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Morphology of Cometary Dust at the Nanometre Scale Detected with MIDAS

Roland Schmied[1], Thurid Mannel[1,2], Klaus Torkar[1], Harald Jeszenszky[1], Jens Romstedt[3], Mark Stephen Bentley[1]

[1.] Space Research Institute, Academy of Sciences, Graz, Austria
[2.] Physics Institute, University of Graz, Universitätsplatz 5, 8010 Graz, Austria
[3.] European Space Research and Technology Centre, Future Missions Office (SREF), Noordwijk, Netherlands.

Prior to the European Space Agency's Rosetta mission, which is revolutionizing our understanding of comets, investigation of cometary dust was primarily carried out by remote observation and brief in-situ (fly-by/impact) measurements and sample return missions. Cometary dust is often considered to comprise low density (porous) aggregates with complex shapes. Evidence for this comes from i) interplanetary dust particles (IDPs) collected in the Earth's stratosphere, some of which are likely from comets, ii) analysis of polarimetric observations and iii) the (highly modified) dust collected by the Stardust mission. The latter provided the first opportunity to investigate cometary dust from a known source on Earth. Although the finest fraction of the particles were heavily modified, Stardust nonetheless showed large compositional and structural heterogeneities – most collected dust grains being composed of many different sub-grains [1,2]. Rosetta offers the opportunity to further characterize highly pristine cometary dust, but extends this to the smallest particles.

Rosetta carries several instruments dedicated to the local study of dust and its evolution, but MIDAS [3] is a unique instrument designed to derive the detailed size, shape, texture and microstructure of cometary dust in-situ with nanometre resolution using the technique of atomic force microscopy (AFM). It is the first such instrument launched and operated in space. Dust is collected via a funnel and collimator onto sticky targets during passive exposures and imaged by AFM, resulting in the 3D topography of the sample [3]. Since the typical relative velocities of Rosetta with respect to 67P are low (less than m/s [4], orders of magnitude below the Stardust relative velocity in the range of km/s), dust particles are expected to be only minimally modified by the collection process.

MIDAS detected some tens cometary dust particles during the collection period of September 2014 to the end of March 2015. The sizes of these particles range from a few tens of micrometres down to hundreds of nanometres, which is far below the resolution of other dust instruments on Rosetta. Morphological analysis reveals that the particles can be divided into different types, representatively shown in figure 1. Large agglomerates (with sizes approaching the technical scan size limitation of several tens of micrometres) have been detected [5] with different packing densities, ranging from rather compact to more porous, see figure 1 (a) as representative example of a two rather compact particles. Small fragments surrounding these particles strongly suggest particle fragmentation during impact or during the scanning process, which indicates a rather fragile nature of these dust particles. This effect leads to a limited number of scans per particle before it is broken or removed [5], which can be seen in figure 1 (b) showing the change after the first scan in figure 1 (a). Also the large number of vertical distortions in figure 1 (a) is a strong indication for a particle modification during the scanning process. In addition to these large, fragile particles, smaller particles in the range of a micrometre have also been imaged, see figure 1 (c). Their structure seems to be more compact and less fragile; little to no fragmentation has been observed amongst this population.

It can be concluded that the first in-situ measurements of cometary dust particles below the optical resolution limit reveal various different structures. Tens of micron sized particles tend to be more fragile and porous than the micron-sized particles. Furthermore the dust particles are so fragile, that a certain particle modification due to the impact and/or scanning cannot be excluded, even though the impact velocities are by orders of magnitude lower compared to former cometary dust collection missions.

