Dust Mobilization on the Lunar Surface

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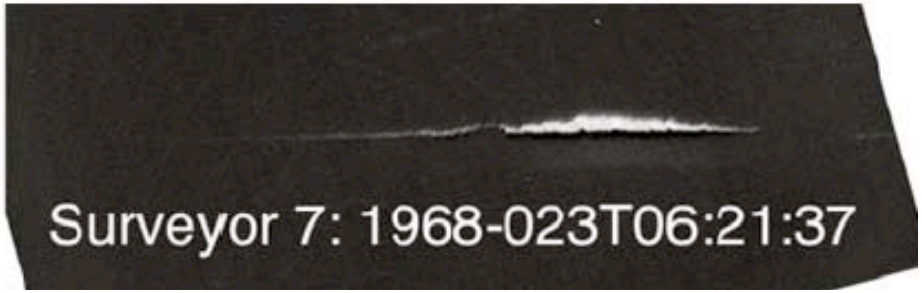
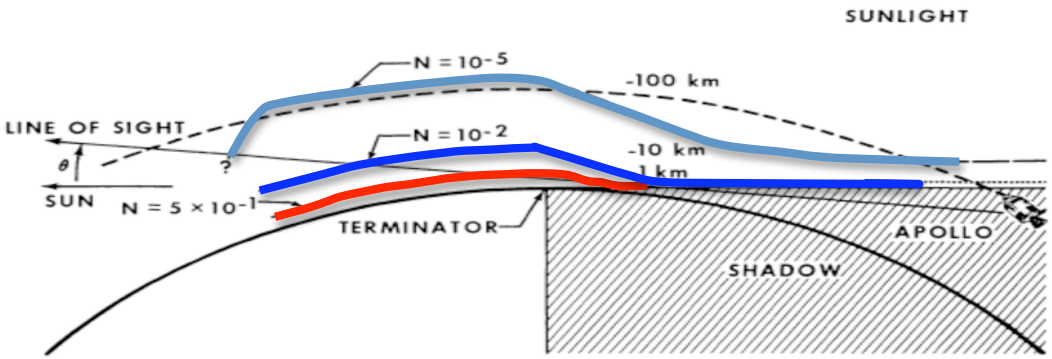
Outline:

1) Existing observations & outstanding issues
2) Laboratory experiments
3) Modeling
4) LADEE/LDEX status
5) New instrument concepts

