ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

NOVEMBER II 1990, PAGE 85

Astron. Astrophys. Suppl. Ser. **86**, 85-93 (1990)

The chemical composition of the extreme halo stars. III. Equivalent widths of 20 dwarfs *

G. Zhao[1][2] and P. Magain[3]**

[1] European Southern Observatory, Karl-Schwarzschild-Str. 2, D-8046 Garching bei München, F.R.G
[2] Department of Astronomy, Nanjing University, Nanjing, People's Republic of China
[3] Institut d'Astrophysique, Université de Liège, 5, avenue de Cointe, B-4200 Cointe-Ougrée, Belgium

Received April 12; accepted April 24, 1990

Abstract. — In the first two papers of this series we discussed the chemical composition of 20 extreme halo stars. The abundances of a number of elements were determined using model atmosphere analysis of equivalent widths from the Cassegrain Echelle Spectrograph (CASPEC) attached to the 3.6 m telescope at the European Southern Observatory (La Silla, Chile). In this paper we present a tabulation of the equivalent width data. A comparison of our measurements with the equivalent widths from different sources allows to asses the quality of our data.

Key words: stellar abundances — population II stars — chemical evolution of the Galaxy.

The chemical composition of the extreme halo stars provides important information about the nucleosynthesis processes and the early galactic evolution. In Paper I (Magain, 1989) and Paper II (Zhao and Magain, 1990) we determined the abundances of a number of elements in 20 extremely metal-deficient stars. The purpose of the present paper is to present the observational journal (Table 1) and the equivalent widths (Table 2) upon which these analyses were based, as well as to give a brief discussion of their accuracy.

The observations were carried out with the Cassegrain Echelle Spectrograph (CASPEC) attached to the 3.6 m telescope at the European Southern Observatory (La Silla, Chile). The detector was a RCA CCD (type 501 EX, 320 × 512 pixels of 30 μm^2 each). The resolving power was of the order of 20000. The exposure time was chosen in order to reach a signal-to-noise ratio of at least 100 over the entire spectral range. Blue and green spectra (covering the ranges 3700 – 4700 Å and 5000 – 6000 Å respectively) were obtained for all stars and reduced with the MIDAS package on the VAX 750 and VAX 8600 computers at ESO (La Silla and Garching). The reduction procedures have been described in detail in Papers I and II. The equivalent widths were determined with the help of the IHAP package running on a HP 1000 computer at ESO. Two different methods were used: (1) direct integration of the line profile and (2) gaussian fitting, the latter being preferable in the case of faint lines, but unsuitable for the strong lines in which the damping wings contribute significantly to the equivalent width. The final equivalent widths are weighted averages of these two measurements.

The accuracy of the data may be estimated by comparing them to completely independent measurements. For two of the stars in the present sample, namely HD140283 and HD166913, we also obtained a significant number of spectra with the ESO Coudé Echelle Spectrometer (CES) fed by the 1.4m Coudé Auxiliary Telescope (CAT). These spectra have higher resolving power ($R \simeq 60000$) and signal-to-noise ratio ($S/N \geq 200$). The comparison is given in Figs. 1 and 2, which show a very good agreement between the two sources of data, with a marginal tendency for the CASPEC equivalent widths to be somewhat (~5%) larger.

A linear least squares fitting gives:

$$\text{E.W.(ZM)} = 1.04(\pm 0.01)\text{E.W.(CES)} + 0.8(\pm 0.5) \quad \text{for HD140283}$$

and

$$\text{E.W.(ZM)} = 1.07(\pm 0.03)\text{E.W.(CES)} - 0.2(\pm 0.9) \quad \text{for HD166913}$$

Send offprint requests to: P. Magain.

[*] Based on observations collected at the European Southern Observatory, La Silla, Chile.

[**] Chercheur Qualifié au Fonds National Belge de la Recherche Scientifique.

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1990A&AS...86...85Z

TABLE 1. *Journal of the observations.*

No.	Star	V	Sp. range(Å)	Obs. date	Exp. (min)
1	HD 3567	9.25	3700 – 4700	13/14 Oct 86	20
			5000 – 6000	14/15 Oct 86	16
2	HD 16031	9.78	3700 – 4700	13/14 Oct 86	25
			5000 – 6000	14/15 Oct 86	20
3	HD 19445	8.05	3700 – 4700	13/14 Oct 86	14
			5000 – 6000	14/15 Oct 86	7
4	HD 34328	9.43	3700 – 4700	13/14 Oct 86	25
			5000 – 6000	14/15 Oct 86	16
5	HD 59392	9.72	3700 – 4700	09/10 May 86	35
			5000 – 6000	10/11 May 86	25
6	HD 74000	9.64	3700 – 4700	09/10 May 86	35
			5000 – 6000	10/11 May 86	18
7	HD 84937	8.30	3700 – 4700	09/10 May 86	12
			5000 – 6000	10/11 May 86	5
8	HD 116064	8.80	3700 – 4700	09/10 May 86	15
			5000 – 6000	10/11 May 86	9
9	HD 122196	8.74	3700 – 4700	09/10 May 86	12
			5000 – 6000	10/11 May 86	12
10	HD 140283	7.21	3700 – 4700	09/10 May 86	4
			5000 – 6000	10/11 May 86	5
11	HD 160617	8.74	3700 – 4700	09/10 May 86	13
			5000 – 6000	10/11 May 86	17
12	HD 166913	8.23	3700 – 4700	09/10 May 86	5
			5000 – 6000	10/11 May 86	5
13	HD 181743	9.69	3700 – 4700	13/14 Oct 86	30
			5000 – 6000	14/15 Oct 86	30
14	HD 194598	8.35	3700 – 4700	13/14 Oct 86	9
			5000 – 6000	14/15 Oct 86	7
15	HD 213657	9.67	3700 – 4700	09/10 May 86	23
			5000 – 6000	10/11 May 86	23
16	BD–10°0388	10.37	3700 – 4700	13/14 Oct 86	60
			5000 – 6000	14/15 Oct 86	40
17	BD+02°3375	9.95	3700 – 4700	09/10 May 86	35
			5000 – 6000	10/11 May 86	30
18	BD+03°0740	9.81	3700 – 4700	13/14 Oct 86	40
			5000 – 6000	14/15 Oct 86	28
19	BD+17°4708	9.47	3700 – 4700	13/14 Oct 86	25
			5000 – 6000	14/15 Oct 86	20
20	CD–33°3337	9.08	3700 – 4700	13/14 Oct 86	20
			5000 – 6000	14/15 Oct 86	13

where E.W.(ZM) refer to the present data.

