A Legacy of Lunar Water Through SOFIA. C. I. Honniball[1], P. G. Lucey[2], and W. T. Reach[3], [1]NASA Goddard Space Flight Center (casey.i.honniball@nasa.gov), [2]University of Hawaii at Manoa, [3]Unversities Space Research Association, SOFIA.

Introduction: Through its unique instrument suite and operational altitude above 99.9% of Earth's atmosphere, the Stratospheric Observatory For Infrared Astronomy (SOFIA) has allowed for molecular water on the sunlit Moon to be detected unambiguously for the first time (Figure 1) [1]. This was accomplished using the H-O-H bending vibration at 6.07 µm that is unique to molecular water and does not occur in any other hydroxyl-bearing species. The H-O-H 6 µm band has been used for decades to detect and quantify water in geologic thin sections using FTIR spectroscopy [2-5].

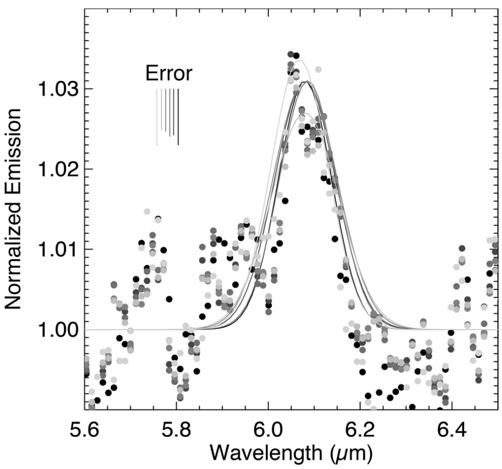

Figure 1: Spectra of high southern lunar latitudes showing strong 6 µm emission bands indicating the presence of H_2O.

The detection of water on the sunlit Moon is of high importance for planetary and lunar science. At this time SOFIA, using the FORCAST instrument, is the only observatory capable of detecting and mapping the 6 µm water band on the Moon. Initial detections of water on the Moon with SOFIA were made at high southern latitudes in one region. Using FORCAST on SOFIA we have tentative approval from the SOFIA project for a 2-year Legacy campaign to map water on the sunlit Moon.

The goals of this Legacy project are to:

1. Address the origin of lunar water by characterizing its variation, mobility, and storage on the lunar surface.
2. Identify rare minerals and exposed lunar mantle material using the Christensen Feature and other spectral features in the 6 µm region.
3. Determine if other highly volatile compounds are present on the lunar surface.

Proposed Observations: For the Legacy project we will use two observing modes, one that samples a large fraction of the lunar surface at many lunar times of day and one that creates complete continuous maps of geologically interesting locations.

By sampling a large fraction of the Moon at many lunar times of day we can address goals 1 and 3. Scanning of the FORCAST slit across the Moon as a push-broom imaging spectrometer will be most efficient at gathering the large amounts of lunar locations needed to address compositional and latitudinal variations of water. With similar latitude and longitudes observed at many lunar times of day, the mobility of water and storage of water on the lunar surface can be addressed by measuring hourly diurnal variations. These observations are accomplished over multiple Earth nights where one Earth day advances the lunar time of day by about one hour.

Complete continuous mapping of volcanic deposits addresses all proposal goals. Continuous mapping of these locations will allow for maps of water and rare minerals (if detected) and may be used for Artemis landing site selection and resource utilization assessment. Goal 2 requires highly silicic features to be observed in order to determine if rare minerals are present from the Christensen feature and to determine if water is concentrated at these locations. Goals 1 and 3 require maps covering pyroclastic deposits to identify water sourced from the lunar interior.

Conclusions: Maps of water across the Moon at multiple lunar times of day, latitudes, and over a range of compositions will allow us to fully characterize the behavior and processes of water on the Moon. We will characterize the mobility of water and determine its correlation with solar wind intensity and other parameters that may indicate its formation mechanisms. Through SOFIA we will advance our understand of water formation, storage, and retention on the lunar surface and extend this to other airless bodies. Maps created through the Legacy program will inform scientists on the availability of water as a resource and how to extract the water and may be used for landing site selection during the Artemis program.

Acknowledgments: Data that support the plot is publicly available from the SOFIA Data Cycle System at https://dcs.sofia.usra.edu and the Infrared Science Archive hosted by the Infrared Processing & Analysis Center (IPAC)).

References: [1] Honniball et al. (2020) Nat. Ast., 5, 121-127. [2] Bartholomew et al. (1980) J. Am. Cerm. Soc. 63, 481–485. [3] Glew and Rath. (1971) Cand. J. Chem. 837-856. [4] McIntosh et al. (2017) Earth Planet. Sci. Let. 401, 1-11. [5] Newman, et al. (1986) Am. Min. 71, 1527-1541.