Mem. S.A.It. Vol. 79, 657

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TNG photometry of the old open clusters Berkeley 20 and Berkeley 66

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Abstract. As part of the Bologna Open Cluster Chemical Evolution (BOCCE) project (described in detail by Bragaglia & Tosi 2006), we used DOLORES at the TNG to obtain BVI CCD photometry of the two distant and old open clusters (OCs) Be 20 and Be 66 (age of ∼ 5 Gyr and ∼ 3 Gyr respectively). For each of them we observed one field including the center of the cluster and an external one for back/foreground decontamination. Be 20 is one of the most distant OCs ($R_{GC} \geq 15$ kpc), making it very interesting for the study of the metallicity distribution in the disk. Be 66, although closer, is one of the relatively rare old clusters and merits further study. We give new estimates for reddening, metallicity, distance modulus and age of these clusters by using the synthetic colour-magnitude diagram method, originally described in Tosi et al. (1991).

Key words. Hertzsprung-Russell (HR) diagram – open clusters and associations: general – open clusters and associations: individual: Be 20 and Be 66

1. Introduction

With the BOCCE project we are deriving precise and homogeneous ages, distances, reddenings and chemical aboundances for a large sample of open clusters (OCs). The final goal is to study the present status of the Galactic disc, its formation and evolution, giving particular attention to the study of old clusters. We present here a photometric study of Berkeley 20 ($\alpha_{2000} = 05^h32^m37^s$, $\delta_{2000} = +00°11'18''$, $l = 203.°48$, $b = -17.°37$) and Berkeley 66 ($\alpha_{2000} = 03^h04^m18^s$, $\delta_{2000} = +58°46'00''$, $l = 139.°43$, $b = 0.°22$).

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Be 20 received more attention in the past and there are two previous photometric studies. The first calibrated photometry was presented by MacMinn et al. (1994), who obtained V, I data on a 5.1×5.1 arcmin^2 field using the KPNO 2.1m telescope. They derived, using isochrones, an age of 6 Gyr, [Fe/H]≃ −0.23, $(m - M)_V \simeq 15.0$ and $E(V - I) \simeq 0.16$. They considered Be 20 interesting because of its large Galactocentric distance ($R_{GC} \simeq 15.8$ kpc) and unusual position below the Galactic plane (about 2.5 kpc). Durgapal et al. (2001) presented B, V, R, I data obtained at the 104-cm Naini Tal State Observatory over a 6×6 arcmin^2 field. Using two different sets of isochrones they concluded for an age of about

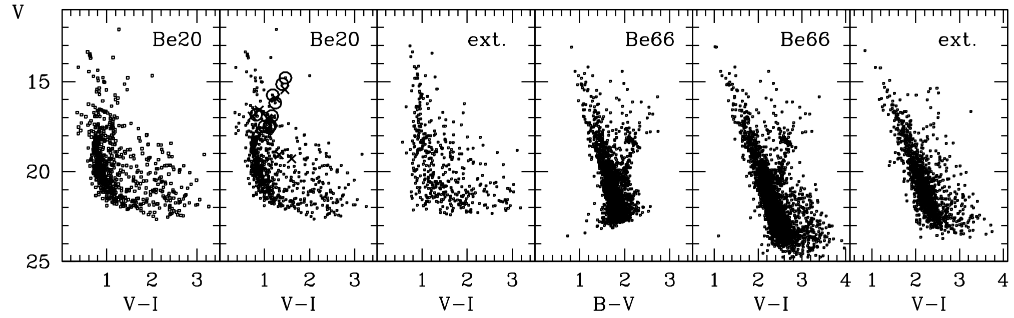

Fig. 1. Observational $V, V - I$ CMDs for Be 20 and its external field (left panels). In the second panel we indicate with different symbols member (open circles) and non member (crosses) stars, according to their radial velocities. Observational $(V, B-V)$ and $(V, V-I)$ CMDs for Be 66 and its external field (right panels).

5 Gyr, $E(B-V) = 0.10$, Z=0.008 (i.e. [Fe/H]$\simeq -0.3$), $(m-M)_V \simeq 15.1$, a cluster radius of about 2.5 arcmin and a $R_{GC} \simeq 17.1$ kpc.

For Be 66, the only available photometry reaching the main sequence Turn-Off is by Phelps & Janes (1996). They observed a 5.1×5.1 arcmin^2 field using the KPNO 2.1m telescope with the V, I filters, obtaining a well defined CMD. They derived the following parameters: age 3.5±1.0 Gyr, $-0.23 \leq$ [Fe/H ≤ 0, $E(V-I) = 1.60 \pm 0.05$, $(m-M)_V = 17.40 \pm 0.20$ (implying a Galactocentric distance $R_{GC} \simeq 12.9$ kpc), radius of 1.2-3.5 arcmin and minimum mass of $\sim$750 $M_\odot$; they also suggested the possibility of differential reddening.

