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The young open cluster NGC 5606

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Abstract. — We have investigated the open cluster NGC 5606 using broad band *UBVRI* photoelectric photometry. The cluster is small and faint with a few star memberships. A mean colour excess $\langle E_{B-V} \rangle = 0.51$ was found in the cluster region and the fitting method yields a distance modulus of $V_0 - M_V = 11.60$. From the cluster "turn-off" point and the fitting of an isochrone with core overshooting we obtained an age of $(6.5 \pm 1.5) \times 10^6$ yr for NGC 5606.

Key words: Open cluster — *UBVRI* photometry.

1. Introduction.

The open cluster NGC 5606 (C1424-594) located unconspicuously in the Centaurus region has not been very much studied in the past. In the Catalogue of Open Clusters South of -45° Declination (Hogg, 1965) it is defined as a small open cluster with few brighter stars in an otherwise uniform area. An angular diameter of only 3′ was attributed to this cluster by Lyngå and Hansson (1972). Hogg (1965) suggested that there may be star groupings near the central cluster zone, specially along the NE-SW line. Lyngå (1964) observed 10 stars in V, $B - V$ and have estimated values for the $U - B$ colours. Later, Moffat and Vogt (1973) listed *UBV* plus Hβ measurements for 15 stars, indicating also that there is a slightly variable reddening across the cluster. They inferred from its low β value that the brightest star HD 126449 may be an emission-line star. In addition, Houk and Cowley (1975) and Fitzgerald *et al.* (1979) classified this star as B0 III and B0 IV respectively, confirming it is an evolved star. In a more recent photometric work, Pedreros (1984) observed 25 stars in the *UBVRI* bands. Finally, Hron *et al.* (1985) included this cluster in a study about radial velocities in 28 southern open clusters.

It becomes interesting to mention that in the center of the cluster there is a very compact group of at least 5 bright stars, which are very difficult to resolve. None of the photometric observers derived individual measurements for the whole group, composed very probably of member stars owing to their position in the core of the cluster. According to Moffat and Vogt's (1973) data this cluster appears to be quite young with an earliest spectral type: B0.5. Then, we decided that it becomes worthwhile to undertake a photometric work in this region aiming at obtaining new *UBVRI* photometric data over an area larger than in previous investigations. In this respect, the observed zone was extended to about 10′ around the central and compact star group.

2. The observations.

The *UBVRI* photoelectric measurements of 49 stars in a field of 10′ around the central region of the open cluster NGC 5606 were obtained with the 60-cm Lowell telescope at CTIO in February 1988 and April 1989. Sky contribution in the star light was always removed individually. Between 11 and 14 standard stars from the Cape E-regions, selected from Vogt *et al.* (1981), were measured each night. Nearly all program stars have been observed, in at least, two different nights. Extinction coefficients and transformation equations for converting the instrumental measurements into the standard *UBVRI* system were obtained in the usual way with the programs available at the CTIO.

Mean external errors in photometry are: $\varepsilon_V = 0.016$, $\varepsilon_{B-V} = 0.009$, $\varepsilon_{U-B} = 0.018$, $\varepsilon_{V-R} = 0.004$, $\varepsilon_{V-I} = 0.010$. Some program stars observed several nights were used to compute the following mean internal errors: at $V < 11.0$ mag., $\varepsilon_V = 0.012$, $\varepsilon_{B-V} = 0.007$, $\varepsilon_{U-B} = 0.010$, $\varepsilon_{V-R} = 0.005$, $\varepsilon_{V-I} = 0.007$; at $V > 11.0$ mag., $\varepsilon_V = 0.016$, $\varepsilon_{B-V} = 0.015$, $\varepsilon_{U-B} = 0.019$, $\varepsilon_{V-R} = 0.014$, $\varepsilon_{V-I} = 0.020$.

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Results of the photoelectric photometry and other useful data are listed in Table 1 in a self-explanatory format. Figure 1 gives the identification of the observed stars. Two stars in the central region, Nos 17 and 18, not observed by us but measured by Moffat and Vogt (1973) are also included in Table 1. A comparison of our data with the measurements listed by Lyngå (1964), Moffat and Vogt (1973) and Pedreros (1984) are presented in Table 2. The mean differences with them are small and show a good agreement of the various data sets.

