# ABSOLUTE MAGNITUDES OF CHEMICALLY PECULIAR STARS

**P. North[1], C. Jaschek[2], B. Hauck[1], F. Figueras[3], J. Torra[3], M. Künzli[1]**

[1]Institut d'Astronomie de l'Université de Lausanne, CH-1290 Chavannes-des-Bois, Switzerland
[2]Observatoire de Strasbourg, 11 rue de l'Université, F-67000 Strasbourg, France
[3]Departament d'Astronomia i Meteorologia, Universitat de Barcelona,
Avda. Diagonal 647, E-08028 Barcelona, Spain

ABSTRACT

The position of different kinds of CP stars of the upper Main Sequence (i.e. Am stars and the four categories of Ap stars: He-weak, HgMn, Si and SrCrEu) in the HR diagram is examined. Using only those stars having a parallax with a relative error smaller than 0.14 ($\sigma(M_v) \leq 0.3$) and an absolutely certain peculiarity, it is shown that their absolute magnitudes are similar to those obtained from CP stars in clusters. CP stars are scattered on the whole width of the Main Sequence band. However, the rapidly oscillating Ap stars seem slightly less evolved, hence less massive as a group, than their non-oscillating counterparts.

The calibrations of the Strömgren and Geneva indices in terms of $M_v$ have been reexamined in the light of the Hipparcos data for Am stars. A new calibration of the $uvby\beta$ system in absolute magnitude is proposed for both normal and Am stars.

The calcium abundance in Am stars is examined as a function of their evolutionary state.

Key words: chemically peculiar stars; absolute magnitudes; stellar evolution.

## 1. INTRODUCTION

By 'chemically peculiar' (hereafter CP) stars, we mean here stars with an intermediate mass displaying exotic abundances *in their atmosphere* (not in their deep interior) probably due to radiative diffusion in a stable atmosphere (e.g. Michaud 1970). Altogether, the CP stars considered here include the He-weak, HgMn, Si, SrCrEu and Am stars. Some of their basic characteristics are quoted in Table 1. Because of their large intrinsic luminosity and long distances which imply uncertain parallaxes, the He-rich stars have not been considered here.

Other characteristics could be mentioned, like slow rotation (usually interpreted as favouring radiative diffusion), a large magnetic field (in the case of CP2 or Ap stars) and a special distribution of orbital parameters for those CP stars which are members of binary systems.

*Table 1. Groups of CP stars with their approximate characteristics.*

| Pec. type | Sp. type | $T_{\rm eff}$ range | magnetic? |
|---|---|---|---|
| He-weak | B4-B8 | 13000-17000 | Yes/No |
| Si | B7-A0 | 9000-14000 | Yes |
| HgMn | B8-A0 | 10000-14000 | No |
| SrCrEu | A0-F0 | 7000-10000 | Yes |
| Am | A0-F0 | 7000-10000 | No |

But here, we focus on the problems regarding the fundamental parameters of these stars: indeed, both spectral type and luminosity class are often ill-defined due to extreme abundance anomalies. Furthermore, the photometric indices are generally distorted because the abundance anomalies are large enough to induce distorsions of the spectral energy distribution. For instance, the magnetic Ap stars are generally bluer than normal stars with the same effective temperature and their Balmer jump is smaller (see e.g. Hauck & North 1982). The main question to be addressed using the Hipparcos data is that of the exact position of these objects in the HR diagram, within the Main Sequence. Although it is now commonly admitted that all CP stars belong to the Main Sequence (e.g. North 1993), their distribution within the main sequence band has remained less certain. There have been some recent claims that Ap stars tend to appear at the end of their main sequence life (Hubrig & Schwan 1991; Hubrig & Mathys 1994), contrary to what is suggested by cluster members; on the other hand, Am stars show a significant trend to appear more frequently in old open clusters than in younger ones (North 1993).

Another important possibility offered by Hipparcos data is to check and finally to revise the photometric calibrations in terms of absolute magnitude, and we discuss below the Am and normal A stars in the Geneva and $uvby\beta$ systems.

Finally, some astrophysical consequences of the new data are presented concerning the magnetic Ap and the Am stars.

