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COLLINDER 228 AND THE η CARINAE COMPLEX

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Photoelectric *UBV* observations of 99 stars in the region of the open cluster Cr 228 are reported. It is shown that some of them belong to a group situated at a distance of 2500 pc, but some others seem to be related to the complex Tr 14/Tr 16. The former group is nearer and less reddened. Its age is less than 5×10^6 years. A discussion about the star HD 93206 is also given.

Key words: open cluster – *UBV* photometry – colour excess

1. INTRODUCTION

In an earlier paper (Feinstein *et al.* 1973, hereinafter called paper I) it was shown that the bright emission nebula NGC 3372, the open clusters Tr 14, Tr 16 and Cr 232 comprise a single structure, including the dark interstellar dust lanes and the peculiar object η Car.

A group of stars, 10′ south of η Car, called Cr 228, is also projected against a very bright part of the nebulae, and may be related to the same structure. Then, as it is of particular interest to study its possible connection, photoelectric observations of this cluster were obtained.

2. THE OBSERVATIONS

Photoelectric *UBV* observations of 79 stars in Cr 228 were carried out at the Cerro Tololo Inter-American Observatory with the 92 cm telescope in March 1973. Later, some of these stars were remeasured and another 20 stars east of the group added with the 83 cm telescope at the La Plata Observatory during February, March and April 1974.

The identification chart of the region is given in figure 1 and in table 1 are listed all the data. The root mean square error of one observation for *V*, *B–V* and *U–B* are about:

$$\varepsilon_v = \pm 0\overset{m}{.}015 \qquad \varepsilon_{B-V} = \pm 0\overset{m}{.}012 \qquad \varepsilon_{U-B} = \pm 0\overset{m}{.}017$$

for the data obtained at Cerro Tololo, and slightly larger for the measures got in La Plata.

These errors are smaller than in paper I as in this cluster the stars we measured were in the mean brighter than those in Tr 14/Tr 16. On the other hand the background contribution from the HII region is in this zone substantially smaller.

3. COLOUR-MAGNITUDE AND COLOUR COLOUR-DIAGRAMS

The observed *UBV* data are plotted in the colour-magnitude diagrams (*B–V*, *V*) and (*U–B*, *V*) and in colour-colour diagram (*B–V*, *U–B*) shown in figures 2, 3 and 4 respectively.

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4. MEMBERSHIP

With the assumptions and methods explained in paper I, the corrected magnitude, intrinsic colours and colour excesses were computed for each star.

During this computation it was soon realized that there was a large number of stars that should be classified as background OB stars (i.e. they had distance moduli greater than the average and colour excesses larger than the surrounding stars). We decided to assign these stars to the southern extension of the Tr 14/Tr 16 complex, behind the more nearby gas-free Cr 228 stars.

Alternative interpretations were considered and subsequently ruled out as follows:

The reddening could be patchy in this region. Against this it can be argued that the structure found in paper I was relatively smoother.

The dispersion in the estimated colour excesses could be as large as to accept frequent $0\overset{m}{.}1$ differences between adjacent stars. The possible causes for this dispersion are examined below.

1) The stars used were of different luminosity classes. Although we have spectral types only for the brightest stars we must assume that fainter members are dwarfs if the reality of the physical group is accepted.

2) Rotation (Maeder and Peytremann 1970) and binarity (Maeder 1968) cause only a minor spread over this part of the two colour diagram.

3) Measurement errors twice as large as those quoted here for one observation shoud give a dispersion in the computed colour excesses of only $0\overset{m}{.}034$ (eq. 12 in Feinstein *et al.* 1973).

Then using primarily the colour excesses and secondly the distance moduli we separated the stars into three groups:

1) Stars which form the open cluster Cr 228.
2) Stars located farther than the cluster Cr 228, which seem to belong to the same structure as Tr 14/Tr 16.
3) Stars not related to the last two groups, mostly foreground.

The corrected magnitudes, colour excesses, and distance moduli of the stars of the three groups are tabulated in tables 2, 3 and 4.

The isocriptic line chart was therefore drawn twice. Once for the stars at the Tr 14/Tr 16 distance (group 2). This map shows the colour excesses between us and the η Car complex in this zone and is depicted in figure 5. When this chart is combined with figure 9 in paper I, the distribution of the excesses is well correlated to the relative absorption map in Dickel (1974).

