DISCRETE LUNAR NEARSIDE ANOMALIES IN NIGHTTIME LYMAN-α ALBEDO MAPS. A.A. Wirth[1,2], J.T.S. Cahill[1], A.R. Hendrix[3], K.E. Mandt[4], Y. Liu[4], K.D. Retherford[4], B.T. Greenhagen[1], B.W. Denevi[1], A.M. Stickle[1], D.M. Hurley[1], T.K. Greathouse[4], F. Vilas[3], and D. Blewett[1]. [1]JHU/APL (Anna.Wirth@jhuapl.edu), [2]Case Western Reserve University, [3]Planetary Science Institute, and [4]Southwestern Research Institute-San Antonio.

Introduction: While the most widely discussed enigmatic photometric regions on the Moon are swirls, recent data sets are cataloguing other unusual photometric anomalies with similarities to lunar swirls, but fundamental differences as well [1, 2]. Lunar swirls have a high visible and near-ultraviolet (NUV) albedo, low far-ultraviolet (FUV) albedo, wispy or sinuous surface morphology, are often associated with magnetic anomalies, and possess curious photometric characteristics [3-6]. However, using ground-based observatories in Uzbekistan (Maidanak) and Crimea, Ukraine (Simeiz), *Shkuratov et al.*, [1] discerned three anomalous regions in the southeast region of Oceanus Procellarum they denoted as 'probable swirls' that are removed from magnetic anomalies mapped by the Lunar Prospector fluxgate magnetometer (**Fig. 1**; ellipses 1-3). *Shkuratov et al.* [1] discriminated these deposits by examining photometric properties of the lunar nearside in several visible spectral bands. Using photometric phase ratios (e.g., $f(23°)/f(44°)$ at $\lambda = 0.53$ μm; $f(44°)/f(96°)$ at $\lambda = 0.53$ μm; $f(39°)/f(86°)$ at $\lambda = 0.65$ μm), *Shkuratov et al.* [1] noted that these three anomalies do not obey the expected inverse correlation between albedo and phase-curve slope. Instead, these three regions demonstrated high phase-curve slopes at intermediate albedo.

Recently, a study using Lunar Reconnaissance Orbiter Camera (LROC) Wide-Angle Camera (WAC) data discovered an additional photometric anomaly further southeast in Mare Nubium [7] (**Fig. 1**; ellipse 5). *Korokhin et al.* [7] characterized this anomaly with low FeO and TiO_2 abundances and little distinguishing thermal properties relative to its surroundings as observed in Diviner rock abundance data [8]. However, *Korokhin et al.* [7] did find that this area has a higher sloped phase function than its surroundings, anomalous behavior they suggest results from a difference of surface structure in the anomaly and surrounding regions on the scale of less than several centimeters. *Korokhin et al.* [7] interpreted the area as a shallow flooding of an elevated formation of highland composition, the material of which could have been excavated and mixed within the upper layers of the lunar surface through meteoroid impact scouring.

LAMP FUV Perspective: The LRO Lyman Alpha Mapping Project (LAMP) routinely collects both day and nighttime data of polar and equatorial regions of the Moon providing insights into the upper ~200 nm of the regolith via the FUV [9-11]. It is ideally suited to study these shallow regolith anomalies. Initial efforts to examine daytime non-polar LAMP data revealed latitudinal variations in hydration and locations of the lunar swirls [5, 12, 13]. We build upon these works by mapping the nighttime Lyman-α (Ly-α; 121.6 nm) albedo values and examining FUV spectra of these spatially discrete photometric anomalies.

