

*Letter to the Editor***A Super Lithium Rich giant
in the metal-poor open cluster Berkeley 21***

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Abstract. We present the analysis of FEROS commissioning spectra of 3 giants in the metal poor cluster Be 21. One of the giants has an exceptionally high Li content, comparable to the original Li in the solar system. These objects are very rare (only a handful are known), and this is the first Super Lithium Rich giant (SLIR) discovered in an open cluster. The reasons for such a high Li abundance are unknown: it could be the result of a short lived internal process, or of accretion from external sources, the former being slightly more likely. From the spectra, the metal abundance is also derived for 3 giants, giving a mean of $[\text{Fe}/\text{H}] = -0.54 \pm 0.2\text{dex}$, in good agreement with recent photometric estimates, but substantially higher than estimates previously obtained.

Key words: stars: abundances – stars: late-type – Galaxy: open clusters and associations: individual: Berkeley 21

1. Introduction

Super Lithium Rich giants (SLIR) are an elusive class of objects, serendipitously discovered. The presence of a substantial amount of Li in ‘normal’ giants is already a puzzle, because, according to current evolutionary theories, very little Li should have remained in the stellar atmosphere of these stars shortly after they leave the main sequence, and they are not expected to produce any substantial amount before the Cameron-Fowler (1971) mechanism becomes active, i.e. before the star gets to the tip of the giant branch and onto the AGB.

In their survey for Lithium Rich giants, Brown et al. (1989) found out of 644 giants, 8 Lithium Rich giants ($N(\text{Li}) \geq 1.2\text{dex}^1$) and only 2 with lithium abundances close to the current interstellar value ($N(\text{Li}) \sim 3\text{dex}$), while the compilation by de la Reza (1996, 1997) quote ~ 40 Lithium Rich giants. With the exception of a recently discovered red giant belonging to the globular cluster M3 (Kraft et al. 1999), all the other giants with

$N(\text{Li}) \sim 3\text{dex}$ belong to the field, and what we report here is the first detection of such an object in an open cluster. This should help us to precisely position the star in the colour-magnitude diagram, to assess its evolutionary status, initial mass, age and metallicity.

Among possible theories of Li enhancement, pollution from an evolved companion, engulfing of a lithium rich low mass (brown dwarf) companion, self production and shell detachment (de la Reza et al. 1996, 1997) have been proposed.

2. Observations and sample

Four giants in the core of Be 21 were observed with FEROS, the new fibre-fed high resolution echelle spectrograph that has been installed in 1998 on the 1.52m telescope in La Silla and has proven to be very stable and sensitive. The spectra were obtained during the commissioning period in November 1998 (Kaufer et al. 1999). Several exposures were obtained per star and the data were reduced by using the FEROS on line data reduction system. Since FEROS also provides simultaneous sky spectra (from a dedicated fiber), for these relative faint stars the sky spectra were used to check for the presence of emission lines in the regions of interest. No detectable sky continuum was found, and therefore we preferred not to subtract the sky spectra, in order not to lower the S/N ratio of the spectra which is $S/N \sim 20/\text{pixel}$ (a quite remarkable result, considering that FEROS is fed by the ESO 1.52m telescope). FEROS resolving power is of $R = 48000$ and FEROS is a rather stable instrument, providing accurate radial velocities.

A brief logbook of these observations is given in Table 1, where the identification of the stars follows the numbering of Tosi et al. (1998).

The radial velocities of the 4 giants are also given in Table 1. The four radial velocities agree clearly very well at a $V_{\text{r, helio}}$ of $12.35 \pm 0.6\text{ km s}^{-1}$, which is compatible to the intrinsic accuracy of FEROS without simultaneous calibration. We therefore conclude (at odds with previous, less accurate measurements by Friel & Janes (1993) that the four giants are likely Be 21 members and that the radial velocity of the Be 21 cluster is 12.35 km s^{-1} .

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* Based on observations collected at the European Southern Observatory, La Silla, Chile.

¹ $N(\text{Li}) = \log(n_{\text{Li}}/n_{\text{H}}) + 12$

Table 1. Logbook of the observations

star	V	$(B - V)$	$(V - I)$	Exp. time	V_{helio} (km s^{-1})
T33	15.85	1.70	2.11	2×1h	12.5
T27	15.66	1.70	2.06	2×1h	12.8
T26	15.62	1.77	2.07	2×1h + 45mn	12.6
T9	15.00	1.95	2.29	2×1h	11.5

The spectra were acquired in a short span one after the other (at most one night difference) and we do not find noticeable radial velocity variations among the different spectra. However, the brightest giant (T9) shows a very broad and slightly asymmetric correlation function, which reflects the complex and broad structure of its lines. We suspect that this star might be a binary, and excluded it from our abundance analysis.

