Preliminary results of principal component analysis on visible near-infrared reflectance spectra of meteorites with comparison to the petrological classification

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Classification of asteroids based on spectral observations by ground- and space-based telescope has been studied for decades to obtaining information of constituent materials of asteroids. Tholen [1] first classified asteroids by principal component analysis (PCA) using 8 colors reflectance spectra (wavelength 0.33-1.1 μm) into 13 types. DeMeo et al. [2] also conducted PCA and classified asteroids in more detail (27 types include subtype) by increasing the range of spectra (0.45-2.45 μm; 41 colors). Considering that meteorites are classified into 45 types (at group level) [3], the increase of asteroid class from Tholen [1] to DeMeo et al. [2] is important in order to correspond asteroids with petrological characteristics of known meteorites, which highlights the importance of the wavelength range and resolution of reflectance spectra.
Britt et al. (1992) [4] compared the reflectance spectra of 103 asteroids and 411 meteorites using principal component analysis. They used the Eight Color Asteroid Survey (8 colors), with a range of wavelength of 0.33 to 1.1 μm. They found that HED meteorite (which is believed to originate from asteroid Vesta) correspond well with V-type asteroids, however, the other major meteorite types do not have clear resemblance with any asteroid types. Because they used reflectance spectra shorter than 1.1 μm, they could not utilize the strong absorption band of pyroxene locating near 2 μm where another major mineral olivine does not have absorption. Our motivation of this study is to conduct principal components analysis using reflectance spectra of meteorites with wider wavelength region from 0.45 to 2.45 μm to compare with conventional petrological classification.
We compiled 709 reflectance spectra of meteorites within the wavelength range from 0.45 to 2.45 μm with high wavelength resolution (41 colors) from the database of RELAB facility at Brown University [6] and conducted principal component analyses. We find that a carbonaceous chondrite and an aubrite have the highest and the lowest PC1, respectively, with aubrites being widely distributed in terms of PC1. The 0.9 μm absorption band of olivine and pyroxene is the primary factor to contribute to PC1 dispersion. PC2 are contributed with 0.9 μm and 2 μm absorption band. On the PC1 space, ordinary chondrites, ureilite meteorites and carbonaceous chondrites (which are all primitive meteorites) locate close to each other, while ureilite meteorites scatter between ordinary and carbonaceous chondrites, suggesting that PC1 may represent the primitiveness of meteorites. In addition, based on PC2, we could be able to distinguish primordial of meteorites (which have information of early solar system) and differentiated meteorites that have experienced large scale melting/differentiation (HED meteorites and Mars) on PC2.
Although the primary minerals of meteorites are olivine and pyroxene, each meteorites has significant diversity such as mineral composition, grain shape and chemical composition, which should affect reflectance and the center of absorption band. Especially only pyroxene minerals have 2 μm absorption, thus the abundance of pyroxene could significantly contribute to the dispersion of PC2. Our spectral analyses using wider wavelength region of meteorites reflectance spectra suggest that based on PC1 and PC2, we may be able to distinguish meteorites at least Class level defined by conventional petrological classification [3].
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