LAMP is a FUV push-broom photon-counting imaging spectrograph collecting data in the 57-196 nm spectral range [9]. The data set examined here is unique in that it observes the lunar nightside via illumination by solar Ly-α scattered off of interplanetary H atoms from all directions. The Ly-α sky glow intensity varies with respect to the motion of the solar system and point sources from UV-bright stars, which are more plentiful in the southern hemisphere owing to the Galactic plane [9, 14]. Thus, the signal-to-noise of the

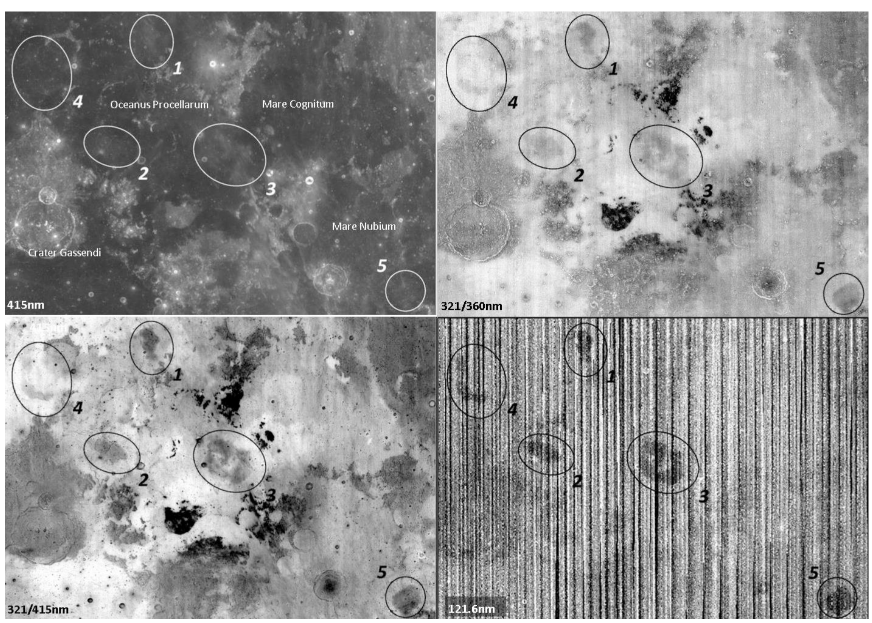

Fig. 1: *Lunar nearside anomalies as observed in (Top left) WAC 415, (Top Right) WAC 321/360 nm, (Lower Left) 321/415 nm, and (Lower Right) nighttime Ly-α observations (30 ppd). (Black ellipses) Enigmatic visible and ultraviolet regions.*

LAMP nighttime data varies with latitude, increasing from north to south.

Observations and Discussion: Several (5) discrete low albedo features are observed and examined in the LAMP Ly-α band within southeastern Oceanus Procellarum and northwestern Mare Nubium (**Fig. 1-2**). These are unique within their region being the only features to crisply stand out in Ly-α. Interestingly, they are characterized with lower Ly-α albedo relative to not only the surrounding maria but also the nearby lunar highlands regions. They also appear more spatially coherent and with a distinctly lower albedo relative to many lunar swirls observed in Ly-α [5]. However, it should be kept in mind that variations in absolute albedo depend on the current calibration and understanding of the variability of the illumination.

Some of these anomalies are not easily observed in LROC WAC 415 nm reflectance, but are able to be discerned in LROC WAC ratio and color composite data [4, 15]. Still, others, like the region in ellipse 4, are not as easily observed in WAC data products (**Fig. 2**). Most do not appear to correlate with a rise or fall in topography, are not observed in Mini-RF S-band data, but do slightly deviate from surrounding CF values and have slightly higher 415 nm reflectance in WAC color composites. They also do not exhibit the wispy or sinuous geomorphology of swirls and are not associated with LP observed magnetic anomalies; this may contribute to the lack of swirl sinuous geomorphology.

Conclusions: LAMP non-polar nighttime data are providing unique views of the Moon. The shallow penetration depth of FUV light ties these features to young features on the lunar surface. Identified within the non-polar nighttime Ly-α (121.6 nm) observations are several (5) low normal albedo regions within the southeastern Oceanus Procellarum and northwestern Mare Nubium regions of the Moon. Three of them are consistent with anomalies from previous photometric ratio studies [1], one is consistent with a very recent LROC analyses [7], and one is newly observed and reported here. They are observed in Ly-α as spatially discrete regions, visually less diffuse and with lower albedos than surrounding highlands terranes, lunar swirls, and pyroclastic deposits. In contrast to swirls, none of them are associated with magnetic anomalies. The low normal Ly-α albedo of these anomalies suggest that at least the uppermost layer of the surface is young and immature and potentially more porous than their lunar maria surroundings. Although *Korokhin et al.*, [7] observed no difference in the thermal inertia properties of these anomalies relative to their surroundings, we note modest differences in the CF feature and concavity values for some of the anomalies. This is due to a difference in either composition or maturity. CF maps at a high enough resolution and corrected for maturity [16] will be useful and consulted in the future.

