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Abstract

The properties of the smallest sub-units of cometary dust contain information on their origin and clues to the formation of planetesimals and planets. The MIDAS Atomic Force Microscope (AFM) on-board the ESA Rosetta orbiter collected dust in the coma of comet 67P/Churyumov-Gerasimenko. These particles, collected at low velocities, were analysed to measure the structural properties of minimally altered material with a known origin. This can be used to further the investigation of our early Solar System.

A novel method is presented to achieve the highest spatial resolution of imaging possible with the MIDAS instrument. 3D topographic images with resolutions of down to 8 nm are analysed to determine the sub-unit sizes of particles on the nanometre scale.

1. Introduction

An AFM works by scanning a sharp tip over the surface of a sample, usually in dynamic mode in which the tip is vibrated such that it “taps” the sample. By sensing the change in amplitude of the tip as it interacts with the sample in a feedback loop, a three-dimensional image of the surface is constructed. In this way MIDAS could repeatedly scan targets previously exposed to the dust emitted from comet 67P.

Analysis of MIDAS data published so far have concentrated on the larger, ten micrometre class, particles [1, 2]. This work investigates the smaller, micron-sized particles and their constituent sub-units [3].

1.1 Reverse tip-imaging

AFM images are always a convolution of the sample under analysis and the shape of the tip. Thus a limiting factor in MIDAS imaging of the (sub-) structure of cometary dust is the finite opening angle of the tip. To overcome this limitation, a reverse tip-imaging procedure was used for this analysis. This took advantage of an on-board calibration target which consisted of an array of many spikes, each considerably sharper (but much shorter) than the AFM tips themselves. Originally designed to image the shape of the tips and study their degradation, these spikes were used to study dust particles that had adhered to the tips during previous scans. Since the calibration spikes were sharper than the AFM tips, a considerably higher resolution was available.

2. Results

Shown in Figure 1 is one such particle and the classification of both distinct larger features (left) and smaller surface features or sub-units (right).

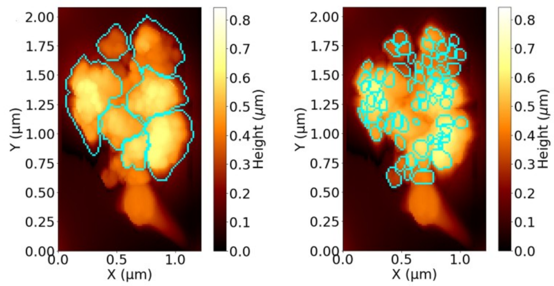

Figure 1: MIDAS topographic image of dust stuck to an AFM tip with its major units (left) and surface structure/sub-units (right)

The unmarked feature at the bottom of the image is the apex of the AFM tip itself, whilst above this a dust particle adhering to the tip is imaged. This particle has a high probability to have been emitted from comet 67P during its perihelion passage, and picked up by the tip during subsequent scanning. Due to limitations of the technique, not all of the surface features can be completely mapped. Nevertheless, a cumulative size distribution of the marked sub-units was produced. Their differential size distributions follow a log-normal distribution with means about 100 nm and standard deviations between 20 and 35 nm as shown in Figure 2.

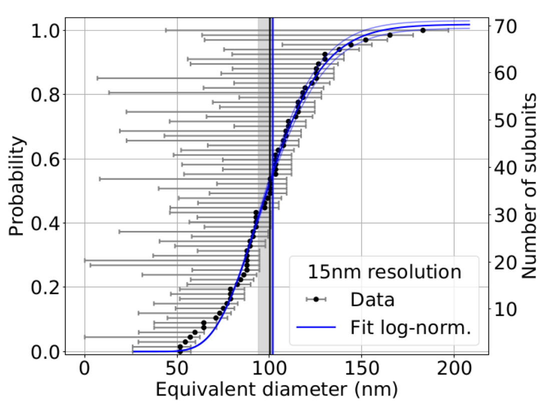

Figure 2: Cumulative size distribution of the sub-units identified in Figure 1 (right). The vertical lines are the arithmetic (black) and fitted (blue) mean values.

3. Summary

The size distributions of the smallest detected surface features were determined, where the differential size distribution was found to follow a log-normal distribution with a mean of about 100 nm and a standard deviation between 20 and 35 nm. The sub-unit sizes are in agreement with indirect measurements of other Rosetta instruments. If the sub-units found in Stardust material or ultracarbonaceous Antarctic Micrometeorites follow similar size distributions is in the range of possibilities and should be investigated in future projects. Chondritic Porous Interplanetary Dust Particles (CP IDPs) show a sub-unit arrangement, shape and size distribution similar to dust of comet 67P which further strengthens the link between comets and CP IDPs. It also indicates that the smallest, 100 nm sized features detected by MIDAS might indeed be subunits, however, it remains uncertain if they represent the fundamental building blocks of comet 67P.

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