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THE SPECTRUM OF 37 LIBRAE

Abstract: Analysed in more detail is the spectrum of the fast moving star 37 Librae (HD 138 716). Determined were both the wave-lengths of spectral lines and the equivalent widths of lines in the UV region. The measurements made served for determining the curve of growth, the excitation temperature for a number of neutral atoms and the relative abundance of elements in the 37 Lib atmosphere. Schwarzschild-Schuster's model atmosphere was used for the analysis.

From the curve of growth the basic parameters of the atmosphere were obtained. Worth noting is the relatively high turbulent velocity of atoms in the atmosphere of the star ($V_c = 9.7$ km sec^{-1}). It appears that the atmosphere of 37 Lib abounds in more neutral atoms of elements with higher atomic numbers than the solar atmosphere. The values for the comparison were taken from Goldberg et al.

1. *Introduction*

Oort (1928) and Lindblad (1925) showed that one of the remarkable star groups in our galaxy consists of stars with considerable spatial motions. These stars are distinguished by their kinematic characteristics and very interesting spectral peculiarities. Examined in more detail were especially the principal departures of the spectrum from the spectra of so called normal stars. These departures have a number of characteristics in common (Keenan 1958, and others).

Spectral type G 5—K 3 shows an attenuation in molecular band CN ($\lambda\lambda$4303, 4216, etc.); for earlier spectral types it was found that the spectra of such stars are less abundant in metallic lines. A number of authors studied the ratio of the intensity of metallic lines to that of CN bands, and especially the ratio of the number of effective hydrogen-atoms to that of metallic atoms or, as the case may be, to the sums of oxygen, nitrogen and carbon atoms.

These findings are obviously based on an inadequate number of observations, especially on spectrograms with sufficient resolving power, no matter how promising are the results of several more recent papers (Wilson 1959; Gratton 1952; Romanov, and others).

Roman (1955) collected data on fast moving stars into a catalogue.

Dr. Wilson and Dr. Perek kindly let me have their spectrograms of high-velocity stars made at at the coudé focus of the 100″ and 200″ reflector at the Mt Wilson and Mt Palomar Observatory respectively. These high-quality spectrograms suggested that the star 37 Librae (HD 138 716) deservesa further investigation. Its basic data are as follows:

Star	37 Librae	
N. Roman's Catalogue No.		370
HD catalogue No.		138 716
Spectrum		K 1 III
AR_{1900}	$15^h27^m.8$	
$Decl_{1900}$	—9°43′	

$m_v = 4^m.63$ B — V $= 1^m.01$ U — B $= 0^m.86$

$\pi = 0.024''$

Radial velocity $V_r = 48$ km/sec^{-1}

$\mu_{AR} = 0.301$, $\mu_{Decl} = -0.242$ } according to GC

Total space velocity $Q = 100$ km/sec^{-1}

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2. *Observational material*

The wave-lengths of the spectral lines were determined and the spectrum more closely analysed on spectrograms made with the 100″ Mt Wilson and 200″ Mt Palomar Observatory reflectors. The resolving power of the spectrograms was 9 Å/mm, 18 Å/mm. The spectrograms were made by the grating spectrograph as described in more detail by Bowen (1953). The analysed spectral region ranges from 4300 Å to extreme ultraviolet, approximately to 3300 Å. The errors and shortcomings due to the spectrograph, developing method, and the like, could not be examined by the present author.

Table I

List of used spectrograms

No.	Mt Wilson No. Mt Palomar No.	Dispersion	Region	Quality
1	Ce 10543	18	3950—UV	very good
3	Ce 10358	18	4000—3500	good
3	Pc 2586	9	4300—3600	very good
4	Pc 2620	9	3940—3500	good

The spectrograms used to analyse the 37 Lib spectrum in more detail are listed in Table I, giving, in the first column, the spectrogram number, in the second, the designation from the Mt Wilson or, as the case may be, Mt Palomar list, and in the following columns: the approximate dispersion in Å/mm, the spectral range for which the spectrogram was made and, in the last column, the quality of the spectrogram.

3. *Processing of observational material*

a) Determination of the wave-length of spectral lines

The main objective of the present paper did not include accurate determinations of the wave-lengths of spectral lines; such determinations were chiefly needed to identify the individual lines, but this problem had to be dealt with very carefully. The wave-lengths of selected spectral lines were determined from measurements made with a Zeiss-Abbe comparator, partly on the basis of Zeiss-Koomes measurements, partly from microphotometer recordings. The Zeiss-Koomes instrument is not designed for spectrogram measurements and hence its measuring errors had to be eliminated.

The wave-lengths of the other spectral lines were calculated by current methods; for sufficiently short spectral segments, however, we only needed the linear dependence between the instrument readings and the wave-length. The quadratic formula was only used in extreme violet. The standards used for determining the wave-lengths throughout the spectrum were the iron lines from Ch. Moore's tables (1945).

For the identification proper of the lines the Revised Multiplet Table (Moore 1945) was used (further on RMT). The number of determined wave-lengths that needed checking against other tables (e.g. Zajcev, Prokofiev, Rajskij, 1952) or comparison with the results of other authors (especially of Davis (1947), Gratton (1952), Warner (1963) and others), was insignificant.

The results for all lines are summarized in Table II.

Painstaking was the identification of the molecular bands, as they were blended—especially in the given case—by a large number of spectral lines. Here we had frequently to resort to L. Wallace's Paper (1962) and to the tables mentioned above.

b) Microphotometric measurements

The spectrograms were microphotometered by a Khol F-3-type recording microphotometer operating on the principle of zero adjustment. The recordings were made in the following magnifications: 20 : 1, 40 : 1, 80 : 1 and 160 : 1. For every region two to four recordings were made in the same magnification. The recording height was 10 to 12 cm in most cases.

Beside the microphotometer we used a (not recording) Zeiss-Schnell-Photometer for checking the central densities, the properties of the Khol F-3 recording photometer, the gradation curves, and the like.

Figure 1 shows the resulting gradation curves according to wave-lengths for one and the same plate.

The characteristic curve was graphically converted into the intensity curve by the combined Stankievič-Dobronravin (1963) method. This procedure was both painstaking and difficult due especially to the overall character of the spectrum. In the ultraviolet region of such spectra (K 1 III), the spectral lines appreciably overlap and are so numerous that the continuous spectrum is difficult to determine.

Dubious determinations of blended spectral lines were clarified by comparing our results with

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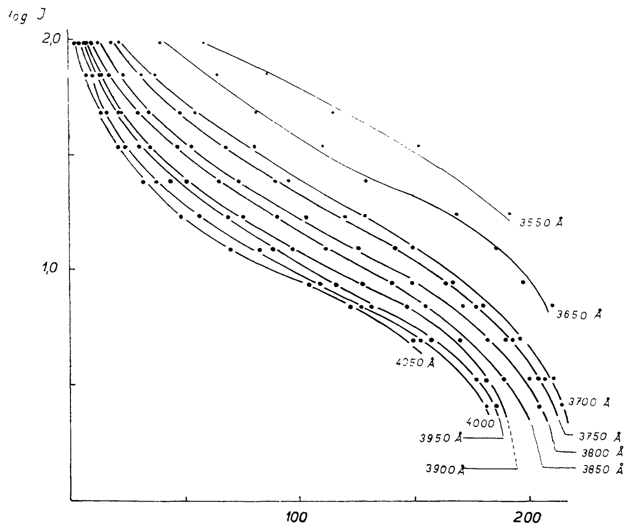

Figure 1. H and D curves of spectrogram Ce 10 543

those of other authors (especially Wright 1948, Davis 1947, Gratton 1952, and Warner 1963).

The continuous spectrum was determined as follows: In the Photometric Atlas of Solar Spectrum the regions were looked up assumed by its authors to represent the continuum. The regions were, then, identified in the spectrograms and duly discussed, especially as to the occurrence of lines in close neighbourhood, their width, and the like. The regions that satisfied the condition were used to draw the curve of the continuous spectrum through them. This method obviously has some serious shortcomings that make the result less dependable.

The continuous spectrum was not corrected for the part of the individual spectral lines.

Like in numerous other papers (e.g. Wright 1948), the equivalent line widths were determined by three methods:

a) By determining the true profiles of the spectral lines and planimetering direct in the intensity curve. This method was used for more than 100 spectral lines, especially those, where the wings were fairly broadened. Here, the correct fitting of the line-wing curve caused difficulties.

b) The equivalent width of medium and low-intensity spectral lines (central intensity) was determined by triangles. In this connection it was found useful slightly to magnify the recording. The number of equivalent line widths determined by this method was highest.

c) By central line-intensities. This method was especially used in cases of appreciably overlapping lines, where the profile could not be determined. Figure 2 shows the central line-intensity in dependence on value W/λ. As anticipated, these quantities agree well for-weak lines; the areement was poorer for lines with considerably broadened wings. Diagram 2 was obtained by planimetering

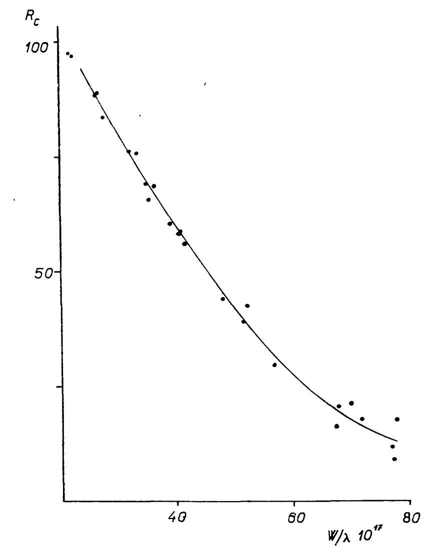

Figure 2. Central intensity R_c on equivalent width of spectral lines in spectrogram Ce 10 543

at the lines in region λ 3750 Å—3920 Å for plate Ce 10345. For the other plates, the mentioned dependence is analogous.

The individual spectral lines identified and measured in the 37 Librae spectrum are listed in Table II. Its first column gives the measured wave-lengths of the line, further columns in succession: the atom (or, as the case may be, the molecule) to which the line belongs according to the mentioned tables, the wave-lenghts of the line according to RMT (only decimals); the last column gives the equivalent line-width in 10^{-6} Å units (logarithm of equivalent width).

Letter *w* indicates lines of very low intensity, where the equivalent width could not be determined reliably.

4. *Measuring errors*

Accurate wave-length determinations were not the main objective of the present paper. Hence the results were not discussed in more detail.

