Laboratory measurements of initial launch velocities of electrostatically lofted dust on airless planetary bodies

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Introduction

- Regolith dust particles charged by solar wind and UV radiation may become lofted
- May be responsible for a number of observed phenomena, such as the lunar horizon glow (LHG) [2]
- Fundamental understanding has been advanced by the Patched Charge Model [1]
  - Microcavities between particles allow for substantial negative charge to cause lofting
  - Electrostatic force overcomes gravity and inter-particle cohesive forces

1

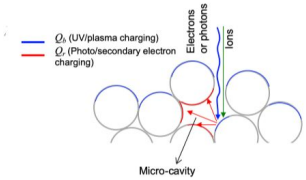


Figure 1 shows the Patched Charge Model, where the blue patch inside the microcavity emits secondary or photoelectrons after it is exposed to plasma/UV radiation. The secondary/photoelectrons are reabsorbed by the red patches.

Experimental Setup

2

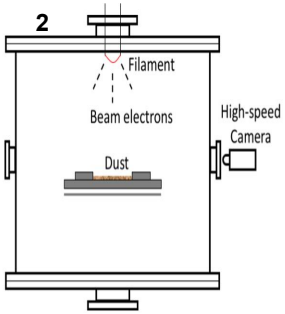


Figure 2 shows a schematic of the experimental set up.

- Vacuum chamber
  - 50 cm diameter, 28 cm tall
- <38 micron diameter lunar highland type dust simulant
- 100 μA electron beam to simulate charging from UV in space
- ~ 10^{-6} Torr pressure
- 5300 frames per second high speed camera
- ~11 μm per pixel resolution

Data Analysis and Error

3

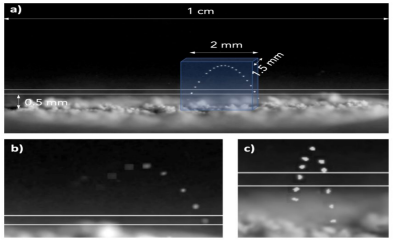


Figure 3 shows **a)** an in focus particle included for analysis, **b)** an out of focus particle excluded, and **c)** an in focus particle that does not meet distance criteria and is excluded.

4

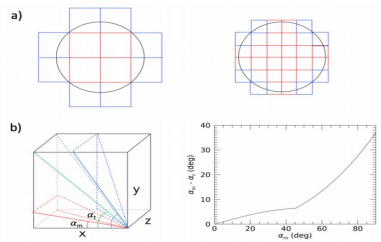
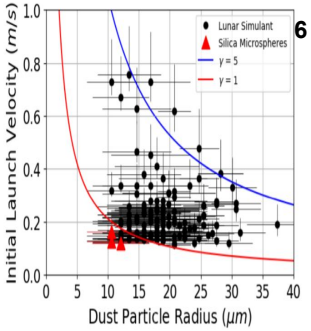


Figure 4 shows **a)** the minimum (red) and maximum (blue) number of pixels for different sized particles, and **b)** the correlation between the measured and true angles

- Velocity calculated from time difference of a particle hitting each line in Figure 3
- Code detects many particles that are not in plane of focus
- Selected particles to include in analysis by finding particles that travelled 2 mm horizontally or vertically while in focus
- Size calculated by averaging number of pixels counted for a given particle for each frame
- Velocity and launch angle error calculated from Figure 4 b)
  - Velocity will always be an underestimate since we are missing a directional component
- Size error calculated from Figure 4 a)

Results and Conclusions

5



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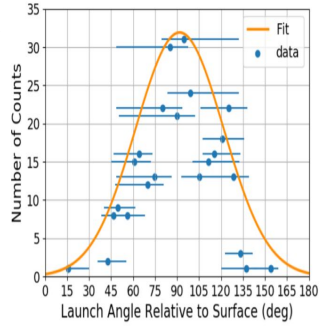

Figure 5 (left) shows the calculated radius vs launch velocity data. The black dots are dust particles, the red triangles are 20 micron diameter silica microspheres. The theoretical lines are the predicted relationship derived from the Patched Charge Model and conservation of energy, with an empirical factor γ to account for irregular particle shape.

Figure 6 (right) shows the calculated launch angle relative to surface of lofted particles. It shows an increased error around 90° due to the finite depth-of-field, as seen in Figure 3 b). A Gaussian fit centered at ~90° with a FWHM of ~70° is shown as a guide to the eye.

- Theoretical equation derived from Patched Charge Model and conservation of energy

$$\upsilon = \gamma \frac{|\phi|}{r} \sqrt{\frac{3\epsilon_0}{\rho}} \qquad (1)$$

- Large spread of velocities for a given size particle
  - Wide range of inter-particle cohesive force due to irregular shape
- Maximum velocity shows an inverse relationship with the dust radius, which is consistent with the theoretical expectation
- Dust shape has a significant effect on the lofting process
- Small particles can reach speeds exceeding escape velocity for small asteroids
- Could explain lack of fine-sized regolith on asteroids Bennu [3], Ryugu [4] and Itokawa [5]

References

[1] Wang, X., Schwan, J., Hsu, H.-W., Grün, E., Horányi, M., 2016a. Dust charging and transport on airless planetary bodies. Geophys. Res. Lett. 43, 6103–6110, doi:10.1002/2016GL069491.
[2] Criswell, D. R., 1973. "Horizon-glow and the motion of lunar dust" in Photon and Particle Interactions with Surfaces in Space, edited by R. J. L. Grard (Springer, New York), pp. 545– 556.
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