Chin. J. Astron. Astrophys. Vol. 2 (2002), No. 4, 377–390
(http://www.chjaa.org or http://chjaa.bao.ac.cn)

Chinese Journal of Astronomy and Astrophysics

Equivalent Widths of 15 Extrasolar-Planet Host Stars

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Received 2002 April 18; accepted 2002 May 15

Abstract We present the equivalent widths of 15 extrasolar-planet host stars. These data were based on the high-resolution, high signal-to-noise ratio spectra obtained with the 2.16 m telescope at Xinglong station. The error in the Xinglong equivalent width is estimated by a comparison of these data with those given in previous studies of common stars.

Key words: stars: planetary systems – stars: late-type

1 INTRODUCTION

The discovery of planets around main sequence stars provides us a most important opportunity to understand the theories of the planetary system and stars. Much has been done in the way of detailed analysis of the chemical abundance of the extrasolar-planet host stars, that will lead to useful information on how systems with large planets have formed.

In Zhao et al. (2002), we presented accurate metallicities and abundance ratios of many elements for 15 extrasolar-planet host stars with the aim of finding out whether all our sample stars follow the same planet-high metallicity relation and how this process acts on different elements by examining the ratios between elements with the same nucleosynthesis history. In this work, the equivalent widths for these stars are given, and these data are compared with other studies for the stars in common.

2 OBSERVATIONS

The observations were carried out with the Coudé Echelle Spectrograph attached to the 2.16 m telescope at the National Astronomical Observatories (Xinglong, China). The detector was a Tek CCD (1024 × 1024 pixels each 24 × 24 μm^2 in size). The spectra have a resolution around 40 000, and a signal-to-noise ratio around 200. A detailed description of the technical aspects of the spectrograph can be found in Zhao & Li (2001). Table 1 lists our observation journal, along with the star name, visual magnitude, spectral type, observation date, exposure time, spectral range, and estimated signal-to-noise ratio. The data reduction follows standard MIDAS routines for order identification, background subtraction, order extraction, wavelength

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calibration, radial velocity shift correction, and spectrum extraction. The spectrum is then normalized by a continuum function determined by fitting a spline curve to a set of pre-selected continuum windows from the solar atlas.

Table 1 Observational Journal

Star	V_{mag}	Sp.	Date	Exp. (s)	Range (nm)	S/N
HD 12661	7.44	K0V	11/01/01	3600	570–890	185
HD 19994	5.06	F8V	11/01/01	600	570–890	232
HD 22049	3.73	K2V	17/10/00	900	580–890	340
HD 29587	7.29	G2V	18/02/97	2700	550–820	170
HD 38529	5.94	G4V	10/01/01	2700	570–890	350
HD 75732	5.94	G8V	18/02/97	900	550–820	185
HD 92788	7.31	G5V	11/01/01	3600	570–890	196
HD 95128	5.10	G0V	18/02/97	360	550–820	170
HD 98230	4.87	F8.5V	18/02/97	300	550–820	175
HD 117176	4.97	G5V	18/02/97	300	550–820	170
HD 120136	4.49	F7V	18/02/97	300	550–820	207
HD 145675	6.67	K0V	10/02/01	3000	570–890	209
HD 187123	7.86	G5V	29/08/99	1800	580–870	191
HD 190228	7.31	G5IV	08/12/00	3600	550–820	260
HD 217014	5.49	G5V	21/09/98	900	550–820	227

3 EQUIVALENT WIDTHS

The equivalent widths are measured using two different methods: direct integration of the line profile and Gaussian function fitting. Usually, the latter is preferable in the case of weak lines but is unsuitable for strong lines in which the damping wings contribute significantly to the equivalent width. The direct integration method gives a better result for strong unblended lines. The final equivalent widths are weighted averages of these two measurements, depending on the line intensity (see Zhao et al. 2000 for details). These data are shown in Table 2. The successive columns give the wavelength, the lower excitation potential, our adopted oscillator strength, the damping enhancement factor and the measured equivalent width.

4 COMPARISON OF EQUIVALENT WIDTHS WITH OTHER WORKS

Some of the sample stars have been analyzed in recent spectroscopic studies. In order to estimate the errors in our EW measurements, we compared the EWs taken from Gonzalez (1998) and this work (see Fig. 1) for four common stars, 55 Cnc, 47 Uma, 70 Vir, and 51 Peg. The comparison shows a very good agreement between the two sources of data, with a tendency for Gonzalez values to be slightly smaller. A linear least squares fitting to 90 common lines gives

$$\mathrm{EW(ZCQ)} = 1.009(\pm 0.020)\mathrm{EW(Gonz)} + 2.556(\pm 1.616)\,.$$

The difference between these two sets of data is small: the standard deviation about the above relation is 6.7 mÅ.

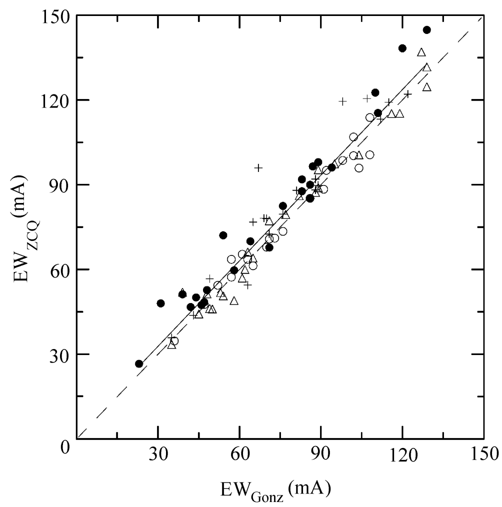

Fig. 1 Comparison of our equivalent widths, EW(ZCQ) and Gonzalez's, EW(Gonz), for four common stars, 55 Cnc (pluses), 47 Uma (filled circles), 70 Vir (open triangles), and 51 Peg (open circles). The dashed line is EW(ZCQ)=EW(Gonz), and the thick line is the linear least squares fitting to the data.

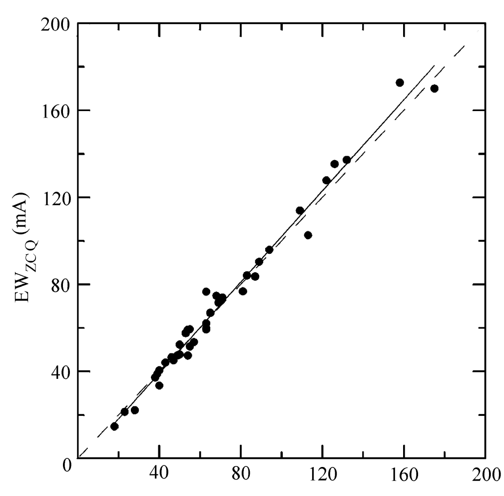

Fig. 2 Comparison of our equivalent widths, EW(ZCQ), with those of Smith, Cunha & Lazzaro (2001), EW(SCL), for HD 19994. The dashed line is EW(ZCQ)=EW(SCL), and the thick line is the linear least squares fitting to the data.

