Optical photometry and basic parameters of 10 unstudied open clusters

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ABSTRACT

We present *BVI* CCD photometry of 10 northern open clusters, Berkeley 43, Berkeley 45, Berkeley 47, NGC 6846, Berkeley 49, Berkeley 51, Berkeley 89, Berkeley 91, Tombaugh 4 and Berkeley 9, and estimate their fundamental parameters. Eight of the clusters are located in the first Galactic quadrant and two are in the second. This is the first optical photometry for eight clusters. All of them are embedded in rich Galactic fields and have large reddening towards them [$E(B - V) = 1.0$–2.3 mag]. There is a possibility that some of these difficult-to-study clusters may be asterisms rather than physical systems, but assuming that they are physical clusters, we find that eight of them are located beyond 2 kpc and six clusters (60 per cent of the sample) are located well above or below the Galactic plane. Seven clusters have ages 500 Myr or less and the other three are 1 Gyr or more in age. This sample of clusters has increased the optical photometry of clusters in the second half of the first Galactic quadrant, beyond 2 kpc, from 10 to 15. NGC 6846 is found to be one of the most distant clusters in this region of the Galaxy.

Key words: open clusters and associations: general – open clusters and associations: individual: Berkeley 43 – open clusters and associations: individual: Berkeley 45 – open clusters and associations: individual: Berkeley 47 – open clusters and associations: individual: NGC 6846 – open clusters and associations: individual: Berkeley 49.

1 INTRODUCTION

Open star clusters are important constituents of our Galactic disc. They are potential tracers of the structure, star formation history and the chemical evolution of the disc. One of the recent such attempts to increase the cluster sample in the first half of the second Galactic quadrant (Subramaniam & Bhatt 2007) found an outwards extension of the Perseus arm consisting of clusters older than 100 Myr. They also found a mild warp in the Galactic disc, beyond 2 kpc. An earlier study to identify northern candidate old open clusters in this region was done by Carraro, Subramaniam & Janes (2006).

With the goal of increasing our knowledge of the cluster system in the first quadrant of the galaxy, we present a *BVI* photometric study of 10 open clusters: Berkeley 43, Berkeley 45, Berkeley 47, NGC 6846, Berkeley 49, Berkeley 51, Berkeley 89, Berkeley 91, Tombaugh 4 and Berkeley 9. These clusters are embedded in rich Galactic fields, so little is known about them; this is the first optical CCD photometric study for eight of the clusters. Berkeley 43 was studied by Hasegawa, Sakamoto & Malasan (2008) and Berkeley 9 was studied by Maciejewski & Niedzielski (2007). Seven of our

Berkeley candidates (except Berkeley 9) are in common with the study by Tadross (2008), using near-infrared *JHK* Two-Micron All-Sky Survey (2MASS) data. Moffat & Vogt (1973) obtained *UBV* photographic data of stars in the field of Tombaugh 4, but they could not estimate any of the parameters since the photometry was not deep enough. Table 1 lists the coordinates of the clusters in the present study.

The plan of the paper is as follows. Section 2 describes the observation strategy and reduction technique. Section 3 deals with the radial density profile and the cluster size. The results for the 10 clusters are presented in Section 4, followed by discussion in Section 5.

2 OBSERVATIONS AND DATA REDUCTION

We obtained our observations with the HFOSC instrument at the 2-m Himalayan Chandra Telescope (HCT), located at Hanle, Indian Astronomical Observatory (IAO), and operated by Indian Institute of Astrophysics. Details of the telescope and the instrument are available at the institute's homepage (http://www.iiap.res.in/). The CCD used for imaging is a 2 k × 4 k CCD, where the central 2 k × 2 k pixels are used for imaging. The pixel size is 15 μm with an image scale of 0.297 arcsec pixel^{-1}. The total area observed is approximately 10 × 10 arcmin^2. Table 2 is a log of our observations.

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Table 1. Basic parameters of the clusters under investigation. Coordinates are for J2000.0.

Name	RA	Dec.	l	b
	(hh : mm : ss)	(° : ′ : ″)	(deg)	(deg)
Berkeley 43	19:15:36	+11:13:00	45.65	−0.182
Berkeley 45	19:19:12	+15:43:00	50.04	1.145
Berkeley 47	19:28:36	+17:22:06	52.561	−0.058
NGC 6846	19:56:28	+32:20:54	68.69	1.92
Berkeley 49	19:59:31	+34:38:48	70.985	2.575
Berkeley 51	20:24:36	+46:03:00	72.147	0.291
Berkeley 89	20:24:36	+46:03:00	83.160	4.822
Berkeley 91	21:10:52	+48:32:12	90.064	0.132
Tombaugh 4	02:28:54	+61:47:00	134.21	1.073
Berkeley 9	03:32:42	+52:39:00	146.07	−2.82

Table 2. Log of photometric observations.

Cluster	Date	Filter	Exp time (s)
NGC 6846	2005 August 30	V	60, 180, 2 × 300
		B	60, 120, 300, 600
		I	10, 30, 3 × 60
Tombaugh 4	2005 August 30	V	60, 300, 600
		B	120, 2 × 600
		I	10, 30, 120, 2 × 300
Be 9	2005 August 31	V	30, 60, 2 × 180
		B	60, 300, 600
		I	10, 30, 2 × 120
Be 43	2008 August 01	V	30, 120, 180, 240
		B	300, 600
		I	10, 30, 60
Be 49	2008 August 01	V	120, 480
		B	600, 1200
		I	10, 60, 180
Be 91	2008 August 01	V	15, 30, 120
		B	60, 180
		I	5, 20, 60
Be 45	2008 August 02	V	5, 20, 120
		B	300, 600
		I	10, 30, 60
Be 47	2008 August 02	V	10, 60, 120
		B	60, 240
		I	0.2, 10, 60
Be 51	2008 August 02	V	3, 5, 30
		B	5, 30, 90
		I	2, 10, 60
Be 89	2008 August 02	V	10, 60, 180
		B	60, 120, 240
		I	5, 10, 120

We reduced the data with the IRAF[1] packages CCDRED, DAOPHOT, ALLSTAR and PHOTCAL using the point spread function method (Stetson 1987).

The nights were photometric and we used the Landolt (1992) standard field SA110 for calibration images at different airmasses during the night to put the photometry on to the standard system.

[1] IRAF is distributed by NOAO, which are operated by AURA under cooperative agreement with the NSF.

Table 3. Coefficients of the calibration equations.

2005 August 30 and 31		
$b_1 = 0.818 \pm 0.008$	$b_2 = 0.26 \pm 0.02$	$b_3 = 0.043 \pm 0.008$
$v_1 = 0.513 \pm 0.005$	$v_2 = 0.14 \pm 0.02$	$v_3 = 0.063 \pm 0.005$
$i_1 = 0.824 \pm 0.009$	$i_2 = 0.08 \pm 0.02$	$i_3 = 0.048 \pm 0.009$
2008 August 01		
$b_1 = 1.038 \pm 0.005$	$b_2 = 0.21 \pm 0.02$	$b_3 = 0.041 \pm 0.004$
$v_1 = 0.720 \pm 0.008$	$v_2 = 0.11 \pm 0.02$	$v_3 = -0.088 \pm 0.006$
$i_1 = 0.900 \pm 0.010$	$i_2 = 0.07 \pm 0.02$	$i_3 = -0.080 \pm 0.010$
2008 August 02		
$b_1 = 1.020 \pm 0.010$	$b_2 = 0.20 \pm 0.02$	$b_3 = 0.052 \pm 0.010$
$v_1 = 0.730 \pm 0.010$	$v_2 = 0.10 \pm 0.02$	$v_3 = -0.079 \pm 0.009$
$i_1 = 0.880 \pm 0.010$	$i_2 = 0.07 \pm 0.02$	$i_3 = -0.050 \pm 0.010$

The calibration equations are of the form

$$b = B + b_1 + b_2 \times X + b_3(B - V)$$
$$v = V + v_1 + v_2 \times X + v_3(B - V)$$
$$i = I + i_1 + i_2 \times X + i_3(V - I),$$

where *BVI* are standard magnitudes, *bvi* are the instrumental ones and X is the airmass; all the coefficient values are reported in Table 3. The standard stars in these fields provide a very good colour coverage [$0.1 \le (B - V) \le 2.2$ and $0.4 \le (V - I) \le 2.6$].