3. Discussion of the data.

Figure 2 presents the colour-colour diagram of all the stars measured relatively to Schmidt-Kaler's (1982) *UBV* relation. It shows clearly that there are two stellar sequences: the first one corresponds to the open cluster NGC 5606 itself (filled circles), while the second sequence (open circles) corresponds to a foreground accumulation of about 11 late B- and A-type stars. Late-type non member stars are denoted with open triangles. When all stars are disposed in the observed colour-magnitude V vs $B-V$ and V vs $U-B$ diagrams (Figs. 3 and 4) it becomes evident that about 24 stars may be members of the cluster NGC 5606. Perhaps a few of the fainter stars are members too, but more data would be necessary to confirm this assumption. As Moffat and Vogt (1973) suggested, a slight differential reddening is evident within the cluster itself.

Figure 5 is the array of the $B-V$ vs $V-I$ observed colour indices for all stars in the field of NGC 5606. The two plotted lines display the intrisic colours relations for luminosity classes V (dashed) and III (dotted) (Cousins, 1978). In the same figure, the path of the reddening line for normal absorbing material (Dean *et al.*, 1978), $R = 3.0$, is also shown. This plot is typical of a normal reddening law in a cluster region.

The assumed member stars were derredened in the usual way (Feinstein and Vázquez, 1989; Vázquez and Feinstein, 1990); their intrisinc magnitudes V_0 and colour indices $(B-V)_0$ and $(U-B)_0$ are listed in Table 3. In addition the individual colour excesses are also presented in the fifth column. From the $B-V$ vs $V-I$ diagram we adopted $R = A_V/E_{B-V} = 3.1$ for the ratio of total to selective absorption of the foreground reddening. The average colour excess for the 24 member stars becomes $\langle E_{B-V}\rangle = 0.51 \pm 0.06$, in good agreement with the value of 0.49 derived by Moffat and Vogt (1973). We believe that the difference of 0.02 mag. in $\langle E_{B-V}\rangle$ results from a larger number of members observed, what causes a major influence of the differential reddening on our data sample. A similar procedure was employed to derreden the 11 foreground stars whose intrinsic data are summarized in Table 4.

4. Distance modulus and cluster age.

The corrected visual magnitudes V_0 vs the intrinsic colour indices $(B-V)_0$ and $(U-B)_0$ for cluster stars and the foreground star group are plotted respectively in Figures 6 and 7. From the fitting of the ZAMS given by Schmidt-Kaler (1982) we found for NGC 5606 a distance modulus of $V_0 - M_V = 11.60 \pm 0.15$, equivalent to a distance of 2.09 ± 0.25 kpc. This value is almost coincident with Moffat and Vogt (1973) who gave $V_0 - M_V = 11.40$. On the other hand, the location of the five brightest stars in the colour-magnitude diagrams and their MK types (Houk and Cowley, 1975; Fitzgerald *et al.*, 1979), indicate that they have evolved away from the zero age main sequence. Using the distance modulus of 11.60 mag. we derived the absolute magnitudes M_V for cluster members. For completeness purpose, intrinsic colour indices and absolute magnitudes were used to give a tentative spectral classification, specially in the case of faint member stars. This is also listed in Table 3. Notice that we only applied to the correspondence of colour indices, absolute magnitudes and spectral MK classification (Schmidt-Kaler, 1982) in those stars where no ambiguity was possible.

Assuming an angular diameter of 10′, where the 90% of the cluster members are located, the linear diameter for NGC 5606 is about 6 pc. With the exception of stars Nos. 7, 33 and 40, located beyond this limit, most of the members of NGC 5606 are remarkably concentrated within a circle of 5′ around star No 2. Nevertheless, as some members were found within the star groupings along the NE-SW line, as Hogg (1965) suggested, the cluster may have an oblate appearance. The group of foreground B- and A-type stars has an approximate distance modulus of $V_0 - M_V = 9.80 \pm 0.03$, which places them close to the near side of the Sagittarius arm.

