Astron. Astrophys. 338, 1073–1079 (1998)

ASTRONOMY
AND
ASTROPHYSICS

The Praesepe open cluster: abundances of Li, Al, Si, S, Fe, Ni, and Eu in A stars*

C. Burkhart[1] **and M.F. Coupry**[2]

[1] Observatoire de Lyon (Un. Lyon I) and UMR 5574 (CNRS), F-69561 Saint-Genis-Laval Cédex, France (burkhart@obs.univ-lyon1.fr)
[2] Observatoire de Paris and URA 335 (CNRS), 61 Av. de l'Observatoire, F-75014 Paris, France (coupry@obspm.fr)

Received 22 June 1998 / Accepted 30 July 1998

Abstract. In the second of a series of papers on the A stars in open clusters, the Praesepe cluster is investigated; in the first paper, it was the Pleiades. Ten A Praesepe stars were observed with the Canada-France-Hawaii telescope at high spectral resolution and high signal-to-noise ratios. Photospheric abundances of the sample, which has turned out to be composed exclusively with Am stars, have been determined for Li, Al, Si, S, Fe, Ni, and Eu from model atmosphere abundance analysis.

The A stars of Praesepe are well advanced in the Main Sequence evolution: several of the observed stars are in the turn-off (and one is a blue straggler). The Li abundance in Am stars is the same as in non-evolved Praesepe F stars on the hot side of the Li dip, and Fe is twice its original value as given by Praesepe F stars. The abundances of the studied elements were found remarkably uniform in the cluster over a large range of T_{eff}, i.e., for various structure envelopes and evolution.

Surface abundances of Li and Fe remain unchanged in Am stars at both ages of the Pleiades and Praesepe clusters.

The Li results for the Am stars challenge predictions from evolutionary model envelopes in the framework of a diffusion-dominant description.

Key words: stars: abundances – stars: chemically peculiar – open clusters and associatiobns: individual: Praesepe

1. Introduction

This paper is the second in a series about the abundances of the trace light element Li for the normal A and Am stars in open clusters of different ages; the abundances of Al, Si, and S; the abundances of iron peak elements, Fe and Ni; and the abundances of the rare earth Eu. This paper is concerned with the A stars of the Praesepe cluster. The first paper (Burkhart & Coupry 1997) dealt with the A stars in the Pleiades. The objectives are, first, the origin and evolution of the anomalous abundances in the Am stars and, secondly, Li abundances in clusters on the hot side of the Li dip. As the age of the Pleiades is about 10^8 years and the A stars are at the beginning of the Main Sequence evolution when the age of Praesepe is nearly ten times, about 7 10^8 years and the A stars are well advanced in their Main Sequence evolution, we may be able to detect if some surface abundances change with time and/or evolution.

The first paper defined our observation and reduction techniques, abundance determination procedure, kept the same throughout the paper series. (See, also, Burkhart & Coupry (1991), Coupry & Burkhart (1992), and references therein). The spectroscopic data have been obtained at the Canada-France-Hawaii (CFH) 3.6m telescope and the f/7.4 coudé spectrograph camera equipped with a Reticon detector (spectra covering 135 Å at a dispersion of 4.83 Å mm^{-1}, with typical signal-to-noise ratios in the range 200-400 at the 2σ level). The equivalent width results were checked both internally with α CMi observed during each run and externally with α CMi (Steffen 1985) and the Sun (Rutten & van der Zalm 1984). The good agreement between the different equivalent width scales supports this work, the computed solar logf values (except for Li with laboratory log gf values), and the stray-light effects neglected since they are comparable for all spectrographs at work. The data reduction was carried out with codes written by M.Spite (private communication); abundances were derived using model atmospheres (Kurucz 1979a, 1979b) with temperatures derived from uvby,β photometry (Moon 1985; Moon & Dworetsky 1985)

