# STUDIES IN PECULIAR STELLAR SPECTRA

## II. THE SPECTRUM OF B.D.-18°3789

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ABSTRACT

The *spectrum* of the star B.D.-18° 3789 has been found to *contain two groups of lines* which periodically *vary in intensity*. The observations are satisfied by a *period* of *3.d18*. The *chromium lines* in the spectrum *form one group*, while four *europium lines* and an unidentified line at λ 4296 *make up the other*. The two groups seem always to be opposite in phase with respect to each other. Wave-lengths and identifications are given for the spectral lines. *Similarities in the* appearance and behavior of the *spectrum to* that of $\alpha^2$ *Canum Venaticorum are pointed out.*

1. Variations in the relative intensities of groups of absorption lines in the spectra of variable stars are rather common phenomena, and can be explained generally as an effect of a change in temperature or pressure, or both. When, however, changes are observed in the case of a star whose light is sensibly constant, the difficulties of finding a satisfactory explanation are greatly increased. The problem becomes even more difficult when the lines of one or two elements are observed to change, while other elements having similar properties remain constant.

Probably the most remarkable examples of variations of this kind are shown by certain groups of lines in the spectra of 12 $\alpha^2$ Canum Venaticorum and 17 Leporis. There are a number of lines in the spectrum of $\alpha^2$ Canum Venaticorum which were found by H. Ludendorff[1] to vary in intensity. A. Belopolsky[2] divided the lines into two groups which varied in a period of 5.5 days. One of these groups was identified by F. E. Baxandall[3] as being due to the rare earth europium, while C. C. Kiess[4] has provisionally identified the other with terbium. O. Struve[5] has found that a large number of the metallic lines in the spectrum of 17 Leporis undergo remarkable changes, both in intensity and in appearance.

[1] *Astronomische Nachrichten*, **173**, 1, 1906.

[2] *Ibid.*, **196**, 1913, and *Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg* (6th ser.), **7**, 689, 1913.

[3] *Observatory*, **36**, 440, 1913, and *Monthly Notices*, **74**, 32, 1913.

[4] *Publications of the Detroit Observatory, University of Michigan*, **3**, 106, 1923.

[5] *Astrophysical Journal*, **72**, 343, 1930.

2. I have recently found another star which seems to belong to this rare and interesting class. The star B.D.-18°3789 (vis. mag. 5.74) is classed as of spectral type A0p by the *Henry Draper Catalogue*. The reason for the designation of "peculiar" was stated to be because of the strength of the *Si* II doublet, λ 4128 and λ 4131.

The remarkable changes that take place in its spectrum were first observed on three spectrograms of the star which had been taken with the Bruce spectrograph in 1928. On the first of these plates, taken on March 4, 1928, the europium lines which help to make the spectrum of $\alpha^2$ Canum Venaticorum so unusual are present, and the strongest, at λ 4205, is one of the most conspicuous lines in the whole spectrum. On the second plate, taken on the following night, March 5, the spectrum has about the same appearance, but on March 18, when the third plate was obtained, the entire character of the spectrum had changed in many respects. The strongest of the europium lines, which fourteen days before had been stronger than any other line in the spectrum with the exception of the hydrogen series, had faded until it was no stronger than a number of other lines in its vicinity. The other three europium lines which had been well marked on March 4 and 5 had become very faint. But the most remarkable change was the appearance of a number of lines which were either entirely absent on the earlier plates, or, in a few cases, at the limit of visibility. It was found that the lines of this second group are due to the element chromium. With a few exceptions, the lines due to other elements seem to be constant in intensity. There is a line at λ 4296.61 which seems to vary in phase with the europium lines. The position agrees well with the *Fe* II line at λ 4296.56, but as the other iron lines in the spectrum seem to be of constant intensity, the identification with iron seems highly improbable.

