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# Photometry of asteroids: Lightcurves of 24 asteroids obtained in 1993–2005

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**Abstract**

The results of 1993–2005 photometric observations for 24 main-belt asteroids: 24 Themis, 51 Nemausa, 89 Julia, 205 Martha, 225 Henrietta, 387 Aquitania, 423 Diotima, 505 Cava, 522 Helga, 543 Charlotte, 663 Gerlinde, 670 Ottegebe, 693 Zerbinetta, 694 Ekard, 713 Luscinia, 800 Kressmania, 1251 Hedera, 1369 Ostanina, 1427 Ruvuma, 1796 Riga, 2771 Polzunov, 4908 Ward, 6587 Brassens and 16541 1991 PW18 are presented. The rotation periods of nine of these asteroids have been determined for the first time and others have been improved.


*Keywords:* Asteroids; Photometry; Lightcurve; Rotational period; Amplitude

## 1. Introduction

Ground-based observations are the main source of knowledge about the physical properties of the asteroid population. The photometric lightcurves are used to determine rotation periods, pole coordinates, sizes and shapes of asteroids, as well as to study the magnitude-phase relation of different type asteroids. The present study is the continuation of a observing program devoted to the investigation of photometric and rotational parameters of the main-belt asteroids of different taxonomic types (Shevchenko et al., 1992, 2003). Here we present mainly the results of photometric observations of the low-albedo asteroids, which are supplemented by those of the objects with higher and moderate albedo.

This paper contains the photometry of 24 main belt asteroids. The observations were obtained during 77 nights in 1993–2005 with the 0.7-m telescope of the Institute of Astronomy of Kharkiv National University and the 1-m telescope of the Crimean Astrophysics Observatory in Simeiz.

## 2. Observations and their reduction

Photometric observations of the asteroids were carried out in 1993–1994 using one-channel photoelectric photometers and since 1995 the CCD-cameras ST-6 and IMG-1024S. The measurements of asteroid lightcurves were performed using the differential method based on determination the difference between the brightness of an asteroid and that of a comparison star. The reduction of photoelectric data were described by Shevchenko et al. (1992). The photometric reduction of the CCD-images was performed by using the synthetic aperture photometry package (ASTPHOT) developed by Mottola et al. (1995). The method of CCD observations and their reduction are explained in Howell (1992) and Krugly et al. (2002). The image reduction included dark subtraction and flat-fielding of the raw images. The flat-field images were obtained during evening/or morning twilight. A large part of the observations was carried out in the V and R bands of the standard Johnson–Cousins photometric system. Several objects were simultaneously observed in the BVRI bands.

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The absolute calibrations of the data were performed with standard stars from Landolt (1992) and Lasker et al. (1988). The accuracy of the absolute photometry is of 0.02–0.03 mag.

To determine the asteroid rotation periods we used a Fourier analysis method similar to that described by Harris et al. (1989). Our observations are mainly presented as composite lightcurves, which were obtained according to the procedures described by Magnusson and Lagerkvist (1990). Verticals shifts of the individual nights are made in order to obtain a best fit. Magnitudes were reduced to the unit heliocentric ($r$) and geocentric ($\Delta$) distances. Time scale was corrected for the light-time. Data are composite with the period shown in the figures. Zero rotational phase of the composite lightcurves (in UT is shown in the figures).

Aspect data of the observed asteroids are listed in Table 1. The columns are: dates of observations, the asteroid heliocentric and geocentric distances $r$ and $\Delta$, the solar phase angle $\alpha$, ecliptic coordinates (longitude $\lambda$ and latitude $\beta$ for equinox J2000), spectral bands of observations and reduced $V$ magnitude, which refers to the maximum of lightcurve. Table 2 presents the results of our observations along with the albedo, diameter and taxonomic class of the object (Bus and Binzel, 2002; Tedesco et al., 2002). In the following paragraph we report the results for individual asteroids. Digital files of the data reported in this paper can be obtained by request to V. Chiorny (chiorny@astron.kharkov.ua).

## 3. Results

24 Themis: Photometric observations of the asteroid C-type 24 Themis were started in 1965 (Van Houten-Groeneveld et al., 1979) and showed the very irregular shape of the lightcurve with several maxima and minima and small amplitude. Our CCD-observations of this asteroid were carried out in the V-band on three nights in October 1995 (see Table 1). The composite lightcurve (Fig. 1) was plotted with the rotation period of 8.374± 0.005 h derived by Harris et al. (1989). It has a very asymmetrical shape with four pairs of extrema and an amplitude of 0.13 mag.

51 Nemausa: This CU-type dark asteroid has diameter of 148 km and was intensively investigated in the past (Gammelgaard and Kristensen, 1991; Belskaya and Dovgopol, 1992; Schober et al., 1994). These observations have revealed the complex form of the lightcurve with three pairs of extrema and a rotation period of 7.783 h. Our photoelectric observations of this asteroid were performed during five nights in September–November 1994. The composite lightcurve shown in Fig. 2 was plotted using a rotation period of 7.7836± 0.0005 h. It has a complicated shape with the maximum amplitude of 0.16 mag.

89 Julia: Previously, this S-type asteroid with a diameter of 151.5 km was observed by Schober and Lustig (1975) on 1972. The lightcurve they obtained very asymmetric with one broad and shallow extremum while the other is narrow and deep. The rotational period resulted of 11.387 h. Our photoelectric observations of 89 Julia were carried out during two nights in November 1993. Fig. 3 shows the composite lightcurve obtained with a period of 11.387 h. The magnitude variations are larger than 0.2 mag.

205 Martha: The asteroid 205 Martha is classified as a C-type object with a diameter of 80.9 km. There are unpublished photometric data of this object (Behrend, 2004) (http://obswww.unige.ch/~ behrend/page_cou.html with indication of rotational period of 11.92 h). Our CCD observations of this asteroid were conducted during two consecutive nights on October 1995. The composite lightcurve (Fig. 4) with two pairs of extrema was plotted with a minimal value of rotational period of 9.78± 0.08 h. Other probable value period is 12.0± 0.1 h or a period within 14.5 to 18.0 h interval.

225 Henrietta: Our photoelectric measurements of the F-type asteroid 225 Henrietta (diameter 120.5 km) were obtained during three nights on September–October 1995 in Simeiz. The composite lightcurve (Fig. 5) was plotted with a period of 7.360± 0.001 h, which is very close to the value 7.356 h determined by Michalowski et al. (2000) based on observations performed during the same opposition.

387 Aquitania: The first photometrical observations of the asteroid 387 Aquitania were carried out in 1977 (Schober, 1979) and a rotation period of 24.0± 0.1 h was obtained. Our CCD-observations of this asteroid were carried out during three nights in January–February 1998. The composite lightcurve has been plotted with a period of 24.14± 0.01 h (Fig. 6). It shows the brightness increase during about 3 h and covers only a short part of the full rotation period.

423 Diotima: The low-albedo asteroid 423 Diotima with a diameter of 208 km is one of the largest C-type asteroids of the main belt. Since 1982 the photometric observations have shown an ambiguity in defining the rotational period of 8.0 h (Schober, 1983) or 4.62 h (Zappala et al., 1985). In Dotto et al. (1995) and Harris et al. (1999) the rotation period of the asteroid 423 Diotima was defined as 4.755 and 4.7748 h, respectively. Our photoelectric observations of the object were carried out during seven nights on November–December 1993 and February 1994. Fig. 7a shows the composite lightcurve of 423 Diotima obtained with a period of 4.7752± 0.0002 h, which is very close to that obtained by Harris et al. (1999). It should be noted that the effect of the phase dependence is evident in the composite lightcurve (compare the lightcurve of 04.12.1993 with a phase angle of 0.54° and that of 18.11.1993 at a phase angle of 5.46°). The magnitude-phase dependence of the asteroid 423 Diotima (Fig. 7b) has been plotted according to the obtained photometric data. The dependence is linear up to the smallest observed phase angle of 0.5°. The obtained linear phase coefficient is 0.052 mag/deg. The HG-function (Bowell et al., 1989) fits badly with the magnitude-phase dependence of this asteroid. The RMS residual of the points with respect to

