STUDY OF THE GALACTIC CLUSTER NGC 581

Ram Sagar and U.C. Joshi

Uttar Pradesh State Observatory, Manora Peak, Nami Tal 263129

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Abstract

Photoelectric magnitudes and colours in the UBV system have been determined for 73 stars in NGC 581. The value of the interstellar reddening is $0^m.38$. The distance modulus to the cluster is estimated at $12^m.16 \pm 0^m.1$ and an age of 4×10^7 years is ascribed The cluster luminosity function is compared with the general and initial luminosity functions.

1. INTRODUCTION

The galactic cluster NGC 581 (≡M 103) in Cassiopeia lies at the outer edge of the Perseus spiral arm(+I). Its coordinates are :—

α 1950 = $01^h29^m.9$; $l_{II} = 128^\circ.02$;

δ 1950 = $+60^\circ27'.0$. $b_{II} = -1^\circ.76$.

The cluster has been assigned a class III2p by Ruprecht (1966). Oja (1966) determined the membership of the stars for the cluster on the basis of a proper motion study and reported 73 stars to be its possible members. Out of these, UBV photoelectric magnitudes and colours are presently known for only twenty stars (of. Mermilliod 1976) while for most of the remaining stars, only photographic magnitudes and colours are known (Hoag et. al. 1961 ; McCuskey and Houck 1964 ; Moffat 1972). The photographic V magnitudes, (B-V) and (U-B) colours obtained by different authors, are compared in Fig. 1(A), Fig. 1(B) and Fig. 1(C) respectively. The mean deviation of the differences in the V magnitudes, (B-V) and (U-B) colours are given in Table 1, where H, K and M refer to Hoag *et al.* (1961), McCuskey and Houck (1964) and Moffat (1972), respectively. There magnitudes and colours of the member stars show significant differences. The distance to the cluster, determined by various authors, lies in the range 0.9 kpc to 3.55 kpc with a modal value of 2.4 kpc (cf. Alter *et al.* 1970).

The present study is aimed at determining the UBV photoelectric magnitudes and colours for the 73 member

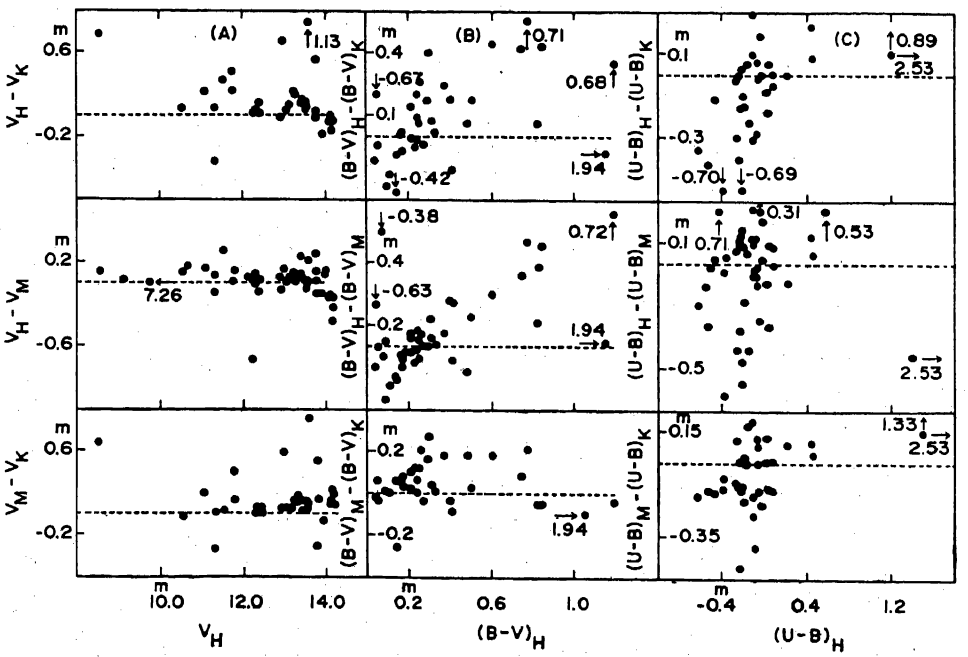

Fig. 1 : (A) Comparison of V magnitudes determined by various authors.
(B) Comparison of (B-V) colours determined by various authors.
(C) Comparison of (U-B) colours determined by various authors.
H, K and M are explained in the text.

stars, the reddening across the cluster, the distance modulus to the cluster and the age of the cluster.

