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Nitrogen Enhancement in Metal-Poor Dwarfs: From Inside or Outside?

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Abstract. The five known metal-poor dwarfs with an enhanced N/Fe ratio have been observed spectroscopically. Two of these dwarfs have no lithium line; the absence of lithium is most probably accounted for by the usual convective destruction. The three other dwarfs have the same lithium abundance as the normal metal-poor dwarfs (Spite, Maillard & Spite 1984). This excludes the deep mixing process as the general source of nitrogen enhancement, since lithium is destroyed in deep (hot) layers. Deep mixing had been previously found unlikely in metal-poor dwarfs (Da Costa & Demarque 1982). The discussion stresses the remarkable uniformity of the lithium abundance in metal-poor dwarfs, and shows that the N-rich contaminating matter has a high N/H ratio. Finally, the Al abundance is not greatly enhanced in these five stars.

Key words: halo dwarfs—nitrogen abundance—lithium abundance—mixing

1. Introduction

Recently, Laird (1985) made a survey of nitrogen abundance anomalies in dwarfs, and among about 40 halo dwarfs he found 4 'nitrogen-rich' dwarfs. We have to clear here immediately two points about the vocabulary. We arbitrarily define halo dwarfs as those that have a metallicity lower than [Fe/H] = –1.0; this limit has already been proposed by Carney (1979), and Spite & Spite (1982). Following Laird, we call the stars 'nitrogen-rich' when the abundance ratio N/Fe is enhanced by more than about a factor of 3 (*i.e.* $\geqslant 0.5$ dex). Obviously, since iron is very deficient in the stars discussed here, nitrogen is also deficient: it is only less deficient than the average.

In this way, Laird (1985) confirmed the discovery of two N-rich dwarfs by Bessell & Norris (1982) and added two more dwarfs. Laird proposed three explanations for these anomalies: primordial nitrogen enhancement, binary mass transfer and internal deep mixing.

2. Previous observations

It so happened that, in the course of a program of determination of lithium abundance (Spite &Spite 1982; Spite, Maillard & Spite 1984), we had already observed two of these stars: HD 25329 (Pagel & Powell 1966; Harmer & Pagel 1973) and HD 97916. The lithium line was absent in the spectra of these stars. As a first guess we thought that the

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* Based on observations collected at ESO and CFHT.

enhancement of the N/Fe ratio was produced by the mixing of surface with deep layers of the dwarf (near the core) where nitrogen is formed. This would explain the absence of the lithium line, since lithium is destroyed in moderately deep layers of the stars, and more so in very deep layers. However this idea is not very appealing. Such a mixing is expected in globular cluster giants (Sweigart & Mengel 1979), but it seems practically impossible in dwarfs (Da Costa & Demarque 1982). Moreover, the absence of lithium in HD 25329 is normal for such a cool star: the other halo dwarfs of similar temperature have also a low lithium abundance. (Spite, Maillard & Spite 1984; Boesgaard & Steigman 1985).

The case of HD 97916 is more complicated. In an earlier work (Spite& Spite 1982) we found that an empirical limit seemed to exist at about [Fe/H] = – 1.0. The dwarfs which had a lower metallicity than this limit (*i.e.* [Fe/H] < –1.0) suffered no lithium destruction for T_{eff} > 5700 K. The dwarfs which had a larger metallicity than the limit (*i.e.* [Fe/H]> –1.0)were in the usual situation found in normal or slightly metal-poor stars: some suffered lithium destruction, some not.

The star HD 97916, with a metallicity [Fe/H] = –1.1 does not support the hypothesis of a limit at exactly [Fe/H] = –1.0. Hence Spite, Maillard & Spite (1984) proposed that the limit be pushed to –1.1, or preferably, that some kind of progressive effect be considered. Among dwarfs around solar temperature and solar metallicity, about 50 per cent have no detectable lithium (Spite 1982; see also Duncan 1981). Among dwarfs with intermediate metallicity, *i.e.* –1.3 < [Fe/H] < − 0.3, about 30 per cent have no detectable lithium; among very metal-poor dwarfs, *i.e.* [Fe/H] < –1.3, none is known, up to now, without a 'normal' lithium abundance (see also Duncan & Hobbs 1987; this issue).

