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Lithium observations in 47 Tucanae*

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Abstract. We present high resolution observations (FWHM=15 km s^{-1}) of the Li region in 5 stars belonging to the old (≈14 Gyrs), metal rich ([Fe/H]≈-0.7) globular cluster 47 Tuc. At the ESO NTT telescope we obtained EMMI spectra for three V∼17.4 magnitude stars located at the turnoff with T_{eff} on the Spite *plateau*. In two of the turnoff stars the lithium line is clearly detected and the mean lithium content [Li] = 2.37± 0.08±0.07 is derived. This value is slightly higher than the Spite *plateau* at [Li]=2.19±0.016 for field halo stars obtained with the same T_{eff} scale by Bonifacio and Molaro (1996).

For the third turnoff star only an upper limit could be derived: [Li]< 2.19. This upper limit may suggest the presence of some dispersion on the plateau stars of 47 Tuc as it is observed in field stars of similar metallicity.

When compared with field dwarfs of [Fe/H] ≈ -0.7 the Li content of 47 Tuc turnoff stars is among the highest observed. Considering the extreme age of 47 Tuc this suggests that no significant depletion affected these stars and it implies a mild Li Galactic enrichment between the epoch of Pop II formation and the formation of 47 Tuc stars with metallicities up to ~ -0.7. Spallation reactions, as deduced from Be observations, can account for such an increase.

The remaining two stars are evolved, and only upper limits could be placed at [Li] <0.7 and <-0.7. These very low values imply some extra depletion mechanism in addition to dilution as it is observed in evolved field stars by Pilachowki et al (1993) and in NGC 6397 by Pasquini and Molaro (1996).

Key words: stars: abundances – stars: Population II – globular clusters: individual: 47 Tuc – Galaxy: halo – cosmology: observations

1. Introduction

The study of light elements, Li and Be and B, has progressed impressively in the last years, both in the theoretical and observational aspects (see e.g. the proceedings edited by Crane 1995).

On the observational side, observations of Li in large, well defined samples, are becoming available, (Brown et al. 1989, Pasquini et al. 1994, Randich et al. 1996), as well as new detailed observations in open clusters of different ages, either young (Soderblom et al. 1993) or as old as the Sun (Balachandran 1995).

For the study of the oldest population of the Galaxy, a large effort has been performed to analyze very metal poor stars in the field (see i.e. Spite 1995 for a review), and the first data on Globular Clusters have become available, for the old, metal poor GC's NGC 6397 (Molaro and Pasquini 1994, Pasquini and Molaro 1996) and M 92 (Deliyannis et al. 1995).

On the theoretical side several models have been developed which include new important features. Standard models have been built with a more realistic treatment of the mixing in the convection zone (D'Antona and Mazzitelli 1994), or with improved opacities (Swenson 1995). Non standard models were also improved and they include mechanisms previously neglected or only partially treated, like rotational mixing (Pinsonneault et al. 1992, Zahn 1994), meridional circulation (Michaud and Charbonneau 1991), diffusion and mass losses (Swenson 1995, Vauclair and Charbonnel 1995).

The homogeneity of stars in G.C. and the knowledge of their overall characteristics offer a powerful tool to address several topics concerning Li abundance. By studying, for instance, the dependence of Li abundance on stellar mass in a given GC, a detailed comparison with theoretical models can be performed, allowing to disentangle between the different mechanisms operating in the stellar interiors. By studying the Li abundance in clusters spanning a large range of ages it would be possible to obtain precious information about the Galactic evolution of lithium (Hobbs and Pilachowski 1988) and its primordial fraction (Trimble 1991).

One interesting target among the near GC is certainly 47 Tuc (=NGC104 = C0021-723). The cluster is well studied; with an age of at least 13± 0.5 Gyr it belongs to the *old* generation of G.C. although its metallicity is more than 30 times higher than other coeval clusters (Hesser et al. 1987). Observations of Li in 47 Tuc and their comparison with the observations in NGC

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* Based on observations collected at ESO, La Silla

6397 and M 92 are therefore particularly suitable for the study of the Lithium behavior with respect to stellar metallicity at a given age.

