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# The Pleiades, Coma, Hyades, and Praesepe open clusters: Li, Al, Si, S, Fe, Ni, and Eu abundances compared in A stars ⋆

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**Abstract.** In the third of a series of papers on the A stars in open clusters, the Coma and Hyades clusters are revisited; in the first and second papers, the Pleiades and Praesepe were respectively investigated. All the spectra were secured with the Canada-France-Hawaii telescope at high spectral resolution and high signal-to-noise ratios. Photospheric abundances have been determined for Li, Al, Si, S, Fe, Ni, and Eu from model atmosphere abundance analysis. All the A stars with enough-sharp lines to be studied for Li were observed in the four clusters. Abundance results are summarized for 31 cluster members, including 21 Am, 7 normal A, and 3 early-A stars.

The Am stars have very uniform Li, Al, Si, S, and Fe abundances in a large temperature range of nearly 1000 K. Compared to normal A stars, Li is significantly deficient in Am stars (by a factor of 3), Al marginally overabundant, Si, S, and Fe are the same, Ni and Eu (with only a few results) overabundant. Those uniform abundances of Li, Al, Si, S, or Fe in Am stars involve that abundances are little affected by the magnitude of the rotational velocity.

For both Am and normal A samples, no abundance trend as a function of age and/or evolution is detected in the case of Li, Al, Si, S, or Fe. The ages considered are in the range 0.8 - 7 $10^8$ years; the evolution is limited from the ZAMS to the cluster turn-off. The build-up of the chemical abundances studied, in particular the Li differentiation between Am and normal A stars, could have taken place very early when the stars arrive on the Main Sequence.

The spread in lithium found for the A stars is reminiscent of that reported in the field and one open cluster for stars of nearly the same mass and slightly evolved out of the Main Sequence. The Li abundance does not change as soon as the star evolves through the subgiant phase and the convection zone becomes deeper. There are two exceptional Am stars: one, in the Hyades, is Li-deficient and the other, in Praesepe, Li-overabundant. They are no obvious circumstances that can distinguish both stars from others in the very same region of their respective cluster sequence. In each of the four clusters, the maximum Li abundance is found in A stars, generally in normal A stars.

The Fe abundance of both Am and normal A groups is found to be twice the original Fe value (on the ZAMS) in each of the four clusters, independently of their age or metallicity. It is well established for the Am group and in only a narrow range of Teff for the normal A group. This behavior is unexpected for normal A stars which are thought to have their original abundances and Fe abundance different from that of Am stars. A larger normal A sample is needed to conclude anything.

Our abundance results for cluster Am stars quantitatively agree with predictions of new models coupling atomic diffusion with turbulent transport (Richer et al. 1999).

**Key words:** stars: abundances – stars: chemically peculiar – Galaxy: open clusters and associations: individual: Coma cluster – Galaxy: open clusters and associations: individual: Hyades – Galaxy: open clusters and associations: individual: Pleiades – Galaxy: open clusters and associations: individual: Praesepe

## 1. Introduction

This paper is the third 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. The first paper (Burkhart & Coupry 1997) dealt with the A stars in the Pleiades and the second one (Burkhart & Coupry 1998) those in Praesepe. This paper completes the study of the Coma and Hyades clusters (respectively Boesgaard 1987a and Burkhart & Coupry 1989) adding results for three stars in each cluster. The age of the Hyades and Praesepe (about 6 and 7 $10^8$ years) is nearly ten times that of the Pleiades (about 0.8 $10^8$ years), that of Coma being between (about 5 $10^8$ years); the Pleiades A stars are at the beginning of the Main Sequence evolution and the Praesepe or Hyades stars are well advanced in their Main Sequence evolution, some of them being in the turn-off. Therefore we may compare four clusters in increasing ages, the Pleiades, Coma, the Hyades, and Praesepe. First, we test any dependence of the abundance anomalies in A stars with age and/or evolution. Second, we study Li abundances on the hot side of the Li dip.

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

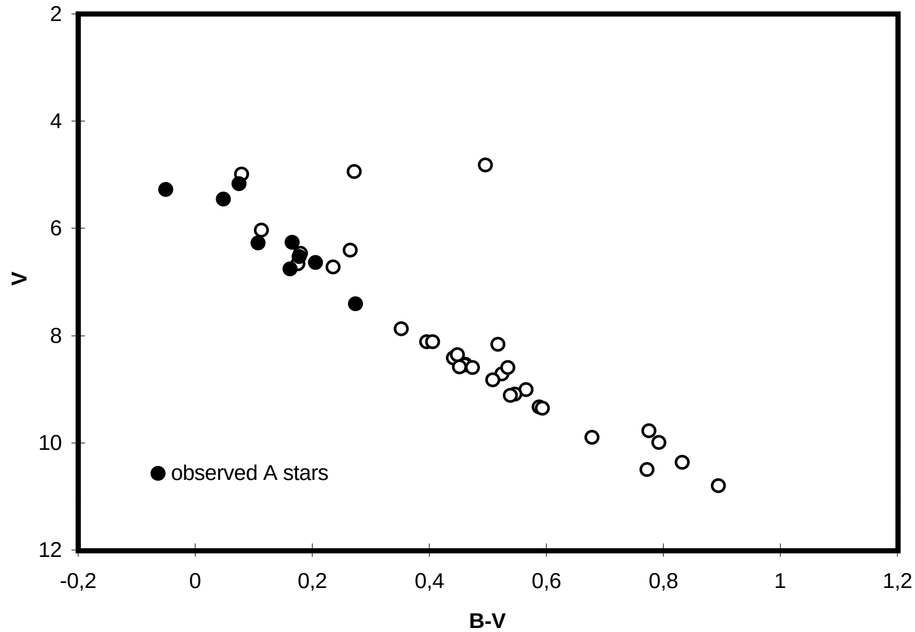



**Fig. 1.** Color-magnitude diagram for the Coma cluster stars (circles). The circles are filled for observed A stars. The UVB photometry comes from Johnson & Knuckles (1955)

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 $2\sigma$ level). 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, $\beta$ photometry (Moon 1985; Moon & Dworetsky 1985). The Kurucz's (1979) models were used in order to maintain consistency with earlier papers of this series and papers by A.Boesgaard and her collaborators. The abundances are compared one another and tests show that newer Kurucz models introduce small abundance variations without altering the relative abundances considered in this paper.

This paper is arranged as follows: the second part deals with Coma and the third with the Hyades, the 4th part resumes in the four clusters the behavior of abundances in A stars and the 5th that of Li on the hot side of the Li dip.

## 2. The Coma cluster revisited

Boesgaard (1987a) studied the sparse Coma cluster and determined abundances of both Li and Fe in the F dwarfs and five A stars. Our observations of seven A stars complete the study of all the cluster A stars with enough-sharp lines to be studied for Li. One of the stars of Boesgaard, HD 108486, was re-observed by us as only an upper limit was determined for Li equivalent width in 1987. Some stellar characteristics and our observation data are collected in Table 1 for all the eleven A stars observed by us and/or Boesgaard. The stars are shown in the hottest part of the cluster color-magnitude diagram (Fig. 1), except two stars, HD 106999 and HD 107655 which are "non members?" following Renson (1990). For the first star, we give the deduced abundances but do not consider them in the figures and discussions. For the second star (quoted in italic letters in Table 1 and not studied later), its spectrum is unworkable: a hot star with a relatively large rotation rate. In Fig. 1, among the three hottest stars, two stars, 21 Com and 13 Com, are in the sequence turn-off and the third, 17 ComA, is a blue straggler. None of them (quoted in italic letters in Table 1) are studied later. 17 ComA and 21 Com are variable magnetic Ap stars; the mere identification of their numerous spectral lines is beyond the scope of these series papers and will involve several observations in a larger spectral range. The 3-pointed line profiles of 13 Com suggest that the star may be a spectroscopic binary with 3-line systems (SB3): more observations are needed to ascertain this and eventually lead to the determination of the abundances.

The equivalent widths of the three stars measured by us 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 found in Table 2 is, then, that of the entire blend and "bd" is put for the satellite line.