Figure 6 shows conversely the distribution of the colour excesses of the stars assumed to be at the Cr 228 distance (group 1). This gives the colour excesses produced only by the interstellar dust up to this relatively closer group of stars. The distribution is consistent with the dust cloud found by Graham (1971).

5. DISTANCE MODULI AND AGE

In figure 7 it is presented the corrected apparent magnitude versus intrinsic colour diagram, where the different groups are marked conveniently. In this diagram the difference in the adopted distance moduli is not great enough to separate neatly both groups.

In figure 8 the stars of group 2 are shown in the evolutionary deviation diagram, where the position of the standard curve was taken from paper I: $V_o–M_v=12\overset{m}{.}6$ and $\Delta m=1\overset{m}{.}0$ at $V_o=7\overset{m}{.}2$. It is possible that some of them are in fact background objects, but the remaining are distributed in the same manner as in the case of Tr 14/Tr 16.

The distance and age estimation of group 1 stars (Cr 228) were achieved by means of the evolutionary deviation diagram shown in figure 9. Using the same arguments discussed in paper I the fitting of the standard curve gave $V_o–M_v=12\overset{m}{.}00\pm0\overset{m}{.}20$ and an age less than 5×10^6 years in the Lindoff (1968) calibration.

The run of the colour excesses from the Sun towards the two groups is presented in figure 10. The foreground reddening seems to be smaller than in paper I, as we are almost outside the dust cloud studied by Graham (1971).

It seems clear that if some stars belonging to the η Car/Tr 14/Tr 16 complex are seen as background objects behind the Cr 228 group, then in the zone of the nucleus of the η Car/Tr 14/Tr 16 complex some stars belonging to the Cr 228 group may be seen as foreground stars or even as binary members. This is one reason that helps to explain the apparently high dispersion in V_o–M_v in figure 8 of paper I.

6. STAR NO. 12

A difficult situation arose in considering star no. 12. It has a colour excess much greater than the surroundings in either group, but, reduced altogether with the remaining, it fits well in the sequence for the Cr 228 group (see figure 9).

Possible explanations for this situation are:

a) This star has a circumstellar shell with the ratio of total to selective absorption not very different from $R=3$.

b) This star is a nearby white dwarf.

Neither of these hypotheses are favoured by our data but we must add here that preliminary unpublished polarimetric measurements indicate that this star is essentially unpolarized compared with the other members of the Cr 228 group.

7. THE STAR HD 93206

This star, no. 33 in table 2, and known as an eclipsing binary, is the brightest in the Cr 228 group according to figure 7. It has been classified as 09.7 Ib: (n) by Walborn (1973).

Light variations have been discussed by Walker and Marino (1972). Combining their observations with our own, which are listed in table 5, we find a preliminar 6.02 days period after applying the method of Lafler and Kinman (1965).

Also, seven spectrograms with a dispersion of 40 Å/mm were taken in May 1974 with the 92 and 152 cm telescopes of the CTIO. Spectrophotometric tracings and radial velocity measures were obtained from these spectrograms with the Grant Osciloscopic comparator at La Plata.

The Balmer lines display variable shapes and in one plate (J.D. 2442179.54) they appear with a double structure. The metastable line He λ3888 is conspicuous and may be an indication of the presence of a shell, which displays oscillations between -26 and $+10$ km s^{-1} along the period.

The interstellar Ca II λ3933 line has an heliocentric radial velocity of -3 km s^{-1} ± 2 km s^{-1} corresponding to -14 km s^{-1}, if it is referred to the LSR, in good agreement with the value tabulated in Feast *et al.* (1957).

