Peculiar Versus Normal Phenomena in A-Type and Related Stars
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AGE DETERMINATION FOR Am STARS

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ABSTRACT From *uvby* and H_β photometry, individual stellar ages for A type stars have been derived using three different evolutionary models. In this paper we evaluate the corrections for metallicity and rotation to be applied to the physical parameters of Am and their influence on the determined ages. A test based on the Hyades open cluster is also presented.

INTRODUCTION

To analyze the kinematic properties of main-sequence A-type stars, we have undertaken a program devoted to the derivation of individual photometric distances and ages from *uvby* and H_β photometry (Figueras et al., 1991; Torra et al., 1990). As 9.8 % of our working sample – more than two thousand field stars extracted from the Hipparcos Input Catalogue (Turon et al., 1992) – are classified spectroscopically as Am stars, we are obliged to review and discuss the specific treatment of these stars when computing their physical parameters. After a brief explanation of the procedure developed for the derivation of individual ages – using different evolutionary models and evaluating the internal and external errors – we discuss the implications of metallicity and rotational effects for the age and compare the amount of the corrections with the errors obtained. The application of the corrections to the Hyades open cluster allows us to check their validity and the use of the up to date stellar evolutionary models for these CP stars.

INDIVIDUAL STELLAR AGES FOR A MAIN-SEQUENCE STARS

After the derivation of the effective temperature and the surface gravity for each star from Strömgren photometry (Figueras et al. 1991), three different evolutionary models – Maeder and Meynet (1991) (hereafter MM), VandenBerg (1985) (hereafter VdB) and Castellani et al. (1992) (hereafter CCS) – have been considered for the computation of individual stellar ages. A linear interpolation between points of corresponding evolutionary status has been performed and special care has been taken to assign an error to each age determination (Asiain, 1992).

Leaving aside the stars close to the ZAMS, the errors obtained when pro-

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pagating the errors in $Teff$ and $logg$ are below twenty per cent of the age.

In order to evaluate the external errors in the determined age, we have compared the three evolutionary models in the region covered by A IV-V stars. The differences are in the range [0,0.2] in $log(age)$ - depending on the region considered - and they reach 0.3 dex only near the ZAMS (Asiain, 1992).

CORRECTIONS FOR METALLICITY AND ROTATION

Dworetsky and Moon (1986) (hereafter DM), from an analysis of main-sequence and Am stars in five open clusters, have proposed a small correction for metallicity to the surface gravity derived from their grids for stars cooler than $T_{eff} \approx 8500K$ ($logg = logg(grid) + 3.442\delta m_o$). To evaluate the effects of this correction on the individual ages of Am stars statistically , we have used the *General catalogue of Ap and Am stars* recently published by Renson et al. (1991). From this sample we have considered the Am stars with Strömgren photometry not known as spectroscopic binaries or delta Del-type stars. We have calculated the individual ages with and without the DM correction. Fig. 1a shows the histogram of the differences in $log(age)$ – in the sense of corrected minus not corrected – when the MM evolutionary tracks are used (the other models give similar results). From this figure it can be seen that more than 20% of the stars in the sample have $\Delta log(age) \geq 0.20$. When no correction is applied, these stars are placed below the first point of the track (in this case, we can only calculate an upper limit of their individual age) whereas, when the correction is done, only 4% of the sample remains in this region.

We can state that, although the correction in surface gravity proposed by DM is small, its implication on age is significant, $\Delta log(age)$ being in some cases greater than the error assigned to the age.

On the other hand, in the process of deriving ages from Strömgren photometry, we cannot ignore the rotation effects on the colors and magnitudes of the stars. We have applied the extensive tabulations of Collins and Sonneborn (1977), which assume rigid rotation, to the Am stars of Renson et al. (1991) catalogue with known $v\ sin\ i$. Due to the fact that the observations cannot determine which set of rotation parameters actually apply for a particular star, computations have been performed assuming two different inclination angles ($i = 30^o$ and $i = 90^o$). Mean values of the corrections to the photometric indices that we have obtained are in table I.

