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LITHIUM IN THE COMA STAR CLUSTER

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ABSTRACT

The F dwarfs in the Hyades cluster show large deficiencies of Li at the temperatures of the middle F stars ($0.40 \le B-V \le 0.47$), shown recently by Boesgaard and Tripicco. A similar result was then noticed by Hobbs and Pilachowski in NGC 752. In order to learn the cause of the Li deficiencies, the effect has been looked for in other open galactic clusters. Observations have been made of Li in the A and F dwarfs of the Coma cluster at high spectral resolution (0.1 Å) and high signal-to-noise ratios (180–450) with the coudé spectrograph of the Canada-France-Hawaii telescope. Abundances of both Li and Fe were determined by a model atmosphere abundance analysis. The two Coma stars that have temperatures in the middle of the Hyades Li "chasm" are very depleted in Li. The Hyades empirical curve seems to fit the Coma stars; in particular, the width of the Li gap is about the same. The five Am stars show real differences relative to one another in both Li content and "metallic-line-ness," as found in field Am stars by Burkhart *et al.* and presumably due to diffusion and mass loss. One Am star shows Li enhanced by a factor of 4. If the Coma cluster "initial" Li content is like that of the two late F stars which show the highest Li, it is log N(Li) = 2.9.

Subject headings: clusters: open — diffusion — stars: abundances — stars: metallic-line

I. INTRODUCTION

The abundance of Li is a key diagnostic of stellar structure and evolution in F and G dwarfs. Nuclear reactions of the (p, α) type destroy Li in stellar interiors at about 2×10^6 K so this element is present only in that thin (by mass) outer layer in main-sequence F and G stars which never reaches that temperature. The outer convection zones in theoretical models of F stars do not reach down to such a temperature (e.g., D'Antona and Mazzitelli 1984) which predicts that the Li present in the convection zone would be undepleted. Observations show that this is true in only about one-third of the early F dwarfs in the field (Boesgaard and Tripicco 1986*a*). For the Li-depleted stars the models are not accurate, and some processes other than circulation by convection to the crucial temperatures must be acting. The abundance of Li thus provides information about stellar interiors for which we have virtually no other observational information.

Boesgaard and Tripicco (1986*b*) have recently discovered a remarkable variation of Li content with stellar surface temperature in the F dwarfs of the Hyades cluster. The hottest stars ($T > 7000$ K) showed Li/H values of 10^{-9}, the maximum observed in F field stars, meteorites, T tauri stars, etc. The Li content showed a decrease toward 6600 K, where it is depleted by over two orders of magnitude, and then a regular rise toward 6300 K where it again peaks at a maximum near 10^{-9}. These results on Li in F dwarfs can be seen in their Figure 2, which also contains the Li results for the Hyades G dwarfs of Cayrel *et al.* (1984). The dip occurs at $B-V = 0.40$–0.47, or in the middle F dwarfs. The Li may have been destroyed through deep circulation which they suggest could be due to differential stellar rotation, possibly during pre–main-sequence evolution. Any successful explanation will have to account for the narrowness of the temperature range where the extreme depletion occurs. Michaud (1986) has calculated the effects of diffusion of Li in these F stars which reproduces the Li depletion pattern fairly well in the temperature range 6400–6800 K. When he includes surface mass loss rates of about $10^{-14}\ M_\odot\ \mathrm{yr}^{-1}$ near the center of the dip at 6600 K and about $10^{-15}\ M_\odot\ \mathrm{yr}^{-1}$ at temperatures near 7000 K, the fit is even better.

In a study of Li abundances in the galactic cluster NGC 752, Hobbs and Pilachowski (1986*a*) have noticed a similar effect: four stars near 6600 K have Li depletions which range up to a factor of more than 30. An additional investigation by Boesgaard and Tripicco (1987) of Li in F stars in visual binaries of known ages shows the same pattern with the five stars in the temperature interval 6400–6700 K having Li depletions by factors of 6–20, while the six hotter stars have normal Li (Li/H = 10^{-9}). In the Boesgaard and Tripicco (1986*b*) study of Li in 75 F dwarfs in the field about half the stars in this temperature interval showed Hyades-like depletion, while the other half were near the 10^{-9} maximum in Li/H.

Similar high signal-to-noise ratio, high-resolution studies of Li in F stars in other clusters should reveal what parameters control the Li depletion. Some of the possible influential parameters include age, metal content, rotation, magnetic (and chromospheric) activity. The stars of the Coma cluster provide an especially interesting context in which to examine the Li abundance. This cluster has the same age as the Hyades, about 8×10^8 yr, but its metallicity is lower by almost a factor of 2 (Nissen 1981; Cayrel, Cayrel de Strobel, and Campbell 1985). Strömgren, Olsen, and Gustafsson (1982) attribute the Hyades color anomaly to a low He abundance but find there to be no such color problem or, therefore, He deficiency in Coma. On the other hand, Campbell (1984) argues that the color anomaly results from starspots in the Hyades stars of type F7 and later. He suggests that the Coma cluster stars are not as heavily spotted since the color anomaly is so small. Thus the degree of chromospheric activity is possibly different in the two clusters. Another possible difference between the two clusters is a different distribution in angular momentum per unit mass (Kraft 1965). The galactic positions of the two clusters are very differ-

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ent with the galactic latitude for the Hyades of $b \approx -22°$ and Coma of $b \approx +85°$. Although Danziger (1969) determined [Li/Ca] values in Coma cluster F and G dwarfs for comparison with those found in the UMa stream, the Hyades and Pleiades clusters, those results cannot be compared with modern observations and analysis techniques; all those data were photographic and of considerably lower spectral resolution and signal-to-noise ratio than the present-day work.

