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Be stars in open clusters.
I. *uvbyβ* photometry[⋆,⋆⋆]

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Abstract. — We present *uvbyβ* photometry for Be stars in eight open clusters and two OB associations. It is shown that Be stars occupy anomalous positions in the photometric diagrams, which can be explained in terms of the circumstellar continuum radiation contribution to the photometric indices. In the $(b-y)_0 - M_V$ plane Be stars appear redder than the non emission B stars, due to the additional reddening caused by the hydrogen free-bound and free-free recombination in the circumstellar envelope. In the $c_0 - M_V$ plane the earlier Be stars present lower c_0 values than absorption-line B stars, which is caused by emission in the Balmer discontinuity, while the later Be stars deviate towards higher c_0 values, indicating absorption in the Balmer discontinuity of circumstellar origin.

Key words: techniques: photometric — stars: emission-line, Be — open clusters and associations: general

1. Introduction

The study of Be stars in open clusters is an issue of special importance in addressing some fundamental and yet unsolved questions regarding these stars, such as their evolutionary status and the origin of the Be phenomenon. The ages, intrinsic colours and distances of Be stars can be inferred from the cluster parameters, and used to test the theoretical attempts to account for their observed characteristics (Mermilliod 1982b; Slettebak 1985).

One of the main problems which prevents the detailed study and modelling of Be stars is the difficulty in determining the precise astrophysical parameters (M_V, $T_{\rm eff}$, log g) of the underlying B star. The usual methods of spectral classification, equivalent widths of Balmer lines or photometric calibrations are not suitable. The spectrum is distorted by the circumstellar envelope lines, while the contribution of the circumstellar continuum radiation contaminates the photometric colours and indices.

The main purpose of the work presented here is to develop a method to determine such intrinsic parameters from *uvbyβ* photometry and Hα spectroscopy. It has been shown by several authors (Dachs et al. 1986, 1988; Kaiser 1989) that the continuum emission of the circumstellar envelope is closely correlated with the equivalent width of the Hα line. Thus, by measuring the Hα emission-line strength, the underlying star contribution to the photometric indices can be decoupled from the circumstellar disk contribution, and then the usual *uvbyβ* calibrations can be applied. A first exposition of this method is given by Fabregat & Reglero (1990).

In order to accurately determine the relationship between the circumstellar continuum emission and the Hα equivalent width, we have developed an observational programme of simultaneous *uvbyβ* photometry and Hα spectroscopy of Be stars in open clusters. In this paper we present the *uvbyβ* photometry. Further work will include the presentation of the spectroscopic observations, the

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[⋆] Based on observations made with the Jacobus Kaptein Telescope operated on the island of La Palma by the Royal Greenwich Observatory, in the spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias, and with the 1.5 m. telescope of the Instituto Geográfico Nacional, jointly operated by the Instituto Geográfico Nacional and the Consejo Superior de Investigaciones Científicas through the Instituto de Astrofísica de Andalucía, at the Calar Alto Observatory

[⋆⋆] Tables 1 and 5 to 15 are only available in electronic form at the CDS via anonymous ftp 130.79.128.5

Table 2. Transformation coefficients to the *uvby* standard system for the three observing runs. CA refers to the Calar Alto Observatory and RM to the Roque de los Muchachos Observatory

Run	A	B	C	D	E	F	G	H	I	J
CA92	19.521	0.041	0.534	0.987	–0.709	0.953	0.765	1.015	0.027	–0.048
RM92	19.381	0.096	0.349	0.980	–0.216	0.999	0.719	1.002	0.136	–0.055
RM93	19.318	0.110	0.278	1.003	–0.176	1.007	0.645	1.023	0.134	–0.069

determination of the astrophysical parameters of the stars observed, the analysis of the Balmer decrements and the physics of the circumstellar envelopes, and the study of the evolutionary state of the Be stars.

2. Observations and reduction procedure

2.1. *The observations*

The observations were made during two runs in December 1992 and September 1993 at the Roque de los Muchachos Observatory (La Palma, Canary Islands, Spain), and a third run in December 1992 at the Calar Alto Observatory (Almería, Spain).

The equipment used in La Palma was the People's Photometer attached to the Cassegrain focus of the 1.0 m. Jacobus Kaptein Telescope (JKT). We used the photometer in a single-channel mode, measuring sequentially the star and the sky background through the four Strömgren *uvby* and the narrow and wide Hβ filters. Observed magnitudes were computed taking into account the photomultiplier dead time of 43 nanoseconds.

