# THE DUST ENVIRONMENT OF THE MOON: EXPECTATIONS FOR THE LUNAR DUST EXPERIMENT (LDEX).

M. Horányi[1,2], Z. Sternovsky[1,2], M. Lankton[1], D. James[1,2], J. Szalay[1,2], K. Drake[1,2], A. Shu[1,2], A. Colette[1], E. Grün[1, 3], S. Kempf [1,2], R. Srama[3,4], A. Mocker[2,3,4], ([1]Laboratory for Atmospheric and Space Physics, and Department of Physics, University of Colorado at Boulder, USA; [2] Colorado Center for Lunar Dust and Atmospheric Studies, U. of Colorado, Boulder, USA; [3]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany;[4] Institute of Space Systems, University of Stuttgart, Stuttgart, Germany)

**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 due to plasma-induced near-surface intense electric fields. The Lunar Dust EXperiment (LDEX) is designed to map the spatial and temporal variability of the dust size and density distributions in the lunar environment onboard the upcoming Lunar Atmosphere and Dust Environment Explorer (LADEE) mission [1, 2]. LDEX is an impact detector, capable of measuring the mass of submicron sized dust grains. LDEX will also measure the collective signal of dust grains that are below the detection threshold for single dust impacts; hence it can search for the putative population of grains with $r \sim 0.1$ µm lofted over the terminator regions by plasma effects. LDEX has been developed at LASP/CCLDAS and has a high degree of heritage based on similar instruments on the HEOS 2, Ulysses, Galileo, and Cassini missions [3]. The LDEX flight model will be tested and calibrated at both the Heidelberg and Boulder dust accelerator facilities. This talk will summarize the expected capabilities of LDEX and make predictions for its measurements in lunar orbit based in our current theoretical models. We will also discuss a proposed LDEX-PLUS instrument that is being developed for a possible LADEE follow-up mission to add the capability for the in-situ chemical analysis of the impacting dust particles in order to verify the existence of water ice on the lunar surface, and to map the density of valuable resources of commercial interest.

**The *LDEX instrument*:** The two expected sources of dust in the lunar environment are ejecta production due to continual bombardment by interplanetary meteoroids, and lofting due to plasma effects. LDEX is an impact ionization dust detector with a sensor area of ~ 0.01 m$^2$. LDEX is a low risk, compact instrument, and uses no flight software (**Figure 1**). In addition to individual dust 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. The expected impact rates, and the signature of lofted small grains expected over the terminators are shown in **Figure 2**.

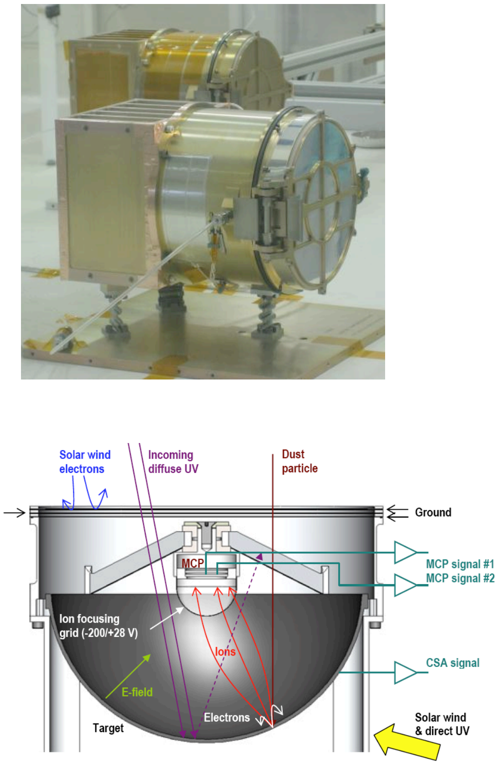

**Figure 1.** LDEX EM and FM units and the schematic drawings of the instrument.

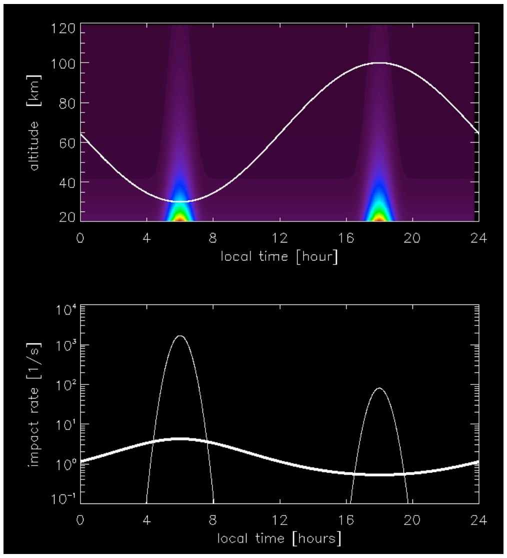

**Figure 2.** Expected impact rates on a 30x100 km orbit with its pericenter over the morning terminator.

Initial test and calibration of the LDEX FM model were done at the CCLDAS dust accelerator facility. Full calibrations are planned in early 2012 at both the Heidelberg and the Boulder facilities. **Figure 3** shows the preliminary test results, indicating that LDEX will meet or exceed its measurement requirements.

