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Strength of cometary particles on the nano- to micrometer scale. Force-curve analysis of MIDAS data

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Abstract

The MIDAS atomic force microscope on board the Rosetta orbiter studied dust particles which provide an insight into cometary properties and cometary formation in the early Solar System. Here the first results of a special measurement mode which allows the strength of the collected dust to be probed at the nano- to micrometer scale will be presented. This technique enabled us to generate the first force-displacement curves ever measured for cometary material.

1. Micro-Imaging Dust Analysis System

To achieve a better knowledge about the properties of the early solar nebula, untouched dust particles which are assumed to be found on comets need to be analysed. The purpose of MIDAS is to study the size, shape, morphology and physical parameters of these cometary dust particles emitted from the nucleus.

MIDAS runs in two different operation modes. Primarily, it operates as an amplitude modulated atomic force microscope in the so called dynamic mode [1].

Furthermore, MIDAS can be used to analyse the physical properties of a dust sample by recording the force-displacement curve throughout an image in the contact mode. The contact mode is especially important for the calculations carried out in this project. In the contact mode the cantilever is statically lowered towards the target and its physical deflection is measured as a value of voltage. As the cantilever hits a dust particle and starts to bend, it exerts a pressure on the dust particle which is proportional to the deflection. The cantilever is further lowered until the dust particle breaks, rolls or gets maximally compacted. These different types of interaction between tip and dust correlate with different shapes of the force curves. To validate the results, scans from before and after the measurement are generated by using the dynamic mode.

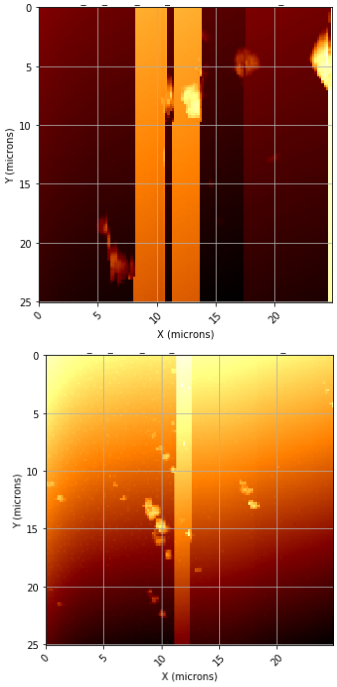

Figure 1: MIDAS scans generated with the dynamic mode immediately before (on top) and after (below) a contact mode scan. The grid has a step size of 5 micrometers in x and y direction.

2. Force measurements

To generate a force curve from the voltage values the Hooke's law is applied [4].

$$F = kx$$

Therefore, the spring constant k and the deflection of the cantilever as a distance x have to be known. The spring constant depends on the used cantilever. In this case the spring constant was derived by using the geometry and the input of the resonance frequency.

3. Interpretation and future goals

A few of the significant force curves are displayed in figure 2. It is possible to divide the force curves into various families which are based on different formation processes. For instance, the red curve, family A, indicates a process of compacting and, at a maximum force, the breaking of a particle. The blue curve, family B, suggests a rather different process. Here the particle most probably rolled away or the tip of the cantilever hit the particle at the edge and pushed it away.

The goal is to derive the physical properties of the dust samples from the force curves we can generate. Therefore, the forces between the subunits of a dust particle must be described. Two models which can be considered for the characterization of the contact between two solid spheres are the JKR model [3] and the DMT model [2]. As a result, the tensile strength, which is needed to separate two adhering subunits of a particle, shall be obtained.

Acknowledgements

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References

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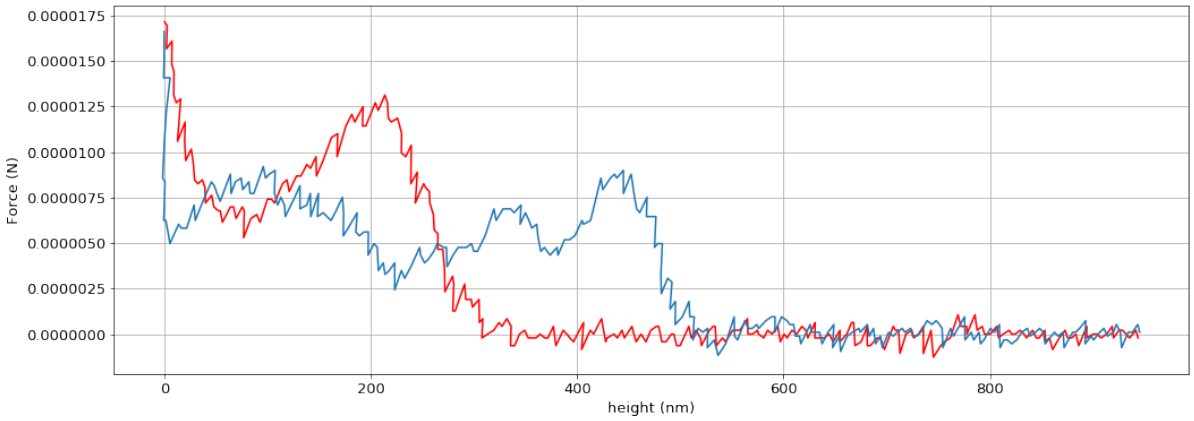

Figure 2: Two Force curves generated from a contact mode scan by MIDAS. The curves display different processes of tip-dust interaction and can be used to obtain a better knowledge about the physical properties of the cometary dust.