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COLLINDER 121: A YOUNG SOUTHERN OPEN CLUSTER SIMILAR TO h AND χ PERSEI*

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ABSTRACT

Three-color photoelectric photometry has been carried out for stars in the open cluster Cr 121. The data state that the cluster is nearly identical to h and χ Persei but has fewer members It was found that some bright and high-luminosity stars in Canis Major ($\gamma, \delta, \eta, \iota, \xi^1, o^1, o^2, \sigma$) are members of this cluster A Wolf-Rayet star (HD 50896) may also be a member according to the observed colors Its position in the color-magnitude diagram is close to the turnoff point of the main sequence. Cr 121 is situated at a distance of 630 pc, and is as young as the double cluster in Perseus. The reddening is very small.

I. INTRODUCTION

The open cluster Collinder 121, which lies around the red supergiant o^1 CMa, was measured in connection with a program of photoelectric observations of some bright southern clusters. This cluster, located in Canis Major ($l^{II} = 235°4$, $b^{II} = -10°4$), became of considerable interest after Roberts (1958) pointed out that a Wolf-Rayet star lies within one cluster radius. Schmidt-Kaler (1961) called attention to Cr 121 because around the K supergiant, which is inside the cluster boundaries, there are some B stars of apparent visual magnitude between $m_v = 1$ and $m_v = 5$ which have similar values of the radial velocities and proper motions. He called this cluster the "core" of the B group. He also emphasized that the presence of the Wolf-Rayet star may characterize this group as an OB association.

II. THE OBSERVATIONS

The observations were made during February, 1964, with the NSF photometer using a refrigerated photomultiplier 1P21 attached to the 32-inch reflector of the La Plata Observatory. Later, in February, March, and November, 1965, other possible members were measured, mostly with the 16-inch telescope of the Cerro Tololo Inter-American Observatory (Chile).

The measurements in the *UBV* system of twenty-one stars contained within 30′ from the center of the cluster made during 1964 are listed in Table 1. The first three columns give the star number (HD or CD) and the spectral type from the *HD.* In the next four columns the observations V, $B - V$, $U - B$, and the number of measures follow.

The mean errors of a single observation derived from the internal consistency of the standard stars are $\epsilon_V = \pm 0.025$ (m.e.), $\epsilon_{B-V} = 0.020$ (m.e.), and $\epsilon_{V-B} = 0.025$ (m.e.). The stars measured during 1965 are listed below (Tables 6 and 7). Since we used the same standard stars at Cerro Tololo and La Plata the systems are exactly comparable, but because of the very good observing conditions at Cerro Tololo the mean error is much smaller (around ± 0.01).

The color-magnitude and color-color arrays for all the stars listed in Table 1 are shown in Figures 1 and 2. In Figure 1 for each star the HD spectral type is indicated. The zero age main sequence ("ZAMS") according to Blaauw (1963) is also exhibited.

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TABLE 1

PHOTOELECTRIC MAGNITUDES AND COLORS FOR STARS IN COLLINDER 121

HD or CD	Sp(HD)	V	$B-V$	$U-B$	No.	Notes
50877	K2p	3 79	+1 76	+1 97	6	K3 Iab
50853	A0	6 20	+0 01	+0 14	5	Non-member
50711	A2	6 46	+0 12	+0 17	4	Non-member
50896	Ob	6 91	−0 28	−0 90	4	WN5
50804	A3	7 47	+0 19	+0 29	5	Non-member
50646	B3	7 71	−0 20	−0 82	3	
50781	F8	8 14	+0 52	0 00	2	Non-member
50680	B8	8 27	−0 20	−0 78	4	
51088	B8	8 28	−0 18	−0 43	4	
51036	B5	8 77	−0 19	−0 80	4	
50740	B9	8 77	−0 05	−0 10	3	
51013	B8	8 78	−0 15	−0 63	4	
51038..	B5	9 03	−0 16	−0 68	3	
−24°4587		9 30	+1 07	+0 86	4	Non-member
−24°4552	..	9 46	+0 56	+0 05	2	Non-member
51035	B9	9 48	−0 09	−0 32	3	
51087	F2	9 51	+0 43	+0 07	3	Non-member
50591.	F8	9 61	+0 48	−0 02	1	Non-member
−24°4556	.	10 16	+0 81	+0 36	1	Non-member
50592	A0	10 30	0 00	−0 17	3	
51111	B9	10 40	−0 04	−0 18	2	

