

ROTATIONAL PROPERTIES OF SMALL ASTEROIDS: PHOTOELECTRIC OBSERVATIONS¹

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ABSTRACT

In 1984 we started an observational program on small asteroids (diameter lower than about 50 km) with the aim to enlarge the available dataset of the rotational periods of this size range objects. In this paper we report the results obtained from photometric observations of ten small asteroids from August 1984 to January 1989 at the European Southern Observatory (La Silla, Chile). We have determined reliable synodic rotational periods for the asteroids 269 Justitia ($P = 16^{\text{h}}545$), 289 Nenetta ($P = 6^{\text{h}}902$), 417 Suevia ($P = 7^{\text{h}}034$), 435 Ella ($P = 4^{\text{h}}623$), 537 Pauly ($P = 16^{\text{h}}250$), 995 Sternberga ($P = 16^{\text{h}}406$), 1186 Turnera ($P = 12^{\text{h}}010$), and 1693 Hertzsprung ($P = 8^{\text{h}}825$), while for 504 Cora ($P = 24^{\text{h}}$) and 1392 Pierre (18^{h}), we obtained only an estimate of the possible rotational period.

1. INTRODUCTION

Several authors (Harris & Burns 1979; Farinella *et al.* 1981; Dermott *et al.* 1984; Binzel 1984; Binzel *et al.* 1989) analyzed statistically the asteroid rotational periods, but have not yet led to conclusive results because the noncomplete available statistical sample, mainly in the small diameter range ($D \lesssim 50$ km), size range where the dispersion in rotation rates among the present sample becomes non-Maxwellian (Binzel *et al.* 1989). For this reason more data are needed and we started an observation campaign aiming the determination of rotational properties of small asteroids.

In this paper we present the results of photoelectric observations of small asteroids carried out at the European Southern Observatory (La Silla, Chile). We obtained 37 single night lightcurves of ten asteroids with diameter smaller than about 55 km.

The photometric observations in the UBV bands were carried out between August 1984 and January 1989 using photoelectric photometers, equipped with an RCA 31034 photomultiplier, attached to the 0.5 and 1 m ESO telescopes. The observing runs, which results are presented in this paper, have been performed using the standard procedure described in Harris & Young (1983), when the target asteroids were nearby the opposition. The data reduction procedure has been carried out applying the standard method described by Hardie (1962) and using the ESO "Snopy" computer program. With the exception of the observations carried out in 1989 and in the second part of August 1984, transformation to the UBV standard system has been performed by means of groups of standard stars taken from Graham (1983). The determination of the rotational periods was computed by using the Fourier analysis as described in Harris *et al.* (1989). All aspect data of the observed asteroids are listed in Table 1, the last two columns give the mean magnitude level $V(\alpha)$, which corresponds to

the zero level each night in the light-curve plots, and the telescope size, respectively.

2. RESULTS

In Table 2 are summarized the synodic rotational period, the light-curve amplitude, the color indices $U - B$ and $B - V$, the *IRAS* diameter, and the taxonomic type of the observed asteroids. In column 3 of the table we list the rotational period quality code. A quality code 2 means a reasonably secure result, so that the period may be wrong by 30% or so or an ambiguity may exist, the code 3 denotes a secure result with no ambiguity and full light-curve coverage (Lagerkvist *et al.* 1989).

A few specific remarks follow on the results found for the observed asteroids.

269 Justitia was observed during five nights (August 6, 7, 13, 14, 15) in 1984 for about 36 hr. The composite light-curve, shown in Fig. 1, was obtained with a rotational period of $16^{\text{h}}545 \pm 0^{\text{m}}001$ and the resulting amplitude is $0.25^{\text{m}} \pm 0^{\text{m}}02$, no alternative periods fit the single night lightcurves. The composite shows an asymmetric trend with a well-defined broad maximum while the secondary extrema are scantily evidenced.

289 Nenetta was observed during three nights (September 8, 10, 11) in 1985 for 22 hr. The composite lightcurve, fitted with a period of $6^{\text{h}}902 \pm 0^{\text{m}}001$, is shown in Fig. 2. The light-curve amplitude is $0^{\text{m}}18 \pm 0^{\text{m}}01$. The light curve shows well definite maxima and minima with the principal maximum narrower than the secondary one. Other possible rotational period were not found.