The position of the four stars in the Colour-Magnitude diagram of Be 21 of Tosi et al. (1998) is shown in Fig. 1, with the SLIR star marked as a circle. Clearly, the colours and magnitudes of the four giants fit very well in the C-M diagram of the cluster and the three fainter giants observed are about 1 magnitude above the He-burning core clump. According to Tosi et al. (1998) and their visual magnitudes, the absolute visual magnitude of the three stars is of $M_V \sim 0$.

3. Analysis

3.1. Stellar atmosphere models

The model atmospheres that we used to derive the abundances were interpolated in a grid of models calculated with codes derived from the MARCS¹, and especially adapted to represent the atmosphere of low gravity stars: Plez’s (1992 and 1997) grid of models, with temperature and gravity ranges ($3500 \leq T_{\text{eff}} \leq 4750$ K and $-0.5 \leq \log g \leq 1.0$ dex) for metallicities $-1.0, -0.6, -0.3, 0., 0.3, 0.6$ dex.

3.2. Effective parameter determination

To determine the effective parameters of the stars the following procedure was adopted:

- *Temperature*: the $(B - V)$ and $(V - I)$ colours of the star are used to determine the effective temperature T_{eff} , which is then checked “spectroscopically”, imposing for the excitation equilibrium to be achieved (lines with high and low excitation potential should produce the same abundance for a given element -here Fe I).
- *Surface gravity*: $\log g_{\text{is}}$ derived from the ionisation equilibrium: we require that the iron abundance deduced from neutral and ionised species should be the same.
- *Microturbulent velocity*: v_t is derived imposing that the iron lines with small and large equivalent width should give the same abundance.

To derive the input T_{eff} we have started from the Tosi et al. values of reddening: $E(B - V) = 0.76$ (thus $E(V - I) = 0.99$)

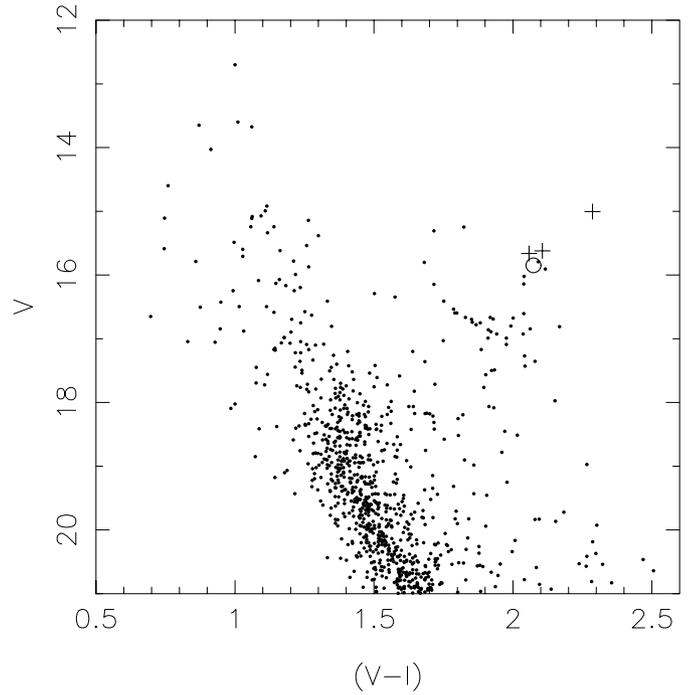


Fig. 1. Observed Colour-Magnitude diagram of the cluster Be 21 from Tosi et al. 1998. The four stars studied here are plotted as crosses and circle respectively for the normal and the SLIR giant.

Table 2. Adopted effective parameters

Star	T_{eff} (K)		Spectr.	$\log g$ (dex)		v_t (km s^{-1})
	$(V - I)$	$(B - V)$		Phot.	Spectr.	
T33	4800	4600	4600	2.2	$\leq 1.$	2.0
T27	4800	4630	4600	2.2	$\leq 1.$	2.0
T26	4630	4520	4500	2.0	1.5	2.0
T9	4300	4380	–	1.7	–	–

and we have applied these values to the stars. The effective temperature calibration of Alonso et al. (1996) has been then applied; in fact, even if this calibration has been mostly developed for dwarf stars, models clearly show that in this range of temperature, it has a very little dependence on gravity, if at all (cf Bessell et al. 1998). The initial guess was found very close to the spectroscopic results, as shown in Table 2, confirming indirectly the quality of the of the Tosi et al. reddening analysis. In the same table, we note, however, that the spectroscopic and photometric gravities do not match very well, in that spectroscopic gravities (derived from ionisation equilibrium) give lower values than the photometric ones. This effect is well known in intermediate metallicity stars and it is due to the fact that the Fe lines suffer of NLTE effects (mainly overionisation). In this case, however, the effect is larger than expected, and this might be due to the extremely small number of ionised lines that could be measured (weak lines with $W < 50\text{\AA}$ were impossible to measure reliably because of the S/N of the spectra). Since the stars belong to a cluster, on the other hand we know that the real gravities cannot be lower than the ones derived from the photometry by