In Calar Alto we used the multipourpose one-channel *UBVRI* photoelectric photometer, at the Cassegrain focus of the 1.5 m telescope of the Instituto Geográfico Nacional. A complete description of the photometer is given by Lahulla & Pensado (1981). As in the JKT, observations were made with the four *uvby* and the two Hβ filters.

In order to determine the atmospheric extinction, every night a set of 2 to 4 standard stars were observed more than four times at air masses ranging from 1 to 2. In each observing run mean zero points were computed for the whole period, before determining the nightly extinction coefficients.

2.2. *uvby transformation*

Most of our programme stars are highly reddened B type stars, and this fact makes the choice of the *uvby* standards for the transformation a very critical issue. Manfroid & Sterken (1987) and Crawford (1994) have shown that transformations made only with unreddened stars introduce large systematic errors when applied to reddened stars, even if the colour range of the standards brackets that of the programme stars. To avoid unwanted effects, we took special care in selecting a standard star list which includes only early type stars (earlier than A3, where the maximum of the Balmer lines appears) and with a wide range of reddening values, so as to bracket the values of the programme stars. No such reddened early type stars are included in the primary *uvby*β standard lists (Crawford & Barnes 1970b; Perry et al. 1987). Then we complemented these lists with stars in the h and χ Persei clusters (Crawford et al. 1970), in the α Persei cluster (Crawford & Barnes 1974) and the Cepheus OB3 association (Crawford & Barnes 1970a). All these photometric lists were obtained with the same Kitt Peak telescopes and instrumentation used to define the standard Crawford & Barnes (1970b) system, and so there is no doubt that the photometric values are in the standard system. As the above papers do not include V values, for the V transformation we used the values given by Johnson & Morgan (1955) for stars in h and χ Persei, Mitchell (1960) for α Persei and Blaauw et al. (1959) for Cepheus OB3. The final standard star list is presented in Table 1.

The instrumental system and transformation equations were computed separately for each individual run, following the procedure described in detail by Grønbech et al. (1976). The transformation coefficients are given in Table 2. A measure of the accuracy of the transformation equations is the standard deviation of the mean catalogue minus transformed values for the sample of standard stars observed. The values obtained for each observing run are given in Table 3.

Table 3. Accuracy of the standard values obtained in the three runs

Run	V	$(b-y)$	m_1	c_1	β
CA92	013	003	004	010	009
RM92	011	006	009	018	008
RM93	008	007	010	009	008

The transformed values of the measured standard stars are given in Table 1. There is a noticeable difference and a large scatter around the standard value found for the c_1 index of star HR 7858. This is caused by the value c_1=0.912 (rms 0.005) obtained from two measures in two consecutive nights in the December 1992 period. In September 1993 we obtained a value of c_1=0.980, much closer to the standard value of c_1=0.983 (Perry et al. 1987). We searched the literature but did not find any other exceptional values for c_1; therefore we would sound a cautionary note about the possible c_1 variability of HR 7858, although no firm conclusion can be presented here.

In the original standard star list prior to the observations we also included stars 2251 and 2488 (BD +56° 586) in χ Persei. Both stars were later rejected, the former for showing a large scatter in the values obtained in different observing periods and the latter for the large residuals from the standard values listed by Crawford et al. (1970).

2.3. *Hβ transformation*

The standard star list for the Hβ standard transformation is basically the same than for the *uvby* transformation described in the previous subsection. Among the programme stars there are several which presented a high level of Balmer line emission during the observations, leading to a very low value for the β index. As no emission line star should be used as standard due to their well known variability, there is no way to avoid extrapolation when applying the standard transformation to the programme star observations. In order to minimize the errors introduced by such extrapolation, we chose the standard star list to cover the maximum range in the β index. The standard stars' range spans 2.582 to 2.918, while the lower observed β index is 2.391.

The instrumental system and transformation equation were computed for each observing run following the procedure described by Crawford & Mander (1966). The transformation coefficients are given in Table 4, and the standard deviation of the mean difference between the catalogue and transformed values are presented in Table 3.

Table 4. Transformation coefficients to the Hβ standard system

Run	a	b
CA92	0.475	1.297
RM92	0.398	1.110
RM93	0.437	1.093

2.4. *The data*

Photometric data for Be stars in eight open clusters and two OB associations are presented in Tables 5 to 14. Within our programme we also observed several cluster stars which are not Be stars. The data for these stars are given in Table 15.