2. The observations

The observations were obtained between October 11 and October 14, 1994 using the EMMI spectrograph (Giraud 1995) at the Nasmyth focus of the 3.5m NTT telescope. EMMI was used in echelle mode, with grism 6 as crossdisperser providing a spectral coverage of 2000 Å. With a Tectronix 2040×2048 CCD and the F/5 Long Camera the scale is 0.067 Å/pixel in the Li region. Due to variable metereological conditions and to rather poor seeing, a slit aperture of 1.5 arcsec was mostly used, which gives a resolving power of ∼ 18000. The slit height, fixed at 10 arcsec, gives enough (35) pixels perpendicular to the dispersion direction to allow a good background-sky subtraction. The CCD was binned by two along the resolution, in order to minimize the contribution of the CCD Read Out Noise. The CCD was also read in 'superslow' mode which gave a RON of about $4e^-$/pixel.

We were able to observe a total of 5 stars in 47 Tuc, from V=12.2 down to V=17.35.

Observations are summarized in Table 1. The data were reduced using MIDAS (Banse et al. 1988) facilities. Special care was taken in the reduction of these low S/N data, in order to precisely subtract the background (interorder+sky) contribution and to take into account the presence of high energy particles events. To check the accuracy of the data the reduction was carried out using different procedures.

The final spectra are presented in Fig. 1. After rebinning to equal (0.12 Å) wavelength step, the spectra were coadded with the proper weight; note that no major spectrograph shifts were recorded during the whole run.

The continuum was traced measuring the intensity of the spectra in several windows in selected regions surrounding the Li line. In the case of very metal poor stars, this procedure can be easily applied because of the featureless appearence of the spectra. At the metallicity of 47 Tuc ([Fe/H] = -0.7), however, the selection of the windows must be done carefully, due to the presence of metallic lines in the spectrum. The continuum regions were therefore selected from the inspection of high resolution, high S/N spectra (Pasquini et al. 1994).

Equivalent widths were measured with simple integration. The FWHM of the Li and Ca I (6717) lines was of ∼ 0.34 Å, in perfect agreement with what was expected from the instrument resolution. In estimating the errors on measured equivalent widths, we have assumed a conservative approach, in view of the uncertainties which influence the accuracy of the data: $\Delta EW = RMS*RES*W^{1/2}$, where RMS is the inverse S/N ratio as measured in the continuum windows close to the Li line, RES the measured resolution and W the number of resolution elements on which the integration has been carried out. To these uncertainties a value up to ∼ 6 mÅ should be added due to the possible uncertainties in positioning the continuuum (Cayrel 1988).

Equivalent widths and S/N ratio are given in Table 3.

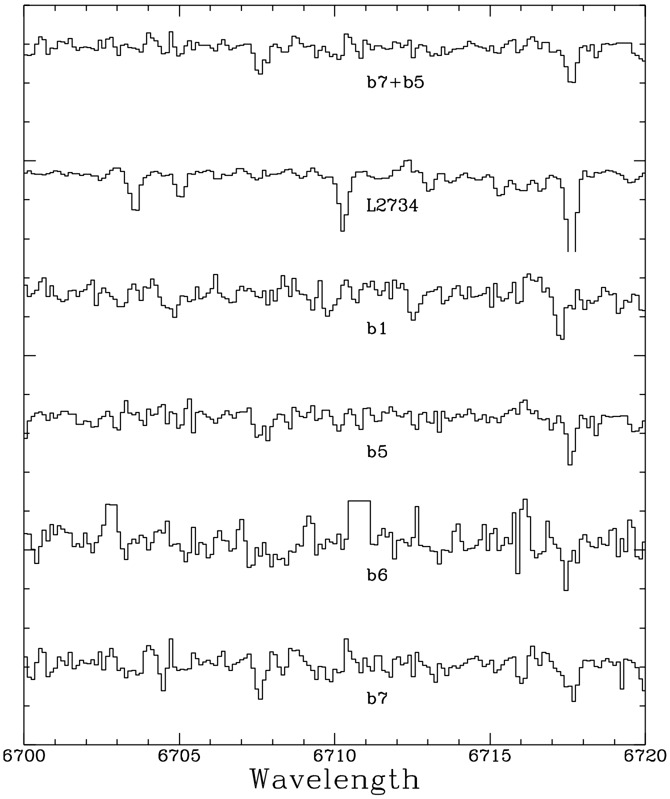

Fig. 1. EMMI spectra of the 5 observed stars around the Li 6708 Å region; the spectra were artificially displaced for better viewing. The first spectrum is the composition of the two turnoff stars (b5 and b7), where Li was clearly detected.

