CCD PHOTOMETRY OF ASTEROIDS AT ROZHEN NATIONAL ASTRONOMICAL OBSERVATORY FROM 2001 TO 2003

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Abstract

The research is based on CCD photometric observations performed at Rozhen National Observatory, Bulgaria, in the period from 2001 to 2003. The photometric observations were made with a 0.5m/0.7m Schmidt telescope using a ST-8E CCD and with a 2m RCC telescope using a CCD camera Photometrics. The results from the photometric research are differential lightcurves of more than ten asteroids. For the first time the synodic periods of rotation for nine asteroids were determined and for five asteroids, the mean values of the color indexes were calculated. The mean values of the color indices for (300) Geraldina, (1011) Laodamia and (3443) Leetsungdao are presented.

The results gathered by photometric observation contribute to the enlargement of the database for rotational characteristics of the asteroids and their classification. These, together with the CCD observations of the asteroids from their next oppositions are expected to contribute in the search for the position of the poles, and the shape of asteroids.

Introduction

The importance of studying the asteroids could be attributed to two main reasons. The first main reason is that asteroids are considered to hold the key for understanding of the Solar system creation. Knowing the physical characteristics, the distribution and the evolution of asteroids is crucial for the understanding of the processes by which the planets were formed. The second reason is connected with the great influence of the asteroids on the evolution of the life on our planet. In order to prevent an impact and diminish the consequences of one, it is necessary to discover all Near Earth Objects and investigate their nature.

The rich metal composition has also led to asteroids being examined from an economical viewpoint, being considered as a source for metals, as well as a source or rare minerals. It makes them a new potential mineral source for humanity in the not-so-distant future, which would improve the chances for keeping the ecological balance of our planet.

The reflected sunlight from the asteroid is varying from several different factors: the variation of the distance between the Earth and the Sun, asteroid axis rotation, the albedo, the solar phase angle α. Specifics of the asteroid photometry are the continuous change of the geometry of the observations and the condition that asteroids could be observed only during short time intervals before and after the opposition. Measurements of the light flux or the magnitude with time reveals the lightcurve (*LC)* of the asteroid. The form of the lightcurve repeats with a period that corresponds to the synodic rotation period of the asteroid.

The asteroids have gone through a rich collision evolution due to which they have mostly irregular shapes. A typical lightcurve of an asteroid with shape closest to a triaxial ellipsoid is most likely to have two different minima and maxima, with a period of rotation between 4 and 12 hours. The theory shows that for asteroids with rotational period less than 2.2 hours the inertial forces from the rotation would cause the asteroid to break apart. The statistics of asteroid spin rates vs size suggest that most of the asteroids are not monolithic structures, but rather they are a conglomerate of several gravitationally bound pieces.

Observations and results

We carried out photometric observations in order to obtain optical lightcurves and calculate the synodic rotational periods of asteroids; and to determine the mean values of the color indices of chosen asteroids from the Main asteroid belt. The obtained results are based on the CCD photometric observations performed at the Bulgarian National Astronomy Observatory (BNAO) – Rozhen.

The regular photometric observations of asteroids (brighter than 13m) at BNAO Rozhen have been carrying out since 1991 with the 60 cm Cassegrain telescope equipped with the electrophotometar. The 2-m RCC telescope was used for fainter objects, in particular for relative photometry during the international observing campaign for (1620) Gegraphos.

By joint efforts of the Bulgarian Academy of Science, the Institute of Physics (Faculty of Natural Sciences) from Skopje and the Space Frontier

Foundation in 2000 a new SBIG ST8-E (Kodak KAF-1602E,1536x1024px, 1px=9μm) camera was purchased. It was mounted on the Schmidt telescope and has been used for observation of asteroids since July 2000.

A small amount of our observations during the last 3 years were carried out with the 2-m RCC telescope using a CCD camera Photometrics (CE200A-SITe, 1024x1024,1px=24μm).

The choice of the objects that were observed was based on the visibility of the objects in the assigned observation schedules, observation capabilities of the used telescopes and detectors at BNAO Rozhen. The quality of the results was, of course, influenced by the weather conditions.

From the measurements of the extinction during longer period at BNAO Rozhen [1] it is shown that out of five nights, one night is photometric, thus every fourth night, or approximately 20% of the total number of nights in a year is a high quality photometric night. On the nights with good photometric quality asteroids were observed through BVRI filters of the standard Johnson-Cousins system. The instrumental magnitudes of the asteroid were transformed into an absolute photometric system and the mean values of the color indices were determined.

