Astronomical paramaters of 14 open clusters projected close to the Galactic plane

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Abstract

Aims. We analyse the colour-magnitude diagrams (CMDs) and stellar radial density profiles (RDPs) built after field-star decontamination and colour-magnitude limited photometry. Field-star decontamination is applied to uncover the cluster’s intrinsic CMD morphology, and colour-magnitude limiters are used to isolate stars with a high probability of being cluster members in view of structural analyses.

Methods. We analyse the colour-magnitude diagrams (CMDs) and stellar radial density profiles (RDPs) built after field-star decontamination and colour-magnitude limited photometry. Field-star decontamination is applied to uncover the cluster’s intrinsic CMD morphology, and colour-magnitude limiters are used to isolate stars with a high probability of being cluster members in view of structural analyses.

Results. The open clusters of the sample are located at \( d = 1.6 \pm 0.4 \) kpc from the Sun and at galactocentric distances \( 5 \pm 0.8 \) kpc, with age in the range 10 Myr to 15 Gyr and reddening \( E(B-V) \) in the range 0.19 to 2.56 mag. The core and cluster radii are in the range 0.27 to 1.88 pc and 11.27 pc, respectively. Cz6 and FSR 198 are the youngest OCs of this sample, with a population of pre-main sequence (PM S) stars, while FSR 178 is the oldest cluster.

Keywords. (Galaxy:) open clusters and associations: general; Galaxy: open clusters and associations: individual; Galaxy: stellar content; Galaxy: structure

1. Introduction

Open clusters (O Cs) are self-gravitating stellar systems formed along the gas- and dust-rich Galactic plane. They range from tens to a few thousand stars distributed in an approximately spherical structure of up to a few parsecs in radius. The structure of most O Cs can be roughly described by two subsystems, the dense core, and the sparse halo (Bonatto & Bica, 2003, and references therein).

Because it is relatively simple to estimate the age and distance of O Cs, they have become fundamental probes of Galactic disc properties (Lynga, 1982; Jansen & Phelps, 1992; Frei, 1995; Bonatto et al., 2006a; Piskunov et al., 2006; Bica, Bonatto & Blum, 2006). However, the proximity of most O Cs to the plane and the corresponding high values of reddening and field-star contamination usually restrict this analysis to the more populous and/or to those located at most a few kpc from the Sun (Bonatto et al., 2006a).

Detailed analysis of O Cs and the derivation of their astrophysical parameters will contribute to future disc studies by unveiling the properties of individual O Cs. These parameters, in turn, can help constrain theories of molecular cloud fragmentation, star formation, and dynamical stellar evolution.

The stellar content of a cluster evolves with time, and internal and external interactions affect the properties of individual clusters. Presently the age distribution of star clusters in the disc of the Galaxy can only be explained if these objects are subjected to disruption timescales of a few times \( 10^6 \) yr (Oort, 1953; Lynga, 1971, 1988; Lamers, Bastian & Gieles, 2004). Open clusters experience external perturbations by giant molecular clouds (GMCs) and by spiral arms and other disc-density perturbations. To understand how O Cs evolve, it is important to take the effect of these external perturbations into account (Gieles, Athanasoulis & Portegies-Zwart, 2001).

Cluster disruption is a gradual process with different mechanisms acting simultaneously. Disruption of O Cs is due to internal processes characterised by three distinct phases. These phases and their typical timescales are: (i) infall (10 yr), (ii) stellar evolution (10^5 yr), and (iii) tidal relaxation (10^7 yr). During all three phases, there are additional external tidal perturbations from e.g. GMCs and disc-shocking that heat the cluster and speed up the process of disruption. However, these perturbations operate on longer timescales for cluster populations and so are more important in tidal relaxation (Lamers, Bastian & Gieles, 2004). The combination of these effects results in a time-decreasing cluster mass, until either its
Fig. 1. Left panel: $10^6 \times$ XDSR image of Cz12. Right panel: $10^6 \times$ XDSR image of Be84. Images centred on the optimised coordinates.

