THE ORBITS OF THREE K-TYPE SPECTROSCOPIC BINARIES*

By WILLIAM H. CHRISTIE

ABSTRACT

The orbital elements of three K-type spectroscopic binaries, corrected by least-squares solutions, are given. Among these are the elements of a dwarf star, the spectra of both components of which are measurable.

BOSS 1953, γ CANIS MINORIS

The binary character of γ Canis Minoris was announced by Reese in 1902.[1] Measures of thirteen spectrograms of this star appear in

TABLE I

ELEMENTS OF THREE SPECTROSCOPIC BINARIES

Elements \ Star	Boss 1953	Boss 2824	Boss 6129
α (1900)	7^h22^m8	10^h32^m2	23^h47^m5
δ (1900)	$+9°08'$	$34°36'$	$+74°59'$
Magnitude	4.60	6.65	6.55
Absolute magnitude	+0.1	+0.3	+6.6
Type	K4	K2	dK5
P(days)	389.0	1510.0	7.75310
T(J.D.)	2399999.53	2427408.4	2420001.264
e	0.31	0.65	0.00 (assumed)
ω	107°.4	37°.6	.....
K_1 (km/sec.)	18.57	9.22	39.88
K_2 (km/sec.)	.....	.....	49.70
γ (km/sec.)	+46.80	+12.62	+1.68
$a_1 \sin i$ (km)	94,400,000	145,000,000	4,250,000
$a_2 \sin i$ (km)	.....	.....	5,300,000
$\frac{m_2^3 \sin^3 i}{(m_1+m_2)^2}$	0.26⊙	0.054⊙	.....
$m_1 \sin^3 i$	.....	.....	0.321⊙
$m_2 \sin^3 i$	.....	.....	0.258⊙

Publications of the Lick Observatory, **16**, and, after an inspection of this list, the writer decided to undertake the investigation of the orbit, for, in addition to the thirteen Lick velocities, three Bonn and

* *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington*, No. 499.

[1] *L.O.B.*, **1**, 159, 1902.

three Mount Wilson velocities were available. Trials for the period were made before further plates were obtained and, when the plate of December 8, 1912, was neglected, a period was readily found which satisfied all the other observations. A few plates were then ob-

TABLE II

OBSERVATIONAL DATA; BOSS 1953

Plate	Date	Julian Date	Vel.	Phase
			km/sec.	
Lick	1900 Oct. 30	2415323.06	+43.6	$152^{d}.5$
Lick	1901 Nov. 6	5695.99	46.8	136.5
Lick	Dec. 22	5741.93	48.8	182.4
Lick	Dec. 30	5749.84	50.4	190.3
Lick	1903 Dec. 8	6457.00	36.4	119.5
Lick	Dec. 24	6473.93	41.0	136.4
Bonn	1912 Feb. 11	9444.62	46.1	384.1
Lick	Dec. 18	9755.82	64.1	306.3
Lick	Dec. 23	9760.02	63.8	310.5
Lick	1913 Jan. 2	9770.78	65.6	321.3
Lick	Jan. 27	9795.86	58.3	346.4
Lick	Jan. 31	9799.76	55.3	350.3
Lick	Feb. 17	9816.84	49.2	366.7
Bonn	Feb. 18	9817.60	54.7	368.1
Lick	Mar. 3	9830.80	46.2	381.3
Bonn	Mar. 12	9389.52	46.9	1.0
Lick	Apr. 10	9868.69	25.4	30.2
γ 15383	1927 Nov. 6	2425191.04	59.6	295.5
15643	1928 Mar. 21	5327.65	29.2	43.1
15644	Mar. 21	5327.66	28.3	43.2
Lick	Nov. 9	5560.04	63.1	275.5
Lick	Nov. 20	5570.95	65.1	286.5
Lick	Nov. 30	5580.92	64.0	296.4
Lick	1929 Dec. 1	5946.96	62.4	273.5
Lick	1930 Feb. 17	6024.79	58.3	351.3
γ 19853	1933 Sept. 6	7323.03	31.8	93.5
19868	Sept. 8	7325.01	34.1	95.5
19959	Oct. 10	7356.96	41.4	127.5
20008	Oct. 31	7377.93	45.5	148.4
20162	Jan. 29	7467.63	53.4	238.1
20166	Jan. 29	7467.82	+52.6	238.3

tained here, measures of which also fitted the provisional period. Suspecting that the discarded observation was in error, I asked Dr. Moore to check the data. He very kindly did so and found an error in the identification of the star on this date and that the spectrum was evidently that of ε Canis Majoris.[2] At the same time he thoughtfully sent me seven additional unpublished velocities of the star.