In order to check the external accuracy of our data we have compared them with the values given by Crawford et al. (1970), Crawford & Barnes (1970a) and Crawford & Perry (1976). In Table 15 there are 16 stars not used as standards in the transformation in common with the above references. Excluding Oo 2196, which shows a large difference, the average differences in the sense of Crawford and co-workers values minus ours are −0.006, 0.002, −0.005 and 0.009, in $(b-y)$, m_1, c_1 and β respectively, with rms scatter of 0.012, 0.012, 0.024 and 0.012. These results allow us to deduce that no systematic errors are present in our data, and our photometric results are well tied to the *uvby* Crawford-Barnes and Hβ Crawford-Mander standard systems. The small differences and the scatter slightly higher than the accuracy of our photometry, as presented in Table 3, may be caused by the variability of some of the stars. Waelkens et al. (1990) showed that at least half of the stars they observed in h and χ Persei are actually variable stars.

3. Cluster photometric diagrams

In this section we analyze the position of Be stars in the cluster photometric diagrams. As we have not observed enough stars in each cluster to determine the main sequence locus, we will consider only the clusters for which published *uvby*β photometric studies exist. NGC 2323 and NGC 7654 meet this condition, but have not been included in the following discussion because of the large reddening variation across the cluster faces (Schneider 1987; Danford & Thomas 1981), which prevented us constructing reddening-free photometric diagrams by subtracting a mean reddening value.

3.1. *h and χ Persei (NGC 869 and 884)*

In Fig. 1 we present the $(b-y)_0 - M_V$ and $c_0 - M_V$ diagrams for the h and χ Persei cluster. Be stars are represented by open squares, and "normal" absorption-line B stars by asterisks. We have included, as well as the data in Tables 5 and 15, photometry of Crawford et al. (1970) of stars not classified as Be, in order to obtain a better definition of the locus of the non emission-line stars in the photometric diagrams. These stars are represented by crosses. We have transformed the observed V, $(b-y)$ and c_1 values to absolute magnitudes and intrinsic colours by correcting for a cluster reddening of $E(b-y)$=0.41 (Crawford et al. 1970) and distance modulus 11.16 (Balona & Shobbrook 1984). Solid lines represent the ZAMS and the isochrone computed with the evolutionary models of Schaller et al. (1992) for a log age of 7.15 (Meynet et al. 1993).

Four stars in Fig. 1, represented by a different symbol (filled circle) are found to be anomalous. Their position at the left of the ZAMS line indicates that they have a reddening value significantly lower than the mean cluster value. All four stars are located outside the cluster

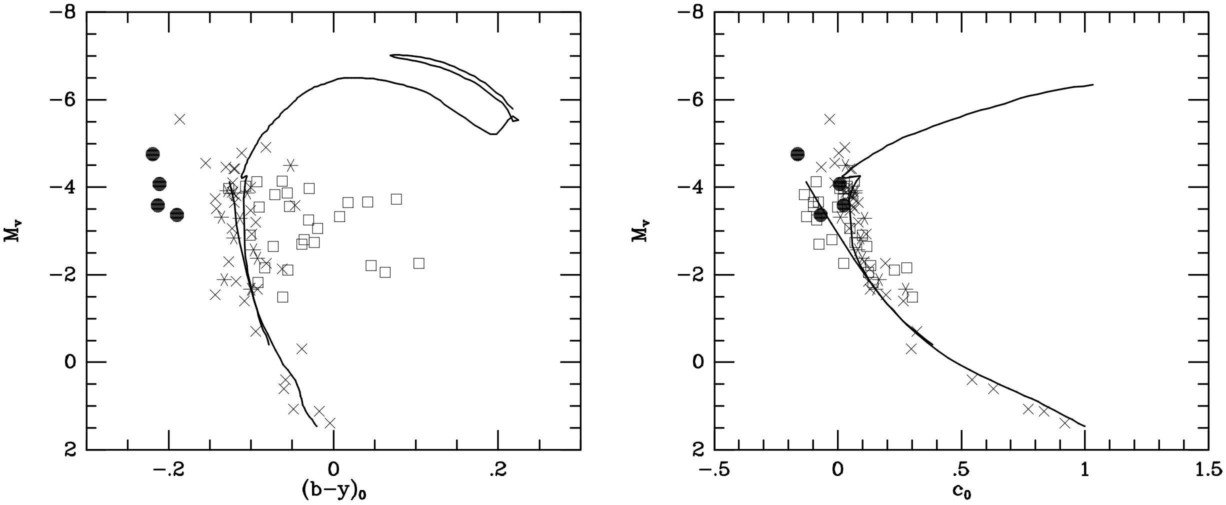

Fig. 1. Photometric diagrams for the *h* and χ Persei open clusters. Open squares represent our data for Be stars, and asterisks our data for absorption line B stars. Crosses represent additional data for B stars retrieved from the literature. Filled circles are probable nonmembers. The lines represent the ZAMS and the cluster isochrones

