

Minor planets and related objects. XXIII. Photometry of asteroid (7) Iris

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Analysis of lightcurves and *UBV* photometry yields a model for (7) Iris as an ellipsoid with axial ratios 3:4:5. The North Pole orientation is near 41° ecliptic latitude and 11° longitude.

INTRODUCTION

SINCE 1950, asteroid (7) Iris has been observed photoelectrically. Groeneveld and Kuiper (1954) concluded on the basis of five lightcurves that the synodic period of rotation of Iris is $7^h 07^m 5 \pm 2^m$. Van Houten-Groeneveld and van Houten (1958), with five additional lightcurves, improved the period to $7^h 08^m 1 \pm 0^m 15$. They also concluded that the pole of Iris is "... considerably inclined toward the plane of the ecliptic." That statement was endorsed by Gehrels and Owings (1962) on the basis of a near-pole-on lightcurve with only a 0.04-mag amplitude (previously observed amplitudes were ~ 0.3 mag). Gehrels and Owings determined the ecliptic longitude of the pole to be $193^\circ \pm 3^\circ$, but they were not certain whether that was the north or south pole of Iris. Chang and Chia-Shiang (1963) stated that their two additional lightcurves confirmed the pole of Gehrels and Owings at 193° ecliptic longitude.

A review of previous photometry by Taylor (1971) gives the values $V(1,0) = 6.01$, $B - V = +0.83$, and $U - B = +0.45$, with a range of lightcurve amplitudes from 0.04 to 0.29 mag over 52 lightcurve hours.

The present paper supplies seven lightcurves (Figs. 1-7) of Iris from two apparitions. The pole and phase analyses are redone.

I. THE OBSERVATIONS

The observations were made at the Kitt Peak National Observatory and the Steward Observatory, both located on Kitt Peak near Tucson, Arizona. The observers and telescopes are acknowledged in the captions of Figs. 1-7. The lightcurves of 15 and 16 December 1973 (Figs. 4 and 5) were observed with the *y* filter of the Strömgren system, which closely approximates the *V* filter of the *UBV* system used on the other nights.

Table I gives the aspect data and Table II lists the comparison stars and quality of each night. Probable errors are used throughout this paper. Table III lists

photometry results for 13 June 1968. The mean values are $V_0(1,\alpha) = 6.12 \pm 0.03$, $B - V = +0.83 \pm 0.01$, and $U - B = +0.56 \pm 0.01$. *UBV* photometry was attempted on the other nights but the results are unreliable due to either observer error or instrument failure.

II. PHOTOMETRIC ANALYSIS

Our lightcurves appear to support the $7^h 8^m 1$ synodic period of van Houten-Groeneveld and van Houten (1958). The upper curve of Fig. 8 is a plot of $\bar{V}$ magnitudes of Iris as a function of phase. The $\bar{V}$ magnitudes have been corrected to the maximum of the lightcurve for that night and to unit distance from Sun and Earth. The data for the plot are listed on the left side of Table

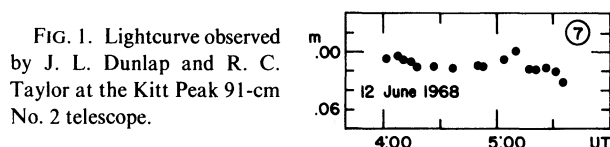


FIG. 1. Lightcurve observed by J. L. Dunlap and R. C. Taylor at the Kitt Peak 91-cm No. 2 telescope.

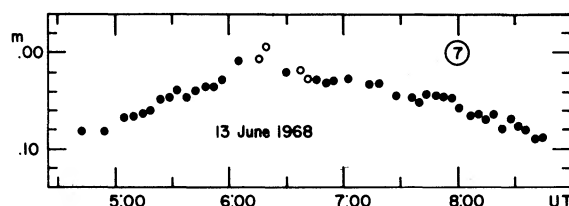


FIG. 2. Same as for Fig. 1.

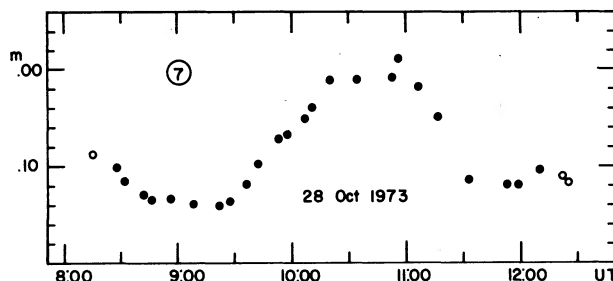


FIG. 3. Lightcurve observed by J. L. Dunlap at the Steward 51-cm telescope.

