EPSC Abstracts
Vol. 13, EPSC-DPS2019-833-1, 2019
EPSC-DPS Joint Meeting 2019
© Author(s) 2019. CC Attribution 4.0 license.

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

LRO Lyman Alpha Mapping Project (LAMP) Far-Ultraviolet Investigation of Lunar South Pole Permanently Shadowed Regions

Lizeth O. Magaña (1,2), Kurt D. Retherford (2,1), Kathleen E. Mandt (3), Paul O. Hayne (4), Cesare Grava (2), Benjamin D. Byron (1,2), Amanda R. Hendrix (5), Thomas K. Greathouse (2), Ujjwal Raut (2,1) and G. Randall Gladstone (2,1); (1) University of Texas at San Antonio, San Antonio, TX, USA, (2) Southwest Research Institute, San Antonio, TX, USA, (3) Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, (4) University of Colorado Boulder, Boulder, CO, USA, (5) Planetary Sciences Institute, Tucson, AZ, USA (lizeth.magana@swri.org)

Abstract

We present far-ultraviolet (FUV) observations of the Moon's south polar Permanently Shadowed Regions (PSRs) using data from the Lyman Alpha Mapping Project (LAMP) FUV imaging spectrograph.

1. Introduction

At the lunar poles, regions of continuous darkness known as permanently shadowed regions (PSRs) exist under extreme temperature conditions which are cold enough to freeze and trap volatiles [10,1,6,3,5]. PSRs receive minimal sunlight and therefore, cannot be explored using many conventional detection methods. The Lyman Alpha Mapping Project (LAMP) on board the Lunar Reconnaissance Orbiter (LRO) however, is capable of measuring surface-reflected UV light from UV-bright stars and the interplanetary medium (IPM) [2] in order to detect frozen resources otherwise hidden within PSRs. Resource identification is crucial to aid future crewed and robotic lunar missions. Here we report initial results of PSR FUV investigations using LAMP data from 2009 to 2016.

2. LAMP Investigations of Permanently Shadowed Regions

We produce brightness and albedo maps of the lunar south pole within four wavelength bands including Lyman-α (117.57-121.57 nm), On-band (129.57-155.57 nm), Edge-band (155.57-175.57 nm), and Off-band (175.57-189.57 nm). These maps are used to derive albedo spectra of south pole PSRs with annual maximum temperatures below 110K, as measured by LRO's radiometer Diviner [6]. Below 110K, water ice is stable since the thermal sublimation rate is minimal < 10^2 kg/m^2/Gyr [8]. We further explore the dependence of albedo spectra within the four spectral bands with temperature to identify possible volatile reserves by searching for regions with high Off-band/On-band ratios. Off-band and On-band refer to the UV wavelength ranges with weak and strong H_2O frost absorption, respectively [3]. A high Off-band/On-band ratio is therefore a spectral characteristic consistent with H_2O frost. These albedo spectra are ideal for constraining the water ice abundance through comparisons with the results of spectral mixing photometric models of known H_2O and regolith mixtures.

2.1 Haworth, Shoemaker, and Faustini

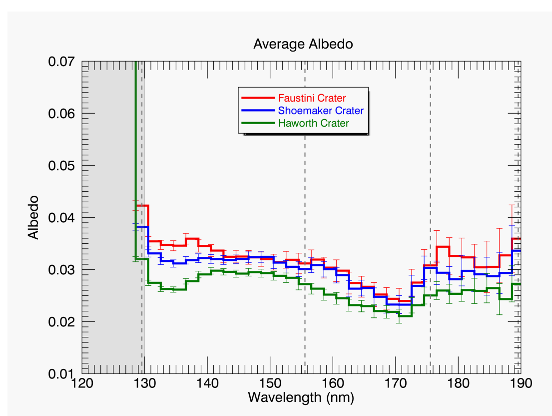

Figure 1: Preliminary FUV albedo spectra of craters Haworth, Shoemaker, Faustini showing a possible water absorption edge at ~170 nm. *We investigate possible H_2O volatile populations within these craters by analyzing albedo spectra.*

PSRs within three south pole craters – Haworth, Shoemaker, and Faustini – have been shown to be spectrally consistent with the presence of water ice as they express high Off-band/On-band ratios when compared to the surrounding area [4,5]. Thus we perform case study analyses for Haworth, Shoemaker, and Faustini and analyze albedo spectra (Figure 1) for possible H_2O populations within these PSRs.

