Lithium in “New” α Per Candidates Discovered by **ROSAT**

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**Abstract:**

We present the results from a lithium survey of 23 new α Persei candidates discovered by **ROSAT**. The log N(Li) vs. \(T_{\text{eff}}\) distribution of these stars is compared with that of previously known members: the distributions for the two samples are in good agreement, although in the 5000–4700 K \(T_{\text{eff}}\) range our sample stars are located on the upper envelope of previously known members. We think that this is most likely due to the X-ray selection bias in our sample. This temperature range is indeed where the rotation-Li connection is most clear.

The merged “old” + “new” sample is then compared both with the Pleiades and the IC 2602 and IC 4665 clusters. α Per stars shows a spread in lithium, but such a spread starts to be seen at a lower effective temperature than in the Pleiades.

A speculative explanation, connecting the dispersion in lithium to a spread in the timescale for disk dissipation, is given.

1. **Introduction**

**ROSAT** PSPC observations of the α Per cluster have provided a large number of new cluster candidates which were not previously identified through proper motion surveys. Follow up photometry and spectroscopy have shown that \(\sim 25\) of these new candidates are *most likely cluster members* as indicated by the position on the C-M diagram and by radial velocities. Another \(\sim 40\) sources have photometry and, when available, H\(\alpha\) consistent with membership; however, radial velocities of these objects were not measured, or they are somewhat off the cluster mean; therefore, their membership has to be confirmed by additional observations (Prosser & Randich 1997, PR in the following; Prosser, Randich, & Simon 1997, PRS in the following).

We obtained lithium and H\(\alpha\) observations of 23 of these new candidates (11 most likely + 12 uncertain ones). Our aim is twofold: on one hand, we want to use lithium for the hotter stars (and H\(\alpha\) for the cooler ones) as an additional indicator for membership. On the other hand, the present sample allows us to significantly enlarge the original sample of Balachandran et al. (1996). In particular, our sample provides a better coverage of the 4500 – 4000 K range where

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only two stars were included in this previous survey. Moreover, since our sample includes active, X-ray selected objects, we can investigate whether the distribution of their Li abundances statistically differs from that of the Balachandran et al.’s sample (which may as well include active stars, but which was not selected on the basis of activity).

2. Observations and Data Analysis

The observations were carried out at the 2.5m Isaac Newton telescope (INT) at La Palma, equipped with the Intermediate Dispersion Spectrograph (IDS). We used the 235mm camera, AgRed collimator, the H1800V grating, and a TEX 1024 × 1024 (24µm) CCD detector. Using a 460µm wide slit (2.49 arcsec on the sky) which projected onto 2 pixels, we achieved a resolution of ∼ 1 Å. Data reduction, including bias subtraction, flat-fielding, and the extraction of one-dimensional spectra, was carried out using MIDAS.

Effective temperatures were inferred from $B-V$ colors using the calibration of Alonso et al. (1996) and $V-I_C$ colors through the calibration of Randich et al. (1995) taking the mean of the two estimates. A reddening $E(B-V)=0.08$ was assumed. Colors were taken from PR and PRS. NLTE lithium abundances were estimated from measured EWs using the curves of growth of Pavlenko et al. (1995), computed with solar metallicity and log $g = 4.5$. In order to correct for the contribution of the Fe I 6707.44 Å line, the equivalent width of this line was computed with an abundance log N(Fe)=7.51 for all the stars and subtracted from the measured Li equivalent width. The final uncertainties in the abundances are of the order of 0.15 – 0.3 dex and take into account the error in measuring the equivalent widths, the uncertainty in $T_{eff}$ (which reflects the dispersion between the two calibrations used and an uncertainty of 0.02 mag in $E(B-V)$), and an error of 0.05 dex reflecting the uncertainties in log $g$ and microturbulence.

3. Results

3.1. Comparison with Previous Surveys in α Per

In Figure 1 we plot NLTE lithium abundances vs. $T_{eff}$ for our sample stars (filled circles) and previously known members from Balachandran et al. (1996) and García López et al. (1994) (open circles). These two datasets have been re-analyzed consistently with our sample, starting from the published EWs. The figure shows the following features:

- Five (∼ 20 %) of the new candidates (indicated by crosses in the figure) are most likely nonmembers. Four of them have log N(Li) considerably below previously known members. Given the very late spectral-type of the fifth one, the absence of lithium is not a definitive proof against membership; however, Hα is not seen in emission, suggesting that it is a nonmember;

- Once dropped the five likely nonmembers are dropped from our sample, abundances for “old” and “new” cluster members are consistent. New candidate members, however, tend to stay on the upper envelope of the
lithium vs. $T_{\text{eff}}$ distribution, in particular in the $\sim 4700 - 5000$ K $T_{\text{eff}}$ interval. Given the selection criteria, our sample is biased toward active stars; if, as previous studies have suggested (see also §4), there is a link between lithium and rotation/activity for stars warmer than $\sim 4500$ K, one would indeed expect stars in our sample to show, on average, a higher lithium.