We derived aperture correction from a sample of bright stars and applied them to the photometry. We found aperture corrections of 0.27, 0.29 and 0.20 mag in *B*, *V* and *I*, respectively.

The final photometric catalogue consisting of 29 226 stars present in 10 clusters (coordinates, *B*, *V* and *I* magnitudes and errors) includes 10 525 stars in NGC 6846, 5751 in Tombaugh 4, 1461 in Berkeley 9, 1280 in Berkeley 91, 1996 in Berkeley 49, 1141 in Berkeley 43, 2871 in Berkeley 45, 637 in Berkeley 47, 1962 in Berkeley 51 and 1602 in Berkeley 89. The limiting magnitudes of the photometry are $B = 21.0$, $V = 22.0$ and $I = 21.0$. The photometry will be made available in an electronic form at the WEBDA[2] site maintained by E. Paunzen.

3 CLUSTER RADII

To identify the most likely cluster members and minimize field star contamination, we derived cluster radii from radial density profiles (RDPs) using star counts. We counted stars in circular annuli of 0.5 arcmin wide around the cluster centres, limiting our counts to stars brighter than $V = 20$ mag. The stellar density profiles are estimated (Fig. 11). We visually fitted the RDP with the function $\rho(R) \propto f_0/[1 + (R/R_0)^2]$, where R_0 is the radius at which the density $\rho(R)$ becomes half of the central density, f_0. The estimated half-power radii based on fits to the profiles are tabulated in Table 4.

By this measurement, the clusters have radii between 0.6 and 1.9 arcmin, making them rather small clusters, possibly located relatively far away. In view of their sparse nature, we simply used their visual appearance and the RDP half-power radii as guides and rounded up the R_0 values to get estimated effective radii. The effective radii are shown in parentheses in Table 4, and the circles in Figs 1–10 are drawn with these radii.

[2] http://www.univie.ac.at/webda/navigation.html

Table 4. Fundamental parameters estimated for the clusters. Along with the half-power radius, the effective radius used to estimate the cluster parameters is given in the parenthesis. The error in the reddening estimate is 0.02 mag. Errors in distances are about 10 per cent.

Name	Radius (arcmin)	$E(B-V)$ (mag)	$E(V-I)$ (mag)	Distance modulus (mag)	Distance (pc)	Log (Age)	Z (pc)
Berkeley 43	1.9(2.5)	2.3	2.5	17.2	1030	8.45–8.5	∼0
Berkeley 45	1.1(1.5)	1.4	1.5	16.2	2350	8.5–8.6	47
Berkeley 47	1.1(2.0)	1.5	1.7	14.8	1070	8.65–8.7	∼0
NGC 6846	1.5(1.5)	1.05	1.35	16.5	4450	8.6–8.7	150
Berkeley 49	0.7(1.5)	1.35	1.55	16.0	2300	8.35–8.5	103
Berkeley 51	0.6(1.0)	1.6	1.6	15.5	1300	9.0–9.05	∼0
Berkeley 89	0.8(1.0)	1.05	1.6	14.8	2040	9.0–9.05	171
Berkeley 91	1.0(1.0)	1.2	0.6	16.8	4100	9.15–9.35	∼0
Tombaugh 4	1.3(2.5)	1.25	1.6	16.8	3850	8.6–8.7	72
Berkeley 9	1.0(2.0)	1.45	1.65	16.3	2300	7.8–8.0	−113
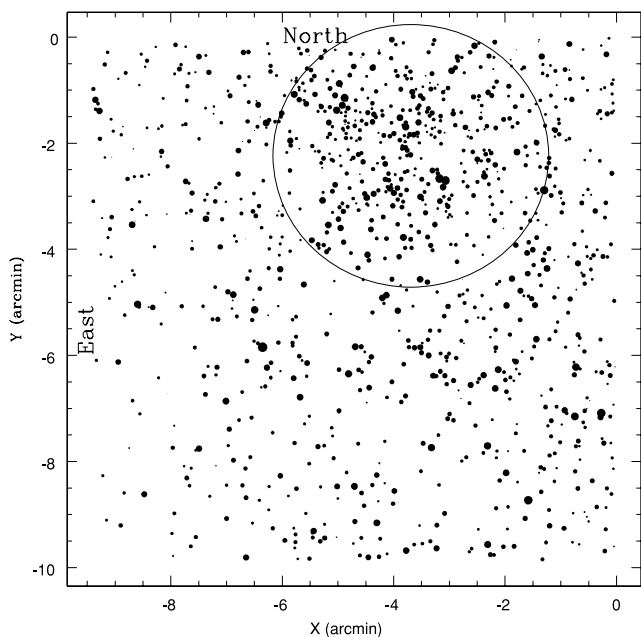
Figure 1. The observed region of Berkeley 43. We considered stars within the circle of a radius of 2.5 arcmin as shown to be within the effective radius of the cluster.
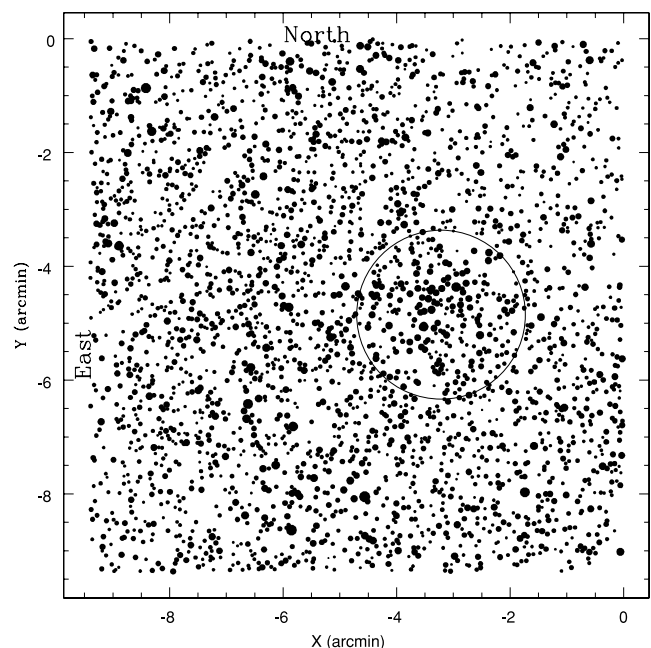

Figure 2. The observed region of Berkeley 45. We considered stars within a radius of 1.5 arcmin as shown to be within the effective radius of the cluster.

4 REDDENING, DISTANCE AND AGE

We constructed colour magnitude diagrams (CMDs) using stars located within the effective cluster radii. Figs 12–21 show the CMDs of both the clusters and the surrounding field regions, consisting of stars located more than 3.5 arcmin from the cluster centres. Since these clusters are sparse and embedded in rich Galactic fields, our conservative choice of the cluster radii maximizes the contrast between the cluster and the field population.

We compared the cluster CMDs with the Girardi et al. (2000) isochrones to estimate the cluster reddenings, distances and ages. Without independent information about a cluster's reddening and distance, it is not possible to make an unambiguous determination of the appropriate age and metallicity isochrone to fit to the cluster. Instead, we have made a visual determination of the most likely isochrone, or range of isochrones, that appears to match the cluster. The estimated isochrone parameters are tabulated in Table 4, and the best fit of the selected isochrones to the individual cluster CMDs [V versus $(B-V)$] are shown in Figs 22 and 23 [V versus

$(V-I)$]. The parameters estimated by Tadross (2008) for the common clusters are tabulated in Table 5, for comparison.