With 24 members the total absolute magnitude of the cluster amounts to $M_V = -6.2$. Furthermore, the total mass of the cluster becomes $\mathcal{M} = 223\ \mathcal{M}_0$ using the data listed by Schmidt-Kaler (1982). The cluster age can be calculated by means of Mermilliod's (1981) algorithm. Thus, the cluster "turn-off" point is either placed between $(U-B)_0 = -1.04$ and $(U-B)_0 = -1.06$, or $(B-V)_0 = -0.30$ and $(B-V)_0 = -0.31$. In both cases, the Mermilliod algorithm does not reach so blue colours and we extrapolated in the formula. This method yields an average age of $(8 \pm 0.5) \times 10^6$ yr from both "turn-off" points. In another way, evolutionary models with overshooting plus mass loss (Maeder and Meynet, 1987, 1988) can be also used to give the age of this cluster. The procedure to do it and the transformation used were explained in a previous work (Vázquez and Feinstein, 1990). Figure 8 is the plot M_V, $(U-B)_0$ for stars in NGC 5606 where the tracks of 15 and 20 $\mathcal{M}_\odot$ are displayed. From the five brighter stars, Nos. 1, 2, 7, 15 and 17, located between the 15 and 20 $\mathcal{M}_\odot$ tracks (star No. 15 is placed above the later track), the lower and upper age limits

were found to be 5 and 8 x 10^6 yr respectively. Finally, we adopted (6.5 ± 1.5) x 10^6 yr as the age of NGC 5606.

5. Conclusions.

NGC 5606 is a very young open cluster placed in the Centaurus region. The cluster is small and faint, and exhibits a highly concentrated star group which compose the cluster core. The overall cluster resembles an anlarged structure. From our analysis 24 out of over 49 measured stars appear to be cluster members. The mean colour excess of NGC 5606 is $\langle E_{B-V} \rangle = 0.51$ while the fitting method yields a distance modulus of $V_0 - M_V = 11.60$ which corresponds to $d = 2090$ pc. From the "turn-off" points and the fitting of models with overshooting a mean age of (6.5 ± 1.5) x 10^6 yr is adopted for this cluster. In spite of its small size and number of members, the cluster has a total mass of around 220 $\mathcal{M}_0$. In addition, there is a star group composed by late B- and A-type stars placed at the foreground of the cluster with a distance modulus of $V_0 - M_V = 9.80$ mag.

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TABLE 1. *Stars measured in the region of NGC 5606.*

No.	V	B-V	U-B	V-R	V-I	n	Rem.	Sp.Type	HD/CPD
1	9.88	0.28	-0.64	0.19	0.39	6	m	BO IV	-59°5580
2	9.83	0.26	-0.66	0.19	0.39	2	m	BO IV	-59°5579
3	11.02	0.35	-0.50	0.25	0.52	3	m		-59°5586
4	10.91	0.31	-0.44	0.21	0.43	6	m		-59°5589
5	10.55	0.41	0.19	0.24	0.47	4			
6	12.78	0.39	-0.10	0.23	0.49	5	m		
7	9.06	0.22	-0.67	0.16	0.32	4	m		
9	13.34	0.37	-0.09	0.24	0.45	1	m		
10	10.94	0.24	-0.53	0.17	0.34	6	m		LSS3241
11	13.22	0.37	-0.08	0.25	0.43	1	m		
12	11.93	0.35	-0.20	0.24	0.46	3	m		
13	13.17	0.25	-0.08	0.16	0.25	2	m		
14	12.48	0.29	-0.33	0.17	0.38:	4	m		
15	8.77	0.26	-0.68	0.18	0.37	2	m	BO IV	126448
17	9.71	0.23	-0.66 #				m	B1 IV	-59°5577
18	10.58	0.20	-0.53 #				m	B1.5 IV	
19	11.74	0.31	-0.34	0.21	0.43	2	m		
27	11.20	0.11	-0.05	0.10	0.26	2	f		
28	10.57	0.42	0.20	0.26	0.52	6			
29	11.34	1.32	1.27	0.68	1.27	2			-59°5574
30	12.50	0.51:	0.14	0.36	0.66:	2			
31	13.07	0.45:	0.17	0.29	0.58	2	m		
32	13.02	0.35	0.02	0.22	0.46	3	m		
33	11.32	0.25	0.21	0.15	0.52	2	f		
34	12.12	0.35	-0.27	0.26	0.52	2	m		
35	12.34	0.30	0.20	0.20	0.48	2	f		
36	12.31	0.34	-0.31	0.23	0.48	4	m		
37	12.63	0.72	0.23	0.43	0.83	3			
39	10.56	0.09	-0.30	0.06	0.11	2	f		
40	11.70	0.33	-0.44	0.25	0.48	2	m		
41	12.87	0.62	0.21	0.45	0.92	2			
42	12.33	0.44	0.18	0.29	0.59	5			
43	13.15	0.33	0.29	0.23	0.30	2	f		
47	12.51	0.49	0.14	0.32	0.66	5			
48	12.50:	1.13	0.89	0.56:	1.08::	3			
49	13.35	0.68	0.09	0.41	0.83	2			
50	12.59	0.44	0.37	0.27	0.57	3	f		
51	12.14	1.16	0.90	0.73	1.41	3			
53	11.18	1.57	1.32:	0.90	1.73	3			
54	13.11	0.44	0.36:	0.25	0.56	2	f		
55	12.19	1.60	-	0.91	1.73	2			
56	12.68	0.52	-0.07:	0.34	0.74	2			
57	12.18	0.48	0.28	0.25	0.53	5			
58	12.63	0.35	-0.26	0.23	0.45	3	m		
59	12.89	0.31	-0.08	0.21	0.48	2	m		
60	13.16	0.35	-0.10	0.23	0.45	1	m		
64	10.48	0.12	-0.33	0.10	0.20	5	f		
65	10.92	0.12	0.08	0.06	0.12	3	f		
66	9.88	0.03	-0.32	0.07	0.12	5	f		
67	12.73	0.51	0.16	0.42	0.91	2			
68	12.45	0.36	0.23	0.17	0.40	3	f		

