SEARCHING FOR VARIATIONS IN H_2 ABUNDANCE WITH LOCAL TIME, MAGNETOTAIL CROSSINGS AND METEOR SHOWERS. J. C. Cook[1], D. M. Hurley[2], K. D. Retherford[3], P. D. Feldman[2], G. R. Gladstone[3], C. Grava[3], T. K. Greathouse[3], S. A. Stern[1], [1]Southwest Research Institute, 1050 Walnut St, Suite 300, Boulder, CO 80302, [2]John Hopkins University, Applied Physics Laboratory, [3]Southwest Research Institute, San Antonio, TX (jccook@boulder.swri.edu)

Introduction: The mass spectrometer, LACE (Lunar Atmospheric Composition Experiment), was the first instrument to detect the Moon's surface bound atmosphere. Since its initial discovery, additional observations have also shown that the lunar atmosphere varies as a function of local time [1, 2], during passages through the Earth's magnetotail [3] and during meteor showers [4, 5].

In September 2009, Lunar Reconnaissance Orbiter (LRO) entered a polar orbit around the Moon. On board LRO is the sensitive UV-spectrograph, LAMP (Lyman Alpha Mapping Project) that covers the spectral range 575 to 1965 Å. LAMP is typically oriented toward the surface in order to map the Moon at these UV wavelengths. However, LAMP can also observe the tenuous lunar atmosphere when the surface is in darkness, and the column of atmosphere below LRO is in sunlight. These "twilight" observations occur twice per orbit, about 11-12 times per Earth day. In a typical orbit, the duration in twilight is about 600 seconds and the observations are concentrated around the north and south poles of the Moon (latitudes $> 80°$). These periods extend to about 3600 seconds, and examine all latitudes, when the angle between the orbit plane and the vector to the Sun, β, is near 90°. We have used such twilight observations in the past to examine the sparse lunar atmosphere [6, 3, 7, 8].

Observations: In 2013, [9] reported the detection of H_2 in the lunar atmosphere. At the time, the detection required the use of most of the data in hand. Three years after that initial discovery, we can now divide the data up and search for H_2 variations (i) in local time, (ii) during magnetotail crossings and (iii) during meteor showers. We will also search for variations in He abundance and the appearance of other species during meteor showers, such as Hg and Ca.

H_2 vs. Local Time: [8] shows how He varies as a function of local time during the lunar night and examination of H_2 at dawn and dusk suggests a dawn/dusk asymmetry of 1.7 [10]. We now use the data on hand to closely examine how H_2 varies as a function of local time in 1-hour time bins. Because the H_2 spectrum is much weaker than He at these wavelengths, we select spectra when the path length is the longest, *i.e.*, when the spacecraft altitude >150 km and a shadow height <50 km. This selects spectra with path lengths of 100 to 150 km. These binned data have total integration times between 0.75 days for locals times near midnight, and close to 4 to 5 days at dawn and dusk.

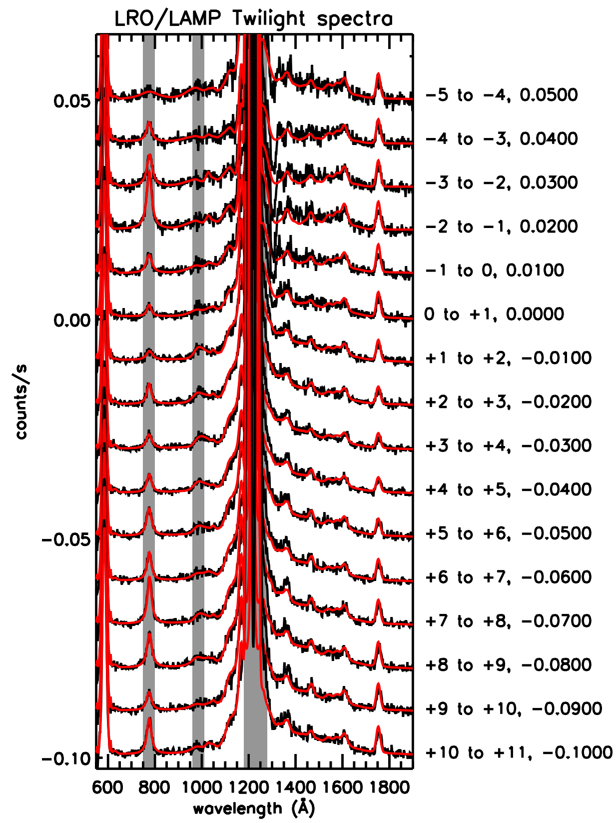

Figure 1: A series of spectra (black) from when the Moon crossed the Earth's magnetotail and best fit models (red). From top to bottom, the spectra correspond to the data obtained from 5 to 4 days before entering the magnetotail to 10 to 11 days after. The spectra are offset by 0.01 counts/s from each other for clarity. The spectrum obtained when just entering the tail is set at the zero level. Near 775 Å there is an instrumental artifact, near 975 Å there is a Ly-α ghost which is mostly removed here and near 1216 Å there is residual reflected Ly-α light. He is located at 584 Å, and its 3rd order reflection is seen near 1752 Å. Peaks seen between 1300 to 1650 Å are attributed to H_2.

Magnetotail Crossing: [3] showed that the He abundance in the lunar atmosphere decreased as the Moon crossed the Earth's magnetotail. Using ARTEMIS (Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun), we identify 53 magnetotail crossings between April 2011 to November 2015 each with a duration of approximately 5 days. We average the LAMP data in 24 hour periods from 5 days before entering the magnetotail to 11 days after. As with the local time observations of H_2, we use observations when the spacecraft is above 150 km, and the lunar shadow is below 50 km. The total integration time for each bin is approximately 0.5 to 1 day.

