THE OPEN CLUSTER Tr 14

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Abstract. New photoelectric UBVRI data for stars in the young open cluster Tr 14 in the Great Carina Nebula (NGC 3372) are presented. The two-color diagram separates clearly the member from the non-member stars. Thus, the membership of about 39 stars is suggested. Those located in the compact core of the cluster, have smaller reddening dispersion than those around it. No star appears above the Main Sequence at the faint end of the color-magnitude diagram. A distance modulus of $V_0 - M_v = 12.20 \pm 0.2$ is obtained, which gives an age of about 5×10^6 yr. From only the photometry it is concluded to be slightly older than the nearby cluster Tr 16.

1. Introduction

The region of the Great Carina Nebula NGC 3372 includes several young clusters. One of them, Tr 14, is a small and compact group about 10 arc min to the northwest of the pecular object η Carinae. In an earlier work Feinstein *et al.* (1973, hereafter referred to as Paper I), discussed its photometric data jointly with Tr 16, including the relation of both to the gas and dust in the same region.

A remarkable dark dust lane near Tr 14 fixes the western border of the bright nebula. The interaction of the neutral material with the cluster stars has been described by Harvey *et al.* (1979) and de Graauw *et al.* (1981).

In particular, it appears interesting to check the result of de Graauw *et al.* (1981) suggesting Tr 14 to be somewhat younger than Tr 16. This means that Tr 14 would be the last formed group of stars in this region. As a newly formed group of stars will be related to the last formed stars (Elmegreen and Lada, 1977), it would be interesting to determine which is the youngest star cluster in this region.

New data for some stars around Tr 14 with a discussion of old and new measures are given here. A comparison with Tr 16 is also presented with the aim to derive a more clear conclusion about their possible differences.

2. The Observations

Besides those stars listed in Paper I, 19 additional stars in the very neighbourhood of Tr 14 were observed in the UBVRI system in February 1980 during one observing run. The 60- and 90-cm telescopes at the Cerro Tololo Inter-American Observatory were

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employed with a RCA 31034A photomultiplier and the standard filters set. Standard stars were selected from the E regions as listed by Graham (1979, 1982).

The new observed stars beginning with number 50 are identified in Figure 1. Some of them located in the dark region to the west of the cluster were classified on CTIO prism plates as of earlier spectral types by J. C. Forte. They were observed in this run and the results have been included here.

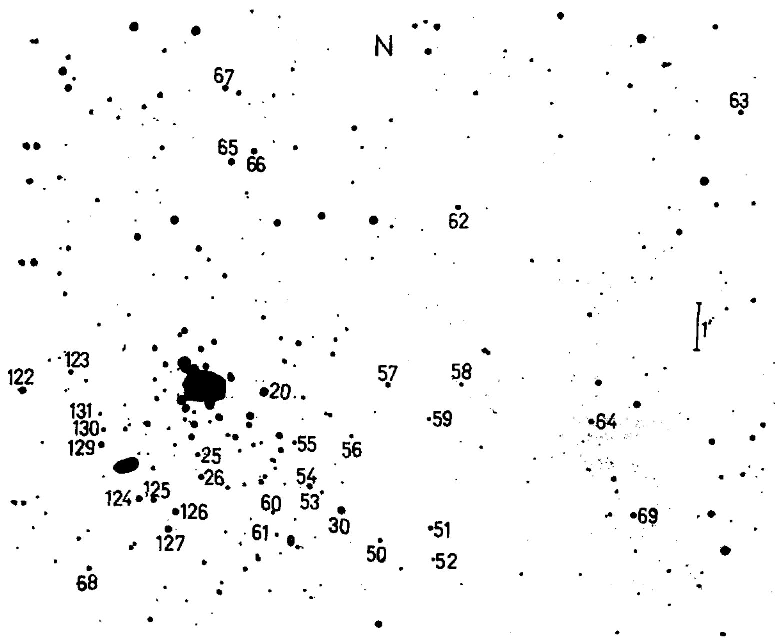

Fig. 1. Identification chart for stars measured in the region of the open cluster Tr 14. There are marked the new observed stars besides a few given in Paper I.

In Table I the magnitudes and color indices of the stars observed in the region of Tr 14 are presented. The last column gives indication about membership: c, means star in the core; sc, surrounds the core; pnm, probably non-member; nm, non-member. New data for two stars measured before are also listed in Table I, but for the remaining stars we have taken the values of Paper I.

