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A Monte Carlo model for the reflection of polarized light on surfaces

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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 on Earth. We have developed an accurate Monte Carlo code to predict polarization signatures of sunlight reflected from the surface of a planetary body. Using this code for predictions of polarization signatures of the Jovian Moon Ganymede, we find that characteristic features near scattering angles around 90 deg. can mark small differences in refractive index, such as may result from ice-stress.

As the phenomenon of reflection of light by a surface occurs locally, we assumed a plane-parallel geometry for our problem. We first considered a surface as a layer of compressed dust grains. A Monte Carlo (MC hereafter) technique was then applied in order to account for multiple scattering and absorption of the individual photons entering the medium. In the MC approach, packets of photons with an initial weight $W = 1$ are launched. Each packet is split into two parts. One goes to the bottom of the surface or to infinity and is subsequently lost from the packet. The other part undergoes scattering into the surface. The optical thickness to the point of scattering is calculated according to a probability density function depending on the distribution of particles. The weight of the scattered part is reduced according to the single scattering albedo of the scatterer. We follow the path of a photon until $W < W_{min}$, and then another one is launched. This MC scattering model has a limitation on the packing of the particles because it is based on the hypothesis that each scatterer is in the far field zone of the others. As a consequence, it is valid only for fluffy media. In order to make a more realistic model, we included a specular (Fresnel) or Lambertian reflection for light reaching the bottom of the layer of compressed dust. So the whole model consists of a plane-parallel solid block that reflects light in a specular or Lambertian way covered by a thin layer of compressed dust with a low packing density.

The main purpose of this modeling is the interpretation of data collected by SPEX, the Spectrometer for Planetary Exploration, that will be proposed to fly to Jupiter and Ganymede on ESA's JUICE mission. Due to mission restrictions, SPEX would orbit Ganymede in a plane that is mostly perpendicular to the direction of the solar incident light. Due to this constraint, observations will be performed only for scattering angles near 90 deg., but will nevertheless allow us to retrieve information on the stress in the surface ice from the observations by SPEX. If ice stress exists on a surface, different zones of the material are under different pressures, which leads to slightly different refractive indices. We found out that very important variations of the maximum of the curve of linear polarization occur at scattering angles around 90 deg. for small changes of the refractive index.