Fe III LINES IN STELLAR SPECTRA

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ABSTRACT

A term analysis of the *Fe* III spectrum in the ultraviolet region enables the writers to predict *Fe* III lines which fall in the astronomically observable region. Several of them are present in B-type stars, both as absorption and as emission lines.

1. Owing to the high cosmic abundance of iron, the permitted lines of *Fe* III are to be expected in several astronomical spectra, namely, as absorption lines in early B-type stars and as emission lines in bright-line stars and novae, in the high chromosphere, etc. Attention has been drawn on several occasions to the possible importance of the *Fe* III forbidden transitions in connection with the spectra of novae, bright-line stars, nebulae, the solar corona, etc. In order to provide the required spectroscopic data for *Fe* III, which thus far have been lacking, we have attempted a term analysis of the *Fe* III spectrum, using vacuum-spark spectra in the region 2400–500 A, supplemented from 2400 to 1000 A by spectra of a spark in nitrogen. The analysis started from Bowen's classification[1] of the three important multiplets $a^5D - z^5P^o$, $a^7S - z^7P^o$, and $a^5S - z^5P^o$. At present the essential part of the septet and quintet terms lower than approximately 150,000 cm^{-1} has been established and some three hundred lines from 808 to 2150 A are classified. The analysis permits a prediction of the two multiplets of lowest excitation which fall in the astronomically observable region and presumably will give the most prominent of the permitted *Fe* III lines in astronomical spectra, namely, (*a*) $3d^5(^4P)4s\,^5P - 3d^5(^6S)4p\,^5P^o$ (from 4352 to 4431 A; excitation potential of the a^5P level = 8.22 e.v.); (*b*) $3d^5(^4D)4s\,^5D - 3d^5(^6S)4p\,^5P^o$ (from 5063 to 5194 A; excitation potential of the ^5D level = 8.62 e.v.).

The prediction and identification of these multiplets constitute the subject of this note.

2. The manner of connecting z^5P^o with a^5P and b^5D, as shown in Figure 1, involves lines with $\nu > 78{,}000$ cm^{-1}, giving an uncertainty

[1] *Phys. Rev.*, **52**, 1153, 1937.

of about 1 cm^{-1} in the absolute position of the predicted multiplets; on the other hand, the separations within each multiplet and between the two multiplets which were determined from transitions around 50,000 cm^{-1} were accurate to 0.1 cm^{-1}. This was sufficient to ascertain the identification of *Fe* III in γ Pegasi (B2), which has spectral characteristics suggesting the probable presence of *Fe* III absorption lines. Since the identification appeared to be certain be-

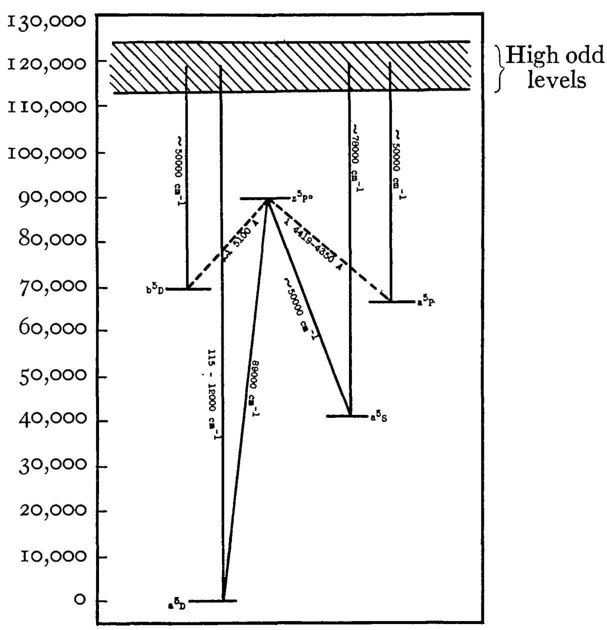

Fig. 1

yond any doubt, the connection by means of lines around 78,000 cm^{-1} was finally replaced by the assumption that the transition $a^5P_3 - z^5P^o_3$ has the value 4419.61 A, this being the mean of Struve's[2] and Kühlborn's[3] measured wave lengths in γ Peg; this meant a change of only 0.2 cm^{-1}. The wave lengths of the components of the two multiplets were calculated accordingly and may be found in Table 1.

3. The first multiplet falls in a region where we are provided with several good lists of wave lengths of absorption lines in B-type

[2] *Ap. J.*, **74**, 225, 1931.