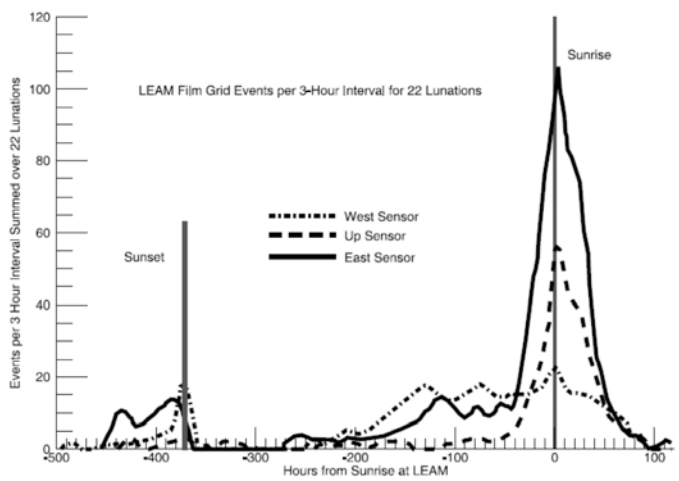
Observations



Horizon glow

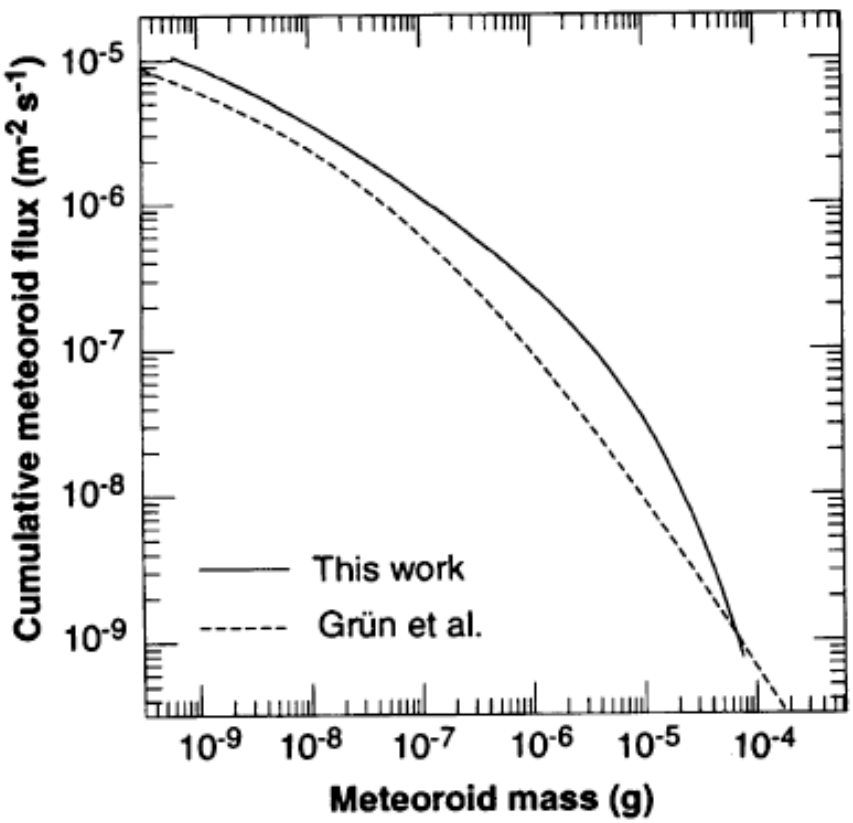


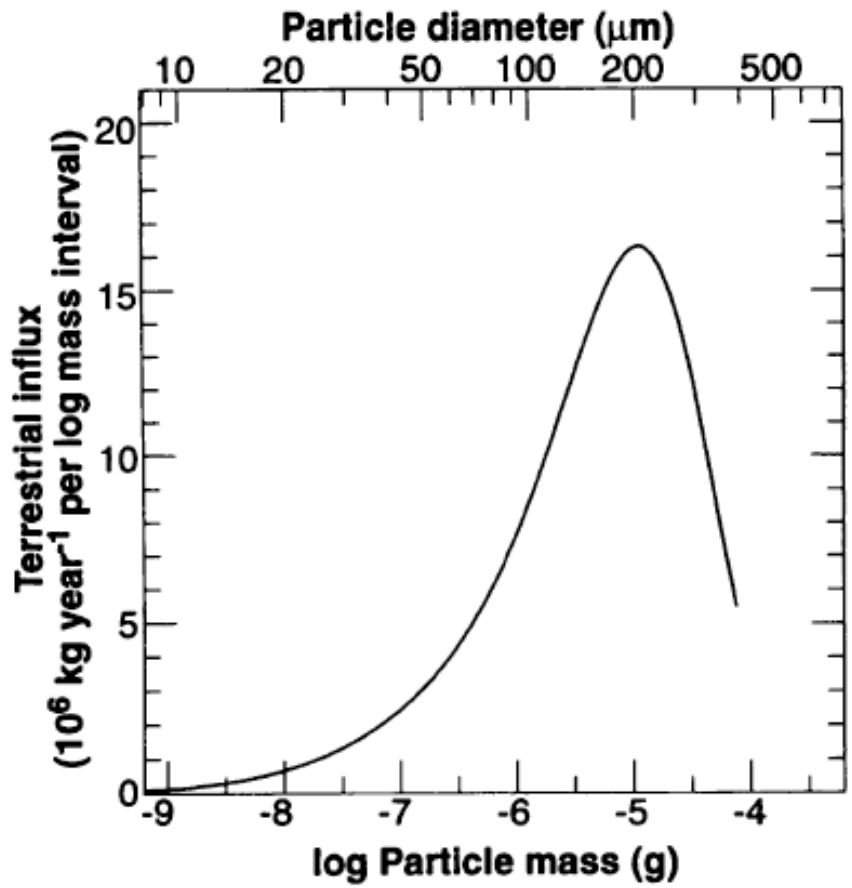
Excess brightness



LEAM

Interplanetary Dust Bombardment



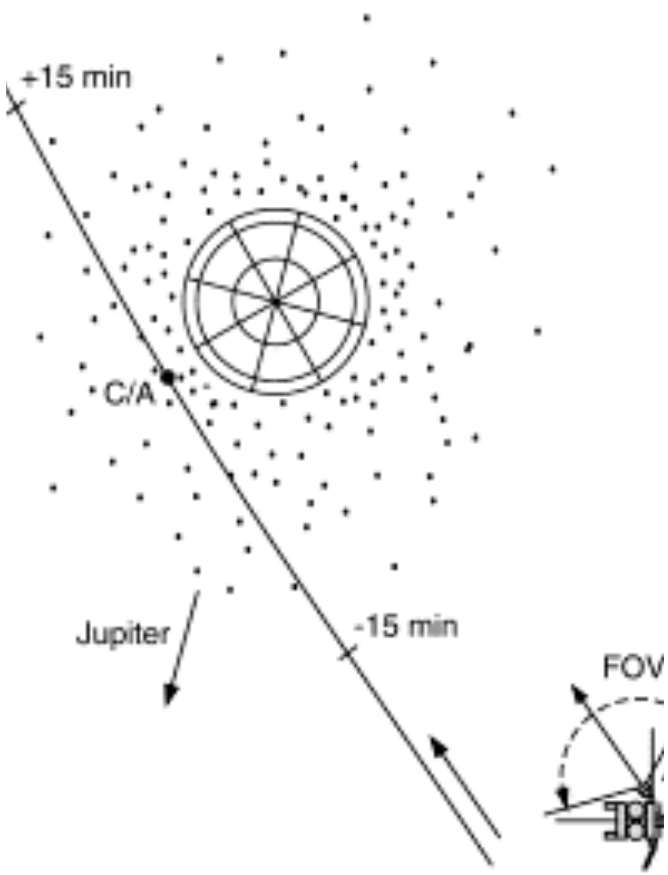


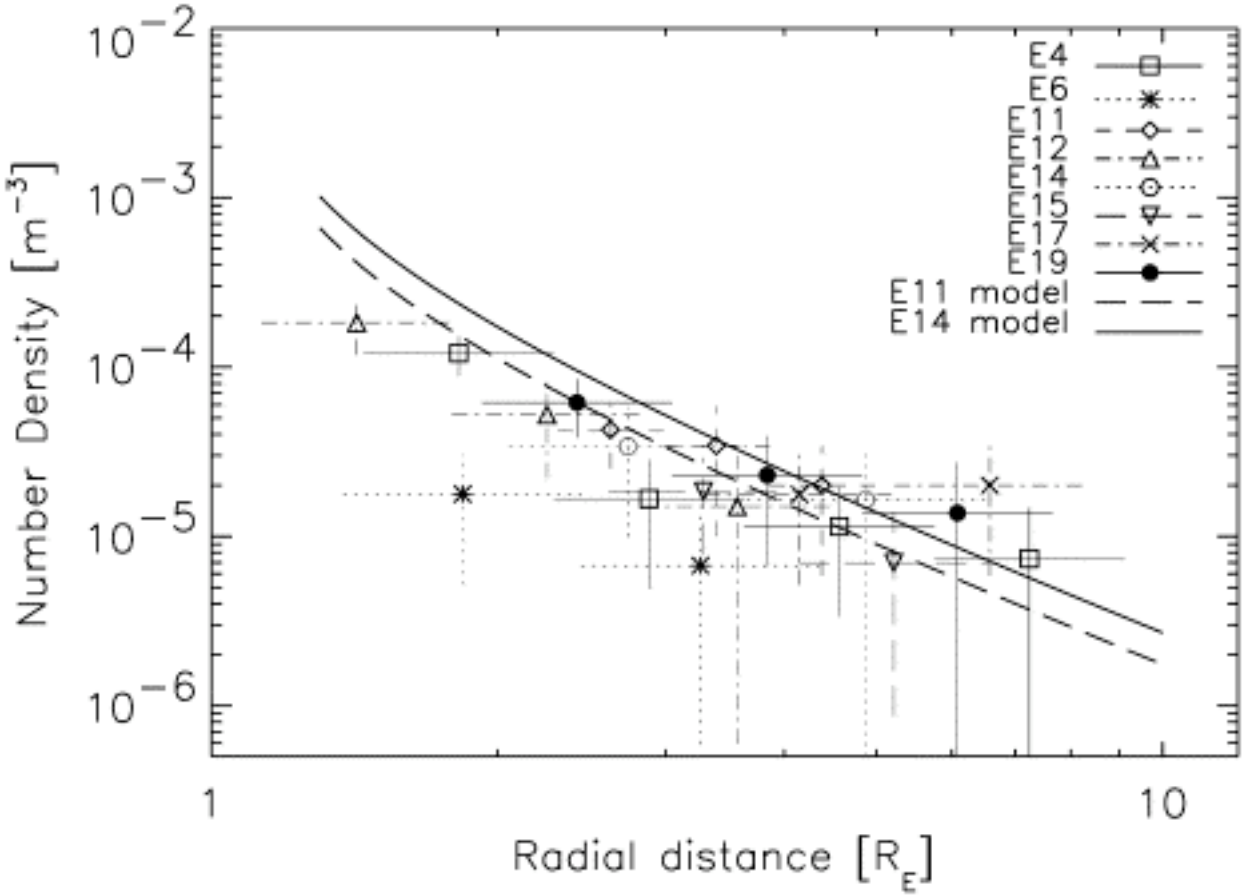
100 ton/day @ Earth → 5 ton/day @ Moon

Love and Brownlee, 1993

Secondary Ejecta

Galileo @ Europa

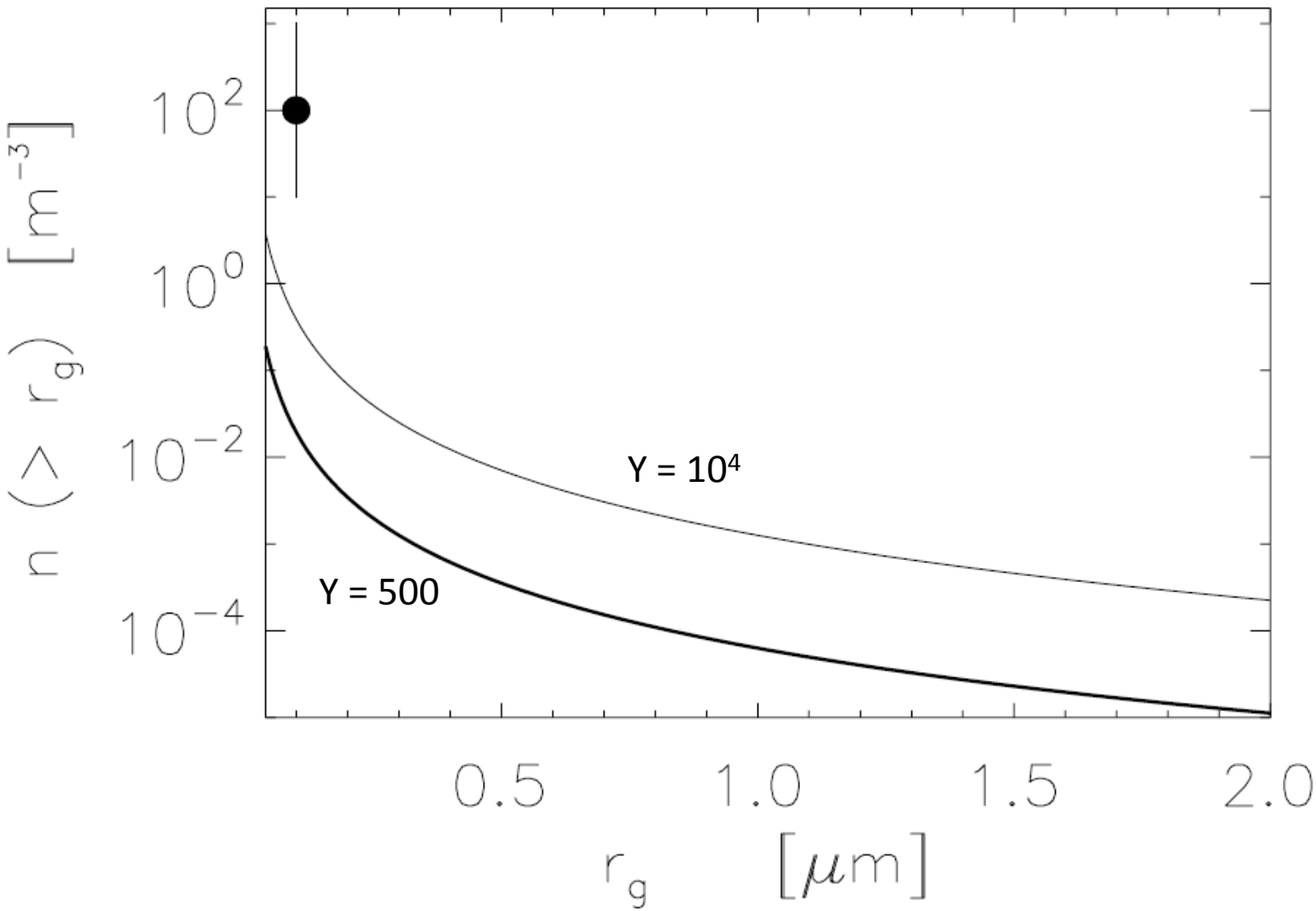




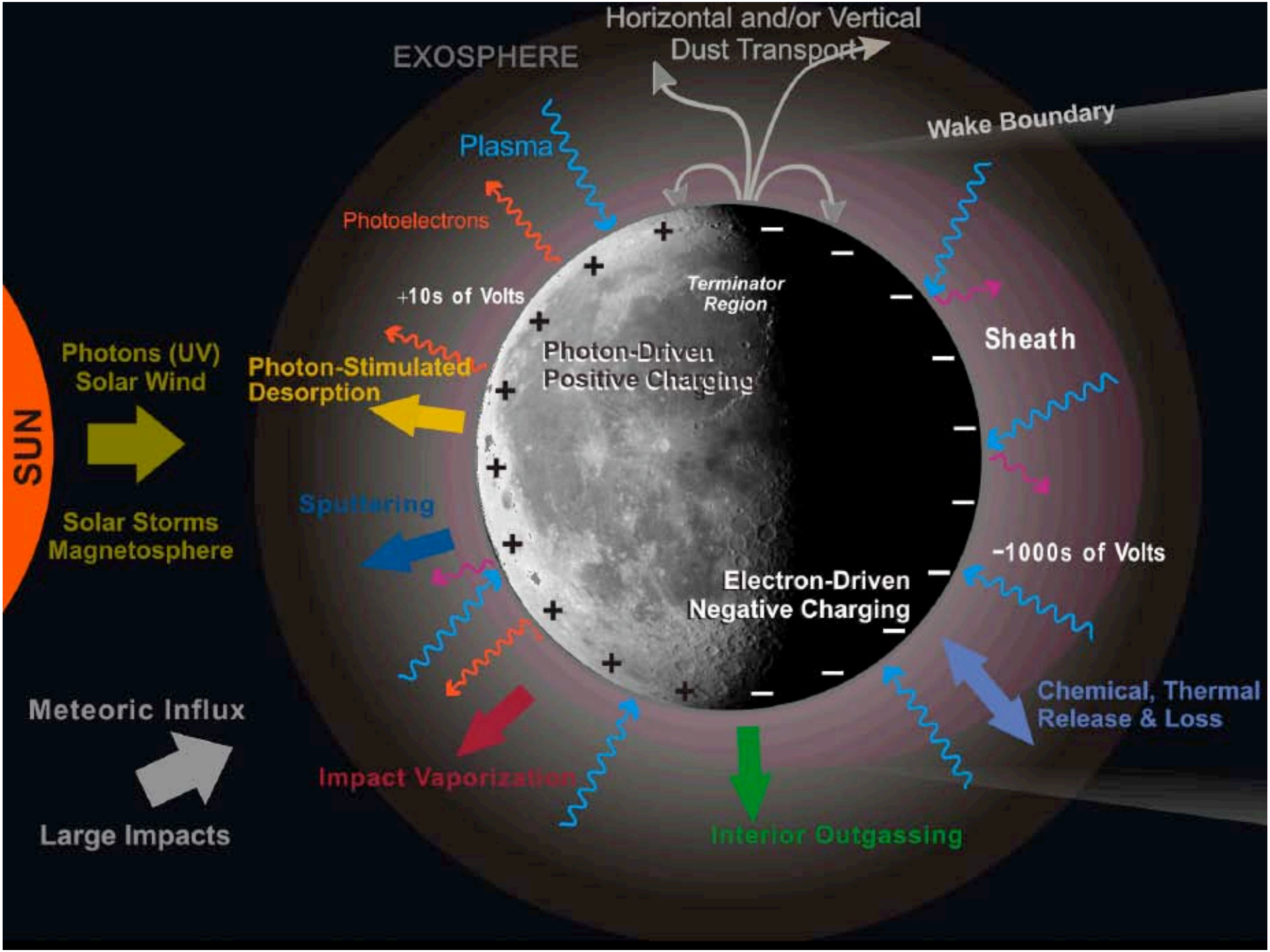
Parameters: yield, ejecta mass and velocity distributions

