MID-INFRARED REFLECTANCE AND EMISSIVTY SPECTRA OF HIGH POROSITY REGOLITHS. A. C. Martin[1,2], J. P. Emery[2], M. Loeffler[2,3], K. L. Donaldson Hanna[1] [1]Department of Physics, University of Central Florida, Orlando, FL 32816 (Audrey.martin@ucf.edu), [2]Department of Astronomy and Planetary Science, Northern Arizona University, Flagstaff, AZ 86011, [3]Center for Materials Interfaces in Research and Applications, Northern Arizona University, Flagstaff, AZ, 86011

Introduction: Mid-infrared (MIR; 5–35 μm) spectroscopy is an abundantly useful tool for understanding planetary surfaces. Since the MIR wavelength region is sensitive to a variety of entwined variables, such as composition, particle size fraction, and environmental conditions, parsing through individual effects in a controlled laboratory setting is necessary for robust and accurate interpretations of distant object surfaces.

In previous works, we have shown that regolith porosity greatly affects MIR spectral features of fine particulate (<63 μm) olivine samples [1]. Using our high porosity olivine lab spectra, we found that the Trojan asteroid Hektor's MIR spectrum is indicative of having over 80% regolith porosity (i.e., void space within the regolith). Our initial laboratory olivine measurements were taken under ambient conditions in reflectance space, now we compare these reflectance spectra of fine-particulate olivine samples with high regolith porosity to emissivity spectra of the same samples taken in both ambient and simulated asteroid environment (SAE) conditions.

Environmental effects: It is important to fully characterize the environmental effects on MIR spectra in the laboratory because previous studies have shown that MIR spectra are highly sensitive to the sample's brightness temperature, the temperature gradient within the upper hundreds of microns of the sample, and the atmospheric pressure of the chamber in which they are measured [e.g., 2,3]. The observed MIR spectral effects owing to the vacuum environment are due to thermal gradients in the near-surface (upper 100 μm) and a material's wavelength-dependent scattering properties [e.g., 4]. The intensity and shape of a thermal gradient is dependent on factors including albedo, brightness temperature, particle size fraction, and regolith porosity – which in turn, affects the contrast and shape of important spectral features used for compositional identification like the Christiansen feature (CF: a surface scattering feature caused by an abrupt change in the refractive index of a material), and reststrahlen bands (RBs: wavelength dependent absorption bands also known as the vibration bands).

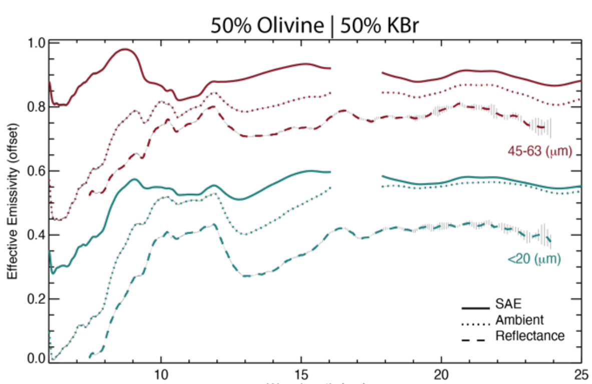

Figure 1 Spectra of 45-63 μm (red) and < 20 μm (teal) olivine mixed with KBr in a 50:50 ratio. The dashed line spectra were taken in reflectance space under ambient conditions. The dotted and dashed line spectra were taken with PASCALE in ambient and SAE conditions respectively.

Sample Measurement: We used a natural forsteritic olivine from the Canary Islands with an Mg# of 91 purchased from Mineralogical Research Company. The olivine was ground and sieved into three particle size fractions (0-20 μm, 20-45 μm, and 45-63 μm) and mixed with potassium bromide (KBr). As KBr is transparent in the MIR, we use it as a proxy for regolith porosity. We mixed samples with KBr in ratios from 0% to 90% by weight, in 10 wt.% intervals.

Reflectance measurements were taken of all samples with a Thermo-Nicolet iS50 Fourier Transform infrared (FTIR) spectrometer, under ambient conditions, using the PIKE Technologies EasiDiff diffuse reflectance accessory and described in [1]. The following ratios of olivine to KBr were also measured in emissivity and described below: 100:0, 90:10, 70:30, 50:50, and 10:90.

