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Studies on line intensities in stellar spectra. I,

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1. *The spectral negatives.*

The present investigation is based on some negatives of star spectra, taken with the Mills spectrograph of the 36 inch refractor at the Lick Observatory. We are highly indebted to Messrs R. G. AITKEN, Associate Director, and W. H. WRIGHT, Astronomer of the Lick Observatory, who kindly put them at our disposal. The plates that could be used in this investigation are contained in Table I; spectrum and absolute magnitude were taken from *Mount Wilson Contrib.* 199; the last column indicates the groups used below.

TABLE I. List of plates.

Star		Plates	M	Sp.	Group
δ Cep	Max	2 pl	−3.3	*F*0?	*c*
δ Cep	Min	2 pl *)	−2.1	*F*9	*c*
α UMi		4 pl	−3.0	*F*9	*c*
α CMi		2 pl	+3.2	*F*3	*dF*
δ Equ **)			+4.0	*F*6	*dF*
ξ UMa	br.		+4.9	*F*9	*dG*
ξ UMa	ft.		+5.3	*G*2	*dG*
μ Cnc			+3.7	*G*3	*dG*
ξ Boo			+6.9	*G*6	*dG*
ε Hya *)			+2.1	*F*9	*dG*
ε Leo			−0.9	*G*0	*gG*0
π Cep			−0.2	*G*2	*gG*0
15 Lyn *)			+0.1	*G*4	*gG*5
β Her			−1.0	*G*5	*gG*5
η Dra			+0.7	*G*6	*gG*5

*) small weight. **) very small weight.

The spectra extend from 4250 to 4880; but the part where the lines are sharp, is much smaller. The distance Hβ—Hγ is 37.5 mm.; for λ 4430 1 Ångström = 0.10 mm. Lines at a distance 0.5 Å. usually are clearly separated. These plates have been used to find the intensities of the absorbtion lines.

In former times the intensities of dark lines in stellar spectra were usually treated as a matter of secondary importance, just as star magnitudes in meridian observations; they were estimated roughly so far as it was necessary for identification. Afterwards the brightness of the stars became a separate object of valuable study, and star photometry developed into a science of exact measures. In the same way the intensities of spectral lines in the last years are acquiring an ever increasing importance, especially in connection with the theory of ionization. Thus methods are necessary which give a more exact knowledge of these line intensities. While mechanical contrivances are developing, promising an exact photometry of spectral lines, it seems also possible to get valuable results by means of the old method of estimates, if performed with special care. This paper will be restricted to the discussion of the results of this method. Only the part of the spectrum between 4387 and 4591 Å. was used, because outside these limits the definition on several plates became less good or the background was too much underexposed to allow exact estimates. After exclusion of the broad and hazy lines there remained 159 usable. In observing the lines were carefully compared with one another and expressed in a mental scale allowing a sufficient gradation of intensities. Each plate was observed three times independently, on three different days; since there are 21 plates the finishing of these series required several months. The plates were mixed in such a way, that the observer never did know which spectrum he was looking at. All these observations were made by REESINCK.

In order to get some knowledge of the accuracy reached in these estimates, for some plates the three series were compared. Each series has its own scale, independent of the others. As a rule the scale depends on the quality of the plate, being wider for the best plates in accordance with the greater accuracy attainable, while for less good, underexposed plates the range of intensities used was as a rule much narrower. But also for the same plate the scales are often very different, and scale reductions, mostly varying with wave length too, must be applied. From the average values of the remaining differences *a—b*, *b—c*, *a—c*, the following values of the probable error of one estimate (including uncertainties in the scale reductions adopted) were derived.

Int.	α CMi I [1])	α CMi II [1])	δ Cep Max [2])	ε Leo [3])	η Dra [3])	15 Lyn [4])
< 1	0.12 (44)	0.11 (41)	0.18 (46)	0.20 (21)	0.26 (10)	0.43 (30)
1—5	0.31 (21)	0.40 (19)	0.45 (21)	0.38 (37)	0.84 (38)	0.60 (82)
5—10	0.34 (24)	0.70 (28)	0.67 (19)	0.8 (24)	1.4 (36)	0.70 (49)
> 10			1.1 (8)	1.9 (8)		

[1]) good [2]) rather good [3]) bad [4]) very bad.

In deducing final results for each plate as a rule the average was taken of the three series of estimates; thus the result is expressed in an average scale. Only in some cases reductions of one series to another were applied beforehand; also in some cases different weights were applied, chiefly in order to prevent that different series of the same plate, which happened to have a narrow and a wide scale, would thereby get really different weights.

In some cases we may controll the probable errors just obtained in an independent way. For some stars (in the same phase) we have two plates; the differences between these plates, representing identical spectra, indicate the errors of estimate increased by the accidental peculiarities of the plates. Here also scale reductions of one plate to another, varying with intensity and with wave length, must be applied first. In this way two plates of α Canis minoris and two of α Ursae minoris were treated; moreover the plates of η Draconis and 15 Lyncis, which are almost identical in spectral character, were compared in the same way, in order to have analogous results for a pair of bad plates. The resulting probable error of one plate (mean of 3 series) is found

Int.	α CMi	α UMi	η Dra-15 Lyn
<1	0.17 (66)	0.16 (30)	0.66 (19)
1—5	0.44 (46)	0.30 (39)	0.7 (70)
5—10	0.43 (35)	0.76 (19)	1.2 (48)
10—20	0.41 (9)	0.60 (45)	2.1 (18)
20—30		0.99 (26)	

Thus it appears that accidental differences between the plates play an important part besides the mere accidental errors of estimate. For the last pair of stars part of the differences may also be attributed to real differences of spectrum.

2. *Catalogue of line intensities.*

The intensities of spectral lines depend on two independent variables, pressure and temperature. By increase of temperature and decrease of pressure the ionization increases, thus causing a relative strengthening of the enhanced lines and a corresponding weakening of the arc lines. In the same atom (neutral or ionized) the frequency of orbits of higher energy level increases with temperature, and thus the series derived from these orbits, the high temperature lines, become more intense. For a star spectrum, where the lines take their origin in a series of layers of widely different temperature and pressure, these determining factors are replaced by effective temperature and gravity. Each star is characterized by these two factors (the last named one is generally expressed as absolute magnitude), and the character of its light thus may be represented by a point in a plane, determined by two coordinates From the relative intensities of the spectral lines this character, i. e. both coordinates, may be determined. In future this may perhaps be done solely by means of an exact knowledge of ionization potentials and energy levels; for the present, however, we must proceed in a more empirical way.

