Cometary dust at the nm scale from the MIDAS AFM

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The MIDAS AFM

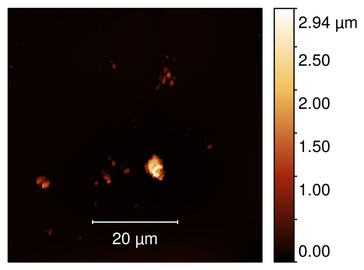
MIDAS is a combination of a dust collection and handling system and an amplitude modulated atomic force microscope (AFM). An AFM works by gently tapping the surface of a solid sample with a sharp tip, and by rastering this tip across the surface builds an 3D image of cometary dust particles.

Since first exposing targets on arrival at comet 67P, MIDAS has collected and imaged several hundred "pieces" of cometary dust. Some are unique particles, some are fragments generated on or shortly before impact, and some are created by fracturing of larger particles during scanning.

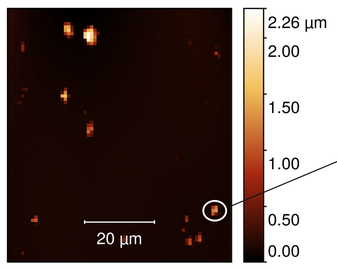
Fewer smaller (< 1 µm) particles than expected have been collected, due to both a shallow size distribution and spacecraft and dust charging effects. In addition, dust has also been collected whose large size pushes the limits of what is possible with MIDAS. A set of selected scans is shown here, emphasising the variety of collected dust size and morphology.

Key results so far include the finding that most dust appears to be aggregates down to the smallest scales, and that the grain tensile strength must be rather low for breakage to occur during scans.

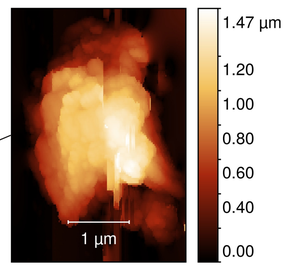
Selected results



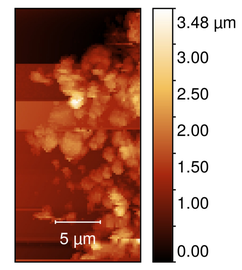
A recent scan showing micron-sized dust collected in the 09/02/15 outburst. The pixel resolution in this image is 313 nm. The search for more dust and high resolution images are planned for the coming weeks!



An example "low" resolution (938 nm/pix) scan from which features are recognised and autonomously zoomed (see next image). Criteria based on shape, height and size can be applied.

