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LIGHT-CURVES AND ELEMENTS OF THE ECLIPSING BINARY TU CAM

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457 observations in B and 465 observations in V of TU Cam have been obtained during four seasons by means of the 10-inch reflecting telescope of the Brorfelde Observatory. Two comparison stars, ξ Aur and 30 Cam, were used simultaneously and minor night-to-night fluctuations were found in their magnitude difference. A new photometric ephemeris based on five earlier minima and one minimum from this investigation is given. The visual magnitudes and (B - V)-values of the variable and the comparison stars have been reduced to the standard system. The light-curves are slightly unstable, and obviously an additional source of light, probably gas between the components, is present. In disagreement with the values of ω and e, given by spectral investigators, no shift of the secondary minimum is found. A set of elements has been computed, that fits both minima in both colours reasonably well.

The primary minimum is due to an annular eclipse of the brightest component. The magnitude differences between TU Cam A and TU Cam B are $3^{m}.4$ and $3^{m}.1$ in B and V, respectively. Thus the mass ratio, determined from two early Yerkes plates which are believed to show double lines, must be considered as unreliable. From the (B - V)-value the spectral type of TU Cam B is around F0.

1. INTRODUCTION

31 Cam (= TU Cam = HR 2027 = Boss 1452 = BD + 59°920 = HD 39220) was discovered as a spectroscopic binary with single lines by Plaskett (1920). Harper (1924) carried through the first spectroscopic analysis on the basis of six plates from December 1918 - February 1919 (dispersion 35 A/mm at Hγ) and 19 plates from the season 1922-23 (29 A/mm at Hγ), all exposed at a one-prism spectrograph attached to the 72-inch reflecting telescope of the Dominion Observatory in Victoria.

The star was also observed at the Lick Observatory (Campbell, 1922), four plates were measured (dispersion 10.9 A/mm at 4500 A) and radial velocities were published by Campbell and Moore (1928). These plates were all believed to show double lines. Of five plates, taken at the Yerkes Observatory between December 1913 and December 1921 (dispersion 30 A/mm at 4500 A), three showed double lines (Frost et al., 1929). However, it was not possible to distinguish any double lines on the plates taken at Victoria. Harper (1935) discussed this apparent discrepancy and concluded that on the Lick plates the effect was very probably due to central reversals in the broad lines. Furthermore, one of the Yerkes plates had to be considered as unreliable for the second component. Thus only two Yerkes plates remained, showing double lines.

Luyten (1936) recomputed the spectroscopic elements by application of the Wilsing-Russell method to Harper's material. Mannino (1954) took 18 plates with the Asiago 120-cm reflecting telescope from February 1951 to January 1954 (dispersion 42 A/mm at Hγ) and based the orbital solution on these and Harper's plates. It was not possible to represent the Asiago and the Victoria values of the radial velocity with a single value of the mean radial velocity (γ), and separate values must be computed. Mannino then found γ (Asiago) = + 11.92 km/sec and γ (Victoria) = - 3.26 km/sec. No double lines were seen on the Asiago plates.

The mass ratio was derived in an empirical way by Colacevich (1938) utilizing the parallax $0''.015$, which was determined by Abetti (1924, 1925); it was found to be 0.33. The two Yerkes plates give 0.36.

Stebbins (1928) discovered that 31 Cam was an eclipsing variable, and he states: "A star .... not previously announced as variable is 31 Cam, of which we now have observations on more than thirty nights in 1924-27. This is an eclipsing system with a primary minimum of $0^m.20$, a secondary of $0^m.10$ and ellipsoidal variation between minima." These photo-electric observations have not been published.

31 Cam received its present name TU Cam by Guthnik and Prager (1936).

TU Cam was observed visually in 1929-30 and in 1933-34 by Zverev (1936). 166 observations were published; the light-curve was similar to that of β Lyrae. From the Potsdamer Durchmusterung (PD) Socher (1950) extracted 80 photographical magnitudes of TU Cam, dating from two periods, 1888-91 and 1900-05. He was able to construct a light-curve (using Zverev's period) and to determine the times of two primary minima.

Several observations were made near the primary minimum by means of a Kunz cell by Wood (1951) during two successive seasons, 1946-47 and 1947-48.

A preliminary report on the present work was published by West (1964).

2. THE OBSERVATIONS

TU Cam was placed on the observing programme of the Brorfelde Observatory of the Copenhagen University in the fall of 1958. Owing to the rather difficult period ($2^d.93$) and poor observing conditions, several seasons elapsed before the light-curve could be covered satisfactorily. A few observations were made in the 1958-59 season; however, the work had to be discontinued because of more urgent programmes. It was not until the three seasons 1961-62, 1962-63, and 1963-64 that it was possible to fill in the lacking parts of the light-curve. Unfortunately, the ingress of the secondary minimum still is not well covered. We were not able to catch this part neither in 1964-65 nor in 1965-66, and as the photocell will soon be replaced, we do not think that it will be possible to reproduce the system safely.

The observations were carried out in the standard colours B and V by means of a conventional photometer with an EMI 5060 cell attached to the 10-inch reflecting telescope of the Brorfelde Observatory. The photocurrent was fed into a d.c. amplifier and registered on a Brown recorder. The filters B and V were of the types given by Johnson (1955), B = Corning 5030 + 2 mm Schott GG 13 and V = Corning 3384. ξ Aur and 30 Cam were used as references. Main data of the three stars are given in table 1.

TABLE 1

Variable and comparison stars*

Star	BD	HD	α (1900)	δ (1900)	m_V	Sp
TU Cam	+59°920	39 220	$5^h46^m00^s$	+59°52'	$5^m.2$	A0
ξ Aur	+55°1027	39 283	5 46 28	+55 41	4.87	A2p
30 Cam	+58°863	38 831	5 43 28	+58 56	6.02	B9

* Data from Catalogue of Bright Stars, 3rd ed. (1964).

In the 1958-59 season, ξ Aur was the only comparison star, and 30 Cam occasionally served as check star. Since then, however, the observational procedure was changed so that ξAur and 30 Cam were observed equally and alternately between the measurements of TU Cam (- ξAur - TU Cam - 30 Cam - TU Cam - ξ Aur - TU Cam - etc.). The deflections on the Brown recorder paper were read directly in magnitudes. We then put

$$\Delta m = m(\mathrm{TU\ Cam}) - \frac{1}{2}\left[m(\xi\ \mathrm{Aur}) + m(30\ \mathrm{Cam})\right] + k \cdot \Delta \sec z,$$

where

$$\Delta \sec z = \sec z(\mathrm{TU\ Cam}) - \frac{1}{2}\left[\sec z(\xi\ \mathrm{Aur}) + \sec z(30\ \mathrm{Cam})\right].$$

Hence we introduce a fictive "mean star" as reference star. For the comparison stars we utilize the measurements immediately preceding and succeeding the measurements of the variable. The individual Δm-values are then not entirely independent; any pair of subsequent values has one common measurement of one of the comparison stars.

The extinction coefficients were determined by means of ξ Aur and 30 Cam whenever practically possible. On a few nights, when the observations were carried out close to the meridian, mean values of k_V and k_B had to be adopted. Because of the close position in the sky of the variable and the "mean star", only minor errors (< $0^m.005$) could possibly have been introduced on these nights. No second-order extinction coefficient was found when comparing ξ Aur and 30 Cam.

3. CONSTANCY OF THE COMPARISON STARS

Since we have observed ξ Aur and 30 Cam equally, it is possible to check their constancy very effectively. Their magnitude difference is

$$\Delta m' = m(30\ \mathrm{Cam}) - m(\xi\ \mathrm{Aur}) + k\left[\sec z(30\ \mathrm{Cam}) - \sec z(\xi\ \mathrm{Aur})\right].$$

For every Δm-value we have computed the corresponding value of $\Delta m'$. Due to the observational procedure the individual $\Delta m'$-values are correlated in a manner similar to the Δm-values. Also the mean error of a single $\Delta m'$ is equal to that of a single Δm, thus furnishing an excellent measure of the quality of the night. The night and seasonal means $\langle\Delta m'\rangle$ are shown in table 2 together with the mean error of one single observation (Δm or $\Delta m'$) and the mean error of $\langle\Delta m'\rangle$.

