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A CORRELATION BETWEEN THE SPECTROSCOPIC AND DYNAMICAL CHARACTERISTICS OF THE LATE F- AND EARLY G-TYPE STARS

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ABSTRACT

Among the giants and dwarfs in the spectral range F5–G5, some stars have systematically weaker lines than others of the same spectral type and luminosity class. On this basis two groups of stars can be distinguished. An examination of the velocity distributions of the two groups shows definite differences. The velocities of the stars with weaker lines have a larger dispersion than those of the stars with stronger lines; the conventional "high-velocity" stars occur only in the weak-line group. The two types of stars are about equally numerous among the bright northern stars. Stars with velocities less than 70 km/sec are found in both groups.

It has long been known that there are many peculiar stars which cannot be placed uniquely on a two-dimensional Hertzsprung-Russell diagram. However, even such well-populated groups as the metallic-line stars are small compared with the normal stars of similar spectral types. Among the late F- and early G-type stars there appear to be two groups of stars which occur with comparable frequency and which can be distinguished spectroscopically, although they occupy the same region of the H-R diagram.

The stars in one of these groups have systematically weaker lines than those in the other group. This cannot be due to a difference in either spectral type or luminosity. In this region of the H-R diagram the hydrogen lines are weakening rapidly as the metallic lines are growing stronger. Thus the weakness of the hydrogen lines would indicate a later spectral type, while the weakness of the remaining lines would indicate an earlier type. The effect occurs in both giants and dwarfs, and, on the average, the lines have the same strength in the giants and in the dwarfs of the same spectral type.

The present discussion is based on ninety-four northern stars brighter than 5.50 mag. for which comparable plates are available. The spectra have a dispersion of 125 A/mm at $H\gamma$. The stars studied include giants and dwarfs in the spectral classes F5–G5, except that the G-type stars which show CN were arbitrarily excluded. Earlier than F5, the broadening of the star lines by rotation makes it difficult or impossible to detect the small differences between the two groups.

The conflicting types derived from the hydrogen lines and from the metallic lines lead to a problem in an attempt to classify the two groups of stars on the same system. In this paper the types are derived from line ratios, and thus it is assumed implicitly that all lines are weakened by approximately the same amount. The resulting type is thus a compromise between the types which would be derived from the absolute strengths of either the hydrogen lines or the metallic lines. It is also assumed that the same absolute-magnitude calibration can be used for the two groups of stars. That these assumptions are reasonable is indicated by the close agreement between the mean radial motion of the stars and the mean tangential motion divided by $\sqrt{2}$, as is shown in Table 1.

While the systematic difference in the intensity of the lines characterizes the two groups throughout the range in spectral types studied, some features can be used more readily than others to discriminate between them on plates of the dispersion used in this study. In the F5 and the F6 stars the metallic lines are fairly weak, and the most obvious difference between the two groups is that λ 4226 of Ca I stands out noticeably in the

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weak-line stars but is merely one of a number of lines in the strong-line stars. By F8, the weakening of the general background of metallic lines is quite obvious in the dwarfs but not particularly striking in the giants. The strength of the hydrogen lines and the G band provide useful criteria throughout the range F5–G5 and are particularly valuable in the F8 and G0 giants. At G0 the ratio of the lines 4340/4325 is noticeably smaller in the weak-line stars for the same strength of λ 4226. The differences are small at best, and comparable plates of high quality are needed to detect them. Also, it is necessary to compare stars of very nearly the same spectral type.

