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Study of Young Open Clusters as Tracers of Spiral Features in our Galaxy. Paper 4: Czernik 20 (OC1 427)

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Abstract. Photoelectric and photographic photometry of 72 stars was done in the field of the not-well-studied open cluster Czernik 20 ≡ OC1 427 in the direction of the Auriga constellation. Of these stars, a total of 43 have been found to be probable members down to $m_v \simeq 15.75$ mag. There is apparently a variable extinction across the field of the cluster with $E(B-V)$ ranging from 0.53 to 0.38 mag. The cluster stars show a range in their ages from 1.0×10^7 to 7.1×10^7 years, indicating that Czernik 20 is young enough to be considered as a spiral-arm tracer in the study of our Galaxy. The distance of this cluster is found to be 4.27 ± 0.14 kpc and it is located inside the outer Perseus arm of the Milky Way.

Key Words: star clusters, open—star clusters, individual—stars, photometry

1. Introduction

Continuing the study of faint young open clusters, which was initiated by the late Prof. M. K. V. Bappu with the main aim of utilizing them as tracers of spiral features in our Galaxy (Babu 1983, Paper 1; 1985, Paper 2; 1987, Paper 3), I present in this fourth paper, the photometric observations of the open cluster Czernik 20 (≡ OC1 427 ≡ C 0516 + 394; $l = 168°.30$; $b = +1°.32$).

Czernik (1966) was the first one to consider this group of stars as a cluster with 325 possible members in it and estimated its angular diameter as 18 arcmin. Accordingly, Ruprecht (1966) classified it as II 2 r in the Trumpler (1930) system, where II indicates that it is a well-bound system with some central condensation. The numeral 2 implies that the stars in this cluster have a medium range in brightness, while the letter 'r' has been used to show that it is a rich cluster with more than 100 stars in it. The richness is obvious on the finding chart which is displayed in Fig. 1. The identification numbers in this figure are introduced in this paper.

2. Selection of the cluster

Since not much earlier work was done on this cluster (Lynga, 1980), it had to be subjected to the rapid selection techniques described in Paper 1 for assessing its

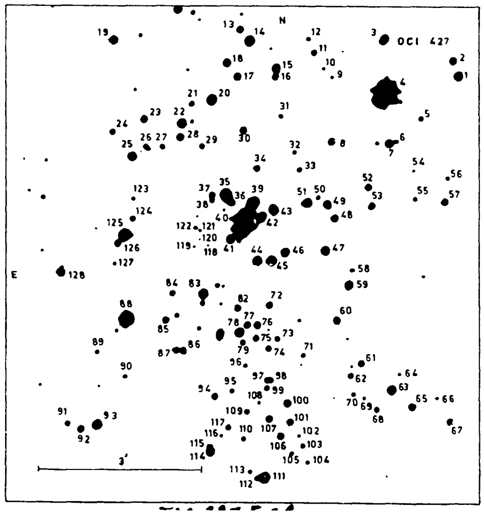

Figure 1. Finding chart for the field of Czernik 20 (OCl 427), reproduced from the Palomar Observatory Sky Survey (POSS) charts. The identification numbers are introduced in the present work.

usability as spiral feature tracer. In that procedure (*cf.* Babu, 1983), low-dispersion spectra of the order of 970 Å mm^{-1} have been obtained for stars in the cluster region with a transmission grating placed in front of the photographic plate at the Cassegrain focus of the Kavalur 102-cm telescope. The exposure time for this modified objective-grating spectroscopy was 75 minutes on a Kodak 103a-O emulsion. Then using the intensity distribution in the shorter wave-length region as the principal criterion, approximate spectral types could be assigned for a total of 16 stars. This small number in the 'r' cluster was due to the fact that the first- and second-order spectra of most of the stars were found to be overlapping each other, which in turn, made it difficult for the estimation of the respective spectral types. They were thus lost in the richness of the cluster. The 16 approximate spectral types are listed in Table 1. The uncertainty in this procedure was about two spectral subclasses. Along with these the respective visual magnitudes, *V*(POSS), estimated from the image diameters on the Palomar Observatory Sky Survey charts (*cf.* Babu 1983) are also given in Table 1. In the plot between these two parameters of the above-mentioned 16 stars, shown in Fig. 2, a total of 10 stars seem to form a main sequence (MS); thus, they could be considered as probable members. Out of the remaining 6 stars, star 4 is perhaps too bright for this cluster; its location in the sky also is marginally away from the "rich" area, making it a probable nonmember. Star 88 appears at the top of the MS, but shifted slightly to its right; therefore this star may be considered as a possible evolved member. Stars 20 and 35 are in all likelihood nonmembers, while stars 45 and 46 could be checked for their membership in the category of giants. However, since star 40, with an approximate spectral type of B2, appears to be a probable member, this cluster may be considered as young enough and may be used as a spiral arm tracer. It has, therefore, been selected for more accurate photometric work.

