ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

JUNE I **1999**, PAGE 363

Astron. Astrophys. Suppl. Ser. **137**, 363–368 (1999)

CCD observations of 11 faint asteroids

K. Sárneczky[1,3], Gy. Szabó[2,3], and L.L. Kiss[2,3]

[1] Department of Physical Geography, ELTE University, H-1088 Budapest, Ludovika tér 2., Hungary
[2] Department of Experimental Physics & Astronomical Observatory, JATE University, H-6720 Szeged, Dóm tér 9., Hungary
[3] Guest Observer at Konkoly Observatory, Hungary

Received December 8, 1998; accepted April 12, 1999

Abstract. We present new CCD observations of 11 poorly studied, faint and moderately faint asteroids. Six of them (1089, 1452, 2415, 9262, 1998 FM5, 1989 UR) have never previously been observed photometrically, thus our lightcurves are the first ones in the literature. The achieved accuracy ranges between $0.01 - 0.03$ mag depending mainly on the brightness of the target objects. The obtained sinodic periods and amplitudes: $1089 -> 4^{\rm h}$, 0.025 mag; $1452 \ -17^{\rm h}.2 \pm 0^{\rm h}.1$, $\geq$0.34 mag; $2415 -> 2^{\rm h}.5$, 0.15 mag; $9262 -> 6^{\rm h}.3$, $\geq$0.08 mag; 1989 UR $-> 4^{\rm h}$, $\geq$0.15 mag; 1998 FM5 $-> 2^{\rm h}.8$, $\geq$0.61 mag.

Additionally, lightcurves are presented for asteroids observed earlier in only one or two oppositions (792, 1508, 1604, 1865). The resulting periods and amplitudes: $792 - 9^{\rm h}.19 \pm 0^{\rm h}.01$, 0.76 ± 0.02 mag; $1508 - 9^{\rm h}.15 \pm 0^{\rm h}.03$, 0.52 ± 0.01 mag; $1604 - 6^{\rm h}.15 \pm 0^{\rm h}.02$, $\geq 0.17 \pm 0.01$ mag; $1865 - 6^{\rm h}.87 \pm 0^{\rm h}.03$, 2.3 ± 0.1 mag. We have conducted shape fitting with a triaxial ellipsoid and determined spin vector and sens of rotation for 1727 combining our new observations with previously published lightcurves. The results are: $\lambda_{\rm p} = 126/306 \pm 10°$, $\beta_{\rm p} = 56 \pm 15°$, $a/b = 1.9 \pm 0.1$, $b/c = 1.6 \pm 0.1$.

Key words: minor planets, asteroids

1. Introduction

Ground-based modelling of the shape and the rotation of the minor planets requires high precision and long-term photometric observations. With the advent of the CCD era it has become possible to study much fainter minor planets than previously. The photometric methods of modelling are based on multi-opposition lightcurves of full phase coverage obtained at very different longitudes (De Angelis 1993; Detal et al. 1994). A new approach to the modelling of rotation is presented in Szabó et al. (1999). It consists of investigating virtual period changes caused by the revolution through the O−C-geocentric longitude diagram. Therefore, observations of light extrema could also be of great importance.

We started a new observing programme in 1998 with the primary purpose of obtaining accurate CCD lightcurves of poorly studied minor planets. The main programme is dedicated to asteroids with available two-opposition lightcurves, where a third lightcurve enables the complex analyis. Additional targets are those asteroids with no previous photometric measurements.

The function of this paper is to present new CCD observations for eleven asteroids with very few photometric data in the literature. The observations are discussed in Sect. 2, while Sect. 3 deals with the detailed observational results.

2. Observations

Unfiltered CCD observations were carried out at Piszkéstető Station of Konkoly Observatory on six nights from January, 1998 to April, 1998. The instrument used was the 60/90/180 cm Schmidt-telescope equipped with a Photometrics AT200 CCD camera (1536 × 1024 KAF 1600 MCII coated CCD chip). The projected sky area is $29' \times 18'$ which corresponds to an angular resolution of $1''.1$/pixel. Although we did not use standard filters, the magnitude measurements fall close to R values based on the spectral sensitivity of the chip (Kelemen 1997).

We made $R_{\rm C}$ filtered observations with the same instrument on three nights between October 22 and October 26, 1998. Unfortunately other filters were not available during this observing run and consequently we could obtain only intrumental differential R magnitudes in respect to closely separated comparison stars.

