Experimental Dust Levitation

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Mooninar
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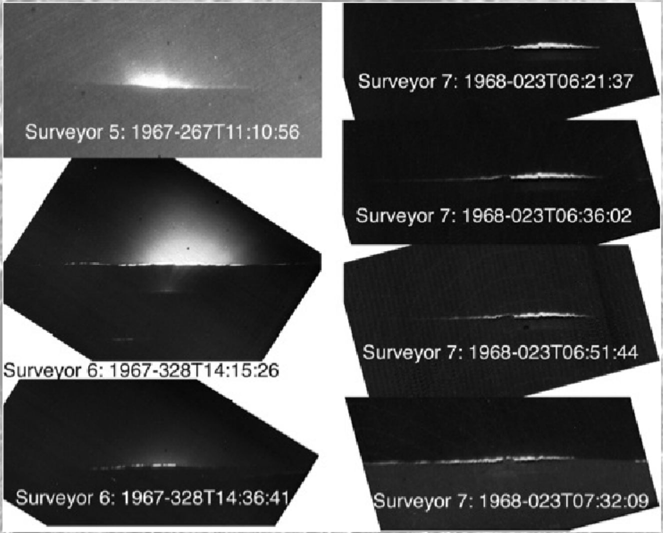
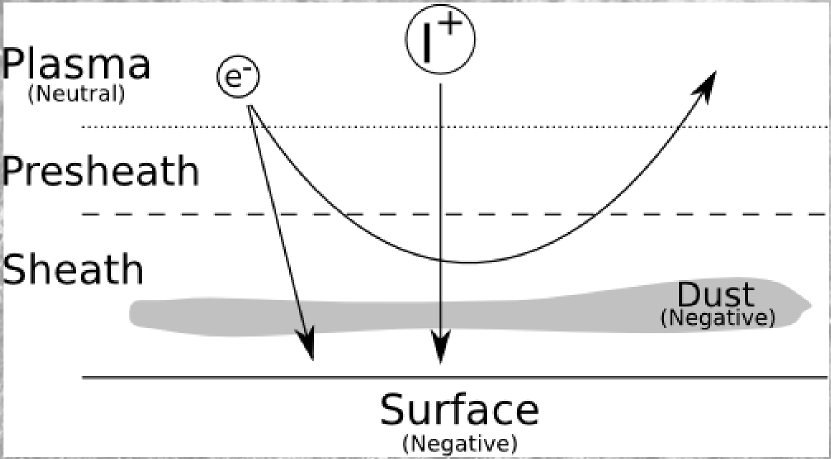
Horizon Glow Observations



Dust Transport

A Picture of the Lunar Dark Side



Preliminary Caveats

Reproducing the environment of the Moon in the lab is difficult! Therefore, we won't try.

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Instead:

- Verify general theoretical ideas.
- Learn how to make measurements (and what measurements to make).
- Prepare experiments for the lunar surface.

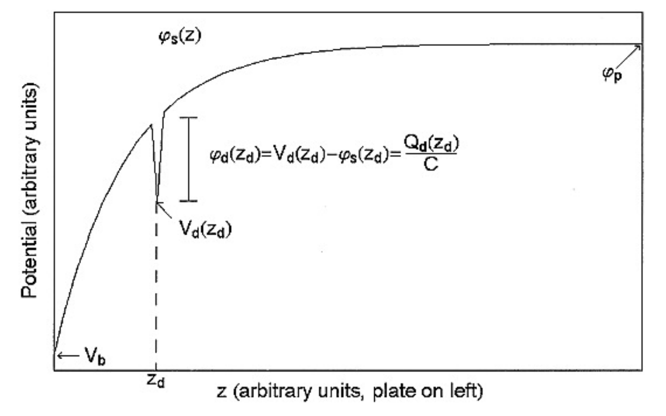
Objectives

1. Explain dust levitation, and observe it in the laboratory.
2. Examine other laboratory processes analogous to those on the Moon.
3. Provide a coherent picture of lunar dust phenomena.
4. Prepare for future measurements on the lunar surface.