3. The star was again put on the spectrographic program in January, 1931, and twelve additional one-prism plates were obtained. The variations which had been observed on the early plates were confirmed, and were found to take place in a period of a few days at most. Because of the faintness of the star and its low southern declination, it is difficult to obtain sufficiently exposed plates. It is also almost impossible to obtain more than one plate on one night. For this reason the period cannot be determined with certainty, since

periods of about 1 day cannot be excluded. The variations in intensity of the lines are, however, satisfied by a period of 3.18 days. Figure 1 shows the variation of *Cr* II 4558 and *Eu* II 4205. The phases are computed from the arbitrary epoch 1931, January 0.0. The elements of variation of *Cr* II 4558 are:

$$\text{Max}=\text{J.D. } 2426343.15+3^{d}.18E \text{ (counted from noon)} .$$

Table I gives the estimates of the intensities of the principal variable lines in the observable part of the spectrum. These estimates

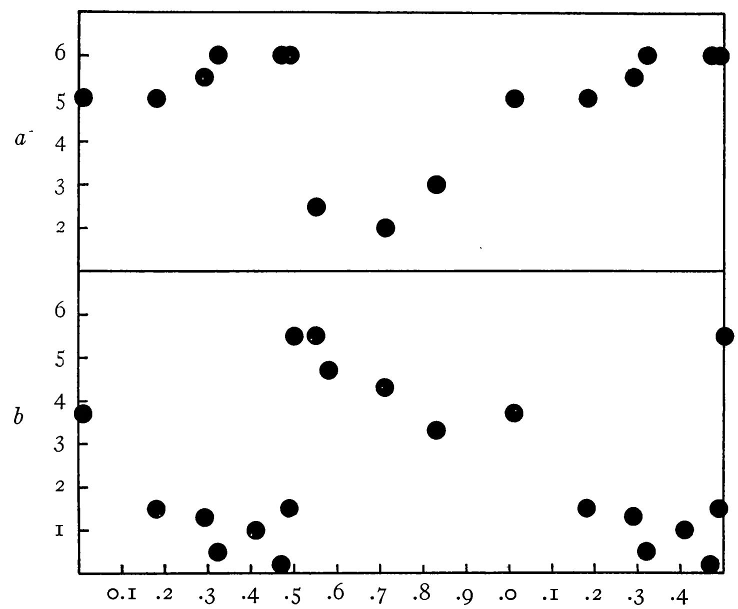
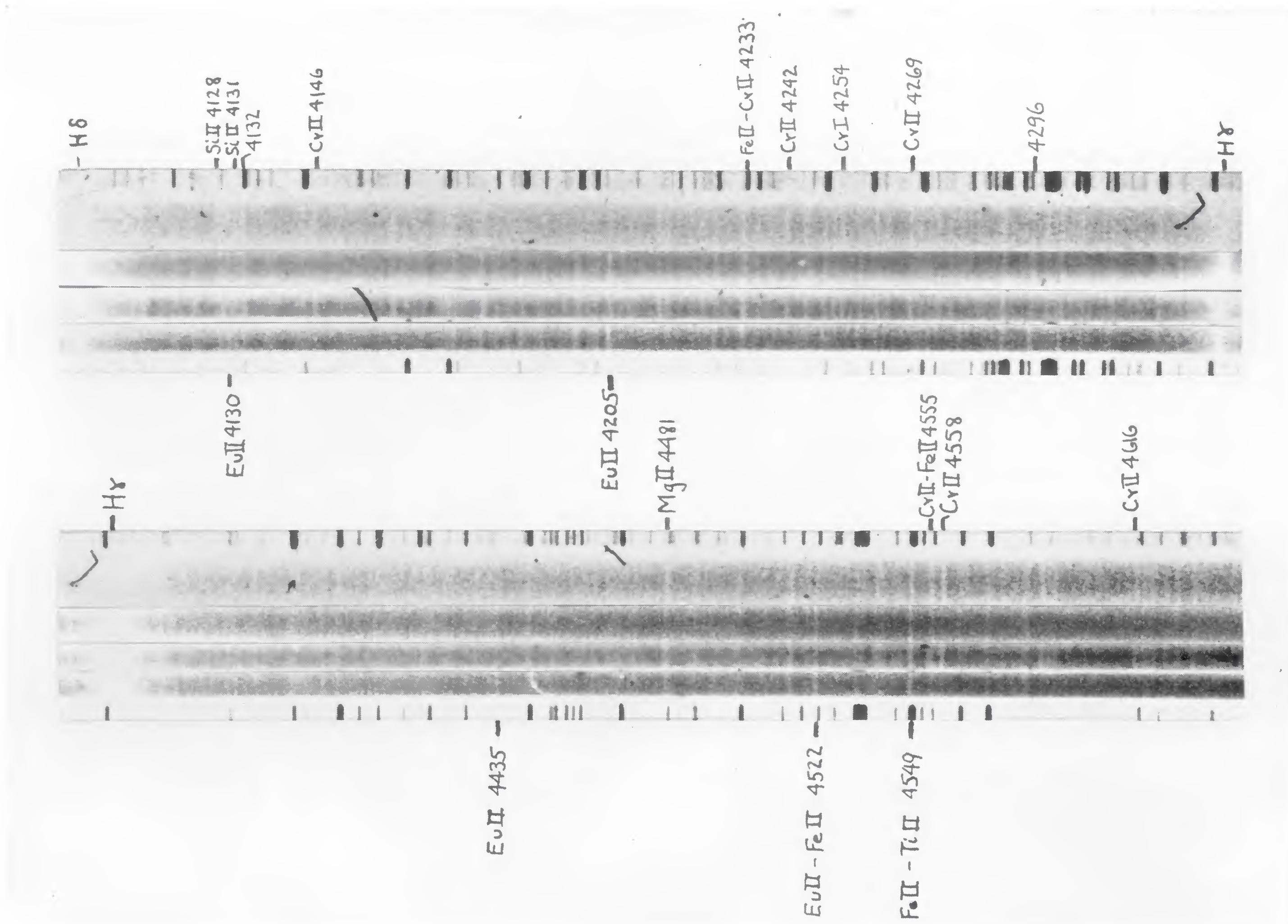



