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Fast-rotating Nearby Solar-type Stars

G. Cutispoto[1], L. Pastori[2], L. Pasquini[3], J.R. de Medeiros[4],
G. Tagliaferri[2], J. Andersen[5]

Abstract. We present the results of high-resolution spectroscopy and high-precision photometry on a sample of 110 fast rotating late-F and G-type nearby stars. We infer spectral types, compute radial velocities, $v\,sin\,i$, Li abundances and X-ray luminosities of these stars. We find statistically higher Li abundances and activity levels than for samples of field stars with similar characteristics but slower rotation. We find a large fraction of binaries ($\simeq 62\%$) and of young single disk stars. At least 8 single stars can be considered bona-fide PMS or ZAMS objects, while 30 stars are identified as SBs for the first time. Surprisingly, we also find al least 3 rapid rotating single MS stars with a very low Li abundance. The results on our sample confirm the presence of young very active stars close to the Sun, in agreement with recent findings coming from UV and X-ray surveys.

1. Introduction

A detailed investigation of young stars is certainly relevant for our understanding of the evolution of PMS stars and of the dynamical and chemical evolution of the Galaxy. To date few PTTS and ZAMS have been studied in the solar neighbourhood, in spite of the fact that these stars are in a very crucial phase of evolution. According to Skumanich (1972) the most relevant signatures of youth are high $v\,sin\,i$, high Li abundance (A_{Li}) and high chromospheric/coronal activity. Moreover, $v\,sin\,i$, A_{Li} and activity should decrease with stellar age. Recent studies have shown that this scenario, although still valid in a broad sense, is more complex than originally thought. In this framework we observed a sample of stars selected on the basis of high $v\,sin\,i$.

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[1] Catania Astrophysical Observatory

[2] Brera Astronomical Observatory

[3] European Southern Observatory

[4] University Federal of Rio Grande do Norte

[5] Copenhagen Astronomical Observatory

2. Data Sample and Observations

We selected a sample of F8-G9 stars brighter than V $\simeq 8.6$ with $v\,sin\,i \geq 8\,\mathrm{km\,s^{-1}}$, as measured from the width of the CORAVEL cross-correlation peak. Out of the 220 stars thus selected, 110 were suitable for observations in the southern hemisphere. High resolution spectroscopy (R$\simeq$100,000 in a region which includes the Li I 6707.8 Å doublet) and high precision $UBV(RI)_c$ photometry have been obtained using the 1.4 m CAT and the 0.5 m ESO telescopes, respectively.

3. Analysis

For each star we inferred accurate spectral type and luminosity class and investigated the presence of companions. We computed A_{Li} including n-LTE corrections and $v\,sin\,i$. We searched the ROSAT all-sky survey catalogue and derived the ROSAT PSPC X-ray luminosity (L_X). Our careful stellar parameters determination was a fundamental step to compute precise A_{Li}, because it allowed to give proper weights to the components of binaries and to infer fairly accurate T_{eff}. Fig.1 shows the $B-V$ vs. M_V diagram for the stars in our sample. In the following, components of visual binaries (VBs) which do not contain spectroscopic binaries (SBs) have been included in the sample of single stars. In fact, the long period binary stars, and in particular components of VBs, lack those peculiar phenomena that can significantly change the evolution and/or the rotational history of a short period binary star.

4. Results

- We discovered that 17 and 13 stars in our sample, given as single in the SIMBAD database, are indeed SB1 and SB2 systems, respectively.
- In our sample 42 stars ($\simeq$38%) are single, 34 ($\simeq$31%) are VBs (13 of them contain at least one SB) and 34 ($\simeq$31%) are SBs. This yields to a single:binaries ratio of 38:62, to be compared with the 57:43 (or 51:49 in a less restrictive case) value found by Duquennoy & Mayor (1991) for nearby F7-G9 field stars. We selected fast rotators, thus binaries, in particular the tidally locked ones, enter more numerous in the sample.
- We inferred A_{Li} values or upper limits for 42 single stars, 20 primary and 15 secondary components of VBs, 40 primary and 21 secondary components of SBs. Fig.2, panel (a) and panel (b) shows A_{Li} vs. $B-V$ for MS single stars plus MS single components of VBs and for evolved single stars plus evolved single components of VBs, respectively.
- A lot of the stars in Fig.2 panel (a) are young, with age of the order of 1 Gyr or less. In fact, out of the 59 MS single stars studied 6 ($\simeq$ 10%) have an A_{Li} higher than that of the Pleiades, 38 ($\simeq$ 64%) have an A_{Li} in between that of the Pleiades and Hyades, 10 ($\simeq$ 17%) have an A_{Li} lower than that of the Hyades. Surprisingly, for 5 stars ($\simeq$ 9%) we measured only an upper limit for A_{Li}. At least 3 of them appear as genuine single fast rotating MS stars; thus, their very low A_{Li} value is quite puzzling.

