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Be vs. Li Abundance in Li-rich Giants: an evidence of Li production in Red Giants

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Abstract. We present Be abundances derived through spectral synthesis for two Li-rich giants and a Li-normal giant, plus α Cen A and B, based on observations of the Be II λ 3130.420 and 3131.066 Å lines obtained with the CASPEC spectrograph at the ESO 3.6m telescope[1].

The values derived for the two Li-rich giants (HD146850, HD787) agree with the one for the Li-normal giant (HD220321), and shows that Be was depleted in these stars (by > 90% i.e. by a factor of 10 or larger from the initial Pop I value (logN(Be)= 1.4)).

This result implies that the original Li in these stars was almost completely destroyed, and that Li is most probably produced in red giants.

1. Introduction

About 2% of the red giants show lithium abundances significantly larger than expected by dilution due to convection and, in some of them, the lithium abundance reaches values similar (and even larger) than the ISM value logN(Li) = 3.3.

Two main interpretations of the Li-rich giants are possible: i) the initial Li has been somehow preserved (perhaps by the inhibition of the classical mixing), ii) on the contrary, a mixing, deeper than the classical one, took place in some (or all) giants, leading to a dilution of the superficial lithium but sometimes overcompensating for it by an internal production of lithium, with transport to the surface (by the Cameron-Fowler mechanism).

Lithium and Beryllium are burned in stars in the deep (hot) layers of the stars, being preserved in the external layers. A shallow mixing of the external layers will deplete lithium, and a deeper one will deplete also Be. The Be abundance determination in Li-rich giants could give important information about the origin of the Li observed in these stars.

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[1] Observations collected at the European Southern Observatory - ESO, Chile.

2. Data and Calculations

2.1. Observations

Observations were carried out using the 3.6m ESO telescope with the CASPEC Spectrograph equipped with the long camera centered at λ 3640 Å (order 156), covering the orders 131 to 190. The Be II λ 3130 Å lines are found at the order 181.

The slit was chosen to have 180x350 μm, corresponding to 2.4" on the sky, and to a resolving power R $\sim$ 32000 (see Castilho et al. 1999 for more details).

The final S/N ratio for the giants ranges from 40 to 20, due mainly to the low atmospheric transmission and low CCD sensitivity at these wavelengths. The spectrum of η Cen was inspected for telluric lines. We observed two Li-rich giants, one Li-poor giant and α Cen A and B as comparison stars.

2.2. Stellar Parameters and Models

Stellar parameters for the program stars were adopted from the literature, as indicated in Table 1. Model atmospheres employed have been interpolated in tables computed with the MARCS code by Gustafsson et al. (1975) and Edvardsson et al. (1993). The α Cen A and B synthetic spectra were also computed with models by Kurucz (1992) and we obtain a very good agreement with the above calculations.

Table 1. Adopted stellar parameters for program stars

Star	T_{eff}	log g	[Fe/H]	v_t	ref.
α Cen A	5800	4.40	0.10	1.0	Primas et al. (1997)
α Cen B	5350	4.50	0.10	1.0	Primas et al. (1997)
HD220321	4490	2.73	-0.40	1.3	McWilliam (1990)
HD146850	4000	1.50	-0.30	1.6	Castilho et al. (1995)
HD787	3890	1.74	0.03	1.5	McWilliam (1990)

2.3. Spectrum Synthesis

The spectrum synthesis calculations assume LTE, and the models described above.

Our list of atomic lines was built trying to adopt only the most reliable data, using the list of identified lines by Moore et al. (1966), and including the updated list and accurate data for Fe I by Nave et al. (1994). Oscillator strengths for atomic lines are adopted from laboratory determinations whenever available (see Castilho et al. 1999) otherwise they were obtained by fitting the solar spectrum.

For all molecular systems the line lists by R. Kurucz (CD ROM 18) were adopted, where we recomputed the 'molecular oscillator strengths', by recomputing their Honl-London factors, employing literature values for the Franck-Condon factors and the electronic oscillator strengths.

