Astron. Astrophys. 317, 701–706 (1997)

ASTRONOMY
AND
ASTROPHYSICS

On the link between rotation and lithium depletion in subgiant stars*

J.R. De Medeiros[1], **J.D. do Nascimento Jr**[1], **and M. Mayor**[2]

[1] Departamento de Física, Universidade Federal do Rio Grande do Norte, Campus Universitário, 59072-970, Natal, R.N., Brasil
[2] Observatoire de Genève, ch. des Maillettes 51, CH-1290 Sauverny, Suisse

Received 16 November 1995 / Accepted 22 May 1996

Abstract. We present projected rotational velocity *Vsini* for 65 F, G and K subgiant stars. In this work we study the link between rotation and Lithium abundance in such class of luminosity. In particular, we look for possible effects of rotational braking on the Lithium depletion. We show that a sharp decrease in Lithium abundances parallels the rotational discontinuity, located at F8IV, in all its aspects. We have found some dependence of Lithium abundance upon rotation for single subgiants, but there is no evident correlation between Lithium abundance and rotational velocity for binary subgiant stars.

Key words: stars: abundances – binaries: spectroscopic – stars: evolution – stars: late-type – stars: rotation

1. Introduction

It has long been known that in late-type giant stars both their rotational velocity and their Lithium abundance decrease with age. In fact, the abundance of Lithium in late-type giants is known to depend strongly on the degree of convective dilution as the star evolves to the red giant branch. Herbig (1965) has suggested that Lithium depletion occurs as a consequence of the convective transportation of Lithium-rich surface material to hotter stellar interiors where Lithium is rapidly destroyed by the reaction ^{7}Li(p,α)^{2}He. Iben (1967a,b) was able to predict the amount of Lithium depletion and dilution in low-mass stars from the stellar evolution theory by using evolutionary models of 1.0-1.5 $M_\odot$ main sequence, subgiant and giant stars. Nevertheless, the physical mechanism responsible for Lithium depletion is not yet well established.

If Lithium abundance is related to age, one should expect some correlation between such parameter and rotational velocity at least for stars of similar spectral type (Skumanich 1972). In this sense, Zahn (1992) and Pinsonneault et al. (1989,1990) have postulated, following different approaches, that the depletion of Lithium in single late-type stars is directly related to the loss of angular momentum. Concerning specifically the subgiant stars, different authors have reported a gradual decrease of Lithium abundances toward later spectral types (e.g.: Duncan 1981; Pallavicini et al. 1987). Such behavior seems to reflect the Lithium depletion process due to the increase of the convective envelope depth, which produces a more efficient convective transport of Lithium-rich material from the surface to the hotter stellar interior. Further, such class of luminosity presents a broad range of Lithium abundances for stars with similar effective temperatures. Such feature is up to now, not completely understood. Several authors consider that this spread of Lithium abundances is related to a spread of ages (Herbig, 1965; Duncan 1981; Soderblom 1983), whereas other authors (Pallavicini et al. 1987; Spite & Spite 1982; Randich et al. 1994) ascribe this spread to other parameters such as metallicity, activity and mass. In addition to the convective mixing, other nonstandard effects have been proposed to affect the Lithium abundances in the subgiant branch. Among such effects one can quote rotational-induced mixing (e.g.: Pinsonneault et al. 1989; Charbonnel & Vauclair 1992), convective overshoot (e.g.: D'Antona & Mazzitelli 1984), mass loss (e.g.: Hobbs et al. 1989; Boothroyd et al. 1991) and gravitational settling (e.g.: Michaud 1986).

The link between rotation and Lithium abundance for subgiant stars is not yet well established. In general, the dearth of rotational velocities, in particular for the generally slowly rotating G and K subgiants has prevented a solid analysis on the relationship between rotation and Lithium abundance in this class of luminosity. Moreover, what has not been determined so far is whether Lithium abundance follows the behavior of the rotation in the spectral region of the rotational discontinuity near the spectral type F8IV (Gray & Nagar 1985; De Medeiros & Mayor 1989; De Medeiros 1990). A cut-off in the distribution of the rotational velocity for subgiant star is very well defined at