More attention was paid to the errors resulting from spectrogram photometering. Wright (1948) shows that errors in spectrogram evaluations arise from the following factors:

a) the spectrograph,
b) the calibration,

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Table II

	Identification			W
3392.676	Fe	.652	(85)	1.87
	Ti	.713	(136)	
92.999	Ni	.992	(20)	1.82
	Cr II	.00	(21)	
93.353	Fe	.382	(376)	2.39
93.702	Cr II	.86	(21)	2.56
94.276	Sc II	.29	(38)	2.09
95.183	Gd II	.120	(91)	2.75
96.043	Fe	5.90	(189)	1.92
96.392	Fe	.386	(25)	2.06
97.003	Fe	6.987	(26)	2.02
97.676	Zr II	.66	(103)	2.46
98.297	Fe	.226	(304)	1.45
99.014	Fe	.230	(302)?	1.6?
99.654	Hf II	.80	(1)	1.95
99.999	Gd II	.991	(20)	1.49
3400.547	Co	.471	(42)	2.00
	V	.395	(46)	
00.813	Sun			
02.248	Fe	.256	(614)	2.10
02.932	Zr II	.87	(91)	1.71
	Gd II	3.081	(73)?	
03.186	V II	.159	(135)	1.99
03.591	Cr	.59	(254)	1.82
04.043	...			1.71
05.029	Gd II	.038	(91)	2.32
	Ti	.094	(86)	
05.644	Ni	.50	(122)	2.22
05.846	Fe	.83	(299)	2.80
	Mo	.934	(9)	
06.347	Fe	.422	(676)	1.75
06.521	...			1.62
06.893	V	.837	(46)	1.80
	Fe	.803	(85)	
07.191	Ti II	.205	(1)	
07.651	Gd II	.61	(24)	
	Gd II	.56	(91)	
	Y II	.7		
08.107	Zr II	.09	(72)	1.84
	N II	.136	(7)?	
09.509	Ni	.578	(5)	2.49
	Cr II	.60	(8)	
	Fe	.40	(445)	
09.928	Y II	.87	(63)	1.94
	Fe	10.031	(542)	
3410.365	Fe	.353	(301)	2.07
11.660	Ti II	.68	(63)	2.22
12.319	Co	.339	(25)	1.81?
13.075	Cb II	.934	(3)	1.86
13.4	Ni	.46	(124)	1.46
13.382	Zr II	.39	(60)	—
13.931	Ni	.939	(17)	
14.113	Fe II	.144	(91)?	1.61
	V II	.192	(135)	
14.681	Zr	.66	(17)	2.05
15.452	Cr II	.47	(100)	2.38
16.293	Fe II	.021	(16)	2.19
17.873	Co	.795	(19)	2.61?
	Fe	.842	(81)	
	Ti	.88	(86)	
	Ne	.904	(4)	
18.588	Sc	.528	(21)	
19.278	Fe	.157	(576)	1.64
	Sc	.358	(21)	
3420.460	Co	.474	(42)	1.78
21.962	Fe II	.97	(11)?	
22.856	Ni	.878	(122)	1.63?
	Gd II	.766	(2)	
23.359	Co	.500	(103)	1.20?
25.107	Ce II	.09	(8)	1.36

	Identification			W
25.871	...			2.06
27.131	Fe	.121		2.28
27.400	Gd II	.362	(91)	1.44
27.818	...			w
28.999	Ti	.955	(186)	1.90
29.148	Sc	.206	(21)	2.01
29.528	Sc	.483	(21)	2.23
3431.207	Cr	.284	(53)	2.15?
32.353	Co	.318	(102)	1.80
32.687	Cb	.708?		1.80
33.123	Ce II	.091	(249)	2.19
33.545	Ni	.558	(19)	2.44
33.828	V II	.767	(134)?	207
	Zr II	.90	(58)	
34.273	...			1.60
34.853	Rh	.893	(2)	1.60
36.279	...			w
36.957	...			2.00
37.836	...			1.86
38.042	Fe	.10	(300)	2.00
38.713	Co	.713	(87)	1.11
39.063	Fe	.050	(299)	1.31
39.764	Gd II	.784	(22)	1.79
3440.119	...			2.22
41.510	Tm II	.505	(—)?	2.36
	Cr	.439	(52)	
42.771	Fe	.672	(26)	2.22
	Fe II	.79	(76)	
43.407	Ti II	.387	(99)	2.21
43.715	Cr	.790	(110)	2.21
	Al	.651	(2)	
44.519	Ti	.403	(120)	2.37
45.079	Cr	.10	(51)	2.28
	Cr II	.04	(110)	
	Fe	.151	(81)	
45.915	Mn	6.0	(9)	2.05
	Mo II	.085	(1)	
	Co	.088	(162)	
46.337	Ni	.263	(20)	2.32
	K	.38	(4)	
47.008	Cr	.015	(52)	1.98
47.566	Cr	.430	(52)	2.06
	Cr	.760	(52)	
48.786	Fe	.786	(372)	1.72
49.646	Gd II	.616	(7)	1.86
49.971	Cr	0.00	(90)	2.18
	Ti	.874	(46)	
3450.237	Fe	.328	(82)	2.07
51.089	V II	.046	(118)	1.39
52.373	Fe II	.33	(89)	2.33
	Ti II	.470	(99)	
52.702	Al	.670	(2)	2.00
53.073	V II	.087	(132)	2.01
53.690	Tm II	.655	(7)	2.23
54.279	...			1.69
54.997	Mn	5.04	(41)	1.88
	Cr II	.98	(136)	
56.049	Fe II	.00	(4)	1.76
56.836	Co	.924	(5)	1.92
57.122	Fe	.090	(374, 835)	1.76
	V II	.153	(147)	
57.797	Mn	.809	(9)	1.82
58.320	Fe	.304	(139)	2.30
59.218	Cr II	.29	(136)	1.75
	Fe	.29	(576)	
3460.248	La II	.31	(119)	2.06
	Mn II	.312	(3)	
60.743	Co	.719	(35)	2.01
	Pd	.76	(2)	
	Gd II	.776	(73)	

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	Identification			W
61.135	Co	.173	(162)	2.19
62.435	Na II	.494	(4)	1.74
63.121	V II	.079	(104)	1.75
63.595	Co	.499	(42)	1.81
	W II	.52	(7)	
	Al II	.63	(55)	
64.162	Gd II	.132	(90)	1.83
	V II	.17	(104)	
64.894	Cr	.82	(51)	1.56
	Fe	.914	(214)	
65.863	Fe		(6)	2.85 standard
66.62	V II	.59	(68)	1.80
68.343	K II	.32	(1)	1.75
69.715	Co	.683	(137)	1.96
	Fe	.843	(242)	
3470.287	V II	.263	(58)	1.55
70.683	Rh	.657	(3)	1.55
	Cr	.72	(77)	
71.375	Ni II	.35	(4)	2.21
	Fe	.350	(130)	
72.134	Co	.196	(161)	2.21
73.302	Fe	.23	(576)	1.86
	Gd II	.210	(7)	
74.366	Cr	.379	(—)	2.28
74.844	La II	.84	(143)	1.77
	Cr	.87	(141)	
75.291	Fe II	.25	(4)	2.34
	Ne II	.25	(35)?	
	Cr	.36	(141)	
76.263	V II	.252	(58)	2.33
77.168	Cr	.161	(141)	2.10
	Ti II	.181	(6)	
78.359	Fe	.382	(185)	1.85
78.709	Co	.744	(67)	1.80
79.169	Cr	.14	(141)	1.72
79.421	Zr II	.39	(46)	1.64
	Ne II	.53	(49)	
3480.791	Ne II	.75	(49)	1.72
	Ti II	.879	(22)	
83.784	Ni	.73	(120)	1.76
	Mn II	.905	(3)	
84.254	V II	.32	(168)	1.80
84.631	V II	.65	(6)	
84.989	Fe	.97	(138)	2.09
	Ce II	.054	(44)	
85.659	Ti	.689	(84)	2.05
85.863	V	.867	(81)	1.94
	Ni	.888	(17)	
86.222	W II	.14	(11)?	1.80
86.727	Fe	.556	(79)	1.71
88.461	Cr	.453	(109)	1.76
89.520	Fe	.670	(442)	1.70
3490.245	...			w
90.535	Fe	.575	(6)	2.40
91.374	Co	.316	(6)	2.07
91.903	Gd II	.954	(6)	1.73
	Co	.987	(159)	
92.183	...			w
93.786	Fe	.69	(297)	2.34
94.523	Cr II	.52	(2)	1.75
94.966	Cr	5.109	(109)	1.82
93.509	Cr II	.56	(—)	1.95
	Ni II	.6	(4)	
96.144	Zr II	.18	(1)	1.76
	Y II	.08	(3)	
	Fe	.19	(186)	
96.600	Fe	.40	(572)	1.91

	Identification			W
97.535	Mn II	.536	(3)	2.22
97.959	Zr II	.90	(58) (84)	1.50
98.697	He	.641	(40)?	1.45
3501.700	Fe	.564	(238)	1.86
	Ni	.852	(6)	
03.106	Fe II	.095	(3)	2.12
03.470	Fe II	.474	(4)	1.60
	Cr	.38	(109)	
05.729	V	.690	(81)	2.20
07.234	Rh	.316	(2)	2.05
07.962	Y II	.964	(47)	1.57
08.525	Fe	.52	(239)	1.92
09.018	V II	.024	(117)	1.75
09.302	Zr II	.32	(15)	1.36
09.711	Fe	.73	(327)	2.22
09.964	Mn II	.971	(9)	2.30
3510.609	Cr	.538	(109)	1.94
11.156	Sm II	.227	(12)	1.72
12.611	Co	.640	(21)	2.08
	Zr II	.67	(57)	
	Fe	.68	(327)	
13.005	Fe	2.95	(501)	1.99
	Cr II	.03	(107)	
	Fe	.065	(48)	
13.480	Co	.478	(5)	2.32
13.854	Fe	.820	(24)	1.88
	V II	.877	(117)	
14.335	...			
14.666	Fe	.62	(183)	2.38
	Zr II	.64	(114)	
15.857	...			1.60
17.152	...			1.50
17.255	V II	.298	(6)	1.61
18.137	Fe	.23	(575)	1.72
19.177	Ce II	.077	(92)	1.94
	Ti	.24	(2)	
19.541	Zr	.60	(13)	1.89
3520.564	Cr	.55	(235)	1.76
	V II	.457	(57)	1.44
20.903	Zr II	.91	(59)	2.10
	Fe	.85	(238)	
22.083	Mo II	.063	(1)	1.65
	Fe II	.05	(10)	
22.371	Fe	.268	(326)	2.22
23.071	Ni	.074	(34)	2.12
24.210	Fe	.236	(130)	2.41
25.309	...			1.41
27.617	Fe	.792	(326)	2.30
28.739	Os	.602	(1)	1.91
29.100	Co	.032	(5)	2.19
29.768	Fe	.818	(326)	2.41
	Co	.816	(22)	
3530.343	Ti	.580	(22)	2.45
	Ni	.595	(121)	
32.863	Cr	.888	(—)	1.70
33.383	Co	.356	(5)	2.30
34.061	Ce II	.031	(44)	1.82
35.416	Ti II	.408	(98)	2.01
35.585	Hf II	.54	(9)?	1.51
36.191	...			1.40
36.521	Fe	.556	(326)	2.40
37.374	Ni	.243	(153)	2.42
	Cr	.25	(50)	
	Fe	.491	(239)	
38.631	Fe	.55	(137)	2.47
39.123	Fe	.121	(329)	2.40
39.340	Th II	.589	(1)	1.65
3540.714	Fe	.709	(23)	2.54