Table 1. Literature and presently optimised coordinates.

| Cluster | Literature (2000) | This paper (2000) |
|---------|------------------|------------------|
|         | (h m s)          | (h m s)          |
| Be63    | 02 19 36         | 02 19 30.8       |
| Be84    | 20 04 43         | 20 04 43         |
| Cz6     | 02 02 00         | 02 01 57         |
| Cz7     | 02 02 24         | 02 03 01         |
| Cz12    | 02 39 12         | 02 39 25         |
| Ru141   | 18 31 19         | 18 31 23         |
| Ru144   | 18 33 34         | 18 33 33         |
| Ru172   | 20 11 34         | 20 11 39         |
| FSR 101 | 18 49 14         | 18 49 14         |
| FSR 1430| 08 51 52         | 08 51 52         |
| FSR 1471| 09 24 08         | 09 24 04         |
| FSR 162 | 20 01 32         | 20 01 26         |
| FSR 178 | 20 13 07         | 20 13 33         |
| FSR 198 | 20 02 24         | 20 02 27         |

.. complete disruption or a remnant (Pavani & Bica, 2007, and references therein) is left.

Probably reacting the Galactocentric-dependence of most of the disruptive effects, the Galaxy presents a spatial asymmetry in the age distribution of OCs. Indeed, van den Bergh & McClure (1980) noted that OCs older than ~1 Gyr tend to be concentrated in the anticentre, a region with a low density of GMCs. In this sense, the combined effect of tidal ejection and encounters with GMCs has been invoked to explain the lack of old OCs in the solar neighbourhood (Gies et al., 2008, and references therein). Near the solar circle most OCs appear to dissolve on a timescale shorter than ~1 Gyr (Bergond, Leon & Guibert, 2001; Bonatto et al., 2006a). In more central parts, interactions with the disc, the enhanced tidal pull of the Galactic bulge, and the high frequency of collisions with GMCs tend to destroy the poorly populated OCSs on a timescale of a few $10^8$ yr (e.g. Bergond, Leon & Guibert, 2001).

Macieszkiew & Niedzielski (2007) studied a large sample of open clusters, in general not previously studied, to derive fundamental parameters, similar to the present analysis.

This paper is organised as follows. In Sect. 2 we provide general data on the target clusters. In Sect. 3 we obtain the 2MASS photometry, introduce the tools, CMDs and stellar decontamination algorithm, and derive fundamental parameters of the OCS candidates. In Sect. 4 we discuss the stellar radial density profiles (RDPs), colour-magnitude diagrams, and derive structural parameters. In Sect. 5 we discuss properties of the OCSs, and concluding remarks are given in Sect. 6.
Fig. 2. Left panel: 2MASS Ks in age 5° 5° of FSR 198. Right panel: 2MASS Ks in age 15° 15° of FSR 1430. In ages centred on the optimised coordinates. The small circle indicates the cluster central region.

Fig. 3. Top panels: stellar surface-density \((\text{stars arcmin}^{-2})\) of Cz12, computed for a mesh size of 3° 3°, centred on the coordinates in Table 1. Bottom: the corresponding isopleth surfaces. Left: observed (raw) photometry. Right: Decontaminated photometry.

Fig. 4. Same as Fig. 3 for FSR 198.

2. The target open clusters and candidates

The OCs selected for the present analysis are shown in Table 1. These objects are listed in the OC catalogues W EBDA [Mennessier, J.C., 1996] and Froebrich, Scholz & Raftery (2007). According to the

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OC catalogues W EBDA  M em il lard, J.C. [1998] and DAM L02  Dias et al. [2003], the target objects do not have published astrophysical parameters, except for Be63, Be84, Ru141, Ru144, and Ru172. The optical image was chosen as a challenge to our analysis tools (Sect. 3 and references therein). They are low Galactic-latitude clusters that are often heavily contaminated, and poorly populated, and that have differential reddening and a few previous parametric determinations at any at all. The infrared candidates [Freibriehl, Scholz & Raftery 2003] were selected from eye inspections that we made on the 2MASS Atlas for promising candidates. In addition, we analysed some of FSR’s quality checking objects. We selected objects that we collected in the present study were concluded to be star clusters (Sects. 3 and 4).

Kharchenko et al. (2005) employed the ASCC-2.5 catalogue to derive parameters for 520 OCs, using proper motions and photon-etic criteria to separate probable members from field stars. However, owing to distance and reddening limitations, the fainter cluster members rely on a few stars. For Ru141 they derived E(B − V) = 0.57, d = 5.5 kpc, and age t = 8 Myr. For Ru172 they derived E(B − V) = 0.20, d = 1.1 kpc, and age t = 0.8 Gyr.