Berkeley 43. The cluster is located near the north side of the observed region (Fig. 1). The stars in the cluster are distributed in two concentrations in the north–south direction. A deficiency of stars on the south-east side of the cluster is probably due to the presence of greater extinction, so the cluster may be located near a dark cloud. This is supported by the high reddening we estimate towards this cluster (Table 4). The CMDs of likely cluster stars and stars located beyond a radius of 3.5 arcmin (assumed to be field stars) are shown in Fig. 12. The cluster sequence is distinctly identifiable, when compared to the field. The isochrone compared to the cluster (Figs 22 and 23) suggests a relatively nearby (∼1 kpc) young cluster [log(age) = 8.4–8.5], very close to the mid-Galactic plane. Hasegawa et al. (2008) estimated a distance of 1500 pc, $E(V-I)$ of 1.96 mag and an age of 1.4 Gyr. We find a much younger age for this cluster. The cluster properties estimated by Tadross (2008), using 2MASS data, match broadly with our estimates.
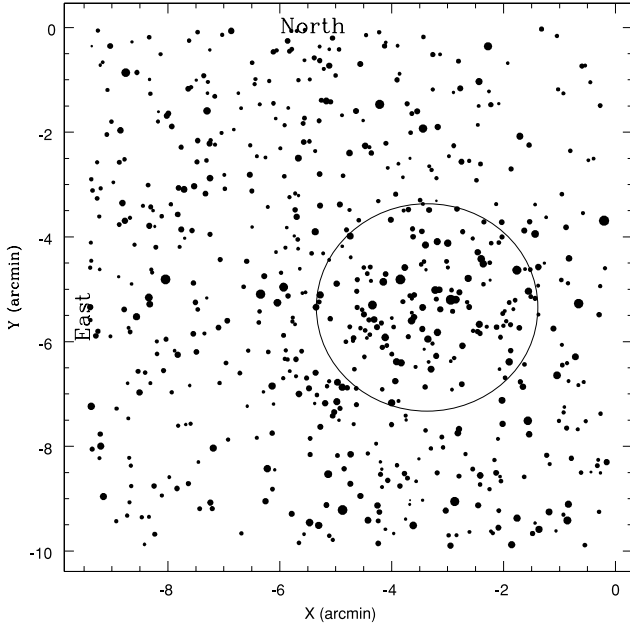
Figure 3. The observed region of Berkeley 47. We considered stars within a radius of 2.0 arcmin as shown to be within the effective radius of the cluster.
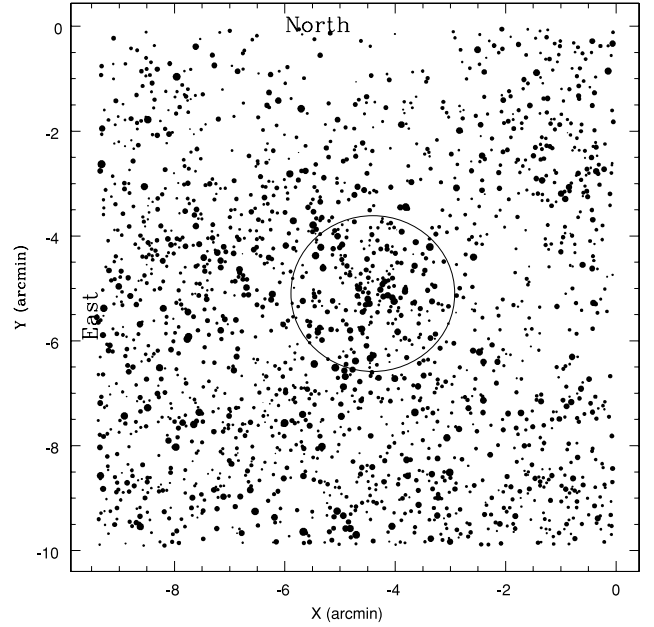

Figure 5. The observed region of Berkeley 49. We considered stars within a radius of 1.5 arcmin as shown to be within the effective radius of the cluster.
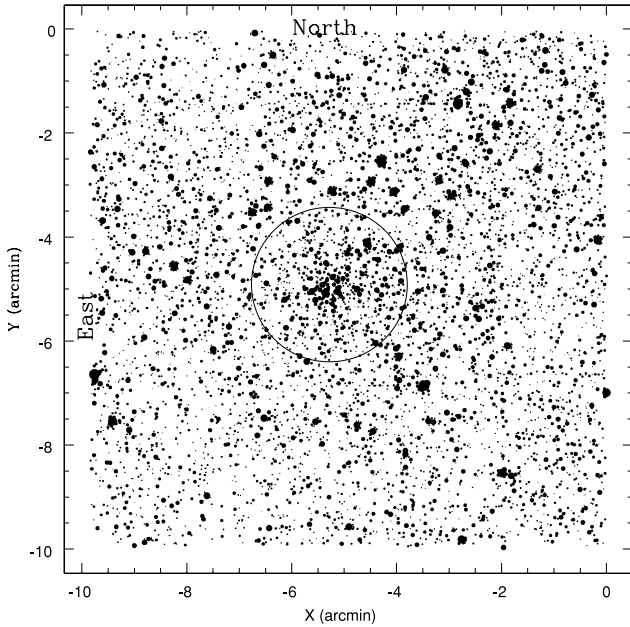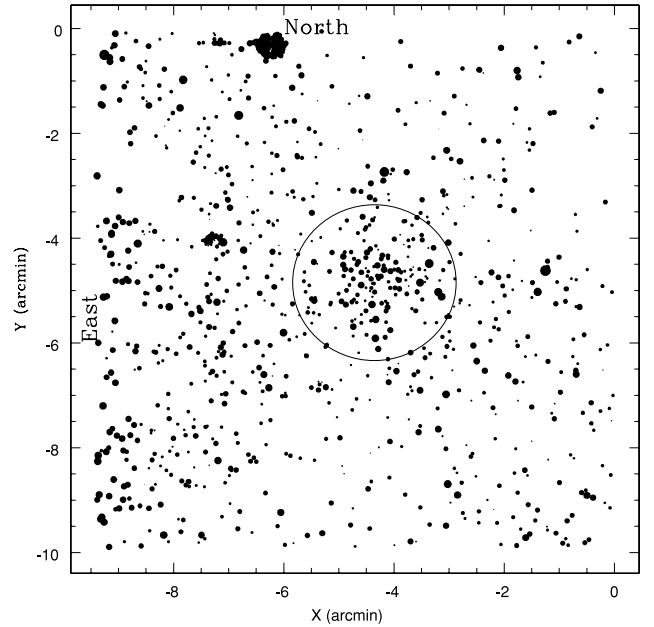

Figure 4. The observed region of NGC 6846. We considered stars within a radius of 1.5 arcmin as shown to be within the effective radius of the cluster.

Figure 6. The observed region of Berkeley 51. Stars within a radius of 1.0 arcmin as shown are considered to be within the effective radius of the cluster.

Berkeley 45. The cluster is located in a fairly rich Galactic field (Fig. 2), visible as a marginal enhancement in the density from the field; it could be a chance asterism. Nevertheless, the presence of the cluster is clearly seen in the RDP (Fig. 11). A decrease in the star density towards the north-west suggests variable extinction in the field. This is a sparse cluster and the cluster and field CMDs are not very different, so it is difficult to identify the main sequence in the CMD (Fig. 13). The only clear difference is the narrow MS with a distinct cut-off/turn-off at the bright end. Therefore, we consider this as a true cluster. The CMD of the cluster region is well matched

by the isochrones suggesting a young [log(age) = 8.5–8.6], cluster, located at an approximate distance of 2350 pc with considerable reddening [$E(B − V) = 1.4$ mag]. In an earlier study, Tadross (2008) estimated a distance of 2.3 kpc and an age of 600 Myr, using 2MASS data. Our estimate of the distance is within errors, but we estimate a marginally younger age for the cluster.