2. Program stars, observations and data reduction

The 10 observed Praesepe stars are in the hottest part of the cluster color-magnitude diagram (Fig. 1). Owing to the weakness of the Li I doublet, they include all the A stars with presumably projected rotational velocities v sin i less than about 60 km s^{-1} from McGee et al. (1967) and Abt (1986). Two stars with higher v sin i (100 for ϵ Cnc and 85 for HD 73818) were added: their double-lined spectroscopic binary (SB2) character may have influenced the v sin i determination. Six out of ten stars lie in the sequence turnoff. Another, 40 Cnc, is a blue straggler. We note for the two coolest stars of our sample that the first one, the SB1 HD 73045 (Bolte 1991), lies above the main sequence in the "second-sequence" composed of photometric binary candidates when the other, the SB2 HD 73818 (Dickens et al. 1968), lies within the main sequence. The cluster SB2 stars are not

Send offprint requests to: C. Burkhart

* Based on observations collected at the Canada-France-Hawaii telescope (Hawaii)

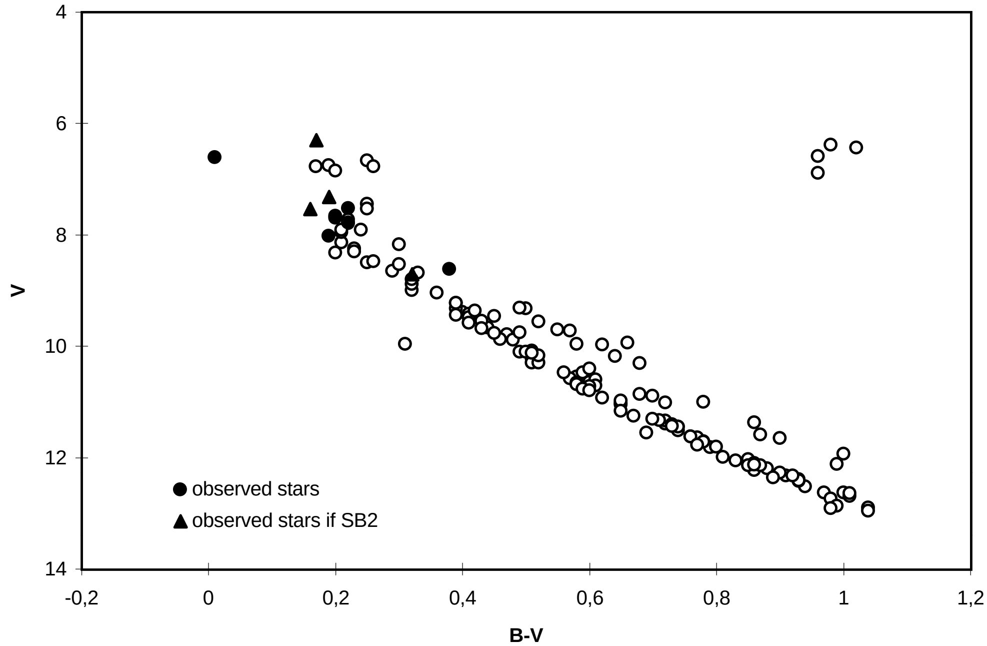

Fig. 1. Color-magnitude diagram for the Praesepe cluster showing observed stars. The UVB photometry first comes from the compilation of Wang et al. (1995), secondly from Johnson (1952)

Table 1. Log book

	Sp type **Gray&Garrison** 1987&1989 Bidelman 1956 (Abt 1986)	Ca/Fe	V	Exp time (mn)	JJ (d) -2440000	Remarks	
HD 72942	A4 or mild Am (A4 V)	Am	7.5	60	8647,91	variable	
HD 73045	A4- -F5 III (A3-A9-F3)	Am	8.6	60 90	8644,91 8644,96	SB1; P=436d	
HD 73174	A4- -FO III (A4-A8-F2)	Am	7.8	30 90 75	7892,94 8645,03 8648,06	triple system (SB1 and 1 unseen companion)	X rays:detected
HD 73618	A4- -FO III (A5-A6-F0)	Am + Am	7.3	90	8646,86	SB2	X rays:detected
HD 73666 40 Cnc	**A0- -A2 IVs(Si)** A1 (A1 IIIp(Si))	hot star	6.6	90 40	7891,96 8646,91	speckle binary blue straggler	
HD 73711	A3- -FO III (A3-A5-F0)	Am + Am	7.5	120	8646,97	SB2 (line profiles in this work)	
HD 73709	**A2-A5-F0 III-IV(Cr)** A3- -F2 III (A4-A7-F2)	Am	7.7	120	8645,94	SB1	
HD 73730	A3- -F2 III (A2-A8-F0)	Am	8.0	90	8646,02		
HD 73731 eps Cnc	**A3-A5-F0 IIIb** A5- -FO III (A5-A6-F0)	Am + Am	6.3	90	7892,03	SB2	Li blend detected in 1 Am
HD 73818	A7- -F2 III (A7-A8-F0)	Am	8.7	120	8647,99	SB2	

always located in the color-magnitude diagram owing to their (now known) spectroscopic binarity (This was, too, noted for Pleiades SB2 stars observed by Burkhart & Coupry (1997)).

