SPECTROGRAPHIC OBSERVATIONS OF PECULIAR STARS. VII*

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ABSTRACT

A list of emission lines is given for VV Cephei in the region λλ 3100–3370 and for BF Cygni in the region λλ 3114–3889. The spectrum of the Be star MWC 56 has strong emission lines of *H* and *Fe* II. Forbidden [*Fe* II] is weakly present. Table 3 lists the radial velocities of Z Andromedae from September, 1939, until October, 1944. The spectra of the components of the double star MWC 451 have been obtained separately. One component has a typical shell-absorption spectrum.

THE ULTRAVIOLET SPECTRUM OF VV CEPHEI

Measures of wave lengths in the ultraviolet region, down to λ 3277, were recently published by Struve.[1] Because of the wealth of emission lines in the ultraviolet region, we have measured a spectrogram of small dispersion secured on January 19, 1942. The results are given in Table 1.

In the identification work considerable importance was attached to the excitation level. This is especially important for *Fe* II,[2] in which lines of low excitation which are weak in the laboratory (arc or spark) are strong in VV Cep, while strong arc or spark lines corresponding to higher excitation are absent in VV Cep (see also next section on BF Cyg). Especially strong in this region are *Fe* II, $a^4P-z^4D^\circ$, $a^4D-z^6D^\circ$. Similar considerations apply to other atoms, such as *Cr* II.

In the table the elements are given in the order of their importance. The table overlaps a little with Struve's table.

The identification of [*Ni* II] 3223.3, a^2D-a^2G, as a contributor to the stellar line is trustworthy; [*Cr* II] would require sharper lines (or higher resolution) to be sure. There is no evidence of [*Mn* II] or [*V* II]. The difficulty of finding new forbidden lines arises from the numerous permitted metallic lines.

THE ULTRAVIOLET SPECTRUM OF BF CYGNI

The spectrum of this star, from λ 3722 to λ 6678, has been recently described by Merrill.[3] We have measured several spectrograms taken at the McDonald Observatory, which extend the ultraviolet limit to λ 3114. Table 2 contains the results. Our spectrograms were taken in the summer of 1942, when, according to Merrill, *Fe* II and [*Fe* III] were of intermediate intensity; [*Fe* II] was relatively weak. We have already given some of our results for *Fe* I, II, [II], and [III] in an earlier paper.[4] On our spectrograms [*Ne* III] is absent. The following notes summarize the essential points derived from the new measurements. The suggested identifications of [*Fe* II], [*Cr* II], [*V* II], etc., are based upon our unpublished tables of forbidden lines of metals.

[*Fe II*].—In addition to the new [*Fe* II] lines published earlier,[4] there are other [*Fe* II] lines contributing to blends in the UV region. But [*Fe* II] was relatively weak in 1942, and the contributions to blends are difficult to ascertain. It would be useful to take spectrograms of this star at other times in the UV region, to supplement the data obtained from the series collected by Merrill in the region $\lambda > 3722$. At stages of strong [*Fe* II] it would

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[1] *Ap. J.*, **99**, 70, 1944.

[2] See our paper, *Ap. J.*, **97**, 208, 1943.

[3] *Ap. J.*, **98**, 334, 1943.

[4] *Op. cit.*, p. 194.