FIG. 1.—Probable curves of variation of: (*a*) *Eu* II 4205; (*b*) *Cr* II 4558. Abscissae are tenths of the probable period of $3^{d}18$; ordinates are visual estimates of intensity.

are, as far as the upper limit of the scale is concerned, independent of the quality of the plates, as the line *Fe* II–*Ti* II 4549 has been taken as the standard for intensity 5. The lower limit of the scale is, of course, more uncertain, because of the varying quality of the plates. Only the 1931 plates have been included in Table I.

4. The range in variation of the strongest chromium lines is greater than that of the europium lines. The ultimate *Cr* I line at λ 4254 ranges between complete invisibility and an intensity of 4, and the strongest of the *Cr* II lines at λλ 4242, 4269, and 4558, vary

PLATE II




a
b
c
d

a
b
c
d

Spectrograms of B.D. $-18^{\circ}3789$

*a*) 1931 Jan 14.475 (U.T.)

*b*) 1931 Jan 17.470 (U.T.)

from almost complete invisibility to intensities of from 4 to 5. Plate II shows the spectrum of B.D.-18°3789. Two spectrograms are reproduced at maximum and two at minimum phases. The spectra extend from about λ 4100 to λ 4650. The principal lines of chromium and europium are marked, and a few other conspicuous lines are identified. The chromium lines will be found to be stronger on the first and third reproductions than on the second and fourth. Probably the most striking illustration of the variation can be gotten by

TABLE I

ESTIMATES OF INTENSITIES

| Date U.T. | Phase | *Eu* II 4205 | *Cr* II 4242 | *Cr I* 4254 | *Cr* II 4269 | ? 4296 | *Eu* II 4435 | *Mg* II 4481 | *Eu* II–*Fe* II 4518 | *Cr* II 4558 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1931 Jan. 14.475... | 0.552 | 2–3 | 3–4 | 3–4 | 3–4 | 1 | 2 | 6 | 2–3 | 5.5 |
| Jan. 16.477... | .182 | 5 | 0 | 0 | 0 | 5 | 3 | 5 | 3 | 1.5 |
| Jan. 17.470... | .494 | 6 | 1? | 0? | 0 | 5 | 2–3 | 3 | 4 | 1.5 |
| Jan. 25.476... | .011 | 5 | 0? | 0? | 0? | 5 | 3 | 3 | 3 | 3.7 |
| Jan. 26.453... | .319 | 6 | 2 | 0 | 0 | 5 | 2–3 | 4 | 4 | 0.5 |
| Jan. 30.459... | .578 | ..... | ..... | ..... | ..... | 2 | 3 | 4 | 3 | 4.7 |
| Feb. 3.435... | .829 | 3 | 3 | 2 | 2 | 3 | 1 | 5 | 2–3 | 3.3 |
| Feb. 5.469... | .468 | 6 | 0 | 0 | 0 | 5 | 3 | 1–2 | 4 | 0.2 |
| Feb. 8.477... | .414 | ..... | ..... | ..... | ..... | ..... | ..... | 5 | 2–3 | 1 |
| Feb. 9.426... | .713 | 2 | 2–3 | 3–4 | 1? | 1: | 1 | 6 | 2 | 4.3 |
| Feb. 14.431... | .287 | 5–6 | ..... | ..... | ..... | 4 | 2 | 2–3 | 3–4 | 1.3 |
| Feb. 21.476... | 0.502 | ..... | ..... | ..... | ..... | ..... | ..... | 6 | 1? | 5.5 |

