ROBERT BAJCÁR

THE SPECTRUM OF TWO LATE-TYPE STARS

Abstract: Analysed and compared are the spectra of two late-type stars (KO III and G 8 IV): HD 37 160 is a high-velocity star, HD 188 512 a standard star. The lines in the region 4144 — 3497 Å are fully identified.

The analysis itself was made by the curve-of-growth method. This curve, obtained from lines in the UV region, served to determine a number of parameters of the atmospheres of both stars. Determined were $T_{exc} = 4315°$ (HD 37 160) and $T_{exc} = 4225°$ (HD 188 512), $\log P_\varepsilon = 0.656$ (HD 37 160) and $\log P_\varepsilon = 0.425$ (HD 188 512). The velocities of the atoms are higher in the atmosphere of HD 37 160 than for normal stars. The relative representation of elements is summarized in Tab. IX; compared in the same table is the composition of the atmosphere with the atmosphere of the Sun.

Part I

Introduction

It is well known that stars with high space velocities markedly differ in certain respects from normal stars. Such differences are, for instance, the intensity weakening in the CN and CH bands, the weakening of metal lines, etc.

HD 37 160 is a high-velocity star. It was studied often and in great detail (e.g. J. Greenstein and P. C. Keenan, 1958) from different points of view. Thus it will be interesting to examine the composition of the atmosphere of this star in largely simplified conditions by the curve-of-growth method (homogeneous model). This method used for atmosphere analysis gives, as a rule, good results, in spite of the marked shortcomings of the procedure. The homogeneous model is justified in our case by, among others, the fact that the spectrum of HD 37 160 (KO III) is rather complicated and the lines are largely blended. We also had difficulties due to the nature of the observational material which covers the UV region of the spectrum, so that the actual line profiles were often relatively difficult to determine.

Our results for HD 37 160 may be compared with the results obtained for the standard star HD 188 512 (G8 IV). The spectrograms of HD 188 512 cover the same spectral region, and the method of processing is also the same.

The difficulties due to the rather complicated spectra were overcome to a certain extent by the high quality of the spectrograms and by their resolving power.

1.1. Observational material

Used were spectrograms made by the Coudé spectrograph of the Mt Palomar and Mt Wilson Observatories. The dispersion of the spectrograms is 18 A/mm and 9 A/mm, which is sufficient for determining the chemical composition and physical parameters of atmospheres. The quality of the spectrograms used was high.

The spectrograms used are listed in Tab. I, which gives, in succession, the designation of the star, the region of the spectrogram, the number of the spectrogram and its quality. In the last column 1 means excellent spectrogram, 2 very good spectrogram.

As said before, the stars had been selected in such a way, as to permit the comparison of the chemical composition and physical parameters of

Table I

List of spectrograms used

Star	Spectral range	No	Quality
HD 37 160	4100—3450	Ce 11 781	1
HD 37 160	3950—3300	Ce 11 786	2
HD 37 160	3900—3300	Ce 11 761	2
HD 188 512	4100—3500	Ce 14 920	1
HD 188 512	4800—4000	Ce 14 920	1

the atmosphere of a high-velocity star (HD 37 160) with the parameters of a standard star (HD 188 512). The principal data on the analysed stars are in Tab. II, which gives the position of the star, the brightness, spectral type, and the U—B and B—V indices.

Table II

Star	AR_{1950}	$Decl_{1950}$	m_v
HD 37 160 = φ^2 Ori	5^h34^m1	$+9°16'$	4.09
HD 188 512 = β Aql	19 52.8	$+6°17'$	3.70

Star	Sp	U — B	B — V
HD 37 160 = φ^2 Ori	KO III	+0.65	+0.95
HD 188 512 = β Aql	G8 IV	+0.49	+0.86

The classification of the spectrum of HD 37 160 differs with author. HD, for instance, classifies it as a G6 type, Greenstein et al. (1958) consider it a G8 III—IV type, O. Eggen (1959) and Evans (1959) a G 8 IIIp type, and certain catalogues give the type KO III.

HD 188 512 is a standard star (HD 188 512 = GC 27 587 = 60 Aql = βAql); its spectral type is G8 IV. HD 37 160 is a high-velocity star with certain spectral peculiarities. (HD 37 160 = No. 129 of the Catalogue of High-Velocity Stars, N. Roman (1955); it is also listed in O. Eggen's catalogue). The components of its spatial motion are as follows: U = 86 km/s, V = +88 km/s, W = —28 km/s, Q = 126, e = 0.68, V_r = +99 km/s.

1.2. *Identification of the spectral lines*

The spectra of the analysed stars in the UV region are rather blended and the line density per 1 mm is so marked, even for the used dispersion, that the identification of the spectral lines required special care.

The individual spectrograms were measured by conventional method on a Zeiss Abbé comparator. In order to make the identification more reliable, we also used microphotometric tracings. As wave-length standard served the iron lines of the comparison spectrum, the wave-lengths of the individual lines having been taken from RMT (Ch. Moore, 1945). The measuring results were then used to determine the wave-lengths of all lines in the spectrum within 4144 A — 3497 A; the wave-lengths had to be corrected for the shift due to radial velocity. The wave-lengths of iron determined in the spectrum of the star and corrected for the shift due to radial velocity agree well with the data in RMT, as is seen in Fig. 1 for HD 188 512. In this diagram, the wave-length is plotted on the horizontal axis, and the differences between the

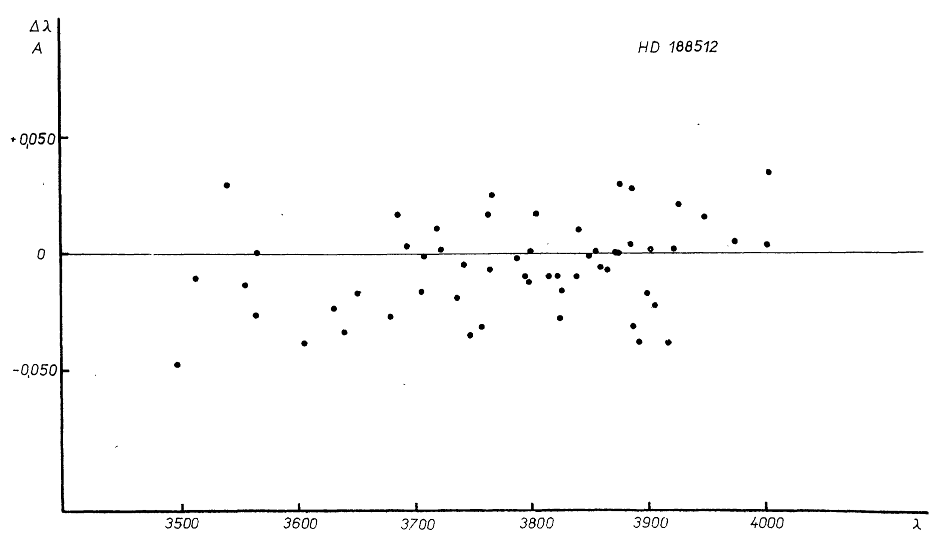

Figure 1.

Table III

λ_{obs}	Identif.	log I_1	log I_2
4143.91	.87 Fe (43)		0.51
43.47	.42 Fe (523)		0.77
	.50 Fe (697)		
42.95	43.05 Ti (253)		1.10
	.86 Y (5) ?		
42.44	.48 Ti (296)		0.97
	.47 Cr (179)		
	.40 Ce II (10)		
41.80	.86 Fe (422)		1.07
	.80 SiH (0, 0) Q		
40.42	.44 Fe (694, 695)		1.19
	.45 Gd II (48)		
	.42 Ti (220)		
4139.93	.93 Fe (18)		1.17
	.70 Cb (1)		
38.96	.84 Fe (117)		1.33
37.31	.42 Fe (1103)		1.08
	.28 Ti (253)		
	.26 Mn (37)		
	.40 SiH (0, 0) Q		
36.97	37.00 Fe (726)		1.08
	.89 Ti (221)		
	37.09 Cb (1)		
36.52	.51 Fe (694)		1.19
	.52 SiH (0, 0) Q		
35.72	.77 Fe (1073)		1.33 ?
	.77 Cr II (163)		
	.68 Zr (50)		
	.70 SiH (0, 0) Q		
35.36	.44 Ce II (188)		0.93 ?
	.32 Nd II (—)		
34.46	.49 V (27)		0.69
	.43 Fe (482, 697)		
	.34 Fe (3)		
33.76	.87 Fe (698)		1.02
	.80 Ce II (4)		
32.84	.90 Fe (357)		0.99
	.94 Fe (44)		
32.02	.06 Fe (43)		0.48
	.02 V (27)		
31.16	.24 Ti (253)		1.13
	.10 Ce II (112)		
	.12 SiH (0, 0) R		
30.60	.54 Co (16)		1.19
	.65 Ba II (4)		
	.66 SiH (0, 0) Q		
30.04	.04 Fe (44, 486)		1.13
4129.45	.46 Fe (695)		1.10
28.05	.07 Ce II (136)		0.99
	.07 V (27)		
	.06 SiH (0, 0) R		
27.64	.72 Gd II (117)		0.92
	.64 Cr (65)		
	.61 Fe (357)		
26.90	.88 Fe (354)		1.21
	.92 Cr (—)		
26.54	.52 Cr (35)		1.36
26.18	.19 Fe (695)		1.08
	.10 Cr (65)		
25.65	.62 Fe (1103)		1.10
23.76	.81 Cb (1)		0.99
	.75 Fe (217, 422)		
	.87 Ce II (60)		
23.39	.39 Cr (108)		1.12
	.38 Zr II (54)		
	.29 Ti (302)		
	.28 Mn (47)		
22.63	.52 Fe (356)		1.06
22.17	.16 Cr (65)		1.36
	.14 Ti (296)		
21.85	.82 Cr (108)		1.17
	.81 Fe (356)		

λ_{obs}	Identif.	log I_1	log I_2
21.31	.32 Co (28)		1.00
	.34 SiH (0, 0) R		
20.58	.61 Cr (65)		1.38
	.54 V (41)		
20.21	.21 Fe (423)		1.19
	.20 SiH (0, 0) R		
4119.83	.88 Ce II (83) ?		1.33
	.78 Ce II (22) ?		
	.66 Fe (320) ?		
19.40	.46 V (41)		1.13
	.44 Cr (65)		
18.80	.90 Fe (559)		0.82
	.77 Co (28)		
18.55	.55 Fe (801)		0.90
	.64 V (41)		
18.19	.18 V (112)		1.27
	.14 Ce II (11)		
17.84	.87 Fe (700, 1103)		1.15
16.93	.97 Fe (558)		1.50
16.54	.47 V (27)		1.08
15.91	.98 Ni (255)		1.33
	.89 Fe (210) p		
	.85 SiH (0, 0) R		
15.19	.18 V (27)		1.08
14.47	.45 Fe (357)		1.15
	.49 SiH (0, 0) Q		
14.11	13.90 Sm II (16)		1.42
	.11 SiH (0, 0) R		
13.57	.52 V (52)		1.42
	.60 SiH (0, 0) R		
12.93	.97 Fe (1103)		1.08
12.30	.35 Fe (695)		1.19
12.03	.09 Fe (766)		0.99
	.17 Fe (275) p		
11.36	.36 Cr (97)		1.33
10.86	.90 Mn (37, 47)		1.21
	.87 Cr (97)		
10.52	.53 Co (29)		1.05
	.47 Nd II (15)		
4109.81	.98 Cr (260)		1.00
	.83 Ca II (17) ?		
	.81 V (41)		
	.81 Fe (357)		
09.46	.58 Cr (65)		1.27
	.54 Mg II (21)		
	.46 Nd II (10)		
	.40 Sm II (28)		
09.04	.07 Nd II (17)		1.36
	.08 Fe (558)		
08.49	.55 Ca (39)		1.33
	.49 Co (2)		
	.40 Cr (65)		
08.09	.13 Fe (559)		1.05
07.45	.49 Fe (354)		1.12
	.49 V (52)		
06.32	.44 Fe (697)		1.59
	.27 Fe (217)		
05.09	.06 Fe (700)		1.13
	.17 V (27)		
04.79	.78 V (112)		1.06
	.77 Fe (320)		
	.88 Cr (108)		
04.10	.13 Fe (356, 558)		1.10
03.49	.61 Fe (831) p		1.33
02.92	.93 Si (2)		1.00
02.13	.16 V (41)		0.98
01.68	.74 Hδ (1)		0.75
	.68 Fe (120)		
01.20	.27 Fe (698)		1.02
	.16 Cr (108)		
00.76	.74 Fe (18)		1.00
	.75 Cr II (4)		

λ_{obs}	Identif.	log I_1	log I_2
00.22	.24 Nd II (57)		1.10
	.17 Fe (—)		
4099.79	.80 V (27)		1.15
	.77 Mg (46)		
99.09	.17 Ti (207)		1.33
	.08 Fe (600, 651)		
98.54	.53 Cr (25)		1.08
	.61 Gd II (49)		
	.44 Cr II (165)		
98.13	.18 Fe (558)		1.10
	.18 Cr (97)		
97.56	.65 Cr (97)		1.38
97.01	.10 Fe (558)		0.99
	.02 Fe (700) p		
	96.96 Fe (174) p		
96.05	.21 Fe (18)		0.93
	.12 Fe (911)		
	95.98 Fe (217)		
95.37	.49 V (41)		1.23
	.27 Fe (1075) p		
94.90	.93 Ca (25)		1.13
93.38	.50 V (52)		1.38
92.46	.41 V (52)		0.86
	.51 Fe (18)		
	.39 Co (29)		
91.56	.56 Fe (357)		1.33
90.94	.98 Fe (695)		1.27
	.95 Ce II (174)		
90.58	.58 V (41)		1.23
90.01	.08 Fe (700)		1.21
4089.22	.22 Fe (422)		1.33
88.57	.57 Fe (906)		1.38
87.77	.79 Fe (832) p		w
	.63 Cr II (19)		
87.12	.10 Fe (694)		1.25
86.71	.72 La II (10)		1.25
86.27	.30 Co (58)		1.05
	.14 Cr II (26)		
85.30	.31 Fe (559)		0.88
	.26 Fe (276)		
85.06	.01 Fe (358)		0.99
84.48	.50 Fe (698)		0.99
83.64	.63 Mn (5)		0.83
	.58 Sm II (24)		
	.55 Fe (117)		
	.71 Y (6)		
82.94	.94 Mn (5)		1.21
82.44	.46 Ti (80)		1.12
	.44 Fe (906)		
	.40 Sc (6)		
82.14	.12 Fe (698)		1.27
81.26	.21 Cr II (165)		1.27
	.22 Ce II (4)		
	.22 Zr II (46)		
80.88	.89 Fe (557)		1.33
80.22	.23 Fe (556)		1.25
	.23 Nd II (18)		
	.22 Cr (66)		
4079.81	.85 Fe (359)		1.17
	.73 Cb (1)		
	.71 Ti (207)		
79.30	.42 Mn (5)		0.86
	.24 Mn (5)		
78.43	.47 Ti (80)		0.92
	.36 Fe (217)		
	.32 Ce II (19)		
	.44 Gd II (15)		
77.73	.71 Sr II (1)		0.65
76.64	.64 Fe (558)		0.85
	.50 Fe (218)		
76.04	.06 Cr (279)		1.07
	.12 Co (16)		

λ_{obs}	Identif.	log I_1	log I_2
74.78	.79 Fe (524)		0.94
	.90 Ni (20)		
73.76	.76 Fe (558)		1.20
	.76 Gd II (44)		
72.54	.56 Cr II (26)		
71.72	.74 Fe (43)		0.45
70.91	.90 Cr II (193)		
	.77 Fe (558)		
70.26	.28 Mn (5)		1.00
	.29 Gd II (49)		
4069.62	.61 Sun		1.07
69.07	.08 Fe (557)		1.28
	68.98 Ti (299)		
68.57	.66 Ti (254)		1.45
	.54 Co (58)		
68.00	.00 Mn (5)		1.00
	67.98 Fe (559)		
67.30	.28 Fe (217)		1.12
	.28 Ce II (22)		
66.97	.98 Fe (358)		1.00
	.94 Cr (66)		
66.31	.36 Co (30)		1.06
65.50	.40 Fe (698)		1.24
	.60 Ti (207)		
65.09	.09 Ti (80)		1.21
	.07 V II (215)		
64.42	.46 Fe (44)		0.98
	.37 Ni (179)		
63.62	.60 Fe (43)		0.23
	.53 Mn (5)		
62.46	.46 Fe (359)		1.03
61.73	.77 Cr II (19)		1.21
	.74 Mn (29)		
61.07	.08 Nd II (10)		1.33
	Fe (Sun)		
60.26	.26 Ti (80)		1.33
4059.73	.73 Fe (767)		1.21
59.35	.39 Mn (29)		1.09
	.37 Gd II (118)		
	.32 Co (2)		
58.82	.77 Fe (120)		0.95
	.77 Cr (251)		
58.22	.23 Fe (558)		1.03
	.22 Gd (5)		
	.18 Co (16)		
57.90	.95 Mn (29)		1.03
	.81 Cr (251)		
	.81 Pb (1)		
57.46	.50 Mg (16)		0.84
	.36 Fe (277)		
	.35 Ni (89)		
56.39	.53 Fe (320)		1.21
	.27 V II (14)		
56.08	.07 Cr II (182)		1.15
	.03 Mo (12)		
55.52	.54 Mn (5)		0.99
54.87	.88 Fe (698)		0.92
	.84 Pr II (30)		
54.14	.18 Fe (557)		1.23
	.11 Cr II (19)		
53.82	.82 Fe (485)		1.23
	.81 Ti II (87)		
53.33	.45 Cr II (19)		1.21
	.29 Gd II (—)		
52.48	.47 Mn (48)		0.99
	.47 Fe (563)		
51.92	.92 Fe (700)		1.15
	.97 Cr II (19)		
51.26	.34 V II (215)		1.20
	.35 V (121)		
50.65	.65 Sun		1.38
4049.71	.78 Cr (251)		1.27

