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First steps towards a database of polarisation spectra of asteroids

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Abstract

We have collected polarisation spectra for over 70 asteroids of various taxonomic classes. Data obtained so far confirm a predictable relation between polarization spectra and albedo, but at the same time indicate also some previously unexplored dependences upon other surface properties, including regolith properties. We show that asteroids exhibiting very similar reflectance spectra can display strong differences in their polarization spectra, and we conclude that spectropolarimetry is a more powerful tool to reveal the great diversity displayed by the small bodies of our solar system than traditional spectro-photometric techniques.

1. Introduction

Light scattered by surfaces is polarized. The state of the polarization of the scattered radiation depends on the structure and composition of the reflecting surface and on the scattering angle, and polarimetric measurements as function of the scattering angle may reveal information about the physical properties of the reflecting surface.

Broadband linear polarization (BBLP) measurements have long been used as a remote sensing tool for the characterisation of the objects of our solar system. BBLP measurements in the standard optical filters are usually plotted as a function of the phase-angle (the angle between the sun and the observer as seen from the target object). The morphology of the resulting phase-polarization curves may be used for the purposes of albedo determinations (see Cellino et al. 2015 and references therein), to infer some properties of the surface regolith such as the average particle sizes, and for asteroid classification (Penttilä et al. 2005, Belskaya et al. 2017).

Comparatively less attention has been paid to the way polarisation depends on wavelength. Most of the relevant works are actually based on multi-filter BBLP measurments (Lupishko & Kiselev 1995; Belskaya et al. 2009; Lupishko & Shkuratov 2016) while low-resolution spectropolarimetry of asteroids was introduced by Bagnulo et al. (2015).

2. Earlier works

Bagnulo et al. (2015) have shown that polarization spectra of low albedo and intermediate albedo asteroids exhibit opposite trends, namely: the polarization spectra of low albedo asteroids always have a positive gradient, and intermediate albedo asteroids always have a negative gradient. This confirmed preliminary results obtained by Lupishko & Kiselev (1995) and Belskaya et al. (2009), based on multi-colour BBLP data, and suggested that the slope of the polarization spectra may be linked to the albedo. Bagnulo et al. (2015) also unveiled an unexpected variety of situations. Some of them show up as violation of the Umov law. The Umov law says that light reflected by darker objects is more polarized than light reflected by objects with higher albedo; however, it was found that in contrast to what expected from basic physical considerations, reflectance and polarization spectra of asteroid (236) Honoria are correlated positively. This discovery represents a challenge for theory, and stimulates further developments of the modelling of the scattered light. Both Belskaya et al. (2009) and Bagnulo et al. (2015) proposed that the slope of the spectral dependence of polarization of asteroids exhibit opposite signs in the negative and in the positive branch

of the curve of polarisation versus phase-angle. This fact was confirmed (on a more systematic basis) by Lupishko & Shkuratov (2016).

If we could establish a firm link between albedo and wavelength-dependence of the degree of polarization (as our preliminary results seem to suggest) we would accomplish a crucial step forward in asteroid science: joint to absolute magnitude measurements, spectropolarimetry would allow us to measure the size of asteroids, with implications particularly important for the characterization of potentially hazardous near-Earth objects.

3. New measurements

Using the ISIS instrument of the William Herschel Telescope and the FORS2 instrument of the ESO Very Large Telescope, we have now collected 144 polarisation spectra of 72 different asteroids belonging to different taxonomic classes and with different albedo, and started to construct the first spectropolarimetric database of asteroids. We have explored in detail the complex taxonomic classes S and C, which include a significant numbers of sub-classes that can correspond to a variety of relevant differences in terms of composition, regolith properties and overall collisonal and thermal histories of the objects. While still working on a classification scheme for spectropolarimetry, we have found examples of asteroids with relatively similar optical reflectance spectra but different polarization properties. The natural interpretation of this finding is that the diversity of surface structures may best revealed via spectropolarimetric measurements than through "usual" spectro-photometry.

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References

[1] Bagnulo, S., Cellino, A., Sterzik. M.F.: Linear spectropolarimetry: a new diagnostic tool for the classification and characterization of asteroids, Monthly Notices of the Royal Astronomical Society, Vol. 446, pp. L11-L15, 2015.

[2] Cellino, A., Bagnulo, S., Gil-Hutton, R., Tanga, P., Cañada-Assandri, M., Tedesco, E.F.: On the calibration of the relation between geometric albedo and polarimetric properties for the asteroids, Monthly Notices of the Royal Astronomical Society, Vol. 451, pp. 3473-3488, 2015.

[3] Belskaya, I.N., Levasseur-Regourd, A.-C., Cellino, A., Efimov, Y.S., Shakhovskoy, N.M., Hadamcik, E., Bendjoya, P.: Polarimetry of main belt asteroids: Wavelength dependence, Icarus, Vol. 199, pp.97-105, 2009.

[4] Belskaya, I.N., Fornasier, S., Tozzi, G.P., Gil-Hutton, R., Cellino, A., Antonyuk, K., Krugly, Yu.N., Dovgopol, A.N., Faggi, S.: Refining the asteroid taxonomy by polarimetric observations, Icarus, Vol. 284, pp. 30-42, 2017.

[5] Lupishko, D. F., Kiselev, N. N.: Inversion Effect of Spectral Dependence of Asteroid Polarization, Bulletin of the American Astronomical Society, Vol. 27, p. 1064, 1995.

[6] Lupishko, D. F., Shkuratov, Yu. G.: On spectral dependence of polarization of asteroids, Solar System Research, Vol. 50, pp. 329-336, 2016.

[7] Penttilä, A., Lumme, K., Hadamcik, E., Levasseur-Regourd, A.-C.: Statistical analysis of asteroidal and cometary polarization phase curves, Astronomy and Astrophysics, Vol. 432, pp. 1081-1090, 2005