The phases are expressed in decimal fractions of the period. Complete absence of a line is denoted by intensity zero.

comparing the *Fe* II–*Ti* II line at λ 4549 with the two chromium lines at λ 4555 and λ 4558. The europium lines vary in the opposite sense. The most marked variation among the europium lines is shown by λ 4205, which is stronger on the second and fourth spectrograms. Only a few of the variable lines have been marked. It is possible that the hydrogen lines and *Mg* II 4481 also vary. Over thirty *Cr* II lines were measured, including a number predicted by T. Dunham and Miss Charlotte E. Moore[1] from a study of incomplete multiplets and found by them in 9α Persei and in the sun. Owing to the fact that B.D.-18°3789 is at a higher temperature than α Persei, many of the arc lines which cause blends with chromium in the cooler star have disappeared, and most of the *Cr* II lines are practically un-

[1] *Ibid.*, **68**, 37, 1928.



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blended. The star is therefore well suited to the study of the relative intensities of the chromium lines which have not been observed in the laboratory.

Table II lists the *Cr* II lines observed in the star between the limits λλ 4030–4635. The columns give: (1) the laboratory wave-lengths for all lines observed in the laboratory and the computed wave-lengths for the lines predicted by Dunham and Miss Moore; (2) the intensities in arc and spark, according to Exner and Haschek; (3) the multiplet number of the lines. The multiplets have been consecutively numbered, from lower to higher wave-length. The final columns in the table give: (4) the wave-lengths in B.D.-18°3789; (5) the maximum and minimum intensities in the star; and (6) notes as to blends, etc.

Dunham states[1] that the strongest lines of neutral and singly ionized chromium are of about equal intensity in α Persei. As the strongest *Cr* I line, located at λ 4254, is approximately equal to the strongest enhanced lines in B.D.-18°3789, we would expect the spectral type of the two stars to be about the same, but in other respects they are quite different.

5. The lines in the spectrum of europium have recently been classified according to temperature by A. S. King,[2] who finds four lines within my observed range which are so strong in the arc that they dominate the spectrum. They are probably lines of low energy-level in the spectrum of *Eu* II, and are strongly reversed in the arc. Table IV gives the wave-lengths of these lines, their intensities in the electric furnace and the arc, the wave-lengths measured in the star, and the estimated intensities of the lines at their greatest and least strength in the star. The estimates are on the same scale as in the preceding tables.

The line at λ 4129.78 is situated between the two *Si* II lines at λ 4128 and λ 4131. It is probably entirely unblended. It seems likely that this line, together with λ 4132, causes the star to seem to have strong *Si* II lines on objective-prism plates. The silicon doublet itself is of only moderate intensity, and seems hardly strong enough to designate the spectrum as "peculiar." In the cooler stars there is a

[1] *Contributions from the Princeton University Observatory*, No. 9, 7, 1929.

[2] *Astrophysical Journal*, **72**, 221, 1930.