The abundance results are summarized in Table 3. The four lines with only Li and Fe abundances give results of Boesgaard (1987a) and the three others our results. The temperatures of Boesgaard are based on (B-V) photometric indices, ours are derived from the uvby,$\beta$ photometry (Moon & Dworetsky 1985). As reported in Burkhart & Coupry (1989), both temperature scales are almost the same (for A stars our temperatures are about 60 K hotter) with a scatter of about 100K and the typical error in $\beta$, equal to $\pm 0.010$ mag., produces an error in temperature of $\pm$100K. Thus, both sets of results can be reliably put together. The normal A or Am character is evaluated from the

**Table 1.** Log book of the Coma A stars observed. Note: (Slettebak) is for (Slettebak et al. 1968), (CCJJ) for (Cowley et al.1969), and (A&M) for (Abt & Morrell 1995)

| | Sp type<br>**Gray&Garrison** 1989a,b<br>Abt&Levato 1977<br>Others | Ca/Fe | V | Exp time<br>(mn) | JJ (d)<br>-2440000 | Remarks |
|---|---|---|---|---|---|---|
| **HD 106999** | | nl? | 7.5 | 60 | 8646.12 | non member? |
| Tr 52 | | | | 60 | 8648.12 | |
| | A5-A5-F0 (Slettebak) | | | | | |
| **HD 107168** | **A5-A5-F0 (III)** | nl | 6.3 | | | |
| Tr 62 | A7-F0-F2 | | | | | |
| 8 Com | A8m: (CCJJ) | | | | | |
| **HD 107513** | **A7-F0-F0 (IV)** | Am | 7.4 | 60 | 8646.07 | $\delta$ Scuti |
| Tr 82 | A6-F0-F2 | | | 60 | 8648.16 | X rays : detected |
| ***HD 107655*** | | *hot star* | *6.2* | *30* | *8647.15* | *non member?* |
| *Tr 89* | | | | | | *unmeasured spectrum* |
| | *A1 III (A&M)* | | | | | |
| ***HD 107966*** | ***A3 IV*** | *hot star* | *5.2* | *15* | *8648.09* | *SB3? (line profiles in this work)* |
| *Tr 107* | *A2 V* | | | | | *variable X rays : detected* |
| *13 Com* | *A3 V (A&M)* | | | | | *Li blend : present* |
| **HD 108486** | **A3-A5-A7 (IV)** | Am | 6.7 | 30 | 8645.08 | variable |
| Tr 139 | A2-A8-F0 | | | 75 | 8647.09 | |
| **HD 108642** | **A2-A7-A7 (IV)** | Am | 6.5 | | | SB2; P=11.78d |
| Tr 144 | A2-A7-F0 | | | | | |
| **HD 108651** | | Am | 6.65 | | | SB1; P=68.29d |
| Tr 145 | A2-A7-F0 | | | | | |
| 17 ComB | | | | | | |
| ***HD 108662*** | | *Ap* | *5.3* | *15* | *8646.15* | *blue straggler* |
| *Tr 146* | *Ap(Si,Cr)* | | | | | *variable; magnetic field* |
| *17 ComA* | *A9: Vp(Cr,Sr,Eu) (A&M)* | | | | | |
| ***HD 108945*** | | *Ap* | *5.5* | *20* | *8647.13* | *$\delta$ Scuti* |
| *Tr 160* | | | | | | *variable; magnetic field* |
| *21 Com* | *A3 IIIp (Sr,Cr) (A&M)* | | | | | |
| **HD 109307** | **A3 IV-Vs** | nl | 6.3 | | | |
| Tr 183 | A3-A7-A7 | | | | | |
| 22 Com | A5 III (CCJJ) | | | | | |

process already used in this series, i.e., from the classification of Gray & Garrison (1989a, 1989b) and/or the line ratio Ca I-6717/Fe I-6678 (Burkhart & Coupry 1991), respectively found in col.2 and 3 of Table 1. There is general agreement between both procedures. The adopted character is given in col.2 of Table 3. Two cases, 8 Com and 22 Com, called Am by Boesgaard and normal in col.2, deserve explanations. 8 Com is sorted out normal A taking into account the Ca I/Fe I line ratio and the spectral type from Ca II K line equal to that from H lines (Gray & Garrison 1989b). This star, however, is a special case: calcium is not underabundant and may be overabundant with probably many other heavier elements (Smith 1971). It looks "supermetallic". 22 Com is unambiguously sorted out normal A by our process in agreement with the MK classification by Cowley et al. (1969), quoted CCJJ in Table 1, but in disagreement with the MK classification by Abt and Levato (1977) and ignoring its outstanding scandium (Cowley 1981).

The microturbulent velocity, $v_t$, is obtained as a pure fitting parameter to obtain equal Fe abundances from lines of different equivalent widths. The value for HD 108486 was found to be 4.5 km $s^{-1}$, that is larger by 1.5 km $s^{-1}$ than those found in Coupry & Burkhart (1992) but equal to those found in this series for the Pleiades normal A and Praesepe Am stars. As no determination was possible for HD 107513, we *a priori* choose a $v_t$ of 4.5 km $s^{-1}$. For HD 106999, $v_t$, poorly determined, seems to have a low value (less than 3 km $s^{-1}$). Microturbulence values used do not affect Li, Al, Si, Ni, and Eu abundances as also Fe abundance of HD 108486, all determined from weak lines. We note that

**Table 2.** Equivalent widths (mÅ) of Coma and Hyades stars. A satellite line is noted “bd”; its equivalent width is included in that given for the main line of the blend

| | | | | | Coma | | | Hyades | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | λ | Mult | χ | log gf | HD 106999 | HD 107513 | HD 108486 | HD 27819 | HD 30210 | HD 33204 |
| **Ni I** | 6 643.638 | 43 | 1.68 | -2.10 | 14? | | 24 | | | |
| **Eu II** | 6 645.127 | 8 | 1.38 | 0.35 | | | 8.5 | | | |
| **Fe I** | 6 677.997 | 268 | 2.69 | -1.67 | 54 | 79 | 66 | 64 | 122 | |
| **Al I** | 6 696.032 | 5 | 3.14 | -1.62 | | 9 | 7.5 | 7 | 17 | 24 |
| **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 | | | 4 | | | 13 |
| **Fe I** | 6 699.136 | 1228 | 4.59 | -2.17 | | | bd | | | bd |
| **Fe I** | 6 705.105 | 1197 | 4.61 | -1.20 | | | 11.5 | 12 | 21 | 21 |
| **Fe I** | 6 707.449 | | | -2.20 | | bd | bd | bd | bd | |
| **Li I** | 6 707.760 | 1 | 0.00 | 0.00 | 7 | 16 | 8 | 16 | 10 | 11 |
| **Li I** | 6 707.980 | 1 | 0.00 | -0.30 | bd | bd | bd | bd | bd | bd |
| **Fe I** | 6 717.527 | 1194 | 4.61 | | bd | bd | bd | bd | bd | bd |
| **Ca I** | 6 717.687 | 32 | 2.71 | | 41 | 52 | 20 | 58 | 32 | 62 |
| **Si I** | 6 721.844 | 38 | 5.86 | -1.20 | 19 | 13 | 17 | 16 | 23 | 29 |
| **Fe I** | 6 726.673 | 1197 | 4.61 | -1.18 | 13 | | 13 | 8 | 19 | 25 |
| **Si I** | 6 741.629 | | 5.98 | -1.62 | | | | | | 22 |
| **Fe Ip** | 6 756.568 | 1120 | 4.29 | -2.61 | bd | bd | bd | bd | bd | |
| **S I** | 6 757.195 | 8 | 7.87 | -0.21 | 67 | 63 | 61 | 67 | 82 | |