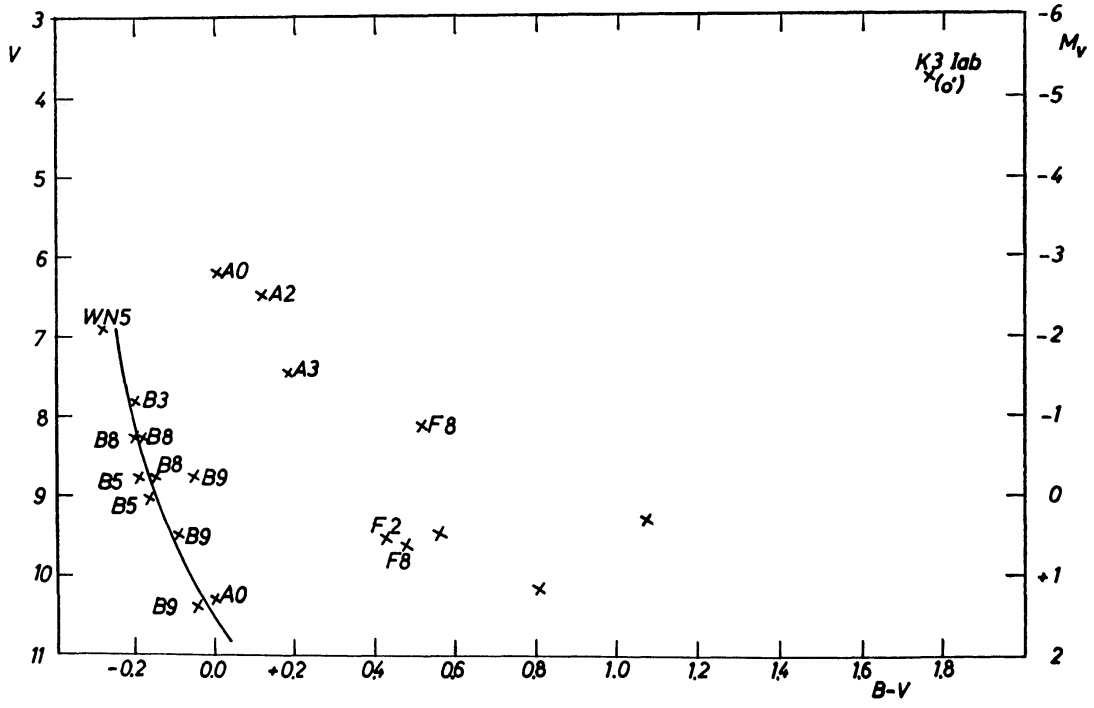


FIG 1.—The color–visual apparent magnitude array of stars in the cluster Collinder 121 (Table 1). The spectral type is taken from the *HD*. It is also indicated the position of the zero-age main sequence.

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Eleven stars, including the Wolf-Rayet star, fall around the position of the mean sequence, and since color and spectral type are very well correlated, there seems to exist no doubt of their membership. The average color excess, as estimated from Table 2, is not more than $E_{B-V} = 0.03$, and the absorption is therefore certainly less than $A_v = 0.1$. In the third and fourth columns of Table 2 are given, respectively, the observed and the intrinsic colors (Johnson 1963) derived from the spectral type.

From the position of the ZAMS the distance modulus results in $m - M = 9.0$, which gives a distance of 630 pc. An interesting feature in Figure 1 is the larger number of A and F foreground stars as compared with the very few G stars.

