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LITHIUM IN THE PLEIADES AND α PERSEI CLUSTERS

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ABSTRACT

We have made observations of the Li region in 23 F dwarfs of the Pleiades and α Per clusters with a TI CCD at the coudé spectrograph of the 200 inch (5.1 m) telescope with a spectral resolution of 0.2 Å and 2 σ signal-to-noise ratios of 100–300. These two clusters are an order of magnitude younger than the Hyades, Coma, and UMa Group where the Li-temperature profile of the F dwarfs is dramatic, with deep depletions of Li in the middle-F dwarfs. All 21 of our stars in the temperature region 6100–7300 K show strong Li I lines with values of log N(Li) near 3.0 [where log N(H) = 12.0]; the mean is 2.98 ± 0.13. Because of the high quality of our data and the care taken in determining the temperatures, the errors in these Li abundances are typically ± 0.07 dex. There is no apparent Li dip in the Pleiades Li-temperature profile, although a decrease to log N(Li) ~ 2.85 near 6500 K cannot be excluded. It is clear that the Li depletions in the mid-F stars did not occur during the pre–main-sequence phase. The dramatic decline in surface Li, possibly caused by diffusion or differential rotation, apparently occurs for cluster stars between the ages of $\sim 5 \times 10^7$ and $\sim 5 \times 10^8$ yr. We have determined the [Fe/H] abundances for each of our Pleiades and α Per stars. The mean [Fe/H] for the Pleiades is 0.00 ± 0.05 and for α Per is $+0.01 \pm 0.07$.

Subject headings: clusters: open — stars: abundances

I. INTRODUCTION

In a spectroscopic survey of Li in the Hyades F stars at high resolution and high signal-to-noise ratio, Boesgaard and Tripicco (1986*a*) discovered a remarkable variation of Li abundance with temperature. The hottest F stars ($T \sim 7000$ K) showed Li/H values of 10^{-9}, while the Li content decreased toward 6600 K where it is depleted by over two orders of magnitude and then shows a regular rise again reaching values close to 10^{-9} near 6300 K. This Li-temperature profile in the Hyades is surprising in the uniformity of Li/H with temperature, in the narrowness of the Li "gap," and in the size of the Li depletions.

Similar Li-temperature profiles have now been observed in F stars in several other galactic clusters. Striking depletions of Li in the middle-F stars have been observed in NGC 752 (Hobbs and Pilachowski 1986), in the Coma Berenices cluster (Boesgaard 1987), in the UMa Group (Boesgaard, Budge, and Burck 1988) and confirmed in a larger sample of Hyades and Praesepe stars by Boesgaard and Budge (1988). In addition, a sample of visual binaries of known age (typical age $\sim 1.5 \times 10^9$ yr) also shows Li depletions in the mid-F star range (Boesgaard and Tripicco 1987). In the survey of F field stars done by Boesgaard and Tripicco (1986*b*) about half of the middle-F dwarfs showed normal Li abundances (Li/H = 10^{-9}), while the other half showed a Hyades-like depletion pattern. The higher Li abundances are found generally in the hotter and younger ($\lesssim 2 \times 10^9$ yr) field stars.

The UMa, Coma, and Hyades clusters are all about the same age (3, 5, and 7×10^8 yr, respectively—see, e.g., Barry, Cromwell, and Hege 1986), while NGC 752 at 1.7×10^9 yr is a little older. We have made observations in the F dwarfs of younger clusters, Pleiades at 7×10^7 yr and α Per at 2×10^7 yr (Janes and Adler 1982), to assess the influence of age on the Li-temperature profile and to determine the Li depletion time scale in the middle-F stars. Boesgaard and Tripicco (1986*a*) discuss the role of circulation of Li to deeper (hotter) layers caused by rotation/differential rotation; such circulation and subsequent Li depletion could occur during pre–main-sequence evolution or on the main sequence. Michaud (1986) has calculated the effect of diffusion of Li atoms below the convection zone in F dwarfs. He finds an order of magnitude Li depletion (not two orders of magnitude) for Hyades mid-F stars, and that the time scale for diffusion would be too long for noticeable effects in the later F dwarfs. For a younger cluster Michaud speculates that the Li "gap will be shallower and narrower."

Danziger and Conti (1966) looked at Li in three F stars and four G stars in the Pleiades over 20 yr ago with photographic spectra from the coudé spectrograph at the 200 inch telescope. More recently, Duncan and Jones (1983) used a melange of telescopes and detectors, including a 2-channel photoelectric scanner, image tubes, intensified Reticons, to investigate the Li distribution in (primarily) Pleiades G and K dwarfs. Our observational data are of significantly higher spectral resolution and higher signal-to-noise ratios than previous work and are primarily of F dwarfs.

II. OBSERVATIONS

Spectroscopic observations have been made of 17 F dwarfs in the Pleiades cluster and six F dwarfs in the α Persei cluster with the 72 inch (1.8 m) camera of the coudé spectrograph at the Hale 5 m telescope at Palomar. The detector was an

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TABLE 1

STARS OBSERVED

No.	HD	BD	Date Obs. (1986)	Sp. Type	$v \sin i$ (km s^{-1})	S/N
PLEIADES						
25.........	23061	24°536	Nov 11	F6 V	40	180
164.........	23158	23°497	Nov 10	F6 V	30	140
233.........	23195	23°499	Nov 10	F5 V	≤20	145
338.........	23247	23°503	Aug 21	F2 V	≤40	290
470.........	23289	22°537	Aug 21	F5	≤40	240
530.........	23326	23°509	Aug 21	F3 V	≤12	265
627.........	23352	24°409	Nov 10	F7 V	25	150
739.........	23386	24° 55	Nov 12	G1 V	≤12	140
948.........	23464	22°549	Nov 12	F8.5 V	≤12	185
1122.........	23511	23°526	Nov 11	F5.5 V	28	180
1132.........	23514	22°550	Nov 11	F5 V	40	150
1139.........	23513	22°551	Nov 10	F5 V	30	148
1200.........	...	22°553	Nov 10	F6 V	≤20	100
1613.........	...	23°545	Nov 12	F6 V	18	130
1726.........	23713	23°548	Nov 11	F7 V	≤12	148
1766.........	23732	...	Nov 11	F5 V	20	145
1856.........	...	23°552	Nov 12	F7 V	12	100
α PERSEI						
135.........	...	49°868	Oct 23	F5 V	≤20	140
361.........	...	49°897	Oct 24	F4 V	30	170
490.........	...	48°892	Oct 24	F3 IV–V	≤20	180
635.........	20969	49°921	Oct 23	A8 V	≤20	205
799.........	...	48°923	Oct 23	F4 V	20	190
1225.........	22326	47°862	Oct 23	F7 IV–V	≤20	170