TABLE 1

EMISSION LINES IN THE REGION λλ 3100–3370 OF VV CEPHEI

λ	Int.	Identification
3102.7.........	1	*V* II 2.30 (2000)
3104.9.........	1	*Ti* II 5.08 (100), *Mg* II 4.75 (30), *Ti* II 4.59 (1, *Fe* II 5.17 (5)
3108.8.........	0	*Cr* II 8.65 (35), *Ti* II 8.93 (15)
3116.5.........	1n	*Cr* II 6.74 (35), *Cr* II 5.65 (40), *Fe* II 6.59 (6)
3123.8.........	1	[*Fe* II] 4.18, (*Fe* II 3.71 (1))
3133.0.........	1	*Cr* II 2.06 (125), *Fe* II 3.05 (4)
3135.3.........	0	*Cr* II 5.74 (30), *Cr* II 5.34 (25), *Fe* II 5.36 (9)
3144.8.........	2	*Cr* II 5.10 (35), *Ti* II 4.73 (20), *Fe* II 4.76 (5)
3147.1.........	0	*Cr* II 7.23 (150), *Fe* II 6.75 (2)
3153.4.........	3	*Cr* II 3.35 (20), *Fe* II 4.21 (12), *Fe* II 3.06 (2)
3162.2.........	8	*Fe* II 1.94 (5), *Ti* II 2.57 (200), *Fe* II 3.09 (5), *Ti* II 1.77 (150), *Cr* II 2.44 (10), *Fe* II 2.80 (8), [*Fe* II] 2.21
3166.8.........	7	*Fe* II 6.70 (4), *Fe* II 7.85 (11)
3176.9.........	0	*Fe* II 7.53 (10), *Fe* II 7.26 (1), *Fe* II 6.73 (0)
3178.8.........	1	*Ti* II 8.63 (25), *Fe* II 9.50 (8), *Fe* II 7.53 (10)
3182.7.........	3	*Fe* II 3.11 (8), *Cr* II 3.32 (150), *Ti* II 2.57 (40)
3185.5.........	5	*Fe* II 6.74 (11), *Fe* II 5.32 (5)
3192.6.........	8	*Fe* II 2.93 (9), *Fe* II 3.81 (11), (*Fe* II 2.06 (3))
3195.9.........	10	*Fe* II 6.08 (10), (*Ti* II 5.72 (20))
3202.4.........	1	*Ti* II 2.54 (200), *Cr* II 2.51 (15), ([*Cr* II] 2.0)
3209.6.........	5	*Fe* II 0.45 (10), *Cr* II 9.18 (125), [*Fe* II] 9.94, *Fe* II 9.60 (1)
3212.6.........	10	*Fe* II 3.31 (13), (*Ti* II 13.14 (25)), ([*Cr* II] 12.5)
3217.4.........	2	*Ti* II 7.06 (150), *Cr* II 7.40 (20), [*Fe* II] 7.51
3223.9.........	1	[*Ni* II] 3.3, *Ti* II 4.24 (150), [*Fe* II] 2.58, [*Fe* II] 4.54, *Fe* II 3.44 (1)
3227.2.........	10	*Fe* II 7.75 (13), ([*Fe* II] 7.0)
3232.6.........	2	*Ti* II 2.28 (100), *Fe* II 2.79 (7)
3237.9.........	1	*Fe* II 7.82 (8), *Fe* II 7.40 (5), ([*Cr* II] 8.8)
3243.5.........	0	*Fe* II 3.72 (8), [*Fe* II] 4.2
3246.9.........	1	*Fe* II 7.17 (9), *Fe* II 7.39 (3), *Cr* II 7.33 (8)
3255.6.........	9	*Fe* II 5.89 (8)
3258.4.........	2	*Cr* II 8.77 (50), *Fe* II 8.77 (10), *Fe* II 9.05 (10), (*Fe* II 7.89 (3))
3271.4.........	0	*V* II 1.12 (1200), *Ti* II 1.65 (125)
3277.2.........	15	*Fe* II 7.35 (9), ([*Fe* II] 7.08), ([*Fe* II] 7.5)
3281.1.........	10	*Fe* II 1.30 (7)
3289.2.........	3	*Fe* II 9.35 (7), ([*Fe* II] 9.5), ([*Fe* II] 9.76)
3296.0.........	7	*Fe* II 5.82 (6), *Cr* II 5.43 (200)
3303.4.........	3	*Fe* II 3.47 (4), *Fe* II 2.86 (4), [*Fe* II] 3.8
3307.5.........	0	*Cr* II 7.04 (30), *Ti* II 7.72 (12)
3322.5.........	3	*Ti* II 2.94 (300), *Fe* II 3.07 (8)
3340.1.........	1	*Cr* II 9.80 (150), *Ti* II 0.34 (100), ([*V* II] 0.37)
3347.6.........	3	*Cr* II 7.84 (125)
3353.2.........	2	*Cr* II 3.13 (50)
3358.8.........	3	*Cr* II 8.50 (200), *Fe* II 8.78 (pred.), *Fe* II 8.25 (3)
3366.4.........	1	*Ti* II 6.18 (50), *Fe* II 6.96 (3)