These facts can be explained by noting that when the metallicity decreases, the opacity also decreases, which implies that the convection zone becomes shallower, which in turn leads to a smaller chance of lithium destruction. More specifically, the computations of W. Däppen (1982, personal communication; see also Cayrel 1986) show that the internal structure of metal-poor dwarfs is significantly different from the structure of normal dwarfs and should produce an effect similar to the observed one. It is also interesting to note that the limit at [Fe/H] = –1.0 previously proposed by Spite & Spite (1982) was linked with the opacity and internal structure problem. This limit also coincides, by chance, with the value of metallicity that discriminates (although not sharply) between halo and disc stars: such a limit was considered by several authors (see *e.g.* Carney 1979); this limit is thus linked with the chemical and dynamical evolution of the Galaxy. If we consider now a progressive effect, about the lithium destruction, and no specific limit, the problem of confusion between the two different limits does not arise any more.

Coming back to HD 97916, the lithium destruction in this star is not surprising, since it is only very slightly below the metallicity limit, the difference in metallicity being smaller than the error bar, and lithium destruction has been observed in many other stars at or slightly above the limit. Thus the observation of these two stars leads to inconclusive results, and it appeared interesting to observe the other members of the list of metal-poor N-rich dwarfs.

3. Observations

We observed the two N-rich dwarfs listed by Laird (1985) and the N-rich dwarf also noted by Carbon *et al.* (1986) who insist that such N-rich stars are very rare (only a few per cent of the halo dwarfs). One of these stars was observed at the coudé spectrograph of the CFH 3.6 m telescope and the other two with the CASPEC spectrograph of the ESO 3.6 m telescope. The description of these stars may be found in Table 1.

The analysis of the stars was made by using a grid of model atmospheres by B. Gustafsson (1981, personal communication; Gustafsson *et al.* 1975). More details about the analysis may be found in another paper (Spite & Spite 1986).

The result is that the three stars (Table 2) have the 'normal' lithium abundance of the metal-poor dwarfs (Spite & Spite 1982; Spite, Maillard & Spite 1984). In other words, 4 of the nitrogen enhanced halo dwarfs including HD 25329 have about the same lithium abundance as the nitrogen-normal halo dwarfs of the same temperature. The lithium abundance of the star HD 97916 is easily compatible with the idea that, within error limits, it is not deviating from the lithium abundance of a nitrogen-normal metal-poor star of similar metallicity.

These results point to the conclusion that the lithium abundance has the same behaviour in metal-poor dwarfs either nitrogen-enhanced or not (Fig. 1). This discards any general explanation of nitrogen-enhancement by mixing of the surface with very deep layers of the dwarfs, and some other process has to be responsible for the nitrogen enhancement. Our observations also bring out an interesting information: in order to increase the N/Fe ratio without lowering the Li abundance (the Li/H ratio) the contaminating nitrogen-rich matter had necessarily to have a high N/H ratio.

As previously noted, the nitrogen enrichment observed in some giant stars in globular clusters may be attributed to mixing, but such a mixing should be different from the mixing considered for the dwarfs. Such giants have enhanced sodium and

Table 1. Main characteristics of nitrogen-rich stars.

	$\log T_{\rm eff}$	$\log g$	[Fe/H]	Ref.	[N/Fe] (Laird)	[N/Fe] (Carbon)
HD 25329	3.685	4.0	−1.5	(1, 6)		+0.45
HD 74000	3.794	4.5	−1.8	(2)	+1.7	+0.9
HD 97916	3.787	4.0	−1.1	(3)	+0.8	
HD 160617	3.768	3.5	−1.6	(4)	+1.7	
HD 166913	3.787	4.3	−1.8	(5)	+0.7	

References:
(1) Spite, Maillard & Spite (1984)
(2) Peterson (1978a)
(3) Peterson (1978b)
(4) Perrin (1986)
(5) Laird (1985)
(6) See also Pagel & Powell (1966); Harmer & Pagel (1973) for nitrogen abundance of HD 25329

Table 2. Abundance of lithium in nitrogen-rich halo dwarfs.