800 × 800 TI CCD that was uv-flooded, liquid-nitrogen cooled with 15 μm pixels; see description of the Palomar CCD camera by Gunn *et al.* (1987). An image slicer of the Bowen-Walraven type was used which gave about eight slices of spectrum in typical seeing conditions. On-chip binning perpendicular to the dispersion of 1 × 2 was used. The spectra were centered at 6700 Å covering 110 Å. The 600 lines mm^{-1} mosaic grating No. 1 gives a nominal dispersion of 9.1 Å mm^{-1}; the measured FWHM of the comparison lines was 1.5 pixels corresponding to a spectral resolution of 0.21 Å.

The stars that were selected to be observed were ones that had been observed by Kraft and colleagues for $v \sin i$ in order to ensure that our spectra had sharp enough lines from which to find accurate abundances. For the Pleiades the major source of $v \sin i$ is Kraft (1967*b*) and the secondary source, Anderson, Stoeckly, and Kraft (1966). All those stars had $v \sin i < 40$ km s^{-1}. We observed all the stars in the α Per cluster from Kraft (1967*a*) that had $v \sin i < 40$ km s^{-1} with $B-V$ values between 0.32 and 0.52.

The exposure times for the selected Pleiades stars were 40–90 minutes, for the α Per stars 90–105 minutes. The resulting values for the signal-to-noise (which are given in Table 1) are 100–300 at the 2 σ level.

The Pleiades spectra were obtained on the nights of 1986 August 21, 1986 November 10, 11, and 12 UT. The α Persei stars, at declination ∼48°, required the use of the five-mirror train to the coudé focus; those spectra were obtained on the nights of 1986 October 23 and 24. Two master flat fields were-taken each night through the image slicer and the spectrograph. The stellar spectra were divided by the mean flat field taken on same night as the star. Most of the cosmic-ray events were removed by a routine that replaces the affected pixel(s) by the mean of the neighboring pixels. The spectra were summed perpendicular to the dispersion. Comparison spectra (usually an Fe-A hollow cathode) from each night were used to define the stellar wavelength scale.

The list of the stars observed, the dates of the observations, spectral types, $v \sin i$'s, and the (conservatively estimated) signal-to-noise ratios are given in Table 1. The identifying numbers of the stars are from Hertzsprung (1947) for the Pleiades and from Heckmann, Dieckvoss, and Kox (1956) for α Per. Samples of the spectra showing most of our wavelength range are shown in Figures 1, 2, and 3 for the Pleiades stars and Figure 4 for the α Per stars.

III. ANALYSIS

In determining temperatures, an attempt was made to take full advantage of the various photometric data available. In the final calculations, $B-V$, $b-y$, and Hβ photometry were ultil-

TABLE 2

PHOTOMETRY FOR PLEIADES STARS

Star HII (1)	Hβ CP (2)	$b-y$ CP (3)	$B-V$ JM; Me (4)	$(b-y)_0$ CP (5)	$(b-y)_0$ K (6)	$(B-V)_0$ B + JM (7)	$(B-V)_0$ B + Me (8)
25.........	2.662	0.317	0.48; 0.48	0.290	0.289	0.445	0.445
164.........	2.652	0.335	0.48; 0.50	0.301	0.304	0.436	0.456
233.........	2.663	0.349	0.52; 0.53	0.209	0.287	0.454	0.464
338.........	2.704	0.307	0.46; 0.48	0.241	...	0.373	0.393
470.........	2.699	0.263	0.39; 0.40	0.245	...	0.371	0.381
530.........	2.691	0.250	0.39; 0.39	0.251	0.252	0.390	0.390
627.........	2.636	0.338	0.50; 0.52	0.323	0.297	0.467	0.487
739.........	2.596	0.392	0.62; 0.63	0.377	0.400	0.601	0.611
948.........	2.606	0.376	0.60; 0.60	0.367	0.380	0.586	0.586
1122.........	2.675	0.311	0.46; 0.46	0.276	0.272	0.414	0.414
1132.........	2.688	0.316	0.49; 0.50	0.284	0.280	0.446	0.456
1139.........	2.673	0.315	0.48; 0.48	0.278	0.274	0.435	0.435
1200.........	2.659	0.358	0.54; 0.54	0.288	0.292	0.458	0.458
1613.........	2.644	0.340	0.54; 0.54	0.324	0.317	0.517	0.517
1726.........	2.652	0.350	0.55; 0.55	0.309	0.304	0.498	0.498
1766.........	2.690	0.311	0.47; 0.47	0.259	0.253	0.403	0.403
1856.........	2.628	0.359	0.56; 0.56	0.347	0.344:	0.535	0.535

NOTES.—CP: Crawford and Perry 1976; JM: Johnson and Mitchell 1958; Me: Mendoza 1967; K: Kraft 1967*b*; B: Berger 1968.

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ized. $R-I$ data were examined for use but rejected on the basis that all calibrations gave consistently lower temperatures than those obtained using the three other indices.