Note: # data from Moffat and Vogt (1973). All MK spectral types from Fitzgerald *et al.* (1979). Star No. 15 was classified BO III by Houk and Cowley (1975).
Remark: *m*, member stars; *f*, foreground stars.
Star No. 10, IDS 14204S5911A; star No. 18, IDS 14204S5911D; star No. 19, IDS 14204S5911E.

TABLE 2. *Systematic differences of stellar data in NGC 5606 in the sense present paper minus other authors.*

Ref.	<ΔV>(s.d.)	<Δ(B-V)>	<Δ(U-B)>	<Δ(V-R)>	<Δ(V-I)>	n
(1)	0.00±0.04	0.00±0.04				10
(2)	0.00±0.04	0.00±0.02	-0.01±0.01			12
(3)	0.03±0.05	-0.00±0.03	0.03±0.08	-0.00±0.01	-0.00±0.02	13

References: (1), Lyngå (1964); (2), Moffat and Vogt (1973); (3) Pedreros (1984).

TABLE 3. *Intrinsic data for stars in NGC 5606.*

No	V_o	$(B-V)_o$	$(U-B)_o$	E_{B-V}	M_V	*Spec. Class.*
1	8.06	-0.30	-1.07	0.58	-3.54	*b0.5 v*
2	8.09	-0.30	-1.08	0.58	-3.51	*b0.5 v*
3	9.10	-0.27	-0.97	0.62	-2.50	*b1/2 v*
4	9.21	-0.24	-0.65	0.55	-2.39	*b2 v*
6	11.13	-0.14	-0.50	0.53	-0.47	*b6/7 v*
7	7.47	-0.29	-1.05	0.51	-4.13	*b0 v*
9	11.77	-0.13	-0.47	0.50	0.17	
10	9.42	-0.25	-0.90	0.49	-2.18	*b2 v*
11	11.67	-0.13	-0.45	0.50	0.07	
12	10.33	-0.17	-0.59	0.52	-1.27	*b5 v*
13	12.09	-0.10	-0.34	0.35	0.49	
14	10.98	-0.20	-0.69	0.49	-0.62	
15	7.01	-0.31	-1.11	0.57	-4.59	*b0 iv*
17	8.09	-0.29	-1.05	0.52	-3.51	*b0.5 v*
18	9.21	-0.24	-0.86	0.44	-2.39	*b2 v*
19	10.14	-0.20	-0.72	0.51	-1.46	*b3 v*
31	11.47	-0.07	-0.22	0.52	-0.13	*b9 iv?*
32	11.85	-0.09	-0.31	0.44	0.05	
34	10.44	-0.19	-0.67	0.54	-1.16	*b3/5 v*
36	10.83	-0.20	-0.72	0.54	-0.97	
40	9.92	-0.24	-0.67	0.57	-1.88	*b2/3 v*
58	11.16	-0.19	-0.66	0.54	-0.44	
59	11.57	-0.12	-0.40	0.43	-0.03	
60	11.66	-0.13	-0.46	0.48	0.06	

