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Orbit of B.A.C. 5890

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ORBIT OF B.A.C. 5890.

BY T. H. PARKER, M.A.

This star ($\alpha = 17^h\ 21^m{\cdot}3$, $\delta = -5°$) was confirmed as a spectroscopic binary by Mr. Burns from the measures of a plate obtained at the Lick Observatory on June 21, 1905. This plate showed a doubling of the lines with a ratio of intensity of about two to one. Two plates had been previously obtained in 1899 and 1900 which had only single lines. In A. J. Vol. 25, a list of measures of eight plates is given. Of this series three gave the velocities of both components with a range of 151 km. The star is an F-type, with fairly broad lines and is of photographic magnitude 4·9. The following orbit was determined from the measures of nineteen plates taken at Ottawa showing both spectra, together with the three Lick observations already mentioned. A large number of plates of this star were obtained here, which were later found to be unsuitable in the determination of the orbit on account of the blending of the two spectra. The latter were only found separated near the primary maximum. Fortunately, however, one of the Lick observations showed double lines at a phase near apastron due to the larger dispersion of the Mills spectrograph. The velocities given by this plate were of great use in finding the values of *K* in the case of each component, as will be noted later. In all thirty-one lines were measured on the various plates of which about a dozen occurred but a few times. A selection was made of eleven of the best lines remaining for which the wave-lengths were corrected as follows:—

TABLE I.

Element.	Wave-Length.	Element.	Wave-Length.
Iron	4549·753	Magnesium-Iron	4233·483
Magnesium	4481·548	Iron	4226·968
Magnesium-Chromium	4352·035	Iron	4143·832
Hydrogen	4340·646	Hydrogen	4101·890
Iron	4271·689	Iron	4045·935
Iron	4260·654		

A summary of the observations used is given in the following tables. In Table II will be found the Lick observations giving the velocities as kindly communicated from the director by Dr. Moore, the Julian day for each plate having been sent previously. It will be noted that the values of the velocity in this table, as recently received, are slightly different from those already published, and which were used in the following solutions. These changes are due to a small correction determined from a discussion of the residuals given by the line λ 4500 on all spectrograms of F-type stars. In each case the residuals of these corrected values of the observed velocities from the final curve are less than those given by the former measures. Table III contains the Ottawa observations and, as in Table II, in each case the phase is reckoned from periastron and the residual from the final curve. The measures are given in detail after Table III.

TABLE II.

LICK OBSERVATIONS.

Plate.	Date.	Julian Day.	Phase.	Component I.		Component II.	
				Vel.	O-C.	Vel.	O-C.
	1905						
3851B	June 21	2,417,018·828	26·104	*+69·0 +69·6	.... −0·6	*−82·0 −80·1	.... −6·1
	1906						
4324B	July 22	414·795	1·690	*+29·0 +28·8	.... −1·6	*−31·0 −31·2	.... +0·5
4348A	Aug. 1	424·714	11·600	−23·8 *−25·0	+0·4	+30·0	+3·3 ....

*Values published in L.O.B. vol. 4, p. 96.

TABLE III.

OTTAWA OBSERVATIONS.

Plate.	Observer.*	Date.	Exposure.	Julian Day.	Phase.	Component I.			Component II.		
						Vel.	Wt.	O-C.	Vel.	Wt.	O-C.
		1910	m.								
3477	P^1	June 9.......	58	2,418,832·796	0·875	+44·8	3	− 5·0	−57·2	½	− 4·8
3506	H-C	July 4.......	93	857·695	25·774	+68·6	7	− 1·6	−71·7	5	+ 2·6
3587	P^1	Aug. 26.......	65	910·605	26·135	+65·0	5	− 5·4	−76·9	3	− 3·6
		1911									
4219	C	April 19.......	65	9,146·873	25·936	+74·8	6	+ 4·1	−58·1	4	+16·3
4226	H	April 20.......	67	147·856	0·644	+61·9	5	+ 4·0	−56·9	2	+ 3·9
4307	P^1	May 16.......	74	173·849	0·363	+66·1	3	+ 3·4	−81·8	2	− 4·0
4416	P	July 6.......	65	224·633	24·873	+62·6	6	+ 4·0	−50·7	3	+10·7
4421	C	July 7.......	80	225·660	25·900	+80·3	5	+ 9·9	−58·9	2	+15·5
4466	H	Aug. 1.......	85	250·575	24·541	+46·8	3	− 4·5	−63·6	2	− 9·2
4502	H	Aug. 29.......	74	278·574	26·266	+65·0	6	− 3·7	−71·8	4	+ 1·1
4586	C	Sept. 22.......	68	302·522	23·939	+25·7	4	−14·8	−61·9	1	−19·8
4595	H	Sept. 26.......	75	306·515	1·658	+43·4	5	+12·8	−27·6	2	+ 5·7
4656	C	Oct. 19.......	70	329·500	24·643	+52·7	1	− 3·9	−71·8	½	−15·5
		1912									
4921	P^1	Mar. 25.......	83	487·902	25·400	+73·0	4	+ 5·7	−64·4	2	+ 8·5
4975	P^1	April 20.......	72	513·833	25·057	+52·9	3	− 7·5	−82·6	2	−19·0
5045	P	June 12.......	100	566·773	25·448	+73·0	4	+ 3·6	−66·9	1	+ 3·3
5051	C-H	June 13.......	90	567·742	0·143	+64·6	5	0·0	−65·1	3	+ 4·0
5172	C	Aug. 29.......	90	644·557	24·410	+51·8	5	+ 2·0	−46·6	2	+ 5·7
		1913									
5589	C-P^1	June 16.......	70	935·743	0·305	+81·6	1	+16·3	−80·7	1	−11·9