Dust is levitated by surface electric fields.

To test our ideas of dust levitation, we:

- Measure the potentials in situ.



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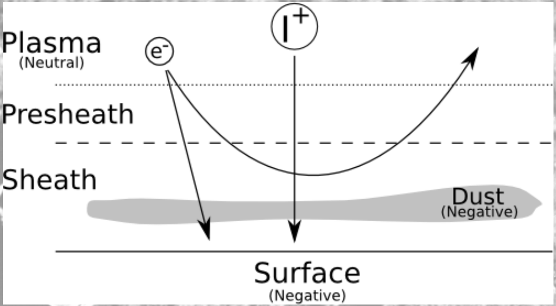
- Once the charge is determined, we balance the electrostatic and gravitational force.

$$F_e(z) - F_g = Q_d(z)E(z) - m_d g = 0$$

Dust charge results from ion-electron balance.

Electrons and ions have different current distributions.



Dust charge at each point is determined by the balance between the electron and ion current:

$$I_e(z) + I_i(z) = 0.$$

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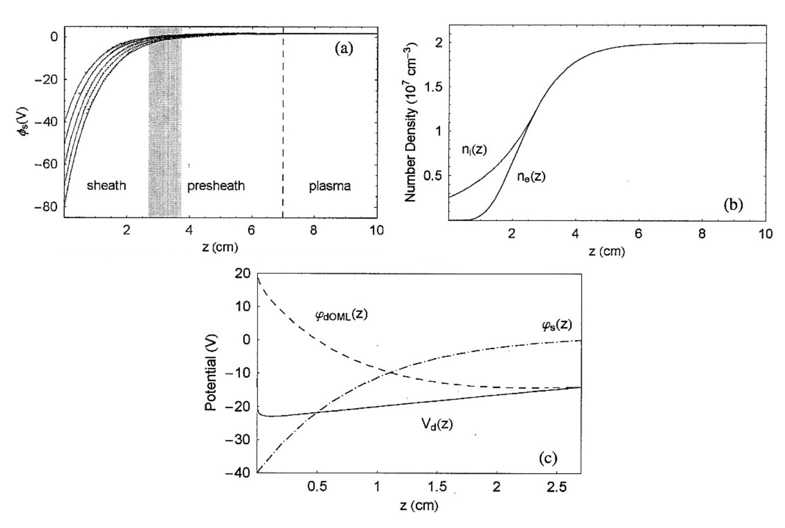
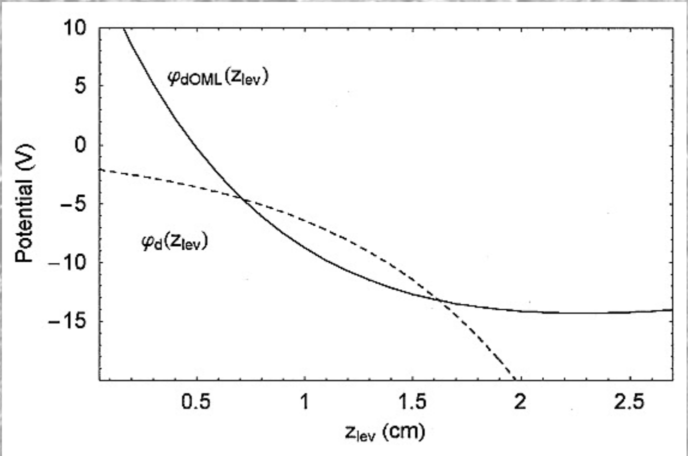
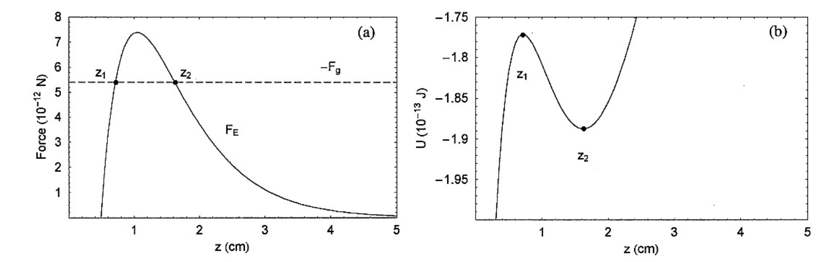


Electrostatic-gravitational balance ⟹ levitation.

$$Q_d(z) = C(r)\varphi_d(z)$$



Electrostatic-gravitational balance $\Longrightarrow$ levitation.