TABLE 4. *Group of foreground stars.*

No.	V_o	$(B-V)_o$	$(U-B)_o$	E_{B-V}
27	10.69	-0.05	-0.16	0.16
33	10.54	0.00	0.03	0.25
35	11.36	-0.02	-0.03	0.32
39	9.88	-0.13	-0.48	0.22
43	12.14	0.00	0.05	0.32
50	11.24	0.00	0.05	0.44
54	11.77	0.01	0.08	0.44
64	9.64	-0.15	-0.53	0.27
65	10.51	-0.01	-0.02	0.13
66	9.40	-0.13	-0.43	0.16
68	11.28	-0.02	-0.05	0.36

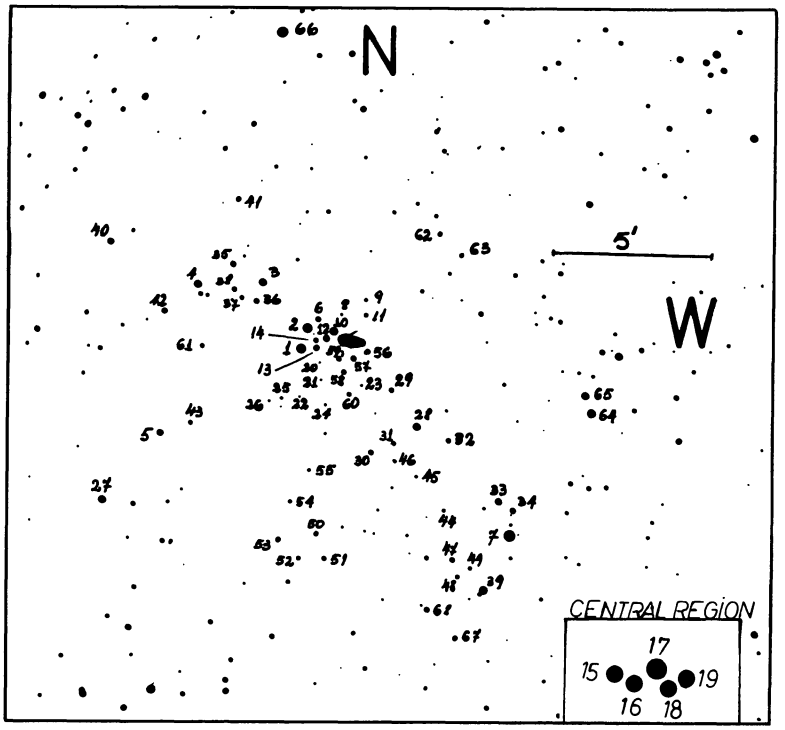

FIGURE 1. Finding chart for program stars in NGC 5606. The chart is reproduced from Hogg (1965).

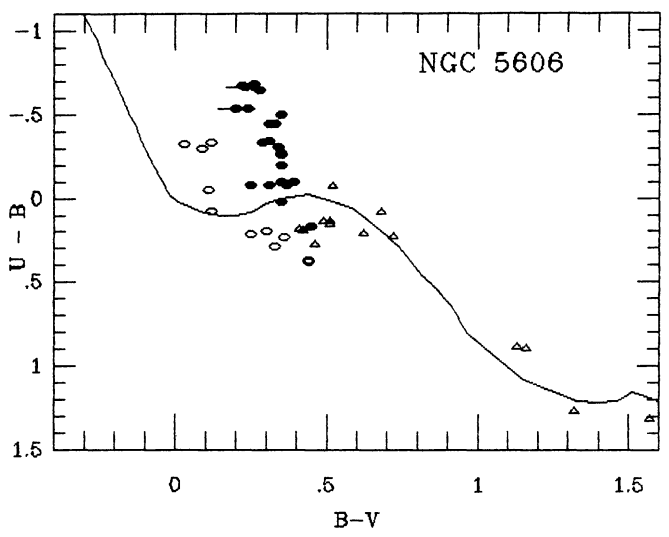

FIGURE 2. The $(U-B)$ vs $(B-V)$ diagram. Filled circles, members; open circles, foreground stars. Triangles, non-member stars. Filled circles with horizontal bar are stars (17, 18) observed by Moffat and Vogt (1973).