In principle, it is possible to estimate the initial Li content with which a cluster was born. This comes from those early and late F stars, on either side of the dip, which show the maximum Li abundance observed. Comparisons can be made of the maximum abundances in various clusters with each other and with the maxima in the field F stars. If they are different, we should be able to determine if there has been enrichment of Li during the lifetime of the galactic disk, and/or if it is dependent on metallicity and/or position in the disk.

II. OBSERVATIONS

A sample of Coma cluster F stars has been selected for which the rotational velocities (Kraft 1965), Hβ photometry (Strömgren 1963; Crawford and Barnes 1969), and *UBV* (Johnson and Knuckles 1955) photometry exist. The observations were made at the CFHT 3.6 m and the f/7.4 coudé spectrograph camera with the 830 lines mm^{-1} grating and the liquid nitrogen-cooled Reticon detector. The spectra cover 135 Å centered at 6700 Å at a dispersion of 4.83 Å mm^{-1} or 0.072 Å pixel^{-1}. The measured full width at half-maximum intensity of the comparison lines was 1.5 pixels or about 0.11 Å. The data were obtained on 1985 April 8 and May 28 and 29 and 1986 April 19, 20, and 21 UT and include spectra of five Am stars and 18 F dwarfs. Under seeing conditions of 1″ a spectrum with signal-to-noise ratio (S/N) of 300 could be obtained of a star with $V = 9$ in about 100 minutes. The coma F dwarfs are fainter ($V = 8.5$–9.4) than those of the Hyades and the prevailing conditions were not as good as those for the Hyades observations, but the calculated S/N values are respectable: 180–450. The stars observed and some basic data as well as the S/N of the observations are given in Table 1.

Multiple series of four flat-field exposures taken to within $\sim 10\%$ of the same exposure level of each star were obtained each night. The stellar spectrum was divided by the average of the appropriate four flat fields to remove the instrumental signature. Any minor remaining nonlinearities were removed by applying a four-channel normalization routine which equalizes the total output from the four channels. Examples of the Li region of some of the reduced spectra of the F stars are shown in Figure 1. This region in four of the Am stars is shown in Figure 2.

The continua were established by a spline fit through interactively selected data points, and equivalent widths were measured with an integration routine. For those stars for which there was more than one exposure, the continuum-flattened spectra were added in proportion to the exposure level; equivalent widths were measured on the individual spectra as well as the summed spectra. Two of the stars, Tr 111 and Tr 144, are double-lined spectroscopic binaries (SB2). Tr 111 consists of two stars of about the same spectral type, but the lines are difficult to measure accurately due to the 35 km s^{-1} rotational broadening in both components. Special care was taken to assess the strength of the Li feature in each star. Tr 144 is a sharp-lined Am star with faint, sharp lines of a G dwarf companion. The spectrum of Tr 144 is shown in Figure 3. Table 2 presents a list of the reliably measured lines of Li I λ6707, Fe I $\lambda\lambda$6678, 6703, 6705, 6727, 6750, and 6752, and Ca I λ6717. The stars are listed in order of temperature (see below) so that the pattern of changes in the lines strengths can be seen. Those patterns seem to show, for example, that Tr 118 is either metal-rich relative to other cluster members or that the photometrically derived temperature is too hot. For the SB2's the measured equivalent widths given in Table 2 in parentheses must be multiplied by factors given below to account for effect of the combined continuum flux.

TABLE 1

COMA CLUSTER STARS OBSERVED

HD	Tr	Sp. Type[a] W	Sp. Type[a] M	Sp. Type[a] AL	V (mag)	B−V (mag)	β (mag)	$v \sin i$ (km s^{-1})	S/N[b]
106103	19	F5 V	F4 V	F5 V	8.12	0.397	2.673	≤12	240, 420
106691	36	F2$^+$V	F3 V	F3 V	8.13	0.407	2.681	30	235, 270
106946	49	F2 V	F2 V	F3 V	7.89	0.353	2.698	50	275
107067	53	F8$^+$V	F9 V	F7 V	8.73	0.525	2.625	≤12	160
107132	58	G0 V	F9 V	F7 V	8.83	0.510	2.626	12	270
107168	62	A4 ML3	Am	Am A7/F0/F2[c]	6.23	0.167	2.868	≤12	800
107214	65	G0 V	G0 V	F5 V	9.02	0.566	2.605	...	80, 275
107399	76	G0 V	G0 V	G0 V	9.10	0.547	2.613	...	300
107611	86	F6$^+$V	F6 V	F7 V	8.55	0.463	2.652	15	135, 300
107685	90	F5$^+$V	F5 V	F6 V	8.56	0.461	2.636	≤12	160, 230
107700	91(SB2)	F8:p	G2 III+A4 V	A4 V + F6 V	4.83	0.497	2.700	35; ≤25	450
......	92	F6$^+$V	F7 V	F8 V	8.61	0.535	2.632	15:	290
107793	97	...	F9 V	F8 V	9.12	0.540	2.617	...	180
107887	101	F5: V	F5 V	F6 V	8.42	0.443	2.666	20	270
108102	111(SB2)	F8$^+$V	F8 V	F8 V	8.17	0.518	2.612	35; 35	300
108154	114	F8 V	F8 V	F7 V	8.60	0.453	2.651	≤12	220
108226	118	F6 V	F6 V	F6 V	8.37	0.449	2.657	≤12	130, 300
108486	139	A4 ML2	Am	Am A2/A8/F0[c]	6.70	0.163	2.851	30	410
108642	144(SB2)	A4 ML2-3	Am	Am A2/A7/F0[c]	6.54	0.179	2.846	≤12	430
108651	145	A4 ML3	Am	Am A2/A7/F0[c]	6.70	0.207	2.843	≤12	450
108976	162	G0 V	F7 V	F7 V	8.61	0.475	2.642	12	390
109307	183	A4 ML1-2	Am	Am A3/A7/A7[c]	6.28	0.108	2.878	8	390

