A New Era in Far-Ultraviolet Surface Reflectance Spectroscopy Enabled by LRO Lyman Alpha Mapping Project (LAMP) Results. K. D. Retherford[1,2], B. D. Byron[2,1], L. O. Magaña[2,1], E. A. Czajka[2,1], U. Raut[1,2], A. R. Hendrix[3], K. E. Mandt[4], J. T. S. Cahill[4], D. M. Hurley[4], A. F. Egan[5], P. O. Hayne[6], T. K. Greathouse[1], G. R. Gladstone[1,2] and the LRO-LAMP Team; [1]Southwest Research Institute, San Antonio, TX (kretherford@swri.edu), [2] University of Texas at San Antonio, San Antonio, TX, [3]Planetary Sciences Institute, Tucson, AZ, [4]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [5]Southwest Research Institute, Boulder, CO, [6]University of Colorado, Boulder.

Far ultraviolet (far-UV) reflectance measurements of the Moon, icy satellites, comets, and asteroids have proven surprisingly useful for advancing our understanding of planetary surfaces, expanding upon the primary historical use of UV instruments to investigate planetary atmospheres and auroral processes. This new appreciation for planetary far-UV imaging spectroscopy is provided in large part thanks to a decade of investigations with the Lunar Reconnaissance Orbiter (LRO) Lyman Alpha Mapping Project (LAMP). LRO-LAMP far-UV spectral-imaging maps of the lunar dayside, nightside, and permanently shaded regions (PSRs) are also useful in the context of understanding numerous other advances, e.g., in our understanding of surface properties of Europa and other icy satellite revealed by robust Hubble Space Telescope (HST) far-UV observing campaigns, Cassini UVIS surveys at Saturn, Rosetta-Alice comet observations, and HST asteroid observations. Future investigations of the icy Galilean satellites with the ultraviolet spectrographs (UVSs) being developed for both Europa Clipper and the Jupiter Icy Moons Explorer (JUICE) missions will capitalize on these advances.

LAMP's innovative nightside observing technique [1,2] has revealed the Moon in a new light, using starlight and Lyman-α skyglow as illumination sources. Dayside far-UV maps are also obtained using the more traditional photometry technique with the Sun as the illumination source, and are very complementary. Together, these LRO-LAMP measurements provide a unique perspective on the lunar "hydrological cycle," connecting the surface abundance of water frost trapped in the Moon's cryosphere to volatile transport processes involving the lunar exosphere.

LAMP studies how water is formed on the Moon, transported through the lunar exosphere, and deposited in PSRs [2,3]. LAMP nightside and dayside brightness maps cover wavelength range 57-196 nm. Lyman-α, on-band and off-band albedo maps (i.e., on and off the water frost absorption band at ~165 nm) are useful for constraining the abundance of surficial water frost [1,4,5]. Detailed far-UV spectral analyses [6] supplemented by laboratory efforts [7] investigate regolith structure/porosity and the relative aging of surface features by space weathering and [8,9,10,11,12], support the previous identification of diurnal variations in hydration features [13,14], and identify compositional signatures in regolith (i.e., feldspar rich highlands) [12].

Global nightside and dayside maps are divided (at ±60° latitude) into polar and equatorial regions with stereographic and equirectangular projections, respectively. Additionally, spectral image cube maps have been created for several regions of interest with 2 nm resolution, and are being expanded to cover the full globe.

Global searches of water signatures outside of lunar PSRs are allowing us to confirm and elucidate the findings of surface water/hydroxyl and its variability [13,14]. The present LRO extended science mission enables more surface reflectance data (60-190 nm) at a variety of incidence and emission angles to improve signal, spectral, and photometric quality and further develop our innovative UV reflectance techniques [15]. Ongoing laboratory studies are constraining the compositional and photometric properties of lunar samples and simulant analogs [16].

Future missions with science goals to search for hydration and/or water frost, to constrain surface ages with relative space weathering comparisons, and to understand the microphysical fairy-castle type structure/porosity of regolith with additional composition constraints should include far-UV surface reflectance investigations to complement visible imaging and near-IR spectroscopy measurements.

References. [1] Gladstone, G. R. et al., Far-Ultraviolet Reflectance Properties of the Moon's Permanently Shadowed Regions, *J. Geophys. Res., 117*, E00H04, 2012. [2] Gladstone, G. R., et al., LAMP: The Lyman Alpha Mapping Project on NASA's Lunar Reconnaissance Orbiter Mission, *Space Sci. Rev., 150*, 161-181, 2010. [3] Gladstone, G. R. et al., LRO-LAMP Observations of the LCROSS Impact Plume, *Science, 330,* 472-476, 2010. [4] Retherford, K. D., et al., LRO/LAMP Far-UV Albedo Maps, *in preparation*, 2020. [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 (volume 255, pages 58-69, doi:10.1016/j.icarus.2015.03.032). [6] Liu et al. (2018) *JGR: Planets, 123,* 2550-2563. [7] Raut, U., et al., Far-Ultraviolet Photometric Response of Apollo Soil 10084. *J. Geophys. Res.: Planets*,123, 2018. [8] Mandt, K. E. et al., (2016) *Icarus,* 273, 114-120.

[9] Byron et al. (2019) *JGR: Planets, 124,* 823-836. [10] Byron et al. (2020) *JGR: Planets, submitted.* [11] Cahill, J. T. S. et al. (2019) *J. Geophys. Res., 124,* https://doi.org/10.1029/2018JE005754. [12] Hendrix, A.R., et al., Lunar swirls: Far-UV characteristics. Icarus, 273, 68-74, 2016. [13] Hendrix, A. R., et al., Lunar Albedo in the Far-UV: Indicator of Hydrated Materials and Space Weathering, *J. Geophys. Res.*, 117, E12001, 2012. [14] Hendrix et al. (2019), *Geophys. Res. Lett.*, 46, 2417-2424, doi: 10.1029/2018GL081821. [15] Davis, M. W., et al., LRO-LAMP failsafe door-open performance: improving FUV measurements of dayside lunar hydration, SPIE, 2017. [16] Gimar et al., LPSC, 2020, *this meeting*.