LICK OBSERVATORY BULLETIN

NUMBER 181

SECOND CATALOGUE OF SPECTROSCOPIC BINARY STARS.

The number of known spectroscopic binary stars increased from 136 on January 1, 1905,—the epoch of the *First Catalogue of Spectroscopic Binaries*,—up to 306 on January 1, 1910. The number of fairly well determined orbits increased in the same period from fewer than 20 to more than 70. To meet the pressing needs of observers and computers, but more especially to furnish an improved basis for the general study of binary stars, this *Second Catalogue* is issued. It aims to list all binary systems discovered prior to the *Epoch of the Catalogue*, January 1, 1910, and to include the principal facts concerning these systems available to me on March 15, 1910.¹ Included in the Catalogue are several well-known visual double stars for which the spectrograph has observed either that the velocity of the principal component is variable or that the velocities of the two components differ appreciably.

The numbers in the first column of the Catalogue, under the designation H. R., are the serial numbers of the stars in *Revised Harvard Photometry*, *Annals H. C. O.*, 50. The Right Ascensions, Declinations, and Visual Magnitudes quoted in columns three, four

and five, respectively, are from the same publication. The star names in column two are from the same source, except in the cases of 3 variable stars not catalogued in *Annals H. C. O.*, 50, and of 15 stars for which Volume 50 does not assign letters or numbers to the constellation designations. To the latter stars are here assigned the numbers in the *Bonner Durchmusterung* (B. D.) and the *Cape Photographic Durchmusterung* (C. P. D.).

A good estimate of the photographic magnitudes can be obtained through the application of the following increments to the H. R. Visual Magnitudes, the table of increments having been kindly supplied by Harvard College Observatory.

Spectral Types	Photo. Mag. —Visual Mag.	Spectral Types	Photo. Mag. —Visual Mag.
Oe5	—0.40	F	+0.32
B	0.31	F2	0.40
B1	0.28	F5	0.51
B2	0.26	F8	0.63
B3	0.23	G	0.71
B5	0.17	G5	0.91
B8	0.07	K	1.17
B9	—0.04	K5	1.43
A	0.00	Ma	+1.68
A2	+0.07		
A3	0.11		
A5	+0.17		

The elements of the orbits are defined on page 34.

NOTE ADDED JUNE 30, 1910.

After the manuscript of the present BULLETIN was entirely completed, there appeared important papers on closely related subjects, by Russell, Bell and Kapteyn (all in *Ap. J.* for April, 1910), by Schlesinger and Baker (in *Publ. Allegheny Observatory*, 1, 135-161, 1910), and by Ludendorff (in *A. N.*, 184, 373-390, 1910). It is scarcely necessary to say that my conclusions were reached independently of those contained in the five papers referred to. The principal results de-

scribed in this BULLETIN were contained in the seventh and eighth of the Silliman Lectures, delivered by me in Yale University on February 3 and 4, 1910, and in the address of the retiring President of the Astronomical Society of the Pacific, on March 25, 1910.

Owing to limited publication facilities, the issuance of this BULLETIN has been and will be unduly delayed.

W. W. CAMPBELL.

H.R. 15	Star α Andromedae	R.A., 1900 0 ^h 3 ^m 2	Decl., 1900 +28° 32'	Vis. Mag. 2.15	Spec. Type A	P Period 97.0	T Jul. Day 2,410,000+	ω 70°	e 0.4	K km. 30.	$m_1^3 \sin^3 i$ ($m + m_1$) ² (0.209)	$a \sin i$ km. 36,000,000
						96.67	7882.40	76.21	0.525	30.75	(0.180)	34,790,000
						96.7	6817.	69.4	0.50	27.25	0.13	31,400,000
99	α Phoenicis	21.3	—42 51	2.44	K	long	.....	.....	.....	.....	.....	.....
104	B.D. +43° 92	22.9	+43 51	5.16	A2	short	.....	.....	.....	.....	.....	.....
142	13 Ceti	30.1	—4 9	5.24	F	2.0818	7484.482	223.1	0.062	34.35	(0.0087)	981,460
154	π Andromedae	31.5	+33 10	4.44	B3	143.72	.....	.....	0.58	47.7	(0.876)	(76,790,000)
179	ξ Cassiopeiae	36.5	+49 58	4.85	B3	.....	.....	.....	.....	.....	.....	.....
189	B.D. +47° 181	38.8	+47 19	5.55	B2	.....	.....	.....	.....	.....	.....	.....
226	ν Andromedae	44.3	+40 32	4.42	B3	4.28284	.....	.....	0.	73.	(0.173)	4,299,000
264	γ Cassiopeiae	50.7	+60 11	2.25	Bp	.....	.....	.....	.....	.....	.....	.....
271	η Andromedae	51.9	+22 52	4.62	G5	.....	.....	.....	.....	.....	.....	.....
.....	U Cephei	53.4	+81 20	var.	A	*2.4928767	.....	.....	.....	.....	.....	.....
383	ν Piscium	1 14.0	+26 44	4.67	A2	.....	.....	.....	.....	.....	.....	.....
424	α Ursae Min.	22.6	+88 46	2.12	F8	3.9683	5398.50	113.6	0.20	(3.00)	(0.00001)	160,400
						3.9683	4890.04	80.0	0.13	3.04	0.00001	164,500
						*1179	4509.	293.	0.35	2.98	0.0098	166,800,000
429	γ Phoenicis	24.0	—43 50	3.40	K5	190.±	.....	.....	.....	.....	.....	.....
496	ϕ Persei	37.4	+50 11	4.19	Bp	126.5	8290.42	347.3	0.428	26.90	(0.189)	42,298,000
						*63.25	8326.58	.....	.....	*6.78	.....	.....
539	ζ Ceti	46.5	—10 50	3.92	K	long	.....	.....	.....	.....	.....	.....
549	ξ Piscium	48.4	+ 2 42	4.84	K	long	.....	.....	.....	.....	.....	.....
553	β Arietis	49.1	+20 19	2.72	A5	107.0	7632.	19.7	0.88	32.6	0.042	22,880,000
590	g Persei	55.6	+54 1	4.99	B8	.....	.....	.....	.....	.....	.....	.....
622	β Trianguli	2 3.6	+34 31	3.08	A5	.....	.....	.....	.....	.....	.....	.....
649	ξ_1 Ceti	7.7	+ 8 23	4.54	G5	.....	.....	.....	.....	.....	.....	.....
779	δ Ceti	34.4	— 0 6	4.04	B2	short	.....	.....	.....	.....	.....	.....
788	12 Persei	35.9	+39 46	4.99	G	.....	.....	.....	.....	.....	.....	.....
811	π Ceti	39.4	—14 17	4.39	B5	.....	.....	.....	.....	.....	.....	.....
815	RZ Cassiopeiae	39.9	+69 13	var.	A	*1.195	.....	.....	.....	(72±)	(0.046±)	1,170,000±
854	τ Persei	47.2	+52 21	4.06	Gp	long	.....	.....	.....	.....	.....	.....
897	θ_1 Eridani	54.5	—40 42	3.42	A2	short	.....	.....	.....	.....	.....	.....
915	γ Persei	57.6	+53 7	3.08	Gp	long	.....	.....	.....	.....	.....	.....
936	β Persei	3 1.7	+40 34	var.	B8	2.8673	*24510	47.2	0.034	43.0	(0.0236)	1,694,300
						.....	2.544	49.27	0.029	42.37	(0.0179)	1,669,800
						.....	2.270	21.	0.031	39.9	(0.0189)	1,570,000
						.....	2.264	21.	0.060	41.3	(0.0209)	1,630,000
						**17899	1901.850	.....	0.000	9.4	(0.0598)	89,000,000
941	κ Persei	2.7	+44 29	4.00	K	.....	.....	.....	.....	.....	.....	.....
[1017	α Persei	17.2	+49 30	1.90	F5]	.....	.....	.....	.....	.....	.....	.....
1030	σ Tauri	19.4	+ 8 41	3.80	G5	.....	.....	.....	.....	.....	.....	.....
1038	ξ Tauri	21.7	+ 9 23	3.75	B8	.....	.....	.....	.....	.....	.....	.....
1066	f Tauri	25.4	+12 36	4.28	K	long	.....	.....	.....	.....	.....	.....
1088	τ_5 Eridani	29.4	—21 58	4.32	B8	short	.....	.....	.....	.....	.....	.....

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
15	—14.	Ludendorff	<i>A. N.</i> , 176, 327, 1907	Curtis, <i>L. O. B.</i> , 3, 84, 1905; Slipher, <i>Lowell O. B.</i> , No. 11, 57, 1904
.....	—11.55	Baker	<i>Publ. A. O.</i> , 1, 22, 1908	
.....	—14.4	Ludendorff	<i>A. N.</i> , 178, 23, 1908	
99	.....			Wright, <i>L. O. B.</i> , 3, 110, 1905. 1903.7, $V = +80$; 1907.8, $V = +70$
104	.....			Baker, unpublished letter. Range 60 km.
442	+10.5	Fox	<i>Ap. J.</i> , 27, 372, 1908	Frost, <i>Ap. J.</i> , 25, 60, 1907. Frost calls "excellent F type"; Fox calls "solar type." This is brighter component of very close visual double whose period is 7 $\times$ 42
154	+ 9.0	Schlesinger	Unpublished letter	Frost and Adams, <i>Ap. J.</i> , 18, 384, 1903
179	.....			Frost and Adams, <i>Ap. J.</i> , 18, 384, 1903
189	.....			Frost and Lee, <i>Ap. J.</i> , 30, 62, 1909. Double spectrum suspected
226	—23.0	Schlesinger	Unpublished letter	Curtis, <i>L. O. B.</i> , 2, 29, 1903. Two spectra visible (Moore, <i>L. O.</i> unpublished)
264	.....			Hartmann, <i>A. N.</i> , 173, 102, 1906. Hartmann's range 22 km.; <i>L. O.</i> observations do not confirm. Double bright H γ on broad partial absorption band
271	—12.±			Campbell, <i>Ap. J.</i> , 12, 256, 1900. Two spectra visible
.....	.....			Slipher, <i>Ap. J.</i> , 25, 284, 1907. Lines apparently complex, perhaps two spectra; Algol variable. This is B.D. +81 $\cdot$ 25. *Photometric period
383	.....			Albrecht, <i>L. O. B.</i> , 5, 174, 1910
424	var.	Hartmann	Unpublished letter	Campbell, <i>Ap. J.</i> , 10, 180, 1899. Triple system
.....	var.	Hobe	Unpublished	*These elements are those for the center of mass of short period (3497) binary system
.....	—14.8	Hobe	Unpublished	
429	.....			Palmer, <i>L. O. B.</i> , 3, 110, 1905
496	+ 3.20	Cannon	Unpublished letter	Campbell, <i>L. O. B.</i> , 1, 158, 1902. Measures are of H γ ; rather narrow absorption line with very bright borders
.....	.....	Cannon	Unpublished	Secondary orbit. *Residuals from elliptic orbit satisfied by simple circular motion in period $\frac{1}{2} P$ and single amplitude 6.78 km.
539	.....			Campbell, <i>L. O. B.</i> , 3, 84, 1905
549	.....			Wright, <i>L. O. B.</i> , 1, 22, 1901
553	— 0.6	Ludendorff	<i>Ap. J.</i> , 25, 325, 1907	Vogel, <i>A. N.</i> , 163, 145, 1903. Vogel suspected duplicity of line $\lambda 4481$ on 2 plates, but Ludendorff found no evidence of duplicity on 74 other plates. For $m = m_1$, $m \sin^3 i = m_1 \sin^3 i = 0.17\odot$; Ludendorff, <i>Ap. J.</i> , 25, 325, 1907
590	.....			Frost and Adams, <i>Ap. J.</i> , 19, 152, 1904. Period rather long, range $60 \pm$ km.
622	.....			Mitchell, <i>Ap. J.</i> , 30, 240, 1909. Two spectra visible; suggests period of 37 days
649	.....			Campbell, <i>L. O. B.</i> , 1, 22, 1901
779	.....			Frost and Adams, <i>Ap. J.</i> , 17, 150, 1903
788	—25.±	Campbell	<i>Ap. J.</i> , 12, 254, 1900	Campbell, <i>Ap. J.</i> , 12, 254, 1900. Two spectra visible
811	.....			Zurhellen deduces $m_1 : m = 0.72 \pm$ and $V_0 = -24.4$; <i>A. N.</i> , 175, 247, 1907
815	—41.±	Hartmann	<i>A. N.</i> , 173, 101, 1906	Moore and Albrecht, <i>L. O. B.</i> , 5, 174, 1910
854	.....			Hartmann, <i>A. N.</i> , 173, 101, 1906; Frost, <i>Ap. J.</i> , 25, 59, 1907. Algol variable. With Hartmann's value of $a \sin i$ and vel. range, assuming $i = 90^\circ$ and $e = 0$, Stein deduces from photometric observations: $a + a_1 = 3,297,000$ km.; $r = 994,000$ km.; $r_1 = 815,000$ km.; $m = 0.646\odot$; $m_1 = 0.356\odot$; $m_1 : m = 0.55$; $m + m_1 = 1.002\odot$; mean density of system $= 0.222 D_0$; <i>Ap. J.</i> , 29, 312, 1909. Hartmann assumes two components of equal mass and deduces $m = m_1 = 0.18\odot$; <i>Ap. J.</i> , 29, 312, 1909. *Photometric period
897	.....			Wright, <i>L. O. B.</i> , 1, 22, 1901
915	.....			Wright, <i>L. O. B.</i> , 3, 110, 1905. Two spectra visible
936	+10.4	Belopolsky	<i>Mit. Pulk.</i> , 2, 214, 1908	Moore, <i>L. O. B.</i> , 5, 61, 1908
.....	+10.38	Belopolsky	<i>Mit. Pulk.</i> , 3, 72, 1908	Vogel, <i>A. N.</i> , 123, 289, 1890; <i>Publ. Potsdam</i> , 7, pt. 1, 111, 1892
.....	— 1.70	Schlesinger	<i>Publ. A. O.</i> , 1, 30, 1908	Period varies slightly. Constants of system by Vogel, assuming $i = 90^\circ$ and $e = 0$: $r = 850,000$ km.; $r_1 = 670,000$; $a + a_1 = 5,200,000$; $m = 0.44\odot$; $m_1 = 0.22\odot$; resulting $d_0 = 0.27 D_0$; <i>Publ. Potsdam</i> , 7, pt. 1, 116, 1892. Several orbits by Belopolsky from 1897 to 1907. *Values T are intervals after light min. Velocity of binary system seems to vary; **Curtiss represents orbit of center of mass by elements quoted, the Julian Day recorded corresponding to min. radial velocity. "Algol"
.....	+ 3.40	Curtiss	<i>Publ. A. O.</i> , 1, 30, 1908	Campbell and Albrecht, <i>L. O. B.</i> , 5, 174, 1910
.....	+ 4.1	Curtiss	<i>Ap. J.</i> , 28, 156, 1908	Goos, <i>A. N.</i> , 180, 57, 1909, suspects velocity to vary with double amplitude 1.4 km. in a period of 290 days, and velocity of system -1.64 km.
941	.....			Moore, <i>L. O. B.</i> , 4, 161, 1907
1017	.....			Campbell, <i>L. O. B.</i> , 5, 62, 1908
1030	.....			Moore, <i>L. O. B.</i> , 4, 162, 1907
1038	.....			Frost, <i>Ap. J.</i> , 25, 63, 1907. Two spectra visible; components about equally bright
1066	.....			
1088	.....			

H.R.	Star	R.A., 1900 3h 38m0	Decl., 1900 +31° 58'	Vis. Mag. 39.4	Spec. Type B1	P Period 4.39 4.419	T Jul. Day 2,410,000+	ω	e	K km. *(110.) 118.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^3}$ (0.754)	$a \sin i$ km. 7,172,000
1131	σ Persei								0.			
1134	δ Fornacis	38.3	—32 15	4.93	B5	.....	.....	.....	.....	.....	.....	.....
1149	20 Tauri	39.9	+24 4	4.02	B5	.....	.....	.....	.....	.....	.....	.....
1175	β Reticuli	42.9	—65 7	3.80	K	.....	.....	.....	.....	.....	.....	.....
1213	τ_6 Eridani	49.5	—24 55	4.76	B5	.....	.....	.....	.....	.....	.....	.....
1220	ϵ Persei	51.1	+39 43	2.96	B	.....	.....	.....	.....	.....	.....	.....
1228	ξ Persei	52.5	+35 30	4.05	Oe5	.....	.....	.....	.....	.....	.....	.....
1239	λ Tauri	55.1	+12 12	var.	B3	*3.9529	.....	.....	0.	60.	(0.0887)	3,300,000
1240	τ_6 Eridani	55.7	—24 18	4.69	Ap	.....	.....	.....	.....	.....	.....	.....
1324	b Persei	4 10.7	+50 3	4.57	A2	.....	.....	.....	.....	.....	.....	.....
1347	ν_4 Eridani	14.1	—34 3	3.59	B9	short	.....	.....	.....	.....	.....	.....
1380	64 Tauri	18.4	+17 13	4.84	A2	short	.....	.....	.....	.....	.....	.....
1392	ν Tauri	20.3	+22 35	4.40	A5	.....	.....	.....	.....	.....	.....	.....
1394	71 Tauri	20.6	+15 23	4.60	A	.....	.....	.....	.....	.....	.....	.....
1412	θ_2 Tauri	22.9	+15 39	3.62	A5	.....	.....	.....	.....	.....	.....	.....
1427	B.D. +15°637	24.8	+15 59	4.84	A5	.....	.....	.....	.....	.....	.....	.....
1458	d Tauri	30.2	+ 9 57	4.38	A2	.....	.....	.....	.....	.....	.....	.....
1463	ν Eridani	31.3	— 3 33	4.12	B2	.....	.....	.....	.....	.....	.....	.....
1473	c Tauri	32.6	+12 19	4.30	A5	.....	.....	.....	.....	.....	.....	.....
1479	σ_2 Tauri	33.5	+15 43	4.85	A	.....	.....	.....	.....	.....	.....	.....
1481	l Eridani	33.6	—14 30	3.98	K	.....	.....	.....	.....	.....	.....	.....
1497	τ Tauri	36.2	+22 46	4.33	A	1.5047	7892.519	247.35	.083	44.43	(0.0136)	916,130
1520	μ Eridani	40.5	— 3 26	4.18	B5	.....	.....	.....	.....	.....	.....	.....
1542	9 Camelopard.	44.1	+66 10	4.38	B	6.33	.....	.....	.....	.....	.....	.....
1547	i Tauri	45.5	+18 40	5.12	A5	.....	.....	.....	.....	.....	.....	.....
1552	π_4 Orionis	45.9	+ 5 26	3.78	B3	9.5191	8279.64	152.27	0.027	25.93	(0.0172)	3,393,000
1567	π_5 Orionis	49.0	+ 2 17	3.87	B3	0.87	.....	.....	.....	.....	.....	.....
1568	7 Camelopard.	49.3	+53 35	4.44	A2	3.8848	.....	.....	.....	.....	.....	.....
1605	ϵ Aurigae	54.8	+43 40	var.	F5p	.....	.....	.....	.....	.....	.....	.....
1612	ζ Aurigae	55.5	+40 56	3.94	Kp	.....	.....	.....	.....	.....	.....	.....
1698	ρ Orionis	5 8.1	+ 2 45	4.64	K	.....	.....	.....	.....	.....	.....	.....
1708	α Aurigae	9.3	+45 54	0.21	G	104.022	4899.5	117.3	0.016	25.76	(0.184)	36,847,900
					(F+)	*104.022	4899.5	297.3	0.016	(32.45)	(0.369)	(46,430,000)
						104.0	.....	.....	.....	.....	.....	.....
1713	β Orionis	9.7	— 8 19	0.34	B8p	21.90	7968.80	254.76	0.296	3.771	(0.00011)	1,108,900
1735	τ Orionis	12.8	— 6 57	3.68	B5	.....	.....	.....	.....	.....	.....	.....
1765	σ Orionis	16.7	— 0 29	4.65	B3	.....	.....	.....	.....	.....	.....	.....
1788	η Orionis	19.4	— 2 29	3.44	B1	7.9896	5720.821	42.3	0.016	144.75	(2.51)	15,901,000
						*7.9896	5720.821	222.3	0.016	(152.4)	(2.15)	(16,750,000)
1811	ψ Orionis	21.6	+ 3 0	4.66	B2	2.5259	7916.36	184.7	0.065	144.12	(0.780)	4,995,100
						*2.5259	7916.36	4.7	0.065	(190.0)	(0.343)	(6,570,000)
1843	χ Aurigae	26.2	+32 7	4.88	B1	.....	.....	.....	.....	.....	.....	.....