Table 2 Line Data and Measured Equivalent Widths

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 12661	19994	22049	29587	38529	75732	92788	95128
				Equivalent Widths (mÅ)							
C I	$\log \epsilon_\odot = 8.45$										
658.7610	8.53	−1.08	1.5	23.2	33.5	3.9	–	29.0	–	–	–
O I	$\log \epsilon_\odot = 8.75$										
777.1954	9.14	0.333	2.5	111.8	124.0	28.6	75.0	106.3	50.0	–	98.0
777.4177	9.14	0.188	2.5	104.1	106.0	22.6	66.1	98.5	50.9	81.5	87.7
777.5395	9.14	−0.034	2.5	87.7	91.0	17.9	47.3	78.1	36.6	–	67.8
Na I	$\log \epsilon_\odot = 6.27$										
568.2650	2.10	−0.652	2.0	–	–	–	–	–	–	–	–
568.8217	2.10	−0.341	2.0	–	–	–	92.1	–	286.8	–	144.8
615.4230	2.10	−1.570	2.0	80.4	45.7	59.0	21.1	82.7	119.5	45.1	39.7
616.0753	2.10	−1.228	2.0	109.0	74.8	94.5	31.5	100.9	–	77.1	64.2
Mg I	$\log \epsilon_\odot = 7.60$										
631.8700	5.11	−1.97	2.5	92.8	–	–	–	87.6	–	86.2	–
631.9200	5.11	−2.20	2.5	–	–	–	–	73.2	–	–	–
738.7700	5.75	−0.970	2.5	141.5	–	–	–	–	–	–	–
765.7606	5.11	−1.188	2.5	138.2	–	127.9	–	–	–	–	–
871.2701	5.93	−1.260	2.5	–	–	70.6	–	–	–	–	–
871.7833	5.93	−0.970	2.5	161.9	103.8	102.3	–	132.2	–	–	–
892.3600	5.94	−1.65	2.5	80.7	–	–	–	82.9	–	–	–
Al I	$\log\epsilon_\odot = 6.37$										
669.6020	3.14	−1.330	1.5	71.4	–	54.9	–	–	–	50.0	–
669.8670	3.14	−1.873	1.5	47.7	21.4	36.4	–	52.7	–	34.4	–
783.5317	4.02	−0.580	1.5	78.3	51.8	60.6	25.0	89.2	121.2	60.5	51.2
783.6130	4.02	−0.400	1.5	112.3	62.9	74.0	37.3	100.9	162.1	86.6	72.1
877.2870	4.02	−0.250	1.5	135.9	–	98.9	–	132.6	–	97.8	–
877.3900	4.02	−0.070	1.5	158.3	107.0	126.1	–	134.9	–	119.2	–
Si I	$\log \epsilon_\odot = 7.64$										
566.5563	4.92	−2.040	1.3	–	–	–	–	–	–	–	–
569.0433	4.93	−1.870	1.3	–	–	–	35.2	–	66.8	–	51.6
570.1108	4.93	−2.050	1.3	–	–	–	–	–	–	–	–
570.8405	4.95	−1.399	1.5	–	–	–	62.8	–	–	–	–
577.2149	5.08	−1.665	1.5	81.6	67.7	–	37.8	–	84.4	99.5	66.3
579.3079	4.93	−1.946	1.3	79.2	58.2	–	–	75.9	–	–	–
579.7865	4.95	−2.050	1.5	84.5	–	–	–	–	–	–	–
594.8548	5.08	−1.190	1.5	116.0	94.6	89.9	62.8	119.7	143.9	99.6	91.4
612.5026	5.61	−1.540	1.3	61.1	44.1	27.1	–	62.4	–	–	–
614.2494	5.62	−1.480	1.3	63.7	50.7	29.2	–	67.2	–	55.3	–
614.5020	5.62	−1.430	1.3	63.8	47.3	26.9	–	65.2	–	56.6	–
703.4910	5.87	−0.810	1.3	100.1	80.1	50.4	–	103.5	–	84.8	–
722.6208	5.61	−1.296	1.5	68.7	85.8	46.6	28.3	–	–	78.1	53.6
740.5790	5.61	−0.681	1.5	124.9	107.6	78.9	71.9	124.5	150.3	111.0	101.0
741.5958	5.61	−0.710	1.3	137.7	125.7	81.9	–	144.8	–	115.0	–
780.0000	6.18	−0.782	1.3	105.7	83.6	53.8	–	101.4	–	101.2	–
791.8383	5.95	−0.536	1.5	155.1	94.0	79.0	65.7	140.2	–	117.9	91.4
793.2351	5.96	−0.352	1.5	137.5	130.6	93.6	89.6	138.9	–	–	128.2
872.8024	6.18	−0.360	1.3	133.9	103.4	74.4	–	123.7	–	–	–
S I	$\log\epsilon_\odot = 7.18$										
604.6030	7.87	−0.230	2.5	34.7	–	–	–	44.6	–	20.7	–
605.2670	7.87	−0.440	2.5	–	–	4.5	–	34.5	–	–	–
869.3958	7.87	−0.740	2.5	28.2	38.0	–	–	20.1	–	–	–
869.4641	7.87	−0.210	2.5	43.6	78.1	11.1	–	54.3	–	31.2	–
K I	$\log\epsilon_\odot = 5.30$										
769.8977	0.00	−0.160	1.5	186.8	172.7	269.8	172.0	199.7	246.4	161.4	173.7
Ca I	$\log\epsilon_\odot = 6.35$										
551.2989	2.93	−0.530	1.8	–	–	–	68.8	–	–	–	100.5
558.1979	2.52	−0.671	1.8	–	–	–	–	–	151.5	–	95.2
558.8764	2.52	0.061	1.8	–	–	–	149.3	–	266.4	–	172.0
559.0126	2.52	−0.702	1.8	–	–	–	75.6	–	154.5	–	103.7

Table 2 Continued

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 12661	19994	22049	29587	38529	75732	92788	95128
				Equivalent Widths (mÅ)							
Ca I	$\log\epsilon_\odot = 6.35$										
560.1286	2.52	−0.523	1.8	–	–	–	87.9	–	–	–	124.8
585.7459	2.93	0.112	1.8	210.9	133.9	241.7	–	–	–	–	156.3
586.7572	2.93	−1.610	1.8	46.2	28.8	50.2	–	43.2	–	37.1	–
610.2727	1.88	−0.790	2.3	181.7	145.8	261.6	145.9	175.6	238.6	157.5	137.9
616.1295	2.52	−1.192	1.8	94.7	76.6	–	49.3	–	–	95.7	71.9
616.3754	2.52	−1.069	2.0	–	–	–	–	–	–	–	–
616.6440	2.52	−1.189	1.8	90.9	73.9	109.5	53.9	100.9	119.4	72.2	77.4
616.9044	2.52	−0.797	1.8	120.4	102.8	157.6	78.1	125.1	163.0	108.1	102.1
616.9564	2.52	−0.511	1.8	147.5	124.2	199.8	96.3	145.1	194.3	134.9	129.6
643.9083	2.52	0.164	1.5	204.6	170.0	–	153.0	212.9	–	204.9	176.3
644.9820	2.52	−0.502	1.5	133.2	120.8	166.9	84.3	–	194.7	127.9	118.5
645.5605	2.52	−1.290	1.5	80.3	53.5	90.3	–	78.6	–	72.1	–
647.1668	2.52	−0.694	0.8	119.7	102.6	137.6	80.3	126.7	166.8	108.7	96.1
649.3788	2.52	−0.092	0.8	148.7	135.3	203.3	120.2	165.4	–	149.1	144.8
649.9654	2.52	−0.811	0.8	102.2	90.4	127.2	72.0	115.6	129.3	100.1	90.2
671.7687	2.71	−0.524	1.5	172.5	134.1	189.7	–	177.5	–	138.1	–
714.8150	2.71	−0.137	1.5	178.7	149.5	232.5	–	179.5	–	159.9	–
Sc II	$\log\epsilon_\odot = 3.29$										
552.6821	1.77	−0.256	2.5	–	–	–	65.2	–	–	–	90.0
565.7880	1.51	−0.603	2.5	–	–	–	48.1	–	82.9	–	79.1
624.5620	1.51	−1.134	2.5	–	57.6	30.0	–	71.5	–	–	–
660.4600	1.36	−1.309	2.5	56.6	47.8	35.5	30.0	66.3	59.4	52.5	46.7
Ti I	$\log\epsilon_\odot = 5.01$										
586.6461	1.07	−0.840	1.5	81.2	43.1	96.0	46.3	81.9	112.9	–	51.2
595.3170	1.89	−0.205	1.5	68.9	–	71.9	28.4	–	99.5	–	38.3
612.6224	1.07	−1.320	1.5	42.7	14.7	60.0	18.2	48.6	72.6	–	26.6
625.8110	1.44	−0.431	1.5	78.8	47.4	93.8	43.0	81.2	103.8	60.8	52.6
626.1106	1.43	−0.479	1.5	78.9	46.5	99.3	36.9	85.2	112.1	62.0	52.7
842.6514	0.83	−1.179	1.5	80.1	48.3	116.8	–	97.0	–	–	45.5
843.5655	0.84	−0.871	1.5	95.6	49.9	129.3	55.7	110.4	142.2	–	61.8
V I	$\log\epsilon_\odot = 4.09$										
572.7057	1.08	−0.012	1.5	–	–	–	29.1	–	–	–	36.0
609.0216	1.08	−0.139	1.5	61.5	30.1	77.3	22.5	–	87.5	50.8	33.8
621.6358	0.28	−0.747	1.5	68.3	36.6	86.8	17.9	78.8	112.6	55.3	38.5
Cr I	$\log\epsilon_\odot = 5.77$										
578.3866	3.32	−0.195	1.5	64.7	41.2	–	27.3	–	96.0	79.0	48.0
578.7926	3.32	−0.181	1.5	55.7	46.0	–	30.6	–	89.8	64.9	50.1
697.8383	3.46	0.142	1.5	105.7	–	104.6	–	111.8	–	–	–
697.9806	3.46	−0.410	1.5	63.0	41.8	63.6	21.2	71.1	85.8	–	39.6
735.5891	2.89	−0.285	1.5	103.8	69.9	–	45.1	108.8	–	90.6	82.1
740.0188	2.90	−0.166	1.5	107.9	70.0	136.2	56.1	113.9	148.2	96.2	82.6
Mn I	$\log\epsilon_\odot = 5.38$										
601.3497	3.07	−0.251	2.5	136.8	95.6	128.0	–	140.8	–	117.2	–
601.6647	3.07	−0.100	2.5	133.7	95.3	140.2	–	–	–	108.9	–
602.1803	3.07	0.034	2.5	134.4	93.5	150.0	–	147.7	–	–	93.7
Fe I	$\log\epsilon_\odot = 7.57$										
550.6791	0.99	−2.710	1.0	–	–	–	122.1	–	–	–	–
552.2454	4.21	−1.550	1.4	–	–	–	–	–	77.5	–	45.6
552.5552	4.23	−1.084	1.4	–	–	–	39.6	–	103.3	–	56.1
554.3944	4.22	−1.140	1.4	–	–	–	40.8	–	95.8	–	67.0
554.6514	4.37	−1.310	1.4	–	–	–	36.3	–	93.6	–	57.7
556.0220	4.43	−1.190	1.4	–	–	–	–	–	79.6	–	54.4
556.9631	3.42	−0.571	1.4	–	–	–	131.1	–	–	–	178.9
557.6099	3.43	−1.000	1.4	–	–	–	98.7	–	245.4	–	138.3
558.6771	3.37	−0.120	1.4	–	–	–	–	–	–	–	246.6
561.8642	4.21	−1.275	1.4	–	–	–	30.0	–	92.8	–	55.7
562.4030	4.39	−1.480	1.4	–	–	–	32.2	–	–	–	55.2
563.3953	4.99	−0.270	1.4	–	–	–	49.4	–	129.6	–	78.2
563.8271	4.22	−0.870	1.4	–	–	–	55.5	–	112.7	–	82.1

