Graz in Space 2012
6.-7. September

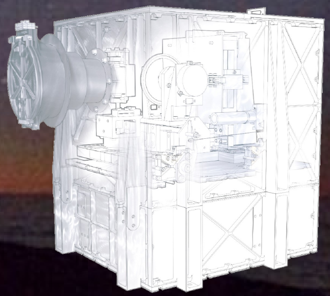
Rosetta, MIDAS and cometary dust

Mark S. Bentley, K. Torkar, H. Jeszenszky, J. Romstedt

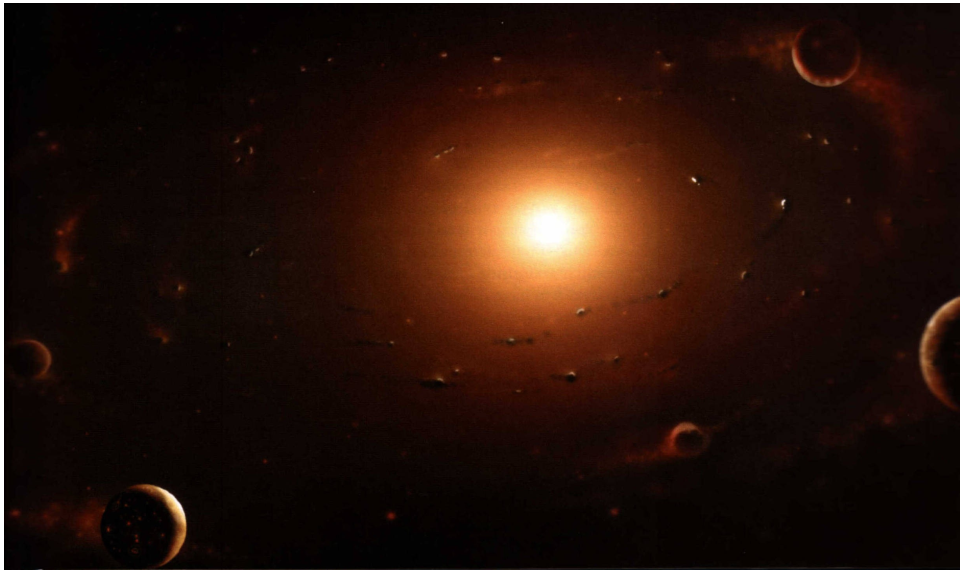
(mark.bentley@oeaw.ac.at)

Space Research Institute

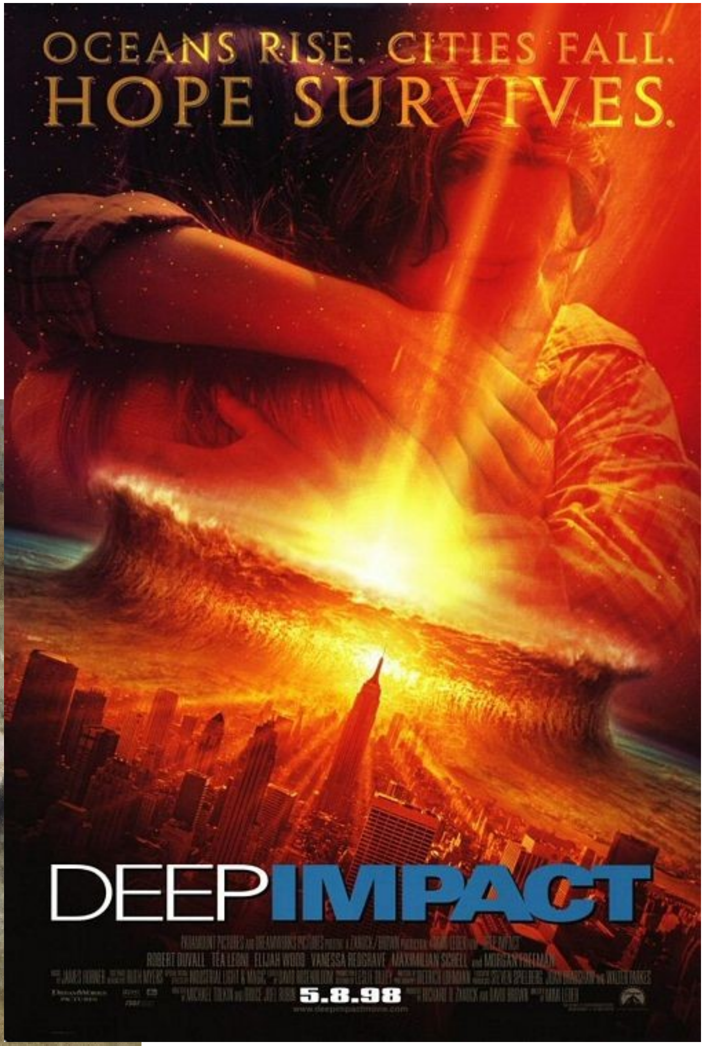
Austrian Academy of Sciences



Why comets?

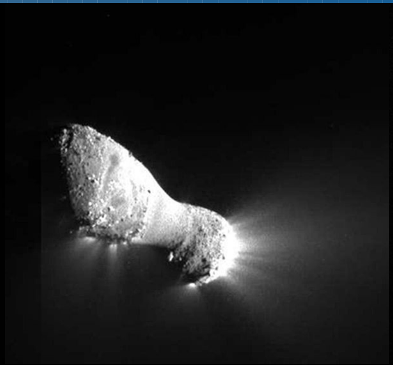
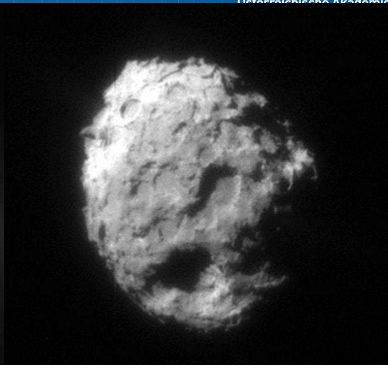


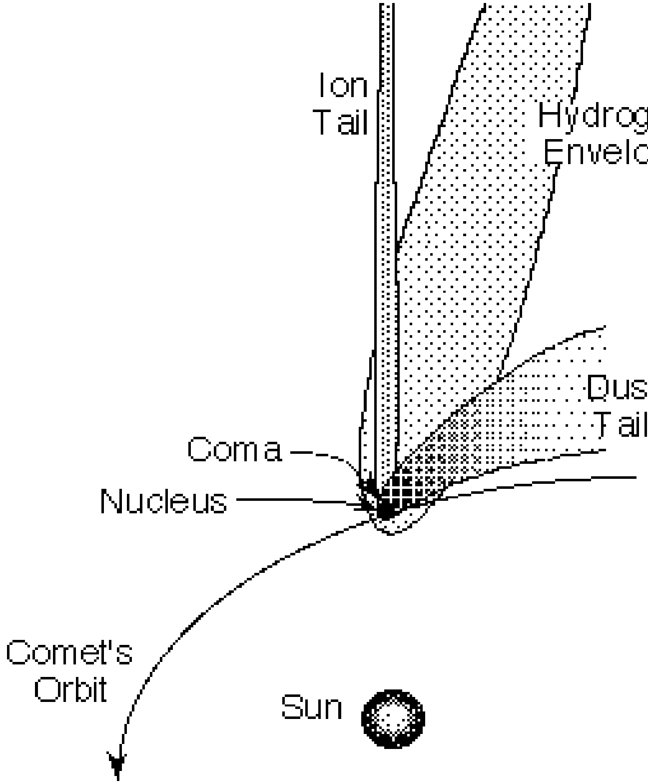
Why comets?



