Space-weathering spectra explained with light scattering simulations

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Space weathering (SW) of regolith particles on the surfaces of atmosphereless Solar System bodies is a mechanism that has been actively studied since the Apollo lunar samples (see, e.g., [1] and references therein). The mechanism has been verified in laboratory experiments and recently by studying samples from asteroid (25143) Itokawa by the Hayabusa mission [2]. It has been identified that the spectral features associated with SW, namely the darkening and reddening of the spectra, are caused by nano- and microphase Fe inclusions in the thin rim of the regolith particles (see, e.g., [3]).

Until now, the physical first-principles model of the SW effects on spectra by Fe inclusions has been lacking. Extensive work has been done in this field using the Hapke model(s) (e.g., [4–6]), but the model only approximates radiative transfer treatment. One deficiency in the model is the lack of a proper treatment of the size effects of the Fe inclusions. Lucey and Riner [7] assessed this by including Mie scattering for the inclusions. However, current state-of-the-art modeling is missing a proper treatment of (i) surface reflections and volume scattering, and (ii) multiple scattering and incoherent fields associated with the inclusions.

We have recently completed a project aimed at improving the theory and computational tools for radiative transfer–type solutions in dense particulate media [8–10]. These are combined with our existing tools for light-scattering simulations with surface and volume scattering [11,12]. Using these light-scattering simulation tools, we develop a detailed view on how the Fe inclusions affect the spectra of non-weathered silicate minerals.

References

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