417 Suevia was observed during three nights (January 7, 8, 9) in 1989 for about 15 hr. The composite lightcurve, shown in Fig. 3, was obtained with a rotational period of $7^{\text{h}}034 \pm 0^{\text{m}}006$. The light-curve amplitude is $0^{\text{m}}20 \pm 0^{\text{m}}01$. The obtained rotational period is unambiguous.

435 Ella was observed during three nights (August 6, 8, 9) in 1986 for 18 h. The composite light curve is shown in Fig. 4. The rotational period is $4^{\text{h}}623 \pm 0^{\text{m}}005$ and the amplitude

¹ Based on observations carried out at the European Southern Observatory (ESO), La Silla, Chile.

TABLE 1. Aspect data of the observed asteroids.

Date (0 UT)	R.A. (1950)	Decl (1950)	Long (1950)	Lat (1950)	r (AU)	Δ (AU)	Phase	V (mag)	Telescope
269 Justitia									
1984 08 06	19 ^h 51 ^m 7	-15°25'	297.0	+05.5	2.0907	1.1000	8°2	12.304	50 cm ESO
08 07	19 51.1	-15 31	296.8	+05.4	2.0918	1.1043	8.7	12.320	"
08 13	19 47.8	-16 07	295.9	+04.9	2.0989	1.1346	11.6	12.503	"
08 14	19 47.3	-16 13	295.8	+04.9	2.1002	1.1404	12.0	12.507	"
08 15	19 46.9	-16 19	295.7	+04.8	2.1014	1.1463	12.5	12.512	"
289 Nenetta									
1985 09 08	22 48.2	-03 33	342.1	+03.8	2.3281	1.3225	2.0	12.431	50 cm ESO
09 10	22 46.8	-03 50	341.7	+03.6	2.3262	1.3226	2.7	12.446	"
09 11	22 46.1	-03 58	341.5	+03.6	2.3253	1.3231	3.1	12.466	"
417 Suevia									
1989 01 07	08 51.6	+07 21	133.3	-09.9	2.5982	1.6926	10.5	—	100 cm ESO
01 08	08 50.9	+07 22	133.1	-09.9	2.5969	1.6855	10.1	—	"
01 09	08 50.3	+07 23	132.9	-09.9	2.5957	1.6786	9.8	—	"
435 Ella									
1986 08 06	21 33.7	-17 49	320.0	-03.2	2.1320	1.1227	3.7	12.569	100 cm ESO
08 08	21 31.9	-17 57	319.5	-03.2	2.1298	1.1185	2.8	12.530	"
08 09	21 31.0	-18 02	319.3	-03.1	2.1288	1.1168	2.3	12.507	"
504 Cora									
1989 01 06	03 15.3	+07 01	48.3	-10.7	2.4598	1.7865	19.7	—	100 cm ESO
01 07	03 15.4	+07 10	48.4	-10.5	2.4620	1.7993	19.9	—	"
01 10	03 15.8	+07 36	48.6	-10.1	2.4688	1.8383	20.4	—	"
01 11	03 16.0	+07 45	48.7	-10.0	2.4710	1.8515	20.6	—	"
01 12	03 16.2	+07 53	48.8	-09.9	2.4733	1.8649	20.7	—	"
537 Pauly									
1985 08 08	00 00.9	-13 54	354.6	-12.8	2.4752	1.4914	6.5	12.129	50 cm ESO
08 10	23 59.6	-14 10	354.2	-12.9	2.4787	1.4920	6.0	12.113	"
08 11	23 58.9	-14 18	354.0	-13.0	2.4805	1.4927	5.8	12.100	"
08 12	23 58.2	-14 26	353.7	-13.0	2.4823	1.4937	5.6	12.091	"
995 Sternberga									
1989 01 07	08 12.2	+00 39	125.2	-18.9	2.8867	1.9734	8.8	—	100 cm ESO
01 08	08 11.3	+00 39	125.0	-18.9	2.8880	1.9705	8.5	—	"
01 09	08 10.5	+00 39	124.7	-19.0	2.8892	1.9678	8.3	—	"
01 12	08 07.8	+00 40	124.0	-19.1	2.8930	1.9613	7.6	—	"
1186 Turnera									
1987 08 29	22 11.6	-28 41	324.5	-16.3	2.7107	1.7362	7.0	13.595	100 cm ESO
08 30	22 10.7	-28 43	324.3	-16.3	2.7105	1.7385	7.2	13.619	"
08 31	22 09.8	-28 45	324.1	-16.3	2.7102	1.7410	7.5	13.634	"
1392 Pierre									
1984 08 20	21 33.3	-27 53	316.6	-12.6	2.4318	1.4436	6.6	—	100 cm ESO
08 22	21 31.0	-27 52	316.1	-12.5	2.4275	1.4440	7.2	—	"
08 23	21 29.9	-27 51	315.9	-12.4	2.4253	1.4446	7.6	—	"
08 24	21 28.8	-27 50	315.7	-12.3	2.4232	1.4455	7.9	—	"
1693 Hertsprung									
1987 08 29	22 45.2	-32 10	330.1	-22.4	2.0997	1.1317	10.7	13.863	100 cm ESO
08 30	22 44.4	-32 14	329.9	-22.3	2.1010	1.1342	10.8	13.866	"
09 02	22 41.9	-32 22	329.3	-22.3	2.1051	1.1428	11.2	13.879	"

