Measuring the Lunar Dust Cloud via in situ Dust Detection

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Abstract: The Lunar Dust EXperiment (LDEX) is an in situ dust detector for the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission to be launched in 2013. It will characterize the dust exosphere by mapping the size and spatial distributions of dust grains in the lunar environment as a function of local time and the position of the Moon with respect to the magnetosphere of the Earth. LDEX will gauge the relative contributions of the two competing dust sources: a) ejecta production due to the continual bombardment of the Moon by interplanetary micrometeoroids, and b) lofting of small grains from the lunar surface due to plasma-induced near-surface electric fields. Given the expected bombardment rate of micrometeoroids, the column density of the lunar dust cloud can be predicted. Additionally, observations of the excess brightness of the solar corona above the lunar terminator during the Apollo 15 and 17 missions can yield a prediction for the column density. However, a disparity exists as these two values differ by an order of magnitude.

Lunar Surface Environment: The surface of the Moon is charged unevenly due to varying plasma conditions on the day and night side (**Figure 1**). On the day side, photoemission currents dominate and the surface charges positive on the order of a few volts. The night side charges negative as high as a few kilovolts due to hot electrons in the lunar wake. If the electric fields surrounding charged dust grains on the surface are strong enough, electrostatic lofting of such grains could occur (Horanyi, Rev. Astron. Astrophys., **34**, 1996). At the terminator, large electric fields can arise due to the contrast between the two charging configurations leading to an increased possibility for dust transport or levitated dust clouds.

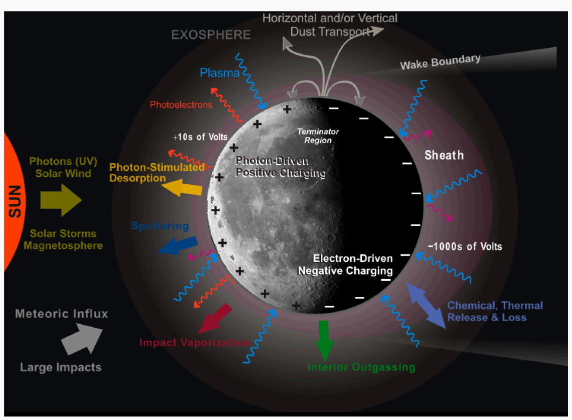

Figure 1. Diagram of lunar surface charging

Scientific Objectives: The LDEX instrument will address the dust science objective of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission, as stated in the NASA Science Definition Team (SDT) Study Report (May 21, 2008):

LADEE science objective 2: "Characterize the lunar exospheric dust environment and measure any spatial and temporal variability and impacts on the lunar atmosphere."

This science objective is addressed by measuring the temporal and spatial variability of the density and size distributions of dust in orbit around the Moon. The SDT report identified the measurement requirement to detect submicron sized particles, in order to gauge the relative importance of the two expected sources of dust (**Figure 2**):
•ejecta production due to continual bombardment by interplanetary meteoroids, and
•lofting due to plasma effects.
Measurement and instrument requirements are summarized in **Table 1**.

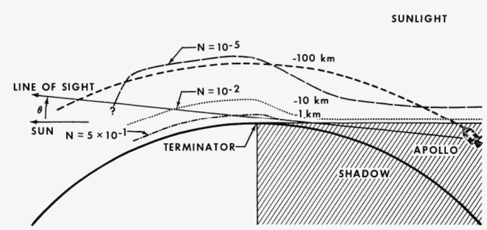

Figure 2. The expected density distribution of ~ 0.1 µm grains over the lunar terminator based on Apollo photography in orbit about the Moon (McCoy, *Proc. Lunar. Sci. Conf.* 7th,1976).

Table 1. *LDEX* Traceability Matrix

Science Requirements	Measurement Requirements	Instrument Requirements	*LDEX* Capability
Map the size and spatial density distribution of dust	**1)** Detect particles with radii r_g from < 1 µm to 5 µm **2)** Measure the size distribution in at least five bins from <1 to 5 µm range **3)** Detect at least 1000 particles per orbit with r_g = 1 µm	**1)** Measure the impact charge in the range of 10^5 e$^-$ < Q_I < 10^7 e$^-$ **2)** Measure Q_I with uncertainty < x 2. **3)** A detector sensitive area A > 0.003 m^2	**1)** 3x10^3 < Q_I < 10^7 e$^-$ **2)** Q_I uncertainty < 10%. **3)** A = 0.01 m^2
Verify the existence of the lofted population of grains in the size range of 0.1 µm < r_g < 0.3 µm and measure their spatial distribution over the terminator	**1)** Measure the combined impact charge from particles 0.1 µm < r_g < 0.3 µm **2)** Make at least 100 measurements in 6 minutes approaching the terminator region	**1)** Measure a cumulative charge deposition rate < 10^5 e$^-$/s **2)** Temporal resolution dt < 3 s	**1)** Cumulative charge measured < 5×10^4 e$^-$/s **2)** Temporal resolution dt ~0.1 s

LDEX instrument: *LDEX* is an impact ionization dust detector with a sensor area of ~ 0.01 m^2, derived from the heritage of the dust instruments operating on HEOS 2, *Galileo*, *Ulysses*, and *Cassini*. *LDEX* is a low risk, compact instrument with no deployable or moving parts, and uses no flight software (**Figure 3**). In addition to individual dust impacts of grains with radii r_g > 0.3 µm, *LDEX* can identify a large population of smaller grains (0.1 < r_g < 0.3 µm) by measuring their collective signal. The expected impact rates, and the signature of lofted small grains expected over the terminators are shown in **Figures 4**.

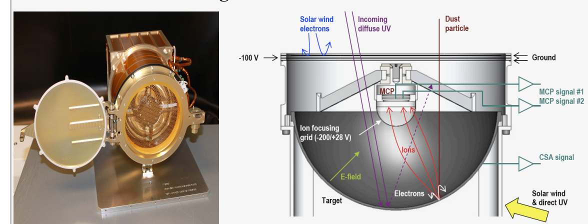

Figure 3. *left:* Image of the LDEX. *right*: A schematic of LDEX.

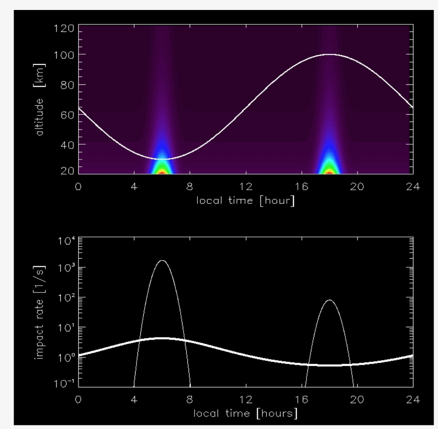

Figure 4. The expected impact rate lofted grains during LADEE's approach of the terminator (0.1 < r_g < 0.3 µm) and impact ejecta particles.

LDEX will bring closure to the LADEE dust science objective.