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Continuation Table II

	Identification			W
40.949	Cb II	.941	(4)?	2.10
	Fe	1.083	(326)	
41.579	. . .			1.51
41.949	Ni	2.00	(119)	2.40
	Fe	2.076	(326)	
42.892	Gd	.768	(51)	
	Co	.976	(19)	2.25
43.420	Fe	.39	(183)	2.38
	V	.500	(53)	
44.123	Y II	.948	(6)	1.59
44.515	Fe	.631	(329)	2.23
44.901	Fe	.88	(154)	2.00
	Gd II	.985	(51)	
45.454	V II	.339	(53)	1.76
45.757	Gd II	.797	(2)	2.42
	Fe	.832	(536)	
	Fe	.639	(321)	
46.025	Cr II	.15	(134)	1.44
46.522	(Co)			1.41
47.037	Ti	.029	(133)	2.00
47.593	Zr	.69	(13)	1.85
47.992	Cr	.98	(—)	1.45
48.594	. . .			1.39
48.942	Y II	.02	(9)	1.49
49.333	Gd II	.365	(7)	1.52
49.782	Fe	.868	(48)	2.40
3550.143	Ti II	.19	(117)	1.70
	Zr II	.11	(124)	
50.659	Cr	.635		1.68
51.028	Fe	.11	(321)	2.34
51.392				1.67
51.918	Zr II	.94	(1)	1.93
52.379	Fe	.42	(42)	2.19
53.824	Fe	.828	(321)	2.09
53.176	Co	.161	(137)	1.90
53.597	Mg II	.51	(11)	1.72
	Gd II	.716	(89)	
54.310				1.68
54.928	Fe	.922	(326)	2.47
55.274	W II	.18	(11)	1.73
	V	.142	(53)	
55.758	. . .			1.40
57.622	Tm II	.796	(10)	1.50
59.324	Ce II	.328	(243)	1.70
3560.323	Co	.306	(64)	1.40
60.580	V II	.594	(4)	1.72
60.992	Co	.891	(21)	1.97
61.532	Ti II	.575	(15)	2.40
62.095	Co	.097	(115)	1.96
62.441	Cr	.48	(281)	1.55
62.848	Co	.912	(64)	1.45
63.716	V II	.71	(4)	1.56
64.892	Co	.947	(19)	1.63
65.326	Ti II	.326	(76)	1.70
66.164	V	.177	(45)	1.83
	V II	.177	(4)	
67.194	S II	.171	(56)?	1.70
	Gd II	.116	(89)	
68.508	Co	.426	(61)	1.95
69.207	. . .			1.45
69.695	Gd II	.566	(51)	1.96
	Mn	.804	(18)	
3570.198	Fe	.100	(24)	2.58
	Fe	.243	(326)	
70.921	V	1.037	(122)	2.08
72.694	Fe	.60	(325)	1.88
	Pb	.734	(3)	
73.332	Fe	.403	(673)	1.84
	Ni	.27	(123)	
73.852	Fe	.842	(181)	2.22
74.198	Cr	.039	(74)	1.80
	Cr	.039	(308)	
74.612				1.39
75.139	Fe	.11	(321)	2.25
	Fe	.249	(322)	
76.086	Fe	.976	(321, 328)	2.31
	Cr II	.00	(78)	
76.694	Fe	.760	(613a)	2.23
77.118	V II	.220	(78)	2.08
	Ni	.240	(3)	
77.570	Ce II	.458	(51)	1.70
77.880	Mn	.870	(8)	2.09
78.240	Zr II	.22	(83)	1.51
78.645	V II	.636	(78)	1.54
79.474	Gd II	.549	(89)	1.52
3582.008	Zr II	.08	(101)	1.39
85.490	Cr II	.44	(13)	1.41
	Fe	.320	(23)	2.22
86.101	Co	.072	(87)	2.08
	Fe	.10	(497)	
	Fe	.114	(611)	
86.535	Mn	.543	(8)	2.04
	Al	.557	(7)	
86.899	Sc II	.83	(40)	1.75
	Al II	.912	(7)	
87.310	Al II	.309	(7)	2.20
	Fe	.253	(325)	
	Al II	.342	(7)	
88.690	Fe	.325	(615)	
87.882	Ni	.931	(16)	1.54
89.392	Ru	.215	(4)	1.77
	Fe	.456	(295)	
89.938	Mn	.973	(25)	1.50
3590.442	Gd II	.468	(22)	1.50
	Sc II	.475	(3)	
91.178	Fe	.099	(573)	1.81
92.236	. . .			1.75
92.836	Fe	.881	(77)	1.65
93.388	Fe	.33	(571)	1.60
	V II	.323	(4)	
94.240				
95.440	. . .			1.53
95.682	Fe	.66	(322)	1.80
96.904	Fe	7.05	(569)	1.81
97.839	Ni	.705	(18)	1.70
98.474	. . .			1.30
99.704	Fe	.624	(809)	1.62
3600.275				
01.536				1.35
02.873	Fe	.77	(370)	2.09
03.199	Fe	.205	(295)	2.00
03.942				
04.507	Co	.469	(136)	1.70
	Cl II	.51	(78)?	
	Cr	.54	(49, 89)	
05.164	Cr?			
05.524	Fe	.50	(322)	1.70
	Sc II	.50	(40)	
	Cr	.52	(252)	
06.143	Ti	.062	(303)	2.12
06.772	Ti	.786	(20)	2.21
07.472	Mn	.537	(8)	2.10
08.406	Cr	.401	(252)	2.13
	Mn	.494	(8)	

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	Identification			W
08.921	Fe	.861	(23)	2.24
	Ti II	.76	(89)	
09.649	Ce II	.687	(179)	1.62
3610.104	Cr	.052	(49)	1.86
	Cr II	.85	(171)?	
	Ti	.154	(58)	
11.110	Y II	.06	(9)	1.42
11.885	Zr II	.90	(113)	
12.879	Ni	.741	(6)	1.72
	Fe	.940	(46)	
	Fe	.940	(77)	
13.536	Gd	.490	(87)	1.43
13.912	Fe	.95	(612)	1.50
14.560	Fe	.550	(—)	w
15.440	Co	.387	(66)	1.53
	Cr II	.45	(147)	
15.977	Fe	.615	(569)	1.62
16.427	Fe	.326	(123)	1.66
	Fe	.522	(—)	
16.984	S II	.916	(56)?	1.58
	Fe	7.09	(535)	
17.343	Fe	.317		1.72
	Cr II	.320	(147)	
17.802	Fe	.788	(496)	1.75
18.171	Co	.010	(36)	1.78
	Fe	.300	(324)	
18.565	K II	.490	(1)	1.78
	Fe	.610	(569)	
19.176	Fe	8.960	(77)	2.48
	Mn	.284	(8)	
19.561	Cb II	.514	(4)	1.52
	Fe	.660	(130)	
3620.198	Fe	.230	(324)	1.58
21.870	Fe	2.000	(233)	1.50
	Fe	2.001	(295)	
22.258	V II	.289	(144)	1.41
22.824	Fe II	.810	(175)	1.40
	Mo II	.850	(1)	
23.955	Zr	.870	(12)	1.42
	Lu	.980	(6)	
24.267	Fe	.300	(133)	1.79
24.634	Ni	.720	(121)	1.55
24.857	Ti II	.826	(52)	1.57
	Fe II	.890	(144)	
25.136	Fe	.140	(323)	1.64
25.582	V II	.608	(76)	w
25.960	Cr II	.920	(147)	2.00
	Co	6.020	(41)	
	Ti	6.085	(20)	
26.950	Sm II	7.014	(30)	1.74
	Fe	7.050	(808)	
27.875	Co	.806	(19)	1.56
	Sm II	.971	(12)	
28.561	Y II	.710	(9)	1.40
28.899	Fe	.820	(438)	1.41
	La II	.830	(13)	
29.500	Gd II	.510	(69)	
3630.495	Fe	.353	(323)	1.82
	Fe	.670	(126)	
31.097	Ca	.974	(9)	1.68
	Fe	.103	(322)	
31.509	Fe	.464	(23)	1.58
	V II	.480	(170)	
	Cr II	.490	(12)	
32.251	Fe II	.292	(112)?	
32.784	Co	.839	(147)	1.83
	Cr	.839	(49)	
33.344	Co	.340	(116)	1.68

	Identification			E
33.788	Fe	.640	(395)	
	Fe	.837	(440)	
34.236	Sm II	.290	(19)	1.47
34.669	Fe	.689	(—)	1.65
	Pd	.710	(1)	
	Co	.713	(146)	
35.104	Fe	.080	(919)	143
35.800	Fe	.820	(321)	1.42
36.153	Fe	.186	(77, 568)	1.59
	Cr	.210	(47)	
36.989	Fe	.995	(233)	1.54
37.381	Co	.319	(117)	
37.794	Fe	.730	(229)	1.68
	Sb	.830	(1)?	
38.058	Ti	7.966	(18)	1.69
	Fe	.160	(324)	
38.645	Ti	.490	(118)	1.40
38.888				1.42
3640.255	Gd II	.180	(23)	2.10
	Fe	.388	(295)	
40.634	...			1.52
41.166	V	.096	(115)	1.57
42.015	...			
42.545	Ni	.387	(75)	2.07
	Ti	.675	(19)	1.94
43.512	Mo II	.470	(1)?	w
43.913	Ni	.941	(174)	
44.493	Fe	.580	(235)	1.40
45.185	Co	.190	(61)	1.81
45.541	Fe	.494	(323, 391, 441)	1.83
	Cr	.590	(48)	
	V	.596	(137)	
46.129	Fe	.100	(324)	1.36
	Cr	.161	(48)	
46.606	Eu II	.750	(13)	1.31
46.925	Ce II	.965	(66)	1.76
47.844	Fe	.840	(569)	2.75
	Fe	.844	(23)	
48.579	Cr	.534	(47)	1.75
3650.136	Cl II	.130	(7)	w
50.781	Zr	.730	(146)	w
51.059	Fe	.030	(571)	1.39
	Al II	.065	(12)	
51.891	Ti	.900	(118)	1.44
52.284	Fe	.260	(494)	1.49
52.607	Co	.540	(4)	1.52
53.255	Fe	.350	(229, 324)	1.39
55.309	Fe	.350	(131)	1.39
56.948	Co	.962	(21)	1.51
57.830	Fe	.890	(395)	1.39
58.703	H	.641	(7)	1.48
3660.302	H	.279	(6)	1.55
60.534	Ti	.631	(18)	1.48
61.072	Hf II	.050	(26)	1.29
61.450	Cr II	.440	(156)	w
62.949	Fe	.900	(436)	1.30
	Sm II	.905	(39)	
63.531	V	.549	(114)	1.40
64.133	Ni	.095	(4)	1.57
64.806	Ti II	.860	(116)	w
65.340	Hf II	.350	(18)	1.36
66.778	Fe	.850	(393)	1.45
67.023	Zr II	.060	(8)	1.48
	Fe	6.944	(46)	
67.273	Fe	.252	(570)	1.52

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	Identification			W
67.594	H	.684	(5)	1.60
69.665	Fe	.680	(436)	1.36
69.950	Fe	.035	(359)	1.72
3670.271	Fe	.230	(47)	1.74
70.778	Fe	.810	(133)	1.97
71.177	Cr II	.120	(6)	1.60
	Gd II	.200	(2)	
	V	.205	(70)	
71.504	H	.478	(5)	1.42
	Fe	.510	(570)	
72.330	. . .			w
73.829	Ti	.920	(177)	1.73
	Fe	.766	(369)	
75.485	Fe	.440	(229)	
	V	.497	(114)	
76.456	Cr	.500	(1)	1.45
77.064	Mn	.959		w
77.578	Fe	.477	(125)	2.08
77.614	Fe	.630	(291)	
78.206	Ca	.240	(28)	1.63
78.788	Fe	.863	(131)	
79.647	Zr II	.640	(122)	1.73
	Ti II	.673	(75)	
3680.620	Fe	.675	(568)	2.75
81.492	K II	.540	(1)	1.83
82.023	W	.101	(4)	1.74?
82.391	Hf	.250	(1)	1.74?
82.918	H	.810	(4)	1.96
	Co	.047	(99)	
83.757	Ca II	.710	(18)	1.72
	Fe	.770	(996)	
83.974	Fe	.77	(996)	1.60
	Li II	.1	(1)	
85.868	Ti	.964	(117)	1.36
86.732	Ti	.710	(222)	1.68
	Cr	.803	(44)	
87.319	Cr	.252	(44)	1.74
	Ti	.354	(19)	
88.113	Cr	.110	(45)	1.50
88.784	Fe	.877	(179)	1.66
89.112	Fe	.020	(178)	2.30
	Y II	.200	(75)	
89.288	Cr	.302	(48)	
89.668	Cr	.630	(216)	1.40
	Ti	.671	(226)	
89.794	Fe	.897	(553)	
3690.116	Fe	.095	(231)	1.70
90.201	V	.281	(29)	
93.756	Fe	.780	(46)	1.98
	Fe	.790	(490)	
94.061	Fe	.005	(394)	1.82
	Ti	.100	(177)	
	Ca II	.110	(18)	
	Mn	.115	(24)	
94.712	V	.622	(114)	1.42
	Ce II	.911	(63)	
95.733	Cr	.860	(217)	1.48
	V	.865	(29)	
97.188	H	.154	(3)	
98.132	Fe	.030	(75)	1.93
	Zr II	.170	(71)	1.46
	Ti	.183	(222)	
98.846	Co I	.017	(145)	1.63
99.744	Hf II	.720	(18)	1.42
	Gd II	.730	(20)	
3701.724	Mn	.730	(7)	1.47
03.096	Ti	.942	(132)	1.42