The scatter of the individual measurements around this relation is of the order of 3 mÅ in both cases, which is thus an upper limit on the random errors in our equivalent widths measurements. Other recent abundance analyses with which we have data in common include Barbuy *et al.* (1985) for BD-10°388 and Gratton and Sneden (1988) for HD140283.

The comparison with Barbuy *et al.*'s data is shwon in Figure 3. The scatter is very large (13 mÅ), probably because of the lower S/N of their electronic camera spectra, but their absolute scale basically agrees with ours. The comparison with Gratton and Sneden's data (Fig. 4) displays a smaller scatter (5 mÅ), but their equivalent widths are significantly larger than ours. This discrepancy is rather surprising, especially in view of the fact that the same instrument was used in both cases. The agreement of our own equivalent widths with the higher resolution CES spectra suggests that the problem is with Gratton and Sneden's data (e.g. an improper substraction of the interorder light).

Table 1 lists the 20 stars for which equivalent widths were measured, along with the *V* magnitude, spectral range, observation date and exposure time.

The equivalent widths are listed in Table 2. The successive columns give the element and ionization stage, the wavelength λ (Å), the lower excitation potential χ (eV), our adopted oscillator strength (from the sources listed in Paper I), the damping enhancement factor f_6 and finally the measured equivalent widths (mÅ). The stars are identified by numbers which relate to the first column of Table 1.

References

Barbuy B., Spite F., Spite M.: 1985, *Astron. Astrophys.* **144**, 343.
Gratton R.G., Sneden C.: 1988, *Astron. Astrophys.* **204**, 193.
Magain P.: 1989, *Astron. Astrophys.* **209**, 211 (Paper I).
Zhao G., Magain P.: 1990, *Astron. Astrophys.*, in press (Paper II).

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1990A&AS...86...85Z

TABLE 2. *Line data and equivalent widths.*

El.	λ	χ	log(*gf*)	f_6	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Na I	5688.21	2.10	-0.410	1.5	14	4	3	11	10	5		6	9	2	15	6	–	31	3	–	–	–	7	25
Na I	5889.97	0.00	0.112	1.2	213	173	158	194	177	171	118	175	192	115	199	190	167	258	151	100	124	59	182	228
Na I	5895.94	0.00	-0.191	1.2	172	149	129	166	150	152	90	154	153	88	174	163	142	216	130	89	103	35	170	197
Mg I	4057.51	4.34	-0.890	1.5							–		–		–	–	–	–	–	–	–	13	–	–
Mg I	4167.27	4.34	-0.710	1.5	105	75	51	97	79	50	38	64	58	33	58	89	77	118	60	33	45	14	79	102
Mg I	4571.10	0.00	-5.430	1.5	38	19	19	40	25	8		16	12	5	18	23	30	52	7	–	10	–	22	45
Mg I	4703.00	4.34	-0.380	1.5	120	95	79	–			–	–	–	–		–	98	150	–	46	–	–	102	119
Mg I	5528.41	4.34	-0.350	1.5	118		85	111	94	64	54	–	75	45	78	100	92	130	70	45	53	25	92	119
Mg I	5711.09	4.34	-1.600	1.5	26	12	10	23	13	9	–	13	10	–	13	22	15	38	9	8	8	–	18	26
Al I	3961.53	0.01	-0.340	1.6	136	108	94	166	113	109	75	96	99	75	124	140	126	198	86	70	84	43	111	145
Si I	5708.40	4.95	-1.470	1.5	20	12		10	9	8	–	–	10	–	6	9	6	27	–	–	–	–	13	13
Ca I	4283.01	1.89	–	1.5	–	71	58	83	–	–	–	–	–	–	–	–	69	99	–	–	–	–	–	91
Ca I	4425.44	1.88	-0.358	1.5	81	54	44	65	62	40	26	45	51	23	54	63	57	84	36	28	27	9	65	75
Ca I	4435.68	1.89	-0.517	1.5	85	50	35	56	–	29	27	42	45	18	54	57	48	72	39	23	25	–	60	73
Ca I	4454.79	1.90	0.258	1.5	–	90	–	–	–	–	61	–	–	49	86	–	87	–	77	54	57	35	95	–
Ca I	4578.55	2.52	-0.697	1.8	31	16		13	19		7	12	11	–	10	19	14	37	7		–	–	26	23
Ca I	4585.87	2.52	–	1.8	55	32	18	36	34	17	12	24	24	8	27	39	22	55	20	12	10	–	35	43
Ca I	5261.70	2.52	-0.579	1.8	37	16	9	26	26	7	8	16	18	4	13	22	12	37	13	–	8	–	23	32
Ca I	5512.98	2.93	-0.447	1.8	19	8		13	13	6	–	8	7	–	9	16	10	31	4	–	–	–	20	19
Ca I	5581.97	2.52	-0.555	1.8	37	22	11	25	25	17	7	19	21	–	20	28	14	41	12	15	–	11	–	32
Ca I	5588.76	2.52	0.358	1.8	83	64	49	71	75	45	41	62	60	24	58	67	52	93	54	32	34	14	73	80
Ca I	5590.12	2.52	-0.571	1.8	41	19	15	26	29	10	7	17	21	8	22	31	16	41	12	7	9	3	27	32
Ca I	5601.28	2.52	-0.523	1.8	43	19	9	25	24	12	9	17	19	–	19	30	16	41	13	6	6	–	28	31
Ca I	5857.45	2.93	0.240	1.8	56	39	30	43	46	26	17	33	35	11	39	52	32	75	30	14	21	–	47	51
Sc II	4246.83	0.31	0.310	1.5	111	84	68	85	99	69	64	79	89	68	91	97	72	99	79	73	56	–	100	94
Sc II	4400.39	0.61	-0.510	1.5	–	35	–	43	48	22	19	26	37	20	43	50	32	–	27	18	13	–	–	69
Sc II	5526.82	1.77	0.024	1.5	36	16	7	17	22	10	7	9	11	–	15	24	10	31	11	13	–	11	16	39
Sc II	5657.88	1.51	-0.603	1.5	22	10	–	8	24	8	–	7	–	–	13	12	7	26	7	–	4	–	12	26
Ti I	4512.74	0.84	-0.480	1.5	16	10	6	13	–	–	–	8	8	–	–	10	–	24	–	–	–	–	13	16
Ti I	4533.24	0.85	0.476	1.5	60	40	29	46	45	23	18	31	36	15	38	45	36	66	25	18	18	–	46	56
Ti I	4534.78	0.84	0.280	1.5	42	32	20	39	36	17	15	23	28	11	28	37	31	47	21	11	11	–	37	48
Ti I	4548.77	0.83	-0.354	1.5	20	9	6	18	13	–	–	9	12	–	11	–	12	30	12	–	–	–	14	21
Ti I	4617.27	1.75	0.389	1.5	18	11	7	14	14	–	–	–	6	–	–	12	–	19	–	–	–	–	16	18
Ti I	4656.47	0.00	-1.345	1.5	21	6	–	11	11	–	–	–	5	–	5	11	–	17	5	–	–	–	10	14
Ti I	4681.91	0.05	-1.071	1.5	23	14	10	16	16	7	8	15	13	–	14	15	12	30	8	–	–	–	16	19
Ti I	5039.69	0.02	–	–	–	–	–	–	10	–	–	8	–	–	6	–	8	16	–	–	–	–	–	15

