A&A 453, 717–722 (2006)
DOI: 10.1051/0004-6361:20054421

Astronomy & Astrophysics

Lithium abundances for early F stars: new observational constraints for the Li dilution*

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Received 26 October 2005 / Accepted 28 February 2006

ABSTRACT

Aims. To investigate any correlation between Li abundances and rotational velocities among F–G evolved stars, we study a large sample of early F stars from the Bright Star Catalogue (BSC), most of them classified in the literature as giant stars.
Methods. Physical parameters and Li abundances are estimated for each star, often for the first time, by comparing observed and synthetic spectra. We analyse the position of the stars in the H–R Diagram based on Hipparcos data using stellar evolutionary tracks and we discuss their Li abundances and projected rotational velocities.
Results. Observed stars are mostly on the turnoff, with masses between 1.5 and 2.0 $M_{\odot}$. The stars with measured A(Li) abundance show high Li content, most of them with abundance near the cosmic value. The A(Li) versus $V \sin i$ diagram shows the same trend as reported in previous studies: fast rotators ($V \sin i \gtrsim 30\,\mathrm{km\,s^{-1}}$) are also stars with high Li content, whereas slow rotators present a wide range of values of A(Li), ranging from no detected Li to the cosmic value.

Key words. stars: evolution – stars: late-type – stars: fundamental parameters – stars: abundances

1. Introduction

Over the past 15 years, much observational effort has been dedicated to the study of Lithium content in evolved Population I stars. As a result the observational behavior of lithium abundance as a function of effective temperature, and by consequent spectral type, is now well established, at least for late-type subgiant and giant stars. In the G to K spectral type regions of the H–R diagram, Li abundance decreases gradually with effective temperature, reflecting mixing effects due to the increase of the convective envelope towards the inner stellar regions. The large survey carried out by Brown et al. (1989) revealed a number of very important aspects of giant stars. In particular, they suggested a decrease of Li abundances in the G to K spectral type regions with a dilution factor higher than predicted by standard theory. Whereas theoretical predictions give a factor of 40 to 60 for typical K-type giants of 1.0 and 2.0 solar masses, respectively, the observations from Brown and collaborators indicated dilution factors of between 400 and 1000 (e.g. de Medeiros et al. 2000). This discrepancy is not explained in the framework of the standard stellar mixing theory, arguing in favor of extra-mixing mechanisms. In addition, in spite of the fact that giant stars with enhanced Li abundance also present high rotation, different works have shown that Li abundances in slow rotating giants and subgiants range from very low to cosmic values (de Medeiros et al. 1997, 2000; de Laverny et al. 2003; Randich et al. 1999).

De Laverny et al. (2003) have determined precise Li abundances for giant stars evolving across the Hertzsprung gap, mostly late F-type stars, which are expected to have finished core hydrogen burning but to have not yet ignited core helium burning. These authors also found no linear relation between Li abundance and rotation, similar to previous results for other luminosity classes and spectral types, in spite of the fact that most of the fast rotators present high Li content. In addition, de Laverny et al. (2003) have shown that, in such spectral region, stars with high Li content are mostly those with an undeveloped convective zone, whereas stars with a developed convective zone present clear signs of Li dilution. Studies on Lithium in F-type giant stars were also carried out by Wallerstein (1966), Alschuler (1975) and Wallerstein et al. (1994), showing a steady decline in Li content from F5III to F8III.

The present paper describes the results of an observational program intended to derive the Lithium abundance for early F-type stars currently classified as luminosity class III. With this study, complementary to that of de Laverny et al. (2003), it will be possible to analyse the behaviour of Li abundances in giants from the turnover to the base of the RGB. Section 2 presents the main characteristics of the sample, the observational procedure and Li abundance analysis. Section 3 contains the main results. Conclusions are presented in Sect. 4. Most of the stars composing the present sample have their physical parameters and Li abundances measured for the first time.

2. The observational program

For this observing program we have composed a preliminary list of 73 F-type stars with luminosity class III in the BSC (Hoffleit & Warren 1991) according to the following criteria: declination $\delta > -20°$ in order to be observed at Observatoire de

* Based on observations collected at Haute-Provence Observatory, Saint-Michel, France.

