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Spectroscopic survey of M type asteroids

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Abstract

We carried out a spectroscopic survey in the visible and near infrared wavelength range (0.4-2.5 μm) of 30 asteroids belonging to the M taxonomic type. The data were obtained during several observing runs during the years 2004-2007 at the TNG, NTT, and IRTF telescopes. We confirm a large variety of spectral behaviors within the M class, and the identification of weak absorption bands, mainly of the 0.9 μm band tentatively attributed to orthopyroxene. A comparison with previously published data indicates that the surfaces of several M asteroids may vary significantly. We attempt to constrain M-type asteroid surface composition by looking for meteorite spectral analogues in the RELAB database and by modelling with geographical mixtures of selected meteorites/minerals. We confirm that iron meteorites, pallasites, and enstatite chondrites are the best matches to the observed M-type spectra.

1. Introduction

M-type asteroids, as defined in the Tholen taxonomy, are medium albedo bodies supposed to have a metallic composition, to be the progenitors both of differentiated iron-nickel meteorites and enstatite chondrites. This interpretation requires parent bodies heated to at least 2000 $^{\circ}C$ to produce iron meteorites [1]. However, polarimetric measurements [2] and radar observations of selected M-type asteroids [3] have revealed a large variety of surface properties that are in some cases inconsistent with only a metallic composition. Rivkin et al. [4] identified the 3 μm band, usually associated to hydrated minerals, on some M type asteroids. If this band is really associated to hydrated mineral, then M type asteroids might not be anhydrous and igneous as previously believed and the thermal scenarios for the inner main belt may need a revision.

In order to investigate the surface composition of M-type asteroids, we carried out a V+NIR spectroscopy survey at the TNG-ENO (on Feb. and Nov. 2004), NTT-ESO (on May 2004, Aug. 2005, and Jan. 2007), and IRTF-NASA telescopes (2004-2008)

2. Results

The observed M asteroids (24 in V+NIR spectroscopy and 6 in V spectroscopy) show different spectral behaviors. Several weak absorption bands have been identified in M-type spectra, showing that their surface compositions are not exclusively metallic (Table 1). In particular on several asteroids we identify a weak feature (1-5 % depth) in the 0.9 μm wavelength region attributed to low-Fe, low-Ca orthopyroxene minerals [5]. All these asteroids belong to the Xk class in the Bus-DeMeo taxonomy. Some asteroids show a band at 0.43 μm (16 Psyche, 22 Kalliope, 69 Hesperia, 216 Kleopatra, 338 Budrosa, and 498 Tokio) that can be attributed to chlorites and Mg-rich serpentines, or to pigeonite or augite, or to an Fe^{3+} spin-forbidden transition in the iron sulfate jarosite. 132 Aethra shows a 0.49 μm band probably due to sulfides such as oldhamite and/or troilite. 135 Hertha has a faint band at $\sim$ 0.51 μm similar to the Fe^{2+} spin-forbidden crystal field transitions in Earth and lunar pyroxene. The spectrum of 755 Quintilla is peculiar with four absorption bands: 0.9 and 1.9 μm features could be attributed to pyroxene silicates, but the origins of the 1.37 and 1.61 μm bands are unknown.

Comparing our spectra with those in the existing literature, we suggest that asteroids 129 Antigone, 325 Heidelberga, 498 Tokio, and 785 Zwetana may display surface variability as they show different spectral behaviors throughout independent observations.

To constrain the possible mineralogies of our asteroids we conducted a search for meteorite and/or mineral spectral analogs (having albedo values comparable to that of the asteroids) using the RELAB spectrum library. Most best matches resulted in iron meteorites, pallasites, or enstatite chondrites, as suggested in the literature (some examples in Fig 1). Only 498 Tokio resembles to the spectra of carbonaceous chondrites, but its albedo is anomalously low (7%) within the M class. Our method of search de-emphasizes the small

Table 1: Summary of the features observed on the M-type asteroids spectra and possible mineralogical interpretation.The Bus-DeMeo (BD) taxonomy is also reported. CFT=crystal field transitions.

band (μm)	asteroids	BD tax.	suggested interpretation
0.43	16, 22, 69,	Xk	chlorites and
	216, 338	Xk	Mg-rich serpentine
			or pigeonite or augite
0.43	498	Xc	iron sulfate jarosite
0.49	132	-	sulfides
0.51	135	Xk	Fe^{2+} spin-forbidden
			CFT in pyroxene
0.90	16, 22, 55, 69	Xk	low-Fe, low-Ca
	110, 135, 216,	Xk	orthopyroxene
	250, 338, 347	Xk	
	369, 755, 872	Xk	
0.93-1.14	129	Xc	antigorite?
0.9-1.3	498	Xc	unknown
1.37,1.61	755	Xk	unknown
1.86	755	Xk	iron bearing pyroxene
0.96 and 2	516	Sq	olivine and pyroxene

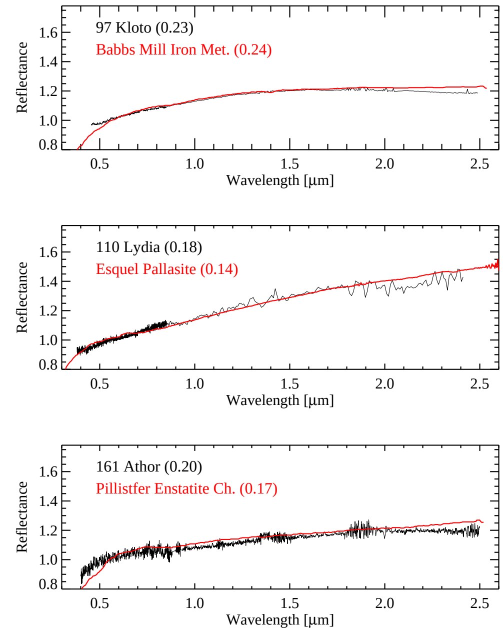

Figure 1: 3 M-type spectra (black) together with the best meteorite match found in the RELAB database (in red). The albedo of the asteroids and meteorites is given in parenthesis.

absorption features. To constrain the abundance of silicate material needed to reproduce the weak 0.9 μm band seen on some spectra, we created spatially segregated (geographical) mixtures of several terrestrial and meteoritic materials in different grain sizes. A few percent (less than 2%) of orthopyroxenes or hydrated silicates (goethite) added to iron meteorites allowed us to reproduce the weak spectral feature around 0.9 μm, but the synthetic spectra did not match both albedo, spectral slope, and band depth and center of the observed asteroids.

A statistical analysis of the M asteroids spectral characteristics versus orbital elements and physical parameters indicated a possible correlation between the continuum slope and semi-major axis, and two anti-correlations between visible slope to albedo and continuum slope to rotational period. M-type asteroids tend to be dark in albedo and red in near infrared slope with increasing value of the semi-major axis. If confirmed, the albedo and slope trends could be due to a difference in composition of objects belonging to the outer main belt, or alternatively to a combination of surface composition, grain size and space weathering effects.

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