EPSC Abstracts
Vol. 16, EPSC2022-151, 2022
https://doi.org/10.5194/epsc2022-151
Europlanet Science Congress 2022

Light backscattering from numerical analog of planetary regoliths

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Analysis of the photopolarimetric observational data obtained for the surfaces of the Solar System bodies requires understanding of the light scattering mechanisms that are responsible for the optical opposition phenomena such as the intensity surge (IS) and the negative polarization (NP) branch [1,2]. The width of the IS and the slope of the intensity curve, the inversion angle of polarization and the position and the depth of the NP feature depend on the physical properties upper layer of planetary regoliths. Measuring intensity and linear polarization as functions of the scattering θ or phase angle ɑ (ɑ = π - θ) one can characterize them and extract the information about the complex refractive index of the material, particles size, packing density and the surface microtopography [1-3]. This is possible if an adequate theoretical model is applied.

We numerically study light scattering from clusters of densely packed irregular particles [4,5] with dimensions much larger than the wavelength. Such structures with bulk packing densities of ρ = 0.5 and numbers of particles up to 5000 represent a realistic model for planetary regoliths (Fig. 1a). The size parameters of constituents are kr = 10 - 30. The Discontinuous Galerkin Time Domain (DGTD) method is applied to obtain a full wave solution of the electromagnetic problem (Fig. 1b). Thus, we avoid many approximations used in the popular radiative transfer models. With a numerically accurate solution one can correctly account for the single-scattering phase function, single-scattering polarization properties of particles and near-field effects. The input parameters like particle size, complex refractive index and packing density are clearly defined in this case as well.

The results of simulation for large clusters of non-absorbing irregular particles demonstrate the role of high packing density for light transport and the backscattering phenomena. Light propagation becomes highly localized in this case and mimics a percolation process that is controlled by the topology and degree of disorder of the medium. The topological differences in the structure of the considered clusters can be seen in the intensity and polarization scattering angle curves [6].

In the case of low-albedo highly absorbing layers the total optical response is determined by the contributions of single and mostly double scattering in the very upper layer. At high bulk packing density, the incident light does not penetrate deeper than a few particle sizes (Fig. 1b) [7].

We can distinguish two sources of NP for bright and dark samples. Single non-absorbing particles comparable with the wavelength can produce strong NP feature which is suppressed by multiple scattering in a dense multi-particle system [6,8]. At high absorption it is double scattering between close neighbour particles that produces NP as a result of coherent backscattering [7,9]. The single scattering component is positively polarized in this case. In Fig. 1c the simulation result for a thick absorbing layer is compared with the polarimetric data obtained for an F-type asteroid 419 Aurelia

[10] and a boron carbide powder with particle size d = 7 μm [11].

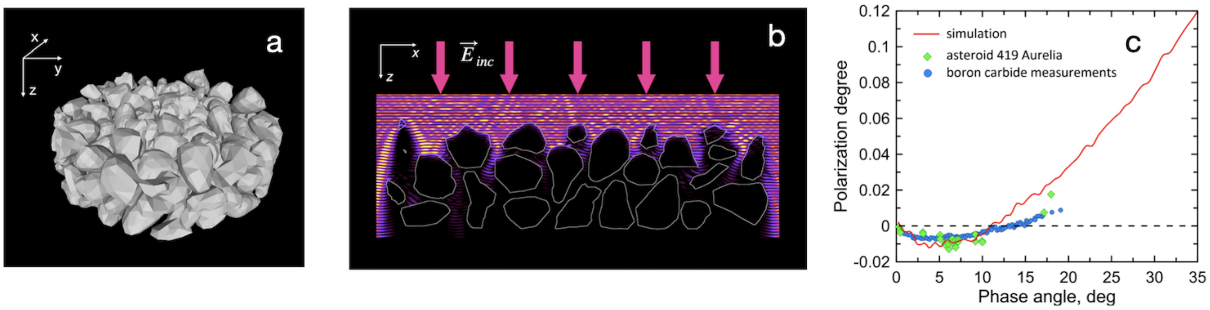

Fig. 1. (a) A sample of a dense particulate layer. (b) Cross-section of the simulation domain showing near field intensity (|E|2) distribution for an absorbing layer illuminated by a plane wave. (c) Comparison of the phase function of linear polarization computed for dense absorbing layers and polarimetric measurements of an F-type asteroid 419 Aurelia [10] and a boron carbide powder with particle size d = 7 μm [11].

Acknowledgment. The authors gratefully acknowledge the computing time granted by the Paderborn Center for Parallel Computing (PC2) and by the John von Neumann Institute for Computing (NIC) on the supercomputer JUWELS at Jülich Supercomputing Centre (JSC).

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