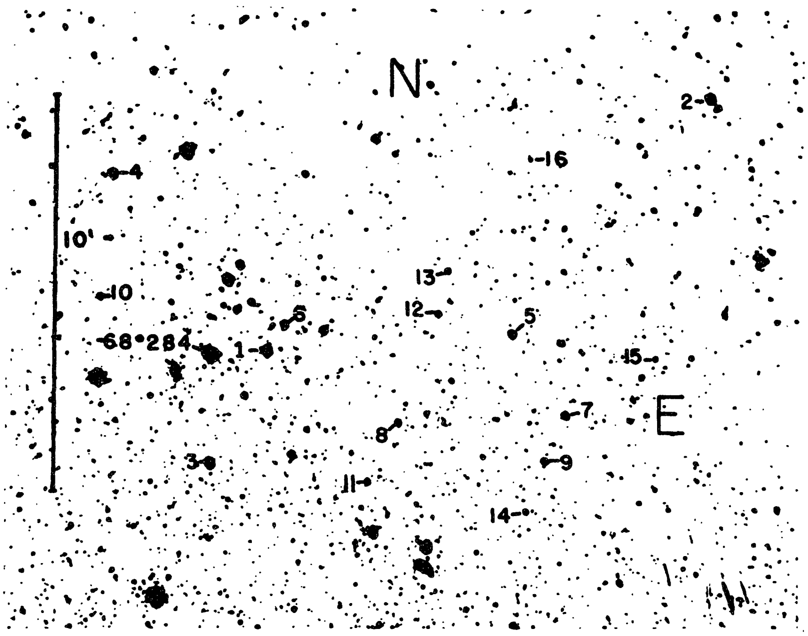
is found to be -0.01 ± 0.035 (p.e.). Mrs. Virginia McKibben Nail, to whom I am indebted for the identification of star 7 with the corresponding star of Miss Mohr's sequence, has advised me that star 7 is somewhat overexposed on the plates used by Miss Mohr and that therefore the photographic magnitude of this star should not be considered very reliable. If we then omit this star in the comparison between the two sequences, we find for the zero-point difference -0.05 ± 0.03 (p.e.).



Finding Chart Large Cloud Sequence

Princeton University Observatory

THE SPECTRUM OF ETA CARINAE IN 1893

By Charles A. Whitney

Abstract:

Harvard objective prism plates showing Eta Carinae between 1892 and 1903 have been reexamined. More than 100 absorption lines have been identified as arising from H, FeI, FeII, TiII, CrII, CrI(?), CaII, CaI, SrII, VII, ZrII, ScII, YII(?). These absorption lines show a negative doppler shift relative to the H emission peaks of 180 ± 40 km/sec.

1. Introduction:

The peculiar variations of Eta Carinae have been discussed in detail elsewhere (H.A., 76, 36, 1916; D. Hoffleit, H.B., 893, 11, 1933). Following a rise in brightness to magnitude 0.3 in 1854, the star faded to about magnitude 7.6 by 1884. It brightened to magnitude 6.9 in 1888 and faded to 7.7 in about 1898. The spectrum of 1893 shows a typical cF5 absorption spectrum (B. J. Bok, Pop. Ast., 38, 399, 1930) with superimposed bright lines of H and FeII. Some [FeII] is also present. During the following decade, the continuous spectrum was not visible on the Harvard 13" objective prism plates.

The increase in the strength of [FeII] emission relative to the FeII and H emission has been studied by Miss Hoffleit. Visual examination of the plates suggests that emission lines increased in absolute intensity during this period. After 1902 the spectrum was a bright line spectrum of H, FeII, [FeII], TiII and CrII on a very weak continuous background (for further remarks and measures of the emission spectrum see: H.A., 28, 175, 1897; Gill, M.N., 61, 456, 1900; Moore & Sanford, L.O.B., 8, 55, 1913; H.A., 76, 36, 1916; Lunt, M.N., 79, 621, 1919; Merrill, Ap.J., 67, 391, 1928; H. S. Jones, M.N., 91, 794, 1931). In the spectrum of this star, Merrill made the first identification of astrophysical [FeII].

