Some results of a spectroscopic study of the atmosphere of 31 Cygni

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Özet : 31 cyg. sisteminin K tipi kompomenti atmosferinde ve tutulmanın muhtelif safhalarında toplam absorbsiyon ölcülmüştür. Bu ölçülerin neticeleri münakaşa edilecektir.

⁂

Abstract : The total absorption is measured in the atmosphere of the K type component of 31 Cygni at different phases of the eclipse. The results of the measurements are discussed.

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§ 1. Introduction

The star 31 Cygni ($m = 4$) was announced in 1898 to have a composite spectrum and later on was found by W. W. Campell[1] to be a spectroscopic binary. In 1936 W. H. Christie[2] determined the approximate spectroscopic orbit of the bright component and in 1944 a more definite orbit was obtained by Miss Vinter Hansen[3].

The system consists of a relatively cold K-type giant and a small and hot B type star. The B-star revolves around the common center of gravity with a period of 3800 days. The K-component has a diameter 150 times that of the sun and an absolute magnitude of at least — 1 m. It could be classified as supergiant. The small B-star has a diameter of 5 times that of the sun only.

In 1950, D. B. Mc Laughlin reported that three spectrograms taken in 1941 showed an atmospheric eclipse.

When the hot and small B-type companion, which has a continuous spectrum, travels beyond the disc of the larger K-star, its light will shine through the teneous atmosphere of the giant star, thus enabling us to study its composition by the absorption spectrum it produces.

The last eclipse of 31 Cygni was late in 1951. Spectroscopic observations have been made at Victoria with the 72-inch reflector and at Ann Arbor with the 37-inch reflector. The atmospheric eclipse began to show its effect on the plates taken on June 1 st, 1951. This effect increased slowly at first, but rapidly later on. After totality on August 13 th, the spectrographic phenomena observed during the ingress took place in reverse order. On January 8th, 1952, in the spectrum a faint chromospheric K-line, which is characteristic for an atmospheric eclipse, was still visible.

Due to full cooperation of all observers at both observatories, a good series of spectrograms has been obtained.

The Victoria plates were taken with the greater resolution, a grating spectrograph giving 4.6 Å/mm being used, while the Ann Arbor plates were largely obtained with a two-prism instrument, dispersion 12.3 Å/mm at 3933.

Exposure times varied according to the observational conditions, but in general were around one hour.

Now, consider the system 31 Cygni, which consists of a K-type primary and a B-type secondary. On its way to the observer the light of the secondary passes through the atmosphere of the primary. So we observe the normal spectrum of the K-giant with the spectrum of the B-star superimposed upon it. This is not quite the normal spectrum of a B-star. Besides its normal absorption lines, it also shows some additional lines produced by those atoms in the atmosphere of the primary star which instantaneously are in the line of sight. These additional lines almost coincide with the normal absorption lines of the K-type spectrum. There is a very slight separation, due to the rotation of the primary star.

For a study of a stellar atmosphere, knowledge of the intensities of absorption lines is a prerequisite. The intensity of an absorption line is related to the number of atoms in the atmosphere of the star. The first problem is to deduce from the measurements of the composite lines the total absorption which the atoms of the different elements in the atmosphere of the primary produce in the spectrum of the secondary.

§ 2. The plates

For this purpose 19 plates were studied which were kindly placed at my disposal by Prof. Aller. Of these, four were taken during totality. The others have been taken in the interval between the beginning and the endof the eclipse and cover the whole atmosphere of the K-star. The plates, taking during totality, were traced with the Moll Microphotometer of the Michigan University Observatory. The others have been traced with the Lake Angelus's Microphotometer. The tracings run from the Hydrogen absorption line H_δ towards the ultraviolet at the end of the plates.

For identification of the lines "A Multiplet table of Astrophysical interest'' by Charlotte Moore and the "Arc Spectrum of Iron" by A. Gatteren and Junkes have been used as reference books.

Thus in Table 1, the lines which have been studied are tabulated and in the other columns their wave-length, configuration and multiplet number are given.

For each line the necessary reduction was made and for each separate date of observation the resulting equivalent whidths, expressed in Å units, has been computed. For all but four of the plates as calibration curves, needed for the reduction of the tracings, curves were used which were constructed by Dr. Aller, and which he kindly permitted me to use. The four remaining calibration curves, e.g. those for totality, were constructed by me.