Berkeley 47. This cluster is located close to Berkeley 45, in the first quadrant. It is a rather poor cluster, but it stands out from the somewhat sparse field (Fig. 3). Although the RDP clearly shows the presence of the cluster, it may also be an asterism. There is a
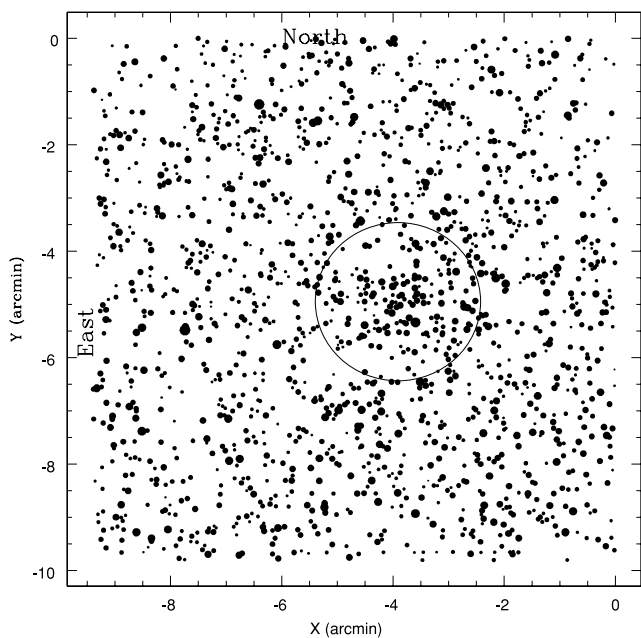
Figure 7. The observed region of Berkeley 89. We considered stars within a radius of 1.0 arcmin as shown to be within the effective radius of the cluster.
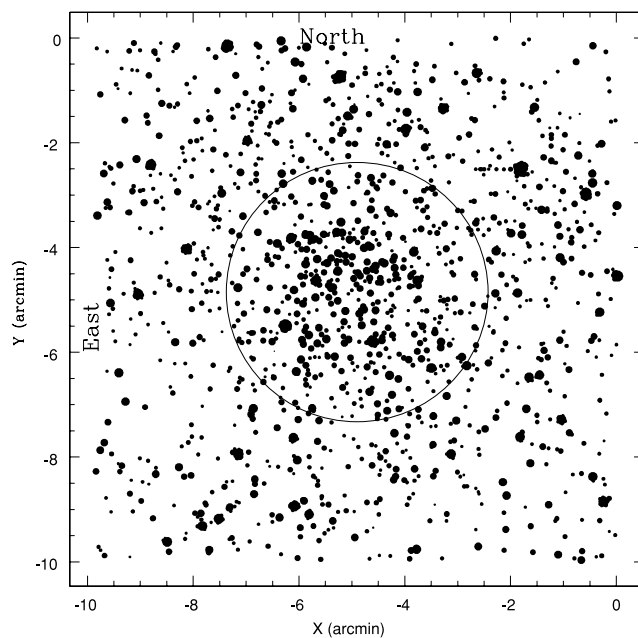

Figure 9. The observed region of Tombaugh 4. We considered stars within a radius of 2.5 arcmin as shown to be within the effective radius of the cluster.
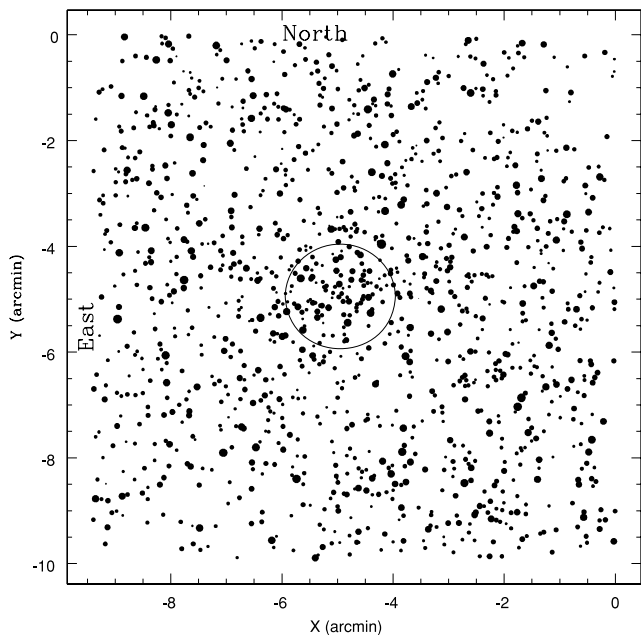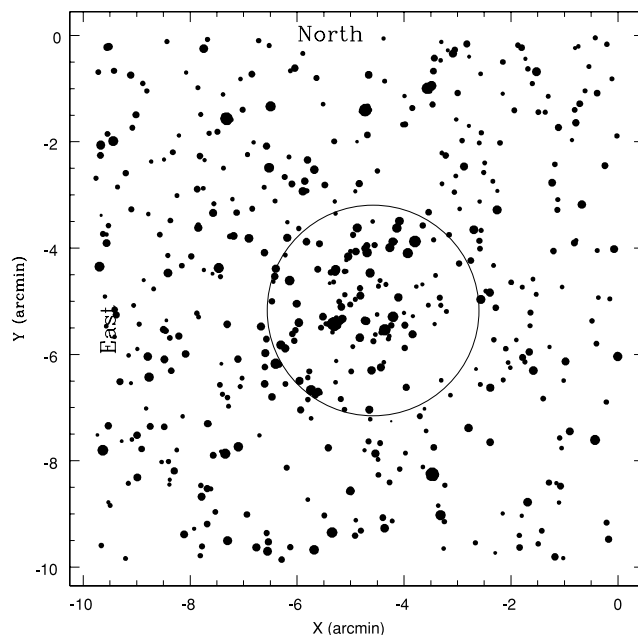

Figure 8. The observed region of Berkeley 91. We considered stars within a radius of 1.0 arcmin as shown to be within the effective radius of the cluster.

Figure 10. The observed region of Berkeley 9. We considered stars within a radius of 2.0 arcmin as shown to be within the effective radius of the cluster.

decrease in the number of field stars on the north-west and south-east sides of the cluster, suggesting that the cluster may be located between two dark clouds. The cluster CMD has a well-defined MS, when compared to the field CMD (Fig. 14). There are no giants present in the CMD and the cluster parameters are estimated based on the MS and its turn-off. The isochrone fitted to the cluster CMD shows a poor match to the lower MS, possibly because of field star contamination. Another possibility is differential reddening, which could be present across the face of the cluster. The fainter stars are located away from the cluster centre (Fig. 3) and hence may be

more reddened. Since this is a poor cluster, it is difficult to attribute the poor fit to any model limitations or to arrive at any definite possibility for the observed deviation.

We find Berkeley 47 to be a moderately young [log(age) = 8.6–8.7] cluster, located at ∼1 kpc with large reddening [$E(B − V) = 1.5$ mag].