[a] W = Weaver 1952; M = Mendoza 1963; AL = Abt and Levato 1977.
[b] Exposures on two nights were obtained for some stars; separate values for S/N are given.
[c] Spectral types from Ca II K, H lines, metallic lines.

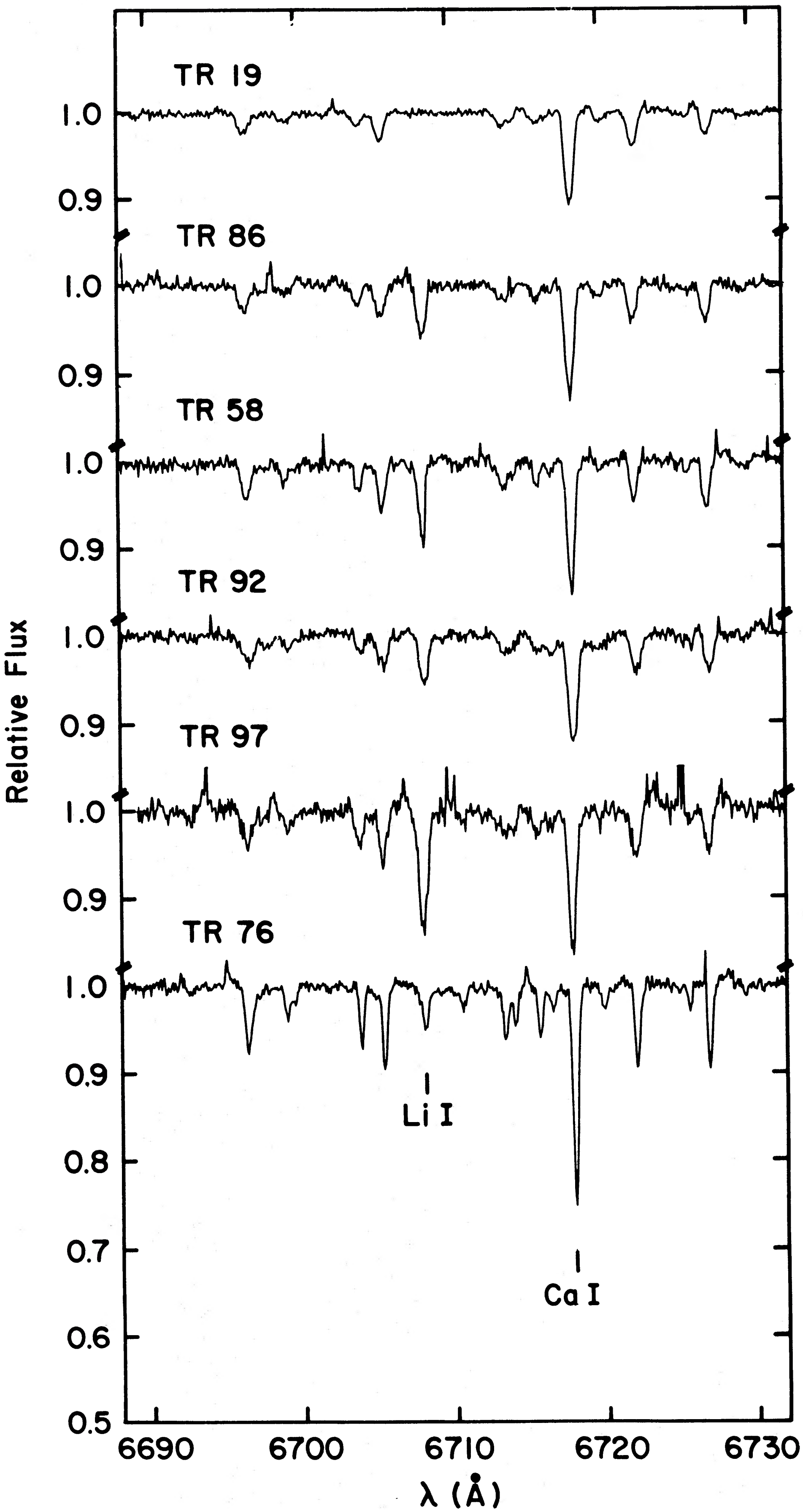

FIG. 1.—Part of the spectral region observed of six of the Coma F dwarfs arranged in order of decreasing temperature *top to bottom.* (Some cosmic-ray events are visible, especially in Tr 97.) Note the absence of a Li I line in Tr 19. For Tr 76 the Li I line seems weaker than expected for its temperature (see text).