Whereas the variations of the seasonal means are nearly within the corresponding mean errors, the night-to-night fluctuations of $\langle\Delta m'\rangle$ are clearly larger than their mean errors. These fluctuations do not seem to be correlated with the zenith distance. Since it is unlikely that they should be due to instrumental effects only, we therefore investigated whether they could be traced to a periodic variability of one of the stars. A periodogram analysis of $\langle\Delta m'_B\rangle$ was carried out for values of P ranging from $1^d.5$ to 20^d with an interval of $0^d.1$. Two weak resonance periods were indeed found ($8^d.22$ and $10^d.82$) but none of them did represent the fluctuations of $\langle\Delta m'_B\rangle$ properly. The $\langle\Delta m'_B\rangle$ and $\langle\Delta m'_V\rangle$ fluctuations are not clearly correlated, and individual comparisons with TU Cam do not allow to judge whether ξ Aur or 30 Cam is the source of variation. There should be little doubt that the small night-

TABLE 2. <Δm'>: night and seasonal means

	B				V			
J.D.	n	<Δm'>	r.m.s.*	m.e.**	n	<Δm'>	r.m.s.*	m.e.**
2 437 649	18	$+1^{m}.0888$	$\pm 0^{m}.0102$	$\pm 0^{m}.0024$	18	$+1^{m}.1632$	$\pm 0^{m}.0094$	$\pm 0^{m}.0022$
2 437 656	11	1.1000	0.0083	0.0025	12	1.1635	0.0084	0.0024
2 437 661	11	1.0950	0.0085	0.0026	12	1.1567	0.0107	0.0031
2 437 671	13	1.0985	0.0078	0.0022	12	1.1633	0.0080	0.0023
2 437 692	18	1.0909	0.0121	0.0029	16	1.1549	0.0142	0.0036
2 437 694	24	1.0965	0.0073	0.0015	24	1.1587	0.0066	0.0014
2 437 952	17	1.0899	0.0038	0.0009	17	1.1546	0.0049	0.0012
2 437 992	20	1.0911	0.0117	0.0026	20	1.1607	0.0134	0.0030
2 437 995	5	1.0900	0.0184	0.0082	5	1.1580	0.0180	0.0081
2 437 999	6	1.0985	0.0063	0.0026	6	1.1643	0.0057	0.0023
2 438 018	23	1.0930	0.0085	0.0018	23	1.1572	0.0090	0.0019
2 438 022	17	1.0966	0.0074	0.0018	18	1.1598	0.0108	0.0025
2 438 030	40	1.0929	0.0054	0.0008	40	1.1581	0.0060	0.0010
2 438 036	28	1.0911	0.0067	0.0013	28	1.1549	0.0131	0.0025
2 438 037	6	1.0905	0.0037	0.0015	6	1.1520	0.0036	0.0015
2 438 041	17	1.0908	0.0043	0.0010	17	1.1589	0.0069	0.0017
2 438 042	17	1.0980	0.0097	0.0023	18	1.1594	0.0087	0.0021
2 438 045	28	1.0927	0.0112	0.0021	24	1.1580	0.0092	0.0019
2 438 046	11	1.0909	0.0131	0.0039	9	1.1589	0.0072	0.0024
2 438 050	6	1.0943	0.0042	0.0017	6	1.1633	0.0056	0.0023
2 438 051	16	1.0895	0.0119	0.0029	17	1.1634	0.0115	0.0028
2 438 343	23	1.0969	0.0089	0.0019	24	1.1675	0.0106	0.0022
2 438 350	4	1.0870	0.0106	0.0053	4	1.1600	0.0071	0.0035
2 438 371	18	1.0909	0.0059	0.0014	18	1.1626	0.0077	0.0018
2 438 372	5	1.0854	0.0099	0.0044	5	1.1648	0.0065	0.0029
2 438 381	6	1.0887	0.0076	0.0031	6	1.1618	0.0078	0.0032
2 438 385	12	1.0930	0.0106	0.0031	12	1.1513	0.0075	0.0022
2 438 409	26	1.0944	0.0054	0.0010	26	1.1590	0.0083	0.0016
1958-59					5	1.159		0.006
61-62	95	1.0953		0.0015	94	1.1600		0.0011
62-63	257	1.0922		0.0005	254	1.1578		0.0006
63-64	94	1.0938		0.0009	95	1.1610		0.0018
1958-64	446	1.0928		0.0004	448	1.1587		0.0006

* r.m.s. : mean error of a single observation (see text).

** m.e. : mean error of the mean.

to-night fluctuations of <Δm'> are real, but since it is impossible unambiguously to trace them back to either ξ Aur or 30 Cam, the only thing to do is to adopt both of them as constant. If only one of them varies, the greatest possible influence on Δm of the observed Δm' fluctuations is less than $0^m.005$.

The 1958-59 observations have been reduced to the same scale as the other observations by setting

$$\Delta m = m(\mathrm{TU\ Cam}) - m(\xi\ \mathrm{Aur}) + k\left[\sec z(\mathrm{TU\ Cam}) - \sec z(\xi\ \mathrm{Aur})\right] + \frac{1}{2} \langle m(\xi\ \mathrm{Aur}) - m(30\ \mathrm{Cam})\rangle,$$

where <m(ξ Aur) - m(30 Cam)> is taken as the four-season mean of table 2.

The mean error of a single observation (Δm or Δm') is, when the four seasons are taken together, ± $0^m.0082$ in B and ± $0^m.0090$ in V.

4. THE EPHEMERIS

In order to determine the time of a primary minimum, observations from six nights (JD 2 437 995, 2 438 022, 2 438 036, 2 438 042, 2 438 045 and 2 438 051) have been superposed utilizing the preliminary period $2^d.933\,25$. By means of the method of Kwee and Van Woerden (1956), one epoch was determined. Separate solutions of the B and the V observations were made and the following mean value was found:

HJD (Min I) = JD 2 438 051.375 48 ± 0.000 24 (m.e.).

The epochs of five earlier minima have been published by Zverev (1936) (2), Socher (1950) (2) and Wood (1951) (1). Photometric periods have been published by the same authors and spectroscopic periods by Harper (1924) and Mannino (1954).

Since the minima of Zverev were determined by visual methods and those of Socher were obtained from photographic plates, we first determined the period directly from the epoch of Wood's minimum and our epoch. There was no doubt about the number of cycles, and the period thus derived was $2^d.933\,254$. The times of the minima and the corresponding (O - C)-values are given in table 3.

TABLE 3

Times of primary minima of TU Cam

Hel. J.D.	Cycle	(O - C)*	(O - C)**	Method	Source
2 411 300.29	- 9120	+ 0.19	+ 0.076	pg	Socher, 1950
2 414 001.58	- 8199	- 0.04	- 0.149	pg	Socher, 1950
2 425 834.46	- 4165	+ 0.09	+ 0.036	v	Zverev, 1936
2 427 676.56	- 3537	+ 0.11	+ 0.060	v	Zverev, 1936
2 432 633.655	- 1847	0	- 0.023	pe	Wood, 1951
2 438 051.3755	0	0	0	pe	West

* P = $2^d.933\,254$. ** P = $2^d.933\,241$.

Obviously, this period does not fit the older minima well. On the other hand, the errors of Wood's and our minima are probably less than $\pm$ $0^{d}.0003$. We conclude that the period must have changed somewhat; however, it is impossible to investigate this quantitatively on the basis of the rather sparse material. A new value of the period was derived by means of a least-squares solution, giving individual weights to the epochs (pg = 1, v = 2, pe = 4, cf. table 3); it turned out to be $2^{d}.933\,241 \pm 0^{d}.000\,007$ (m.e.).

When using this period, no significant discrepancies were detected between observations made in 1958-59 and 1962-63, respectively, on the most sensitive part of the light-curve, the descending branch of the primary minimum. In the reduction we used the following ephemeris:

$$\text{HJD (Min I)} = 2\,438\,051.375\,48 + 2^{d}.933\,241\ n.$$

The (O - C)-values corresponding to this ephemeris are also given in table 3.

5. COMPARISON WITH SPECTROSCOPIC ELEMENTS

There is a reasonable agreement between the spectroscopic period determined by Mannino (1954), and our period. The epoch of Mannino's ephemeris was taken over from Harper (1924) (T_{sp} = JD 2 421 938.356). Applying our ephemeris we find the phase of T_{sp} to be - 5493.248, i.e., the periastron passage occurs close to the photometric phase 0.75. Mannino gives $\omega = 8^{\circ}.5$, a value not very far from ours. Therefore, the primary minimum is due to the eclipse of the intrinsically most luminous component, hereafter denoted as TU Cam A.

Three values of the eccentricity have been obtained by Mannino, Luyten and Harper, respectively. The mean value is 0.035. As the periastron lies between the secondary and the primary minimum, the mid-eclipse of the secondary accordingly should be shifted towards a later phase. Using $\omega = 8^{\circ}.5$ and $e = 0.035$, we find θ (mid-eclipse sec. min.) = 188° = 0.522, in disagreement with the light-curves, which do not show any displacement of the secondary minimum of this order.

6. VISUAL MAGNITUDES AND COLOURS

In order to transform our (B, V) observations into the standard system of Johnson and Morgan (1953), 35 of the stars listed by Johnson (1955) were observed on four nights in the spring of 1963. Two relations:

$$V_J = V_{Br} + 0.1347\,(B - V)_{Br} + \text{constant},$$

$$\text{and } (B - V)_J = 1.164\,(B - V)_{Br} + \text{constant},$$

where indices "J" and "Br" refer to "Johnson" and "Brorfelde", respectively, were established. These relations came out very close to those determined earlier with the same telescope and filters (Gyldenkerne and Jaeger, 1963), thus ensuring the stability of the system. The r.m.s. values were $\pm$ $0^{m}.019$ in the V and $\pm$ $0^{m}.013$ in the (B - V) relation. The V_J and $(B - V)_J$-values for the comparison stars and those for TU Cam in the extrema are given in tables 4 and 5, and the depths of the minima in table 6.