The first thing to be done is the separation of the lines according to their behaviour, whether enhanced or neutral, whether sensitive for increasing temperature or not. For this purpose we make use of our knowledge of the character of the stars used. To distinguish enhanced and arc lines the best criterion is the difference of intensity between Cepheids and *F* and *G* dwarfs; in a less degree it may also be given by the difference between *G* giants and *G* dwarfs. The influence of temperature upon a line may be found from three differences: between *F* dwarfs and *G* dwarfs, between *G* 0 and *G* 5 giants, between δ Cep Max and α UMi (combined with δ Cep Min). The spectral class of δ Cep Max is somewhat uncertain; ADAMS and JOY give it F0, deduced from the hydrogen lines, F9 from the general aspect of the spectrum (Some spectral characteristics of Cepheid Variables, *Communic. Mt. Wilson* N°. 53, 1918). We may be sure that it represents a higher stage of temperature than α UMi; and we will assume that the average of all Cepheids corresponds to the mean of our dF and our dG group. Thus the results for the line intensities for the separate stars were condensed into averages for the groups indicated in Table I. These group results, in order to make them comparable, must be reduced to the same scale. The real difference between spectra having strong lines and spectra having only faint ones cannot be separated from the subjective differences in scale width due to differences in definition and blackness; by expressing them all in the same scale we restrict ourselves to purely relative differences of line intensities. At first we have tried to use for the scale reduction only the lines known as arc lines. Since, however, their number was not large and they appeared to be not a quite homogeneous set, another way was chosen, viz. using all lines and reducing to the average of the whole mass of lines. All groups were reduced to the scale of dF. Rather regular reduction curves could be adopted, the scale varying only slowly with intensity. Of course these scale reductions are much more uncertain than in the case of reductions of different series of the same plate or the same star; and it was not possible to determine a dependance on wave length with sufficient certainty. Though such a dependance is indicated in some cases, its influence on the adopted intensities will seldom reach one scale unit.

Table II contains the reduced line intensities for all the lines used. The other lines between the limits chosen, which owing to their indistinct or varying aspect have been omitted, are given separately, after this table; their place in the table is indicated by asterisks before the following wave length. In notes at the bottom of the table attention is drawn to some lines, which, though included in the estimates, presented more difficulties and may be subject to greater errors than the others. Columns 2 to 6 give the intensities for the groups c (Cepheids), dF, dG, gG0 and gG5. The next columns contain the differences $a_1 = (c) - \frac{1}{2}(dF + dG)$; $a_2 = \frac{1}{2}(gG0 + gG5) - dG$; $b_1 = dF - dG$; $b_2 = gG0 - gG5$; $b_3 = cF$ (written for δ Cep Max) — cG (written for α UMi + δ Cep Min). The values a_2 and b_2 are not exactly the differences between the columns gG0, gG5 and dG; they have been deduced from direct scale reductions of gG5 to gG0 and dG to gG0, thus avoiding the complication of two reduction curves to dF. The deviations between these direct comparisons and the differences from the first columns — taking into account the different scale units — may give an idea of the errors caused by the uncertainty of the scale reductions. For $cF - cG$ the unit, being the original unit of the observed c intensities, is considerably smaller than for the reduced column c. The next columns contain estimates on spectra of Sirius and Arcturus, belonging to the Yerkes Observatory *Series for Educational Purposes*, and having nearly the same disperson; these estimates were made after the completion of the other series, one series for each star, and have not the same accuracy. (For Sirius lines below 0.5 are doubtful).

TABLE II. Average line intensities and their differences.

λ	c	dF	dG	gG0	gG5	a_1	a_2	b_1	b_2	b_3	Sir.	Arct.	Classification	Origin
4387.0 [1])	6.8	3.3	2.2	4.8	1.8	+ 4.0	+ 0.9	+ 1.1	+ 2.2	+ 0.1	0 1	2	E H	*Ti* + (1); *Ce*;
88.1 [1])	1.9	1.1	1.9	1.6	1.3	+ 0.4	— 0.4	— 0.8	+ 0.2	— 0.2	0.1	2	AE L	*Fe* IV, *Co* (2);
88.6 [1])	2.3	2.3	2.4	2.1	0.8	— 0.1	— 0.9	— 0.1	+ 1.0	— 0.4		2	AE M	*Fe* IV (3); *Er*;
89.4 [1])	0.8	0.4	0.9	1.4	1.0	+ 0.2	+ 0.3	— 0.5	+ 0.3	— 1.2		3	AE LL	*Fe* II (2);
90.1 [1])	0.9	0.7	3.2	2.4	3.8	— 1.1	+ 0.1	— 2.5	— 1.8	— 1.7		3	A LL	V (2); Mg + $(2\pi_1 - 4\delta)$?
91.2 [1])	6.0	5.0	5.2	4.3	4.8	+ 0.9	— 0.3	— 0.2	— 1.4	— 0.5	1	3	AE M	*Fe* IV (2); *Ti* + (1); *Gd*; *Sm*;
91.9 [1])	1.9	1.6	5.1	8.3	6.2	— 1.5	+ 2.2	— 3.5	+ 0.5	— 2.1		8	A LL	*Cr* I $(p_3 - d^1_2)$ (1); *Co* (0); *Ce*;
92.7 [1])	0.1	0.3	0.4	0.1	0.1	— 0.3	— 0.2	— 0.1	0.0	— 0.2		0		
93.4 [1])	0.2	0.6	3.1	2.6	2.4	— 1.6	— 0.5	— 2.5	— 0.3	— 0.2		4	A LL	V? (0); *unkn* (1)
94.2 [1])	5.8	4.4	3.0	4.0	3.8	+ 2.1	+ 1.0	+ 1.4	— 0.4	+ 0.5		8	E H	*Ti* V + (2);
95.2	17.3	15.7	14.4	14.9	13.7	+ 2.3	+ 1.2	+ 1.3	— 1.0	— 0.8	2	15	AE M	*Ti* V + (3); V, *Zr* (2); [12])
96.0	5.4	3.6	1.1	1.0	1.0	+ 3.0	— 0.1	+ 2.5	0.0	+ 0.2		0.5	E H	*Ti* V + (1);
97.2	0.0	0.1	0.8	0.3	1.3	— 0.4	— 0.1	— 0.7	— 0.8	0.0		1	A L	*unkn* (1);
98.3	8.5	4.3	2.6	5.4	3.6	+ 5.1	+ 1.7	+ 1.7	+ 0.9	— 1.3		5	E M	$Y + (2d^1 - 1p_2)$ (1)
99.9	8.4	8.0	6.6	4.5	3.9	+ 1.1	— 2.2	+ 1.4	— 0.1	+ 0.6	0.8	5	AE H	*Ti* V +, *Cr* III (3);
4400.6	9.5	7.0	6.7	6.6	6.6	+ 2.7	+ 0.3	+ 0.3	— 1.7	— 0.9		9	E M	*Sc* III + $(F_3{}^3 - F_4{}^3)$ (3); V (1); [12])
01.6	7.3	12.5	13 6	10.8	9.2	— 5.7	— 3.8	— 1.1	— 0.5	— 2.1		9	A L	*Fe* (2); *Fe* (1); *Ni* (2);
03.4	2.4	2.1	3.9	3.8	3.2	— 0.6	— 0.2	— 1.8	0.0	— 1.7		2	AE LL	*unkn* (1): *Zr* +, *Cr* III (0);
04.9	18.4	21.5	31.0	26.0	37.9	— 7.8	+ 8.0	— 9.5	— 20.0	(0.0)	2.6	35	A LL	*Fe* II $(\overline{F_3{}^1} - \overline{g_4{}^1})$ (10);
06.7	0.1	0.3	2.2	1.0	2.2	— 1.1	— 0.4	— 1.9	— 1.2	— 0.3		3	A LL	V (2); *Gd*;
07.8	4.1	5.8	6.6	4.5	3.6	— 2.1	— 2.2	— 0.8	+ 0.3	— 0.5		5	A M	*Fe* III (4); V (2);

