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THE OPEN CLUSTER NGC 3293 AND THE OB COMPLEX IN CARINA

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Photoelectric measures in *UBVRI* of 46 stars in and around the open cluster NGC 3293 are presented. A distance modulus of $V_0 - M_v = 12.1 \pm 0.15$ (s.d.), corresponding to 2.6 kpc, was derived from the photometric data for 34 member stars. This is similar to distances found for other young groups in the Carina region. One M supergiant and one Be star are members of the cluster. The brightest stars on the main sequence are of type B1. Several stars that have evolved away from the upper main sequence have been classified as giants and supergiants. The age of the cluster is about 7×10^6 years. The star HD 91824 (no. 1), spectral type O7 V((f)), is not a member of the group. The interstellar reddening is normal in front of this cluster.

Key words: open cluster—*UBVRI* photometry—polarization—OB complex

I. Introduction

NGC 3293, an open cluster located in the Carina region, ($\alpha = 10^h33^m\!.9$, $\delta = -57°58'$ (1950) and $\ell = 287°$, $b = 0°$) is about 2.5 degrees northwest of η Carinae. However, it is assumed to belong to the η Carinae OB complex. In a spectroscopic study of this cluster, Feast (1958) derived spectral types and radial velocities of 35 stars, mostly in the cluster itself but a few around it. The earliest type star (no. 1) classified O7 V((f)) by Walborn (1971) would suggest a very young cluster, but, as it is neither the brightest star nor in the center of the cluster, there are some doubts about its membership. The cluster is involved in a faint nebulosity, an extension of the bright H II region NGC 3372 (the Carina nebula).

With the aim of having a clear picture of its relation to other clusters in the same region it was decided to undertake a detailed photometric study.

II. The Observations

Photoelectric *B,V* observations of 46 stars in NGC 3293 were obtained in March and April 1977 with the 50-cm telescope of the Porto Alegre Observatory in Brazil. A single-channel photoelectric photometer, with a cooled EMI 9658 photomultiplier and standard glass filters, was employed. In April 1979 *UBVRI* measures were obtained at Cerro Tololo Inter-American Observatory with the 40- and 60-cm telescopes, using an RCA 31034A photomultiplier plus standard filters.

The stars observed were selected from those identified by Feast (1958), but a few fainter ones were added (Fig. 1). The photometric system was calibrated with stars in E regions (Cousins 1973, 1976). From the transformation equations of the standards stars, the rms errors, $\sigma_V = 0.017$, $\sigma_{B-V} = 0.016$, $\sigma_{U-B} = 0.025$, $\sigma_{V-R} = 0.015$, and $\sigma_{R-I} = 0.014$ were derived.

The measures obtained at both observatories were combined; taking into account a systematic difference in *V* which amounts to 0.03 ± 0.04 (s.d.) in the sense of Porto Alegre minus Cerro Tololo measures. All of them were reduced to those of Cerro Tololo. No correction was applied to the $(B-V)$ measures.

The mean data for the stars observed are listed in Table I. The first column gives the Feast numbers (new numbers for fainter stars are added). The HD or CPD designation follows. Then we list the magnitude *V* and $(B-V)$, $(U-B)$, $(V-R)$, and $(V-I)$ color indices. The next two columns give the total number of measures and the number of measures made only at Porto Alegre (P.A.). The last column presents the spectral types from Feast (1958), except stars nos. 1 and 21, classified by Walborn (1971) and Keenan (1973), respectively.

The "Perrine" 76-cm telescope at El Leoncito (San Juan, Argentina) was employed during April and May 1978 in conjunction with the rotating-analyzer polarimeter of La Plata Observatory to obtain polarization measurements in the *B* and *V* bands of the standard *UBV* system. The analyzer was a KN-36 Polaroid sheet. Each observation consisted of a two-minute integration in each color. The measurements and reduction procedures were the same used by Marraco (1978).

The polarimetric measurements are summarized in Table II where the position angles are in the equatorial system.

III. Diagrams

Figure 2 is the $(U-B,B-V)$ diagram plotted from the data contained in Table I. The intrinsic main sequence according to FitzGerald (1970) is also included. Plotted in Figure 3 is the observed color-magnitude diagram in which the spectral type and the luminosity class of each star is added. In this diagram all but two stars represent-

