PHOTOELECTRIC PHOTOMETRY OF THE OPEN CLUSTER Tr-1

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Abstract. The H-R diagram of the open cluster Tr-1 based on Oja-membership and *U*, *B*, *V* photoelectric photometry is presented. The colour excess $E(B-V)$ is $0^m.52$. The distance modulus to the cluster and its age are, respectively, estimated at $11^m.6$ and 2.6×10^7 yr.

1. Introduction

The extremely concentrated galactic cluster Tr-1 in Cassiopeia (centre: $\alpha_{1950}=01^h32^m.3$, $\delta_{1950}=+61°02'$; $l^{II}=128°.2$ and $b^{II}=-1°.1$) lies at the outer edge of the Perseus spiral arm (+I) and has been assigned a class I 3*p* by Ruprecht (1966). McCuskey and Houk (1964) studied the cluster photographically in the *UBV* system while Steppe (1974) has presented three colour RGU photographic photometry. The region considered by these authors had an angular radius of 3'.7 around the cluster centre. Oja (1966), through proper motion study, has determined the membership of the stars in the cluster in a region of radius 2'.4 around the same centre.

Oja reported 37 stars to be physical members and another one star as possible member of the cluster. In the same region McCuskey and Houk had on the basis of *UBV* photographic photometry, earlier reported 18 stars to be the physical members while Steppe on the basis of RGU photographic photometry reported 22 physical member stars. The apparent standard magnitudes and colours of the stars observed in the cluster field considered by Oja are listed in Table I along with their cluster-membership status as considered variously by McCuskey and Houk (1964), Oja (1966) and Steppe (1974). A comparison of photometric and proper motion membership methods in open clusters by Sanders (1976) indicates a roughly 50% uncertainty in the method of photometric cluster memberships. Therefore, the members and probable members of the cluster assigned by Oja (1966) (except star No. 1168 which was not possible to observe with our 104-cm telescope due to its faintness) alone are considered here. Even the photographic magnitudes and colours are known barely for one-half of the member stars (Oja-membership). Thus the colour-magnitude diagram of the cluster is incomplete. The distance to the cluster determined by various authors lies in range 1.2 kpc to 3.33 kpc with a modal value of 2.2 kpc (cf. Alter *et al.*, 1970). We have, in this work, given the photoelectric H-R diagram and have discussed the distance modulus and age of the cluster.

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TABLE I

The apparent standard magnitudes and colours of stars in Tr-1. The star number is borrowed from Oja (1966)

Oja Star No.	V	$(B-V)$	$(U-B)$	Membership*				
				Oja (1966)	Steppe (1974)		McCuskey and Houk (1964)	
					Star No.	Membership	Star No.	Membership
1078	$13^m.09$	$0^m.59$	$0^m.48$	m	39	f	48	f
1085	15.03	0.40	0.05	f	36	m	27	m
1088	13.18	0.78	0.29	f	41	f	47	f
1090	13.47	0.75	0.27	f	—		—	
1097	13.44	0.47	−0.20	f	32	m	21	m
1112	13.72	0.41	−0.06	m	—		—	
1115	13.98	0.44	−0.13	m	—		—	
1117	14.52	0.45	0.06	m	52	m	30	m
1118	14.79	0.52	0.17	m	60	m	—	
1125	13.61	0.40	0.13	m	100	f	—	
1126	14.88	0.36	0.13	m	44	m	32	m
1127	14.46	0.53	0.26	m	45	m	—	
1130	14.14	0.48	−0.04	m	46	m	44	m
1137	12.71	0.39	−0.22	m	—		—	
1138	14.18	0.38	0.15	m	47	f	43	m
1140	14.19	0.24	0.10	m	48	f	42	m
1143	10.67	0.30	−0.42	m	d	m	—	
1144	13.87	0.43	−0.12	m	50	m	18	m
1145	14.50	0.25	−0.12	m	63	m	61	m
1146	12.09	0.30	−0.27	m	61	m	—	
1150	11.30	0.33	−0.36	m	—		—	
1152	13.55	0.42	0.03	m	49	f	41	m
1153	12.02	0.41	−0.48	m	c	f	—	
1156	14.24	0.43	0.07	m	96	m	64	m
1157	15.11	0.21	−0.08	m	62	f	—	
1158	9.97	0.32	−0.20	pm	b	m	—	
1163	15.33	0.62	0.32	m	64	f	—	
1164	11.48	0.30	−0.36	m	a	m	—	
1170	11.39	0.26	−0.42	m	65	m	98	m
1173	12.54	0.36	−0.24	m	59	m	—	
1178	15.04	0.34	0.19	m	54	m	34	m
1181	14.86	0.44	0.23	m	—		—	
1182	14.28	0.45	0.11	m	57	m	40	m
1183	15.26	0.34	0.16	m	—		—	
1184	13.58	0.74	0.31	f	94	f	—	
1187	13.92	0.51	−0.10	m	58	m	—	
1188	13.86	0.91	0.38	m	56	f	39	f
1191	12.76	0.40	−0.01	m	66	f	—	
1193	12.37	0.31	−0.38	m	67	m	—	
1208	14.76	0.36	0.13	m	55	m	35	m
1223	14.35	0.65	0.17	m	77	f	78	m
1246	14.07	0.42	−0.09	m	75	m	38	m
1248	13.99	0.86	0.20	f	81	f	77	m