3. Diagrams and Discussion

The color-magnitude and color-color diagrams are shown in Figures 2, 3, and 4. The color-color diagram suggests that those stars located below the intrinsic two-color sequence which are separated by a gap from the brighter stars may be nonmembers of the cluster. They are probably foreground objects of late *B* or *A* spectral types.

Another interesting point is related to the different reddening of the stars located in the conspicuous cluster's core, in comparison with the stars around it. This contrast is displayed in the two-color diagram of Figure 4, where the stars in the core have smaller

TABLE I
All stars in the region of Tr 14

No.	V	$B-V$	$U-B$	n	$V-R$	$R-I$	n	Remarks
A. From Paper I								
93160	7.82	0.17	−0.77					sc
93161	7.82	0.21	−0.70					sc
124	11.13	0.24	−0.65					sc
125	12.15	0.65	−0.04					nm
126	10.97	0.41	−0.47					sc
127	10.70	0.35	−0.55					sc
129	11.57	0.38	−0.28					pnm
130	12.72	0.30	−0.34					sc
131	13.48	0.32	−0.30					sc
93128	8.84	0.25	−0.74					c
93129	6.97	0.16	−0.78					c
3	10.80	0.26	−0.65					c
4	11.08	0.24	−0.68					c
5	11.41	0.33	−0.59					c
6	11.23	0.19	−0.68					c
7	12.12	0.32	−0.45					c
8	9.40	0.17	−0.75					c
9	9.92	0.21	−0.72					c
10	12.48	0.27	−0.50					c
11	12.78	0.39	0.05					nm
12	12.64	0.24	−0.48					c
13	12.63	0.24	−0.40					c
14	12.62	0.23	0.37					nm [a]
15	12.01	0.30	−0.15					pnm
16	13.60	0.27	−0.27					c
17	12.65	0.29	−0.32					c
18	12.15	0.27	−0.59					c
19	11.58	0.34	−0.42					c
20	9.61	0.28	−0.73					sc
21	10.88	0.34	−0.63					sc
22	12.34	0.32	−0.48					sc
24	12.12	0.37	−0.49					sc
25	12.88	0.32	−0.20					sc
26	11.93	0.37	−0.57					sc
28	12.50	0.39	−0.53					sc
29	11.97	0.50	−0.33					sc
New stars measured								
27	11.29	0.31	−0.59	4	0.26	0.34	2	sc
30	10.07	0.51	−0.53	3	0.37	0.43	1	sc
50	12.69	1.35	1.30	1				
51	12.38	0.37	0.11	1				nm
52	13.52	0.55	0.07	1				nm
53	13.48	0.56	−0.32	2	0.46	0.46	1	sc
54	12.11	0.20	−0.21	1				pnm
55	13.15	0.58	0.31	1				nm
56	13.32	0.30	0.25	1				nm
57	12.63	1.19	0.88	1				pnm
58	13.23	1.57	1.81	1				
59	13.18	0.34	0.28	2	0.20	0.23	1	nm
60	13.63	0.49	−0.33	1				sc
61	13.32	0.62	−0.29	1				sc
62	12.72	0.38	−0.28	1	0.32	0.35	2	sc
63	12.88	0.29	0.28	2	0.22	0.27	2	nm
64	12.53	0.22	0.19	2	0.12	0.13	2	sc
65	12.05	0.61	−0.45	2	0.44	0.47	2	nm
66	12.18	0.22	0.16	2	0.10	0.10	2	nm
67	12.62	0.30	−0.30	2	0.20	0.28	2	sc
69	11.88	0.19	−0.43	2	0.14	0.16	2	sc

[a] Star is unusual position.

