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Relative photometry of numbered asteroids (3712), (4197), (5587), (28753) and (66063)

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Abstract. The Astronomical Observatory in Modra, Slovakia, turned to center on asteroid photometry. Several lightcurves were obtained to reveal a rotation period of the targets, though data were not calibrated. Five asteroids presented here were photometrically observed at other observatories previously. Our results are in agreement with the published data.

Key words: asteroids – photometry

1. A new station for asteroid photometry in Modra

A 0.6-m, f/5.5 reflector with a CCD-camera in its primary focus is the main equipment of the Astronomical Observatory in Modra. This belongs to Comenius University, Bratislava. The first CCD-camera was installed there at the end of 1994. It was a SBIG ST6 camera with a small field of view (FOV). It was replaced by an ST8 camera in 1998 and at the end of 2003 by an AP8 camera. FOV increased from about $9' \times 7'$ through $15' \times 10'$ to $25' \times 25'$.

Several observational programs were performed at the observatory in the field of cometary and asteroidal research, but priority was gradually changed from astrometry (MPC code 118) to asteroid photometry. This happened after obtaining a larger FOV and as large survey telescopes began to produce a huge quantity of asteroid positional data. In 1998 the first photometrical tests were carried out on three main belt asteroids (MBAs) with the known rotational period and amplitude (e.g. Babiaková, 1999; Svoreň and Babiaková, 2002). Several additional MBAs and many Near-Earth asteroids (NEAs) have been photometrically observed since 2001. The results were not published in a paper form. Just a brief note concerning our own software for data processing (it was under development) with some lightcurve examples was presented by Világi (2002). An updated summary of all objects observed from that station with the time period of observations is available at

Table 1. The aspect data for 5 numbered asteroids observed at Modra; d and r are the geocentric and heliocentric distances, respectively, α is the phase angle, L_{PAB} and B_{PAB} are the ecliptic coordinates of the phase angle bisector.

Object	Time	d [AU]	r [AU]	α [°]	L_{PAB} [°]	B_{PAB} [°]
(3712) Kraft	2003 02 17.9	1.2669	2.0311	22.52	109.11	-9.84
(3712) Kraft	2003 02 18.9	1.2760	2.0308	22.86	109.26	-10.06
(4197) 1982 TA	2003 09 22.0	0.4875	1.3448	37.65	34.55	2.47
(4197) 1982 TA	2003 09 23.1	0.4696	1.3309	38.04	35.30	2.77
(4197) 1982 TA	2003 09 26.1	0.4220	1.2926	39.37	37.55	3.70
(4197) 1982 TA	2003 09 28.9	0.3792	1.2565	41.05	39.93	4.75
(4197) 1982 TA	2003 10 02.9	0.3216	1.2043	44.54	43.98	6.63
(5587) 1990 SB	2001 05 27.0	0.3038	1.1372	58.71	240.89	43.99
(5587) 1990 SB	2001 06 24.9	0.3380	1.0800	70.19	284.15	52.56
(5587) 1990 SB	2001 07 06.9	0.3464	1.0893	68.79	303.67	50.43
(5587) 1990 SB	2001 08 07.0	0.3488	1.1964	51.06	335.93	35.92
(5587) 1990 SB	2001 08 29.0	0.3756	1.3236	28.60	344.74	22.94
(5587) 1990 SB	2001 08 30.0	0.3785	1.3300	27.56	344.98	22.35
(5587) 1990 SB	2001 09 04.0	0.3961	1.3627	22.59	346.10	19.46
(5587) 1990 SB	2001 09 27.9	0.5573	1.5291	15.23	350.88	7.95
(5587) 1990 SB	2001 10 03.9	0.6175	1.5724	17.40	352.24	5.81
(28753) 2000 HA	2003 01 11.9	0.8485	1.8164	08.05	117.72	-8.85
(28753) 2000 HA	2003 01 16.0	0.8407	1.8160	05.95	117.90	-7.66
(28753) 2000 HA	2003 01 25.9	0.8411	1.8162	06.29	118.31	-4.65
(28753) 2000 HA	2003 01 29.0	0.8469	1.8167	07.94	118.47	-3.69
(28753) 2000 HA	2003 01 30.9	0.8517	1.8171	09.06	118.57	-3.10
(28753) 2000 HA	2003 02 01.9	0.8579	1.8176	10.29	118.70	-2.49
(28753) 2000 HA	2003 02 09.8	0.8924	1.8203	15.13	119.37	-0.10
(66063) 1998 RO_1	2003 09 16.0	0.2152	1.2130	13.98	1.47	4.70
(66063) 1998 RO_1	2003 09 17.1	0.2031	1.2023	12.82	0.80	5.58
(66063) 1998 RO_1	2003 09 17.9	0.1947	1.1944	12.25	0.25	6.28
(66063) 1998 RO_1	2003 09 18.9	0.1845	1.1845	12.06	359.46	7.22
(66063) 1998 RO_1	2003 09 20.0	0.1739	1.1734	12.75	358.45	8.36
(66063) 1998 RO_1	2003 09 21.0	0.1649	1.1632	14.34	357.39	9.50