---

Send offprint requests to: J.R. De Medeiros

* Based on observations collected at the Haute-Provence Observatory, Saint-Michel, France, and at The European Southern Observatory, La Silla, Chile

(B-V) near 0.55, which corresponds to the spectral type F8IV. Essentially, if one puts aside the synchronized binary systems, all subgiants located to the right of the rotational discontinuity are slow rotators. On the left side of the discontinuity there is a large spread of *Vsini* values, with rotational velocities scattered over a range of about 2.0 km.s^{-1} to about 150.0 km.s^{-1}. Whereas the most plausible explanation for the rotational discontinuity seems to be a strong magnetic braking (Gray & Nagar 1985; Rutten & Pylyser 1988; De Medeiros & Mayor 1989; De Medeiros 1990), the bahavior of the rotational velocity to the right of such discontinuity seems to be controlled by the increasing of the moment of inertia, as result of the increasing in stellar radius and change in the internal radial distribution of mass, associated with angular momentum loss via a magnetized wind as stars cross the subgiant branch (Pinsonneault et al. 1989; De Medeiros 1990). More recently, Lebre et al. (1995) have claimed a discontinuity in the abundances of Lithium of single subgiant stars near the spectral type F8IV. A study on the effects of enhanced rotation on the process of convective mixing of Lithium in RSCVn binaries and related chromospherically active stars was addressed in a remarkable series of papers by Pallavicini et al. (1992, 1993) and Randich et al. (1993, 1994). These authors have shown that the Lithium abundance is poorly correlated with rotation and chromospheric emission, suggesting that Lithium abundance among chromospherically active evolved stars may not be directly related to chromospheric activity. In these later studies one finds 22 subgiants, essentially binary stars.

In the present work, we address specifically the question of the link between rotation and Lithium abundance in single and binary subgiant stars by using a sample of stars larger than those studied previously, and for which we have now precise rotational velocity. In particular, we look for the link between the rotational discontinuity and the decline in Lithium abundance. In Sect. 2, we present the observational data. In Sect. 3, we present and discuss our results and finally, a summary is given in Sect. 4.

2. The sample and observational data

The data sample selected for the present work has as main characteristic the high precision of the rotational velocities. In fact, we have selected all F–G–K subgiant stars listed in the Bright Star Catalog (Hoffleit & Jaschek 1982) northern of 0.0° and all the subgiant stars listed in the Catalog of Chromospherically Active Binary Stars of Strassmeier et al. (1988). The rotational velocities were obtained with the CORAVEL spectrometer (Baranne et al. 1979) at the Haute-Provence Observatory, France, and at the European Southern Observatory, Chile. For the *Vsini* values lower than about 50 km.s^{-1}, CORAVEL measurements indicate a precision of about 1.0 km.s^{-1}. However, for larger rotators we must be cautious about the analysis of the rotational velocities because the uncertainties may become important. For a complete discussion on the observational procedure, calibration and error analysis the reader is referred to De Medeiros & Mayor (1996).

