POLARIMETRY OF THE GALILEAN SATELLITES AND JUPITER NEAR OPPOSITION.

N. N. Kiselev[1], V. K. Rosenbush[1], F. P. Velichko[2], S. V. Zaitsev[1], [1]MAO NASU, Zabolotnoho str., 27, 03680 Kyiv, Ukraine (kiselev@mao.kiev.ua), [2]Astronomical Institute of Kharkiv National University, Sumskaya str., 35, 61022 Kharkov, Ukraine.

Introduction: The phase-angle and wavelength dependences of polarization near opposition for different ASSBs are still in the center of attention because behavior of polarization at small phase angles is the key test for alternative models of light scattering by regolith surfaces. Nevertheless, the available polarimetric data even for bright satellites of Jupiter are very few and they are mutually contradictory. Rosenbush et al. [1, 2] first detected the secondary minimum of polarization for high-albedo Galilean satellites Io, Europa, and Ganymede, the so-called polarization opposition effect, at very small phase angle, less than 1°, and with amplitude of about 0.35%. Contrary, Morozhenko [3, 4] and Chigladze [5] found for all Galilean satellites that there is the inversion point at the phase angle where polarization changes sign.

In this work we present the new polarimetric observations of the Galilean satellites and their analysis together with the previous observations.

Observations and results: The polarimetric observations of Io, Europa, Ganymede, and Callisto were carried out with a one-channel photoelectric photometer-polarimeter mounted at the 70-cm reflector of the Chuguev Observational Station (Ukraine) on June 5–8, 2007. Phase angles for satellites were changed within the range of -0.13°–0.62°. We used the 19″ circular diaphragm and the V filter for all observations. The parameters of instrumental polarization are defined from the observations of unpolarized standard stars [6]: $q_i = -0.066\pm0.010\%$ and $u_i = 0.050\pm0.011\%$. The zero-point of the position angle of polarization plane was determined with accuracy 0.7° from the observations of standard stars with large polarization [6]. The errors of polarization degree for satellites include the statistical errors and errors of the instrumental polarization and does not exceed 0.03%.

From observations we calculated the angles $\theta_r = \theta - (\theta_{sca} \pm 90)$ between the polarization plane θ and perpendicular to the scattering plane θ_{sca}. Figure 1 presents the phase-angle dependence of angles θ_r for satellites including our present observations in 2007 (open circles) and in 2000 [2] (filled circles), observations in 1988 [1] (open diamonds), and data obtained by Morozhenko in 1986 [4] (straight crosses). One can see that our data obtained in 2007 are in a good agreement with data obtained in 1988 and 2000 oppositions. In these cases, the plane of polarization of satellites lies in the plane of scattering and θ_r is close to 90°, i.e. polarization is negative for satellites.

In accordance with θ_r Fig. 2 presents the phase-angle dependence of polarization for satellites for our above-mentioned observations. For comparison, the regular branches of negative polarization for satellites calculated on the basis of all published data at phase angles greater than 2° are shown [2]. The phase-angle dependences of polarization for the leading and trailing hemispheres of Io, Europa, Ganymede, and Callisto are shown according to [2, 7].

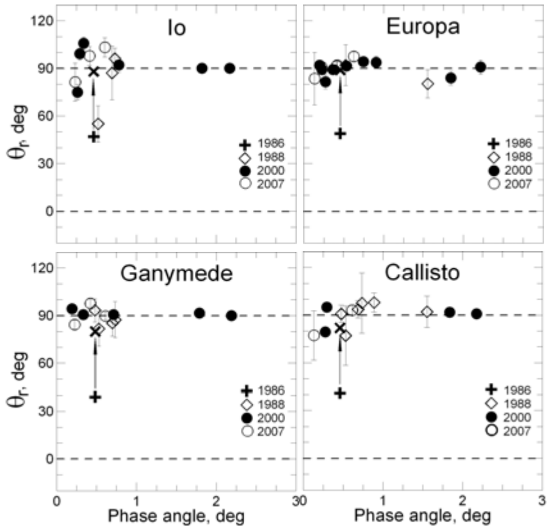

Fig. 1. The phase-angle dependence of angle θ_r for the Galilean satellites according to observations by Rosenbush et al. (1988, 2000), this work (2007), and Morozhenko (1986, straight crosses (+) are original data and oblique crosses (×) after correction).

