PHOTOMETRY OF OPEN CLUSTER NGC 1931

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Abstract. Photoelectric *UBV* magnitudes and colours have been determined for stars in the field of NGC 1931. The reddening across the cluster varies from $0^m.33$ to $1^m.20$. A distance of 2.16 kiloparsecs has been estimated for the cluster. It is concluded that the age of the cluster lies between the ages of NGC 6231 and NGC 2362 groups.

1. Introduction

The young open cluster NGC 1931 ($\alpha_{1950} = 5^h28^m.1$, $\delta_{1950} = 34°13'$; $l^{II} = 173°.90$, $b^{II} = +00°.28$) is situated in the spiral arm which is probably an extension of the strong Perseus arm (Moffat *et al.*, 1979). Moffat *et al.* (1979) has obtained photoelectric magnitudes of four stars in the cluster field. The cluster was put on our observing program during the period January 1984 to February 1985. The aim of the present study

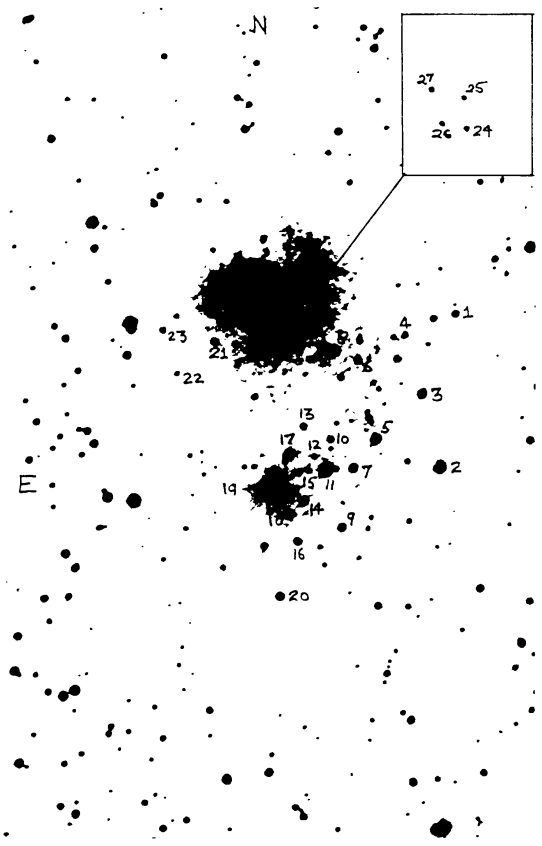

Fig. 1. Identification chart for NGC 1931.

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is to determine the *UBV* photoelectric magnitudes of the cluster members, reddening across the cluster, distance, and age of the cluster. The identification chart of the cluster obtained by enlargement from POSS chart is shown in Figure 1.

2. Observations

The observations were carried out on the 104 cm reflector of the observatory using thermoelectrically cooled (− 20 °C) EMI 6094S photomultiplier and standard *UBV* filters. Each star was observed at least on two different nights. Star No. 19 was taken as a comparison star. The *UBV* magnitudes of the comparison star were found to be constant within the accuracy of observation; i.e., $\pm 0^m.015$ in *V* and *B* and $\pm 0^m.020$ in *U*. The differential instrumental magnitudes were determined using nightly extinction coefficients and these were subsequently standardized in the *UBV* system. The magnitudes and colours of the stars thus obtained are listed in Table I. The *V*, (*B* − *V*), and (*U* − *B*) magnitudes of the three common stars observed by Moffat *et al.* (1979) alongwith the present observations are given in Table II for comparison. There is

TABLE I

Photoelectric magnitudes and colours of stars in NGC 1931

Star No.	*V*	*B* − *V*	*U* − *B*	*E*(*B* − *V*)
1	$14^m.52$	$0^m.60$	$0^m.27$	$0^m.64$
2	11.61	0.50	0.04	0.60
3	13.46	0.36	0.31	0.33
4	14.96	0.57	0.48	0.53
5	13.01	0.52	0.35	0.52
6	15.11	0.67	0.47	0.67
7	13.75	0.73	0.45	0.75
8	12.47	0.37	− 0.26	0.54
9	14.50	0.47	0.42	0.43
10	15.31	0.93	0.32	1.04
11	12.03	0.30	− 0.30	0.47
12	15.53	0.97	0.61	0.99
13	16.10	0.53	0.39	0.51
14	15.10	0.41	0.32	0.39
15	15.57	0.81	0.40	0.87
16	13.58	1.21	0.84	1.20
17	13.36	0.34	− 0.17	0.47
18	14.94	0.41	0.15	0.45
19	11.17	0.31	− 0.44	0.52
20	13.91	0.77	0.24	0.87
21	14.97	0.92	0.41	1.00
22	15.62	0.75	0.04	0.91
23	15.36	0.84	0.27	0.94
24	12.13	0.53	− 0.42	0.79
25	12.99	0.52	− 0.31	0.74
26	11.53	0.37	− 0.49	0.61
27	13.98	0.52	− 0.02	0.64