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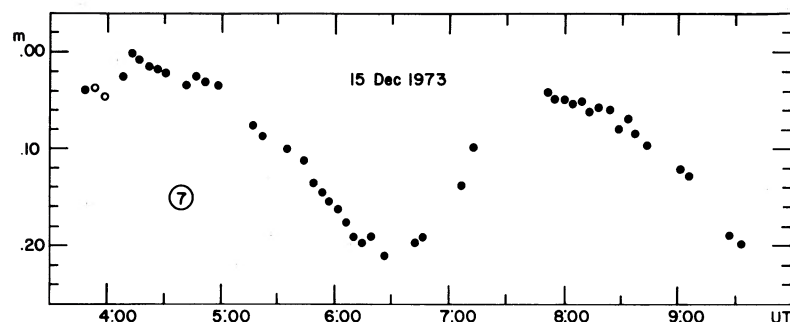


FIG. 4. Lightcurve observed by R. C. Taylor at the Kitt Peak 41-cm No. 4 telescope.

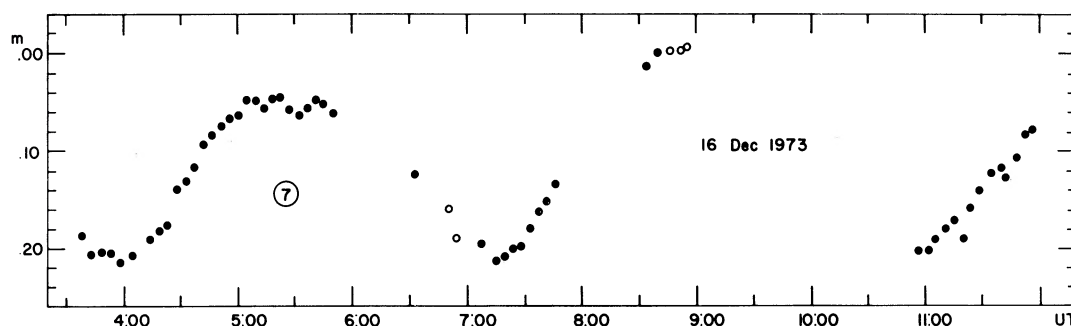


FIG. 5. Same as for Fig. 4.

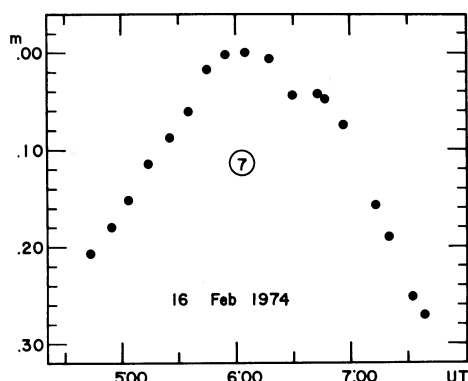


FIG. 6. Lightcurve observed by R. C. Capen at the Steward 51-cm telescope.

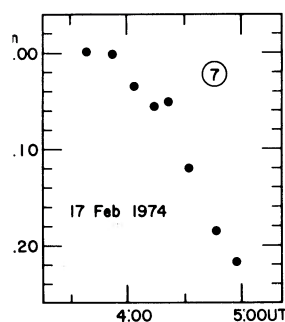


FIG. 7. Same as for Fig. 6.

IV. The scatter in the phase function indicates that V_0 has aspect dependence (Sather 1976). The scatter is removed in the lower curve of Fig. 8 by assuming the shape of Iris to be a three-axis ellipsoid (Taylor *et al.* 1976); the procedure will be described in the following paragraph. $V_0(1,0,90)$ is the visual magnitude corrected to equatorial, i.e., 90° , aspect. The phase coefficient of Iris is 0.029 ± 0.001 mag/degree of phase, and the absolute magnitude $V_0(1,0) = 5.97 \pm 0.01$.

Two criteria were established to determine the shape of the three-axis ellipsoid and the orientation of the north pole. The *first criterion* is the above, where the magnitudes corrected for aspect, using the method described by Sather (1976), must lie on the average within ± 0.02 mag (double the probable error of the photometry) of the

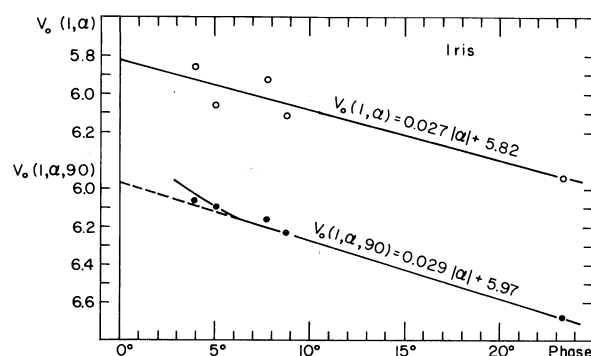


FIG. 8. Phase functions of Iris. Upper part is for data uncorrected for aspect. Lower curve is after correction to equatorial aspect.