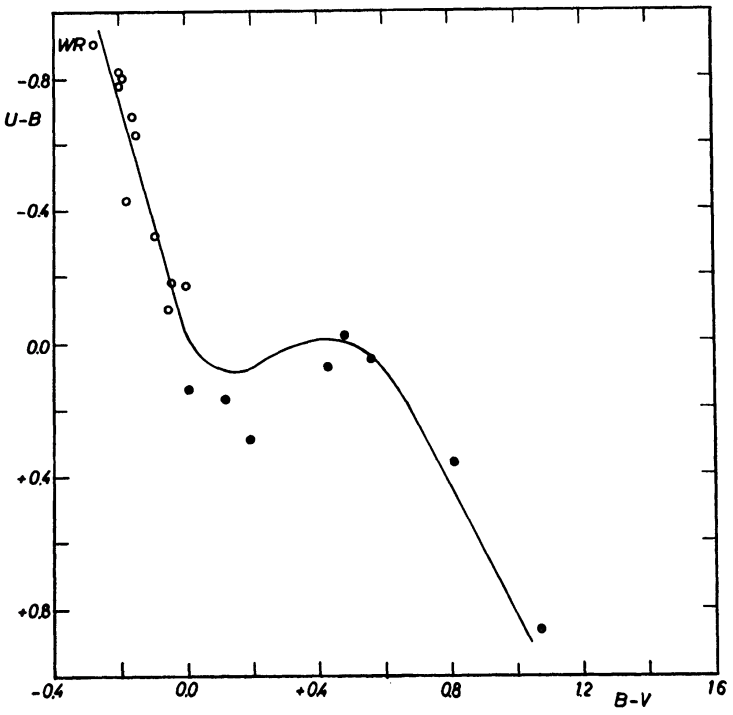


FIG. 2 —The color-color array of stars in the cluster Collinder 121. The circles stand for stars which are certain members of the cluster, and the dots are probably non-members The position of the Wolf-Rayet star is indicated.

TABLE 2

B − V COLORS OF THE MAIN-SEQUENCE STARS

HD	Sp	$B-V$	$(B-V)_0$
50646	B3	−0 20	−0 20
50680	B8	− 20	− 09
51088	B8	− 18	− 09
51036	B5	− 19	− 16
50740	B9	− 05	− 06
51013	B8	− 15	− 09
51038	B5	− 16	− 16
51035	B9	− 09	− 06
50592	A0	00	.00
51111	B9	−0 04	−0.06

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III. THE TWO BRIGHTEST STARS

The only cluster stars classified in the MK system are the two brightest: the red supergiant o^1 CMa (HD 50877) and the Wolf-Rayet star HD 50896.

HD 50877.—The red supergiant o^1 CMa classified by Morgan and Roman (1950) as K3 Iab, has an absolute magnitude of $M_v = -5.0$ from our diagram, which places it in the position of the red branch of the double cluster h and χ Persei. Its absolute magnitude is confirmed from the measure of the emission K-line made by Wilson and Bappu (1957), who quoted $M_v = -5.2$, in very good agreement with us. From the calibration of the spectral types and luminosity classes in the MK system, Blaauw (1963) gives for K3 Iab an absolute magnitude of $M_v = -6.0$.

Comparing our observations made at 1964 and 1965 (Table 3) we conclude that the star may vary somewhat in brightness. In the same table the measures of R and I made with a photomultiplier RCA 7102 and adequate filters for the Johnson system are also indicated (Johnson 1964).

If we try to correlate the colors $U - V = 3.76$, $B - V = 1.74$, $V - R = 1.13$, and $V - I = 2.03$ with the values suggested by Johnson (1964) for supergiants of luminosity class I, we find a better coincidence with a K5 I type slightly reddened, for which Johnson indicates $U - V = 3.31$, $B - V = 1.59$, $V - R = 1.20$, and $V - I = 2.08$.