In an effort to place Miss Hoffleit's eye estimates of emission intensities on a more quantitative basis, microdensitometer tracings were made of the spectra on Harvard plates X4044 (May 1892), X4079 (June 1893), X6480 (May 1895), X10722 (June 1903). The relative increase of [FeII] emission during this period was easily detected. A comparison of these measures with the estimates of other workers suggests that either a) the H emission was stronger relative to the FeII emission during the period 1892-1903 than during the periods investigated hitherto or b) the eye estimates tend to favor the weaker lines and reduce the contrast between the H intensity and the FeII intensity. A striking, though exceptional example, is the ratio H 4861/FeII 4924 which Jones estimated to be about 3 while the present writer measured a value of 10.

2. *Wave length Measures in the Absorption Spectrum:*

Thackeray's recent success[1] in photographing the absorption features in the spectrum of this remarkable star suggested that an examination of the old Harvard plates might contribute to ideas about the development of the star.

The absorption spectrum present on plate X4709 is truly remarkable for a plate of its type. The number of lines visible far exceeds that on any other plate of the series, and in certain regions it is difficult to distinguish emission features from spaces between absorption lines. In 1930, B. J. Bok measured 70 of the absorption lines present on this plate and identified most of them. He concluded that the spectrum corresponded to that of a cF5 star but his measures are no longer available.

The spectrum on X4709 did not, of course, have any comparison spectrum impressed near it since it was an objective prism plate. The wave length scale was established by determining the Hartmann coefficients from the H absorption in neighboring spectra. By a suitable shift in zero-point these Hartmann coefficients were used to reduce the measures in Eta Carinae. Using the peak of intensity of the Hδ emission as the zero-point with wave length 4101.8 it was found that the Hartmann formula with the adapted coefficients gave the correct values for the wave lengths of the Hα and Hβ emissions as well as the several others which could be identified with certainty. By identifying a few strong absorption lines, an approximate idea of the wave length shift between the absorption and emission spectra was obtained. This was used as a preliminary correction on wave lengths calculated from the Hartmann formula "zeroed" on the emission spectrum.

The procedure for determining the doppler shift of the absorption relative to the emission lines was essentially the following. Using the Hartmann dispersion formula and laboratory wave lengths of the H emission lines, the observed wave lengths of the absorption lines were calculated from plate measures. To these wave lengths (called "observed" in the table below) a correction of +2.5 A.U. was applied as a preliminary reduction to laboratory wave lengths. This shift was determined from identification of several prominent absorption lines. All lines were then identified, keeping in mind that the wave lengths were only good to 0.5 A.U. These identifications are given in Table I. As a further check on the identifications, the differences between the observed and the identified laboratory wave lengths were plotted against wave length for 39 favorable lines. From this plot, mean wave length shifts were obtained for each spectral region and these shifts were added, giving the "corrected" wave lengths of Table I. These should coincide with the laboratory wave lengths in the identification column. Identifications were made from the Princeton Multiplet Tables and the numbers in parentheses are the multiplet numbers given in those tables. Column 3 of Table I contains line-intensity estimates based on microdensitometer measures supplemented in some cases by eye estimates. Negative numbers designate emission intensities.

In Table II are given the wave length shifts, λ laboratory minus λ observed. Radial velocities were determined from these shifts. These radial velocities are given in Table III. The first column

1 Private Communication.

gives the mean velocity of all absorption lines relative to the emission lines. The second and third columns are the mean velocities for the FeI lines alone and for all lines excluding the FeI lines. Mean errors are also given.

