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SPECTRAL CLASSIFICATION OF THE LATE COMPONENT OF STARS WITH COMPOSITE SPECTRA

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Previous classification of stars with composite spectra has been in the blue region of the spectrum. When the system consists of an early and a late type star, the classification of the late component is often uncertain because of the domination of the spectrum by the early component. As a result, many of the composite spectra with one member of type B or A and the other later than F were listed as having simply a G or a G5 component, there being no attempt at assigning a luminosity class. To assign more specific types, it was decided to make use of the visual region of the spectrum where the late component might be expected to be more prominent.

The stars observed were taken from an unpublished compilation by L. W. Ross (mostly from Hynek[1] and the *General Catalogue of Stellar Radial Velocities*) who selected suitable bright stars with composite spectra on the basis of one component being of type A or B and the other later than F. Spectra of 64 such stars were obtained with the 7-inch grating spectrograph of the 36-inch refractor at Lick Observatory with a dispersion of 88 Å/mm covering the region from 5200 Å to 6700 Å on 103a-F(3) plates. In addition, spectra of standard stars (Johnson and Morgan[2]) were obtained for all luminosity classes for spectral types later than F5. Classification was then determined by direct comparison of the composite spectrum with those of the standard stars. Due to the lack of suitable lines in this region the classification is not very reliable for types earlier than G0. For a star classified as G0 III, however, there is no question but that it is earlier than G5. The spectral types become more reliable as one proceeds to later stars.

The resulting classifications of the late component of 64 composite stars are listed in Table I. Of these stars, five show emission at Hα (two of which are binaries of the VV Cephei type),[3] and 27 are known spectroscopic binaries of which seven are known to show Ca II emission.[3] (The radial-velocity range is listed in parentheses if known.) In many cases considerable differences from earlier classifications such as the *Henry Draper* are present. However, with few exceptions the agreement is fairly good for more recent and reliable spectral types from Bidelman[3,4] and from Bahng's multicolor wide-band photoelectric photometry.[5]

An interesting feature is the large number of stars that appear to lie in the Hertzsprung gap. That a gap should be present can be inferred from galactic cluster data such as the HR diagram for NGC 752 by Roman.[6] It shows no stars earlier than F2, a giant branch, and a distinctive Hertzsprung gap. The A and early F stars having most recently evolved off the main sequence must have passed very quickly through the gap region since no stars are found there. Now in the case of binaries, stars earlier (i.e. more massive) than the A or early F component will have already evolved off the main sequence to become the later type now observed; and if the evolution were similar to that of the

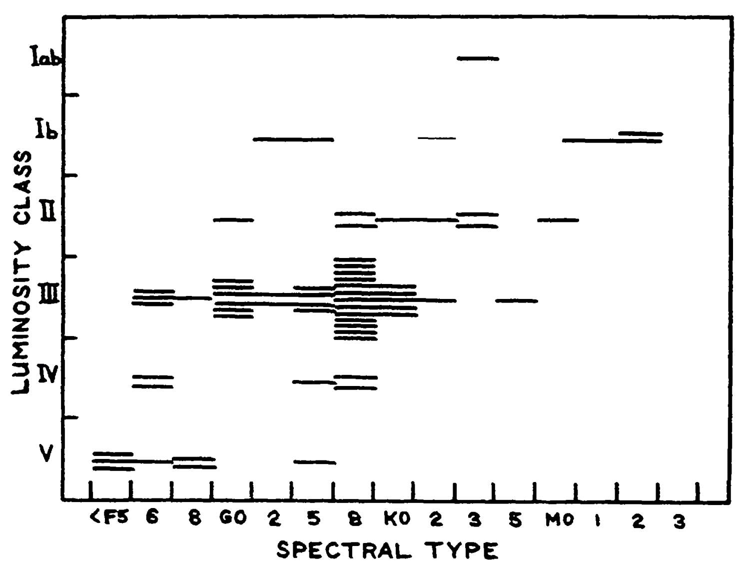

FIG. 1.—Distribution of late component with spectral type and luminosity class. Each bar represents one star.