nuclei, defined by the stars plotted in charts 2 and 4 in Oosterhoff (1937). The brightest of these stars is Oo 2172, a blue straggler of the Perseus OB1 association (Mathys 1987) in which *h* and χ Persei are included. The membership of Oo 2172 within the χ Persei cluster itself has been discussed by Crawford et al. (1970) and Mermilliod (1982a), and in both references the membership is considered doubtful. To contribute to this discussion, we have computed the reddening value of Oo 2172 from our data, using the procedure described by Crawford (1978). The obtained value is $E(b-y)$=0.319, in good agreement with the value of 0.31 found by Crawford et al. (1970). This value differs by more than 3σ of the mean cluster reddening of 0.41±0.02 (Crawford et al. 1970). We have also computed the mean radial velocity of the cluster stars using the data published by Liu et al. (1989, 1991). These authors have obtained precise radial velocity measurements of 21 stars in h and χ Persei. After rejecting a nonmember and the stars identified by their radial velocity variability as spectroscopic binaries, the mean of the 14 remaining stars is $-45\pm$ 5 km s^{-1}. The mean value of Oo 2172 given by Mermilliod (1982a) from his literature search is -18 km s^{-1}. This value is again different by more than 3σ from the cluster mean. Thus we conclude that Oo 2172 is not a member of the χ Persei cluster.

The other three stars at the left of the cluster ZAMS are Oo 146, Oo 245 and Oo 566. As in the previous case we have computed the individual reddening for each star, obtaining 0.313, 0.346 and 0.308 respectively. These values are also significantly lower than the cluster mean. Moreover, as Oo 146 and Oo 566 are Be stars, the $E(b-y)$ value quoted above is an upper limit for the interstellar reddening, because part of the reddening can be of circumstellar origin. Only one of these stars, Oo 146, has a measured radial velocity, with a value of -60 km s^{-1} (Wilson 1953), which also differs by 3σ from the cluster mean. Therefore we consider it highly probable that all three stars are nonmembers. The alternative hypothesis, that the reddening in the outer region of the clusters can be lower than in the cluster nuclei, is not likely. Most of the outer region stars observed by Crawford et al. (1970) present the same reddening as the cluster nuclei.

Be stars deviate systematically from the loci of the normal cluster stars in both diagrams. In the $(b-y)-M_V$ plane they deviate towards redder $(b-y)$ values. In the c_0-M_V plane the bulk of the Be stars deviate to the left, to lower "bluer" values. This behaviour, however, does not seem to be followed by the faintest Be stars. Three of them appear clearly displaced to the right of the main sequence. In both diagrams some Be stars are located in the same position as normal B stars. Fabregat et al. (1994a) showed that most of these stars present their hydrogen lines in absorption, indicating that they are in an inactive phase. They concluded that inactive Be stars are indistinguishable from normal B stars, and the anomalous behaviour of the active Be stars in the photometric diagrams is due to the contribution of the circumstellar continuum emission and not to the underlying star itself. We will discuss this issue in detail in the next section.

3.2. *NGC 663*

The photometric $(b-y)_0-M_V$ and c_0-M_V diagrams of NGC 663 are presented in Fig. 2, with the same symbol criteria as in Fig. 1. As in the previous case, we have added to our data photometric data from Tapia et al. (1991) for cluster stars not classified as Be. The accuracy of the