	λ	c	dF	dG	gG 0	gG 5	a_1	a_2	b_1	b_2	b_3	Sir.	Arct.	Classification	Origin
	4408.6	5.1	6.9	8.5	9.5	8.1	−2.6	+0.7	−1.6	−0.5	−3.5		12	A L	*Fe* III (3); *V* (2);
	09.5	8.5	5.0	2.0	6.6	4.5	+5.0	+3.2	+3.0	+0.9	−2.4		5	E M	*Ti* + (0); *unkn* (1); *Er*;
**	12.1	4.1	2.3	1.1	4.9	4.8	+2.4	+3.4	+1.2	−0.8	+0.2		10	E H	*Ti* + (1); *V* (00);
	13.8	3.2	1.1	0.7	1.9	1.0	+2.3	+0.5	+0.4	+0.6	+1.6		2	E H	*unkn* (1); *Cr* + (0); *Co* +;
**	17.0	7.6	5.5	2.3	3.8	5.0	+3.7	+2.1	+3.2	−2.0	+3.8	2.8	5	E HH	*Ce* (2)
	17.9	8.9	6.6	4.7	4.3	4.3	+3.3	−0.2	+1.7	−0.7	+1.7	1.6	4	E H	*Ti* V + (3) [12]
	18.5	3.3	3.7	2.2	2.6	1.9	+0.3	+0.2	+1.5	+0.2	+0.6		3	AE H	*Ti* V + (1)
	19.0	0.2	0.1	0.5	1.0	0.7	−0.1	+0.2	−0.4	+0.3	−0.7	0.2	0.5	AE L	*Ce* (00); *Gd* (00);
	20.7	1.9	0.2	0.4	2.7	2.6	+1.6	+1.9	−0.2	−0.4	−1.4		4	E L	*Zr*, *Sm* (00);
	22.0 [9]	3.2	2.2	2.7	3.9	4.1	+0.8	+1.3	−0.1	−0.8	+1.1		8	E M	*Ti* + (1); *Ti* III (0);
	22.8 [9]	3.8	4.2	3.6	4.8	4.4	−0.1	+1.0	+0.6	−0.5	−0.4		6	AE M	*Fe* III, *Y* + $(2d''-1p_3)$ (3)
	23.4 [9]	0.9	1.0	2.2	2.9	4.6	−0.7	+1.5	−1.2	−2.2	−0.4		5	AE LL	*Fe* (1); *Cr* III (0); *V*;
**	25.6	4.7	7.7	8.3	11.3	8.8	−3.3	+2.5	−0.6	+0.9	+0.4		17	A M	*Ca* $(1p_2-2d)$ (4)
	27.4	8.2	8.6	10.4	11.3	9.1	−1.3	+0.3	−1.8	+0.4	−4.6		12	AE L	*Ti* III (2); *Fe* V (5);
	28.0	0.1	0.2	0.0	0.2	0.1	0 0	+0.1	+0.2	0.0	−0.1		0		*La*; *Ce*;
	28.7	0.2	0.3	1.8	1.9	1.7	−0.8	0.0	−1.5	0.0	−0.5		3	A LL	*V*, *Cr* III (1); *Ce*;
	29.4	0.8	0.2	0.3	1.9	1.1	+0.6	+1.0	−0.1	+0.5	−1.1		2	E L	*Ce*, *Pr* (00);
**	31.5	1.1	0.1	0.0	0.7	0.5	+1.1	+0.4	+0.1	+0.2	−1.2		2	E M	*Sc* V + $(F_2^3-F_4^3)$ (0); *Ti*;
	32.2	1.1	0.2	0.3	0.5	0.8	+0.9	+0.2	−0.1	−0.2	−0.8		2	E L	*Cr* III (0);
	33.4	1.4	2.7	3.5	1.9	2.0	−1.7	−1.3	−0.8	−0.4	−0.2		2	A L	*Fe* IV (3); *Mg* + $(2\pi_1-4\sigma)$; *Mo* +;
	34.0	1.4	2.1	2.7	2.7	2.9	−1.0	+0.2	−0.6	−0.7	−0.5		4	A L	*Fe* (1); *Ti* III (00); *Sm*;
	35.2	6.3	9.6	11.0	6.4	6.8	−4.0	−4.5	−1.4	−2.0	−0.9		10	A L	*Ca* $(1p_2-2d')$ (5); *Fe* II (2);
	35.8	3.9	5.0	3.7	3.1	3.1	−0.5	−0.5	+1.3	−0.5	−1.5		3	AE M	*Ca* $(1p_2-2d')$ (4); *Eu* +;
	36.5	0.2	0.8	1.5	2.7	1.8	−1.0	+0.6	−0.7	+0.4	−0.5		3	A LL	*Mn* III (2); *V* (0); *Gd*;
	37.1	0.3	1.0	1.3	0.9	1.3	−0.9	−0.2	−0.3	−0.3	−0.7		2	A L	*Fe*, *Ni* (2)
	37.8	0.1	0.4	0.3	2.4	2.5	−0.3	+1.8	+0.1	−0.5	−0.2		4	AE M	*V* (0); *unkn* (0)
	38.4	0.2	0.6	0.8	1.1	1.0	−0.5	+0.2	−0.2	+0.2	0.0		1	A M	*Fe* (1); *Ti* IV, *Zr* (00);
**	40.6 [7]	0.5	0.3	0.7	0.3	1.1	0.0	0.0	−0.4	−0.7	+0.2		1.5	AE M	*Zr* + (1); *Ti* III (00)
	41.0 [7]	0.2	0.4	1.3	1.1	1.8	−0.6	−0.5	−0.9	−0.6	+0.4		1	A L	*Fe* (0): *Ce* (1);
	41.9	3.5	2.3	1.5	2.4	2.2	+1.6	+0.7	+0.8	−0.2	−0.1	0.2	2	E M	*V* (3); *Ti* IV;
	42.5	3.8	5.7	5.0	4.0	4.3	−1.6	−0.7	+0.7	−0.9	−0.8		3	A M	*Fe* III (6);
	43.3	5.3	4.0	4.8	6.0	4.3	+0.9	+0.4	−0.8	+0.6	−2.1		4	AE L	*Fe* III (3); *Zr* + (0);
	44.0	9.5	7.7	4.7	5.3	2.7	+3.3	−0.6	+3.0	+1.7	+6.5	1.6	4	E HH	*Ti* V + (5); [12]
	44.7	5.5	3.2	2.0	4.0	4.2	+2.9	+2.0	+1.2	−0.8	−0.6		4	E M	*Ti* V +, *Fe* (2); *Ce*;
	45.5	0.0	0.1	0.6	0.8	1.4	−0.4	+0.5	−0.5	−0.6	−0.2		2	A L	*Fe* I (1);
	46.5 [7]	0.4	0.1	0.0	0.5	0.4	+0.4	+0.3	+0.1	+0.2	−0.6		0.5	E M	*Nd*;