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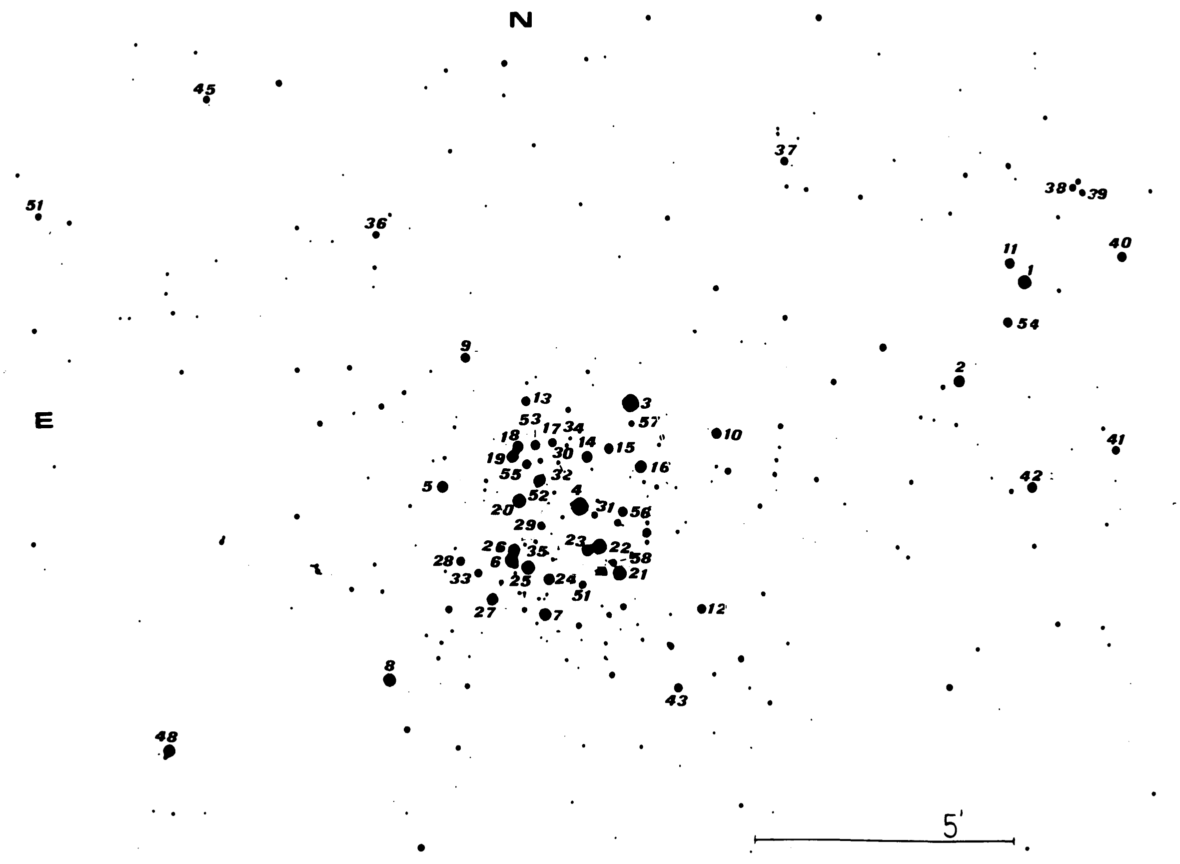

FIG. 1—Finding chart for those stars in and around NGC 3293. The star numbers follow the designation of Feast (1958), plus additional stars starting with no. 52.

ed are of type B; thus only the subclass and luminosity class designations are shown. The exceptions are star no. 1, O7((f)) (Walborn 1971) and star no. 21, an M supergiant. The dots correspond to stars which are surely members and the open circles are assumed to be nonmembers according to the discussion presented in the next section. Note, for example, that star no. 1 is probably a nonmember.

Some features of the *UBV* color-magnitude diagram should be noted: (1) the two supergiants, HD 91943 (B0.5 I*b*) and 91969 (B0 I*b*), are both well above the bright end of the main sequence. (2) The stars following in decreasing brightness are classified as luminosity III. All of them fall to the right of the main sequence which is a good evidence of their evolutionary stage.

The derivation of the intrinsic color indices $(B-V)_0$ and $(U-B)_0$, and the corrected magnitude V_0 have been computed individually for each star by the formulae

$$(U-B)_0 = 3.68\,(B-V) + 0.03$$

$$\frac{E(U-B)}{E(B-V)} = 0.69 + 0.05\,E(B-V) \quad ,$$

for which we adopted the ZAMS calibration from Blaauw (1963) plus the ratio of total to selective extinction $R = 3.0$.

IV. Cluster Membership

In Table III we present the intrinsic data for 34 member stars. A few other stars appear to be nonmembers (Table IV) from the discussion presented below. Stars observed only at Porto Alegre have no $(U-B)$ color index so no attempt was made to discuss their data and to include them in the diagrams.

Star no. 1 is an interesting object. Walborn (1971) classified it as O7 V((f)), but in view of the corrected color-magnitude diagram (Fig. 4) and its location with respect to the evolutionary curve (Fig. 5), it is clearly a background early-type star. Its $E(B-V) = 0.29$ is about the same as the average of member stars, but its distance modulus $V_0 - M_v = 12.38$ is larger than the one derived for the cluster. This corresponds to a distance about $d = 3$ kpc, the same as the open cluster NGC 3324 (Clariá 1977). It may be a run-away object from this cluster.

Stars nos. 12 and 51 are background objects on the basis of their large $E(B-V)$ and $V_0 - M_v$ values. This conclusion is confirmed by the $(V_0 - M_v, V_0)$ diagram as