Tadros (2008) presents astrophysical parameters of 24 open clusters of the Berkeley list, using 2MASS photometry and the proper motions of the Naval Observatory Merger Astrometric Dataset (NOMAD). For Be63 he derived E(B − V) = 0.90, d = 3.3 kpc, RGC = 11.0 kpc, and age t = 500 Myr. For Be84 he derived E(B − V) = 0.76, d = 2.0 kpc, RGC = 8.1 kpc, and age t = 120 Myr.

Table 2. Previous determinations.

| Cluster | Age (Myr) | E(B − V) | d (kpc) | Source |
|---------|-----------|----------|---------|--------|
| Be63    | 500       | 0.90     | 3.3     | 1      |
| Be84    | 120       | 0.76     | 2.0     | 1      |
| Ru141   | 8         | 0.57     | 5.5     | 2      |
| Ru144   | 151       | 0.62     |         | 2      |
| Ru172   | 800       | 0.20     | 1.1     | 2      |

Table Notes: References: (1) − Tadros 2008; (2) − Kharchenko et al. 2005.

In Fig. 5, 2MASS CMDs extracted from the R = 3′ region of Ru172 and Cz12, respectively. Top panels: observed CMDs. Middle panels: equal area comparison. Bottom panels: red-star decontaminated CMDs. The 900 Myr Padova isochrone (solid line) for Ru172 and 1250 Gyr for Cz12. The colour−magnitude data were used to isolate cluster M S/evolved stars shown as a shaded region.

3. The 2MASS photometry

The 2MASS catalogue (Skrutskie et al. 2006) was employed in the present work because of the homogeneity and the possibility of large-area data extractions. Also, part of the sample cannot be studied in the optical. Vizier was used to extract J, H, and Ks 2MASS photometry. Our previous experience shows that, as long as no other cluster is present in the field and differential absorption is not prohibitive, such large extraction areas provide the required statistics for red-star characterisation. To maximise statistical significance and representativeness of background star counts, we use a wide external region to represent the stellar component. The RDPs produced with the W EBDA coordinates presented in general a dip in the innermost bin. For these we searched for new coordinates that maximise the star-counts at the centre. For each cluster we made circular extractions centred on the optimised coordinates of the clusters. The W EBDA and optimised central coordinates are given in Table 1.

The statistical significance of astrophysical parameters depends directly on the quality and depth.

1 Extracted from the Canadian Astronomy Data Centre (CADC), at http://cadc.com/cadc/

2 The Two Micron All Sky Survey, available at www.ipac.caltech.edu/2mass/releases/allsky/

3 http://vizier.u-strasbg.fr/viz-bin/VizieR?source=II/246.
Fig. 6. Same as Fig. 5 for the decontaminated J (J−H) CMDs of the central regions of each object.

Table 3. Derived fundamental parameters.

| Cluster | Age (Gyr) | N1 | E(B−V) | d (kpc) | Rcc (kpc) |
|---------|-----------|----|--------|---------|-----------|
| Be83    | 0.03      | 0.01 | 3.7 | 0.06 | 0.03 | 5.7 | 11.8 |
| Be84    | 0.06      | 0.05 | 5.4 | 0.08 | 0.06 | 1.7 | 6.8 |
| Cz6     | 0.01      | 0.005 | 8.3 | 0.26 | 0.03 | 2.7 | 6.9 |
| Cz7     | 0.22      | 0.05 | 3.6 | 0.70 | 0.03 | 3.3 | 9.7 |
| Cz12    | 1.25      | 0.04 | 4.6 | 0.26 | 0.03 | 2.0 | 8.8 |
| Ru141   | 0.03      | 0.02 | 12.8 | 0.45 | 0.1 | 1.8 | 5.5 |
| Ru144   | 0.45      | 0.1 | 7.7 | 0.27 | 0.1 | 1.6 | 5.7 |
| Ru172   | 0.8       | 0.2 | 5.6 | 0.64 | 0.06 | 6.1 | 7.0 |
| FSR1430 | 1.0       | 0.3 | 8.3 | 2.07 | 0.03 | 1.9 | 7.1 |
| FSR1471 | 1.0       | 0.2 | 6.2 | 1.22 | 0.02 | 2.7 | 7.7 |
| FSR162  | 0.2       | 0.05 | 3.5 | 1.57 | 0.03 | 7.1 | 7.5 |
| FSR178  | 1.5       | 0.5 | 3.9 | 1.34 | 0.03 | 3.7 | 6.4 |
| FSR198  | 0.01      | 0.005 | 6.6 | 0.96 | 0.03 | 1.7 | 6.9 |