Theory predicts an observable levitation height.

This levitation height is well-defined only for a given radius of particle:

$$Q_d(z) = C\varphi_d(z) = 4\pi\varepsilon_0 r_d(V_d(z) - \varphi_s(z))$$

So it is advantageous to perform experiments with particles of a known size.

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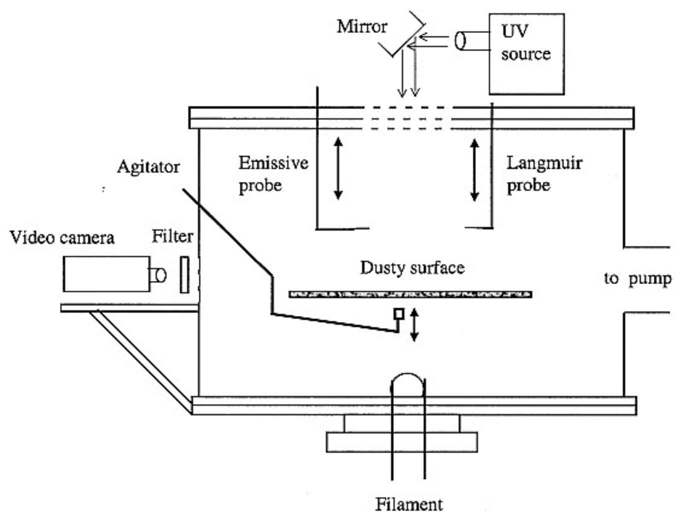
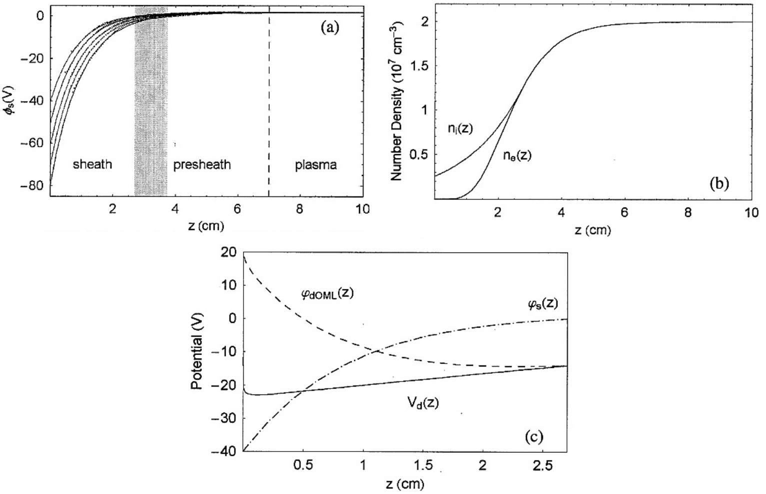
In practice, we must:

1. Measure the potential above the surface, and hence the electric field.
2. Measure plasma properties to determine the dust charge.
3. Compute theoretical levitation heights.
4. Compare theory with observation.