NGC 6846. This is a compact and distant cluster embedded in a rich Galactic field, including a number of bright foreground stars.
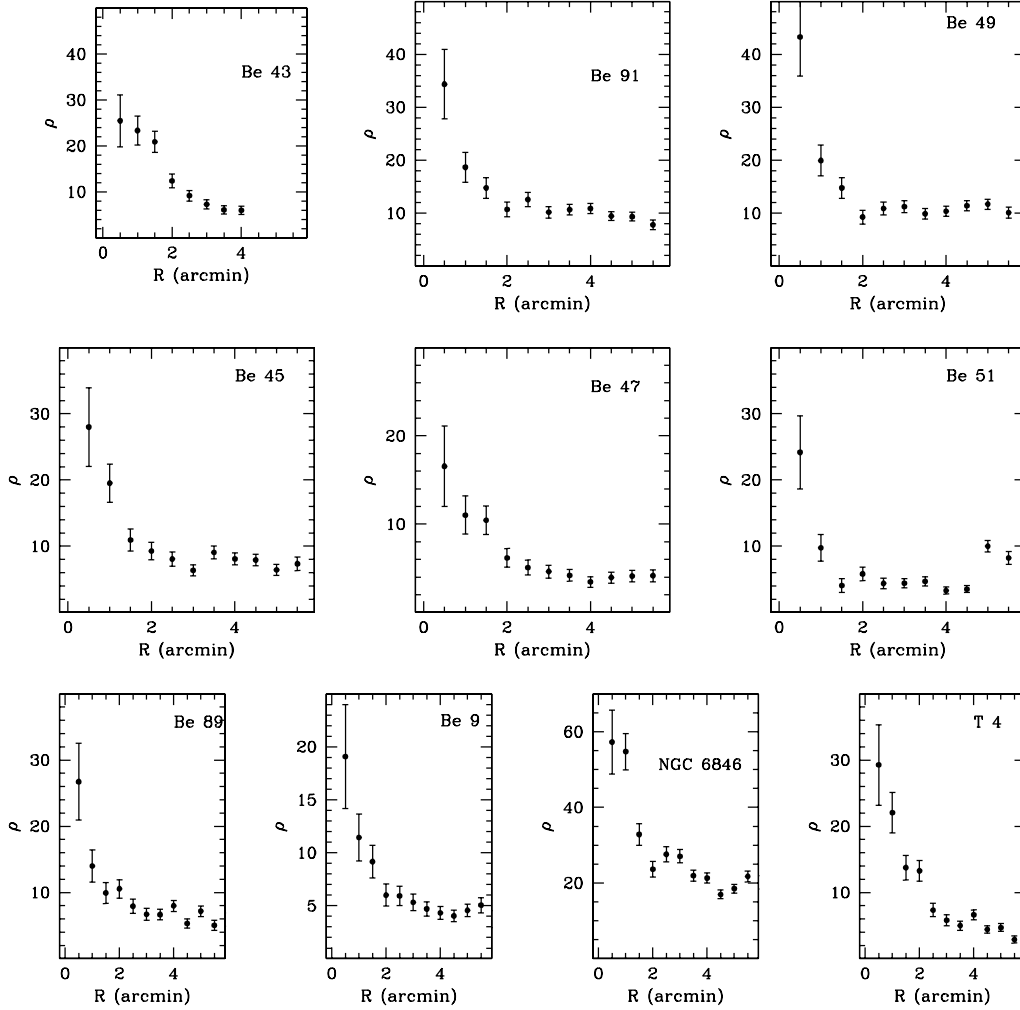
Figure 11. The estimated RDPs for 10 clusters. The cluster names are indicated inside each figure.
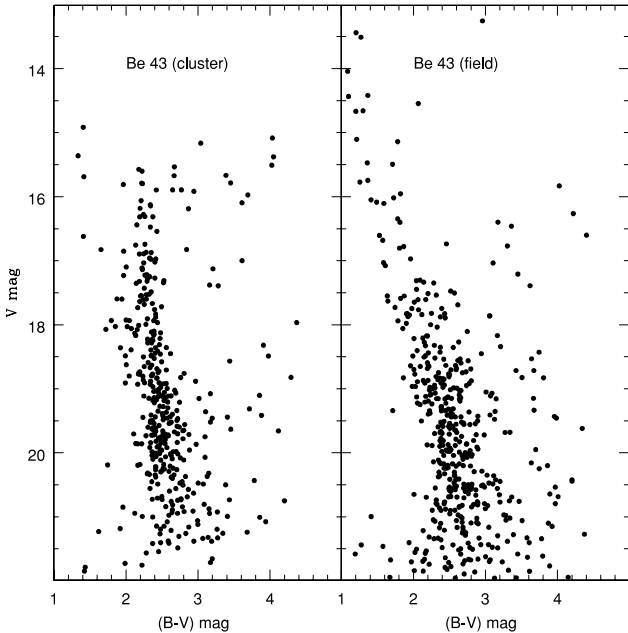

Figure 12. The *V* versus (*B* − *V*) CMDs of the cluster Berkeley 43 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.
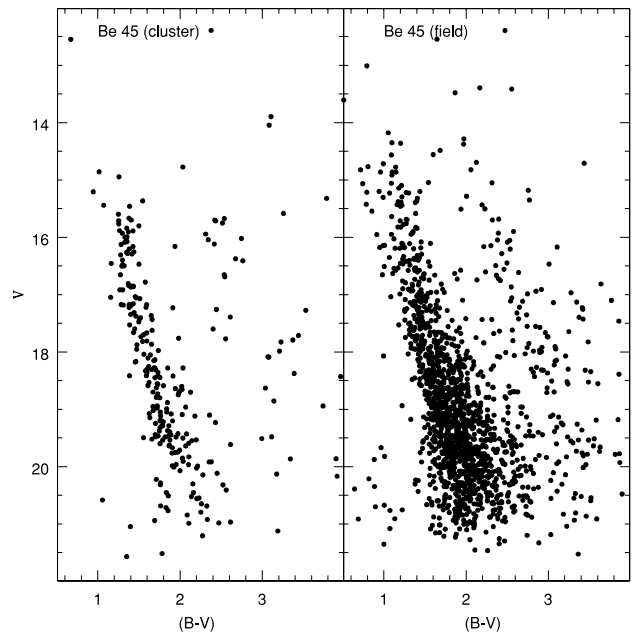
Figure 13. The *V* versus (*B* − *V*) CMDs of the cluster Berkeley 45 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.
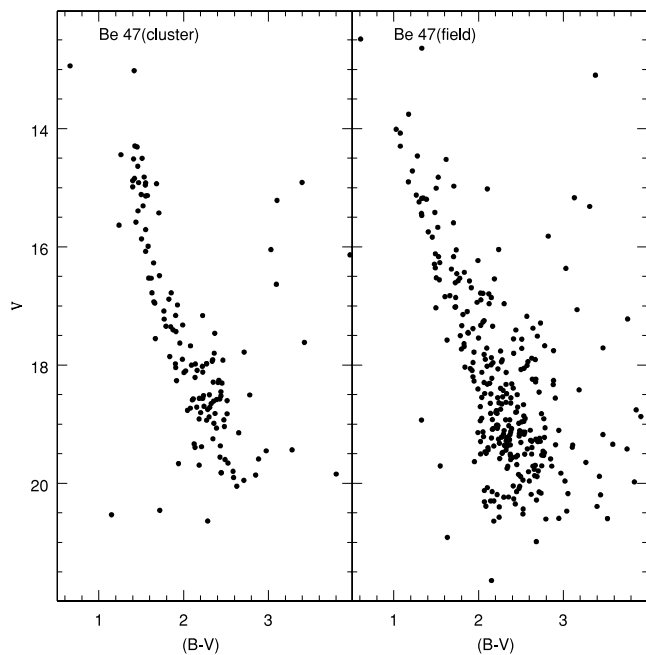
Figure 14. The V versus $(B - V)$ CMDs of the cluster Berkeley 47 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.
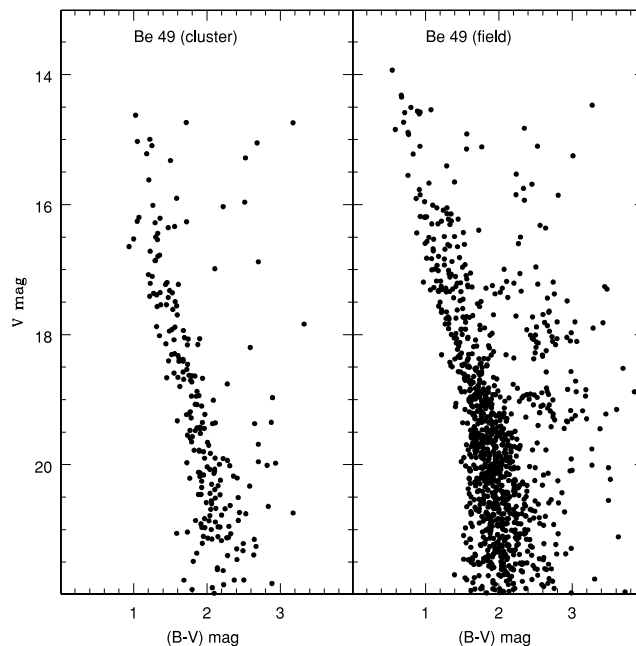

Figure 16. The V versus $(B - V)$ CMDs of the cluster Berkeley 49 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.
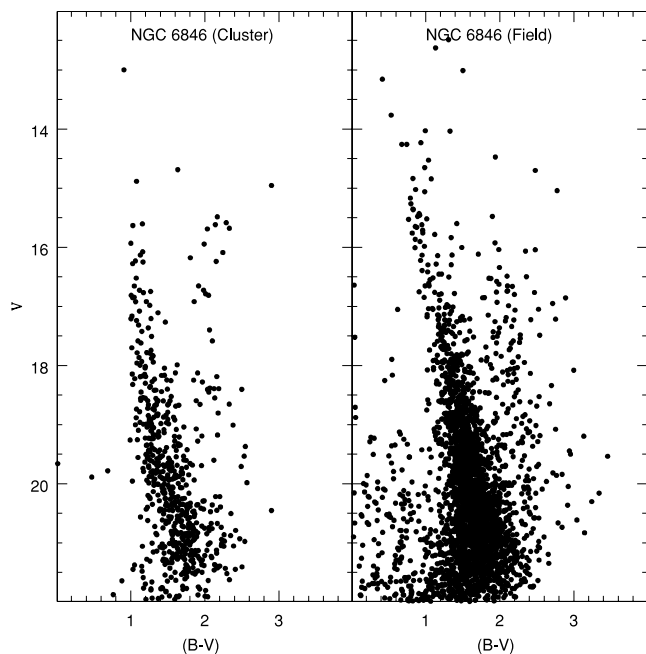

Figure 15. The V versus $(B - V)$ CMDs of the cluster NGC 6846 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.

