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Study of Stellar Populations in M 33 OB Associations

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Abstract. Young stellar populations are investigated in 17 classical OB associations/complexes in M 33, using precise UBVRI photometry from the recently published Local Group Survey (Massey et al. 2005). The star formation history in the associations is reconstructed roughly on the base of age and extinction estimates.

1 Introduction

The Triangulum galaxy M 33 is the third-brightest member of the Local Group. It is a late-type spiral of type Sc II–III. The large angular size of the M 33 and its intermediate inclination i=56° [9], make it particularly suitable for study of spiral structure and stellar content. General data on the galaxy used in this paper are given in Table 1.

M 33 shows two main spiral arms, both of which have a rather patchy and discontinuous structure. The spiral arms are most clearly outlined by H II regions but less recognizable as concentrations of loose star clouds and OB associations. The study of the OB associations and of the young stellar population in Triangulum galaxy at all was very intensive in the last two decades. In two subsequent works, Ivanov (1987, 1991) detected 289 associations on UBV plates, taken with 2-m RCC Bulgarian telescope. In an extensive research of the circumnuclear region, [10] found 41 associations, using UBV CCD photometric

Table 1. General data on Triangulum galaxy

RA(J2000.0)	$01^h33^m50\overset{s}{.}9$	Distance modulus [1]	24.64±0.15
DEC(J2000.0)	$+30°39'\,37''$	A_V [8]	$0\overset{m}{.}139$
l	$133\overset{\circ}{.}61$	$E(U-V)$ [8]	$0\overset{m}{.}088$
b	$-31\overset{\circ}{.}33$		

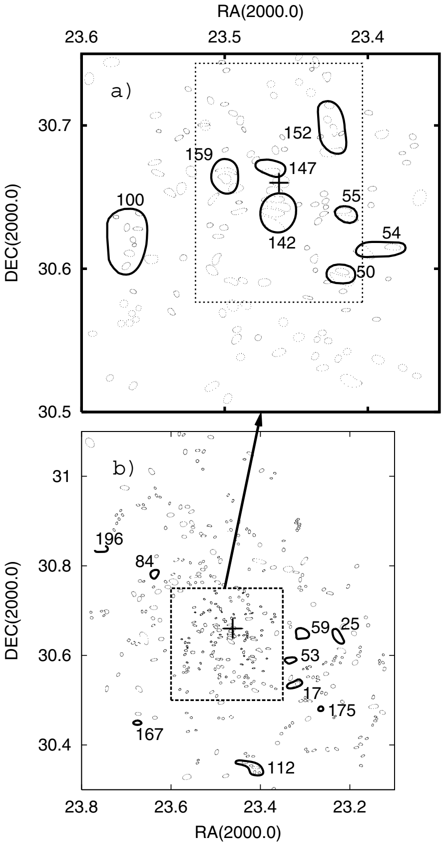

Figure 1. Map of the chosen OB associations in M 33: a) The circumnuclear region with the frame (dashed) of [10]; b) The whole area with outline of the circumnuclear region (dashed).

observations with the 3.6-m CFHT and 60-in Palomar telescope. She estimated their mean radii, masses and ages and pointed out their considerably smaller size in comparison with previous estimations. Young massive populations and their spatial correlation were studied also by [4] who found a pronounced gradient of the blue-to-red stars ratio with the galactocentric distance. Typical absolute photometric limit in all aforementioned studies was $\sim 21^m$.

2 Observational Data

We use accurate and deep UBV stellar photometry of 17 associations and complexes in Triangulum galaxy from the recently published Local Group Survey [7]. Imaging was done with Mosaic CCD camera on KPNO and CTIO 4-m