3. Stellar parameters

At a distance of ∼ 4.5 Kpc, 47 Tuc is one of the best studied globular clusters. It is located at high Galactic latitude and the reddening is rather low. In the literature reddening estimates range from E(B-V)=0.00 of Cannon (1974) up to values of 0.08 (Menzies 1973). However, best evidence is for intermediate values: Crawford and Snowden (1975) derived E(B-V)=0.029±0.004; Hesser and Philip (1976) obtained E(B-V)=0.024±0.021 and Lee (1977) obtained E(B-V)=0.04±0.01. In the following we will adopt E(B-V)= 0.04 as suggested by Hesser et al. (1987), but an error of 0.02 is possible here, and this is rather important in deriving the absolute value for Li in the cluster. After a controversial discrepancy between the spectroscopic and photometric results, the last estimates of metallicity converge between the [Fe/H]=−0.65, derived photometrically by Hesser et al. (1987) and the [Fe/H]=−0.8 derived spectroscopically by D' Odorico et al. (1985). In the following, a value of [Fe/H]= -0.7 will be adopted, but note that the uncertainties in metallicity have no significative influence in the determination of the Li abundances.

The observed stars are listed in Table 1. Finding charts were provided by Briley et al. (1994), together with stellar colours and magnitudes, which are summarized in Table 2. With a visual magnitude around V∼ 17.35 and rather blue colors, 3 stars lie

Table 1. Summary of the observations: in column 1 the star names are given, the b suffix corresponds to stars from Briley et al. 1994, the L suffix for stars from Lee (1977)

Name	Int. Time	Comments
b7	5×2 H	R=18000 Poor weather Conditions
b6	3×1.5 H	R=23000
b5	2×2 H	R=18000
b1	2×1.5 H	R=18000
L2734	2×0.5 H	R=18000

Table 2. Photometric data for the observed stars, 'b' indicates stars from Briley et al. (1994), 'L' from Lee (1977).

Star	V	(B-V)	$(B\text{-}V)_o$	V_r (Km/sec)
b7	17.38	0.57	0.53	-16
b6	17.35	0.59	0.55	-24
b5	17.35	0.59	0.55	-17
b1	16.18	0.83	0.79	-34
L2734	12.21	1.43	1.39	-16

at the bright blue edge of the turnoff, indicating that they are in the upper part of the main sequence.

To determine the stellar effective temperature, we have adopted the temperature scale of Alonso et al. (1996b), based on the IRFM (see Alonso et al. 1996a), to be able to compare the 47 Tuc abundances directly with the most recent determination of the Li *plateau* (Bonifacio and Molaro 1996) which is based on the Alonso et al. (1996a) effective temperatures. We note that the effective temperature used are in a very good agreement (within 50 K) with those obtained by using the Briley et al. (1994) scale and with the Vandenberg and Bell (1985) scale used for NGC 6397 by Pasquini and Molaro (1996).

For star L2734, the effective temperature was derived from Buser and Kurucz (1992) , because none of the over mentioned scales is suitable for such a cool, evolved object. The uncertainty of this determination is somewhat higher than the one for the turnoff stars, but we note that the effective temperature adopted is not critical for this cool star.

From our spectra it was also possible to derive radial velocities for the observed stars. They were computed mostly by using the Ca I 6717 line, but also checked using other lines in the spectra. The results are given in Table 2. No radial velocity standards were observed during our run, therefore the absolute values of the measured V_r can have a systematic zero offset by a value probably up to 5 Km/sec. Due to the possibility of checking the wavelengths of sky lines, instead, our internal accuracy is better than 2 Km/sec. As can be seen, two of the stars (b1 and b6) differ by a significant amount (7 and 17 Km/sec respectively) from the others, which are in good agreement with the *mean* systemic velocity of the cluster of -19.4 Km/sec (Mayor et al. 1984). The observed stars belong to a field centered at a distance of $\sim$ 11 arcmin from the core of the cluster, almost perfectly alligned to the west (Briley et al. 1994). Mayor et al. (1984) showed that, due to the cluster dynamics, in 47 Tuc the mean radial velocities and the velocity dispersion vary with the distance from the cluster center and with the orientation. The measured dispersion at 11 arcmin from the core is about 7 Km/sec, and the expected velocity towards the west is very close to the the mean cluster value. The velocity measured for star b6 is therefore well compatible with the Mayor et al. (1984) results, while for b1 the membership is only marginal (2σ). Some additional spread among the observed stars may be expected, considering that their distance from the cluster center differs by 7 arcmin.