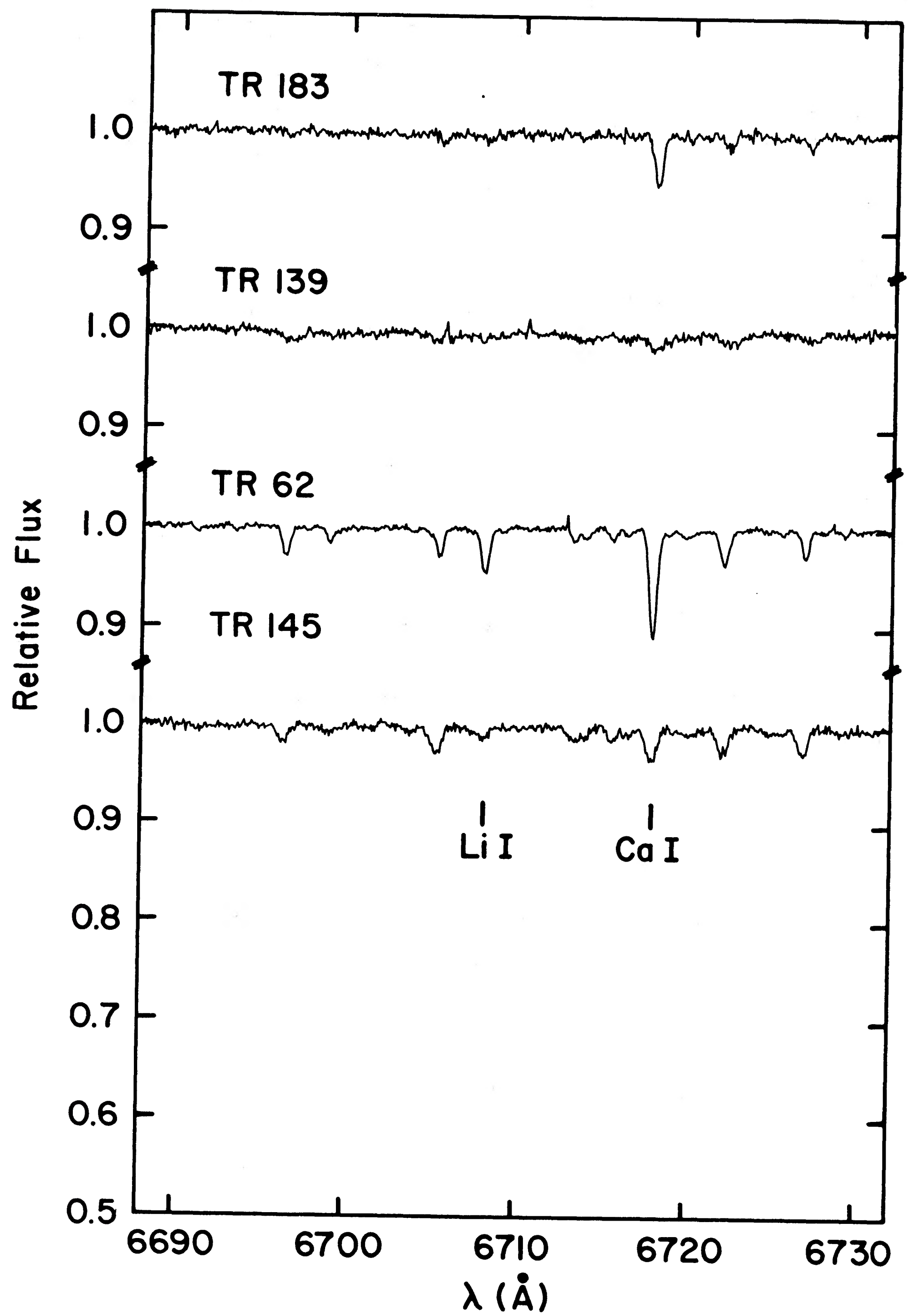

FIG. 2.—Part of the spectral region observed for four Am stars, in order of decreasing temperature. Note the strong Li I line in Tr 62.

III. ABUNDANCE ANALYSIS

The abundance results are dependent on the temperatures used, but there is virtually no dependence on gravity for the Fe I or Li I lines. For example, a temperature increase of 100 K causes an increase in the derived [Fe/H] of 0.05 and in log N(Li) of 0.1. Photometric indicators of temperatures for F stars like $B-V$ and β can be measured with a high degree of internal consistency in stars in open clusters and thus internally consistent temperatures can be found. In this comparative study of Li in various clusters the temperatures of stars in different clusters must be derived similarly for reliable intercomparisons. Several temperature indicators and calibrations have been investigated. The final adopted temperatures for the Coma cluster stars are, on the average, 85 K cooler than they would have been if the scale that was specifically derived for the Hyades by Carney (1983) had been adopted—as was done by Boesgaard and Tripicco (1986*b*) for their Hyades study.

Böhm-Vitense (1981) has recently reviewed the effective temperature scales for stars. For F dwarfs she shows two cali-