[2] *Pub. A.S.P.*, **45**, 311, 1933.

With these additional observations the period was well established and the data sufficient for a least-squares solution for the most probable elements of the orbit.

The observational data are given in Table II. After rejection of the three Bonn plates, the remaining twenty-eight observations were grouped according to phase into thirteen normal places, each weighted according to the number and quality of the observations

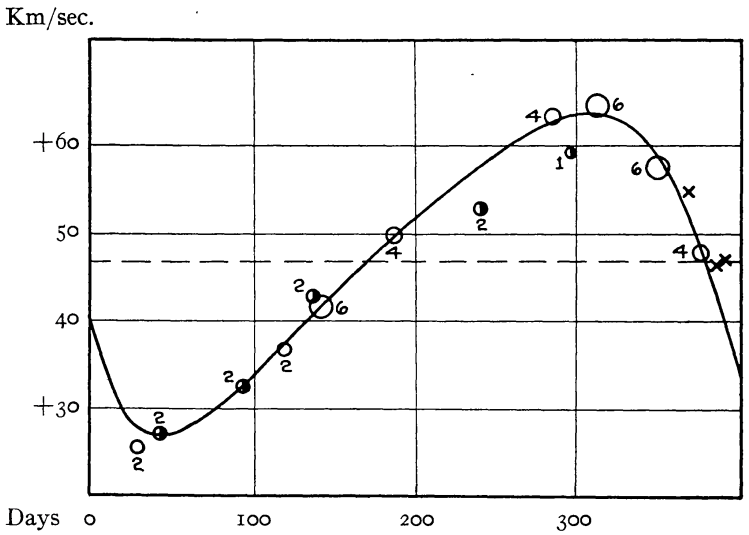

FIG. 1.—Velocity-curve of Boss 1953. Half-filled circles, Mount Wilson observations; open circles, Lick observations; crosses, Bonn observations. Numerals indicate number of observations in group.

included. All Lick plates were weighted unity; those of Mount Wilson, $\frac{1}{2}$, after a correction of -0.5 km/sec. had been applied to reduce them to the Lick system.[3] Since thirty-one orbital revolutions of the star had taken place between the first and last observations, the period was not included in the solution. The final elements are given in Table I; the corresponding velocity-curve in Figure 1. The sum of the squares of the residuals was reduced from 1464 to 958, or about 32 per cent; the probable error of a normal place of weight unity is ± 0.58 km/sec.

BOSS 2824

The binary character of Boss 2824 was announced by H. H. Plaskett in 1921.[4] The investigation of the orbit was commenced by

[3] *Pub. Lick Obs.*, **18**, xii, 1932. [4] *Pub. Dom. Ap. Obs.*, **1**, No. 26, 1922.