TABLE 4

Visual magnitudes and colours of the comparison stars

	V_J	$(B - V)_J$
ξ Aur	$4^m.927$	$+ 0^m.041$
30 Cam	6 .089	- 0 .033

TABLE 5

Visual magnitudes and colours of TU Cam

	Δm_V	$\Delta m_B - \Delta m_V$	V_J	$(B - V)_J$
Min I	$- 0^m.221$	$+ 0^m.008$	$5^m.286$	$+ 0^m.013$
Max I	- 0 .386	- 0 .006	5 .123	- 0 .003
Min II	- 0 .294	- 0 .007	5 .215	- 0 .004
Max II	- 0 .386	- 0 .001	5 .122	+ 0 .003

TABLE 6

Depths of the minima

	Max	Δ Min I	Δ Min II
V_J	$5^m.122$	$0^m.164$	$0^m.097$
B_J	5 .122	0 .177	0 .089

7. GENERAL DESCRIPTION OF THE LIGHT-CURVES

A total of 457 observations in B and 465 observations in V has been obtained on 32 nights in four seasons. They are listed in tables 7 and 8 and the light-curves have been plotted in figure 1, utilizing individual observations. In this figure is also shown the colour-curve, derived by means of normal points.

The light-curves clearly indicate that the system is a β Lyrae-type system. There are, however, some additional features which will be discussed.

TABLE 7

Individual observations of TU Cam in B

Fraction Hel. J. D.	Phase	Δm
J. D. 2436543		
.3752	.8929	-0.353
J. D. 2436544		
.4898	.2728	-0.392
J. D. 2436549		
.2782	.9053	-0.356
.2835	.9071	-0.339
.3563	.9319	-0.334
.3612	.9336	-0.346
.3881	.9427	-0.323
.3933	.9446	-0.324
.4116	.9508	-0.305
.4257	.9556	-0.296
J. D. 2436602		
.2994	.9813	-0.227
J. D. 2437649		
.3175	.9305	-0.345
.3244	.9328	-0.341
.3312	.9351	-0.345
.3369	.9371	-0.332
.3424	.9390	-0.331
.3491	.9412	-0.340
.3578	.9442	-0.325
.3664	.9472	-0.318
.3759	.9504	-0.326
.3849	.9535	-0.314
.3943	.9566	-0.305
.4020	.9593	-0.287
.4109	.9623	-0.275
.4189	.9651	-0.276
.4272	.9679	-0.260
.4361	.9709	-0.254
.4457	.9742	-0.248
.4572	.9781	-0.248
J. D. 2437656		
.5255	.3878	-0.368
.5395	.3926	-0.351
.5489	.3958	-0.361
.5600	.3996	-0.360
.5891	.4095	-0.359
.6064	.4154	-0.359
.6164	.4188	-0.364
.6249	.4217	-0.343
.6456	.4288	-0.356
.6571	.4327	-0.352
.6659	.4357	-0.348
J. D. 2437661		
.3750	.0411	-0.302
.3859	.0448	-0.308
.3946	.0478	-0.328
.4080	.0524	-0.332
.4170	.0554	-0.331
.5910	.1148	-0.368
.5994	.1176	-0.357
.6087	.1208	-0.360
.6172	.1237	-0.359
.6371	.1305	-0.354
.6488	.1344	-0.359
J. D. 2437671		
.4443	.4740	-0.302
.4577	.4785	-0.299
.4693	.4825	-0.294
.5253	.5016	-0.298
.5339	.5045	-0.306
.5571	.5124	-0.301
.5648	.5150	-0.288
.5752	.5186	-0.301
.5831	.5213	-0.309
.5936	.5248	-0.304
.6012	.5274	-0.307
.6109	.5307	-0.304
.6188	.5334	-0.314
J. D. 2437692		
.3035	.5853	-0.352
.3104	.5876	-0.345
.3164	.5896	-0.351
.3218	.5915	-0.346
.3276	.5935	-0.352
.3332	.5954	-0.352
.3383	.5971	-0.342
.3684	.6074	-0.357
.4656	.6405	-0.370
.4709	.6423	-0.367
.4763	.6442	-0.366
.4818	.6460	-0.355
.4882	.6482	-0.353
.4938	.6501	-0.357
.5000	.6522	-0.354
.5057	.6542	-0.372
.5116	.6562	-0.367
.5172	.6581	-0.368
J. D. 2437694		
.3119	.2700	-0.384
.3180	.2720	-0.392
.3242	.2742	-0.394
.3296	.2760	-0.388
.3357	.2781	-0.386
.3674	.2889	-0.381
.4044	.3015	-0.384
.4352	.3120	-0.369
.4407	.3139	-0.379
.4462	.3157	-0.370
.4521	.3177	-0.378
.4576	.3196	-0.382
.4641	.3218	-0.376
.4714	.3243	-0.371
.4772	.3263	-0.370
.4823	.3281	-0.372
.4886	.3302	-0.368
.4941	.3321	-0.366
.5007	.3343	-0.367
.5060	.3361	-0.373
.5126	.3384	-0.366
.5177	.3401	-0.364
.5234	.3421	-0.367
.5286	.3438	-0.361
J. D. 2437952		
.5817	.3192	-0.385
.5872	.3211	-0.376
.5929	.3231	-0.383
.5995	.3253	-0.379
.6059	.3275	-0.377
.6125	.3298	-0.378
.6194	.3321	-0.373
.6263	.3344	-0.374
.6328	.3367	-0.379
.6398	.3390	-0.377
.6465	.3413	-0.373
.6530	.3436	-0.373
.6600	.3459	-0.373
.6664	.3481	-0.379
.6731	.3504	-0.373
.6801	.3528	-0.370
.6870	.3552	-0.368
J. D. 2437992		
.3385	.8731	-0.339
.3446	.8752	-0.346
.3520	.8777	-0.350
.3580	.8798	-0.347
.3674	.8830	-0.345
.3729	.8848	-0.350
.3791	.8870	-0.349
.3852	.8890	-0.344
.3917	.8913	-0.350
.3980	.8934	-0.347
.4043	.8956	-0.346
.4108	.8978	-0.330
.4177	.9001	-0.346
.4237	.9022	-0.340
.4302	.9044	-0.345
.4361	.9064	-0.334
.4425	.9086	-0.331
.4491	.9108	-0.355
.4559	.9132	-0.339
.4615	.9151	-0.345
J. D. 2437995		
.4737	.9420	-0.322
.4798	.9441	-0.324
.4963	.9497	-0.312
.5025	.9518	-0.291
.5074	.9535	-0.290
J. D. 2437999		
.6443	.3638	-0.360
.6498	.3657	-0.355
.6559	.3678	-0.357
.6632	.3702	-0.356
.6694	.3724	-0.359
.6763	.3747	-0.364
J. D. 2438018		
.3339	.7355	-0.385
.3395	.7374	-0.384
.3457	.7395	-0.380
.3510	.7413	-0.396
.3562	.7431	-0.397
.3614	.7448	-0.392
.3666	.7466	-0.395
.3725	.7486	-0.394
.3777	.7504	-0.388
.3830	.7522	-0.383
.3887	.7541	-0.379
.3945	.7561	-0.384
.3999	.7580	-0.383
.4059	.7600	-0.388
.5065	.7943	-0.380
.5120	.7962	-0.381
.5173	.7980	-0.381
.5230	.7999	-0.385
.5285	.8018	-0.385
.5344	.8038	-0.379
.5846	.8210	-0.379
.5926	.8237	-0.375
.6023	.8270	-0.385
J. D. 2438022		
.1836	.0479	-0.302
.1898	.0500	-0.301
.2691	.0771	-0.344
.2745	.0789	-0.332
.2798	.0807	-0.342
.2861	.0828	-0.348
.2943	.0857	-0.336
.2967	.0865	-0.338
.5877	.1857	-0.382
.5947	.1881	-0.381
.5999	.1898	-0.385
.6051	.1916	-0.384
.6134	.1944	-0.386
.6184	.1962	-0.391
.6234	.1979	-0.381
.6290	.1998	-0.382
.6342	.2015	-0.379
J. D. 2438030		
.2095	.7841	-0.388
.2146	.7858	-0.385
.2194	.7875	-0.387
.2242	.7891	-0.389
.2293	.7908	-0.381
.2336	.7923	-0.385
.2382	.7939	-0.388
.2435	.7957	-0.386
.2486	.7974	-0.391
.2539	.7992	-0.388
.2584	.8008	-0.384
.2635	.8025	-0.389
.2684	.8042	-0.381
.2734	.8059	-0.384
.2803	.8082	-0.381
.2854	.8100	-0.381
.2919	.8122	-0.379
.2966	.8138	-0.382
.3027	.8159	-0.378
.3075	.8175	-0.376
.3140	.8197	-0.378
.3194	.8216	-0.381
.3245	.8233	-0.379
.3296	.8251	-0.379
.3346	.8268	-0.385
.3399	.8286	-0.378
.3448	.8302	-0.375
.3495	.8318	-0.371
.3564	.8342	-0.375
.3591	.8351	-0.376
.3642	.8368	-0.376
.3696	.8387	-0.381
.3747	.8404	-0.371
.3804	.8424	-0.371
.3855	.8441	-0.377