Table 2 Continued

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 12661	19994	22049	29587	38529	75732	92788	95128
				Equivalent Widths (mÅ)							
Fe I	$\log\epsilon_\odot = 7.57$										
564.1448	4.26	−1.180	1.4	–	–	–	40.3	–	105.5	–	65.7
567.9032	4.65	−0.920	1.4	–	–	–	38.9	–	95.2	–	66.9
570.1557	2.56	−2.132	1.4	–	–	–	–	–	133.1	–	87.8
570.5473	4.30	−1.355	1.4	–	–	–	19.8	–	73.9	–	45.1
571.7841	4.28	−1.130	1.4	–	–	–	41.0	–	114.5	–	70.6
573.1772	4.26	−1.300	1.4	–	–	–	44.6	–	100.3	–	60.9
575.3132	4.26	−0.760	1.4	–	–	–	58.5	–	131.9	–	92.0
577.5088	4.22	−1.165	1.4	75.3	56.6	–	–	–	–	84.8	–
580.6732	4.61	−1.050	1.4	75.2	59.4	63.9	32.5	76.7	84.6	76.5	52.7
580.9224	3.88	−1.840	1.4	74.0	48.3	–	–	78.6	92.1	58.1	53.5
585.2228	4.55	−1.330	1.4	64.0	39.7	54.2	–	66.5	71.6	57.1	47.7
585.6096	4.29	−1.327	1.4	–	37.8	–	18.8	56.5	65.5	–	39.1
585.9596	4.55	−0.660	1.4	104.2	82.9	97.1	54.1	100.0	120.5	79.6	82.5
586.2368	4.55	−0.450	1.4	119.5	97.5	117.6	65.8	108.6	165.2	108.7	96.5
590.5680	4.65	−0.730	1.4	80.9	59.9	72.8	37.3	81.8	88.7	74.0	63.4
591.6257	2.45	−2.994	1.3	88.9	56.5	85.8	41.8	95.0	96.5	–	59.1
592.7797	4.65	−1.090	1.4	61.8	46.3	53.1	–	65.5	75.7	62.9	50.7
592.9682	4.55	−1.410	1.4	65.9	45.5	–	24.8	60.2	71.7	58.4	46.6
593.0191	4.65	−0.230	1.4	116.9	96.1	119.7	67.1	120.7	133.4	105.5	94.4
593.4665	3.93	−1.170	1.4	96.9	78.1	112.0	54.4	107.9	147.9	92.5	85.4
595.2726	3.98	−1.440	1.4	91.8	75.9	90.6	38.2	–	133.7	86.9	83.9
595.6706	0.86	−4.498	1.1	73.1	42.6	83.3	34.6	83.9	89.3	59.1	50.9
600.3022	3.88	−1.120	1.4	106.9	84.3	123.0	58.4	112.3	139.2	96.6	95.2
602.4068	4.55	−0.120	1.4	144.5	113.9	161.6	86.6	139.2	197.6	131.2	122.6
602.7059	4.07	−1.089	1.4	82.9	71.6	78.1	45.8	93.2	92.0	72.8	70.0
605.6013	4.73	−0.460	1.4	100.9	76.8	95.0	48.9	99.4	124.1	91.8	88.0
606.5494	2.61	−1.572	1.4	147.6	121.7	190.7	96.4	159.5	210.3	132.0	116.3
607.9016	4.65	−1.120	1.4	68.6	52.3	65.3	24.9	66.6	75.5	65.7	48.3
609.3649	4.61	−1.500	1.4	50.5	33.1	36.1	16.4	48.9	54.5	39.4	34.6
609.6671	3.98	−1.930	1.4	57.7	38.9	51.7	17.9	63.5	72.1	61.6	38.1
613.6624	2.45	−1.405	1.3	176.6	–	–	116.6	–	–	168.3	–
613.7702	2.59	−1.370	1.4	190.2	135.7	223.3	117.0	195.3	–	–	144.9
615.1623	2.18	−3.282	1.2	71.5	45.1	70.2	31.5	76.2	82.6	59.0	52.4
615.7733	4.07	−1.260	1.4	82.0	72.9	77.1	41.7	101.8	105.3	93.3	88.7
616.5363	4.14	−1.473	1.4	67.0	47.0	58.3	28.9	71.8	78.2	59.2	54.6
617.3341	2.22	−2.880	1.2	88.6	73.7	96.3	48.9	105.2	104.7	84.4	78.4
618.0209	2.73	−2.586	1.4	98.3	60.9	84.5	34.2	105.1	131.3	82.6	70.6
618.7995	3.94	−1.720	1.4	75.3	53.4	67.8	27.7	76.6	86.1	66.0	52.7
619.1571	2.43	−1.416	1.3	–	–	–	–	175.8	–	166.1	–
620.0321	2.61	−2.442	1.4	100.6	76.6	102.1	53.4	106.3	115.1	88.3	76.2
621.3437	2.22	−2.579	1.2	104.9	85.0	118.8	64.9	115.9	122.1	98.8	84.1
621.5149	4.19	−1.134	1.4	–	–	100.1	48.5	–	–	–	88.5
621.9287	2.20	−2.430	1.2	116.0	94.0	133.0	72.4	130.3	152.6	–	92.9
622.9232	2.84	−2.805	1.4	62.1	35.9	59.1	–	69.6	84.8	61.0	41.4
623.2648	3.65	−1.223	1.4	112.4	85.9	126.8	–	116.7	–	105.7	–
624.0653	2.22	−3.269	1.2	70.2	53.7	73.6	28.7	–	90.8	51.9	53.3
624.6327	3.60	−0.877	1.4	156.0	118.2	200.2	92.7	147.4	234.6	132.6	119.1
625.2565	2.40	−1.727	1.3	153.0	127.6	183.1	105.6	159.6	209.6	138.3	124.9
626.5141	2.18	−2.500	1.2	113.7	87.1	118.9	68.7	123.3	149.9	94.5	85.3
627.0231	2.86	−2.609	1.4	79.0	57.5	76.9	30.2	87.9	89.7	70.7	64.7
629.7799	2.22	−2.733	1.2	–	–	106.9	–	–	145.3	84.3	77.1
630.1508	3.65	−0.718	1.4	141.5	–	–	–	178.4	–	130.6	–
630.2499	3.69	−0.910	1.4	117.4	–	155.2	–	110.1	–	115.2	–
632.2694	2.59	−2.446	1.4	98.2	81.0	101.7	57.7	110.1	115.6	96.3	–
633.0852	4.73	−1.740	1.4	64.4	32.1	41.4	14.6	55.7	–	51.7	45.6
633.5337	2.20	−2.177	1.2	118.8	102.6	151.3	83.7	136.1	–	102.7	–
633.6830	3.69	−0.856	1.4	148.3	111.5	172.9	87.9	142.5	177.7	115.9	110.1
634.4155	2.43	−2.897	1.3	–	69.4	87.5	41.6	89.1	104.9	99.1	68.4
635.8687	0.86	−4.166	1.1	109.1	74.7	119.1	58.1	115.2	135.2	113.2	81.8
638.0750	4.19	−1.290	1.4	71.2	59.2	61.9	33.8	84.5	87.2	–	54.9