- In Fig.2 panel (b) the A_{Li} values are, on average and as expected, lower than the values in panel (a). For 5 stars we measured only an upper limit and this is difficult to explain. Surveys of evolved stars have shown a sharp decrease in A_{Li} just after the objects leave the MS (Randich et al. 2000; Lèbre et al. 1999), but such drastic drop has been associated with effects related to the stellar rotational history, while our stars are still pretty fast rotators. Finally, there are two stars with A_{Li}=3.3, a value never found among giants. We regard these objects as PMS stars.

- Fig.3 shows A_{Li} vs. $B-V$ for MS close binary (panel a) and for evolved close binary (panel b). In panel (a) a large number of stars with low A_{Li} and a mixed age population is evident. This is expected: high rotation can be sustained by tidal interaction also in old systems with low A_{Li}. Out of the 47 MS binaries 3 ($\simeq 8\%$) have an A_{Li} higher than that of the Pleiades, 16 ($\simeq 40\%$) have an A_{Li} in between the Pleiades and Hyades, 5 ($\simeq 12\%$) have an A_{Li} lower than that of the Hyades, while for 16 stars ($\simeq 40\%$) we were able to measure only an upper limit. One star in panel (b) has A_{Li}=3.3. We regard this object as a binary PMS.

- In Fig.4 we plot A_{Li} vs. $\mathrm{v} \sin \mathrm{i}$. We did not see any difference between MS and evolved stars. Instead, there is a clear difference between single (panel a) and binary (panel b) stars. All single stars with $v\,sin\,i > 18\,km\,s^{-1}$, have $A_{Li} \geq 2.0$, while there are binaries with $v\,sin\,i \sim 30$ $\mathrm{km\,s^{-1}}$ for which we were only able to infer an upper limit for A_{Li}.

- In Fig.5 we show the L_X vs. $v\,sin\,i$ relationship. As it is well known, L_X of single stars (panel a) is associated with the star rotation, although with a large scatter, and all single fast rotators are also very active in the X-ray. A similar situation is present for the binaries (panel b).

- In Fig.6 we plot the L_X vs. A_{Li} for single MS (panel a) and evolved (panel b) stars. L_X is clearly correlated with A_{Li}. This correlation is particularly evident for evolved stars, although the sample is small and we cannot draw any strong implications. For binaries no correlation is seen.

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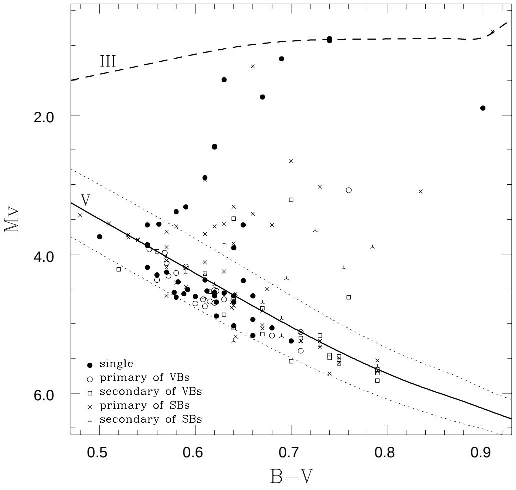

Figure 1. $B-V$ vs. M_V diagram for the stars in our sample. The continuous line and the long-dashed lines are the MS and the class III giant sequences, respectively, from Hipparcos data (Houk et al. 1997); the short-dashed lines indicate the limits of the dispersion of MS stars

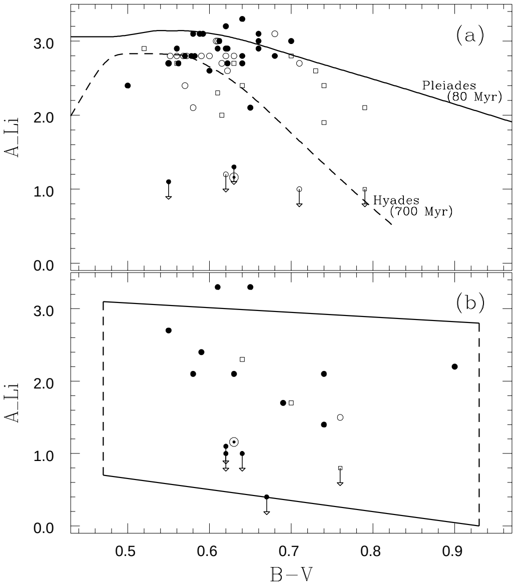

Figure 2. A_{Li} vs. $B-V$ for single stars and single components of VBs. Symbols are as in Figure 1. Panel (a): stars on the MS; the solid curve and the dashed curve are the fiducial A_{Li} vs. $B-V$ curves for the Hyades and Pleiades clusters (adapted from Deliyannis 2000), respectively; Panel (b): evolved stars; the area inside the quadrangle is the region populated by subgiants, giants and supergiants (adapted from Mallik 1999). The position of the Sun is shown