TABLE 2

EMISSION LINES IN BF CYGNI

λ	Int.	Identification
		Spectrogram QQ f/2 3120 (July 21, 1942)
3114.3	0	*Fe* II 4.29 (7)
3125.8	0	*Cr* II 4.98 (100), (*Cr* II 5.02 (15)), (*Cr* II 5.46 (7)), (*Fe* I 5.65 (400)), (*V* II 5.28 (600))
3128.8	0	*Cr* II 8.70 (40), *Ti* II 8.64 (70), (*Fe* II 9.01 (1))
3149.8	1n?	(*Cr* II 9.83 (20)), (*Cr* II 0.11 (20))
3162.6	1	*Fe* II 3.09 (5), *Fe* II 1.94 (5), *Ti* II 1.77 (150), *Ti* II 2.57 (200), [*Fe* II] 2.21, (*Cr* II 2.44 (10)), (*Fe* II 2.80 (8))
3179.2	1–0	*Fe* II 9.50 (8), (*Ti* II 8.63 (25))
3183.1	2	*Fe* II 3.11 (8), (*Ti* II 2.57 (40)), (*Cr* II 3.32 (40), (*Zr* II 2.86 (35))
3185.5	1–0	*Fe* II 5.31 (5), (*Si* III 5.16 (3)), (*Si* III 6.01 (2))
3187.8	1	*He* I 7.74 (200), *Fe* II 6.74 (11), (*Fe* II 7.29 (8)), (*V* II 7.72 (200))
3190.6	1?	*Ti* II 0.87 (200), *V* II 0.69 (500), (*Fe* II 1.37 (1)), (*Fe* II 0.84 (pred.))
3193.2	3	*Fe* II 2.93 (9), *Fe* II 3.81 (11)
3196.3	4	*Fe* II 6.07 (10), (*Fe* I 6.93 (500)), (*Cr* II 6.96 (20)), (*Si* III 6.50 (3))
3198.9	0	(*Cr* II 8.00 (15))
3203.5	0	*Cr* II 3.53 (15), (*Fe* II 3.51 (1)), (*Fe* II 3.74 (0)), (*Si* II 3.89 (2))
3210.7	3n	*Fe* II 0.45 (10), (*Si* II 0.04 (3)), (*Si* III 0.52 (3)), [*Fe* II] 9.94, [*Fe* II] 0.74
3213.7	4	*Fe* II 3.31 (13)
3217.4	0	*Cr* II 7.44 (50), *Ti* II 7.06 (150), *V* II 7.12 (400), (*Cr* II 6.55 (20)), ([*Fe* II] 7.51)
3227.8	4	*Fe* II 7.73 (13)
3233.5	1	*Cr* II 4.06 (50), (*Fe* II 2.79 (7)), (*Si* III 4.00 (5)), (*Fe* I 3.97 (300)), (*Fe* II 4.92 (0))
3239.3	0	*Ti* II 9.04 (300), *Cr* II 8.77 (50), *Fe* I 9.44 (400), ([*Cr* II] 8.8), ([*Fe* III] 9.7)
3247.8	0	*Cr* II 7.33 (8), (*Fe* II 7.17 (9)), (*Fe* I 8.21 (200)), (*Fe* II 7.39 (3))
3256.0	4	*Fe* II 5.89 (8), ([*Fe* II] 6.3), ([*Fe* II] 6.7)
3259.2	1	*Fe* II 8.77 (10), *Fe* II 9.05 (10), *Cr* II 8.77 (30), ([*V* II] 9.25)
3273.5	0	(*Fe* II 3.50 (3)), (*Zr* II 3.04 (75)), ([*V* II]3.98)
3277.6	10	*Fe* II 7.35 (9), ([*Fe* II] 7.08), ([*Fe* II] 7.5)
3281.6	3	*Fe* II 1.30 (7), (*Ti* II 2.33 (150)), ([*V* II] 1.59)
3285.1	1	*Fe* II 5.42 (3), (*Fe* II 5.00 (0)), ([*V* II] 4.98).
3295.6	1	*Fe* II 5.82 (6), (*Cr* II 5.43 (50)), ([*V* II] 5.69)
3303.3	1	*Fe* II 2.86 (4), *Fe* II 3.47 (4), ([*Fe* II] 3.8), ([*V* II] 2.13), ([*V* II] 2.93), ([*V* II] 2.61)
3312.9	0	*Fe* II 2.71 (1), *Cr* II 2.18 (40), *Cr* II 1.93 (40), *Cr* II 3.08 (20)
		Spectrograms CQ 1517 and 1584 (July 6 and 18, 1942)
3443.1	1n	*Ti* II 3.39 (35), *Ti* II 4.31 (150), *O* III 4.10 (5), (*Fe* II 2.24 (3)), (*Fe* II 3.83 (pred.))
3454.1	1	*Ni* II 4.16 (5), (*Fe* II 3.59 (2)), (*Cr* II 4.98 (35))

TABLE 2—*Continued*

λ	Int.	Identification
		Spectrograms CQ 1517 and 1584 (July 6 and 18, 1942)—*Continued*
3459.7	0	*Mn* II 0.31 (75), *Mn* II 0.04 (8), (*Cr* II 9.29 (25)), ([*Fe* II] 0.2)
3471.0	0	*Ni* II 1.35 (2), (*Fe* II 0.24 (1))
3475.4	0	*Cr* II 5.13 (20), *Fe* I 5.45 (400), *Fe* II 5.74 (pred.), *Fe* II 5.25 (pred.)
3482.6	2	*Mn* II 2.90 (40), *Cr* II 2.58 (12), (*Fe* II 2.43 (2))
3484.0	0	*Cr* II 4.15 (20), *Ti* II 3.80 (70), (*Fe* II 4.35 (1)), ([*Fe* II] 4.0)
3488.8	0	*Mn* II 8.68 (40), *Fe* II 7.99 (3)
3494.7	3nn	*Fe* II 3.47 (10), *Fe* II 4.67 (5), *Fe* II 5.62 (4), *Cr* II 5.37 (25), *Cr* II 5.56 (20), *Mn* II 5.83 (40), (*Ni* II 5.6 (pred.))
3501.4	1	(*Co* II 1.73 (200)), ([*Fe* II] 1.6)
3507.9	1	*Fe* II 7.39 (3), *Fe* II 8.21 (1)
3511.5	0	*Cr* II 1.84 (35), *Ti* II 0.84 (125), (*Fe* II 1.25 (pred.))
3513.9	1	*Ni* II 3.93 (8), *Fe* I 3.82 (400)
3576.4	0	([*V* II] 6.20), ([*Fe* II] 5.7), (*Ni* II 6.76 (3)), (*Zr* II 6.88 (20))
3585.3	1	*Cr* II 5.31 (60), *Cr* II 5.54 (40)
3589.9	0	*V* II 9.74 (1000), (*Si* III 0.46 (8))
3601.0	0	(*Y* II 0.73 (300))
3614.3	0	*He* I 3.64 (30), *Fe* II 4.87 (5), *Sc* II 3.84 (70), (*Cr* II 3.21 (20)), (*Cr* II 3.26 (15)), ([*V* II] 3.84), (*Zr* II 4.79 (18))
3664.8	1	*H* 28 4.68, (*Cr* II 4.95 (30)), ([*Fe* II] 4.7)
3665.8	1	*H* 27 6.10
3667.6	3	*H* 26 7.68
3669.4	3	*H* 25 9.47
3671.2	4	*H* 24 1.48
3673.6	6	*H* 23 3.76
3676.2	7	*H* 22 6.36
3677.5	3	*Cr* II 7.69 (40), *Cr* II 7.93 (30), *Cr* II 7.86 (50)
3679.3	8	*H* 21 9.35
3682.5	10	*H* 20 2.81
3685.2	0–1	*Ti* II 5.19 (700), (*Cr* II 4.25 (25))
3686.6	12	*H* 19 6.83
3688.5	1	....
3691.4	15	*H* 18 1.56 (2)
3694.9	2	(*Cr* II 4.97 (4)), (*Fe* I 5.05 (200))
3697.0	15	*H* 17 7.15 (3)
3699.6	1	....
3701.5	1	(*Fe* I 1.09 (300)), (*V* II 0.34 (200))
3703.6	15	*H* 16 3.85 (4)
3705.4	3nn	*Fe* I 5.57 (700), *He* I 5.00 (30), (*Ti* II 6.23 (125))
3709.6	1	[*Fe* II] 9.1, *Fe* I 9.25 (600), (*Zr* II 9.27 (60)), (*Y* II 0.29 (150))
3711.9	18	*H* 15 1.97 (5)
3715.1	2	*Cr* II 5.19 (20), *V* II 5.48 (1200), *Cr* II 5.45 (20)
3719.6	1	*Fe* I 9.93 (1000), (*Fe* II 0.17 (pred.))
3721.8	20	*H* 14 1.94 (6)
3725.5	1n	*Fe* II 5.30 (3)
3727.3	1–2	*Cr* II 7.37 (40), *Fe* II 7.04 (4), *V* II 7.35 (1000), (*Fe* I 7.62 (200))
3729.7	0	....
3733.6	1	*Fe* I 3.32 (400), *He* I 2.86 (10), (*V* II 2.76 (800))
3734.3	20	*H* 13 4.37 (8)

