

POLARIMETRY AND PHOTOMETRY OF ASTEROID 4 VESTA AT SOUTHERNMOST ASPECT.

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Introduction: One of the largest main belt asteroids 4 Vesta has a diameter of 530 km, quite regular shape with the semiaxes ratio $a/b=1.1$ and $b/c=1.2$, and the rotation period of 5.342^h. According to IRAS data, the asteroid belongs to the high-albedo class ($p_v = 0.42$). The orientation of the asteroid spin axis ($\lambda_o=301^\circ$; $\beta_o=41^\circ$) make it possible to observe its whole surface including the north and south polar areas. A unique feature of Vesta is above all that it is the only nearly intact asteroid that has undergone the planetary-like differentiation of material. The surface of Vesta is mainly covered by pyroxene, olivine, and feldspar minerals which are characteristic of magmatic material. The photometric, polarimetric, and spectral measurements as well as direct images revealed albedo variations over its surface. These albedo changes are related to spatial variations in the surface composition and to the action of space weathering (aging process). A giant crater with a diameter of 430 km was discovered near the south pole of Vesta [1].

We present new results of polarimetric and photometric observations of asteroid 4 Vesta performed during periods of its visibility in 1988, 1994, 1998/1999, and 2005/2006. The geometry of observations allowed us to obtain data under the most south aspects of Vesta ($\zeta \approx 130^\circ$), i.e. to observe the region where the vast crater is located.

Observations and results: *Polarimetry.* Observations of asteroid 4 Vesta was carried out from December 1, 1998 to May 8, 1999 in the V-band within the range of phase angles 2.5° – 24.7° . A photoelectric photometer-polarimeter mounted at the 0.7-m reflector of Kharkiv National University was used [2]. Polarimetric observations were also performed in the period December 28, 2005 – January 11, 2006 that corresponded the range of phase angles 0.6° – 5.0° . The 1.25-m telescope equipped with the UBVRi photometer-polarimeter of the Crimean Astrophysical Observatory was used.

Figure 1 shows the phase-angle dependence of linear polarization, including our data as well as all available observations of Vesta, in the V-band under southernmost aspects. Data in the 2005/2006 apparition were shifted by +0.12% to give a best fit. The parameters of phase curve of polarization, $P_{\min} = -0.62 \pm 0.02\%$, $\alpha_{\min} = 7.8 \pm 0.3^\circ$, $\alpha_{\text{inv}} = 22.3 \pm 0.5^\circ$, and $h = 0.059 \pm 0.004$ mag/deg, are in a good agreement with those calculated from the observations close to equatorial aspect of the asteroid [3]. Albedo of Vesta based on the $P_{\min}$ parameter obtained is 0.24 that is in contradiction with IRAS classification of it as high-albedo asteroid.

Phase-angle curves of polarization for 4 Vesta in different photometric bands and spectral dependencies of their parameters are obtained and their characteristics will be discussed.

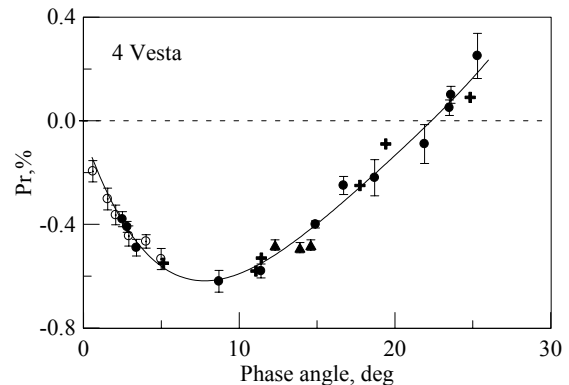


Fig. 1. Phase dependence of polarization of the asteroid 4 Vesta under southernmost aspect (+ – 1958/1959 [4]; ○ – 1988 [5]; ● – 1998/1999; ○ – 2005/2006).

Long-term polarimetric observations of asteroid 4 Vesta allowed us to investigate changes of the degree and plane of polarization due to strong albedo heterogeneities over its surface with rotation phase. The systematical variations of polarization degree (up to 0.06%) and polarization plane (up to 5°) with rotation phase are confirmed for the asteroid [5,6]. It is found that the variations of polarization plane are in antiphase with changing the degree of polarization. This effect can be explained by albedo as well as macrostructure heterogeneities over its surface.

Photometry. The photometric observations of asteroid 4 Vesta were carried out with photoelectric photometer on November 12, 1994 and with CCD camera ST-6UV on January 6 and 26, 2006 at phase angles 0.4° – 17.3° . The 0.7-m reflector of Kharkiv National University was used.

Figure 2a shows the lightcurve of the asteroid 4 Vesta obtained for the phase angle $\alpha=17.3^\circ$ on November 12, 1994. Amplitude of brightness variations is 0.13 mag. One can see that there is small hit of brightness (the Px feature) with amplitude 0.02 mag at the end of the broad lightcurve maximum around 21.3 UT. Position of the Px feature correlates with minimum of the pyroxene band at $\lambda=0.92 \mu\text{m}$ (see Fig.2b) [7,8].

