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The X-type asteroids: spectroscopic results

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Abstract

We have carried out a spectroscopic survey in the 2004-2007 years of X-type asteroids in the visible and near infrared range at the NTT, TNG and IRTF telescopes. In this paper we present new VIS-NIR spectra of 24 asteroids belonging to the X type as defined by Tholen & Barucci [1], that is an "E–M–P" type asteroid for which albedo information was not available at the time of their classification. We find a large variety of near-infrared spectral behaviors within the X class, and we identify weak absorption bands in spectra of 11 asteroids. Our spectra, together with the new albedo values [2], can be used to suggest new Tholen classifications for these objects. To constrain their compositions, we conduct a search for meteorite analogues using the RELAB database, and we model the asteroid surface composition with geographical mixtures of selected minerals when a meteorite match is not satisfactory. In addition, we present an analysis of X complex spectral slope values and class distributions in the asteroid main belt, where we include previously published observations of M and E-type asteroids obtained during the same survey [3,4].

1. Introduction

The X complex in the Tholen taxonomy comprises the E, M and P classes which have very different inferred mineralogies but which are spectrally similar to each other and featureless in the visible wavelengths. By convention X-types with measured geometric albedos are classified into Tholen E-type (high albedo, $p_v > 0.3$), M-type (medium albedo, $0.1 < p_v < 0.3$), or P-type (low albedo, $pv < 0.1$) asteroids [1]. The X-type asteroid indicates an "EMP" asteroid for which we do not have albedo information. The X complex includes bodies with very different mineralogies: M asteroids may be composed of metals such as iron and nickel and may be the progenitors of differentiated iron-nickel meteorites, and/or of the enstatite chondrites; E-type asteroids have high albedo values and their surface compositions are consistent with iron-free or iron-poor silicates such as enstatite, forsterite or feldspar, and they are thought to be the parent bodies of the aubrite meteorites; P-type asteroids have low albedo values, featureless red spectra, and they have no clear meteorite analogues, even if they are presumed to be similar to carbonaceous chondrites, but with a higher organic content to explain the strong red spectral slopes.

1.1. Results and conclusions

We observed 24 X-type asteroids during in the 2004-2007 years at the TNG, ESO-NTT and NASA-IRTF telescopes. Our data reveal a large variety of spectral behaviors within the X class, and we identify weak absorption bands on 11 asteroids. We combine our spectra with the albedo values available since 2002 for the observed bodies to suggest new Tholen-like classifications. We find: 1 A-type (1122), 1 D-type (1328), 1 E-type (possibly, 3447 Burckhalter), 10 M-types (77, 92, 184, 337, 417, 741, 758, 1124, 1146, and 1355), 5 P-types (275, 463, 522, 909, 1902), and 6 C-types (50, 220, 223, 283, 517, and 536). Four new M-type asteroids (92 Undina, 337 Devosa, 417 Suevia, and 1124 Stroobantia) show a faint band in the 0.9 μm region, attributed to low calcium, low iron orthopyroxene. Indeed, several works based on spectral and radar observations show that not all the M-type asteroids have a pure metallic composition [3].

Three low albedo asteroids (50 Virginia, 283 Emma, and 517 Edith) show a weak band centered at 0.43 μm that we interpreted as due to Fe^{3+} spin-forbidden transition in hydrated minerals (hematite, goethite). Also the medium albedo bodies 337 Devosa and 1355 Magoeba have the same absorption. In this case the band may be associated with chlorites and Mg-rich serpentines or pyroxene minerals such us pigeonite or augite. 50 Virginia shows also two absorptions centered at $\sim$ 0.69 and 0.87 μm which are typical of hydrated silicates.

