Asteroids' albedo and reflectance spectra: implication from a comet-asteroid transition object (3200) Phaethon

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Asteroids have been classified into several types based on principal component analysis of their reflectance spectra and their spectral similarities to some meteorites have been suggested. Different types of meteorite samples, however, can yield similar reflectance spectra such as black ordinary chondrites and carbonaceous chondrites. This degeneracy of reflectance spectra may suggest that there is an application limit of the current classification scheme based solely on reflectance spectra. Albedo data also have been accumulated, however, their relationship with reflectance spectra are not fully understood. Our objective is to combine albedo with reflectance spectra in an attempt of improving asteroid classification and extracting a hidden variable.

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. 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.

The albedo-spectra shows 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. 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).

Crystal size may explain the albedo-spectra map as follows: smaller crystals generally result in darker reflectance because of the multiple Mie scattering. 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. 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.

On the albedo-spectra map, asteroid (3200) Phaethon is a particularly interesting object which transit between C/D-type cluster and S-type cluster. Since Phaethon has been suggested as a comet-asteroid transition object, its behavior on the albedo-spectra map may represent an evolutionary track of asteroids and comets. Therefore in-situ exploration of Phaethon, such as JAXA’s DESTINY+ mission, would provide a great insight to understand what controls asteroids’ albedo and reflectance spectra.

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