3. Observations and reductions

The photoelectric observations of 15 stars in the field of this cluster were done using a standard *UBV* photometer at the 61-cm telescope of the Australian National

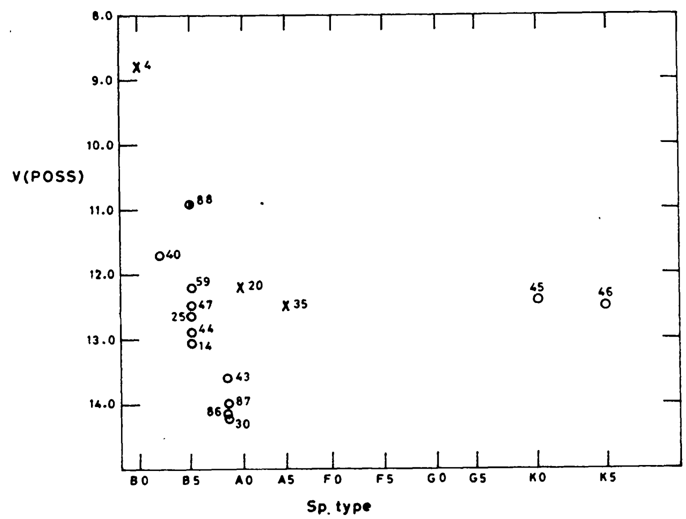

Figure 2. The approximate spectral types obtained from the modified objective grating spectra are plotted against the V magnitudes estimated from the POSS charts, for the stars in the field of OC1 427. The unfilled circles, the half-filled circle and the crosses respectively denote the probable members, doubtful members and the non-members.

University located at Siding Spring Observatory in Australia. A dry-ice-cooled photomultiplier was employed along with an on-line computer to collect the data; a maximum of three sets of observations were taken for each star. The instrumental magnitudes, after correcting for the atmospheric extinction, were standardized with the help of the photometric sequence taken from the work of Landolt (1973). The averaged values are listed in Table 1.

In order to reach the fainter members of the cluster, photographs of the cluster region were obtained using the 102-cm telescope of the Indian Institute of Astrophysics situated at Kavalur Observatory in India. The plate and filter combinations are given in Table 2 along with the corresponding exposure times. From these plates, the photographic magnitudes in U, B and V were obtained for a total of 72 stars (including all the 15 photoelectrically observed ones) on an arbitrary scale using the PDS microdensitometer in conjunction with the computational facilities available at the Mount Stromlo Observatory in Australia. These magnitudes were then standardized using the photoelectric observations and are also listed in Table 1.

4. Reddening

The $(B-V)$ versus $(U-B)$ diagram of the stars in this cluster region is given in Fig. 3. In this figure, most of the stars seem to follow a sequence and show a general shift from the unreddened main sequence given by Schmidt-Kaler (1982). Further, this observed sequence shows a spread, the major causes for which have been outlined by Burki (1975). It was pointed out by him that all the physical and observational causes put together may produce only a small spread which may be termed as natural dispersion. The differential extinction across the field of the cluster, if present, would however, cause a much larger spread. Thus, in order to find the amount of this spread in the above-mentioned colour-colour diagram, the unreddened curve is shifted (following

Table 1. The observational data for individual stars in the open cluster OC1 427.