* f=field star; m=member star; pm=possible member star.

2. Observations and Reductions

The observations were carried out between October 1974 and February 1975, on the 104-cm Sampurnanand reflector of the Uttar Pradesh State Observatory. The instrumentation and method of observation were the same as described by Joshi *et al.* (1975). For standardizing the instrumental magnitudes, photoelectric sequences employed by Hoag *et al.* (1961) for the open cluster NGC 2169, were used after applying necessary corrections for nightly extinction. The computed standard deviations of our observations are better than $\pm 0^m.02$ in V, B and U.

3. Results and Dicussions

The interstellar reddening was determined from the colour-colour diagram of the cluster stars (Figure 1), taking the slope of the reddening line to be 0.72. The distance to the cluster is obtained by fitting the standard zero-age main-sequence to the observed cluster main-sequence (Figure 2). The results obtained are:

$E(B - V) = 0^m.52$; $(m - M)_0 = 11^m.64$;

$E(U - B) = 0^m.37$; Distance = 3.3 kpc.

$A_v = 1^m.66$;

In the colour-magnitude diagram of the cluster (Figure 2), a well-defined cluster main-sequence is seen and no giant branch appears. From the positions of star Nos.

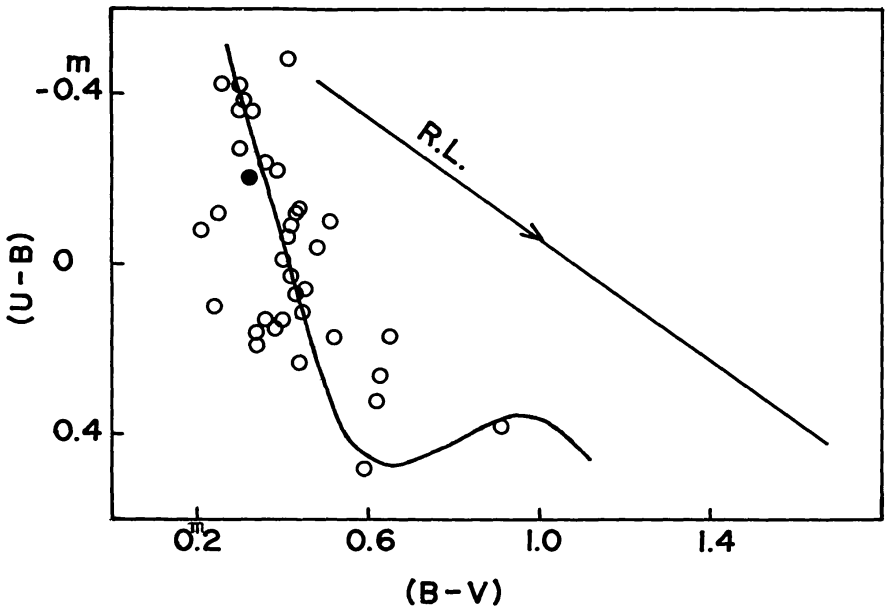

Fig. 1. The colour-colour diagram of the open cluster Tr-1. The cluster members and probable cluster members are denoted by ○ and ● respectively.