Kruger et al, 2003

Lunar Ejecta



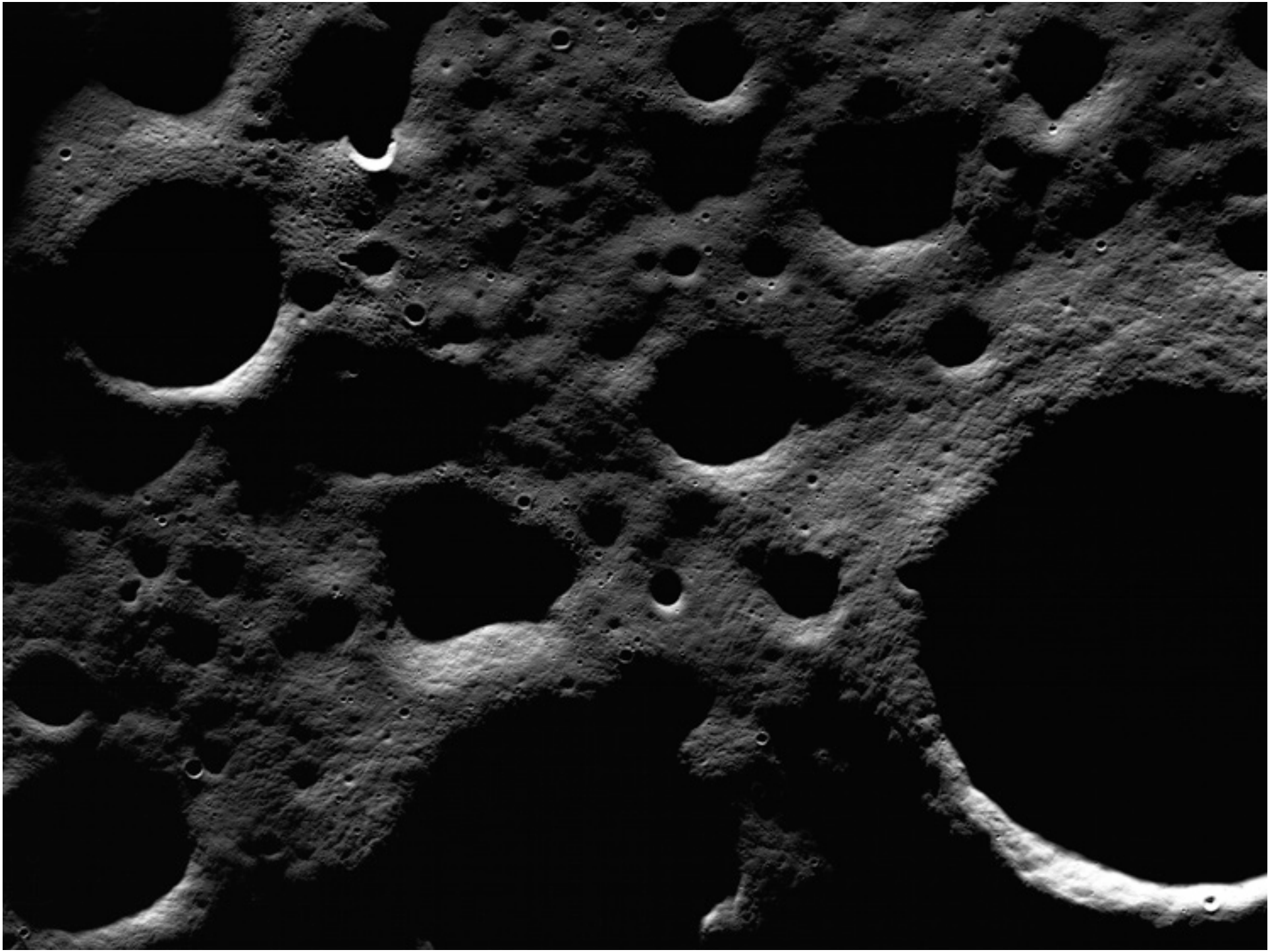
CCLDAS


Horizontal and/or Vertical
Dust Transport
EXOSPHERE
Wake Boundary
Plasma
Photoelectrons
+10s of Volts
Terminator
Region
Sheath
Photon-Driven
Positive Charging
Photons (UV)
Solar Wind
Photon-Stimulated
Desorption
SUN
Sputtering
Solar Storms
Magnetosphere
-1000s of Volts
Electron-Driven
Negative Charging
Chemical, Thermal
Release & Loss
Meteoric Influx
Impact Vaporization
Large Impacts
Interior Outgassing

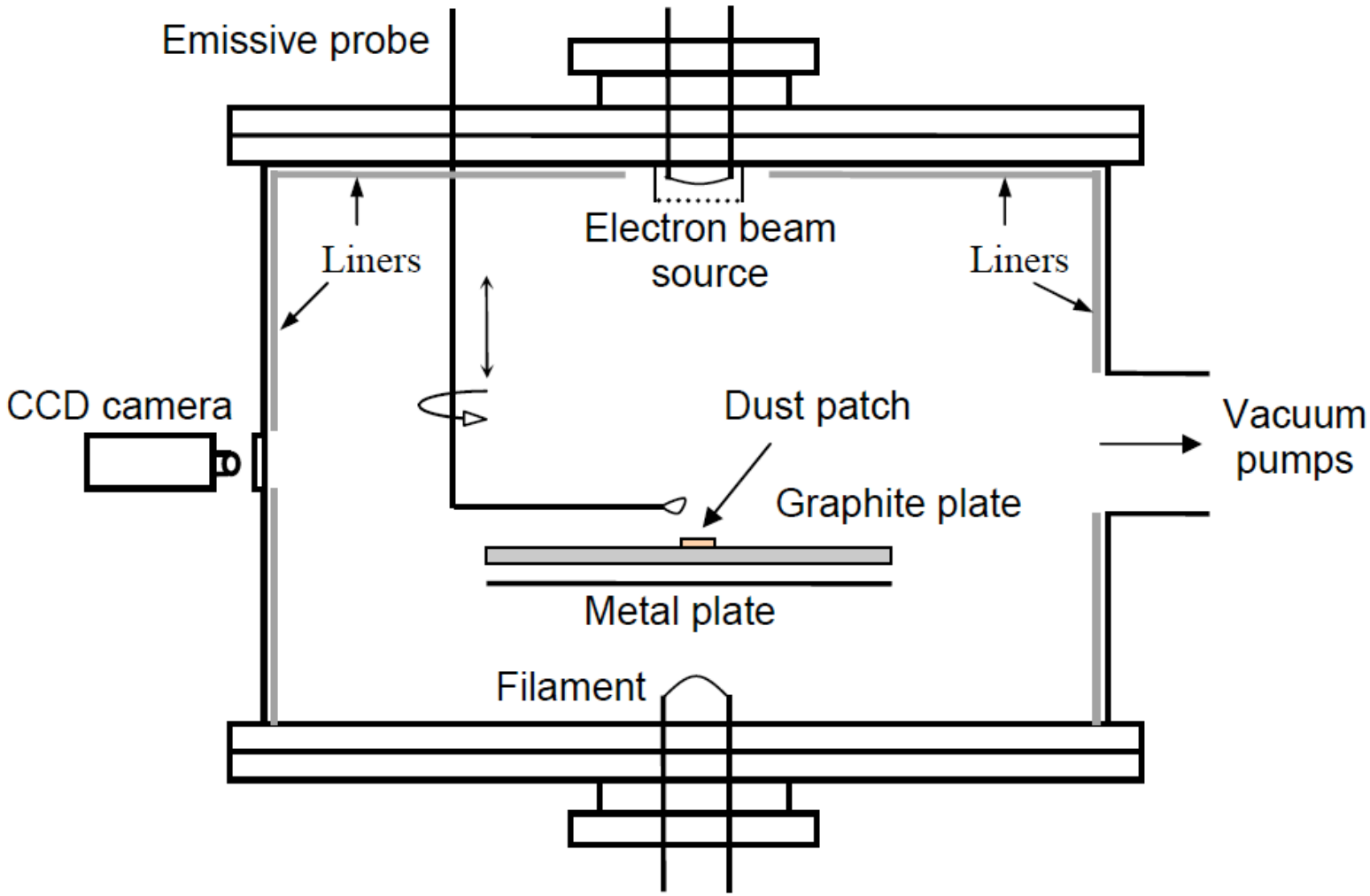
SOLAR WIND CONDITIONS

			DAYSIDE	NIGHTSIDE
Photoelectron flux	Γ_0	$cm^{-2}s^{-1}$	3×10^9	0
Plasma density	n_p	cm^{-3}	100	0.01
Plasma temperature	T_P	eV	2	10
Debye length	λ_D	m	1	$> 10^3$
Surface potential	Φ_S	V	+5	-1000
Surface charge density	σ_e	cm^{-2}	3×10^4	2×10^3
Surface electric field	E_s	V/m	5	< 1
Probability of 1 e charge	P_e		$10^{-3} a_\mu^2$	$5 \times 10^{-4} a_\mu^2$