[3] *Veröff. Babelsberg*, **12**, Heft 1, 1938.

stars, especially those of Struve and of Kühlborn. The identifications are summarized in Table 2.

The multiplet appears also in emission in Be stars. In BD + 11°4673, Merrill[4] measured an emission line at 4419.8 with an absorption component on the violet side.[5] Possibly the faint emission line measured by Lunt[6] at λ 4419.11 in η Carinae may be also due to

TABLE 1

$a^5P - z^5P^o$		λ	$b^5D - z^5P^o$		λ
1	1	4365.67	0	1	5063.52
1	2	4395.79	1	1	5073.79
2	1	4352.59	1	2	5114.53
2	2	4382.53	2	1	5086.78
2	3	4431.03	2	2	5127.72
3	2	4371.35	2	3	5194.26
3	3	4419.61	3	2	5127.38
....	....	....	3	3	5193.91
....	....	....	4	3	5156.10

TABLE 2

Predicted Laboratory Wave Length	Wave Length in Struve's List	Wave Length in Kühlborn's List	Intensity in γ Peg (B2) (Kühlborn)	Remarks
4419.61	4419.62	4419.601	3	Observed also by Dawson,* Marshall,† Pillans,‡ possibly Struve and Dunham§
4382.53	4382.43	4382.52	2–3	....
4365.67	....	4365.66	1	Blend with *Ne* II (5.72)
4371.35	....	4371.23	1–2	Blend with *A* II (1.36)
4431.03	4431.03	4431.08	2	Blend with *A* II (1.02) and possibly *S* II (1.02)
4352.59	4352.47	4352.48	1–2	Questionably attributed to *A* II (2.23) by Kühlborn, the principal contributor being unknown
4395.79	Blended with O II	blended	....	....

* *Pub. U. of Michigan Obs.*, **2**, 158, 1916.
† *Ibid.*, **5**, 137, 1934.
‡ *Ap. J.*, **80**, 51, 1934.
§ *Ibid.*, **77**, 321, 1933.

[4] *Ap. J.*, **69**, 330, 1929.

[5] A search for *Fe* III lines in "iron stars" would presumably give interesting results.

[6] *M.N.*, **79**, 621, 1919.

Fe III, though the wave length discrepancy seems somewhat large. In the list of emission lines of γ Cassiopeiae recently published by R. B. Baldwin,[7] the three lines at 4419.57 (intensity 1), 4382.63 (int. 0.3), and 4395.60 (int. 0) may be attributed to *Fe* III.

The second multiplet $b^5D - z^5P^o$ does not appear in Marshall's list[8] of lines of γ Ori (B2) and β Tau (B8) but may well be expected in suitable stars.

Dr. Struve has kindly called our attention to the following facts: λ 4419.61 is very conspicuous in P Cygni[9] both in emission and in absorption (int. 7 in absorption and 5 in emission); λ 4431 is also present as a fairly strong emission line (int. 4) and a weak absorption line (int. 3); λ 4352 is present in P Cygni as an emission line (int. 2); λ 4382.5 is also possibly present (int. 3 in emission and 1 in absorption); λ 4371 is probably present, although Struve identified it tentatively with *O* II 4369, in which case it gives a discordant radial velocity. There is also fairly good evidence that the second multiplet is present in P Cygni, giving an identification of the lines measured by Struve at roughly 5071 and 5125 A. The latter was measured both in emission and in absorption, the former only in absorption.[10] The density of the spectrograms used by Struve decreased very rapidly on the long wave-length side of λ 5154, and it is therefore not surprising that λ 5194 is not listed by him.

4. *Ionization potential of Fe III.*—The $(^6S)5s^7S$ term has been found at 119194.96 cm^{-1} above $(^6S)4s^7S$. This gives an ionization energy of about 26.7 e.v. from the $4s^7S$ level. No intercombination between quintets and septets has been found as yet, but it seems safe to assume that the $4s^7S$ is somewhere around 29,500 cm^{-1} above the ground level, which gives an ionization energy of approximately 30.3 e.v. from the ground level a^5D.

The analysis is being continued with the hope of discussing the forbidden transitions.

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[7] *Ap. J.*, **87**, 573, 1938.

[8] *Ibid.*, **82**, 97, 1935.

[9] *Ibid.*, **81**, 73, 1935.

[10] *Op. cit.*, p. 95.