

Minor planets and related objects. XXI. Photometry of eight asteroids

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Lightcurves, *UBV* colors, rotational periods, phase coefficients, and absolute magnitudes are presented. The asteroids studied are (1) Ceres, (4) Vesta, (16) Psyche, (78) Diana, (281) Lucretia, (451) Patientia, (1212) Francette, and (1362) Griqua. The rotation axis of Lucretia is nearly perpendicular to the plane of the ecliptic. Ceres appears to be nearly spherical with an absolute magnitude of $B(1,0) = 4.42$ which is 0.3 mag fainter than previously reported. The determination of the absolute magnitude for an asteroid depends on its aspect and for each opposition there is, therefore, a different absolute magnitude.

THIS paper continues our surveying of shapes and spin periods of the asteroids (Sec. I). In addition, Sec. I has information on magnitudes and colors and, for (281) Lucretia, an attempt to determine the orientation of the rotation axis. In Sec. II we shall discuss the definition of absolute magnitude particularly as it is affected by aspect. That is, even when the rotational variation is allowed for there is the variation of aspect angle (between the line of sight and the spin axis), and different projected cross sections are observed at different times.

I. THE OBSERVATIONS

Table I gives the aspect data and Table II lists the comparison stars and quality of each night. Ephemeris time is used ($ET = UT + 0^m7$). Table III summarizes the photometric results; $V_0(1,0)$ is the absolute magnitude of the lightcurve maximum, V_0 , linearly extrapolated to zero phase angle; "Mean $V(1,0)$ " is the absolute magnitude, similarly extrapolated to zero phase, of the brightness averaged over the lightcurve. Probable errors are used in all tables.

A. (1) Ceres

Previous lightcurves of Ceres (Ahmad 1954; Gehrels and Owings 1962) show a small amplitude, less than 0.05 mag. The present lightcurve (Fig. 1) again shows small

amplitude. (We also have a 1-h lightcurve of 18 October 1970, consistent with Fig. 1.) Ceres must be nearly spherical.

Ahmad saw what appeared to be a secondary maximum, and he determined, from superposition of his lightcurves of different nights, a period of $9^h 04^m.7$. Gehrels and Owings had a single long lightcurve from which the period cannot be determined, but after $9^h 04^m.7$ elapsed time the same brightness level is not quite attained so that (although it is an effect of only 0.01 mag) there is some doubt on that period. The present Fig. 1 shows a periodicity in about 9 h, but only one maximum and one minimum are clearly seen, unless the short secondary maximum at $\sim 6^h 10^m$ in Ahmad's Fig. 3 occurs at $\sim 3^h 40^m$ on 10 October 1970 (present Fig. 1). On the other hand, such submaxima as Ahmad saw have been observed on other asteroid lightcurves, for example, on (6) Hebe (see Fig. 5 in Taylor 1971). In summary, the period of $9^h 04^m.7$ probably is correct, but further verification appears in order.

Ahmad (1954) observed far from opposition, he used a phase coefficient of 0.050 mag/deg (Calder 1935), and he derived a mean opposition magnitude $V(a,0) = 6.82$ from which follows $V(1,0) = 3.37$. Figure 2 is a plot of V magnitudes and colors as a function of phase. The linear extrapolation in V is shown with a dashed line, while the nonlinear brightness surge called the "opposition effect" is also shown. A least-squares reduction of the linear relation, with half-weights given the Calder and Fichera values, yields

$$V_0(1,\alpha) = 3.70 + 0.036 |\alpha|,$$

and Mean $V(1,0) = 3.72$. This still is, however, a preliminary result because of the arbitrary shifting, due to

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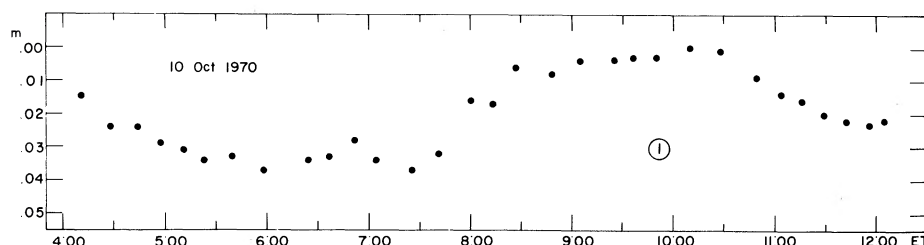


FIG. 1. Lightcurve of (1) Ceres, observed by J. L. Dunlap at the Kitt Peak 41-cm No. 3 telescope.

PHOTOMETRY OF ASTEROIDS

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TABLE I. Aspect data for the asteroids.

