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The footprint of cometary dust analogs in the lab: comparison with Rosetta data

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Abstract

The structure of cometary dust provides a window on growth mechanisms in the early solar nebula. Measurements made by the Rosetta spacecraft of the coma dust population of comet 67P/Churyumov-Gerasimenko show particles up to a few hundred μm in size to have a granular structure. However, these dust particles are likely to have been modified during their collection by the spacecraft instruments. In this contribution, we will present the results of a series of experiments to simulate the impact of dust aggregates onto the detector surfaces of the Rosetta COSIMA and MIDAS instruments. These experiments provide a tool to retrieve the structure of cometary dust before it entered the spacecraft. We find that in most cases only part of the particle sticks, and velocity is the main driver for the appearance of deposits. Extending this conclusion to the Rosetta data implies that COSIMA and MIDAS measure only part of the initial particle, and that the same species of particle may produce a variety of morphologies. In a second series of experiments, we varied the size distribution of the silica dust particles. We find that in order to reproduce the rubble pile-like structure observed by the Rosetta instruments, the presence of small monomers is needed.

1. Introduction

Comets are considered to be the most pristine bodies in the solar system that survive to this day. They were formed in a range of environments within the protoplanetary disk, and their structure contains traces of dust growth mechanisms [1].

Measurements by the Rosetta spacecraft have returned images of the dust in the coma of comet 67P/Churyumov-Gerasimenko. These particles, up to a few hundred μm in size, are seen to have a granular structure up to sub-μm scale [2, 3]. Also, different morphologies of particles are detected. COSIMA detects two different families of deposits; 'single' deposits of intact agglomerates, and rubble-pile-like deposits consisting of a loose array of smaller elements [4]. A key question is whether these two groups are dust types with an intrinsically different substructure, or that their different appearance only depends on the velocity and subsequent breakup of their parent particles. To find the answer to this question, and to derive the makeup of their parent particles, experiments are needed.

2. Methods

Dust aggregates are mechanically launched within a vacuum chamber onto replicas of the COSIMA and/or MIDAS target plate, using a parameter space in size and velocity that overlaps the results found by Rosetta instruments. We use synthetic SiO_2 aggregates whose size, velocity and bulk density are comparable to cometary dust aggregates. The impact of particles is monitored by a high-speed camera, and the resulting deposits on the targets are studied with the COSIMA and MIDAS flight spares so as to allow a direct comparison to the spacecraft data. Additional imaging at higher resolution with optical and laser confocal microscopes provides a further tool to interpret structures seen on Rosetta data not accessible to the resolution limit of the spacecraft instrument.

We will present the results of two series of experiments, using aggregates of sizes in the range 30 – 400 μm consisting of different test material:

1. SiO_2 aggregates consisting of amorphous monomers with a polydisperse (0.5-10 μm) size distribution (Ellerbroek et al., submitted to MNRAS)

2. SiO_2 aggregates consisting of spherical monomers with a monodisperse size distri-

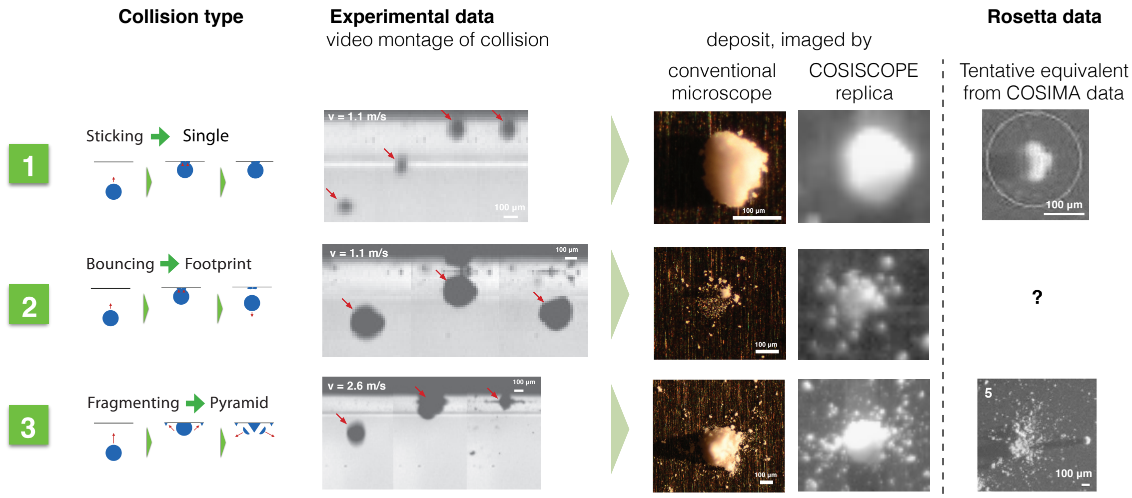

Figure 1: Summary of three cases of collisions of aggregates of polydisperse SiO_2 on COSIMA targets, and their comparison with COSIMA data.

bution (three samples: 0.3, 1.0 and 1.5 μm) (Ellerbroek et al., in prep.)

3. Results

Figure 1 displays a summary of the different cases of collisions on COSIMA targets observed at different velocities, and the deposits left on the target surface. The results are consistent earlier experiments of collisions of silica aggregates [5], although this is the first study to describe and quantify the deposits on the target plate.

Three collision types are seen to occur:

- Sticking - small ($< 80\mu$m) particles at velocities < 2 m s^{-1}: the entire particle sticks to the target surface;
- Bouncing - large ($> 80\mu$m) particles at velocities < 2 m s^{-1}: the bulk of the particle stays intact and bounces off the target surface, leaving a shallow footprint of small fragments;
- Fragmenting - particles at velocities > 2 m s^{-1}: the particle fragments, leaving a deposit with a pyramid-shaped core surrounded by smaller fragments on the target surface.

Qualitatively, different morphologies observed by COSIMA [2] can be produced in our experiments. The 'shallow footprint' left on the targets after a bouncing collision has no apparent equivalent in the COSIMA data.

The result of the second series of experiments with a varying range of monomer sizes confirms the theoretical prediction that particles with smaller monomers have a higher internal strength. As a result, the amount of mass transferred onto the target scales negatively with the aggregate size. This result implies that in order to produce the morphologies detected by COSIMA, a mixture of large and small size elements is needed.

4. Summary and work in progress

We have conducted experiments where silica aggregates of different porosity were impacted onto detector surfaces of the COSIMA and MIDAS instruments. Different morphologies detected by the Rosetta instruments were qualitatively reproduced by varying only impact velocity. In subsequent experiments, material properties will be varied further, so as to refine the interpretation of cometary dust measurements.

References

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