Table 2 Continued

λ	χ_l	$\log gf$	f_6	HD 12661	19994	22049	29587	38529	75732	92788	95128
(nm)	(eV)			Equivalent Widths (mÅ)							
Fe I	$\log\epsilon_{\odot} = 7.57$										
639.3612	2.43	−1.561	1.3	169.4	132.9	236.0	107.8	180.1	267.7	153.1	143.0
640.8026	3.69	−1.011	1.4	138.0	108.2	156.9	–	155.8	–	127.5	–
641.1658	3.65	−0.646	1.4	163.5	127.8	224.6	107.3	165.5	264.8	157.6	141.3
641.9956	4.73	−0.240	1.4	123.4	102.3	118.0	60.7	128.9	145.9	115.7	96.1
643.0856	2.18	−1.976	1.2	148.2	115.3	181.3	94.7	158.5	208.3	130.3	115.4
648.1878	2.28	−2.972	1.2	94.0	73.4	89.4	43.3	102.7	105.1	83.4	71.7
649.4994	2.40	−1.304	1.3	207.2	163.4	266.1	138.1	218.8	–	194.6	177.5
649.6472	4.79	−0.570	1.4	97.3	–	90.5	38.7	102.2	99.7	96.4	66.3
649.8945	0.96	−4.699	1.1	71.4	42.9	80.4	31.0	87.7	88.2	58.8	48.4
651.8373	2.83	−2.455	1.4	87.3	65.0	83.7	39.8	104.7	95.0	82.8	60.6
659.3884	2.43	−2.422	1.3	115.9	83.6	126.6	65.1	124.2	154.5	119.3	91.9
660.9118	2.56	−2.661	1.4	97.0	66.9	95.4	49.9	106.0	117.8	93.4	75.1
667.7997	2.69	−1.418	1.4	170.0	125.5	224.3	115.8	173.1	264.4	151.4	141.3
670.3576	2.76	−3.160	1.4	51.6	36.2	59.5	24.9	70.4	76.8	52.8	44.5
672.6673	4.61	−1.000	1.4	70.9	48.4	59.8	–	67.9	–	58.6	–
675.0164	2.42	−2.604	1.3	97.6	70.5	102.2	58.0	104.0	113.2	79.5	77.2
675.2716	4.64	−1.204	1.4	67.0	33.7	52.2	19.8	66.2	92.2	43.0	47.3
680.6856	2.73	−3.210	1.4	57.8	29.7	55.7	25.5	63.4	78.0	47.6	33.4
681.0267	4.61	−0.986	1.4	74.9	52.2	66.3	29.9	75.6	88.0	71.1	54.8
682.8596	4.64	−0.920	1.4	77.1	63.8	74.7	37.0	92.3	117.1	72.3	64.1
683.9835	2.56	−3.450	1.4	–	39.7	54.7	17.6	66.5	85.8	–	34.4
684.1341	4.61	−0.750	1.4	114.8	–	93.9	42.8	125.2	–	91.6	65.0
684.2689	4.64	−1.320	1.4	68.3	–	52.5	–	71.9	–	–	41.3
684.3655	4.55	−0.930	1.4	82.6	74.0	79.3	38.4	90.7	112.6	72.2	64.6
685.5166	4.56	−0.614	1.4	106.5	84.6	95.3	–	107.9	–	87.7	–
685.8155	4.61	−0.930	1.4	72.5	51.5	63.0	25.9	78.7	99.4	62.1	51.0
694.5210	2.42	−2.452	1.3	109.3	83.7	114.2	64.7	122.2	140.3	85.7	85.0
697.8862	2.48	−2.490	1.3	110.1	–	125.0	–	–	–	–	–
699.9885	4.10	−1.560	1.4	80.7	56.1	77.1	34.9	86.1	100.5	80.5	64.9
702.2957	4.19	−1.250	1.4	91.4	62.8	95.0	45.3	88.6	127.1	75.7	–
702.4065	4.07	−2.208	1.4	–	–	40.5	–	–	–	–	30.6
703.8220	4.22	−1.300	1.4	91.3	68.7	88.2	39.2	105.4	–	–	63.0
707.1866	4.61	−1.700	1.4	49.2	33.2	37.4	–	50.7	56.1	–	35.2
709.0390	4.23	−1.210	1.4	96.3	71.9	90.8	50.1	101.8	109.4	80.2	69.9
711.2170	2.99	−2.994	1.4	61.2	27.1	50.4	10.7	64.3	73.6	51.5	32.8
713.0925	4.22	−0.790	1.4	129.3	90.5	136.7	64.4	127.0	–	103.2	117.7
713.2985	4.07	−1.628	1.4	66.4	45.1	52.7	–	74.4	–	60.0	–
721.9680	4.07	−1.353	1.4	–	47.6	58.7	33.9	–	–	64.9	52.5
728.4842	4.14	−1.750	1.4	64.8	44.5	49.9	–	69.7	–	–	–
730.6570	4.18	−1.740	1.4	67.8	46.0	59.5	–	66.4	71.6	–	44.5
740.1691	4.19	−1.599	1.4	63.9	48.0	50.4	25.8	76.2	80.4	64.5	44.6
741.8672	4.14	−1.376	1.4	75.5	53.2	59.8	28.2	81.7	95.2	69.8	49.5
744.3026	4.19	−1.820	1.4	71.5	44.9	50.5	17.9	81.9	–	–	41.5
751.1031	4.18	0.099	1.4	244.2	166.8	–	–	225.1	–	206.1	–
758.3796	3.02	−1.885	1.4	113.1	91.7	112.3	–	121.0	–	105.0	–
758.6027	4.31	−0.137	1.4	174.8	124.9	199.5	–	150.4	–	161.0	–
771.0367	4.22	−1.112	1.4	104.3	66.4	95.6	–	103.5	–	91.7	–
772.3210	2.28	−3.617	1.2	–	–	71.1	–	85.4	120.0	69.7	42.3
774.8284	2.95	−1.751	1.4	158.6	125.6	151.7	91.1	153.5	169.1	–	106.9
775.1116	4.99	−0.720	1.4	78.8	–	59.6	–	79.2	–	–	–
778.0568	4.47	−0.085	1.4	159.2	117.3	196.5	–	159.3	–	157.5	–
791.2870	0.86	−4.848	1.1	95.4	40.2	91.1	31.4	108.6	–	–	60.5
794.1096	3.27	−2.580	1.4	59.6	47.6	62.6	24.1	76.3	78.6	58.4	46.2
822.0388	4.32	0.275	1.4	–	198.0	270.7	–	–	–	–	–
832.7061	2.20	−1.535	1.2	224.4	–	–	–	213.1	–	–	187.2
836.5640	3.25	−2.042	1.4	96.2	65.0	101.3	–	102.7	–	–	–
838.7782	2.18	−1.503	1.2	233.6	172.9	–	159.1	231.5	–	–	176.6
851.4082	2.20	−2.215	1.2	–	110.5	180.2	89.7	166.7	210.5	131.6	113.1
851.5122	3.02	−2.073	1.4	107.1	89.9	111.9	–	128.5	–	97.7	–

