ABNORMAL BEHAVIOUR OF LITHIUM IN COEVAL STARS?

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MOTIVATION

Due to its fragility, the light element lithium (Li) is an excellent and very used indicator of stellar processes. Our interest here is to explore and try to understand the Li dispersion observed in some stellar open clusters which are not explained by the standard theories. A typical and historical case, for example, is that found for stars cooler than the stellar effective temperature Teff ~ 5500 K in the Pleiades cluster with an age of ~130 My (see details in Figure 2).

What is the mechanism that provokes this dispersion? Up to now, mainly three mechanisms are being proposed; (1) Episodic accretion during the protostellar phase (Baraffe et al. 2010). (2) Rotational stellar Internal mixing shears due to a star-disk interaction (Eggenberger et al. 2012) and (3) Li depletion by an increased stellar radius (Somers et al. 2014).

We will explore this problem using the rotational option (2) (Chavero et al. 2014) and also identifying stellar interlopers in some groups.

SOME RESULTS AND SOME QUESTIONS

1) Identifying the interlopers or filtering the cluster members

Using the WEBDA catalog of stellar clusters members and collecting from the literature the values of Ab(Li), Teff and vsini, (where Ab(Li) is the Li abundance, Teff the stellar effective temperature and vsini the projected rotational velocity) we present here the distribution of Ab(Li) versus Teff and Ab(Li) versus vsini of four open clusters with different ages: NGC 2264 (9Myr), Pleiades (135 Myr), NGC 1039 (177Myr) and Hyades (787Myr). Here, the observed Li abundance is given by Ab(Li) = 12 + log (n(Li)/n(H)), where Ab(Li) = 3.2 is the interstellar Li abundance with which the stars born.

In the case of the Pleiades, which is the cluster with more data, the dispersion of Ab(Li) vs Teff increases largely for Teff < 5500 K (see Fig 2) For Ab(Li) vs vsini (Fig. 3) the dispersion appears to be minor with the exception of near 10 points with values of Ab(Li) much depleted for their correspondent Vsini values (sred circle in Fig. 3).

A critical kinematical analysis was performed in order to identify the real stellar members of the Pleiades cluster. This leads us to the following distribution of the stellar members concerning the Li abundances as a function of vsini as can be seen in Fig. 3. Here, , we found that in general for vsini < 10 km/s stars are Li-depleted. Contrary, for vsini > 10 km/s stars are much less Li depleted from interstellar value. This pattern is expected following the results of Chavero et al. (2014). Nevertheless, there is a group of near seven stars (yellow points) of real members of the Pleiades cluster, which can be considered as "abnormal" members in respect to the pattern mentioned above. That is largely Li depleted for their large vsini values. We note, however, that surprisingly, all these stars are (moderate?) flare stars.

Stellar flares are the result of a larger stellar activity. If we consider that stars spots are at the origin of these flares, as seems to be the case for the super flare detected by Kepler (Wichman et al. 2014, arXiv: 14060612), we must admit that these intermediate type spots are somehow related to the observed Li depletion.

2) Can single stellar rotation explains the Li dispersion?

In the rotation stellar model (2) mentioned above Eggenberger et al. (2012) uses the fact that " the increase of the disk lifetime leads to a decrease in the Li content during the first ~ 10 Myr evolution of a solar-type star (Teff ~ 5800 K) owing to the larger amount of differential rotation generated during the disk locking phase "

The longer (9 Myr) braking by a disk magnetically connected to the star, the slowest will be the external rotation (vsini) and the larger will be the internal rotation and mixing (leaving to a larger Li destruction). This happens between the internal base of the convective envelope and the radiative stellar centre. Contrary, for a smaller braking time of ~ 3 Myr larger surface values of the rotation vsini will result with less or almost no Li depletion.

In Chavero et al. (2014) an important number of solar type stars with disks and no disks, with planets and no planets have been observed to measure the Li abundances. The general results confirm the Eggenberger et al. model and is in agreement with the Ab(Li) distribution versus vsini shown in Fig. 3.