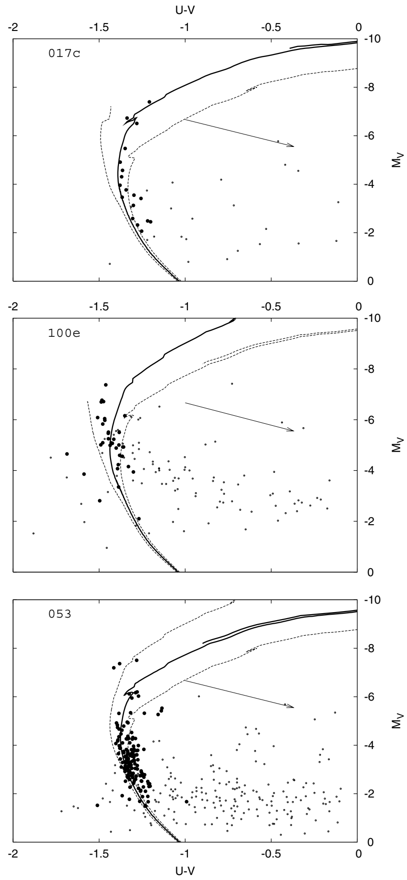

Figure 2. CM diagrams of 3 associations with increasing number of OB stars ($U - V <$ $0.$). The dereddened objects (large dots) and the reddening vector (arrow) are shown. Plotted isochrones correspond to the mean age of the association (solid thick line) and its error range (dashed).

telescopes of all the Local Group galaxies where recent star formation is observed, including 3 fields in M 33. Photometric errors are small: typically, in the range 0.001-0.003, increasing up to ~ 0.10 around the photometric completeness limit ($\sim 23^m$). The largest and richest complexes chosen are located in the circumnuclear region, studied initially by [10] who traced there the beginnings of two spiral arms. Map of the region with the outlines of the chosen associations is shown in Figure 1. The numbering of the associations is according to [2].

3 Dereddening Method

First look on the associations' CM diagrams reveals that the intrinsic individual extinctions vary in a large range. We performed a dereddening procedure, based on the method in [6], applied to several associations in M 31. Adopting fixed 'standard' value of total-to-selective-extinction ratio $R_V = 3.1$ and letting A_V to take values from 0.1 to 3.0, we calculate the χ^2 for each star, comparing its color with the predicted one from a set of Geneva isochrones with ages ($\lg(t)$) in range 5.8 to 7.6 [5]. The method is quite successful when the errors of photometry are small and the steps ΔA_V are comparable with the spacing between isochrones. After individual dereddening, the mean ages of the associations were determined by calculating the χ^2 of the dereddened stellar group to each isochrone and using it as a weight.

4 Results and Discussion

Color-magnitude diagrams of poor associations seemingly favor the hypothesis of coeval star formation (Figure 2, upper panel). However, when one considers associations with growing number of members, evidence for different stellar generations emerge (Figure 2, lower panels). It is obvious that significant fraction of stars formed more than 10^7 ago. Thus the determined mean ages (Table 2) of the associations correspond to some intermediate wave of star formation. Picture of continuous star formation becomes more clear when CMDs of the large complexes in the circumnuclear (Figure 3) and in the outer region (Figure 4) are examined. Youngest generation with $\lg(t) \sim 6.0 - 6.1$ is well pronounced especially in the central complexes where the star formation efficiency did not decrease essentially.

Table 2. Mean ages and extinctions of some of the studied associations. The average galactocentric distance in the rectified plane is given in Column 2. $N(OB)$ signifies the number of the dereddened blue stars ($U - V < 0.0$).

Ass. #	r_{gc}	$N(OB)$	lg (t)	$< A_V >$
17b	11.932	103	$6.59^{+0.17}_{-0.29}$	0.68±0.04
25	19.303	265	$6.57^{+0.15}_{-0.24}$	0.81±0.03
50a	4.466	60	$6.66^{+0.16}_{-0.24}$	0.95±0.06
50b	4.704	185	$6.57^{+0.15}_{-0.23}$	0.86±0.03
53	10.091	153	$6.69^{+0.14}_{-0.19}$	1.11±0.04
54a	4.974	67	$6.57^{+0.15}_{-0.23}$	0.92±0.06
54b	5.134	39	$6.57^{+0.15}_{-0.24}$	0.82±0.09
55a	3.422	73	$6.60^{+0.18}_{-0.28}$	0.99±0.06
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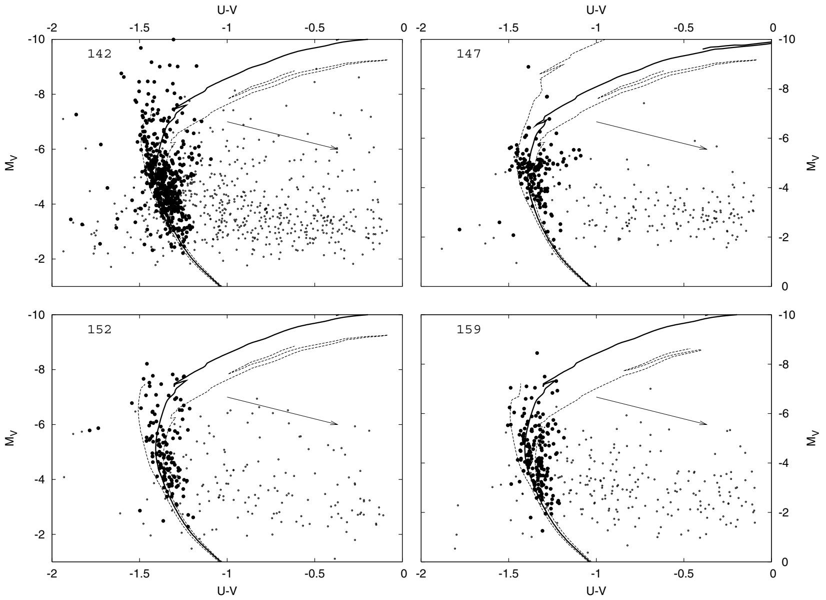

