Characterization of Electrostatically Lofted Dust Environment at High Lunar Latitudes

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Science Concept and Rationale

Dust encountered during the early unmanned and manned missions to the Moon was found to be a ubiquitous component of the lunar surface environment, posing a significant challenge and potential risk to assets placed on the surface. Thus, it is critical for the engineering design of future missions to the Moon to include a thorough assessment of the dust environment to be encountered; including electrostatically lofted dust populations(1). As humans return to the Moon, it is crucial that all potential short and long-term effects of dust on systems(2) and on physical health are examined and evaluated(3,4,5,6,7,8,9), and that feasible remediation efforts are considered(10,11,12). Characterization of the local dust environment is listed as an Exploration Physics topic within the 'Fundamental Lunar Science' theme, and as one of the Exploration Requirements for the 'Platform to Study the Universe' theme within the Artemis Science Plan (presented at the Lunar Surface Science Virtual Workshop, 30 May 2020).

The lunar regolith is a several meter thick layer of material above the primordial lunar bedrock, comprised of a loose mixture of dust, pebbles, and unconsolidated rocks. Micrometeoroid impacts along with radiation and solar wind plasma, and in conjunction with the absence of a significant atmosphere or global magnetic field, have resulted in the creation of a layer of unprocessed surface dust with a size range of ~10 nm to ~1 mm(13). The largest forces acting upon the regolith (and especially the dust component) are gravitational and electrostatic forces; the latter of which arises from charging of the dust by photoemission, charged particle deposition, triboelectric charging, and interactions with the local plasma environments of the solar wind and magnetotail. The magnitude of the electrostatic force can be comparable to the magnitude of the gravitational force on the dust(14), causing particles to be lofted above and transported along (depending on the configuration of the electrostatic forces) the lunar surface. The characteristics of the lofted dust population are therefore complex, and depend upon the size and shape of the particles, the spatial distribution of dust in the topmost portion of the regolith, and the complicated interactions between the charged dust and the local plasma populations, including the effects of photoelectrons(15).

The lofted dust environment at the lunar high latitudes (such as a landing site within 6 degrees of the South Pole) is likely to be substantially different from that which has been previously observed at lower latitudes. The physical processes (i.e., electrostatic potential differences) involved in lifting dust off the lunar surface near the dawn and dusk terminators occur over different spatial scales at high latitudes where the dawn and dusk terminators converge, and may result in an essentially ever-lasting population of lofted dust.

Study Goals

In order to quantitatively characterize electrostatically lofted dust near (up to several tens of meters above) the lunar surface, the following specific science questions need to be answered: 1) What is the dust *number density profile* as a function of altitude near and along the lunar terminator? 2) What is the dust *particle size distribution* as a function of altitude along the horizon of the lunar terminator?, and 3) How does the lofted lunar dust *vary with time* as the local surface transitions between daylight and darkness?

It is especially important and timely to answer these science questions while the lunar environment remains in a pristine state. The answers to these questions advance the current state of scientific knowledge about the Moon’s surface, providing insights into the physical processes involved in the formation, distribution, composition, and evolution of lunar dust over the eons.

General Description of Instrument Concept, Observations, and Analyses

Multiple wavelength low-light digital imaging of scattered sunlight intensities by the lofted dust (Lunar Horizon Glow) by a dedicated, low SWaP/Cost camera pointing just above the horizon at lunar dusk and dawn is to be used to readily take the required observations in order to quantify the dust density profiles, size distributions, and variations with local time and latitude. The analyses of these important observations need to carefully distinguish scattered sunlight by lofted dust from that of Coronal and Zodiacal light, as well as any reflections of sunlight by lunar geologic features. A simulation[16] of the different sources and altitude and azimuthal variations in the scattered sunlight is presented in Figure 1. These observations, in conjunction with theory and modeling efforts, is then to be used to fully characterize the electrostatically lofted dust environment at high lunar latitudes, and can then be directly compared with observations taken at lower latitudes.

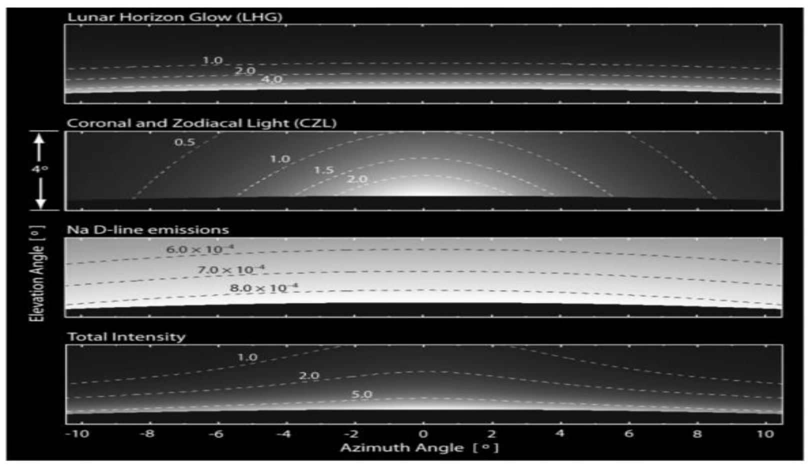

Fig. 1: Lunar Horizon Glow from lofted dust, and Coronal and Zodiacal Light (CZL)[16]. Detailed knowledge of the CZL contributions to the observed scattered light enables the dust characteristics to be isolated and quantified as a function of altitude and azimuth angle (https://www.nasa.gov/centers/goddard/news/features/2010/lhg.html Credit: NASA).

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