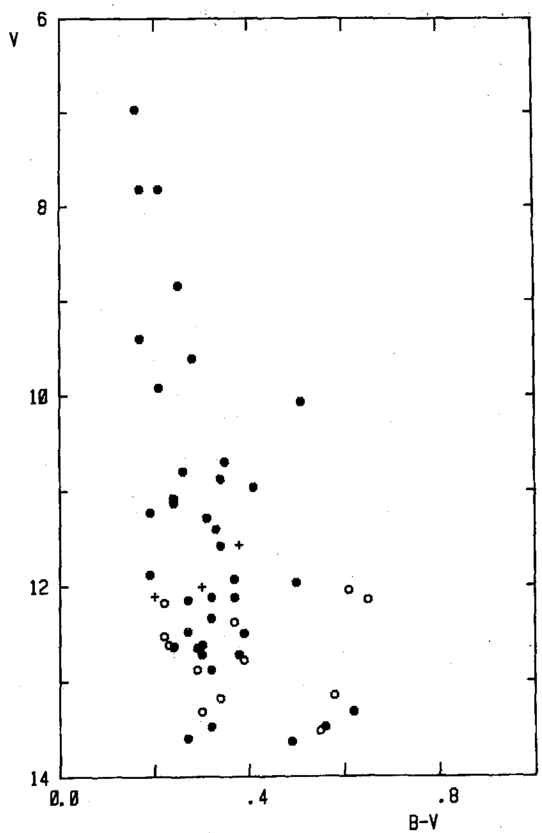

Fig. 2. The $(V, B - V)$ diagram for stars in Tr 14. Dots correspond to member stars, open circles to nonmembers, probable nonmember stars are plotted as plus signs.

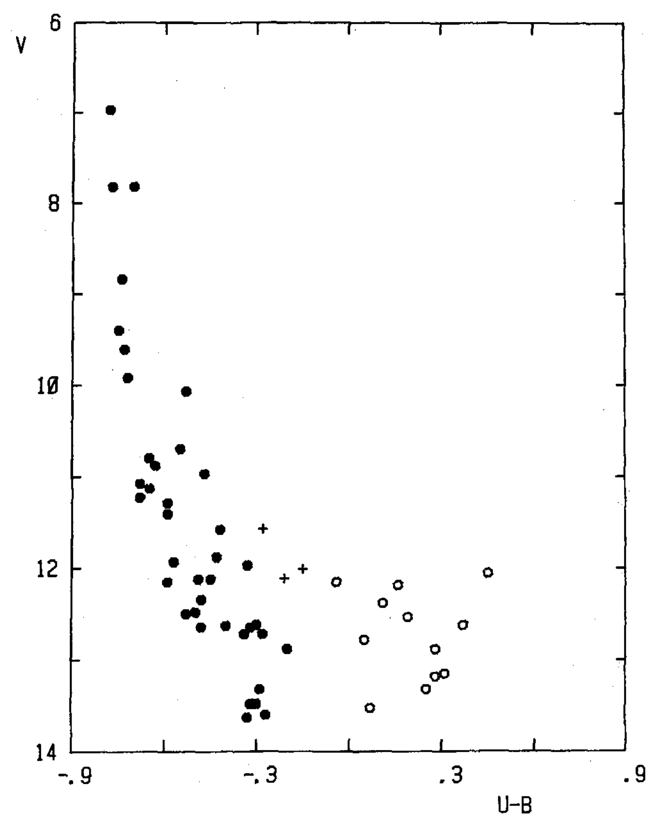

Fig. 3. The observed $(V, U - B)$ diagram for stars in Tr 14. The symbols are as in Figure 2.

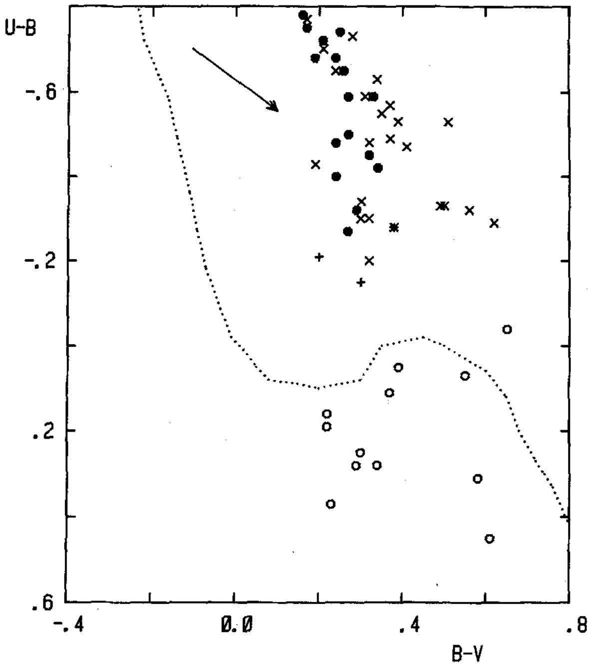

Fig. 4. The observed color-color diagram for stars in Tr 14. Dots are member stars in the core, crosses are those around the core. Nonmember stars are plotted as open circles, probable nonmembers as plus signs. The intrinsic relation for dwarfs is given as dashed line, the arrow indicates the direction of reddening.

dispersion about a mean than those stars around the cluster. It shows clearly that some of those outward of the core have greater reddening than those inside it. We define the core as the zone within approximately 1 arc min diameter around the center of the brightest stars.

