Atomic force microscope on Mars

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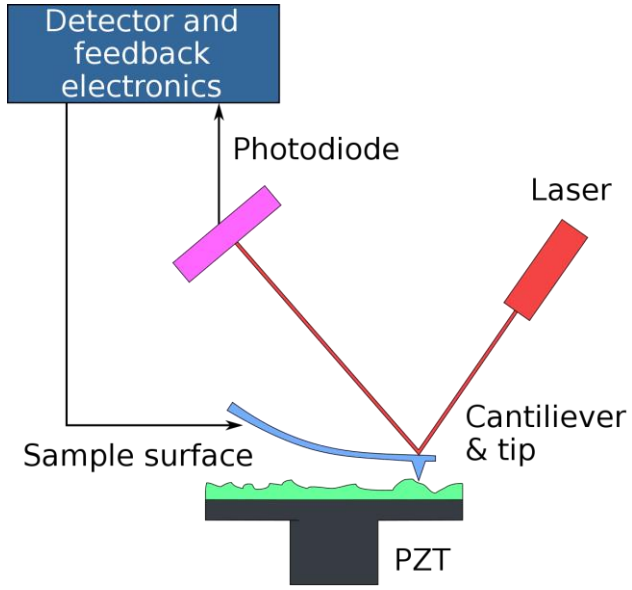
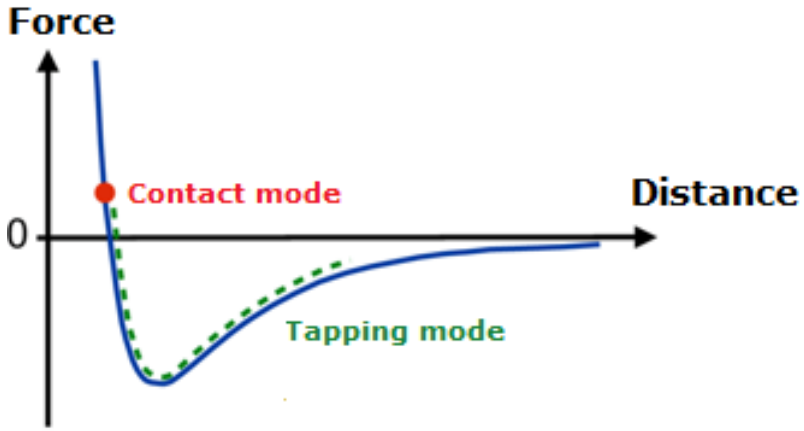
Atomic force microscopy

- Measure the forces between the tip and the sample
- Deflection of a cantilever, a sharp tip mounted underneath
- The deflection measured by various techniques (**laser beam**, capacitive, etc.)
- Contact or non-contact mode
- Constant deflection, make a topography map
- Movement by piezoelectric ceramics (~0.05nm)





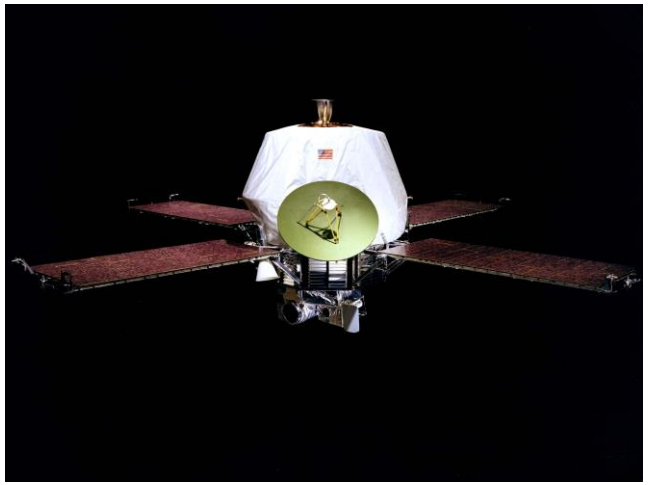
Typical sample-tip iinteractions

- Short-range forces
  - Repulsive
  - Overlapping of the electron clouds (Pauli exclusion)
- Van der Waals i.a.
  - Attractive
  - From dipole-dipole i.a.
- Capillary forces
- Electrostatic forces

$$U_{LJ} = -4\epsilon \left(\frac{\sigma^6}{r^6} - \frac{\sigma^{12}}{r^{12}} \right)$$