## 2. MEAN $M_V$ OF EVERY GROUP

In order to estimate the mean absolute magnitude of every group of CP stars defined above, we proceeded in the following way. First of all, only CP stars with a *very reliable* spectral classification were considered, which considerably reduced the available sample. Each different group needs an appropriate treatment:

- He-weak stars: we relied upon the usual bibliography, i.e. Jaschek & Egret (1982), Bertaud & Floquet (1974), Hoffleit & Jaschek (1982), Hoffleit et al. (1983). Only stars described spectroscopically as He-weak were retained, excluding stars discovered photometrically or through narrow-band photometry based upon He lines.
- Si-$\lambda$4200 stars: the same bibliography as above was used. Stars with intermediate types like SiCr and SiEu were excluded. When the classification was based upon objective-prism material, two independent classifiers must have reached the same result for the star to be included.
- HgMn stars: since the lines of Mn are difficult to observe at medium dispersion, the list is mostly based upon classifiers using high-dispersion material, i.e. Aikman (1976) and Wolff & Preston (1978).
- CrEuSr stars: same sources as for the Si-$\lambda$4200 stars. SiCr and SiEu stars were also excluded.
- Am stars: the census was based mostly upon the lists by Cowley et al. (1969), Gray & Garrison (1987), Gray & Garrison (1989a), Gray & Garrison (1989b), Garrison & Gray (1994) and Abt & Morrell (1995). A star was accepted as Am if it was so classified by two independent observers.

Then, only stars with a small relative error of 14 per cent on the parallax were considered. $\sigma(\pi)/\pi \leq 0.14$ imply $\sigma(M_V) \leq 0.3$ mag.

The remaining stars colours and absolute magnitude were corrected for interstellar absorption and multiplicity effects when necessary:

- for all CP stars but the CrEuSr and Am stars, the usual dereddening procedure for $UBV$ photometry was adopted. The star was dereddened (slope 0.72) to the average sequence in the $U-B$ versus $B-V$ diagram. Because of the intrinsic width of the sequence, the procedure was applied only when $E(B-V) > 0.03$;
- for visual doubles we used data from the BSC and its supplement (Hoffleit & Jaschek 1982, Hoffleit et al. 1983). There is no problem as far as the magnitude difference $\Delta m_V$ between the components is known;
- for spectroscopic binaries we used the catalogue by Pedoussaut et al. (1996). SB2 binaries are the easiest cases, since one can infer their $\Delta m_V$ from their mass ratio (given by the ratio of the $V_r$ amplitudes) through a mass-luminosity relation. SB1 systems are more problematic; as a compromise, we applied a correction of 0.2 mag, which corresponds to a magnitude difference of 1.7 mag between the components. Since not all stars of our sample had their radial velocity studied, we further applied our 0.2 mag correction to all stars mentioned in the BSC as being 'radial velocity variable'.

  The correction for binary companions is important but surely incomplete. To see how large is its influence upon the average absolute magnitude of the group, we provide in Table 2 the average amount of this correction and also the percentage of the sample that was corrected.

For each group, the average $M_V$ was computed, weighted by the inverse square of the parallax error. The rms standard deviation was computed as well. The results are given in Table 2.

How do the above results compare with those obtained before Hipparcos from cluster stars? We started from the work of North (1993) which was largely based on Renson's (1991) catalogue. The list of cluster CP stars was expurgated of all stars having a doubtful classification (such as 'Am ?'). Cluster stars have the inconvenience that corrections for multiplicity are difficult to apply, since in most cases multiplicity was not investigated, at least using radial velocities. This makes the results somewhat uncertain by amounts which should be similar to the correction given for field stars. Furthermore, usually one classification only is available for cluster stars, very often obtained at small dispersion, a fact which enhances the possibility of misclassification. The same averages have been computed for cluster stars (where $M_V$ is directly obtained from the known distance modulus of the cluster) as for field ones, and the results are displayed in Table 3.

The agreement is very good for all but He-weak stars, whose number is small in any case. As a whole, the results coincide with North's (1993) finding that CP stars are normal stars, as far as the average absolute magnitude is concerned.