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
1131	0. +17.0	Vogel Schlesinger	<i>Ap. J.</i> , 17, 212, 1903 Unpublished letter	Adams, <i>Ap. J.</i> , 15, 214, 1902; strong evidence of secondary spectrum. Vogel thought the center of mass close to or within primary star, and on this assumption $(a + a_1) \sin i = 6,640,000$ km. and $(m + m_1) \sin^3 i = 0.65\odot$; <i>Ap. J.</i> , 17, 219, 1903. *Estimated from velocity curve. Schlesinger finds two spectra visible; unpublished letter. Slipher reports H and K sharp, and yielding constant velocity; unpublished letter
1134				Moore, <i>L. O. B.</i> , 6, 4, 1910
1149				Adams, <i>Ap. J.</i> , 19, 341, 1904
1175				Palmer, <i>L. O. B.</i> , 4, 97, 1906
1213				Frost, <i>Ap. J.</i> , 25, 64, 1907. Some evidence of double spectrum
1220				Frost and Adams, <i>Ap. J.</i> , 19, 152, 1904
1228				Frost and Adams, <i>Ap. J.</i> , 18, 388, 1903. Frost and Ichinohe report H and K sharply defined and giving velocities different from those afforded by other lines; <i>Ap. J.</i> , 29, 236, 1909; Plaskett, <i>Jour. R. A. S.</i> , 2, 325, 1908
1239	+10.	Schlesinger	Unpublished letter	Belopolsky, <i>A. N.</i> , 145, 281, 1897. Two spectra visible, Algol variable. *Photometric period
1240				Frost, <i>A. N.</i> , 177, 174, 1908
1324				Curtis, <i>L. O. B.</i> , 5, 174, 1910
1347				Wright, <i>L. O. B.</i> , 3, 110, 1905. Two spectra visible; components about equally bright. Called X <i>Eridani</i> in A. G. C.
1380				Lee, <i>Ap. J.</i> , 29, 240, 1909. Period of 12 days suggested
1392				Frost, <i>Ap. J.</i> , 29, 239, 1909. Two spectra visible
1394				Lee, <i>Ap. J.</i> , 29, 241, 1909. Indications of a second spectrum
1412				Moore, <i>L. O. B.</i> , 5, 62, 1908. Frost, <i>Ap. J.</i> , 29, 238, 1909. Frost finds some evidence of second spectrum. Period probably short
1427				Barrett, <i>Ap. J.</i> , 29, 237, 1909
1458				Moore, <i>L. O. B.</i> , 4, 162, 1907
1463				Frost and Adams, <i>Ap. J.</i> , 17, 151, 1903
1473				Barrett, <i>Ap. J.</i> , 29, 237, 1909
1479				Lee, <i>Ap. J.</i> , 29, 242, 1909. Two spectra visible
1481				Moore, <i>L. O. B.</i> , 5, 62, 1908
1497	+13.49	Parker	Unpublished	Frost and Adams, <i>Ap. J.</i> , 17, 246, 1903
1520				Yerkes Ob. Unpublished
1542		Frost	Unpublished	Frost and Adams, <i>Ap. J.</i> , 19, 350, 1904. Frost and Adams find that very sharp H and K calcium lines yield variable radial velocity different from that given by the broad lines
1547				Lee, <i>Ap. J.</i> , 29, 241, 1909; Jordan, <i>Publ. A. O.</i> , 1, 114, 1909. Lee finds many lines complex
1552	+23.27	Baker	<i>Publ. A. O.</i> , 1, 110, 1909	Reese, <i>Publ. A. S. P.</i> , 15, 20, 1903, and <i>L. O. B.</i> , 2, 29, 1903; Frost and Adams, <i>Ap. J.</i> , 17, 153, 1903
1567		Frost	Unpublished	Frost and Adams, <i>Ap. J.</i> , 17, 150, 1903
1568		Harper	Unpublished	Moore, <i>L. O. B.</i> , 4, 162, 1907
1605				Vogel, <i>Ap. J.</i> , 17, 243, 1903; two spectra visible. From light curve, Ludendorff thought this star is an Algol variable, period 27.12 years (<i>A. N.</i> , 164, 81, 1903); but on other considerations concluded that this is improbable (<i>A. N.</i> , 171, 49, 1906)
1612				Wright, <i>L. O. B.</i> , 5, 62, 1908
1698				Moore, <i>L. O. B.</i> , 5, 62, 1908
1708	+30.17 +30.17 +27.5± +22.62	Reese Reese Newall Plaskett	<i>L. O. B.</i> , 1, 34, 1901 <i>L. O. B.</i> , 1, 34, 1901 <i>M. N. R. A. S.</i> , 60, 418, 1900 <i>Ap. J.</i> , 30, 31, 1909	Campbell, <i>Ap. J.</i> , 10, 177, 1899; Newell, <i>M. N. R. A. S.</i> , 60, 2, 1899. Two spectra visible. *Orbit of secondary. From Reese's elements $m \sin^3 i = 1.19\odot$; $m_1 \sin^3 i = 0.94\odot$; $m_1 : m = 0.79$
1713				Plaskett, <i>Ap. J.</i> , 30, 26, 1909; suspected by Vogel, <i>Publ. Potsdam</i> , 7 (I), 146, 1892; Ludendorff finds evidence of triplicity, <i>A. N.</i> , 183, 9, 1909
1735				Frost, <i>Ap. J.</i> , 25, 64, 1907
1765				Frost and Adams, <i>Ap. J.</i> , 18, 385, 1903
1788	+35.5 +35.5	Adams	<i>Ap. J.</i> , 17, 71, 1903	Frost and Adams, <i>Ap. J.</i> , 15, 214, 1902. Two spectra visible; Frost, unpublished letter. $m_1 : m = 0.95$; Schlesinger, unpublished letter. Slipher reports H and K sharp and yielding constant velocity; unpublished letter. *Orbit of secondary based upon Schlesinger's ratio of masses, $m \sin^3 i = 11.2\odot$, $m_1 \sin^3 i = 10.6\odot$
1811	+12.02	Plaskett	<i>Ap. J.</i> , 28, 272, 1908	Frost and Adams, <i>Ap. J.</i> , 17, 246, 1903. Baker finds two spectra visible, <i>Publ. A. O.</i> , 1, 100, 1909. $m_1 : m = 0.76$; Schlesinger, unpublished letter. *Orbit of secondary based upon Schlesinger's ratio of masses, $m \sin^3 i = 5.53\odot$, $m_1 \sin^3 i = 4.19\odot$
1843				Frost and Adams, <i>Ap. J.</i> , 18, 385, 1903

H.R.	Star	R.A., 1900 5 ^h 26 ^m 9	Decl., 1900 — 0° 22'	Vis. Mag. 2.48	Spec. Type B	P Period 5.7325	T Jul. Day 2,410,000+	ω	e	K km. (108.1)	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$ 0.601	$a \sin i$ km. 7,906,600
1852	δ Orionis							339.3	0.103			
1876	ϕ_1 Orionis	29.3	+ 9 25	4.53	B	.....	.....	.....	.....	.....	.....	.....
1892	c Orionis	30.4	— 4 54	4.65	B3	.....	.....	.....	.....	.....	.....	.....
1895	θ_1 Orionis	30.4	— 5 27	5.36	Oe5	.....	.....	.....	.....	.....	.....	.....
1897	θ_2 Orionis	30.5	— 5 29	5.17	B1	.....	.....	.....	.....	.....	.....	.....
1899	ι Orionis	30.5	— 5 59	2.87	Oe5	29.136	7587.993	113.28	0.754	109.90	(1.14)	28,907,000
1903	ϵ Orionis	31.1	— 1 16	1.75	B	.....	.....	.....	.....	.....	.....	.....
1910	ζ Tauri	31.7	+21 5	3.00	B3	138.	5769.9	9.8	0.180	14.95	(0.0455)	27,900,000
1922	ν Doradus	32.8	—62 33	3.81	F5	.....	.....	.....	.....	.....	.....	.....
1931	σ Orionis	33.7	— 2 39	3.78	B	.....	.....	.....	.....	.....	.....	.....
1934	ω Orionis	33.9	+ 4 4	4.54	B3	.....	.....	.....	.....	.....	.....	.....
1952	B.D. —1°1004	35.8	— 1 11	5.00	B3	27.160	7961.465	87.02	0.765	93.04	(0.6067)	22,380,000
2084	139 Tauri	51.8	+25 57	4.90	B2	.....	.....	.....	.....	.....	.....	.....
2088	β Aurigae	52.2	+44 56	2.07	Ap	3.968 3.9599	1340.23	87.7	0.156 0.0	 *222.	.....	..... *12,000,000
						3.9600244	**241901	107.9	0.005	*219.0	.....	*11,899,000
2124	μ Orionis	56.9	+ 9 39	4.19	A2	0.77	.....	.....	.....	.....	.....	.....
2134	1 Geminorum	58.0	+23 16	4.30	G5	.....	.....	.....	.....	.....	.....	.....
2159	ν Orionis	6 1.9	+14 47	4.40	B2	131.4	.....	.....	.....	.....	.....	.....
2199	ξ Orionis	6.3	+14 14	4.35	B3	.....	.....	.....	.....	.....	.....	.....
2216	η Geminorum	8.8	+22 32	var.	Ma	long	.....	.....	.....	.....	.....	.....
2282	ζ Canis Maj.	16.5	—30 1	3.10	B3	.....	.....	.....	.....	.....	.....	.....
2294	β Canis Maj.	18.3	—17 54	1.99	B1	0.25	.....	.....	0.1±	9.8±	0.00002	33,510
2296	δ Columbae	18.4	—33 23	3.98	G5	long	.....	.....	.....	.....	.....	.....
2310	T Monocerotis	19.8	+ 7 8	var.	G	*27.0122	.....	.....	.....	.....	.....	.....
2332	RT Aurigae	22.1	+30 34	var.	G	3.7282	*34403	95.02	0.368	17.96	(0.0018)	856,500
2343	ν Geminorum	23.0	+20 17	4.06	B5	.....	.....	.....	.....	.....	.....	.....
2387	ξ_1 Canis Maj.	27.6	—23 21	4.35	B1	.....	.....	.....	.....	.....	.....	.....
2397	C.P.D. —31°1218	28.9	—31 57	5.70	B3	.....	.....	.....	.....	.....	.....	.....
2421	γ Geminorum	31.9	+16 29	1.93	A	long	.....	.....	.....	.....	.....	.....
2451	ν Puppis	34.7	—43 6	3.18	B8	.....	.....	.....	.....	.....	.....	.....
2456	S Monocerotis	35.5	+ 9 59	4.68	Oe5	.....	.....	.....	.....	.....	.....	.....
2490	42 Camelopard.	40.5	+67 41	5.04	B3	.....	.....	.....	.....	.....	.....	.....
2491	α Canis Maj.	40.7	—16 35	1.58	A	.....	.....	.....	(0.59)	.....	.....	.....
2553	τ Puppis	47.5	—50 30	2.83	K	long	.....	.....	.....	.....	.....	.....
2554	A Carinae	47.6	—53 31	4.38	G5	.....	.....	.....	.....	.....	.....	.....
2650	ζ Geminorum	58.2	+20 43	var.	G	10.154	*14313	333.	0.22	13.2	(0.0023)	1,797,800
2653	α_2 Canis Maj.	58.8	—23 41	3.12	B5p	24.3±	.....	.....	.....	5.±	(0.0003±)	(1,670,000)
2693	δ Canis Maj.	7 4.3	—26 14	1.98	F8p	$\frac{3}{4}$ year	.....	.....	.....	1.5±	(0.0001)	(5,650,000)
2745	27 Canis Maj.	10.2	—26 10	4.66	B5	.....	.....	.....	.....	.....	.....	.....
2770	C.P.D. —36°1208	13.3	—36 25	5.01	B3	.....	.....	.....	.....	.....	.....	.....
2781	29 Canis Maj.	14.5	—24 23	4.90	Oe	short	.....	.....	.....	.....	.....	.....

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
1852	+23.1	Hartmann	<i>Ap. J.</i> , 19, 278, 1904	Deslandres, <i>C. R.</i> , 130, 379, 1900. Hartmann finds calcium K gives apparently constant velocity and suggests absorption by intervening calcium mass. Hartmann finds, on assumption of $m = m_1$, the minimum value of $m + m_1 = 4.8\odot$
1876	.....			Frost and Lee, <i>Ap. J.</i> , 30, 63, 1909; H and K calcium lines give variable velocity different from those yielded by other lines
1892	.....			Frost and Lee, <i>Ap. J.</i> , 30, 64, 1909; seem to be traces of second component
1895	.....			Frost and Adams, <i>Ap. J.</i> , 19, 153, 1904. This is star C of Trapezium
1897	.....			Frost and Adams, <i>Ap. J.</i> , 19, 153, 1904
1899	+21.34	Plaskett-Harper, <i>Ap. J.</i> , 30, 379, 1909		Frost and Adams, <i>Ap. J.</i> , 18, 386, 1903. Slipher reports H and K sharp and giving constant velocity; unpublished letter. Plaskett reports residuals from elliptic orbit represented by simple circular motion of same period, 29d36, and single amplitude 8.4 km. per sec.
1903	.....			Frost, <i>Ap. J.</i> , 29, 235, 1909
1910	+16.4	Adams	<i>Ap. J.</i> , 22, 118, 1905	Frost and Adams, <i>Ap. J.</i> , 17, 150, 1903
1922	.....			Palmer, <i>L. O. B.</i> , 3, 3, 1904
1931	.....			Frost and Adams, <i>Ap. J.</i> , 19, 153, 1904
1934	.....			Yerkes Ob., unpublished letter
1952	+26.12	Plaskett-Harper, <i>Ap. J.</i> , 30, 376, 1909		Frost, <i>Ap. J.</i> , 23, 264, 1906. Residuals from elliptic orbit represented by simple circular motion of period 27d160 and single amplitude 10.2 km. Several orbits by Plaskett
2084	.....			Frost and Lee, <i>Ap. J.</i> , 30, 64, 1909. Indications of two spectra
2088	.....	Rambaut	<i>M. N. R. A. S.</i> , 51, 327, 1891	Miss Maury, <i>Fourth Rep. Draper Mem.</i> , 1890, p. 9; two spectra visible, components about equally bright. Vogel found $(m + m_1) \sin^2 i = 4.5\odot$. Zurhellen gives several values of ω , T , and e ; <i>A. N.</i> , 175, 250-8, 1907. Ludendorff finds $m_1 : m = 0.98$; <i>A. N.</i> , 183, 115, 1909. Schlesinger gives $m_1 : m = 0.99$, unpublished letter. *Quantities quoted are $K + K_1$ and $(a + a_1) \sin i$. ** T is interval after coincidence of two spectra. With Belopolsky's elements, $(m + m_1) \sin^2 i = 4.32\odot$
—20.		Vogel	<i>A. N.</i> , 165, 113, 1904	
—19.8		Ludendorff	<i>A. N.</i> , 183, 115, 1909	
—18.2		Belopolsky	<i>Mit. Pulk.</i> , 3, 133-6, 1909	
2124	.....	Yerkes Ob.	Unpublished letter	Frost, <i>Ap. J.</i> , 23, 266, 1906. Spectrum of secondary strongly suspected
2134	.....			Moore, <i>L. O. B.</i> , 4, 96, 1906
2159	.....	Harper	Unpublished	Frost and Adams, <i>Ap. J.</i> , 18, 386, 1903
2199	.....			Frost and Adams, <i>Ap. J.</i> , 19, 154, 1904
2216	.....			Reese, <i>L. O. B.</i> , 1, 158, 1902. Variable star, period 231d4
2282	.....			Paddock, <i>L. O. B.</i> , 5, 60, 1908; Mitchell, <i>Ap. J.</i> , 30, 242, 1909
2294	+33.7±	Albrecht	Unpublished	Albrecht, <i>L. O. B.</i> , 5, 62, 1908. Elements only approximate
2296	.....			Palmer, <i>L. O. B.</i> , 3, 110, 1905
2310	.....			Frost, <i>Ap. J.</i> , 23, 266, 1906. Cepheid variable. *Photometric period
2332	+21.43	Duncan	<i>L. O. B.</i> , 5, 121, 1909	Duncan, <i>L. O. B.</i> , 5, 86, 1908. Cepheid variable. * T is interval after light max.
2343	.....			Yerkes Ob., unpublished letter
2387	.....			Frost, <i>Ap. J.</i> , 25, 64, 1907
2397	.....			Curtis, <i>L. O. B.</i> , 5, 139, 1909
2421	.....			Burns, <i>L. O. B.</i> , 3, 84, 1905; Slipher, <i>Ap. J.</i> , 22, 84, 1905. Slipher suggests period $3\frac{1}{2} \pm$ years and large eccentricity
2451	.....			Wright, <i>L. O. B.</i> , 5, 61, 1908. Spectrum of secondary suspected
2456	.....			Frost and Adams, <i>Ap. J.</i> , 19, 154, 1904. Range at least 30 km.
2490	.....			Yerkes Ob., unpublished letter
2491	— 7.4	Campbell	<i>L. O. B.</i> , 3, 80, 1905	Campbell, <i>L. O. B.</i> , 3, 80, 1905. Auwers estimated $m = 2.20\odot$, $m_1 = 1.04\odot$, <i>A. N.</i> , 129, 232, 1892. Lohse's elements of visual system, $P = 49^d32$, $e = 0.59$, $i = \pm 44^\circ 5$, <i>Publ. Potsdam</i> , 20, No. 58, 89, 1908. Campbell finds i positive.
— 9.3		Ludendorff	<i>A. N.</i> , 183, 119, 1909	Four <i>L. O.</i> spectrograms epoch 1909.6 $V = -7.98$ km.; four Mt. Wilson high dispersion spectrograms epoch 1910.0 $V = -7.82$ km.; mean resulting $V_0 = -7.6$ km.
2553	.....			Curtis and Palmer independently, <i>L. O. B.</i> , 5, 60, 1908
2554	.....			Wright, <i>L. O. B.</i> , 3, 111, 1905
2650	+ 6.8	Campbell	<i>Ap. J.</i> , 13, 93, 1901	Belopolsky in unpublished lecture, <i>Russ. Astr. Gesells.</i> ; see <i>A. N.</i> , 149, 239, 1899. Campbell and Wright, <i>Ap. J.</i> , 9, 86, 1899. Cepheid variable, period 10d15. * T is interval after min. brightness. Campbell finds residuals from elliptic curve satisfied by simple circular motion in period 34385 with single amplitude 2.25 km. per sec.
2653	.....	Curtis	Unpublished	Mitchell, <i>Ap. J.</i> , 30, 242, 1909. Approximate orbit
2693	+34.±	Wright	<i>L. O. B.</i> , 5, 176, 1910	Wright, <i>L. O. B.</i> , 5, 176, 1910
2745	.....			Suspected by Albrecht and Paddock independently; confirmed by Paddock, <i>L. O. B.</i> , 6, 4, 1910
2770	.....			Paddock, <i>L. O. B.</i> , 5, 139, 1909. Spectrum of secondary suspected
2781	.....			Frost, <i>Ap. J.</i> , 23, 265, 1906

H.R.	Star	R.A., 1900 7 ^h 14 ^m 9	Decl., 1900 —16° 12'	Vis. Mag. var.	Spec. Type F	P Period *1.136	T Jul. Day 2,410,000+	ω	e	K km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$	$a \sin i$ km.
2788	R Canis Maj.											
2854	γ Canis Min.	22.8	+ 9 8	4.60	K	long						
2878	σ Puppis	26.1	—43 6	3.27	K5							
2890	α_1 Geminorum	28.2	+32 6	2.85	A	2.934			0.12	33.4		
						2.928285	6828.057	102.52	0.01	31.76	(0.0097)	1,279,000
2891	α_2 Geminorum	28.2	+32 6	1.99	A	9.218826	6746.385	265.35	0.503	13.56	(0.0015)	1,485,000
2890-1	α Geminorum	28.2	+32 6	1.58	A							
2973	σ Geminorum	37.0	+29 7	4.26	K							
3080	α Puppis	48.8	—40 19	3.76	G5							
3129	V Puppis	55.3	—48 58	var.	B1p	*1.454475			(0.)			**12,200,000
3185	ι Argus	8 3.3	—24 1	2.88	F5	long						
3223	ϵ Volantis	7.6	—68 19	4.46	B5							
3447	$\circ$ Velorum	37.4	—52 34	3.68	B3							
3454	η Hydrae	38.0	+ 3 46	4.32	B3							
3457	δ Carinae	38.5	—59 24	4.42	B2							
3482	ϵ Hydrae	41.5	+ 6 47	3.48	F8	*[15 $\times$ 7]	1901.0	95.	0.6	8.4	0.18	550,000,000
3574	H Velorum	53.3	—52 21	4.77	B5							
3591	w Velorum	56.3	—40 52	4.42	F8							
3615	α Volantis	9 0.9	—66 0	4.18	A5							
3623	κ Cancri	2.4	+11 4	5.14	B8	6.393	6486.897	162.3	0.149	67.8	(0.200)	5,890,000
3624	τ Ursae Maj.	2.7	+63 55	4.74	F8p							
3659	α Carinae	8.4	—58 33	3.56	B3	6.744	6533.81	115.84	0.18	21.5	(0.0066)	1,960,000
3665	θ Hydrae	9.2	+ 2 44	3.84	A							
3734	κ Velorum	19.0	—54 35	2.63	B3	116.65	6459.00	96.23	0.19	46.5	(1.15)	73,200,000
3754	ω Leonis	23.1	+ 9 30	5.52	G							
3852	$\circ$ Leonis	35.8	+10 21	3.76	F5p		*7309.60					**23,743,000
						14.4980	*4656.477		<0.02	(54.0)	(0.238)	10,775,000
						‡14.4980			<0.02	(63.1)	(0.378)	12,571,000
3884	l Carinae	42.5	—62 3	var.	G	*35.523						
3912	m Velorum	47.9	—46 5	4.56	G5							
3994	λ Hydrae	10 5.7	—11 52	3.83	K							
4023	q Velorum	10.5	—41 38	4.09	A2							
[4057-8	γ Leonis	14.5	+20 21	{2.61 3.80	{K K}							
4069	μ Ursae Maj.	16.4	+42 0	3.21	K5							
4072	B.D. +66°664	16.9	+66 4	4.92	A	11.6 $\pm$						
4118	δ Antliae	25.0	—30 5	5.65	B9	short						
4133	ρ Leonis	27.5	+ 9 49	3.85	Bp							
4167	p Velorum	33.1	—47 42	4.06	F2							
4248	ω Ursae Maj.	48.2	+43 43	4.84	A							
4295	β Ursae Maj.	55.8	+56 55	2.44	A	27.16	8036.12	60.3	0.79	7.75	0.0003	1,774,000
4301	α Ursae Maj.	57.6	+62 17	1.95	K	long						
4337	π Carinae	11 4.4	—58 26	4.02	F8p							
4343	β Crateris	6.7	—22 17	4.52	A2							
4375	ξ Ursae Maj.	12.9	+32 6	4.41	G	1 $\times$ 8						
4380	55 Ursae Maj.	13.7	+38 44	4.78	A2							
4499	C.P.D. —61°2514	36.2	—61 32	4.88	G							
4527	93 Leonis	42.8	+20 46	4.54	F8							