TABLE I

UBVRI measures of stars in NGC 3293

No.	HD or CPD -57°	V	B-V	U-B	V-R	R-I	n total	n P.A.	Sp. T.
1	91824	8.22	-0.05	-1.01	0.01	0.04	6	4	O7 V((f))
2	91850	9.09	0.15	-0.73	0.13	0.19	8	6	B1 III
3	91943	6.73	0.06	-0.88	0.07	0.09	10	8	B0.5 Ib
4	91969	6.53	0.00	-0.96	0.04	0.05	10	8	B0 I(b?)
5	92024	9.02	-0.02	-0.90	0.01	0.03	5	4	B1 III
6	92007	8.24	0.07	-0.84	0.19	0.10	3	2	B0.5 III
7	91983	8.58	0.04	-0.83	0.04	0.08	5	4	B1 III
8	92044	8.26	0.16	-0.73	0.11	0.17	5	4	B0.5 III
9	303065	9.98	0.00	-0.80	0.03	0.03	7	6	B2 V
10	303067	9.54	0.04	-0.75	0.06	0.14	9	8	B1 V
11	303068	9.79	-0.01	-0.85	0.02	0.09	5	4	B1 V
12	303075	9.90	0.13	-0.82	0.14	0.25	5	4	B1 V
13	-57°3522	10.13	-0.02	-0.80	0.00	0.07	7	6	B2 V
14	3507	9.28	-0.05	-0.88	0.00	0.04	5	2	B1 V
15	3504	9.17	0.00	-0.69	0.03	0.05	8	6	B1 V
16	3500	8.76	-0.01	-0.82	0.02	0.04	9	7	B1 III
17	3514	10.50	-0.02	-0.72	0.02	0.07	6	4	B2-3 V:
18	3524	9.24	-0.04	-0.81	0.00	0.04	4	3	B1 V
19	3524	9.04	0.18	-0.69	0.15	0.20	5	4	B1 III
20	3523	8.02	0.02	-0.85	0.03	0.06	7	6	B1 III
21	3502	7.28	2.09	2.09	1.14	1.08	7	5	M1.5 Iab-Ib
22	3506	7.60	0.08	-0.75	0.10	0.10	7	6	B1 II
23	3506	9.13	0.02	-0.79	0.19	0.07	6	4	B1 III
24	3517	9.18	0.06	-0.80	0.05	0.08	5	4	B1 III
25	3521	8.14	0.07	-0.81	0.10	0.14	7	6	B1 III
26	3526	8.21*	0.06	-0.81	0.05	0.10	5	4	B1 III
27	3527	8.94	0.06	-0.74	0.04	0.10	5	4	B0.5 III
28	3531	10.29	0.03	-0.69	0.02	0.09	1	0	B1 V
29	3518	10.62	0.02	-0.67	0.07	0.12	5	4	B2 V
33	-57°3528	10.69	0.06	-0.63	0.05	0.13	3	2	B2 V
34	--	12.87	0.03	-0.29	0.04	0.09	1	0	B8 V
35		12.90	0.09	-0.29	0.14	0.14	1	0	B6-8 V:
40	303072	9.61	1.21	--	--	--	2	2	
41	303073	10.72	0.66	--	--	--	4	4	
42	303074	9.74	-0.02	-0.33	-0.01	0.05	5	4	
43	303076	9.73	1.65	--	--	--	4	4	

TABLE I (Continued)

No.	HD or CPD -57°	V	B-V	U-B	V-R	R-I	n total	n P.A.	Sp. T.
48	92121	8.64	0.23	--	--	--	4	4	
50	303064	8.23	0.19	--	--	--	4	4	
51	303063	10.70	0.12	-0.76	0.07	0.20	5	4	
52	3515	9.07	-0.02	-0.83	0.02	0.05	5	4	
53	3519	9.96	-0.04	-0.81	-0.01	0.06	5	4	
54	3465	10.01	0.02	-0.80	0.06	0.12	3	2	
55	3520	10.23	0.00	-0.70	0.05	0.08	3	2	
56	3503	9.85	0.04	--	--	--	2	2	
57		11.33	0.11	-0.62	0.03	0.06	1	0	
58		10.74	0.15	0.27	0.15	0.27	1	0	

* Variable 8.21 - 8.86 (this series)

TABLE II

Polarization measures of stars in NGC 3293

No.	P_V	Θ_V	P_B	Θ_B	n
1	1.29±.11	102.9±2.4	1.05±.18	92 ±5	1
3	1.04±.05	109.6±1.4	0.95±.06	105.6±1.8	3
4	1.58±.06	114.9±1.1	1.45±.06	116.3±1.2	3
5	1.56±.21	129 ±4	1.03±.17	129 ±5	1
6	0.77±.17	122 ±6	1.23±.22	116 ±5	1
7	1.10±.20	124 ±5	1.04±.13	124 ±4	1
8	1.22±.12	162.0±2.9	1.21±.07	154.3±1.8	1
20	1.24±.17	107 ±4	1.13±.07	107.4±1.8	1
21	1.58±.08	114.7±1.5	0.88±.30	115 ±9	1
22	1.54±.08	113.0±1.4	1.44±.13	112.7±2.6	1
25	0.97±.32	108 ±9	1.50±.10	114.7±1.9	1
48	0.89±.20	120 ±6	0.76±.20	121 ±8	1

both are well above the evolutionary curve.

The star no. 42 appears to be nonmember according to the small excess color $E(B\text{-}V) = 0.10$ and also from its location to the right of the main sequence (Fig. 4). The small values of $E(B-V)$ for stars nos. 34 and 35 and their location in the lower end of the main sequence throws some doubt on their membership.

The visual magnitude of the M supergiant (no. 21), corrected for the mean interstellar absorption and subtracted from the distance modulus gives $M_v = -5.8$, therefore there is a high probability of its being a member. According to Keenan (1973) its spectral classification is M1.5 I*ab*–I*b*), which agrees quite well with this absolute magnitude.