## 3. GROUND-BASED PHOTOMETRY AND HIPPARCOS

Here we examine the calibrations of the Geneva and $uvby\beta$ systems in terms of absolute magnitude, and propose a new preliminary calibration of the latter system for A and Am stars.

### 3.1. Geneva System

We first have to consider normal stars to check the quality of the $M_V$ calibration devised by Hauck (1973). We found 30 stars in Proposal 55 which are normal, single A dwarfs with $\Delta d \leq 0.100$ ($d$ is sensitive to the Balmer jump and is equivalent to $c_1$ of Strömgren's photometry) and $\sigma(\pi)/\pi \leq 0.14$. The absolute magnitudes obtained from the calibrated Geneva colours (essentially $d$ and $B2-V1$) are compared with those from the Hipparcos parallaxes in

*Table 2. Results based on the Hipparcos parallaxes. $< M_V >$ is the average absolute magnitude, $\sigma(M_V)$ the scatter of it, N the number of stars considered. <bin. corr.> is the average correction for multiplicity (with respect to the number of stars having a correction), while % is the percentage of stars to which a correction for multiplicity has been applied. Max. and Min. are the extreme absolute magnitudes in the group.*

| Pec. type | $< M_V >$ | $\sigma(M_V)$ | N | $< (U-B)_o >$ | $\sigma(U-B)$ | <bin. corr.> | % | Max. brightness (mag) | Min. brightness (mag) |
|---|---|---|---|---|---|---|---|---|---|
| He-weak | -0.55 | 0.68 | 15 | -0.57 | 0.13 | 0.36 | 40 | -2.4 | +0.2 |
| Si-Si-$\lambda$4200 | -0.41 | 0.79 | 28 | -0.40 | 0.14 | 0.24 | 54 | -1.5 | +1.5 |
| HgMn | 0.20 | 0.49 | 28 | -0.35 | 0.10 | 0.27 | 78 | -0.7 | +1.1 |
| CrEuSr | 1.17 | 0.60 | 49 | 0.02 | 0.11 | 0.17 | 76 | -0.1 | +2.6 |
| Am | 1.64 | 0.68 | 96 | 0.22* | 0.07 | 0.38 | 58 | 0.3 | +2.8 |

$^*(B-V)_o$

*Table 3. Results based on cluster members.*

| Pec. type | $< M_V >$ | $\sigma(M_V)$ | N | $< (U-B)_o >$ | $\sigma(U-B)$ | Max. brightness (mag) | Min. brightness (mag) |
|---|---|---|---|---|---|---|---|
| He-weak | -1.21 | 0.34 | 9 | -0.50 | 0.20 | -3.0 | -0.1 |
| Si-Si-$\lambda$4200 | -0.41 | 0.79 | 28 | -0.40 | 0.14 | -2.6 | +0.7 |
| HgMn | -0.20 | 0.99 | 16 | -0.35 | 0.17 | -1.6 | +1.9 |
| CrEuSr | 1.26 | 0.74 | 10 | 0.01 | 0.10 | 0.3 | +3.1 |
| Am | 1.95 | 0.65 | 46 | 0.18* | 0.09* | 0.4 | +3.0 |

$^*(B-V)_o$ was used instead of $(U-B)_o$

Figure 1. The agreement is excellent, the fit giving:

$$M_V(\text{Geneva}) = \underset{\pm 0.035}{0.997} \quad M_V(\text{Hip}) + \underset{\pm 0.085}{0.129} \qquad (1)$$

$$\sigma_{\text{res}} = 0.18 \text{ mag}$$

On the contrary, for the Am stars the result is rather bad: starting from the sample of *certain* Am stars defined above, we find 71 objects measured in the Geneva system and with $\Delta d \leq 0.100$ ($M_V$ was corrected for multiplicity whenever possible). Figure 2 shows that not only is the slope of the regression much different from 1, but also that the residual scatter is much larger:

$$M_V(\text{Geneva}) = \underset{\pm 0.048}{0.466} \quad M_V(\text{Hip}) + \underset{\pm 0.080}{1.331} \qquad (2)$$

$$\sigma_{\text{res}} = 0.27 \text{ mag}$$

With the present calibration, Geneva photometry underestimates the luminosity of the hottest Am stars; the explanation is probably that the Balmer jump of Am stars is smaller than that of normal stars at same $T_{\text{eff}}$ and $\log g$ (Glagolevskij & Topilskaya 1987), due to a redistribution of the blocked UV flux into the visible, which is also observed in magnetic Ap stars. Another contributing factor might be an underestimate of the parallax by Hipparcos, due to orbital motion of binaries.

