**A SEARCH FOR ORGANIC SPECTRAL FEATURES ON THE LUNAR SURFACE** C. M. Ferrari-Wong[1], C. I. Honniball[1], P. G. Lucey[1], A. Gabrieli[1], S. Li[1], and A. J. Flom[1], [1]University of Hawaii at Manoa, Hawaii Institute of Geophysics and Planetology, HI 96822 (cferrariwong@higp.hawaii.edu).

**Introduction** The solar wind has long been hypothesized to be the source of chemical reactions on the lunar surface, implanting hydrogen, and resulting in OH (hydroxyl) [1], $H_2O$ (water) [2], and $CH_4$ (methane) [3]. With the collection of new data by several missions, there have been recent discoveries of water and other volatiles on the lunar surface [4, 5, 6, 7].

Along with these discoveries, there are several lines of evidence that hydrocarbons or other organics may be an important volatile species on the Moon: there has been methane detected in lunar samples [3], and in the lunar exosphere [8]; dark lag deposits possibly composed of organic residues topping ice deposits in Mercurys polar deposits, which serve as analogs to lunar polar deposits [9]; carbon-hydrogen bonds detected in lunar glasses prepared to minimize contamination [10]; and organic detections by The Lunar Crater Observation and Sensing Satellite (LCROSS) that impacted a large projectile into the permanently shaded Cabeus crater near the lunar south pole [11].

Infrared spectra of organic contaminants on such minerals as antigorite, muscovite, montmorillonite, and silica gel show organic absorption features at 3.4 $\mu m$ due to $CH_2$ and 3.5 $\mu$m due to $CH_3$ [12]. Similar contaminant features are observed in reflectance spectra of lunar soils prepared with methanol rinses (Figure 1). The goal of this project is to determine if the Moon exhibits a carbon-hydrogen stretch emission feature in the 3.4-3.5 $\mu$m band, and if not detected, to establish upper limits on organic abundance.

In order to get the spectral, spatial, and lunar TOD coverage necessary to conduct a full search for organic features, we use the SpeX infrared cross-dispersed spectrograph [13] at the NASA InfraRed Telescope Facility (IRTF) at Mauna Kea Observatory, where we can obtain lunar data from 1.67 to 4.2 $\mu$m at 1-2 km resolution.

**Methods** On June 24th and 26th, 2018, observations of the lunar surface for four target locations were obtained, three near the dawn terminator and one at the subsolar point. Data was then calibrated using SPEXTOOL [14], and the sky emission removed.

Raw SpeX data include the transmission spectral properties of the terrestrial atmosphere. Typically observations of solar analog stars are used to remove these features by dividing the object spectrum by the star spectrum. However, the success of this process depends on the stability of the atmosphere between the lunar and star observations that can be separated by large fractions of an hour. To increase the robustness of our observations against variations in water vapor or methane absorptions, we use an atmospheric model to remove atmospheric absorption features.

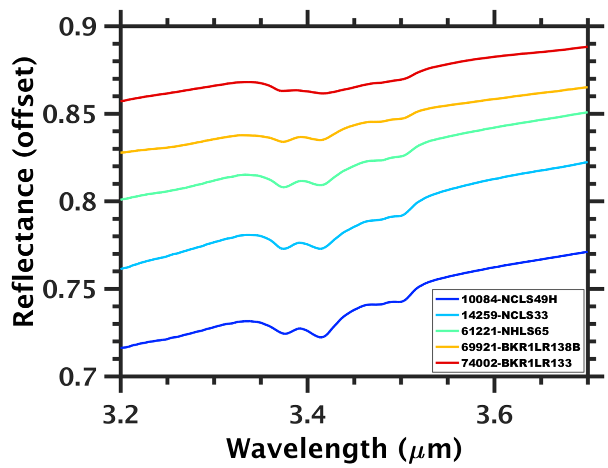


Figure 1: *Reflectance spectra of 5 lunar soils showing 3.4 $\mu m$ C-H features from organic contaminants in data from RELAB (Brown University).*

Using MODTRAN6 [15], line-of-sight atmospheric spectral transmittances can be computed for the near-IR spectral range, providing an accurate method of correcting spectral ground based observations to mitigate the presence of methane and other atmospheric lines. Spectral transmissions were computed for the optical conditions at the time of the observations using atmospheric data from the University of Wyoming Atmospheric Soundings [16]. The spectra were fitted to the resulting atmospheric model, and the effects of the atmosphere divided out.

**Results** The resulting lunar spectra systematically showed emission features in the 3.4-3.5 $\mu$m region. However, we suspected this could be contamination of the telescope or instrument optics. Assuming stars would not exhibit organic emissions or reflectance features consistent with solids, we processed a solar standard star using the MODTRAN6 atmospheric removal.

