Observations and laboratory simulations of asteroids by polarization measurements

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We present polarization observations of C-type asteroids and of (21) Lutetia, one of the targets of the Rosetta mission. The (21) Lutetia phase curves are compared to C-type and M-type asteroid phase curves. In a second part of the work, we use powdered meteorites to compare their polarization at two wavelengths to those observed for different asteroids, e.g., (21) Lutetia and (2867) Steins (the second asteroid observed by Rosetta).

INTRODUCTION

Sunlight scattered by asteroidal surfaces is partially linearly polarized. The polarization depends on the physical properties of the dust particles and on the geometry and wavelength of the observations. The polarization phase curves (hereafter PPC) are typical of irregular particles with a bell-shaped positive branch and a shallow negative branch. Except for a small number of mostly near-Earth objects, the asteroidal observations are limited to relatively small phase angles. The PPC parameters allow a classification into various types [1,2], which are similar to the spectral classification. They also provide information on, e.g., the bulk surface albedo by the slope at inversion and a two-parameter empirical function [3, 4].

To better document the database in the red wavelength domain and, more recently, in three other domains (green, red, and infrared), low-albedo asteroids have been observed at Observatoire de Haute-Provence, France (OHP). At the same time, (21) Lutetia, which is a target of the Rosetta mission (flyby 2010 July 10) and still has a controversial type, was also observed. Supplementary observations have been obtained at IUCAA Girawali Observatory (IGO) near Pune in India.

Some meteorites are fragments of asteroids ejected during collisions or fragmentation. Some of them are related to their parent body (or to an asteroidal type). Powdered meteorites deposited on a surface can be thus used as regolith analogs of their parent body. Such work is in progress with the PROGRA² experiment (http://www.icare.univ-lille1.fr/progra2), and we present a study of an aubrite meteorite as an analog of (2867) Steins, an E-type asteroid [5].

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OBSERVATIONS

The two telescopes, the 0.80-m one at OHP and the 2-m one at IGO, are in a Cassegrain configuration. Four polaroid filters are placed on a rotating wheel at OHP, whereas a half-wave plate with a Wollaston is used at IGO. BVRI filters are used.

C-type asteroids

Figure 1 presents the data points and trigonometric fits in blue-green and red wavelength domains. The polarization value increases with wavelength in the two phase-angle regions in both the negative and positive branches. Table 1 gives the parameters of the PPC. The bulk surface albedo is estimated with coefficients from [3]. An albedo of 0.08 ± 0.01 is derived from slope and P_{min}.

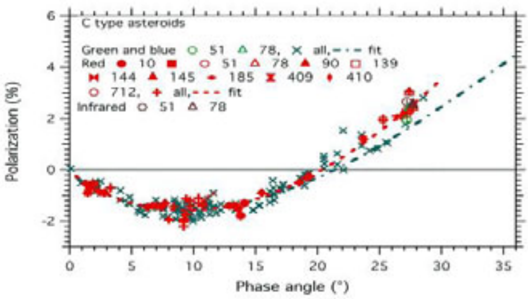

Figure 1. C-type asteroid polarization phase curves. Our observations are indicated by the asteroid number, other observations by crosses.

Table 1. Minimum polarization P_{min}, phase angles at minimum polarization α_{min} and at inversion α_0, and slope h at inversion for C-type asteroids.

Filters	α_{min} (°)	P_{min} (%)	α_0 (°)	h (% per deg)
Blue-green	9 ± 1	-1.6 ± 0.1	21.5 ± 0.5	0.23 ± 0.01
Red	9± 1	-1.6 ± 0.1	20.3 ± 1.0	0.28 ± 0.03

(21) Lutetia and M-type asteroids

Figure 2a presents the data points and a trigonometric fit for each wavelength range for (21) Lutetia. The negative branch becomes more pronounced as the wavelength increases. The inversion angle seems to be identical in the two domains. Figure 2b presents the synthetic data from the literature and fits in B-V (grouped together) and R domains. A possible dichotomy between M-type asteroids is noticed [8]. (21) Lutetia seems to belong to the new W type, which shows a deeper negative branch. The deeper negative branch is also shown by C-type asteroids; nevertheless, the wavelength behavior seems to be different for (21) Lutetia.

Our new observations of (21) Lutetia have allowed us to obtain phase curves for longer wavelengths than the classical blue-green and confirm the more pronounced negative branch with increasing wavelength [9]. The estimated bulk albedo is (0.12 ± 0.02) %.

