BH 176 and AM-2: globular or open clusters?

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Abstract. We have obtained $VI$ photometry for two low Galactic latitude star clusters: BH 176 and AM-2, using the 2.2 m and the 3.5 m NTT telescopes at ESO. Their $VI$ colour-magnitude diagrams reveal that: BH 176 may be a globular cluster, or a borderline object between a globular cluster and a disk cluster, showing a red horizontal branch and an extended red giant branch. We estimate $E(B-V) = 0.77$ and $d_0 = 13.4$ kpc. AM-2 appears to be an intermediate age open cluster, for which a reddening $E(B-V) = 0.44$ and $d_0 = 12.4$ kpc are estimated. It is located in the outer regions of the Galactic disk.

Key words: HR diagram – globular clusters. BH 176 – open clusters: AM-2

1. Introduction

Globular clusters belong to the oldest stellar population in our Galaxy. On the other hand, open clusters are considerably younger and only a few have been identified to be in the age interval of 6 to 10 Gyr, e.g., NGC 188, NGC 6791 (Demarque et al. 1992 and references therein).

The problem of the classification of open (globular) clusters in our Galaxy is based mainly on the colour magnitude diagram (CMD) properties, even if structurally the indications are contradictory (e.g., most of the Palomar clusters).

Interesting borderline objects have been recently studied in detail through CMDs, as Pal 12, Rup 106 and Lynga 7 (Gratton & Ortolani 1988a; Buonanno et al. 1990; Ortolani et al. 1993). The aim of this paper is to study two additional borderline star clusters at low Galactic latitude, which are BH 176 and AM-2.

BH 176 was discovered in a survey of star clusters in the Southern Milky Way by van den Bergh & Hagen (1975). BH 176, also designated as ESO 224-SC8 and IAU 1535-499 is located at $\alpha_{1950} = 15^h 35^m 29^s$, $\delta_{1950} = -49^\circ 53' 18'', and $l = 328.42^\circ$, $b = +4.34^\circ$. It is a loose cluster with very little information in the literature. Webbink (1985), in his compilation of globular clusters, gives some preliminary estimates of the cluster properties.

AM-2 was discovered by Madore & Arp (1979) on the UKSRC blue sky survey. AM-2 is also designated as ESO 368-SC7 and IAU 0737-337 and its coordinates are $\alpha_{1950} = 07^h 37^m 18^s$, $\delta_{1950} = -33^\circ 44' 00'', and l = 248.17^\circ$, $b = -5.80^\circ$. A $BV$ CMD study by Gratton & Ortolani (1988b) indicated that AM-2 could be a very old open cluster. Structurally, it was classified as a new loose globular cluster with a concentration parameter $c = 0.50$ (Träger et al. 1993).

In Sect. 2 we present the observations and reduction procedures. In Sect. 3 we discuss the CMDs of BH 176 and in Sect. 4 those of AM-2. The concluding remarks of this work are provided in Sect. 5.

2. Observations

The observations of BH 176 and AM-2 were obtained in two different runs at the European Southern Observatory (ESO), La Silla, using Johnson–Cousins $V, I$ filters.

2.1. Observations and reductions of BH 176

BH 176 was observed in 1993 with the 3.5 m NTT telescope equipped with the ESO Multimode Imager (EMMI) used as direct imager/focal reducer through the red path. The CCD detector employed was a thick, UV coated LORAL ESO No. 34 with pixel size of $15\mu m$ (0.35") on the sky. The total size of the field corresponding to $2048\times2048$ pixels is of about $11.5'' \times 11.5''$. An I image of BH 176 is shown in Fig. 1.

The reduction procedures follow those described in Ortolani, Bica & Barbuy (1992, OBB92), using Midas and Daophot II at the ESO Garching computing center.