	Identification			W
04.321	Ti	.295	(117)	1.37
	Fe	.336	(609)	1.73
05.038	V	.035	(29)	1.51
06.185	Ti II	.219	(73)	1.45
06.740	Sm II	.752	(47)	w
07.673	. . .			w
08.078	Mn II	.060	(2)	w
08.472	Fe	.450	(436)	2.13
09.936	Ti	.963	(83)	1.75
3711.897	Fe	.920	(178)	1.37
	Zr II	.950	(8)	
13.511	Eu II	.450	(12)	1.40
	La II	.540	(26)	
16.069	Fe	5.911	(124)	1.68
16.552	Cr	.531	(269)	1.40
	K II	.600	(2)	
17.052	Zr II	.020	(82)	w
19.017	Mn	.8.930		1.53
3722.021	V	1.998	(91)	1.57
	Fe	.028	(291)	
	Gd II	.068	(119)	
22.574	Fe	.564	(5)	2.77
	Ti	.568	(17)	
24.996	V II	5.050	(102)	
	La II	5.061	(13)	
25.482	Fe	.498	(534)	2.24
27.535	Fe	.530	(705)	2.05
28.231	Nd II	.130	?	1.73
	V II	.335	(116)	
29.491	Mn II	.490	(8)	w
3730.375	Fe	.386	(533)	1.81
30.999	Fe	.945	(228)	1.42
31.411	Fe	.374	(225)	1.65
	La II	.420	(137)	
31.851	Mn	.932	(—)	1.45
32.984	He	.992	(24)?	w
33.299	Fe	.319	(5)	2.70
33.894	Al II	.910	(11)	
35.424	Fe	.325	(388)	2.34
36.850	Ni	.813	(30)	1.55
	Ca II	.901	(3)	
37.608	Cr II	.550	(117)	1.53
38.890	Ti	.901	(166)	1.37
39.764	Ni	.782	(180)	2.00
3740.733	. . .			w
41.585	V	.504	(124)	1.68
	Fe II	.560	(15)	
	Ti II	.633	(72)	
42.139	Fe	.070	(225)	1.39
	Fe	.140	(978)	
42.655	Fe	.560	(389)	1.90
	Fe	.621	(387)	
43.153	Cr II	.200	(6)	
43.912	Cr	.884	(43)	1.57
	Tm	.4.066		
46.128	Zr II	5.970	(112)	1.53
46.457	Fe	.486	(73)	2.42
47.507	Hf II	.480	(27)	1.71
	Y II	.550	(8)	
48.785	Gd II	.880	(105)	
49.520	Fe	.487	(21)	2.43
	Zr II	.550	(112)	
3750.028	Co	9.930	(95)	1.76
	H	.154	(2)	

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	Identification			W
52.275	Fe	.420	(385, 392)	1.62
52.985	Ti	.860	(17)	1.71
	Al II	3.100	(39)	
	Fe	3.154	(177)	
53.406	Ca	.367	(27)	w
54.126	Rh II	.120	(7)	w
54.996	Fe	.890	(949)	1.71
	Cr II	5.130	(20)	
55.978	Fe	6.079	(74)	2.41
57.445	Fe	.459	(668)	1.84
	Sm II	.529		
58.740	Cr	.720	(12)	2.15
59.722	Co	.684	(131)	2.03
3760.543	Fe	.534	(76)	1.67
60.960	Gd II	.920	(20)	1.62
	Fe	1.060	(706)	
61.831	P II	.820	(1)	1.86
	Ti II	.866	(107)	
	Pr II	.867	?	
62.748	Fe II	.894	(192)?	1.52
64.278	Fe	.210	(74)	2.44
	Sm	.370	(34)	
66.062	Eu II	5.930	(11)	1.70
	Fe	.092	(226)	
67.667	Cl II	.570	(6)	1.48
	V II	.720	(100)	
	Fe	.730	(918)	
68.608	Cr II	.570	(6)	1.58
	Cr	.620	(42)	
69.765	Pr II	.695	(16)	1.64
	Fe	.995	(387)	
3772.077	Zr II	1.980	(44)	1.57
	Zr II	0.60	(31)	
73.006	V II	2.962	(100)	1 53
	La II	.120	(141)	
75.146	P II	.030	(19)	1.45
	V	.187	(97)	
75.994	Fe	.860	(287)	1.67
	Ti II	6.062	(72)	
76.383	Fe	.454	(74)	1.69
76.925	Fe	7.061	(432)	1.65
77.870	Ru II	.919	(1)	1.61
	Cr	.930	(41)	
79.160	Fe	.213	(290)	1.69
79.903	Hf II	0.090	(18)	
3782.051	Fe	1.938	(917)	1.92
	Ti	.139	(82)	
83.933	...			1.42
86.475				1.36
87.112	Cb	.064	(3)	2.33
	Fe	.164	(916)	
87.563	Gd II	.560	(20)	1.67
88.254	Sm II	.125	(25)	1.53
	Rh	.474	(6)	
3790.528	V	.469	(69)	2.06
	Fe	.656	(387)	
91.142	Gd II	.170	(85)	1.60
	Cb	.209	(2)	
93.878	Fe	.872	(367)	1.58
	Cr	.879	(139)	
94.745	La II	.780	(12)	1.39
95.346	Ce II	.256	(50)	1.56
97.223	Cr	.126	(139)	1.75
	Sm II	.283	(11)	
98.290	Mo	.259	(1)	1.50
	Ti	.276	(115)	
98.821	Cl II	.800	(62)	2.13
	Ru	.901	(1)	
99.893	Ti II	.810	(13)	2.25
	V	.912	(28)	
3801.609	Fe	.681	(367)	1.60
03.053	...			
04.020	Fe	.013	(702)	1.80
04.657	V	.589	(97)	1.37
	Cr	.798	(139)	
05.309	Fe	.345	(608)	2.04
06.214	Fe	.203	(731)	1.44
06.725	Mn	.719	(6)	1.58
07.317	V	.505	(28)	1.48
	Ni	.144	(33)	1.97
08.076	Co	.102	(17)	1.42
	Cr	7.926	(139)	
08.621	Fe	.731	(222)	1.56
	V	.521	(9)	
09.080	Fe	.043	(367)	1.43
09.625	V	.597	(28)	1.60
	Mn	.592	(6)	
3810.690	Fe	.759	(665)	1.90
11.330	Ti	.385	(165)	1.40
11.924	Fe	.892	(287)	1.82
12.933	Fe	.964	(22)	2.03
	Fe	.059	(222)	
13.394	Be	.402	(5)	1.35
	V	.450	(28)	
13.954	Fe	.891	(854)	2.32
	Fe	.940	(176)	
16.891	Co	.876	(86)	1.73
17.632	Ti	.639	(189)	1.50
	Fe	.640	(701)	
18.255	V	.244	(9)	1.53
	N	.270	(11)	
3820.433	Fe	.428	(20)	2.75
21.797	Fe	.834	(222)	1.92
22.294	Rh	.262	(8)	1.40
22.945	Mo	.987	(8)	1.93
24.444	Fe	.444	(4)	2.14
25.872	Fe	.882	(20)	2.50
26.785	V	.774	(44)	1.70
27.761	Fe	.825	(45)	2.08
29.450	Fe	.458	(366, 663)	2.44
	Mg	.35	(3)	
3830.815	Fe	.850	(284)	1.63
31.718	Ni	.690	(31)	2.02
32.297	Mg	.300	(3)	2.67
34.149	V	.220	(80)	2.45
	Fe	.225	(20)	2.45
35.306	H	.386	(2)	2.70
38.224	Mg	.29	(3)	2.44
39.218	Fe	.259	(529)	1.64
3840.456	V	.440	(44)	
	Fe	.439	(20)	2.30
41.052	Fe	.051	(45)	2.12
41.902	V	.890	(8)	1.40
42.995	Ni	.276	(137)	1.42
46.880	Fe	.949	(176)	1.55
47.883	...			w
48.931	Cr	.983	(69)	1.37
49.980	Fe	.969	(20)	2.19
3850.793	Fe	.820	(22)	1.96
51.461	Fe	.580	(—)	
52.473	Fe	.574	(73)	1.98

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	Identification			W
53.260	Cr	.176	(69)	1.51
54.452	Fe	.375	(567)	1.51
56.395	Fe	.373	(4)	2.14
58.265	Ni	.301	(32)	2.00
	Fe	.480	(565)	
3860.389	CN (1,1)			2.50
	CN (0,0)			
61.473	Fe	.341	(283)(663)	2.00
63.660	Fe	.700	(565)	1.63
	Co	.607	(131)	
66.081	Ti (M)			1.97
66.885	CN (0,0) R			
67.319	Fe	.450	(221)	1.45
	Fe	.22	(488)	1.96
67.924	Fe	.925	(221)	w
68.548	Ti	.397	(175)	1.33
	CN (1,1) P			
69.190	Ti	.275	(175)	1.61
	Nd II		(34)	
3872.470	Fe	.504	(20)	2.19
73.102	Co	.120	(18)	w
	Ti	.176	(176)	
74.042	Fe	.053	(120)	1.81
	Tb II (M)?			
74.656	Cr	.470	(138)	1.61
	CN (0,0) P?			
75.244	Ti	.262	(15, 175)	1.41
75.939	V	.902	(7)	1.65
	Ca	.807	(26)	
76.906	Co	.831	(17, 62)	1.63
77.412	Ti	.591	(175)	1.81
78.036	Fe	.021	(20)	2.13
79.680	CN (0,0) P			
3880.177	CN (0,0) P			
80.719	Sm II	.776	(10)	2.20?
	CN (0,0) P			
81.297	Cr	.214	(138)	1.50
84.370	Fe	.359	(282)	1.75
85.228	Cr	.218	(23)	1.75
	Co	.275	(31)	
86.276	Fe	.284	(4)	2.15
87.062	Fe	.051	(20)	2.06
88.517	Fe	.517	(45)	2.02
89.863	Fe	.920	(564)	1.42
3890.324	Zr	.320	(8)	1.72
	Fe	.39	(567)	
90.939	Nd II	.940		1.65
	Fe	.844	(280)	
91.951	Mg	.976	(47)	
	Fe	.928	(733)	
92.990	Fe	.980	(98)	1.93
93.878?	Fe	.825	(488)	1.58
94.038	Cr	.035	(23)	1.99
	Fe	.01	(663)	
97.480	Fe	.449	(429)	1.86
97.986	K II	.920	(1)	1.72
	Fe	.896	(280)	
	Fe	8.01	(20)	
98.474	Ti	.487	(13)	
99.107	Fe	.037	(175)	1.51
99.730	Fe	.709	(4)	2.05
	Ti	.668	(15, 175)	
3900.571	Ti II	.546	(34)	1.93
	Fe	.519	(565)	
	Zr	.51	(6)	
02.983	Mo	.968	(1)	2.03
	V	.558	(43)?	
	Fe	.748	(45)	
	Cr	.92	(23)	

