WATER AND HYDROXL FEATURES AT REINER GAMMA Abigail Flom[1], Paul Lucey[1], Casey Honniball[1], Chiara Ferrari-Wong[1] [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 2500 Campus Rd, Honolulu, HI 96822 (aflom@hawaii.edu)

Introduction: A common view of the Moon as inherently dry abruptly changed when water was detected in lunar regolith. A Moon-wide 3 μm band has been detected by multiple remote sensing instruments: EPOXI High Resolution Instrument, Cassini Visual and Infrared Mapping Spectrometer (VIMS), and the Moon Mineralogy Mapper (M^3) [1, 2, 3]. This band signifies the presence of OH and possibly H_2O (collectively referred to as total water), which has been backed up with recent reanalysis of Apollo samples[4]. The study of this surface water and how it behaves on the Moon has important implications for understanding volatiles on airless bodies throughout the Solar System.

A key hypothesis for the origin of lunar water is the chemical interaction of solar wind hydrogen with lunar surface oxygen [5] and key geologic features for the understanding of the origin of detected total water and the influence of solar wind are lunar swirls. Lunar swirls are bright albedo features on the lunar surface that have been linked to the presence of local magnetic fields [6, 7, 8] A magnetic field could shield the surface from the solar wind, which is believed to decrease the amount of space weathering that the surface beneath it undergoes, causing that material to be brighter than the surrounding material. Solar wind is also hypothesized to be the source of the observed water via hydrogen implantation onto exposed oxygen in fractured mineral surfaces. A swirls unique ability to show differences in the water band due to differences in solar wind intensity while keeping other parameters constant make it a natural laboratory for studying solar wind interaction.

This project focuses on the behavior of water on and around the Reiner Gamma swirl (figure 1). In a previous study with Moon Mineralogy Mapper (M^3) data by Kramer et al. 2011, they found that there was a greater band depth at 2.82 μm off swirls versus on swirls. In fact, it was suggested that swirls can be better identified with this feature than with other methods [9]. This correlation of water abundance and inferred solar wind intensity supports the hypothesis that solar wind hydrogen reactions is a source of lunar surface water.

However, data in the 3 μm region is complicated by the presence of both emitted and reflected radiation, and there is debate about how to best correct for thermal emission in M^3 data, which does not contain any wavelengths beyond 3 μm to constrain thermal models for the data. Bandfield et al. [10] after thermal correction found a 3 μm feature across the Moon, but do not see differences with latitude or lunar time of day. On the other hand, Li et al. [11] and Wohler et al. [12] see strong differences with these parameters.

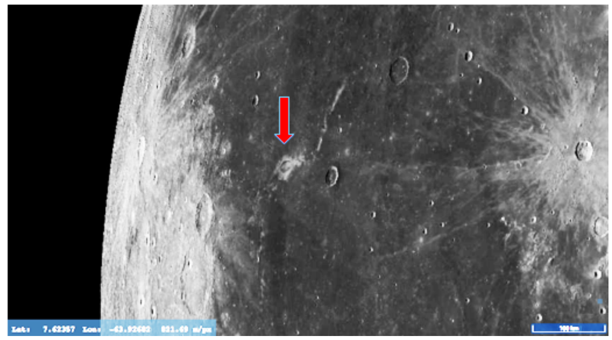

Figure 1: *This image from the LROC quickmap shows the location of Reiner Gamma awithin Oceanus Procellarum. lat: 7^{o}N lon:-59^{0}E*

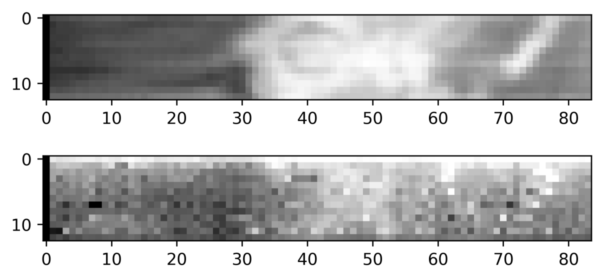

Figure 2: *The top image is a reflectance image of the lunar swirl Reiner Gamma and the bottom image is a corresponding 3 μm band depth map. Both images were created using SPeX data.*

However, M^3 data is limited in its wavelength coverage. A strong test of thermal corrections is their quality at longer wavelengths where thermal emission is increasingly dominant. To deal with this thermal modeling problem, this work uses observations that are taken from the Mauna Kea Observatory using the SPeX infraed cross-dispersed spectrograph at the NASA InfraRed Telescope Facility (IRTF). This instrument collects data from 1.67 to 4.2 μm and the spectral range provides several advantages over Moon Mineralogy Mapper data on the same region of the Moon. First, the complete 3 μm feature is covered allowing the whole absorption feature to be observed. Second, the spectrum extends out to longer wavelengths where the thermal emission dominates, allowing for an accurate thermal correction based off of the data. Third, observations can be taken at lunar times of day that are not available in M^3, including the early morning and late afternoon.