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
2788	.....			Frost, <i>Ap. J.</i> , 22, 213, 1905. Algol variable. *Photometric period
2884	.....			Reese, <i>L. O. B.</i> , 1, 159, 1902
2878	.....			Palmer, <i>L. O. B.</i> , 3, 111, 1905
2890	- 4.1	Belopolsky	<i>Mem. Acad. St. Peters.</i> , 11, No. 4, 83, 1900	Belopolsky, <i>Bull. Acad. Sci.</i> , St. Petersburg, Jan., 1897
	- 0.98	Curtis	<i>L. O. B.</i> , 4, 58, 1906	Several orbits by Belopolsky for years 1896-98-99
2891	+ 6.20	Curtis	<i>L. O. B.</i> , 4, 64, 1906	Curtis, <i>L. O. B.</i> , 3, 84, 1905
2890-1	.....			Curtis finds relative radial velocity of 7 km. for α_1 and α_2 as above. Visual orbit very uncertain
2973	.....			Reese, <i>L. O. B.</i> , 2, 29, 1903
3080	.....			Wright, <i>L. O. B.</i> , 3, 111, 1905
3129	.....			Pickering, <i>H. C. O. Circ.</i> , No. 14, 1896. Two spectra visible, max. relative velocity of components 610 km.: <i>H. C. O. Circ.</i> , No. 21, 1898. Algol variable. Assuming $e=0$ and equal masses, $m \sin^3 i = m_1 \sin^3 i = 17.1\odot$. **This is $(a + a_1) \sin i$. *Photometric period
3185	.....			Campbell, <i>L. O. B.</i> , 2, 29, 1903. Also called ρ Puppis
3223	.....			Curtis, <i>L. O. B.</i> , 5, 139, 1909
3447	.....			Curtis, <i>L. O. B.</i> , 5, 60, 1908
3454	.....			Frost and Adams, <i>Ap. J.</i> , 19, 155, 1904
3457	.....			Paddock, <i>L. O. B.</i> , 5, 60, 1908
3482	+37.7	Curtis	Unpublished, approx.	Campbell, <i>L. O. B.</i> , 1, 23, 1901. Aitken, visual orbit, $P=15^d.7$, $e=0.685$; <i>L. O. B.</i> , 3, 170, 1905. *Period assumed
3574	.....			Paddock, <i>L. O. B.</i> , 5, 139, 1909
3591	.....			Palmer, <i>L. O. B.</i> , 3, 3, 1904
3615	.....			Wright, <i>L. O. B.</i> , 3, 111, 1905. Two spectra visible
3623	+26.3	Ichinohe	<i>Ap. J.</i> , 25, 318, 1907	Frost and Adams, <i>Ap. J.</i> , 19, 350, 1904. Two spectra visible. The elements refer to the brighter component
3624	.....			Suspected by Stebbins, confirmed by Moore and Burns, <i>L. O. B.</i> , 4, 68, 1906
3659	+23.3	Curtis	<i>L. O. B.</i> , 4, 154, 1907	Wright, <i>L. O. B.</i> , 3, 111, 1905. Some evidence of second spectrum
3665	.....			Campbell and Albrecht, <i>L. O. B.</i> , 5, 174, 1910
3734	+21.9	Curtis	<i>L. O. B.</i> , 4, 156, 1907	Wright, <i>L. O. B.</i> , 3, 111, 1905
3754	.....			Frost, <i>Ap. J.</i> , 25, 61, 1907. Brighter component of visual double observed. See's period of visual binary system 116 $\times$ 2
3852	+27.23	Zurhellen	<i>A. N.</i> , 173, 353, 1907	Campbell, <i>Ap. J.</i> , 8, 291, 1898. Two spectra visible. * T is time when observed velocity of each component is equal to the velocity of the system, with principal component between the center of mass and the solar system. **This is the value of $(a + a_1) \sin i$. Zurhellen determines $m \sin^3 i = 1.358\odot$, $m_1 \sin^3 i = 1.185\odot$, $m_1 : m = .87$; Plummer determines $m \sin^3 i = 1.302\odot$, $m_1 \sin^3 i = 1.116\odot$, $m_1 : m = .86$. † orbit of secondary
	+27.07	Plummer	<i>L. O. B.</i> , 5, 21, 1908	
	+27.07	Plummer	<i>L. O. B.</i> , 5, 21, 1908	
3884	.....			Wright, <i>L. O. B.</i> , 3, 3, 1904. Cepheid variable. *Photometric period
3912	.....			Wright, <i>L. O. B.</i> , 4, 97, 1906
3994	.....			Wright and Burns, <i>L. O. B.</i> , 4, 68, 1906
4023	.....			Paddock, <i>L. O. B.</i> , 5, 61, 1908
4057-8	.....			Visual double. Belopolsky finds a relative velocity of two components 2.2 km.; <i>A. N.</i> , 147, 92, 1898. <i>L. O. obs.</i> differ only 0.1 km. for the two components
4069	.....			Moore, <i>L. O. B.</i> , 4, 68, 1906
4072	.....			Schlesinger and Baker, <i>Publ. A. O.</i> , 1, 121, 1909. Rather eccentric orbit
4118	.....			Curtis, unpublished. Period 2 or 3 days. Two spectra visible
4133	.....			Campbell, <i>L. O. B.</i> , 5, 174, 1910
4167	.....			Wright, <i>L. O. B.</i> , 3, 111, 1905. Two spectra visible
4248	.....			Vogel, <i>A. N.</i> , 163, 145, 1903. Two spectra visible
4295	-16.8	Ludendorff	<i>A. N.</i> , 180, 271, 1908	Ludendorff, <i>A. N.</i> , 177, 235, 1908. Assuming $m = m_1$ Ludendorff finds $m \sin^3 i = m_1 \sin^3 i = 0.0012\odot$
4301	.....			Campbell, <i>L. O. B.</i> , 5, 174, 1910
4337	.....			Wright, <i>L. O. B.</i> , 4, 161, 1907
4343	.....			Paddock, <i>L. O. B.</i> , 5, 139, 1909
4375	.....	Wright	<i>L. O. B.</i> , 5, 26, 1908	Wright, <i>Ap. J.</i> , 12, 254, 1900. The brighter visual component. Period of visual binary 60 $\times$ 8. Nörlund finds a perturbation, of period 1 $\times$ 80, in the orbit of the visual binary. The radial velocities are represented by elliptic motion with this period; <i>A. N.</i> , 170, 123, 1905
4380	.....			Lee, <i>Science</i> , 28, 853, 1908
4499	.....			Paddock, <i>L. O. B.</i> , 5, 139, 1909
4527	.....			Campbell and Wright, <i>Ap. J.</i> , 12, 255, 1900

H.R.	Star	R.A., 1900		Decl., 1900		Vis. Mag.	Spec. Type	P Period	T Jul. Day 2,410,000+	ω	e	K km.	$m_1^3 \sin^3 i$ ($m + m_1$) ²	$a \sin i$ km.
4589	π Virginis	11 ^h 55 ^m 7		+ 7° 10'		4.57	A3	-----	-----	-----	-----	-----	-----	-----
4603	θ_2 Crucis	59.2		—62 36		4.98	B3	-----	-----	-----	-----	-----	-----	-----
4662	γ Corvi	12 10.7		—16 59		2.78	B8	short	-----	-----	-----	-----	-----	-----
4689	η Virginis	14.8		— 0 7		4.00	A	71.9	6206.93	180.0	0.254	26.8	(0.130)	25,290,000
								71.9	7643.50	185.0	0.40	*(27.6)	(0.126)	25,750,000
4775	η Corvi	26.9		—15 38		4.42	F	-----	-----	-----	-----	-----	-----	-----
[4825-6	γ Virginis	36.6		— 0 54		{3.65 3.68	{F F}	-----	-----	-----	-----	-----	-----	-----
4853	β Crucis	41.9		—59 9		1.50	B1	-----	-----	-----	-----	-----	-----	-----
[4905	ϵ Ursae Maj.	49.6		+56 30		1.68	Ap]	-----	-----	-----	-----	-----	-----	-----
4963	θ Virginis	13 4.8		— 5 0		4.44	A	-----	-----	-----	-----	-----	-----	-----
5054	ζ_1 Ursae Maj.	19.9		+55 27		2.40	Ap	20.6 20.54 20.536	5472.84	101.3	0.502	*142.	(3.96)	*35,000,000
5055	ζ_2 Ursae Maj.	19.9		+55 26		3.96	A2	-----	-----	-----	-----	-----	-----	-----
5056	α Virginis	19.9		—10 38		1.21	B2	4.0134 4.01416 4.01416	*1492.4 7955.846 -----	----- 328. **148.	0. 0.10 0.1	91. 126.1 207.8	(0.314) (0.833) (3.68)	(5,021,000) 6,930,000 11,400,000
5062	g Ursae Maj.	21.2		+55 30		4.02	A5	-----	-----	-----	-----	-----	-----	-----
5105	$\circ$ Virginis	29.1		+ 4 10		4.93	Ap	-----	-----	-----	-----	-----	-----	-----
5110	B.D. +37°2426	30.3		+37 42		4.96	F	-----	-----	-----	-----	-----	-----	-----
5190	ν Centauri	43.5		—41 11		3.53	B2	31±	-----	-----	-----	-----	-----	-----
5231	ζ Centauri	49.3		—46 48		3.06	B2p	8.024	-----	-----	-----	-----	-----	-----
5235	η Bootis	49.9		+18 54		2.80	G	489.14	8249.455	322.3	0.177	8.46	(0.0293)	56,010,000
5260	ν_2 Centauri	55.4		—45 7		4.39	F5	-----	-----	-----	-----	-----	-----	-----
5291	α Draconis	14 1.7		+64 51		3.64	A	51.38	7403.0	18.	0.42	-----	-----	30,057,900
								51.38	7403.0	18.8	0.429	-----	-----	29,664,000
								51.38	7403.284	19.1	0.384	46.25	(0.416)	30,173,000
5304	d Bootis	5.8		+25 34		4.82	F5	-----	-----	-----	-----	-----	-----	-----
5313	B.D. +3°2867	7.2		+ 2 53		4.90	Ap	-----	-----	-----	-----	-----	-----	-----
5361	A Bootis	13.8		+35 58		4.83	G5	-----	-----	-----	-----	-----	-----	-----
5392	B.D. +6°2875	19.3		+ 6 16		5.08	A3	-----	-----	-----	-----	-----	-----	-----
5413	C.P.D. —48°6496	23.7		—49 4		5.52	A2	-----	-----	-----	-----	-----	-----	-----
5440	η Centauri	29.2		—41 43		2.65	B3p	-----	-----	-----	-----	-----	-----	-----
5459-0	α Centauri	32.8		—60 25		{0.33 1.70	{G K5	*(81±18)	-----	-----	-----	-----	-----	-----
5469	α Lupi	35.3		—46 58		2.89	B2	-----	-----	-----	-----	-----	-----	-----
5531	α_2 Librae	45.3		—15 38		2.90	A2	-----	-----	-----	-----	-----	-----	-----
5571	β Lupi	52.0		—42 44		2.81	B2p	-----	-----	-----	-----	-----	-----	-----
5576	κ Centauri	52.7		—41 42		3.35	B3	-----	-----	-----	-----	-----	-----	-----
5586	δ Librae	55.6		— 8 7		var.	A	2.32770	*1489	29.2	0.054	76.5	(0.110)	2,450,000
5651	ϵ Lupi	15 6.1		—44 8		4.92	B3	-----	-----	-----	-----	-----	-----	-----
5723	ϵ Librae	18.8		— 9 57		5.08	F	-----	-----	-----	-----	-----	-----	-----

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
4589	.....			Albrecht, <i>L. O. B.</i> , 5, 175, 1910
4683	.....			Paddock, <i>L. O. B.</i> , 5, 139, 1909
4682	.....			Campbell and Curtis, <i>L. O. B.</i> , 2, 126, 1903
4689	- 0.4	Ichinohe	<i>Ap. J.</i> , 26, 282, 1907	Frost and Adams, <i>Ap. J.</i> , 17, 152, 1903; Campbell and Curtis, <i>L. O. B.</i> , 2, 126, 1903. Two spectra visible. Ichinohe makes velocity of center of mass of faint component +30 km. with non-elliptic curve suggesting a third component.
	+ 2.2	Harper	<i>Ap. J.</i> , 27, 160, 1908	*Estimated from published curve
4775	.....			Albrecht, <i>L. O. B.</i> , 5, 175, 1910. Two spectra visible
4825-6	.....			Visual binary. Belopolsky finds relative velocity of the two components 2.1 km.; <i>A. N.</i> , 147, 89, 1898. L. O. observations show no difference in velocities
4853	.....			Wright, <i>L. O. B.</i> , 5, 177, 1910
4905	.....			Adams suspects variable velocity, <i>Ap. J.</i> , 18, 68, 1903; Ludendorff suspects variable velocity, -8 to -18, mean -13 km., in period of 2.1 years; <i>A. N.</i> , 180, 273, 1909
4963	.....			Mitchell, <i>Ap. J.</i> , 30, 241, 1909; H and K lines give variable velocity different from that yielded by other lines; suspects period of 4 months
5054	-16.	Vogel	<i>Ap. J.</i> , 13, 328, 1901	Pickering, <i>Amer. Jour. Sci.</i> , 39, 46, 1890. First spectroscopic binary discovered.
	-14.2	Vogel	Unpublished letter	Two spectra visible; components equal in brightness. Vogel finds masses of two components very nearly equal; unpublished letter. Ludendorff determines $m_1 : m = 0.99$. Assuming $m = m_1$ we have according to Vogel's orbit $m \sin^2 i = 2.0\odot$. * $K + K_1$ and $(a + a_1) \sin i$
	-12.6	Ludendorff	<i>A. N.</i> , 180, 276, 1909	
5055	.....			Frost and Lee, <i>A. N.</i> , 177, 171, 1908. Range -17 to +10 km. Variation independently suspected by Ludendorff, range -7.3 to -17.7 km. <i>A. N.</i> , 177, 9, 1908
5056	-14.8	Vogel	<i>Publ. Potsdam</i> , 7, 136, 1892	Vogel, <i>A. N.</i> , 125, 305, 1890, <i>Publ. Potsdam</i> , 7, Th. I, 127, 1892. * T is instant when velocity equals that of center of mass. Spectrum of companion suspected by Vogel and confirmed by Baker. Baker finds $m \sin^2 i = 9.6\odot$ and $m_1 \sin^2 i = 5.8\odot$. **Elements of secondary orbit
	+ 1.6	Baker	<i>Publ. A. O.</i> , 1, 72, 1909	
	+ 1.6	Baker	<i>Publ. A. O.</i> , 1, 72, 1909	
5062	.....			Frost, <i>A. N.</i> , 177, 172, 1908. Two spectra visible; period exceedingly short. This star is "Alcor"
5105	.....			Mitchell, <i>Ap. J.</i> , 30, 241, 1909
5110	.....			Wright and Allen, <i>L. O. B.</i> , 5, 175, 1910
5190	.....			Palmer, <i>L. O. B.</i> , 4, 97, 1906
5231	.....			Fleming, <i>Director's Rep. H. C. O.</i> , 1899. Two spectra visible. Components unequal in brightness
5235	- 0.2	Harper	Unpublished letter	Moore, <i>L. O. B.</i> , 3, 85, 1905
5260	.....			Wright, <i>L. O. B.</i> , 4, 97, 1906
5291	-16.7	Harper	<i>Jour. R. A. S. Can.</i> , 1, 244, 1907	Campbell and Curtis, <i>L. O. B.</i> , 2, 126, 1903. Many orbits were computed by Plaskett; <i>Rep. Chief Astron.</i> (Can.), 1907. App. 3, p. 146; and <i>Jour. R. A. S. Can.</i> , 1, 244, 1907
	-17.0	Plaskett	<i>Rep. Chief Astron.</i> (Can.), App. 3, p. 146, 1907	
	-17.0	Harper	Unpublished	
5304	.....			Wright, <i>Ap. J.</i> , 12, 255, 1900
5313	.....			Baker, <i>Publ. A. O.</i> , 1, 121, 1909
5361	.....			Moore, <i>L. O. B.</i> , 4, 162, 1907
5392	.....			Jordan, <i>Publ. A. O.</i> , 1, 121, 1909
5413	.....			Curtis, <i>L. O. B.</i> , 5, 140, 1909. Two spectra visible
5440	.....			Wright, <i>L. O. B.</i> , 5, 177, 1910
5459-0	.....			Wright, <i>Publ. L. O.</i> , 9 (unpublished), finds for epoch 1904.7 difference of radial velocities equal 5.34 km. Using Roberts' $P^* = 81\text{r}185$, $e = 0.529$, and $m_1/m = 49/51$, Wright deduced $\pi = 0.73$, $a = 3.64 \times 10^9$ km., $m + m_1 = 2.2\odot$, $m = 1.12\odot$, $m_1 = 1.08\odot$, $V_0 = -22.18$ km.
5469	.....			Wright, <i>L. O. B.</i> , 5, 177, 1910
5531	.....			Slipher, <i>Lowell O. B.</i> , No. 11, 57, 1904; two spectra may be visible
5571	.....			Fleming, <i>H. C. O. Circ.</i> , No. 21, 1898. Two spectra visible
5576	.....			Curtis and Paddock, <i>L. O. B.</i> , 5, 178, 1910
5586	-45.0	Schlesinger	<i>Publ. A. O.</i> , 1, 126, 1910	Adams, <i>Ap. J.</i> , 15, 214, 1902. Algol variable. * T is interval after light min. From spectrographic and photometric observations Schlesinger determined $r = 2,250,000$ km., $r_1 = 2,000,000$, $a = 2,500,000$, $a_1 = 3,400,000$, $i = 81.5^\circ$, $m + m_1 = 1.5\odot$; if densities of two bodies are assumed equal then $d_0 = 0.026 D_0$, $m = 0.87\odot$, $m_1 = 0.63\odot$, $m_1 : m = 0.70$
5651	.....			Curtis, <i>L. O. B.</i> , 5, 140, 1909
5723	.....			Campbell, <i>Ap. J.</i> , 10, 178, 1900

H.R.	Star	R.A., 1900		Decl., 1900		Vis. Mag.	Spec. Type	<i>P</i> Period	<i>T</i> Jul. Day 2,410,000+	ω	<i>e</i>	<i>K</i> km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$	<i>a</i> sin <i>i</i> km.
5747	β Coronae Bor.	15 ^h 23 ^m 7		+29° 27'		3.72	Fp	-----	-----	-----	-----	-----	-----	-----
5793	α Coronae Bor.	30.5		+27 3		2.31	A	17.355	7725.054	303.68	0.277	32.97	(0.0573)	7,560,000
								17.36	7742.55	312.2	0.387	34.93	(0.0602)	7,671,000
5863	A ₂ Serpentis	40.9		— 1 30		5.37	B8	-----	-----	-----	-----	-----	-----	-----
5883	χ Lupi	44.6		—33 19		4.11	B9	-----	-----	-----	-----	-----	-----	-----
5944	π Scorpil	52.8		—25 50		3.00	B2p	1.57	-----	-----	-----	-----	-----	-----
5953	δ Scorpil	54.4		—22 20		2.54	B	-----	-----	-----	-----	-----	-----	-----
5971	ι Coronae Bor.	57.4		+30 7		4.91	A	short	-----	-----	-----	-----	-----	-----
5984	β Scorpil	59.6		—19 32		2.90	B1	6.9	-----	-----	-----	-----	-----	-----
5986	θ Draconis	16 0.0		+58 50		4.11	F8	3.0708	5368.962	126.1	0.014	23.47	(0.0041)	990,000
6027	ν Scorpil	6.1		—19 12		4.29	B3	-----	-----	-----	-----	-----	-----	-----
6084	σ Scorpil	15.1		—25 21		3.08	B1	30±	-----	-----	-----	-----	-----	-----
6098	ζ Triang. Austr.	17.6		—69 52		4.93	G	-----	-----	-----	-----	-----	-----	-----
6102	γ Apodis	18.1		—78 40		3.90	K	-----	-----	-----	-----	-----	-----	-----
6118	χ Ophiuchi	21.2		—18 14		4.85	B3	-----	-----	-----	-----	-----	-----	-----
6134	α Scorpil	23.3		—26 13		1.22	Map	5880	6673.582	289.	0.20	2.12	(0.0020)	(60,490,000)
6148	β Herculis	25.9		+21 42		2.81	K	410.575	5500.374	24.6	0.550	12.782	0.0519	60,280,000
6149	λ Ophiuchi	25.9		+ 2 12		3.85	A	-----	-----	-----	-----	-----	-----	-----
6212	ζ Herculis	37.5		+31 47		3.00	G	-----	-----	-----	-----	-----	-----	-----
6247	μ_1 Scorpil	45.1		—37 53		3.09	B3p	1.45	-----	-----	-----	-----	-----	*9,173,000
6315	<i>h</i> Draconis	55.4		+65 17		4.82	F5	-----	-----	-----	-----	-----	-----	-----
6322	ϵ Ursae Min.	56.2		+82 12		4.40	G5	-----	-----	-----	-----	-----	-----	-----
6324	ϵ Herculis	56.5		+31 4		3.92	A	4.0126	7721.334	191.65	0.070	56.24	(0.0735)	3,095,000
								4.0235	7725.113	267.97	0.074	52.75	(0.0608)	2,907,000
								*4.0235	7725.113	87.97	0.074	(77.7)	(0.194)	(4,286,000)
6410	δ Herculis	17 10.9		+24 57		3.16	A	-----	-----	-----	-----	-----	-----	-----
6431	α Herculis	13.6		+33 12		var.	B3	2.05102	8125.80	66.15	0.053	99.50	(0.205)	2,800,000
								*2.05102	-----	246.15	0.053	253.	(3.43)	7,120,000
6493	B.D. —4:4275	21.3		— 5 0		4.61	F	-----	-----	-----	-----	-----	-----	-----
6508	ν Scorpil	24.0		—37 13		2.80	B3	-----	-----	-----	-----	-----	-----	-----
6527	λ Scorpil	26.8		—37 2		1.71	B2	5.6	-----	-----	-----	-----	-----	-----
6555	ν_2 Draconis	30.3		+55 14		4.95	A5	-----	-----	-----	-----	-----	-----	-----
6556	α Ophiuchi	30.3		+12 38		2.14	A5	-----	-----	-----	-----	-----	-----	-----
6561	ξ Serpentis	31.9		—15 20		3.64	A5	-----	-----	-----	-----	-----	-----	-----
6596	ω Draconis	37.5		+68 48		4.87	F5	5.27968	7385.493	333.76	0.011	36.26	(0.0261)	2,632,300
6616	X Sagittarii	41.3		—27 48		var.	F8	7.01185	6723.05	93.65	0.40	*(15.2)	(0.0016)	1,334,000
6661	Y Ophiuchi	47.3		— 6 7		var.	G	17.1207	*246	209.2	0.10	8.5	(0.0011)	1,999,000
.....	Z Herculis	53.6		+15 9		var.	F	*3.9927	-----	-----	-----	-----	-----	-----
6742	W Sagittarii	58.6		—29 35		var.	F5	7.59532	*6420	70.0	0.320	19.5	0.0050	1,930,000
6752	70 Ophiuchi	18 0.4		+ 2 31		4.28	K	87886	-----	-----	-----	-----	-----	-----
6771	72 Ophiuchi	2.6		+ 9 33		3.73	A2	-----	-----	-----	-----	-----	-----	-----
6812	μ Sagittarii	7.8		—21 5		4.01	B8p	180.2	4968.4	74.7	0.441	64.5	(3.63)	143,500,000
6863	Y Sagittarii	15.5		—18 54		var.	G	5.77336	*4446	32.0	0.16	19.0	(0.0040)	1,485,000

