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Lithium abundance and activity in a sample of RS Canum Venaticorum and BY Draconis stars

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Abstract. Observations of the Li I doublet at 6707.8 Å for a sample of active binary systems RS CVn and BY Dra have been carried out at the Calar Alto Observatory with the 2.2 m telescope. In addition, some single stars with different chromospheric activity levels have also been observed mainly for comparison purposes.

Gaussian fits have been performed in order to separate the Fe I line at 6707.4 Å which is usually blended with the Li I doublet. Once the fit was achieved, the equivalent width was measured for each separated line.

The contributions due to the continuum from both components have been taken into account to correct the equivalent width measurements. A curve-of-growth method has been used to derive lithium abundances. We have obtained a Li excess in the binary systems, in particular the K type stars.

A correlation of the Li abundance with the activity levels is confirmed, as it was found by other authors, but RS CVn and BY Dra systems are 0.5 dex more active than single stars for the same Li abundance.

Key words: stars: abundances – stars: activity – stars: binaries: close – stars: chromospheres

1. Introduction

Lithium is a light element characterized by its easy destruction by (p,α) nuclear reactions in the stellar interiors. The observations of galactic open clusters reveal that the photospheric Li abundance in late-type stars is strongly related to spectral type and age. In particular, different authors have proposed empirical expressions for the Li abundance as a function of the age (Rebolo 1989; Boesgaard 1991). Several investigations of the well-studied Hyades cluster indicate that the Li abundance in G-type cluster stars is higher than in cooler stars of this cluster (Duncan 1981; Cayrel et al. 1984; Boesgaard & Tripicco 1986b; Rebolo & Beckman 1988; Soderblom 1990; Boesgaard 1991). The same characteristics have been found in other clusters (NGC 752, Coma open cluster, The Ursa Majoris Group, Praesepe, Pleiades, NGC 188 and α Persei). Moreover, in clusters older than 10^8 years there is a narrow effective temperature range (6400-6900 K) which shows a large depletion of Li abundance, called the Li gap (Boesgaard & Tripicco 1986b; Michaud & Charbonneau 1991).

Different mechanisms, including turbulent mixing induced by rotation, have been proposed for explaining Li depletion. For example, Baglin et al. (1985) showed that the Li depletion in G stars can be very well reproduced assuming that meridional circulation is present. Charbonneau & Michaud (1990) also interpreted this low abundance of Li using diffusion turbulence, taking into consideration stellar evolution. More recently, Charbonnel et al. (1992) have taken into account the deceleration of the rotation and gravitational settling. Others have proposed mass loss over the main-sequence lifetime for G stars (Hobbs et al. 1989). Pinsonneault et al. (1989,1990) obtained rotating models, including mixing induced by transport of angular moment in the stellar interior. Finally, García-López & Spruit (1991) suggested that the Li depletion in F stars is driven by internal gravity waves.

None of the proposed mechanisms fully explains all the observed characteristics of the depletion phenomenon. Among the different problems without a solution we could mention the uncertainties in topics such as: Li abundance of protostellar clouds, the primordial Li abundance, the sensitivity of the Li depletion to the stellar metallicity, the characteristic time scales for the Li depletion as a function of mass (Soderblom 1991) and the galactic chemical evolution (Rebolo 1989). However, rotation might play a very important role in Li depletion.

Active binary systems like RS CVn and stars like BY Dra also show in their spectra the Li I doublet at 6707.81 Å (Spite et al. 1984; Randich & Pallavicini 1991). RS CVn systems have high chromospheric, transition region and coronal activity levels and their orbital periods are normally synchronized with the rotational periods. The components of BY Dra binaries are main sequence stars, which have strong Ca II H and K emission lines,

