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Abstract
We have developed a regolith radiative transfer model (RRT) based on a first-principles approach to regolith modeling that is essential for near-to-far infrared observations of grainy surfaces, and is readily configured to answer fundamental questions about popular models with which all remote observations of all airless solar system bodies with granular surfaces are currently interpreted. Our model accounts for wavelength-size regolith particles which are closely packed and can be heterogeneous in composition and arbitrarily shaped. Here we present preliminary results showing the role of porosity on layer reflectivity.

Introduction
Regolith scattering can be categorized by two major optical regimes defined by the refractive indices of the regolith material. The first regime is referred to as "surface scattering" (where real and/or imaginary indices, and surface reflectance are large). The second regime is "volume scattering" (where the imaginary index is low and the real index is greater than or close to unity) which has moderate surface reflectance and low internal absorption. Restrahlen bands fall into the first category and "transparency regions" including the Christiansen feature (where the real index $n = 1$) fall into the second (Mustard and Hays 1997, MH97). Mineral identification and grain size estimation are accomplished from remote sensing data using the shapes and relative strengths of these strong bands, and it is in these strong bands and the transparency regions between them where the shortcomings of standard theoretical models are the most apparent. In a general way, the variations of these different feature strengths with regolith grain size variations are somewhat in accord with predictions of current models, which assume independent grain scattering and most often time, grains much larger than wavelength. However, at a closer look, the correspondence is poor, as shown by Moersch and Christensen (MC95) for granular silicates with well known composition and size distribution. The reason for this is because their basic assumptions are violated by key physical properties of regolith surfaces (close packing, irregular particles, wavelength size grains). The fact that these popular models fail to capture important features of laboratory silicate data casts doubt on their validity for compositional grain size inferences from remote observations of planetary surfaces. Our regolith model is based on the discrete dipole approximation (DDA) where scattering calculations are not limited by packing density, shape, or size of particles in the regolith.

Model description
The DDA calculates the scattering and absorption of electromagnetic waves by a target object of arbitrary geometry and thereby automatically accounts for all close packing effects and grain size dependence. In the DDA approach, target objects are modeled as a regular lattice of individual polarizable dipoles with size smaller than a wavelength. The polarizability of each dipole can be adjusted to represent the refractive index of an arbitrary material (Draine and Flatau 1994).
To apply the DDA approach to a regolith layer, we have made several changes from the normal way it has been used. In one novel modification, horizontally extended, semi-infinite slabs of regolith, made up of closely packed grains of arbitrary size and shape, are modeled using a single target 'unit cell' subject to periodic horizontal boundary condition (PBC) (see figure 1). In a second novel modification, the emergent intensities are calculated in the near field of the layer (see figure 2). This is a new approach to calculating scattering using the DDA method since traditionally all scattering calculations have been done in the far field. This step itself has two parts: evaluating the scattered electric field on a planar 2-D grid, and evaluating the hemispherical angular intensity distribution using a Fourier transform approach. The emergent intensity can be averaged to obtain reflectivity and emissivity for comparison with observations.

Results
The various parts of this approach have been thoroughly tested at limiting cases. In addition we have results for scattering by granular layers of various porosities, all having the same optical depth τ (see

larly reflected and directly transmitted peak present at 40^o. The less dense layers are more reflective and less transmissive. There is a transition layer at $\%50$ filling factor which has no directly transmitted beam (where phase shift of light as it travels between many surface interfaces plays an important role in transmission). It's apparent in the different layer porosities that extinction does not scale simply as optical depth of independent particles, and spacing does matter. This result has further implications about the transition region between multiple and coherent scattering. More results will be discussed at the meeting.

Acknowledgements

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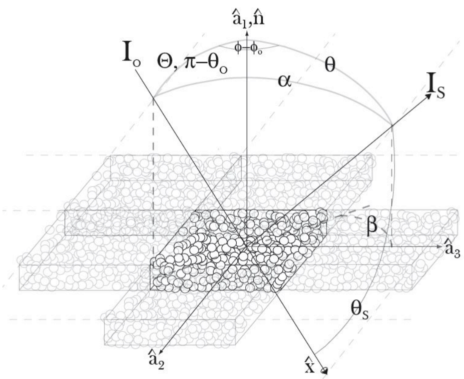

Figure 1: Schematic of the DDA code operated in the PBC regime, with the TUC shown in the center and image cells arrayed around. I_o indicates the incident flux and I_s indicates the scattered flux. Θ is the angle between the incident beam and normal axis of the particle layer and ϕ is the azimuthal rotation around the normal of the layer. θ is between scattering ray and normal.

References

Draine, B. T. and Flatau, P. J. (1994) J. Opt. Soc. Am. 11, 1491-1499.
Moersch, J. E. and Christensen, P. R. (1995) J. Geophysical Research, 100, 7465-7477.
Mustard, J. F. and Hays, J. E. (1997) Icarus, 125, 145-163.

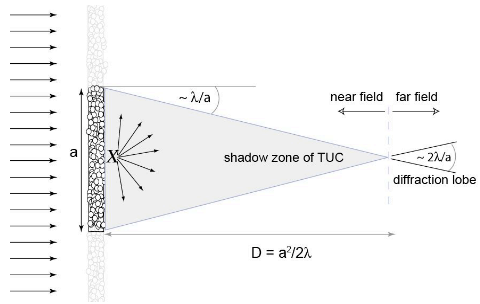

Figure 2: Schematic of our approach to determining the forward scattered intensity at point X in the shadow zone of the TUC. The diffuse reflectivity will be determined in a similar geometry on the lit side of the TUC.

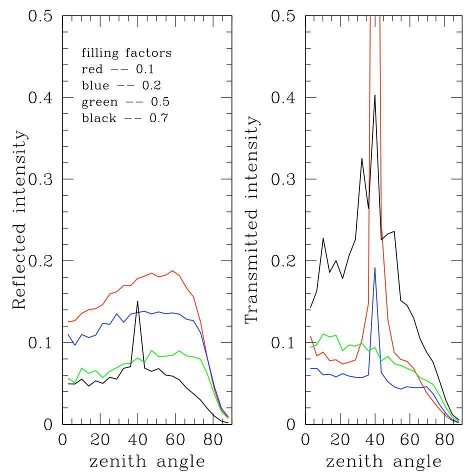

Figure 3: Reflected and transmitted intensity as a function of zenith angle for granular layers of various filling factors. All layers are composed of quartz monomers and illuminated by a 15.5μ beam at 40^o zenith angle.