In summary, the analysis of the data for the stars observed in the region of NGC 3293 indicates that 24 blue stars are members, plus an additional red supergiant. From the member stars we have derived with the (V_0-M_v, V_0) diagram (Fig. 5), a distance modulus of $V_0-M_v = 12.1 \pm 0.15$ (s.d.), which corresponds to a distance of 2.6 kpc.

The average color excess of the cluster members (Table III) is $E(B-V) = 0.31 \pm 0.07$ (s.d.), which is slightly smaller than in the region of Tr 14/16 (Feinstein, Marraco, and Muzzio 1973) where a range of $0^{m}.38 < E(B-V) < 0^{m}.83$ was derived. The color excess for NGC 3293 members varies as follows: $0^{m}.14 < E(B-V) < 0^{m}.47$. As this scatter is larger than we expect from the photometric errors, we conclude that the reddening in NGC 3293 is nonuniform.

Figure 4 shows the *UBV* intrinsic color-magnitude diagram. The absolute magnitude scale on the right margin and the position of the ZAMS (Blaauw 1963) have been adjusted to the distance modulus values, 12.1.

V. Variable Star

Only one star displays indications of variability, that is star no. 26. Our data show discordant values in the magnitude *V* and differences in comparison with the values

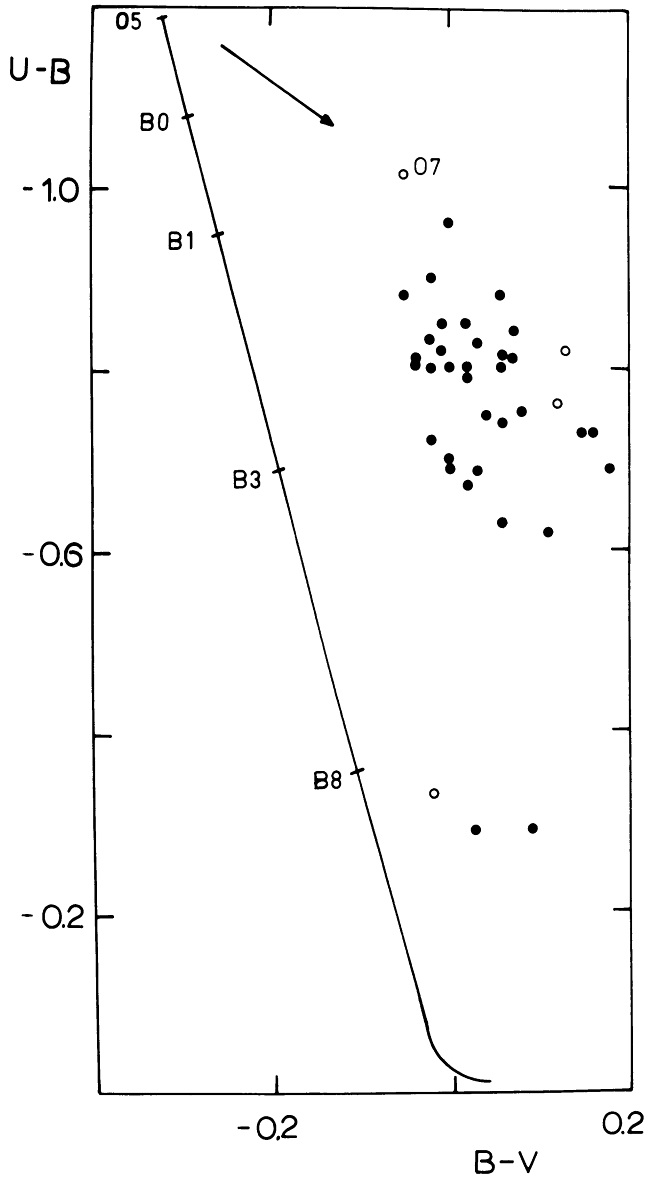

FIG. 2—Two-color diagram for the stars observed in NGC 3293. The open circles are nonmember stars.