The $VI$ calibrations were obtained using Landolt (1992) star fields. The derived calibration equations are:

$V = v + 0.02(V - I) + 23.86 \pm 0.015$

$I = i - 0.015(V - I) + 23.58 \pm 0.015$
where \( v \) and \( i \) are the instrumental magnitudes for 15 s exposures, at airmass of 1.2. Crowding conditions in such low latitude fields are important and the main source of error in the absolute calibration comes from the transfer of aperture magnitudes to the convoluted ones. In order to minimize the effect we calibrated the deep exposures, containing several saturated stars, by means of short exposures. We estimate the total zero point uncertainties to \( \pm 0.04 \), taking also into account the shutter delay problems. The details of the observations are summarized in the log-book presented in Table 1. \( VI \) data for BH 176 are given in Table 2, available at CDS.

2.2. Observations and reductions of AM-2

AM-2 was observed in 1993 with the 2.2 m telescope equipped with a Thompson UV coated 1000 \( \times \) 1000 pixel ESO CCD No. 19 with pixel size 19\( \mu \)m \( \times \) 19\( \mu \)m (0.33\( \arcsec \) on the sky). The EFOSC camera in the focal reducer mode was employed giving a final field of 5.5\( \arcmin \) \( \times \) 5.5\( \arcmin \). A \( V \) image of AM-2 is provided in Fig. 2.

The reduction of the AM-2 frames were carried out as in Sect. 2.1. Details on the calibration procedures are given in Carraro & Ortolani (1994). The observations obtained are reported in Table 1. Table 3, reporting \( VI \) data for AM-2, is available at CDS.
Fig. 2. V image of AM-2. The field dimensions are 5.5' × 5.5'.

3. The star cluster BH 176

A preliminary BV CMD of BH 176 by Gratton & Ortolani (unpublished) revealed that BH 176 is not a young cluster, with the presence of a very red horizontal branch (HB). We present in Figs. 3a,b the V vs. (V − I) and I vs. (V − I) CMDs from a circular extraction of r < 53''.

In Fig. 4 a coordinate map was produced for stars with I < 17, where different symbols are used for those of (V − I) > 2.3 belonging to the cluster, in a concentrated area, and (V − I) < 2.3 belonging to the field, these latter ones uniformly distributed in the frame. Prominent features in Figs. 3a,b are:

(i) on the blue side the presence of disk field main sequence (MS) which considerably contaminates the CMD of the cluster. 

(ii) the bright red sequence of the cluster including an extended red giant branch (RGB), a red HB, and a subgiant branch (SGB) which merges with the field MS. The RGB curvature (Ortolani et al. 1991) indicates a high metallicity similar to that of NGC 6528 (OBB92), i.e., basically solar. The RGB extension spans ∆(V − I) = 3.0 at least, which is absent in the surrounding field (Fig. 5). A very extended RGB has been detected in other clusters such as NGC 6528 (OBB92) and NGC 6791 (Garnavich et al. 1994).

The HB is located at V ≈ 19.0±0.15 and (V − I) = 2.15 ± 0.10. We derive the reddening from the colour of the RGB at
the level of the HB, at \((V - I) \approx 2.25 \pm 0.10\), together with the same locus for an old cluster RGB at solar metallicity from the new Padova group isochrones (Bertelli et al. 1994), where \((V - I)_0 = 1.23\), and we derive for BH 176 \(E(V - I) = 1.02\). This converts to \(E(B - V) = 0.77 \pm 0.10\), using Dean et al. (1978)'s ratio \(E(V - I)/E(B - V) = 1.33\).

For the distance derivation we assume Buonanno et al. (1989) value of \(M^\text{HP} = 1.06\) for solar metallicity (which basically coincides with the value from the isochrones). We obtain a true distance modulus of \((m - M)_0 = 15.63\) and a distance from the sun of \(d_\odot = 13.4\) kpc. Adopting a distance for the Galactic center of 8 kpc (Reid 1993), the Galactocentric coordinates are \(X = -3.4\) kpc, \(Y = -7\) kpc, \(Z = 1\) kpc (\(X < 0\) means the other side of the Galaxy).