## TABLE II

LINES OF *Cr* II

| λ | Int. | Mult | λ Star | Max. Int. | Min. Int. | Notes |
|---|---|---|---|---|---|---|
| 4030.37.... | Pred. | 1 | 4030.48 | 3: | 0 | |
| 4053.44.... | Pred. | 2 | ......... | ..... | ..... | |
| 4054.10.... | Pred. | 2 | 4054.05 | 3–4 | 1 | |
| 4064.05.... | Pred. | 1 | 4064.00 | 3–4 | 0? | Blended with *Fe* I 4063.61; *Cr* II probably disappears at minimum |
| 4070.94.... | 0–4 | ..... | 4070.84 | ..... | ..... | |
| 4072.63.... | Pred. | 3 | 4072.74 | 2 | 0 | |
| 4075.66.... | Pred. | 2 | 4075.73 | 2 | 1 | |
| 4076.87.... | Pred. | 2 | 4076.93 | 3 | 0 | |
| 4077.55.... | Pred. | 2 | 4077.61 | 4 | 1–2 | *Sr* II and *Cr* II contribute about equally at maximum |
| 4087.63.... | Pred. | 2 | 4087.47 | 1 | 0 | |
| 4088.85.... | Pred. | 2 | ......... | ..... | ..... | |
| 4111.09.... | 0–4 | ..... | 4110.98 | 3 | 0 | |
| 4112.57.... | Pred. | 4 | ......... | ..... | ..... | |
| 4145.78.... | 0–6 | .. | 4146.00 | 4 | 0 | Enhanced line listed by Lockyer |
| 4146.45.... | Pred. | 3 | | | | |
| 4170.64.... | Pred. | 4 | 4170.79 | 2 | 1 | |
| 4171.92.... | Pred. | 4 | 4171.95 | 3–4 | 1 | |
| 4172.62.... | Pred. | 4 | ......... | ..... | ..... | |
| 4179.41.... | 0–3 | 3 | 4179.22 | 4 | 0? | |
| 4207.34.... | Pred. | 3 | 4207.45 | 1 | 1 | Line may not be due to *Cr* II |
| 4215.78.... | Pred. | 4 | 4215.60 | 3–4 | 1–2 | *Sr* II and *Cr* II contribute about equally at maximum |
| 4217.08.... | Pred. | 4 | 4217.38 | 3 | 3 | *Cr* II probably contributes little, if at all, to the star line. In Lockyer's list of enhanced lines; not mentioned by Dunham |
| 4224.86.... | 0–2 | ..... | 4224.58 | 3–4 | 1 | |
| 4229.82.... | Pred. | 3 | 4229.77 | 2 | 2 | The contribution of *Cr* II is probably negligible |
| 4233.28.... | Pred. | 5 | 4233.25 | 8 | 5 | *Cr* II and *Fe* II about equal in intensity at maximum |
| 4242.37.... | 1–5 | 5 | 4242.48 | 3–4 | 1 | |
| 4252.65.... | 0–1 | 5 | 4252.61 | 3 | 0 | |
| 4261.81 ... | 0–2 | 6 | 4261.94 | 3 | 2–3 | Line apparently not variable |
| 4261.90 | | 5 | | | | Probably a blend |
| 4269.30.... | 0–1 | 5 | 4269.11 | 3–4 | 0 | |
| 4275.58.... | 0–1 | 5 | 4275.32 | 3 | 1–2 | |
| 4279.00.... | Pred. | 6 | | | | |
| 4280.34.... | Pred. | 6 | 4280.83 | 1–2 | 2–3 | Line probably not due to *Cr* II |
| 4284.20.... | 0–2 | 5 | 4284.20 | 2 | 0 | |
| 4504.56.... | Pred. | 7 | | | | |
| 4507.22.... | Pred. | 7 | (4507.74) | 1 | 1: | Blended with *Fe* II 4508.29 |
| 4542.82.... | Pred. | 7 | | | | |
| 4544.69.... | Pred. | 7 | | | | |
| 4555.09.... | 1–3 | 8 | 4555.21 | 4n | 2 | Blended with *Fe* II 4555.89 |
| 4558.66.... | 1–20 | 8 | 4558.71 | 5–6 | 1: | |
| 4558.84.... | Pred. | 8 | | | | |

TABLE II—*Continued*

| λ | Int. | Mult | λ Star | Max. Int. | Min. Int. | Notes |
|---|---|---|---|---|---|---|
| 4571.30.... | Pred. | 7 | 4572.20 | 2 | 2 | Line probably entirely due to *Ti* II 4571.98 |
| 4572.83.... | Pred. | 7 | | | | |
| 4588.21.... | 1–15 | 8 | 4588.10 | 2–3 | 1 | |
| 4588.40.... | Pred. | 7 | | | | |
| 4589.89.... | Pred. | 8 | 4590.07 | 2 | 1: | |
| 4592.06.... | 0–2 | 8 | 4592.07 | 2 | 1: | |
| 4616.72.... | 0–3–4 | 8 | 4616.37 | 3 | 1: | |
| 4618.82.... | 0–8 | 8 | 4619.00 | 2 | 0 | |
| 4621.51.... | Pred. | 9 | | | | |
| 4634.12.... | 0–8 | 8 | 4634.18 | 2n | 0 | |

TABLE III

LINES OF *Cr* I

| λ | Int. | Mult | λ Star | Max. Int. | Min. Int. | Notes |
|---|---|---|---|---|---|---|
| 4254.348... | 50R–50 | 1 | 4254.39 | 3–4 | 0 | |
| 4274.808... | 50R–30 | 1 | ......... | 1–2? | 0 | Partially masked by 4275.32? |
| 4289.731... | 30R–30 | 1 | 4289.89 | 4 | 3–4 | Blended with *Ti* II 4290.23 |

