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Metal abundances of A-type stars in three galactic clusters*

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Abstract. Investigations have been carried out for 11 A stars in young open clusters (α Per, Coma, and Praesepe) and three field stars by means of high resolution spectroscopy. Detailed abundance analyses have been made for Mg, Ca, Sc, Cr, Fe, and Ni.

The results are discussed in the framework of element stratification processes as invoked by time-dependent diffusion mechanisms in Am stars. The youngest cluster of our sample, α Per, seems to show some untypical abundance patterns which might be identified as early Am phases.

Key words: open clusters: α Per; Coma; Praesepe – stars: abundances; chemically peculiar

1. Introduction

The Am stars are classically defined by the weakness of their Ca or Sc lines with regard to stars of similar effective temperatures (see for instance the review paper of Preston 1974). This characteristic is usually explained by underabundances of Ca or Sc compared to the solar value. These anomalies are nowadays considered to be mainly due to the microscopic diffusion process. Indeed, many studies have shown clear correlations between diffusion velocities of metals in Am stars and their observed abundance anomalies. However, these correlations are not sufficient to understand the details of the Am phenomenon since diffusion is a complex time-dependent process which depends on large scale motions in the stars and thorough modelling is needed. A simple model is to assume that abundances are homogeneous and solar when the star arrives on the main sequence, then large scale motions are slowed down and elements stratify due to diffusion. It may take more than 10^6 years for abundances to appear abnormal at the surface of Am stars. Several authors (Michaud & Charland 1986; Alecian 1986) have shown that the building of stratification is not a steady process: the abundance of an element may with time have ups and downs before stabilization. Recently, Alecian (1996) performed time-dependent simulations of the behaviour induced by diffusion of Ca and Sc in the superficial layers of A stars without the He convection zone (as suggested in the diffusion model for Am stars). His results show that different patterns of the observable abundance of Ca and Sc can develop depending on the values of parameters such as the mixing layer's extent or the mass loss rate. For some sets of these parameters' values, phases of overabundance of Calcium and Scandium can even occur shortly after the arrival on the main sequence of these stars, around log(age)$\approx$ 7 (years). This may question the classification of young Am stars to be only stars showing underabundances of Ca or Sc. To better constrain the models, it appears particularly important to determine detailed abundances in young main-sequence stars. This is why we have decided to investigate young stars of well-known characteristics such as age and initial chemical composition (metallicity). The good candidates are found in clusters since they are generally assumed to be born at the same time and from the same interstellar medium. They also form a homogeneous photometric sample so that we can derive internally consistent temperature and gravity values.

For this study we have chosen a young nearby open cluster, α Per. Its age is around $2\,10^7$ years following Janes & Adler (1982) or $5\,10^7$ years according to Meynet et al. (1993). A study of membership through proper motions has been carried out by Heckmann et al. (1956), and showed that α Per is a loose cluster comprising about 160 members around the brightest star, α Per, an evolved F supergiant. The metallicity in this cluster, determined by observations of F dwarfs, is almost solar with $\log(\mathrm{Fe/H})_* - \log(\mathrm{Fe/H})_{\mathrm{Sun}} = 0.004 \pm 0.033$ (Boesgaard 1989). Kraft (1967) has measured the rotational velocities for 83 stars and pointed out that the mean $v \sin i$ was larger than for field stars. This was a severe constraint for the selection of our sample.

Spectra of field stars and Am stars belonging to the older clusters of Coma and of Praesepe (whose age are around 10^9 years) have also been taken to be compared with the α Per stars.

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* Based on observations collected at the Observatoire de Haute-Provence (France)

Table 1. Basic data for the programme stars

Name	Cluster/field	HD or BD	Sp. type	V mag.	Remarks
HDK 501	α Per	+48°894	F0IV (1)	9.14	δ Scuti
HDK 606	α Per	20919	A8V (1)	8.98	δ Scuti, SB2 (this work), Am (5)
HDK 635	α Per	20969	A8V (1)	9.05	
HDK 694	α Per	21092	A5V (1)	8.48	SB?, Am (5), non member?
HDK 885	α Per	21527	A7IV (1)	8.79	SB?, Am (5)
HDK 1050	α Per	+49°967	A6mF2 (1)	9.48	SB ?
KW 538	Praesepe	73045	Am (2)	8.61	SB1?
KW 224	Praesepe	73618	Am (2)	7.32	SB2
KW 279	Praesepe	73709	F2III (2)	7.70	SB1, Am (6)
Tr 82	Coma Ber	107513	A9V (3)	7.39	δ Scuti, Am (7)
Tr 145	Coma Ber	108651	Am (3)	6.65	SB
HR 178	Field	3883	A7m (4)	6.3	Var.
α CMa	Field	48915	A1Vm (4)	-1.46	SB
α CMi	Field	61421	F5IV-V (4)	0.40	SB

