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Reflection of polarized light by rough surfaces: Monte Carlo modeling compared to measurements

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A Monte Carlo model of light scattering in a dense medium was developed in order to simulate the reflection of polarized light by rough surfaces [1]. This model calculates all four Stokes parameters of light scattered in all directions by a surface made of any material. Although multiple scattering is allowed, there is a limitation in the packing density of the medium, as independent scattering is assumed. The model can be applied to the study of light scattering by fluffy icy/dusty surfaces, e.g., various types of planetary or lunar regolith-type surfaces, icy moons or comets.

The main goal of this work is to test the model by comparing scattering matrix elements calculated with the Monte Carlo model to experimentally measured scattering matrix elements as functions of the phase angle. We use a Sahara sand surface for this. The experimental scattering matrix is measured at the new apparatus developed at the University of Cantabria (Spain) [2]. Sample surfaces are prepared by putting together dust grains with a water-diluted glue coating. A surface's top layer was made with pure sand, to preserve the air-sand refractive index ratio. Calibration measurements have already been carried out successfully by using Spectralon as a Lambertian surface. After calibration, measurements of a surface made of Sahara sand were performed. In such measurements, deviations from Lambertian behavior were found, as well as a very prominent forward peak in the (1,1)-element of the matrix for grazing illumination angles.

The values of I and -Q/I calculated by the model for the vertical scattering plane and non-polarized incident light were compared to the measured F_{11} and $-F_{21}/F_{11}$ elements for several incident directions. A good agreement between measurements and calculations was achieved. The forward-scattering peak of the (1,1)-element can be interpreted as a result of single scattering of horizontally incident light by the small features of the non-flat surface. In this case, light does not penetrate deeper into the surface. Fitting this peak by assuming the refractive index of the sample and spherical grains gives us an approximate assessment on the typical size of the macrophysical features of the surface, which is extra information for the case of horizontally incident light.

[1] D. Guirado, D. M. Stam, "Monte Carlo model for the reflection of polarized light on a rough surface", in preparation.

[2] J. M. Sanz, J. M. Saiz, F. González, and F. Moreno, "Polar decomposition of the Mueller matrix: a polarimetric rule of thumb for square-profile surface structure recognition", Applied Optics, Vol. 50, Issue 21, pp. 3781-3788 (2011).