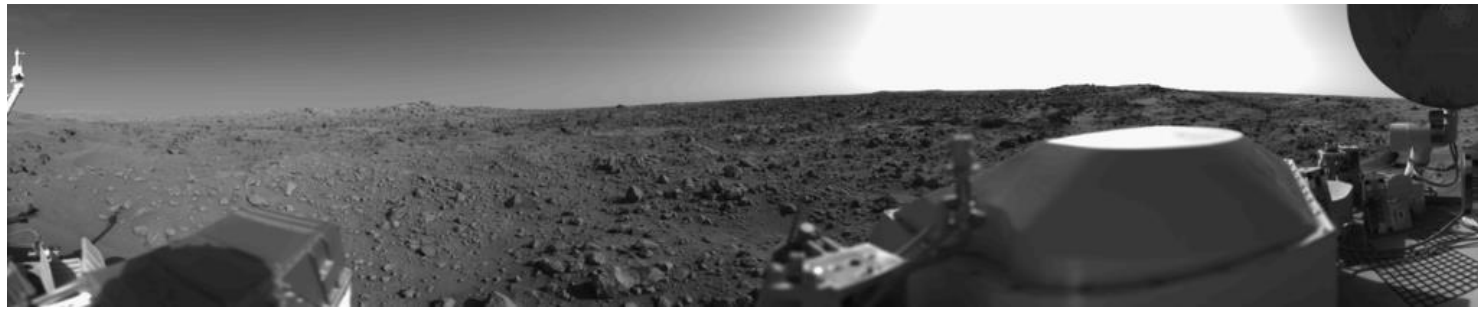
The first Mars missions

- Mariner 4
  - 1965
  - First succesful flyby
  - Made pictures from the surface
  - Measurements on the interplanetary space (radiation, atmosphere, spectroscopy)
- Mariner 9
  - 1971
  - First succesful orbiter
  - Mapping the surface (70% succesful)

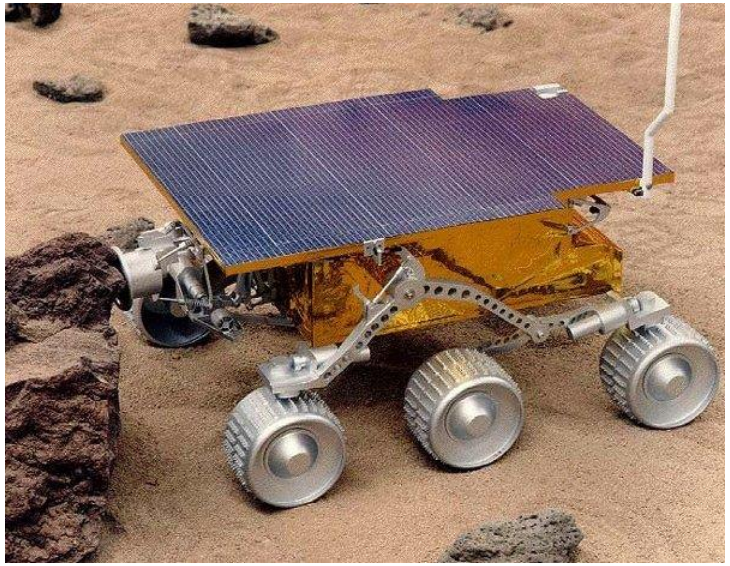


The first Mars missions

- Viking 1 and Viking 2
  - 1976
  - First succesful landers
  - Search for life, biological experiments



- Pathfinder
  - 1997
  - First rover
  - Investigations on the Martian soil and atmosphere