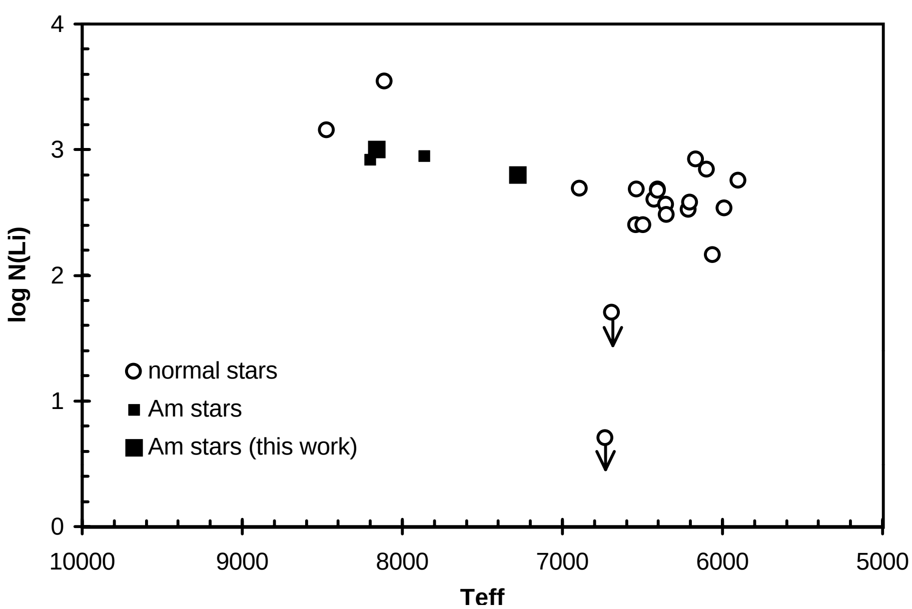



**Fig. 2.** The Li temperature profile of A stars with F stars (Boesgaard 1987a) in Coma (on the scale of log N(H) = 12.00)

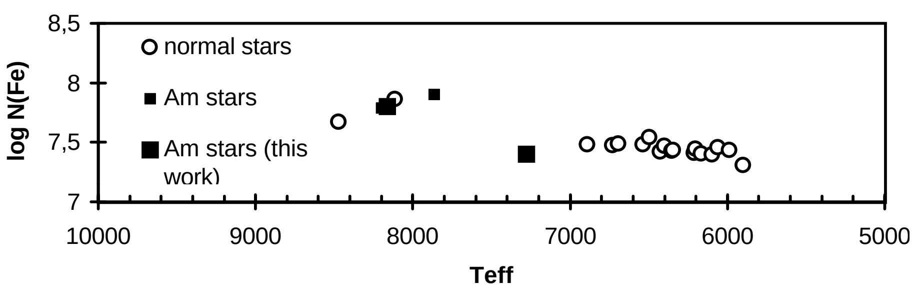



**Fig. 3.** The Fe temperature profile of A stars with F stars (Boesgaard 1987a) in Coma (on the scale of log N(H) = 12.00)

**Table 3.** Abundances of Coma and Hyades stars (on the scale of log N(H) = 12.00)

| | | **Teff** (°K) **log g** | $v_t$ | **log N (Li)** | **log N (Al)** | **log N (Si)** | **log N(S)** | **log N (Fe)** | **log N (Ni)** | **log N (Eu)** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Coma** | | | | | | | | | | |
| **HD 106999** Tr 52 | nl? member? | 8160 4.0 | ≤3.0 | 3.0 | | 7.8 | 7.5 | 7.85 | 6.4 | |
| **HD 107168** 8 Com | nl | 8110 4.5 | 1.7 | 3.54 | | | | 7.86 | | |
| **HD 107513** Tr 82 | Am | 7280 4.0 | 4.5 : | 2.8 | 6.1 | 7.3 | 7.2 | 7.4 | | |
| **HD 108486** Tr 139 | Am | 8180 4.0 | 4.5 | 3.0 | 6.4 | 7.75 | 7.3 | 7.8 | 6.6 | 1.2 |
| **HD 108642** Tr 144 | Am, SB2 | 8200 4.5 | 1.7 | 2.92 | | | | 7.79 | | |
| **HD 108651** 17 ComB | Am | 7865 4.5 | 1.7 | 2.95 | | | | 7.9 | | |
| **HD 109307** 22 Com | nl | 8470 4.5 | 1.7 | 3.15 | | | | 7.67 | | |
| **Hyades** | | | | | | | | | | |
| **HD 27819** 64 Tau | nl | 8200 4.0 | 4.0 | 3.4 | 6.25 | 7.8 | 7.4 | 7.9 | | |
| **HD 30210** vB 112 | Am | 8110 4.0 | 5.0 : | 3.05 | 6.8 | 7.9 | 7.5 | 8.1 | | |
| **HD 33204** vB 131 | Am | 7670 4.0 | 5.0 : | 2.85 | 6.8 | 7.8 | | 7.85 | | |
| **Sun** | | | | | 6.47 | 7.55 | 7.21 | 7.51 | 6.25 | 0.51 |

the "non member?" HD 106999 has the very same abundances (and temperature) as the Coma member, HD 108486.

Boesgaard (1987a) can take into account the SB2 character of HD 108642 since the Am spectrum dominates that of the G companion and thus gives reliable abundances of Li and Fe.

The Li- and Fe-temperature profiles of A stars (Table 3) are shown respectively in Fig. 2 and Fig. 3 with F stars (Boesgaard 1987a).

In the cluster the maximum Li abundance is found for both normal A stars. The mean of log N(Li), 3.35, is higher by about +0.45 dex than both highest values on the cool side of the Li dip. The difference seems significant to us. It is more conspicuous (+0.8 dex) if we compare normal A stars with the "Li peak" in Coma (Boesgaard 1991) in the range 5950 to 6350 K. The four Am stars, with a mean of log N(Li) = 2.9, are clearly deficient in Li compared with both normal A stars; they have the same Li content as upper-envelope stars of the "Li peak".

In the case of Fe, for Coma F dwarfs, the mean of [Fe/H], equal to log $(Fe/H)_\star$ - log $(Fe/H)_\odot$, has been found to be -0.07 $\pm$ 0.02 (Boesgaard 1987a). In this series, log $(Fe/H)_\odot$ is taken equal to 7.51, thus log $(Fe/H)_{F\star}$ = 7.44. The three Am around 8000 K and both normal A stars are found to be equally overabundant in Fe compared with F stars (+0.35 dex). The coolest Am star near 7200 K, HD 107513, has the same Fe content as F dwarfs.

Beside normal Fe compared with Coma F stars or the Sun, HD 107513 is, also, peculiar for Al and Si, deficient compared with the Sun (-0.35 and -0.25 dex, respectively). We could invoke the choice of a too low temperature but the choice was done as for the other stars and we have no particular reason to suspect it. These results are consistent with the classification by Gray & Garrison (Table 1) suggesting Ca deficient but other elements rather normal.

The well-established abundances of the star HD 108486 are compared with the Sun:

- Al, Si, and S are normal or marginally overabundant (+0.1, +0.2, and +0.1 dex).
- Fe and Ni are overabundant (+0.3 and +0.35 dex).
- Eu is largely overabundant (+0.7 dex).

## 3. The Hyades cluster revisited

Burkhart & Coupry (1989) studied six A stars in the Hyades cluster and determined their Li, Al, Si, and Fe abundances. (The Ca abundances were also given but found to be unreliable, except for 68 Tau, an early A star.) Observations of three new stars complete the study of all the A stars with enough-sharp lines to be studied for Li. The spectrum of vB 131 was obtained by R.Cayrel at the CFH telescope in 1987. For this star the configuration of the f/7.4 coudé spectrograph was that

