A PHENOMENOLOGICAL THEORY OF THE REFLECTANCE OF PARTICULATE MEDIA: SCATTERING REGIMES AND LORENTZ BAND FEATURES

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Introduction: The confounding effects of particle morphology on the spectra of particulate surfaces can impede the remote detection and identification of planetary minerals. Hunt and Vincent (1968) [1], and later Moersch and Christensen (1995) [2], showed how the interplay of surface scattering and volume scattering behavior leads to four classes of Lorentz band features. Class 1 features are reflectance peaks that increase with increasing particle size; Class 2 features evolve from troughs to peaks, while Class 3 features are troughs that decrease in contrast with increasing particle size. Class 4 features refer to the Christiansen effect where n passes through unity. While [1] and [2] document these classes, using supporting examples from measured mineral spectra, they do not provided a unified theory or framework that predicts the transition from volume to surface scattering behavior or the complex dependence of band classes on the two refractive indices, $\{n, k\}$, as well as size parameter, R_x. It is the goal of this presentation to present a phenomenological theory of the reflectance of particulate media in the three-dimensional space of $\{n, k, R_x\}$.

Methods: We use a numerically exact solution to the conventional one-dimensional radiative transfer equation (RTE) for the reflectance, R, of a homogeneous slab of scatters [3]. This modeling approach computes R for normal incidence assuming a Lorenz-Mie single scattering phase function for spherical particles [3] that is averaged over a small range of neighboring particles diameters to remove the small ripples that are superimposed on the larger Mie resonances.

Results: Using 3000+ solution to the 1D RTE, we determine analytic boundaries, as a function of $\{n, k, R_x\}$, that separate volume and surface scattering, as well as Class 1-3 band feature behavior, for size parameters $R_x \geq 1$. We find a transition in scaling for $k > 1.5$ associated with the known complex formulation of extinction of light in a single sphere at large k; this transition is estimated analytically. Implications for the evolution of reststrahlen features with particle size are highlighted. Contour plots showing the sensitivity of reflectance to changes in particle morphology and refractive indices are presented and explained in separate $\{k, R_x\}$ and $\{n, k\}$ spaces. We apply our phenomenological theory to published spectra of calcite, quartz, gypsum, and various phyllosilicates.

References: [1] G. R. Hunt and R. K. Vincent, (1968) J. Geophys. Res. **73**(18), 6039–6046. [2] J. E. Moersch and P. R. Christensen, (1995) Journal of Geophysical Research **100**(E4), 7465–7477. [3] M. I. Mishchenko, J. M. Dlugach, E. G. Yanovitskij, and N. T. Zakharova, (1999) J. Quant. Spect. Rad. Trans. **63**, 409–432.