Table 1

No. of common stars		V	(B - V)	(U-B)
H-K	35	$0^m.21$	$0^m.20$	$0^m.21$
H-M	46	0.12	0.15	0.19
M-K	41	0.18	0.09	0.17

Table 2

Photoelectric magnitudes and colours of stars in NGC 581. The stars with asterisked serial number belong to the photoelectric sequence by Hoag *et al.* (1961).

Sl. No.	Star number by Oja (1966)	V	(B-V)	(U-B)
1	2	3	4	5
		m	m	m
1	610	13.18	0.30	—0.33
2	618	14.62	0.34	0.12
3	626	14.37	0.67	—0.06
4	629	14.04	0.75	0.45
5	632	14.51	0.41	0.25
6	633	14.37	0.57	0.49
7	638	13.42	0.28	—0.09
8	648	15.13	0.35	0.29
9	660	13.80	0.28	—0.22
10*	661	13.49	0.37	—0.07
11*	662	10.45	0.24	—0.34
12	664	13.19	0.17	—0.25
13*	666	11.77	0.22	—0.33
14	667	14.52	0.46	—0.28
15	669	12.38	0.20	—0.28
16	671	14.33	0.77	0.30
17	672	15.17	0.34	0.29
18	673	14.08	0.37	—0.06
19	674	14.45	0.29	0.10
20	676	13.96	0.58	0.27
21	677	13.64	0.34	—0.07
22*	679	7.22	0.26	—0.39
23	681	14.45	0.44	0.10
24	682	14.64	0.12	0.38
25	683	13.85	0.39	0.11
26	684	10.09	—0.01	—0.40
27	688	11.89	0.16	—0.44
28	691	11.45	0.21	—0.46
29	692	13.67	0.35	0.03
30	693	12.30	0.20	—0.24
31*	694	11.23	0.23	—0.48
32	700	13.25	0.22	—0.08
33	703	11.85	0.15	—0.47
34*	705	12.42	0.12	—0.15
35	706	13.66	0.66	0.28
36	708	15.05	0.39	0.30
37	710	14.43	0.56	0.16
38	711	14.46	0.20	0.12
39*	712	10.59	0.17	—0.49
40	714	11.09	0.22	—0.46

Table 2 (*Continued*)

Sl. No.	Star Number by Oja (1966)	V	(B-V)	(U-B)
1	2	3	4	5
41*	717	13.57	0.75	0.25
42	719	13.57	0.21	—0.26
43	721	11.38	0.16	—0.20
44	722	12.41	0.15	—0.24
45	724	13.85	0.36	—0.08
46	729	13.40	0.11	—0.28
47	730	14.91	0.38	0.32
48	732	14.20	0.42	0.18
49	735	13.12	0.16	—0.12
50*	737	8.98	0.20	—0.54
51*	740	13.28	0.48	0.39
52	742	8.34	2.09	2.38
53	744	13.29	0.37	—0.12
54	745	10.99	0.17	—0.46
55	750	13.70	0.24	—0.18
56	752	13.57	0.27	—0.07
57	755	12.50	0.24	—0.16
58	756	12.24	0.20	—0.30
59	763	14.92	0.42	0.19
60	765	14.67	0.24	—0.12
61	769	15.07	0.36	0.10
62	770	13.96	0.30	0.13
63	773	14.72	0.29	0.00
64	779	13.35	0.38	0.07
65	780	14.68	0.30	0.26
66	783	14.52	0.50	0.43
67	785	13.21	0.26	—0.28
68	790	13.22	0.64	0.41
69	793	13.68	0.73	0.25
70	799	13.28	0.27	—0.18
71	810	14.41	0.34	0.13
72	813	14.80	0.35	0.25
73	815	13.41	1.11	0.97

2. OBSERVATIONS AND REDUCTIONS

The observations were carried out between September 1976 and December 1976 on the 104-cm Sampurnanand reflector of the Uttar Pradesh State Observatory. The method of the observations and the instrumentation are the same as described earlier (Joshi *et al.* 1975 ; Sagar and Joshi 1978b). For standardizing the instrumental magnitudes, we have used the photoelectric sequences given by Hoag *et al.* (1961). The computed standard deviations of our observations are $\pm 0^m.032$, $\pm 0^m.021$ and $\pm 0^m.016$ in U, B and V filters, respectively.