Table 1
Observational circumstances and reduced magnitudes

| Date (UT) | $r$ (AU) | $\Delta$ (AU) | $\alpha$ (deg) | $\lambda_{2000}$ (deg) | $\beta_{2000}$ (deg) | Band | $V(1,\alpha)$ (mag) |
|---|---|---|---|---|---|---|---|
| 24 Themis | | | | | | | |
| 1995 Oct 24.80 | 3.215 | 2.227 | 2.44 | 38.836 | 0.006 | V | $7.318 \pm 0.018$ |
| 1995 Oct 27.90 | 3.211 | 2.219 | 1.29 | 38.220 | 0.016 | V | $7.200 \pm 0.014$ |
| 1995 Oct 28.80 | 3.212 | 2.220 | 0.94 | 38.025 | 0.019 | V | $7.179 \pm 0.016$ |
| 51 Nemausa | | | | | | | |
| 1994 Sept 04.90 | 2.522 | 1.569 | 9.46 | 6.512 | −0.221 | V | $7.945 \pm 0.015$ |
| 1994 Sept 10.95 | 2.522 | 1.542 | 6.74 | 5.210 | −0.631 | V | $7.771 \pm 0.017$ |
| 1994 Sept 14.90 | 2.522 | 1.530 | 4.91 | 4.275 | −0.904 | V | $7.538 \pm 0.014$ |
| 1994 Sept 27.90 | 2.521 | 1.521 | 1.62 | 0.976 | −1.793 | V | – |
| 1994 Nov 07.80 | 2.517 | 1.774 | 17.87 | 354.187 | −3.881 | V | – |
| 89 Julia | | | | | | | |
| 1993 Nov 20.90 | 2.318 | 1.402 | 11.77 | 73.597 | 24.700 | V | – |
| 1993 Nov 25.00 | 2.326 | 1.400 | 10.86 | 72.543 | 24.606 | V | – |
| 205 Martha | | | | | | | |
| 1995 Oct 25.90 | 2.689 | 1.811 | 12.14 | 66.262 | −6.041 | R | – |
| 1995 Oct 27.00 | 2.689 | 1.804 | 11.80 | 66.112 | −6.130 | R | – |
| 225 Henrietta | | | | | | | |
| 1995 Sept 20.90 | 2.718 | 1.726 | 4.07 | 359.804 | 10.835 | V | – |
| 1995 Sept 22.95 | 2.723 | 1.730 | 3.88 | 359.346 | 10.567 | V | – |
| 1995 Oct 17.85 | 2.779 | 1.872 | 10.37 | 354.650 | 7.011 | V | – |
| 387 Aquitania | | | | | | | |
| 1998 Jan 28.70 | 3.306 | 2.321 | 0.27 | 127.04 | −0.25 | V | – |
| 1998 Jan 30.75 | 3.303 | 2.320 | 1.07 | 126.52 | −0.11 | V | – |
| 1998 Feb 06.75 | 3.296 | 2.326 | 3.65 | 124.91 | 0.33 | V | – |
| 423 Diotima | | | | | | | |
| 1993 Nov 17.90 | 3.160 | 2.209 | 5.81 | 74.552 | −0.307 | V | $7.912 \pm 0.013$ |
| 1993 Nov 18.90 | 3.160 | 2.204 | 5.46 | 74.362 | −0.259 | V | $9.856 \pm 0.015$ |
| 1993 Nov 20.80 | 3.161 | 2.197 | 4.74 | 73.990 | −0.167 | V | – |
| 1993 Nov 24.00 | 3.161 | 2.188 | 3.59 | 73.354 | −0.014 | V | $7.778 \pm 0.017$ |
| 1993 Dec 04.80 | 3.164 | 2.178 | 0.54 | 71.072 | 0.515 | V | $7.590 \pm 0.015$ |
| 1994 Feb 06.80 | 3.174 | 2.740 | 17.26 | 65.107 | 2.873 | V | – |
| 1994 Feb 07.80 | 3.175 | 2.753 | 17.36 | 65.185 | 2.896 | V | $8.458 \pm 0.020$ |
| 505 Cava | | | | | | | |
| 1993 May 10.90 | 3.117 | 2.229 | 10.41 | 197.787 | 12.264 | V | – |
| 1993 May 11.85 | 3.118 | 2.237 | 10.69 | 197.616 | 12.204 | V | – |
| 522 Helga | | | | | | | |
| 2005 Sept 12.80 | 3.361 | 2.373 | 3.83 | 1.847 | −5.518 | R | – |
| 2005 Sept 14.00 | 3.362 | 2.371 | 3.51 | 1.663 | −5.534 | R | – |
| 2005 Oct 10.80 | 3.363 | 2.408 | 5.86 | 357.166 | −5.656 | R | – |
| 543 Charlotte | | | | | | | |
| 1995 Aug 19.00 | 2.747 | 1.920 | 14.58 | 7.007 | 10.336 | V | – |
| 1995 Aug 23.00 | 2.742 | 1.883 | 13.48 | 6.720 | 10.623 | V | – |
| 1995 Aug 23.90 | 2.741 | 1.875 | 13.21 | 6.641 | 10.687 | V | $10.077 \pm 0.017$ |
| 663 Gerlinde | | | | | | | |
| 1995 Aug 25.80 | 3.529 | 2.696 | 10.64 | 8.002 | 19.554 | V | – |
| 1995 Aug 30.00 | 3.530 | 2.665 | 9.76 | 7.407 | 19.656 | V | $9.707 \pm 0.017$ |
| 1995 Aug 30.80 | 3.530 | 2.659 | 9.57 | 7.128 | 19.691 | V | – |
| 1995 Aug 31.90 | 3.530 | 2.652 | 9.34 | 6.954 | 19.708 | V | $9.685 \pm 0.025$ |
| 1995 Sept 15.00 | 3.532 | 2.587 | 6.49 | 4.548 | 19.733 | V | – |
| 1995 Oct 13.80 | 3.535 | 2.622 | 7.58 | 358.729 | 18.404 | V | – |
| 1995 Oct 16.90 | 3.535 | 2.640 | 8.22 | 358.197 | 18.160 | V | – |
| 670 Ottegebe | | | | | | | |
| 2000 Feb 10.10 | 3.301 | 2.476 | 10.87 | 180.740 | −0.889 | R | – |
| 2000 Feb 11.10 | 3.301 | 2.467 | 10.60 | 180.618 | −0.867 | V | $9.985 \pm 0.015$ |
| 2000 Feb 25.00 | 3.310 | 2.375 | 6.68 | 178.600 | −0.552 | R | – |

Table 1 (*continued*)