Table I

Element	Wave-length	Conf.	Multp.
Sr II	4077.71	5^2 S — 5^2 P^0	1
Fe I	4071.74	a^3 F — y^3 P^0	43
Fe I	4064.46	a^3 F — y^5 P^0	44
Fe I	4045.82	a^3 F — y^3 P^0	43
Mn I	4034.49	a^6 S — z^6 P^0	2
Mn I	4033.07	»	»
Mn I	4030.76	»	»
Fe I	4005.25	a^3 F — y^3 F^0	43
Ti I	3998.64	a^3 F — y^3 F^0	12
Ti I	3989.76	»	»
Ti I	3982.48	a^3 F — z^5 S^0	11
Al I	3961.52	3^2P^0— 4^2 S	1
Al I	3944.01	»	»
Fe I	3930.30	a^5 D — z^5 D^0	4
Fe I	3927.93	a^5 D — z^5 D^0	4
Fe I	3922.91	»	»
Fe I	3920.26	»	»
Ti II	3913.46	a^2 G — z^2 G^0	34
Fe I+	3902.95	a^3 F — y^3 D^0	45
Ti II	3900.55	a^2 G — z^2 G^0	34
Fe I+	3899.71	a^5 D — z^5 D^0	4
Fe I	3895.66	»	»
Fe I+	3886.28	»	»
Fe I	3865.53	a^5 F — y^5 D^0	20
Fe I	3859.91	a^5 D — z^5 D^0	4
Fe I	3856.37	»	»
Fe I	3849.97	a^5 F — y^5 D^0	20
Fe I++	3841.05	a^3 F — y^3 D^0	45
Mg I	3838.29	3^3 P^0— 3^3 D	3
Mg I	3832.30	»	»
Mg I	3829.35	»	»
Fe I	3827.83	a^3 F — y^3 D^0	45
Fe I	3825.88	a^5 F — y^5 D^0	20
Fe I	3824.44	a^5 D — z^5 D^0	4
Fe I	3820.43	a^5 F — y^5 D^0	20
Fe I	3815.84	a^3 F — y^3 D^0	45
Fe I	3812.97	a^5 F — z^3 P^0	22
Fe I+	3795.00	a^5 F — y^5 F^0	21
Fe I	3763.79	»	»
Ti II	3761.32	a^2 F — z^2 F^0	13
Ti II	3759.29	a^2 F — z^2 F^0	13
Fe I	3758.24	a^5 F — y^5 F^0	21

\+ identification uncertain

++ blended line

With this kind of problem a great difficulty which we encounter is the drawing of the continuous background on the tracings. In normal K-type spectra the continuous background is partially obliterated by the overlapping absorption lines. In stars like 31 Cygni this effect is enhanced by the additional absorption lines during the atmospheric eclipse.

Great care was taken to draw the continuous spectrum as accurate as possible. The wave-lengths, believed to be unaffected by absorption, were selected and for all plates the continuous spectrum was drawn through these points.

The behavior of any line is almost as follows : In table II are tabulated the equivalent-widths, expressed in Angström units, as obtained for different dates including that of totality.

The intensity is almost constant during an eclipse. Of this phase the plates were taken on August 29th — October 12 th. The intensity abruptly decreased as soon as the eclipse was over and this decrease continued until the intensity was considerably lower than that during the total phase.

This behavior is as would be expected for a small star emerging from behind a larger star with an extansive atmosphere. At the beginning of the emergency, the light of the small B-star is affected more than twice as much by absorption as that of the large star, because its light passes obliquely through the atmosphere of the K-star. Therefore the resultant spectrum shows an increase in total absorption. If the atmosphere of the large star did not diminish in density with altitude, this excess of total absorption would continue until the small star had completely emerged. But at the end of. the emergency the leading limb of the B-star is already shining through the less dense atmosphere and the total absorption has begun to diminish.

Our problem is : given the measured composite spectrum, to find what part of the total absorption in the spectrum of the B-companion is due to the elements in the atmosphere of the K-type primary. We will adopt the usual definition and apply the method used by Wilson.

According to usual definition $r_k = I_k/I_{ck}$ is the value of r at any point in the normal K spectrum. In other words, r_k is the ratio of the line intensity to the intensity of the continuous background at the point.

Similarly, without the atmosphere of the K-star in front of the B-star we could write $r_b = I_b/I_{cb}$. Actually from the tracing, we measure the composite value r_{bk} which by definition is equal

$$r_{bk} = \frac{I_k + I_b}{I_{ck} + I_{cb}}$$

For any line the equivalent width is given by the expression of

$$W = \int (1 - r)\, d\lambda$$

During the totality, the total absorption as measured is

$$W_k = \int (1 - r_k)\, d\lambda$$

Let $W_b = \int (1 - r_b)\, d\lambda$ be the total absorption for the B spectrum.