The exposure times were limited by two factors: firstly, the asteroids were not allowed to move more than the half of the FWHM of the stellar profiles (varying from night

Send offprint requests to: l.kiss@physx.u-szeged.hu

Table 1. The journal of observations. (r – geocentric distance; Δ – heliocentric distance; λ – ecliptic longitude; β – ecliptic latitude; α – solar phase angle; aspect data are referred to 2000.0)

Date	RA	Decl.	r(AU)	Δ(AU)	λ	β	α
792 Metcalfia							
1998 10 22	23 30.22	+10 15.5	1.900	2.787	8.1	8.3	11.3
1998 10 23	23 29.75	+10 08.8	1.907	2.786	8.3	8.3	11.6
1998 10 26	23 28.47	+09 49.1	1.926	2.782	8.9	8.4	12.5
1089 Tama							
1998 04 04	13 25.62	−03 26.8	1.388	2.381	198.1	3.0	3.6
1452 Hunnia							
1998 02 28	05 31.88	+40 47.9	2.037	2.503	107.1	14.2	22.3
1998 03 01	05 32.72	+40 42.7	2.048	2.503	107.2	14.2	22.4
1508 Kemi							
1998 10 22	00 51.16	+14 30.9	1.206	2.187	22.8	4.6	6.0
1998 10 26	00 44.48	+14 58.0	1.201	2.168	23.9	5.1	8.2
1604 Tombaugh							
1998 01 04	05 52.13	+31 33.8	2.147	3.101	93.0	5.6	5.4
1998 01 05	05 51.23	+31 30.4	2.152	3.101	92.0	5.5	5.7
1727 Mette							
1998 02 26	10 42.01	+29 08.8	0.811	1.733	154.4	18.7	11.2
1998 02 27	10 41.05	+29 33.1	0.814	1.774	154.8	18.7	11.6
1865 Cerberus							
1998 10 23	05 24.42	+13 44.1	0.377	1.261	42.8	−2.8	38.7
1998 10 26	05 29.72	+11 24.4	0.347	1.242	44.9	−3.4	38.5
2415 Ganesa							
1998 04 04	13 15.62	−04 05.3	1.672	2.669	197.3	−2.3	2.3
9262							
1998 10 22	00 53.80	+14 46.3	1.250	2.230	22.7	−4.6	5.8
1989 UR							
1998 10 22	03 38.01	+36 27.7	0.263	1.218	34.8	3.5	28.7
1998 FM5							
1998 04 03	08 59.67	+19 50.2	0.293	1.168	155.5	−1.6	48.7

to night) and secondly, the signal-to-noise (SN) ratio had to be at least 10. This latter parameter was estimated comparing the peak pixel values with the sky background during the observations. The journal of observations is summarized in Table 1.

The image reduction was done with standard IRAF routines. The relatively high electronic noises and low angular resolution did not permit the use of psf-photometry and that is why a simple aperture photometry was performed with the IRAF task *noao.digiphot.apphot.qphot.* The applied differential photometry consisted of using a comparison and a check star close to the asteroid. The precision was estimated with the rms scatter of the comp.−check magnitudes (tipically $0.01-0.03$ mag). The presented magnitudes throughout the paper are based on magnitudes of the comparison stars taken from the Guide Star Catalogue (GSC). Therefore, their absolute values are fairly uncertain (at level of $\pm\ 0.2-0.3$ mag). Fortunately this is a less significant factor, since it does not affect the main photometric parameters needed in the minor planet studies, such as the amplitude, or photometric period. The final step in the data reduction was the correction for the light time[1].

[1] Individual data are available upon request from the second author (`szgy@neptun.physx.u-szeged.hu`).

Composite diagrams were calculated using APC11 by Jokiel (1990) and are also light time corrected. Times of zero phase are included in the individual remarks.

3. Discussion

In this section we present the first lightcurves in the literature for six asteroids. These are 1089 Tama, 1452 Hunnia, 2415 Ganesa, 9262, 1989 UR and 1998 FM5. Three minor planets in our programme (792, 1508, 1865) have been observed in one previous opposition. Therefore, no models can be derived for them, as modelling requires at least three well-observed oppositions. 1727 Mette have been observed in a third opposition in order to determine a model for its shape and rotation. Earlier measurements are summarized in Table 3. Based on these data, models are determined with an AM-method described in Michałowski (1993). The individual remarks are as follows.