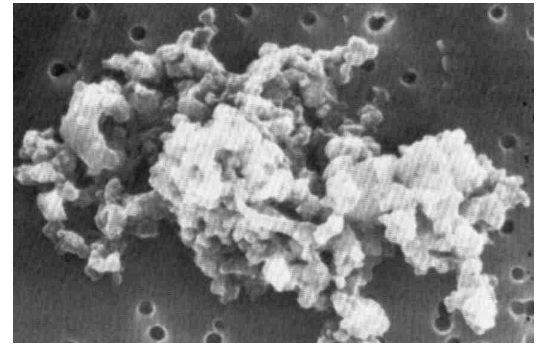
Anatomy of a comet

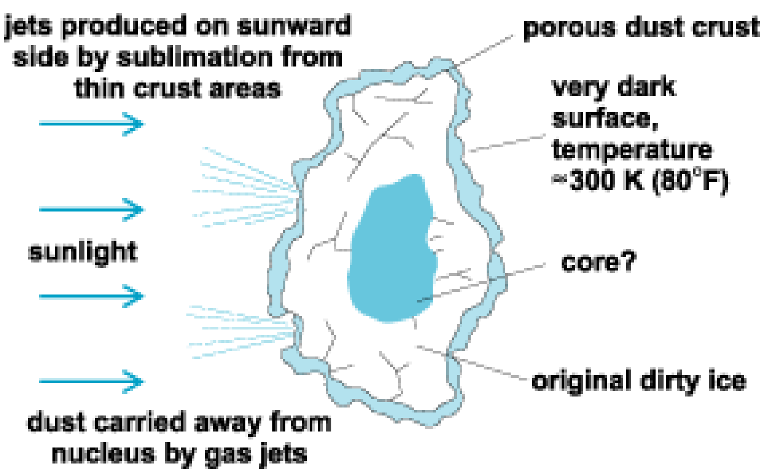


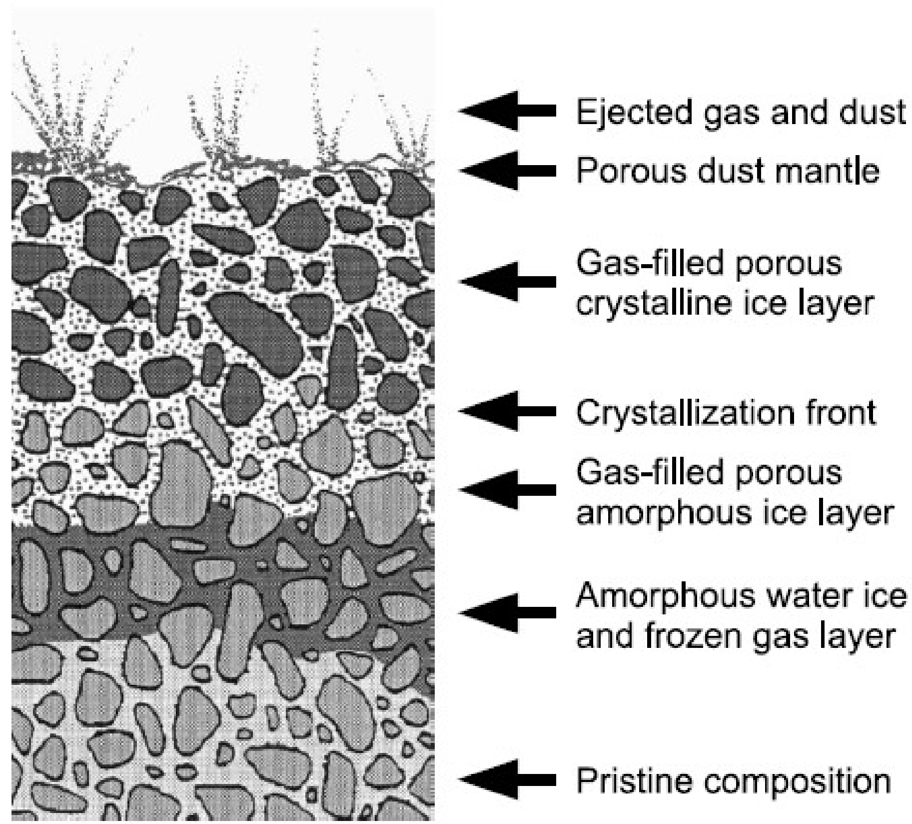






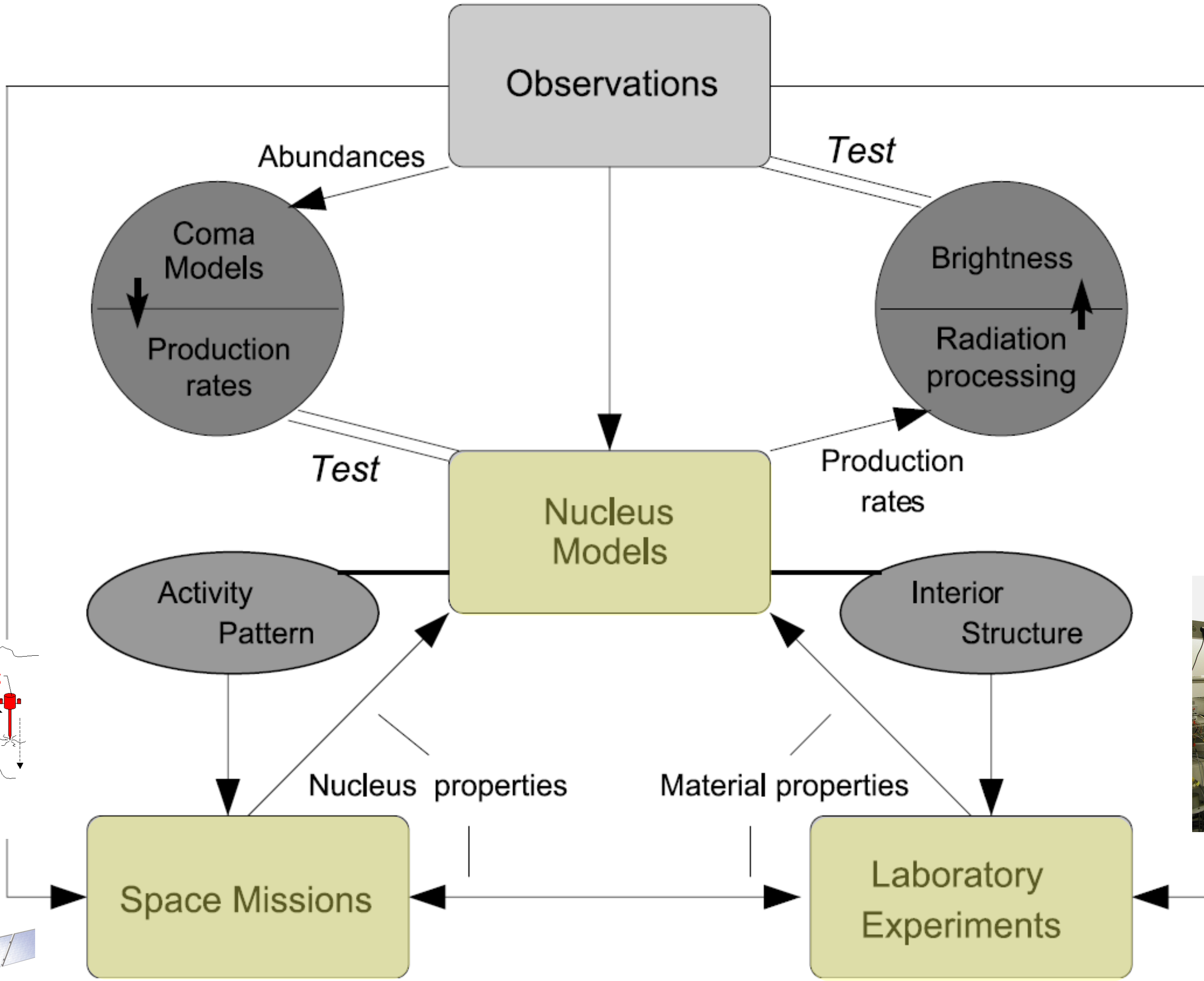
The comet nucleus

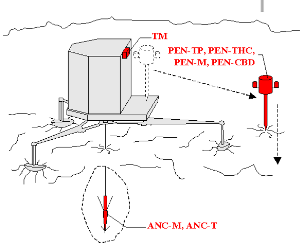


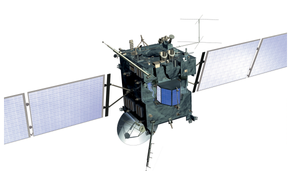




How we learn about comets





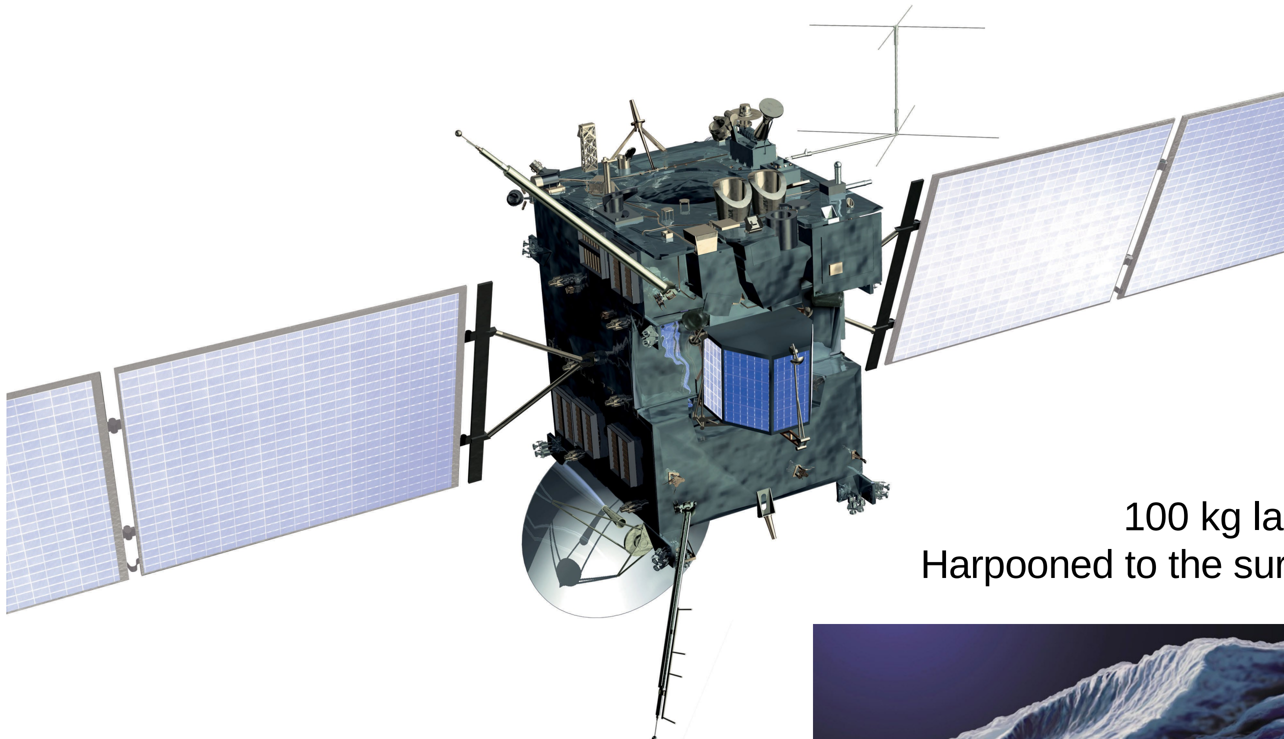


Rendezvous with a comet

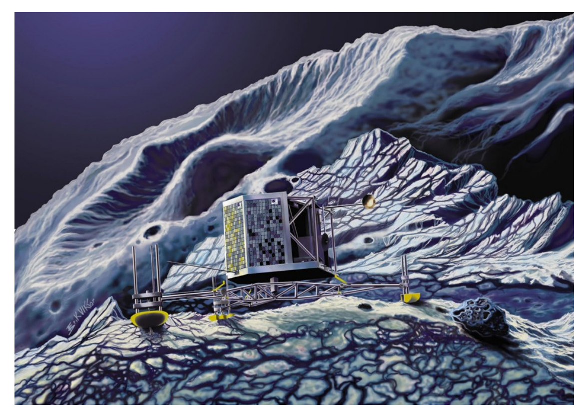
Instruments on the orbiter	
ALICE	UV spectrometer
CONSERT	Radar
COSIMA	Dust spec.
GIADA	Dust mass/vel
MIDAS	Dust microscopy
MIRO	Microwave spec.
OSIRIS	Camera
ROSINA	Mass spec.
RPC	Plasma
RSI	Radio science
VIRTIS	NIS-NIR spec.