	47.1 [7]	0.8	3.2	4.1	3.7	2.9	−2.8	−0.6	−0.9	+0.2	−0.8		1.5	A L	*Fe* (2); *Mn* +, *Fe* IV (2);
	47.9	3.9	5.6	7.2	5.4	4.6	−2.5	−2.0	−1.6	−0.1	0.0		4	A L	*Fe* III (6);
	49.4 [2]	1.8	1.0	3.0	5.4	3.4	−0.2	+1.2	−2.0	+1.1	−1.3		2	AE L	*Ti* III (2);
	50.7	11.2	8.3	9.0	11.1	7.4	+2.6	+0.8	−0.7	+2.3	−0.6		10	E M	*Ti* V + (2); *Zr* (1); *Ce*;
	51.8 [2]	2.1	4.2	2.7	3.9	2.9	−1.3	+0.7	+1.5	+0.4	+0.7		1.5	A H	*Mn* II (3); *Fe* +;
*	54.9 [6]	15.6	14.4	17.8	14.9	11.6	−0.5	−5.3	−3.4	+1.9	−2.6		12	AE L	*Ca* $(1p_1-2d)$ (5); *Fe* III (3); *Mn* (1); [10]
	56.0 [2]	2.1	5.4	4.3	1.9	1.9	−2.7	−2.0	+1.1	−0.3	−0.1		1	A H	*Ca* $(1p_1-2d')$ (3); *Mn* III (2);
	56.7	1.3	1.6	2.3	1.9	1.8	−0.7	−0.5	−0.7	−0.1	+0.2		1	A M	*Ca* $(1p_1-2d'')$ (2); *V*; *Nd*;
	57.6	1.8	3.0	3.7	2.9	2.4	−1.6	−0.9	−0.7	−0.1	−1.3		2	A L	*Ti* II, *V*, *Zr* + (2); *Mn* (2);
	58.3	1.4	3.7	3.5	2.9	1.7	−2.2	−1.1	+0.2	+0.8	−1.5		1	A M	*Mn* II (2); *Fe* (2);
	59.3	6.4	10.8	9.7	8.0	7.1	−3.8	−2.0	+1.1	−0.9	+0.2		7	A M	*Fe* III (3); *Ni* (2); *Fe*, *Cr* (1);
	60.4	1.8	0.8	1.8	2.4	2 7	+0.5	+0.8	−1.0	−0.7	+1.1		1.5	E M	*Mn* (1); *V* (0); *Ce*;
*	63.5 [3]	1.1	0.7	1.5	4.6	3.0	0.0	+2.0	−0.8	+0.9	+0.1		2	AE L	*Ti* III, *Ni* (0); *Ce*;
	64.7	11.4	9.8	10.6	11.6	8.0	+1.2	−0.4	−0.8	+2.2	+0.3		10	AE M	*Ti* V + (2); *Mn* (2);
	66.8	5.4	7.0	9.3	8.4	5.5	−2.8	−2.3	−2.3	+1.4	−0.4		10	A L	*Fe* II (5);
	67.6	0.2	0.0	0.0	0.3	0.1	+0.2	0.0	0.0	+0.2	−0.1		0		*Sm*, *Nd*, *Ce*;
	68.7	10.7	8.5	5.4	4.5	3.1	+3.7	−1.5	+3.1	+0.7	+3.5	1.2	4	E H	*Ti* V +;
	69.5	7.3	9.1	7.9	8.8	6.6	−1.2	0.0	+1.2	+0.5	+1.1		6	AE H	*Fe* IV (4); *Ti* V (1); *Co* (0);
*	73.0	6.5	5.2	5.5	7.6	6.5	+1.1	+1.7	−0.3	−0.6	−0.8		5	AE M	*Mn* III (0); *Fe* (1); *Ce*;
**	76.2	6.0	7.9	8.4	6.5	4.2	−2.2	−3.0	−0.5	+1.2	+1.7		3	A M	*Fe* III (4); *Ag* $(1\pi_2-3\sigma)$ (3);
*	81.4	12.1	15.7	6.9	4.6	3.5	+0.8	−2.7	+8.8	+0.4	+8.2	10	2	AE HHH	*Mg* + $(2\delta-3\varphi)$, *Ti* III (1);
	82.4	4.8	7.1	7.5	5.3	5.7	−2.5	−1.7	−0.4	−1.7	−2.3		5	A L	*Fe* I (5; 3);
	82.9	0.2	0.8	1.4	1.4	1.1	−0.9	−0.1	−0.6	+0.3	+0.3		2	A M	*Ti* III, *Fe* (1);
	84.3 [2]	3.0	4.5	5.2	4.0	3.4	−1.8	−1.3	−0.7	0.0	−0.2		3	A M	*Fe* IV (4); *Ti* IV; *Ce*;
	85.9 [2]	1.9	2.2	3.7	3.4	2.4	−1.1	−0.7	−1.5	+0.4	−1.3	0.4	1	A L	*Fe* IV (3);
	87.1 [2]	0.9	0.0	0.7	1.6	1.1	+0.5	+0.4	−0.7	+0.3	−2.0	0.4	0.5	E L	*Ce* (0);
	88.4	3.7	4.0	3.1	2.1	2 6	+0.1	−0.5	+0.9	−0.8	+0.6	0.2	2	AE H	*Ti* V + (1); *unkn* (1);
	89.3	5.1	5.4	4.0	4.0	3.6	+0.4	0 0	+1.4	−0.2	+1.5	1.2	3	AE H	*Ti* III (0); *Fe* + (2); [11]
*	90.8	0.3	2.3	2.0	2.7	1.6	−1.9	0.0	+0.3	+0.7	−1.0		1	A M	*Fe* (2); *Ni* (0)
	91.6	5.1	4.8	1.9	2.9	1.3	+1.7	+0.1	+2.9	+1.2	+3.5		1	E HH	*Fe* + (2);
	92.7	0.1	0.3	1.1	1.3	1.3	−0.6	+0.1	−0.8	0.0	+0.8		2	A M	*Cr* III, *Fe* (0); *Ti* III;
	93.7	1.7	0.4	0.6	0.8	0.9	+1.2	+0.2	−0.2	−0.1	+1.0		0.5	E M	*unkn* (1)
	94.7	5.7	6.1	7.7	10.1	8.0	−1.2	+1.9	−1.6	+0.3	−0.8		7	A L	*Fe* III (6); *Zr* +; [10]
	95.6	0.4	0.2	0.6	1.0	0.6	0.0	+0.2	−0.4	+0.4	+0.2		0.5	AE M	*Ce*, *Ti* (0);
	96.2	0.2	0.6	1.3	2.3	2.0	−0.8	+0.8	−0.7	−0.1	−0.1		4	A L	*Ti* III, *V* + (1); [11]

