OPTICAL POLARIMETRY OF THE GALILEAN SATELLITES, IAPETUS, AND 64 ANGELINA NEAR OPPOSITION

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Detailed measurements of polarization of the Galilean satellites of Jupiter, Saturn's satellite Iapetus and the asteroid 64 Angelina in the UBVRI filters around opposition, which were obtained at the Kharkiv, Crimean, and Pik Terskol Observatories in 1998–1999, are presented. Undoubtedly, there is a sharp peak of negative polarization centered at a very small phase angle which is superimposed on the negative branch of the regular phase angle dependence of polarization. Detection of the photometric opposition spike and polarization opposition peak for the researched objects suggests that at least partially their surfaces are covered with an optically thick layer composed of nonabsorbing (or weakly absorbing) submicrometer–sized grains.

INTRODUCTION

There are two interesting phenomena observed for some atmosphereless Solar System bodies near opposition: the photometric opposition effect and negative linear polarization. Their study attracts particular interest because of a great importance not only for understanding properties of the scattering surface but also for understanding the physics of the radiation scattering process itself. These effects may be observed in both wide (as linear increase of brightness and the regular negative polarization branch) and narrow (as a very sharp brightness spike and peak of negative polarization at phase angles less than 1°–2°) ranges of phase angles.

The main purpose of our investigations is the study of behavior of polarization of different cosmic bodies near opposition. We present new, detailed measurements of polarization of the Galilean satellites, the Saturn's satellite Iapetus and the asteroid 64 Angelina.

OBSERVATIONS

Galilean satellites. Imaging polarimetry of satellites of Jupiter was carried out with the 70–cm reflector of the Astronomical Observatory of Kharkiv National University on September 9–25, 1998 at phase angles ranging from $-1^\circ.41$ to $2^\circ.28$. The one–channel polarimeter with a quasi–continuous rotating polaroid was used. CCD camera has 752×582 pixels (60×60 arcsec). To reduce the influence of a background of Jupiter the 15×15 arcsec area was selected for observations of satellites. The observations were carried out in the V standard band. The photopolarimeter and the program complex IRIS developed for automation of observations and initial processing of digital images are described in more detail in paper [5].

Iapetus and 64 Angelina. Observations of Iapetus and the asteroid 64 Angelina were carried out with the five–channel UBVRI photopolarimeter attached to the 1.25–m telescope of the Crimean Astrophysical Observatory. Iapetus was observed from October 11, 1998 to January 18, 1999 in the phase angle range from $-1^\circ.38$ to $6^\circ.1$. Observations of 64 Angelina were carried out on October 17–23, 1995 and September 3 – October 16, 1999. They covered the phase angle ranges from $0^\circ.75$ to $-2^\circ.59$ and from $-3^\circ.3$ to $13^\circ.0$ in 1995 and 1999, respectively. A description of the equipment is given in [4].

Observations of Iapetus and the asteroid 64 Angelina were also made with the 2–m telescope of Pik Terskol Observatory (Northern Caucasus) equipped with two–channel focal reducer of the Max–Planck Institute for Aeronomy (Germany). Simultaneously two images are received in passbands close to the B ($\lambda = 0.43/0.09$ μm) and R ($\lambda = 0.68/0.11$ μm) filters. The technique of polarimetric measurements and description of a device are given by [3]. The CCD images were processed using the MIDAS reduction package.

Standard unpolarized and polarized stars have been observed together with the program objects to determine the instrumental polarization and the zero–point of position angle of the polarization plane, respectively. The total errors (the mean square error and the error of the instrumental system) in the degree of polarization are: 0.1–0.2% in the U filter, 0.03–0.07% in the R filter and 0.06–0.15% in others.

RESULTS AND DISCUSSION

Galilean satellites. The phase dependence of polarization for Io, Europa, Ganymede and Callisto is shown in Fig. 1. In spite of the significant scatter of the data points, it is obvious that Io, Europa and Ganymede have a sharp peak of negative polarization centered at a very small phase angle ($< 1^\circ$) and superimposed on the regular negative polarization branch. There is no such effect for Callisto.