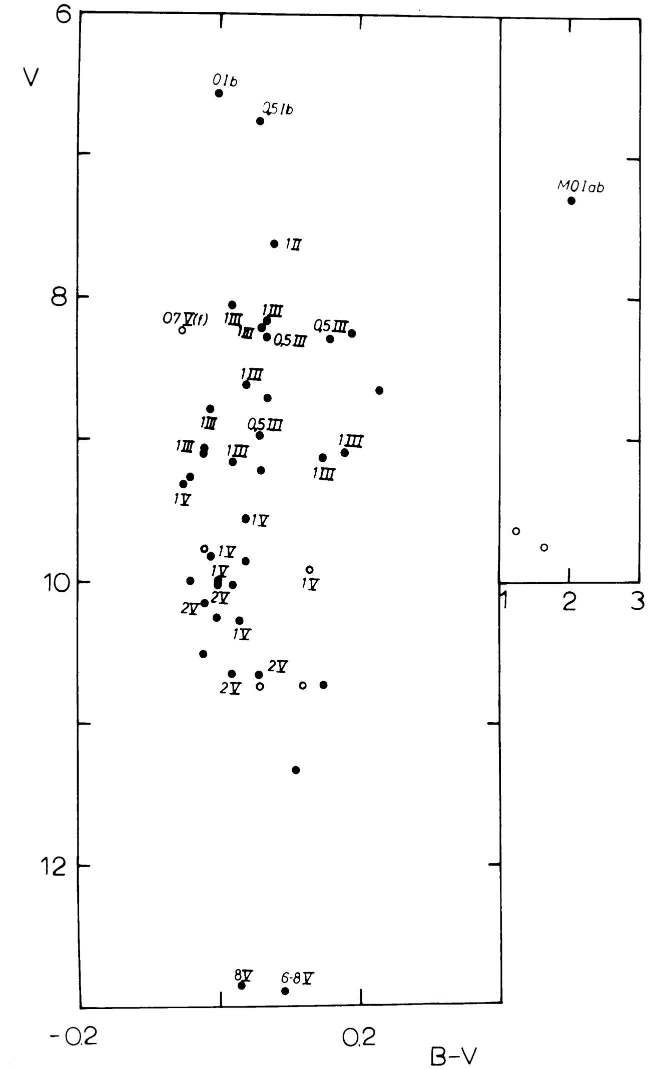

FIG. 3—The ($V, B-V$) diagram for the observed stars in NGC 3293. The B-type subclass and luminosity class are indicated.

given by Feast (1958). In Table V are listed all data about this star. Feast suggested that it probably has variable radial velocity and also possibly there is indication of line doubling.

VI. Age

When studying open clusters with red supergiants, Schild (1970) discussed this cluster and found that it has similar characteristics to those clusters with turnoff points in the main sequence at spectral types B0.5–B2. His analysis also showed that this kind of cluster is the only kind having M supergiants, as stars of these characteristics are not present in younger or older clusters.

According to the classification of open clusters made by Harris (1976), NGC 3293 belongs to group II. In this group are included all the clusters having stars brighter than $M_V = -4^m$ and evolved away from the main sequence, as well as M supergiants of about $M_V = -6^m$. The derived ages range between $6.8 < \log \text{age} < 7.2$ for these objects. For the cluster NGC 3293 the Lindoff (1968) calibration leads to an age of about 7×10^6 years. In agreement with the classification given by Harris for clusters with M supergiants, the star of earliest spectral type but still in the main sequence is B1.

VII. Radial Velocities

The radial velocities (RV) of stars in NGC 3293 were mostly obtained by Feast (1958), but a few more values are listed in the Abt and Biggs catalogue (1972), from data derived by Feast, Thackeray, and Wesselink (1955, 1963).

Omitting star HD 303075 (no. 12, nonmember) with RV $= -56$ km s^{-1}, the average RV for 23 stars is -10.9

TABLE III

Intrinsic data for member stars of NGC 3293

No.	$(B-V)_0$	$(U-B)_0$	E_{B-V}	V_0	$V_0 - M_V$
2	-0.29	-1.04	0.44	7.79	10.89
3	-0.32	-1.15	0.38	5.62	9.62
4	-0.33	-1.20	0.33	5.56	10.01
5	-0.31	-1.10	0.29	8.19	11.79
6	-0.31	-1.11	0.38	7.10	10.70
7	-0.30	-1.07	0.34	7.59	10.89
8	-0.30	-1.05	0.46	6.93	10.03
9	-0.28	-1.00	0.28	9.18	12.03
10	-0.27	-0.97	0.31	8.62	11.22
11	-0.29	-1.05	0.28	8.97	12.07
13	-0.27	-0.98	0.25	9.40	12.00
14	-0.29	-1.05	0.24	8.53	11.63
15	-0.24	-0.86	0.24	9.28	11.18
16	-0.28	-1.01	0.27	7.97	10.82
17	-0.25	-0.88	0.23	9.84	11.94
18	-0.27	-0.97	0.23	8.56	11.16
19	-0.29	-1.02	0.47	7.68	10.78
20	-0.30	-1.08	0.32	7.09	10.39
22	-0.28	-1.01	0.36	6.54	9.38
23	-0.28	-1.00	0.30	8.26	11.11
24	-0.29	-1.05	0.35	8.15	11.25
25	-0.30	-1.07	0.37	7.06	10.36
26	-0.30	-1.06	0.36	7.14 *	10.44
27	-0.27	-0.98	0.33	7.96	10.55
28	-0.25	-0.89	0.28	9.45	11.55
29	-0.24	-0.85	0.26	9.88	11.78
33	-0.24	-0.84	0.30	9.77	11.67
34	-0.11	-0.39	0.14	12.44	11.99
35	-0.13	-0.44	0.22	12.24	12.09
52	-0.28	-1.02	0.26	8.31	11.16
53	-0.27	-0.97	0.23	9.30	11.90
54	-0.28	-1.01	0.30	9.11	11.96
55	-0.24	-0.87	0.24	9.52	11.42
57	-0.24	-0.87	0.36	10.26	12.16

* assuming V= 8.21

TABLE IV

Computed intrinsic data for non member stars

No.	$(B-V)_0$	$(U-B)_0$	E_{B-V}	V_0	$V_0 - M_V$
1	-0.34	-1.21	0.29	7.38	12.38
12	-0.32	-1.14	0.45	8.58	12.58
42	-0.11	-0.40	0.10	9.48	9.18
51	-0.30	-1.06	0.42	9.50	12.60

km s^{-1} ± 7.3 (s.d.). A few stars are listed as variables in RV. The nonmember star no. 1 is listed as having RV = −15 km s^{-1}; similar to the derived average for the cluster.