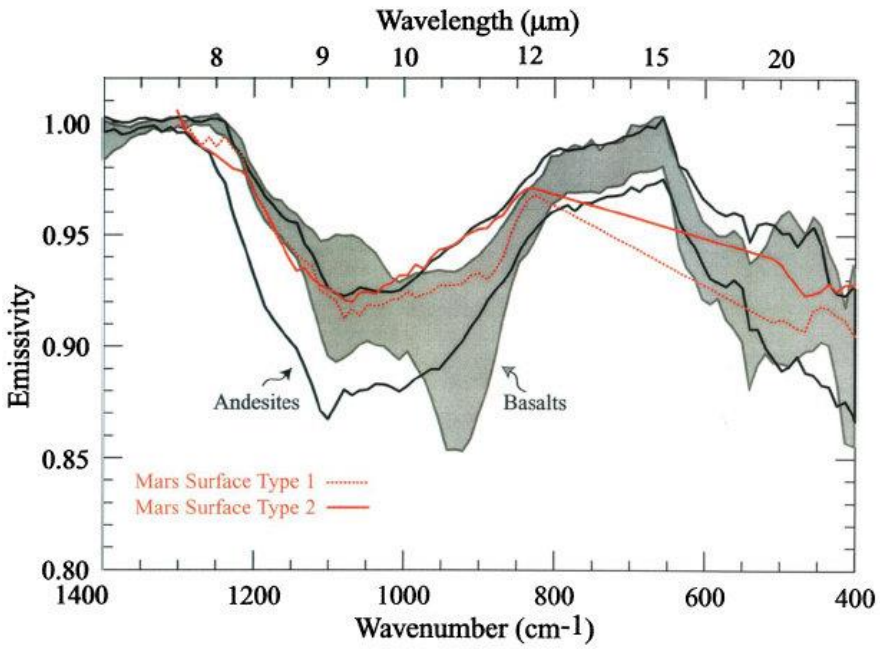


Phoenix spacecraft

- Stationary lander landed on 2008
- Access the local habitability
- Research the history of the water on Mars
- Several scientific instruments
- Thermal and Evolved Gas Analyzer (TEGA)
  - High temperature furnace with a mass spectrometer
- Microscopy, Electrochemistry, and Conductivity Analyzer (MECA)
  - Wet chemistry lab
  - Optical and atomic force microscopes
  - Thermal and electrical conductivity probe

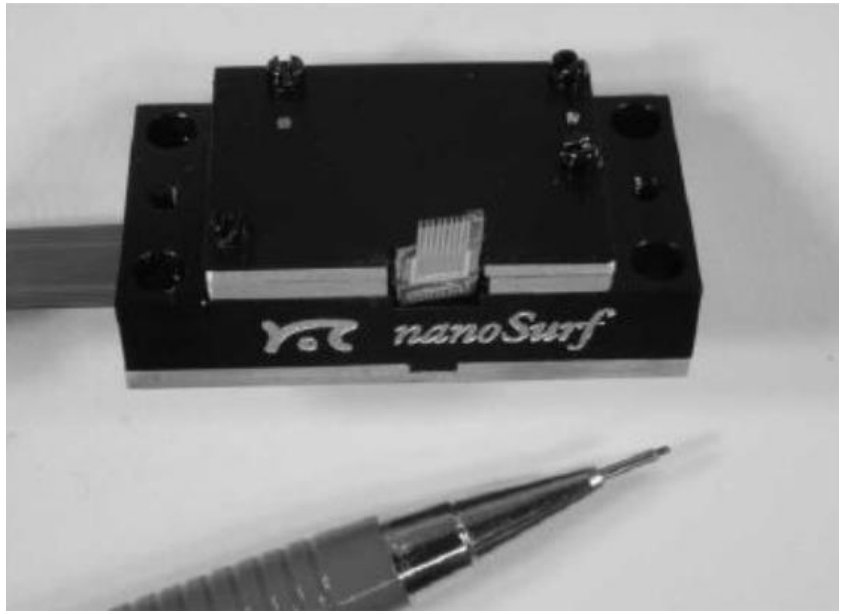
Grain size of the Martian soil

- Indirect informations
  - Mars Global Surveyor (1997)
  - Thermal emission spectrum
  - Grain size can be obtained from chemical composition
  - Can be smaller than 2 micrometer
- Direct measurements
  - With microscopes (optical has too low resolution)
  - **AFM**



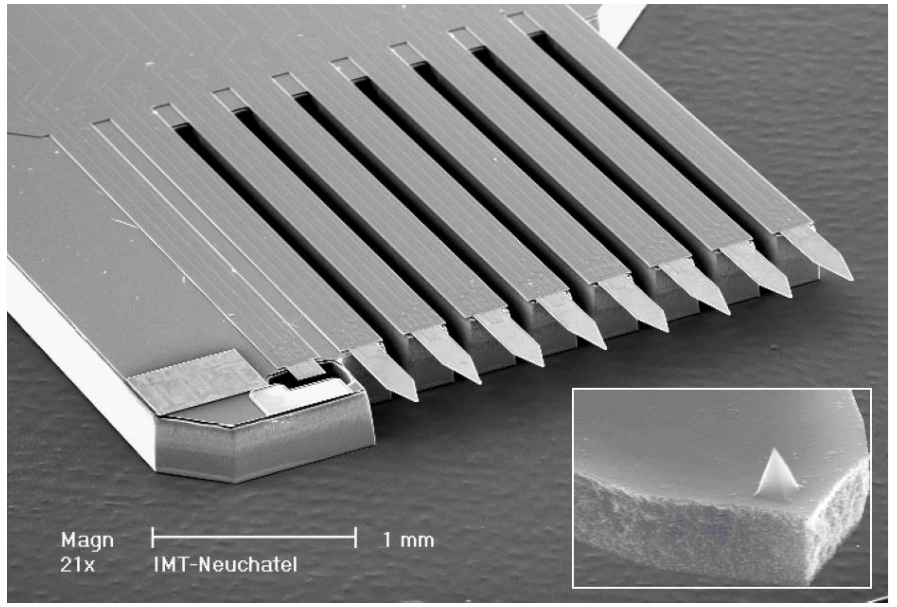
The AFM of the Phoenix space probe

- Has to be very small
- Work in extreme conditions
  - Mechanical stress during launch
  - Low temperature
  - Low pressure, higher rate of electric discharge
  - Cosmic radiation
- Made by a Swiss consortium led by University of Neuchatel
- Dosens of technical solutions