λ_{obs}	Identif.	log I_1	log I_2
	98.05 Fe (276)		
97.40	.39 Fe (278)	1.12	0.96
	.49 Fe (556) p		
97.04	.13 V II (9)	1.12	1.17
	96.97 Fe (945)		
96.62	.61 Sc (7)	1.12	1.33
95.99	96.00 Fe (279)	1.15	1.20
95.29	.31 Co (31)	1.03	0.97
94.56	.54 Co (17)	1.12	1.08
	.56 Ti (186)		
94.00	93.97 Cr (67)	1.12	1.01 bl
	.00 Fe (560) p		
93.18	.21 Gd II (1)	1.34	1.48
92.80	.80 V (89)	1.20	1.22
	.84 Cr (67)		
92.34	.40 Fe (604)	1.21	1.31 bl
	.39 Ce II (135)		
	.25 Sun		
91.67	.68 Co (17)	1.15	1.10
	.67 Cr (38)		
91.09	.12 Cr (38)	1.20	1.23
90.34	.38 Fe (527)	1.12	1.06
	.30 Co (58)		
3989.79	.76 Ti (12)	1.00	0.85
	.80 V II (32)		
	.86 Fe (768)		
89.02	.06 Sc II (8)	1.15	1.10
88.48	.51 La II (40)	1.34	1.23
87.97	.98 Yb (2)	1.43	1.59
87.58	.63 Ti II (11) p	1.31	1.31
87.07	.10 Mn (33)	1.03	0.87
	.09 Ni (137)		
	.12 Co (16)		
86.74	.75 Mg (17)	1.05	0.92
86.19	.18 Fe (655)	1.20	1.06
85.32	.32 Fe (219) p	1.24	0.95
	.39 Fe (661)		
84.65	.68 Ce II (252)	1.34	1.25
	.60 V (89)		
84.31	.31 Ti (188)	1.23	1.17 bl
	.34 V (89)		
	.34 Cr (38)		
83.92	.96 Fe (277)	1.04	0.89
	.91 Cr (38)		
83.18	.24 Cr (213)	1.31	1.30
	.14 Sm II (38)		
82.95	.90 Ce II (172)	1.21	1.13 bl
	83.01 Sun		
82.51	.48 Ti (11)	1.06	1.01
	.58 Mn (33)		
	.59 Y (26)		
81.78	.78 Fe (278)	1.02	0.98 bl
	.76 Ti (12)		
81.11	.11 Fe (122)	1.34 bl	1.22 bl
	.23 Cr (67)		
80.59	.65 Fe (153)	1.36	1.31
3979.54	.52 Co (3)	1.06	0.97
	.65 Fe (561)		
78.43	.47 Fe (361)	1.15 bl	1.01 bl
77.72	.74 Fe (72)	1.18	0.99
	.73 V II (10)		
76.94	.87 Fe (431, 662)	1.34	1.22
	.99 Sun		
76.66	.66 Cr (38)	0.99	0.78
	.62 Fe (729)		
75.88	.85 Fe (977)	1.23	1.09
75.25	.21 Fe (163)	1.25	1.06
74.73	.77 Fe (72)	0.95	1.05 bl
	.73 Co (18)		
74.44	.40 Fe (564)	1.01	0.80 bl
73.64	.56 Ni (31)	0.77	0.65
	.66 Fe (769)		

λ_{obs}	Identif.	log I_1	log I_2
	.71 Ca (6)		
73.17	.14 Co (58)	1.01	0.88
72.20	.17 Ni (29)	0.83	0.75
	.13 Ti (81)		
71.30	.33 Fe (277)		
70.58	.53 Sm II (1)		
	.50 Ni (151)		
70.33	.39 Fe (488)		
3969.24	.26 Fe (43)		
	.29 Gd II (20)		
	.12 Co (128)		
	70.07 H_5 (1)		
68.53	.47 Ca II (1)		
68.04	.11 V II (9)		
	67.96 Fe (561)		
67.31	...	0.31	0.41
66.57	.53 Fe (562, 652, 766)	0.70	0.54
66.08	.07 Fe (45)	0.66	0.59
65.46	.45 Fe (658)	0.86	0.76 bl
64.90	.90 Eu (10)	0.97	0.88
	65.01 Co (31)		
64.55	.52 Fe (361)	0.97	0.83
	.57 Fe II (29)		
64.20	.26 Ti (12)	0.86	0.80
	.26 Pr II (33)		
63.69	.69 Cr (38)	0.99	0.87
	.63 Os (3) ?		
63.13	.11 Fe (562)	0.95	0.80
	.11 Nd II (39)		
62.88	.85 Ti (12)	0.98	0.85 bl
62.37	.35 Fe (566)	1.06	0.87
	.42 Fe (560)		
62.06	.09 Sun (Fe ?)	0.95	0.83 bl
61.51	.52 Al (1)	0.43	0.23
61.00	.00 Co (128)	1.06	1.03 bl
60.69	.76 Cr (68)	1.31	1.16
60.28	.28 Fe (913)	1.32	1.18
3958.70	.74 Sun (Fe)	1.36	1.18
58.19	.21 Ti (13)	1.04	0.96
	.24 Zr II (16)		
57.90	.93 Co (18)	1.13	1.03
57.65	.62 Fe (564)	w	1.18
57.00	.03 Fe (562)	1.11	0.95
	.05 Ca (6)		
56.65	.68 Fe (278)	1.07	
56.35	.33 Ti (13)	0.87	0.73
55.98	.96 Fe (488)	1.23	1.08
55.29	.35 Fe (562)	1.20	1.01
	.22 Fe (527)		
54.68	.72 Fe (606)	1.31	1.20 bl
53.89	.86 Fe (362)	1.31	1.20
53.54	.50 Fe (770) p	1.33	1.25
	.52 Pr II (9)		
	.52 Nd II (—)		
53.14	.16 Fe (430)	0.82	0.66
	.16 Cr (136)		
	.09 Sun		
52.58	.61 Fe (278)	0.83	0.70
	.57 Ce II (113, 117)		
52.34	.33 Co (16)	1.20	1.08
51.91	.97 V II (10)	1.25	1.15
	52.00 Gd II (1)		
51.60	.59 Y II (16)	1.45	1.23
51.13	.16 Fe (661)	1.13	0.94
	.15 Nd II (19)		
50.32	.35 Y II (6)	1.31	1.10
3949.94	.95 Fe (72)	1.11	0.97
49.12	.14 Fe (730)	1.10	0.94
	.10 La II (41)		
48.74	.78 Fe (604)	0.83	0.73
	.67 Ti (13)		
48.10	.10 Fe (562)	1.20	0.99

λ_{obs}	Identif.	log I_1	log I_2
	.71 Ni (169)		
49.42	.43 Gd II (50)		1.13
	.40 Ti (185)		
	.34 Fe (218)		
48.75	.76 Mn (5)		0.98
	.78 Cr (251)		
	.68 Zr II (43)		
47.76	.79 Sc (7)		1.23
	.88 Y II (6)		
47.26	.32 Fe (117, 853)		1.13
	.21 K (3)		
45.81	.82 Fe (43)		0.20
44.59	.61 Fe (359)		0.92
	.57 Zr (46)		
43.88	.90 Fe (276, 557)		0.86
	.78 Ti (208)		
43.31	...		1.38
42.28	.25 Cr (36)		1.41
41.34	.36 Mn (5)		0.86
	.29 Fe (603, 654)		
40.71	.65 Fe (655)		1.06
	.76 Ce II (138)		
39.96	.94 Fe (276)		1.15
	.83 Y (5)		
39.18	.10 Cr (251)		1.36
38.73	.62 (600, 728)		1.15
	.Sun		
37.71	.72 Fe (118)		1.45
	.66 Ce II (218)		
37.21	.29 Cr (36)		1.28
36.74	.80 Cr (36)		1.33
	.78 V II (9)		
36.34	.37 Fe (279)		1.42
35.70	.73 Mn (5)		0.80
	.63 V II (32)		
35.21	.25 Fe (831) p		1.33
	.11 Sm II (33)		
34.48	.49 Mn (2)		0.71
33.66	.67 Mn (M)		1.20
33.07	.07 Mn (2)		0.45
32.56	.64 Fe (44)		0.94
	.63 Ti (297)		
	.64 Fe (320)		
31.82	.97 Fe (655)		1.03
	.81 Nd II (—)		
	.75 Ti (185)		
	.73 Fe (427) p		
31.22	.24 Fe (486)		1.15 ?
30.76	.76 Mn (2)		0.56
30.22	.19 Fe (72)		0.71 ?
	.28 Cr II (19)		
4029.66	.64 Fe (556, 563)		0.94 ?
	.64 Ti II (87) p		
	.68 Zr II (41)		
28.78	.78 Fe (Sun)		1.15
28.35	.44 Ce II (47)		1.17
	.33 Ti II (87)		
27.08	.10 Cr (37)		1.36
	.03 Co (3)		
26.50	.44 Mn (—)		1.15
	.54 Ti (185)		
26.19	.17 Cr (37)		1.15
25.83	.87 La II (42)		1.25
	.88 Sun		
25.47	.44 Ni (117)		1.33
	.44 Cr (37)		
25.13	.14 Ti II (11)		1.10
	.11 Ni (240)		
24.60	.74 Fe (560) ?		0.94
	.57 Ti (12)		
24.09	.11 Fe (277)		1.23
23.72	.74 Cr (268)		1.33

λ_{obs}	Identif.	log I_1	log I_2
	.69 Sc (7)		
23.43	.40 Co (59)		1.28
	.39 V II (32)		
22.71	.74 Fe (556, 654)		1.33
22.22	.26 Cr (268)		1.25
21.86	.87 Fe (278)		0.98
	.81 Ti (185)		
20.90	.90 Co (16)		1.15
	.87 Nd II (19)		
20.40	.40 Sc (7)		1.00
	.49 Fe (913)		
20.12	.05 Fe (556) p		0.94
	19.98 Sm II (16)		
4019.09	.06 Ni (72)		1.21
	.05 V II (201)		
	.05 Fe (219)		
18.17	.10 Mn (5)		0.86
	.28 Fe (560)		
17.50	.56 Ni (171)		1.06
	.47 Sun		
17.13	.16 Fe (527)		0.90
	.10 Fe (279)		
16.40	.43 Fe (560)		1.21
	.26 Ti (186)		
15.59	.61 Sun		1.17
14.94	.90 Ce II (157)		1.42
14.54	.53 Fe (802)		1.02
	.49 Sc II (8)		
13.89	.89 Fe (120)		0.93
	.94 Co (58)		
13.67	.64 Fe (557)		1.02
	.59 Ti (187)		
12.40	.39 Ce II (206)		0.93 ?
	.37 Ti II (11)		
11.72	.71 Fe (153)		1.25
11.40	.41 Fe (218)		1.33
10.75	.77 Fe (219, 320)		1.13
10.17	.18 Fe (915)		1.42
4009.69	.71 Fe (72)		0.90
	.65 Ti (11)		
08.94	.93 Ti (12)		1.02
08.00	.05 Ti (187)		1.08
07.31	.28 Fe (277)		1.08
	.23 Fe (119)		
06.74	.77 Fe (320)		0.92
	.63 Fe (488)		
06.28	.31 Fe (603)		1.08
05.72	.71 V II (32)		0.94 bl
4005.25	.25 Fe (43)	0.69	0.56 bl
04.94	.98 Fe (486, 557)	0.90	0.74 bl
	.83 Fe (601) ?		
04.37	.40 Zr (M) ?	1.36	1.62
03.73	.76 Fe (728)	1.23	1.23
	.77 Ce II (188)		
	.79 Ti (188)		
02.90	.94 V II (9)	1.30	1.36
	.95 Zr II (142)		
02.53	.55 Fe II (190)	1.36	1.45 bl
	.55 Zr (46)		
	.48 Cr II (166)		
	.47 Ti (188)		
02.03	.07 Fe II (29)	1.46	w
01.64	.67 Fe (72)	1.12	1.15
01.12	.18 Mn (M) ?	1.06	1.06
	.17 Sun		
00.44	.47 Fe (426)	1.11	1.09 bl
	.49 Nd II (64)		
3999.30	.34 Ti (188)	1.27	1.39
	.24 Ce II (57)		
98.99	.98 Zr II (16)	1.23	1.31
98.61	.64 Ti (12)	1.00	0.96
97.96	.90 Co (32)	0.94	0.83

λ_{obs}	Identif.	log I_1	log I_2
47.70	.77 Ti (14)	1.05	0.89
47.45	.39 Fe (153)	1.05	0.92
47.00	.00 Fe (561)	1.11	1.03
46.55	.63 Co (60)	1.31	1.18
	.51 Sm II (17)		
45.85	.86 Sun	1.33	1.18 bl
45.30	.33 Co (29)	1.04	0.88
44.80	.77 Fe (361)	1.01	0.85
44.00	.01 Al (1)	0.47	0.33
43.31	.34 Fe (72)	0.84	0.87
42.79	.75 Ce II (57)	1.22	1.03
42.45	.44 Fe (364)	0.99	0.83
41.77	.73 Co (17)	0.97	0.90
	.86 Ni (171)		
41.23	.28 Fe (562)	0.97	0.87
40.84	.88 Fe (20)	0.91	0.84
	.89 Co (18)		
40.06	.04 Fe (731)	1.06	0.97 bl
3939.33	...	1.06	0.96 bl
38.39	.40 Mg (18)		
37.35	.33 Fe (278)		
35.91	.96 Co (32)		
34.14	33.66 Ca II (1)		
30.32	.30 Fe (4)		
3929.86	.88 Ti (13)		
29.18	.21 Fe (659)	0.79	
	.15 Ti II (97) p		
28.64	.64 Cr (23)	0.88	0.80
27.92	.92 Fe (4)	0.39	0.41 bl
26.45	.47 Mn (44)	1.13	1.02
25.98	.95 Fe (364)	0.90	0.86
	26.00 Fe (562)		
25.57	.65 Fe (364)	1.03	1.00
	.55 Fe (660) p		
25.16	.15 Co (131)	1.10	1.07
	.20 Fe (567)		
24.54	.53 Ti (13)	1.03	1.05
24.14	.18 Ni (240) p	1.36	1.28
	.08 Mn (—)		
22.90	.91 Fe (4)	0.45	0.58
22.06	.08 Fe (153) p	1.13	1.10
	.09 Fe (564) p		
	.00 Ce II (50)		
21.55	.54 La II (40)	1.01	1.00
	.42 Ti (14) ?		
21.06	.02 Cr (23)	0.99	0.92
	.02 Zr II (42) p		
20.65	.65 Fe (153)	0.97	0.92
20.25	.26 Fe (4)	0.59	0.67
3919.75	.81 Ce II (60)	1.43	1.38 bl
	.82 Ti (130)		
19.07	.07 Fe (430)	1.11	1.00
	.16 Cr (23)		
18.61	.64 Fe (430)	1.26	1.03
18.31	.32 Fe (124)	1.11	0.92
17.84	...	1.70	1.62
17.13	.18 Fe (20)	1.03	0.97
16.68	.73 Fe (606)	1.43	1.22
16.28	.24 Cr (23)	1.41	1.18
16.00	.05 La II (42)	1.09	1.06
	15.94 Zr II (17)		
15.55	.50 Co (113)	1.33 bl	1.20 bl
15.12	.22 Sun	w	w
14.31	.33 Ti (15)	1.01	0.92
	.33 V II (33)		
13.48	.46 Ti II (34)	1.07	1.02
12.93	.98 Ni (15)	1.53	1.49
	.90 Pr II (17)		
	.89 V (42)		
12.22	.21 V (42, 43)	1.58	1.41
	.31 Ni (151)		
11.82	.81 Sc (8)	1.33	1.26

λ_{obs}	Identif.	log I_1	log I_2
10.86	.84 Fe (284)	1.35	1.19
10.46	.52 Fe (562) p	1.31	1.14
	.54 Sun		
3909.81	.83 Fe (364)	1.00	0.95
	.89 V (7)		
08.76	.76 Cr (23)	1.27	1.25
	.68 Fe (153)		
08.31	.41 Ce II (65)	1.37	1.37 bl
07.87	.94 Fe (280)	1.25	1.25
07.51	.46 Fe (284)	1.41	1.35 bl
	.48 Sc (8)		
07.08	.10 Eu II (5)	1.41	1.43 bl
06.46	.48 Fe (4)	0.82	0.83
05.90	.89 Nd II (—)	1.16	1.03
05.51	.53 Si (3)	0.76	0.71
04.76	.78 Ti (56)	1.23	1.10
04.30	.34 Ce II (91)	w	w
03.86	.90 Fe (423)	1.22	1.09
02.93	.95 Fe (45)	0.73	0.73
	.92 Cr (23)		
02.21	.25 V (7)	1.29	1.26 bl
01.85	.85 Nd II (—)	1.33	1.26
01.55	.49 Sun	1.31 ?	1.26
00.84	.96 Ti (15)	1.43	1.51
00.49	.52 Fe (565)	1.12	1.04
	.51 Zr (6)		
	.55 Ti II (34)		
3899.67	.71 Fe (4)	0.65	0.71
	.67 Ti (15, 175)		
99.04	.04 Fe (175)	1.13	1.14
98.40	.48 Co (58)	1.16	1.15
	.49 Ti (13)		
	.40 Sun		
97.92	.90 Fe (280)	0.85	0.83
	98.01 Fe (20)		
97.42	.45 Fe (429)	1.48	1.37
96.50	.53 Zr (9)	1.41	1.27
	.47 Sun	1.37	0·72
96.11	.16 V (43)		
	.16 V II (10)		
	.11 Fe II (23)		
95.63	.66 Fe (4)	0.70	1.02
95.04	.01 Fe (663)	1.03	1.06
	94.98 Co (18)		
94.55	.49 Fe (566)	1.58	w
93.99	.92 Fe (175)	0.95	0.94
	94.00 Fe (663)		
	94.04 Cr (23)		
	94.07 Co (34)		
93.35	.32 Fe (364)	1.07	1.17
	.38 Mg (47)		
	.39 Fe (430)		
92.93	.90 Fe (283)	1.07	
	.86 V (7)		
	.98 Fe (567)		
92.52	...	1.58	w
91.86	.93 Fe (733)	1.33	1.29
	.78 Ba II (4)		
91.47	.39 Zr (11)	w	1.55
91.15	.12 V (—)	1.37	1.33
90.85	.84 Fe (280)	1.16	1.19
90.35	.32 Zr (8)	1.28	1.26
	.39 Fe (567)		
3889.87	.95 Ti (15)	1.18	1.17
	.92 Fe (564)		
89.25	.25 V (M)	1.02	0.96
	.05 H_8 (2)		
88.74	.82 Fe (488)	1.04	0.95
88.52	.52 Fe (45)	0.75	0.73
87.96	.87 Nd II (31)	1.51 bl	1.46 bl
87.07	.05 Fe (20)	0.67	0.73
86.27	.28 Fe (4)	0.37	0.60