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
5747	.....			Moore, <i>L. O. B.</i> , 4, 162, 1907
5793	+ 0.50	Cannon	<i>Jour. R. A. S. Can.</i> , 3, 152, 1909	Hartmann, <i>A. N.</i> , 163, 31, 1903. Cannon's elements quoted depend upon H β , H γ , H δ , K: Mg 4481 used alone gave velocity of system +6.7 km., eccentricity 0.35, etc.
	+ 0.36	Jordan	<i>Publ. A. O.</i> , 1, 89, 1909	Jordan, <i>Publ. A. O.</i> , 1, 121, 1909. Range at least 120 km.
5863	.....			Paddock, <i>L. O. B.</i> , 6, 4, 1910. Two spectra visible
5883	.....			Cannon, <i>Director's Rep. H. C. O.</i> , 1899. Two spectra visible
5944	.....			Frost and Lee, <i>Ap. J.</i> , 30, 65, 1909; two spectra visible. Maury had suspected this star to be spec. bin., <i>An. H. C. O.</i> , 28, 94 and 176, 1897-1901
5953	.....			Baker, <i>Publ. A. O.</i> , 1, 121, 1909
5971	.....			Slipher, <i>Lowell O. B.</i> , No. 1, 4, 1903; Adams, <i>Ap. J.</i> , 18, 69, 1903. Slipher reports H and K sharp and yielding constant velocity; unpublished letter
5984	.....			Campbell, <i>Ap. J.</i> , 9, 311, 1899
5986	— 8.36	Curtis	<i>L. O. B.</i> , 4, 157, 1907	Slipher, unpublished letter: "5 obs. in 1909 vary 65 km.; period not longer than a few days"
6027	.....			Slipher, <i>Lowell O. B.</i> , No. 11, 57, 1904. Slipher estimates period about 30 ^d ; reports H and K sharp and yielding constant velocity; unpublished letter
6084	.....			Curtis, <i>L. O. B.</i> , 5, 140, 1909
6098	.....			Suspected by Wright, confirmed by Curtis; <i>L. O. B.</i> , 5, 177, 1909
6102	.....			Campbell and Albrecht, <i>L. O. B.</i> , 5, 175, 1910
6118	.....			Wright, <i>L. O. B.</i> , 4, 98, 1906
6134	— 3.09	Halm	<i>An. Cape Obs.</i> , 10, pt. 3, 56c	Campbell, <i>Ap. J.</i> , 11, 140, 1899
6148	—25.52	Plummer	<i>L. O. B.</i> , 5, 25, 1908	Frost, <i>A. N.</i> , 177, 174, 1908
6149	.....			Wright, <i>L. O. B.</i> , 1, 159, 1902. Visual binary period 34 ^r . Radial velocities show that $i = -50^\circ$ (unpublished)
6212	.....			Bailey, <i>H. C. O. Circ.</i> , No. 11, 1896. Two spectra visible. Max. relative radial velocity 460 km. per sec.; <i>H. C. O. Circ.</i> , No. 21, 1898. $*(a + a_1) \sin i$. Assuming equal masses, $m \sin^2 i = 7.2\odot$
6247	.....			Campbell, <i>Ap. J.</i> , 10, 178, 1899
6315	.....			Campbell, <i>Ap. J.</i> , 10, 179, 1899
6322	.....			Campbell and Curtis, <i>L. O. B.</i> , 2, 126, 1903; Adams, <i>Ap. J.</i> , 18, 69, 1903. Residuals from elliptic orbit found by Harper satisfying simple circular motion with period $\frac{1}{3}$ principal period and single amplitude 8 to 12 km. Two spectra visible. *Orbit of secondary based upon Schlesinger's ratio of masses and Harper's second elements; $m \sin^2 i = .548\odot$, $m_1 \sin^2 i = .372\odot$; $m_1 : m = 0.68$, Schlesinger's unpublished letter
6324	—29.19	Harper	<i>Jour. R. A. S. Can.</i> , 3, 238, 1909	Harper, <i>Jour. R. A. S. Can.</i> , 2, 107, 1908
	—27.29	Harper	<i>Jour. R. A. S. Can.</i> , 3, 384, 1909	Frost and Adams, <i>Ap. J.</i> , 17, 381, 1903. Two spectra visible. Baker finds $m \sin^2 i = 6.8\odot$ and $m_1 \sin^2 i = 2.6\odot$; $m_1 : m = 0.39$. Variable, β Lyrae type, irregular period. *Orbit of secondary
6410	.....			Burns, <i>L. O. B.</i> , 4, 96, 1906. Two spectra visible
6431	—21.16	Baker	<i>Publ. A. O.</i> , 1, 82, 1909	Wright, <i>L. O. B.</i> , 5, 177, 1910
	—21.16	Baker	<i>Publ. A. O.</i> , 1, 82, 1909	Slipher, <i>Lowell O. B.</i> , No. 4, 23, 1903
6493	.....			Albrecht, <i>L. O. B.</i> , 5, 62, 1908
6508	.....			Frost, <i>A. N.</i> , 177, 174, 1908
6527	.....	Slipher	<i>Lowell O. B.</i> , No. 4, 23, 1903	Curtis, <i>L. O. B.</i> , 3, 85, 1905
6555	.....			Campbell, <i>Ap. J.</i> , 10, 179, 1899
6556	.....			Slipher, <i>Lowell O. B.</i> , No. 11, 57, 1904. Cepheid variable. *K estimated from published curve
6561	.....			Albrecht, <i>L. O. B.</i> , 4, 68, 1906. Cepheid variable. *T is time after light max.
6596	—13.68	Turner	<i>L. O. B.</i> , 4, 164, 1907	Frost, <i>Ap. J.</i> , 22, 214, 1905. Algol variable with secondary minimum. This is B.D. +15°3311. *Photometric period
6616	—13.50	Moore	<i>L. O. B.</i> , 5, 111, 1909	Curtiss, <i>L. O. B.</i> , 3, 31, 1904. Cepheid variable. Curtiss finds residuals from elliptic curve satisfied by simple circular motion of period equal to half the principal period and single amplitude 5 km. *T is time after light max.
6661	— 5.0	Albrecht	<i>L. O. B.</i> , 4, 132, 1907	Campbell, <i>L. O. B.</i> , 5, 63, 1908. Radial velocities show that the inclination of visual orbit plane is $-58^\circ 5'$, and approximate radial velocity of center of mass -7.4 km. Lohse's period of the visual binary is 87 ^r 858. <i>Publ. Potsdam</i> , 20, 143, 1908
6742	—28.6	Curtiss	<i>L. O. B.</i> , 3, 36, 1904	Frost and Lee, <i>Ap. J.</i> , 30, 65, 1909. Two spectra visible
6752	.....			Frost and Adams, <i>Ap. J.</i> , 19, 351, 1904. Mills spectrograph observations in 1899-1900 not represented by orbit
6771	.....			Curtiss, <i>L. O. B.</i> , 3, 40, 1904. Cepheid variable. *T is interval after light max.
6812	— 7.	Ichinohe	<i>Ap. J.</i> , 26, 161, 1907	
6863	+ 4.0	Duncan	<i>L. O. B.</i> , 5, 85, 1908	

H.R.	Star	R.A., 1900 18 ^h 22 ^m 1	Decl., 1900 + 0° 8'	Vis. Mag.	Spec. Type	P Period	T Jul. Day 2,410,000+	ω	e	K km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$	$a \sin i$ km.
6918	δ Serpentis			5.33	Ap	-----	-----	-----	-----	-----	-----	-----
6920	ϕ Draconis	22.2	+71 17	4.24	Ap	-----	-----	-----	-----	-----	-----	-----
6927	χ Draconis	22.9	+72 41	3.69	F8	281.8	4864.3	119.0	0.423	17.95	(0.126)	(63,000,000)
6934	δ_1 Telescopii	24.4	—45 59	5.05	B8	-----	-----	-----	-----	-----	-----	-----
6938	δ_2 Telescopii	24.7	—45 49	5.33	B5	-----	-----	-----	-----	-----	-----	-----
.....	RX Herculis	26.0	+12 30	var.	A	-----	-----	-----	-----	-----	-----	-----
7020	δ Scuti	36.8	— 9 9	4.74	F	-----	-----	-----	-----	-----	-----	-----
7039	ϕ Sagittarii	39.4	—27 6	3.30	B8	-----	-----	-----	-----	-----	-----	-----
7051	ϵ_1 Lyrae	41.0	+39 34	5.06	A3	-----	-----	-----	-----	-----	-----	-----
7056	ζ_1 Lyrae	41.3	+37 30	4.29	F	4.29991	*8109.722	-----	0.00	51.24	(0.0601)	3,030,000
7063	β Scuti	41.9	— 4 51	4.47	G	-----	-----	-----	-----	-----	-----	-----
7069	111 Herculis	42.6	+18 4	4.37	A3	-----	-----	-----	-----	-----	-----	-----
7106	β Lyrae	46.4	+33 15	var.	B2p	12.91	-----	263.4	0.07	181.0	(7.89)	32,040,000
						12.91	-----	83.4	0.07	(89.3)	(0.95)	15,800,000
						12.91	*2368.85	*259.3	*0.11	(194.6)	(9.71)	*34,339,000
						12.91	-----	79.3	0.11	(89.7)	(0.95)	15,836,000
7107	κ Pavonis	46.6	—67 21	var.	F5	*9.09155	-----	-----	-----	-----	-----	-----
7125	σ Draconis	49.7	+59 16	4.78	K	-----	-----	-----	-----	-----	-----	-----
7131	δ_1 Lyrae	50.2	+36 51	5.51	B3	-----	-----	-----	-----	-----	-----	-----
7133	113 Herculis	50.5	+22 32	4.56	G5	-----	-----	-----	-----	-----	-----	-----
7178	γ Lyrae	55.2	+32 33	3.30	A	25.6±	-----	-----	-----	-----	-----	-----
7180	ν Draconis	55.6	+71 10	4.91	K	-----	-----	-----	-----	-----	-----	-----
7234	τ Sagittarii	19 0.7	—27 49	3.42	K	-----	-----	-----	-----	-----	-----	-----
7248	Y Aquilae	2.3	+10 55	5.10	B8	short	-----	-----	-----	-----	-----	-----
7298	η Lyrae	10.4	+38 58	4.46	B3	-----	-----	-----	-----	-----	-----	-----
7326	U Sagittae	14.4	+19 26	var.	A	*3.38067	-----	-----	-----	-----	-----	-----
7342	ν Sagittarii	16.0	—16 8	4.58	B8p	-----	-----	-----	-----	-----	-----	-----
7352	τ Draconis	17.5	+73 10	4.63	K	-----	-----	-----	-----	-----	-----	-----
7377	δ Aquilae	20.5	+ 2 55	3.44	F	-----	-----	-----	-----	-----	-----	-----
7402	U Aquilae	24.0	— 7 15	var.	G	*7.0240	-----	-----	-----	-----	-----	-----
7478	ϕ Cygni	35.5	+29 56	4.79	K	-----	-----	-----	-----	-----	-----	-----
7518	SU Cygni	40.8	+29 1	var.	F5	3.844	*245	345.8±	0.21±	25.±	(0.0058±)	1,350,000±
7536	δ Sagittae	42.9	+18 17	3.78	Map	-----	-----	-----	-----	-----	-----	-----
7570	η Aquilae	47.4	+ 0 45	var.	G	7.176	*1492	90.0	0.163	16.3	(0.0031)	(1,587,000)
						7.176	**6.210	68.91	0.489	20.59	(0.0043)	(1,773,000)
7582	ϵ Draconis	48.5	+70 1	3.99	K	-----	-----	-----	-----	-----	-----	-----
7609	S Sagittae	51.5	+16 22	var.	G	8.3832	*143	69.9±	0.35±	19.±	(0.0049±)	2,000,000±
7623	θ_1 Sagittarii	53.2	—35 33	4.39	B3	-----	-----	-----	-----	-----	-----	-----
7710	θ Aquilae	20 6.1	— 1 7	3.37	A	17.117	7816.697	17.53	0.685	44.69	(0.0613)	7,665,000
						17.112	7731.504	25.57	0.695	49.97	(0.0824)	8,452,000
						*17.117	7816.697	197.53	0.685	(50.21)	(0.087)	(8,600,000)
7735	31 Cygni	10.5	+46 26	3.95	Kp	-----	-----	-----	-----	-----	-----	-----
7751	32 Cygni	12.3	+47 24	4.16	G5	-----	-----	-----	-----	-----	-----	-----

H.R.	V_o km.	Computer	Reference	Discoverer and Remarks
6918	.....			Frost and Lee, <i>Ap. J.</i> , 30, 66, 1909. Cannon says "this spectrum is clearly composite"; <i>An. H. C. O.</i> , 56, 108
6920	.....			Frost and Lee, <i>Ap. J.</i> , 30, 66, 1909. Two spectra visible. This is brighter component of visual binary
6924	+32.38	Wright	<i>Ap. J.</i> , 11, 133, 1900	Wright, <i>Ap. J.</i> , 8, 292, 1898
6934	.....			Curtis, <i>L. O. B.</i> , 5, 140, 1909
6938	.....			Curtis, <i>L. O. B.</i> , 5, 140, 1909
.....	.....			Frost, <i>Ap. J.</i> , 22, 215, 1905. Perhaps two spectra visible
7020	.....			Wright, <i>Ap. J.</i> , 12, 256, 1900
7039	.....			Frost, <i>Sci.</i> , 28, 853, 1908
7051	.....			Frost, <i>A. N.</i> , 177, 174, 1908. This is A of ϵ_1
7056	-25.97	Jordan	<i>Publ. A. O.</i> , 1, 118, 1909	Curtis, <i>L. O. B.</i> , 3, 85, 1905. * T is time of max. positive velocity
7063	.....			Wright, <i>Ap. J.</i> , 12, 255, 1900
7069	.....			Wright, <i>L. O. B.</i> , 5, 63, 1908
7106	-14.8	Belopolsky	<i>Ap. J.</i> , 6, 328, 1897	Pickering, <i>A. N.</i> , 128, 40, 1891; suggests circular orbit with period equal to photometric period. Important spectrographic observations by Vogel, Belopolsky and others. At least two spectra visible, interpretation difficult. From Belopolsky's spectrographic and Argelander's photometric observations Meyers estimates $r=19,545,000$ km., $r_1=25,900,000$, $a+a_1=50,175,000$, $e=0.018$, $m=9.65\odot$, $m_1=20.91\odot$, $m_1:m=2.2$, $d_o=.0006 D_o$. The smaller body is 2.5 times as bright as the larger. Meyers suspects increase of eccentricity and motion of line of apsides between 1855 and 1892. Terkan estimates inclination at 51° , <i>A. N.</i> , 170, 171, 1905. *Meyers' values of T , ω , e , $a \sin i$ and V_o deduced from Belopolsky's spectrographic observations. β Lyrae variable (prototype)
.....	-14.8	Belopolsky	<i>Ap. J.</i> , 6, 328, 1897	
.....	-.0.8	Meyers	<i>Ap. J.</i> , 7, 1, 1898	
.....	-0.8	Meyers	<i>Ap. J.</i> , 7, 1, 1898	
7107	.....			Wright, <i>L. O. B.</i> , 3, 3, 1904. Cepheid variable. *Photometric period
7125	.....			Burns, <i>L. O. B.</i> , 5, 175, 1910
7131	.....			Frost and Adams, <i>Ap. J.</i> , 19, 352, 1904
7133	.....			Wright, <i>Ap. J.</i> , 12, 256, 1900
7178	.....	Mitchell	<i>Ap. J.</i> , 30, 241, 1909	Mitchell, <i>Ap. J.</i> , 30, 240, 1909. Perhaps two spectra visible
7180	.....			Burns, <i>L. O. B.</i> , 5, 175, 1910
7234	.....			Wright, <i>L. O. B.</i> , 3, 3, 1904; Curtis, <i>L. O. B.</i> , 3, 85, 1905
7248	.....			Frost and Adams, <i>Ap. J.</i> , 18, 387, 1903. Range at least 90 km.
7298	.....			Albrecht, <i>L. O. B.</i> , 5, 175, 1910
7326	.....			Frost, <i>Ap. J.</i> , 22, 214, 1905. Algol variable. *Photometric period
7342	.....			Campbell, <i>Ap. J.</i> , 10, 241, 1899. Bright helium lines which, according to Frost, are variable
7352	.....			Albrecht, <i>L. O. B.</i> , 5, 175, 1910
7377	.....			Campbell and Curtis, <i>L. O. B.</i> , 2, 126, 1903
7402	.....			Albrecht, <i>Publ. A. S. P.</i> , 18, 142, 1906. Period seems to be coincident with light variation. Cepheid variable. *Photometric period
7478	.....			Suspected by Plummer, confirmed by Campbell, <i>L. O. B.</i> , 5, 63, 1908. Two spectra visible
7518	-33.4 $\pm$	Maddrill	Unpublished	Maddrill, <i>L. O. B.</i> , 4, 97, 1906. Cepheid variable. Period coincident with photometric period
7536	.....			Campbell, <i>L. O. B.</i> , 4, 96, 1906
7570	-13.7	Belopolsky	<i>Ap. J.</i> , 6, 399, 1897	Belopolsky, <i>Ap. J.</i> , 6, 393, 1897. * T is interval after min. brightness. ** T is interval after max. brightness. Cepheid variable
.....	-14.16	Wright	<i>Ap. J.</i> , 9, 66, 1899	
7582	.....			Campbell, <i>L. O. B.</i> , 5, 175, 1910
7609	-12.5 $\pm$	Maddrill	Unpublished	Curtiss, <i>L. O. B.</i> , 3, 40, 1904. Cepheid variable
7623	.....			Paddock, <i>L. O. B.</i> , 6, 4, 1910
7710	-30.10	Baker	<i>Publ. A. O.</i> , 1, 50, 1908	Deslandres, <i>C. R.</i> , 136, 205, 1903. Baker's residuals from elliptic orbit satisfied by simple circular motion in period $\frac{1}{2}$ principal period and single amplitude 2.4 km. per sec. and he finds increase of period in years 1902-08 of 0.072 days per year, with probable changes in other elements of orbit. Harper finds independently residuals from elliptic orbit satisfied by simple circular motion in period $\frac{1}{2}$ principal period, and single amplitude 2.6 km. per sec.; he favors probable rotation of line of apsides and not change in length of period. Schlesinger later finds two spectra visible; this probably accounts for residuals from elliptic orbit; he also finds $m_1:m=0.89$ (unpublished letter), from which it follows that $m \sin^3 i=.311\odot$, $m_1 \sin^3 i=.276\odot$ and $(m+m_1) \sin^3 i=.587\odot$. *Elements of secondary from Schlesinger's ratio of masses and Baker's elements of primary
.....	-25.91	Harper	<i>Jour. R. A. S. Can.</i> , 3, 87, 1909	
7735	.....			Campbell, <i>L. O. B.</i> , 1, 22, 1901
7751	.....			Burns, <i>L. O. B.</i> , 4, 96, 1906

H.R.	Star	R.A., 1900	Decl., 1900	Vis. Mag.	Spec. Type	P Period	T Jul. Day 2,410,000+	ω	e	K km.	$m_1^3 \sin^3 i$ ($m + m_1$) ²	$a \sin i$ km.
7776	β Capricorni	20 ^h 15 ^m 4	—15° 6'	3.25	Gp	1375.3	6035.	124.0	0.44	22.2	1.13	377,000,000
7790	α Pavonis	17.7	—57 3	2.12	B3	11.753	6379.90	224.80	0.01	7.25	(0.00046)	1,170,000
7850	θ Cephei	27.9	+62 39	4.28	A	.....	.....	.....	.....	.....	.....	.....
7884	ι Aquilae	33.2	— 1 27	4.51	K	.....	.....	.....	.....	.....	.....	.....
7932	X Cygni	39.5	+35 14	var.	F5p	*16.3855	.....	.....	.....	.....	.....	.....
7949	ϵ Cygni	42.2	+33 26	2.64	K	.....	.....	.....	.....	.....	.....	.....
7988	T Vulpeculae	47.2	+27 52	var.	F	4.43578	*3476	111.	0.43	17.6	(0.0018)	969,180
8001	57 Cygni	49.7	+44 0	4.68	B3	short	.....	.....	.....	.....	.....	.....
						2.85	.....	.....	.....	.....	.....	.....
8079	ξ Cygni	21 1.3	+43 32	3.92	K5	long	.....	.....	.....	.....	.....	.....
8115	ζ Cygni	8.7	+29 49	3.40	K	long	.....	.....	.....	.....	.....	.....
8123	δ Equulei	9.6	+ 9 36	4.61	F5	*5x70	1901.25	200.6	0.36	.....	.....	.....
8130	τ Cygni	10.8	+37 37	3.82	F	.....	.....	.....	.....	.....	.....	.....
8131	α Equulei	10.8	+ 4 50	4.14	A8p	.....	.....	.....	.....	.....	.....	.....
8143	σ Cygni	13.5	+38 59	4.28	B8p	.....	.....	.....	.....	.....	.....	.....
8167	ι Capricorni	16.7	—17 16	4.30	K	.....	.....	.....	.....	.....	.....	.....
8178	β Equulei	17.9	+ 6 23	5.14	A	22.7±	.....	.....	.....	.....	.....	.....
8204	ζ Capricorni	21.0	—22 51	3.86	Gp	.....	.....	.....	.....	.....	.....	.....
8238	β Cephei	27.4	+70 7	3.32	B1	0.1904	.....	.....	.....	(*17.4)	(0.0001)	45,000
8254	ν Octantis	30.4	—77 50	3.74	K	.....	.....	.....	.....	.....	.....	.....
8260	ϵ Capricorni	31.5	—19 54	4.72	B5p	.....	.....	.....	.....	.....	.....	.....
8305	ϵ Piscis Austr.	39.0	—33 29	4.35	A	.....	.....	.....	.....	.....	.....	.....
8315	κ Pegasi	40.1	+25 11	4.27	F5	6±	.....	.....	.....	.....	.....	.....
8322	δ Capricorni	41.5	—16 35	2.98	A5	.....	.....	.....	.....	.....	.....	.....
8430	ι Pegasi	22 2.4	+24 51	3.96	F5	10.21312	4820.966	251.8	0.008	47.99	(0.117)	6,740,000
8465	ζ Cephei	7.4	+57 42	3.62	K	.....	.....	.....	.....	.....	.....	.....
8485	B.D. +38°47'11	9.6	+39 13	4.64	K	.....	.....	.....	.....	.....	.....	.....
8518	γ Aquarii	16.5	— 1 53	3.97	A	.....	.....	.....	.....	.....	.....	.....
8523	2 Lacertae	16.9	+46 2	4.66	B5	2.6164	8193.30	180.	0.015	80.3	(0.141)	2,890,000
						2.6164	.....	*0.	0.015	98.8	(0.0262)	3,550,000
8571	δ Cephei	25.4	+57 54	var.	G	5.367	*1407	88.	0.46	20.5	(0.0034)	1,300,000
						5.367	*1.002	82.81	0.355	19.81	(0.0037)	1,370,740
						16x36	**1889.08	.....	0.0	116.40	(0.063)	204,400,000
8579	6 Lacertae	26.1	+42 36	4.54	B3	.....	.....	.....	.....	.....	.....	.....
8650	η Pegasi	38.3	+29 42	3.10	G	818.0	5196.7	5.60	0.155	14.20	(0.234)	157,800,000
8725	16 Lacertae	51.9	+41 4	5.54	B3	.....	.....	.....	.....	.....	.....	.....
8762	α Andromedae	57.3	+41 47	3.63	B3	.....	.....	.....	.....	.....	.....	.....
8819	π Cephei	23 4.7	+74 51	4.56	G5	.....	.....	.....	.....	.....	.....	.....
8820	ι Gruis	4.7	—45 47	4.10	K	.....	.....	.....	.....	.....	.....	.....
8926	B.D. +57°27'48	25.4	+58 0	4.89	B3	6.07	.....	.....	.....	.....	.....	.....
8961	λ Andromedae	32.7	+45 55	4.00	K	20.538	4571.81	336.2	0.132	6.48	(0.0006)	1,810,000
						20.546	6683.46	301.0	0.086	7.07	(0.0007)	1,990,000
8965	ι Andromedae	33.2	+42 43	4.28	B8	.....	.....	.....	.....	.....	.....	.....
9091	ζ Sculptoris	57.2	—30 16	4.99	B5	.....	.....	.....	.....	.....	.....	.....