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Table 1 Observed *UBV* data of the region CR 228

*	V	B−V	U−B	N	HD/SP/REMARKS
1	8.04	0.27	−0.71	5	93130 O6III(F)
2	8.48	−0.02	−0.18	4	93191 A0
3	6.48	−0.02	−0.88	5	93131 WN7
4	8.68	0.17	−0.69	6	305520 B
5	8.94	0.05	−0.82	4	305536 B
6	8.08	0.08	−0.84	5	93222 O7III((F))
7	9.28	0.30	−0.72	3	305524 B
8	9.69	0.06	−0.76	4	305522 B
9	9.56	0.07	−0.02	2	
10	9.40	1.87	1.36	3	
11	9.67	0.13	−0.75	3	305534 B
12	9.47	0.82	−0.29	2	
13	8.97	−0.06	−0.78	5	93056 B4
14	8.72	0.00	−0.86	4	93027 O9.5V
15	8.59	0.66	0.08	4	305544 G5
16	9.81	0.06	−0.69	3	305521 B
17	7.74	1.77	0.90	2	93281 K0
18	11.07	0.25	−0.70	2	
19	10.52	0.09	−0.70	3	
20	10.41	0.67	−0.22	3	
21	9.31	0.02	−0.86	4	
22	9.71	0.38	−0.59	2	305518 B9
23	9.06	0.02	−0.80	2	305437 B8
24	8.80	−0.01	−0.89	2	305438 B
25	9.39	0.04	−0.44	3	305535 B5
26	10.63	0.21	−0.03	2	
27	8.36	−0.06	−0.89	3	93028 O9V
28	9.74	0.05	−0.77	3	305543 B5 DW CAR VAR. 9.6−10.2
29	10.21	0.07	−0.36	2	305451 B0
30	10.80	0.05	−0.69	2	
31	9.87	0.06	−0.77	2	305516 B8
32	8.49	0.18	−0.76	6	305523 O9II
33	6.28	0.14	−0.80	13	93206 O9.7IB.(N) VAR. 6.16−6.43
34	9.82	1.66	2.01	2	
35	10.18	−0.01	−0.16	3	
36	10.23	0.10	−0.62	3	
37	10.81	0.21	−0.63	2	
38	10.20	0.34	−0.74	3	305532 B
39	9.92	0.32	−0.76	2	
40	10.62	1.14	0.86	1	
41	11.06	0.21	−0.63	1	
42	10.48	0.66	0.20	2	
43	10.40	0.22	−0.66	1	
44	10.35	0.09	−0.59	1	305515 B8
45	10.18	0.99	0.70	2	
46	10.74	0.16	0.15	1	
47	10.32	0.13	−0.51	1	305533 B
48	11.00	−0.03	−0.62	2	
49	11.20	0.01	−0.36	1	
50	12.04	0.26	−0.34	1	
51	11.88	0.10	−0.61	1	
52	12.50	0.40	0.25	1	
53	10.94	0.10	−0.65	1	
54	12.72	0.64	0.17	1	
55	11.71	0.31	0.14	1	
56	13.42	0.25	−0.18	1	
57	9.86	0.09	0.08	1	3.5519 A
58	12.71	0.35	0.10	1	
59	12.89	0.60	0.02	1	
60	12.71	0.37	−0.26	1	
61	11.70	0.22	−0.59	1	
62	12.69	1.16	0.59	1	
63	13.63	0.23	−0.13	1	
64	12.85	0.62	0.47	1	
65	8.44	0.02	−	1	93146 O6.5V((F))
66	9.79	0.07	−0.79	1	
67	8.77	0.00	−0.82	1	
68	10.16	0.05	−0.73	1	
69	9.76	−0.02	−0.81	1	93097 A2
70	10.76	0.86	0.23	1	
71	11.40	1.00	0.44	1	
72	13.27	0.18	−0.21	1	
73	12.92	1.14	0.80	1	
74	11.66	0.18	−0.43	1	
75	11.15	0.32	0.19	1	
76	12.44	0.04	−0.45	1	
77	11.57	0.20	−0.58	1	
78	11.44	0.18	−0.36	1	
79	11.13	1.22	1.21	1	
80	10.28	0.13	−0.49	2	305528 B
81	10.89	0.20	−0.62	2	
82	10.53	0.25	−0.53	2	305538 B
83	10.74	0.09	−0.60	3	305537 A0
84	11.05	0.25	−0.44	2	
85	11.20	0.78	0.50	1	
86	11.06	0.98	1.28	4	
87	10.55	0.16	−0.12	3	305541 A0
88	8.79	0.14	0.17	3	93421 A0
89	10.43	−0.03	−0.69	2	
90	9.44	0.11	0.15	2	93647 A0
91	10.05	0.09	−0.05	3	305540 B8
92	8.39	0.29	−0.73	2	93632 B0
93	9.57	0.25	−0.69	3	93576 B
94	9.90	0.27	−0.74	2	305539 B2
95	10.98	0.02	−0.63	2	
96	9.08	0.10	−0.67	2	93501 B3
97	10.36	0.51	−0.64	1	
98	10.00	0.68	−0.42	2	305525 B
				0	
				0	

