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Primitiveness of cometary dust collected by MIDAS on-board Rosetta

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Comets are thought to have preserved dust particles from the beginning of Solar System formation, providing a unique insight into dust growth mechanisms. The Rosetta mission offered the best opportunity to investigate nearly pristine cometary dust particles of comet 67P/Churyumov–Gerasimenko. Among the three in-situ dust instruments, the MIDAS (Micro-Imaging Dust Analysis System) atomic force microscope collected cometary dust particles with sizes from hundreds of nanometres to tens of micrometres on dedicated targets and recorded their 3D topographic information (Bentley et al. 2016a). However, the straightforward dust collection strategy, i.e., simply hitting the collection targets, leads to an unknown degree of collection alteration (Bentley et al. 2016b)

We aim to understand and determine which structural properties of the MIDAS dust particle remained pristine during collection. First, we generate sophisticated dust maps showing the distribution of the dust particles on the collection targets and investigate dust clustering, i.e., determination of which particles stem from a single parent particle that fragmented upon the collection impact. Additionally, in the collaboration with Longobardo et al. 2020a, we use an algorithm to determine from which cometary source regions which MIDAS particles were stemming (Longobardo et al. 2020b). Next, we develop MIDAS particle shape descriptors such as aspect ratio (i.e., height of the particle divided by the square root of area), elongation, circularity, convexity, and particle surface/volume distribution. Furthermore, we compare structures of the MIDAS dust particles and clusters to those found in the laboratory experiments (Ellerborek et al. 2017) and by COSIMA/Rosetta (Langevin et al. 2016). Finally, we combine our findings to calculate a pristinity score for MIDAS particles and determine the most pristine particles and their properties.

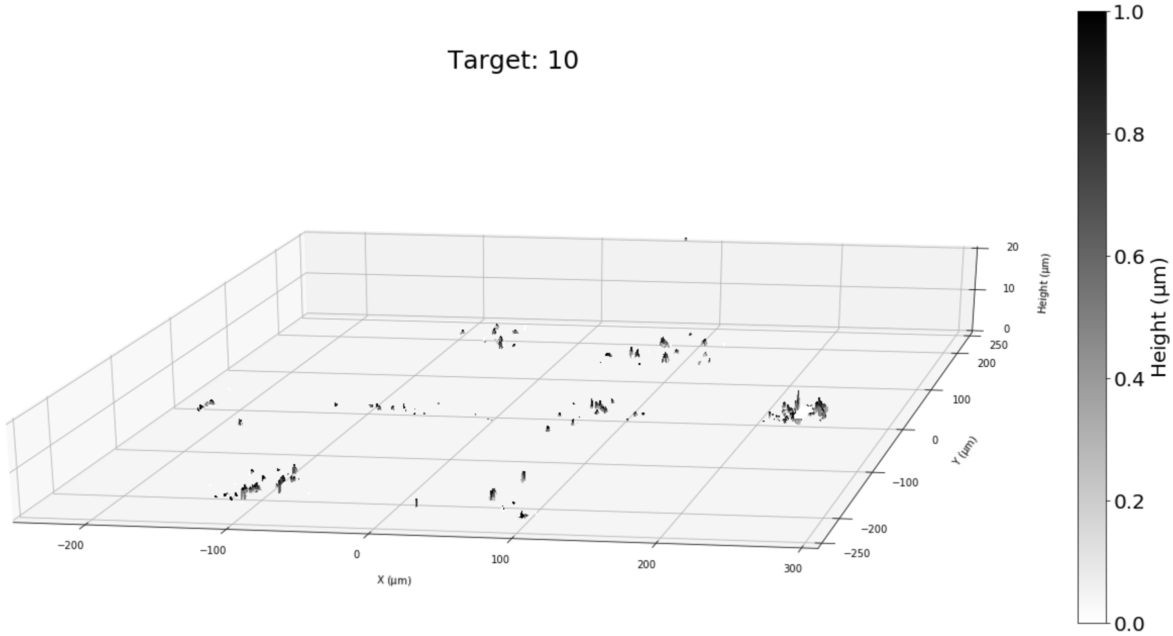

Fig 1. 3D dust coverage map of target 10

We find that there is only a weak trend between shape descriptors and cometary source regions, cluster morphology, and particle characteristics. For example, particles ejected from smooth or rough terrain are similar in their shape properties, which implies that dust particle activity such as dust ejection, partial dry out, and backfall are not responsible for the structure of particles at micrometre scales. Furthermore, the aspect ratio distributions suggest that the subunits of different cluster types are similar in their shape and composition. Thus, the different cluster morphologies detected by MIDAS are not created by a change in subunit properties, but rather by different impact velocities (Lasue et al. 2019). Next, the types of clusters found in MIDAS show good agreement (Ellerbroek et al. 2017), however, there are some differences to those found by COSIMA (Lasue et al. 2019). Furthermore, we found that almost half of the MIDAS particles suffered severe alteration by impact, which indicates dust alteration was inevitable with the given dust collection strategy. Consequently, only ~ 20 particles were rated 'moderately pristine' particles, i.e., not substantially flattened by impact, not fragmented, and/or not part of a fragmentation cluster. The microphysical properties of pristine cometary materials are established in this study and can be translated into properties of laboratory analogue materials for future study.