792 Metcalfia
It was discovered by Metcalf in Taunton, on March 21, 1907. Previous measurements are from two nights in 1979, when Carlsson & Lagerkvist (1981) took 186 data points. They measured an amplitude of 0.64 mag and sinodic period of $9^{\rm h}\!.17$.

Table 2. The comparison stars. The typical uncertainty in the magnitude values is as large as $\pm\ 0.2 - 0.3$ mag

Date	Comp. star	m(GSC)	filter
792 Metcalfia			
1998 10 22	GSC 1172 1780	13.49	R
1998 10 23	GSC 1172 1886	13.33	R
1998 10 26	GSC 1162 21	15.00	R
1089 Tama			
1998 04 04	GSC 4962 345	13.63	unf.
1452 Hunnia			
1998 02 28	GSC 2914 1257	14.20	unf.
1998 03 01	GSC 2914 1257	14.20	unf.
1508 Kemi			
1998 10 22	GSC 611 279	13.04	R
1998 10 26	GSC 1188 1230	13.23	R
1604 Tombaugh			
1998 01 04	055124+313149[2]	14.4	unf.
1998 01 05	GSC 2405 993	13.30	unf.
1727 Mette			
1998 02 26	GSC 1979 1205	14.7	unf.
1998 03 27	GSC 1979 708	13.7	unf.
1865 Cerberus			
1998 10 23	GSC 708 1342	15.16	R
1998 10 26	GSC 718 270	14.31	R
2415 Ganesa			
1998 04 04	GSC 4961 542	13.57	unf.
9262			
1998 10 22	GSC 611 279	13.04	R
1989 UR			
1998 10 22	GSC 2367 1895	14.90	R
1998 FM5			
1998 04 03	GSC 1397 133	14.44	unf.

[1] USNO number.

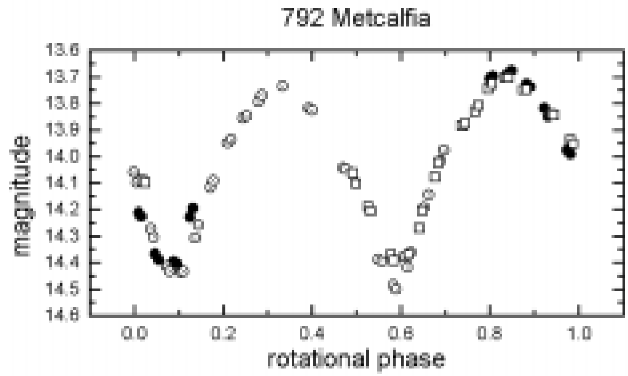

Fig. 1. The composite R lightcurve of 792 (symbols: open squares – October 22; dotted circles – October 23; solid circles – October 26)

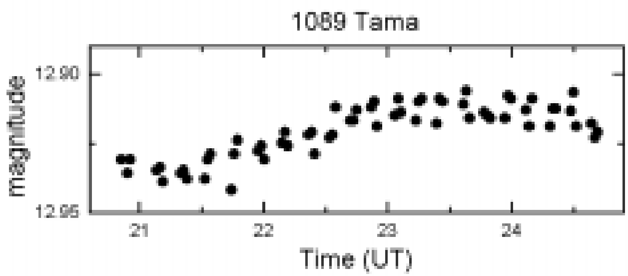

Fig. 2. The unfiltered lightcurve of 1089 on April 4/5, 1998

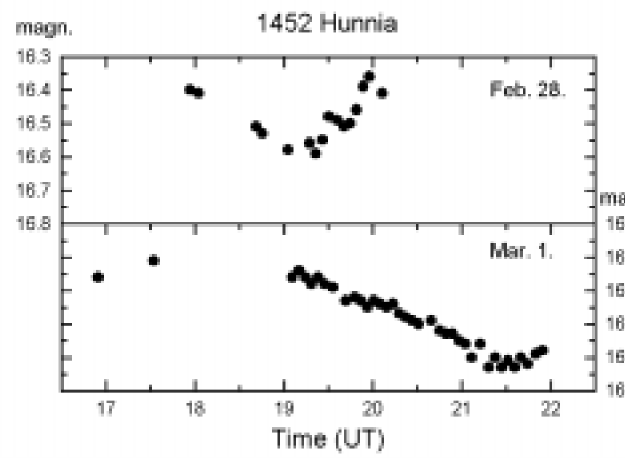

Fig. 3. The unfiltered lightcurves of 1452 obtained on February 28 (*top*) and March 1 (*bottom*)