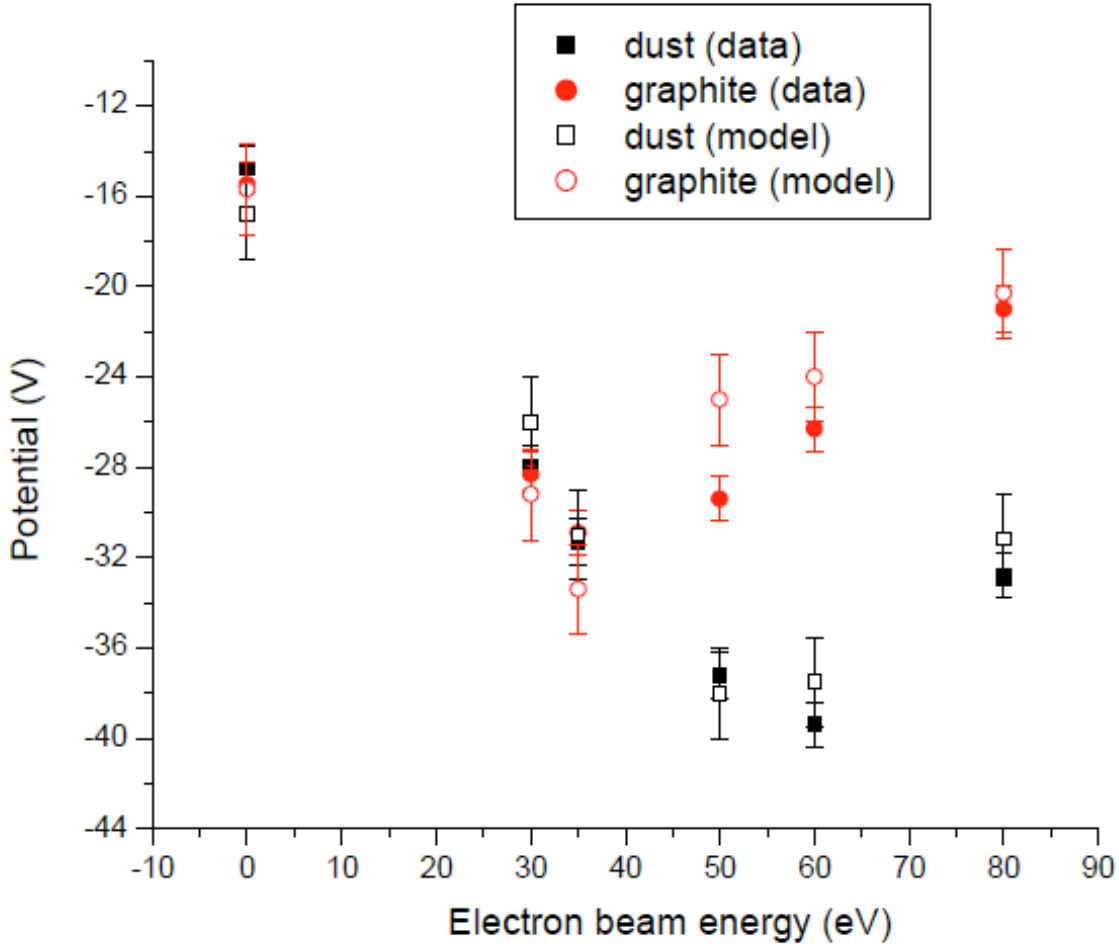
Dust liftoff due to sheath fields alone is unlikely!



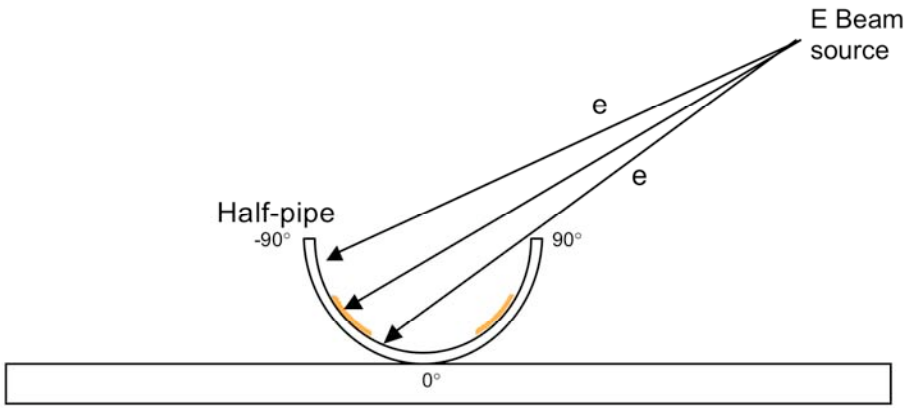
Laboratory Experiments

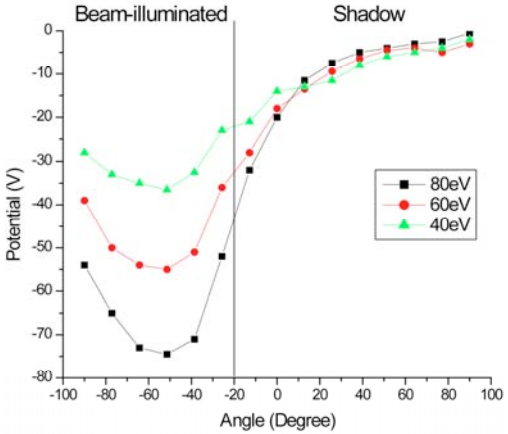


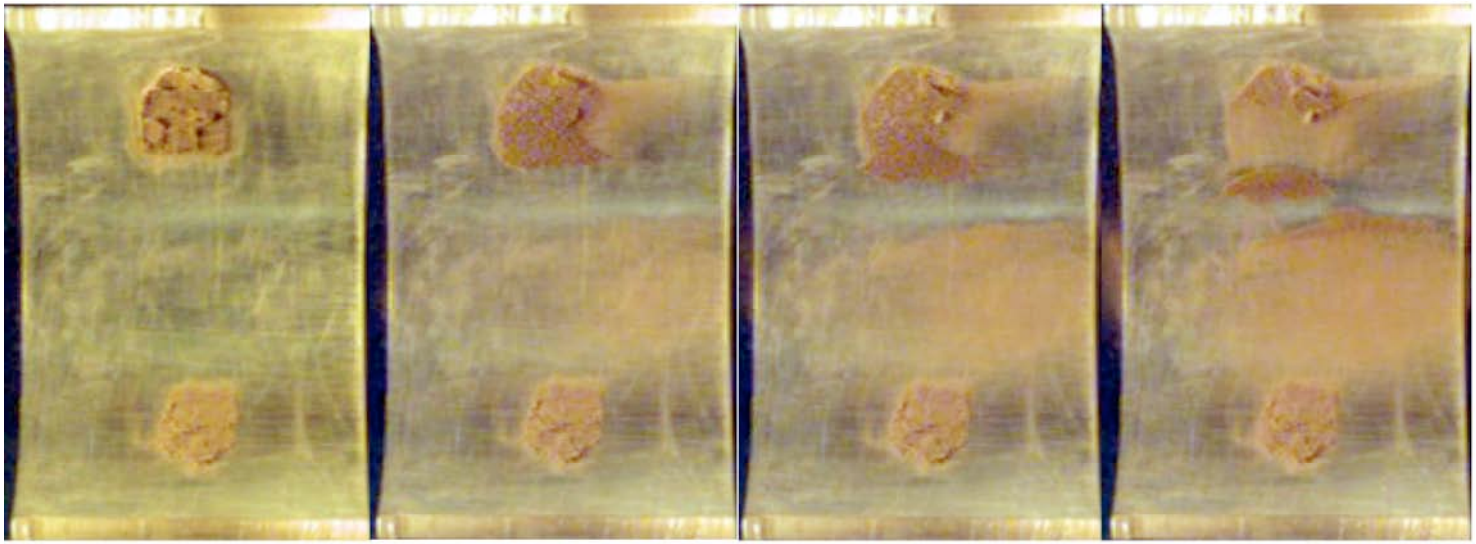
X. Wang, M. Horanyi, S. Robertson, Investigation of dust transport on the lunar surface in a laboratory plasma with an electron beam
J. Geophys. Res., submitted, 2010.



X. Wang, M. Horanyi, S. Robertson, Dust transport near electron beam impact and shadow boundaries
Planetary and Space Science, submitted, 2010.