λ_{obs}	Identif.	$\log I_1$	$\log I_2$
85.84	.87 Ni (1) p	0.96	0.94
85.50	.51 Fe (124)	1.20	1.08
85.16	.14 Fe (430)	1.07	0.92
	.19 Pr II (18)		
	.22 Cr (23)		
84.63	.60 Co (32)	1.41 bl	1.27 bl
	.66 Fe (565)		
84.32	.36 Fe (282)	1.06	1.01
	.29 Sun		
83.69	.66 Cr (138)	w	w
83.31	.39 Cr (23)	0.74	0.73
	.28 Fe (663)		
	CN (0, 0)		
82.36	.31 Ti (176)	0.94	0.88
	.47 CN (0, 0) P ?		
81.96	.87 Co (18)	0.90	0.89
	CN		
81.62	.63 CN (0, 0) P	1.06	1.04
81.32	.40 Ti (15)	1.02	0.97
	.38 Sm II (33)		
	CN		
81.03	.04 V II (143)	1.10	1.06
	.05 CN (0, 0) P		
80.76	.77 Sm II (10)	1.12	1.11
	.78 Nd II (32)		
	.76 CN (0, 0) P		
80.38	.35 CN (0, 0) P	1.12	1.04
80.04	.03 CN (0, 0) P	1.10	0.99
3879.61	.64 CN (0, 0) P	1.13	1.19
79.24	.22 Cr (138)	1.13	1.07
	.20 CN (0, 0) P		
78.62	.66 Fe (175)	0.40	0.54
	.58 Fe (4)		
78.00	.02 Fe (20)	0.44	0.67
77.42	.45 CN	1.16	1.06
76.86	.83 Co (17, 62)	0.92	0.95
	.98 CN		
76.41	.42 CN	1.31	1.31
75.92	.90 V (7)	0.95	0.92
	76.04 Fe (22)		
	.81 Ca (26)		
75.30	.26 Ti (15, 175)	1.35	1.29
	.29 CN		
75.10	.08 V (7)	1.14	1.25
	.14 Cr (138)		
74.73	.73 CN (0, 0) P ?	1.33 bl	1.31 bl
74.53	.57 Cr (138)	1.22 bl	1.33 bl
	.53 Sun		
74.02	.05 Fe (120)	0.90	0.90
	.95 Co (18)		
73.76	.76 Fe (175)	1.17	1.14
73.62	. . .	1.20	1.17 ?
73.08	.12 Co (18)	0.90	0.90
	.20 Ti (176)		
72.49	.50 Fe (20)	0.55	0.68
72.09	.06 CN	0.97	0.97
71.78	.78 Sm II (18)	0.95	0.97
	.75 Fe (429)		
71.33	.37 CN (1, 1)	0.85	0.81 bl
	CH (0, 0) Q ?		
70.13	.24 CN (Sun)	1.08	1.05
3869.85	. . .	1.10	1.05
69.60	.59 Fe (284)	0.98	0.95
	.67 CN		
69.28	.28 Ti (175)	1.06	1.04
69.07	.04 Nd II (34)	1.02	0.95
	.18 CN		
68.74	.77 CN (1, 1) P	1.23 bl	1.17 bl
68.48	.40 Ti (175)	1.08	1.04
	.58 CN (1, 1) P		
68.00	.04 CN	1.06	0.97
	67.92 Fe (221)		
	67.99 W (7) ?		
67.71	.74 Ti (176)	1.07 bl	1.02 bl
67.25	.22 Fe (488)	1.14	1.05
	.39 CN		
66.86	.74 V II (11)	1.10	1.05
	.83 CN (0, 0) R		
66.45	.45 Ti (176)	1.20	1.22
66.00	.01 Cr II (130)	1.10	1.05
	.03 Ti (M)		
	65.99 CN (Sun)		
65.50	.53 Fe (20)	0.62	0.6 ?
65.07	.13 CN (0, 0) R	1.12	1.19
	CN (1, 1) P		
64.53	.49 La II (141)	1.26	1.27
	.59 CN		
64.04	.12 Mo (1)	1.23 bl	1.17 bl
	.11 Sun (Fe)		
63.69	.74 Fe (280)	1.00	0.96
	.70 Fe (565) p		
63.35	.33 Nd II (27)	1.12	1.12
	.41 Nd II (26)		
	.40 CN		
62.90	.82 Ti (175)	1.28	1.33
62.50	. . .	1.15	1.12
61.63	.60 Fe (663)	0.90	0.84
	.60 CN		
61.20	.16 Co (33)	0.85	0.84
60.61	.63 CN (1, 1)	0.97	0.84
	CN (0, 0)		
3859.89	.91 Fe (4)	0.00	0.00
59.19	.21 Fe (175)	0.87	0.86
58.84	.90 Cr (138)	0.95	0.91
58.59	.69 CN	1.00	
58.26	.30 Ni (32)	0.79	0.78
57.63	.63 Cr (69)	1.05	1.00
	.67 CN		
57.09	.08 CN (1, 1)	1.26	1.19
56.35	.37 Fe (4)	0.44	0.62
55.87	.85 Fe (567)	1.03	0.97
	.84 V (9)		
55.60	.57 Cr (69)	1.08	1.06
	.56 Gd II (2)		
55.30	.29 Cr (69)	1.11	
54.85	.91 La II (55) ?	0.97	0.94 bl
	.86 CN (1, 1) ?		
54.59	.57 CN	0.73	
54.22	.22 Cr (69)	1.08	0.86
	.21 Sm II (—)		
53.75	.72 Ti (176)	1.17	1.15
53.40	.46 Fe (429)	1.02	0.95
53.22	.18 Cr (69)	1.25	1.05 bl
	.16 Ce II (39) ?		
52.54	.57 Fe (73)	0.98	0.95
	.58 Cr (11)		
	.45 Gd II (2)		
	.41 CN		
52.13	.22 Cr (24)	1.26 bl	1.36 bl
	.11 CN		
51.82	.75 Nd II (35)	1.46	
	.85 Co (128)		
51.64	.62 Pr II (—)	1.19	1.04
	.68 CN		
51.24	.17 V (44)	1.19	1.04
	.29 CN		
50.82	.82 Fe (22)	0.77	0.78
3849.96	.97 Fe (20)	0.43	
49.34	.36 Cr (138)	1.13	1.05
	.32 V (—)		
48.95	.98 Cr (69)	1.08	1.00
	.85 CN		
48.52	.52 Nd II (—)	1.25	1.26
	.60 Ce II (36)		

λ_{obs}	Identif.	$\log I_1$	$\log I_2$
48.25	.29 Fe (224) p	1.15	1.17
47.86	.78 CN	1.01	1.11
47.31	.32 V (7)	1.22	1.17
	.32 V II (156)		
46.79	.80 Fe (664)	0.99	0.92
46.38	.41 Fe (804)	1.07 bl	1.06 bl
46.00	.00 Fe (703)	1.25	1.20
45.44	.47 Co (34)	1.00	0.98
45.18	.17 Fe (124)	1.07	0.98
44.54	.58 Gd II (2)	1.35	1.26
	.44 V (7)		
44.21	.28 Ni (137)	1.12	1.08
43.97	.98 Mn (6)	1.19	1.20
43.69	.72 Fe (703) p	1.07	1.17
	.69 Co (84)		
43.26	.26 Fe (528)	1.14	1.09
42.95	.98 Fe (221)	0.93	0.92
	43.03 Zr II (7)		
42.58	. . .	1.48	1.27
42.38	. . .	1.51	1.36
41.89	.89 V (8)	0.95	0.92
41.06	.05 Fe (45)	0.53	0.64
	.08 Mn (6)		
40.42	.44 Fe (20)	0.32	0.51
40.12	.14 V (66)	0.87	0.86
	.20 Fe (120) p		
3839.78	.78 Mn (6)	1.00	0.94
39.20	.26 Fe (529)	0.91	0.86
	.14 CN		
38.76	.75 CN	0.88 bl	0.87 bl
38.27	.29 Mg (3)	0.18	0.45
	.28 Zr II (17)		
37.76	.83 CN	0.86	0.82 bl
37.14	.13 Fe (222)	1.15	1.09
36.80	.76 Ti (—)	1.12	1.09
	.76 Zr II (16)		
36.32	.33 Fe (664)	1.10	1.00
36.05	.05 V (44)	1.19	1.10
	.07 Cr (70)		
	.08 Ti II (12)		
35.32	.39 H_9 (2)	1.00	0.94
	.21 CN		
34.74	.74 Cr (70)	0.94	0.96
34.24	.22 Fe (20)	0.23	0.43
	.22 V (80) p		
33.86	.86 Mn (6)	0.81	0.73
	.83 Sm II (29)		
	.79 CN		
33.28	.31 Fe (221)	0.99	0.91
32.84	.84 V (80)	0.84	0.89
	.88 Ni (1)		
32.31	.30 Mg (3)	0.37	0.43
31.70	.69 Ni (31)	0.83	0.79
31.04	.03 Cr (24)	1.09	1.00
	.02 V II (3)		
30.74	.76 Fe (224)	0.97	0.91
30.05	.03 Cr (—)	1.20	1.04
3829.67	.68 Mn (6)	0.87 bl	0.68 bl
	.66 V II (3)		
29.31	.35 Mg (3)	0.44	0.54
28.81	.84 V (67)	1.25	1.01 ?
28.52	.51 Fe (287)	1.00	0.96
	.56 V (9)		
27.80	.82 Fe (45)	0.51	0.87
27.27	.27 Zr II (—)	1.07	0.96
26.80	.84 Fe (283)	0.91	0.92
	.77 V (44)		
25.85	.88 Fe (20)	0.18	0.48
25.25	.27 Zr (M)	0.86	0.88
24.42	.44 Fe (4)	0.43	0.48
23.83	.89 Mn (6)	0.95	0.96 bl

λ_{obs}	Identif.	$\log I_1$	$\log I_2$
23.49	.51 Mn (6)	1.20	1.18
	.52 Cr (24)		
22.92	.89 V (28)	1.07	1.09
22.36	.41 Zr (10)	1.25	1.21
	.33 CN		
21.84	.83 Fe (222)	0.90	0.90
21.16	.18 Fe (608)	0.91	0.92
20.41	.43 Fe (20)	0.25	0.46
3819.58	.57 Cr (88) p	1.00	0.95
	.56 Cr (70)		
	.67 Eu II (1)		
19.06	.07 CN	1.31 bl	1.16?bl
18.62	.62 Sun	1.50	
18.48	.48 Cr (40)	1.43	1.26 bl
18.24	.24 V (9)	1.27	1.16
17.64	.64 Ti (189)	1.19	1.10
	.64 Fe (701)		
16.92	.88 Co (86)	1.42	1.19
	.92 Fe (387) p		
16.34	.34 Fe (73)	1.07	0.84?
	.32 Co (62)		
15.82	.84 Fe (45)	0.63	0.70
	.83 Ce II (37)		
15.41	.43 Cr (71)	1.10	1.02
14.81	.86 Ti (189)	1.29 bl	1.17 bl
	.79 Sun		
14.48	.52 Fe (22)	1.05	1.10
	.46 Co (62)		
13.94	.94 Fe (176) p	1.31	1.25
	.89 Fe (854)		
	.97 Gd II (2)		
13.41	.39 Ti II (12)	1.07	1.11
	.45 V (28) p		
	.49 V (9)		
12.94	.96 Fe (22)	0.89	0.95
	13.06 Fe (222)		
12.13	.07 Sm II (10)	1.53	1.36?
	.18 Y II (61)		
11.90	.89 Fe (287)	1.21	1.25
11.34	.38 Ti (165)	1.60	1.53
	.32 Ni (15)		
11.01	.05 Fe (223, 287)	1.59	1.43
	.06 Co (31)		
10.68	.76 Fe (665)	1.29	1.34
	.71 Sun		
10.26	.29 Sun	1.75 bl	1.72 bl
3809.60	.60 V (28)	1.24	1.21
	.59 Mn (6)		
	.69 CN		
09.08	.04 Fe (367)	1.57	1.53
	.16 Sun		
08.70	.73 Fe (222)	1.51	1.53
08.12	.10 Co (17)	1.34	1.40
	07.93 Cr (139)		
07.53	.53 Fe (53)	1.15	1.14
	.50 V (28)		
07.13	.14 Ni (33)	1.10	1.19
06.73	.72 Mn (6)	1.19	1.17
	.70 Fe (607)		
06.36	.38 Sun (Fe)	1.51	1.42
	.45 CN		
06.18	.20 Fe (731)	1.45	1.40
05.78	.77 Co (M)	1.72	w
05.35	.34 Fe (608)	1.34	1.32
	.36 Nd II (19)		
04.57	.59 V (97)	1.40	1.37
04.01	.01 Fe (702)	1.51	1.53
03.47	.47 V (28)	1.70	w
	.47 Nd II (—)		
03.10	.10 Ce II (37)	1.45	1.40
	.09 CN		
02.70	.81 Sun (CN?)	1.60 bl	1.75 bl

λ_{obs}	Identif.	log I_1	log I_2
02.26	.28 Fe (666)	1.66	1.70
01.82	.80 Fe (367)	1.22	1.14
01.68	.68 Fe (367)	1.31	1.35
01.28	.29 Gd II (—)	1.41 bl	1.42 bl
00.58	.55 Mn (45)	1.82	1.70
	.63 Sun		
3799.90	.91 V (28)	1.37?	1.14?
	.81 Ti II (13)		
99.55	.55 Fe (21)	0.74	0.88
98.51	.51 Fe (21)	0.87	0.94 bl
97.92	.95 Fe (222)	1.26	1.24
	.90 H_{10} (2)?		
97.48	.52 Fe (607)	1.32	1.28
97.15	.13 Cr (139)	1.37	1.38
96.84	.90 Ti II (12)	1.32	1.34
	.80 Sun		
96.43	.47 Zr II (71)	1.60	1.62
	.37 Gd II (2)		
96.08	.00 Fe (176)	1.51	1.51
95.79	...	1.60	w
95.46	.45 Sun	1.53	bl
94.99	95.00 Fe (21)	0.78	0.91
94.28	.34 Fe (177)	1.45	1.42
93.90	.87 Fe (367)	1.45	1.53
	.88 Cr (139)		
93.48	.48 Fe (387)	1.11	1.10
92.78	.83 Fe (84)	1.38	1.40
	.69 Sun		
92.28	.32 Zr II (81)	1.51	1.51
	.33 Ce II (129)		
	.34 Ni (2)		
92.11	.14 Cr (139)	1.46	1.59
	.16 Fe (287)		
91.76	.73 Fe (703)	1.60	1.66
	.72 Gd II (46)		
91.41	.39 Zr (8)	1.57 bl	1.61 bl
	.38 Cr (139)		
91.05	.17 Gd II (85)	1.66	w
	.21 Cb (2)		
	.11 CN		
90.72	.76 Fe (73, 127)	1.24	1.29
90.11	.10 Fe (22)	1.00	1.04
3789.74	.72 Cr (24)	1.23	1.32
89.45	.49 Cr (41)	1.32	1.26 bl
	.42 Sun		
89.16	.18 Fe (289)	1.42	1.43
	.29 Ti (115)		
88.75	.75 Ce II (47)	1.60	1.60
	.70 Y II (7)		
	.80 Ti (16)		
87.87	.89 Cr II (6)	0.84	0.94
	.88 Fe (21)		
87.56	.56 Gd II (20)	1.51	1.50
87.14	.06 Cb (3)	1.50	1.50
86.63	.68 Fe (22)	1.34	1.29
	.63 Ce II (51)		
86.01	.04 Ti (57)	1.02	1.10
85.69	.71 Fe (608)	1.66 bl	1.53 bl
85.29	...	1.64	1.62
84.46	...	1.74	w
83.83	.90 Sun	1.68	w
83.47	.53 Ni (30)	1.26	1.31
82.98	...	1.74	w
82.50	.45 Fe (388)	1.57	1.55
	.52 Ce II (142)		
82.08	.14 Ti (82)	1.45	1.60
81.62	.62 Ce II (163)	1.59	1.61
81.15	.19 Fe (74)	1.74	1.70
80.70	.67 La II (55)	1.57	1.62
	.76 Sm II (—)		
80.41	.39 Nd II (19)	1.66 bl	1.77 bl
	.42 CN		

λ_{obs}	Identif.	log I_1	log I_2
3779.79	...	1.74	w
79.69	.65 V (69)	1.62	
79.44	.44 Fe (665)	1.22	1.26
	.49 Fe (74)		
	.42 Fe (222)		
79.14	.21 Fe (290)	1.64	1.80
78.71	.70 Fe (73)	1.41	1.46
	.68 V (28)		
78.40	.36 V II (21)	1.55 bl	1.61 bl
	.32 Fe (367)		
77.98	.93 Cr (41)	1.48	1.55
	78.06 Ni (15)		
77.38	.45 Fe (223)	1.43	1.46
77.01	.06 Fe (432)	1.64	1.80
76.44	.45 Fe (74)	1.32	1.55
76.04	.06 Ti II (72)	1.46	1.48
75.56	.57 Ni (33)	1.25	1.37
75.20	.19 V (97)	1.72	w
74.80	.82 Fe (73)	1.45	1.48
74.61	.65 Ti II (12)	1.43	1.48
	.64 Mn (45)		
	.60 Co (96)		
74.28	.33 Ti (16)	1.46	1.70 ?
	.33 Y II (7)		
	.29 Sm II (43)		
73.97	...	1.72	w
73.65	.70 Fe (386)	1.50	1.57
73.34	.36 Fe (531)	1.60	1.70
72.93	.96 V II (100)	w	w
72.51	.53 Ni (15)	1.42	1.61
72.08	.06 Zr II (31)	1.68	w
	.10 CN		
71.59	.65 Ti (17)	1.37	
	.50 Fe (607) p		1.48
71.33	...	1.50	
70.97	.97 V II (21)	1.50	1.61
70.58	.63 H_{11} (2) ?	1.40	1.51
	.60 Sun		
70.33	.30 Fe (287)	1.20	1.28
3769.99	.99 Fe (387)	1.38	1.51
69.41	.46 Ni II (4)	1.68	1.75
	.37 Cr II (6)		
68.98	69.00 Cr (42)	1.64	1.80
68.64	.62 Cr (42)	1.53	1.61
68.22	.24 Cr (43)	1.43 bl	1.45 bl
	.23 Fe (368)		
68.03	.03 Fe (73)	1.34	1.38
	.08 Cr (42)		
67.20	.19 Fe (21)	0.63	0.49
66.66	.66 Fe (386)	1.16	1.25
	.65 Cr II (20)		
66.10	.09 Fe (226)	1.51 bl	1.57 bl
	.24 CN		
65.53	.54 Fe (608)	1.23	1.21
64.29	.21 Fe (74) p	1.15	1.08
	.28 CN		
63.80	.79 Fe (21)		0.85
62.96	63.00 Gd II (1)	1.59 bl	1.57 bl
	63.00 Sun		
62.62	.62 Ni (—)	1.66	1.68
62.21	.20 Fe (705)	1.37	
61.81	.87 Ti II (107)	1.48	1.59
61.30	.32 Ti II (13)	0.97	1.09
	.42 Fe (227)		
60.98	.92 Gd II (20)	1.31 bl	1.59 bl
	61.06 Fe (706) p		
60.50	.53 Fe (76)	1.37	1.46
60.04	.05 Fe (177)	1.37	1.46
	.03 Ru (2)		
3759.24	.29 Ti II (13)	0.93	1.28
58.20	.24 Fe (21)	0.56	0.78
57.63	.66 Cr (43)	1.09	1.11

