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

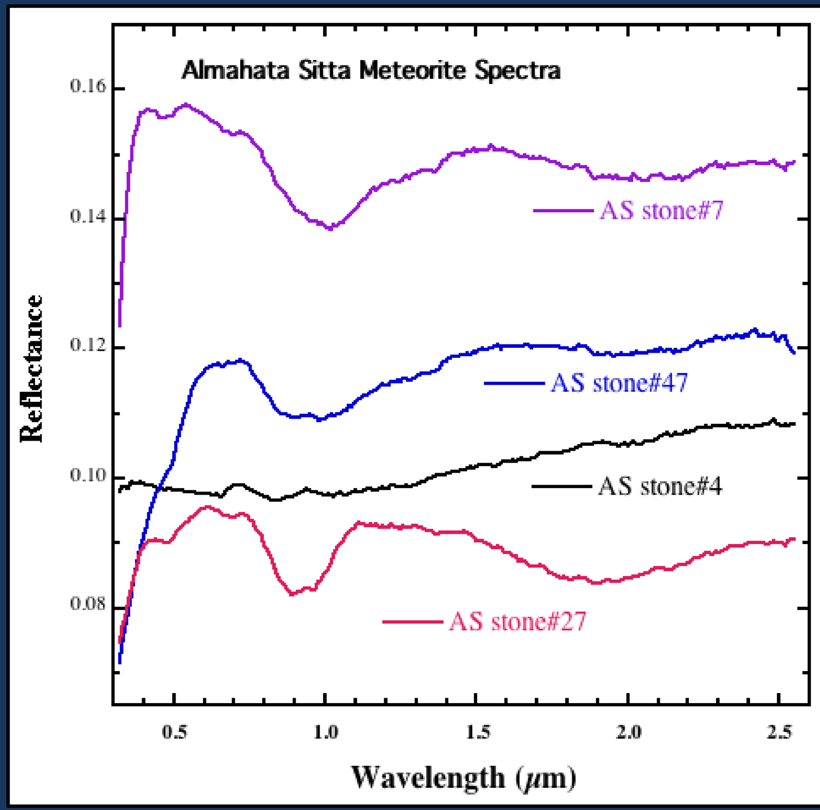
William Freeman[1,2], J. Bishop[2,3], F. Marchis[2,4], J. Emery[2,5], A. E. Reiss[5], T. Hiroi[6], D. Barrado[7], M. H. Shaddad[8], P. Jenniskens[2]

[1]Louisiana State University, [2]SETI Institute, [3]NASA Ames Research Center, [4]UC-Berkeley, [5]University of Tennessee, [6]San Francisco State University, [7]Brown University, [8]LAEX-CAB & Calar Alto Observatory, Spain, [9]University of Khartoum, Sudan.