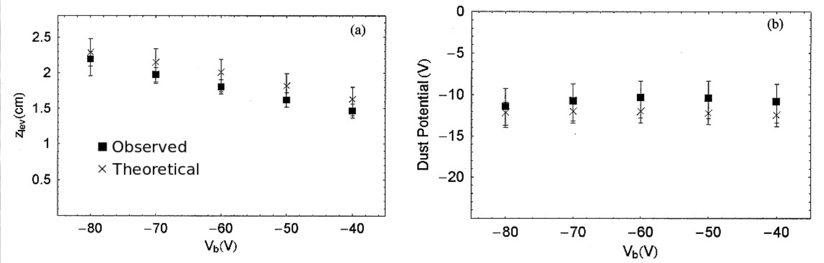
Laboratory Setup

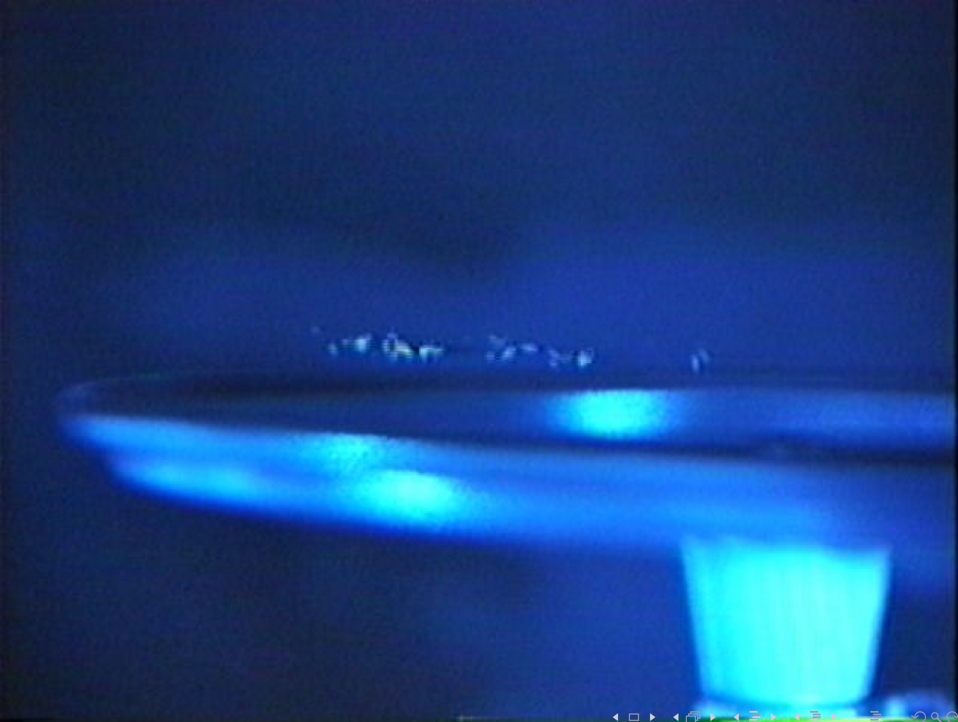


Inputs to Theory

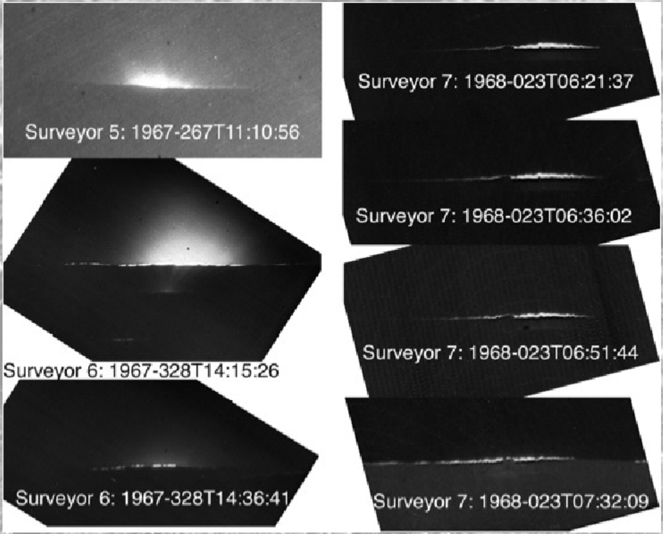


Observed Levitation Heights





What have we learned?