TABLE I
Classification of Late Type Components

HD Number	Star	α (1900)	δ (1900)	m_v	Spectral Type Kuhi	Spectral Type HD	Note p. 453
962		0h08m9	60°10′	7.8	G2 III	A0	*
4775-6	HR233	0 44.7	63 42	5.4	G0 III	F2A2	1
9352-3	HR439	1 27.0	57 49	6.0	K3 I*ab*	K0A0	
14262-3	HR676	2 13.3	22 43	6.4	F6 IV	A5G	SB(20)
16082-3		2 29.9	51 32	7.3	K0 III	G5A5	
17878-9	τ Per	2 47.2	52 21	4.1	G5 IV	G0A5	2, SB
18925-6	γ Per	2 57.6	53 07	3.1	G8 III	F5A3	3, SB
19926-7	HR958	3 07.1	6 18	5.8	K5 IIIep	G5A5	SB(31)
21224		3 20.4	59 34	7.5	G8 III	F8	
23089-90	HR1129	3 37.3	63 02	5.0	G0 III	F5A	4
26673-4	52 Per	4 08.1	40 14	4.9	G8 III	G0A5	5, SB(35)
29094-5	58 Per	4 29.7	41 04	4.5	K0 III	K0A3	6, SB
33883-4	HR1701	5 08.3	1 51	6.2	F6 III	A2G	
34318-9		5 11.5	—11 28	6.5	G8 III	G0A2	
34807		5 15.0	39 28	7.4	G8 III	A2	*
37269	26 Aur	5 32.2	30 26	5.5	G0 III	A2	7
39118-9	HR2024	5 45.3	2 00	6.2	G8 IV	G0A0	
39286	HR2030	5 46.5	19 50	6.0	G5 IIIe	B9	
39847		5 50.1	25 19	7.7	F6 IVe	A2	
40369-70	HR2099	5 53.2	12 48	5.7	K0 III	G5A5	8
41724-5		6 01.8	35 08	7.7	F6 III	A2G	
47579-80		6 34.2	—23 29	6.6	G8 III	G0A3	
50730-31		6 49.3	— 5 53	7.9	K0 III	K0A3	
51565-6		6 52.7	2 26	7.7	G2 IIIe	A2G	SB(69)
55684-5		7 08.8	— 4 59	7.5	F8 III	A0G5	SB(48)
55899-900		7 09.8	— 1 12	7.1	G8 III	G0A3	
60414-5	HR2902	7 29.2	—14 18	5.1	M2 I*b*ep	K5B	9, SB(32)
69479-80		8 12.1	4 31	6.7	G5 III	G0A2	SB(32)
70442-3	HR3279	8 16.9	—19 46	5.6	G8 III	G0A3	SB(29)
74228-9	45 Cnc	8 37.7	13 03	5.6	F8 V	A3G	SB(51)