Table Notes: The parameter N1 corresponds to the ratio of the number of stars in the decontaminated CMD with respect to the 1 Poisson fluctuation measured in the observed CMD. Col. 4: reddening in the cluster's central region. Col. 5: Rcc calculated using R = 72 kpc (Bica et al. 2003) as the distance of the Sun to the Galactic centre. Uncertainties in d and Rcc are of the order of 0.1 kpc.

Fig. 7. 2M ASS CMDs extracted from the R = 4′ region of FSR 198. Top panels: observed CMDs J (J−H) (left) and red star decontaminated CMDs tied with MS + PM S isochrone solutions. Shaded polygons show the MS (dark) and PM S (light) colour-magnitude regions used to isolate cluster MS/evolved stars (right). Bottom panels: equal area copy parison eli (left) and J (J Ks) red star decontaminated CMDs tied with MS + PM S isochrone solutions. Reddening vectors for Aν = 0 Å are shown in decontaminated CMDs.

of the photometry (Bonatto, Bica & Pavan, 2004; Bonatto, Bica & Santos Jr., 2005). As a photometric quality constraint, 2M ASS extractions were restricted to stars with magnitudes (i) brighter than those of the 99% Point Source Catalogue completeness limit in the cluster direction, and (ii) with errors in J, H, and Ks smaller than 0.1 mag. The 99% completeness limits are different for each cluster, varying with Galactic coordinates. A typical distribution of uncertainties as a function of magnitude, for objects projected towards the central parts of the Galaxy, can be found in Bonatto & Bica (2007a). About 75%–85% of the stars have errors below 0.06 mag.

3.1. Field-star decontamination

The CMD is an important tool for searching for the fundamental parameters of the star clusters, but the red-star contamination is an important source of uncertainty, particularly for low-latitude OCs and/or those projected against
the bulge. Our sample of OCs is located in crowded disc zones near the plane, and because of the low latitude, elder stars contaminate the CMDs, especially at faint magnitudes and red colours.

To uncover the intrinsic cluster CMD morphology, we use the elder decontamination procedure described in [Bonatto & Bica (2007a), previously applied in the analysis of low-contrast (Bica & Bonatto, 2005), embedded (Bonatto et al., 2006b), young (Bonatto et al., 2006a), main Bica, Bonatto & Blumberg, 2005), or in dense elders (Bonatto & Bica, 2007d) OCs. The algorithm works on a statistical basis that takes the relative number densities of stars in a cluster region and set elder into account. The algorithm works with three dimensions, the J magnitude and the (J − H) and (J − Ks) colours, considering as well the respective 1 uncertainties in the 2MASS bands. These colours provide the maximum discrimination among CMD sequences for star clusters of different ages (e.g., Bonatto, Bica & Girod, 2004).

Basically, the algorithm (i) divides the full range of magnitude and colours of a given CMD into a 3D grid whose cubic cells have axes along the J, (J − H), and (J − Ks) directions, (ii) computes the expected number density of elder stars in each cell based on the number of comparison elder stars within 1 Poisson uncertainty with magnitude and colours compatible with those of the cell, and (iii) subtracts the expected number of elder stars from each cell. Consequently, this method is sensitive to local variations in elder star contamination with magnitude and colours. Cell dimensions are J = 1.0, and (J − H) = (J − Ks) = 0.15, which are adequate to allow sufficient star-count statistics in individual cells and preserve the morphology of the CMD evolutionary sequences. The dimensions of the colour/magnitude cells can be changed subsequently so that the total number of stars subtracted throughout the whole cluster area matches the expected one, with the 1 Poisson uncertainty.

Three different grid specifications in each dimension are used to minimize potential artifacts introduced by the choice of parameters, thus resulting in 27 different outputs. They occur because for a CMD grid beginning at magnitude J0 (with cell width J), we also include additional runs for cell centres shifted by J0 ± J. Also when considering the same strategy applied to the 2 colours, we end up with 27 outputs. The average number of probable cluster stars Ncl is computed from these outputs. Typical standard deviations of Ncl are at the 25% level. The final elder-decontaminated CMD contains the Ncl elder stars with the highest number frequencies. Stars that remain in the CMD after the elder star decontamination are in cells...
where the stellar density presents a clear excess over the ecl. Consequently, they have a significant probability of being cluster members. Further details on the algorithm, including discussions of subtraction efficiency and limitations, are given in Bonatto & Bica (2007b).

