RESULTS FROM PHOTOMETRIC STUDIES OF ASTEROIDS AT ROZHEN NATIONAL OBSERVATORY, BULGARIA

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ABSTRACT

The results from CCD photometry of seven asteroids with unknown period so far are presented here. The derived synodic periods are: (300) Geraldina – $6,818\,\mathrm{h}$; (698) Ernestina – $5,07\,\mathrm{h}$; (1011) Laodamia – $5,17\,\mathrm{h}$; (1019) Strackea – $3,832\,\mathrm{h}$; (3443) Leetsungdao – $3,313\,\mathrm{h}$; (4324) 1981YA1 $\approx 26,5\,\mathrm{h}$ and (5240) Kwasan – $5,346\,\mathrm{h}$.

1. BACKGROUND

The study of the Solar System bodies is traditional for astronomy in Bulgaria. New research possibilities, based on astronomical observations were revealed with setting up the National Astronomical Observatory (NAO) – Rozhen. Geographic coordinates of the observatory are: $\lambda = 24{,}^{\circ}82$, $\varphi = +41{,}^{\circ}72$ and $h = 1750\,\mathrm{m}$. There are 3 optical telescopes as follows: 2m Ritchey–Cretien–Coude telescope (1/f=8), 50 cm/70 cm Schmidt telescope (1/f=3.44) and 60 cm Cassegrain telescope (1/f=12.5) equipped with single–channel photometer. All the three telescopes, admittedly to a different extent, are used for observations of asteroids and comets.

Regular astrometric observations of small planets using Schmidt telescope were started in 1983. We also took part in the first international programme for searching of new asteroids (INAS) organized by E. Helin. Along with International Halley Watch (IHW) campaign in 1986 we began studies of physico-chemical processes in comets, which continues nowadays, too.

In 1991 we began regular photoelectric observations of asteroids (brighter than 13^m).

Because of terrible financial hardships, continuing nowadays, awhile the main instrument for observations of asteroids (Schmidt telescope) was out of work. By joint efforts of Bulgarian Academy of Sciences, Institute of Physics, Skopje and Space Frontier Foundation grant a new CCD camera for Schmidt telescope and computers for observations and data reduction were purchased. Our choice of CCD camera was guided from our aims to work parallel on two programmes: follow up observation of NEOs and CCD photometry of asteroids. According to our financial funds a CCD camera SBIG ST-8E with pixel dimension 1μm and spatial resolution of 1.1"/px was the most efficient solution.

In this paper we present our photometric results based on observations at NAO Rozhen from the beginning of 2001 till now.

2. OBSERVATIONS AND RESULTS

Initially, we chose bright objects near the opposition, in order to acquire methods of observation and data reduction. Until the choice of objects, in the literature and in the Internet there was no information for photometric observations of those asteroids. The lightcurves are obtainted mostly from observations with the Schmidt telescope and a part of them – with 2m RCC telescope. Characteristics of the used optical systems is presented in table 2.

In the preliminary image reduction we performed master bias (dark frame) subtraction (Howell, 2000). Flat field correction with precision$<1\%$ was made using twilight and dawn sky flat fields.

Table 2. Optical characteristics of the used telescopes and CCD cameras at NAO – Rozhen

	2m RCC telescope	50 cm/70 cm Schmidt telescope
1/f	8	3.44
Resolution	$12.89''$/mm	$120''$/mm
FOV	$1^{\circ} \times 1^{\circ}$	$5^{\circ} \times 5^{\circ}$
Detector	CCD Photometrics	CCD SBIG ST–8E
	CE200A – SITe	Kodak KAF–1602E
	$1024 \times 1024\,\mathrm{px}^2$	$1536 \times 1024\,\mathrm{px}^2$
	1px=24μm	1px=9μm
Cooling	Liquid nitrogen	Thermoelectric
FOV	$5' \times 5'$	$27'.6 \times 18'.4$
Filters	$UBVRI$	$UBVRI$