The first four columns of Table 2 and the first three of Table 3 contain the photometric data from several sources used in temperature calibration. For the Pleiades, the Hβ and $b-y$ photometry of Crawford and Perry (1976) and the $B-V$ photometry of both Mendoza (1967) and Johnson and Mitchell (1958) were used. Similarly, for α Per, the Hβ and $b-y$ photometry of Crawford and Barnes (1974) and the $B-V$ photometry of Mitchell (1960) were used. Additionally, for the Pleiades, the $(b-y)_0$ data of Kraft (1967*b*) were ultilized. The last four columns of Table 2 and the last two colums of Table 3 show the values of $B-V$ and $b-y$ corrected for reddening. Because both clusters exhibit significant differential reddening, we used $E(B-V)$ and $E(b-y)$ values derived for each star, as opposed to using the global corrections of the cluster means. The $b-y$ data were corrected using the $E(b-y)$ values of Crawford and Perry (1976) for the Pleiades and those of Crawford and Barnes for α Per. The Pleiades $B-V$ data were

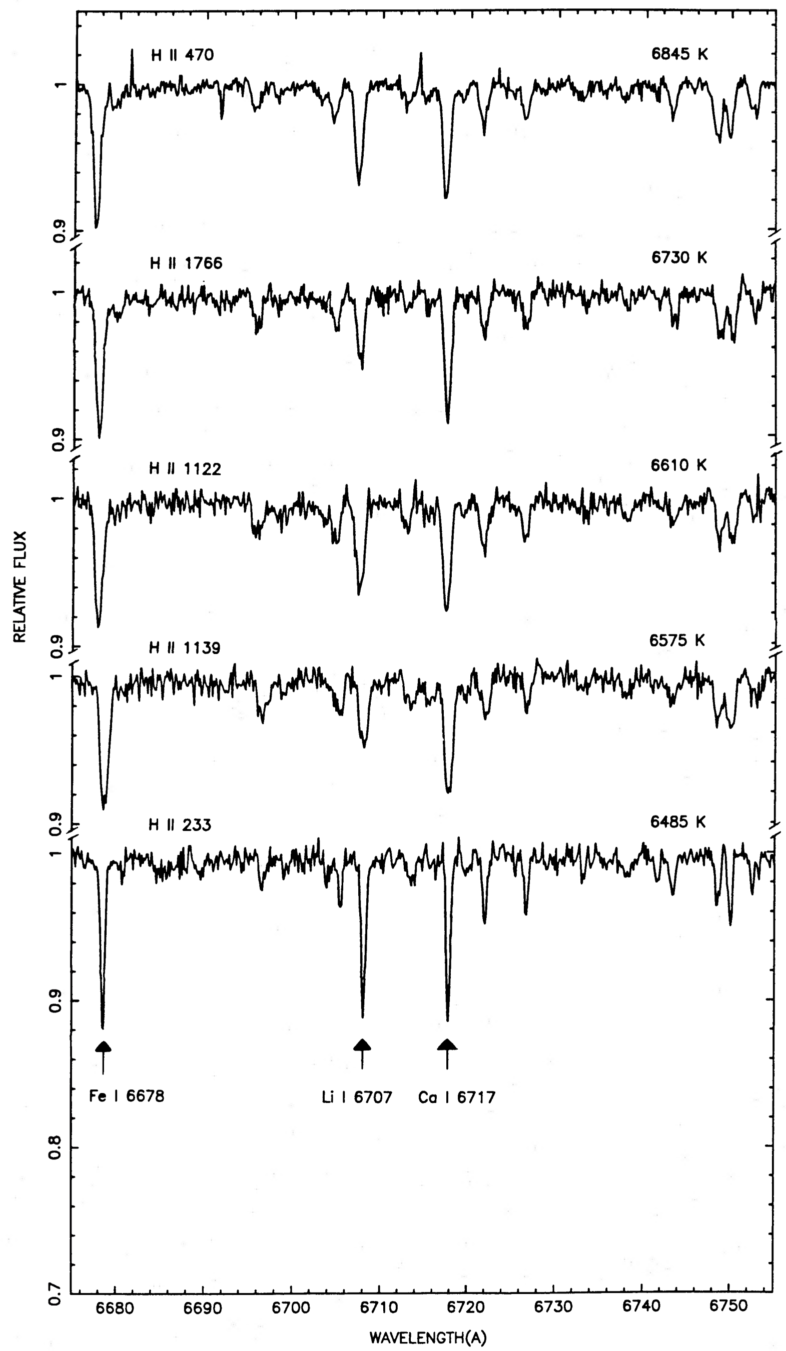

FIG. 1.—Samples of the spectra of the some of the hotter F dwarfs in the Pleiades

corrected mainly by using the $E(B-V)$ values of Breger (1968). For the two stars Breger did not include in his survey, HII 948 and HII 1132, we calculated $E(B-V)$ from $E(b-y)$ using the relation of Crawford (1973): $E(b-y) \approx 0.73\ E(B-V)$. We further ultilized this relationship in calculating $E(B-V)$ for all the α Per stars, where no separately derived $E(B-V)$ data were available.

Table 4 shows temperatures calculated from the previously described photometry. The calibrations used in determining temperatures from the $(B-V)_0$ data were those of Böhm-Vitense (1981) and Saxner and Hammerbäck (1985). The Böhm-Vitense $(B-V)_0$ calibration is in the form of a temperature versus $(B-V)_0$ diagram with two branches, the lower presumably more applicable to more rapidly rotating stars. We obtained a temperature from each $(B-V)_0$ measurement by first averaging the two temperatures obtained from the two branches of the Böhm-Vitense diagram and then averaging this with the temperature obtained from the Saxner and Hammerbäck calibration. If a star had more than one $(B-V)_0$ measurement, as most of the Pleiades stars did, we then averaged the temperatures obtained with the above method from the various $(B-V)_0$ measurements of a star to obtain a final $T(B-V_0$. These temperatures are shown in column (3). For the hottest stars, we gave further weighting to the temperatures obtained using the upper branch of the Böhm-Vitense diagram in the derivation of a final effective temperature. Therefore, we include these temperatures, herein denoted as $T(B-V)_{\rm up}$, in column (2) of Table 4.