	$W_{\rm Li}$	$N_{\rm Li}$
HD 25329	<3	<0.0
HD 74000	24.5	2.16
HD 97916	<3	<1.2
HD 160617	42	2.20
HD 166913	40	2.17

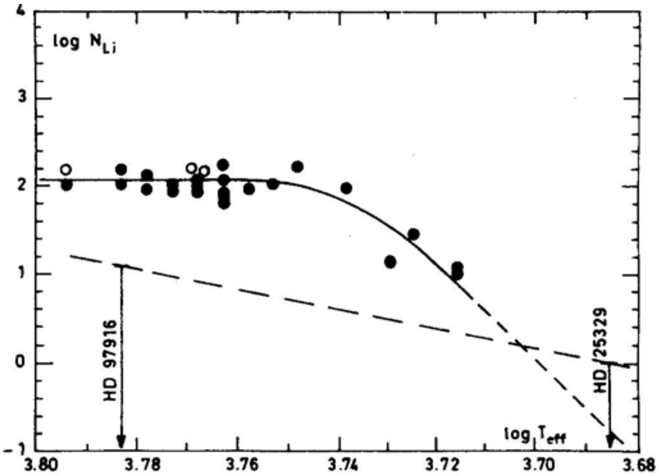

Figure 1. The lithium abundance log N_{Li} (in the standard scale where log N_{H} = 12) in halo dwarfs, according to Spite, Maillard & Spite (1984) with a few additional stars. The nitrogen-rich metal-poor stars are represented by open symbols when their lithium abundance is measurable; when the lithium line is not detected, an arrow is drawn, originating at the maximum possible abundance. The dashed line represents the detection limit on our CFHT spectra (*i.e.* the lithium abundance corresponding to an equivalent width W_{Li}=3 mÅ)

aluminium abundances (Cottrell & Da Costa 1981). It is interesting to check if this effect is also present (and stronger) in the N-enriched dwarfs.

In four of the dwarfs, the red Al doublet is not detectable, as it should be if the Al abundance is not greatly enhanced. In HD 97916 the Al doublet is measurable and leads to an abundance [Al/Fe] = + 0.12 (Francois 1986), which is normal for halo dwarfs. These observations show that the aluminum abundance is not *greatly* enhanced in the N-enriched halo dwarfs.

4. Conclusion

The observations described above show that

1. Lithium is present with 'normal' abundance in three of the nitrogen-enhanced metal-poor dwarfs, absent in the coolest one (as expected) and, not surprisingly, absent in the fifth star. Generally speaking, lithium behaves similarly in N-enhanced and in 'normal' metal-poor dwarfs. This excludes mixing as a general explanation of nitrogen enhancement, since lithium is destroyed in deep layers.

   At this IAU meeting (New Delhi 1985) Bruce Carney and David Latham announced that the metal-poor dwarfs with an enhanced N/Fe ratio are spectroscopic binaries or suspected binaries, so that the final (general) explanation for N enhancement is probably the binary mass exchange.
2. As previously noted (Spite, Maillard & Spite 1984) the lithium abundance of metal-poor dwarfs is noticeably constant and independent of the temperature (for $T_{\mathrm{eff}} > 5500$K), mass, metallicity (for [Fe/H] < –1.0 or –1.1), galactic orbit and eccentricity of the star. These observations show that this abundance is also independent of the N/Fe ratio.

3. The contaminating (N-rich) matter has therefore a high N/H ratio, in order to be able to enhance the nitrogen abundance in the star without lowering the lithium abundance.
4. The A1/Fe ratio is not *greatly* enhanced in these stars.

Acknowledgments

It is not so often that several conclusions may be drawn from the analysis of only 5 stars. This was only possible owing to the work of those who built efficient telescopes, spectrographs and detectors, and maintained them, and also because of those who made extensive surveys and selected the stars which are of special interest. We are especially indebted to R. Cayrel, W. Däppen and P. Francois for communication of results before publication.

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