A REDISCUSSION OF THE ORBITS OF SEVENTY-SEVEN SPECTROSCOPIC BINARIES

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ABSTRACT

The orbital elements for 77 spectroscopic binaries with small eccentricities are rediscussed from the point of view of determining the real uncertainties in the published values of e and ω. For this reason, too, the Fourier analysis method of Wilsing and Russell has been used throughout, since in this method the significant variables remain separated. It is thus found that for thirty-three of the binaries analyzed the eccentricity is too small to be determinable at the present time, and circular orbits have been adopted. For the remaining cases elliptic elements have been retained, even though it is felt that unknown systematic errors may well be the cause of spurious eccentricities in many instances.

I. INTRODUCTION

As compared with the first few decades of spectroscopic binary investigations, a definite change in viewpoint appears to have taken place in recent years. In the early work the emphasis was largely on approximate values of the elements with a view to statistical discussions concerning periods, masses, eccentricities, and orientation of the planes; in recent years, however, this emphasis seems to have shifted more in the direction of a greater accuracy in order to investigate effects due to rotation and reflection, but also for the purpose of looking for possible secular changes. Among the latter a rotation of the line of apsides overshadows all others in importance, partly because of the possibilities it offers for calculating the internal density distribution of the stars. The number of stars for which an apsidal rotation has been definitely demonstrated is still small—half a dozen at most—but for a large number of stars there exist orbits determined long enough ago that reobservation at the present time or in the near future might lead to valuable conclusions. The orbits that could come into consideration are naturally those of short period and small eccentricity, but the selection of likely cases where such apsidal rotation might be found is hampered by the lack of uniformity in the early determinations of the elements.

The chief difficulty lies in the fact that in the least-squares solutions used for most of these orbits, either T or ω was kept fixed, with the result that not only do the calculated probable errors of ω or T give no indication of the real uncertainty in these elements, but often the adopted value for ω may differ markedly from that determined by other and more independent methods.

In the writer's opinion the fault lies mainly in the fact that the usual least-squares solution—that of Lehmann-Filhés or its modification by Schlesinger—is not really applicable to orbits of small eccentricity. Of all the methods found in the literature, it appears to the writer that only one is free from objections, namely, that originally proposed by Wilsing and modified by Russell. In this method all five variables are completely independent of each other and hence the errors found are genuine errors. The elements as usually given—viz., γ, K, e, ω and T—can then be very simply calculated, but it is immediately seen that T and ω are strongly dependent. For this reason the writer feels that T is not suitable as an element in the case of orbits of small eccentricity, but should be replaced by some more appropriate epoch such as the time of nodal passage, which can be given with much greater certainty than T and is almost wholly independent of ω.

Moreover, the usual practice has been to select any arbitrary epoch as T—often the time when the earliest plate was taken, and many years before the mean epoch of observation. Strictly speaking, the error given for such a T is not the real error, for the latter should include the cumulative uncertainty in P and may thus be much larger. Giving the elements referred to the mean epoch of observation, moreover, simplifies the interpretation of secular changes. For these various reasons it was decided to calculate elements anew for all orbits with $e < 0.1$, not, of course because the published elements were thought to be in error, but chiefly for the purpose of establishing all elements on a uniform system in which T is always meant to be the instant when the primary passes through its ascending node (maximum velocity of recession), on or about the mean epoch of observation. Moreover, as will be seen from the detailed discussions given below, special considerations entered into the case of many individual stars—such as the possibility that a wrong period had been used.

2. DESCRIPTION OF THE METHOD

The Fourier-analysis method of Wilsing and Russell has been fully described by the latter, but the practical application of it naturally leads to difficulties which require some comment. In order to make the calculation of the elements as uniform as possible, the observations were always plotted against the mean anomaly, and the plot extended over two full periods; a free-hand curve was then drawn—likewise through the two full periods, which would insure correct readings uninfluenced by a truncated curve at the end of an interval—and values for the velocity were read off at twelve equidistant points. When the observations were very numerous or their scatter considerable, it sometimes became necessary to take the means first and to plot such normal places. Sometimes the published normal places were used directly and elements were calculated from them. Since these normal places are almost never equidistant in phase, the calculations then become enormously more complicated, but several trials convinced the writer that this extra labor is rarely justified and that the values for the elements thus obtained do not constitute a real improvement over those found by the simple graphical reading.

If the twelve velocities are read off the curve and are represented by V_0, V_{30}, V_{60}, V_{90} . . . . V_{330}, respectively, then, in Russell's notation, we have for any V_θ

$$V_\theta=\gamma+S_1 \sin \theta+C_1 \cos \theta+S_2 \sin 2\theta+C_2 \cos 2\theta ,$$

from which follows immediately in the present case

$$\gamma=\frac{\Sigma V}{12} , \qquad S_1=\frac{\Sigma V_\theta \sin \theta}{6} , \qquad C_1=\frac{\Sigma V_\theta \cos \theta}{6} , \qquad S_2=\frac{\Sigma V_\theta \sin 2\theta}{6} ,$$
$$C_2=\frac{\Sigma V_\theta \cos 2\theta}{6} .$$

Since θ only takes on values which are multiples of 30°, the trigonometric functions involved only take on the values 0, ± 0.50, ± 0.866, or ± 1, and hence the entire calculation of the elements can be done mentally and consumes less than half an hour.

In addition to this substantial saving in time, the Wilsing-Russell method offers the further advantage of a rapid calculation of the errors of the elements, which in this instance are real errors.

In this connection it may first be mentioned that the writer's experience has been that the use of weights for either individual observations or normal places usually has such a trivial effect upon the resulting elements that for the sake of convenience all weights may well be taken equal to unity (with rare exceptions). The first step is always the calculation of the error for a single plate, which has to be done for any method. In the usual notation this is given by

$$\sigma_1^2 = \frac{\Sigma vv}{n-5} .$$

Here the writer sees no reason to multiply σ by the factor 0.6745 in order to obtain that horrible misnomer—the probable error. This factor has significance only if one is certain that the normal law of error is satisfied, and this is almost never the case in actual practice. And even then the root-mean-square deviation σ has at least as much justification as the halfway error ρ. The chief practical argument for the use of the probable error appears to be that it is smaller, but in the writer's opinion this is a serious drawback. To almost anyone the statement $e=0.017\pm.014$ (p.e.) will convey a better determination of the eccentricity than $e=0.017\pm0.021$ (m.e.), although actually they are identical.

Assuming the ideal case, where all n individual observations are evenly distributed over the entire curve and all are of the same weight, we immediately have $\sigma_\gamma=\sigma_1/\sqrt{n}$, while the mean errors of all other quantities (S_1, C_1, S_2, and C_2) are equal to $\sigma_1\sqrt{2}/\sqrt{n}$; hence this also equals the mean error of $A_1(=K)$ and A_2. Since in all cases under consideration e is small, and $e=A_2/A_1$, we find further

$$\sigma_e = \frac{\sigma_1}{K} \cdot \sqrt{\frac{2}{n}}$$

and

$$\sigma_\omega = \frac{\sigma_1}{A_2} \cdot \sqrt{\frac{2}{n}} \text{ (in radians)} .$$

In actual practice we never have the ideal case; moreover, the derivation of errors tacitly assumes that they shall be infinitesimals compared with the quantities themselves—a situation which is never realized. Owing to the first objection, the actual error of γ usually remains nearly equal to that given here, that in K may sometimes be even smaller, and those in e and ω are invariably larger, especially in the case of double-lined binaries where a large proportion of the observations fall at or near the velocity extremes. The effect of the second objection is hard to correct for, but its chief importance is that the real error of ω is much larger than that calculated. To take a concrete example: Suppose that we find $S_2 = +1.7 \pm 1.3$; $C_2 = -0.9 \pm 1.3$, giving $A_2 = 2.0 \pm 1.3$ and indicating an uncertainty of 66 per cent in A_2 and hence also in e. But no one will believe that the real uncertainty in ω amounts to only 38°, on the contrary, our experience tells us that the orbit is so nearly circular as to defy determination of either e or ω. In the writer's opinion, all orbits in which the mean error of e amounts to more than 50 per cent of e itself, should be regarded with suspicion but in what follows all orbits in which a single determination indicated $e \geqq \sigma_e$ have been retained as elliptic.