TABLE 2. Physical parameters of the observed asteroids.

Asteroids	Rot. Period (hr)	Rel. Code	Amplitude (mag)	D (km)	Tholen class	Barucci class	$U - B$	$B - V$
269 Justitia	16.545	3	0.25	55			0.419 + 0.035	0.871 + 0.017
289 Nenetta	6.902	3	0.18	41	<i>A</i>	<i>A0</i>	0.577 + 0.029	0.992 + 0.024
417 Suevia	7.034	3	0.20	43	<i>X</i>		—	—
435 Ella	4.623	3	0.38	43	<i>DCX</i>		0.288 + 0.018	0.724 + 0.016
504 Cora	24.06	2	> 0.40	31			—	—
537 Pauly	16.250	3	0.18	47	<i>DU:</i>		0.369 + 0.035	0.832 + 0.025
995 Sternberga	16.406	2	0.15	33			—	—
1186 Turnera	12.010	3	> 0.20	39	<i>S</i>		0.380 + 0.041	0.793 + 0.016
1392 Pierre	18.	2	0.09	30	<i>DX</i>		—	—
1693 Hertsprung	8.825	3	0.45	39	<i>CBU</i>	<i>C0</i>	0.343 + 0.047	0.754 + 0.020

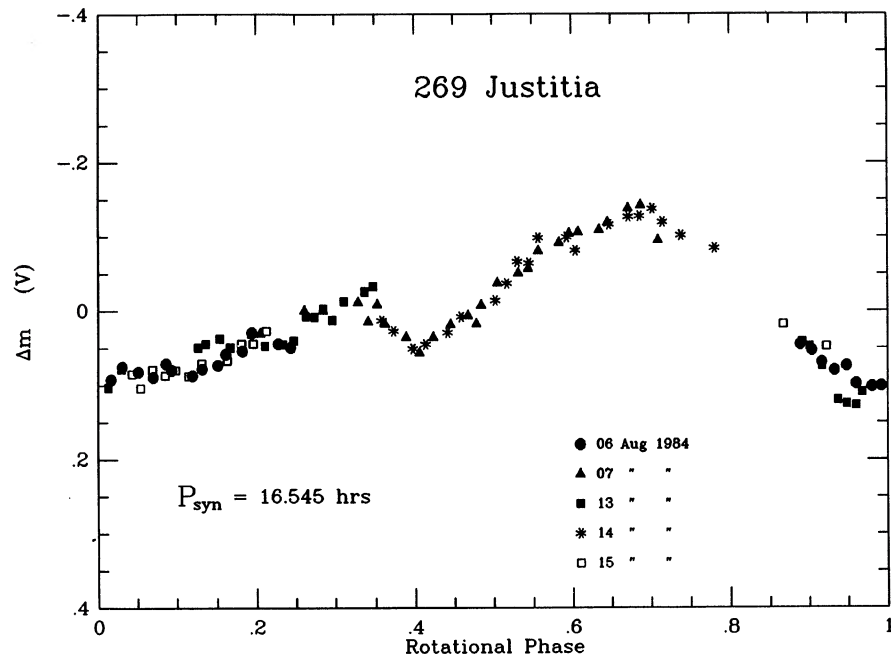


FIG. 1. Composite light curve of the asteroid 269 Justitia in rotational phase. The 0 phase time corresponds to JD 2445918.672.

