Modeling of light scattering by icy bodies

L. Kolokolova[1], D. Mackowski[2], K. Pitman[3], A. Verbiscer[4], B. Buratti[5], and T. Momary[5]

[1]University of Maryland, USA
[2]Auburn University, USA
[3]Planetary Sciene Institute, USA
[4]University of Virginia
[5]Jet Propulsion Laboratory, USA

As a result of ground-based, space-based, and in-situ spacecraft mission observations, a great amount of photometric, polarimetric, and spectroscopic data of icy bodies (satellites of giant planets, Kuiper Belt objects, comet nuclei, and icy particles in cometary comae and rings) has been accumulated. These data have revealed fascinating light-scattering phenomena, such as the opposition surge resulting from coherent backscattering and shadow hiding and the negative polarization associated with them. Near-infrared (NIR) spectra of these bodies are especially informative as the depth, width, and shape of the absorption bands of ice are sensitive not only to the ice abundance but also to the size of icy grains. Numerous NIR spectra obtained by Cassini's Visual and Infrared Mapping Spectrometer (VIMS) have been used to map the microcharacteristics of the icy satellites [1] and rings of Saturn [2]. VIMS data have also permitted a study of the opposition surge for icy satellites of Saturn [3], showing that coherent backscattering affects not only brightness and polarization of icy bodies but also their spectra [4]. To study all of the light-scattering phenomena that affect the photopolarimetric and spectroscopic characteristics of icy bodies, including coherent backscattering, requires computer modeling that rigorously considers light scattering by a large number of densely packed small particles that form either layers (in the case of regolith) or big clusters (ring and comet particles) . Such opportunity has appeared recently with a development of a new version MSTM4 of the Multi-Sphere T-Matrix code [5].

Simulations of reflectance and absorbance spectra of a "target" (particle layer or cluster) require that the dimensions of the target be significantly larger than the wavelength, sphere radius, and layer thickness. For wavelength-sized spheres and packing fractions typical of regolith, targets can contain dozens of thousands of spheres that, with the original MSTM code, would require enormous computer RAM and CPU. MSTM4 adopts a discrete Fourier convolution (DFC), implemented using a fast Fourier transform (FFT), for the evaluation of the exciting field. This approach is very similar to that used in the discrete-dipole approximation (DDA) codes, with the difference that it considers 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. Example of MSTM4 modeling is shown in the Figure.

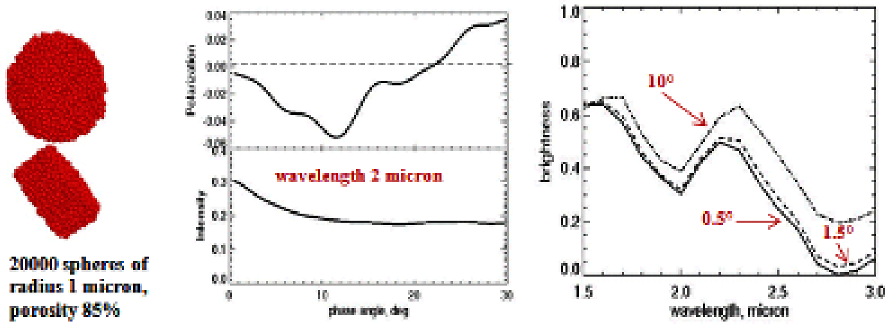

Figure: MSTM4 modeling of the light scattering by icy regolith layer (target is shown on the left): backscattering behavior of intensity and polarization (middle), and brightness spectrum for three solar phase angles.

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