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Modeling Backscattering Spectra of Icy Bodies Using Multi-Sphere T-Matrix Approach

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Backscattering phenomena are of special interest in light-scattering modeling because they are strongly affected by the coherent backscattering effect. It produces not only a steep opposition surge in the photometric phase curve and a narrow negative polarization feature in polarimetric measurements of high-albedo objects, but also causes variations of the depth of absorption bands with solar phase angle. We study this effect using ground-based and Cassini Visual and Infrared Mapping Spectrometer observations for icy satellites of Saturn and Uranus. We study the observed behavior of the near-infrared spectra of icy satellites and determine how the depth of the ice absorption bands depends on phase angle. We always see phase-angle variations in the depth of absorption bands, although for normalized spectra, the depth can increase as well as decrease with phase angle depending on the albedo of the surface. For modeling the spectra and their phase-angle variations, we use a new version of the Multi-Sphere T-Matrix code MSTM4 (Mackowski and Mishchenko, 2013, JQSRT, 123, 103, 2013). This code permits modeling of light scattering in an icy regolith by representing it as a slab of spherical particles. For wavelength-sized spheres and packing fractions typical of regolith, targets can contain approximately dozens of thousands of spheres that, with the original MSTM code, would require enormous computer RAM and CPU. To resolve this problem, MSTM4 adopts a discrete Fourier convolution (DFC), implemented using a fast Fourier transform (FFT), for evaluation of the exciting field. This approach is very similar to that used in discrete dipole approximation (DDA) codes, with the difference that it takes into account the multipole nature of the translation operators and does not require that the sphere origins be located on a regular lattice. The MSTM4 code not only allows us to consider a larger number of constituent particles but also is about 100 times faster in wall-clock time than the original version of the MSTM code. Our modeling can reproduce the observed variations of the spectra with phase angle and determine how these variations depend on the size of particles and porosity of the medium. We show what characteristics of the regolith reproduce the observed spectra of Saturn and Uranus satellites.

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