IMPROVED DUST DETECTORS AND ANALYZERS FOR PLANETARY MISSIONS

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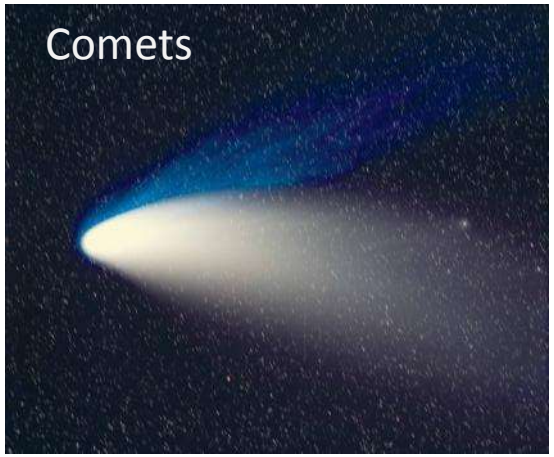
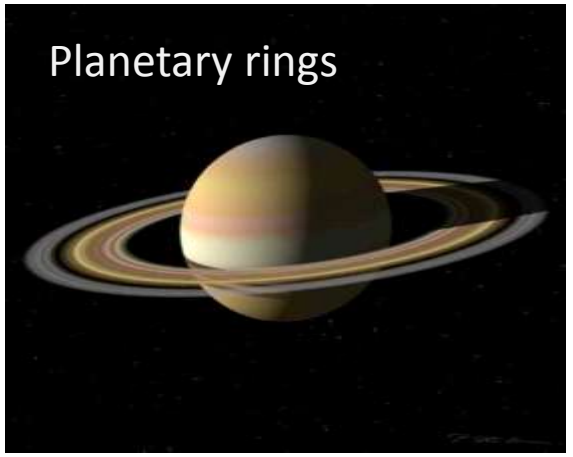
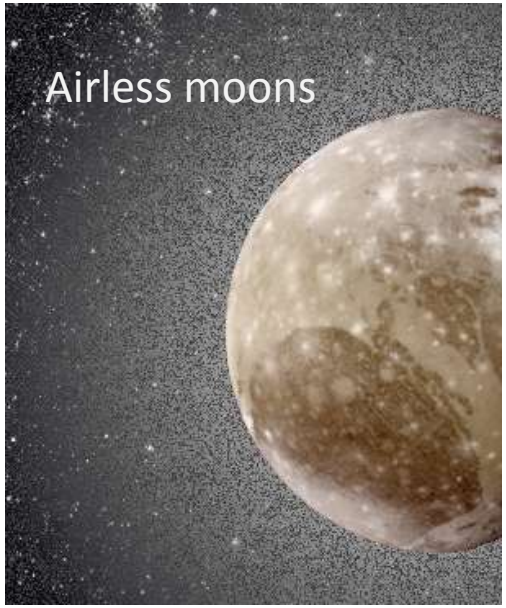
Outline

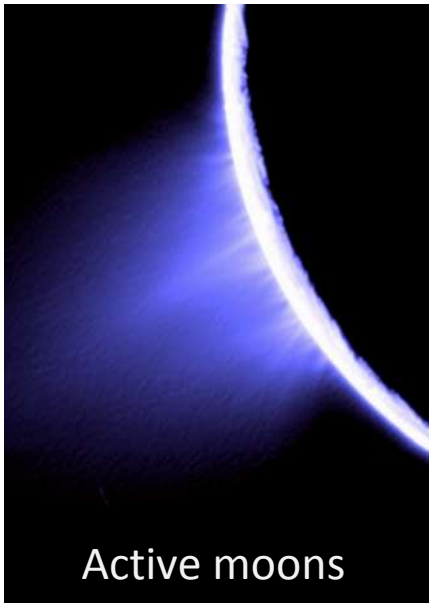
- Dust is abundant in space
- Dust measurements provide compelling contribution to planetary sciences
- Dust instruments advanced significantly over the last decade
- Overview of the instruments developed at LASP, Univ. of Colorado

