

Identifying the spectral signatures of surface adsorbed water on lunar relevant mafic minerals . E. A. Fisher¹, Paul Lucey¹, Lingzhi Sun¹. fisher.elizabethanne@gmail.com (1)2500 Campus Rd, Honolulu, HI 96822

Introduction & Background: Recent spectral studies of Moon's ubiquitous 3 μm water absorption strongly suggest that the abundance of water detected on the lunar surface changes as a function of time of day ⁴⁻⁷. These diurnal variations imply that the amount of water on the surface of lunar regolith grains is changing, and that mobile water may be adsorbed to the lunar surface. How much water in the lunar regolith is adsorbed to grain surfaces vs. internally bound has major implications for this modern lunar hydrogen cycle, as well as lunar formation and petrologic evolution ¹⁻³.

Current studies are limited to estimating concentration of OH and H₂O in bulk ⁴ and are unable to differentiate between water that is internally bound within lunar soil grains, and adsorbed to grain surfaces. This is because the 3 μm absorption region convolves multiple vibrational absorptions including the fundamental symmetric (v1) and asymmetric (v3) H₂O stretches at 2.8-2.9 μm , the first overtone of the H₂O bend at 3.1 μm (2v2), and hydroxyl absorptions between 2.7 and 2.8 μm ⁹. The precise locations and relative intensities of these absorptions depend on their bonding environment (e.g. mineral structure, composition, bond strength) ¹. Past studies observe clear variations in 3 μm absorption shape associated with changes in surface water abundance & mineral substrate. This abstract seeks to further connect 3 μm mineral observations/spectra with quantitative information about hydrogen speciation, abundance, & mode of preservation, with a focus on mafic minerals. This capability will prove critical to future campaigns investigating lunar volatiles.

We will isolate the spectral signatures of internal vs. surface adsorbed water on mafic minerals by using Hapke radiative transfer modeling ¹⁰⁻¹² to characterize differences in the shape and intensity of the 3 μm region as the proportion of surface water on a given mineral changes, which we proxy via mineral particle size/surface to volume ratio, following the methods of Fisher et al., LPSC 2021. In this abstract we present preliminary results of shape analysis of water's 3 μm absorption region for San Carlos Olivine.

Methods: Samples were ground and wet sieved into five size fractions [25-45 μm , 45-63 μm , 63-125 μm , 125-250 μm , 250-500 μm] to prevent the spectral influence of fines clinging to larger particles. VNIR-IR reflectance spectra (0.3-25 μm) of each size fraction were measured at the NASA RELAB facility at Brown University using a bi-directional reflectance spectrometer under standard geometry ($i=30^\circ$, $e=0^\circ$) and a Nicolet Nexus 870 FTIR spectrometer with a diffuse gold standard. We estimated the optical

constants [$k(\lambda)$], also known as extinction coefficients, of each size fraction using the Hapke radiative transfer model (RTM) ¹⁰ parameterization of ¹². This study's approach, developed by ^{12,13} obtains extinction coefficients from pure mineral reflectance by inverting the Hapke RTM.

Results & Discussion:

Reflectance spectra & extinction coefficients [$k(\lambda)$] of each particle size fraction are shown in **Figures 1 & 2**. Ideally, k is only a function of a material's interior absorption characteristics, and values of k calculated for different particle sizes of the same material will be very similar. However, if sample grains are coated in an adsorbing species, this relationship should break down, and different grain size separates of the same material will show different absorption characteristics. From ~2.6-3.6 μm , water's absorption band, extinction coefficients deviate from each other as sample surface area increases, including changes to the absorption's shape relative intensity. Outside the 3 μm region and within our samples' internal iron absorptions, k values are extremely similar regardless of particle size. This suggests that the Hapke model is successfully accounting for multiple scattering and particle size and further indicates that our modeling approach is successfully isolating the spectral signature of surface adsorbed water in the 3 μm region.

Conclusions: Preliminary results with Hapke modeling of reflectance spectra show changes in the 3 μm region water absorptions with particle size, distinct from crystal field absorptions near 1 μm . Future work includes quantitative comparisons of 3 μm band shape as a function of particle size, and forward modeling of water-free olivine spectra using independently calculated optical constants.

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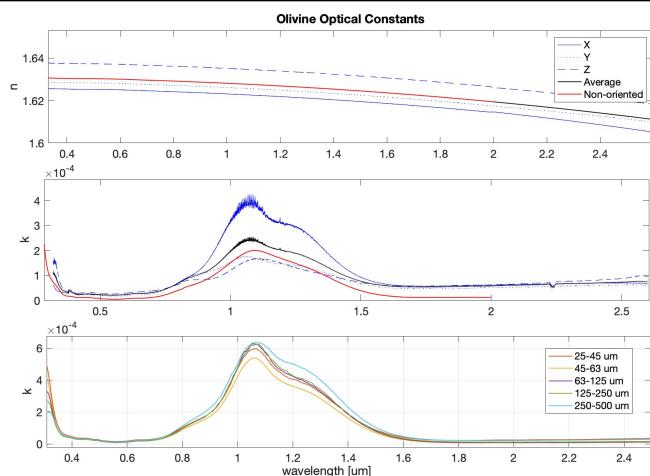


Fig 2a. Optical constants of San Carlos Olivine from existing literature [18,19, top & middle panels], and calculated by this study [bottom panel]. Note the degree of similarity between k curves for different particle sizes despite noticeable differences in their reflectance curves in fig.1.

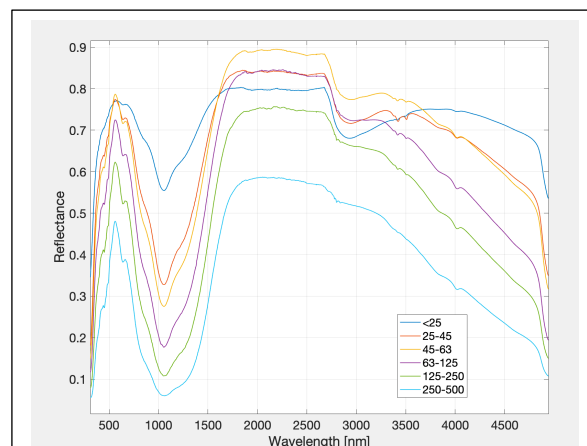


Fig 1. Reflectance spectra of San Carlos Olivine particle size separates, before Hapke modeling.

Fig 2b. Extinction Coefficients (k) of San Carlos Olivine deviating in the 3 micron water absorption region as a function of particle size, caused by the presence of surface adsorbed water.

