EPSC Abstracts
Vol. 6, EPSC-DPS2011-1637, 2011
EPSC-DPS Joint Meeting 2011

The Lunar Albedo as Measured by LRO-LAMP: Space Weathering Effects

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1. Introduction

The Lunar Reconnaissance Orbiter (LRO) has been in orbit since July 2009. The Lyman Alpha Mapping Project (LAMP) [1] on board LRO has a primary focus of investigating the lunar poles (see abstracts by Gladstone et al. and Retherford et al., this meeting), searching for water frost in the permanently shadowed regions, as well as studying the lunar atmosphere. LAMP also makes measurements of the dayside lunar surface on each orbit. In this project, we utilize the LAMP dayside data to study the lunar surface and to understand its spectral variations.

The canonical method for investigating the surface composition of planetary surfaces is near-infrared spectroscopy. Here we utilize the ultraviolet wavelength range, shown to be sensitive to weathering effects and also containing diagnostic compositional features. We focus on data in the 110-190 nm range.

2. UV wavelengths: clue to space weathering

Space weathering, the bombardment of airless bodies by micrometeoroids and irradiation by solar wind particles, profoundly affects the surfaces of airless bodies such as the Moon, impacting the compositional information that is obtained through remote sensing. (Recent results suggest that solar wind interaction processes dominate over micrometeoroid bombardment at the Moon [15].) The ultraviolet wavelength range is a particularly sensitive indicator of space weathering effects. Lunar soil samples and S-class asteroids are spectrally bluer at UV wavelengths than their less-weathered counterparts, crushed lunar rock samples and ordinary chondrite meteorites, respectively [3]. This is due to the disappearance of the UV absorption edge as a result of weathering. This UV edge is present in nearly all materials and its strength is therefore an excellent indicator of exposure. The UV absorption edge is often due to the Fe^{3+} intervalence charge-transfer transition band seen in almost all iron-bearing silicate surfaces. Silicate minerals are dominated by an exciton/valence-conduction transition band system below 200 nm [4][6][14]; they are bright in the VNIR, but the wings of the band system make the minerals start to decrease in brightness in the near-UV (NUV, ~200-350 nm) - referred to here as the “UV dropoff,” or the “UV absorption edge.” Opaque materials (such as iron) are dominated by surface scattering, and are thus spectrally flat over a wide range of wavelengths; in opaques, there is no UV absorption edge in the 150-450 nm region. Thus, compared to materials such as pyroxenes and feldspars, iron-bearing minerals can be relatively bright at UV wavelengths. The technique of studying space weathering by investigating the strength of the UV absorption edge has been applied to lunar samples and UV data of asteroids [2][3] and more recently has been used to look for weathering effects on the Moon in LROC WAC images (e.g., [16]).

In the far-UV (FUV, ~100-200 nm), the effects of weathering are present as well. The Apollo-17 Ultraviolet Spectrometer (UVS) (e.g., [7]) scanned the sunlit surface of the Moon in the FUV during the course of 38 orbits. A significant discovery from this experiment was the lunar spectral reversal: at 147 nm, the lunar maria are brighter (by 5-10%) than the lunar highlands, while it is well known that at visible wavelengths, the highlands are brighter than the maria. The brightness of the Moon was mapped out [7] along two swaths in the region spanning Mare Serenitatis and Mare Crisium, demonstrating this spectral reversal trend. The spectral reversal phenomenon was confirmed in EUVE images [8]. The cause of the spectral reversal is tied to the bulk compositions of the maria and highlands – maria contain greater amounts of opaques which are relatively bright in the FUV [7]. However, it has been noted [9] that the correlation between Apollo-17 FUV brightness and terrain was imperfect and that FUV data therefore contain more information than simply a correlation with terrain type. Far-UV measurements probe a different portion of the grain than do visible-wavelength measurements and the FUV is thus more sensitive to potential coatings on grains that are the result of weathering processes such as impact vitrification or vapor deposition [7][9]. Such "space weathered rims" have been noted in optical measurements (e.g., [10]).

3. New results from LAMP

The LAMP dayside dataset is vast and provides ~500 m resolution coverage over a range of observational geometries. We find that, in general, the mare regions appear to be up to ~20% brighter than highlands at wavelengths < ~175 nm. This is the “spectral reversal” seen in Apollo 17 UVS results, and could be due to the larger amounts of opaque minerals, which are relatively bright in the UV, in mare regions. Mare regions are found to be generally bluer than highlands in the 160-195 nm region. Comparing some sample highlands regions with a (presumably relatively fresh) bright ray region, the highlands are darker and spectrally bluer at λ>170 nm – much like some weathered soil samples [3]. We expand upon these preliminary results by looking at a wider sampling of regions from the LAMP dataset and present data from specific regions across the Moon.

Acknowledgements

The LRO Project and entire LAMP team are thanked for their support in this study. The research described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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