TABLE 2—*Continued*

λ	Int.	Identification
		Spectrograms CQ 1517 and 1584 (July 6 and 18, 1942) —*Continued*
3736.8	(3)	*Fe* I 7.13 (1000), [*Fe* II] 6.2, (*Cr* II 6.56 (1))
3741.6	1	*Ti* II 1.65 (200), (*Fe* II 1.56 (pred.))
3743.1	1	(*Fe* I 3.36 (200))
3745.6	2n	*Fe* I 5.56 (500), *V* II 5.81 (800), (*Fe* I 5.90 (150))
3748.4	3	*Fe* I 8.26 (500), *Fe* II 8.49 (8), (*Cr* II 8.68 (7)), (*Ti* II 8.00 (25))
3750.0	20	*H* 12 0.15 (10)
3754.4	0–1	*Cr* II 4.57 (20), (*Fe* II 5.56 (4)), (*Cr* II 5.13 (2))
3757.9	1	*Fe* I 8.23 (700), *Ti* II 7.69 (100)
3759.9	1	*Ti* II 9.30 (400), *Fe* II 9.46 (6), *O* III 9.87 (9), (*Fe* I 0.05 (150))
3761.5	2n	*Ti* II 1.32 (300), (*Cr* II 1.90 (8)), (*Cr* II 1.69 (7))
3764.1	2	*Fe* II 4.09 (pred.), *Fe* I 3.79 (500)
3766.9	0	*Fe* I 7.19 (500), *Fe* II 6.05 (2), (*Zr* II 6.83 (25)), (*Cr* II 6.65 (4))
3770.5	20	*H* 11 0.63 (15)
3773.6	2	Unidentified; also present in Z And
3777.6	0	....
3779.7	1	[*Fe* II] 9.3, (*Fe* II 9.58 (pred.)), (*Fe* I 9.45 (100))
3783.3	3	*Fe* II 3.35 (4)
3785.7	1–2	(*Fe* II 6.37 (pred.)), (*Fe* I 5.95 (125))
3788.2	0–1	*Fe* I 7.88 (500), (*Y* II 8.70 (30))
3791.7	1	*Si* III 1.41 (3)
3795.7	2	*Si* III 6.11 (4), *Fe* I 5.00 (500)
3797.8	20	*H* 10 7.90 (20)
3805.4	3	*Fe* I 5.34 (400), (*He* I 5.76 (3))
3806.6	4	*Si* III 6.56 (5), *Fe* I 6.70 (200), ([*Fe* II] 6.3), (*Fe* II 6.82 (pred.))
3812.9	1–2	*Fe* I 2.96 (400), (*Ti* II 3.39 (20))
3814.3	1–2	*Fe* II 4.12 (4), *Ti* II 4.58 (35), *Cr* II 4.00 (12)
3815.8	1–2	*Fe* I 5.84 (700)
3818.6	2A}	*He* I 9.61 (50), (*Fe* I 0.43 (800))
3819.9	4E}	
3822.0	1–0	*Fe* II 1.92 (pred.), *Fe* II 2.74 (3)
3824.8	3	*Fe* II 4.91 (3), (*Fe* I 4.44 (150))
3826.9	0	*Fe* II 7.08 (4)
3829.5	1	*Mg* I 9.35 (100)
3832.2	3	*Mg* I 2.31 (250), (*Fe* II 2.96 (2))
3835.3	30	*H* 9 5.39 (40)
3838.2	3	*Mg* I 8.26 (300)
3843.0	1	(*Mn* II 2.98 (1)), (*Zr* II 3.03 (30)), (*Fe* I 3.26 (125))
3848.3	2–3	*Mg* II 8.24 (10)
3850.2	3	*Fe* I 9.97 (500), *Mg* II 0.40 (5)
3853.1	1	*Si* II 3.67 (3), (*Fe* I 2.57 (150))
3856.0	6	*Si* II 6.03 (8), *Fe* I 6.37 (500)
3859.4	0	*Fe* I 9.92 (1000), *Fe* I 9.22 (100)
3862.5	4	*Si* II 2.59 (6)
3865.5	1–2	*Cr* II 5.59 (75), *Fe* I 5.5 (600)
3867.5	0	*He* I 7.48 (15), (*Fe* I 7.22 (150))
3872.3	3	*Fe* I 2.50 (300), *Fe* II 2.76 (pred.), (*Fe* I 1.75 (100)), (*He* I 1.82 (5))
3878.6	1	*Fe* I 8.02 (400), *Fe* I 8.57 (300), *V* II 8.71 (300)
3882.0	0n	*Ni* II 1.92 (1), ([*Fe* II] 2.7)
3886.5	1	*Fe* I 6.28 (600)
3887.4	5A}	*H* 8 9.05 (60), *He* I 8.65 (1000)
3888.7	35E}	