Table 2 Colour excesses, corrected apparent magnitudes and distance moduli for the stars of group 1

Star	$E(B-V)$	V_0	$V_0 - M_v^0$
3	0.28	5.64	8.93
5	0.35	7.90	11.19
8	0.34	8.67	11.51
11	0.42	8.40	11.49
12	1.14	6.06	11.05
13	0.20	8.38	10.72
16	0.32	8.86	11.20
21	0.32	8.34	11.63
23	0.30	8.15	10.99
24	0.30	7.91	11.50
27	0.24	7.66	10.75
28	0.33	8.75	11.59
30	0.30	9.89	11.98
31	0.34	8.84	11.68
32	0.49	7.02	10.61
33	0.42	4.98	7.58
36	0.34	9.20	11.09
37	0.48	9.36	11.95
41	0.48	9.61	12.20
44	0.32	9.39	11.08
48	0.18	10.46	11.75
51	0.34	10.86	12.75
53	0.35	9.88	11.97
56	0.38	11.04	11.98
63	0.34	12.61	12.15
66	0.36	8.70	11.79
67	0.29	7.91	11.00
68	0.32	9.21	11.80
69	0.26	8.99	11.83
72	0.30	12.36	12.05
76	0.21	11.81	12.35
83	0.32	9.77	11.46
89	0.21	9.82	11.51
95	0.25	10.24	11.93

Note: star no. 3, WN 7, was treated as a main-sequence star.

Table 3 Colour excesses, corrected apparent magnitudes and distance moduli for the stars of group 2

Star	$E(B-V)$	V_0	$V_0 - M_v^0$
1	0.59	6.28	10.27
4	0.45	7.32	10.16
6	0.39	6.90	10.49
7	0.63	7.40	11.84
14	0.30	7.82	11.11
18	0.56	9.40	12.99
19	0.36	9.45	12.04
22	0.76	7.43	10.95
38	0.67	8.19	13.14
39	0.67	7.92	13.41
43	0.51	8.88	11.97
50	0.45	10.70	11.64
60	0.56	11.04	11.98
61	0.48	10.25	12.59
74	0.38	12.53	11.62
77	0.45	10.21	12.30
81	0.47	9.49	12.08
82	0.50	9.03	11.12
84	0.47	9.64	11.13
92	0.62	6.54	10.98
93	0.55	7.91	11.20
94	0.58	8.15	12.14
97	0.86	7.77	13.26
98	1.00	6.99	10.98

Table 4 Colour excesses, corrected apparent magnitudes and distance moduli for the stars of group 3

Star	$E(B-V)$	V_0	$V_0 - M_v^0$
2	0.05	8.34	7.38
9	0.10	9.25	8.00
25	0.21	8.77	9.31
26	0.28	9.79	8.83
29	0.22	9.56	9.75
35	0.05	10.03	8.98
47	0.34	9.29	10.58
49	0.14	10.77	10.61
57	0.09	9.58	8.03
78	0.35	10.38	10.92
80	0.34	9.27	10.56
91	0.14	9.64	8.48
96	0.36	8.00	10.34

Table 5 Photoelectric observations of HD 93206

J.D. 2.400.00+	V	$B-V$	$U-B$
38477.63	6.23	0.13	−0.82
481.63	6.25	0.14	−0.85
878.63	6.49	0.14	−0.87
41762.60	6.23	0.15	−0.83
763.60	6.36	0.16	−0.77
764.60	6.24	0.16	−0.80
765.60	6.16	0.15	−0.78
768.60	6.21	0.17	−0.77
770.60	6.27	0.17	−0.78
771.60	6.22	0.16	−0.77
42099.68	6.43	0.12	−0.83
124.68	6.24	0.12	−0.84
132.60	6.43	0.10	−0.82