Table 1. Physical parameters for the programme stars

HD	Sp. Type	B-V	*Vsini*		LognLi	Status
400	F8IV	0.48	5.6		2.27[a]	S
2151	G2IV	0.62	6.0		2.5[b]	S
3229	F5IV	0.44	5.0	$<$	1.97[a]	S
4813	F7IV-V	0.50	3.9		2.11[c]	SB
9562	G2IV	0.64	4.2		2.5[b]	S
11443	F6IV	0.49	90:	$<$	1.50[a]	SB
13421	G0IV	0.56	9.9		2.08[a]	S
14643	G1IV	0.85	40.0		1.35[d]	SB
15524	F6IV	0.41	70:		3.25[a]	S
15798	F4IV	0.45	7.2		3.04[a]	SB
16399	F6IV	0.44	16.5		3.10[a]	SB
18262	F7IV	0.48	9.9		2.10[a]	S
22468	K1IV	0.98	14.8		1.3[e]	SB2
23249	K0IV	0.92	1.0		0.9[b]	S
25621	F6IV	0.50	15.3		3.01[a]	S
26337	G5IV	0.67	39.5		1.8[d]	SB2
26913	G5IV	0.70	3.9		1.91[c]	SB
26923	G0IV	0.59	4.3		2.55[c]	S
27536	G8IV	0.91	1.0		1.05[d]	S
31738	G5IV	0.71	21.7		1.15[d]	SB2
34411	G2IV-V	0.63	1.9	$<$	1.57[c]	SB
43386	F5IV-V	0.42	18.8	$<$	2.30[c]	S
60532	F6IV	0.51	8.1	$<$	1.34[a]	S
61421	F5IV-V	0.42	6.1	$<$	1.95[c]	SB
65626	F9IV+G5IV	0.57	12.9		3.1[e]	SB2
71071	K1IV	0.95	2.3		0.95[d]	SB
73752	G6IV	0.73	4.4		1.20[c]	SB
78154	F6IV	0.49	5.8	$<$	2.00[c]	S
82328	F6IV	0.46	8.3		3.33[a]	SB
84117	F9IV	0.53	5.6		2.5[b]	S
89449	F6IV	0.45	17.3	$<$	1.67[c]	S
99028	F4IV	0.41	16.0		3.25[a]	S
114642	F6IV	0.46	13.3		3.15[a]	S
118216	K1IV	0.88	12.0		1.5[e]	SB2
120136	F6IV	0.48	15.5		2.35[c]	SB
121370	G0IV	0.58	13.0	$<$	1.81[a]	SB
123999	F9IVw	0.54	12.7		2.65[a]	SB2
127535	K1IV-V	1.07	10.0		1.15[d]	SB
127986	F8IVw	0.51	5.7	$<$	1.30[a]	S
130945	F7IVw	0.48	18.7		2.30[a]	S
133484	F6IV	0.46	21.2		3.01[a]	S

(continuing)

We have combined our rotational velocity measurements with Lithium abundances available in the literature to analyse the link between rotation and Lithium contents. We have found Lithium abundances for a sample of 65 subgiant stars from which 34 are spectroscopic binaries: 12 stars were taken from Randich et al. (1993, 1994), 35 stars from Balachandran (1990), 7 stars from Pallavicini et al. (1987) and 6 stars from Duncan (1981). Because the Lithium abundances have been taken from different authors, we have compared the abundance values for those stars in common in the given sources. For four stars observed respectively by Randich et al. (1993) and Randich (1994)

Table 1.(continued)

HD	Sp. Type	B-V	*Vsini*		LognLi	Status
136064	F9IV	0.53	5.0		1.87^a	S
137052	F5IV	0.44	10.2		3.06^a	SB
144284	F8IV	0.52	28.0	<	1.86^a	SB
150680	G0IV	0.65	4.8		1.40^c	SB
151769	F7IV	0.47	11.3	<	1.55^a	SB
155078	F5IV	0.52	52.5		2.55^a	SB
156846	G3IV	0.58	4.8	<	1.41^a	S
157482	G5IV+F	0.67	3.3		1.6^e	SB2
163930	K0IV	0.79	30.8		0.6^e	SB2
176095	F5IV	0.46	13.2		2.93^a	S
181096	F6IV	0.44	6.6	<	1.65^a	S
184663	F6IV	0.41	69:	<	1.90^a	S
186185	F5IV	0.46	15.6		2.64^a	SB
196885	F8IV	0.55	7.8		2.76^a	SB
206901	F5IV	0.43	24.5		3.05^a	SB2
207978	F6IV-Vvw	0.42	7.2	<	1.83^a	S
212487	F5IV	0.49	8.8		2.20^a	S
216385	F7IV	0.48	5.9	<	0.82^a	S
216437	G2-3IV	0.66	6.0		1.8^b	S
218804	F5IV	0.44	17.8	<	1.68^a	SB
219113	K1IV	0.82	70:		1.6^e	SB2
219834	G5IV	0.80	3.2		1.7^b	SB
224085	K2-3 V-IV	1.01	21.0		1.1^e	SB
224617	F4IV	0.42	49.9		3.20^a	S

Sources: a – Balachandran (1990); b – Pallavicini et al. (1987); c – Duncan (1981); d – Randich et al. (1993); e – Randich et al. (1994)