Ast. No.	Obs. date ET	Phase angle	Distance from Sun (AU)	Distance from Earth (AU)	Light time	R.A. 1950	Dec. 1950	Ecliptic Long. 1950	Lat. 1950	Fig. No.
1	70.10.10	-7°27	2.873	1.920	0d 01m 10s	2h 22m 4	+0° 37'	33°51	-12°81	1
	70.10.18	-5.09	2.867	1.892	109	2 16.0	+0 13	31.82	-12.65	...
4	74.06.08	+25.99	2.198	1.657	95	12 33.7	+6 12	185.27	+9.04	3
	74.06.09	+26.12	2.198	1.667	96	12 34.2	+6 4	185.44	+8.96	3
	72.02.06	-8.26	3.196	2.290	32	11 2.5	+6 36	164.22	+0.42	4
	74.08.08	+2.39	2.719	1.710	98	20 42.3	-16 33	308.59	+1.63	5
16	74.08.10	+3.21	2.717	1.710	98	20 40.7	-16 42	308.18	+1.58	6
	74.08.11	+3.65	2.715	1.711	98	20 39.9	-16 46	307.98	+1.57	7
	74.08.12	+4.08	2.714	1.712	98	20 39.1	-16 50	307.78	+1.55	8
	74.08.13	+4.50	2.713	1.714	99	20 38.3	-16 55	307.57	+1.52	9
78	69.03.02	-1.87	2.161	1.171	67	10 56.9	+3 46	164.02	-2.30	11
	69.11.30	+6.79	1.900	0.926	53	3 28.0	+24 36	55.76	+5.55	12
	69.12.13	+14.11	1.912	0.987	57	3 16.6	+24 25	53.20	+6.03	...
	72.08.14	-21.65	2.018	1.190	68	0 40.7	-2 27	8.38	-6.29	13
281	72.08.16	-20.95	2.016	1.171	67	0 40.7	-2 27	8.37	-6.28	14
	72.09.01	-14.31	1.995	1.053	60	0 36.8	-2 46	7.36	-6.20	15
	74.04.13	+6.59	2.413	1.433	82	12 29.4	-0 12	186.83	+2.74	16
	74.04.14	+7.05	2.414	1.437	83	12 28.5	-0 9	186.60	+2.69	17
	69.12.30	-2.03	2.887	1.907	110	6 54.2	+27 30	102.03	+4.61	21
	69.12.31	-1.80	2.888	1.907	110	6 53.9	+27 36	101.96	+4.71	22
451	70.01.01	-1.66	2.888	1.907	110	6 51.4	+27 42	101.40	+4.76	23
	74.12.23	+9.81	2.856	1.959	113	4 4.1	+13 39	61.69	-7.00	24
	74.12.24	+10.19	2.856	1.959	113	4 3.4	+13 44	61.54	-6.88	25
1212	72.01.15	-4.49	3.257	2.297	132	8 36.7	+13 46	127.99	-4.66	26
	72.01.16	-4.18	3.256	2.293	132	8 36.1	+13 50	127.84	-4.64	27
1362	71.11.20	-15.91	2.266	1.412	0.0081	5 28.8	-8 50	80.90	-32.04	28
		±0.01	±0.002	±0.002	±0.0001	±0.2	±1	±0.02	±0.02	

TABLE II. Comparison stars and quality of nights.

Ast. No.	Obs. date ET	R.A. 1950	Dec. 1950	V (mag)	B - V (mag)	Scatter of comp. readings (mag)	Remarks
1	70.10.10	2h 22m 4	+ 0° 30'	8.08	+1.07	±0.002	
4	74.06.08	12 34.2	+ 6 8	...	...	0.010	Windy and dusty
	74.06.09	12 34.6	+ 6 3	...	...	0.014	Seeing very bad
	72.02.06	11 2.4	+ 6 36	...	...	0.012	Not photometric, clouds
	74.08.08	20 42.1	-16 32	...	...	0.009	clouds early
16	74.08.10	20 40.3	-16 44	8.55	0.80	0.019	
	74.08.11	20 39.7	-16 35	9.61	1.22	0.001	
	74.08.12	20 38.6	-16 47	...	...	0.014	Stopped by clouds
	74.08.13	20 38.1	-16 55	9.03	1.50	0.011	Stopped by clouds
78	69.03.02	10 58.5	+ 3 36	10.89	0.73	0.011	Some clouds
	69.11.30	3 28.0	+24 36	14.20	0.84	0.034	Some clouds
	72.08.14	0 40.9	- 2 29	12.85	1.07	0.006	
281	72.08.16	0 40.9	- 2 29	12.85	1.07	0.008	
	72.09.01	0 37.1	- 2 45	13.18	0.84	0.017	Stopped by clouds
	74.04.13	12 29.4	- 0 12	12.06	0.58	0.003	
	74.04.14	12 28.5	- 0 9	11.18	0.61	0.002	
	69.12.30	6 54.2	+27 30	10.92	0.42	0.010	Cirrus
	69.12.31	6 53.9	+27 36	10.52	0.33	0.010	Windy
451	70.01.01	6 51.0	+27 39	10.60	0.64	0.011	
	74.12.23	4 4.1	+13 39	8.99	0.70	0.009	Stopped by clouds, windy
	74.12.24	4 3.1	+13 40	11.90	0.97	0.011	
1212	72.01.15	8 36.8	+13 47	11.58	0.63	0.008	Seeing poor
	72.01.16	8 36.1	+13 51	...	...	0.011	Stopped by clouds
1362	71.11.20	5 29.0	- 8 41	13.54	+0.99	±0.010	
		± 0.2	± 1	±0.02	±0.03		

TABLE III. Photometric observations of asteroids.