TABLE 3

PHOTOELECTRIC MEASURES OF HD 50877

Date	V	$B-V$	$U-B$	No	R	$R-I$	No
February, 1964	3 79	1 76	1 97	6	. . .	. . .	.
November, 1965	3 88	1 74	2 02	4	2 75	0 90	7

HD 50896.—The brightest star on the main sequence is a Wolf-Rayet object which has been classified by Wilson (1948) and Smith (1955) as WN5, and as WN6 by Ross (1961) and Andrillat (1957). Assuming its membership to be certain we get $M_v = -2.0$ from the color-magnitude diagram, which implies a large discrepancy with Allen (1963), who quoted $M_v = -4.0$.

It was shown by Ross (1961) that there are some abrupt changes of the order of 0.08 mag in the brightness of this star. Our photometry supports this conclusion as shown in Table 4, where the individual values of our observations are listed.

From the comparison between the intrinsic colors of main-sequence stars given by Johnson (1965) and our observations the W-R star is very well correlated in the U and B with a B1 V object (Table 5), but in R and I it has a noticeable excess of radiation which suggests a red companion.

Kuhi (1966) and Pyper (1966) took into account, in a quantitative way, the color's contamination of the W-R stars by the broad emission lines. The star HD 50896, with small or no reddening at all, may be an O9 V star according to the conclusions derived by Kuhi for all the single W-R stars. On the other hand, the correction for this star obtained by Pyper displaces it to the right and away from the main sequence in the C-M diagram.

Summarizing, from the observed magnitude and colors the W-R star should belong to the cluster, although its membership would become doubtful when the colors corrected by the effect of the emission lines are computed.

One interesting point is that the Wolf-Rayet star without the correction by the emission lines is very near the turnoff point; the same fact was also found by Westerlund (1961) for two clusters in the Large Magellanic Cloud.

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IV. THE CLUSTER AND THE NEARBY BRIGHT STARS

From the C-M diagram presented in Figure 1 we find o^1 CMa in the same place where the red-giant branch of h and χ Persei lies (Wildey 1964), which implies that both clusters may be similar. This brings up the question of why there are no stars near the main sequence, or evolved from it, between $M_v = -5$ and $M_v = -2$. Searching around the cluster Cr 121 for some bright stars with high luminosity class, Schmidt-Kaler (1961) found that the bright stars, δ CMa (F8 Ia), o^2 CMa (B1 Ia), η CMa (B5 Ia), γ CMa (B8 II), have approximately the same radial velocity as o^1 CMa (see Table 6). This

TABLE 4

PHOTOELECTRIC MEASURES OF THE WOLF-RAYET STAR HD 50896

Julian Date	V	$B-V$	$U-B$	Julian Date	R	$R-I$
2438400+29	6 89	−0 29	−0 90	2439000+81	6 54	0 22
39	6 95	−0 31	−0 90	83	6 54	0 22
43	6 92	−0 28	−0 90	88	6 50	0 23
44	6 90	−0 27	−0 92	89	6 52	0 27
				90	6 55	0 27
Mean	6 91	−0 28	−0 90			
				Mean	6 53	0 24
2439000+80	6 77	−0 26	−0 86			
85	6 80	−0 28	−0 85			
93	6 84	−0 27	−0 84			
Mean	6 80	−0 27	−0 85			

TABLE 5

OBSERVED COLORS OF HD 50896 AND INTRINSIC COLORS OF MAIN SEQUENCE STARS

Object	$U-V$	$B-V$	$V-R$	$V-I$	Source
HD 50896	−1 11	−0 27	+0 27	+0 52	. . .
B0 V	−1 38	− 30	− 13	−0 41	Johnson (1965)
B1 V	−1 19	−0 26	−0 11	−0 36	Johnson (1965)

would suggest a physical connection of some nearby stars with the cluster. So we decided to examine all the stars lying around the cluster that could fill the diagram from $M_v = -2$ ($m_v = 7$) to higher luminosities.