Table I

Eta Carinae Absorption Spectrum of 1893

Wave length Observed	Corrected	*Intensity*	*Identification*
4924.7	4924.7	-20	FeII (42) 23.9
4861.6	4861.6	-320	Hβ 61.3
4844.0	4847.4	10	CrII (30) 48.2, FeI (67) 47.1
4820.5	4823.9	30	CrII (30) 24.1
4801.7	4805.1	40	TiII (92) 05.1
4777.1	4780.5	30	TiII (92) 80.0, FeII (50) 80.6
4761.1	4764.5	30	TiII (48) 64.5, FeII (50) 63.8, CrI (231) 64.3
4728.6	4731.9	10	FeII (43) 314, (FeI (67) 31.8)
4705.3	4708.6	10	CrI (195) 07.7, TiII (49) 08.7
4719:	4722	5	CrI (195) 22.7
4695:	4698	5	CrI (146) 98.6, 98.9, CrI (62) 97.1, 98.6, CrII (177) 97.6
4667.6	4670.9	20	ScII (24) 70.4, FeII (25) 70.2
4653.4	4658.7	15	FeII (43) 57.0, TiII (59) 57.2, (TiII (38) 55.7)
4636.7	4636.7	-10	[FeII] (4F) 39.7
4631.9	4635.1	30	TiII (38) 36.3, FeII (186) 35.3, FeI (349) 35.8
4625.5	4628.7	30	FeII (37) 29.3, TiII (38) 29.3
4620.2	4620.2	- 5	FeII (38) 20.5
4615.4	4618.6	60	CrII (44) 18.8, CrI (81) 19.5, + ??
4586.3	4589.5	50	CrII (44) 88.2, (TiII (50) 90.0)
4579.6	4582.8	25	FeII (38) 83.8, FeII (37) 82.8, TiII (39) 83.4
4568.4	4571.6	35	TiII (82) 72.0, (MgI 71.8)
4561.3	4564.5	20	TiII (50) 63.8, (VII (56) 64.6)
4551.7	4554.9	50	FeII (37) 55.9, (CrII (44) 58.7), BaII 54.0
4548.7	4548.7	-10	FeII (38) 49.5
4544.2	4547.4	35	TiII (82) 49.6, FeII (38) 49.5, TiII (39) 49.8
4539.3	4542.5	30	FeII (38) 42.5, CrI (149) 42.6, 41.5, CrI (100) 43.7 (FeI)
4534.8		- 5	?
4529.4	4531.6	} 50	TiII (50) 34.0
4524.4	4527.6	}	VII (56) 28.5, FeI (897) 27.9, CrI (82) 27.4
4522.0	4522.0	- 2	FeII (38) 22.6
4518.6	4521.7	35	FeII (38) 22.6, + ??
4512.2	4515.3	20	FeII (37) 15.3
4507.9	4507.9	- 5	FeII (38) 08.3
4505.0	4508.1	20	FeII (38) 08.3, TiII (30) 06.7
4496.8	4499.9	35	TiII (31) 01.3, CrI (81) 01.8
4485.8	4488.9	40	FeII (37) 89.2, TiII (115) 88.3, (CrI (267) 90.6)

