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Lithium abundances in metal-poor stars

I. New observations*

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Abstract. We present the lithium measurements of a continuing programme of light element abundances in metal-poor stars. New equivalent widths of the Li I λ670.8 nm resonance line in 67 metal-poor stars covering the metallicity range $-3.5 \leq [\mathrm{Fe/H}] \leq -0.4$ are reported. For about half of this sample, the observations presented here represent the first measurement of the Li I line. The sample allowed a statistical comparison with previous measurements from other authors and a study of the consistency and reliability of the quoted error bars. This paper shows that for most of the stars these error bars are good estimates of the true uncertainties associated with the determination of the equivalent widths of the Li I line. However, about 20% of the stars with two or more independent measurements show discrepancies in the Li I equivalent widths; in these cases, other sources of uncertainty not properly taken into account (binarity effects, cosmic rays, imperfect flat-field correction, continuum determination, etc.) could also be important. Conclusions on the possible lithium abundance trends versus effective temperature or metallicity and on any intrinsic scatter should be treated cautiously until their robustness vis-à-vis these additional uncertainties is proved.

Key words: Galaxy: evolution — stars: abundances — stars: late-type — stars: Population II

1. Introduction

According to the standard big bang nucleosynthesis model, lithium is one of the few elements synthesized in the first minutes of the Universe. In this scenario the primordial synthesis of lithium is very sensitive to the baryon/photon ratio ($n_{\mathrm{b}}/n_{\gamma}$), and the astronomical determination of its primordial abundance can constrain the baryonic contribution to the density of the Universe. Since the discovery of a rather uniform lithium abundance, the so called *lithium plateau*, in the hotter halo dwarfs (Spite & Spite 1982; Rebolo et al. 1988) at about a value $\log n(\mathrm{Li}) = 2$ (on the usual scale where $\log n(\mathrm{H}) = 12$), there has been a long debate on whether or not this abundance reflects the primordial one. Some theoretical models suggest that processes such as diffusion, rotational mixing etc. may have depleted the initial lithium abundance of the hotter ($T_{\mathrm{eff}} \geq$ 5600 K) halo dwarfs and reduced it to its present atmospheric value. The fingerprint of such a process has been searched and claimed to be possibly manifest in a trend of the Li abundance versus [Fe/H] and T_{eff} (Thorburn 1994; Norris et al. 1994; Ryan et al. 1996), or in a spread of the lithium abundance around the *plateau* (Deliyannis et al. 1993, 1995).

The observational evidence for a global depletion process acting on these halo dwarfs is not conclusive. Molaro et al. (1995) using a reddening-free temperature scale and Bonifacio & Molaro (1997) using direct infrared flux method temperatures provided by Alonso et al. (1996) have made a bivariate analysis of a large sample of halo dwarfs, and conclude in both cases that there is no evidence of these trends versus metallicity and effective temperature. The same conclusion has been reached by Spite et al. (1996), who re-analysed an important part of the current observations using temperatures determined from several independent methods; these authors propose that

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* Based on observations made with the Isaac Newton and Nordic Optical Telescopes, which are operated on the island of La Palma by the Isaac Newton Group and the NOT Scientific Association, respectively, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