Star No.	Spectral Type (approx.)	V (POSS)	V	$(B-V)$	$(U-B)$	V_0	$(B-V)_0$	$(U-B)_0$	$E(B-V)$	Membership
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Photoelectric Photometry										
4	BO	8.8	9.12	0.01	−0.20	—	—	—	—	—
8	—	—	14.45	0.27	−0.18	13.15	−0.13	−0.46	0.40	m
20	AO	12.2	12.63	0.68	0.82	—	—	—	—	—
30	B8	14.2	14.67	0.38	−0.03	13.07	−0.11	−0.39	0.49	m
40	B2	11.7	11.47	0.17	−0.45	10.20	−0.22	−0.72	0.39	m
59	B5	12.2	12.59	0.19	−0.52	11.23	−0.23	−0.83	0.42	m
73	—	—	15.92	0.59	0.21	—	—	—	—	—
75	—	—	15.76	0.59	0.22	—	—	—	—	—
77	—	—	15.40	0.49	0.11	—	—	—	—	—
82	—	—	15.29	0.51	0.35	13.80	0.05	0.03	0.46	m
83	—	—	11.73	1.43	1.13	10.27	0.98	0.81	0.45	m
84	—	—	15.77	0.64	0.37	14.28	0.18	0.05	0.46	m
85	—	—	14.45	0.42	0.20	12.96	−0.04	−0.14	0.46	m
88	B5	10.9	10.53	0.20	−0.35	9.33	−0.17	−0.61	0.37	m?
93	—	—	12.19	0.20	−0.59	10.70	−0.26	−0.92	0.46	m
Photographic Photometry										
2	—	—	13.44	−0.11	0.15	—	—	—	—	—
3	—	—	13.67	0.68	0.15	—	—	—	—	—
11	—	—	15.44	0.33	−0.15	13.91	−0.14	−0.49	0.47	m
13	—	—	14.98	0.39	0.24	13.65	−0.02	−0.06	0.41	m
14	B5	13.0	12.84	0.21	−0.56	11.35	−0.25	−0.88	0.46	m
15	—	—	13.80	0.28	0.17	—	—	—	—	—
16	—	—	14.95	1.06	0.35	—	—	—	—	—
17	—	—	14.30	0.50	0.33	—	—	—	—	—
18	—	—	14.05	0.34	−0.07	12.59	−0.11	−0.39	0.45	m
19	—	—	12.71	0.25	−0.47	11.18	−0.22	−0.80	0.47	m

22	—	—	13.17	0.25	−0.55	11.51	−0.26	−0.92	0.51	m
23	—	—	13.88	0.28	−0.13	12.58	−0.12	−0.42	0.40	m
24	—	—	14.07	0.84	0.12	—	—	—	—	—
25	B5	12.6	12.80	0.23	−0.57	11.21	−0.26	−0.92	0.49	m
28	—	—	14.50	0.33	−0.10	13.17	−0.12	−0.42	0.41	m
29	—	—	15.94	1.00	0.95	—	—	—	—	—
35	A5	12.5	12.07	0.78	0.14	—	—	—	—	—
37	—	—	16.14	0.61	0.53	—	—	—	—	—
39	—	—	12.72	0.24	−0.55	11.13	−0.25	−0.90	0.49	m
41	—	—	14.94	0.68	0.24	—	—	—	—	—
42	—	—	16.02	0.82	0.57	—	—	—	—	—
43	B8	13.6	13.47	0.25	−0.31	12.11	−0.17	−0.61	0.42	m
44	B5	12.9	13.25	0.25	−0.42	11.76	−0.21	−0.74	0.46	m
45	KO	12.4	11.97	1.30	0.97	10.80	0.94	0.71	0.36	m
46	K5	—	12.23	1.45	1.12	10.74	0.99	0.80	0.46	m
47	B5	12.5	12.90	0.20	−0.58	11.44	−0.25	−0.90	0.45	m
48	—	—	14.29	0.25	0.38	—	—	—	—	—
49	—	—	14.36	0.20	−0.06	—	—	—	—	—
51	—	—	12.26	1.35	0.99	10.54	0.82	0.68	0.53	m
52	—	—	14.54	0.29	−0.20	13.11	−0.15	−0.52	0.44	m
53	—	—	14.19	1.12	−0.22	—	—	—	—	m
55	—	—	14.41	1.89	0.61	—	—	—	—	—
57	—	—	13.70	0.28	−0.23	12.27	−0.16	−0.55	0.44	m
60	—	—	13.47	0.24	−0.41	12.01	−0.21	−0.73	0.45	m
62	—	—	15.39	0.52	−0.58	—	—	—	—	—
63	—	—	12.51	0.19	−0.58	11.21	−0.21	−0.90	0.40	m
65	—	—	13.57	0.33	−0.17	12.05	−0.14	−0.51	0.47	m
67	—	—	12.38	1.21	0.94	—	—	—	—	—
68	—	—	15.83	1.08	−1.20	—	—	—	—	—
70	—	—	16.40	0.80	0.41	14.71	0.28	0.03	0.52	m
71	—	—	16.51	0.81	1.01	—	—	—	—	—
72	—	—	15.58	0.81	0.18	—	—	—	—	—
76	—	—	14.51	0.32	−0.14	13.05	−0.13	−0.46	0.45	m
78	—	—	13.44	0.25	−0.37	12.02	−0.19	−0.68	0.44	m
86	B8	14.2	14.40	0.32	−0.07	13.00	−0.11	−0.37	0.43	m