The space velocity was computed for each of the ninety-four stars. These velocities were based on spectroscopic parallaxes and corrected for a solar motion of 20 km/sec toward $A = 271°$, $D = +28°$. The frequency distributions of the total space velocities

TABLE 1

CHARACTERISTICS OF THE MOTIONS OF THE TWO GROUPS OF STARS

Group	No. of Stars	Mean Radial Velocity (Km/Sec)	Mean Tangential Velocity/$\sqrt{2}$ (Km/Sec)	Mean Speed (Km/Sec)	Standard Deviation (Km/Sec)
Strong-line......	47	14.5	13.6	28.1	13.8
Weak-line.......	47	22.2	21.9	43.9	23.4

are strikingly different for the two groups of stars. These are shown in Figure 1 and in Table 1. While the distributions overlap to a considerable extent, both the mean and the dispersion are larger for the weak-line stars than for the strong-line stars. However, it is important to note that the knowledge of the speed alone is not sufficient to determine the group to which a particular star belongs, with the possible exception of stars with speeds greater than 70 km/sec.

Table 2 lists the stars included in the strong-line group, together with their 1900 positions, apparent visual magnitudes, spectral types,[1] spectroscopic parallaxes, and space velocities. Table 3 gives the same data for the weak-line stars. In each table a number of visual and spectroscopic binaries have been included. These are described in the notes to the tables. They have no effect on the velocity characteristics found for the two groups of stars; identical values of the mean speeds and the standard deviations are obtained if the two-line spectroscopic binaries and the close visual binaries are excluded from the solution.

This work developed from several discussions with Dr. W. W. Morgan, to whom I am also indebted for the use of plates of many of the stars included in this paper.

[1] On the system of *An Atlas of Stellar Spectra* by Morgan, Keenan, and Kellman (Chicago: University of Chicago Press, 1943).

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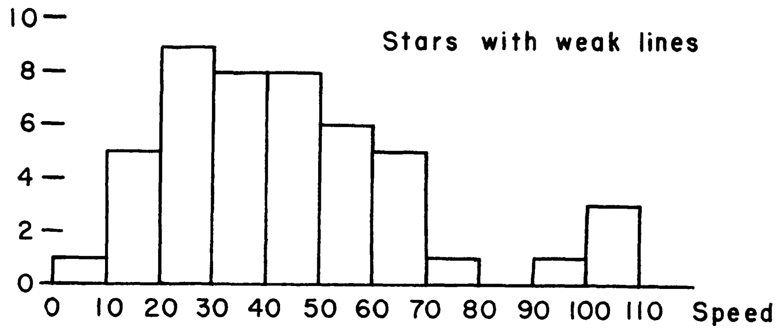