We performed a search for meteorite and/or mineral

Table 1: RELAB Matches: p_v is the asteroid albedo; [a]: Murchison heated to 600°C; [b]: Murchison heated to 700°C; [c] Mighei laser irradiated

ASTEROID	p_v	Met class	Met refl	Name	Grain Size(μm)
50 Virginia	0.04	CM	0.03	MET00639	<75
77 Frigga	0.14	IM	0.18	Chulafinnee	
92 Undina	0.25	IM	0.23	Babb's Mill	
92 Undina	0.25	Pall	0.14	Esquel	<63
184 Dejopeja	0.19	Pall	0.14	Esquel	<63
275 Sapientia	0.04	CM	0.03	Murchison[a]	<63
283 Emma	0.03	CM	0.03	MET00639	<75
337 Devosa	0.16	IM	0.16	Landes	slab
417 Suevia	0.20	IM	0.15	DRP78007	75-125
517 Edith	0.04	CM	0.03	Murchison[b]	63–125
522 Helga	0.04	CM	0.05	Migei[c]	<45
758 Mancunia	0.13	IM	0.16	Landes	slab
909 Ulla	0.03	CM	0.05	Migei[c]	<45
1124 Stroobantia	0.16	IM	0.12	DRP78007	<25

spectral matches between the asteroids observed in the visible and near infrared range (with published albedo values) and the RELAB database (Table 1).
We find that 7 of the new M-types can be fit with metallic iron (or pallasite) materials, and that the low albedo C/P-type asteroids are best fitted with CM meteorites, some of which have been subjected to heating episodes or laser irradiation. We tried to constraint the asteroids' surface compositions using geographical mixing models for new M-types having the 0.9 μm feature. We found good spectral matches by enriching the iron or pallasite meteorites with small amounts ($< 3\%$) of orthopyroxene or goethite.

The whole sample of asteroids included in our work is 72 X-type objects (we exclude the A, D and S/Sq-type asteroids), partly published here and partly already published in Fornasier et al. [3, 4]. On the basis of their spectral behavior and albedo values, we classified 22 E-types and distributed them into 3 subclasses I, II, and III [4]. Our survey includes 38 M-types, ten of which (77, 92, 184, 337, 417, 741, 758, 1124, 1146) were originally classified as X-types, 7 C-types (498 Tokio was originally classified as an M-type, and all the others as X-type), 1 D (originally classified as X-type), 5 P-type (originally classified as X-type), 3 A-types (2577, 7579 and 1122 which were originally classified as E-types, and an X-type, respectively), and 2 S-types (5806 and 516, which were originally classified as an E and M-type, respectively). In Fig. 1 we show the spectral slope value S_{VIS} calculated in the visible wavelength range versus the semimajor axis for all the E, M and C/P-types observed. As expected, high albedo E-type asteroids populate mainly the Hungaria region and the inner part of the main belt, while

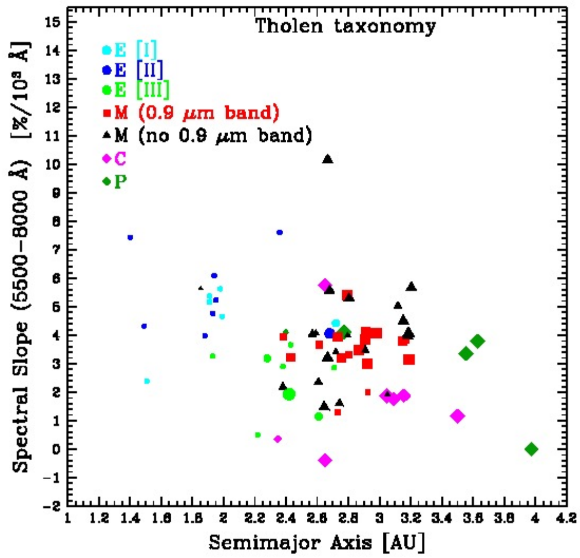

Figure 1: Spectral slope value (S_{VIS}) versus the semimajor axis for the different asteroids observed, classified following the Tholen taxonomy. The size of the symbols is proportional to the asteroids' diameter.

low albedo C and P-types are located mainly in the outer part of the main belt or beyond it, and M-type are located between 2.4 and 3.2 AU.

The analysis of this complete sample has clearly shown that, although the mean visible spectral slopes of M-, E- and P-type asteroids are very similar to each other, the differences in albedo indicate major differences in mineralogy and composition.

References

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