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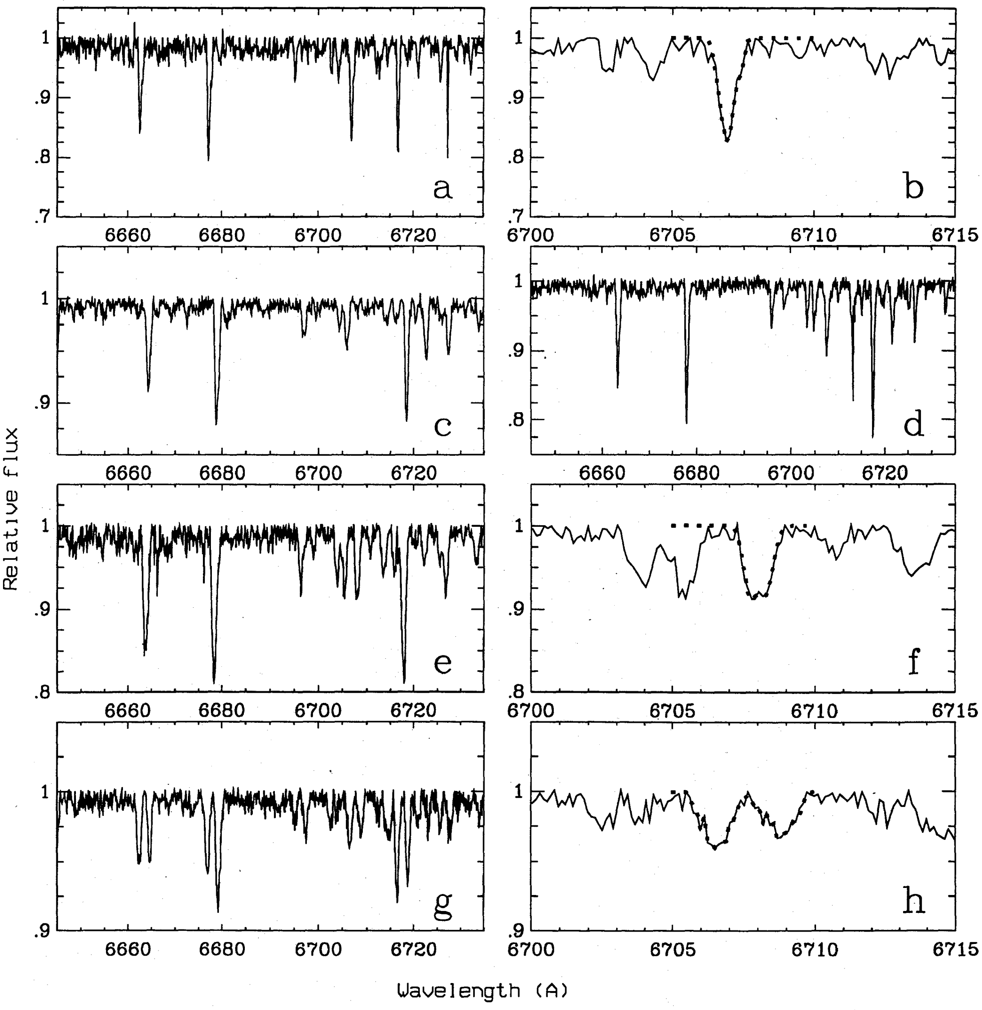

Fig. 1 a-h. Different kind of normalized spectra: **a** spectrum of HR 8314, where the strong Li I doublet can be clearly seen. **b** same spectrum around the Li I doublet at 6707.81 Å and, overplotted, the fit to the whole feature at 6707 Å. **c** Spectrum of ι Vir, no spectral feature can be identify with the Li doublet at 6707.81 Å. **d** Spectrum of σ^1 CrB. **e** V478 Lyr, a RS CVn binary system of G8 V spectral type. Despite its high projected rotational velocity (v sini=21 Kms^{-1}) it is possible to discriminate the Li I and Fe I lines (**f**). **g** SB2 spectrum of the system σ^2 CrB. and the detail around the Li I and Fe I features and the fit (**h**)

whereas the RS CVn systems have at least a cool evolved component (Fekel et al. 1986). The presence of the Li I doublet in these stars is difficult to explain with the above mentioned theories which predict a large depletion in stars with deep convective zones.

In this paper, we present new observations of the Li I 6707.81 Å doublet for a sample of RS CVn and BY Dra binaries and also for some single active stars. Our aim is to investigate the relationship between Li abundance and chromospheric activity. The results provide additional data to improve the understanding of the mechanisms involved in the Li depletion phenomenon.

2. Observations and reduction

The observations were carried out in 1990 June 1-7 at the Coudé focus of the 2.2 m telescope at the Calar Alto Observatory using the RCA CCD detector. The resolution of the spectra is 0.12 Å per pixel which gives an effective resolution $\lambda/\Delta\lambda \sim 30000$ at the central wavelength of 6700 Å. The total spectral range spans is $\sim$ 100 Å, and the typical signal-to-noise ratios are $\sim$ 100. The exposure times ranged from a few minutes for the brighter stars to an hour for the fainter ones.

