THE MODELING OF THE MAGNETITE REFLECTANCE SPECTRA REVISITED: A GENERALIZED HAPKE'S FORMALISM

L. Teodoro[1*], T. Roush[2], D. Blewett[3] and J. Cahill[3], [1]BAER, NASA Ames Research Center, [2]NASA Ames Research Center, [3] Johns Hopkins University Applied Physics Laboratory *luis.f.teodoro@nasa.gov

Introduction: Magnetite is an accessory mineral found in terrestrial environments, some meteorites, and the lunar surface. The reflectance of magnetite powers is relatively low [1], and this property makes it an analog for other dark Fe- or Ti-bearing components, particularly ilmenite on the lunar surface. Three literature values of magnetite optical constants [2-4] were used to calculate the bidirectional reflectance, via Hapke theory using two particle phase function representations (isotropic and non-isotropic [5]), but could not reproduce the laboratory measured bidirectional reflectance [6]. This result has motivated us to apply Hapke theory to estimate the complex refractive indices of magnetite from the measured reflectance spectra using the techniques described in [7-11]. We have also implemented the ability to use a Mie scattering representation of the particle phase function.

Methods: To obtain the real component of the refraction refractive index we have applied the following procedure:

1. Use the Hapke theory in a generalized chi-square minimization procedure to obtain the imaginary component of the complex refractive indices index of a coarse (67.5 microns) and fine (22.5 microns) grain size.

Given the complex refraction refractive indices of the two grain populations obtained from the above procedure we employ our generalized Hapke code to obtain the reflectance spectrum of the populations. In this code the single scatter albedo can use either the traditional version of the Hapke formalism or replace its single scatter albedo equation by a Mie calculation of a spherical grain (hereafter Hapke+Mie). In Figure 1 we present the tests performed to assess the reliability of the new code. In all the above analysis we have set the Hapke h to 0.05 The blue and green present the measured reflectance according to [2]. The simple Hapke analysis (dashed-yellow and dashed-orange denote yielded the same values as the Cloutis measurements [2], full green and blue lines represent the Cloutis Measurements [2] of coarse and fine (blue) magnetite grains, respectively. The Hapke+Mie calculations, violet (fine) and brawn brown (coarse), present gross similarities with the standard Hapke model. However, the Hapke+Mie spectra are flatter and have subdued 1 micrometer bands. The two Hapke+Mie also present small scale variance. We hypothesize this
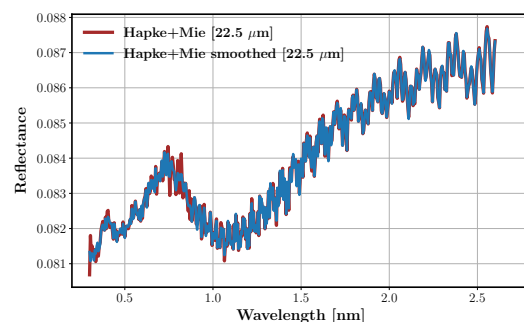
is due to *i)* variance in the derived refraction indices s or *ii)* interference patterns resulting from the reflections of the photons on the surfacewithin the grains of the assumed spherical geometry.

Discussion:
The spectra computed with the simple Hapke code shows that, given the optical constants derived from the Hapke analysis, we can reproduce the reflectance spectrum from which the optical constants were derived. This gives confidence that the Hapke code is internally consistent.
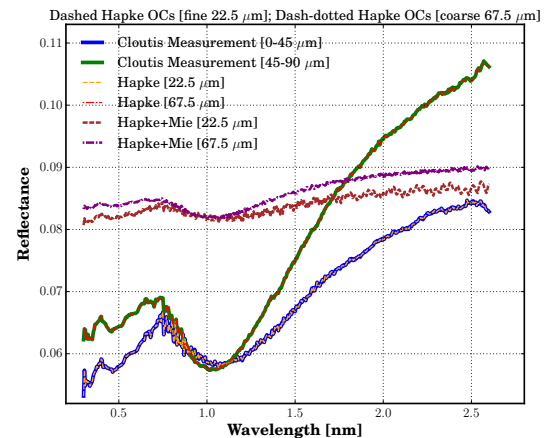
Figure 1. Reflectance versus Wavelength. The Hapke h parameters was set to 0.05. Full lines represent the Cloutis Measurements [2] of coarse (green) and fine (fine) magnetite grains.

Figure 2. Coarse grain Hapke+Mie reflectance versus wavelength for smoothed (blue) and unsmoothed (red) imaginary refraction indices.

To understand the origin in of the internal variance of the Hapke+Mie curves we smooth the imaginary component of the refraction index. In Figure 2 we demonstrate that the reflectance for smoothed and unsmoothed refractive indices are very similar ruling out the fluctuations in the derived imaginary indices via the Hapke model. This suggests that the high frequency sinusoidal behavior likely arises from the constructive and destructive interference patterns associated with the Mie code.

References: [1] Adams, J.B. 1974 in Infrared and Raman Spectroscopy of Lunar and Terrestrial Minerals, C. Karr Ed., Academic Press, New York, 109-116. [2] Querry, M.R, 1985, Optical Constants, CRDCCR-85034, US Army Armament, Munitions, and Chemical Command, Aberdeen Proving Ground, MD. [3] Huffman, D.R. and J.L. Stapp 1973, in Interstellar Dust and Related Topics, J.M. Greenberg and H.C. Van de Hulst, Eds., IAU Symposium 52, 297-301. [4] Triaud, A., www.astro.uni-jena.de/Laboratory/ OCDB/mgfeoxides.html. [5] Mustard, J.F. and C.M. Pieters 1989 JGR, 94, 13,619-13,634. [6] Roush, T.L. et al., 2016, 47th LPSC, abstract 2289, Lunar Planetary Institute, Houston, TX. [7] Roush, T.L. et al. 1990, Icarus 83, 355-382 [8] Lucey,P.G.. 1998 *JGR 103 E1,*1703-1713[9] Roush, T.L. 2003 *Met. Planet. Sci, 38,* 419-426 [10] Roush, T.L. 2005 *Icarus, 179,* 259-264 [11] Roush et al 2007 *JGR 112,* E10003