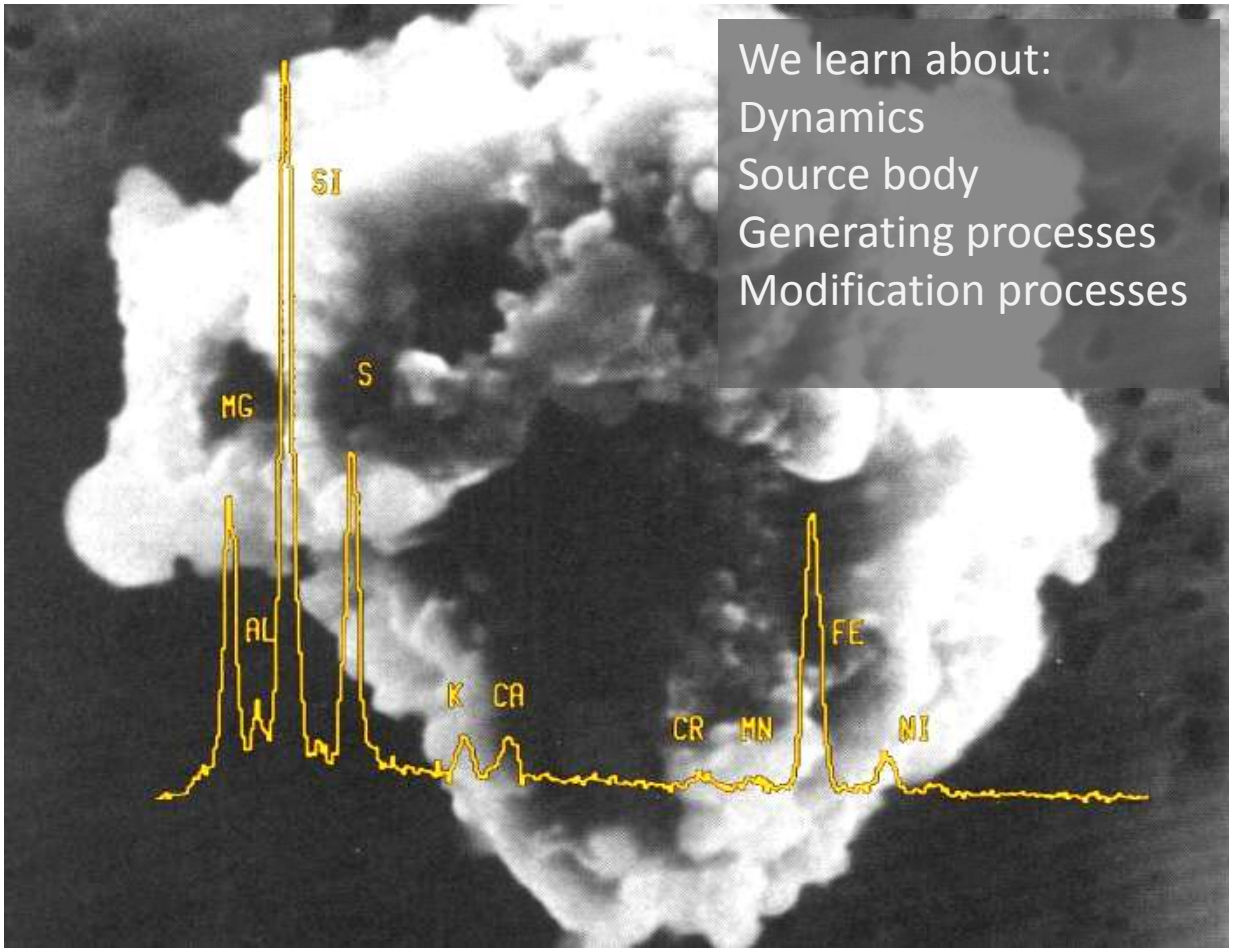
Dust within the solar system



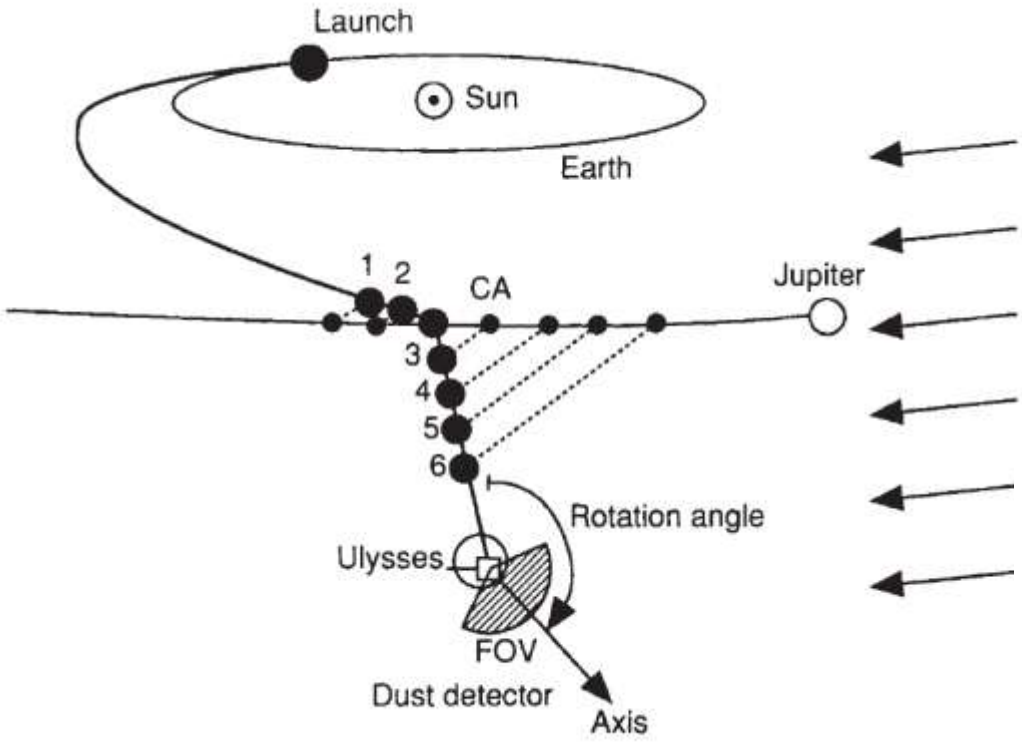




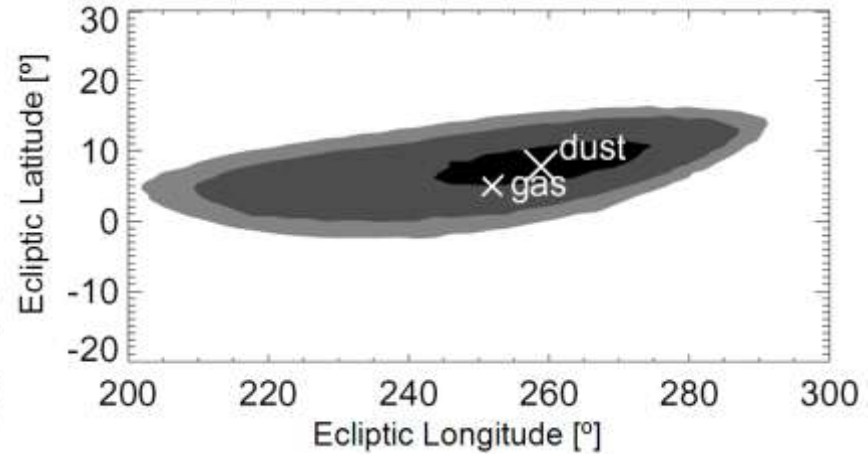


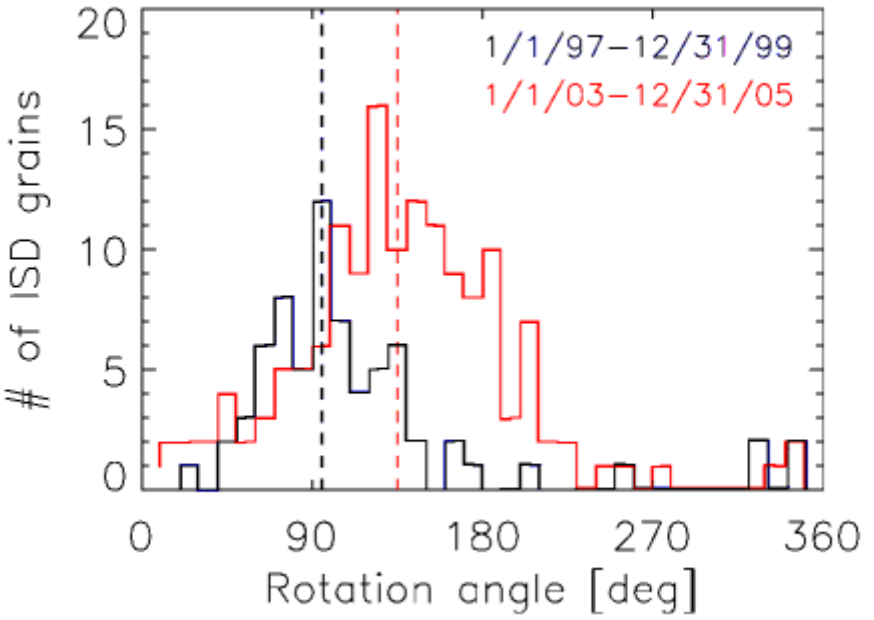

We learn about:
Dynamics
Source body
Generating processes
Modification processes
SI
MG
S
AL
K
CA
CR
MN
FE
NI

Discoveries I: Interstellar matter within the solar system



Gruen et al. NATURE · VOL 362 · 1 APRIL 1



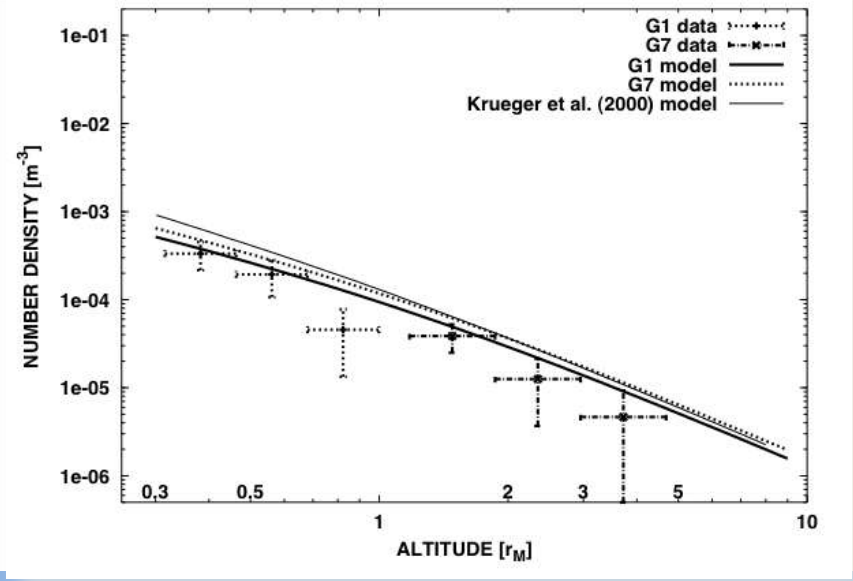


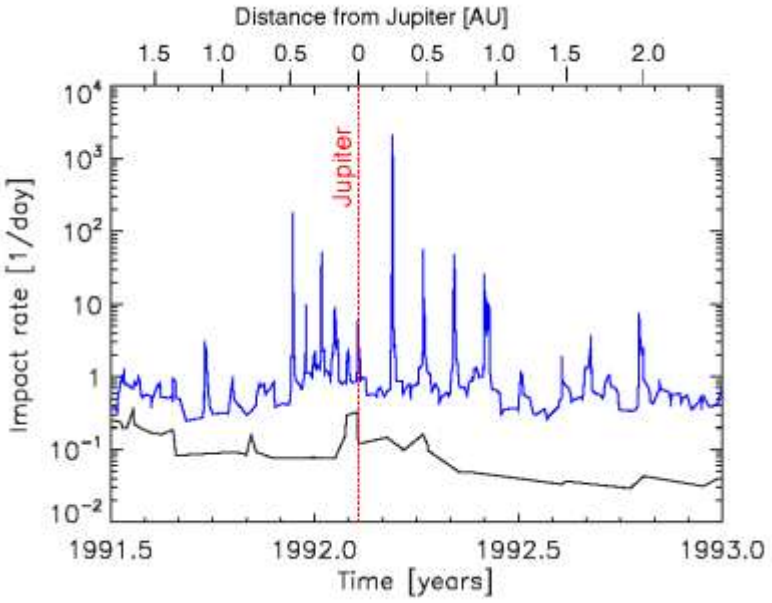
Interstellar dust identified by:

- Retrograde orbit
- High impact velocity (> 26 km/s)

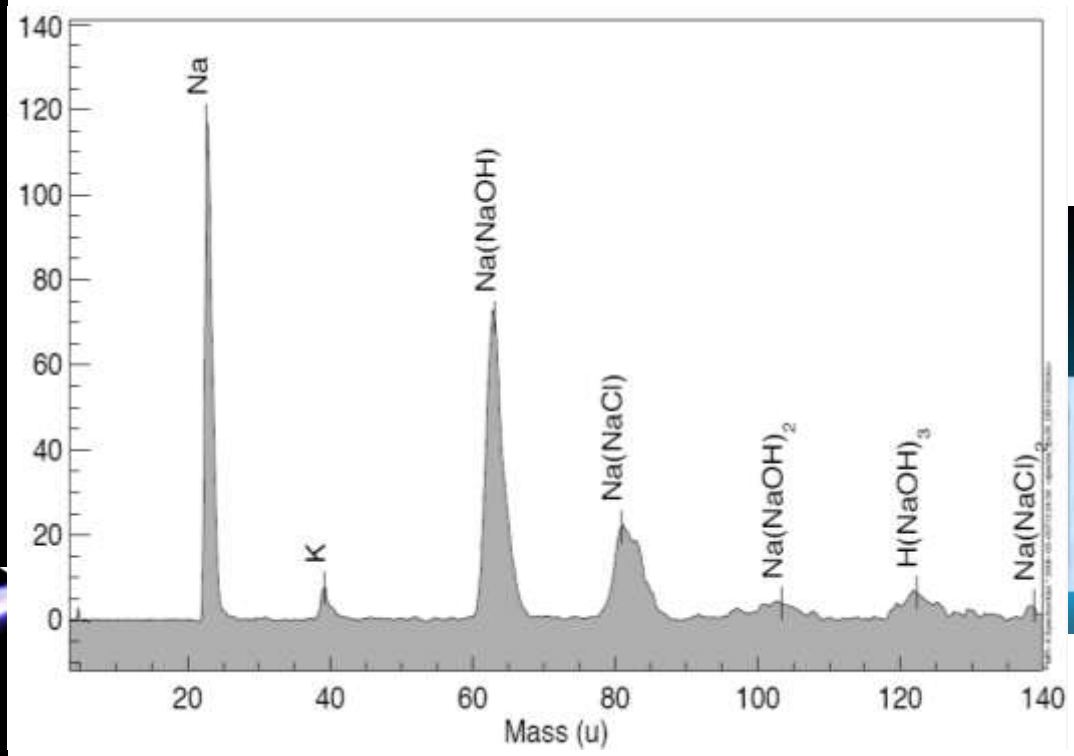
Discoveries II: Jovian system

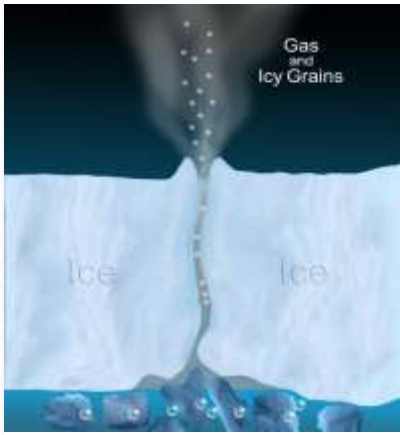
Krivov et al., PSS, 2003





Discoveries III: Plumes of Enceladus





- Pronounced signatures of sodium and potassium salts in a water matrix
- NaCl and NaHCO3 are identified.
- Important implications for subsurface water reservoir (Postberg et al., Nature 2009)

Relevant outstanding questions

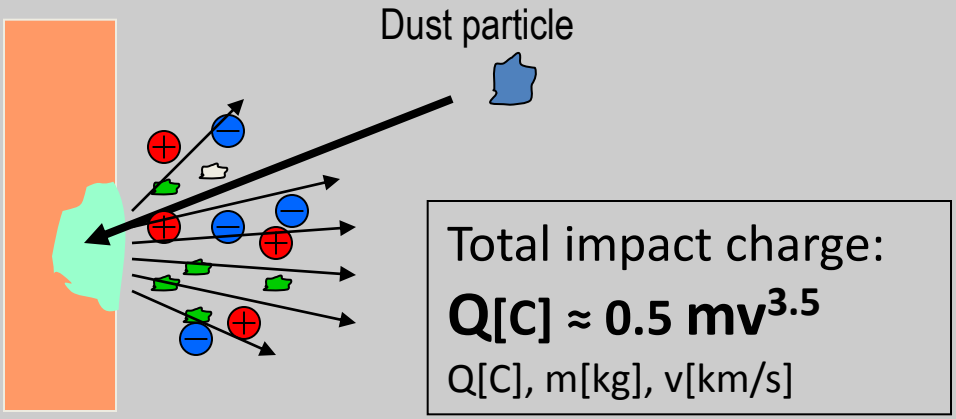
- Elemental/organic/isotopic composition of interstellar dust
- Chemical inventory in fresh cometary and asteroidal materials
- Habitability, surface chemistry, geological processes of airless bodies (Europa, Ganymede, Moon,…)
- Geology/geochemistry of active moons (Io, Enceladus, Europa?)
- Characterizing basic processes (ejecta production)
- Dust interaction with magnetospheres/heliosphere
- Dynamics of slow-moving dust near the Moon or asteroids

High performance instruments are now available

- Higher sensitivity
- Better mass resolution
- Large collection area
- Accurate velocity vector measurement
- Detection of slow moving dust

In-situ Detection Principle - Impact Ionization

Hypervelocity impact (> 1 km/s)

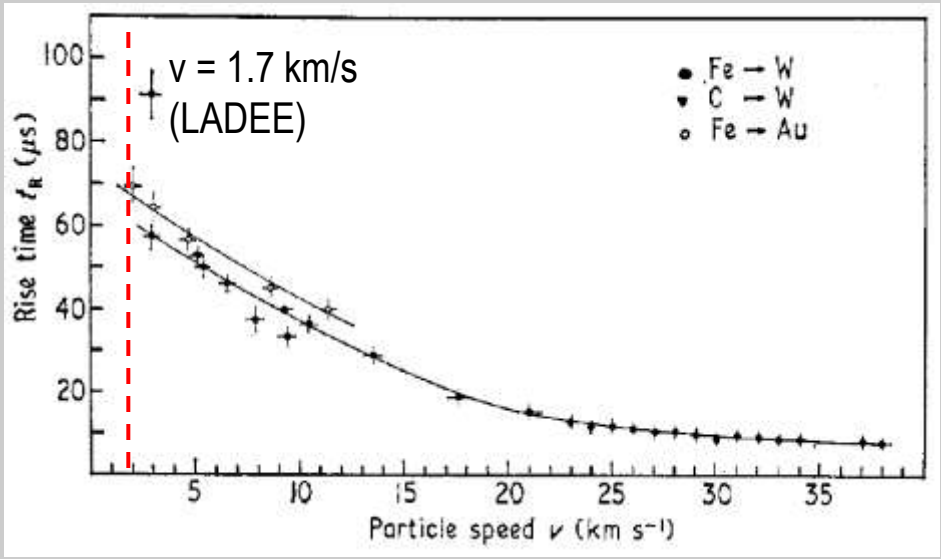


Total impact charge:

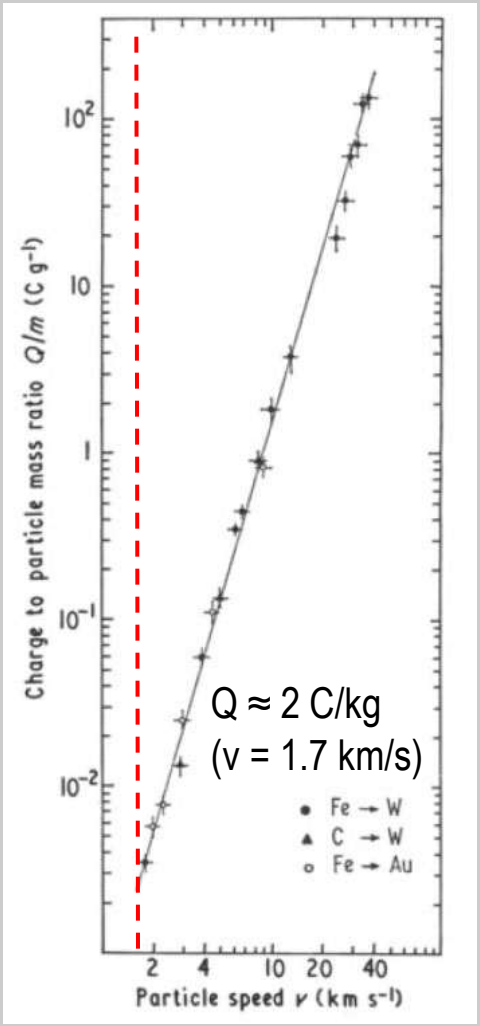
$$Q[C] \approx 0.5\, m v^{3.5}$$

Q[C], m[kg], v[km/s]

Velocity determined from signal rise-time



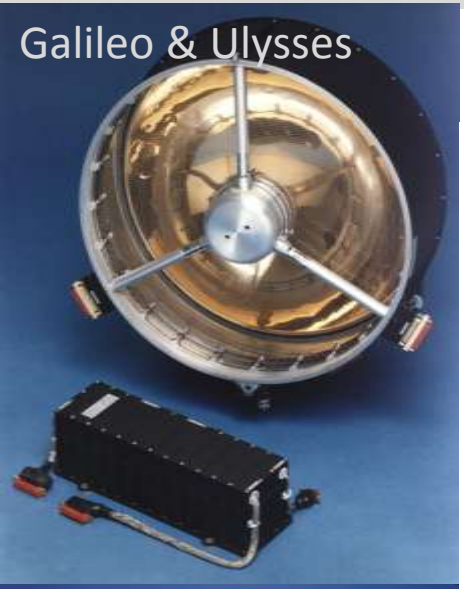
Mass determined from impact charge



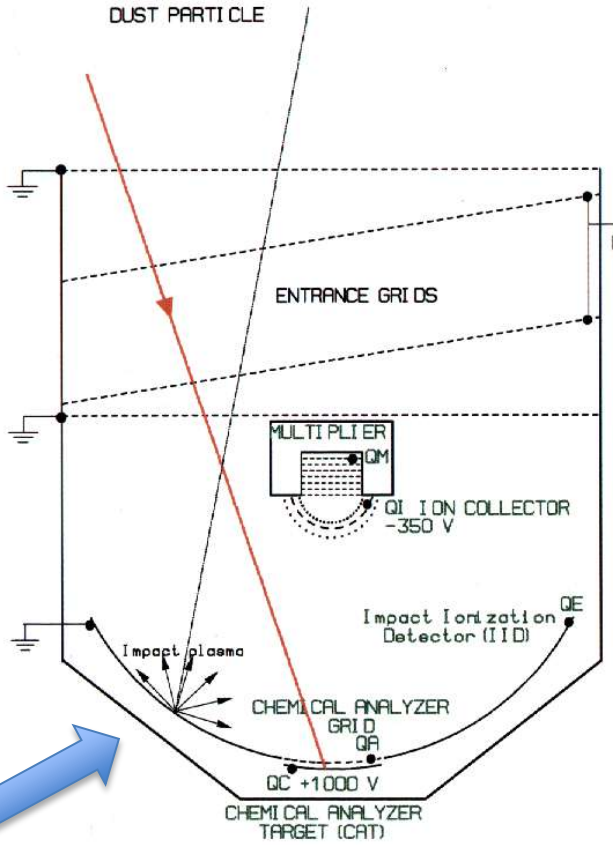
Dietzel et al., J Phys E (1973)

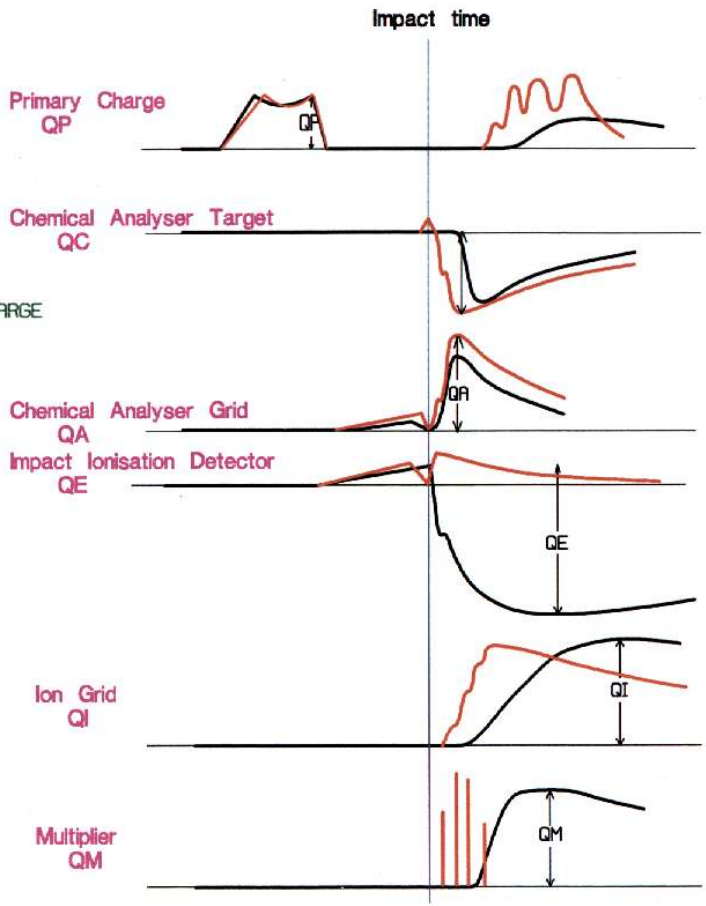
Galileo, Ulysses & Cassini dust instruments