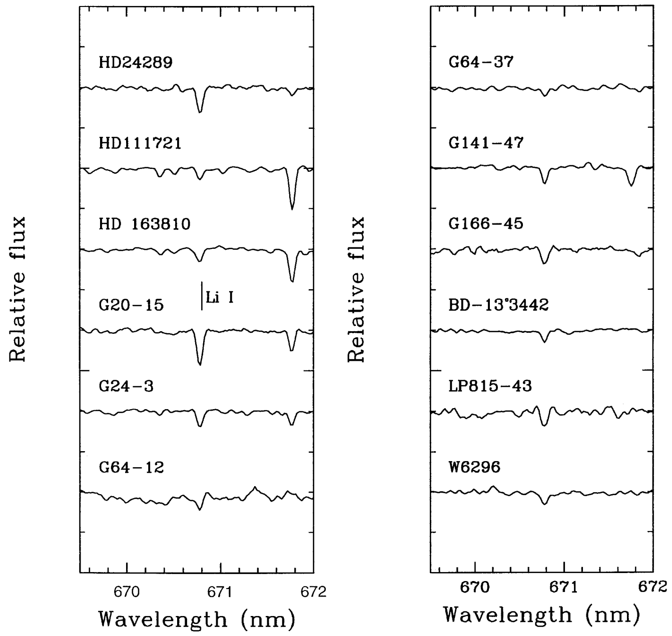

Fig. 1. Spectra of several stars of our sample in the Li I λ 670.8 nm region. A three pixels box-car smoothing was applied to each spectrum

the observed spread around the *plateau* is due to error measurements and uncertainties in effective temperatures. On the other hand, Ryan et al. (1996) used a temperature scale similar to the scale of Carney et al. (1994) and in this case, a multiple-regression analysis shows that the correlations actually exist, especially when the most metal-poor stars are included in the sample.

This is the first paper of a series that intend to revisit the lithium problem in halo dwarfs. The paper presents new Li I λ670.8 nm observations in 67 metal-poor stars. Here, the observations and the comparison with other works are presented. The main analyses and implications will be given in a forthcoming paper.

2. Observations and data reduction

The observations presented here were obtained as part of an international collaboration at the observatories of the Canary Islands in several campaigns during the years 1990 and 1991. We used the Cassegrain foci of the 2.5 m Isaac Newton (INT) Telescope and Nordic Optical (NOT) Telescope at the Observatorio del Roque de los Muchachos (La Palma). Spectra in the region of the Li I line were obtained using the Intermediate Dispersion Spectrograph (IDS) and the IACUB echelle spectrograph at the INT and NOT, respectively. The H1800V grating and the 500 mm camera with a 385 × 578 GEC-CCD were used at the IDS, providing a dispersion of 0.22 Å per pixel. The adopted slit-width was usually 1 arcsec giving an effective resolution of 0.44 Å. The IACUB echelle spectrograph (McKeith et al. 1993) was used with a Thomson 1024 × 1024 CCD binned in the spectral direction to provide a dispersion of 0.1 Å per pixel. The 0.7 arcsec slit width employed gave a final effective resolution of ∼ 0.22 Å (in the case of G181-47 we used a 1 arcsec slit which gave 0.30 Å). Typically, we recorded spectra with exposure times ∼ 1800 s. For the fainter stars, two or more exposures were combined in order to have a homogeneous sample with signal to noise in the range 100 − 200. Using the same instrumental configuration, several flat-field lamps were recorded each night. For wavelength calibration Cu – Ar lamp spectra were used.