3. MATERIAL REDISCUSSED

A beginning has been made by rediscussing all orbits with e less than 0.1 published in the *Lick Observatory Bulletins, the Publications of the Allegheny Observatory*, the *Publications of the Dominion Observatory* and the *Publications of the Dominion Astrophysical Observatory*, as well as a few other, special cases.

The following table contains data for seventy-seven binaries, comprising most of those having a published eccentricity of less than 0.1. For some of the remaining stars revisions of the orbits have already been given by the writer. For only one star, TV Cassiopeiae, an originally circular orbit is here suggested to possess a measurable eccentricity, where for thirty-three originally elliptic orbits the rediscussion indicates that the eccentricity is too small to be determined from the observations. While, in general, only the values of e and ω derived by the writer have been given, it should

TABLE I

	Star	1900—Position α δ	m	Sp.	γ	Reference
1. .	TV Cas	0:13.9+58:35	7.4	B9	+ 1.2 ±1.5	*D.A.O.*, **2**, 141, 1922
2. .	π Cas	37.9+46:29	5.0	A5	+12.4 ±0.8	*D.O.*, **4**, 135, 1917
3. .	ζ And	42.0+23:43	4.3	K0	−23.6 ±0.40	*Cape Ann.*, **10**, 8, 35
4. .	γ Phe	1:24.0−43:50	3.4	K5	+26.0 ±0.20	*L.O.B.*, **9**, 116, 1918
5. .	α Tri	47.4+29:06	3.6	F5	{−12.6 ±0.58 −12.8 ±0.7	*D.O.*, **3**, 113, 1915 . . . .
6. .	6 Tri Cr	2:06.6+29:50	5.5	G0	−19.1 ±0.8	*D.A.O.*, **2**, 129, 1921
7. .	6 Tri ft	06.6+29:50	6.7	F4	−19.8 ±1.2	*Ibid.*, p. 129, 1921
8. .	8 Tri	10.8+33:46	5.1	G0	− 5.8 ±0.10	*L.O.B.*, **11**, 131, 1923
9. .	Boss 613	36.2+67:24	5.8	A2	+ 4.3 ±0.6	*D.A.O.*, **4**, 313, 1930
10. .	RZ Cas	39.9+69:13	6.4	A0	−39. ±1.4	*A.O.*, **3**, 137, 1914
11. .	π Ari	43.7+17:03	5.3	B5	+ 8.0 ±0.85	*D.O.*, **4**, 69, 1917
12. .	HD 19820	3:06.2+59:11	7.1	B5	− 4.1 ±1.0	*D.A.O.*, **4**, 67, 1927
13. .	HR 976	09.8+34:19	6.4	A2	+24.1 ±0.8	*Ibid.*, **6**, 79, 1932
14. .	Boss 809	26.9+39:34	5.8	A0	+ 2.8 ±1.0	*Ibid.*, **4**, 43, 1927
15. .	υ^4 Eri	4:14.1−34:02	3.6	B9	+17.8 ±0.56	*L.O.B.*, **8**, 168, 1915
16. .	HR 1401	21.9+72:20	6.0	A5	+ 9.0 ±0.8	*D.A.O.*, **4**, 316, 1930
17. .	d Tau	30.2+ 9:57	4.4	A3	−29.0 ±0.4	*A.O.*, **3**, 93, 1914
18. .	HD 29376	32.5+ 7:07	6.9	B5	+25.6 ±1.5	*D.A.O.*, **6**, 59, 1932
19. .	Boss 1082	33.0+52:54	5.3	K0	−40.5 ±1.2	*D.O.*, **4**, 175, 1918
20. .	HR 1528	42.8+32:25	5.9	A3	+20.3 ±0.8	*D.A.O.*, **6**, 82, 1932
21. .	π_4 Ori	45.9+ 5:26	3.8	B3	+23.3 ±0.45	*A.O.*, **1**, 107, 1907
22. .	α Aur	5:09.3+45:54	0.2	G0	+30.2 ±0.14	*L.O.B.*, **1**, 32, 1901
23. .	ψ Ori	21.6+ 3:00	4.5	B2	+12.0 ±1.6	*Ap.J.*, **28**, 266, 1908
24. .	Boss 1452	46.0+59:52	5.3	A0	− 3.7 ±0.9	*D.A.O.*, **3**, 159, 1924
25. .	136 Tau	47.0+27:35	4.5	A0	−17.2 ±0.9	*D.O.*, **2**, 119, 1915
26. .	45 Aur	6:13.6+53:30	5.4	F5	− 1.3 ±0.7	*D.A.O.*, **3**, 189, 1925
27. .	HD 44701	18.0− 3:14	6.6	B5	+ 8. ±3.0	*Ibid.*, **6**, 70, 1932
28. .	+6:1309	32.0+ 6:13	6.1	B0	+23.9 ±1.7	*Ibid.*, **2**, 147, 1922
29. .	19 Lyn	7:14.7+55.28	5.6	B8	+ 6.0 ±1.5	*D.O.*, **4**, 235, 1918
30. .	63 Gem	21.8+21:39	5.3	F5	+24.4 ±1.8	*D.A.O.*, **3**, 225, 1925
31. .	σ Gem	37.0+29:07	4.3	K0	+45.8 ±0.55	*D.O.*, **1**, 263, 1911
32. .	Boss 2463	9:06.4+61:50	5.2	F8	−15.0 ±0.48	*D.A.O.*, **2**, 205, 1923
33. .	m Vel	47.8−46:04	4.6	G5	+11.0 ±0.25	*Cape Ann.*, **10**, 8, 53, 1928
34. .	19 LMi	51.6+41:32	5.2	F5	−10.7 ±0.35	*D.A.O.*, **3**, 194, 1925
35. .	HR 4535	11:44.1+16:48	6.0	A2	−24.0 ±0.50	*Ibid.*, **3**, 331, 1926