*P=Plaskett; H=Harper; C=Cannon; P^1=Parker.

MEASURES OF B.A.C. 5890.

λ	3477 p.*		3477 s.*		3506 p.		3506 s.		3587 p.		3587 s.			
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753	+ 35·90	½	....	....	+ 82·86	¼	− 69·01	¼	+ 92·04	¼	....	....	....	....
4481·548	+ 34·20	½	....	....	+ 77·51	½	− 29·33	¼	+ 61·99	¼	....	....	....	....
4352·035	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4340·646	....	....	....	....	+ 69·55	1	− 85·90	½	+100·01	½	− 79·10	¼	....	....
4271·689	....	....	....	....	+ 98·45	¼	− 70·69	¼	....	....	− 56·60	¼	....	....
4260·654	....	....	....	....	+ 81·24	1	− 68·83	¼	....	....	− 40·00	¼	....	....
4233·483	....	....	....	....	+ 73·13	1	− 56·09	¼	....	....	− 50·90	¼	....	....
4226·968	+ 63·64	¼	− 72·18	¼	+ 88·14	1	− 58·80	1	+108·26	¼	....	....	....	....
4143·832	+ 55·46	½	− 26·63	⅛	+ 87·27	1	− 52·54	¼	+ 91·89	½	....	....	....	....
4101·890	....	....	....	....	+ 78·57	1	− 53·52	¼	....	....	....	....	....	....
4045·935	....	....	....	....	+ 60·38	¼	− 35·75	¼	....	....	− 42·30	¾	....	....
Weighted mean	+ 44·97		− 57·01		+ 79·59		− 60·71		+ 92·34		− 49·52		....	
V_a	+ ·24		+ ·24		− 10·64		− 10·64		− 26·94		− 26·94		....	
V_d	− ·16		− ·16		− ·09		− ·09		− ·16		− ·16		....	
Curv.	− ·28		− ·28		− ·28		− ·28		− ·28		− ·28		....	
Radial Velocity	+ 44·8		− 57·2		+ 68·6		− 71·7		+ 65·0		− 76·9		....	

*p. = primary.
s. = secondary.

MEASURES OF B.A.C. 5890—*Continued.*

λ	4219 p.		4219 s.		4226 p.		4226 s.		4307 p.		4307 s.			
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753	+ 59·61	⅛	....	....	+ 60·01	½	− 80·25	⅛	+ 56·90	⅛	− 49·84	⅛	....	....
4481·548	+ 56·50	¼	− 73·83	⅛	....	....	....	....	....	....	....	....	....	....
4352·035	+ 52·99	¼	−101·02	⅛	+ 33·76	½	....	....	....	....	....	....	....	....
4340·646	+ 58·80	½	....	....	+ 39·61	½	....	....	+ 52·39	¼	....	....	....	....
4271·689	....	....	− 85·45	¼	....	....	....	....	+ 58·92	¼	−111·56	½	....	....
4260·654	+ 50·06	½	− 73·27	½	+ 36·82	½	− 87·22	¼	....	....	....	....	....	....
4233·483	+ 46·63	¼	....	....	+ 35·07	½	....	....	....	....	....	....	....	....
4226·968	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4143·832	....	....	....	....	....	....	....	....	+ 47·16	⅛	− 64·76	⅛	....	....
4101·890	....	....	....	....	+ 31·17	¼	− 58·77	⅛	....	....	....	....	....	....
4045·935	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Weighted mean	+ 52·98		− 79·86		+ 40·48		− 78·36		+ 54·45		− 93·48			
V_a	+ 22·09		+ 22·09		+ 21·79		+ 21·79		+ 12·05		+ 12·05			
V_d	− ·02		− ·02		− ·09		− ·09		− ·12		− ·12			
Curv.	− ·28		− ·28		− ·28		− ·28		− ·28		− ·28			
Radial Velocity	+ 74·8		− 58·1		+ 61·9		− 56·9		+ 66·1		− 81·8			

