PREDICTIONS FOR THE LUNAR HORIZON GLOW OBSERVED BY THE LUNAR RECONNAISSANCE ORBITER CAMERA.

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Introduction: There is strong evidence that electrostatically charged lunar dust is transported about the surface of the Moon [1, 2, 3, 4]. Such evidence includes observations of a "lunar horizon glow" (LHG) from orbit by Apollo astronauts [2, 3], and possibly by the Star Tracker cameras aboard the Clementine spacecraft [5]. This LHG is thought to be caused by sunlight scattered by exospheric dust above the terminator [3]. However, the lunar dust-plasma environment is poorly characterized and the fundamental physical processes are not well understood.

NASA's Lunar Reconnaissance Orbiter (LRO) mission is due to launch in October 2008 and will carry a multispectral Wide Angle Camera (WAC) to the Moon as part of the Lunar Reconnaissance Orbiter Camera (LROC) suite [6]. During the exploration phase, LROC's objective will include imaging the lunar surface at meter-scale resolution in order to characterize landing sites and the permanently shadowed regions (PSRs). This will require LROC to be nadir pointing (i.e., toward the lunar surface).

However, during the subsequent science phase the National Research Council (NRC) has recommended that LROC, and the other imagers aboard LRO, point off-nadir toward the lunar limb in order to view and characterize LHG [7]. This will provide an unprecedented opportunity to determine the concentration and distribution of dust in the lunar exosphere, as well as to investigate how it is formed and the nature of its dynamics. At an altitude of 50 km LRO will be far closer to the source of the LHG than any previous observations. In addition, LROC has a much higher spatial resolution than the Clementine Star Tracker camera, as well as having the capability to observe at 7 different spectral bands centered at 315 to 690 nm [6].

Sources of Lunar Horizon Glow: We assume here that the LHG is caused by sunlight scattered by submicron dust in the lunar exosphere. However, another possible source of scattered sunlight is the exospheric gases, in particular sodium (Na) and potassium (K) [8]. The easiest way to distinguish between contributions from exospheric dust and gases is to determine the scale height, H, of the LHG. Exospheric Na and K emissions have $H \sim 100$ km [9, 10], whereas the LHG observed during Apollo had $H \sim 10$ km [3]. It has also been suggested that exospheric gas emissions are too faint to see with the human eye [3]. Given the limited set of LHG observations, it is important to keep an open mind regarding the various mechanisms that could contribute to LHG.

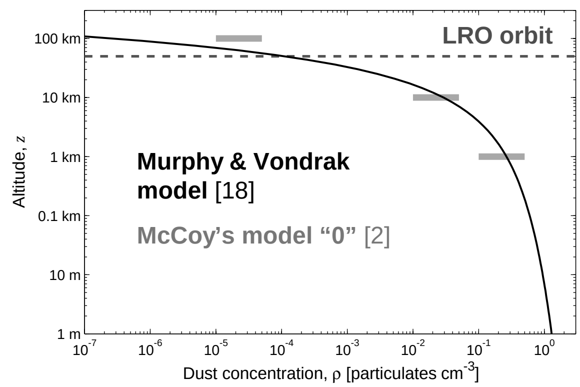

Figure 1. Predictions using Eq. (1).

Lunar Surface Charging: The Moon is permanently immersed in various plasma environments and exposed to solar ultraviolet and X-rays, which cause its surface to become electrically charged [11, 12, 13]. The lunar dayside charges to ~+10 V due to the photoemission of electrons by incident solar UV/X-rays (i.e., loss of negative charge), while the near-terminator region charges to ~−100 V due to the high fluxes of fast moving plasma electrons (i.e., accumulation of negative charge) [13]. A plasma sheath forms above the Moon that effectively shields the surface electric charge from the surrounding plasma [14].

Lunar Exospheric Dust Dynamics: We focus on the 0.1μm-scale lunar dust that appeared to reach in excess of 100 km altitude [2, 3]. Currently, the only mechanism that can explain how dust can reach such altitudes is the dynamic dust fountain model [15, 16]. In this model, a charged dust grain becomes detached from the lunar surface and is rapidly accelerated through the sheath by the near-surface electric field. Once above the sheath it subsequently follows a ballistic trajectory under gravity.