$$http://www.uniba.sk/\sim ago/fotobs.htm$$

The links to several lightcurves corrected for light time are accessible from that page as well.

Observations with the ST8 CCD-camera were not calibrated to a standard photometrical system. The main reason was the fact that gradients in the intensity of the background of the images were not removed properly. Affected data prevented to recognize a long synodic rotation period P of asteroids with a small lightcurve amplitude A.

As for the targets, depending on their apparent motion, asteroids up to 15 - 16 magnitude were observed with the ST8 CCD-camera. NEAs were preferred to MBAs. The relative uncertainty of measurements reached 0.05 mag or less in most cases. Based on the data alone, only asteroids with $A > 0.1$ mag could be revealed. The AP8 CCD-camera is more sensitive so that NEAs weaker by 1 mag could be chosen as photometrical targets.

Since 2001 photometrical data (with ST8 camera) from Modra have been at first intended to be compared with and joined (if possible) to those obtained at the Ondřejov Observatory, which are of high quality and quantity and centered on NEAs. Then (with the AP8 camera), the collaboration between both observatories have advanced to augment the number and quality of photometrically observed NEAs as more telescope time is available. A large amount of information obtained (and still growing) has not been published in a paper form yet. As for the remaining objects, some of them were observed unsatisfactorily (due to weather and technical limitations) to be used for P determination, the others were MBAs, some were published meanwhile (e.g. binaries), and so on. Despite limitations of relative photometry mentioned above we present here successfull observations of five asteroids using the ST8 CCD-camera to see a typical output of a configuration.

2. Targets

Numbered asteroids (3712) Kraft, (4197) 1982 TA, (28753) 2000 HA and (66063) 1998 RO_1 were observed in 2003, while (5587) 1990 SB in 2001. Their aspect data are listed in Tab. 1. Two of them are MBAs, three are NEAs.

2.1. (3712) Kraft

Two successive nights close to the full Moon period were dedicated to the so called target of opportunity. The main belt asteroid (3712) Kraft (semimajor axis $a \sim 2.73$ AU, eccentricity $e \sim 0.26$, absolute magnitude $H = 11.6$) was chosen from the recommended objects for a given time according to Collaborative Asteroid Lightcurve Link (CALL) (Warner, 2003) that emphasized objects in good geometrical conditions. In that case, the asteroid was near perihelion of its orbit when near opposition and its (V) magnitude was below 15 during 3 months. Although such conditions repeat every 9 years - these helped also to its discovery in 1984/1985 - no lightcurve was known prior to that apparition. The first rotation period of 9.34 h and amplitude of the lightcurve of 1.2 mag was successfully derived by Koff (2004).