Methods: Observations of Reiner Gamma were obtained on October 23rd, 2018 near the dawn terminator

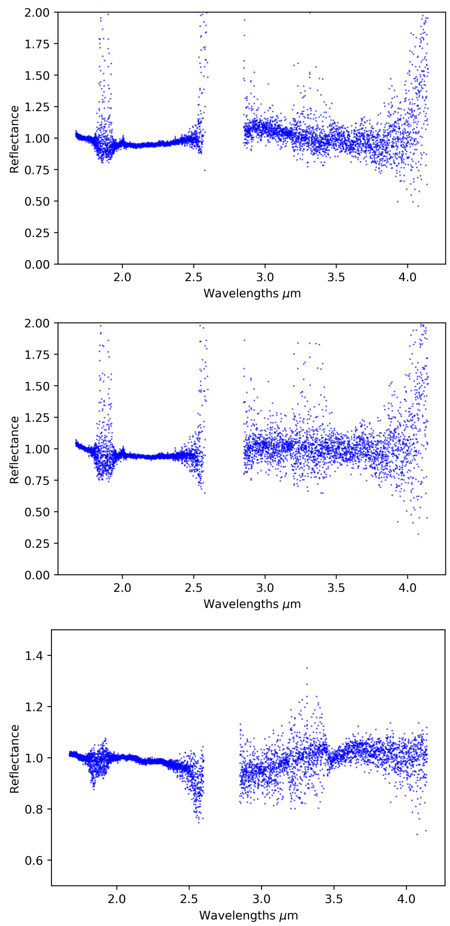

Figure 3: *These three spectra show an averaged spectrum from on the swirl (top), off the swirl (middle), and a ratio of on the swirl to off the swirl (bottom)*

on the moon. A map of the feature was created by scanning the slit over the swirl region. After the collection of each map, data were taken on the sky near by the moon and a standard star was observed at a similar airmass to the Moon observations. Spectra were obtained from the image data using the SPEXTOOL software [13].

First, the data must be corrected for effects due to the telescope and the atmosphere. To remove effects of atmospheric emission a sky spectrum is taken near by the target and then subtracted from the data. Then, a solar-type star at a similar air mass is observed and used to correct for atmospheric transmission as well as instrument response. This leaves a radiance spectrum that consists of both reflectance and thermal components.

The thermal component is removed from the data using the asteroid approach to radiation removal [14, 15, 16]. When fitting the data with the thermal model surface roughness effects are taken into account [10]. After, removal, a continuum removed reflectance spectrum remains and is used for analysis.

Results: Figures 3 display averaged spectra with linear continua removed. Differences between these spectra are subtle, but are emphasized in the ratio of the spectrum off the swirl to the spectrum on the swirl (Figure 4). There is an evident absorption feature apparent near three microns. Figure 2 shows an 3 μm band depth image, as well as a simple reflectance image. As concluded by Kramer et al., the maria surrounding the swirl show deeper 3 μm bands than the bright portions of the swirl. However, the correlation of reflectance and 3 μm band depth is less than that reported by Kramer et al.: some portions of the bright parts of the swirl show stronger 3 μm band depths. Figure 2 shows the correlation between reflectance and 3 μm band depth demonstrating only a weak offset in band depth between the dark maria and the bright portions of the swirl.

Discussion: The differences between previous results on the swirl and what we are observing are interesting and could be influenced by several factors. First, M^3 does not have full spectral coverage of the 3 μm feature, so the Kramer results could be influenced by incomplete thermal correction. In addition, the thermal corrections for the data are different and the strength of the thermal correction could be causing changes in the observed depth of the absorption band. Beyond that, the data presented here are from a near dawn lunar time of day, which is a time of day not observed by M^3. It is possible that near the terminator the temperature is not yet settled into equilibrium, or there may even be migration of water and hydroxyl molecules. Data from different lunar times of day has been collected and may shed more light on the effects of this variable on the data.

Conclusions: We have mapped the Reiner Gamma swirl at near dawn times of day and found similarities and differences with previous observations of the swirl. Existing data not presented at different lunar times of day may provide further insight into the diurnal behavior.

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