Relationship between albedo and reflectance spectra of asteroids: implication to asteroids' thermal processes

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Large amounts of visible and near-infrared reflectance spectra data of asteroids have been obtained by ground- and space-based telescopic observations. Using the reflectance spectra, asteroids have been classified into several types based on principal component analysis [1]. Different types of meteorite samples, however, can yield similar reflectance spectra such as black ordinary chondrites and carbonaceous chondrites [2]. Thus the degeneracy of reflectance spectra may suggest that there is an application limit of the classification scheme based solely on reflectance spectra. Albedo data also have been accumulated, however, their relationship with reflectance spectra are not fully understood [3]. Our objective is to combine albedo with reflectance spectra in an attempt of improving asteroid classification.
We compiled visible/infrared reflectance spectra within the region of 0.45 to 2.45 μm based on published databases. Most of the spectra are from IRTF Near-IR Spectroscopy of Asteroids [3]. All the spectra were sampled with cubic spline fits at a wavelength interval of 0.05 μm, resulting in 41 data points. We defined the spectral type index *R*, which is the difference between correlation coefficients with average S and C-type spectra. Positive *R* values more closely approximate C-type spectra, while negative *R* values S-type. We also compiled geometric albedo data mostly from Supplemental IRAS Minor Planet Survey [4].
The albedo-spectra map indicates that there is a general trend in the distribution of asteroid types. V-type, C-type and S-type asteroids are distinctly separated from each other on the albedo-spectra map. The variance of each cluster appears to increase in the order of V-type, S-type and C-type. It appears that geometric albedo plays a significant role in the resulting spectral signature. There are many possible factors which could influence albedo, such as (1) mineral and/or elemental composition, (2) fragmented particle size, (3) space weathering and (4) crystal size. We consider, however, crystal size to be the primary factor in the resultant albedo-spectra map because: (1) based on the analyses of meteorites, there is no significant difference between ordinary and carbonaceous chondrites in terms of carbon content or modal composition, (2) smaller particles tend to yield higher albedo, though not enough to explain the significant albedo difference observed among asteroids, and (3) spectral darkening due to space weathering requires reduced Fe (noting that there is no clear evidence that C-type asteroids, which are significantly darker than S-type or V-type asteroids, have higher Fe abundances). With the above consideration, we discuss the crystal size in the context of thermal processes of asteroids to help explain albedo-spectra map.
Smaller crystals generally result in darker reflectance. V-type asteroids are believed to have experienced differentiation and magmatism, as evidenced by the analyses of HED meteorites. Thus the crystals would become coarser due to a slow cooling rate, resulting in brighter and more pyroxene-rich surface spectra. On the other hand, S- and C-types would be undifferentiated chondrite asteroids, believed to correspond to ordinary and carbonaceous chondrites, respectively. Those meteorites preserve chondrules generally having finer crystals due to rapid cooling in the presolar nebula [5]. This would result in dark featureless surface spectra of C-types. S-type asteroids have experienced moderate thermal metamorphism after their accretion, causing recrystallization which results in larger crystals and in more evident pyroxene signals than C-type.

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