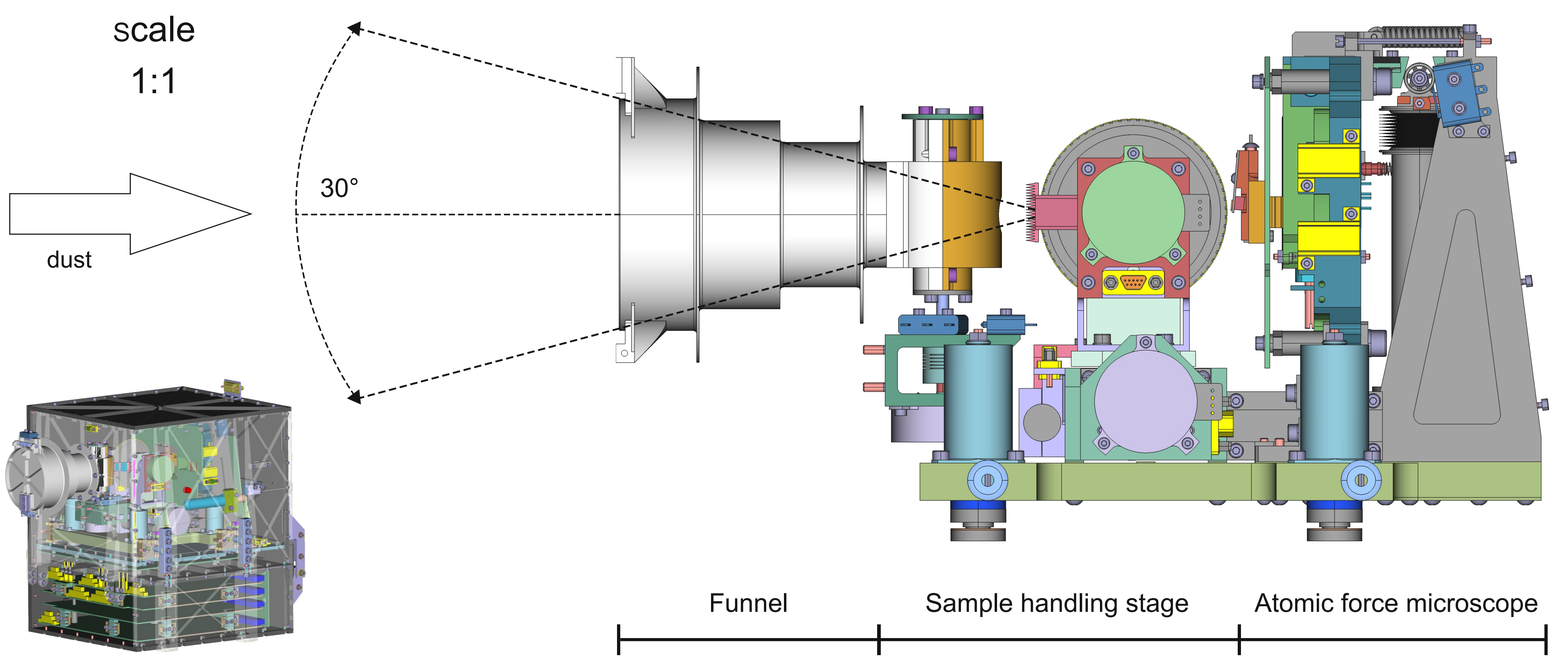


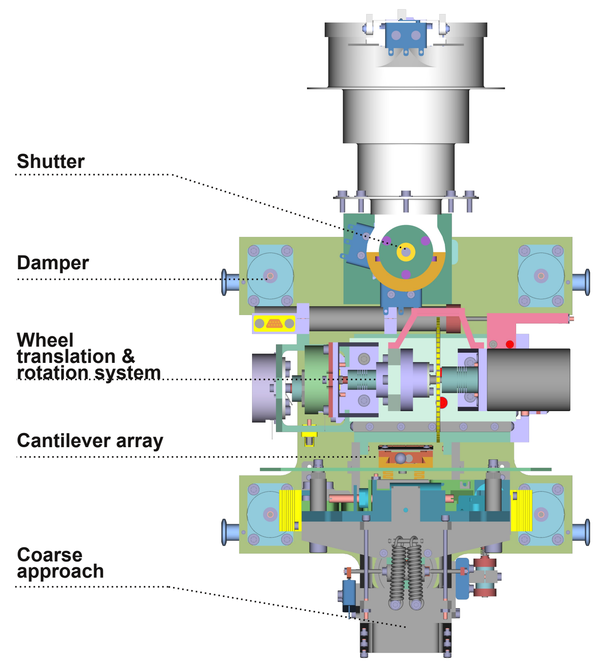
The subsequent high resolution (15 nm in X, 29 nm in Y) zoom showing a highly textured grain surface. This grain is probably a fragment of a larger dust particle.



Part of a large aggregate particle, with a structure strikingly similar to interplanetary dust particles. This particle was probably much larger, but broke apart during scanning.

The instrument in detail





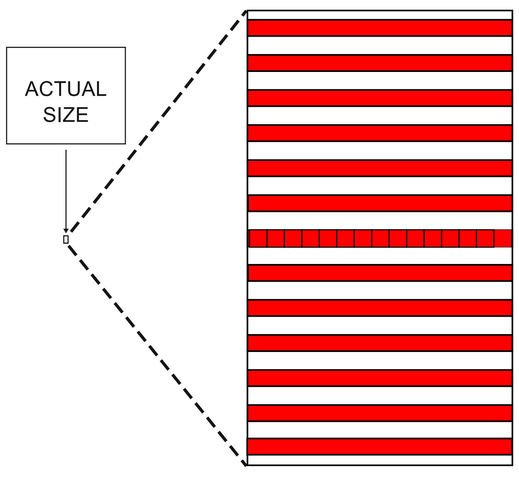
Consumables

Targets

64 targets are available (3 calibration, 4 silicon, 57 solgel coated). Each target is 1.4 x 2.4 mm. About half of the target can be scanned with the AFM (red stripes), and the maximum area which can be imaged in a single scan is shown by the black squares.

Three calibration targets allow the microscope to be calibrated in X/Y, in Z (height) and to show the tip shape.

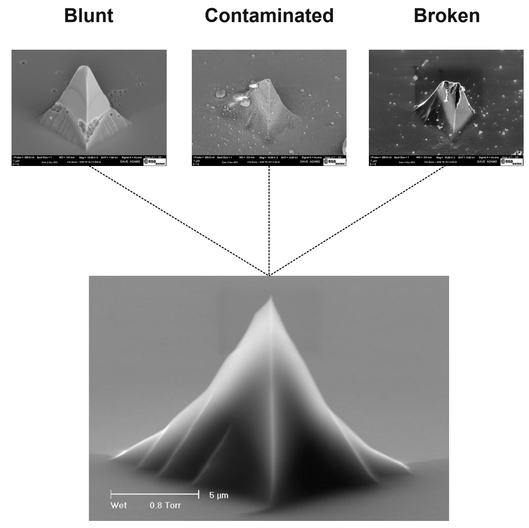
Before exposure, an appropriate area of the target must be pre-scanned at various resolutions to ensure unambiguous detection of cometary material (see panel below).