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1990A&AS...86...85Z

TABLE 2. *(continued)*

El.	λ	χ	log(*gf*)	f_6	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Ti I	5192.97	0.02	-1.040	1.5	28	13	10	19	23	7	–	13	11	7	17	16	12	34	10	–	–	–	19	29
Ti I	5210.39	0.05	-0.884	1.5	27	14	11	27	25	5	5	17	14	12	13	20	13	32	11	–	9	–	21	27
Ti II	4394.06	1.22	-1.670	1.5	–	–	–	–	–	–	14	22	27	9	32	35	–	–	19	–	–	–	–	–
Ti II	4395.04	1.08	-0.650	1.5	–	–	–	–	104	88	76	86	97	72	99	104	–	–	84	–	72	–	–	–
Ti II	4395.84	1.24	–	1.5	–	–	–	–	27	13	11	11	20	7	26	27	–	–	18	–	–	–	–	–
Ti II	4399.77	1.24	-1.290	1.5	–	60	–	60	71	42	36	44	58	36	67	69	54	–	50	35	35	17	–	78
Ti II	4417.72	1.60	-1.160	1.5	82	62	42	–	75	41	39	46	61	34	65	70	53	80	54	36	32	17	71	83
Ti II	4418.34	1.24	–	1.5	45	23	11	13	30	–	12	12	19	–	25	28	–	43	15	13	–	–	23	40
Ti II	4443.81	1.08	-0.690	1.5	108	91	71	95	91	67	70	–	–	66	89	93	77	105	81	73	64	51	95	112
Ti II	4444.56	1.12	-2.220	1.5	44	20	–	19	25	–	–	–	–	8	21	25	15	31	13	11	–	–	21	41
Ti II	4468.50	1.13	-0.610	1.5	101	84	79	89	94	76	75	76	90	68	94	92	80	101	82	73	65	50	92	109
Ti II	4470.85	1.16	–	1.5	38	–	8	19	26	–	–	–	17	7	21	24	39	32	11	8	8	–	18	35
Ti II	4501.27	1.12	-0.740	1.5	110	88	69	–	92	67	70	75	83	60	88	94	70	102	80	62	59	44	95	108
Ti II	4563.76	1.22	-0.820	1.5	100	78	64	80	85	62	61	61	81	54	79	83	69	96	75	57	51	37	88	98
Ti II	4571.98	1.57	-0.340	1.5	119	89	69	85	91	69	67	72	85	54	86	92	78	–	77	74	57	40	100	111
Ti II	4589.95	1.24	-1.650	1.5	59	40	22	–	54	20	16	21	35	17	38	48	27	58	30	18	16	6	45	58
Ti II	5154.07	1.57	-1.420	1.5	39	21	14	19	29	8	8	21	21	–	23	28	10	40	17	8	10	–	25	–
Ti II	5185.91	1.89	-1.460	1.5	43	19	11	19	31	13	10	13	19	6	22	28	15	39	16	8	7	5	29	37
Ti II	5336.79	1.58	-1.590	1.5	43	26	10	27	31	13	10	10	22	9	26	35	17	43	18	10	7	9	29	46
Cr I	4254.34	0.00	-1.108	1.5	111	93	83	110	102	68	68	79	88	69	89	97	90	126	79	66	67	38	91	110
Cr I	4545.96	0.94	-1.379	1.5	22	8	–	14	14	9	–	12	9	–	9	10	9	31	8	–	–	–	8	17
Cr I	4600.75	1.00	-1.276	1.5	18	7	6	11	15	–	–	6	9	–	10	12	–	35	–	–	7	–	15	18
Cr I	4616.13	0.98	-1.206	1.5	28	10	6	18	19	–	–	–	12	–	11	19	14	38	10	–	7	–	17	26
Cr I	4626.18	0.97	-1.340	1.5	29	11	4	18	11	–	–	8	14	–	–	16	–	33	–	–	7	–	16	–
Cr I	4651.29	0.98	-1.476	1.5	19	9	–	10	–	–	–	7	7	–	7	6	12	23	–	–	–	–	9	15
Cr I	4652.16	1.00	–	1.5	37	14	10	24	20	9	–	9	16	6	12	19	12	40	6	–	–	–	18	32
Cr I	5247.57	0.96	-1.627	1.5	16	5	7	10	9	–	5	–	–	–	–	9	8	19	–	–	–	–	11	13
Cr I	5296.70	0.98	-1.394	1.5	22	6	7	14	10	10	–	13	12	7	9	11	7	31	7	–	–	–	11	16
Cr I	5297.38	2.90	0.167	1.5	15	7	–	10	12	–	–	–	8	–	9	8	4	22	–	–	–	–	13	11
Cr I	5345.80	1.00	-0.975	1.5	45	20	12	26	24	13	8	15	16	5	19	23	21	46	14	–	6	–	26	33
Cr I	5348.32	1.00	-1.294	1.5	27	9	–	14	16	–	4	13	12	–	–	14	12	34	–	–	–	–	19	23
Cr I	5409.79	1.03	-0.715	1.5	47	21	13	31	34	17	10	28	28	9	25	37	23	61	13	9	11	–	32	41
Cr II	4558.65	4.07	–	1.5	53	26	13	20	30	18	15	17	27	10	26	32	20	47	23	12	10	–	33	45
Cr II	4588.20	4.07	–	1.5	38	19	7	20	19	12	7	9	20	6	20	28	9	34	16	–	6	–	25	33
Cr II	4634.07	4.07	–	1.5	25	13	9	10	–	–	–	–	9	–	10	13	–	25	7	–	–	–	14	25
Cr II	5237.32	4.07	-1.090	1.5	24	6	6	6	10	5	6	15	12	–	8	13	8	17	–	7	–	–	10	14