3.2. Comparison with Other Young Clusters

In the lower panel of Figure 2 we show log N(Li) vs. $T_{\text{eff}}$ for $\alpha$ Per considering the merged “old” plus “new” sample (filled symbols) and the Pleiades (open symbols), while in the upper panel $\alpha$ Per is compared with IC 2602 (30 Myr, open squares) and IC 4665 (35 Myr, open circles). The figures shows that:

- warm stars above $5300$ K ($0.9 \, M_\odot$) in $\alpha$ Per and the Pleiades have, on average, the same distribution. No major spread is visible. The two younger clusters start showing some depletion only around $5800-5700$ K ($\sim 1M_\odot$); this suggests, as already pointed out by Randich et al. (1995) and Martin & Montes (1997), that no PMS Li burning occurs for masses larger than $\sim 1M_\odot$;

- in the four clusters, stars cooler than $5300-5200$ K show a dispersion in log N(Li), although the range of the spread and the temperature at which it is first seen differ from cluster to cluster. In particular, the spread in $\alpha$ Per starts to be seen at a later spectral–type than in the Pleiades;
Figure 2. Lower panel: log N(Li) vs. $T_{\text{eff}}$ for $\alpha$ Per merged “old” and “new” samples (filled symbols) and the Pleiades (open symbols). Upper panel: same as lower panel, but open symbols represent IC 2602 and IC 4665 members.
stars cooler than 4500 K in the four clusters are strongly depleted; however, cool stars in α Per (and the IC clusters) do not have, on average, more lithium than the Pleiades, as one would expect given the difference in age. A statistical test has shown that this is not due to the small size of the α Per sample.

4. Discussion

In Figure 3 we plot again log N(Li) vs. $T_{\text{eff}}$ for α Per (upper panel) and the Pleiades (lower panel) in the 4500 – 5500 range. Objects with different $v \sin i$ are represented with different symbols; instead of considering a continuous distribution of velocities, as is usually done, we subdivided the sample in objects with $v \sin i$ above and below (filled and open symbols, respectively) a threshold velocity $v_{\text{thr}}$. We choose $v_{\text{thr}} = 15 \text{ km/sec}$. Crosses indicate known binaries (both photometric and spectroscopic ones) or radial velocity variables. The figure confirms the now well known result that, in this temperature interval, rapid rotators have higher lithium than slow rotators (e.g., Soderblom et al. 1993). However, the figure shows an additional feature: rapid rotators appear to be characterized by a narrower spread than slow rotators.

This result gives a possible key to distinguish between different mechanisms which have been proposed to explain the dispersion. Bouvier et al. (1997) modeled the early rotational evolution of solar-type and low mass stars, assuming disk-locking. Differential internal rotation is needed in order to fit the distribution for slow rotators (Bouvier 1997), while the one for fast rotators is well reproduced by the assumption of solid body. Due to the decrease of the moment of inertia, slow rotators undergo a strong angular momentum loss during the PMS phase, and both the velocity on the ZAMS and the amount of angular momentum lost depend more strongly on the timescale for the dissipation of the disk ($\tau_{\text{disk}}$) than on the initial angular momentum. Angular momentum transport, and thus mixing of material and Li burning, are thus expected during PMS and should also depend on $\tau_{\text{disk}}$. We point out that there is a difference between this qualitative picture and the model of Pinsonneault et al. (1990): they proposed that different initial angular momenta would result in different amounts of mixing, and eventually in a dispersion in lithium. On the contrary, in the assumption of disk-locking + differential rotation, $\tau_{\text{disk}}$ seems to be the most important parameter for the rotational evolution of slow rotators. One could therefore hypothesize that the spread in lithium which is seen among slow rotators mainly reflects a spread in $\tau_{\text{disk}}$. On the other hand, fast and moderate rotators have dissipated their circumstellar disks at early stages of their evolution, and thus spin-up on their way to the MS. These objects do not undergo dramatic losses of angular momentum until they reach the ZAMS; therefore strong transport of angular momentum and differential lithium depletion due to different angular momentum loss should not occur.
Figure 3. Upper panel: log N(Li) vs. \( T_{\text{eff}} \) for \( \alpha \) Per stars with \( v\sin i > 15 \) km/sec (filled symbols) and \( v\sin i \leq 15 \) (open circles); Lower panel: same as upper panel, but Pleiades are shown. Crosses indicate binaries or radial velocity variables (i.e., possible binaries).
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