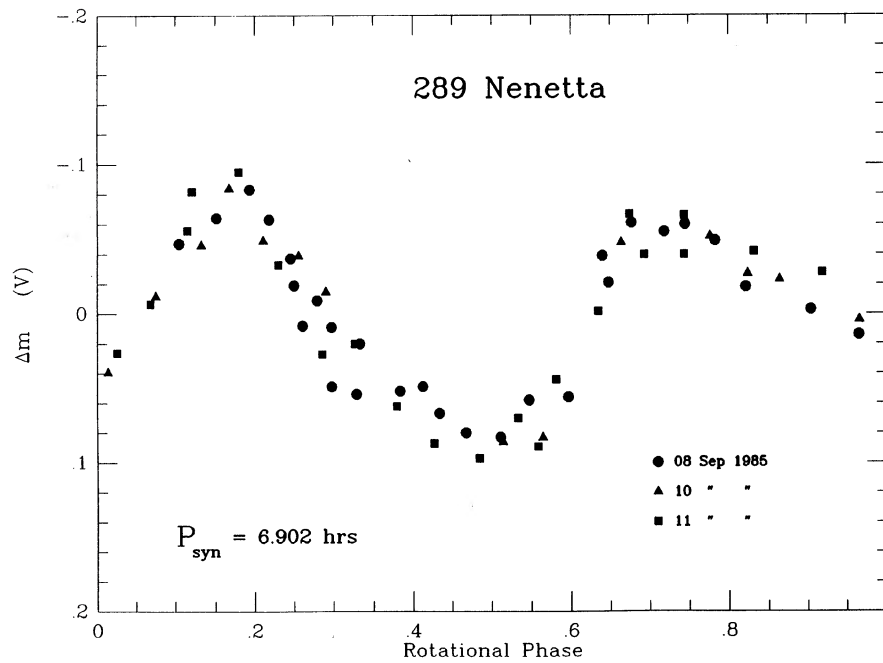


FIG. 2. Composite light curve of the asteroid 289 Nenetta in rotational phase. The 0 phase time corresponds to JD 2444315.990.

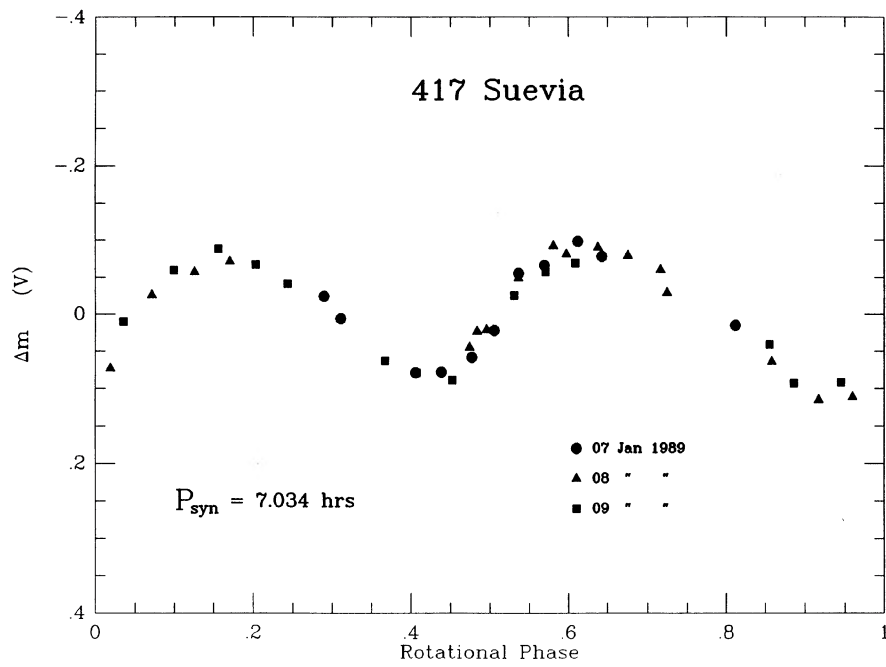


FIG. 3. Composite light curve of the asteroid 417 Suetia in rotational phase. The 0 phase time corresponds to JD 2447534.792.