Considering that the position of b1 in the color magnitude diagram fits well the cluster mean curve, we retain at this stage also b1 as a possible cluster member. Note also that the membership of b1 is not at this stage very relevant for the following discussion, which is mainly centered on the turnoff stars.

4. Li abundances

The Lithium line is clearly present in two of the 3 turnoff stars observed. In the spectrum of the turnoff star b6, no clear feature is present at the lithium rest wavelength, but a possible absorption line of $\sim$40 mÅ is present 0.1 Å blueward from the nominal wavelength. We set this value as an upper limit to the Li equivalent width.

Abundances are computed by using synthetic profiles generated by the SYNTHE code and atmospheric models from the Atlas 9 (Kurucz 1993). Convection is treated with the mixing length theory, with a scale height over pressure scale of 1.25, but without the overshooting option. The resulting COG's are very similar to those obtained with the old Kurucz and Bell and Gustafsson model (see the discussion in Molaro et al. 1995). If the Kurucz (1993) grid with overshooting would be used, the Lithium abundances presented here will increase by $\approx$ 0.05 dex. Microturbulence was fixed to 1.0 Km/sec.

The Fe 6707.43 Å line is not resolved in our spectra, but its contribution was considered in the computation. At the 47 Tuc metallicity and for the range of temperatures analyzed the FeI line has an equivalent width of about 1-2 mÅ.

Because of the similarity among the turnoff stars, and the relatively low S/N ratio of the observations, we have decided to coadd the spectra of the two turnoff stars, b5 and b7, with a clear detection of Li. The coadded spectrum is also shown in Fig. 1 and it has a mean S/N ratio of 50. In this spectrum the Li line has an equivalent width of 52 mÅ and the Ca I line of 71 mÅ. For a 5866 K star these values correspond to [Li]=2.37 and [Ca/H]=-0.33 and -0.54 , with a microturbulence of 1 and 2 Km/sec respectively. This is consistent with the general cluster metallicity [Fe/H]$\approx$-0.7 considering an enhancement by 0.3 dex which is typical at these metallicities (Edvardsson et al. 1993).

The T_{eff} vs. M_v diagram for the observed stars is given in Fig. 2.

5. Discussion

5.1. Comparison with PopII stars and globular clusters

In Table 3 temperatures, equivalent widths and Li abundances for the stars observed in 47 Tuc are given. The errors in the Li

Table 3. Effective temperatures, measured equivalent widths and Li abundances. Errors in the EW are 1σ. Errors in Li abundances reflect only errors in EW.

Star	T_{eff}	E.W.	S/N	N(Li)
b7	5899	53 ± 8	40	2.41 ±0.08
b6	5823	<40	23	< 2.19
b5	5823	56 ± 11	30	2.37 ±0.11
b1	5030	<10	30	< 0.73
L2734	3940	<10	80	<-0.70
b7+b5	5866	52 ± 6.7	50	2.37 ± 0.07

abundances include only uncertainties coming from the equivalent widths measurements but an other comparable source of uncertainty comes from the error in the stellar T_{eff} determination. Considering the uncertainty (± 0.02) in the reddening and possible systematic effects in the temperature scale adopted, an uncertainty in T_{eff} of ± 100 K is assumed, which would correspond to ±0.075 dex in [Li]. Other sources of uncertainty in the Li determination come from the errors in the adopted gravity and microturbulence, and their contribution is only of 0.02 dex, much lower than the equivalent width and effective temperature terms.

Therefore the Li abundance on the plateau of 47 Tuc is:

$$[\mathrm{Li}] = 2.37 \pm 0.15$$

The [Li] abundance in 47 Tuc is consistent with the *plateau* level of [Li]= 2.19 ± 0.016 (Bonifacio and Molaro 1996) at 1.2 σ level, but the Li level measured in 47 Tuc is possibly slightly higher than the *plateau*. This would imply a moderate Li production for 47 Tuc, which is not surprising considering the higher metallicity of 47 Tuc.