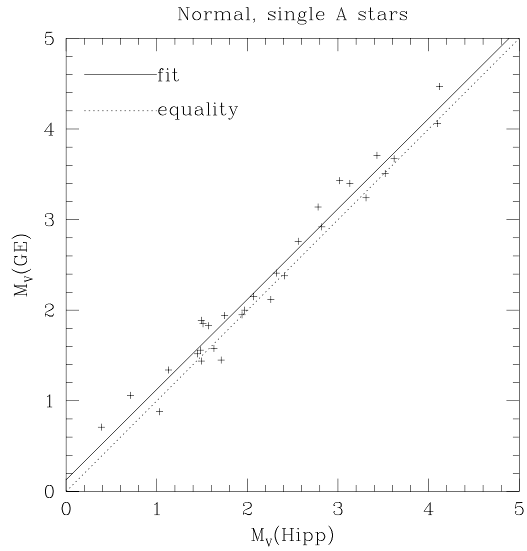


*Figure 1. Comparison between photometric and Hipparcos $M_V$ for normal A dwarfs of Proposal 55 measured in the Geneva system.*

### 3.2. *uvbyβ* System

A sample of 97 normal, single A3-A9 stars was selected from Proposal 35; all stars have $uvby\beta$ photometry (they belong to Strömgren's late group) according to Hauck & Mermilliod (1996), $V \sin i$ data from Abt & Morrell (1995) and $\sigma(\pi)/\pi \leq 0.14$. On the other hand, we have from Proposal 55 a sample of 97 *certain* Am stars with $\sigma(\pi)/\pi \leq 0.14$, 82 of which have $uvby\beta$ photometry. 91 of them have a $V \sin i$ value from Abt & Morrell (1995) and 4 from Uesugi & Fukuda (1981). We have tested two $M_V$ calibrations: that of Crawford (1979):

$$M_v = M_v(\beta)_{\text{ZAMS}} - 9.0 \times \delta c_0 \qquad (3)$$

and that of Guthrie (1987), which takes into account metallicity and rotational effects:

$$M_v = M_v(\beta)_{\text{ZAMS}} - (9.1 \times \delta c_0' + 0.1) \qquad (4)$$

$$\delta c_0' = \delta c_0 - 1.2 \times \delta m_0 - 1.1 \times 10^{-6}(v \sin i)^2 \qquad (5)$$

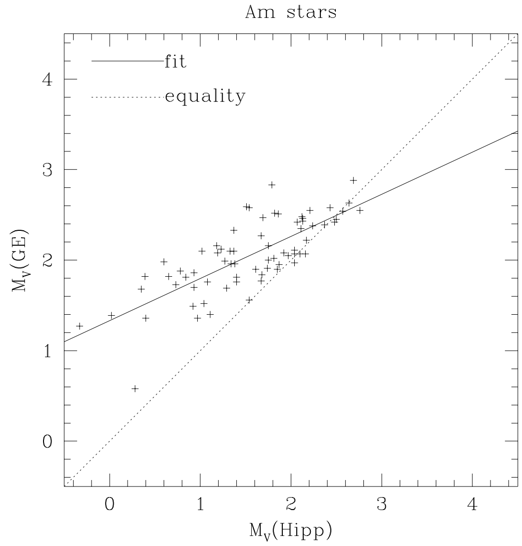


*Figure 2. Comparison between photometric and Hipparcos $M_V$ for Am stars of Proposal 55 measured in the Geneva system.*