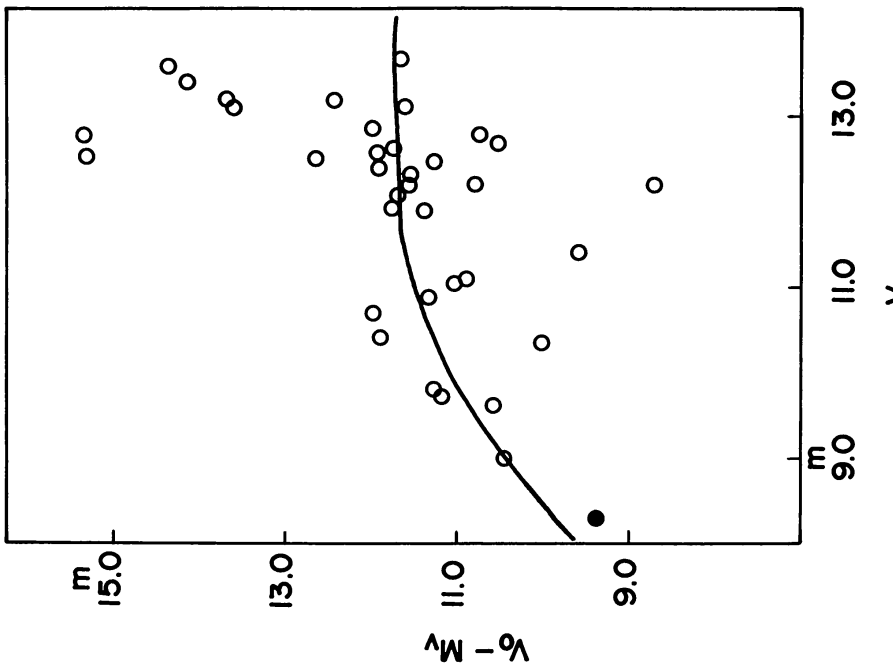

Fig. 3. The evolution deviation curve of the open cluster Tr-1. The cluster members and probable cluster members are denoted by ○ and ● respectively.

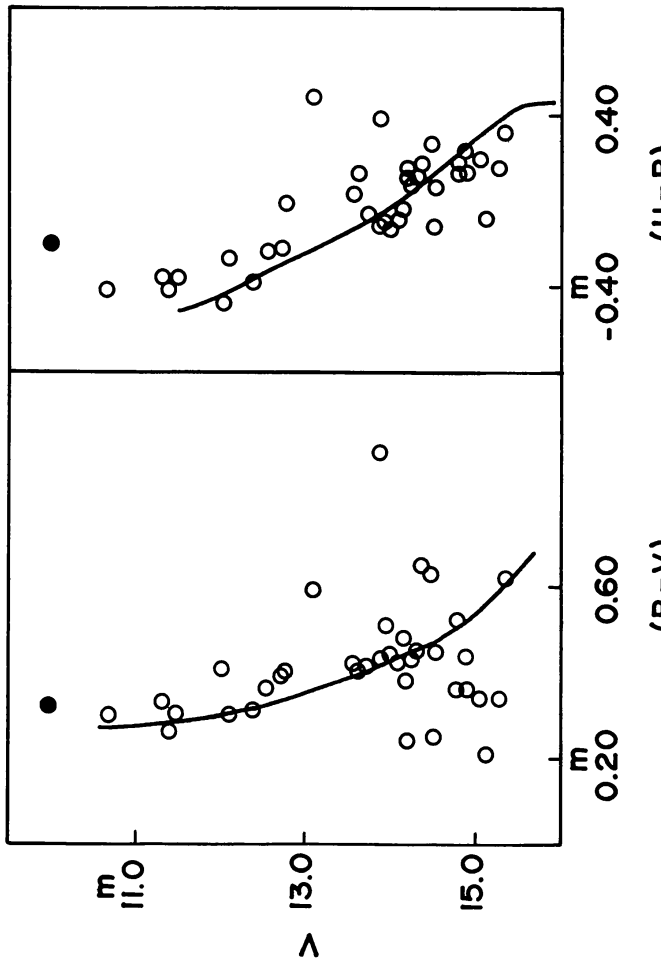

Fig. 2. The colour-magnitude diagram of the open cluster Tr-1. The cluster members and probable cluster members are denoted respectively by ○ and ●. The solid lines represent the best fit zero-age main-sequence.

1188 and 1078 in the colour-magnitude diagram, it appears that they are in the pre-main sequence contraction phase.

Alongside, using the observed values of $(U-B)$ and $(B-V)$ colours for stars of spectral types earlier than A0 and lying on the observed cluster main sequence, the colour excesses $E(B-V)$ and $E(U-B)$ have been calculated in the same manner as described by Sagar (1976) with the results: $E(B-V)=0^m.51$, $E(U-B)=0^m.38$, which are in good agreement with the values obtained from the colour-colour diagram (Figure 1).

The evolution deviation curve (V_0, V_0-M_v) (Figure 3) is constructed for the member stars. The fitting of the theoretical evolution deviation curve (Johnson, 1960) to the calculated one leads to a corrected distance modulus of $11^m.75$ which is in fair agreement with the value determined above.