Haute Provence (France), and a spectral type between F0 and F5. These stars, except for some of them with a spectral type as late as F5III, are not included in the study by de Laverny et al. (2003) that is essentially dedicated to giant stars later than F5III.

2.1. Observations

We use spectra obtained during three observing runs at the Observatoire de Haute Provence, from July 2 to July 5, 2002, from December 9 to December 12, 2002, and from December 21 to December 23, 2003.

High-resolution spectra ($R \approx 40\,000$) centered on the Li λ6708 Å line were obtained with the *Aurélie* spectrograph (Gillet et al. 1994) installed on the 1.52 m telescope. This spectrograph uses a cooled 2048-photodiode detector forming a 13 μm pixel linear array. The entrance spherical diaphragm was $3''$. A grating with 1800 grooves mm^{-1} was used, giving a mean dispersion of 4.7 Å mm^{-1}. The spectral coverage was about 120 Å.

Thorium lamps were observed before and after each stellar observation for wavelength calibration. At the beginning, the end and the middle of each night, a series of flat-fields were obtained using an internal lamp (Tungsten).

All spectra and calibration files have been processed with the MIDAS package. A series of synthetic spectra with effective temperature 6500 K $\leq T_{\rm eff} \leq$ 7500 K, gravity log $g = 4$ and solar metallicity have been calculated using MARCS stellar atmosphere models (Gustafsson et al. 1975; Plez et al. 1992) and recent values of atomic and molecular opacities. From these synthetic spectra, some short windows of wavelength where the continuum value was near to the unity have been identified in our observed spectra and used for the drawing of the continuum level. After normalization by the continuum of observed spectra, corrections for radial velocities were performed by using a MIDAS cross-correlation procedure between observed and synthetic spectra. To estimate the *S/N* ratio of our data, we partitioned the wavelength region into bins of 500 pixels, each bin corresponding to 15 Å. Within each bin i we calculated the average F_i of the relative flux, the standard deviation σ_i, and the ratio F_i/σ_i. The *S/N* ratio, which is a function of λ, was estimated from the *continuum* of the curve F_i/σ_i versus i.

In order to perform a good spectral analysis (see Sect. 2.2), we excluded 14 stars whose spectra were of poor quality ($S/N \ll$ 50 and/or very flat spectra), or obtained in poor observing conditions. Three stars were also excluded due to obvious effects of variability and/or duplicity in their spectra. Our preliminary sample of stars was reduced to 56 stars which constitute the so-called working sample in Table 1.

2.2. Spectral analysis and lithium abundances

We adopted the same spectral synthesis method used by Lèbre et al. (1999) and Jasniewicz et al. (1999) in order to derive the lithium abundances from the resonance LiI λ6708 Å line. The reader is referred to these authors for a description of our abundance analysis assuming LTE.

All the stars selected for the present study have well determined photometric color indices in the literature. To determine their effective temperature we used the $B - V$ color-temperature relation from Sekiguchi & Fukugita (2000), with typical errors of about 250 K. For these stars in the short range of spectral type [F0−F5], the bolometric correction is very small and estimated to be about −0.1 (Drilling & Landolt 2000). From the Hipparcos parallax (ESA 1997) we derived $M_{\rm bol}$, and from theoretical tracks of the Geneva Observatory (Schaller et al. 1992), we derived approximate values log g for each star. The microturbulence velocity was set at 2 km s^{-1}, which is a value commonly adopted for Pop. I giant stars.

From these stellar parameters, synthetic spectra were computed with tools from the Uppsala Stellar Atmospheres Group. Model atmospheres were interpolated into the grid of MARCS models presented by Asplund et al. (1997). We used the line list extensively described by Lèbre et al. (1999).

Projected rotational velocities $V \sin i$ were obtained from an initial fit of the observed spectra with synthetic ones, using our first guess on the stellar atmospheric parameters. The effective temperatures of all the stars were then corrected, when necessary, to improve the fit quality of the several FeI and other metallic lines found in the observed spectral range (i.e. about 20 Å wide around the Li line). These metallic lines (mostly iron) also allowed us to derive the mean metallicity of the target stars. Observed and synthetic spectra in the spectral Li region for four program stars are given in Fig. 1.