Wave length *Observed*	*Corrected*	*Intensity*	*Identification*
4470.7	4473.8	10	FeII (171) 74.2, FeII (37) 72.9
4466.0	4469.1	}	TiII (31) 68.5, TiII (40) 70.9,
		70	TiII (18) 69.2
4462.7	4465.8	}	CrII (191) 65.8, FeI (350) 66.5,
			CrI (34) 66.1
4447.4	4450.4	15	TiII (19) 50.5, FeI (476) 50.3
4440.5	4443.5	45	TiII (19) 43.8, FeI (350) 43.2
4418.2	4421.2	20	TiII (93) 21.9, FeI (350) 22.6
4414.2	4417.2	20	TiII (40) 17.7, TiII (51) 18.3,
			FeII (27) 16.8
4407.5	4410.5	20	TiII (115) 11.1, CrI (102) 11.0
4396.8	4399.8	40	TiII (51) 99.8, TiII (93) 00.6
4390.7	4393.7	40	TiII (19) 95.0, TiII (51) 94.1
4381.4	4384.3	50	FeII (27) 85.4, FeII (32) 84.3,
			(FeI (41) 83.5)
4371.9	4374.8	30	TiII (93) 74.8, CrI (104) 74.2
4365.0	4367.9	20?	TiII (104) 67.7, CrI (130) 68.2
4359.8	4359.8	-50	[FeII] (21F) 58.4, FeII (7F) 59.3
4353.8	4353.8	-50	[FeII] (21F) 53.8, FeII (27) 51.8
4343.6	4343.6	-60	?
4340.3	4340.3	-35	Hγ 40.5
4336.5	4340.3	30	Hγ 4340.5
4331.9	4331.9	- 5	?
4327.7	4330.5	15	TiII (41) 30.8, TiII (94) 30.3 + ??
4322.3	4325.0	20	FeI (42) 25.8, ScII (15) 25.0,
			CrI (104) 25.1
4317.7	4320.5	5	ScII (15) 20.7, FeII (220) 19.7,
			(TiII (41) 21.0)
4311.1	4313.9	25	ScII (15) 14.1, TiII (41) 15.0,
			FeII (32) 14.3, 13.6
4305.0	4307.8	10	TiII (41) 07.9, FeI (42) 07.9,
			FeI (476) 05.5
4298.9	4301.6	50	TiII (41) 00.1, TiI (44) 01.9, (00.6)
4291.2	4293.9	30	TiII (20) 94.1, ScII (15) 94.8,
			FeI (214) 94.0
4288	4288	-20	[FeII] (7F) 87.4
4286	4289	20	TiII (41) 90.2
4280.3	4283.0	5	FeI (71) 82.4, ??
4276.3	4276.3	-20	[FeII] (21F) 76.8
4269.9	4272.6	20	FeI (42) 71.8, FeI (152) 71.2,
			FeI (70) 71.6
4247.2	4247.2	-20	[FeII] (21F) 44.2, 45.5 ?
4244.5	4247.2	15	ScII (7) 46.8, FeI (693) 47.4
4241.8	4241.8	- 5?	?
4238.3	4240.9	15	FeI (416) 39.7, CaI (38) 40.5,
			FeI (18) 39.8
4234.0	4234.0	-35	FeII (27) 33.2, ([FeII] (21F) 33.2)
4229.8	4232.4	40	FeII (27) 33.2, VII (25) 31.2,
			(CrI (132) 30.5)
4224.5	4227.1	30	CaI (2) 26.7, FeI (693) 27.4
4217.7	4220.3	15	FeI (800) 19.4, FeI (419) 19.4
4213.5	4216.0	15	SrII (1) 15.5, FeI (419) 15.4,
			CN band head (0,1)
4206.4	4208.9	20	ZrII (41) 09.0, (CrII (162) 09.0)

Wave length		*Intensity*	*Identification*
Observed	*Corrected*		
4200.8	4203.3	5	Fe I (42) 02.0, V II (25) 02.3, Fe I (521) 02.6
4195.2	4197.7	5	Cr I (249) 97.2, Ti II (96) 97.9, CN band head (1,2)
4178.6	4178.6	- 5	Fe II (28) 78.9, [Fe II] (21F) 7.2
4176.1	4178.6	5	V II (25) 78.4, Fe II (28) 78.9, Cr I (250) 79.3, 79.1, Cr I (179) 79.3
4173.9	4173.9	- 2	Fe II (27) 73.4, (Cr II (18) 1.9, 72.6)
4171.0	4173.5	35	Fe II (27) 73.4, Fe I (19) 74.9, 73.9, 72.7
4168.8	4171.2	35	Ti II (105) 71.9, (Fe I 482) 70.9)
4164.8	4164.8	-10	Ti II (105) 63.6, ??
4161.2	4163.6	50	Ti II (105) 63.6, Fe I (274) 63.7, Fe I (699) 63.7
4147.7	4150.1	30	Zr II (41) 49.2, Fe I (942) 49.5
4142.4	4144.7	10	Fe I (43) 43.9, Fe I (523) 43.4, (Fe I (274) 45.2)
4135.7	4138.0	10	Fe I (726) 37.0, (Fe II (150) 38.2), Ti I (253) 37.3
4126.2	4128.5	25	Fe II (27) 28.7, Fe I (727) 27.8
4120.7	4123.0	25	Cr I (108) 23.4, 218, Fe II (28) 27.6
4112	4112	-25	Cr II (18) 11.0, 13.2, 12.6
4101.8	4101.8	-80	Hδ 01.8
4099.4	4101.6	40	Hδ 01.8
4094.4	4096.6	10	Fe I (851) 95.6, (Fe I (911) 96.1), Fe I (558) 97.1
4075.3	4077.5	20	Sr II (1) 77.7, + ??
4069.7	4071.9	30	Fe I (43) 71.7, (Cr II (26) 4072.56)
4062.1	4064.3	60	Fe I (43) 63.6, (Ti II (106) 64.3)
4052.7	4054.8	15	Fe I (218) 55.0, (Ti I (80) 55.0), (Cr II (19))
4043.3	4045.4	45	Fe I (43) 45.8
4023.0	4025.1	60	Cr I (37) 27.1, 26.2, 26.1, (Fe II (127) 24.5), Ti II (11) 25.1
4011.1	4013.2	20	Ti II (11) 12.4
4003.0	4005.1	20	Fe I (43) 05.2
3980.5	3982.0	30	Ti II (11) 82.0, Y II 82.6, Fe II (3) 81.6
3969	3971	300?	Ca II (1) 68.5, Hε 70.1, Fe II (3) 69.4
3930	3932	300?	Ca II (1) 33.7