TABLE 7 (continued)

Fraction Hel. J. D.	Phase	Δ m
.3909	.8459	-0.372
.3963	.8478	-0.368
.4029	.8500	-0.374
.4075	.8516	-0.366
.4123	.8532	-0.367
J. D. 2438036		
.6070	.9651	-0.269
.6132	.9672	-0.262
.6186	.9691	-0.261
.6229	.9705	-0.243
.6289	.9726	-0.247
.6337	.9742	-0.238
.6396	.9762	-0.240
.6441	.9778	-0.235
.6505	.9799	-0.234
.6578	.9825	-0.224
.6637	.9844	-0.219
.6688	.9862	-0.221
.6748	.9883	-0.215
.6814	.9905	-0.209
.6874	.9925	-0.198
.6911	.9938	-0.212
.6971	.9959	-0.220
.7025	.9977	-0.212
.7084	.9997	-0.212
.7139	.0016	-0.214
.7198	.0036	-0.224
.7248	.0053	-0.216
.7312	.0075	-0.208
.7368	.0094	-0.209
.7431	.0115	-0.224
.7495	.0137	-0.227
.7553	.0157	-0.228
.7609	.0176	-0.223
J. D. 2438037		
.2779	.1938	-0.382
.2831	.1956	-0.385
.2888	.1976	-0.392
.3321	.2123	-0.377
.3378	.2143	-0.382
.3429	.2160	-0.383
J. D. 2438041		
.2559	.5500	-0.336
.2659	.5534	-0.344
.2713	.5553	-0.340
.2774	.5574	-0.341
.2836	.5595	-0.344
.2896	.5615	-0.342
.2955	.5635	-0.338
.2998	.5650	-0.346
.3047	.5667	-0.350
.3108	.5688	-0.348
.3158	.5705	-0.344
.3211	.5723	-0.344
.3260	.5739	-0.344
.3309	.5756	-0.335
.3375	.5779	-0.347
.3426	.5796	-0.342
.3477	.5813	-0.346
J. D. 2438042		
.5290	.9841	-0.218
.5345	.9859	-0.213
.5413	.9882	-0.214
.5477	.9904	-0.218
.5548	.9929	-0.226
.5611	.9950	-0.212
.5665	.9969	-0.215
.5714	.9985	-0.225
.5770	.0004	-0.218
.5829	.0024	-0.200
.5885	.0043	-0.202
.5943	.0063	-0.207
.5995	.0081	-0.216
.6060	.0103	-0.207
.6110	.0120	-0.213
.6171	.0141	-0.211
.6222	.0158	-0.211
J. D. 2438045		
.3604	.9493	-0.322
.3663	.9514	-0.302
.3723	.9534	-0.303
.3775	.9552	-0.298
.3828	.9570	-0.285
.3898	.9594	-0.288
.4944	.9950	-0.222
.4993	.9967	-0.225
.5035	.9981	-0.219
.5081	.9997	-0.211
.5121	.0010	-0.215
.5169	.0027	-0.206
.5211	.0041	-0.212
.5261	.0058	-0.210
.5307	.0074	-0.216
.5361	.0092	-0.216
.5413	.0110	-0.206
.5462	.0127	-0.212
.5508	.0143	-0.219
.5567	.0163	-0.212
.5634	.0185	-0.224
.5690	.0205	-0.219
.5744	.0223	-0.228
.5798	.0242	-0.235
.5846	.0258	-0.248
.5898	.0276	-0.243
.5962	.0297	-0.248
.6031	.0321	-0.271
J. D. 2438046		
.2224	.2432	-0.395
.2281	.2451	-0.385
.2332	.2469	-0.389
.2379	.2485	-0.392
.2431	.2503	-0.390
.2484	.2521	-0.400
.2538	.2539	-0.398
.2594	.2558	-0.393
.2651	.2578	-0.383
.2702	.2595	-0.400
.2763	.2616	-0.394
J. D. 2438050		
.4517	.6851	-0.377
.4585	.6874	-0.373
.4635	.6891	-0.375
.4704	.6914	-0.372
.4760	.6934	-0.380
.4833	.6958	-0.380
J. D. 2438051		
.2789	.9671	-0.252
.2845	.9690	-0.249
.2906	.9711	-0.252
.2964	.9730	-0.247
.3016	.9748	-0.237
.3168	.9800	-0.225
.3575	.9939	-0.208
.3634	.9959	-0.210
.3707	.9984	-0.210
.4209	.0155	-0.230
.4259	.0172	-0.219
.4283	.0180	-0.221
.4372	.0211	-0.224
.4420	.0227	-0.241
.4528	.0264	-0.254
.4581	.0282	-0.247
J. D. 2438343		
.2834	.5172	-0.293
.2901	.5195	-0.298
.2971	.5219	-0.299
.3044	.5244	-0.305
.3117	.5269	-0.298
.3195	.5295	-0.304
.3263	.5318	-0.304
.3349	.5348	-0.306
.3419	.5371	-0.315
.3487	.5395	-0.307
.3560	.5419	-0.317
.3624	.5441	-0.312
.3690	.5464	-0.321
.3754	.5486	-0.317
.3819	.5508	-0.331
.3885	.5530	-0.331
.3954	.5554	-0.330
.4025	.5578	-0.327
.4092	.5601	-0.344
.4159	.5624	-0.342
.4219	.5644	-0.332
.4290	.5668	-0.339
.4367	.5695	-0.337
J. D. 2438350		
.4898	.9740	-0.247
.4962	.9762	-0.239
.5034	.9787	-0.241
.5098	.9808	-0.231
J. D. 2438371		
.2878	.0644	-0.337
.2945	.0667	-0.333
.3009	.0689	-0.334
.3554	.0875	-0.344
.3612	.0895	-0.345
.3669	.0914	-0.344
.4357	.1149	-0.351
.4423	.1171	-0.353
.4475	.1189	-0.355
.5170	.1426	-0.369
.5229	.1446	-0.369
.5290	.1467	-0.370
.5432	.1515	-0.369
.5501	.1539	-0.366
.5557	.1558	-0.366
.6311	.1815	-0.375
.6368	.1834	-0.379
.6422	.1853	-0.378
J. D. 2438372		
.2678	.3985	-0.353
.2755	.4012	-0.351
.2823	.4035	-0.344
.2901	.4061	-0.350
.2975	.4087	-0.339
J. D. 2438381		
.4227	.5196	-0.293
.4350	.5238	-0.297
.4426	.5264	-0.305
.4495	.5288	-0.300
.4579	.5317	-0.295
.4661	.5344	-0.305
J. D. 2438385		
.4046	.8771	-0.361
.4111	.8794	-0.360
.4188	.8820	-0.354
.4265	.8846	-0.365
.4331	.8869	-0.346
.4427	.8901	-0.348
.4500	.8926	-0.345
.4567	.8949	-0.351
.4642	.8975	-0.351
.4711	.8998	-0.356
.4783	.9023	-0.361
.4957	.9082	-0.340
J. D. 2438409		
.3737	.0487	-0.312
.3818	.0515	-0.323
.3888	.0538	-0.325
.4038	.0590	-0.338
.4124	.0619	-0.332
.4208	.0648	-0.332
.4315	.0684	-0.332
.4390	.0709	-0.340
.4465	.0735	-0.337
.4541	.0761	-0.339
.4615	.0786	-0.337
.4695	.0813	-0.351
.4751	.0832	-0.342
.5189	.0982	-0.345
.5262	.1007	-0.345
.5331	.1030	-0.343
.5399	.1054	-0.345
.5474	.1079	-0.349
.5558	.1108	-0.348
.5631	.1133	-0.353
.5771	.1180	-0.352
.5887	.1220	-0.348
.5968	.1247	-0.353
.6068	.1281	-0.348
.6140	.1306	-0.355
.6219	.1333	-0.358

