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Collision of centimeter-sized particles

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Abstract. A characterisation of the collision properties between icy interstellar grains is crucial to understand planet formation. Here, we measure collision properties on a reference elastic system to evaluate the inelasticity of ice particles collisions. We propose upgrades to correct for some experimental biases and to investigate water evaporation as possible explanation for the energy loss during collision.

Keywords. astrochemistry, methods: laboratory, planetary systems: formation

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1. Introduction

To this date, more than 4000 exoplanets have been detected. Their formation is generally assumed to originate from the coagulation of dust grains from the nanometer-sized particles we observe in the interstellar medium to the kilometer-sized planetesimals present in stellar systems. However, whereas this growth mechanism is well understood for small and large grain sizes, it is still unclear how milimeter-sized dust grains can grow into ten-meter sized rocky bodies; this parameter zone is known as the *bouncing barrier*. In that respect, it has been hypothesised that ice could enhance the sticking properties and allow icy bodies to overcome this bouncing barrier. Several experimental setups have been built to study the collisional properties of icy dust grain analogues (Gärtner *et al.* (2017) and references therein) and these generally show that most of the collisions end up in non-sticking of the two colliding icy dust grain analogues. In addition, Hill *et al.* (2014) reported that between 10 and 80 % of the energy would be dissipated after the shock. In order to give a reference point for these measurements, we propose to use a reference system of colliding plastic centimeter-sized balls, assumed to collide elastically, and performed on the same experimental setup.

2. Experimental methods

The experimental apparatus has been previously described in detail (Salter *et al.* (2009)) and is shown in Figure 1. The experiment combines three main components. The first one is a temperature-controlled vacuum chamber, which can be cooled to liquid nitrogen temperature i.e. 77K and reach a pressure of 10^{-6} mbar. This chamber contains a collosseum which can store 180 particles prior to collisions, and is rotated until two holes are diametrically aligned to allow a collision. The second part consists in two hydraulic pistons which can be accelerated to velocities ranging from 0.1 to 0.6 $m.s^{-1}$, and "fire" the particles one towards another before retracting to their back end. The last part is a high speed camera which records pictures from the top side of the experiment, at 1000 fps.

The reference experiments are carried out with 6 mm PTFE spherical balls previously inserted in the collosseum. Ten collisions are recorded for each input acceleration of

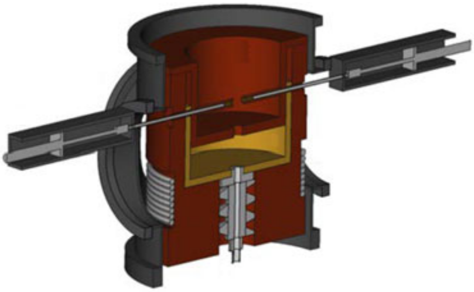

Figure 1. Computer aided design schematic of the experimental setup (adapted from Salter *et al.* (2009)).

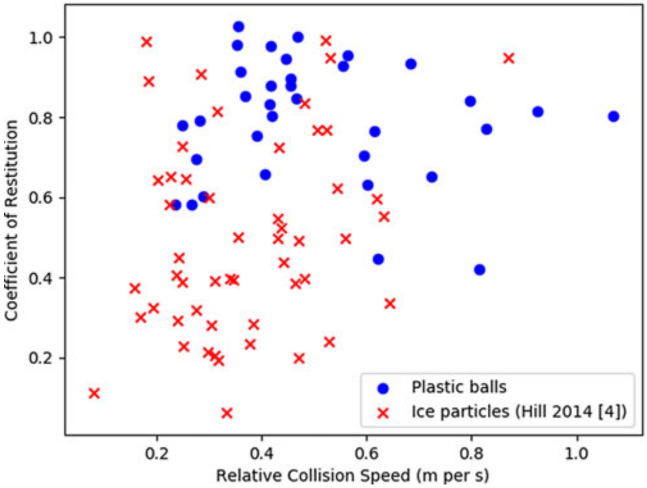

Figure 2. Coefficient of restitution obtained for plastic particle collisions (blue circles), and compared to icy particles (red crosses) (adapted from Hill *et al.* (2014))

the pistons for statistics. The collisions images are then analysed to monitor the ball position with respect to time. These positions will be analysed to obtain time-depending ball velocities before and after the collisions and calculate the coefficient of restitution (COR) given by the ratio between the relative velocities before and after the collision, and ranging from 0.1 and 1.5 m.s^{-1}.

3. Results

In Figure 2, the COR is plotted for our test plastic particles and for previous data of icy particles. As expected, the COR does not exhibit any clear dependence on the incoming velocity. The COR obtained for plastic particles ranges between 0.4 and 1.0 with a global average of 0.83 which is higher than for icy particles. From these results, we reach two major conclusions and propose perspectives accordingly.

First, the reference system exhibits slightly inelastic collisions what likely originate from the material properties of the plastic balls. Moreover, a good description of the particles depth movement of the particles or their rotation is prevented by the top-sided view of the camera; this can partially explain the increased dispersion of the results at low relative velocities. In order to solve this issue, we propose here to upgrade this experiment with a second similar synchronized camera for a better 3D reconstruction of the images.

Second, the high inelasticity of the icy particles has been confirmed thanks to the reference measurement. We propose that this energy loss could be explained by ice particles fragmentation or water evaporation.

These system improvements will allow us to precise the collisional properties of icy particles, thanks to another campaign in the laboratory and on parabolic flights in order to access various ranges of relative velocities.

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