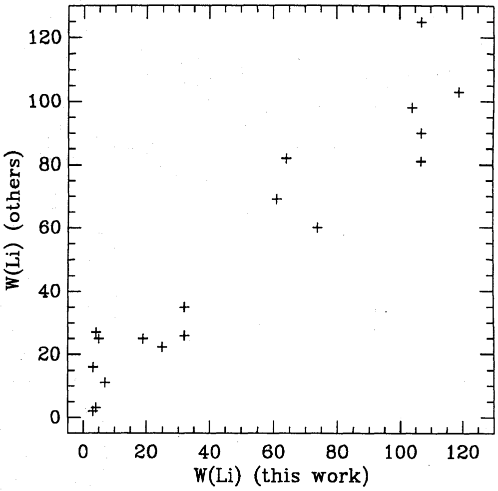

Fig. 2. Comparison of our measurement of the Li equivalent width obtained with gaussian fit and those measurements obtained by other authors for the same stars (Duncan 1981; Anderson et al. 1984; Boesgaard & Tripicco 1987; Balanchandran 1990)

Table 1. Relevant stellar parameters. Sources: 1.- Bright Star Catalogue, 2.- Gimenez et al. (1991), 3.- Rutten (1987), 4.- Strassmeier et al. (1990), 5.- Noyes et al. (1984), 6.- Simon et al. (1989), 7.- Strassmeier et al. (1988), 8.- Duncan (1981), 9.- Montesinos (1986), 10.- Reglero et al. (1991), 11.- Boesgaard et al. (1987), 12.- Soderblom (1990), 13.- Popper (1980)

Name	HD	Sp. Type	V	$B-V$	$P_{\rm rot}$ (days)	$v \sin i$ ($Km\,s^{-1}$)	Duplicity	source
HD 107067	HD 107067	F8 V	8.73	0.525		≦12	S?	11,12
HD 108102	HD 108102	F8 V/F8 V	8.16	0.518	0.82	35/35	SB2	4,7
RS CVn	HD 114519	F5 IV/K0 IV	8.59/9.16	0.42/0.91	4.79		SB2	2,4,13
β Com	HD 114710	G0 V	4.26	0.57	12.4	6	S	1,3,4,5
59 Vir	HD 115383	G0 V	5.22	0.59	4.9^V	7	S	1,5
HD 115404	HD 115404	K3 V		0.93	18.8		S	3,5
HR 5110	HD 118216	F2 IV/K2 IV	4.98	0.34/1.36		≃10/	SB2	1,2,4,7
τ Boo	HD 120136	F6 IV	4.50	0.48	7^V	14	S	1,4,5
ι Vir	HD 124850	F6 IV-III	4.08	0.52	7.6	15	S	1,3,5,6
α Boo	HD 124897	K1 III	-0.04	1.23	353^V	≦17	S	1,3
HR 5384	HD 126053	G1 V	6.27	0.63	34.0^V	1	S	1,3,5
5 Ser	HD 136202	F8 III-IV	5.06	0.54	39^V	2	S	1,5
GX Lib	HD 136905	[G-K V]/K1 III	7.31	1.02	11.13	/32	SB1	4,7
λ Ser	HD 141004	G0 V	4.43	0.60	18.0	≦6	S	1,5
χ Her	HD 142373	F8 VFe	4.62	0.56	17^V	0	S	1,3,6
ρ CrB	HD 143761	G2 V	5.41	0.60	21^V	7	S	1,3
σ^2 CrB	HD 146361	F6 V/G0 V	5.64	0.47	1.14	25/26	SB2	1,4,7
σ^1 CrB	HD 146362	G1 V	6.66			≦30	S	1
WW Dra	HD 150708	G2 IV/K0 IV	8.22	0.60/0.97	4.63		SB2	2,4,7,9,13
V792 Her	HD 155638	F3 V/K0 III	8.50	0.45/1.07	27.07	6/21	SB2	2,4,7
HR 6469	HD 157482	F2 V/[G0V]?:G5 IV	5.51	0.68	83.2	22/ :6	SB1	1,4,7
26 Dra	HD 160269	G0 Va	5.23	0.61		[10-41]	S	1,8
84 Her	HD 161239	G2 IIIb	5.71	0.65	28.5^C	≦10	S	1,5,9
Z Her	HD 163930	F4 V-IV/K0 IV	7.3	0.47/0.91	3.962		SB2	2,4,7,13
V772 Her	HD 165590	G1 V/[M1 V]:G5 V	7.07	0.59/	0.87/	75/ :18	SB1	4,7,10
V815 Her	HD 166181	G5 V/[M1-2 V]	7.66	0.72	1.8	27/	SB1	4,7
α Lyr	HD 172167	A0 Va	0.03	0.00		15	S	1
HR 7162	HD 176051	F9 V	5.22	0.59	17.5^C	4	S	1,2
V478 Lyr	HD 178450	G8 V/[dK-dM]	7.72	0.74	2.185	21/	SB1	4,7
17 Cyg	HD 187013	F7 V	4.99	0.47	6.4^V	9	S	1,3,5,8
ER Vul	HD 200391	G0 V/G5 V	7.27	0.68		85/85	SB2	4,7
HR 8314	HD 206860	G0 V	5.94	0.59	4.70	11	S	1,5
BY Dra	HD 234677	K4 V/K7.5 V	8.07	1.221	3.82	8.0/7.4	SB2	4,7

