THE DUST ENVIRONMENT OF THE MOON AS SEEN BY THE LUNAR DUST EXPERIMENT (LDEX).

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Introduction. The lunar dust environment is expected to be dominated by submicron-sized dust particles released from the Moon due to the continual bombardment by micrometeoroids, and possibly due to UV radiation and plasma-induced near-surface intense electric fields. The Lunar Dust EXperiment (LDEX) instrument is designed to map the spatial and temporal variability of the dust size and density distributions in the lunar environment onboard the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission [1, 2] orbiting the Moon since 10/6/2013. LDEX is an impact detector, capable of reliably detecting and measuring the mass of submicron and micron sized dust grains. LDEX also measures the collective currents from low-energy ions and from the impacts of dust grains that are below the detection threshold for single dust impacts; hence it can search for the putative population of grains with radii ~ 0.1 μm lofted over the terminator regions by plasma effects. This talk will summarize the preliminary analysis of the observations to date: 1) LDEX identified the dust ejecta cloud that is maintained by micrometeoroid bombardment. As predicted, the density of the dust ejecta cloud rapidly increases toward the surface, and it also shows strong temporal variability, most likely related to the stochastic nature of the meteoroid impacts. 2) LDEX, as of yet, has not confirmed the existence of levitated dust clouds. This puts strict new upper limits on the density of small lofted grains, especially during periods of low ion fluxes entering the instrument.

The LDEX instrument. LDEX is an impact ionization dust detector with a sensor area of ~ 0.01 m^2. (**Figure 1**). It captures coincident signals and full waveforms to reliably identify dust impacts. In addition to individual impacts of grains with radii r > 0.3 μm, LDEX can identify a large population of smaller grains (0.1 < r < 0.3 μm) by measuring their collective signal. Dust particles with speeds > 1 km/s generate a plasma cloud when impacting the hemispherical target of the instrument. The electrons are collected on the target itself, and ions from the impact are accelerated into a microchannel plate (MCP) ion detector. The waveforms are used to identify the mass of the impactor. The signal of the MCP is continuously integrated for periods of 0.1 sec, to enable the identification of regions with a high-density of particles that are too small to trigger the recording of the waveform generated by the plasma cloud from their impact. The LDEX cover was deployed on 10/16/2013 after a thorough testing of all functionalities of the instrument. Since the cover deployment LDEX continues to make dust observations. By the end of 2013 LDEX has recorded about 65,000 MCP and target waveform pairs, indicating potential dust impacts. The unambiguous identification of dust impacts is ongoing, based on the analysis of the individual waveforms. The major milestones of LDEX operations are summarized in **Figure 2**.

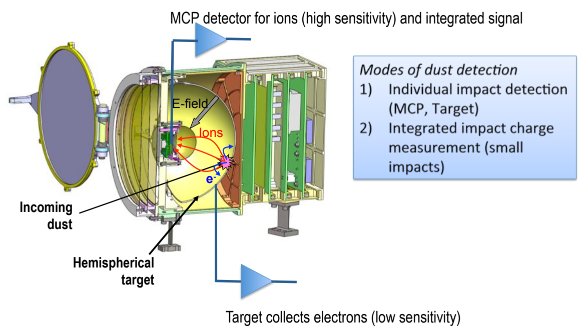

Figure 1. The schematic drawing of LDEX. Dust particles enter the detector through a triplet of transparent grids that prevent solar wind electrons flooding the instrument.

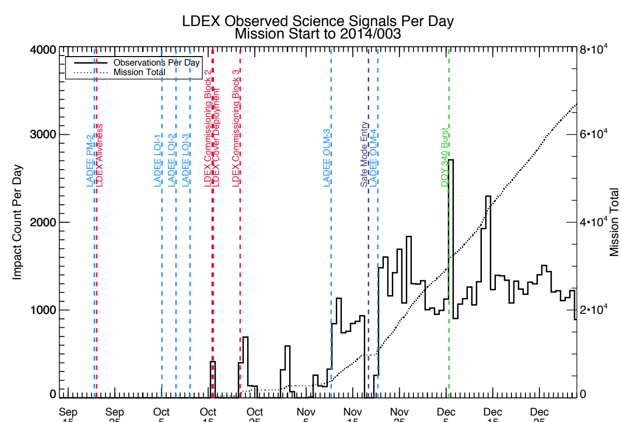

Figure 2. Summary of LADEE/LDEX activities through 1/3/2014. The number of recorded events (noise and dust impacts) sharply increased following LADEE orbit lowering maneuvers (OLM). An unusually large burst of events was observed on 11/12/2013, most likely related to the Taurids meteor shower. The following intense period starting 12/13/2013 coincides with the Geminids shower and the landing of Chang'e-3.

LDEX was tested and calibrated at the dust accelerator facilities of the University of Colorado, and MPI-K, Heidelberg, Germany. The facilities are capable of providing particles with typical radii of 0.1 to 2 µm with speeds >> 10 km/s. **Figure 3** and **4** show a comparison between waveforms recorded at the accelerator and in space.