In 1998, the observed amplitude in R was $0.76\ \pm\ 0.02$ mag, while its period turned out to be $9^{\mathrm{h}}\!.19\ \pm\ 0^{\mathrm{h}}\!.01$. This result is based on 79 data points obtained on three nights. The newly obtained rotational period is in good agreement with the earlier determination of $9^{\mathrm{h}}\!.17$ (Carlsson & Lagerkvist 1981). The zero phase of the presented composite diagram (Fig. 1) is JD 2451110.2050.

1089 Tama

It was discovered in 1927 by Oikawa. This asteroid is rather small; the assumed diameter is only 14.1 ± 0.8 km. The observed unfiltered amplitude is extremely low, only 0.025 mag, while the sinodical period is longer than 4 hours. The lightcurve is plotted in Fig. 2.

1452 Hunnia

This asteroid was discovered by Kulin in 1938. No previous lightcurve has been found in the literature. 1452 was observed on February 28 and March 1, 1998 (Fig. 3). The unfiltered total amplitude was $\geq 0.34\ \pm\ 0.05$ mag.

The relative magnitudes were calculated in respect to the same comparison star, which enables a direct comparison of the lightcurves. Two minima of different magnitudes were observed. The brightness difference is most likely due to the fact that those minima were separated by a half of the rotation. Assuming this, a possible rotational period of $17^{\mathrm{h}}\!.2\ \pm\ 0^{\mathrm{h}}\!.1$ can be derived, although the poor phase coverage does not exclude other probable values.

1508 Kemi

The minor planet was discovered by Alikoski in Turku, in 1938. Its diameter is 25.9 km. In 1995, 44 data points were measured by Holliday (1995). He determined two possible period of about $11^{\mathrm{h}}\!.36$ or $10^{\mathrm{h}}\!.21$. Our observations do not

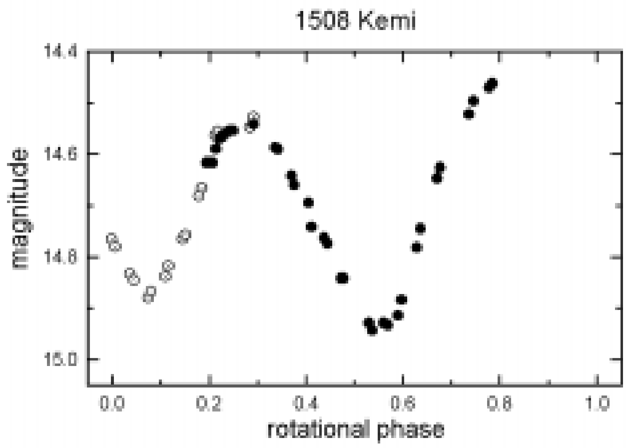

Fig. 4. The composite R lightcurve of 1508 (symbols: dotted circles – October 22; solid circles – October 26)

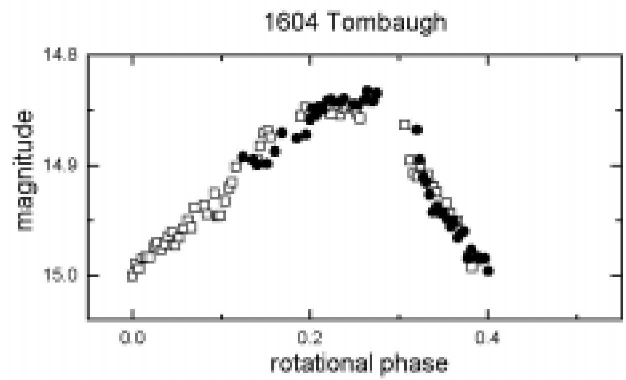

Fig. 5. Unfiltered lightcurve of 1604 (symbols: open squares – January 4; solid circles – January 5)

support these values, as they suggest a possible period of around $9\overset{h}{.}15 \pm 0\overset{h}{.}03$. The amplitude was 0.52 ± 0.01 mag in R. Unfortunately the time span is fairly short, thus periods determined by Holliday (1995) cannot be either approved nor disapproved. The zero phase of the composite diagram (Fig. 4) is JD 2451113.3458.

