**IMPLICATIONS FOR INTERPRETING LRO LAMP OBSERVATIONS FROM AN EXAMINATION OF APOLLO 16 HIGHLANDS SOILS IN THE FUV THROUGH MIR.** J.T.S. Cahill[1], K.R.S. Cahill[1], C.A. Hibbitts[1], K. Livi[2], C.D. Waller[1], and K.D. Retherford[3], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD (Joshua.Cahill@jhuapl.edu), [2]Johns Hopkins University-Baltimore, [3]Southwest Research Institute, San Antonio, TX.

**Introduction:** Limited modern day laboratory far-ultraviolet (FUV) reflectance data of minerals, ices, and a near absence of Apollo soil measurements beyond those collected a few decades ago [1, 2], has hindered a more complete understanding of the lunar surface observations returned by the Lunar Reconnaissance Orbiter's Lyman-Alpha Mapping Project (LRO-LAMP) relative to other instruments. Measurements in the FUV are relatively demanding as compared to measurements in the near-ultraviolet (NUV) through thermal infrared (TIR), due to vacuum requirements and far lower signal available for collection. These requirements have likely disenchanted past researchers to investigate the region since lower hanging fruit was available in the longer wavelength regions. However, since LAMP and the LRO Camera Wide Angle Camera (WAC) have been returning observations, the researchers of the lunar FUV have begun collecting topics that necessitate further investigation in a laboratory to gather additional context.

Recent work at APL's Laboratory for Spectroscopy under Planetary Environmental Conditions (LabSPEC) and SwRI's Southwest-ultraviolet reflectance chamber (SwURC) facilities have been at the forefront to remedy this. Recent examinations of minerals, glasses, analogs, lunar soil simulants, and Apollo soils are under way or have recently been published [3-5]. In this study, we examine the lunar highland Apollo soils 61220, 61141, and 62231. These lunar soils were selected to examine maturity in not only the FUV, but the FUV as compared to the MUV through the mid-infrared (MIR). They have similar low-iron and low-titanium chemistries, and a range of maturities with $I_s$/FeO intensities of 9.2, 56, 91 for 61220, 61141, and 62231, respectively [6].

**Methods:** Spectra were collected in the APL LabSPEC facility. Spectra of the standard and sample are collected under high vacuum conditions ($10^{-6}$-$10^{-7}$ Torr). FUV-NUV data were collected using a McPherson monochromator (130-570 nm) using $MgF_2$ as the standard and a scintillating material in front of a photomultiplier tube attached to chamber. VIS-NIR data are collected using a Spectra Vista Corporation (SVC) HR-1024i point spectrometer (350-2500 nm) using $MgF_2$ as the standard. MIR data are collected with a Bruker Vertex 70 lab FTIR (1.8-8 μm) using diffuse Au as the standard. Both use a halogen light source with beam splitters (Quartz, KBr) and both spectrometers are mounted outside the chamber at dedicated ports that are 60° from the light source (i=15°, e=45°). The SVC and FTIR detectors are mounted on a linear stage that allows us to toggle between the two spectrometers. A full UV to MIR (~0.13 to ~8 μm) spectrum is generated by combining 3 spectral ranges, scaled to the SVC VIS.

**Results:** Starting in the familiar NIR to MIR (Fig. 1a), samples 61220, 61141, and 62231 show what is typically expected of their maturities. Samples 61141 and 62231 show the darkened albedo and reddened spectral slopes we have come to recognize of maturing soil samples. The 3 μm water absorption feature may show some slight attenuation as well, pending confirmation. In the VIS (Fig. 1b), these characteristics continue, but also apparent is the differences in albedo between sample spectra decrease, particularly for the submature and mature samples (61141 & 62231). This gradual decrease in albedo difference continues in the NUV until there no longer appears to be a statistical difference between 61141 and 62231 in the MUV (~225 nm; Fig. 1c). In the FUV (Fig. 1d), any remaining differences between immature, submature, and mature Apollo soils samples is gone by ~160 nm. Measurements <150 nm can be collected (Fig. 1d), but signal is insufficient here.

**Discussion**: The potential implications of these measurements for the interpretation of the lunar surface are consequential for our understanding of the lunar surface. The darkening and lessening of differences in albedo and slope between lunar soils of differing maturity levels moving from the MIR to the UV, particularly the dramatic changes in the transition from the VIS to NUV, is not new. However, these measurements do appear to confirm that the UV, and the MUV to FUV in particular, are more sensitive to the effects of space weathering on airless body soils [7]. In fact, conditions and samples measured here present an instance where there is an inability to differentiate submature from mature soils. However, these measurements do potentially explain differences we are observing between LRO's LAMP and LROC WAC. For example, on the global Moon only younger craters, like Copernican and younger (Tycho, Jackson, etc.), are observable. In a more specific locality, Reiner Gamma shows differences in what is detectable as a swirl, or albedo difference, between LAMP FUV and the WAC NUV. In particular, where magnetic intensity lessens in the southern and northern 'limbs' of Reiner Gamma (Fig. 2), it is more difficult to definitively detect these regions of the swirl with LAMP [8]. *Waller et al.* [8] suggest this may be due to lessened solar wind stand-off as a result of solar wind variability, where submature and mature sample trends are indistinguishable in the FUV (Fig. 1). However, these surface regions still possess "swirl-like" patterns detectable by

WAC NUV because of ongoing solar wind standoff reducing weathering, where submature and mature sample trends become more discernable in the NUV-MIR (Fig. 1). However, this stands in contrast to reports by [9, 10] of photometric anomalies and swirls being detected by LAMP but not necessarily by the LROC WAC. In fact, the laboratory measurements collected here initially suggest the opposite appears to be taking place. In this context, it is important to note those observations were made during a different nighttime context, under hemispheric (interplanetary medium + starlight) rather than point illumination conditions, and deeper in the FUV at Lyman-α (121.6 nm). The Apollo laboratory spectra collected here demonstrate that at those low wavelengths, below ~150 nm, a different scattering regime is dominating. Further evidence additional laboratory measurements are necessary in the FUV region.