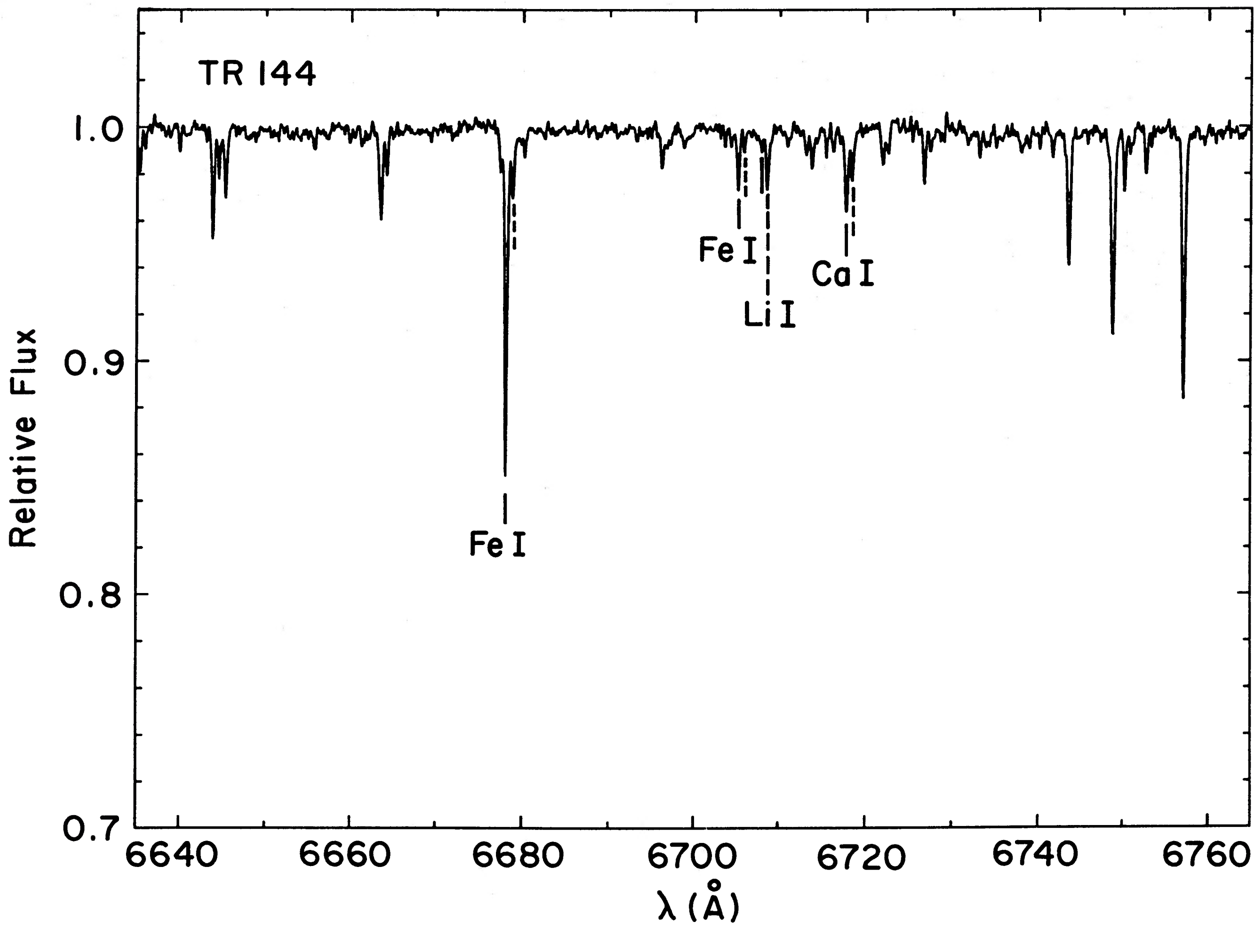

FIG. 3.—Spectrum of the double-lined spectroscopic binary, Tr 144. The solid lines identify the features in the Am star due to Fe I λ6678, Fe I λ6705, Li I λ6707, and Ca I λ6717, while the dashed lines point to those features in the G star companion. The G star lines appear only weakly because the Am star continuum dominates, but even so the Li I line is unmistakeable in the G star.

brations between $B-V$ and effective temperature, $T_{\rm eff}$, and suggests that the lower branch corresponds to rapid rotators and the upper one to slow rotators. For stars which have $B-V$ values greater than 0.45, the two branches coincide. A new calibration for F stars of $T_{\rm eff}$ with $B-V$, β, and $(b-y)$ has been published by Saxner and Hammarback (1985). In this work in finding temperatures for the Coma cluster stars, use has been made of both $B-V$ and β photometry. The Böhm-Vitense $B-V$ calibration and the Saxner and Hammarback β calibration have been used for stars with $B-V$ greater than 0.45. Temperatures from the former are about 90 K hotter than the latter; in general the average of the two has been used.

The stars in the $B-V$ range where Böhm-Vitense finds two branches, the upper branch was used for the four stars with low values of $v \sin i$, ≤ 12 to 30 km s^{-1}. For Tr 49 with $v \sin i = 50$ km s^{-1}, the mean of the two branches was used. The Saxner and Hammarback $B-V$ calibration generally follows the lower branch and was not used. Their β calibration results in somewhat hotter temperatures, typically closer to the Böhm-Vitense upper branch, but still lower by 100 K or so. In addition the ratio of Cr I λ6748 to Fe I λ6750 could be used as a temperature indicator. For those Coma cluster stars with the best determined temperatures, this ratio versus those temperatures gave the same calibration as that found by Boesgaard and Tripicco (1987) for the range in $T_{\rm eff} = 5900$–6900 K.

The four metallic-line stars have $B-V$ and β values that are out of range of the Saxner and Hammarback calibration, but back in the single branch domain for the Böhm-Vitense work. Temperatures based on $B-V$ and the Böhm-Vitense calibration were used. One metallic-line star, Tr 144, and one F dwarf pair, Tr 111, are double-lined spectroscopic binaries. For these stars measurements of the line strength ratios of Fe I λ6703/Fe I λ6705 (Boesgaard and Tripicco 1986*a*), Cr I λ6748/Fe I λ6750 and Cr I λ6748/Fe I λ6752 (Boesgaard and Tripicco 1987) were used to estimate temperatures. The measured line strengths were then increased by the multiplication factors that were derived as discussed by Boesgaard and Tripicco (1986*a*). In Tr 144 the Am stars spectrum dominates and the lines of the secondary are sharp, clearly visible and measurable, but weak. In Tr 111 the two stars have nearly equal temperatures, but because of the rotational broadening of $v \sin i = 35$ km s^{-1} the line ratios are hard to measure because of the line blending.