© European Southern Observatory • Provided by the NASA Astrophysics Data System

TABLE 2. *(continued)*

El.	λ	χ	log(*gf*)	f_6	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Fe I	3906.46	0.11	-2.243	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	-
Fe I	3922.92	0.05	-1.651	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82	-	-
Fe I	4005.25	1.56	-0.610	1.1	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-
Fe I	4045.82	1.48	0.280	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	99	-	-
Fe I	4071.74	1.61	-0.022	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81	-	-
Fe I	4126.19	3.33	-	2.0	-	-	-	-	-	-	-	-	-	-	-	21	-	-	11	-	-	-	-	-
Fe I	4132.06	1.61	-	1.1	-	99	-	-	111	87	79	95	110	83	99	-	-	-	94	74	82	55	-	132
Fe I	4132.90	2.84	-0.960	1.5	-	33	-	-	43	22	14	25	42	14	32	-	29	-	25	9	-	-	-	54
Fe I	4137.00	3.41	-0.640	1.5	-	27	-	-	30	13	-	23	26	12	29	30	-	-	18	9	-	-	25	46
Fe I	4143.87	1.56	-0.450	1.1	-	105	103	-	115	95	82	102	109	86	106	-	-	-	97	81	85	64	106	130
Fe I	4147.67	1.48	-2.104	1.1	65	44	29	50	51	23	15	29	-	25	47	48	42	68	28	15	23	-	42	60
Fe I	4157.78	3.42	-	2.0	55	38	23	45	42	22	13	26	35	15	36	46	31	68	26	13	15	-	34	48
Fe I	4174.91	0.91	-2.969	1.0	-	33	22	48	34	14	-	21	30	16	31	42	-	-	15	-	-	-	35	-
Fe I	4175.64	2.84	-0.750	1.5	68	49	37	55	49	26	19	34	39	23	42	52	43	79	31	-	25	-	46	58
Fe I	4176.57	3.37	-0.740	2.0	51	-	-	37	32	13	12	22	-	-	31	37	34	64	13	-	-	-	-	50
Fe I	4184.90	2.83	-0.890	1.5	57	30	28	48	37	25	18	24	39	17	40	410	37	67	31	-	19	-	49	48
Fe I	4187.04	2.45	-0.548	1.3	95	65	58	83	76	58	46	67	71	54	74	77	71	-	59	38	44	-	83	88
Fe I	4187.81	2.42	-0.554	1.3	112	78	64	94	85	59	50	71	78	55	79	84	85	-	67	44	46	-	80	105
Fe I	4195.34	3.33	-	2.0	-	-	25	-	45	21	15	25	39	19	36	45	38	-	27	10	16	-	47	64
Fe I	4202.04	1.48	-0.708	1.1	-	102	96	-	106	83	78	98	101	86	99	108	109	-	82	77	81	54	107	-
Fe I	4208.60	3.40	-	2.0	33	13	-	23	24	-	-	13	15	-	-	22	-	-	12	-	-	-	26	28
Fe I	4213.65	2.84	-1.370	1.5	47	19	15	34	26	12	-	16	19	-	18	31	-	51	18	-	-	-	28	38
Fe I	4216.19	0.00	-3.356	1.0	76	47	47	67	65	33	21	46	58	42	55	58	55	78	37	22	31	11	61	79
Fe I	4220.34	3.07	-1.380	1.5	35	15	-	21	-	-	-	-	14	8	12	16	-	40	-	9	-	-	18	25
Fe I	4222.22	2.45	-0.967	1.3	79	55	36	67	-	-	25	41	56	34	52	57	-	89	38	22	33	-	53	75
Fe I	4233.61	2.48	-0.604	1.3	87	69	59	-	68	56	35	55	78	45	72	79	70	104	57	35	47	-	71	90
Fe I	4238.02	3.42	-	2.0	36	21	15	-	28	13	9	15	23	9	23	27	-	56	17	-	16	-	20	43
Fe I	4238.81	3.40	-0.360	1.5	55	40	29	55	47	31	21	32	41	21	45	52	46	78	34	15	23	-	45	64
Fe I	4250.13	2.47	-0.405	1.3	101	75	64	87	81	57	46	74	76	56	78	90	87	112	62	51	54	25	82	97
Fe I	4260.48	2.40	-	1.3	-	109	99	-	111	88	81	104	102	76	-	104	-	-	92	74	81	-	115	-
Fe I	4271.16	2.45	-0.349	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-
Fe I	4271.77	1.49	-0.164	1.1	-	133	135	-	-	113	97	130	-	108	-	138	144	-	113	100	109	83	139	-
Fe I	4282.41	2.18	-0.790	1.3	-	68	65	77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	74	91
Fe I	4404.76	1.56	-0.142	1.1	-	133	130	-	-	110	99		140	109	141	160	155	-	112	95	107	82	-	-
Fe I	4415.13	1.61	-0.650	1.1	-	108	100	120	114	89	78	104	107	87	107	109	109	-	89	76	87	58	-	-
Fe I	4427.31	0.05	-3.044	1.0	102	73	67	86	82	50	38	-	76	-	78	82	-	105	54	39	44	-	77	100
Fe I	4430.62	2.22	-1.659	1.3	62	30	25	44	38	15	11	28	35	17	31	42	28	70	22	11	13	-	38	51
Fe I	4442.34	2.20	-1.255	1.3	79	53	45	63	55	-	30	44	50	31	56	58	57	87	-	24	30	-	54	80