Let I_{cb}/I_{ck}, the ratio of the intensities of the continuous spectra of the two stars, be indicated by α. Then the measured composite spectrum will be

$$W_{bk} = \int (1 - r_{bk})\, d\lambda$$

Since,

$$r_{bk} = \frac{I_k + I_b}{I_{ck} + I_{cb}} = \frac{r_k + \alpha\, r_b}{1 + \alpha}$$

$$W_{bk} = \frac{(1 + \alpha - r_k - \alpha\, r_b)}{1 + \alpha}\, d\lambda$$

$$W_{bk} = \frac{(1 - r_k) + \alpha\,(1 - r_b)}{1 + \alpha}\, d\lambda$$

Hence we have

$$W_b = \frac{1 + \alpha}{\alpha} W_{bk} - \frac{1}{\alpha} W_k$$

or simplifying further

$$W_b = W_{bk} + \frac{1}{\alpha}(W_{bk} - W_k) \qquad (1)$$

On the right hand side of the equation W_{bk} is the measured total absorption of the composite line. This method of reducing the composite spectrum was applied for all lines enumerated in Table I and for all observed phases of the eclipse. The results appear in Table II.

Table II

Total absorption in the composite spectrum : W_{bk}

Wave-length	Ident.	Agust. 29	Sept. 12	Oct.10		Oct.12
4077.71	Sr II	1.18	1.06	0.99		0,86
4071.75	Fe I	1.07	.68	.94		.17
4064.46	Fe I	1.37	.92	1.09		
4045.82	Fe I	2.07	1,17	1.02	1.60	.53
4031.49	MnI	0,87	.56	.82	.40	.41
4033.07	MnI	.74	.64	.69	.63	.54
4030.76	MnI	.96	.79	.72	.79	.71
4005.25	Fe I	.54	.60	.66	.64	.52
3998.64	Ti I	.55	.66	.39	.51	.42
3989.76	Ti I	64	.66	.78	.58	.56
3982.48	Ti I	.35	.27	.79	.38	.51
3961.52	Al I		.80	.82	.43	.72
3944.01	Al I		.99	.94	.41	.88
3930.30	Fe I		.21	.12	.19	.25
3927.93	Fe I		.54	.28	.23	.35
3922.91	Fe I		.57	.35	.23	.30
3920.26	Fe I		.68	.62	.24	.50
3913.46	Ti II		.39	.31	.30	.33
3900.55	Ti II		.67	.40	.40	.48
3895.66	Fe I		.88	.88	.53	.80
3865.33	Fe I		.86	.44	.37	62
3859.91	Fe I		1.57	.96	.39	.80
3856.37	Fe I		.65	.56	.37	.45
3849.97	Fe I		.90	.80	.24	.51
3838.29	MgI		.73	.51	.59	.50
3822.30	MgI		.96	.53	.71	.62
3829.35	MgI		52	.40	.47	.34
3827.83	Fe I		.60	.40	.30	.33
3825.88	Fe I			.57	.41	.35
3824.44	Fe I		1.44	.63	.38	.63
3820.43	Fe I				.50	1.00
3815.84	Fe I		.70	.50	.33	.54
3812.97	Fe I		.73	.52	.21	.42
3763.79	Fe I				.40	.65
3761 32	Ti II			.55	.77	.45
3759.29	Ti II			.63	.72	.45
3758.24	Fe I			.77	.60	.77

Table II

Total absorption in the composite spectrum: W_{bk} (continued)

Wave-length	Ident.	.Oct. 15		Oct. 17	Oct. 18	Oct. 20	Oct 21.
4077.71	Sr II	.94	1.04				
4071.75	Fe I	.86	.68				
4064.46	Fe I						
4045.81	Fe I	1.81	1.57	.86	1.40	1.60	1.56
4034.49	MnI	.56	.56	.37	.38	.38	.37
4033.07	MnI	.68	.78	.48	.50	.50	.57
4030.76	MnI	.76	1.00	.62	.57	.67	.56
4005.25	Fe I	.84	.80	.60	.62	.59	.70
3998.64	Ti I	.62	.69	.34	.37	.35	.41
3989.76	Ti I	.76	.70	.40	.49	.48	.50
3982.48	Ti I	.47	.44	.23	.22	.24	.21
3961.52	Al I	.72	.75	.33	.30	.31	.32
3944.01	Al I	.73	.87	.29	.30	.29	.23
3930.30	Fe I	.57	.61	.19	.21	.21	.18
3927.93	Fe I	.50	.53	.19	.18	.22	.12
3922.91	Fe I	.43	.58	.25	.23	.22	.13
3920.26	Fe I	.55	.53	.27	.23	.28	.15
3913.46	Ti II	.60	.57	.34	.34	.30	.24
3900.55	Ti II	.66	.67	.45	.43	.35	.35
3895.66	Fe I	.89	.92	.41	.47	.46	.43
3865.53	Fe I	.54	.45	.22	.20	.21	.19
3859.91	Fe I	.86	.52	.64	.57	.45	.43
3856.37	Fe I	.82	.43	.41	.41	.36	.31
3849.97	Fe I	.61		.23	.22	.21	.17
3838.29	MgI	.63		.67	.74	.52	.42
3822.30	MgI			.64	.76	.44	.38
3829.35	MgI	.60		.49	.31	.30	.24
3827.83	Fe I	.53		.31	.26	.32	.18
3825.88	Fe I	.60		.59	.47	.32	.26
3824.44	Fe I	.78		.45	.37	.28	.27
3820.43	Fe I				.64	.52	.30
3815.84	Fe I	.60		.30	.28	.28	.21
3812.97	Fe I	.83		.35	.32	.22	.18
3763.79	Fe I	.68		.40	.55	.37	.22
3761.32	Ti II	.87		.74	.67	.54	.51
3759.29	Ti II	.92		.76	.76	.73	.39
3758.24	Fe I	.97		.56	.55	.48	.16