TABLE III

OBSERVATIONAL DATA; BOSS 2824

Plate	Date	Julian Date	Vel.	Phase
Victoria:		2420000+	km/sec.	
3746	1920 Feb. 24	2329.9	+13.1	$96^{d}1.5$
5813	1921 Mar. 29	2778.9	23.1	1410.5
5863	Apr. 5	2785.9	25.0	1417.5
5899	Apr. 9	2788.8	19.0	1420.4
5979	May 3	2813.8	27.6	1445.4
11329	1925 Mar. 18	4227.8	23.3	1349.4
11408	Apr. 6	4247.9	21.3	1369.5
11435	Apr. 8	4249.8	19.5	1371.4
11466	Apr. 10	4251.9	16.8	1373.5
13382	1926 May 12	4647.6	10.6	259.2
13403	May 20	4655.8	10.6	267.4
13440	June 2	4668.7	5.9	280.3
13453	June 3	4669.7	7.0	281.3
13471	June 7	4673.7	7.2	285.3
13486	June 10	4676.7	8.4	288.3
Mt. Wilson:				
γ 16577	1929 May 19	5751.6	19.1	1363.2
16590	May 21	5753.7	18.6	1365.3
C 5204	June 14	5777.7	21.6	1389.3
γ 16966	Oct. 9	5894.0	22.5	1505.6
16974	Oct. 10	5895.0	22.9	1506.6
17066	Nov. 14	5931.0	17.8	32.6
17077	Nov. 15	5932.0	17.4	33.6
17108	Nov. 22	5939.0	11.0	40.6
17163	Dec. 22	5969.0	9.9	70.6
17171	Dec. 23	5970.0	8.5	71.6
17190	1930 Jan. 19	5997.0	8.5	98.6
17195	Feb. 5	6012.9	9.6	114.5
17203	Feb. 6	6013.9	8.6	115.5
17333	Mar. 17	6054.7	10.9	156.3
17347	Mar. 18	6055.9	10.7	157.5
17388	Apr. 15	6082.6	10.0	184.2
17431	May 10	6107.6	5.7	209.2
17466	May 19	6116.7	5.8	218.3
17469	May 19	6116.8	5.6	218.4
17497	June 7	6135.7	5.5	237.3
17566	July 6	6164.7	10.0	266.3
17582	July 13	6171.7	13.3	273.3
17810	Oct. 13	6263.0	5.4	364.6
17841	Nov. 1	6283.0	9.0	384.6
17848	Nov. 2	6284.0	4.1	385.6
17907	Nov. 29	6310.0	7.5	411.6
17916	Nov. 30	6311.0	3.6	412.6
17968	Dec. 9	6320.0	12.1	321.6
17984	Dec. 12	6323.0	12.6	424.6
17986	Dec. 24	6335.8	17.0	437.4
17988	Dec. 24	6336.0	12.8	437.6
17991	Dec. 26	6337.9	14.9	439.5
18078	1931 Mar. 1	6402.8	0.3	504.4
18124	Mar. 9	6410.8	+ 7.6	512.2

TABLE III—*Continued*

Plate	Date	Julian Date	Vel.	Phase
Mt. Wilson—*Continued:*		2420000+	km/sec.	
γ 18138	1931 Mar. 13	6414.8	+ 6.8	$516^d.4$
18158	Mar. 30	6431.6	8.2	533.2
18168	Mar. 31	6432.9	10.2	534.5
18184	Apr. 5	6437.8	5.8	539.4
18210	Apr. 30	6462.7	7.8	564.3
18223	May 3	6465.8	10.6	567.4
18281	June 3	6496.7	14.0	598.3
18555	Nov. 17	6664.0	9.0	765.6
18560	Nov. 18	6665.7	12.8	767.3
18631	Dec. 30	6707.0	12.8	808.6
18685	1932 Jan. 29	6736.8	14.8	838.4
18692	Feb. 19	6757.8	12.1	859.4
18698	Feb. 20	6758.7	10.8	860.3
18758	Mar. 22	6789.7	8.6	891.3
18759	Mar. 23	6790.6	9.3	892.2
18809	Apr. 21	6819.8	7.1	921.4
18811	Apr. 22	6820.8	7.7	922.4
18855	May 24	6852.7	8.5	954.3
18921	June 25	6885.7	12.9	987.3
19184	Oct. 10	6992.0	10.7	1093.6
19238	Nov. 6	7019.0	10.7	1120.6
19259	Nov. 8	7021.0	16.3	1122.6
19343	Dec. 5	7048.0	13.2	1149.6
19359	Dec. 6	7049.0	14.3	1150.6
19536	1933 Mar. 9	7141.6	16.9	1243.6
19593	Apr. 9	7172.6	19.4	1274.2
19649	May 14	7207.6	20.5	1309.2
19657	May 15	7208.6	18.2	1310.2
19663	May 31	7224.7	24.4	1326.3
19971	Oct. 11	7358.0	28.2	1459.6
20010	Oct. 31	7378.0	24.8	1479.6
20039	Nov. 9	7387.0	24.8	1488.6
20047	Nov. 10	7388.0	23.8	1489.6
20071	Dec. 1	7409.0	22.5	0.6
20117	1934 Jan 2	7441.0	15.4	32.6
20168	Jan. 29	7467.9	13.5	59.5
20202	Feb. 2	7471.8	+ 5.3	63.4

Pearce in 1925, but at his suggestion was continued by me while serving as observing assistant at the Dominion Astrophysical Observatory during the summer of 1926. In all, eighty-seven usable spectra were taken before the preliminary elements could be determined with any degree of accuracy, sixteen at Victoria, the remainder at Mount Wilson. The observational data are given in Table III.