TABLE 8

Individual observations of TU Cam in V

Fraction Hel. J. D.	Phase	Δm
J. D. 2436544		
.3896	.2369	-0.392
.3936	.2401	-0.395
.4784	.2690	-0.390
.4851	.2712	-0.385
.4961	.2750	-0.384
.6440	.3254	-0.366
J. D. 2436549		
.2590	.8987	-0.347
.3096	.9160	-0.340
.3142	.9176	-0.352
.3423	.9271	-0.340
.3463	.9285	-0.343
.3670	.9356	-0.338
.3750	.9383	-0.322
.3842	.9414	-0.337
.3989	.9465	-0.323
.4052	.9486	-0.314
.4164	.9525	-0.300
.4200	.9536	-0.302
.4332	.9581	-0.288
.4589	.9669	-0.261
J. D. 2436602		
.2921	.9787	-0.232
.3070	.9838	-0.226
J. D. 2437649		
.3162	.9300	-0.351
.3234	.9325	-0.343
.3297	.9346	-0.339
.3357	.9367	-0.336
.3412	.9386	-0.340
.3479	.9409	-0.343
.3566	.9438	-0.324
.3652	.9467	-0.332
.3749	.9500	-0.325
.3836	.9530	-0.312
.3932	.9563	-0.301
.4009	.9589	-0.275
.4097	.9619	-0.282
.4176	.9646	-0.286
.4261	.9675	-0.262
.4351	.9706	-0.264
.4445	.9738	-0.247
.4558	.9776	-0.249
J. D. 2437656		
.5240	.3873	-0.364
.5380	.3921	-0.367
.5504	.3963	-0.360
.5585	.3991	-0.348
.5798	.4063	-0.363
.5881	.4092	-0.357
.6077	.4158	-0.363
.6150	.4183	-0.354
.6262	.4222	-0.347
.6470	.4292	-0.354
.6557	.4322	-0.354
.6674	.4362	-0.360
J. D. 2437661		
.3763	.0416	-0.311
.3847	.0444	-0.308
.3972	.0487	-0.325
.4065	.0519	-0.334
.4185	.0560	-0.332
.5900	.1144	-0.363
.6077	.1204	-0.359
.6130	.1222	-0.362
.6184	.1241	-0.362
.6273	.1271	-0.359
.6385	.1310	-0.360
.6471	.1339	-0.367
J. D. 2437671		
.4426	.4734	-0.296
.4559	.4779	-0.292
.4675	.4818	-0.285
.5241	.5012	-0.291
.5354	.5050	-0.292
.5559	.5120	-0.299
.5659	.5154	-0.296
.5739	.5181	-0.291
.5844	.5217	-0.306
.5921	.5243	-0.300
.6025	.5279	-0.310
.6202	.5339	-0.316
J. D. 2437692		
.3020	.5847	-0.357
.3120	.5882	-0.339
.3176	.5901	-0.343
.3231	.5919	-0.345
.3287	.5938	-0.355
.3671	.6069	-0.361
.4670	.6410	-0.372
.4690	.6417	-0.364
.4749	.6437	-0.362
.4803	.6455	-0.366
.4867	.6477	-0.364
.4927	.6498	-0.356
.4982	.6516	-0.353
.5045	.6538	-0.354
.5104	.6558	-0.355
.5155	.6575	-0.370
J. D. 2437694		
.3135	.2705	-0.375
.3194	.2725	-0.387
.3253	.2745	-0.390
.3309	.2764	-0.389
.3369	.2785	-0.391
.3687	.2893	-0.380
.4057	.3019	-0.374
.4363	.3124	-0.367
.4423	.3144	-0.371
.4477	.3162	-0.373
.4536	.3183	-0.375
.4592	.3202	-0.362
.4673	.3229	-0.384
.4729	.3248	-0.371
.4786	.3268	-0.367
.4834	.3284	-0.359
.4898	.3306	-0.364
.4955	.3325	-0.369
.5018	.3347	-0.360
.5073	.3366	-0.365
.5140	.3389	-0.365
.5189	.3405	-0.357
.5248	.3425	-0.361
.5300	.3443	-0.358
J. D. 2437952		
.5802	.3187	-0.381
.5884	.3215	-0.377
.5943	.3236	-0.380
.6009	.3258	-0.381
.6075	.3281	-0.382
.6141	.3303	-0.385
.6208	.3326	-0.379
.6280	.3350	-0.374
.6343	.3372	-0.378
.6412	.3395	-0.373
.6477	.3418	-0.373
.6545	.3441	-0.370
.6613	.3464	-0.371
.6678	.3486	-0.376
.6745	.3509	-0.371
.6815	.3533	-0.366
.6888	.3558	-0.368
J. D. 2437992		
.3398	.8736	-0.363
.3460	.8757	-0.344
.3532	.8781	-0.368
.3597	.8804	-0.358
.3660	.8825	-0.360
.3716	.8844	-0.352
.3777	.8865	-0.354
.3839	.8886	-0.351
.3900	.8907	-0.355
.3967	.8930	-0.365
.4029	.8951	-0.354
.4094	.8973	-0.349
.4163	.8997	-0.352
.4223	.9017	-0.360
.4289	.9039	-0.354
.4349	.9060	-0.348
.4409	.9080	-0.350
.4475	.9103	-0.347
.4546	.9127	-0.353
.4604	.9147	-0.355
J. D. 2437995		
.4725	.9416	-0.343
.4786	.9437	-0.323
.4949	.9492	-0.321
.5010	.9513	-0.319
.5088	.9539	-0.307
J. D. 2437999		
.6432	.3634	-0.364
.6486	.3653	-0.359
.6546	.3673	-0.362
.6615	.3697	-0.358
.6680	.3719	-0.355
.6748	.3742	-0.359
J. D. 2438018		
.3350	.7359	-0.391
.3411	.7379	-0.380
.3466	.7398	-0.386
.3522	.7417	-0.387
.3571	.7434	-0.391
.3625	.7452	-0.396
.3678	.7470	-0.396
.3736	.7490	-0.385
.3788	.7508	-0.381
.3842	.7526	-0.385
.3899	.7546	-0.389
.3957	.7566	-0.382
.4011	.7584	-0.383
.4071	.7604	-0.379
.5055	.7940	-0.387
.5108	.7958	-0.383
.5162	.7976	-0.380
.5217	.7995	-0.380
.5273	.8014	-0.381
.5332	.8034	-0.386
.5857	.8213	-0.373
.5938	.8241	-0.369
.6034	.8273	-0.367
J. D. 2438022		
.1825	.0475	-0.310
.1884	.0496	-0.313
.1940	.0515	-0.316
.2679	.0767	-0.343
.2735	.0786	-0.349
.2786	.0803	-0.341
.2849	.0824	-0.342
.2904	.0843	-0.355
.2954	.0860	-0.362
.5902	.1865	-0.386
.5961	.1886	-0.381
.6009	.1902	-0.385
.6063	.1920	-0.386
.6145	.1948	-0.378
.6196	.1966	-0.379
.6247	.1983	-0.379
.6302	.2002	-0.386
.6357	.2020	-0.383
J. D. 2438030		
.2106	.7845	-0.385
.2156	.7862	-0.392
.2204	.7878	-0.381
.2252	.7894	-0.382
.2304	.7912	-0.390
.2346	.7927	-0.393
.2393	.7943	-0.388
.2446	.7961	-0.394
.2500	.7979	-0.381
.2548	.7996	-0.381
.2595	.8011	-0.389
.2645	.8028	-0.384
.2695	.8046	-0.390
.2744	.8062	-0.386
.2813	.8086	-0.379
.2864	.8103	-0.383
.2892	.8113	-0.383
.2956	.8135	-0.384
.3009	.8153	-0.379
.3066	.8172	-0.382
.3128	.8193	-0.374
.3184	.8212	-0.379
.3232	.8229	-0.374
.3286	.8247	-0.381
.3334	.8264	-0.368
.3388	.8282	-0.378
.3437	.8299	-0.376

TABLE 8 (continued)

