Classification and radiative-transfer modeling of meteorite spectra

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The interpretation of asteroid spectra is closely tied to surface structure and composition. Asteroid surfaces are usually assumed to be covered with a regolith, which is a mixture of mineral grains ranging from micrometers to centimeters in size. The inverse problem of deducing the characteristics of the grains from the scattering of light (e.g., using photometric and polarimetric observations) is difficult. Meteorite spectroscopy can be a valuable alternative source of information considering that unweathered meteoritic ”falls” are almost pristine samples of their parent bodies.

Reflectance spectra of 18 different meteorite samples were measured with the Finnish Geodetic Institute Field Goniospectrometer (FIGIFIGO) covering a wavelength range of 450–2250 nm [1,2]. The measurements expand the database of reflectance spectra obtained by Paton et al. [3] and Gaffey [4]. Principal Component Analysis (PCA) performed on the spectra indicates a separation of the undifferentiated ordinary chondrites and the differentiated achondrites. The principal components also suggest a discrimination between the spectra of ordinary chondrites with petrologic grades 5 and 6. The distinction is not present when the data are supplemented with the spectra from the two other data sets obtained with differing measuring techniques. To further investigate the different classifications, the PCA is implemented with selected spectral features contrary to the previous analyses, which encompassed the complete spectra.

Single-scattering albedos for meteoritic fundamental scatterers were derived with a Monte Carlo radiative-transfer model [1]. In the derivation, realistic scattering phase functions were utilized. The functions were obtained by fitting triple Henyey-Greenstein functions to the measured scattering phase functions of olivine powder for two different size distributions [5,6]. The simulated reflectances for different scattering phase functions were matched to the measured meteorite spectra. The single-scattering albedos for the analyzed ordinary chondrites range from 0.65 to 0.9, which is in line with the largest single-particle albedo values of 0.50 ± 0.25 for the ordinary chondrite Bjurböle measured by Piironen et al. [7]. Based on the analysis, meteorites with higher petrologic grades have higher single-scattering albedos across the wavelength range. Using the larger single scatterers in the model results in a lower albedo but a wider range in albedo values.

In order to refine the radiative-transfer modeling, we initiate a numerical study on the interrelation of scattering phase functions for a particle in free space and for the same particle embedded in a homogeneous host medium. As example particles, we may utilize spherical and spheroidal particle shapes and exact Mie and T-matrix computations.

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