become a source of interesting results, since [*Ni* II], [*Cr* II], etc., would probably also reach their maximum intensity at the same time.

Fe II.—The enhancement of the lines of low excitation potential is such that identifications must proceed very cautiously. Sometimes a weak laboratory line, or even a predicted one, of low excitation potential plays a greater role than a very strong laboratory line of higher excitation potential.

Si II.—As usual, λλ 4128–4131 are weak compared with λλ 3856–3863.

Fe III.—No permitted line observed (excitation level in the star is too low).

[*Fe III*].—Since the $3d^5D-3d^3F$, ^3P transitions are very intense,[5] the absence of $3d^5D-3d^3D$ (λ 3239, λ 3368, etc.) may at first appear strange. For a full discussion of the problem it would be essential to know the transition probabilities of the three multiplets $^5D-^3F$, ^3D, ^3P of [*Fe* III]. Such numerical data would also be of help in spectroscopic studies of novae or nebulae. But it may well be that a low transition probability is not required for the $^5D-^3D$ multiplet relative to $^5D-^3F$, ^3P to explain its absence in the spectra of shell stars. The excitation potential of $3d^3D$ is 3.8 volts, while those of ^3P and ^3F are 2.5 and 2.7 volts, respectively. An increase in excitation potential by 1.1 volts will probably correspond to a considerable decrease in population on the excited level. There is every reason to believe that the excitation of the [*Fe* III] lines is mainly due to collisions, as is that of the *Fe* II lines. In the case of *Fe* II the enhancement of the lines of low excitation potential suggests a reduction in line intensities by a factor of at least 10, relative to laboratory intensities, when the excitation potential increases by 1 volt. A similar reduction is brought about in the Boltzmann populations corresponding to an electron temperature of the order of 6000° when the excitation potential increases by 1 volt. (Such an electron temperature seems logical to adopt for shells of Be stars.)

It is true that forbidden lines of higher excitation are observed in BF Cyg, as, for example, the strong [*O* III] line at λ 4363, e.p. 5.33 volts; but this is probably due to the high abundance of oxygen as compared to iron.

[*Ni II*].—This was weak in 1942. But it must be strong at times (probably together with [*Fe* II]). In Merrill's paper there is an unidentified line at λ 4326.6 which is almost certainly the leading transition $\frac{5}{2}-\frac{5}{2}$ in the a^2D-b^2D forbidden multiplet of *Ni* II.[6] An unidentified line is also present in η Carinae at λ 4326.72. The line measured by Merrill at λ 4314 is, at least partly, due to the $\frac{7}{2}-\frac{9}{2}$ transition (λ 4314.9) in the a^4F-a^2G multiplet of [*Ni* II]. [*Ni* II] may also contribute to λλ 4200, 4314, and 4629 in Merrill's list (there is also a weak line at λ 4200.9 in η Car).

[*Mn II*].—The strongest multiplet to be expected, $4s^7S-a^5P$, falls in the region of λ 3340, which could not be measured on our plates. [*Mn* II] may be expected in [*Fe* II] stars or novae.

[*V II*].—A number of coincidences with predicted [*V* II] lines are found, but they are not convincing. One of the strongest forbidden lines of *V* II should be $a^5D_4-c^3F_4$ at λ 3334.66. An otherwise unidentified line has recently been found at λ 3334.69 in HD 45677.[7]

[*Cr II*].—The strongest line predicted at λ 3238.8; may participate in a blend at λ 3239.3, but this is not certain.

[*Ti II*], [*Co II*], [*Zr II*].—No lines are found in BF Cyg.

MWC 56

The star MWC 56 = MW 128[8] was discovered by Merrill, Humason, and Burwell[9] to have strong bright lines of $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$. These authors also state that "several indistinct maxima in the continuous spectrum may be additional bright lines." The spec-

[5] See Pl. XXII in Merrill's paper (*op. cit.*, opp. p. 337).

[6] Swings, *Pub. A.S.P.*, 55, 276, 1943.

[7] *Ap. J.*, 98, 90, 1943.

[8] $\alpha = 2^h35^m.0$, $\delta = +60°\ 50'$, mag. 11.6, sp. Bep.