Fraction Hel. J. D.	Phase	Δ m
.3485	.8315	-0.373
.3534	.8331	-0.372
.3600	.8354	-0.367
.3654	.8372	-0.368
.3706	.8390	-0.365
.3756	.8407	-0.362
.3816	.8428	-0.368
.3866	.8445	-0.362
.3924	.8465	-0.368
.3989	.8487	-0.370
.4019	.8497	-0.378
.4066	.8513	-0.368
.4113	.8529	-0.358
J. D. 2438036		
.6080	.9655	-0.273
.6140	.9675	-0.263
.6195	.9694	-0.262
.6241	.9710	-0.257
.6300	.9730	-0.248
.6348	.9746	-0.252
.6407	.9766	-0.247
.6456	.9783	-0.246
.6520	.9805	-0.239
.6589	.9828	-0.229
.6652	.9850	-0.219
.6701	.9866	-0.225
.6775	.9892	-0.224
.6800	.9900	-0.227
.6861	.9921	-0.213
.6924	.9942	-0.216
.6983	.9963	-0.217
.7037	.9981	-0.217
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.7150	.0019	-0.228
.7209	.0040	-0.230
.7264	.0058	-0.236
.7326	.0080	-0.226
.7382	.0098	-0.225
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J. D. 2438037		
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.3307	.2119	-0.387
.3365	.2139	-0.380
.3419	.2157	-0.378
J. D. 2438041		
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.2649	.5531	-0.342
.2702	.5549	-0.341
.2762	.5569	-0.345
.2823	.5590	-0.341
.2885	.5612	-0.337
.2964	.5638	-0.345
.3008	.5653	-0.349
.3062	.5672	-0.359
.3118	.5691	-0.348
.3170	.5709	-0.344
.3221	.5726	-0.357
.3270	.5743	-0.342
.3320	.5760	-0.345
.3364	.5775	-0.338
.3416	.5792	-0.343
.3466	.5810	-0.347
J. D. 2438042		
.5276	.9836	-0.223
.5333	.9855	-0.224
.5399	.9878	-0.213
.5465	.9900	-0.218
.5522	.9920	-0.223
.5601	.9947	-0.224
.5653	.9964	-0.223
.5704	.9982	-0.220
.5755	.9999	-0.224
.5815	.0020	-0.221
.5873	.0039	-0.219
.5929	.0059	-0.222
.5983	.0077	-0.218
.6046	.0098	-0.220
.6098	.0116	-0.215
.6157	.0136	-0.219
.6209	.0154	-0.219
.6276	.0177	-0.217
J. D. 2438045		
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.3651	.9509	-0.312
.3712	.9530	-0.314
.4935	.9947	-0.226
.4982	.9963	-0.222
.5023	.9977	-0.225
.5071	.9993	-0.222
.5112	.0008	-0.215
.5159	.0024	-0.210
.5202	.0038	-0.216
.5249	.0054	-0.227
.5297	.0071	-0.227
.5349	.0088	-0.215
.5398	.0105	-0.212
.5451	.0123	-0.222
.5497	.0139	-0.224
.5552	.0158	-0.228
.5619	.0180	-0.238
.5678	.0201	-0.247
.5732	.0219	-0.237
.5789	.0238	-0.236
.5836	.0254	-0.236
.5950	.0293	-0.267
.6017	.0316	-0.282
J. D. 2438046		
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.2269	.2447	-0.387
.2322	.2465	-0.382
.2370	.2482	-0.378
.2415	.2497	-0.386
.2473	.2517	-0.395
.2640	.2574	-0.380
.2691	.2591	-0.385
.2745	.2610	-0.375
J. D. 2438050		
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.4575	.6870	-0.366
.4624	.6887	-0.367
.4688	.6909	-0.374
.4749	.6930	-0.376
.4818	.6953	-0.372
J. D. 2438051		
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.2830	.9685	-0.275
.2894	.9707	-0.245
.2950	.9725	-0.233
.3004	.9744	-0.250
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.3656	.9966	-0.208
.3720	.9988	-0.221
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.4246	.0168	-0.231
.4269	.0175	-0.228
.4384	.0214	-0.229
.4433	.0231	-0.254
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J. D. 2438343		
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.2818	.5167	-0.279
.2887	.5190	-0.286
.2955	.5213	-0.289
.3029	.5239	-0.287
.3102	.5263	-0.292
.3180	.5290	-0.301
.3281	.5324	-0.317
.3364	.5353	-0.304
.3436	.5377	-0.320
.3503	.5400	-0.321
.3575	.5425	-0.325
.3637	.5446	-0.327
.3706	.5469	-0.334
.3767	.5490	-0.330
.3833	.5512	-0.337
.3901	.5536	-0.337
.3972	.5560	-0.341
.4037	.5582	-0.349
.4108	.5606	-0.353
.4173	.5628	-0.348
.4235	.5649	-0.341
.4307	.5674	-0.350
.4384	.5700	-0.355
J. D. 2438350		
.4910	.9744	-0.269
.4979	.9768	-0.257
.5049	.9791	-0.245
.5110	.9812	-0.235
J. D. 2438371		
.2862	.0639	-0.336
.2931	.0663	-0.337
.2996	.0685	-0.337
.3566	.0879	-0.349
.3625	.0899	-0.358
.3681	.0918	-0.355
.4373	.1154	-0.366
.4435	.1175	-0.362
.4489	.1194	-0.357
.5157	.1421	-0.378
.5215	.1441	-0.379
.5277	.1463	-0.369
.5447	.1520	-0.376
.5515	.1543	-0.372
.5570	.1562	-0.374
.6300	.1811	-0.380
.6354	.1830	-0.381
.6408	.1848	-0.381
J. D. 2438372		
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.2739	.4006	-0.362
.2808	.4030	-0.354
.2883	.4055	-0.358
.2954	.4080	-0.347
J. D. 2438381		
.4211	.5191	-0.296
.4365	.5243	-0.292
.4439	.5269	-0.307
.4508	.5292	-0.310
.4596	.5322	-0.302
.4679	.5351	-0.304
J. D. 2438385		
.4029	.8766	-0.359
.4095	.8788	-0.365
.4171	.8814	-0.352
.4249	.8841	-0.353
.4316	.8864	-0.354
.4399	.8892	-0.354
.4485	.8921	-0.363
.4552	.8944	-0.358
.4623	.8968	-0.355
.4696	.8993	-0.349
.4765	.9017	-0.355
.4993	.9094	-0.347
J. D. 2438409		
.3722	.0482	-0.320
.3798	.0508	-0.316
.3874	.0533	-0.333
.4011	.0580	-0.335
.4104	.0612	-0.346
.4190	.0641	-0.345
.4291	.0676	-0.349
.4369	.0703	-0.352
.4447	.0729	-0.334
.4525	.0756	-0.344
.4597	.0780	-0.345
.4680	.0808	-0.341
.4738	.0828	-0.343
.5175	.0977	-0.350
.5247	.1002	-0.347
.5314	.1025	-0.360
.5383	.1048	-0.352
.5456	.1073	-0.353
.5540	.1102	-0.350
.5615	.1127	-0.362
.5805	.1192	-0.374
.5901	.1225	-0.362
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.6238	.1340	-0.372

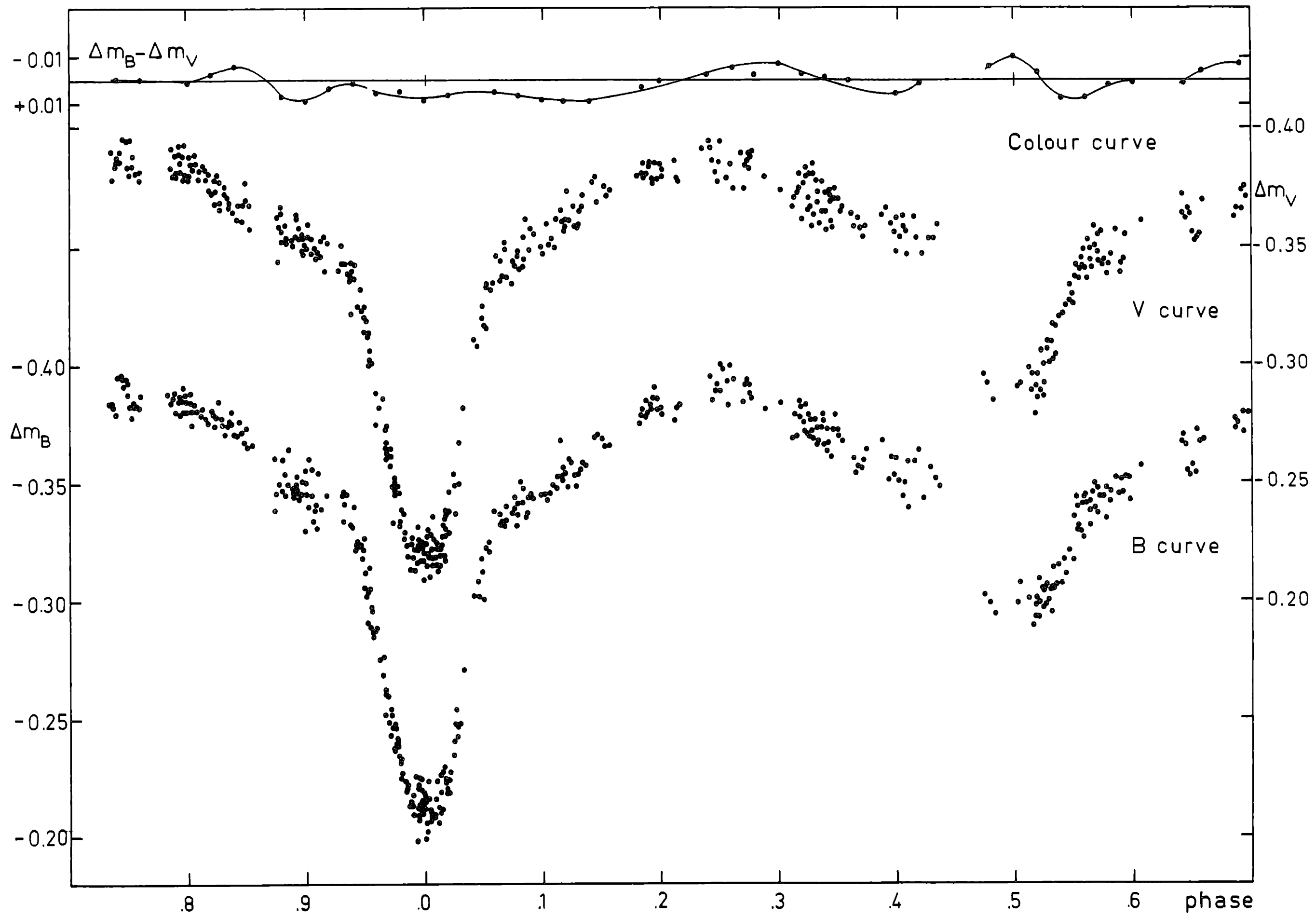

Figure 1. Individual observations in B and V and the colour-curve.