Some rotational periods have been obtained from $v \sin i$ -*V*- or from the chromospheric activity -*C*-

Each CCD exposure was reduced separately using standard procedures (with bias subtraction and flat-field correction from a continuous source) and the MIDAS package. The wavelength scale was obtained by taking spectra of a Th-Ar lamp, with an associated error less than 0.05 Å.

The sample includes 14 systems with chromospheric activity of the type RS CVn and BY Dra, from which there are 23 available spectra of spectral type F, G and K, and luminosity classes V, IV and III, and 19 single stars with different chromospheric activity levels. Most of the single stars have been selected from the work by Noyes et al. (1984). The relevant stellar parameters are given in Table 1. The chromospherically active binaries have been selected from the catalogue by Strassmeier et al. (1988).

The Li I unresolved doublet at 6707.81 Å is very close to the Fe I line at 6707.41 Å. Since most of the stars in our sample are fast rotators, the Li I doublet is blended with the Fe I line due to rotational broadening. In order to obtain the Li I equivalent width, the contribution from the Fe I line was subtracted using an interactive routine, based on Gaussian fits to the line profiles, where the shifts of the line centres due to radial velocity were calculated in order to obtain the best possible fits. In this way, we were able to separate the Li and the Fe lines in most of the stars of our sample. If the FWHM criterion is used, it is possible to separate, at least, stars which rotate with v sini ≦ 22 Kms^{-1}. We have checked this assumption using 2 different lines (Fe I 6680 Å and Ca I 6717 Å).

For single stars, only two gaussian functions were required to fit the Li I and Fe I lines. As an example we show in Fig. 1a the normalized spectrum of HR 8314 where it is possible to see a very strong Li I doublet. This is an active single star, classified as G0 V in the Bright Star Catalogue (Hoffleit & Jaschek 1982).

The v sini value is relatively large (11 kms^{-1}), being close to the v sini value for other stars in the Hyades of the same spectral type. Figure 1b shows the same spectrum around the Li I doublet at 6707.81 Å (solid line) and the fit to the whole feature at 6707 Å (dotted line). There are also stars where the Li doublet is absent. As an example, the spectrum of ι Vir is plotted in Fig. 1c, where, within errors, no spectral feature can be identified with the Li doublet at 6707.81 Å, even so, an upper limit to the equivalent width was obtained. The spectral type of this star is F7 IV and the projected rotational velocity is also large (v sini=15 Kms^{-1}). We have also obtained the spectrum of σ^1 CrB (Fig. 1d), whose spectral type is G1 V.

Another kind of spectra are those corresponding to SB1 systems. In these cases, it is straightforward to fit gaussian functions to the line profiles and the whole process is very similar to the one carry out on single stars. Figure 1e shows the spectrum of V478 Lyr, a BY Dra binary system with spectral type G8 V. Despite its large projected rotational velocity (v sini=21 kms^{-1}) it is possible to separate the Li I and Fe I lines (Fig. 1f).