Previous Observations Lunar Exospheric Dust Concentrations: Using McCoy's model "0" [2] and the Lunokhod-II observations [17], Murphy and Vondrak [18] developed an expression for exospheric dust concentration above the lunar terminator, ρ, as a function of dust radius, a, and altitude, z:

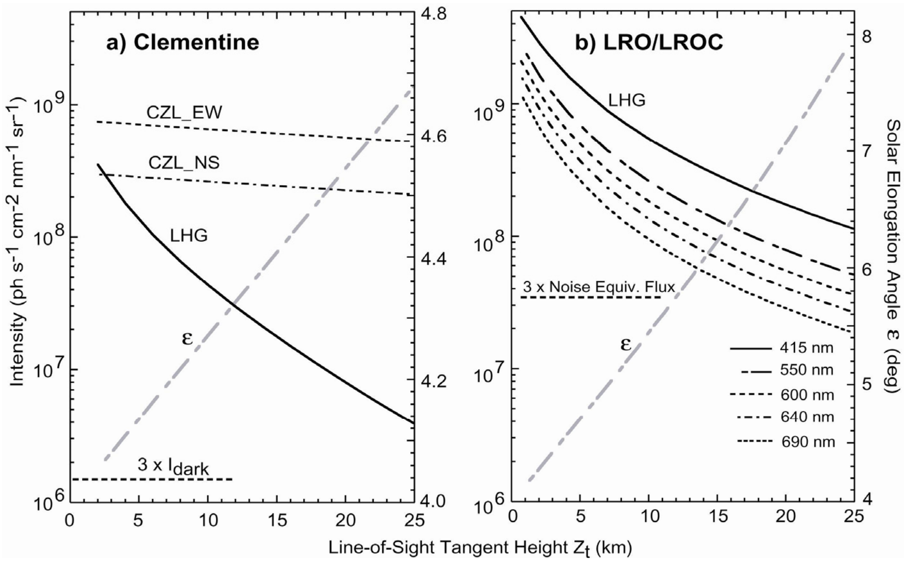

Figure 2. 1-dimensional model predictions of LHG for: (a) Clementine Star Tracker at z = 1000 km and (b) LROC/WAC at z = 50 km, based on Eq. (1). Solar elongation angle, ε, (at Z_t = 0) is fixed at 4° in both cases. Radiances for Coronal and Zodiacal light (CZL) are from [20]. LROC/WAC will be able to provide information on the low-altitude dust size-distribution via measurements at multiple wavelengths.

$$\rho(a,z) = (n_0/a)\exp\left(-a^{8/3}z/20\right), \tag{1}$$

where n_0 is a scaling factor for dust concentration. Using a Mie scattering code, they found that a total column concentration of $n_c = 1.4 \times 10^3$ cm^{-2} for $0.1 < a < 6$ μm produced the best fit to the data (Fig. 1).

New LHG Intensity Predictions for Clementine and LROC/WAC: Fig. 2 shows model simulations of path integrated, line-of-sight LHG as seen by (a) the spectrally broad Clementine Star Tracker CCD camera [19, 20], and (b) several color channels of the LROC/WAC [21]. Dust vertical size distributions in these simulations are given by Eq. (1), and the spectral properties for dust scattering (i.e., single scattering albedo and phase function shape) have been computed within the framework of Mie models, using refractive index values typical of those measured for JSC lunar regolith simulants [22]. The LROC/WAC should observe significantly brighter LHG than Clementine, as a consequence of improved vertical resolution at the limb (~630 m, compared with ~6 km) and the ability to observe at shorter wavelengths, where dust optical depth is larger. Our simulations show that the observed LHG arises mostly from dust grains with ~$0.1 < a <$ ~0.3 μm, but this represents a sensitive balance between rapidly declining concentrations of large dust grains, and the rapidly increasing scattering cross-section with grain size. Multi-wavelength observations by the LROC/WAC as a function of solar elongation angle, ε, will strongly constrain both the dust vertical distribution and its local time dependence.

Note that the LROC sensitivity limits (based on 10s integration time) in Fig. 2 are somewhat higher than Clementine, due to the narrow (15-40 nm) spectral filter widths (the Clementine CCD camera has no wavelength filters). However this restriction is offset by higher LHG expected at short wavelengths as well as improved spatial resolution.

Conclusions: The LROC/WAC could provide an unprecedented opportunity to determine the concentration and distribution of dust in the lunar exosphere, as well as to investigate how it is formed and the nature of its dynamics. These observations could also distinguish the contribution to LHG from the lunar exospheric gases.

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