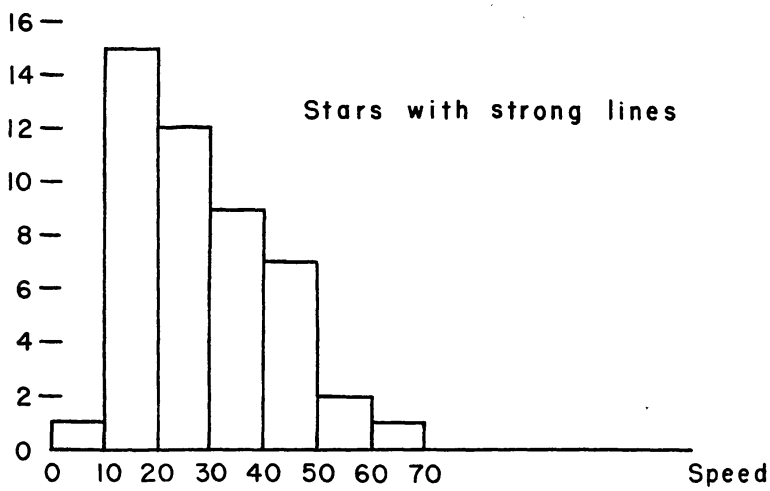

FIG. 1.—The frequency distributions of the speeds of the two groups of stars

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TABLE 2

THE STRONG-LINE STARS

Name	$\alpha_{(1900)}$	$\delta_{(1900)}$	m	Spectral Type	π_{sp}	Speed (Km/Sec)
ρ And......	$0^h 15^m.9$	$+37°25'$	5.20	F5 III	0".018	14
ϕ^2 Cet......	0 45.1	−11 11	5.24	F8 V	.060	36
HR 244....	0 47.1	+60 34	4.93	F8 IV	.044	46
σ Cet......	2 27.4	−15 41	4.82	F5 IV	.038	48
12 Per†.....	2 35.9	+39 46	4.99	F8 V	.048	30
τ^1 Eri......	2 40.4	−19 0	4.61	F6 V	.069	17
κ Cet......	3 14.1	+ 3 0	4.96	G5 V	.104	17
43 Per†....	3 49.2	+50 24	5.47	F5 V	.029	26
π^3 Ori	4 44.4	+ 6 47	3.31	F6 V	.125	19
ξ Gem.....	6 39.7	+13 0	3.40	F5 III	.042	17
α CMi.....	7 34.1	+ 5 29	0.48	F5 IV	.276	20
9 Pup‡.....	7 47.1	−13 38	5.34	G1 V	.058	44
μ Cnc......	8 1.9	+21 52	5.38	G2 IV	.038	49
ζ Cnc A§...	8 6.5	+17 57	5.56	F8 V	.050	24
σ^2 UMa....	9 1.6	+67 32	4.87	F6 IV	.040	16
HR 3750...	9 22.8	− 5 38	5.44	G2 V	.072	39
HR 3881...	9 42.1	+46 29	5.20	G2 V	.079	30
19 LMi*....	9 51.6	+41 32	5.19	F5 V	.046	16
HR 4251...	10 48.6	−19 36	5.28	F6 V	.050	33
47 UMa....	10 53.9	+40 58	5.14	G0 V	.072	21
β Vir.......	11 45.5	+ 2 20	3.80	F8 V	.114	49
18 Com....	12 24.5	+24 40	5.49	F5 III	.016	24
31 Com....	12 46.8	+28 5	5.07	G0 III	.013	15
53 Vir	13 6.7	−15 40	5.09	F6 III–IV	.026	56
β Com.....	13 7.2	+28 23	4.32	G0 V	.104	52
59 Vir......	13 11.8	+ 9 57	5.22	G0 V	.069	29
η Boo*.....	13 49.9	+18 54	2.80	G0 IV	.119	15
12 Boo†....	14 5.8	+25 34	4.82	F8 IV	.032	25
ι Vir.......	14 10.8	− 5 31	4.16	F6 III	.029	64
18 Boo.....	14 14.4	+13 28	5.31	F5 IV	.030	33
ϵ Lib*	15 18.8	− 9 58	5.08	F5 V	.048	6
ξ Sco‖......	15 58.9	−11 6	4.77	F6 IV	.042	21
θ Dra*.....	16 00.0	+58 50	4.11	F8 IV	.063	23
HR 6493†..	17 21.3	− 5 0	4.61	F5 V	.043	19
ψ Dra A ...	17 43.7	+72 12	4.90	F5 V	.053	37
35 Dra.....	17 53.9	+76 59	5.04	F6 IV	.038	19
θ Cyg......	19 33.8	+49 59	4.64	F5 IV	.041	25
HR 7496....	19 37.9	−15 42	5.50	F6 IV	.030	35
β Del#.....	20 32.9	+14 15	3.72	F5 III	.030	11
δ Equ†.....	21 9.6	+ 9 36	4.61	F8 V	.057	20
κ Peg**....	21 40.1	+25 11	4.27	F5 IV	.038	12
ι Peg*......	22 2.4	+24 51	3.96	F5 V	.079	10
π Peg......	22 5.5	+32 41	4.38	F5 II–III	.012	23
37 Peg††...	22 24.9	+ 3 55	5.47	F5 III	.013	49
σ Peg......	22 47.3	+ 9 18	5.30	F6 V	.050	41
υ Peg......	23 20.4	+22 51	4.57	F8 III	.019	36
ω Psc*.....	23 54.2	+ 6 19	4.03	F4 III	0.032	10

* One-line spectroscopic binary.

† Two-line spectroscopic binary.

‡ Close visual binary. $\Delta m = 0.9$ mag.

§ Close visual binary. $\Delta m = 0.70$ mag.