Observations exist for the globular clusters NGC 6397 (Molaro and Pasquini 1994; Pasquini and Molaro 1996) and M 92 (Deliyannis et al 1995), which have [Fe/H]=-2 and -2.25 respectively. The mean value for the abundances so far observed in stars close to the turnoff (ignoring upper limits) are [Li]=2.3 and 2.13 for NGC 6397 and M 92, respectively. These values are, within the errors, consistent with the plateau abundance and slightly lower than in 47 Tuc.

In Fig. 2 the stars observed in 47 Tuc (triangles) are overimposed with those observed in NGC 6397 (squares), after scaling the stellar apparent luminosities according to the respective cluster distances and reddening (Alcaino et al. 1987, Hesser et al. 1987), and the Li abundances are given. In the same figure the observations of M 92 from Deliyannis et al. (1995) (hexagons) are included. For M 92 a distance module of 14.75 and a reddening of E(B-V)=0.03 have been assumed. The effective temperatures of the stars in M 92 and NGC 6397 have been computed using the (Alonso et al. 1996) scale adopted for 47 Tuc.

The Li abundances for M 92 were recomputed from Deliyannis et al. (1995) Li equivalent widths using the same atmospheric models adopted in this work and for NGC 6397. The clusters are therefore in the same effective temperature reference scale and also the abundances are derived with the same atmospheric models. Measurements errors are affecting the diagram of Fig. 2 in a complex way. On the top of known uncertainties, those from the (B-V) photometry will change slightly the stellar effective temperature, not only giving different Li abundances, but also moving the stars in the diagram.

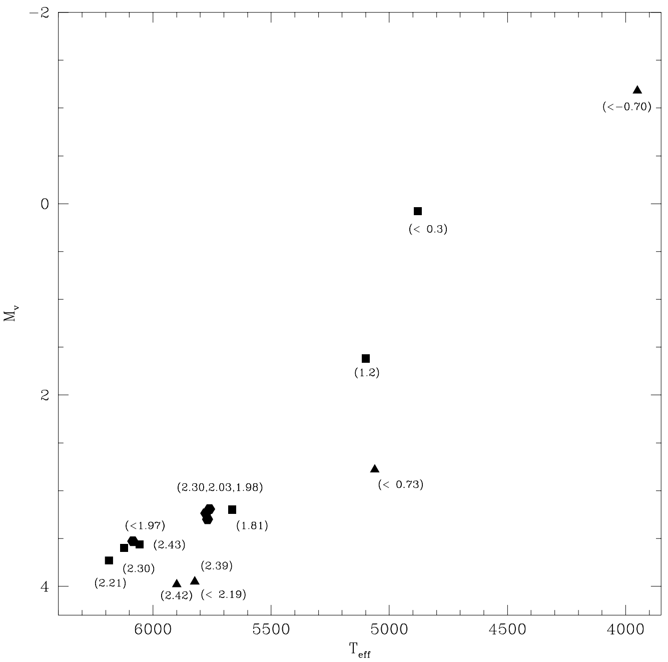

Fig. 2. Absolute magnitudes and Li abundances vs. T_{eff} for the 47 Tuc stars (Triangles), the stars observed in NGC 6397 (squares) and M 92(exagons). The apparent stellar magnitudes were corrected for the distance modulus of the cluster and for reddening. The derived Li abundances are given.

The overall similarity in the Li abundance among 47 Tuc, the other globular clusters and the *plateau* is remarkable, confirming that essentially the same Li abundance is observed over three orders of magnitude variation in the metallicity. If, as suggested by Boesgaard (1991) primordial Li was an order of magnitude higher and the Li observed in these clusters has been depleted by diffusion, winds, rotational mixing or other mechanism, then our observations require these mechanisms to be highly metallicity independent in the range -3.5 $\leq$[Fe/H]$\leq$-0.7. The same mechanism has instead to be strongly metallicity dependent at higher metallicity in order to reproduce the smooth increase of the Li abundance envelope observed in the Li-Fe diagram of field stars (Rebolo et al. 1988, see also next section). On the other hand, if these stars are essentially undepleted, the difference can be easily accomodated by a modest Galactic Li production, with most of the Galactic Li production occurring later on.

