**SOFIA 6 MICRON SPECTROSCOPY OF THE GRUITHUISEN DOMES.** A. Arredondo¹ P. G. Lucey,² C. I. Honniball¹, W. T. Reach¹, A. J. Thorpe¹, E. Malarek², and M. J. Poston¹, ¹Southwest Research Institute, San Antonio, TX, USA, aarredondo@swri.org, ²University of Hawaii at Manoa, Honolulu HI, USA, ³University of Maryland, College Park, MD, USA, ⁴Space Science Institute, Boulder, CO, USA, ⁵Universities Space Research Association, Columbia, MD, USA, ⁶Applied Coherent Technology, Inc. Herndon VA USA

**Introduction:** The unique nature of the Gruithuisen domes has prompted the Lunar Vulcan Imaging and Spectroscopy Explorer (Lunar-VISE) mission, set for launch in 2024. The goal of Lunar-VISE is to land on one of the Gruithuisen domes (γ) and determine the composition and physical properties of the rocks and regolith comprising the domes [1].

Because they are silica-rich anomalies [2], the Gruithuisen domes were not expected to contain hydrated minerals. However, data from the Moon Mineralogy Mapper (M³) from India’s Chandrayaan 1 mission detected an absorption feature at 2.6-3 μm that is due to OH and possibly H₂O showing that the domes are consistent with ~200 μg/g H₂O [3]. While water is unexpected in silicate material, [4] showed that small amounts of water are present in KREEP (potassium, rare-earth elements and phosphorus) rich and evolved rocks.

The detection of a spectral feature at 6 μm can confirm or deny the presence of molecular H₂O, without confusion from OH [5,6,7]. We present observations of the Gruithuisen domes in the 6 μm region using the Stratospheric Observatory for Infrared Astronomy (SOFIA) as part of a larger legacy program.

An overview of the SOFIA lunar legacy program can be found in [8]. Major findings of the program are a correlation of H₂O and latitude, with H₂O concentrations of ~100 μg/g at Gruithuisen-like latitudes (36°N) and ~250 μg/g near the poles. We also find that water concentration is inversely correlated with temperature, with a rate of change of about 2 μg/g per kelvin. Observations of an area at different lunar times of day may reveal variations in 6 μm peak height.

**Data:** Spectra were obtained using the Faint Object infraRed CAmera for the SOFIA Telescope (FORCAST; [9]). The observations used the G063 grism to obtain spectra between 5-8 μm. The size of the slit is 2.4 x 194 arcseconds corresponding to a resolution of λ/Δλ = 180. FORCAST was operated as a pushbroom spectrometer, by obtaining a spectrum in one location and then moving the slit by one slit width to obtain the next spectrum. We combined 20 of these offsets to create individual flux maps of size 19” x 190” (Fig. 1), where each pixel corresponds to one spectrum.

*Fig. 1. Flux map for F871 made by operating FORCAST like a pushbroom spectrometer. Features of interest are marked with arrows.*

To remove systematic effects, all spectra are divided by a spectrum from a “dry” reference site obtained immediately before or after each map. Because the final flux is a ratio between target and reference, all measurements of the strength of the 6 μm feature are relative to the amount of molecular water present in the reference site. For these nights the reference sites were Mare Fecunditatis and Mare Procellarum, and were chosen because they were dry in M³ data.

The Gruithuisen region was mapped on four separate nights in May 2022. The exact region mapped varies slightly between nights because of the rotation of the Moon and the location of SOFIA at time of observation; however, each map contains data at Gruithuisen γ and δ, Mairan A, and a portion of Sinus Iridum. The observations span a quarter of a lunar day, which is enough time to see the strong correlation between temperature and the 6 μm peak reported by [8]. Details of the observations are given in Table 1.

<table>
<thead>
<tr>
<th>Flight</th>
<th>UT Date</th>
<th>Subsolar Longitude</th>
<th>Lunar time of day</th>
<th>Brightness temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>F869</td>
<td>20220513</td>
<td>33</td>
<td>07:00</td>
<td>330</td>
</tr>
<tr>
<td>F870</td>
<td>20220517</td>
<td>-16</td>
<td>10:30</td>
<td>378*</td>
</tr>
<tr>
<td>F871</td>
<td>20220518</td>
<td>-28</td>
<td>11:00</td>
<td>360</td>
</tr>
<tr>
<td>F872</td>
<td>20220519</td>
<td>-41</td>
<td>12:00</td>
<td>395</td>
</tr>
</tbody>
</table>

*We expect the brightness temp of F870 < F871. It is probably a calibration issue that we are looking into.*
Results: Fig. 2 shows a comparison between spectra from multiple locations in the region. Also plotted is the location and strength of the 6 μm emission found by [6]. None of the spectra show a feature of similar strength or location, implying that molecular water is not present. Because our data is a ratio of target flux to reference flux, this could also mean that the target had the exact same amount of molecular H₂O as the reference site, but reference sites were chosen because they are expected to be dry. This indicates that the 3 μm band reported by [3] is probably due to hydroxyl rather than water. We find a similar lack of 6 μm peak in all four nights of data, suggesting that its absence is not caused by temperature differences.

The Christiansen Feature (CF) is an emissivity maximum caused by the transition from surface scattering to volume scattering regimes, and is usually found between 7.5-10.0 μm for silicates. Data from the Diviner Lunar Radiometer Experiment show that the CF for the Gruithuisen domes should be < 8 μm [10]. We do not see any evidence for a CF in any of the four data sets. As seen in Fig. 2, the spectra are highly variable at the ends of the detector, so the lack of CF might be due to the instrument. Because our data is a ratio of target flux to reference flux, it is also possible that we divide out the CF if it is in the same place as the reference; however, show that the lunar mare are expected to have a CF at longer wavelengths than the Gruithuisen domes [10].

Discussion: In other regions of the Moon, we see variation of the strength of the 6 μm peak with location. For example, [11] shows that a portion of the central peak of Moretus crater near the south pole is dry compared to the rest of the crater. Both the central peak of craters and volcanic domes are examples of lunar mantle material that has been brought to the surface. A lack of water at these features could suggest a lack of water in the lunar mantle. The SOFIA dataset contains other regions of mantle material brought up to the surface, and we can use 6 μm to either confirm this hypothesis or if the interior of the Moon is heterogeneous.

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