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How MIDAS improved our understanding of micrometre-sized cometary dust

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Abstract

The MIDAS atomic force microscope on the Rosetta orbiter was an instrument developed to investigate, for the first time, the morphology of nearly unaltered cometary dust. It acquired the 3D topography of about 1 - 50 µm sized dust particles with resolutions down to a few nanometres. These images showed the agglomerate character of the dust and confirmed that the smallest subunit sizes were less than 100 nm. MIDAS acquired the first direct proof of a fractal dust particle, opening a new approach to investigate the history of our early Solar System and of comets.

1. Introduction

As comets are considered the least altered bodies in our Solar System, the properties of their building blocks are key parameters in understanding our early Solar System and its evolution. Remote observations, fly-by missions and sample return have provided a foundation for our knowledge about cometary dust particles, which has been tested and greatly extended by the dust instruments onboard Rosetta, namely COSIMA, GIADA and MIDAS. The latter was a novel instrument selected to investigate the morphology of micro- to nanometer sized particles collected around the comet. Being able to collect the least altered cometary dust particles from a known body, MIDAS gave a first view of the morphology at the smallest scales. This paper summarises advances in the understanding of the smallest cometary dust with focus on the findings of MIDAS and suggests possible directions for future research.

2. The MIDAS atomic force microscope

MIDAS was designed to make the first *in situ* atomic force microscope (AFM) measurements of cometary dust to address key questions about the size, shape, texture and morphology of the smallest particles [1]. It collected dust by exposing specially coated silicon targets to the dust flux coming from comet 67P/Churyumov-Gerasimenko and imaged the particles with an AFM [1,2]. The key data were 3D topographic images with nano- to micrometre resolution which gave the first view on the smallest, nearly pristine, cometary particles.

3. Post-Rosetta knowledge

Pre-Rosetta models of cometary dust predicted that cometary dust at the (sub-)micrometre scale would fall in two groups: compact particles and porous agglomerates [3,4]. Contrary to these expectations MIDAS only found an agglomerate character at all size scales and for all collection periods. The particle surfaces show clusters of small, bulbous subunits. These characteristic features can also be found for the order of magnitude larger dust particles collected with the COSIMA instrument at comet 67P [5] and for the most primitive interplanetary dust particles (IDPs) collected in Earth's atmosphere [2]. However, in contrast to IDPs, MIDAS observed no evidence of euhedral crystalline structures. The larger dust particles show an extreme fragility, which often leads to fragmentation during AFM scans. None of the particles broken apart in this way showed an interior structure different from that observed on the surface, suggesting that most of the tens of micron-sized cometary particles are indeed agglomerates throughout. Despite this commonality, dust at 67P falls in two groups. The majority shows an arrangement of the subunits with a medium packing density. However, due to the gentle dust collection at Rosetta, one extremely porous particle was detected. Its structure was found to be fractal with a dimension of 1.7 ± 0.1 [6]. As the existence of a majority of denser dust particles and a minority of fractal dust was confirmed by the GIADA instrument [7], comet

67P is suggested to consist mainly of the denser dust particles, where the voids between them can be filled by fractals [8]. The latter structure is characteristic of early dust agglomeration in the protoplanetary disc but is thought to be compacted to denser, non-fractal dust before inclusion in comets. The existence of fractals nevertheless strongly constrains the dust environment in the early Solar System and the evolution of the comet [9]. This theory is supported by the surprisingly similar subunit sizes of the fractal and more compact particles. The smallest subunits comprising the agglomerates are less than 100 nm in size [10]. However, these measurements appear to be still limited by instrument resolution and the presence of smaller dust grains cannot be excluded.

A further surprise was the size of the collected dust. The number of collected particles was estimated by optical observations and data from the Halley fly-by, which had large uncertainties for the flux of the small, micro- to nanometre sized particles [1]. However, it was always expected that in a given period more small than large dust particles would be collected. Surprisingly, this was not the case; MIDAS detected several particles larger than about tens of micrometres, but only few with micrometre size and none at smaller sizes [2]. To date it is not clear if the dust size distribution of comet 67P is depleted in particles smaller than some micrometres, or if there was a bias preventing their detection (e.g. spacecraft charging).

4. Conclusions and possible directions for future research

MIDAS acquired a unique dataset revealing the morphology of dust particles with sizes between about 1 and 50 µm at resolutions of 8 to 1500 nm per pixel. The expectation of porous agglomerate dust particles with subunits having sizes down to less than 100 nm was confirmed. A new approach to decipher the processes in our early Solar System and its evolution might be found in the shape of the fractal dust population. The lack of individual compact particles, the absence of clear euhedral structures, and the low flux of particles smaller than a few micrometres were surprising and are not yet fully understood. As MIDAS data has not yet been exhaustively analysed, it still holds the potential to reveal a wealth of cometary dust properties as, e.g., its material strength or the detection of magnetic inclusions. Further open questions concern the true end of the smallest subunit sizes, and the internal structure of the particles. Answering these would further define processes in the early Solar System, and help to understand cometary physics like, e.g., the comet's internal structure, heat transport, and the to date unclear mechanism leading to dust ejection.

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References

[1] W. Riedler, et al., MIDAS The Micro-Imaging Dust Analysis System for the Rosetta Mission, Space Sci. Rev. 128, 2007.

[2] M.S. Bentley, et al., Aggregate dust particles at comet 67P/Chruyumov-Gerasimenko, Nature, 537, 2016.

[3] A.C. Levasseur-Regourd, et al., Physical properties of cometary and interplanetary dust, Planet. Space Sci. 55, 2007.

[4] A.T. Kearsley, et al., Dust from comet Wild 2: Interpreting particle size, shape, structure, and composition from impact features on the Stardust aluminum foils, Meteorit. Planet. Sci. 43, 2008.

[5] Y. Langevin, et al., Typology of dust particles collected by the COSIMA mass spectrometer in the inner coma of 67P/Churyumov Gerasimenko, Icarus, 271, 2016.

[6] T. Mannel, et al., Fractal cometary dust – a window into the early Solar system, MNRAS, 462, 2016.

[7] M. Fulle, et al., Comet 67P/Churyumov-Gerasimenko preserved the pebbles that formed planetesimals, MNRAS, 462, 2016.

[8] J. Blum, et al., Evidence for the formation of comet 67P/Churyumov-Gerasimenko through gravitational instability of a pebble cloud, submitted to MNRAS, 2017.

[9] M. Fulle and J. Blum, Fractal dust constrains the collisional history of comets, MNRAS, in press, 2017.

[10] M.S. Bentley, et al., On the building blocks of cometary dust, submitted to MNRAS, 2017.