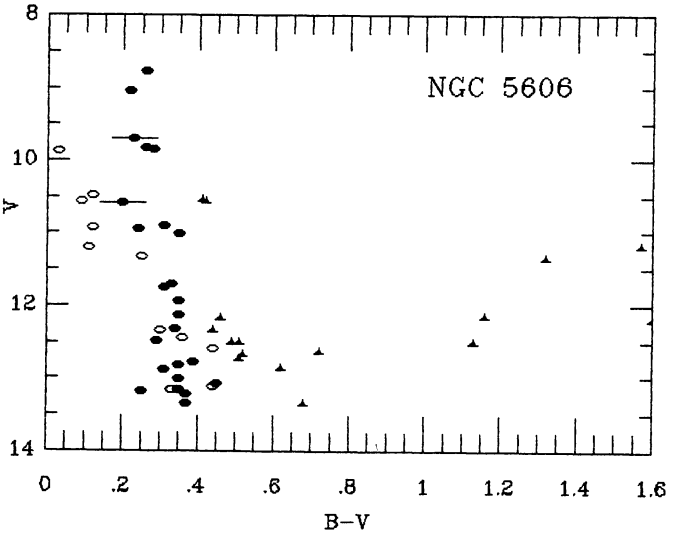

FIGURE 3. The V vs $(B-V)$ colour-magnitude diagram Symbols as in Fig. 2.

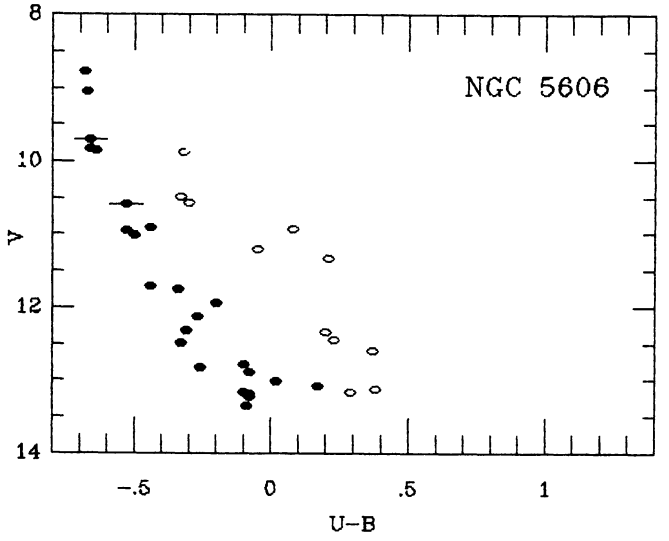

FIGURE 4. The V vs $(U-B)$ colour-magnitude diagram. Symbols as in Fig. 2.

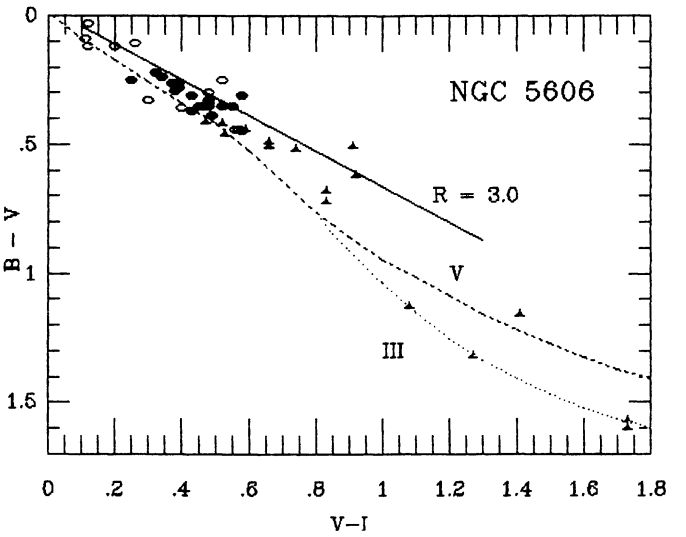

FIGURE 5. The plot of $(B-V)$ vs $(V-I)$ colour indices. Symbols as in Fig. 2. Intrinsic lines for luminosities V and III and the path of the normal reddening law, $R = 3.0$ are shown.