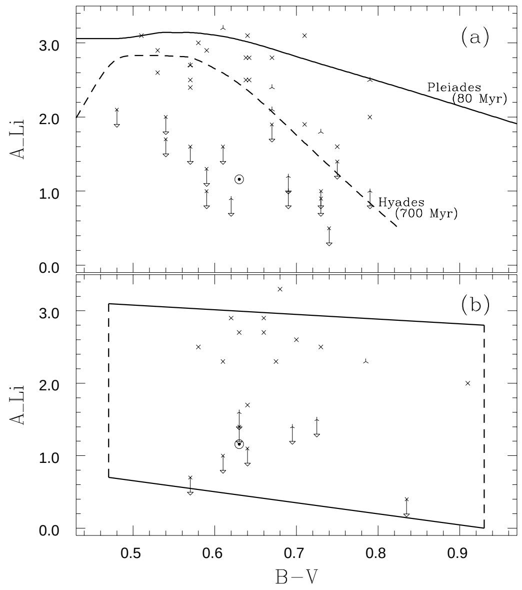

Figure 3. A_{Li} vs. $B-V$ for close binaries. Symbols are as in Figure 1, curves are as in Figure 2. Panel (a): stars on the MS; panel (b): evolved stars. The position of the Sun is shown

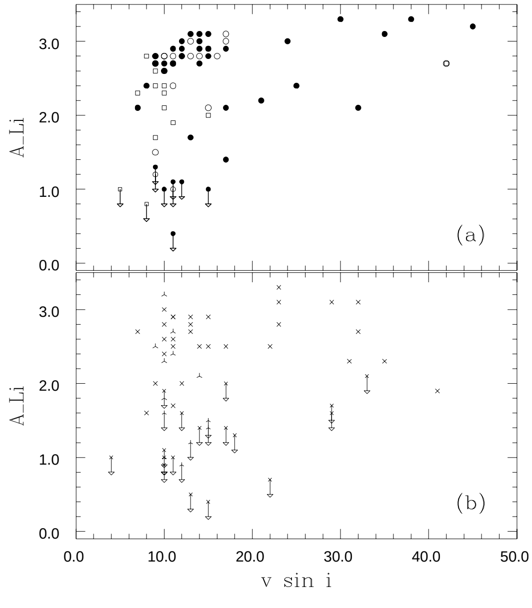

Figure 4. A_{Li} vs. $v\,sin\,i$ for single (panel a) and binary stars (panel b). Symbols are as in Figure 1. Note that while all single stars with vsini $> 18\,km\,s^{-1}$ have $A_{Li} \geq 2.0$, there are binaries with vsini $\sim 30\,km\,s^{-1}$ for which only an upper limit of A_{Li} was obtained. In our sample of fast rotators single stars have, on average, higher A_{Li} values than binary stars

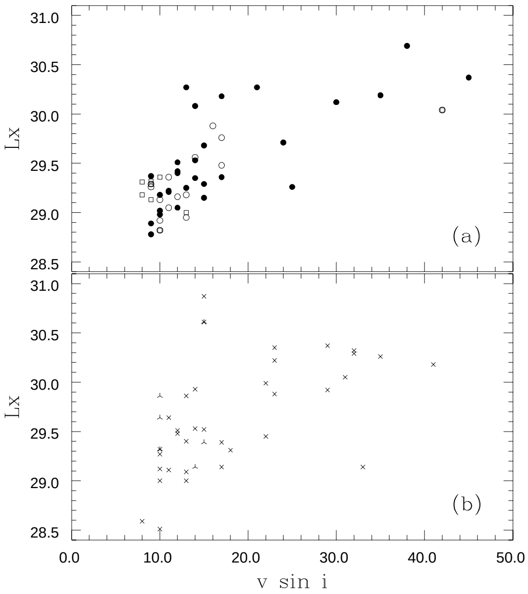

Figure 5. L_X vs. $v \sin i$ for the single (panel a) and the binary (panel b) stars in our sample for which we found a detection in the RASS. Symbols are as in Figure 1. As expected L_X correlates with the star rotation rate, although with a large scatter, and all fast rotators are also very active in the X-ray

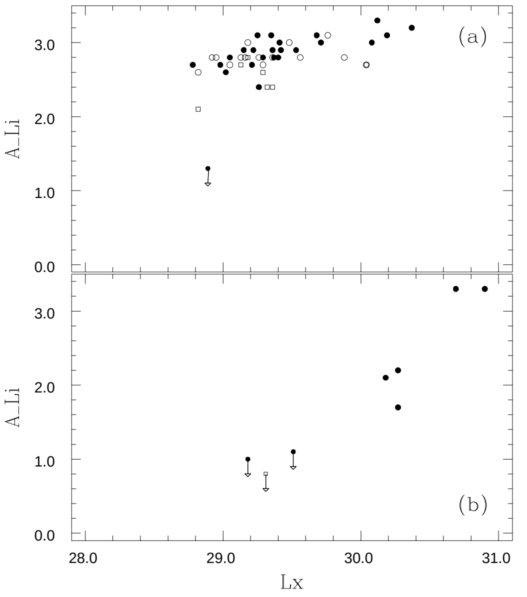

Figure 6. L_X vs. A_{Li} for single stars. Symbols are as in Figure 1. L_X is clearly correlated with A_{Li}. This correlation is particularly evident for evolved stars (panel b), although the latter sample is rather small