Bonatto & Camargo (2007) introduce the parameter $N_1$, which corresponds to the ratio of the number of stars in the decontaminated CMD with respect to the Poisson fluctuation measured in the observed CMD. By definition, CMDs of overdensities must have $N_1 > 1$. It is expected that CMDs of star clusters have $N_1$ significantly larger than 1. The $N_1$ values for the present sample are given in col. 3 of Table 2.

3.2. Fundamental parameters

Astronomical fundamental parameters are derived with solar-metallicity Padova isochrones (Girardi et al., 2002) convolved with the 2MASS $J$, $H$, and $K_s$. Islers produced isochrones very similar to the Johnson-Kron-Cousins ones (e.g. Bessel & Brett, 1988), with differences of at most 0.01 in $(J-H)$ (Bonatto, Bica & Girardi, 2004). The best fits are superimposed on decontaminated CMDs. Parametric fits derived from the isochrones are the observed distance modulus $(m-M)_0$ and reddening $E(J-H)$, which converts to $E(B-V)$ and $A_V$ with the relations $A_J=A_V=0.276$, $A_H=0.176$, $A_K=0.18$, $E(J-H)=2.76$, $E(J-H)=0.33$, $E(B-V)=0.33$ (Bica, Santiago & Bica, 2002), assuming a constant total-to-selective absorption ratio $R_V=3.1$. The resulting age, $E(J-H)$, $d$, and $R_{GC}$ are given in col. 3 to 6 of Table 2. FSR 198 and Cz 6 present a significant population of pre-main sequence (PMS) stars. Isochrones of Siess, Dufour & Forestini (2000) are used to characterise the PMS sequences of these objects (Figs. 4 and 5).

In Fig. 6 we present the $J$ $(J-H)$ CMDs extracted from a region $R = 3'$ centred on the optimum coordinates of Ru 172 and Cz 12 (top-panel). In the middle panels we show the background eclipsing corresponding to a ring with the same area as the central region. In the bottom panels we build the eclipse decontaminated CMDs.

Both Ru 172 and Cz 12 can be recognised as a cluster by the presence of M S and a prominent giant clump. These features are not present in the comparison ecliptic (Fig. 6 in middle panels). Figure 6, shows 9 OCS. FSR 162 and FSR 178 are probable remnant OCS. The present sample of OCS has in general low stellar-density contrast with respect to the background owing to the projection close to the plane (Table 2).

Cz 7 is not a populous cluster, but the results point to a relatively young OCS (age $220$ Myr). The decontamination leads to an age of $30$ Myr for Be 63, but deep observations are required for more conclusive results. Deeper photometry is essential in most cases, especially for faint and/or distant OCS, close to the plane. A
Table 4. Structural parameters.