MEASURES OF B.A.C. 5890—*Continued.*

λ	4416 p.		4416 s.		4421 p.		4421 s.		4466 p.		4466 s.			
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753	+ 61·43	¼	....	....	....	....	− 46·52	½	+ 74·51	¼	− 39·18	¼	....	....
4481·548	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4352·035	....	....	....	....	+100·90	½	....	....	....	....	....	....	....	....
4340·646	+ 95·63	½	....	....	+ 92·51	¼	....	....	+ 43·43	⅛	− 51·04	⅛	....	....
4271·689	+ 78·94	¼	− 48·97	¼	....	....	....	....	+ 69·38	¼	− 41·40	⅛	....	....
4260·654	+ 68·68	½	− 37·20	¼	+ 82·26	¼	− 43·18	½	....	....	....	....	....	....
4233·483	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4226·968	....	....	....	....	+ 83·04	¼	− 67·17	¼	....	....	....	....	....	....
4143·832	+ 64·85	½	− 33·46	½	+ 94·58	¼	− 33·75	¼	....	....	....	....	....	....
4101·890	....	....	....	....	....	....	....	....	+ 68·21	½	− 37·46	½	....	....
4045·935	+ 68·95	¼	− 42·34	¼	....	....	....	....	....	....	....	....	....	....
Weighted mean	+ 74·36		− 39·08		+ 92·46		− 46·80		+ 67·21		− 40·10			
V_o	− 11·47		− 11·47		− 11·81		− 11·81		− 21·60		− 21·60			
V_d	+ ·01		+ ·01		− ·04		− ·04		± ·00		± ·00			
Curv.	− ·28		− ·28		− ·28		− ·28		− ·28		− ·28			
Radial Velocity	+ 62·6		− 50·7		+ 80·3		− 58·9		+ 45·3		− 62·0			

MEASURES OF B.A.C. 5890—*Continued.*

λ	4466*p.		4466*s.		4502 p.		4502 s.		4586 p.		4586 s.			
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753	+ 85·40	¼	− 21·95	¼	+ 98·43	½	− 50·64	⅛	+ 59·70	¼				
4481·548					+100·53	¼	− 24·84	⅛	+ 31·47	½				
4352·035	+ 70·10	¼	− 41·70	¼					+ 46·42	¼	− 24·62	⅛		
4340·646					+ 91·01	½	− 51·51	¼	+ 62·97	½				
4271·689	+ 67·10	¼	− 55·50	¼	+ 83·79	½	− 44·70	½						
4260·654														
4233·483														
4226·968									+ 57·70	¼	− 42·80	⅛		
4143·832									+ 72·47	¼				
4101·890	+ 63·80	¼	− 60·10	¼										
4045·935					+ 94·97	¼	− 39·78	⅛						
Weighted mean	+ 71·60		− 44·80		+ 92·74		− 44·12		+ 53·89		− 33·71			
V_a	− 21·60		− 21·60		− 27·29		− 27·29		− 27·75		− 27·75			
V_d	± ·00		± ·00		− ·16		− ·16		− ·16		− ·16			
Curv.	− ·28		− ·28		− ·28		− ·28		− ·28		− ·28			
Radial Velocity	+ 49·7		− 66·7		+ 65·0		− 71·8		+ 25·7		− 61·9			

*Check measures.

MEASURES OF B.A.C. 5890—*Continued.*

λ	4595 p.		4595 s.		4656 p.		4656 s.		4921 p.		4921 s.			
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753									+ 53·96	½	− 93·18	¼		
4481·548	+ 87·94	⅛	+ 16·08	⅛										
4352·035														
4340·646	+ 70·93	¼	+ 23·89	¼					+ 66·02	¼				
4271·689														
4260·654					+ 75·96	¼	− 48·61	¼	+ 38·39	½	− 97·23	½		
4233·483	+ 62·89	¼	− 25·94	¼										
4226·968														
4143·832	+ 74·00	⅛	+ 3·42	⅛					+ 26·44	¼	− 69·07	¼		
4101·890														
4045·935	+ 52·28	⅛	− 13·85	⅛										
Weighted mean	+ 71·22		+ 0·20		+ 75·96		− 48·61		+ 46·20		− 89·18			
V_a	− 27·36		− 27·36		− 22·78		− 22·78		+ 27·02		+ 27·02			
V_d	− ·18		− ·18		− ·24		− ·24		+ ·04		+ ·04			
Curv.	− ·28		− ·28		− ·28		− ·28		− ·28		− ·28			
Radial Velocity	+ 43·4		− 27·6		+ 52·7		− 71·9		+ 73·0		+ 62·4			