H.R.	V_0 km.	Computer	Reference	Discoverer and Remarks
7776	-18.8	Merrill	<i>L. O. B.</i> , 6, 6, 1910	Campbell, <i>Ap. J.</i> , 10, 241, 1899
7790	+ 2.0	Curtis	<i>L. O. B.</i> , 4, 154, 1907	Suspected by Wright, confirmed by Albrecht, <i>L. O. B.</i> , 4, 154, 1907
7850	.....			Suspected by Moore, confirmed by Campbell and Albrecht, <i>L. O. B.</i> , 5, 176, 1910. Two spectra visible but not separated
7884	.....			Curtis, <i>L. O. B.</i> , 3, 86, 1905
7932	.....			Frost, <i>Ap. J.</i> , 25, 60, 1907. Cepheid variable. *Photometric period
7949	.....			Suspected by Curtis, confirmed by Burns, <i>L. O. B.</i> , 4, 97, 1906
7988	- 1.3	Albrecht	<i>L. O. B.</i> , 4, 135, 1907	Frost, <i>Ap. J.</i> , 20, 296, 1904. Cepheid variable. * T is interval after light max.
8001	.....			Frost and Adams, <i>Ap. J.</i> , 17, 381, 1903. Two spectra visible, $m_1 : m = 0.96$; Schlesinger unpublished letter
8079	.....	Schlesinger	Unpublished letter	Campbell, <i>L. O. B.</i> , 4, 162, 1907
8115	.....			Stebbins and Burns, <i>L. O. B.</i> , 4, 97, 1906
8123	+33.±			Campbell, <i>L. O. B.</i> , 1, 23, 1901. Two spectra visible. This is visual double of shortest known period. *Elements quoted are for Lewis's orbit, visual binary, in which $i = 77^\circ 3$ and $a = 0''.31$, from which Miss Hobe computes $a + a_1 =$ 883,900,000, $m + m_1 = 6.36\odot$, $\pi'' = 0''.05+$ (unpublished)
8130	.....			Barrett, <i>A. N.</i> , 177, 174, 1908. Brighter component of close double
8131	.....			Wright, <i>L. O. B.</i> , 1, 159, 1902
8143	.....			Campbell, <i>L. O. B.</i> , 5, 176, 1910
8167	.....			Moore, <i>L. O. B.</i> , 4, 97, 1906
8178	.....	Mitchell	<i>Ap. J.</i> , 30, 240, 1909	Mitchell, <i>Ap. J.</i> , 30, 239, 1909. Two spectra visible
8204	.....			Campbell and Albrecht, <i>L. O. B.</i> , 5, 176, 1910
8238	- 5.	Frost	<i>Ap. J.</i> , 24, 259, 1906	Frost, <i>Ap. J.</i> , 15, 340, 1902. *Estimated from curve
8254	.....			Wright, <i>L. O. B.</i> , 5, 61, 1908
8260	.....			Slipher, <i>Lowell O. B.</i> , No. 11, 58, 1904. Perhaps two spectra visible
8305	....			Curtis, <i>L. O. B.</i> , 5, 140, 1909. Two spectra visible
8315	.....			Campbell, <i>Ap. J.</i> , 12, 257, 1900. Visual double star, period 11 $\times$ 37, not known which component is spectroscopic binary
8322	.....			Slipher, <i>Ap. J.</i> , 24, 361, 1906
8430	- 4.12	Curtis	<i>L. O. B.</i> , 2, 172, 1904	Campbell, <i>Ap. J.</i> , 9, 310, 1899; Belopolsky, <i>A. N.</i> , 154, 210, 1901. Zurhellen from Bonn observations obtains velocity of center of mass -3.81 km. per sec., and other elements closely approximating to Curtis's, <i>A. N.</i> , 177, 333, 1908
8465	.....			Moore, <i>L. O. B.</i> , 4, 162, 1907
8485	.....			Allen, <i>L. O. B.</i> , 5, 176, 1910
8518	.....			Plaskett, <i>Jour. R. A. S. Can.</i> , 2, 272, 1908
8523	- 9.0	Baker	<i>Publ. A. O.</i> , 1, 98, 1909	Frost and Adams, <i>Ap. J.</i> , 18, 387, 1903. Two spectra visible. Baker finds $m \sin^2 i$ $= 0.87\odot$, $m_1 \sin^2 i = 0.71\odot$, $m_1 : m = 0.82$. *Secondary's elements
8571	+ 0.5	Belopolsky	<i>Ap. J.</i> , 1, 160, 1895	Belopolsky, <i>Ap. J.</i> , 1, 160, 1895. Cepheid variable (prototype)
	var.	Belopolsky	<i>Mitt. Pulk.</i> , 3, 69, 1909	Belopolsky thinks the system is triple; <i>Mitt. Pulk.</i> , 3, 70, 1909. †Elements of cir- cular orbit of binary system around center of mass of three bodies. * T is in- terval after light minimum. ** T is time when center of mass of binary system is at the point in the orbit farthest away from solar system, reduced to
	-16.0	Belopolsky	<i>Mitt. Pulk.</i> , 3, 70, 1909	Gr. M.T. by applying -408. ‡This is $\frac{m_2^3 \sin^3 i}{(m + m_1 + m_2)^2}$
8579	.....			Frost and Adams, <i>Ap. J.</i> , 18, 387, 1903
8650	+ 4.31	Crawford	<i>L. O. B.</i> , 1, 29, 1901	Campbell, <i>Ap. J.</i> , 8, 159, 1898
8725	.....			Yerkes Ob., unpublished letter
8762	.....			Wright, <i>L. O. B.</i> , 1, 159, 1902
8819	.....			Wright, <i>L. O. B.</i> , 1, 22, 1901. Close visual double, brighter component spectro- scopic binary
8820	.....			Wright and Curtis, <i>L. O. B.</i> , 4, 161, 1907
8926	.....	Schlesinger	Unpublished letter	Frost and Adams, <i>Ap. J.</i> , 18, 388, 1903. Range = 120 km.
8961	+ 6.34	Burns	<i>L. O. B.</i> , 4, 89, 1906	Campbell, <i>Ap. J.</i> , 10, 178, 1899. Old series
	+ 7.43	Burns	<i>L. O. B.</i> , 4, 89, 1906	New series
8965	.....			Plaskett, <i>Jour. R. A. S. Can.</i> , 2, 272, 1908
9091	.....			Paddock, <i>L. O. B.</i> , 6, 4, 1910

The elements of the orbits are defined as follows:

P = apparent period of revolution in mean solar days, unless specified in mean solar years. The true period of revolution, P_0 , may be found from the apparent period by means of the equation

$$P_0 = P / (1 + \frac{V_0}{300,000}).$$

(The apparent period, P , is more frequently used than P_0 in dealing with binary systems; but for triple systems, such as that of *Polaris*, P is variable, and the variations must be taken into account.)

T = Greenwich mean time of periastron passage, expressed in Julian Days; except (1) that for variable star orbits the quantity in the column T is the mean solar interval after maximum or minimum brightness, as specified in each case; and (2) that for circular orbits T has been given significance by the computers, as described in the column "Remarks."

ω = angular distance of periastron from the ascending node, measured in the direction of orbital motion. (At the ascending node the radial velocity of the observed body has its maximum value. Spectrographic observations enable the computer to distinguish between the ascending and descending nodes; but micrometer observations of visual double stars do not distinguish between the two nodes, and they also leave the value of ω uncertain by 180° .)

e = eccentricity of the orbit.

K = semi-amplitude of velocity curve of the primary member of the system, with reference to the center of mass of the system.

K_1 = semi-amplitude of velocity curve of the secondary member of the system, with reference to the center of mass of the system.

$K + K_1$ = semi-amplitude of the velocity curve of one member of the system, with reference to the other member of the system.

a = semi major-axis of the orbit of the primary member of the system, with reference to the center of mass of the system.

a_1 = semi major-axis of the orbit of the secondary member of the system, with reference to the center of mass of the system.

$a + a_1$ = semi major-axis of the orbit of one member of the system, with reference to the other member of the system.

i = inclination of the orbit plane, conveniently defined as the angle between the line of sight and the normal to the orbit plane. (Spectrographic observations leave the value of i unde-

termined; micrometer observations of a visual binary system leave the quadrant of i undetermined; spectrographic and micrometer observations combined determine i completely, but the number of known systems available for both classes of observation is at present very limited.)

m = mass of primary member of system.

m_1 = mass of secondary member of system.

$m + m_1$ = mass of system.

$\odot$ = mass of Sun.

V_0 = radial velocity of the center of mass of the system.

V = radial velocity of the primary member of system at any instant.

V_1 = radial velocity of the secondary member of system at the same instant.

r = radius of primary member.

r_1 = radius of secondary member.

d = mean density of primary member.

d_1 = mean density of secondary member.

d_0 = mean density of system.

D_0 = mean density of Sun.

The following equations have been employed in checking the quantities referred to in their first members, or in supplying these quantities, when missing, as indicated within parentheses (). In several cases these equations do not exactly reproduce the published values. The latter values have been retained, in most cases, as the differences seem to arise from neglected decimals. The value of P must be expressed in mean solar days.

I. One stellar spectrum observed, with comparison spectra:

$$a \sin i = [4.13833] (1 - e^2)^{\frac{1}{2}} K P, \quad (1)$$

$$\frac{m^3 \sin^3 i}{(m + m_1)^2} = [3.01642 - 10] (1 - e^2)^{\frac{3}{2}} K^3 P \odot. \quad (2)$$

II. Two stellar spectra observed, either without comparison spectra, as by means of objective-prism spectrographs, or with comparison spectra:

$$(a + a_1) \sin i = [4.13833] (1 - e^2)^{\frac{1}{2}} (K + K_1) P, \quad (3)$$

$$(m + m_1) \sin^3 i = [3.01642 - 10] (1 - e^2)^{\frac{3}{2}} (K + K_1)^3 P \odot. \quad (4)$$

III. Two stellar spectra observed, with comparison spectra:

$$\frac{m^3 \sin^3 i}{(m + m_1)^2} = [3.01642 - 10] (1 - e^2)^{\frac{3}{2}} K_1^3 P \odot, \quad (5)$$

$$m \sin^3 i = [3.01642 - 10] (1 - e^2)^{\frac{3}{2}} (K + K_1)^2 K_1 P \odot, \quad (6)$$

$$m_1 \sin^3 i = [3.01642 - 10] (1 - e^2)^{\frac{3}{2}} (K + K_1)^2 K P \odot, \quad (7)$$

$$\frac{m}{m_1} = \frac{K_1}{K} = \frac{(V_1 - V_0)}{(V - V_0)}. \quad (8)$$

Coincident with the preparation of the Catalogue, a study has been made of those binary systems for which the periods of revolution and other elements of the orbits have been determined. The results of this investigation are described in the following pages.

Harvard College Observatory formulated,² several years ago, a system of classification for stellar spectra in which the types corresponding to advancing stages of development are represented by the capital letters Q, O, B, A, F, G, K, and M; Q and O representing the earliest types of stellar life, and M the oldest type. Gradations within the types are described by means of steps expressed in numerals or lower-case letters. For example, the class immediately preceding B is Oe5B, and the class approximately midway between B and A is B5A, or B5. This classification has been utilized in the present and other studies with advantage.

TABLE I contains the orbital data for those spectroscopic binaries of O and B types (stars effectively young) whose periods of revolution have been fairly well determined. These binaries are arranged in the order of the length of period. Except in the case of the last star on the list, which refers, apparently with considerable uncertainty, to the center of mass of the binary system of *Algol* in revolution around the center of mass of itself and a suspected third body, the periods are all under one-half year; and two-thirds of them are under ten days. An inspection of column *e* shows that the eccentricities are, in general, small for the short periods and relatively large for the longer periods; that is, that the orbits are more nearly circular for the short-period binaries than for those whose periods are relatively long.

² *Annals H. C. O.*, 28 (II), 1901.

TABLE II contains corresponding facts for the A type stars; that is, those stars which are believed to be further along in their processes of development than the O and B types. The last star on the list, *Sirius*, is the well-known visual binary; and some of the elements of the visual orbit are included here, for the reason that the spectrograph has measured the velocity of the brighter component in the system and found it to vary in accordance with the requirements of the visual orbit. In this list, also, the eccentricity is seen to be, in general, a function of the period of revolution.

TABLE III contains corresponding data for F type stars, of greater effective age. Again the short periods have orbits of small eccentricity, and the long periods of great eccentricity. The Cepheid-Geminid variables, many of which have F type spectra, are not included in this tabulation, for these variables appear to belong in a class by themselves.

TABLE IV contains orbital data for stellar systems of G, K and M types, which represent advanced stellar age. The eccentricities are again a function, in general, of the length of period. This table also does not include the Cepheid-Geminid variables of G, K and M types, for the reason stated in the preceding paragraph.

Reviewing the four tables, we note that two-thirds of the O and B types of binaries have periods less than ten days; half the A types and half the F types have periods less than ten days; and it is a striking fact that there are no known binaries of the G, K and M types (excepting possibly H. R. 142, 13 *Ceti*) whose periods are less than twenty days.

TABLE I.
SPECTROSCOPIC BINARIES, O AND B TYPES.

H.R.	Star	Type	Period	e	$a \sin i$ km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
779	δ Ceti	B2	short *						
1088	τ_5 Eridani	B8	short						
1347	ν_4 Eridani	B9	short						
2781	29 Can. Maj.	Oe	short						
4118	δ Antliae	B9	short						
4662	γ Corvi	B8	short						
6027	ν Scorpil	B3	short						
7248	Y Aquilae	B8	short						
8238	β Cephei	B1	0.19	small	45,000	0.0001☉			
2294	β Can. Maj.	B1	0.25	0.1±	33,510	0.00002			
1567	π_5 Orionis	B3	0.87						
3129	V Puppis	B1p	1.45	(0.)	6,100,000		17.1☉	17.1☉	1.0
6247	μ_1 Scorpil	B3p	1.45		4,586,000		7.2	7.2	1.0
5944	π Scorpil	B2p	1.57						
6431	η Herculis	B3	2.05	0.05	2,800,000	0.205	6.8	2.6	0.39
6431 ₁	η Herculis		2.05	0.05	7,120,000	3.43			
1811	ψ Orionis	B2	2.53	0.06	4,995,100	0.780	5.53	4.19	0.76
1811 ₁	ψ Orionis		2.53	0.06	6,570,000	0.343			
8523	2 Lacertae	B5	2.62	0.02	2,890,000	0.141	0.87	0.71	0.82
8523 ₁	2 Lacertae		2.62	0.02	3,550,000	0.026			
8001	57 Cygni	B3	2.85						0.96
936	Algol	B8	2.87	0.04	1,600,000	0.020	0.44	0.22	0.50
1239	λ Tauri	B3	3.95	0.	3,300,000	0.089			
5056	α Virginis	B2	4.01	0.10	6,930,000	0.833	9.6	5.8	0.60
5056 ₁	α Virginis		4.01	0.10	11,400,000	3.68			
226	ν Androm.	B3	4.28	0.	4,299,000	0.173			
1131	σ Persei	B1	4.42	0.	7,172,000	0.754			
6527	λ Scorpil	B2	5.6						
1852	δ Orionis	B	5.73	0.10	7,906,600	0.601			
8926	BD +57°2748	B3	6.07						
1542	9 Camelopard.	B	6.33						
3623	κ Cancri	B8	6.39	0.15	5,890,000	0.200			
3659	α Carinae	B3	6.74	0.18	1,960,000	0.007			
5984	β Scorpil	B1	6.9						
1788	η Orionis	B1	7.99	0.02	15,901,000	2.51	11.2	10.6	0.95
1788 ₁	η Orionis		7.99	0.02	16,750,000	2.15			
5231	ζ Centauri	B2p	8.02						
1552	π_4 Orionis	B3	9.52	0.03	3,393,000	0.017			
7790	α Pavonis	B3	11.75	0.01	1,170,000	0.0005			
7106	β Lyrae	B2p	12.91	0.07	33,000,000	9.7	9.6	20.9	2.2
7106 ₁	β Lyrae		12.91	0.07	15,800,000	1.0			
1713	β Orionis	B8p	21.90	0.30	1,108,900	0.0001			
2653	σ_2 Can. Maj.	B5p	24.3±		1,670,000±	0.0003±			
1952	BD —1°1004	B3	27.16	0.76	22,380,000	0.607			
1899	ϵ Orionis	Oe5	29.14	0.75	28,907,000	1.14			
6084	σ Scorpil	B1	30.±						
5190	ν Centauri	B2	31.±						
3734	κ Velorum	B3	116.65	0.19	73,200,000	1.15			
496	ϕ Persei	Bp	126.5	0.43	42,298,000	0.189			
2159	ν Orionis	B2	131.4						
1910	ζ Tauri	B3	138.	0.18	27,900,000	0.046			
154	π Androm.	B3	143.72	0.58	76,790,000	0.876			
6812	μ Sagittarii	B8p	180.2	0.44	143,500,000	3.63			
936 ₁	Algol	B8	1790	0.	89,000,000	0.060			

* The periods marked "short" are unknown.

TABLE II.
SPECTROSCOPIC BINARIES, A TYPES.

H.R.	Star	Type	Period	<i>e</i>	<i>a</i> sin <i>i</i> km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$	<i>m</i> sin ³ <i>i</i>	<i>m</i> ₁ sin ³ <i>i</i>	<i>m</i> ₁ : <i>m</i>
104	BD +43°92	A2	short*						
897	θ ₁ Eridani	A2	short						
1380	64 Tauri	A2	short						
5971	ι Cor. Bor.	A	short						
2124	μ Orionis	A2	0.77						
815	RZ Cassiop.	A	1.20		1,170,000	0.05±0	0.650	0.360	0.55
1497	τ Tauri	A	1.50	0.08	916,130	0.0136			
5586	δ Librae	A	2.33	0.05	2,450,000	0.110	0.8	0.6	0.7
	U Cephei	A	2.49						
2890	α ₁ Gemin.	A	2.93	0.01	1,279,000	0.0097			
7326	U Sagittae	A	3.38						
1568	7 Camelopard.	A2	3.88						
2088	β Aurigae	Ap	3.96	0.00	6,000,000		2.16	2.16	1.0
2088 ₁	β Aurigae	Ap	3.96	0.00	6,000,000				
6324	ε Herculis	A	4.02	0.07	2,900,000	0.061	0.37	0.25	0.7
6324 ₁	ε Herculis		4.02	0.07	4,286,000	0.194			
2891	α ₂ Gemin.	A	9.22	0.50	1,485,000	0.0015			
4072	BD +66°664	A	11.6±	large					
7710	θ Aquilae	A	17.11	0.69	7,665,000	0.061	0.31	0.28	0.89
7710 ₁	θ Aquilae		17.11	0.69	8,610,000	0.087			
5793	α Cor. Bor.	A	17.36	0.33	7,600,000	0.059			
5054	ζ ₁ Urs. Maj.	Ap	20.54	0.50	17,500,000	3.96	2.0	2.0	1.0
5054 ₁	ζ ₁ Urs. Maj.	Ap	20.54	0.50	17,500,000				
8178	β Equulei	A	22.7±						
7178	γ Lyrae	A	25.6±						
4295	β Urs. Maj.	A	27.16	0.79	1,774,000	0.0003			
622	β Triang.	A5	37.±						
5291	α Draconis	A	51.38	0.40	30,000,000	0.42			
4689	η Virginis	A	71.9	0.33	25,500,000	0.126			
15	α Androm.	A	96.7	0.51	33,000,000	0.155			
553	β Arietis	A5	107.0	0.88	22,880,000	0.042	0.17	0.17	1.0
2421	γ Gemin.	A	375±	large					
2491	Sirius	A	4973	0.59					

* The periods marked "short" are unknown.

TABLE III.
SPECTROSCOPIC BINARIES, F TYPES.
(Cepheid variables not included.)

H.R.	Star	Type	Period	<i>e</i>	<i>a</i> sin <i>i</i> km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$	<i>m</i> sin ³ <i>i</i>	<i>m</i> ₁ sin ³ <i>i</i>	<i>m</i> ₁ : <i>m</i>
2788	R Can. Maj.	F	1414						
142	13 Ceti	F	2.08	0.06	981,460	0.00870			
5986	θ Draconis	F8	3.07	0.01	990,000	0.0041			
424	α Urs. Min.	F8	3.97	0.13	164,500	0.00001			
	Z Herculis	F	3.99						
7056	ζ ₁ Lyrae	F	4.30	0.00	3,030,000	0.060			
6596	ω Draconis	F5	5.28	0.01	2,632,000	0.0261			
8315	κ Pegasi	F5	6.±						
8430	ι Pegasi	F5	10.21	0.01	6,740,000	0.117			
3852	ο Leonis	F5p	14.50	<0.02	10,775,000	0.238	1.300	1.120	0.86
3852 ₁	ο Leonis	F±	14.50	<0.02	12,571,000	0.378			
2693	δ Can. Maj.	F8p	¾ yrs.±		5,650,000	0.0001			
6927	χ Draconis	F8	281.8	0.42	63,000,000	0.126			
8123	δ Equulei	F5	577	0.36					
424 ₁	α Urs. Min.	F8	1179	0.35	166,800,000	0.0098			
3482	ε Hydrae	F8	1577	0.6	550,000,000	0.18			
3185	ι Argus	F5	long*						

* The period marked "long" is unknown.

TABLE IV.
SPECTROSCOPIC BINARIES, TYPES G TO M.
(Cepheid variables not included.)

H.R.	Star	Type	Period	<i>e</i>	$a \sin i$ km.	$\frac{m_1^3 \sin^3 i}{(m + m_1)^2}$ ($m + m_1$) $\odot$	$m \sin^3 i$	$m_1 \sin^3 i$	$m_1 : m$
8961	λ Androm.	K	20454	0.11	1,900,000	0.0006 $\odot$			
1708	Capella	G	104.02	0.02	36,847,900	0.184	1.19 $\odot$	0.94 $\odot$	0.79
1708 ₁	Capella	F+	104.02	0.02	46,430,000	0.369			
429	γ Phoenic.	K5	190.±						
6148	β Herculis	K	410.58	0.55	60,280,000	0.052			
5235	η Bootis	G	489.14	0.18	56,010,000	0.0293			
4375	ξ Urs. Maj.	G	178						
8650	η Pegasi	G	2724	0.16	157,800,000	0.234			
7776	β Capric.	Gp	3777	0.44	377,000,000	1.13			
6134	α Scorpii	Map	578	0.20	60,490,000	0.0020			
6212	ζ Herculis	G	347	0.46					
5459	α_1 Centauri	G	81718	0.53					
5460	α_2 Centauri	K5	81718	0.53					
6752	70 Ophiuchi	K	87786	0.50					
99	α Phoen.	K	long*						
539	ζ Persei	K	long						
549	ξ Piscium	K	long						
854	τ Persei	Gp	long						
915	γ Persei	Gp	long						
1066	f Tauri	K	long						
2216	η Gemin.	Ma	long						
2296	δ Colum.	G5	long						
2553	τ Puppis	K	long						
2854	γ Can. Min.	K	long						
4301	α Urs. Maj.	K	long						
8079	ξ Cygni	K5	long						
8115	ζ Cygni	K	long						

* The periods marked "long" are unknown.