Instruments on the lander
APXS
ÇIVA
CONSERT
COSAC
MODULUS PTOLEMY
MUPUS
ROLIS
ROMAP
SD2
SESAME

Spacecraft: 2.8 x 2.1 x 2.0 m
2.2 m diameter communications dish
Two 14-metre solar panels, total area of 64 m^2



100 kg lander
Harpooned to the surface

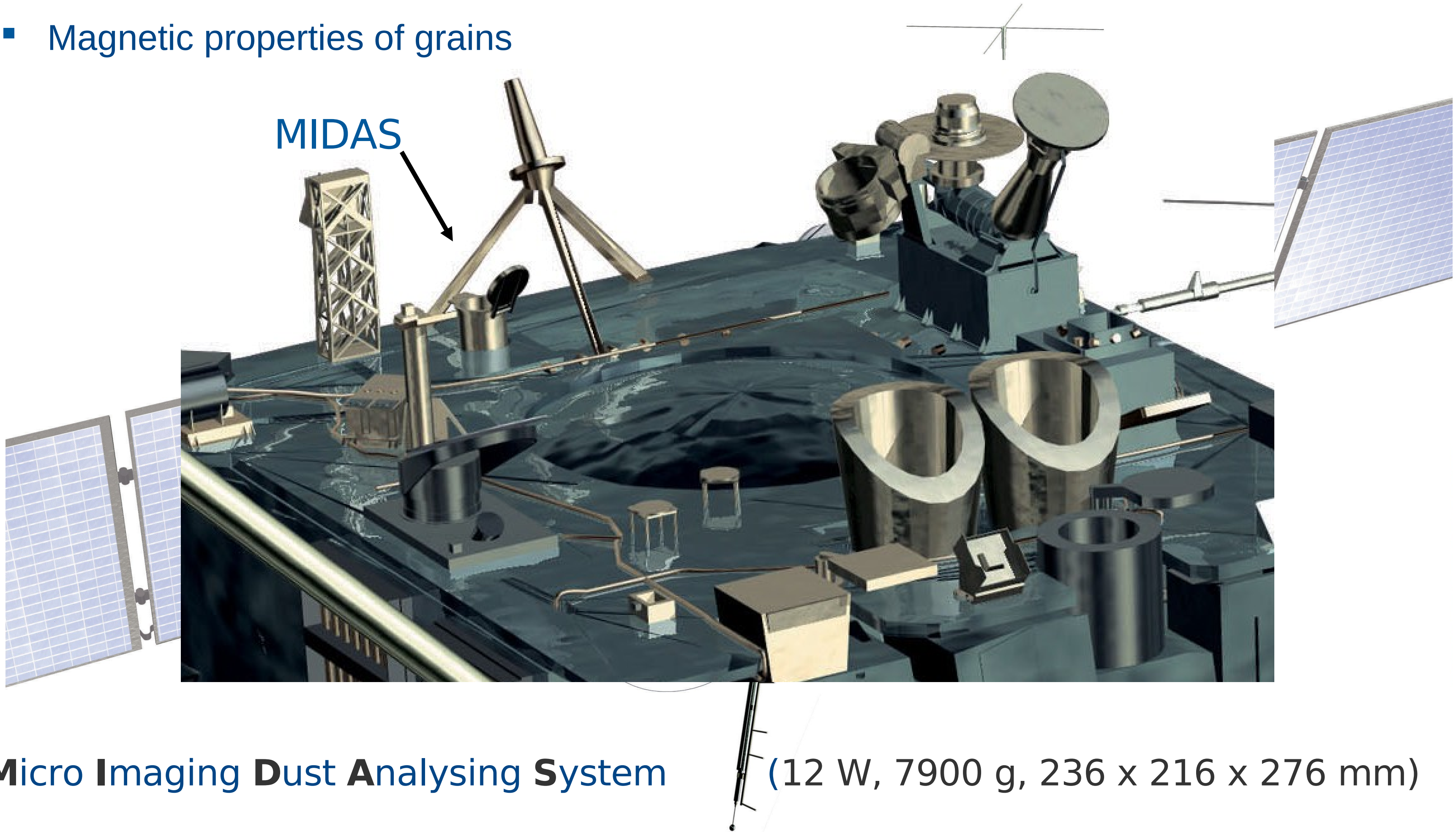


10 year cruise phase
Currently in hibernation
2 asteroids (2867 Šteins & 21 Lutetia)

Rosetta and MIDAS

Scientific aims

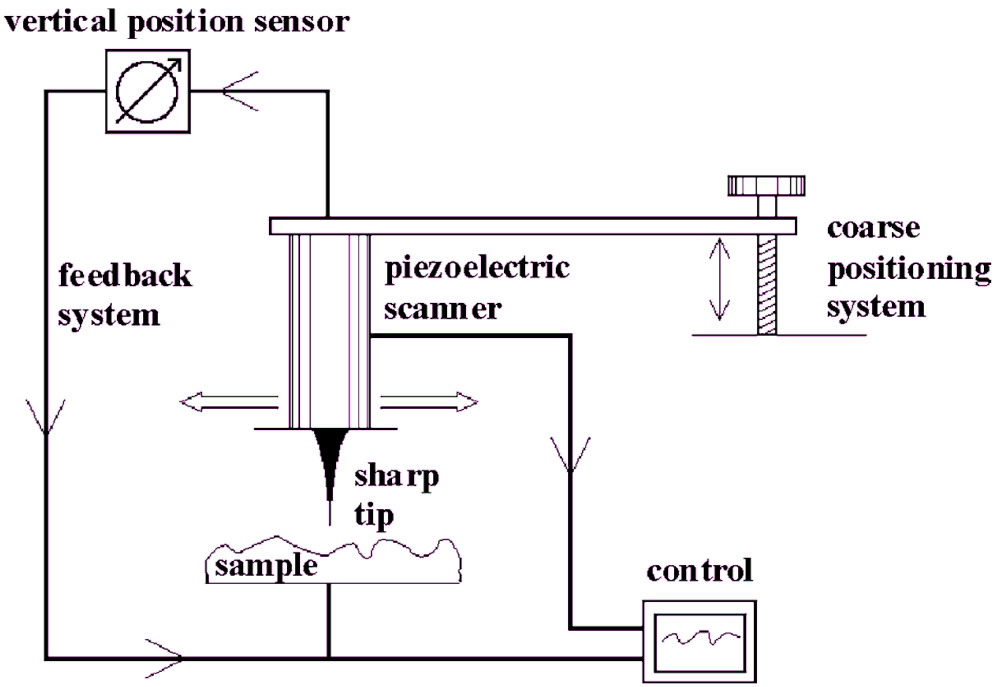
- 3D images of single particles, and agglomerates
- Statistical evaluation of the particles by size, volume and shape
- Variation of particle fluxes on time scales of hours/days
- Magnetic properties of grains



Micro **I**maging **D**ust **A**nalysing **S**ystem (12 W, 7900 g, 236 x 216 x 276 mm)