λ	c	dF	dG	gG 0	gG 5	a_1	a_2	b_1	b_2	b_3	Sir.	Arct.	Classification		Origin
4497.1	3.7	3.8	3.9	2.8	2.5	− 0.1	− 1.0	− 0.1	− 0.2	− 1.1		2	AE	L	*Cr* I (P_2-d_3''') (3); *Zr* + (0);
98.0	0.3	0.2	0.4	1.0	1.0	0.0	+ 0.4	− 0.2	0.0	− 0.5		1	AE	L	*Ti* III (0); *Ce*, *Nd*;
99 1	0.7	1.7	3.6	3.1	3.8	− 1.9	0.0	− 1.9	− 1.2	− 0.8		2	A	LL	*Mn* III (1);
4500.5	0.6	0.4	0.8	1.2	1.6	0.0	+ 0.4	− 0.4	− 0.4	− 0.8		0.5	AE	L	*Cr* III (0); *Er*;
01.5	10.2	7.7	5.6	6.0	4.6	+ 3.6	− 0.4	+ 2.1	+ 0.3	+ 0.9	2	3	E	H	*Ti* V + (5);
02.4[4])	0.1	0.4	2.2	2.3	3.2	− 1.2	+ 0.5	− 1.8	− 1.2	0.0		2	A	LL	*Mn* III (2);
03.5	0 0	0.0	0.1	0.6	0.2	0.0	+ 0.3	− 0.1	+ 0.3	0.0		0.5		L	
05.0	0.3	0.2	0.8	0.6	1.1	− 0.2	− 0.1	− 0.6	− 0.3	− 0.9		1	AE	L	*Fe* (1)
06.8	0.8	0.0	0.3	1.1	1.0	+ 0.6	+ 0.6	− 0.3	0.0	− 0.2		3	E	M	*Gd*, *Ti* (00); *Mn* (0); *Nd*;
08.4	7.5	6.1	2.2	2.7	1.5	+ 3.3	− 0.2	+ 3.9	+ 0.8	+ 3.9	2	1.5	E	HH	*Fe* + (4); (*Ti* IV);
09.5[4])	0 0	0.4	1.0	1.3	1.3	− 0.7	+ 0 2	− 0.6	0.0	− 0.1		0.5	A	L	*Ni* +, *V* (0);
10.7	0.0	0.0	0.1	0.5	0.1	0.0	+ 0.1	− 0.1	+ 0.2	0.0		0.2			
12.0	0.3	0.2	0.4	0.8	0.5	0.0	+ 0.1	− 0 2	+ 0.2	− 0.4		1	AE	L	*Cr* III (1); *Sm*;
13.0	0.3	0.6	1.3	1.2	0.8	− 0.7	− 0.2	− 0.7	+ 0.3	− 0.7		2	A	L	*Ti* II (3); *Ni* (0 ; *Al* +;
13.6	0.0	0.0	0.1	0.4	0.4	0.0	+ 0.1	− 0.1	+ 0.1	+ 0.1		0.5		L	
14.5	0.7	1.6	2.7	1.9	2.9	− 1.5	− 0.2	− 1.1	− 1.3	− 0.2		1.5	A	LL	*Fe*, *Co* (1); *Cr* III (0); *V* +, *Gd* + (1);
15.5	7.0	5.0	2.2	3.6	3.0	+ 3.4	+ 1.0	+ 2.8	0.0	+ 3.5	1.6	2	E	HH	*Fe* + (3);
* 20.4	6.3	5.3	3.5	4.2	3.6	+ 1.9	+ 0.5	+ 1.8	− 0.1	+ 3.0	1.2	1	E	H	*Fe* + (3);
22.8	12.6	7.9	8.5	9.5	8.7	+ 4.4	+ 1.1	− 0.6	− 1.3	− 0.8	3	5.5	E	M	*Fe* + (3); *Ti* II (2); *Eu* +;
25.2	7.5	5.4	5.8	5.5	5.2	+ 1.9	− 0.3	− 0.4	− 0.8	+ 0.3		2	E	M	*Fe* IV (5); *Ba* + ($2\pi-2\sigma$);
** 28.8	7.9	8.9	11.4	11.0	10.5	− 2.3	0.0	− 2.5	− 2.0	+ 0.8		7	A	L	*Fe* II (8); *V* +;
29.7	5.2	5.8	5.8	5.8	5.2	− 0.6	− 0.1	0.0	− 0.7	+ 2.3		3	AE	M	*V* (1); *Ti* V + (1); *Al* + (1);
* 33.3	2.0	4.0	6.6	5.1	4.3	− 3.3	− 1.6	− 2.6	− 0.1	− 1.4		4	A	LL	*Ti* II (4);
34.2	12.1	9.8	6.3	7.2	5.0	+ 4.1	− 0.2	+ 3.5	+ 0.7	+ 2.6	2.4	3.5	E	H	*Ti* V +, *Co* (6);
35.0	0.3	1.6	3.0	2.7	1.4	− 2.0	− 0.8	− 1.4	+ 0.9	− 0.6		3	A	LL	*Ti* II (4);
36.0	5.3	7.8	13.1	13.1	9.6	− 5.1	− 1.4	− 5.3	+ 2.3	− 4.4		12	A	LL	*Ti* II (3); *Cr* II (1): *Zr* (0); *Ti* (2; 2);
38.0	0.1	0.0	0.0	0.1	0.2	+ 0.1	+ 0.2	0.0	− 0.1	− 0.3		0.2			*V* +, *Gd*, *Sm*;
39.0	0.1	0.4	0.6	1.2	1.8	− 0.4	+ 0.8	− 0.2	− 0.6	− 0.3		1	A	L	*Ti*; *Fe* (0; 0); *Ce*;
39.9	1.6	0.8	0.6	1.6	1.0	+ 0 9	+ 0.6	+ 0.2	+ 0.5	+ 2.0	0.2?	0.5	E	H	*Cr* III (0); *Ce*;
40.7	0.5	1.5	2.0	1.9	2.4	− 1.3	+ 0.2	− 0.5	− 0.8	+ 0.4		2	A	M	*Cr* II, III (2; 2);
41.7	4.1	2.5	1.7	1.6	2.2	+ 2 0	+ 0.3	+ 0.8	− 0.8	+ 2.0		0.5	E	H	*Fe* + (0); *Cr* III (2); *Nd*;
42.7	0.6	0.7	0.8	1.6	2.3	− 0.2	+ 0.9	− 0.1	− 0.9	+ 0.8		1.5	AE	M	*Fe* (1); *Zr* (0); *Cr* III (0); *Nd*;
44.1	1.9	1.0	0.7	1.6	1.6	+ 1.1	+ 0.6	+ 0.3	− 0.1	0.0		1	E	M	*Co* (0); *Ti* (1); *Sm*;
