Mem. S.A.It. Suppl. Vol. 22, 117

Memorie della
Supplementi

Li in carbon-enhanced metal-poor stars

T. Masseron[1,2], J. Johnson[2], S. Lucatello[3,4], A. Karakas[5], B. Plez[6], T. Beers[7], and N. Christlieb[8]

[1] Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, CP 226, Boulevard du Triomphe, B-1050 Bruxelles, Belgium
e-mail: tmassero@ulb.ac.be
[2] Department of Astronomy, Ohio State University, 140 W. 18th Ave., Columbus, OH 43210, USA
[3] INAF, Osservatorio Astronomico di Padova, vicolo dell'Osservatorio 5, 35122 Padova, Italy
[4] Excellence Cluster Universe, Technische Universität München, Boltzmannstr. 2, D-85748 Garching, Germany ; Max-Planck-Institut für Astrophysik, D-85741 Garching, Germany
[5] Research School of Astronomy & Astrophysics, The Australian National University, Mount Stromlo Observatory, Cotter Road,Weston, ACT 2611, Australia
[6] LUPM cc072, Université Montpellier II, F-34095 Montpellier cedex 5, France
[7] Department of Physics & Astronomy and JINA: Joint Institute for Nuclear Astrophysics, Michigan State University, E. Lansing, MI 48824, USA
[8] Zentrum für Astronomie der Universität Heidelberg, Landessternwarte, Königstuhl 12, 69117, Heidelberg, Germany

Abstract. Carbon-enhanced metal-poor (CEMP) stars are believed to show the respective chemical imprints of more massive stars (M> $0.8M_\odot$) that are now extinct. In particular, it is expected that the observed abundance of Li should deviate in these stars from the standard Spite lithium plateau. We study here a sample of 11 metal-poor stars and a double-lined spectroscopic binary with -1.8 < [Fe/H] < -3.3 observed with VLT/UVES spectrograph. Among these 12 metal-poor stars, there are 8 CEMP stars for which we measure or constrain the Li abundance. In contrast to previous arguments, we demonstrate that an appropriate regime of dilution permits the existence of "Li-Spite plateau and C-rich" stars, whereas some of the "Li-depleted and C-rich" stars call for an unidentified additional depletion mechanism that cannot be explained by dilution alone. We found some evidence that rotation is related to depletion in some CEMP stars.

Key words. metal-poor stars, carbon-rich stars, abundances

1. Introduction

One of the striking observational facts that has been established through extensive surveys for metal-poor stars is the large number of C-rich stars, with as much as 25% of the stars with [Fe/H] < -2.5 having [C/Fe] > +1.0) (Lucatello et al. 2005, 2006). The origin of these carbon-enhanced metal-poor (CEMP) stars is important for understanding conditions in the early Universe, because the competing theories predict pollution from different nucleosynthetic