References: (1) Morgan et al. (1971); (2) Bidelman (1956); (3) Mendoza (1963); (4) Hoffleit (1982); (5) Abt (1978); (6) Abt (1986); (7) Weaver (1952)

2. Observations and reductions

2.1. The sample

Six stars have been selected in the α Per cluster. Since Alecian (1996) predicts possible overabundances of Ca and Sc, we have not only considered known Am stars but also stars that are qualified as "normal". Our main selection criteria were: (i) sufficiently low projected rotational velocities to allow the determination of the abundances of Ca and Sc, and (ii) existence of $uvby\ \beta$ data for a determination of effective temperature and surface gravity with a good reliability. The same criteria have been applied for the Coma and the Praesepe clusters and for the field stars. Data about the programme stars are gathered in Table 1. For the cluster stars, the first column give the HDK number (Heckmann et al. 1956) for α Per, the KW number (Klein Wassink 1927) for Praesepe and the Tr number (Trumpler 1938) for Coma.

2.2. Data collection and reduction

The observations were made at the Observatoire de Haute-Provence in December 1995 with the spectrograph AURELIE (Gillet et al. 1994) attached at the coudé focus of the 152 cm telescope. This instrument was set with a 1800 lines mm^{-1} grating working at its first order, yielding an approximate spectral resolution of 34000 and a linear dispersion of 5 Åmm^{-1}. For this study, we chose the spectral region 5495-5620 Å. The detector was a linear diode array Thomson TH 7832 with 2036 pixels of size 13 by 750 μm. Except for α CMa and α CMi, the integration time varied from 2 to 3 hours according to the star's magnitude and to the atmospheric absorption. We obtained signal-to-noise ratios (SNR) ranging mostly from less than 100 up to 300. For three stars the SNR is greater than 500 (α CMa, α CMi and HR 178). For the stars observed with too low SNR, we took additional spectra, when possible, to reach a SNR compatible with our purpose. During each night, we regularly have measured the offset level and taken exposures of a tungsten lamp for the flat-fields and of a thorium-argon hollow cathode lamp for the wavelength calibration. The two measurements of the dark current showed that its level was very low for a typical integration time of two hours (less than 20 ADU).

The reduction of the spectra is carried out using codes written by M. Spite (1967, 1996 private communication). The reduction of a spectrum is done with a mean flat-field, which comes from the average of all the flat-fields taken during the corresponding night, and with a mean offset level obtained similarly as the instrument was very stable. The wavelength calibration is achieved using the last hollow cathode spectrum taken before the stellar exposure. For the sharp-lined stars, the wavelength shift arising from the geocentric velocity is corrected by adjusting selected "clean" stellar lines to their true position in the wavelength scale. Stars for which the lines are too broadened by rotation are treated by correlation of their spectrum with a reference star's spectrum for which the geocentric velocity has been measured by the first method. The continuum level was referred to by a hand-drawn broken line. Several spectra are presented in Fig. 1.

We have tested the agreement of our equivalent width scale with those of other studies. Our values are mostly obtained using the method of Cayrel et al. (1985), which fits a gaussian curve to the observed line. This method provides accurate measurements for lines of equivalent widths less than 70 m Å. The values given for stronger lines are underestimated since the wings, which have an increasing contribution with increasing W$_\lambda$, are not fitted correctly. For the solar spectrum, we have 8 lines in common with the study of Rutten et al. (1984), seven of which being smaller than 60 m Å. The comparison of these 7 lines yields

$$\begin{aligned} \mathrm{W}_{\lambda(\text{this study})} &= 0.94\,\mathrm{W}_{\lambda(\text{Rutten et al.})} + 1.43 \\ &\pm\ 0.14 \qquad\qquad\quad \pm 6.51 \end{aligned}$$