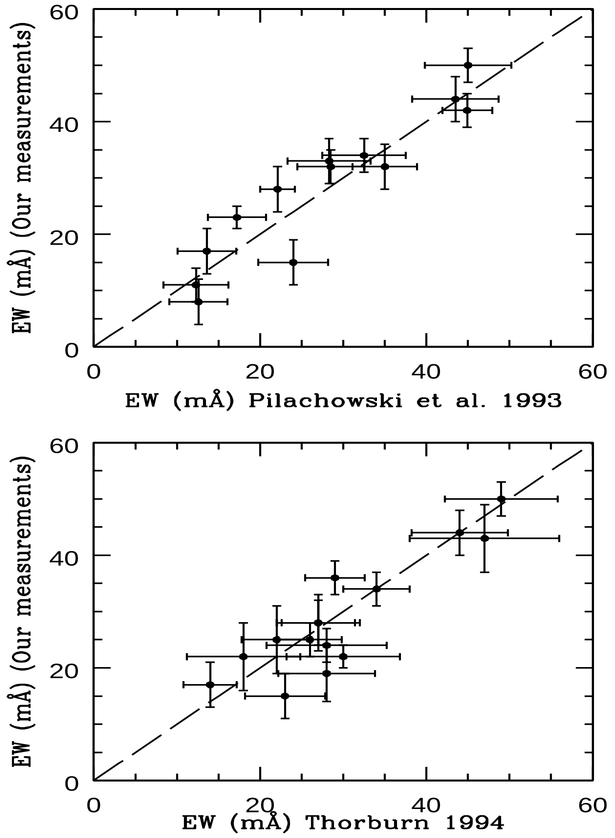

Fig. 2. Comparison between our measurements of the Li I λ670.8 nm equivalent widths and those by Pilachowski et al. (1993; top) and Thorburn (1994; down). The error bars represent the estimated 95% confidence limits

Most of the objects were selected from the sample of metal-poor stars in the works of Carney et al. (1987), Laird et al. (1988), and Schuster & Nissen (1988, 1989). Table 1 lists the stars observed, telescopes used, epoch of observation, exposure times and visual magnitudes. Several typical spectra in the region of the Li I line are plotted in Fig. 1. Table 2 lists the relevant photometric data and metallicities which will be used in a forthcoming paper to determine the stellar parameters $T_{\rm eff}$ and $\log g$ needed for the abundance analysis. Photometric magnitudes were obtained from the literature and the SIMBAD data base. Metallicities were also obtained from the literature using mainly the compilations by Schuster & Nissen

Table 1. Programme stars

Star	Other designations	Telescope	Epoch	$t_{\rm exp}$ (s)	V
HD 4906	G32-53, BD+18°111	NOT	1991 Aug.	1200	8.76
HD 24289	G80-28, BD−04°680	INT	1991 Jan.	2×1500	9.977
HD 45282	BD+3°1247	INT	1991 Jan.	1000	8.028
HD 88725	G44-6	INT	1991 May	1200	7.750
HD 101063		INT	1991 May	1400	9.440
HD 103912	G122-57, BD+49°2098	INT	1991 May	800	8.360
HD 106038	G12-21, BD+14°2481	INT	1991 Jan.	2×1500	10.179
HD 108976	BD+28°2125	INT	1991 Jan.	1200	8.61
HD 111721	BD−12°3709	INT	1991 May	600	7.988
HD 112573	G61-24	INT	1991 May	1200+1145	8.97
HD 126681	BD−17°4092	INT	1991 May	1200	9.300
HD 134439	BD−15°4042	INT	1991 May	1200	9.058
HD 134440	BD−15°4041	INT	1991 May	1200	9.419
HD 149414	G17-25, BD+53°1871	INT	1991 May	1200+1000	9.611
HD 157948	G182-7, BD+38°2932	INT	1991 May	2×1200	8.095
HD 158226	G181-47, BD+31°3027	NOT	1991 Aug.	2×1200	8.500
HD 161770	G154-21, BD−9°4604	INT	1991 May	2×1300	9.66
HD 163810	G154-36, BD−13°4807	INT	1991 May	1300+1000	9.635
HD 179626	G22-20, BD−00°3676	INT	1991 May	1200	9.210
HD 184448	G229-34	NOT	1991 Aug.	600+1000	8.050
HD 199476	G261-29	NOT	1991 Aug.	2×600	7.810
HD 200580	G25-15	INT	1991 May	250	7.340
HD 204155	G25-29	NOT	1991 Aug.	1200	8.500
HD 215065	G241-18, BD+65°1796	NOT	1991 Aug.	2×1200	7.460
HD 215257	G27-44, BD+03°4763	NOT	1991 Aug.	1800	7.420
HD 216588	G157-21	NOT	1991 Aug.	1200	9.270
HD 218209	G241-42,BD+67°1498	NOT	1991 Aug.	2×1200	7.480
HD 221613	G171-3, BD+42°4700	NOT	1991 Aug.	2×600	7.140
G3-16	BD+04°302	INT	1990 Oct.	1900+1500	10.507
G16-9	BD+05°3080	INT	1991 May	1200+800	9.140
G20-15	BD−08°4501	INT	1991 May	1500	10.591
G24-3		INT	1990 Oct.	1800+1200	10.467
			1991 May	1500+1400	
G26-9	BD−00°4234	INT	1990 Oct.	120	9.798
G29-23	BD+02°4651	INT	1990 Oct.	500+1700	10.230
G41-41	BD+9°2190	INT	1991 May	2×1500+400	11.14