TABLE I—*Continued*

	P	T 2400000+	K	e	ω	n	σ_1
1...	1^{d}812635	22642.287± .007	87.3 ± 2.0	.024±.021	203±50	21	6.7
2...	1.96408	21246.446± .003	117.3 ± 1.4 119.0 ± 1.5	0	....	34 ..	7.0 7.4
3...	17.7678	22012.48 ± .05	25.9 ± 0.56	0	....	91	4.2 2.1
4...	193.79	19544.92 ± .05	16.0 ± 0.28	0	....	31	1.0
5...	1.73652 2.3413	20616.102± .010 20616.21 ± .03	12.1 ± 0.85 11.4 ± 0.9	.121±.066 .11 ±.08	136±38 190±40	85 ..	5.5 6.0
6...	14.732	22567.057± .082	56.5 ± 1.8 57.0 ± 2.2	.043±.025	5±35	30	3.7 6.4
7...	2.2365	22653.719± .008	95.4 ± 2.0 101.0	0	....	25	5.8
8...	9.92912	23378.407± .028	8.82± 0.14	.050±.017	16±19	23	0.46
9...	2.53636	25319.979± .006	55.1 ± 0.8	0	....	27	3.0
10...	1.19525	19526.909± .007	69.1 ± 2.0	.048±.030	170±35	71	10.8
11...	3.854	21055.52 ± .033	24.9 ± 1.2	.07 ±.05	90±40	50	5.5
12...	3.3690	24561.916± .007	141.6 ± 1.2 291. ± 5.0	.099±.010	300±5	22	3.6 15.3
13...	5.54348	26482.721± .022	62.0 ± 1.4	.038±.025	60±37	19	3.4
14...	0.91718	23384.954± .002	94.9 ± 1.4	.027±.015	238±33	29	5.1
15...	5.0105	17836.144± .012	63.7 ± 0.80 64.8 ± 0.80	.020±.013	116±38	39	3.4
16...	4.195	26034.645± .036	31.3 ± 1.8	0	....	18	3.0
17...	3.57120	19560.896± .006	74.2 ± 0.53 158. ±20.0	0	....	95	......
18...	2.2075	25598.178± .007	124.5 ± 2.7 235.8 ± 2.9	.077±.018	0±16	14 ..	7.0 7.5
19...	121.	21404.0 ±1.0	28.2 ± 1.8	0	....	44	......
20...	7.0507	26420.600± .028	57.7 ± 1.2	.031±.021	278±38	21	3.4
21...	9.5191	18275.65 ± .034	25.8 ± 0.6	.033±.023	165±40	36	2.6
22...	104.02	14761.76 ± .13	25.78± 0.20	.016±.008	120±30	31	0.73
23...	2.52588	17960.362± .008	144.0 ± 2.2 228. ± 7.0	.055±.016	180±17	37	10.0
24...	2.93317	23176.160± .008	76.2 ± 1.3	.040±.020	30±30	25	4.5
25...	5.969	20147.25 ± .027	48.9 ± 1.4 71.	0	....	60	6.9
26...	6.5013	23459.153± .026	31.6 ± 1.0	0	....	28	3.5
27...	1.19033	25478.323± .005	172. ± 4.0 263. ± 8.0	.04 ±.02	3±28	19	11.0
28...	14.414	23111.051± .040	207 ± 2.3 247 ±30.0	.035±.013	187±22	30	8.5
29...	2.25960	22601.018± .010	106.4 ± 2.1 199.1 ± 4.0	.042±.020	146±28	38	11.0 5.0
30...	1.93265	24017.010± .007	94.6 ± 2.6 116.8 ± 4.8	0	....	39 ..	7.2 10.5
31...	19.605	18962.43 ± .07	34.2 ± 0.77	0	....	38	3.3
32...	16.2382	22863.284± .050	34.8 ± 0.62	.090±.030	169±19	24	2.4
33...	329.30	23596.5 ±1.3	14.1 ± 0.25	0	....	56	1.4
34...	9.283	23888.75 ± .05	15.1 ± 0.50	0	....	33	1.8
35...	2.7818	24563.938± .010	30.7 ± 0.70	0	....	21	2.2

TABLE I—*Continued*

	Star	1900—Position α δ	m	Sp.	γ	Reference
36..	Boss 3138	11:55.8−19:06	5.3	B3	+6. ±2.0 +8 ±2.0	*D.O.*, **4**, 125, 1917 *Ap.J.*, **75**, 348, 1932
37..	Boss 3182	12:07.5+78:10	5.1	A5	+0.3 ±1.0	*Ibid.*, **43**, 320, 1916
38..	Boss 3511	13:30.3+37:42	5.0	F0	+6.4 ±0.8 +6.6 ±0.8 +6.2 ±0.8	*D.O.*, **4**, 223, 1918
39..	δ Lib	14:55.6− 8:07	4.8	A0	−44.9 ±0.7	*A.O.*, **1**, 123, 1909
40..	HR 5702	15:15.4+32:54	6.1	A2	−25.8 ±1.1	*D.A.O.*, **4**, 55, 1927
41..	TW Dra	15:32.4+64:14	7.8	A5	− 0.1 ±1.3	*Ibid.*, **1**, 145, 1919
42..	ζ^2 CrB	35.6+36:58	5.1	B8	−32 ±3.0	*Ibid.*, **3**, 179, 1925
43..	π Sco	52.8−25:50	3.0	B2	− 4 ±3.3	*Ap.J.*, **66**, 217, 1927
44..	θ Dra	16:00.1+58:50	4.1	F8	− 8.4 ±0.30	*L.O.B.*, **4**, 156, 1907
45..	σ^2 CrB	10.9+34:07	5.8	G0	−12 ±1.5	*D.A.O.*, **3**, 231, 1925
46..	ϵ Her	56.5+31:04	3.9	A0	−24.2 ±1.1	*A.O.*, **2**, 21, 1910
47..	TX Her	17:15.4+42:00	8.1	A5	− 5.3 ±1.0	*D.A.O.*, **1**, 207, 1920
48..	HR 6506	23.2+34:47	5.9	B9	−22.7 ±0.40	*Ibid.*, **3**, 307, 1925
49..	ω Dra	37.5+68:48	4.9	F5	−13.7 ±0.24	*L.O.B.*, **4**, 163, 1907
50..	HR 6611	39.8+14:27	6.1	A3	−32.2 ±1.8	*D.A.O.*, **4**, 81, 1928
51..	Boss 4507	44.4+47:39	6.3	A0	−27.1 ±0.4	*Ibid.*, **1**, 125, 1919
52..	Boss 4622	18:13.0+56:34	6.4	F0	− 8.3 ±0.9	*Ibid.*, p. 307, 1921
53..	112 Her	48.0+21:18	5.3	B9	−19.6 ±0.28	*L.O.B.*, **13**, 49, 1927
54..	50 Dra	49.6+75:19	5.4	A0	− 8.4 ±0.8	*D.O.*, **4**, 364, 1920
55..	113 Her	50.5+22:32	4.6	G0	−23.3 ±0.12	*L.O.B.*, **7**, 106, 1913
56..	HD 176853	57.1−10:52	6.7	B5	−12.9 ±1.9	*D.A.O.*, **4**, 75, 1927
57..	Boss 4870	19:03.0+41:16	6.1	B3	−21.2 ±0.36	*Ibid.*, **2**, 173, 1922
58..	HR 7267	04.2+16:42	6.5	F5	+ 9.0 ±1.5	*Ibid.*, **3**, 236, 1925
59..	Boss 4876	04.4+38:46	7.5	A3	−29.8 ±1.8	*Ibid.*, **6**, 7, 1930
60..	RS Vul	13.4+22:16	7.4	B8	−22.2 ±0.7	*Ibid.*, **1**, 141, 1919
61..	U Sge	14.4+19:26	6.8	B9	−16.4 ±1.2	*Ap.J.*, **71**, 336, 1930
62..	2 Sge	19.8+16:45	6.0	A0	+11.2 ±0.7	*D.O.*, **4**, 54, 1917
63..	HD 185936	36.5+13:35	5.8	B3	−14.2 ±1.3	*D.A.O.*, **6**, 11, 1930
64..	φ Aql	51.5+11:09	5.3	A2	−28.0 ±0.8	*Ibid.*, **2**, 179, 1922
65..	Boss 5173	20:06.4+26:36	5.5	A2	−13.0 ±1.0	*D.O.*, **4**, 199, 1918
66..	22 Vul	11.2+23:12	5.4	G5	−23.7 ±0.35	*D.A.O.*, **3**, 201, 1924
67..	HD 193536	15.6+46:00	6.3	B1	− 9.1 ±2.3	*Ibid.*, **4**, 103, 1928
68..	α Pav	17.7−57:03	2.1	B3	+ 2.0 ±0.25	*L.O.B.*, **4**, 154, 1907