MEASURES OF B.A.C. 5890—*Continued.*

λ	4975 p.		4975 s.		5045 p.		5045 s.		5051 p.		5051 s.			
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753	+ 4·99	½	−132·10	½	+103·62	¼	− 59·29	¼	+ 48·12	¼				
4481·548														
4352·035					+ 62·60	¼								
4340·646	+ 32·74	½			+ 78·76	½			+ 69·89	¼				
4271·689					+ 47·85	¼	− 72·51	¼						
4260·654											− 53·50	¼		
4233·483	+ 57·12	½	−104·40	¾	+ 72·04	¼			+ 73·43	½				
4226·968														
4143·832														
4101·890	+ 33·52	¼	− 88·30	½										
4045·935			− 78·70	¼							− 66·80	¾		
Weighted mean	+ 31·62		−104·08		+ 73·94		− 65·90		+ 66·22		− 63·47			
V_a	+ 21·55		+ 21·55		− ·78		− ·78		− 1·28		− 1·28			
V_d	+ ·04		+ ·04		+ ·07		+ ·07		− ·07		− ·07			
Curv.	− ·28		− ·28		− ·28		− ·28		− ·28		− ·28			
Radial Velocity	+ 52·9		− 82·8		+ 73·0		− 66·9		+ 64·4		− 65·1			

MEASURES OF B.A.C. 5890—*Concluded.*

λ	5172 p.		5172 s.		5589 p.		5589 s.							
	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.	Vel.	Wt.
4549·753	+ 67·68	¼												
4481·548	+ 52·07	¼												
4352·035														
4340·646	+ 97·59	¼			+ 84·55	¼	− 77·82							
4271·689	+100·34	¼	− 18·15	¼										
4260·654														
4233·483														
4226·968														
4143·832														
4101·890														
4045·935	+ 80·04	¼	− 19·63	¼										
Weighted mean	+ 79·54		− 18·89		+ 84·55		− 77·82							
V_a	− 27·35		− 27·35		− 2·58		− 2·58							
V_d	− ·14		− ·14		− ·09		− ·09							
Curv.	− ·28		− ·28		− ·28		− ·28							
Radial Velocity	+ 51·8		− 46·6		+ 81·6		− 80·7							

The nineteen Ottawa observations were grouped into five normal places, and those from Lick were taken separately to form three additional places. In the latter case equal weights were assigned and each place was given approximately three times the weight of an average single Ottawa observation. The normal places for both components are given in Table IV, together with the mean phase from periastron, mean velocity, weight, and residual from computed velocities of the preliminary elements.

TABLE IV.

NORMAL PLACES I.

Number.	Mean Phase.	Mean Velocity.	Weight.	O–C.
1	25·026	+42·1	1·5	+ 0·8
2	25·645	+58·9	1·0	− 2·2
3	0·194	+74·9	3·0	− 1·0
4	0·567	+69·0	1·5	− 2·7
5	0·834	+63·3	2·0	− 2·9
6	1·829	+48·5	1·5	+ 6·5
7	2·421	+29·0	1·5	− 0·5
8	12·340	−25·0	1·5	− 1·4
9	25·108	−56·0	0·5	−10·5
10	25·660	−64·5	0·5	− 2·4
11	0·227	−64·2	1·5	+10·7
12	0·567	−82·0	1·0	−10·2
13	0·818	−73·6	1·5	− 6·5
14	1·860	−45·5	0·5	− 2·4
15	2·421	−31·0	1·0	+ 0·9
16	12·340	+30·0	1·0	+11·8

Using the graphical method, these preliminary elements were obtained:—

$P = 26{\cdot}2742$ days
$e = \;\;{\cdot}55$
$\omega_1 = 350^\circ$
$\omega_2 = 170^\circ$
$K_1 = 50$ km.
$K_2 = 47{\cdot}3$ km.
$\gamma = -2{\cdot}08$ km.
$T = 2{,}418{,}410{\cdot}794$ J. D.

As previously noted, one of the Lick observations was a great help in fixing the values of K_1 and K_2 above. This plate (4348A) is the third in Table II, with velocities of $-25{\cdot}0$ km. and $+30$ km. for the first and second components respectively. It is the only plate giving any idea of the minimum of the primary or the maximum of the secondary. The note accompanying the measure speaks of the secondary as the strong, and the primary as the weak component. This is just the opposite to what has been found in all other plates. Although as will be seen later, the masses of the two bodies are not very different, and consequently the secondary may show stronger than the primary in some cases.

A least-squares solution was employed to improve the elements obtained in this way. The period, deduced by using the early Lick observations in connection with our own, covering a great number of cycles, was taken as fixed. As had been previously suggested by Dr. King*, the observations of both components were combined into one set of observation equations, from the solution of which only one set of elements result. For the value of ω in the case of the first component we must use $180° + \omega$ in the second. Sixteen observation equations were formed as follows:—

TABLE V.

OBSERVATION EQUATIONS I.

