NIR SPECTROSCOPIC STUDY OF MULTIPLE ASTEROID SYSTEMS. F. Marchis[1,2], J. E. Enriquez[1] and J. P. Emery[3], [1]Carl Sagan Center, SETI Institute (189 Bernardo Av, Mountain View CA 94043 USA, eenriquez@seti.org) [2]Department of Astronomy at UC Berkeley (601 Campbell Hall, Berkeley CA 94720 USA). [3] University of Tennessee at Knoxville (306 EPS Building, 1412 Circle Drive, Knoxville, TN 37996, USA).

Introduction: Images of the asteroid (243) Ida captured by the Galileo spacecraft revealed the presence of a small satellite named Dactyl, unambiguously confirming the existence of multiple asteroids. The advent of high angular resolution imaging permitted the visual discovery of new binary, and even triple, asteroids [1]. About 75 systems have currently been imaged, and ~120 other binaries are suspected based on lightcurve studies [2]. Formation scenarios for multiple asteroid systems include catastrophic collisions [3], fission via the YORP effect [4], and tidal disruption [5]. Satellite orbital parameters, size and shape of the components, surface properties, porosity, and material densities are needed to refine and evaluate these formation scenarios [6]. Two main questions in the study of multiple asteroids are:

- Are certain compositional classes more likely to form binary and multiple systems than other?
- Is there a link between the bulk density of a binary asteroid system and its taxonomic class?

Instruments and Observations: Compositional characterization of asteroid surfaces is most robust when carried out over the widest possible wavelength range. Different wavelength ranges are often sensitive to different aspects of composition, grain size, or surface structure. We use SpeX on the IRTF to measure near-infrared (0.8 to 2.5 µm) reflectance spectra of known binary asteroids. The current sample of observable multiple asteroid systems is estimated to be ~80 targets (V<17). For ~85% of these targets, no visible and NIR spectra can be found in the literature, so their taxonomic class remains unknown. The dominant mafic minerals in terrestrial bodies (pyroxene, olivine, spinel) usually display very different spectral morphologies in this wavelength region. SpeX excellent wavelength coverage (0.8- to 2.4-µm) – and a sufficient signal-to-noise ratio (SNR) – should allow the acquisition of high-quality spectra.

All observed targets, including the observation of 19 multiple main-belt asteroids and one NEA from one night in Aug. 2008 and two nights in Sep. and Nov. 2010, are listed in Table 1. Three additional nights of observations are scheduled in 2011A.

Data reduction and Data Analysis: The spectra were processed following the procedure described in [7]. Data frames were taken in pairs with the object dithered along the slit. Subtraction of these pairs produces a first order removal of sky emission. The maximum on-chip integration time is 120 s to minimize the effects of variability of the sky emission. For each frame we applied a linearity correction. Typically, multiple frames are taken with the maximum on-chip integration time and summed together during data reduction in order to increase the signal-to-noise ratio (S/N). Nearby solar analog stars were observed regularly throughout the asteroid observations to ensure good correction of atmospheric absorption and solar spectral slope. We checked for the quality of each solar analog star by cross-comparison with each other. With SpeX, flat field images are obtained by illuminating an integrating sphere which is in a calibration box attached to the spectrograph. This box also contains an argon lamp that is used for wavelength calibration. The final reflectance spectra of a few asteroids are presented in Fig. 1.

We inferred the taxonomic class of these asteroids, using the webtool from [8] who developed an asteroid taxonomy with 24 classes based on principal component analysis of spectral data spanning wavelengths from 0.45 to 2.45 µm. Table 1 shows that there is good agreement between the taxonomic classes which were determined from our 0.8 to 2.45 µm spectra and the taxonomic class determined from visible 0.44-0.92 µm spectra by [9] and [10].

We will present an improved data analysis for all these asteroids by combining both visible and NIR spectra.

Discussion: The equivalent diameter of these multiple asteroids listed in Table 1 was determined from IRAS photometric observations [11], from Spitzer/IRS [12], direct imaging [13], or assuming a geometric albedo from the derived taxonomic class (6% for C-complex, 30% and 40% for S- and V- type asteroids respectively).