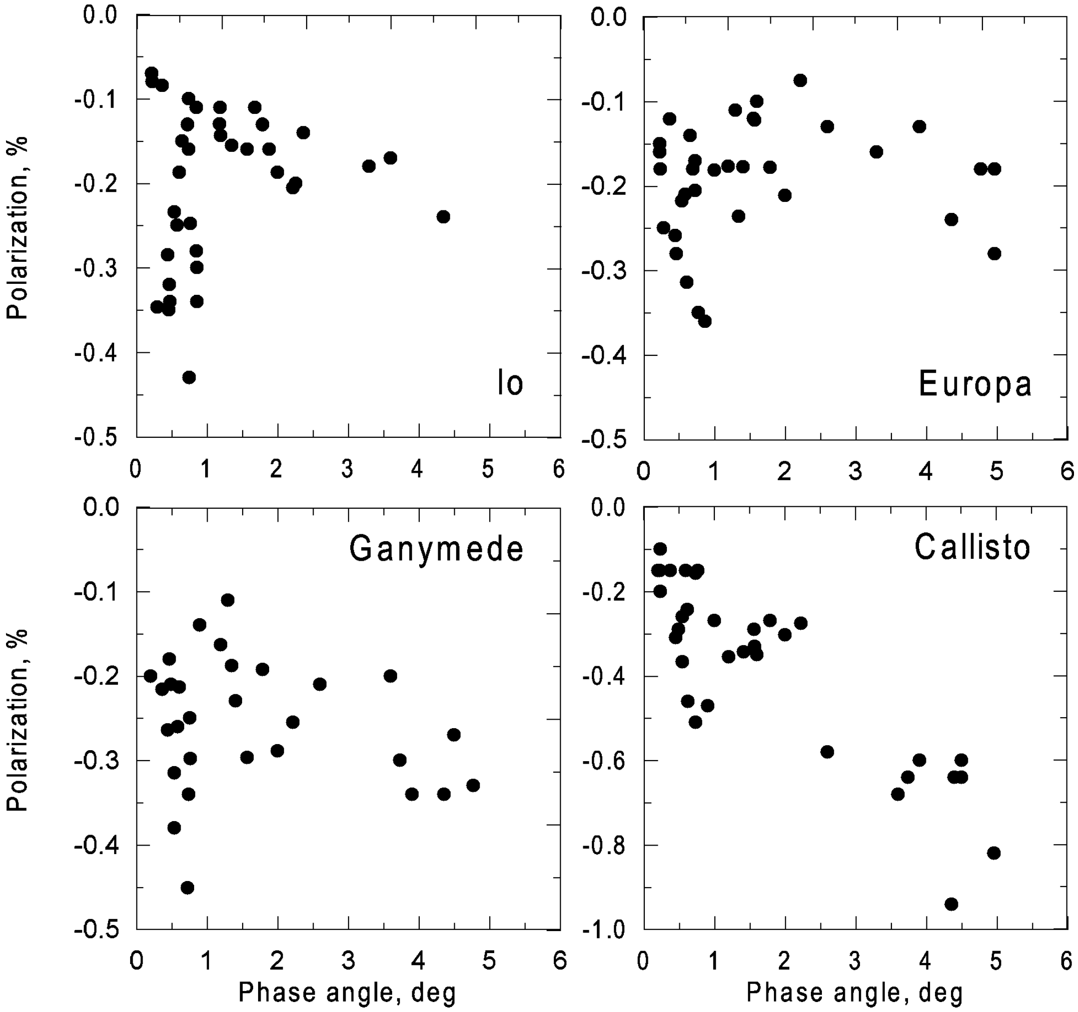

Figure 1: The polarization opposition effect for the Galilean satellites in the V filter

64 Angelina. The results of observations of 64 Angelina in the B and V bands are presented in Fig. 2. There is the regular phase dependence of polarization with the parameters P_{min} = –0.28% at $\alpha_{min} = 7.^\circ 1$ and P_{min} = –0.33% at $\alpha_{min} = 8.^\circ 9$) in the B and V bands, respectively. Noticeable increase of the negative polarization is observed at the phase angles less than 4°. Amplitude of P_{min} in the B filter is somewhat larger than that in the V filter. For both bands, the parameters P_{min} differ for before and after opposition.

