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The relation between polarimetric properties and geometric albedo of the asteroids: Some progress

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Abstract

Since a long time it has been known that a relation exists between the polarimetric properties exhibited by atmosphereless Solar system bodies and their geometric albedo. For this reason, polarimetry is a very important observing technique, being able to provide estimates of the albedo directly resulting from measured polarimetric properties, without need of any additional ancillary data (like the absolute magnitude in the case albedo determination using thermal radiometry). The most serious problem in asteroid polarimetry comes from the fact that the relation linking the geometric albedo with polarimetric properties includes some calibration parameters which are affected by noticeable uncertainty. By obtaining new polarimetric data for a selected list of target asteroids having well-established albedoes, we are improving the situation. Some preliminary results are shown.

1. Introduction

The light that we receive from asteroid at visible wavelengths is scattered sunlight. As a consequence of the scattering process, this radiation is in a state of partial linear polarization. The degree of linear polarization is found to vary as a function of the illumination conditions at the epoch of observation. In particular, the degree of linear polarization turns out to be a function of the *phase angle* (the angle between the directions to the Sun and to the observer as seen from the target). The plane of polarization is also found to vary as a function of phase angle. In particular, the plane of polarization is found to be parallel to the plane containing the Sun, the asteroid and the observer (*scattering plane*) in a wide interval of phase angles, extending approximately between 0 and 20 degrees. Beyond this limit (*inversion angle*) the plane of polarization becomes perpendicular to the scattering plane. In asteroid polarimetry it is customary to call *negative polarization* the case corresponding to the plane of polarization parallel to the scattering plane, and *postitive polarization* the other case. The so-called P_r parameter is commonly used to describe both the degree of linear polarization observed at a given epoch, and the orientation of the polarization plane. In particular, the sign of P_r corresponds to either negative or positive polarization, whereas its absolute value gives the degree of linear polarization.

Plots of the variation of P_r as a function of the phase angle display the so-called *phase - polarization curves* of the objects. Practically all asteroids observed so far exhibit a similar general behavior, as shown as an example in Figure 1.

Since a long time it has been known that parameters describing the depth of the negative polarization branch and the slope (normally indicated as h in most papers) of the linear trend of the phase - polarization curve around the inversion angle (see Figure 1) are diagnostic of the geometric albedo. The relation which is commonly adopted is the following:

$$\log p_v = C_1 \log h + C_2 \quad (1)$$

where p_V is the geoemtric albedo and h the slope of the phase - polarization curve, as mentioned above. A major problem in asteroid polarimetry is that different values for the C_1 and C_2 parameters have been published by different authors, and there is not a general consensus about the best choice of them, with different authors adopting different published values. Moreover, the nominal uncertainties of these parameters, when published, turn out to be non-negligible. As a consequence, most of the uncertainty in the determination of asteroid albedos using the polarimetric technique comes usually from the uncertainty in the two calibration constants [4]. Due to this reason, the Commission 15 of the International Astronomical Union has recommended that this problem should be solved, and has set-up a Task Force, dedicated to this purpose.

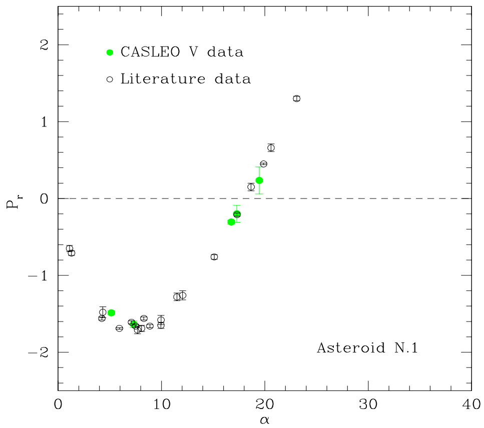

Figure 1: Phase - polarization curve for the dwarf-planet (1) Ceres. α is the phase angle. The general trend of this curve is fully representative of the behavior exhibited by asteroids. CASLEO data for Ceres have been obtained by the authors at the Complejo Astronomico El Leoncito in Argentina, and are still partly unpublished.

2. Improving the calibration of the albedo - polarization relation

[5] have published a list of asteroids for which the albedo is thought to be known with good accuracy. The objects in this list are either asteroids explored *in situ* by space probes, or asteroids whose size has been obtained with good accuracy by means of star occultation measurements. At the same time, the absolute magnitudes of these objects are also thought to be known with good accuracy, therefore for them a correspondingly accurate albedo value can be derived. In order to improve the accuracy of the calibration constants in Equation (1), the basic idea is therefore to obtain high-quality phase - polarization curves, in order to derive polarimetric parameters, including the slope h, which can then be used to derive an improved computation of the calibration constants.

In recent years we have been involved in an observational effort aimed at obtaining better phase - polarization curves of both main belt and near-Earth asteroids. The observations have been mostly carried out at the Complejo Astronomico El Leoncito (San Juan, Argentina) and have already produced in the past a number of publications [1, 2, 3]. More recently, we have increase our efforts in order to obtain some new high-quality polarimetric slopes h for the objects in the [5] list, in order to use these values to directly improve the C_1 and C_2 constants in Equation (1). We present here the current results of this exercise. More in general, however, we are exploring the possibility that the relation between albedo and polarization might be better described by using different analythical relations. This work is in progress, and we can present here only a few preliminary results.

3. Conclusions

By improving the calibration of the relation between state of linear polarization and geometric albedo, we are trying to produce a major improvement in asteroid polarimetry. If our attempt is successful, the role of polarimetric observations of asteroids will become more important and widespread with respect to current situation. A first, immediate application that can be imagined is the determination of the albedo of newly-discovered Potentially Hazardous Objects. In the case of these bodies, which approach the Earth and can be visble from short distances and consequently at larger phase angles than normal main belt asteroids, the advantage is that the difference in the polarimetric slope of objects having different albedo can lead to accurate albedo determination having at disposal only a few, or even one single, measurement at large phase angle, bacause at large phase angles the differences in the degree of linear polarization for objects having different albedo become much greater than the corresponding differences observed at small phase angles.

Asteroid polarimetry is a powerful tool for the physical characterization of asteroids. By improving the reliability of albedo determinations based on polarimetric data, we will improve the role of polarimetry as a very nice complement of more commonly adopted techniques like spectroscopy and thermal radiometry.

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