CHAPTER VIII

THE DISCOVERY OF ECLIPSING STARS

It has long been known that there must be a considerable number of eclipsing systems among the short-period spectroscopic binaries, and the first two stars, β Aurigae and δ Orionis, which I tested in 1910, turned out to be eclipsing variables. We now have considerably more evidence from the numerous stars that have since been observed. In his study of spectroscopic binaries[1] Otto Struve has exhibited in several diagrams for different spectral classes the relation between the semi-amplitude K of the velocity-variation and the logarithm of the period. As all of the data in regard to eclipsing stars was not available to Struve, it seems worth while to reconstruct his diagrams for the O, B, and A stars, and to show the relation between the eclipsing and non-eclipsing systems.

To that end there are brought together in Table I the stars which may be considered to have been detected as variable from the tests of spectroscopic binaries. There are included the previously known eclipsing stars brighter than magnitude 6.5, which would presumably have been on the radial-velocity programs independently of their large light variation. Stars south of declination —30° are omitted from this discussion. In addition to the eclipsing stars are several ellipsoidal or continuous variables, and the two so-called Cepheids, β Cephei and 12 Lacertae. All of the variables are of spectrum B or A, with the exception of ζ Andromedae which is the only star of later type that I have been able to establish as a regular ellipsoidal variable. The list contains twenty-nine stars, of which eight were discovered visually, one by Hertzsprung from photographic tests, five by Guthnick, while fifteen are the result of the present work. It is believed that no question can be raised as to the variability of any of these stars. I have omitted several objects as insufficiently tested, among them α Virginis[2] for which there is no good comparison star available. Another case is H. R. 8427 which seems to have a continuous variation with range of $0^{M}.10$, but this needs further study. A star in the list not previously announced as variable is H. R. 2027, 31 Camelopardalis, of which we now have observations on more than thirty nights in 1924-1927. This is an eclipsing system with a primary minimum of $0^{M}.20$, a secondary of $0^{M}.10$, and ellipsoidal variation between minima.

As the list in Table I is used to show the high probability of light-variation among the spectroscopic binaries, the inclusion of any other stars would simply increase the proportions of variables.

[1] *Monthly Notices*, **86**, 63, 1925.
[2] *Astrophysical Journal*, **39**, 475, 1914.

TABLE I

VARIABLE STARS

Boss	H. R.	Star	Mag.	Spec.	P	K_1	Remarks
					d	km/sec.	
46	65	Boss 46	6.12	B0	3.52	217	Two spectra. Guthnick
150	192	21 Cassiop.	5.59	A2	4.47	72	
164	215	ζ Androm.	4.30	K0	17.77	26	Ellipsoidal
....	815	RZ Cassiop.	6.4	A0	1.20	69	Visual
708	936	β Persei	2.1	B8	2.87	42	Visual
844	1131	*o* Persei	3.94	B1	4.42	112	Two spectra. Continuous, Guthnick
920	1239	λ Tauri	3 3	B3	3.95	56	Two spectra. Visual
....	....	H. D. 25833	6.61	B3	2.03	165	Two spectra.
986	1324	*b* Persei	4.57	A2	1.53	42	Two spectra. Ellipsoidal
1159	1567	π^5 Orionis	3.87	B3	3.70	58	Ellipsoidal
1301	1788	η Orionis	3.44	B1	7.99	145	Two spectra
1339	1852	δ Orionis	2.48	B0	5.73	100	
1349	1868	VV Orionis	5.37	B2	1.48	132	Photographic, Hertzsprung
1452	2027	31 Camelop.	5.26	A0	2.93	76	Two spectra
1478	2088	β Aurigae	2.07	A0p	3.96	109	Two spectra
1607	2291	Boss 1607	5.50	A3	9.94	67	Guthnick
1646	2372	WW Aurigae	5.98	A0	2.52	116	Two spectra. Visual
3371	4915	α Can. Ven.	2.90	A0p	5.50	22	Continuous, Guthnick
3825	5586	δ Librae	4.84	A0	2.33	76	Visual
3961	5793	α Coronae	2.31	A0	17.36	35	
....	6414	U Ophiuchi	5.76	B8	1.68	180	Visual
4388	6431	*u* Herculis	4.6	B3	2.05	100	Two spectra. Visual
4776	7106	β Lyrae	3.36	B8p	12.91	181	Two spectra. Visual
5018	7474	σ Aquilae	5.17	B3	1.95	164	Two spectra
5070	7567	Boss 5070	5.62	B2	12.43	94	
5532	8238	β Cephei	3.32	B1	0.190	17	Cepheid, Guthnick
5856	8640	12 Lacertae	5.18	B2	0.193	17	Cepheid
5996	8864	9 Androm.	5.90	A3	3.22	74	
6046	8926	1 H. Cassiop.	4.89	B3	6.07	59	

In Figure 9 are included the Class-B spectroscopic binaries for which orbits are given in Moore's Third Catalogue, with distinguishing marks for variables, non-variables, and stars not tested photometrically. The boundary curve is the same as drawn by Struve. As he pointed out, the region in the diagram in which to look for eclipsing stars is at the upper left where the components must be near together and the inclination high, unless the mass is unusually great. Actually there are five eclipsing systems in this group, a proportion of 100 per cent for these favorable cases. The two stars above the curve are β Lyrae and Plaskett's massive star; the latter turns out to be constant in light. There are three O stars, all non-variable, which have been included with Class B.

The A stars in Figure 10 show smaller orbital velocities, as is well known, but still in the upper part of the figure are a fair number of variables.

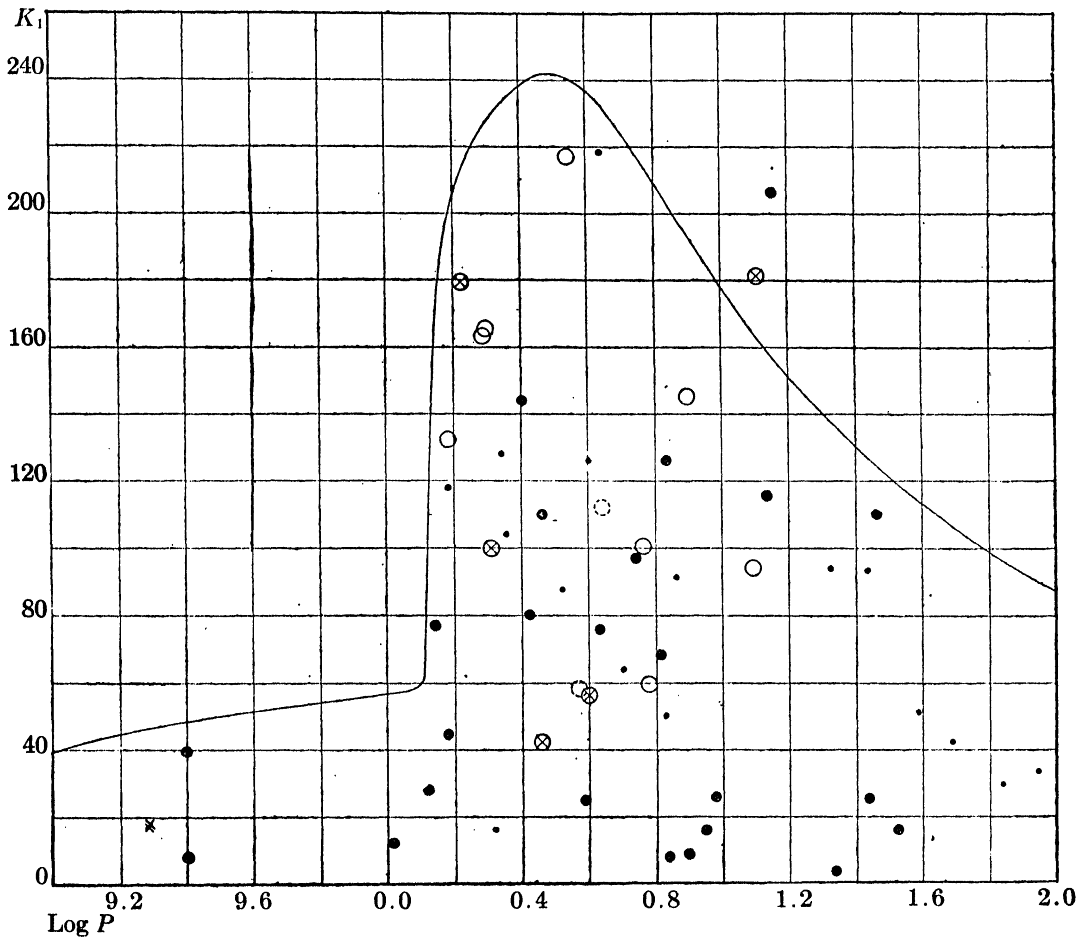

FIGURE 9—Spectroscopic Binaries of Spectrum Class B
Open circles —Eclipsing systems discovered photo-electrically.
Crossed circles—Eclipsing systems discovered visually.
Broken circles—Ellipsoidal or continuous variables.
Crosses —Cepheid variables.
Large dots —Stars tested and found constant in light.
Small dots —Stars not yet tested.

