SPECTROSCOPY OF O-TYPE ASTEROIDS. T. H. Burbine[1], R. Duffard[2], P. C. Buchanan[3], E. A. Cloutis[4], and R. P. Binzel[5], [1]Department of Physics and Earth Sciences, Framingham State University, Framingham, MA 01701, USA, tburbine@framingham.edu, [2]Instituto de Astrofísica de Andalucía - CSIC, Granada, 18008, Spain, [3]Kilgore College, Kilgore, TX 75662, USA, [4]Department of Geography, University of Winnipeg, Winnipeg, Manitoba, Canada R3B 2E9, [5]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA.

Introduction: O-type asteroids are one of the least-studied taxonomic classes. This is primarily due to the previous identification of only one asteroid (3628 Božněmcová) with such a distinctive visible and near-infrared spectrum. Binzel et al. [1] found that Božněmcová had an unusual visible spectrum that resembled the spectra of LL chondrites. Binzel et al. [1] proposed the O-type classification for Božněmcová due to its spectral similarity in the visible to ordinary chondrites. Burbine and Binzel [2] in their near-infrared spectral survey out to 1.65 µm found that Božněmcová had an unusually wide 1 µm feature that was not similar to ordinary chondrites.

From these visible and near-infrared data, Cloutis et al. [3] interpreted Božněmcová as having a composition similar to angrites. Using a SpeX (near-infrared) spectrum of Božněmcová (Figure 1) combined with visible data [1], the DeMeo et al. [4] taxonomy defined the spectral properties of O-types out to 2.45 µm.

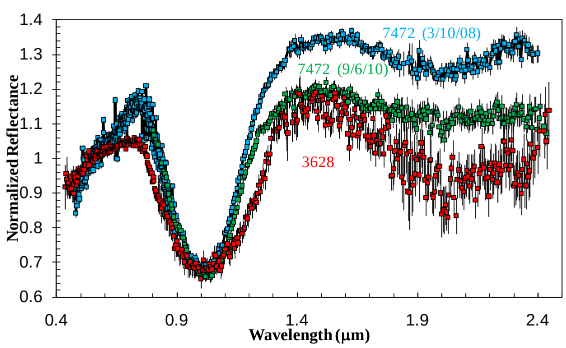

Figure 1. Visible and near-infrared (SpeX) spectra of 3628 Božněmcová (red points) and 7472 Kumakiri (blue and green points). Two different Kumakiri SpeX spectra are plotted with the visible [5] and March 10, 2008 data plotted with blue points and the September 6, 2010 data plotted with green points. All spectra are normalized to unity at 0.55 µm. Error bars are one sigma.

A SpeX spectrum of main-belt asteroid 7472 Kumakiri (Figure 1) taken on March 10, 2008 has allowed this object to be also classified as an O-type using the DeMeo et al. [4] taxonomy. Duffard and Roig [5] originally identified Kumakiri as a V-type from its visible spectrum but its near-infrared SpeX spectrum is not similar to other V-types.

Another SpeX spectrum of 7472 Kumakiri (Figure 1) was taken on September 6, 2010 to confirm the unusual spectral characteristics of Kumakiri. Those unusual characteristics are confirmed, although the principal component scores formally place the object over the O/Q boundary of the DeMeo et al. [4] taxonomy due to there being only one previous object (Božněmcová) that could be used for guidance on the arbitrary boundary for O/Q placement. Overall the spectral characteristics of Kumakiri are more comparable to Božněmcová than any other asteroid. This work will discuss the spectral characteristics of O-type asteroids. Possible mineralogies of these objects will also be discussed.

Data: The reflectance spectra of the two asteroids (Figure 1) have a number of similarities and differences. Both objects have 1 µm (Band I) and 2 µm (Band II) bands that are characteristic of pyroxenes. Božněmcová has a wider 1 µm band than Kumakiri. In both spectra, Kumakiri has a weaker 2 µm band than Božněmcová. The Kumakiri SpeX spectrum taken on September 6, 2010 is less red-sloped and has a shallower 2 µm band than the spectrum taken on March 10, 2008.