Table II

Total absorption in the composite spectrum : W_{bk} (continued)

Wave-length	Ident.	Oct. 31	Nov. 6	Nov. 10	Nov.11	Nov. 21
4077.71	Sr II			.41	.53	
4071.75	Fe I			.61	.71	
4064.46	Fe I			.90	.78	
4045.82	Fe I	1.63	1.75	1.62	1,53	1.43
4034.49	Mn I	.38	.37	.38	.40	.39
4033.07	Mn I	.64	.51	.45	.45	40
4030.76	Mn I	.66	.45	.61	.52	.40
4005.25	Fe I	.60	.49	.53	.57	.56
3998.64	Ti I	.38	.39	.38	.37	.35
3939.76	Ti I	.41	.39	.40	.38	.34
3982.48	Ti I	.14	18	.20	.18	.20
3961.52	Al I	.20	.21	.23	.19	.12
3944.01	Al I	.18	.17	.17	.13	.14
3920.30	Fe I	.10	.06	.07	.06	.07
3927.92	Fa I	.25	.16	.11	.15	.12
3922.91	Fe I	.22	.18	.18	.14	.14
3920.26	Fe I	.14	.22	.22	.20	.18
3913.46	Ti II	.17	.16	.17	.16	.14
3900.55	Ti II	.21	.20	.17	.20	.18
3895.66	Fe I	.29	.30	.29	.31	.27
3865.53	Fe I	.24	.23	.25	.25	.20
3859.91	Fe I	.28	.30	.32	.25	.26
3856.37	Fe I	.25	.27	.26	.21	.28
3849.97	Fe I	.21	.14	.18	.14	.18
3838.29	Mg I	.23	.18	.19	.17	.14
3822.30	Mgg I	.16	.15	.15	.16	.17
3829.35	Mg I	.16	.13	.14	.13	.13
3827.83	Fe I	.21	.15	.13	.16	.10
3825.88	Fe I	.18	.14	.17	.14	.14
3824.44	Fe I	.17	.14	.25	.17	.16
3820.43	Fe I	.18	.25	.18	.20	
3815.84	Fe I	.23	.15	.12	.14	.15
3812·97	Fe I	.22	.16	.18	.20	.18
3763.79	Fe I	.28	.32	.28	.23	.18
3761·32	Ti II	.38	.19	.13	.13	.19
3759.29	Ti II	.35	.17	.28	.22	.15
3758.24	Fe I	.28	.19	.12	.24	.10

Table II

Total absorption in the composite spectrum W_{bk} (continued)

Wave-length	Ident.	Oct. 22	Oct. 25	Oct. 26	Oct. 28	Oct. 30
4077.71	Sr II					
4071.75	Fe I					
4064.46	Fe I					
4045.82	Fe I	1.47	1.20	1.28	1.50	1.72
4034.49	Mn I	.32	.36	.34	.46	.46
4033.07	Mn I	.46	.39	.43	.45	.45
4030.76	Mn I	.71	.51	.65	.66	.63
4005.25	Fe I	.68	.57	.50	.65	.63
3998.64	Ti I	.36	.38	.36	.42	.44
3989.76	Ti I	.46	.38	.38	.42	.32
3982.48	Ti I	.27	.24	.25	.21	.24
3961.52	Al I	.25	.25	.27	.28	.20
3944.01	Al I	.26	.21	.17	.18	.18
3930.30	Fe I	.12	.10	.06	.13	.07
3927.93	Fe I	.20	.26	.14	.12	.14
3922.91	Fe I	.20	.20	.15	.19	.15
3920.26	Fe I	.27	.26	.19	.23	.21
3913.46	Ti II	.24	.24	.20	.16	.16
3900.55	Ti II	.27	.21	.21	.28	.27
3895.66	Fe I	.43	.34	.35	.38	.38
3865.53	Fe I	.20	.21	.24	.24	.23
3859.91	Fe I	.44	.36	.37	.39	.38
3856.38	Fe I	.27	.27	.36	.32	.33
3849.97	Fe I	.19	.15	.21	.27	.24
3838.29	Mg I	.37	.24	.31	.19	.20
3822.30	Mg I	.38	.22	.12	.14	.16
3829.35	Mg I	.22	.18	.13	.17	.17
3827.83	Fe I	.15	.24	.22	.22	.15
3825.88	Fe I	.23	.19	.24	.23	.14
3824.44	Fe I	.22	.22	.18	.18	.20
3820.43	Fe I	.36	.29	.24	.18	.27
3815.84	Fe I	.15	.21	.23	.23	.25
3812.97	Fe I	.26	.20	.23	.26	.16
3763.79	Fe I	.33	.31	.30	.23	.38
3761.32	Ti II	.54	.58	.59	.45	.29
3759.29	Ti II	.62	.42	.50	.48	.31
3758.24	Fe I	.30	.19	.28	.22	.33