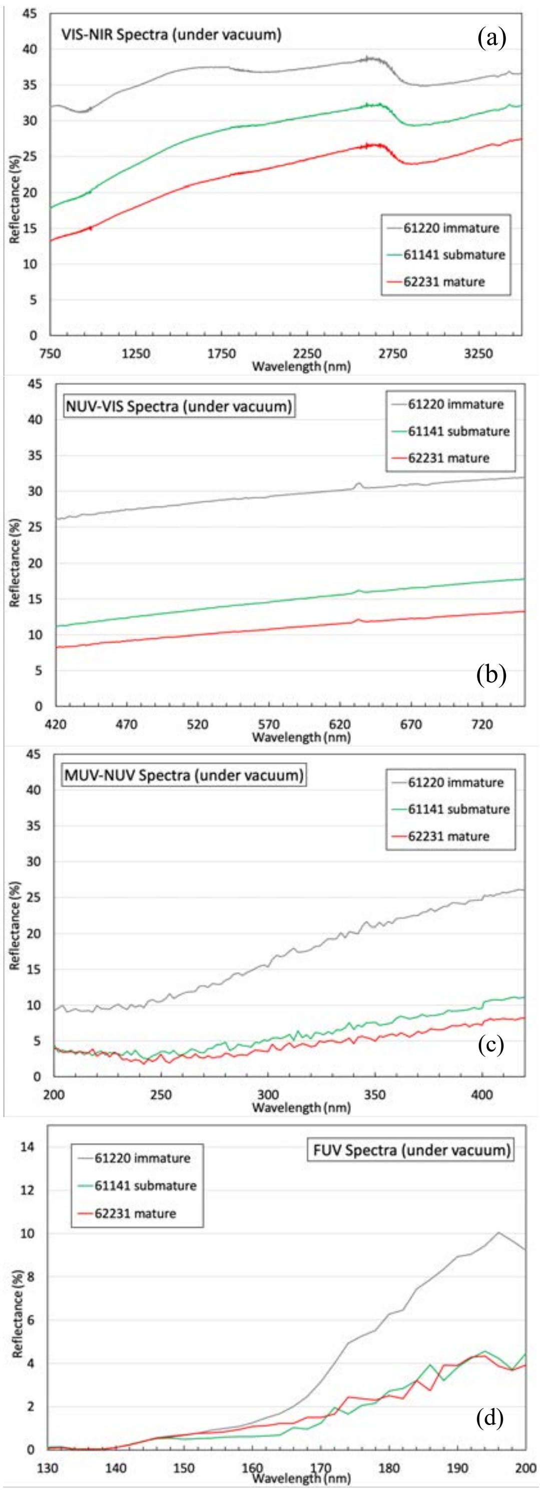


*Figure 1: Immature (black), sub-mature (green), and mature (red) Apollo 16 lunar highlands soils.*

**Conclusions:** Initial measurements of Apollo 16 lunar soils show similar weathering trends in the FUV as longer wavelength regions. However, measurements also confirm a greater sensitivity in the UV to the effects of space weathering on lunar soils. This manifests by the alteration of FUV spectra by space weathering in an accelerated fashion relative to other wavelength regions. Solidly submature lunar soils appear mature in the FUV. This helps explain and confirms recent observations and interpretations of global lunar FUV observations as well as FUV interpretations of the Reiner Gamma swirl [8].

**References:** [1] Lucke (1976) *AJ*, 81, 1162 [2] Wagner (1987) Icarus, 69, 14. [3] Hibbitts & Stockstill (2018) AAS/DPS, 50, 504-2, [4] Raut (2018), JGR, 2018JE005567. [5] Gimar (2022) JGR, 127, (11). [6] Morris (1978) *LPSC*, 2287. [7] Hendrix & Vilas (2006) *AJ*, 132, 1396, [8] Waller (2022) *FASS.*, 9, fspas.2022.926018. [9] Cahill (2019) JGR, 2018JE005754, [10] Cahill (2017) LPSC, 48, 2947.

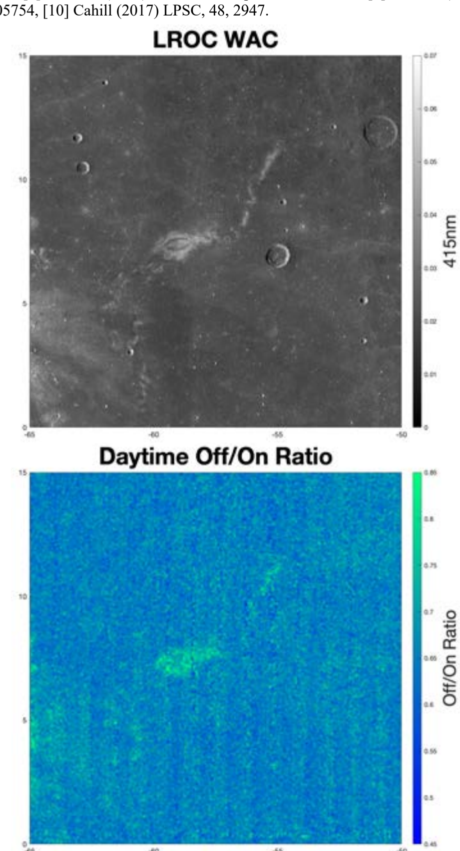


*Figure 2: Observations of Reiner Gamma lunar swirl in LROC WAC NUV and LAMP FUV off/on band ratio.*