3. MEMBERSHIP

McCuskey and Houck (1964) and Moffat (1972) reported cluster membership on the basis of UBV photographic photometry while Steppe (1974) did it on the basis of RGU photographic photometry. Following earlier discussions (Joshi and Sagar 1977), we have based cluster membership on Oja's (1966) proper motion study alone. In doing so, we do realize that the proper motions only pick out stars which may be cluster members, with a possibility that some foreground and background field

stars that have the same proper motion as the cluster members are also accidentally included. Alternatively, radial velocity too can be used to sort out the field stars, but the absence of pertinent data in the present case does not permit application of this criterion. Again, while considerations of spatial distribution towards the cluster centre enable one to estimate the number of field stars, this still does not enable picking out of individual field stars.

The apparent standard V magnitudes and the (B-V), (U-B) colours of the 73 member stars in NGC 581 are isted in Table 2.

4. REDDENING

The interstellar reddening was determined from the colour-colour diagram (CCD) of the member stars, taking the slope of the reddening line to be $0^m.72$ (Fig. 2). The values of the colour excesses, E(B-V) and E(U-B), thus obtained are $0^m.38$ and $0^m.27$, respectively.

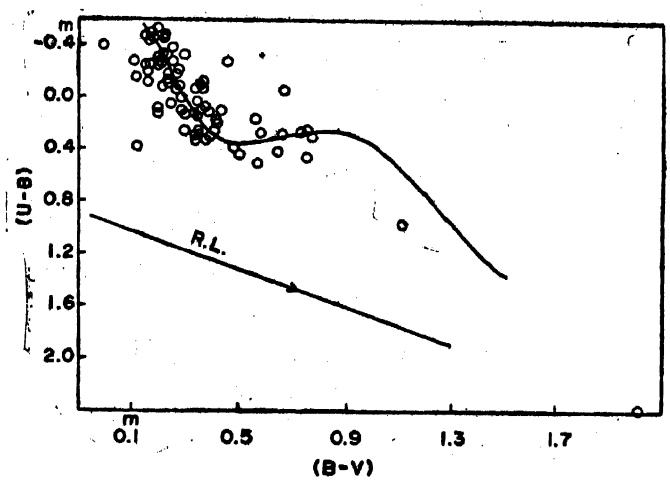

Fig. 2: The colour-colour diagram of the open cluster NGC 581.

An improved Q-method for the determination of intrinsic colour indices of early-type main sequence stars has been given by Gutierrez-Moreno (1975). Using equations (3), (5) and (20) in the last mentioned work, the colour excess E(B-V) can be written as :—

$$E(B\text{-}V)=29.94-10\ (8.964+0.2C_1)^{\frac{1}{2}} \text{ for } X \geqslant 0.70,$$

where $C_1 = (U\text{-}B)-3.714(B\text{-}V)-0.004$, X is the slope of the reddening line, and (B-V) and (U-B) are the observed colours of the star. Applying this method for the determination of reddening, to stars of spectral types earlier than A0 and lying on the zero-age main sequence (ZAMS), the mean values of E(B-V) and E(U-B), thus obtained are $0^m.37$ and $0^m.29$, respectively, which are in fair agreement with the values obtained from the CCD.

In Table 3, the average values of the reddening (determined from early type members) in different areas of the cluster have been listed. To determine these we have divided the cluster field into areas of 2×2 square minutes of arc. From Table 3, it appears that the reddening does hot appreciably vary across the cluster.

The values $E(B\text{-}V) = 0^m.38$ and $E(U\text{-}B) = 0^m.28$, have, therefore, been adopted by us as the reddening values for the cluster. These values are in fair agreement with the values determined by other authors (cf. Alter *et al.* 1970 ; Moffat 1972).

Table 3

Variation of redening across the cluster NGC 581. The average value of the reddening, E(B-V) in areas 2'x2' is indicated in the appropriate boxes along with the number of early type stars used for the determination of reddening given in brackets.

δ \ α	+60°20'.5 to +60°22'.5	+60°22'.5 to +60°24'.5	+60°24'.5 to +60°26'.5
$01^h29^m52^s$ to 01 : 30 : 00	0.41 (5)	0.40 (4)	0.39 (6)
01 : 30 : 00 to 01 : 30 : 08	0.35 (3)	0.35 (9)	0.35 (8)
01 : 30 : 08 to 01 : 30 : 16	0.40 (4)	0.35 (7)	0.39 (3)