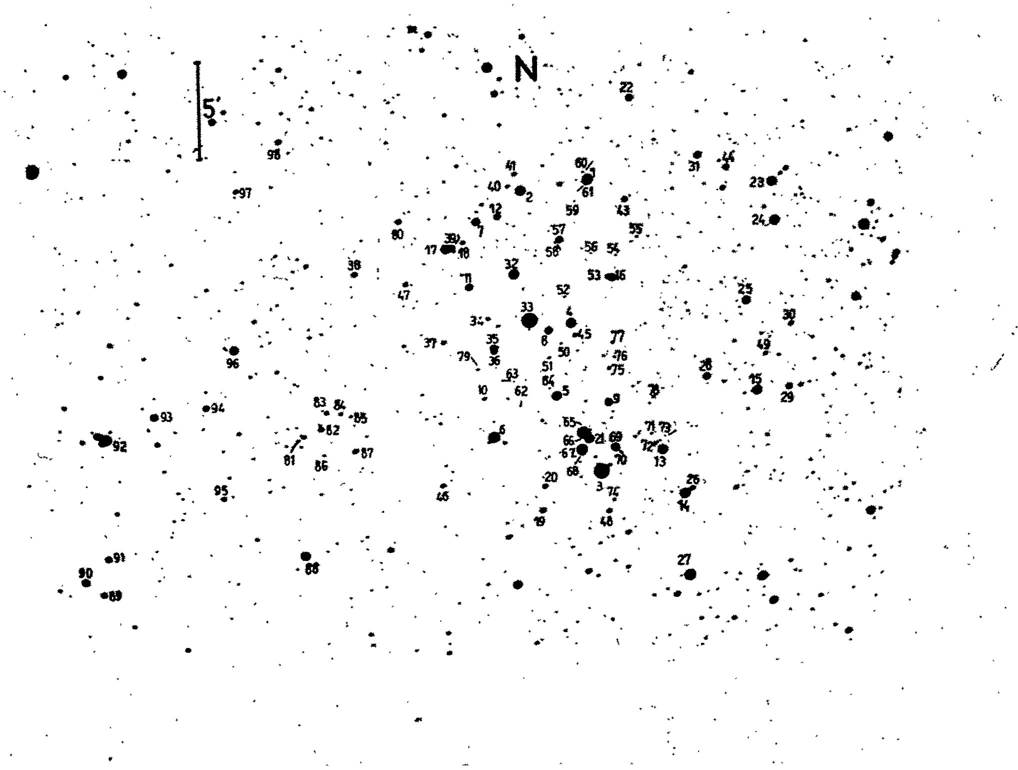

Figure 1 The identification chart for the region of Cr 228. This chart is to the south of the one given in paper I (figure 1). Star no. 22 is the same as no. 19 in paper I, which by mistake was not plotted.

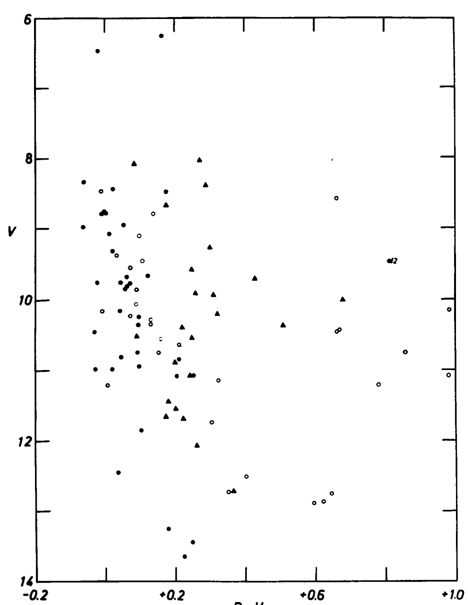

Figure 2 The observed colour-magnitude diagram (B–V, V). Filled circles stand for those stars belonging to Cr 228, filled triangles for Tr 14/Tr 16, and open circles are nonmembers.

