

Active OB stars: structure, evolution, mass loss, and critical limits

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B stars in open clusters: fundamental parameters

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Abstract. We use the BCD spectrophotometric classification system to derive fundamental parameters of B stars in NGC 2439, NGC 3766 and NGC 6087. We are able to perform a complete study of each open cluster by deriving spectral classification of its members, distance modulus and age as well.

Keywords. stars: distances, stars: emission-line, Be, stars: fundamental parameters

1. Introduction

Color-magnitude and color-color diagrams of open clusters are important tools to derive distances and ages useful to study the structure of the Galaxy. In addition, photometric studies provide information on the interstellar extinction and stellar evolution. Nevertheless, some cluster's age and distance remain somewhat uncertain and so are the properties of the stars belonging to these systems. The uncertainties could be related to the overlapping of different stellar groups in the line of sight, and to the presence of a generally inhomogeneous interstellar medium, and circumstellar envelopes around early-type stars.

In this work, we aim at obtaining distances, ages and fundamental parameters of B stars in galactic clusters based on the BCD spectrophotometric classification system (Barbier & Chalonge, 1941; Chalonge & Divan, 1952).

2. Methodology, Observations and Results

The BCD system is based on measurable quantities in the stellar continuum spectrum around the Balmer's discontinuity (BD). In particular the height of the BD is a strong function of T_{eff} while the spectral average position of the BD measured by λ_1 is related to the star's surface gravity [for details see Zorec *et al.* (2009)]. One of the advantages of the BCD system is that D and λ_1 are free from interstellar extinction and absorption/emission from the circumstellar envelope (Zorec & Briot, 1991). Furthermore, D and λ_1 allow us to determine not only the fundamental parameters T_{eff} , $\log g$, the spectral type and the luminosity class of a star but also M_v and M_{bol} , making use of the calibrations given by Zorec (1986) and Zorec *et al.* (2009).

Low resolution spectra in the range 3500–4600 Å were taken during multiple observing runs in 2002 March and 2003 February, using the B&C spectrograph attached to the 2.15m telescope in CASLEO, Argentina. We observed 11 stars of NGC 2439, 32 of NGC 3766, and 15 of NGC 6087.

Individual distance moduli for the stars of each cluster were derived using apparent magnitudes and color excesses from photometric data available in the literature, together

Table 1. Be stars with second component in the BD. Stars nomenclature is taken from White (1975) for NGC 2439, Ahmed (1962) for NGC 3766, and Fernie (1961) and Breger (1966) for NGC 6087. m_v values were taken from SIMBAD database.

| ID | ID | D [dex] | λ_1 [Å] | ST & LC | T_{eff} [K] | log g [dex] | M_v [mag] | M_{bol} [mag] | m_v [mag] | $(m_v - M_v)_0$ [mag] |
|--------------|-------------|------------|--------------------|---------|-------------------------|------------------|----------------|--------------------|----------------|--------------------------|
| NGC 2439 070 | CD-31 4897b | 0.162 | 32.23 | B3 II | 17500 | 2.89 | -4.80 | -5.90 | 12.11 | 15.763±0.5 |
| ... | HD 62033 | 0.358 | 61.88 | B8 V | 12200 | 4.26 | 0.22 | -0.80 | 8.32 | 6.86±0.3 |
| NGC 3766 232 | HD 100943 | 0.123 | 21.02 | B5 Ib | 16000 | 2.25 | -8.00 | -8.63 | 7.15 | 14.55±0.5 |
| NGC 3766 240 | ALS 2401 | 0.224 | 30.95 | B4 III | 15500 | 2.75 | -4.00 | -4.75 | 9.61 | 13.01±0.5 |
| NGC 3766 264 | HD 306657 | 0.198 | 84.58 | B3 | 19000 | > 4.30 | -1.10 | -3.10 | 10.49 | 10.99±0.5 |
| ... | HD 308852 | 0.318 | 53.71 | B6 V | 13700 | 4.10 | -4.43 | -1.35 | 10.10 | 13.93±0.3 |
| NGC 6087 007 | HD 146483 | 0.300 | 30.67 | B6 III | 12500 | 2.83 | -2.80 | -3.50 | 8.29 | 10.46±0.5 |
| NGC 6087 007 | HD 146483 | 0.240 | 60.02 | B4 V | 16700 | 4.21 | -0.88 | -2.50 | 8.29 | 8.54±0.3 |
| NGC 6087 009 | HD 146484 | 0.285 | 79.42 | B8 VI | 14000 | > 4.30 | -0.65 | -1.70 | 9.48 | 9.50±0.3 |
| NGC 6087 009 | HD 146484 | 0.350 | 52.58 | B7 V | 12500 | 4.00 | -0.45 | -1.00 | 9.48 | 9.30±0.3 |
| NGC 6087 010 | HD 146324 | 0.290 | 41.00 | B6 III | 15000 | 3.35 | -1.75 | -2.50 | 7.92 | 9.04±0.5 |
| NGC 6087 011 | HD 146294 | 0.290 | 67.95 | B7 VI | 14100 | ~ 4.40 | -0.28 | -1.57 | 9.43 | 9.08±0.3 |
| NGC 6087 014 | CPD-57 7791 | 0.370 | 67.03 | B9 V | 11300 | ~ 4.39 | 0.52 | -0.50 | 9.70 | 8.55±0.3 |
| NGC 6087 156 | CD-57 6346 | 0.230 | 73.79 | B6 VI | 15000 | ~ 4.43 | -0.63 | -2.00 | 9.20 | 9.20±0.3 |

with the BCD absolute magnitudes. The distance modulus for each cluster is an average of the individual determinations. Our values are 12.48 ± 0.44 mag, 10.07 ± 0.31 mag and 9.32 ± 0.33 mag for NGC 2439, NGC 3766 and NGC 6087, respectively. Cluster ages were derived by fitting the isochrones computed by Bressan *et al.* (1993). We obtained $12.6 \text{ Myr} < t < 20 \text{ Myr}$ for NGC 2439, $16 \text{ Myr} < t < 24 \text{ Myr}$ for NGC 3766 and $40 \text{ Myr} < t < 79 \text{ Myr}$ for NGC 6087. The results show excellent agreement with previous photometric determinations. Moreover, the BCD system has allowed us to detect 12 stars with the Be phenomenon, since they display a second BD which is an indicative of the presence of an extended envelope (see Table 1). Seven of these objects have been reported as Be stars for the first time. Likewise, the observation of the BD in two different epochs revealed that the stars 007 and 009 of NGC 6087 are variable.

3. Conclusions

The BCD method has allowed us to perform a complete study of the members of open clusters. We derive not only the spectral classification but the cluster’s distance modulus and age as well. It is worth mentioning that the BCD spectrophotometric system is a powerful tool to study far galactic and extragalactic clusters with the large telescope generation since BCD parameters are free of interstellar and circumstellar extinction. Furthermore, the method is appropriate for the study and detection of Be stars.

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