Table 2 Continued

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 12661	19994	22049	29587	38529	75732	92788	95128
				Equivalent Widths (mÅ)							
Fe I	$\log\epsilon_\odot = 7.57$										
852.6676	4.91	−0.760	1.4	90.9	71.8	79.0	–	101.4	–	87.8	–
858.2271	2.99	−2.133	1.4	112.8	79.0	107.9	–	114.8	–	97.7	–
859.8836	4.39	−1.088	1.4	–	69.5	–	–	91.6	–	69.8	–
861.1812	2.84	−1.900	1.4	–	–	144.7	–	–	–	–	–
862.1618	2.95	−2.320	1.4	103.3	69.5	99.9	–	109.5	–	–	–
867.4756	2.83	−1.730	1.4	144.4	113.0	–	–	149.2	–	–	–
868.8642	2.18	−1.202	1.2	–	206.0	–	–	297.9	–	–	–
869.9461	4.95	−0.380	1.4	101.8	65.6	78.2	–	93.1	–	92.1	–
875.7199	2.84	−1.954	1.4	–	95.9	138.8	–	137.1	–	115.9	–
Fe II	$\log\epsilon_\odot = 7.53$										
599.1378	3.15	−3.557	2.5	41.4	51.3	14.9	18.6	54.2	39.2	53.9	48.1
614.9249	3.89	−2.724	2.5	48.9	59.3	17.4	23.2	59.3	35.8	49.4	44.4
624.7562	3.89	−2.257	2.5	75.2	92.0	30.3	34.0	86.7	56.7	64.6	64.4
641.6928	3.89	−2.740	2.5	52.6	59.8	35.0	21.8	57.5	49.3	58.5	51.0
643.2683	2.89	−3.583	2.5	54.2	62.1	28.3	25.6	65.0	43.8	50.6	47.4
645.6391	3.90	−2.075	2.5	81.9	101.1	39.3	42.3	92.0	57.9	77.8	80.9
651.6083	2.89	−3.104	2.5	73.8	80.7	–	36.0	91.7	70.5	67.7	74.1
771.1731	3.90	−2.470	2.5	71.3	86.4	23.3	27.3	72.8	44.6	48.4	55.3
Ni I	$\log\epsilon_\odot = 6.28$										
557.8729	1.68	−2.796	2.5	–	–	–	–	–	114.3	–	58.1
558.7868	1.93	−2.140	2.5	–	–	–	–	–	101.4	–	–
559.3746	3.90	−0.840	2.5	–	–	–	21.3	–	80.5	–	45.7
562.5328	4.09	−0.700	2.5	–	–	–	25.0	–	74.9	–	45.9
568.2208	4.10	−0.456	2.5	–	–	–	34.5	–	95.6	–	61.2
569.4991	4.09	−0.610	2.5	–	–	–	34.0	–	–	–	–
575.4666	1.93	−2.330	2.5	–	–	–	63.4	–	138.4	–	–
578.2136	1.64	−1.780	1.5	136.2	86.2	–	48.0	–	154.5	118.9	81.2
580.5226	4.17	−0.640	2.5	59.5	44.4	38.7	27.3	66.1	66.9	60.2	43.0
585.3688	0.60	−1.010	3.0	–	–	–	50.9	–	–	–	–
608.6288	4.26	−0.530	2.5	69.0	48.2	46.2	25.8	72.1	79.8	57.9	49.1
610.8125	1.68	−2.625	2.5	70.0	66.6	80.3	46.3	96.0	108.6	79.7	68.2
611.1078	4.09	−0.807	2.5	61.3	40.4	37.5	18.6	61.7	67.3	52.3	41.1
612.8984	1.68	−3.330	2.5	51.2	27.4	38.9	–	61.2	62.9	47.3	26.4
613.0141	4.26	−0.960	2.5	45.6	26.4	23.8	–	48.3	46.8	–	–
617.6816	4.09	−0.260	2.5	93.4	76.0	66.2	41.7	96.9	96.4	78.1	69.9
632.7604	1.68	−3.110	2.5	62.6	37.2	55.0	25.7	80.6	85.5	49.5	41.8
648.2809	1.93	−2.630	2.5	65.1	49.4	54.8	24.6	87.1	86.4	83.9	47.7
658.6319	1.95	−2.733	2.5	69.9	40.5	74.3	24.0	80.1	80.6	58.9	47.6
664.3638	1.68	−2.300	2.5	126.8	95.9	118.4	84.0	136.0	133.1	115.6	94.8
676.7784	1.83	−2.170	2.5	109.1	84.1	99.6	65.4	114.2	119.2	96.8	87.6
677.2321	3.66	−0.953	2.5	78.7	59.4	55.9	29.9	82.2	88.6	55.1	53.1
711.0905	1.93	−2.915	2.5	72.7	29.7	57.4	24.2	76.0	85.5	–	36.3
712.2206	3.54	−0.229	2.5	149.7	104.9	138.6	83.4	150.1	186.4	128.4	111.4
738.5244	2.74	−1.970	2.5	69.0	51.1	52.7	33.9	79.6	87.0	41.2	49.5
741.4514	1.99	−2.570	2.5	104.2	72.1	90.5	45.5	117.6	128.0	82.4	71.4
742.2286	3.63	−0.325	2.5	136.4	102.4	120.6	80.6	137.2	195.9	–	97.0
752.5118	3.63	−0.653	2.5	107.1	82.4	82.6	–	116.3	–	95.3	–
757.4048	3.83	−0.607	2.5	105.7	78.7	77.0	–	102.0	–	96.2	–
771.4310	1.93	−1.913	2.5	158.7	109.3	133.6	96.3	167.9	197.7	147.7	109.8
771.5591	3.70	−0.954	2.5	94.9	–	57.6	–	96.3	–	–	–
772.7616	3.68	−0.170	2.5	137.0	111.3	110.6	71.0	127.8	162.7	117.8	104.1
774.8894	3.70	−0.328	2.5	148.2	123.7	109.4	–	137.8	–	137.6	–
778.8933	1.95	−2.420	2.5	134.6	94.5	115.5	65.7	140.0	143.5	122.0	–
779.7588	3.90	−0.298	2.5	108.7	81.5	90.6	–	110.9	–	103.9	–
Ba II	$\log\epsilon_\odot = 2.20$										
585.3688	0.60	−1.010	3.0	–	–	–	50.9	–	–		–
649.6908	0.60	−0.377	3.0	110.6	–	126.6	80.2	–	–	111.6	110.4
614.1727	0.70	−0.077	3.0	135.8	137.2	–	83.3	154.9	170.4	126.5	131.6

Table 2 Continued

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 98230	117176	120136	145675	187123	190228	217014
						Equivalent Widths (mÅ)				
C I	$\log\epsilon_\odot = 8.45$									
658.7610	8.53	−1.08	1.5	–	–	–	18.7	17.4	–	–
O I	$\log\epsilon_\odot = 8.75$									
777.1954	9.14	0.333	2.5	86.5	57.0	160.0	55.7	74.7	39.4	84.2
777.4177	9.14	0.188	2.5	80.6	51.8	148.0	53.9	68.2	–	73.2
777.5395	9.14	−0.034	2.5	53.2	44.3	129.3	–	55.7	23.6	59.8
Na I	$\log\epsilon_\odot = 6.27$									
568.2650	2.10	−0.652	2.0	–	–	–	–	–	109.4	–
568.8217	2.10	−0.341	2.0	120.5	–	–	–	–	131.5	–
615.4230	2.10	−1.570	2.0	20.9	38.3	40.6	106.9	–	–	57.3
616.0753	2.10	−1.228	2.0	47.6	68.8	–	137.4	–	64.8	70.8
Mg I	$\log\epsilon_\odot = 7.60$									
631.8700	5.11	−1.97	2.5	–	–	–	–	–	46.8	–
631.9200	5.11	−2.20	2.5	–	–	–	–	–	–	–
738.7700	5.75	−0.970	2.5	–	–	–	186.4	–	72.7	–
765.7606	5.11	−1.188	2.5	–	–	–	156.7	–	107.1	–
871.2701	5.93	−1.260	2.5	–	–	–	149.5	–	–	–
871.7833	5.93	−0.970	2.5	–	–	–	184.5	–	–	–
892.3600	5.94	−1.65	2.5	–	–	–	115.2	–	–	–
Al I	$\log\epsilon_\odot = 6.37$									
669.6020	3.14	−1.330	1.5	–	–	–	95.9	–	–	–
669.8670	3.14	−1.873	1.5	–	–	–	74.3	–	24.4	–
783.5317	4.02	−0.580	1.5	23.9	49.0	–	130.2	61.1	40.1	–
783.6130	4.02	−0.400	1.5	35.6	64.1	–	146.6	71.9	54.9	–
877.2870	4.02	−0.250	1.5	–	–	–	174.7	–	–	–
877.3900	4.02	−0.070	1.5	–	–	–	208.0	–	–	–
Si I	$\log\epsilon_\odot = 7.64$									
566.5563	4.92	−2.040	1.3	–	–	–	–	–	39.9	–
569.0433	4.93	−1.870	1.3	33.1	52.2	51.3	–	–	41.2	–
570.1108	4.93	−2.050	1.3	–	–	–	–	–	42.6	–
570.8405	4.95	−1.399	1.5	66.5	87.4	105.9	–	–	–	–
577.2149	5.08	−1.665	1.5	37.1	58.4	67.5	–	–	54.9	–
579.3079	4.93	−1.946	1.3	–	–	–	–	–	41.4	63.6
579.7865	4.95	−2.050	1.5	–	–	–	–	–	43.8	–
594.8548	5.08	−1.190	1.5	69.5	85.7	93.7	123.1	105.5	78.6	106.9
612.5026	5.61	−1.540	1.3	–	–	–	–	45.3	26.8	–
614.2494	5.62	−1.480	1.3	–	–	–	67.4	45.3	31.9	–
614.5020	5.62	−1.430	1.3	–	–	–	68.7	51.8	28.6	–
703.4910	5.87	−0.810	1.3	–	–	–	105.3	79.6	55.5	–
722.6208	5.61	−1.296	1.5	32.6	46.6	62.9	86.2	–	41.3	–
740.5790	5.61	−0.681	1.5	73.6	92.1	114.5	125.8	103.5	85.1	110.5
741.5958	5.61	−0.710	1.3	–	–	–	128.1	107.3	92.8	–
780.0000	6.18	−0.782	1.3	–	–	–	–	78.0	53.5	–
791.8383	5.95	−0.536	1.5	66.5	102.6	111.1	158.6	104.1	84.2	–
793.2351	5.96	−0.352	1.5	–	116.2	–	151.0	129.6	90.7	–
872.8024	6.18	−0.360	1.3	–	–	–	127.2	–	–	–
S I	$\log\epsilon_\odot = 7.18$									
604.6030	7.87	−0.230	2.5	–	–	–	32.5	29.9	–	–
605.2670	7.87	−0.440	2.5	–	–	–	30.2	17.3	8.5	–
869.3958	7.87	−0.740	2.5	–	–	–	20.0	–	–	–
869.4641	7.87	−0.210	2.5	–	–	–	–	–	–	–
K I	$\log\epsilon_\odot = 5.30$									
769.8977	0.00	−0.160	1.5	158.1	170.1	155.6	229.8	165.3	169.9	–
Ca I	$\log\epsilon_\odot = 6.35$									
551.2989	2.93	−0.530	1.8	76.4	126.3	–	–	–	–	99.4
558.1979	2.52	−0.671	1.8	85.3	116.0	–	–	–	103.9	–
558.8764	2.52	0.061	1.8	149.2	179.7	159.7	–	–	155.0	–
559.0126	2.52	−0.702	1.8	84.2	102.0	118.1	–	–	100.8	–