(1989), and Carney et al. (1987). In general, the differences between these metallicities for the objects in common are of order $0.1 - 0.2$ dex, but in a few of them (the most metal-poor stars) these differences can be as large as 1 dex.

All the images were processed with the IRAF[1] package following standard techniques of bias subtraction, flat-field corrections, optimal spectrum extraction and sky subtraction, wavelength calibration and linearization, and continuum normalization. The identification of the Li I λ670.8 nm line was performed on the basis of the radial velocities measured by Laird et al. (1988), and Carney & Latham (1987), and/or the relative positions of the Fe I λ667.8 and Ca I λ671.7 nm lines. An unambiguous identification of the Li I spectral feature was always possible for the stars in Table 1. Those few very metal-poor stars in our original sample with poor signal to noise ratio and nearly featureless spectra for which the radial velocity was unknown have not been included in this paper.

3. Equivalent widths

The equivalent widths (EWs) were measured by direct integration under the continuum using the subroutine SPLOT of the IRAF package. They were determined independently by three of us to minimize the effects of a subjective location of the continuum. The finally adopted EWs and the quoted errorbars result from a critical discussion of these determinations. Table 2 presents the resulting Li I EWs with the estimated 95% confidence limit error bars. The uncertainties are in general ≤ 5 mÅ.

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[1] IRAF is distributed by National Optical Astronomical Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation, U.S.A.

Table 1. continued

Star	Other designations	Telescope	Epoch	$t_{\rm exp}$ (s)	V
G59-27	BD+28°2137	INT	1991 May	3×1500	10.892
G60-26	BD+13°2567	INT	1991 May	1000	9.813
G63-46	BD+13°2698	INT	1991 Jan.	1500	9.378
G64-12		INT	1991 May	4×1500	11.458
G64-37		INT	1991 May	5×1500 2×1600	11.144
G66-22	BD+06°2932	INT	1991 May	2×1600+1200	10.47
G69-4A	HD3266	NOT	1991 Aug.	2×1200	7.980
G69-4B		NOT	1991 Aug.	2×1200	7.980
G74-5	BD+29°366	NOT	1991 Aug.	2×1200	8.771
G88-27	BD+19°1730	INT	1991 May	1200+1500	10.712
G88-32	BD+24°1676	INT	1990 Oct.	2100+1500	10.780
G90-3		INT	1990 Oct.	1500	10.397
G101-34	BD+38°1456	INT	1990 Oct.	2×1500	10.730
G123-9	BD+44°2166	INT	1991 May	2×1400	10.500
G125-13	BD+35°3659s	INT	1991 May	1200	10.238
G125-64	BD+42°3607	INT	1991 May	1500	10.110
G140-46	BD+05°3640	INT	1991 May	1500+1600	10.348
G141-19	BD+13°3683	INT	1991 May	2×1500 2×1200+1400	10.582
G141-47	BD+23°3130	INT	1991 May	2×1400	10.540
G166-45	BD+26°2606	INT	1991 Jan.	1500+640	9.731
G180-58		INT	1991 May	2×1600	11.318
G182-31	BD+36°2964	INT	1991 May	2×1400	10.370
G188-30		INT	1990 Oct.	2×1300+800	11.000
G192-43		INT	1991 Jan	1500+1260	10.307
G205-42	BD+42°3187	INT	1991 May	2×1200	9.955
G206-34		INT	1991 May	3×1500	11.409
G207-5	BD+38°3327	NOT	1991 Aug.	600	7.160
BD−13°3442		INT	1991 May	3×1500	10.26
CD−24°1782		INT	1991 Jan.	1800	9.93
LP815-43		INT	1991 May	1100+1500	10.91
W6296		INT	1991 Jan.	4×1800	10.92
W8296		INT	1991 May	2×1500	10.68

The table also lists previous measurements by other authors giving 95% confidence limit error bars[2].