TABLE II

Comparison of present observations with that of Moffat *et al.* (1979)

Star No.		Moffat *et al.*			Present		
Moffat	Present	V	$B-V$	$U-B$	V	$B-V$	$U-B$
1	19	$11^m.13$	$0^m.30$	$-0^m.41$	$11^m.17$	$0^m.31$	$-0^m.44$
2	26	11.49	0.41	0.57	11.53	0.37	−0.49
3	27	13.99	0.52	0.19	13.98	0.52	−0.02

appreciable difference in $(U-B)$ magnitudes for stars numbered 26 and 27 between the two measures. However, the magnitudes of the two stars obtained by us on different nights are constant within the observational error.

3. Reddening

Reddening across the cluster has been determined using the colour-colour diagram of the cluster shown in Figure 2. The slope of the reddening line has been taken to be 0.72 (Johnson and Morgan, 1953) and the intrinsic Main Sequence has been taken from Mermilliod (1981). The maximum and minimum values of the reddening estimated by sliding fit method come out to be $E(B-V)_{max} = 1^m.00$ and $E(B-V)_{min} = 0^m.47$.

For all stars in the cluster field, Q-method (Johnson and Morgan, 1953) has been used for estimating the reddening. The values of reddening for individual stars, thus obtained

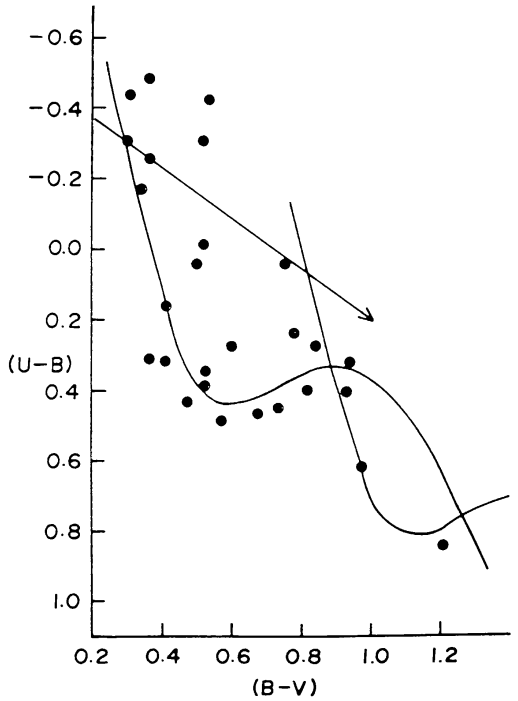

Fig. 2. Colour-colour diagram of NGC 1931.

are given in column 5 of Table I and these have been used for the subsequent discussions. The maximum and minimum values estimated using the Q-method are, $E(B-V)_{max} = 1^m.20$ and $E(B-V)_{min} = 0^m.33$. Since the value of $\Delta E(B-V)$ is greater than $0^m.11$, therefore, using the criteria given by Burki (1975), we infer that the reddening across the cluster is non-uniform. Unreddened colour-colour diagram of the cluster is shown in Figure 3.

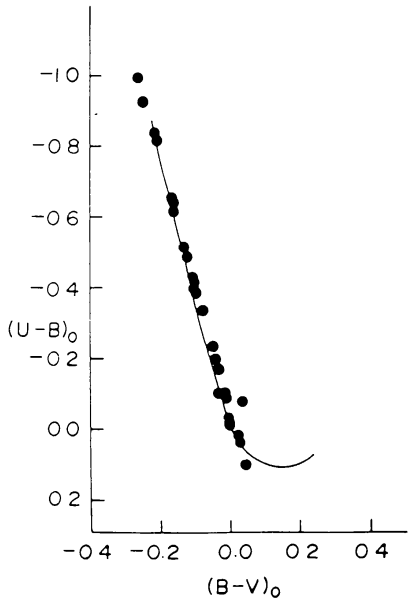

Fig. 3. Unreddened colour-colour diagram of NGC 1931.