5.2. Comparison with PopI stars

Several field stars with measured Li abundance exist having metallicities similar to those of 47 Tuc. In Figs. 3a,b observations collected from several authors are plotted. The compilation includes all the field stars observed in Li with a metallicity between -0.4 and -1, bracketing the metallicity of 47 Tuc, with effective temperatures higher than 5500 K and estimated gravities ≥3.5, to avoid object which may have undergone depletion or dilution.

It is known that at these metallicities a real spread in Li abundances exists among field stars (Rebolo et al. 1988). The spread is present at temperatures far from those of the 'lithium dip' or from those where convective induced depletion occurs. The spread is also unlikely an evolutionary effect, because the stars are quite firmly classified as genuine dwarfs. This spread has been interpreted in terms of different degrees of depletion and/or in terms of an age spread in the sample. One could expect that older stars are on average the more depleted ones.

Thus, it is remarkable that none of the field stars, which are on average younger than 47 Tuc, have abundances significatively higher than those observed in 47 Tuc. Only HD 14221 (Balachandran 1990) with a metallicity of -0.4 and [Li]=2.9 is definitively higher, but, due to its high metallicity, this object cannot be taken as a safe counterexample.

The upper values of the observed [Li] both in field stars *and* 47 Tuc at ∼ 2.4 indicate that the [Li] vs. Fe abundance curve given by the upper envelope of Figs. 3a,b is basically independent of age, weakening the interpretation that an age-dependent depletion mechanism is in force (Boesgaard 1991).

These upper values are easily understood if no depletion has affected these stars. This in turn would suggest that we are just observing the increase of the Galactic Li enrichment. It would imply that only a very marginal increase in Li abundance has occurred in the Galaxy from the primordial value up to metallicities of ∼ -0.5. In addition, since among field stars several are expected to be younger than 47 Tuc, this may also suggest that Li enrichment depends more on metallicity rather than on age. We have to remember, however, that in old Pop I stars some age-independent mechanism is acting, which increases the scatter of [Li] abundances with respect to the metal poor objects (Pasquini et al. 1994), and this mechanism has not yet been satisfactorily identified.

According to the Be measurements in metal poor stars and the expected Li/Be yields, the observed enhancement can be explained by high energy Cosmic Ray production, without the need of invoking other mechanisms. In fact, according to Molaro et al (1996), at [Fe/H]≈-0.8, Be is [Be]=0.94 and the corresponding inferred Li by the same spallation processes is [Li]=1.9, when only ^{7}Li isotope is considered. This value added to a primordial value of [Li]=2.20 gives [Li]=2.38, which is precisely what it is observed in 47 Tuc.

Since an abundance up to [Li]∼3.1 is observed in the 4 Gyrs old, solar metallicity cluster M 67 (Pallavicini et al. 1996), this interpretation would imply an increase of Li abundance by 0.7 dex in the time (and metallicity) interval between 47 Tuc and M 67.

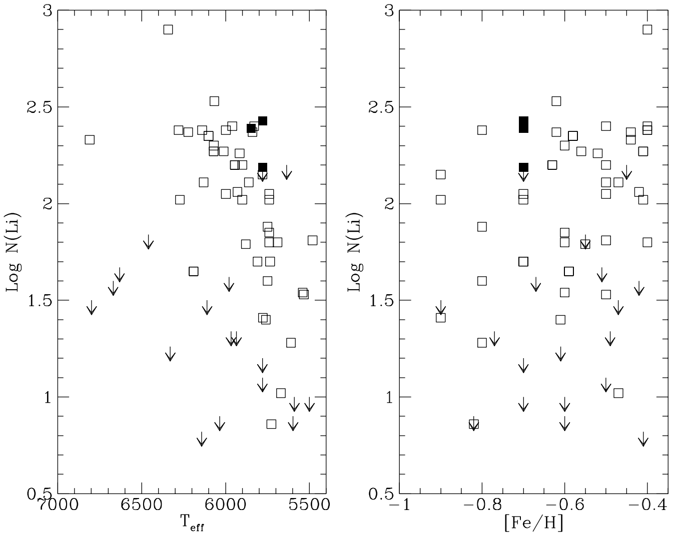

Fig. 3. a Li abundance vs. T_{eff} for the turnoff stars of 47 Tuc and field dwarfs having similar metallicities to the cluster. **b** Li abundance vs. metallicity, for the same sample of **a**.

