THE OPTICAL CONSTANTS OF OLIVINE IN THE NEAR-INFRARED AS A FUNCTION OF IRON CONTENT. D. Trang[1], P. G. Lucey[1], and J. J. Gillis-Davis[1], [1]Hawaii Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, 1680 East-West Rd. POST517, Honolulu, HI 96822 (dtrang@higp.hawaii.edu).

Introduction: Iron-bearing olivine is detected on the basis of its broad absorption at 1-μm [1]. Identification of olivine is important because it is a common mineral found on rocky bodies and comets [2] in the Solar System. In fact, olivine has even been detected in circumstellar disks around young stars [3]. The broad 1-μm absorption is the result of olivine's orthorhombic structure, which gives rise to absorption maxima at ~0.91-, 1.08-, and ~1.25-μm (Fig. 1) [1].

Disentangling the 1-μm feature in spectra will allow us to derive the Fo content of olivine. Yet, unraveling the three absorptions in spectra of rocky bodies becomes difficult because the large variation of parameters for planetary surfaces (e.g., complex mineral mixtures, surface temperatures, degree of space weathering, particle size and composition of olivine). Hence, the use of laboratory spectra to deconvolve the physical and compositional properties of planetary spectra would require an infinite number of experiments to be done [4]. Alternatively, a quantitative method developed by [5,6] allows modeling a multitude of physical and compositional properties of a material. However, the radiative transfer modeling requires the optical constants of each material used in the calculations. Optical constants are physical parameters that describe the interaction of electromagnetic radiation and the material and are fundamental to first-principles modeling of the spectral properties of planetary surfaces.

Optical constants for olivine as a function of Fo content are available from [4]. In that work a series of olivine spectra from 0.4-2.5-μm were converted to optical constants, as a function of Fo. In this work we followed the method of [7] who fit input spectra with the modified Gaussian model (MGM) of [8], then regressed the Gaussian parameters on mineral chemistry. This method yields improved optical constants when compared to [4] for the following reasons: 1) It is able to use an entire spectrum to characterize an absorption, 2) It uses fewer parameters to quantify a spectrum by an order of magnitude, 3) Includes many wavelengths for derivation of each optical constant, which improves data quality, and 4) Provides optical constants at any arbitrary set of wavelengths, thus eliminating the need to resample the data.

Optical Constants and MGM: Optical constants are represented by $\boldsymbol{n}=(n+ik)$, where n is the real index of refraction, and k is the coefficient of the imaginary index of refraction [5]. For transparent material, the index of refraction governs how light bends as it crosses between two media [5]. In the near IR, this value is nearly constant for any silicate mineral. In contrast, the imaginary part, k, represents how efficiently the material absorbs light [5]. Here, we are interested in the values of k and how it varies as a function of Fe content in olivine. To lessen the number of coefficients compared to [4], we used Gaussians to represent the three absorptions. This method was proven successful by [7] to demonstrate how pyroxene absorptions varied as a function of Fe and Ca content. The MGM is represented by the equation,

$$g(x) = s \cdot \exp\left(\frac{-(x^n - \mu^n)^2}{2\sigma^2}\right),$$

where s is the strength, μ is the center, σ is the width, and n controls the symmetry or relative slopes of a Gaussian [8]. In this study, n, the Gaussian parameter, is equal to 1 because we are working in units of wavelength [8]. Identical to the work of [7], the goal of this study is to represent the 1-μm feature with three Gaussians superimposed on a continuum. Each Gaussian is governed by three parameters: strength, center, and width, and the continuum is modeled as a straightline in units of energy defined by two points, which totals to 11 parameters. We then used a least-square linear regression on each parameter as a function of Fo content, which totals to 22 parameters: 11 parameters for the slope and 11 for the y-intercept. To simplify the parameterization of the olivine spectrum other possible absorptions outside the 1-μm feature were ignored.

Methods: We used olivine reflectance spectra from [4,9]. In total, there are 53 individual measurements of olivine ranging from Fo_{01} to Fo_{97}. At further inspection, 40 of the 53 spectra have $>Fo_{80}$. We applied the equations from [4] to the three data sets, which converted the data sets from reflectance spectra to k-spectra or single scattering albedo [5].

Before we fit Gaussians to absorptions in k-spectra, it was necessary to find the baseline that the Gaussians would be superimposed on; this is called the continuum (Fig.1). The continuum is a line in units of energy, which is roughly tangent to the spectrum [8]. However, in units of wavelength, the continuum curves upwards at wavelengths closer to zero (Fig. 1) [7]. In this study, we calculated the continuum in two steps: 1) It is observed in k-spectra in general that the continuum has lower values at shorter wavelengths. For this purpose, we subtracted the slope that intersects the origin and the lowest k/wavelength ratio in the data. This additional step allows us to calculate the continuum with the point slope equation. 2) As noted, the continuum is flat in energy, which allows the continuum to be calculated by two points in energy. The continuum is given by this point slope formula,

$$C(x) = y_1 + \frac{y_2 - y_1}{x_2^{-1} - x_1^{-1}} \cdot (x - x_2^{-1})$$

The two points that defines the continuum are selected to minimize influence by absorptions. Accordingly, we choose 0.6- and 1.85-µm to represent the continuum.