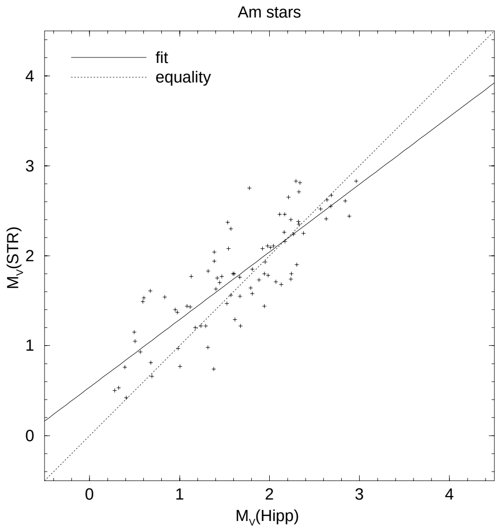


*Figure 3. Comparison between photometric and Hipparcos $M_V$ for Am stars in the Strömgren system. Guthrie's (1987) calibration was used.*

For normal stars, Crawford's calibration is quite good, with an rms difference $(M_{\rm phot} - M_{\rm Hip}) = 0.31$ mag: there is no systematic trend. For Am stars, on the contrary, this calibration overestimates the parallaxes by 4 mas with respect to Hipparcos ones, with exactly the same trend observed above in the Geneva system. Guthrie's calibration is much less successful than Crawford's for normal stars (systematic trend and rms difference of 0.43 mag) but succeeds relatively well for Am stars (Figure 3): no systematic trend is found and the rms difference is 0.40 mag.

In view of the above results, it appeared useful to redefine a calibration which would hold for both the normal A and the Am stars, and that was done using the BCES algorithm (Bivariate Correlated Errors and intrinsic Scatter) devised by Akritas & Bershady (1996). This algorithm has the advantage of allowing for measurement (possibly correlated) errors or intrinsic scatter on both variables, although it can as yet be applied only to simple linear regressions on two variables. Since only one variable can be correlated at a time with $M_V$, the BCES method was applied first to $\beta$ (temperature effect), then to $\delta c_1$ (evolution), $\delta m_1$ (metallicity) and $V \sin i$ (rotation). The process was iterated a few times until convergence of the coefficients and resulted in the following relation:

$$\begin{aligned} M_v = (12.60 \pm 0.03) - (3.66 \pm 0.7)\beta \\ -(8.3 \pm 0.3)\delta c_1 + (6.5 \pm 1.0)\delta m_1 \\ +(7.2 \pm 1.1) \times 10^{-6} (v \sin i)^2 \end{aligned} \quad (6)$$

The scatter of the residuals is quite good: 0.31 mag (normal A+Am), 0.25 (normal A) and 0.36 mag (Am stars).

## 4. SOME ASTROPHYSICAL ISSUES

### 4.1. Distribtion of Ap Stars in the HR Diagram

All kinds of CP stars appear to be more or less *uniformly distributed* on the Main Sequence band, just like in clusters, which contradicts the suggestion of Hubrig & Mathys (1994). Our result, however, entirely confirms the very recent study of Wade (1997), who estimates the evolutionary state of 10 magnetic Ap stars from their rigid rotator geometries. This means that magnetic fields and chemical peculiarities may be present *whatever the age* on the main sequence; therefore, the magnetic fields present in Ap stars are probably primordial, in the sense that they do not build up *during* the main sequence life but result rather from some processes taking place before the arrival of the star on the ZAMS.

### 4.2. roAp versus noAp Stars

The so-called *rapidly oscillating Ap* (roAp) stars pulsate in high radial overtone, low $l$ pressure modes with periods of 5 to 15 minutes, the pulsation axis being colinear with the magnetic axis (Kurtz 1990). In the same range of colours, there are some *non-oscillating Ap* (noAp) stars of the same type which do *not* pulsate, as testified by hours of careful monitoring by Kurtz and co-workers. The question then is what difference can be found between these two categories of stars, except for the existence of pulsation? Absolute magnitude or evolutionary state might yield the clue, as proposed by Mathys et al. (1996) who made a pre-Hipparcos study based on mean parallaxes and on kinematics.

