Ca II H and K and Hα, and Li Abundances in the Pleiades Late K Main-Sequence

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Abstract: We have observed seven main sequence stars in the Pleiades, with $B-V$ between 0.98 and 1.41 (5100–3900 K), and with a wide range of rotational velocities, in Ca II H and K, Hα and have derived Li abundances. Our results, combined with literature data, indicate that the most chromospherically active stars are rapid rotators, and that at a given effective temperature the Li-rich stars show the highest chromospheric activity. A different surface coverage of active regions could influence the dichotomy observed in the Li abundance distribution.

1. Introduction and observations

The Pleiades is a nearby, young ($6-7\times10^7$ yrs), open cluster. Differences of a few 10^7 years have been proposed between the age derived from the MS-turnoff and the age estimated by pre-MS modelling of the low mass stars (Herbig, 1962; Stauffer, 1980; Duncan and Jones, 1983; Stauffer *et al.*, 1984), implying a spread of times of star formation. Recently, however, Mazzei and Pigatto (1989) have obtained an age of 1.5×10^8 yrs, by comparing the cluster HR diagram with isochrones derived from overshooting evolutionary models, thus reducing the importance of a star formation that is dispersed in time.

In this cluster the K and M stars are particularly useful for studying the common age question. Plots of $v\sin i$ (Stauffer and Hartmann, 1987) show a trend to lower values at later spectral type, and an apparently bimodal distribution, with a gap for $20 < v\sin i < 50$ km s^{-1}. Butler *et al.* (1987) found in 4 rapid rotators out of 11 K Pleiades stars Li to be more abundant by an order of magnitude than in 4 slow rotators, suggesting that this difference in Li is due to an age difference between the two groups.

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We observed 7 Pleiades dwarfs with $B-V$ between 0.98 and 1.41, on 17^{th} and 19^{th} Nov. 1989, with the ISIS spectrograph at the Cassegrain focus of the 4.2 m William Herschel telescope on La Palma. ISIS permits simultaneous blue and red observations. In the red, using a CCD, we could observe both Hα (λ6563 Å) and Li I λ6708 Å at a dispersion of 0.37 Å pixel^{-1} and a resolution $\lambda/\Delta\lambda \sim 1 \times 10^4$. In the blue we observed Ca II H and K ($\lambda\lambda$3933, 3969 Å) using an IPCS detector at a dispersion of 0.11 Å pixel^{-1}, with a resolution $\lambda/\Delta\lambda \sim 1 \times 10^4$. A standard data reduction was performed using the IRAF software package.

2. Chromospheric activity and Li abundances

We computed the absolute flux in Ca II H and K emission using the method of Linsky *et al.* (1979), which calibrates the continuum near H and K against $V - R$. In Figure 1 we show Ca II K flux (F(K)) versus effective temperature ($T_{\rm eff}$), including also the results of Blanco *et al.* (1974). The diameters of the symbols are proportional to the size of $v \sin i$. We see an upper envelope in the flux, which falls towards later spectral type, similar to the relation found in field stars (Kelch *et al.*, 1979; Strassmeier *et al.*, 1990). For each spectral type the most active stars tend to be the rapid rotators, as expected for dynamo-induced activity. Also, comparing the mean flux in Ca II K for a given spectral type with those from the literature for older systems, we find a clear fall-off in chromospheric activity with age, comparable to that found in G dwarfs by Barry (1988). In fact, the mean value of this activity can be used as a criterion for cluster membership (Kraft and Greenstein, 1969).

We have found that the equivalent width of Hα shows a clear trend to higher values with later spectral type, as already presented by Stauffer and Hartmann (1987). For Hα, just as for Ca II K, the rapid rotators of a given spectral type show more activity.

In Fig. 2 we show the abundances of Li against $T_{\rm eff}$, found using our equivalent widths and those from Butler *et al.* (1987), (for details see García López *et al.*, 1990). There is clearly a large scatter at a given spectral type, reaching an order of magnitude at certain $T_{\rm eff}$ values. The Li dichotomy between rapid and slow rotators found by Butler *et al.* (1987) seems to be present, but confined to stars hotter than 4500 K. Two of our stars in this range have low $v \sin i$ but Li abundances comparable with those of the rapid rotators. They could be rapid rotators whose axes are oriented near to the line of sight, a hypothesis supported by their Ca II K fluxes which are comparable with those from the rapid rotators (Fig. 1).

The abundance scatter could be real, or, in part, an observational effect due to chromospheric activity. The Li-rich stars are generally the most chromospherically active stars. The largest flux variations in Ca II K detected in Fig. 1 for a given spectral type are in the range 40–70 %. The differences in surface coverage by active regions between the "Li-rich" and "Li-poor" stars, giving rise to the detected differences in chromospheric activity, could affect the derived values of the Li abundances. Therefore the scatter in Li abundances may not imply a sequential

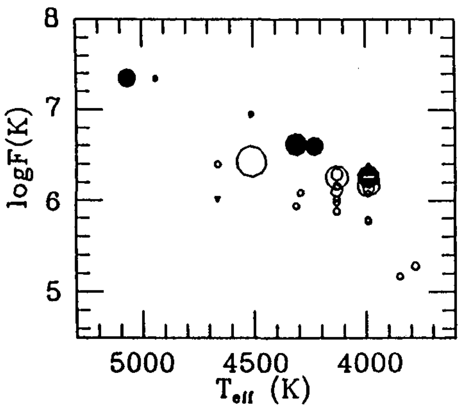

Fig. 1. Ca II K flux against $T_{\rm eff}$ for K and M dwarfs in the Pleiades. The diameters of the symbols are proportional to $v \sin i$. Open symbols are values given by Blanco *et al.* (1974); filled symbols correspond to this work.

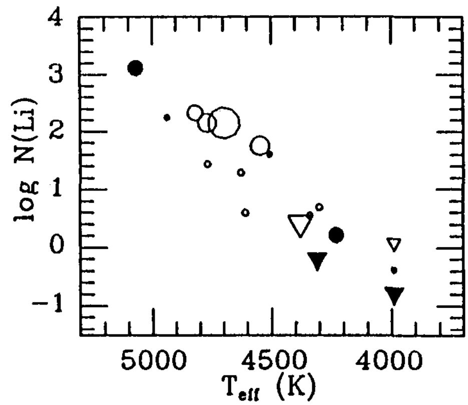

Fig. 2. Li abundances v. $T_{\rm eff}$ for low mass Pleiades stars. Open symbols: our measurements; filled symbols: equivalent widths given by Butler *et al.* (1987); their sizes are proportional to $v \sin i$.

formation in the cluster. For stars cooler than 4500 K there is no apparent relation between $v \sin i$ and logN(Li). In these very cool stars the differences between the photospheric and spot temperatures are less, and the resulting effect on the Li abundance correspondingly reduced. Further observations are required to test these effects in the hotter stars.

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