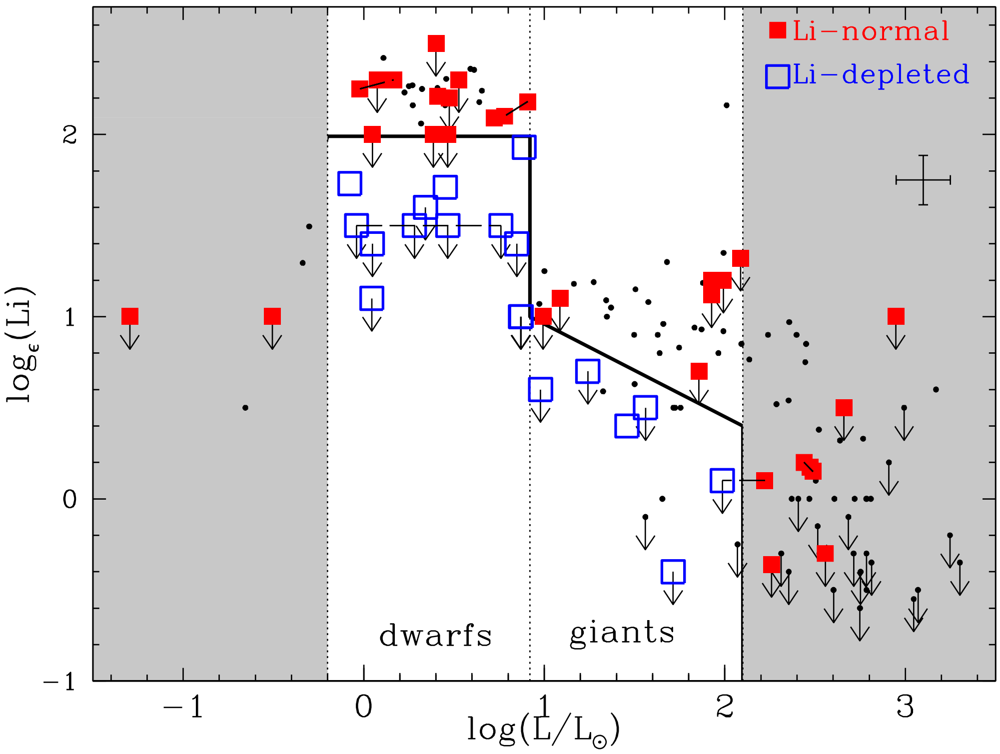

Fig. 1. Li abundance as a function of luminosity in metal-poor stars. The solid line represents the empirical limit between Li-normal and Li-depleted CEMP stars. We also plot some non-C-rich metal-poor stars ([Fe/H]< -1.5) extracted from the SAGA database (Suda et al. 2008). These non-C-rich metal-poor stars are used as "standard" stars to define empirically the limit where Li can be considered as abnormally depleted. There is a broad range of Li abundances for CEMP stars. The Li abundance in the Li-normal CEMP stars is fully compatible with the Li abundances of metal-poor stars without carbon-enhancement and, in particular, no examples of stars with Li abundances above the Spite plateau are observed.

sources. Many CEMP stars exhibit radial velocity variations, and s-process elements enhancements (e.g., Masseron et al. 2010) indicating that the CEMP stars are likely to have been created by mass transfer from a now extinct AGB companion star.

In Figure 1, we plot the Li abundance as a function of luminosity for the extended sample of CEMP stars. In this figure, we first notice that CEMP stars exhibit a broad range of Li abundances for their evolutionary stage. To discuss the origin of the observed scatter in Li abundances more quantitatively in the following sections, we respectively refer to "Li-normal" stars and "Li-depleted" stars, the stars above and the stars below the thick line in Figure 1, respectively.

2. "Li-normal" stars

Observations of CH stars, which are the result of AGB mass transfer in moderately metal-poor ([Fe/H] < -1) binary systems (McClure 1984), show that they are Li depleted (Smith et al. 1993, Norris et al. 1997). Similarly, other authors found CEMP stars with Li abundances near the Spite plateau (Thompson et al., 2008; Sivarani et al. , 2006; Behara et al., 2010) . AGB material is expected to be depleted in Li, but rich in C. Therefore, they argued that the Li abundance had to be the result of Li production

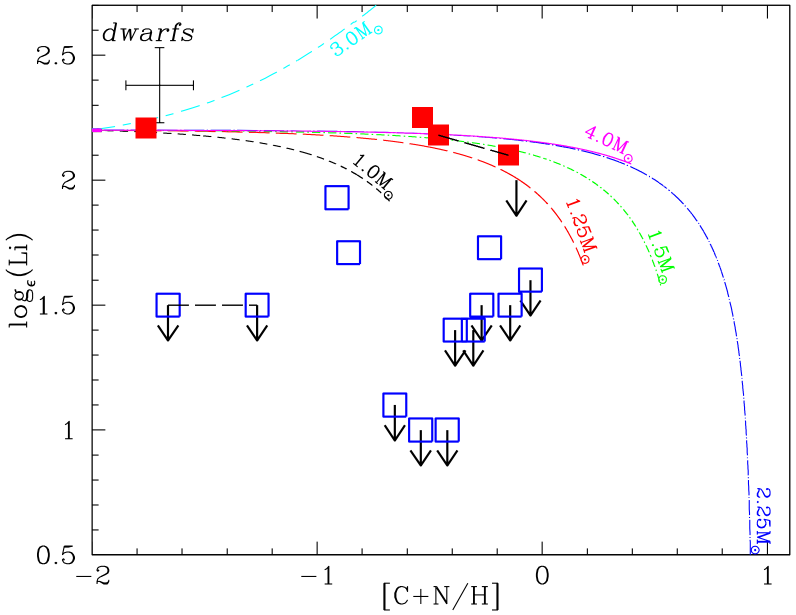

Fig. 2. Lithium abundance as a function of [(C + N)/H] in CEMP dwarfs. The different lines represent the dilution of the yields of Karakas & Lattanzio (2010). In general, the more AGB material is transferred, the more the Li will decrease, whereas C will increase.