Emissivity measurements were made using the Planetary Analogue Surface Chamber for Asteroid and Lunar Environments (PASCALE), a vacuum chamber built by the University of Oxford that simulates the near-surface environments of airless bodies, and is attached to a Bruker FTIR spectrometer [5]. First, emissivity measurements of samples in ambient conditions were taken by backfilling the chamber with ~1,000 mbar of N_2, holding the chamber at ambient temperature, and heating the sample from below to 353 K. Next, we induced a thermal gradient in each sample by decreasing the chamber's atmospheric pressure (< 1 x 10^{-4} mbar) and temperature (< 125 K), heating the sample from below to 333 K, and increasing the surface brightness temperature to 350 K using a solar-like halogen lamp. These temperature and pressure conditions create thermal gradients consistent with those expected within the regolith found on asteroids' surfaces. Results of the 50% olivine – 50% KBr spectra are shown in Figure 1.

Discussion: In previous works, we found that spectra of samples with low regolith porosity were characteristic of the surface scattering regime, whereas spectra of samples with high regolith porosity were characteristic of the volume scattering regime – and the transition from surface to volume scattering is gradual [1]. Emissivity spectra taken in ambient conditions follow a very similar scattering regime trend, yet the SAE spectra are more reticent to transition into a volume scattering regime (Figure 2). For example, as spectra transition from surface to volume scattering, the CF reduces in spectral contrast. As seen in Figure 2, CFs in SAE spectra are seen to reduce in spectral contrast as regolith porosity increases, but CF spectral contrast reduction is greater in the ambient spectra. The difference in CF spectral contrast likely stems from a combination of effects that alter the thermal gradient in the top hundreds of microns in the sample. Photons associated with the CF can be emitted from deeper in the sample (or regolith), and have a different temperature compared to near surface photons resulting in different spectral contrasts and positions. The disparity between CF position and shapes increases with increasing regolith porosity.

Future Work: We were unable to measure many of the highest regolith porosity and smallest particle size fraction olivine samples with PASCALE in SAE, because the samples could not get hot enough. Notably, it is easier to heat and maintain thermal gradients in low-albedo and lower porosity materials [6, 7], which are present on many asteroids. Thus, future studies that include low-albedo material to our sample mixtures should not only help high porosity samples reach the proper temperature but will also be more applicable to planetary surfaces.

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References: [1] Martin A. C. et al. (2022) *Icarus* 378. [2] Maturilli A. et al. (2016) *Earth, Planets and Space* 68. [3] Donaldson Hanna K. L. et al. (2017) *Icarus* 283, 326-342. [4] Henderson B. G. et al. (1997) *JGR* 102, 6567-6580. [5] Donaldson Hanna K. L. et al. (2021) *JGR* 126. [6] Donaldson Hanna K. L. et al. (2019) *Icarus* 319, 701-723. [7] Bates H. C. et al. (2021) *JGR* 126.

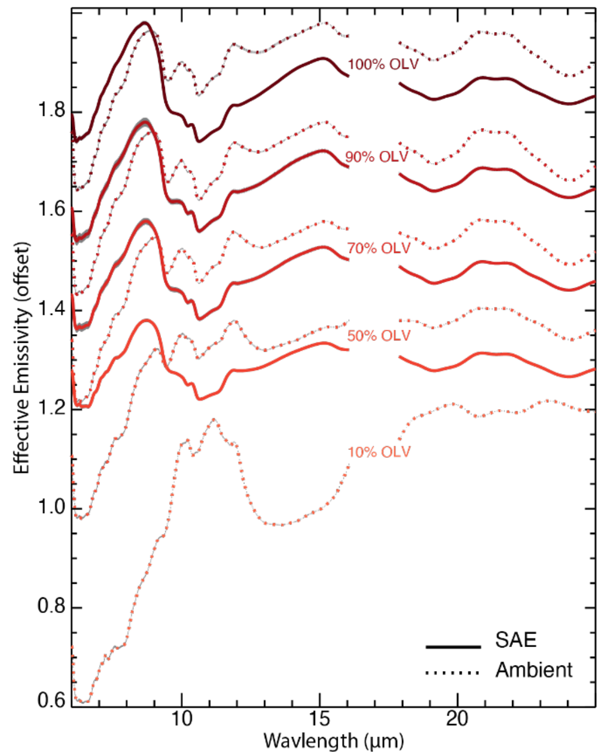

Figure 2 Spectra of 45-63 µm olivine (OLV) mixed with KBr. The dotted and dashed line spectra were taken with PASCALE in ambient and SAE conditions respectively. Note that there is no SAE measurement of the 10% OLV sample as the sample could not get hot enough.