‖ Close visual binary. $\Delta m = 0.30$ mag.

Close visual binary. $\Delta m = 1.0$ mag.

** Close visual binary. $\Delta m = 0.5$ mag.

†† Close visual binary. $\Delta m = 1.4$ mag.

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TABLE 3

THE WEAK-LINE STARS

Name	$\alpha_{(1900)}$	$\delta_{(1900)}$	m	Spectral Type	π_{sp}	Speed (Km/Sec)
η Cas‡.....	0^h43^m0	+57° 17′	3.64	G0 V	0″144	27
ω And......	1 21.7	+44 58	4.96	F5 III	.020	69
υ And......	1 30.9	+40 54	4.18	F8 IV	.060	45
δ Tri.......	2 10.9	+33 46	5.07	G0 V	.072	62
θ Per.......	2 37.4	+48 48	4.22	F6 V	.083	28
ι Per.......	3 1.8	+49 14	4.17	G0 V	.109	66
10 Tau.....	3 31.8	+ 0 5	4.40	F8 V	.087	32
λ Aur......	5 12.1	+40 1	4.85	G2 IV–V	.068	74
χ Cnc......	8 14.0	+27 32	5.16	F6 V	.052	31
HR 3579§..	8 54.2	+42 11	4.09	F5 V	.071	29
τ^1 Hya.....	9 24.1	− 2 20	4.78	F6 V	.063	11
θ UMa.....	9 26.2	+52 08	3.26	F6 III	.043	102
40 Leo.....	10 14.3	+19 59	4.97	F6 V	.058	7
HR 4084...	10 18.9	+83 4	5.34	F5 III	.016	24
36 UMa....	10 24.2	+56 30	4.84	F8 V	.072	17
ξ UMa‖....	11 12.9	+32 6	4.41	G0 V	.090	26
HR 4439#..	11 26.7	+61 38	5.47	F6 V	.035	43
β CVn.....	12 29.0	+41 54	4.32	G0 V	.104	22
α Com**...	13 5.1	+18 4	5.22	F5 V	.032	55
61 Vir......	13 13.2	−17 45	4.80	G5 V	.114	44
70 Vir......	13 23.5	+14 19	5.16	G5 IV–V	.064	37
τ Boo......	13 42.5	+17 57	4.51	F6 IV	.048	34
θ Boo......	14 21.8	+52 19	4.06	F6 IV	.058	33
μ Vir*......	14 37.8	− 5 13	3.95	F5 III	.032	50
α^1 Lib......	14 45.2	−15 35	5.33	F5 IV	.030	16
45 Boo.....	15 2.9	+25 16	5.03	F5 V	.050	33
5 Ser.......	15 14.2	+ 2 9	5.18	F8 IV	.038	104
η CrB†† ...	15 19.1	+30 39	5.58	G0 V	.058	28
λ Ser.......	15 41.6	+ 7 40	4.42	G0 V	.100	50
χ Her......	15 49.2	+42 44	4.61	F8 V	.079	65
γ Ser.......	15 51.8	+15 59	3.86	F6 IV	.063	100
ζ Her‡‡....	16 37.5	+31 47	3.00	G0 IV	.109	57
20 Oph	16 44.3	−10 36	4.73	F6 III	.023	43
19 Dra*....	16 55.5	+65 17	4.82	F6 V	.063	25
72 Her.....	17 16.9	+32 36	5.36	G2 V	.072	92
26 Dra.....	17 34.0	+61 57	5.31	G2 V	.076	46
ω Dra*	17 37.5	+68 48	4.87	F5 V	.053	16
99 Her.....	18 3.2	+30 33	5.21	F8 V	.060	23
110 Her....	18 41.4	+20 27	4.26	F5 IV	.048	51
11 Aql.....	18 54.5	+13 29	5.37	F8 III–IV	.022	40
17 Cyg.....	19 42.6	+33 30	5.03	F5 V	.050	49
HR 7955...	20 42.9	+57 13	4.63	F8 IV	.050	39
ϵ Eql A§§...	20 54.1	+ 3 55	5.29	F5 III	.014	68
μ Cyg A‖‖..	21 39.7	+28 17	4.73	F6 V	.066	35
ζ Aqr##....	22 23.7	− 0 32	4.42	F5 III	.024	44
ξ Peg.......	22 41.7	+11 40	4.31	F6 III–IV	.038	56
ι Psc.......	23 34.8	+ 5 5	4.28	F8 V	0.091	16

* One-line spectroscopic binary.