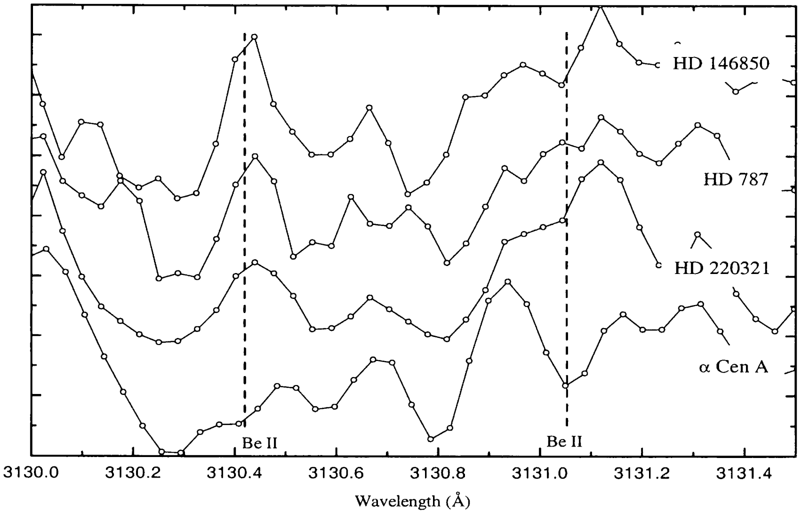

Figure 1. Comparison between α Cen A (bottom) where we can see the Be II lines and the other three giants where the lines are nearly absent.

3. Results

In Table 2 we report the derived Be abundances (Castilho et al. 1999) and literature values of Li abundances, including for reference the Be and Li abundances of the Sun according to Grevesse, Noels & Sauval (1996).

Table 2. Be abundances (present work) and Li abundances (literature)

Star	logN(Be)	logN(Li)	ref. for logN(Li)
α Cen A	1.20±0.1	1.37	King et al. (1997)
α Cen B	0.80±0.2	$\leq$0.4	Chmielewski et al. (1992)
HD 220321	0.40±0.3	$\leq$-0.2	Brown et al. (1989)
HD 146850	-0,50±0.4	1.6 (1.9nlte)	Castilho et al. (1995)
HD 787	0.00±0.4	2.2 (3.1nlte)	de la Reza & da Silva (1995)
Sun	1.15±0.1(6)	1.16±0.10	Grevesse et al. (1996)

The Be abundance estimated for the three red giant stars show that the Be abundance has been very depleted (by >90% i. e. by a factor of 10 or larger) from the initial Pop I value (logN(Be)= 1.4). By computing the Be abundance for HD 220321 and HD 787 using the atmospheric parameters used by Brown

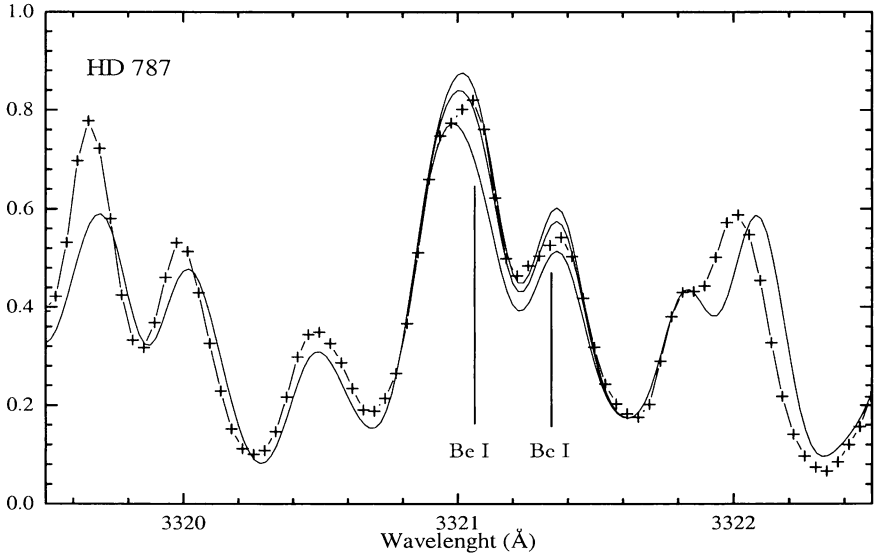

Figure 2. HD787 (+ +) spectrum and three synthetic spectra overimposed, with Be abundances logN(Be) = -1.0, 0.0(best fit), and 1.42.

et al. (1989) $T_{\rm eff}$ = 4510 K and 4220 K; log(g)=2.3 and 1.5 and [Fe/H]=-0.32 and 0.07, we find Be abundances of logN(Be)= 0.1 and -0.2 respectively.

In Fig. 1 we compare the observed spectrum of α Cen A, where we can see the Be II lines, to the other three giants where the Be II lines are essentially absent.

Our results for Be show good agreement with recent calculations by C. Charbonnel, carried out for giants of [Fe/H] = 0.0 and -0.5 and masses between 1.2 and 2.0 $M_\odot$, where mean values of Be/Be$_\odot$ $\sim$ 0.1 and Li/Li$_\odot$ $\sim$ 0.05; our depletions for Li are larger than predicted by the models, but an extra Li depletion is expected.

