LITHIUM AND BINARITY IN M67

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ABSTRACT.

A study of the lithium abundances in binaries of the old open cluster M67 is presented. Abundances were estimated using curves of growth and equivalent widths of the LiI6707.8 Å doublet. We have corrected of the effects of the companion on the measured equivalent width and on the color indices by deconvolving the photometry, computing colors and magnitudes for each component.

As happens in the Hyades cluster, there are some lithium excesses in main–sequence and evolved TLBS binaries with respect other binaries and single stars, although the M67 data have large errors.

1. The data

We present a study of lithium abundances in M67 binaries, selected from 2 different photometric studies: Sanders (1989) and Montgomery et al. (1993). Our sample covers systems in a variety of evolutionary stages and orbital periods.

Three different observing runs were carried out at Kitt Peak National Observatory (Jan 1994, Jan 1996 and Jan 1997), using the Mayall 4m telescope. We also used the 2.5m INT and the 4.2m WHT telescopes (March 1996 in the first case, May 1996 and March 1997 in the second) at the "Roque de los Muchachos" Observatory. The final resolutions were R$\sim$ 45 000, 50 000 and 12 000, for the KPNO, WHT and INT data.

Binaries are, on average, brighter that single stars and/or than the cluster isochrone at the same (B–V) value. Following Barrado y Navascués & Stauffer (1996), we have deconvolved the photometry of our binaries to obtain colors, magnitudes of their components and continuum correction factors. The actual deconvolution process consists on the calculation of fictitious binaries using the photometric data from the isochrone, adding pairs of stars as primary and secondary. The comparison between the calculated and the observed data provides the best solution for the deconvolution.

Fig. 1 shows the computed location of binaries in the V-(B–V) plane. The wide solid line represents a 4×10^9 yr old isochrone, using (m–M)=9.60, E(B-V)=0.04, and the dotted lines corresponds to different series of calculations. Although the deconvolution of the photometry can be very powerful, our results should be taken with some caveats due to the uncertainties in the original data.

In order to estimate the lithium abundances of our sample of stars, we measured equivalent widths of the LiI6707.8 Å feature. Since some of these binaries have poor or unknown ephemerides, we measured the wavelength of very prominent lines in the

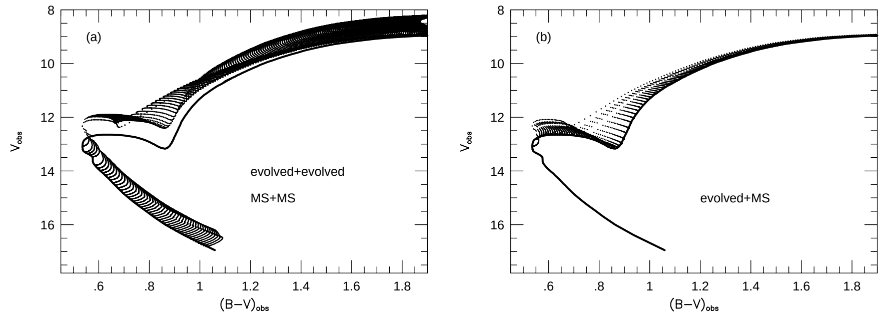

Fig. 1. M67 isochrone in the Color-Magnitude Diagram (wide solid line) and the location of computed binaries. **a.-** Binaries formed by MS components only or by evolved stars only. **b.-** Systems having an evolved primary and a MS secondary.

spectral range around the lithium feature for the primary component in the case of SB1 spectra, and for both, in the case of the SB2 systems. Then, we identified the FeI6707.4 Å and LiI6707.8 Å lines. In some cases, due to the resolution and/or the Doppler broadening, both features were blended. However, we normally did not have problems to deblend them by fitting Gaussian curves and to obtain the respective equivalent widths. When this process was not possible, we only measured the total equivalent width and eliminated the contribution of the FeI line by measuring the equivalent widths of other iron lines. Then we used empirical relations to determine the contribution. We estimated the effective temperatures using Thorburn et al. (1993) scale.

Preliminary lithium abundances were estimated using curves of growth. We selected the Pallavicini et al. (1987) set, adding a curve from Soderblom et al. (1993) for T_{eff}=4000 K. These abundances are still tentative, since we are improving the corrections of the spectral continuum and the colors due to the presence of a companion.

2. Lithium in the Main Sequence and beyond

Fig 2a shows the T_{eff}–Log N(Li) plane. Some evolved binaries have higher abundances than similar single stars. Almost half of the sample of main–sequence binaries have abundances close to their initial level –Log N(Li)$\sim$3.2–. This phenomenon is clearly illustrated in Fig. 3, which contains the normalized histograms for the lithium abundances of main–sequence binary and single stars. We selected stars having temperatures higher than 5900 K. Although the sample is not large, both the minimum and the maximum abundances of binaries are larger than their counterparts for the single stars, and the values of the abundances of binaries show a peak around Log N(Li)$\sim$2.9. Tidally Locked Binary Systems (TLBS) belonging to the Hyades have larger abundances than its singles members (Barrado y Navascués & Stauffer 1996), and binaries with no coupling between the orbital and the rotational periods have over and under abundances when comparing with single stars. Fig. 2b includes data corresponding to binaries from the Hyades and