Ast. No.	Obs. date ET	$V_0(1,\alpha)$ (mag)	$B - V$ (mag)	$U - B$ (mag)	$V_0(1,0)$	Mean $V(1,0)$
1	70.10.10	3.91	+0.70	+0.40	3.70	3.72
	70.10.18	3.79	0.69	0.48		
16	74.08.10	6.20	0.75	0.28	6.1	6.4
	74.08.11	6.21	0.74	0.26		
	74.08.13	6.27	0.74	0.25		
78	69.03.02	8.31	0.71	0.37	8.2	8.3
	69.11.30	12.31:	1.03	0.37		
	69.12.13	12.59:	0.91	0.57		
281	72.08.14	12.69	0.91	0.28	12.14	12.31
	72.08.16	12.74	0.89	0.52		
	72.09.01	12.54	0.85	0.53		
	74.04.13	12.29	0.95	0.46		
	74.04.14	12.31	0.93	0.57		
	69.12.30	6.80	0.65	...		
	69.12.31	6.84	0.67	0.30		
451	70.01.01	6.80	0.66	0.32	7.0	7.0
	74.12.23	7.26	0.66	0.31		
	74.12.24	7.27	0.67	0.31		
1212	72.01.15	7.42	0.69	0.23	7.3	7.3
1362	71.11.20	11.95	+0.72	+0.36	11.6	11.7
		± 0.02	± 0.03	± 0.04		

the lack of an absolute calibration, of the Calder and Fichera observations (see the Legend of Fig. 2). We shall discuss the absolute magnitude further in Sec. II. The colors of Ceres are

$$B - V = +0.700 + 0.001 |\alpha|$$

and

$$U - B = +0.430 + 0.001 |\alpha|.$$

B. (4) Vesta

The lightcurves of Vesta in Fig. 3 were obtained to correlate with the infrared spectral observations of Larson and Fink (1975) who, incidentally, found no compositional variations over Vesta's surface.

We found an error in Taylor (1973) namely that the signs of the approximate aspect angles (first column of Table VI of Taylor 1973) should be the opposite of what was published. Fortunately, the error has no noticeable effect on the conclusions of that paper.

C. (16) Psyche

Van Houten-Groeneveld and van Houten (1958) established the period of Psyche to be $4^h 18^m 2 \pm 0^m 1$, which is corroborated by our Figs. 4-9. We have an additional lightcurve namely of 27 May 1973 but the comparison star appears to be variable.

Figure 10 shows the magnitudes and colors as a function of solar phase angle. Least-squares analysis, with half-weight given the 13 August observation because of a higher probable error in the UBV photometry for that night, yields

$$V_0(1,\alpha) = 6.14 + 0.021 |\alpha|.$$

This is a preliminary conclusion, for lack of data, and it is based on the unlikely assumption that there is no opposition effect. An opposition effect may well be present; additional data at different aspects could reveal an aspect variation in $V_0(1,\alpha)$ that might produce a steeper phase function as well as an opposition effect (this is discussed further in Sec. II). The colors of Psyche are

$$B - V = +0.760 - 0.005 |\alpha|$$

and

$$U - B = +0.260 - 0.001 |\alpha|.$$

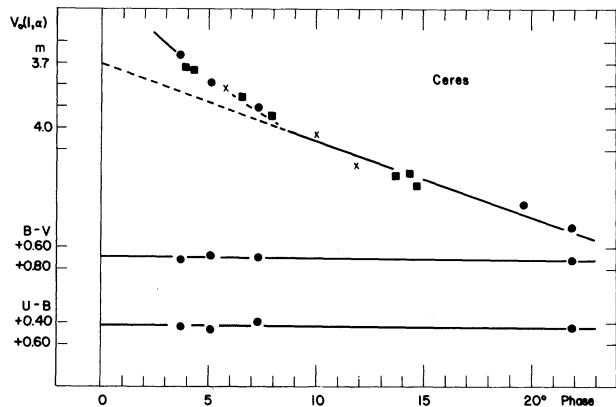


FIG. 2. Phase functions of (1) Ceres. The 1934 and 1935 results of Calder (1935) (squares) and the 1956 results of Fichera (1958) ("x" marks) have been arbitrarily shifted vertically to give a general best fit with the results (filled circles) of Groeneveld and Kuiper (1954), Ahmad (1954), and this paper.

FIG. 3. Composite lightcurve of (4) Vesta, observed by R. C. Taylor on 8 June and R. E. Sather on 9 June at the Kitt Peak 41-cm No. 4 telescope.

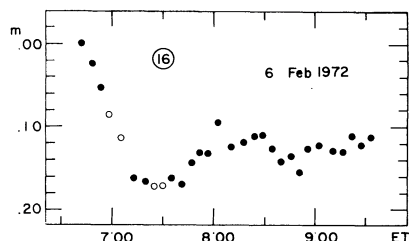
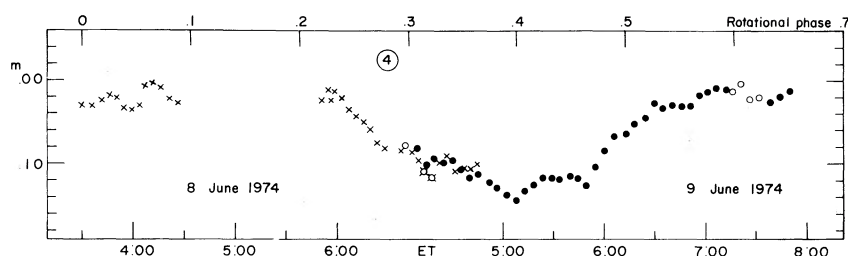


FIG. 4. Lightcurve of (16) Psyche, observed by M. L. Howes at the Kitt Peak 41-cm No. 3 telescope.