| Cluster | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---------|-----|-----|-----|-----|-----|-----|-----|------|------|------|
|         | (pc) | (pc²) | (pc²) | (pc) | (pc²) | (pc²) | (pc²) | (pc²) | (pc²) | (pc²) |
| Be63    | 1.54 | 0.01 | 0.95 | 1.62 | 3.20 | 11.5 | 3.0 | 0.02 | 0.08 | 0.00 | 0.00 |
| Be84    | 0.50 | 0.21 | 0.10 | 2.45 | 1.00 | 5.7 | 0.3 | 0.02 | 0.02 | 0.02 | 0.00 |
| Cz6     | 2.81 | 0.05 | 0.27 | 4.00 | 1.20 | 14.2 | 1.2 | 0.03 | 0.04 | 0.02 | 0.02 |
| Cz7     | 0.85 | 0.02 | 0.58 | 5.2 | 1.5 | 6.2 | 0.5 | 0.02 | 0.03 | 0.09 | 0.05 |
| Cz12    | 0.57 | 0.06 | 0.08 | 2.9 | 1.0 | 11.8 | 0.3 | 0.02 | 0.02 | 0.05 | 0.02 |
| Ru143   | 0.53 | 0.07 | 0.25 | 3.0 | 1.2 | 14.5 | 2.0 | 0.08 | 0.09 | 0.20 | 0.10 |
| Ru144   | 0.47 | 0.09 | 0.02 | 5.6 | 1.0 | 5.2 | 0.5 | 0.08 | 0.10 | 0.05 | 0.12 |
| Ru172   | 0.89 | 0.06 | 0.06 | 6.1 | 1.0 | 14.2 | 0.3 | 0.06 | 0.07 | 0.01 | 0.08 |
| FSR 101 | 0.54 | 0.04 | 0.04 | 2.2 | 0.5 | 23.5 | 6.8 | 0.32 | 0.01 | 0.02 | 0.09 |
| FSR 1430| 1.25 | 0.05 | 0.04 | 2.1 | 1.3 | 13.0 | 5.4 | 1.7 | 0.05 | 0.05 | 0.24 |
| FSR 1471| 0.78 | 0.05 | 0.04 | 0.05 | 0.06 | 5.5 | 1.6 | 6.1 | 0.30 | 0.07 | 0.03 |
| FSR 162 | 2.05 | 0.05 | 0.05 | 3.0 | 1.1 | 6.5 | 4.2 | 0.25 | 0.05 | 0.02 | 0.03 |
| FSR 178 | 1.70 | 0.06 | 0.06 | 3.2 | 0.7 | 20.6 | 5.7 | 0.40 | 0.06 | 0.04 | 0.06 |
| FSR 198 | 0.49 | 0.07 | 0.10 | 7.5 | 1.0 | 14.2 | 0.3 | 0.06 | 0.15 | 0.02 | 0.09 |

Col. Notes. Col. 2: arcmin in parsec scale. To minimize degrees of freedom in RDP ts with the King-like profile (see text), by was kept xed (measured in the respective col parison elds) while s and Rcore were allowed to vary. Col. 11: col parison eld ring. Col. 12: correlation coe cient.

Fig. 12. Consistent RDPs are produced with our approach (empty circles) and that considering bins containing a xed num ber of stars (lined).

by 2M ASS completeness limits. Cz6 and FSR 198 are very young OCs (10 M yr). Be84 turns out to be moderately young (age 360 M yr), similar to Ru144 with 450 M yr.

A xed decontamination, Ru141 corresponds to the bluest sequence in that diagram (age 30 M yr). Since Ru141, Ru144, and Ru172 are located about very low Galactic latitudes (Table 1), important absorption variations across the cluster area and/or background may occur, which can produce residual ects in decontaminated CMDs. In particular, Ru141 has a strong absorption in J for the background stars at 25° to the northeast. It also has a strong absorption in B at 6° to the east. Indeed, Ru141 shows sig- nificant residuals in the CMD (Fig. 8). We point out that the eld of Ru141 also contains the OC Ru142 at 10°. Finally, FSR 162 is a faint and distant OC (d = 71kpc). Only eld decontamination m ade possible to probe cluster properties. Their OC nature is further supported by their decontaminated structural properties (Sect. 4).

We note that there are some di erences in the fund-amental parameters with respect to previous works (e.g. Kharchenko et al. 2003; Tadross et al. 2002), especially for cluster age. This occurs especially for young clusters in which eld contamination has not been properly taken into account. In these cases, PM S stars in conjunction with im- portant eld contamination m ay m in in older ages. A clear example is FSR 198 (Fig. 7).

4. Structural parameters

Structural parameters have been derived by means of the stellar RDPs, de ned as the projected number of stars per area around the cluster centre. RDPs are built with stars selected after applying the respective CM lers to the observed photometry. The colour-magnitude lers (CM lers) are shown in Figs. 5–8 as the shaded region superimposed on the eld-star decontaminated CMDs. Colour-magnitude lers are only used to discard stars with colours comparable to those of the foreground/background eld. This tool was previously applied to the structural analysis of the OCs M 67 (Bonatto & Bica, 2003), NGC 3680 (Bonatto, Bica & Pavani, 2004),

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relations involving structural parameters of OCS. Empty circles: nearby OCS, including two young ones. Triangles: OCS projected on dense fields towards the centre. Stars: the similar OCS FSR 31, FSR 89 and FSR 1744. Black circles: the present work OCSs.