No.	x	y_1	y_2	z	u	v	$-n$	Weight.
1	1	+ ·867	....	−·852	+·521	−·758	− ·800	1·5
2	1	+1·263	....	−·186	+·394	−·735	+ 2·200	1·0
3	1	+1·541	....	+·484	+·036	+·028	+ 1·000	3·0
4	1	+1·475	....	+·163	−·132	+·389	+ 2·700	1·5
5	1	+1·365	....	−·192	−·236	+·550	+ 2·900	2·0
6	1	+ ·881	....	−·899	−·423	+·563	− 6·500	1·5
7	1	+ ·631	....	−·898	−·450	+·453	+ ·500	1·5
8	1	− ·430	....	+·476	−·072	+·024	+ 1·400	1·5
9	1	....	− ·918	+·755	−·484	+·732	+10·500	·5
10	1	....	−1·269	+·163	−·370	+·691	+ 2·400	·5
11	1	....	−1·540	−·446	−·021	−·057	−10·700	1·5
12	1	....	−1·475	−·154	+·125	−·368	+10·200	1·0
13	1	....	−1·374	+·157	+·217	−·512	+ 6·500	1·5
14	1	....	− ·868	+·855	+·402	−·528	+ 2·400	·5
15	1	....	− ·631	+·849	+·426	−·428	− ·900	1·0
16	1	....	+ ·430	−·450	+·068	−·023	−11·800	1·0

Where $x = \delta\gamma$
$y_1 = \delta K_1$
$y_2 = \delta K_2$
$z = 100\delta e$
$\omega = 100\delta\omega$
$v = \dfrac{100\mu\delta T}{(1-e^2)^{\frac{3}{2}}}$

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*P.D.O. vol. I, p. 327.

Normal equations were derived from these as follows:—

$$\begin{array}{rrrrrrr}
21x & +13\cdot754y_1 & -\;7\cdot575y_2 & -1\cdot432z & -\;\cdot117u & +\;\cdot229v & +\;5\cdot800=0 \\
 & +18\cdot877y_1 & +\;\cdot000y_2 & -1\cdot613z & -\;\cdot533u & +1\cdot736v & +11\cdot231=0 \\
 & & +10\cdot752y_2 & -\;\cdot619z & -\;\cdot539u & +1\cdot444v & -15\cdot617=0 \\
 & & & +6\cdot651z & +\;\cdot835u & -\;\cdot592v & +27\cdot569=0 \\
 & & & & +1\cdot824u & -2\cdot690v & +\;2\cdot132=0 \\
 & & & & & +4\cdot383v & -\;4\cdot080=0
\end{array}$$

The solution of these gave

$$\begin{aligned}
x &= +2\cdot170 \\
y_1 &= -3\cdot499 \\
y_2 &= +1\cdot688 \\
z &= -6\cdot115 \\
u &= +25\cdot681 \\
v &= +16\cdot585
\end{aligned}$$

whence,

$$\begin{aligned}
\delta\gamma &= +2\cdot17 \text{ km.} \\
\delta K_1 &= -3\cdot50 \text{ km.} \\
\delta K_2 &= +1\cdot69 \text{ km.} \\
\delta e &= -\cdot061 \\
\delta\omega &= +14^\circ\cdot71 \\
\delta T &= +\cdot404 \text{ day.}
\end{aligned}$$

Hence the corrected values of the elements,

$$\begin{aligned}
e &= \cdot489 \\
\omega_1 &= 4^\circ\cdot71 \\
\omega_2 &= 184^\circ\cdot71 \\
K_1 &= 46\cdot5 \\
K_2 &= 48\cdot99 \\
\gamma &= +\cdot09 \text{ km.} \\
T &= 2{,}418{,}411\cdot198 \text{ J. D.}
\end{aligned}$$

These new values of the elements reduced Σpvv from 642 to 463, or nearly 28 per cent. The agreement however between the computed and observation equation residuals was not satisfactory and a second solution was accordingly carried through.

New normal places were formed as in Table VI.

TABLE VI.

NORMAL PLACES II.

No.	Mean Phase.	Mean Velocity.	Weight.	O–C.	Equation-Ephemeris.
1	24·626	+42·1	1·5	− 3·7	+ 0·7
2	25·246	+58·9	1·0	+ 0·2	− 0·8
3	26·070	+74·0	3·0	+ 4·9	+ 1·1
4	0·166	+69·0	1·5	+ 0·8	+ 2·6
5	0·466	+63·3	2·0	− 1·6	+ 2·8
6	1·426	+48·5	1·5	+ 4·4	+ 1·0
7	2·026	+29·0	1·5	− 1·6	+ 0·3
8	11·936	−25·0	1·5	− 1·3	− 0·6
9	24·706	−56·0	·5	− 6·2	0·0
10	25·256	−64·5	·5	− 2·6	+ 0·8
11	26·100	−64·2	1·5	+ 8·5	− 1·4
12	0·166	−82·0	1·0	−10·3	− 2·4
13	0·426	−73·6	1·5	− 5·0	− 2·5
14	1·456	−45·5	·5	0·0	− 0·7
15	2·026	−31·0	1·0	+ 1·1	0·0
16	11·936	+30·0	1·0	+ 4·8	0·0

Whence the observation equations as below:—

TABLE VII.