Some stellar characteristics and observational data are collected in Table 1. ϵ Cnc, the brightest star in Praesepe, is the only star that has not been previously always considered as *bona fide* member. In the late high-precision study of proper motions and membership in Praesepe (Wang et al. 1995), this star appears as a member with high probability; this agrees with HIPPARCOS results. Memberships are, so, confirmed for all the observed stars. The normal A or Am character is evaluated from the classification of Gray & Garrison (1987, 1989) in col. 2 and/or the line ratio Ca I-6717/Fe I-6678 (Burkhart & Coupry 1991) in col.3. There is a general agreement between both proceedings (and with classifications by Bidelman (1956) and Abt (1986)). Our sample is composed exclusively of Am stars. These are the slowly rotating A stars. As the discrimination of the observed A stars in the cluster was made only against large projected rotation rates, seemingly no normal A star is seen nearly pole-on. The many binary (or triple) systems agree with the general properties of Am stars. For SB2 stars, the different classifications in col. 2 were done with the system seen as a single-lined star, but from the Ca/Fe line ratio the Am character of each component can be found in favorable circumstances.

The equivalent widths are given in Table 2. Each of the Al, Li, Ca, and S lines is the main line of a blend with a weak Fe line; the equivalent width value found in Table 2 is, then, that of the entire blend and "bd" is put for the satellite line. For Eu, the equivalent width value is that of the blend. Different cases arose with the SB2 systems. Only in the spectrum of ϵ Cnc, we observed both line systems; both components are Am stars; some lines could be separately measured. From comparison with our other spectra it visually appears that v sin i of each component is about 50 $km\,s^{-1}$ and not 100 $km\,s^{-1}$ as previously given. For HD 73618, the two line systems are not separated but visible in the line profiles, matching similar Am stars. The spectrum of HD 73818 has a relatively low signal-to-noise ratio (about 130), no SB2 feature could be detected. Further, the line profiles of HD 73711, a single star up to now, are asymmetrical. They are all similar except the Ca profile. This likely excludes a non-radial pulsator signature and favors an SB2 explanation with 2 Am stars from their Ca/Fe ratios. The spectra of the other 3 SB2 stars were processed as single-lined stars.

3. Analysis and results

Table 3 summarizes our Pleiades abundance results. In col. 3 the temperatures derived from the uvby,β photometry are given. The observed indices are the homogeneous means given in the catalogue of Hauck & Mermilliod (1980), they are essentially those of Crawford & Barnes (1969).

The microturbulent velocity, v_t, is obtained as a pure fitting parameter to obtain equal Fe abundances from lines of different equivalent widths. The v_t determination is good for (single-lined), sharp-lined stars, whose many lines are measured easily and accurately: 4 stars in Table 2. Their microturbulences (v_t = 4.5 to 5 km/s) are larger by 1.5 km/s than those found in Coupry & Burkhart (1992). In this series large microturbulences were also found for the Pleiades normal A stars; no observational reason can be brought forward since for α CMi our equivalent width scale (and so the v_t deduced) is in good agreement with those of Coupry & Burkhart (1992) and Steffen (1985). As no determination was possible for the 4 SB2 stars and HD 72942, we *a priori* choose a v_t of 4.5 km/s. Microturbulence values affect only abundances determined from strong lines, that is, for S with every star (except the hot star, HD 73666, whose all lines are very weak) and Fe when the only measured line is that at 6678 Å.

The abundance results (Table 3) are far more affected by double-lined spectroscopic binarity: the abundance analyses are compulsorily hampered by assumptions about the poorly-known parameters of the system (temperatures, masses . . .). The results quoted for ϵ CncA are minimum values: the dilution effect is not taken into account. Our process for the 3 other systems is equivalent to assume both components to be identical and the results correspond to a "mean" star. We note that the same choice is done in all previous spectroscopic and/or abundance studies.

