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 (H₂O). Currently there are no methods available to distinguish H₂O from OH.

To detect the presence of H₂O on the Moon, new techniques are needed to detect it. Fortunately, H₂O expresses a fundamental vibration at ~6 μm, the H-O-H bend, that can only be produced by H₂O 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 H₂O [6,8,15]. To estimate the abundance of H₂O 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 H₂O from water-bearing glasses formerly used to estimate the abundance of hydration at 3 μm [14]. We estimate abundances of 100 to 412 ppm H₂O is present in the Clavius region with an average of 250 ppm H₂O.

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 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 H₂O. 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 H₂O on the Moon outside the permanent shadows at the lunar poles.

References: