Mem. S.A.It. Suppl. Vol. 6, 151


**Memorie** della
**Supplementi**

# Asteroid photometric observations at Catania and Padova Observatories

D. Gandolfi, C. Blanco and M. Cigna

Dipartimento di Fisica e Astronomia, Universitá degli Studi di Catania
Via S. Sofia 78 I-95123 Catania - Italy

**Abstract.** We present new photometric observations of 27 *Euterpe*, 173 *Ino*, 182 *Elsa*, 539 *Pamina*, 849 *Ara*, 2892 *Filipenko*, 3199 *Nefertiti* and *2004 UE*, carried out between January 2003 and November 2004 at Catania Astrophysical Observatory and Padova Astronomical Observatory. The first determination of the synodic rotational period value of 2892 *Filipenko* and *2004 UE* was obtained. For 182 *Elsa*, using the *H-G* magnitude relation (Bowell et al. 1989), we determined the absolute magnitude *H* and the slope parameter *G*.

**Key words.** Asteroids: photometric observations – lightcurve – synodic rotational period – color index – *H-G* relation

## 1. Introduction

Photometric observations allow us the determination of asteroidal rotational parameters like lightcurve trend, value of synodic rotational period, spin axis direction and shape. Such information are important to understand the collisional evolution of single minor planets, of asteroid families and of the whole asteroidal population. The results reported in this paper are part of the photometric programme undertaken at the Department of Physics and Astronomy of Catania University. The aim of this programme is to enlarge the number of asteroids with well-known rotational parameters, to improve the database necessary for the investigation of minor planet evolution history. We present 27 *Euterpe*, 173 *Ino*, 182 *Elsa*, 539 *Pamina*, 849 *Ara*, 2892 *Filipenko*, 3199 *Nefertiti* and *2004 UE* photometric observations carried out at M.G. Fracastoro station of Catania Astrophysical Observatory (CT) and at Asiago station of Padova Astronomical Observatory (PD). The analysis and study of observational data allow us to determine the values of synodic rotational period (for 2892 *Filipenko* and *2004 UE* it is the first determination), color index and lightcurve amplitude. For asteroid 182 *Elsa* the *H-G* magnitude relation (Bowell et al. 1989) was obtained.

## 2. Observations and data reduction

The photometric observations reported in the paper were carried out at M.G. Fracastoro station of Catania Astrophysical Observatory and at Asiago station of Padova Astronomical Observatory.
At M.G. Fracastoro station the 91-cm Cassegrain telescope, equipped with a cooled photon-counting single-head photometer

*Send offprint requests to*: D. Gandolfi
e-mail: dgandolfi@ct.astro.it

and an EMI 9863 QA/35 photomultiplier, was used. The observations were perfomed through *B* and *V* Johnson filters, using a 1.5-mm diameter diaphragm, limiting the telescope field to an aperture of about 22". Nearby solar spectral type comparison stars were selected to neglect the effects of extinction chromatic variations compared to asteroids. The observing set-up and the data reduction were the same already adopted during previous observational campaigns (Di Martino et al. 1994). The *B* and *V* extiction coefficients were determined nightly through the comparison stars. The reduction to the Johnson standard system was made observing standard stars taken from Blanco et al. (1968) and Landolt (1992).

CCD photometric observations were perfomed at Asiago station, through *V* and *R* Johnson filters, using the 67/92-cm Schmidt telescope equipped with the CCD *ITANET* camera (Blanco et al. 2004). Taking into account the telescope plate scale of 95″.9/mm, the resulting projected sky area was about 29′×29′ with an angular resolution of 0″.89/pixel.

The CCD's images pre-reduction was made with standard *IRAF* routines, removing bias and dark current from images. Nigthly twilight flat-fields were used to correct images for optical vignetting, dust shadow and pixel-to-pixel sensitivity variation. In order to maximize the asteroid S/N ratio (especially in cases of elongated images of fast moving asteroid), elliptical aperture photometry was done using the software *SExtractor* devoloped by Bertin and Arnouts (1996). A set of comparison stars having magnitude value similar to the asteroid one was selected nightly along the asteroid path. From this set of stars, the non-variable star with the smallest error in the flux measurement was chosen as nightly reference star. The reduction to the Johnson standard system was made observing standard stars taken from Landolt (1992) and Stetson et al. (2000).

Both for photoelectric and CCD data, the final mean error of the single measurements is ±0.01 mag. The nightly lightcurves of each asteroid were corrected for light-travel times and the asteroid *V* magnitudes were reduced to the unit geocentric and heliocentric distances. For each object, the value of synodic rotational period, the composite lightcurve, the mean reduced magnitudes $\bar{V}(1,\alpha)$ and the nightly magnitude shifts were obtained by applying the Fourier analysis, as described in Harris et al. (1989).

Table 1 contains aspect data and reduced mean magnitude $\bar{V}(1,\alpha)$ of the observed asteroids for each observing night.

## 3. Results

The composite lightcurves obtained from our observations are presented in Figs. 1 to 7. The different symbols denote different observing nights. The magnitude shifts, applied by the Fourier analysis method to the single night ligtcurve (when standardized) to obtain the composite one (Harris et al. 1989), are reported, in brackets, near the date. The rotational phases were computed according to the period value reported in each Figure and in Table 2, where the period reliability code (Harris et al. 1983), the lightcurve amplitude and the *B-V* color index of some asteroids are also listed.

### 3.1. 27 Euterpe

The first determination of the synodic rotational period of 27 *Euterpe* was by Chang & Chang (1962), who found a value of $8^h.500$. During the 2001 apparition Stephens et al. (2001) estimated a different rotational period of $10^h.410 \pm 0^h.002$.

We observed this object on three nights in November 2004, obtaining a lightcurve (Fig. 1) covering about 80% of the rotational phase. The derived value of the synodic rotational period is $10^h.377 \pm 0^h.008$, slightly shorter than Stephens et al.'s (2001) one. The amplitude of the *V* lightcurve is 0.14 ± 0.02 mag and the mean value of the *B-V* color index is 0.85±0.02 mag.

### 3.2. 173 Ino

The first published ligtcurves of this C-type asteroid are by Schober (1978), who observed 173 *Ino* during three nights in 1977, obtaining a rotational period of $5^h.93 \pm 0^h.01$. A

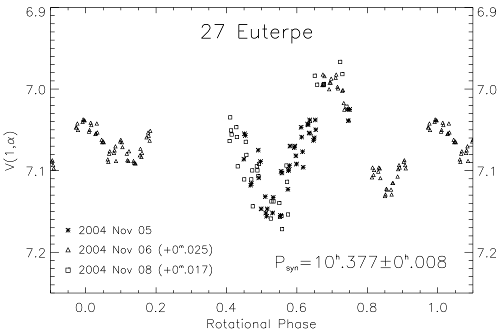


**Fig. 1.** Composite $V(1, \alpha)$ lightcurve of 27 *Euterpe*, vs. rotational phase. The zero phase corresponds to JD 2453317.0 (corrected for light-time).

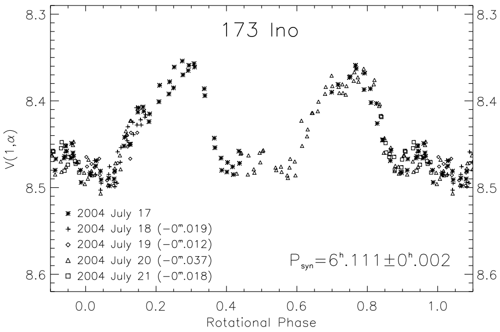


**Fig. 2.** Composite $V(1, \alpha)$ lightcurve of 173 *Ino*, vs. rotational phase. The zero phase corresponds to JD 2453206.0 (corrected for light-time).

longer period was found by Debehogne et al. (1990) and Erikson (1990), who reported $P = 6^h.15 \pm 0^h.02$ and $P = 6^h.11 \pm 0^h.06$, respectively.

Michalowski (1993) and De Angelis (1995) computed the spin axis direction and the shape of this large asteroid ($D$=159 Km)(Tedesco 1989).

Our five observational nights of 173 *Ino* were carried out in July 2004. The composite $V$ lightcurve (Fig. 2), obtained using a synodic rotational period value of $6^h.111 \pm 0^h.002$ (in good agreement with Erikson's one), shows an amplitude of 0.14 ± 0.01 mag. The mean $B$-$V$ colour index is 0.71 ± 0.01 mag.

### 3.3. 182 Elsa

From previous 182 *Elsa*'s photometric observations, carried out during 1978 and 1981 apparitions by Harris et al. (1980, 1992), an indication of a rotational period value of about 80 hours is given.

Our observations of this S-type asteroid spanned eleven nights, from September 8 to October 17, 2004. The value of the synodic rotational period that we determined is $80^h.23 \pm 0^h.08$. The composite $V$ lightcurve shows a nearly sinusoidal trend with an amplitude of 0.69 ± 0.02 mag (Fig. 3). The mean value of the maesured color index $B$-$V$ is 0.86 ± 0.01 mag.

During 182 *Elsa*'s observational run the solar phase angle varied between 5° and 14°. We use the mean reduced magnitudes $\bar{V}(1, \alpha)$ of each night to obtain a least-squares fit with the $H$-$G$ magnitude relation, as described by Bowell et al. (1989). The mean reduced magnitude $\bar{V}(1, \alpha)$ and the fitted phase curve, both vs. phase angle, are plotted in Fig. 4. The resulting $H$ value is 9.26 ± 0.09 mag with a slope parameter $G$ equal to 0.34 ± 0.12.

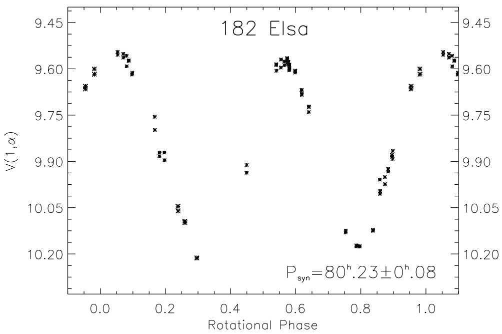


**Fig. 3.** Composite $V(1, \alpha)$ lightcurve of 182 *Elsa* vs. rotational phase. The zero phase corresponds to JD 2453271.0 (corrected for light-time). The same point-symbol for all the eleven observing nights was used to not confuse the figure.

### 3.4. 539 Pamina

This asteroid was observed on only one night in August 1981, by Harris et al. (1992), who obtained a $B$-$V$ color index of 0.70 ± 0.01 mag. They also detected magnitude variations but without any indication of a possible rotational period or amplitude.

Our observations were carried out only during two nights in September 2004. We found

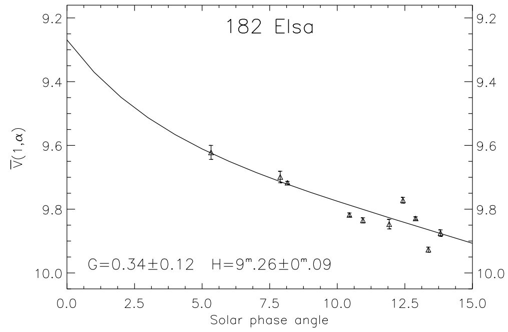


**Fig. 4.** Phase dependence on the mean reduced $\bar{V}(1, \alpha)$ magnitude of 182 *Elsa*.

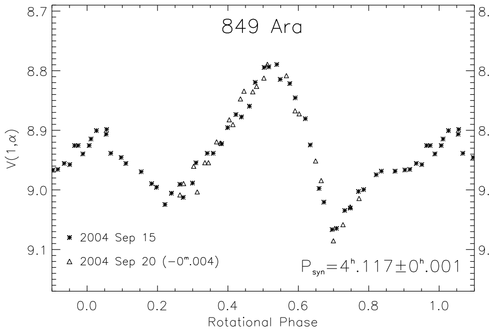


**Fig. 5.** Composite $V(1, \alpha)$ lightcurve of 849 *Ara*, vs. rotational phase. The zero phase corresponds to JD 2453266.0 (corrected for light-time).

a mean *B*-*V* color index of 0.71 ± 0.01 mag, in good agreement with Harris et al.'s (1992) one, but we were not able to give any value of the rotational period.

### 3.5. 849 Ara

The only published lightcurve of this M-type asteroid was obtained during six observing nights in May-June 1981 by Harris et al. (1992), who found a rotational period of $4^h.11643 \pm 0^h.00005$.

In the framework of our photometric observation programme, this asteroid was observed on September 15 and 20, 2004. The rotational period value of $4^h.117 \pm 0^h.001$, is in very good agreement with the previous published one. The composite lightcurve (Fig. 5) shows four well-defined estrema and a 0.26 ± 0.01 mag amplitude. The measured *B*-*V* color index is 0.70 ± 0.01 mag, which is in good agreement with the one reported by Tedesco (1989).

### 3.6. 2892 Filipenko

We observed this asteroid on six nights in November 2004, through *V* and *R* filters at Asiago station. No lightcurve or rotational period value have been published yet. From a preliminary reduction of our observational data, we estimate a synodic rotational period of about $15^h.0 \pm 0^h.1$ and an amplitude of 0.23 ± 0.01 mag.

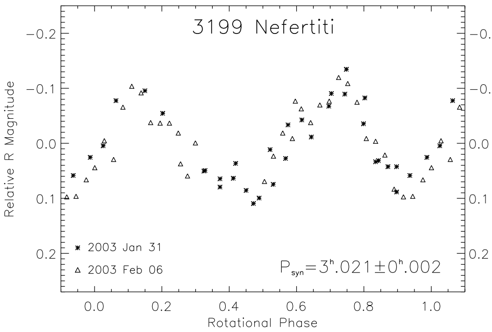


**Fig. 6.** Composite Δ*R* lightcurve of 3199 *Nefertiti*, vs. rotational phase. The zero phase corresponds to JD 2452675.0 (not corrected for light-time).

### 3.7. 3199 Nefertiti

The first observations of this S-Amor asteroid have been perfomed by Harris et al. (1985) who obtained a rotational period of $3^h.01$. During the 1986 apparition Wisniewski (1987) derived a shorter period of $2^h.816$. Pravec et al. (1997) give a value of $3^h.0207 \pm 0^h.0002$.

We observed 3199 *Nefertiti* during two nights in January and February 2003 using the 67/92-cm Schmidt telescope of Asiago. Due to technical problems, we were able to use only the *R* filter, so that the reduction to the standard photometric system was no possible. The composite relative *R* lightcurve, plotted in Fig. 6, shows a symmetric trend with four well-defined extrema and an amplitude of 0.19 ± 0.01 mag. The derived synodic rotational period, $3^h.021 \pm 0^h.002$, is in good agreement with Pravec et al.'s (1997) one.

**Table 1.** Aspect data of the observed asteroids for each observing night. Heliocentric ecliptic longitude ($\lambda$) and latitude ($\beta$), asteroid distance to the Sun ($r$) and Earth ($\Delta$), and solar phase angle ($\alpha$) referred to the mean-time of the observing night. In the last three columns the mean reduced magnitude $\bar{V}(1, \alpha)$, the used wide band filters and the Observatory are listed.

| Date (UT) | $\lambda$ (2000.0) | $\beta$ (2000.0) | r (AU) | $\Delta$ (AU) | PA ($\alpha$) | $\bar{V}(1, \alpha)$ (mag) | Filt. | Obs. |
|---|---|---|---|---|---|---|---|---|
| ***27 Euterpe*** | | | | | | | | |
| 2004 Nov 05 | 44°.63 | −1°.22 | 2.038 | 1.048 | 1°.349 | 7.062 | B,V | CT |
| 2004 Nov 06 | 44°.97 | −1°.21 | 2.037 | 1.047 | 1°.152 | 7.087 | B,V | CT |
| 2004 Nov 08 | 45°.72 | −1°.20 | 2.034 | 1.045 | 1°.610 | 7.079 | B,V | CT |
| ***173 Ino*** | | | | | | | | |
| 2004 Jul 17 | 299°.41 | 6°.99 | 2.513 | 1.513 | 5°.319 | 8.435 | B,V | CT |
| 2004 Jul 18 | 299°.66 | 6°.93 | 2.511 | 1.509 | 5°.091 | 8.416 | B,V | CT |
| 2004 Jul 19 | 299°.92 | 6°.88 | 2.509 | 1.506 | 4°.888 | 8.423 | B,V | CT |
| 2004 Jul 20 | 300°.15 | 6°.83 | 2.506 | 1.503 | 4°.740 | 8.398 | B,V | CT |
| 2004 Jul 21 | 300°.41 | 6°.77 | 2.504 | 1.500 | 4°.616 | 8.417 | B,V | CT |
| ***182 Elsa*** | | | | | | | | |
| 2004 Sep 08 | 2°.64 | −1°.94 | 2.106 | 1.172 | 13°.829 | 9.875 | B,V | CT |
| 2004 Sep 09 | 2°.98 | −1°.94 | 2.104 | 1.165 | 13°.372 | 9.927 | B,V | CT |
| 2004 Sep 10 | 3°.33 | −1°.94 | 2.102 | 1.158 | 12°.897 | 9.829 | B,V | CT |
| 2004 Sep 11 | 3°.67 | −1°.95 | 2.100 | 1.152 | 12°.425 | 9.772 | B,V | CT |
| 2004 Sep 12 | 4°.02 | −1°.95 | 2.099 | 1.145 | 11°.924 | 9.847 | B,V | CT |
| 2004 Sep 13 | 4°.33 | −1°.95 | 2.097 | 1.140 | 11°.489 | 9.589 | B,V | CT |
| 2004 Sep 14 | 4°.70 | −1°.95 | 2.095 | 1.134 | 10°.953 | 9.835 | B,V | CT |
| 2004 Sep 15 | 5°.04 | −1°.96 | 2.094 | 1.128 | 10°.453 | 9.818 | B,V | CT |
| 2004 Sep 20 | 6°.76 | −1°.97 | 2.086 | 1.104 | 7°.889 | 9.699 | B,V | CT |
| 2004 Oct 12 | 14°.43 | −2°.00 | 2.053 | 1.064 | 5°.331 | 9.622 | B,V | CT |
| 2004 Oct 17 | 16°.26 | −2°.00 | 2.046 | 1.072 | 8°.163 | 9.717 | B,V | CT |
| ***539 Pamina*** | | | | | | | | |
| 2004 Sep 10 | 1°.24 | 6°.80 | 2.162 | 1.213 | 11°.907 | – | B,V | CT |
| 2004 Sep 11 | 1°.59 | 6°.80 | 2.161 | 1.208 | 11°.477 | – | B,V | CT |
| ***849 Ara*** | | | | | | | | |
| 2004 Sep 15 | 339°.39 | 18°.29 | 2.672 | 1.789 | 12°.597 | 8.941 | B,V | CT |
| 2004 Sep 20 | 340°.63 | 18°.15 | 2.679 | 1.819 | 13°.488 | 8.945 | B,V | CT |
| ***2892 Filipenko*** | | | | | | | | |
| 2004 Nov 12 | 61°.55 | 16°.87 | 2.489 | 1.595 | 12°.176 | – | V,R | PD |
| 2004 Nov 15 | 62°.43 | 16°.85 | 2.490 | 1.586 | 11°.591 | – | V,R | PD |
| 2004 Nov 16 | 62°.70 | 16°.84 | 2.490 | 1.584 | 11°.425 | – | V,R | PD |
| 2004 Nov 17 | 62°.99 | 16°.83 | 2.490 | 1.582 | 11°.262 | – | V,R | PD |
| 2004 Nov 18 | 63°.23 | 16°.83 | 2.490 | 1.580 | 11°.139 | – | V,R | PD |
| 2004 Nov 19 | 63°.56 | 16°.81 | 2.491 | 1.578 | 10°.976 | – | V,R | PD |
| ***3199 Nefertiti*** | | | | | | | | |
| 2003 Jan 31 | 150°.47 | 6°.18 | 1.647 | 0.792 | 24°.738 | – | R | PD |
| 2003 Feb 06 | 152°.66 | 4°.78 | 1.669 | 0.765 | 20°.176 | – | R | PD |
| ***2004 UE*** | | | | | | | | |
| 2004 Nov 08 | 47°.86 | −0°.08 | 1.010 | 0.025 | 39°.128 | – | V,R | PD |

**Table 2.** Synodic rotational period value, realibilily code, amplitude of $V$ lightcurve and mean $B$-$V$ color index of observed asteroids

| Asteroid | $P_{syn}$ | Reliabylity code | Amplitude | $B$-$V$ |
|---|---|---|---|---|
| 27 *Euterpe* | $10^h.377 \pm 0^h.008$ | 3 | $0^m.14 \pm 0^m.02$ | $0^m.85 \pm 0^m.02$ |
| 173 *Ino* | $6^h.111 \pm 0^h.002$ | 3 | $0^m.14 \pm 0^m.01$ | $0^m.71 \pm 0^m.01$ |
| 182 *Elsa* | $80^h.23 \pm 0^h.08$ | 3 | $0^m.69 \pm 0^m.02$ | $0^m.86 \pm 0^m.01$ |
| 539 *Pamina* | — | — | — | $0^m.71 \pm 0^m.01$ |
| 849 *Ara* | $4^h.117 \pm 0^h.001$ | 3 | $0^m.26 \pm 0^m.01$ | $0^m.70 \pm 0^m.01$ |
| 2892 *Filipenko* | $15^h.0 \pm 0^h.1$ | 2 | $0^m.23 \pm 0^m.01$ | — |
| 3199 *Nefertiti* | $3^h.021 \pm 0^h.002$ | 3 | $0^m.19 \pm 0^m.01$ | — |
| *2004 UE* | $5^h.6 \pm 0^h.2$ | 2 | $0^m.98 \pm 0^m.02$ | — |