The formation of the photometric anomalies is still up for debate [1, 7, 8]. However, potential mechanisms include shallow scouring by a meteoritic swarm or a highlands feldspathic or silicic butte or mesa being buried by a thin layer of mare basaltic material, then undergoing subsequent mechanical and mineralogical mixing. Either of these may have provided conditions that would lead to an increase in porosity, higher NUV and lower FUV reflectance, and lower FeO and TiO_2 chemistries in these photometric anomalies without adding additional topography or decimeter scale roughness features.

References: [1] Shkuratov Y. et al. (2010) Icarus, 208, 20-30. [2] Kaydash V. et al. (2009) Icarus, 202, 393-413. [3] Blewett D.T. et al. (2011) JGR, 116, 1-30. [4] Denevi B.W. et al. (2016) Icarus, 10.1016/j.icarus.2016.01.017. [5] Cahill J.T.S. et al. (2016) Lunar and Planetary Science Conference, 47. [6] Kinczyk M.J. et al. (2016) LPSC, 47, 2343. [7] Korokhin V. et al. (2016) PSS, 122, 70-87. [8] Bandfield J.L. et al. (2011) JGR, 116, 10.1029/2011JE003866. [9] Gladstone R.G. et al. (2012) JGR, 117, 10.1029/2011JE003913. [10] Hayne P.O. et al. (2015) Icarus, 255, 68-69. [11] Mandt K.E. et al. (2015) Icarus, 10.1016/j.icarus.2015.07.031. [12] Hendrix A.R. and LAMP Team (2012) JGR, 117. [13] Hendrix A.R. et al. (2016) Icarus, 273, 68-74. [14] Pryor W.R. et al. (1992) AJ, 394, 363-377. [15] Denevi B.W. et al. (2014) JGR, 119, 976–997. [16] Lucey P.G. et al. (2016) Icarus, 10.1016/j.icarus.2016.05.010.

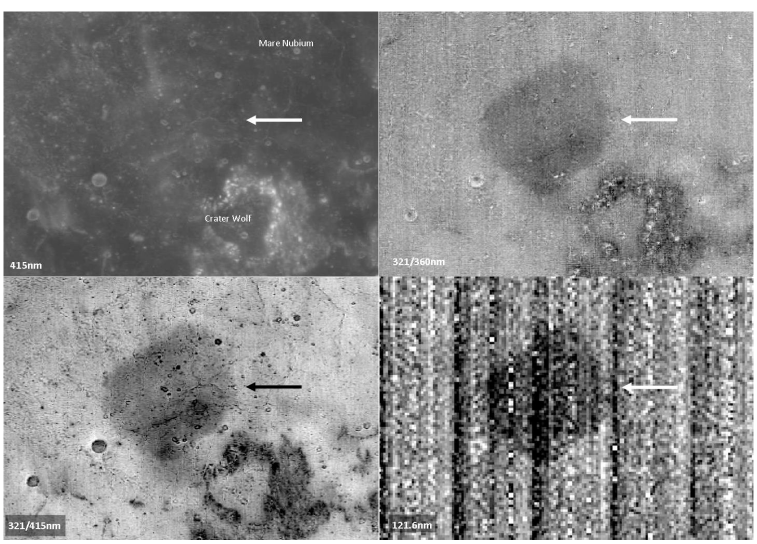

Fig. 2*: Anomaly #5 northwest of Wolf Crater. (Top Left) WAC 415 nm, (Top Right) WAC 321/360 nm, (Bottom Left) WAC 321/415 nm, and (Bottom Right) Ly-α albedo maps.*