Using the technique of Gray (1965), the apparent integrated magnitude $I(V)$ and colour $I(B-V)$, $I(U-B)$ have been found to be

$$I(V)=8^m.61, \quad I(B-V)=0^m.34, \quad I(U-B)=-0^m.27.$$

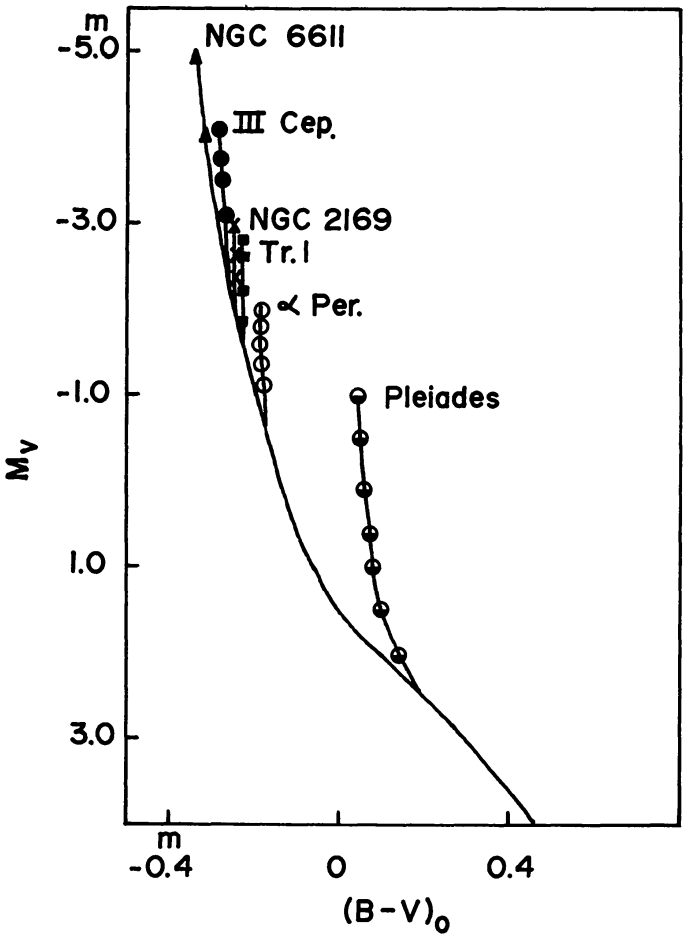

Fig. 4. Position of Tr-1 in the colour-magnitude diagram of clusters with well-determined ages.

An evolutionary effect is visible in the colour magnitude diagram of the cluster. The absolute magnitude of the brightest member star is $M_v = -3^m.3$ and the intrinsic colour $(B-V)_0 = -0^m.20$, which corresponds to spectral type B3. The value of the $(B-V)_T$, the colour at the turn-off point, is estimated to be $-0^m.23$ for this cluster. The age t of the cluster is estimated, using the expression (Sandage, 1957)

$$t = 1.1 \times 10^{10} ML^{-1},$$

where M and L are the mass and the luminosity, both in terms of the Sun, of the main sequence turn-off point. Using the value of $(B-V)_T = -0^m.23$, an age of 2.6×10^7 yr is estimated which is in fair agreement with the estimate of 10^7 yr by Steppe (1974). To compare the cluster Tr-1 with other clusters, we have plotted a composite colour-magnitude diagram (Figure 4) for some clusters with well-determined ages. This diagram shows that cluster Tr-1 is older than III Cep of age 1.6×10^6 yr (cf. Alter *et al.*, 1970), and NGC 2169 of age 0.9×10^7 yr (Sagar, 1976) but is younger than α-Per Cluster of age 3×10^7 yr (cf. Alter *et al.*, 1970). This supports the above age estimation for the cluster Tr-1.

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References

Alter, G., Ruprecht, J., Vanýsek, V., and Balasz, B.: 1970, *Catalogue of Star Clusters and Associations*, 2nd edn., Akadēmiai kiadō, Budapest.
Gray, D. F.: 1965, *Astron. J.* **70**, 362.
Hoag, A. A., Johnson, H. L., Iriarte, B., Mitchell, R. I., Hallam, K. L., and Sharpless, S.: 1961, *Publ. US Naval Obs., 2nd Series*, **17** (part 7), 410.
Johnson, H. L.: 1960, *Lowell Obs. Bull.* **5**, 17.
Joshi, U. C., Sagar, R., and Pandey, P.: 1975, *Pramána* **4**, 160.
McCuskey, S. W. and Houk, N.: 1964, *Astron. J.* **69**, 412.
Oja, T.: 1966, *Arkiv Astron.* **4**, 15.
Ruprecht, J.: 1966, *Bull. Astron. Inst. Czech.* **17**, 34.
Sagar, R.: 1976, *Astrophys. Space Sci.* **40**, 447.
Sandage, A.: 1957, *Astrophys. J.* **125**, 435.
Sanders, W. L.: 1976, *Astron. Astrophys.* **46**, 131.
Steppe, H.: 1974, *Astron. Astrophys. Suppl.* **15**, 91.