Galileo & Ulysses



Cosmic dust analyzer on Cassini





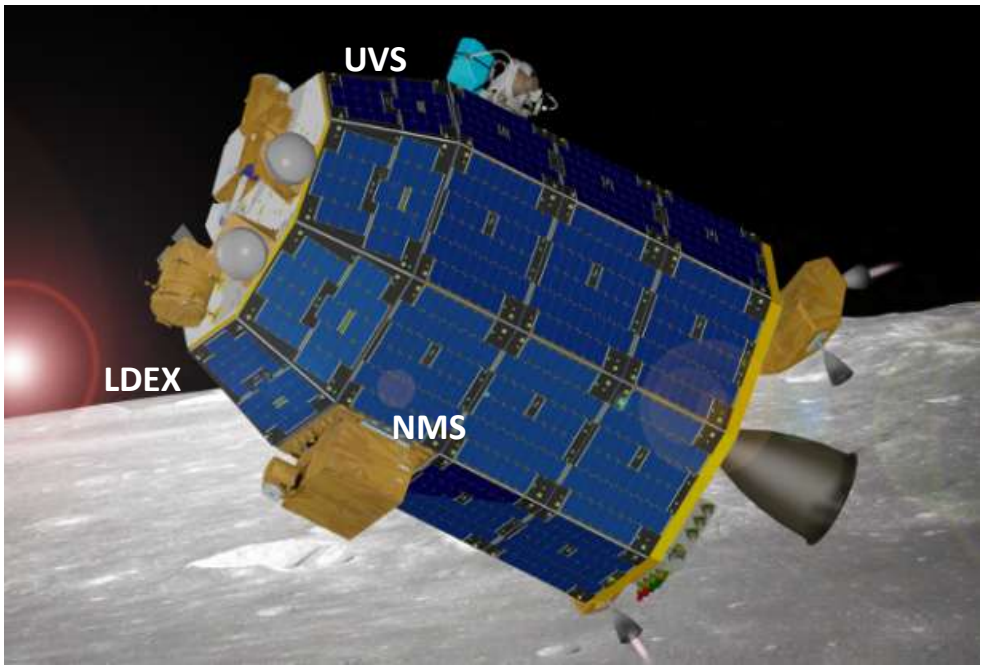
M/dM ~ 20-30

LADEE: Upcoming Lunar Mission

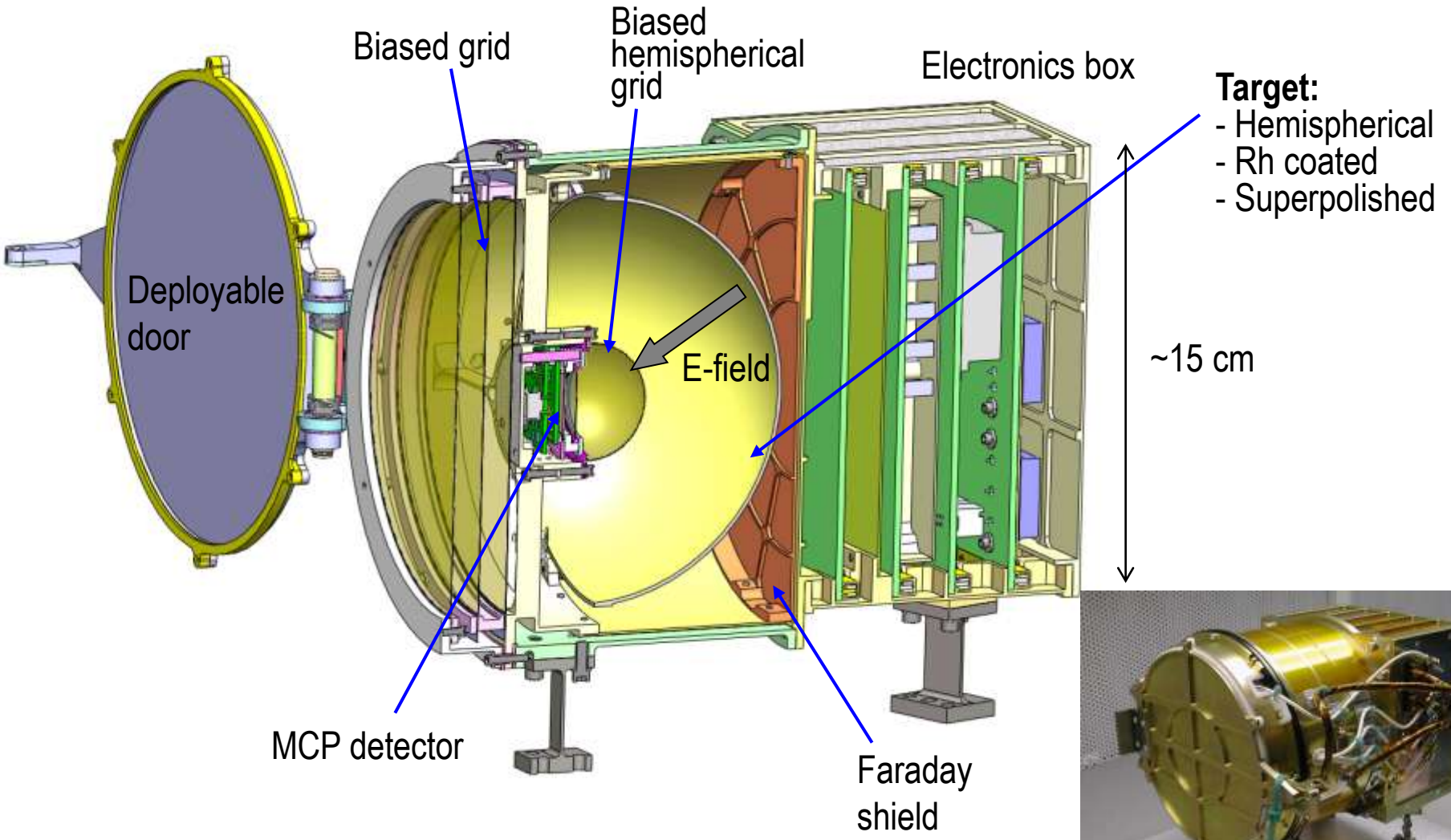
Lunar **A**tmosphere and **D**ust **E**nvironment **E**xplorer

Launch: Aug 2013

Orbit: ~50x200 km elliptical orbit, 100 days of operation

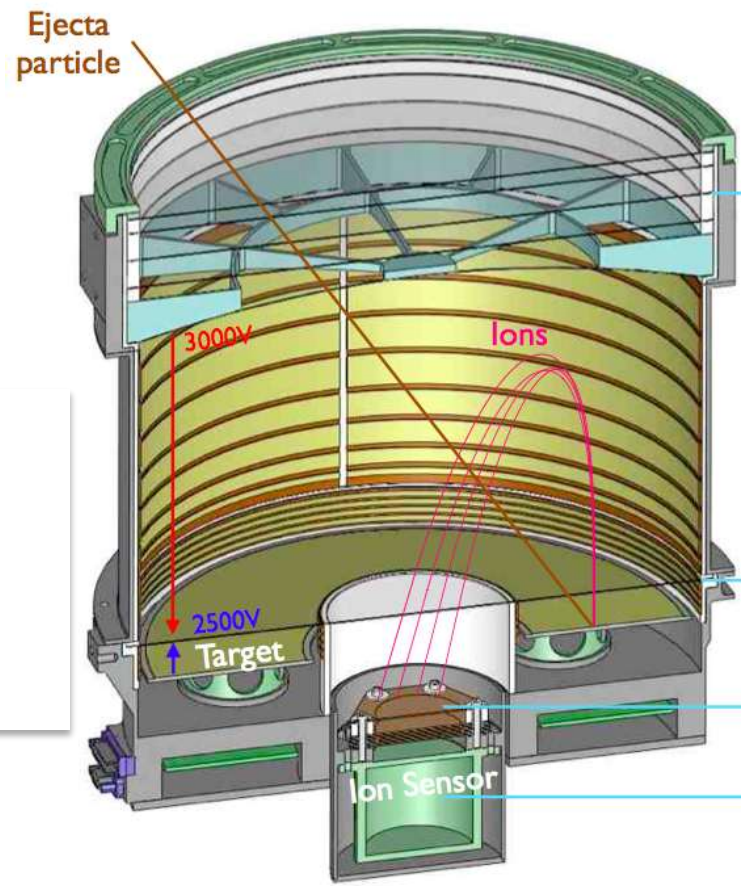


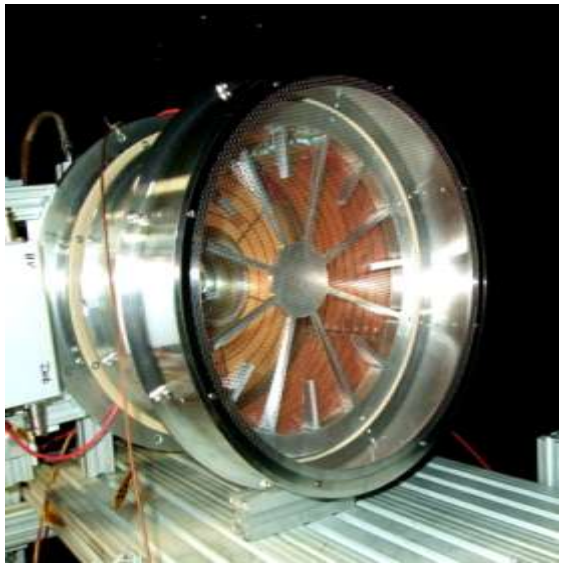
LDEX Instrument



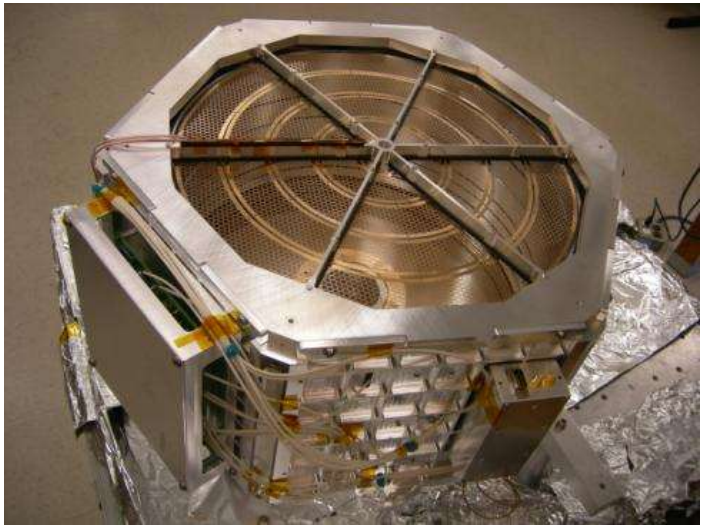
- High sensitivity (0.25 micron @ 1.7 km/s)
- Insensitive to solar and reflected UV