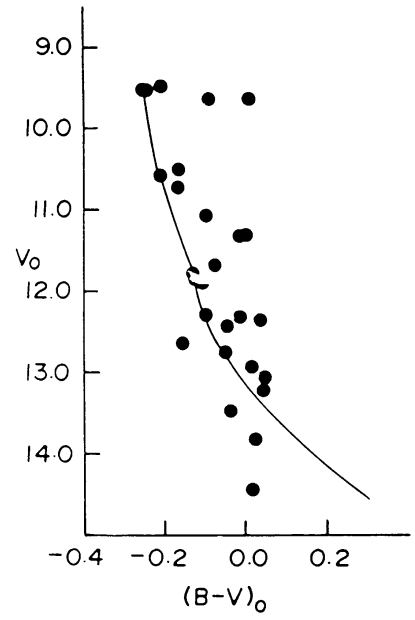

Fig. 4. $V_0, (B-V)_0$ diagram of NGC 1931.

4. Distance

The relation Av = 3.25 $E(B - V)$ (Moffat and Schmidt-Kaler, 1976) has been used to compute the unreddened magnitudes V_0 of the stars in the cluster field. The distance modulus to the cluster obtained by fitting the ZAMS given by Mermilliod (1981) to the lower portions of the $[V_0, (B - V)_0]$ and $[V_0, (U - B)_0]$ colour magnitude diagrams shown in Figures 4 and 5, comes out to be $11^m.55$ and $11^m.80$, respectively. Thus, the mean value of the distance modulus for the cluster is estimated to be $11^m.68$ which corresponds to a distance of 2.16 kiloparsecs. Moffat *et al.* (1979) has estimated a distance of 1.8 kiloparsecs for the cluster which is based on their observations of only three stars of the cluster.

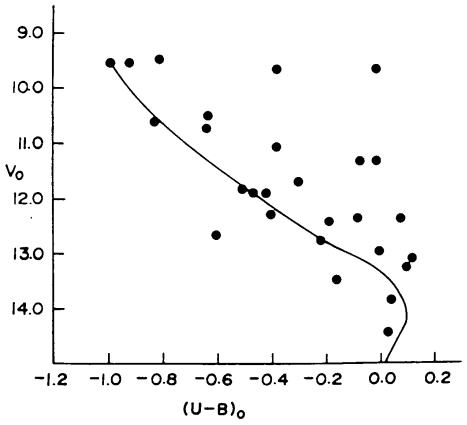

Fig. 5. $V_0, (U - B)_0$ diagram of NGC 1931.

5. Membership

The kinematical data are not available for the cluster. Therefore, on the basis of the $[V_0, (B - V)_0]$ and $[V_0, (U - B)_0]$ diagrams the following conclusions are drawn:

(1) The stars numbered 13, 14, 18, and 22 lie considerably below the Main Sequence in the $[V_0, (B - V)_0]$ and $[V_0, (U - B)_0]$ diagrams. Therefore, these stars are background stars.

(2) The stars numbered 1, 2, 3, 5, 7, 8, 9, 11, 12, 16, 19, 20, and 21 lie considerably above the Main Sequence in the $[V_0, (B - V)_0]$ and $[V_0, (U - B)_0]$ diagrams. Therefore, these stars are foreground stars.

6. Age

$[M_v, (B - V)_0]$ and $[M_v, (U - B)_0]$ diagrams for the cluster members have been plotted in the Figures 6 and 7, respectively. The age of the post-Main-Sequence cluster stars has been estimated using the composite isochrones given by Mermilliod (1981). From the $[M_v, (B - V)_0]$ and $[M_v, (U - B)_0]$ diagrams the age of the cluster lies between the ages of NGC 6231 and NGC 2362 groups.