3. Spectral Mixing Models

To constrain the abundance of H_2O ice within lunar PSRs we produce spectral mixing models of regolith with varying porosity and varying amounts of water ice (Figure 2). Spectral mixing models are produced using Apollo 10084 soil optical constants [7] and water ice optical constants [9] for 200 μm grains.

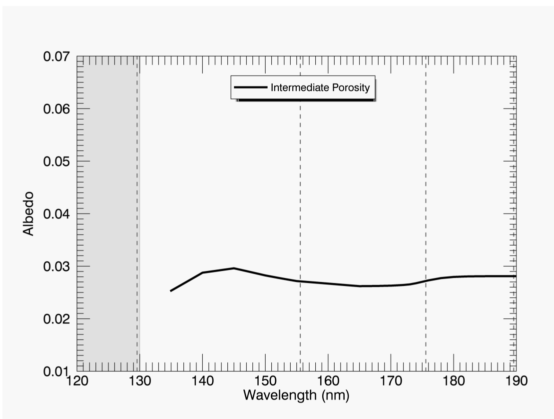

Figure 2: Modeled FUV albedo of intermediate porosity (K=1.88) Apollo soil 10084 mixed with ~2% water ice by mass with the water absorption edge shifted to ~170 nm. *We present preliminary albedo spectra of lunar regolith mixed with varying amounts of water ice and fits with observational data.*

We employ single-scatter albedo formulations for intimate mixtures from such that

$$\omega_s = S_e + \Theta (1 - S_e) * (1 - S_i) / (1 - S_i \Theta) \qquad (1)$$

Where ω_s is the single-scatter albedo for each component, S_e and S_i are the external and internal scattering coefficients, respectively, and Θ is the internal transmission factor [4].

Lastly, the hemispheric albedo A_h is given by,

$$A_h = (1 - \sqrt{1-\omega}\,) / (1 + 2\mu \sqrt{1-\omega} / K) \qquad (2)$$

We further fit these models to LAMP-derived albedo spectra for PSRs to constrain the water ice abundance.

4. Summary

Characterization of volatile populations within PSRs reported here are crucial for resource identification and thus, for future robotic and crewed lunar missions. We employ LAMP UV observations of the south pole from the start of the mission (September 2009) through September 2016 to increase signal to noise ratios and increase statistical significance.

References

[1] Arnold, J. R.: Ice in the lunar polar regions, J. Geophys. Res., Vol. 84, pp. 5659–5668, 1979.

[2] Gladstone, G. R. et al.: LAMP: the Lyman alpha mapping project on NASA's Lunar reconnaissance orbiter mission. Space Science Reviews, Vol. 150, pp. 161-181, 2010.

[3] Gladstone, G. R., et al.: Far‐ultraviolet reflectance properties of the Moon's permanently shadowed regions. Journal of Geophysical Research: Planets, 117.E12, 2012.

[4] Hapke, B. Theory of reflectance and emittance spectroscopy. Cambridge university press, 2012.

[5] Hayne, P. O., et al.: Evidence for exposed water ice in the Moon's south polar regions from Lunar Reconnaissance Orbiter ultraviolet albedo and temperature measurements. Icarus, Vol. 255, pp. 58–69, 2015.

[6] Paige, D. A., et al.: Diviner Lunar Radiometer observations of cold traps in the Moon's south polar region, Science, Vol. 330, pp. 479–482, 2010.

[7] Raut, U., et al.: Far-ultraviolet photometric response of Apollo soil 10084. Journal of Geophysical Research: Planets, Vol. 123, pp. 1221–1229, 2018.

[8] Schorghofer, N, and Taylor, G. J.: Subsurface migration of H2O at lunar cold traps. Journal of Geophys. Research: Planets Vol. 112.E2, 2007.

[9] Warren, Stephen G., and Richard E. Brandt.: Optical constants of ice from the ultraviolet to the microwave: A revised compilation. Journal of Geophysical Research: Atmospheres, Vol. 113.D14, 2008.

[10] Watson, K., Murray, B. C., and Brown H.: The behavior of volatiles on the lunar surface, J. Geophys. Res., Vol. 66, pp. 3033–3041, 1961.