Abundances of metals in five nearby open clusters

A. Hui-Bon-Hoa

D.A.E.C., Observatoire de Meudon, MEUDON F-92195, FRANCE

Abstract. Abundances of Mg, Ca, Sc, Cr, Fe, and Ni are derived for A stars of five nearby open clusters of various ages using high resolution spectroscopy. We point out a correlation between the abundance of Ca and that of Sc, suggesting that the abundance anomalies of these elements arise from the same physical process. Pronounced Am patterns are rather found in the oldest cluster stars whereas younger targets show weaker Am anomalies and atypical patterns for some of them.

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

1. Introduction

The abundance anomalies of the Am stars (and, as a rule, of most of the Chemically Peculiar stars) are nowadays broadly considered to be produced by microscopic diffusion. Indeed, the observed anomalies are consistent with the computed diffusion velocities for many elements. Nevertheless, the detailed understanding of the Am phenomenon requires more thorough studies since the stratification process is time-dependent and affected by the other physical processes at play in the stellar medium. Calcium and scandium are elements of special interest since their deficiencies are usually used to detect Am stars (Conti 1970; Preston 1974). The evolution of the abundances of Ca and Sc in the superficial layers of an A star has been computed by Alecian (1996) assuming no helium convection zone, as suggested by the diffusion model for Am stars. His results show that the behaviour of both elements are strongly dependent on the strength of the large scale motions introduced in the computations, namely, a mass-loss and the extension of the superficial mixing zone beneath the convective zone. In some cases, phases of overabundance occur when the star is around 10 million years old. So, the classification criterion of Am stars based on the calcium or scandium deficiency is questionable for young A stars.

Abundance determinations in young main-sequence A stars can constrain such computations. Open cluster stars are the best candidates since their age is known with much greater accuracy than for field stars. Few abundance studies in open clusters have been done up to now (see Burkhart & Coupry 1997 and references therein). The use of electronic detectors (Reticon and CCDs) and the

Contrib. Astron. Obs. Skalnaté Pleso **27**, (1998), 309– 313.

Table 1. Basic data for the clusters.

Cluster	Age (yr)	Number of stars
α Per	$5\,10^7(1)$	6
Pleiades	$10^8(1)$	9
Coma Ber	$4.3\,10^8(2)$	6
Hyades	$6.7\,10^8(2)$	6
Praesepe	$7.6\,10^8(2)$	7

References: (1) Meynet et al. (1993); (2) Boesgaard (1989)

subsequent improvement in the quality of the spectra made possible the study of the lithium abundance and, by the way, renewed the interest for open clusters: observations of A-type stars were carried out by Boesgaard (1987) in Coma, and by Burkhart & Coupry (1989; 1997) in the Hyades and Pleiades.

This paper summarizes the work undertaken in collaboration with G. Alecian and C. Burkhart concerning the abundance of calcium and scandium in open cluster A stars. More details are provided in Hui-Bon-Hoa et al. (1997) and Hui-Bon-Hoa & Alecian (1998).

2. Observational data

2.1. The sample

We chose 34 A-type stars belonging to the northern open clusters: α Per, Pleiades, Coma, Hyades, and Praesepe (see Table 1). The ages of these clusters are well spread over the time interval covered by the simulations of Alecian (1996). The selection criteria for each star were:

- rotational velocity compatible with abundance determinations using the lines of our wavelength domain;

- availability of $uvby\,\beta$ photometry for the estimation of effective temperature and surface gravity.

We have included all A stars that match these criteria in our sample since Alecian (1996) suggests that a phase of overabundance of Ca and Sc can occur for young Am stars.

Three field stars have also been observed: HR 178 (HD 3883), Sirius (α CMa, HD 48915), and Procyon (α CMi, HD 61421).

2.2. Instrumentation

The spectra were obtained during two runs in December 1995 and December 1996 at the Observatoire de Haute-Provence using the AURELIE spectrograph at the coudé focus of the 152 cm telescope. This instrument was set to yield a spectral resolution of about 34000 (linear dispersion of 5 Åmm^{-1}). The limiting V magnitude was around 9 for an integration time of 3 hours and a typical signal-to-noise ratio of 300. We chose the spectral interval 5495–5620 Å , which allows abundance determinations of Mg, Ca, Sc, Cr, Fe, and Ni.