© European Southern Observatory • Provided by the NASA Astrophysics Data System

TABLE 2. *(continued)*

El.	λ	χ	log(*gf*)	f_6	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Fe I	4447.72	2.22	-1.342	1.3	79	52	38	63	52	29	18	37	46	26	48	52	53	78	–	–	25	–	52	69
Fe I	4461.66	0.09	-3.210	1.0	–	54	48	–	67	42	26	47	57	45	–	54	63	–	43	24	35	11	60	–
Fe I	4466.56	2.83	-0.650	1.5	74	51	44	67	58	–	29	46	53	30	53	56	51	80	38	21	29	–	53	71
Fe I	4484.22	3.60	–	2.0	37	17	13	26	23	12	7	17	16	–	20	21	16	47	12	–	5	–	23	32
Fe I	4485.68	3.69	–	2.0	17	–	4	9	11	–	–	5	–	–	–	–	–	22	–	–	–	–	9	17
Fe I	4489.74	0.12	-3.966	1.0	45	19	16	39	30	13	8	21	22	–	–	30	21	52	16	–	–	–	23	34
Fe I	4494.57	2.20	-1.136	1.3	88	59	52	68	65	43	31	51	60	40	57	70	59	93	46	28	31	11	63	80
Fe I	4528.62	2.18	-0.822	1.3	102	74	62	88	82	58	45	68	74	50	76	84	80	108	61	45	53	23	79	100
Fe I	4531.15	1.48	-2.180	1.1	66	43	33	58	47	26	17	32	43	22	42	51	41	76	30	13	19	–	44	66
Fe I	4533.25	0.00	–	1.5	64	41	31	48	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	60
Fe I	4547.85	3.55	-0.890	1.5	33	14	9	19	18	10	9	16	16	–	15	19	18	44	10	5	–	–	14	28
Fe I	4602.00	1.61	-3.154	1.1	12	–	–	10	11	–	–	–	7	–	–	8	–	20	–	–	–	–	9	11
Fe I	4602.94	1.48	-2.220	1.1	62	36	29	57	49	25	14	31	43	19	39	45	40	70	25	10	17	7	41	58
Fe I	4625.05	3.24	–	2.0	28	13	8	17	15	–	–	12	12	–	14	17	–	37	–	–	8	–	16	27
Fe I	4647.44	2.95	–	1.5	41	15	9	24	25	9	–	10	18	7	20	23	–	41	11	–	7	–	23	36
Fe I	4678.85	3.60	–	2.0	40	24	14	28	22	12	10	16	24	9	24	28	21	50	14	–	7	–	26	35
Fe I	5049.82	2.28	-1.420	1.3	74	–	31	95	55	23	23	32	51	17	41	48	40	73	32	14	19	5	47	61
Fe I	5068.77	2.94	-1.200	2.0	49	23	23	37	32	13	11	22	28	10	25	32	23	57	16	–	14	–	29	47
Fe I	5074.75	4.22	-0.270	2.0	47	22	16	29	24	11	8	19	22	4	23	23	26	57	13	11	6	5	24	36
Fe I	5083.34	0.96	-2.958	1.0	57	24	24	45	33	–	11	26	29	14	28	42	35	55	19	5	18	7	32	52
Fe I	5090.78	4.26	-0.490	2.0	26	9	5	13	12	–	–	–	12	6	–	20	9	32	6	–	–	–	8	21
Fe I	5123.73	1.01	-3.068	1.0	47	20	17	40	27	10	9	25	28	13	24	31	27	54	13	5	9	–	27	44
Fe I	5127.36	0.91	-3.307	1.0	41	24	15	39	20	11	–	17	23	17	17	24	21	46	10	–	6	6	18	35
Fe I	5131.47	2.22	–	1.3	24	12	8	22	11	16	–	–	9	–	10	11	10	32	4	–	7	–	7	22
Fe I	5133.69	4.18	–	2.0	61	39	26	45	43	–	–	38	37	16	37	47	29	–	28	12	19	5	42	64
Fe I	5151.91	1.01	-3.322	1.0	38	16	14	26	22	7	6	15	17	–	18	21	13	45	12	–	6	–	15	28
Fe I	5162.28	4.18	–	2.0	51	31	18	43	37	20	14	21	34	10	31	38	27	62	23	7	14	–	35	55
Fe I	5165.41	4.22	–	2.0	24	5	5	10	12	4	5	8	–	–	10	11	–	27	–	–	–	–	11	20
Fe I	5166.28	0.00	-4.195	1.0	39	20	16	32	27	8	–	18	23	10	22	25	23	50	9	–	6	–	18	43
Fe I	5171.61	1.48	-1.793	1.1	85	62	58	85	72	41	35	54	60	44	67	76	60	100	48	35	39	15	66	86
Fe I	5191.46	3.04	–	–	75	46	36	57	56	34	21	42	50	23	48	56	50	85	32	17	21	11	55	68
Fe I	5194.94	1.56	-2.090	1.1	68	47	34	56	58	27	19	38	47	24	47	52	44	73	33	20	23	11	51	65
Fe I	5198.71	2.22	-2.135	1.3	40	17	13	23	24	7	10	14	19	7	17	20	17	44	11	–	10	–	23	33
Fe I	5215.18	3.26	–	–	44	17	13	33	30	10	9	18	21	9	22	24	25	51	16	5	7	–	25	37
Fe I	5216.28	1.61	-2.150	1.1	66	30	31	52	52	19	12	32	42	20	43	43	41	69	27	12	20	6	35	59
Fe I	5217.39	3.21	–	–	36	15	9	28	22	–	–	12	19	6	20	19	17	48	11	8	7	–	18	28
Fe I	5232.95	2.94	-0.150	2.0	113	74	67	96	87	63	48	81	82	52	79	88	80	123	62	40	53	22	82	94