	Identification			W
03.941	Fe	.902	(429)	1.96
04.872	Ti	.785	(56)	1.79
05.567	Si	.527	(3)	2.18
06.471	Fe	.482	(4)	2.07
07.718	Cr	.778	(262)	1.50
08.649	Fe	.680	(153)	w
09.886	V	.894	(7, 63)	w
	Co	.93	(3)	
	Fe	.83	(364)	
3910.799	V	.790	(42)	w
12.082	Cr	11.950	(—)	
12.950	Ni	.979	(15)	1.33
	V	.89	(42)	
13.573	Fe	.635	(120)	w
14.386	Ti	.334	(15)	1.51
	Fe	.27	(567)	
	V II	.33	(33)	1.42?
15.913	Ti	.879	(15)	1.51
	Zr II	.940	(17)	
	Cr	.84	(136)	
17.214	Fe	.185	(20)	1.97
18.498	Fe	.418	(364)	1.60
	Fe	.64	(430)	
19.166	Cr	.150	(136)	1.56
	Fe	.159	(23)	
3922.943	Fe	.914	(4)	2.10
	Mn	.75	(—)	
24.579	Ti	.527	(13)	1.90
25.663	Fe	.646	(364)	2.10
26.033	Fe	.001	(562)	2.31
27.985	Fe	.930	(361)	1.55
	V	.926	(90)	
3930.334	Fe	.229	(4)	2.69
33.840	Ca II	.664	(1)	3.56
3940.960	Co	.887	(18)	1.93
	Fe	.882	(20)	
42.442	Fe	.443	(364)	1.93
44.060	Al	.009	(1)	2.21
45.072	Fe	.119	(280)	2.13
47.629	Ti	.770	(14)	2.03
	Fe	.426	(361)	
48.812	Ca	.901	(6)	1.71
	Fe	.779	(604)	
49.165	Fe	.140	(730)	1.90
49.996	Fe	.954	(72)	2.02
3950.394	Y II.	.350	(6)	1.50
	S II	.420	(45)	1.60
51.207	Fe	.164	(661)	1.85
	Nd II	.154	(19)	
52.906	Co	.917	(28)	1.53
55.345	Fe	.352	(562)	1.72
56.430	Ti	.336	(13)	1.62
	Fe	.459	(604)	1.70
57.098	Rb	.865	(7)	1.62
	Ca	.05	(6)	1.65
	Fe	.03	(562)	2.23
58.182	Ti	.206	(13)	1.70
	Zr II	.24	(16)	
3961.526	Al	.523	(1)	2.39
64.336	Ti	.269	(12)	1.96
66.107	Fe	.066	(45)	2.31
66.613	Fe	.630	(282, 562)	2.22
68.628	Ca II	.470	(1)	3.50
3973.715	Ca	.707	(6)	2.12
	Ni	.56	(31)	1.80
76.688	Cr	.665	(38)	2.05
	Fe	.615	(729)	1.70

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	Identification			W
77.790	Fe	.743	(72)	1.98
78.558	Fe	.446	(361)	1.63
79.597	Co	.518	(3)	1.87
3981.160	Fe	.106	(22)	1.81
	Cr	.23	(67)	
81.883	Fe	.775	(278)	1.78
	Ti	.76	(12)	
82.570	Mn	.583	(33)	1.45
	Ti	.48	(11)	1.92
	Y II	.59	(6)	
83.971	Fe	.960	(277)	1.57
	Cr	.91	(38)	
85.377	Fe	.320	(219)	1.56
	Fe	.393	(661)	
86.275	Fe	.300	(560)	1.79
	Fe	.18	(655)	
86.988	Ni	.090	(137)	1.67
	Mn	.826	(33)	
	Mg	.753	(17)	
88.561	Zr	.680	(46)	1.53
	La II	.510	(40)	1.20
89.065	Sc II	.060	(38)	1.56
89.832	Fe	.859	(768)	1.40
3991.672	Co	.684	(17)	1.58
	Cr	.673	(38)	
92.326	Fe	.395	(604)	1.53
94.026	Fe	.000	(560)	1.59
	Fe	.12	(526)	
	Gd II	.17	(49)	
	Cr	3.968	(67)	1.53
94.636	Ti	.683	(188)	1.70
	Co	.54	(17)	
95.310	Co	.306	(31)	1.56
97.456	Fe	.480	(563)	1.81
	Fe	.39	(278)	1.74
97.990	Co	.901	(32)	1.52
98.655	Ti	.635	(12)	1.96
4000.405	Fe	.466	(426)	1.50
	Dy II Sun			
01.192	K II	.240	(6)?	
	Sun			
01.679	Fe	.666	(72)	1.85
03.83	Ti	.789	(188)	1.50
	Fe	.764	(728)	
05.246	Fe	.246	(43)	2.13
07.327	Fe	.277	(277)	1.80
	Ti	.195	(187)	1.49
08.026	Ti	.046	(187)	1.49
08.949	Ti	.926	(12)	1.52
09.678	Ti	.653	(11)	1.45
	Fe	.714	(72)	
4012.380	Cr	.490	(268)	1.67
	Ti II	.372	(11)	
13.789	Fe	.798	(485)	1.44
	Fe	.641	(557)	
	Fe	.822	(486)	
14.547	Fe	.534	(802)	1.69
	Cr	.668	(268)	
15.546	Sun			1.40
16.450	Fe	.432	(560)	1.37
17.141	Fe	.156	(527)	1.51
17.516	Ni	.560	(171)	1.47
18.207	Fe	.282	(560)	1.50
	Mn	.102	(5)	
19.142	Co	.288	(18, 16)	1.60
	Ni	.055	(72)	
4020.294	Sc	.399	(7)	1.70
20.931	Ca	.898	(16)	1.50

	Identification			W
21.794	Ti	.812	(185)	1.50
	Fe	.87	(278)	
24.080	Fe	.109	(277)	1.65
24.654	Ti	.573	(12)	1.67
	Fe	.74	(560)	
26.520	Ti	.539	(185)	1.69
	Mn	.435	(—)	
27.098	Cr	.103	(37)	1.48
	Co	.032	(3)	
	Ti II ?			
28.417	Ti	.427		1.82
29.665	Fe	.640	(556, 563)	1.47
	Zr II	.68	(41)	
4030.501	Ti	.51	(185)	
	Fe	.50	(560)	
30.735	Mn	.755	(2)	2.91
31.280	Fe	.24	(486)	2.14
31.828	Ti	.75	(185)	1.87
32.610	Fe	.64	(44)	2.23
	Ti	.53	(297)	
33.116	Mn	.073	(2)	2.01
33.88	Ti	.88	(208)	1.85
34.507	Mn	.490	(2)	2.00
35.727	Mn	.728	(5)	2.36
	Sm II ?			
37.236	Cr	.294	(36)	1.85
	Gd II	.33	(39)	
38.808	Fe ?			1.56
	Sun			
4040.046	. . .			1.81
	Sun			
40.688	Fe	.650	(655)	2.10
41.375	Mn	.361	(5)	2.32
43.877	Fe	.901	(276, 557, 559)	1.93
44.591	Zr	.570	(46)	2.24
	Fe	.614	(359)	1.92
45.829	Fe	.815	(43)	2.43
48.739	Mn	.755	(5)	1.70
	Zr II	.68	(43)	
49.511	Ni	.710	(160)	2.00
	Gd II ?			
4051.260	. . .			1.81
51.956	Fe	.923	(700)	2.11
52.543	Mn	.472	(48)	2.13
	Fe	.664	(524)	
53.383	. . .			1.99
54.034	. . .			w
54.892	Fe	.883	(698)	1.92
55.570	Mn	.543	(5)	1.93
56.311	V II	.270	(14)	1.79
57.458	Mg	.505	(16)	2.05
	Fe	.77	(120)	
58.823	Cr	.912	(251)	1.99
	Ca	.772	(40)	
	Mn	.930	(5)	
59.401	Mn	.392	(29)	1.20
59.753	Fe	.726	(767)	1.98
4061.859	Mo	.090	(12)	1.40
	Mn	.735	(29)	
62.473	Mn	.528	(5)	1.95
63.597	Fe	.548	(43)	2.40
65.346	Fe	.402	(689)	1.60
66.964	Cr	.938	(66)	2.07
	Fe	.979	(358)	
67.307	. . .			2.07
	La II		(26)?	
67.976	Fe	.984	(559)	2.01
	Mn	.003	(5)	
68.590	Co	.541	(58)	1.71

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Continuation Table II

	Identification			W
69.087	Fe	.080	(557)	1.68
69.620	... Sun?			w
4070.280	Mn	.279	(5)	1.89
70.786	Fe	.766	(558)	2.17
71.751	Fe	.740	(43)	2.17
73.704	Fe	.760	(558)	2.42?
74.789	Fe	.749	(524)	1.79
76.045	Cr	.061	(279)	1.84
76.668	Fe	.636	(558)	1.94
77.734	Cr	.677	(279)	1.96
	Sr II	.714	(1)	2.03
78.412	Ti	.471	(80)	1.88
79.298	Mn	.241	(5)	2.40
79.831	Fe	.784	(359)	1.72
	Cb	.726	(1)	
	Ti	.708	(207)	
4080.210	Fe	.23	(558)	
	Zr	.220	(46)	2.05
	Cr	.22	(66)	
81.258	Ce II	.222	(4)	1.93
	Zr	.22	(46)	
82.478	Co	.593	(16)	1.74
	Ti	.456	(80)	
	Sc	.40	(6)	
82.993	Mn	.944	(5)	2.09
83.662	Mn	.628	(5)	2.15
	Y	.71	(6)	
	Fe	.554	(117)	
84.484	Fe	.498	(698)	1.98
85.216	Fe	.26	(276)	2.20
	Fe	.31	(559)	
86.300	Co	.300	(58)	1.94
87.132	Fe	.099	(694)	1.72
87.755	Fe	.790	(832)	1.81
88.622	Fe	.567	(906)	1.95
89.210	Fe	.225	(422)	1.89
4090.086	Fe	.085	(700)	1.94
90.502	V	.579	(41)	1.40
	Zr	.52	(29)	
91.562	Fe	.561	(357)	1.40
92.554	Fe	.512	(18)	2.33
94.947	Ca	.930	(25)	1.91
95.381	Fe	.210	(1075)	1.56
	Sun			
96.104	Fe	.118	(911)	
	Fe	.21	(18)	
97.017	Fe	.020	(700)	2.06
	Fe	.10	(558)	
	SiH?			
98.137	Fe	.183	(558)	1.70
	Cr	.180	(97)	
	SiH?			
98.544	Ca	.533	(25)	2.20
99.077	Fe	.080	(600, 651)	1.75
	Cr	.016	(108)	
	Ti	.166	(207)?	
99.818	V	.796	(27)	1.63
4100.224	SiH		(00)R	2.05
00.821	Fe	.910	(173)	1.91
	Fe	.745	(18)	
	Cb	.92	(1)	
01.679	Fe	.684	(120)	2.17
	H	.74	(1)	
02.917	Si	.926	(2)	2.13
	SiH		(0, 0)R	
03.549	Fe	.61	(831)	1.65
	SiH		(0, 0)R	
04.245	Sun			1.82
	Fe	.97	(694)	