3. Abundance determination

We used model atmospheres computed with the ATLAS9 code (Kurucz 1992a, b). The atmospheric parameters are derived from *uvby* β photometry through the grids of Moon & Dworetsky (1985) which are still quite reliable for single stars as shown by Napiwotski et al. (1993).

The abundance analysis is carried out assuming LTE with a series of codes written by M. Spite (1967, 1996 private communication). We used solar oscillator strengths deduced from a solar spectrum obtained with the same instrumentation as for the programme stars. We mostly used a curve of growth method and the equivalent widths are measured with a procedure developed by Cayrel et al. (1985), which fits gaussian profiles to the observed spectrum. When the rotational velocity is above 30 km/s, the gaussian profile is not suitable anymore and the lines are fitted with a rotational profile.

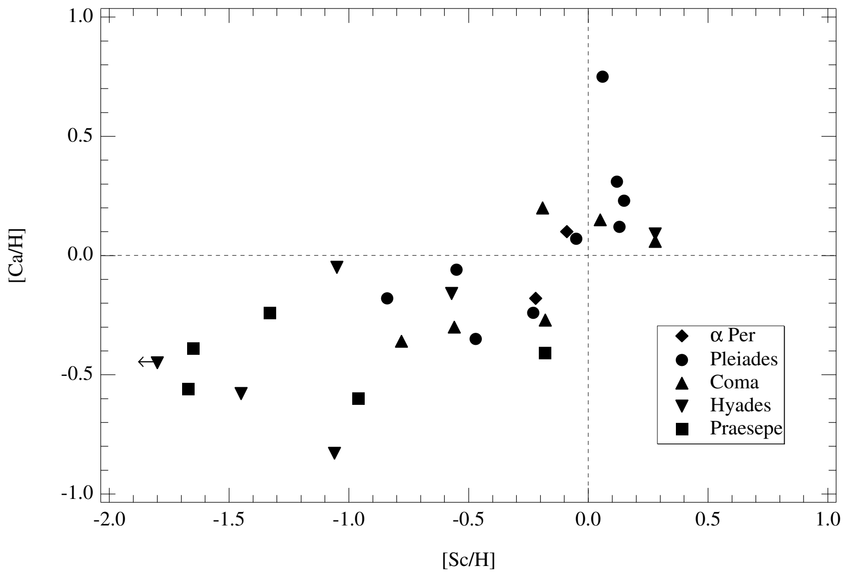

Figure 1. [Ca/H] vs. [Sc/H] for the cluster stars. The arrow means an upper limit for the Sc abundance.