λ_{obs}	Identif.	log I_1	log I_2
	.68 Ti II (72)		
57.36	.38 Dy II (Sun) ?	1.22	bl
56.86	.94 Fe (805)	1.43	1.59
56.06	.07 Fe (74)	1.72	1.75
55.42	.45 Co (96)	1.59	1.72
54.82	...	1.59	w ?
54.48	.51 Fe (386)	1.50	1.28
53.58	.61 Fe (73)	1.26	1.34
	.62 Ti (17)		
53.19	.15 Fe (177)	1.51	1.48
52.84	.86 Ti (17)	1.25	1.35
52.39	.42 Fe (385, 392)	1.46 bl	1.48 bl
51.77	.82 Fe (287)	1.50	
51.55	.60 Zr II (71)	1.50	1.51 bl
	.62 Co (98)		
51.12	.09 Fe (74) p	1.50	1.55
	.22 V II (100)		
50.72	.68 Fe (225)	1.40 bl	1.40 bl
	.65 Zr II (18)		
50.25	.35 Ca (27)	1.12	0.94
	.30 Sun		
3749.44	.49 Fe (21)		0.80
48.98	.97 Fe (386)		0.90
	49.00 Cr (43)		
	49.04 Ni (1)		
48.22	.26 Fe (5)		0.88
47.49	.55 Y II (8)		1.16 bl
47.23	.26 Cr (289)	1.38	1.43
46.92	.93 Fe (386)	1.24	1.23
46.50	.49 Fe (73)	1.29	1.19
45.91	.90 Fe (5)	0.63 bl	0.85 bl
	.97 Zr II (112) ?		
45.52	.56 Fe (5)	0.58	0.76
	.49 Co (34)		
45.10	...	0.97	1.03
44.86	...	0.97	
44.46	.49 Cr (43)		1.45
44.10	.10 Fe (385)	1.45	1.45
43.78	.78 Fe (290) p	1.37 bl	1.32 bl
	.87 Sm II (98, 34)		
	.88 Cr (43)		
43.36	.36 Fe (21)	0.78	0.85
42.89	.94 Fe (704)	1.40	1.40
	.97 Cr (43)		
42.59	.62 Fe (387)	1.46	1.40
42.07	.07 Fe (225)	1.59	1.62
41.59	.63 Ti II (72)	1.22	1.32
41.06	.06 Ti (17)	1.40	1.62
40.64	...	1.82	w
40.17	.25 Fe (667)	1.37	1.40
	.24 V (98)		
3739.50	.53 Fe (—)	1.68	1.42 ?bl
39.18	.23 Ni (2)	1.06	1.16
	.12 Fe (75)		
38.29	.31 Fe (609)	1.11	1.21
37.94	.99 V (91)		0.93 bl
	38.07 Sun		
37.10	.13 Fe (5)		0.80
35.99	.93 Co (95)	1.16	1.16
	.98 Sm II (29)		
35.58	.66 Ti (—)	1.16	0.94
35.36	.32 Fe (388)	0.95	0.87
34.79	.88 Fe (21)		0.74
34.07	.14 Co (96)	1.03 bl	1.07 bl
33.30	.32 Fe (5)	0.75	0.84
32.72	.76 V II (15)	1.45	1.38
32.34	.39 Co (62)	1.25	1.07
	.40 Fe (76)		
31.95	.98 V II (92)	1.48	1.46
	32.03 Cr (2)		
31.67	.64 V II (101)	1.74	1.70
31.29	.27 Co (96)	1.46	1.48

λ_{obs}	Identif.	log I_1	log I_2
	.26 Zr II (112)		
	.26 Sm II (11)		
30.80	.81 Cr (2)	1.23	1.25
	.75 Ni (2)		
30.35	.39 Fe (533)	1.03	1.10
	.43 Ru (2)		
3729.75	.81 Ti (17)	1.38	1.53
	.74 Zr II (8)		
29.54	.49 Mn II (8)	1.77	w
29.29	...	1.77	1.75
28.92	.93 Ni (181)	1.53	1.57
	.89 Mn (24)		
28.64	.67 Fe (227)	1.59	1.68
	.68 Ti (116)		
28.33	.34 V II (116)		
	.42 Ce II (47)		1.48 bl
28.03	.03 Ru (2)		
27.62	.62 Fe (21)	1.11	0.84
27.40	.35 V II (21)		1.11
	.37 Cr II (117) ?		
26.95	.93 Ru (2)		1.08
	.93 Fe (385)		
	.93 Mn (24)		
26.46	...	1.59	1.68
26.03	.06 Fe (433) p	1.74	w bl
25.48	.50 Fe (534)	1.62	1.75
25.15	.16 Ti (83)	1.55 ?	1.25 ?
24.81	.83 Ni (182) ?	1.38	1.25
	.90 Sm II (5)		
	.94 Eu II (2)		
24.40	.38 Fe (124)	1.50	1.38
24.04	.11 Ti II (73)	1.27 ?	1.59
23.84	...	1.60 bl	1.57 bl
23.57	.63 Ti II (72)	1.45	1.62
23.17	...	1.43 ?	1.67 ?
22.56	.56 Fe (5)		0.94
	.57 Ti (17)		
22.21	.24 Fe (127) p		1.19
	.23 Fe (490) p		
21.95	22.03 Fe (291)	1.12	1.26
	22.00 V (91)		
21.55	.51 Fe (389)	0.93	1.06
	.61 Fe (437)		
	.63 Ti II (13)		
21.22	.19 Fe (491)	1.03 bl	1.19 bl
	.28 Fe (75, 705)		
20.78	...	1.35	1.26
20.56	...	1.16	1.13
20.20	.17 Fe II (23) ?	0.94	1.00
3719.96	.94 Fe (5)	0.44 ?bl	0.83 ?bl
18.83	.86 Zr II (9)	1.56 bl	1.44 bl
18.35	.41 Fe (292)	1.58	1.44
	.38 Ce II (37)		
17.81	.84 Fe (706) p	1.88	1.79
16.76	.71 Fe (434) p	1.65	1.68
16.42	.44 Fe (388, 705)	1.47	1.40
	.36 Ce II (40)		
16.14	...	1.93	1.74
15.89	.91 Fe (124)	1.73	1.71
15.43	.48 V II (15)	1.62	1.71
	.46 Cr II (145)		
15.15	.19 Cr II (20)	1.80	1.95
14.74	.77 Zr II (18)	1.90	1.95
13.65	.70 Ni (74)	w	w
	.73 Ti (116)		
13.31	.34 Ni (74)	1.85	w
12.90	.97 Cr II (12)	1.68	1.68
	13.02 Cb (3)		
12.47	.50 Cr (269)	1.84	w
	.53 V II (157)		
12.20	.18 Co (84)	1.76	1.79
11.86	.92 Fe (178) p	1.79 bl	1.85 bl

λ_{obs}	Identif.	log I_1	log I_2
	.95 Zr II (8)		
11.28	.22 Fe (228)	1.52	1.51
	.29 Cr II (—)		
10.81	.87 Sm II (19)	w	w
	.87 Eu II (14)		
10.28	.30 Y II (7)	1.82	1.63
	.22 Cr II (6)		
3709.92	.96 Ti (83)	1.65	1.71
	.93 Ce II (40)		
09.54	.54 Fe (435)	1.73	1.24 ?bl
09.25	.25 Cr II (6)	0.87	0.94
	.25 Fe (21)		
	.27 Zr II (45)		
08.90	.82 Co (98)	1.52	1.50
08.56	.60 Fe (178, 225)	1.58	1.55
	.62 Ti (268)		
08.24	.18 Fe (228) p	1.62	1.61
07.86	.83 Fe (5)	0.97	1.06
	.92 Fe (76)		
07.46	.44 Co (96)	1.39	1.36
	.55 Ti (177)		
07.01	.05 Fe (385, 392)	1.55	1.55
	.01 Co (85)		
06.58	.63 Zr (M)	1.95	1.95
06.05	.03 Ca II (3)	1.15	1.10
	.04 V (104)		
05.55	.57 Fe (5)	0.83	0.96
05.01	.04 V (29)	1.55	1.55
04.75	.70 V (29)	1.74	1.55 ?
04.38	.34 Fe (609)	1.45	1.45
	.30 Ti (117)		
04.05	.06 Co (35)	1.44	1.52
	.01 Fe (495)		
03.60	.56 Fe (291, 292)	1.21	1.25
	.58 V (29)		
	.70 Fe (389)		
02.90	.94 Ti (132)	1.85	w
02.40	.29 Ti (83)	1.76 bl	
	.50 Fe (46, 75)		1.66 bl
02.03	.03 Fe (369)	1.66	
01.82	.73 Mn (7)	1.90	w
	.81 La II (136)		
01.05	.09 Fe (385)	1.54	1.41
00.59	.60 Sun	w	w
00.25	.34 V II (116)	1.88	w
3699.80	.83 Sun	1.96	w
99.07	.15 Fe (490)	1.68	1.71
	.02 Co (145)		
98.60	.61 Fe (491)	1.76	1.71
98.10	.17 Zr II (71)	1.80	1.76
	.03 Fe (75) p		
97.45	.43 Fe (389)	1.33	
	.49 Zr II (7)		
96.90	.88 Ti (177)	1.76	1.78
	.91 Ni (172)		
96.58	.57 Mn (24)	1.31 bl	1.59 bl
95.88	.86 V (29)	1.78	1.78
	.86 Cr (217)		
95.52	.51 Fe (225, 707)	1.81	1.73
95.03	.05 Fe (229, 534a)	1.70	1.71
94.77	.82 Dy II (Sun)?	1.84	1.94
94.44	.44 Ti (117)	1.90	1.84
94.02	.00 Fe (394)	1.17	1.16
	93.99 Sm II (2)		
	93.93 Ni (15)		
93.74	.78 Fe (46) p	1.66	1.70
	.79 Fe (490) p		
93.40	.36 Co (64)	1.55?	1.84?
93.03	.01 Fe (439)	1.55	1.70
	.09 Cr (216)		
92.63	.65 Fe (Sun)	1.93	1.90
	.60 Zr II (56)		

λ_{obs}	Identif.	log I_1	log I_2
92.23	.22 V (29)	1.80	1.80
91.78	...	1.95	w
91.29	.30 Fe (Sun)	1.80	1.90
90.72	.73 Fe (807)	1.80	1.78
	.72 Co (16)		
90.39	.45 Fe (497, 570)	1.78	1.75
	.28 V (29)		
3689.89	.90 Fe (533)	1.73	1.75
	.92 Ti (18)		
89.40	.46 Fe (369, 386)	1.37	1.36
88.87	.88 Fe (179)	1.76 bl	1.62 bl
88.82	...	1.64 bl	
88.42	.42 Ni (5)	1.54	1.55
	.42 Eu II (2)		
	.46 Cr (48)		
88.11	.11 Cr (45)	1.54	1.62
	.07 V (29)		
87.47	.46 Fe (21)		0.92
	.47 V (114)		
87.11	.10 Fe (75)		1.15
86.73	.71 Ti (222)	1.73	1.70
	.80 Cr (44)		
86.21	.26 Fe (131)	1.66	1.66
	.26 V (70)		
	.18 Cr (44)		
85.96	86.00 Fe (385)	1.51	1.44
	.96 Ti (117)		
85.53	.55 Cr (44)	1.75	1.62
85.14	.19 Ti II (14)		1.16
84.49	.48 Co (99)	1.80	1.84
84.09	.11 Fe (292)	1.62	1.62
83.57	.62 Fe (130, 671)	1.85	1.90
83.03	.05 Co (99)	1.32	1.34
	.05 Fe (5)		
82.56	.53 Sun	1.70 bl	1.66 bl
82.17	.15 Fe (386) p	1.39	1.31
	.17 Fe (385) p		
	.23 Fe (772)		
81.61	.64 Fe (390)	1.73	1.84
	.69 Cr (89)		
81.20	.27 Fe (177)	1.90 bl	1.80 bl
	.23 Sun (Fe)		
80.89	.80 Fe (—)	1.66	
80.71	.68 Fe (568)	1.43	1.55
80.37	.39 Sun	1.65	1.62
3679.90	.92 Fe (5)	0.95	0.98
79.36	.33 Fe (228)	1.78	1.61
78.90	.98 Fe (124)	1.51	1.48
	.91 Zr II (101)		
	.86 Fe (131)		
78.24	.24 Ca (28)	1.73	1.66
77.91	.93 Cr II (12)	1.75	1.51 bl
	.86 Cr II (12)		
	.91 Sun (Fe ?)		
77.63	.63 Fe (291)	1.55	1.31
	.69 Cr II (12)		
77.30	.31 Fe (773)	1.28	1.16
	.48 Fe (125)		
76.84	.88 Fe (389)	1.73	1.70
76.56	.55 Co (145)	1.70	1.66
76.25	.31 Fe (228)	1.64	
	.33 Cr (89)		
75.93	...	1.97	w
75.70	.70 V (29)	1.81	w
75.24	.26 Sc II (10)	1.96	w
	.31 Ca (28)		
74.70	.77 Fe (369)	1.66	1.75
	.74 Zr II (9)		
	.69 V II (93)		
74.36	.41 Sun (Fe)	1.90	1.90
74.06	.06 Ni (15) p		1.31
	.15 Ni (32) p		

λ_{obs}	Identif.	log I_1	log I_2
73.07	.09 Sun	1.55	1.59
72.68	.69 Fe (180)	1.76	1.84
	.65 Zr II (1)		
72.10	. . .	1.92	w
71.61	.67 Ti (19)	1.72	1.68
71.22	.20 V (70)	1.82	1.98
	.20 Gd II (2)		
70.76	.81 Fe (133)	1.64	
70.41	.43 Ni (4)	1.36	1.40
70.01	.04 Fe (369)	1.65	1.58
	.04 Co (64)		
	.07 Fe (435)		
3669.47	.52 Fe (291)	1.48	1.44 bl
69.16	.15 Fe (457)	1.36	1.36
68.89	.89 Fe (229)	1.57 bl	1.56 bl
	.96 Ti (18)		
68.47	.49 Y II (46)	1.73	1.84
67.97	68.00 Fe (438, 569)	1.72	1.66
	.98 Ce II (40)		
67.22	.25 Fe (570)	1.82	1.78
66.88	.85 Fe (393) p	1.47	1.44
	.94 Fe (46)		
66.55	.54 Sc II (2)	1.65	1.56 bl
	.59 Ti II (116)		
66.22	.24 Fe (179, 389)	1.61	1.58
	.22 Rh (3)		
	.19 Cr (46)		
66.00	65.98 Cr (48)	1.63	1.75
65.65	.73 Sun	1.94	w
65.34	. . .	w	w
64.98	.98 Sun	1.80	1.75
64.60	.62 Y II (9)	1.33	1.37
	.60 Gd II (—)		
64.04	.10 Ni (4)		1.31
63.46	.46 Fe (229, 231)		1.51
63.24	.25 Fe (439)	1.58	
	.21 Cr (46)		
62.75	.73 Fe (490) p	1.73	1.70
	.84 Cr (46)		
62.51	. . .	1.78	1.95
62.17	.16 Co (115)	1.49	
	.24 Ti II (75)		1.55
61.88	.95 Ni (16)	1.62	
61.64	. . .	1.73	1.78
61.34	.36 Fe (179)	1.83	1.79
	.35 Ru (3)		
	.36 Sm II (6)		
60.65	.63 Ti (18)	1.63	1.73
	.64 Ce II (42)		
60.29	.33 Fe (323)	1.66	1.67
	.21 Sun		
3659.73	.77 Ti II (75)	1.70	1.64
59.48	.52 Fe (180)	1.59	1.67 bl
59.17	.23 Ce II (54)	1.78	w
58.84	. . .	1.80	w
58.53	.55 Fe (231)	1.82	1.97
57.96	.99 Rh (1)	1.32	1.29
	.94 Cr II (170)		
	58.02 Fe (438)		
57.73	.70 Ni (183)	1.62?	1.73?
	.71 Sun		
57.41	.42 Sun	1.78	w
57.06	.14 Fe (130)	1.72	1.95 bl
	56.96 Co (21)		
56.68	.71 V (115)	1.80	w
56.22	.26 Cr (46)	1.47?	1.62?
	.23 Fe (—)		
55.63	.68 Fe (M)	1.68	
55.42	.46 Fe (369)	1.49	1.51
54.97	.99 Fe (M)	1.76	1.83
54.60	.59 Ti (18)	1.51	1.58
	.62 Gd II (4)		
	.66 Fe (77)		
54.40	.44 Co (63)		
54.21	. . .		
53.84	.76 Fe (180)	1.58	1.58
53.44	.50 Ti (19)	1.38	1.83?
52.98	53.10 Ce II (38)	1.82	w
	53.02 Sun		
52.54	.54 Co (4)	1.62	1.70
52.21	.26 Fe (494) p	1.74	1.83
51.80	.80 Sc II (2)	1.26	1.29
51.45	.47 Fe (295)	1.40	1.40
51.07	.10 Fe (322, 674)	1.43	1.51
50.52	.54 Sun	1.64	1.74
50.26	.28 Fe (180)	1.47	1.53
3649.98	50.03 Fe (394)	1.47	1.51
49.76	.70 Fe (391) p	1.47	
49.38	.30 Fe (5)	1.17	1.16
	.33 Co (146)		
48.90	49.00 Cr (47)	1.55	1.65
	.97 V (115)		
	.82 Sun		
48.52	.53 Cr (47)	1.32	1.70?
47.81	.84 Fe (23)	0.87	1.02
	.84 Fe (569)		
47.40	.40 Cr II (1)	1.15?	1.40?
	.43 Fe (46)		
46.98	.96 Ce II (66)	1.55	1.55
	47.08 Co (118)		
46.48	. . .	1.62	1.73
46.16	.20 Ti (18)	1.54	1.63
	.19 Gd II (2)		
	.16 Cr (48)		
45.78	.82 Fe (496)	1.54	1.66
45.36	.43 La II (14)	1.06	1.20
	.39 Sm II (35)		
	.31 Sc II (2)		
45.03	.09 Fe (323, 495)	1.31	1.39
	44.99 Ca (9)		
44.68	.70 Ti (—)	1.27	1.31
	.70 Cr II (1)		
	.76 Ca (9)		
44.36	.41 Ca (9)	1.46	1.56 bl
43.68	.63 Fe (385)	1.20	1.27
	.72 Fe (233)		
43.14	.18 Co (99)	1.48	1.59
	.22 Cr II (1)		
42.69	.68 Ti (19)	1.08	1.24
	.78 Sc II (2)		
42.24	.28 Sun	1.50	1.74
41.81	.83 Cr (47)	1.54	
	.78 Co (99)		
41.33	.33 Ti II (52)	1.36	
40.96	41.01 Cr (47)	1.80	1.93
40.38	.39 Fe (295)	1.47	1.55
	.39 Cr (47)		
3639.80	.80 Cr (47)	1.65	
39.48	.44 Co (64)	1.50	1.58
39.24	.29 Y (M)?	1.60	1.75
38.78	.77 Sm II (—)	1.60	1.89
38.22	.30 Fe (294)	1.24	1.21
37.81	.86 Fe (385)	1.48 bl	1.47 bl
	.73 Fe (229)		
37.23	.25 Fe (180)	1.64	1.87
36.99	37.00 Fe (233)	1.57	1.59
36.58	.59 Cr (47)	1.35	1.20
36.14	.19 Fe (77, 568)	1.58	1.57
35.78	.82 Fe (321) p	1.92	1.92
35.40	.46 Ti (19)	1.47 bl	1.36 bl
35.19	.20 Ti (20)	1.50	1.36 bl
	.19 Fe (490)		
34.97	.94 Ni (33)	1.37	1.57 bl
34.63	.70 Fe (—)	1.56	1.36? bl