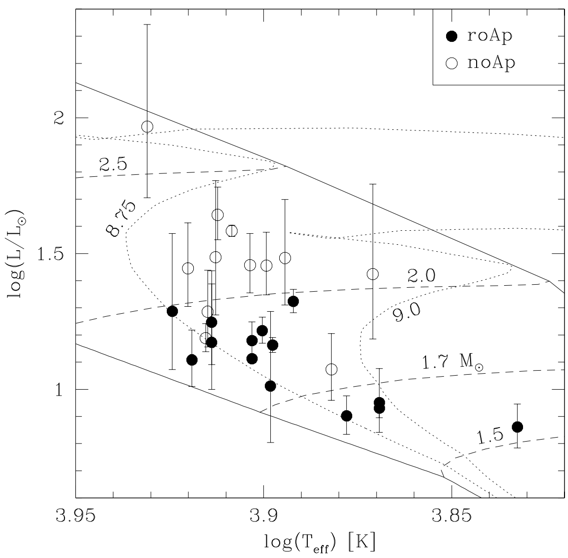


*Figure 4. HR diagram for roAp (full dots) and noAp (open dots) stars.*

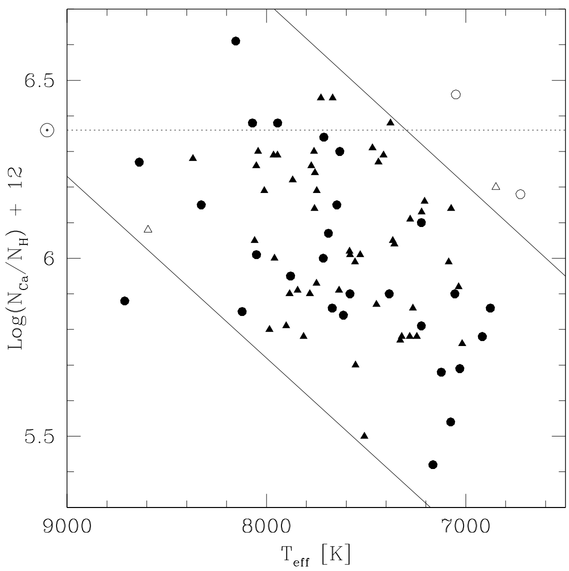


*Figure 5. Ca abundance versus $T_{\rm eff}$ (obtained from Geneva colours and the calibration of Künzli et al. 1997) for Am stars measured at OHP (full disks) and published by Guthrie (1987, full triangles). A few normal (open triangles) and metallic giant (open circles) F stars are also shown. The horizontal line indicates the solar abundance.*

Here we reconsider the work of Mathys et al. (1996) in the light of the Hipparcos data, but using only the parallaxes. Starting from the lists of roAp and noAp stars compiled by these authors, we end up with 14 roAp stars and 12 noAp stars, some of which have a large relative error on the parallax (up to 0.28 for the roAp and 0.35 for the noAp). In fact many more noAp stars could have been considered, since the list of Mathys et al. (1996) contains only those stars with a well-known radial velocity, but we checked they would not change the result. Figure 4 shows the resulting HR diagram, where the $T_{\rm eff}$ have been taken as such from Table 2 of Mathys et al. (1996) and the luminosities were obtained using bolometric corrections of Lanz (1984) and $M_{b\odot} = 4.75$. Interstellar reddening was estimated by Erspamer (1996) using the maps of Lucke (1978).

One clearly sees that in general, noAp stars are *more evolved* and *more massive* than the roAp stars, the dividing line being about 2 $M_\odot$. We have not corrected for biases such as the Lutz-Kelker one, but if they may be significant in an absolute way, they are probably not when comparing both samples. Cumulative distributions of $M_V$ for both samples confirm they are different to a confidence level better than 99 per cent according to the Kolmogorov-Smirnov test. The samples are relatively small, however, and it will be interesting to reconsider this question when the complete Hipparcos catalogue become available.