	Identification			W
05.013	Fe	.060	(700)	1.86
06.414	Fe	.434	(697)	1.94
07.462	Mo	.477	(12)	1.90
	V	.487	(52)	
	Fe	.49	(354)	
08.293	Fe	.310	(833)?	2.03
	Co	.488	(2)	
	Ca	.554	(39)?	
09.016	Fe	.070	(658)	1.40
	Nd II	.455	(10)	
	Si H		(0, 0)R	2.35?
09.793	V	.786	(27)	2.20
	Fe	.808	(357)	
	SiH		(0, 0)	
	Co	.71	(1)	
4110.697	Mn	.903	(37, 47)?	2.17
	Co	.532	(29)	
11.781	V	.785	(27)	2.01
	Cr	.67	(97)	
12.296	Fe	.35	(695)	2.00
12.929	Fe	.972	(1003)	1.86?
14.465	Fe	.449	(357)	1.86
14.465	SiH		(0, 0)Q	
15.169	V	.185	(27)	1.82
15.928	Ni	.928	(255)	1.80
	SiH		(0, 0)R	
16.561	V	.600	(27)	1.03
17.799	Fe	.710	(833)	2.04
	Fe	.872	(700, 1003)	
18.730	Co	.774	(28)	1.70
	V	.64	(41)	
19.396	Cr	.44	(65)	1.66
	SiH		(0, 0)R	
4120.156	Ti	.037	(253)	2.00
	Fe	.211	(423)	
	SiH		(0, 0)R	
21.314	Co	.318	(28)	1.97
	SiH		(0, 0)R	
21.756	Fe	.806	(356)	1.82
	Cr	.82	(108)	
22.579	Fe	.522	(356)	1.97
23.094	Na II	.069	(19)	2.14?
	V	.188	(112)	
	SiH		(0, 0)R	
	La II?			
26.103	Cr	.099	(65)	2.19
	Fe	.19	(695)	
27.810	Fe	.807	(558, 727)	1.83
27.276	Cr	.302	(35)	1.00?
29.834	Eu II	.73	(1)	1.77
	SiH		(0, 0)Q	
4131.141	Ti	.244	(253)	1.75
	SiH		(0, 0)R	
32.069	Ce II	1.099	(112)	1.20
33.777	Sun ?			2.05
	Fe	.896	(698)?	
34.425	Fe	.433	(482, 697)	2.09
	Fe	.34	(3)	
	V	.49	(27)	
35.729	Fe	.770	(1073)	1.81
	Zr	.68	(50)	
	SiH		(0,0)Q?	
36.512	Fe	.512	(694)	1.60
	SiH		(0, 0)Q	
37.000	Fe	.002	(726)	2.13
	Cb	.09	(1)	
37.280	Ti	.284	(253)	2.15
	Mn	.257	(37)	
39.855	Fe	.933	(18)	1.71
	Cb	.70	(1)	

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	Identification			W
4141.807	Fe	.862	(422)	1.50
	SiH		(0, 0)Q	
42.421	Ti	.480	(296)	1.76
	Cr	.470	(179)	
	SiH		(0, 0)Q	
43.442	N	.420	(6)	1.77
	Fe	.42	(523)	
43.880	Fe	.871	(43)	2.07
46 008	Fe	.071	(422)	1.30
47.560	Mn	.532	(37)	1.15
	Sun			
49.298	Fe	.372	(694)	2.03
	Zr II	.22	(41)	
4152.128	Fe	.172	(18)	2.00
53.924	Fe	.906	(695)	2.22
	Cr	.065	(35)	
54.520	Fe	.502	(355)	1.93
54.800	Ti	.865	(221)	2.04
	Fe	.813	(694)	
57.240	CN			1.94?
	SiH		(0, 0)	
57.890	Fe	.788	(695)	1.95
	SiH		(0, 0)P	
58.812	Fe	.798	(695)	2.11
	SiH		(0, 0)P	
59.210	Sun			1.60
4161.369	Ti II	.52	(21)	1.67
	Ni	.340	(86)	
	Cr	.415	(305)	
63.556	Cr	.625	(35)	1.97
	Fe	.699	(274)	
64.212	Fe	.240	(694)	1.60
	CN			
64.712	Cb	.661	(1)	1.73
	CN			
65.300	CN, SiH?			1.75?
66.288	Ti	.311	(163)	1.75
	SiH		(1, 1)R	
67.776	Cr	.800	(107)	2.00
	Mg	.271	(15)?	
	SiH		(1, 1)R	
4170.983	Fe	.906	(482)	2.11
	Ti	.018	(206)	
71.905	Fe	.904	(650)	2.07
	Fe	.75	(19)	
72.691	Fe	.641	(689)	2.16
	Ti	.609	(163)	
73.414	Fe	.322	(355)	2.04
74.001	Fe	.926	(19)	2.01
	Ti	.088	(55)	
74.914	Cr	.941	(278)	2.06
	Fe	.917	(19)	
	SiH		(0, 0)P	
75.610	Fe	.640	(354)	1.92
	SiH		(0, 0)P	
76.504	Fe	.570	(689)	2.00
	Fe	.57	(695)	
77.543	Co	.590	(2)	2.05
	Fe	.60	(18)	
79.368	V	.419	(25)	1.71
	CN			
4180.380	Fe	.410	(274)	2.14
	CN			
80.605	Ti	.498	(206)	1.81
81.736	Fe	.758	(354)	2.35
82.341	Fe	.384	(476a)	1.75
83.389	Zr	.310	(51)	1.01
	Ti	.294	(220)	
84.681	Ni	.475	(89)	1.87
	SiH		(0, 0)P	
85.639	Fe	.660	(1104)	1.71
	CN, SiH		(2, 2)	
86.344	Cr,	.359	(249)	1.93
	CN, SiH			
87.022	Fe	.044	(152)	1.96
88.865	Ti	.69	(220)	2.23
	SiH		(1, 1)Q	
89.498	Co	.500	(2)	1.92
4190.103	Cr	.160	(84)	1.30
	CN			
90.681	Cr	.660	(35)	1.83
	Co	.71	(1)	
91.404	Fe	.436	(152)	2.01
93.690	Cr	.662	(248)	1.71
	CN			
94.774	Cr	.951	(248)	1.69
95.434	Ni	.531	(239)	2.08
	Fe	.337	(693)	
96.681	Ti II	.640	(21)	2.12
	Fe Sun?			
98.280	Fe	.310	(152, 268)	2.37
99.093	Fe	.098	(522)	2.26
99.925	Fe	.970	(3)	2.02
4200.738	Ti	.752	(220)	1.96
03.530	Ti	.465	(220)	1.98
	Fe	.570	(19)	
04.009	Fe	.987	(355)	2.12
	Cr	.190	(35)	
04.985	CH		(0, 0)R	1.76
05.446	Fe	.546	(689)	1.89
06.647	Fe	.702	(3)	1.88
4210.035	CN			
	V	.857	(24)	2.42
	Fe	.352	(152)	
10.922	Cr	.770	(106)	1.72
	CN? CH		(0, 0)R	
11.274	Cr	.349	(133)	1.75
11.816	Ti	.729	(279)	1.82
12.620	. . .			1.37
13.578	Fe	.650	(355)	1.83
	CN			
17.165	O	.090	(33)	1.83
17.526	Fe	.551	(693)	2.00
18.267	Fe	.210	(172)	2.05
18.719	V	.710	(24)	2.00
	CH		(0, 0)R	
19.315	W	.383	(3)	2.30
	Fe	.364	(800)	
4220.282	Fe	.347	(482)	1.78
22.180	Fe	.219	(152)	1.99
24.140	Fe	.176	(689)	1.87
24.457	Fe	.509	(689)	2.23
25.351	Fe	.460	(693)	2.05
	Fe	.79	(118)	
25.966	Fe	.956	(521)	1.96
26.698	Ca	.728	(2)	2.60
29.454	Fe	.516	(416) (649)	1.94
29.761	Fe	.760	(41)	1.95
	CH		(0, 0)R	
4230.429	Cr	.481	(132)	1.89
	Ni	.390	(150)	
30.954	Ni	.040	(136)	2.05
	La II	.990	(83)	
31.550	Fe	.525	(647)	1.90
33.556	Fe	.608	(152)	1.96
35.155	Mn	.140	(23)	2.07
	Fe	.94	(152)	2.05
35.878	Fe	.840	(172)	2.12

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Continuation Table II

	Identification			W
37.053	Fe	.085	(19)	2.26
	CH		(0, 0)R	
37.893	Ti	.889	(284)	2.54
	Cr	.71	(132)	
38.778	Fe	.816	(693)	2.22
39.772	Fe	.735	(416)	2.07
	Mn	.725	(23)	
4240.350	Zr	.350	(45)	2.21
	Fe	.372	(764)	
	Ca	.456	(38)	
42.456	Fe	.588	(273)	2.20
	CH		(0, 0)R	
	AlH		(0, 0)	
43.314	Fe	.368	(906)	2.36
	CH		(0, 0)R	
45.221	Fe	.258	(352)	1.95
45.962	Fe	.020	(649)	2.08
	Sun, Fe	6.090	(906)	
46.748	Fe	.790	(216)	2.21
	Sc II	.893	(7)	2.00?
47.344	Fe	.310	(172)	1.24
	Fe	.43	(693)	
48.266	Fe	.228	(482)	2.10
	Cr	.344	(131)	
	Fe	.40	(19)	
49.522	CH		(0, 0)	1.69
	AlH		(0, 0)R	
4250.037	Fe	.125	(152)	2.01
54.256	Fe	.715	(42)	2.10
	Cr	.346	(1)	2.03
54.862	Fe	.938	(419, 477)	2.03
	N	.700	(4)	1.40
55.486	Fe	.499	(416)	1.61
	Cr	.502	(105)	1.51
55.775	CH		(0, 0)R	1.83
56.136	Fe	.212	(690)	1.69
58.368	Fe	.320	(3)	2.25
59.046	Fe	.956	(419)	2.36
	Cr	.150	(131)	2.33?
4260.030	Fe	.998	(689)	2.56
	AlH		(0, 0)Q	
60.446	Fe	.479	(152)	2.15
65.822	Mn	.924	(23)	1.30
	Ti	.723	(162)	
66.780	Cr	.820	(105)	1.62
67.250	CH		(0, 0)R	1.51
67.774	Fe	.830	(482)	1.77
68.614	V	.643	(88)	1.65
4271.054	Fe	.159	(152)	2.01
	Cr	.061	(154)	
73.295	Ti	.312	(251)	2.01
73.756	Fe	.870	(478)	2.20
	CH		(0, 0)R	

	Identification			W
74.659	Ti	.584	(44, 162)	1.86
	Cr	.803	(1)	
75.870	Cr	.973	(240)	1.81
	Fe	.720	(215)	
77.388	Fe	.410	(214)	1.71
	Zr II	.37	(4)	
78.111	Ti	.231	(291)	1.68
	Fe	.234	(291)	
79.783	Fe	.864	(351)	1.85
4280.361	Cr	.405	(247)	1.96
80.894	Sm II	.678	(27)	1.39
82.385	Fe	.293	(70)	2.05
	Fe	.413	(71)	
82.881	Ti	.702	(162)	1.93
	Ca	.010	(5)	
84.056	V	.055	(88)	1.82
	Mn	.084	(23)	
84.779	Cr	.725	(96)	1.65
85.349	Fe	.445	(597)	1.80
85.918	Ti	.006	(44)	1.41
86.370	Fe	.440	(414)	1.76
86.857	. . .			1.70
87.309	Ti	.405	(44)	1.32
87.888?	Ni	.005	(178)	1.87
88.927	Fe	.962	(214)	1.99
89.632	Cr	.721	(1)	1.90
4290.165	Ti II	.222	(41)	1.67
90.915	Ti	.933	(44)	1.64
92.026	Fe	.130	(70)	1.72
	Sm II?			
92.975	Zn	.885	(1)	w
94.103	Ti II	.101	(20)	1.76
94.963	Fe	.939	(598)	2.36
95.776	Cr	.757	(64)	1.16
	Ti	.751	(44)	
	Ni	.888	(178)	
96.634	Sm	.743	(3)	1.70
	Ce II	.680	(2)	
96.996	Cr	.050	(64)	1.72
97.917	V	.029	(120)	1.76
98.875	Ca	.986	(5)	1.76
	Ni	.767	(28)	
99.978	Ti	.636	(43)?	1.82
4300.465	Ti	.520	(205)	1.99
00.998	Fe	.828	(976)	1.74
	Ti	.089	(44)	
02.480	Ca	.527	(5)	2.90
03.637	. . .			1.89
04.432	Fe	.552	(414)	1.85
05.218	Fe	.200	(760)	1.68
05.851	Ti	.910	(44)	1.75
06.646	Ti	.945	(43)	1.82
	Fe	.580	(691)	
07.906	Fe	.906	(42)	2.50

c) the developing method,

d) micrometering,

e) reduction of microphotometer recordings.

