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Experimental studies of the collisional behavior of Saturnian ring particles

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1. Introduction

Saturn's dense main rings predominantly consist of 1-cm- to 10-m-sized water ice particles. Their dynamical behavior is dominated by two counteracting effects. On the one hand gravitational perturbations of the ring particles' motion by Saturn or nearby moons and moonlets increase the eccentricity of their orbits and the thickness of the rings. On the other hand frequent inelastic collisions of ring particles at very low relative velocities (below $\sim 1\ \mathrm{cm\,s^{-1}}$) result in circularization of their orbital motion and confine the thickness of the rings to only a few meters. Additionally, the ring particles' collisions play an important role for the formation, damping and disappearance of phenomena like waves and wakes.

In this work we will present results of low-velocity collision experiments of cm-sized water ice particles mimicking the constituents of Saturn's main rings.

2. Experimental Setup

To better understand the means of energy dissipation in Saturn's dense rings we designed an experimental setup capable of colliding a large number of 1-cm-sized water ice spheres at very low relative velocities. The setup, which was built to be operated in the microgravity environment of the Bremen drop-tower facility, consist of a glass-made collision chamber of $150 \times 150 \times 15\ \mathrm{mm}^3$ with two oppositely mounted sample reservoirs attached. The entire assembly can be cooled to temperatures of about 100 K by means of liquid nitrogen. At the beginning of each experiment run the ice particles are synchronously pushed into the test cell at a velocity of $\sim 10\ \mathrm{cm\,s^{-1}}$ and, as they undergo several inelastic collisions during the 4.7 s of microgravity, the relative velocities decrease over time (Fig. 1). This effect provides an effective tool to observe encounters at very low collision velocities of only a few millimeters per second [1] as they are found in Saturn's dense rings.

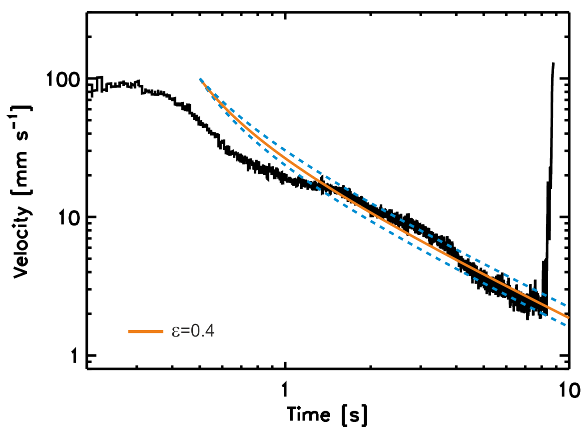

Figure 1: A preliminary analysis of the ice particles' velocities shows the equilibration phase followed by a velocity decrease. Thus collision velocities of only a few millimeters per second can be achieved.

The collisions are captured using two synchronized high-speed cameras operated at a recording speed of 1000 frames per second. They are mounted at an angle of 45° to provide three-dimensional trajectory information for all ice particles.

3. Collision Experiments

We were able to perform three different types of experiment to study the influence of varying size and mass ratios and the effect of the surface roughness, like created by a layer of regolith.

The size effects were probed by placing a larger ice body with a larger mass and radius of curvature in the center of the collision chamber. The target was either cylindrical with a radius of 50 mm (see Fig. 2) or of lenticular shape with a length of 100 mm and a width of 50 mm. Both targets had a height of 12 mm and thus, were freely movable within the test cell. The de-

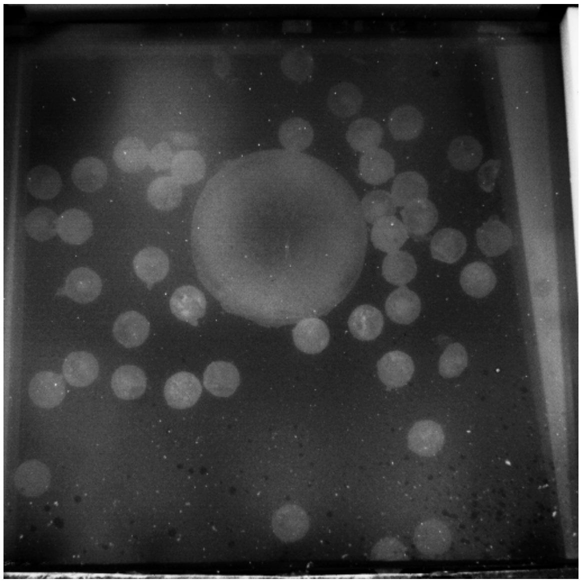

Figure 2: Snapshot of an experiment run using 1-cm-sized ice spheres and a cylindrical target of 50 mm diameter and 12 mm height.

pendency of the energy dissipation on the presence of surface regolith layers was investigated by coating the ice particles' surfaces with a silicate powder of 0.5 to 10 μm grain size. We will present measurements of the coefficient of restitution ε, namely the ratio of velocities after and before the impact, as parameter for the energy loss in encounters obtained from the binary collisions and the particle target collision for both of the studied surface properties.

Acknowledgements

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References

[1] Heißelmann, D., Blum, J., Fraser, H. J., and Wolling, K.: Microgravity experiments on the collisional behavior of saturnian ring particles, Icarus, Vol. 206, pp. 424-430, 2010.