The calibrations of Saxner and Hammerbäck were used in calculating temperatures from the Hβ and $(b-y)_0$ data. Once again, if a star had more than one $(b-y)_0$ measurement, we averaged the temperatures obtained from each measurement to obtain a final $T(b-y)_0$. These temperatures are displayed in columns (4) and (5). One α Per star, H635, had values of Hβ

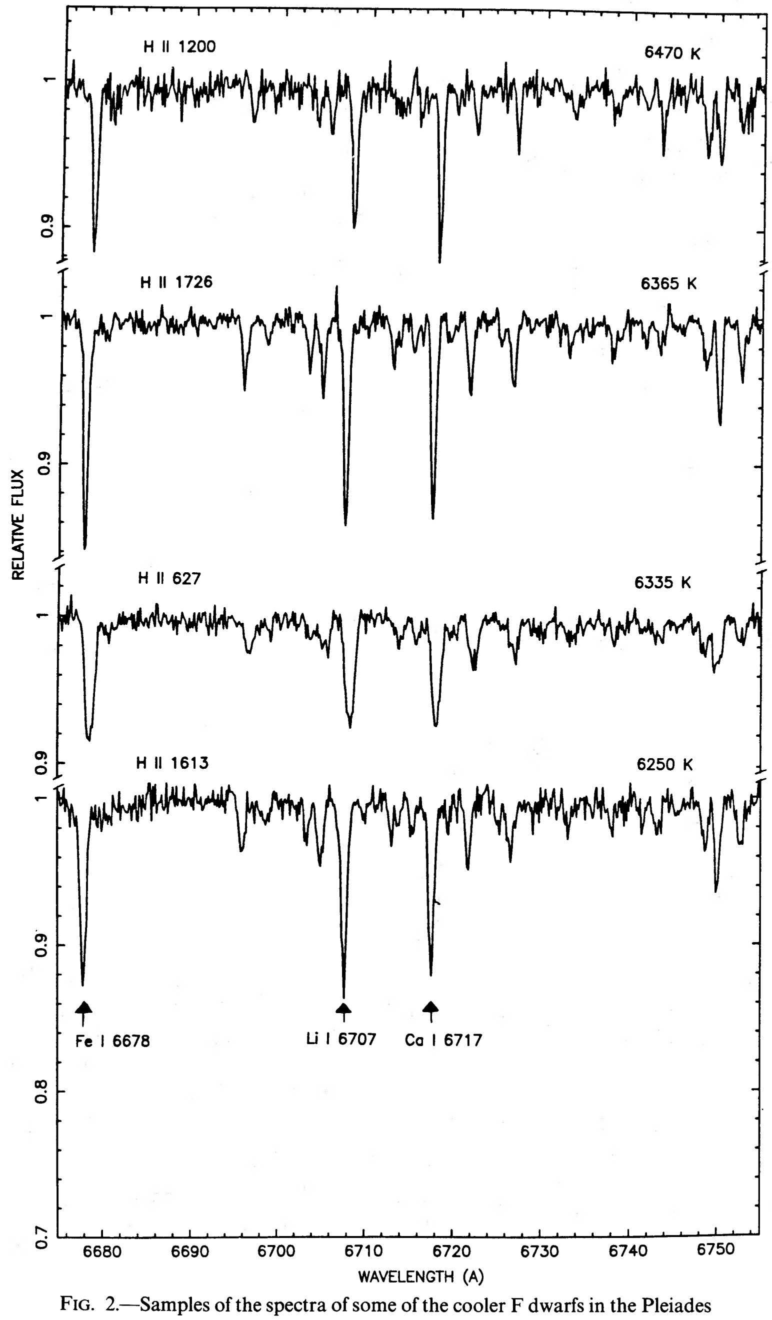

FIG. 2.—Samples of the spectra of some of the cooler F dwarfs in the Pleiades

TABLE 3

PHOTOMETRY FOR α PER STARS

Star H (1)	Hβ CB (2)	$b-y$ CB (3)	$B-V$ Mi (4)	$(b-y)_0$ CB (5)	$(B-V)_0$ C (6)
135	2.683	0.328	0.488	0.263	0.399
361	2.686	0.292	0.439	0.260	0.395
490	2.696	0.294	0.446	0.247	0.382
635	2.758	0.215	0.338	0.185	0.297
799	2.673	0.312	0.446	0.270	0.388
1225	2.651	0.328	0.492	0.305	0.460

NOTES.—CB: Crawford and Barnes 1974; Mi: Mitchell 1960; C: Crawford 1973.

and $(b-y)_0$ out of range of the calibrations. Therefore, we did not calculate temperatures from these data, nor include such temperatures in the final calculation of $T_{\rm eff}$.

For the cooler stars, effective temperatures were obtained by taking the mean of $T(B-V)_0$, $T(b-y)$. amd $T(\rm H\beta)$. For the hottest stars, the final $T_{\rm eff}$ was derived by taking the mean of these preliminary temperatures and $T(B-V)_{\rm up}$. The dispersion around the mean, σ, was calculated from the preliminary temperatures. The final values for $T_{\rm eff}$ and σ are included in columns (6) and (7) of Table 4. Those values of σ reflect only the random errors from the agreement of the various photometric indices and the calibration. There may be additional systematic errors from the calibrations.

We used a computer routine to fit splines through continuum points, which were selected interatively, to get continuum-flattened spectra. An integration routine was used to measure the equivalent widths of Li I λ6707, Fe I λλ6678, 6703, 6705, 6727, 6750, 6752, and Ca I λ6717. The repeatability of these measurements (same observer, same continuum) was 1–2 mÅ. Independent determinations of the continua and the equivalent widths by two of us agreed to 1–2 mÅ also. Experience with similar spectra in the UMa Group shows that equivalent widths measured from multiple spectra of the same star agree to a mean difference of 1.7 mÅ (Boesgaard, Budge, and Burck 1988). A conservative estimate of the errors is ±2 mÅ. The equivalent width measurements are contained in Table 5. For some of the stars one or more of the Fe I lines were not clear enough or were too blended with another line to measure accurately; these lines are not included in the table and were excluded from further consideration. The curves of growth derived from the model atmospheres of Kurucz (1979) were used to combine temperature and equivalent width data to

