Searching for Variations in H_2 Abundance with Local Time, Magnetotail Crossings and Meteor Showers.

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Introduction: The mass spectrometer, LACE (Lunar Atmospheric Composition Experiment), was the first instrument to detect the Moon's surface bound exosphere. Since its initial discovery, additional observations have also shown that the lunar atmosphere varies as a function of local time (Hoffman et al, 1973, 1975), during passages through the Earth's magnetotail (Feldman et al, 2012) and during meteor showers (Colaprete et al, 2015, Stubbs et al, 2015).

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 space lunar atmosphere (Feldman et al., 2012, Cook et al., 2013; 2014, Stern et al., 2013).

Observations: In 2013, Stern et al. 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 attempt to divide the data up and search for H_2 variations (*i*) in local time, (*ii*) during magnetotail crossings (*iii*) during meteor showers and (*iv*) with latitude. We also show the variations in He abundance.

Local Time:
- Divide the data into 1-hour local time bins.
- Longest path lengths (LRO altitude > 150 km, lunar shadow < 50 km)
- Integration times vary from 0.6 days around local midnight to several days near dawn and dusk

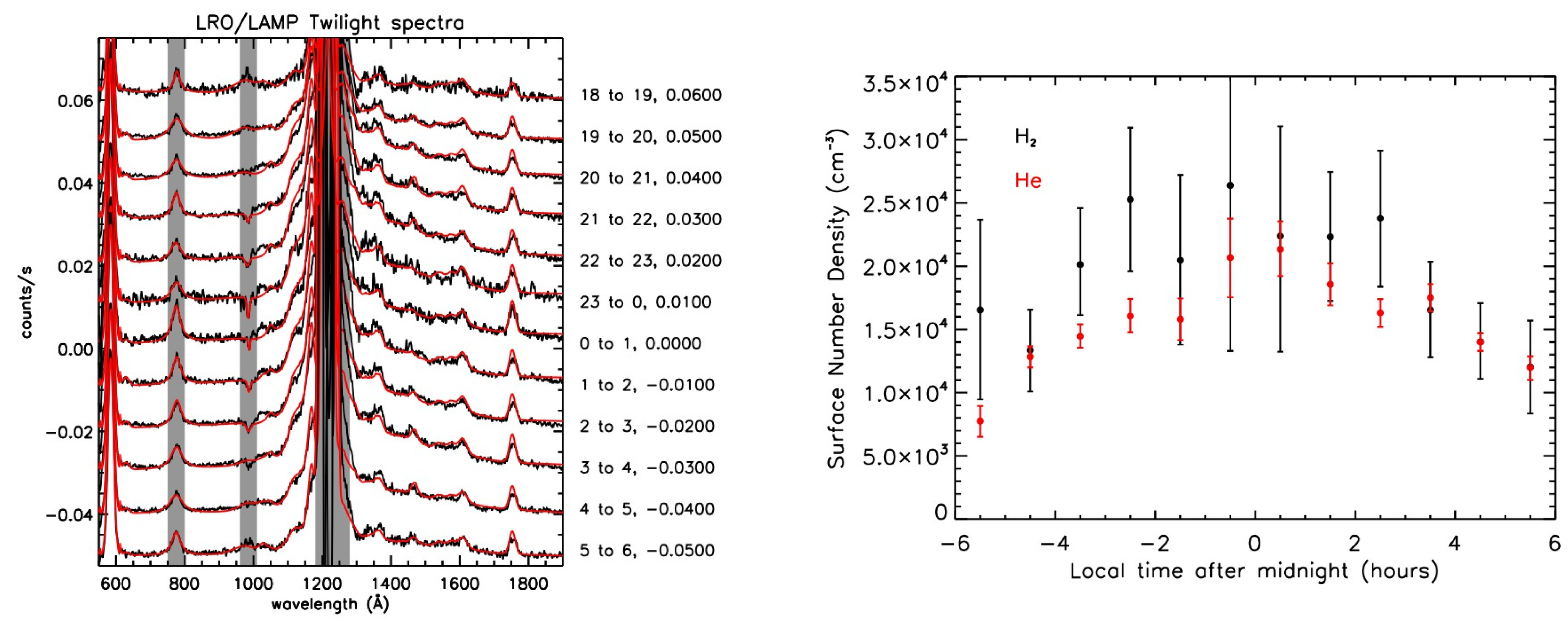
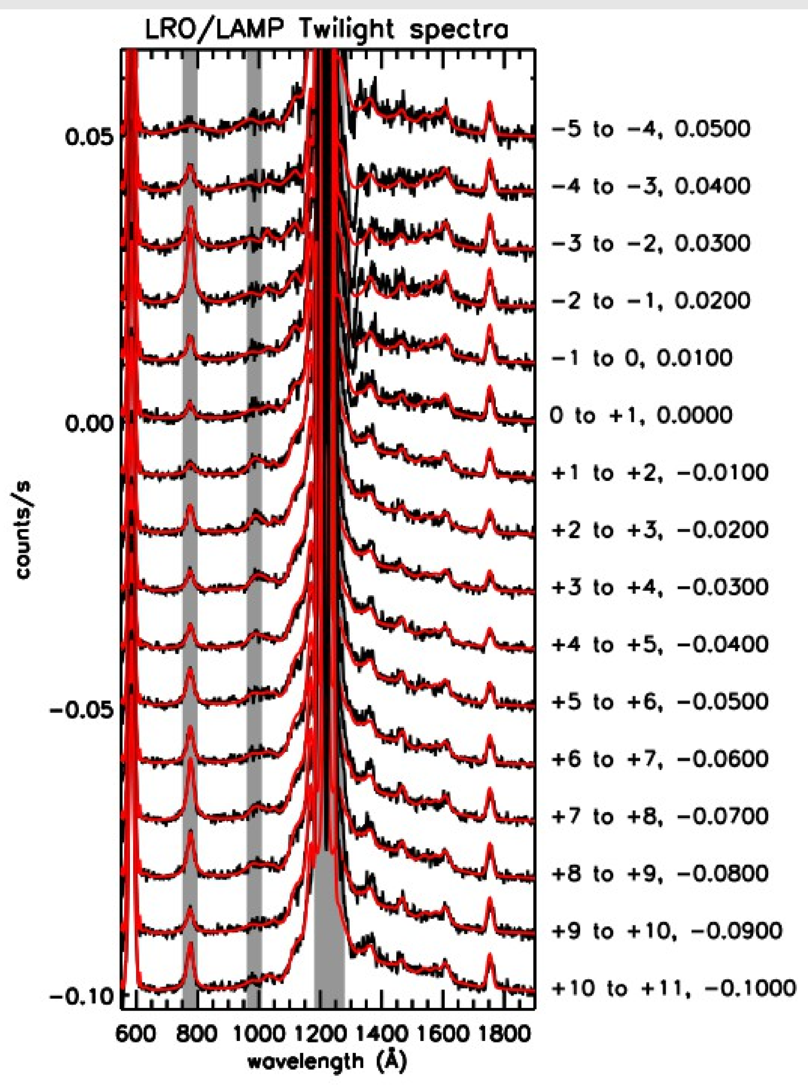