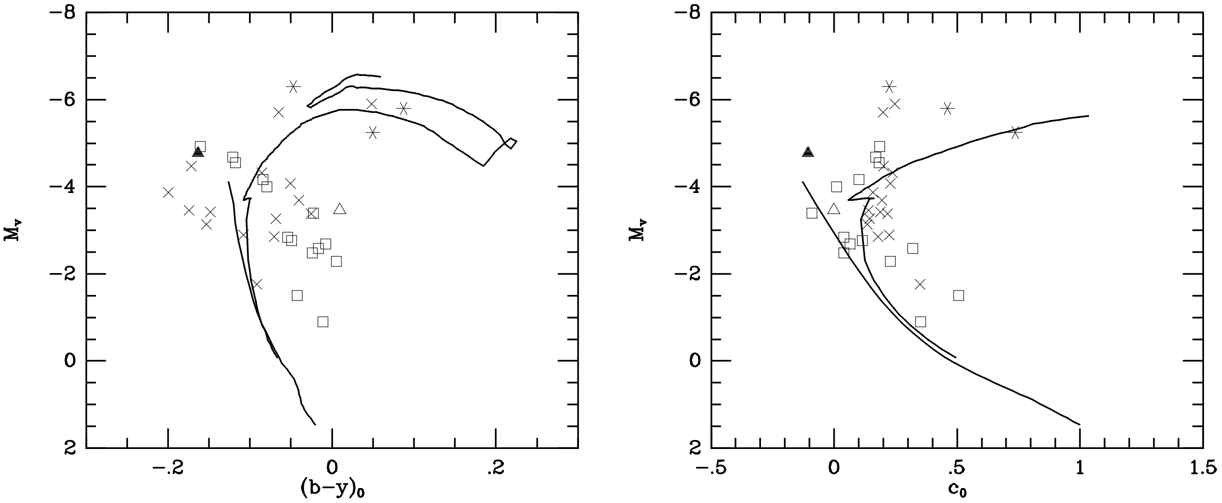

Fig. 2. Photometric diagrams for NGC 663. Symbols and lines as in Fig. 1. The filled triangle represents the blue straggler BD +60 329. The open triangle represents the Be/X-ray binary LS I +61 235 (RX J0146.9+6121)

Tapia et al. *uvby* data has been analyzed by Crawford (1994), who concluded that their photometry is well tied to the standard Crawford-Barnes system, with the exception of a systematic zero-point difference in the c_1 index. This difference, however, is so small than Crawford used the Tapia et al. data together with his own data without any correction, and we did the same in the analysis that follows.

To transform the observed values to absolute magnitudes and intrinsic colours we used the values of $E(B-V)$=0.80 and distance modulus of 12.25 given by Phelps & Janes (1994). The $E(B-V)$ value was transformed to $E(b-y)$=0.59 by means of the relation $E(B-V)$=1.35 $E(b-y)$ given by Crawford & Mandwewala (1976). The isochrone was computed with the models of Schaller et al. (1992), for an age of 21 Myr given by Leisawitz (1988), which fits our data much better than the age of 12−15 Myr found by Phelp & Janes (1994).

In the $(b-y)-M_V$ plane, the normal B stars show a large scatter in the $(b-y)$ values. This is due to the variable reddening across the cluster, reported by several authors (e.g. van den Berg & de Roux 1978; Tapia et al. 1991). Five among the six stars which lie to the left of the ZAMS line are placed in the southern part of the cluster, indicating that the reddening in this area is lower than the average. The sixth star (W 162, BD +60° 329), marked with a different symbol (filled triangle), deserves a more careful analysis. In the c_0-M_V plane it is also situated in an anomalous position, at the left of the isochrone and close to the ZAMS line. We have separately analyzed the photometry of this star given by Tapia et al. and have obtained a reddening value of $E(b-y)$=0.550, close to the assumed cluster mean value of $E(b-y)$=0.59. The intrinsic colours, when compared with the average parameters for MK types given by Crawford (1978), indicate a spectral type earlier than B0 and luminosity class V. As the spectral type of the cluster turnoff from the main sequence is B2 (Mermilliod 1981), we conclude that W 162 is a previously undetected blue straggler. Further spectroscopic work, to accurately determine the spectral type and radial velocity to firmly establish its membership of the cluster, would be of great interest in confirming this conclusion.

The behaviour of Be stars in the photometric diagrams is the same as that for *h* and χ Persei. In the $(b-y)_0-M_V$ plane they deviate to redder $(b-y)$ values. There is however one exception, W 243, which is situated to the left of the ZAMS line, close to W 162. This star lies in the southern part of the cluster, where the reddening is significantly lower, as stated above. In the c_0-M_V plane most of the Be stars deviate to the left but, as in the case of *h* and χ Persei, the faintest Be stars are situated to the right, above the isochrone. The dividing line between these two different behaviours is the same in both clusters, and is situated around an absolute magnitude $M_V\sim-2$. This absolute magnitude corresponds to a spectral type B2-B3 for luminosity class V, and B4-B5 for class III. It is well known (e.g. Mermilliod 1982b) that the distribution of Be stars as a function of spectral type has two marked maxima at types B1-B2 (early Be stars) and B7-B8 (late Be stars). Using this, we can interpret the position of Be stars in the c_0-M_V diagram in the sense that stars of the two groups behave in different ways, the early Be stars deviating to the left of the main sequence, and the late Be stars to the right.