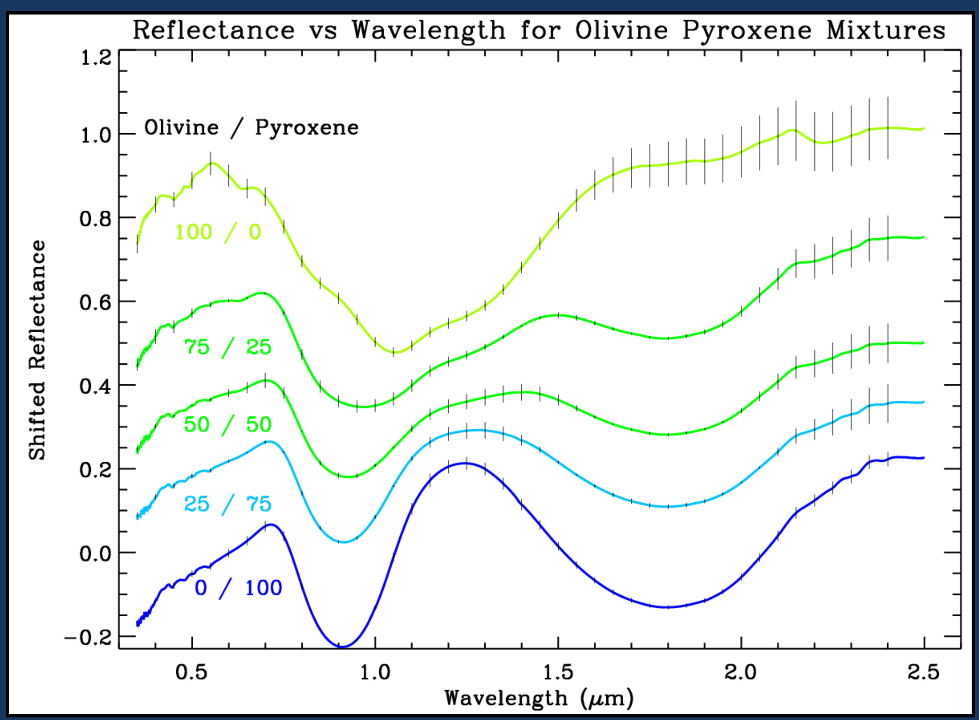
Abstract

We present a comparative study of F-type asteroids, 2008 TC3, the Almahata Sitta meteorites, and lab mixtures of simulated ureilites. We are attempting to use these data to connect the Almahata Sitta meteorites and their parent asteroid, 2008 TC3, with a specific class of asteroids. We prepared mixtures of olivine, pyroxene and graphite in the lab as simulated ureilite meteorites and measured their spectral properties. We have processed spectra of twelve F-type asteroids that are potential sources of 2008 TC3.

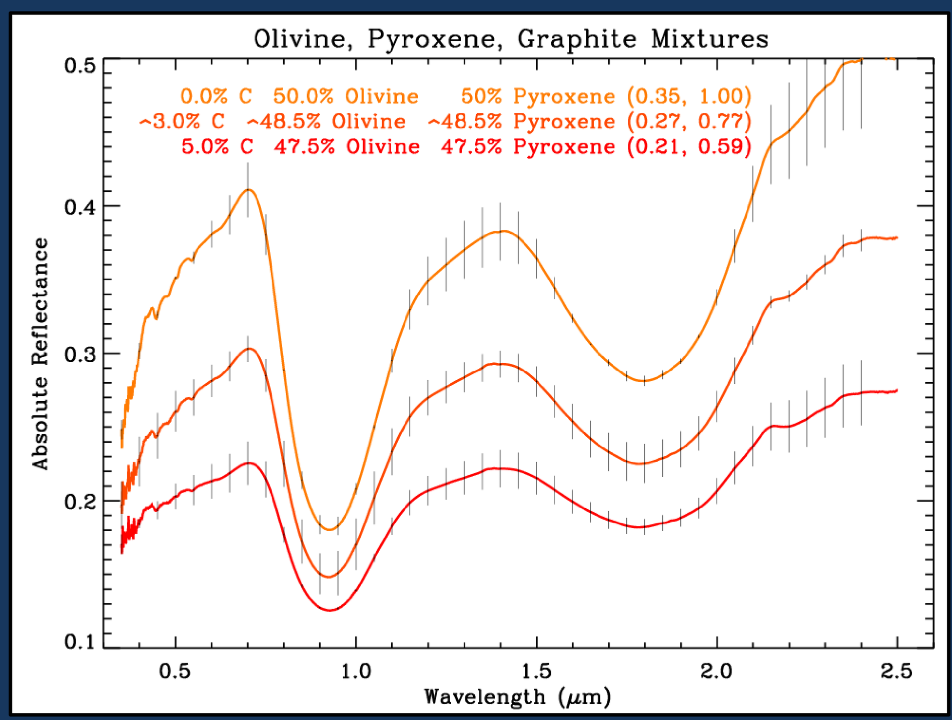
On the right are reflectance spectra of several Almahata Sitta meteorite samples (from Hiroi et al. 2010). These spectra contain 1 and 2 µm bands that are characteristic of olivine and pyroxene spectra.



