IMPACT LOFTED EJECTA CONTRIBUTION TO THE LUNAR EXOSPHERE: EXPERIMENTS AND RESULTS FROM THE LADEE ULTRAVIOLET VISIBLE SPECTROMETER

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Introduction: A main scientific objective of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission, currently in orbit around the moon, is to directly measure the lunar exospheric dust environment and its spatial and temporal variability. Past studies (e.g., [1]) have suggested that impacts could excavate material into a dust cloud surrounding the moon. Meteor showers, in particular, present a large number of concentrated impact events on the surface. The current flux of material falling on the moon is dominated by small bolides and should cause frequent impacts that eject dust at high speeds. For example, between 1 and 25 LCROSS-sized (~20-30m diameter) craters are statistically expected to be naturally formed on the moon during any given year (from, for example, [2],[3], respectively), with vastly more at smaller scales.

In this study, we will present preliminary results of lunar limb observations from the Ultraviolet and Visible Spectrometer (UVS) onboard LADEE and discuss new experiments and modeling of the impact ejected contribution to the lunar dust exosphere.

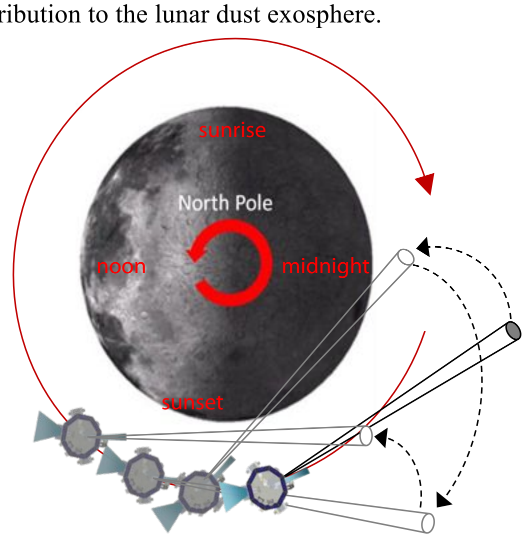

Figure 1. Schematic of a LADEE "nod" operation to detect dust and gases at the lunar limb with the UVS. Nod begins in the stare orientation, scans down to lunar surface, up to higher altitudes, then back to stare. This activity provides science data at many altitudes down to lunar surface. The telescope can also be pointed 180° opposite from normal Limb stare orientation to allow for observations in forward scatter at sunset terminator.

LADEE UVS Observations: The Ultraviolet and Visible Spectrometer, a CCD spectrograph which operates between 230 – 810 nm with a spectral resolution of <1 nm, is designed to make observations of the lunar exosphere and search for dust. Observations of the lunar limb using the UVS three-inch telescope include limb "stares" ranging from ~20 km above the surface at the terminators to ~40 km at around local noon time. At the terminators, the spacecraft can "nod" the telescope between the surface and about 50 km (Figure 1). Both "backward" looks (stares that point in the anti-velocity direction of the spacecraft), and "forward" looks (which flip the spacecraft to allow UVS to look in the ram direction) have been completed to permit observations in both back and forward scattering regimes. The spectra are taken at relatively high cadence (between 1 and 10 seconds each) during these observations and allow a temporally and spatially resolved view of the scatter in the exosphere (Figure 2). Convolution of these profiles with expected contributions from impact events can permit characterization of present day impacts on the moon.

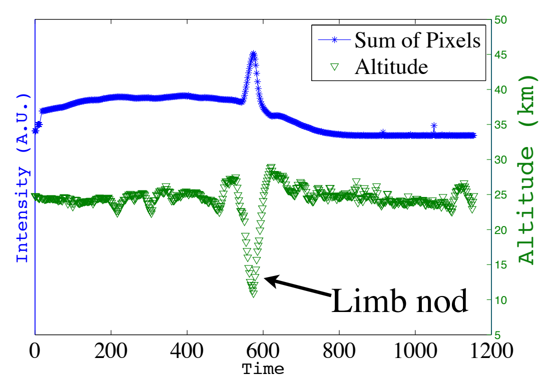

Figure 2. Example UVS limb scan activity with nod. Blue "sum of pixels" is the spectrometer response integrated over all wavelengths (arbitrary units) as a function of time (seconds). Telescope boresite altitude (green; using right ordinate) is held at ~25km before beginning "nod" decent to ~10km and then back to stare altitude.

