LICK OBSERVATORY BULLETIN

NUMBER 79

FIRST CATALOGUE OF SPECTROSCOPIC BINARIES

The application of the Doppler-Fizeau principle to the study of the stars, by photographic means, has led to the discovery of an entirely new class of stellar systems, known as Spectroscopic Binaries. This term is in general applied to those stars which are apparently single when viewed through our most powerful telescopes, but which the spectrograph has shown to be accompanied by invisible companions. However, the condition that the companions shall be invisible is too limited, and it is more satisfactory to class with the spectroscopic binaries all stars whose radial velocities have been observed to vary. The discovery of the first spectroscopic binary, Zeta Ursae Majoris, was made by Professor Pickering in 1889. The objective-prism spectrograms of this star showed that it consisted of two components, approximately equal in brightness, in rapid revolution around their center of mass. The second discovery, made by Professor Vogel from plates secured with a slit spectrograph, related to Algol and the massive and relatively very dark companion which partially occults the bright primary, for terrestrial observers, once each revolution. In successive years additions to the list were made by Pickering, Vogel, Belopolsky, Miss Maury, Mrs. Fleming and Bailey, until, in the summer of 1898, thirteen spectroscopic binaries were known. Since that date the number has increased with great rapidity. The systems observed up to January 1, 1905, numbered one hundred and forty. A tabulation of these by Observatories may be of interest.

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Deduct for binaries independently discovered at two Observatories	7
Total	140

The literature concerning the discovery, observation and study of these systems is quite widely scattered, and the requirements of the work with the Mills Spectrograph have led us to collect and tabulate the data. The time appears to have arrived when their publication, in a form which we venture to entitle a "First Catalogue of Spectroscopic Binaries," will prove useful to many investigators in this and other departments of astronomy. The arrangement of the catalogue, and the significance of the contents, call for a few explanations.

The right ascensions and declinations have been taken from the Draper Catalogue, and the visual magnitudes from Annals Harvard College Observatory, Volume 45. Visual magnitudes for stars not contained in that volume are printed in italics, and are taken from the Bonn Durchmusterung in the case of northern stars and from Gould's Uranometria in the case of southern stars. The magnitudes of variable stars are from Annals Harvard College Observatory, 48, Part 3. Where three designations of spectral type occur the first is that of the Draper catalogue; the second the later Harvard classification (Annals, 28, Parts 1 and 2, and 45), and the third, that used at Potsdam (Potsdam Publications, 12, Part 1). A dagger placed after a quantity indicates that the result stated is subject to considerable uncertainty.

In the Column *T*, giving the time of periastron, a number of dates are expressed in years instead of the Julian Date. In order to prevent any ambiguity such dates have been written thus,—1894 09. In cases where the spectra of both components have been observed this fact is stated in the last column. It does not seem wise, at least at the present time, to divide binaries into two classes on this basis, for the reason that some stars, now showing only one spectrum may eventually show the spectra of both components.