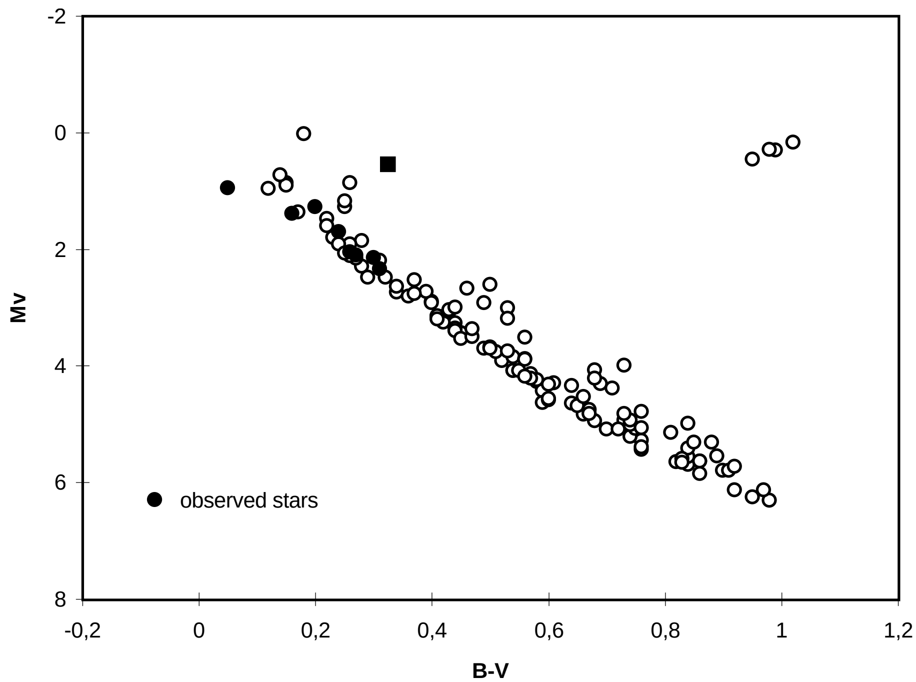



**Fig. 4.** Color-magnitude diagram for the Hyades cluster stars (circles). The circles are filled for observed A stars. The Mv and (B-V) values are those found in Schwan (1991). The filled square denotes $\gamma$ Cap, an Am star in the Hyades group

used in our Hyades study in 1989: a 1800 lines/mm holographic grating instead of the 830 lines/mm grating used in this series. The different equivalent-width scales were checked (Coupry & Burkhart 1992; Burkhart & Coupry 1997) and the comparisons supported the merging of all the results: this series with Hyades paper of 1989, and with Coma paper (Boesgaard 1987a), the observations of this last paper being secured at the CFH telescope with the spectrograph configuration of this series.

The observed A stars are shown in the hottest part of the cluster color-magnitude diagram (Fig. 4). The star $\mu$ Ori, observed in 1989, is rejected and no more considered as its membership is not confirmed by the paper of Perryman et al. (1998) based on HIPPARCOS measurements. Among the three hottest stars, one star, 68 Tau, is a blue straggler and the two others, 64 Tau and vB 112, are just before the sequence turn-off. The normal or Am character was easily evaluated since all the eight Hyades A stars were classified by Gray & Garrison(1989a, 1989b). In agreement with the Ca I/Fe I ratio, the classification of six stars is Am and that of 64 Tau normal A. The case of 68 Tau has to be inspected. Without applying the process used in this series, it was called Am by us in 1989. As 68 Tau is classified A2 IV-Vs by Gray & Garrison and the Ca I/Fe I ratio is useless for an early A star, this star is unambiguously sorted out (hot) normal star in this work.

The equivalent widths and abundance results of the newly-studied Hyades stars are given in Table 2 and Table 3 with those of Coma stars.

Our temperature scale for the Hyades A stars is that of this series and so that of Coma A stars found to be about 60 K hotter than Boesgaard scale for five Coma A stars (1987a). As Boesgaard (1987a) claimed her scale for Coma (mostly F) stars is 85 K cooler than the scale adopted for the Hyades F stars (Boesgaard & Tripicco 1986) our and her Hyades scales are both the same. However, we must not overlook some difficulties. On the one hand, the photometric temperature calibration used by us is tested with HIPPARCOS data for detached eclipsing binaries by Ribas et al. (1998). Their tight correlation between photometric and HIPPARCOS temperatures is linear from 10000 to 5000K and independent of metallicism (defined by the photometric index, $\delta m_0$) in the range 8500-6000 K. This justifies our approach when comparing A stars with cooler stars and Am with normal A stars. On the other hand, Balachandran (1995) examined the temperature scale used by Boesgaard and co-workers for the Hyades. By mainly imposing a constant Fe abundance for the star sample, she concluded that Boesgaard calibration overestimated the temperatures of early F stars. This involves the systematic trend found toward higher Fe abundances for the stars hotter than 6600 K. The trend may be spurious; it is obvious in the Fe-temperature profile of Fig. 5 in Boesgaard & Budge (1988) but missing in those of Fig. 3 in Boesgaard (1989) and Fig. 4 in Boesgaard & Friel (1990) when the temperature scale is the same in the three papers. In the last two papers, the hotter stars are sparse and better selected. One Am star, with, *a priori*, an overabundance of Fe, is removed. Some “difficult” stars are, too, removed: one is the secondary in an SB2 system, some others have large v sin i (a common case in the hotter stars). We, also, note the puzzling case of the star vB 11. It has a high Fe value ([Fe/H] = +0.30) in the first paper, significantly different from those of both later papers (+0.09 and +0.107 respectively); however equivalent width data of the first two papers are the same. Ignoring the criticism of Balachandran, we directly compare our results to those of Boesgaard and co-workers for Hyades F stars and of Cayrel et al. (1985) for Hyades G stars (their temperature scale is the same as Boesgaard).

The Li temperature profile of A stars (this work; Burkhart & Coupry 1989) is shown in Fig. 5 with F stars (Boesgaard

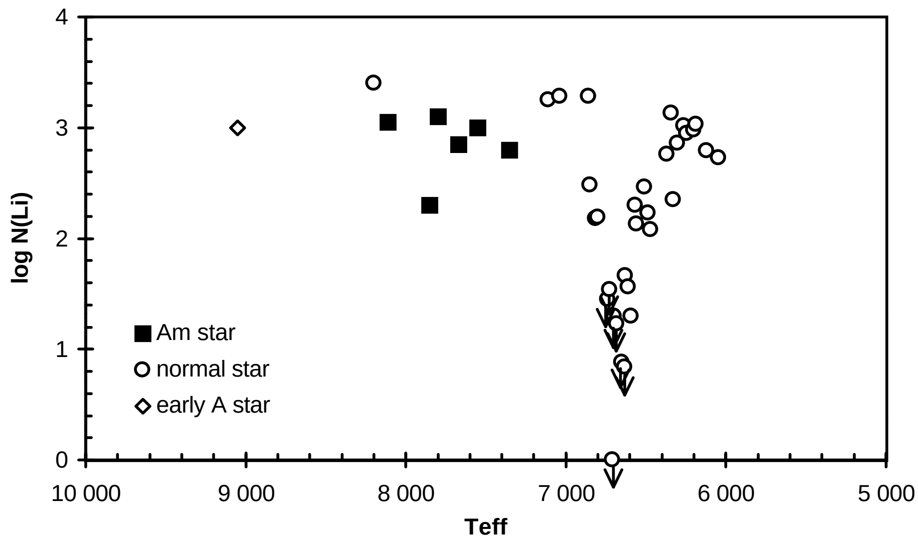



**Fig. 5.** The Li temperature profile of A stars with F stars (Boesgaard 1987b) in the Hyades

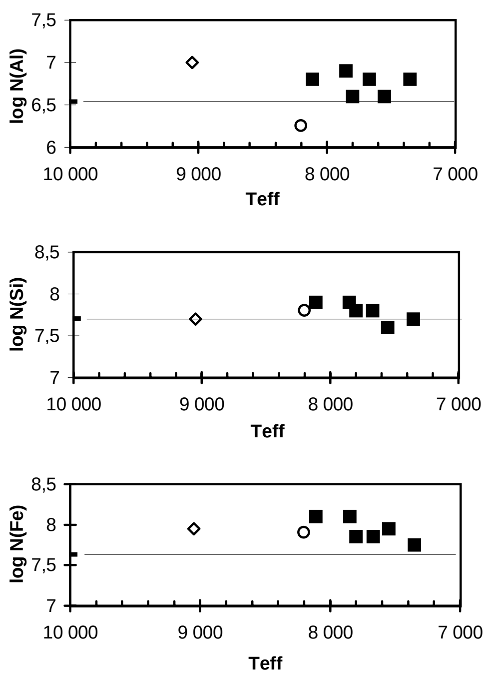



**Fig. 6.** The Al, Si, and Fe abundances of A stars in the Hyades. The symbols are those of Fig. 5. The horizontal lines display mean abundances for cooler Hyades stars: F stars for Fe (Boesgaard 1989 and Boesgaard & Friel 1990) and G stars for Al and Si (Cayrel et al. 1985)

1987b). The abundances of Al, Si, and Fe are shown in Fig. 6. We bring Fe values onto a common scale by lowering those of 1989 by 0.16 dex, taking into account the solar abundance adopted (equal to 7.67) at that time.

