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THE SPECTROSCOPIC ORBIT OF TV CASSIOPEIAE

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ABSTRACT.—The eclipsing variable TV Cassiopeiæ was investigated for its spectroscropic orbit from 21 spectrograms obtained in three seasons. Although the photometric orbit indicates that the fainter body only gives 15 per cent of the light both spectra have been measured. The observations indicate a circular orbit with practical agreement between spectroscopic and photometric phase. A semi-amplitude of the primary of 87·9 and of the secondary of 150 km. give the brighter star a mass of 1·8 and the fainter 1·0 times the sun. The separation of the two stars is about 8·9 solar radii while from the photometric orbit we obtain the mean radii of the two bodies, which are elliptical in shape, as 2·5 and 2·8 times the sun.

The eclipsing variable TV Cassiopeiae, R.A. $0^h\ 13{\cdot}9^m$., Dec.+58° 35′ (1900), maximum magnitude 7·3, spectral type Ao, was placed under spectroscopic observation at Victoria on July 26, 1919. Spectra were secured at intervals in the next two seasons, the final observation being made on Sept. 29, 1921. In all 21 plates were obtained and used in the determination of the spectroscopic orbit.. The period and elements of the photometric orbit were obtained by R. J. McDiarmid at Princeton in 1915. According to this orbit the period is 1·812635 days and the initial epoch J.D. 2,420,117·742 and these were used in the spectroscopic orbit with which they agreed within the limits of observational error.

The spectrum is of type Ao with the diffuse lines generally characteristic of eclipsing variables. The lines measured in the spectrum are given in the table below, the maximum number of lines measured in any one plate being 11, the average number 6. The lines are generally faint and diffuse and it is difficult to make accurate settings, this being indicated by the probable error of measurement of a single plate which is ±4·6 km. per second. Most of the plates were remeasured the values given in the table of observations being the mean value of the measures. According to the photometric orbit the brighter star gives about 85 per cent of the total light of the system and one would consequently not expect to find the second spectrum present. Nevertheless measures of the second spectrum have been made on 12 of the 21 plates and although the lines are very faint and difficult, they appear in the normal position as companions to the stronger lines of the primary and there seems to be little doubt of their presence. Although the measures are by no means very accordant they are about as good as can be expected, corresponding to a probable error per plate of ±13·1 km. per second. As the mass relation of the two bodies, given by the relative velocities of primary and secondary, is of the same order as would be expected from their relative brightness and from the known masses of other eclipsing variables, it seems probable that the lines measured as due to the second spectrum, even though they are often only on the border line of visibility, are really present and that we, therefore, have a fairly reliable value of the dimensions of the system. The average number of lines measured of the second component is 3 and their wave lengths are given in the table.

LINES MEASURED IN TV CASSIOPEIAE

Principal W.L.	Component Element	Secondary W.L.	Component Element
4584·018	Fe	4584·018	Fe
4572·158	Ti	4572·158	Ti
4549·700	Ti-Fe	4549·700	Ti-Fe
4534·139	Ti	4534·139	Ti
4528·798	Fe	4528·798	Fe
4508·455	Fe	4494·738	Fe
4501·448	Ti	4481·400	Mg
4494·738	Fe	4404·880	Fe
4481·400	Mg	4352·000	Cr-Mg
4404·880	Fe	4325·920	Fe
4352·000	Cr-Mg	4307·980	Fe
4340·634	H	4236·000	Fe
4325·920	Fe	4227·107	Ca
4307·980	Fe	4101·890	H
4282·834	Fe	3933·825	Ca
4271·675	Fe		
4260·557	Fe		
4236·000	Fe		
4233·425	Fe		
4227·107	Ca		
4143·839	Fe		
4131·047	Si		
4128·211	Si		
4101·890	H		
4071·888	Fe		
3933·825	Ca		

The observations are given in the following table, the columns in order being plate number, date, Julian date, phase obtained from photometric orbit, measured velocities of primary and secondary and residuals, O—C, from the final orbit.

