THREE-COLOUR PHOTOMETRY OF TW CAS

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Abstract. Photoelectric elements of the system TW Cas have been determined in *U*, *B* and *V* filters. A refined period of $1^{\mathrm{d}}.428\,324\,77$ has been given though no change in period is noticed. Spectroscopic elements given by Struve have been used to get the absolute elements. The system is found to be a detached one.

1. Introduction

The eclipsing system TW Cas (BD+65°289=HD 16 907) was first discovered by Miss Leavitt (1907) and has since been widely observed. Zinner (1912, 1913) from his earlier observations assessed it as an irregular variable but later classed it as an Algol system and was the first to assign the correct period of $1^{\mathrm{d}}10^{\mathrm{h}}16^{\mathrm{m}}.7$ ($=1^{\mathrm{d}}.428$) which was later supported by the radial velocity observations of Struve (1950). Plaut (1950) derived the orbital elements based on the light curves obtained by McDiarmid (1915) but using a period of $1^{\mathrm{d}}.428$, which indicates the primary eclipse to be a transit. Huffer (1951) found the depth of secondary minimum to be $0^{\mathrm{m}}.07$ and believed the primary eclipse to be annular, but gave no photometric elements. McCook (1971) observed this system in *B* and *V* filters and obtained elements which indicate that the primary eclipse is a partial occultation, which is at variance with the findings of Plaut and of Huffer.

2. Observations

Photoelectric observations have been made on 14 nights during the years 1968 to 1970 with the 38 cm and the 56 cm reflectors, through the standard *U*, *B* and *V* filters. An unrefrigerated 1P21 photomultiplier and standard d.c. techniques were employed. The comparison star used is BD+65°291. The probable error of observations determined for three randomly chosen nights falls in the range $0^{\mathrm{m}}.001$–$0^{\mathrm{m}}.008$.

All the observations have been reduced to the standard *U*, *B*, *V* magnitudes of the Johnson and Morgan System by observing 13 standard stars (Johnson *et al.*, 1966). In all, 346 observations in *U*, 372 in *B* and 369 in *V* have been obtained.

3. Light Curve and Period

The light curves given in Figure 1 do not show any reflection and ellipticity effect while the *V* light curve given by McCook (1971) clearly shows these effects. The depths

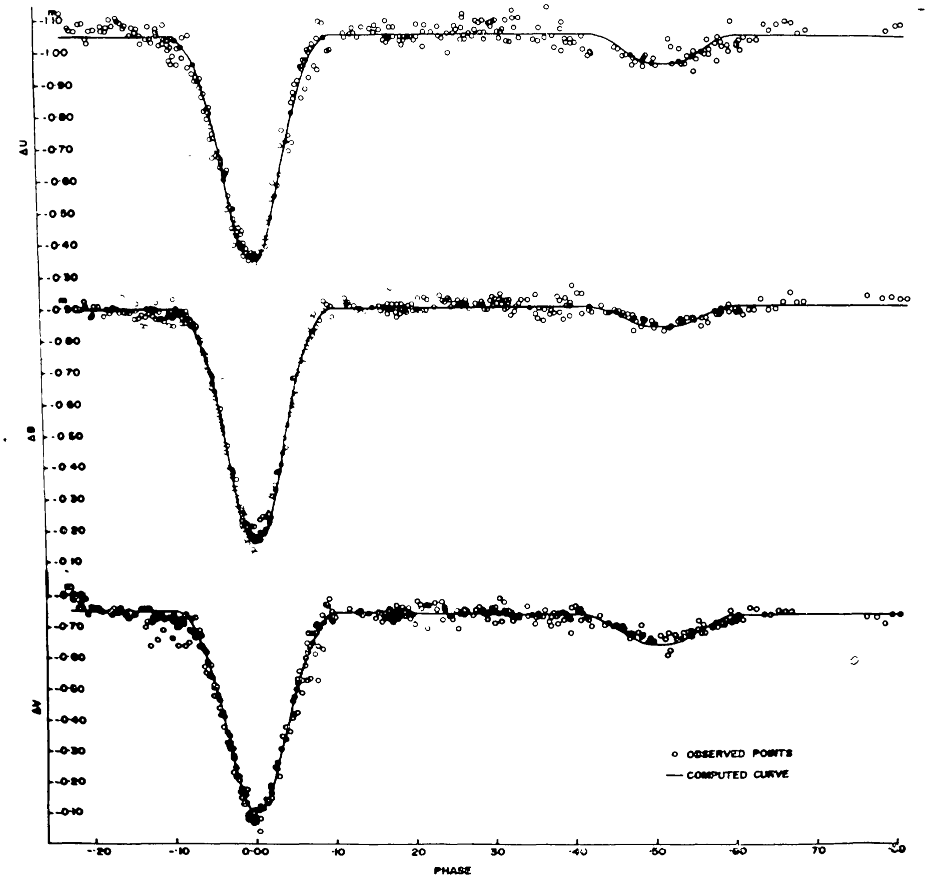

Fig. 1. Light curve of TW Cas.

of primary and secondary minima are:

	U	B	V
Primary min.	$0^m.693$	$0^m.725$	$0^m.649$
Secondary min.	$0^m.095$	$0^m.065$	$0^m.075$

The secondary minimum falls at phase $0^p.5$

The period of the system has been thought to be irregular by some observers (Munch, 1909) and a change in period has been suspected by others (McCook, 1971). However, the period of $1^d.428\,324\,77$ determined from our times of minima (Table I) satisfies