Table II

Wave length Shifts

Observed	*Lab.*	Δλ	*Identification*
4820.5	24.1	+3.6	Cr II (30)
4801.7	05.1	3.4	Ti II (92)
4777.1	80.2	3.1	Ti II (92), Fe II (50)
4728.6	31.6	3.0	Fe II (43)
4667.6	70.3	2.7	Sc II (24)
4653.4	57.1	3.7	Fe II (43), Ti II (59)
4625.5	29.3	3.8	Fe II (37), Ti II (38)
4579.6	83.4	3.8	Fe II (37), (38)
4568.4	72.0	3.6	Ti II (82)

Observed	*Lab.*	$\Delta\lambda$	*Identification*
4561.3	63.8	2.5	TiII (50)
4539.3	42.5	3.2	FeII (38)
4512.2	15.3	3.1	FeII (37)
4496.8	01.3	4.5	TiII (31)
4447.4	50.4	3.0	TiII (19)
4440.5	43.6	3.1	TiII (19)
4407.5	11.1	3.6	TiII (115)
4371.9	74.6	2.7	TiII (93)
4305.0	07.9	2.9	TiII (41)
4291.2	94.3	3.1	TiII (20), FeI
4269.9	71.6	1.7	FeI (42)
4244.5	47.0	2.5	ScII (7), FeI
4224.5	26.7	3.2	CaI (2)
4217.7	19.4	1.7	FeI
4213.5	15.5	2.0	SrII (1), FeI
4206.4	09.0	2.6	ZrII (41)
4200.8	02.1	1.3	FeI
4176.1	78.6	2.5	VII (25), FeII
4168.8	71.9	3.1	TiII (105)
4161.2	63.6	2.4	TiII (105), FeI
4147.7	49.3	1.6	ZrII (41)
4142.4	43.7	1.3	FeI (43)
4099.4	01.8	2.4	Hδ
4075.3	77.7	2.4	SrII (1)
4069.7	71.7	2.0	FeI (43)
4062.1	63.7	1.6	FeI (43)
4052.7	55.0	2.3	FeI (218)
4043.3	45.8	2.5	FeI (43)
4011.1	12.4	1.3	TiII (11)
4003.0	05.2	2.2	FeI (43)

Table III

Radial Velocities
Absorption relative to Emission

Group	*All Lines*	*FeI only*	*Excluding FeI*
Velocity (km/sec)	−180 ± 40	−130 ± 30	−200 ± 30