2. Observations and data reduction

Observations of the two clusters and the two comparison fields were performed during three nights in October and November 2000 using DOLORES (field of view of 9.4×9.4 arcmin^2) at the 3.5m Telescopio Nazionale Galileo, with exposure time ranging from 10s to 900s respectively in the three filters. We refer to Bragaglia et al. (2006) and Andreuzzi et al. (2004) for details on observation and reduction procedures. The final catalogues for the two clusters will be made available at the BDA [1].

To check our calibration we directly compared our resulting photometric data with published the ones, finding that differences were always small (of the order of about 0.02 mag).

3. Be 20

The three left panels of Figure 1 show the CMD obtained for the field centered on Be 20 and for the comparison field, while Figure 2 shows the comparison between the observational CMD in the innermost 2 arcmin radius (top panel) and the synthetic ones. The observational CMD is best reproduced by stellar models with a metallicity about half of solar (Z=0.008 or 0.01), in perfect agreement with high resolution spectroscopic estimates (Yong et al. 2005; Sestito et al. 2007). Its age is between 5 and 6 Gyr from stellar models with overshooting and between 4.3 and 4.5 Gyr from models without it. The distance modulus from the best fitting models is always $(m-M)_0 = 14.7$, while the reddening $E(B-V)$ ranges between 0.13 and 0.16.

The best values of the parameters are found by selecting the cases providing a synthetic CMD with morphology, colour, number of stars in the various evolutionary phases and Luminosity Functions in better agreement with the observational ones. We have attributed to the synthetic stars the photometric errors derived from the artificial stars tests performed on the actual images. They are retained in (or excluded from) the synthetic CMD according to the photometry completeness fac-

[1] *http://www.univie.ac.at/webda//webda.html*

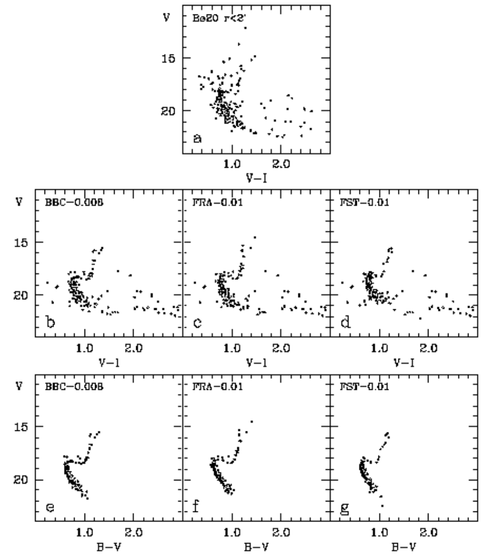

Fig. 2. Comparison between observational and synthetic CMDs for Be 20. Panels b, c and d: synthetic V-I CMDs of best fitting cases of each type of stellar model. Panels e, f and g indicate the corresponding B-V CMDs. The displayed cases assume: Z=0.008, age = 5.8 Gyr, E(B-V) = 0.13 (BBC); Z = 0.01, Age = 4.3 Gyr, E(B-V) = 0.16 (FRA); Z = 0.01, age = 5.0 Gyr, E(B-V) = 0.14 (FST).

tors, for which the limit of 90% is reached at $V = 19$ for both Be 20 and the external field. To compute the synthetic CMDs we assumed that 30% of the cluster stars are members of binary systems (following Bragaglia & Tosi 2006). To test the effects of the adopted stellar evolution models on the derived parameters, we have run the simulations with three types of stellar tracks (BBC: (Fagotto et al. 1994); FRA: (Dominguez et al. 1999); FST: (Fagotto et al. 1994)) with different assumptions for the treatment of convection, opacities and equation of state. The transformations from theoretical luminosity and effective temperature to the Johnson-Cousins magnitudes and colours have been performed using Bessell et al. (1998) conversion tables and assuming $E(V-I) = 1.25\ E(B-V)$ for all sets of models. To minimize contamination of the field without loosing too many cluster stars, we have considered as reference CMD the diagram of stars located within 2 arcmin from the cluster center and including 269 stars.

4. Be 66

Our photometry for Be 66 represents the first deep BVI photometry for this cluster (V $\simeq$ 24 in *VI* and $\simeq$ 23 in *BV*). The three right panels of Figure 1 show the *BVI* CMDs for the cluster and the comparison field. These results represent only the first step of a work aimed to obtain new and precise estimates of the cluster parameters.

Acknowledgements. We gratefully acknowledge the use of software written by P. Montegriffo, and of the BDA database, created by J.C. Mermilliod and now taken care of by E. Paunzen. This project has received partial financial support from the Italian MIUR under PRIN 2003029437.

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