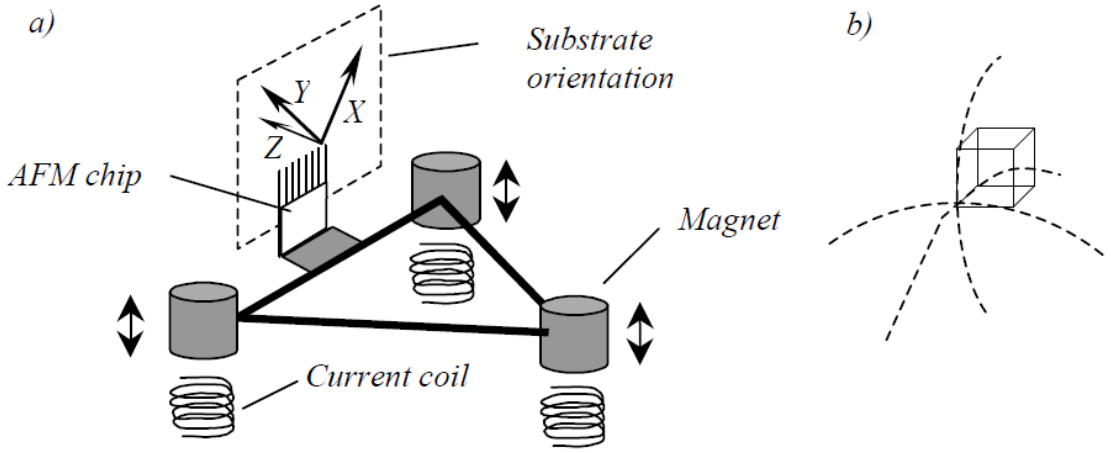
The AFM of the Phoenix space probe

- Except the actuators everything is on a chip
- Piezoelectric detetction
  - Smaller energy consumption
  - Easier calibration
- Piezoelectric actuator is not suitable
  - Low pressure CO2 atmosphere
  - 100 V
  - Easier to ionize
  - Higher rate of electrical discharges



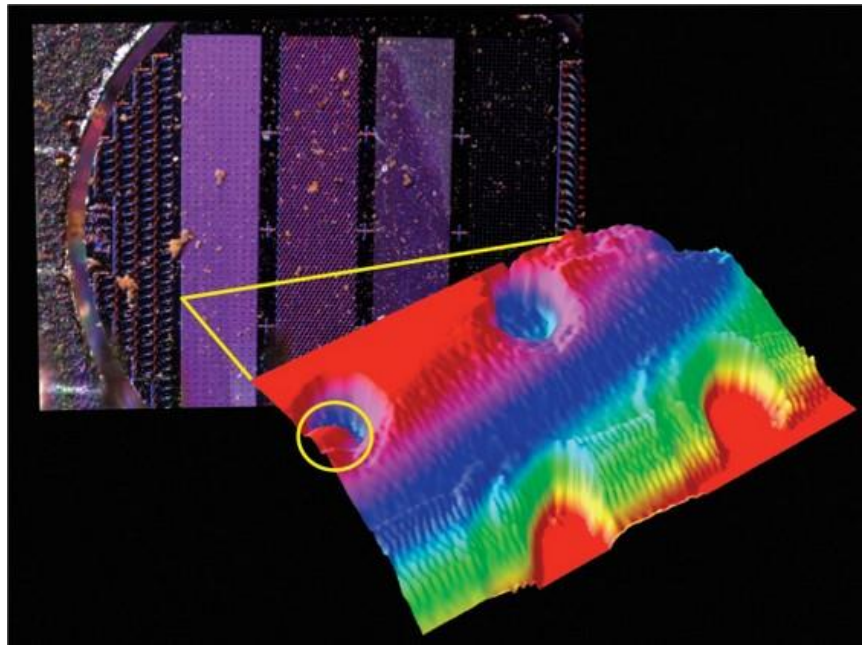
The AFM of the Phoenix space probe

- New scanner
- Based on 3 electromagnetic actuators
- 12 V
- Each actuator consists
  - Electromagnetic coil
  - Leaf spring suspended permanent magnet
- Current through a coil will attract or repel the magnet
- Describe the motion in speherical coordinates
- The magnification is 100x larger than the optical



Results of the Phoenix mission

- Made observations about the weather
  - Snow observed
  - Wind speed, temperature
- Climate cycles
  - Calcium carbonate in the soil
  - Site had been wet
- Surface chemistry
  - Alkaline (pH 7.7)
- First images from the Martian dust
  - No statistical distribution of the grain size



Thank you for your attention!