7.1. B-curve

Just before the ingress of the primary minimum we notice a rather large increase in the scatter of the observations. When computing normal points between phases .8 and .95, a short interval of nearly constant light between phases .88 and .94 appears to be present. This might also happen before the secondary minimum. From the colour-curve we find that the system is redder than normal. It therefore appears that the B-curve is somewhat depressed before ingress and that the light emitted around these phases varies from cycle to cycle. On a set of 77 observations obtained around the primary minimum by Wood (1951) (kindly put to the author's disposal), an interval of constant light just after egress can be recognized. Furthermore, the light-curve of Zverev (1936) has some depressions before ingress; they seem, however, to occur a little earlier than those noticed here.

Similar effects have been mentioned by other authors in case of other eclipsing systems in the same spectral region, to our knowledge most recently by Mannino (1963, private communication) for BF Aur and by Cousins (1966) for δ Pic. A possible explanation is the existence of a gas layer (stream) which is eclipsed just before ingress. The occurrence of the effect just before ingress is in qualitative agreement with current theories of ejection of matter in close binary systems (e.g. Plavec and Kříž, 1965).

7.2. V-curve

A "hump" effect equal to that mentioned above is particularly noticeable before the secondary minimum. Also the durations of the minima seem to be rather well defined, contrary to many β Lyrae systems.

Two series of observations (JD 7694 and JD 7952) cover the same phase interval near .34. They deviate systematically by $0^{m}.015$. It proved impossible to explain the effect in terms of a variability of either ξ Aur or 30 Cam, and by careful analysis of the material, including the determination of the extinction coefficient, the only possible source left was TU Cam itself. There seemed to be some other, but less pronounced cycle-to-cycle fluctuations, discernible at other phases.

7.3. Colour-curve

From the $(\Delta m_B - \Delta m_V)$-values in the minima we conclude that the primary minimum is due to an eclipse of the hotter component.

The system is redder than the mean just before ingress and just after egress of both minima. This effect very probably originates in a gas layer in the vicinity of the components. It would be interesting to observe the star spectroscopically at these phases.*

We conclude that the light-curves are somewhat unstable and that a third source of light, i.e. the gas, may play an important role.

8. ANALYSIS OF THE LIGHT-CURVES

Since both minima are very shallow, it should be stressed that this analysis is only tentative and because of the obvious existence of additional and disturbing gas effects, the accuracy of the derived elements should not be overestimated.

After the observations had been arranged according to phase, a determination of the phase of external contact (θ_e) was made and a subsequent Fourier analysis on the observations outside the minima was carried out as described in an earlier paper (West, 1965). From the Fourier coefficients, given in table 9, preliminary rectification constants were computed by means of the statistical formulae

TABLE 9

Fourier coefficients. $\theta_e = 21^{\circ}.3$

	A_0	A_1	A_2	A_3	B_1	B_2	B_3
V	+ 0.9772 ± 0.0003	- 0.0026 ± 0.0006	- 0.0215 ± 0.0006	- 0.0045 ± 0.0006	+ 0.0016 ± 0.0004	- 0.0005 ± 0.0004	+ 0.0012 ± 0.0004
B	+ 0.9716 ± 0.0003	- 0.0040 ± 0.0006	- 0.0264 ± 0.0006	- 0.0032 ± 0.0006	+ 0.0010 ± 0.0004	- 0.0010 ± 0.0004	- 0.0004 ± 0.0004

* Visual inspection of several spectra of TU Cam around phases .9 and .1, kindly taken by Dr. T. Herczeg with the 1-m telescope of the Hamburg Observatory in Bergedorf (dispersion 35 A/mm at Hγ), failed to show any features in the blue region, incompatible with a normal A0 spectrum.

of Russell and Merrill (1952, p. 50), assuming the eclipses to be complete, and a preliminary rectification was performed. A set of elements was derived by means of the nomograms of Merrill (1953), and the rectification constants were recomputed by means of eq. (107) of Contr. Princeton Univ. Obs. No. 26, with the inclination i equal to 78°. From some Fourier analyses with a different number of terms it clearly turned out that a satisfactory representation of the observations outside eclipse was only obtained when utilizing seven terms.

In order to find the constant z of the phase rectification, an assumption concerning the limb darkening coefficient u had to be made. Setting u = 0.4, 0.6 and 0.8, respectively (i.e. N = 2.2, 2.6 and 3.2), we obtained the following values of z: 0.039, 0.033, 0.027 in V and 0.048, 0.041, 0.033 in B. Since z is a geometric quantity and thus should be the same for the V- and B-curve, we adopt u(V) = 0.6 and u(B) = 0.8, in reasonable agreement with the theoretical values given by Kopal (1959).

A second rectification was carried out by means of the rectification constants given in table 10. The rectified minima are shown in figures 2, 3 and 4.

TABLE 10

Rectification constants

	C_0	C_1	C_2	C_3	z
V	0.0053	0.0026	0.0017	0.0045	0.033
B	0.0058	0.0040	0.0019	0.0032	0.033

We then proceeded to investigate the type of the primary minimum. One type, total occultation, could be excluded at once due to its small depth. Next, when comparing the χ-values of the two minima it seemed very unlikely that the primary minimum should be an occultation at all, since χ(sec) > χ(pr) in both colours. By means of Merrill's nomograms we found that the primary minimum was due to a partial, but very nearly annular transit (p_0 = -0.9).

The three possibilities, primary minimum due to either a partial occultation, a partial transit or an annular eclipse, were investigated by making successive runs on the GIER electronic computer by means of the element computing programme previously described (West, 1965). When assuming a partial occultation, the value of k, the quantity to be iterated, diverged quickly and no iteration was obtained. In case of a partial transit, k also diverged, but less pronounced and only just became too small to imply a partial transit, thus pointing at a nearly grazing, annular eclipse.

Therefore, we assumed that the primary minimum was due to an annular eclipse. Although both minima were used simultaneously in the computations when assuming a partial eclipse, the observations during the presumed annular phase (we tentatively adopted θ_i = 4°) had to be excluded in the solution (cf. the computations on AR Cas in the paper mentioned above).

The iteration of k now converged rapidly in both colours and without any doubt the primary minimum is due to an annular eclipse and the secondary to a total occultation.

If the depths of the secondary minima were known accurately, k could be determined by means of the depth relation. Unfortunately, this is not the case, owing to the few observations situated at the bottom of this minimum. It was therefore decided to tackle the problem in a slightly unorthodox way.

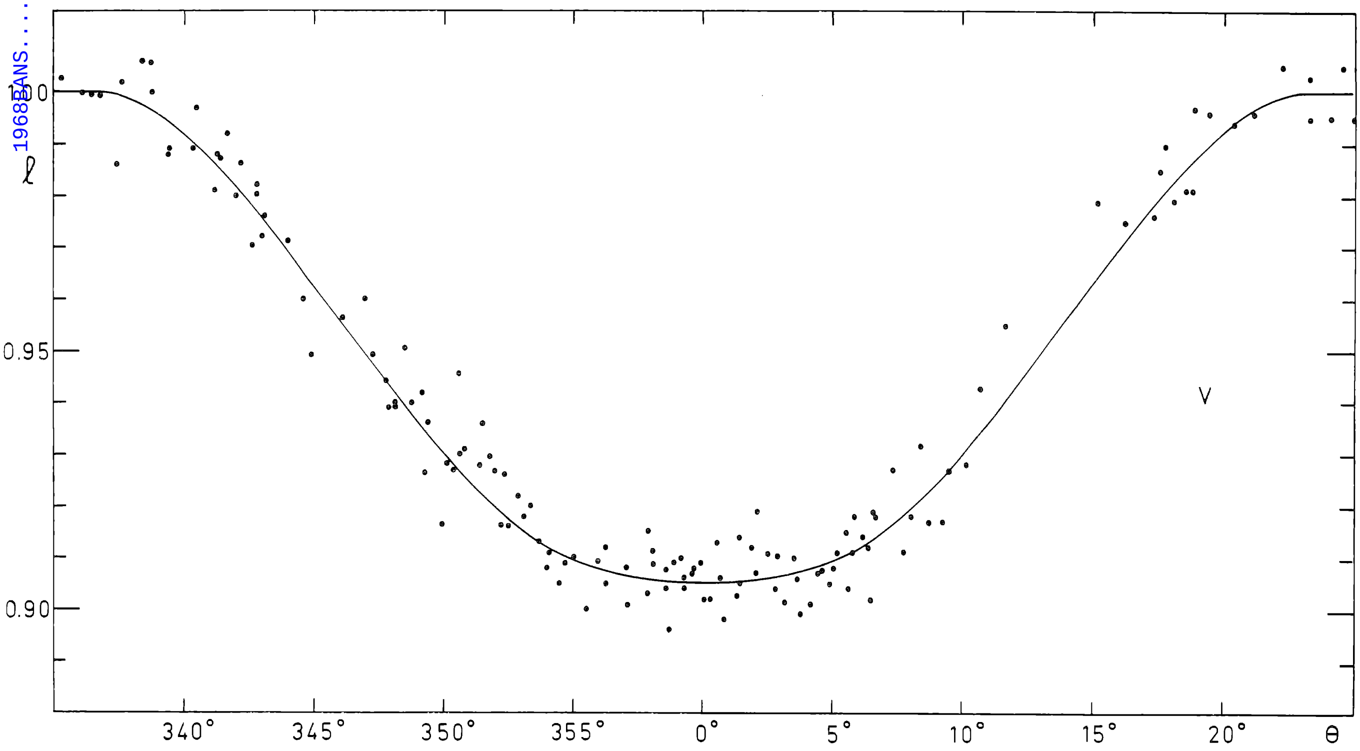

Figure 2. Primary minimum in V and computed light-curve.