The variation of the brightness of the asteroids is a periodic function and this gives the possibility of gathering and combining the lightcurves from several nights into one composite lightcurve (CLC). The size of the CCD frame enables us to choose an asteroid and at least two non variable stars in the same frame. On this way the atmospheric effects are eliminated and a very accurate lightcurve data and period of rotation of the asteroid could be determined, without using the absolute photometric system. During the constructing of the individual lightcurves the main goal is to cover the rotational phase of the asteroid as much as possible. The method for constructing the composite lightcurve, as well as for the calculation of the rotational period [2] is a semi-automatic and allows to choose and combine those lightcurves that do not differ much by the phase angle ($\Delta\alpha < 5°$) and are in a time interval of no more then 15 days.

The synodic periods are calculated for the first time for (698) Ernestina, (1019) Strackea, (4324) 1981 YA1 and (5240) Kwasan [3]. The values of color indices for (1474) Beira and it's synodic period and periods for (1309) Hyperborea and (2525) O'Steen are calculated for the first time [4]. In Table 1 the aspect data for each asteroid and each night of observations are reported. The position of the asteriod is given by the ecliptic longitude λ and the ecliptic latitude β. The fifth column contains the

Earth – asteroid distances Δ, the sixth column contains the Sun – asteroid distances r, and in the last column α is the phase angle.

Table 1.

Object	**Date**	$\lambda[°]$	$\beta[°]$	Δ[AU]	r[AU]	α[°]
(300) Geraldina	10.01.2002	143.46	1.01	2.406	3.276	9.4
	11.01.2002	143.33	1.01	2.399	3.276	9.1
	25.03.2003	210.80	0.34	2.445	3.370	7.4
(698) Ernestina	13.02.2002	126.83	18.24	1.630	2.556	9.6
(1000) Piazzia	22.08.2003	348.8	9.93	2.123	3.086	6.9
	23.08.2003	348.50	10.00	2.121	3.089	6.6
	26.08.2003	347.86	10.30	2.118	3.096	5.7
(1011) Laodamia	9.02.2002	177.49	4.99	0.709	1.612	21.5
	11.02.2002	177.41	5.26	0.704	1.617	20.3
	26.06.2003	295.89	-3.16	2.187	3.157	6.7
(1019) Strackea	16.06.2001	219.44	47.91	1.070	1.783	30.4
	17.06.2001	219.46	47.62	1.073	1.783	30.5
	22.06.2001	219.75	46.00	1.091	1.782	31.0
	24.06.2001	219.96	45.38	1.099	1.781	31.2
	26.06.2001	220.21	44.72	1.107	1.781	31.5
(1309) Hyperborea	12.01.2002	141.41	-14.63	1.904	2.788	10.8
	14.01.2002	141.10	-14.69	1.894	2.789	10.2
(1474) Beira	24 08.2003	22.44	27.42	0.806	1.607	31.5
	25.08.2003	22.79	28.00	0.799	1.602	31.5
	21.09.2003	30.79	47.54	0.672	1.493	33.5
(2525) O'Steen	23.09.2003	20.72	-3.95	1.778	2.545	17.8
(3443) Leetsungdao	16.07.2001	316.28	26.94	0.713	1.655	20.2
	18.07.2001	316.07	26.87	0.708	1.656	19.4
	20.07.2001	315.82	26.76	0.704	1.657	18.8
	21.08.2001	310.85	20.80	0.726	1.689	16.0
(4324) 1981 YA1	18.09.2001	40.34	13.10	1.232	2.062	20.4
	19.09.2001	40.34	13.18	1.224	2.062	20.1
	18.10.2001	36.82	14.77	1.075	2.044	8.9
	19.09.2001	36.79	14.78	1.073	2.044	8.5
	20.09.2001	36.39	14.79	1.071	2.043	8.2
(5240) Kwasan	20.12.2001	82.4	-4.4	1.180	2.153	3.6