Iapetus. The phase dependence of polarization for Iapetus in the B and R filters is presented in Fig. 3. One can see a high degree of polarization within the phase angle range $1.^\circ 5$ to $0.^\circ 3$. However, the lack of observations outside of this range does not allow to make any certain conclusions about the presence of the polarization opposition effect at phase angles less than 1°.

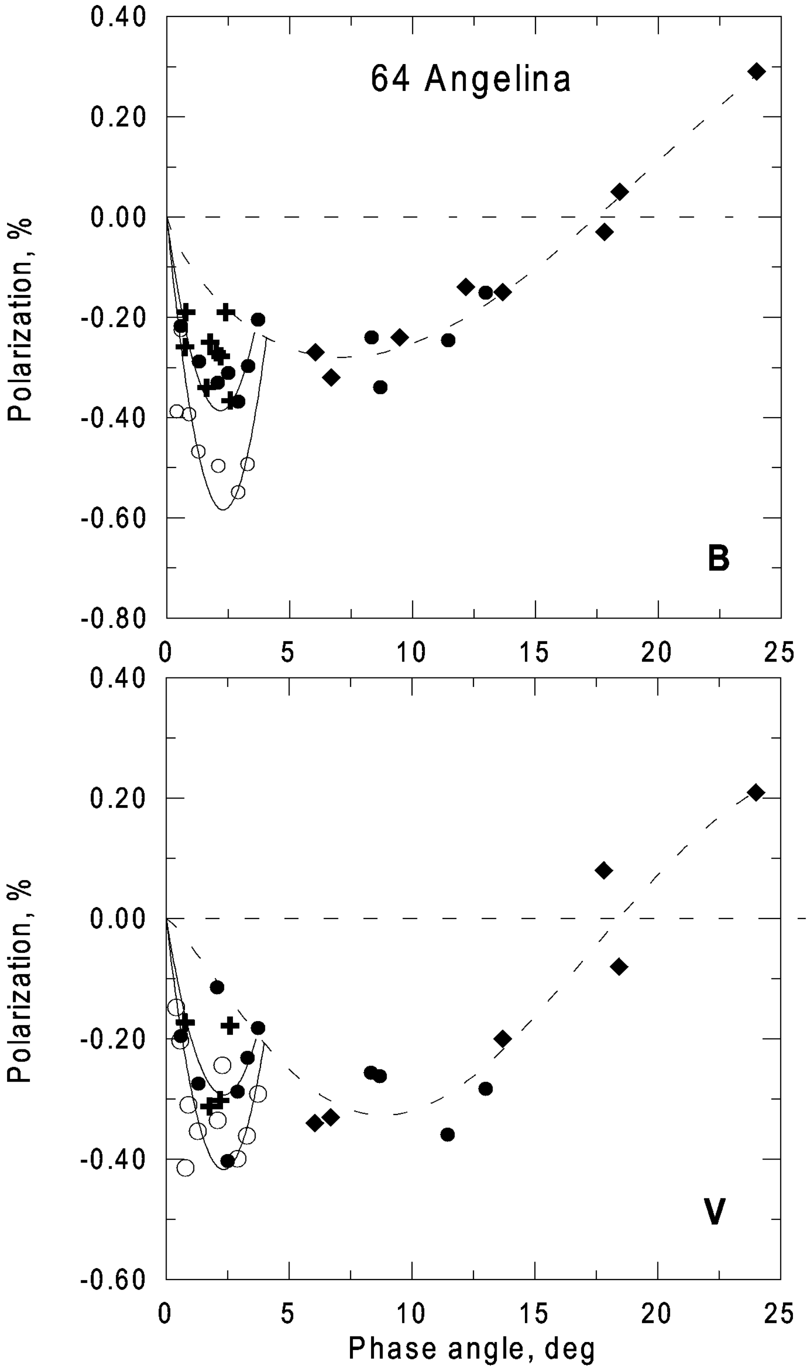

Figure 2: The regular negative polarization branch (dashed curve) and the negative polarization peak produced by coherent backscattering (solid curve) for the asteroid 64 Angelina. The data are shown separately for before (open circles) and after (filled circles) opposition of 1999. The data for opposition 1995 are marked by pluses. The measurements made by Zellner and Gradie [8] are designated by diamonds