Meteor Showers: We examine LAMP data during meteor showers to determine how the lunar atmosphere changes, if at all. We average data in 24-hour bins centered around the peak day of activity for the Perseid, Leonid and Geminid meteor showers. We restrict the data to when the spacecraft was $>$100 km from the lunar surface and the shadow height was $<$50 km. We use observations from all local times. The total integration time for each bin is approximately 0.5 day.

Analysis: We measure surface densities by fitting a model spectrum that includes H_2, He, instrument artifacts (*i.e.* the Ly-α ghost), and background level. As an example, we show the spectra and best fit models in Fig. 1 for spectra obtained during the magnetotail crossing. Spectral features and artifacts in the spectra are explained in the figure caption. An error in the code to calculate the H_2 density was noted while preparing this abstract. This error only effects the calculation of H_2 and not He. Therefore our analysis of H_2 should be treated as preliminary. Final results will be presented at the meeting.

Results: Figures 2-4 show our preliminary results. He is shown in each figure to help guide the eye. While it is clear in Fig. 2 that He increases after dusk, peaks after local midnight and then decreases before dawn, the behavior of H_2 is not as clear. In Fig. 3, He shows a clear decrease from day 0 to 4, similar to what [3] observed as the Moon passed through the Earth's magnetotail. H_2, however, does not show the same clear variation. While H_2 does appear high just before the magnetotail crossing, the H_2 abundance never appears to recover to the same value afterward. Examination of Fig. 4 shows that there may be a $\sim$15% increase in He during a shower, but we lack sufficient signal to determine whether or not there is any variation in H_2. We searched the spectrum for additional emission lines, like those seen after the LCROSS impact (*i.e.* Ca, Hg), and do not see any evidence for additional species.

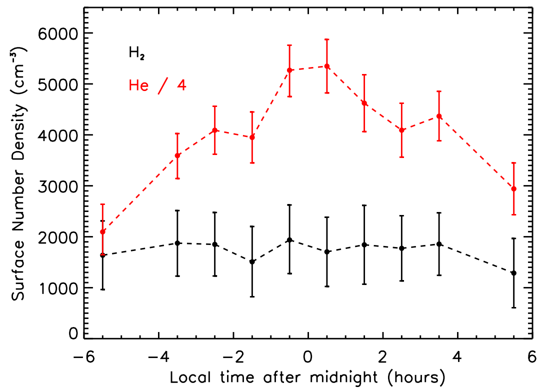

Figure 2: H_2 and He as a function of local time.

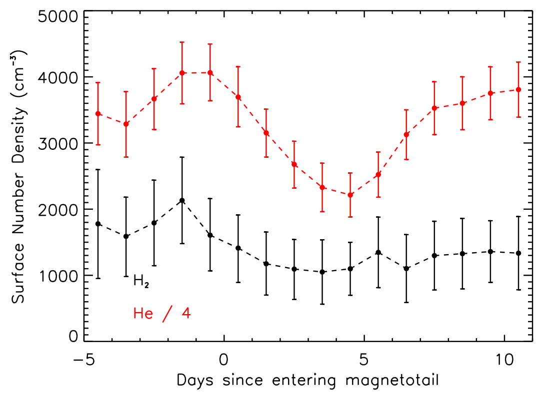

Figure 3: He and H_2 surface number density as a function of time as the Moon passes through the Earth's magnetotail. The data are averaged over 53 months.

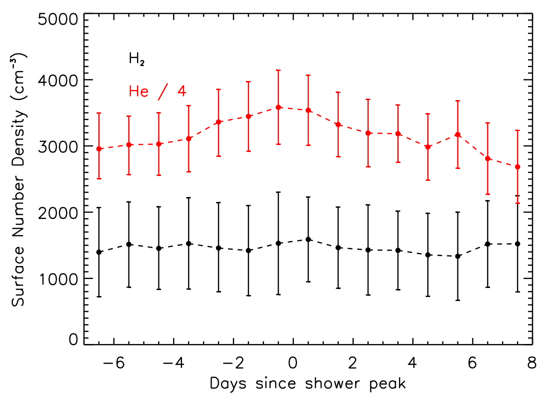

Figure 4: He and H_2 surface number density as a function of time as the Moon passes through meteor showers. The data are centered around the height of activity for the Perseid, Leonid and Geminid meteor showers.

References: [1] Hoffman, J. H., et al. (1973) vol. 4 of *Lunar and Planetary Science Conference Proceedings* 2865. [2] Hoffman, J. H., et al. (1975) *Moon* 14:159. [3] Feldman, P. D., et al. (2012) *Icarus* 854–858. [4] Colaprete, A., et al. (2015) vol. 46 of *Lunar and Planetary Inst. Technical Report* 2364. [5] Stubbs, T. J., et al. (2015) vol. 46 of *Lunar and Planetary Inst. Technical Report* 2984. [6] Stern, S. A., et al. (2012) *Geophys. Res. Lett.* 39:L12202. [7] Cook, J. C., et al. (2013) *Icarus* 225:681. [8] Cook, J. C., et al. (2014) *Icarus* 236:48. [9] Stern, S. A., et al. (2013) *Icarus* 999:4. [10] Hurley, D. M., et al. (2015) *AGU Fall Meeting Abstracts*.