
Introduction: Dust transport on the Moon affects many aspects of lunar surface science, such as the eradication of small craters, rock burial and exposure, and particle track dating of grains [1]. Moreover, as we learned from the Apollo program, dust mitigation is important for successful human exploration on the Moon [2]. One observable phenomenon that could yield constraints on dust transport processes is scattered sunlight from exospheric dust grains. The brightest measurements of this lunar horizon glow (LHG) come from Apollo 15 coronal photographs taken from the Command Module near the dawn terminator around the time of a relatively active meteor stream [3,4]. However, a variety of other measurements have placed limits on the dust density orders of magnitude below that inferred from Apollo 15 [5,6,7,8]. These observations raise new questions on the time variability of the dust environment, the answers to which have implications for dust transport and planetary exploration, in general.

To address these questions, the Lunar Orbiter Laser Altimeter (LOLA) aboard the Lunar Reconnaissance Orbiter (LRO) is conducting a campaign to search for LHG with the LOLA Laser Ranging (LR) system. Advantages of this LOLA LHG search include: (1) the LOLA-LR telescope can observe arbitrarily close to the Sun for extended periods without damaging itself or the other LRO instruments, (2) a long temporal baseline and regular sampling with an emphasis on meteor stream, which will improve the chances of detecting LHG, and (3) the observations will focus on altitudes < 20 km, the same range as the majority of Apollo 15 measurements. In this contribution, we describe the instrument, methodology, and some preliminary results.

Instrument: LOLA is a time-of-flight laser altimeter operating at a firing rate of 28 Hz [9]. The instrument has 5 separate detectors, or channels, dedicated to each of the 5 laser spots that collectively comprise the LOLA footprint on the lunar surface [10]. Each detector records the background noise counts, which are a function of the number of collected photons, over an integration time of 0.0357 sec. As part of the one-way LR experiment between Earth stations and LRO [11], channel 1 is also connected via a fiber optic cable to a telescope mounted on, and co-aligned with, the LRO high-gain antenna (HGA). The light collected by this LR telescope, which has a 1.75° field-of-view (FOV), is fed to the detector through a 0.3-nm bandpass filter centered on 532 nm.

Method: During a typical sunrise horizon observation, the HGA is stowed in the spacecraft’s -Z direction while LRO performs a multi-axis slew so that the HGA and LR telescope are pointed at the limb for several minutes leading up to sunrise. At sunrise, the Sun is usually within the LR FOV and, thus, such a scan probes a range of elongation angles (the angle between the LR line-of-sight and the Sun), tangent point altitudes (the height above the lunar surface at the line-of-sight’s tangent point to the Moon), and distances to the terminator. LRO is presently in an elliptical polar orbit with periapsis of ~30-50 km in the south and apoapsis of ~140-160 km in the north. Thus, the LR FOV samples a range of tangent point altitudes mostly < 20 km. Because of LRO’s polar orbit, these observations tend to occur at high latitude, but as the beta angle (the angle between the Sun and LRO’s orbital angular momentum vector) shifts throughout the year, there are periods when eclipse occurs closer to the equator.

Results: Figure 1 shows the signal measured during one scan from 2016 DOY 099. The data (black points) have been dark-subtracted and averaged over 4-sec bins (n ~ 100 in each bin). The black lines above and below the data show ±3 times the standard error of the mean in each bin (3σ√n). The blue horizontal lines show ±3 times the dark noise standard deviation that is estimated from the black points over the ~15 mins preceding the timespan plotted. The elongation angle ranges from ~5° at 4800 sec to ~0.5° at sunrise (4983 sec).

The photometric calibration of the LR system to solar brightness units (Bsun, the mean brightness of the solar disk) is presently achieved by fitting the data from this particular scan to a semi-empirical model for the coronal and zodiacal light (CZL) shown by the orange line in Fig. 1. The resulting photometric scale factor is then used for all other scans. The CZL model is based on SOHO/LASCO C2 and C3 images taken on DOY 099. Most of the data collected so far resemble Fig. 1, with a rise in signal within ~2° of the Sun interpreted as the CZL, and a similar dark noise level. For comparison, the Apollo 15 measurement of LHG...
reached a brightness of \( \sim 10^9 \) B\(_{\text{sun}}\) at elongation angles of 2-3° [4]. We therefore expect to be able to detect such an event at the 3\( \sigma \) level within \( \sim 3^\circ\) of the Sun.

The observed signal is, in general, largely controlled by the elongation angle and sky visibility within the FOV, namely, the fraction of the FOV that sees the sky, or that is unobscured by topography. To estimate the sky visibility, we sub-sample the FOV with 500 sightlines and determine whether each sightline intersects the lunar surface of the LOLA shape model, and if not, what CZL value it would measure. As the FOV scans along the horizon, new topography continuously enters and leaves the FOV, and the sky visibility changes. This is most clearly seen in the data at high beta angle, when it is possible to stare at a fixed elongation angle for the few minutes between sunset and sunrise. Figure 2 shows a scan from one such time on 2016 DOY 142 when the elongation angle was fixed at \( \sim 0.7^\circ\). Fluctuations in the signal are correlated with the sky visibility (Figure 3) indicating that the signal is dominated by a source in the sky. In addition, the magnitudes of these fluctuations are sometimes less than the formal 3\( \sigma \) dark noise uncertainty (blue lines) indicating we can measure real signal variations less than this amount.

The CZL model in Fig. 2 is generated in the same manner as in Fig. 1 with the same LASCO images. Thus, time variations in the solar K-corona could contribute to the residuals between the CZL model and data, as well as the fact that smooth 2-dimensional models for the solar K and F corona had to be used to fill in the region blocked by the LASCO C2 coronagraph within 0.67° of the Sun.

**Summary:** We are conducting a campaign to search for lunar horizon glow at altitudes < 20 km with the LR system of the LOLA instrument onboard LRO. With repeated observations, including during large meteor streams, and by focusing on elongation angles < 3°, we can improve the likelihood of detecting episodic impact-related dust enhancements such as that inferred from the Apollo 15 measurements [3,4].

**References:**