### 4.3. Calcium Abundance versus Age in Am Stars

A sample of 27 Am stars had been measured in 1994 and 1995 with the Aurélie spectrograph attached to the 1.5m telescope at OHP, France, to obtain their calcium abundance from the Ca II K line using synthetic spectra. The purpose was to test how the Ca abundance varies with the evolutionary state of Am stars, which at the time could only be obtained through photometric $M_V$ values. The idea was essentially to test the hypothesis put forward by Berthet (1992), of an evolutionary link between the Am stars (Ca and Sc deficient), the $\delta$ Delphini stars (more evolved, abundances similar to those of Am stars, except for Ca and Sc which are nearly solar) and the metallic A-F giants (Ca and Sc solar, heavier species overabundant).

Our calcium abundances are in good agreement with those obtained through narrow-band photometry by Guthrie (1987) (there are 8 stars in common), so his results can be added to ours, especially as his stars also have Hipparcos measurements. The whole sample then includes 76 Am stars, all with $M_V$ derived from Hipparcos and whose age can be interpolated in the evolutionary tracks of Schaller et al. (1992).

Plotting Ca abundance against age gives a rather dispersed but significant anticorrelation: older Am stars are more Ca-deficient (hence have a more pronounced peculiarity). Such a result is very tantalizing, because it is qualitatively consistent with the theoretical predictions of Alecian (1996). However, cooler Am stars are statistically older than hotter ones, so that the Ca abundance versus age correlation reflects a relation between Ca abundance and $T_{\rm eff}$. Indeed, Figure 5 shows the latter correlation is real, and numerical simulations confirm our suspicion: artificial Am stars with masses and ages distributed at random and having Ca abundances loosely correlated with $T_{\rm eff}$ *only*, will yield N(Ca) decreasing with increasing $\log t$. Such an equivalence is expected, since a star evolves on the main sequence with a decreasing $T_{\rm eff}$: it is fundamentally impossible to identify the physical cause of the Ca deficiency with either $t$ or

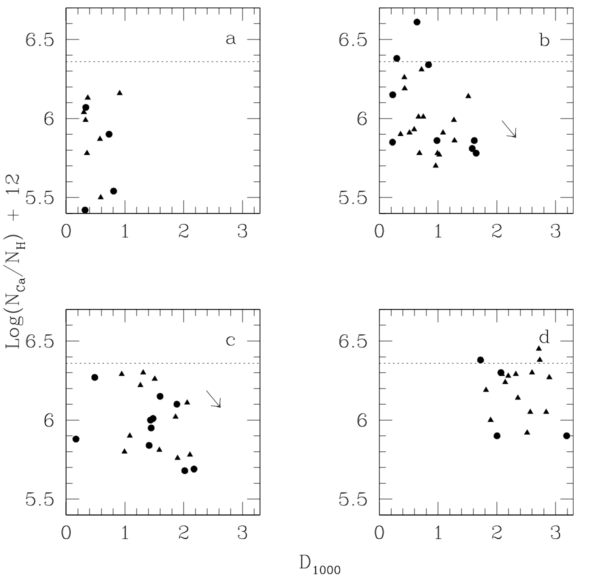


*Figure 6. Calcium abundance versus evolution ($D_{1000}$ is the distance from the ZAMS in arbitrary units, roughly along an evolutionary track) for Am stars measured at OHP (full dots) and published by Guthrie (1987, full triangles). Each panel refers to a specific mass range: (a) $1.5 \leq M/M_{\odot} \leq 1.7$; (b) $1.7 \leq M/M_{\odot} \leq 1.9$; (c) $1.9 \leq M/M_{\odot} \leq 2.1$; (d) $M/M_{\odot} \geq 2.1$.*

$T_{\rm eff}$, since both vary together. Only three Am star in the sample are younger than $\log t = 8.6$: this fits well the results of North (1993), who showed that the frequency of Am stars in open clusters rises significantly with age.

Figure 6 confirms that, contrary to what was suggested by Guthrie (1987) and Berthet (1992), Am stars which have nearly completed their main sequence life do not tend to have a larger Ca abundance. The parameter $D_{1000}$ in Figure 6 is the distance, along an evolutionary track, between the representative point of a star in the HR diagram, and the ZAMS; it is zero on the ZAMS and increases as the star evolves. Clearly, for a given mass, the Ca abundance shows no increasing trend; there is even a slight indication for the contrary. This is yet another argument against Berthet's scenario, which has also been challenged by Künzli & North (1997).

