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Lithium in the Old Open Cluster NGC 2243

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Abstract. We report observations of lithium in a sample of 11 stars in the metal-poor open cluster NGC 2243, that were obtained from high-resolution spectroscopy at CASPEC (ESO 3.6m telescope). The targets are located at the turnoff region, plus one red giant star.

NGC 2243 is one of the most metal-poor open cluster, almost as deficient as 47 Tuc, but substantially younger (~4 Gyrs and [Fe/H]=-0.5 dex), which makes it a very interesting case to compare with more metal rich coeval clusters on the one hand, and old metal-rich globular clusters (47 Tuc) on the other hand. The preliminary Lithium abundances obtained are discussed in this framework.

1. Introduction

Lithium abundance of turnoff and dwarf stars in open clusters of various ages and metallicities will provide keys to the understanding of the lithium destruction mechanisms in main sequence stars. Being of known ages, metallicities, masses and evolutionary stages, cluster stars are the perfect way to disentangle the effect of each of these parameters on mixing phenomena (see Pasquini 1999, this volume).

NGC 2243 is an old and metal poor open cluster located towards the anticenter, at R_g = 10.76kpc and z = 1.1kpc below the plane of our Milky Way. With an age of 3 to 5 Gyrs (Bonifazzi et al. 1990, Bergbusch et al. 1991, Friel 1995), NGC 2243 has a metallicity of [Fe/H]~ -0.5dex (Gratton et al. 1994), ie very close to that of the old metal-rich Pop II globular cluster 47 Tuc (age $\sim$ 13Gyrs and [Fe/H]~ -0.7dex). It is therefore the perfect target to disentangle age from metallicity effects on lithium depletion. Moreover, with a low reddening (E$(B-V)$=0.04 Bonifazzi et al. 1990) and a distance modulus of $(M-m)_V$=13.05 (Bonifazzi et al.1990), turnoff stars in NGC 2243 are of magnitudes between 15.5 and 17, just within reach of the high resolution spectrograph CASPEC mounted on the 3.6m telescope at ESO, La Silla.

2. Observations and analysis

Table 1 gives a summary of the basic parameters of the observed stars in NGC 2243, together with a summary of the observations. CASPEC was used for this purpose as a single-order spectrograph in long-slit mode, the order containing the Liλ6708Å line being selected by a filter. The long slit was oriented in a way to align as many as 4 targets along one single slit. The S/N reported in Table 1 refer to the measured S/N per pixel of the combined extracted spectra for each star. The achieved resolution is R≈19000 and the wavelength coverage λ6670-6740Å.

Table 1. Log book of the observations

Star	V	$(B-V)$	$(V-I)$	$(B-V)_o$	$(V-I)_o$	S/N	Exp. time
I1	14.90	0.91	0.91	0.87	1.10	80	2x1.5h
II4	15.66	0.50	0.59	0.46	0.69	45	2x1.5h+1.2h+3x1h*
II67	15.83	0.49	0.57	0.45	0.66	50	1.8h+1h+1.5h
I91	15.73	0.52	0.64	0.48	0.75	50	2x1.5h
I23	16.02	0.46	0.55	0.42	0.64	50	2x1.5+3x1h*
I33	16.30	0.46	0.57	0.42	0.67	35	1.8h+2x1.5h
I36	16.04	0.46	0.53	0.42	0.61	30	2x1.5h+1.2h
I31	16.35	0.47	0.57	0.43	0.66	25	2x1.5h
I25	16.05	0.49	0.60	0.45	0.70	35	1h+1.5h
II3	16.63	0.45	0.55	0.41	0.64	20	2x1.5h+1.2h
I90	17.77	0.63	0.80	0.59	0.96	25	2x1.5h

Identifications after Van den Bergh 1977.
$(B-V)$ *from Bergbusch et al. 1991*
$(V-I)$ *from Kaluzny et al. 1996* ($(V-I)_o$ *transformed to Johnson colours)*
* EMMI echelle spectra Dec96

The spectra were processed using standard MIDAS routines including flatfielding, cosmic rejection, order extraction, wavelength calibration and sky subtraction. The radial velocity for each spectrum was then determined using the Ca Iλ6718Å line, and the spectra of each star were then coadded. Figure 1 displays an example of reduced coadded spectra for 3 stars in the sample.

