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Light scattering in planetary regoliths: hybrid geometric optics and radiative transfer

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Abstract

Multiple light scattering in arbitrary finite discrete random media in the geometric optics regime is approximated by mixing radiative transfer and by mixing radiative transfer and geometric optics. In the hybrid approach, the core of a finite medium is treated using radiative transfer and the mantle of the medium is composed of close-packed finite particles treated using geometric optics. Preliminary results show that the new hybrid model is better than purely using the radiative transfer when the studied media is dense.

1. Introduction

Multiple light scattering in the geometric optics regime is computationally heavy when a large number of objects are present. This is a problem especially with planetary regoliths, such as in the case of asteroid Vesta, and hence the multiple scattering has been approximated by using radiative transfer [1].

In order to improve the model, we created an improved version of the SIRIS [2, 3, 4] capable of solving light scattering from multiple particles and a packing program capable of generating densely packed random media from arbitrary particles. These programs were used to compare the results obtained by using the generalized Snel's law, a pure radiative transfer approach, and a new hybrid model, for spherical dense discrete random media composed of Gaussian random sphere particles [2] following a power law distribution. The preliminary results show improvement compared to the pure radiative transfer approach.

2. Hybrid model

In the mixed model, discrete random media is divided into two parts. Crust is made of discrete particles, and the light propagates according to the Fresnel and generalized Snel's laws. In the core, the multiple scattering is approximated by using radiative transfer with a corrected mean free path. The corrected mean free path is obtained by logging the lengths of the scattering events with a separate program and using the logged distribution to generate distances to a next scattering event.

3. Results

128 discrete random media composed of a hundred different Gaussian sphere particles were generated. The particles were scaled according to a power law (index a=3, wavenumber k=$2\pi/\lambda$, in which λ is a wavelength, minimum radius kr=50, and maximum kr=200), placed randomly into a periodic box, and packed to volume fraction ν=0.4 by using the simplified version of the mechanical contraction [5]. From the packed media, spherical media of radius kR=2000 were culled, and the light scattering characteristics of each geometry were solved and averaged by using the SIRIS. Input geometries for the hybrid model were generated by replacing inner particles with a sphere of size (kR = 1400). The pure radiative transfer approach was simulated by using a spherical medium of size kR=2000 and statistical diffuse particle made of light scattering characteristics of individual particles, which were used to generate the discrete random media. The refractive index was set to 1.5+i0.0001.

4. Summary and Conclusions

Fig. 1 shows that the new hybrid model approximates the multiple scattering characteristics better than the pure radiative transfer model. The figure shows that the largest discrepancies are in the backscattering direction and around α=90°. The results could be improved by modelling the core's surface better and improving the corrected mean free paths. The new hybrid model could be used to model any regolith surfaces in the geometric optics regime.

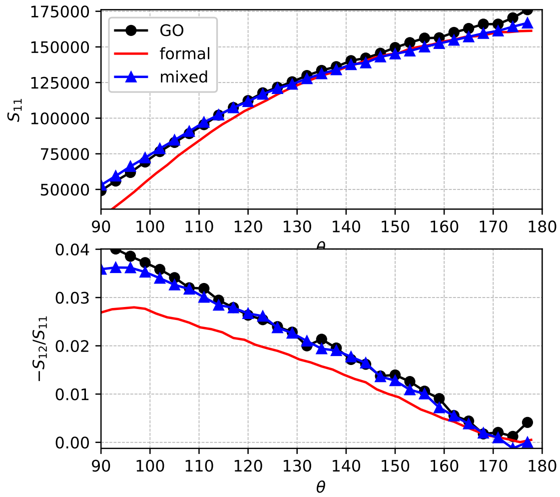

Figure 1: Intensity (up) and degree of linear polarization (down).

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