The same feature was found in the standard star spectra after removing the effects of the sky and atmospheric transmission (Figure 2). Confirming possible organic contamination and to account for it, a standard star was processed and divided out, using the star data to characterize the effects of the organic contaminant.

After the division of the standard star, the organic feature is no longer present (Figure 3). The slope in the data is due to the ratio of the spectral slope of the

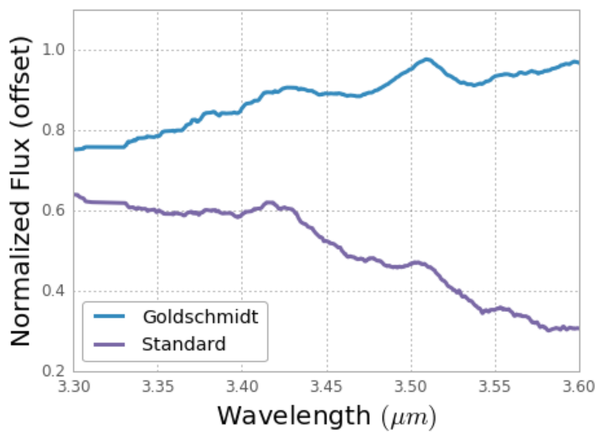


Figure 2: *Flux ratio spectra of Goldschmidt crater and a standard star taken the same night, both showing 3.4 and 3.5 μm C-H features in data from SpeX.*

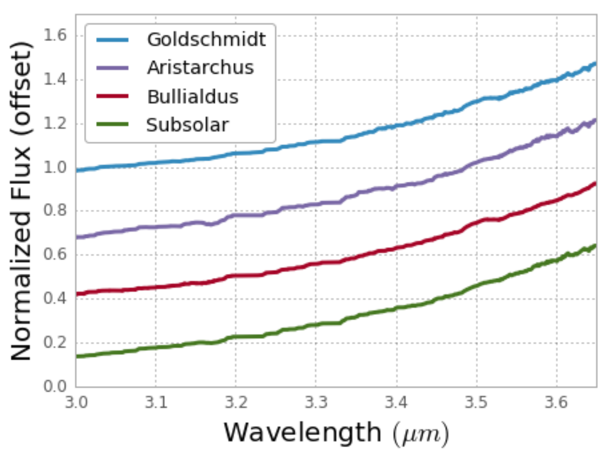


Figure 3: *Flux ratio spectra of four target locations divided by a standard star.*

lunar thermal emission divided by the solar-like spectrum of the star. We fit this slope with a 4th order polynomial continuum to isolate any residual features. The four spectra examined show no obvious features, with the noise level after filtering to 10 nm spectral resolution at about 1% (Figure 4).

**Discussion** The results shown here are only four spectra of thousands of spectra we have obtained with SPEX over several observing runs. However, this experiment shows that there is no ubiquitous organic spectral feature on the lunar surface, even at high latitudes where low temperature might encourage organic accumulation. As the noise level after filtering is about 1%, we could reliably detect a 3% feature. We are in the process of examining our entire data set for any local organic anomalies that might occur, for example near recent meteorite impacts, or adjacent to regions in permanent shadow. We are also conducting laboratory experiments to establish detection limits for these observations.

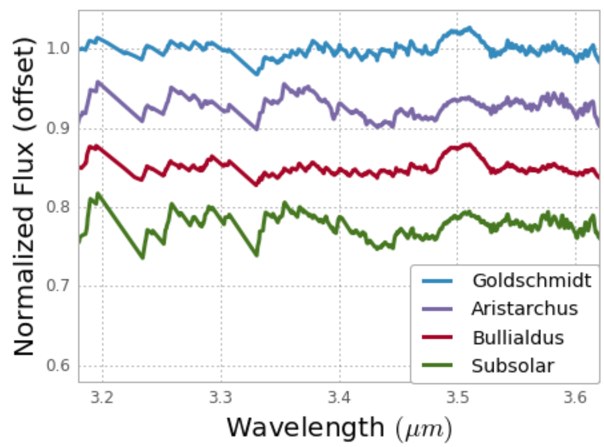


Figure 4: *Flux ratio spectra of four target locations after filtering to 10 nm spectral resolution. No obvious features are present.*

**Conclusions** A small survey of the lunar spectrum in the region of strong C-H absorption features led to no detections of organic features to about the 1% level. We have extensive existing coverage of the Moon at these wavelengths to enable a much more comprehensive survey. Laboratory experiments will be used to establish detection limits for the astronomical observations.

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