λ_{obs}	Identif.	log I_1	log I_2
	.71 Pd (1)		
34.31	.33 Fe (389)	1.31	1.17
	.29 Sm II (19)		
33.86	.84 Fe (440)	1.66	1.79
33.46	.46 Ti (—)	1.59	1.91
	.49 Zr II (102)		
32.99	.98 Fe (135)	1.22	1.38
	33.13 Y II (2)		
32.53	.56 Fe (437)	1.58	1.79
32.03	.04 Fe (496)	1.17	1.27
31.47	.46 Fe (23)	0.74	0.99
	.48 Cr II (170)		
	.48 V II (76)		
31.14	.10 Fe (322)	1.02	1.22
	.97 Ca (9)		
30.70	.74 Sc II (2)	1.17	1.27
	.75 Ca (9)		
30.30	.35 Fe (323)	1.54	1.64
3629.88	.91 Ni (182)	1.63	1.84
29.67	.74 Mn (8)	1.68	1.93 bl
29.32	.35 Sun	1.80	w
28.72	.71 Y II (9)	1.67	1.74
28.24	.25 Ce II (113)	w	1.90 bl
28.07	.09 Fe (77)	1.72	
27.72	.71 V II (76)	1.61	1.70
	.71 Ti II (62)		
27.37	.35 Fe (395) p	1.89	w
27.04	.05 Fe (808)	1.80	1.96
	.01 Sm II (30)		
26.71	.74 Sun (Fe)	1.80	1.98
26.10	.08 Ti (20)	1.69	
	.19 Sun		
25.69	...	1.89	
25.46	.51 Sun	1.80	1.98 bl
25.15	.14 Fe (323)	1.66	1.68
24.76	.73 Ni (2)	1.25	1.43
	.83 Ti II (52)		
24.26	.30 Fe (133)	1.69	1.66
	.34 Co (41)		
24.05	.06 Fe (570) p	1.52	1.51
	.11 Ca (9)		
23.77	.77 Fe (323)	1.47	1.56
	.79 Mn (8)		
23.45	.44 Fe (233, 438)	1.63	1.78
	.51 Fe (393) p		
	.51 Sun		
23.15	.19 Fe (180)	1.57	1.71
22.62	...	1.88	w
22.02	.00 Fe (295)	1.58	1.66
	.00 Fe (233) p		
21.68	.72 Fe (808)	1.71	1.62
21.43	.46 Fe (294)	1.53	1.51
21.13	.19 Fe (574) p	1.53	1.59
	.20 V II (76)		
20.93	.95 Y (8)	1.47	
	.88 Sun		
20.49	.50 V II (181)	1.50	1.76 ?
	.42 Co (116)		
20.26	.23 Fe (324)	1.56	1.63
20.03	.00 Fe (324) p	1.50?	1.27? bl
	.02 Ti (Sun)?		
3619.38	.39 Ni (35)	0.93	1.03
	.28 Mn (8)		
18.78	.77 Fe (23)	0.74	1.01
18.33	.30 Fe (324) p	1.12	1.23
	.39 Fe (295, 571)		
17.80	.79 Fe (496)	1.28	1.38
17.35	.32 Fe (—)	1.50	1.66
	.32 Cr II (147)		
16.98	17.09 Fe (535)	1.55	
	17.01 Sun (Fe)		
16.57	.57 Fe (—)	1.65	1.85

λ_{obs}	Identif.	log I_1	log I_2
16.19	.15 Fe (569) p	1.50	1.68
	.22 Sun		
15.82	.82 Nd II (69)	1.67?	1.98?
15.64	.64 Cr (3)	1.62?	1.94?
	.66 Fe (46)		
15.15	.19 Fe (569)	1.65?	1.95?
14.64	.67 Nd II (38)	1.42	1.40
	.55 Fe (—)		
14.10	.10 Co (64)	1.55	w?
13.78	.84 Sc II (2)	1.17	1.27
13.45	.45 Fe (672) p	1.48	1.55
13.12	.15 Fe (324)	1.48	1.54
	.08 Zr II (1)		
12.70	.74 Ni (6)	1.25	1.43
12.05	.07 Fe (325)	1.57	1.77
11.67	.70 Co (115)	1.56	
11.49	...	1.62?	1.85
11.08	.06 Y II (9)	1.59	1.78
10.54	.46 Ni (18)	1.03 bl	1.11 bl
10.16	.16 Fe (321)	1.07 bl	
	.15 Ti (58)		
3609.33	.31 Ni (16)	1.10	1.21
08.86	.88 Fe (23)	0.75	1.03
08.40	.40 Cr (252)	1.11	1.23
08.12	.15 Fe (325)	1.37	1.41
07.50	.54 Mn (8)	1.59?	1.82
06.66	.68 Fe (294)	1.11	1.27
06.36	.38 Fe (233) p	1.56?	1.85?
05.96	.92 Sun (Fe)		1.72
	06.06 Ti (303)		
05.34	.33 Cr (4)	0.75	
	.37 Co (20)		1.01
05.07	.05 Cr (49) p	1.62	
	.02 Co (97)		
04.70	.70 Sun (Fe ?)	1.81	1.88
04.28	.28 Ti (21)	1.56	1.68
	.28 Sm II (47)		
03.88	.86 Cr II (13)	1.47	
	.84 Ti (20)		
	.83 Fe (496)		1.33
03.68	.74 Cr (74)	1.54	
03.15	.20 Fe (295)	1.71	1.69
02.48	.53 Fe (324, 391)	1.46	1.46
	.46 Fe (322)		
02.00	.10 Fe (322)	1.54	1.69
	.08 Co (4)		
	01.93 Y II (9)		
01.63	.67 Cr (74)	w	w
01.20	.18 Zr (13)	w	w
	.16 Ti (172)		
00.72	.74 Y II (9)	1.88	1.97
	.80 Co (63)		
00.01	...	w	w
3599.58	.62 Fe (809)	1.96	1.97
	.53 Ni (121)		
99.04	98.98 Fe (322)	1.83	
	.15 Sun		1.83
98.69	.71 Ti (59)	1.94	
	.71 Fe (674)		
98.26	.27 Sun	w	w
97.69	.70 Ni (18)	1.40	1.59
97.28	...	w	w
97.02	.05 Fe (569)	w	1.83
96.54	.51 Co (118)		w
96.06	.05 Ti II (15)	1.71	1.73
95.81	.87 Fe (181)	1.96	1.89
95.56	.66 Fe (322)	1.94	1.89
95.27	.29 Fe (322)	1.71	
94.92	.87 Co (4)	1.77	
	.89 Sc II (40)		1.74
94.62	.63 Fe (322)	1.91	
94.05	.10 Fe (154) p	1.90	1.86

λ_{obs}	Identif.	log I_1	log I_2
	.00 Sun		
93.49	.49 Cr (4)	1.13	1.12
92.97	.92 Y (8)	1.85	1.85
92.57	.60 Sm II (39)	1.87	1.83
	.60 Nd II (—)		
92.03	.01 V II (4)	1.94	w
91.75	.75 Co (134)	w	w
91.41	.48 Fe (568)	1.83	
	.34 Fe (321)		1.83 bl
91.04	90.99 Fe (573)	w	
90.89	. . .	w	w
90.45	.48 Sc II (3)	1.50	1.48
3589.99	.97 Mn (25)	1.67	1.59
	90.08 Fe (440)		
89.65	.64 Sc II (3)	1.34	
	.74 V II (4)		1.45
89.41	.46 Fe (295)	1.67	
89.08	.11 Fe (23)	1.58	1.52
88.57	.62 Fe (325)	1.63	1.62
88.25	.23 Fe (47) p	1.90	1.78
	.30 Cr II (107)		
	.32 Zr II (10)		
87.66	.69 Fe (322) p	1.54	1.45
	.75 Y (—)		
87.01	86.98 Fe (23)	0.90	1.14
86.76	.75 Fe (325) p	1.47 bl	1.37 bl
86.49	.54 Mn (8)	1.64	1.57
86.16	.11 Fe (611)	1.58	1.43 bl
85.74	.71 Fe (23)	1.15	1.15
	.81 Co (100)		
85.30	.32 Fe (23)	1.02	1.08
84.95	.96 Fe (395, 611)	1.33	1.27
	.96 Gd II (7)		
84.65	.66 Fe (294)	1.31	1.27
84.55	.53 Y II (9)	1.80	1.60
83.91	.91 CN	1.72	1.55
83.70	.70 V (45)	1.64	1.55
	.68 Mn (25)		
83.34	.34 Fe (574)	1.54	1.55
82.98	. . .	1.64	1.69
82.64	.69 Fe (328)	1.50	1.46
	.56 Fe (181)		
82.29	.34 Fe (568) p	1.43	1.43
	.20 Fe (612)		
81.61	.64 Fe (295)	1.27 bl	1.15 bl
81.17	.20 Fe (23)	0.88	1.00 bl
80.91	.93 Sc II (3)	0.89	1.08
80.41	. . .	1.32	1.40 bl
3579.86	.83 Fe (573) p	1.77	1.60
79.49	.55 Gd II (89)	1.85	1.75
	.56 Sun		
79.00	.03 Co (41)	1.70	1.58 bl
78.70	.69 Cr (4)	1.51	1.40 bl
	.69 Ti II (117)		
78.44	.38 Fe (321)	1.01	1.00
77.80	.86 V II (78)	1.74	1.63
	.88 Mn (8)		
77.42	.46 Ce II (51)	w	
	.39 Sun		
77.22	.22 V II (78)	w	1.87
	.24 Ni (3)		
	.26 Co (41)		
77.03	. . .	1.93	1.96
76.76	.76 Fe (613a	1.84	1.72
	.76 Ni II (4)		
	.77 Gd II (51)		
76.33	.34 Sc II (3)	1.67	1.67
	.38 Ti II (76)		
75.94	.98 Fe (321, 328)	1.88	1.81
	.95 Ni (120)		
75.68	. . .	w	1.94
75.29	.25 Fe (322)	1.53	1.37?
	.36 Co (4)		
74.91	.94 Cr (74)	1.62	1.65
	.97 Co (21)		
74.36	.34 V II (78)	1.87	1.77
	.37 Fe (181)		
	.38 Cr (—)		
73.80	.84 Fe (181)	1.32	1.33
	.74 Ti II (15)		
73.37	.40 Fe (673)	w	1.89
73.00	.09 Zr II (9)	w	w
	.07 Sun		
72.53	.52 Sc II (3)	1.43	1.41
	.47 Zr II (1)		
72.00	.00 Fe (321)	1.21	1.20
	71.97 Cr (157)		
71.82	.87 Ni (5)	1.90	w bl
71.21	.23 Fe (46)	1.77	1.64
	.16 Pd (1)		
70.22	.11 Fe (24)	0.89	1.00
	.24 Fe (326)		
	.04 Mn (18)?		
3569.76	.80 Mn (18)	1.23	1.15
69.40	.37 Co (35)	1.34	1.27
	.49 Mn (18)		
68.90	.98 Fe (294)	1.65	1.48
	.94 V (122)		
	.83 Fe (673)		
68.40	.42 Fe (321)	1.81	1.70
	.43 Co (61)		
67.72	.70 Sc II (3)	1.67	1.66
67.35	.36 Fe (183)	1.88	1.88
67.00	.04 Fe (325)	1.79	1.62
66.76	.84 Sm II (—)	1.50	1.42
66.35	.37 Ni (36)	1.06	1.16
65.86	.83 Fe (371) p	1.06	1.42
65.38	.38 Fe (24)	0.84	1.05
	.33 Ti II (76)		
64.96	.95 Co (19)	1.28	1.64
	.95 Cr (308)		
64.52	.56 Fe (183) p	1.67	1.88
	.51 Fe (183) p		
64.08	.11 Fe (48)	1.80	1.98
	.12 Co (159)		
63.73	.71 V II (4)	w	w
63.11	.16 CN	w	w
62.53	.60 Fe (237) p	1.92	1.98
	.61 Sun		
62.13	.10 Co (115)	1.81	1.75
61.69	.75 Ni (2)	1.53	1.64
	.58 Ti II (15)		
61.26	.28 Sun (CN)	1.95	1.98
60.86	.89 Co (21)	1.66	
	.80 Ce II (51)		1.59
60.18	.16 Sun	1.67	
3559.84	.93 Ni (118)	1.96	1.85
	.78 Cr (89)		
	.82 CN		
59.69	.60 Co (17)	1.86	1.80
	.78 Cr (89)		
59.12	.10 Sm II (—)	1.79	1.80
	.08 Sun		
58.79	.77 Co (20)	1.85	1.80
58.50	.52 Fe (24)	1.01	1.26
	.54 Sc II (3)		
58.00	.08 Fe (572) p	1.84	1.83
57.75	. . .	w	w
57.36	. . .	w	w
57.09	.05 Gd II (22)	1.95	w
56.83	.88 Fe (327)	1.34	1.45
56.60	.68 Fe (325)	1.90	
	.61 Zr II (9)		
56.24	.18 Ti (—)	w	w

λ_{obs}	Identif.	$\log I_1$	$\log I_2$
55.80	.95 CN?	w	w
55.42	.46 Sun	1.86	1.88
54.94	.93 Fe (326)	1.48	1.36
54.47	.50 Fe (325)	1.79	1.62
	.44 Fe (395) p		
	.45 Sun		
54.30	...	1.65	1.73
54.10	.12 Fe (23)	1.73	1.68
53.74	.74 Fe (810)	1.73	1.66
53.44	.48 Ni (16)	1.64	1.59
53.17	.16 Co (137)	1.79	1.85
	.27 V (53)		
52.82	.83 Fe (321)	1.48	1.45
	.85 Ti II (15) p		
52.41	.42 Fe (182) p	1.77	1.83
51.99	.94 Zr II (1)		1.68 bl
	52.11 Fe (499)		
51.55	.53 Ni (5)	1.66	1.68
	.67 Co (57)		
51.06	.11 Fe (321) p	1.87	1.88
50.56	.59 Co (4)	1.79	1.75
50.17	.22 CN	1.88	1.93
	.22 Sun		
3549.82	.87 Fe (48)	1.75	1.83
49.36	.36 Gd II (7)	1.95	1.96
	.37 CN		
48.95	49.02 Y II (9)	1.85	1.88
	.91 CN		
48.54	.55 CN	1.92	1.83
	.44 Co (41)		
48.16	.20 Mn (18)	1.50	1.38
	.18 Ni (3.20)		
47.77	.80 Mn (18)	1.61	1.48
	.69 Zr (13)		
47.17	.20 Fe (321, 613)	1.80	1.80 bl
	.18 Sun		
46.75	.71 Co (41)	1.87	w bl
	.78 CN		
46.18	.21 Fe (183)	1.96	1.96
	.19 Ce II (131)		
45.80	.83 Fe (536)	1.57	1.62
	.80 Gd II (2)		
	.83 CN		
45.61	.64 Fe (321)		1.57
	.60 Ce II (44)		
45.17	.19 V II (5)	1.81	1.83
	.16 Ni (76)		
44.60	.63 Fe (239)	1.93	1.94
44.12	.09 CN	1.94	1.94
	.23 Sun		
43.70	.70 Fe (734)	1.96	1.88
43.31	.39 Fe (183)	1.75	1.71
	.53 Co (64)		
43.10	42.98 Co (19)	1.87	1.97
42.66	.65 Zr II (113)	1.90	1.85
	.56 Fe (321) p		
	.66 V (45)		
42.11	.08 Fe (326)	1.51	1.37
	.00 Ni (119)		
41.09	.08 Fe (326)	1.61	1.32
40.72	.71 Fe (23)	1.59	1.56
40.14	.12 Fe (329)	w	1.83
35.39.83	.90 CN	w	w
39.23	...	w	w
38.86	.77 Fe (811)	w	w
	.94 CN		
38.50	.55 Fe (137)	w	w
	.50 Sun		
38.24	.31 Fe (775)	1.89	1.71
	.24 V II (4)		
37.84	.90 Fe (327)	1.77	1.58
37.49	.40 Fe (239)	1.88	1.76

λ_{obs}	Identif.	$\log I_1$	$\log I_2$
37.16	.24 Ni (153)	w	1.97
	.25 Cr (50)		
36.97	.94 Zr II (10)	w	1.97
36.56	.56 Fe (326)	1.74	1.50 bl
36.03	.12 Sun	w	w
35.68	.63 Fe II (75)	1.83	1.76
	.73 Sc II (11)		
	.65 Sm II (44)		
35.35	.41 Ti II (98)	1.81	1.76
	.30 Cb (4)		
34.90	.91 Fe (48)	1.87	1.83
	.95 Sun		
34.54	.52 Fe (811)	1.96	1.93
34.21	.26 Sun	w	w
33.81	.87 Ti II (98)	w	1.97
	.76 V (53)		
33.31	.36 Co (5)	1.62?	
	.20 Fe (326)		1.32? bl
32.96	33.01 Fe (326)	1.68?	
32.57	.58 Sun (Fe)	1.69	1.68
32.05	.12 Mn (18)	1.65	1.49
	.00 Mn (18)		
31.73	.85 Mn (18) ?	1.72	1.72
	.71 Sun		
31.40	.43 Fe (182)	1.88	1.86
	.44 Cr (263)		
	.48 V II (4)		
30.75	.76 V II (5)	1.87 bl	1.77 bl
30.40	.38 Fe (326)	1.92	1.79
3529.81	.82 Fe (326)	1.62	1.42
	.82 Co (22)		
29.54	.53 Fe (537)	1.80	1.76
	.62 Ni (76)		
28.97	.94 Fe (23) p	1.65	1.65
	29.03 Co (5)		
28.60	.60 Os (1)	w	w
	.54 Gd II (23)		
28.31	.24 Fe (182) p	1.88	1.78
	.32 Sun		
27.86	.87 V II (117)	1.43	1.36
	.79 Fe (326)		
	.90 Fe (296) p		
27.60	.61 Sun	1.81	
26.82	.85 Co (4)	1.23	1.05
26.05	.04 Fe (6)	1.12	0.89
	.02 Fe (240)		
25.57	.62 Sun		1.50
24.87	.87 Ti II (118)	1.69	1.50
24.53	.54 Ni (18)	0.72	0.96
24.08	.08 Fe (239)	1.27	1.21
23.74	.70 Co (66)	1.79	1.67
23.39	.42 Co (21)	1.37	1.42
	.44 Ni (16)		
22.84	.90 Fe (330)	1.69	1.69
	.86 Co (159)		
22.24	.27 Fe (326)	1.80	1.77
21.82	.83 Fe (78)	1.68	1.58 bl
	.84 V II (57)		
21.53	.57 Co (20)	1.40	1.36
	.53 Cr (263)		
21.25	.26 Fe (24)	1.16 bl	1.21 bl
20.77	.85 Fe (238)	1.79	1.71
	.87 Zr II (19)		
20.48	.52 Ce II (55)	w	w
20.09	.08 Co (4)	1.51	1.45
	.02 V II (5)		
3519.70	.77 Ni (5)	1.44	1.45
	.67 Ti II (118) p		
	.60 Zr (13)		
18.87	.86 Fe (78)	1.75	1.67
18.32	.34 Co (36)	1.74	1.71
17.84	.89 Gd II (88)	w	w