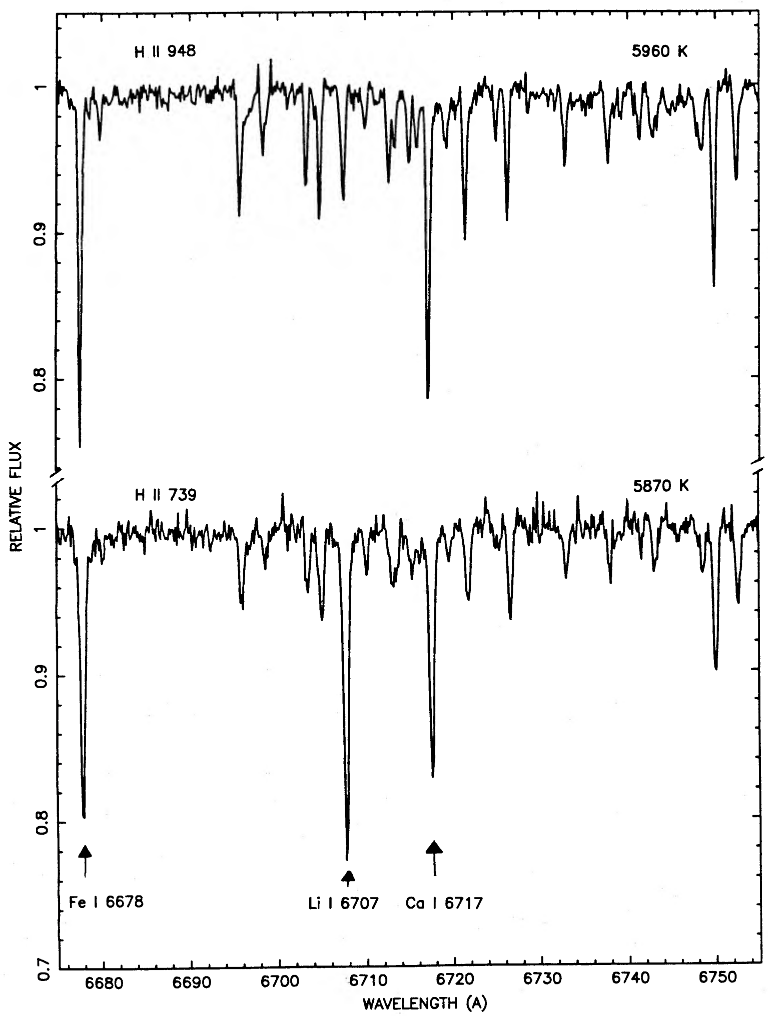

FIG. 3.—Spectra of the coolest two Pleiades stars in our sample

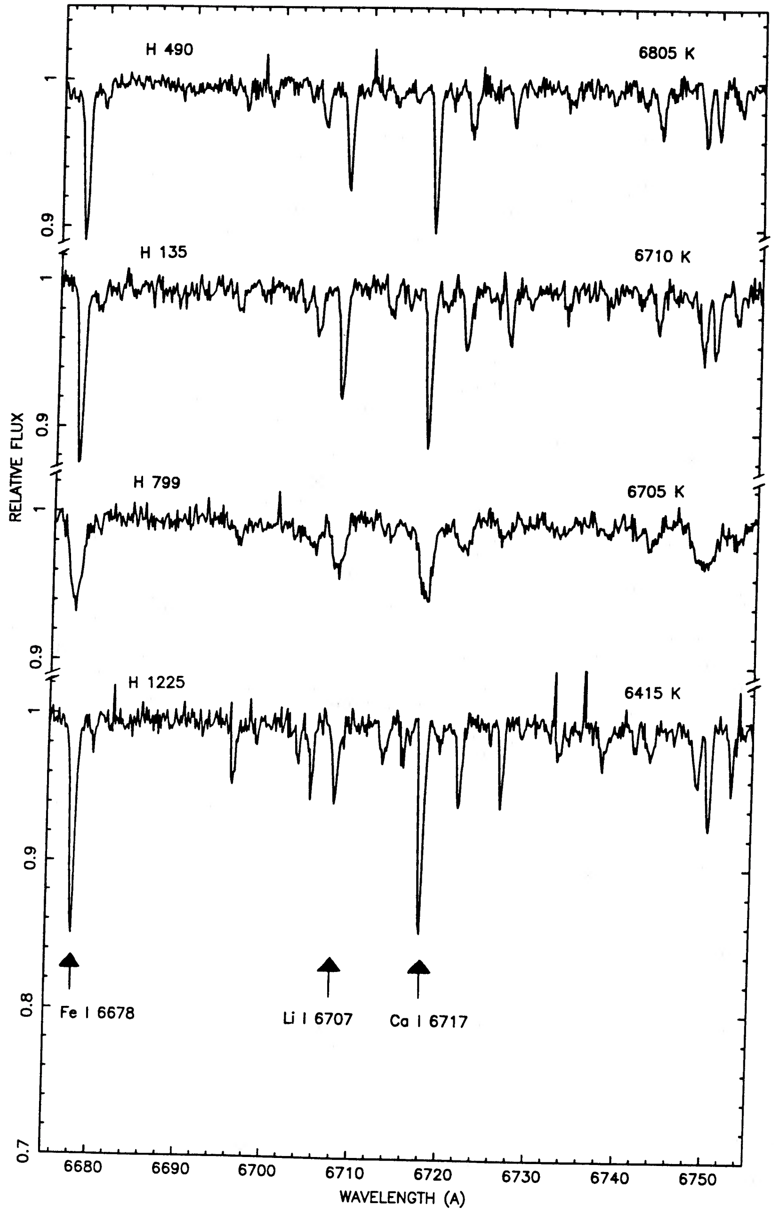

FIG. 4.—Samples of the spectra of the α Per dwarfs

obtain abundances. We note that neither the Li line nor the Fe lines that we have used are sensitive to the value of log g. We have used log $g = 4.5$ throughout. Since the Li I λ6707 line is really a blend of Li I and a weak Fe I line, the metallicity of each cluster was calculated from the Fe abundances before the Li abundances were determined in order to correct for this effect. For both clusters, the metallicities are close enough to [Fe/H] = 0.0 so that the curve of growth for the Li–Fe blend with this metallicity was used (see Boesgaard and Tripicco 1986*b*).