W_k is the total absorption of the normal K-type star. This can be obtained by measuring its spectrum, the secondary being absent. That is to say, W_k is the total absorption during the phase of total eclipse. These W_k values also appear in table II, viz the W_k values on the dates of total eclipse.

The unknown value α, which is the ration of the intensities of the continua of the two stars, systematically depends on the wavelength. From the considerations of Christie and O. Wilson we know the equation (1) still to be true when $W_b = 0$. This is the case when the eclipse is entirely over. Thus from (1) we have

$$\alpha = \frac{W_{bk}}{W_k} - 1 \tag{2}$$

In the usual way the values α as computed from equation (2) were plotted against λ and through the points, obtained in this way, the mean curve was drawn. On the whole, the values of α satisfactorily agree with each other. The drawing of the continuous background and the measurements of the absorption lines in the spectral region where $\lambda \leq 3800$ Å were rather difficult and in this region the values α show a considerable scattering. The mean curve which was drawn is that which fits the scattered points as smoothly as possible.

The values α which were needed for computing W_b and the total absorption in the B spectrum were read from this graph.

These computed values have also been tabulated in table III. The values α which have been used for drawing the graph also appear in Table III.

The main value we like to obtain is W_b; using the equation (1), these values have been computed and tabulated in Table IV. These values represent the total absorption in the B spectrum, suffered by the light of the B-star while traversing the atmosphere of the K-star, and depend on the depth of the atmosphere which is traversed. If the nature of this dependency is known, the number of effective atoms in the line of sight can be computed.

The relation between the observed total absorption and height above the photosphere has been studied for different lines. The behavior of the mean total absorption for different types of lines was studied from graphs in which the mean total absorptions were plotted against the date of observation in Julian days.

Table III

Wave-length	Ident.	W_k	W_{bk}	$\alpha = W_k/W_{bk} - 1$	From α graph
4077.71	Sr II				
4071.74	Fe I				
4064 46	Fe I				
4045.81	Fe I				
4034.49	Mn I	0.60	0‘34	0.60	0.62
4033.07	Mn I	.65	.35	.40	.65
4030.76	Mn I	.82	.62	.30	.62
4005.25	Fe I	.68	.59	.15	1.08
3998.64	Ti I	.55	.36	.53	.94
3989.76	Ti I	.67	.41	.63	1.00
3982.48	Ti I	.46	.20	1.30	1.10
3961.52	Al I	.61	.24	1.54	1.30
3944.01	Al I	.69	.23	2 00	1.38
3930.30	Fe I	.30	.11	1.73	1.58
3927,93	Fe I	.40	.15	1.66	1.59
3922.91	Fe I	.41	.16	1.56	1.63
3920:26	Fe I	.52	.20	1.60	1.65
3913.46	Ti II	.47	.18	1.60	1.65
3900.54	Ti II	.55	.20	1.75	1.82
3895.66	Fe I	.84	.30	1.80	1.84
3865.53	Fe I	.55	.17	2.23	2.04
3859.91	Fe I	1.03	.36	1.87	2.08
3856.37	Fe I	.53	.26	1.05	2.13
3849.97	Fe I	.60	.20	2.00	2.13
3838.29	Mg I	.60	.21	1.76	2.23
3832.30	Mg I	.72	.22	2.27	2.30
3829.35	Mg I	.46	.15	2.06	2.32
3827.82	Fe I	.46	.20	1.03	2.33
3825.88	Fe I	.48	.22	1.18	2.35
3824.44	Fe I	.71	.26	1.73	2.36
3820.43	Fe I	.75	.28	1.64	2.38
3815.84	Fe I	.55	.20	1.75	2.40
3812.97	Fe I	.54	.22	1.45	2.43
3763.79	Fe I	.48	.31	0.77	2.76
3761.32	Ti II	.66	.42	0.57	2.76
3759.29	Ti II	.71	.38	0.86	2.78
3758.23	Fe I	,72	,28	1.61	2.80