TABLE V.
SPECTROSCOPIC BINARIES.—GENERAL SUMMARY.

	Periods	"Short"	0 ^d .5 ^d	5 ^d .10 ^d	10 ^d +	Years	"Long"
O and B types		8	15	10	14	1	
Period		short	244	649	7342	179	
Eccentricity			(10) 0.04	(5) 0.10	(11) 0.34	(1) 0.0:	
A types		4	10	1	12	2	
Period		short	2465	942	4242	26745	
Eccentricity			(5) 0.04	(1) 0.50	(8) 0.55	(1) 0.59	
F types		0	6	2	4	3	1
Period			341	546	14541	1171	long
Eccentricity			(4) 0.05	(1) 0.01	(3) 0.15	(3) 0.44	
G to M types		0	0	0	3	9	13
Period					10448	2473	long
Eccentricity					(2) 0.06	(8) 0.38	
Total		12	31	13	33	15	14
Mean period		short	2459	6490	7345	2075	long
Mean eccentricity			(19) 0.04	(7) 0.14	(24) 0.36	(13) 0.38	

The relations existing between the spectral types, lengths of period and eccentricities are put in a more condensed form in Table V. This table is double entry, with known lengths of period divided into four classes, as described in the first line; and the corresponding spectral types, average periods and average

eccentricities in the following twelve lines. We note that for the O and B types, for the A types, and for the G, K and M types the eccentricity values increase with increasing periods in each division. That this cannot be said for the F types is a fact of small weight, as the exceptional case refers to but a single

star. A different division of periods would remove this apparent exception to the rule. Indeed, the remarkable fact is that there are not more apparent exceptions, considering the great number of divisions under which the few orbits are treated statistically.

The decrease in the relative number of short binary systems, with advancing stellar age, is graphically evident in the table, from the zero in the F division and the three zeros in the G-K-M division.

The relation between length of period and eccentricity is brought out even more forcibly in the last three lines of the table. The second line from the last, "Total," sums up the number of binaries listed under the four spectral types, for which we have orbital data. The next to the last line contains the average periods of these binary systems. The last line contains the average eccentricity of all those binaries in each division for which the eccentricities have been determined; the number of eccentricity values in each case being indicated in the parentheses. The relationship existing between length of period and eccentricity is unmistakable.

Let us refer again to the first four tables. The second column from the last quotes the mass of the brighter member of each system multiplied by the cube of the sine ($\sin^3 i$) of the inclination of its orbit, in terms of the Sun's mass as unit, for those few systems in which the *two* members have been observed spectrographically. The next to the last column quotes similarly the mass of the fainter member of the system. The last column contains the ratio of the mass of the fainter member to that of the brighter member. It is characteristic of the orbits, as determined by means of the spectrograph, that the inclination of the orbit plane to the line of sight cannot be determined. Examining the tabular data for the masses of the two bodies,—17 systems in all,—we note that these masses, multiplied as they are by the sine-cube of the inclination, are on the average many-fold greater than the mass of the Sun. It can be shown for an indefinitely great number of binary systems, whose orbital planes are distributed at random, that the average inclination would be $57:3$, in accordance with the formula

$$i_0 = \frac{2}{\pi} \int_0^{\pi} \int_0^{\pi} i \sin i \, di \, d\phi = 1.$$

The average value of $\sin^3 i$, however, would not be $\sin^3 57:3$ ($= .65$), but approximately 0.59 , in accordance with the formula

$$\sin_0^3 i = \frac{2}{\pi} \int_0^{\pi} \int_0^{\pi} \sin^3 i \, di \, d\phi = \frac{3}{16} \pi = 0.59.$$

It would not be permissible to use this as the average value of $\sin^3 i$, for there is the practical consideration

that binary systems whose orbital planes have large inclinations are more readily discoverable than those whose inclinations are small. For example, the maximum variation of radial velocity in an orbit whose inclination is 5° will be but one-twelfth the corresponding variation of velocity in the orbit. It is clear, therefore, that many systems whose orbital inclinations are less than 10° , and even less than 20° , will escape detection, in the present state of spectrographic observation. The number of inclinations less than 10° would, however, be relatively small, for the same reason that the area of the surface of a sphere lying within 10° of one of its poles is small in comparison with the area of a hemisphere. Under ordinary circumstances, and when dealing with a considerable number of orbits, a compromise value of $\sin^3 i = 0.65$ might in fairness be applied. We should use a still larger value in dealing with the 18 cases before us, for six of the stars are *Algol* or *β Lyrae* variables whose orbital inclinations are in every case probably between 60° and 90° . Assuming $\sin^3 i = 0.75$ for the present list, we find the average mass of the 18 principal components to be 4.2 times the Sun's mass, and for the 18 secondary components 4.2 times the Sun's mass. Excluding *β Lyrae*, on account of very considerable uncertainty in the interpretation of its spectrum, these values reduce to 4.0 and 3.3. The O and B type systems appear to be the more massive, but the data are too meager to venture this as a conclusion.

With only one exception the principal (brighter) component is more massive than its secondary. The exception relates to *β Lyrae*, in which system the fainter member is accredited with a mass 2.2 times that of the brighter member. The two members are believed to be nearly in contact, and Meyers has suggested³ that the greater brightness of the less massive companion may be due to the influence of a heavy absorbing atmosphere which completely encloses both members of the system; the more massive component drawing this atmosphere more densely around itself, leaving the atmosphere overlying the less massive component thinner and less absorptive, thereby permitting "the smaller (less massive) to appear brighter even though it might be intrinsically darker than the larger (brighter) body."

There arises the question whether the masses deduced for the 17 systems involved are representative of the masses in spectroscopic binary stars in general, discovered and undiscovered. The data are too meagre to answer this question satisfactorily. The spectroscopic binary systems thus far detected and investigated are on the whole those most readily discoverable. They are of stars brighter than the average, and therefore of masses above the average. They

³ *Ap. J.*, 7, 21-22, 1898.

are systems in which the range of radial velocity is large, and systems whose periods of revolution are short. Systems with small velocity amplitudes and systems with long periods remain undiscovered in proportions unduly large. It will be seen from equations (6), (7), and (4) that the smaller future values of K will decrease the corresponding values of m , m_1 and $m + m_1$, and the larger future values of P will increase the corresponding values of m , m_1 and $m + m_1$. The prevailing tendencies of the K 's and P 's in future systems will therefore counterbalance one another in these equations, though attention should be called to the fact that the K 's enter as cubes and the P 's enter to the first power.

In the great majority of systems thus far investigated we have orbital elements for the brighter components only. There is a relationship expressed in equation (2) which we have computed and entered in the first four tables; namely, $m_1^3 \sin^3 i / (m + m_1)^2$. These quantities convey little definite information. They range from 9.7, in the case of β *Lyrae*, down to .00001 for *Polaris*. If we assume that the average value of $\sin^3 i$ which has entered into these quantities is 0.65, we shall see that the secondary members of the systems are in general of considerably smaller mass than their primaries; and this would appear to be a reliable conclusion, though there are a few probable exceptions. The larger values of this quantity, as may be seen from the tables, seem not to show preference for any spectral type or types.

Let us consider next some obvious relations between spectroscopic and visual binary systems. TABLE VI catalogues the 50 visual double stars of shortest known period for which we have good orbits, selected in accordance with present day knowledge of the subject. Acknowledgments are due to Dr. Aitken for assistance in the selection of the materials. These systems are listed in the order of their lengths of period, in groups of ten. The spectra are H. R. designations, excepting that of the forty-ninth star on the list, which is from the Draper Catalogue. The

TABLE VI.
VISUAL DOUBLE STARS.

Star	Period	e	Spectrum
δ Equulei	5.70	0.36	F5
13 Ceti	7.42	0.74	F
κ Pegasi	11.37	0.40	F5
ϵ Hydrae	15.70	0.68	F8
β 883	16.35	0.48	?
ζ Sagittarii	21.17	0.18	A2
β 612	22.8	0.48	A
9 Argus	23.3	0.68	F8
82 Ceti	24.00	0.15	K
42 Comae	25.56	0.46	F5
	17.33	0.461	

Star	Period	e	Spectrum
85 Pegasi	25.70	0.43	G
β Delphini	27.66	0.36	F5
Σ 3121	34.00	0.33	F?
ζ Herculis	34.53	0.46	G
20 Persei	36.	0.75	F
β 581	41.2	0.53	?
η Cor. Bor.	41.51	0.28	G
ξ Scorpii	44.5	0.77	F8
μ_1 Herculis	45.39	0.21	?
β 416	45.90	0.62	K5
	37.64	0.453	
Σ 2173	46.0	0.20	G
Sirius	49.4	0.50	A*
O Σ 298	52.0	0.58	?
β 513	53.0	0.35	A2
γ Andr. BC	55.0	0.82	K†
τ Cygni	53.±	0.31±	F
ζ Caneri	59.1	0.38	F
ξ Urs. Maj.	59.8	0.41	G
99 Herculis	64.5	0.81	F8
O Σ 235	66.0	0.50	F
	55.8	0.495	
8 Sextantis	68.8	0.60	A2
γ Cor. Bor.	73.0	0.48	A
O Σ 234	77.0	0.30	?
O Σ 400	81.0	0.46	?
α Centauri	81.2	0.53	G, K5
γ Centauri	88.0	0.80	A
70 Ophiuchi	88.4	0.50	K
O Σ 387	90.0	0.60	?
O Σ 285	97.9	0.60	?
ϕ Urs. Maj.	99.7	0.44	A2
	84.4	0.531	
Σ 3062	104.6	0.45	F
ω Leonis	116.2	0.54	G
Σ 228	123.1	0.31	?
ξ Bootis	148.5	0.54	K5p
γ Cor. Aus.	152.7	0.42	F8
Σ 2	166.2	0.40	A
α_2 Eridani BC	180.0	0.13	G5‡
25 Can. Ven.	184.0	0.75	F
Σ 2107	186.2	0.39	N?
γ Virginis	194.0	0.90	F
	155.6	0.483	

SUMMARIES FOR VISUAL BINARIES.

Spectra	No. of Stars	No. of Stars	P_0	e_0
O-B	0	25	32.78	0.48
A	9	25	108.1	0.51
F	18			
G-K	14			
M-N	0			

* Star A = —1.5, A type.

Star B = 9, yellow.

† Star A = 2.28, K type.

Star BC = 5.08, blue.

‡ Star A = 4.5, G5 type.

Star BC = 9, blue.

type is unknown for ten of the fainter systems. Summarizing the spectral types, two facts are striking:

First, there are no visual binaries of known periods less than 50 years, or of any satisfactorily determined periods, belonging to the O and B types. This is in strong contrast with the very large proportion of spectroscopic binaries of O and B types. It is apparent that the component stars in an O or B type binary system are in general too close together to be separated by direct telescopic observation.

Second, there are no visual binary systems of determined periods belonging to the M type, but the apparent explanation is a very different one. The periods in such systems are so long, in comparison with the interval covering accurate micrometer studies of double stars, that we have no reliable information concerning the period of revolution for even one system.

Dr. Aitken has tabulated the spectral types of 164 double stars on his observing list of the more rapidly moving systems. All assignments of type but one, that of γ *Lupi*, were taken from the Draper Catalogue. The results are as follows:

O type	0 stars
B type	4 stars
A-F type	131 stars
G-K type	28 stars
M-N type	1 star?
Total	164 stars

Visual double stars clearly abhor the O and B types, and visual double stars of relatively short periods clearly abhor M and N types.

TABLE VII.
SPECTROSCOPIC AND VISUAL BINARIES.

	No. of Stars	P_0	e_0
Spectroscopic binaries	31 (19)	2.59 days	0.04
Spectroscopic binaries	13 (7)	6.90	0.14
Spectroscopic binaries	33 (24)	73.5	0.36
Spectroscopic binaries	15 (13)	20.5 years	0.38
Visual binaries	25 (25)	32.8	0.48
Visual binaries	25 (25)	108.1	0.51

The eccentricities, grouped in means of ten each, cannot be said to establish a direct relation between periods and eccentricities. The summary at the bottom of the table, dividing the fifty stars into two groups of twenty-five each, is more definite and more reliable. If we were to add to this summary a third group of twenty-five stars whose assigned periods are all greater than 200 years, the mean of their assigned eccentricities would approximate 0.6, and give apparent evidence of increasing eccentricity with increasing length of period. However, the orbits of visual double stars with assigned periods greater than 200 years are so uncertain that their inclusion would not add to the strength of the investigation.

Doberck appears to have been the first to study the possible relation existing in visual double-star orbits between periods and eccentricities.

"There seems according to the latest results to be a slight tendency to great eccentricity in orbits of great period, while some quickly revolving double stars move in nearly circular orbits, but of course no certain conclusions can be drawn in the present state of our knowledge."—Doberck, *Astr. Nach.*, **91**, 122, 1877.

"I have lately re-investigated the connection and find from the best determined orbits, which are all different from those used in 1877, that the mean eccentricity of orbits whose period is above 120 years (mean 206 years) is 0.62; that the mean eccentricity for periods between 50 and 120 years (mean 75 years) is 0.50; and that the mean eccentricity for periods below 50 years (mean 30 years) is 0.37."—Doberck, *Astr. Nach.*, **147**, 251, 1898.

[The best orbits with periods under 50 years, 21 in number, as in TABLE VI, give $e_0 = 0.45$.—W. W. C.]

In TABLE VII let us bring together data for the spectroscopic and visual binaries. As in TABLE V, the parentheses contain the numbers of individual eccentricities which enter into the mean values of the eccentricities; and the unbracketed numbers denote the numbers of periods represented in the average periods.

The period of revolution in a binary system is, in general, a function of the spectral type; and the eccentricity is, in general, a function of the period. What is the significance of these facts? Darwin and Poincaré have studied the origin of binary stars from theoretical considerations. Not to review their work in technical detail, nor to define the underlying assumptions, they came to the conclusion that a condensing nebulous mass, rotating about an axis, constantly faster and faster, to keep pace with loss of heat through radiation, should eventually separate into two nebulous masses revolving around their mutual center of mass. These two masses would in the beginning be revolving in contact in orbits essentially circular. With advancing time, tidal disturbances within the bodies, more or less viscous, would cause them to draw apart, rapidly at first and less rapidly later. Jeans⁴ and others have called attention to certain limitations in these investigations, which their authors recognize. Darwin has, in fact, stated⁵ that the assumed conditions in the parent mass are necessarily not in strict accord with probable distribution of density and other conditions. However, confidence prevails that the deductions are substantially correct.

⁴ *Phil. Trans.*, **199** A, 1, 1902.

⁵ *Darwin and Modern Science*, pp. 548-9, Cambridge, 1909.

See's valuable study of visual double stars, *Die Entwicklung der Doppelstern Systeme*, 1892, taking note of the high eccentricities of their orbits, established that their periods and their eccentricities should increase as a gravitational effect resulting from tidal friction in the viscous components of the system.

In the spectroscopic and visual binary systems described in the present paper we have a tolerably complete sequence of systems illustrative and confirmative of the Darwin-Poincaré-See hypotheses. Short period orbits should be circular or nearly so, and they should appertain preferentially to stars of early spectral types; long period orbits should, in general, attach to the more eccentric orbits and to the older spectral types. These are the facts unquestionably established by spectrographic and micrometer observations of actual binary systems. There are many lines of supporting evidence which we shall consider.

TABLE VIII.

VARIABLES OF ALGOL AND β LYRAE TYPES.

ALGOLS.			β LYRAE.	
No. of Stars	Periods in Days		No. of Stars	Periods in Days
9	0 to 1		3 or 4	0 to 1
11	1 to 2		2 or 1	1 to 2
17	2 to 3		1	2 to 3
12	3 to 4		1	3 to 4
4	4 to 5		1	13
4	5 to 6		1	37
4	6 to 7		1?	38
1	7 to 8		1	79
1	8 to 9		1	?
2	9 to 10			
0	10		10 to 12	
0	11			
2	12			
1	13			
1	31			
1	32			
1	35			
1	262			
72				
TOTAL.		SPECTRA.		
No. of Stars	P in Days	B type	8 stars	
56	0 to 4	A type	15 stars	
16	4 to 10	Early F type	3 stars	
12	10 to 272	G-K-M types	0 stars	
84		Unknown type	58 stars	
			84	
DENSITIES (ALGOLS).			SPECTROGRAPHIC ORBITS.	
	No. of Stars	Average Density		P
Roberts	4	0.13 D_0	β Persei	.03 2487
Roberts	6	0.06	λ Tauri	v. small 3.95
Russell	17	<0.20	V Puppis	v. small 1.45
Ristenpart	10	0.07	δ Librae	.05 2.33
			α Herculis	.05 2.05
			β Lyrae	.05 $\pm$ 12.91

The *Algol* and β *Lyrae* variable stars are of very great interest in this connection. It is customary to treat these two classes separately, but there is scarcely a doubt that they are closely related. The β *Lyrae* stars vary in luminosity without pause, except as they pass through maxima or minima, and they seem to repeat their photometric curves with absolute fidelity as to form and period, neglecting possible secular changes. Praiseworthy investigations by Roberts, Meyers and others appear to have established that the observed variations may be accounted for, in all cases studied, within the unavoidable errors of observation, by the mutual eclipses of two attenuated components nearly or quite in contact. This being true, the β *Lyrae* variables are *Algols* of an extreme type. It is not certain, however, that minor brightness variations, due to tidal surgings reasonably to be expected, may not be involved. However, the data for the *Algol* and β *Lyrae* variables in which we are here interested are for the most part kept separate in TABLE VIII, though they are combined in the totals at the bottom of the table. The 72 *Algol* stars listed in *V. J. S. Astr. Gesell.*, 44, 391-2, 1909, are assorted according to the lengths of their periods in the first two columns of the table. Similar data for the β *Lyrae* stars from the same publication, pages 322-365, are tabulated in columns three and four.

The great preponderance of short periods is striking. Of the 84 stars in both classes, 56 have periods less than 4 days long; 16 have periods between 4 and 10 days; and only 12 have periods between 10 and 272 days.

Most of the stars in these classes are faint, and their types of spectra have not been determined at Harvard College Observatory or elsewhere. Of the 26 spectra described, 8 are of B type, 15 are of A type, 3 are of F type, and none are of G-K-M types. The preference for early spectral types is marked, which fact has often been commented upon.

Roberts⁶ has computed, upon reasonable assumptions, the densities in 8 *Algol* systems; Russell,⁷ in 17 systems; and Ristenpart,⁸ in 10 systems. The mean of the densities assigned by the three investigators is 0.13 of the Sun's mean density.

Considering the preference of these stars for short periods, early spectral types and low densities, it is easy to reach conclusions as to why we have *Algol* and β *Lyrae* variables.

The two members in *Algol* and β *Lyrae* systems are, in general, so near each other and so great in diameter that the eclipse phenomena for any one

⁶ *Ap. J.*, 10, 314, 1899, and *Rep. B. A. A. S.*, p. 256, 1905.

⁷ *Ap. J.*, 10, 317, 1899.

⁸ *A. N.*, 178, 31, 1908.

system are observable throughout a wide volume of sidereal space; and the eclipses are of long duration in reference to the periods of revolution, so that even the unsystematic observations of the past have readily detected variable brightness. It is not necessary that celestial observers be in or at all near to the orbital plane of the binary eclipsing system, nor that highly organized programs of observation be followed, in order to detect a variation in luminosity. As the two members of a system grow farther and farther apart, corresponding to the longer periods of TABLE VIII, the number of eclipsing pairs decreases very rapidly, as indicated in the same table. Increasing density and diminution in diameter must keep step with increasing length of period. *Algol* and β *Lyrae* stars of G-M types appear not to have been observed, for the reasons that the binary stars of these types have components, in general, far apart and of small diameters. Terrestrial observers would have to be in or nearly in the orbital planes; and even so the eclipses would be of short duration relatively to the period of revolution.

We need scarcely recall that all spectroscopic binary systems would be *Algol* variables for observers situated in the planes of their orbits.

Much light is thrown upon conditions existing in

Algol and β *Lyrae* systems by the data collected in TABLE IX, in which the photometric work of Roberts, Duner, Meyers, Hartwig, Wendell and others enters. No effort has been made to have the data complete, but for future convenience all known β *Lyrae* stars are listed. There are many interesting and significant facts brought out concerning the eccentricities of orbits, relative brightness and size of the component stars, the average density, the distance between components, etc.; though it should be said, I think, that studies of this kind, based exclusively upon photometric data, without the illuminating assistance of radial velocity measurements for orbital proportions and scale values, must be considered as roughly approximate. The relatively high eccentricities, 0.14 to 0.25, assigned to three *Algol* stars with periods under four days are surprising, but probably approximately correct; but the distances between the components in two of these systems, as determined by Duner, afford abundance of space for revolution without direct interference. The diameters of the secondaries are large relatively to their luminosities, and the mean densities are very low. These facts, however, do not appear to be out of harmony with characteristics perhaps more definitely supplied by other means of binary investigation.