Table 2 Continued

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 98230	117176	120136	145675	187123	190228	217014
				Equivalent Widths (mÅ)						
Ca I	$\log\epsilon_\odot = 6.35$									
560.1286	2.52	−0.523	1.8	95.6	155.6	–	–	–	120.8	–
585.7459	2.93	0.112	1.8	–	148.6	–	–	–	144.3	–
586.7572	2.93	−1.610	1.8	–	–	–	62.9	–	25.8	–
610.2727	1.88	−0.790	2.3	137.0	147.0	–	242.9	–	152.6	–
616.1295	2.52	−1.192	1.8	57.5	90.8	–	150.6	–	80.4	–
616.3754	2.52	−1.069	2.0	62.7	–	–	–	–	–	–
616.6440	2.52	−1.189	1.8	55.2	77.4	69.2	123.6	73.1	76.4	–
616.9044	2.52	−0.797	1.8	87.6	102.6	–	174.7	104.9	106.4	–
616.9564	2.52	−0.511	1.8	102.6	122.1	–	196.4	126.6	124.3	–
643.9083	2.52	0.164	1.5	180.3	207.5	182.0	276.8	183.3	177.8	–
644.9820	2.52	−0.502	1.5	100.0	140.5	–	–	116.3	113.0	–
645.5605	2.52	−1.290	1.5	–	–	–	101.4	61.4	63.8	67.9
647.1668	2.52	−0.694	0.8	85.4	100.6	98.3	135.7	99.3	94.0	100.3
649.3788	2.52	−0.092	0.8	123.6	148.7	145.9	214.1	153.9	152.0	–
649.9654	2.52	−0.811	0.8	76.8	93.5	88.7	137.4	100.4	88.6	–
671.7687	2.71	−0.524	1.5	–	–	–	213.1	–	124.3	–
714.8150	2.71	−0.137	1.5	–	–	–	235.2	–	149.7	–
Sc II	$\log\epsilon_\odot = 3.29$									
552.6821	1.77	−0.256	2.5	78.1	89.0	–	–	–	88.7	88.4
565.7880	1.51	−0.603	2.5	58.8	–	–	–	–	74.6	–
624.5620	1.51	−1.134	2.5	–	–	–	67.9	43.3	45.8	–
660.4600	1.36	−1.309	2.5	28.6	51.4	–	65.1	45.1	44.8	–
Ti I	$\log\epsilon_\odot = 5.01$									
586.6461	1.07	−0.840	1.5	32.0	66.5	30.7	–	54.6	61.5	65.9
595.3170	1.89	−0.205	1.5	22.5	56.0	–	–	–	50.6	46.3
612.6224	1.07	−1.320	1.5	18.7	33.5	–	76.6	23.4	33.6	34.7
625.8110	1.44	−0.431	1.5	38.4	68.0	37.2	106.0	56.8	71.6	–
626.1106	1.43	−0.479	1.5	31.8	66.2	32.2	–	54.4	73.5	63.6
842.6514	0.83	−1.179	1.5	40.9	72.6	–	121.0	60.3	–	–
843.5655	0.84	−0.871	1.5	45.9	77.3	–	145.7	65.8	–	–
V I	$\log\epsilon_\odot = 4.09$									
572.7057	1.08	−0.012	1.5	25.6	60.8	–	–	–	61.5	56.0
609.0216	1.08	−0.139	1.5	19.4	46.3	–	88.6	44.2	50.8	42.6
621.6358	0.28	−0.747	1.5	19.7	46.3	26.4	112.8	45.5	51.1	–
Cr I	$\log\epsilon_\odot = 5.77$									
578.3866	3.32	−0.195	1.5	26.8	52.0	41.6	–	–	51.0	65.4
578.7926	3.32	−0.181	1.5	28.4	50.7	44.7	–	–	45.7	–
697.8383	3.46	0.142	1.5	46.9	67.6	–	151.1	–	85.9	–
697.9806	3.46	−0.410	1.5	24.6	41.8	–	85.6	51.5	40.8	–
735.5891	2.89	−0.285	1.5	59.6	86.3	–	–	–	75.9	–
740.0188	2.90	−0.166	1.5	58.3	82.0	69.9	152.3	85.0	88.3	–
Mn I	$\log\epsilon_\odot = 5.38$									
601.3497	3.07	−0.251	2.5	–	–	102.8	155.8	103.5	94.8	102.8
601.6647	3.07	−0.100	2.5	–	–	–	165.1	105.9	104.2	–
602.1803	3.07	0.034	2.5	67.3	97.1	–	166.7	104.1	102.0	–
Fe I	$\log\epsilon_\odot = 7.57$									
550.6791	0.99	−2.710	1.0	124.1	–	–	–	–	162.2	–
552.2454	4.21	−1.550	1.4	33.7	54.4	–	–	–	–	54.0
552.5552	4.23	−1.084	1.4	44.0	63.1	–	–	–	74.7	–
554.3944	4.22	−1.140	1.4	63.3	79.2	67.7	–	–	–	–
554.6514	4.37	−1.310	1.4	44.1	60.8	–	–	–	–	–
556.0220	4.43	−1.190	1.4	35.3	59.7	56.8	–	–	53.8	–
556.9631	3.42	−0.571	1.4	150.9	190.5	143.6	–	–	162.4	–
557.6099	3.43	−1.000	1.4	104.2	137.0	111.7	–	–	124.1	–
558.6771	3.37	−0.120	1.4	210.5	262.9	193.6	–	–	217.3	–
561.8642	4.21	−1.275	1.4	40.9	57.3	56.9	–	–	54.2	–
562.4030	4.39	−1.480	1.4	–	–	–	–	–	–	–
563.3953	4.99	−0.270	1.4	56.3	76.3	70.9	–	–	74.7	–
563.8271	4.22	−0.870	1.4	67.1	84.7	83.7	–	–	83.6	–