| Date (UT) | $r$ (AU) | $\Delta$ (AU) | $\alpha$ (deg) | $\lambda_{2000}$ (deg) | $\beta_{2000}$ (deg) | Band | $V(1,\alpha)$ (mag) |
|---|---|---|---|---|---|---|---|
| 693 Zerbinetta | | | | | | | |
| 1995 Sept 15.90 | 2.959 | 2.091 | 11.71 | 28.247 | 8.081 | V | 10.027 ± 0.022 |
| 1995 Sept 24.90 | 2.962 | 2.034 | 8.95 | 27.094 | 9.351 | V | – |
| 1995 Sept 25.90 | 2.962 | 2.029 | 8.59 | 26.921 | 9.438 | V | 9.955 ± 0.020 |
| 1995 Oct 15.00 | 2.967 | 1.982 | 3.69 | 23.015 | 10.876 | V | – |
| 694 Ekard | | | | | | | |
| 1996 Aug 31.95 | 1.812 | 0.877 | 17.38 | 342.47 | 32.24 | V | 9.915 ± 0.012 |
| 2005 Nov 09.87 | 2.123 | 1.133 | 1.23 | 49.980 | 0.860 | V | – |
| 713 Luscinia | | | | | | | |
| 1995 Oct 18.80 | 2.853 | 1.867 | 3.47 | 16.371 | 5.162 | V | – |
| 1995 Oct 23.80 | 2.857 | 1.885 | 5.25 | 15.211 | 4.934 | V | – |
| 1995 Oct 24.90 | 2.858 | 1.890 | 5.62 | 15.260 | 4.772 | V | – |
| 2005 Mar 31.90 | 3.934 | 2.940 | 1.70 | 189.652 | −6.503 | V | – |
| 2005 Apr 01.80 | 3.933 | 2.939 | 1.77 | 189.497 | −6.482 | V | – |
| 2005 Apr 07.90 | 3.930 | 2.944 | 2.92 | 188.386 | −6.316 | V | – |
| 2005 Apr 28.80 | 3.919 | 3.043 | 8.23 | 185.100 | −5.588 | V | – |
| 800 Kressmania | | | | | | | |
| 1997 July 19.00 | 1.755 | 0.946 | 27.6 | 349.538 | 0.479 | V | – |
| 1251 Hedera | | | | | | | |
| 2005 Feb 05.10 | 3.006 | 2.021 | 0.31 | 136.98 | −0.660 | V | 10.806 ± 0.014 |
| 2005 Feb 05.90 | 3.007 | 2.021 | 0.23 | 136.80 | −0.630 | VR | 10.748 ± 0.022 |
| 2005 Feb 06.90 | 3.008 | 2.022 | 0.57 | 136.55 | −0.600 | BVRI | 10.843 ± 0.017 |
| 2005 Feb 07.80 | 3.009 | 2.024 | 0.89 | 136.36 | −0.580 | V | – |
| 2005Feb 12.00 | 3.014 | 2.033 | 2.60 | 135.39 | −0.460 | VR | – |
| 2005 Mar 11.70 | 3.042 | 2.218 | 12.29 | 130.51 | +0.270 | V | – |
| 1369 Ostanina | | | | | | | |
| 1995 July 07.90 | 2.427 | 1.506 | 12.93 | 310.195 | 20.490 | R | – |
| 1995 July 18.95 | 2.425 | 1.462 | 9.88 | 308.382 | 20.430 | V | – |
| 1995 July 19.95 | 2.425 | 1.459 | 9.65 | 308.196 | 20.410 | V | – |
| 1995 July 21.00 | 2.425 | 1.457 | 9.41 | 307.988 | 20.370 | V | – |
| 1427 Ruvuma | | | | | | | |
| 2002 Dec 04.10 | 2.794 | 1.816 | 2.90 | 64.086 | −3.028 | V | – |
| 1796 Riga | | | | | | | |
| 1997 May 15.95 | 3.200 | 2.305 | 10.00 | 253.30 | 28.250 | V | – |
| 2771 Polzunov | | | | | | | |
| 2004 July 23.90 | 2.071 | 1.143 | 15.36 | 323.033 | 25.031 | R | – |
| 2004 July 24.85 | 2.071 | 1.139 | 15.09 | 322.886 | 25.071 | R | – |
| 2004 July 25.80 | 2.071 | 1.135 | 14.83 | 322.730 | 25.107 | R | 12.812 ± 0.020 |
| 4908 Ward | | | | | | | |
| 2001 Oct 09.86 | 1.685 | 0.720 | 13.39 | 353.611 | 0.630 | BVRI | – |
| 2001 Oct 10.78 | 1.686 | 0.724 | 13.94 | 353.514 | 0.542 | BVRI | – |
| 6587 Brassens | | | | | | | |
| 1995 Sept 13.9 | 2.316 | 1.310 | 0.60 | 351.35 | 0.200 | V | 13.804 ± 0.015 |
| 16541 1991 PW18 | | | | | | | |
| 2001 Aug 23.86 | 2.826 | 1.860 | 7.44 | 351.927 | 1.638 | V | 13.645 ± 0.017 |

the best fit HG-function is 0.035 mag—greater in comparison with the calibration errors ($<0.02$ mag, see Table 1). The maximal deviation is at small phase angle and equal about 0.1 mag.

505 Cava: Detailed photoelectric observations of this object have been carried out in 1982 by Young and Harris (1985) who determined a rotational period of 8.1796 h. Our photoelectric observations of 505 Cava were carried out during two consecutive nights on May 1993. Fig. 8 shows the composite lightcurve which allowed us to estimate an amplitude of about 0.22 mag.

522 Helga: This rather large (diameter 101 km) C-type asteroid of Cybele group was previously observed in 1990 (Lagerkvist et al., 2001) and the period of rotation was determined to be 2.9 or 3.4 h. It is unusual for an asteroid as big as 522 Helga to have such a short period of rotation.

Table 2
Physical characteristic of observed of asteroids

| Asteroid | Albedo | D (km) | Type | Period (h) | Ampl. (mag) | Comment |
|---|---|---|---|---|---|---|
| 24 Themis | 0.101 | 161 | C | $8.374 \pm 0.005$ | 0.13 | Harris et al. (1989) |
| 51 Nemausa | 0.093 | 147.9 | CU | $7.7836 \pm 0.0005$ | 0.16 | Gammelgaard and Kristensen (1991) |
| 89 Julia | 0.176 | 151.5 | S | (11.387) | 0.20 | Schober and Lustig (1975) |
| 205 Martha | 0.055 | 80.9 | C | $9.78 \pm 0.08$ | 0.14 | In this work |
| 225 Henrietta | 0.040 | 120.5 | F | $7.360 \pm 0.001$ | 0.22 | Michalowski et al. (2000) |
| 387 Aquitania | 0.190 | 100.5 | S | $24.14 \pm 0.01$ | $>0.17$ | Harris et al. (1992) |
| 423 Diotima | 0.052 | 208.8 | C | $4.7752 \pm 0.0002$ | 0.20 | Improved |
| 505 Cava | 0.054 | 108 | FC | (8.1789) | 0.21 | Young and Harris (1985) |
| 522 Helga | 0.039 | 101.2 | C | $8.1236 \pm 0.001$ | 0.25 | In this work |
| 543 Charlotte | 0.260 | 34.4 | Xe | $10.718 \pm 0.005$ | 0.23 | In this work |
| 663 Gerlinde | 0.036 | 100.9 | XC | $10.253 \pm 0.001$ | 0.35 | Improved |
| 670 Ottegebe | 0.183 | 34.1 | S | $10.375 \pm 0.002$ | 0.34 | In this work |
| 693 Zerbinetta | 0.068 | 67.7 | ST | $11.475 \pm 0.001$ | 0.29 | In this work |
| 694 Ekard | 0.046 | 90.8 | CP | (5.922) | 0.39 | Weidenschilling et al. (1987) |
| 713 Luscinia | 0.041 | 105.5 | C | $8.4155 \pm 0.001$ | 0.09 | Improved |
| 800 Kressmania | 0.160 | 15.8 | S | (4.464) | 0.12 | Di Martino (1986) |
| 1251 Hedera | 0.41 | 13.2 | E | $19.985 \pm 0.002$ | 0.45 | In this work |
| 1369 Ostanina | 0.102 | 41.6 | C | $8.397 \pm 0.002$ | 0.84 | In this work |
| 1427 Ruvuma | 0.066 | 37.6 | – | (4.797) | 0.18 | Bembrick and Allen (2006) |
| 1796 Riga | 0.038 | 73.8 | C | (11.0) | $>0.05$ | Warner (2004) |
| 2771 Polzunov | 0.10[a] | 16.7[a] | SC | (11.66) | 0.14 | Stephens (2005) |
| 4908 Ward | 0.180 | 4.5 | S | $21.86 \pm 0.05$ | 0.93 | In this work |
| 6587 Brassens | 0.20[b] | 4.0[b] | – | $5.2 \pm 0.1$ | 0.27 | In this work |
| 6541 1991 PW18 | – | – | – | $>9$ | 0.22 | In this work |

[a] Harris (2005).
[b] In this work.

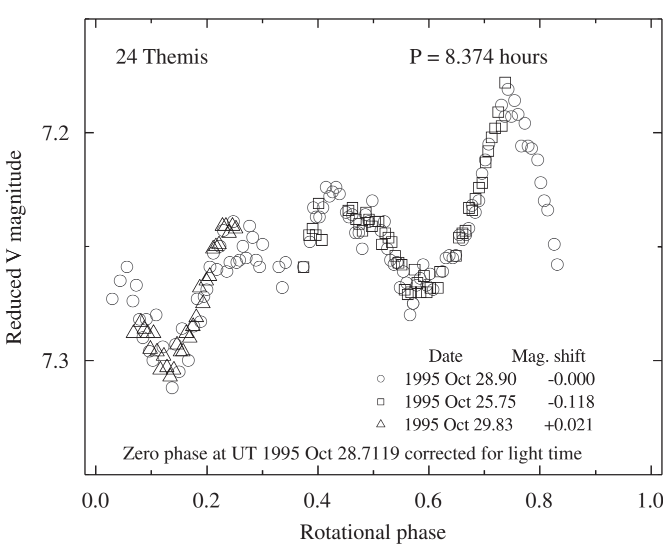


Fig. 1. Composite lightcurve of asteroid 24 Themis on 1995.

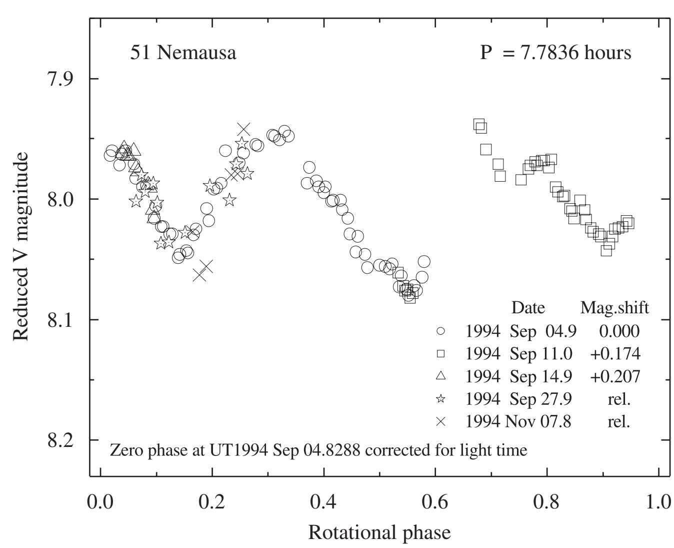


Fig. 2. Composite lightcurve of asteroid 51 Nemause on 1994.

Our CCD-observations of this object were carried out during three nights on September–October 2005. The rotational period is radically different from that obtained in Lagerkvist et al. (2001). The composite lightcurve of Helga was plotted using a period of $8.1236\pm$ 0.001 h (Fig. 9). This value is slightly different from that of 8.126 h obtained by Licchelli (2006) on the base of observations carried out on August–September 2005.

543 Charlotte: Our CCD-observations of the Xe-type asteroid 543 Charlotte were carried out on three nights in August 1995. Fig. 10 shows the composite lightcurve of this asteroid. The rotational period we determined as $10.718\pm$ 0.01 h with a lightcurve amplitude of 0.23 mag.

663 Gerlinde: This is low-albedo asteroid with a diameter of 101 km. Our CCD-observations were carried out during seven nights on August–October 1995. The composite

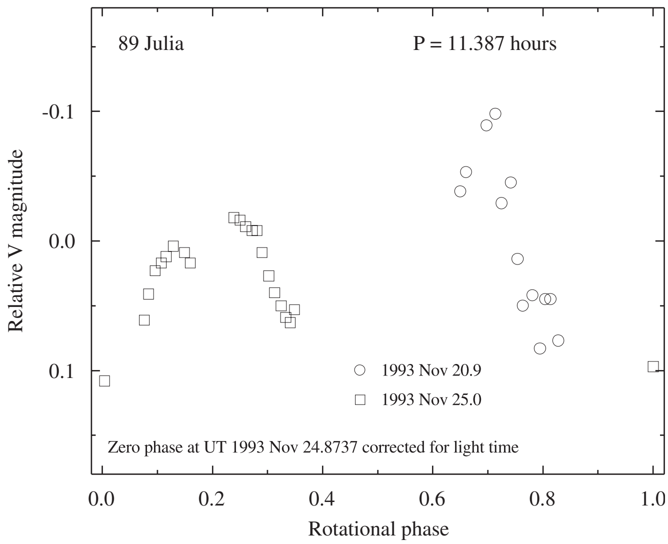


Fig. 3. Composite lightcurve of asteroid 89 Julia on 1993.

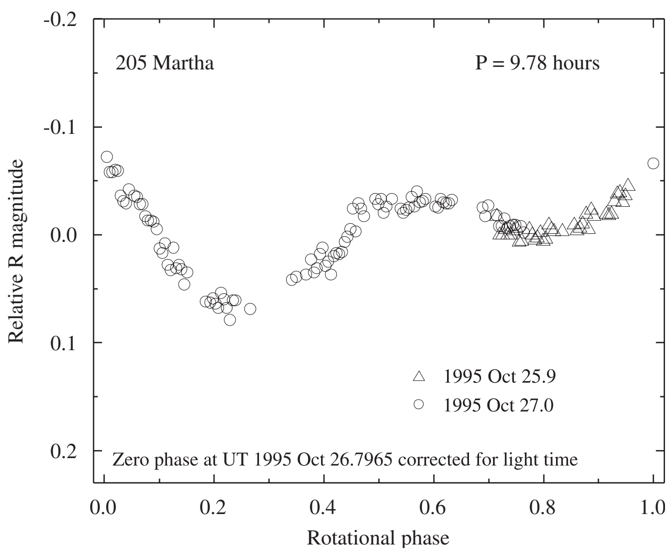


Fig. 4. Composite lightcurve of asteroid 205 Martha on 1995.

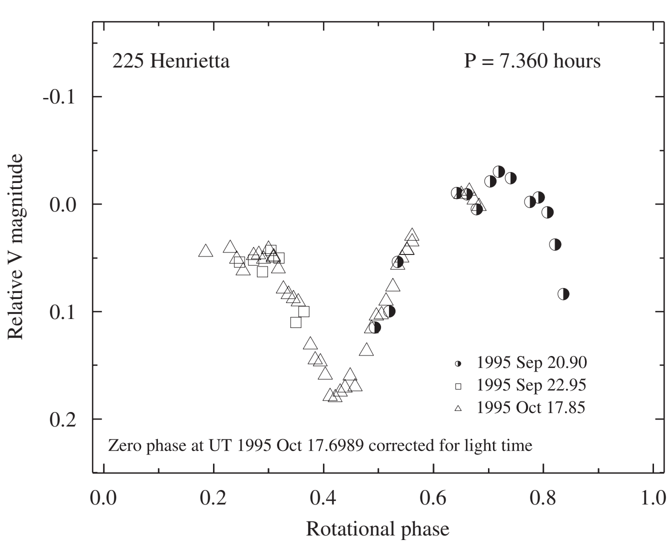


Fig. 5. Composite lightcurve of asteroid 225 Henrietta on 1995.

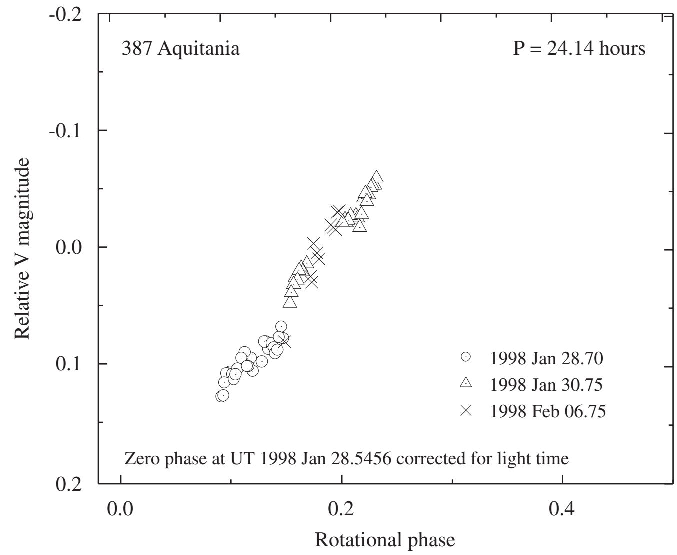


Fig. 6. Composite lightcurve of asteroid 387 Aquitania on 1998.

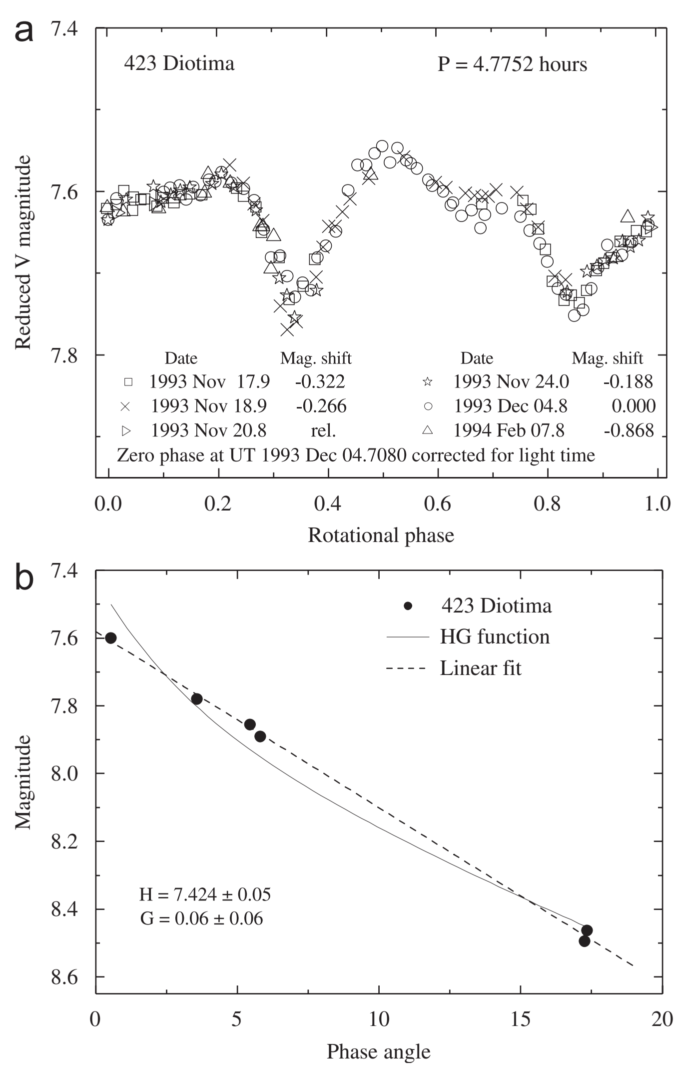


Fig. 7. (a) Composite lightcurve of asteroid 423 Diotima on 1993–1994; (b) magnitude-phase curve of asteroid 423 Diotima.

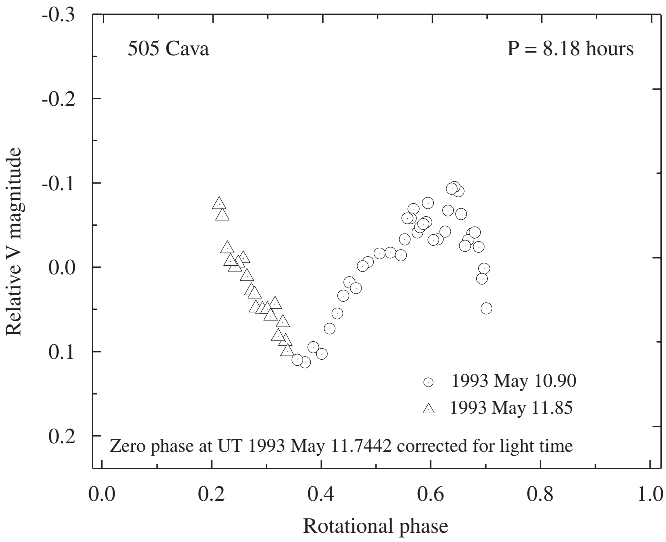


Fig. 8. Composite lightcurve of asteroid 505 Cava on 1993.

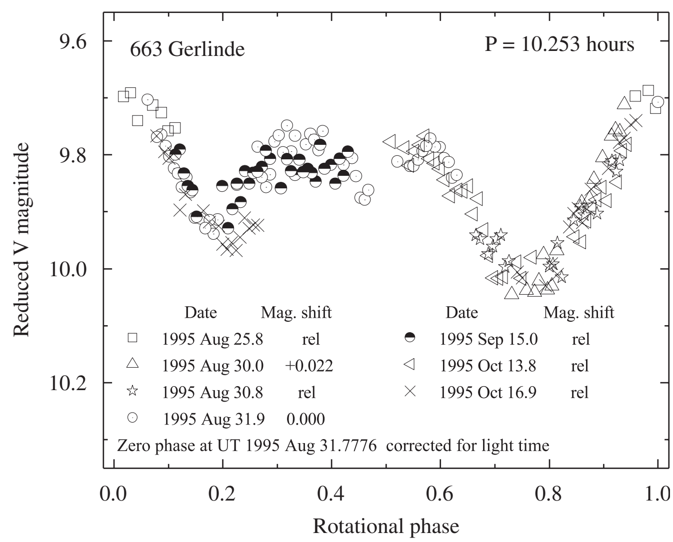


Fig. 11. Composite lightcurve of asteroid 663 Gerlinde on 1995.

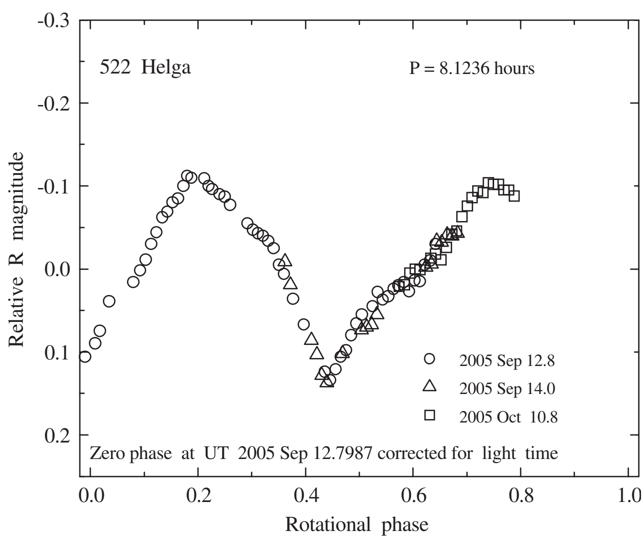


Fig. 9. Composite lightcurve of asteroid 522 Helga on 2005.

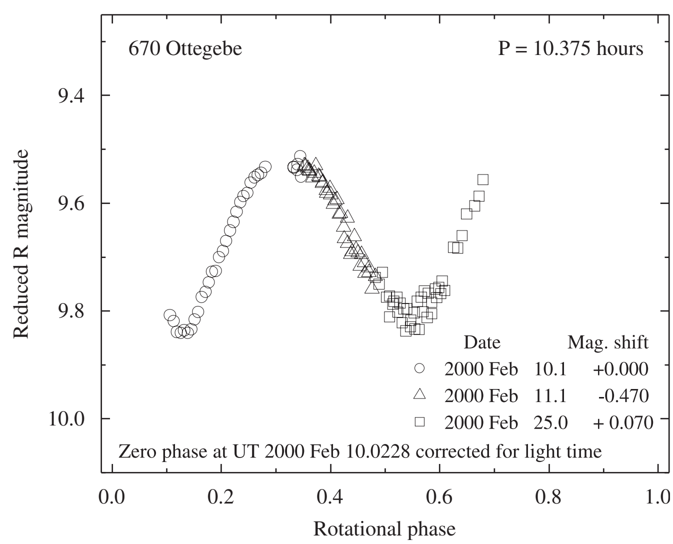


Fig. 12. Composite lightcurve of asteroid 670 Ottegebe on 2000.

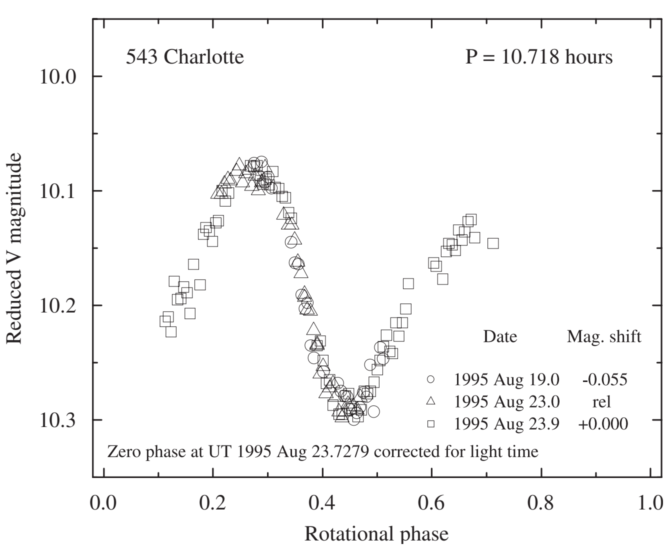


Fig. 10. Composite lightcurve of asteroid 543 Charlotte on 1995.

lightcurve of 663 Gerlinde (Fig. 11) is plotted with a period of 10.253± 0.001 h and shows a wide maximum with many depressions. The rotational period we obtained is slightly different from that of 10.240 h determined by Warner (2006) on the base of observations carried out on July 2005.