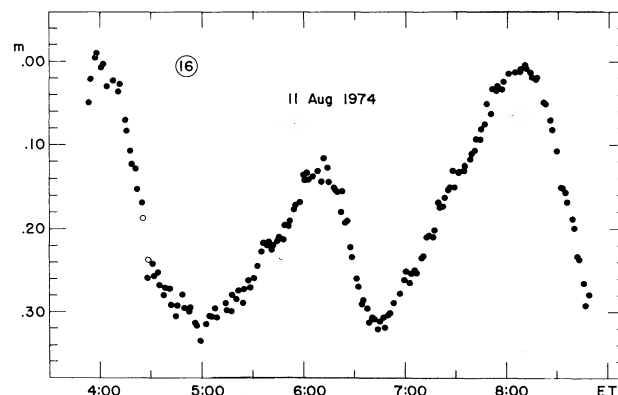


FIG. 7. Lightcurve of (16) Psyche, observed by R. C. Capen at the Kitt Peak 41-cm No. 3 telescope.

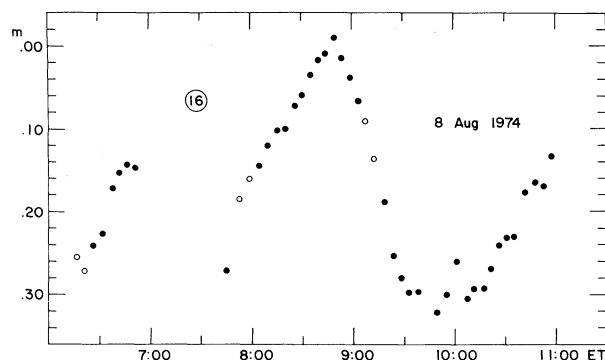


FIG. 5. Lightcurve of (16) Psyche, observed by R. C. Capen at the Kitt Peak 41-cm No. 3 telescope.

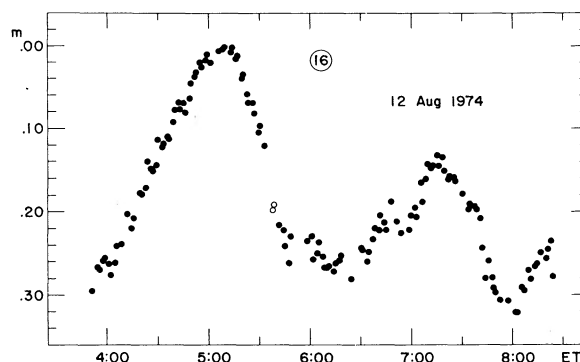


FIG. 8. Lightcurve of (16) Psyche, observed by R. C. Capen at the Kitt Peak 41-cm No. 3 telescope.

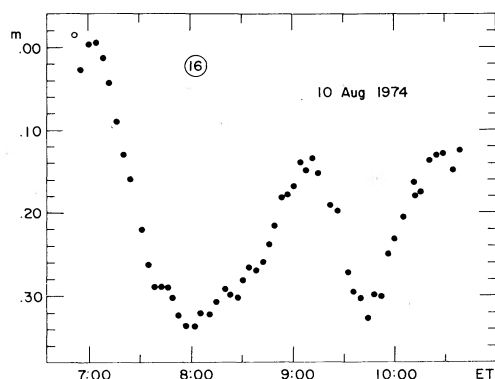


FIG. 6. Lightcurve of (16) Psyche, observed by R. C. Capen at the Kitt Peak 41-cm No. 3 telescope.

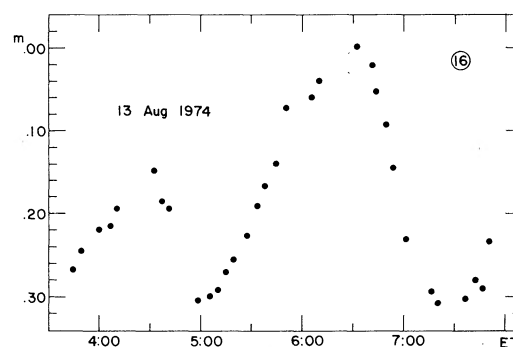


FIG. 9. Lightcurve of (16) Psyche, observed by R. C. Capen at the Kitt Peak 41-cm No. 3 telescope.

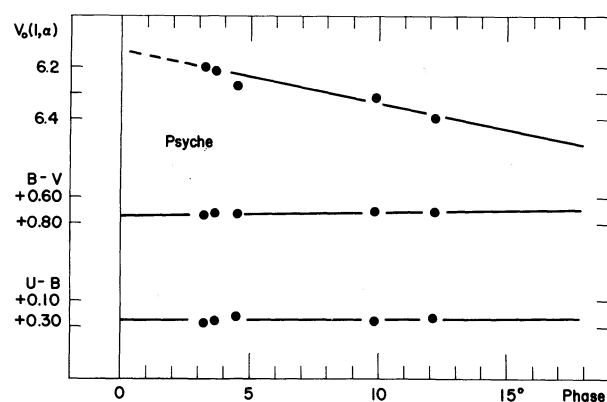


FIG. 10. Preliminary phase functions of (16) Psyche, assuming that there is no opposition effect.

D. (78) Diana

Figure 11 is our only lightcurve for Diana. Two distinct maxima are seen suggesting a period on the order of 8 h. Since the phase at opposition is well within the domain of the opposition effect, we assumed the shape of the phase curve of Diana to be similar to that of Massalia (see Sec. II) in order to determine the value of $V_0(1,0)$ of 8.2 mag.

E. (281) Lucretia

Figures 12–17 are lightcurves of Lucretia; another one, of 13 December 1969, is not included because the scatter of the comparison star is ± 0.04 mag while on a good night it is ± 0.005 mag; that lightcurve has three maxima, one being 0.2 mag brighter than the others, possibly due to the asteroid passing near a faint star.