The fitting of the 6707 Å feature in the spectra of SB2 binaries is a difficult task. Nevertheless, it is possible to discriminate lines arising from both components of the binary system in these spectra. An example is shown in Fig. 1g, which corresponds to σ^2 CrB. This system is composed of two stars of spectral type F6 V and G0 V. The double Fe I lines at 6664.4 Å and 6678.0 Å, the double Li I and Fe I blended lines at 6707 Å and the double Ca I line at 6717.7 Å are clearly seen. We show the spectrum around the Li I and Fe I features and the fit in Fig. 1h. The SB2 spectra present two additional complications: at orbital phases where the relative velocity between the components reaches a maximum, the Li I doublets from each component might be well separated, but in this case they might also be blended with other near line (e.g. Fe I 6705.1 Å) arising from the other component. At orbital phases where the relative velocity is zero, the Li I and the Fe I lines from each component are blended altogether. The latter situation was the most complicated to deal with.

Once the best fit was achieved, the equivalent width was measured for each separated line. In order to check the consistency of the fitting procedure, we compared equivalent width for the Fe I line with measurements in other stars of the same spectral type (e.g. Hyades stars). Furthermore, it was assumed that the equivalent width of the whole Li feature contains no significant contribution from ^{6}Li. In fact, this is not an important source of error since the ratio $^6\mathrm{Li}/^7\mathrm{Li}$ is always less than 0.1 (Anderson et al. 1984). This procedure allowed us to measure equivalent widths of a few mÅ with uncertainties of the same order. Following the work by Boesgaard & Tripicco (1986b), the measured equivalent widths of SB2 spectra were corrected for the contributions from both components to the continuum.

When gaussian fits were not feasible, we measured the total equivalent width and estimated the contribution from the blends from measurements on spectra of stars with similar spectral type and luminosity class.

In Fig. 2 we compare our measurement of the Li equivalent widths with those obtained by other authors for the same stars (Duncan 1981; Anderson et al. 1984; Boesgaard & Tripicco 1987; Balanchandran 1990). The agreement between the values is good, but for small equivalent widths there are differences between the sample of Duncan and our results. The reason for these discrepancies is mainly that the equivalent widths from Duncan sample include the Fe I contribution to the whole feature. This contribution is usually less than 15 mÅ.

The equivalent width of the Li doublets was converted into abundances using the curves of growth computed by Pallavicini et al. (1987), which were based on the atmospheric models of Bell & Gustafsson (Gustafsson et al. 1975; Bell et al. 1976). These curves span the temperature range 4500–6500 K, with gravities $3.75 < \log g_* < 4.50$. The T_{eff} for the components of non-eclipsing binaries was assigned according to their spectral type, whereas the calibration of Böhm-Vitense (1981) was used for single stars. For the 3 stars which have an effective temperature out of the range, we have adopted the nearest one, in order to obtain the Li abundance. A common value of gravity, namely $\log g_* = 4.5$, was used for main sequence stars and $\log g_* = 3.75$ was used for giants and subgiants. In Table 2 we list the adopted effective temperatures, equivalent widths and abundances, together with the Ca II chromospheric fluxes. The accuracy of the derived Li abundances (on a scale where $\log N_{\mathrm{H}} = 12.00$) is $\sim$ 0.30 dex for the binary systems. The main source for this uncertainty is the error in the assumed effective temperatures, because small differences in T_{eff} affect not only the determination of the Li abundances, but also the correction of the contribution from both components to the continuum.

3. Results and discussion

We have got the result that some of the sample stars have higher abundances than the adopted value for the interstellar medium (ISM) which is close to $\log N_{\mathrm{Li}} = 3.1$ (Lemoine et al. 1992). Other authors have reached this same conclusion. Basri et al. (1991) found that some T Tauri stars earlier than late K show Li abundances larger than that for the ISM. Randich & Pallavicini (1991) and Pallavicini et al. (1992) have also observed chromospherically active stars that show overabundances.

In Fig. 3a we have plotted Li abundance versus effective temperature. RS CVn and BY Dra systems are represented by crosses ($\times$) and single stars by plus symbols (+). It can be seen that the Li abundance is larger in hot stars than in cooler ones, as expected. Similar plots for chromospherically active stars drawn by Randich & Pallavicini et al. (1991) and Pallavicini et al. (1992) show the same result. A comparison between the binary systems (RS CVn and BY Dra) and the single stars shows that binary systems have higher Li abundance than single stars at the same effective temperature, in particular for late G and K stars ($T_{\mathrm{eff}} \leqq 5500$K). It is well known that the Li abundance decreases with stellar age. However, an age effect cannot explain the Li excess in binary systems, since most of them are RS CVn with an evolved cool component. Nevertheless, Pallavicini et al. (1992) showed that an anomalously high Li abundance can be found in some presumably single chromospherically active giants.