For all the stars of the working sample, Table 1 presents the final adopted stellar parameters, effective temperature $T_{\rm eff}$, gravity log g, metallicity [Fe/H], and the derived Li abundances A(Li)[1]. If A(Li) is marked "?" in Col. 9, it means that $T_{\rm eff}$ and $V \sin i$ were too high to allow any quantitative Li abundance; the star marked "+", HD 190390, probably has a very high Li content. The projected rotational velocities presented in Table 1, calculated in the present work, were compared with values published in the literature by De Medeiros & Mayor (1999), Nordström et al. (2004) and Royer et al. (2002). For common stars in these surveys, the comparisons between $V \sin i$ values present a quite good agreement with a standard deviation of 8 km s^{-1}. As already discussed by Lèbre et al. (1999) and de Laverny et al. (2003), the major source of uncertainty for the present abundance analysis is errors in the determination of the effective temperature. They have been estimated from the examination of the fit quality of the metallic lines when varying the temperature in a range of ±500 K, and were found to be smaller than 200 K. The error on the mean metallicity estimated from the fit of the iron lines found in the vicinity of the Lithium line is around 0.1 dex. The final adopted uncertainty of the Li abundances is around 0.2 dex.

Ten stars of the present sample are in common with Wallerstein et al. (1994). Their estimated effective temperatures are in very good agreement with those determined in the present work. The differences are always smaller than 100 K except for the δSct variable star HD 17584, for which a discrepancy of 350 K is found (but still consistent within the error bars in both works). Regarding the projected rotational velocity, both estimates also agree very well except for HD 36994. Their derived $V \sin i$ (76 km s^{-1}) for this star is incompatible with our spectra that leads to $V \sin i$ = 150 km s^{-1}. We do not have any clear explanation for this disagreement since we are confident in the $V \sin i$ value obtained in the present work. On the other hand, de Medeiros & Mayor (1999) give a $V \sin i$ value of about 56 km s^{-1} for HD 36994. Nevertheless, as reported by these authors, the $V \sin i$ measurements based on their procedure becomes difficult for rotations above 30 km s^{-1} because large differences between the fitted Gaussian and CORAVEl dip are observed. In this context, for fast rotators such as HD 36994,

[1] In the standard notation where log(H) ≡ 12 is the abundance of hydrogen by number.

Table 1. Stellar parameters for the present working sample. $T_{\rm eff}$, $M_{\rm bol}$, $\log g$, $V \sin i$, [Fe/H] and lithium abundance A(Li) have been calculated in the framework of the present study. If A(Li) is marked "?" in Col. 9, it means that $T_{\rm eff}$ and $V \sin i$ were too high and did not allow any quantitative Li abundance; the star marked "+" is probably Li-rich. Some stars are noted Spectral or Visual Binary (respectively SB and VB) and/or variable (SR: semi-regular pulsating star). The stars marked "R" have also been observed by de Laverny et al. (2003).