OBSERVATIONS OF TV CASSIOPEIAE

Plate	Date	Julian Date	Phase	Velocity		Residual (O-C)	
				Prin.	Sec.	Prin.	Sec.
2539	1919, July 26	2,422,166·972	0·952	+16·7		+ 1·7	
2855	Aug. 28	2,199·949	1·302	+82·6	−140·9	− 4·4	+ 5·1
2973	Sept. 15	2,217·819	1·046	+44·1		+ 3·5	
3450	1920 Jan. 3	2,327·583	0·239	−73·3		−10·3	
4532	July 1	2,507·960	1·165	+78·3	− 99·2	+ 7·8	+18·3
4669	July 22	2,528·974	0·427	−74·3	+143·4	+ 8·4	+ 6·5
4798	Aug. 5	2,542·985	1·750	+36·0		+16·3	
4876	Aug. 12	2,549·956	1·470	+76·1	−110·1	− 0·9	+24·5
5017	Sept. 2	2,570·946	0·709	−55·9	+129·7	− 2·8	+33·0
5077	Sept. 16	2,584·940	0·202	−55·2	+128·7	− 1·7	+32·2
5097	Sept. 27	2,595·865	0·251	−68·1	+134·6	− 2·0	+19·6
5152	Oct. 8	2,606·817	0·327	−75·1	+122·1	+ 0·1	−12·8
5583	1921, Jan. 9	2,699·753	0·818	−35·8	+ 63·9	−10·8	+15·9
5665	Feb. 16	2,737·605	0·605	−82·7	+118·0	−10·9	−13·2
6360	July 31	2,902·956	1·007	+29·4		− 0·6	
6446	Aug. 11	2,913·983	1·158	+63·1	−115·0	− 5·4	− 0·8
6548	Sept. 11	2,944·976	1·336	+78·5		+ 9·8	
6586	Sept. 22	2,955·842	1·326	+88·4		+ 0·9	
6613	Sept. 29	2,962·851	1·085	+58·5		+ 5·7	
6884	Dec. 14	3,038·606	0·709	+58·8	+111·0	− 3·8	+14·3
6899	Dec. 15	2,423,039,588	1·691	+38·6		+ 3·4	

These observations were combined into 13 normal places the maximum difference of phase being 0·155 days and the average 0·044 days. Although there is considerable difference of quality in the different plates, the simple plan of weighting according to the number of plates in each normal place was followed. The following table contains the normal places, the columns in order giving the number, the weight (the number of plates), the mean phase, the mean velocity of principal and secondary and the residuals of the principal component from preliminary and final orbits respectively.

NORMAL PLACES TV CASSIOPEIAE

Number	Weight	Phase	Velocity		Residuals	
			Prin.	Sec.	Prel.	Final
1............	1	0·202	−55·2		− 1·71	− 0·09
2............	2	0·245	−70·7	+134·6	− 8·38	− 6·09
3............	1	0·327	−75·1	+122·3	+ 0·09	+ 3·40
4............	1	0·427	−74·3	+143·4	+ 8·36	+12·59
5............	1	0·605	−82·7	+118·0	−10·93	− 6·57
6............	2	0·709	−57·4	+120·4	− 4·26	− 1·37
7............	1	0·818	−35·8	+ 63·9	−10·78	− 8·59
8............	2	0·980	+23·1		+ 2·02	+ 1·65
9............	2	1·065	+51·3		+ 7·92	+ 5·94
10............	2	1·162	+70·7	−107·1	+ 6·40	+ 2·89
11............	3	1·322	+83·2	−140·9	+ 0·90	− 4·34
12............	1	1·470	+76·1	−110·1	− 0·88	− 6·47
13............	2	1·720	+37·3		+11·11	+ 7·76

These normal places were plotted on cross section paper and preliminary elements determined graphically. Although the photometric orbit indicated a sensible eccentricity, the spectroscopic observations appeared to be better satisfied by circular motion and as any determination of small eccentricity from observations of the accuracy possible from such a poor lined spectrum would be very uncertain, it was felt to be preferable to apply least-square corrections only to the velocity of the system, to the semi-amplitude and to the phase, and not for eccentricity. Further, as the observations of the secondary component are relatively very uncertain, it was felt undesirable to include them in the corrections which were consequently applied to the preliminary elements of the principal component which were taken as

Eccentricity	e	$= 0$
Semi-amplitude	K_1	$= 83$ km
Velocity of system	γ	$= \pm 0$ km
Phase	T	$= 0$ (same as photometric)

An ephemeris was computed from these elements, observation and normal equations obtained which resulted in the following corrected values of the elements.

Eccentricity	$e = 0$
Semi-amplitude	$K_1 = 87 \cdot 92 \pm 0 \cdot 94$ km.
Velocity of system	$\gamma = +0 \cdot 54 \pm 0 \cdot 70$ km.
Phase	$\theta = 0° \cdot 86 \pm 0° \cdot 69$, $T = - \cdot 0045 \pm \cdot 0035$ dys.