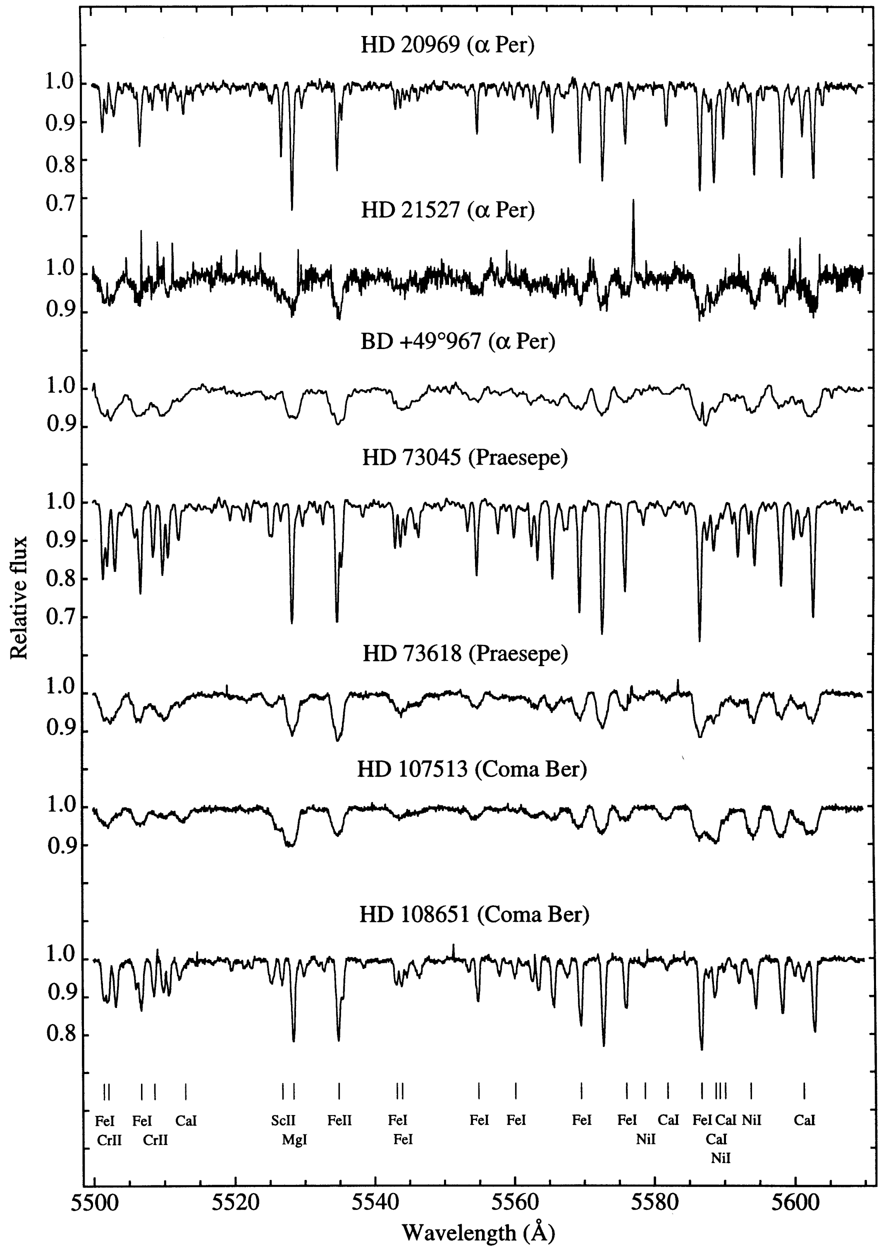

Fig. 1. Several spectra of our programme stars.

We have also compared our results with those of Steffen (1985) who has measured the lines of Procyon using the atlas of Griffin & Griffin (1979). For 11 lines

$$\begin{aligned} W_{\lambda(\text{this study})} &= 0.99\,W_{\lambda(\text{Steffen})} - 2.04 \\ &\pm\ 0.01 \qquad\qquad \pm 1.07 \end{aligned}$$

The agreement is quite good though we have noticed a general trend of our values to be smaller than in these other studies.