45.2[5])	4.0	2.4	3.2	4.8	4.3	+ 1.2	+ 1.4	− 0.8	− 0.3	− 1.1		2	E	L	*Ti* II (3); *Ti* + (1); *Cu* +;
46.1	0.8	1.2	1.7	1.0	1 0	− 0.6	− 0.5	− 0.5	0 0	+ 0.7		1	A	M	*Cr* I (P_2-d_2'''), *Fe* (3);
47.1	1.0	1.9	3.1	2.4	3.2	− 1.5	− 0.1	− 1.2	− 1.2	0.0		2	A	L	*Fe* ($F_3'-f_2^3$) (2); *Ni* (1);
48.0	0.9	1.7	1.9	1.0	1.0	− 0.9	− 0.7	− 0.2	0.0	+ 1.0		1	A	M	*Fe* V (3);
48.9	0.2	0.4	1.1	0.9	0.9	− 0.6	− 0.2	− 0.7	0.0	− 0.3		1	A	L	*Ti* II (2);
49.8	28.0	21.4	12.4	13.1	10.5	+ 11.1	+ 0.3	+ 9.0	+ 1.0	(0.0)	8	5	E	HH	*Ti* V +, *Co* (6); *Fe* + (2);
51.0	0.2	0.8	0.8	0.5	0.1	− 0.6	− 0.5	0.0	+ 0.4	+ 0.2		0	A	M	*Fe* (2); *Ni*;
52.6	4.4	3.3	6.4	4.0	5.4	− 0.4	− 1.3	− 3.1	− 2.3	− 0.9	0.2?	3.5	AE	LL	*Fe* (1); *Ti* (2);
54.2	9.1	8.0	7.4	8.6	5.7	+ 1.4	0.0	+ 0.6	+ 1.3	+ 0.2		2	E	M	*Ba* + ($1\sigma-1\pi_1$) (8); *Zr* +;
55.1[8])	1.2	1.0	0.6	0.5	0.3	+ 0.4	− 0.1	+ 0.4	+ 0.2	+ 5.0		0.5	E	H	*Cr* + (2); *Sm*;
56.1	9.4	7.8	6.0	5.0	3.4	+ 2.5	− 1.7	+ 1.8	+ 0.8	+ 2.2	1.6	1	E	H	*Fe* + (3); *Fe* V, *Cr* III (4);
58.8	6.7	4.5	2.0	2.0	2.3	+ 3.5	+ 0.2	+ 2.5	− 0.5	+ 3.2	2	0.2	E	HH	*Cr* + (3); *La*;
60.4	0.7	0.3	1.4	0.8	1.8	− 0.1	− 0.1	− 1.1	− 1.0	− 1.5		1	AE	LL	*Fe* (2); *Ce*, *Sm* (00);
61.3	0.3	0.1	0.1	0.1	0.6	+ 0.2	+ 0.1	0.0	− 0.4	− 0.7		0.2	E	L	*unkn* (1): *Ce*;
62.5	0.8	0.0	0.3	0.2	0.6	+ 0.6	+ 0.1	− 0.3	− 0.4	− 1.2		0.5	E	LL	*Ce* (0);
63.9	7.4	5.4	4.7	3.6	3.1	+ 2.4	− 1.2	+ 0.7	− 0.1	+ 2.9		2.5	E	M	*Ti* V + (4);
64.8	0.6	0.8	1.0	0.8	0.7	− 0.3	− 0.2	− 0.2	0.0	+ 0.9		0.2	AE	M	*V* + (0); *Fe* (0)
65.8	3.6	2.9	5.3	7.2	6.2	− 0.5	+ 1.6	− 2.4	− 0.7	− 0.1		2.5	AE	L	*Cr* I (p_2-d_3'') (3); *Co*, *Fe* (2), *Zr*;
66.9	0.1	0.4	2.3	1.6	1.3	− 1.3	− 0.8	− 1.9	+ 0.2	+ 0.5		0.5	A	L	*Fe* (1); *Fe* (1);
68.6	1.3	0.6	1.9	2.7	2.9	+ 0.1	+ 0.9	− 1.3	− 0.7	+ 1.4		1	AE	M	*Fe* (1);
71.3	1.0	1.0	3.1	2.7	2.9	− 1.0	− 0.1	− 2.1	− 0.7	− 2.7		2	A	LL	*Mg* ($1S-1p_2$) (5);
72.2	11.0	7.7	6.8	7.7	5.5	+ 3.2	− 0.1	+ 0.9	+ 0.8	− 0.5	1.6	3	E	M	*Ti* V + (6);
74.9	1.2	0.3	0.8	2.1	2.0	+ 0.6	+ 0.9	− 0.5	− 0.1	− 0.9		0.5	E	LL	*Fe* (2); *La*;
76.5	4.2	2.9	0.8	0.3	1.3	+ 2.4	− 0.1	+ 2.1	− 0.8	+ 4.2	0.8	0.5	E	HH	*Fe* + (2);
78.8	0.6	1.9	2.0	0.6	1.4	− 1.4	− 0.8	− 0.1	− 0.6	+ 0.1		0.8	A	M	*Ca* ($1d''-3f$) (3); *V* (00);
80.3[5])	4.2	2.6	4.1	6.0	6.2	+ 0.8	+ 2.2	− 1.5	− 1.6	+ 0.9		6	E	L	*Cr* I (P_2-d_1''), *La* (3); *V* + (1);
81.6	3.1	5.2	6.9	6.3	6.1	− 2.9	− 0.6	− 1.7	− 1.3	+ 0.8		2	A	M	*Ca* ($1d'-3f$) (4); *Co*, *Fe* (4);
82.9	3.2	1.2	1.0	0.8	0.4	+ 2.1	− 0.4	+ 0.2	+ 0.4	+ 1.1		0.2	E	H	*unkn* (1)
84.0	10.7	6.7	4.5	4.3	3.4	+ 5.1	− 0.5	+ 2.2	+ 0.2	+ 3.1	2	1	E	H	*Fe* + (4); *V* +;
85.0	0.2	0.5	1.5	1.0	1.0	− 0.8	− 0.4	− 1.0	+ 0.2	− 0 7		0.1	A	LL	*Fe* (1) *Sm* (2)
86.1	2.0	3.4	7.2	6.0	6.5	− 3.3	− 0 6	− 3.8	− 2.0	− 0.4		5	A	LL	*Ca* ($1d-3f$) (4)
87.2	0.1	0.5	0.8	0.2	0.6	− 0.5	− 0.4	− 0.3	− 0.2	− 0.3		0.2	A	L	*Fe* (2);
88.4	4.4	3.0	1.4	0.6	0.7	+ 2.2	− 0.6	+ 1.6	0.0	+ 4.3	1.6	0	E	HH	*Cr* + (3);
90.3	4.4	3.2	1.7	1.2	1.0	+ 2.0	− 0.5	+ 1.5	+ 0.1	+ 3.2		0.2	E	HH	*Ti* V + (3);