1604 Tombaugh
This asteroid has been discovered in Flagstaff, 1931, by Lampland. Its diameter is 33.8 ± 2.0 km. The minor planet was observed in 1975 (Lagerkvist 1978) and in 1984 (Binzel 1987). New measurements of this minor planet were carried out on January 4 and January 5, 1998. The unfiltered amplitude was 0.17 ± 0.01 mag, with $6\overset{h}{.}15 \pm 0\overset{h}{.}02$ sinodic period. Lightcurves are plotted in Fig. 5.

1727 Mette
This asteriod was discovered in 1965 by Andrews. Its diameter is about 20 kilometers. Previous observations were made in 1986 (Wisniewski & McMillan 1987) and in 1988 (Prokof'eva et al. 1992). Precise lightcurves were presented, so we could model this moderately faint asteroid (13.9 mag during our observing run). Earlier observations are summarized in Table 3.

Table 3. Earlier photometric observations in the literature for 1727

	year	λ	β	α	ref.
1727 Mette	1986	290	25	18	(1)
	1988	167	35	25	(2)

References: (1) – Wisniewski & McMillan (1987); (2) – Prokof'eva et al. (1992).

The unfiltered amplitude of the light variation was 0.19 ± 0.01 mag, with rotational period of $3\overset{h}{.}22 \pm 0\overset{h}{.}02$. We have to discuss this determination in details as the previous results for the period ($2\overset{h}{.}637 \pm 0\overset{h}{.}004$) significantly differ. The longer data sequence from 27 February is close to the cited period ($2\overset{h}{.}47$ vs. $2\overset{h}{.}637$). The magnitude difference between the starting and ending points is quite high and a very sharp brightness decrease would be needed at the end of the light curve in order to match the phase diagram. Therefore, we accepted the above mentioned period value as it gives much smoother composite diagram as the shorter period does. The composite lightcurve is presented in Fig. 6 (the zero phase is JD 2450872.3320).

This asteroid has been observed in the third opposition, therefore its model could be derived. Based on earlier data, models are determined with an AM-method described in Michałowski (1993). Using the relation between the amplitude and the aspect, we fitted of the pole and the shape. Lacking a long-term lightcurve showing the phase dependence of the amplitude, the m parameter required for correcting the amplitude for zero solar phase (see Eq. (6) in Michałowski 1993) cannot be determined photometrically. Also 1727 was not classified in the IRAS taxonomic system, and consequently, the m parameter cannot be estimated by the approximate relations of Michałowski (1993). We have to note that we used V and unfiltered magnitudes simultaneously, thus our model has to be considered as an approximate one.

The obtained pole coordinates: $\lambda_{\rm p} = 126/306 \pm 10°$, $\beta_{\rm p} = 56 \pm 15°$. The axis ratios of the fitted ellipsoid: $a/b = 1.9 \pm 0.1$, $b/c = 1.6 \pm 0.1$. The observed amplitudes versus longitudes with the determined fit is presented in Fig. 7.

1865 Cerberus
This asteroid has one of the largest observed amplitudes among all minor planets. Kohoutek discovered it, and the first photometry including 41 data points was discussed in Harris & Young (1989). Later, Wisniewski et al. (1997) presented the lightcurve of this asteroid. The amplitude is about 2 mag, which may imply a highly elongated shape.

We obtained 158 data points through R filter between October 23 and October 26, 1998. The amplitude in R was 2.3 ± 0.1 mag. The rotational period is $6\overset{h}{.}87 \pm 0\overset{h}{.}03$ hours. The composite diagram is plotted in Fig. 8 (the zero phase

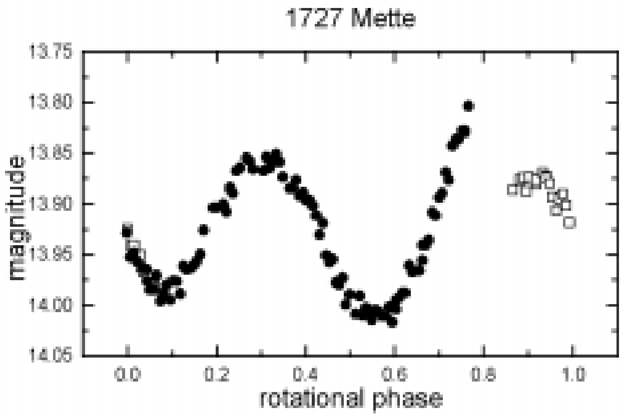

Fig. 6. The composite unfiltered lightcurve of 1727 (symbols: open squares – February 26; solid circles – February 27)