SPECTROSCOPIC BINARIES

No.	Star	R.A. 1900	Decl. 1900	Mag. Vis. Phot.		Type	Period	<i>e</i>
1.	α Andromedae	0 ^b 3 ^m 2	+ 28° 33'	2.3	2.8	A; A Pec. VIII P; Ia 2	100 ^d †	high
2.	α Phoenicis	21.3	— 42 51	2.4	2.6	K	long	.....
3.	π Andromedae	31.5	+ 33 10	4.5	4.5	A; Ib	short	.....
4.	ξ Cassiopeiae	36.5	+ 49 58	4.9	4.9	A.	short†	.....
5.	ν Andromedae	44.3	+ 40 32	4.4	4.7	B; Ib!	short†	.....
6.	η Andromedae	51.9	+ 22 52	4.6	5.4	K	.....	.....
7.	α Ursae Minoris	1 22.6	+ 88 46	2.1	4.4	F? XIIIac; IIa to Ia 3	3 ^d .9683	0.2001
8.	γ Phoenicis	24.0	— 43 50	3.5	...	K 5 M	190 ^d	.....
9.	ϕ Persei	37.4	+ 50 11	4.2	4.3	B; L; Ia 2?	.....	.....
10.	ζ Ceti	46.5	— 10 50	4.0	4.9	K?	several y'rs	.....
11.	ξ Piscium	48.4	+ 2 42	4.9	5.4	I	long	.....
12.	β Arietis	49.1	+ 20 19	2.7	3.7	A; Xa; Ia 2	.....	.....
13.	g Persei	55.6	+ 54 1	5.0	...	A.	.....	.....
14.	ξ_1 Ceti	2 7.7	+ 8 23	4.6	5.1	I	.....	.....
15.	δ Ceti	34.4	— 0 6	3.9	4.1	B; IVa; Ib!	short	.....
16.	12 Persei	35.9	+ 39 46	5.0	5.3	F	short	.....
17.	τ Persei	47.2	+ 52 22	4.1	4.9	G; XIV. C	long†	.....
18.	β Persei	3 1.6	+ 40 34	2.1—3.2	...	A; VIa; Ib	2 ^d .87	.....
19.	σ Persei	38.0	+ 31 59	3.9	4.4	A; IIIa, b; Ib	4 ^d .39	small
20.	20 Tauri (Maia)	39.9	+ 24 4	4.1	4.2	A; B5 A, Va; Ia 1	.....	.....
21.	ϵ Persei	51.1	+ 39 43	2.9	3.8	A; IIa	.....	.....
22.	λ Tauri	55.2	+ 12 13	3.3—4.2	...	B; IVb; Ib	3 ^d .91	.....
23.	X Eridani	4 14.1	— 34 2	3.6	...	B 9 A	short	.....
24.	ν Eridani	31.3	— 3 34	4.0	4.0	A; IVa; Ib	short	.....
25.	τ Tauri	36.2	+ 22 46	4.3	4.2	B Ib	.....	.....
26.	9 Camelopardalis	44.1	+ 66 10	4.4	4.7	A; Ia 2? Ib	.....	.....
27.	π^4 Orionis	45.9	+ 5 26	3.7	4.0	B; B 3 A, IVa; Ib	.....	.....
28.	π^5 Orionis	49.1	+ 2 17	3.9	4.0	B; IVa; Ib!	short	.....
29.	ϵ Aurigae	54.8	+ 43 41	var.	irr.	F; XIIc; IIa!	several y'rs	.....
30.	α Aurigae	5 9.3	+ 45 54	0.2	...	F,G;XIVa; IIa!!	104 ^d .022	0.0164
31.	σ Orionis	16.7	— 0 28	4.6	4.6	B Ib!!	.....	.....
32.	η Orionis	19.4	— 2 29	3.4	3.9	B; IIIa; Ib!	7 ^d .9896	0.016
33.	ψ Orionis	21.6	+ 3 1	4.6	4.5	B Ib	short	.....
34.	χ Aurigae	26.2	+ 32 8	4.7	5.0	A; IIIa, b	.....	.....
35.	δ Orionis	26.9	— 0 23	2.6	var.	B; IIb; Ib!	5 ^d .7333	0.103
36.	θ^1 Orionis	30.3	— 5 27	4.9	...	D?; Oe 5 B, Ib; Ib?	.....	.....
37.	θ^2 Orionis	30.4	— 5 29	5.3	...	D?; IIIb; Ib?	.....	.....
38.	ι Orionis	30.5	— 5 59	2.8	3.4	B; Oe 5 B; Ib	.....	.....
39.	ζ Tauri	31.7	+ 21 5	3.0	3.4	A; Ib!	long	.....
40.	β Doradus	32.7	— 62 33	3.9	...	F; F 5 G	.....	.....
41.	σ Orionis	33.7	— 2 39	3.7	4.0	A; IIb; Ib	short†	.....
42.	β Aurigae	52.2	+ 44 57	2.1	3.5	A; A Pec, VIIIa; Ia 2!!	3 ^d .9597	small
43.	ν Orionis	6 1.8	+ 14 47	4.2	4.6	A; IVa, b; Ib	.....	.....

DISCOVERED BEFORE JANUARY 1, 1905.

No.	ω	T. Jul. Day	$a \sin i$ km.	Vel. of System km.	Discoverer and References
1.					Slipher, Lowell Obs. Bull. No. 11, 1904; also Campbell and Curtis, L.O.B. No. 70, 1905.
2.					Wright, L.O.B. No. 75, 1905.
3.					Frost and Adams, Aph. J. 18, 383, 1903.
4.					Frost and Adams, Aph. J. 18, 383, 1903.
5.					Curtis, L.O.B. No. 31, 1902; Aph. J. 17, 308, 1902.
6.				-12	Campbell, Aph. J. 12, 254, 1900. Both spectra visible.
7.	113°33'9	5398.50	160,400	var.	Triple; Campbell, Aph. J. 10, 180, 1899. Hartmann, Aph. J. 14, 52, 1901. Quoted elements by Hartmann (unpublished). Long period > 12 years, cf. Campbell and Curtis, L.O.B. No. 70, 1905.
8.					Palmer, L.O.B. No. 75, 1905.
9.					Campbell, L.O.B. No. 20, 1902. Bright hydrogen lines, Espin, A. N. 124, 177.
10.					Campbell, L.O.B. No. 70, 1905.
11.					Campbell, L.O.B. No. 4, 1901.
12.					Vogel, A. N. 163, 145, 1903. λ 4481 double(?).
13.					Frost and Adams, Aph. J. 19, 151, 1904.
14.					Campbell, L.O.B. No. 4, 1901.
15.					Frost and Adams, Aph. J. 17, 150, 1903. Range 10 km.
16.				-24	Campbell, Aph. J. 12, 254, 1900. Both spectra visible. M : m :: 4:3.
17.					Campbell, L.O.B. No. 4, 1901.
18.					Vogel, A. N. 121, 241; 123, 289, 1889; Potsdam Pub. 7, 1, 111.
19.			6,640,000	small	Adams, Aph. J. 15, 214, 1902. Range 220 km. Elements by Vogel, Berlin Sitz, Ber. 53, 1113-1121, and Aph. J. 17, 212, 1903.
20.					Adams, Aph. J. 19, 338, 1904. Range 27 km.
21.					Frost and Adams, Aph. J. 19, 151, 1904.
22.					Belopolsky, A. N. 145, 281, 1898. Both spectra visible.
23.					Wright, L.O.B. No. 75, 1905. Both spectra visible.
24.					Frost and Adams, Aph. J. 17, 150, 1903.
25.					Frost and Adams, Aph. J. 17, 246, 1903.
26.					Frost and Adams, Aph. J. 19, 350, 1904.
27.					Curtis, L.O.B. No. 31, 1902; Aph. J. 17, 309, 1903; cf. Frost and Adams, Aph. J. 17, 153, 1903.
28.					Frost and Adams, Aph. J. 17, 150, 1903.
29.					Vogel, Aph. J. 17, 243, 1903; cf. Campbell and Curtis, L.O.B. No. 70, 1905. Ludendorff, A. N. 164, 81 (cf. Marekwick, M. N. 65, 83), finds it an Algol variable, period 27 years.
30.	117°3	4899.5	36,847,900	+30.2	Campbell, Aph. J. 10, 177, 1899; also Newall, M. N. 60, 418, 1899. Both spectra visible. Orbit by Reese, L.O.B. No. 6, 1901.
31.					Frost and Adams, Aph. J. 18, 383, 1903. Range small.
32.	42°16'	5720.821	15,901,000	+35.5	Frost and Adams, announced Dec., 1901; Aph. J. 15, 214, 1902. Range 285 km. Orbit by Adams, Aph. J. 17, 68.
33.					Frost and Adams, Aph. J. 17, 246, 1903. Range > 260 km.
34.					Frost and Adams, Aph. J. 18, 383, 1903.
35.	33°18'9	5793.35	7,906,600	+23.1	Deslandres, C. R. 130, 379, 1900. Cf. Wright, L.O.B. No. 4, 1901. Orbit by Hartmann, Aph. J. 19, 268, 1904.
36.					Frost and Adams, Aph. J. 19, 151, 1904. Range 60 km.
37.					Frost and Adams, Aph. J. 19, 151, 1904. Range 140 km.
38.					Frost and Adams, Aph. J. 18, 383, 1903.
39.					Frost and Adams, Aph. J. 17, 150, 1903.
40.					Wright, L.O.B. No. 60, 1904.
41.					Frost and Adams, Aph. J. 19, 151, 1904. Range 21 km.
42.					Maury, 1889, Fourth Rep. Draper Memorial, 1890. Both spectra visible. Cf. Belopolsky, A. N. 127, 251, 1891; Vogel, A. N. 126, 265, 1891; Maury, Aph. J. 8, 173, 1898; Tiekhoff, A. N. 164, 49; Vogel, A. N. 165, 113, 1903, and Aph. J. 19, 360, 1904.
43.					Frost and Adams, Aph. J. 18, 383, 1903.