OBSERVATION EQUATIONS.

No.	x	y_1	y_2	z	u	v	$-n$	Weight.
1	1	+ ·983	·000	−·599	+·385	−·588	+ 3·700	1·5
2	1	+1·261	·000	−·170	+·276	−·538	− ·200	1·0
3	1	+1·484	·000	+·444	+·019	−·082	− 4·900	3·0
4	1	+1·464	·000	+·421	−·118	+·218	− ·800	1·5
5	1	+1·395	·000	+·246	−·214	+·416	+ 1·600	2·0
6	1	+ ·946	·000	−·577	−·432	+·655	− 4·400	1·5
7	1	+ ·656	·000	−·774	−·477	+·577	+ 1·600	1·5
8	1	− ·512	·000	+·460	−·033	+·004	+ 1·300	1·5
9	1	·000	−1·019	+·589	−·395	+·623	+ 6·200	·5
10	1	·000	−1·265	+·170	−·289	+·565	+ 2·600	·5
11	1	·000	−1·486	−·476	−·008	+·061	− 8·500	1·5
12	1	·000	−1·464	−·443	+·124	−·230	+10·300	1·0
13	1	·000	−1·401	−·276	+·218	−·425	+ 5·000	1·5
14	1	·000	− ·930	+·626	+·459	−·688	·000	·5
15	1	·000	− ·656	+·816	+·503	−·608	− 1·100	1·0
16	1	·000	+ ·512	−·485	+·035	−·004	− 4·800	1·0

with the same substitutions as before.

The normals obtained from these were:—

$$\begin{array}{rrrrrrl}
21x + 13\cdot809y_1 & - \; 7\cdot547y_2 & - \; \cdot497z & - \; \cdot243u & + \; \cdot211v & - \; 6\cdot050 & =0 \\
+19\cdot135y_1 & + \; \cdot000y_2 & + \; \cdot556z & - \; \cdot912u & +1\cdot224v & -19\cdot570 & =0 \\
 & +10\cdot846y_2 & + \; 808z & - \; \cdot763u & +1\cdot135v & -13\cdot186 & =0 \\
 & & +5\cdot197z & + \; \cdot613u & - \; \cdot622v & - \; 3\cdot773 & =0 \\
 & & & +1\cdot603u & -2\cdot385v & + \; 3\cdot591 & =0 \\
 & & & & +3\cdot680v & - \; 6\cdot795 & =0
\end{array}$$

from which,

$$\begin{aligned}
x &= \cdot289 \\
y_1 &= \cdot861 \\
y_2 &= +1\cdot359 \\
z &= -\cdot149 \\
u &= +18\cdot1321 \\
v &= +12\cdot8532
\end{aligned}$$

and hence,

$$\begin{aligned}
\delta\gamma &= +\cdot29 \text{ km.} \\
\delta K_1 &= +\cdot86 \text{ km.} \\
\delta K_2 &= +1\cdot36 \text{ km.} \\
\delta e &= -\cdot0015 \\
\delta\omega &= +10^\circ\cdot39 \\
\delta T &= +\cdot357 \text{ day.}
\end{aligned}$$

These gave the second corrected values of the elements as follows:—

$$\begin{aligned}
e &= \cdot4875 \\
\omega_1 &= 15^\circ\cdot10 \\
\omega_2 &= 195^\circ\cdot10 \\
K_1 &= 47\cdot36 \\
K_2 &= 50\cdot35 \\
\gamma &= +\cdot38 \\
T &= 2{,}418{,}411\cdot555 \text{ J. D.}
\end{aligned}$$

The value of Σpvv was now reduced from 463 to 380, but still the agreement between the computed and observation equation residuals was not satisfactory, as will be seen from a glance at the last column in Table VIII.

Another least-squares solution was therefore applied, and the normal places were again set up as in Table VIII.

TABLE VIII.

NORMAL PLACES III.