Table 1. Continued.

Star No.	Spectral Type (approx.)	V (POSS)	V	$(B-V)$	$(U-B)$	V_0	$(B-V)_0$	$(U-B)_0$	$E(B-V)$	Membership
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
87	B8	14.0	14.32	0.34	0.01	12.92	−0.09	−0.30	0.43	m
89	—	—	15.92	1.49	−0.03	—	—	—	—	—
90	—	—	15.24	1.48	0.24	—	—	—	—	—
91	—	—	14.43	0.31	−0.20	12.94	−0.15	−0.53	0.46	m
92	—	—	13.65	0.29	−0.17	12.28	−0.13	−0.48	0.42	m
100	—	—	13.68	0.40	−0.10	11.93	−0.14	−0.49	0.54	m
101	—	—	14.31	0.41	−0.61	—	—	—	—	—
106	—	—	14.16	0.38	0.25	12.89	−0.01	−0.03	0.39	m
107	—	—	14.45	0.36	0.01	12.99	−0.21	−0.75	0.45	m
111	—	—	12.11	0.24	−0.50	10.58	−0.23	−0.84	0.47	m
112	—	—	15.82	0.71	1.25	—	—	—	—	—
114	—	—	12.90	0.26	0.47	11.31	−0.23	−0.84	0.49	m

Table 2. Journal of photographic observations.

Band	Plate	Filter	Exposure time
U	103a–O	UG 2	60 min
B	103a–O	GG 13	60 min
V	II a–D	GG 11	60 min