λ_{obs}	Identif.	log I_1	log I_2
17.33	.30 V II (6)	1.81	1.78
	.38 Ce II (230)		
16.85	.84 Ti (167)	1.93	1.91
16.50	.40 Fe (442)	1.78	1.71
	.55 Fe (326)		
16.26	.23 Ni (123)	1.90	
15.74	...	1.79 ?	1.94 ?
15.43	.41 Fe (243)	1.52	1.47
15.12	.05 Ni (19)	0.95	1.27
14.90	...		1.05
14.67	.62 Fe (183)	1.60	1.49
	.64 Zr II (114)		
14.46	.48 Fe (47) p	1.68	1.67
	.42 V II (57)		
13.84	.82 Fe (24)	0.91	1.02
	.88 V II (117)		
	.93 Ni (17)		
13.52	.48 Co (5)	1.37	1.51
	.59 Fe (327) p		
13.03	.06 Fe (48)	1.70	1.63
	.03 Cr II (107)		
12.64	.64 Co (21)	1.51	1.51
	.67 Zr II (57)		
12.34	...	1.85	1.74
12.16	.22 Gd II (38)	1.83	1.73
	.24 Fe (326)		
11.78	.84 Cr II (2)	1.66	1.67
	.75 Fe (238)		
11.55	.63 Ni (152)	w	w
	.55 Zr II (124)		
	.63 Ti (22)		
11.20	.23 Sm II (12)	1.80	w
10.80	.84 Ti II (88)	1.68	1.60
10.32	.34 Ni (18)	0.78	1.03
3509.76	.84 Co (22)	1.45	1.46
	.84 Ti II (88)		
09.36	.32 Zr (15)	1.86	1.98
09.08	.12 Fe (326)	1.79	1.89
08.48	.49 Fe (442)	1.69	1.75
08.14	.09 Cr (—)	1.92	1.95
	.21 Fe II (4)		
07.69	.69 Ni (3)	1.77	1.81
07.37	.39 Fe (500)	1.86	1.96
	.39 Fe II (16)		
	.43 Ti (—)		
07.14	.14 Fe (835) p	1.78	1.77
	.21 Sun		
06.87	.84 V (81)	w	1.91
06.53	.50 Fe (130)	1.46	
	.57 V II (193)		1.32
	.58 Fe (327) p		
06.29	.31 Co (21)	1.26	
	.23 Fe (327)		
05.72	.67 Zr II (1)	1.87	1.91
	.69 V (81)		
05.34	.29 Sun	1.87	1.81
04.90	.89 Ti II (88)	1.87	1.46
	.87 Fe (131)		
04.66	.73 Co (135)	1.50	1.46
04.37	.43 V II (6)	1.87	1.89
	.46 Fe (371)		
03.98	...	w	w
03.60	...	1.93	w
03.40	.47 Fe II (4)	1.91	w
	.38 Cr (109)		
02.91	.86 Sun	w	w
	.99 Co (135)		
02.57	.60 Ni (3)	1.50	1.45
	.63 Co (6)		
02.26	.28 Co (21)	1.31	1.37
01.68	.73 Co II (2)	1.87	1.87
	.70 Sun		
01.33	.33 Zr (14)	w	w
00.84	.85 Ni (6)	1.43	1.48 bl
00.52	.56 Fe (238)	1.74	1.71 bl
00.27	.34 Ti II (6)	1.71	1.73 bl
3499.79	.88 Fe II (115)	w	w
	.82 V II (5)		
99.28	.27 Sun	w	w
99.00	.10 Ti (84)	1.85	1.80
	98.94 Ru (4)		
98.74	...	1.82	1.80
98.50	...	1.82	1.80
98.16	.19 Ni (2) p	1.63	1.45
	.18 Fe (326) p		
97.82	.84 Fe (6)	0.95	1.02

computed and tabulated wave-lengths are plotted on the vertical axis. The wave-lengths were determined using the quadratic dependence between the reading on the comparator and the wave-length.

The sources used for referring the elements and multiplets to the individual spectral lines were as follows:

a) Ch. Moore, A Multiplet Table of Astrophysical Interest. Revised Edition. 1945 (hereinafter RMT).

b) L. Gratton, Study of Spectra of K Giants, 1952, ApJ 115, 5.

c) B. Warner, Spectrum Line Identification 3184—4000 A in Late Type Giant Stars. 1963, Comm. Univ. Obs. London No. 59.

d) D. Davies, The Spectrum of Beta Pegasi. 1947, ApJ 106, 28,

e) K. O. Wright, A Study of Line Intensities in the Spectra of Four Solar Type Stars. 1948, Publ. Dominion Obs. 8, 1.

The full identification of the measured spectral lines is given in Tab. III. Listed in this table are the determined wave-length of the line (1), the decimals of the wave-length according to RMT, the element and the corresponding multiplet (2), and, from wave-length 4005 A, the central intensities of lines for HD 37 160 (3). Symbol w in the last column indicates that the line in question is very weak.

1.3. *Microphotometry of the spectrograms*

The spectrograms were measured on a recording compensation microphotometer Khol-F-3. The magnification for the microphotometric measurement was 1 : 80 or 1 : 160. Unfortunately, the spectral lines overlapping in the UV region of the spectrum of the analysed stars permitted no reliable determination of the profiles of all lines, nor the determination of their equivalent widths, so that our attention concentrated on slightly blended lines and lines with slightly distorted wings. The conversion proper of blackening to intensities was made by the graphical method given by Stankievič (1963). The processing of the spectrograms required the solution of a number of fundamental problems.

a) Important for the determination of the equivalent widths of spectral lines is the fitting of the level of the continuous spectrum. It was determined as follows: We looked up the regions of maximum blackening in the microphotometer tracings. Next we looked up, for the spectral region analysed, such regions in the Photometric Atlas of Solar Spectrum (1940) for which the authors of the atlas presume a continuous spectrum. The windows of the continuous spectrum thus found were mutually confronted and through them we passed the level of the continuous spectrum.

b) The equivalent line-widths were determined, with a few exceptions, partly by direct planimetric measurements of the areas, partly by the triangle method. The latter method consists in replacing, with sufficient accuracy, the resulting line profile by an isosceles triangle, whose area is well expressive of the equivalent line-width. We determined about 75 % of all areas by this method: the rest was determined by direct planimetric measurements, and only a very small number of

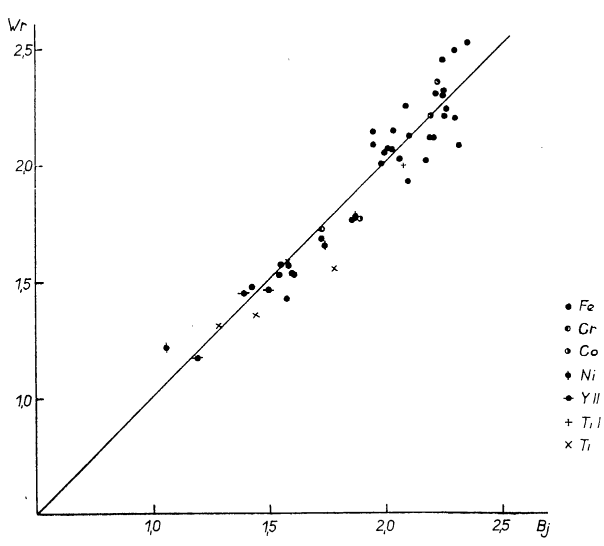

Figure 2.

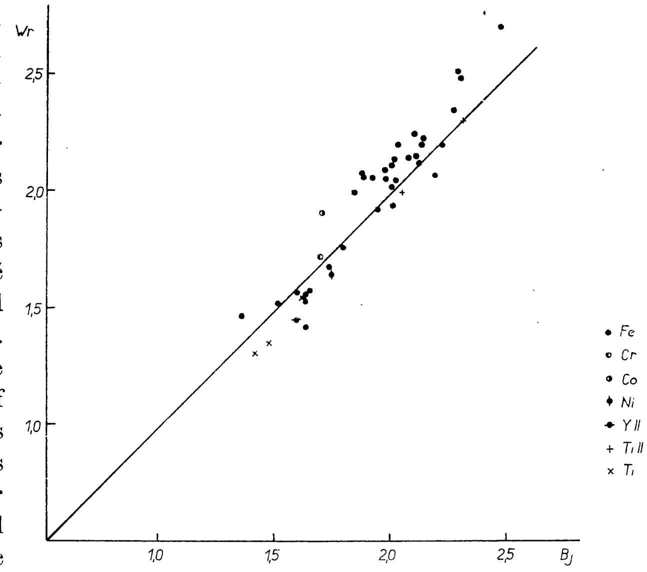

Figure 3.

areas had to be determined from the dependence between the central intensity of the line and its area. This area was determined from data obtained by triangles and planimetric measurements.

Taking into consideration the fact that these operations involve instrumental errors (focussing the spectrograph, focussing the photometer, microphotometer errors, etc.), errors resulting from the method of processing (graphical conversion of the blackening to intensities, errors in measuring and determining of areas, etc.) as well as errors due to the character of the spectra (continuous spectrum, blending, and the like) we have to be prepared, no matter how conscientious the procedure, that errors as large as 25 % may occur in individual cases. This value was determined by repeated independent processing of one and the same material; it is, on the whole, in keeping with the error in microphotometric measurements, as found and discussed by O. K. Wright (1948).

In spite of the fact that we have to take into consideration the individual differences in stellar spectra, it is worth while comparing the equivalent widths used by us with the values found by other authors. The number of papers dealing with the UV region and coming into consideration for this comparison is very limited at present, and therefore we used Wright's measurements (1948) of the solar spectrum. We obtained Figures 2 and 3 which compare the equivalent widths, as used by us, with the equivalent widths of the same lines in the solar spectrum, as given by K. O. Wright.

Table IV

Element	Mult	λ	χ	gf	log W/λ	log W/λ
Mg	3	3838.30	2.70	8.6	2.22	2.23
		3832.30	2.70	5.1	2.10	2.26
		3829.36	2.70	2.4	2.04	2.22
Al	1	3961.52	0.01	0.31	2.19	2.08
		3944.01	0.00	0.15	2.05	2.02
Si	1	3905.53	1.90	0.20	2.01	2.07
Ca	6	3973.71	1.89	0.34	1.85	1.79
		3957.05	1.88	0.36	1.74	1.66
	9	3624.11	1.87	0.18	1.73	1.67
		3644.41	1.89	0.36	1.76	1.78
Sc	7	4020.40	0.00	2.4		1.21
	8	3911.81	0.02	3.3	1.48	1.36
		3907.48	0.00	2.7	1.36	1.19
Sc II	2	3613.84	0.02	2.2	1.93	2.06
		3651.80	0.01	0.39	1.80	1.82
	3	3572.52	0.02	1.1	1.95	2.02
	11	3535.73	0.31	0.46		1.56
Ti	12	3998.64	0.05	1.5	1.61	1.79
		3989.76	0.02	1.0	1.65	1.86
		3981.76	0.00	0.82	1.67	1.60
		4024.57	0.05	0.22		1.60
		4008.93	0.02	0.17		1.70
		3962.85	0.00	0.17	1.60	1.70
	13	3958.21	0.05	1.00	1.65	1.82
		3956.34	0.02	0.84	1.69	1.76
		3924.53	0.02	0.21	1.53	1.60
		3929.88	0.00	0.16	1.66	
	14	3947.77	0.02	0.20	1.67	
	15	3900.96	0.02	0.15	1.57	1.35
	17	3752.86	0.05	1.3	1.64	1.59
		3741.06	0.02	0.79	1.46	1.45
	19	3653.50	0.05	2.0	1.59	1.60
	80	4060.26	1.05	0.71		1.07
Ti II	13	3759.29	0.60	2.2	2.07	2.09
	15	3596.05	0.60	0.19	1.49	1.54
V	7	3902.25	0.07	0.55	1.46	1.59
		3875.07	0.04	0.45	1.46	1.38
	9	3818.24	0.00	0.38	1.79	1.87
	27	4115.18	0.29	1.3		1.72
		4116.47	0.27	0.52		1.50
	28	3822.89	0.29	0.25	1.75	1.64
	29	3704.70	0.29	1.1	1.35	1.68
		3705.04	0.27	0.35	1.40	1.68
		3688.07	0.29	0.86	1.48	1.57
		3675.70	0.27	0.18	1.06	1.15
		3690.28	0.26	0.64	1.20	
V II	4	3592.01	1.09	1.7	0.84	1.07
	5	3545.19	1.09	2.1	1.41	1.44
Cr	4	3593.49	0.00	1.4	2.02	2.09
		3605.34	0.00	1.0	2.12	2.14
	23	3916.24	0.96	0.064	1.06	
	38	3963.69	2.53	22	1.50	
		3991.12	2.53	11	1.28	
	47	3639.80	2.53	15	1.41	1.10
Mn	2	4030.76	0.00	0.33		2.30
		4033.07	0.00	0.23		2.15
		4034.49	0.00	0.13		2.02
	5	4055.54	2.13	3.0		1.55
		4035.73	2.13	2.4		1.72
	6	3843.98	2.18	0.76	1.36	1.62
		3823.89	2.15	1.2	1.71	1.82

Element	Mult	λ	χ	gf	log W/λ	log W/λ
		3839.78	2.18	0.76	1.62	1.70
	7	3701.73	2.13	0.25	1.20	
	8	3586.54	2.13	4.0	1.69	1.73
		3629.74	2.15	0.79	1.38	1.24
	18	3531.85	2.27	3.0	1.66	
Fe	4	3886.28	0.05	0.14	2.19	2.25
		3906.48	0.11	0.012	1.86	1.96
		3824.44	0.00	0.061	2.10	2.27
		3856.37	0.05	0.070	2.26	2.24
		3895.66	0.11	0.032	2.01	2.01
		3922.91	0.05	0.042	1.91	2.21
		3930.30	0.09	0.062	1.96?	
		3927.92	0.11	0.061	1.96	
		3920.26	0.12	0.032	1.93	2.19
	5	3719.94	0.00	0.52	2.46	
		3737.13	0.05	0.32		2.36
		3748.26	0.11	0.15		2.27
		3679.92	0.00	0.059	2.12	2.23
		3705.57	0.05	0.079	2.10	2.18
		3733.32	0.11	0.076	1.99	2.23
	20	3820.43	0.86	2.7	2.44	2.36
		3825.88	0.91	1.9	2.20	2.29
		3840.44	0.99	0.57	2.18	2.21
		3887.05	0.91	0.20	1.93	2.12
		3878.02	0.95	0.32	2.00	1.96
		3872.50	0.99	0.23	2.02	2.21?
		3865.53	1.00	0.25	1.96	
		3917.18	0.99	0.026	1.50	1.55
	21	3749.49	0.91	2.7		2.30
		3758.24	0.95	2.2	2.29	2.31
		3763.79	0.99	1.3		2.27
		3767.19	1.01	0.97	2.13	2.28
		3727.62	0.95	0.57		2.21
		3743.36	0.99	0.48	2.10	2.14
		3798.51	0.91	0.20	1.99	2.08
		3799.55	0.95	0.33	2.3?	2.23
		3795.00	0.95	0.43	2.11	2.12
	22	3790.10	0.99	0.045		1.92
	23	3618.77	0.99	1.9	2.25	2.18
	36	3608.86	1.01	2.0	2.27	2.18
		3589.11	0.86	0.050	1.73	1.88
	3	3585.32	0.95	0.33	2.04	2.15
	24	3521.26	0.91	0.32	1.99	2.07
	43	4045.82	1.48	5.3		2.22
		4063.60	1.55	2.5		2.19
		4071.74	1.60	2.3		2.13
		4005.25	1.55	0.87	2.06	2.05
		4143.87	1.55	0.76		2.04
	45	3827.82	1.55	3.4	1.99	2.26
		3888.52	1.60	0.96	1.86	2.03
	74	3776.45	2.17	0.11	0.87	
	124	3724.38	2.27	1.2	1.62	1.60
		3885.51	2.41	0.44	1.25	
	175	3859.21	2.39	1.0	1.71	
	278	3956.68	2.68	2.1	1.63	
	294	3606.68	2.68	13		1.93
		3621.46	2.72	9.9	1.56	1.79
		3638.30	2.75	5.6		1.98
	295	3603.20	2.68	6.3	1.51	1.73
	326	3541.08	2.84	12		1.88
Co	4	3526.85	0.00	0.48	2.05	2.08
		3594.87	0.17	0.19	1.60?	1.59
		3550.59	0.17	0.058	1.50	1.55
	18	3873.12	0.43	0.50	1.88	1.96
	20	3521.57	0.43	0.55	1.84	1.81
		3558.77	0.58	0.026	1.05	
	21	3505.28	0.43	2.0	1.98	2.00
		3506.31	0.51	1.7	2.00	2.05
		3560.89	0.63	0.33	1.52	1.77
	31	3995.31	0.92	1.4	1.67	1.78

Element	Mult	λ	χ	gf	log W/λ	log W/λ
	34	3845.47	0.92	2.0	1.69	1.75
Ni	3	3507.69	0.16	0.0080	1.32	1.36
	4	3670.43	0.16	0.020	1.68	1.53
		3664.09	0.27	0.030		1.60
	18	3524.53	0.03	0.85	2.20	2.26
		3510.34	0.21	0.43	2.08	2.09
		3610.46	0.11	0.15	1.91	
	33	3807.14	0.42	0.14	1.72	1.88

Element	Mult	λ	χ	gf	log W/λ	log W/λ
		3775.57	0.42	0.12	1.73	1.75
Y	8	3620.95	0.07	1.2	1.67	1.66
Y II	6	3950.35	0.10	0.20	1.08	1.20
	9	3611.06	0.13	0.70	1.53	1.44
		3628.71	0.13	0.17	1.48	1.42
Zr	9	3896.53	0.07	0.030	1.23	1.23

1.4 Oscillator strengths

The curve of growth represents, in principle, the dependence between the equivalent width of a spectral line and the product Nf, where N is the number of effective atoms and f the oscillator strength. Used, at present, are oscillator strengths determined by one of the following methods: laboratory methods, theoretical intensities, solar or stellar intensities determined from the solar curve of growth and the stellar curves of growth, respectively.

A few years ago, C. H. Corliss and W. Bozman (1962) published laboratory values of oscillator strengths for a large number of spectral lines and elements. A large part of the published data is on lines in the UV spectral region. Moreover, as is seen when comparing their values with the quantities found by other authors, the oscillator strengths given in Experimental Transition Probabilities of Spectral Lines of Seventy Elements, represent a sufficiently ample, homogeneous and reliable material for determining the curves of growth of the stars analysed. In the following we shall therefore use these oscillator strengths. The results obtained on this basis are virtually identical with those obtained for both stars independently from solar intensities determined from the solar curve of growth (Goldberg, Pierce).

1.7 Material used—summary

The basic data used are summarized in Tab. IV. The values are classified according to the individual elements and, within this classification, according to growing multiplets. Table IV lists data only concerning unblended lines or lines with negligible overlap. Hence we could dispense with notes on the dependability of the measurements. The quantities concerning the excitation potential and the values of oscillator strengths (gf) were taken directly from RMT or Corliss' and Bozman's tables.

Table IV. lists: in the first column the element, in the second column the multiplet according to RMT, followed by the wave-length of the line, the excitation potential (from RMT), the oscillator strength (as given by Corliss) and, eventually, the logarithm of the equivalent width divided by the wave-length in units of 10^{-6} A for HD 37 160 and HD 188 512, in the last column.

Part II

2.1. The curve of growth

One of the methods most used for analysing stellar spectra, determining the chemical composition of stellar atmospheres, is the curve-of-growth method. It is relatively fast and gives sufficiently accurate results, even for less reliable observational materials.

The analysis of stellar spectra by the curve-of-growth method is rooted, today, in one of the two existing conceptions of the structure of stellar atmospheres. The first (S. S. model) assumes that the star itself emits a continuous spectrum and that absorption, and hence also the absorption spectrum, only results from a relatively thin reversing layer. The second concept (M. E. model) assumes that the spectrum forms all over the extensive atmosphere, so that the ratio $\eta = \frac{\alpha\nu}{\varkappa\nu}$ between the line coefficient and the coefficient of continuous absorption is independent of optical depth.