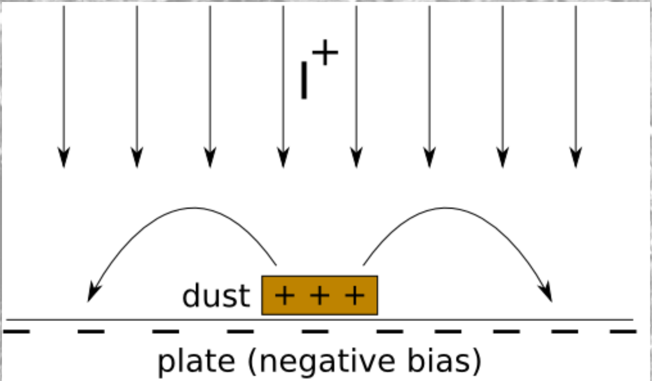


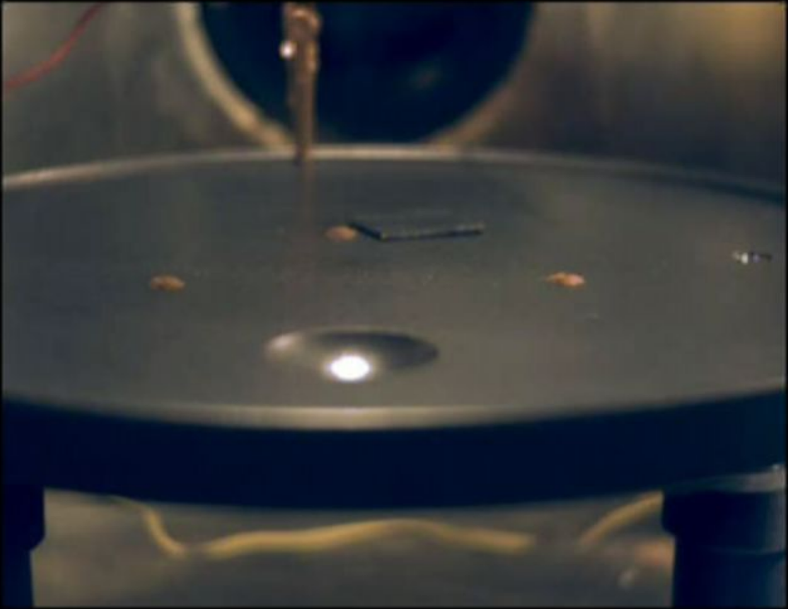
A curious case...

Lofting and spreading occur spontaneously

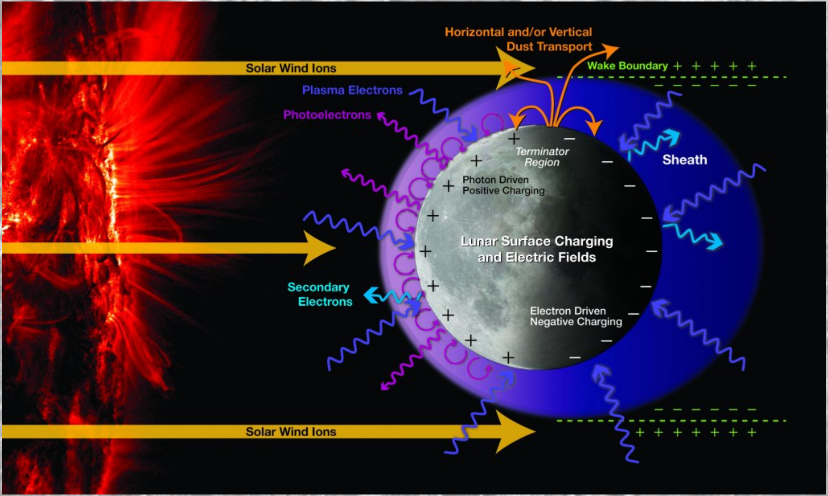
Dust can levitate, but it must first be ejected from the surface.