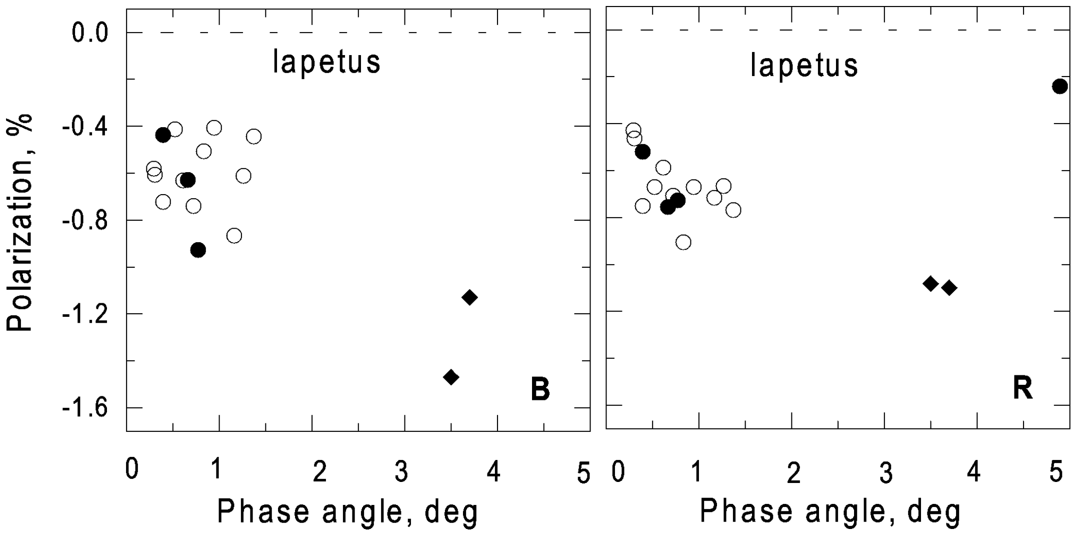

Figure 3: Phase-angle dependence of the degree of linear polarization for Iapetus in the B, and R filters. The Crimean data are shown by the filled (before opposition) and open (after opposition) circles and the Terskol data by diamonds

Our observations as a whole do not contradict the theory of the coherent backscattering enhancement [6]. According to this theory, the objects with a high albedo should exhibit the photometric opposition spike at small phase angles ($< 1°$). Besides, the theory predicts that the photometric opposition effect should be accompanied by polarization opposition peak. All objects, for which we have discovered a sharp peak of the negative polarization, have a high albedo (64 Angelina – 0.55; Io – 0.61; Europa – 0.64; Ganymede – 0.42) and show the brightness spikes [2, 1, 7]. Albedo of Callisto is only 0.2 and it exhibits neither the photometric opposition spike nor a polarization opposition peak. The angular semiwidth and the position of polarization peak exactly at the backscattering direction are comparable to that of the photometric opposition spike. This indicates that the same submicron-sized grains and the same optical mechanism of coherent backscattering are responsible for both effects. Since the surfaces can be covered by grains of different size, the coherent peak produced by smallest grains can be superposed on the regular negative polarization branch produced by larger grains and by surface irregularities. At the same time, the position and amplitude of the observed polarization peak and brightness spike for the satellite Europa and the asteroid 64 Angelina are different. Therefore, it is reasonable to assume that even within the framework of the same mechanism of the coherent backscattering enhancement the influence of different properties of particles (albedo, size, refractive index, porosity) may be different for the photometric and polarimetric opposition effects.

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