TABLE I Mean values of the corrections to the photometric indices

	$\Delta(b-y)$	Δm_1	Δc_1	$\Delta\beta$
$i = 30^o$	$-.013 \pm .016$	$.005 \pm .008$	$.022 \pm .038$	$.012 \pm .017$
$i = 90^o$	$-.012 \pm .009$	$.006 \pm .004$	$.020 \pm .018$	$.016 \pm .011$

When assuming a random orientation hypothesis, 59 % of the sample has $54^o \leq i \leq 90^o$ and only 19 % has $0^o \leq i \leq 36^o$. Hereafter we consider, for the sake of simplicity, only the case $i = 90^o$. Fig. 1b shows the histogram of $\Delta log(age)$ – in the sense of corrected minus not corrected – when using CCS evolutionary

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models and taking into account the correction for metallicity. Although Am stars are slow rotators (Abt, 1979), we find that the correction is also significant when compared with the errors assigned to the ages.

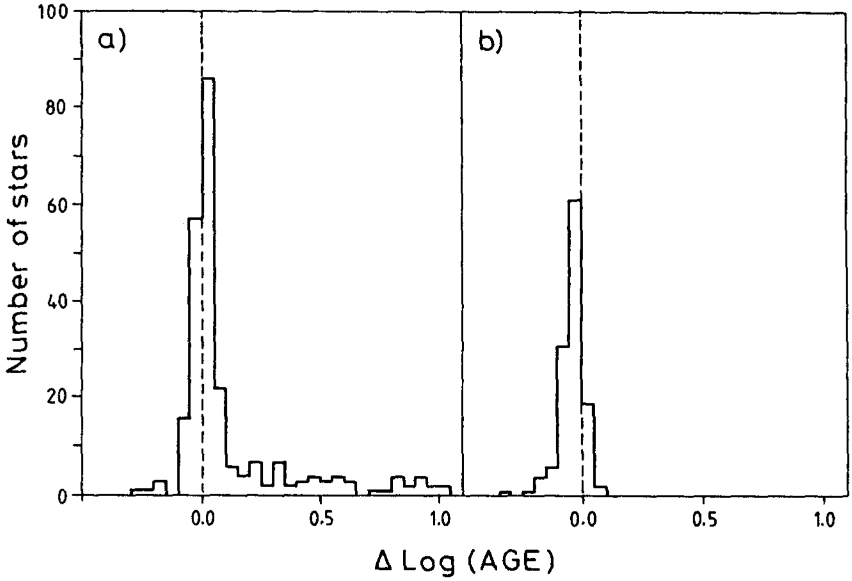

Fig. 1. Frequency distribution of $\Delta log(age)$ for Am stars. a:*Metallicity effect* ; b: *Rotation effect*

We can state that for Am stars not close to the ZAMS, the two corrections – rotation and metallicity – are of the same order of magnitude. On average, correction for rotation implies a younger age while metallicity can act in both senses, depending on the specific position of the star in the HR diagram.

Although we have evaluated two important corrections for Am stars, the binarity problem remains. To correct this effect we need to know the mass ratio for each recognized binary system; this is a parameter which cannot at the moment be evaluated observationally for the amount of data we are considering. We leave the statistical treatment of this problem for a future work.

APPLICATION TO THE HYADES

The hypothesis that the evolutionary status of normal and Am stars in a cluster is the same allows us to check, as a whole, the validity of specific corrections for rotation and metallicity above discussed. In this section we analyze their application to the Hyades open cluster. First we have selected all the stars adopted as Hyades members – from the recent work of Schwan (1991) – with known rotational velocity and effective temperature in the range 7000 - 8200 K

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(which includes all Am stars in this cluster). Among the 25 stars in this range, we have considered as Am only those qualified as well-known or very probable Am stars in the Renson et al. (1991) catalogue.