Our observations were done a little later but totally independently. According to them P could be about 9.4 h and the lightcurve amplitude close to 1.0 mag, as it can be seen in Fig. 1. From our additional observations those values could be derived much more precisely and reliably. Fortunately, it was not necessary as the preliminary results by Koff with reliability code 3 (which means secure

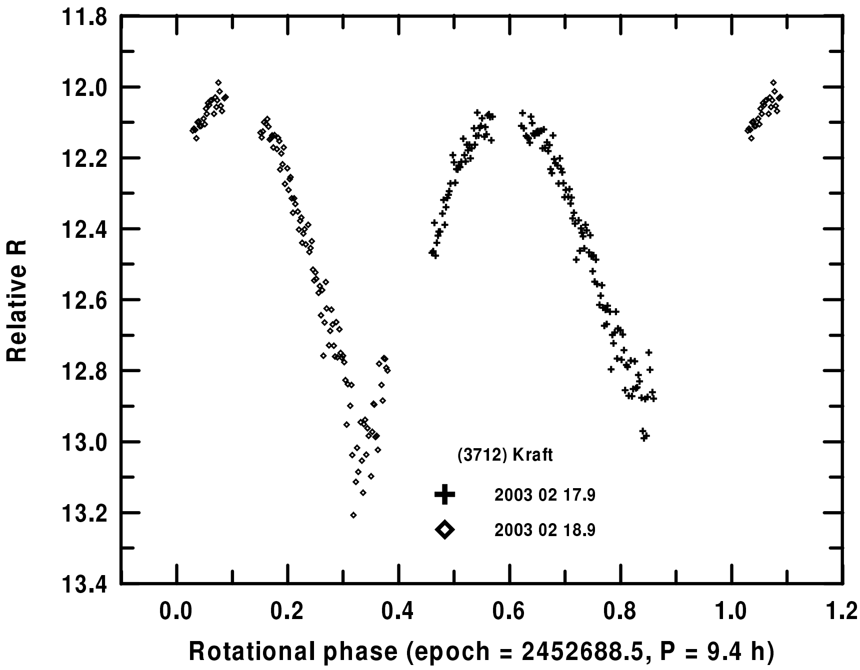

Figure 1. Composite lightcurve of (3712) Kraft

result with no ambiguity and full lightcurve coverage) meanwhile appeared at *http://www.minorplanetobserver.com/DATA/submissions_results.htm.*

2.2. (4197) 1982 TA

The best observational window for physical study of the Near-Earth asteroid (4197) 1982 TA after its discovery occured in 1996. It passed the Earth within 0.1 AU and photometric, spectral and radar campaigns were successful. Orbital elements were derived much more precisely ($a \sim 2.30$ AU, $e \sim 0.77$), but H seemed to be overestimated by 0.2 - 0.3 mag. According to the results by Pravec et al. (2000), who investigated the object thoroughly at that time with comparison to all previous results, $P \sim 3.538$ h, $A \sim 0.3 - 0.5$ mag (depending on aspect) and $H \sim 14.9$.

Seven years later this asteroid approached the Earth again and we studied it on five nights. The geometry was a little different in comparison to the previous observations - a larger phase angle α by about 15°, but similar L_{PAB} and B_{PAB} to their first part. The best fit to the obtained data revealed $P = 3.5387$ h and $A \sim 0.4$ mag, as it can be seen in Fig. 2. Even with larger relative uncertainties

