**POLARIZED LIGHT SCATTERED FROM ASTEROID SURFACES. V. CAN WE ESTIMATE POLARIZATION MAXIMUM FOR MAIN BELT ASTEROIDS?** D.I. Shestopalov, L.F. Golubeva, Shemakha Astrophysical Observatory, Shemakha AZ-3243 Azerbaijan, (shestopalov_d@mail.ru), (lara_golubeva@mail.ru).

**Introduction:** A dependence of linear polarization on phase angle, $P(\alpha)$, derived from an astrophysical observations of celestial bodies represents a discrete set of points on a polarization – phase angle plot. In order to calculate as accurately as possible the curves of the phase dependence of the polarization of atmosphereless bodies the following five-parameter approximation formula has been proposed [1]:

$$P(\alpha) = B(1-e^{-m\alpha})(1-e^{-n(\alpha-\alpha_i)})(1-e^{-l(\alpha-\pi)}),$$

where a scaling factor $B$ is expressed in terms of a slope $h$ of the polarization curve at an inversion angle $\alpha_i$ , namely

$$B = \frac{h}{n(1-e^{-m\alpha_i})(1-e^{-l(\alpha_i-\pi)})}.$$

We used the polarimetric measurements of lunar sites and lunar samples collected in [2] as well as that of Mercury [3] to test the efficiency of the formula and were repeatedly convinced of the good accuracy of polarization-phase curve fitting. Figure 1 demonstrates the approximation of polarimetric curves of the Moon observed by Lyot [4].

For the majority of asteroids one can measure polarization in the range of small phase angles ~ 1 – 30$^o$, so called negative polarization. In the case of main belt asteroids, the phase angles where positive polarization degree reaches maximum are inaccessible to groundbased observations. In order to approximate suitably the negative polarization branches of asteroids one can use simpler expression on condition that $n$, $l$ ~ 0:

$$P(\alpha) = \frac{h(1-e^{-m\alpha})(\alpha-\alpha_i)(\alpha-\pi)}{(1-e^{-m\alpha_i})(\alpha_i-\pi)}.$$

Even such a cutoff function has a second extreme $P_{max}$ near $\alpha_{max}$ ~ 100$^o$. Figure 2 illustrates this circumstance for high- and moderate-albedo asteroids. Reasoning by analogy with the polarimetric observations of near-Earth asteroids in the range of large phase angles one can roughly estimate the errors of the $\alpha_{max}$ and $P_{max}$ prediction: $\Delta\alpha_{max}$ ~ 5$^o$ and $\Delta P_{max}/P_{max}$ ~ 0.1.

What are the $P_{max}$ and $\alpha_{max}$ parameters inferred from the approximation function? To answer this question the following tests were carried out.

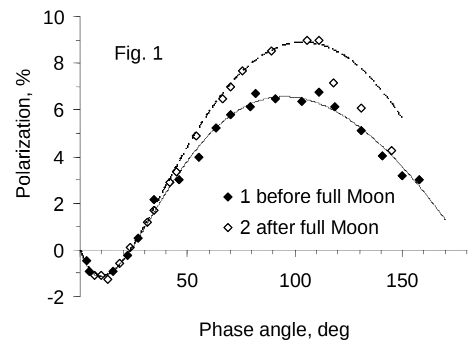
**The albedo – $\mathbf{P_{max}}$ relation:** Empiric correlation between the normal albedo and the maximum polarization degree $P_{max}$ of lunar areas in orange light (λ = 0.6 μm) is determined by equation [6]:

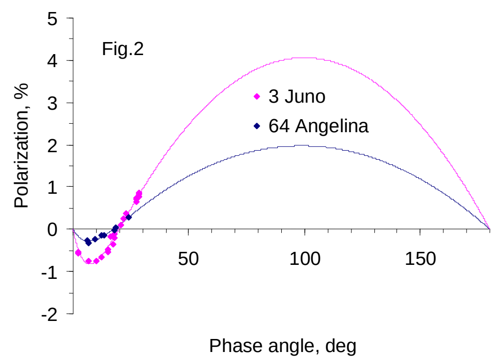
$\log A = (-0.724\pm0.005) - (0.36\pm0.02)P_{max}$.

In the case of asteroids we used the values of geometric albedo from [7, 8] and the original polarimetric data of good quality obtained in the B, G, V bandpasses [5]. After fitting asteroid polarization phase curves by the above-mentioned approximation formula, we found:

$\log A = (-0.70\pm0.08) - (0.14\pm0.07)P_{max}$.

This dependence between the geometric albedo of asteroids and $P_{max}$ is plotted in Fig. 3. The correlation for lunar areas denoted as dashed line is also shown in this Figure. Notable, the slopes of these lines are practically equal. The shift between the straight lines is seemingly on account of the fact that lunar regolith is finer than the asteroidal [10].




**The $\mathbf{\alpha_{max}}$ – $\mathbf{P_{max}}$ relation:** As was shown in [6] there is correlation between the $P_{max}$ parameter of lunar areas and the phase angle at which polarization maximum is achieved:

$\alpha_{max} = 97^o + 0.517\,P_{max}$ .

Observations were made in orange light at $\lambda$ = 0.6 μm.

We verified this relationship using the spectropolarimetric observations of lunar sites collected in [2]. After the approximation of lunar polarimetric curves observed in the spectral range of 0.420 – 0.783 μm, we found the following correlation equation:

$\alpha_{max} = (98.1^o \pm 0.6^o) + (0.65 \pm 0.05)P_{max}$ ,

which is very close to the foregoing.