The method of Storm [6] was used to calculate band minima for the spectra. The spectral slope over the 1 µm band in each spectrum is divided out. No spectral slope is divided out over the 2 µm band in each spectrum. Then a second-degree polynomial is fit over the bottom third of each band and a band center was determined. Each reflectance value was then randomly resampled using a Gaussian distribution for the observational error and then fit using another second-degree polynomial. Each spectrum was resampled ninety-nine times. The derived one-hundred band centers were then averaged to calculate an average band center and the sample standard deviation. Approximately ten percent of the fits to the 2 µm band of the September 6, 2010 spectrum of Kumakiri did not have a band minimum, indicating a very weak band.

Calculated band minima from the Božněmcová and Kumakiri spectra (Figure 2) are very similar in value. However, the band minima are unusual compared to values for typical low- and high Ca-pyroxenes. The displayed pyroxene region in Figure 2 is from the Cloutis and Gaffey [7] spectral study of terrestrial pyroxenes. The band minima for terrestrial pyroxenes tend to follow a distinct trend with the Band II minimum increasing as the Band I minimum increases.

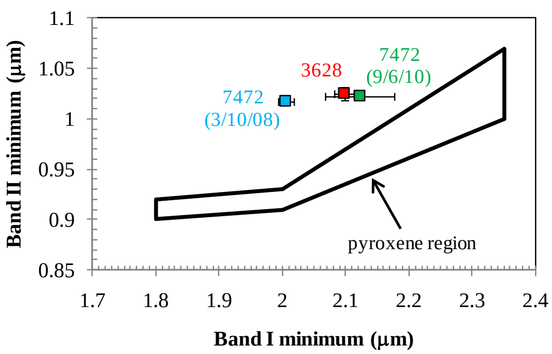

Figure 2. Band I and II minima for Božněmcová and 7472 Kumakiri are plotted versus a region defined by terrestrial pyroxenes. Error bars are one sigma.

No temperature corrections to room temperature are done to the band positions for the asteroid spectra. Such corrections for Božněmcová and Kumakiri will shift the band positions to slightly longer wavelengths. For pyroxenes, Band I minima will shift approximately +0.002-0.003 µm and Band II will shift approximately +0.02-0.03 µm. However, such a shift will not move the band minima for Božněmcová and Kumakiri into the pyroxene region.

Analysis: Even though the shapes of the absorption bands for Božněmcová and Kumakiri are characteristic of pyroxenes, the Band I and II minima for these objects are offset from the typical values found for pyroxenes. Band minima for HEDs (howardites, eucrites, and diogenites) and V-type asteroids [8], which also have absorption features characteristic of pyroxenes, are consistent with values found for terrestrial pyroxenes. The reflectance spectra of Božněmcová and Kumakiri appear unlike any measured meteorite assemblage.

We are currently investigating why the band minima for these objects are so different from terrestrial pyroxenes. One possible explanation is a the presence of an unusual type of pyroxene or pyroxenoid such as pyroxferroite [9], which has an absorption spectrum with absorption bands at similar wavelengths to the asteroids.. Also, Cloutis and Gaffey [7] found that pyroxenes that are zoned or contain exsolved phases fall off the distinct Band I-Band II minima trend for terrestrial pyroxenes. Maybe Božněmcová and Kumakiri contain two distinct pyroxene assemblages that result in the anomalous band positions. Preliminary MGM (Modified Gaussian Model) fitting of the Kumakiri spectrum taken on March 10, 2008 indicates both low- and high-Ca pyroxenes on this asteroid.

We are also investigating whether an assemblage dominated by olivine (~60-80 wt%) but also containing high-Ca pyroxene and minor low-Ca pyroxene could have a reflectance spectrum similar to these asteroids. Olivine would cause the reflectance spectrum of the assemblage to have a Band I minimum near ~1.02 µm and a mixture of high- and low-Ca pyroxene would have a Band II minimum around ~2.0-2.1 µm. Such an assemblage would have a relatively small Band Area Ratio (ratio of the areas of the Band I and Band II), which is consistent with the asteroid spectra. This assemblage would have a composition consistent with some angrites but no measured angrite has a reflectance spectrum that resembles these asteroids [10].

Conclusions: O-type asteroids 3628 Božněmcová and 7472 Kumakiri have absorption bands similar to pyroxenes but with band minima that are not typically found for terrestrial pyroxenes and known pyroxene-dominated meteorite assemblages. We are currently investigating what is causing such a discrepancy.

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