[9] *Ap. J.*, 76, 178, 1932.

trum has apparently not been observed since 1932. Two spectrograms were obtained at the McDonald Observatory on October 15 and 17, 1944, with the Cassegrain quartz spectrograph giving a dispersion of 40 A/mm at λ 3933. The spectrum (Pl. XII) contains strong emission lines of *H*, which can be seen to *H* 19 or *H* 20. The emission lines of $H\gamma$, $H\delta$, $H\epsilon$, $H\zeta$, and perhaps one or two other members of the Balmer series are superposed centrally over very weak, broad absorption lines, which suggest that the underlying star may be a main-sequence object of type B. There are, however, no other absorption lines which can be identified with certainty; *He* I 4472 and 4026 may be present in absorption, but the lines are very indistinct. There are, however, numerous other emission lines. Most of them belong to *Fe* II. But forbidden [*Fe* II] is represented by λλ 4244, 4287, and 4359; other faint emission lines have been identified with *Ca* II K, *Si* II 3856 and 3863, *Ti* II 3761 and 4301, *Ni* II 4067, and *Mg* II 4481. The spectrum is intermediate between that of an ordinary Be star with bright *H* and *Fe* II and that of a peculiar star like Z Andromedae, where the forbidden lines are very strong. The radial velocity from the mean of all emission lines is −58 km/sec.

Z ANDROMEDAE

The increase in excitation reported in November, 1943,[10] has continued. The lines of [*Fe* VII] and [*Ne* V] were very strong on May 14 and October 5, 1944, while *Fe* I was extremely weak and *Fe* II somewhat weaker than on June 28, 1943. Of interest is the fact that, while the permitted lines of *Fe* II have decreased in intensity since June, 1943, the forbidden lines of [*Fe* II] have become stronger. We are therefore concerned not solely with changes in the conditions affecting the relative intensities of permitted and forbidden lines. The illustration in Plate XIII should be compared with that of Plate VIII in Volume **99** of this *Journal* to appreciate the significance of the spectral changes. As was recently pointed out by Merrill,[11] the radial velocities suggest changes with a recurrence of about 680 days. These changes are probably closely correlated with the changes in the relative intensities of the emission lines and with the observed changes in the brightness of the star. Prager[12] has given a period of 650 days for the variations in brightness. In order to supplement Merrill's velocity data, we have assembled in Table 3 his results and our recent measures. The scatter is very large: Merrill had already remarked that the "radial velocities derived from various groups of bright lines present a baffling complexity." But the general trend of his measurements is supported by the additional material. The tendency of *Ca* II K to give a more positive velocity than the other lines, at least since 1941, when the expanding-shell features had disappeared, may be caused by interstellar absorption. Incidentally, it is rather striking that when the *Ca* II K emission line was weak, as, for example, in October, 1944, there was no visible trace of an interstellar absorption line. It is probable that the distance of Z And is not very great and that its luminosity is considerably lower than that of an average star of class B0. Another point of interest consists in the systematic difference between *O* III and [*O* III]:

$$\text{Vel. of } O\ \text{III} - \text{Vel. of } [O\ \text{III}] = -28\ \text{km/sec}\,.$$

The wave lengths used for these lines were:

O III. . . . λ 3312.30	*O* III . . . . λ 3444.10
O III. . . . λ 3340.74	[*O* III]. . . . λ 4363.21

It is probable that the *O* III velocities and not those of [*O* III] are vitiated. The effect may be of instrumental origin and should perhaps not be regarded as physically significant.

MWC 451 = HDE 236970 = ADS 1934

Bidelman observed this double star in 1942 and found a composite spectrum similar to that of α Cygni, with helium lines, and suggested that the brighter component may be

[10] *Ap. J.*, **99**, 209, 1944. [11] *Ap. J.*, **99**, 23, 1944. [12] *Pop. Astr.*, **47**, 335, 1939.

a shell star, while the fainter might also be of type B. The separation is 0.8″, and the difference in magnitude is 0.5 mag., according to Van Biesbroeck, who also noted that the star appeared about as red as a G star. Bright $H\alpha$ was discovered at Mount Wilson, and Bidelman noted that $H\beta$ was abnormally weak on his spectrograms. On a night of good seeing (October 14, 1944) Dr. C. U. Cesco and one of the authors (Struve) obtained separate spectrograms of the two components. The visually fainter, blue star, which is the brighter of the two photographically, shows a typical shell spectrum with very sharp