0 min 75 min 140 min 230 min

Theory

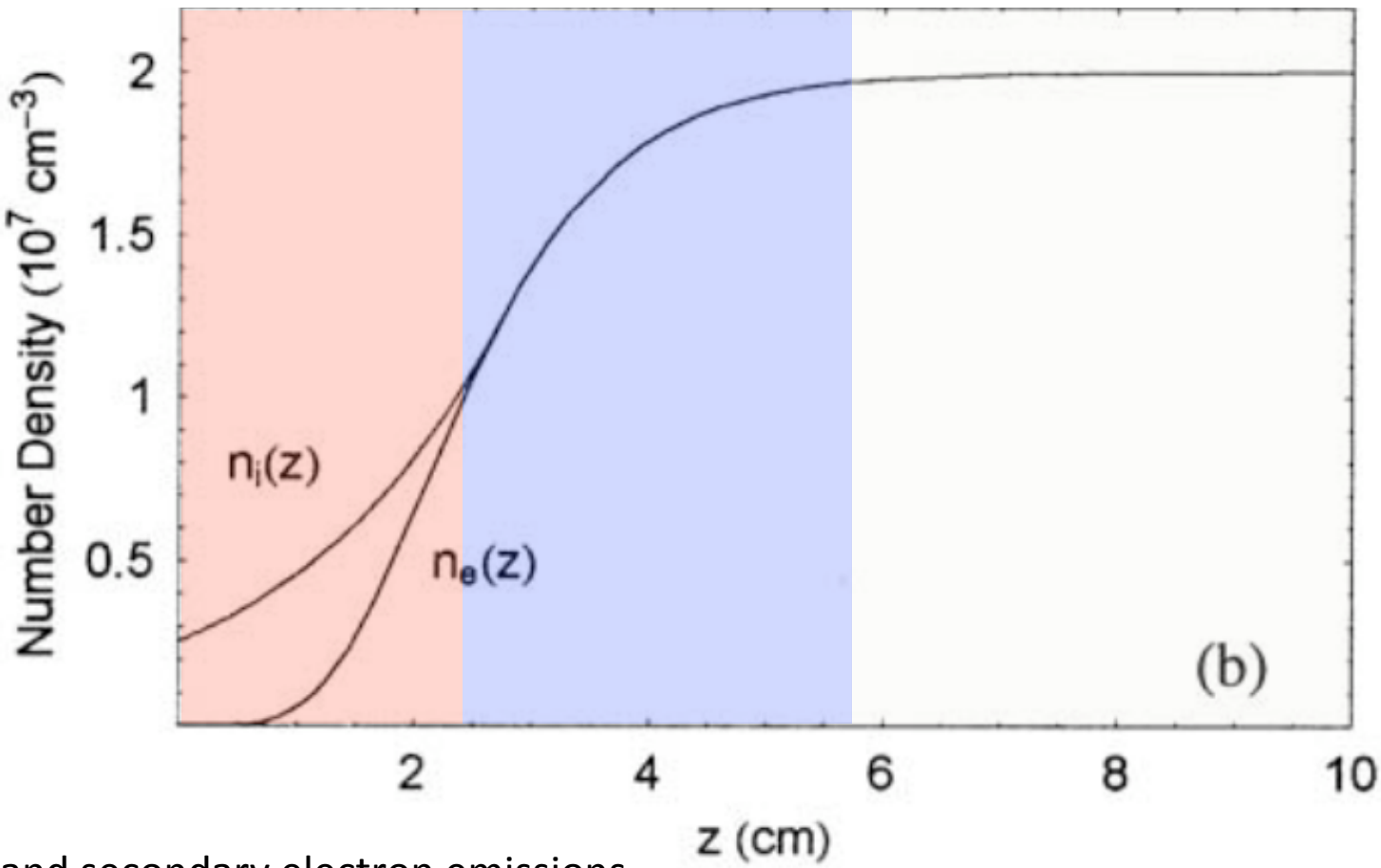
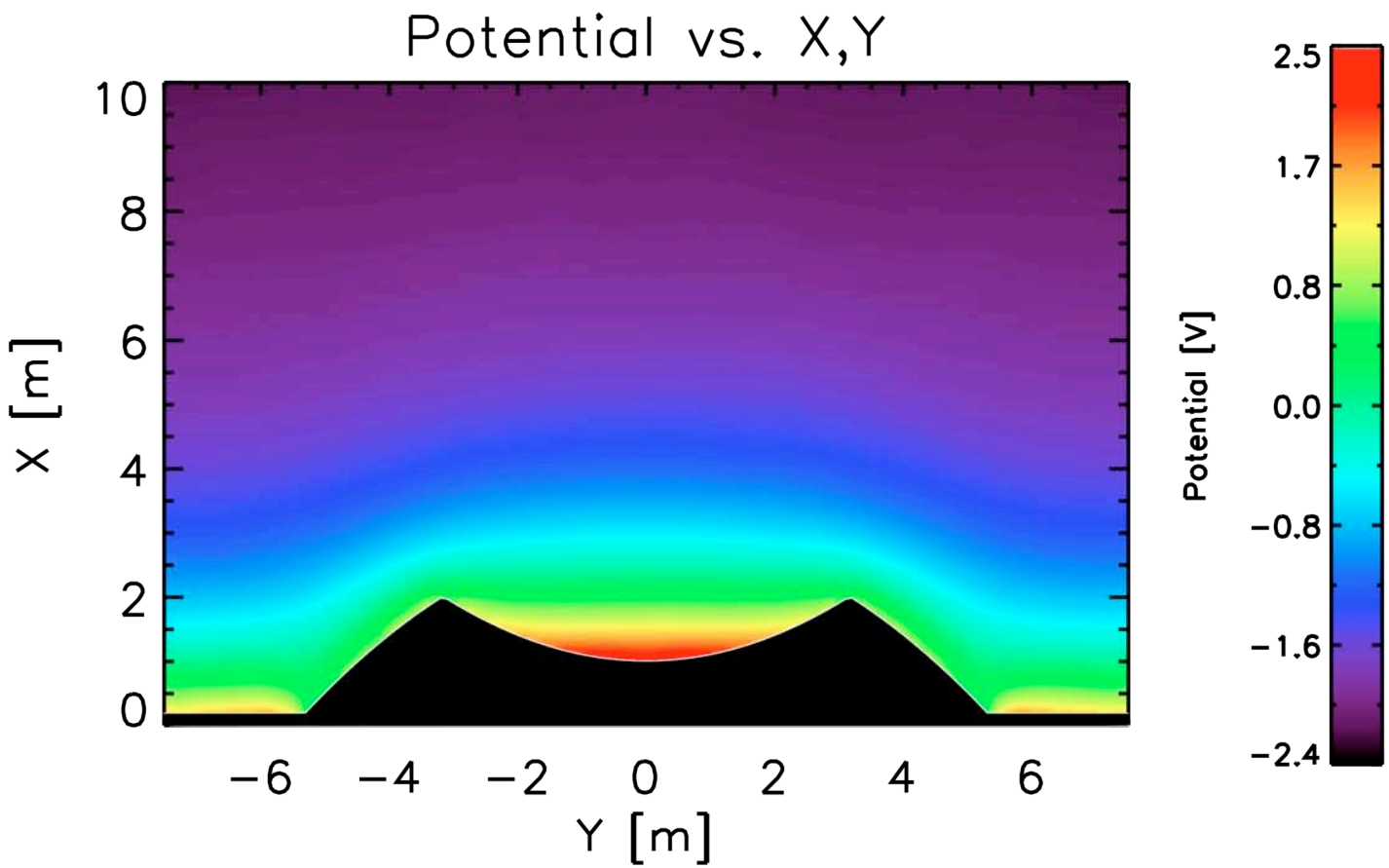
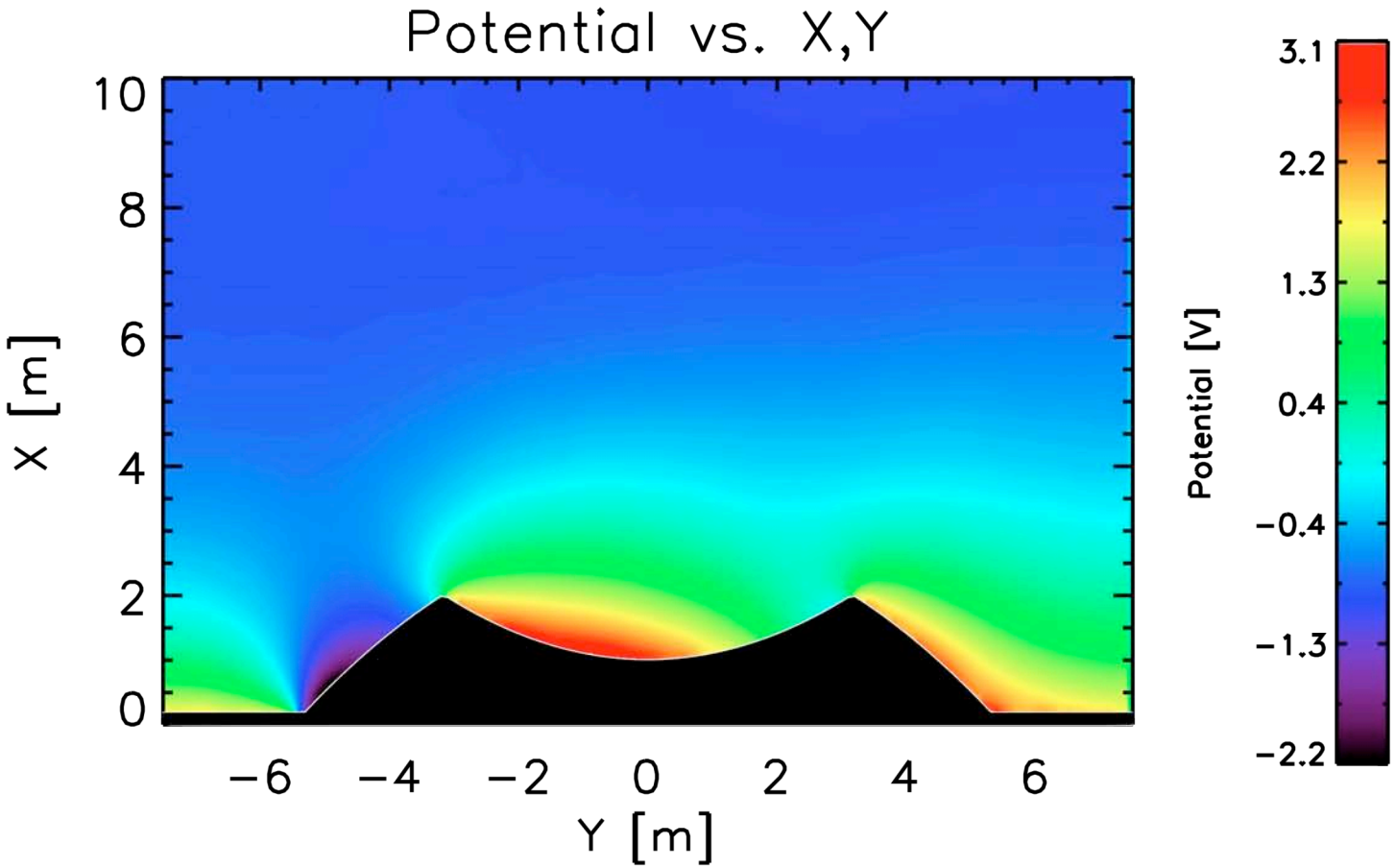


Photo and secondary electron emissions
Reflected ions
3D topography
Magnetic fields

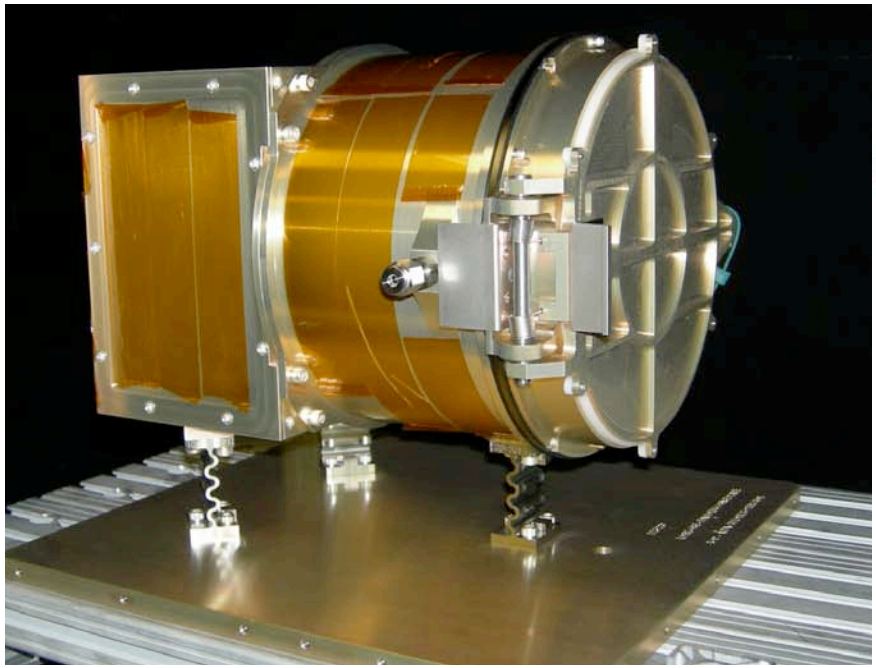

Potential vs. X,Y
X [m]
Y [m]
Potential [V]
10
8
6
4
2
0
−6
−4
−2
0
2
4
6
2.5
1.7
0.8
0.0
−0.8
−1.6
−2.4

