

VISIBLE AND NEAR INFRARED SPECTRA OF MAIN BELT AND NEAR EARTH ASTEROIDS

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Introduction: Asteroids provide unique insights into the origin and early history of the solar system. Near-Earth asteroids (NEAs) are also interesting because of the collisional hazard and value to solar system exploration as intermediate targets between the Moon and Mars. Reflectance spectra of twenty-five main belt and NEAs (Table 1) have been obtained in the near infrared (0.8 – 2.5 μm). Here we present a progress report of these studies.

Experimentation: The main belt asteroids in this study were chosen to provide a range of asteroid types while the NEAs were chosen on the basis of observability. Our spectra were obtained at Mauna Kea between 2004 and 2006 using the NASA IRTF equipped with the SpEX infrared spectrometer. The data were reduced by IRAF and other commonly used methods. The data were then coupled with spectral data in the visible wavelengths (0.4 – 0.9 μm) from the MIT SMASS [2, 3, 4, 6, 7, 8, 9, 10] database to provide a spectrum covering the visible to near infrared. The spectra were analyzed using the Modified Gaussian Model (MGM) [11] and will soon be analyzed by the other methods.

Results: Our spectra are shown in Fig. 1. The spectra of the asteroids were grouped by visual inspection. We began by placing the spectra which had absorption features in the 1 and 2 μm region together and arranging them according to the relative strengths of the two features. These were further divided according to the strength of the 1 μm feature and the relative strength of the 2 μm feature. The remainder of the spectra were separated based on the presence and strength of a 1 μm feature and the basic shape of the spectra. We found seven distinct groups consistent with published taxonomies.

Discussion: The largest of these seven groups contains nine asteroids eight of which are all classified as an S, S1, Sa or Sk in Bus and Binzel's [10] taxonomy. The ninth, asteroid 54509, has not previously been classified in this way because of the lack of a visible spectrum. The second group contains 3908, a V type asteroid, and two other as yet unclassified asteroids. Group three contains three asteroids that are classified as C or Cb asteroids. The fourth group contains one Ch and one S1 asteroid. Group five is comprised of four asteroids classified as Ld, X and C. The sixth group contains an Xk and a Ch classified asteroid and the last group also has two asteroids both classified as X. Classifications we have assigned to previously unclassified asteroids are indicated in Table 1.

Table 1

Asteroid	Type	% CPX 1 μm /2 μm	Mean Albedo
<u>Main Belt Asteroids</u>			
6 – Hebe	S	51/47	0.27 [†]
18 – Melpomene	S	61/65	0.22 [†]
34 – Circe	Ch	--	0.05 [†]
45 – Eugenia	C	--	0.04 [†]
51 – Nemausa	Ch	--	0.09 [†]
52 – Europa	V	--	0.06 [†]
63 – Ausonia	Sa	68/42	0.16 [†]
87 – Sylvia	X	--	0.04 [†]
88 – Thisbe	B	--	0.07 [†]
93 – Minerva	C	--	0.09 [†]
129 – Antigone	X	--	0.17 [†]
167 – Urda	Sk	45/42	0.22 [†]
181 – Eucharis	Xk	--	0.12 [†]
191 – Kolga	Cb	--	0.04 [†]
269 – Justitia	Ld	--	0.10 [†]
354 – Eleonora	S1	Olivine	0.19 [†]
<u>Near-Earth Asteroids</u>			
1036 – Ganymed	S	41/41	0.17 [†]
3908 – Nyx	V	90/57	0.38 [†]
7753 – 1988 XB	B	--	d [†]
1999 JW3	S	56/54	mh [†]
2003 YQ117	V*	50/51	
22771 – 1999 CU3	S1	61/61	
54509 – 2000 PH5	S/V*	--	m [†]
66251 – 1999 GJ2	S*	--	
68950 – 2002 QF15	V*	52/58	

*Present work, †Near-Earth Objects – Dynamic Site [12],

‡Planetary Data System [13]

In pyroxene-bearing asteroids (the first two groups in Fig. 1), there are two or three individual absorption bands that combine to make up the characteristic 1 μm and 2 μm bands which MGM can separate. The component band strength ratio (CBSR) was calculated for both the 1 and 2 μm regions using the methods of Sunshine and Pieters [11]. From this the percentage of clinopyroxenes relative to the total pyroxenes was determined for these asteroids (Table 1). In general there is agreement (within uncertainties) in the amount of %CPX calculated from each band, although asteroids 63, 354 and 3908 are exceptions. Asteroid 63, an Sa type has a spectra that is intermediate between the S type and the olivine-rich A type based on their UV slope [10]. This could indicate that asteroid 63 contains more olivine than is typical

of S asteroids. The apparent absence of olivine-rich asteroids has concerned researchers [5], so this asteroid may have considerable significance. Asteroid 3908 is a V type (Tholen classification – no SMAS-SII classification) asteroid and contains considerable plagioclase neglected in the CBSR calculation. Asteroid 354 is an S1 type asteroid whose spectrum suggests an olivine-rich (A type) asteroid, with strong ultraviolet and 1 μm absorption bands [5]. Again abundant olivine would upset the CBSR calculation and is of considerable interest for the reasons discussed above.

Our study includes four previously unclassified asteroids, 2003 YQ117, 54509, 66251 and 68950 to which we assign classifications in Table 1. Except for the recent work of Abell, et.al. [1], there was no visible data for these asteroids. Of the nine NEAs observed, one-third are currently classified as S type asteroids with the possibility of one or two more (54509 and 66251). Including 2003 YQ117, 68950 and 54509, it is possible for nearly half to be V type asteroids.

