Simulated reflectance spectra for space weathered lunar regolith

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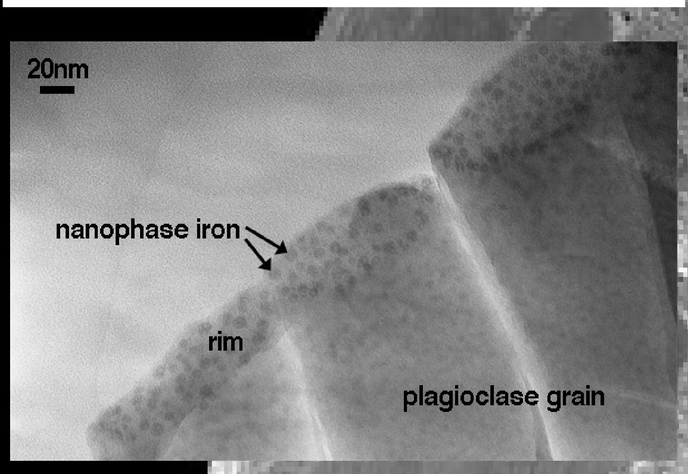
Lunar samples

Lunar regolith are composed mainly by silicates like olivine and pyroxenes. These particles suffer an aging process called space weathering when exposed to atmosphereless enviroments. An iron nanosphere phase is produced by solar wind sputtering, cosmic rays and meteorite bombardment.



TEM bright field image of a grain of lunar soil 10084 with a weathered rim (Wikimedia Commons).

The degree of space weathering can be characterized by the maturity index I_S/FeO, which is the ratio between the characteristic ferromagnetic resonance from microscopic iron (I_S) and the weight percent of FeO. Space weathering affects reflectance spectra by subduing the absorption bands, and darkening and reddening the spectrum. In Figures 1 and 2 we present the reflectance spectra of three lunar regolith samples with different maturity indices: sample 12030 (I_S/FeO=14, inmature) and sample 14163 (I_S/FeO=57, submature).

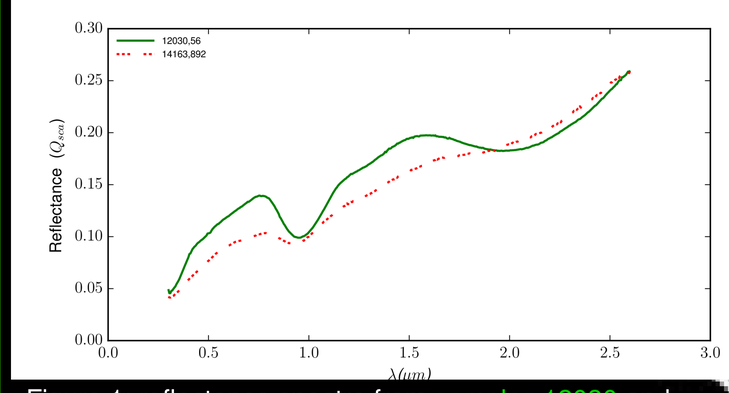


Figure 1: reflectance spectra from samples 12030 and 14163.

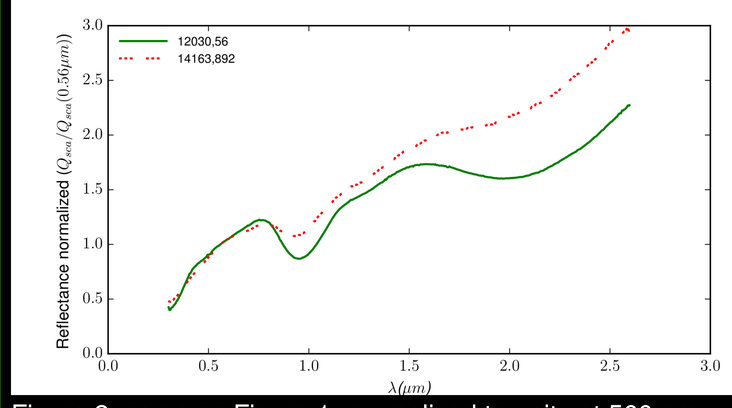
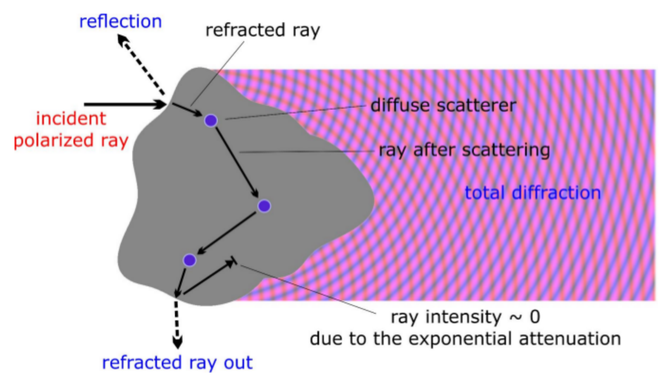


Figure 2: same as Figure 1, normalized to unity at 560 nm.