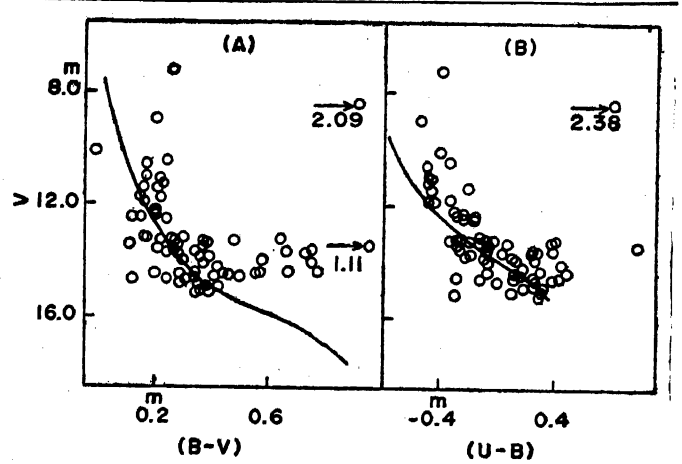

Fig. 3: (A) The (V, B-V) colour-magnitude diagram of NGC 581. (B) The (V, U-B) colour-magnitude diagram of NGC 581. The solid line represents the ZAMS fitted to the observations of members.

5. DISTANCE

The distance modulus to the cluster has been obtained by fitting the ZAMS given by Schmidt-Kaler (1965) to the (V, B-V) and (V, U-B) colour magnitude diagrams (Fig. 3(A) and (B)). The average value of the uncorrected distance modulus obtained in this way is $13^m.3\pm0^m.1$. The corrected distance modulus, obtained after adopting the ratio of total to selective absorption to be 3.0, is $12^m.16\pm0^m.1$, implying that the distance to the cluster is (2.7 ± 0.13) kpc. For the same cluster, a distance of 2.44 kpc has been estimated by Moffat (1972), of 3.11 kpc by Steppe((1974) and of 2.645 kpc by Purgathofer (1961).

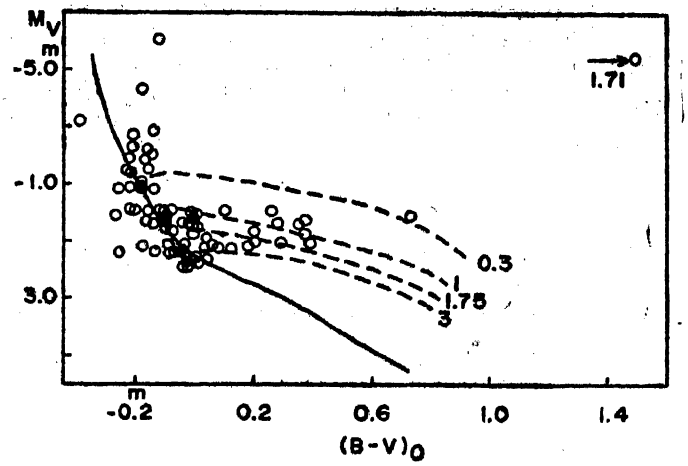

Fig. 4: H-R diagram NGC 581. The solid line represents the ZAMS and the dotted lines represent the theoretical gravitational isochrones for 0.3, 1, 1.75 and 3 million years.

6. H-R DIAGRAM AND AGE

The H-R diagram of NGC 581 is plotted in Fig. 4 assuming a uniform reddening of $0^m.38$. From the H-R diagram, the following inferences can be drawn:—

1. Stars having $(B-V)_0$ colour greater than $0^m.08$ have not yet reached the ZAMS and are still under gravitational contraction.

2. An evolutionary effect is apparent from the H-R diagram of the cluster. Stars having colours in the range $-0^m.22 < (B-V)_0 < -0^m.12$ and brighter than $M_V = -2^m.0$ have moved off the ZAMS. The brightest member star with $M_V = -6^m.1$ and $(B-V)_0 = -0^m.12$ is a supergiant of spectral type B5Ib (Moffat 1972)

3. One star has reached the red giant phase.

4. A few stars situated in the region $M_V > 0^m.10$ and $(B-V)_0 \leqslant -0^m.18$ are well below the ZAMS. Since one cannot expect quite so many subdwarfs in the cluster, these could be more distant background stars. A similar situation prevails also in the open cluster Tr 1 (Sagar and Joshi 1978a).

The value of the turn-off colour is estimated to be $-0^m.19 \pm 0^m.03$, which corresponds to an age of 4.7×10^7 years, on the Sandage 1957) scale. Using the theoretical evolutionary curves by Barbaro *et al.* (1969), the age-estimate works out to be 3.1×10^7 years. On these estimates, an age of 4×10^7 years can be ascribed to the clustere This value is somewhat higher than a photometric age of 9×10^6 years assigned by Steppe (1974).