In the cluster the maximum Li abundance is found for the normal A star. It is significantly higher by +0.3 to +0.4 dex than the highest values on the cool side of the Li dip and marginally higher (+0.1 dex) than the highest values on the hot side. Five (out of six) Am stars, with a mean of log N(Li) = 2.96 $\pm 0.13$, are clearly deficient (- 0.4 dex) compared to the normal A star; they have the same Li content as the early A star ,68 Tau, and the Hyades "Li peak" of Boesgaard (1991). The sixth Am star, 16 Ori, is largely deficient in Li: -0.7 dex compared to the five other Am stars and -1.1 dex compared to the normal A star. The reality and circumstances of this deficiency were addressed in Burkhart & Coupry (1989).

The six Am stars exhibit abundance patterns remarkably close to each other for Al, Si, and Fe (Fig. 6): the standard deviation of each abundance mean is less than 0.15 dex. They form a very homogeneous group including the Li-deficient star, 16 Ori. We note, however, that, in each range of abundances, the value for 16 Ori is one of the highest. The six Am stars are compared with the normal A star:

- Al is overabundant (+0.5 dex),
- Si and Fe are normal (and so is S, obtained for only one Am star and the normal A star - see Table 3).

The early A star has abundances in Al, Si, and Fe very similar to those of the Am stars, even if Al abundance is something higher. Its Ca abundance is that of the G stars (Cayrel et al.1985).

We compare our results with the accurate results for cooler Hyades stars: Fe abundances of F stars (Boesgaard 1989 and Boesgaard & Friel 1990) and Al, Si, S, and Fe abundances of G stars (Cayrel et al.1985). Cooler stars are supposed to keep their original chemical composition during Main Sequence evolution; we, thus, obtain the outcome of the possible chemical variations undergone for A stars up to the age of the Hyades.

- The (6) Am stars are marginally overabundant in Al (+0.2 dex) and the normal A star is deficient (-0.3 dex).
- All the (8) A stars are normal in Si (+0.1 dex).
- All the (8) A stars are overabundant in Fe (+0.3 dex).
- (One Am star and the normal A star are normal in S).

16 Ori is the only Am star of an open cluster known to be largely Li deficient. Its O, Ca, and Sc underabundances are among the largest in the Hyades Am stars studied for oxygen by Takeda & Sadakane (1997) and calcium and scandium by Hui-Bon-Hoa & Alecian (1998) while Al, Si, and Fe contents are similar to those of other Am stars (this work).

## 4. Comparative abundances in the Pleiades, Coma, Hyades, and Praesepe clusters

All the A stars with enough-sharp lines to be studied for Li (projected rotational velocity, v sin i, less than about 60 $\mathrm{km\,s^{-1}}$) were observed. We summarize the abundance results obtained for 31 cluster members in Fig. 7. The sample includes 7 stars in the Pleiades, 6 in Coma, 8 in the Hyades, and 10 in Praesepe. By a homogeneous process we sort 21 Am and 7 normal A stars, 3 stars with Teff more than 9000 K being called early A or hot stars. In the A-type stars, the rapid and slow rotators divide nearly completely between the normal and chemically peculiar CP stars (Abt & Morrell 1995). Connected with the "v sin i" criterion, a bias is introduced. The ratio of Am to A stars observed here is equal to 3/4 when the unbiased ratio would be equal to about 1/4. From the results of Abt & Morrell (1995) it is plausible that the observed normal stars are actually rapidly rotators seen nearly pole-on and the observed Am stars have velocities v distributed all over the range 0-100 $\mathrm{km\,s^{-1}}$.

Among the three early A stars (Fig. 7), the unevolved star in the Pleiades and the blue straggler in Praesepe were classified hot Am stars; their sparse abundances, in agreement, are very similar to those of their cooler Am cluster-companions; a typical high Eu abundance is worthy of notice. On the other hand, the blue straggler in the Hyades, classified normal A star (Part 3), has the typical Li and Al abundances of the Hyades Am stars. Early A stars certainly lead to specific problems. For the Hyades blue straggler, we recall the strong Sc deficiency found by Conti (1965) and the fine abundance analysis by Adelman (1994) conducing to a hot Am star. From these few results in the early A domain, it is impossible to draw any conclusion upon the influence of stellar evolution and age, except that the "blue straggler stage" involves no large changes in the atmospheric abundances.

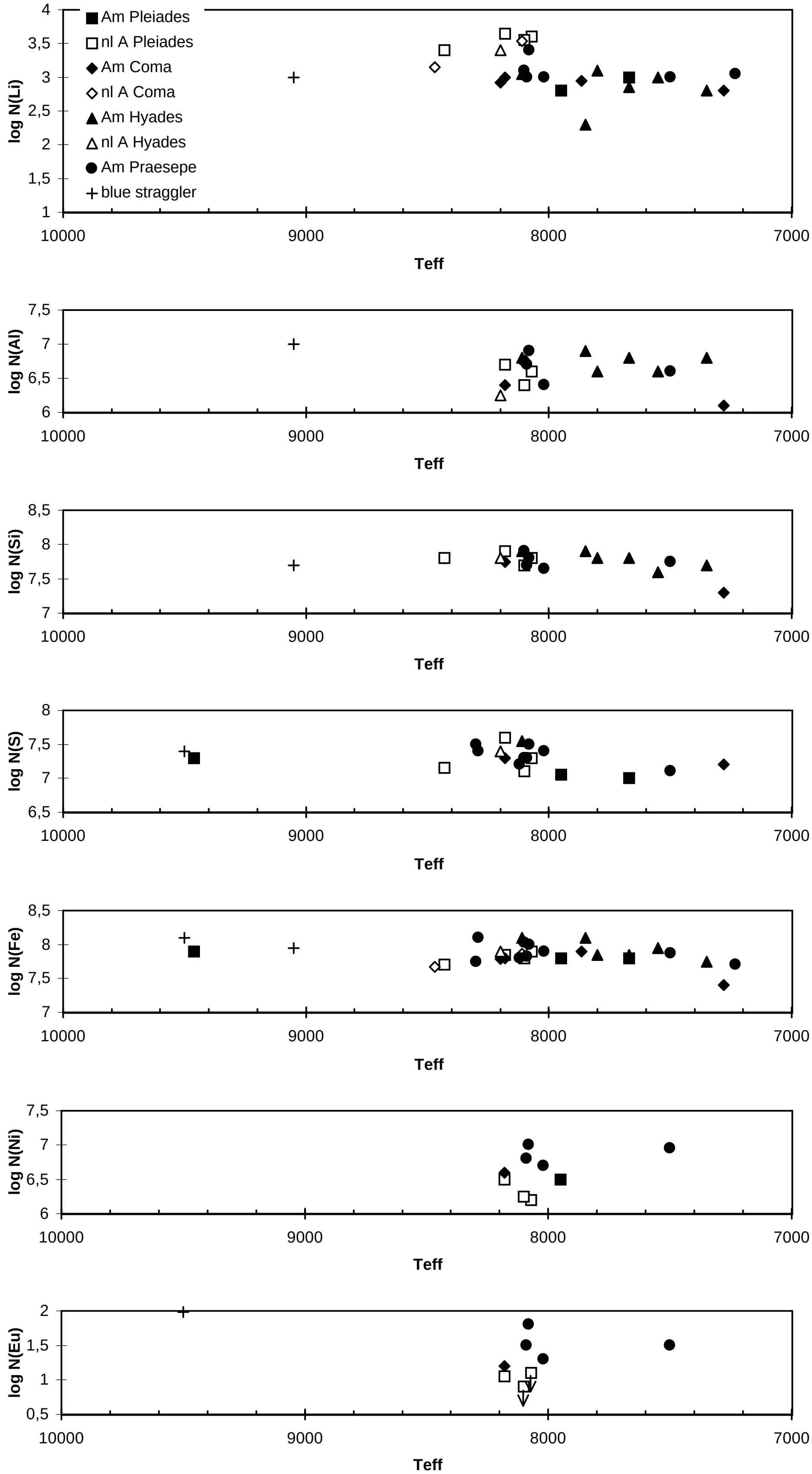
In Fig. 7, the "Am" dots are fairly well distributed with respect to the temperature and cluster membership in the range of temperature 8300-7200 K (with both exceptions of Ni and Eu). On the other hand, the "normal A" dots are found in the narrow range 8500-8000 K. The most meaningful "Am versus normal A" comparisons are to be found around 8300-8000 K. The corresponding stars have various evolution stages: Praesepe stars are in the cluster turn-off, Hyades stars just before, Coma stars clearly before, and Pleiades stars unevolved from the ZAMS.