Figure 1: Local time observations. (Left) Spectra (black) with best fit model (red). Regions in gray indicate known instrument artifacts. (Right) The H_2 and He number density from 6 hours before and after local midnight. The error bars represent the 1-σ variance in the data.

Magnetotail Crossing:
- Use ARTEMIS to find the start of 53 magnetotail crossings from April 2011 and November 2015.
- Average data in 24 hour bins
- Apply the same restrictions on spacecraft altitude and shadow height as for the local time analysis
- Total integration times around 0.8-0.9 days. Min./max. integration time is 0.5 and 1.0 days



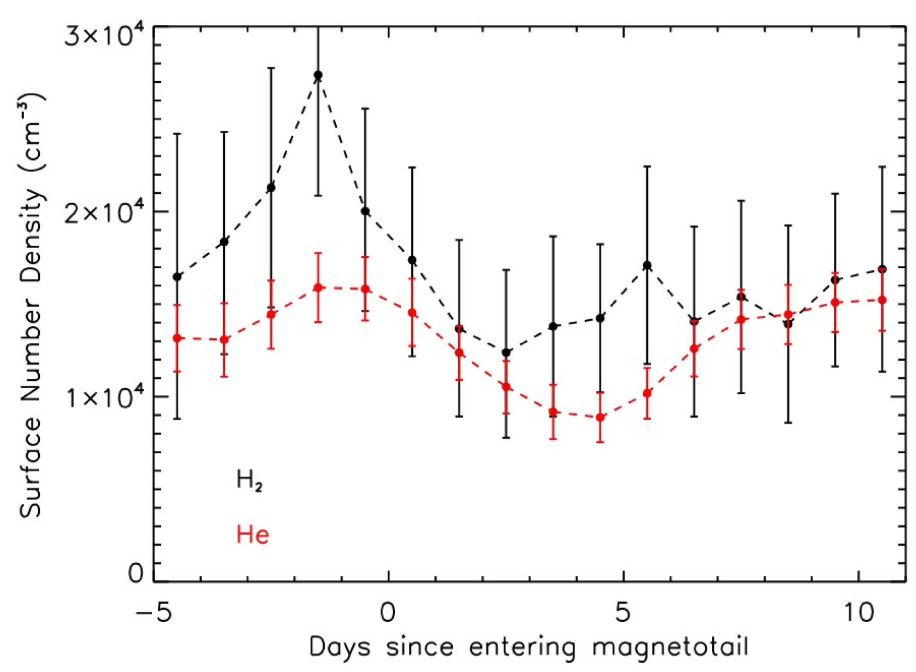


Figure 2: Similar to Figure 1, but for the magnetotail observations. The spectra are shown to the left, and the number densities as a function of time are shown above. We obtain spectra from 5 days before the initial magnetotail encounter to 11 days after.

Meteor Showers:
- Average data in 24-hour bins around the peak of the Perseid, Leonid and Geminid showers.
- Restrict data to spacecraft altitudes > 100 km, and shadow heights of < 50 km.
- Total integration time of about 0.5 days.

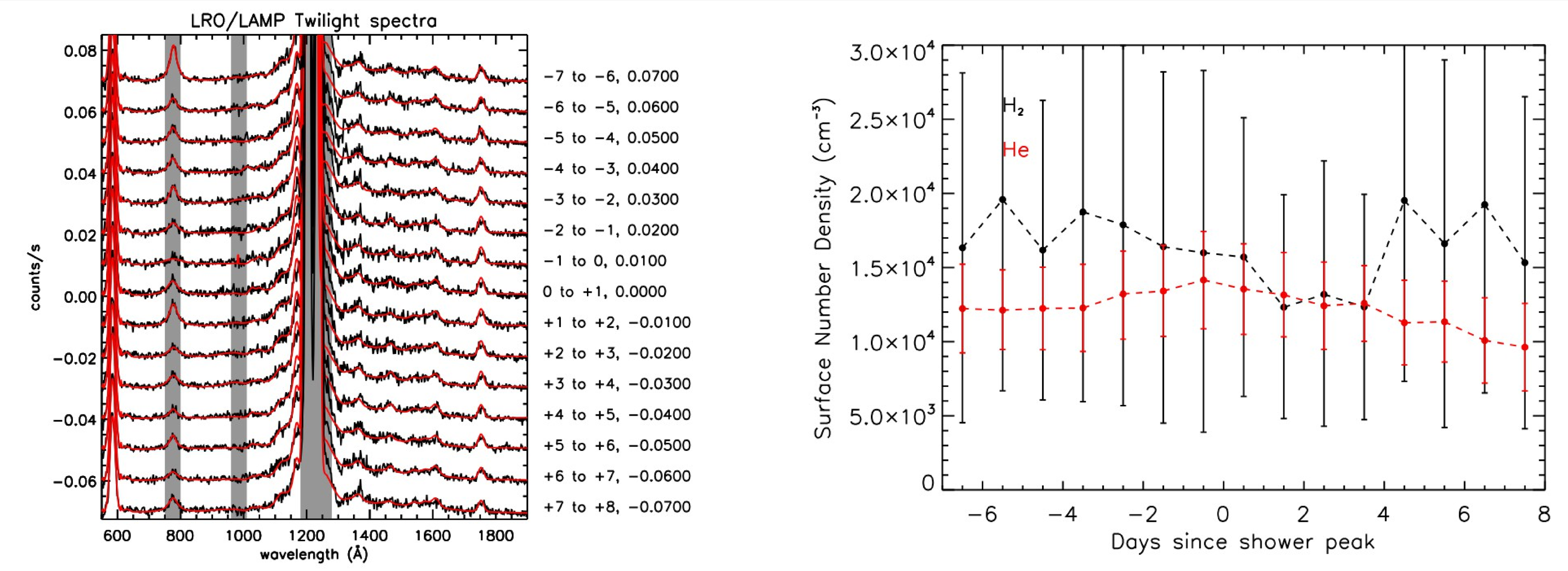


Figure 3: Similar to Figure 1, but for meteor shower observations. The spectra are shown on the left, and the number density as a function of time in on the right. We examine spectra from 6 days before to 7 days after the shower peak.

Latitude at Dusk and Dawn:
- Restrict data two hours after sunset or before sun rise.
- 20° latitude bins, but no restriction on spacecraft altitude or lunar shadow height.
- Total integration time between 3 and 6 days.