Thus, eleven stars are probably nonmembers and another three doubtful members. Their color-color diagram (Figure 4) is similar to that of Tr 16 (see Figures 4 and 5 in Feinstein, 1982).

Star No. 54 may be a foreground object as it is located to the left of the observed B-dwarf sequence in the two-color diagram. Besides, it has also the smallest color excess of the possible member stars. The membership of star No. 125 becomes dubious, as it has a large color excess, $E(B - V) = 0.88$, in a place where these values look not so high. Moreover, stars Nos. 15 and 129 are also uncertain members according to the discussion which follows below.

All the stars were dereddened in the usual way; the intrinsic magnitudes V_0, and color indices $(B - V)_0$ and $(U - B)_0$ are listed in Table II. In addition, the color excesses and the distance modulus based on Schmidt-Kaler (1982) ZAMS are also presented in the last two columns. These data were computed with a similar procedure as in the revised discussion of the cluster Tr 16 (Feinstein, 1982), where we adopted $R = 3.2$ for the ratio of total to selective absorption of the reddening up to the cluster, and $R = 3.9$ for the intracluster correction. No solution appears possible for star No. 14, located in an

TABLE II
Corrected data for stars in Tr 14

No.	V_0	$(B-V)_0$	$(U-B)_0$	$E(B-V)$	$V_0 - M_v$
A. Members stars					
93160	6.22	−0.31	−1.11	0.48	10.02
93161	6.10	−0.30	−1.06	0.51	9.35
124	9.34	−0.29	−1.03	0.53	12.24
126	8.59	−0.27	−0.96	0.68	10.99
127	8.52	−0.28	−1.01	0.63	11.12
130	11.04	−0.20	−0.70	0.50	12.14
131	11.76	−0.19	−0.66	0.51	12.71
93128	6.89	−0.32	−1.15	0.57	11.29
93129	5.41	−0.31	−1.12	0.47	9.21
3	8.93	−0.29	−1.05	0.55	11.83
4	9.25	−0.30	−1.07	0.54	12.50
5	9.27	−0.29	−1.04	0.62	12.17
6	9.63	−0.29	−1.02	0.48	12.53
7	10.21	−0.24	−0.85	0.56	12.11
8	7.84	−0.30	−1.09	0.47	11.09
9	8.20	−0.30	−1.09	0.51	11.45
10	10.76	−0.24	−0.87	0.51	12.66
12	11.08	−0.23	−0.82	0.47	12.78
13	11.19	−0.20	−0.72	0.44	12.29
16	12.16	−0.17	−0.58	0.44	12.71
17	11.05	−0.19	−0.66	0.48	12.00
18	10.32	−0.27	−0.98	0.54	12.72
19	9.63	−0.23	−0.83	0.57	11.33
20	7.54	−0.32	−1.17	0.60	11.94
21	8.62	−0.31	−1.10	0.65	12.42
22	10.39	−0.25	−0.89	0.57	12.49
24	9.90	−0.27	−0.95	0.64	12.30
25	11.32	−0.15	−0.54	0.47	11.52
26	9.63	−0.29	−1.05	0.66	12.53
27	9.26	−0.28	−1.02	0.59	11.86
28	10.16	−0.28	−1.02	0.67	12.76
29	9.32	−0.25	−0.87	0.75	11.42
30	7.11	−0.32	−1.13	0.83	11.51
53	10.56	−0.26	−0.92	0.82	12.81
60	11.06	−0.24	−0.86	0.73	12.96
61	10.16	−0.26	−0.94	0.88	12.41
62	10.73	−0.20	−0.69	0.58	11.83
67	11.02	−0.18	−0.65	0.48	11.77
69	10.63	−0.20	−0.71	0.39	11.73
B. Probable non-member stars					
129	9.58	−0.20	−0.69	0.58	10.68
15	10.61	−0.13	−0.46	0.43	10.46
54	11.10	−0.13	−0.44	0.33	10.95
C. Non-member stars					
11	11.18	−0.09	−0.29	0.48	10.48
51	10.98	−0.06	−0.20	0.43	9.98
52	11.18	−0.12	−0.42	0.67	10.88
55	10.97	−0.05	−0.14	0.63	9.92
56	12.42	0.00	0.04	0.30	10.92
59	12.13	0.00	0.04	0.34	10.63
64	11.95	0.00	0.04	0.22	10.45
65	9.91	−0.01	0.00	0.62	8.51
66	11.56	−0.01	0.00	0.23	10.16
125	9.15	−0.19	−0.65	0.84	10.10