The Be star W 194 (LS I +61° 235) has been marked with a different symbol (open triangle). It is the optical counterpart of the X-ray source RX J0146.9+6121 (Motch et al. 1991; Coe et al. 1993). Its position in the photometric diagrams together with the rest of the cluster Be stars indicates that it is a member of the cluster. It would be very interesting to further confirm its cluster membership by means of a radial velocity measurement, as yet lacking in the literature. This confirmation would be very useful in order to assign the cluster reddening and distance modulus to the individual star, and then determine accurate astrophysical parameters for this Be/X-ray system.

3.3. *Pleiades (Melotte 22)*

The Pleiades photometric diagrams are presented in Fig. 3. The additional data are from Crawford & Perry (1976). The observed values have been transformed to absolute magnitudes and intrinsic colours using $E(b-y)$=0.04 and a distance modulus of 5.54, as given by Crawford & Perry (1976). The isochrone has been computed for a log age=8.0 (Meynet et al. 1993).

The brightest Be star, Hz 1432, is included in the list of blue stragglers given by Mermilliod (1982a), although he consider this classification uncertain. The position of this star in Fig. 3, at the left of the cluster isochrone, seems to confirm that HZ 1432 is actually a blue straggler. The other three Be stars are situated in the same position as the non-emission stars in the cluster. The faintest Be star, Hz 2181 (Pleione) is a well studied star which usually shows a high level line emission, so it is surprising that its position does not appear as abnormal. This fact has already been noted by Crawford & Perry (1976).

3.4. *NGC 2422*

The photometric diagrams for this cluster are presented in Fig. 4. Additional photometry has been taken from Shobbrook (1984), and the values of $E(b-y)$=0.060 and distance modulus of 8.0 are from the same reference. The isochrone is for a log age=7.9 (Van Rensbergen et al. 1978). Notice that this cluster age is very close to the Pleiades age, and both clusters have been classified in the same age group by Mermilliod (1981).

The brightest Be star, vS 45, is a blue straggler (Mermilliod 1982a). One of the other two Be stars deviates to the right in the two $(b-y)_0 - M_V$ and $c_0 - M_V$ photometric planes, while the remaining Be star occupies a normal position among the absorption-line B stars in both diagrams.

3.5. *α Persei (Melotte 20)*

The photometric diagrams for the α Persei cluster are presented in Fig. 5. The additional data and the reddening value $E(b-y)$=0.07 used are from Crawford & Barnes (1974). The distance modulus of 6.35 is given by Balona & Shobbrook (1984). Only one of the three Be stars observed, HDK 955, is actually a member of the cluster. It is a late Be star, and in both photometric diagrams lies among the absorption-line B stars.

4. Discussion

It is well known that Be stars usually occupy anomalous positions in the color-magnitude diagrams, lying above the main sequence. This fact was first interpreted in evolutionary terms. Schmidt-Kaler (1964) suggested that Be stars occur during the overall contraction phase following the exhaustion of hydrogen in the core. But this conclusion was not supported by further observational work on Be stars in open clusters. Schild & Romanishin (1976) detected 41 Be stars in the 29 young open clusters they analyzed, finding a significant fraction of them close to the ZAMS. Mermilliod (1982b) and Slettebak (1985), on the basis of a larger amount of data, concluded that Be stars occupy the whole main sequence band, and can be found in very different evolutionary states. Consequently, they are not confined to any particular evolutionary phase.

Alternatively, Be star anomalous positions can be explained by additional reddening of circumstellar origin. Dachs et al. (1988) and Kaiser (1989) showed the presence of an excess emission in the Paschen continuum, well correlated with the Hα equivalent width, which can be ascribed to hydrogen free-bound and free-free recombination in the circumstellar envelope. The position of Be stars in the photometric diagrams discussed in the previous section can be interpreted in the same way. In the $(b-y)_0 - M_V$ plane we can find Be stars in the same position as the normal absorption-line B stars, but most of the Be stars deviate systematically towards redder $(b-y)$ colours. In a previous work (Fabregat et al. 1994a) we showed that most of the Be stars which share the same position as B stars are inactive Be stars, i.e., observed with the Balmer lines in absorption, indicating the occurrence of a disk-loss phase. This mean that Be stars devoid of the circumstellar envelope are indistinguishable from the cluster "normal" B stars. These inactive stars are found at different positions along the cluster's isochrone, and so they have different evolutionary statii. Conversely, active Be stars clearly deviate towards redder colours, due to the circumstellar continuum emission.