(300) Geraldina

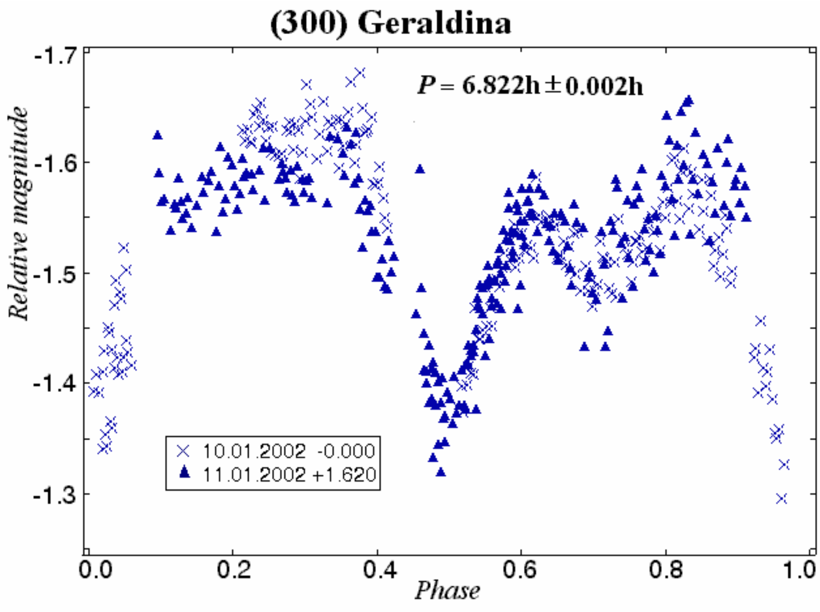

Fig 1.

This asteroid belongs to the outer part of the asteroid belt and according to the IPMS (IRAS Minor Planet Survey) Base Ground Data it has a diameter of 78 km. The observations of (300) Geraldina were carried out with the 2m RCC telescope. Two nights observations: 10 and 11 January 2001, were used for determination of the synodic period P = 6.822h ± 0.002h and the amplitude of the composite lightcurve $A = 0.303^m \pm 0.020^m$.

The reduction to the BVRI standard system of the asteroid magnitude was made by means of the observations of "dipper asterism" region from the open cluster M67 [5]. In this CCD standard-star field eight stars were used for calculation of the atmospheric extinction and transformation coefficients. On 25 March 2003, using a standard Johnson-Cousins set of filters, Geraldina was observed in B, V, R and I bands. The mean values of the color indices of the asteroid were measured as: $B\text{-}V = 0.784 \pm 0.152$, $V\text{-}R = 0.388 \pm 0.024$ and $R\text{-}I = 0.369 \pm 0.007$. The CLC has a rather complex form (Fig.1). The big scatter of observing points influenced the big error in the calculated values of the color indices.

(1011) Laodamia

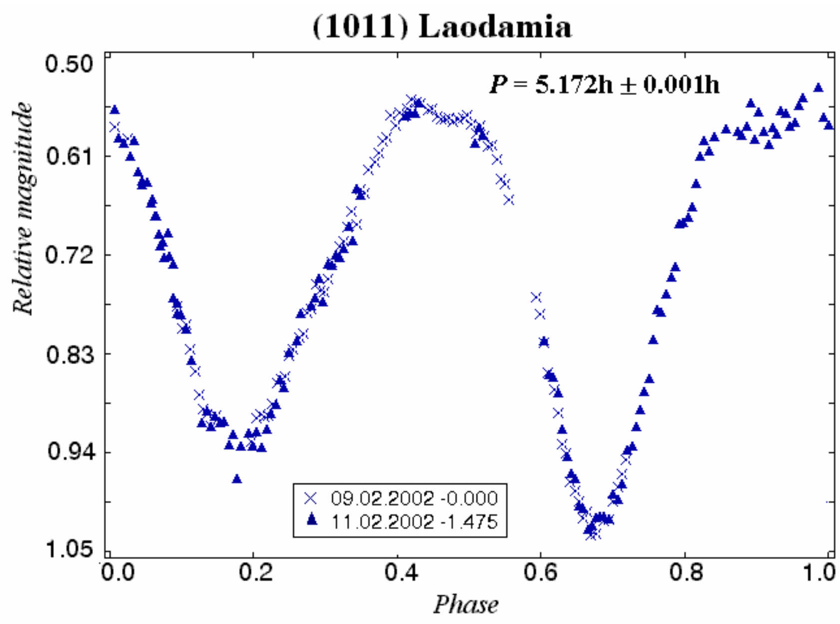

Fig 2.

(1011) Laodamia, is a Mars crosser asteroid. The CLC shown in Fig. 2 is constructed from observations from two nights in February 2002. It shows a non-symmetric form as to the depth of the minima and the humps of the maxima, which indicates an irregular shape. It needs more observations to determine it. The calculated period is P = 5.172h ± 0.001h and the amplitude of the CLC is $A = 0.470^m \pm 0.008^m$.

In order to transform observations to a standard magnitude scale standard field SA98 from the catalogue of Landolt [6] were observed on 9 February 2002. The mean values of the color indices are: B-V = 0.819 ± 0.135, V-R = 0.461 ± 0.020 and R-I = 0.399 ± 0.031. The calculated value of B-V confirms that Laodamia belongs to S-type as it was in Tholen taxonomy [7]. The stony asteroids or S-type have an albedo of 0,1 do 0,22 and are composed of silicates and approximately 10 percent of nickel and iron. This S-type accounts for some 15% of all known asteroids.