Mineral Mixtures

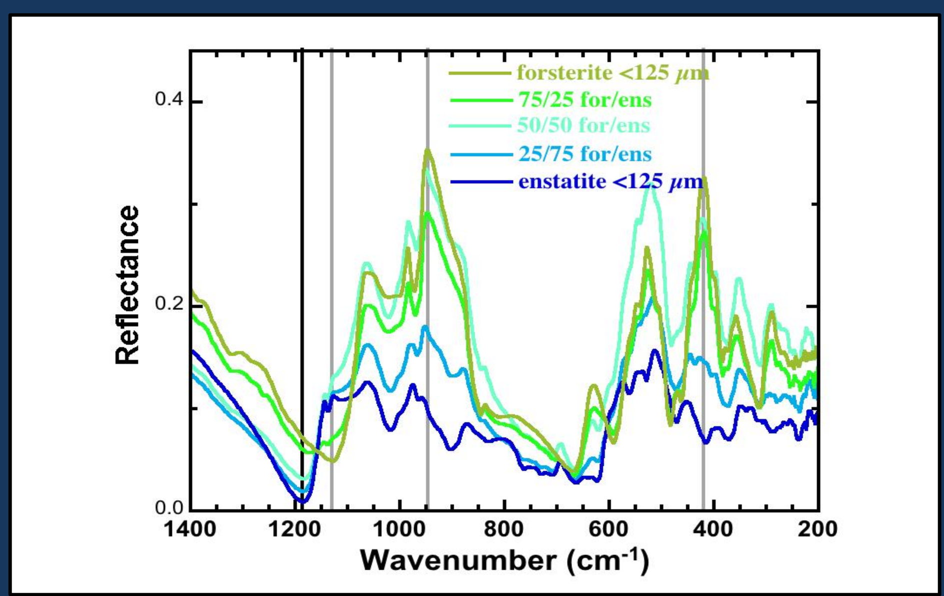


Olivine and pyroxene were ground to < 125 µm and mixed together by weight in different ratios. Visible/Near-infrared (VN) reflectance spectra of each sample were taken using an ASD spectrometer at 2 nm spectral sampling. Three mixtures and the two endmember spectra are shown with error bars in the plot above. The spectra are offset for clarity. These data show nonlinear trends in the character of the 1 and 2 µm bands, illustrating the need for lab mixtures in order to interpret spectra of meteorites such as Almahata Sitta.



The Almahata Sitta meteorite spectra are much darker than the spectra of the olivine and pyroxene mixtures. In addition to these mafic minerals, the Almahata Sitta meteorites contain fine-grained carbon. In order to test the effect of this component, carbon graphite with a grain size <45 µm was mixed with the 1:1 olivine to pyroxene mixture (gold spectrum). The mixture with ~3% C reduced the average reflectance by ~25% (orange spectrum) and the mixture with 5% C reduced it by ~40% (red spectrum).

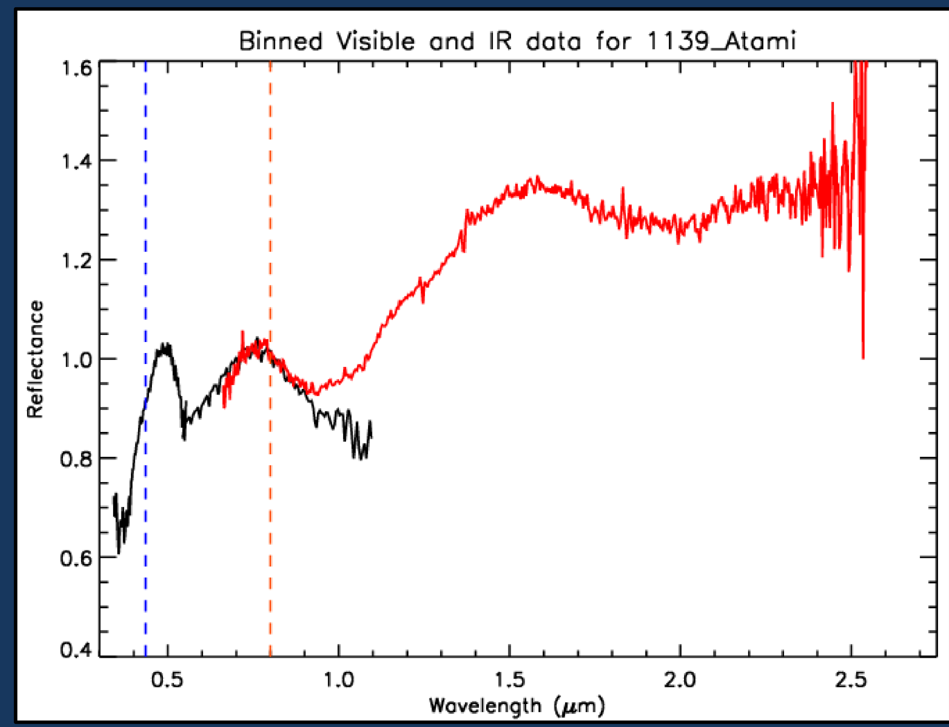
Mid-Infrared reflectance spectra were also measured of the mixtures at RELAB and are shown in the plot on the right (color-coded to the VN spectra above). A shift in the Christiansen frequency is observed from near 1180 cm^{-1} for enstatite (pyroxene) to near 1130 cm^{-1} for forsterite (olivine). This reflectance minimum is shifted towards that of pyroxene for only 25 wt.% enstatite. Additional features are observed here due to Si-O stretching and bending vibrations.