Remarks. [1]) on some plates difficult. [2]) nebulous. [3]) nebulous band. [4]) broad. [5]) broad, sometimes double. [6]) broad band, sometimes resolved. [7]) often not clearly separated. [8]) very difficult. [9]) this group shows a variable aspect, cf ALBRECHT *Lick Bulletin* IV, 90 (1906), *Aph. J.* 54.161 (1921). [10]) used for spectroscopic parallaxes at Mt Wilson, Victoria and Sidmouth. [11]) used for sp. par. at Victoria (4489.3 with add. line 4490.0). [12]) used for sp. par. at Sidmouth.

Additional lines.

λ	Int.	Origin	Remarks
4410.7	(2)	*Ni* (2)	sometimes one line
4411.2	(5)	*Ti* +; *Cr* (1)	
4415.3	(30)	*Fe* II (8)	sometimes one line
4415.7	(5)	*Sc* III + (3)	first line in Sirius 1.2
4424.0	(2)	*Fe?* (2)	sometimes broad band
4424.5	(2)	*Cr* (0)	
4430.1	(3)	*Fe* IV (1)	sometimes one band
4430.7	(5)	*Fe* III (3)	
4439.4	(0)	*unkn* (0)	faint line, sometimes visible
4440.0	(0)	*Fe* IV (1)	» » » »
4452.7—54.0	(7)	*Mn* III (1) *Ti* II (2) *Ti* III (1)	broad band, sometimes double
4461.1—62.5	(15)	*Mn* III (1); *Fe* I (4); *Fe* IV, *Mn* III (3) etc.	at incr. w. l. side nebulous [10])
4470.3—71.9	(10)	*Mn* III (1); *Ti* IV (1); etc.	nebulous band
4474.0	(1)		faint line
4474.9	(1)	*Ti* III (0)	faint line
4477.0—80.0	(6)	*Mn* (0) *Fe* IV (1);	neb. band, often many lines
4490.0	(9)	*Fe* I (4); *Mn*, *Fe* IV (3)	accidentally omitted
4516.4—18.4	(1)	*Fe* (3), *Ti* II (3)	at short w. l. side nebulous
4526.6	(3)	*Cr* (2)	two nebulous lines, usually separated
4527.3	(3)	*Ca?* (3) *Ti* II (3)	
4531.2	(10)	*Fe? Co* (2) *Fe* II (5)	broad line

[10]) used for spectroscopic parallaxes at Mt Wilson, Victoria and Sidmouth.

This table has been used as a basis for the classification of the lines. By the method of reduction positive differences *a* indicate enhanced lines (E), negative *a* indicate arc lines (A). Small values of *a* in the vicinity of zero will appear, when the line is a blend of enhanced and arc lines of nearly equal strengh; this is indicated by AE. Of course many cases of blends will occur, where one of the lines dominates and the combined line shows a definite character A or E. If, on the other hand, some kind of atoms in a stellar atmosphere is already highly ionized in the dwarfs, or only little ionized in the giants, their lines will show little variation and may also get the index AE. The values a_2 are not always concordant with a_1; since they are due to a smaller difference of ionization and moreover rest on less good plates, their indication was only taken into account when a_1 was small. In the same way positive and negative values of *b* indicate high and low temperature lines (denoted by H and L). Since this is not a qualitative but a quantitative distinction, occurring in various degrees, we will distinguish more steps: by M a medium class is denoted, with *b* in the vicinity of zero, while HH and LL designate strong positive and negative values. Here also the three values b_1 b_2 and b_3 are sometimes discordant, making the classification difficult and somewhat arbitrary; usually in thus singling out the lines small weight was attached to b_2, deduced from the G stars. Part of these differences may be real; if in a blend one component dominates in the dwarfs, another in the giants, its temperature behaviour will be different for dwarfs, giants and Cepheids. For some faint lines the classification could not be made out with certainty and has been omitted.

For the origin of the lines, indicated in the last column, the tables of ROWLAND, LOCKYER, MITCHELL and KING *) have been used. The intensity values in parentheses are taken from ROWLAND's solar spectrum. Roman figures indicate KING's temperature classes. Additional elements are added from MITCHELL's list or from KAYSER (Handbuch der Spectroscopie, V, VI). For *Ca*, *Mg*, *Fe*, *Cr*, *Y*+, *Sc*+ the designations for the series and multiplets are given, following FOWLER's Report, LAPORTE, GIESELER. Often the behaviour in star spectra clearly indicates the enhanced character of a line, or at least an enhanced component, where only neutral elements are given. In this case either one of these elements must be ionized, or in such a line still another component of enhanced character must be present in the Cepheids. The first case occurs with some lines of the rare earths. The stellar intensities indicate that the *Ce* lines 4417, 4429, 4487, and 4562 certainly belong to *Ce* +; by the constant differences found by PAULSON (*Astrophys. Journal* **40**, 298) this must be true also for a great number of other lines. For *Sm* the same is indicated by 4544, for *Er* by 4389 and 4500, for *Nd* by 4446.

*) H. A. ROWLAND, Preliminary Table of Solar Spectrum Wave Lengths, IV—V (*Aph. J.* 1); S. A. MITCHELL, Wave-lengths in the Chromosphere (*Aph. J.* 38); J. N. LOCKYER, Tables of Wave-Lengths of Enhanced Lines (1906, *Solar Physics Committee*); A. S. KING, *Contributions Mount Wilson Obs.* 66, 76, 198, 211. 247 (*Aph. J.* 37, 39, 41, 53, 56).

3. *Conclusions from the catalogue.*

The arc lines are classified here for the greater part as low temperature lines (LL, L or M), the enhanced lines as high temperature lines (M, H, HH). This may be explained as an effect of the increase of ionization with temperature, which for constant pressure must cause a strengthening of the enhanced, a weakening of the arc lines with increasing temperatures. There are some exceptions, part of which (e. g. 4456 AH, 4545 EL) may be attributed perhaps to the combination of lines of different character. Most of them, however, show something systematical; in five cases of EL (4421, 4429, 4487, 4562, 4580) the lines are due to rare earths, wholly or partially. Thus it may be inferred firstly that the lines of ionized rare earths are very low temperature lines, indicating a low ionization potential, and secondly, that the lines 4432 (*Cr*), 4561 (unknown), 4575 (*Fe*), which also are classified EL, have the same origin.