Table IV

Total absorption in the B spektrum : W_B

Wave-length	Ident	Oct. 18	Oct. 20	Oct. 21	Oct. 22	Oct. 25	Oct. 26	Oct. 28
		J. D. 2433 937.5	J. D. 2433 939.5	J. D. 2433 940,5	J. D. 2433 941.5	J. D. 2433 944.5	J. D. 2433 945.5	J. D. 2433 947.5
4077.71	Sr II							
4071.75	Fe I							
4064.46	Fe I							
4045.82	Fe I	1.67						
4034.49	Mn I	.03	—.13	.00	—.13	—.02	—.07	.15
4033.07	Mn I	.27	.27	.35	.18	.00	.10	.15
4030.76	Mn I	.23	.44	.23	.54	.15	.39	.42
4005.25	Fe I	.58	.51	.72	.68	.47	.52	.62
3998.64	Ti I	.17	.13	.26	.16	.20	.16	.28
3989.76	Ti I	.31	.29	.33	.25	.09	.09	.17
3982.48	Ti I	.00	.04	—.01	.10	.04	.06	—.01
3961.52	Al I	.14	.16	.18	.11	.05	.04	.14
3944.01	Al I	.17	.16	.06	.13	.02	—.01	.01
3930.30	Fe I	.20	.20	.11	.02	—.02	—.08	.03
3927.93	Fe I	.05	.11	—.05	.08	.02	.01	—.05
3922.91	Fe I	.12	.11	—.04	.08	.08	.00	.06
3920.26	Fe I	.06	.14	—.07	.12	.10	—.01	.05
3913.46	Ti II	.27	.20	.11	.11	.11	.04	—.02
3900.55	Ti II	.36	.24	.24	.12	.02	.02	.02
3895.66	Fe I	.27	.26	.19	.19	.07	.09	.13
3865.53	Fe I	.03	.04	.01	.04	.03	.09	.09
3859.91	Fe I	.25	.17	.14	.16	.05	.06	.08
3856.37	Fe I	.35	.27	.21	.15	.15	.28	.22
3849.97	Fe I	.05	.03	—.03	.00	—.06	.03	.12
3838.29	Mg I	.80	.48	.34	.27	.08	.18	.01
3832.30	Mg I	.78	.32	.23	.23	.00	—.14	—.11
3829.35	Mg I	.25	.23	.13	.12	.06	—.01	.10
3827.82	Fe I	.17	.26	.06	.02	.15	.12	.12
3825.88	Fe I	.17	.25	.17	.13	.07	.14	.13
3824.44	Fe I	.25	.12	.11	.04	.04	—.02	—.02
3820.43	Fe I	.59	.42	.11	.20	.10	.03	—.14
3815.84	Fe I	.17	.17	.07	.01	.07	.10	.10
3812.97	Fe I	.23	.09	.03	.15	.06	.10	.15
3763.79	Fe I	.58	.33	.13	.28	.25	.24	.14
3761.32	Ti II	.69	.51	.45	.51	.57	.57	.39
3759.29	Ti II	.81	.75	.29	.60	.2	.44	.41
3758.24	Fe I	.50	.41	—.03	.16	.01	.14	.05

Table IV

Total absorption in the spektrum : W_B (Continued)

Wave-Length	Ident	Oct. 30	Oct. 31	Nov. 6	Nov. 10	Nov. 11	Nov. 11
		J. D. 2433 949.5	J. D. 2433 950.5	J. D. 2433 956.5	J. D. 2433 960.5	J. D. 2433 961.5	J. D. 2433 962.5
4077.71	Sr II						
4071.75	Fe I						
4064.46	Fe I						
4045.82	Fe I						
4034.49	Mn I	.24	.03	.00	.03	.08	.05
4033.07	Mn I	.15	.35	.30	.15	.15	.17
4030.76	Mn I	.34	.42	—.10	.30	.07	—.10
4005.25	Fe I	.59	.53	.32	.39	.47	.46
3998.64	Ti I	.32	.19	.21	.19	.17	.13
3989.76	Ti I	—.03	.15	.11	.13	.09	.01
3982.48	Ti I	.04	—.15	—.07	—.03	—.07	—.03
3961.52	Al I	.00	.00	.04	.05	—.02	—.03
3944.01	Al I	—.01	.01	—.01	—.01	—.04	—.06
3930.30	Fe I	—.07	—.02	—.08	—.07	—.08	—.07
3927.93	Fe I	.02	.16	.08	—.06	.00	—.05
3922.91	Fe I	.00	.11	.04	—0.4	—.01	—.01
3920.26	Fe I	0.2	—.09	.04	0.4	.00	—.02
3913.46	Ti II	—.02	.00	—.02	.00	—.02	—.05
3900.55	Ti II	.01	.02	.01	—.03	.01	—.02
3895.66	Fe I	.13	.00	.03	.02	.05	0.2
3865.53	Fe I	.07	.09	.07	.10	.10	0.4
3859.91	Fe I	.07	—.08	—.05	—.02	—.14	—.12
3856.37	Fe I	.24	.17	.15	.14	.05	.16
3849.97	Fe I	.06	.03	—.07	—.01	—.07	—.01
3838.29	Mg I	.27	.17	.00	.01	—.02	.04
3832.30	Mg I	—.01	—.01	—.08	—.08	—.01	—.05
3829.35	Mg I	.05	—.01	—.01	.00	—.01	—.01
3827.82	Fe I	.02	.10	.02	—.01	.03	—.05
3825.88	Fe I	.00	.05	.00	.04	.00	.00
3824.44	Fe I	.01	—.04	—.08	.08	—.04	—0.5
3820.43	Fe I	.07	—.04	.04	—.06	—.02	
3815.84	Fe I	.05	.10	.01	—.06	—.03	.01
3812.97	Fe I	.00	.09	.00	.03	.09	.03
3763.79	Fe I	.32	.21	.22	.21	.14	.07
3761.32	Ti II	.17	.29	0.4	—.05	—.05	.04
3759.29	Ti II	.18	.23	—.01	.06	0.6	—.04
3758.24	Fe I	.15	.14	.01	0.8	.08	—.11

