Multivariate analysis of visible to near-infrared reflectance spectra of meteorites and asteroids

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Asteroids and meteorites have been considered as remnants of the early evolution of the solar system and understanding their formation history provide constraints on the physical and chemical conditions of the solar nebula and its subsequent evolution [1]. In order to better understand the compositions of asteroids, mineralogical relationship between asteroids and meteorites have been studied based on reflectance spectra obtained by ground- and space-based telescope [2]. Their relationship, however, remains poorly constrained except for a S-type asteroid Itokawa and LL chondrites [3]. Although spectral similarities have been suggested between V-type asteroids and HED meteorites and between carbonaceous chondrites and C- and/or D-type asteroids, detailed relationship is not well constrained. The major obstacle to compare asteroids and meteorites is that the classification scheme between asteroids and meteorites are fundamentally different. Asteroids are classified mainly based on the shape of their reflectance spectra and orbital parameters [4], while meteorites are classified by detailed petrology and mineralogy [5]. Based on principal component analysis, Britt et al. (1992) [6] compare reflectance spectra of asteroids with those of meteorites. They find that most of principal components of meteorite spectra are offset from those of the bulk of the asteroid population. However they used only eight color spectra and the spectra are limited within visible wavelength from 0.35 to 1.0 μm. Since characteristic absorptions are observed in the near-infrared range, including pyroxene (2 μm) and hydrated silicates (3 μm), using reflectance spectra with a wider wavelength range could result in a better spectral matching between asteroids and meteorites. In this study we developed a database of reflectance spectra for asteroids and meteorites with wavelengths ranging from 0.4 to 4 μm and perform multivariate analysis.
We obtained reflectance spectra for meteorites and asteroids from RELAB [7] and the database of Planetary Spectroscopy at MIT [8], respectively. Asteroid spectra for 3 μm band are obtained from previous studies [e.g., 9]. All the spectra were sampled with cubic spline fits at a wavelength interval of 0.05 μm. Meteorite spectra are chosen based on the following criteria: (1) particulate sample, (2) phase angle is 30°, (3) sample is from valid/known meteorite, (4) not heated/laser-irradiated, inclusion or impact melt sample, (5) not moon sample or lunar meteorite. The developed database includes 534 meteorite spectra and 369 asteroid spectra. We performed principal component analysis on the database and measure how well each meteorite group and asteroid group is separated on the principal component space. Our preliminary analyses show that (1) using spectra from 0.4 to 2.5 μm, accuracy of separation among ordinary chondrites, carbonaceous chondrites, HED meteorites is significantly improved compared with the case using spectra from 0.4 to 1.0 μm, and (2) the accuracy of separation is not significantly improved when using meteorite spectra from 0.4 to 4 μm compared with the case using spectra from 0.4 to 2.5 μm.

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