670 Ottegebe: Photometric observations of this asteroid were performed by Kirkpatrick et al. (2003) on four consecutive nights in September 2002 and the rotational period resulted to be 10.045 h. Our CCD-observations of this asteroid were carried out on three nights in February 2000. The composite lightcurve of this object (Fig. 12) was plotted with a period of 10.375± 0.002 h on the base of observations in V and R bands (see Table 1). The amplitude of the obtained lightcurve is 0.31 mag Color index V–R = 0.47 mag is close for the mean color index of S-type asteroids 0.49 mag (Shevchenko and Lupishko, 1998).

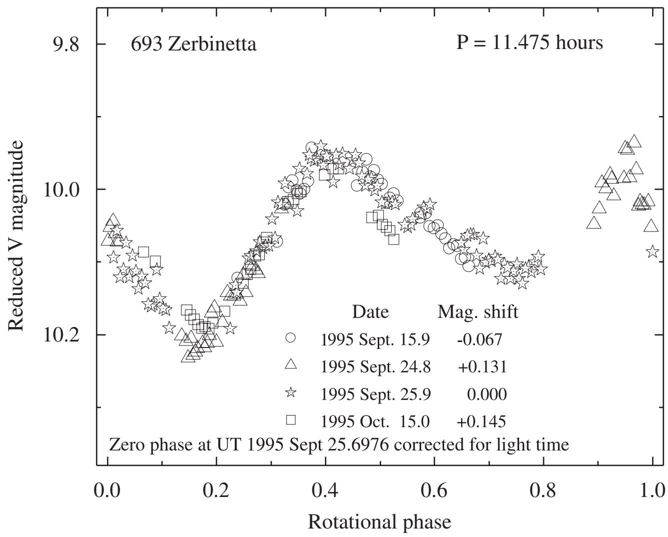


Fig. 13. Composite lightcurve of asteroid 693 Zerbinetta on 1995.

693 Zerbinetta: Our CCD-observations of this low-albedo asteroid were carried out during four nights on September–October 1995. The composite lightcurve is asymmetric with two pairs of extreme (Fig. 13). The rotational period we obtained is 11.475± 0.001 h. The amplitude of the lightcurve is equal to 0.29 mag.

694 Ekard: Our CCD-observations of the low-albedo asteroid 694 Ekard were carried out on 31 August 1998 and 9 November 2005. The lightcurves (Fig. 14a and b) cover the full rotation cycle with a rotational period of 5.922 h, which was obtained earlier by Weidenschilling et al. (1987).

713 Luscinia: The asteroid 713 Luscinia, which belongs to the Cybele group, was observed on 1992 by Lagerkvist et al. (2001) who obtained a rotational period of 8.28 h. The photoelectric observation of this object on October 1995 (Blanco et al., 2000) provided a period of 9.274 h. The object was also observed for three nights on October 1995 with a photoelectric photometer and the 1-m telescope of the Crimean Astrophysics Observatory in Simeiz.

We performed CCD-observations of this object during four nights on February 2005. The composite lightcurve (Fig. 15) was obtained using a $8.4155 \pm 0.001$-h rotational period, which is different from the earlier accepted of 8.28 h. This lightcurve shows four extrema and an amplitude of 0.09 mag.

800 Kressmania: The first photometrical observations of the small ($D = 15.8$ km) S-type asteroid 800 Kressmania were carried out in 1984 (Di Martino, 1986) and a period of rotation in 4.464 h was obtained. Our CCD-observations of this asteroid were carried out on 18 August 1997. The lightcurve (Fig. 16) shows one maximum, a slightly brightness decrease during 1 h, and an amplitude at least of 0.1 mag.

1251 Hedera: The asteroid 1251 Hedera with diameter of 13.2 km is classified as a high-albedo E-type object (Tedesco et al., 1989). We observed this asteroid for the first time on July–September 1998 (Shevchenko et al., 2003)

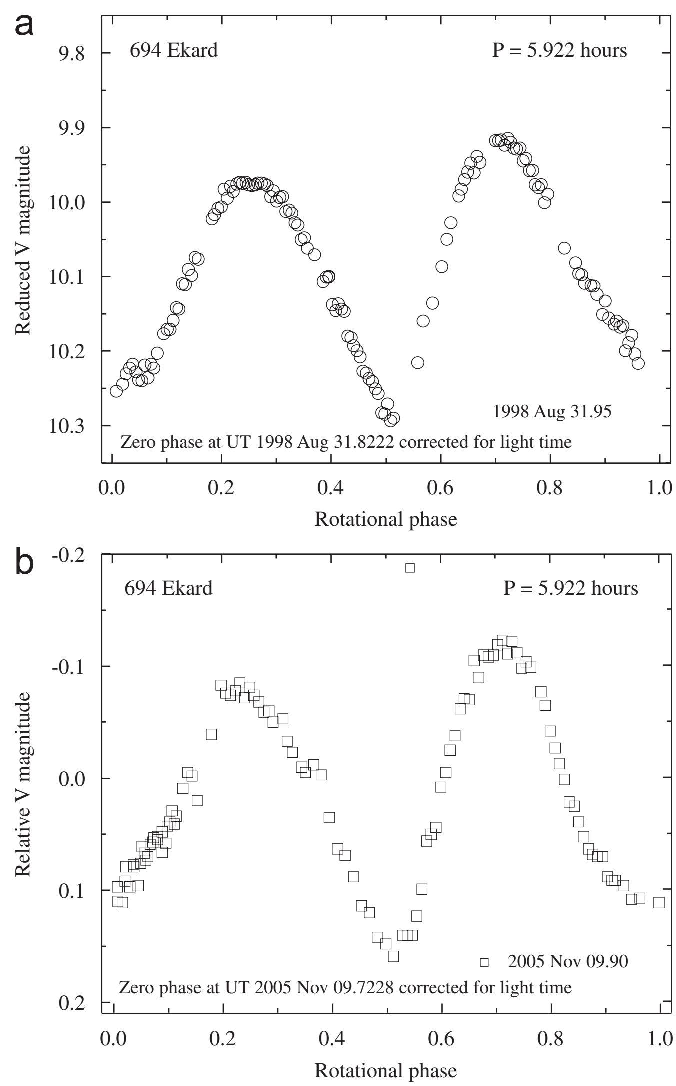


Fig. 14. (a) Lightcurve of asteroid 694 Ekard on 1996, August 31.9; (b) lightcurve of asteroid 694 Ekard on 2005, November 09.9.

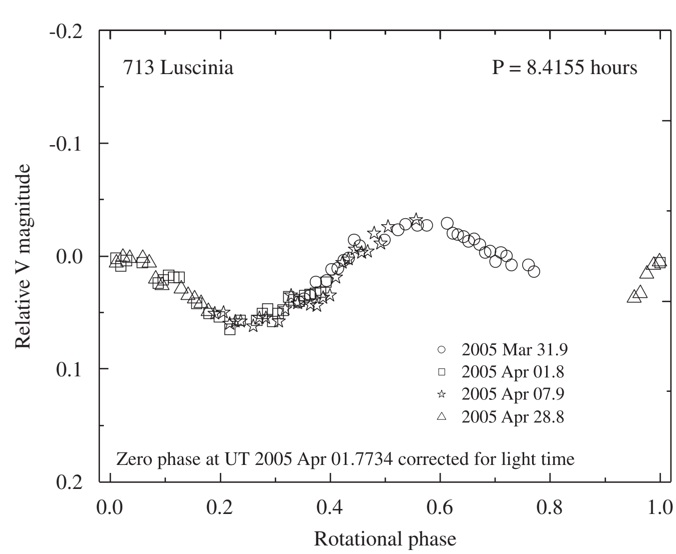


Fig. 15. Composite lightcurve of asteroid 713 Luscinia on 2005.