Care has been taken to eliminate systematic errors in the wave lengths. It is evident that the values of the absorption line radial velocities will depend on accurate determination of the positions of the H emission lines. Unfortunately the problem is complicated somewhat by the asymmetry of Hβ and Hδ emissions. Hβ is steeper to the red than the blue and shows no definite absorption feature. Hδ is steeper to the blue than the red due to a distinct absorption feature on the blue side. The pair of emission lines at 4340 and 4344 show an absorption feature on the blue side but no real asymmetry is apparent. The peak intensity was chosen for the location of these H lines. Since the constants for the dispersion formula were obtained from neighboring spectra on the plate, one can say that the accuracy with which the wave lengths of Hγ and Hβ were given indicates that the zero point for wave lengths was correctly chosen (Cf. above). There is no systematic error apparent in the wave lengths of the iron emission lines. The writer feels that systematic errors in the radial velocities are less than 100 km/sec and probably less than 50 km/sec. The systematically small relative displacement of the FeI absorption lines should be noted in view of the peculiar intensities of these lines mentioned below.

A. D. Thackeray has kindly communicated to Mrs. C. H. P. Gaposchkin the preliminary results of his measures on 1951 plates of Eta Carinae. He has found that the average relative displacement for absorption lines other than CaII is about -420 km/sec. This displacement is significantly greater than the value found for the plate of 1893. Unfortunately no later plates are measurable in this series, so we must await future work in the southern hemisphere to determine whether or not the deduced acceleration is a continuous phenomenon which is still taking place. It should be remembered that the spectrum of this star was undergoing important changes at least until 1903. Between then and 1930, it remained almost unchanged. In view of this one would think that the acceleration of the absorption spectrum may have been completed by 1903.

A general inspection of the absorption spectrum of 1893 verifies the cF5 character attributed by B. J. Bok. The strength of the CaII H and K lines relative to the H absorption (Partly masked?) and the absence of the G band confine the spectrum to within several decimal classes of F5. A comparison with Alpha Persei brings out the great strength of TiII, FeII, FeI and ZrII in the Eta Carinae absorption spectrum. The intensities of the typical supergiant lines of FeII at 4172 and 4178 A.U. relative to SrII 4077 and CaI 4227 emphasize the supergiant nature of the spectrum. TiII was also well represented in the emission spectrum.

The remarkable strength of some absorption lines of FeI, especially 4064, 4072, is puzzling. The laboratory intensities of the lines of the a^3F - y^3F° multiplet (#43 in the Princeton tables) to which these lines belong are given below in Table IV along with the intensities measured in the spectrum X4709.

Table IV

Intensities of FeI a^3F - y^3F°

Wave length	*Lab.*	*X4709*
4045.81	60	45 ± 5
4063.60	45	60 ± 5
4071.74	40	30 ± 5
3969.26	30	CaII H
4005.25	25	20 ± 3
4143.87	30	10 ± 3
4132.06	25	Blended

For comparison the intensity of SrII 4077 measured on X4709 was 20. In Epsilon Aurigae, F0Ia, 4045.8 is only slightly stronger than SrII 4077. In Alpha Persei, SrII 4077 is at least 5 times stronger than 4045.80. These figures suggest two things: a) Multiplet 43 is abnormally strong in Eta Carinae, b) there is an unidentified absorption contributing to the intensity of 4063. The other lines of FeI which are definitely identified, are with few exceptions, lines belonging to multiplet 42, the transitions being a^3F - z^3G°. Of the lines of multiplet 41 (a^3F - z^5G°) of comparable laboratory intensity, 4383 is present (blended) while 4404 is probably absent. No other lines originating in the a^3F level are of comparable laboratory intensity in the observed region. We tentatively conclude that at least multiplets 42 and 43 of FeI are anomalously strong and that perhaps the entire a^3F level is over-populated in the Eta Carinae absorption layer. It is interesting to speculate on this in view of the small negative doppler displacement noted above.

Further investigations of this fascinating spectrum should include more extensive line intensity comparisons with the spectra of comparable classes. The similarity of this spectrum to that of Nova Aurigae in February 1892 has been pointed out (H.A., 28, 175, 1897) and suggests many possible lines of work.

It is a pleasure to thank Mrs. Gaposchkin for her help in the preparation of this paper.