TABLE IV

LINES OF EUROPIUM

| λ (KING) | INT. | | λ (STAR) | INT. | |
|---|---|---|---|---|---|
| | Fur. | Arc | | Max. | Min. |
| 4129.639.......... | 4? | 25? | 4129.78 | 2–3 | 2: |
| 4129.734.......... | 80 | 500R | | | |
| 4204.909.......... | 5? | 30? | 4205.04 | 7 | 3–4 |
| 4205.046.......... | 100 | 600R | | | |
| 4435.473.......... | 10 | 20? | 4435.49 | 3–4 | 1: |
| 4435.602.......... | 80 | 400r | | | |
| 4522.602.......... | 50 | 200r | 4522.56 | 4–5 | 2–3 |

rather strong line of ionized yttrium at λ 4204.69, but apart from the disagreement in wave-length with the *Eu* II line at λ 4205.05, the star does not seem to contain any yttrium lines. There is also a line due to *V* II at λ 4205.09, but, as stronger lines due to the same element seem to be absent, it can make no sensible contribution to the intensity of the well-marked star line. There is a strong neutral calcium doublet at the position of *Eu* II 4435, but as the ultimate line of *Ca* I at λ 4226 is either absent or very weak in the star, it does not seem that calcium can sensibly disturb the europium line. *Eu* II 4522.56 is blended with the *Fe* II line at λ 4522.64. The two elements probably contribute about equally to the intensity of the stellar line.

6. The principal lines in the spectrum, with the exception of the hydrogen series, were measured for wave-length. The measures were made when the chromium lines were strong. Table V gives the wave-lengths and identifications for the strongest star lines between the limits λ 4030 and λ 4634. The columns give: (1) the measured wave-length; (2) the intensity of the stellar line; (3) the identification and wave-length of the line in the laboratory. In the cases of serious blends the method of Dunham has been used to show the approximate share of the different elements in the blend. Thus, if two elements contribute equally, each is preceded by one plus sign (+). If one contributes twice as much as the other, it is preceded by two plus signs (++), while the other is preceded by one plus sign (+). The approximate share of the different elements in the case of blends was determined from the intensities of unblended members of the same multiplets to which the elements involved belong. A few notes on peculiarities of individual lines are placed at the end of the table.

7. The plates were all measured for radial velocity. The results are shown in Table VI. The columns give (1) the date on which the plate was obtained; (2) the radial velocity; (3) the quality of the plate; and (4) the measurer of the radial velocity.

In spite of the poor quality of most of the plates, the scatter in the measures is larger than it should be, if the velocity is constant. The two best plates of the 1931 series give positive velocities, while the three 1928 plates give negative velocities of from 14 to 23 km. The observations in 1931 were plotted according to the phases computed from the variable chromium line at λ 4558. No certain periodicity was shown. It seems probable that the radial velocity is variable, but a long series of good plates will be necessary to settle the question.

Adams and Joy[1] have published a value of $-9.5 \pm 1.8$ km/sec. for the radial velocity. This value was determined from five plates. The

[1] *Ibid.*, 57, 149, 1923.

mean velocity from the Yerkes measures is $-8.2$ km/sec., in very good agreement with the Mount Wilson value.