Table 2. Orbital parameters for subgiant binary systems

HD	P.orb(days)	eccentricity	Notes
11443	1.767	0.07	a
14643	18.379	0.06	b
22468	2.837	0.00	b
26337	1.947	0.00	b
65626	11.068	0.11	b
71071	16.537	0.13	b
99028	*	0.54	a
118216	2.613	0.00	b
121370	494.173	0.26	a
123999	9.604	0.19	a
127535	5.998	0.00	b
137052	226.95	0.68	a
144284	3.070	0.01	a
150680	*	0.45	a
157482	2018	0.68	b
163930	3.992	0.00	b
219113	3.965	0.00	b
219834	2323.6	0.08	a
224085	6.724	0.00	b

Sources: a – Batten et al. (1989); b – Strassmeier et al. (1993);

we find an excellent agreement with a mean of the difference of about 0.01 dex; for six stars with Lithium abundances from Pallavicini et al. (1987) and from Duncan (1981) the mean of the difference in the Lithium abundance is 0.27 dex, whereas for ten stars observed respectively by Balachandran (1990) and Duncan (1981) the mean of the difference is 0.20 dex, in the sense that both measurements from Pallavicini et al. (1987) and Balachandran (1990) are larger than the measurements from Duncan (1981). Despite the discrepancies between the measurements from Duncan (1981) and those given by Pallavicini et al. (1987) and Balachandran (1990), the comparison indicates, indirectly, a good agreement between the Lithium abundance values obtained respectively by Pallavicini et al. (1987) and Balachandran (1990). Further, the detailed error analysis made by Balachandran (1990) and Randich et al. (1993, 1994) indicates that their measurements have the same high quality. Let us recall that for the observations of Pallavicini et al. (1987), Balachandran (1990) and Randich et al. (1993, 1994) the signal-to-noise ratio was in most cases greater than 100.

Table 1 gives the measured rotational velocities as well as the Lithium abundances for the final list of 65 stars. Table 2 lists the orbital period and eccentricity available in the literature for 21 binary systems of the sample. The orbital period for the visual binary system HD 99028 and HD 150680 are respectively 192 yr and 34.487 yr.

3. Results and discussion

We present the measured rotational velocities *Vsini* in Table 1. These rotation rates are plotted in Fig. 1 as a function of the color index (B-V). In spite of the limited sample studied here, this figure shows clearly the sudden decline in rotation near (B-V) = 0.55, which corresponds to the spectral type F8IV. Such rotational discontinuity is particularly very well defined for the single subgiants and for those binary subgiants with orbital period greater than about 20 days, typically binary systems with orbital eccentricity greater than about 0.10. In fact, except for HD 71071, all the binary systems with orbital period lower than 20 days and circular orbit located to the right of the rotational discontinuity present enhanced rotational velocities which are very likely to result from the synchronization between the axial rotation and orbital revolution. The orbital parameters for the double-lined system HD 31738 are not yet determined, but from 19 radial velocity measurements obtained with the CORAVEL spectrometer we found a velocity range of about 50 km.s^{-1} indicating a short orbital period for such star. To the left of the rotational discontinuity, one sees a wide range of *Vsini* values, which reflects the broad distribution of rotation rates for the progenitors of the subgiant stars. Unfortunately, the number of stars to the right of the discontinuity presented in Fig. 1 is very limited, but as shown by De Medeiros (1990) in this side of the discontinuity the rotation for the single subgiants decreases

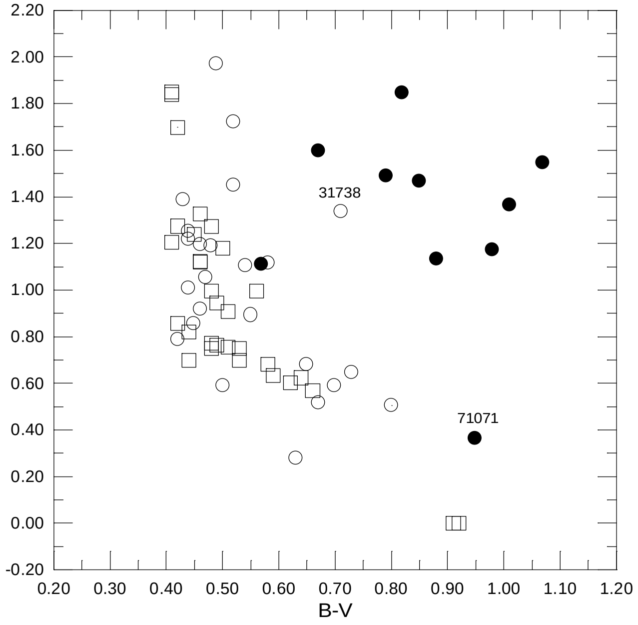

Fig. 1. Rotational velocity as a function of (B-V) color index for all of the programme stars. Single stars are identified by squares and binaries by circles, which are filled for the systems with circularized orbit