TABLE I—*Continued*

	P	T 2400000+	K	e	ω	n	σ_1
36...	2.96310	21002.68 ± .016	116 ± 3.6	.063 ± .030	212 ± 27	31	......
	2.96310	26435.67 ± .013	117 ± 3.0	.039 ± .025	280 ± 40	14	......
37...	1.271022	....	63.2 ± 1.4	0	....	60	7.8
38...	2.613	21416.195 ± .05	10.0 ± 1.2	0	....	38	4.6
	1.61100	21416.762 ± .05	10.1 ± 1.2	0	....	38	4.7
	0.723228	21416.573 ± .05	9.4 ± 1.2	0	....	38	5.1
39...	2.32735	18092.311 ± .007	76.3 ± 1.1	.048 ± .016	30 ± 20	60	4.7
40...	3.5753	24455.641 ± .017	58.5 ± 1.4	.071 ± .030	30 ± 25	29	4.6
41...	2.80654	22122.10 ± .012	65.4 ± 1.8	.053 ± .028	96 ± 30	14	4.8
42...	12.58	23978.400 ± .050	134.7 ± 4.4	0	....	32	17.7
			137.6 ± 5.9	....	....	..	22.6
43...	1.571	25042.437 ± .009	138.0 ± 4.5	.054 ± .033	91 ± 35	48	22.0
			180.0 ± 7.0				
44...	3.0708	15733.325 ± .009	23.4 ± 0.42	0	....	32	1.3
45...	7.974	23773.01 ± .04	61.0 ± 2.0	0	....	60	9.0
			70.0 ± 2.0	....	....	..	10.0
46...	4.0235	17947.242 ± .014	70.7 ± 1.5	.023 ± .021	138 ± 50	72	8.4
			112.0 ± 4.0				
47...	2.059786	22501.505 ± .005	120.0 ± 1.4	0	....	14	3.9
			141.0 ± 4.0	....	....	..	10.8
48...	5.9182	23821.683 ± .025	25.0 ± 0.58	.024 ± .024	28 ± 60	35	2.2
49...	5.27968	17385.871 ± .008	36.1 ± 0.35	0	....	26	1.1
50...	3.894	25024.424 ± .027	96.6 ± 2.8	.033 ± .025	60 ± 50	26	8.5
			108.0 ± 5.6	....	....	..	15.8
51...	2.82424	22137.553 ± .056	60.2 ± 0.7	0	....	23	1.9
52...	2.0476	22621.461 ± .003	104.9 ± 1.4	.037 ± .015	211 ± 22	60	6.3
			108.0 ± 1.5	....	....	..	6.8
53...	6.3624	23905.389 ± .024	17.7 ± 0.40	.106 ± .024	198 ± 15	35	1.5
54...	4.1175	20753.318 ± .010	80.0 ± 1.2	0	....	52	6.9
			82.0 ± 1.2	....	....	..	7.2
55...	245.3	18709.73 ± .35	16.0 ± 0.17	.116 ± .011	171 ± 6	30	0.6
56...	1.84908	25070.158 ± .005	150. ± 2.6	.036 ± .016	160 ± 25	15	6.4
			241. ± 4.2	....	....	..	10.0
57...	1.03088	22356.182 ± .008	12.1 ± 0.52	0	....	45	2.4
58...	4.812	24154.400 ± .020	86.0 ± 2.5	.050 ± .020	57 ± 25	23	4.3
			86.0 ± 2.5	....	....	..	5.5
59...	1.54039	24900.725 ± .005	88.7 ± 2.8	0	....	23	6.0
60...	4.477325	12136.795 ± .010	55.0 ± 1.1	0	....	15	2.7
			176. ± 15.0				
61...	3.38058	25003.010 ± .028	66.7 ± 1.7	0	....	43	16.0
62...	7.390	21047.175 ± .024	52.8 ± 1.0	0	....	44	4.5
			77.6 ± 8.0				
63...	2.4968	25001.647 ± .016	47.3 ± 1.8	.052 ± .037	85 ± 45	70	8.0
64...	3.3204	23323.574 ± .014	38.0 ± 1.1	0	....	17	2.4
65...	9.316	21103.17 ± .03	78.5 ± 1.4	0	....	60	7.1
			86.3 ± 1.4	....	....	..	10.3
66...	251.0	23333.24 ± .75	26.8 ± 0.50	.050 ± .019	140 ± 23	27	1.6
67...	2.98474	24556.790 ± .016	115.0 ± 3.6	.07 ± .03	110 ± 25	34	11.7
			141.0 ± 5.5	....	....	..	16.6
68...	11.753	17547.68 ± .010	7.2 ± 0.38	0	....	22	1.1

TABLE I—*Continued*

	Star	1900—Position α δ	m	Sp.	γ	Reference
69..	Boss 5442	21:04.4+29:48	5.6	A0	−27.0	*D.A.O.*, **2**, 183, 1922
70..	HR 8170	17.2+39:55	6.5	F8	+0.40± 0.35	*Ibid.*, **1**, 113, 1919
71..	Boss 5579	38.4+40:37	5.5	A0	−25.5 ±2.0	*Ibid.*, **3**, 324, 1926
72..	δ Cap	41.5−16:35	3.0	A5	− 5.0 ±0.8	*Ap.J.*, **54**, 127, 1921
73..	ι Peg	22:02.4+24:51	4.0	F5	− 4.1 ±0.15	*L.O.B.*, **2**, 169, 1904
74..	2 Lac	16.9+46:02	4.7	B5	− 9.0 ±1.0	*A.O.*, **1**, 93, 1909
75..	HR 8584	27.0+29:02	6.3	A5	+ 1.0 ±0.6	*D.A.O.*, **6**, 203, 1933
76..	Boss 5996	23:13.7+41:13	5.9	A3	− 4.9 ±0.6	*D.O.*, **4**, 83, 1917
77..	Boss 6070	32.6+16:17	6.2	A0	−27.3 ±0.36	*D.A.O.*, **3**, 163, 1925

NOTES TO TABLE I

1. *TV Cassiopeiae.* Plaskett remarks that, whereas the photometric observations indicate some eccentricity, this is not apparent in the spectroscopic observations—a state of affairs contrary to that usually found. My own rediscussion gives $e=0.024\pm.021$, $\omega=203^\circ\pm50^\circ$; and while I am far from convinced that e is real, yet it appears larger than for RS Vulpeculae, where Plaskett considers it conspicuous. With the values given here, secondary minimum (principal star in front) should occur thirty-six minutes earlier than the halfway point. McDiarmid (*Princeton Contrib.* No. 7) states that his secondary minimum occurs seventeen minutes early. More observations, especially simultaneous photometric and spectroscopic observations, are urgently required.
2. η *Cassiopeiae.* Harper finds $e=0.010\pm.010$, $\omega=45^\circ.1\pm0^\circ.4$ (T fixed); but with such an extremely small eccentricity only a circular orbit appears justified.
3. ζ *Andromedae.* Cannon finds $e=0.037\pm.032$, $\omega=182^\circ.22\pm1^\circ.9$ (T fixed). Jones gives $e=0.017\pm.020$, $\omega=80^\circ.60\pm11^\circ.7$, and points out that the great divergence in ω is due to the fact that Cannon kept T fixed. Jones thus adopts the Cape value for ω as final, but overlooks the fact that the Ottawa value was derived from a preliminary graphical solution and cannot, therefore, be wholly rejected. The uncertainty given for the Cape value of ω is probably a mistake, for, if the error in e is larger than e itself, ω must be wholly indeterminate. My own calculations give

$$e=0.039\pm.032,\ \omega=135^\circ\pm50^\circ\ \text{(Ottawa)}$$
$$e=0.005\pm.022,\ \omega=34^\circ\ \text{(Cape)}\ .$$

It is clear that only a circular orbit is justified. The times when the primary passes through the ascending node at mean epoch are found to be J.D. 2420389.00±.09 (Ottawa) and J.D. 2422876.50±.06 (Cape). Since 140 cycles have elapsed, the period is $17^{d}.7678\pm0^{d}.0008$, as given in the table; the value of T given is a "weighted mean" of the two determinations.

4. γ *Phoenicis.* Wilson gives $e=0.005$, $\omega=267^\circ$; but from the errors given we calculate that the mean error of the second harmonic is 0.28 km/sec, or larger than the quantity itself. My own values are $e=0.008\pm.016$, $\omega=220^\circ$, and a circular orbit should be adopted.