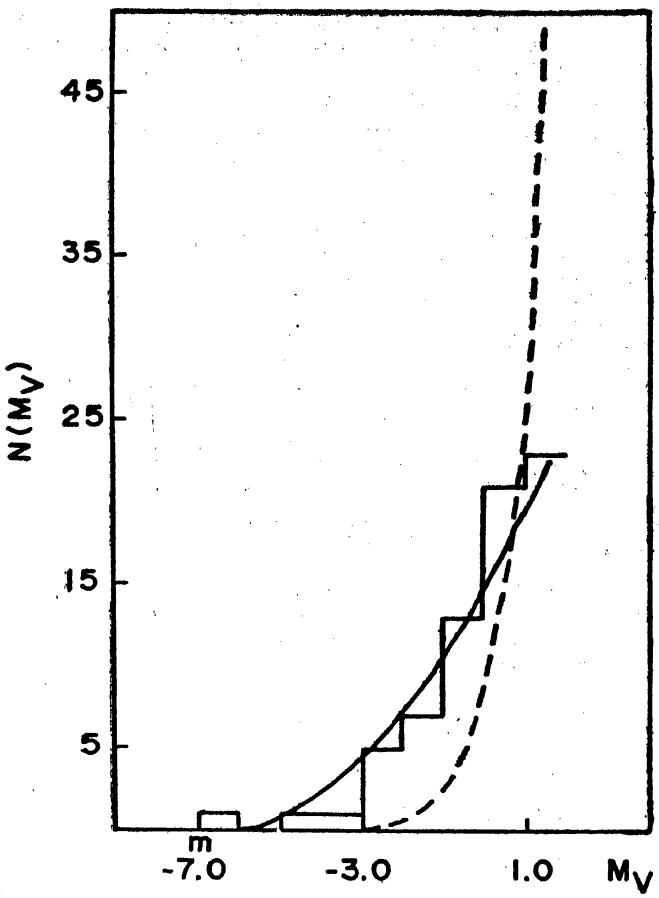

Fig. 5: The histogram is the luminosity function of NGC 581. The broken line represents the general luminosity function, ϕ (M_V) and the continuous line the initial luminosity function ψ (M_V).

From the fit of the theoretical gravitational isochrones (*cf.* Sagar and Joshi 1978b) to the H-R diagram of the cluster, it is found that about one fifth of the cluster members are still in the pre-main sequence gravitational contraction stage.

We see that the ages of the premain sequence stars (one to three million years) are less than those of the evolving stars (4×10^7 years). Such a dispersion in ages is possible (cf. Hartmann 1970), particularly if the cluster continues to accrete matter from a more extended concentration of interstellar matter around it (cf. Larson 1972). However, the possibility that these stars are non-member foreground stars cannot be ruled out.

7. LUMINOSITY FUNCTION

The luminosity functions for the cluster have been calculated in the same manner as described earlier (Sagar and Joshi 1978a). They are listed in Table 4 and are plotted in Fig. 5, which indicates that the initial luminosity function is a considerably better approximation to the cluster luminosity function than the general luminosity function.

Table 4

Luminosity function for NGC 581

M_V	Observed number of star	$\phi(M_V)$	$\psi(M_V)$
1	2	3	4
-6.99 to -6.00	1	—	—
-5.99 to -5.00	0	0.0	0.4
-4.99 to -4.00	1	0.0	1.5
-3.99 to -3.00	1	0.1	3.3
-2.99 to -2.00	5	0.3	5.7
-1.99 to -1.00	7	1.2	8.9
-0.99 to 0.00	13	4.6	12.6
0.01 to 1.00	21	15.7	16.9
1.01 2.00	23	49.1	21.7
TOTAL	71	71.0	71.0

ACKNOWLEDGEMENT

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(Continued from page 17)

The forthcoming eclipse of 1980 is expected to be almost ideal for the purpose of obtaining optical observations of the solar chromosphere and corona. The Sun will be at a convenient altitude, and clear weather is usually prevalent in southern India in mid-February. Many scientific teams are planning to set up their camps for observing this eclipse. New sophisticated techniques of observation are going to be used on this occasion, which may yield new information about the solar chromosphere and corona.

The path of totality is shown in Fig. 1. Among the important places along the path of totality will be the towns of Karwar, Dharwar, Hubli, Raichur, Mahboobnagar, Nalagonda, Gopalpur, Puri and Bhubaneswar. Some large cities like Hyderabad and Vijayawada will fall just outside this path and thus narrowly miss the total phase. The Japal-Rangapur Observatory of the Osmania University will be in the belt of totality and in a position to observe the total phase.

J.C. Bhattacharyya

Indian Institute of Astrophysics
Banglore 560034

Added in press (Editor) : Prof. J. C. Bhattacharyya has been appointed the official national coordinator for this total solar eclipse. Astronomers seeking information should contact him.