The errors due to the quality of the spectrograph, calibration and developing method could not be examined. It appears, however, that they are of the same order of magnitude as those given by Wright (1948), that is about 3 per cent. Obviously, the errors due to spectrogram reduction and microphotometering are greater.

The microphotometering errors were analysed more in detail. The Khol F-3-type microphotometer has not been used for similar procedures yet, and hence it had to be subjected to a simple check-up.

The errors likely to be introduced by this instrument into the measurements may chiefly come from a poor-quality compensating wedge, worn electrical equipment, such as amplifiers (their non-linearity) and, last but not least, from

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certain mechanical shortcomings (non-uniform spectrogram-and chart-drive, etc.). The quality of the photometric wedge was given a check-over by the Zeiss-Schnellphotometer; the measurements showed that the departures from linearity did not exceed 0.5 per cent (probable error). The errors due to the other microphotometer parts (the focussing error included), on the other hand, were higher and reached about 5 per cent.

The largest errors of processing naturally result from the overall character of the spectrum, of 37 Lib that is from the unreliability of the continuous-spectrum determinations, the overlapping of spectral lines and hence also from the difficult conversion of density to intensity recordings and equivalent line-width determination. These errors may, in individual cases, reach values higher than given by Wright (1948).

5. *Curve of growth*

The processes in stellar atmospheres and thus also the formation of spectral lines are currently interpreted on two models representing the structure of the upper layers of such atmospheres: the Schwarzschild-Schuster and the Milne-Eddington models. Either model leads to the unambiguous conclusion that the equivalent width of the spectral line depends on the number of atoms of the given element in the atmosphere and on the physical parameters characteristic of the stellar atmosphere.

The interdependence of the physical characteristics of stellar atomspheres was dealt with in detail by Unsöld (1938, 1955), Menzel (1936), Ambarcumyan (1952), Mustel (1960), Aller (1953) and others, who especially studied the increase in the equivalent line-width with rising number of active atoms in the stellar atmosphere.

The equivalent width of the spectral line depends in particular on mumber N_i of active atoms over a unit area of the stellar photosphere and on oscillator strength f_{ik}, both the number of atoms and oscillator strengths being referred to a certain state or to the transition from state i into state k. Equivalent width W of the spectral line, fully representative of the true radiation absorption, is

$$W_\nu = \int (1 - r_\nu)\, \mathrm{d}\nu \tag{1}$$

where r_ν is the residual intensity of the line. The authors mentioned above showed that residual intensity r_ν of the spectral line for the SS-model is

$$r_\nu = \frac{1}{1 + \frac{3}{4}\tau_\nu^\sigma}, \tag{2}$$

where τ_ν^σ is the optical thickness of the reversing layer throuhout. Symbols σ and ν indicate that the absorption coefficient for the given frequency must be taken into account.

Optical thickness τ_ν^σ at the centre of the spectral line is

$$\tau_\nu^\sigma = X_c = N_i s_\nu = \frac{\pi\varepsilon^2}{m_\varepsilon c}\frac{f_{ik}}{\Delta\nu_D} N_i, \tag{3}$$

where s_ν is the absorption coefficient,
ε — the electron charge,
m_ε — the electron mass,
f_{ik} — the oscillator strengths,
$\Delta\nu_D$ — the Doppler broadening due to thermal motion of the atoms,
N_i — the number of active atoms nad,
c — the velocity of light.

The optical thickness for pure Doppler broadening is

$$\tau_\nu^\sigma = s_\nu N_i = X_c\, \mathrm{e}^{-\left(\frac{\nu - \nu_0}{\Delta\nu_D}\right)^2} \tag{4}$$

and if only natural damping applies,

$$\tau_\nu^\sigma = s_\nu N_i = X_c \frac{\gamma}{4\pi\sqrt{\pi c}} \frac{\Delta\nu_c}{(\nu - \nu_c)^2}, \tag{5}$$

where γ is the damping constant.

It was shown by numerous authors (e.g. Ambarcumyan 1952, Mustel 1960 and others) that for pure Doppler broadening of the spectral line equivalent width W_λ may be written as follows:

$$W_\lambda = 2\int_{\lambda_0}^{\infty} \frac{1}{1 + \frac{\mathrm{e}^{\left(\frac{\Delta\lambda}{\Delta\lambda_0}\right)^2}}{X_c}} \Delta\lambda \tag{6}$$

or else, if only natural damping applies

$$W_\lambda = 2\int_{\lambda_0}^{\infty} \frac{1}{1 + \frac{4\pi\sqrt{\pi c}\,(\Delta\lambda)^2}{X_0 \gamma \lambda_0 \Delta\lambda_0}} \mathrm{d}\lambda. \tag{7}$$

The integrals can be solved by expansion, hence and after due adjustement we have

$$\frac{W_\lambda}{\lambda} = \sqrt{\pi}\, X_0 \frac{v_0}{c} \tag{8}$$

for $X_0 < 55$ and, eventually

$$\frac{W_\lambda}{\lambda} = 2\frac{v_0}{c}\sqrt{\ln X_0}$$

for $X_0 > 55$

$$\frac{W_\lambda}{\lambda} = \frac{\pi^{\frac{1}{2}}}{2}\sqrt{X_0 \gamma \frac{v_0}{c}\frac{\lambda}{c}}. \tag{10}$$

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Quantities W_λ/λ and X_o are variable in these formulae, thermal velocity v_o of the atoms for the atmosphere of the star being assumed constant in the first approximation. By logarithmic calculation we have from equations (8), (9) and (10)

$$\log \frac{W_\lambda}{\lambda} = \log X_o + C_1 \qquad \text{for } \log X_o < -0.3, \tag{8a}$$

$$\log \frac{W_\lambda}{\lambda} = \frac{1}{2} \log \log X_o + C_2 \quad \text{for } \log X_o > 1.75, \tag{9a}$$

$$\log \frac{W_\lambda}{\lambda} = \frac{1}{2} \log X_o + C_3. \tag{10a}$$

where C_1, C_2 and C_3 are different constants dependent on the temperature and mean atomic weight of the star.

Plotting $\log \frac{W_\lambda}{\lambda}$ against $\log X_o$ (with regard to the mentioned observations) into a diagram we have the sought for dependence between the growing equivalent width of the spectral line and the concentration of active atoms in the atmosphere of the star, in other words, we have the curve of growth.

From equation (3) we see that the parts played by N_i (number of atoms) and f_{ik} (the oscillator strength) are virtually equivalent.

Hence follows that the parts played by N_i and f_{ik} in the construction of the curve of growth are virtually equivalent. If, therefore, we take a multiplet for plotting the curve of growth of the given star, we may assume that the number of atoms participating in the formation of the lines of this multiplet is equal for all lines. Then, if we plot oscillator-strength values $\log f_{ik}$ that correspond to the individual lines, every multiplet will give us a portion of the line of growth, shifted by a certain part. These individual portions of the curve added up give the complete curve of growth of the given star.

In the following we shall endeavour to identify the determined curve of growth with one of the theoretic curves of growth by shifting it in the direction of both the horizontal and vertical axis. From these shifts we may directly determine quantity c/v_o and hence velocity v_o of the thermal motion of the atoms on the one side, and quantity Γ/ν (where Γ is the damping constant) on the other side. (For details see, for instance, Mustel 1960, Wright 1948, etc.)

By this method we obtained Figures 3 and 4 for 37 Lib and determined values v_o or, as the case may be, Γ/ν as follows:

$$\log v_o/c = 1.49 \qquad \text{that is } v_o = 9.7 \text{ km/sec}^{-1}.$$
$$\log \Gamma/\nu = -2.39$$

(Note. The oscillator-strength values found by Corlis and Warner (1964) could not yet been used in the present paper.)

6. Excitation temperature

We shall assume that, in the atmosphere of the star, Boltzman's equation

$$N_i = N_{ik} = \frac{N}{\mu_k} g_{ik}\, e^{-\frac{\chi_i}{kT_e}} \tag{11}$$

applies to the numerical distribution of the atom-quantum-state at temperature T. The new symbols in this equation are as follows:

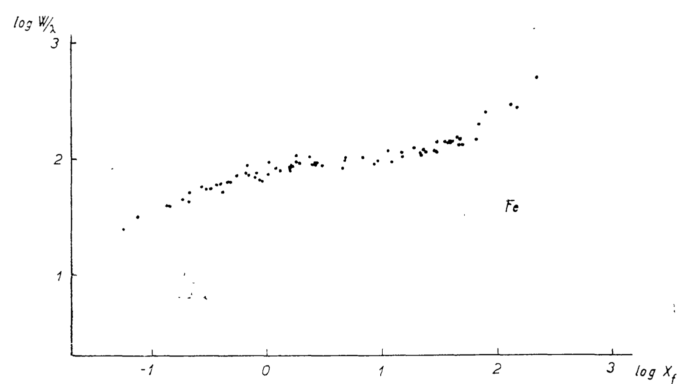

Figure 3. Curve of growth of 37 Lib for Fe I

k for Boltzman's constant,

T_e — the excitation temperature of the stellar atmosphere,

g_i — the statistic weight of i times ionized atom,

χ_i — the excitation potential,

u_i — the partition function of i times ionized atom and

N_i — the total number of atoms of the given type in i-times ionized state.

Then we may write (E.P. Mustel, 1960, and others):

$$\log X_o = \log \left\{ \frac{\sqrt{\pi}\, \varepsilon^2}{m_e c} \frac{N_i}{u_i} \frac{1}{v_o} \right\} + \log g_i f_{ik} \lambda_o - \frac{5040}{T_e} \chi_i. \tag{12}$$

The excitation potential in equation (13) is already expressed in electron-volts directly. From this equation we have

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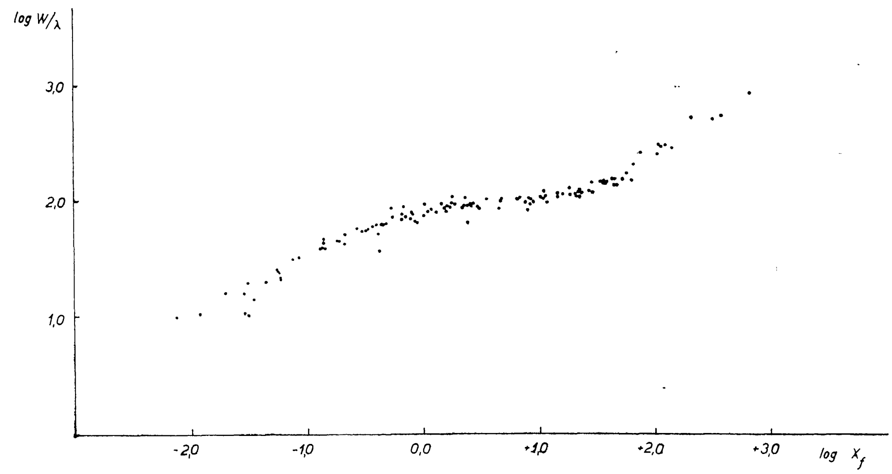

Figure 4. Curve of growth for 37 Lib (all lines)

$$Y_i = \log X - \log g_i f_{ik} \lambda_o = L - \frac{5040}{T_e} \chi_i \tag{13}$$

where apparently

$$L = \log \left\{ \frac{\sqrt{\pi}\, \varepsilon^2}{m_\varepsilon c} \frac{N_i}{u_i} \frac{1}{v_o} \right\}. \tag{13a}$$

The mutual shift of the empirical curve of growth, as obtained from the known oscillator-strength values, against the theoretical curve actually is value Y_i given by equation (13). Thus, by determining the shift in the empirical curve of growth we may determine values Y_i for all multiplets used for plotting the curve.