VIII. Emission-Line Stars

NGC 3293 has a few stars with abnormal spectra.

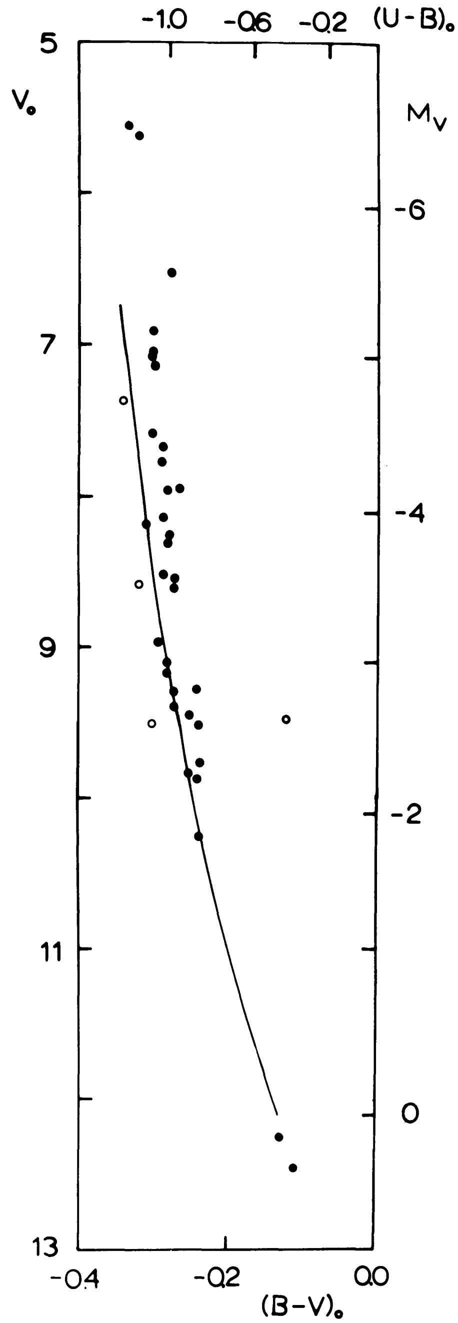

FIG. 4—The $(V_0,(B-V)_0)$ diagram for the cluster NGC 3293. The solid line represents Blaauw's ZAMS (1963) for a distance modulus of 12.1. The absolute magnitude scale is given in the right margin.

There is one star, no. 32, classified by Feast (1958) as B8 Ve, but we didn't measure it. Schild (1970) cited a reference from Sanduleak, who found that star no. 12 (HD 303075) (which is very probably an outlying member) had strong Hα emission features. However, Feast classified this star as B1 V without any indication of emission. This star shows a discordant radial velocity compared to the mean of cluster members. Moreover, Feast reported "lines broad and indication of doubling".

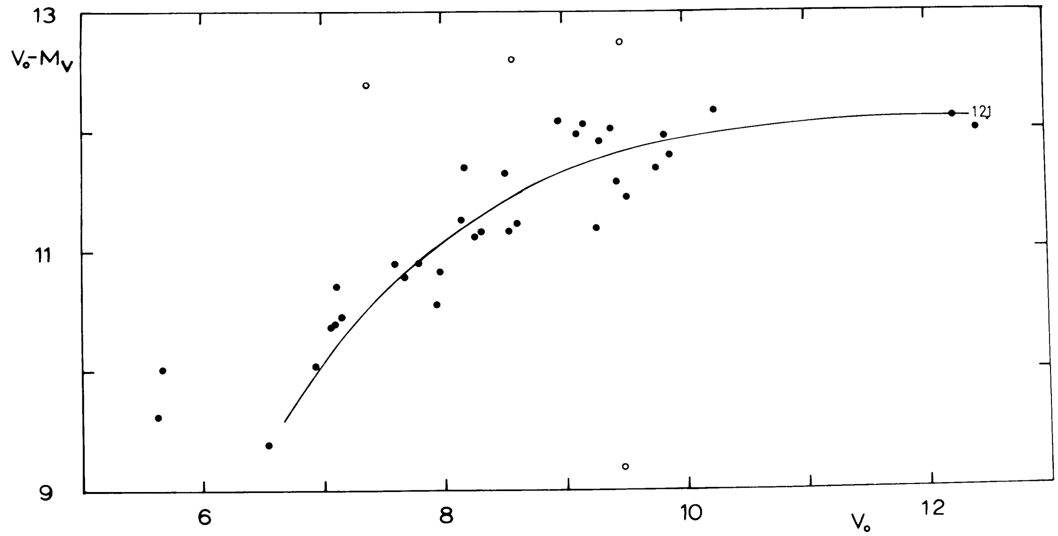

FIG. 5—The evolutionary curve for NGC 3293. The nonmember stars are indicated by open circles.

TABLE V

Photometric data of star No. 26

Date	V	B-V	References
J.D. 2443000+			
----	9.28	-0.04	Feast (1958)
228.60	8.86	0.04	this paper
228.61	8.85	0.04	
246.61	8.87	0.07	
246.62	8.86	0.06	
993.81	8.21	0.07	

From the position of this star in the (V_0-M_v, V_0) diagram its membership appears doubtful.

