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An experimental view on the collisional properties of particles in Saturn's rings

D. Heißelmann (1), J. Blum (1), and F. Spahn (2)
(1) Institut für Geophysik und extraterrestrische Physik, Technische Universität Braunschweig, Germany (d.heisselmann@tu-bs.de / Fax: +49-531-3915220)
(2) Institut für Physik und Astronomie, Universität Potsdam, Germany

Introduction

The Cassini mission revealed numerous structures, jets, waves, and other features in Saturn's impressive ring system. In general, models and numerical simulations are used to reproduce and explain these phenomena or derive ring parameters, such as density, particle sizes and velocities, from observations. The parameters included into the calculations must be carefully selected, in order to be able to rely on simulation results. One way of assuring the most realistic choice of input values is the comparison to benchmark experiments and the direct measurement of critical properties from laboratory studies.
In this work, we will present two recently conducted experiment series investigating both, high-speed impacts and low-velocity collisions of water ice mimicking processes in Saturn's rings.

Experiments

High-Speed Impacts

We performed collision experiments of dm-sized solid water ice spheres with a massive ice block to simulate the impact of particles in Saturn's F ring on larger moonlets. The projectile spheres were dropped from a height of ~ 120 m inside the Bremen drop tower's vacuum tube achieving impact speeds of about $45\,\mathrm{m\,s^{-1}}$. The fragmenting collisions were recorded by three high-speed, high-resolution digital cameras providing information about the spatial and temporal distribution of the ejected fragments (Fig. 1). The analysis of the particles' motion allows for the computation of their velocity and angular dispersion.

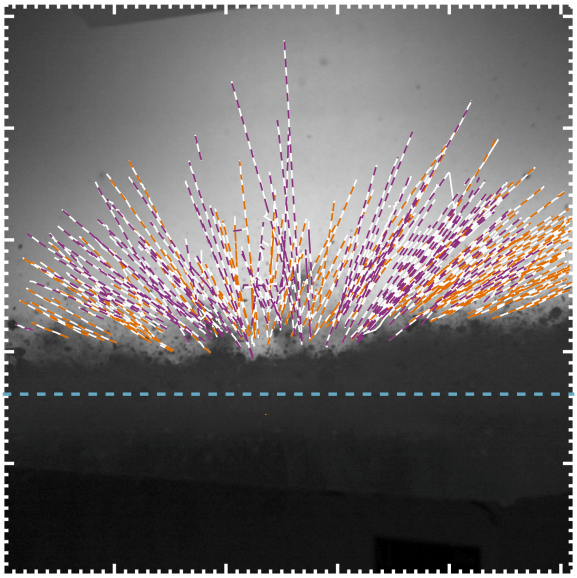

Figure 1: Trajectories of the fragments after an impact of a dm-sized water ice sphere onto a massive ice block. The horizontal line (dashed) denotes the level of the ice block's surface. The white curves show the measured tracks, whereas the orange and purple curves represent the fits to the data obtained from two perpendicluar views.

Low-velocity collisions

To study the collisional behavior of typical particles in Saturn's main rings, we build an experiment to collide ensembles of up to 100 cm-sized water ice spheres in a microgravity environment. The particles were injected into a glass-made chamber at a velocity of $\sim 10\,\mathrm{cm\,s^{-1}}$ and were recorded by high-speed, high-resolution digital cameras. From image processing the particles' positions were obtained for each image frame and the trajectories could be determined. Analysis shows that during the experiment run of approxi-

mately 9 s duration, the particle velocities rapidly decreased to values of the order of $2\,\mathrm{mm\,s^{-1}}$ due to frequent inelastic collisisions. The velocity distribution of the ensemble can be treated statistically (Fig. 2), providing a mean value for the coefficient of restitution (the ratio of velocities after and before an impact) of $\varepsilon \approx 0.4$. This value is in agreement with the value obtained in previous microgravity experiments at higher velocities [1]. Additional analysis of individual collisions yield the total range of coefficients of restitution as well as their dependence on the impact geometry.

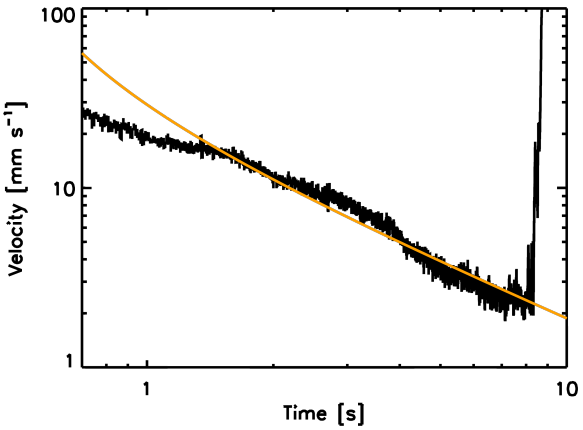

Figure 2: The statistical treatment of the particle velocities as a function of the expeiment duration shows a decrease that can be explained by a mean coefficient of restitution of $\varepsilon \approx 0.4$ (orange curve).

Additionally, in some collisions sticking of two icespheres to each other could be observed.

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.