HD	Sp.	$T_{\rm eff}$ (K)	$M_{\rm bol}$	$\epsilon(M_{\rm bol})$	$\log g$	$V \sin i$ km s^{-1}	[Fe/H]	A(Li)	Note
1671	F5III	6500	1.63	0.28	4.0	50	0.0	2.8	R
2630	F2III	6800	2.92	0.28	4.3	50	0.3	3.0	
4757	F4III	6600	1.77	0.57	4.0	100	0.3	2.8	
4758	F5III	6600	1.87	0.57	4.0	100	0.2	2.8	
5357	F4III	6900	2.41	0.29	4.3	30	0.0	3.1	
8634	F5III	6600	1.66	0.39	4.0	30	0.0	3.1	SB
11171	F3III	7000	2.70	0.20	4.3	50	0.3	3.0	
13174	F2III	7000	−0.08	0.57	3.7	150	0.3	3.2	
15257	F0III	7200	1.81	0.30	4.0	100	0.0	2.3	
17584	F2III	6700	1.14	0.25	4.0	150	0.0	3.1	
17918	F5III	6500	1.04	0.59	4.0	150	0.3	3.2	
21770	F4III	6800	2.40	0.23	4.3	30	0.0	3.1	
34045	F2III	6900	1.75	0.43	4.0	100	0.0	2.9	
36994	F5III	6500	1.77	0.61	4.0	150	0.3	3.2	
37077	F0III	7400	−0.13	0.51	3.7	50		?	
40136	F1III	7100	2.73	0.16	4.3	20	0.1	3.0	
43905	F5III	6600	1.47	0.31	4.0	10	0.1	3.2	SB
44497	F0III	7200	1.91	0.42	4.3	100	0.0	3.1	
48737	F5III	6600	2.08	0.17	4.3	70	0.3	3.2	R
59881	F0III	7600	−1.77	1.02	3.7	50		?	
61110	F3III	6600	1.37	0.33	4.0	100	0.0	2.8	
71433	F4III	6300	1.41	0.55	4.0	30	0.0	2.6	
71766	F2III	6500	−1.49	1.46	3.7	100	0.2	2.4	
73596	F5III	6700	0.96	0.54	4.0	30	−0.1	2.2	
75486	F2III	7200	0.91	0.39	4.0	100		?	
76292	F3III	6900	1.50	0.36	4.0	50	0.0	2.9	
76990	F2III	7100	1.42	0.35	4.0	150	0.0	3.2	
82043	F0III	7700	0.23	0.86	4.0	70		?	
89025	F0III	7100	−1.16	0.41	3.7	100	0.0	3.2	
92787	F5III	7250	2.34	0.23	4.3	45	−0.3	2.5	R
98991	F5III	6500	1.78	0.28	4.0	20	0.0	< 1.0	SB
108722	F5III	6600	1.28	0.38	3.6	100	0.0	3.2	R
129502	F2III	6800	2.44	0.19	4.3	40	0.0	3.2	
136407	F0III	6900	2.37	0.38	4.3	100	0.0	3.0	
138803	F3III	7100	2.41	0.37	4.3	100	0.0	3.0	
138936	F0III	7400	2.61	0.32	4.3	100		?	
150682	F2III	6800	2.67	0.25	4.3	30	−0.2	3.0	SB2
156971	F1III	7100	3.00	0.35	4.3	20	−0.3	3.0	
159026	F6III	6300	−1.07	1.01	3.0	140	0.0	< 2.0	R
171802	F5III	6700	2.60	1.13	4.3	10	0.2	2.8	
174589	F2III	7200	1.33	0.43	4.0	100	0.0	3.1	
175824	F3III	6500	2.13	0.23	4.3	60	0.2	3.2	VB $\delta S ct$
178233	F0III	7300	2.37	0.22	4.3	150		?	
184705	F0III	7300	1.70	0.40	4.0	100		?	
186005	F1III	7100	1.32	0.34	4.0	150	0.0	2.9	
186357	F1III	7000	1.88	0.37	4.3	100	0.2	3.0	
187764	F0III	7200	0.20	0.51	4.0	100		?	
190004	F2III	6900	1.11	0.41	4.0	150		?	VB
190172	F4III	6800	2.56	0.46	4.3	15	−0.2	2.6	
190390	F1III	6200	−1.67	1.99	3.7	10		+	SR
199611	F0III	7100	2.11	0.24	4.3	150	0.0	3.0	
203842	F5III	6400	1.11	0.51	3.0	90	−0.3	3.1	R
203843	F0III	7000	2.03	0.42	4.3	100	0.3	3.2	
207760	F0III	6800	2.02	0.38	4.3	100	0.0	3.1	
207958	F1III	6700	2.77	0.21	4.3	100	0.1	3.2	
209166	F4III	6900	1.29	0.38	4.0	10	−0.1	3.1	

CORAVEL observations can only give a qualitative indication that they have a high $V \sin i$, typically larger than 30 to 50 km s^{-1}.