The condition to be fulfilled by a star to become candidate for membership is the similarity of the radial velocity, proper motions, apparent magnitude, color, spectral type, and luminosity class, with the corresponding values of the other cluster members. The list of possible members, headed by the two brightest members of the cluster, o^1 CMa and the W-R HD 50896, is presented in Table 6 and plotted in Figure 3. Most of these stars are of high luminosity class. We do not include in the table the star ϵ CMa (B2 II) since its membership is very doubtful because of its spectral type and luminosity class as contrasted with its position in the diagram ($V = 1.50$, $B - V = -0.22$), in spite of the very good agreement on the radial velocity ($VR = +27$ km/sec). The star σ CMa (M0 Iab) may be a member despite the disagreement of the radial velocity; γ CMa may not be a member because of its proper motion (+0″.002, −0″.008), but its other data agree very closely with those of the cluster.

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TABLE 6

BRIGHT STARS AROUND CR 121

Designation	HD	Sp	Ref *	RV (km/sec)	μ_α	μ_δ	V	$B-V$	$U-B$	Ref *	M_v (diagram)
o^1 CMa	50877	K3 Iab		+36	−0 008	−0″010	3 79	+1 76	+1 97	(8)	−5 2
HR 2583	50896	WN5	..	..	− 010	000	6 91	−0 28	−0 90	(8)	−2 1
ζ^1 CMa	46328	B0 5 IV	(1)	+27v	− 004	+ 010	4 35	−0 25	−0 98	(9)	−4 6
10 CMa	48917	B2 Ve	(2)	+34	− 019	+ 006	5 29	−0 13	−0 92	(8)	−3 7
15 CMa.	50707	B1 IV	(1)	+31	− 006	+ 004	4 82	−0 21	−0 96	(9)	−4 2
HR 2595	51283	B3 II–III	(1)	+38	− 017	+ 001	5 28	−0 17	−0 76	(8)	−3 7
ι CMa	51309	B3 II	(3)	+41	− 003	+ 010	4 39	−0 06	−0 68	(9)	−4 6
	52812	B3 V	(4)	+37	(− 005	− 002)	6 91	−0 17	−0 70	(8)	−1 7
σ CMa	52877	M0 Iab	(5)	+22	− 003	000	3 43	+1 72	+1 87	(9)	−5 6
o^2 CMa	53138	B3 Ia	(6)	+48	000	000	3 01	−0 11	−0 83	(9)	−6 0
γ CMa	53244	B8 II	(7)	+30v	+ 003	− 008	4 11	−0 11	−0 46	(9)	−4 9
δ CMa..	54605	F8 Ia	(3)	+34v	− 004	+ 003	1 80	+0 67	+0 53	(9)	−7 2
HR 2695	54669	B3 V	(4)	+30v	− 014	− 012	6 61	−0 18	−0 78	(8)	−1 7
HR 2734	55857	B3 IV	(4)	..	− 027	+ 003	6 08	−0 23	−1 00	(8)	−2 9
η CMa..	58350	B5 Ia	(3)	+41	− 007	+ 004	2 41	−0 07	−0 70	(9)	−6 6
HR 2855	58978	B0 IVpe	(1)	+48	−0 011	+0 001	5 64	−0 12	−1 05	(8)	−3 2