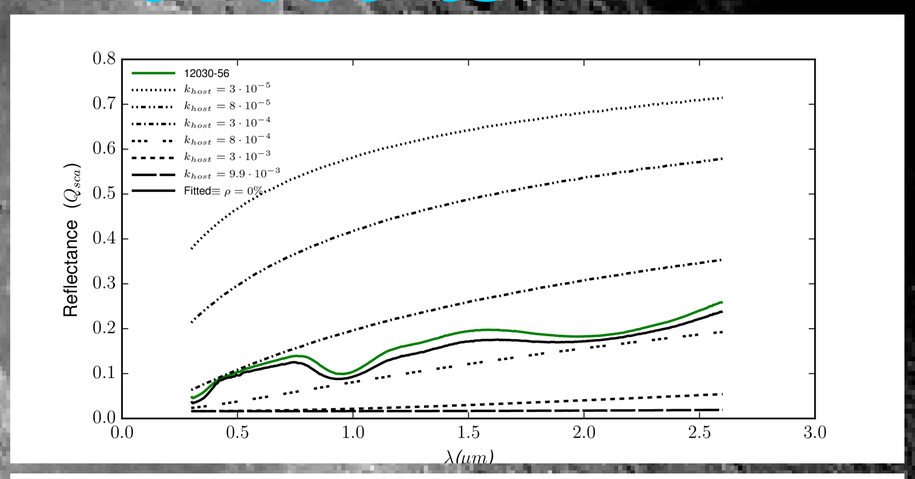
SIRIS code

SIRIS is based on ray optics with diffuse and specular interactions. Surface roughness and internal scatterers can be taken into account to compute the scattering matrix, among other optical properties. For this work, a particle of 33.5 microns is computed for all simulations for wavelengths from 300 to 2600 nm. Internal inclusions are used to mimic the space weathering.



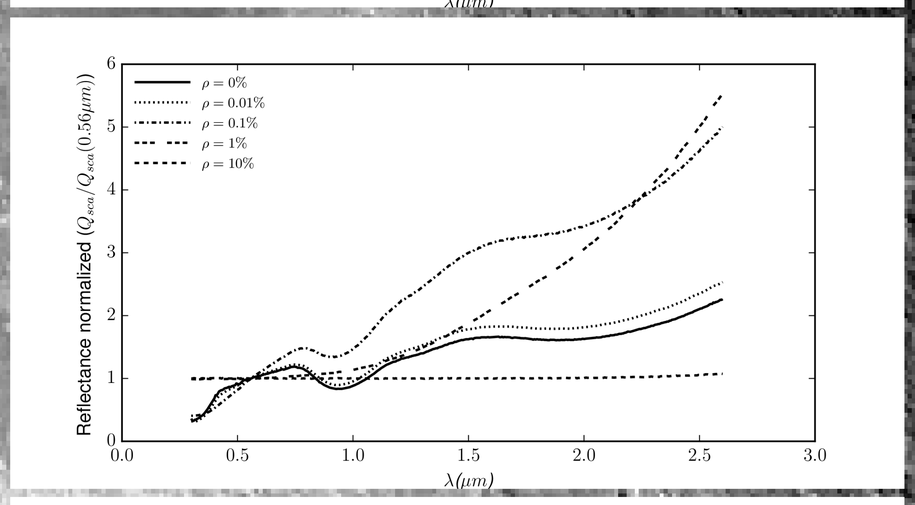
*Muinonen et al. (2009), JQSRT 110.

The results



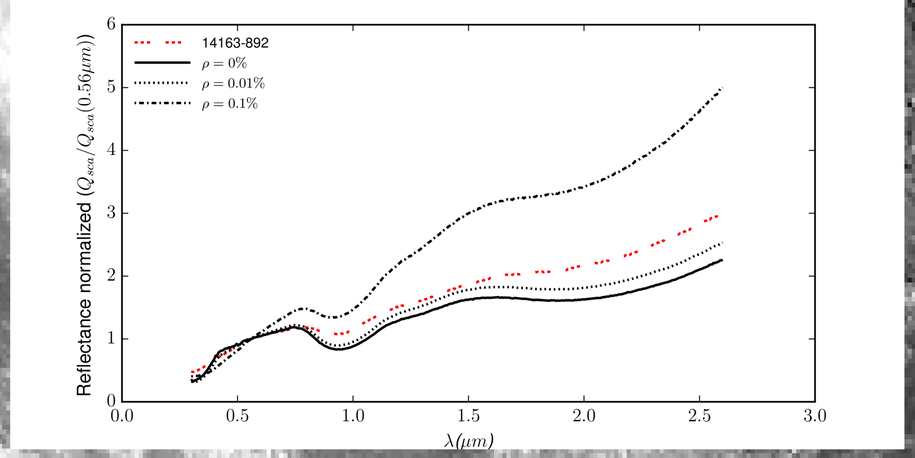
Firstly, simulations with six different refractive indices ($m=1.65+i.k_{host}$) are made (Figure 3). We fitted the reflectance spectrum of the 12030 lunar sample by combining all six computed spectra. From the best-fitted reflectance spectrum we retrieve the refractive index of an inmature lunar sample.

Figure 3: Fitting the sample 12030 with computations for constant k_{host}.



To simulate the space weathering, we add inclusions to the simulations, by increasing the volume fraction of inclusions, i.e. ρ (Figure 4). The increase of ρ produces reddening and band softening in the computed spectra.

Figure 4: Computations (normalized) for different space weathering concentrations.



Finally, a comparison between sample 14163 and simulations is made (Figure 5). This method give us a first approximation to characterize the iron nanosphere density in space weathered lunar regolith.

Figure 5: Comparison between sample 14163 and some simulations (both normalized).

Summary and Conclusions

- SIRIS code can reproduce the effects of space weathering in the reflectance spectra of lunar regolith, i.e., darkening, reddening and band features softening.
- These results show that space weathering has to be taken into account in studies of dust samples expected to be in atmosphereless bodies such as planets, satellites, comets and asteroids.
- Some refinements need to be made, as produce a better non-weathered reflectance spectra, or take into account in some way the chemical composition of the samples.