Table 6 contains the abundance results for each star in order of decreasing temperature: log N(Li), and σ, the errors in the abundances from a combination of the temperature errors, the equivalent width errors (1–2 mÅ) and the internal agreement of the Fe lines (which incorporates the errors in the input physics and models), and [Fe/H] and σ, from the internal agreement of the Fe lines and the temperature errors. In the cases where there are few Fe lines or their strengths were difficult to measure, the internal agreement is *not* a good indicator of the error in Li; for those stars the errors bars quoted for Li result from the comparison of the quality of the spectra in the Li region with those of stars of similar temperature, v sin i, and S/N. The error in log N(Li) just due to a temperature error of ± 65 K (1%) at 6500 K is ± 0.04. The error from the ± 2 mÅ measurement for a 75 mÅ line in a 6500 K star is ± 0.015. The error estimates in Table 6 do not include any estimates of possible systematic errors in the models or temperature calibrations.

TABLE 4

TEMPERATURES

A. Pleiades

Star HII (1)	$T(B-V)_0$(up) JM (2)	$T(B-V)_0$ mean (3)	$T(\beta)$ CP (4)	$T(b-y)_0$ mean (5)	T(adopted) (K) (6)	σ (7)
25	…	6485	6510	6495	6495	±15
164	…	6485	6415	6415	6440	±40
233	…	6440	6520	6500	6485	±40
338	6975	6730	6915	6760	6845	±120
470	6995	6755	6865	6770	6845	±110
530	6870	6695	6790	6730	6770	±75
627	…	6370	6250	6385	6335	±70
739	…	5900	5825	5885	5870	±40
948	…	5965	5935	5975	5960	±20
1122	…	6600	6640	6590	6610	±25
1132	…	6470	6570	6540	6525	±50
1139	…	6525	6620	6575	6575	±50
1200	…	6440	6480	6490	6470	±25
1613	…	6220	6330	6200	6250	±70
1726	…	6640	6415	6390	6365	±65
1766	6795	6640	6780	6700	6730	±70
1856	…	6150	6170	6140	6155	±15

B. α Persei

Star H	$T(B-V)_0$(up) Mi	$T(B-V)_0$ Mi	$T(\beta)$ CB	$T(b-y)_0$ CB	T(adopted) (K)	σ
135	6815	6655	6715	6660	6710	±75
361	6835	6675	6740	6680	6730	±75
490	6920	6695	6840	6760	6805	±100
635	7465	7110	*	*	7285	±250
799	6880	6705	6620	6615	6705	±125
1225	…	6435	6405	6400	6415	±20

TABLE 5

EQUIVALENT WIDTHS IN mÅ

Star	T(K)	Fe I 6677.993	Fe I 6703.573	Fe I 6705.117	Fe I 6726.668	Fe I 6750.152	Fe I 6752.724	Li I 6707.881	Ca I 6717.685
					Pleiades				
338	6845	93.9	…	…	24.9:	…	16.4:	57.3	63.4
470	6845	98.1	12.2	25.7	23.3	34.2	22.7	69.0	77.7
530	6770	88.7	…	22.5	21.8	33.7	16.7	59.7	74.2
1766	6730	96.6	…	25.7	24.3	32.6	18.7:	45.7	82.0
1122	6610	94.9	…	32.0:	26.2	32.7	…	73.8	82.5
1139	6575	103.4	…	…	…	42.7	24.9	56.8	97.3
1132	6525	94.5	…	…	…	43.3	…	52.0	96.6
25	6495	87.3	15.6:	31.6	22.4:	…	…	61.4	74.0
233	6485	74.2	…	22.0	24.2	28.3	14.0	72.8	69.0
1200	6470	83.5	17.1:	23.6	22.8	38.2	…	73.9	75.9
164	6440	98.4	12.7:	28.4	…	…	23.5	65.4	92.2
1726	6365	109.2	20.5	29.7	33.0	45.9	25.7	101.4	92.6
627	6335	104.6	15.5:	26.2	29.7	40.4	…	89.3	87.6
1613	6250	109.2	20.3	38.8	38.1	48.2	26.8	109.9	98.5
1856	6155	101.0	29.8	43.1	40.0:	47.0	33.0	92.6	104.0
948	5960	117.9	32.0	40.2	41.2	67.9	36.3	47.4	116.3
739	5870	139.8	25.6	44.5	37.6	66.8	34.6	160.6	120.7
					α Persei				
635	7285	76.7:	…	…	14.7	14.0	…	38.1	55.0
490	6805	84.3	10.9	26.0	23.8	23.7	…	57.4	72.1
361	6730	…	…	…	19.4::	…	…	59.9::	…
135	6710	97.9:	16.4	31.2	30.2	35.8	…	62.3	80.7
799	6705	93.7	…	25.9:	18.3	…	…	51.7	82.5
1225	6415	108.0	17.8:	32.4	30.5	47.1	25.2	46.2	96.6

IV. RESULTS AND DISCUSSION

We have six stars in common with the Pleiades stars observed by Duncan and Jones (1983). For only one of these stars, HII 1766, are our Li I equivalent widths and log N(Li) results in good agreement. Two are in substantial disagreement; for HII 739 we find $W_\lambda = 161$ mÅ and log $N(\text{Li}) = 3.08$ versus 215 mÅ and 3.8 of Duncan and Jones and for HII 1139 we find 57 mÅ and 2.89 mÅ versus <25 mÅ and <2.46. Our data set is not only consistent, having all been done at the same telescope with the same detector, but also it is of both higher S/N ratio (~ 200 versus 25) and better resolution (0.2 Å versus 0.4 Å).