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TABLE I. Aspect data for Iris.

Obs. date (UT)	Phase angle	Distance from Sun (AU)	Distance from Earth (AU)	Light time	R.A. (1950)	Dec. (1950)	Ecliptic Long. (1950)	Lat. (1950)	Fig.
68.06.12	+8°23	2.877	1.919	0 ^d 0111	15 ^h 35 ^m 7	-21°26'	236°74	-2°03	1
68.06.13	+8.79	2.876	1.927	0.0111	15 34.7	-21 21	236.49	-2.03	2
73.10.28	-29.10	1.882	1.258	0.0073	6 50.5	+24 0	101.52	+1.05	3
73.12.15	-8.73	1.960	1.000	0.0058	6 44.1	+20 47	100.31	-2.27	4
73.12.16	-8.22	1.963	0.999	0.0058	6 43.1	+20 45	100.08	-2.32	5
74.02.16	+22.79	2.103	1.380	0.0080	6 6.0	+18 39	91.43	-4.79	6
74.02.17	+23.01	2.105	1.391	0.0080	6 6.4	+18 39	91.52	-4.79	7
	±0.01	±0.002	±0.002	±0.0001	±0.2	±1	±0.02	±0.02	

TABLE II. Comparison stars and quality of nights.

Obs. date (UT)	R.A. (1950)	Dec. (1950)	Scatter of comp. readings (mag)	Remarks
68.06.12	15 ^h 35 ^m 8	-21°26'	±0.002	
68.06.13	15 34.5	-21 14	±0.009	$V = 9.27, B - V = +1.07$
73.10.28	6 50.5	+24 00	±0.011	
73.12.15	6 43.6	+20 31	±0.001	Passing star at 7:30 UT
73.12.16	6 43.1	+20 45	±0.013	Occasional cirrus
74.02.16	6 6.0	+18 39	±0.008	Haze
74.02.17	6 6.4	+18 39	±0.008	Stopped by clouds
	±0.2	±1		

TABLE III. Photometry of 13 June 1968 for Iris.

UT	V (mag)	B - V (mag)	U - B (mag)	$V_0(1, \alpha)$ (mag)
4 ^h 26 ^m	9.98	+0.82	+0.54	6.18
4 55	9.87	+0.82	+0.54	6.08
6 05	9.81	+0.83	0.57	6.08
6 30	9.85	+0.84	+0.58	6.11
7 03	9.87	+0.84	0.56	6.12
7 28	9.91	+0.84	+0.56	6.14
	±0.03	±0.01	±0.01	±0.03

pole solution at 193° was the north or south pole, is now answered: It is the south pole.

The *second criterion* deals with amplitudes. For each three-axis ellipsoid and selected pole orientation, the model will produce an amplitude based on the function

$$\text{Amplitude} = 2.5 \log \left(\frac{a \sqrt{b^2 \cos^2 \xi + \sin^2 \xi}}{b \sqrt{a^2 \cos^2 \xi + \sin^2 \xi}} \right),$$

where the axes $a > b > c = 1$, and ξ is the aspect angle

mean relation at less than 8° phase for the five asteroids in Fig. 29 of Gehrels and Taylor (1977). The enclosed area of Fig. 9 represents the region where Iris' north pole could be located according to the first criterion. The question of Gehrels and Owings (1962), whether their

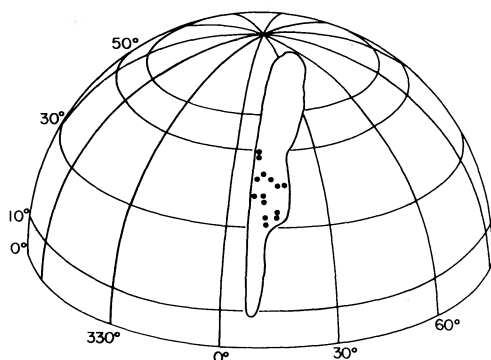


FIG. 9. Location of pole solutions from magnitude-phase relation (enclosed region) and amplitude-aspect relation (points). The scales are in ecliptic coordinates.