One possible process:

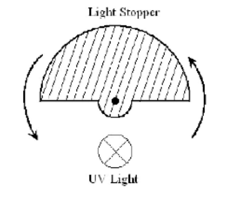


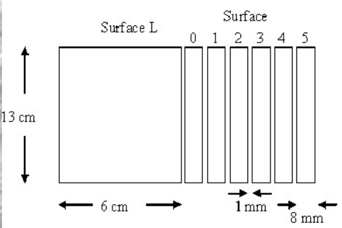


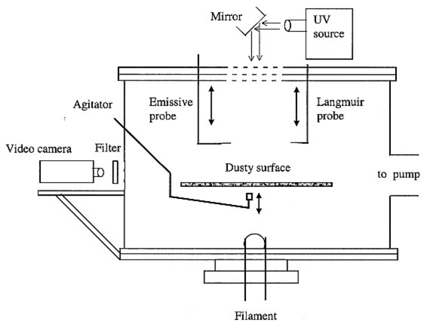
Day-night potentials provide source of electric field



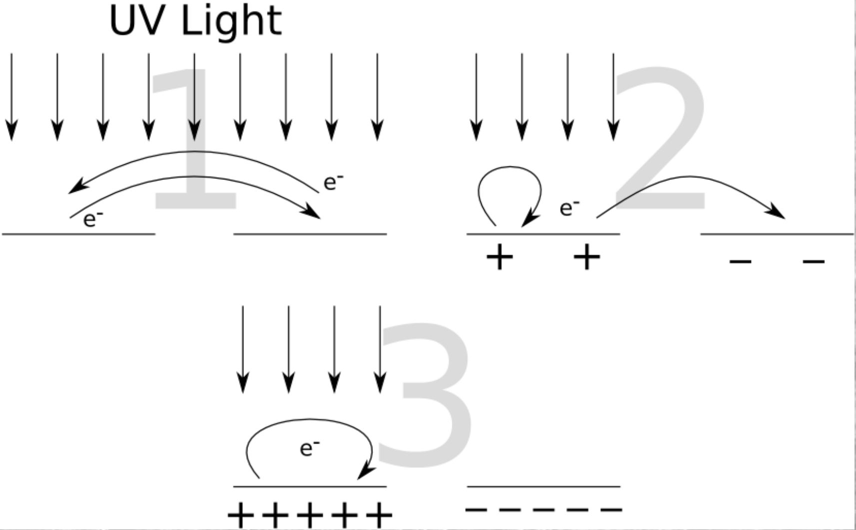
Time-Dependent Ultraviolet Flux



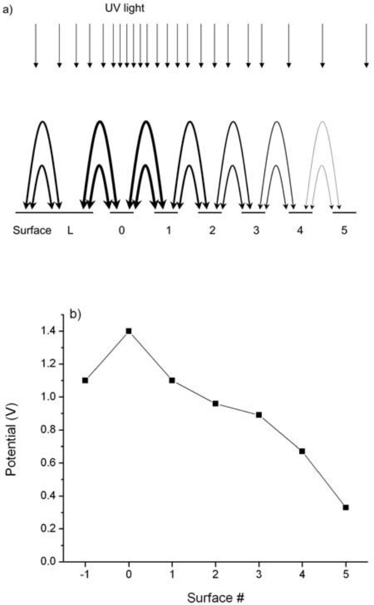


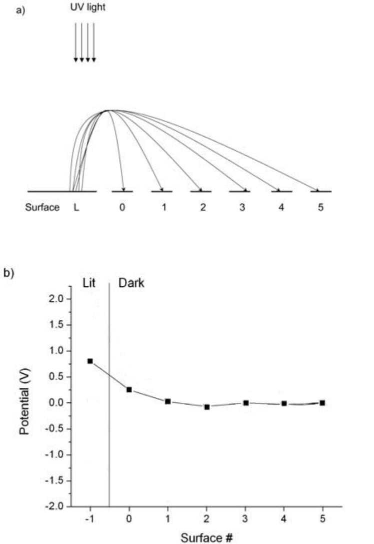


Expectations

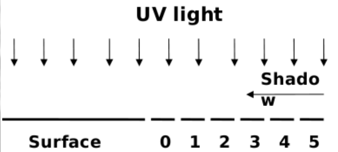


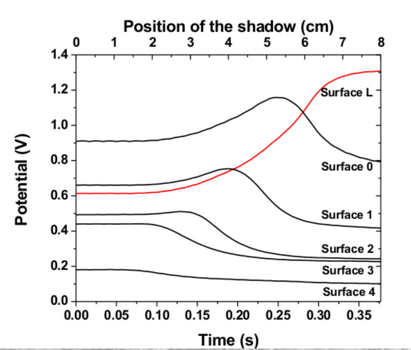
Static Charging

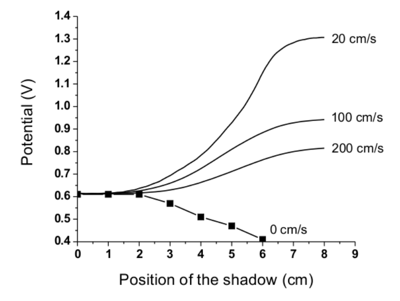




Velocity Dependence





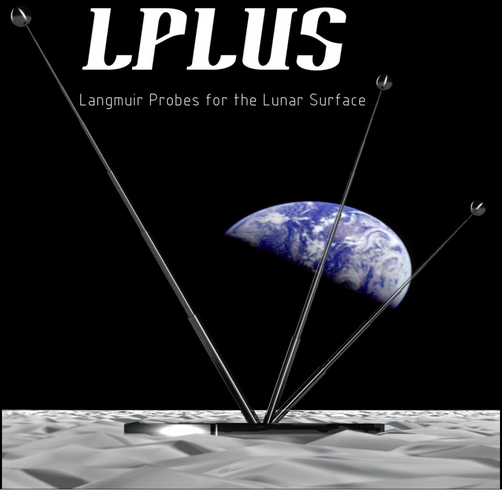


Concept proven; Now what?

Moon-like conditions are difficult and in some cases impossible to reproduce on Earth.