TABLE IX.—DATA DEDUCED FROM PHOTOMETRIC CURVES

Star	R.A.	Vis. Mag.	Spectrum H.C.O.	Type of Variable	P	e	i	$br_1 : br$	$r_1 : r$	d_0
RR Centauri	14 ^h 9 ^m 9	7.4—7.8	F	β Lyrae	0.61	0.02	.....	0.8	1.	0.25 D_0 .
				Short P.	0.303	.....	.....	.....	.....	.....
U Pegasi	23 52.9	9.3—9.9		β Lyrae	0.375	0.03	73°	0.7	1.	0.36
				β Lyrae	.....	.....	90	0.77	0.78	.....
				Short P.	.....	.....	.....	.....	.....	.....
WZ Cygni	20 49.3	9.9—10.8		β Lyrae	0.584	.....	.....	.....	.....	.....
X Carinae	8 29.8	7.9—8.7	A	β Lyrae	1.082	0.02	84	0.92	1.	0.05
					0.541	.....	.....	.....	.....	.....
				Algol	.....	.....	.....	.....	.....	.....
V Puppis	7 55.3	4.1—4.8	B1	β Lyrae?	1.454	0.02	74	0.75	1.	0.02
										
				Algol?	.....	.....	.....	.....	.....	.....
u Herculis	17 13.7	4.6—5.4	B3	β Lyrae	2.051	.....	.....	.....	.....	.....
V Serpentis	18 11.1	9.5—11.1	A	β Lyrae	3.453	.....	.....	.....	.....	.....
RS Sagittarii	18 11.0	5.9—6.3		Algol	2.416	0.25	.....	.....	.....	0.16 & 0.21
Y Cygni	20 48.1	7.1—7.9		Algol	3.00	0.14	.....	1.	1.	.....
					1.498	.....	.....	.....	.....	.....
Z Herculis	17 53.6	7.1—7.9		Algol	3.993	0.25	90	0.50	1.	.....
					.....	0.20	90	.....	.....	.....
β Lyrae†	18 46.4	3.4—4.1	B2p	β Lyrae	12.908	0.02	.....	.....	.....	Atmospheric
					.....	0.02	83	0.4	1.	0.0003
					.....	0.04	.....	.....	.....	.....
SX Cassiop.	0 5.5	8 — 9±		β Lyrae	36.572	.....	.....	.....	.....	.....
V Vulpeculae	20 32.3	8.2—9.8		β Lyrae	75.	.....	.....	0.4	.....	0.00002
				Cepheid?	37.79	.....	.....	.....	.....	.....
RV Tauri	4 41.0	9.3—10.5		β Lyrae	79.0	.....	.....	.....	.....	.....
RT Sculptoris	0 32.5	9 — 10±		β Lyrae	?	.....	.....	.....	.....	.....

* This list includes all known β Lyrae variables.

† In Meyers's investigations of the β Lyrae system, and in Schlesinger's investigations of the δ Librae system, described in the main catalogue, pages 30 and 26, photometric observations played a prominent part.

Graff, from studies of photometric curves of 10 Algol variables, found 6 curves "symmetrical," 3 "practically symmetrical," and only one "markedly unsymmetrical," indicating a large proportion of circular or nearly circular orbits. He found the luminosities of the secondaries in the 10 systems remarkably low, average only 0.05 the luminosity of the primaries.—*Mitt. Hamburger Sternwarte*, No. 11, 94-100.

Russell found maximum limit of mean densities of 17 Algol variables from 0.03 D_0 to 0.73 D_0 , average 0.20 D_0 .—*Ap. J.*, 10, 315, 1899.

Ristenpart found densities of 10 Algol variables from 0.02 D_0 to 0.35 D_0 , average 0.08 D_0 .—*A. N.*, 178, 31, 1908.

OF ALGOL AND β LYRAE* STARS.

Star	Remarks	Authority for Type of Variable, P , and other Data
RR Centauri	Two stars overlap by .02 ($a + a_1$)	Roberts, <i>Rep. B. A. A. S.</i> , 256, 1905, and <i>Mon. Not.</i> , 66, 140, 1906 <i>V. J. S.</i> , 44, 365, 1909
U Pegasi	Dist. between surfaces, .07 ($a + a_1$) Dist. between surfaces, 0.	Roberts, <i>Rep. B. A. A. S.</i> , 256, 1905; <i>H. C. O. Circ.</i> , No. 23 Meyers, <i>Ap. J.</i> , 8, 172, 1898 <i>V. J. S.</i> , 44, 351, 1909
WZ Cygni		<i>V. J. S.</i> , 44, 365, 1909
X Carinae	Dist. between surfaces, 0.	Roberts, <i>Rep. B. A. A. S.</i> , 253-6, 1905 Roberts, <i>An. H. C. O.</i> , 55 (I), 41, 1907 <i>V. J. S.</i> , 44, 355, 1909
V Puppis	Dist. between surfaces, 0.1 ($a + a_1$) $r = r_1 = 12,500,000$ km.; $a + a_1 = 27,000,000$ km.	Roberts, <i>Rep. B. A. A. S.</i> , 253-6, 1905 <i>V. J. S.</i> , 44, 387, 1909
u Herculis		<i>V. J. S.</i> , 44, 364, 1909
V Serpentis		Wendell, <i>An. H. C. O.</i> , 55 (I), 51, 1907
RS Sagittarii		Roberts, <i>Ap. J.</i> , 10, 309-10, 1899
Y Cygni	$a = a_1 = 4r = 4r_1$	Duner, <i>Ap. J.</i> , 11, 190, 1900 <i>V. J. S.</i> , 44, 370, 1909
Z Herculis	$a + a_1 = 6 (r + r_1)$	Duner, <i>Ap. J.</i> , 1, 294, 1895 Hartwig, <i>A. N.</i> , 152, 309, 1900
β Lyrae†	$a + a_1 = 67,000,000$ km., increasing. Stars in contact	Meyers, <i>Ap. J.</i> , 7, 1, 1898 Roberts, <i>Rep. B. A. A. S.</i> , 254-6, 1905 v. Hepperger, <i>Sitz. Akad. Wien</i> , 108 (6), 938, 941, 946 <i>V. J. S.</i> , 44, 364, 1909
SX Cassiop.		<i>V. J. S.</i> , 44, 364, 1909
V Vulpeculae	Nearly in contact, e rather large Seares thinks it Cepheid variable	Roberts, <i>Rep. B. A. A. S.</i> , 255, 1905 <i>An. H. C. O.</i> , 55 (I), 60
RV Tauri		<i>V. J. S.</i> , 44, 326, 1909
RT Sculptoris		<i>V. J. S.</i> , 44, 353, 1909

Of interest are the stars with composite spectra, observed by Harvard College Observatory. The principal facts at my command are tabulated below.

TABLE X.

STARS WITH COMPOSITE SPECTRA (OBJECTIVE PRISM).

H.R.	Star	R.A.	Br. Sp.	Ftr. Sp.	Vis. Mag.	Remarks
595-6	α Piscium	1 ^h 56 ^m 9	A2p	I type	5.23-4.33	Visual double, $s=3'6$, $p=336^\circ$
603-4	γ Androm.	1 57.8	K	I type	2.28-4.96	Visual Triple, BC-A, $s=10''$, $p=62^\circ$ Perhaps small variation in V
643	b Androm.	2 6.9	Kp		5.08	No observations
854	τ Persei	2 47.2	Gp	I-II type	4.06	Spectroscopic binary
915	ν Persei	2 57.6	Gp	I type	3.08	Spectroscopic binary
1129	— Camelop.	3 37.3	G	A	4.96	Velocity apparently constant
1211-2	w Eridani	3 49.2	G5	B?	6.33-4.95	Visual double, $s=6'7$, $p=347^\circ$ Br. component perhaps variable V Observed rad. V approx. constant
1230	— Cephei	3 53.3	F8p		5.25	No observations
1252	36 Tauri	3 58.4	A	G	5.67 ¹	No observations
1306	f Persei	4 8.1	K	A	4.89	Velocity apparently constant
1612	ζ Aurigae	4 55.5	Kp	Orion	3.94	Spectroscopic binary
2303	— Can. Maj.	6 19.2	Kp		6.40	"Probably composite," no obs.
3307	ϵ Carinae	8 20.5	Kp	Orion	1.74	Perhaps small variation in obs'd V
3428	— Caneri	8 34.6	A5p		6.40	"Probably composite," no obs.
3619	f Urs. Maj.	9 1.9	A3 ²	F5	4.54	No observations
3624	τ Urs. Maj.	9 2.7	F8p	I-II type	4.74	Spectroscopic binary
3852	σ Leonis	9 35.8	F5p	I type	3.76	Spectroscopic binary
4707	12 Com. Ber.	12 17.5	G	A	4.78	Spectroscopic binary ³
5064	i Virginis	13 21.4	Kp		5.59	"Composite?" no obs.
5440	η Centauri	14 29.2	B3p	A2	2.65	Spectroscopic binary
5505-6	ϵ Bootis	14 40.6	K	A type	5.12-2.70	Visual double, $s=2'6$, $p=321^\circ$ Br. component perhaps variable V
5571	β Lupi	14 52.0	B2p		2.81	Spectroscopic binary
5609	— Bootis	14 59.1	G5p		5.66	No observations
5704	γ Circini	15 15.4	B5p	F8	4.54	1 observation only
6134	α Scorpii	16 23.3	Map	A3	1.22-7	Approx. equal photo. magnitudes Spectroscopic binary Visual double, $s=2'6$, $p=273^\circ$
6497	— γ phiuchi	17 21.5	F5p		5.98	No observations
6729-0	95 Herculis	17 57.2	A3	G5	5.21-5.13	Visual double, $s=6'1$, $p=262^\circ$
6918	d Serpent.	18 22.1	A	G	5.33	Spectroscopic binary
7342	ν Sagittar.	19 16.0	B8p	B $\pm$	4.58	Spectroscopic binary
7417	β Cygni	19 26.7	Kp	I-II type	3.24	Br. component of visual double Velocity apparently constant
7536	δ Sagittae	19 42.9	Map	I type	3.78	Spectroscopic binary
7735	31 Cygni	20 10.5	Kp		3.95	Spectroscopic binary
7751	O ₂ Cygni	20 12.3	G5	I type	4.16	Spectroscopic binary
7776	β Capricor.	20 15.4	Gp	I type	3.25	Spectroscopic binary
7866	47 Cygni	20 30.0	K5	B?	4.85	Spectroscopic binary ⁴
8131	α Equulei	21 10.8	A8p	I type	4.14	Spectroscopic binary
8278	γ Capricor.	21 34.6	Fp	F $\pm$	3.80	Perhaps small variation in obs'd V
8417	ξ Cephei	22 0.9	A3 ⁵	G	4.57-6.47	Visual double, $s=5'6$, $p=289^\circ$ Perhaps small variation in obs'd V
8762	O Androm.	22 57.3	B3	Orion	3.63	Spectroscopic binary
8817	c_2 Aquarii	23 4.5	Gp	A2	4.94	Observed rad. V. approx. constant

¹ Visual companion, 12½ mag., too faint to affect spectrograms.

² "Spectrum is peculiar and appears to be composite." *Ann. H. C. O.*, 56 (IV), 70, 1908.

³ Variable velocity found at Lick Observatory after January 1, 1910.

⁴ Variable velocity found at Lick Observatory after January 1, 1910.

⁵ Burnham, No. 11483, assigns colors yellow and blue to br. and ftr. components.

Of the 40 stars in this list (*Annals H. C. O.*, **23**, 93 and 229; **50**, 200-225; and **56**, 113):

6 are moderately close visual double stars whose component spectra overlap on the original photographs, and the resulting spectra appear to be composite for this reason.

8 are fainter than visual magnitude 5.0, and seem not to have been placed on existing programs for radial velocity measurement.

1 has been observed only once for radial velocity.

Of the 25 remaining, 18 have been found to be spectroscopic binaries; 2 others seem to have exhibited slight variations of radial velocity; and the remaining 5, observed several times each, have not shown variable radial velocity, but this may be due to unfavorable distribution of observation times, or more probably to long periods of revolution. It is probable that the binary character of the 7 last referred to will be established in the future.

Omitting the visual doubles in the list, all the repeatedly observed B or A types have been shown to be spectroscopic binaries. Those whose velocities appear to be constant, or to have varied but slightly, are of F5 or more advanced spectral types. The Harvard observers have described both components of the spectra in 31 out of 40 systems. In 22 cases out of the 31 the spectra of the fainter components are of earlier types than the spectra of the brighter components; in 2 cases the types are essentially equal; and in the remaining 7 the fainter spectra are of later type than the brighter spectra. In one of the 7 cases, that of γ *Circini*, the photographic magnitudes are approximately equal; and in 2 others of the 7 the difference in types seems to be small. In those systems for which the fainter spectrum is of the newer type, essentially all types from B to M are concerned.

For 62 close binary systems contained in the Catalogue, the spectra of both components have been observed on the spectrograms, or strongly suspected. These systems are distributed among the spectral types as follows:

O and B types	30 systems
A type	23 systems
F type	5 systems
G type	3 systems
K type	1 system
M type	0 system
Total	62 systems

From the published descriptions of the double spectra, it is fairly well established that when the two spectra are substantially equal in brightness they are identical in type; and when one spectrum is considerably fainter than the other, the spectrum of the secondary is apparently of a slightly earlier type

than the spectrum of the primary. There appear to be no exceptions to this rule, though the difficulty in the way of giving accurate descriptions of the fainter spectrum must be recognized. Another fact, seemingly of great significance, holds for every one of these systems, so far as they have been investigated, excepting possibly for β *Lyrae*: the fainter and earlier type spectrum belongs to the less massive member of the system. The wide visual and spectroscopic binary, α *Centauri*, appears to controvert this rule, slightly, in that the fainter component has the older type of spectrum; but according to the data in TABLE XI, a doubt exists as to which of the components is the more massive.

Attempts have been made to determine the relative masses of the two components in several well known visual double stars. The most of these investigations are based upon the apparent orbit of the primary, as determined from meridian observations, and upon micrometer observations of the secondary with reference to the primary. Lewis's *Struve Double Stars*, xxi, 1906, contains results for 19 systems. These were obtained for the most part by himself and other Greenwich investigators, but for very little of this Greenwich work have I been able to find published details. Estimates of the reliability of the results are therefore difficult. In general, they attribute much greater mass to the secondary members than to the primaries; in the case of α *Geminorum*, twenty times as great, but to this I think we need not attach any weight, for would not another value of the assigned proper motion in declination (p. 215) change the resulting value of m_1/m ? In fact, was it not necessary to assume a position for the center of mass of the system and therefore the ratio of the masses before a value of the proper motion could be deduced? Neither does it appear that sufficient attention has been paid to the elimination of the systematic errors of observation, which we should expect to be large and variable for the same observers, as well as for different observers. Doubts as to the reliability of many of the results quoted in Lewis's table arise on comparing them with those secured by other investigators. For example, in the system of ϵ *Hydrae*, Lewis assigns to m_1/m the value 6; Seeliger's value is 0.9. In the system of σ *Coronae Borealis*, Lewis's value of m_1/m is 4.; Hadley's is 1.1. Prey's value of m_1/m for 70 *Ophiuchi* is 4.; whereas, from substantially the same data, Comstock obtains 1.0, and Lau 0.5. In the system of 85 *Pegasi*, three Greenwich observers, using two methods, assign to m_1/m the value $3\frac{1}{2}$, whereas Comstock obtains 1.6. Schorr's value for the system ξ *Scorpii*, 1.36, appears to be uncertain, for it is based upon $P=105.2$ years, $e=0.12$; and we now know the correct values to be approximately $P=44.5$

TABLE XI.—VISUAL DOUBLE STARS

Star	R.A.	α	P	Colors	Vis. Mags.	m_1/m	Computer	Observational Basis
η Cassiopeiae	0 ^h 43 ^m 0	8 ^s 5			4.0—7.6	0.37	L. Struve	Merid. and mier.
			233 $\pm$ 3	Y-P	4.0—7.6	0.5	Lewis	Merid. and mier.
			233.3		3.6—7.9	0.76	Boss	Merid. and mier.
ϵ_2 Eridani, B & C	4 10.7	6.2	180.	B-B	9.2—10.2	1.1	Lewis	Mier. meas. of A & B
α Canis Maj.	6 40.7	7.6	49.4		—1.5—9	0.47	Auwers	Merid. and mier.
				W-Y		0.5	See	Merid. and mier.
			48.8		—2 — 8	0.39	Boss	Merid. and mier.
α Geminorum*	7 28.2	[6 $\pm$]	[350. $\pm$]	Y-Y	2.7—3.7	20.	Furner	Merid.
α Canis Min.	7 34.1	5 $\pm$	40.	Y-G		0.20	See	Merid. and mier.
			39.		0.2—9.0	0.33	Boss	Merid. and mier.
ζ Cancri, A & B	8 6.5	0.9	60.	Y-Y	5.5—6.2	1.	Seeliger	Mier. meas. C with A & B
ϵ Hydrae, A & B†	8 41.5	0.2	15.7		4.0—5.5	0.9	Seeliger	Mier. meas. C & AB
		0.3	15.	Y-B	3.0—6.0	6.	Lewis	Merid. and mier.
ξ Ursae Maj.	11 12.9	2.5	60.	Y-Y	4. — 5.	1.5	Bowyer	Merid. and mier.
			60.		4.1—5.1	1.0	Boss	Merid. and mier.
γ Virginis	12 36.6	3.9	182.	Y-Y	3.0—3.0	1.0	Lewis	Merid. and mier.
			194.		3.6—3.6	1.0	Boss	Merid. and mier.
25 Canun Ven.	13 33.0	1.1	220.	W-B	5.0—8.5	2.	Furner	Merid. and mier.
α Centauri‡	14 32.8	17.7	81.			1.0	Elkin	Merid. and mier.
				Y-Y	1. — 2.	1.05	Gill	Merid. and mier.
						0.96	Roberts	Merid. and mier.
			81.2		0. — 1.5	0.85	Boss	Merid. and mier.
ξ Bootis	14 46.8	5.3	137.	Y-P	4.5—6.5	1.25	Bowyer	Merid. and mier.
			148.5		4.8—6.7	0.87	Boss	Merid. and mier.
ξ Scorpii, A & B||	15 58.9	0.7	44.5	Y-	5.0—5.2	[1.36]	Schorr	Mier. meas. C & AB
σ Coronae Bor.	16 10.9					1.1	Hadley	Merid. and mier.
		3.8	340.	Y-B	5.0—6.0	4.	Lewis	Merid. and mier.
			370.		5.7—6.8	0.47	Boss	Merid. and mier.
λ Ophiuchi	16 25.9	1 $\pm$	134.	Y-B	4.0—6.1	4.3	Lewis	Merid. and mier.
ζ Herculis	16 37.5	1.4	34.	Y-B	3.0—6.0	1.0	Lewis	Merid., mier. and spectr.
			34.5		2.8—6.5	0.43	Boss	Merid. and mier.
70 Ophiuchi	18 0.4	4.6	88.	Y-P	4.5—6.0	4.	Prey	Merid. and mier.
						1.0	Comstock	Merid. and mier.
		4.5	87.5			0.5	Lau	Mier., A and 3d star
			88.4		4.3—5.8	0.82	Boss	Merid. and mier.
85 Pegasi§	23 56.9	0.8	25.	Y-B	6.0—10.0	1.6	Comstock	Mier., A and 3d star
						4.	Furner	Merid. and mier.
						3.	Lewis	Merid. and mier.
			24.5			4.5	Bowyer & Furner	Merid. and mier.
						2.7	Bowyer & Furner	Mier., A and 3d star
			25.7		6.0—11.	1.0	Boss	Merid. and mier.

* α Geminorum. Would not another value of proper motion in Dec. change resulting value of m_1/m ? Boss says “The problem of computing the relative masses of the components from the meridian observations is manifestly indeterminate.” *Prelim. Gen. Cat.*, 266. Lewis deduces $m_1 = 0.01\odot = 10$ Jupiter’s mass. Lewis’s Σ *Doub. Stars*, 216.

† ϵ Hydrae. Seeliger’s mass ratio rests on prior deduction that the effective light-center of AB is at $1/7$ distance A — B from A; if this distance were $1/8$ (A — B), the mass ratio would be 0.8.

‡ α Centauri. Stone considered $m = m_1$ as close approximation to truth; *Mon. Not.*, 36, 264-5, 1876.

See obtained $m + m_1 = 2.00\odot$; *Evolution Stellar Systems*, 148. Boss’s values of ratio: from fainter component, in R. A. 0.67 (wt. 8), in Dec. 0.78 (wt. 55); from brighter component, in R. A. 0.89 (wt. 14), in Dec. 0.91 (wt. 70); adopted 0.85.

|| ξ Scorpii. Schorr’s investigation is based upon $P = 105.2$ years, $e = 0.12$, whereas the correct values are approx. $P = 44.5$ years, $e = 0.77$.

§ 85 Pegasi. Boss says mass ratio is “extremely uncertain.” “The computation is scarcely warranted by weight of meridian observations.” “The meridian observations have a total weight . . . much less than for any other binary treated.” *Prelim. Gen. Cat.*, 278.

WHOSE MASS RATIOS HAVE BEEN DETERMINED.

	Reference and Remarks
η Cassiopeiae	See's <i>Evolution Stellar Systems</i> , 76 Lewis's Σ <i>Double Stars</i> , xxi and 18; $m = \frac{2}{3}\odot$, $m_1 = \frac{1}{3}\odot$ Boss's <i>Prelim. Gen. Cat.</i> , xxiii and 264; in R. A. 1.63 (wt. 60), in Dec. 0.41 (wt. 85), adopted 0.76
α_2 Eridani, B & C	Lewis's Σ <i>Double Stars</i> , xxi and 113-4. Visual triple system
α Canis Maj.	<i>A. N.</i> , 129, 232, 1892; $m = 2.20\odot$, $m_1 = 1.04\odot$ Lewis's Σ <i>Double Stars</i> , xxi Boss's <i>P. G. Cat.</i> , xxiii and 265; in R. A. 0.387, in Dec. 0.393, mean 0.39
α Geminorum	Lewis's Σ <i>Double Stars</i> , xxi and 215
α Canis Min.	<i>Astron. Jour.</i> , 19, 60, 1898; $m = 4.95\odot$, $m_1 = 0.99\odot$ Boss's <i>P. G. Cat.</i> , xxiii and 267
ζ Cancri, A & B	<i>Denksch. kk. Akad. Wien</i> , 44, 62, 1881. Visual triple system
ϵ Hydrae, A & B	<i>A. N.</i> , 173, 325, 1906. Visual quadruple system. Max. separation A & B is 0'73 Lewis's Σ <i>Doub. Stars</i> , xxi and 255
ξ Ursae Maj.	Lewis's Σ <i>Doub. Stars</i> , xxi and 306 Boss's <i>P. G. Cat.</i> , xxiii and 269; in R. A. 1.43, in Dec. 0.75, mean 1.09, adopted 1.0
γ Virginis	Lewis's Σ <i>Doub. Stars</i> , xxi and 341 Boss's <i>P. G. Cat.</i> , xxiii and 270-1; in R. A. 0.65 (wt. 1), in Dec. 1.53 (wt. 2), mean 1.1, adopted 1.0
25 Canum Ven.	Lewis's Σ <i>Double Stars</i> , xxi and 364
α Centauri	<i>Über die Parallaxe von α Centauri</i> , 1880, see <i>Mem. R. A. S.</i> , 48, 14, 1884 Lewis's Σ <i>Doub. Stars</i> , xxi; original reference not known, and method unknown <i>A. N.</i> , 139, 10, 1895; $m = 1.02\odot$, $m_1 = 0.98\odot$ Boss's <i>P. G. Cat.</i> , xxiii and 271; see note † below
ξ Bootis	Lewis's Σ <i>Doub. Stars</i> , xxi Boss's <i>P. G. Cat.</i> , xxiii and 272; in R. A. 1.5 (wt. 2), in Dec. 0.69 (wt. 5), mean 0.87
ξ Scorpiae, A & B	<i>Untersuch. über die Bewegungsverhältnisse im dreif. Sternsystems ξ Scorpiae</i> , München, 1889. Visual triple system
σ Coronae Bor.	<i>Pop. Astr.</i> , 13, 264, 1905; in R. A. 1.19, in Dec. 1.01, mean 1.1 Lewis's Σ <i>Doub. Stars</i> , xxi and 446-7 Boss's <i>P. G. Cat.</i> , xxiii and 273; in R. A. 0.85, in Dec. 0.32, adopted 0.47, small wt.
λ Ophiuchi	Lewis's Σ <i>Double Stars</i> , xxi and 456. Orbit very uncertain. Small wt.
ζ Herculis	<i>Mon. Not.</i> , 61, 87, 1900 Boss's <i>P. G. Cat.</i> , xxiii and 274; in R. A. 0.39, in Dec. 0.50, adopted 0.43
70 Ophiuchi	<i>A. N.</i> , 165, 158, 1904 <i>A. N.</i> , 178, 18, 1908; in R. A. 0.84, in Dec. 1.03, mean by wts. 0.91, adopted 1.0 <i>Bul. Astron.</i> , 25, 141, 1908 Boss's <i>P. G. Cat.</i> , xxiii and 275; in R. A. 0.92, in Dec. 0.72, mean 0.82
85 Pegasi	<i>Ap. J.</i> , 17, 220, 1903; in R. A. 1.52, in Dec. 1.71, mean 1.6 Lewis's Σ <i>Doub. Stars</i> , xxi Lewis's Σ <i>Doub. Stars</i> , xxi <i>Mon. Not.</i> , 66, 425, 1906; in R. A. 5.75, in Dec. 3.2, mean 4.5 <i>Mon. Not.</i> , 66, 429, 1906; in R. A. 2.9, in Dec. 2.5, mean 2.7 Boss's <i>P. G. Cat.</i> , xxiii and 278; in R. A. 1.0, in Dec. 5.2, mean by wts. 1.8, adopted 1.0

years, $e = 0.77$. To the system of λ *Ophiuchi* Lewis assigns $m_1/m = 4.3$, but Burnham's comment is, "Nothing whatever is known concerning the orbit." (*General Catalogue*, II, 717, 1906.)