The abundance results of Table 3 are shown in Fig. 2: the determinations concerning SB2 stars are distinguished from others owing to their *sui generis* uncertainties. The determinations are better established for the 5 single-lined and sharp-lined stars. On one hand, it is the hot star 40 Cnc with few lines in its spectrum and consequently few elements studied. On the other hand, they are HD 73045, HD 73174, HD 73709, and HD 73730.

These four Am stars exhibit abundance patterns remarkably close to each other : the standard deviation of each abundance mean is almost 0.2 dex or less; they form a very homogeneous group. Since no normal A star could have been studied in Praesepe owing to too large projected rotational velocities, the abundance results are to be compared with those in the Sun and/or cooler Praesepe stars. Compared with the Sun:

- Al, Si, and S are marginally overabundant (+0.2, +0.2, and +0.1 dex).
- Fe and Ni are overabundant (+0.4 and +0.6 dex).
- Eu is largely overabundant (+1.0 dex).

If we turn to the accurate results for F Praesepe stars (Friel & Boesgaard 1992), the mean of [Fe/H], equal to log $(Fe/H)_\star$ - log $(Fe/H)_\odot$, has been found to be +0.04 $\pm$ 0.04, i.e., a mean Fe abundance slightly larger than that of the Sun with small intrinsic dispersion. So in their atmospheres, Am Praesepe stars are overabundant in Fe compared with F Praesepe stars (+0.35 dex).

For lithium, we turn to a study in Praesepe F and G star dwarfs by Soderblom et al. (1993) which extends that of Boesgaard & Budge (1988). Fig. 3, a partial reproduction of their Fig. 4(a) such as found in Soderblom et al. (1995), shows the Li-temperature profile of all our observed stars with theirs, T_{eff} less than 5400 K and/or upper limits excluded. For late-F to early G dwarfs in the range 6350 to 5950 K, the relationship between Li abundance and temperature is not tight and one-to-one, the most deviant stars not being systematically known binaries. The cluster "Li peak", on the cool side of the Li dip, is, so, poorly defined and comparing the Li content in Am stars with it is questionable. On the hot side of the Li dip, for the three normal F dwarfs near 6700 and 6800 K, the mean of log N(Li) is 3.04; these hot F stars have the same Li content as the Am stars, wether SB2 or not. There is, however, one exception: the Am star, HD 73709, undoubtedly is more abundant than all the others (by a factor of 2).

The hot star, 40 Cnc, has abundances in S, Fe, and Eu very similar to those of the four cooler stars, even if Fe and Eu abundances are something higher. These results seem too few possibly to promote to a better understanding of blue stragglers in open clusters. We note the significant overabundance