Figure 5 gives the distribution of lithium abundance with temperature derived from the above analysis. Error bars are included that give our estimate of the uncertainties of the measured abundances. The measured equivalent widths are highly reproducible when measured independently by the different authors; the uncertainty is therefore dominated by the uncertainties in the temperatures and in the atomic physics and model atmospheres used in the analysis. We have estimated the uncertainties due to the latter from the scatter in measured iron abundance for the six lines for which we have measured equivalent widths. This has been combined with the uncertainties due to the known scatter in the temperature estimates to produce the error bars shown (see § III).

The mean value of log N(Li) for the stars hotteer than 6000 K is 2.98 for each cluster, which we take as the primordial lithium abundance for these clusters and which is close to the corresponding value for the Hyades (Boesgaard and Tripicco 1986*a*). For all 21 stars in both clusters the value is log $N(\text{Li}) = 2.98 \pm 0.13$. There is little indication of significant depletion of lithium anywhere in the temperature range studied, although there is considerable disagreement between the two coolest objects studied in the Pleiades.

It is clear that the abundance difference between these two

TABLE 6

ABUNDANCES

Star	T(K)	log N(Li)	σ	[Fe/H]	σ
Pleiades					
338.........	6845	3.09	± 0.10	0.04:	± 0.06
470.........	6845	3.18	± 0.09	0.09	± 0.06
530.........	6770	3.06	± 0.09	-0.04	± 0.03
1766.........	6730	2.90	± 0.08	0.01	± 0.03
1122.........	6610	3.07	± 0.06	-0.01	± 0.09
1139.........	6575	2.89	± 0.06	0.08:	± 0.02
1132.........	6575	2.81	± 0.06	-0.02:	± 0.09
25.........	6495	2.88	± 0.06	-0.08:	± 0.13
233.........	6485	2.98	± 0.06	-0.26	± 0.13
1200.........	6470	2.97	± 0.06	-0.13	± 0.14
164.........	6440	2.88	± 0.06	-0.06:	± 0.05
1726.........	6365	3.08	± 0.07	0.00	± 0.04
627.........	6335	2.98	± 0.07	-0.09	± 0.04
1613.........	6250	3.04	± 0.08	0.00	± 0.05
1856.........	6150	2.86	± 0.06	0.01	± 0.12
948.........	5960	2.30	± 0.04	0.01	± 0.06
739.........	5870	3.08	± 0.05	-0.02	± 0.10
α Persei					
635.........	7285	3.18	± 0.17	-0.05:	± 0.08
490.........	6805	3.06	± 0.09	-0.03	± 0.09
361.........	6730	3.03	± 0.11	-0.15:	...
135.........	6710	3.04	± 0.08	0.11	± 0.05
799.........	6705	2.93	± 0.10	-0.04:	± 0.11
1225.........	6415	2.66	± 0.04	0.03	± 0.03

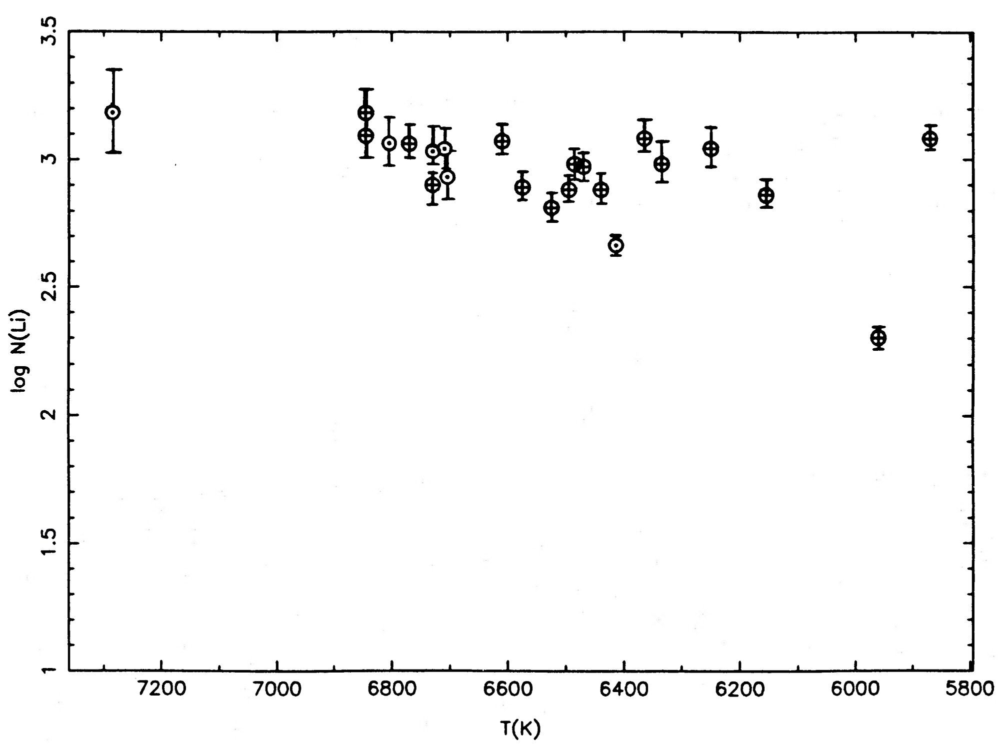

FIG. 5.—The Li-temperature profile for the Pleiades and the α Per dwarfs. The circled plusses are the Pleiades stars, circled dots are the α Per stars. The error bars are the combination of the errors in temperature, in equivalent width measurement, and of errors due to the input physics and models. For these young cluster stars there is no evidence for the large Li depletions found in the middle-F dwarfs in the older clusters: Hyades, Coma, and UMa Group.