A comparison of our results for the arc lines with KING's temperature classification is difficult, because very few lines in the star spectra have a single origin. If, however, we make use of all lines, where a *Fe* or *Ti* line probably dominates the character, we find for KING's *Fe* I and *Fe* II all L or LL (5 lines); for *Fe* III the average M4L *) (9), for *Fe* IV M2L (8), for *Fe* V one line L (blend), one M (single). Among KING's *Ti* II all are L or LL (6), for *Ti* III the average is M6L (7), for *Ti* IV 2 lines give M. Thus on the whole there is a sufficient concordance. Of course the star lines, because they are mostly blends, cannot give the same exactness in classification as KING's laboratory experiments. If, however, it will be possible to resolve these blends by a greater dispersion, the star spectra may be useful in adding a range of higher temperatures to the laboratory range 1600°—2600° C.

In KING's laboratory work the enhanced lines (for such elements as *Fe*, *Ti*, *Cr*, *Mn*) are all contained in a single class V. Our table shows that *with the higher stellar temperatures the enhanced lines show a great variety in their behaviour. Among them low, middle and high temperature lines may be distinguished*, corresponding to the designations L or M, H and HH. The extreme case is formed by the well known high level *Mg* + line 4481 **); it is blended with a *Ti* line that occupies the same place in the sun and the cooler stars. The *Ba* + line in this region belongs to the lowest class, as could be presumed, it being a member of the resonance doublet. The *Fe* + lines are chiefly high temperature lines, as are also the *Cr* + lines; while the *Ti* + lines are distributed over different classes; this may be inferred from the following table, where only the lines have been inserted where the temperature character probably is not vitiated by other components.

Fe +		*Ti* +	
4489	H	4394	H
4492	HH	4396	H
4508	HH	4418	H
4515	HH	4418	H
4520	H	4444	HH
4576	HH	4469	H
		4488	H
Cr +		4501	H
4555	H	4550	HH
4559	HH	4564	M
4588	HH	4572	M
		4590	HH

Such a separation of the enhanced lines in different temperature classes may perhaps be useful in disentangling the spectrum of ionized *Ti* and *Fe* into series and multiplets. We must, however, bear in mind that much uncertainty is left — appearing in the often contradictory information of the different *b* — chiefly owing to the composite character of most of the stellar lines. This difficulty can only be removed if it is possible to get star spectra of a much greater dispersion and purity.

In the assigning of temperature classes to the lines no use has been made of the Sirius and Arcturus spectra; they may now be compared subsequently. In the following Table the average intensities in Procyon (*dF*) and Sirius are given for all lines > 1 (in *dF*) of each temperature class, as well as the number in Procyon and the number visible in Sirius.

	HHH	HH	H	M	L and LL
Av. Intensity Procyon	15.7	6.4	5.1	5.2	4.9
Av. Intensity Sirius	10	2.0	0.65	0.22	0.09
Number of lines Procyon	1	10	22	34	35
Number visible in Sirius	1	8	10	4	4

The relative intensity in Sirius, as well as the percentage visible in Sirius, increases with the temperature class; only the strongest low temperature arc lines (the *Fe* lines 4383, 4405, 4415) are visible besides the high temperature lines. Arc lines are less visible than enhanced lines of the same temperature class. A stronger influence of ionization appears if we compare α Cygni (using the intensity values of SCHEINER and LOCKYER); the strong *Fe* arc lines 4383, 4405, 4415 disappear wholly or are much weakened, compared with the other lines. The relative intensity of these arc lines and the other metallic

*) This denotes a value 0.4 of an interval below M, 0.6 above L.

**) That it is found AE is probably due to the mean *c* corresponding to a lower temperature than $\frac{1}{2}$ ($dF + dG$).

lines may afford a spectral criterion for determining the second coordinate (the gravity -index) for the A type stars.

A comparison of Arcturus with Procyon is given in the following table, containing averages for groups of lines arranged after the intensity in Procyon (excluding the lowest group I < 1, because it gives systematic errors).

LL Pr. Arct.	L Pr. Arct.	M Pr. Arct.	H Pr. Arct.	HH Pr. Arct.
1.4 4.2 (6)	2.0 2.5 (10)	1.8 2.0 (10)	1.5 2.3 (6)	3.7 0.4 (5)
4.1 5.3 (5)	5.1 6.8 (8)	4.9 3.6 (15)	3.9 2.8 (6)	6.1 3.1 (4)
21.5 35. (1)	10.8 10. (5)	9.1 8.2 (10)	7.2 3.0 (11)	18.6 3.5 (2)

The relative increase of the low temperature lines and the relative decrease of the high temperature lines for Arcturus is clearly marked; just as the comparison with Sirius this table confirms the reality of the distinction between each of the temperature classes. Some great individual deviations occur, which may be partly due to the appearance of other components in the lines.

The discrimination between enhanced lines of higher and of lower temperature may throw some light upon the contradictions in the spectral variations of δ Cephei. It now appears that not only the hydrogen lines, for which it has been stated by ADAMS and JOY, but also the high temperature enhanced lines increase considerably from minimum to maximum. That the bulk of the other lines does not show a variation of type must then be ascribed to the effects of increasing temperature being neutralized by the decreasing pressure.

4. *Remarks on spectral classification.*

Though originally the classification of spectra was made after characteristics allowing to distinguish different types in the easiest way, it soon appeared that the spectral classification was really a temperature classification. Thus in an ideal classification all stars with the same effective temperature should be placed in the same spectral division, whatever may be their other characteristics (e. g. absolute magnitude) *). What lines should be used for this purpose? *In abstracto* the comparison of lines emitted by the same atoms (i. e. in the same state of ionization) at different energy levels will afford a pure temperature scale; but such lines will seldom be at hand in comparable intensities. But also from the comparison of high and low temperature arc lines of different elements, or high and low temperature enhanced lines, reliable results for the themperature class may be expected. A spectrum, however, determined by comparing high temperature enhanced with low temperature arc lines will be vitiated by absolute magnitude. Since the Balmer lines of hydrogen in stellar spectra behave as enhanced lines, the comparison of these typical high temperature lines with the low temperature *Ca* + line K, which is the basis of the Harvard classification, will give a right temperature scale. At Mount Wilson (*Communications* 199 p. 20) the "measured" spectrum, since it is derived from a comparison of Hβ and Hγ with some strong *Fe* (and *Cr*) arc lines, must deviate from a true temperature index. For the "estimated" type chief attention was given to the lines 4227 *Ca* I and 4255 and 4275 *Cr* II, arc lines of low temperature class, which increase with advancing type. It is not stated whether they were compared with other lines or estimated as to their absolute visibility. Since we do not know the exact reason why all the metallic lines decrease and at last disappear going from K and G to A and B, we have, in the latter case, no theoretical basis to judge the relation of this "estimated" spectrum to a pure temperature scale.

*) In *Monthly Notices* of Jan. 1925 (85, 237) Prof. R. A. SAMPSON also advocates the use of a temperature classification as the standard of spectral classification.