Table 2. Adopted effetive temperature, Li and Fe equivalent widths, Li abundance and flux in Ca II H and K lines

Name	$T_{\rm eff}$ (K)	$W_\lambda(Li+Fe)^{(1)}$ (mÅ)	$W_\lambda(Fe)^{(2)}$ (mÅ)	$W_\lambda(Li)^{(3)}$ (mÅ)	Log N(Li)	F_{HK} ($10^6 \mathrm{erg\,cm^{-2}\,s^{-1}}$)
HD 107067	6205	121	10	104	3.26	
HD 108102 hot	6200	13	3	22	2.18	5.066
HD 108102 cool	6200	15	1	28	2.29	7.098
RS CVn hot	6700	35*	13	35	$\geqq$ 2.76	
RS CVn cool	5065	12	7	16	0.92	3.590
β Com	6024	78	4	74	2.71	1.288
59 Vir	5948	117	(10)	107	2.98	2.979
HD 115404	5015	15	8	9	0.61	
HR 5110 hot	6880	*	2	6	$\geqq$ 1.93	
HR 5110 cool	4670	*	6	136	1.87	3.614
τ Boo	6400	5 + 6	6	5	1.73	1.616
ι Vir	6226	3 + 5	5	$\leqq$ 3	1.31	1.748
α Boo	4600	27	13	7	-.07	0.145
HR 5384	5790	6	3	7	1.25	0.780
5 Ser	6142	7	5	4	1.34	0.682
GX Lib	4600	35	16	18	0.37	1.473
λ Ser	5910	26	4	19	1.80	0.672
χ Her	6062	68	(7)	61	2.62	0.646
ρ CrB	5910	15	14	4	1.1	0.608
σ^2 CrB hot	6360	38	(3)	64	3.01	9.854
σ^2 CrB cool	6030	48*	(2)	68	2.66	9.016
σ^1 CrB	5945	75	11	63	2.53	2.064
WW Dra hot	5910	43*	3	48	2.35	1.291
WW Dra cool	4915	21	6	38	1.21	3.865
V792 Her hot	6540	54*	1	87	3.43	
V792 Her cool	4672	92*	11	82	1.37	2.125
HR 6469	5460	35	14	19	1.43	
26 Dra	5870	68	4	64	2.49	
84 Her	5710	17	13	6	1.11	0.430
Z Her hot	6445	53*	(7)	61	3.06	
Z Her cool	5065	60	(22)	78	1.89	2.570
V772 Her	5590	94	22	72	2.37	1.295
V815 Her	5350	191	(13)	178	3.30	6.497
α Lyr	9480	35				
HR 7162	5948	57	1	46	2.35	1.023
V478 Lyr	5570	99	45	51	2.11	4.740
17 Cyg	6445	42	12	32	2.65	1.112
ER Vul hot	6030	$\leqq$4 + 2	$\leqq$2	$\leqq$ 7	$\leqq$ 1.46	4.183
ER Vul cool	5770	$\leqq$ 9	$\leqq$ 6	$\leqq$ 9	$\leqq$ 1.35	4.506
HR 8314	5948	127	4	119	3.08	2.830
BY Dra hot	4590	19	16	7	-0.10	0.907
BY Dra cool	4060	41*	(6)	8	$\leqq$ -.16	