The preliminary period of 1510 days was not definitely ascertained until the end of 1933, and some difficulty was encountered in deter-

mining the preliminary elements because of peculiar irregularities in the run of the individual observations. These irregularities suggest a secondary variation, in a period of about 220 days, superimposed upon the longer period. The individual observations from 1929 to 1932, inclusive, decidedly favor such a variation. Since the amplitude of this secondary variation, if real, amounts to only 7 km/sec., higher dispersion than that of the one-prism spectrographs used throughout this investigation is necessary to settle the question;

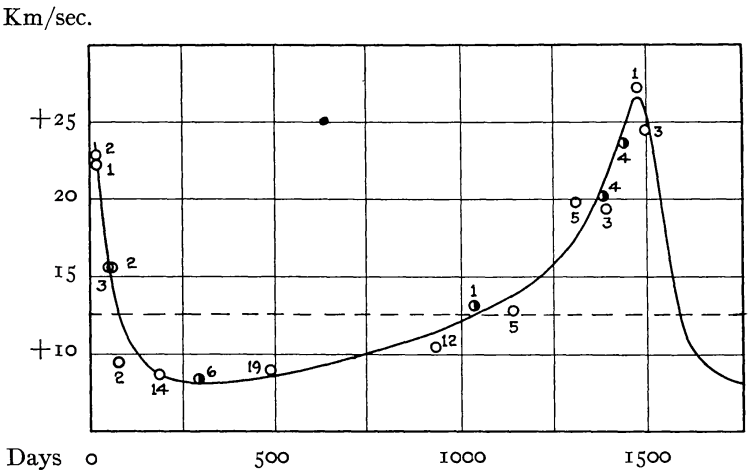

FIG. 2.—Velocity-curve of Boss 2824. Open circles, Mount Wilson observations; half-filled circles, Victoria observations. Numerals indicate number of observations in group.

but since the star is not bright, the time consumed by such a procedure would be prohibitive.

In order to include the Victoria plates in the solution, they were remeasured here and reduced by the use of the Mount Wilson tables; hence, unless there is a large systematic instrumental effect, the material should be fairly homogeneous.

The eighty-seven observations were grouped according to phase into eighteen normal places, weighted according to the number of observations in each group. After satisfactory preliminary elements had been derived from the data, a solution was made for the most probable values. The resulting corrected elements are given in Table I, the corresponding velocity-curve in Figure 2. The probable error of a normal place of weight unity is ± 0.38 km/sec. The sum

of the squares of the residuals was reduced from 1018 to 807, about 21 per cent.

BOSS 6129

The binary character of Boss 6129 was announced in 1917 by Adams and Joy.[5] A spectrogram of this star taken by the writer in

TABLE IV

OBSERVATIONAL DATA; BOSS 6129

Plate	Date	Julian Date	Vel. Br.	Vel. Ft.	Remarks
			km/sec.	km/sec.	
γ 2888...	1913 Nov. 15	2420087.842	+23.2	.....	Shows traces of doubling
3894...	1914 Nov. 24	0461.725	+16.7	.....	Single lines; omitted
4293...	1915 July 28	0707.983	+27.2	.....	Shows traces of doubling
4928...	1916 July 12	1056.943	+41.4	−41.8	
4995...	Aug. 16	1091.962	−43.1	+48.8	
5089...	Sept. 17	1124.842	+11.9	.....	Questionable; omitted
5427...	1917 Jan. 6	1235.626	+51.6	−51.9	
19677...	1933 June 1	7225.973	−31.2	+45.1	
19692...	June 9	7233.975	−24.0	+37.7	
19699...	June 10	7234.985	+ 3.6	.....	
19710...	June 30	7254.983	−16.7	+27.8	
19748...	July 12	7266.950	+27.4	.....	
19756...	July 13	7267.909	+44.7	−61.1	
19797...	Aug. 11	7296.877	+ 7.1	.....	
19809...	Aug. 12	7297.959	+28.9	.....	
19815...	Aug. 13	7298.896	+38.7	−40.2	
19849...	Sept. 6	7322.846	+35.2	−33.1	
19858...	Sept. 7	7323.835	+ 8.6	.....	
19963...	Oct. 10	7356.802	−44.4	+57.6	
19954...	Oct. 11	7357.729	−27.8	+35.1	
20016...	Nov. 2	7379.907	−32.1	+48.6	
20034...	Nov. 9	7386.677	−13.9	+26.7	Blend +3.1 km/sec.
20041...	Nov. 10	7387.631	−38.1	+35.0	