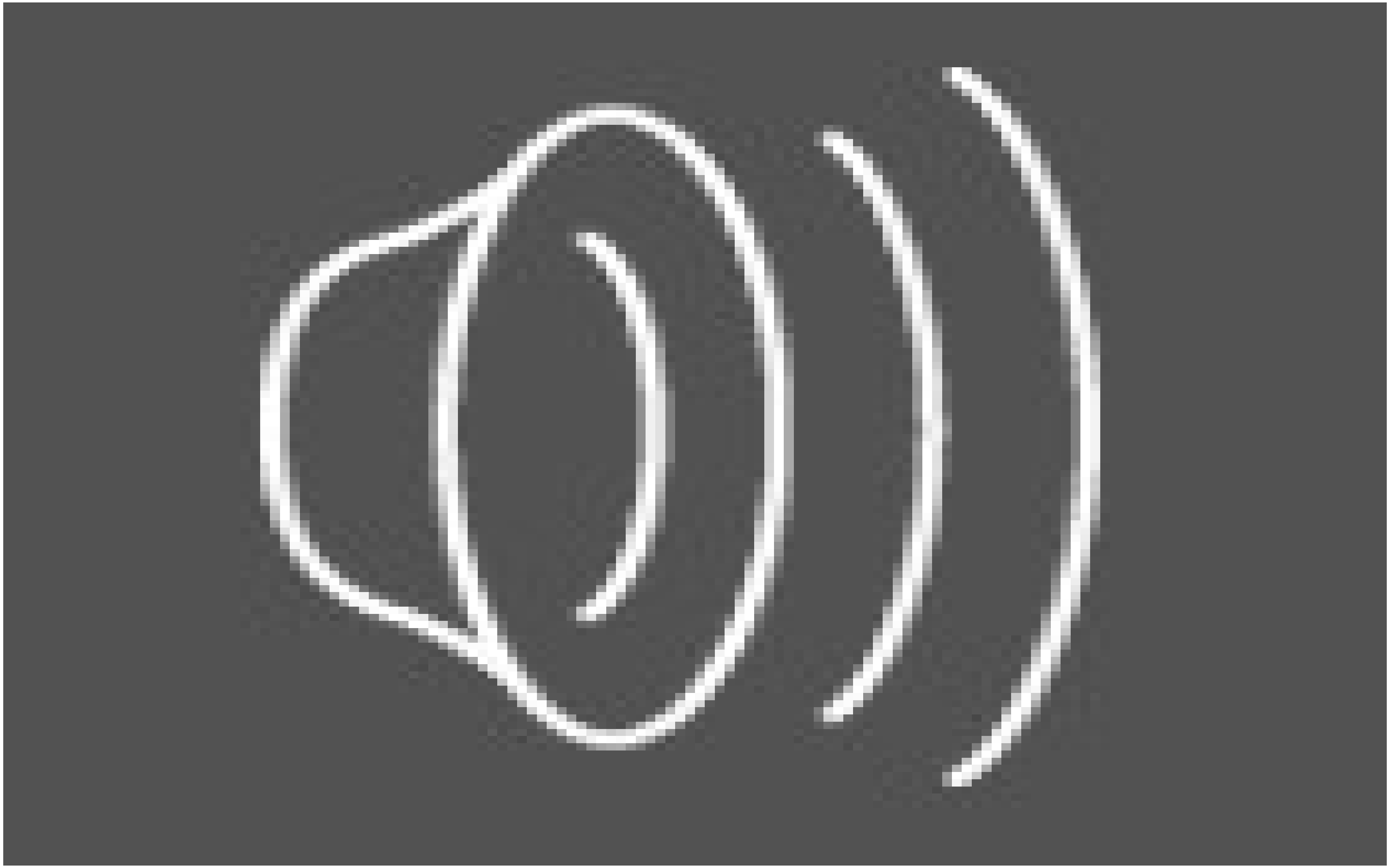
Principles of AFM

- Basic principle:
  - A sharp (radius ~10 nm) tip is moved towards to a sample
  - Various tip-sample forces act on the tip and cantilever
  - The cantilever amplitude responds to these forces
  - At a given amplitude change, the Z position is recorded

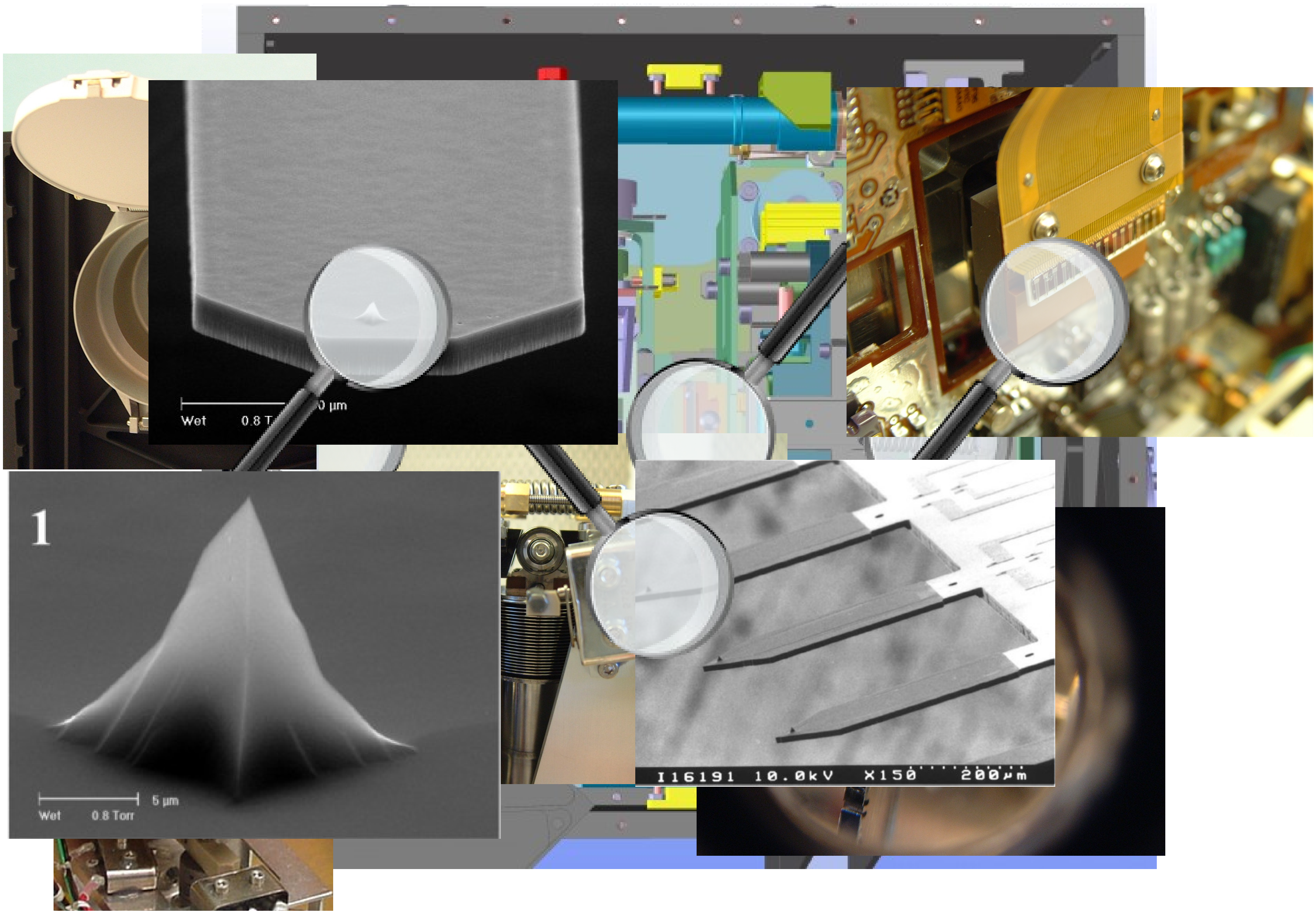


Parameter	In-flight performance
Lateral resolution	3.8 nm
Height resolution	0.16 nm
Height range	8 µm
Scan field	min: 0.97 µm max: 94 µm
Image resolution	up to 512x512 pixels 14 bit/pixel
Working modes	Contact, Dynamic, Single point, Magnetic
Data channels	Topography, error signal, phase shift, cantilever DC, AC, X/Y/Z-voltage & position