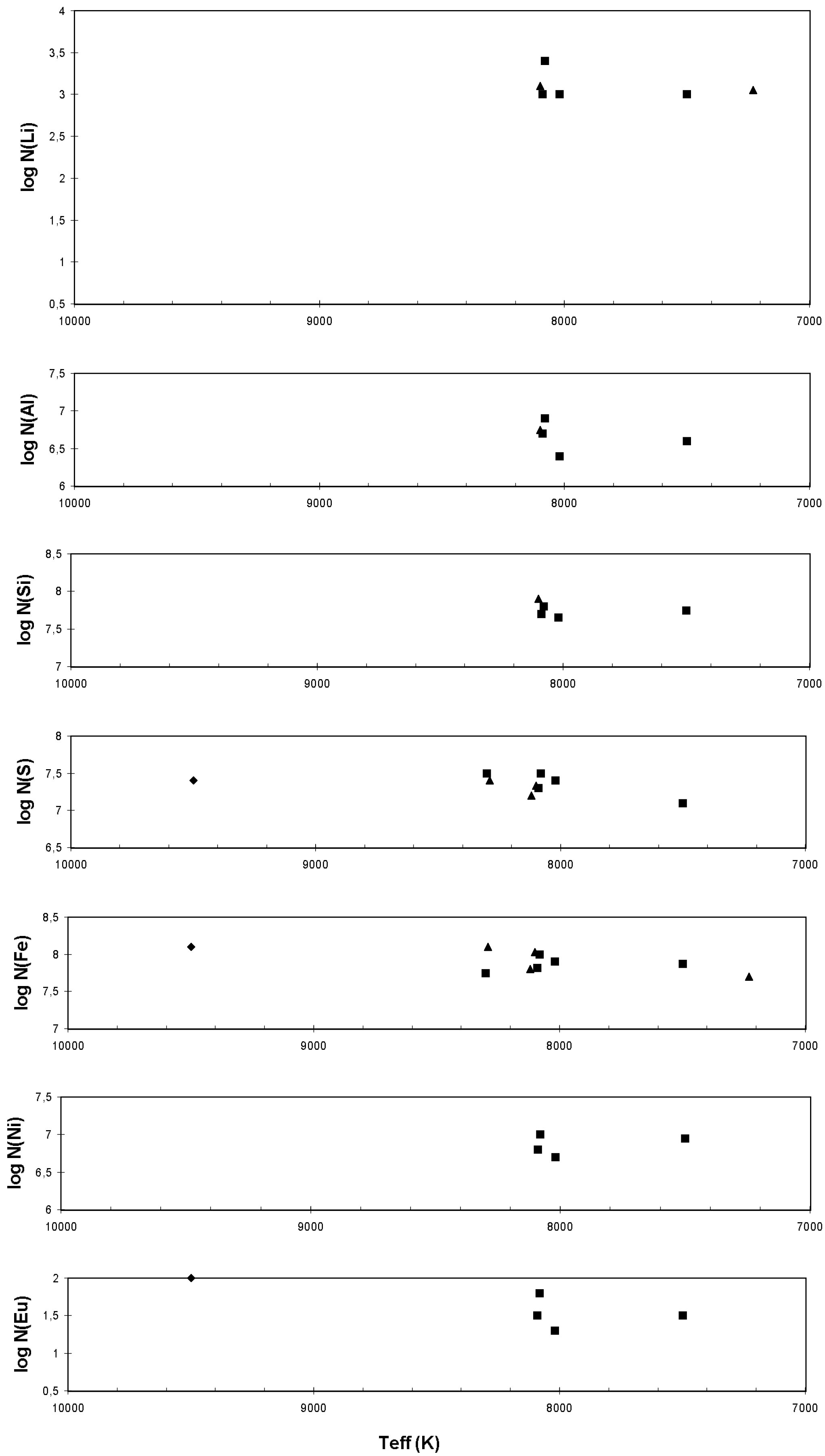

Fig. 2. Abundances of Li, Al, Si, S, Fe, Ni, and Eu (on the scale of log N(H) = 12.00) as a function of effective temperature for the Praesepe A stars. The filled squares (triangles if SB2) denote Am stars, that is, underabundant Ca. The filled diamond denotes a hot Am star

Table 2. Equivalent widths (mÅ)

	λ		Mult.	χ	log gf	HD 72942	HD 73045	HD 73174	HD 73618	HD 73666	HD 73711	HD 73709	HD 73730	HD 73731 A - B	HD 73818
Ni I	6 635,137		264	4,42	-0,80		28	10,5							
Ni I	6 643,638		43	1,68	-2,10		70	30,5				49	35		
Eu II	6 645,127	HF	8	1,38	0,35		28	15		4		28	12		
Fe I	6 677,997		268	2,69	-1,67	48	125	70	90	11	81	96	90	65 - 37.5	130
Al I	6 696,032		5	3,14	-1,62		21	12,5	15			18	10		
Fe I	6 696,322		1255	4,83	-1,60		bd	bd	bd			bd	bd		
Al I	6 698,669		5	3,14	-1,91		11					10			
Fe I	6 699,136		1228	4,59	-2,17		bd					bd			
Fe I	6 705,105		1197	4,61	-1,20		31	12,5	20			20	18		29
Fe I	6 707,449				-2,20	bd	bd	bd	bd		bd	bd	bd		bd
Li I	6 707,760		1	0,00	0,00	<12	22	8,5	11	<1,5	<14	20	11		35?
Li I	6 707,980		1	0,00	-0,30	bd	bd	bd	bd	bd	bd	bd	bd		bd
Fe I	6 713,745		1255	4,79	-1,59			4							
Fe I	6 715,386		1174	4,61	-1,52		13	5							
Fe I	6 717,527		1194	4,61		bd	bd	bd	bd		bd	bd	bd		
Ca I	6 717,687		32	2,71		20 ?	30	26	48,5	6	18	32	21	32 -	
Si I	6 721,844		38	5,86	-1,20		32	13,5	22			22	16		
Fe I	6 726,673		1197	4,61	-1,18		28	12	17			18	15		
Fe I	6 733,153		1195	4,64	-1,53		11	4	5,5?			9			
Si I	6 741,629			5,98	-1,62		10	7				6			
Fe I	6 750,164		111	2,42	-2,78		33	12,5				14			
Fe I	6 752,716		1195	4,64	-1,33		21	10,5				12			
Fe Ip	6 756,568		1120	4,29	-2,61	bd	bd	bd	bd		bd	bd	bd		
S I	6 757,195	F	8	7,87	-0,21	66	57	60	65	16	64,5	79	75	49 -	

