SEARCHING FOR VARIATIONS IN H₂ ABUNDANCE WITH LOCAL TIME, MAGNETOTAIL CROSSINGS AND METEOR SHOWERS. J. C. Cook¹, D. M. Hurley², K. D. Retherford³, P. D. Feldman², G. R. Gladstone⁴, C. Grava³, T. K. Greathouse⁵, S. A. Stern¹, ¹Southwest Research Institute, 1050 Walnut St, Suite 300, Boulder, CO 80302, ²John Hopkins University, Applied Physics Laboratory, ³Southwest 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 H₂ 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 H₂ 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.

H₂ vs. Local Time: [8] shows how He varies as a function of local time during the lunar night and examination of H₂ at dawn and dusk suggests a dawn/dusk asymmetry of 1.7 [10]. We now use the data on hand to closely examine how H₂ varies as a function of local time in 1-hour time bins. Because the H₂ 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.

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 iden-
tify 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-$\alpha$ 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 affects 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.