For about 40 stars of the sample this represents the first spectroscopic study in the region of the Li I feature. The rest have been observed by other authors (mainly by Pilachowski et al. 1993, and Thorburn 1994). The common stars among these works allow a comparison between measurements, constituting a test of consistency and on the validity of the observations. On the measurements presented in Table 2 there are 16, 9 and 3 stars with 2, 3 and 4 independent observations respectively, adding in total 49 pairs of measurements to compare. For a couple of measurements $(x_i \pm \sigma_{x_i})$ and $(y_i \pm \sigma_{y_i})$ of the i-star, the difference is (a_i, σ_{a_i}), being $a_i = x_i - y_i$ and $\sigma_{a_i} = \sqrt{\sigma_{x_i}^2 + \sigma_{y_i}^2}$. The quantity $\sum_i^{49} a_i^2/\sigma_{a_i}^2$ follows approximately a χ^2 distribution with 49 degrees of freedom. The variance of the distribution is $\sim 2 \times 49$ which defines the 1σ and the 2σ level as the ranges $38 \leq \chi^2 \leq 59$ and $31 \leq \chi^2 \leq 71$, respectively. In our case $\chi^2 = 116$, which is not in the mentioned ranges and a value extremely unlikely if all measurements were consistent. To test the possible presence of systematic errors in some of the measurements, we have removed from the above comparison the measurements in which $|a_i|/\sigma_{a_i} \geq 2.5$. Doing the same analysis than above, the value obtained now is $\chi^2 = 52$ for 41 pairs of measurements, which is in good agreement with the statistical expectations. This seems to indicate that in $\sim$ 20% of the common pairs of measurements there are additional sources of error not included in the uncertainty provided by the quoted errorbars. Other statistical tests give the same conclusion. Explicitly we suspect of the following stars:

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[2] For the measurements by Pilachowski et al. 1993, we compute the errorbars from the SNR values provided by C. Pilachowski (private communication) and using $\sigma = 1.6({\rm FWHM}\delta x)^{1/2}/{\rm SNR}$ (Cayrel 1988), where δx is the dispersion per pixel and SNR the signal to noise ratio.

Table 2. Photometry and Li I equivalent widths of the programme stars

Star	$V-K$	Ref_1.	$E(B-V)$	c_1	$b-y$	$E(b-y)$	[Fe/H]	Ref_2	EW this work (mÅ)	EW others (mÅ)	Ref_3
HD 4906				0.297	0.483	0.041	−0.84	4	≤ 13		
HD 24289	1.63	1	0.02	0.288	0.388	0.045	−1.64	5	50 ± 3	49 ± 6.8, 45 ± 5.2	8, 4
HD 45282	1.91	2		0.277	0.451	0.029	−1.51	5	≤ 16	9.9 ± 5.2	4
HD 88725	1.57	3	0.00	0.325	0.409		−0.65	6	≤ 14		
HD 101063				0.272	0.499	0.091	−1.35	5	11 ± 3	12.3 ± 3.9	4
HD 103912	2.17	1	0.00	0.306	0.527		−1.71	6	≤ 4	≤ 4, ≤ 3	8, 4
HD 106038			0.00	0.264	0.342		−1.45	6	68 ± 3		
HD 108976				0.382	0.304				33 ± 7		
HD 111721	2.16	1		0.296	0.511	0.069	−1.11	5	23 ± 2	17.2 ± 3.5	4
HD 112573	1.69	3	0.00	0.250	0.420		−0.53	6	≤ 12		
HD 126681	1.66	1		0.191	0.400	0.008	−1.16	5	16 ± 4		
HD 134439	2.04	2	0.00	0.165	0.484		−1.92	7	≤ 10		
HD 134440	2.28	3	0.00	0.173	0.524		−1.52	6	≤ 6		
HD 149414			0.00	0.162	0.476		−1.54	6	10 ± 3		
HD 157948	2.00	3	0.00				−0.71	6	17 ± 3		
HD 158226	1.52	3	0.00	0.312	0.389		−0.61	6	≤ 4		
HD 161770	2.03	2		0.301	0.489		−1.38		42 ± 3	44.9 ± 3	4
HD 163810	1.91	2	0.03	0.199	0.423		−1.55	6	28 ± 4	22.1 ± 2.1	4
HD 179626	1.58	1	0.05	0.293	0.373	0.019	−0.94	6	27 ± 2		
HD 184448			0.00	0.327	0.409		−0.61	6	≤ 9		
HD 199476			0.00				−0.49	6	≤ 6		
HD 200580	1.55	3		0.262	0.368		−1.00		29 ± 3	32 ± 4	15
HD 204155	1.51	3	0.00				−0.80	6	≤ 13		