[1] Measured equivalent widths

[2] Measured or assumed equivalent widths

[3] Equivalent width corrected by continuum

* Lines blended with others arising from the other component

( ) Assumed equivalent widths

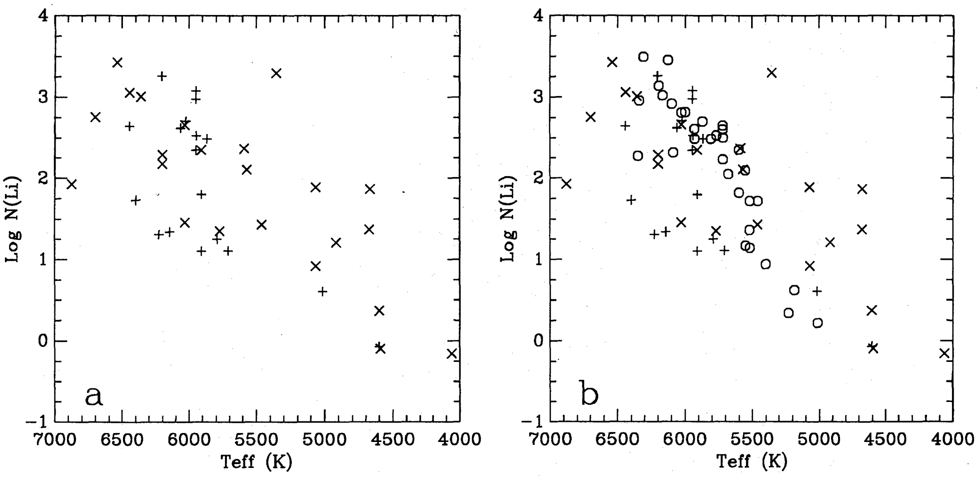

Fig. 3 a and b. log $N_{\rm Li}$ versus $T_{\rm eff}$: **a** the values for RS CVn and BY Dra systems are represented by the symbol (×) and the value for single stars by crosses (+), **b** the same plot as **a** and overplotted a Hyades sample (open circle symbols)

In Fig. 3b we show the same plot as 3a where we have added a Hyades sample (open circles). The data for the Li I equivalent widths of stars of the Hyades cluster were taken from different authors (Cayrel et al. 1984; Hobbs et al. 1988; Rebolo et al. 1988; Soderblom et al. 1990). We have used the same curves of growth to obtain the Li abundances for the Hyades sample obtaining larger abundances in hot stars (with $T_{\rm eff} \geqq 6000K$) than other authors. The same outcome described above can be seen: two Hyades stars (vB 88 and vB 121) have Li abundances higher than of the ISM. The comparison between the Hyades stars (young stars), single stars and binary systems (old stars in average) seems to confirm, again, that: a) there is an anomalous Li abundance in the binary systems and, probably, in some single chromospherically active stars and b) this effect is not related with the stellar age.

On the other hand, a group of late F and early G binaries (both components of ER Vul) and single stars have less Li abundance than the average. An age effect could explain the difference for the single stars. Concerning the binary systems we must note that stars with large depletion are dwarfs. If one compares their Li abundances with the higher abundances of evolved stars of similar masses which belong to a binary system (RS CVn binaries), one concludes that, in this case, the age is not the unique cause for the Li depletion.

The Li depletion phenomenon is, probably, related to rotation (turbulent mixing induced by rotation or/and mixing by angular momentum loss). In this sense the exceptionally high Li abundance of the RS CVn and BY Dra systems could be understood as a consequence of their low rotational periods, which are synchronized with the orbital periods. As it is well known, the enhanced chromospheric activity in these systems is also related to fast rotation. Therefore, we have looked for a correlation between Li abundance and chromospheric activity. We have used the fluxes in the Ca II H and K lines for the single stars and the binary systems from Noyes et al. (1984) and Fernández-Figueroa et al. (1992), respectively. In Fig. 4 we show that there exits a clear correlation between flux in H and K and Li abundance: as the chromospheric flux becomes stronger, the Li abundance increases. Duncan (1981) and Pallavicini et al. (1987) found the same trend studying only single stars. However, the most relevant feature of Fig. 4 is that both groups, the binary and the single stars, are well separated. Power laws of the type log $F_{\rm HK} = A + B$ log N_{Li} can be fitted (shown as solid lines). Different values of the parameter A for each group (binary systems and single stars) are obtained, but the slope, close to 1/4, is the same for both subsamples