TABLE V

WAVE-LENGTHS AND IDENTIFICATION OF LINES

| λ | Int. | Identification | λ | Int. | Identification |
|---|---|---|---|---|---|
| 4046.02 | 2–3 | *Fe* I 45.82 | 4289.89 | 4 | *Ti* II 90.23 |
| 4049.07 | 3 | −?*Cr* I 48.76 | 4294.23 | 1 | +*Fe* I .13; +++*Ti* II .10 |
| 4054.05 | 3–4 | +*Cr* II .08; +*Ti* II 53.84 | 4296.61 | 1 | *Fe* II .56 |
| 4064.00 | 4 | +++*Cr* II .05; +*Fe* I .60 | 4299.87 | 2 | *Ti* II 00.05 |
| 4070.84 | 2: | *Cr* II .99 | 4301.97 | 2 | *Ti* II .93 |
| 4072.74 | 3 | *Cr* II .63 | 4303.19 | 3 | *Fe* II .18 |
| 4075.73 | 2 | *Cr* II .66 | 4307.80 | 1–2 | ?*Ti* II .89 |
| 4076.93 | 3 | *Cr* II .88 | 4312.87 | 1–2 | *Ti* II .88 |
| 4077.61 | 4 | +*Sr* II .71; +*Cr* II .58 | 4314.96 | 3 | *Ti* II .98 |
| | | | 4325.61 | 4 | −*Fe* I .77 |
| 4113.26 | 3–4 | ........................ | 4330.53 | 3 | +*Ti* II .26; +*Ti* II .71 |
| 4119.23 | 1–2N | ........................ | 4351.82 | 1 | *Fe* II .77 |
| 4122.98 | 3–4N | −?*Fe* II .67 | 4367.97 | 2–3 | *Ti* II .67 |
| 4128.02 | 3–4 | *Si* II .05 | 4374.72 | 2 | *Sc* II .46 |
| 4129.91 | 2 | *Eu* II .73 | 4383.57 | 2 | *Fe* I .55 |
| 4131.02 | 1–2 | *Si* II 30.88 | 4385.17 | 2–3 | *Fe* II .39 |
| 4132.37 | 4 | ?☉ .54; ?*Fe* I .07 | 4395.27 | 2 | *Ti* II .04 |
| 4138.10 | 1–2N | ........................ | 4400.01 | 2 | *Ti* II 99.77 |
| 4143.50 | 2–3 | −?*Fe* I .88 | 4404.99 | 1 | *Fe* I .75 |
| 4146.00 | 4 | *Cr* II 45.78 | 4410.85 | 1 | *Ti* II 11.10 |
| 4161.40 | 4 | −?*Ti* II .52 ch | 4415.00 | 1 | *Fe* I .13 |
| 4163.85 | 2–3 | *Ti* II .65 ch | 4416.82 | 2 | *Fe* II .81 |
| 4170.79 | 2 | *Cr* II 64 | 4435.44 | 1: | *Eu* II .60 |
| 4171.95 | 3–4 | ++*Cr* II .92; +*Ti* II .90 | 4444.23: | 2–3N | ?*Ti* II 43.80 |
| 4173.53 | 2–3: | *Fe* II .48 | 4481.31 | 5 | *Mg* II .25 |
| 4179.22 | 4 | +++*Cr* II .41; +*Fe* II 78.87 | 4489.02 | 1–2N | *Fe* II .21 |
| 4181.85 | 2 | ?*Fe* I .77 | 4501.02 | 2n | *Ti* II .27 |
| 4186.92 | 3 | ?*Fe* I 87.05 | 4507.81 | 1 | +*Cr* II .22; ++*Fe* II 08.29 |
| 4190.28 | 2 | −?*Ti* II .29 | 4511.74 | 2 | ?*Cr* I .91 |
| 4191.37 | 2 | ?*Fe* I .44 | 4515.49 | 3–4 | +*Fe* II .34 +? |
| 4195.46 | 2 | ?*Fe* I .34 | 4520.16 | 2 | *Fe* II .24 |
| 4198.43 | 3 | ?*Fe* I .31 | 4522.60 | 2–3 | +*Fe* II .64; +*Eu* II .60 |
| 4205.10 | 3–4 | *Eu* II .05 | 4533.97 } 2–3NN | { 1–2 | *Ti* II .97 |
| 4207.45 | 1 | *Cr* II .34 | 4535.52 } | { 1: | ........................ |
| 4215.60 | 3–4 | +*Cr* II 78; +Sr II .52 | 4540.57 | 4NN | ........................ |
| 4217.38 | 3 | *Cr* II .08 | 4545.68 | 2NN | ........................ |
| 4224.58 | 3 | ?*Cr* II .86 | 4549.58 | 5 | +++*Ti*; .64++*Fe* .48 |
| 4227.49 | 3 | −?*Fe* I .44 | 4555.21 | 4n | *Cr* II .09 |
| 4229.77 | 2 | *Cr* II .82 | 4558.71 | 5 | +++*Cr* II .66; ?+*Cr* II .84 |
| 4233.25 | 7 | +*Cr* II .28; *Fe* II 16 | | | |
| 4242.48 | 3–4 | *Cr* II .37 | 4563.93 | 1 | *Ti* II .77 |
| 4246.66 | 3 | *Sc* II .83 | 4565.76 | 1 | ?*Cr* I .51 |
| 4250.40 | 3N | +*Fe* I .13; +++*Fe* I .79 | 4572.20 | 2–3 | −*Cr* II 71.30; +++*Ti* 71.98; −*Cr* II 72.83 |
| 4252.61 | 3 | *Cr* II .65 | | | |
| 4254.39 | 3–4 | *Cr* I .34 | 4576.53 | 1–2 | *Fe* II .31 |
| 4258.09 | 3 | ?*Fe* II .17 | 4583.11 | 3NN | +*Fe* II 2.84; ++*Fe* II 3.84 ++? |
| 4261.94 | 3 | +*Cr* II .81; +++*Cr* II .90 | 4588.10 | 3 | +++*Cr* II .21; +*Cr* II .41 |
| 4263.96 | 3NN | ........................ | 4590.07 | 2 | +[*Cr* II .89; *Cr* II 95] ++*Ti* II .96 |
| 4269.11 | 3–4 | *Cr* II .30 | | | |
| 4271.56 | 2 | *Fe* I .76 | 4592.07 | 2 | *Cr* II .06 |
| 4273.35 | 2 | *Fe* II .33 | 4616.37 | 3 | *Cr* II .72 |
| 4275.32 | 3 | *Cr* II .58 | 4619.00 | 2 | *Cr* II 18.82 |
| 4278.04 | 2–3 | *Fe* II .17 | 4625.55 | 2–3 | +?*Fe* I .05; +?*Cr* I 26.18 |
| 4280.83 | 1 | +*Cr* II .34; +++*Cr* II 81.08 | 4629.22 | 2 | *Fe* II .33 |
| | | | 4634.18 | 2n | *Cr* II .12 |
| 4284.20 | 2 | *Cr* II .20 | | | |