83808-9	*o* Leo	9 35.8	10 21	3.8	F6 III	F5A3	10
85558	γ Sex	9 47.5	— 7 38	5.1	F	A2	
107700	12 Com	12 17.5	26 24	4.8	G0 III	F5	
110026-7		12 34.2	14 54	8.0	G0 III	A3G	
157978	HR6497	17 21.5	7 41	6.0	G2 I*b*	A0G	11, SB(70)
166391-2		18 05.3	—17 24	8.9	G5 V	G5A0	
167570-1		18 10.7	—20 34	7.1	G8 III	G5A5	
169689-90	HR6902	18 20.8	7 59	5.6	G8 IV	G0A3	SB(51)
169985-6	59 Ser	18 22.1	0 08	5.3	G8 III	A0G	12, SB(56)
171347		18 29.3	—17 04	7.0	F	A2	*
172806		18 37.1	3 56	8.0	F5 V	B9	*
174348		18 45.0	10 34	8.1	F6 V	A3	
174485		18 45.6	11 24	7.1	F8 V	A0	
175492-3	113 Her	18 50.5	22 32	4.5	G5 III	G0A3	13, SB
181657-8		19 16.2	35 21	7.8	K1 IIp	A0K	14
184398-9	HR7428	19 29.2	55 31	6.5	K2 III	K2A3	15, SB
186518-9	HR7508	19 39.8	26 54	6.6	K3 II	K0A0	
187076-7	δ Sge	19 42.9	18 17	3.8	M2 I*b*	M A0	16, SB
192577-8	31 Cyg	20 10.5	46 26	4.0	K2 II	K0B8	17, SB(20)
192909-10	32 Cyg	20 12.3	47 24	4.2	K3 II	K0A3	18, SB
193495-6	β Cap	20 15.4	—15 06	3.2	G8 II	G0A0	SB
196093-4	47 Cyg	20 30.0	34 54	4.8	K2 I*b*	K5A3	19, SB
196753-4	HR7895	20 34.3	23 19	6.1	K0 III	K0A3	SB
199378-9		20 51.7	14 27	7.5	G8 III	K0A2	
200428-9		20 58.3	15 23	7.7	M0 II	G5A5	
201270-1		21 03.3	45 17	7.3	G5 III	G0A0	
202447-8	α Equ	21 10.8	4 50	4.1	G0 II	F8A3	20, SB(38)
203338-9	HR8164	21 16.5	58 13	5.8	M1 I*b*ep	K0A0	21, SB
205114-5	HR8242	21 28.1	52 11	6.2	G8 III	K0A3	
208253		21 49.9	53 32	6.6	G8 III	A2	*
213310-11	5 Lac	22 25.4	47 11	4.6	M0 I*b*	K0A0	22, SB(33)
216572		22 48.9	60 22	7.6	G0 III	A0	*
223047	Ψ And	23 41.1	45 52	5.1	G5 I*b*	K0A5	23
223932-3		23 48.6	—18 56	7.4	G8	G5A3	

cluster members then no presently observed late component should lie in the gap. However, even taking into account the uncertainties in classifying the G0 stars, one is left with an unusually large fraction in the gap; the effect is therefore probably real. The frequency distribution with spectral type and luminosity class is shown in Figure 1. A similar diagram constructed for 47 visual binaries compiled from data of Stephenson[7] and Bidelman[8] shows that there are virtually no stars earlier than G5 and none in the Hertzsprung gap. This different distribution of later components is illustrated more clearly in Figure 2 which shows the frequency distribution of giant components with spectral type. The lack of stars earlier than G5 for visual binaries is quite marked. A similar though less marked effect also exists for field stars (e.g. see Keenan and Morgan Fig. 1.1 in *Astrophysics* J. A. Hynek, ed., (New York: McGraw-Hill, 1951)).

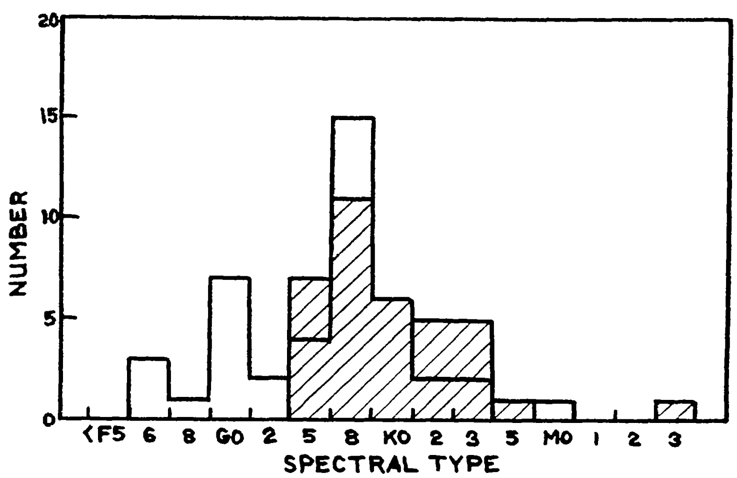

FIG. 2.—Distribution of giants with spectral type for composite stars (plain area) and for visual binaries (cross-hatched area).

