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On the synergy of polarimetry and spectroscopy for the physical characterization of the asteroids

A. Cellino
(1) INAF, Osservatorio Astrofisico di Torino, Italy (cellino@oato.inaf.it / Fax: +39-011-8101930)

Abstract

The synergic use of polarimetry and visible/near-IR reflectance spectroscopy is a fundamental tool for the purposes of physical characterization of small solar system bodies, in particular the asteroids. A couple of major applications are asteroid taxonomy, and the study of the so-called Barbarian asteroids. In the field of taxonomy, a new identification of the F taxonomic class previously found in the 80s and then substantially lost due to a lack of spectroscopic data at short wavelengths is one of the expected results of the on-going Gaia mission. As for Barbarians, there are indications that they might be extremely old and primitive.

1. Introduction

Reflectance spectroscopy is one of the most intensively adopted technique to obtain data of utmost importance for the purposes of asteroid physical characterization. Reflectance spectra are extensively used to infer information about the most likely composition of asteroid surfaces and are also the basis of asteroid taxonomy. Polarimetry has been known since a long time to be a primary tool for the determination of the geometric albedo and of the sizes of surface regolith particles, but due to the fact of requiring several observations of any single object, observed at different phase angles, polarimetry has been strongly under-exploited for a long time. The recent availability of new observing facilities and the beginning of new dedicated observing campaigns, like the *Calern Asteroid Polarimetric Survey* (CAPS), in addition to a first systematic project of spectro-polarimetric observations has started to change the situation. Two fields in which the synergy of polarimetry and reflectance spectroscopy is particularly promising are asteroid taxonomy and the study of the so-called Barbarian asteroids.

2. Asteroid taxonomy: the recovery of the F class

Polarimetric data were used in the first era of asteroid taxonomic classification to distinguish among objects having nearly identical UBVRI colours, but very different albedo. Subsequently, taxonomy started to be based on full reflectance spectra obtained in the framework of extensive campaigns like the SMASS [1], while the data-set of asteroid polarimetric data became fully insufficient to be used as a support to taxonomic classification. Modern asteroid spectroscopy has covered mostly the visible and near-IR spectral region, while the blue part of the spectrum has been essentially lost. As a consequence, the previously identified F class [2] has been no longer recognized in modern taxonomies, and the objects previously found to belong to the F class are now included in a bigger class named B. However, polarimetric data in V colour clearly show that F class asteroids are clearly distinct, being characterized by low values of the inversion angle of polarization, as shown in Fig. 1. Interestingly, some asteroids previously classified as F have been subsequently found to exhibit some cometary activity, like in the case of (4015) Wilson Harrington, and of (3200) Phaethon, the likely parent body of the Geminids meteor shower. This makes F-class asteroids particularly interesting. One of the expected results of the ongoing Gaia mission will be that of being able to identify F class asteroids taking profit of the fact of performing spectroscopy over a wavelength range including the blue. Ground-based polarimetric data will be essential to confirm and validate Gaia results in this field.

3. Barbarians

Barbarian asteroids, so called after the prototype of the class, asteroid (234) Barbara, are characterized by unusually large values of the polarization inversion angle (the phase-polarization curve of (234) Bar-

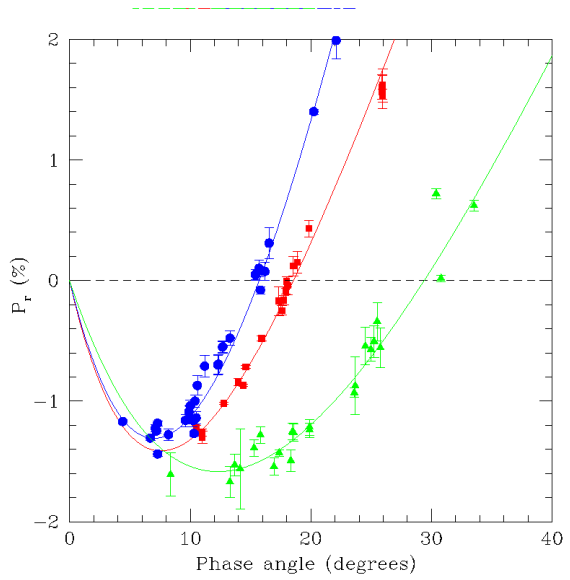

Figure 1: Phase-polarization curves of (704) Interamnia (F class, blue circles), (2) Pallas (B class, red squares) and (234) Barbara (Barbarian, green triangles). The best-fit curves corresponding to an exponential-linear function are also shown for each object.

bara is shown in Fig. 1). This property, first found by [3], is now shared by about 20 asteroids, most of which are fairly big in size (> 50 km). Barbarians are now known to be characterized by peculiar reflectance spectra, interpreted in terms of an anomalous composition rich in spinel, a refractory mineral found in Calcium-Aluminum-rich inclusions (CAIs) in many meteorites. CAIs are considered to be the oldest samples of solid material found in the solar system [4]. The Barbarian properties are not due to a thin surface layer, but they are structural, as indicated by the discovery of a family of Barbarian asteroids [5]. Barbarians could therefore potentially represent the Holy Graal in asteroid studies, namely survivors of the first generation of planetesimals accreted in the inner solar system. For this reason, spectro-polarimetric studies of these objects are being actively carried out by different teams.

4. Summary and Conclusions

The synergy of polarimetry and spectroscopy is reveling new and exciting fields of investigation in the field of asteroid science. In addition to the use of separate polarimetric and spectroscopic data, the simultaneous application of polarimetry and spectroscopy, made possible by the spectro-polarimetric observing mode offered at the ESO-VLT and at the WHT telescope, has been recently tested and preliminarily found to provide very interesting results ([6]). The reduction and analysis of a much larger data-set of measurements more recently obtained is currently under way, and a paper is in preparation.

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