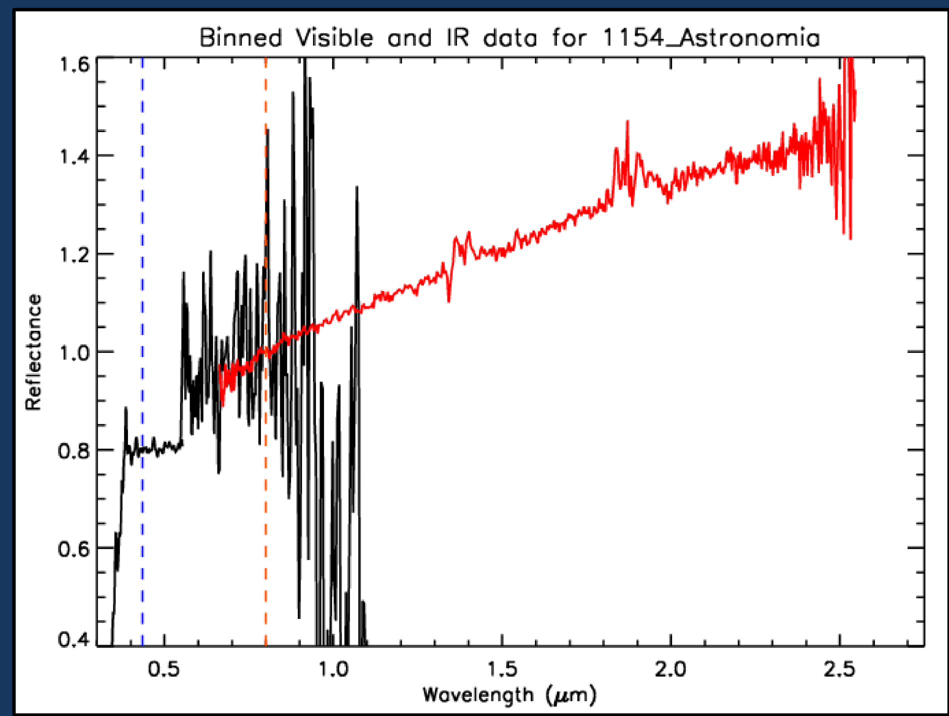


Asteroid Data

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. Three of these spectra are plotted here in black.