TABLE I—*Continued*

	P	T 2400000+	K	e	ω	n	σ_1
69...	Elements too uncertain						
70...	3.2434	21921.598± .005	62.0 ± 0.7	.023±.013	350±30	16	1.4
71...	1.72897	24255.750± .010	110.0 ± 3.5	0	....	50	15.0
			110.0 ± 3.5	....	....	..	16.0
72...	1.02275	21424.847± .004	65.4 ± 1.0	0	....	68	5.7
73...	10.21312	15508.295± .007	48.1 ± 0.22	0	....	43	0.84
74...	2.6164	18194.608± .007	80.3 ± 1.4	0	....	84	8.0
			98.8 ± 1.8	....	....	..	10.8
75...	2.34092	26938.992± .005	80.0 ± 3.0	.023±.013	27±30	28	3.4
76...	3.2195	21136.841± .070	73.6 ± 0.84	.036±.012	41±20	40	3.7
77...	11.2298	23796.041± .032	27.0 ± 0.54	.043±.019	253±25	41	2.2

5. *α Trianguli.* Harper derives $P=1^{d}.74$ and $e=0.12$, but since the scatter of the observations is large, the two alternative periods should be investigated. The shorter of these, $P=0^{d}.700$, appears to be unsatisfactory, but the longer, $P=2^{d}.3413$, appears to represent the observations tolerably well, even the first Lick observation. It leaves a residual of +15 km/sec in the last Lick observation, but since this is less than some of the Ottawa residuals in Harper's solution, the longer period is not necessarily ruled out. A graphical solution yields the elements given; future observations will have to decide between these alternative periods.
6. *6 Trianguli* (*Br*). Harper's published error for e is probably a misprint, and should read 0.02 instead of 0.002; the error in ω must likewise be much larger than 14°. The errors given here have been calculated from that given for a single plate.
7. *6 Trianguli* (*Ft*). Harper gives $e=0.010\pm.015$ and I believe a circular orbit should be adopted.
8. *δ Trianguli.* Pearce finds $e=0.059\pm.012$ (p.e.), $\omega=19°\pm1°.10$ (p.e.), but the latter should read 11°, thus making the probable error of T $0^{d}.30$ instead of $0^{d}.004$ as given. My own values are $e=0.046\pm.017$, $\omega=13°.5\pm23°$.
9. *Boss 613.* Harper gives $e=0.014\pm.013$, $\omega=0°.93\pm0°.72$ (T fixed). My own values are $e=.010\pm.025$, $\omega=129°$, hence a circular orbit has been adopted.
10. *RZ Cassiopeiae.* Jordan finds $e=0.052\pm.037$, $\omega=154°.7\pm30°$. My own values are $e=0.044\pm.031$, $\omega=195°\pm38°$. Rejection of all observations within $P/8$ of light minimum does not materially alter these values; and although from photometric observations we have every reason to believe that the eccentricity, if any, must be less than 0.01, yet we must accept the spectroscopic values for the moment.
11. *π Arietis.* Young adopts $e=0.042\pm.037$, $\omega=78°.27\pm32°$, but remarks that $e=0.10$, $\omega=105°$, would fit almost as well. My own values are $e=0.080\pm.048$, $\omega=102°\pm36°$.
12. *HD 19820.* Pearce gives $e=0.1019\pm.011$, $\omega=300°.78\pm5°.0$. My own values, calculated for each component separately, are

primary..........$e=0.090\pm.009$, $\omega=305°.5\pm6°.0$
secondary.........$e=0.102\pm.011$ $\omega=97°\pm12°$.

If averaged, these would yield $e=0.093\pm.010$, $\omega=300°\pm6°$.

13. *HR 976.* Harper gives $e=0.040 \pm .027$, $\omega=90\overset{\circ}{.}66 \pm 1\overset{\circ}{.}4$ (T fixed). My own values are $e=0.035 \pm .025$, $\omega=60° \pm 38°$.
14. *Boss 809.* Harper finds $e=0.082 \pm .047$, $\omega=32\overset{\circ}{.}47 \pm 3\overset{\circ}{.}7$. A new solution yielded $e=0.070 \pm .044$, $\omega=17° \pm 34°$. The unusually high value of 9.6 km/sec for the mean error of a single plate, together with the extraordinarily large mass function, suggest that the wrong period was used. Of the two alternatives, that equal to $1\overset{d}{.}094$ gave even worse residuals, but $P=0\overset{d}{.}917$ immediately showed promise. Adjustment then gave $0\overset{d}{.}91718$ as the best value for the period, and there seems little doubt but that this is substantially correct, the mean error for one plate now having dropped to 5.1 km/sec.
15. v_4 *Eridani.* Paddock gives $e=0.014 \pm .010$, $\omega=124°20' \pm 40°$. My own solutions yield the following:

$e=0.020 \pm .013$	$\omega=77° \pm 38°$ (primary, λ 4481)
$e=0.055 \pm .043$	$\omega=227° \pm 30°$ (primary, $H\gamma$)
$e=0.032 \pm .013$	$\omega=308° \pm 25°$ (secondary, λ 4481)
$e=0.043 \pm .040$	$\omega=232° \pm 55°$ (secondary, $H\gamma$).

It is clear that the measures of $H\gamma$ do not add anything to the knowledge obtained from λ 4481; if means are taken, we get

$$e=0.025 \pm .010 \qquad \omega=108° \pm 23° .$$

There seems to be no alternative but to accept the elliptic orbit, even though the fact that this rests upon the measures of but a single line on thirty-nine plates causes considerable hesitancy.
16. *HR 1401.* Harper gives $e=0.043 \pm .052$, $\omega=18\overset{\circ}{.}90 \pm 1\overset{\circ}{.}8$ (T fixed), but his values for T probably should read 2425950.989 instead of 2415950.989. My own calculations give $e=0.051 \pm .045$, $\omega=273°$, and, accordingly, a circular orbit has been adopted.
17. *88d Tauri.* Three orbits are available: by Wilson (*Lick Obs. Bull.*, **7**, 104, 1911), by Harper (*Pub. Dom. Obs.*, **1**, 113, 1911), and by Daniel (*Pub. Allegheny Obs.*, **3**, 93, 1912); the values adopted are derived as a mean of all three. It does not seem to have attracted attention that Harper has measured lines of the secondary on several plates and has derived the mass ratio $m_2/m_1=0.47 \pm .04$.
18. *HD 29376.* Pearce finds $e=0.076 \pm .020$, $\omega=2\overset{\circ}{.}38 \pm 4\overset{\circ}{.}7$ (primary). My own values are

$e=0.053 \pm .022$	$\omega=15° \pm 25°$ (primary)
$e=0.089 \pm .012$	$\omega=165° \pm 8°$ (secondary),

A mean would be $e=0.078 \pm .018$, $\omega=353° \pm 15°$.
19. *Boss 1082.* Cannon finds $e=0.019 \pm .062$, $\omega=285° \pm 63\overset{\circ}{.}4$, which values give convincing evidence for the unreliability of the usual least-squares method, for if the mean error of e is more than three times as large as e itself, ω is wholly indeterminate. A circular orbit must be adopted.
20. *HR 1528.* Harper derives $e=0.033 \pm .016$, $\omega=289\overset{\circ}{.}66 \pm 17°$. My own values are $e=0.029 \pm .021$, $\omega=266° \pm 38°$, and with some hesitation the eccentricity has been retained.