TABLE I

Times of primary minima

(i)	JD 2 440 184.419
(ii)	207.270
(iii)	907.148
(iv)	914.291

most of the minima reported in the literature and we do not suspect that the period of the system has been changing. The (O–C) of 39 minima have been plotted (Figure 2) taking the values of period as $1\overset{\mathrm{d}}{.}428\,328$ (used by Struve) and $1\overset{\mathrm{d}}{.}428\,324\,77$ (our refined period). The former shows systematically negative values of (O–C). The large scatter for some of the observations may perhaps be due to incorrect times of minima. Our observations are best represented by

$$\text{Primary min.} = \text{JD } 2\,419\,823.647 + 1\overset{\mathrm{d}}{.}428\,324\,77\ E.$$
$$\pm\, 0.000\,000\,04$$

4. Orbital Elements

The elements have been determined for the observations in all the three filters. As the observations between the eclipses do not show any variation of light, no rectification was felt necessary. A solution for the elements was first tried by nomographic method assuming the primary eclipse as a partial transit and then as a partial occultation. A solution could not be obtained in either case even after taking different values for the limb darkening coefficient. The nomograms, however, pointed towards a situation in which the primary eclipse was perhaps annular. Therefore, the R/M method given by Russell and Merrill (1952) was used. The solution satisfactorily represents the

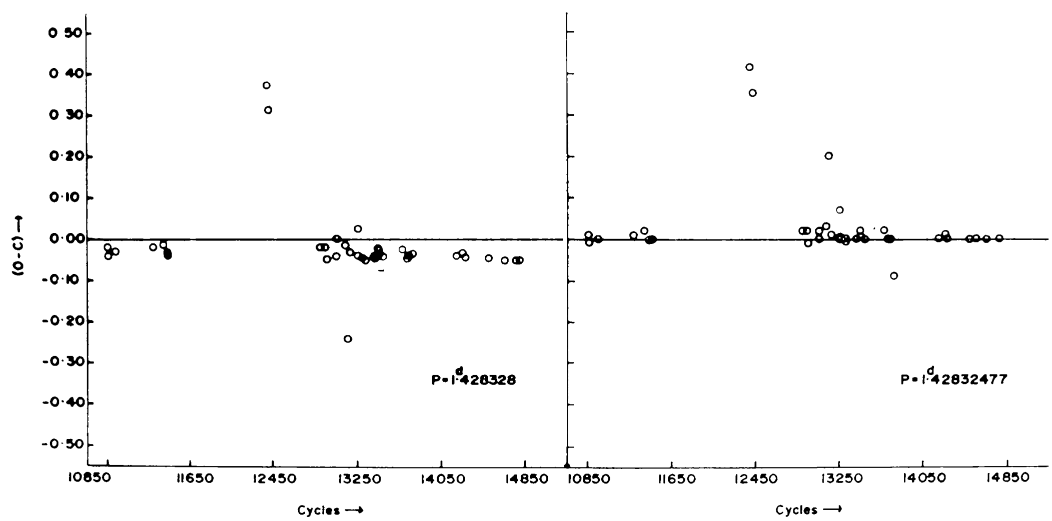

Fig. 2. Period study of TW Cas.

primary and secondary minimum observations in the U and B filters. However the solution in V gives a good fit for the corresponding primary minimum observations only (Figure 2). The elements arrived at are listed in Table II.

By use of the spectroscopic elements

$$f(m) = 0.098\,_{\odot}, \qquad A \sin i = 1.7 \times 10^{6}\ \text{km},$$

TABLE II

Orbital elements

Geometric (Mean for U, B and V Filters)		Photometric			
			U	B	V
k	0.66	x_{tr}	0.5	0.6	0.6
r_g	0.338	1–10 oc	0.472	0.487	0.450
r_s	0.224	1–10 tr	0.084	0.058	0.084
θ_e	34°.1	α_0	1.065	1.05	1.06
θ_i	6°.0	L_g	0.916	0.942	0.916
i	87°.5	L_s	0.084	0.058	0.084

TABLE III

Absolute elements

m_1	4.1 $M_\odot$
m_2	1.4 $M_\odot$
R_1	3.1 $R_\odot$
R_2	2.1 $R_\odot$
A	9.4 $R_\odot$
M_1 (bol)	$-1^m.115$
M_2 (bol)	$+3^m.050$

given by Struve (1950), the absolute elements have been derived. These are given in Table III.

The Roche constants for equipotential surfaces are

$C_0 = 3.88$ (adopted from Kopal, 1959, for the case $m_2/m_1 = 0.35$),
$C_1 = 5.12$,
$C_2 = 4.44$.

Since $C_1/C_2 = 1.15$ (i.e., close to 1), the system is a detached one.

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References

Huffer, C. M.: 1951, *Astron. J.* **56**, 42.

Johnson, H. L., Mitchell, R. I., Iriarte, B., and Wisniewski, W. Z.: 1966, *Lunar and Planetary Laboratory, Commun.* No. **63**.

Kopal, Z.: 1959, *Close Binary Systems*, Chapman & Hall, London.
Leavitt, H. S.: 1907, *Harvard Circ.* **127**, 4.
McCook, G. P.: 1971, *Astron. J.* **76**, 449.
McDiarmid, R. J.: 1915, *Astrophys. J.* **42**, 412.
Munch, W.: 1909, *Astron. Nachr.* **182**, 113.
Plaut, L.: 1950, *Groningen Publ.* **54**, 16.
Russell, H. N. and Merrill, J. E.: 1952, *Princeton Contr.* No. **26**.
Struve, O.: 1950, *Astrophys. J.* **112**, 184.
Zinner, E.: 1912, *Astron. Nachr.* **190**, 377.
Zinner, E.: 1913, *Astron. Nachr.* **195**, 453.