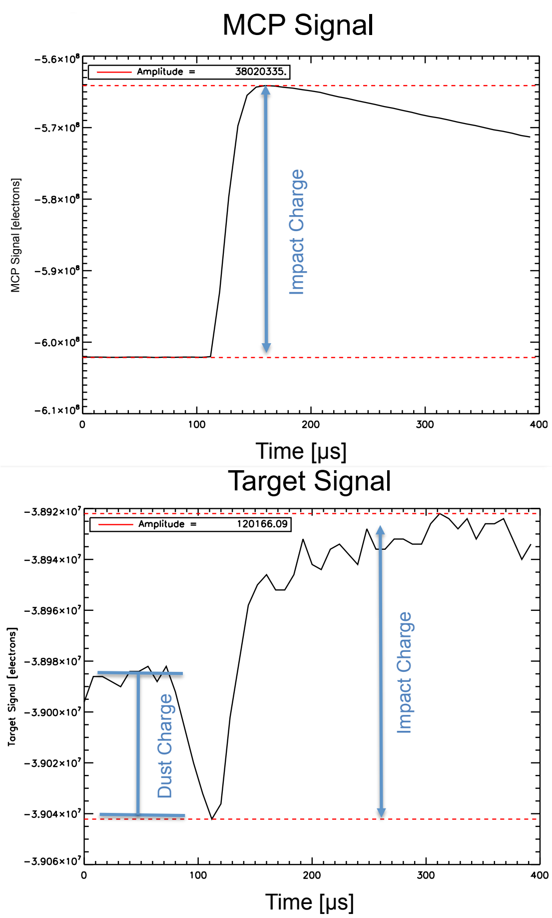

Figure 3. Impact waveforms recorded by LDEX at the Colorado dust accelerator of an iron particle with a radius of 1.06 µm and speed of 1.89 km/s. The waveforms are recorded (50 samples with a dt of 8 µs) and transmitted to ground. At the accelerator the dust particles are highly charged and the target signal also shows the effect of their 'image' charge on the target.

LDEX observations. LDEX observations are the first to identify the ejecta clouds around the Moon sustained by the continual bombardment of interplanetary dust particles. Ejecta clouds were first observed by the Galileo mission during flybys of the icy moons of Jupiter: Europa, Ganymede, and Callisto [3]. No ejecta clouds were directly identified as of yet by the Cosmic Dust Analyzer onboard Cassini in orbit around Saturn. However, modeling the observations indicate that ejecta particles have to make a non-negligible contribution to the dust environment, in addition to the active plumes on Enceladus. Most of the dust particles generated in impacts have insufficient energy to escape and follow ballistic orbits, returning to the surface, 'gardening' the regolith. Ejecta clouds are expected to engulf all airless planetary

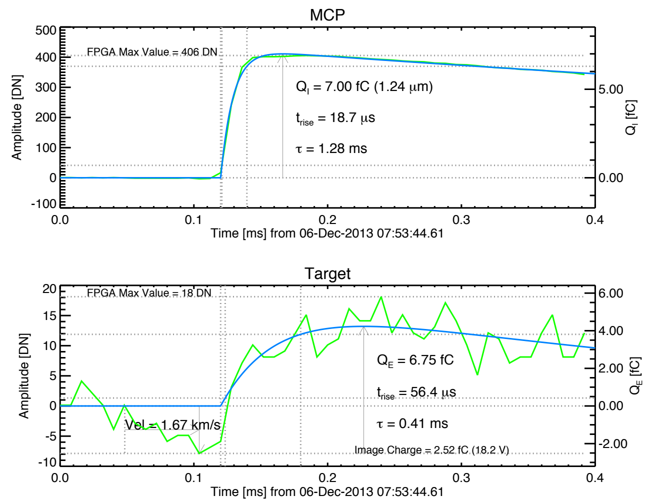

Figure 4. Impact recorded in orbit around the Moon on 12/06/2013. Based on preliminary analysis, this particle had a radius of ~1.2 µm, and carried a charge of ~2.5 fC. The green and blue lines show the recorded waveforms and an analytical fit, respectively.

objects, including the Moon, Mercury, and the moons of Mars: Phobos and Deimos. LDEX is expected to characterize in detail the ejecta cloud surrounding the Moon, including the size, velocity, and angular distribution of the ejecta particles.

LDEX also continues to search for plasma-lofted particles. These particles, with characteristic radii of ~ 0.1 µm [4], have been suggested to lift off the surface due to charging and intense localized electric fields. The processes involved remain controversial. The combination of the remote sensing optical observation by the LADEE Ultraviolet and Visible Spectrometer (UVS) and the in situ LDEX instruments will establish new strict upper limits for the density of these particles.

References: [1] Elphic *et al., Proc. Lunar. Sci. Conf.* 44th, 1719 (2013), [2] Horanyi *et al*., *Proc. Lunar. Sci. Conf.* 43th, 1659 (2012). [3] Krueger *et al., PSS* 48, 1457 (2000). [4] McCoy, *Proc. Lunar. Sci. Conf.* 7th, (1976).