3. Analysis

3.1. Effective temperature and surface gravity

Effective temperatures derived from photometric indices are of high consistency for stars belonging to the same cluster. So, we determine the effective temperature and surface gravity for our cluster stars using $uvby\ \beta$ photometry and the grids of Moon & Dworetsky (1985). The values of effective temperature obtained this way show excellent agreement with those re-determined in the recent paper of Napiwotski et al. (1993). Concerning the two field stars, we take the values of Burkhart & Coupry (1991), which are estimated using exactly the same method. The typical error in our temperature estimate is ± 200 K due mostly from the uncertainties of the photometric measurements and the error bars of the grids. Similarly, the errors on log g are around 0.14. The $uvby\ \beta$ data are from Crawford & Barnes (1974) for α Per, Crawford & Barnes (1969a) for Coma and Crawford & Barnes (1969b) for Praesepe. For Coma and Praesepe, we have corrected the photometric indices for reddening by following the procedure of Crawford & Barnes (1974) so that the values ob-

Table 2. Equivalent widths for the programme stars (mÅ)

Element	λ	BD +48° 894	HD 20969	HD 21092	HD 21527	BD +49° 967	HD 73045	HD 73618	HD 73709	HD 107513	HD 108651	HD 3883	HD 48915	HD 61421
FeI	5501.47	-	51.6	14.6	-	73.9	100.6	57.5	69.2	40.0	65.0	90.3	-	88.4
CrII	5502.09	-	31.5	-	-	-	84.6	66.1	90.7	35.2	67.9	62.7	26.2	33.1
FeI	5506.79	106.4	64.6	34.2	82.0	103.9	131.7	91.7	104.5	60.6	89.4	112.9	-	96.2
CrII	5508.64	-	25.5	-	-	-	75.0	-	79.6	-	59.1	56.4	20.6	28.7
CaI	5512.99	-	37.3	-	-	-	12.5	-	17.3	-	13.9	24.1	-	63.2
ScII	5526.82	101.1	75.7	53.1	91.0	$<$13.3	23.6	5.1	10.2	97.2	37.4	15.4	2.2	110.0
MgI	5528.42	191.9	152.9	113.2	153.0	155.4	167.6	174.6	161.7	162.8	137.5	155.2	39.6	204.0
FeII	5534.85	-	91.9	-	-	-	158.2	-	191.3	109.5	135.1	214.3	71.0	87.8
FeI	5543.20	-	26.8	-	-	-	59.0	-	45.8	-	43.7	56.5	4.8	46.0
FeI	5543.95	-	24.8	-	-	-	59.5	-	50.2	-	44.6	59.0	-	43.8
FeI	5554.90	75.9	51.3	27.4	96.0	53.1	96.8	61.0	76.7	39.4	66.2	87.0	12.8	67.9
FeI	5560.22	-	17.5	-	-	-	47.6	32.1	36.5	-	32.3	36.6	2.8	33.5
FeI	5569.63	144.8	84.0	40.7	116.0	112.6	147.1	112.2	125.2	83.9	107.1	144.4	18.9	101.2
FeI	5576.10	95.7	63.5	17.7	102.0	69.8	116.4	67.6	87.9	52.9	80.2	108.6	9.3	84.5
NiI	5578.73	-	6.6	-	-	-	34.1	27.6	24.8	-	14.6	23.5	-	22.3
CaI	5581.98	85.2	46.6	14.1	-	-	24.2	32.4	23.9	49.6	19.4	31.9	-	75.0
FeI	5586.77	-	128.4	66.3	134.5	131.5	201.2	160.8	188.6	127.0	152.5	202.0	42.8	132.5
CaI	5588.77	-	118.8	45.1	-	-	67.7	101.8	72.5	122.0	64.3	94.1	-	139.0
NiI	5589.37	-	17.0	-	-	-	36.5	-	35.8	-	14.5	23.5	-	16.8
CaI	5590.13	-	58.5	-	-	-	25.7	26.0	22.5	-	19.7	28.7	-	87.8
NiI	5593.75	-	19.4	-	-	-	43.7	23.9	40.0	35.3	23.0	36.1	-	22.2
CaI	5601.29	-	58.5	-	-	-	55.8	46.6	46.8	64.0	38.8	57.8	-	90.0

tained for Coma and Praesepe are consistent with those already dereddened for α Per, provided in this last paper.

3.2. Abundance determinations

All the steps of this analysis are performed with the codes written by M. Spite.

The model atmospheres are interpolated in the grids of Kurucz' ATLAS9 models (Kurucz 1992a and b). The microturbulent velocity appears as a by-product of the abundance determination. It is obtained by the constraint that all the lines of a same element should yield the same abundance.