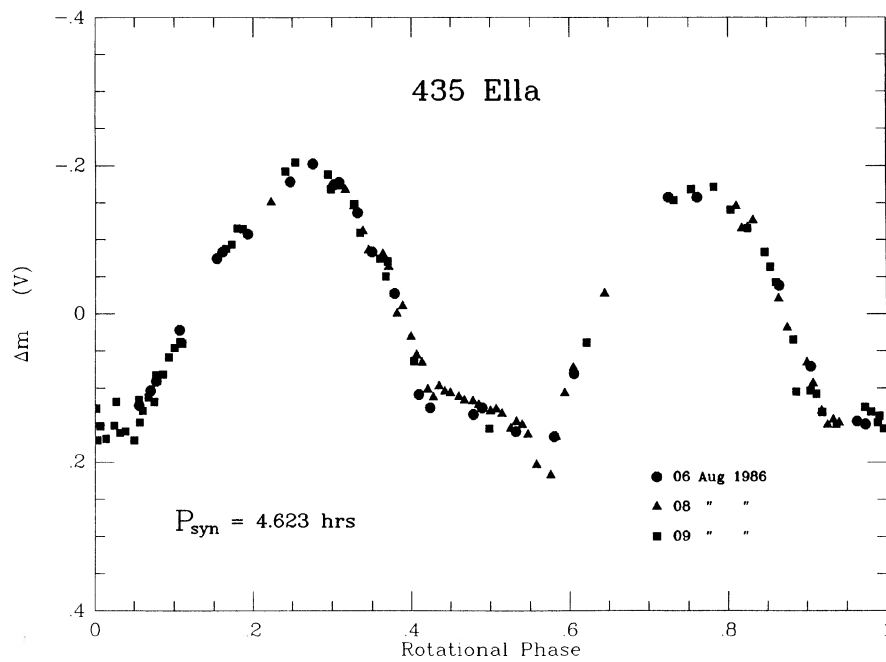


FIG. 4. Composite light curve of the asteroid 435 Ella in rotational phase. The 0 phase time corresponds to JD 2446650.617.

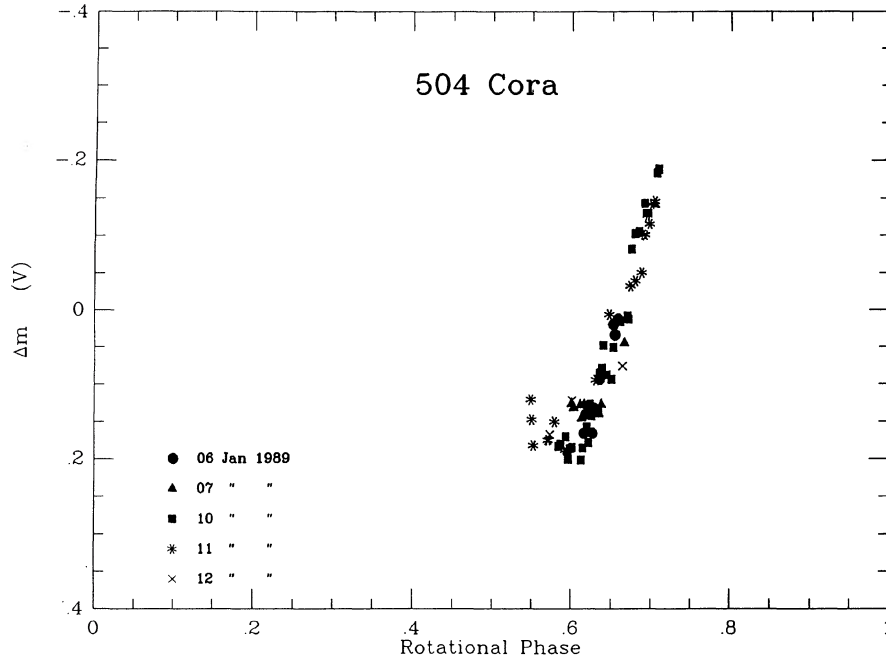


FIG. 5. Composite light curve of the asteroid 504 Cora in rotational phase. The 0 phase time corresponds to JD 2447537.034.

$0^m38 \pm 0^m01$. The two maxima are almost symmetric while the minima appear flat. Only the rotational period we have determined can fit the light curves obtained during the three night of observation.