Table IV contains the epochs of maximum light for the asteroid. A weighted average of the synodic periods (with weights proportional to the number of cycles) gives

$$P_{\text{syn}} = 0^{\text{d}}181\,16 \pm 0^{\text{d}}000\,05$$

or

$$4^{\text{h}}\,20^{\text{m}}87 \pm 0^{\text{m}}07 \text{ (p.e.).}$$

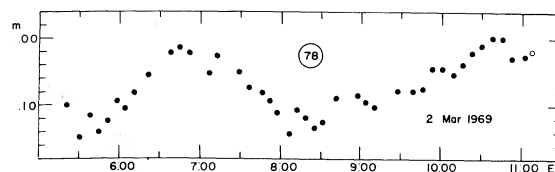


FIG. 11. Lightcurve of (78) Diana, observed by J. L. Dunlap at the Kitt Peak 41-cm No. 4 telescope.

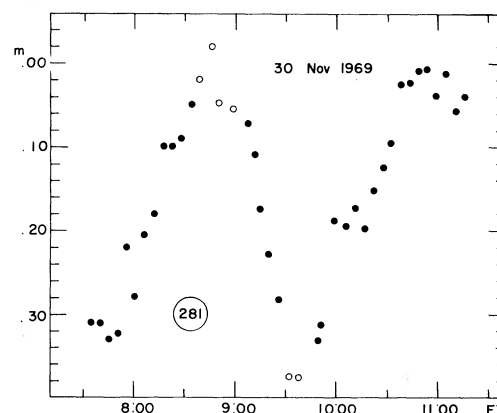


FIG. 12. Lightcurve of (281) Lucretia, observed by R. C. Taylor at the Kitt Peak 91-cm No. 2 telescope.

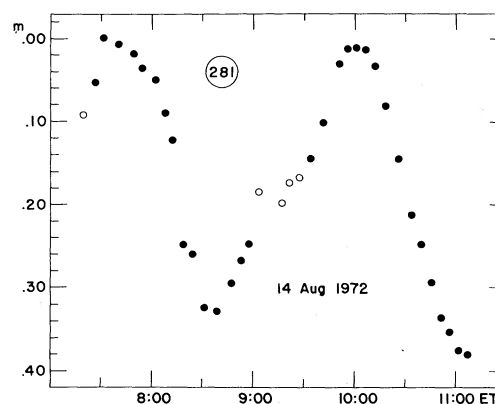


FIG. 13. Lightcurve of (281) Lucretia, observed by M. L. Howes at the Kitt Peak 127-cm telescope.

TABLE IV. Observed epochs and synodic periods for (281) Lucretia.

Obs. data ET	Observed ET	JD (c) 2440000+	Interval	Number of cycles	P_{syn}
72.08.14	10 ^h 00 ^m	1543 ^d 9098			
72.08.16	9 49	1545.9022	1 ^d 9924	11	0 ^d 181 127
72.09.01	8 33	1561.8502	15.9480	88	0.181 122
74.04.12	6 54	2149.7792			
74.04.13	9 00	2150.8667	1.0875	6	0.181 250
74.04.14	6 45	2151.7730	0.9063	5	0.181 260
	± 2	± 0.0014			

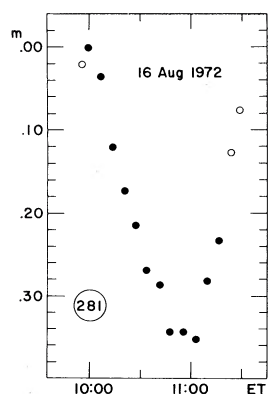


FIG. 14. Lightcurve of (281) Lucretia, observed by M. L. Howes at the Kitt Peak 127-cm telescope.

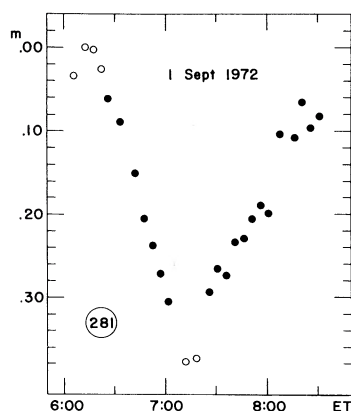


FIG. 15. Lightcurve of (281) Lucretia, observed by R. C. Taylor at the Kitt Peak 127-cm telescope.

Figure 18 shows the magnitudes and colors as a function of phase. Least-squares reductions were made with the three data points near 7° phase given half-weight as they may occur within the usual opposition effect. The results are

$$V_0(1, \alpha) = 12.14 + 0.028 |\alpha|.$$

The colors are

$$B - V = +0.970 - 0.005 |\alpha|$$

and

$$U - B = +0.500 + 0.002 |\alpha|.$$

Figures 19 and 20 are composite lightcurves for the 1972 and 1974 oppositions. The small amplitude variations between individual dates may be due to aspect changes or to differences in phase angle (such effects are reviewed in Sec. VI of Taylor 1973; also see Fig. 7 of Gehrels 1956). There is good qualitative agreement between Fig. 12 which is at 56° longitude, and the two composite lightcurves, which are at 8° and 186° longitude. We therefore conclude that the polar axis of Lucretia is nearly perpendicular to the ecliptic.

F. (451) Patientia

Figures 21–25 are lightcurves of Patientia; a 1-h lightcurve of 3 January 1970 is not included. We were unable to determine a period from the available data but estimate it to be on the order of 20 h.