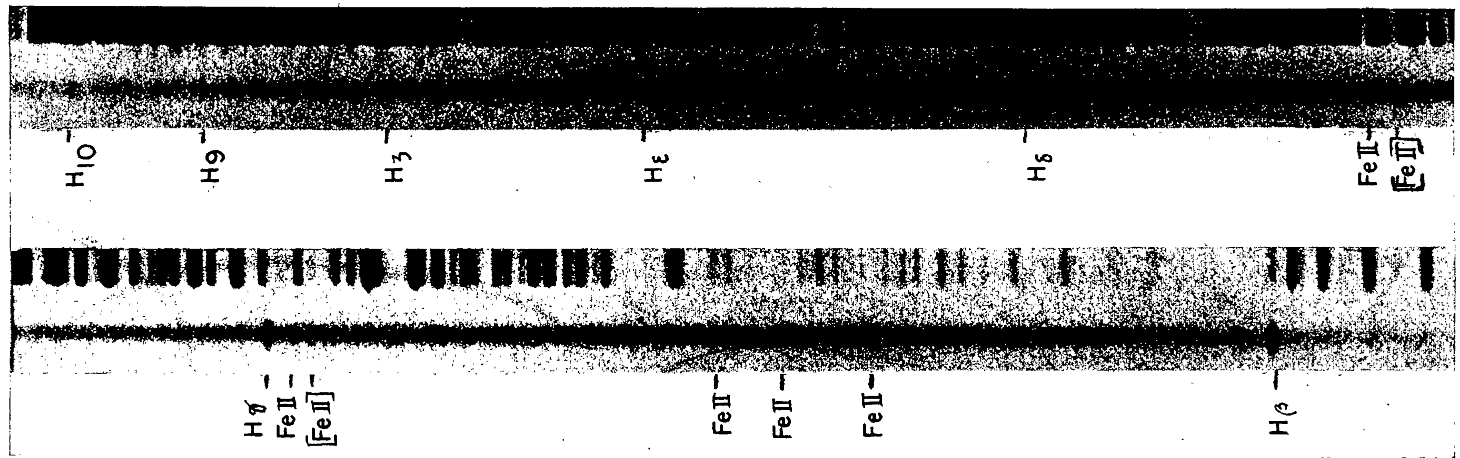
TABLE 3

RADIAL VELOCITIES OF Z ANDROMEDAE

Obs.	Date	Mag.	Disp. at $H\gamma$ (A/mm)	*H*	*He* I	*Fe* II	*Ti* II	*Si* II	*Mg* II	*Ca* II	*O* III	[*O* III] λ 4363	[*Ne* III]	[*Ne* V]	[*Fe* VII]
	1939														
McD.......	Sept. 16	8.1	60	+23	......	+ 3	− 8	+ 8	.....	− 3	.....	......	......	.....	......
Mt.W......	Oct. 3	7.8	75	(+38)	......	......	.....	......	.....	......	.....	......	......	.....	......
Mt.W......	4	7.8	40	+40	......	+10	+10	......	.....	+23	.....	......	......	.....	......
McD.......	18	7.8	60	+60	......	+35	+28	......	.....	+36	.....	......	......	.....	......
Mt.W......	23	7.9	40	+37	......	+18	+28	......	.....	+31	.....	......	......	.....	......
McD.......	Dec. 5	8.0	60	+59	......	+42	+50	+62	.....	+28	.....	......	......	.....	......
	1940														
Mt.W......	Jan. 20	8.3	40	+44	......	+21	+18	+17	.....	+33	.....	......	......	.....	......
Mt.W......	May 29	9.2	75	+42	(+ 5)	(+19)	.....	(+16)	.....	......	.....	− 3	+12	.....	......
Mt.W......	July 20	9.5	40	+28	+17	+ 1	+12	+ 6	.....	......	.....	+ 6	+ 2	.....	......
McD.......	Aug. 15	?	60	+35	+21	−13	.....	+ 2	−16	......	−50	+23	−10	− 2	+29
Mt.W......	Sept. 17	9.6	40	+ 7	+ 4	− 7	− 2	− 6	.....	+10	.....	− 2	+ 4	.....	......
Mt.W......	Oct. 19	9.6	40	+ 5	+ 5	− 2	− 3	− 3	.....	+17	.....	− 6	+ 6	.....	......
	1941														
Mt.W......	Jan. 15	9.6	75	− 3	− 9	−21	.....	−14	.....	− 6	.....	− 3	+ 2	.....	......
Mt.W......	July 13	8.8	65	+ 2	+ 4	(−14)	−10	−13	.....	−14	.....	......	−22	.....	......
Mt.W......	14	8.8	40	+ 9	+ 5	− 6	− 8	......	.....	......	.....	−12	......	.....	......
McD.......	25	?	60	+ 6	+28	−15	.....	−13	−25	+20	.....	−17	+11	.....	......
McD.......	Aug. 6	?	60	+14	+15	−11	.....	−13	−22	+19	−34	− 6	+ 5	.....	......
Mt.W......	7	8.6	40	+ 7	+ 8	+ 1	− 2	+ 3	.....	+20	.....	− 7	− 7	.....	......
McD.......	Oct. 29	?	60	+23	+33	+ 2	.....	+25	.....	......	.....	− 4	+ 4	.....	......
McD.......	Nov. 6	?	60	+ 8	......	−13	.....	......	.....	......	.....	......	......	.....	......
McD.......	7	?	60	+21	+24	+ 7	+ 1	+19	.....	+34	−31	+ 4	− 4	+18	−14
Mt.W......	10	9.0	75	+19	+20	+ 9	.....	+14	.....	+28	.....	......	−12	.....	......
Mt.W......	Dec. 6	9.1	65	+16	+19	+ 9	.....	+11	.....	+45	.....	− 4	+ 2	.....	......
	1942														
McD.......	Jan. 14	?	60	+16	+30	0	.....	+ 3	.....	− 6	.....	− 7	+ 3	.....	......
McD.......	Feb. 1	?	60	+10	+ 1	−20	.....	+ 5	.....	+21	−21	−25	+11	−31	−24
McD.......	July 15	?	60	+31	+28	+ 2	.....	− 1	.....	+48	− 6	+15	+ 9	+ 6	+ 1
Mt.W......	Oct. 23	10.2	65	−14	− 9	− 9	.....	+ 2	.....	+24	.....	− 5	− 2	.....	......
McD.......	Nov. 23	?	60	+ 6	0	0	.....	......	.....	+28	−10	+36	+10	+ 2	−25
Mt.W......	Dec. 2	10.0	75	−16	+ 2	− 5	.....	(− 3)	.....	(+ 9)	.....	− 2	+ 8	.....	......
	1943														
McD.......	Jan. 21	?	60	−10	− 7	−12	.....	+ 2	+26	+12	−23	− 5	+ 5	+ 8	......
McD.......	June 28	?	60	−12	− 1	−10	−14	−20	−14	+10	−43	−10	−15	0	−56
Mt.W......	Aug. 11	9.1	65	− 9	− 2	− 9	−15	− 8	.....	+23	.....	−23	− 1	.....	......
McD.......	Nov. 14	?	60	+ 4	+ 4	− 1	0	0	.....	− 6	.....	− 6	+10	.....	......
	1944														
McD.......	May 14	?	60	− 2	+ 4	+ 1	.....	−27	.....	+16	− 6	+ 6	+10	+ 5	−23
McD.......	Oct. 5	?	60	+ 1	− 3	− 6	.....	− 2	+17	+22	−10	+ 6	+14	+ 4	+ 1