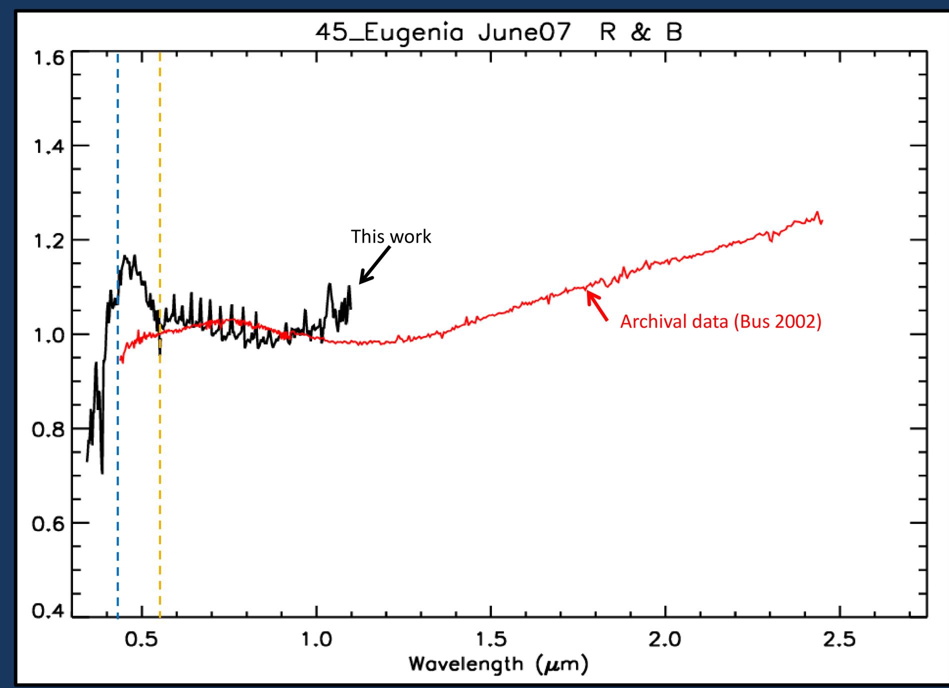
Additionally, eight spectra were taken with IRTF and the SpeX low-resolution spectrograph in the near-infrared (1-2.5 µm) region. These data are plotted in red.





On the three surrounding plots, the orange line indicates where the black and red spectra are both normalized to one. The blue line is at 0.475 µm and shows the cutoff of the Bus & Binzel (2002) classification system. Atami (top), Astronomia (middle), and Eugenia (bottom) all exhibit a 0.35 µm absorption feature which distinguishes the F (Tholen) and B (Bus & Binzel 2002) classes.

The data reduction of the visible spectra collected with 2.2m/CAFOS is still in progress since they were collected recently in May-July 2010. Instrumental errors (fringing) and limitation in sensitivity at wavelengths larger than 0.7 µm need to be fully characterized before reaching conclusions and being able to classify these asteroids into the DeMeo *et al.* (2009) taxonomic classes. Additional data of 5 F-type asteroids (not shown here) were taken with the Lick/KAST spectrograph in 2009 and will be included in our analysis.



A Principle Component Analysis (PCA) was performed on the spectra of asteroids collected in the visible region, and the results are in the table to the right. We were able to assign a type to three previously unclassified asteroids according to the Bus and Binzel (2002) taxonomic classification. We quantified the depth of the 0.35 µm feature in a similar fashion to Hiroi et al. (1996). For PC2' and the 0.35 µm feature, a smaller number indicates a larger absorption feature.

Object	slope	PC2'	PC3'	0.35 µm feature	0.35 µm feature	Type	Type
name	reflectance/ wavelength	1µm feature	Higher Order	(Hiroi et al 1996)	Y/N	Tholen or BB 2002	This work
1154 Astronomia	-13.98	-0.99999	-0.00217	-0.363	Y	?	F
2287 Kalmykia	-1.40	-0.00233	0.00420	-0.029	?	?	S
1655 Comas Sola	-16.76	-0.00216	0.99999	1.873	N?	B	?
3888 Hoyt	-0.32	-0.00077	0.00092	-1.150	Y	?	S/F??
1796 Riga	3.45	-0.00047	0.00107	-0.437	Y	Cb	C/Cb
45 Eugenia	-0.04	-0.00012	0.00015	-0.237	Y	C	C
1139 Atami	0.15	-0.00007	-0.00004	-0.237	Y	S	S
2261 Keeler	71.27	0.00029	0.00037	-0.043	N?	?	S

Conclusions

- Lab mixtures provide a good first order match to the Almahatta Sitta meteorite data
- Carbon is needed to match the reflectivity
- Telescopic data shows 0.35 µm absorption that differentiates F and B types
- Classified using PCA: 2-F, 1-B, 2-C, and 3-S
- Noisy data is making classifying and analyzing difficult

Future Work

- Apply Modified Gaussian Modeling
- Prepare additional olivine/pyroxene/C mixtures with varying abundances
- Acquire more spectral data of F-type and other asteroids
- Bin pixels to reduce noise (BB2002)
- Investigate other methods of reducing noise
- Apply UV absorption analysis to Kast data

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Contact email: billfreeman44@yahoo.com