Since we cannot distinguish the cluster turn-off of BH 176, the precise determination of the cluster age remains open. The global morphology of the observed CMD is however compatible with one of a metal-rich globular cluster such as NGC 6528 and NGC 6553, but it still could be a borderline case or even a very old disk open cluster, similar to NGC 6791 (Garnavich et al. 1994). Nevertheless, structurally, it looks rather like a globular cluster.

We show in Fig. 5 the \(V\) vs. \((V - I)\) field CMD surrounding the cluster BH 176 corresponding to the stars in the frame for \(r > 2.9'\). The MS is considerably wide (\(\Delta(V - I) \approx 1.3\) mag) and presents internal structure, which can be interpreted as the line of sight crossing different spiral arms, differentially reddened. We note that the cluster is located slightly above the Galactic plane, at Galactocentric radius similar to that of the Sun, at a direction \(\approx 30^\circ\) with respect to the center of the Galaxy.

4. The star cluster AM-2

The brighter part of the CMD of AM-2 was studied in \(B, V\) by Gratton & Ortolani (1988b). The aim of the present work is to analyse in more detail the HB and turn-off regions of the cluster based on deep \(V, I\) CMDs. We show in Fig. 6 a \(V\) vs. \((V - I)\) CMD of AM-2 for an extraction \(r < 100''\). In Fig. 7 we provide the whole frame \(V\) vs. \((V - I)\) diagram, where the field contamination becomes more important. The \(V, I\) features are considerably deep so that the upper parts (\(V \lesssim 17.0\)) of the diagrams in Figs. 6, 7 are affected by saturation. In Fig. 5 the cluster morphology in terms of MS, turnoff, subgiant branch and HB are well defined.

In Fig. 8 a pixel coordinate map for stars of \(V < 19\) is shown, where different symbols are adopted for those of \((V - I) < 1.5\) and \((V - I) > 1.5\): the bluer stars have a uniform distribution, while redder stars, more probably belonging to the cluster, are more concentrated around the cluster area.

The cluster HB is located at \(V = 17.75 \pm 0.10\) and \((V - I) \approx 1.69 \pm 0.05\). The turn-off is located at \(V \approx 20.0 \pm 0.15\).
The magnitude difference between the HB and turn-off is
\[ \Delta V(\text{TO} - \text{HB}) = 2.25 \pm 0.18. \] This age indicator reveals that AM-2 is an intermediate age open cluster similar to M67. Indeed M67 presents \( \Delta V(\text{TO} - \text{HB}) = 2.20, \) whereas for the oldest disk clusters NGC 188 and NGC 6791 these values are considerably larger (e.g., Barbuy et al. 1993). As the RGB of M67 is redder than that of AM-2 (Gratton & Ortolani 1988b), we conclude that AM-2 is less metallic, of the order of \([\text{Fe/H}] \approx -0.3.\) The HB locus of AM-2 together with that in the new isochrones of the Padova group for intermediate age clusters of nearly solar metallicity \((V - I)_0 = 1.10\) leads to a reddening of \(E(V - I) = 0.59,\) which converts to \(E(B - V) = 0.44,\) compatible with the estimates in Gratton & Ortolani (1988b). Adopting for the absolute HB level \(M_V = 0.97\) for a cluster of \([\text{Fe/H}] = -0.3\) (Buonanno et al. 1989), we derive a true distance modulus of \((m - M)_0 = 15.46\) and a distance from the Sun \(d_0 = 12.4 \text{kpc}.\) The Galactocentric coordinates are \(X = +3.42,\) \(Y = -11.45,\) \(Z = -1.25 \text{kpc}.\) The cluster is located in the outer regions of the Galactic disk.

5. Conclusions
The CMD characteristics of BH 176 and AM-2 reveal that AM-2 is an intermediate age open cluster, whereas for BH 176 we could not decide, but it should be a true globular cluster or a very old open cluster such as NGC 6791.
Fig. 8. AM-2: position map of stars of $V < 19$, where open circles: $(V - I) > 1.5$ (cluster), and dots: $(V - I) < 1.5$ (field)

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