The Am stars have very uniform Li, Al, Si, S, and Fe abundances in a temperature range of nearly 1000 K. There are 3 exceptional stars: one Li-deficient Hyades Am and one Praesepe Am with Li of normal A's, and the coolest Coma Am with Al, Si, and Fe deficiencies. The corresponding exceptional abundances are excluded in the determination of the different Am-plateaux given in Fig. 7. Compared to normal A stars, Li is significantly deficient in Am stars, Al marginally overabundant, Si, S, and Fe are the same, Ni and Eu (with only a few results) overabundant. The very small dispersion in each plateau is most remarkable all over a so large temperature range. It is consistent with observational error alone. Any explanation of the Am phenomenon must take into account the occurrence of these plateaux when the envelope structure of stars changes with their masses and ages (Richer et al. 1992).

The abundance of Fe, identical for Am and normal A stars, is doubly surprising: Am are classically said to be overabundant in Fe (compared with normal stars), and normal A stars are thought to have their initial chemical composition. The particular specifications of this series, compared to previous studies, were addressed in the Pleiades paper (Burkhart & Coupry 1997), supporting the results. In particular, if uncertainties in the absolute temperature scale of this work may shift the abundances of both normal-A and Am groups in a similar way, the relative $T_{\rm eff}$ values of Am versus normal-A stars, (therefore their relative abundance values), are well established. Smalley & Dworetsky (1993) check and validate the empirically calibrated "uvby, $\beta$" grids (Moon & Dworetsky 1985) which are not significantly affected by metal abundance. As is reported in Part 3, the same holds true from the study of detached eclipsing binaries (Ribas et al. 1998). On the other hand, the normal A stars observed are very sparse in each of the clusters and the sample is biased by the "v sin i" criterion. Statistical samples in a variety of open clusters are needed to confirm this abundance behavior. Non-LTE abundance corrections of Fe (Rentzsch-Holm 1996) are unlikely to change the circumstances: in the range 8500-8000 K, they are $\leq 0.15$ dex for solar Fe and $\leq 0.10$ dex for 3-times solar Fe. When an "Am versus normal A" comparison is made, the change due to non-LTE corrections will be of about 0.05 dex at most.

In each of the four clusters, the initial abundance of Fe (on the ZAMS) is known thanks to the study of F-G stars since no chemical composition change in the surface abundances is expected during their Main Sequence evolution. We can, therefore, have access to the Fe enrichment of the A stars. In Fig. 8, the Fe enrichment for a given cluster A star, $\delta$(Fe), equals log N(Fe/H)$_{A*(cluster)}$ - log N(Fe/H)$_{F-G*(cluster)}$. Log N(Fe/H)$_{F-G*(cluster)}$ is determined from the combined data of Table 5 in Friel & Boesgaard (1992) and the solar Fe abundance, log N(Fe/H)$_{\odot}$ = 7.51 in this series. Fig. 8 is similar to the Fe-$T_{\rm eff}$ profile of Fig. 7 with smaller dispersion. The three coolest Am stars, one each in Coma, the Hyades, and Praesepe, have nearly the original Fe of their respective cluster as if the Am phenomenon efficiency is progressively decreasing for Fe toward decreasing temperatures (and masses). For the Am and normal A stars in the range 8500-7400 K, on an average Fe is twice the original value of the cluster (on the ZAMS). The Fe enrichment of A stars in each of the four clusters ranges from +0.30 to +0.35 dex: it is constant and seems independent of the cluster age and metallicity.

Besides, since observed Am stars have not the same rotational velocity (but, likely, velocities all over the range 0-100 $\mathrm{km\,s^{-1}}$), the occurrence of the plateaux involves no strong influence of rotation on Li, Al, Si, S, and Fe abundances. This has to be put together with Burkhart's (1979) conclusion: regarding the relationship between the photometric index $\delta$ $m_1$ and the projected rotational velocity v sin i of Am stars, the degree of metallicity does not disappear progressively with increasing rotational velocity. In agreement, theoretical computations of




| | nl A | Am |
|---|---|---|
| <log N(Li)> | 3,45 | 2,95 |
| σ | 0,15 | 0,1 |
| n | 7 | 16 |

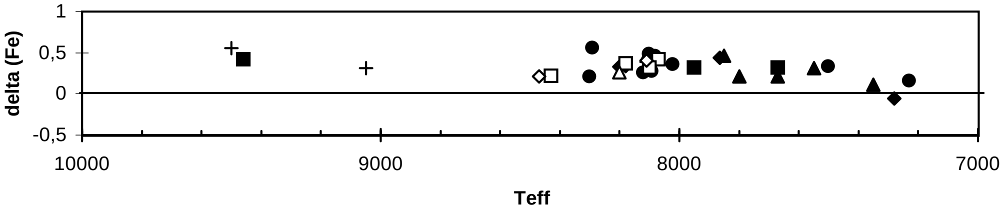
| | nl A | Am |
|---|---|---|
| <log N(Al)> | 6,5 | 6,7 |
| σ | 0,15 | 0,15 |
| n | 4 | 12 |

| | nl A | Am |
|---|---|---|
| <log N(Si)> | 7,8 | 7,8 |
| σ | 0,05 | 0,1 |
| n | 5 | 12 |

| | nl A | Am |
|---|---|---|
| <log N(S)> | 7,3 | 7,3 |
| σ | 0,2 | 0,15 |
| n | 5 | 13 |

| | nl A | Am |
|---|---|---|
| <log N(Fe)> | 7,81 | 7,88 |
| σ | 0,09 | 0,12 |
| n | 7 | 20 |

**Fig. 7.** Comparative abundances in the Pleiades, Coma, Hyades, and Praesepe. The Li-deficient Hyades Am and the Praesepe Am with Li of normal A's are excluded in the determination of the Am-plateau of Li, as also the coolest Coma Am for Al, Si, and Fe




| 8500-7400K | nl A | Am |
|---|---|---|
| <delta(Fe)> | 0,32 | 0,35 |
| σ | 0,08 | 0,10 |
| n | 7 | 18 |

**Fig. 8.** Fe enrichment of A stars in the Pleiades, Coma, Hyades, and Praesepe. The symbols are those of Fig. 7

diffusion models (Charbonneau & Michaud 1991) have shown that while meridional circulation has a determining influence on the settling of He, it has no significant effect on the diffusion of heavier metals. With a similar approach to that of Burkhart, Kodaira (1975) reached the opposite conclusion. The question was recently revisited by Takeda & Sadakane (1997) thanks to an extensive study of Hyades A stars: oxygen and iron abundances, v sin i, $v_t$... The star sample is smaller but the results are more homogeneous and accurate. Regarding $\delta$ $m_0$, log N(Fe), or log N(O) versus v sin i, both authors conclude that the Am anomaly is essentially controlled by the rotational velocity which is the trigger factor and governs the extent of peculiarity. For the Am Hyades stars in their respective Figs. 7c and 7b, we see, however, no correlation between v sin i and respective $\delta$ $m_0$ and log N(Fe). On the other hand, with the exception of the early A star, 68 Tau, a real tendency to larger O underabundances with smaller v sin i's appears in their Fig. 7a.

For both Am and normal A samples, no abundance trend as a function of age and/or evolution is manifest in any of the Li, Al, Si, S, or Fe-temperature profiles of Fig. 7 or Fig. 8 for Fe, the age being limited from 0.8 to 7 $10^8$ years and the evolution from the ZAMS to the cluster turn-off. This means that, for stars with masses of 1.6-2.2 $M_\odot$, the build-up of the chemical abundances studied in this series attains an equilibrium before the age of the Pleiades and this equilibrium does not change during the remainder of the Main Sequence lifetime. Other clues lead to think that the chemical anomalies are rapidly built when the stars arrive on the Main Sequence and present during the entire Main Sequence stage:

- HIPPARCOS results show that field Am stars fill the whole Main Sequence band in the H-R diagram like normal A stars, and no significant differences arise between the evolutionary state of Am and main sequence normal A stars (Domingo & Figueras 1999).