21. π_4 *Orionis.* Baker gives $e=0.027\pm.020$, $\omega=152\overset{\circ}{.}27\pm1\overset{\circ}{.}1$ (T fixed); my own values are $e=0.038\pm.023$, $\omega=167^{\circ}\pm33^{\circ}$.
22. α *Aurigae.* Reese gives $e=0.0164\pm.0082$, $\omega=117\overset{\circ}{.}3\pm27^{\circ}$, but Merrill recalculates $e=0.0086$ (*Ap. J.*, **56**, 40, 1922). My own values are $e=0.0159\pm.008$, $\omega=121^{\circ}\pm30^{\circ}$, practically identical with those of Reese. There appear to be no recent observations of this binary, and it is not possible, therefore, to investigate Merrill's interesting suggestion of a motion of the line of nodes. Where the radii of the stars are of the order of 1/20 of their separation and there seems to be no third body of comparable mass present, observable perturbations appear highly improbable.
23. ψ *Orionis.* This is one of the most promising cases for finding a rotation of the line of apsides. Plaskett gives $e=0.0651\pm.0165$, $\omega=184\overset{\circ}{.}71\pm1\overset{\circ}{.}04$, but the real error in ω is clearly much larger. My own values are $e=0.052\pm.016$, $\omega=172^{\circ}\pm17^{\circ}$, and the approximate value of $\omega=180^{\circ}$ should perhaps be adopted. The *Third Catalogue of Spectroscopic Binaries* states that Baker's observations at Allegheny indicate a mass ratio of 0.76, but I have been unable to find anything beyond a statement that both spectra have been observed. Harper (*Pub. Dom. Obs.*, **4**, 344, 1919) has remeasured thirteen of Plaskett's spectra and finds the mass ratio to be 0.63 ± 0.02.
24. *Boss 1452.* Harper gives $e=0.030\pm.024$, $\omega=359\overset{\circ}{.}25$ (T fixed); my own values are $e=0.045\pm.022$, $\omega=39^{\circ}\pm26^{\circ}$.
25. *136 Tauri.* Cannon finds $e=0.0217\pm.021$, but a recalculation yields $e=0.005\pm.030$ and a circular orbit has been adopted.
26. *45 Aurigae.* Harper calculates $e=0.019\pm.039$, $\omega=330\overset{\circ}{.}60\pm61\overset{\circ}{.}10$. My own values are $e=0.024\pm.031$, $\omega=130^{\circ}$. It is clear that a circular orbit should be adopted.
27. HD *44701.* Pearce gives $e=0.036\pm.016$, $\omega=9^{\circ}\pm19^{\circ}$. My own calculations, made separately for each component, yield

$\gamma=+7.8\pm2.8$. $e=0.077\pm.024$. $\omega=352^{\circ}\pm20^{\circ}$. (primary)
$\gamma=-9.1\pm5.5$ $e=0.051\pm.030$ $\omega=193^{\circ}\pm35^{\circ}$. (secondary).

but it is clear that only approximate values for the elements can now be adopted: if systematic errors cause the large difference between the two values of the systemic velocity, e may well be as large as 0.06, but if an average is forced through, this is naturally lowered somewhat.

28. *+6°:1309.* Plaskett gives $e=0.035\pm.013$, $\omega=181\overset{\circ}{.}95\pm3\overset{\circ}{.}8$ (T fixed). My own values are $e=0.035\pm.013$, $\omega=187^{\circ}\pm22^{\circ}$.
29. *19 Lyncis.* For the primary, Harper finds $e=0.076$, $\omega=126\overset{\circ}{.}11$; my own values, obtained by using also Pearce's later observations at Victoria, are $e=0.042\pm.020$, $\omega=146^{\circ}\pm28^{\circ}$. Although the free-hand curve exhibits no conspicuous eccentricity, it would perhaps be safer to adopt this latter value.
30. *63 Geminorum.* Harper gives $e=0.002\pm.025$, $\omega=104\overset{\circ}{.}84\pm1\overset{\circ}{.}5$ (T fixed), and a circular orbit seems indicated.
31. σ *Geminorum.* Harper gives $e=0.022$, $\omega=330^{\circ}15'\pm1^{\circ}03'$, but from his published errors we find $e\sin\omega=0.38\pm0.77$, $e\cos\omega=0.65\pm0.77$, and a circular orbit has accordingly been adopted.
32. *Boss 2463.* Young gives $e=0.090\pm.030$ and from this we calculate that the mean error of ω must be of the order of 20° instead of 10°.
33. *m Velorum.* Jones finds $e=0.019\pm.019$, $\omega=311\overset{\circ}{.}48\pm1\overset{\circ}{.}4$ (T fixed), but only one observation—and that an isolated one, taken thirteen years before the bulk of the

others—falls in the interval from $M=90°$ to $M=221°$, or more than one-third of the period. The decrease in velocity after positive maximum is clearly indicated by the observations, but the same cannot be said of the part of the curve just preceding minimum. Consequently, a circular orbit should be adopted.

34. *19 Leonis Minoris.* Harper gives $e=0.048\pm.030$, $\omega=351^\circ.09\pm22^\circ.42$. My own calculations yield $e=0.043\pm.033$, $\omega=96°\pm44°$; with this large discrepancy in ω and the large uncertainty in e, a circular solution should be adopted.

35. *HR 4535.* Petrie gives $e=0.018\pm.027$, $\omega=61^\circ.45\pm23^\circ.52$, but ω really should be indeterminate. My own values are $e=0.025\pm.024$, $\omega=83°\pm55°$, and a circular solution should be adopted.

36. *Boss 3138.* Cannon first determined the orbit, but his period was subsequently shown by Struve to be erroneous (*Pop. Astr.*, **36**, 411, 1928) and new elements were derived by Van Arnam (*Ap. J.*, **75**, 348, 1932) using new Yerkes observations. My own values, derived separately for the Ottawa and Yerkes observations, are

$$\gamma=+6\pm2,\quad K=116\pm3.6,\quad e=0.063\pm.030,\quad \omega=212°\pm27° \text{ (Ottawa)}$$
$$\gamma=+8\pm2,\quad K=118\pm3\ ,\quad e=0.039\pm.025,\quad \omega=280°\pm40° \text{ (Yerkes).}$$

It would be unwise to ascribe reality to the difference in ω, but the star does merit further observation.

37. *4 H Draconis.* A circular orbit was derived by Lee, but subsequently Voikevitch-Oculitch (*Pulkovo Bull.*, **10**, 26, 1925) found $e=0.07$ My recalculation gave:

$$e=0.03\pm.02.\quad \omega=266\pm40° \text{ (Yerkes)}$$
$$e=0.06\pm.04.\quad \omega=\ 24\pm40° \text{ (Pulkovo)}$$

The large differences and uncertainties point to the conclusion that a circular orbit is all that is justified. From the two values for the primary's nodal passage 2420-284.900±.005 (Yerkes) and 2420822.542±.007 (Pulkovo), we derive a value of $1^d.271022\pm.000020$ for the period.

38. *Boss 3511.* Harper finds $P=1^d.61100$ and $e=0.054$, but the scatter of the observations is so large that we calculate a mean error of 0.110 for e, hence a circular orbit may well be accepted. Inspection of the residuals for the individual lines on each plate indicates that the mean error of an average plate should be about 2.3 km/sec, whereas the O−C from the curve indicates 4.7 km/sec. Consequently, other periods may be tried, viz., $P_1=2^d.6130$ and $P_3=0^d.723228$. Which of the three orbits listed —if any—is the true one can only be decided by continuous observation on successive nights, or by observation in different longitudes.

39. *δ Librae.* Schlesinger derives $e=0.054\pm.018$, $\omega=29^\circ.2\pm1^\circ.5$ (T fixed), and calls attention to a discrepancy of at least an hour between the observed time of eclipse and that calculated spectroscopically. My own values are $e=0.041\pm.015$, $\omega=32°\pm19°$. If all observations lying within $P/8$ of light minimum are disregarded, we should get $e=0.028$, but the present spectroscopic observations evidently do not permit a circular orbit.

40. *HR 5702.* Christie gives $e=0.079\pm.033$, $\omega=245°\pm22°$ (T not fixed). My own values are $e=0.064\pm.030$, $\omega=37°\pm24°$.

41. *TW Draconis.* Plaskett derives $e=0.054\pm.028$, $\omega=90°$ (assumed). My own calculations give $e=0.053\pm.028$, $\omega=96°\pm30°$. With only fourteen observations and with

ω and e near to the values which they have for μ Herculis and δ Librae, we strongly suspect that the orbit is in reality circular.

42. ζ^2 *Coronae Borealis*. Plaskett gives $e=0.030\pm.027$, $\omega=90°$ (assumed), but comments upon the broad and fuzzy lines and the consequent large errors for a single plate, of the order of 20 km/sec. Separate calculations for both components give

$$e=0.025\pm.033 \qquad \omega=148° \text{ (primary)}$$
$$e=0.045\pm.043 \qquad \omega=334° \text{ (secondary).}$$

It cannot be denied that the plot of the observations carries a faint suggestion of eccentricity which is amply borne out by the closely concordant values for ω_1. Yet because of the large uncertainties in e and P and the discrepancy with Plaskett's value of ω, the writer feels that a circular orbit should be adopted.

