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Toward a taxonomy of asteroid spectra in the 3-µm region

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Abstract

Roughly one hundred low-albedo asteroids have been observed with SpeX in the 2-4 µm region in the past decade, and a variety of band depths and band shapes are found. We will present examples of this variety and discuss current and expected means of classifying spectra in the 3-µm region.

1. Introduction and observations

The 3-µm spectral region is a critical one for measuring or constraining the presence and distribution of volatiles. On asteroids, absorptions due to OH in minerals and H2O as ice have been reported in this spectral range, first in a series of papers by Lebofsky and his colleagues, later by a larger community (for instance, [1-5]) With the installation of the SpeX instrument at the 3-m NASA Infrared Telescope Facility (IRTF) [6], observations of asteroids in the 2-4 µm region ("LXD mode") have become commonplace.

As a result of the ease of LXD observations, a de facto SpeX LXD-mode asteroid survey (the "L-band Main belt/Near earth asteroid Observing Program" (LMNOP)) has been ongoing for the past decade via the concatenation of several independent spectral projects. At this writing, 97 low-albedo asteroids (C complex, D and T asteroids, and low-albedo members of the X complex), which are the focus of this work, have been observed 142 times.

While the two taxonomic systems in use for visible-near IR (0.4-1.0 µm) asteroid spectroscopy, those of Tholen and Bus (extended to 2.5 µm by DeMeo et al.), utilize hundreds or thousands of asteroid spectra, the beginnings of asteroid taxonomy involved far fewer objects [7-9]. For instance, [10] grouped roughly 100 objects into 13 spectral classes. In this spirit we seek to begin classifying the similar number of low-albedo objects for which LXD spectra are available, though at this point only a small number of classes have been specified.

2. Band shapes and classes

A range of 3-µm band shapes seen in the lw albedo asteroid population is shown in Figure 1, along with the medium-albedo asteroid 21 Lutetia [11]. These spectra show the "type examples" of the 3-µm classes thus far identified: "Pallas types", which have roughly linear band shapes and band minima in the 2.5-2.85 µm region (where atmospheric water vapor precludes ground-based observations), "Ceres types" with a narrow, sharp band centered near 3.05 µm, and "Themis types" with a broader, rounded absorption near 3.1 µm. Both Ceres and Themis have had compositional fits made to their spectra (a brucite/carbonate mixture and a ice- and organics-bearing carbonaceous surface, respectively [4,12]), but while we expect objects with similar spectra to share similar compositions, formal fits to other Ceres- and Themis-type objects remain future work at this writing. Takir and Emery find similar band shapes in their sample, though they use different names for their groupings [5].

To this point, classifications have been done by inspection. However, we are moving toward developing more quantifiable criteria for classifications. Figure 2 shows one possible approach, using the band depths at 3.2 and 2.9 µm. Figure 2 shows with an arrow an array of points with similar band shapes but differing band depths, not only in the asteroid data but also in mineralogical and meteoritical spectra [13,14], all appearing as Pallas types by inspection. In addition to that array, however, a circled cluster of points can be found where the 3.2 µm band depth ≥ 2.9 µm band depth: the non-Pallas types. Interestingly, there is an excellent correlation between the Ch asteroids in the Bus-DeMeo taxonomy and the Pallas types: 29 of 31 Ch objects in the sample are clearly Pallas-types, with the remaining two ambiguous but likely Pallas-types.

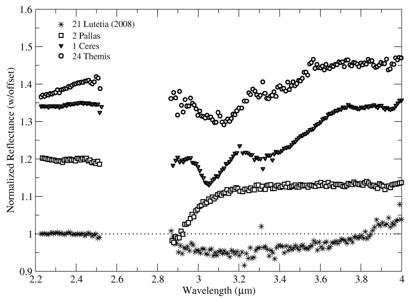

Figure 1: Three types of 3-µm bands on low-albedo asteroids are shown here, along with the spectrum of Lutetia for comparison.

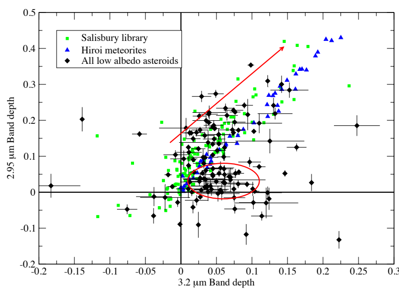

Figure 2: Meteorite spectra and hydrated mineral spectra have roughly linear band shapes that can be described by band depths at two wavelengths [14,15]. The Pallas types have similar band shapes, with increasing band depth along the trend shown by the arrow. The non-Pallas types are clustered in the red ellipse region, and include likely icy bodies.

3. Future Work

The use of band depth plots shows promise of separating these spectral types from one another, but more work is required to identify the optimal wavelengths. In addition, we have begun exploring the use of principal component analysis (PCA), as has been done for shorter-wavelength data. We also hope to use data from other asteroids and perhaps icy satellites to help guide our analysis.

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