The equivalent width of the lithium Li Iλ6708Å and Ca Iλ6718Å lines were measured by gaussian fitting and checked by straight integration of the combined spectra. Table 2 reports the measured radial velocities and equivalent width (gaussian fitting) for all stars.

The *atmospheric parameters* T_{eff} $\log g$ reported in Table 2 were determined for each star from photometry:

- T_{eff} was taken as the mean of the two temperature determinations using the Alonso et al. 1996 $(B-V)_o$ and $(V-I)_o$ calibrations, adopting a reddening of $E(B-V)$=0.04. The difference between the two indicators is small: temperatures deduced from $(B-V)$ are 36 ± 140K cooler than temperatures deduced from $(V-I)$. The estimated error on the adopted T_{eff} is therefore ±150K, which corresponds to a 0.11 dex uncertainty in lithium abundance.

- $\log g$ was determined from the bolometric magnitude of the stars, adopting the bolometric corrections of Alonso et al. 1996.

- the microturbulence velocity was assumed to be $vt = 1.5$km/s

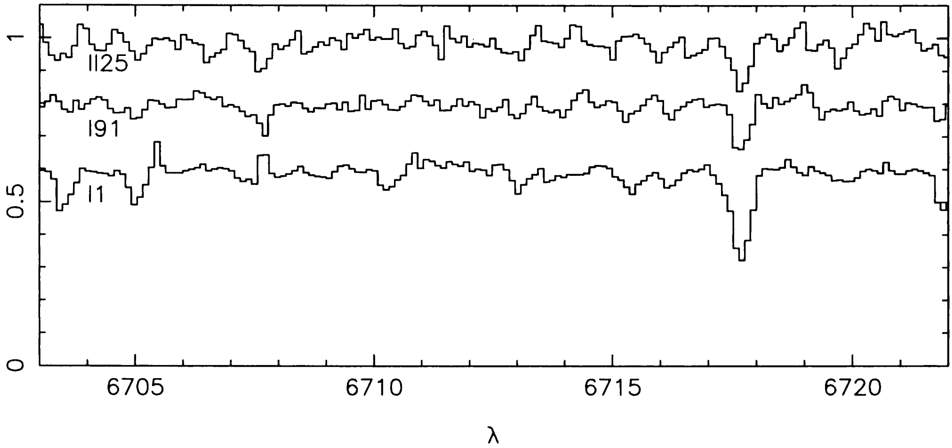

Figure 1. Example of a portion of three reduced spectra, containing the Li I and Ca I lines: I25, I91 and I1 (the spectra of I91 and I1 were shifted vertically by -0.2 and -0,4 for clarity). Lithium is detected in I25, I91, but not in I1, which is the most evolved star of our sample.

Finally, the Li and Ca abundances reported in Table 2 were computed, using Gustafsson et al. 1975 (and subsequent extensions) models.

The lithium line could be detected in 4 stars. In all cases where the lithium line was successfully detected, the Li abundance is reported in Table 2 together with its associated uncertainty (1σ); in all other cases, an upper limit for the equivalent width of the line was established via the Cayrel (1988) formula and translated into an upper limit on the Li abundance (denoted by a "<" sign).

Examination of the radial velocities of the sample of 11 stars reveal that only one star (I36) is a suspected non-member, with a radial velocity differing by more than 20 km/s from the mean value of the sample $Vr = 53.57 \pm 2.6$km/s (10 stars). I36 was hence excluded from the following discussion, as probable non-member.