In practice, however, the curve of growth has to be constructed with certain simplifying assumptions, such as that Planck's function is a simple (e.g. linear) function of temperature. This method permits us to determine, for certain given conditions, the theoretical curve of growth which represents the exact dependence between the equivalent width $\log \frac{W}{\lambda}$ of the spectral line and the quantity $\log N \frac{\alpha_0}{\varkappa_\lambda}$, where N is the number of active absorbing atoms above the photosphere, α_0 the atomary coefficient of absorption in the line, $\varkappa_\lambda$ the coefficient of continuous absorption. This relation may also be written in the form

$$\log \frac{N_{rs}}{\varkappa_\lambda} \frac{\pi \varepsilon^2}{mc} \frac{c}{V_0 \nu \sqrt{\pi}} f \tag{1}$$

where V_0 is the atom velocity, f the oscillator strength, symbols π, ν, ε, m, c have their conventional meaning. From the measured equivalent widths and known oscillators strengths we may draw empirical curves of growth for the individual stars. Comparing these empirical curves of growth with suitable theoretical curves, we may determine the corresponding parameters of the atmosphere.

Theoretical curves of growth have been designed by a number of authors for simplified conditions. M. Wrubel (1949) drew a number of suitable curves for the M. E. model and for different parameters of the atmosphere. These curves have been used in our considerations.

The empirical curves of growth of the stars analysed were constructed using the equivalent widths given in Tab. IV. Drawing the curves, we plotted on the horizontal axis the values

$$\log X_f = \log gf\lambda - \Theta\chi_{rs} \tag{2}$$

where gf is the oscillator strength, $\Theta = \frac{5040}{T_{\text{exc}}}$, ($T_{\text{exc}}$ is the excitation temperature), χ_{rs} is the excitation potential. The oscillator strengths were taken from Corliss and Bozman's tables (1962), the excitation potentials from RMT. The preliminary temperature values of both stars were estimated from their spectral type and the value accepted for the curve of growth was $\Theta = 1.20$ in both cases.

The character of the spectrograms did not permit an arbitrary selection of spectral lines, and hence we concentrated our attention on unblended, or very slightly blended iron lines. The empirical curves of growth determined this way were compared with the theoretical curves of growth constructed by M. Wrubel (1949). Plotted on the horizontal axis in these curves is the quantity

$$\log \eta_\nu = \frac{\alpha_\nu}{\varkappa_\nu} N_{ri} \tag{3}$$

where α_ν is the coefficient of absorption in the line, $\varkappa_\nu$ the coefficient of continuous absorption and, eventually, N_{ri} the number of actively absorbing atoms of the given element, at the stage of ionization i and excitation r, per 1 g of hydrogen. Wrubel's curves are computed for different parameters $\frac{B_0}{B_1}$ where B_0 and B_1 are coefficients of the linear dependence of Planck's function on optical depth τ, that is

$$B(\tau) = B_0 + B_1\tau \tag{4}$$

and the relation between them is

$$\frac{B_0}{B_1} = \frac{8}{3} \frac{\varkappa_\lambda}{\varkappa} \frac{1 - e^{-u}}{u} \tag{5}$$

where $U = \frac{h\nu}{kT}$, T designating the limiting temperature and k being a constant.

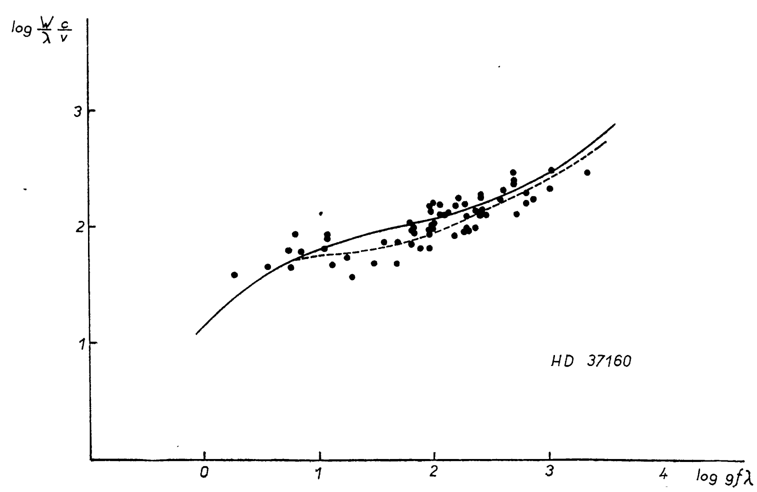

Figure 4.

For comparing the empirical curves of growth with the theoretical curves we used those of Wrubel's curves in which $\frac{B_0}{B_1} = 1/3$.

The shape of the curves of growth depends on a range of additional factors. Important among them is damping. Wrubel computed theoretical curves of growth for different values of the coefficient of damping (log a), so that the comparison itself of the theoretical and empirical curves of growth is relatively very simple.

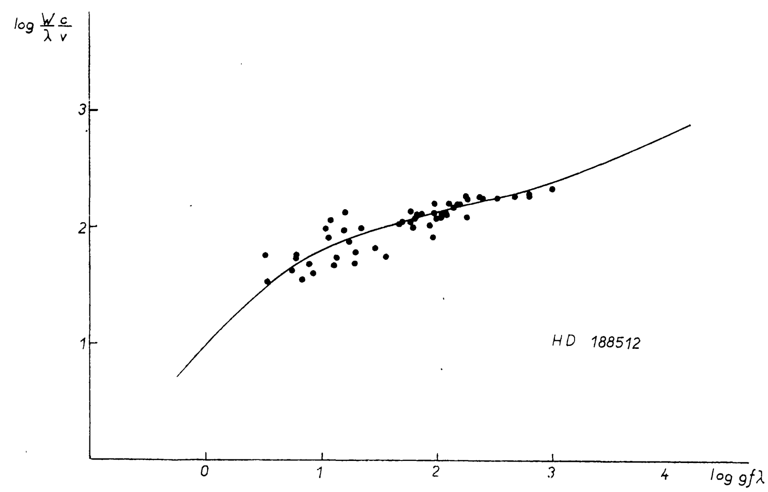

Figure 5.

This comparison is in Figs. 4 and 5. The diagrams give for the unblended Fe lines the empirical curves of growth of both stars analysed. The full line in the diagrams represents Wrubel's curve of growth of the parameters mentioned. It is seen that for HD 188 512 the theoretical and empirical curve of growth virtually cannot be told apart. For HD 37 160, on the other hand, the difference between the theoretical and empirical curve of growth is well apparent, and it indicates certain peculiarities in the atmosphere. It appears that the macro- and microturbulent motions in the atmosphere are more involved than assumed in the model used. Possible, moreover, are departures from LTE. These last surmises, however, could not be investigated more in detail in the material available. Such an investigation requires a larger number of unblended lines which, however, do not exist in the region we examine.

2.2 Determination of the excitation temperature

If we are to bring all lines of a given element at the same stage of ionization into a single empirical curve of growth, the curve ought to be drawn from lines which form for transitions from different levels. If the assumed Boltzmann distribution of atoms is satisfied, the number of atoms at a given level s and in a ionization stage r equals

$$N_{rs} = N_r \frac{g_{rs}}{u_r(T)} e^{-\chi_{rs}/kT} \quad (6)$$

where g_{rs} is the statistic weight of the respective state, $u_r(T)$ the partition function, k the Boltzmann constant and T temperature. The optical depth in the centre of the line may be expressed (cf. e.g. Aller, 1960) in the form

$$X_0 = N_{rs} \frac{\pi \varepsilon^2}{mc} f \frac{1}{\sqrt{\pi}} \frac{c}{V_0 \nu_0} \quad (7)$$

(ν_0 being the frequency in the centre of the line) or in the form

$$\log X_0 = \log N_r + \log g_{rs} f\lambda - \Theta_{\chi_{rs}} - \\ - \log V_0 u(T) + \log \frac{\sqrt{\pi}\, \varepsilon^2}{mc} \quad (8)$$

For a given element all quantities on the right-hand side are constant, so that we may write

$$\log X_0 = \log C_{rT} + \log gf\lambda - \Theta_{\chi_{rs}} \quad (9)$$

log $gf\lambda$ is known for each line, and hence we may construct for each line the diagram of the dependence between the equivalent width log $\frac{W}{\lambda}$ and quantity log $gf\lambda$, which is the curve of growth. If we wish to have a single curve of growth we have to displace the thus determined partial curves of growth in horizontal direction. The value of this shift equals

$$\log Y = \log X_0 - \log gf\lambda = \log C_{rT} - \Theta_{\chi rs} \qquad (10)$$

It is seen that the displacement depends upon value Θ and on the excitation potential. It is evident that the slope of the straight line expressed by equation (10) gives directly the value Θ_{exc}, that is, value T_{exc} may be made more precise.

The determination of the excitation temperature is one of the important steps in determining stellar parameters. This question is especially important for late type stars, for the excitation temperature is actually one of the few quantities accessible to direct measurement which may be used for determining other parameters.

The number of multiplets and lines apt for determining the excitation temperature is rather

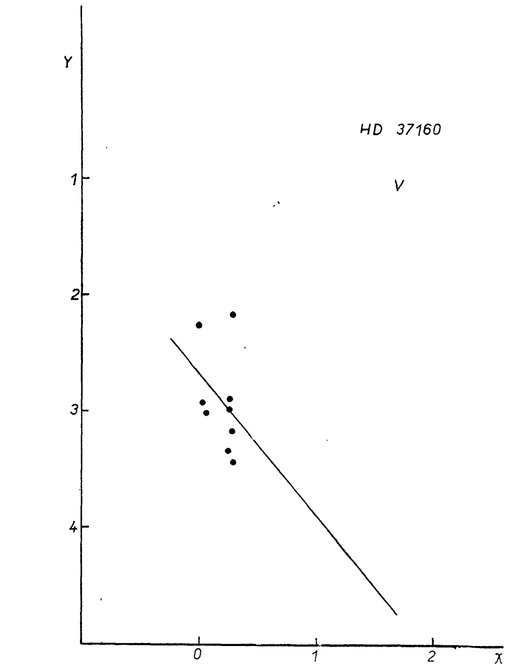

Figure 6.

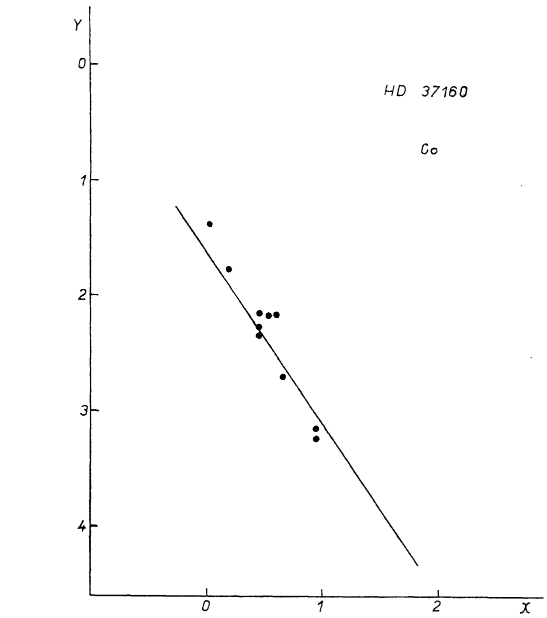

Figure 7.

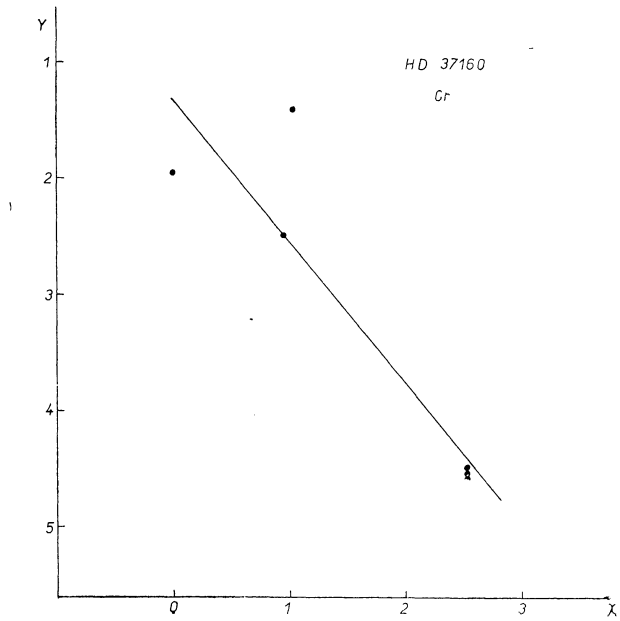

Figure 8.

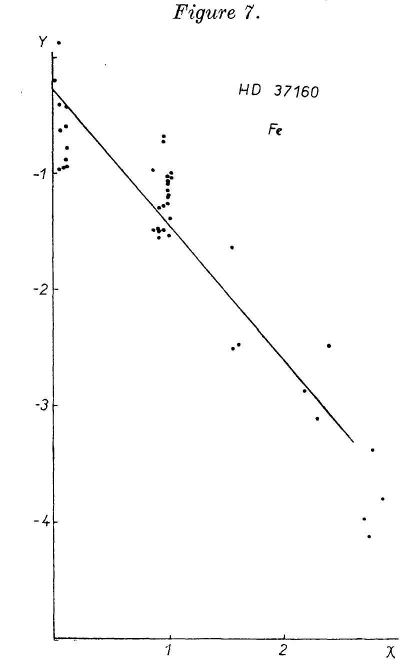

Figure 9.

small in the observational material analyzed. The most suitable are the Fe lines which are also sufficiently represented, and the shift of the empirical curve of growth determined from them is the most reliable.

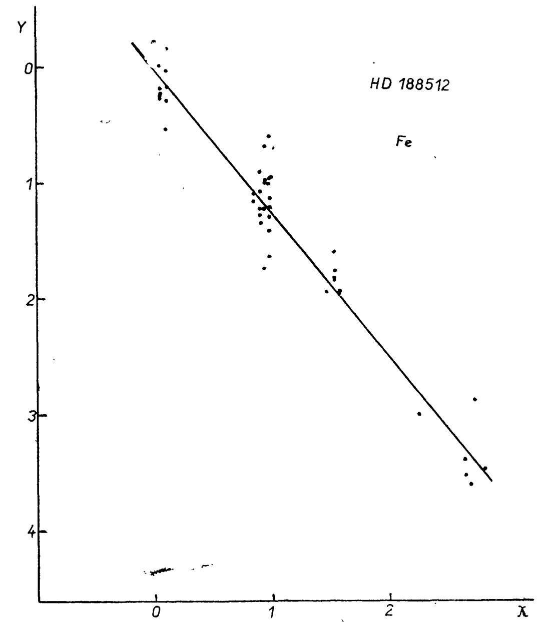

Figure 10.

The procedure mentioned was carried out and the results are given in Figures 6 through 12. The dots in them indicate the displacement of the individual lines, since many multiplets are only represented by individual lines. The total values are in Tab. V giving, in addition to the values obtained for both stars, the weighed averages of T_{exc}. It should be added that the weights given in Tab. II are rounded-off values of the weights

Table V

Excitation temperatures

HD 37 160			HD 188 512		
Element	Θ_{exc}	Weight	Element	Θ_{exc}	Weight
Fe	1.151	5	Fe	1.231	5
V	1.219	1	Co	1.354	1
Cr	1.219	0.5	V	1.057	1.5
			Mn	1.029	
	1.168			1.193	

obtained from the individual values. For HD 37 160, Θ_{exc} is higher that expected, for instance, from the spectral type. It should be noted, however, that Greenstein and Keenan (1958) also accepted an equally higher value ($\Theta = 1.08$) on the basis of Keenan's paper (1951).

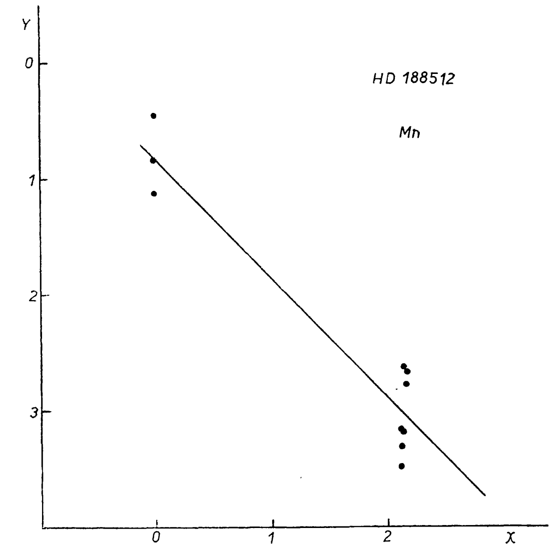

Figure 11.

Table VI

Effective temperatures

Star	Spectrum	T_{exc}	T_{eff}	Author
HD 37 160	KO III	4315	5260	this paper
	KO IV		4650	Unsöld (1955)
HD 188 512	G8 IV	4225	5150	this paper
	G8 III		4440	Unsöld (1955)
ε Vir	G8 III		4940	Cayrel (1963)
ε Tau	KO III	4245	5180	Helfer Wallerstein (1964)

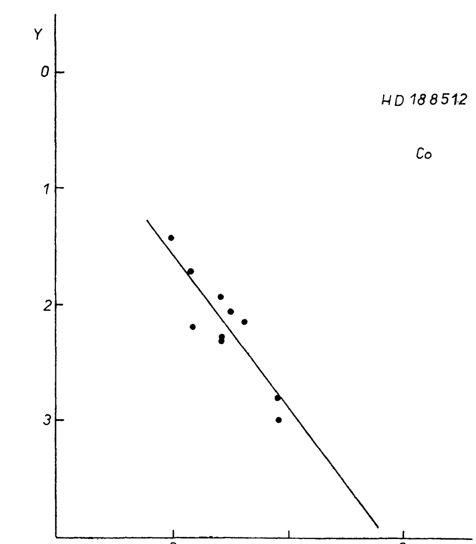

Figure 12.

Tab. VI lists the T_{exc} values and, together with them, the T_{eff} values as determined from relation

$$T_{eff} : T_{exc} = 1 : 0.82 \qquad (11)$$

on the basis of T_{exc} from Tab. V. Given, in addition, are temperature values determined by other authors for similar stars and, eventually, the temperatures, determined from the spectral type (according to Unsöld, 1955).

The temperatures determined by us are, in general, slightly higher than those obtained from the spectral type, and also in comparison with other papers. The differences, however, are not essential and we shall use the values, as determined by us.

2.3 Velocities in the atmosphere

By comparing the theoretical and empirical curves of growth we may also determine other parameters of the atmosphere. If the shape of the theoretical and empirical curve is to be equal, there must also be shift in vertical direction. The value of this shift gives directly $\log \frac{c}{V_0}$ where V_0 is the velocity of atoms in the atmosphere.

The velocity V_0 of atoms in the atmosphere is made up of two components; of the motion due to the existing temperature T (hereinafter V_{Temp}) and of the turbulent motions V_{Turb}. The mutual relation between these velocities is

$$V_0^2 = V_{Temp}^2 + V_{Turb}^2 = \left(\frac{2kT}{M}\right)^2 + V_{Turb}^2 \qquad (12)$$

where M is the atomic weight of the given element, k a constant and T temperature.