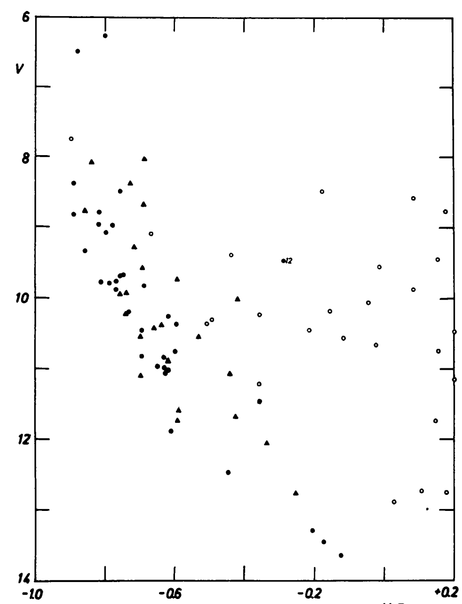

Figure 3 The observed colour-magnitude diagram (U–B, V). The references are the same as in figure 2.

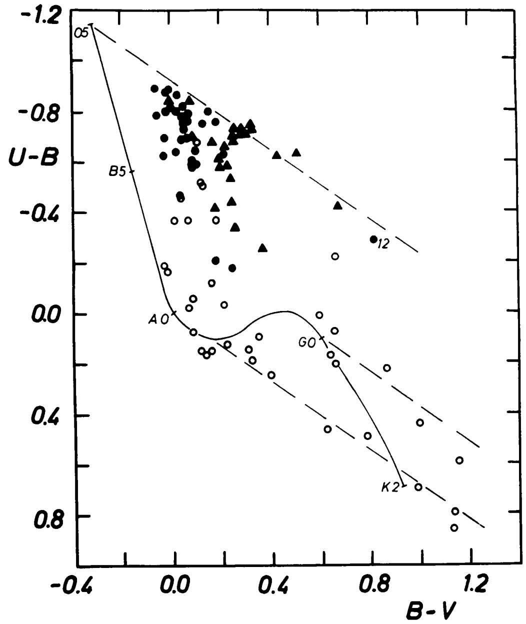

Figure 4 The observed colour-colour diagram (*B–V*, *U–B*). The intrinsic colour-colour relation is also indicated. The references are the same as in figure 2.

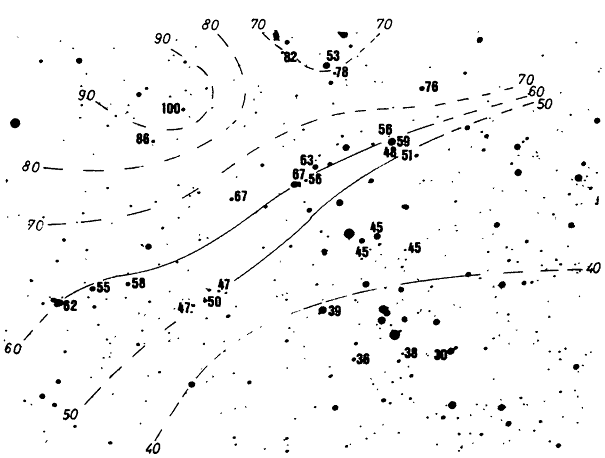

Figure 5 The distribution of the colour excesses for the stars which belong to the cluster Tr 14/Tr 16. Each star is labeled with its colour excess expressed in hundredths of magnitude. The isocryptic lines are labeled in the same way.

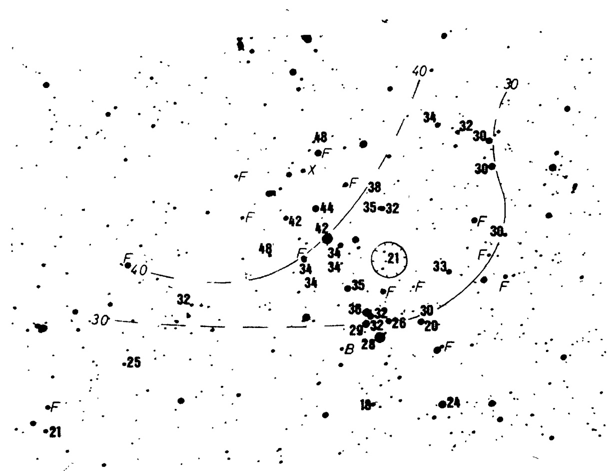

Figure 6 The distribution of the colour excesses for the stars which compose the cluster Cr 228. The references are the same as in figure 5, besides *F* stands for foreground stars; *X* for star no. 12; and *B* for a background star. A star with a value of 21 near the centre of the cluster may suggest a minimum.