Overview of the instrument

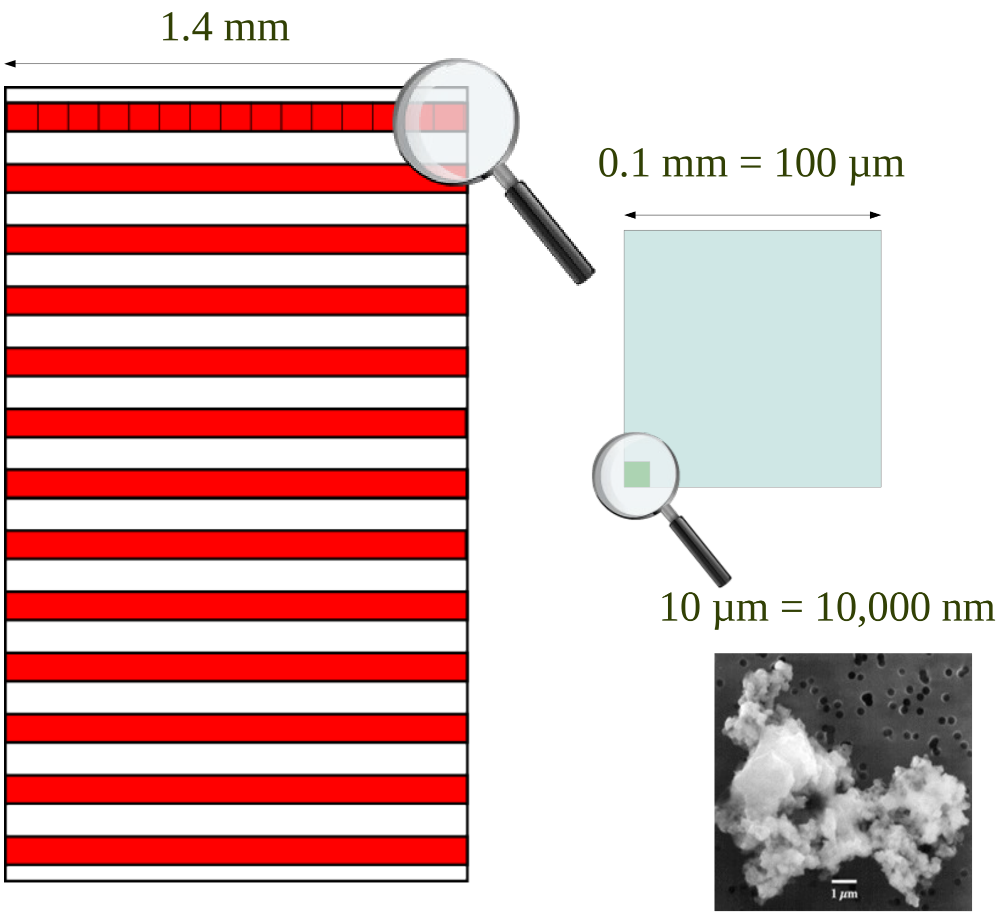


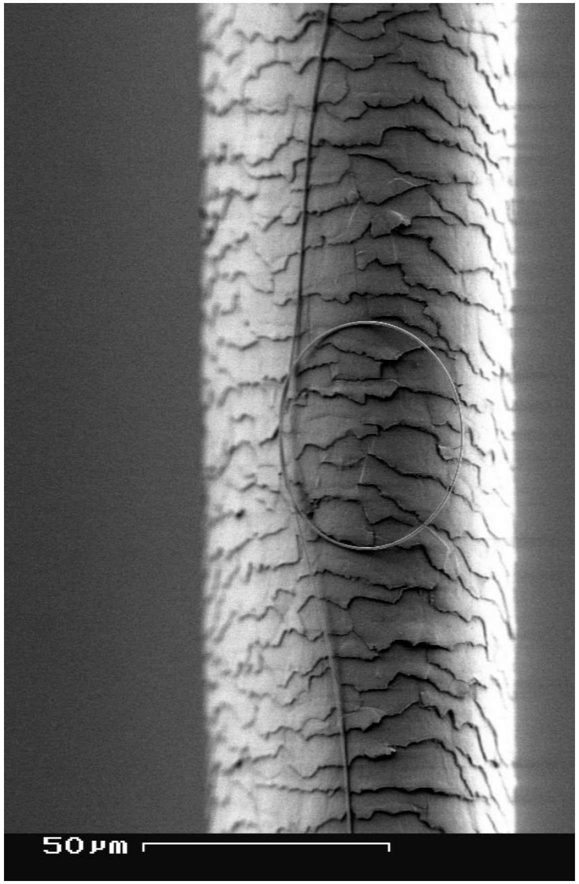
Overview of the instrument



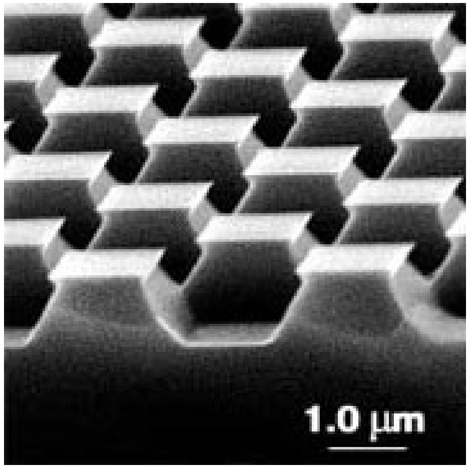
How small is a nanometre?

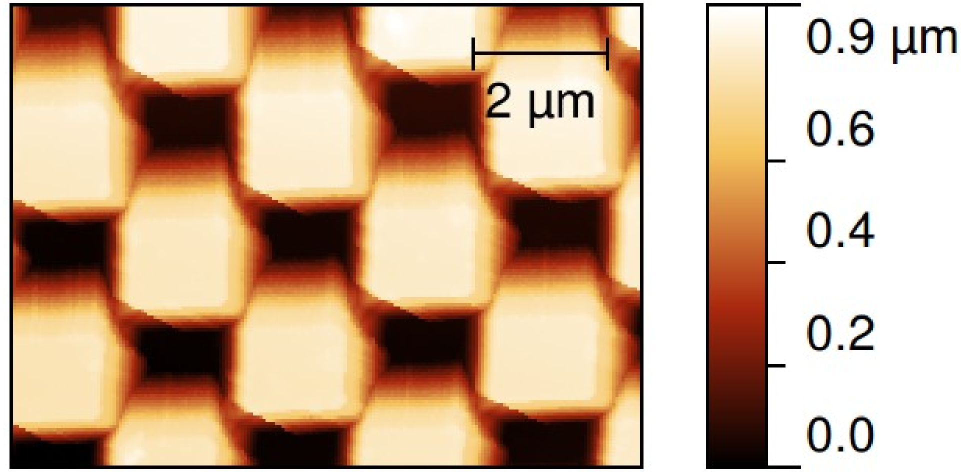
- MIDAS has a resolution of 4 nm – but how big is this?
  - human hair is ~50 µm (50,000 nm) across
  - nanowire is 50 nm across

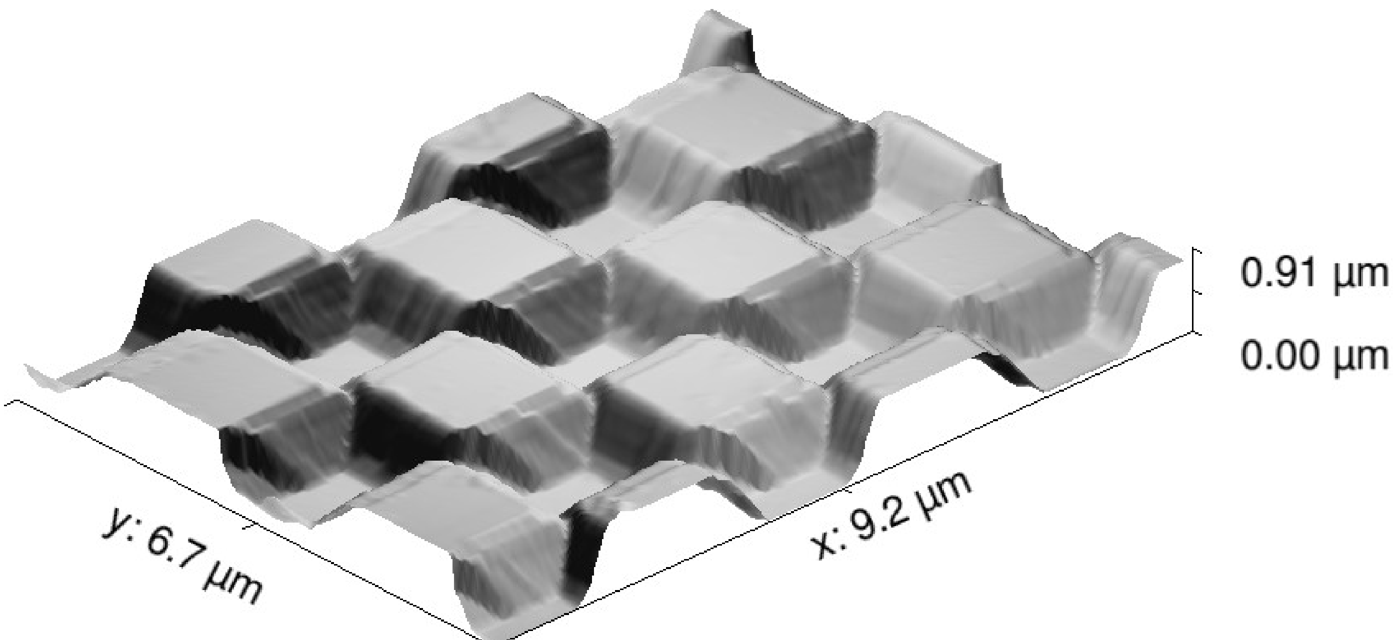




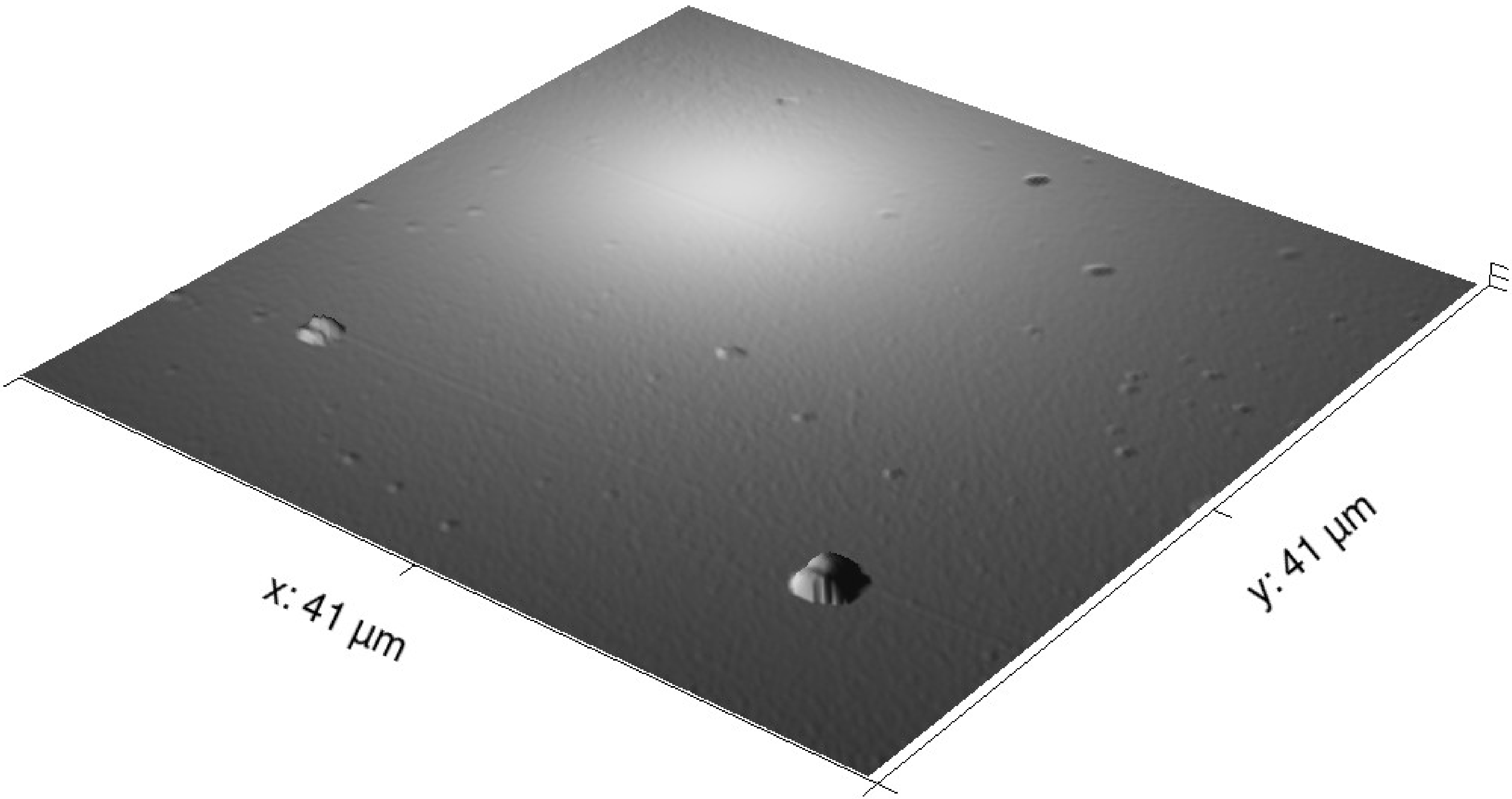
MIDAS images (1)