unusual position in the two-color diagram. Several explanations for stars of this kind were already discussed (Feinstein, 1982).

Stars Nos. 15 and 129 appear to the right of the Main Sequence in the H–R diagram and not in the faint end, which could be their position from the two-color diagram. This excludes both as members of the cluster. With the only exception of star No. 69, at 10 arc min to the southwest of the cluster, none other of the observed stars located in the dark region at the western border of the right nebula is likely to be a cluster member. Stars Nos. 30, 53, 60, and 61, very near to the dark border and in the southwestern direction have the largest reddenings in this region, $0.73 < E(B - V) < 0.88$. This might be due to their location close to the dense dust lane. The mean color excess for the cluster, if we do not take into account these four stars, is $E(B - V) = 0.55 \pm 0.08$.

The data of Table II have been used to construct the intrinsic color-magnitude array (Figure 4), including the fit of the ZAMS calibration given by Schmidt-Kaler (1982). Afterwards, the distance modulus for each star is computed, and in Figure 5 it is presented the $V_0 - M_v$ vs V_0 array which shows the evolutionary deviation diagram. The

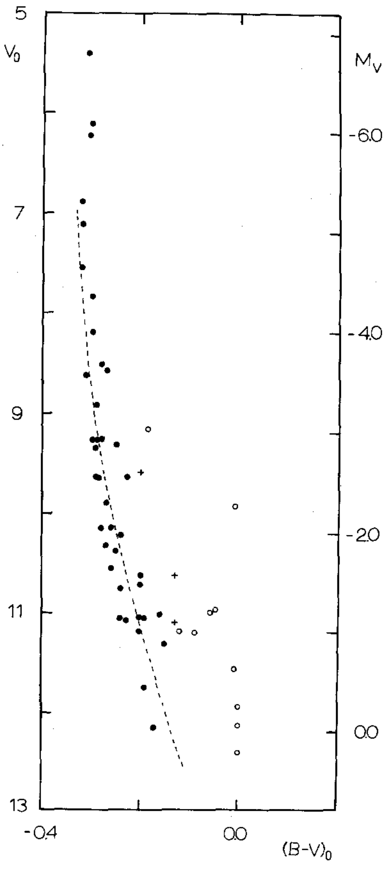

Fig. 5. The corrected color-magnitude diagram V_0 vs $(B - V)_0$ for stars in Tr 14. The dotted line represents the ZAMS shifted for $V_0 - M_v = 12.20$. The symbols are as in Figure 2.

curve correspond to 5.4×10^6 yr as given by Lindoff (1968). Finally, a distance modulus $V_0 - M_v = 12.20 \pm 0.2$ was adopted for the cluster Tr 14, which is approximately the value for Tr 16 (Feinstein, 1982), and almost coincident with $V_0 - M_v = 12.26$, as derived by Walborn (1982) in his discussion of the O3-type stars in the same region.

It is difficult to estimate with reliable precision the age of the cluster. The turn-off point at approximately $M_v = -4.5$, $(B - V)_0 = -0.32$, corresponds to a mass of $20 M_\odot$ (Schmidt-Kaler, 1982). A star of this mass begins to evolve at an age of about 5×10^6 yr, based on the models computed by Stothers (1972). We consider this number as the probable age of the cluster with an uncertainty of about 1.5×10^6 yr.