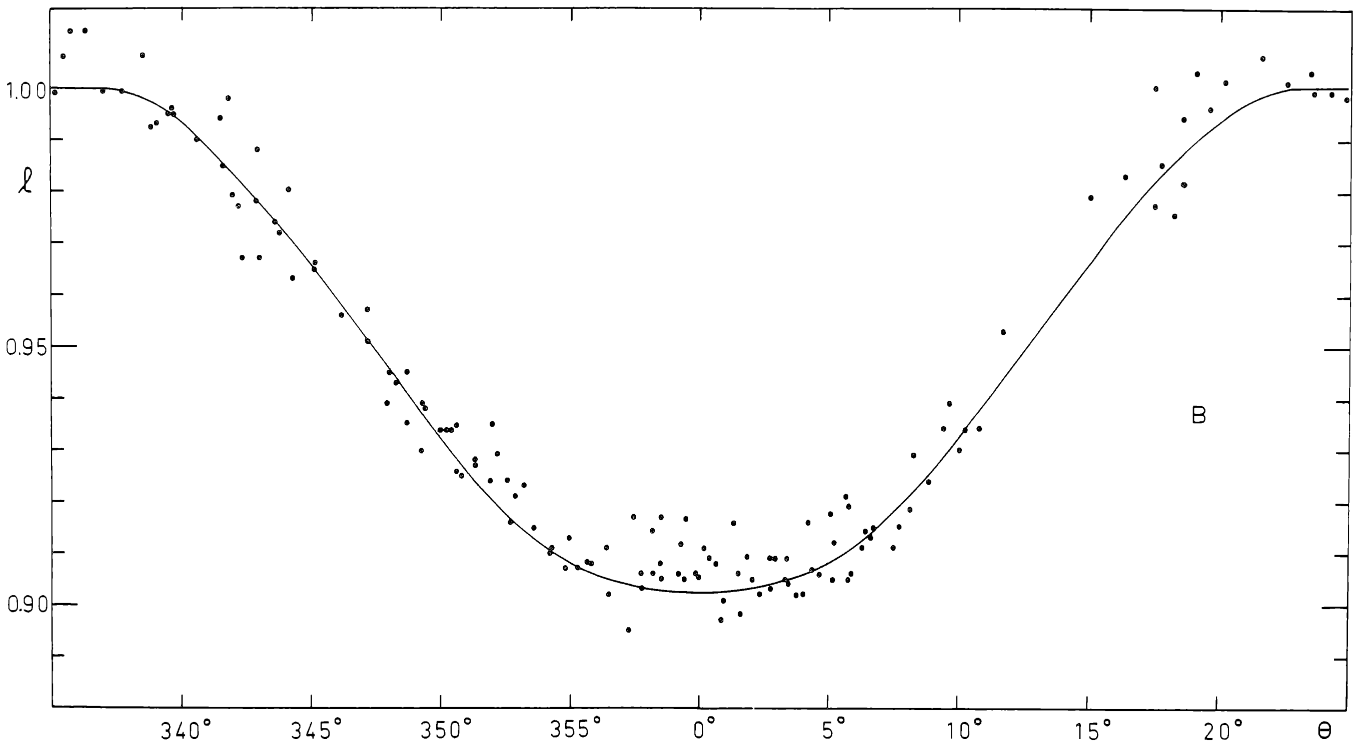

Figure 3. Primary minimum in B and computed light-curve.

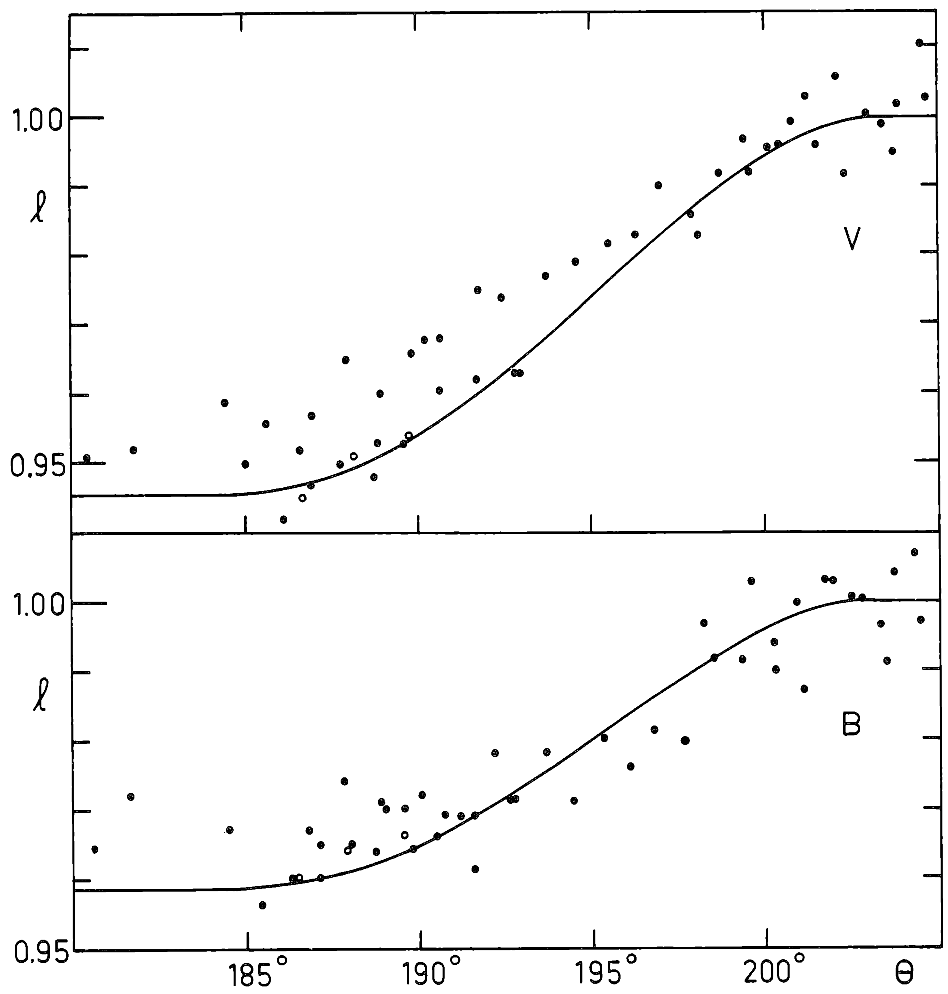

Figure 4. Secondary minima in B and V and computed light-curves. Open circles denote observations which have been reflected around θ = 180°.

The depths of the primary minima were fixed by means of some 25 observations in the central phases. We then computed the geometrical elements using the observations in the primary minima, and found that the B-elements implied a very plausible depth of the secondary B minimum, whereas the V-elements did not. When applying the B-elements to the V-curve, it turned out that they also fitted this one very well. However, a slight revision of r_1 and k (- 0.001 in r_1 and - 0.002 in k) improved the fitting in the secondary minima considerably.

The elements, especially i, were very close to those derived in the preliminary analysis. Because of the uncertainties involved in the problem, it would be of no use to try to improve these elements. We still do not know the influence of the additional light source, and furthermore the rectification procedure introduces some simplifying assumptions that certainly are not fulfilled by TU Cam.

The elements, corrected for ellipticity, are given in table 11, and the corresponding theoretical light-curves have been drawn in figures 2, 3 and 4. Possibly, u(B) is somewhat less than 0.8 and the secondary V minimum too deep, but apart from this, the general agreement is satisfactory.

TABLE 11

Elements

			B	V
k	0.311	u(A) = u(B) (adopted)	0.8	0.6
r(A)	0.334	L(A)	0.9587	0.9455
r(B)	0.104	L(B)	0.0413	0.0545
i	77°.7	λ_{pr}	0.9072	0.9085
ε	0.017	λ_{sec}	0.9587	0.9455

9. CONCLUSION

We have derived geometric and photometric elements for TU Cam. Although it would be tempting to carry the analysis further, utilizing the mass ratio mentioned above, we do not think this is justified. The values of L_A and L_B correspond to a difference of $3^m.4$ in B and $3^m.1$ in V between TU Cam A and B. The two remaining Yerkes plates which are supposed to show double lines are probably not reliable. The mass ratio considered as unknown, we can only determine the absolute value of the relative orbital semi-axis of TU Cam A. From Mannino's elements (and e = 0) we find $a_A = 3.14 \times 10^6$ km.

The colour of TU Cam B is (B - V) = + $0^m.3$, corresponding to the spectral type F0.

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