Table 2 Continued

λ	χ_l	$\log gf$	f_6	HD 98230	117176	120136	145675	187123	190228	217014
(nm)	(eV)					Equivalent Widths (mÅ)				
Fe I	$\log\epsilon_\odot$ = 7.57									
564.1448	4.26	−1.180	1.4	54.3	73.7	–	–	–	72.4	–
567.9032	4.65	−0.920	1.4	47.9	66.5	65.3	–	–	58.9	–
570.1557	2.56	−2.132	1.4	74.6	92.5	–	–	–	99.2	–
570.5473	4.30	−1.355	1.4	–	48.0	–	–	–	–	–
571.7841	4.28	−1.130	1.4	59.8	70.2	71.3	–	–	–	–
573.1772	4.26	−1.300	1.4	47.1	65.5	–	–	–	60.2	–
575.3132	4.26	−0.760	1.4	68.0	88.8	–	–	–	79.0	87.8
577.5088	4.22	−1.165	1.4	–	–	–	91.1	–	66.6	–
580.6732	4.61	−1.050	1.4	42.7	68.1	65.8	92.9	63.2	52.8	–
580.9224	3.88	−1.840	1.4	37.2	65.0	52.7	94.5	56.2	54.5	–
585.2228	4.55	−1.330	1.4	28.8	50.0	51.6	80.0	43.4	38.3	–
585.6096	4.29	−1.327	1.4	–	–	–	64.2	38.8	40.6	–
585.9596	4.55	−0.660	1.4	60.3	79.5	87.2	116.9	82.7	73.0	85.2
586.2368	4.55	−0.450	1.4	75.2	95.3	98.2	139.4	97.2	87.5	100.6
590.5680	4.65	−0.730	1.4	45.5	64.9	52.6	89.9	71.5	55.3	–
591.6257	2.45	−2.994	1.3	40.4	68.4	50.2	105.1	66.4	74.4	–
592.7797	4.65	−1.090	1.4	29.8	48.9	49.9	73.0	49.3	40.2	–
592.9682	4.55	−1.410	1.4	27.5	49.5	–	81.0	–	–	–
593.0191	4.65	−0.230	1.4	74.9	93.9	–	148.4	98.9	87.8	–
593.4665	3.93	−1.170	1.4	61.5	85.4	80.3	131.9	85.9	–	–
595.2726	3.98	−1.440	1.4	46.6	74.3	–	119.3	–	70.3	–
595.6706	0.86	−4.498	1.1	–	–	–	87.5	–	72.9	–
600.3022	3.88	−1.120	1.4	68.8	98.4	81.9	137.9	95.9	88.8	–
602.4068	4.55	−0.120	1.4	100.7	115.3	115.2	180.1	–	108.6	127.3
602.7059	4.07	−1.089	1.4	51.8	77.3	68.4	92.5	69.9	69.8	73.5
605.6013	4.73	−0.460	1.4	61.2	78.6	90.8	120.5	85.6	73.3	88.3
606.5494	2.61	−1.572	1.4	–	124.7	107.5	193.2	–	130.3	138.0
607.9016	4.65	−1.120	1.4	34.5	51.9	49.0	84.4	59.0	–	–
609.3649	4.61	−1.500	1.4	17.0	34.0	25.3	59.1	–	31.9	–
609.6671	3.98	−1.930	1.4	22.3	42.3	31.0	73.9	42.4	40.0	49.5
613.6624	2.45	−1.405	1.3	–	–	–	239.2	–	–	–
613.7702	2.59	−1.370	1.4	119.3	161.8	134.5	254.1	–	150.7	–
615.1623	2.18	−3.282	1.2	–	59.8	34.1	78.2	55.1	61.3	–
615.7733	4.07	−1.260	1.4	54.7	76.1	83.7	106.9	66.5	70.3	–
616.5363	4.14	−1.473	1.4	–	49.4	44.6	84.5	46.1	48.7	–
617.3341	2.22	−2.880	1.2	55.5	79.6	70.0	112.7	75.5	80.1	–
618.0209	2.73	−2.586	1.4	43.9	78.5	54.1	112.1	61.2	70.5	–
618.7995	3.94	−1.720	1.4	33.1	56.9	48.1	85.8	53.1	49.7	–
619.1571	2.43	−1.416	1.3	–	–	–	–	–	–	–
620.0321	2.61	−2.442	1.4	58.2	83.5	67.1	122.7	80.8	84.7	–
621.3437	2.22	−2.579	1.2	71.5	90.7	75.9	131.5	88.0	91.6	–
621.5149	4.19	−1.134	1.4	51.2	86.4	83.2	–	–	84.8	–
621.9287	2.20	−2.430	1.2	78.1	101.4	84.9	145.7	–	102.1	–
622.9232	2.84	−2.805	1.4	–	49.3	30.4	74.5	46.9	49.8	–
623.2648	3.65	−1.223	1.4	–	–	–	139.9	90.9	93.6	95.9
624.0653	2.22	−3.269	1.2	32.7	60.8	–	89.6	52.4	64.0	60.4
624.6327	3.60	−0.877	1.4	110.6	126.5	112.7	202.0	–	119.6	–
625.2565	2.40	−1.727	1.3	111.5	131.7	115.4	194.0	–	135.1	–
626.5141	2.18	−2.500	1.2	76.7	97.4	84.3	139.2	92.0	100.3	98.6
627.0231	2.86	−2.609	1.4	38.2	59.4	42.3	86.4	64.2	62.0	–
629.7799	2.22	−2.733	1.2	63.3	85.9	66.7	127.0	82.5	87.0	–
630.1508	3.65	−0.718	1.4	–	–	–	203.0	–	117.3	133.4
630.2499	3.69	−0.910	1.4	–	–	–	148.3	–	114.0	–
632.2694	2.59	−2.446	1.4	61.5	88.3	80.7	118.4	85.2	86.2	–
633.0852	4.73	−1.740	1.4	20.1	37.7	38.2	70.5	41.0	29.7	–
633.5337	2.20	−2.177	1.2	–	115.2	96.5	156.9	–	112.7	113.8
633.6830	3.69	−0.856	1.4	90.7	123.3	105.6	–	–	110.2	–
634.4155	2.43	−2.897	1.3	55.7	76.0	–	–	–	81.1	–
635.8687	0.86	−4.166	1.1	60.8	97.1	79.8	129.4	–	98.5	–
638.0750	4.19	−1.290	1.4	43.2	59.7	59.4	92.7	57.6	54.0	–

Table 2 Continued

λ (nm)	χ_l (eV)	$\log gf$	f_6	HD 98230	117176	120136	145675	187123	190228	217014
				Equivalent Widths (mÅ)						
Fe I	$\log\epsilon_\odot = 7.57$									
639.3612	2.43	−1.561	1.3	117.4	149.5	124.5	220.9	–	143.2	147.7
640.8026	3.69	−1.011	1.4	–	–	–	175.1	–	104.0	–
641.1658	3.65	−0.646	1.4	128.5	145.6	121.1	219.5	–	133.3	–
641.9956	4.73	−0.240	1.4	89.3	95.3	92.4	139.7	–	85.5	–
643.0856	2.18	−1.976	1.2	106.3	–	108.8	193.9	–	131.9	–
648.1878	2.28	−2.972	1.2	47.6	76.8	74.3	101.2	–	77.8	–
649.4994	2.40	−1.304	1.3	151.6	188.9	165.8	–	–	174.8	–
649.6472	4.79	−0.570	1.4	60.6	85.0	–	113.3	–	–	–
649.8945	0.96	−4.699	1.1	30.7	60.0	–	92.8	59.2	65.0	–
651.8373	2.83	−2.455	1.4	47.1	73.7	–	108.6	–	63.5	–
659.3884	2.43	−2.422	1.3	75.8	–	78.1	–	98.1	104.0	–
660.9118	2.56	−2.661	1.4	52.3	81.2	68.8	122.2	70.7	76.5	–
667.7997	2.69	−1.418	1.4	110.4	148.1	129.3	226.5	–	143.4	–
670.3576	2.76	−3.160	1.4	21.9	46.0	26.6	76.6	42.5	46.1	–
672.6673	4.61	−1.000	1.4	–	–	–	79.9	54.6	48.9	–
675.0164	2.42	−2.604	1.3	62.9	86.1	72.1	112.8	82.1	86.7	86.3
675.2716	4.64	−1.204	1.4	29.7	55.1	44.0	79.6	49.0	43.2	–
680.6856	2.73	−3.210	1.4	19.5	44.3	–	77.2	37.7	–	46.8
681.0267	4.61	−0.986	1.4	45.1	53.6	54.6	90.8	54.5	49.1	61.3
682.8596	4.64	−0.920	1.4	47.9	61.8	77.1	96.2	53.9	47.9	–
683.9835	2.56	−3.450	1.4	22.4	45.5	–	–	36.6	43.0	–
684.1341	4.61	−0.750	1.4	50.6	95.2	94.1	140.9	83.8	83.0	–
684.2689	4.64	−1.320	1.4	24.8	49.3	–	82.4	49.1	40.0	–
684.3655	4.55	−0.930	1.4	45.0	66.6	69.9	109.1	70.1	58.9	76.8
685.5166	4.56	−0.614	1.4	–	–	–	118.6	90.1	88.2	–
685.8155	4.61	−0.930	1.4	34.4	55.1	62.6	89.6	57.9	54.3	66.3
694.5210	2.42	−2.452	1.3	71.8	99.8	86.2	149.8	88.7	89.0	–
697.8862	2.48	−2.490	1.3	68.3	92.4	–	132.8	–	89.6	–
699.9885	4.10	−1.560	1.4	43.4	66.0	–	111.2	64.4	–	–
702.2957	4.19	−1.250	1.4	51.3	68.1	–	111.3	–	64.7	–
702.4065	4.07	−2.208	1.4	–	–	–	–	–	–	–
703.8220	4.22	−1.300	1.4	–	75.5	–	–	–	93.8	–
707.1866	4.61	−1.700	1.4	16.5	33.4	–	57.3	36.8	26.0	–
709.0390	4.23	−1.210	1.4	47.7	73.2	59.8	119.0	74.3	73.0	–
711.2170	2.99	−2.994	1.4	19.9	41.5	–	81.3	42.5	37.9	–
713.0925	4.22	−0.790	1.4	–	120.4	98.4	–	–	97.6	–
713.2985	4.07	−1.628	1.4	–	–	–	82.2	53.1	47.2	–
721.9680	4.07	−1.353	1.4	36.8	–	52.4	81.9	–	56.5	–
728.4842	4.14	−1.750	1.4	24.6	–	–	78.6	42.2	–	–
730.6570	4.18	−1.740	1.4	31.8	46.8	–	90.6	–	55.7	–
740.1691	4.19	−1.599	1.4	27.9	47.4	–	77.2	51.2	45.3	55.8
741.8672	4.14	−1.376	1.4	–	55.5	52.1	81.4	56.2	59.4	–
744.3026	4.19	−1.820	1.4	21.5	45.3	–	80.1	–	39.8	–
751.1031	4.18	0.099	1.4	–	–	–	295.1	–	171.6	–
758.3796	3.02	−1.885	1.4	–	–	–	134.7	91.9	88.4	–
758.6027	4.31	−0.137	1.4	–	–	–	222.4	–	109.5	–
771.0367	4.22	−1.112	1.4	–	–	–	125.9	80.0	69.0	–
772.3210	2.28	−3.617	1.2	26.9	54.3	–	102.1	59.3	60.9	–
774.8284	2.95	−1.751	1.4	97.0	115.5	–	170.7	–	112.4	–
775.1116	4.99	−0.720	1.4	–	–	–	88.8	49.4	45.9	–
778.0568	4.47	−0.085	1.4	–	–	–	209.8	–	120.4	–
791.2870	0.86	−4.848	1.1	28.4	76.7	–	126.3	55.9	79.6	–
794.1096	3.27	−2.580	1.4	28.5	57.0	–	77.2	46.4	47.7	–
822.0388	4.32	0.275	1.4	–	–	–	–	–	–	–
832.7061	2.20	−1.535	1.2	165.1	196.8	–	–	–	–	–
836.5640	3.25	−2.042	1.4	–	–	–	127.0	–	–	–
838.7782	2.18	−1.503	1.2	180.5	215.4	–	–	–	–	–
851.4082	2.20	−2.215	1.2	114.0	–	–	192.2	–	–	–
851.5122	3.02	−2.073	1.4	–	–	–	138.3	–	–	–