504 Cora was observed during five nights (January 6, 7, 10, 11, 12) in 1989 for about 16 hr. The composite light curve, shown in Fig. 5, of this Koronis family member provides the best fit with a period of $24^h06 \pm 0^h02$, the resulting amplitude is higher than 0^m40 . A period of 12 or 16 h (the

latter implying that opposite minima were observed on successive nights) cannot be ruled out.

537 Pauly was previously observed by Weidenschilling *et al.* (1990) which proposed a rotational period of 13.5 or 20 h. We observed this asteroid during four nights (September 8, 10, 11, 12) on 1985 for more than 18 h. We obtained the best fit for the composite light curve, shown in Fig. 6, with an unambiguous rotational period of $16^h250 \pm 0^h005$. The amplitude is $0^m18 \pm 0^m01$. Our data cannot fit with the periods

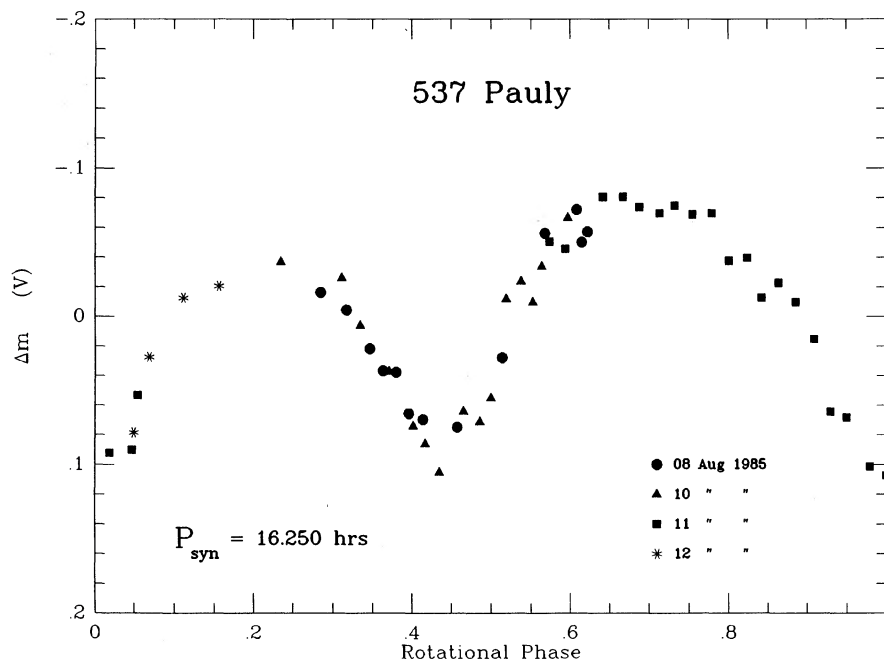


FIG. 6. Composite light curve of the asteroid 537 Pauly in rotational phase. The 0 phase time corresponds to JD 2446316.483.

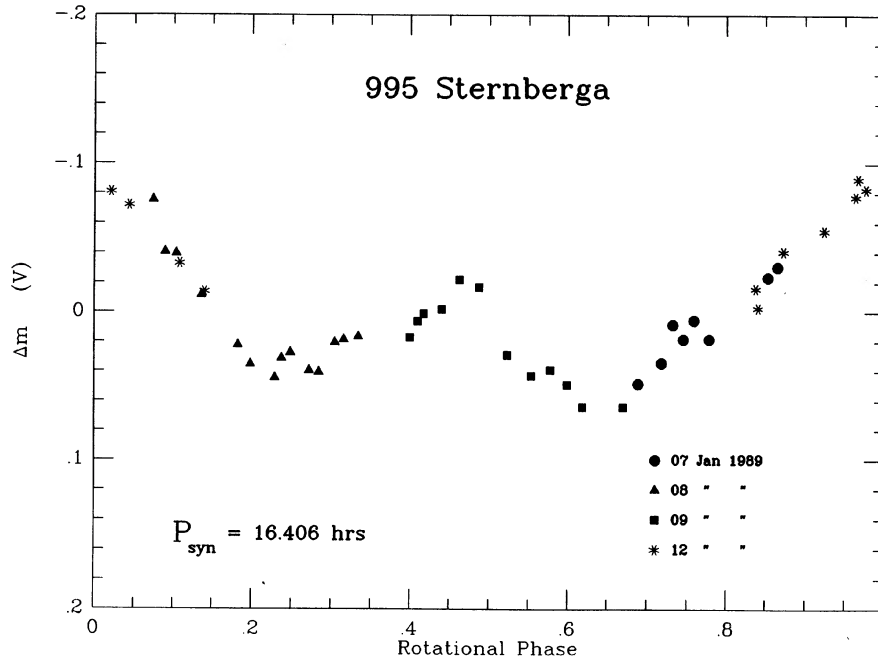


FIG. 7. Composite light curve of the asteroid 995 Sternberga in rotational phase. The 0 phase time corresponds to JD 2447534.626.