In the chosen wavelength interval, we have selected lines of Mg I, Ca I, Sc II, Cr II, Fe I, Fe II, and Ni I. These lines have been retained since they are the most free of blending in the slowly rotating stars. Their oscillator strengths are determined by fitting the solar lines of the spectrum obtained with the same instrument as the programme stars to the lines computed with the Kurucz solar model. The solar abundances are from Grevesse & Noels (1993) and the adopted values are listed in Sect. 4. We used the value of 1 km.s^{-1} for the microturbulent velocity. The hyperfine structure of Sc has not been taken into account.

The equivalent width measurements are shown in Table 2. No measurement is presented for HD 20919 since we found that this star is very likely an SB2: one of its spectra, although very noisy, shows clearly two systems of lines. We will discuss briefly this star in Sect. 4.

We have tested the influence of the errors in the determinations of temperature and log g on the derived abundance. An increase of 200 K in T_{eff} induces increases around 0.07 dex on the singly ionized species. The neutral lines are also affected and the increase of abundance ranges from 0.05 up to 0.12. Small changes in surface gravity have little effects on the abundances derived from the lines of neutral species as usual. For the singly ionized species, an increase of 0.3 in log g (twice the error) induces an enhancement of the abundances of 0.1.

4. Results

The results of the abundance determinations are presented in Table 3. Most of the columns are self-explanatory, nevertheless we give details hereafter about some of the given values. For several stars we give values from earlier determinations, which are presented beneath those of this work. The projected rotational velocities are from Kraft (1967), Bernacca & Perinotto (1971), and Kraft (1965) for respectively the α Per, Praesepe, and Coma clusters. The $v \sin i$ for α CMa is an estimate of Burkhart et al. (1987). For HR 178, we followed the method used in this last paper to derive an upper limit for the rotational velocity. Microturbulent velocity values followed by (lit.) or by (CB92) could not be estimated with our data and are respectively found in the literature or determined from Fig. 1 of Coupry & Burkhart (1992). The values for the other stars are consistent with the curve of their Fig. 1. We use the following values for the solar abundances: Mg, 7.58; Ca, 6.36; Sc, 3.17; Cr, 5.67; Fe, 7.50; Ni, 6.25. The script [X] for any quantity X means $\log(X)_{*} - \log(X)_{\mathrm{Sun}}$. The error bars comprise the error made in the abundance determination due to the uncertainties in the equivalent width measurements and the dispersion of the values given by the different lines of a same ion.

Table 3. Abundances for the programme stars

Name	HD or BD	Remarks	v sin i (km/s)	T_{eff} (°K)	log g	V_T (km/s)	[Mg/H]	[Ca/H]	[Sc/H]	[Cr/H]	[Fe/H]	[Ni/H]	Pattern
HDK 501	+48° 894	δ Scuti	75	7470	4.23	3.5	0.24	0.17	-0.10	-	0.21 (±0.13)	-	I
HDK 635	20969		<20	7340	4.2	2	0.18	-0.08 (±0.22)	-0.22	-0.01	-0.06 (±0.14)	0.19	I
(1)				7285							-0.05		
HDK 694	*21092*	*SB?, Am (7), non-member?*	*75*	*8500*	*4.5*	*1.5*	*0.31*	*-0.02*	*-0.01*	-	*-0.07* *(±0.27)*	-	*I*
HDK 885	21527	SB?, Am (7)	80	8180	4.25	3 (CB92)	0.26	-	0.08	-	0.56 (±0.24)	-	III
HDK 1050	+49° 967	SB?, Am (8)	60	8000	4.15	3 (CB92)	0.44	-	<-1.00	-	0.31 (±0.26)	-	II
KW 538	73045	SB1?, Am (9)	10	7520	4.27	3.5	0.15	-0.54 (±0.27)	-1.00	0.70	0.59 (±0.14)	0.80	II
(2)											0.36		
KW 224	73618	SB2, Am (9)	60	8060	3.87	3 (CB92)	0.53	-0.02	-1.66	0.45	0.46 (±0.20)	0.86	II
(2)											0.52		
KW 279	73709	SB1, Am (10)	20	8060	3.95	3.5	0.17	-0.24 (±0.17)	-1.33	0.65	0.58 (±0.17)	1.03	II
(2)											0.49		
Tr 82	107513	δ Scuti, Am (11)	50	7270	4	3	0.05	-0.15	-0.17	0.00	-0.36 (±0.10)	0.53	I/III
Tr 145	108651	SB, Am (12)	<12	8090	4.24	2	0.34	-0.30 (±0.15)	-0.56	0.68	0.66 (±0.13)	0.71	II
(3)				7865							0.39		
HR 178	3883	Var., Am (13)	<10	7800	3.8	3.5	-0.06	-0.24 (±0.12)	-1.27	0.27	0.53 (±0.13)	0.77	II
(4)				7750	3.5	6.2	-0.05	-0.45	–1.05	0.25	0.35	0.90	
α CMa	48915	SB, Am (13)	< 20	9870	4.4	2 (lit.)	-0.03	-	-1.06	0.54	0.49 (±0.29)	-	II
(5)				9870	4.4						0.25		
α CMi	61421	SB	6	6610	4	2 (lit.)	0.34	0.03 (±0.20)	0.13	-0.04	-0.11 (±0.15)	-0.02	I
(6)				6750	4		0.07	-0.05	0.04	-0.03	0.00	0.01	