Phase-angle dependence of brightness of the asteroid at the maximum of the V-band lightcurve (including the Px feature) is presented in Fig. 3. A well pronounced brightness opposition effect is visible at phase angles less than $\alpha \approx 5^\circ$. The data

were fitted using the standard H , G magnitude system and obtained the following parameters:

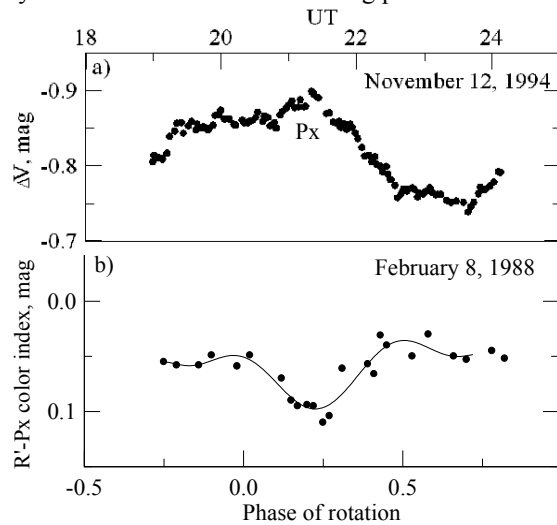


Fig. 2. V-band lightcurve (a) and variations of color index $R'(0.65 \mu\text{m}) - Px(0.92 \mu\text{m})$ [7,8] (b) under southernmost aspect of asteroid Vesta.

$H = 3.14 \pm 0.01$ mag; $G = 0.32 \pm 0.01$, linear part of the curve may be presented by $V_0(1, 0) = 3.37 \pm 0.01$ mag and $\beta_v = 0.029 \pm 0.001$ mag/deg. In Fig.3, triangle symbols show brightness of the asteroid under the aspect close to equatorial one [9]. The linear parts of the phase curve for two aspects are in a good agreement. It means that the shape of 4 Vesta has a weak flattening in the polar direction. Furthermore, the surface feature forming Px of lightcurve and minimum of the “pyroxene” curve is not located in the south circumpolar area. Therefore it can be observed under both south and equatorial aspects.

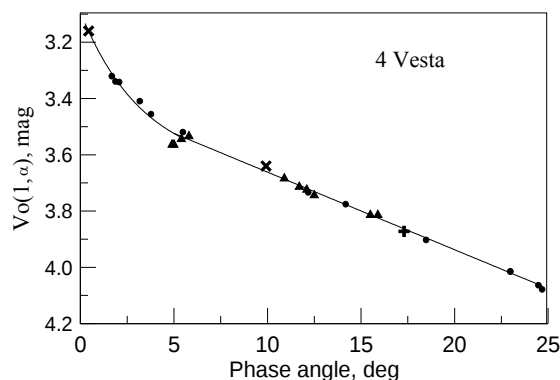


Fig. 3. Phase dependence of brightness for 4 Vesta under southernmost aspect (● – 1958/1959 [10]; + – 1994; x – 2006) and close to equatorial one (▲ – 1986 [9]).

To estimate the opposition effect parameters in different photometric bands we used a modified four-parameter exponential-linear function [11]. For the V band, the amplitude of opposition peak is $\Delta m = 0.32 \pm 0.02$ mag and its semi-width is $HWHM = 2.7 \pm 0.3^\circ$. It turned out that the shape of the photometric opposition effect and its parameters are

close to moderate-albedo asteroids. This is one more additional evidence that asteroid 4 Vesta has lower albedo ($p_v = 0.24$) than that from IRAS data ($p_v = 0.42$).

References: [1] Keil K. (2002) in *ASTEROIDS III* (Univ. of Arizona Press) 573-582. [2] Velichko S. et al. (2005) *Earth, Moon, and Planets* 97, 379-386. [3] Lupishko D. et al. (1988) *Soviet Astron. Vestnik* 22, 142-146. [4] Zellner B., Gradie J. (1976) *Astron. J.* 81, 262. [5] Broglia P., Manara A. (1989) *Astron. Astroph.* 214, 389-390. [6] Lupishko D. et al. (1999) *Solar Syst. Res.* 33, 45-48. [7] Vdovichenko V. et al. (1990) *Kinemat. Phys. Neb. Tel* 6, 70-76. [8] Vdovichenko V. et al. (1990) *Astron. Tsirk. № 1543*, 29-30. [9] Velichko F. et al. (1988) *Soviet Astron. Vestnik* 22, 136-142. [10] Gehrels T. (1967) *Astron. J.* 72, 929-938. [11] Keränen et al. (2000) in *Light Scattering by Nonspherical Particles: Halifax Contributions* (Army Research Laboratory, USA), 279-282.