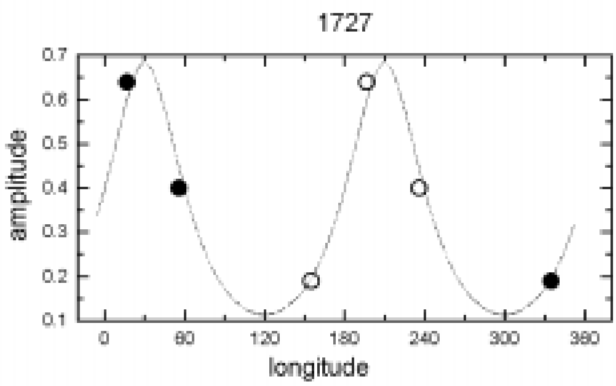

Fig. 7. The observed amplitudes vs. longitudes with the determined fit for 1727 Mette

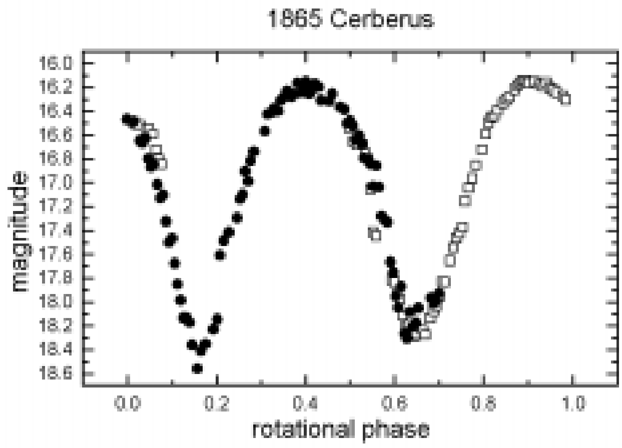

Fig. 8. The composite R lightcurve of 1865 (symbols: open squares – October 23; solid circles – October 26)

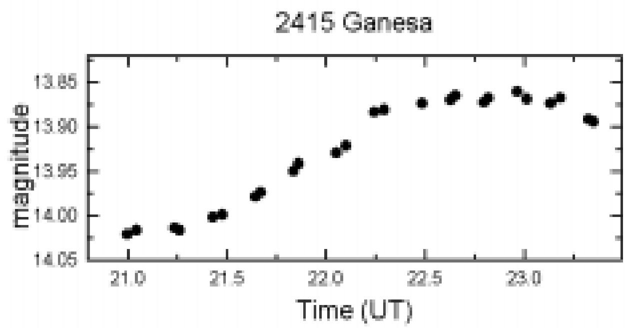

Fig. 9. The unfiltered lightcurve of 2415 on April 4, 1998

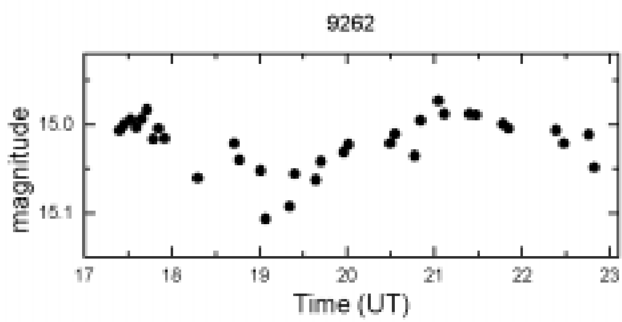

Fig. 10. The R lightcurve of 9262 on October 22, 1998

is JD 2451113.5000). The individual lightcurve of October 26 has considerably smaller scatter (± 0.05) than that obtained on October 23.

2415 Ganesa

It was discovered by Giclas in 1978. The assumed diameter is 26.2 km. The observed unfiltered amplitude is 0.15 ± 0.01 mag and the sinodical period is longer than 2.5 hours. We plotted its lightcurve in Fig. 9.

9262

This asteroid with 20 km diameter showed an ambiguous light variation with 0.08 ± 0.015 R magnitude amplitude during the observing session. The lightcurve is presented in Fig. 10. The rotational period is longer than 6.3 hours, the quite symmetric lightcurve suggests a probable value of around 9 hours.