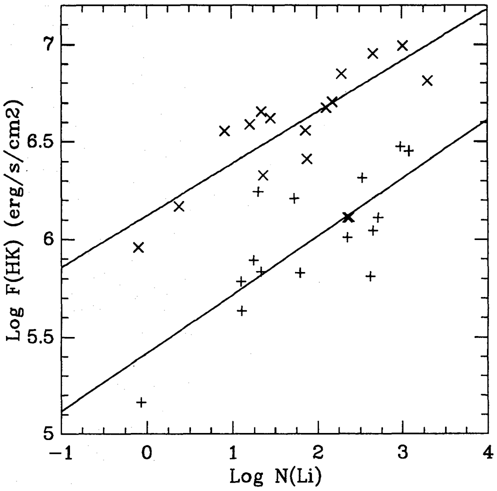

Fig. 4. Chromospheric flux in Ca II H and K versus log $N_{\rm Li}$

The trend for the single stars can be explained because the age and the effective temperature dominate as much the Li abundance as the chromospheric flux for this sample. Late F and G stars have high Li abundance and large chromospheric activity levels. The spread in the data can be attributed to an age effect, since the single stars were randomly chosen and they span a large age range. However, the effective temperature and age effects cannot explain the relation found for the binaries, because there is simultaneously high Li abundances and chromospheric fluxes in some cool components of the binary systems. Furthermore, the chromospheric flux in Ca II H and K does not depend on effective temperature, as can be seen in Fig. 5, where it is possible to find a large spread in the chromospheric flux for a fixed $T_{\rm eff}$, in particular for binary systems. The same lack of correlation for a larger sample of RS CVn and BY Dra systems has been found by Fernández-Figueroa et al. (1992). Thus, the obvious correlation between both observables for the binary systems is probably due to the synchronized rotational period with the orbital period. This peculiarity must affect to the transport mechanisms in the stellar interior (it is likely that for this reason Li is depleted in lesser extent). The differences in chromospheric flux and Li abundances between similar stars that belong to different binary systems can be due to rotational evolution, which are entirely different for each system. If the Li depletion is due to the induced transport mechanism by loss of angular momentum (Pinsonneault et al. 1989, 1990), each component of each binary system has its own way to deplete the Li and the exact way for both influences is unknown. It is necessary to compute new evolutionary models for binary systems in order to reproduce this effect.

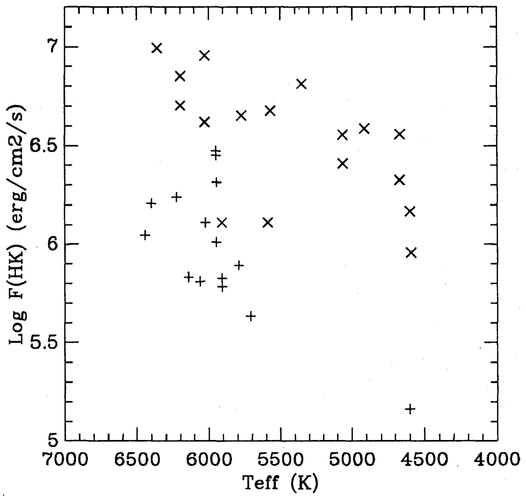

Fig. 5. Chromospheric flux in Ca II H and K versus $T_{\rm eff}$. It is possible to find a large spread for a fixed $T_{\rm eff}$ in the chromospheric flux, specially for binary systems (×)

It is easy to appreciate in Fig. 4 that the RS CVn and the BY Dra systems are 0.5 dex more active on average than single stars in Ca II H and K for the same Li abundance. Therefore, some stars which belong to close binary systems have enhanced activities and also higher Li abundances, being this last the most affected. However, the difference between the binary systems and the single stars could be understood in the dynamo mechanism context. This one can be parameterised by the Rossby number (R_o), defined as the ratio between the rotational period and the turnover time for a large convective cell. R_o is smaller in RS CVn and BY Dra systems than in single stars, because rotational periods are short for the first group. Hall & Henry (1990) obtained a correlation between R_o and the coefficient k, which measures the differential rotation in latitude. These authors showed that differential rotation at first increases when R_o becomes smaller, reaches a maximum around $R_o = 1$, and then progressively diminishes. This last behaviour is opposite to the prediction of the linear dynamo theory, where k is proportional to the inverse of R_o, but consistent with non-linear dynamo theory. Since the differential rotation in latitude decreases when R_o attains lower values in our active binaries, it could be expected that the radial differential rotation also decreases. This possibility is confirmed by the results of Moss (1986) in linear dynamo theory, since the radial differential rotation and the differential rotation in latitude depend on R_o in the same way.

The results presented in this work do not provide a quantitative model for the role of rotation on the Li depletion, but the suggested connection found between reduced Li depletion and fast rotation on tidally interactive binaries agrees with the evolutionary model of Pinsonneault et al. (1989, 1990) and with Balanchandran (1990), who suggested that the Li depletion may occur by mixing induced by differential rotation when a rapidly rotating star spins down on the main sequence. In this context, it is easy to understand the connection between Li abundance and the activity in RS CVn and BY Dra binary systems. We suggest that radial differential rotation and the Rossby number in these systems are smaller than in single stars. Therefore, the turbulent mixing is diminished and the chromospheric activity is enhanced. For this reason, these stars show high Li abundance correlated with high chromospheric fluxes.

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