Table 3. Abundances of the Praesepe stars

		Teff °K	log N (Li)	log N (Al)	log N (Si)	log N (S)	log N (Ca)	log N (Fe)	log N (Ni)	log N (Eu)
HD 72942	Am	8300	< 3,3			7,5		7,75		
HD 73045	Am	7500	3,0	6,6	7,75	7,1		7,87	6,95	1,5
HD 73174	Am	8090	3,0	6,7	7,7	7,3		7,82	6,8	1,5
HD 73618	Am, SB2	8100	3,1	6,75	7,9	7,3		8,03		
HD 73666	hot Am	9500	< 3,45			7,4	6,8	8,1		2,0
HD 73711	Am, SB2	8290	< 3,4			7,4		8,1		
HD 73709	Am	8080	3,4	6,9	7,8	7,5		8,0	7,0	1,8
HD 73730	Am	8020	3,0	6,4	7,65	7,4		7,9	6,7	1,3
HD 73731 A	Am, SB2	8120				> 7,2		> 7,8		
HD 73818	Am, SB2	7230	3,05					7,7		
Sun				6,47	7,55	7,21	6,36	7,51	6,25	0,51

in Ca (+0.45 dex compared with the Sun). On the other hand, K-line and metallic-line types only differ by two temperature classes, which are highly reliable following Gray & Garrison (1987). This would mean an underabundance in Ca compared with other metallic elements. We have found a weak underabundance Ca/Fe (-0.15 dex). Thus, there is indeed no contradiction.

For the four SB2 stars, HD 73618, HD 73711, HD 73731, HD 73818, and the broad-lined star, HD 72942, only (Li), S, and Fe could be typically studied. The abundances have been found remarkably near those better established for the four single-lined stars. Both components of HD 73618 show similar Am spectra, suggesting identical stars; the abundances of the "mean" star consistently are those of each component. They have been found the same as those of the three single stars with the same temperature (8100- 8000 K).

This paper series, that of Boesgaard and co-workers, and that of Soderblom and co-workers, separately are homogeneous. Through similar discussions to those stated in Paper I and not redone here, especially concerning temperature scales, our various comparisons are found relevant and significant.

We note the very good agreement with results by Hui-Bon-Hoa and co-workers (1997, 1998): for five stars in common, HD

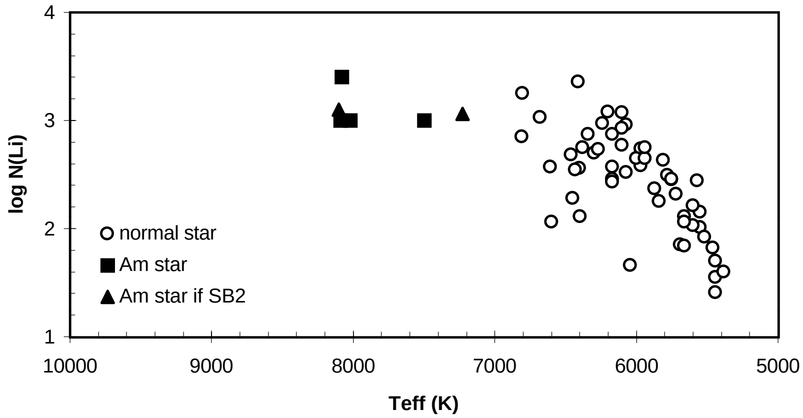

Fig. 3. The Li temperature profile of A stars with F and G stars (Boesgaard & Budge 1988; Soderblom et al. 1995) in Praesepe. The Am stars are plotted with filled squares, triangles if SB2