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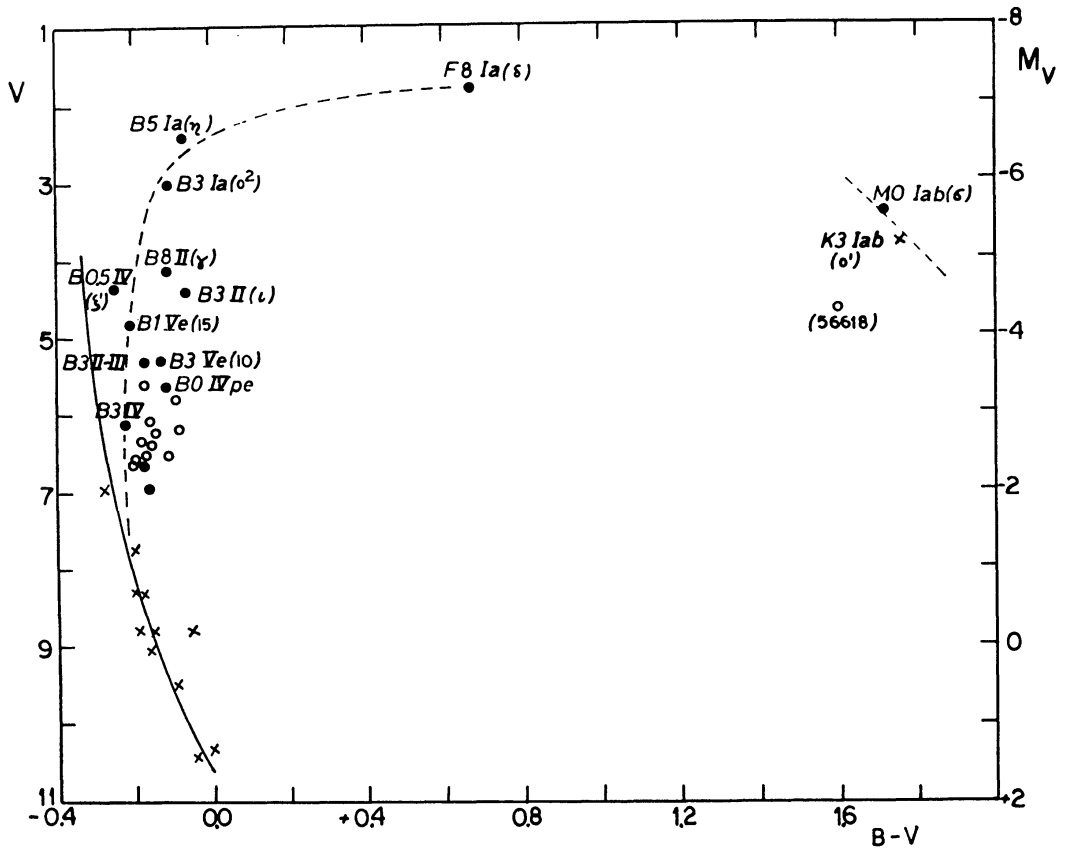


FIG. 3 —The color-magnitude diagram of stars in the cluster Collinder 121 (*crosses*), the bright stars in Canis Major (*dots*), and some nearby faint stars (*circles*). The spectral types in the MK system on the stars with known classifications are shown, and also their designations.

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V. FAINTER STARS

Since it was shown in § IV that some of the apparent bright stars around the cluster are members of Cr 121, it becomes of interest to search for other possible members of fainter apparent magnitude. Some stars between apparent visual magnitude 5.5 and 6.5, within a radius of 5° around the cluster, were selected on the basis of their apparent magnitudes and spectral types. They are listed in Table 7, which gives the HR number, followed by the HD spectral type or the MK type when available, the radial velocity, and the proper motion components. The last four columns present the observed photometric data (V, $B - V$, $U - B$) and the number of measures. All these stars, observed in 1965, are plotted in Figures 2 and 3 as circles.

The next question is how many of the stars of Table 7 are certain members. Although all of them lie in the right place of the diagram, very few would remain members according to their radial velocities and proper motions. If any one of these stars is not a member, it can be either a foreground dwarf of lower luminosity or a background reddened

TABLE 7

STARS AROUND CR 121

HR	HD	Sp *	RV	μ_α	μ_δ	V	$B-V$	$U-B$	No
2497	49038	B8 IV	+18	−0 030	+0 015	6 54	−0 11	−0 48	4
2509	49333	B8	+20v	− 013	+ 003	6 07	−0 16	−0 62	4
2603	51630	B8		− 006	− 017	6 64	−0 20	−0 80	5
2611	51823	B3	..	− 036	+ 002	6 22	−0 14	−0 67	4
2616	52018	B3	+28v	− 012	+ 012	5 59	−0 17	−0 71	4
2621	52140	B8	+14	000	+ 019	6 39	−0 15	−0 62	4
2741	55958	B3	+28v	+ 018	− 004	6 56	−0 17	−0 77	4
2743	55985	B3	+19v	− 018	− 008	6 32	−0 18	−0 83	4
2766	56618	gM3	+42	− 015	+ 038	4 65	+1 60	+1 88	5
2824	58325	B3 V	+ 7	− 022	+ 007	6 58	−0 19	−0 79	5
2826	58346	B9		− 015	− 003	6 16	−0 08	−0 35	4
2841	58612	B9		− 022	+ 001	5 78	−0 09	−0 39	4