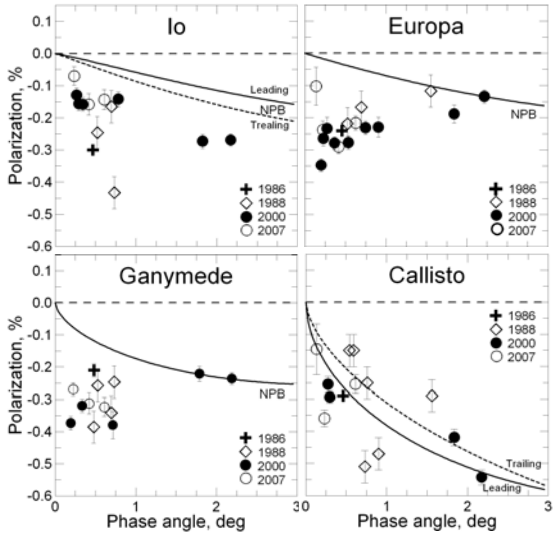

Fig. 2. The phase-angle dependence of polarization for the Galilean satellites. Designations are the same as in Fig.1. Regular negative polarization branches (solid and dashed lines) for satellites are taken from [2, 7]. Data for the satellites are not reduced for the longitudinal effect of polarization.

Discussion: The presented new observations completely confirmed the presence of polarization opposition effect for high-albedo satellites Io, Europa, and Ganymede at phase angles less than 1° firstly discovered by Rosenbush et al. [1]. No polarization opposition effect was found for the moderate- albedo satellite Callisto. Moreover, our data did not confirm the statement by Morozhenko [3, 4, 8] that "plane of polarization does not coincide with the plane of scattering and is not perpendicular to it" (straight crosses in Fig. 1). To determine the plane of polarization for the satellites Morozhenko used observations of the polar regions of Jupiter believing that the plane of polarization for these regions is orthogonal to the scattering plane, i.e. θ_r = 90°. However, before Chigladze [5] found that for Jupiter's polar regions the angle θ_r turns sharply at phase angles less than 1° (Fig. 3, left plot). In order to examine this we carried out observations of the polar regions of Jupiter and confirmed the effect obtained (Fig. 3, right plot). The preliminary explanation of this effect is given by Shalygina et al. [9].

Using new value of $\theta_r = 41°$ for the polar regions of Jupiter and data obtained by Morozhenko [4] we found that the plane of polarization for satellites coincides with the plane of scattering (oblique crosses in Fig. 1).

Thus, the statements by Morozhenko [4, 8] that: on the one hand, the difference between the plane of polarization and the plane of scattering is about 45°; on the other hand, there are large values of negative polarization (straight crosses in Fig. 2) for all four Galilean satellites at phase angle 0.4° are essentially contradictory. Really, for the angle $\theta_r \approx 45°$, the degree of polarization is related to the scattering plane, i.e. the degree of negative polarization is close to 0% according to the expression $P_r = P_{obs}\cos 2\theta_r$ (see, for example [10]).

We also analysed data of Chigladze and concluded that his calculations of the scattering plane are mistaken. Therefore, we conclude that there is no the second inversion point near the phase angle 0.5° for the Galilean satellites.

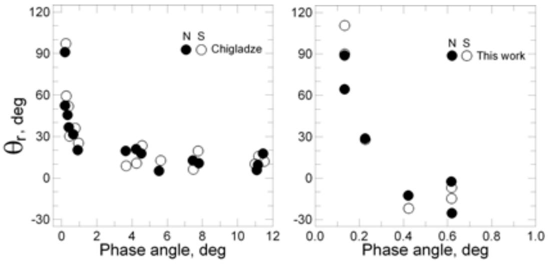

Fig.3. Change of the angle θ_r with decreasing the phase angle toward opposition for north (full circles) and south (open circles) Jupiter's polar regions. The left plot presents data by Chigladze, in the right plot our new data are shown.

Gradie and Zellner [11] were the first who paid attention "that the polarization of Ganymede does not vanish at zero phase angle". But they explained this fact as "possibly the result of icy polar cups". Rosenbush et al. [1] for the first time interpreted significant negative polarization of Io, Europa, and Ganymede at very small phase angles as the polarization opposition effect which is produced by coherent backscattering mechanism. This effect was theoretically predicted by Mishchenko [12] who called a sharp and very narrow peak of negative polarization at nearly zero phase angle as "the polarization opposition effect". Later, the polarization opposition effect for the Galilean satellites Io, Europa, and Ganymede was confirmed by Rosenbush and Kiselev [2]. Moreover, these authors found it in other high-albedo objects, such as E-type asteroids [13, 14, 15], satellite of Saturn Iapetus [15], and Dollfus (see in [1]) detected this effect for the A and B rings of Saturn. Thus, a whole class of high-albedo objects with the polarization opposition effect was found [16].

Conclusion: New observations of the Galilean satellites of Jupiter in 2007 are in a good agreement with our previous observations. We have found the causes of differences between our observations and observations by Chigladze and Morozhenko [3-5].

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