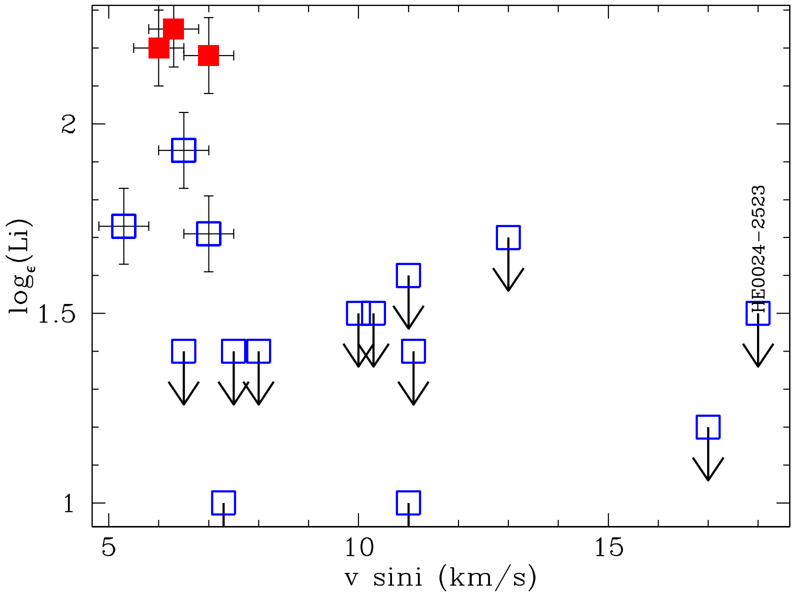

Fig. 3. Li abundance as function of rotational velocity in CEMP stars determined from the broadening profile of lines. The position shortest orbital period CEMP stars know (3 days) HE0024-2523 is indicated and shows the largest rotational period.

in the AGB companion, because otherwise the pollution by Li-free material would lower the abundance to below the plateau value .

However, Figure 2 shows that there is a regime where C remains high, while the Li abundance is almost identical to the Spite Li plateau. This corresponds to a dilution factor of 10%, similar to that found by Thompson et al. (2008). This suggests that the Li abundances observed in these stars might not require any production by the AGB companion, in contrast to the conclusions of Norris et al. (1997), Sivarani et al. (2006), and Thompson et al. (2008).

3. "Li-depleted" stars

We also see in Figure 2 that it is the Li-depleted dwarfs with low [C/H] that cannot be reproduced by the dilution tracks. Consequently, it seems that an additional mechanism further deplete Li after the AGB stars has expelled its material. In Figure 3, CEMP stars with large rotational velocities show depleted Li. Additionally, all Li-normal stars have low rotational velocities. This indicates that rotation may play an important role for depletion in some CEMP stars (at least for the fastest rotators). We note also that Li-depleted CEMP stars with low rotational velocities exist. Nevertheless, due to the unknown projection angle of the rotation axis of the stars, it is impossible to conclude for these stars whether the rotation is actually low in these stars or another mechanism is at work to deplete the Li.

4. Conclusions

Although we cannot completely rule out that some Li may have been produced in a former AGB companion, it is definitely not required to invoke that process to explain the CEMP stars with Li abundances close to the Spite plateau value. In contrast, it appears difficult to explain the CEMP stars where the Li is depleted without additional Li depletion in the CEMP star itself. Hence, extra mixing is required. Rotation seems to play a prominent role for most CEMP stars. This result is in line with the recent findings of Smiljanic et al. (2010) and Canto Martins et al. (2011), showing that the inclusion of rotation in the evolutionary models can reproduce Li depletion in open clusters. Actually, Charbonnel & Lagarde (2010) studied the complex interplay between rotation and thermohaline mixing and found that rotation favors the occurrence of thermohaline mixing in low-mass solar metallicity RGB stars. Furthermore, Stancliffe & Glebbeek (2008) show that, beyond rotation and thermohaline mixing, other mechanisms such as gravitational settling may play some role in dwarf CEMP stars and subsequently affect the observed Li abundances. In the end, the various contributions of all these physical processes may explain the observed Li abundance scatter. Because the current sample of CEMP stars with Li measurements is still small, we could not definitively infer a dependency of the rotational velocity on the amount of Li depletion. Larger samples and more systematic radial velocity monitoring is required to confirm these results.

References

Behara, N. T., et al., 2010, A&A, 513, A72

Canto Martins, B. L., et al., 2011, A&A, 527, A94

Charbonnel, C., & Lagarde, N. 2010, A&A, 522, A10

Lucatello, S., Tsangarides, S., Beers, T. C., et al. 2005, ApJ, 625, 825

Lucatello, S., Beers, T. C., Christlieb, N., et al. 2006, ApJL, 652, L37

Masseron, T., Johnson, J. A., Plez, B., et al. 2010, A&A, 509, A93

Masseron, T., Johnson, J. A., Lucatello, S., et al. 2012, ApJ, 751, 14

McClure, R. D. 1984, ApJL, 280, L31

Norris, J. E., Ryan, S. G., & Beers, T. C. 1997, ApJ, 488, 350

Sivarani T., et al., 2006, A&A, 459, 125

Smiljanic, R., Pasquini, L., Charbonnel, C., & Lagarde, N. 2010, A&A, 510, A50

Stancliffe, R. J., & Glebbeek, E. 2008, MNRAS, 389, 1828

Suda, T., Katsuta, Y., Yamada, S., et al. 2008, PASJ, 60, 1159

Thompson, I. B., et al. 2008, ApJ, 677, 556