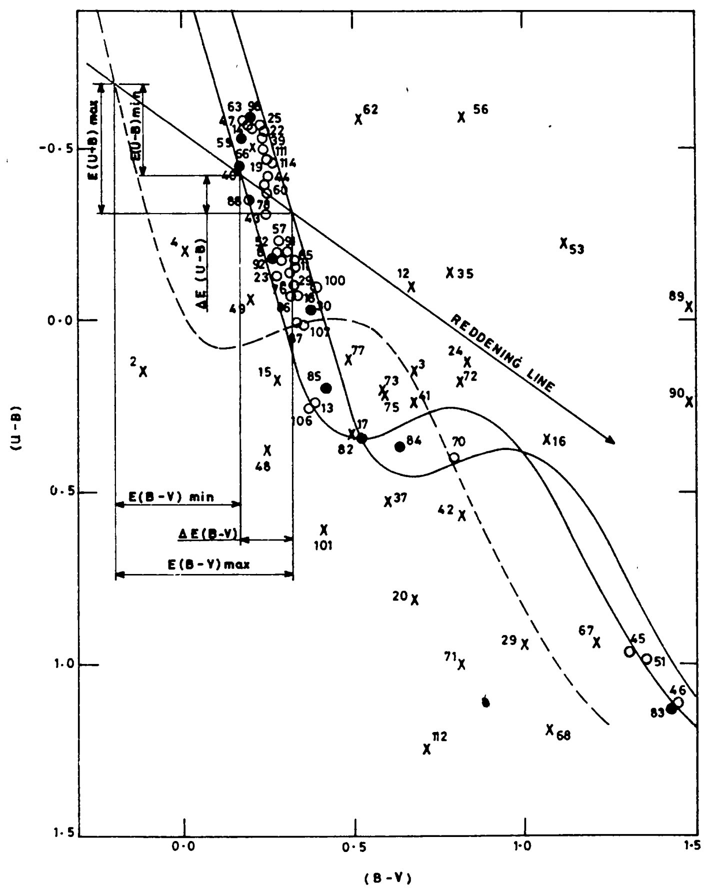

Figure 3. The $(B-V)$ versus $(U-B)$ diagram of the stars in the field of the open cluster OC1 427. The filled circles and the unfilled circles represent respectively the members which are observed photoelectrically and photographically. The half-filled circle is the doubtful member and the crosses denote the non-members. The dashed line is the main sequence (MS) for the unreddened stars (Schmidt-Kaler 1982), while the solid lines represent the MS when it is fitted to the observations with the maximum and minimum reddening by shifting it parallel to the reddening line (Hiltner & Johnson 1956).

Burki 1975) on to the observed sequence, in such a way that the shift is parallel to the reddening line (Hiltner & Johnson 1956), for determining the minimum and maximum colour excesses of the stars in the sequence as shown in Fig. 3.

The difference Δ between $E(B-V)_{\max}$ and $E(B-V)_{\min}$ is found to be

$$\Delta E(B-V) = E(B-V)_{\max} - E(B-V)_{\min}$$
$$= 0.53 - 0.38 = 0.15 \text{ mag.}$$

Similarly,

$$\Delta E(U-B) = E(U-B)_{max} - E(U-B)_{min}$$
$$= 0.38 - 0.27 = 0.11 \text{ mag.}$$

These values, being slightly larger than the values due to the natural dispersion (*cf.* Burki 1975), suggest a variable extinction across the field of the cluster. Hence the individual corrections for interstellar reddening were applied to such stars which are determined to be the cluster members (*cf.* next section). These individual $E(B-V)$ values have also been included in Table 1.

Using the $E(B-V)$ values, the corresponding values of A_v were obtained from the expression

$$A_v = RE(B-V)$$

where R is the ratio of total-to-selective absorption, taken to be 3.25 ± 0.05 as suggested by Moffat & Schmidt-Kaler (1976). These A_v values are found to be between 1.72 mag and 1.24 mag, which in turn, were utilized for correcting the observed V values. All these individually corrected magnitudes and colours are included in Table 1 as V_0, $(B-V)_0$ and $(U-B)_0$.

5. Membership

Since this work is aimed at utilizing the cluster as a spiral feature tracer in our Galaxy, the complete membership assignment is not a necessary requirement. The members should be able to define the colour-magnitude sequence, which in turn is mainly needed to determine the distance modulus and then to estimate the probable age of the cluster. With this in view and in the absence of any other earlier information about this cluster, only photometric criteria were used for determining the membership of the individual stars. As described by Vogt & Moffat (1972), the colour-colour diagram (Fig. 3) and the two colour-magnitude diagrams (Figs 4 and 5) were examined for this purpose. In spite of the slightly larger scatter, a majority of the stars are seen to be forming the corresponding sequences in all the three diagrams. Then, following the criteria given by Vogt & Moffat, a total of 43 stars have been found to be common in all the three sequences and thereby have been adopted as the probable members of the cluster out of the observed 72 stars. Among these 43, there are four stars (45, 46, 51 and 83) in such a region where they could perhaps be considered as belonging to the giant sequence of the cluster. Star 88 appears to be a little too bright and is considered as a doubtful member. This star is indicated as "m?" in Table 1 and is denoted by a half-filled circle in the diagrams. The other members are marked with letter "m" in the table. The members based on the photoelectric photometry and photographic photometry are respectively denoted by filled and unfilled circles in all the diagrams. The rest of the stars are denoted by crosses in Figs 2, 3, 4 and 5.