Table 3. Abundances for the three Be 21 giants

Star	T33			T27			T26		
$T_{\text{eff}}, \log g$	4600, 2.0			4600, 2.0			4500, 2.0		
	[X/H]	σ	n	[X/H]	σ	n	[X/H]	σ	n
N(Li)	3.0	–	2	≤ 0.5	–	–	≤ 0.5	–	–
Na I	–0.33	–	1	0.06	–	1	+0.02	–	1
Al I	–0.38	–	1	–	–	–	–	–	–
Si I	–0.07	–	1	–0.09	–	1	–0.47	–	1
Ca I	–0.61	0.27	6	–0.56	0.25	5	–0.73	0.18	7
V I	–0.59	0.09	5	–0.29	0.18	5	–0.15	0.08	4
Ti I	–0.55	0.25	7	–0.37	0.26	5	–0.29	0.23	7
Ti II	+0.08	0.21	2	–0.33	–	1	–	–	–
$[\alpha/\text{H}]$	–0.56	0.24	19	–0.39	0.25	16	–0.42	0.30	20
Cr I	–0.86	–	1	–0.76	–	1	–	–	–
Fe I	–0.58	0.21	31	–0.55	0.23	24	–0.44	0.24	27
Fe II	+0.21	0.08	3	+0.07	0.08	2	–0.34	0.26	4
Ni I	–0.56	0.16	7	–0.64	0.21	6	–0.48	0.22	6
$[\text{“Fe”}/\text{H}]$	–0.58	0.20	39	–0.57	0.22	31	–0.44	0.24	33

Note: In addition to the individual elements abundances, we display also for each star the mean of two groups of elements: the α -elements $[\alpha/\text{H}]$, including Si, Ca, V and Ti, and the iron-group elements $[\text{“Fe”}/\text{H}]$, including Cr, Fe, and Ni.

more than a factor 2. We have therefore in the following the photometric gravities. This implies that the Fe II lines were not used to determine the mean $[\text{Fe}/\text{H}]$ abundance.

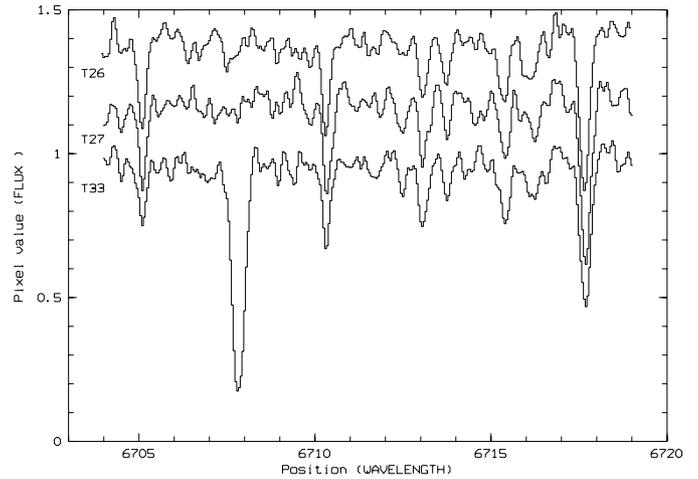
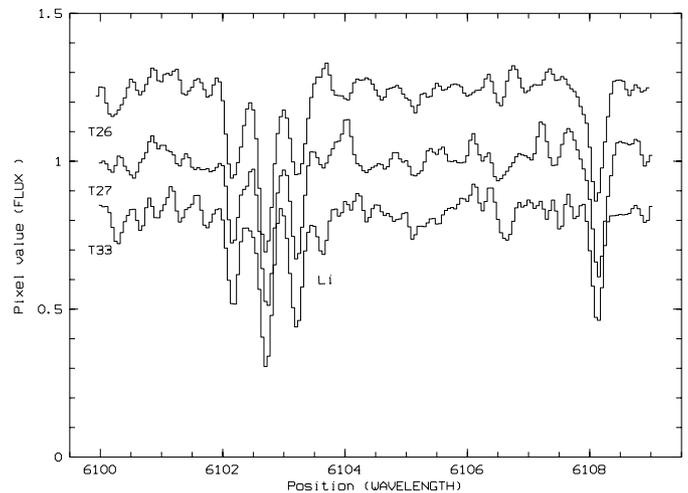
Table 2 summarizes the various determinations of effective parameters for each star.

3.3. Metallicity

Metal abundances were derived by measuring the equivalent width of isolated lines by the Gaussian approximation and deducing the abundances from these measurements. We have also checked with the curve of growth method, finding consistent results. In Table 3 the abundance of elements analysed together with the number of lines and the scatter obtained are given.