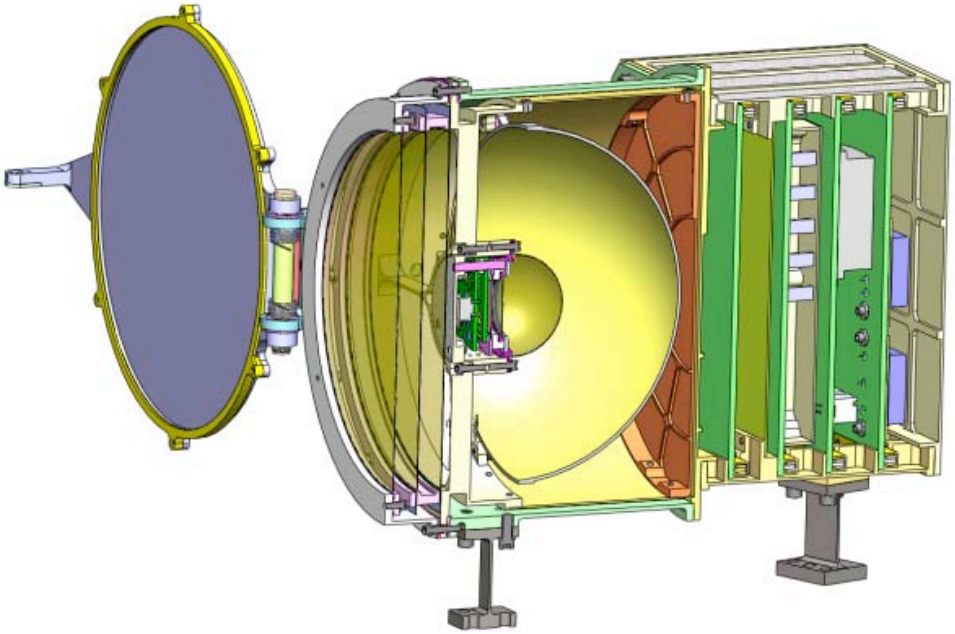
Oblique incidence



Lunar Atmosphere and Dust Environment Explorer: Dust Experiment (LDEX)

- Engineering Model is assembled and functionally tested
- EM has been calibrated at the dust accelerator at Max Planck Institute for Nuclear Physics in Heidelberg





From: Zoltan Sternovsky <Zoltan.Sternovsky@lasp.colorado.edu>
Subject: **First dust**
Date: June 29, 2010 10:46:33 AM MDT
To: "LDEX@lasp.colorado.edu" <LDEX@lasp.colorado.edu>
Cc: Keith J Drake <keith.drake@colorado.edu>
1 Attachment, 161 KB

Dear All,

I am happy to report (for Keith and Charles as well) that we have the first dust impacts. The pressure in the chamber went down to < 2 x 10-6 Torr and we turned on LDEX step by step: MCP, hemispherical grid, ion focusing grid. It took only a second to capture the first dust particle signal. The noise levels are low and the impact signals are nice and clean. Attached you will find one saved data set analyzed.

The measured MCP charge is 1.58x10e9 electrons
The measured target charge is 6.19x10e6 electrons
The MCP gain calculated from above is G = 255. Considering the MCP quantum detection efficiency of about 50% and the effect of the two grids (50% combined open area), the actual gain is about G = 1000. This is close to the G ~ 2000 given by Hamamatsu for the applied voltage. We will investigate this effect more.

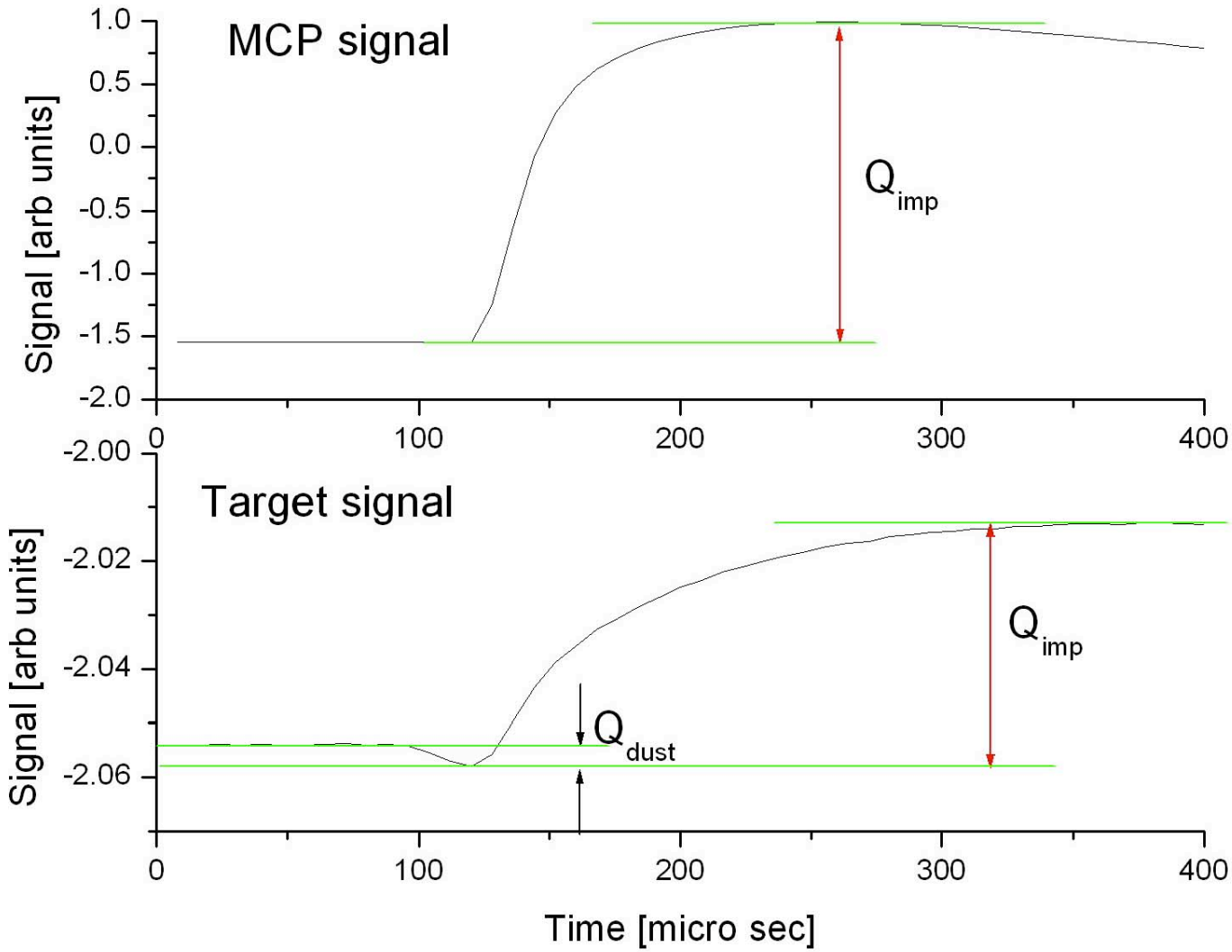
In other words, we are happy with how smoothly things have been going so far (will keep our fingers crossed though). Again, I need to acknowledge the excellent support we are getting from members of the local dust group.

The goal for today was to make sure that everything is working well. Tomorrow we start the systematic calibration measurements.

All the best to Boulder.

Cheers,
Zoltan

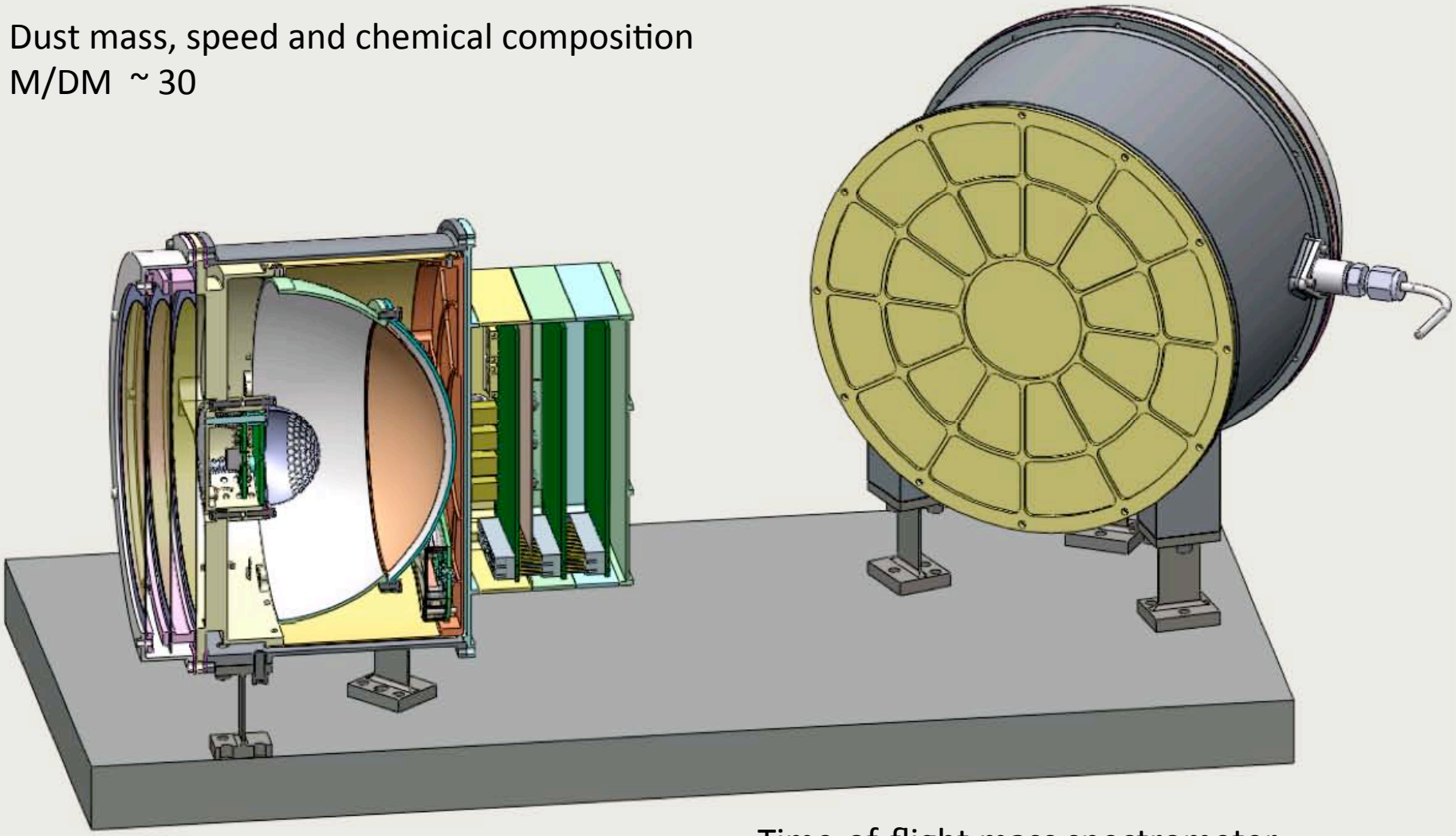
First dust signal ……..