No.	Mean Phase.	Mean Velocity.	Weight.	O–C.	Equation-Ephemeris.
1	24·269	+42·1	1·5	− 4·5	−0·11
2	24·889	+58·9	1·0	+ 0·7	−0·01
3	25·713	+74·0	3·0	+ 4·7	+0·57
4.	26·083	+69·0	1·5	− 0·7	+0·61
5	·089	+63·3	2·0	− 4·1	+0·41
6	1·069	+48·5	1·5	+ 2·5	−0·15
7	1·669	+29·0	1·5	− 1·5	−0·14
8	11·579	−25·0	1·5	− 0·6	−0·09
9	24·349	−56·0	·5	− 5·7	+0·18
10	24·899	−64·5	·5	− 3·2	−0·05
11	25·743	−64·2	1·5	+ 8·9	−0·62
12	26·083	−82·0	1·0	− 8·6	−0·68
13	·069	−73·6	1·5	− 2·5	−0·53
14	1·099	−45·5	·5	+ 1·8	+0·21
15	1·669	−31·0	1·0	+ 0·6	+0·11
16	11·579	+30·0	1·0	+ 3·3	+0·14

Fresh observation equations were formed as in the following table:—

TABLE IX.

OBSERVATION EQUATIONS III.

No.	x	y_1	y_2	z	u	v	$-n$	Weight.	$v-v^1$
1	1	+ ·975	·000	−·644	+·349	−·520	+4·460	1·5	+0·01
2	1	+1·221	·000	−·320	+·253	−·504	−0·700	1·0	−0·01
3	1	+1·456	·000	+·347	+·022	−·170	−4·680	3·0	−0·01
4	1	+1·465	·000	+·483	−·113	+·116	+0·740	1·5	+0·01
5	1	+1·415	·000	+·422	−·216	+·343	+4·110	2·0	+0·01
6	1	+ ·964	·000	−·444	−·472	+·743	−2·470	1·5	+0·04
7	1	+ ·636	·000	−·770	−·527	+·676	+1·480	1·5	0·00
8	1	− ·523	·000	+·473	−·006	−·015	+0·620	1·5	−0·02
9	1	·000	−1·007	+·656	−·361	+·557	+5·680	·5	−0·01
10	1	·000	−1·225	+·332	−·267	+·535	+3·220	·5	+0·01
11	1	·000	−1·459	−·388	−·012	+·158	−8·900	1·5	0·00
12	1	·000	−1·465	−·514	+·120	−·124	+8·640	1·0	0·00
13	1	·000	−1·421	−·458	+·221	−·348	+2·450	1·5	−0·01
14	1	·000	− ·947	+·497	+·507	−·790	−1·800	·5	−0·02
15	1	·000	− ·636	+·819	+·561	−·719	−0·630	1·0	−0·01
16	1	·000	+ ·523	−·503	+·006	+·016	−3·300	1·0	0·00

The normal equations resulting were:—

$$\begin{aligned}
21x + 13{\cdot}695y_1 - 7{\cdot}489y_2 - {\cdot}512z - {\cdot}328u + {\cdot}212v - {\cdot}685 &= 0\\
+18{\cdot}913y_1 + {\cdot}000y_2 + {\cdot}691z - 1{\cdot}124u + {\cdot}838v - 4{\cdot}163 &= 0\\
+10{\cdot}755y_2 + 1{\cdot}024z - {\cdot}869u + {\cdot}809v - 3{\cdot}707 &= 0\\
+5{\cdot}434z + {\cdot}473u - {\cdot}738v - 2{\cdot}424 &= 0\\
+1{\cdot}744u - 2{\cdot}551v + {\cdot}246 &= 0\\
+3{\cdot}875v + {\cdot}038 &= 0
\end{aligned}$$

Solving these,

$$\begin{aligned}
x &= {\cdot}061\\
y_1 &= {\cdot}131\\
y_2 &= {\cdot}321\\
z &= {\cdot}367\\
u &= -1{\cdot}085\\
v &= -{\cdot}753.
\end{aligned}$$

whence,

$$\begin{aligned}
\delta\gamma &= +{\cdot}06 \text{ km.}\\
\delta K_1 &= +{\cdot}13 \text{ km.}\\
\delta K_2 &= +{\cdot}32 \text{ km.}\\
\delta e &= +{\cdot}0037\\
\delta\omega &= -0^\circ{\cdot}62\\
\delta T &= -{\cdot}021 \text{ day.}
\end{aligned}$$

giving the third corrected values as follows:—

$$\begin{aligned}
P &= 26{\cdot}2742 \text{ days}\\
e &= {\cdot}4912\\
\omega_1 &= 14^\circ{\cdot}48\\
\omega_2 &= 194^\circ{\cdot}48\\
K_1 &= 47{\cdot}49 \text{ km.}\\
K_2 &= 50{\cdot}67 \text{ km.}\\
\gamma &= +{\cdot}44 \text{ km.}\\
T &= 2{,}418{,}411{\cdot}534 \text{ J. D.}
\end{aligned}$$

The value of the elements will be seen to be little changed. The value of Σpvv was found to be reduced very slightly, from 380 to 378, but the agreement between the computed and observation equation residuals was now excellent, as may be seen in Table IX $(v-v^1)$, and these elements were accepted as final. The following table contains a summary of the preliminary, first, second and third corrected values, together with the probable error of each element.