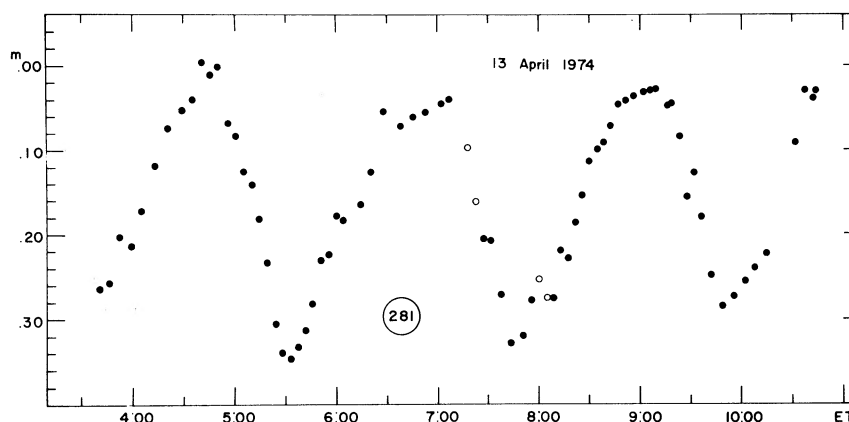
Our lightcurves have small amplitudes, 0.01 mag for both oppositions, indicating a spherical shape provided the observations were not near a polar aspect. A third lightcurve at an appreciably different ecliptic longitude should resolve the issue.

Assuming a phase coefficient of 0.023 mag/deg and the presence of an opposition effect, the absolute magnitude V_0 is 7.0 mag. The colors at 0° phase are $B - V = +0.66$ and $U - B = +0.30$.

G. (1212) Francette and (1362) Griqua

Figures 26 and 27, lightcurves of Francette, indicate that the period of rotation must be long, probably greater than 16 h. Figure 28, a lightcurve of Griqua, suggests the period may be about 13 h. The colors are given in Table III; the absolute magnitudes are computed with the phase factor of 0.023 mag/deg (see Sec. II).

FIG. 16. Lightcurve of (281) Lucretia, observed by R. C. Taylor at the Catalina 154-cm telescope.



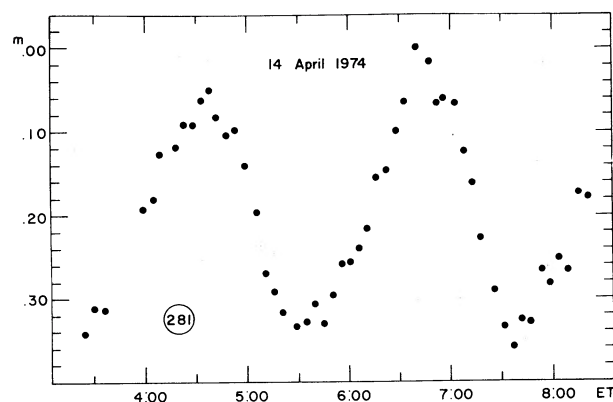


FIG. 17. Lightcurve of (281) Lucretia, observed by R. C. Taylor at the Catalina 154-cm telescope.

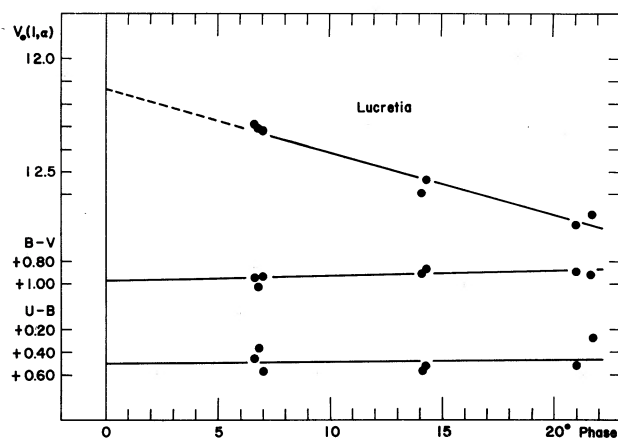


FIG. 18. Phase functions of (281) Lucretia.

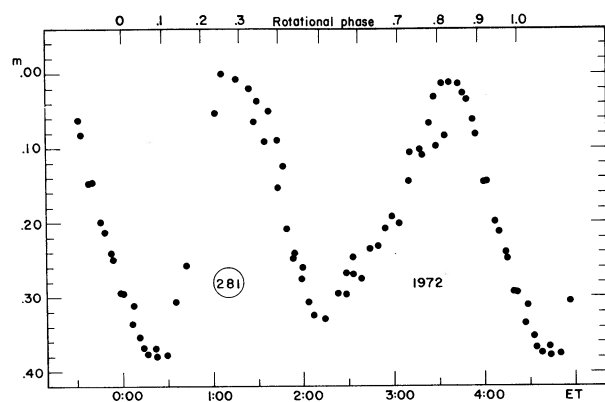


FIG. 19. A composite lightcurve of Figs. 13-15 with 2:03 ET of this figure corresponding to 7:00 ET on 1 September 1972.