The assumption of Boltzman's distribution of atoms shows that the dependence between Y_i and value χ_i of the excitation potential must be linear for the individual multiplets. Hence follows that if we plot for the individual multiplets values Y_i on the vertical axis and values χ_i of the excitation potentials on the horizontal axis, we obtain a straight line. By extending this line to value $\lambda = 0$ we may find quantity L and hence directly number N_r of the active atoms in the atmosphere of the star. In the general case, naturally, the ionization degree of the element will have to be taken into consideration.

The slope of the linear dependence between quantities Y_i and χ_i eventually permits us to determine excitation temperature T_e for the given element in the atmopshere of the star.

The method just described, though not quite perfect, is being used for basic analyses of the properties and composition of stellar atmospheres, and was also used for analysing the spectrum of 37 Lib. The results are given in Figures 5, 6 and 7 and listed in Table III, a summary of all values

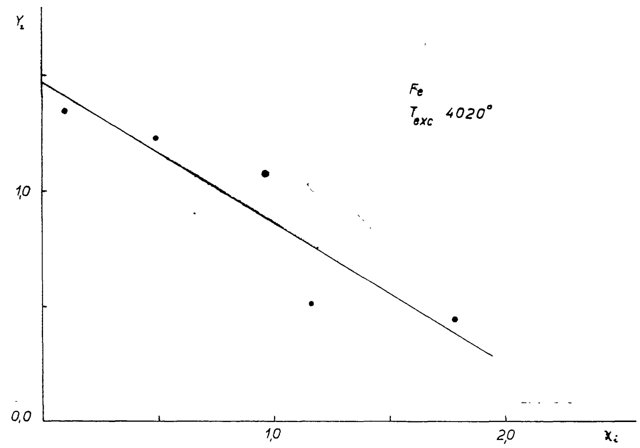

Figure 5. Excitation temperature for Fe I

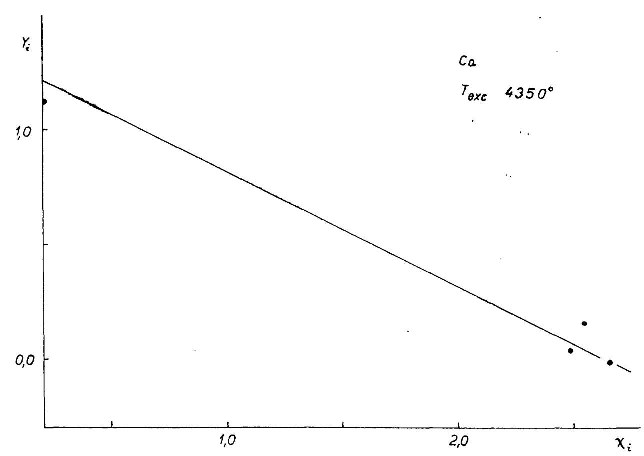

Figure 6. Excitation temperature for Ti I

determined. In Table III, the weights of the obtained values were duly respected.

Special attention was paid to the occurrence of neutral metallic atoms in the 37 Lib spectrum. The results of this analysis are listed in Table IV,

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Table III

Excitation Temperature of 37 Lib

Atom	T_{exc}	Weight
Fe I	4020°	4
Ca I	4350	1
Ti I	4050	2
V I	3920	1
Cr I	3980	1
Mean	4050°	

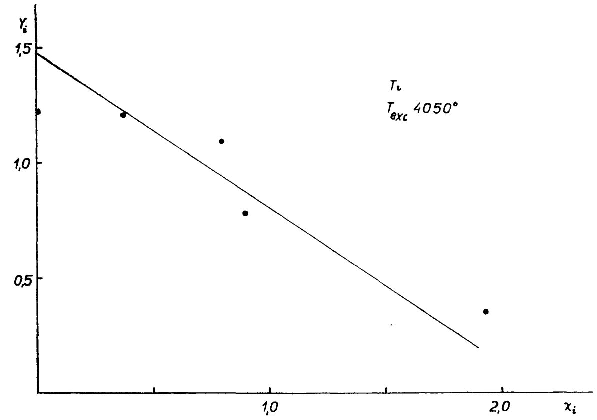

Figure 7. Excitation temperature for Ca I

Table IV

Relative Abundances of Elements in the 37 Lib Atmosphere

Atomic Number	Element	log $N_\odot$ (Goldberg)	log N 37 Lib	log $N_\odot$ —log N_*
11	Na I	6.30	4.15	2.15
12	Mg I	7.40	5.77	1.63
13	Al I	6.20	5.90	0.30
14	Si I	7.50	6.20	1.30
20	Ca I	6.15	4.77	1.38
21	Sc I	2.82	2.70	0.12
22	Ti I	4.68	5.61	—0.93
23	V I	3.70	6.31	—2.61
24	Cr I	5.36	5.03	—0.33
25	Mn I	4.90	5.55	—0.65
26	Fe I	6.57	6.57	
27	Co I	4.64	5.12	—0.48
28	Ni I	5.91	6.14	—0.23
30	Zn I	4.40	4.94	—0.54
38	Sr I	2.60	3.10	—0.50
40	Zr I	2.23	3.20	—0.97

giving in the first column the symbols of the examined elements, then atomic number A, and in the following columns the log N values according to Goldberg, Müller and Aller's paper (1960). These values were reduced in that we took value log N_{Fe} = 12.00 for hydrogen. The next column includes the values determined in the present paper; they have been linked on to Goldberg's et al. paper (1960) in that log N_{Fe} for iron Fe I was put equal to the value given in the cited paper. The last column, eventually, lists differences log N_A — log N_{Fe}. Table 4 is also synoptically plotted in Figure 8, where the crosses (connected by interrupted line) stand for the values obtained

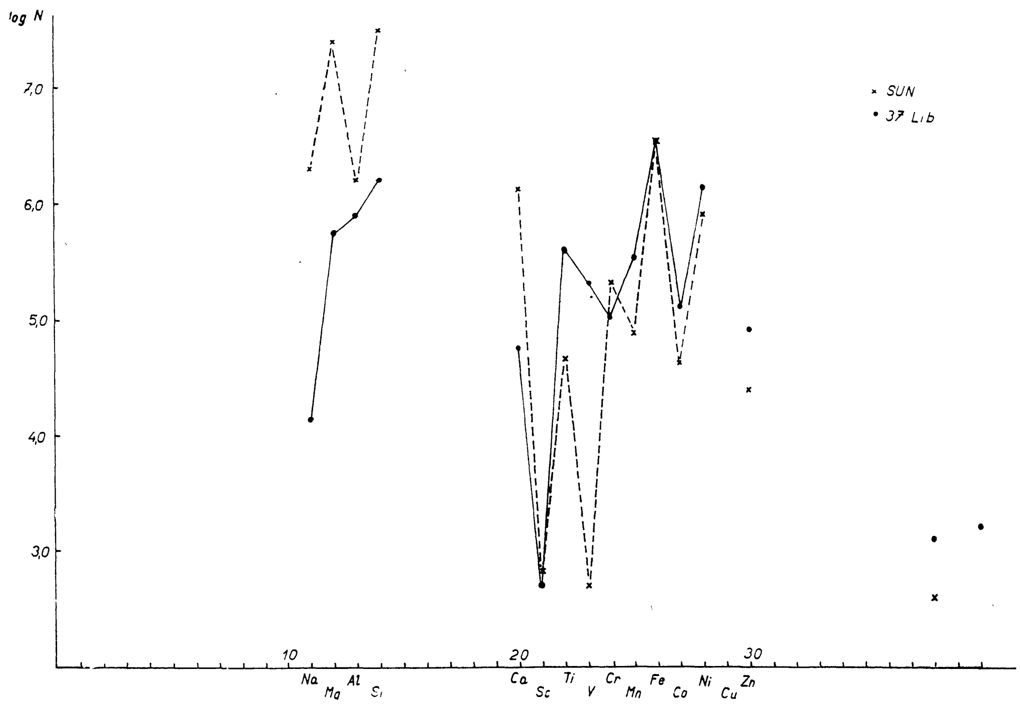

Figure 8. Relative abundance of elements in 37 Lib

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for the Sun, the full circles (connected by full line) for star 37 Lib.

7. *Summary of results*

The results for some parameters of the atmosphere of 27 Lib cannot be generalized with safety, it appears, however, that the group of high-velocity stars represents an interesting group, as already shown by numerous authors. Especially remarkable are the relatively high turbulence in the atmospheres of the stars (cf. paper to follow) on the one side, and the slight rise in the abundance of elements with higher atomic number as against the composition of the Sun's atmosphere, on the other side. A systematic analysis of the atmospheres of stars with high space velocities might be very interesting.

In conclusion, the author wishes to thank O.C. Wilson and L. Perek for kindly letting him use the spectrograms of the star investigated. He is indebted to L. Petrík, I. Petras for valuable help and to M. Plavec for suggestions and comments.

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Р. БАЙЦАР

СПЕКТР ЗВЕЗДЫ 37 ВЕСОВ

Звезда 37 Весов принадлежит к группе звезд с быстрым движением в нашей Галактике; ее относительная скорость 100 км/сек$^{-1}$. Многие авторы отметили некоторые особенности этой группы звезд, в первую очередь ослабление интенсивности спектральных линий металлов, ослабление поясов молекул CN и т. п.

В представленной работе исследуется подробно спектр звезды 37 Весов. Из спектрограми с дисперсиями 9 А/мм и 18 А/мм было эстановленно наличие линий элементов в УВ-области спкетра (3392 А—4300 А). Была определена также эквивалентная ширина спектральных линий и на их основании кривые роста, температура возбуждения и наличие относительно Солнца элементов в атмосфере звезды.

При анализе применялась модель атмосферы Шварцшильда—Шустера. Изучение криыой роста показывает сравнительно большую скорость движения атомов в атмосфере ($v_c = 9{,}7$ км/сек$^{-1}$). По сравнению с атмосферой Солнца звезда 37 Весов показывает большее содержание элементов с более высокими атомными числами (табл. IV).

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R. BAJCÁR

SPEKTRUM HVIEZDY 37 LIBRAE

Hviezda 37 Librae patrí k skupine hviezd o značnom pohybe v našej Galaxii; jej relatívna rýchlosť je 100 km/sec^{-1}. Viacerí autori poukázali na niektoré zaujímavé zvláštnosti tejto skupiny hviezd, najmä zoslabenie čiar kovov v spektre, zoslabenie pásov molekúl CN a pod.

V predloženej práci sa podrobnejšie analyzuje spektrum hviezdy 37 Lib. Bola určovaná prítomnosť čiar prvkov v UV oblasti spektra (3392 Å—4300 Å) zo spektrogramov o disperzii 9 Å/mm a 18 Å/mm. Okrem toho boli určované ekvivalentné šírky spektrálnych čiar a na základe týchto meraní bola odvodená krivka rastu, excitačná teplota a relatívna prítomnosť prvkov v atmosfére hviezdy (vzhľadom k Slnku).

Pre analýzu bol použitý Schwarzschildt-Schusterov model atmosféry. Z rozboru krivky rastu vyplýva pomerne značná rýchlosť pohybu atómov v atmosfére ($v_c = 9.7$ km/sec^{-1}) a okrem toho sa zdá, že atmosféra 37 Lib je bohatšia na prvky o vyšších atómových číslach ako naše Slnko. (Pozri tab. IV.)

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