In conclusion, the data available suggest that one Be star is surely a member and another is not likely to be a member and may be perhaps a binary.

IX. The Interstellar Reddening and the Magnetic Field

The *RI* data combined with the *UBV* data would give us an indication of the law of interstellar reddening valid in the region of the cluster. In Figure 6 the $(V-I)$ color index versus the $(B-V)$ color index is plotted for all stars. We also include reddening lines with the corresponding slopes for the two-color relation. The smallest slope, 1.25, corresponds to the normal value $R = 3.0$, according to Dean, Warren, and Cousins (1978). For comparison purposes the reddening lines that correspond to slightly larger values of R are also drawn in the same figure. That of slope 1.41 is about what is found for the

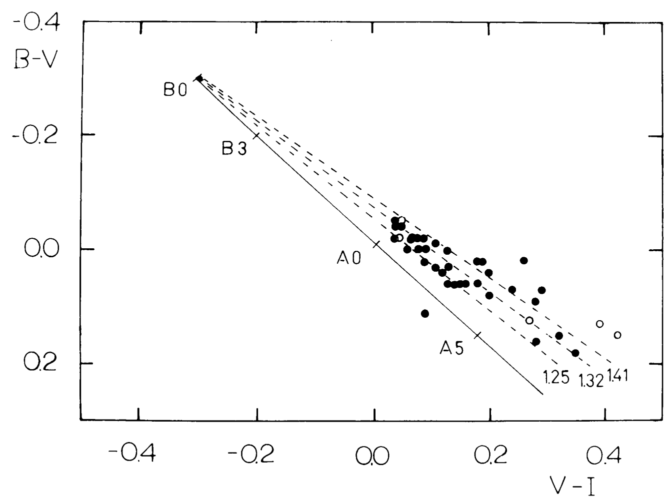

FIG. 6—The $(B-V, V-I)$ diagram for the member stars of NGC 3293. The reddening line of $R = 3$ corresponds to the color-color ratio of 1.25. The other two lines are related to larger values of R.

region of clusters Tr 14/16.

In the case of NGC 3293, the distribution of most of the points is consistent with a normal value of $R = 3$ for the interstellar extinction. However, a few points are above the line and these are very difficult to interpret. Several possibilities arise, as (1) circumstellar matter producing anomalous extinction, (2) peculiar distribution of energy in the stars, (3) unseen companions, and (4) errors in the measures.

The polarization measures provide another way of deriving the interstellar reddening in this region.

A weighted mean of the observed values of P_V/P_B gives 1.08 ± 0.04, which according to formulae (11) and (4) of Serkowski, Mathewson, and Ford (1975) corresponds to $\lambda_{max} = 0.57 \pm 0.04\ \mu$. The last value agrees with $R = A_v/E_{B-V} = 3.2 \pm 0.2$ according to equation

(5) in Whittet and van Breda (1978). The external and internal errors used in the derivation of the mean value of P_V/P_B show that there is no significant individual departure from the mean value. Thus, we conclude that the dust associated with the cluster shows the normal interstellar law. Using again formula (4) of Serkowski et al. (1975) with $\lambda_{max} = 0.57\ \mu$, the value of P_m, the polarization at λ_{max}, is given approximately by $P_m \simeq P_V$ and $P_m \simeq 1.1\ P_B$. A weighted mean between these two values was used to compute P_m for each star.

Figure 7 shows a plot of P_m as a function of $E(B-V)$. There is no correlation between both quantities as is usual when the reddening and polarizing material are widely spread along the line of sight (Krzeminski and Serkowski 1967; Serkowski 1958). No star shows an indication of an asymmetric circumstellar shell.

Using P_m and the mean value of θ_B and θ_V, Figure 8 was produced showing the projection of the polarization vectors over the plane of the sky. Most of the vectors lie in the direction of the galactic plane which is also shown in the figure. Star no. 48 in the SE is apparently a foreground object. The remaining stars seem to follow an arc extending from star no. 1 toward star no. 8 whose position angle is 36° away from the galactic plane. This arc suggests a connection with the nearby cluster NGC 3324 (d = 3.12 kpc, Clariá 1977) about 25′ to the SE, but stars HD 92207 and HD 92206 in this cluster do not have their polarization vectors aligned with this arc. Both stars have higher (about 3%) polarization than stars in NGC 3293 and their position angles are smaller than

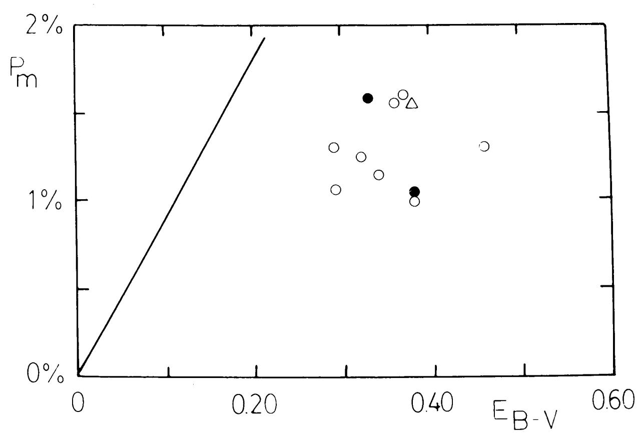

FIG. 7—The $(P_m, E(B-V))$ diagram. The triangle represents the M supergiant, star no. 21. Filled circles correspond to stars observed more than once. The line representing the relation $P_m = 9\ E(B-V)$ corresponds to maximum alignment efficiency and represents the maximum P_m possible by interstellar reddening for a given $E(B\text{-}V)$. Star no. 48 is omitted from this diagram.