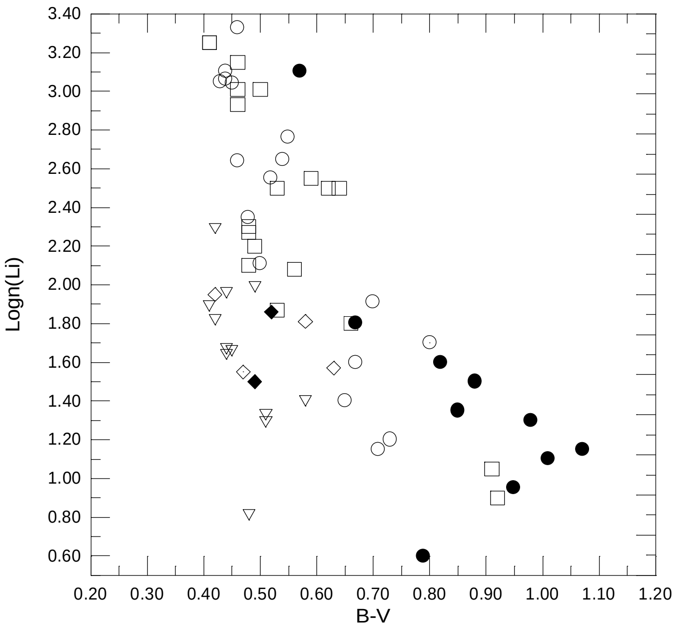

Fig. 2. Lithium abundance as a function of (B-V) color index for the programme stars. Squares and triangles represent respectively measured and upper limit Li abundances for single stars; circles and diamonds represent respectively measured and upper limit Li abundances for binaries, which are filled for systems with circularized orbit

smoothly from the G to the K spectral region, with a mean rotational velocity of about 6.0 km.s^{-1} near the spectral type G0IV and a mean rotation velocity of about 1.0 km.s^{-1} near the spectral type K0IV. Fig. 2 presents Lithium abundance as a function of the color index (B-V) for all the stars listed in Table 1. This figure shows the familiar decrease of Lithium abundance with increasing (B-V), but rather than a gradual decrease it seems to exist a drop in the distribution of the Lithium abundance as a function of colors near (B-V) = 0.55, corresponding to the spectral type F8IV or to the effective temperature of 6000K. A careful comparison between Figs. 1 and 2 indicates that the location of the sudden decline in rotation almost coincides nearly with the drop in Lithium abundance. Based on this result, one might ask whether these two properties, the rotation discontinuity and the drop in Lithium abundance, have the same root cause. A strong argument may be in favor of this hypothesis if a correlation could be found between rotational velocity and Lithium abundance.

In Fig. 3, we plot Lithium abundance versus rotational velocity for the stars listed in Table 1, which are separated in three intervals of color (B-V) $<$ 0.55, 0.55 $<$ (B-V) $<$ 0.75 and (B-V) $>$ 0.75. We have carried out least-squares regression analysis for the stars presented in Fig. 3. A log-linear least-squares fit for Logn(Li) versus Log*Vsini* was derived first for the sample of single stars and then for the binary stars. In our calculations for the single stars we have included only those presenting at least two CORAVEL radial velocity measurements, that is, we have ignored HD 184663 which has just one radial velocity measurement, not enough to define its single or binary status. From the sample of single stars given in Table 1, except for HD 184663, we have found a linear correlation coefficient of about 0.70 and a standard deviation of 0.52. Thus, the Lithium abundance is almost linearly proportional to the rotation rate. For the entire sample of binary stars our least-squares solution yields a linear correlation coefficient of 0.01 and standard deviation of 0.74. Our calculations give also very poor linear correlation coefficient and standard deviation if we take into account just the binary stars with orbital period lower than about 20 days and eccentricity lower than about 0.10. We regard the slopes of the relations resulting from these calculations, except for single stars, as indistinguishable from zero and conclude that, at least for the present sample, Lithium abundance is independent of rotation rate in binary subgiant stars. Similar least-squares fits were obtained for each color interval given in Fig. 3, and an equally poor correlation was found for the color intervals (B-V) $<$ 0.55, 0.55 $<$ (B-V) $<$ 0.75 and (B-V) $>$ 0.75. Additional evidence of no correlation between Lithium abundance and projected rotational velocity *Vsini* in binary subgiants was provided by Randich et al. (1994), particularly for active subgiant stars.