The interpretation of the $c_1 - M_V$ diagram is more difficult, since we can distinguish two different behaviours. First, we will recall that the c_1 index is defined in order to provide a measure of the Balmer discontinuity strength (Crawford & Barnes 1970). In the previous section we showed that the earlier Be stars tend to deviate to lower c_1 values, which implies weaker Balmer jumps. It has been shown by several authors (Schild et al. 1974; Schild 1978; Kaiser 1989) that Be stars present a second Balmer discontinuity in emission, due to additional emission from the circumstellar envelope at the Balmer series limit. This circumstellar emission fills-in the photospheric Balmer discontinuity and is the cause of the observed lower c_1 values.

The Be stars later than B5, however, behave in a different way. They either do not present any deviation, occupying the same position as normal B stars, or deviate

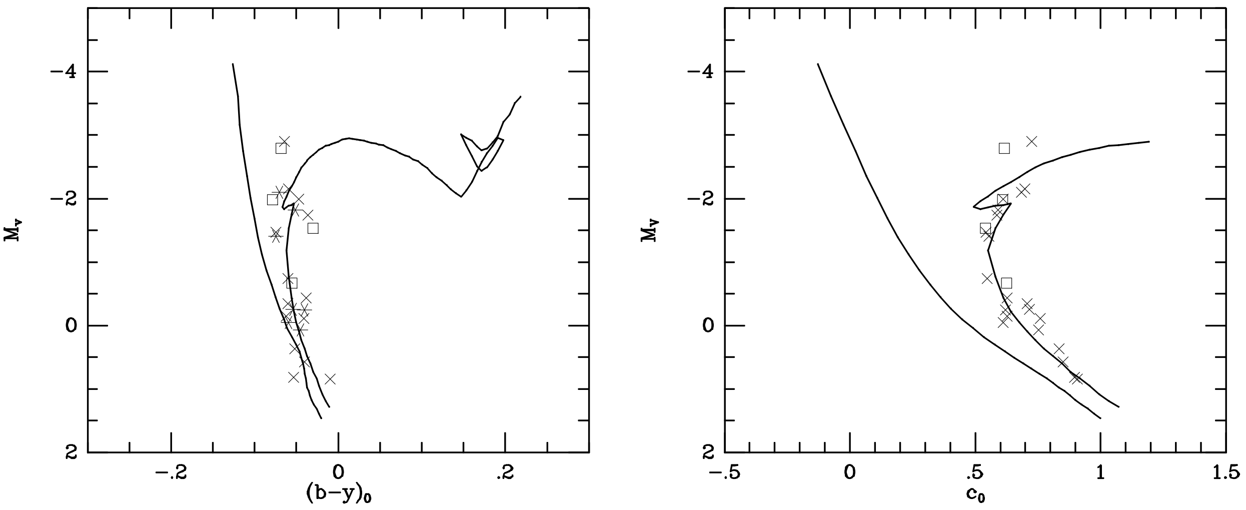

Fig. 3. Photometric diagrams for the Pleiades. Symbols and lines as in Fig. 1

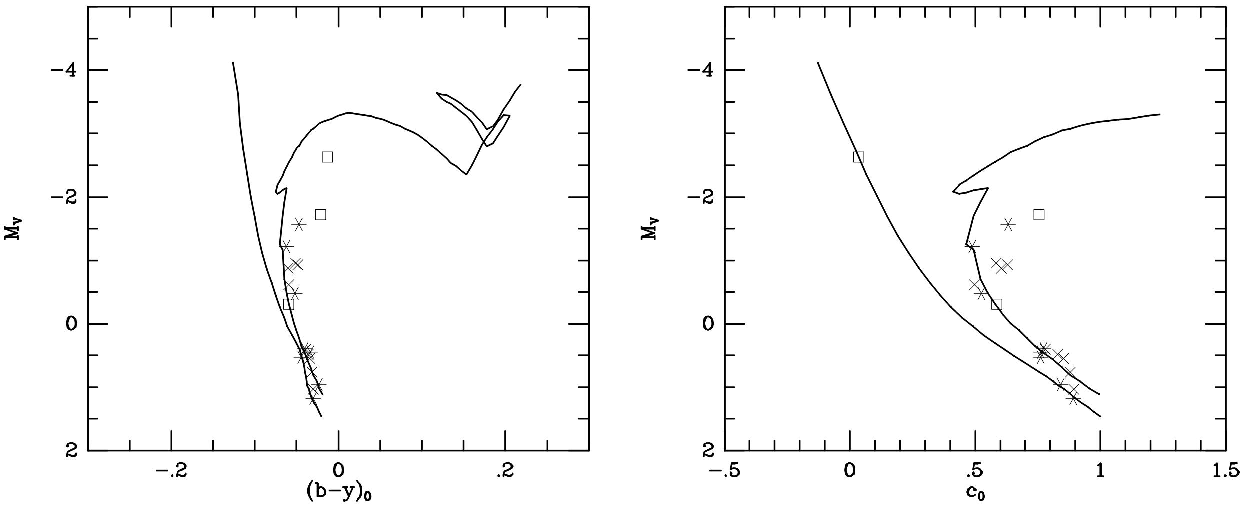

Fig. 4. Photometric diagrams for NGC 2422. Symbols and lines as in Fig. 1

to higher c_1 values, indicating deeper Balmer discontinuities than normal B stars of the same spectral type. If we consider this effect as also being produced by the circumstellar envelope, we have to conclude that the envelopes of late Be stars produce absorption in the Balmer continuum. To check this result we have analyzed the energy distribution for late type Be stars given by Schild (1978) and Kaiser (1989) (No late