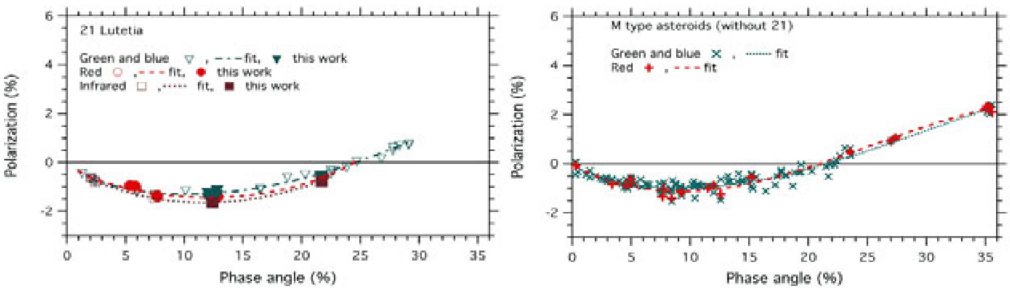

Figure 2. (21) Lutetia and M-type asteroid synthetic PPC. Our observations indicated by filled symbols, other observations by open symbols.

Table 2. Minimum polarization P_{min}, phase angles at minimum polarization α_{min} and at inversion α_0, and slope h at inversion for (21) Lutetia and M-type asteroids.

	Filters	α_{min} (°)	P_{min} (%)	α_0 (°)	h (% per deg)
21 Lutetia	Blue-green	10 ± 1	-1.31 ± 0.04	24.6 ± 1.0	0.17 ± 0.01
	Red	12 ± 2	-1.43 ± 0.06	24.5 ± 2.0	0.28 ± 0.03
	Infrared	12 ± 2	-1.64 ± 0.08	26 ± 2	--
M-type	Blue-green	9 ± 1	-0.99± 0.05	21 ± 1	0.14 ± 0.01
	Red	9 ± 3	-1.13 ± 0.06	21 ± 2	0.16 ± 0.01

LABORATORY SIMULATIONS

Powdered meteorites of different classes are tentatively used as analogs to retrieve polarization phase curves. For example, aubrite meteorites are estimated to originate from E-type asteroids. This was confirmed by the first results obtained by the observations of (2867) Steins from Rosetta. An aubrite sample (ALHA 78113,82) from the Antarctic Working Group was studied in a coordinated work [8]. The E-type asteroids data corresponding to (44) Nysa, (64) Angelina, (214) Aschera, (620) Drakonia, (2867) Steins, and 1998 WT_{24} are used to build synthetic PPC through R and V filters (Fig. 3). P_{max} is estimated to be about 1.6% with a very small difference between green and red wavelengths. The slope at inversion is (0.3 ± 0.1)% per degree.

The observations are compared to laboratory measurements on deposited grains for two size distributions with sizes s < 125 μm and 125 μm < s < 250 μm with the PROGRA²-surf instrument (Fig. 4a). From micro-gravity measurements with the PROGRA²-vis instrument, the variation of P_{max} as a function of size of the grains is deduced for lifted grains (Fig. 4b). When the grains are on a surface a similar decrease is noticed [9]. The values for deposited grains are included in Fig. 4b for an average size measured on SEM images for the two samples. For P_{max} of about 2 %, an average size smaller than 50 μm can be suspected for the (2867) Steins surface.

For (21) Lutetia analogs, CV3 and CO3 meteorites have been suggested as an alternative to a metal-rich surface. The laboratory work is in progress.

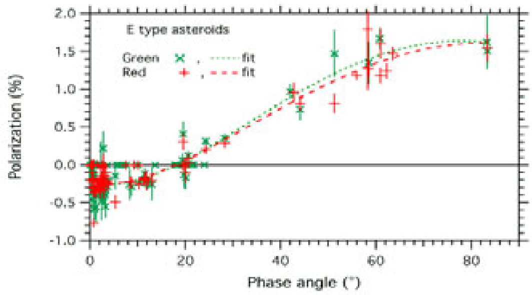

Figure 3. E-type asteroid (44, 64, 214, 620, 2867, 1998 WT_{24}) polarization phase curves.

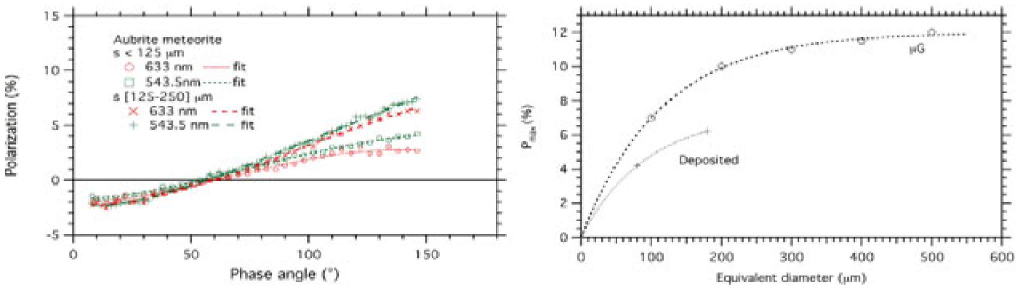

Figure 4. a) Aubrite meteorite polarization phase curves. b) P_{max} vs. grain size (*s*).

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