1989 UR

The faintness of this asteroid did not allow us to obtain an accurate lightcurve. During the observations the scatter was comparable with the whole range of variations, which was caused by the unfavorable weather conditions. During the observations the asteroid has shown a 0.15 mag brightening in R, thus the period is suspected to be longer than 4 hours. The lightcurve is presented in Fig. 11.

1998 FM5

It is an earth-grazing minor planet, which was discovered by the Near Earth Asteroid Tracking (NEAT) Team on March 24, 1998. The angular motion of this asteroid was quite fast, therefore the maximal exposure time was only 1 minute (even this short exposure did not prevent the trailed profile). The unfiltered amplitude of the light variation is 0.61 ± 0.01 mag, which is a common value among

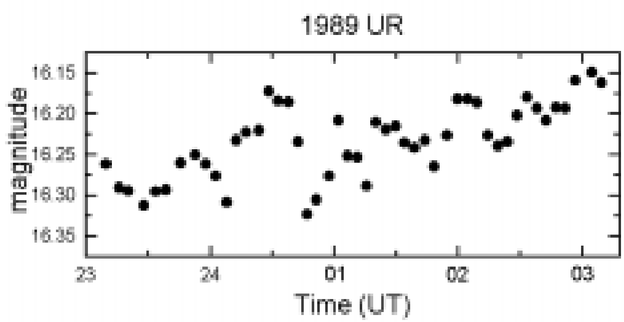

Fig. 11. The R lightcurve of 1989 UR on October 22/23, 1998

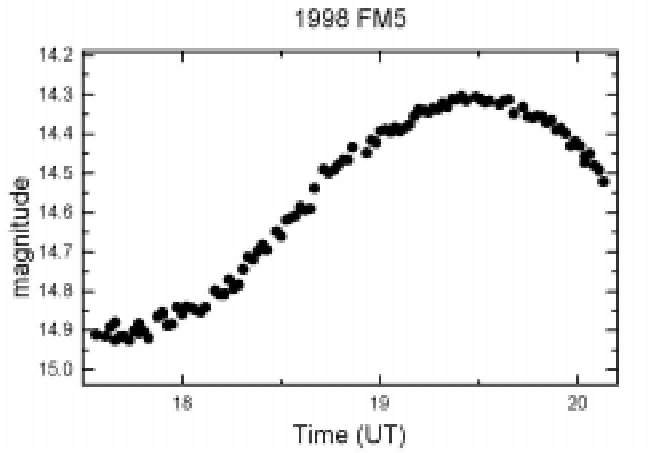

Fig. 12. The unfiltered lightcurve of 1998 FM5 on April 3, 1998

the earth-grazing asteroids. The sinodical period is longer than 2.8 hours. The lightcurve is presented in Fig. 12.

Acknowledgements. This research was supported by the Szeged Observatory Foundation, OTKA Grant W015239 and Grant PFP 5191/1997. The warm hospitality of the staff of Konkoly Observatory and their provision of telescope time is gratefully acknowledged. The authors also acknowledge suggestions and careful reading of the manuscript by K. West. The anonymous referee has greatly improved the paper with his/her notes and suggestions. The NASA ADS Abstract Service was used to access references.

References

Carlsson M., Lagerkvist C.-I., 1981, A&AS 45, 1
De Angelis G., 1993, P&SS 41, 285
Detal A., Hainaut O., Pospieszalska-Surdej A., Schils P., Schoeber H.J., Surdej J., 1994, A&A 281, 269
Harris A.W., Young J.W., 1989, Icarus 81, 314
Holliday B., 1995, Minor Planet Bull. 22, 43
Jokiel R., 1990, Astronomical Observatory of Adam Mickiewicz University, Poznan
Kelemen J., 1997, Inf. Bull. Var. Stars, No. 4496
Lagerkvist C.-I., 1978, A&AS 34, 203
Michałowski T., 1993, Icarus 106, 563
Prokof'eva V.V., Demchik M.I., Golub A.I., 1992, Astronomicheskii Vestnik 26, 68
Szabó Gy., Sárneczky K., Kiss L.L., 1999, Icarus (submitted)
Wisniewski W.Z., McMillan R.S., 1987, AJ 93, 1264
Wisniewski W.Z., Michałowski T.M., Harris A.W., McMillan R.S., 1997, Icarus 126, 395