EPSC Abstracts
Vol. 7 EPSC2012-594-1 2012
European Planetary Science Congress 2012
© Author(s) 2012

Monte Carlo and T-matrix modeling of the reflection of polarized light by rough, planetary surfaces

D. Guirado and D. Stam
SRON Netherlands Institute for Space Research, The Netherlands (d.guirado.rodriguez@sron.nl)

Abstract

Reflection of light on a rough surface has been modeled by a Monte Carlo technique and the T-matrix method. A high sensitivity of the maximum of the degree of linear polarization to the real part of the refractive index has been found.

1. Introduction

An accurate modeling of the reflection of polarized light on rough surfaces is crucial for the interpretation of polarimetric observations of planets and moons, as well as of remote sensing measurements of Earth. The main purpose of our modeling of light that is reflected by rough, planetary surfaces is the interpretation of data to be collected by SPEX, the Spectrometer for Planetary Exploration, a small and robust spectropolarimeter that has been designed to fly on planetary orbiters on missions to e.g. Mars, the Jovian moon Ganymede, and that will be proposed to fly on Earth remote-sensing missions.

As a first approach to the problem we thought of a surface as a thick layer of compressed dust grains. A Monte Carlo (MC hereafter) technique may be applied then. MC models are flexible (particles of a range of sizes and compositions may be used) and they can run reasonably fast in modern desktop computers.

As MC radiative transfer models are not valid for compact media, we used the T-matrix technique to perform calculations of the polarization signatures of light reflected from the surface of a densely packed body and to calculate the validity limit of MC.

2. Description of the MC model

These are the input parameters of the model: wavelength and incidence angle of the incoming light, packing density factor (ratio between the actual density of the medium and that of the pure substances in it), and scattering matrix and single scattering albedo of the particles forming the surface.

Packets of photons are launched onto the surface with an initial weight $W_0 = 1$. Each packet is split into two parts: one that is absorbed at the bottom of the surface or escapes through the top, and another one that undergoes scattering into the surface. The optical depth to the next scattering point is calculated according to the probability given by the packing density of the medium. The weight of the scattered part of the packet is reduced according to the single scattering albedo. We follow the path of a photon until $W < W_{min}$ and then launch another one. Each time a part of a packet of photons escapes the surface through the top, we record its direction and Stokes parameters. Stokes parameters of light escaping in the same direction are added.

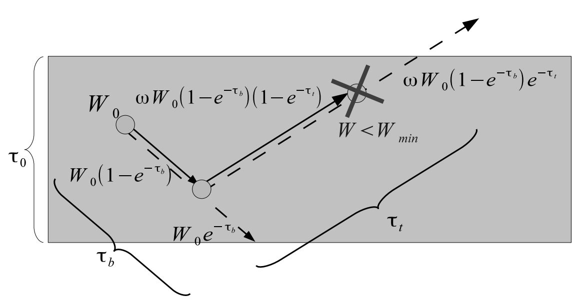

Figure 1: Description of our MC radiative transfer model. W_0 is the initial weight of the packet of photons. It is reduced when a part of it goes to the bottom of the surface (being τ_b the optical path lenght) or to the top (at an optical distance of τ_t). The weight of the packet is also reduced by a factor ω (single scattering albedo) in each scattering event. The path of a packet of photons is followed until its weigh becomes smaller than a certain threshold W_{min}.

3. T-matrix calculations

As the phenomenon of reflection of light by a surface occurs locally, light scattering by a single particle can be a good approximation to reflection by a surface if we illuminate the particle with a gaussian beam and the size of the grain is enough to avoid boundary effects. Calculations are being performed by using the recently released Multiple Sphere T-Matrix Fortran-90 Code by D. Mackowski [1]. Some of the results are being checked by DDA-computations with the ADDA code, which works faster than others for grains in a single orientation [2].

We generated random aggregates of spheres by a particle-cluster aggregation method (see Fig. 2). The spheres that form the particles may have different sizes and compositions.

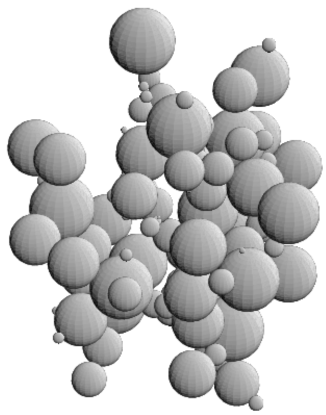

Figure 2: A particle-cluster aggregate of spheres.

4. Results and discussion

In Fig. 3 we show some results of our MC model. Very different values of the maximum of the degree of linear polarization (DLP hereafter) are achieved for small changes in an icy-like refractive index. This means that slight differences in composition or crystallization of the ice (ice stress) could be detected by observing the DLP from above a planet when it is illuminated from a direction perpendicular to the orbital plane of the instrument. This will be very likely the situation for SPEX, as flying in such an orbit, it could get power from solar flux all the time.

The validity limit of the MC method must be obtained by comparing its results to those of T-matrix for more and more densely packed media until we find a difference. Above that limit, just T-matrix will be used.

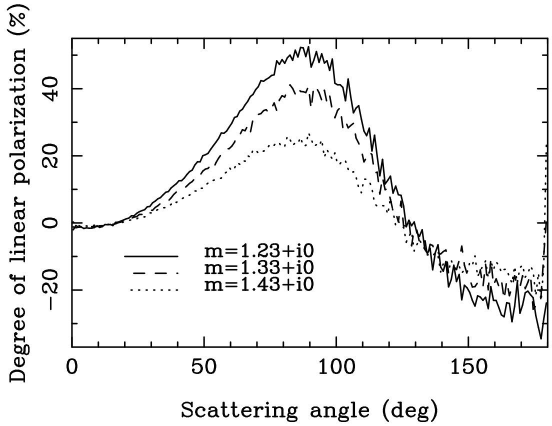

Figure 3: DLP of the reflected light as a function of the scattering angle for three slightly different refractive indices as calculated by our MC model. The surface was modeled as a polydisperse sample of spherical grains with a power-law size distribution with an index of 3 in the range [0.1, 10000] micron. A wavelength of 400 nm was used for calculations and the packing density factor was set to 0.1%. We launched 10^8 photons in order to achieve good statistics.

5. Conclusions

- A MC model for the reflection of light on a rough surface has been developed. A constrain exists on the packing density.
- Slight changes of the refractive index of the surface material can be detected by this model in the maximum of the DLP, at 90 deg. scattering angle.
- T-matrix must be used to find the packing density validity limit of the MC technique and to model surfaces above that limit.

References

[1] Mackowski D.W and Mishchenko, M.I., A multiple sphere T-matrix Fortran code for use on parallel computer clusters, JQSRT, Vol. 112, pp. 2182-2192, 2011.

[2] Penttilä A., Zubko E., Lumme K., Muinonen K., Yurkin M.A., Draine B., Rahola J., Hoekstra A.G., and Shkuratov Y.: Comparison between discrete dipole implementations and exact techniques, JQSRT, Vol. 106, pp. 417-436, 2007.