High-resolution mass analyzers





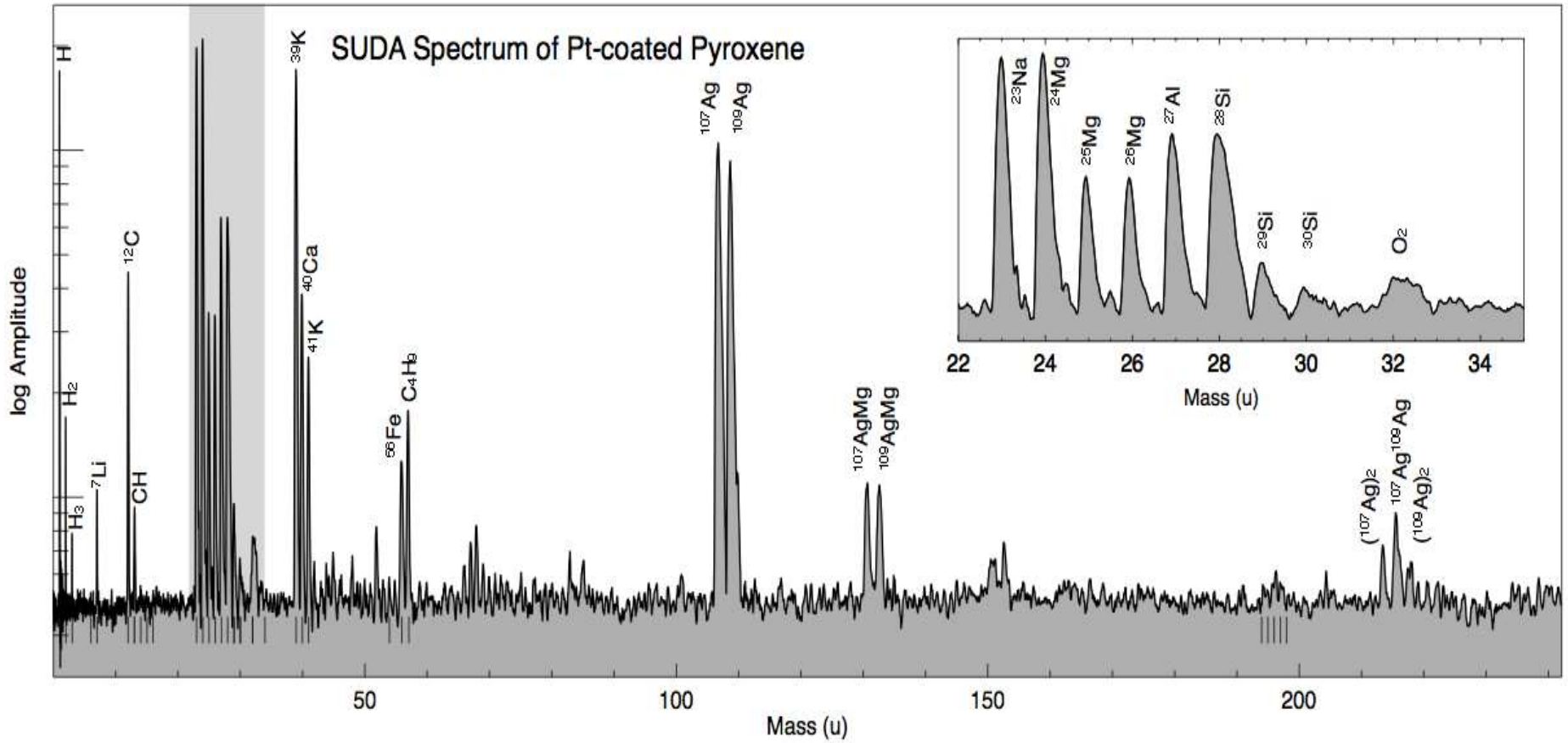
~200 cm^2



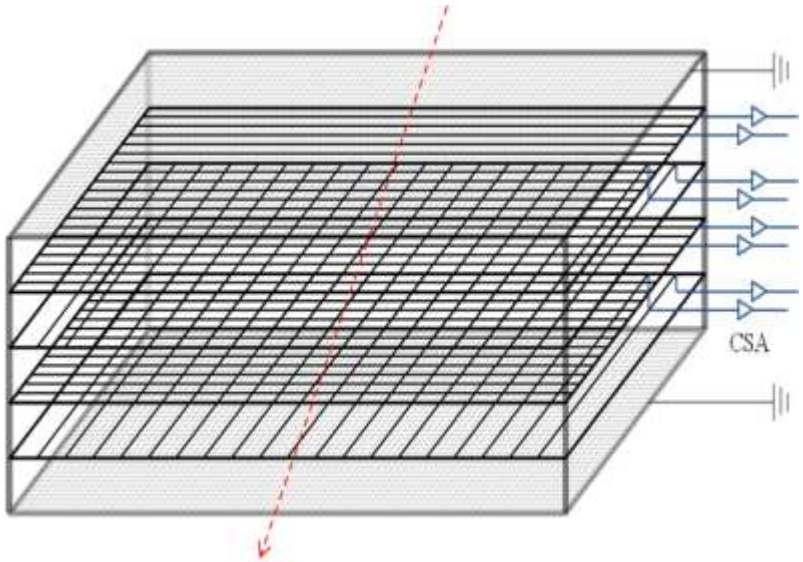
~1,000 cm^2

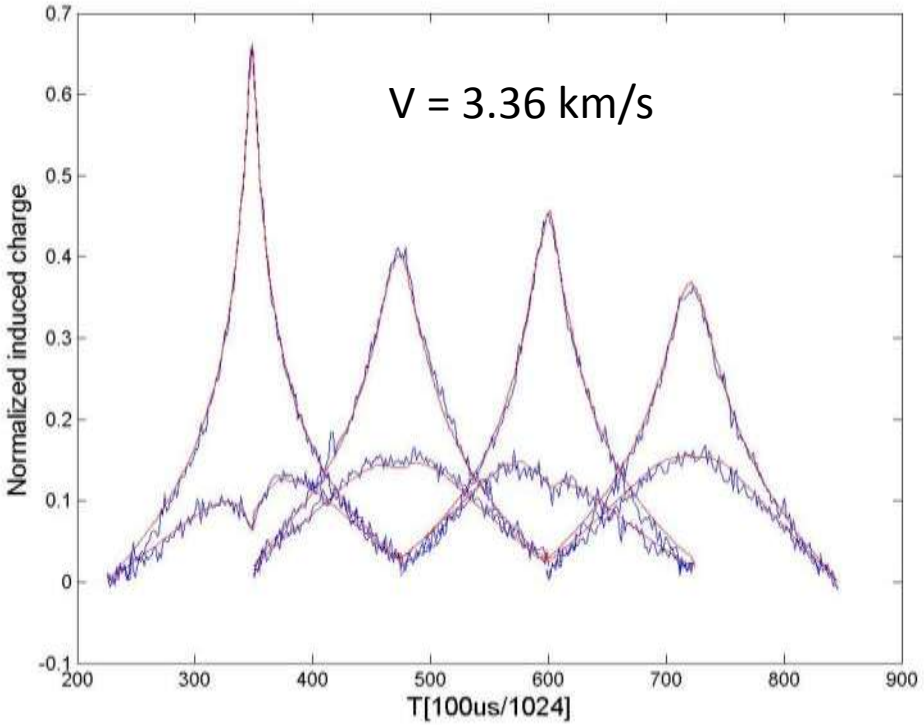
- Reflectron-like ion optics
- Target area ~-0.02 - 0.2 m^2
- $m / dm \geq 200$