suggested by Weidenschilling *et al.*

995 Sternberga was observed during four nights (January 7, 8, 9, 12) on 1989 for about 18 hr. The composite light curve shown in Fig. 7 was obtained with a rotational period of $16^h40^m6^s \pm 0^m006^s$. The resulting amplitude is $0^m15 \pm 0^m01$. The trend of the light curve is quite asymmetric with a magnitude difference between the two maxima of about 0.04 mag. The overlapping of the single night light curves is very

poor, consequently we rank the period with code 2.

1186 Turnera was observed during four nights (August 29, 30, 31) in 1987 for about 20 hr. The composite light curve, shown in Fig. 8, has been obtained with a rotational period of $12^h01^m0^s \pm 0^m005^s$. The amplitude is larger than 0^m20 . Even if the observations cover only about 60% of the rotational phase interval, the found rotational period can be considered unambiguous.

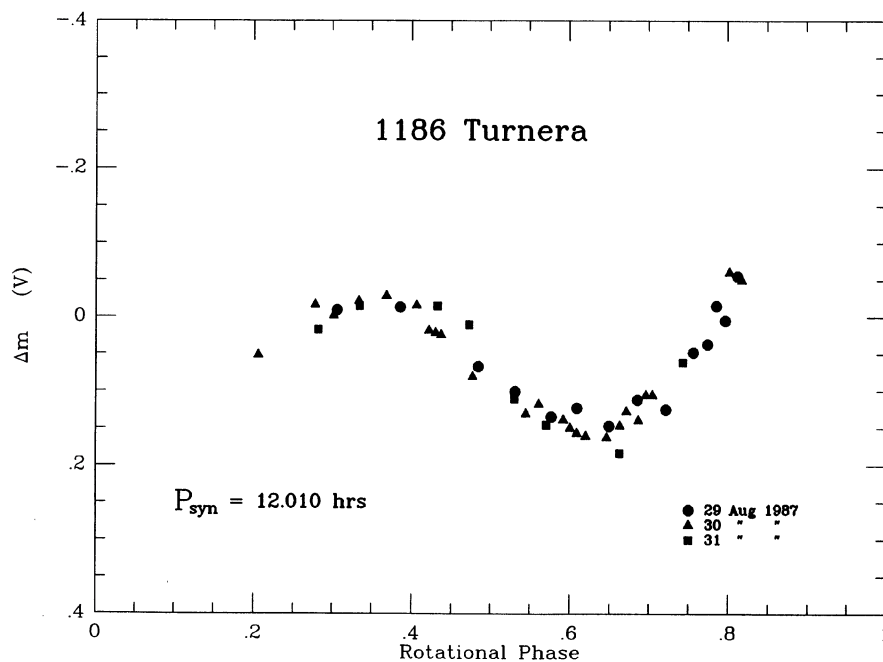


FIG. 8. Composite light curve of the asteroid 1186 Turnera in rotational phase. The 0 phase time corresponds to JD 2447036.497.