Wallerstein et al. (1994) derived [Li/Fe] abundances with the equivalent width and curve-of-growth technique. Assuming our [Fe/H] measurements and a A(Li) = 1.05 in the Sun (Asplund et al. 2005), the estimated lithium abundances in both works are in very good agreement for the 10 common stars but one. For the spectroscopic binary HD 8634 (see Fig. 1), Wallerstein and

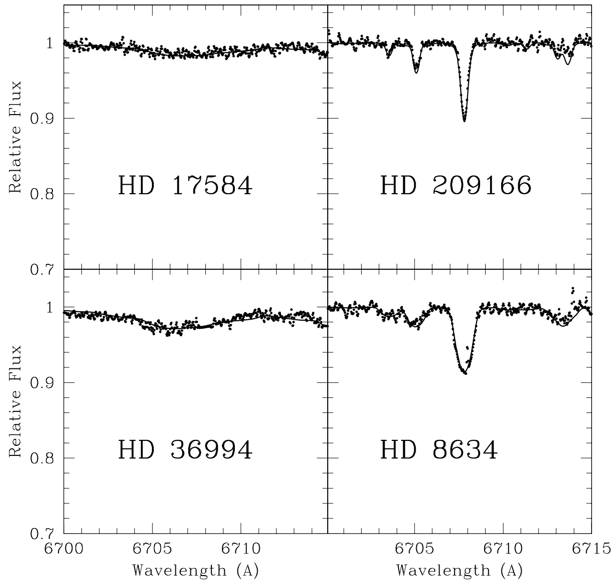

Fig. 1. Lithium spectral region for four program stars, three being in common with Wallerstein et al. (1994). Observations and synthetic spectra (whose parameters can be found in Table 1) are shown with dots and continuous lines, respectively.

collaborators report $A(\mathrm{Li}) = 3.7 \pm 0.3$ dex (actually larger than the well-accepted cosmic value) while we have found $A(\mathrm{Li}) = 3.1 \pm 0.2$ dex. We carefully checked the present Li abundance estimation and we can exclude a higher value than the one reported here. The rather small discrepancy could be partly explained by binarity effects and/or the technique used by Wallerstein and coworkers, since they need to deblend the large measured equivalent width of the Li line in this star before estimating its Li abundance. This procedure could have introduced some additional uncertainty in their method, although it is difficult to estimate this source of error. Nevertheless, it is quite clear that, except for one star, their derived abundances are in excellent agreement with the present study.

3. Results and discussion

3.1. The behaviour of lithium

The measured Li abundances listed in Table 1 show a high Li content for the large majority of stars composing the present working sample, following the theorectical predictions for early-F type giant stars. Such a result is clearly seen in Fig. 2, where the Li abundance of the observed stars, represented by circles, is displayed as a function of effective temperature. The 38 stars plotted in Fig. 2 are extracted from Table 1 according to the following criteria: $A(\mathrm{Li})$ is not marked "?", the last Note is not marked "R", and the star is not a short-period binary with $P < 250$ days (HD 8634, HD 43905 and HD 150682 are thus excluded).

In addition, Fig. 2 shows the Li abundances of late F to early G giants given by de Laverny et al. (2003) and Lèbre et al. (1999), represented by squares and triangles, respectively, for an enlarged analysis of Li behaviour in these spectral types. While the estimated effective temperature has typical errors between 100 and 200 degrees, distances and therefore bolometric magnitudes have a large range of errors. Error bars in magnitude are indicated for all the stars. For a more solid location of the evolutionary stage and mass of stars, Fig. 2 displays theoretical tracks from Schaller et al. (1992). Although all the observed stars in the present sample are classified in the BSC with a luminosity class III, it appears that some of them could be not as evolved as expected. As shown in Fig. 2, most of the stars composing the present observed sample, with about 1.5 and 2.0 $M_\odot$, are located at or near the turnoff.

By considering that early F-type stars have a rather undeveloped convective envelope, the high Li abundances found in this work mainly reflect primordial values, with no significant dilution effects. It is clear from the combined data in Fig. 2 that, at the turnoff and along the early-F type spectral region of the H−R diagram, most of the stars in the mass range 1.5 to 3.0 $M_\odot$ seem to present the cosmic Li abundance. According to do Nascimento et al. (2002), these stars, populating the blue side of the Hertzsprung gap, have not yet experienced mixing processes, presenting undeveloped convective envelopes. The increase in mass of the convective envelope arises only when giants evolve along the late F-type region, with a strong dependence on the stellar mass. Theoretical predictions presented by these authors show the onset of Li dilution for giants with 1.5, 2.0 and 3.0 $M_\odot$ occuring at ~5600 K, ~5500 K and ~5400 K, respectively. The high Li content observed in stars of the present sample follows the predictions of the standard stellar evolution models.