‡ Close visual binary. Δm = 3.8 mag.

§ Close visual binary. Δm = 2 mag.

‖ Close visual binary. Δm = 0.46 mag. Each component is a spectroscopic binary.

\# Close visual binary. Δm = 0.3 mag.

** Close visual binary with equal components.

†† Close visual binary. Δm = 0.50 mag.

‡‡ Close visual binary. Δm = 3.5 mag.

§§ Close visual binary. Δm = 0.5 mag.

‖‖ Close visual binary. Δm = 1.35 mag.

\## Visual binary. Δm = 0.17; ρ = 3″

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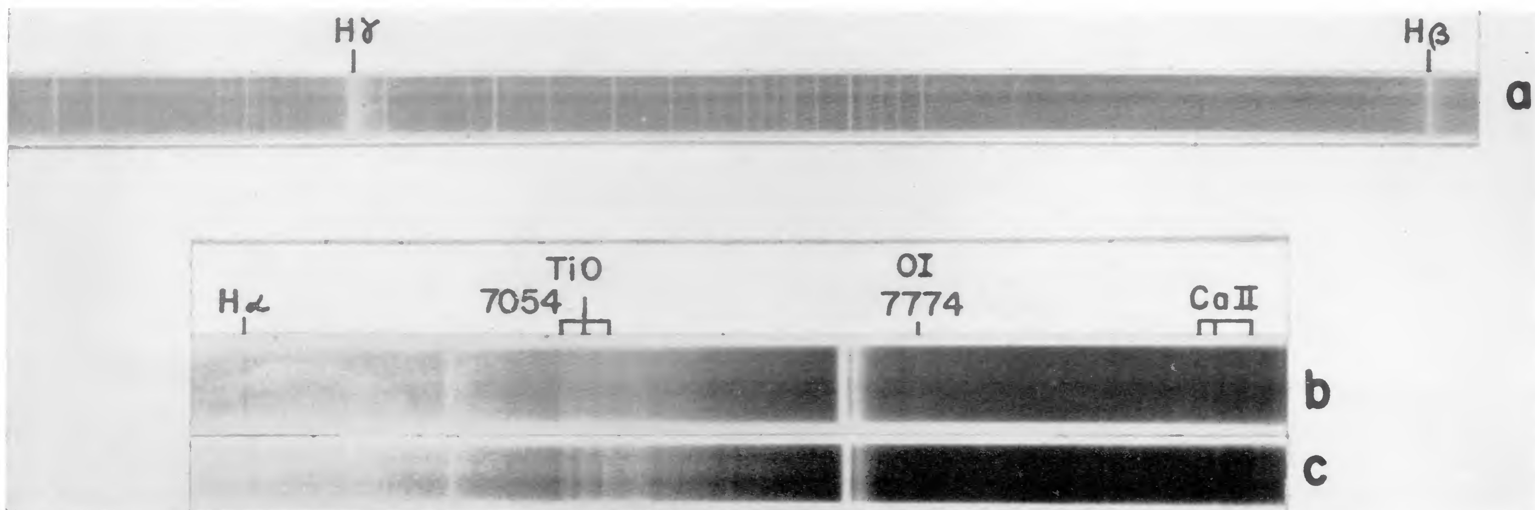

FIG. 1.—*a*, the spectrum of 17 Leporis in the blue region, taken on January 17, 1950; *b*, a portion of the infrared spectrum of 17 Leporis, taken on the same date; *c*, the M2 III star μ Coronae Borealis.

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