LITHIUM IN METAL DEFICIENT BINARIES

M. SPITE¹, T.FLEMIN², R.CAYREL³, L. PASQUINI⁴, F. SPITE¹

¹Observatoire de Paris section de Meudon, Meudon, France
²University of Arizona, Steward Observatory, Tucson, USA
³Observatoire de Paris, Paris, France
⁴European Southern Observatory, La Silla, Chile

ABSTRACT. Since it is expected that tidally locked binaries exhibit larger lithium abundances than single stars or long period binaries a systematic study of the lithium abundance in Pop II binaries has been initiated. In the region of the "plateau" there is no indication that short period binaries are more lithium rich than the other stars leading to the impression that no depletion has occurred in hot Pop II single stars.

1. Introduction

According to stellar evolution, the lithium abundance in the atmosphere of a star should be uniquely determined by the mass, the metallicity, the age of the star and the loss of angular momentum. The braking of the star is supposed to induce an "extra-mixing" (cf. Pinsonneault et al. 1989; Zahn 1992, 1994).

It is thus expected that tidally locked binaries which keep a constant angular momentum, exhibit a larger lithium abundance than similar single stars or long period binaries.

An international program has been initiated to study the lithium abundance in the largest possible number of old metal-deficient binaries in the northern and the southern hemisphere.

Let us note that, in Population I, several short period binaries had already been found "lithium-rich" in the Pleiades (Soderblom et al. 1993) and in the Hyades (Thornburn et al. 1993) and in M67 (Deliyannis et al. 1994).

A first paper (Spite, Pasquini & Spite, 1994) has presented the results obtained for some Pop II and old disk (moderately metal-poor) southern stars. We present here the current state of this work (northern and southern stars). Several (24) old binaries have been up to now reduced. They have been observed:

- with the 3.6m telescope + CASPEC (ESO) (échelle spectra)
- with the NTT + EMMI (ESO) (échelle spectra)
- at the McMath - Pierce telescope + stellar spectrograph (simple spectra)
- at the Haute Provence Observatory - 1.93m telescope + Elodie (échelle spectra)
2. Results

2.1. What is the period for which a binary can be considered as tidally locked?

Following Zahn (1992, 1994) the longest period for a binary to be tidally locked and preserve its lithium content is 8 days for young PopI binaries and 6 days only for old metal deficient PopII binaries.

However Latham et al. (1992) after measuring the eccentricity of 24 PopII binaries concluded that the transition between circular and eccentric orbits occurs at about 19 days. Since circularization is achieved after synchronization (e.g. Van't Veer & Maceroni 1992, Zahn 1977), we retain also 19 days as a critical value of the period.

2.2. Is the lithium abundance dependent on the period of the binary?

The lithium abundance has been plotted versus temperature. In order to have a proper comparison, we have parted the stars in tow subsamples:

- The Pop II stars with $[\text{Fe/H}] \leq -1.4$ (Fig. 1)
- The old disk stars with $-1.1 \leq [\text{Fe/H}] \leq -0.4$ (Fig. 2)

Moreover different symbols have been used for each range of periods:
  - $P > 19$ days, open circles
  - $6$ days $< P < 19$ days, crossed circles
  - $P < 6$ days, filled circles

The dotted lines represent the mean relation between the lithium abundance and the temperature, observed in single dwarfs with about the same metal deficiencies.

From these figures, the situation is rather confusing... Several short period binaries are "above" the mean curve defined by single dwarfs, but some other are below this curve...

However:
1. In the region of the "plateau" $T_{\text{eff}} > 5600K$ for the PopII binaries and $T_{\text{eff}} > 5800K$ for the old disk stars:
   The lithium abundance appears to be independent of the period of the binary.

   One very short period binary of the old disk (HD85091) has an undetectable lithium line, but its gravity indicates that it could be a subgiant star and could be thus evolving from a "Boesgaard gap". It could be also a star which suffered a strong wind (Cayrel, 1994).

   We can say at least that there is no clear indication that in this region of the diagram a short period induces a high lithium abundance.

2. In the intermediate region $5100 < T_{\text{eff}} < 5600$ for PopII, and $5100 < T_{\text{eff}} < 5800$ for Pop I:
   The lithium abundance in single stars is clearly very dependent of the temperature of the star, and thus lithium has certainly been destroyed. It could be expected that different brakings induce different lithium depletions and thus different lithium abundances.

   Let us remark that in two short period old disk binaries only an upper limit of the lithium abundance could be detected (BD30°2130 $P=6.6$ days and BD36°2193 $P=7.2$ days). However this upper limit is sufficient to conclude that these short period binaries are not "lithium-rich" when compared to single stars (dotted line) or to long period binaries.

   There is no indication that the short period binaries in this region of the diagram are more lithium rich.

3. In the cooler part of both diagrams: $T_{\text{eff}} < 5100K$
   The short and very short period binaries appear to be in general more lithium-rich than the long period binaries and single stars.

   Let us note however that HD89499 is clearly a giant star ($\log g=2$) and from the data of Pilachowski et al. (1993) it can be shown that many single cool giants are more lithium-rich than the single cool dwarfs. Is HD89499 lithium rich because it is a very short period binary or because it is a PopII giant star?
For one short period binary in this region (BD5*3080, \( P=9.9d \)) only an upper limit of the lithium abundance could be computed. This upper limit is compatible with an overabundance of lithium but a higher signal to noise would be necessary to firmly conclude.

3. Conclusion

The final aim of this work is naturally to progress towards the determination of the cosmological value of the lithium abundance. The important question is:

**Has lithium been destroyed in the single stars of the PopII plateau?**

In the current state of the work it is very difficult to firmly conclude. The sample of very short period PopII binaries is very small and will not be easily extended.

However in the Pop II binaries of the plateau (Teff > 5600K) there is no indication that lithium is less abundant than in the single stars, leading to the impression that no depletion has occured in hot single stars.

It is possible that in fact, in tidally locked binaries several phenomena operate. For example following G. Cayrel et al. (1994) it could be that:

- on hand the absence of braking helps to preserve lithium from depletion, but
- on the other hand, an unbraked fast rotation in a 15Gyr old star, does maintain a strong stellar wind over an "uneasually long period of time, supplying a possible explanation (mass loss) for the depletion of lithium in some of the old disk binaries.

References