73045, HD 73174, HD 73618, HD 73709, and HD 73730, our Fe mean is equal to 7.92 with σ = 0.09 and theirs equal to 7.93 with σ = 0.13. The methods are similar, the temperature scales identical, and the spectral intervals different. Yet, one star in common, HD 72942, was excluded from the comparison: the effective temperatures derived from the uvby,β photometry with the same code (Moon 1985; Moon & Dworetsky 1985) differ by about 200 K. This disagreement is explained by the difficult and ambiguous assignment of the star to a group.

4. Discussion

We collect the observational results that have been well established and must be taken into account by any global explanation of the Am phenomenon.

In Praesepe cluster, the Am stars are overabundant in Fe by a factor of 2 (+0.35 dex) compared with the F-G stars, which are not evolved and have the initial abundance. In the first paper, we similarly have found an overabundance of + 0.30 dex in a younger cluster, the Pleiades.

Just like for the Pleiades, our Li results in Praesepe challenge predictions from model envelopes coupling diffusion and evolution in non-rotating Population I A stars by Richer & Michaud (1993): at the age of Praesepe no lithium is expected to be observed in the slowly-rotating Am stars. Richer and co-workers (1997, 1998) improve radiative force calculations and show up the possible strong coupling that can exist between the radiative force of one element and the abundance of another one. For example the Li force, which is coupled with the He abundance, increases by a large factor when helium abundance decreases by gravitational settling. Richer and co-workers foresee to calculate self-consistent evolution models with the refined forces. Significant changes are expected in the evolution of the lithium distribution in the radiative stellar envelope, leading to Li better supported, i.e., smaller photospheric underabundances for stars in the range 9000-7200 K and a better agreement with our observational results.

In the range 8100-8000 K, the three stars, HD 73174, HD 73709, and HD 73730 with well-defined abundances lie at the same place inside the sequence turn-off of the cluster in Fig. 1. So is the place of the SB2 HD 73618 when assuming its binarity with both similar components. We are, thus, studying four stars of the same cluster; they presumably have the same age, mass, and initial chemical composition. They are turn-off stars at the same stage of evolution: the standard deviation of the mean of the V magnitude is 0.15. They have begun their evolution out of the Main Sequence: they are brighter than ZAMS stars of the same temperature by about one magnitude. These four Am stars have the same abundances, particularly in Si, S, and Fe for which the standard deviation of each mean is about 0.10 dex. We,however, note that the abundances of HD 73709 are the highest of each range. Li is even significantly higher and similar to that of cluster normal A stars when for the three other Am stars Li is similar to that of cluster Am stars (Burkhart & Coupry 1995). Many stellar parameters are the same. Another important parameter can make the difference between HD 73709 and the others: rotation or more exactly angular momentum history. During the whole evolution, this can affect the thickness of the mixing zone and the temperature at its bottom, and lead to "Li is affected when Fe and Si are not.".

A more extended refined abundance analysis of this "8100-8000 K" Am quartet will be fruitful. It is technically possible in consideration of the magnitudes and projected rotational velocities. We can imagine that the peculiar behavior of Li (and others elements to be found) may add enough constraints upon the models to test them.

The cooler well-studied star, HD 73045, at 7500K, is not distinguished from the quartet with respect to abundances of Li, Al, Si, Fe, and Ni, although that star is normally less evolved.

5. Conclusion

In Praesepe cluster, all A stars with enough sharp lines for Li to be studied were observed. They are ten Am stars.

- The Am stars have the same Li content as the F stars on the hot side of the Li dip. This result relies upon only a few stars. One star stands out with Li more abundant and similar to that of normal cluster stars. Extending the abundance analysis of this star and the others of the same effective temperature would be interesting.

- Al, Si, and S are marginally overabundant compared with the Sun, keeping in mind that weak Al blends may be difficult to manage and strong S lines are dependent on the microturbulent velocity, not well determined for some stars of this work.

- Compared with the Sun or the Praesepe F stars, the Fe overabundance by a factor of 2 at least is well established.