Concerning the good coincidence between the location of the rotational discontinuity and the drop in Lithium abundance near the spectral type F8IV, it is important to emphasize here that a magnetic braking seems to play a relevant role as the root cause of the rotational discontinuity in subgiant stars (Gray & Nagar 1985; Rutten & Pylyser 1988; De Medeiros & Mayor 1989, 1990). Could we conclude that Lithium depletion in single subgiant stars is also affected by magnetic braking?

Another interesting trend emerges from Fig. 2. Despite the limited number of stars with (B-V) $>$ 0.55, it seems that synchronized binary subgiants located to the right of the rotational discontinuity have a tendency to retain more of their original

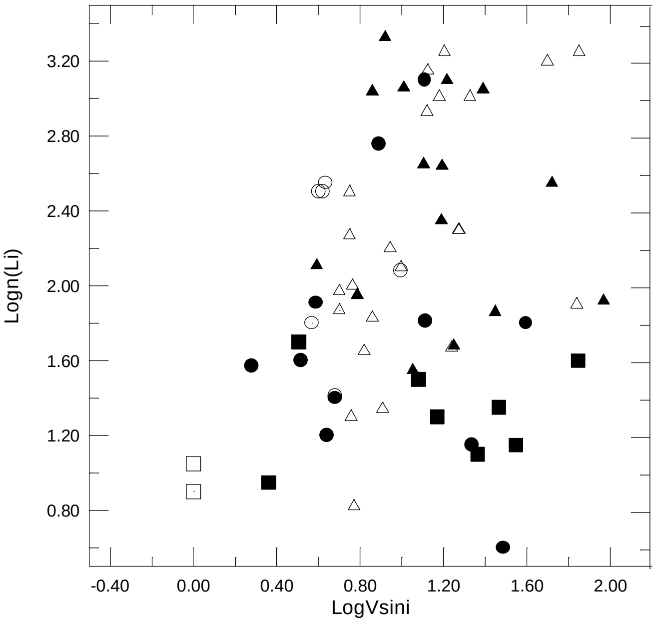

Fig. 3. Lithium abundance versus rotational velocity for all of the programme stars. Triangles denote stars with (B-V)<0.55, circles denote stars with 0.55≤(B-V)<0.75 and squares those with (B-V)≥0.75. Single stars are identified by open symbols and binaries by filled symbols

Lithium than both their single counterparts, and the non synchronized binary subgiants. Zahn (1994) has shown that late-type binaries of short enough orbital period, typically orbital periods below 8 days for solar-type stars of population I, and 6 days for halo stars, retain more of their original Lithium than their single counterparts. Spite et al. (1994) have found the same trend in a sample of old disk and halo stars. The results of the present work indicate that the same behavior could be present in K-type binary subgiant stars.

3.1. The rotational discontinuity and the drop in Lithium abundance

Because the magnetic braking, associated to the origin of the rotational discontinuity, is expected to operate when the convection zone becomes deep, while Lithium dilution also depends on the growth of the convection zone, a relationship between the two would, in principle, be expected. Nevertheless, one should first inquire if the drop in the abundance of Lithium shown in Fig. 2 is real. Firstly, we must be cautious with the size of the sample and the nature of the Lithium abundances analyzed here. In this sense, Lebre et al. (1995) have claimed a drop in the distribution of the equivalent width of the Lithium line 6707.81 Å near the spectral type F8IV, on the basis of a larger sample of subgiant stars than the one used in the present work. Single subgiant stars located to the right of this spectral type show no important Lithium line feature. Concerning the sources of the Lithium abundances presented in Table 1, as we have pointed out in Sect. 2, the detailed error analysis effectuated by Balachandran (1990), Pallavicini et al. (1987) and Randich et al. (1993, 1994) shows that their data have the same high quality, particularly with a same interval of values for the signal-to-noise ratio. The Lithium abundances from these authors are the most relevant in the definition of the drop in Lithium shown in Fig. 2. These two points appear to indicate that the drop in Lithium is not a result of selection effects.