SPECTROSCOPIC BINARIES

No.	Star	R.A. 1900	Decl. 1900	Mag. Vis. Phot.		Type		Period	<i>e</i>
44.	ξ Orionis	6 ^h 6 ^m 2	+ 14° 14'	4.4	4.4	B; IVa, b;	Ib!	.....	.....
45.	η Geminorum	8.8	+ 22 33	3.2—4.2	...	M; XVIIIa		long	.....
46.	δ Columbae	18.4	— 33 23	4.0	3.8	G 5 K		long†	.....
47.	γ Geminorum	31.9	+ 16 29	1.9	2.9	A; VIIIa;	Ia 2!	long	.....
48.	S Monocerotis	35.5	+ 10 0	4.9—5.4	...	A; Ib;	Ib?	.....	.....
49.	α Canis Majoris	40.7	— 16 34	—1.7	...	A; VIIa;	Ia 2	48.84 years	0.5875
50.	ζ Geminorum	58.2	+ 20 43	3.8—4.3	...	H; XIVae		10 ^d .154	0.22
51.	γ Canis Minoris	7 22.8	+ 9 8	4.6	5.4	I		long	.....
52.	σ Puppis	26.1	— 43 6	3.3	...	K 5 M		.....	.....
53.	α ₁ Geminorum	28.2	+ 32 7	3.7	...	A; VIIIa;	Ia 2	2 ^d .92835	0.07
54.	α ₂ Geminorum	28.2	+ 32 7	2.7	...	A; VIIIa		9 ^d .21883	0.503
55.	α Geminorum	28.2	+ 32 7	...	...	.....		347 years	0.4409
56.	σ Geminorum	37.0	+ 29 7	4.4	5.5	I; XVa		short	.....
57.	α Puppis	48.8	— 40 19	3.9	...	G 5 K		.....	.....
58.	V Puppis	55.3	— 48 58	4.1—4.8	...	B 1 A Pec.		1 ^d .454	.....
59.	ι Argus	8 3.3	— 24 1	2.9	3.8	G; F 5 G, XIIa		long	.....
60.	η Hydrae	38.0	+ 3 46	4.4	4.2	A; IVab;	Ia 2? Ib	short	.....
61.	ε Hydrae	41.5	+ 6 48	3.5	4.3	F; XIIIa;	IIa	15.7 years	0.685
62.	w Velorum	56.3	— 40 52	4.5 var.	...	F 8 G		.....	.....
63.	α Volantis	9 0.9	— 66 0	4.2	...	A 5 F		.....	.....
64.	κ Cancri	2.4	+ 11 4	5.0	5.3	A	Ib	.....	.....
65.	ο Leonis	35.8	+ 10 21	3.7	4.3	G; XII. C.;	Ia 3 to IIa	14 ^d .5	.....
66.	l Carinae	42.5	— 63 3	3.6—5.0	...	G; G		.....	.....
67.	γ Leonis	10 14.4	+ 20 21	2.4	3.7	K; XVa		402 ^d .62	0.739
68.	p Velorum	33.2	— 47 43	4.1	...	F 2 G		.....	.....
69.	ω Ursae Majoris	48.2	+ 43 43	4.8	4.7		I a 2	.....	.....
70.	ξ Ursae Majoris (brighter component)	11 12.9	+ 32 6	3.9	4.7	G; XIVa		.....	.....
71.	93 Leonis	42.8	+ 20 46	4.5	4.8	F;	Ia 3 to IIa	.....	.....
72.	γ Corvi	12 10.7	— 16 59	2.7	3.3	A; VIa		short	.....
73.	η Virginis	14.8	— 0 6	4.0	4.2	A; VIIIa;	Ia 2	short	.....
74.	γ Virginis	36.6	— 0 54	2.9	3.8	F; XIab;	Ia 2 N to Ia 3 S	180 years	0.898
75.	ε Ursae Majoris	12 49.6	+ 56 30	1.4	...	A; VIII P;	Ia 2	long	.....
76.	ζ Ursae Majoris	13 19.9	+ 55 27	2.1	...	A; VIIIa;	Ia 2!	20 ^d .54	.....
77.	α Virginis	19.9	— 10 38	1.2	2.4	A; B 2 A, IIIb;	Ib!	4.0	.....

DISCOVERED BEFORE JANUARY 1, 1905.

No.	ω	T Jul. Day	$a \sin i$ km.	Vel. of System km.	Discoverer and References
44.	.....	.....	.....	.....	Frost and Adams, Aph. J. 19, 151, 1904. Range 22 km.
45.	.....	.....	.....	.....	Reese, L.O.B. No. 20, 1902. Period of light variation 231.4d.
46.	.....	.....	.....	.....	Palmer, L.O.B. No. 75, 1905.
47.	.....	.....	.....	.....	Burns, L.O.B. No. 70, 1905.
48.	.....	.....	.....	.....	Frost and Adams, Aph. J. 19, 151, 1904. Range 25 km.
49.	147°53.6	1894 ^v .09	.....	- 7.4	Campbell, L.O.B. No. 70, 1905; Aph. J. 21, 176, 1905. Cf. Adams, Aph. J. 15, 214, 1902. Visual elements by Zwiers, Proc. Amsterdam Acad., May 27, 1899.
50.	333°	.....	1,797,800	+ 6.8	Belopolsky, in (apparently unpublished) lecture before Russ. Astr. Gesellschaft (cf. A. N. 149, 239, 1899), and Campbell, Aph. J. 9, 86, 1899. Orbit by Campbell in Aph. J. 13, 90. Subordinate period of 3.38d, double amplitude 4.5 km.
51.	.....	.....	.....	.....	Reese, L.O.B. No. 20, 1902.
52.	.....	.....	.....	.....	Palmer, L.O.B. No. 75, 1905.
53.	.....	.....	.....	var.	Belopolsky, Bull. Acad. Sci., St. Petersburg, Dec., 1896; Mem. Acad., St. Petersburg, 11, 4, 1900; period 2.934d with revolution of line of Apsides in 1460 days; $e=0.12$; ω (1896, Jan. 0 ^h 0) = 80°. Quoted elements by Curtis, 1904 (unpublished).
54.	265°35	6746.385	.....	var.	Curtis, L.O.B. No. 70, 1905. Elements by Curtis, unpublished.
55.	33°93	1969 ^v .82	$a=5^{\circ}76$	.....	Curtis, L.O.B. No. 70, 1905, finds (1905.0) velocity of the system of a_1 , -2 km., for a_2 , +6 km. Quoted elements of visual system by Dobereck, A. N. 166, 145, 1904.
56.	.....	.....	.....	.....	Reese, L. O. B. No. 31, 1903.
57.	.....	.....	.....	.....	Wright, L.O.B. No. 75, 1905.
58.	.....	.....	.....	.....	Pickering, H.C.O. Circ. No. 14 and 21, A. N. 142, 107, 1896. Both spectra visible. Relative velocity 610 km. Roberts, Aph. J. 13, 177, finds companion to revolve in contact.
59.	.....	.....	.....	.....	Campbell, L.O.B. No. 31, 1903; Aph. J. 17, 309, 1903.
60.	.....	.....	.....	.....	Frost and Adams, Aph. J. 19, 151, 1904.
61.	264°7	1901 ^v .1	$a=0^{\circ}24$	.....	Campbell, L. O. B. No. 4, 1901. Elements are for the visual orbit by Aitken, L. O. B. No. 36, 1903.
62.	.....	.....	.....	.....	Wright, L.O.B. No. 60, 1904. The light period is 35.523d
63.	.....	.....	.....	.....	Wright, L.O.B. No. 75, 1905. Both spectra visible.
64.	.....	.....	.....	.....	Frost and Adams, Aph. J. 19, 350, 1904. Both spectra visible.
65.	.....	.....	.....	.....	Campbell, Aph. J. 8, 291, 1898.
66.	.....	.....	.....	.....	Wright, L. O. B. No. 60, 1904.
67.	194°32	1741 ^v .11	$a=2^{\circ}00$	-38.4	Visual Binary. Belopolsky, A. N. 147, 92, 1898, finds relative velocity of the two components =2.2 km., giving $\pi=0^{\circ}02$; $M+m=6.5 \odot$. Quoted visual elements by Dobereck.
68.	.....	.....	.....	.....	Wright, L.O.B. No. 75, 1905. Both spectra visible.
69.	.....	.....	.....	.....	Vogel, A. N. 163, 745, 1903.
70.	.....	.....	.....	.....	Wright, Aph. J. 12, 254, 1900. A triple system. The elements are, for the visual system, $P=60^{\circ}80$, $e=0.4159$, $\omega=235^{\circ}0$, $T=1875.26$, $a=2^{\circ}58$ (Gledhill and Wilson, 273)
71.	.....	.....	.....	.....	Campbell and Wright, Aph. J. 12, 254, 1900.
72.	.....	.....	.....	.....	Campbell and Curtis, L.O.B. No. 46, 1903.
73.	.....	.....	.....	.....	Frost and Adams, Aph. J. 17, 150, 1903; also Campbell and Curtis, L.O.B. No. 46, 1903. Both spectra visible.
74.	93°92	1836 ^v .45	$a=3^{\circ}94$	-20.7	Visual Binary. Belopolsky, A. N. 147, 89, 1898, finds relative velocity of the two components =2.1 km., giving $\pi=0^{\circ}05$; $M+m=15 \odot$. Quoted visual elements by Dobereck.
75.	.....	.....	.....	.....	Adams, Aph. J. 18, 67, 1903, from Vogel's early measures. Cf. Vogel, A. N. 163, 145, 1903.
76.	.....	.....	.....	.....	Pickering, 1889, H.C.O. Circ. No. 11; M. N. 50, 296; Amer. Jour. of Science, 39, 46. Period by Vogel (unpublished). Cf. Vogel, Aph. J. 13, 324, A. N. 126, 265, 1891; 155, 317, 1901. Both spectra visible. First spectroscopic binary.
77.	.....	.....	.....	.....	Vogel, A. N. 125, 305, 1890; 127, 255, 1891. Pots. Pub. 7, 127.

SPECTROSCOPIC BINARIES

No.	Star	R.A. 1900		Decl. 1900	Mag. Vis. Phot.		Type		Period	<i>e</i>
78.	ζ Centauri	13 ^h 49 ^m 3		— 46° 47'	2.8	...	B 2 A Pec.		8 ^d .024	.....
79.	η Bootis	49.9		+ 18 54	2.8	3.8	G; XIVa;	Ia!	long	.....
80.	α Draconis	14	1.7	+ 64 51	3.6	4.0	A; VIIa;	Ia 1? to Ia 2	.....	.....
81.	d Bootis	5.9		+ 25 34	4.8	5.2	F	Ia 3 to IIa	short	.....
82.	α Centauri	32.8		— 60 25	{ 1.0 3.5	...	{ G G K 5 M		81 ^d .185	0.52865
83.	α Librae	45.4		— 15 37	2.7	3.3	A; IXab		short	.....
84.	β Lupi	52.0		— 42 44	2.8	...	B 2 A Pec.		.....	.....
85.	δ Librae	55.6		— 8 7	5.0—6.2	...	A; VII a		2 ^d .33	.....
86.	ε Librae	15	18.8	— 9 57	5.0	4.8	F		90 + days	.....
87.	α Coronae Borealis	30.4		+ 27 3	2.2	3.4	A; VIIIab;	Ia 2	.....	.....
88.	π Scorpil	52.8		— 25 49	3.0	3.5	B 2 A Pec., IIIb		1 ^d .57	.....
89.	β Scorpil	59.6		— 19 32	2.7	3.0	B; B 1 A, IIIb		6 ^d .88±	.....
90.	θ Draconis	16	0.1	+ 58 50	4.1	4.8	F; XIIIa;	Ia!	3 ^d .0708	0.016
91.	σ Scorpil	15.1		— 25 21	3.0	3.8	A; B 1 A, IIa, b		short	.....
92.	β Herculis	26.0		+ 21 42	2.9	4.2	K; XVa		410 ^d .58	0.55
93.	ζ Herculis	37.5		+ 31 47	2.9	3.9	G; XIVa;	Ia to IIIa!	33.9 years	0.560
94.	μ ¹ Scorpil	45.1		— 37 53	3.1	...	B 3 A Pec.		1 ^d .45	.....
95.	h Draconis	55.4		+ 65 17	4.9	5.3	F;	Ia 3!	.....	.....
96.	ε Ursae Minoris	56.2		+ 82 12	4.4	4.9	K; XIVa		short	.....
97.	ε Herculis	56.5		+ 31 4	3.8	3.9	A; VIIa;	Ia 2	short	.....
98.	u Herculis	17	13.6	+ 33 12	4.6—5.4	...	A	Ib	short	.....
99.	λ Scorpil	26.8		— 37 2	1.4	...	B 2 A		5 ^d .6±	.....
100.	ξ Serpentis	31.8		— 15 20	3.6	4.0	A; Xa, b.		short	.....
101.	ω Draconis	37.5		+ 68 48	4.9	5.3	F;	Ia 3 to IIa!	short	.....
102.	X Sagittarii	41.3		— 27 48	4.4—5.4	...	K; F 8 G		7 ^d .01	.....
103.	W Sagittarii	58.6		— 29 35	4.3—5.1	...	G; F 5 G		7 ^d .5946	0.32
104.	μ Sagittarii	18	7.8	— 21 5	4.0	4.2	F; B 8 A Pec, VIc		.....	.....
105.	Y Sagittarii	15.5		— 18 55	5.4—6.2	...	G		5 ^d .7734	0.3±
106.	χ Draconis	22.8		+ 72 42	3.7	4.2	F; XIIIa;	IIa	281 ^d .8	0.423
107.	2 Scuti	36.8		— 9 9	4.6	4.9	F		.....	.....
108.	ζ Lyrae, pr.	41.3		+ 37 30	4.2	4.7	A;	Ia 2 to Ia 3	.....	.....
109.	β Scuti	41.8		— 4 51	4.5	4.8	H		long†	.....
110.	β Lyrae	46.3		+ 33 15	3.4—4.1	...	G; C, L;	Ib!! and Ic 2!!	12 ^d .908	0.07
111.	κ Pavonis	46.6		— 67 21	3.8—5.2	...	F 5 G		9 ^d .091?	.....
112.	δ' Lyrae	50.2		+ 36 51	5.6	...	A; IVb		.....	.....
113.	113 Herculis	50.5		+ 22 32	4.6	5.3	G		.....	.....
114.	τ Sagittarii	19	0.7	— 27 49	3.5	4.5	H; K		.....	.....
115.	18 Aquilae	2.3		+ 10 55	5.1	4.7	A	Ib	.....	.....
116.	ν Sagittarii	16.0		— 16 8	4.4	5.2	F; C, L.		.....	.....
117.	δ Aquilae	20.5		+ 2 55	3.4	4.0	A; XIa, b;	Ia 3	.....	.....
118.	η Aquilae	47.4		+ 0 45	3.7—4.5	...	G; XIVac.		7 ^d .176	0.489
119.	S Sagittae	51.5		+ 16 22	5.5—6.1	...	G		8.3832	.....
120.	θ Aquilae	20	6.2	— 1 7	3.4	3.6	A; VIIa;	Ia 2	17 ^d±	.....

DISCOVERED BEFORE JANUARY 1, 1905.

No.	e	T Jul. Day	$a \sin i$ km.	Vel. of System km.	Discoverer and References
78.					Fleming, 1899. Both spectra visible, components unequally bright.
79.					Moore, L.O.B. No. 70, 1905.
80.					Campbell and Curtis, L.O.B. No. 46, 1903.
81.					Wright, Aph. J. 12, 254, 1900.
82.	52°01	1875 ^v .715	$a = 17''.71$	-21+	Visual Binary. Wright, L.O.B. No. 60, 1904, finds relative velocity of 5.17 km., giving $\pi = 0''.76$; $a = 3.46 \cdot 10^2$; $M + m = 1.9 \odot$. Quoted visual elements by Roberts, A. N. 133, 105, 1893 and 139, 7, 1896.
83.					Slipher, Lowell Obs. Bull. No. 11, 1904. Range of 80 km.
84.					Fleming, 1897, cf. H.C.O. Circ. No. 21. Both spectra visible.
85.					Adams, Aph. J. 15, 214, 1902.
86.					Campbell, Aph. J. 10, 178, 1900.
87.					Hartmann, A. N. 163, 31, 1903. Range > 60 km.
88.					Cannon, 1899. Both spectra visible.
89.					Slipher, Lower Obs. Bull. No. 1, 1903; also Adams, Aph. J. 18, 69, 1903.
90.	103°47	5368.772	.....	- 8.4	Campbell, Aph. J. 9, 311, 1899. Elements by Curtis, unpublished.
91.					Slipher, Lowell Obs. Bull. No. 11, 1904. Range of 50 km.
92.	29°73	.....	63,560,000	-25.5	Campbell, Aph. J. 11, 140, 1899. Elements by Reese, unpublished.
93.	101°	1898 ^v .09	$a = 1''.40$	.....	Campbell, L.O.B. No. 20, 1902. Visual binary. Quoted visual elements by Lewis, M. N. 61, 74, 1900. Negatively increasing velocities show that in visual orbit i is -50° (unpublished). Belopolsky, A. N. 133, 257, 1894, and A. and A. P. 1894, p. 130.
94.					Bailey, H.C.O. Circ. No. 11, A. N. 141, 271; 142, 11, 1896. Both spectra visible. Relative velocity 460 km.
95.					Campbell, Aph. J. 10, 178, 1899.
96.					Campbell, Aph. J. 10, 179, 1899.
97.					Campbell and Curtis, L.O.B. No. 46, 1903, and Adams, Aph. J. 18, 67, 1903.
98.					Frost and Adams, Aph. J. 17, 381, 1903. Variable of irregular period.
99.					Slipher, Lowell Obs. Bull. No. 4, 1903.
100.					Curtis, L.O.B. No. 70, 1905.
101.					Campbell, Aph. J. 10, 179, 1899.
102.					Slipher, Lowell Obs. Bull. No. 11, 1904. Range 23 km.
103.	70°0	2855.65	1,930,000	-28.6	Curtiss, L.O.B. No. 62, 1904, and Aph. J. 20, 149, 1904. Elements by Curtiss who finds a secondary curve of period 3.80d and range of 9.7 km.
104.					Frost and Adams, Aph. J. 19, 350, 1904.
105.					Curtiss, Aph. J. 20, 231, 1904, and L.O.B. No. 62, 1904.
106.	119°0	4864.3	62,020,000	+32.4	Campbell, Aph. J. 8, 292, 1898. Elements by Wright, Aph. J. 11, 131, 1900.
107.					Wright, Aph. J. 12, 254, 1900.
108.					Curtis, L.O.B. No. 70, 1905.
109.					Wright, Aph. J. 12, 254, 1900.
110.	83°	.....	32,000,000	-15	Pickering, A. N. 128, 39, 1891. Both spectra visible. Vogel, A. and A. P., 1894, pp. 358, 562; Lockyer, <i>ibid.</i> , p. 575; Belopolsky, Aph. J. 6, 328, 1897; Myers, Aph. J. 7, 1, 1898; Sidgreaves, M. N. 64, 3, p. 168.
111.					Wright, L.O.B. No. 60, 1904. The period is probably the same as that of the light variation.
112.					Frost and Adams, Aph. J. 19, 350, 1904.
113.					Wright, Aph. J. 12, 254, 1900.
114.					Wright, L.O.B. No. 60, 1904; also Curtis, L.O.B. No. 70, 1905.
115.					Frost and Adams, 18, 383, 1903.
116.					Campbell, Aph. J. 10, 241, 1899. Bright helium.
117.					Campbell and Curtis, L.O.B. No. 46, 1903.
118.	68°91	.....	1,545,000	-14.2	Belopolsky, Aph. J. 1, 160, 1895; 6, 393, 1897. Elements by Wright in Aph. J. 9, 59, 1899.
119.					Curtiss, L.O.B. No. 62, 1904, Aph. J. 20, 231. The period is that of the light variation.
120.					Deslandres, Bull. Astr. 20, 129, 1903.

SPECTROSCOPIC BINARIES

No.	Star	R.A. 1900	Decl. 1900	Mag. Vis.	Phot.	Type	Period	<i>e</i>
121.	α^1 (31) Cygni	20 ^h 10 ^m 5	+ 46° 26'	4.0	5.2	K; XV. C; Ia 2	.....	.....
122.	β Capricorni	15.4	— 15 5	3.2	4.2	G; XIV. C	3.3 years	.....
123.	71 Aquilae	33.2	— 1 27	4.6	5.4	H	long†	.....
124.	T Vulpeculae	47.2	+ 27 52	5.5—6.2	...	F	4 ^d .4358	.....
125.	57 Cygni	49.7	+ 44 0	4.6	4.7	B	Ib	short
126.	61 Cygni	21 2.4	+ 38 15	5.3	6.2	H	very long	.....
127.	δ Equulei	9.6	+ 9 36	4.6	5.1	F; IIa!	5.7 years	0.46
128.	α Equulei	10.8	+ 4 50	4.2	4.6	A; XIII. C; Ia 3 to IIa	long†	.....
129.	β Cephei	27.4	+ 70 7	3.4	3.8	A; IIIa; Ib	a few days	.....
130.	ϵ Capricorni	31.5	— 19 54	4.7	4.4	A	short	.....
131.	κ Pegasi	40.2	+ 25 11	4.3	5.0	F; XIIa; Ia 3!	6 ^d+	.....
132.	ι Pegasi	22 2.3	+ 24 51	4.0	4.4	F; XIIa; IIa!	10 ^d .2131	0.0085
133.	2 Lacertae	16.9	+ 46 2	4.7	4.6	A	Ib	.....
134.	δ Cephei	25.4	+ 57 54	3.7—4.6	...	F; XIVac; IIa!	5 ^d .367	0.46
135.	6 Lacertae	26.1	+ 42 36	4.6	4.5	B; Ib	.....	.....
136.	η Pegasi	38.3	+ 29 42	3.0	4.2	G; XIVa	818 ^d .0	0.1548
137.	α Andromedae	57.3	+ 41 47	3.5	3.9	A; V. C; Ia 2? Ib	.....	.....
138.	π Cephei	23 4.7	+ 74 51	4.6	5.5	H	.....	.....
139.	1 Hev. Cassiopeiae	25.4	+ 57 59	4.8	5.0	B IVb	Ib	.....
140.	λ Andromedae	32.6	+ 45 56	3.9	5.0	K; XVa.	20 ^d .5	.....

DISCOVERED BEFORE JANUARY 1, 1905.

No.	ω	T Jul. Day	$a \sin i$ km.	Vel. of System km.	Discoverer and References
121.					Campbell, L.O.B. No. 4, 1901.
122.					Campbell, Aph. J. 10, 241, 1899.
123.					Curtis, L.O.B. No. 70, 1905.
124.					Frost, Aph. J. 20, 296, 1904. The period is probably that of the light variation which is the one given here.
125.					Frost and Adams, Aph. J. 17, 381, 1903. Both spectra visible.
126.				-62	Adams, Aph. J. 18, 67, 1903, finds a velocity of -62 km. for 61 ₁ Cygni and -63 km. for 61 ₂ Cygni. Visual double star.
127.		1901 ^v .5	$a = 0''.28$	.....	Campbell, L.O.B. No. 4, 1901. Hussey, from relative velocity of 20.5 km. derives $\pi = 0''.071$, $M + m = 1.89 \odot$. Elements are for the visual system by Hussey in L.O.B. No. 32, 1903.
128.					Wright, L.O.B. No. 20, 1902.
129.					Frost and Adams, Aph. J. 15, 340, 1902.
130.					Slipher, Lowell Obs. Bull. No. 11, 1904.
131.				var. ?	Campbell, Aph. J. 12, 254, 1900. System triple, as star is a visual binary with a period of 11 years.
132.	251°81	4820.966	6,740,000	-4.1	Campbell, A. N. 155, 249, 1901; Aph. J. 9, 310, 1899. Elements by Curtis, L.O.B. No. 53, 1904; Aph. J. 19, 212, 1904.
133.					Frost and Adams, Aph. J. 18, 383, 1903. Both spectra visible.
134.	272°	.....	1,300,000	-18	Belopolsky, A. N. 136, 281, 1894; 140, 17, 1896; Aph. J. 1, 160, 1895; cf. also Aph. J. 3, 227, 1896. Elements by Belopolsky.
135.					Frost and Adams, Aph. J. 18, 383, 1903.
136.	5°605	5288.7	157,800,000	+4.3	Campbell, Aph. J. 8, 159, 1898. Cf. Belopolsky, A. N. 148, 127, 1898. Orbit by Crawford, L.O.B. No. 5, 1901.
137.					Wright, L.O.B. No. 20, 1902.
138.					Campbell, L.O.B. No. 4, 1901.
139.					Frost and Adams, Aph. J. 18, 383, 1903.
140.					Campbell, Aph. J. 10, 178, 1899

Strictly speaking, the six stars α_1 - α_2 Geminorum, γ Leonis, γ Virginis, α Centauri, 61 Cygni and δ Equulei, have not yet been observed as spectroscopic binaries. The *differences* of the radial speeds of their components have been measured, but these differences have not been observed to vary. However, their inclusion is a convenience and, we think, unobjectionable. While every visual binary carries the possibility of measurement as a spectroscopic binary, the number of such stars available for observation in the near future is limited, and all such may well be placed upon the spectrographic observing list.

The number of spectroscopic binary systems, not resolvable by our powerful telescopes, is relatively very large. Of the stars studied with the Mills Spectrograph, at least one in seven seems to be an invisible binary of short period. For the "Orion" type stars, observed especially with the Bruce Spectrograph, the remarkable proportion of one in three was found.

Only those systems have been detected whose periods are relatively short, and for which the variations of radial speed are considerable. The smallest observed variation is that of Polaris,—six kilometers per second. Had the variation for Polaris been only one kilometer, it would no doubt have escaped detection. Such a variation could be measured by present instruments and methods; but this range would not have excited the observer's suspicion, and the discovery would have remained for the future. It is probable that there are more systems with variations of speed under six kilometers than there are with larger ones; and all such are awaiting discovery. The velocity of our sun through space varies slightly, because it is attended by companions,—very minute ones compared with the invisible bodies discovered in spectroscopic binary systems. It is revolving around the center of mass of itself and its planets and their moons. Its orbit around this center is small, and the orbital speed very slight. The total range of speed is but three one-hundredths of a kilometer per second. An observer favorably situated in another system, provided with instruments enabling him to measure speeds with absolute accuracy, could detect this variation, and in time say that our sun is attended by planets. At present, terrestrial observers have not the power to measure such minute variations. As the accuracy attainable improves with experience, the proportional number of spectroscopic binaries discovered will undoubtedly be enormously increased. In fact, the star which seems not to be attended by dark companions may be the rare exception. There is the further possibility that the stars attended by massive companions, rather than by

small planets, are in a decided majority; suggesting, at least, that our solar system may prove to be an extreme type of system, rather than a common or average type.

The number of spectroscopic binaries discoverable by present means is certainly a large proportion of the stars brighter than the eighth photographic magnitude. This is about the present limit for successful observation. It must be remembered that in a spectrum the light is spread over a large area. The recording of the spectrum of a ninth magnitude star, using moderate dispersion, is perhaps comparable with photographing a twentieth magnitude star by means of our powerful reflecting telescopes. Further, the successful measurement of moderate dispersion spectrograms requires that the image be of good intensity and that the observational conditions be favorable.

In any given list of stars the number of binaries discoverable by spectrographic means seems to exceed greatly the number observable visually. Messrs. Hussey and Aitken have found that of stars brighter than the ninth magnitude, one in eighteen is double in the 36-inch refractor, with components less than 5" apart. This limit of 5" represents in general a continually increasing linear separation of the components as we pass to fainter and fainter stars. The ability of the spectrograph to resolve close pairs, on the other hand, is independent of their distances from us, provided they supply sufficient light for accurate observation and their spectra contain measurable lines.

The companions of binaries discovered by means of the spectrograph have not been observed visually in our powerful telescopes, although they have been carefully searched for. They may be so close to the principal star that, viewed from our distance, the two images cannot be resolved. The separation of the components is probably less than one hundredth of a second of arc for most of the binaries thus far announced. Again, for very few of the systems are the spectra of both components recorded. This does not establish that the companion is a dark body, but only that it is at least one or two photographic magnitudes fainter than the primary. The fourth-magnitude companion of a second-magnitude star would scarcely be able to impress its lines upon the primary's spectrum. The invisible components in many spectrographic binaries might be conspicuous stars if they stood alone.

It is evident that future catalogues of spectroscopic binaries will contain thousands of entries. It will be neither possible nor desirable for them to include the observational data. Mainly for this reason

we have decided in the present catalogue to let references to the original publication suffice in nearly all cases.

The blank spaces in the columns of orbital elements emphasize the strong need for work in that direction. There can be little doubt that a comparative study of spectroscopic orbits, and of spectro-

scopic and visual orbits, would be most fruitful of results.

The following four binaries were discovered after January 1, 1905, and are therefore omitted from the catalogue. They include all that are known to us at the date of publication.

Star	R.A. 1900	Dec. 1900	Mag.	Type	Discoverer
θ , Eridani	2 ^h 54.5 ^m	—40° 42'	3±	K 2 M	Wright, L. O. B. No. 75, 1905. Both spectra visible.
A Carinae	6 47.6	—53 31	4.4	G 5 K	Wright, L. O. B. No. 75, 1905.
a Carinae	9 8.4	—58 33	3.5	B 3 A	Wright, L. O. B. No. 75, 1905. Some evidence of second spectrum.
κ Velorum	9 19.0	—54 35	2.6	B 3 A	Wright, L. O. B. No. 75, 1905.

April 10, 1905.

W. W. CAMPBELL,
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