- Ni, one element of the Fe group, too, is overabundant (by a factor of 4) compared with the Sun. It is well established but for a few stars.

- The rare earth Eu is largely overabundant compared with the Sun: the factor of 10 is not accurate taking into account difficulties encountered in studying the Eu blend as explained in the first paper in the series.

There is remarkably an only abundance value for the studied elements, even if some star may have a little outstanding element. To the elements studied in this series of papers we can add Sc and Ca, each of which exactly shows uniform underabundance for five stars in common with Hui-Bon-Hoa and co-workers (1997; 1998). At the age of Praesepe (log t(years) = 8.8), must we think that there is enough time for interior transport processes to act and to reach the same stable photospheric chemical composition for stars with different structure envelopes (since so are the effective temperatures and stages of evolution)?

From the age of the Pleiades till that of the Hyades and Praesepe, Hui-Bon-Hoa & Alecian (1998) claim that they find significant differences in abundance patterns of A stars, especially for Sc and Ca. In this paper, on the contrary, the behavior of Li and Fe in Am stars of Praesepe is found very similar to that of the Pleiades. New constraints are, so, put on abundance evolution between both ages of the clusters, i.e., in the log t interval of 8.0-8.8. Time dependence of the abundances would be better tested in the next paper in the series dealing with new results in Coma and Hyades clusters, which have ages similar to Praesepe.

Acknowledgements. We acknowledge the excellent support by the CFHT staff, especially J.Glaspey, and the night help at the telescope. One author (C.B.) thanks in Lyon, France, the computing Department for its support. This research used the bibliographical stellar database, Simbad, operated at the "Centre de Données Stellaires" in Strasbourg, France. We thank the referee, S.J.Adelman, for his careful reading of the manuscript and his suggestions.

References

Abt H.A.,1986, PASP 98, 307
Bidelman W.P., 1956, PASP 68, 318
Boesgaard A.M., Budge K.G., 1988, ApJ 332, 410
Bolte M., 1991, ApJ 376, 514
Burkhart C., Coupry M.F., 1991, A&A 249, 205
Burkhart C., Coupry M.F., 1995, MSAIt 66, 357
Burkhart C., Coupry M.F., 1997, A&A 318, 870
Coupry M.F., Burkhart C., 1992, A&AS 95, 41
Crawford D.L., Barnes J.V., 1969, AJ 74, 818
Dickens R.J., Kraft R.P., Krzeminski W., 1968, AJ 73, 6
Friel E.D., Boesgaard A.M., 1992, ApJ 387, 170
Gray R.O., Garrison R.F., 1987, ApJS 65, 581
Gray R.O., Garrison R.F., 1989, ApJS 70, 623
Hauck B.,Mermilliod M., 1980, A&AS 40, 1
Hui-Bon-Hoa A., Burkhart C., Alecian G., 1997, A&A 323, 901
Hui-Bon-Hoa A., Alecian G., 1998, A&A 332, 224
Johnson H.L., 1952, ApJ 116, 640
Kurucz R.L., 1979a, ApJS 41, 1
Kurucz R.L., 1979b, Dudley Obs. Rep. No. 14, 363
McGee J.D., Khogali A., Baum W.A., Kraft R.P., 1967, MN 137, 303
Moon T.T., 1985, Commun. Univ. Lond. Obs. No. 78
Moon T.T., Dworetsky M.M., 1985, MNRAS 217, 305
Richer J., Michaud G., 1993, ApJ 416, 312
Richer J., Michaud G., Massacrier G., 1997, A&A 317, 968
Richer J., Michaud G., Rogers F., Iglesias C., Turcotte S., LeBlanc F., 1998, ApJ 492, 833
Rutten R.J., Van der Zalm E.B.J., 1984, A&AS 55, 171
Smalley B., Dworetsky M.M., 1993, A&A 271, 515
Soderblom D.R., Fedele S.B., Jones B.F., Stauffer J.R., Prosser C.F. ,1993, AJ 106, 1080
Soderblom D.R., Fedele S.B., Jones B.F., Stauffer J.R., Prosser C.F. ,1995, AJ 109, 1402
Steffen M., 1985, A&AS 59, 403
Wang J.J., Chen L., Zhao J.H., Jiang P.F., 1995, A&AS 113, 419