CCLDAS

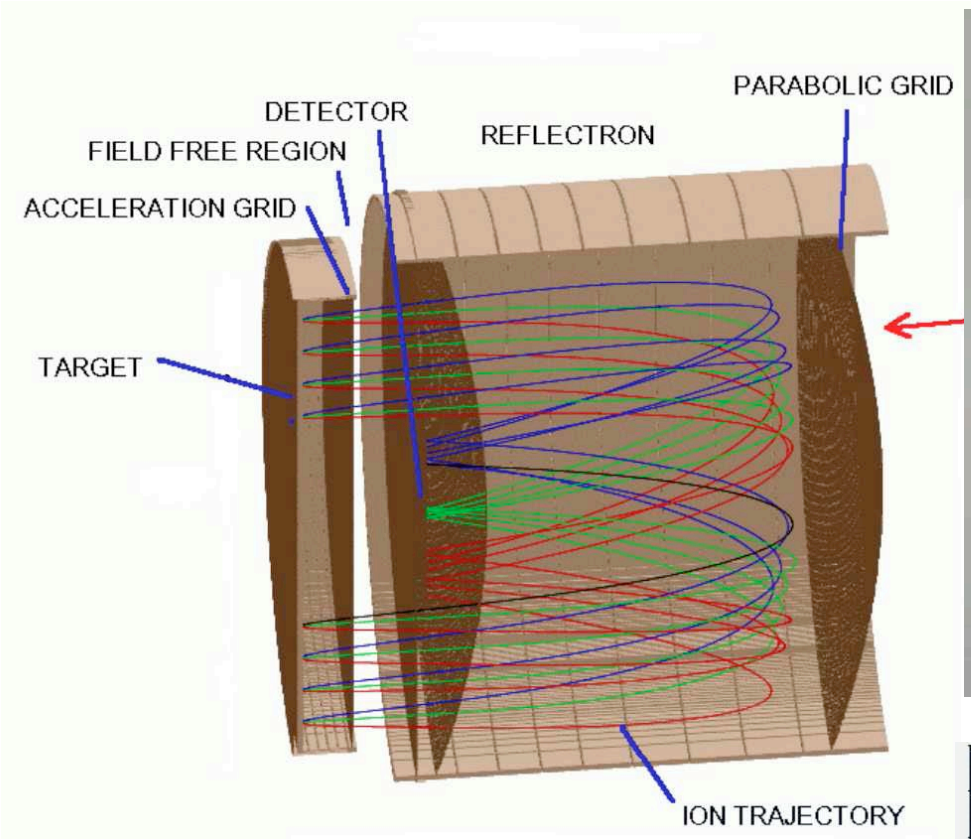
New Experiments: LDEX-2 for LADEE-2

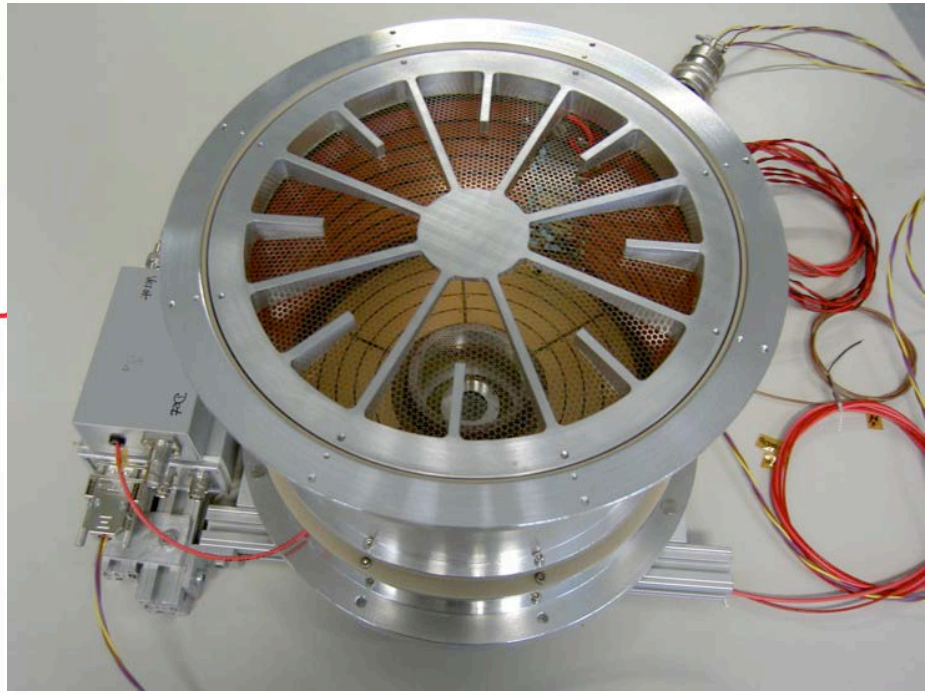
Dust mass, speed and chemical composition
M/DM ~ 30



Time-of-flight mass spectrometer

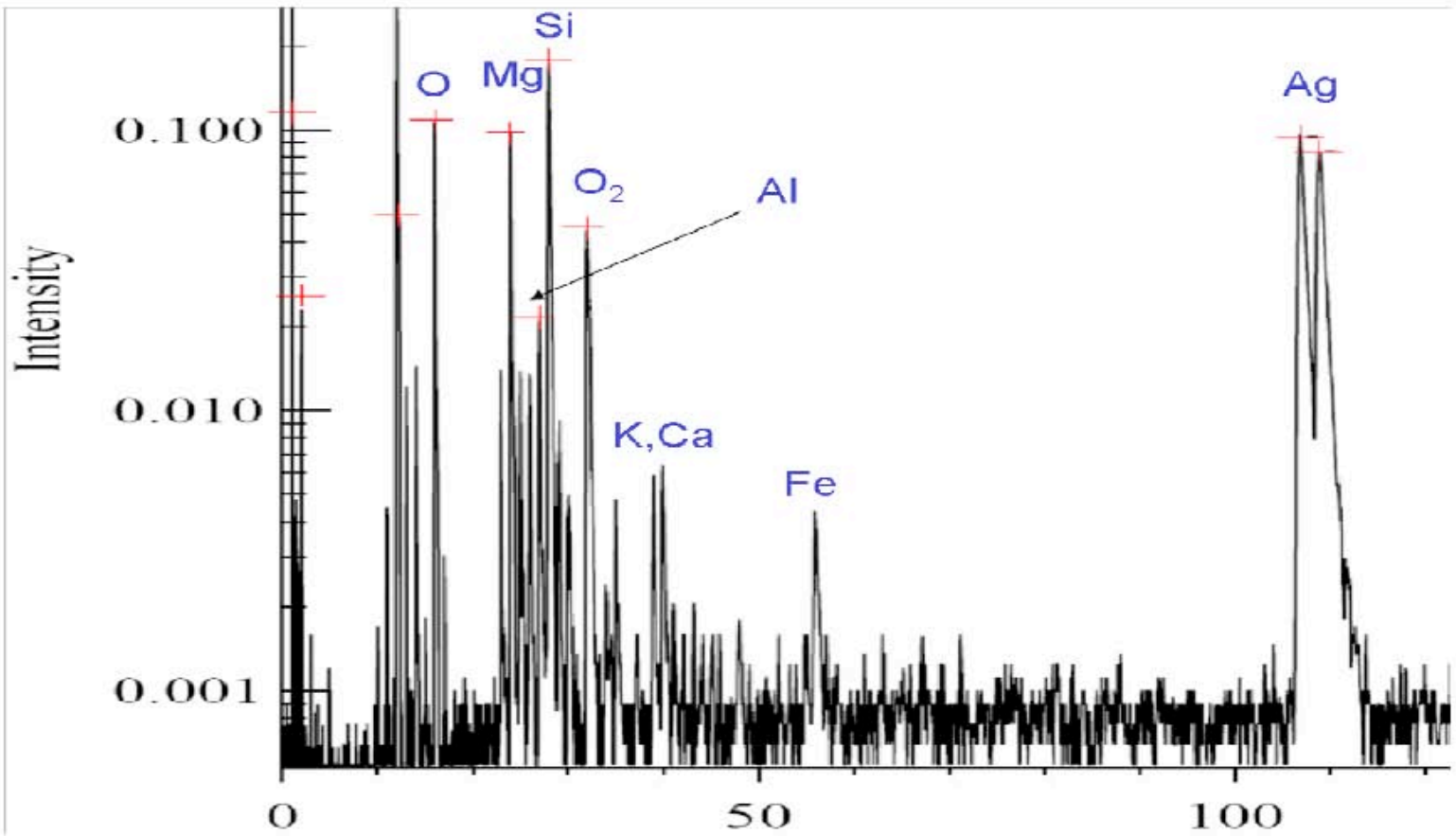
LDEX - 3





Mass	4 kg
Diameter	268 mm
Height	250 mm
- Trajectory Sensor	171 mm
- Height Mass Spectrometer	60 mm
Sensitive Area	220 cm^2
Power Consumption	5 W

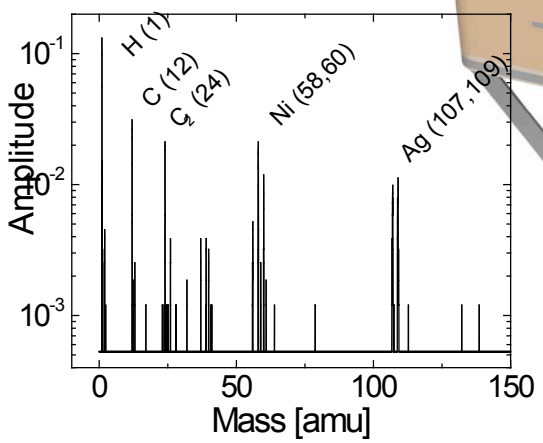
Dust mass, speed and chemical, and isotopic composition
M/DM > 150