## REFERENCES


Abt H.A., Morrell N.I., 1995, ApJS, 99, 135

Aikman G.C.L., 1976, Publ. Dominion Obs. Victoria 14, 379

Akritas M.G., Bershady M.A., 1996, ApJ, 470, 706

Alecian G., 1996, A&A 310, 872

Bertaud C., Floquet M., 1974, A&AS 16, 71

Berthet S., 1992, A&A 253, 451

Cowley A., Cowley C., Jaschek M., Jaschek C., 1969, AJ 74, 375

Crawford D.L., 1979, AJ 84, 1858

Erspamer D., 1996, Private communication

Garrison R.F., Gray R.O., 1994, AJ 107, 1556

Glagolevskij Yu.V., Topilskaya G., 1987, Astrofizik Issledovanija 25, 13

Gray R.O., Garrison R.F., 1987, ApJS 65, 581

Gray R.O., Garrison R.F., 1989a, ApJS 69, 301

Gray R.O., Garrison R.F., 1989b, ApJS 70, 623

Guthrie B.N.G., 1987, MNRAS, 226, 361

Hauck B., 1973, in: Problems of calibration of absolute magnitudes and temperature of the stars, IAU Symp. No 54, eds. B. Hauck and B.E. Westerlund, Reidel, Dordrecht, p. 117

Hauck B., Künzli M., 1996, Baltic Astronomy 5, 303

Hauck B., Mermilliod J.C. 1996, Private comunication

Hauck B., North P., 1982, A&A 114, 23

Hoffleit D., Jaschek C., 1982, The Bright Star Catalogue, 4th ed., Yale University Observatory

Hoffleit D., Saladyga M., Wlasuk P., 1983, A Supplement to the Bright Star Catalogue, Yale University Observatory

Hubrig S., Mathys G., 1994, Astron. Nachr. 315, 343

Hubrig S., Schwan H., 1991, A&A 251, 469

Jaschek M., Egret D., 1982, Publ. Spéc. du CDS No 4

Künzli M., North P., A&AS, in press

Künzli M., North P., Kurucz R.L., Nicolet B., 1997, A&AS 122, 51

Kurtz D.W., 1990, ARA&A 28, 607

Lanz T., 1984, A&A 139, 161

Lucke P.B., 1978, A&A 64, 367

Mathys G., Kharchenko N., Hubrig S., 1996, A&A 311, 901

Michaud G., 1970, ApJ 160, 641

Moon T.T., Dworetsky M.M., 1985, MNRAS 217, 305

Napiwotsky R., Schönberner D., Wenske V., 1993, A&A 268, 653

North P., 1993, in: Peculiar versus normal phenomena in A-type and related stars, eds. M.M. Dworetsky, F. Castelli and R. Faraggiana, ASP Conf. Series Vol. 44, p. 577

Pedoussaut A., Rochette J., Capdeville A., Bourdoncle P., 1996, Catalogue of orbits of spectroscopic binaries (floppy disk)

Renson P., 1991, Catalogue Général des Etoiles Ap et Am, Institut d'Astrophysique, Université de Liège

Schaerer D., Charbonnel C., Meynet G., Maeder A., Schaller G., 1993, A&AS 102, 339

Schaerer D., Meynet G., Maeder A., Schaller G., 1993, A&AS 98, 523

Schaller G., Schaerer D., Meynet G., Maeder A., 1992, A&AS 96, 269

Schmidt-Kaler Th., 1982, in: Landolt-Bornstein, ed. K.-H. Hellwege, Springer, Group VI, Subvolume 2b, pp. 453-454

Uesugi, A., Fukuda, I. 1981, Catalog III-63; v sini (Microfiche; Strasbourg: Centre de Données Stellaires)

Wade G.A., 1997, A&A, in press

Wolff S.C., Preston G.W., 1978, ApJS 37, 371