Figure 17. The V versus $(B - V)$ CMDs of the cluster Berkeley 51 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.

The region towards the south of the cluster has relatively lower field star density, indicating variable interstellar extinction. The cluster and the field CMDs (Fig. 15) are rather different from one another. There are a few red giants in the cluster CMD, some of which may be members. The most likely isochrone fit to the cluster suggests that it is moderately young [log(age) = 8.6–8.7], located about 5.1 kpc away, with substantial reddening [$E(B - V) = 1.05$ mag]. This cluster is located well above the Galactic plane ($Z \sim 170$ pc). This
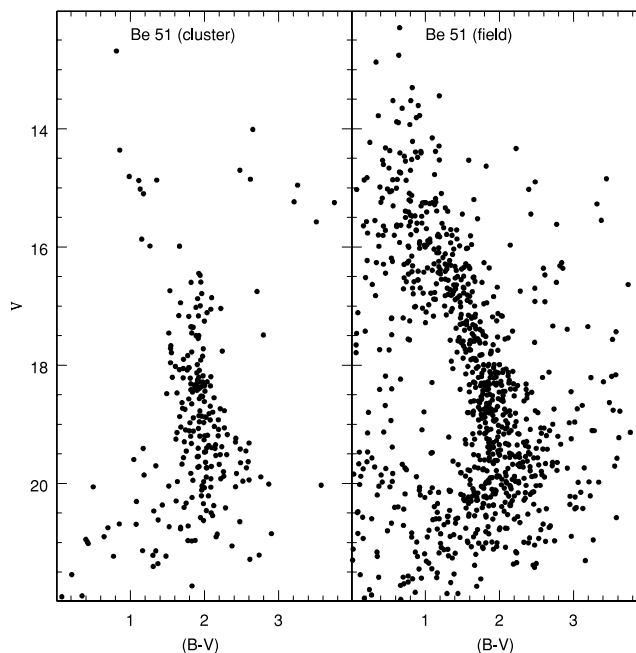
cluster is the most distant cluster in the first quadrant, more distant than IC 1311, an older cluster located at about 4.0 kpc (Delgado et al. 1994). The stars in NGC 6846 are potential targets to study the abundances of the Galactic disc in these regions.

Berkeley 49. This cluster is also in a rich Galactic field and does not stand out from the field, especially because of its clumpy nature. It can be seen from Fig. 5 that there is a gap with fewer stars located towards the north-west of the cluster. Like several of the other clusters, this one is located in a region of variable extinction. This is
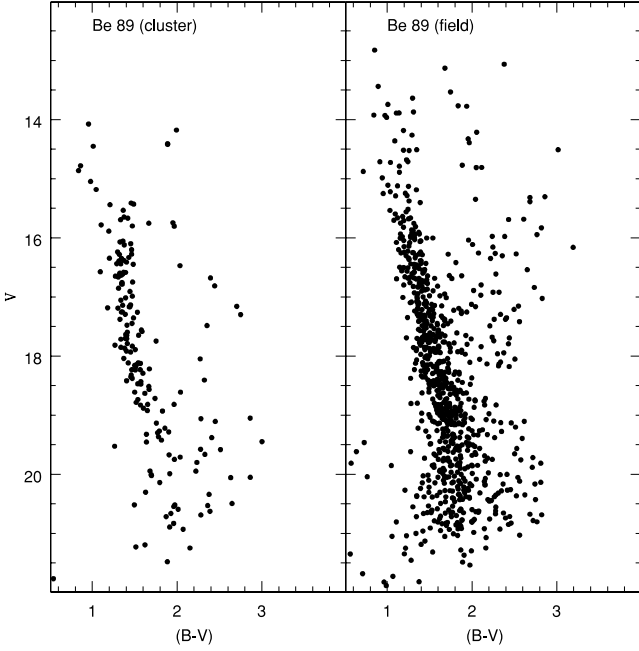
Figure 18. The V versus $(B - V)$ CMDs of the cluster Berkeley 89 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.

Figure 20. The V versus $(B - V)$ CMDs of the cluster Tombaugh 4 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.

Figure 19. The V versus $(B - V)$ CMDs of the cluster Berkeley 91 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.
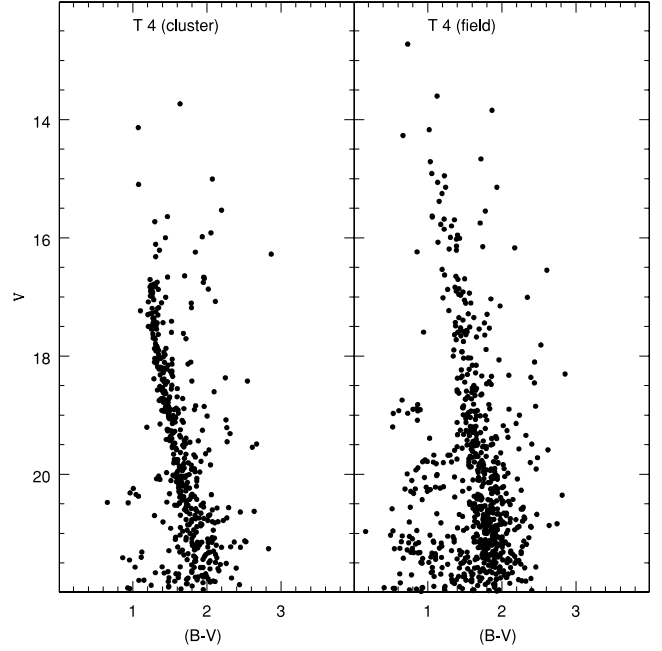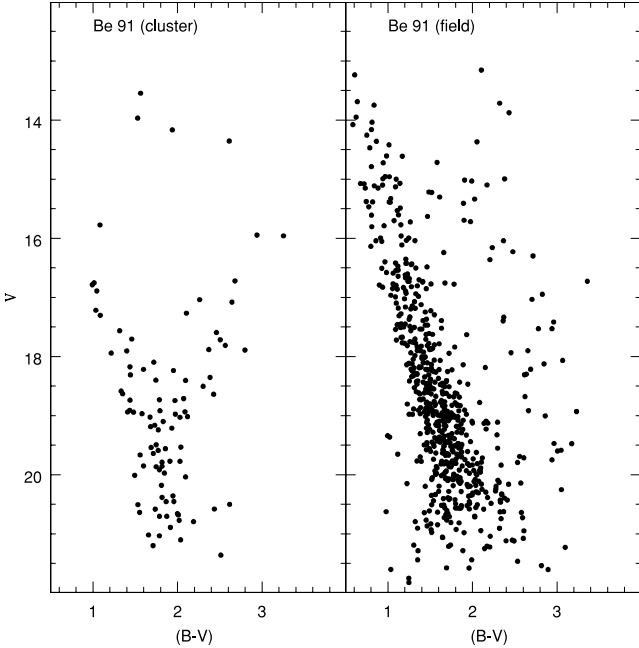
Figure 21. The V versus $(B - V)$ CMDs of the cluster Berkeley 9 (left) and field region (right). We assumed that stars located beyond a radius of 3.5 arcmin are field population.
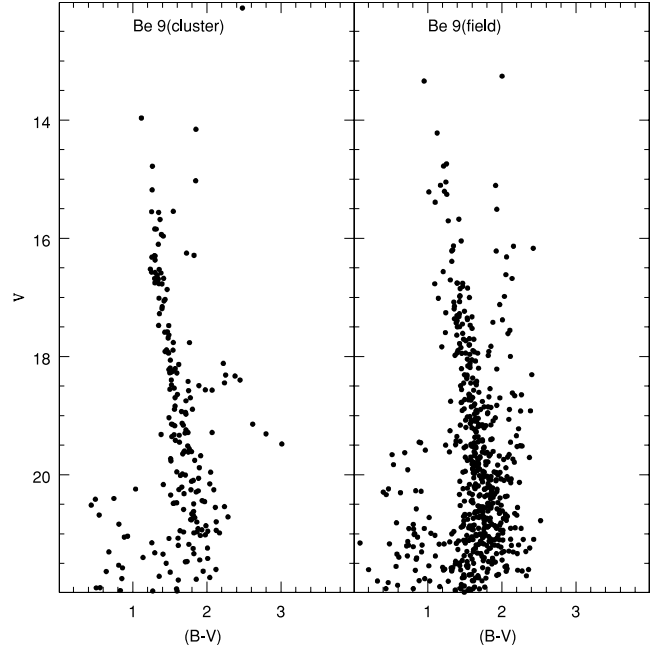
supported by the high reddening estimated for the cluster [$E(B - V) = 1.35$ mag]. The RDP suggests a dense core and a very small radius for the cluster. The cluster CMD shows a narrow MS when compared to the field CMD (Fig. 16), even though the field and the cluster CMDs do not look very different. There is a possibility that this cluster is a chance grouping of stars. The isochrone fits to the cluster CMD suggest that Berkeley 49 is a young cluster [log(age) = 8.35–8.5], located about 2.3 kpc away. In a previous study, Tadross

(2008) estimated a distance of 2.0 kpc and an age of 160 Myr, using 2MASS data, which are similar to the present estimates.

