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Numerical analysis of space weathering effects on light scattering by asteroid surfaces

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Abstract

We analyze the effects of space weathering on light-scattering features of small atmosphereless planetary bodies. We have developed a novel radiative transfer (RT) approach to model light scattering by dense discrete random media. In this work, we combine the RT approach to the geometric optics which allows us to model space-weathering effects on light scattering by planetary surfaces more rigorously that has been possible before.

1. Introduction

Airless planetary bodies are exposed to the space weathering processes such as the energetic solar and cosmic radiation, implantation and sputtering from solar wind particles, and micrometeorite bombardment. Space weathering is known to alter physical and chemical composition of the surface of an airless body. For example, a significant effect of the space weathering is the production of nanophase iron (npFe^0) near the exposed surface [1, 2]. This, in turn, impacts the remote light-scattering observables, e.g., the visible and infrared spectra. Typically, space-weathered materials are darker at visible wavelengths but differences in brightness vanish at near infrared. Moreover, the diagnostic absorption bands in the spectrum are much weaker for space-weathered materials.

2. Numerical method

We model light scattering by asteroids with the hierarchical geometric optics (GO) / radiative transfer (RT) approach. The asteroid is assumed to consist of densely packed Gaussian random sphere (GRS) grains of mean size 40 microns. Spherical npFe^0 particles are embedded in each grain with the specified packing density. Contributions of the npFe^0 particles are treated by the Monte Carlo RT algorithm. Reflections and refractions on the grain surface and propagation in the grain are addressed by the GO. The approach provides the ensemble average phase function which is used in the higher level RT algorithm as an input parameter to compute the scattering characteristics of the entire asteroid.

The mean free path and the volume-element scattering matrix are the input parameters for the higher level RT algorithm. Since the npFe^0 inclusions are expected to have a strong contribution to the total scattering, their contribution must be carefully addressed. We compute interactions of the npFe^0 particles in the volume element exactly by the fast superposition T-matrix method (FaSTMM) [3] in order to retrieve the incoherent mean free path and the ensemble averaged incoherent scattering matrix [4, 5].

3. Numerical example

Fig. 1 shows an example of calculated spectra with varying npFe^0 density for two different size distributions. The asteroid is assumed to be of a GRS shape with a radius of 100 m, and it is composed of 40 microns GRS olivine grains. We observe that the npFe^0 volume density has a major effect on the spectrum at visible wavelengths.

4. Conclusions

We have developed a novel numerical approach to compute scattering characteristics of space-weathered planetary bodies. Our method applies more rigorous an algorithm to treat the contributions of the npFe^0 particles compared to the standard methods. We have observed that the size and volume fraction of the npFe^0 particles have a significant effect on the light-scattering features of an asteroid. Hence our numerical method may allow for a quantitative interpretation of the spectroscopic observations of space-weathered asteroids.

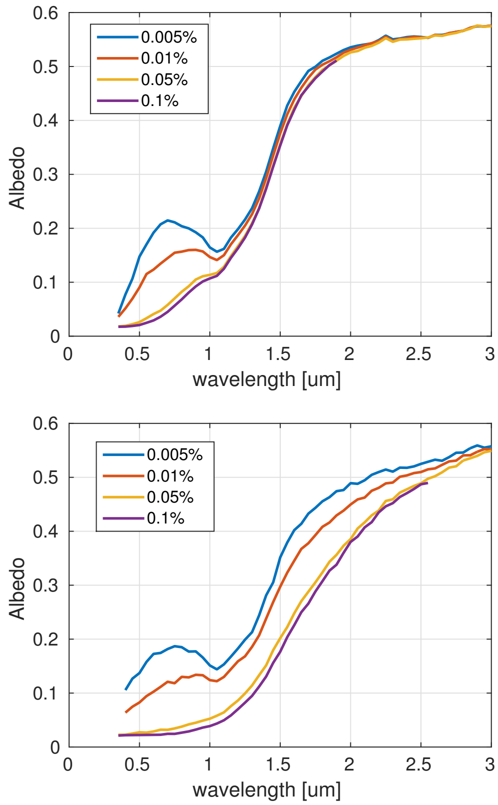

Figure 1: Computed spectra using our model with varying packing densities. The mean radius of npFe^0 particles are 10 nm (top) and 20 nm (top) with the standard deviations of 5 nm (top) and 10 nm (bottom).

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References

[1] Hapke B. Space weathering from Mercury to the asteroid belt, *J. Geophys. Res.*, 106(E5), 2001.

[2] Carle M. Pieters, and Sarah K. Noble, Space weathering on airless bodies, *J. Geophys. Res. Planets*, 121, 1865–1884, 2016.

[3] Johannes Markkanen, and Alex, J. Yuffa: Fast superposition T-matrix solution for clusters with arbitrarily-shaped constituent particles, *J. Quant. Spectr. Rad. Trans.*, Vol. 189, pp. 181-188, 2017.

[4] Zurk L. Scattering properties of dense media from Monte Carlo simulations with application to active remote sensing of snow, *Radio Science* 31(4), 1996.

[5] Karri Muinonen, Johannes Markkanen, Antti Penttilä, Timo Väisänen, and Jouni Peltoniemi, Multiple scattering by dense random media: Numerical solution, *2016 URSI International Symposium on Electromagnetic Theory (EMTS)*, Espoo, pp. 400-403, 2016.