- In the Orion OB1 association (age about 3 $10^6$ years) Levato et al. (1994) count up to 15 Am stars, five of which are classical Am stars with, at least, 5 subtypes between K- and metallic-lines spectral types.

- The behavior of Li in the slow-rotator Am stars versus the rapid-rotator normal A stars in the Pleiades is exactly comparable with that found in the "low v sin i" versus "high v sin i" stars with similar masses in the Orion association, as if Li differentiation between Am and normal A stars might have taken place during pre-Main-Sequence evolution (Burkhart & Coupry 1997).

On the side of post-Main-Sequence evolution, A stars are the progenitors of the slightly evolved early-F field stars with masses of 1.6 - 1.8 $M_\odot$ studied by Balachandran (1991). Balachandran finds some few stars with log N(Li) in the range 2.2 - 2.5. Conceivably Li-deficient A stars such as 16 Ori hold the clue to the low abundances of those few early-F stars. We note that the A stars, Am and normal A, show a spread in Li of 1.35 dex in the four clusters; this spread is just the same as that found by Balachandran in her sample. Further evidence that some spread in lithium of A stars is existing during the Main Sequence phase is provided by the cluster NGC 7789 with an age of about 16 $10^8$ years (Pilachowski 1986). The four turn-off stars observed have masses of about 1.8 $M_\odot$, i.e., are evolved late A stars; they range in Li abundances from 3.3 to 2.4, that is a spread of 0.9 dex reminiscent of that seen in this series for "2.0 - 2.2 $M_\odot$" stars. If microscopic diffusion caused the observed lithium abundances in the absence of other particle transport processes, surface chemical anomalies were to be wiped out by evolution since microscopic diffusion is a surface effect. The observations put constraints and competing hydrodynamical processes (turbulence, mass loss, etc.) have to be considered in addition.

The abundance comparisons between the different clusters are warranted by the completely homogeneous way used by us from the observations to the determination of the abundances. In particular the temperatures, upon which abundances are very much dependent, are, all, derived from "uvby, $\beta$" observed indices by the same procedure. This must ensures a single temperature scale. The zero of the scale may be, however, questioned. So, the temperatures of detached eclipsing binaries coming from HIPPARCOS distances are slightly smaller than the photometric determinations (Ribas et al. 1998); taking into account the differential character of this series study, it is of no consequence on our conlusions; but the absolute abundances may have to be adjusted by decreasing them.

Above the "uvby, $\beta$" observed indices, we assumed the consistency of uvby, $\beta$ photometry for the four clusters. This may be not fully justified. Sets of data were tested by Taylor & Joner (1992) in the case of the Hyades and Coma and by Joner & Taylor (1995) in that of Praesepe. Joner & Taylor concluded that the Hyades and Coma data of Crawford and his collaborators (1966; 1969a) turned out to be on the same system; on the contrary, the color indices (b-y) and $\beta$, deduced from Praesepe data of Crawford & Barnes (1969b) require corrections of 11 and 18 mmag to put them on the Hyades-Coma system. The proposed corrections involve an increase of the temperatures equal to about 170 K, that is, an increase of the Praesepe abundances by about 0.1 dex. The corrections cannot be directly performed. On the one hand, the photometric indices of this series are the homogeneous means of various sets given in the catalogue of Hauck & Mermilliod (1980), even if for Praesepe the indices are essentially those of the set tested by Joner & Taylor. On the other hand, the problem is not completely cleared up for the moment since discrepancies appear between corrections proposed by Nissen (1988) and Joner & Taylor (1995) (see Joner & Taylor 1997). Those limitations are to be compared to the dispersions of our different abundances: they are about the same and may be an important part of those observed dispersions.

Microturbulence values, $v_t$, affect only abundances determined from strong lines, that is, in this series, S with every star (except the hot stars) and Fe when the only measured line is that at 6678 Å. We can put this dependency of S abundances together with their dispersions which are among the largest in Fig. 7 when the equivalent widths of S lines are accurately measured. Among the dozen stars with a good $v_t$ determination, two Am stars in each of the Pleiades and Hyades clusters follow the trend of $v_t$ with temperature shown in Coupry & Burkhart (1992) since their $v_t$ values range from 3.0 to 3.75 $km\,s^{-1}$ with Teff about 8000-7500 K. The other eight stars have significantly larger $v_t$ from 4.5 to 5 $km\,s^{-1}$: normal A stars of the Pleiades and Am stars of Coma and Praesepe. The $v_t$ magnitude does not divide between Am and normal A stars. One of the Praesepe stars with large $v_t$, HD 73709, would have a rather strong magnetic field equal to about 5 kG (North 1999, private communication). Spectral lines may have been broadened through the Zeeman effect and lead to a simulated large microturbulence. In that hypothesis, are the other large-$v_t$ stars magnetic stars? On the other hand, Landstreet (1998) recently detected atmospheric velocity fields in A stars; they are related to microturbulence velocities such as derived in our abundance analysis. The microturbulence range of 3 to 5 $km\,s^{-1}$ would, thus, be related to a range in the atmospheric velocity fields; the occurrence of the different abundance Am-plateaux involves no strong dependence between velocity and abundance values. This is consistent with chemical separation processes operating below the convection and mixed zones.

Richer, Michaud and Turcotte (1999) calculate detailed evolutionary models coupling atomic diffusion with turbulent transport. They use recently available atomic data which make possible calculations throughout stellar models (Richer et al. 1998). They study the slowly rotating stars which are assumed to correspond with the observed Am stars. The turbulent diffusion coefficient is varied and turbulence is assumed large enough to mix the regions between (superficial) convection zones. Their detailed comparison of models with individual cluster Am stars shows that many of the abundances are nicely reproduced. We compare our abundance results globally for cluster Am stars (Figs. 7 and 8) with their predictions in Fig. 14 (Richer et al. 1999); that figure shows the $T_{\rm eff}$ dependence of abundance anomalies in models of different masses but a common turbulence model and same initial composition, at 3 ages nearly covering the range of our cluster ages. In Fig. 14 of Richer et al., abundance anomalies are reckoned from the initial abundances (except for Li); in the observed Am results, from cluster normal A or cooler F-G stars. Those comparison stars are assumed least affected by atomic diffusion and abundances of F-G stars are currently considered as initial abundances of the cluster (except for Li). We recall that our abundances are calculated in the framework of the Sun and are dependent on the chosen solar abundances (given in Table 3), except for Li calculated from the accurate laboratory $\log gf$ values.

For $T_{\rm eff}$ ranging from 8500 to 7000 K, the general behavior is predicted as follows: the abundances decrease toward lower temperatures (very weakly for some elements) and the abundance anomalies, when they are dependent on age, increase with it.

- Li. As observed, models predict a deficiency (-0.1 to -0.4 dex, compared to the chondrite value, 3.31) and the occurrence of plateaux at every age. The plateau heights are dependent on age: from -0.1 dex at $10^8$ years to -0.3, -0.4 dex at 7 $10^8$ years. This is not observed.

- Al and Si. No dependence on time and weak dependence on $T_{\rm eff}$ (less than about 0.1 and 0.15 dex respectively) involve both observed plateaux. The almost original abundances found (up to +0.1 and down to -0.15 dex respectively) are possible facing the observed anomalies (+0.2 and 0.0 dex respectively) of the Am stars compared to normal A stars. In agreement we note the abundance anomalies of the Hyades Am stars (cf. Part 3): +0.2 and +0.1 dex respectively compared to the original Al and Si abundances defined by cooler Hyades stars.

- S. Weak dependence on time and $T_{\rm eff}$ (in the range +0.05 to -0.2 dex) is supported by the observations: occurrence of the plateau and S abundance similar in Am and normal A stars.

-Fe. The overabundances of 0.3-0.2 dex, predicted for all ages, are equal to the Fe enrichment observed in Am stars of each cluster (enrichment from the initial Fe which is obtained from cooler stars). The weak decrease observed toward cooler stars, down to no more anomaly, is reproduced.