Table 1. Aspect data for observed asteroids

Asreroid	Date	Asteroid position		Δ[AU]	r[AU]	Phase
		λ_{2000}	β_{2000}			angle
(300) Geraldina	10.01.2001	143.5	1.0	2.406	3.276	9.4
	11.01.2001	1143.3	1.0	2.397	3.276	9.1
(698) Ernestina	13.02.2002	1126.8	18.2	1.630	2.556	9.6
(1011) Laodamia	10.02.2002	1177.5	5.1	0.707	1.614	20.9
	11.02.2002	1177.4	5.3	0.704	1.617	20.3
(1019) Strackea	16.06.2001	1219.4	47.9	1.069	1.783	30.4
	17.06.2001	1219.4	47.6	1.072	1.782	30.5
	22.06.2001	1219.7	46.0	1.090	1.781	31.0
	23.06.2001	1219.8	45.7	1.094	1.781	31.2
	24.06.2001	1219.9	45.4	1.098	1.780	31.3
	26.06.2001	1220.2	44.7	1.106	1.780	31.5
(3443) Leetsungdao	18.07.2001	316.1	26.9	0.708	1.656	19.4
	20.07.2001	315.8	26.8	0.704	1.657	18.8
	21.08.2001	310.8	20.8	0.725	1.689	16.0
(4324) 1981 YA1	18.09.2001	40.3	13.1	1.231	2.062	20.4
	19.09.2001	40.3	13.2	1.224	2.062	20.1
	18.10.2001	36.8	14.8	1.075	2.044	8.9
	19.10.2001	36.6	14.8	1.072	2.044	8.5
	20.10.2001	36.4	14.7	1.071	2.043	8.3
(5240) kwasan	20.12.2001	82.4	-4.1	1.180	2.153	3.6

For photometric measurements we used CCDPHOT software (Buie, 1998).
The composite lightcurves and preliminary synodic periods are obtained using procedure described in Magnusson & Lagerkvist (1990). The obtained lightcurves are fitted by Fourier function from order which best describe observations. Further to improve the period, the preliminary one is changed with a small step in the two directions and χ^2 from Fourier analyzing are examined. The period which has optimal χ^2 is accepted as the synodic period. The variation of χ^2 till $\frac{\chi^2}{(n-k)}$, where n is number of all observation (i.e. all points in all lightcurves) and $k = 2m + p + 1$, where m is order of Fourier function and p is the number of individual lightgurves (i.e. number of observational nights) determines the error of the synodic period. Composite lightcurves (CL) are presented in relative magnitudes. The amplitude of the CL was measured using the highest maxima and the lowest minima from Fourier fit. The error is calculated as mean value of photometric errors plus its deviation from Fourier fit of all points around the extrema. The interval of the extrema is defined as the place where the gradient of the magnitude decreases with value less or equal to the amplitude for one period, i.e.: $\frac{d(m)}{d(ph)} \leq A$.

(300) Geraldina

Observations were carried out with 2m RCC telescope during two nights: 10 and 11 Jan 2002. No photometric data are available for this object. The synodic period of this object was obtained: $P_{\rm syn} = 8.818 \pm 0.010\,{\rm h}$. The amplitude is $A = 0^{m}_{.}317$. The CL is fitted with Fourier function of order 6. The form of CL is rather complex. Maybe the big scatter is caused by bad photometric conditions during the nights.

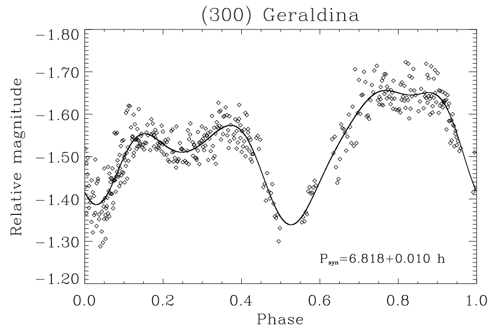

Figure 1. CL of asteroid (300) Geraldina – 10 and 11 Jan 2002.

(698) Ernestina

Although this object was observed only in one night, 13 Feb 2002, we obtained a very symmetrical lightcurve which covers the whole rotational cycle. The observations were made with the Schmidt telescope and the extinction in V band was $k_v = 0.153 \pm 0.003$. Our determinated synodic period is $P_{\rm syn} = 5.07 \pm 0.01\,{\rm h}$ and the amplitude is $A = 0^{m}_{.}637$. The order of Fourier fit is 9. A little different period $P_{\rm syn} = 5.036h$ and amplitude $A = 0.690$ from observations carried out three weeks before were published in the web-site http://obswww.unige.ch/~behrend/page_cou.html by Bernasconi, L.

