EPSC Abstracts
Vol. 11, EPSC2017-544-1, 2017
European Planetary Science Congress 2017

Multiple scattering modeling pipeline for spectroscopy, polarimetry, and photometry of airless Solar System objects

A. Penttilä (1), T. Väisänen (1), J. Markkanen (1), J. Martikainen (1), M. Gritsevich (1), and K. Muinonen (1,2)
(1) Department of Physics, University of Helsinki, Finland, (2) Finnish Geospatial Research Institute FGI
(antti.i.penttila@helsinki.fi)

Abstract

We are developing a set of numerical tools that can be used in analyzing the reflectance spectra of granular materials such as the regolith surface of atmosphereless Solar System objects. Our goal is to be able to explain, with realistic numerical scattering models, the spectral features arising when materials are intimately mixed together. We include the space-weathering-type effects in our simulations, i.e., mixing of the host mineral locally with small inclusions of another material in small proportions.

1. Introduction

We are combining a set of numerical tools to analyze the reflectance spectra of granular materials. Our motivation for this study comes from the present lack of such tools when it comes to intimate mixing of materials, including space-weathering effects with nano- or micron-sized inclusions in the host matrix. The current common practice is to apply a semi-physical approximate model such as some variation of the Hapke models (e.g., [1]) or the Shkuratov model [2]. These models are expressed in a closed form so that they are relatively fast to apply. They are based on simplifications on the radiative transfer theory. The problem is that the validity of the model is not always guaranteed, and the derived physical properties related to particle scattering properties can be unrealistic [3]. The Hapke space-weathering model does not include correct size dependence for the nanophase iron inclusions [4].

2. The analysis pipeline

Our numerical tool consists of individual scattering simulation codes and a main program that chains them together, calling the codes and converting the output of one code as input for the next code. The chain for analyzing a macroscopic target with space-weathered mineral would go as follows:

1. Scattering properties of small inclusions inside an absorbing host matrix can be derived using exact methods solving the Maxwell equations of the system. From the scattering properties, we use the so-called incoherent fields and the corresponding incoherent Mueller matrices as input for the next step [5, 6].

2. Scattering by a single regolith grain is solved using a geometrical optics method accounting for surface reflections, internal absorption, and possibly the internal diffuse scattering (See Fig. 1 for SIRIS geometrical optics method).

3. The radiative transfer simulation is executed inputting the regolith grains in the previous step as the basic scatterers in a macroscopic spherical, planar, or arbitrary shaped volume element (See Fig. 2 for a schematic presentation of this chain).

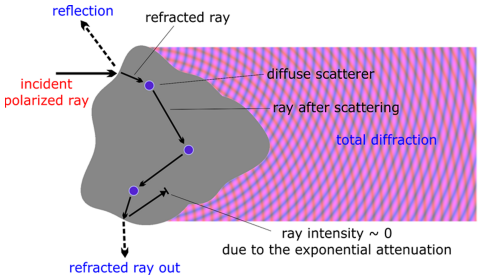

Figure 1: A presentation of the scattering concepts in the SIRIS geometrical optics code by Muinonen et al.[7].

For the most realistic asteroid reflectance model, the abovementioned chain would produce the scattering properties of a planar surface element. Then, a shadowing simulation over the target surface elements would be considered, and finally the asteroid phase

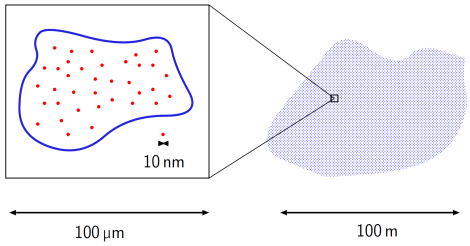

Figure 2: A schematic presentation of the chain of scattering computations for an macroscopic object (in the right) constituting of regolith grains that can include nanoscale internal diffuse scatterers (in the left).

function would be solved by integrating the bidirectional reflectance distribution function of the planar element over the object's realistic shape model.

For mixing intimately two or more minerals with sizes larger than the wavelength of light, the first step of the abovementioned chain would be omitted. Instead, the single grain properties would be computed for every material, and then averaged into imaginary average grain. The macroscopic properties would be computed following the recipe above.

The tools in the proposed chain already exist, and practical task for us is to tie these together into an easy-to-use public toolchain. We plan to open the abovementioned toolchain as a web-based open service. In detail, we are building this chain in a dedicated (virtual) server, using Django application server and Python environment for the chain main functionality. The individual programs to be ran under the chain can still be programmed with Fortran, C, or other.

Acknowledgements

The authors acknowledge the financial support from the European Research Council, Advanced Grant No. 320773 entitled Scattering and Absorption of Electromagnetic Waves in Particulate Media (SAEMPL). The computational resources are provided by CSC — IT Center for Science Ltd., Finland.

References

[1] B. Hapke. Bidirectional reflectance spectroscopy: 6. Effects of porosity. *Icarus*, 195(2):918–926, 2008.

[2] Yu. Shkuratov, L. Starukhina, H. Hoffmann, and G. Arnold. A model of spectral albedo of particulate surfaces: Implications for optical properties of the Moon. *Icarus*, 137(2):235–246, 1999.

[3] Y. Shkuratov, V. Kaydash, V. Korokhin, Y. Velikodsky, D. Petrov, E. Zubko, D. Stankevich, and G. Videen. A critical assessment of the Hapke photometric model. *J Quant Spectrosc Radiat Transf*, 113(18):2431–2456, 2012.

[4] P.G. Lucey and M.A. Riner. The optical effects of small iron particles that darken but do not redden: Evidence of intense space weathering on mercury. *Icarus*, 212(2):451–462, 2011.

[5] K. Muinonen, J. Markkanen, A. Penttilä, A. Virkki, and D. Mackowski. Multiple scattering by dense random media: Volume-element extinction. In *URSI Electromagnetic Theory Symposium EMTS'16*, pages 751–754, Espoo, Finland, 2016.

[6] K. Muinonen, J. Markkanen, A. Penttilä, T. Väisänen, and J. Peltoniemi. Multiple scattering by dense random media: Numerical solution. In *URSI Electromagnetic Theory Symposium EMTS'16*, pages 400–403, Espoo, Finland, 2016.

[7] K. Muinonen, T. Nousiainen, H. Lindqvist, O. Muñoz, and G. Videen. Light scattering by Gaussian particles with internal inclusions and roughened surfaces using ray optics. *J Quant Spectrosc Radiat Transf*, 110:1628–1639, 2009.