- G205-42: There are two additional measurements by Pilachowski et al. (1993) and Thorburn (1994). For this star our measurement is in disagreement with the other two.
- HD 111721 and HD 163810: For these stars there is only one additional measurement by Pilachowski et al. (1993), clearly in disagreement with the values reported in this work.
- G88-32: Our measurement (19 ± 5 mÅ) is discrepant with two previous measurements by Hobbs & Thorburn (1991; 26 ± 4.4 mÅ) and Thorburn (1994; 28 ± 5.8 mÅ).
- G166-45: This is a very intriguing double lined spectroscopic binary. While Hobbs & Thorburn (1991) and Thorburn (1994) measure 29 ± 3.6 mÅ, our determination gives 36 ± 3 mÅ, in agreement with the measurement by Rebolo et al. (1988; 35 ± 3 mÅ). In the spectrum obtained by Rebolo et al. (their Fig. 1b) it is possible to appreciate a small asymmetry in the red wing of the Li I line. The new spectrum recorded in 1991 January also shows this asymmetry, possibly indicating that the secondary star also has a Li I line.
- BD −13°3442: Here we report 22 ± 2 mÅ, which presents a serious discrepancy of 8 mÅ with the measurement of Thorburn (1994; 30 ± 6.8 mÅ). However, our measurement is in better agreement with that obtained by Ryan et al. (1996; 19 ± 2 mÅ).
- LP815-43: We report here 25 ± 6 mÅ. The situation here is confused with several measurements giving around 25 mÅ and others close to 15 mÅ.

Removing these stars from the statistical analysis, we found $\chi^2 = 26$ for the remaining 31 pair of measurements indicating that the inconsistency of the sample is due to the stars removed. Previous work on this have been done by Ryan et al. (1996) and Deliyannis et al. (1993). For instance, applying the above analysis to the sample analyzed by Ryan et al. we obtain $\chi^2 = 248$ for 148 pair of measurements. Removing 5 stars (Ryan et al. recognized problems in 4 of them) involving in total 10 pair of measurements, the value obtained for χ^2 is now compatible with the value expected from the quoted noise of each measurement.

The comparison between our measurements and those by Thorburn (1994) and Pilachowski et al. (1993) is summarized in Fig. 2. Defining Δ_{P} and Δ_{T} as the mean differences between our measurements and the ones by these authors, respectively, we obtain $\Delta_{\mathrm{P}} = +0.7$ and $\Delta_{\mathrm{T}} = -0.9$ mÅ, values which show the absence of significant

