Investigation of the Origin of 2008 TC_3 Through Spectral Analysis of F-type Asteroids and Lab Spectra of Almahata Sitta and Mineral Mixtures

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During a routine sky survey, the Catalina Sky Survey observed an object that was headed straight for Earth. This object, 2008 TC_3, is the first asteroid to have a predicted trajectory that predicted an impact with the Earth. The asteroid, 2008 TC_3, was classified as an F-type asteroid, a rare asteroid type with a negatively sloping visible reflectance spectrum and a 0.35 μm absorption band. After impact, meteorites were recovered that are called Almahata Sitta. The Almahata Sitta meteorites were classified as an achondrite, a polymict ureilite (Jenniskens et al. 2009). The goal of this project was to study the origin of 2008 TC_3 by taking, reducing, and analyzing spectra of asteroids that are in families that could potentially be the source of 2008 TC_3 and to create a ureilite analog in the lab using mixtures of olivine, pyroxene, and carbon.

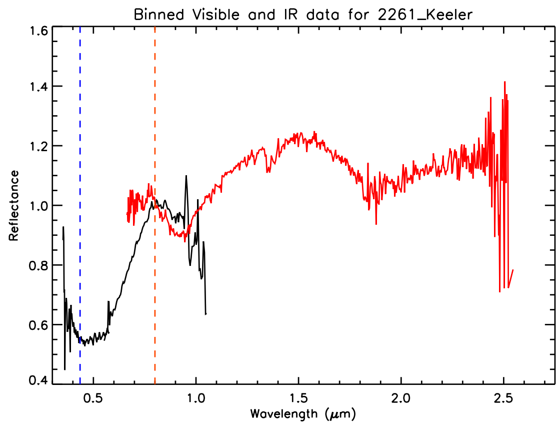

Figure 1: The reflectance spectrum of this S-type asteroid shows absorption bands at 1.0 and 2.0 μm. The vertical orange dashed line shows the wavelength at which the reflectance is normalized to unity. The blue dashed line shows the cutoff wavelength for the Bus and Binzel classification system.

Asteroid Spectra from Kast, CAFOS, and IRTF

Last summer, The Kast Double Spectrograph was used at the Shane 3-m Telescope at LICK observatory to take spectra of five F-type asteroids. This summer, spectra of seven main-belt, F-type, low albedo asteroids were observed with the 2.2m telescope at Calar Alto using the CAFOS low resolution spectrograph in R-400 (0.47-1.1 μm) and B-100 (0.32-0.58 μm) modes. Targets for this summer were selected from Jenniskens et al. (2010). Existing code was modified to reduce and analyze these spectra. Additional data was taken of 8 asteroids with IRTF and SpeX low-resolution spectrograph in the near-infrared (0.7-2.5 μm) region. These spectra were combined with the CAFOS data to provide a full wavelength coverage from 0.32-2.5 μm. For asteroids with both CAFOS and IRTF data, the spectra were combined and normalized so that the reflectance at 0.8 μm is unity.

After the data were reduced, Principle Component Analysis (PCA) was performed on each spectra. With this analysis, eight asteroids were classified, including 4 that were previously unclassified, as follows: 2-F, 1-B, 2-C, and 3-S.

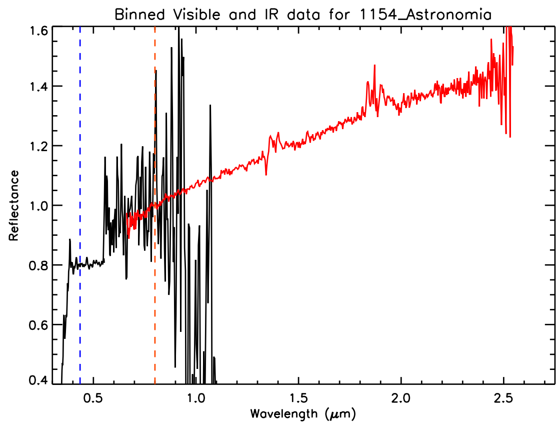

Figure 2: Although the red end of the CAFOS data for this F-type asteroid is noisy, we can still see a lack of the 1.0 and 2.0 μ absorption bands in the IRTF data. The spectrum is featureless except for a 0.35 μm absorption feature which is typical of F-Type asteroids

Reflectance Spectra of Olivine, Pyroxene, and Carbon

Reflectance spectra of simulated ureilites comprised of mixtures of olivine, pyroxene and fine-grained carbon