We could actually only use the spectral lines of iron for the stars analyzed. The results are interesting and would, especially for HD 37 160, require a more detailed analysis, but the nature of the material made it impossible to obtain further sufficiently reliable results. This applies to the distribution of turbulent velocities and to their dependence on the excitation potential, and to the turbulent velocities of further elements.

The results are summarized in Tab. VII, which gives the values V_{Turb} of the turbulent velocities for both stars.

Comparing the velocities obtained for the two stars we see virtually no higher velocities in the atmosphere of HD 188 512, while, in HD 37 160, velocities are slightly above normal limits. It is not excluded that the turbulent motion determined is due in part to the character of the spectrum (weak atom lines, etc.,) and to the peculiar conditions in the atmosphere.

Table VII

Star	V_0	V_{Turb}
HD 37 160	9.6 km sec^{-1}	9.5 km sec^{-1}
HD 188 512	2.2 km sec^{-1}	0.8 km sec^{-1}

2.4 Electron pressure

The electron pressure plays an important role in the atmosphere and, as will be seen from equation (13), it has to be known as a secondary factor for the determination of the chemical composition of stellar atmospheres. The number of reliable electron-pressure values determined for late-type giants directly from observations is scarce. The relation between P_ε, T_{eff} and gravitation for cool stars is, for instance, given by Aller (1953), who found only small variations in P_ε in the region of the given values, gravitation, however, being of major importance. Aller's diagram shows, at first sight, that $\log P_\varepsilon$ ranges between —0.9 and +1.5 within the interval of temperatures which apply to late spectral types.

The electron pressure may be determined from Saha's formula, provided we know the number of atoms of the same element in two succesive ionization stages. In the spectra of the stars analyzed we may use lines Ti and Ti II, V and V II, Sc and Sc II, Y and Y II for determining the electron pressure. The effect of further ionization stages is already negligibly small.

The $\log P_\varepsilon$ values, as obtained from the ratio of the number of atoms by Saha's formula are in Tab. VIII, which gives, among others, also the weights of the individual values.

From these $\log P_\varepsilon$ values we may estimate the coefficient $\bar{\varkappa}$ of continuous absorption, which is a function of temperature and electron pressure. It is due to the absorption by the atoms of the negative hydrogen ion, by atoms of hydrogen, helium, metals and molecules. The contribution of the absorption by metals and molecules to total absorption is not known well enough. The contribution of hydrogen and helium is negligible in the first approximation, so that absorption is mainly due to negative hydrogen ions.

The mean coefficient $\bar{\varkappa}$ was determined from M. S. Vardya's (1964) values, who determined the

Table VIII

Electron pressure

Star	Element	$\log P_\varepsilon$	Weight
HD 37 160	Ti	+0.45	15
	Sc	+0.33	5
	V	+0.94	6
	Y	+1.71	4
		+0.656	S.E. ± 0.007
HD 188 512	Ti	+0.26	16
	Sc	+0.09	8
	V	+0.71	7
	Y	+1.26	4
		+0.425	S.E. ± 0.004

coefficient of opacity for a broad region of $\log P_\varepsilon$ and Θ. He took into consideration different ratios He vs. H of atoms and the ratios of metals vs. hydrogen. Computing $\log \bar{\varkappa}$ he considered different hydrogen states, different helium states and also the dispersion, etc. These tables permitted to determine by interpolation for Θ and P_ε, as found, the values of $\log \bar{\varkappa}$ for the composition He : H = = 1 : 8 and the ratio of metals vs. hydrogen 0.00201 (Tab. Vardya No. 20). So we have

$$\log \bar{\varkappa}_{HD37\,160} = -0.90, \ \log \bar{\varkappa}_{HD188\,512} = -1.16$$

These values are naturally higher than those we would obtain if we only considered the absorption H^- according to Chandrasekhar and Münch's tables (1946).

2.5 *The chemical composition of stellar atmospheres*

We have, today, two methods of determining the chemical composition of stellar atmospheres, but it is difficult to draw a line between them. The first method is based on the computation of the atmosphere model from certain accepted parameters, the second, used more frequently, is based upon the interpretation of the curve of growth. The second method is relatively fast and gives sufficiently good results, even from less reliable observational materials. However, we have to introduce certain simplifying conditions, such as the presumption that the determined values (electron pressure, temperature, etc.) apply to the atmosphere throughout and do not change with optical depth.

In practice it is of advantage to solve the problem of the chemical composition of a given stellar atmosphere by comparing the results obtained with the parameters of a known star. In our case, we shall use the Sun for this purpose.

Comparing the theoretical and empirical curve of growth we have

$$\log N_r = [\log X_0 - (\log gf\lambda - \Theta_{\chi_{rs}})] + \log V_0 u(T) + \log \bar{\varkappa} - \log \frac{\sqrt{\pi}\, \varepsilon^2}{mc} \qquad (13)$$

The meaning of the individual symbols is conventional. Equation (13) applies to every ion. It is evident that

$$\log X_0 - (gf\lambda - \Theta_{\chi_{rs}}) \qquad (14)$$

is the shift in horizontal direction in the empirical curve of growth in comparison with the theore-

Table IX

Relative abundances

Element	HD 37 160				HD 188 512				
	Number of lines	log N*	$\log \frac{N^*}{N_{Fe}}$	$\log \frac{N^*/N_{Fe}}{N^\bullet/N_{Fe}}$	Number of lines	log N*	$\log \frac{N^*}{N_{Fe}}$	$\log \frac{N^*/N_{Fe}}{N^\bullet/N_{Fe}}$	$\log \frac{N^\bullet}{N_{Fe}}$
Mg	3	8.22	+0.25	—0.58	3	7.50	+0.13	—0.70	+0.83
Al	2	6.85	—1.12	—0.75	2	5.52	—1.85	—1.48	—0.37
Si	1	8.93	+0.96	+1.89	1	8.14	+0.77	—0.16	+0.93
Ca	4	7.02	—0.95	—0.53	3	6.14	—1.23	—0.81	—0.42
Sc	2	4.17	—3.30	+0.45	3	3.36	—4.01	—0.26	—3.75
Ti	13	5.56	—2.41	—0.52	14	4.87	—2.50	—0.61	—1.89
V	6	5.62	—2.35	+0.52	7	5.05	—2.32	+0.55	—2.87
Cr	6	6.34	—1.63	—0.42	3	5.29	—2.08	—0.87	—1.21
Mn	6	6.84	—1.13	+0.54	8	5.86	—1.51	+0.16	—1.67
Fe	42	7.97			47	7.37			
Co	10	6.60	—1.37	+0.56	10	5.76	—1.61	+0.32	—1.93
Ni	7	7.18	—0.97	—0.31	7	6.40	—0.97	—0.31	—0.66
Y	1	5.19	—2.78	+1.54	1	4.23	—3.14	+1.18	—4.32
Zr	1	6.37	—1.60	+2.74	1	5.46	—1.91	+2.43	—4.34

tical curve of growth. Equation (13) suggests the interpretation that the expression on the left-hand side represents the number of absorption atoms in the atmosphere of the star.

The results are summed up in Tab. IX. In addition to the elements (first column), the table gives, for each star individually, the number of lines used for determining log N* (second and

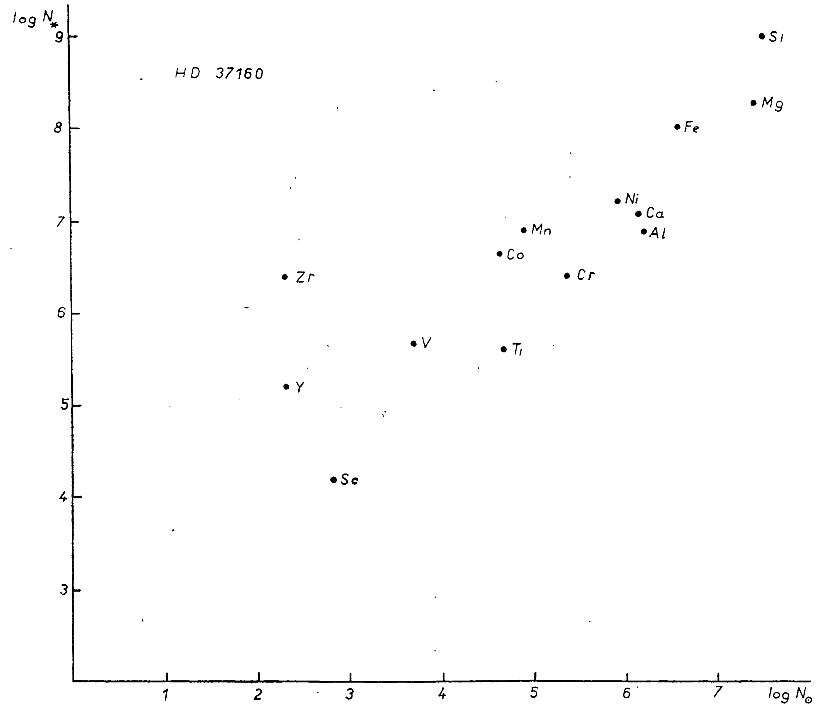

Figure 13.

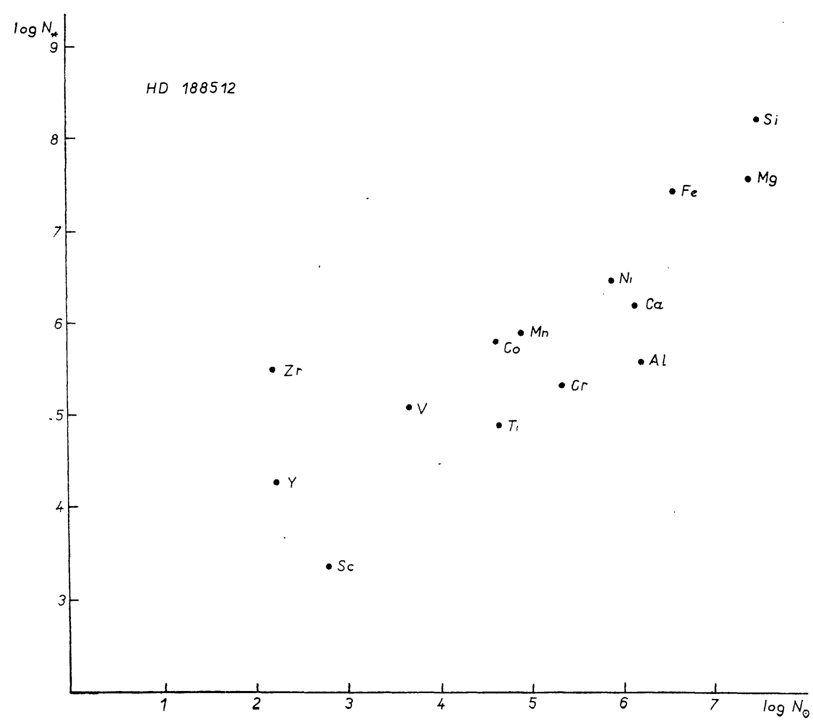

Figure 14.

sixth column), the number log N^* of atoms, as obtained from equation (1) and from the values already determined. Tab. IX lists also the ratios log N^*/log N_{Fe} for all elements in both stars and the same ratio for the Sun, and, eventually, ratio log N^*/N_{Fe} : log $N^\bullet/N_{Fe}$ (fifth and ninth column). The values of log $N^\bullet/N_{Fe}$ for the Sun were taken from the paper by L. Goldberg, E. A. Müller and L. H. Aller (1960).

For illustration we add diagrams 13 and 14, in which log $N^\bullet$ is plotted on the horizontal axis and log N^* on the vertical axis for all elements from Tab. IX.

Tab. IX shows that the composition of the atmospheres of both stars does to exceed the relative representation of atoms in normal stars. The differences determined for Si, Y and Zr are due to the poorer reliability of the log N^* determination (only from a single line). The over-all relatively higher log N^* values given by us especially for HD 37 160, are largely influenced by the relatively high value of velocity V_0. However, even a reduction of V_0 to the lowest permissible limit cannot completely invalidate this conclusion.

Likewise, this fact cannot be explained by a low value of coefficient log $\bar{\varkappa}$, whose value is relatively high for the stars analyzed. Log $\bar{\varkappa}$, as taken from Vardya's tables (1964), is higher than if we only took into consideration the absorption of negative hydrogen ions. However, the absorptive effect of molecules and metals may have been largely underestimated. This would especially apply to HD 37 160.

It should be emphasized, however, that the molecule bands CN and CH are weak in the spectrum HD 37 160. This characteristic of the spectra of certain stars with high space velocities has been emphasized by numerous authors. The problem was investigated in great detail by J. L. Greenstein and P. C. Keenan (1958).

A further comparison of values log N^*/N_{Fe} and log $N^\bullet/N_{Fe}$ shows differences in certain cases which, however, may be accounted for in part by the character of the spectrum and the poorer reliability of the observational material. For instance, the ratio log N^*/N_{Fe} for Al for both stars (for HD 37 160 log $N/N_{Fe} = -1.12$, for HD 188 512 it is equal to -1.85) differs from the same ratio for the Sun (log $N^\bullet/N_{Fe} = -0.37$). It should be noted, however, that this ratio in the number of atoms could be determined for both stars only from two very strong lines ($\lambda = 3961$A and $\lambda = 3944$A).

The simplifying assumptions introduced (homogeneous atmosphere-model) and the analysis of the spectra of the stars made on their basis suggested certain interesting conclusions. It is evident that the structure of the upper atmosphere layers, as assumed, leads for HD 37 160 to values of relative atom representation which do not differ markedly from the normal relative composition of atmospheres. It appears, however, that certain processes in the atmosphere may largely affect the general character of the spectrum, but these processes are not represented in the homogeneous model.

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R. BAJCÁR

SPEKTRUM DVOCH HVIEZD NESKORÉHO TYPU

Poznanie chemického zloženia atmosfér subgigantov neskorých spektrálnych typov má značný astrofyzikálny i kozmologický význam. Je to tak z viacerých dôvodov. Jedným z nich je napr. zistenie, že skupina hviezd spomenutých vlastností sa rozpadá na niekoľko grúp. Niektoré zásadné rozdiely diferencujúce jednotlivé grupy sú už známe. Tak napr. sú známe spektrálne diferencie hviezd normálnych a hviezd s veľkým priestorovým pohybom a pod.

V súčasnej dobe nie je ešte k dispozícii dostatočne početný homogénny materiál na presnejšie definovanie jednotlivých skupín hviezd neskorých spektrálnych typov. Rovnako ostáva otvorenou otázkou priradenie správneho, napr. kozmogonického významu jednotlivým nájdeným diferenciám.

Napriek spomínaným ťažkostiam bolo možné metódou krivky rastu (M. E. model) určiť základné parametre atmosféry. Tak bola nájdená $T_{exc} = 4\,315°$ (HD 37 160) a $T_{exc} = 4\,225°$ (HD 188 512). Z nich odvodené efektívne teploty sú $T_{eff} = 5\,260°$ (HD 37 160) a $T_{eff} = 5\,150°$ (HD 188 512). Z pomeru počtu atómov v dvoch po sebe nasledujúcich štádiách ionizácie boli odvodené elektrónové tlaky a bolo nájdené $\log P = 0{,}625$ (HD 37 160) a $\log P = 0{,}425$ (HD 188 512). Rýchlosť atómov v atmosfére HD 37 160, ktorá bola nájdená ($V = 9{,}6$ km/sec), je pomerne vysoká, zato rýchlosť atómov v atmosfére HD 188 512 neprevyšuje hodnotu nájdenú u podobných hviezd. Relatívne chemické zloženie atmosféry v porovnaní so Slnkom je zhrnuté v tabuľke IX.

Preto v programe tejto práce je nájdenie relatívneho chemického zloženia atmosfér dvoch hviezd (HD 188 512 a HD 37 160) a jeho porovnanie s relatívnym zastúpením na našom Slnku. Prvá z hviezd (HD 188 512) je štandardná hviezda spektrálneho typu G8 IV, druhá hviezda (HD 37 160) patrí k skupine hviezd o veľkej priestorovej rýchlosti.

Zloženie atmosféry sa robilo zo spektrogramov s dostatočne veľkou disperziou (9—18 A/mm). Na druhej strane však spektrogramy boli exponované v UV oblasti spektra. Posledný fakt značne sťažoval prácu a určitým spôsobom sa odráža v dosiahnutých výsledkoch. Ťažkosti vyplývajúce z pozorovacieho materiálu nedovoľovali použiť ľubovoľné čiary — ich výber bol značne obmedzený vzájomným blendovaním. Okrem toho preloženie spojitého spektra v UV oblasti spektra týchto hviezd vplýva na určenie ekvivalentnej šírky čiar.

V programe práce bolo vykonať úplnú identifikáciu spektrálnych čiar v oblasti λ 4144—3497 A.

Р. БАЙЦАР

СПЕКТР ДВУХ ЗВЕЗД ПОЗДНЕГО СПЕКТРАЛЬНОГО ТИПА

Знание химического состава атмосфер субгигантов поздних спектральных типов имеет большое астрофизическое и космологическое значение благодаря многим причинам. Одной из них, например, является установление, распадается ли группа звезд упомянутых свойств на несколько групп. Некоторые основные различия, отличающие отдельные группы, уже известны. Так, например, известны спектральные отличия нормальных звезд и звезд с большой пространственной скоростью и т. д.

В настоящее время мы еще не располагаем достаточным количеством равномерного материала для точного определения отдельных групп звезд поздних спектральных типов. Точно так же остается открытым вопрос о правильном, например космологическом, значении отдельных найденных различий.

Вопреки упомянутым трудностям стало возможным с помощью кривой роста (M. E. модель) определить основные параметры атмосферы. Так была найдена $T_{exc} = 4\,315°$ (HD 37 160) и $T_{exc} = 4\,225°$ (HD 188 512). Из них определены эффективные температуры $T_{eff} = 5\,260°$ (HD 37 160) и $T_{eff} = 5\,150°$ (HD 188 512), Из отношения количества атомов в двух следующих друг за другом стадиях ионизации были определены электронные давления и были найдены $\log P = 0{,}625$(HD 37 160) и $\log P = 0{,}425$(HD 188 512). Скорость атомов в атмосфере HD 371 60, которая была определена ($V = 9{,}6$ км/сек), относительно большая, а скорость атомов в атмосфере HD 188 512 не превышает величину, определенную для подобных звезд. Относительный химический состав атмосфер в сравнении с Солнцем представлен в таблице IX.

Поэтому цель настоящей статьи состоит в том, чтобы найти относительный химический состав атмосфер двух звезд (HD 188 512 и HD 37 160) и сравнить его с относительным составом на Солнце. Первая из звезд (HD 188 512) — стандартная звезда спектрального типа G8 IV, вторая звезда (HD 37 160) относится к группе звезд с большой пространственной скоростью.

Состав атмосферы был определен из спектрограмм с достаточно большой дисперсией (9 до 18 A/мм). Однако с другой стороны спектрограммы были сняты в UV области спектра. Последний факт значительно затруднил работу, что определенным образом отражается на полученных результатах. Трудности, связанные с накопленным материалом, не позволяли использовать произвольные линии — их выбор был весьма ограничен взаимным блендованием. Кроме того наложение непрерывного спектра в UV область спектра этих звезд влияет на определение эквивалентной ширины линии.

Целью статьи было провести полную индентификацию спектральных линий в области λ 4144—3497 A.