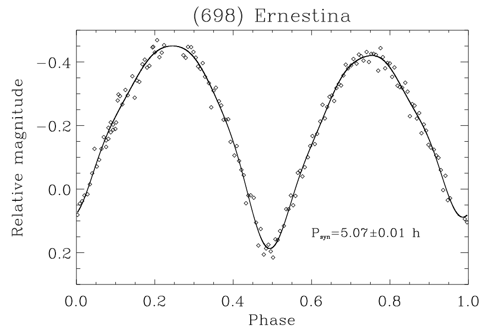

Figure 2. CL of asteroid (698) Ernestina – 13 Feb 2002

(1011) Laodamia

Observation of this object was carried out with Schmidt telescope in two nights: 10 and 11 Feb 2002. The estimated rotational period is $P_{\rm syn} = 5.17 \pm 0.01\,{\rm h}$ with an amplitude $A = 0^{m}\!.451$. The presented fit is a Fourier function of order 9. This is the first observed by us unusual asteroid, chosen from Ephemerides of minor planets (2002). The same period and amplitude from observations carried out two months later were published in the above mentioned web-site by Bernasconi, L.

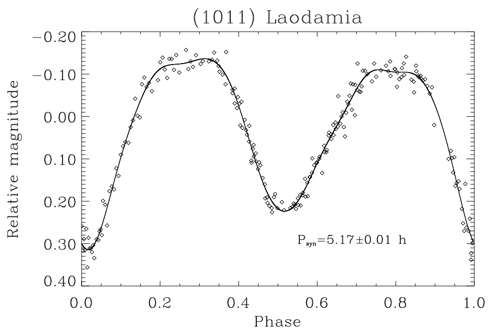

Figure 3. CL of asteroid (1011) Laodamia – 10 and 11 Feb 2002

(1019) Strackea

The asteroid (1019) Strackea was observed in three nights: 17 and 18 Jun 2002 with 2m RCC telescope, and on 26 Jun 2001 with Schmidt telescope. The obtained CL is slightly asymmetric with maxima which differ from each other by shape. Our estimated rotational period is $P_{\rm syn} = 3.832 \pm 0.002\,{\rm h}$. The amplitude of the lightcurve is $A = 0^{m}\!.314$. The order of presented Fourier fit is 6. This is an asteroid referred to so called Fast Rotation Asteroids (FRA) (Pravec, 1999).

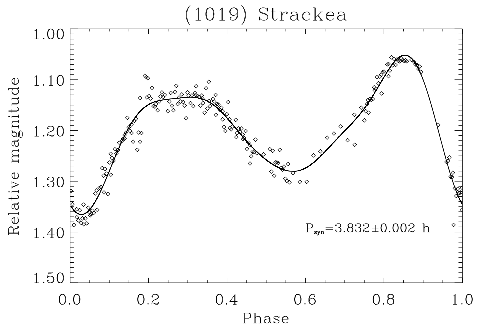

Figure 4. CL of asteroid (1019) Strackea – 17 and 18 Jun 2002

(3443) Leetsungdao

This object was observed in three nights: 18 and 20 Jul 2001 and 21 Aug 2001. The calculated synodic period is $P_{\rm syn} = 3.313 \pm 0.001\,{\rm h}$ and the amplitude is $A = 0^{m}\!.297$. The solid line is a Fourier fit of order 6. This object, also referred to FRA, is the asteroid with the smallest period we have observed. A different period and the same amplitude from observations carried out two weeks later were published in the above mentioned web-site by Bernasconi, L., Charbonnel, S. and Goncalves, R.