My belief that the data referred to are not of great weight was strengthened by learning of the results secured by Professor Boss for many of the same systems, early in February of the present year. His conclusions, already in type, but communicated to me orally, have reached me before April 1st, by virtue of a personal copy of his *Preliminary General Catalogue of Stars for 1910*, in time to be inserted in TABLE XI. Boss's results are based upon meridian observations from which systematic errors have been eliminated with the utmost thoroughness; and they would seem to form the basis, almost exclusively, upon which we should judge as to the mass ratios in the double star systems concerned.

On Lewis's list of 19 systems there are assigned $m_1 > m$ in 13 systems, $m_1 = m$ in 3 systems, $m_1 < m$ in 3 systems. There are 11 in which the fainter companion is said to be the bluer; 7 in which the colors are estimated to be equal; and 1 (*Sirius*) in which the fainter companion is believed to be the redder.

Boss's general conclusion is, "there appears to be no case in which the fainter companion can be asserted with high probability to have a larger mass than that of the brighter component."—*Prelim. Gen. Cat.*, xxiii, 1910.

Boss's mean for the 11 computed values of m_1/m is 0.81, and the mean of the 11 adopted values is 0.72. The great weight of these individual results, assuming that the eleven systems are representative of double star systems in general, must give them an important place in theories of the development of binary systems.

Students of visual double stars since the days of Herschel and Wilhelm Struve have frequently referred to the color relationships existing between the primary and secondary components. When the two components are equal or approximately equal in brightness the colors of primary and secondary are substantially the same, and preferentially yellowish. There appear to be no striking exceptions to this rule of equality of color. When the visual magnitudes of the components are markedly unequal, the prevailing colors are in nearly all cases described as dissimilar, with the less brilliant secondary in general bluer and whiter than the primary. The system of *Sirius* offers an apparent exception to this rule; the primary is usually described as blue or white, and the secondary as yellow. Attempts have recently been made at the Lick Observatory to photograph the spectrum of the companion of *Sirius*, principally to

determine its type and color relationship to that of the principal star; but the attempts have thus far failed, on account of diffused light from the primary. It must be recognized that there are difficulties in the way of making reliable estimates of color in close systems with unequally bright components. Dr. Aitken's great experience confirms my opinion that no weight can attach, for example, to the published color estimates "yellow and blue" for the 3.0 and 6.0 components in the system of ϵ *Hydrae*, the maximum angular separation of the two components being 0".3. Dr. Aitken's experience is that there is less contrast in the colors of the components of a double star as seen with the 36-inch refractor than as seen with the 12-inch. Exceedingly valuable evidence to the same end is that of Müller and Kempf, that stars apparently blue or white exist in greater proportions amongst the fainter stars than amongst the bright ones,—undoubtedly for the most part a subjective effect.⁹

Boss's investigations of the mass relations in 11 double star systems, while reversing views previously held, that the bluer and whiter secondaries are more massive than their primaries, do not reverse the conclusion generally accepted that the yellower primaries are many-fold more effective as radiators of light than the secondaries are. This may be regarded as an established fact, for it can scarcely be doubted that the secondaries, being in general less massive than the primaries and at the same time bluer and probably of lower average density, have diameters at least as great as those of the primaries.

The spectrographic observations at the Yerkes Observatory have established that at least one star in three, on the average, of very early-type stars is a spectroscopic binary. The Lick Observatory observations have been confined more largely to the middle and later stellar types, with the result that here one star in six, more or less, has been proved to be a spectroscopic binary. The explanation for the discrepancy appears not to be difficult. The earlier types are of shorter periods in general, and they are characterized by a higher range of velocity variations. On both accounts, their discovery is in that sense easier and more prompt in accomplishment. The spectroscopic binaries of the older types, revolving in longer periods, implying smaller velocity amplitudes, are more difficult of discovery. Binaries of early types and short periods may or may not be more numerous than those of later types and long periods. Aitken's double star investigations have shown that one star, on the average, out of every 18, is a visual binary, with a larger proportion of bright

⁹ *A. N.*, 180, 20, 1909.

stars double than of faint ones. He has also shown that close binary systems are more numerous than those whose components are farther and farther apart. These results are somewhat surprising, for with an infinity of time to pass through their evolutionary processes, preferences would be unexpected. My radial velocity studies of stars seem to indicate that the stars of different apparent magnitudes are mixed more thoroughly than has heretofore been supposed. It is quite probable, therefore, in the absence of accurate parallax data, that the fainter double star systems are relatively closer to us, on the average, than the early investigations would lead us to believe. Measures of the large number of relatively faint and close double stars discovered at the Lick Observatory may throw light on this point. If close merely by reason of great distance from us, no angular motion would, in general, be expected in less than half a century. If actually close, and hence relatively near us, change would be shown in many instances in a decade. Further, we must not overlook the probability that large parent nebulae should divide into two components more freely than nebulae of relatively small mass.

In describing Tables III and IV, I stated that the Cepheid-Geminid variables of types F to K were not included, for the reason that they appear to stand apart from other binary and variable star systems. Fifty-three of the Cepheid-Geminid variables were known up to the beginning of the present year. These are classified in TABLE XII, in the order of their lengths of period. To 7 are assigned periods less than one day. It is probable that some of these extremely short period variables may later be assigned to the Cluster variables, or it is not impossible that the Cluster variables are, in fact, entitled to classification with the Cepheid-Geminid variables. None of the many hundred Cluster variables discovered by Harvard College Observatory have yet been submitted to radial velocity measurements, owing to their faintness. There are 28 Cepheid-Geminid variables with periods between 3 and 8 days. The small number with periods between 1 and 3 days may or may not be significant of different conditions existing in the systems with periods on opposite sides of this minimum. Only 18 are known to have periods longer than 8 days. The numbers and periods corresponding to the different spectral types are quoted in the table. There are none of O, B, K, or M types, so far as known. There is only one A type, and there are 40 of F to K5 types. The length of periods seems from this tabulation to increase slowly with the spectral types, but the relationship is not strongly marked. All of the brighter members of the group have been

TABLE XII.
CEPHEID-GE MINID VARIABLES.

No. of Stars	Period days	Spectrum	No. of Stars	P_0
7	0- 1	O-B	0	
0	1- 2	A	1	0.6 days
1	2- 3	F	14	8.2 days
5	3- 4	G-K5	26	11.4 days
5	4- 5	Unknown	12	7.9 days
5	5- 6		—	
5	6- 7		53	
8	7- 8			
1	8- 9			
3	9-10			
1	10			
2	12			
1	14			
1	16			
2	17			
1	20			
1	27			
1	35			
1	38			
1	39			
1	41			
—				
53				

11 orbits computed.
 $P_{11} = 7.3$ days.
 $e_{11} = 0.31$ days.

investigated, as to their radial velocities, and without exception found to be spectroscopic binary systems. TABLE XIII contains the principal orbital elements so far as known for 16 of these systems, arranged in the order of their periods. All of those investigated are substantially identical in spectral type, the Harvard assignments varying merely from F5 to G. There is no evidence that the eccentricities are functions of the length of period, as in all other classes of stars discussed in this paper; and for this and other reasons about to be described, the Cepheid-Geminid variables are discussed separately. Mutual eclipses within the systems appear not to be factors affecting the photometric curves. Yet the synchronism in photometric and velocity periods in every case is evidence of the strongest kind that the variation is due, either directly or indirectly, to the influence of the secondaries of the systems. A most peculiar discovery concerning these systems, made by Dr. Albrecht several years ago, is described in the last two columns of TABLE XIII. Each star has its maximum brightness at or near the time when the primary member of the system is approaching most rapidly toward the observer, and its minimum at or near the time when the primary is receding most rapidly from the observer. Enough stars have been investigated to guarantee beyond reasonable doubt this conclusion, that the time of maximum in each of the systems is a function of the observer's position in space. Many theories to account for this strange phenomenon have been advanced and discussed, only to be found wholly or largely unsatisfactory. It is difficult to conceive

TABLE XIII.
CEPHEID-GEMINID VARIABLES.

H.R.	Star	Type	Period	e	$a \sin i$ km.	$m_1^3 \sin^3 i / (m + m_1)^2$	Min.-Max ₁	Max.-Min ₁
2332	RT Aurigae	G	3.73	0.37	856,500	0.0018	+0.42	+0.44
7518	SU Cygni	F5	3.84	0.21±	1,350,000±	0.0058±	+0.2±	0.0±
7988	T Vulpec.	F	4.44	0.43	969,180	0.0018	+0.3	+0.1
8571	δ Cephei	G	5.37	0.36	1,371,000	0.0037		
6863	Y Sagittar.	G	5.77	0.16	1,485,000	0.0040	+0.78	+0.1±
6616	X Sagittar.	F8	7.01	0.40	1,334,000	0.0016	-0.2±	-1.3±
7402	U Aquilae	G	7.02				-0.5	
7570	η Aquilae	G	7.18	0.49	1,773,000	0.0043	0.0±	-0.6
6742	W Sagittar.	F5	7.60	0.32	1,930,000	0.0050	-0.1	+0.2
7609	S Sagittae	G	8.38	0.35±	2,000,000±	0.0049±	-0.2±	+0.4±
7107	κ Pavonis	F5	9.09					
2650	ζ Gemin.	G	10.15	0.22	1,797,800	0.0023	-0.2	-0.3
7932	X Cygni	F5p	16.39					
6661	Y Ophiuchi	G	17.12	0.10	1,999,000	0.0011	-1.3	+0.5±
2310	T Monocer.	G	27.01					
3884	l Carinae	G	35.53				-2½±	

that the secondary influences directly the luminosity of the primary through tidal surgings or otherwise, for the eccentricities in some of the systems are rather small; and in *Algol* systems of even shorter periods and comparable eccentricities (according to Duner, Roberts and Hartwig) there has been observed no direct photometric influence of the secondary upon the primary, not accounted for by the geometry of an eclipse. The values of $a \sin i$ are all less than two million km., which is evidence that the primaries revolve in orbits whose dimensions may be described as minute. The values of $m_1^3 \sin^3 i / (m + m_1)^2$ are also abnormally small, the largest being about 0.005. We have here a tolerably clear indication that the masses of the companion stars are very small in proportion to the masses of their primaries, for it is not probable that smallness of the angle of inclination, i , is a peculiarity of these systems. The efficacy of a resisting medium, causing the advancing face of a star to be rendered more luminous by virtue of collisions, or by virtue of the absorbing atmosphere being swept back to the opposite hemisphere, is doubtful; for it would appear that the presumably smaller secondary, traveling with much greater speed than the primary, should show some trace of any bombardment effects in the system.

It is reasonably certain that all Cepheid-Geminid variables are spectroscopic binary systems. The future will probably establish that the Cluster variables are binaries as well.

Attention should be called to certain radial velocity results obtained from the sharp and narrow H and K calcium absorption lines in several of the hydrogen and helium stars whose other lines are usually broad and hazy. Frost has stated that a very large proportion of the stars of these classes

which contain sharp H and K lines are spectroscopic binaries and that this characteristic may almost serve as a criterion of variable radial velocity;¹⁰ but the remarkable condition appears in several instances that the range of velocity yielded by one or both of the two calcium lines is different from and smaller than velocities obtained from other lines in the same spectra. The first observation bearing upon this subject was made by Hartmann, who noted¹¹ for the spectroscopic binary system δ *Orionis* that the calcium K line, faint but sharp, did not share in the periodic displacements of the other lines caused by orbital motion of the star. He attributed this result "with a pretty fair degree of certainty to the presence of an absorbing layer of gas not in immediate connection with the star." Frost and Adams,¹² on the contrary, feel certain that the velocity afforded by the K line in the spectroscopic binary system 9 *Camelopardalis* is variable; and other Yerkes plates show a small range of calcium variation for other stars, but with different average values from those obtained from the broad lines. Frost has suggested that in such stars we may have quaternary systems.

Slipher reports¹³ similar observations of sharp but faint K lines in the spectra of a number of stars of the helium type, whose other lines are wide and indefinite. Among these are several spectroscopic binaries, but others are not now known to be binary. The radial velocities from the K lines seem to remain stationary within the errors of observation, and when the observed velocities are corrected for the motions of the Earth and Sun the results approach zero within the errors of observation. He believes that

¹⁰ *Ap. J.*, 29, 234-6, 1909.

¹¹ *Ap. J.*, 19, 273, 1904.

¹² *Ap. J.*, 19, 350, 1904.

¹³ Unpublished letter, March 15, 1910.

the ordinary stellar origin of the calcium line is insufficient to explain the observations.

With so large a proportion of these stars known spectroscopic binaries, and with the possibility that all will later prove to be binary, we are hardly justified in attributing these anomalies to causes not associated with binary systems. The existence of a calcium envelope completely surrounding a close binary system, such as Meyers suggested in the case of β *Lyrae*, has something to commend itself, but observational data at present available do not justify me in amplifying the suggestion.

Facts at present puzzling but full of promise as to future aids in the interpretation of binary systems are the discrepancies in the times of variable star minima, as observed in light of different wave lengths, and the discrepancies in the times of minima for photometric curves and corresponding radial velocity curves. Belopolsky and Tikhoff¹⁴ report that the minima of β *Aurigae* occur 0.015 day earlier in blue light than in violet light. Albrecht has observed for *T Vulpeculae* that "Wilkin's¹⁵ light curve, determined by a photographic method, gives the epoch of maximum 0.4 day earlier than the curves which were determined by visual methods. A longer series of photographic observations is desirable to establish definitely this apparent difference between the times of maximum brightness for the visual and photographic radiations." The minimum in Albrecht's velocity curve falls between the times of visual and photographic maximum light, but nearer to the photographic maximum. Nordmann¹⁶ estimates that in β *Persei* the $\lambda 6800$ minimum precedes the $\lambda 4300$ minimum by 16 minutes, and that the $\lambda 5400$ minimum precedes the $\lambda 4300$ minimum by 9 minutes. Schlesinger and Curtiss¹⁷ observed that the photometric minimum of β *Persei* in visual rays lags from one and a half to two hours behind the time required by the velocity determinations based upon blue rays; and Schlesinger finds that Belopolsky's¹⁸ observations of the same star give a result in accord with his own. Schlesinger¹⁹ further observed a similar effect amounting to at least an hour in the system of δ *Librae*. The explanation of these facts seems to lie in the physical conditions existing in the variable stars referred to. Lebedew²⁰ has shown pretty conclusively that these observations cannot be considered as evidence of the

dispersion of light in transit through interstellar space.

Having presented on preceding pages the principal facts of observation, it remains to summarize what appear to be the most probable incidents in the life history of binary systems. It is recognized that some important points remain in doubt, and that apparent exceptions to reasonably general rules exist.

The parent nebula, rotating ever more rapidly about an axis, divides into two masses. Our knowledge of mass ratios in spectroscopic and visual binary systems indicates that the masses of the two component nebulae are not very unequal. They revolve about their mutual center of mass almost or quite in contact, in orbits nearly circular. Their radiating powers, as observed from any point in space, are proportional to their projected areas as viewed from that point. Their spectra are similar, and both spectra are visible in a large number of cases. In general, the masses are large, for it would seem that a large nebulous mass is more liable than a small one to divide into two masses. It may be, for this reason, that binary systems are on the average more massive than those consisting of a single star. Synchronism of revolution and rotation probably exist at first, and may persist throughout a long period of time. Herein may lie a reason why visual triple and quadruple stellar systems are comparatively scarce. Spectroscopic triple systems, such as *Polaris*, and combination spectroscopic and visual triple or multiple systems, such as 13 *Ceti*, *a Geminorum*, ϵ *Lyrae*, etc., are characterized in general by both long and short periods in the same system. The synchronism referred to, in a system originally binary, may have prevented further fission in one or both of the components until after these components had become widely separated.

With advancing time condensation is attended with increasing mean distance and increasing eccentricity, and the type of spectrum gradually changes. Here enters the important and difficult question as to which component, the more massive or the less massive, will live its life the more rapidly, as interpreted by resulting spectral types. The general rule that the secondary members of binary systems are bluer and whiter than the primaries led naturally to the conclusion that the secondaries were the more massive components: the ratios of their surface areas to their masses were smaller than in the cases of the primary components; and the secondary components therefore retained their heat within themselves the more efficiently, thus prolonging the qualities of youth. The geometrical investigations of mass ratios published prior to the present year lent support to

¹⁴ Publ. School of Mines Jekatermoslaw, 32-33, 1905.

¹⁵ L. O. B., 4, 137, 1907.

¹⁶ C. R., 146, 266 and 383, 1908.

¹⁷ Publ. A. O., 1, 32, 1908.

¹⁸ Mitt. Pulk. Stern., 1, 103, 1906.

¹⁹ Publ. A. O., 1, 127-129, 1909.

²⁰ Ap. J., 29, 101, 1909.

this view.²¹ Boss's mass ratios seem now to controvert it strongly. An hypothesis by Huggins, suggested at first²² rather casually, and later²³ discussed more seriously, appears to me to be of great merit, especially when Schuster's extension²⁴ of the hypothesis is applied. Huggins's suggestion is as follows: "Another way of looking at the problem is perhaps possible. May it be that the effect of the great mass on surface density, together with the working of Lane's law, by which the temperature of a condensing gaseous mass so long as it is subject to the laws of a purely gaseous body will continue to rise, will favor in such stars the coming in of a solar type of spectrum at a somewhat relatively early time?" Schuster's extension suggests in effect that the lighter gases,—hydrogen, helium, and so on,—which surround a star in its early age will be pulled down upon a star of small mass but lightly, and a long period will be required for the absorption of these gases. Such a star would remain effectively young, as judged by its spectral type, longer than its more massive primary. In the latter the greater gravitational power would lead to more rapid absorption of the lighter surrounding gases, and the predominant influence of metallic absorption would enter earlier. It seems reasonable to suppose that the greater internal gravitation of the more massive primary will generate heat more rapidly, and cause it to live its life more rapidly than in the case of the less massive secondary. We can easily cite apparent objections to this theory, notably in the case of *Sirius* and its less massive but more yellow companion. It is not impossible that this and other apparent exceptions will disappear through the discovery that the rapidity of evolutionary processes is not dependent upon the single factor gravity, but that there may exist other factors such that for a star lying on one side of certain critical conditions and for a star lying on the other side of these critical conditions life will be lived at different rates.

Excepting the systems of *Sirius* and β *Lyrae*, the facts of observation described in the preceding pages appear to support the view that the more massive component in a binary system lives its life more rapidly than the less massive component. In the case of slit spectrograms showing the spectra of two components, the fainter spectrum belongs to the less massive component. This is true for systems of considerable age, such as α *Leonis*, α *Aurigae*, as well as for O, B and A type systems. In the Harvard list of stars with composite spectra, 22 cases out of 31,

representing essentially all spectral types, assign to the fainter (photographic) spectrum the earlier type. Boss's mass ratios in well known visual binary systems unmistakably attribute greater masses to the primaries of the older spectral type than to the secondaries of the newer spectral type.

It is not intended to convey the impression of a belief that all double stars are developed from single parent nebulae. It may well have occurred that two widely separated nuclei existed as centers of attraction in the very early history of a present double star, such that rotational forces had no part in the formation of these nuclei. The prevailingly high eccentricities in widely separated pairs will of course have to be considered, and difficulties may arise in explaining their existence.

Roberts has said that in the study of *Algol* and β *Lyrae* systems we are searching for facts concerning stars in their early youth. The investigations of spectroscopic binary systems confirm and emphasize this view. Our knowledge of these wonderful systems is covered by a span of but twenty years. That it exceeds in fact our knowledge of visual binary systems is due not so much to the energy and admirable instrumental equipment and methods of spectrographic observers, but chiefly to the condition that the periods of revolution are short. There is danger that the fruitfulness of the newer field of labor will withhold attention from the equally important older field of visual binaries. It is of the utmost desirability that available instruments be applied to the accurate observation of the positions of the primary members in double star systems, with reference to the surrounding stars, by photography, micrometer, heliometer or other applicable means. It is equally desirable that spectroscopic observers measure the radial velocities in as many visual systems as practicable; the velocities of both members where possible, and of the primaries in other cases. Appreciable variations in the positions and speeds, in many cases, may not occur for centuries; but the securing of these observations, for the benefit of posterity, is a pressing duty.

For many numerical data and for valued suggestions concerning the main Catalogue, I am under great obligations to Messrs. E. C. Pickering, Schlesinger, Frost, Slipher and Plaskett, as well as to several of my colleagues. The assistance of Miss Hobe, Carnegie Institution Assistant, and of Miss Glancy, Fellow in the Lick Observatory, in the compilation of the tables is gratefully acknowledged.

W. W. CAMPBELL.

April 15, 1910.

²¹ *Ap. J.*, 25, 65-6, 1907.

²² *Ap. J.*, 6, 326, 1897.

²³ *Atlas of Rep. Spectra*, 68-71, 1899.

²⁴ *Ap. J.*, 17, 165-200, 1903.