6. Distance

The value of the distance modulus of this cluster has been determined by fitting the relevant zero-age main sequences (ZAMS) given by Schmidt-Kaler (1982) onto the V_0,

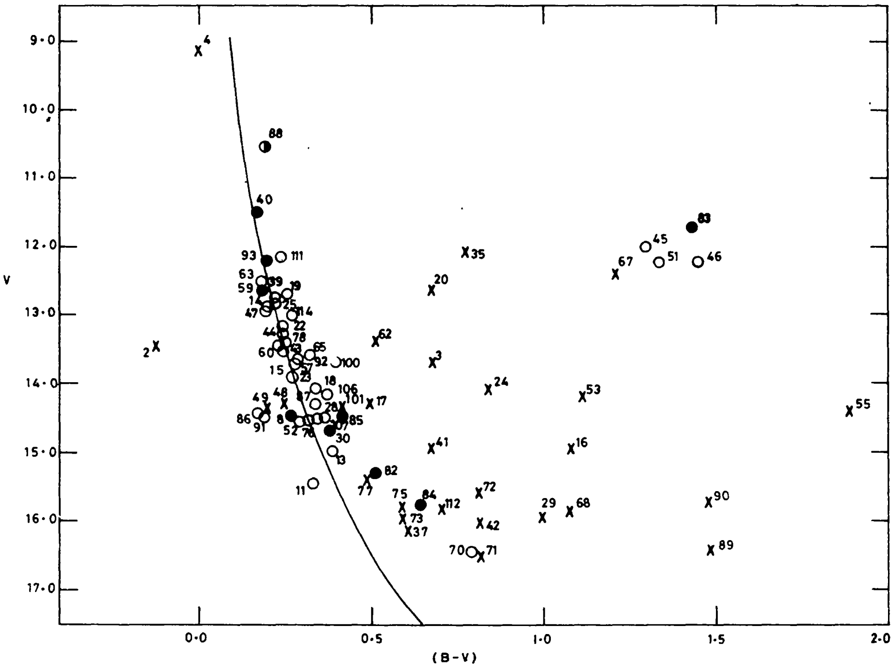

Figure 4. The $(B-V)$ versus V magnitude diagram of the stars in the field of OC1 427. The solid curve represents the zero-age main sequence (ZAMS) (*cf.* Schmidt-Kaler 1982), which is shifted to match with the observations. The symbols are same as in Fig. 3.