Thus one is left with the question of why there are more stars in the Hertzsprung gap among composite stars than among visual binaries and field stars. The above results seem to indicate that for the same type of present early component the present late component has not evolved as far off the main sequence for the composite pair as it has for the visual pair. This would suggest that the closeness of the components has somehow affected their mutual evolution. Close binaries do show synchronization of rotation and orbital revolution leading to possible interaction. Some close double stars and eclipsing binaries show violent activity on a large scale which must alter the evolution of the two components; a less violent interaction may be responsible in this case. However, in either case the observed range in radial velocities does not seem excessive and the spectra exhibit no great peculiarities aside from Hα emission in a few so that for most of the pairs such interactions do not seem too likely. Selection effects probably also play a significant role in this discussion but no allowance for them has been made. Higher-dispersion spectra to determine radial-velocity variations and possible rotational effects will be required to clarify the situation.

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[1] J. A. Hynek, *Perkins Obs. Contr.,* **1,** 185, 1938.
[2] H. L. Johnson and W. W. Morgan, *Ap. J.,* **117,** 313, 1953.
[3] W. P. Bidelman, *Ap. J. Supplements,* **1,** 218, 1958 (No. 7).
[4] W. P. Bidelman, *Pub. A.S.P.,* **69,** 148, 1957.
[5] J. D. R. Bahng, *Ap. J.,* **128,** 586, 1958.
[6] N. G. Roman, *Ap. J.,* **121,** 454, 1955.
[7] C. B. Stephenson, *A. J.* **65,** 60, 1960.
[8] W. P. Bidelman, *Pub. A. S. P.,* **70,** 168, 1958.

Notes to Table I:

1. G0 III + A4 V (ref. 5).
2. G4 III + A4 V (ref. 5).
3. G8 III + A3 V (ref. 5).
4. G0 III + A3 V (ref. 5).
5. K2 III + A6 V (ref. 5); G5 II + A,B (ref. 4).
6. K4 III + A3 V (ref. 5); G8 II + B (ref. 3).
7. G5 III + A3 V (ref. 8).
8. K2 III + A5 V (ref. 5).
9. M2 I*ab*ep + B (ref. 3).
10. F8 III + A5 V (ref. 5); F6 II (W. P. Bidelman, private communication).
11. G0 III-IV + A3 (G. H. Herbig and B. A. Turner, *Ap.J.*, **118**, 477, 1953).
12. G0 III + A6 V (ref. 5); G0 + A2 (E. C. Tilley, *Ap.J.*, **98**, 347, 1943).
13. G4 III + A6 V (ref. 5).
14. K3 III + A (ref. 7).
15. K2 II-III + A (ref. 3).
16. M2 II +A0 V; M2 I*b*-II + A (ref. 3).
17. K2 II + B3 V (ref. 3).
18. K3 I*b*-II + B (ref. 3).
19. K2 I*b* + B5 V (ref. 5).
20. G0 III + A5 V (ref. 5).
21. M1 I*b*ep + B (ref. 3).
22. K5 I*b* + B7 V (ref. 5); M0 I*b*-II (ref. 3).
23. G5 I*b* (N. G. Roman, *Ap.J.*, **116**, 122, 1952).

* A-type K line plus G band characteristic of a later type and also Balmer decrement characteristic of composite spectra (A. Slettebak and J. J. Nassau, *Ap.J.*, **129**, 88, 1959).

SB: Spectroscopic binary with radial-velocity range in parentheses.