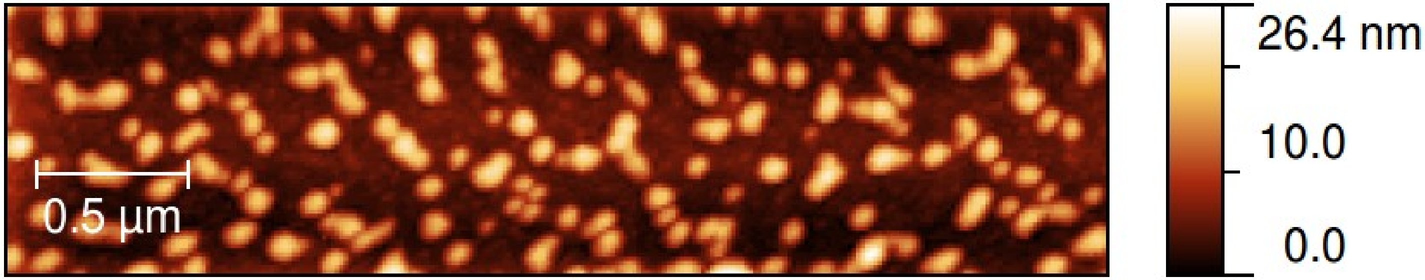




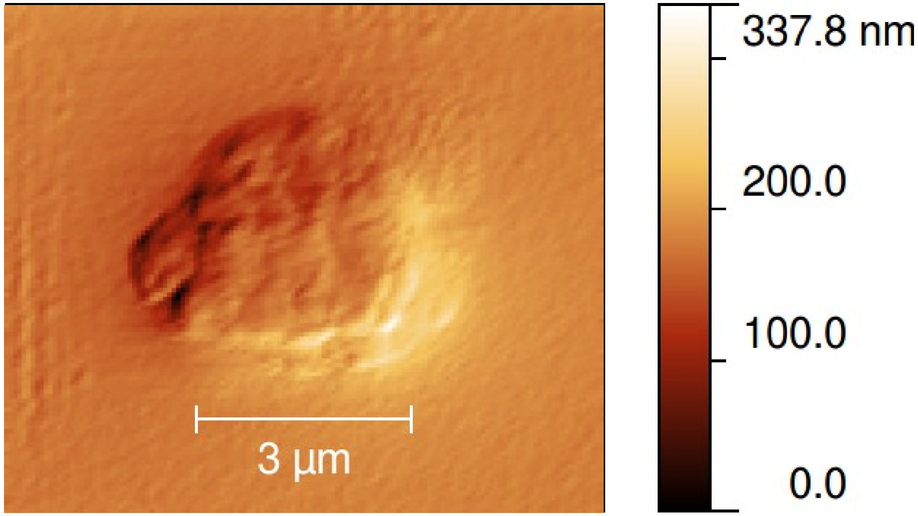
MIDAS images (2)

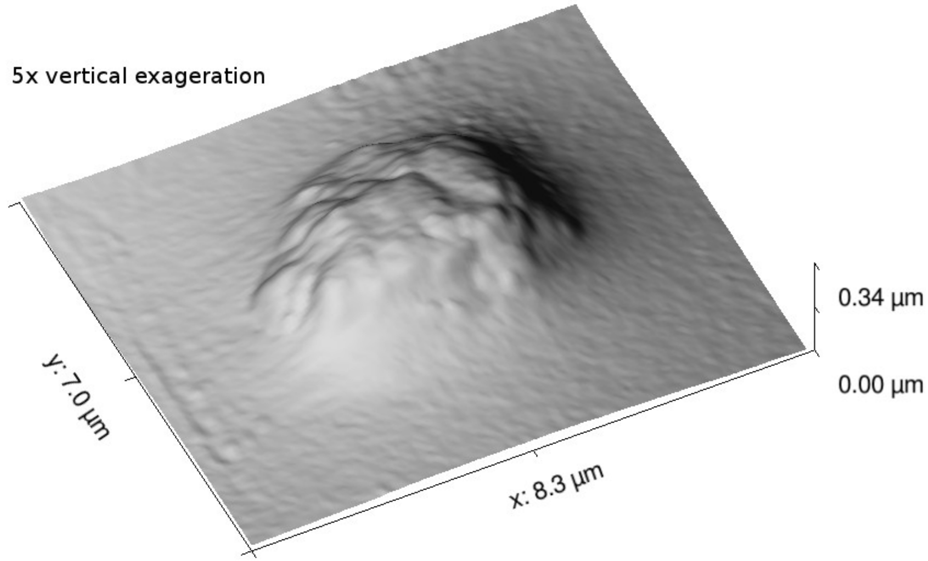


MIDAS images (3)