Impact Experiments: A suite of impact experiments designed to study the high speed component of impact ejecta was performed at the NASA Ames Vertical Gun Range (AVGR) in Moffett Field, CA. In this study, aluminum projectiles were launched orthogonally into granular targets. Particle Tracking Velocimetry

(PTV) techniques were developed and employed to non-intrusively measure the velocity, position, and number of particles in the profile of the ejecta curtain to high spatial and temporal resolution. High-speed cameras (>15,000 frames per second or fps) allow measurements of particle velocity over a significant dynamic range from ~700 m/s for the fastest material to a few meters per second. See [4] for a full description of the development and application of the technique.

Discussion: “Larger” impact events (e.g., impactor size>>target grain size), which are expected to form sporadically over the course of a year, are capable of lofting a considerable amount of material for a measureable period of time (Figure 4). As these ejecta return to the surface (or encounter local topography), they impact at hundreds of meters per second or higher, thereby “scouring” the surface with low-mass oblique dust impacts. While these high-speed ejecta represent only a small fraction of the total ejected mass, the lofting and subsequent ballistic return of this dust has a high potential for mobilization.

The actual visibility of these ejecta clouds diminishes with height and time as the particles spread ballistically. Given the amount of material expected to be lofted above 5km, these results indicate that there is a significant chance of LADEE observations of a primary ejecta cloud even from relatively small impacts- if they occur at the right time and place (e.g., at a location and recently enough to enter the fields of view of the instruments before spreading too much). The chances of observing such an event grow significantly higher during a meteor shower, which have been observed to cause very frequent impact flashes on the moon. around the moon for durations of several hours. These smaller, more frequent, craters can loft diminished (but measurable with the UVS & LDEX instruments) amounts of regolith for tens of minutes.

References:

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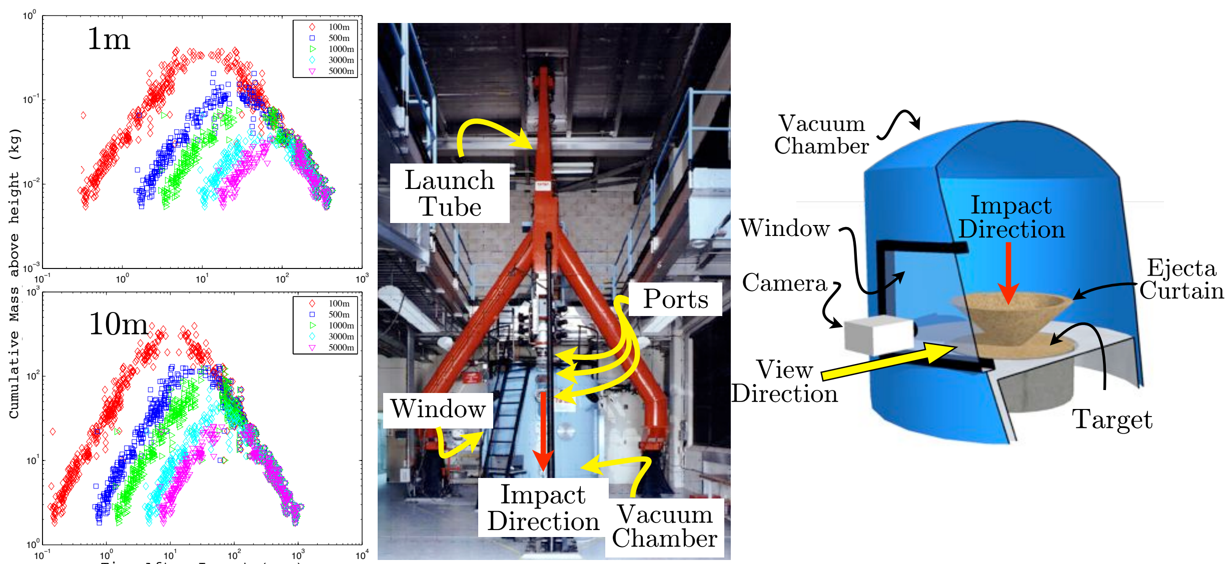

Figure 3. On left, the estimated cumulative mass above a given height (convolved with instrument FOV) as a function of time after impact for representative crater sizes (in upper right corner). Middle and right panels describe experimental setup and schematic for studies at the AVGR (side view).