### 3.8. 2004 UE

This small Apollo-type asteroid ($D$~150 m) was discovered by LINEAR on October 2004. During its close path to the Earth on November 8, 2004, the asteroid got its V maximum brightness of about 14.2 mag. Due to bad weather conditions and asteroid fast proper motion ($2700''/hr$) we could not observe this NEO for more than one night. Moreover, its fast proper motion and the crowded stars field did not permit exposure time greater than 30 sec. The relative $R$ lightcurve is presented in Fig. 7. The rotational period results longer than the observing interval, nevertheless, assuming the obtained lightcurve as part of a simple symmetrical one, the period value may be about $5^h.6{\pm}0^h.2$. The measured amplitude of the light variation is $0.98 \pm 0.02$ mag.

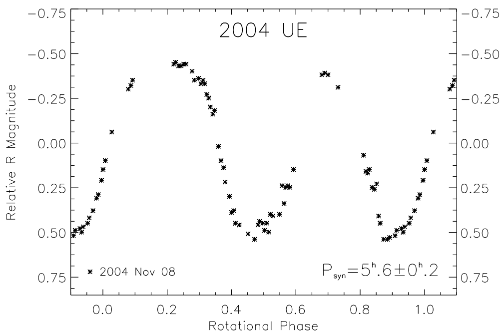


**Fig. 7.** Composite $\Delta R$ lightcurve of 2004 UE, vs. rotational phase. The zero phase corresponds to JD 2453319.0 (not corrected for light-time).

*Acknowledgements.* We thank the Padova Astronomical Observatory for the use of the telescope. We are also kindly grateful to R. Claudi and to 67/92-cm Schmidt telecope technicians for the precious assistance during the observations.

## References

Bertin, E., & Arnouts, S. 1996, A&A, 117, 393-404.
Blanco, C. et al. 2004, *Proceedings of the V Convegno di Scienze Planetarie , Gallipoli (Lecce), September 15-19, 2003.*, p. 131-134
Blanco, V.M. 1968, Publ. US Naval Observatory 21.
Bowell, E. et al. 1989, in *AsteroidII*, pp. 524-556, Univ. of Arizona press, Tucson.
Chang, Y.C., & Chang, C.S. 1962, Acta Astron. Sin. 10, 101-111.
De Angelis, G. 1995, Planet. Space Sci., 43, 649-682
Debehogne, H. et al. 1990, Asteroids, comets, meteors III, *Proceedings of AMC 89, Astronomical Observatory of the Uppsala University, June 12-16, 1989, Uppsala*, p. 45
Erikson, A. 1990, Asteroids, comets, meteors III, *Proceedings of AMC 89, Astronomical Observatory of the Uppsala University, June 12-16, 1989, Uppsala*, p. 55
Harris A.W. et al. 1980, Icarus, 41, 316-317.
Harris, A.W., & Young, J.W. 1983, Icarus, 54, 59-109.
Harris, A.W., & Young, J.W. 1985, BAAS, 17, 726.
Harris, A.W., & Young, J.W. 1989, Icarus, 77, 171-186.
Harris, A.W. et al. 1992, Icarus, 95, 115-147.
Landolt, A.U. 1992, AJ, 104, 340-371.
Michalowski, T. 1993, Icarus, 106, 563-572
Pravec, P. et al. 1997, Icarus, 130, 275-286
Schober, H.J., 1978, A&AS, 34, 377-381.
Stephens, R.D. et al., 2001, MPBu, 28, 1-2.
Stetson, P.B., 2000, PASP, 112, 925-931.
Tedesco, E.F. 1989, in *AsteroidII*, pp. 1090-1138, Univ. of Arizona press, Tucson.
Wisniewski, W.Z. 1987, Icarus, 70, 566-572