The combined data displayed in Fig. 2 show a significant number of stars with effective temperature around 6000 K and low $A(\mathrm{Li})$, which are very probably associated with the Hyades-like lithium gap phenomenon (Boesgaard & Tripicco 1986). For these stars, Li depletion occurs early in stellar life, leaving the main sequence with low Li content. As Fig. 2 shows, early F stars with masses around and smaller than about 1.5 $M_\odot$ present mostly a low Li content, indicating that most of the low mass stars evolving off the main-sequence have already suffered a Li depletion during their main-sequence life. As already underlined, convective dilution off the main sequence is expected only at the late-F spectral region, corresponding to effective temperatures lower than 5600 K. Two stars from Lèbre et al. (1999) plotted in this figure, HD 26923 ($T_{\mathrm{eff}} = 5970$ K, $V \sin i = 4\,\mathrm{km\,s^{-1}}$, $A(\mathrm{Li}) = 2.8$) and HD 41700 ($T_{\mathrm{eff}} = 6140$ K, $V \sin i = 16\,\mathrm{km\,s^{-1}}$, $A(\mathrm{Li}) = 2.8$), violate this apparent trend, presenting Li abundance near the cosmic value. HD 26923, which is listed as G0IV in the BSC, with a rotation period of 5.6 days, is classified by different authors (e.g.: Noyes et al. 1982) as an active young solar-type main sequence star. HD 41700, which is listed as G0IV-V in the BSC, shows a period of rotation of about 3 days (Wright et al. 2004) and presents an IR excess most probably due to a debris disk-like Vega phenomenon (Decin et al. 2003) and an enhanced CaII K emission (Cutispoto et al. 2002). Both evolutionary statues justify, in principle, their observed high Li content. Thus, the present analysis indicates a clear trend: early-F type stars with mass greater than about 1.5 $M_\odot$ present mostly a moderate to high Li content, indicating that most of these low mass stars have have not yet suffered a Li depletion; early-F type stars with mass lower than about 1.5 $M_\odot$ show low Li content as a result of Li depletion during their main-sequence stage.

The behaviour of the Li content in the late-type F region, typically stars with T_{eff} less than about 5600 K, confirms the results found by previous works, with single stars at the giant stage presenting low Li abundances. Such behaviour seems to reflect two different stages of dilution: the first one for stars with masses smaller than 1.5 $M_\odot$ during their Hyades-like lithium gap phenomenon at the main sequence and the second one for stars more massive than about 1.5 $M_\odot$, due to convective dilution during the late-F spectral stage. Two stars, namely HD 98991, with a mass