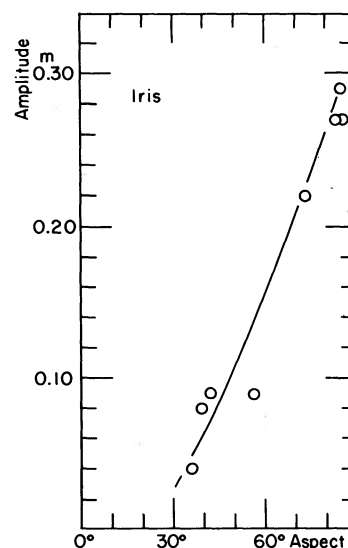


FIG. 10. The amplitude-aspect relation for the adopted model of Iris. The circles are observed amplitudes, the line is for calculated amplitudes ($\lambda_0 = 11^\circ$, $\beta_0 = +41^\circ$).

TABLE IV. Data for pole analysis.

Obs. date (UT)	$V_0(1,\alpha)$	Phase angle	Observed amplitude (mag)	Aspect ^a	Reference
50.08.12	...	+17°8	0.29	+85°	Groeneveld and Kuiper (1954)
52.01.28	6.06	+5.1	0.22	+73	Groeneveld and Kuiper (1954)
56.01.02	6.44	-23.4	0.08	+39	van Houten-Groeneveld and van Houten (1958)
56.03.08	5.86 ^b	+4.0	0.09 ^b	+42	van Houten-Groeneveld and van Houten (1958)
58.11.05	5.93	+7.8	0.04	-36	Gehrels and Owings (1962)
63.02.02	...	+12.6	0.27	+83	Chang and Chia-Shiang (1963)
68.06.13	6.12	+8.8	0.09	+56	This paper
73.12.15	...	-8.5	0.21	+89	This paper
74.02.16	...	+22.9	0.27	+86	This paper

^a Positive aspect (the angle between the line of sight and the rotation axis) is from the north pole.

^b The maximum of the Iris lightcurve was not observed; a 0.04-mag correction to V_0 was applied.

(the angle between the line of sight and the rotational axis). The second criterion is that the observed amplitudes be in agreement with the model amplitudes. The 14 points on Fig. 9 are the pole locations, within the bounds of the first criterion, with the smallest mean residual of observed and model amplitudes, namely ± 0.02 mag. It is a bit surprising that the precision is not better; the seven lightcurves of this paper have a mean scatter of ± 0.006 mag so the amplitude should be accurate to ± 0.01 mag. The reason for the rather poor agreement between observed and model amplitudes may be that Iris is not a perfect three-axis ellipsoid or that the phase angle differences are affecting the amplitudes (see Sec. II of Gehrels and Taylor).

The adopted solution is the mean of the 14 best agreements, namely:

$$\begin{aligned} \text{north pole longitude} & 11^\circ \pm 2^\circ, \\ \text{north pole latitude} & +41^\circ \pm 4^\circ, \\ \text{ratio of axes} & a = 1.77 \pm 0.05, \\ & b = 1.35 \pm 0.05, \\ & c = 1. \end{aligned}$$

Figure 10 shows the amplitude-aspect relation of the adopted model-pole solution (solid line) compared with the observed amplitudes for the same pole orientation (circles). The data for that plot are listed in Table IV. I can not get a better fit for the reasons stated above.

III. CONCLUDING REMARKS

Previously published conclusions concerning the orientation of the pole have been further confirmed. The

latitude of the pole is intermediate between 0° and 90° . A three-axis ellipsoid model provides an absolute magnitude, a phase coefficient, and axial ratios. Additional *UBV* photometry is needed to firm up the phase relation. I suspect reddening with phase in $U - B$, for which I presently adopt $U - B = +0.58$ at $\sim 5^\circ$ phase angle. Additional lightcurve observations should be made near equatorial aspect in an effort to determine why there are varying amplitudes in that region.

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REFERENCES

- Chang, Y. C., and Chia-Shiang, C. (1963). *Acta Astron. Sinica* **11**, 149.
 Gehrels, T., and Owings, D. (1962). *Astrophys. J.* **135**, 906.
 Gehrels, T., and Taylor, R. C. (1977). *Astron. J.* **82**, 229 (Paper XXII).
 Groeneveld, I., and Kuiper, G. P. (1954). *Astrophys. J.* **120**, 529.
 Sather, R. E. (1976). *Astron. J.* **81**, 67 (Paper XIX).
 Taylor, R. C. (1971). *Physical Studies of Minor Planets*, edited by T. Gehrels (U.S. GPO, Washington, DC), NASA-SP 267, p. 117.
 Taylor, R. C., Gehrels, T., and Capen, R. C. (1976). *Astron. J.* **81**, 778 (Paper XXI).
 van Houten-Groeneveld, I., and van Houten, C. J. (1958). *Astrophys. J.* **127**, 253.

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