Berkeley 51. This cluster is located close to Berkeley 49 in the Galactic mid-plane. It is rich and compact, but like several others in this sample it is located in a clumpy Galactic field. Adjoining regions towards the north-west and south show fewer field stars, indicating variable extinction. The cluster is easily identified in the field due to its high density. The RDP shows that the cluster has a dense core
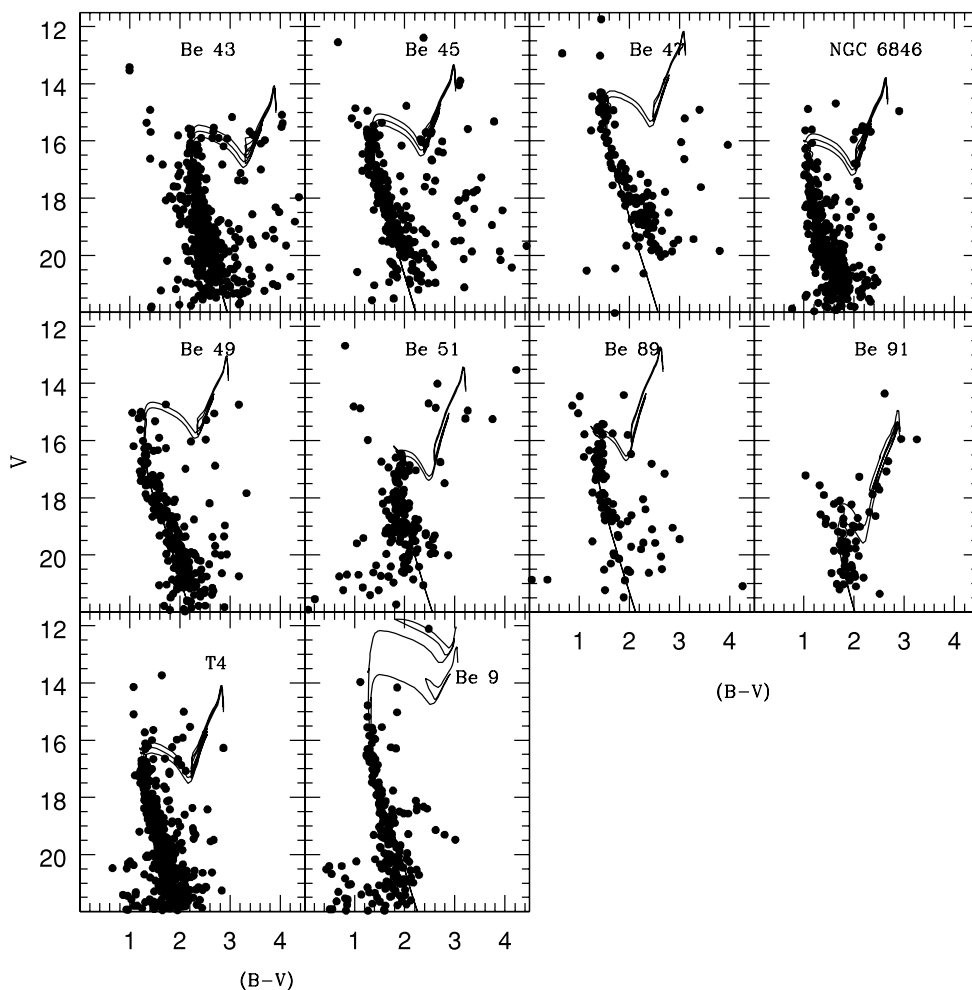
Figure 22. Isochrone fits to the *V* versus $(B - V)$ CMDs of 10 clusters. We have used Girardi et al. (2000) isochrones.

and a small radius. The cluster and the field CMDs are shown in Fig. 17. The cluster CMD is very different from the field CMD. The short and faint MS shows an older cluster embedded in a Galactic field rich in younger stars. The best isochrone comparison to the cluster CMD confirms that Berkeley 51 is probably a moderately old cluster [log(age) = 9.0–9.05], located at a distance of 1.3 kpc, with large reddening [$E(B - V) = 1.6$ mag]. In a previous study, Tadross (2008) estimated a distance of 3.2 kpc and an age of 150 Myr, using 2MASS data. This does not agree with the present estimations. Since it is a cluster of faint stars located in a rich and bright Galactic field, it is very likely that the parameters estimated by Tadross (2008) refer to the majority of field stars and not the faint cluster members.

Berkeley 89. This cluster is located at a somewhat higher Galactic latitude than the other clusters. It is relatively poor (Fig. 7) located in a rich Galactic field and only marginally distinct from the field. This cluster may also be an asterism. Nevertheless, a cluster sequence is clearly visible, when compared to the field CMD (Fig. 18), and the RDP shows a cluster although without a dense core, gradually merging with the field population. The best-matching isochrone indicates that the cluster is similar in age to Berkeley 51 with log(age) = 9.0–9.05. Berkeley 89 is located at a distance of 2.0 kpc, with a reddening of $E(B - V) = 1.05$ mag. In his previous study, Tadross (2008) estimated a distance of 3.0 kpc and an age of ∼1 Gyr, using 2MASS data. The cluster is dynamically relaxed and mass segre-

gation is likely to be present. This leads to the spatial separation of low-mass stars in the outer regions and high-mass stars near the cluster centre. Since we have considered a radius which is not much larger than the core radius, we probably do not sample enough low-mass stars to populate the lower MS.

Berkeley 91. The cluster is a relatively poor cluster with relatively faint stars in a rich field. The RDP shows that this is a sparse but small cluster. It may not be a real cluster. In order to identify the cluster sequence clearly, we used the core radius of the cluster to identify cluster stars. The cluster CMD shows a well-defined MS, a short sub-giant branch and a red giant branch (Fig. 19). If it is real, it is clearly the oldest of the sample studied here. The cluster sequence is also very different than the field CMD. The cluster CMD is well matched to old cluster isochrones [log(age) = 9.15–9.35], yielding a distance of 4.1 kpc.

Tombaugh 4. This is a fairly rich, compact cluster with several bright stars (Fig. 9). The RDP shows that the cluster has a dense core. The field is clumpy with an uneven distribution of stars. The cluster CMD has a narrow and well-defined MS, when compared to the field CMD (Fig. 20). The cluster MS has a sharp turn-off and a few red giants may be cluster members. The isochrone fits suggest that Tombaugh 4 is a moderately young cluster [log(age) = 8.6–8.7], located at a distance of 3.85 kpc.