4. Be I lines

The determination of Be abundance through Be I lines would be a good confirmation of our results for Be II lines. There are three lines of Be I in the λ 3321 Å region: λ 3321.010 Å(χ_{ex} = 2.725 eV, log *gf* = -1.465), λ 3321.081 Å(χ_{ex} = 2.725 eV, log *gf* = -0.982) and λ 3321.340 Å(χ_{ex} = 2.725 eV, log *gf* = -0.773). All three lines are blended at R = 32000, and the strongest one at λ 3321.340 Å is blended to an Fe I line even at higher resolutions.

Although the Be I/Be II fraction in 4000 K giants is higher than in solar type stars, and we should expect strong lines, due to the severe depletion of Be in the program stars, we can not see the Be I lines even with R = 32000 and S/N $\approx$ 150.

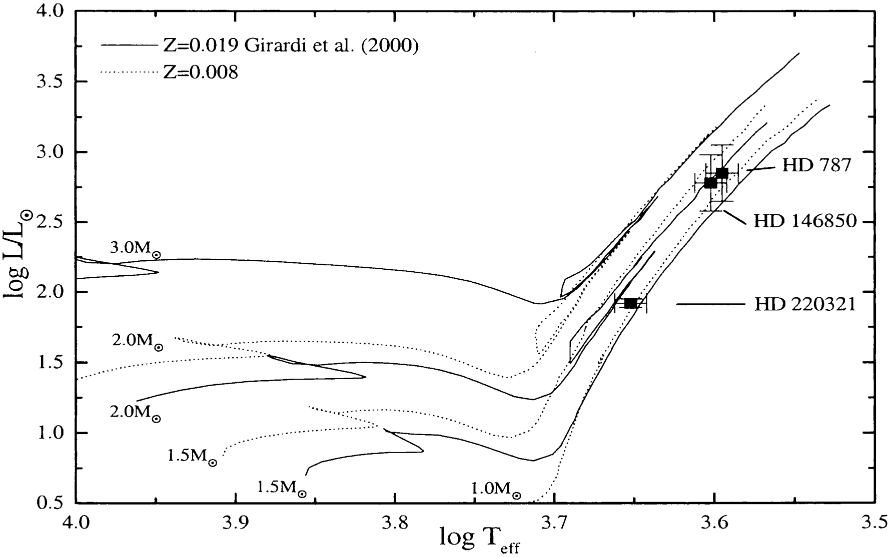

Figure 3. Position of the program stars in the HR diagram

The upper limits obtained for the three giants agree with the abundances determined from Be II lines. In Figure 2 we show the Be I region for HD 787 together with three synthetic spectra, with Be abundances logN(Be) = -1.0, 0.0(best fit), and 1.42.

5. Evolutionary Stage and Mass

In order to determine the position of our program stars in the H-R diagram and their masses we have determined the bolometric magnitude for them using the Hipparcos parallaxes to determine the distance, the interstellar reddening was estimated following the procedure used by Bond (1980), and the bolometric corrections were taken from Lejeune, Cuisinier & Buser (1998).

The luminosities for the giants where then calculated using the classical relation and the masses were determined overimposing the evolutionary tracks by Girardi et al. (2000) to the H-R diagram. In Table 3 we show the results for the three giants and in figure 3 we show the position of the stars in the H-R diagram. The error bars in figure 3 represent the error on the luminosities due parallaxes errors and a 100 K error in the temperatures.

Table 3. Luminosity and mass for the program stars

Star	π (m")	r (pc)	log $L/L_\odot$	M ($M_\odot$)
HD 787	5.33 ±0.87	187	2.85±0.2	1.9 ±1.0
HD 146850	3.77 ±0.85	265	2.78±0.2	1.3 ±1.0
HD 220321	20.14 ±0.72	50	1.92 ±0.03	1.1 ±0.5

6. Conclusion

The small Be abundance found in the Li-rich giants suggests a Be depletion, since the Be depletion found in the giants is larger than the one found in the region of the dip. Moreover, it is not likely that these two stars had by chance a low Be initial abundance, in spite of the fact that the Be abundance in Pop I stars shows some spread. Therefore, Be is not preserved, and its depletion should be due to a rather deep mixing, implying that the original Li in these stars must have been strongly depleted, as in the case of HD 220321. As a consequence, the high Li abundance found in the two Be-poor Li-rich giants studied here (and in all Li-rich giants) is probably due to a further Li production (cf. Sackmann & Boothroyd 1999).

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