After the computation of the physical parameters, individual stellar ages have been derived using the three evolutionary models. Table II shows the mean ages and the dispersions around the mean with and without applying the corrections for rotation (Collins and Sonneborn, 1977) and metallicity (Dworetsky and Moon, 1986).

First, we can state from Table II that the dispersions diminished significantly when the two corrections are considered. This may be seen in Figures 2a and 2b where we have plotted the normal (16) and the Am stars (9) jointly with the MM isochrones computed for the mean values $log(age)$ = 8.96 and $log(age)$ = 8.95 respectively.

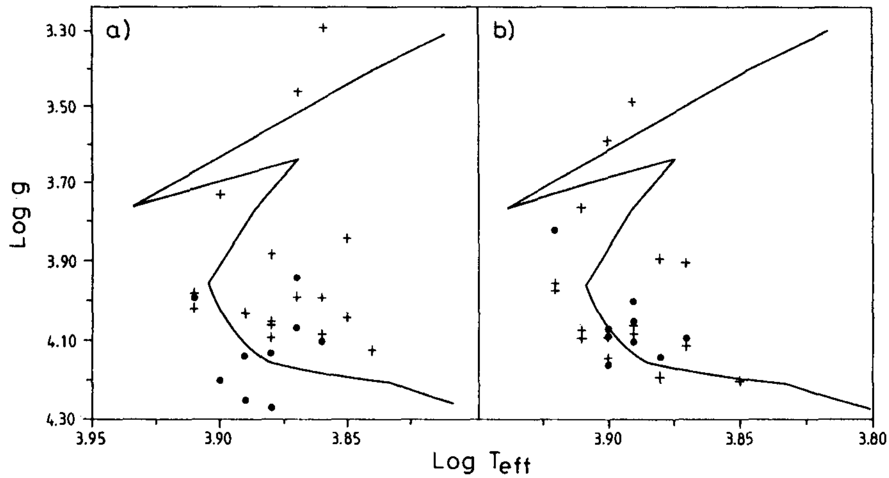

Fig. 2. The Hyades HR diagram. *Crosses*: A-normal stars. *Dots*: Am stars. a: without corrections and overimposing $log(age)$ = 8.96 MM isochrone. b: with corrections for rotation and metallicity, and overimposing $log(age)$ = 8.95 MM isochrone.

Second, when no corrections are performed, the three models are coherent, giving a mean age for the Am stars that is lower than for normal stars. As expected, when the correction for rotation is considered, all the mean values diminish but the Am stars remain younger than the A normal. However, this difference is reduced to 0.01 dex when the correction for metallicity is applied. In general, although the dispersions are higher than the amount of the corrections above described, the fact that the three models reflect the same tendency allows

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us to conclude that the correction for metallicity given by Dworetsky and Moon (1986) should be applied when their grids are used for the derivation of effective temperature and surface gravity from Strömgren photometry.

TABLE II Mean *log*(*ages*) and dispersions for the Hyades

		without corrections	with correction for rotation	with correction for rotation and metallicity
MM (1991)	A normal	9.02 ± 0.11	8.94 ± 0.07	8.94 ± 0.07
	Am	8.87 ± 0.23	8.77 ± 0.25	8.96 ± 0.06
	All	8.96 ± 0.17	8.88 ± 0.17	8.95 ± 0.06
VdB (1985)	A normal	9.00 ± 0.16	8.94 ± 0.11	8.94 ± 0.10
	Am	8.96 ± 0.09	8.90 ± 0.09	8.95 ± 0.07
	All	8.98 ± 0.14	8.93 ± 0.10	8.94 ± 0.09
CCS (1992)	A normal	8.95 ± 0.15	8.88 ± 0.10	8.88 ± 0.09
	Am	8.88 ± 0.13	8.81 ± 0.13	8.90 ± 0.06
	All	8.92 ± 0.15	8.86 ± 0.12	8.89 ± 0.08

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