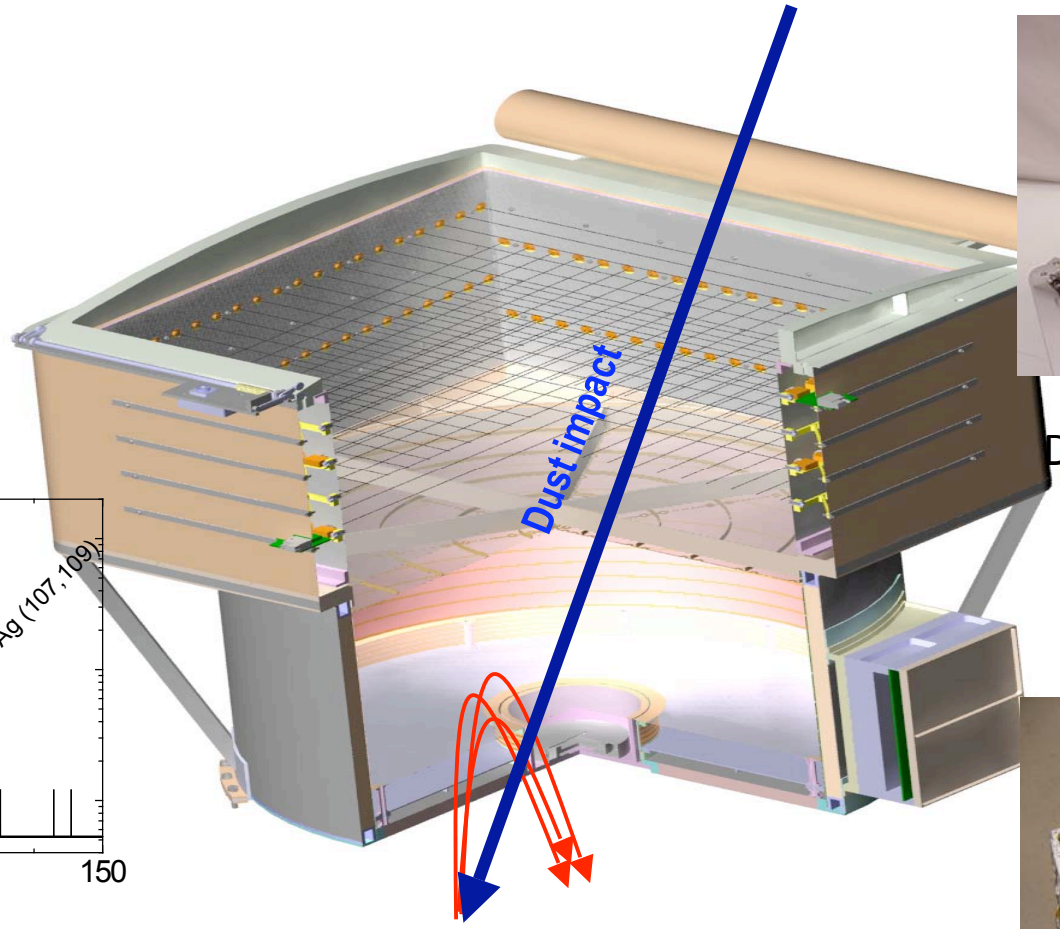


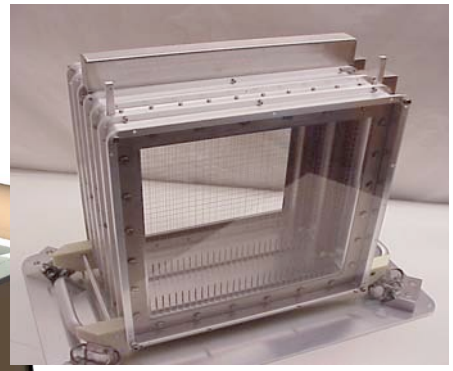
Mass spectrum of a 0.3 micron orthopyroxene grain impacting with 20 km s^{-1} onto a silver target.

LDEX – 4: Dust Telescope on the lunar surface

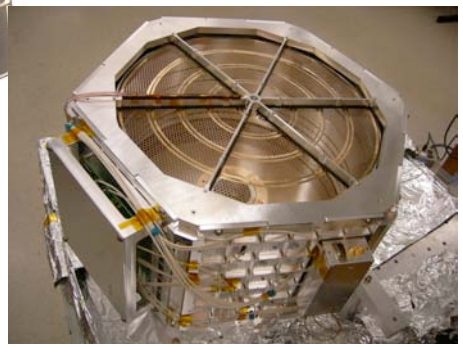
DTS Signals







Dust Trajectory Sensor (DTS)



Large Area Mass Analyzer (LAMA)

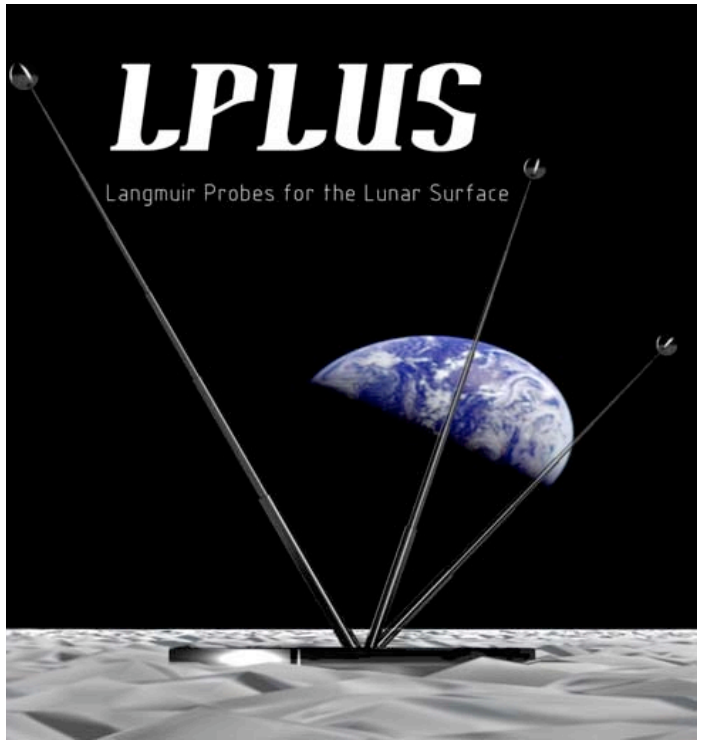
Dust mass, velocity vector and chemical, and isotopic composition M/DM > 200

Package to address dust charging, mobilization and transport:

Dust Detector:
a) charge, mass, velocity vector for slow moving (< 100 m/s) lunar dust
b) charge, mass, velocity vector, chemical and isotopic composition of IPD and ISD grains

Fields and Particles Instruments:
a)Plasma density, composition, energy distribution
b)Small scale (1 – 100 m) electric fields

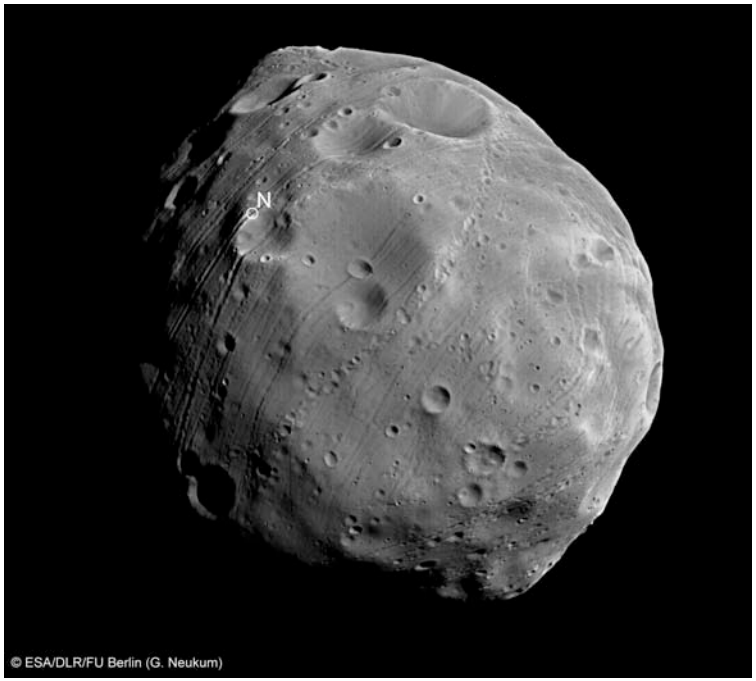
Optical cameras
a)Stereo imaging of the horizon glow
b)Phase function, color

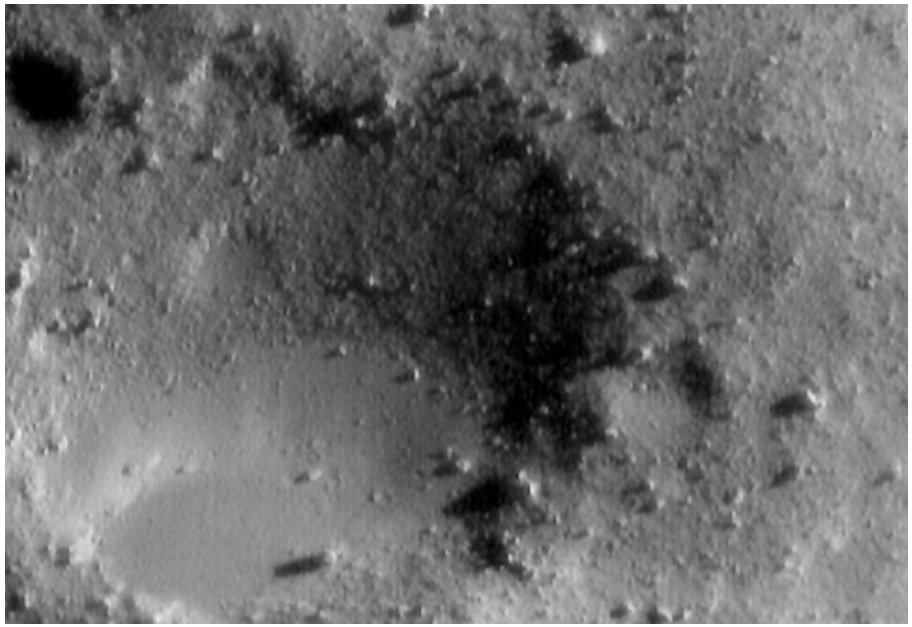


Moral

Evidence of dust transport seen on other bodies: Eros 433 dust ponds

Phobos / Deimos, Mercury …..





No matter where humans explore, there'll be dust…

Dusty plasma processes at the Moon are relevant for all airless planetary bodies throughout the solar system