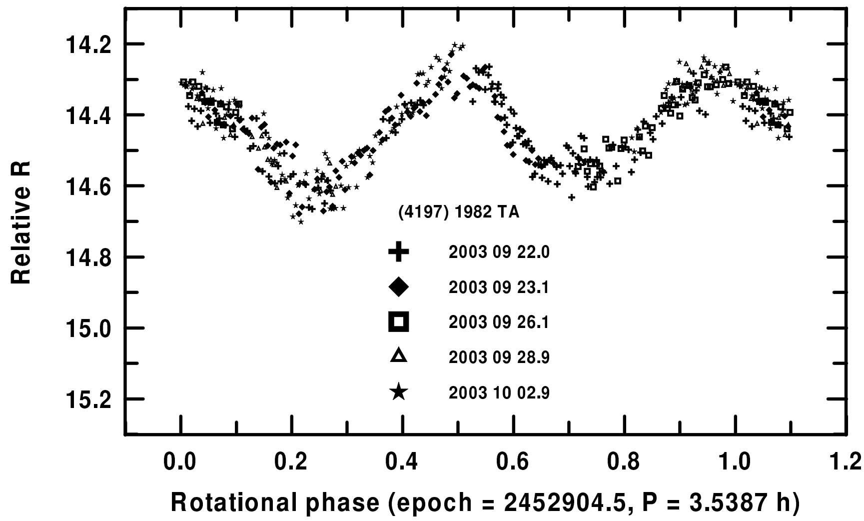

Figure 2. Composite lightcurve of (4197) 1982 TA

that lied within 0.05 mag, the results were in accordance with those by Pravec et al. (2000).

2.3. (5587) 1990 SB

An extremely long observational window opened in 2001 for asteroid (5587) 1990 SB on an Amor type orbit ($a \sim 2.39$ AU, $e \sim 0.55$, $H \sim 13.6 - 13.8$). More than half a year its magnitude was below 15. It was one of the brightest NEAs at that time and it was observed from many observatories around the world. As viewing geometry gradualy changed, P and A also changed their values. The former between 5.049 and 5.052 h, the latter between 0.7 and 1.25 mag (e.g. Koff et al., 2002; Krugly et al., 2002).

Gradual changes of P and A are also seen in our data. However, the measurements were affected by the gradient in the images. The composite lightcurve can be seen in Fig. 3. The mean P was 5.0494 h, but the last observations clearly differ from the rest. Under a closer inspection of the data, we can see decreasing A with a minimum around the late August and early September being just 0.68 mag. Then A increased. Changes in P indicated the retrograde sense of rotation.