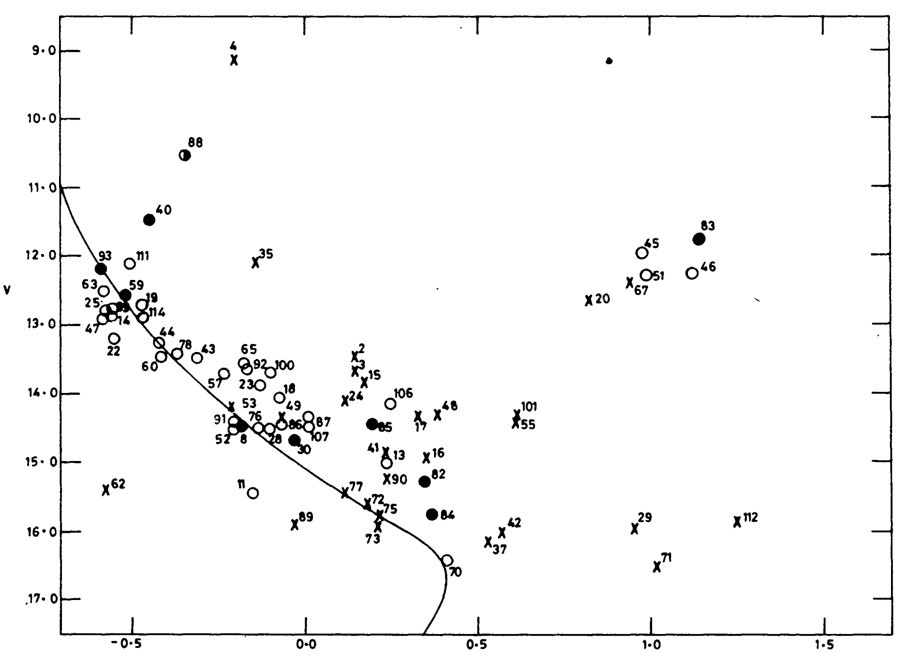

Figure 5. The $(U-B)$ versus V magnitude diagram of the stars in the field of OC1 427. The solid curve represents the ZAMS (*cf.* Schmidt-Kaler 1982) which is shifted to match with the observations. The symbols are same as in Figs 3 and 4.

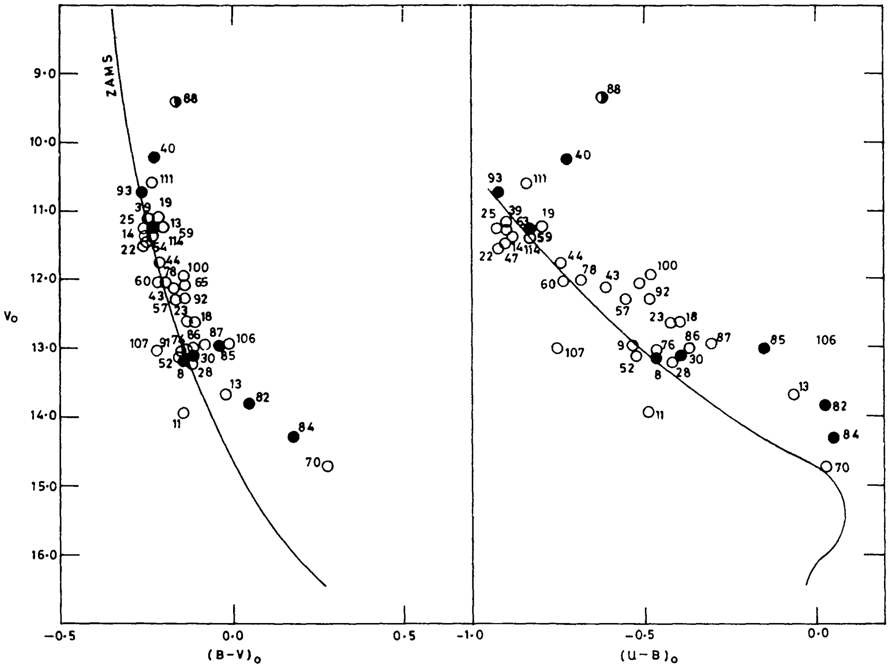

Figure 6. The intrinsic $(B-V)_0$, V_0 and $(U-B)_0$, V_0 diagrams of OCl 427. The solid curves represent the respective ZAMS taken from Schmidt-Kaler (1982). The symbols are same as in Figs 3–5, with all the non-members deleted.

$(B-V)_0$ and V_0, $(U-B)_0$ diagrams respectively, as shown in Fig. 6. The estimates of the true distance modulus as obtained from these two colour-magnitude diagrams are 13.25 mag and 13.05 mag respectively, yielding an average value of 13.15 mag. Then the distance D to the cluster is obtained as

$$D = 4.27 \pm 0.14 \text{ kpc},$$

from the expression $\log D = 0.2\,(V-M)+1$ where $(V-M)$ is the distance modulus.

7. Age of the cluster

The HR-diagram of the cluster is plotted in Fig. 7 for the above-mentioned true distance modulus of 13.15 mag. On this diagram, the post-MS isochrones given by Barbaro, Dallaporta & Fabris (1969) have been superimposed along with the ZAMS in order to determine the age from the MS and post-MS stars. Two of the stars, 40 and 88, indicate the slightly evolved phase and show a range in age as 2.2×10^7 years. The members in the red-giant region give a slightly older age range of 5.0×10^7 to 7.1×10^7 years.