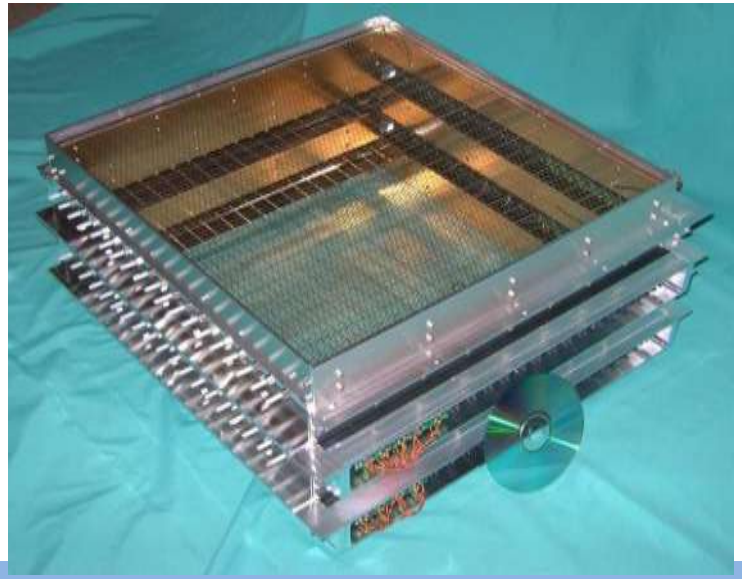
Example mass spectrum



Dust Trajectory Sensor

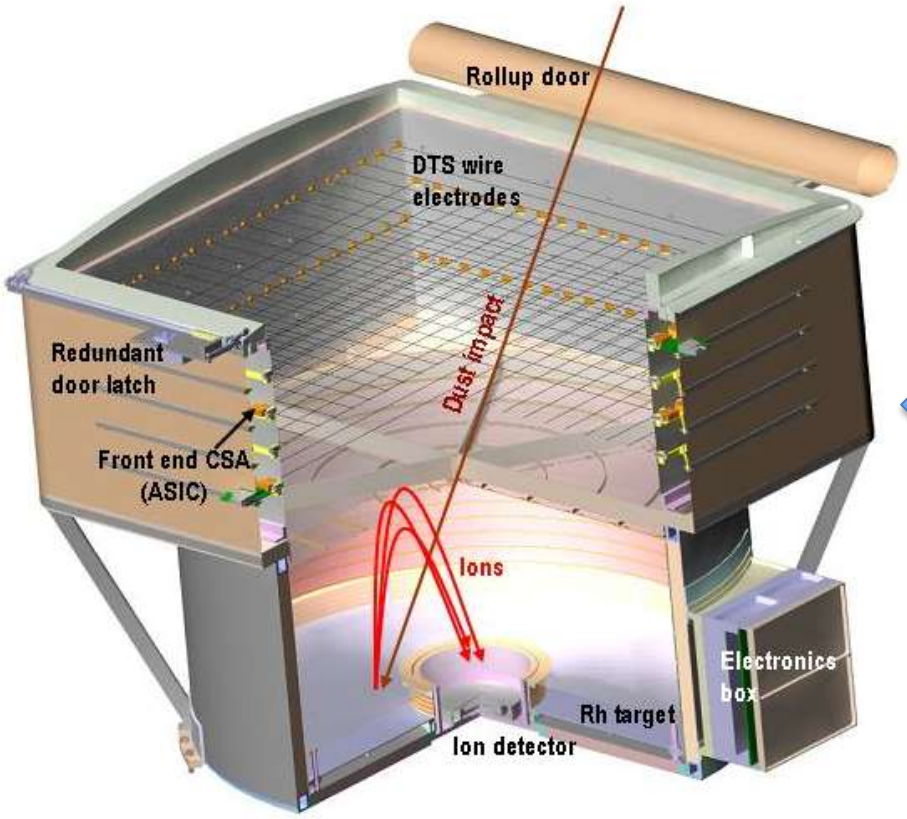


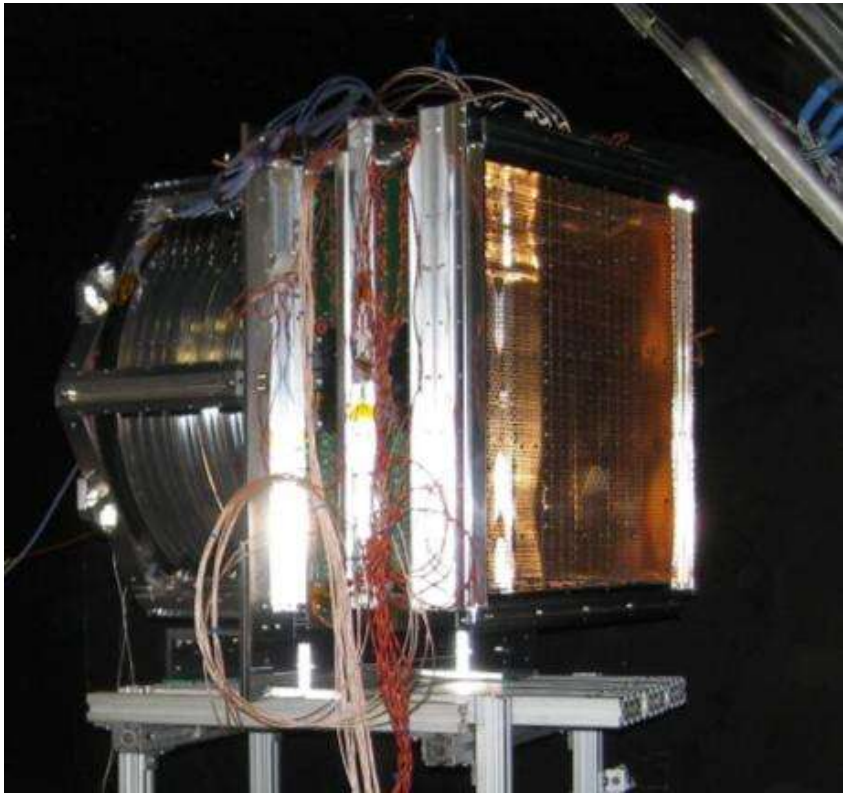




- The data analysis is done by fitting the measured signals with numerical simulations.
- Expected performance:
  - sensitivity ~ 0.3 micron radius (5V)
  - Velocity accuracy: ~ 1% or better
  - Angular accuracy: ~ 1 degree or better