Table 2. Atmospheric parameters and Lithium abundances of the program stars

Star	T_{eff}	log g	M_V	W_{Ca}	W_{Li}	[Ca/H]	N(Li)	Vr(km/s)
I1	4987.	3.5	2.1	129	15	-0.27	<0.94	48.6
II4	6251.	4.0	2.9	61	20	-0.43	2.18±0.10	57.4
II67	6309.	4.0	3.0	52	15	-0.57	<2.09	55.7
I91	6101.	4.0	2.9	59	31	-0.55	2.26±0.05	54.5
I23	6441.	4.2	3.2	64	29	-0.29	2.48±0.15	52.6
I33	6384.	4.2	3.5	37	13	-0.75	<2.09	53.6
I36	*6489.*	*4.2*	*3.2*	*70*	*20*	*-0.17*	*<2.35*	*32.5*
I31	6364.	4.2	3.5	50	20	-0.56	<2.24	54.1
I25	6255.	4.2	3.2	62	41	-0.44	2.49±0.07	50.1
II3	6464.	4.4	3.8	69	25	-0.24	<2.41	53.8
I90	5578.	4.6	4.9	77	20	-0.68	<1.65	55.3

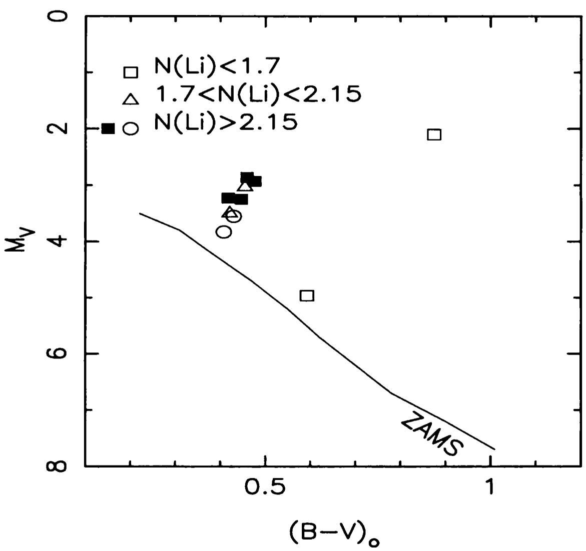

Figure 2. Color-magnitude diagram of the observed stars in NGC 2243. The lithium abundance determined is coded by symbols: open symbols are upper limits whereas filled symbols are detections. The ZAMS is a semi-empirical locus from Vandenberg 1989, for a metallicity of [Fe/H]=-0.65 and Y=0.24.

3. Discussion

Let us now examine the significance of the four Li detections and six upper limits that were established.

The status of the two coolest stars in our sample is rather straight-forward: the giant I1 is sufficiently evolved to have diluted its lithium, whereas the dwarf I90 is simply too cool (5600K) to have kept its lithium on the MS. Accordingly, no Li line was detected in either star, but stringent upper limits of N(Li)=0.94 and 1.67 were established, a factor respectively 35 an 6 times less than the maximum lithium abundance detected in this cluster : these stars have evidently undergone severe depletion.

3.1. Lithium *dip*

In open clusters such as the Hyades, it is well known that the lithium "plateau" that is observed for stars hotter than 5800K is interrupted by the so-called lithium *dip*, a narrow temperature (or mass) range where lithium is severely depleted by factors up to 100 (eg. Balachandran 1995 Fig.12), and interpreted as the signature of an extra-mixing mechanism. Moreover, Balachandran (1995) has shown that this *dip* appears at a *constant ZAMS temperature*, for clusters of a range of ages, whether the stars either side of the *dip* are still on the MS (for the younger clusters) of already evolved to the turnoff and subgiant region (for older clusters such as M67).