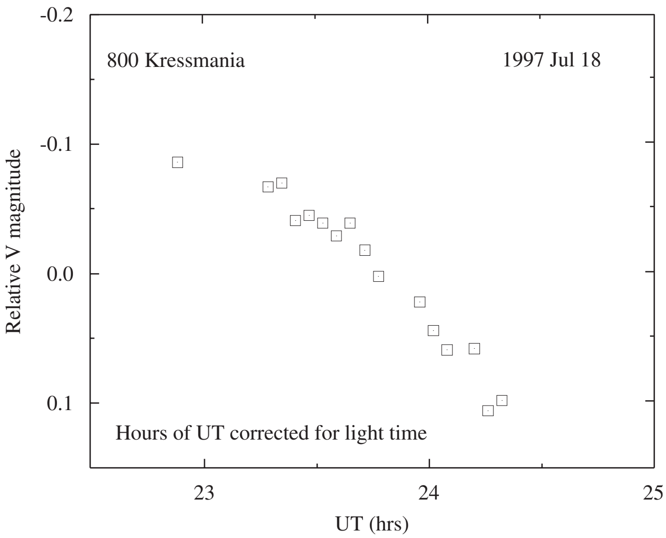


Fig. 16. Lightcurve of asteroid 800 Kressmania on 1997, July 19.0.

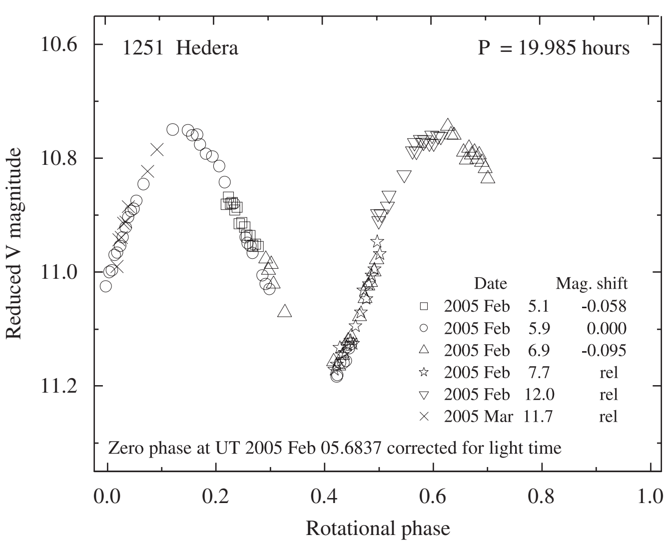


Fig. 17. Composite lightcurve of asteroid 1251 Hedera on 2005.

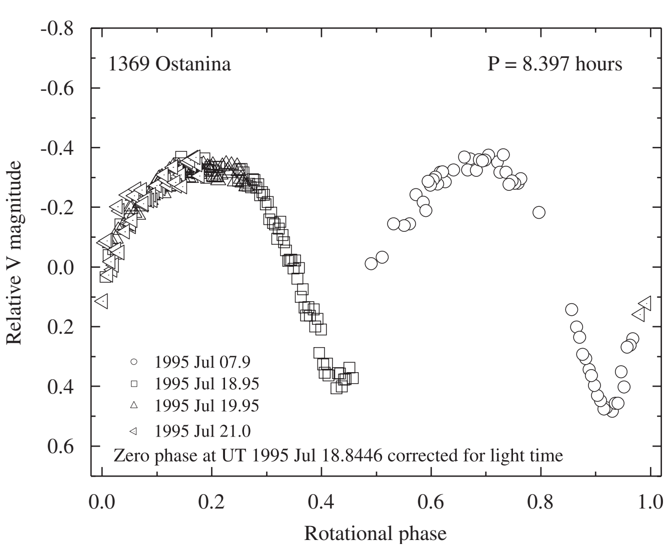


Fig. 18. Composite lightcurve of asteroid 1369 Ostanina on 1995.

and a probable rotation period 15.015 h was found. Here we present the results of six-nights CCD observations carried out on February–March 2005. The composite lightcurve on Fig. 17 has been obtained with a rotational period of 19.985± 0.002 h with an amplitude of 0.45 mag. The color indexes we have obtained are B–V = 0.68 mag and V–R = 0.40 mag.

1369 Ostanina: Our CCD-observations of the low-albedo asteroid 1369 Ostanina were carried out during four nights in July 1995. The first lightcurve was obtained in a spectral band close to standard R, the rest were obtained in the standard V band. The composite lightcurve looks rather symmetric with two pairs of extrema (Fig. 18) and provides a value of the rotation period equal to 8.397 ± 0.002 h with an amplitude of 0.84 mag. The first published results of photometric observations of this asteroid are by Blanco et al. (2000), which provided an estimate of the rotational period (6.145 h) based on a very incomplete lightcurve obtained during the 1985 opposition.

1427 Ruvuma: The minor planet 1427 Ruvuma was observed for the first time by Bembrick and Allen (2006) during three nights on June 2001 and during four nights on April 2005. The synodic rotational period found was 4.797± 0.003 h. Our CCD observations were carried out on 4 December 2002. The lightcurve for 1427 Ruvuma does not cover the full rotational cycle (Fig. 19), but it confirms the rotational period of 4.797 h obtained by Bembrick and Allen (2006).

1796 Riga: Our CCD-observations of the low-albedo asteroid 1796 Riga were carried out on 15 May 1997. The lightcurve of 1796 Riga (Fig. 20) shows a slow brightness decrease during about 3 h and covers only a short part of the full rotational period (from maximum to minimum), and an amplitude large than 0.05 mag. A more complete composite lightcurve of 1795 Riga was obtained by Warner (2004), who determined a rotational period of about 11 h.

2771 Polzunov: CCD photometric observations of this asteroid were performed by Stephens (2005) during eight

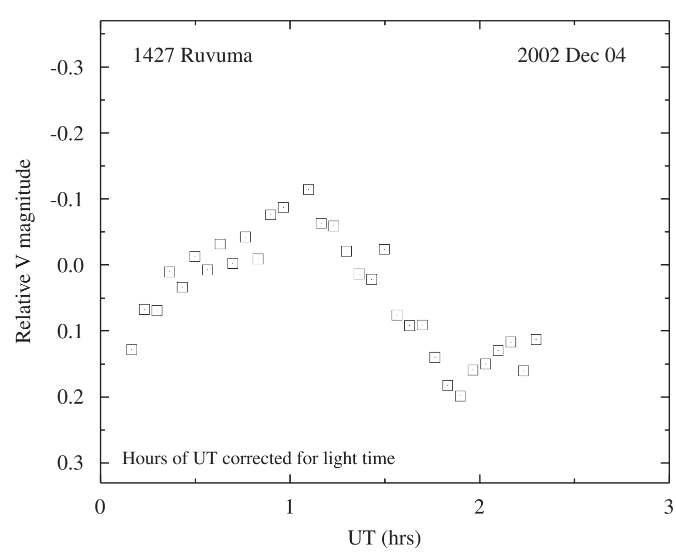


Fig. 19. Lightcurve of asteroid 1427 Ruvuma on 2002, December 04.05.

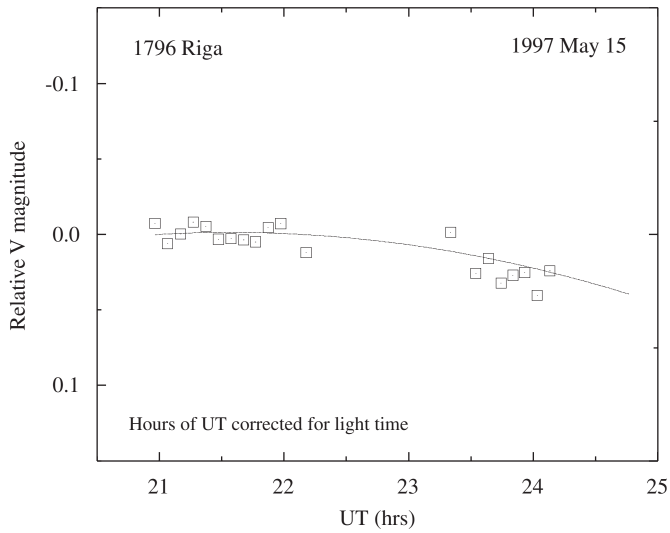


Fig. 20. Lightcurve of asteroid 1796 Riga on 1997, May 15.9.