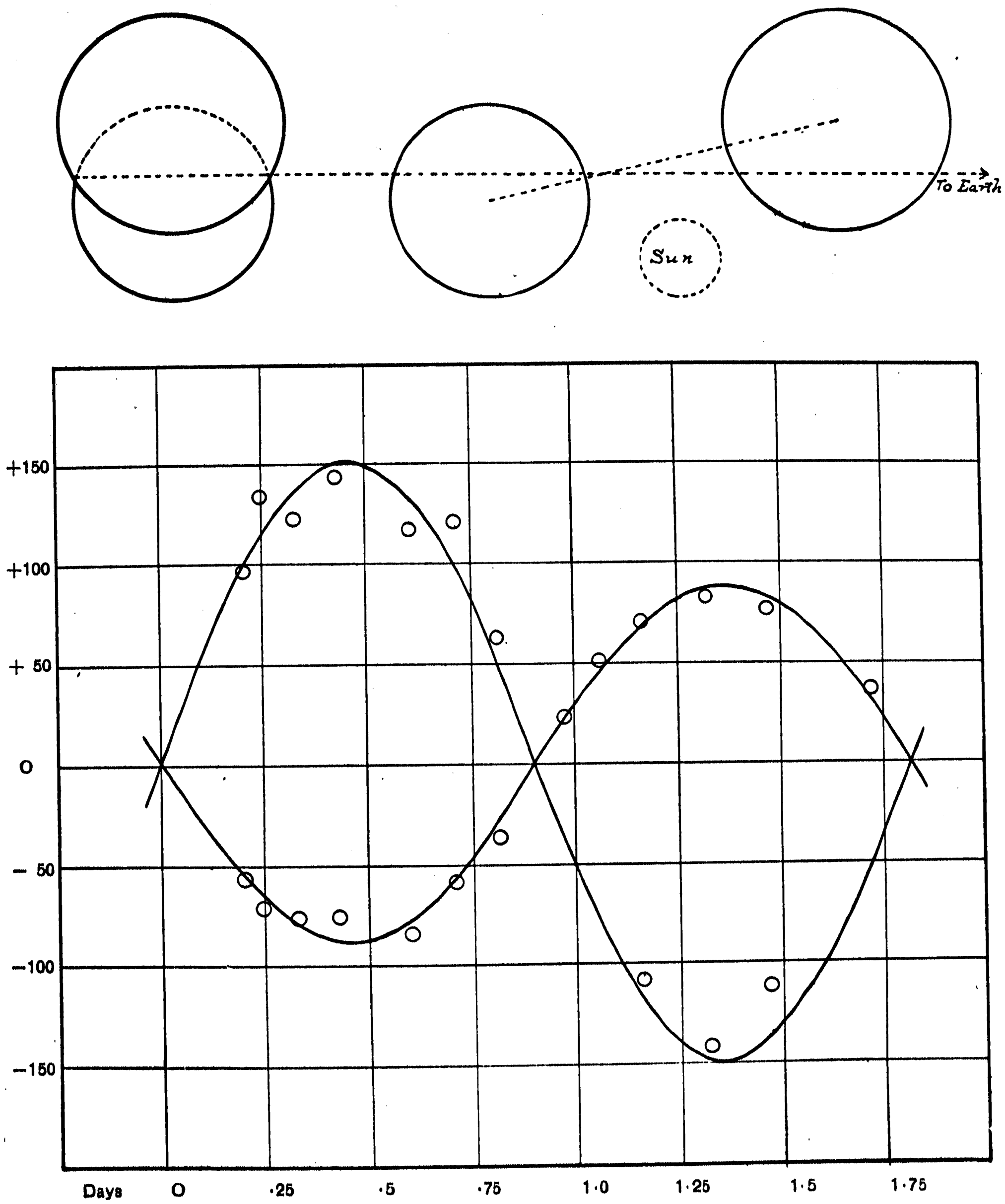
The probable error of a normal place of unit weight is $\pm 4 \cdot 1$ km. while Σpv^2 is reduced by the correction from 950 to 676 or nearly 30 per cent. The correction in phase is so small as to be practically negligible and does not add materially to previous knowledge in regard to difference between photometric and spectroscopic phases.

Taking these final values of the elements of the principal component curves were drawn through the observations of the secondary component assuming different values of K_2 and the best agreement seemed obtained for a value $K_2 = 150$ km.

Combining these spectroscopic values with McDiarmid's photometric orbits we obtain the following values for the dimensions of the system TV Cassiopeiae.

Separation of two stars	a	$= 8 \cdot 86 \odot$
Radius brighter star	r_b	$= 2 \cdot 50$
Radius fainter star	r_f	$= 2 \cdot 83$
Mass brighter star	m_b	$= 1 \cdot 83$
Mass fainter star	m_f	$= 1 \cdot 01$
Density brighter star	ρ_b	$= 0 \cdot 118$
Density fainter star	ρ_f	$= 0 \cdot 044$

Although McDiarmid obtained different orbits on the assumption of uniform and darkened discs and although he was able to show that the stars were elongated by mutual attraction and that the near sides of the two stars were brightened by mutual radiation, the spectroscopic observations, owing to the diffuseness of the lines, are not of sufficient precision to justify taking these refinements into account and the above dimensions were obtained from the mean values from uniform and darkened discs and from the mean of the semi-axes of the ellipsoidal form of the stars. A velocity curve showing the normal places and a graphical representation of the relative dimensions of the system as compared with the sun is given.



Velocity Curve and Relative Dimensions of TV Cassiopeiae.

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