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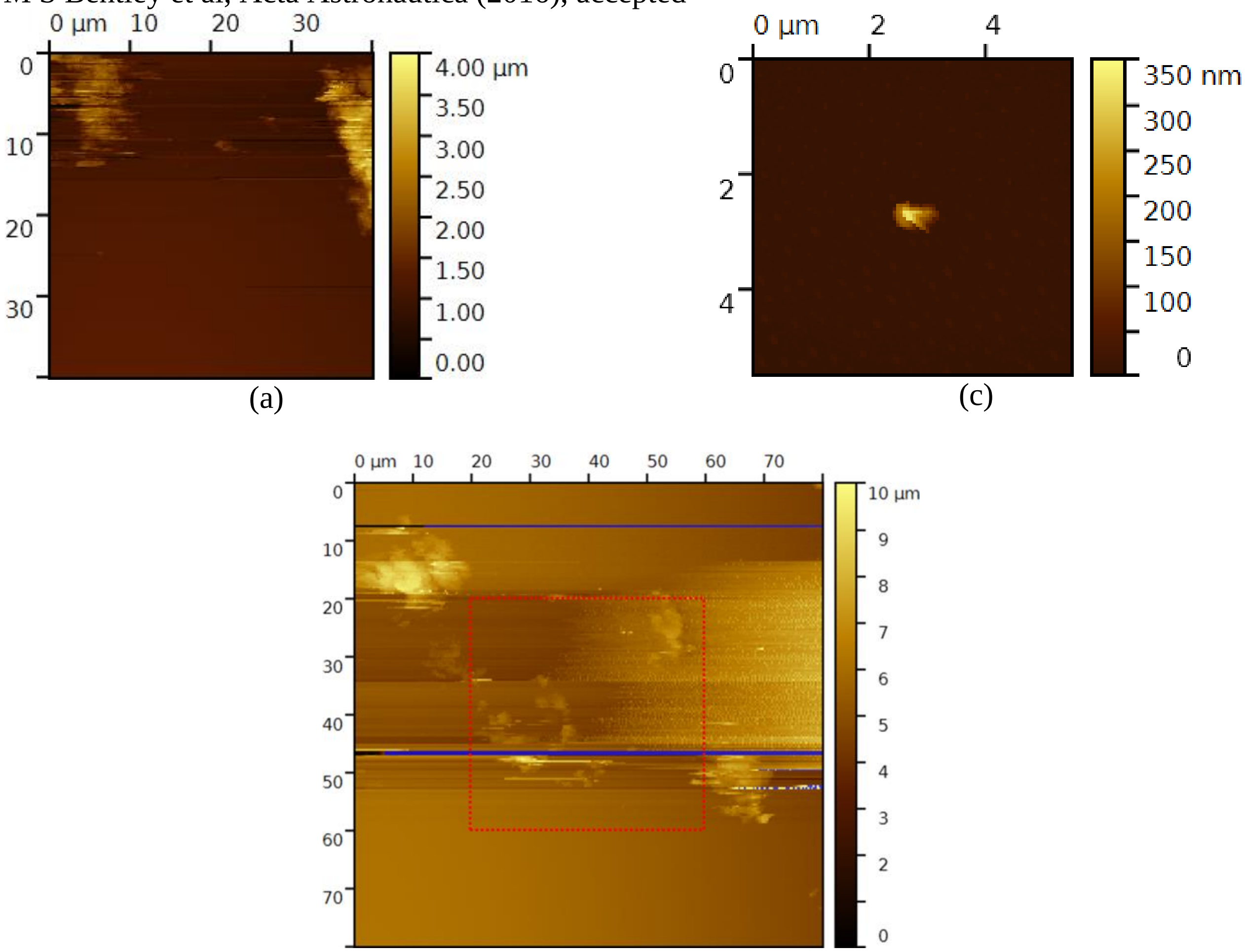

(b)

Figure 1. (a) First topography scan of two rather compact particles revealing their visible sizes in the range of a few tens of micrometres and heights of up to 4 micrometres. (b) Re-scan of the particles in (a) (red dotted square marks the original position with a possible positional inaccuracy of a few micrometres [5] – blue lines are showing aborted line scans) with extended scan size showing the particle modification and even more distortion. (c) Representative example of an sub-micron sized particle with approximately 350 nm height revealing tip convolution to the bottom right to get important at those sizes.

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