Be stars are included in the work of Schild et al. 1974). Among the Be stars in open clusters studied by Schild (1978), six are later than B5. Four of them present a deeper Balmer discontinuity than the comparison stars of the same spectral type, while the other two have the same strength. In Kaiser (1989) there are five late type Be stars. Among them, three have deeper Balmer jumps than the B stars used as standard, one have the same level and only one appears in emission.

It should be noted that the behaviour of the late Be stars in the $c_1 - M_V$ diagram could be explained in an alternative way. As the slope of the main sequence is flatter in this spectral region, the circumstellar contribution to the V magnitude can move the Be star position upwards, while an eventual Balmer discontinuity emission moves this position leftwards along the main sequence locus. The combination of both effects could moves the Be star position above the main sequence, as observed. However, we cannot find any alternative explanation to the deeper Balmer jumps observed by Schild (1978) and Kaiser (1989), and consequently we propose our first explanation as the most likely one. We conclude that the circumstellar material in Be stars later than B5 produces absorption in the Balmer continuum, and therefore there

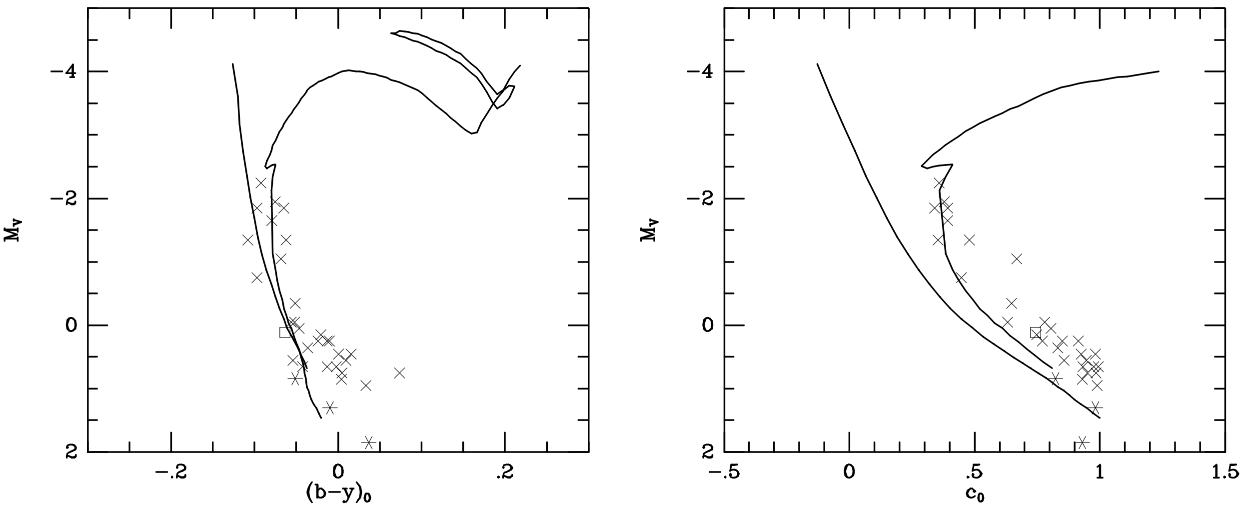

Fig. 5. Photometric diagrams for the α Persei cluster. Symbols and lines as in Fig. 1

are significant physical differences between the envelopes of early and late type Be stars.

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