In-situ measurements are required.

ASEN students are working on this right now!



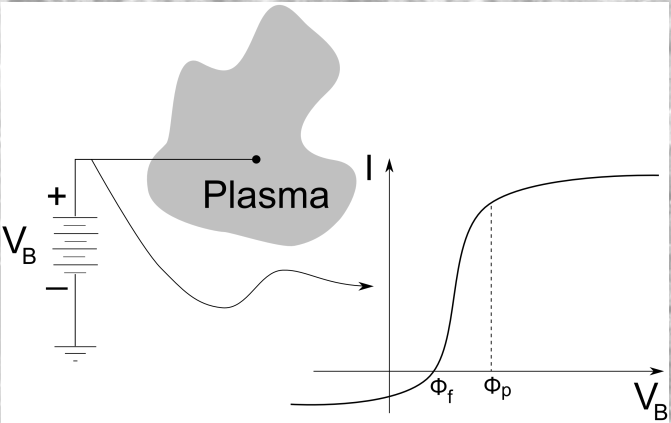
Preliminary Design Review

Andrew Berg
Kristian Hahn
Trent Hanson
Louise Martinez
Ryan Mayerle
Mike Siegers
Shaun Valdez

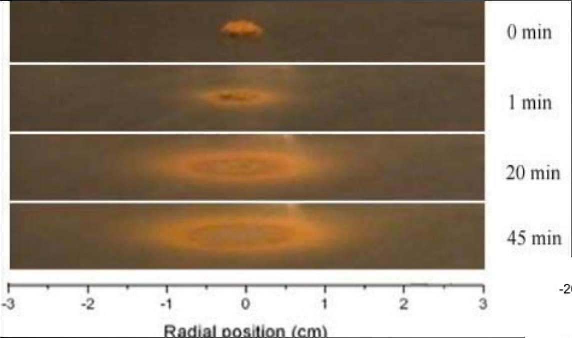
The Dusty Moral

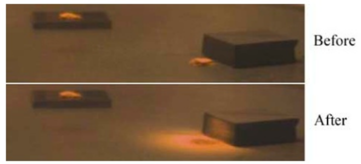
- Dust can levitate once injected into a plasma sheath.
- Injection can be caused either by direct agitation of sufficiently strong electric field.
- The lunar terminator provides a useful source of time-varying electric field.
- In situ experiments are required to fully characterize the lunar plasma environment.