Table 2 Continued

λ	χ_l	$\log gf$	f_6	HD 98230	117176	120136	145675	187123	190228	217014
(nm)	(eV)					Equivalent Widths (mÅ)				
Fe I	$\log\epsilon_\odot = 7.57$									
852.6676	4.91	−0.760	1.4	–	–	–	117.0	–	–	–
858.2271	2.99	−2.133	1.4	–	–	–	130.3	95.5	–	–
859.8836	4.39	−1.088	1.4	–	–	–	101.9	–	–	–
861.1812	2.84	−1.900	1.4	–	–	–	–	–	–	–
862.1618	2.95	−2.320	1.4	–	–	–	126.5	–	–	–
867.4756	2.83	−1.730	1.4	–	–	–	183.3	–	–	–
868.8642	2.18	−1.202	1.2	–	–	–	–	–	–	–
869.9461	4.95	−0.380	1.4	–	–	–	111.8	–	–	–
875.7199	2.84	−1.954	1.4	–	–	–	159.3	–	–	–
Fe II	$\log\epsilon_\odot = 7.53$									
599.1378	3.15	−3.557	2.5	29.3	49.2	67.0	38.1	42.9	35.1	–
614.9249	3.89	−2.724	2.5	33.0	42.1	65.0	39.0	42.7	31.3	–
624.7562	3.89	−2.257	2.5	52.2	60.2	99.9	58.0	64.0	50.7	–
641.6928	3.89	−2.740	2.5	42.9	48.2	62.1	49.2	43.8	36.9	–
643.2683	2.89	−3.583	2.5	33.9	46.2	72.5	45.2	48.8	39.7	47.6
645.6391	3.90	−2.075	2.5	63.4	68.9	–	64.8	–	56.9	64.7
651.6083	2.89	−3.104	2.5	–	62.5	85.6	69.3	–	53.8	61.5
771.1731	3.90	−2.470	2.5	44.0	44.2	86.8	54.3	45.6	46.5	–
Ni I	$\log\epsilon_\odot = 6.28$									
557.8729	1.68	−2.796	2.5	37.9	76.8	48.0	–	–	73.8	74.4
558.7868	1.93	−2.140	2.5	–	–	–	–	–	–	–
559.3746	3.90	−0.840	2.5	26.1	46.9	–	–	–	40.9	–
562.5328	4.09	−0.700	2.5	25.4	52.8	–	–	–	–	–
568.2208	4.10	−0.456	2.5	40.0	60.0	–	–	–	57.2	–
569.4991	4.09	−0.610	2.5	32.5	51.3	49.6	–	–	–	–
575.4666	1.93	−2.330	2.5	64.2	96.1	–	–	–	94.6	–
578.2136	1.64	−1.780	1.5	41.9	100.2	74.7	–	–	98.3	–
580.5226	4.17	−0.640	2.5	25.5	43.1	50.3	66.0	48.0	28.5	58.2
585.3688	0.60	−1.010	3.0	72.0	–	–	–	–	–	–
608.6288	4.26	−0.530	2.5	25.8	47.0	44.8	80.7	53.2	45.2	61.7
610.8125	1.68	−2.625	2.5	43.3	79.7	56.3	105.7	75.2	83.1	81.8
611.1078	4.09	−0.807	2.5	18.1	41.5	39.1	68.6	41.7	34.1	–
612.8984	1.68	−3.330	2.5	15.0	31.9	–	66.5	32.1	35.7	–
613.0141	4.26	−0.960	2.5	13.3	24.3	–	53.6	30.2	22.7	–
617.6816	4.09	−0.260	2.5	47.5	68.2	80.0	98.9	80.1	64.9	–
632.7604	1.68	−3.110	2.5	19.3	49.3	28.9	87.4	47.1	51.5	–
648.2809	1.93	−2.630	2.5	25.1	52.7	–	82.8	47.0	49.9	–
658.6319	1.95	−2.733	2.5	21.9	49.6	–	87.5	52.5	54.1	–
664.3638	1.68	−2.300	2.5	75.1	108.7	76.2	144.6	101.0	109.7	–
676.7784	1.83	−2.170	2.5	61.3	87.3	72.6	123.3	79.3	89.5	95.1
677.2321	3.66	−0.953	2.5	46.5	66.3	50.5	86.7	55.1	52.0	64.0
711.0905	1.93	−2.915	2.5	17.2	45.8	–	98.5	35.3	44.0	–
712.2206	3.54	−0.229	2.5	84.8	110.1	102.3	189.7	115.9	104.7	–
738.5244	2.74	−1.970	2.5	31.1	49.5	28.2	85.5	57.8	52.5	–
741.4514	1.99	−2.570	2.5	48.1	79.9	55.3	119.4	–	90.8	–
742.2286	3.63	−0.325	2.5	74.7	100.6	105.9	151.3	110.0	101.9	–
752.5118	3.63	−0.653	2.5	–	–	–	125.5	82.7	69.2	–
757.4048	3.83	−0.607	2.5	–	–	–	114.7	71.8	65.1	–
771.4310	1.93	−1.913	2.5	88.4	129.1	98.7	186.5	–	128.8	–
771.5591	3.70	−0.954	2.5	–	–	–	96.3	–	53.9	–
772.7616	3.68	−0.170	2.5	78.3	97.6	91.0	141.8	98.7	91.4	–
774.8894	3.70	−0.328	2.5	–	–	–	142.0	98.1	93.5	–
778.8933	1.95	−2.420	2.5	65.7	108.8	74.7	153.4	–	109.1	–
779.7588	3.90	−0.298	2.5	–	–	–	118.3	85.9	81.0	–
Ba II	$\log\epsilon_\odot = 2.20$									
585.3688	0.60	−1.010	3.0	72.0	–	–	–	–	–	–
649.6908	0.60	−0.377	3.0	107.9	113.1	–	121.0	122.6	116.8	–
614.1727	0.70	−0.077	3.0	128.7	131.0	134.1	152.9	134.1	130.9	123.3

We also compared the EWs given by Smith et al. (2001) with our measurements for HD 19994 (see Fig. 2). The comparison also shows a good agreement, with a slight tendency for the equivalent widths of Smith et al.(2001) to be somewhat smaller for the strongest lines. A linear least squares fitting to a total of 40 common lines gives

$$\mathrm{EW\ (ZCQ)} = 1.047(\pm 0.023)\ \mathrm{EW\ (SCL)} + 2.771(\pm 1.757)\,.$$

The scatter between the two sets of data is about 5.0 mÅ, which is slightly smaller than in the comparison with the work of Gonzalez (1998). Both the resolution and signal-to-noise ratio of their spectra are slightly higher than ours.

From the above comparison, we estimated that the error of equivalent widths measured from Xinglong spectra is around 4 mÅ for these stars.

Acknowledgements This work is supported by NKBRSF G1999075406 and the National Natural Science Foundation of China under grant No. 10173014.

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