TABLE II

K_1	Classes B and O		Class A	
	Stars Tested	Variable	Stars Tested	Variable
km/sec.				
200–240	2	1	..	..
160–200	4	4	..	..
120–160	4	2	..	..
80–120	9	4	4	2
40– 80	8	4	22	7
Total, 40–240	27	15	26	9
0– 40	14	2	15	2

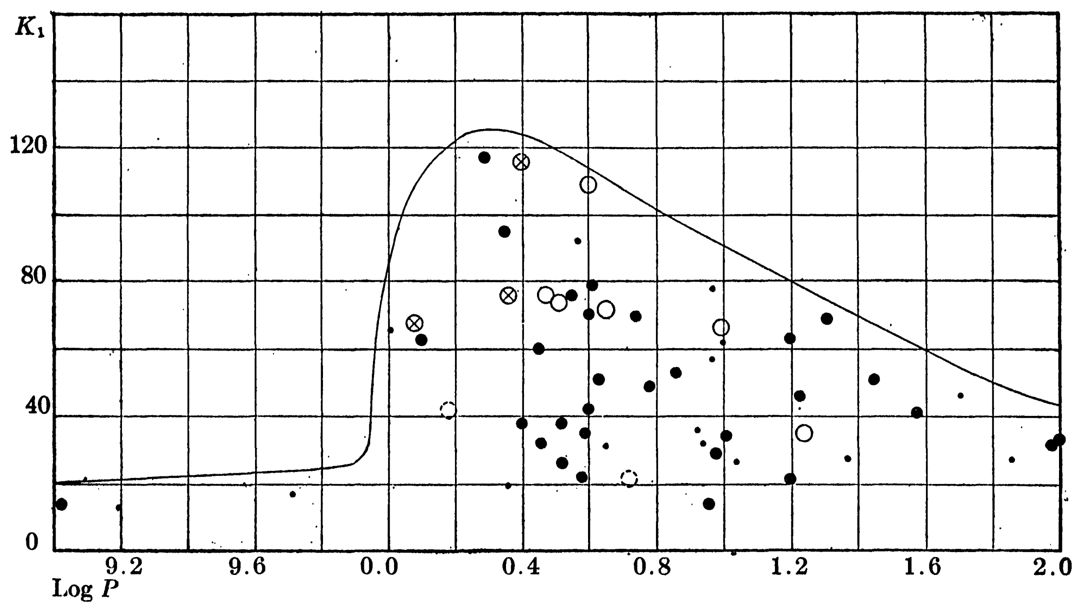

FIGURE 10—Spectroscopic Binaries of Spectrum Class A
(See legend of Figure 9.)

These results are also in Table II where it is seen that for stars with K_1 greater than 40 km/sec. the proportion of variables is over one-half for the B stars, and about one-third for the A's. Of the four variables with K_1 less than 40 km/sec., only α Coronae with a period of 17.360 days is an eclipsing system, giving one such star out of about thirty tested. This is just what might have been expected; the large and massive companions are easily discovered, first from their gravitational effect, and then because of the probability of eclipses, but a small or distant second body is very difficult of detection.

If the companion of α Coronae were only half projected on the bright star at greatest eclipse the loss of light could still be measured, and as the radius of the primary is one-twentieth that of the relative orbit it readily follows that the probability of such an eclipse, or of one of greater extent, is also one-twentieth[3]. We should therefore have to test twenty such stars as α Coronae in order to get one variable, and considering the various factors involved, we may consider the discovery of the eclipses of this star as a rare piece of good fortune.

As stars of long period give small chance of eclipses, the figures and Table I are limited to 100 days. Similarly for F, G, and K spectra the number of stars available for tests is too small for any conclusions to be drawn. It is evident however that the spectroscopic binaries of early spectral class furnish an especially fertile field for the picking up of new variables, and in the cases corresponding to the upper parts of the diagrams the stars which do not vary in light may even be in the minority.

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[3] *Astrophysical Journal*, 34, 108, 1911.