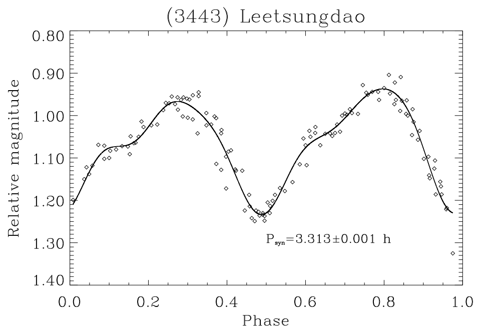

Figure 5. CL of asteroid (3443) Leetsungdao – 18 and 20 Jul 2001 and 21 Aug 2001

(4324) 1981 YA1

The observations of this asteroids were carried out in September and October 2001 at 18,19 and 18, 19, 20 respectively. Even though, it was observed during one and the same opposition, construcyion of a CL is very difficult due to the vastly changed phase angle. Assuming a standart lightcurve with two pears of extrema we estimate period $P_{\rm syn} \approx 26.5\,{\rm h}$ and amplitude $A \approx 0\overset{m}{.}626$. The individual lightcurves are fitted with Fourier function of order 4. For more precise determination of the synodic period further observations are needed. This is the object with the longest period that we have observed.

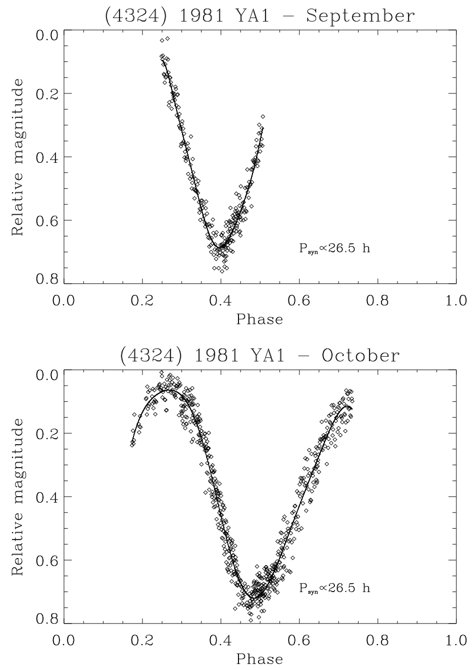

Figure 6. Lightcurves of asteroid (4324) 1981 YA1 – 18 and 19 September and 18, 19 and 20 October 2001

(5240) Kwasan

This object was observed only in one night for 7.5 h, 20 Dec 2001. The period is $P_{\rm syn} = 5.346 \pm 0.010\,{\rm h}$ and the amplitude is $A = 0\overset{m}{.}481$. The Fourier fit of order 4 is presented with solid line.

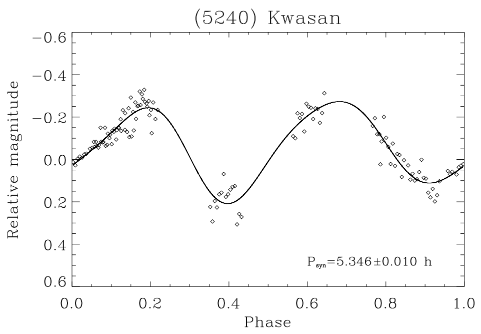

Figure 7. CL of asteroid (5240) Kwasan – 20 Dec 2001

3. CONCLUSIONS

The observational programme gives opportunity for solving more problems, connected with the determination of the rotational parameters as well as the physical characteristics of asteroids. Both problems have significant importance for understanding the evolution of the Solar System, clarifying of the role of the impact processes in it as well as the structure of the asteroid belt. In the future, having in mind the importance of NEAs, from scientific point of view, as well as from interest for space flights, we intend to make observations mainly of those objects. 2m RCC telescope observational time will be used for exploration of Kuiper belt objects.
Our experience shows that it is better initialy to determine the synodic period in one colour observations (usually V) and after that observation for estimating a taxonomical class to be implemented.
This manner of observations allow us to achieve easier both goals: the first – determination of the spin-vectors, also possible from lightcurves in relative magnitudes (Kaasalainen, 2001), and the second one – determination of surface colours.
As well, for more efficient achievement of those goals nowadays a scientific cooperation of astronomers from three Balkan countries (Bulgaria, Macedonia and Serbia) is being established. The observations, astrometric and photometric, will be made with telescopes of NAO Rozhen, still the largest observatory in the South–East Europe. This cooperation is opened for other contries, too.

ACKNOWLEDGMENTS

This research was supported by contract Num. NZ-904/99 with the National Science Fund, Ministry of Education and Sciences, Bulgaria and by contract with the Minisrty of Education and Sciences, R. of Macedonia and a Space Frontier Foundation grant.

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