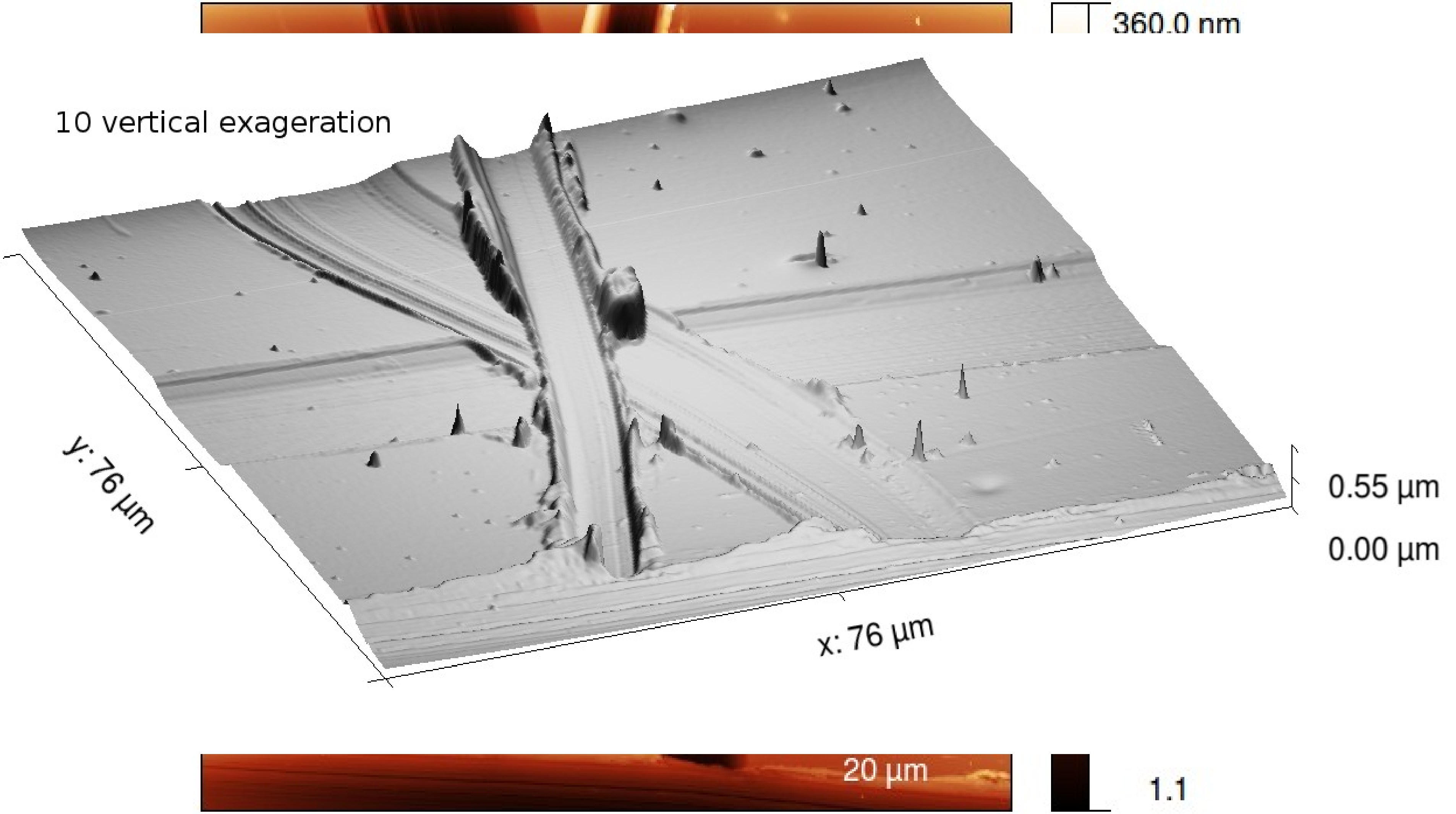
5 nm gold spheres





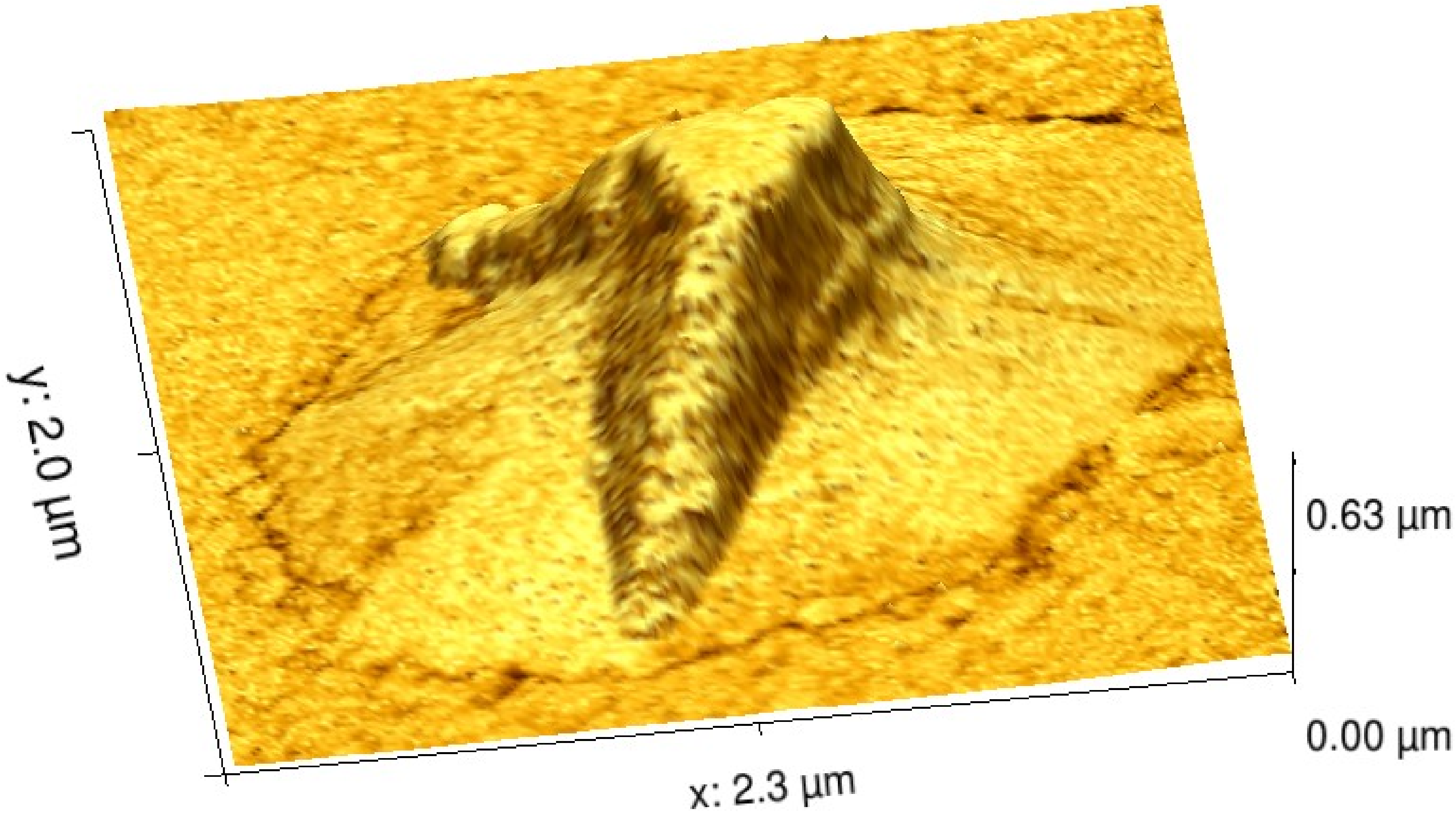
Calcite grain

MIDAS images (4)

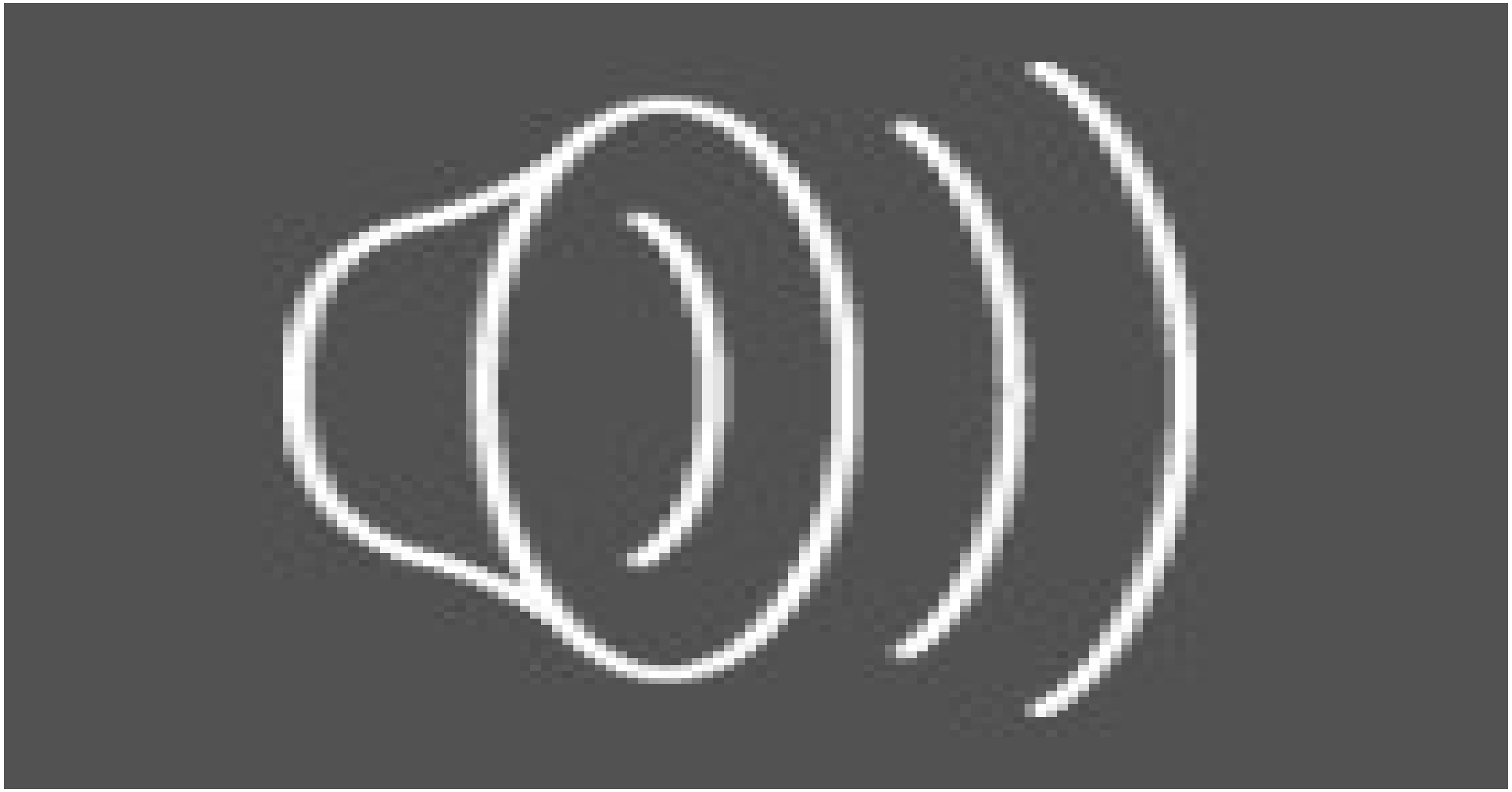


MIDAS images (5)

Tip imaging, multiple channels



... don't forget these are 3D!

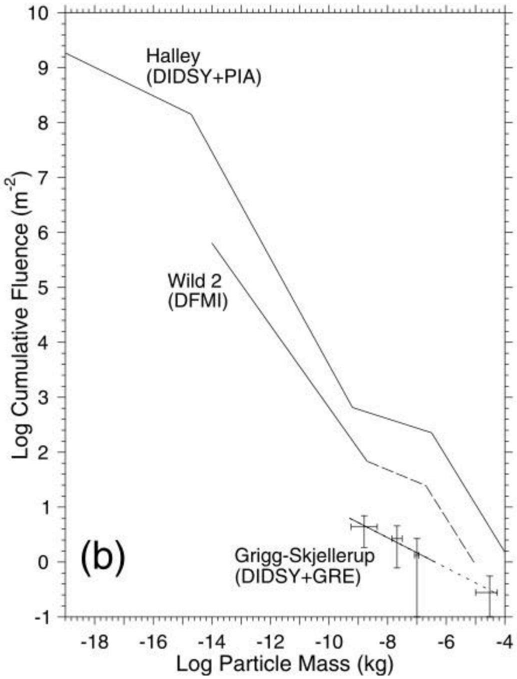


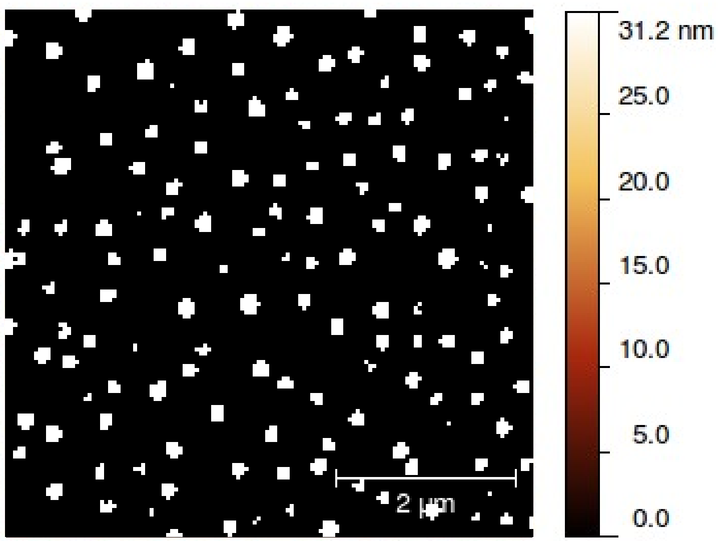
What can we do with the data?