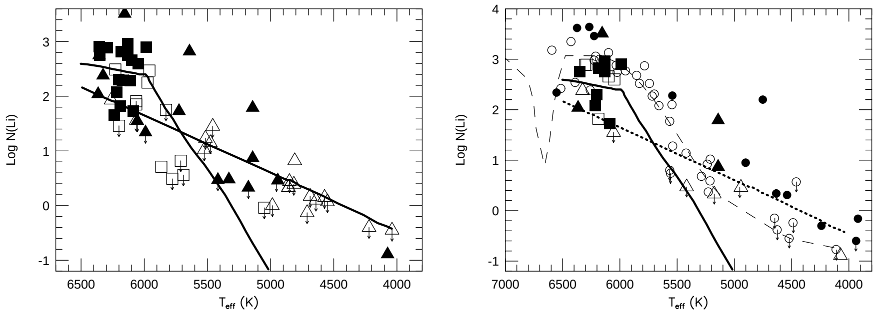

Fig. 2. Li abundances against effective temperatures. **a.-** Single stars are shown as open symbols and binaries as solid ones (triangles for evolved systems and squares MS). **b.-** Hyades (circles) and M67 binaries (triangles). Solid symbols represent synchronized binaries, whereas open ones show other binaries The solid, dashed and dotted lines represent the behavior of main–sequence M67, evolved M67 and main–sequence Hyades single stars.

M67. For Hyades binaries, we have assumed that those systems having $P_{orb} \leq 9$ days are synchronized, since they are expected to arrive the Zero Age Main Sequence (ZAMS) with equal rotational and orbital periods. In the case of M67 binaries, we have assumed synchronization for MS binaries if $P_{orb} \leq 10$ days, whereas evolved M67 binaries with $P_{orb} \leq 20$ days are in fact TLBS. This happens because they can synchronize the rotation with the orbital period during the main–sequence life–time or during the evolution off the MS, when deep convective external layers are developed.

Fast rotators belonging to the Pleiades (70–120 Myr) have larger abundances than slow ones (García–López et al. 1994), but the few Pleiades TLBS have abundances compatible with their single counterparts. This fact probably rules out that the lithium overabundance in TLBS develops during the PMS life–time.

Hyades TLBS appear to show Li excesses for objects in the range 6500–4000 K, when comparing with longer period binaries or single stars. In the case of M67 dwarf binaries, they appear to have Li excesses. However, several TLBS have abundances below the *maximum* values of single stars. There are also several binaries having longer orbital periods and abundances close to the maximum values of the TLBS, demonstrating that there is no clear link between Li and P_{orb} for old binaries. In any case, the average abundance is larger in the case of TLBS than other binaries or single stars.

A preliminary conclusion can be drawn from Fig. 2b, that Li depletion is inhibited in M67 TLBS, although the reason why is not clear. On one hand, these possible excesses could appear during the first gigayear (till the Hyades' age or a little longer) due to the inhibition related to rotation (see discussion in Barrado y Navascués & Stauffer 1996) and they could decrease afterwards. On the other hard, these M67 stars are quite close to the turn off point and to the Li dip. The fast and important evolution of the internal structure which take place at that moment, together the uncertainties in T_{eff}, make the interpretation of this phenomenology difficult.

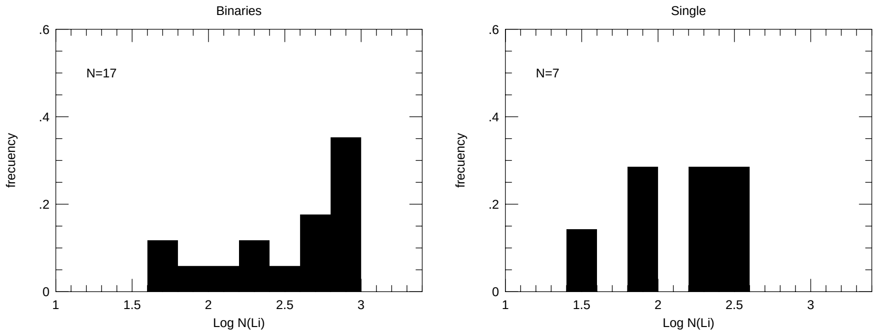

Fig. 3. Histograms of the distribution of lithium abundances in main–sequence M67 stars (6500 > T_{eff} > 5900 K). **a** Binaries. **b** Single stars.

Fig. 2b shows that binarity could be an important factor in the evolution of lithium in evolved stars. All four evolved TLBS have been synchronized on the MS (or, perhaps, during the evolution along the giant gap). They show Li in their spectra, and their abundances are larger than the average values for their temperatures.

This fact could be interpreted as a prove that quasi-synchronous systems at ZAMS (binaries close to synchronization, but with P_{orb} slightly larger than 8 days) have enough transfer of angular momentum to prevent some lithium depletion.

3. conclusions

This study establishes several preliminary conclusions: MS binaries seem to have larger abundances, on average, than their single counterparts. These excesses should be tested by more exhaustive analysis. These excesses could appear between Pleiades and Hyades' age. We have also found lithium in several TLBS giant binaries.

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