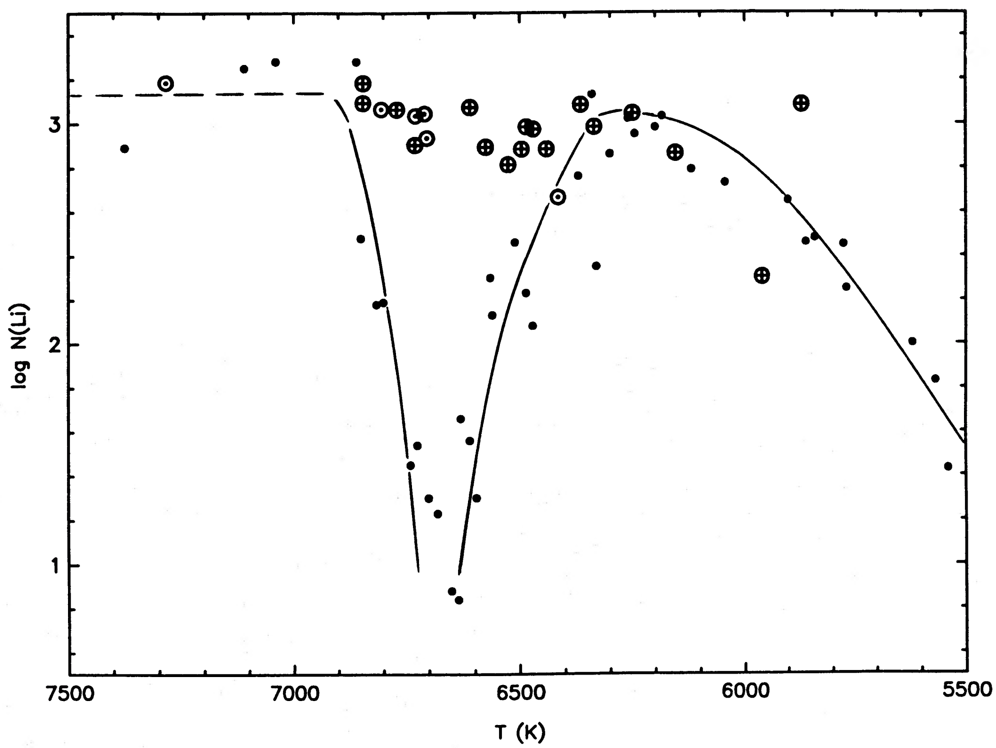

FIG. 6.—A comparison of the Li-temperature profile for the young clusters, Pleiades and α Per, with that for the Hyades. The circled plusses are the Pleiades stars, the circled dots are the α Per stars, and the solid dots are the Hyades stars. The light line represents the Hyades data. A dip in Li in the Pleiades/α Per stars down to log N(Li) $\sim$ 2.85 near 6500 K cannot be ruled out, but it is clear that no substantial Li depletion has taken place in stars only 7×10^7 yr old.

stars, HII 948 and HII 739, is genuine. Figure 3 illustrates that the difference in equivalent width is unquestionable, and it is unlikely that the difference is due to an incorrect measurement of the temperature. We also consider it unlikely that either of the stars is not a member of the Pleiades. We note that Butler *et al.* (1987) have measured Li abundances for Pleiades G and K dwarfs and find a bimodal distribution in Li abundance and an apparent correlation between Li abundance and $v \sin i$. They interpret this as resulting from an age spread among these dwarfs. HII 739, the more lithium-abundant of our two cool stars, appears to have the larger value of $v \sin i$, supporting this result.

Figure 6 plots the distribution of Li abundance with temperature in both the Pleiades-α Per age group and the Hyades abundances are taken from the work of Boesgaard and Tripicco (1986*a*), from subsequent measurements made at the 5 m telescope at Palomar Observatory (Boesgaard and Budge 1988), and from Cayrel *et al.* (1984) for the cooler stars. The difference in the region of the Hyades lithium gap is striking. There is no evidence for such a dramatic and deep gap in the Pleiades-α Per age group. A slight dip near 6500 K down to values near log N(Li) = 2.85 is possible on the basis of these data. It seems clear though that the mechanism responsible for the Li gap in the Hyades, Coma, and UMa Group stars was not acting during the pre–main-sequence phase, since it has not had time to deplete lithium in the younger Pleiades-α Persei age group. These results add some constraints to the theoretical developments regarding the Li depletion mechanism. Neither the α Per stars at age 2×10^7 yr nor the Pleiades stars at age 7×10^7 yr show mid-F star Li depletions while star clusters like UMa at 3×10^8 yr, Coma at 5×10^8 yr, and Hyades at 7×10^8 yr are old enough for significant loss of their surface Li content. Michaud (1986) has suggested that in younger clusters the effects of diffusion would not be as pronounced due to the shorter timespan when diffusion could operate.

We have determined the metallicities of these two clusters from these same spectra with our assessments of the temperatures. The values for the individual stars appear in Table 6. The mean [Fe/H] for the 13 Pleiades stars, which have σ([Fe/H]) $\leq \pm 0.10$, is $+0.003 \pm 0.054$. For the α Per stars (without H361) the mean [Fe/H] is $+0.007 \pm 0.069$. Both of these young clusters have solar metallicity to within small errors in contrast with the Hyades cluster which is older but has higher metallicity at [Fe/H] = $+0.12 \pm 0.03$ (Cayrel, Cayrel de Strobel, and Campbell 1985). The UMa Group and Coma which are similar to the Hyades in age have lower metallicity at -0.08 ± 0.05 and -0.07 ± 0.02, respectively (Boesgaard, Budge, and Burck 1988). These new results, also based on high signal-to-noise spectroscopy, provide additional evidence for the conclusion of Boesgaard *et al.* that the galactic disk is not well mixed in the solar neighborhood on time scales of $\leq 7 \times 10^8$ yr.

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Note added in proof.—A paper on Li abundances in Pleiades F stars by Pilachowski, Booth, and Hobbs is to appear in 1987, *Pub. A.S.P.*, **99**, 1228. Nine stars were observed in common, although our data have 2.5 times better resolution and typically 3 times higher signal-to-noise ratios. (Direct comparisons can be made for HII 1766, 1122, 1139, 233, and 948, for which the spectra are illustrated in both papers.) Their results are similar: the Li abundance dip in the mid-F stars is not present in the Pleiades so the Li dip arises only after about 10^8 yr. For the case of HII 1139, where there is divergence between our results and those of Duncan and Jones (1983), the Li I equivalent width and the Li abundance of Pilachowski *et al.* are virtually identical to ours. In addition, they too find HII 948 to be underabundant in Li ($T = 5960$ K) compared to the other stars.

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