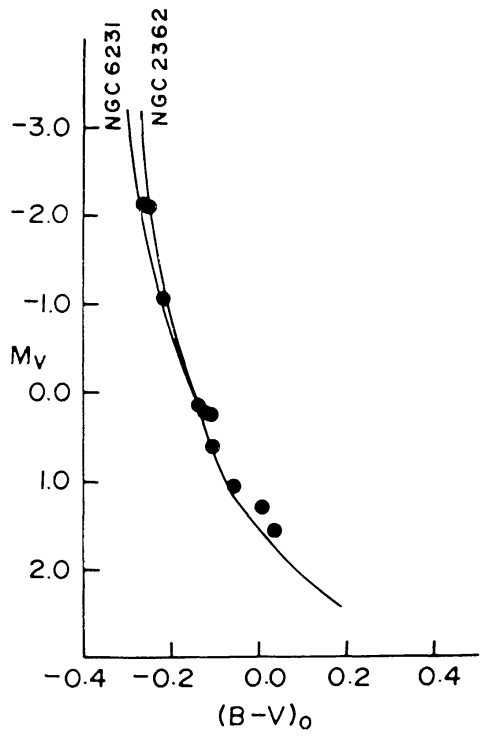

Fig. 6. $M_v, (B - V)_0$ diagram of NGC 1931.

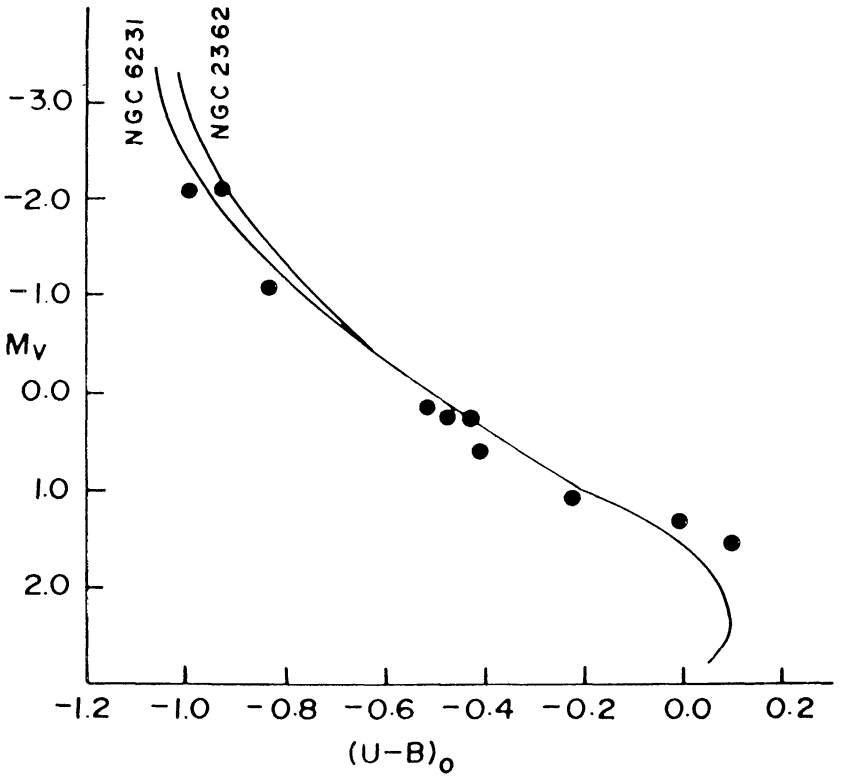

Fig. 7. $M_v, (U - B)_0$ diagram of NGC 1931.

7. Discussion

Reddening is non-uniform across the cluster field, but there is no systematic variation in the reddening. If we assume that the nebulous cloud is a part of the cluster field, the reddening for the stars located in this region would be higher as compared to the reddening for the stars located outside the nebulous region, specially for those which are background stars in the nebulous region. However, the values of reddening, obtained for individual stars, show that:

(1) Stars numbered 16 and 20 are located outside the smaller cloud patch and these are reddened by $1^m.20$ and $0^m.87$, respectively, while star No. 19 which is located in the nebulous region, is reddened by only $0^m.52$. Similarly star No. 10, which is almost outside the nebulous region, is reddened by $1^m.04$. The background stars numbered 14 and 18 located in the nebulous region are reddened by only $0^m.39$ and $0^m.45$, respectively.

(2) Stars numbered 21, 22, and 23 are outside the nebulous region, but the values of $E(B - V)$ for these stars are higher as compared to the values for the stars numbered 24, 25, 26, and 27 which are located in the nebulous region.

Therefore, on the basis of the above discussions, we infer that the nebulous cloud is in the background towards the direction of the cluster field.

Acknowledgement

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