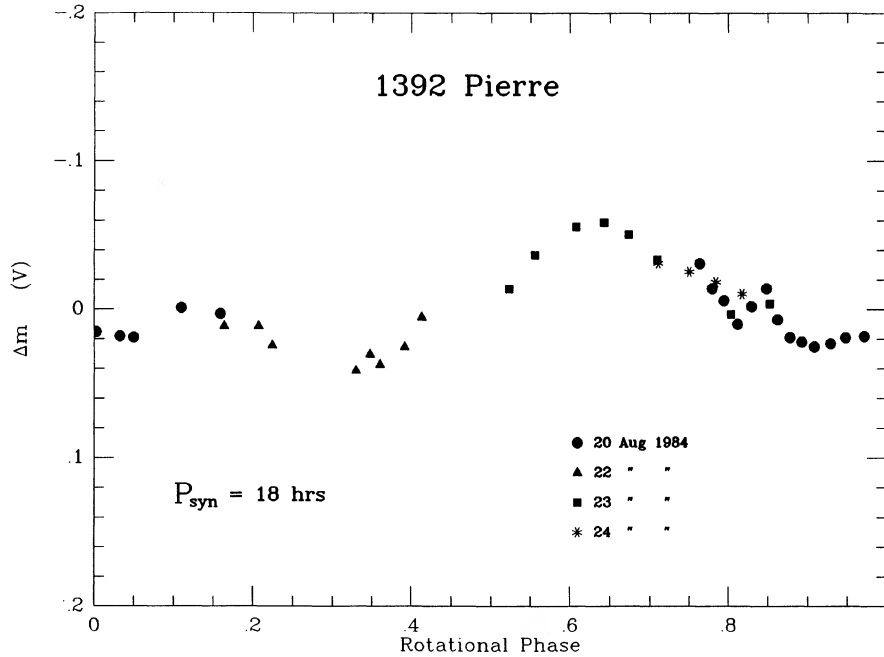


FIG. 9. Composite light curve of the asteroid 1392 Pierre in rotational phase. The 0 phase time corresponds to JD 2445935.256.

1392 Pierre was observed during four nights (August 21, 22, 23, 24) in 1984. The obtained composite light curve, shown in Fig. 9, was obtained with a rotational period of 18^h, but, because of the not good quality of the single light curves

(the brightness of the asteroid was at the limit of the telescope capability), this value must be considered not sure. The amplitude of the composite is $0^{\text{m}}09 \pm 0^{\text{m}}01$.

1693 Hertzprung was observed during four nights (Au-

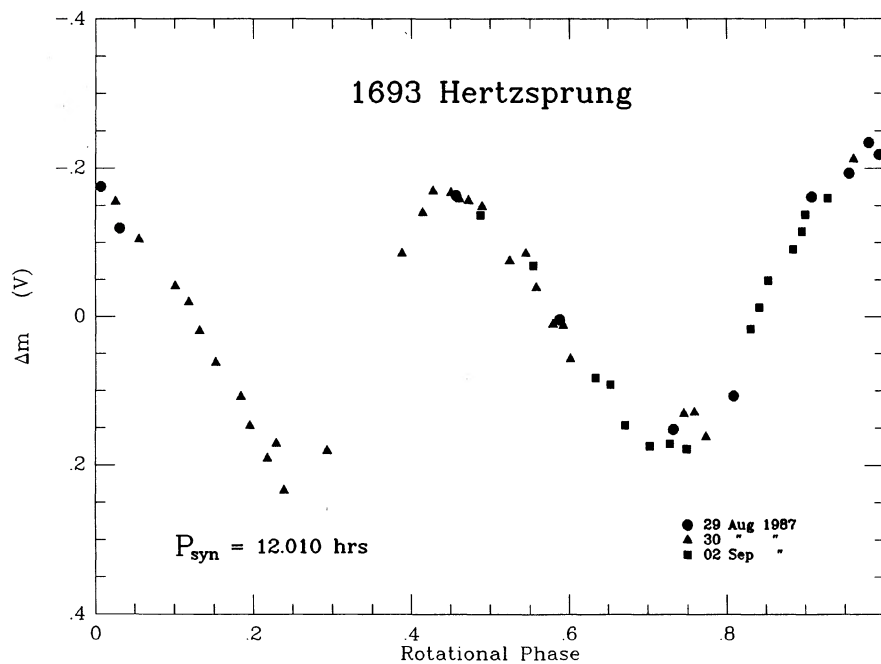


FIG. 10. Composite light curve of the asteroid 1693 Hertzprung in rotational phase. The 0 phase time corresponds to JD 2447037.529.

gust 29, 30, and September 2) on 1987. The composite light curve, shown in Fig. 10, was fitted with a rotational period of $8^{\text{h}}825 \pm 0^{\text{m}}001$, the amplitude is $0^{\text{m}}45 \pm 0^{\text{m}}02$. Also for this asteroid the rotational period we have determined must be considered as unambiguous.

These data are used to reanalyze the rotation rate distribution of the asteroids with diameter lower than about 50 km (Fulchignoni *et al.* 1992) and to interpret it in terms of evolution of the asteroid population.

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