Future work on this project will refine this study by continuing with MGM while also looking at adding other analysis methods.

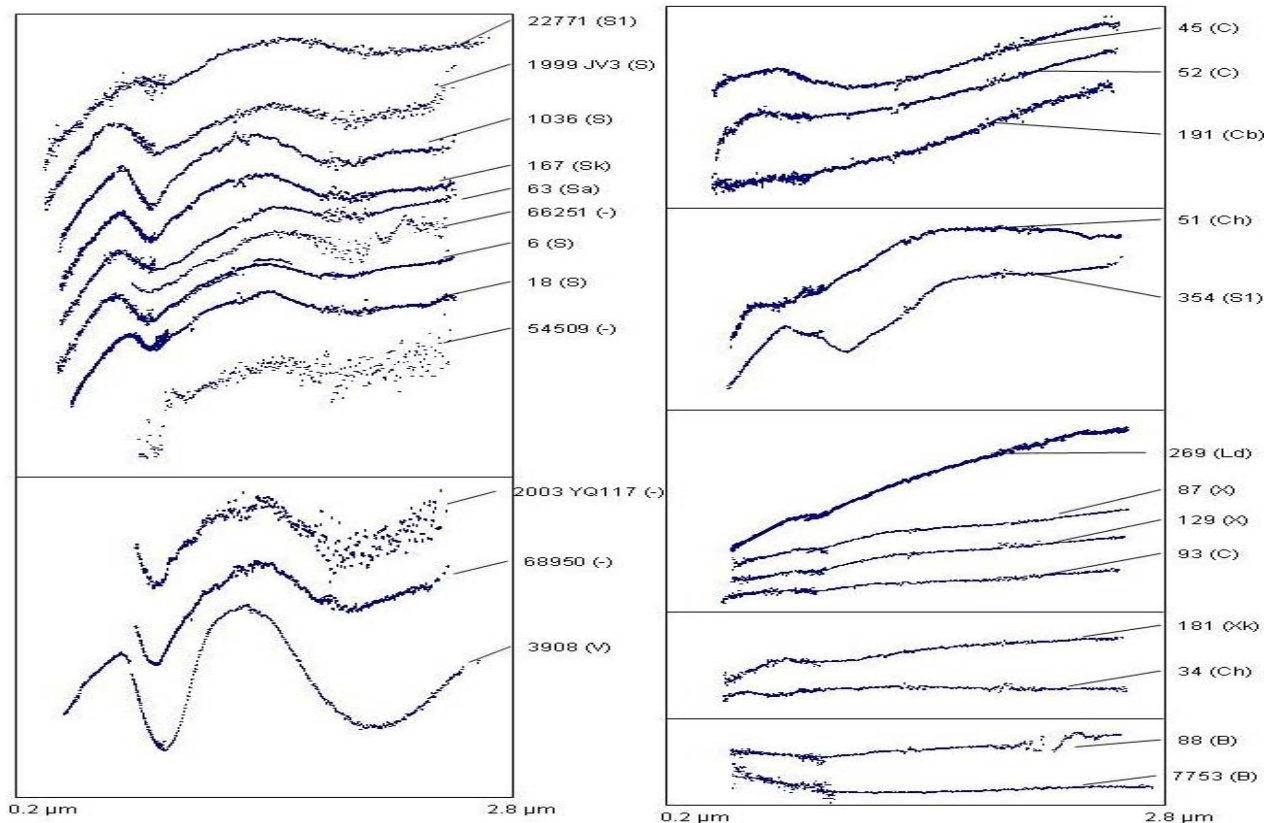


Figure 1: Spectra of twenty-five asteroids placed into seven groups by spectral shape. The range of the x-axis is 0.2 – 2.8 μm on all spectra. The near-infrared spectrum of asteroid 66251 appears to fit best into group one which would indicate a classification of S type. The spectrum of asteroid 54509 is also grouped into the first group. Even though there is quite a bit of scatter, there are some definite features apparent. The 1 μm feature is very strong compared to the other asteroids in group 1 (indicating a possible classification of V type), however, the 2 μm feature is not as strong relative to the 1 μm feature (indicating a possible classification of S type). Both 2003 YQ117 and 68950 have a strong 1 μm feature and a 2 μm that is relatively strong compared to the 1 μm feature and could be classified as a V type asteroid.

References: [1] Abell, P., et.al. (2006) *AAS/DPS*, #38. [2] Binzel, R. P., et.al. (2001) *Icarus*, 151, 139-149. [3] Binzel, R. P., et.al. (2004) *MAPS*, 39, 351-366. [4] Binzel, R. P., et.al. (2004) *Icarus*, 170, 259-294. [5] Burbine, T. H., et.al. (1996) *MAPS*, 31, 607-620. [6] Burbine, T. H. (2000) *Ph. D. Thesis, MIT*. [7] Burbine, T. H. and Binzel, R. P., (2002) *Icarus*, 159, 468-499. [8] Bus, S. J. (1999) *Ph.D. Thesis, MIT*. [9] Bus, S. J. and Binzel, R. P. (2002) *Icarus*, 158, 106-145. [10] Bus, S. J. and Binzel, R. P. (2002) *Icarus*, 158, 146-177. [11] Sunshine, J. M. and Pieters, C. M. (1993) *JGR*, 98, 9075-9087. [12] *Near-Earth Objects – Dynamic Site*, <http://newton.dm.unipi.it/cgi-bin/neodys/neoibo>, [13] *NASA Planetary Data System*, <http://pds.jpl.nasa.gov/>.