Nissen (1981) has done a study of microturbulent velocities, ξ, in F stars and derived an expression for ξ in terms of $T_{\rm eff}$ and gravity, log g. That expression was adopted here. Each atmosphere in the grid of model atmospheres used in the abundance program is characterized by $T_{\rm eff}$ and log g; the value for ξ found for those from Nissen's formula was incorporated in the abundance calculation. The model atmospheres used were those of Kurucz (1979) for values of log $g = 4.5$. (Nissen's

TABLE 2

EQUIVALENT WIDTHS (mÅ)

Star	T_{eff}(K)	Fe I 6677.993Å	Fe I 6703.573Å	Fe I 6705.117Å	Fe I 6726.668Å	Fe I 6750.152Å	Fe I 6752.724Å	Fe I + Li I 6707.441Å + 6707.761Å 6707.912Å	Ca I 6717.685Å
Am Stars									
183	8470	33.9	...	8.6:	8.2:	2.5:	...	7.5:	30.2
144b	8200	67.2	2.5	11.6	9.7	10.5	9.3	6.6	19.1
139	8130	67.0	...	...	7.8:	7.8:	...	≤5.7	15.9
62	8110	79.1	3.0	15.6	13.3	14.3	8.5	27.5	61.2
145	7865	87.3	4.8	21.1	19.0	24.3	16.8	11.8	27.7
F Stars									
49	6890	86.8	...	23.6	20.3	...	...	25.5	83.5
19	6730	94.1	11.9	23.1	20.1	34.1	...	≤2.3	75.9
36	6690	94.8	10.9	25.6	24.2	...	...	≤5.5	91.5
111b	6540	...	...	...	...	...	...	(12.4)	...
101	6535	94.5	13.8	25.6	21.6:	51.1:	23.7:	39.0	91.4
118	6495	102.0	18.0	31.8	32.3	43.8	20.7	25.6	90.6
86	6425	94.2	15.5	27.2	25.9	43.0:	...	39.6	85.7
114	6400	95.3	15.8	33.3	27.2	47.1	24.7:	47.8	87.3
111r	6400	...	...	...	...	...	...	(22.2)	...
90	6350	101.4	15.5	28.9	31.5	43.2	...	41.0	93.7
162	6345	103.0	16.6	≥27.7	31.2	46.7	22.4	36.0	92.1
92	6210	97.0	15.6	33.2	27.5	51.6:	29.8:	45.3	93.8
58	6200	...	20.0	36.4	33.4	51.5	23.5	51.9	95.0
53	6165	...	...	36.5	25.4	53.4:	...	97.9	106.8
97	6095	114.0	22.7	33.5	26.0:	48.3:	28.0:	95.6	98.6
76	6060	...	25.3	39.4	≥34.7	61.9	27.4	30.2	110.0
65	5985	124.9	27.3	36.1	35.4	59.2	29.4	68.8	114.4
144r	5900	(12.6)	(3.0)	(3.5)	(4.5)	...	(2.4)	(11.9)	(9.1)
sun	5770	137	38	47	48	75	38	≤2	120

NOTE.—For Tr 144b, the numbers shown have been multiplied by the factor 1.13 to account for the contribution of the G star, Tr 144r, to the continuum; for Tr 144r, the numbers given in parentheses need to be multiplied by a factor of 8.5 to correct for the A star contribution. For Tr 111b and Tr 111r, the numbers in parentheses should be multiplied by 1.881 and 2.135, respectively, to correct for the contributions of the companion.

relationship is good over the range in log g of 3.35 to 4.4 and in T_{eff} of 5800 to 7200 K; slight extrapolations were done here to log $g = 4.5$ and $T_{eff} = 7500$ K.) Table 3 gives the values of ξ.

The model atmosphere abundance analysis routine was described by Boesgaard and Tripicco (1986*a*), along with the various atomic parameters used. New calculations were made for the adopted microturbulent values and the Fe I line at λ6752 was included. Solar equivalent widths were taken from Branch, Lambert, and Tomkin (1980) and Beckers, Bridges, and Gilliam (1976). Not all the Fe I lines could be measured reliably in every star due to rotational blending, cosmic ray hits, etc. The final values for $[Fe/H] = \log (Fe/H)_*/(Fe/H)_\odot$ are the log of mean of the numerical values from the line-by-line, stellar-to-solar ratios, based on three to six lines. For Li, the curves of growth calculated for the Li-blend were used; the curves with solar Fe/H were the ones selected because the Coma cluster stars are only mildly deficient in Fe (see below).

TABLE 3

MICROTURBULENT VELOCITIES, ξ, USED FOR MODEL ATMOSPHERES WITH LOG $g = 4.5$ AND VARIOUS EFFECTIVE TEMPERATURES

T_{eff}(K)	ξ (km s^{-1})
6000	1.10
6500	1.30
7000	1.45
7500	1.60[a]
8000	1.70[a]

[a] Out of Nissen's calibration range.

Table 4 gives the temperatures which were used for each star and the abundance found for Li/H as log N(Li), where log $N(H) = 12.00$, for Fe/H as [Fe/H], and for Ca/H as [Ca/H], based on solar Ca/H from the one Ca I line at λ6717.