(3443) Leetsungdao

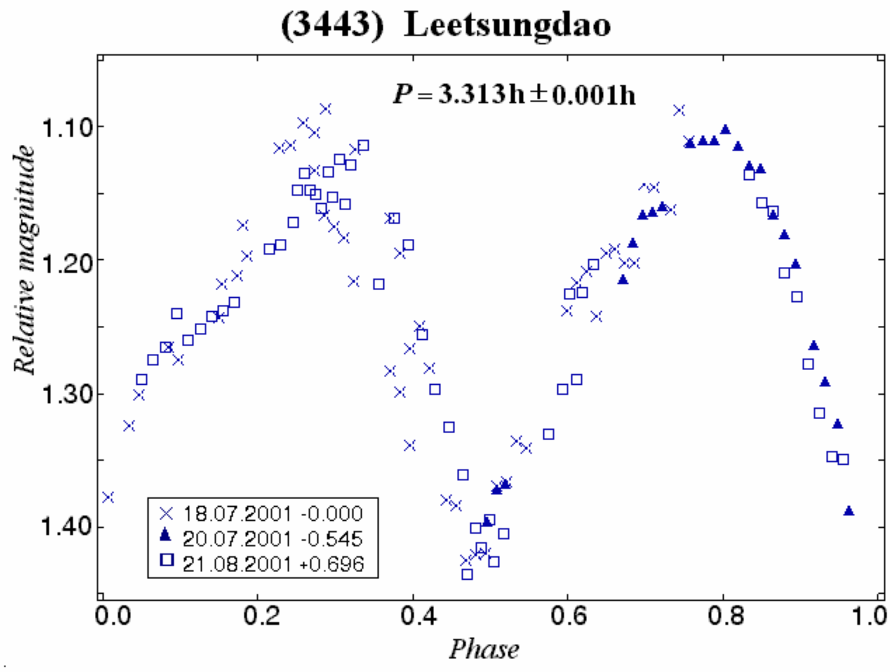

Fig. 3

The minor planet (3443) Leetsungdao is named after the Chinese theoretical physicist, Nobel prise winner - Tcung-dao-Lee. It's orbit comes close to the orbit of Mars and so some authors consider Leetsungdao as a Mars crosser asteroid. In order to construct a CLC presented in Fig. 3, we choose for the reference lightcurve the LC with the best quality and most observed points. All other LC are shifted along the ordinate axis according to the referent LC. Leetsungdao with the calculated period of P = 3,313h ± 0.001h may be referred to as a fast rotation asteroid. It is the asteroid with the shortest period we have observed. The amplitude of the composite lightcurve, Fourier fitted of order 6, is $A = 0.297^m \pm 0.015^m$.

Standards fields SA110 and SA114 from the catalogue of Landolt were observed on 16 July 2001. According to the determined values of the color indices: B-V = 0.606 ± 0.075, V-R = 0.625 ± 0.034 and R-I = 0.625 ± 0.034 it could be concluded that the asteroid Leetsungdao is a member of the group of carbonate asteroids. This C-type accounts for some 75% of all known asteroids. They are similar to the carbonate hondrite meteorites. It is assumed that they represent unprocessed material from the time of the formation of the solar system. Carbonate asteroids are very dark, with an albedo of approximately 0,05 and are hard to notice in observations in the visible part of the spectrum.

Conclusion

The study of small bodies in the Solar system has enormous significance due to the fact that they are composed from the same protomatter as that from which the solar system was formed. Studying physical and chemical processes of these objects and their dynamic behaviour, scientists hope to understand the conditions and make-up of matter during the creation of our solar system, the only one, so far, that we can study in detail. The significance of this research is increasing due to the fact that lately, planets have been found around number of other stars as well.

The results from the CCD photometric research in BNAO Rozhen during the period from 2001 to 2004 are more than 20 differential lightcurves of 11 asteroids. The constructed composite lightcurves were used to evaluate for the first time the synodic period of rotation for 10 asteroids. Out of the fitted composite lightcurves the amplitudes of the variation of the light were calculated. For five asteroids, the mean values of the color indexes were calculated.

The results gathered by photometric observations contribute to the enlargement of the database of known rotational and physical properties of asteroids and could be used in their taxonomically classification These, together with the CCD observations of the asteroids from their next oppositions are expected to contribute in the calculation of the pole position, and shape of asteroids.

Acknowledgments

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