TABLE 2. *(continued)*

El.	λ	χ	log(*gf*)	f_6	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Fe I	5242.50	3.63	-0.970	2.0	30	12	11	19	17	9	7	15	13	–	14	16	14	32	8	–	–	9	18	23
Fe I	5250.65	2.20	–	–	41	21	13	26	24	14	5	18	22	10	20	22	15	52	12	–	13	–	21	37
Fe I	5263.31	3.26	-0.980	2.0	44	22	17	32	26	10	6	20	22	7	23	31	20	55	13	–	10	5	26	39
Fe I	5266.56	3.00	-0.520	2.0	85	57	47	68	64	39	30	54	57	30	59	70	54	93	44	21	30	9	62	75
Fe I	5281.79	3.04	-1.020	2.0	58	36	22	46	38	23	14	33	31	14	37	46	32	67	25	9	13	–	35	55
Fe I	5283.62	3.24	–	–	67	48	30	56	49	29	–	41	48	22	45	55	39	78	33	13	20	8	47	62
Fe I	5302.30	3.28	-0.880	2.0	49	24	18	39	33	14	11	27	32	14	35	38	22	62	18	5	15	–	33	45
Fe I	5307.36	1.61	-2.987	1.1	24	7	5	12	11	–	–	9	10	4	8	12	7	30	5	5	–	–	12	15
Fe I	5324.19	3.21	-0.220	2.0	93	62	54	74	67	–	34	60	59	32	58	74	55	103	50	26	38	14	69	76
Fe I	5339.93	3.26	-0.730	2.0	59	29	26	42	41	20	13	27	30	14	31	38	36	67	22	12	14	–	36	51
Fe I	5364.88	4.44	–	2.0	45	27	15	35	24	17	12	18	23	9	27	30	23	54	–	7	8	2	26	39
Fe I	5365.40	3.57	–	–	20	7	5	9	10	–	–	–	8	–	5	7	7	17	–	–	–	4	9	17
Fe I	5367.47	4.41	0.320	2.0	58	34	21	–	33	21	12	25	31	10	35	42	28	65	23	14	14	5	30	49
Fe I	5369.97	4.37	0.320	2.0	64	32	26	40	39	25	17	31	35	11	37	50	33	73	26	14	19	4	44	55
Fe I	5383.38	4.31	0.520	2.0	67	44	32	52	46	28	24	38	50	–	44	50	38	77	35	20	23	10	52	56
Fe I	5389.48	4.41	–	2.0	22	10	–	12	14	6	7	–	7	–	6	12	12	31	–	9	–	–	7	18
Fe I	5393.17	3.24	-0.910	2.0	53	29	22	36	40	20	18	35	32	11	30	38	30	67	22	11	14	3	32	48
Fe I	5397.14	0.91	-1.993	1.0	99	82	75	93	88	68	56	90	80	67	85	91	76	113	74	46	59	21	86	99
Fe I	5405.78	0.99	-1.844	1.0	94	77	75	95	86	67	58	86	84	69	83	92	76	112	78	46	64	22	93	94
Fe I	5415.21	4.39	0.470	2.0	65	32	29	44	47	25	24	31	37	16	33	46	30	72	33	8	19	7	44	51
Fe I	5424.08	4.32	–	2.0	72	47	37	54	53	32	27	38	47	21	45	57	42	80	37	19	27	9	55	65
Fe I	5434.53	1.01	-2.122	1.0	89	–	65	93	79	49	39	69	75	55	74	77	74	93	55	32	44	16	83	87
Fe I	5445.05	4.39	–	2.0	48	24	18	28	28	14	7	19	22	–	20	28	22	53	13	7	10	10	25	35
Fe I	5446.92	0.99	-1.880	1.0	123	80	77	97	–	66	51	85	96	69	96	101	86	135	71	46	58	25	102	113
Fe I	5473.91	4.15	-0.850	2.0	20	8	7	13	11	–	–	10	6	–	6	15	8	21	–	6	9	–	10	15
Fe I	5487.75	4.14	–	2.0	22	9	–	14	15	6	–	8	7	–	9	17	–	31	5	–	9	–	10	19
Fe I	5497.52	1.01	-2.849	1.0	–	35	29	50	44	16	9	31	39	17	38	43	35	70	22	10	19	11	37	61
Fe I	5501.47	0.96	-2.970	1.0	56	26	19	40	35	15	11	25	31	14	31	35	32	58	21	11	19	–	30	52
Fe I	5506.79	0.99	-2.797	1.0	64	35	31	46	43	17	14	36	34	22	40	45	40	71	25	13	17	4	49	57
Fe I	5569.63	3.42	-0.580	2.0	55	26	19	41	37	22	–	24	34	11	34	47	24	66	17	7	17	4	36	46
Fe I	5572.85	3.40	-0.330	2.0	75	42	33	–	45	–	17	43	40	16	41	62	47	90	34	13	25	–	55	69
Fe I	5576.09	3.43	–	–	38	–	9	29	19	16	7	13	17	–	–	34	–	45	18	–	11	–	18	–
Fe I	5586.77	3.37	-0.202	2.0	79	58	48	74	67	41	26	54	58	25	55	66	54	105	42	23	29	11	63	69
Fe I	5624.55	3.42	-0.900	2.0	49	20	7	31	27	8	–	16	22	12	19	19	19	45	13	7	12	–	25	37
Fe I	5763.00	4.21	-0.510	2.0	34	19	6	23	12	–	–	16	13	–	13	26	13	39	17	8	4	–	21	31
Fe I	5862.36	4.55	–	2.0	19	–	6	10	12	4	6	–	10	–	8	12	–	26	6	–	–	–	–	10
Fe I	5930.19	4.65	–	2.0	21	5	–	8	15	–	–	–	8	–	11	12	7	23	6	–	–	–	20	14

