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Polarimetry and BVRI photometry of the potentially hazardous near-Earth Asteroid (23187) 2000 PN_9 ☆

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ABSTRACT

The results of V-band polarimetric observations of the potentially hazardous near-Earth Asteroid (23187) 2000 PN_9 at large phase angles are presented as well as its photometric observations in BVRI bands. Observations were made in March–April 2006 during its close approach to the Earth using the 1.82-m Asiago telescope (Italy) and the 0.7-m telescope at the Chuguevskaya Observational Station (Ukraine). We obtained polarimetric measurements at the phase angle of 115°, the largest phase angle ever observed in asteroid polarimetry. Our data show that the maximum value of the polarization phase curve reached 7.7% and occurred in the phase angle range of 90–115°. The measured values of linear polarization degree, BVRI colors and magnitude-phase dependence correspond to the S-type composition of this asteroid. Based on our observations the following characteristics of the Asteroid (23187) 2000 PN_9 were obtained: a rotation period of 2.5325 ± 0.0004 h, a lightcurve amplitude of 0.13 mag, an albedo of 0.24 ± 0.06 and a diameter of 1.6 ± 0.3 km.

1. Introduction

Asteroid (23187) 2000 PN_9 discovered by LINEAR is a near-Earth asteroid (NEA) with a semimajor axis of 1.84 AU and an orbital eccentricity of 0.59 (Apollo group). The asteroid makes periodic close approaches to the Earth and is categorized as a Potentially Hazardous Asteroid (see http://cfa-www.harvard.edu/iau/lists/Dangerous.html). Optical and radar observations of the asteroid were made in 2001 when it approached within 0.061 AU of the Earth. They revealed a rotational period of 2.5325 h with a lightcurve amplitude of 0.15 mag (http://www.asu.cas.cz/~ppravec/neo.html) and roughly spherical shape with an estimated diameter of 1.7 km (Busch et al., 2006). The next close approach of the Asteroid (23187) 2000 PN_9 occurred in March 2006 which was nearly three times closer to the Earth (0.020 AU) than in 2001. We have used this favorable opportunity for polarimetric observations of the asteroid in order to determine its albedo and compositional type.

The paper presents results of the V-band polarimetric observations of 2000 PN_9 at large phase angles near the maximum of polarization phase dependence as well as its photometric observations in the BVRI bands.

2. Observations

2.1. Polarimetry

Observations were carried out in service mode at the 1.82-m Asiago telescope (Italy) using the Asiago Faint Object Spectrographic Camera (AFOSC). The AFOSC polarimeter consists of a double Wollaston prism which splits the incoming light into four polarized beams at 0°, 45°, 90°, and 135°, separated by 20 arcsec (Pernechele et al., 2003). These four beams are sufficient to determine the Stokes parameters I, Q and U simultaneously with a single exposure. The CCD has 1024×1024 pixels (the pixel size is 24 μm), providing a total field of view of 8.14×8.14 arcmin, with a pixel scale of 0.473 arcsec/px. The input field has been masked at the telescope focal plane by a field selective mask to avoid the overlap of the final images on the CCD detector. The four output beams emerge collimated from the double Wollaston prism and are then focused on the CCD detector by the focal camera of AFOSC. The final image is formed by four strips from which the I, Q, and U parameters can be extracted. From the analysis of several unpolarized and polarized standard stars, it is seen that the instrumental polarization is fairly constant and always below 0.4%, while the systematic errors in the position angle are below 1.5° (Desidera et al., 2004).

The NEA 2000 PN_9 was observed during two consecutive nights on March 6 and 7, 2006, when it was at phase angles of 115 and 90.7°, respectively. Nine exposures of 60 s each were ac-

☆ Based on observations carried out at the Asiago Astrophysical Observatory, Italy.

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Table 1
Results of polarimetric observations for Asteroid (23187) 2000 PN_9 in the V band.

Date (UT)	r (AU)	Δ (AU)	α (deg)	ϕ (deg)	P (%)	σ_P (%)	θ (deg)	σ_θ (deg)	P_r (%)	θ_r (deg)
2006 March 06.8204	0.9822	0.0232	115.0	44.0	7.68	0.08	133.2	1.0	7.68	179.3
2006 March 07.8886	0.9913	0.0368	90.7	59.8	7.63	0.08	149.3	1.0	7.63	179.7

quired in the Johnson V band centered at 5474 Å with a bandpass of 899 Å. We discarded three of them due to the tracking problem so the total exposure time for the asteroid was 360 s each night. The observational procedure included bias and flat field acquisitions, together with the observation of polarized and unpolarized standard stars (taken from Schmidt et al., 1992; Turnshek et al., 1990) during each night to calibrate the instrumental polarization. The flat field images were acquired in two different sets corresponding to the adapter position of 0° and 90° to average the polarization induced by the reflections on the dome screen of the flat field lamp. The images were bias subtracted and then divided by the flat field. Aperture photometry was then performed for the four polarimetric channels, properly subtracting the sky contribution. The evaluation of polarimetric parameters has been performed following the procedure described in Fornasier et al. (2006).

Aspect data of observations and the final results are reported in Table 1. It contains the UT time at the mean time of observations, the heliocentric r and geocentric Δ distances, the phase angle α, the position angle of the scattering plane ϕ, the polarization degree P and the position angle θ in the equatorial coordinate system, and the calculated values of the polarization degree P_r and position angle θ_r in the coordinate system referring to the scattering plane as defined by Zellner and Gradie (1976b). The measured degree of the linear polarization is about 7.6% at both phase angles.