Dust Telescope





Chemical Analyzer + Dust Trajectory Sensor

Effective target area: ~ 0.1 m^2

Velocity: < 1% accuracy

Direction: < 1 degree

Mass resolution: M/dM > 200

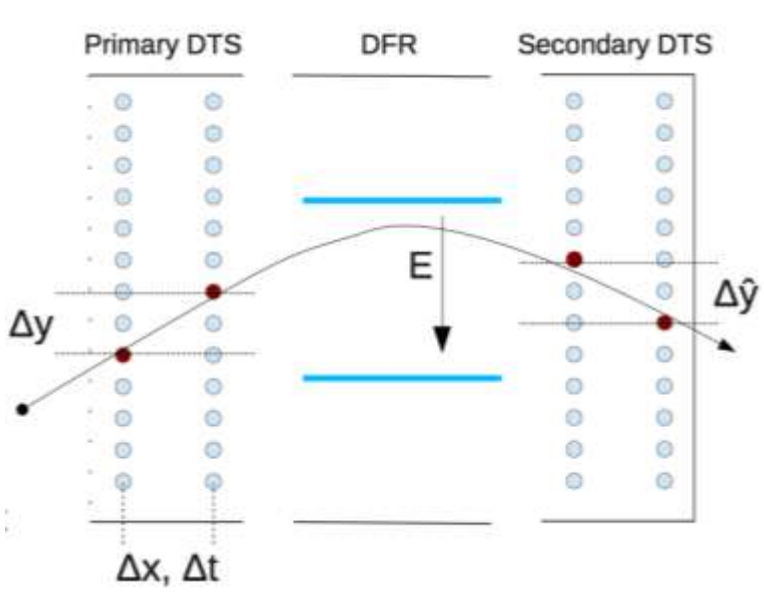
Dust Astronomy =

Identify source

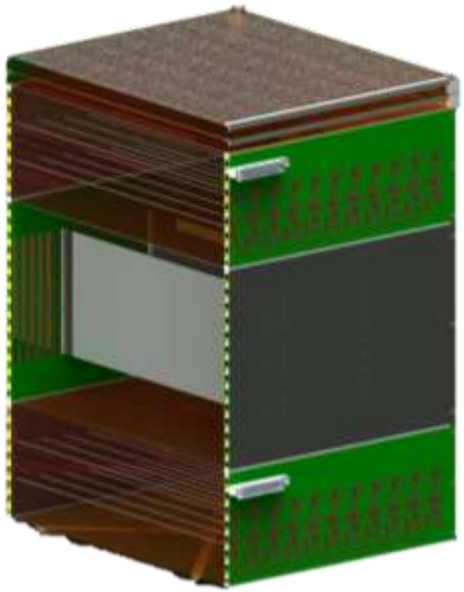
+

Measure composition

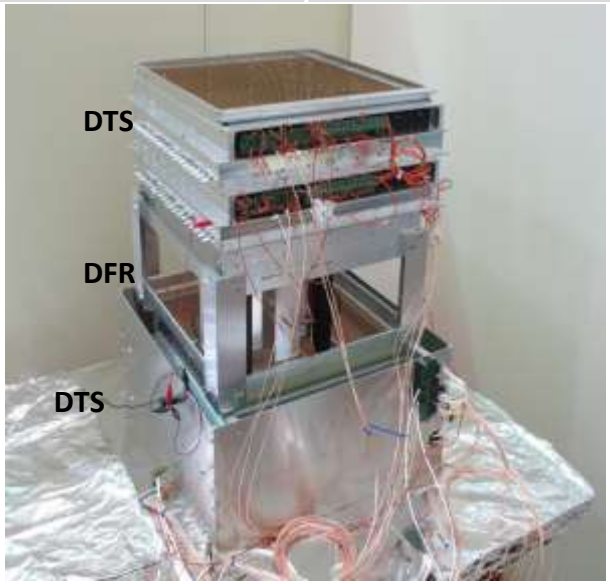
Slow moving dust detection



Concept

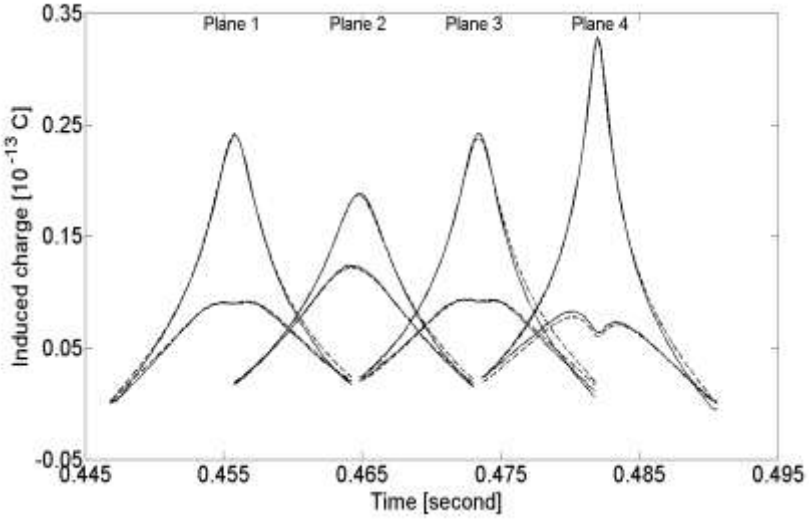


Design



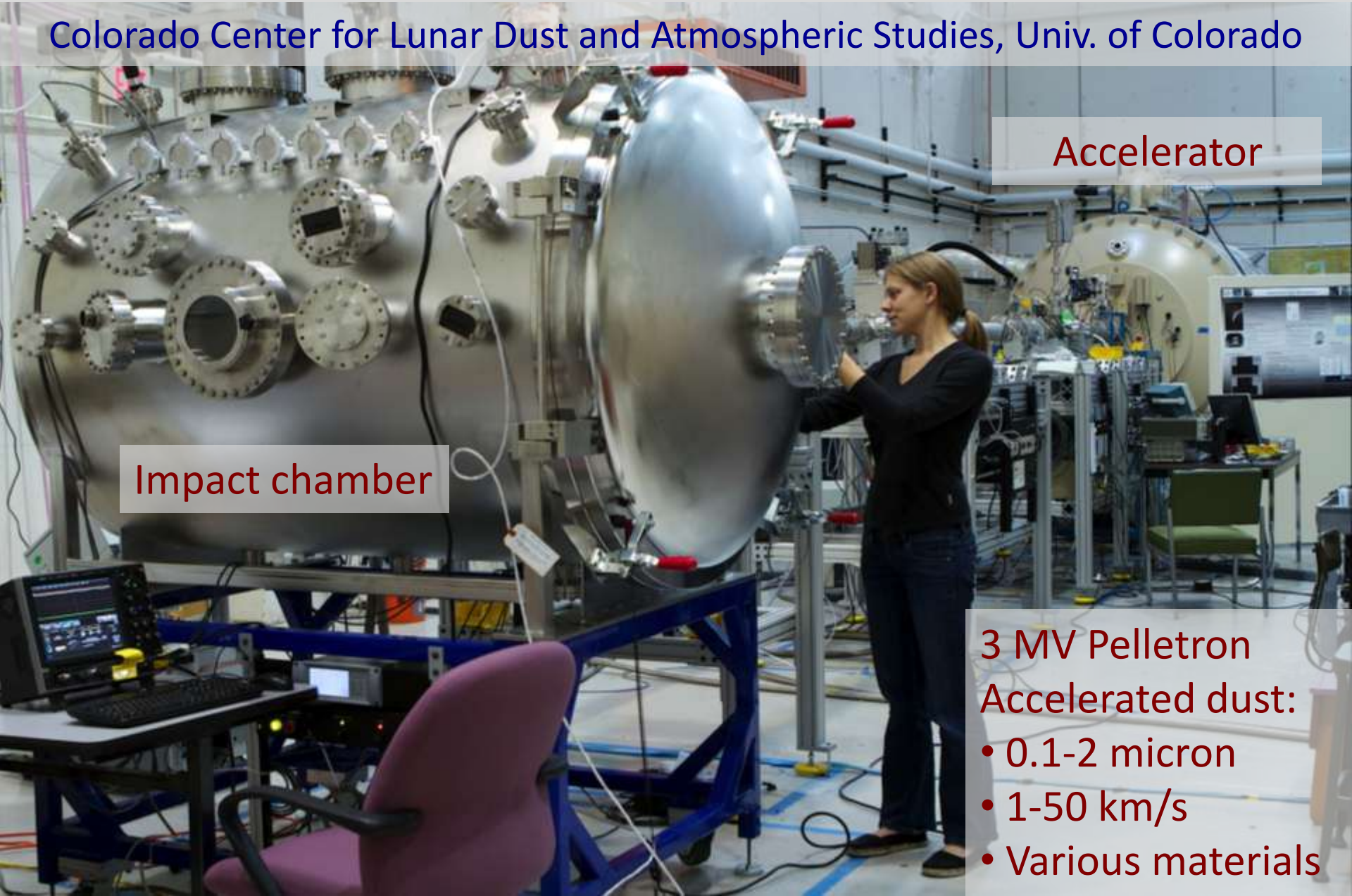
Prototype

- Electrostatic Lunar Dust Analyzer (***ELDA***)
- Low velocity (1-100 m/s), micron sized charged dust
- Measures: Q, m, v (charge, mass, velocity vector)
- 1 degree, 1% velocity vector measurements
- Submicron-size dust sensitivity



Testing and calibration (dust accelerator)

Colorado Center for Lunar Dust and Atmospheric Studies, Univ. of Colorado



3 MV Pelletron
Accelerated dust:
- 0.1-2 micron
- 1-50 km/s
- Various materials

Summary

- Dust is abundant in the solar system
- Major discoveries on every planetary mission
- Dust science: *more than just density/size distributions*
- LDEX on LADEE to map out dust around the Moon
- Continual improvement of instrument performance