Water in B-type Asteroids

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Background

Water is the major constituent of all living organisms. More importantly, liquid water was essential for the origin of life. Compared with the major planets in the solar system, small bodies (e.g. comets, asteroids) have experienced less thermal evolution and their surfaces may be relatively unmodified. As such, their physical and dynamical characteristics are well preserved. Investigating water features among small bodies is important for studying water distribution in the early solar system, which will shed light on the unsolved puzzle of the origin of water on the Earth.

Typically, meteoroid streams are associated with the orbits of active comets. However, several meteoroid streams are found to be associated with near earth asteroids. Interestingly, these meteor shower-associated asteroids (e.g. 3200 Phaethon, 2001 YB_5) are reported to have optical colors that are bluer than the solar color [1, 2], which is uncommon. In fact, only 1 of every 25 asteroids is found to show negatively sloped (blue) spectra in the optical (0.4 - 0.9 μm). These rare, blue asteroids, of which 2 Pallas is the largest and most famous example, are classified as B-types in the Bus spectral taxonomy [3]. In addition, observations of the newly-established main-belt-comets (MBCs) found that the two most well-studied MBCs, 133P/Elst-Pizarro and 176P show neutral/bluish spectra that are similar to spectra of B-type asteroids [4].

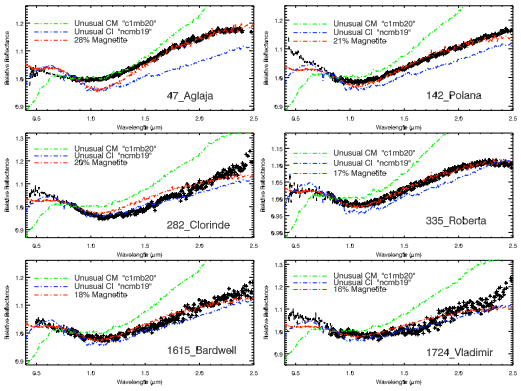

Figure 1: Illustration of obtained spectra of the B-type asteroids in this study together with linear mixing spectral models. Spectra of the B-type asteroids are shown as black lines (the visible spectra) and black pluses (the NIR data). The best-fit models are shown as red dashed lines, which suggest that magnetite may be an important component of B-type asteroids. Spectra of unusual CM and unusual CI chondrites are shown as blue and green dashed lines, respectively. The spectrum of magnetite is from the USGS Spectroscopy Lab and CI chondrite spectra are from the RELAB

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Observation and Spectral Modeling

The paucity of B-type asteroids itself is interesting. More importantly, previous observations indicate a possible link between B-type asteroids and cometary activity. Therefore, we expect that B-type asteroids may contain significant amount of water ice. We conducted a focused, near infrared (NIR) spectroscopic survey of the B-type asteroids to search for spectral features which are diagnostic of water ice. Moreover, to further investigate compositional properties of the B-type asteroids, we applied linear mixing spectral models to fit observational data using laboratory spectra from various digital spectral libraries, namely the RELAB and the USGS Spectroscopy Lab.

Results

We found no water ice features in the sample of 20 B-type asteroids. However, we noticed that many B-type asteroids in our sample show a broad absorption band in their reflectance spectra. The band center is typically in the range from $\sim$ 1.0 μm to 1.5 μm. The presence of the 1-μm absorption bands explains the negative slope of B-type asteroids in the optical since their visible spectra lie in wings of the broad bands. Our spectral modeling shows that the observed 1-μm band is best fit by the reflection spectrum of magnetite (Fe_3O_4). Although the origin of magnetite is currently under considerable debate[5, 6], the presence of magnetite in B-type asteroids indicates that these objects have experienced intensive aqueous alterations. Furthermore, we found that the unusual CI chondrite (Yamada-82162) generally matches the shape of asteroid spectra. Consistently, CI chondrites contain large amounts of hydrated minerals (phyllosilicates) and magnetite[7]. Our observations suggest that liquid water was once present in B-type asteroids.

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