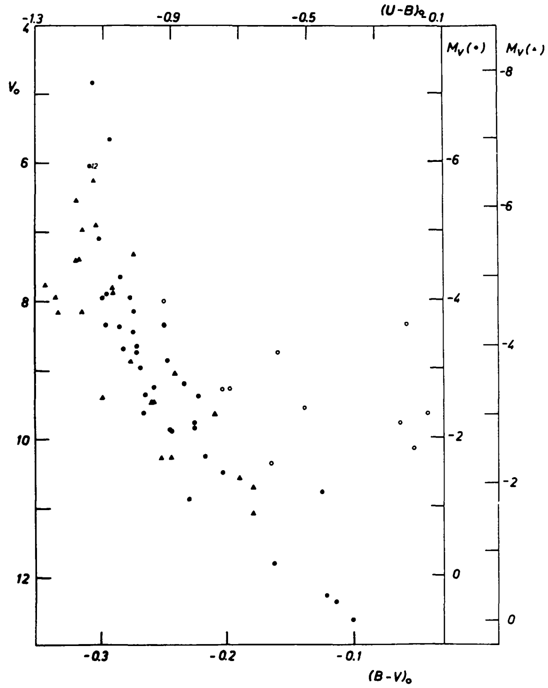

Figure 7 The corrected colour-absolute magnitude diagram. At the right border are given the absolute magnitude for the members of Cr 228 (filled circles), and for the members of Tr 14/Tr 16 (filled triangles). The open circles stand for nonmember stars.

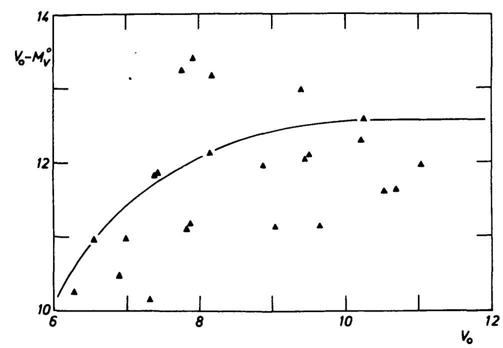

Figure 8 The evolutionary curve for the stars belonging to the Tr 14/Tr 16 in the corrected magnitude versus distance modulus diagram.

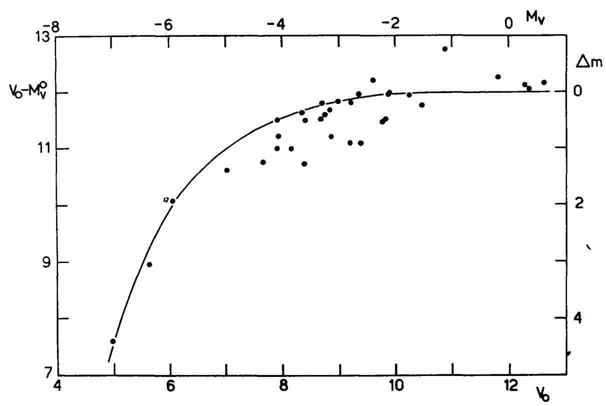

Figure 9 The evolutionary curve of the stars belonging to Cr 228.

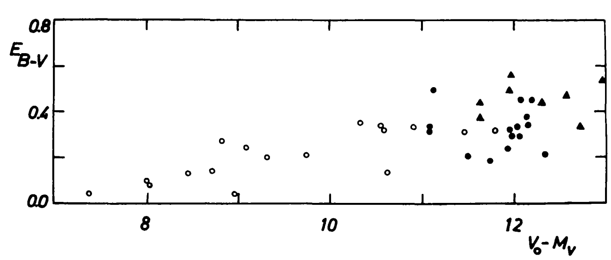

Figure 10 The plot of the colour excess for member and non-member stars according to the distance modulus.