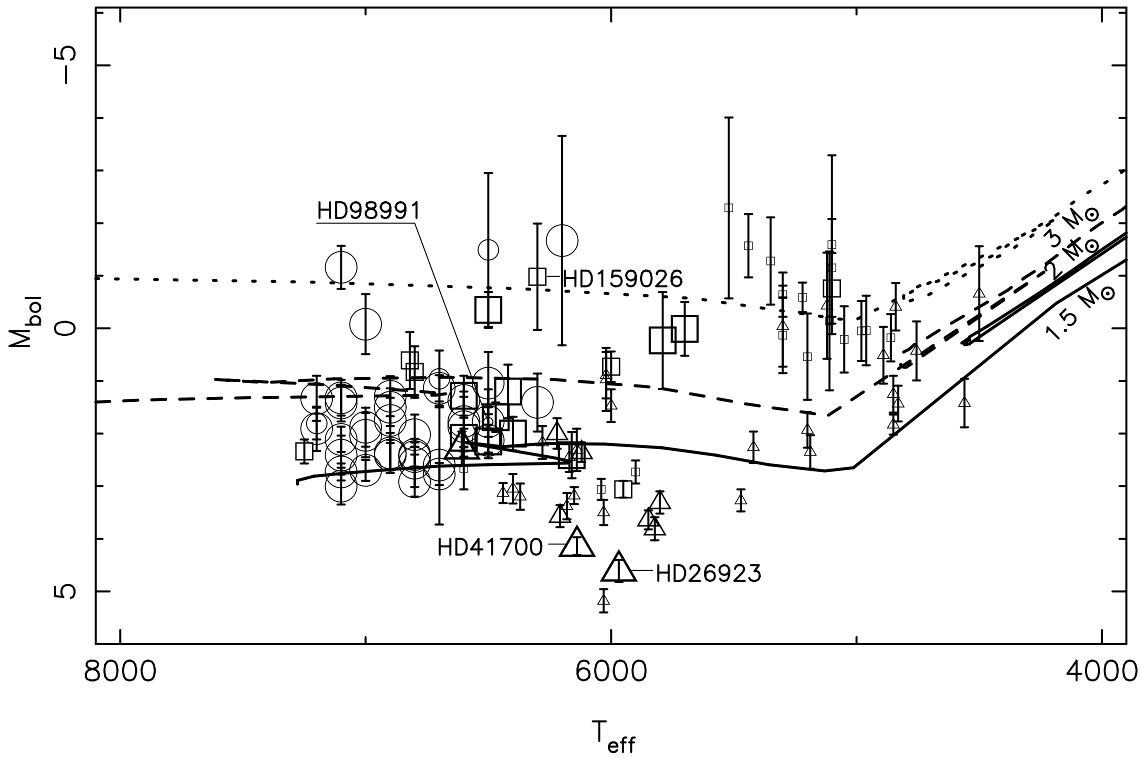

Fig. 2. The H−R diagram with the program stars represented by circles. The stars from de Laverny et al. (2003) are represented by squares; triangles stand for stars from Lèbre et al. (1999). The size of symbols are proportional to the Li content (A(Li) > 2.5, 1.5 ≤ A(Li) ≤ 2.5, A(Li) < 1.5). The error on $T_{\rm eff}$ is better than 200 K and that on $M_{\rm bol}$ comes from the Hipparcos parallax error. Solid, dashed and dotted lines represent Geneva evolutionary tracks (Schaller et al. 1992) for a 1.5, 2.0 and 3.0 $M_\odot$, respectively, with $Z = 0.020$.

around 1.5 $M_\odot$, and HD 71766 with a mass around 3.0 $M_\odot$, show an unexpectedly low Li abundance. As shown by Suchkov et al. (2002), HD 71766 presents an infrared excess, indicating for circumstellar dust.

3.2. Lithium versus rotational velocity

Effective temperatures, rotational velocities and lithium surface abundances are closely related in dwarfs and giant stars. Extended convection automatically reduces both the Li surface abundance and the surface rotation rates simultaneously (Böhm-Vitense 2004). Figure 3 shows the Li abundance versus projected rotational velocity $V \sin i$ for the present stellar sample (i.e. the 38 stars plotted in Fig. 2), combined with those from de Laverny et al. (2003) and Lèbre et al. (1999). The stars composing the present sample show the same trend observed in previous studies on the Li versus rotation link (e.g.: De Medeiros et al. 2000; de Laverny et al. 2003): fast rotators are also stars with high Li content, whereas slow rotators present a wide range of Li abundance, from no detection to the cosmic value. This result is more striking when we analyse the combined sample. The observed low rotation for some stars presenting high Li content may be due to the $\sin i$ effect. For an assumed isotropic distribution over the rotational axis, large $\sin i$ values are more likely than small ones; e.g. the probability that $\sin i < 0.25$ is about 3%. Therefore, it is difficult to accept that such a projection effect influences all the observed stars, including those from other studies. We expect the bulk of these stars to be intrinsically slow rotators. Several stars have an unexpected relation between rotation and Li content: HD 40136, HD 43905, HD 156971, HD 171802, HD 190172 and HD 209166, all presenting cosmic Li content, A(Li) ∼ 3, and $V \sin i$ lower than about 20 km s^{-1}. Except for