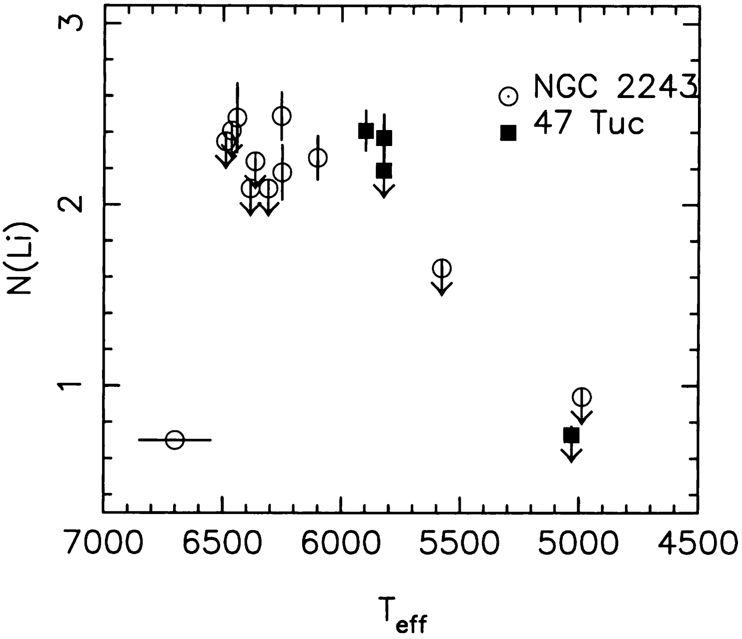

Figure 3. Li abundances versus effective temperature for the NGC 2243 stars (this paper), compared with literature data for stars in the globular cluster 47 Tuc (Pasquini & Molaro 1997)

Interestingly, Figure 2 indicates that in the case of NGC 2243, the stars in which we successfully detected the lithium line (filled symbols) are in fact those which have the hotter ZAMS temperatures (the larger masses) and are now evolved off the MS. On the other hand, stars closer to the MS have only upper limits for their lithium abundance. This fact could be interpreted as the signature of the *dip*: the stars on the blue side of the *dip* (hotter side) have already evolved from the MS, while the stars in the *dip*, which have destroyed lithium, are seen as hardly evolved above the MS.

This hypothesis could be tested by enlarging the sample towards the upper main sequence of the cluster: these stars should fall on the red side of the *dip* (cooler side) and show detectable lithium again. However, such observations require larger telescopes, since the magnitudes of the stars of interest will be V>17, and the signal to noise needed, larger than 30.

3.2. Lithium abundance in the Galaxy Evolution context

If this interpretation is correct, then the stars for which we could detect strong lithium should show no strong depletion, similarly to stars on the blue side of the *dip* in the Hyades. In this respect, the comparison to 47 Tuc is also interesting, and is shown in Figure 3, where the Lithium abundance of 5 stars in 47 Tuc (Pasquini & Molaro 1997) are shown together with the present determinations for NGC 2243. The "plateau" for temperatures hotter than 5800K is visible, and above this value, the two clusters show surprisingly similar lithium abundances: N(Li)=2.37 for 4 stars in 47 Tuc and 2.35 for the 4 detections in NGC 2243.

Considering that, with a similar metallicity, one would expect the two clusters to have started with a similar lithium abundance. The fact that the present day lithium abundance in the atmosphere of turnoff stars in the two clusters are so similar indicate that, if they have suffered MS lithium depletion, then the depletion has been of similar amplitude in the two clusters, despite the fact that NGC 2243 is almost 10 Gyrs younger than 47 Tuc.

Finally, we would like to note that, if the N(Li)=2.35 indeed represents the lithium abundance enrichment level reached by the galactic ISM at metallicities of [Fe/H]=-0.5 dex (ie if the NGC 2243 and 47 Tuc stars have not suffered significant MS Li depletion), then Galactic Chemical Evolution models predict too high lithium in this metallicity range. Moreover, the increase of lithium abundance between [Fe/H]=-0.5 and solar metallicities would be of a factor of 10, much more than predicted by Chemical Evolution models.

As compared to the standard Pop II field stars *lithium plateau* value of 2.15, or the recent lithium measurements of 2.18 ± 0.18 and 2.28 ± 0.10 in two metal poor old globular clusters M92 and NGC 6397 (Deliyannis et al. 1995, Boesgaard et al. 1998), the 47 Tuc and NGC 2243 stars are only slightly enriched in lithium: again, this very small enrichment is at variance from Chemical Evolution models predictions.

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