The mean iron abundance of the three stars is $[\text{Fe}/\text{H}] = -0.54$ dex. This metallicity is larger than what had been found in previous studies, from photometric arguments or medium-resolution spectroscopy (Friel & Janes 1993), but in good agreement with the results obtained by Tosi et al. (1998). Being Be 21 one of the most metal poor clusters known (Friel 1995), this result may have an impact on the models of Galactic chemical evolution. We also note that a $[\text{Fe}/\text{H}]$ of -0.9 dex as proposed by Friel & Janes (1993) would require adopting drastically lower effective temperatures for our stars, clearly violating the excitation equilibrium criterium.

We also note that the α -elements abundances seem to be on average slightly higher than that of the iron group, in good agreement with what is observed at these metallicity in disk stars of similar metallicities (cf. for example Edvardsson et al. 1993).

**Fig. 2.** Observed Lithium 6707 Å line in the three Be 21 giants.**Fig. 3.** Observed Lithium 6104 Å line in the three Be 21 giants.

3.4. Lithium

The spectral region around the 6708 Å Li I resonance line is given in Fig. 2 for the three giants. For the star T33 the LTE analysis gives $N(\text{Li}) = 3$ dex; we caution that for these saturated line the abundance can be much larger than what given, in particular if an NLTE treatment is done (de la Reza & da Silva 1995). In any case, this implies that the Li abundance of this star is comparable to the initial Li abundance of the cluster or even higher. Since the secondary Li I line at 6104 Å is also included in our spectrum, we checked for this line, as given in Fig. 3. Given the limited S/N ratio of the data, all we can say is that the line is present and the equivalent width ($W \sim 48\text{m}\text{\AA}$) is consistent with the abundance found from the 6708 Å resonance line.

For T26 and T27, only an upper limit of $N(\text{Li}) = 0.5$ dex can be derived, assuming $30\text{m}\text{\AA}$ for the detection limit of the 6708 Å line.

4. Discussion and conclusions

The mechanisms proposed to explain SLIR giants can be basically divided in two type: pollution and self enrichment.

Pollution can happen either via the mass transfer in a binary system where the more massive star evolves first to a white dwarf and pollutes its companion by novae-explosions, or via the engulfing of a low mass companion (i.e. brown dwarf) rich in Li. We cannot at the moment exclude any of these mechanism. The two spectra of T33 were too close in time to detect radial velocity variations, and anyhow, major radial velocity variations are not expected when the companion is a white dwarf. Also, we have no access to the Be region to test the abundance of this material, which could rule out the BD engulfing scenario, as shown for two Lithium Rich field giants by Castilho et al. (1999). But the similarity of the radial velocity of this giant to the three others reduces the probability that it is a binary system. Concerning the BD scenario, however, we note also that the difference in Li abundance between T33 and the other two giants is so large (a factor ~ 1000) that the engulfing hypothesis would have problems in providing such an amount of Li (Siess & Livio 1999). Also, in such a scenario, the engulfed low-mass companion would transfer angular momentum to the giant, leading to a substantial spin-up of the giant. This is not observed the case of T33, which does not seem to be rotating any faster than the two similar giants T26 and T27.

A variation of the Fowler-Cameron self enrichment mechanism has been proposed by Sackmann & Boothroyd (1999) and it has been advocated by Kraft et al. (1999) as a possible explanation of their SLIR giant in M3. At the moment this is an hypothesis, which possibly also needs of some link with the presence of dust shell as observed by de la Reza et al. (1996). With respect to Kraft's SLIR giant in M3 we note that although T33 is more luminous than the cluster clump, its absolute magnitude is about 2 magnitudes fainter than the M3 star. The star in M3 is also substantially cooler. Another comparison can be done with the other SLIR field star HD39853 (Gratton and D'Antona 1989): with a metallicity similar to T33 its Hipparcos parallax indicates that this star is about 1 magnitude brighter and substantially cooler than T33: HD39853 should therefore be very similar to the Be 21 star T9, which does not show a strong Li abundance.

A possible argument in favour of pollution could be proposed: observations of Li in giants of clusters are limited to some

tens of objects, and, if the few cluster SLIR giants discovered so far were indicative of the trend, the percentage of SLIR giants in clusters could be higher than what is observed in the field (cf. Brown et al. 1989). This suggests therefore that environment may have an important role. On the other hand, we have also to note that these clusters are typically more metal poor than the field stars, and, for instance, the Sackmann & Boothroyd mechanism should work better at lower metallicities. However, a proper statistical analysis could only be performed if complete samples of cluster giants were observed, which is not the case at present, where only scarce lithium data are available for open cluster giants.

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