- Ni. The overabundances calculated are significant (+0.2 to +0.8 dex). They increase with age (about 0.3 dex from $10^8$ to 7 $10^8$ years) and decrease towards cooler stars (about 0.3 dex in the range of temperatures considered). The few Ni observed values are consistent with those results.

For the first time an "observations versus models" comparison gives such a quantitative agreement. The observed age independence of the Li abundance may be the only problem. Two parameters could have an effect. First, the (unknown) initial Li abundance of each cluster is not necessarily the same. Secondly, the models are calculated with a common turbulence model. The turbulence may be sometimes inadequate and too strong as shown by some "model-individual cluster star" comparisons of Richer et al. (1999).

## 5. Lithium on the hot side of the Li dip

On the hot side of the Li dip, which is for $T_{\rm eff}$ more than about 7000 K, lithium of Am stars is depleted by a factor of 3 compared to normal A stars (see Part 4). Both exceptions, already noted, are the Li-deficient Hyades Am star, 16 Ori, and the Praesepe Am star, HD 73709, with Li of normal A stars. Other Li-deficient Am stars are known in stellar groups: an uncertain member of the Pleiades, HD 22615, with log N(Li) $<$ 2.4 (this series) and a star in the Hyades group, $\gamma$ Cap, with log N(Li) $<$ 2.0 (Burkhart & Coupry 1991). The case of $\gamma$ Cap is peculiar: its HIPPARCOS magnitude, Mv, is equal to 0.54, and $\gamma$ Cap is evolved by two magnitudes, just outside the Main Sequence of the Hyades cluster (Fig. 4). Its mass may be equal to 2.2 $M_{\odot}$, the Hyades turn-off mass. Is the specificity of 16 Ori to be found in the fact that it belongs to the rare group of long period Am binaries? Budaj and co-workers (Budaj 1997; Iliev et al. 1998) think so and show possible dependence between abundance anomalies and orbital parameters (period P, eccentricity e) thanks to a sort of stabilization versus tidal mixing. The mechanism of the tidal effects requires more data to be tested. It will be, anyhow, much intricate since observed Am stars of the Li-plateau have various orbital parameters. On the other hand, long period Am binaries with no Li deficiency are already known:

- in the same cluster and with similar temperatures, vB 131 with P = 11725d (Stefanik & Latham 1992) and 81 Tau with tentative P = 106d and e = 0.5 (Abt & Levy 1985);
- in Praesepe, the Hyades "twin" cluster, HD 73045 with P = 436d (Bolte 1991).

The large Li abundance of HD 73709 has to be compared with the high Li content of both components of the SB2 Am star, HR 8293, in the Hyades group (log N(Li) equal to 3.8 and 3.6 in Burkhart & Coupry 1991). Abundance determinations encounter intrinsic difficulties in the case of double-line spectroscopic binaries. This can cast doubts on the exact Li overabundances (compared to other Am stars) but not on their reality, taking into account the favorable circumstances of this system (a mass ratio near one, spectral types and line intensities very similar for both components) and the unique pattern of the observed spectrum (the Li lines, with the Fe-6678 lines, dominate the spectrum). As above-mentioned, HD 73709 may exhibit the specificity to be a magnetic star, but HR 8293 is a very common Am binary (P = 6.37d and e = 0.0).

Those few Li-abnormal Am stars in clusters (2 out of 18) and stellar groups have, generally, many similar parameters with the other Am stars. Does one (or more) peculiar characteristic(s) and/or evolution history induce the Li difference, noting that other elements such as Al, Si, S, and Fe are not remarkable?

In each of the four clusters, the maximum Li abundance was found in A stars, more precisely in normal stars except for Praesepe. In this cluster, there is no Li results in any normal star and the maximum Li abundance is that of the exceptional Am star, HD 73709. The constancy of the recurrence of a maximum abundance in normal A stars might be an argument in favor of its being the original abundance. Moreover, the A stars are believed to undertake no Li burning in their envelope on the pre-Main Sequence and the Main Sequence, and normal A stars, being fast rotators, are less affected by settling and other chemical separation processes than Am stars (Charbonneau & Michaud 1991). But observationally they are not completely unaffected: the Fe abundance (for 7 normal A stars) is twice the cluster original value as given by cooler stars (Part 4 and Fig. 8). Stellar abundances need to be more fully understood to safely claim that the original Li abundance of a cluster is likely to be found on the hot side of the Li dip, actually in normal A stars.

## 6. Conclusion

All A stars with enough-sharp lines to be studied for Li have been observed in four clusters, including the Pleiades, Coma, Hyades, and Praesepe. Abundances of Li, Al, Si, S, Fe, Ni, and Eu are summarized for 21 Am, 7 normal A, and 3 early A stars (Fig. 7 and Fig. 8).

The Am stars are defined in this series as weak-Ca-lined stars (from spectral classification and/or Ca/Fe line ratio) compared to other A stars, called normal A stars. They have very uniform Li, Al, Si, S, and Fe abundances in a large temperature range of nearly 1000 K. No correlation is apparent with the magnitude of the rotational velocity, the age (from 0.8 to 7 $10^8$ years) and degree of evolution inside the Main Sequence band, an eventual dependence on orbital parameters of the many Am binaries appearing unlikely.

In the H-R region of the A stars the influence of rotation is observed as follows: the slow-rotator Am stars have less Li (and Ca) than the rapid-rotator normal A stars; more Al(marginally), Ni(?), and Eu; Si, S, and Fe being the same for both groups. The build up of the chemical anomalies, in particular that of Li, is shown to be rapidly attained when the stars arrive on the Main Sequence (or before?) and not directly wiped out at the beginning of the post-Main-Sequence evolution.

The Hyades Am star, 16 Ori, exhibits peculiar abundance behavior. Li is exceptionally underabundant whereas O is only marginally underabundant compared to some other Hyades stars (60 Tau, 63 Tau, vB131); Ca and Sc are among the largest underabundances (but not the largest one); and Al, Si, and Fe are similar in all Hyades Am stars. What peculiar circumstances have induced the specificity of 16 Ori, compared to stars of the same age and initial composition, and even nearly same mass (such as 81 Tau)?

In each of the four clusters the Li temperature profile has its maximum in (normal) A stars; this maximum might be a good guess at the original Li abundance of the corresponding cluster.

The enrichment in Fe is the same for both Am and normal A groups, twice its original value. These Fe results are unexpected for normal A stars since they are thought to preserve their original abundances and to be underabundant in Fe compared with Am stars. The normal A sample is sparse; this warrants further investigation and, if confirmed, normal A stars would be proven to be affected by settling.

A global comparison of our abundance results with predictions of recent evolutionary models coupling atomic diffusion with turbulent transport (Richer, Michaud and Turcotte 1999) gives an almost complete agreement for Al, Si, S, Fe, and Ni; some problem may remain for Li.

In this series we suppose that the four clusters of different ages can be treated as an evolutionary sequence, notwithstanding different metallicities, rotational velocity distributions, or peculiar histories; some of our results may simply reflect stochastic behaviors in samples of modest size (eg. the normal A group). On the other hand, does Coma actually represent the "standard" for an open cluster of intermediate age: only a few A stars, a large variety of peculiar stars (two variable magnetic Ap stars, two non-standard normal A stars, peculiar Al and Si in the coolest Am star). At the same time, both Am and normal A groups show regular and homogeneous abundance behaviors in younger and older clusters. Statistical samples in a variety of open clusters are within reach as telescopes and instruments allow us to observe similar stars in more distant clusters of similar ages. But those more distant clusters are less studied and difficulties to sort "good" stellar targets encountered when membership and spectroscopic binarity, among other data, are poorly known.

A more promising way could be to increase, in some cluster stars of this series, the chemical elements observed through a wider spectral range. A good choice among our sample stars will be every star with certain membership and a spectrum with single and narrow lines. The last point corresponds to a spectrum with a great many lines measured compared to others. An accurate knowledge of the abundances of many elements simultaneously for one star will give as many constraints on stellar models. Extending the pioneering comparisons by Richer, Michaud and Turcotte (1999) is a way to test their model and have access to internal stellar hydrodynamics.

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