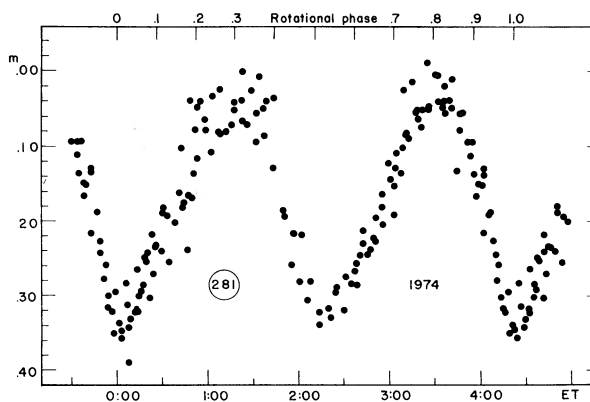


FIG. 20. A composite lightcurve of Figs. 16 and 17 with 2:30 ET of this figure corresponding to 8:00 ET on 13 April 1974.

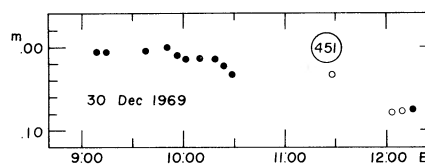


FIG. 21. Lightcurve of (451) Patientia, observed by F. Pilcher at the Kitt Peak 41-cm No. 3 telescope.

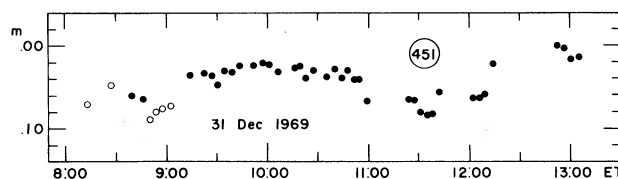


FIG. 22. Lightcurve of (451) Patientia, observed by R. G. Thomas at the Kitt Peak 41-cm No. 3 telescope.

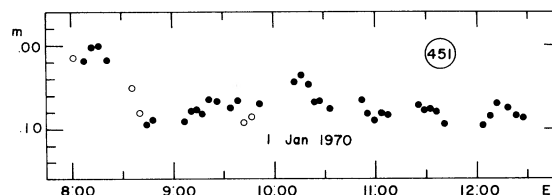


FIG. 23. Lightcurve of (451) Patientia, observed by R. G. Thomas at the Kitt Peak 41-cm No. 3 telescope.

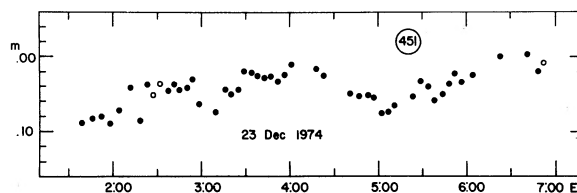
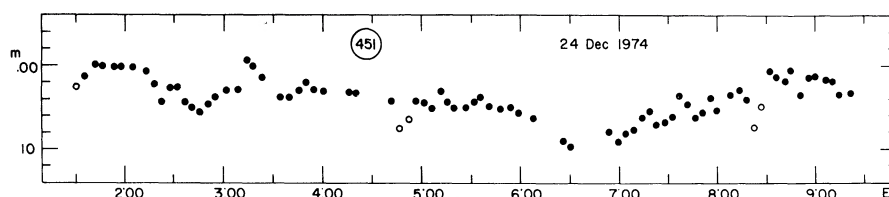


FIG. 24. Lightcurve of (451) Patientia, observed by R. C. Taylor at the Kitt Peak 41-cm No. 3 telescope.

FIG. 25. Lightcurve of (451) Pa-tientia, observed by R. C. Taylor at the Kitt Peak 41-cm No. 4 tele-scope.



II. THE DEFINITION OF ABSOLUTE MAGNITUDE

There is a new purpose to the determination of precise absolute magnitudes, namely as a part of the studies of asteroid sizes and reflectivities. Because of the uncertainty in the definition we now have the rather embarrassing situation that the absolute magnitude is not precisely known even for Ceres, the largest of the asteroids, while its reflectivity should be precisely established to verify the indication of its composition, probably that of a "C" type, the carbonaceous type of asteroid. We also have basic calibration problems with another interesting asteroid, (16) Psyche, for which there are spectroscopic indications that it may have a metal-rich enstatite surface. Figure 10 indicates that this may be the only one of the asteroids for which no opposition effect has been found which, if true, would be an interesting confirmation of Psyche being a metallic object. For the time being, however, we would believe that Psyche indeed does have an opposition effect and we rather think that changes in aspect and uncertainty in the definition of phase relation and absolute magnitude should explain Fig. 10.

The results on (1) Ceres in Sec. I illustrate the problem of the definition of absolute magnitude. Ahmad (1954) did not know about opposition effects, as they had not been discovered at that time, and he put a straight line through all the observations, that were rather poor at that; the result was $V(1,0) = 3.37$. The opposition effect was first discovered on (20) Massalia (Gehrels 1956) and since then it has been established for other asteroids, the Moon, and indeed for almost every solid object in the solar system. We now have four asteroids for which the opposition effect is closely the same: (1) Ceres, (4) Vesta, (20) Massalia, and (110) Lydia [see the present Fig. 2 and also Fig. 13 of Taylor *et al.*

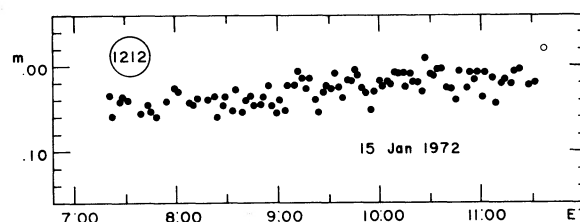


FIG. 26. Lightcurve of (1212) Francette, observed by T. Gehrels at the Catalina 154-cm telescope.

