SENSITIVITY OF HAPKE MODELING OF MIXTURES TO GRAIN SIZE; Marcia L. Nelson (Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, 87521)

In its most basic form, Hapke reflectance theory (1981) calculates the reflectance of a surface from the effective single scattering albedo of the surface. The single scattering albedo of a mineral can be determined by fitting the theory to a spectrum of that mineral, or calculated from the optical constants. The effective single scattering albedo of a mixture is a weighted average of the single scattering albedos of the minerals present. Several investigators have shown that these equations can be used to determine mineral abundances from a reflectance spectrum of a mixture, given the single scattering albedos of the component minerals.

The majority of the work done to date has been with laboratory samples. The single scattering albedo of the component minerals has been determined by fitting the theory to a spectrum of the pure mineral sample from which the mixture has been made. This technique has assured that the grain size of the minerals in the mixture is the same as that from which the component single scattering albedo has been derived. An early attempt to apply the technique to analyzing the spectrum of Vesta (Nelson and Bell, 1988) illustrated the problem with this technique when samples of the actual surface are unavailable. Component spectra were chosen from the literature, to match the mineral chemistry of the eucrite meteorites as closely as possible. No grain size information was available for the component spectra chosen, but the pyroxene was obviously quite large, due to the low albedo. The fit grossly overestimated the abundance of the plagioclase in order to raise the albedo of the mixture to match that of the asteroid. It also showed that the grain size of the minerals in the actual surface is not included in the fit at all.

Many laboratory studies have shown that the reflectance of a mineral varies, sometimes significantly, with the grain size. Therefore, a single scattering albedo derived by a fit to a spectrum is not unique to that mineral. The single scattering albedo of a sample is a function of the grain size as well as the absorption coefficient of the mineral. Hapke includes an equation for calculating the single scattering albedo from the optical constants, the grain size, and some internal scattering parameters which vary with the index of refraction.

Nelson and Clark (1988) have shown that it is possible to invert these equations to determine the abundance of minerals in a laboratory mixture of two glasses. This approach separates the grain sizes of the component minerals from that of the actual surface. The study found determined the abundances to within 10% for mixtures of 90/10 & 75/25, increasing to 20% for the 50/50 mixture. The grain sizes of the component minerals were carefully determined from SEM images of the actual grains. The study also showed that the grain size determined by fitting the theory to the spectrum of the pure mineral, assuming everything else constant, was slightly different than the grain size calculated from SEM images of the glass particles, which was slightly different from the average grain size of the sieve size fraction used.

Hapke theory defines the grain size as the diameter of the sphere which has the same geometric cross-sectional area as the average geometric cross-section of the particles in the surface. This can be calculated from an SEM image of the sample, but the previous study indicated that even this approach doesn't exactly match the optical grain size determined by

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fitting the theory. It is also not obvious how accurate this description would be for a sample with a grain size distribution similar to the lunar regolith.

Ultimately, additional laboratory work will be required to fully characterize the dependence of the abundance determinations on the accuracy of the grain size used in the model, but some useful information can be derived from the glass mixture spectra used in the previous study. These samples are extremely well characterized, therefore they are suitable for determining the best way to relate the measured grain size to that determined from a fit of the model. This will be necessary for determining the optical constants of a mineral from laboratory data.

Preliminary modeling indicates that, not surprisingly, the abundance fits are slightly improved by using the grain sizes determined by fitting to the component spectra over that calculated from the SEM images. Work in progress models each component as a mixture of two grain sizes determined from the bimodal histogram of the measured dimensions. These results will be compared with the other approaches to determine which gives the most accurate abundances. This approach will also be used to derive the absorption coefficient from the reflectance spectrum, to determine how much it differs from that derived using a single grain size.

References:

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