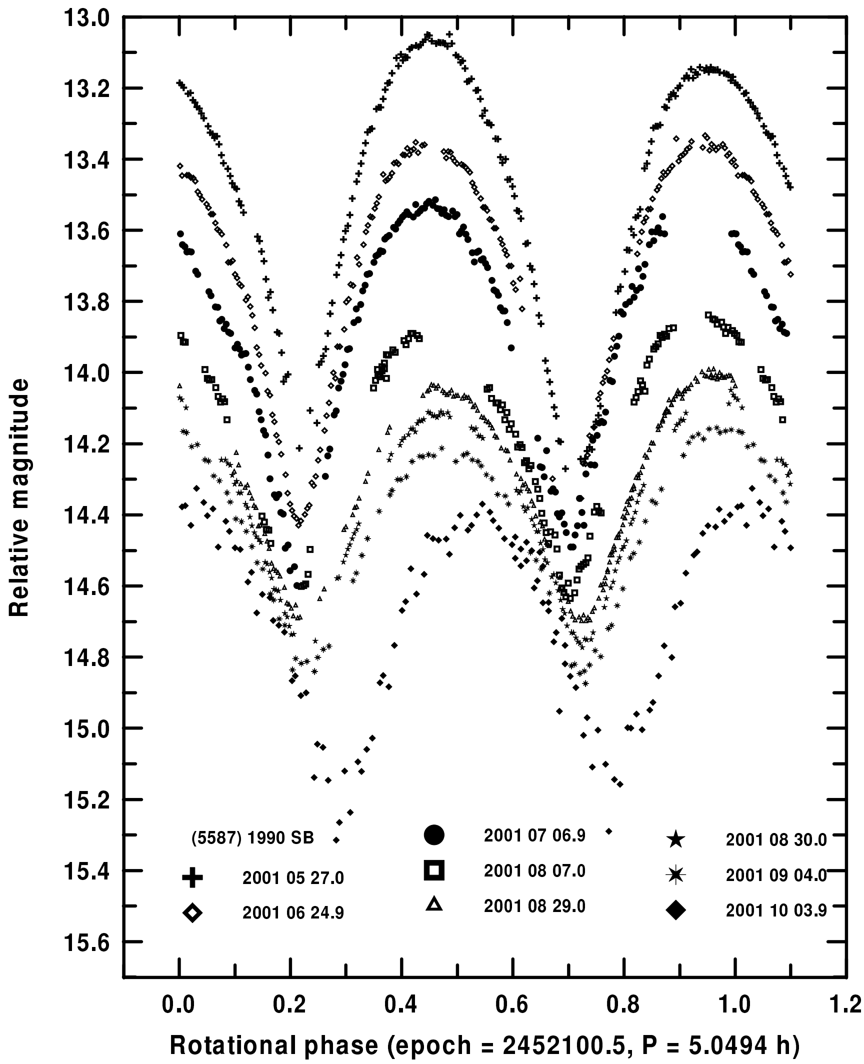

Figure 3. Composite lightcurve of (5587) 1990 SB

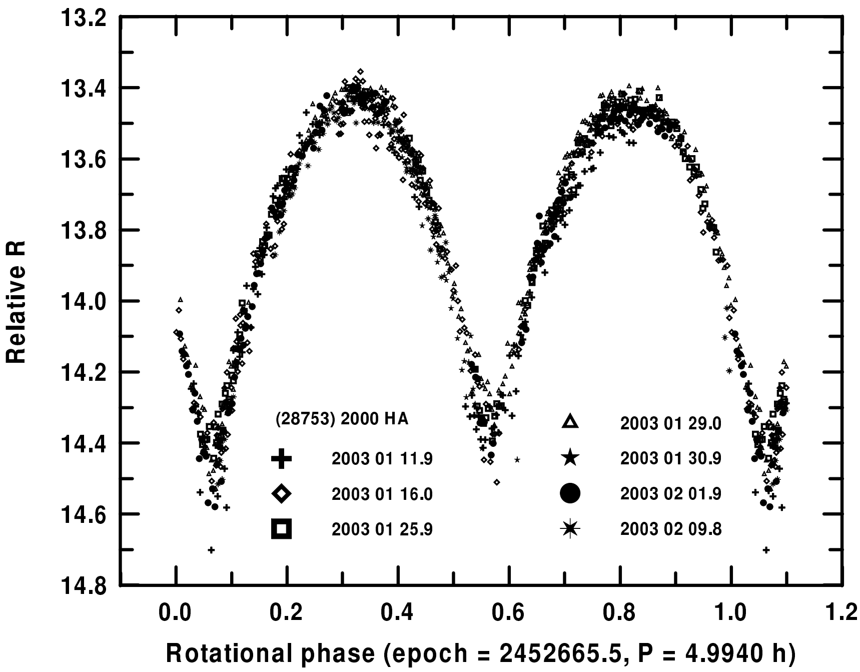

Figure 4. Composite lightcurve of (28753) 2000 HA

2.4. (28753) 2000 HA

Several MBAs were discovered as a by-product of astrometrical observations in Modra. Their brightnesses were usually insufficient to observe them photometrically by the same equipment. However, at the beginning of 2003 our asteroid (28753) 2000 HA became the first exception to this rule. At that time it was near perihelion of its orbit ($a \sim 2.34$ AU, $e \sim 0.22$, $H = 13.5$) and at the same time near opposition. As such an event is extraordinary for us - to analyse properties of one of our own discovery - this target was included to the observational program. Its magnitude reached 15 so it was also included to the CALL (Warner, 2003) and observed consecutively and independently by Ditteon et al. (2003) on three nights in February. According to his result $P = 4.993$ h and $A \sim 1.1$ mag.

According to our observations based on 7 nights $P = 4.9940$ h and $A \sim 1.0-1.1$ mag. Our asteroid is quite elongated with the lower limit of the equatorial axis ratio a/b of about 2.5. The uncertainties sometimes exceeded 0.05 mag as the observations continued even under worse seeing conditions, or near the bright Moon. The composite lightcurve is shown in Fig. 4.

