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Light-Scattering Simulations of Space-Weathering Effects on Asteroid and Meteorite Spectra

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Space weathering introduces changes to the reflectance spectra of asteroid surfaces. In silicate minerals, space weathering is known to darken the spectra, reduce the silicate absorption band depths, and increase the spectral positive slope in visual and near-infrared wavelengths (see, e.g., T. Kohout et al., Icarus 237, p. 72–83, 2014, and references therein).

The space-weathering process is believed to influence the spectra by generating small nanophase iron ($npFe^0$) inclusions in the surface layers of mineral grains. The $npFe^0$ inclusions are believed to be one to some tens of nanometers in size. This mechanism has been linked to the Moon and to a certain extent also to the silicate-rich S-complex asteroids and to the ordinary chondrite meteorites.

We will present light-scattering simulations that validate the space-weathering and $npFe^0$ effects on the spectra of olivine. All the observed effects, i.e., the darkening and reddening of the spectra, as well as the decreasing of the 1-µm absorption band, can be reproduced in the simulations. We use a radiative-transfer solution for a semi-infinite slab of olivine and compute the reflectance spectra over the wavelengths from 0.5 µm to 2.5 µm. Laboratory-measured, wavelength-dependent complex refractive indices of olivine are used in the model as input. To include the $npFe^0$ in the host material, we use the Maxwell-Garnett effective-medium theory to model the effect of small Fe inclusions on the refractive index. The resulting spectra show all the observed space-weathering effects.

We will improve the light-scattering model with exact scattering simulations (i.e., based on the T-matrix or volume-integral equation methods) to model the single scatterer, which can include $npFe^0$ inclusions, together with a radiative-transfer approach that can use this computed single scatterer information as input (K. Muinonen, Waves in Random Media 14, p. 365, 2004). With this approach, we can avoid using the effective medium theory, and study the size effect of $npFe^0$ inclusions more thoroughly.