© European Southern Observatory • Provided by the NASA Astrophysics Data System

TABLE 2. *(continued)*

El.	λ	χ	log(*gf*)	*f*₆	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Fe II	4178.85	2.58	-2.600	1.5	69	40	24	35	49	24	21	–	45	19	44	44	–	65	30	24	19	–	46	61
Fe II	4416.82	2.78	-2.610	1.5	56	30	14	–	37	8	13	18	29	10	31	32	22	44	22	11	10	–	36	–
Fe II	4489.18	2.83	-2.980	1.5	39	17	5	17	29	12	7	15	19	–	19	30	11	29	16	8		–	23	34
Fe II	4491.40	2.85	-2.780	1.5	46	21	7	24	27	11	11	11	23	12	20	23	16	43	18	–	-	-	23	40
Fe II	4508.28	2.85	-2.400	1.5	64	38	21	34	44	19	17	21	37	16	35	41	25	62	24	20	15	–	39	55
Fe II	4515.34	2.84	-2.560	1.5	55	–	–	23	33	19	14	20	34	15	31	33	–	58	22	14	10	–	40	48
Fe II	4522.63	2.84	-2.260	1.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9	–	–
Fe II	4541.52	2.85	-3.060	1.5	32	10	6	16	19	5	6	10	–	6	12	18	7	30	10	–	4	–	19	28
Fe II	4576.33	2.84	-3.050	1.5	31	14	8	12	21	6	7	7	16	–	16	21	–	–	10	–	–	–	25	30
Fe II	4582.83	2.84	-3.270	1.5	–	–	–	6	15	–	–	7	7	–	12	11	7	24	6	–	–	–	14	15
Fe II	4583.83	2.81	-2.020	1.5	87	59	37	55	76	46	48	49	65	40	68	72	–	80	55	34	35	21	68	81
Fe II	4620.52	2.83	-3.343	1.5	23	10	5	9	-	–	–	–	7	–	90	10	–	22	–	–	–	–	13	18
Fe II	5197.57	3.23	-2.490	1.5	53	30	14	22	40	18	19	18	31	13	37	30	18	51	24	9	11	6	34	48
Fe II	5234.63	3.22	-2.280	1.5	59	32	17	30	39	21	18	26	35	14	37	42	21	52	25	11	12	6	38	52
Fe II	5284.11	2.89	-3.220	1.5	28	10	31	6	15	9	10	–	–	–	13	15	9	24	11	–	–	–	13	28
Ni I	5035.37	3.63	0.140	1.75	36	15	7	20	17	8	–	–	21	5	13	21	13	39	–	–	11	–	17	31
Ni I	5080.53	3.65	–	–	35	17	10	28	20	12	–	11	15	9	15	28	14	–	10	8	–		22	35
Ni I	5081.11	3.85	0.130	1.75	25	10	9	18	16	7	7	8	12	6	13	21	11	32	9	6	–	5	20	29
Ni I	5084.10	3.68	-0.020	1.75	25	16	7	19	–	–	–	10	12	8	9	20	11	25	4	–	3	–	7	25
Ni I	5115.39	3.83	-0.140	1.75	12	–	–	9	6	–	–	–	11	–	6	8	6	20	–	–	6	–	–	14
Ni I	5155.77	3.90	–	–	15	6	–	6	8	–	6	–	4	–	14	12	–	20	5	–	–	–	8	11
Ni I	5587.86	1.93	-2.420	1.75	–	–	9	–	6	–	5	–	–	–	–	4	–	8	–	–	–	–	–	6
Sr II	4077.72	0.00	0.150	1.5	–	128	103	166	–	114	106	117	119	79	112	159	126	–	–	91	90	62	130	170
Sr II	4215.53	0.00	-0.170	1.5	150	111	92	135	139	102	90	97	114	70	117	131	110	150	105	84	79	55	120	151
Y II	3774.33	0.13	0.210	1.5	61	37	–	53	53	24	14	31	46	11	47	53	–	–	24	–	–	–	–	–
Y II	3788.70	0.10	-0.070	1.5	70	40	–	40	52	26	23	24	32	–	40	43	–	50	23	–	14	–	–	–
Y II	3950.35	0.10	-0.490	1.5	29	23	–	26	36	15	–	17	16	–	25	34	–	40	15	–	–	–	24	37
Y II	4398.02	0.13	-1.000	1.5	–	–	–	–	13	15	–	–	–	–	7	14	–	–	–	–	–	–	–	–
Y II	5087.42	1.08	-0.170	1.5	24	8	–	9	10	16	6	–	9	–	10	15	8	9	–	–	–	–	4	17
Y II	5200.41	0.99	-0.570	1.5	8	6	–	8	9	–	–	6	7	–	6	5	–	10	–	–	–	–	5	8
Zr II	4208.98	0.71	-0.460	1.5	25	–	–	14	20	9	–	8	–	–	14	18	12	–	–	–		–	12	24
Ba II	4554.03	0.00	0.163	3.0	128	84	65	103	112	71	54	79	88	21	105	104	79	118	75	49	44	12	95	117
Ba II	5853.68	0.60	-1.010	3.0	27	6	–	16	20	9	–	6	8	-	15	17	10	31	6	–	–	–	12	27
La II	4086.71	0.00	0.320	1.5	23	–	–	9	20	–	–	6	–	–	8	10	5	18	–	–	–	–	8	12
Eu II	4129.72	0.00	0.200	1.5	48	13	10	–	21	–	3	12	5	–	8	10	–	–	6	6	–	–	15	25