Note: the error bars are only given for Calcium when the 5 lines are used for the abundance determination. References: (1) Boesgaard et al. (1988); (2) Burkhart & Coupry (1996); (3) Boesgaard (1987); (4) Van't Veer et al. (1985); (5) Burkhart & Coupry (1991); (6) Steffen (1985); (7) Abt (1978); (8) Morgan et al. (1971); (9) Bidelman (1956); (10) Abt (1986); (11) Weaver (1952); (12) Mendoza (1963); (13) Hoffleit (1982)

4.1. The α Per cluster

Two stars, HD 20969 and HD 21092 show almost normal abundances with respect to the solar values. Our value of the iron abundance for HD 20969 agree very well with that determined by Boesgaard et al. (1988) as one can see in Table 3. For HD 21092, we thus do not confirm its classification as Am star as suggested by Abt (1978). Although suspected to be a spectroscopic binary (Kraft 1967), there is neither variation of radial velocity between the two exposures we have taken nor changes in the spectra. Another point is that the membership of this star has been questioned by consideration of radial velocity and distance modulus (see Abt 1978 for instance) so that it will be discarded from further discussion. The data for this star are shown in italic in Table 3.

BD + 49°967 is an Am star (Morgan et al. 1971). The iron overabundance and the scandium deficiency confirm the Am character, along with a marginal underabundance of Ca.

The case of HD 21527 is interesting because we can observe overabundances for Fe and Mg along with a quasi normal value for Sc. If we take the iron abundance as reference, Sc is deficient by 0.5 dex. This can be related to the Am character found by Abt (1978). But this star can also be considered as Am since it presents abundance anomalies that can be explained by the diffusion process. This will be discussed more thoroughly in the next section.

BD + 48°894 shows globally normal abundance values.

Concerning the likely double system HD 20919, it seems that the component that has the most intense lines (hereafter component A) shows underabundances of Ca and Sc when we introduce a dilution factor of 1.25, value which yields a solar