TABLE 4

ABUNDANCE RESULTS

Star	T_{eff}(K)	Li/H	log N(Li)	[Fe/H]	σ	[Ca/H]
Am Stars						
183	8470	1.4 (− 9)	3.15	+0.163	±0.328	−0.11
144b	8200	8.3 (−10)	2.92	+0.280	±0.098	−0.52
139	8130	≤6.3 (−10)	≤2.80	+0.186	±0.037	−0.65
62	8110	3.5 (− 9)	3.54	+0.351	±0.043	−0.20
145	7865	9.0 (−10)	2.95	+0.387	±0.072	−0.50
F Stars						
49	6890	4.9 (−10)	2.69	−0.031	±0.167	−0.06
19	6730	≤5.0 (−12)	≤0.70	−0.039	±0.114	−0.26
36	6690	≤5.0 (−11)	≤1.70	−0.028	±0.115	+0.03
111b	6540	2.5 (−10)	2.40	...	...	...
101	6535	4.8 (−10)	2.68	−0.031	±0.140	−0.05
118	6495	2.5 (−10)	2.40	+0.025	±0.128	−0.08
86	6425	4.0 (−10)	2.60	−0.090	±0.140	−0.23
114	6400	4.8 (−10)	2.68	−0.044	±0.165	−0.23
111r	6400	4.7 (−10)	2.67	...	...	...
90	6350	3.6 (−10)	2.56	−0.088	±0.140	−0.12
162	6345	3.0 (−10)	2.48	−0.079	±0.108	−0.15
92	6210	3.3 (−10)	2.52	−0.101	±0.211	−0.20
58	6200	3.8 (−10)	2.58	−0.070	±0.090	−0.18
53	6165	8.4 (−10)	2.92	−0.108	±0.155	−0.03
97	6095	7.0 (−10)	2.84	−0.113	±0.169	−0.18
76	6060	1.95(−10)	2.16	−0.056	±0.075	0.00
65	5985	3.4 (−10)	2.53	−0.079	±0.110	−0.01
144r	5900	5.6 (−10)	2.75	−0.207	±0.151	−0.61
sun	5770	1 (−11)	1.0	0.00	...	0.00

IV. RESULTS AND DISCUSSION

Two of the stars, Tr 19 and Tr 36, in the sample of F stars are in the temperature range, $T_{eff} = 6400$–6700 K, where the Hyades show large Li depletions. Neither of those stars shows a Li I line and the upper limits are 2.3 and 5.5 mÅ, respectively. The published value of $v \sin i$ for Tr 36 is 30 km s^{-1} compared with the published upper limit of ≤ 12 km s^{-1} for Tr 19, so the upper limit on the equivalent width is larger for Tr 36 than for Tr 19. Both stars are severely depleted in Li compared to the rest of the F stars. This can be seen in Figure 4 which shows Li abundances as a function of temperature. The empirical curve for the Hyades is included in the figure. The Coma cluster stars appear to follow that curve fairly well. In particular, the gap seen in the Hyades between 6400 and 7000 K seems well matched by the Coma data. The width seems to be about the same, and the degree of the depletion seems to be as strikingly large: at least two orders of magnitude.

The stars cooler than $\sim$6400 K appear to show some scatter about a mean of log N(Li) ≈ 2.65, probably due to intrinsic, individual variations in the Li depletion rates, rather than to errors in the Li I equivalent widths or in temperatures, given the high quality of the spectra and the internally consistent temperature determinations. Such variations may be due to differences in mass loss rates, initial angular momentum, magnetic activity, etc. Tr 76 at $T_{eff} = 6060$ and log N(Li) $= 2.16$ seems to show more than typical depletion. According to the temperatures derived in § III, Tr 76 is similar in temperature to Tr 97 (with $T_{eff} = 6095$), so for those two stars to have similar Li/H values, the Li I equivalent widths should be about the same. As can be seen in the spectra plotted in Figure 1 and the equivalent width measures Table 2, this is not true: Li I in Tr 76 is only 30 mÅ compared to 96 mÅ for Tr 97. The log N(Li) values are 2.16 versus 2.84 for those two stars. On the other hand the measured strengths of the Fe I lines indicate that Tr 76 may be cooler than the temperature found from the photometric indices, perhaps similar to or cooler than Tr 65 at 5985 K. A decrease in T_{eff} of 200 K would also decrease the value of log N(Li) to about 1.96; the star would move closer to, but still be below, the *Hyades G star* depletion curve. The Coma G stars could have a steeper depletion-temperature curve or it could set in at higher temperatures. The one star that is above the Hyades curve at $T_{eff} = 5900$ K is the spectroscopic binary red star component of Tr 144 for which both the temperature and the Li abundance are uncertain.

The five Am stars also show real differences in Li abundance and real differences in the degree of "metallic-line–ness." Although Tr 62 and Tr 145 are similar in spectral classification (A4 ML3) and in [Fe/H] (which is higher by a factor of 2.3 than the solar value), Li/H is enhanced by a factor of 4 in Tr 62, relative to both Tr 145 and the typical Population I star maximum [log N(Li) ≈ 3.0]. The differences in the Li/H in the two stars is beyond the errors in the temperatures and in the equivalent widths; as can be seen in Figure 2, the strength of Li I relative to the neighboring Fe I line at λ6705 is marked. Only if the temperature of Tr 62 were as low as about 7500 K would the Li/H and the [Fe/H] be "normal." A recent study of Li in 9 Am stars by Burkhart *et al.* (1987) shows that the Li abundance in Am stars has a range of two orders of magnitude and may be normal, overabundant, or underabundant relative to the nominal Pop I cosmic value, log N(Li) $= 3.0$. Microscopic diffusion processes are presumably the cause of the Am phenomenon (Vauclair *et al.* 1978; Michaud *et al.* 1983). In the case of Li, the surface abundance will also depend on the mass-loss rate according to Michaud (1986). Thus, the Li/H values found in the Am stars in the Coma cluster are consistent with those in the field Am stars which can be understood by microscopic diffusion and mass loss.