NGC 188 Bonatto, Bica & Santos Jr., 2005, NGC 6611 Bonatto, Santos Jr. & Bica, 2006, NGC 4755 Bonatto et al. (2006), M 52 and NGC 3690 Bonatto & Bica, 2006) and the dwarf OCSs BH 63, Lynga 2, Lynga 12 and King 20 Bica, Bonatto & Blumberg, 2004. The inner regions were defined based on the distribution of the decontaminated star sequences in the CMDs of open clusters. They are wide enough to accommodate cluster MS and evolved star colour distributions, allowing for 1 photon stellar uncertainties. CM inner widths should also account for binonational or dynamical evolution-related effects, such as enhanced fractions of binaries and other multiple systems towards the central parts of clusters, since such systems tend to be more massive (e.g. Bonatto & Bica, 2007) and the dwarf OCSs BH 63, Lynga 2, Lynga 12 and King 20 (Bica, Bonatto & Blumberg, 2004). However, residual ellipses with colours similar to those of the cluster are expected to remain inside the CM inner region. They act the intrinsic RDP to a degree that depends on the relative densities of ellipses and cluster stars. The contribution of the residual contamination to the observed RDP is statistically considered by means of the comparison ellipse. In practical terms, the use of CM inner regions in cluster sequences enhances the contrast of the RDP against the background level, especially for objects in dense elliptical fields (see e.g. Sect. 4) in Bonatto & Bica, 2007).

Fig. 13. Relations involving structural parameters of OCS. Empty circles: nearby OCS, including two young ones. Triangles: OCS projected on dense fields towards the centre. Stars: the similar OCS FSR 31, FSR 89 and FSR 1744. Black circles: the present work OCSs.

To avoid oversampling near the centre and undersampling for large radii, the RDPs were built by counting stars in concentric rings of increasing width with distance to the centre, the number and width of rings are adjusted so that the resulting RDPs represent adequate spatial resolution with moderate Poisson errors. The coordinate (and respective uncertainty) of a given ring corresponds to the average distance to the cluster centre (and standard deviation) computed for the stars within the ring. The residual background level of each RDP corresponds to the average number of CM—inner stars measured in the comparison ellipse. A similarly, we built RDPs with bins of variable sizes to check for any systematic biases that may have been introduced by our method. Following Mackay, APELLANIZ & UBEDA (2005) and Manschberger & Kroupa (2005), we computed the RDPs with bins that contain a fixed number of stars, 10 for $0 < R < 1$, 100 for $1 < R < 10$, and 1000 for $R > 10$. With uncertainties, both approaches produce similar RDPs, as shown by the examples illustrated in Fig. 14.

Structural parameters were derived by fitting the two-parametric King (1966a) surface-density profile to the colour-magnitude grid RDPs. The two-parametric King model essentially describes the intermediate and central regions of globular clusters King (1966a, 1966b; Trager, King & Djorgovski, 1993). The fit was performed using a nonlinear least-squares routine that uses the errors as weights. The best-fit solutions are shown in Figs. 10 and 11 as a solid line superposed on the RDPs. King's law is expressed as $R_s = a + b < \frac{R}{R_R} > c$, where $a$ is the background surface density of stars, $b$ is the central density of stars and $R_R$ is the core radius. The cluster radius ($R_{RDP}$) and uncertainty can be estimated by considering the uncertainties of the RDPs with respect to the residual background, and $R_{RDP}$ corresponds to the distance from the cluster centre where RDP and comparison
5. Relations among astrophysical parameters

At this point it is interesting to compare the structural parameters derived for the present OCs with those measured in different environments (Fig. 13). We considered (i) a sample of bright nearby OCs (Bonatto & Bica, 2005), including the two young OCs NGC 6611 (Bonatto, Santos Jr., & Bica, 2008), and NGC 4755 (Bonatto et al., 2006), (ii) OCs projected against the central parts of the Galaxy (Bonatto & Bica, 2007a), and (iii) the recently analyzed OCs FSR 1744, FSR 89 and FSR 31 (Bonatto & Bica, 2007a) projected against the central parts of the Galaxy, and (iv) the present sample.