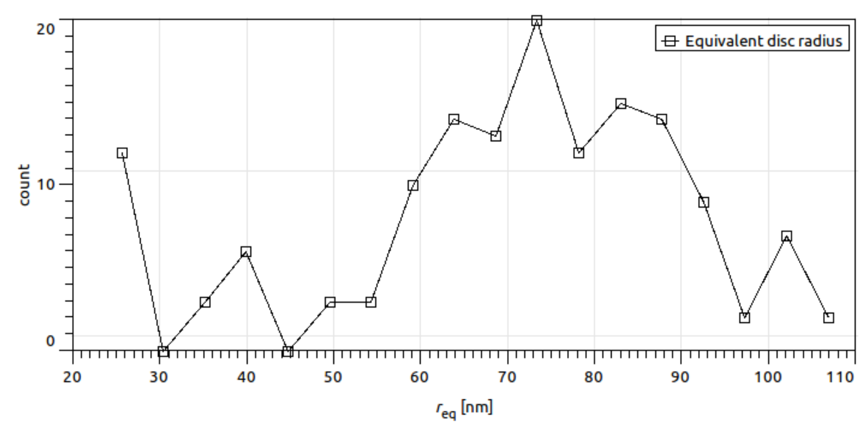
- In situ exploration of the cometary environment by AFM
  - first space-borne AFM to be launched (not the first to operate!)
- We collect 3D images of single particles, and aggregates, allowing:
  - statistical evaluation of the particles by size, volume and shape
    - *and derived properties, e.g. fractal dimension*
  - study of particle fluxes on time scales of hours/days
- These are interesting in themselves, and can address some issues
  - how does the size distribution extend to the smallest particles?
  - are most particles amorphous or crystalline?
- But the real fun is in applying them to the bigger picture, e.g.
  - are most particles aggregates? how small are the primary blocks?
  - can we say anything about their mineralogy / formation environment?
  - how does gas interact with particles with these shape/size/texture?
  - how would collections of such particles behave, e.g. in the mantle?

Sub-µm size distribution

- Data at comet Halley points to a large number of small particles
  - even relatively far from the nucleus
- Stardust at Wild-2 sees swarms and bursts
  - possibly due to fragmentation of aggregates etc.
- Smallest unit component?
  - Stardust → 10s of nm
    - *from crater residue*

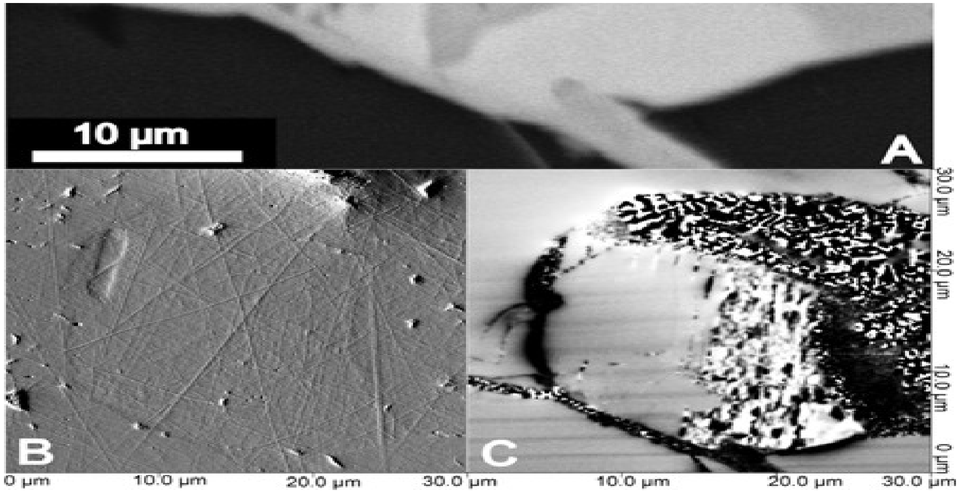




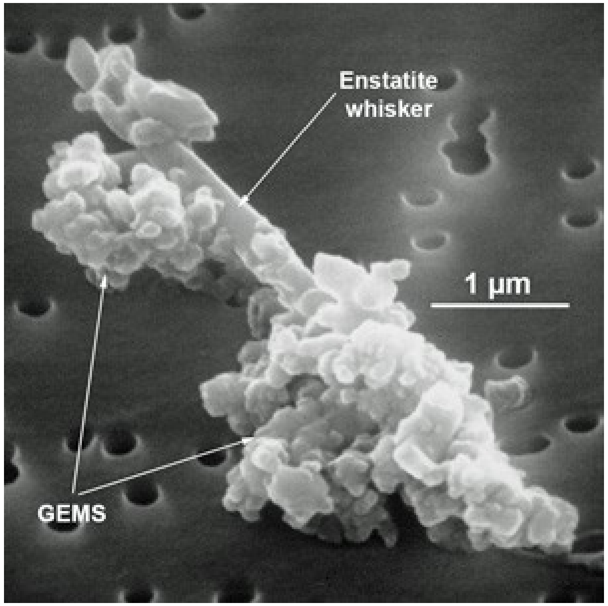


Searching for magnetic minerals

- 4 MIDAS needles are coated in cobalt and can be used for MFM
  - and should be able to identify and map magnetic domains
- Will 67P contain GEMS-like material? With nanophase inclusions?
  - prevalent in anhydrous IDPs, not uniquely identified in Stardust samples
- In situ MFM will be a first!
  - implemented but not yet tested
  - ground test campaign this year



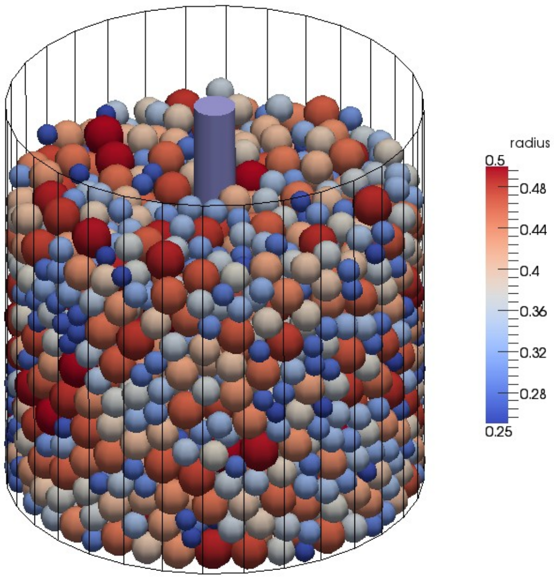
http://www.lpi.usra.edu/meetings/lpsc2004/pdf/1541.pdf

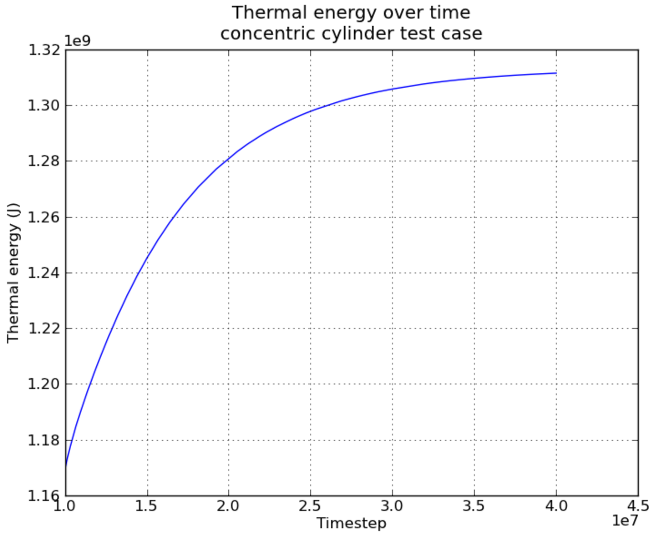


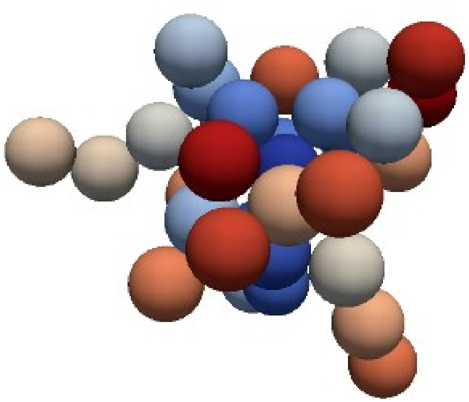
10.1126/science.1150683

Constraining mantle properties

- Assuming that collected particles in some way represent the mantle
  - we can evaluate how collections of such particles behave
    - *using discrete element modelling, for example*
- In µg, inter-particle forces >> weight
  - and particle shape, size, roughness contribute to these forces
- Thermal properties should also follow
  - since conduction through intimate grain contact is important







Dust + light/gas interaction

- The interaction between dust and gas is not trivial
  - the flow regime is complex to calculate
  - the drag coefficient is usually guestimated
  - in reality drag force is anisotropic, gas molecules are multiply scattered
- With a statistical number of particle shapes, we can model this!
  - e.g. DSMC code to model non-Maxwellian distribution of gas

---

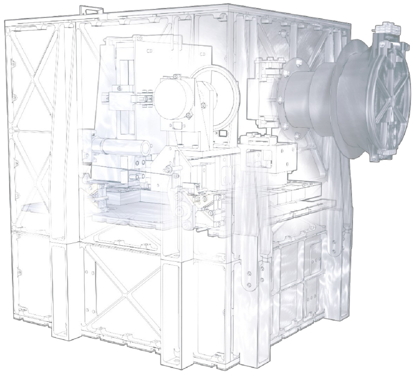
- Polarisation data are well fit by models of porous aggregates
- From MIDAS data we can model light scattering with “real” shapes
  - of course we don't measure the full 3D particle (only the upper half)
  - we only see the small particles (<~5 µm)
    - *but often co-expose with COSISCOPE – 13.7 µm/pix*
- Images of fluffy aggregate analogues coming soon!

Challenges

- The main challenge is that we *only* measure topography
  - so whilst some mineralogy may be possible with an AFM, we cannot use another instrument to confirm etc.
- The flux of small particles is largely unknown
  - this affects both our collection and scanning strategy
  - fortunately is easy to work with once the environment is known
    - *early task → constrain the small particle size/flux*
- The exact properties of our tips/cantilevers in flight are unknown
  - e.g. tip shape, cantilever spring constant, magnetic moment
    - *fortunately they don't affect basic imaging!*
- We have to learn the operating environment
  - in particular dealing with temperature drift

Summary

- The MIDAS instrument is healthy
  - and the Flight Spare (ESTEC, NL) and Qualification Model (IWF, Graz)
  - new needles and samples will be installed this year
- We understand how to get good images from the instrument
- Planning activities are ongoing
- Now is the time to prepare the framework for data analysis!



Thanks!

mark.bentley@oeaw.ac.at