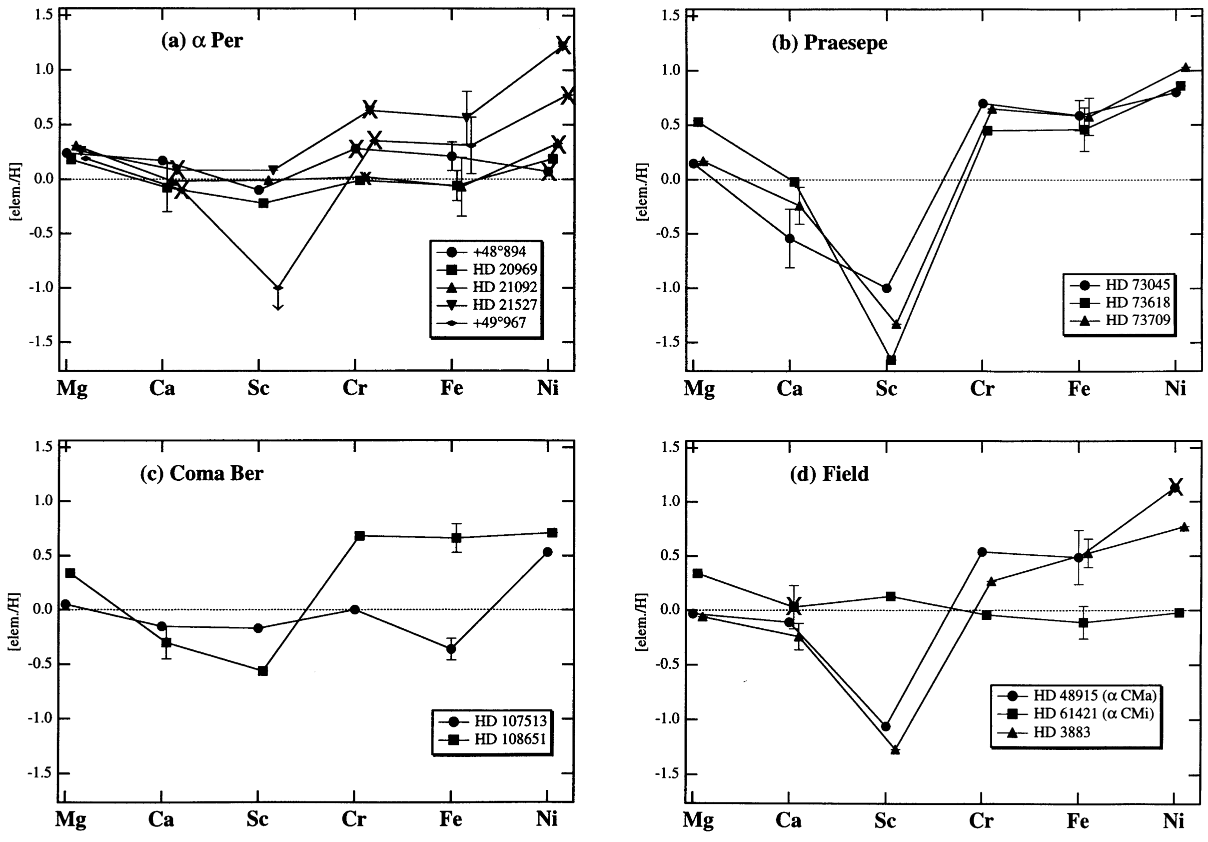

Fig. 2a–d. Abundance values versus atomic number for each studied element: **a** for the α Per cluster; **b** for Praesepe; **c** for Coma; **d** for field stars. Crossed points denote abundance values derived through very uncertain equivalent widths measurements.

abundance for iron. The other component (B) shows almost normal values of [Ca/Fe] and [Sc/Fe] whatever the dilution factor introduced (values between 1 and 2.5) and is therefore probably a normal star. The deficiencies of Ca and Sc of the component A would be consistent with the Am character discovered by Abt (1978). Yet, these results are derived assuming that the effective temperature and surface gravity are the same for both components and are those estimated considering the system as a single star. Thus, they should be considered carefully.

4.2. The older clusters of Praesepe and Coma

The age of these clusters are respectively 4.3 10^8 and 7.6 10^8 years for Coma and Praesepe (Boesgaard 1989). The two stars HD 73045 and HD 73709 of Praesepe show typical Am star abundance anomalies. HD 73618 is an SB2 for which we have no data. In the only spectrum we have of this star we see a single system of lines. By treating this star like an individual one, assuming that the two components have similar temperature and gravity, we found that Ca is normal, Sc well-underabundant, the other elements being overabundant. This system may thus be formed by two Am stars. We stress that these conclusions must be considered very cautiously and need confirmation by a further study of this system.

For Coma, HD 107513 shows a curious abundance pattern: Mg, Ca, Sc, and Cr are almost normal, Fe is slightly underabundant. HD 108651 exhibits the abundance pattern of Am stars.

4.3. Field stars

The spectra for the field stars have been taken to allow comparisons with previous studies.

HR 178 is a classical Am star which have been studied by several authors. We have compared our results with those of Van't Veer et al. (1985) and we found a fairly good agreement.

α CMa is a hot Am star but its abundance pattern for the studied elements is very close to that of a cooler Am such as HR 178 (see Fig. 2).

α CMi is presented to show the abundance for a normal star obtained from the lines of the chosen spectral region. Our results agree very well with those of Steffen (1985). However, we can notice a slight discrepancy of 0.25 dex for the abundance of Mg, but this difference is smaller if we compare our value with that of Steffen for the same line (λ 5528.42).

5. Discussion

We shall now discuss the results detailed in the previous section in the framework of the diffusion model. We will mainly focus on the behaviour of three elements for which very recent computations have been done: Ca and Sc by Alecian (1996) and Seaton (1996); Fe by LeBlanc & Michaud (1995) and Seaton (1996). LeBlanc & Michaud (1995) and Seaton (1996) have computed very accurate radiative accelerations. Accelerations are less accurate for Alecian (1996) but he has carried out time dependent diffusion (evolution of Ca and Sc in Am stars over 10^9 years).