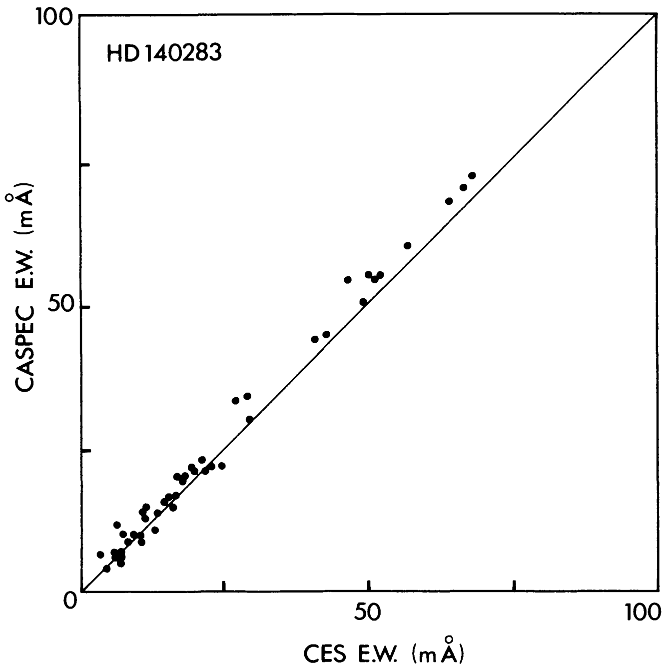

FIGURE 1. Comparison of the equivalent widths measured on our CASPEC and CES spectra for HD140283.

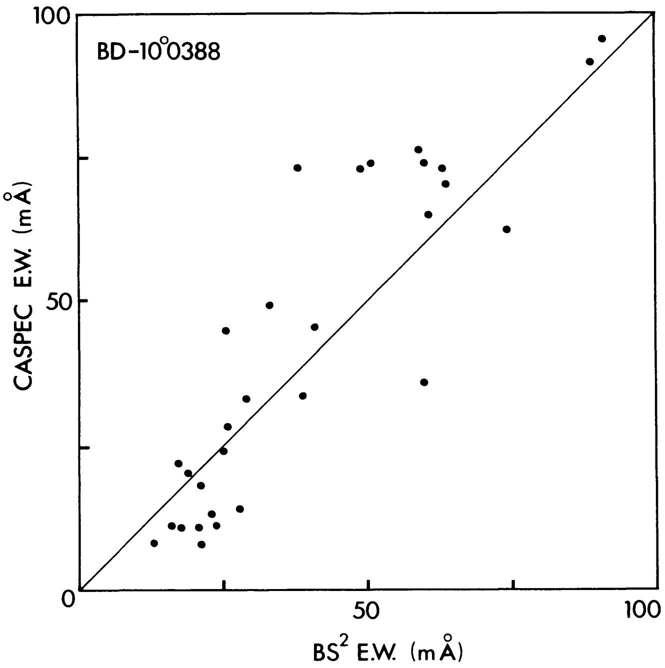

FIGURE 3. Comparison of our equivalent widths with those of Barbuy *et al.* for BD-10°338.

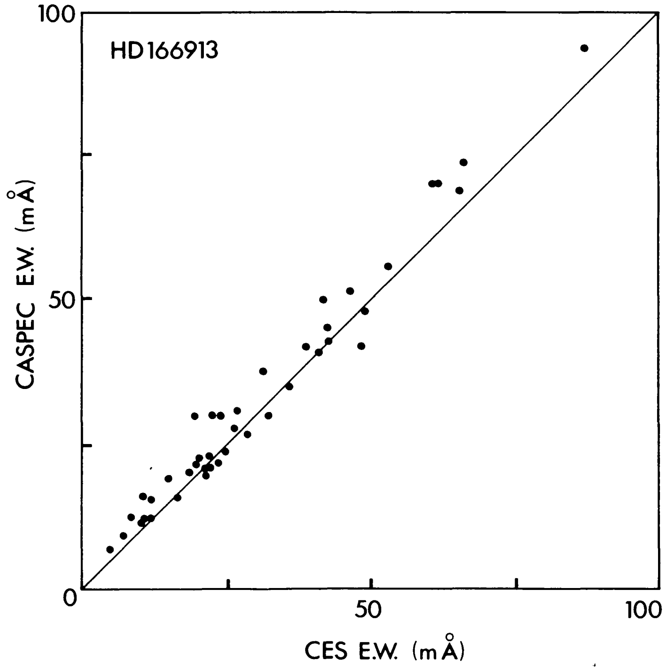

FIGURE 2. Comparison of the equivalent widths measured on our CASPEC and CES spectra for HD166913.

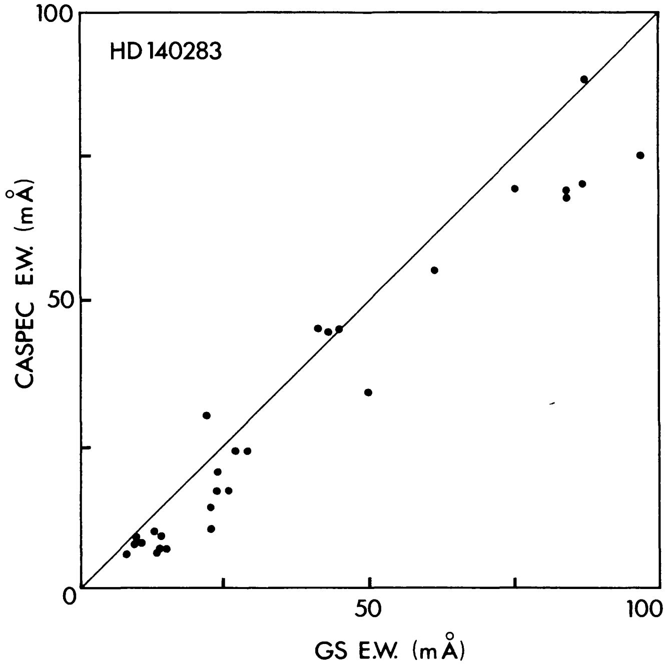

FIGURE 4. Comparison of our equivalent widths with those of Gratton and Sneden for HD140283.