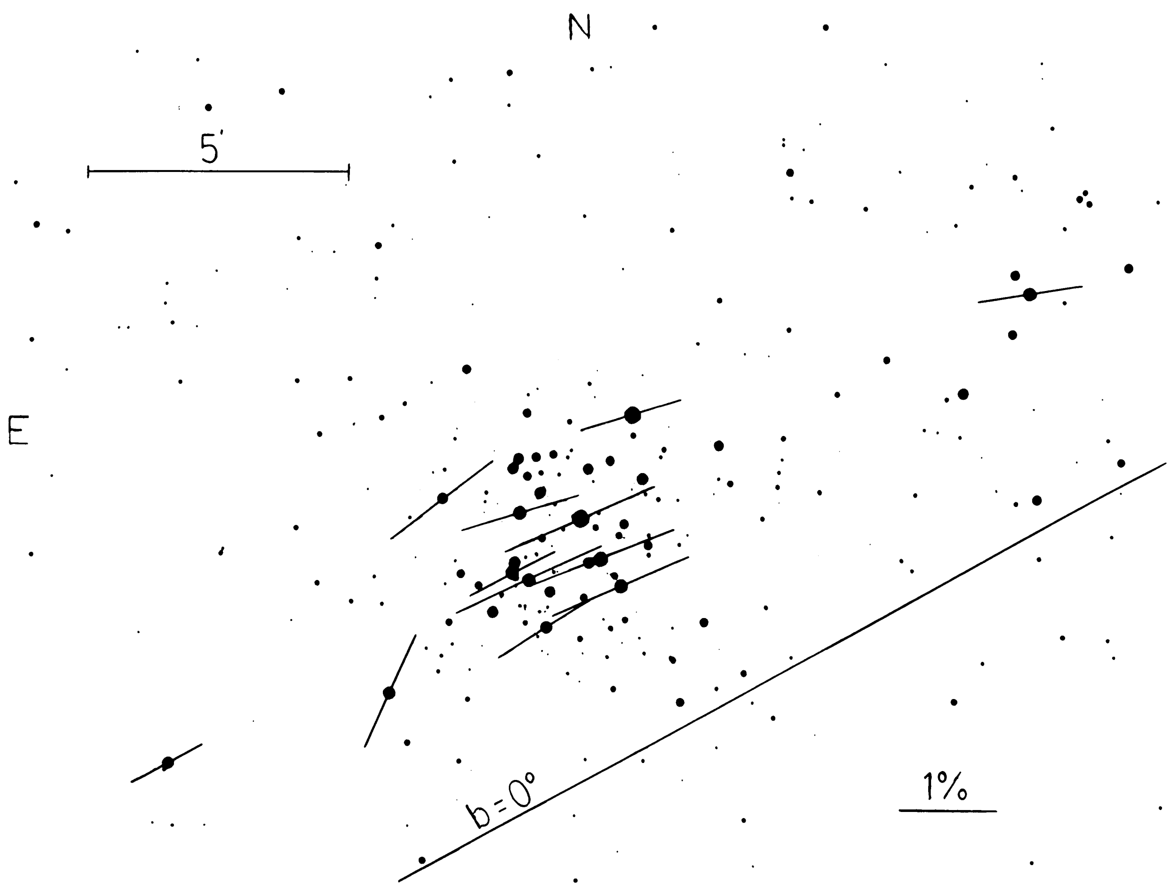

FIG. 8—The polarization projected onto the plane of the sky. The galactic plane is indicated.

TABLE VI

Open clusters in the Carina region

Cluster	distance	Sp. Type in turnoff	References
Tr 14/16	2,65 kpc (R=4)	05/06	Feinstein, Marraco and Muzzio (1973)
Cr 228	2.5	09	Feinstein, Marraco and Forte (1976)
Tr 15	2.6	09	Feinstein, FitzGerald and Moffat (1980)
NGC 3293	2.6	B1	this paper

119° (the direction of the galactic plane).

X. Conclusions

In summary, we conclude from the present investigation that the open cluster NGC 3293 is at a distance of 2.6 kpc, with a variable color excess among the member stars ranging from $0^{m}_{.}14$ to $0^{m}_{.}47$. The reddening derived from photometric and polarimetric data appears to be normal. The brightest stars on the main sequence are of spectral type B1. One O7 star located within a short angular distance from the cluster is a background object. The derived age for the cluster is 7×10^6 years.

It should be noted from this study that the cluster, located in the Carina region, is at about the same distance as other young open clusters closer to η Carinae. On the hypothesis that all these groups (Table VI) belong to the same complex, the overall diameter is approximately 120 pcs, similar to the Scorpio-Centaurus association, which is about 100 pcs in diameter (Allen 1973).

However, the age of each of these clusters is not the same. NGC 3293 is the oldest of the clusters listed in Table VI, as the stars which lie in the turnoff point are of later spectral type than the stars at the turnoff point in the other clusters. These data are presented in the last two columns of Table VI.

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