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Far-Ultraviolet Investigation of New Impact Craters and Cold Spots on the Moon Using the LRO LAMP Data

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Abstract

We present the far-ultraviolet (FUV) observations of new impact craters and cold spots on the Moon using LRO LAMP data. Our results show distinct spectral response to these features in FUV wavelengths.

1. Introduction

The Lunar Reconnaissance Orbiter (LRO) Lyman Alpha Mapping Project (LAMP) provides global coverage of both nightside and dayside of the Moon in the far ultraviolet (FUV) wavelengths between 57 and 196 nm [1]. The innovative nightside observations use roughly uniform diffuse illumination sources from interplanetary medium Lyman-α sky glow and UV-bright stars. The dayside observations use the more traditional photometry technique with the Sun as the illumination source which is very complementary.

Global albedo maps are produced at Lyman-α, on-band and off-band, which are used to constrain the abundance of water frost based on the strength of the on and off the water frost absorption edge at ~165 nm [1]. The nightside FUV albedo measurements over a few PSRs in south pole indicate 1-2% water frost abundances [2]. The dayside data reveals a distinct diurnal variation in hydration level across the surface of the Moon [3]. The spectral images cubes with 2 nm resolution are created to characterize lunar swirls for several regions of interests by the reddened FUV spectra of immature materials [4].

In this work, we introduce photometric corrections for LAMP dayside observations. We investigate the spectral properties of new impact craters detected by LROC instrument and cold spots identified by DIVINER instrument, using LAMP FUV data.

2. Photometric Correction

LAMP dayside observations use sunlight as the illumination source where bidirectional reflectance is measured. The bidirectional reflectance is dependent both upon the observation geometry and the soil properties. To compare the same area covered from multiple observations with different viewing geometries, photometric corrections are needed to normalize the reflectance as if it is measured in the same observation geometry. In this work, we use a simplified Hapke's bidirectional reflectance distribution function (BRDF) to simulate LAMP's reflectance [5]. By modeling the lunar phase curve (i.e., reflectance as a function of phase angles) at FUV wavelengths, we retrieve the wavelength-dependent Hapke parameters by using the Levenberg-Marquardt regression analysis algorithm. The retrieved Hapke parameters are then used for photometric corrections of LAMP data using the Hapke BRDF model. The photometrically corrected data will be used to investigate the new impact craters and cold spots on the Moon.

3. New Impact Craters

Numerous new craters have been detected by LROC NAC paired observations [7]. For example, more than 200 new impact craters have formed in past 9 year, which indicates that new craters are forming on the surface of the moon more frequently than model had predicted [7]. These new impact events excavate new materials from the subsurface of the Moon, and also the impact induced jetting or scouring has potentially modified the lunar surface in a great distance. Our initial analysis over a 70 m diameter new crater, formed in Mare Humorum in October 2012, shows distinct overall albedo changes at FUV wavelengths before and after impact. Figure 1 shows the albedo at 165 nm before and after impact as a function of distance to the impact center. After impact, the albedo increases significantly especially within 100 km radius of the impact. The albedo generally decreases with increase of the distance, but the albedo differences are even visible at 150 km away from the impact, indicating the great influence of the impact during the formation of this 70 m crater.

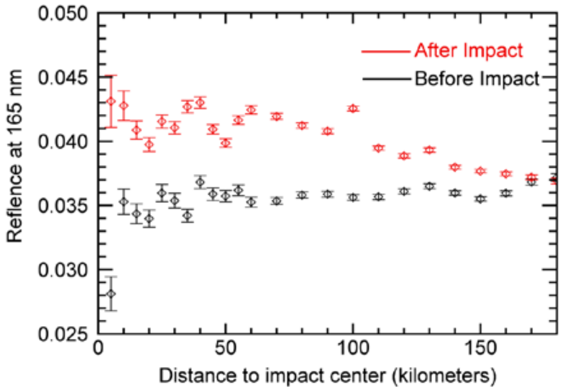

Figure 1: Reflectance at 165 nm before and after impact as a function distance to the impact site.

4. Cold Spots

A class of anomalous cold surfaces (termed “cold spots”) has been identified by Diviner radiometer [8]. These “cold spots” are mostly associated with fresh craters with unique ejecta morphology. Cold spots extent ~30-60 crater radii, which have rayed profiles that mimic the visible proximal ejecta deposits. However these cold spot features cannot be explained by the emplacement of ejecta alone. Specifically, there is no spectral/albedo evidence of deposition and/or scouring from visible and near infrared data [8]. Our analysis over cold spots using LAMP FUV data, however, shows distinct spectral signatures. We initially analyzed three cold spots and our results consistently show that the cold spot surfaces tend to be more mature than the center fresh crater but are less mature than surrounding terrains (Figure 2). The results indicate that the FUV data are likely more sensitive to the regolith modification over the cold spot surfaces than longer wavelengths, or the disruption of the regolith by exacting or depositing new materials or by impact induced jetting or scouring over cold spot surfaces are more profound than previous thought.

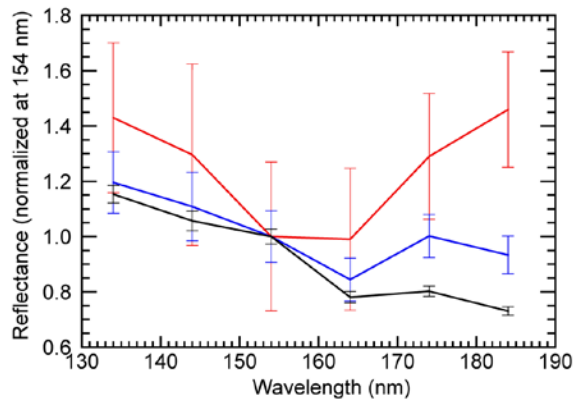

Figure 2: FUV reflectance spectra over the center fresh crater (in red), cold spot surfaces (in blue), and surrounding terrains (in black), respectively, for a representative cold spot.

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