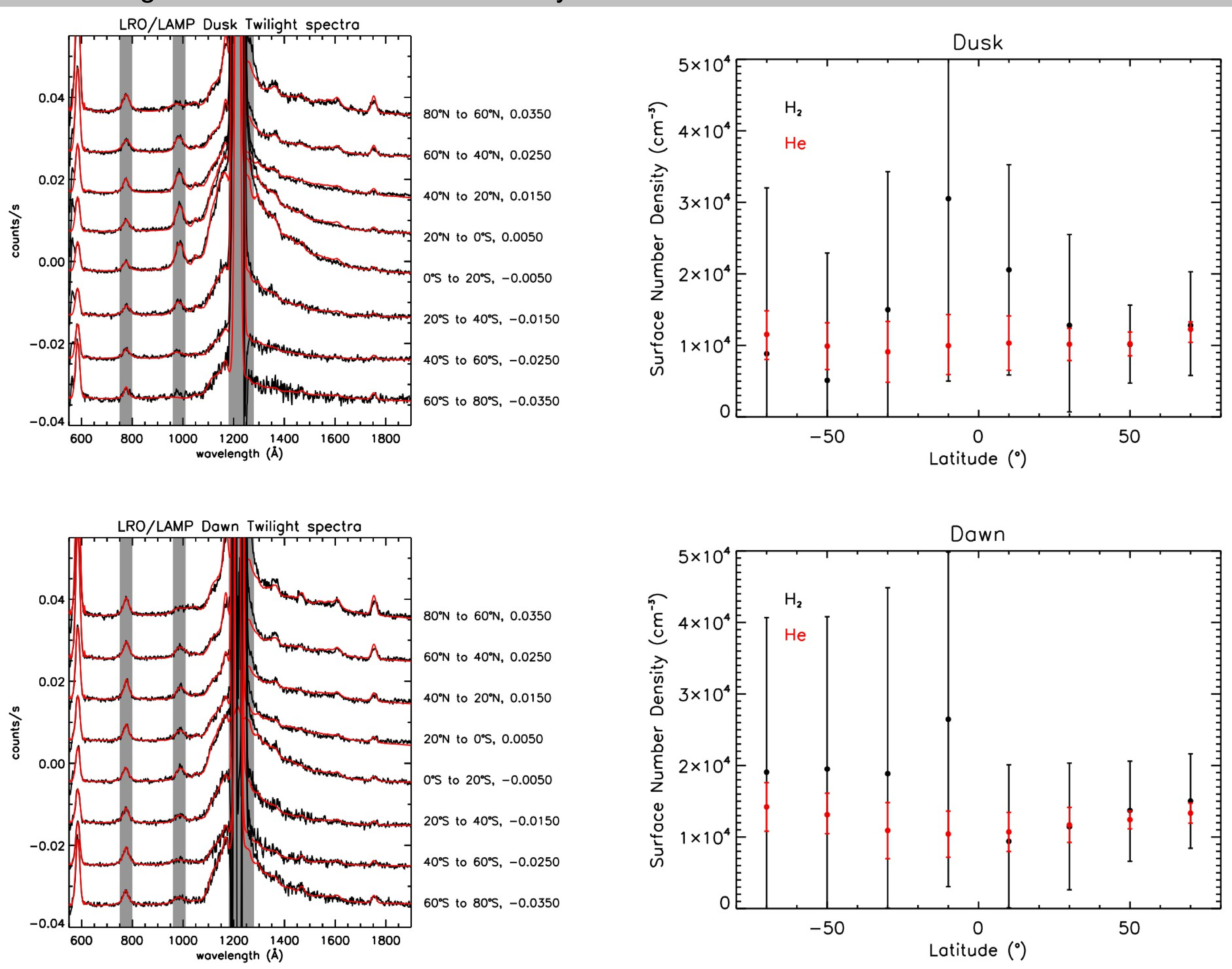


Figure 4: Similar to Figure 1, but for latitude observations. The spectra are shown on the left, and the measurements on the right. The data in the top row are obtained at dusk and the bottom at dawn.

Discussion & Conclusion: Compared to our understanding of He, we are just beginning to learn about H_2 in the lunar atmosphere. We find that that the number density of H_2 at the surface is similar to He. This change (a factor of ~10) is a direct result of a computational error that was present in our earlier work (Stern et al., 2013). Our analysis suggests that H_2 varies with local time, similar to He, peaking sometime after local midnight. Our results are not as clear when considering the magnetotail crossings, meteor showers or different latitudinal regions. Data collected over the next few years will continue to help us to improve the signal-to-noise of these observations.

References

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