Berkeley 9. This is an irregular cluster located in a somewhat sparse Galactic field. It appears only as a mild density enhancement
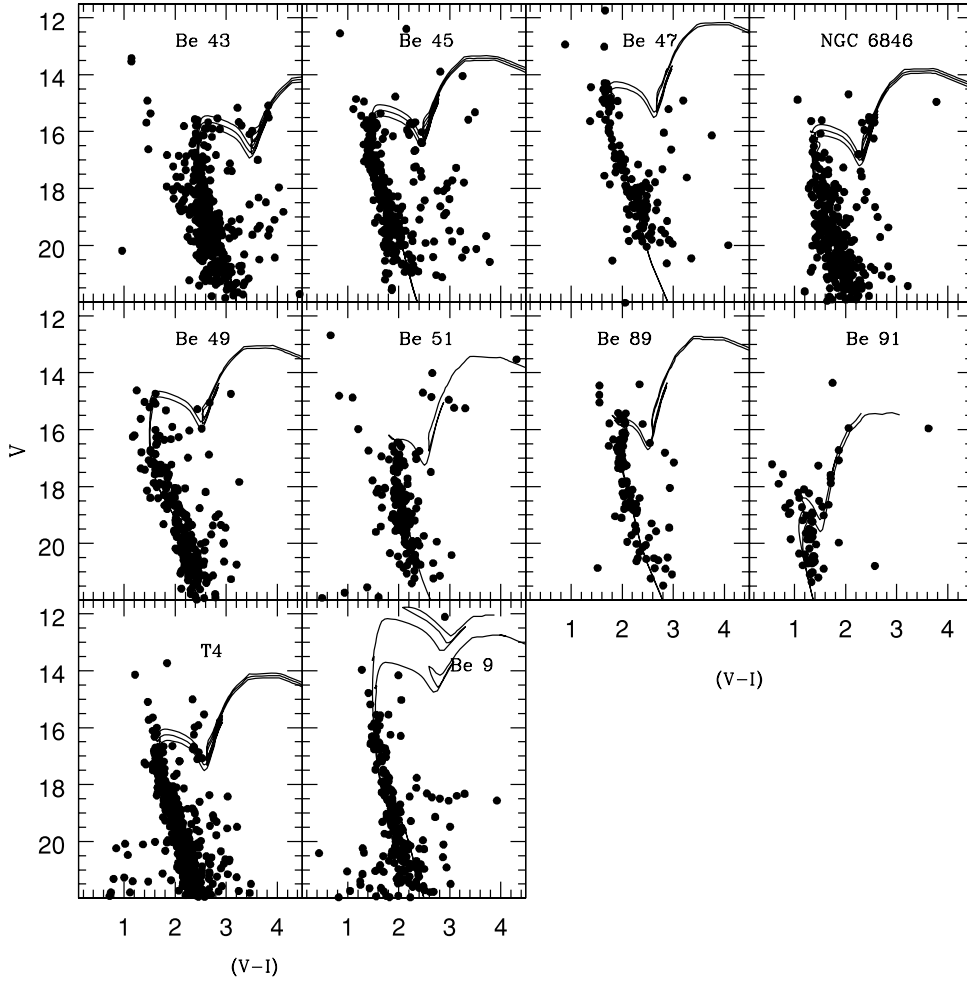
Figure 23. Isochrone fits to the *V* versus (*V* − *I*) CMDs of 10 clusters. We have used Girardi et al. (2000) isochrones.

Table 5. Cluster parameters as estimated by Tadross (2008), using 2MASS data.

Name	Radius (arcmin)	$E(B-V)$ (mag)	Distance (pc)	Log (Age)
Berkeley 43	4.5	1.52	1355 ± 60	8.6
Berkeley 45	3.5	0.82	2300 ± 105	8.77
Berkeley 47	2.0	1.06	1420 ± 65	8.2
Berkeley 49	2.4	1.57	2035 ± 110	8.2
Berkeley 51	1.5	1.66	3200 ± 145	8.17
Berkeley 89	2.5	1.03	3005 ± 135	8.9
Berkeley 91	1.7	1.00	2400 ± 110	8.7

in the field. The cluster MS is found to be well defined (Fig. 21), even though there is not much of difference between the cluster and the field CMD. The isochrone fit suggests that the cluster is young, [log(age) ∼ 7.8–8.0], and located at a distance of 2.3 kpc. This is the only cluster in our sample, about 100 Myr old and located below the Galactic plane ($Z = -113$ pc). Maciejewski & Niedzielski (2007) studied Be 9 and found the cluster to be very old [log(age) = 9.6], with $E(B - V) = 0.76$ and distance modulus 12.03. They identify a much fainter turn-off for the cluster. We find a good number of bright MS stars, above the turn-off identified by Maciejewski and Niedzielski and hence we estimate a much younger age for this cluster. This is also supported by the *V* versus (*V* − *I*) CMD.

5 DISCUSSION

This study presents the basic parameters of 10 previously neglected open clusters. The estimated parameters are summarized in Table 4. Eight of the clusters studied here are located in the first Galactic quadrant, five of them beyond a distance of 2 kpc. There are 10 previously studied clusters located between $l = 45°–90°$ and farther than 2 kpc. This study adds another five (Dias et al. 2002).

A plot with the previously known clusters and the clusters studied here (asterisk) is shown in Fig. 24. The only cluster studied previously, using CCD photometry in the range $l = 45°–57°$, is Berkeley 44 from our previous study, Carraro et al. (2006). In the present study, we have filled this gap with three more clusters. NGC 6846 is at a larger distance than IC 1311 (about 4 kpc away; Delgado et al. 1994), previously the most distant cluster known in this general direction. Because of its distance and age, NGC 6846 is a potential candidate to study the properties of the young Galactic disc in the first quadrant.

Most of the clusters studied here are embedded in rich Galactic fields and have large reddening towards them [$E(B - V) = 1.0–2.3$ mag]. They are also all rather sparsely populated clusters. Thus these clusters are difficult to study, and in spite of the appearance of the cluster CMDs and the radial density plots, there is a real possibility that some of them are simply asterisms of random, unrelated stars superposed on the Galactic background. Without proper motions or spectroscopy, it is not possible to ascertain which of them
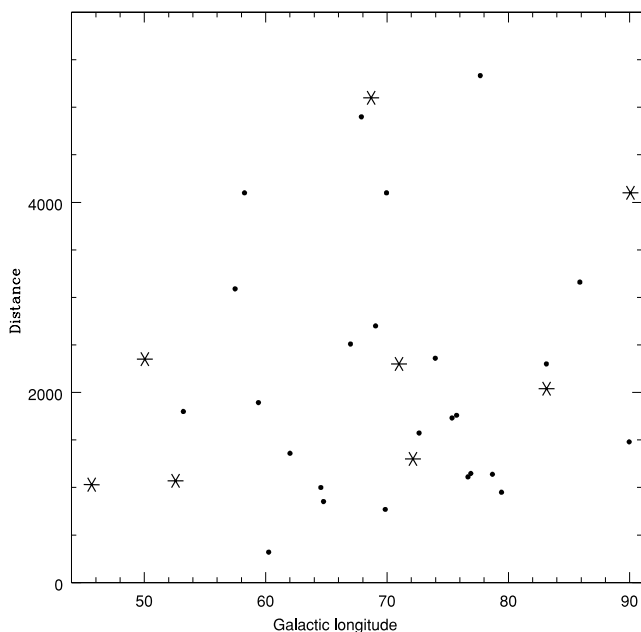
estimated by Hasegawa et al. (2008) for Berkeley 43 match well, except that we find a much younger age for the cluster.

The clusters studied here could be used to trace the structure of the disc, especially in the second half of the first quadrant. An interesting result is that the three clusters at $l = 70$–80 are above the plane, as expected from our knowledge of the warp, which is found above the plane in the first quadrant and below in the third both in optical (Momany et al. 2006) and in H I (Levine, Blitz & Heiles 2006).

Tombaugh 4 is a moderately young cluster located in the second quadrant. Subramaniam & Bhatt (2007) found an extension of the Perseus arm. This cluster appears to be part of this extension.

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Figure 24. Clusters studied so far using *UBV* CCD photometry in the second Galactic are shown as dots. Clusters studied in this paper as shown as asterisks.

might be accidental stellar configurations. Future studies of these clusters should note that some of them may not be real clusters. If some are found to be asterisms, then their contribution to the understanding of the Galactic structure, as discussed in this paper, is not valid.

Assuming that they are all real, our best estimates are that six of the clusters are likely to have ages less than 500 Myr and three more may be as old as or older than 1 Gyr. For comparison, Tadross (2008) estimated parameters of seven clusters in common with this study using 2MASS data. The estimated parameters broadly match for Berkeley 43, Berkeley 45, Berkeley 49 and Berkeley 89. The mismatch in the estimated parameters is probably a consequence of the fact that they are located in rich Galactic fields. The parameters