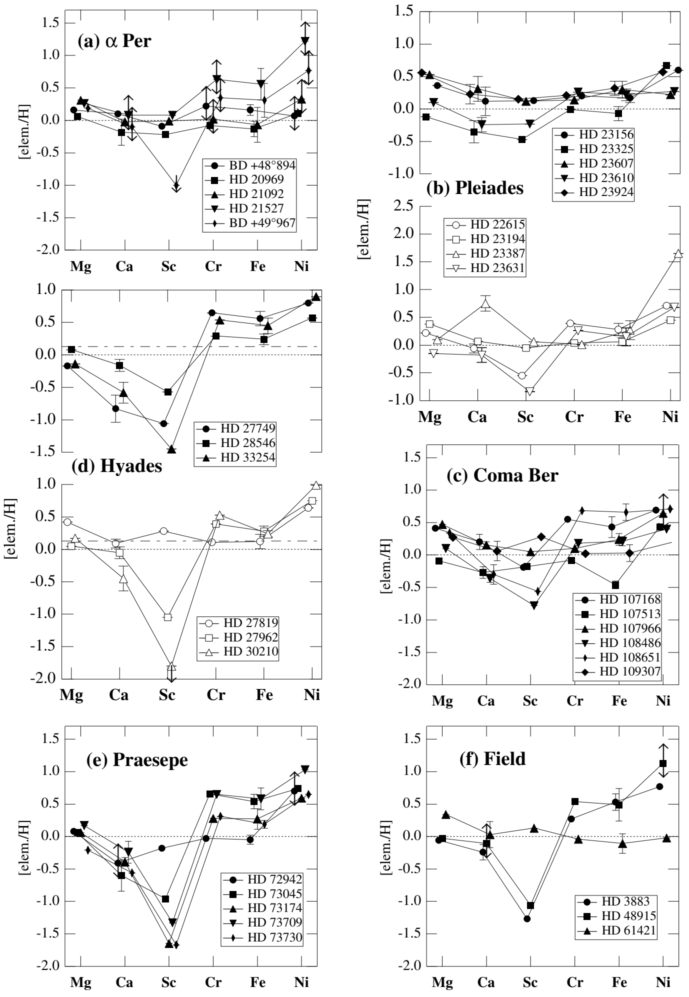

Figure 2. Abundance patterns for the stars of: **a** α Per; **b** the Pleiades; **c** Coma; **d** the Hyades; **e** Praesepe; **f** field stars. The metallicity of the Hyades is indicated by a dash-dotted line.

4. Results and discussion

As usual, the script [X] for any quantity X means $\log{(\mathrm{X})_*} - \log{(\mathrm{X})_\odot}$. In Fig. 1, we can see a loose correlation between [Ca/H] and [Sc/H] for our cluster stars. This suggests that the anomalies of these two elements come from the same physical process. Besides, the more pronounced deficiencies (left part of the graph) are found in the oldest stars (members of the Hyades and Praesepe).

Younger targets (in α Per, Pleiades) show weak underabundances or marginal overabundances (right part of the graph).

The abundance patterns for our sample stars are shown in Fig. 2. In ordinates are the logarithmic differences between the abundance value in the star of concern and the solar one for Mg, Ca, Sc, Cr, Fe, and Ni. The corresponding points are linked for each star. An arrow means upper limit and error bars ended by arrows denote very uncertain values. We can see that the Am pattern is well-marked in the oldest cluster stars (Hyades and Praesepe) of our sample as well as for the field Am stars. In the youngest clusters (α Per, Pleiades), the Am pattern is almost absent and several objects show atypical patterns with marginal overabundances of Ca and/or Sc. This would suggest that stars of these clusters are in transient phases of the stratification process.

The marginal overabundances of Ca and Sc in α Per and Pleiades are not strong enough to confirm the phase of overabundance predicted by Alecian (1996). Either the youngest clusters of our sample are already too old and their stars have passed the phase of overabundance or this phase does not exist. In this last case, the extension of the mixing zone should be less than one pressure scale height and the mass-loss rate about $10^{-14} M_\odot$/yr.

These conclusions need to be confirmed by observations of more clusters and younger targets. Also, elements that could help a better understanding of the Am phenomenon deserve to be studied (rare earths for instance).

Acknowledgements. Many thanks to M. Spite who has kindly provided us with her codes and to C. van't Veer for having introduced us to the ATLAS9 code. Thanks also to G. Michaud and S. J. Adelman for useful suggestions and to the OHP staff for their excellent support.

References

Alecian, G.: 1996, *Astron. Astrophys.*, **310**, 872
Boesgaard, A.M.: 1987, *Astrophys. J.*, **321**, 967
Boesgaard, A.M.: 1989, *Astrophys. J.*, **336**, 798
Burkhart, C., Coupry, M.-F.: 1989, *Astron. Astrophys.*, **220**, 197
Burkhart, C., Coupry, M.-F.: 1997, *Astron. Astrophys.*, **318**, 870
Cayrel, R., Cayrel de Strobel, G., Campbell, B.: 1985, *Astron. Astrophys.*, **146**, 249
Conti, P. S.: 1970, *Publ. Astron. Soc. Pac.*, **82**, 781
Hui-Bon-Hoa, A., Burkhart, C., Alecian, G.: 1997, *Astron. Astrophys.*,**323**, 901
Hui-Bon-Hoa, A., Alecian, G.: 1998, *Astron. Astrophys.*, in press
Kurucz, R.L.: 1992a, *Rev. Mex. Astron. Astrof.*, **23**, 45
Kurucz, R.L.: 1992b, *Rev. Mex. Astron. Astrof.*, **23**, 181
Meynet, G., Mermilliod, J.-C., Maeder A.: 1993, *Astron. Astrophys.*, **98**, 477
Moon, T.T., Dworetsky, M.M.: 1985, *Mon. Not. R. Astron. Soc.*, **217**, 305
Napiwotski, R., Schönberner, D., Wenske, V.: 1993, *Astron. Astrophys.*, **268**, 653
Preston, G.W.: 1974, *ARA&A*, **12**, 257
Spite, M.: 1967, *Ann. d'Astrophys.*, **30**, 211