An important aspect of the sample studied here concerns its evolutionary stage. Balachandran (1990) has shown that F stars, slightly evolved off the main sequence, present a large scatter in Lithium abundances, indicating that the Lithium depletion is not related to age, *Vsini* or spectral types alone. This author has identified two groups of F slightly evolved stars, a first one with Lithium abundances between 2.0 and 3.5, and a second one presenting upper limits with abundances lower than 2.0 presumably presenting Lithium depletion. Following the analysis of Balachandran (1990), the first group is composed by stars with masses between 1.1 $M_{\odot}$ and 1.85 $M_{\odot}$, whereas the second group appears to be concentrated between 1.1 $M_{\odot}$ and 1.5 $M_{\odot}$. From the 35 stars of Balachandran (1990) listed in Table 1 of the present paper, 22 stars belong to the first group defined above and 13 stars, those with upper limits, belong to the second group. So, one can conclude that in the spectral region of the drop in Lithium abundance stars have probably masses between 1.1 $M_{\odot}$ and 1.85 $M_{\odot}$. If we consider that the subgiant branch represents an evolutionary sequence, then we expect the stars on the right side of the drop in Lithium to have evolved from the same population as the stars on the left side of the drop. Unfortunately, the number of stars on the right side of the drop in Lithium is very limited and, consequently, a study to determine the kinematic-age relation between stars on both side, of the drop is not possible here. Nevertheless, a kinematic-age analysis by De Medeiros (1990) for subgiants F, G and K of population I, based on the dispersion of the radial velocity, shows no significant increase of the velocity dispersion from the left side through the right side of the rotational discontinuity. This fact indicates that cool G and K subgiants arose from the same population in mass as the hotter F subgiants.

It is interesting to point out that a study of the Lithium behavior in halo subgiants by Pilachowski et al. (1993) shows no drop in the distribution of the Lithium abundances with the effective temperature or spectral type. These authors have shown that the spread in Lithium abundance for such stars near Teff = 6500 K, which corresponds to the spectral type F8IV, is small and that the mean value is near logn(Li) = 2.1. Note that unlike the population I subgiants studied in the present paper, which seems to have masses between 1.1 $M_{\odot}$ and 1.85 $M_{\odot}$, the halo subgiants evolve from a restricted range of mass on the main sequence. The masses of the halo subgiants are substantially lower than those of the population I subgiant stars. Further, it is important to underline that differently of the population I subgiants there is no sign of rotational discontinuity for halo subgiant stars. This difference may result from the fact that the precursors of the population I subgiants present a spread in rotational velocity from a few km.s^{-1} to about 150 km.s^{-1}, whereas the halo subgiants seem to have had slowly rotating precursors. According to Pinsonneaut et al. (1989), the strength of the Lithium depletion in late F-type stars will depend upon the magnitude of the change in the rotational velocity. On the basis of this scenario, the sudden decrease in the rotation of the subgiants presented in Fig. 1 should correspond to a similar decrease in the abundance of Lithium for this class of stars. This fact indicates that the rotational discontinuity and the drop in the abundance of Lithium for population I subgiants, both observed near the spectral type F8IV, seem to be controlled by the same root cause.