We show in Fig. 2, the abundance patterns we have determined for our sample. We present four plots corresponding to (a) α Per, (b) Praesepe, (c) Coma, and (d) field stars. In each plot, abundances (with respect to the solar value) are given versus the atomic number of each chemical elements (Mg, Ca, Sc, Cr, Fe, Ni). For a given star, all points are linked by a solid line. At first sight, one may notice three main types of patterns:

(I) pattern with all points at ± 0.4 dex (we call them "normal stars"),

(II) pattern of HR 178 (typical Am star with underabundances of Ca or almost normal Ca, underabundances of Sc, and overabundances of other metals),

(III) untypical pattern with significant overabundance of some metals (namely Fe and/or Ni) and possible anomalies for the others. This pattern may include the subgroup "c" of Am stars as defined by Conti (1970).

We indicate in Table 3, column 14, the pattern we identify for each star.

The first two patterns are standard and have been already explained qualitatively by previous works on diffusion. According to the simplest of the diffusion models (which neglects the detailed evolution effects of stellar internal structure during the stay on the main-sequence), heavy element stratifications begin as soon as the superficial convection zone due to Helium has disappeared (this occurs only for Am stars). This means that before the beginning of the stratification process, all stars have pattern I. Normal main sequence A stars keep pattern I (due to strong mixing motions) while old Am stars evolve towards pattern II. Michaud & Charland (1986) and Alecian (1986) have suggested that young Am stars may have different pattern which may correspond to pattern III. For these intermediate cases, Alecian (1996) has predicted possible overabundances of Ca and Sc according to the mass loss rate and the depth of the superficial mixing zone.

If we analyse more precisely Fig. 2, the following remarks may be done.

- For all stars of type (II) and (III), except HD 107513, iron is overabundant by about 0.5 dex. For type (II), as already stressed in Sect. 4, this is in agreement with previous determinations in Am stars (see Burkhart & Coupry 1991 for instance). This overabundance seems consistent with the most recent radiative accelerations computed for Iron by Seaton (1996). According to this author, previous computations by LeBlanc & Michaud (1995) have underestimated accelerations of Iron. The correction induced by Seaton's computations, just below the superficial convection of Am stars, seems compatible with the 0.5 dex overabundance for Iron. However, this needs confirmation.
- All three patterns in Praesepe are remarkably close to each other (type II). This is consistent with the standard diffusion model since Praesepe is a relatively old cluster (about 10^9 years) and time evolution of the patterns may be stabilized.
- One cannot draw any conclusions for Coma, since only two stars with different type have been observed. Our pattern identification are uncertain for this cluster.
- The youngest cluster (α Per) show all the three patterns. This may be the signature of intermediate phases of the stratification process. For pattern identification, we are more confident here than for Coma.

Concerning the last point, the small number of stars in our sample and the insufficient accuracy of the abundance determinations do not allow us to clearly assert that intermediate phases (type III) are really observed. Moreover, one cannot be sure that the possible small overabundances of BD + 48°894 in α Per, can be identified with a phase of overabundance as predicted by Alecian (1996). Existence or lack of such overabundant phases in future observations could give information on the thickness of superficial mixing layers and rate of mass-loss because Calcium stratification is particularly sensitive to these parameters. However, the systematic lack of Sc overabundance in our observations suggests that, in our sample, mass-loss rate might be always smaller than 10^{-14} solar mass per year, but as stressed by Alecian (1996), this needs more accurate time-dependent diffusion computations.

6. Conclusion

We have obtained high resolution spectra for 11 A stars in young open clusters and 3 field stars using the spectrograph AURELIE at the Observatoire de Haute-Provence. We have made detailed abundance analysis and tried to detect pre-Am stars.

Although our working conditions are close to the instrumental limits, we have obtained acceptable results for the majority of our stars. Yet, the accuracy of our measurements are insufficient to draw firm conclusion on evolutionary aspects. The youngest cluster of our sample, α Per, seems to show some untypical abundance patterns which might be identified as early Am phases. This needs to be confirmed by further investigations with better accuracy, with more stars, and younger clusters. This work must be considered as a step toward detailed understanding of stratification processes, Am phenomenon and for the use of young open clusters for stellar structure studies.

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