TABLE X.

Element.	Preliminary.	I.	II.	III.	Prob. Error.
P	26·2742 days	26·2742	26·2742	26·2742 days	
e	·55	·489	·4875	·4912	± ·011
ω_1	350°	4°·71	15°·10	14°·48	±7°·55
ω_2	170°	184°·71	195·10	194°·48	
K_1	50 km.	46·5 km.	47·36 km.	47·49 km.	±1·03 km.
K_2	47·3 km.	48·99 km.	50·35 km.	50·67 km.	±1·18 km.
γ	−2·08 km.	+·09 km.	+·38 km.	+·44 km.	±1·03 km.
T	2,418,410·794 J. D.	2,418,411·198 J. D.	2,418,411·555 J. D.	2,418,411·524 J. D.	± ·30 day
$a \sin i$				14,950,000 km.	

The probable error of a single observation of average weight was found to be ±5·6 for the primary component and ±6·6 for the secondary.

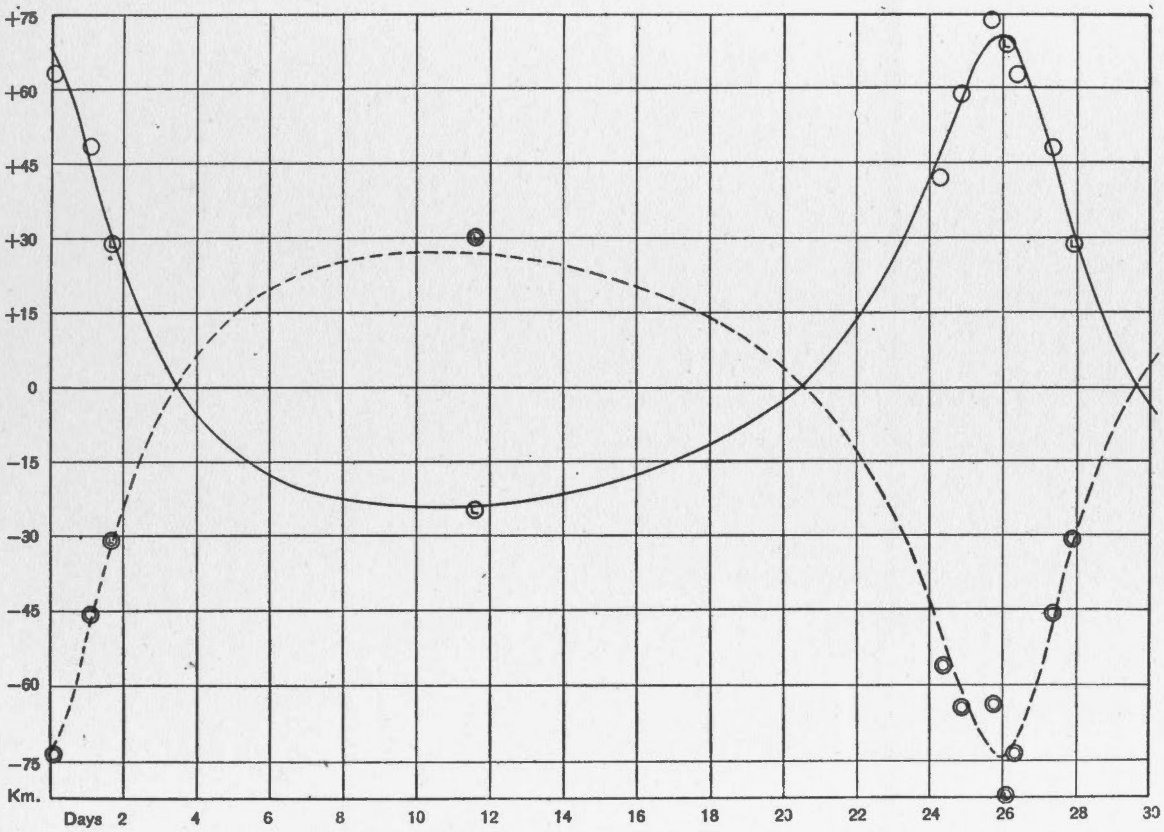
The probable error of a normal place for the primary is ±4·0 and for the secondary component ±5·2.

In the published note in L.O.B. Vol. IV, it is stated that it seems probable that the masses of the stars are not very different, and from the elements determined above this would appear to be the case.

The relation between the masses of the two stars is given by $M_1 : M_2 = K_2 : K_1 = 25 : 24$.

In the accompanying figure, the single circles indicate the observations of the primary and the double circles those of the secondary component. The Lick observations are shown by an L within the circle.

Dominion Observatory,
Ottawa,
June, 1915.



Velocity Curve of B. A. C. 5890.