3) Can superflare stars exists among these clusters?

Superflare stars have been discovered recently in the Kepler satellite data and some field solar G- type stars present larger super Li abundances (Ab(Li) = 4.0 in some cases), Honda et al. (2014) suggest that Li could be created by spallative nuclear reactions in these strong flares. The results appear however contradictory as respect which is the mechanism originating these flares. In some stars with vsini values between 25 and 40 km/s these super Li values are present. However, also slow rotators (vsini < 10 km/s) present large but normal Ab(Li) values between 3 and 2. This result is absolutely independent on the outlined stars which are typified as flare stars. A fundamental progress can be made at this respect if the 6Li isotope (formed only by spallation reactions) is detected in the spectra of these super Li rich stars mentioned above.

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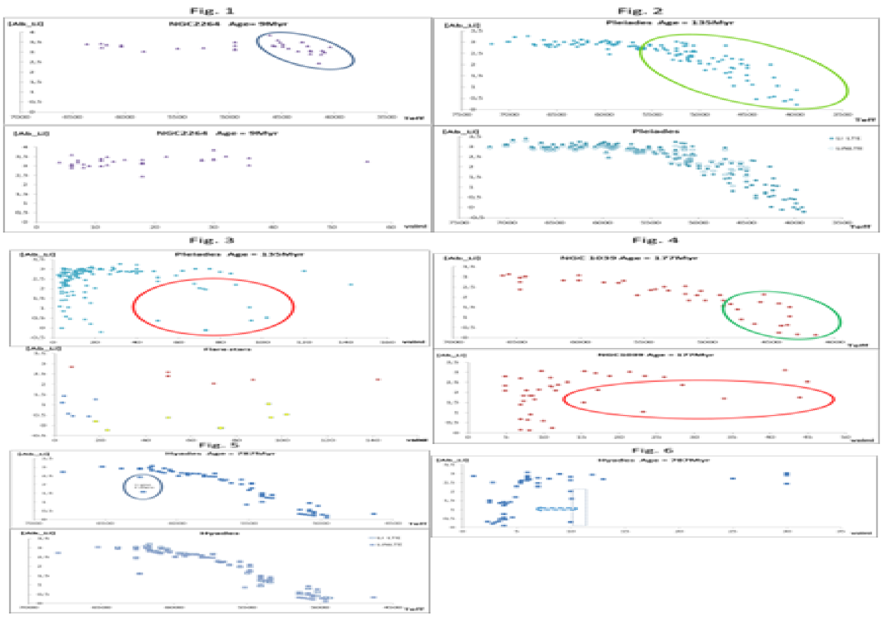

Figure caption: Figures present here the distribution of the Li abundances with age for Teff and for vsini.

For Teff:
For the very young cluster NGC 2264 (9 Myr) we can see that the Li dispersion appears only for Teff < 4500 K. For the older clusters as the Pleiades (~130 Myr), NGC 1039 (177Myr) and Hyades (500Myr) these dispersions begin at hotter temperatures ≥5500 K. The known "Li Gap for F type stars" between 6000 K and 7000 K, appears to begin at ~ 150 Myr (Steinhauer & Deliyannis 2004). It is interesting to note that one or two points of NGC 1039 (177 Myr) are also indicating the beginning of this Li Gap at 6500 K (Fig. 4). This Li Gap is more developed for the older Hyades (see the points at ~ 6250 K). Abundances calculated in LTE or NLTE show slight differences as to take them into consideration.

For vsini:
The distribution of Ab(Li) vs rotation (vsini) is even more interesting. In general, for clusters with ages beginning at ~130 Myr and older the distribution follows a typical pattern (if the stars in the indicated circles do not belong to the clusters as is the case of the Pleiades) in which in general, for values of vsini < 10 km/s the stars are largely Li depleted. Contrary, for more rapid rotators (vsini > 10 km/s) stars are much less Li depleted. Note that for the very young cluster NGC2264 (9Myr) Li depletion by rotation effect seems not to have the time to appear.
Circles stuffed in yellow represent flares stars members of Pleiades cluster.