In panel (a) of Fig. 13, core and cluster radii of the OCs in sample (i) are almost linearly related by $R_{\text{RDP}} = (8.9 \times 0.03) \times R_{\text{core}}^{(0.5)}$, which suggests that both kinds of radii undergo a similar scaling, in the sense that on average, larger clusters tend to have larger cores. However, some of the OCs in sample (ii) do not follow that relation, which suggests that they are either intrinsically small or have been suffering important evaporation e ects. The core and cluster radii in sample (iii) and the OCs of this work (iv) are consistent with the relation at the level. A dependence of core size on galactocentric distance is shown in panel (b), as previously suggested by Lynga (1982) and Padro (2002). In panels (c) and (d) we compare core and cluster radii with cluster age, respectively. This relationship is intimately related to cluster survival/disappearance rates. Both kinds of radii present a similar dependence on age, in which part of the clusters expand with time, while some seem to shrink. The bifurcation occurs at an age 1 Gyr. A similar e ect was observed for the core radii of LMC and SM C star clusters (e.g., Mackey & Gilmore, 2003), which have core radii $(0.5 < R_{\text{pc}} < 8)$ and mass $(10^3 < M (M) < 10^5)$ significantly more than the present cores. The core radius distribution of most LMC and SM C clusters is characterized by a trend toward increasing core radius with age with an apparent bifurcation (core shrinkage) at several hundred My. Mackey & Gilmore (2003) argue that this relationship represents the physical evolution of these clusters, with some clusters developing expanding cores due to the stellar mass black holes, and some that contract because of dynamical relaxation and core collapse (Mackey & Gilmore, 2003). We also note that the radii of the young clusters (age < 200 Gyr) of our sample are related to the age similarly to the Galactic ones (Pa
cine, 2009). Similar relations involving core and cluster radii were found by Mackey & Niederhofer (2003) for an optical cluster sample.

Finally, Fig. 14 shows the spatial distribution in the Galactic plane of the present OCs, compared to that of the OCs in the WEBDA database. We consider two age ranges, < 1 Gyr and > 1 Gyr. We compute the projections on the Galactic plane of the Galactic coordinates (l,b). OI OCs are primarily found outside the solar circle, and the inner Galaxy contains a few OCs detected so far. The interesting point here is whether inner Galaxy clusters cannot be observed because of strong absorption and crowding, or have been systematically dissolved by the di erent tidal e ects combined (Bonatto & Bica, 2007a, and references therein). In this context, the more OCs identi ed (with their astrophysical parameters derived) in the central parts, the more constraints can be established to settle this issue.

Differential reddening provides uncertainties in OC astrophysical parameters. Most OCs of our sample occur close to spiral arms. Since they are located close to the plane (Table 1), they may have interacted with the arms, especially by many encounters with GMCs.

6. Concluding remarks

In the present work, we have derived astrophysical parameters of 14 OCs projected close to the Galactic plane by means of 2MASS CMDs and stellar RDPs. Field-star decontamination is applied to uncover the cluster’s intrinsic CMD morphology, and photometric errors are used to isolate probable cluster members. That stellar decontamination leads to consistent CMDs and RDPs shows that we are dealing with OCs, instead of extended clusters. In particular, the present CMD and RDP analyses indicate that 6 IR objects from Froebrich, Scho 
zel, & Raftery (2007), initially identified as cluster candidates from overdensities, are star clusters (Table 5).

Our sample contains OCs with ages in the range 10^5 M yr (C26 and FSR 198) to 1500 Gyr (FSR 178), at distances from the Sun in the range of 16 kpc (Ru144) to 71 kpc (FSR 162) and galactocentric distances $R_{\text{GC}}$ of 55 kpc for Ru141 to 118 kpc for Be 63. Be 84, Ru141, and Ru144 are relatively young surviving OCs located inside the solar circle. Clusters in that region are expected to suffer important tidal stress in the form of shocks from disc and bulge crossings, as well as encounters with massive molecular clouds. In the long run, these processes tend to dynamically heat a star cluster, which enhances the rate of mass star evaporation and produces a cluster expansion on scales. However, for some OCs, mass segregation and evaporation may also lead to a phase of core contraction. Consequently, these clusters tend to disrupt most clusters, especially the less populous ones. On the other hand, FSR 1430, FSR 1471 and Cz12 are older. One of the reasons for this longevity may be...
their large Galacticocentric distance, which minimises the disruption effects. The newly formed open clusters Cz6 and FSR 198 show PM's stars in the CMDs.

The present study contributes new open cluster parameters and some revisions to the DAM L02 and WEBDA open cluster databases.

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