Most of the large (D > 100 km) multiple asteroids with one or two distant moonlets (type T1) belong to the C-complex. By contrast, small (D < 20 km) multiple asteroids which were discovered mostly by lightcurve analysis [2] and labeled T3 (asynchronous close satellite with a size ratio of at least 1/20) or T2 (close and similarly–sized binary asteroids) are members of the S-complex.

To improve this preliminary statistical survey, we anticipate doubling the number of observed targets by the end of 2011. To constrain the surface compositions of these asteroids, their reflectance spectra will be combined with mid-IR emissivity spectra collected with Spitzer/IRS. We will analyze them using a Hapke model that considers size grain distribution, composition, and space-weathering contamination to constrain the surface composition.

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References:

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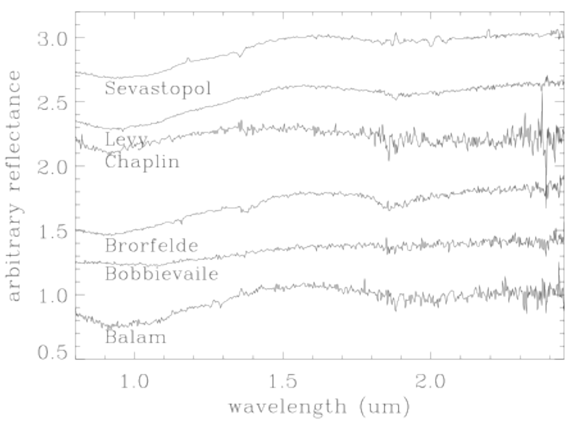

Figure 1: Spex/IRTF 0.8-2.45 um spectra of several small (D_{eq}<15 km) multiple asteroids. The spectra were shifted by an arbitrary value of 0.4. Based on [8] taxonomic classification, all these asteroids belong to the S-complex.

ID	Name	Population	Discovery Technique	Binary Type	NIR Class	visible Class	Equ. Diam km
41	Daphne	MB IIb	AO obs	T1	Cgh, Ch	Ch	177 (SIMPS)
45	Eugenia	MB Iib	AO obs	T1	D	C	210 [12]
93	Minerva	MB Iib	AO obs	T1	Cb,C	C	141 (SIMPS)
107	Camilla	MB	HST obs	T1	B, C	P	241 [12]
130	Elektra	MB IIIb	AO obs	T1	C, K?	Ch	182 (SIMPS)
216	Kleopatra	MB Iib	AO obs	T1	X	M	135 [13]
283	Emma	MB IIIb	AO obs	T1	D	C	144 [12]
762	Pulcova	MB IIIb	AO obs	T1	C, K?	Cb	137 (SIMPS)
809	Lundia	MB	LC	T2	V	V	~10 [12]
2121	Sevastopol	MB	LC	T3	Sq	Sl	~8 (from H)
3309	Brorfelde	MB	LC	T3	Sq	S	~4 (from H)
3623	Chaplin	MB IIIa	LC	T2?	S, L	none	11 [12]
3673	Levy	MB I	LC	T3	Sq	none	~6 (from H)
3749	Balam	MB	AO+LC	T3	Sq	none	~5 [12]
3868	Mendoza	MB I	LC	T3	Sq	none	~8 (from H)
3982	Kastel	MB	LC	T3	V	none	~4 (from H)
4674	Pauling	MB	AO obs	T1	Sq	none	4.7 (Spitzer)
5407	1992 AX	Amor II	LC	T3	S	Sk	4 [12]
6406	1992 MJ	MB	LC	T2?	V	none	~7 (from H)
6708	Bobbievaile	MB I	LC	T3	K	none	~15 (from H)

Table 1: List of multiple asteroids observed with IRTF/SPEX in 2008 & 2010. Their taxonomic class is derived using our NIR observations combined with [8] classification. The equivalent diameter is derived using various sources including radiometric measurements [11,12], direct AO imaging [13], or using the absolute magnitude (H) of the asteroids with an approximated geometric albedo pv of 0.06 (C-complex), 0.30 (S-type), 0.40 (V-type)