are some new experiments under way which certainly will give very important insight [1]. On the theoretical side, it is important to simultaneously develop models for the physics of coagulation which will allow to predict the outcomes of experiments and which can thereby be tested. We have studied the frictional processes that will occur when tangential forces are applied to dust grains in contact. Numerical simulations of collisions between dust aggregates which include these processes show, that small aggregates of 0.1 μm sized grains will survive collisions below 100 cm/s almost undeformed. Velocities of approximately 1000 cm/s compress the involved aggregates. At higher impact energies, both aggregates are destroyed. The critical velocities as well as the amount of compression that can be reached are strongly material dependent.

2 Method and Results

The basis to our description of the contact forces is taken from the JKRS theory of an adhesive contact of two elastic spheres [6]. Dynamical processes during a collision lead to the excitation of elastic wave which are responsible for some dissipation [2]. Since this theory covers only the response to normal forces, we have added a description for the effects of tangential forces. Tangential forces applied to a contact first deform the two bodies and then lead to sliding and rolling which are accompanied by energy dissipation [4, 5]. Taking everything together we are now in the position to model coagulation of grains and collisions between grain aggregates in a selfconsistent manner.

We have calculated and will present simulation results of a collision of two aggregates consisting of 40 particles each. As an example we show in Fig. 1 the results of collisions at different velocities between two identical aggregates made of icy grains. In the first picture (collision velocity 200 cm/s), two original aggregates only stick together and hardly deform. With increasing velocity, both aggregates are compacted quite effectively, until, at 5000 cm/s they break up into a few smaller structures. At even higher velocities, both aggregates are completely destroyed, leaving only the the single grains behind.

3 Conclusions

The results shown above indicate, that at the rather small velocities typical for the early solar nebula [3] will likely lead to sticking of grains of different materials. Collisions of aggregates do not have sufficient energies to compact the aggregates effectively or even destroy them at this state. For effective compression, velocities in the range of 1000 cm/s are needed, exact values depending strongly on material properties.
Figure 1: Final state of collisions of two 40 particle aggregates at different collision velocities. The material of the grains is ice, each grain has a radius of $10^{-5}$ cm.

References