Motivation: Carbonate minerals are of interest to questions involving volatile and climate history on Mars [e.g., 1,2]. In particular, the abundance of carbonate-bearing minerals can provide useful bounds on the amount of CO$_2$ out-gassed into the atmosphere over Martian history and their spatial distribution and mineralogy can constrain the environments in which they formed. Infrared spectral observations from aircraft and Earth-orbiting satellites provided evidence for carbonates in the Martian environment [3,4]. Infrared observations made from spacecraft near Mars were interpreted to indicate the presence of carbonates [5,6]. The carbonates were associated with the surface dust and the mineralogy was interpreted as being consistent with magnesite [6]. Recent near-infrared observations from Mars orbit have been interpreted to show magnesite outcrops in restricted locations [7].

Quantitative abundance estimates of carbonates on Mars is <5% [3,6,8,9]. Additional quantitative estimates can be provided via theoretical modeling of the reflectance from the Martian surface. However, such modeling relies upon optical constants, the real ($n$) and imaginary ($k$) indices of refraction, of candidate materials. In the near-infrared data to determine $n$ and $k$ of calcite and magnesite have been available for ~100 years [10,11] but at relatively poor spectral sampling. More recently [12] reported $n$ and $k$ for calcite, but not magnesite. This lack of $n$ and $k$ prompted me to estimate them for magnesite for use in quantitative Martian compositional modeling.

Approach: To derive wavelength dependent $n$ and $k$ the approach of [13] is used. In summary, this consists of estimating $k$ from reflectance measurements via a model, combining the results with independent estimates of $k$ at longer wavelengths, and then applying a subtractive Kramers-Kronig calculation to get $n=f(\lambda)$. This process is iterated until there are negligible changes in $n$ and $k$. The interested reader is referred to [13] for more details. The average visible $n$ of magnesite was used for initial estimates [14]. Independent $n$’s and $k$’s at longer wavelengths can assist in the iterative approach [13]. To estimate the $n$ and $k$ of magnesite at infrared wavelengths, I use dispersion analysis that describes the Fresnel reflectance of a sample in terms of a series of classical oscillators [e.g. 15].

Available laboratory data: A total of eleven spectra, containing data in the 0.3-5 μm wavelength region and labeled as magnesite were acquired from the CRISM, RELAB, and ASTER spectral libraries [16-18]. Those samples having documented mineral contaminants were eliminated, leaving a total of eight remaining samples that are shown in Fig. 1.

Figure 1. Reflectance spectra of magnesite (top two panels) and siderite (bottom panel). Spectra in panel a exhibit features near 1.5 and 2 μm likely due to molecular water. Spectra in panel b exhibit a feature near 1.2 μm consistent with the Fe band in siderite.

The spectral behavior of the remaining samples was visually compared, and two groups of spectral behavior were observed. One exhibits two broad absorptions near 1.5 and 2 μm whose positions and shapes are consistent with the presence of molecular water in the sample (Fig. 1, panel a). The other group exhibits a broad absorption centered near 1.2 μm (Fig. 1, panel
b), whose position is consistent with an electronic transition due to ferrous iron [19], as shown by comparison to Fig. 1, panel c, where the spectra of iron carbonate (siderite) are shown. Magnesite samples SIG-002 and EAC-006 are both from Norway, and documented to contain Fe [20,21]. Differing amounts of Fe in dolomites gave rise to increasing absorption near 1.2 \( \mu \text{m} \) [22,23]. Based upon this information I assign the 1.2 \( \mu \text{m} \) feature in the magnesite samples to Fe substitution within the mineral. Because magnesite sample EAC-006 contains two separate grain size fractions, I chose to use this sample for determination of \( n \) and \( k \) of magnesite in the near-infrared and visual region.

The ASU-TES spectral library [24] contains two magnesite samples that had been previously discussed in detail [25]. I chose sample C55 because its reflectance, calculated via Kirchoff’s law, exhibited the highest values with most distinct peaks in the regions of the fundamental carbonate vibrational modes.

**Initial Results:** Using a mean grain size of 67.5 \( \mu \text{m} \) for the larger grain size EAC-006 sample, the 0.3-6 \( \mu \text{m} \) \( k \)'s were estimated with constant \( n \). The 5-40 \( \mu \text{m} \) data were modeled to determine both \( n \) and \( k \). The resulting \( k \)'s from the two analyses were combined and a subtractive Kramers-Kronig analysis was used to estimate the wavelength dependent behavior \( n \) at all wavelengths. These initial results are shown in Fig. 2.

**Future Work:** These initial estimates will be improved by including independent analyses of the smaller grain size fraction of EAC-006. Additionally, a comparison of the infrared wavelengths \( n \)'s and \( k \)'s to those of [26] will be undertaken.

Sample EAC-006 has spectral signature due to Fe. To estimate \( n \)'s and \( k \)'s of an Fe-free magnesite, I will estimate the spectral signature using the spectra lacking an absorption near 1.2 \( \mu \text{m} \).

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**References:**


![Figure 2.](https://example.com/figure2.png)