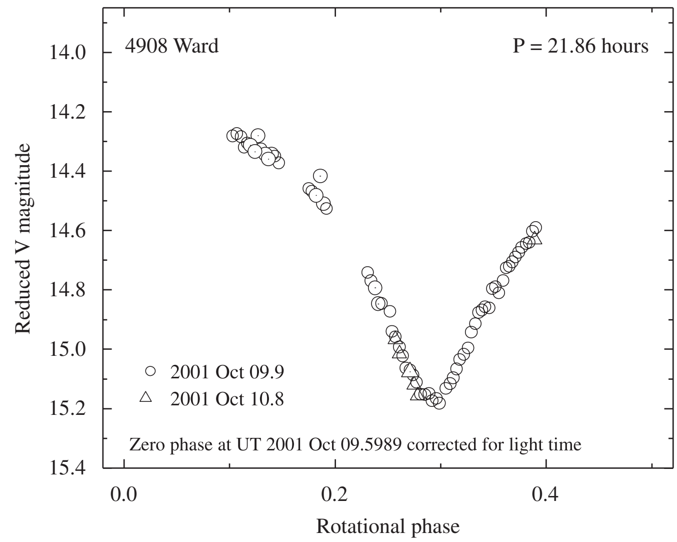


Fig. 22. Composite lightcurve of asteroid 4908 Ward on 2001.

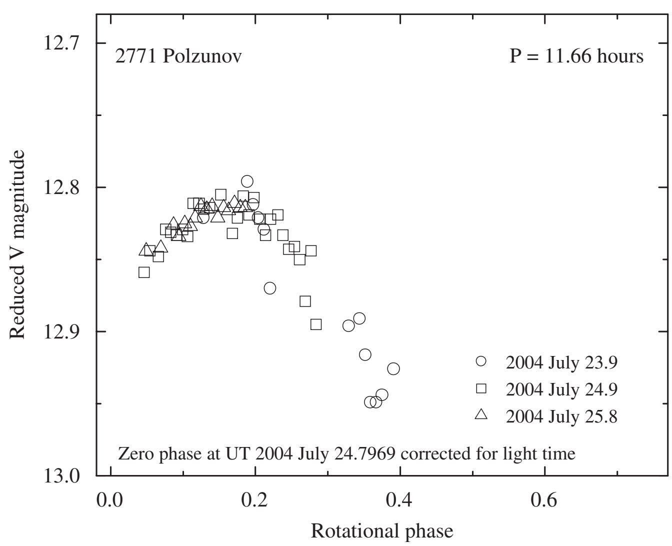


Fig. 21. Composite lightcurve of asteroid 2771 Polzunov on 2002.

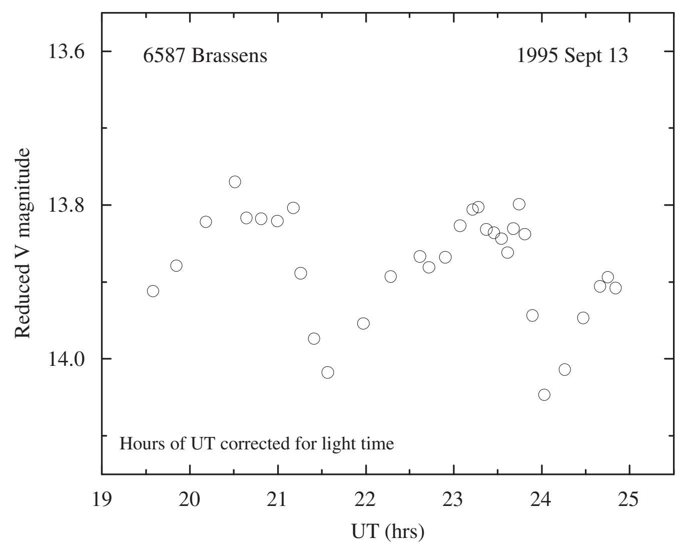


Fig. 23. Lightcurve of asteroid 6587 Brassens on 1995, September 13.9.

nights on July–August 2004, who found rotational period of about 11.66± 0.01 h. We observed 2771 Polzunov during the same opposition. Our CCD-observations were carried out during three consecutive nights on July 2004 in Simeiz. The rotational period of 11.66 h has been confirmed (see Fig. 21).

4908 Ward: CCD-observations of the S-type asteroid 4908 Ward were carried out on October 2001 in BVRI spectral bands. The composite lightcurve (Fig. 22) suggests that the most probable value of the rotational period is equal to 21.86 h. The amplitude of the lightcurve composite at least 0.93 mag. The color indexes we have obtained are B–V = 0.89 mag, V–R = 0.56 mag, and R–I = 0.47 mag.

6587 Brassens: Our CCD-observations of the asteroid 6587 Brassens were carried out on 13 September 1995. The lightcurve (Fig. 23) has two pairs of similar extrema and an amplitude of 0.27 mag. The most probable value of the rotational period of 6587 Brassens is 5.2± 0.1 h. On the basis of our data, the diameter of this asteroid has been estimated about 4.0 km, always supposing an albedo $p_v = 0.20$, typical for S-type asteroids.

16541 1991 PW18: Our CCD-observations of the asteroid 16541 1991 PW18 were carried out on 23 August 2001. On the base of the obtained lightcurve the rotational period has been estimated in the range 9–10 h (Fig. 24) with a regularly shaped lightcurve and an amplitude of at least 0.23 mag.

## 4. Conclusion

The main results of the given study are represented by the photometric lightcurves of 14 low-albedo asteroids of different taxonomic types as well as the definitions their of rotational period. Among the 24 observed asteroids the shortest rotation periods are those of the low-albedo

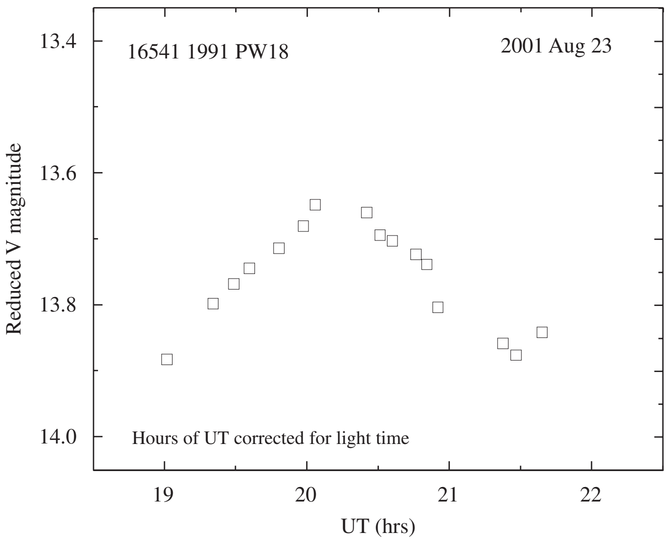


Fig. 24. Lightcurve of asteroid 16541 1991 PW18 on 2001, August 23.9.

asteroids 423 Diotima and 1427 Ruvuma (4.7752 and 4.797 h, respectively), as well as the medium-albedo 6567 Brassens (5.2 h), while as the longest rotational periods are those of the asteroids 1251 Hedera (E-type) and 4908 Ward (S-type) (19.985 and 21.860 h, respectively). All the studied asteroids belong to the main belt and their orbits have semi-major axes within the range of 2.0–3.6 a.u.

As a result of observations new rotational periods of nine asteroids were determined for the first time, i.e. low-albedo asteroids 205 Martha, 693 Zerbinetta, and 1369 Ostanina, as well as medium and high-albedo asteroids 543 Charlotte, 670 Ottegebe, 1251 Hedera, 4908 Ward, 6587 Brassens, and 16541 1991 PW18.

The lightcurves of the asteroids 24 Themis, 51 Nemausa, 225 Henrietta, 387 Aquitania, 423 Diotima, 522 Helga, 694 Ekard, 1429 Ruvuma and 2771 Polzunov confirmed unambiguity of their known periods. The incomplete lightcurves of the asteroids 89 Julia, 505 Cava and 800 Kressmania have been shown with periods determined earlier.

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