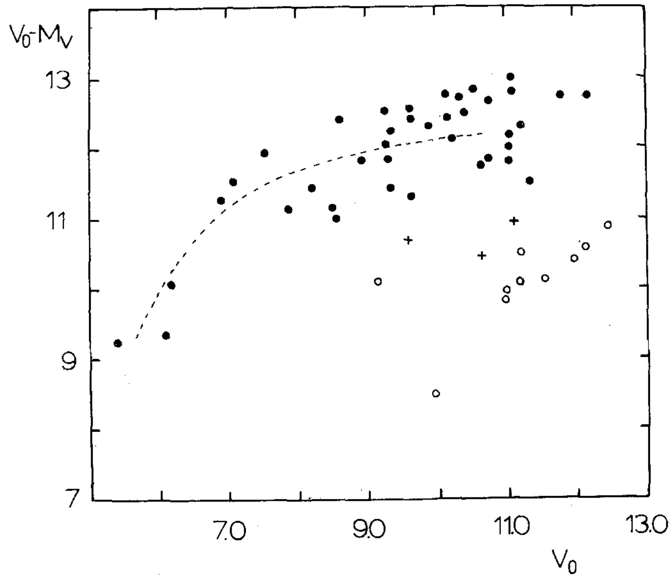

Fig. 6. The $V_0 - M_v$ vs V_0 for stars of Tr 14. The position of the evolutionary deviation curve from Lindoff (1968) is indicated by a dashed line. The symbols are as in Figure 2.

In order to make a comparison between the two nearby aggregates; Tr 16 and Tr 14, we present in Figure 7 the corresponding corrected magnitude V_0 vs the reddening-free parameter Q for member stars of both clusters. Since the brightest stars belonging to Tr 16 appear slightly bluer than those of Tr 14, this should imply that Tr 16 is somewhat younger, contrary to the conclusion of de Graauw *et al.* (1981). A solution for this disagreement would be highly desirable.

4. Summary

The analysis of the *UBV* data in the region of the cluster Tr 14 have yielded the following results: (1) 39 member stars have been identified from the two-color diagram. It is clear that stars with $U - B > -0.1$ are nonmembers. (2) The color excesses of stars in the core, about 1 arc min diameter, have smaller dispersion than those of the stars around

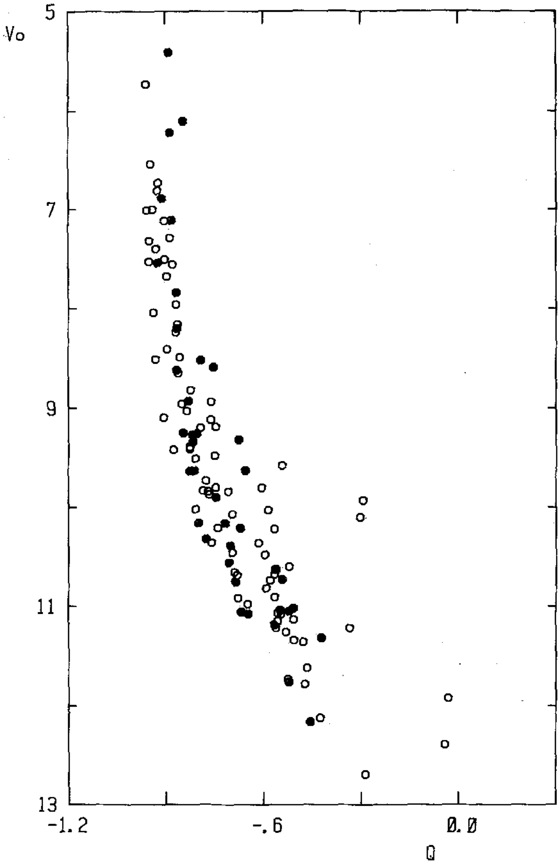

Fig. 7. The corrected magnitude V_0 vs the reddening-free parameter Q for member stars of Tr 14 (dots) and Tr 16 (open circles).

it. (3) The distance modulus inferred from the volutionary deviation curve is $V_0 - M_v = 12.20 \pm 0.2$, based on the ZAMS of Schmidt-Kaler (1982). (4) The age is estimated at $5 \times 10^6 \pm 1.5 \times 10^6$ yr. But, it is clear that in this particular case the photometry is not precise enough to derive accurate ages. (5) In conclusion, Tr 14 is likely to be not younger than Tr 16, at least from the photometric data. Spectroscopic information about their member stars, especially the brightest, will throw more light on the study of these very young clusters and on their origin and evolution.

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