the summer of 1933 showed double lines. On looking over the seven older plates, taken between 1912 and 1918, three were found on which the lines were distinctly double, while on two others they showed definite traces of duplicity. As double-line spectroscopic binaries of type K or later are extremely rare (the companion to Castor being the only other example known to the writer), the star

[5] *Pub. A.S.P.*, **29**, 114, 1917.

was placed on the program for further observation. Eleven of the fourteen spectrograms obtained during the summer and fall of 1933 showed the spectra of both components sufficiently separated to be measured with confidence.

Except for an intensity difference of about 1 mag., the two spectra appear to be quite similar. According to Adams, Joy, and Humason, the spectral type and absolute magnitude of the brighter star are dK5 and 6.5, respectively. The trigonometric parallax, kindly fur-

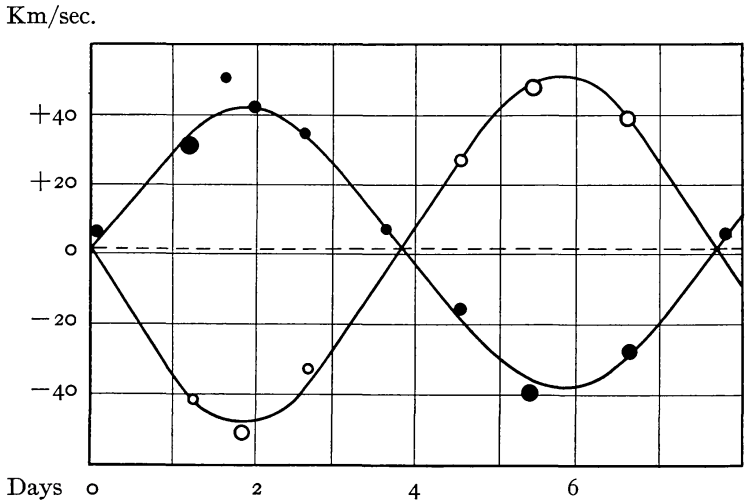

FIG. 3.—Velocity-curve of Boss 6129. Size of circles proportional to weights

nished by van Maanen, is $0''.090 \pm 0''.004$, which, with an adopted visual magnitude of 6.8 for the primary, gives an absolute magnitude of +6.6, in excellent agreement with the spectroscopic value. The secondary spectrum is somewhat difficult to measure, and the scatter for the individual lines is rather large. Nevertheless, these results appear to be quite reliable, for the errors are no greater than may be expected. Even when the lines of the two spectra overlap, it has been found possible to measure them with some accuracy.

The period was found without difficulty and, because of the twenty-year interval between the first and last observations, there was no necessity of including it in the least-squares solution. The observational data are given in Table IV. The observations of the primary, with the exceptions noted in the "Remarks" column of the

table, were grouped according to phase into nine normal places, each weighted according to the number of observations included.

As no eccentricity was apparent, this element was assumed to be zero, and a least-squares solution was made for γ, K, and T. The secondary was not included in the solution because of the small weight assigned to the measures, but, by using the final values of γ and T derived from the primary, a correction was made to the semi-amplitude of the secondary. The final elements are given in Table I, the velocity-curve in Figure 3.

The probable error of a normal place of weight unity is ± 0.39 km/sec. for the primary and ± 1.13 km/sec. for the secondary. The sum of the squares of the residuals for the primary was reduced from 380 to 234, and for the secondary from 265 to 81, or about 39 and 70 per cent, respectively.

CARNEGIE INSTITUTION OF WASHINGTON
MOUNT WILSON OBSERVATORY
April 1934