E-, S-, M-type asteroids, for which polarimetry was carried out in B, G, and V bandpasses, show the $\alpha_{max}$ – $P_{max}$ relation similar to the lunar one:

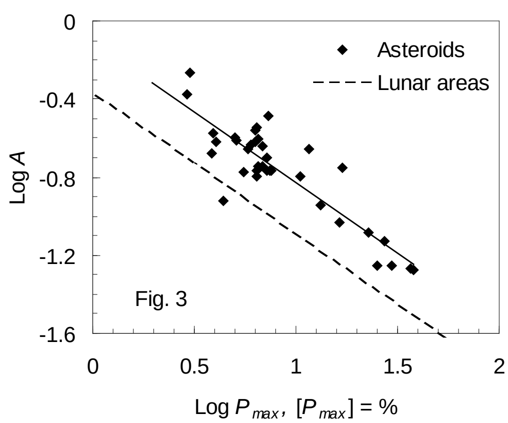
$\alpha_{max} = (96.8^o \pm 0.5^o) + (0.77 \pm 0.08)P_{max}$ .

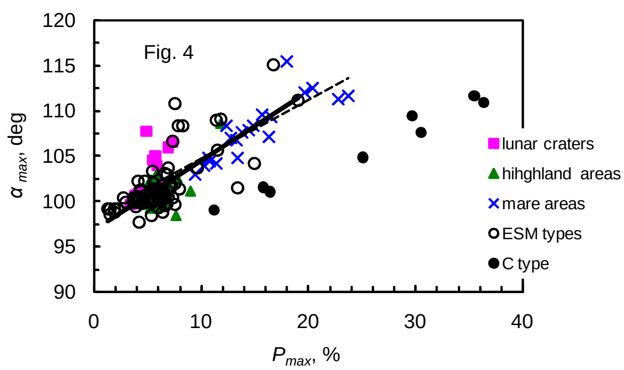
Figure 4 demonstrates almost identical correlations between $\alpha_{max}$ and $P_{max}$ obtained for lunar areas (solid line) and high- and moderate-albedo asteroids (dashed line). In turn, low-albedo C-type asteroids are arranged along another line. It is unclear now whether such a behavior of C asteroids arises because of a mistake of our extrapolation in the range of maximum polarization degree or due to the properties of the asteroid surfaces.

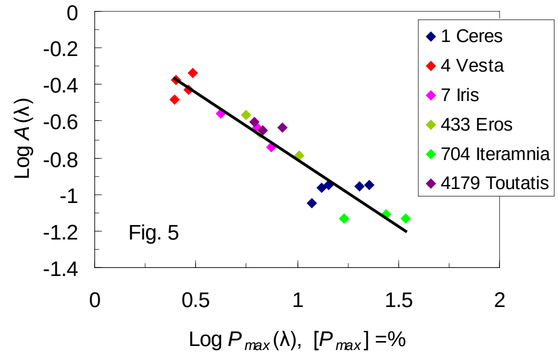
**The A(λ) – $P_{max}$(λ) relation:** Since the typical spectra of lunar areas are reddish (i.e. d$A(\lambda)$/dλ >0 in the vis-NIR spectral range) then according to Umov law $P_{max}(\lambda)$ decreases when wavelength increases (e.g., [2, 6]). This rule operates unconditionally for all lunar areas studied. Because of this, the constants of the regression equation between albedo and $P_{max}$ could slightly depend on wavelength. We checked this property in relation to several asteroids having UBVRI polarimetry of good quality [5] and precise spectra [9, 10]. Figure 5 shows the strong correlation between the parameters under study. Moreover, the regression equation,

$\log A(\lambda) = (-0.72\pm0.06) - (0.08\pm0.06) P_{max}(\lambda)$,

is almost the same as we have obtained above for asteroids in V bandpass (see the first test and Fig. 3). However the low-albedo asteroids 1 Ceres and 704 Interamnia do not show the dependence of $P_{max}(\lambda)$ parameter on spectral albedo. Now we cannot say whether such a deviation from "spectral" Umov law is an artefact or a dark asteroid surface property.




**Summary:** We can make the following conclusions. At least for high and moderate-albedo asteroids, the properties of $P_{max}$ and $\alpha_{max}$ parameters extrapolated from the polarimetric observations of the asteroids at small phase angles are similar to those found for lunar surface and terrestrial rocks that are the analogues of lunar regolith. Probably, such a similarity may be caused by the fact that the surface of the asteroids and the Moon is rich in mafic minerals as pyroxenes and olivines. Questions remain in relation to low-albedo asteroids. Their unusual behavior in positive polarization could be a subject of further investigation.

A crucial test for the findings stated here could be an outcome of "polarimetric hunt" for near-Earth asteroids in an effort to catch a necessary aspect at which the degree of positive polarization reaches maximum.

**References:**

[1] Shestopalov D. (2004) *JQSRT 88*, 351–356. [2] Kvaratskheliya O.I. (1988) *Bull. Abastuman. Astrophys. Obs.64*, 1–312. [3] Kiselev N.N. and Lupishko D. F. (2004) *Solar Sys. Res. 38*, 85–92. [4] Lyot B. (1929) *Ann.Obs.Meudon 8*, 1–161. [5] Lupishko D.F. and Vasilyev S.V. (2008) *NASA PDS*, Asteroid Polarimetric Database V6.0. EAR-A-3-RDR-APD-POLARIMETRY-V6.0. [6] Dollfus A. and Bowell E. (1971) *Astron.Astrophys.10*, 29–53. [7] Tedesco E.F. et al. (2002) *Astron. J. 123*, 1056–1085. [8] Shevchenko V. G. and Tedesco E.F. (2006) *Icarus 184*, 211–220. [9] Zellner B. et al. (1985) *Icarus 61*, 355–416. [10] Xu S. et al. (1995) *Icarus 115*, 1–35 [10] Geake J. E. and Dollfus A. (1986) *Mon. Not. R. Astr. Soc. 218*, 75–9.