Discussion of results :

Of aluminium the lines λ 3961 and 3944 were measured and reduced. We first discuss the results obtained from these lines. The lines λ 3961 and λ 3944 are situated on the wings of the calcium-K line. Therefore, the drawing of the continuum is rather difficult and the results correspondingly are uncertain. Judging from appearances, it may be stated that in the atmosphere of the star aluminium is a low level element.

The mean of manganese depends on three lines which are well defined on the tracings. But, instead of getting great accuracy, the points are largely scattered. This must be due to some effect in the line contour rather than to differences in distribution. A smooth curve has been drawn through the points mentioned above. It is believed that manganese is distributed all through the star's atmosphere.

The identification of the magnesium lines has been rather difficult. Three lines have been picked out and reduced. The general behavior of the curve indicates that this element also can be classified as a low level element.

The evaluation of the behavior of titanium depends on three Ti I lines which show that the distribution of this element is such that it occurs up to high levels in the star's atmosphere. Ti II also extends to rather high levels.

List of Literature

[1] Lick Obs. Bull. 1, 22, 1901
]2] Ap. J. 83, 433, 1936
[3] Ap. J. 100, 8, 1936
[4] Ap. J. 81, 441, 1935
[5] Publ. Mich. Obs. Vol. III, 1, 1939

Department of Astronomy
Ankara, December, 1955

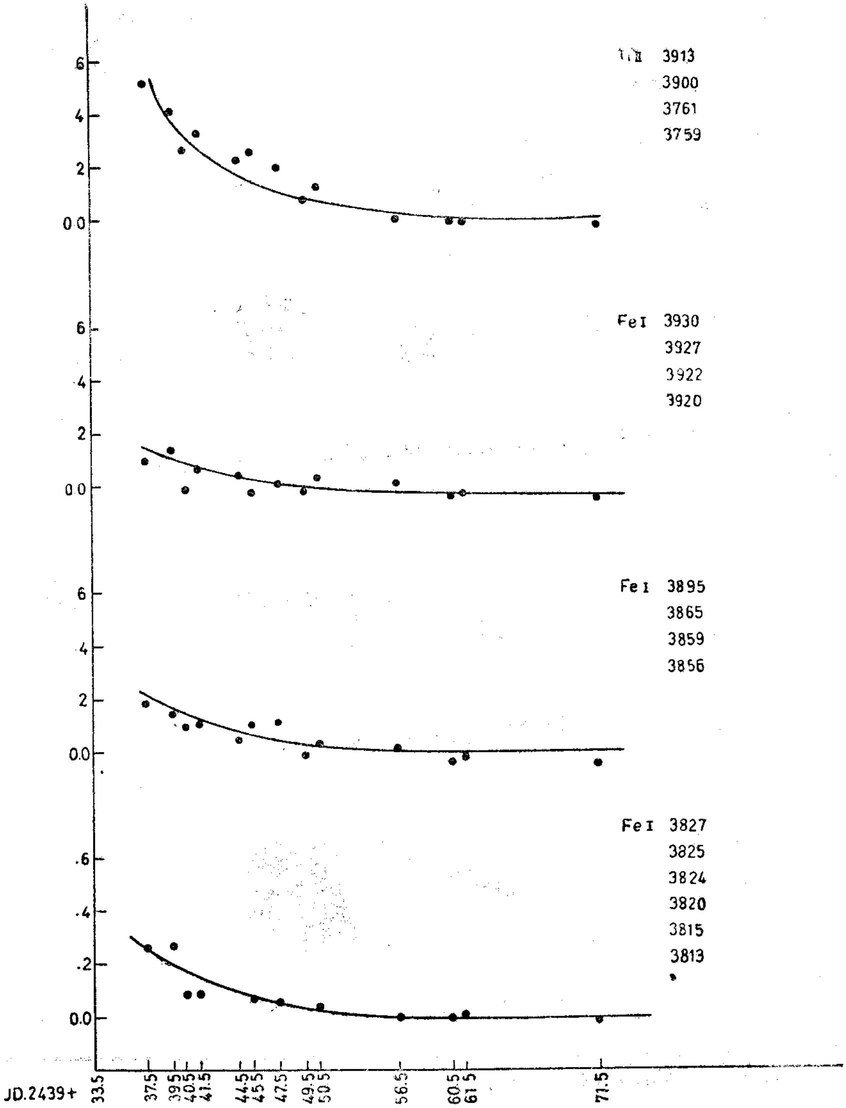
Ti II 3913
3900
3761
3759
Fe I 3930
3927
3922
3920
Fe I 3895
3865
3859
3856
Fe I 3827
3825
3824
3820
3815
3813
6
4
2
0.0
6
4
2
0.0
6
4
2
0.0
.6
.4
.2
0.0
JD.2439+
33.5
37.5
39.5
40.5
41.5
44.5
45.5
47.5
49.5
50.5
56.5
60.5
61.5
71.5