There are a few stars, which are apparently located in the pre-MS contracting phase. According to the isochrones given by Iben (1965) for this phase, it is found that they are about the age of 1.75×10^6 years. It is quite likely that these pre-MS contracting stars are indeed part of the cluster since most of the stars in the upper part of the MS are in the range of 1.0×10^7 to 2.2×10^7 years, thus making the cluster sufficiently young. However, this aspect throws some doubts on the membership of the stars in the red-

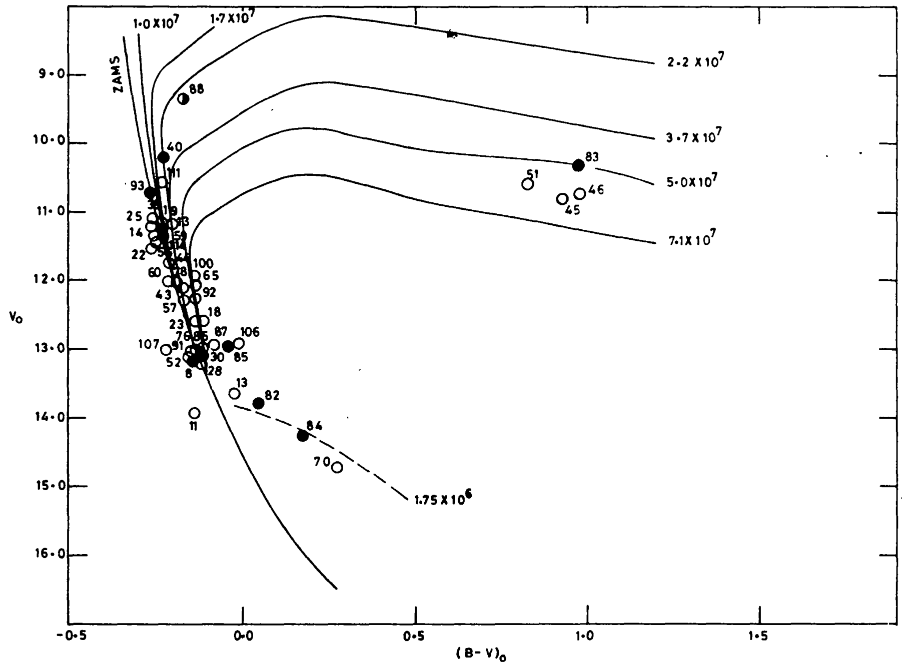

Figure 7. The HR-diagram of the open cluster OC1 427. The ZAMS is the same as in Fig. 6, but drawn for the true distance modulus. The post-MS isochrones are from Barbaro, Dallaporta & Fabris (1969) and the dashed line represents the pre-MS isochrones taken from Iben (1965). The ages are indicated in years alongside the isochrones. The symbols are same as in Figs 3–6.

giant area. Nevertheless, dispersion in ages of cluster stars is possible, since star formation in clusters is not necessarily coeval (*cf.* Herbig 1962; Iben & Talbot 1966; Williams & Cremin 1969; McNamara 1976; Piskunov 1977; Gotz 1977; Sagar & Joshi 1978a, 1978b, 1979).

The age of the cluster has also been determined on the basis of the earliest $(B-V)_0$ on the MS. This value is -0.26 mag and yields an age of 1×10^7 years. Thus, the total dispersion in age seems to be from 1.0×10^7 to 7.1×10^7 years, if the pre-MS stars are not considered.

8. Conclusions

The open cluster Czernik 20 is found to contain at least 43 stars as probable members down to $m_v \approx 15.75$ mag. Four of these stars could be members in the red-giant branch. The cluster stars show a range in their ages from 1.0×10^7 to 7.1×10^7 years suggesting the non-coeval nature of the cluster. Further the presence of a variable extinction across the field of the cluster combined with the presence of some stars belonging to the probable pre-MS contracting phase makes the cluster a star-forming region. These factors lead to the conclusion that the cluster may be young enough to be used as a spiral arm tracer.

Thus, at the distance of 4.27 ± 0.14 kpc, this cluster is expected to be a part of a spiral feature. Indeed the location of this cluster in the map of the Galaxy is inside the Outer Perseus arm in the direction of Auriga constellation.

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