43. π *Scorpii*. Struve and Elvey give $e=0.05$, $\omega=90°$, using a preliminary solution only, owing to the great scatter of the observations. With the high value of K and the short period, one would expect apsidal rotation to become apparent in a short time, in which case it is important to know the uncertainties in e and ω. My calculations give $e=0.053\pm.033$, $\omega=91°\pm35°$.

44. θ *Draconis*. Curtis finds $e=0.0141\pm.0166$, $\omega=126\overset{\circ}{.}112\pm58\overset{\circ}{.}6$ (p.e.), but where even the probable error of e amounts to more than 100 per cent, it is only by courtesy that an error can be attached to ω; actually, it is wholly indeterminate, and the orbit is plainly circular.

45. σ^2 *Coronae Borealis*. Harper gives $e=0.081\pm.005$, but this is probably a misprint since, with an error of 5 per cent in K, that in e should be 60 per cent or 0.050. My own values are $e=0.065\pm.026$, $\omega=4°\pm23°$ (primary), and $e=0.006\pm.024$, $\omega=247°$ (secondary). If a mean is forced through, we get $e=0.033\pm.025$, $\omega_1=7°\pm42°$, still very far from Harper's, and I believe, therefore, that a circular orbit should be adopted.

46. ϵ *Herculis*. Baker finds $e=0.023\pm.024$, $\omega=180°$ (assumed). My own values give $e=0.023\pm.021$, $\omega=138°\pm50°$. The elliptical solution appears to possess a certain degree of stability and has been retained, although the writer is far from convinced of its reality. The mean error of 50° for ω gives no adequate expression of the real uncertainty in ω, of course.

47. *TX Herculis*. Plaskett considers the orbit circular; separate solutions give $e=0.050\pm.012$, $\omega_1=96°\pm15°$ (primary), and $e=0.023\pm.029$, $\omega_2=108°$ (secondary), indicating that a circular orbit is the only justifiable one.

48. *HR 6506*. Christie finds $e=0.031\pm.016$ (p.e.), $\omega=35\overset{\circ}{.}74\pm5\overset{\circ}{.}33$ (p.e.), but if the uncertainty in e amounts to more than 50 per cent, that in ω must amount to about 30° instead of 5°, and that in T to $P/12$ or $0\overset{d}{.}49$ instead of $0\overset{d}{.}064$ as published. A new solution gives $e=0.017\pm.024$, $\omega=21°$, and if we retain an elliptical orbit at all, it is plain that ω must be extremely uncertain.

49. ω *Draconis*. Turner has made four different solutions, finding values of e ranging from 0.006 to 0.01071 and of ω ranging from 319°50′ to 342°59′. The accepted value of ω is given to $0\overset{\prime}{.}1$, but it is clear that even the quadrant is uncertain. My solution gives $e=0.015\pm.010$, $\omega=310°\pm38°$, but, considering that the second harmonic amounts to only 0.56 ± 0.35 km/sec, I do not feel that anything beyond a circular orbit has been established.

50. *HR 6611.* Petrie finds $e=0.027\pm.023$, $\omega=74\overset{\circ}{.}29\pm55^\circ$. My own values are $e=0.015\pm.029$, $\omega_1=4^\circ$, but the few observations of the secondary indicate a marked eccentricity of about 0.08 with $\omega_2=240^\circ$. In view of this, an elliptical orbit may perhaps be retained with reservations, but it is far from certain.

51. *Boss 4507.* Harper gives $e=0.017$, $\omega=30^\circ$, but from the published residuals we find that the mean error of a single plate amounts to 2.0 km/sec, hence that in e will be 0.012. A circular solution with $\gamma=-27.1$, $K=60.2$, appears to give even smaller residuals than those of Harper.

52. *Boss 4622.* Harper gives $e=0.039\pm.012$, $\omega=195\overset{\circ}{.}10\pm0\overset{\circ}{.}52$ (T fixed); my own values are $e=0.031\pm.013$, $\omega=211^\circ\pm22^\circ$.

53. *112 Herculis.* Meyer finds $e=0.116\pm.025$, $\omega=195\overset{\circ}{.}53\pm8\overset{\circ}{.}7$; my own values are $e=0.096\pm.024$, $\omega=200^\circ\pm15^\circ$.

54. *50 Draconis.* Harper finds that either $\omega=115^\circ$ or $\omega=203^\circ$ will give a good fit, but finally adopts $e=0.012\pm.013$, $\omega=107\overset{\circ}{.}6\pm13\overset{\circ}{.}3$. My own values are $\omega_1=304^\circ$, $\omega_2=357^\circ$, but if a mean is forced through, $e=0.021\pm.015$, $\omega=217^\circ\pm50^\circ$, and a circular orbit should be adopted.

55. *113 Herculis.* Wilson determines graphically $e=0.12$, $\omega=169\overset{\circ}{.}5$, but gives no errors. My values are $e=0.116\pm.011$, $\omega=172\overset{\circ}{.}8\pm6^\circ$.

56. *HD 176853.* Pearce gives $e=0.033\pm.016$, $\omega=156\overset{\circ}{.}16.\pm17\overset{\circ}{.}5$ I find $e=0.074\pm.017$, $\omega=165^\circ\pm14^\circ$ (primary), $e=0.007\pm.019$, $\omega=300^\circ$ (secondary). Forcing a mean through, we find $e=0.041\pm.017$, $\omega=163^\circ\pm23^\circ$. In view of the discrepancy between the values for the two components, I do not feel too sanguine about the reality of the eccentricity; yet this value, almost identical with that of Pearce, appears to be several times larger than its mean error, and it has therefore been retained.

57. *Boss 4870.* Boothroyd gives $e=0.015\pm.013$, $\omega=20\overset{\circ}{.}02\pm147^\circ$, and it is evident that a circular orbit only is justified. Where the period is so close to one day, the alternative value of $0\overset{d}{.}97$ should perhaps also be investigated.

58. *HR 7267.* Harper finds $e=0.073\pm.025$, $\omega=59\overset{\circ}{.}16\pm1\overset{\circ}{.}65$ (T fixed). My own calculations give $e=0.051\pm.022$, $\omega=21^\circ\pm23^\circ$ (primary), and $e=0.046\pm.026$, $\omega=270^\circ\pm32^\circ$ (secondary); if averaged, we obtain $e=0.037\pm.022$, $\omega=55^\circ\pm35^\circ$, only the latter being close to Harper's value.

59. *Boss 4876.* Harper gives $e=0.008\pm.027$, $\omega=142\overset{\circ}{.}8\pm1\overset{\circ}{.}5$ (T fixed); where the second harmonic is thus seen to equal 0.72 ± 2.8 km/sec, it is clear that a circular orbit should be adopted.

60. *RS Vulpeculae.* Plaskett claims that "it is at once seen that the orbit is not circular" and derives $e=0.053\pm.022$, $\omega=236\overset{\circ}{.}26\pm1\overset{\circ}{.}25$ (T fixed). Krat has repeatedly tried to derive a rotation of the line of apsides from this, but I have shown that the uncertainties are far too great. A new calculation gives $e=0.018\pm.020$, $\omega=178^\circ$, hence a circular orbit has been adopted.

61. *U Sagittae.* Fowler finds $e=0.035\pm.018$, $\omega=44\overset{\circ}{.}14\pm45^\circ$; Joy gives $e=0.035$, $\omega=260^\circ$. My own recalculations yield $e=0.031\pm.028$, $\omega=50^\circ\pm50^\circ$ (Allegheny), and $e=0.062\pm.054$, $\omega=285^\circ$ $\pm50^\circ$ (Mount Wilson), K_1 being 66.7 km/sec in both cases. Joy has derived a periodic term in the light-elements, but I have given reasons for believing that this is not warranted by the observations (*Pub. U. of Minnesota Obs.*, **2**, 41, 1935). Where eighteen hundred periods have elapsed be-

tween the Allegheny and Mount Wilson observations, it thus appears that the difference in ω cannot be real, and consequently a circular orbit has been adopted.