Figure 3. CM diagrams of 4 giant complexes in the circumnuclear region. The symbols are the same like in Figure 2.

The average extinction in the associations does not vary significantly while individual extinctions do and carry some information about the star formation process. In several cases dense cores of the complexes are outlined by stars with low extinction which indicates exhaustion of the interstellar material. These cores correlate spatially with the youngest and luminous stellar generation.

Table 3. Mean ages and extinctions of some of the studied complexes. The designations are the same like in Table2.

Com. #	r_{gc}	$N(OB)$	$\lg(t)$	$< A_V >$
17	11.900	136	$6.57^{+0.17}_{-0.29}$	0.71±0.04
54	5.054	106	$6.57^{+0.15}_{-0.24}$	0.88±0.05
55	3.584	148	$6.54^{+0.17}_{-0.27}$	0.85±0.04
112	20.226	224	$6.56^{+0.17}_{-0.28}$	0.72±0.03
142	1.316	578	$6.58^{+0.15}_{-0.23}$	0.95±0.02
147	0.964	167	$6.63^{+0.14}_{-0.20}$	1.28±0.04
152	4.647	143	$6.58^{+0.17}_{-0.28}$	1.09±0.05
159	3.239	207	$6.61^{+0.16}_{-0.27}$	1.10±0.04

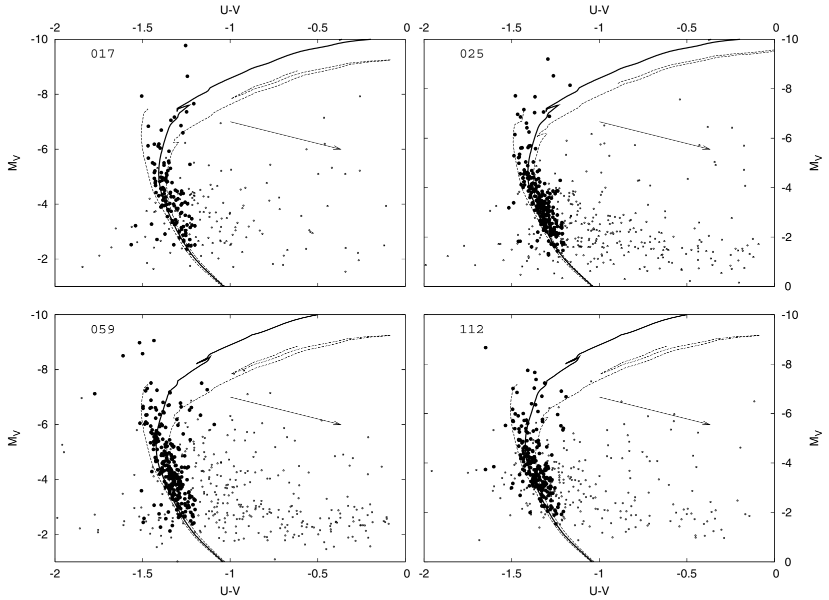

Figure 4. CM diagrams of 4 complexes in the outer region (see Figure 1). The symbols are the same like in Figure 2.

Acknowledgments

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