It is difficult to assess the "initial" Li content in the Coma cluster because, as can be seen in Figure 4, there are apparently no stars that are out of the Li "dip" in the temperature range of about 7000–7400 K. The two Coma F stars with the highest Li content, Tr 53 and Tr 97, at temperatures of 6165 and 6095 K, respectively, have log N(Li) $= 2.9$. For the Hyades there are six stars which can be used to find "initial" Li, three in the 7000–7400 K range and three near 6300 K. The result is log

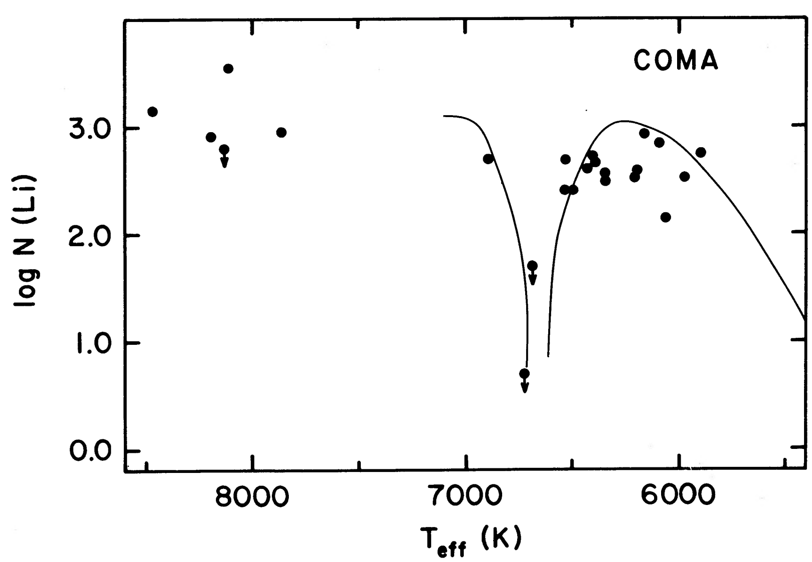

FIG. 4.—The Li abundance as log N(Li), where log N(H) $= 12.00$, plotted against T_{eff} for the Coma cluster A and F dwarfs. The light line is the empirical curve found by Boesgaard and Tripicco (1986*b*) for the Hyades. The two stars which fall in the middle of the Hyades Li "chasm," Tr 19 and Tr 36, are also severely Li-depleted. Tr 76 at (6060, 2.16) seems to be more depleted than the Hyades G star depletion curve predicts. One Am star, Tr 62, is enhanced in Li by a factor of about 4 relative to the cluster maximum, presmably due to diffusion.

N(Li) = 3.1 ± 0.2. As mentioned in § III the temperature scale for the Coma stars is about 85 K lower than that for the Hyades on the average; this difference alone would make the Coma stars show less Li by ~0.1 dex. Within the errors of the temperature and abundance determinations, there is no evidence that the "initial" Li for the Hyades stars is any different than that for the Coma stars. For the early F dwarfs in the field, Boesgaard and Tripicco (1986*a*) found log N(Li) = 3.01; those stars had ages of $< 2 \times 10^9$ yr. They also studied Li in F dwarfs in visual binaries of known age (Boesgaard and Tripicco 1987) and found log N(Li) = 3.08 (±0.14) for the five stars with $T > 6800$ K whose average age was 1.3×10^9 yr. For NGC 752 at 1.7×10^9 yr. Hobbs and Pilachowski (1986*a*) give initial Li/H as 1×10^{-9}, or log N(Li) = 3.0. The two stars near the main-sequence turn-off in NGC 7789, age = 1.6×10^9 yr, studied by Pilachowski (1986) show that that cluster has the same initial log N(Li) within the accuracy of the data. In the Hobbs and Pilachowski study of M67 (1986*b*), which is 5×10^9 yr old, they can only say that initial log N(Li) ≥ 2.65 because the cluster turn-off point is cooler than stars would be to still have initial Li undepleted. A similar result for M67 was reported by Spite *et al.* (1987). Thus all these examples of Population I stars show the same value, within the measurement error, for initial Li: log N(Li) = 3.0.

Although the Coma cluster and the Hyades cluster have the same age, they differ in metallicity and in galactic latitude. Cayrel, Cayrel de Strobel, and Campbell (1985) find a mean metallicity for the Hyades of [Fe/H] = +0.12 ± 0.03. For the subset of Coma cluster F stars with sharp lines and the best determined temperatures, the mean [Fe/H] = −0.07 ± 0.02, for an Fe/H difference of a factor of 1.5. (As opposed to Li/H values, the small difference in metallicity in these two clusters is believable since it is based on more lines, more stars, and small internal variations from star to star.) The Coma stars are at high galactic latitude, $b = +85°$, whereas the Hyades are in the galactic plane, $b \approx -22°$. Since neither cluster is very far away, this apparent difference in latitude may not be especially meaningful, however. In any event, it appears that small differences in position and metallicity do not have any discernible influence on the appearance of the mid-F star dip in Li/H, or in initial Li.

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