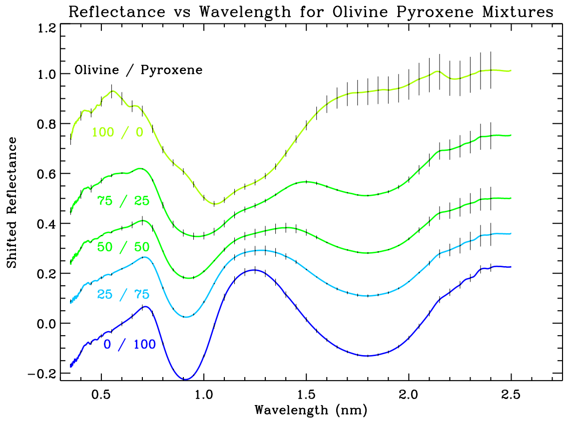

Figure 3: Here is the reflectance spectra of the olivine pyroxene mixtures. The 1.0 and the 2.0 μm band shifts nonlinearly based on the relative amounts of olivine and pyroxene. The vertical black lines are the standard deviation of the multiple measurements of the spectra taken. Each spectrum is shifted for clarity.

have been created and acquired from 0.35-2.5 μm using an ASD spectrometer at 2 nm spectral sampling. Olivine and pyroxene samples were ground to less than 124 μm and mixed together. Mixtures were created with olivine/pyroxene ratios of 100/0, 75/25, 50/50, 25/75, and 0/100. Reflectance spectra of the mixtures are shown in Figure 3.

Next, Montmorillonite was mixed with three different types of carbon to test the effects of the carbon and how they would effect the olivine and pyroxene mixtures. Graphite, Glassy, and Nanopowder carbon, which have grain sizes of 45, 6, and .05 μm respectively, were mixed with the clay. These spectra are shown unshifted in Figure 4. The three types of carbon affect the clay differently, and the graphite was chosen to mix with the small amount of olivine and pyroxene that we had.

The third set of mixtures was with the 50/50 olivine/pyroxene mixture and the carbon graphite. One of the mixtures has 5% carbon and due to a lab mishap, the other mixture's carbon content is not as precisely known, but it is around 3%. The reflectance spectra of these mixtures is shown in Figure 5.

In the future, we will attempt to characterize ureilite spectral properties using Gaussian modeling (Sunshine et al. 1993) and analysis of the band centers and depths due to the olivine and pyroxene minerals observed in spectra of the Almahata Sitta samples (Hiroi et al. 2010).

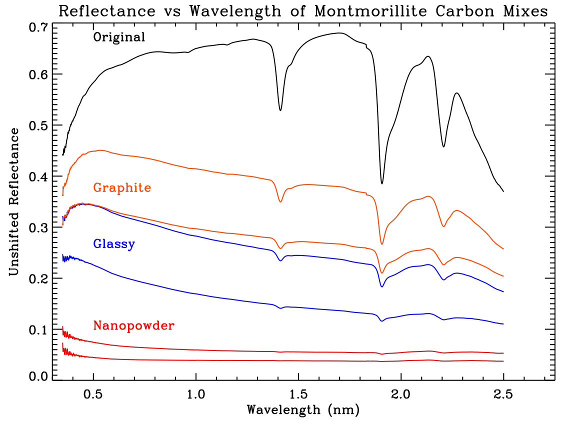

Figure 4: The black is the original Montmorillonite spectrum, orange is mixed with graphite, blue is mixed with glassy, and red is mixed with nanopowder. Of each color, the top line is 2% carbon and the bottom line is 5% carbon. These spectra are unshifted and show how the carbon is effecting the absolute reflectivity of the mixture.

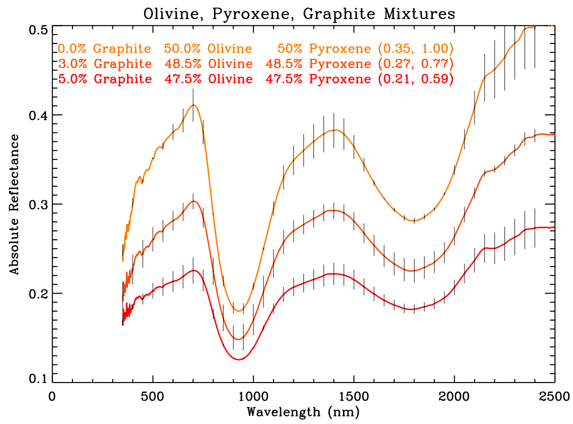

Figure 5: Absolute reflectance of mixtures of olivine, pyroxene, and carbon. There is an equal ratio of olivine to pyroxene in all three mixtures. Carbon was mixed in at about 3% and 5% for the lower two spectra respectively.