THE LUNAR FAR-UV ALBEDO: INDICATOR OF HYDRATION AND SPACE WEATHERING.

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The ultraviolet is an ideal region of the spectrum in which to study both hydration and space weathering processes and effects because a strong H_2O absorption exists in this spectral regime, and because the UV senses largely surface scattering, proportional to Fresnel reflectance, rather than volume scattering. That is, the measured reflectance is directly related to the index of refraction [1]. The index of refraction of many materials increases with decreasing wavelength, so that they become brighter at shorter wavelengths. In the surface scattering regime, absorption (high k) can produce a reflectance maximum. Furthermore, since UV radiation is less penetrating than visible radiation, short wavelengths are more sensitive to thin coatings on grains that may be the result of weathering processes. UV wavelengths are also sensitive to the topmost grains of the lunar regolith, which experience different thermal variations than grains deeper in the regolith.

Hydration. The presence of a strong water absorption edge in the far-UV (near 165 nm) allows the study of lunar hydration by the Lyman Alpha Mapping Project (LAMP) onboard the Lunar Reconnaissance Orbiter (LRO). To map the presence and strength of the water feature in the LAMP data, *Hendrix et al*. [2] made a straight line fit to each reflectance spectrum in the 164-173 nm range, where the presence of any water is expected to most strongly affect the slope and determined the slope of that line, after photometrically correcting using the Lommel Seeliger term $\mu_0/(\mu+\mu_0)$. For comparison, *Hendrix et al.* [2] also studied the slopes in the 175-190 nm range, where the slope is not expected to change due to hydration effects. *Hendrix et al.* [2] found a relationship between the 164-173 nm slope and time-of-day, with steeper (redder) slopes (consistent with increased hydration) earlier and later in the day, and at higher latitudes. Near noon, the slopes were the bluest. The slopes in the 175-190 nm range showed no relationship with time-of-day. These spectral slope changes are consistent with small abundances (~1%) of hydration, with the abundance varying over the course of a day. Far-UV wavelengths are sensitive to the uppermost ~100 nm of the lunar regolith, suggesting that the hydration sensed by LAMP on the lunar dayside is surficial and transient.

Space Weathering. Our work has shown that the UV bluing effects associated with weathering and first discovered at near-UV wavelengths [2][3][4] extend into the far-UV (100-200 nm), as confirmed using data from LRO LAMP. The 'bluing' of the spectrum (i.e., a negatively-sloped spectrum) is in contrast with the spectral reddening (with a positively-sloped spectrum) that is seen at visible to near-infrared wavelengths (VNIR) with weathering. The bluing is related to the spectral behavior of iron (modeled as inclusions in grains); the addition of sub-microscopic iron (SMFe), likely specifically in the grain rims, tends to mask the typical Fe^{3+} UV/blue IVCT (intervalence charge transfer) absorption edge (near 300-400 nm) of silicates. LAMP data show that the Moon in general is FUV blue, consistent with early results from IUE [5]. In the LAMP data, mare regions rise steadily in reflectance from 190 nm down to 130 nm while the highlands regions are spectrally flat between ~160 and 190 nm and rise with a blue slope shortward of 160 nm. Maria are bluer than highlands regions due to greater abundances of opaques such as ilmenite and some pyroxenes.

LAMP data also demonstrate significant spectral differences between mature and immature terrains, particulary in highlands regions. Mature, weathered highlands regions are spectrally blue in the FUV; immature highlands are less blue, especially at wavelengths > ~160 nm.

We have also used LAMP data to study the magnetically-anomalous lunar swirl regions Reiner Gamma and Gerasimovich [6]. The FUV characteristics of both swirls are consistent with lower levels of maturity than the immature lunar terrains that were studied, in accordance with the lower amounts of weathering expected in a solar wind standoff scenario (e.g., [8]). Swirls in both highlands and mare regions are spectrally relatively red (or less blue) than surrounding terrains, consistent with less weathering

References: [1] Henry et al. 1976, *Moon*, 15, 51. [2] Hendrix and Vilas 2006, *Astron. J.*, 132, 1396-1404 [3] Hapke, Wagner, Cohen 1978, *LPSC IX,* 456-458. [4] Wagner, Hapke, Wells 1987, *Icarus,* 69, 14–28. [5] Wells and Hapke 1980, *B.A.A.S.* 12, 660. [6] Hendrix et al. 2015, Far-UV characteristics of lunar swirls, *Icarus, accepted*. [7] Vilas and Hendrix 2015, *Astron. J.* 150, 64-78. [8] Blewett et al. 2011, *J. Geophys. Res.,* 116, E02002, doi:10.1029/2010JE003656.