MOLECULAR WATER ON THE SUNLIT LUNAR SURFACE: DETECTION OF THE 6 µm H-O-H FUNDAMENTAL WITH THE SOFIA AIRBORNE OBSERVATORY. C. I. Honniball[1,5*] (cih@higp.hawaii.edu), P. G. Lucey[1], S. Li[1], S. Shenoy[2,] T. M. Orlando[3], C. A. Hibbitts[4], D. M. Hurley[4], W. M. Farrell[5], [1]HIGP, University of Hawaiʻi at Mānoa, Honolulu, HI, [2]Space Science Institute, Boulder, CO, [3]School of Chemistry and Biochemistry, School of Physics and Center for Space Technology and Research, Georgia Institute of Technology, Atlanta, GA, [4]APL, Johns Hopkins University, Laurel, MD, [5]NASA Goddard Space Flight Center, Greenbelt, MD

Introduction: Hydration on the lunar surface was first reported in 2009 by three spacecraft [1-3] manifested as an absorption at 3 µm. The 3 µm absorption is caused by the symmetric and asymmetric stretching of the O-H bond [4], which can be produced by both hydroxyl (OH) attached to metal cations, and by molecular water (H_2O). Currently there are no methods available to distinguish H_2O from OH.

To detect the presence of H_2O on the Moon, new techniques are needed to detect it. Fortunately, H_2O expresses a fundamental vibration at ~6 µm, the H-O-H bend, that can only be produced by H_2O and is absent in other OH-bearing compounds [5-12]. Until recently, no observations of the Moon at 6 µm had been conducted and no current or planned lunar spacecraft or ground-based telescopes are able to conduct 6 µm observations of the Moon.

SOFIA Lunar Observations: In August 2018 we conducted the first observations of the Moon at 6 µm with the NASA/DLR Stratospheric Observatory For Infrared Astronomy (SOFIA), an airborne 2.5 m telescope used for infrared and submillimeter astronomy [13]. We used the Faint Object infraRed CAmera for the SOFIA Telescope (FORCAST) spectrograph providing a wavelength coverage of 5 to 8 µm at a spectral resolution of 30 nm. We observed the Clavius crater region at high southern latitudes that is known to have a high abundance of hydration in 3 µm data acquire with the Moon Mineralogy Mapper [14].

Water on the Moon: Data of the Clavius crater region reveal a 1-3% 6 µm emission band that we attribute to molecular water on the Moon (Fig. 1).

Previous studies show that the absorption strength of the 6 µm band correlates with the absolute content of H_2O [6,8,15]. To estimate the abundance of H_2O in the remote sensing data of the Moon we derived an empirical relationship between the 6 µm band depth in reflectance and the absolute abundance of H_2O from water-bearing glasses formerly used to estimate the abundance of hydration at 3 µm [14]. We estimate abundances of 100 to 412 ppm H_2O is present in the Clavius region with an average of 250 ppm H_2O.

We compared the position of the lunar 6 µm band to: literature values of the center position of the H-O-H bend in crystalline hydrates [16]; 6 µm bands of water-bearing glasses [14]; and meteorites with water adsorbed from the terrestrial environment [17]. We find

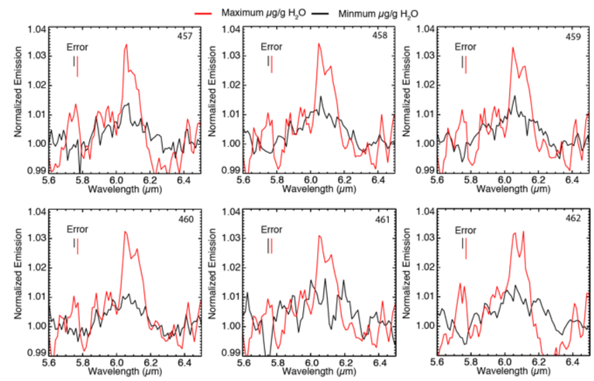

Figure 1: Spectra of the Clavius region show a strong 6 µm emission band indicating the presence of H_2O.

the Moon, water-bearing glasses, and meteorite band centers fall within the reported band center range for the H-O-H bend in crystalline hydrates. Based on these comparisons, we are confident the 6 µm band on the Moon is due to H_2O. We are unaware or any other lunar material that may exhibit an isolated 6 µm band.

In conclusion, we have detected molecular water on the illuminated lunar surface using the SOFIA FORCAST instrument. This is the first direct, unambiguous detection of H_2O on the Moon outside the permanent shadows at the lunar poles.

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