Table 2. continued

Star	$V-K$	Ref$_1$.	$E(B-V)$	c_1	$b-y$	$E(b-y)$	[Fe/H]	Ref$_2$	EW this work (mÅ)	EW others (mÅ)	Ref$_3$
HD 215065			0.00				−0.61	6	≤ 8		
HD 215257	1.51	1	0.00	0.273	0.358		−0.88	6	31 ± 4		
HD 216588			0.00				−0.76	6	≤ 12		
HD 218209			0.00	0.258	0.419		−0.64	6	≤ 7		
HD 221613			0.00	0.279	0.396		−0.55	6	26 ± 3		
G3-16				0.319	0.317	0.012	−1.92	5	33 ± 4		
G16-9	2.20	3	0.00	0.247	0.514		−0.88	6	≤ 10		
G20-15	1.83	3	0.10	0.247	0.452		−1.99	6	33 ± 4	28.3 ± 5.0, 35.1	4, 11
G24-3	1.46	2	0.02	0.271	0.363	0.022	−1.81	6	32 ± 3	28.5 ± 4.0	4
G26-9	2.83	1		0.188	0.588		−1.19	5	24 ± 4		
G29-23	1.35	1		0.332	0.339	0.012	−1.75	5	34 ± 2	27	17
G41-41	1.27	1	0.01	0.382	0.305		−2.80:	6	22 ± 6	18 ± 6.8, 20 ± 3	8, 9
G59-27	1.35	2	0.00	0.312	0.324	0.000	−2.20	6	28 ± 5	27 ± 4.4	8
G60-26	1.85	1		0.236	0.433	0.032	−1.15	5	17 ± 4	13.6 ± 3.5	4
G63-46	1.53	1	0.00	0.272	0.385		−1.03	6	≤ 15		
G64-12	1.20	3	0.00	0.336	0.312	0.034	−3.38	7	24 ± 3	28 ± 7.2, 23 ± 10, 27.6, 25, 31	8, 10, 11, 12, 13
G64-37	1.19	1	0.01	0.329	0.299	0.013	−3.38	7	17 ± 4	14 ± 3.2, 16 ± 3.0, 18.0, 14	8, 9, 11, 14
G66-22	2.02	1	0.00	0.190	0.452	0.015	−1.30	6	20 ± 4		
G69-4A			0.00				−0.80	6	≤ 5		
G69-4B			0.00				−0.63	6	≤ 5		
G74-5	1.55	3	0.00	0.335	0.389		−1.05	6	11 ± 3	14 ± 4	15
G88-27	1.38	1	0.01	0.310	0.336		−1.65	6	45 ± 8		
G88-32	1.28	2	0.01	0.356	0.311		−2.71	6	19 ± 5	28 ± 5.8, 26 ± 4.4	8, 16
G90-3	1.57	2	0.01	0.291	0.370	0.032	−2.47	6	44 ± 4	43.5 ± 5.2, 44 ± 5.8	4, 8
G101-34	2.11	1	0.01	0.284	0.506		−1.98	6	16 ± 3		