Results and Discussion: The MGM model yielded quality fits to the *k*-spectra olivine data sets (Fig. 1) Table 1 lists the 22 Gaussian parameters derived here and their associated R^2 values. The lowest standard deviations are for Cloutis and Sunshine data sets range between 10^{-6}-10^{-7}. Currently, the fits for the King data set are between 10^{-5}-10^{-6}. We are still working on finding the lowest standard deviation fits for King data set. Also, we provided fits for only 51 of the 53 spectra. One of the *k*-spectra had an anomalous spike while the other *k*-spectra did not generate a satisfactory fit. The resulting strength, width, and center of the three Gaussians as well as the two points in the continuum did show a relationship to Fo number (Fig. 2).

Conclusion: We successfully parameterized the *k*-spectra as a function of iron in 22 parameters and determined that these optical constants correlate with olivine composition (Fig. 2). Optical constants from this work will improve quantitative mineral abundances and chemistry compositions using radiative transfer modeling of rocky bodies in our Solar System.

Future work will address minor errors that we encountered, including: 1) accounting for other absorptions, 2) expanding the program so that the Gaussians can search for more ways to modify themselves in order to find the lowest standard deviation and 3) finding the lowest standard deviation fits for the King data set.

References: [1] Burns R.G. (1993) *Mineralogical Applications of Crystal Field Theory,* 2nd ed. [2] Lisse et al. (2006) *Science*, 313, 635-640. [3] Lisse et al. (2008) *ApJ*, 673, 1106-1122. [4] Lucey P.G. (1998) *JGR*, 103, 1703-1714. [5] Hapke B. (1993) *Theory of Reflectance and Emittance Spectroscopy*. [6] Clark R.N. and Roush T.L. (1984) *JGR*, 89, 6329-6340. [7] Denevi et al. (2007) *JGR*, 112, E05009. [8] Sunshine et al. (1990) *JGR*, 95, 6955-6966. [9] Sunshine (1994) Ph.D. Dissertation.

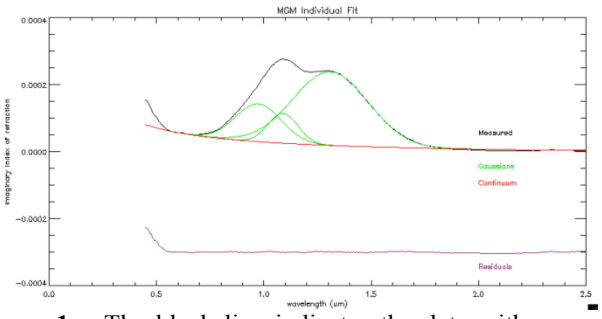

Figure 1 – The black line indicates the data with an Fo_{01}. The green line represents the Gaussians fitting the data. The red is the modeled continuum. The bottom line is the residuals, or the difference between the data and the model.

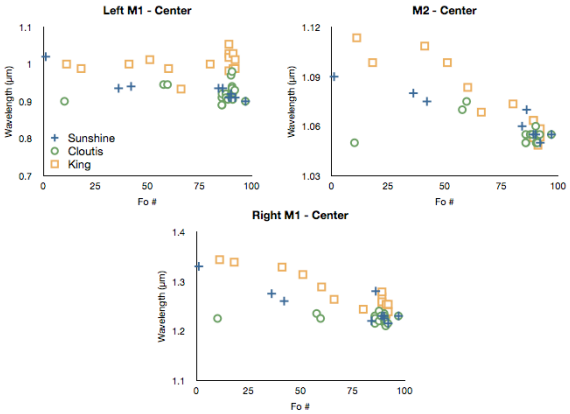

Figure 2 – These graphs represent a sample of the derived parameters from the MGM model. The samples are the center of each Gaussian.

	Ax	B	R^2
Center M1-L	-0.0005	0.9632	0.1549
Center M2	-0.0003	1.0806	0.4748
Center M1-R	-0.0007	1.2841	0.4432
Strength M1-L	-1.05E-06	0.0001	0.5962
Strength M2	-4.99E-07	8.58E-05	0.2182
Strength M1-R	-1.08E-06	0.0002	0.6057
Width M1-L	-4.68E-05	0.1951	0.0111
Width M2	-1.73E-05	0.1498	0.0049
Width M1-R	-0.0001	0.2425	0.1649
Continuum 0.6-µm	-8.77E-07	9.12E-05	0.6657
Continuum 1.85-µm	-1.57E-06	0.0002	0.5911

Table 1 – L denotes the left Gaussian and R is the right Gaussian of M1. x is the variable representing Fo content. These data are only from Cloutis and Sunshine spectra since we are still improving the fits for the King spectra.