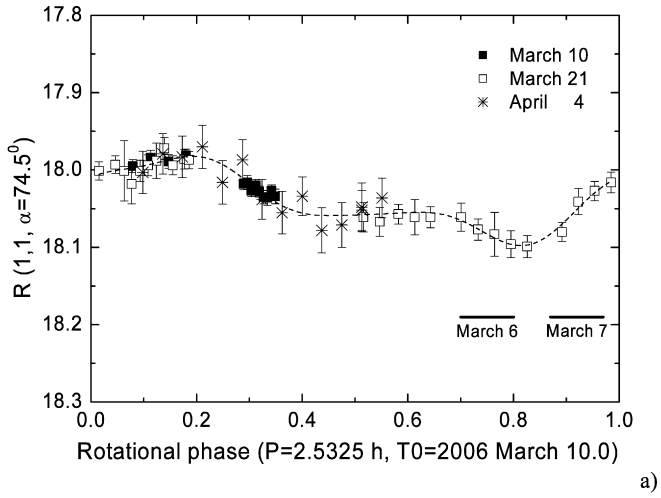
2.2. Photometry

Observations were carried out in the standard Johnson–Cousins BVRI photometric system using the 0.7-m telescope at the Chuguevskaya Observational Station (70-km to the south-east of Kharkiv). We used the CCD camera SBIG ST-6UV (375 × 242 pixels, field of view of 10.5 × 8 arcmin, and a pixel scale of 1.7 × 2.0 arcsec/px). The integration time was in the range of 30–300 s, giving an uncertainty of a single measurement about 0.01–0.03 mag (rms). To compensate for the asteroid movement during the integration time a correction of the telescope tracking was applied. Absolute calibration of the data was done with standards from Skiff (2007). The image reduction included dark subtraction and flat-field correction of the raw images. A standard aperture photometry routine was performed with the AstPhot software developed by Mottola et al. (1995). The method of observations and data reduction is described in more details by Krugly et al. (2002).

Aspect data and magnitudes are given in Table 2. It contains the mean time of observations in UT, the heliocentric (r) and geocentric (Δ) distances, the solar phase angle (α), the photometric band, the mean magnitudes reduced to unit distances from the Sun and the Earth together with their standard deviations, and the number of measurements N used to obtained the mean value.

Table 2
Results of photometric observations for Asteroid (23187) 2000 PN_9.

Date (UT)		r (AU)	Δ (AU)	α (deg)	Band	Magnitude	N
2006 March	10.028	1.0100	0.0723	74.45	R	18.015 ± 0.020	13
2006 March	10.018	1.0099	0.0721	74.50	B	19.368 ± 0.010	5
2006 March	10.016	1.0099	0.0722	74.49	V	18.472 ± 0.011	5
2006 March	10.017	1.0099	0.0721	74.49	I	17.610 ± 0.010	4
2006 March	20.987	1.1083	0.2665	58.66	R	17.623 ± 0.040	25
2006 April	04.047	1.2379	0.5131	51.22	R	17.475 ± 0.035	14



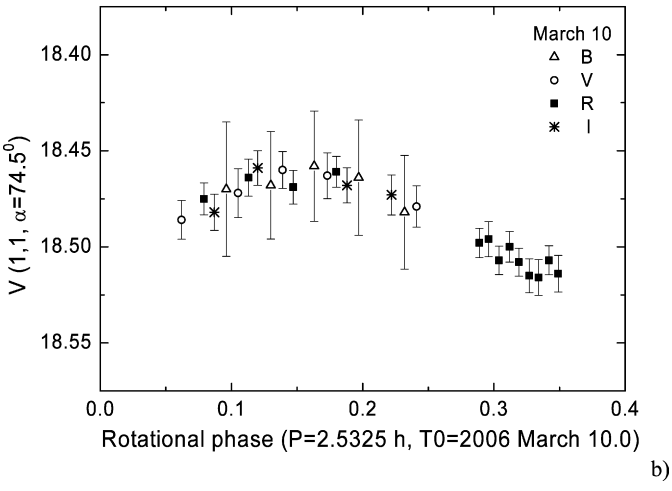


Fig. 1. Composite lightcurve of 2000 PN_9 in the R band (a) and observations on March 10 in BVRI bands versus rotational phase (b). Rotational phases of polarimetric observations on March 6 and 7 are shown as solid lines.

3. Results and discussion

Our photometric observations covered the phase angle range from 51 to 74°. We search for the rotation period using a Fourier analysis method similar to that described by Harris et al. (1989). We found that $P = 2.5325 \pm 0.0004$ h gives minimal dispersion however a number of longer periods cannot be fully excluded by our observations. We adopted the above-mentioned value since it coincides with the value 2.5325 ± 0.0001 h measured by P. Pravec et al. in the 2001 opposition and given as prepublished value at http://www.asu.cas.cz/~ppravec/neo.html. The composite lightcurve in the R band corresponding to this rotational period is shown in Fig. 1a. All magnitudes were reduced to the phase angle of 74.5 deg using the phase coefficient of 0.027 mag/deg. The lightcurve is characterized by a small ampli-