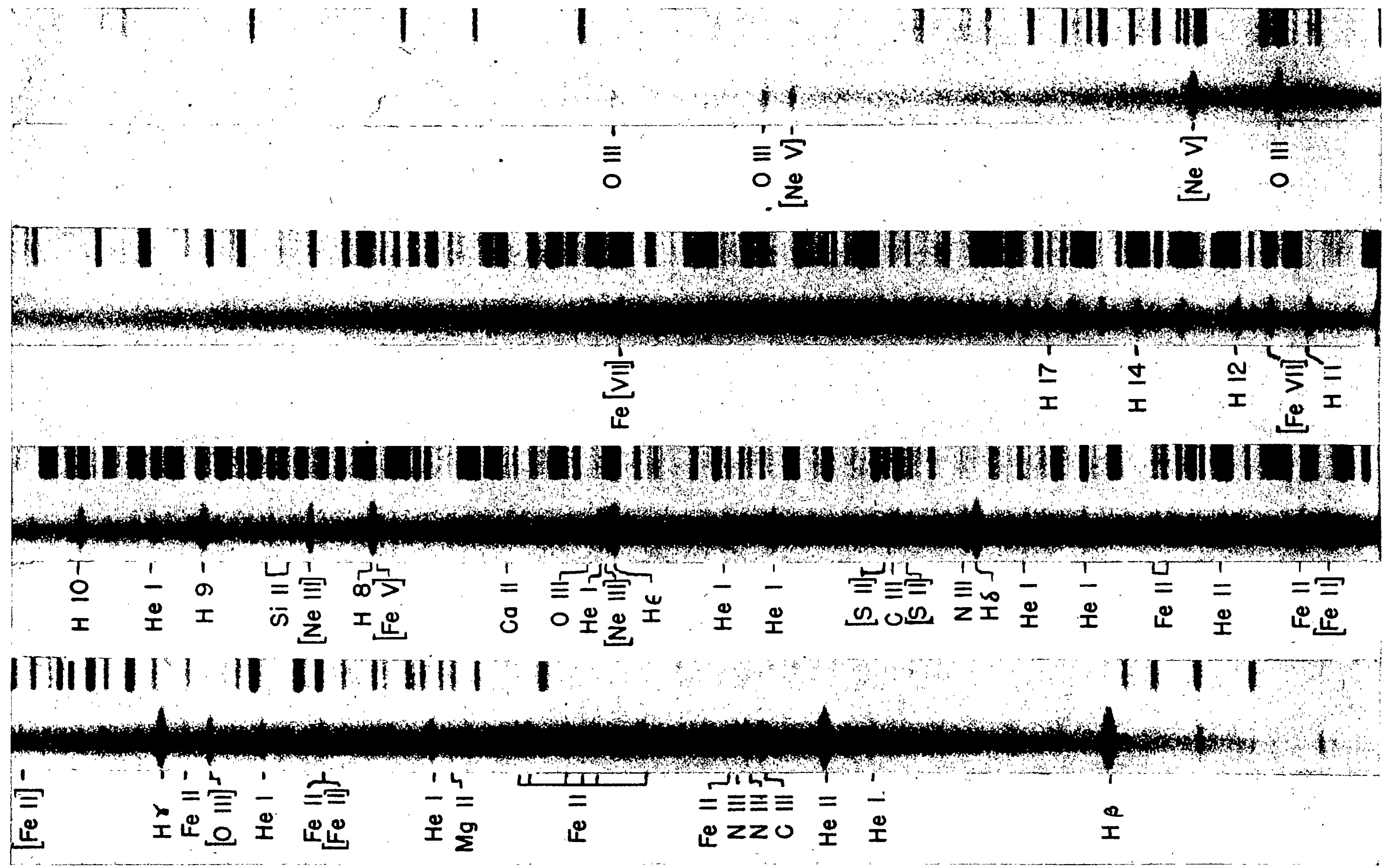
and narrow absorption lines of *H* extending to *H* 28, with strong, sharp *Ca* II K and with narrow and weak lines of *Fe* II. In addition, there are broad lines of *He* I and *Mg* II. The visually brighter star has a normal spectrum of type around G5, or a little earlier. Since the photographic magnitude of this star must be considerably fainter than 10, our spectrogram is somewhat underexposed. There is, however, no indication that the luminosity is great: the *Sr* II lines are not conspicuous. Combined spectra of both components obtained without trailing, but with the slit placed along the line joining the two stars, confirm this result. Spectrograms obtained without trying to separate the components show very striking changes from night to night. We attribute these changes entirely to the effect of seeing combined with the tendency of the observer to guide on the visually bright G-type component.

PLATE XII



THE SPECTRUM OF MWC 56

PLATE XIII



The Spectrum of Z Andromedae on October 5, 1944