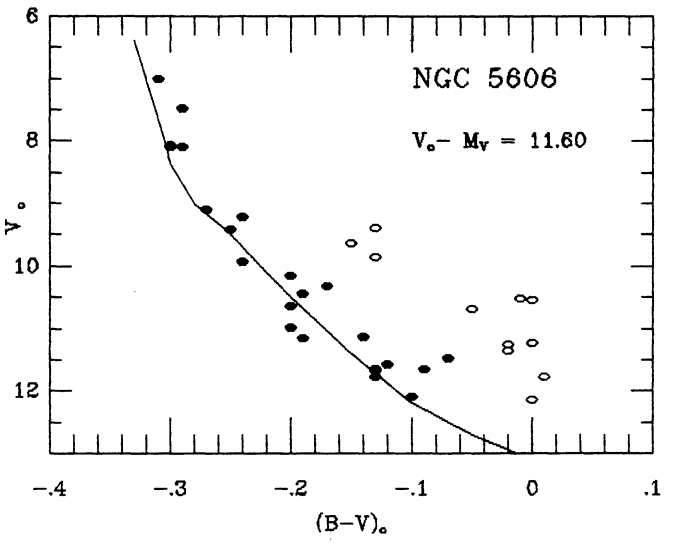

FIGURE 6. The free-absorption diagram V_0 vs $(B-V)_0$. The solid line is the ZAMS fitted to $V_0 - M_V = 11.60$ mag. Open circles are the foreground stellar group with $V_0 - M_V = 9.80$ mag.

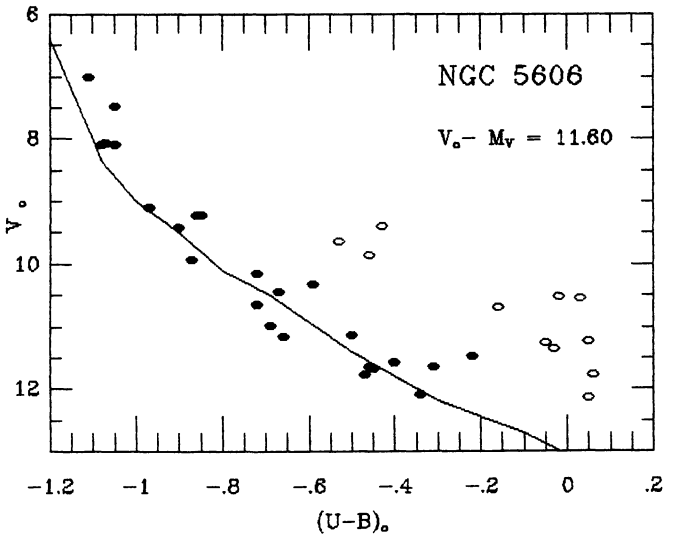

FIGURE 7. Same meaning as in Fig. 6 for V_0 vs $(U-B)_0$.

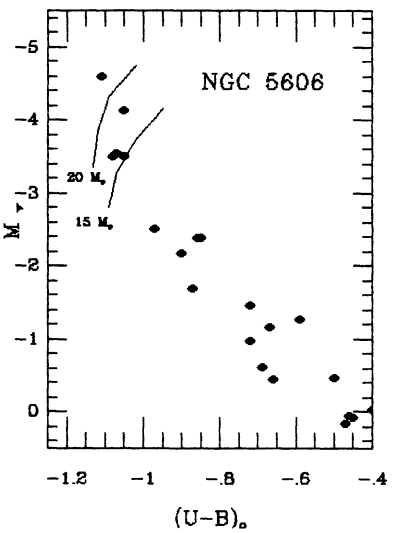

FIGURE 8. The members of NGC 5606 in the M_V, $(U-B)_0$ plane. The evolutionary tracks of 15 and 20 $\mathcal{M}_0$ are shown.