Table 2. continued

Star	$V-K$	Ref$_1$.	$E(B-V)$	c_1	$b-y$	$E(b-y)$	[Fe/H]	Ref$_2$	EW this work (mÅ)	EW others (mÅ)	Ref$_3$
G123-9	1.71	3	0.00	0.207	0.421		−1.32	6	21 ± 3		
G125-13				0.231	0.355	0.002	−1.39	5	40 ± 4		
G125-64	1.51		0.04	0.185	0.377		−2.13	6	43 ± 6	47 ± 9	8
G140-46	2.08	1	0.00	0.141	0.474		−1.36	6	≤ 8		
G141-19	2.05	1	0.06	0.259	0.505	0.140	−2.42	7	34 ± 3	34 ± 4, 32.5 ± 5.0	8, 4
G141-47	1.57	3	0.1	0.288	0.390	0.1	−1.34	6	32 ± 4	35 ± 3.9	4
G166-45	1.37	2	0.00	0.280	0.336		−2.58	6	36 ± 3	29 ± 3.6, 35 ± 3, 29 ± 4.4	8, 15, 16
G180-58	1.90	2	0.00	0.104	0.488		−2.36	6	≤ 10		
G182-31			0.01				−2.53	6	25 ± 3	26 ± 3.8	8
G188-30	1.87	1	0.01	0.130	0.464		−1.86	6	11 ± 3		
G192-43	1.32	1	0.01	0.304	0.322		−1.49	6	73 ± 8		
G205-42	1.80		0.00	0.231	0.430	0	−2.18		15 ± 4	23 ± 4.8, 24.0 ± 4.2	8, 4
G206-34	1.36	3	0.04	0.263	0.342	0.035	−2.88:	6	28 ± 4	27 ± 5.0	8
G207-5			0.00				−0.43	6	33 ± 3		
BD-13°3442			0.01	0.413	0.311		−3.14	7	22 ± 2	30s ± 6.8, 19 ± 2	8, 9
LP815-43			0.04				−3.20	7	25 ± 6	22 ± 4.2, 27.0, 15	8, 13, 14
CD-24°1782			0.023	0.287	0.466		−2.56	5	8 ± 4	12.6 ± 3.5	4
W6296	1.33	1		0.348	0.330	0.017	−2.54	5	25 ± 3		
W8296	1.72	1		0.183	0.415	0.019	−1.53	5	21 ± 4		

Note: Ref$_1$, Ref$_2$ and Ref$_3$ give references for the values quoted for $(V-K)$, [Fe/H] and EW others, respectively.
References:
(1) Alonso et al. 1994. (2) Carney 1983. (3) Laird et al. 1988. (4) Pilachowski et al. 1993. (5) Schuster & Nissen 1988, 1989. (6) Carney et al. 1987; Laird et al. 1988. (7) Ryan et al. 1991. (8) Thorburn 1994. (9) Ryan et al. 1996. (10) Rebolo et al. 1987. (11) Spite et al. 1996. (12) Spite et al. 1987. (13) Spite et al. 1993. (14) Norris et al. 1994. (15) Rebolo et al. 1988. (16) Hobbs & Thorburn 1991. (17) Spite et al. 1984.

systematic effects between the three sets of measurements. The rms of the differences are 4.4 and 4.6 mÅ for the comparison with the samples of Pilachowski et al. and Thorburn, respectively, values which are slightly larger than the expectations in terms of the error bars (~ 2.7 and ~ 3.5 mÅ, respectively). If we remove in the comparison with Thorburn the stars G88-32, G166-45, G205-42, BD -13° 3442, and do the same with HD 111721, HD 163810 and G205-42 in the comparison with Pilachowski et al., we found that the rms of the differences were now in perfect agreement with expectations in terms of noise. These results confirm our claims on the inconsistency in $\sim$20% of the common measurements.

We conclude that for $\sim 20\%$ of the stars there are systematic effects not taken into account in the reported uncertainties, and we shall bear in mind that any conclusion inferred from the global sample should be robust against rejection of subsamples comprising this fraction of the stars. Repeated independent observations may guarantee a sufficient number of reliable determinations along the Li $-$ $T_{\rm eff}$ and Li $-$ [Fe/H] planes to solve the scatter problem. It would be particularly useful to conduct such programme in photometric and spectroscopic twin halo dwarf stars. One possible case of twin stars is that of G64-37 and G64-12. These are the two stars in our sample with the largest number of determinations, all of them being consistent. Our new measurements are in agreement with the best previously estimated values. When our own values are taken into account the new best estimated Li I EWs are 25.2 ± 1.2 and 15.4 ± 0.9 mÅ for G64-12 and G64-37, respectively. This Li I EW difference between both stars was noted by Ryan et al. (1996) and is reinforced by our new measurement. Given the strong similarity in their $V - K$ and c_1 indices (see Table 2) we could expect very similar $T_{\rm eff}$ and gravity and therefore rather different lithium abundances. However, as we can also see in Table 2, when the reddening is taken into account, the stars do not look as similar as was thought. This question will be addressed in more detail in a forthcoming paper.

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