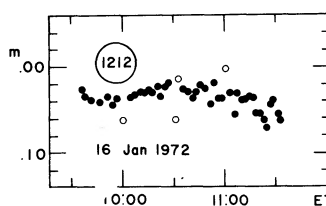
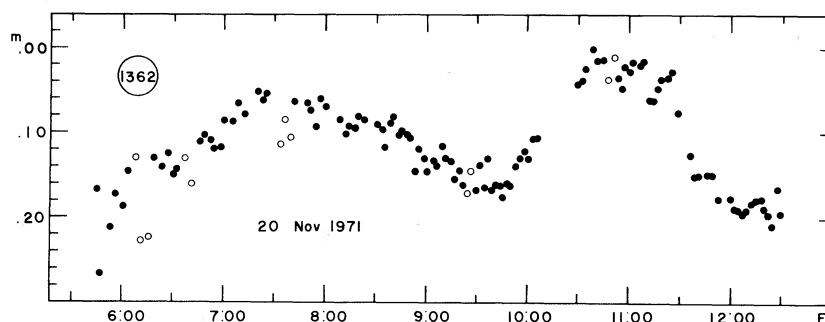


FIG. 27. Lightcurve of (1212) Francette, observed by T. Gehrels at the Catalina 154-cm telescope.

(1971)]. Whereas Ahmad's observations were at large phase angles ($\geq 18^\circ$), so that the phase corrections are important, Gehrels and Owings (1962) observed at 3.7° phase and they did use an opposition effect, namely the one of Massalia; the result was $V(1,0) = 3.71$. In this paper, the observations are near 5° and 7° phase, and the reductions take an opposition effect into account; the result is $V(1,0) = 3.72$.

In addition to the opposition effect, which may not be the same for all asteroids, there is the uncertainty in the slope of the linear part of the phase curve, i.e., in the phase factor. A "standard phase correction" was established by Gehrels (1957), namely with the Massalia opposition effect and a phase factor of 0.023 mag/deg; this was based on the photoelectric observations for

FIG. 28. Lightcurve of (1362) Griqua, observed by T. Gehrels at the Catalina 154-cm telescope.



Massalia and on photographic observations of 112 asteroids. The weakest link in the derivation of absolute magnitude, especially from observations at phase angles larger than $\sim 10^\circ$, may well be in the adopted phase factor, and we can illustrate this with another example for (1) Ceres namely in the observations recently made by Bowell (personal communication 1976). Bowell made photoelectric observations near 8° phase angle, late 1975, and he used the standard phase correction, rather than the one of the present Fig. 2; the result was $V(1,0) = 3.85$. Had Bowell known about the present phase factor of 0.036 mag/deg and used it instead of the adopted 0.023 value (this, incidentally, would have been contrary to our agreements, see below), the result would have been $V(1,0) = 3.74$.

The corrections to absolute magnitude are further made uncertain by the changes in aspect, i.e., the changes in the angle between the line of sight and the rotation axis. As mentioned before, we suspect that Psyche's phase relation of Fig. 10 is affected by such aspect variation, especially because Psyche has appreciable rotational variation which indicates an irregularly shaped body. The classical paper on these effects was written by Sather (1976) who, for a similarly irregular body namely that of (39) Laetitia, used the effects of aspect variation upon the phase function in order to determine the orientation of the rotation axis in space. Another interesting example is that of (4) Vesta where the absolute magnitude $V(1,0) = 3.47$ and the phase factor is 0.0253 mag/deg if the pole is at ecliptic latitude $+65^\circ$ and longitude 126° , but 3.57 and 0.023 for $+47^\circ$, 139° , and 3.55, 0.024 for $+39^\circ$, 333° .

For individual studies of phase effects the observations are costly as they have to be made carefully over a wide range of phase angles and particularly at the time near opposition when the brightness changes fast as well as the position in the sky (most asteroids usually do not come close to 0° phase because of their appreciable inclination). The paper of Sather (1976) showed conclusively that for the phase relation the maximum of the lightcurve, V_0 , must be used rather than "Mean V " since the latter will have aspect dependence—the amount depending on the amplitude and shape of the lightcurve—which introduces scatter into the phase function. V_0 may or may not have aspect dependence; if not, the shape of the phase function will be smooth and one can infer that the overall shape is that of a two-axis ellipsoid. If V_0 does have aspect dependence, this will also intro-

duce scatter in the phase function which may be removed by assuming that the shape is near that of a three-axis ellipsoid.

For cataloging mean asteroid magnitudes we propose to continue the usage of the "standard phase correction," that is with the Massalia/Ceres/Vesta/Lydia opposition effect and 0.023 mag/deg for phase factor. This continued agreement will avoid confusion in derivation of the absolute magnitude and the subsequent usage of that absolute magnitude to predict an apparent magnitude at a certain phase angle. The cataloging of the absolute magnitudes for the asteroids is further discussed by Gehrels and Gehrels (1977).

For certain statistical studies, however, it may be necessary to take the wavelength dependence of the phase factor into account, and to use phase factors larger than 0.023. Van Houten *et al.* (1970) found for the faint asteroids of the Palomar-Leiden Survey that the opposition effect is about the same as that of Massalia, but that the phase factor is ~ 0.039 mag/deg. Bowell (1976, personal communication) finds a systematic difference between the mean phase factors of "C" and "S" asteroids.

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