62. *2 Sagittae.* Young finds $e=0.05$, $\omega=332\overset{\circ}{.}6$, but gives no errors and comments upon the uncertainty in ω. Recalculation gives $e=0.020\pm.020$, $\omega=15^\circ$, and a circular orbit should be adopted. Young derives $K_2=1.40K_1$, but where a few observations lie far enough from the nodes as to make their inclusion in a single normal place for each node cause a decrease in K_2, a curve was drawn through them, which gave $K_2=1.47K_1$.

63. *HD 185936.* Hill derives first $\omega=60^\circ$, later $e=0.056\pm.040$, $\omega=95\overset{\circ}{.}7\pm52^\circ$; my own values are $e=0.048\pm.037$, $\omega=75^\circ\pm45^\circ$.

64. *φ Aquilae.* Harper finds $e=0.055\pm.033$, $\omega=56\overset{\circ}{.}0$, but from the mean error in e we find that that in ω must be of the order of 30°. My own calculations give $e=0.035\pm.034$, $\omega=52^\circ\pm56^\circ$, which throws considerable doubt upon the reality of the eccentricity, and a circular orbit has been adopted.

65. *Boss 5173.* Harper gives $e=0.012$, $\omega=103\overset{\circ}{.}15$ (T fixed); from the published error for a single plate we find that the mean error in e amounts to 0.025, hence a circular orbit is indicated.

66. *22 Vulpeculae.* Harper gives $e=0.042\pm.022$, $\omega=121^\circ\pm1\overset{\circ}{.}4$ (T fixed); I find $e=0.058\pm.020$, $\omega=145^\circ\pm21^\circ$.

67. *HD 193536.* Plaskett gives $e=0.0978\pm.020$, $\omega=103\overset{\circ}{.}17\pm2\overset{\circ}{.}6$ (T fixed). My calculations indicate $e=0.076\pm.030$, $\omega=113^\circ\pm23^\circ$ (primary), and $e=0.004\pm.040$ (secondary). It is evident that the uncertainty is much greater than indicated by Plaskett's errors.

68. *α Pavonis.* Curtis gives $e=0.01$, $\omega=224\overset{\circ}{.}80$; from the O–C given we find that the second harmonic amounts to only 0.07 ± 0.3 km/sec, and hence a circular orbit is indicated.

69. *Boss 5442.* An orbit was derived by Young, who considers the period of $3\overset{d}{.}3137$ established even though, perhaps, the observations cannot be represented by simple elliptic motion. Where the observations were mostly obtained at about the same sidereal time, the two alternative periods might be tried. These should have values of about $1\overset{d}{.}43$ and $0\overset{d}{.}767$, but it was quickly seen that for both the fit is even worse than that for $3\overset{d}{.}3137$ adopted by Young. Inspection of the data shows that on seven nights two plates were taken, while on July 20, 1921, no less than nine plates were secured. The internal deviations of these plates indicate a mean error for a single plate of 6 km/sec, whereas the residuals from the curve yield 10.5 km/sec. Considering further the decidedly systematic run of the residuals and the fact that two of these amount to 21 and 25 km/sec, respectively (almost as large as K itself), the writer feels that the orbit cannot yet be considered as even approximately known, and should not be included in catalogues intended for statistical analysis.

70. *HR 8170.* Plaskett gives $e=0.0223\pm.013$, $\omega=357\overset{\circ}{.}55$ (T fixed); my own values are $e=0.025\pm.013$, $\omega=349^\circ\pm30^\circ$. The eccentricity has been retained in the catalogue although it is far from certain, especially in view of the paucity of observations.

71. *Boss 5579.* Harper finds $e=0.033\pm.025$, $\omega=256\overset{\circ}{.}0\pm2\overset{\circ}{.}0$ (T fixed). Where the two components are nearly equal in strength, have equal values of K and almost equal

mean errors for a single plate, the stability of the solution may be tested by deriving elements for each component separately. We thus find:

$K_1=110.9\pm 3.5$ $e=0.063\pm .032$ $\omega_1=229^\circ\pm 29^\circ$ (primary)
$K_2=108.5\pm 3.5$ $e=0.026\pm .032$ $\omega_2=189^\circ$ (secondary).

The disagreement in ω is violent; if an average is forced through, we get $e=0.023\pm .025$, $\omega=250^\circ$, but, on the whole, a circular solution seems preferable.

72. *δ Capricorni.* Crump finds $e=0.019\pm .012$, $\omega=149^\circ.057\pm 0^\circ.69$ (T fixed), but the probable error of a single plate should read 3.8 km/sec instead of 2.75 as published, which increases the mean errors of e and ω to 0.016 and 50°, respectively. My own solution gives $e=0.014\pm .016$, $\omega=159^\circ$, and a circular orbit is indicated.

73. *ι Pegasi.* Curtis gives $e=0.0085\pm .006$, $\omega=251^\circ.807\pm 2^\circ.04$ (T not fixed). The error in ω is presumably a misprint since, when the uncertainty in e amounts to 70 per cent, that in ω should be of the order of 40°. My own calculations give $e=0.007\pm .005$, $\omega=282^\circ\pm 35^\circ$; but since the second harmonic amounts to only 0.34 ± 0.23 km/sec, a circular solution seems the only safe alternative.

74. *2 Lacertae.* Baker gives $e=0.015\pm .012$, $\omega=180^\circ\pm 0^\circ.9$ (T fixed). Owing to the comparatively long interval when the lines are blended and the consequent uncertainty in the fixing of γ and hence of e, the writer feels that a circular orbit should be adopted.

75. *HR 8584.* Harper derives $K=79.2\pm 0.8$, $e=0.016\pm .012$, $\omega=30^\circ.1\pm 0^\circ.6$ (T fixed), while Albitzky finds $K=84.8\pm 1.2$, $e=0.0309\pm .013$, $\omega=49^\circ.4$, although values of 28°.91 and 17°.95 have also been considered. My own solutions give $e=0.022\pm .012$, $\omega=30^\circ\pm 30^\circ$ (Victoria), and $e=0.028\pm .014$, $\omega=22^\circ\pm 30^\circ$ (Pulkovo), with essentially the same values for K as before. The agreement for e and ω is as good as may be desired, and inspires confidence in their reality, but the large discrepancy in K is puzzling, for the larger value is derived from the Pulkovo plates with their much longer exposures. Ascending node passages give

2,426,932.629 ± .005 (Victoria) and
2,426,705.560 ± .005 (Pulkovo),

indicating $P=2^d.34092\pm .00007$.

76. *Boss 5996.* Young gives $e=0.0365\pm .010$, $\omega=40^\circ.5\pm 11^\circ$ (T not fixed), but since the mean error of a single plate is given as 3.7 km/sec, we calculate that the mean error in e should be 0.012, and hence that in ω around 20°.

77. *Boss 6070.* Smith finds $e=0.037\pm .016$, $\omega=236^\circ.80\pm 20^\circ.60$. My own values are $e=0.050\pm .019$, $\omega=264^\circ\pm 20^\circ$.

be emphasized that in each case a full calculation of all the elements was made, but the differences in γ and K were rarely significant enough to be mentioned.

4. DESCRIPTION OF THE CATALOGUE

Table I has been divided into two parts, the left-hand page giving such information as concerns the star as a system: serial number, designation, position for 1900, apparent magnitude, spectral class, and systemic velocity, as well as a reference to the source of the observations. The right-hand page contains the data characterizing the star as a binary, and gives, in order, the serial number, P, T, K, e, and ω in the usual notation. Except for the period, all elements are given with their mean errors; T denotes the instant when the primary passes through the ascending node at the mean epoch of observation. The last two columns give the number of observations and the mean error of a single plate. In the case of double-lined binaries a second line gives values of K and σ_1 for the secondary component.

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