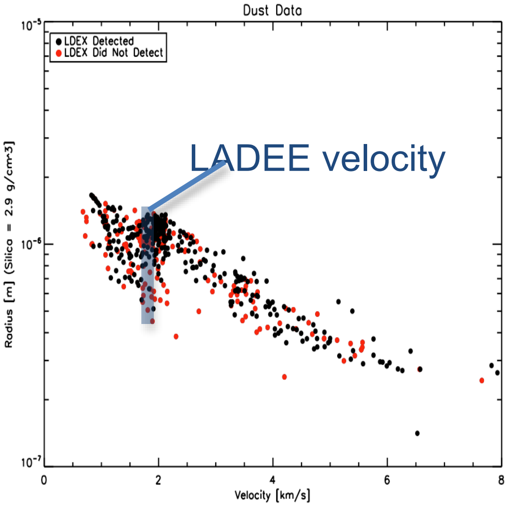

**Figure 3.** Initial test results for the LDEX FM instrument showing the detected particle mass versus their velocity. At the expected impact speed of 1.6 km/s, LDEX will detect particles with radii r > 0.4 μm. The ratio of detected and undetected particles matches the expected value due to the duty cycle of the electronics and the transparency of the screens that provide shielding and exclude the solar wind electrons from entering LDEX.

**The *LDEX-PLUS instrument*** extends the LDEX capabilities to also measure the chemical composition of the impacting particles with a mass resolution of M/ΔM > 30. Traditional methods to analyze surfaces of airless planetary objects from an orbiter are IR and gamma-ray spectroscopy, and neutron backscatter measurements. A complementary method is to analyze dust particles as samples of planetary objects from which they were released. The source region of each analyzed grain can be determined with accuracy at the surface that is approximately the altitude of the orbit. This 'dust spectrometer' approach provides key chemical constraints for varying provinces on the lunar surfaces**.** LDEX-PLUS is of particular interest to verify from orbit the presence of water ice in the permanently shadowed lunar craters.

LDEX-PLUS combines the impact detection capabilities of LDEX with a linear time-of-flight system, similar to the Cassini Cosmic Dust Analyzer (CDA) instrument. **Figure 4** shows an example time-of-flight mass spectrum of an ice-bearing dust grain.

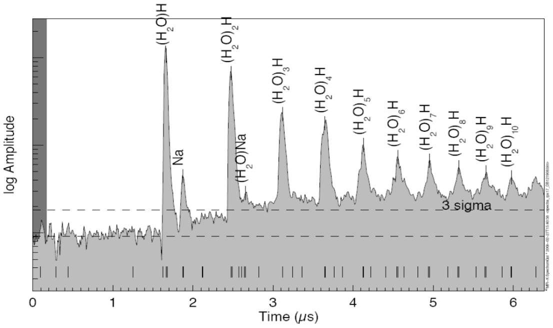

**Figure 4.** Spectrum of a water ice particle obtained at ~ 4 km/s impact speed by the Cassini CDA instrument in Saturn's E ring The dominant peaks are mass lines of water cluster ions $(H_2O)_nH^+$, generated upon impact of an ice-bearing particle [6].

**Conclusions.** LDEX, onboard LADEE, is scheduled to launch in May 2013, and will be capable of mapping the density distributions of both the large ejecta particles and the collective signal of the small lofted grains. LDEX-PLUS, onboard a follow-up lunar mission, can collect a large number of samples from a greater part of the entire surface for analysis. The instrument is especially sensitive to the metallic compounds of minerals and any species which easily form ions (e.g. water). The accuracy of the trajectory back-tracing to the surface is comparable to the altitude of the satellite. This in-situ method allows compositional surface mapping of the Moon. Since the dust spectrometer is particularly sensitive to refractory compounds which are difficult to access by other methods it is also complementary to remote sensing spectroscopy and an ion or neutral mass spectrometer. A ram pointing dust spectrometer and a nadir pointing remote sensing instrument collect data from approximately the same spot on the surface of the Moon, hence the combination of these measurements greatly enhances our ability to map the chemical composition of the surface and identify water-bearing regions. An LDEX-PLUS type instrument can also address many of the science goals of a Europa Jupiter System Mission (EJSM) about the surface chemistry of icy satellites.

**References:** [1] Delory *et al., Proc. Lunar. Sci. Conf.* 40*th*, 2025 (2009). [2] Delory *et al., Proc. Lunar. Sci. Conf.* 41*th*, 2459 (2010). [3] Horanyi *et al.*, *Proc. Lunar. Sci. Conf.* 40*th*, 1741 (2009). [4] Krüger *et al.*, *Icarus 164*, 170, (2003). [5] McCoy, *Proc. Lunar. Sci. Conf.* 7*th*, (1976). [6] Postberg *et al., Planetary and Space Sci*. 59, 1815, (2011).