Fig. 1

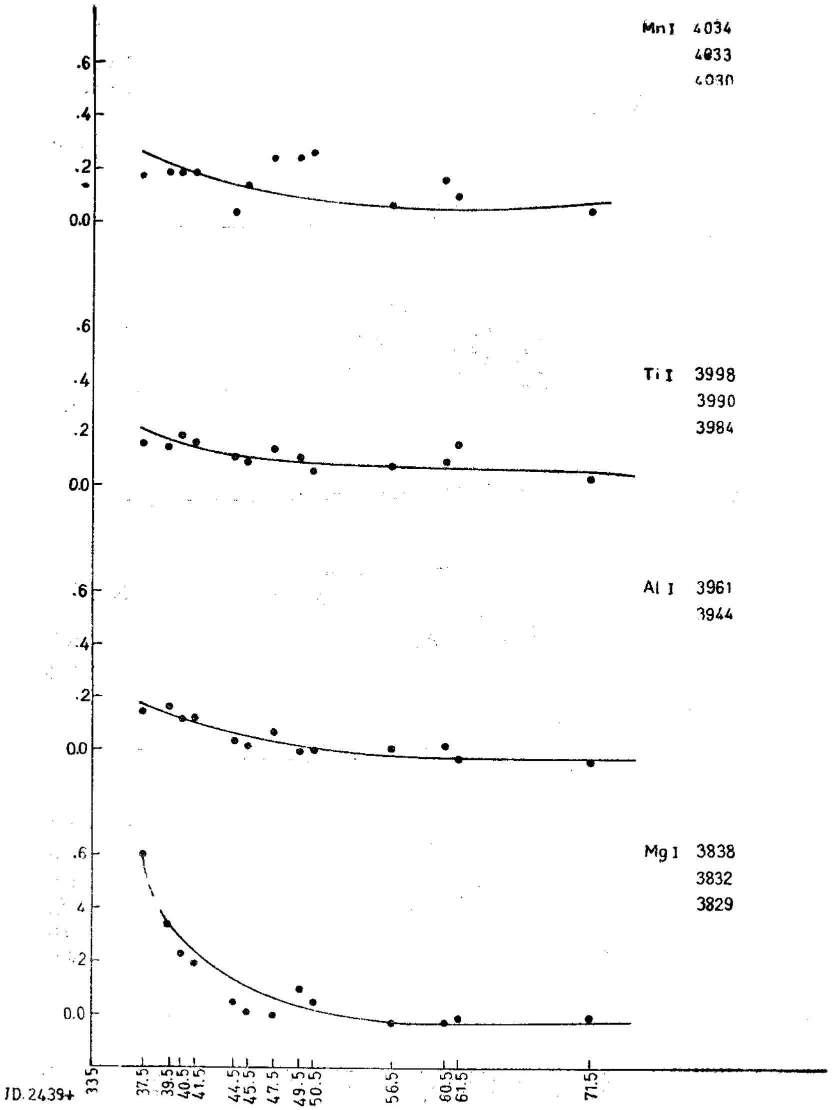
Mn I 4034
4033
4030
Ti I 3998
3990
3984
Al I 3961
3944
Mg I 3838
3832
3829
.6
.4
.2
0.0
JD 2439+
33.5
37.5
39.5
40.5
41.5
44.5
45.5
47.5
49.5
50.5
56.5
60.5
61.5
71.5

Fig. 2