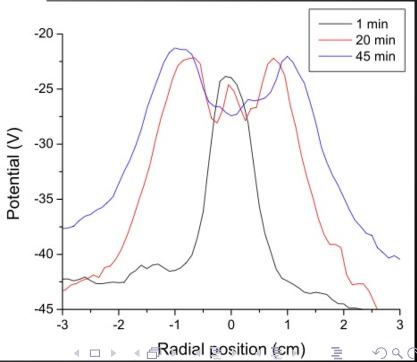
What's this Langmuir thing anyway?



Dust Transport







< 25µm JSC-Mars-1 grains

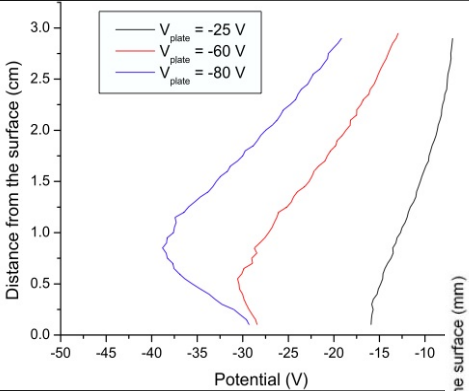
Φ_0 = -60 V

N_e ~ 10^8 cm^{-3}

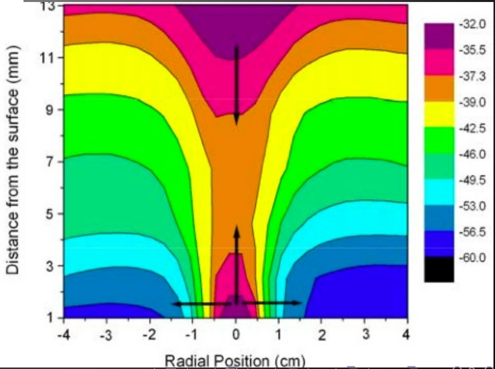
T_e ~ 4 eV

λ_{De} ~ 0.15 cm

Potential Distributions



Surface biased to -80 V

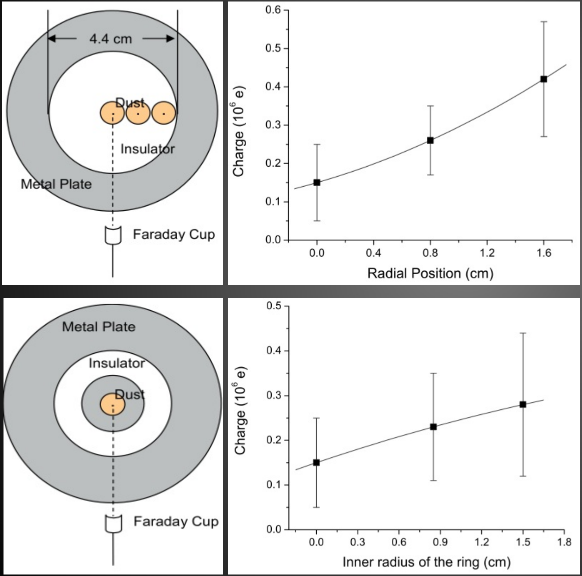


$N_e \sim 10^7\ cm^{-3}$

$T_e \sim 4\ eV$

$\lambda_{De} \sim 0.4\ cm$

Dust Charge



- ~100 µm JSC-Mars-1
- Surface biased to -60 V
- Charge increases toward edge of insulator

Potential falls slower at center – dust collects fewer ions to reach equilibrium

- 4 cm insulating disc
- Surface biased to -60 V
- Sheath effect reduced over center,