2.5. (66063) 1998 RO_1

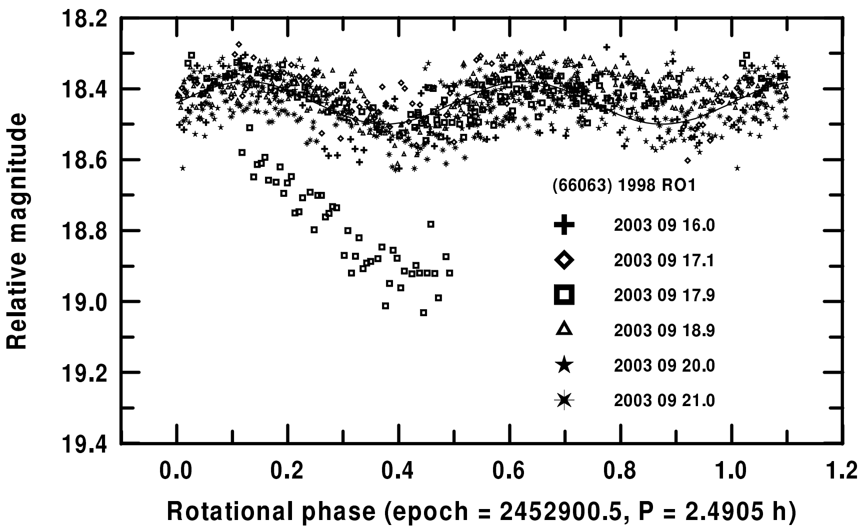

Figure 5. Composite lightcurve of (66063) 1998 RO_1

Asteroid (66063) 1998 RO_1 is on an Aten type orbit ($a \sim 0.99$ AU, $e \sim 0.72$). In the years 2002 - 2006 it approaches the Earth within a distance of 0.2 AU nearly at the same time of year. After analyzing the data from 2002 apparition photometrists at Ondřejov suspected this object could be a binary. This was confirmed in 2003 (Pravec et al, 2003).

As H was derived to be $\sim 17.8 - 18.1$, and knowing its small amplitude of the order of 0.1 mag, this object was normally not a good target for our equipment with the ST8 camera (beyond 15 mag and increasing its apparent motion in the sky). However, attenuations due to eclipses or occultations could be revealed. Observations with the R filter were too noisy in the first night, thus the rest on 5 successive nights were done without it. These were done just due to later comparisons with much more precise and calibrated Ondřejov data obtained at the same time and thus they could be interrupted by other astrometric observations.

The derived $P \sim 2.491$ h is in accordance with the published data for the primary, but it could hardly be assessed without knowing the result in advance - the data were analysed using software by Pravec at first. In Fig. 5 there is a composite lightcurve. Gradients in data were removed as much as possible as these strongly affects the derived A value. According to the fit line which is burried in the symbols A is ~ 0.12 mag. The attenuation due to the companion was observed only in one part of the night.

3. Discussion and the future

After a comparison with the good quality data from the Ondřejov Observatory it seems that several photometrical observations of asteroids obtained with the older and less sensitive ST8 CCD-camera in Modra were promising. The latter were uncalibrated and of lower quality, and that degraded the effectiveness of the observations. Nevertheless, some data when joined together improve determinations of P and A obtained separately.

Some of the remaining lightcurves (not joined with unpublished data from Ondřejov) can be compared with the published results. Here we presented lightcurves from five asteroids to demonstrate a typical lightcurve output from Modra with the older camera. The results were in accordance with the published data.

Modra became a new station where asteroid photometry is performed. Moreover, a new AP8 CCD-camera that was installed at the end of 2003 has several advantages (more sensitive, a larger field of view, insignificant gradient) so this station is ready for producing reliable good-quality and calibrated data.

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