The line at λ 4113.26 seems to vary in phase with the *Cr* II lines. Exner and Haschek list a chromium line of intensity 1 in the spark at λ 4113.18. The line at 4444.23 gave discordant velocities on several of the plates. It is possible that it varies in position.

8. If the variation in intensity of the *Cr* II lines be considered as due to periodic changes in effective excitation in the atmosphere of the star, difficulties immediately arise. On the assumption of changes in excitation, neutral chromium should vary oppositely in phase to ionized chromium, since the increased strength of *Cr* II would be obtained at the expense of *Cr* I. (From the general appearance of the spectrum, it would seem that the higher stages of ionization can be

TABLE VI

MEASURES OF RADIAL VELOCITY

| Date U.T. | Vel. | Qual. | Meas. |
|---|---|---|---|
| 1928 Mar. 4.438.... | −20.4 | g | $\sigma$ |
| | −23.3 | | M |
| Mar. 5.342.... | −17.9 | g | $\sigma$ |
| | −17.9 | | M |
| Mar. 18.381.... | −13.7 | g | $\sigma$ |
| | −16.0 | | M |
| 1931 Jan. 14.475.... | −15.1 | f | M |
| Jan. 16.477.... | −16.2 | p | M |
| Jan. 17.470.... | + 5.1 | g | M |
| Jan. 25.476.... | − 9.2 | p | M |
| Jan. 26.453.... | + 2.4 | g | M |
| Jan. 30.459.... | − 7.9 | vp | M |
| Feb. 3.435.... | − 9.7 | p | M |
| Feb. 5.469.... | + 7.2 | f-p | M |
| Feb. 8.477.... | − 3.8 | p | M |
| Feb. 9.426.... | − 0.8 | f | M |
| Feb. 14.431.... | − 7.0 | p | M |
| Feb. 21.476.... | −13.7 | p | M |

$\sigma$ = O. Struve; M = W. W. Morgan.

neglected.) The observations, however, show that the line of *Cr* I at λ 4254 varies in phase with *Cr* II. The other two members of the ultimate triplet of *Cr* I do not show much variation, probably because of blends. It thus seems that, as far as can be judged by appearances, the actual number of chromium atoms effective in absorbing the observed lines varies in the period of the variation in intensity. In the case of the europium lines, there is no check on the behavior of the lines of the neutral atom. It is difficult to find any relationship between the elements chromium and europium, but their complementary behavior seems very suggestive.

It also seems remarkable that, in the only other star known to contain strong lines of europium, the same lines form a group which varies in intensity. In $\alpha^2$ Canum Venaticorum the europium lines vary from almost complete invisibility to intensities which place them among the strongest lines in that star's spectrum. It is not possible to generalize with only two stars, but it seems possible that europium is connected with some state of physical change. It would be necessary to find more of such stars before an adequate study could be made of the phenomenon. The importance of such a study can hardly be overemphasized, as it seems that in stars of this class we are observing results of changes which may illustrate the basic laws of stellar evolution.

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Williams Bay, Wis.
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