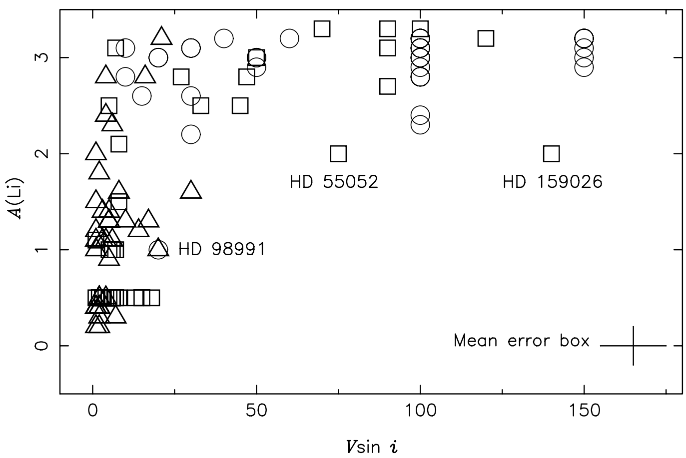

Fig. 3. A(Li) versus projected rotational velocity $V \sin i$ of the program stars. The symbols follow the same definition given in Fig. 2. For most of the stars with A(Li) < 1.5, only an upper value of A(Li) is plotted. The probable error on $V \sin i$ is about ±10 km s^{-1} for fast rotators ($V \sin i \gtrsim 30$ km s^{-1}) and better than 10% for slow rotators, whereas that on A(Li) is about ±0.2 dex.

HD 43905, a well-known SB system, the other stars present no particularity in the literature. This indicates that these stars have already left the main-sequence as slow rotators, with their primordial Li preserved, or that they have experienced some extra spin-down mechanism once evolved off the main-sequence, which had no effect on surface Li. This may indicate a scenario where these stars have left the main-sequence with low rotation and low Li, and once evolving in the early-F region have experienced some extra mechanism that increased their surface

Li content. Different mechanisms could explain high Li content among slow rotators, including dredge-up of Li hidden below the convective envelope by atomic diffusion in the post turn-off stage, as in the model by Richard et al. (2002), from which one can expect a decrease in rotation. Another mechanism is the scenario of planets or brown dwarfs engulfed by their hosting star (e.g. Siess & Livio 1999), with no significant angular momentum transfer. Nevertheless, different studies (e.g. Melo et al. 2005) have not yet found clear observational evidence supporting such a scenario.

Two stars in the present sample show low Li content in contrast to the other observed stars, namely HD 98991 and HD 159026. HD 55052 ($T_{\rm eff}$ = 6820 K, A(Li) < 2.0, $V \sin i$ = 75 km s^{-1}) observed by de Laverny et al. (2003), exhibits a similar low Li surface abundance. Whereas for HD 98991 the Li-rotation relation seems normal, HD 159026 and HD 55052 show a rather abnormal behaviour in the framework of standard theory, with moderate to low Li and very high rotation. These stars need further investigation.

4. Conclusions

We report lithium abundances of early-F type giant stars, most of them located near or at the turnoff in the mass range around 1.5 to 3.0 $M_{\odot}$. Cosmic Li content is found for the large majority of the stars, following the framework of standard stellar evolution theory, which predicts no Li dilution in this spectral region. For the stars with low Li content and mass lower than about 1.5 $M_{\odot}$, the observed low Li content may be explained by considering that the stars have passed through the accepted Li Hyades-gap phenomenon.

The lithium abundance versus rotation relation shows the now well established trend: stars with high rotation present also high Li content, whereas stars with low Li content present a large dispersion in the values of Li abundances, reaching at least 3 orders of magnitude. We suggest that physical phenomena such as dredge-up of Li by atomic diffusion or the engulfing of a sub-stellar companion could be responsible for this high Li content. An interesting observational test of the first scenario is the determination of abundances for other chemical species that could be affected by atomic diffusion. For the second one, information on activity level and infrared behaviour may give helpful informations. As predicted by Siess & Livio (1999), IR excess and enhanced activity are expected as a result of engulfing phenomena, in addition to high Li. The measurements of CNO abundances may bring important constraints on the real evolutionary stage for these stars, shedding light on their enhanced Li content versus low rotation behaviour. Also, the present study shows that one should be cautious about the evolutionary status of F stars indicated in the literature as evolving off the main-sequence. For most of the stars analysed in this paper, we have indeed found that they are evolving, particularly at the turnoff.

Acknowledgements. This work is supported by continuous grants of the CNPq Brazilian Agency. G.J. and P.L. thank the PNPS/CNRS for financial support. J.R.M. thanks the FAPERN Rio Grande do Norte Agency for partial financial support. A.R.B. also acknowledges support from ESA. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France. We thank the anonymous referee for helpful remarks on the text.

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