Tips

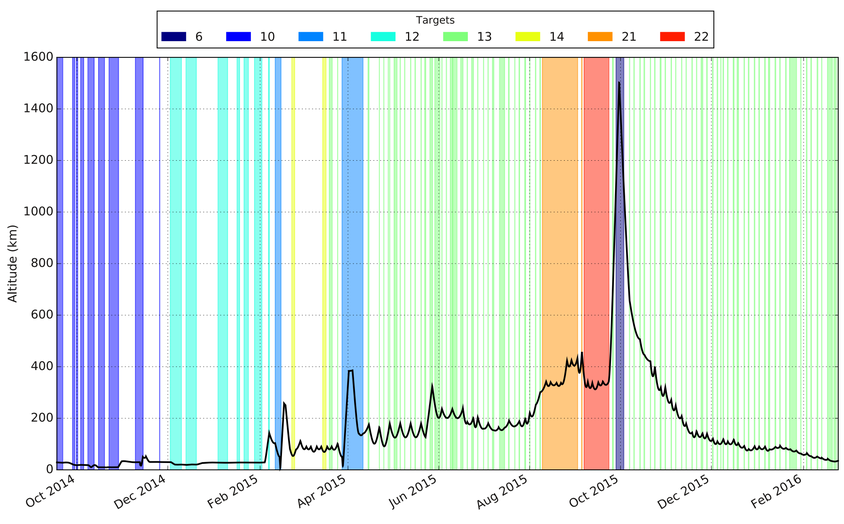
MIDAS has 16 redundant sharp tips. Four are magnetised and can be used to search for and map out magnetic minerals. During scanning the tips can become worn, break, or are contaminated by cometary dust itself. The SEM images shown here demonstrate this process on the MIDAS Flight Spare.

A calibration target allows the state of the tip to be checked at any time. This process actually allows images of the contaminating dust particles to be acquired at very high resolution! Attempts can then be made to remove the contaminant by vibrating the cantilever at its resonance frequency. If this is not possible, the convolution of tip and sample shape must be considered.

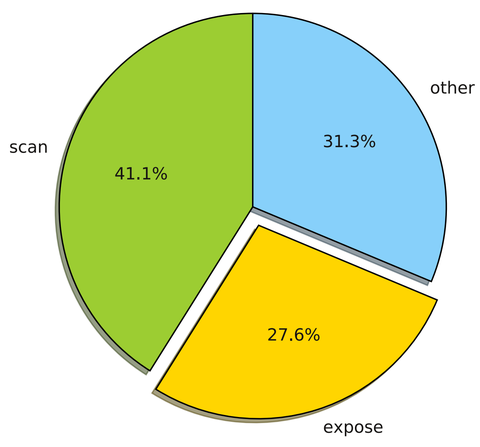


Pristine tip

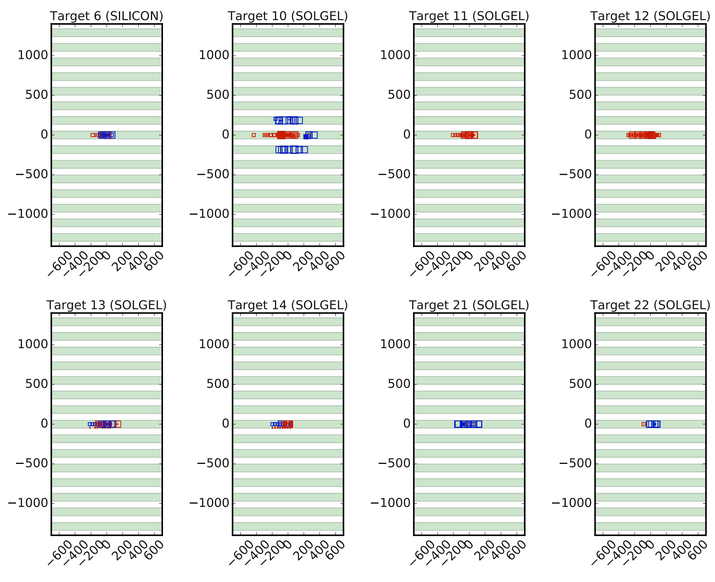
Vital statistics



Exposures per target overlayed on the Rosetta/comet distance



Fraction of time scanning or exposing (arrival to 03/16)



Schematic showing the area of exposed targets scanned to date