4. Conclusions

Precise rotational velocities have been determined for 66 subgiant stars by using the CORAVEL spectrometer. From these data, one sees clearly the rotational discontinuity at nearly (B-V) = 0.55, which corresponds to the spectral type F8IV. To the right of this discontinuity, only synchronized binary systems, typically those with orbital period lower than about 20 days and eccentricity lower than about 0.10, show enhanced rotation. These measurements of rotational velocity offer strong support to a detailed analysis of the link between rotation and Lithium abundance in subgiant stars. Based on this sample, we have found a clear dependence of Lithium abundance upon rotation for single subgiants. For the binary systems we have found that Lithium abundance is independent of rotational velocity. There is a very good coincidence between the location of the rotational discontinuity and the drop in Lithium abundance. By considering that magnetic braking plays a relevant role as the root cause of the rotational discontinuity, this fact might indicate that Lithium abundance is also affected by magnetic braking. Binary systems with orbital period lower than 20 days and circularized orbit, located to the right of the drop in Lithium, seem to retain more of their original Lithium than the binary systems with orbital period greater than about 20 days and non circularized orbit, and also more than their single subgiant counterparts.

Acknowledgements. This work has been supported by continuous grants from the Swiss National Science foundation. J.R.M. and J.D.N.Jr. acknowledge partial financial support from the CNPq Brazilian Agency. We are also grateful to the referee M.H. Pinsonneault for many constructive remarks and suggestions that helped us to improve the original manuscript.

References

Balachandran S., 1990, ApJ **354**, 310
Baranne A., Mayor M., Poncet J.L., 1979, Vistas in Astron. **23**, 279
Batten A.H., Fletcher J.M., MacCarthy D.G., 1989, Publ. Dom. Astrophys. Obs. vol. **17**, 1
Boothroyd A.I., Sackmann I,-J., Fowler W.A., 1991, ApJ **377**, 318
Charbonnel C., Vauclair S., 1992, A&A **265**, 55
D'Antona F., Mazzitelli I., 1984, A&A **138**, 431
De Medeiros J.R., 1990, Ph.D. Thesis, Geneva Observatory
De Medeiros J.R., Mayor M., 1989,"Sixth Cambridge workshop on cool stars, stellar systems and the sun", Astron. Soc. of the Pacific Conf. Series, Vol.9, pp 404 (ed. G. Wallerstein)
De Medeiros J.R., Mayor M., 1996 "A catalogue of rotational and radial velocities for evolved stars", A&A submitted
Duncan D.K., 1981, ApJ **248**, 651
Gray D., Nagar P., 1985, ApJ **298**, 756
Herbig G.H., 1965, ApJ **141**, 588
Hobbs L. M., Iben I., Pilachowski C., 1989, ApJ **347**, 817
Hoffleit D., Jaschek C., 1982, The Bright Star Catalogue,(4^{th} ed. Yale University Observatory, New Haven)
Iben I. Jr., 1967a, ApJ **147**, 624
Iben I. Jr., 1967b, ApJ **147**, 650
Lebre A., Charbonnel C., De Medeiros J.R., 1995, "9^{th} Cambridge Workshop on Cool Stars, Stellar Systems and The Sun", Florence, Italy
Michaud G., 1986, ApJ **302**, 650
Pallavicini R., Cerruti-Sola M., Duncan D.K., 1987, A&A **174**, 116
Pallavicini R., Randich S., Giampapa M.,1992, A&A **253**, 185
Pallavicini R., Cutispoto G., Randich S., Gratton R., 1993, A&A **267**, 145
Pilachowski C.A., Sneden C., Booth J., 1993, ApJ **407**, 699
Pinsonneault M.H., Kawaler S.D., Sofia S., Demarque P., 1989, ApJ **338**, 424
Pinsonneault M.H., Kawaler S.D., Demarque P., 1990, ApJS **74**, 501
Randich S., Gratton R., Pallavicini R., 1993, A&A **273**, 194
Randich S., Giampapa M.S., Pallavicini R., 1994, A&A **283**, 893
Rutten R.G.M., Pylyser E., 1988, A&A **191**, 227
Skumanich A., 1972, ApJ **171**, 565
Soderblom D.R., 1983, ApJS **53**, 1
Spite F., Spite M., 1982, A&A **115**, 357
Spite M., Pasquini L., Spite F., 1994, A&A **290**, 217
Strassmeier K.G., Hall D.S., Zeilik M., Nelson E., Eker Z., Fekel F.C., 1988, A&AS **72**, 291
Strassmeier K.G., Hall D.S., Fekel F.C., Scheck M., 1993, A&AS **100**, 173
Zahn J.P., 1992, A&A **265**, 115
Zahn J.P., 1994, A&A **288**, 829

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.