5.3. Li dispersion in 47 Tuc

For the third turnoff star (b6) only an upper limit could be obtained. If the presence of Li abundance scatter among 47 Tuc stars will be confirmed, this would indicate that the scatter observed in field stars at the 47 Tuc metallicities is not due to age or chemical composition differences, but rather to an extra mechanism capable of overdepleting Li.

It should be noticed that single stars in each cluster present Li abundances which are as high as ∼2.4. In presence of a real dispersion of the Li abundances in the clusters stars, only these high values would be close to the initial one.

The presence of a spread in Li abundances for similar stars belonging to M 92 has been claimed by Deliyannis et al. (1995) and successive observations (Boesgaard et al. 1996) confirmed that a statistically significative difference in the measured Li equivalent widths exists. The three M 92 stars considered are subgiants, and they have an effective temperature around 5750 K, that is very close to the point where subgiant dilution begins to be present (Pilachowski et al. 1993). These stars are just 100 K hotter than star C4044 in NGC 6397, where the signs of dilution are evident (cf. Fig. 2). Photometric uncertainties may play an important role. An uncertainty in the (B-V) colours of 0.02, as given by Stetson and Harris (1988) for two of the stars observed, corresponds to a difference in temperature of almost 100 K. This error is not only relevant for the derived abundances (± 0.07), but it may also shift the stars into the temperature regime where dilution is observed. A lower reddening, still allowed by the photometric observations, would result into lower effective temperatures, also moving the stars closer to the dilution zone. In addition, Boesgaard et al. (1996) observed for the Li-rich subgiant also different Mg lines, and this could indicate that other intrinsic differences exist among the M 92 stars.

In 47 Tuc the comparison between star b6 with stars b5 and b7 may also suggest the presence of a scatter. For this case the stars have a temperature too hot to expect that depletion or dilution are effective, but with the S/N ratio of our observations the possible difference cannot be considered as definitive. It is worth noticing that stars b5 and b7 have the same Li and they are respectively CN rich and CN poor according to Briley et al. (1994); therefore CN inhomogeneities among main sequence stars of 47 Tuc may not be related to the dispersion of Li. The independence of the Li abundance of nitrogen abundance had already been found by Spite and Spite (1986) by studying a sample of nitrogen rich field stars, and our result confirms Spite's conclusion that nitrogen enhancement is not produced by deep mixing.

Pending more accurate observations, we can only conclude at the moment that the spread among similar stars of the same cluster has to be confirmed.

5.4. Evolved stars

Very low Li abundances are derived for the evolved stars in 47 Tuc and NGC 6397. This conclusion is not affected by the considered uncertainties. As pointed out by Pilachowski et al. (1993) and Pasquini and Molaro (1996), all present theories predict a levelling of the Li abundance at [Li]$\sim$1.1 for evolved stars with temperature below $\sim$ 5100 K (Swenson 1995), while observations in field and NGC 6397 subgiants show a dramatic drop. Our tight upper limits on b1 and L2734 in 47 Tuc confirm these previous studies, indicating that some other mechanism should be present, in addition to dilution, to produce an extra Li depletion when stars are ascending the RGB.

6. Conclusions

In this work we have presented and analyzed the first Li observations in 5 turnoff and evolved stars of the old, metal rich globular cluster 47 Tuc. Pushing the NTT telescope to its limits we have obtained high resolution observations for three V$\sim$ 17.4 stars located in the Spite *plateau*.

The main results are:

1) The Li abundance derived in two of the turnoff stars and from their composite spectrum is 2.37 ± 0.15. This value is slightly higher than the 2.20 found in the Pop II stars suggesting at most a mild increase in the Li abundance. Spallated Li as deduced from the observed [Be] can account for such an increase.

2) This finding, together with the fact that no field star in the metallicity range -1 to -0.4 show Li levels substantially higher than the 47 Tuc turnoff stars, pose strong requirements on the possible models of Li depletion in the stellar interior. Proposed models have to account for an almost constant Li level which extends from the most metal poor stars known up to metallicity -0.7.

3) For the third turnoff star only an upper limit could be obtained. If the presence of Li abundance scatter among 47 Tuc stars were confirmed, this would indicate that the scatter observed in field stars with similar metallicities is not due to age or chemical composition differences, but rather to an extra mechanism capable of overdepleting Li.

4) The tight upper limits for the 2 evolved stars confirm the finding that some extra depletion has to be present in evolved stars in addition to dilution.

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