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The dust environment of airless planetary bodies

M. Horányi(1,2), J. Szalay (3), X. Wang(1,2)
(1) Department of Physics and Laboratory for Atmospheric and Space Physics, U. of Colorado, CO, USA
(2) NASA-SSERVI: Institute for Modeling Plasmas, Atmospheres, and Cosmic Dust (IMPACT), U. of Colorado, CO, USA
(3) Southwest Research Institute, San Antonio, TX, USA

Abstract

The Moon, as all airless bodies in the solar system, is continually bombarded by interplanetary dust particles, it is also immersed in the solar wind plasma flow and UV radiation. There are several controversial observations from the Apollo era that can now be revisited due to new spacecraft data, and recent dedicated laboratory experiments. Hypervelocity dust impacts generate secondary dust ejecta particles, neutral and ionized gases, sustaining the recently discovered, permanently present dust cloud engulfing the moon, and contributing to the production of the dilute lunar atmosphere and ionosphere. UV and plasma exposure results in the electrostatic charging of the lunar regolith, that can lead to the mobilization, transport, and large-scale redistribution of the lunar fines. We focus on the recent results of in situ observations, as well as the latest laboratory results, a combination which resulted in a much improved understanding of the lunar dust environment, and its expected similarity to the surfaces of other airless planetary bodies.

1. Dust measurements in space

The Lunar Dust Experiment (LDEX) on board the Lunar Atmosphere and Dust Environment Explorer mission was designed to make in situ dust measurements while orbiting the Moon [1, 2]. Particles with radii $a \geq 0.3$ μm were detected as impacts [3]. LDEX was also capable of measuring the collective signal generated from dust impacts with sizes below its single-particle detection threshold. A putative population of electrostatically lofted grains above the lunar terminator with radii of approximately 0.1 μm has been suggested to exist since the Apollo era. LDEX performed the first search with an in situ dust detector for such a population. Fig.1 shows the LDEX observations taken over the lunar terminator indicating no evidence of electrostatically lofted grains in the altitude range of 3 - 250 km above the lunar terminator, with an upper limit of 40-100 cm^{-}3 [3, 4]. This has also been supported by the remote sensing observations of the Clementine and LRO missions [5, 6]. Contrary to these observations, the LADEE UVS instrument's [7] spectral data did suggest the existence of at least an intermittent nanodust exosphere at the Moon containing a population of particles sufficiently dense to be detectable via scattered sunlight. Near the peak of the Quadrantid meteoroid stream the observed negative spectral slope is consistent with backscattering of sunlight by nanodust grains with radii less than 20 to 30 nm [8]. This population is suggested to be generated by impacts during the Quadrantid stream, similar to the enhancements observed by LDEX during this and other shower periods [3, 9]. While to date there is no evidence of high-altitude lofted dust due to electrostatic effects over the lunar surface, there is strong supporting evidence from recent laboratory experiments that dust charging can lead to significant effects near the surface of an airless planetary body.

2. Laboratory experiments

New laboratory experiments shed light on dust charging and transport that have been suggested to explain a variety of unusual phenomena on the surfaces of airless planetary bodies. Lofted large aggregates and surface mobilization are related to many space observations. New experiments (Fig.1) have successfully shown that the emission and re-absorption of photoelectrons and/or secondary electrons at the walls of micro-cavities formed between neighboring dust particles below the surface are responsible for generating unexpectedly large negative charges and intense particle-particle repulsive forces to mobilize and lift off dust particles [10, 11].

3. Summary and Conclusions

This talk will summarize the LADEE/LDEX results identifying the permanently present and intermittently

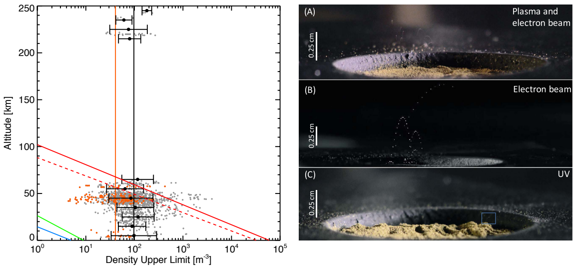

Figure 1: *Left*:The upper limit of the density of dust particles as a function of altitude, derived from the LDEX current measurements. Each gray dot represents a terminator crossing. Black dots show the averages in 10 km increments. The orange points indicate LDEX measurements taken in Earth's magnetotail [4]. *Right*: Images of dust transport and hopping trajectories in (a) plasma and electron beam, (b) electron beam, and (c) UV experiments. A blue square highlights a hopping trajectory captured under UV illumination. Deposits of dust particles on the surface outside the crater also indicate their hopping motions in all three images. Large aggregates up to 140 μm in diameter are lofted in addition to individual particles in the range of 38 - 45 μm in diameter [10].

enhanced lunar dust ejecta cloud that is sustained by the continual bombardment by interplanetary dust particles originating form the sporadic background population, as well as the meteoroid streams. The measurements indicate no high-altitude dust density enhancements over the terminator regions, as it was anticipated due to dust charging and strong electric fields in this region. However, there is strong supporting evidence for efficient dust mobilization and transport near the surface, a process that is likely to be responsible for the observed dust ponding on asteroids [12].

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