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What can the polarimetric properties of M-type asteroids tell us about their composition?

Irina Belskaya[1], Andrei Berdyugin[2], Yurij Krugly[1], Vasilij Rumyantsev[3], Zahary Donchev[4], Alexey Sergeyev[5,1], and Sofiia Mykhailova[1]

[1]V.N. Karazin Kharkiv National Universiry, Kharkiv, Ukraine (irina@astron.kharkov.ua)

[2]Department of Physics and Astronomy, FI-20014 University of Turku, Finland

[3]Crimean Astrophysical Observatory, Nauchny, Crimea

[4]Institute of Astronomy and NAO, Bulgarian Academy of Sciences, Sofia, Bulgaria

[5]Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, France

Introduction

The letter M (metal) to classify several asteroids was proposed for the first time by Zellner and Gradie [1] because of similarity of their polarimetric and spectral properties to iron meteorites. However, the possible meteorite analogues according to spectral data of these asteroids included not only iron meteorites but also some types of enstatite chondrites [2]. M-class was one of seven major classes in Tholen's taxonomy well separated from other classes by featureless spectra and moderate surface albedo [3]. In the recent classifications based on spectral data alone [4,5] M-class is a part of X-complex which includes all asteroids with featureless spectra regardless of their albedo.

M-asteroids have caused a great interest to their study because it was believed that these asteroids could be the remnants of the metal cores of differentiated planetesimals. The largest M-type asteroid (16) Psyche has been selected as a target of the forthcoming NASA space mission. However, numerous observations of M-type asteroids by different techniques revealed that they can have diverse composition. In [6,7] the spectroscopic and radar observations were analyzed together to clarify the composition of M-type asteroids. According to their estimates, only about a third of M-type asteroids can be metal-dominated asteroids [6,7] although there is some inconsistency in compositional predictions between spectroscopic and radar observations [6].

Our goal is to consider polarimetric observations of M-type asteroids as complimentary technique to spectral and radar data and explore how polarimetry can improve our understanding of the nature and diversity of M-type asteroids. Here we present the results of new polarimetric observations of M-type asteroids and their analysis using all available data.

Observations

For observations we selected targets from the list of asteroids classified as M-type in [3] or X-complex asteroids in [4,5] with moderate surface albedo from 0.1 to 0.35. The main aim of our observations was the reliable determination of the values of polarimetric parameters characterizing the negative branch of polarization, i.e. the depth of polarization minimum P_{min} and the inversion angle. Observations were started in 2020 and involved three telescopes: the 2.6-m telescope of the

Crimean Astrophysical Observatory, the 2-m telescope of the Bulgarian National Astronomical Observatory in Rozhen and the remotely controlled Tohoku 60-cm telescope at Haleakala Observatory, Hawaii. Observations were made using CCD polarimeters in V or R filters at the 2-m and 2.6-m telescopes, and simultaneously in BVR filters at the 60-cm telescope. In total, polarimetric observations of 18 asteroids have been carried out from August 2020 to May 2021.

Results

We have analyzed the new observational data together with the available literature data on the polarimetry of M-type asteroids. The number of M-type asteroids for which it is possible to determine at least one of the polarimetric parameters (P_{min} or the inversion angle) has increased to 45 objects. This is more than 70% of all main belt asteroids with diameters over 40 km that can be attributed to the M-type. The previous analysis by Gil-Hutton [8] included a data-sample of 26 M-type asteroids. We searched for possible relationships of polarimetric parameters with visible and infrared spectral slopes and broadband colors as well as infrared and radar albedos. We found that polarimetric parameters are diagnostic on asteroid's composition and can be used to improve our current understanding of the composition of M-type asteroids based on spectral and radar data.

Conclusion

Polarimetric observations of M-type asteroids, analyzed together with their spectral and radar data, provide a better understanding of the composition and nature of M-type asteroids.

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