*P M Morris, *M N R A S*, **122**, 325 (1961); D Hoffleit, *Catalogue of Bright Stars* (3d rev ed ; New Haven, Conn : Yale University Obs)

supergiant star. But the last possibility may be ruled out according to Figure 4 (color-color diagram), because all stars are on the main sequence or very near it, and the effect of reddening is practically unnoticeable. Therefore, from the position of these stars in the diagram, we conclude that all of them should be dwarfs, and since they occupy the proper position in the C-M diagram it is highly probable that they belong to the cluster.

It should be added that accurate spectral classification of these stars would help considerably to clarify the situation.

VI. COMPARISON WITH h AND χ PERSEI

In Figure 5 is drawn the schematic color–absolute magnitude diagram of h and χ Persei taken from Wildey (1964). In the same diagram are plotted the stars which could belong to Cr 121 according to the present paper.

It is difficult to compare details of h and χ Persei with Cr 121, since in the latter cluster we have fewer members than in the former; but nevertheless we notice some different features: (*a*) the evolved branch in Cr 121 is older than the youngest evolved branch of h and χ Persei; (*b*) all the stars above $M_v = -2$ had already evolved from the main sequence; (*c*) the width of the sequence at $M_v = -3$ is quite similar, being about 0.2 mag; (*d*) two red supergiants are in the same sequence as in h and χ Persei; another

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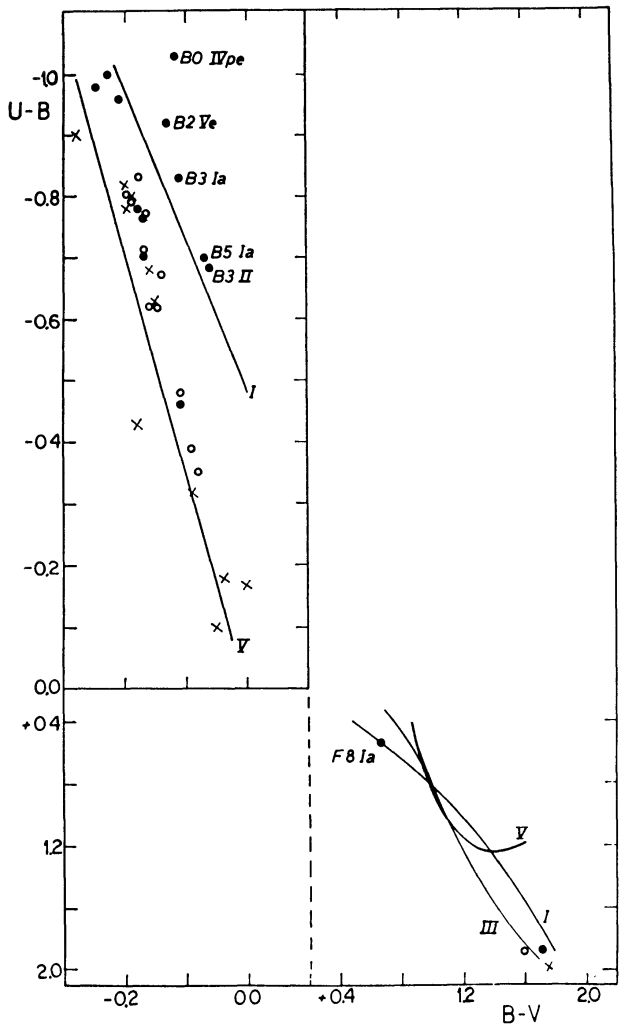


FIG. 4.—Color-color diagram for the same stars of Fig 3 *Dots:* bright stars; *circles:* fainter stars; *crosses:* stars in Collinder 121. The lines represent the dwarf, giant, and supergiant sequences.

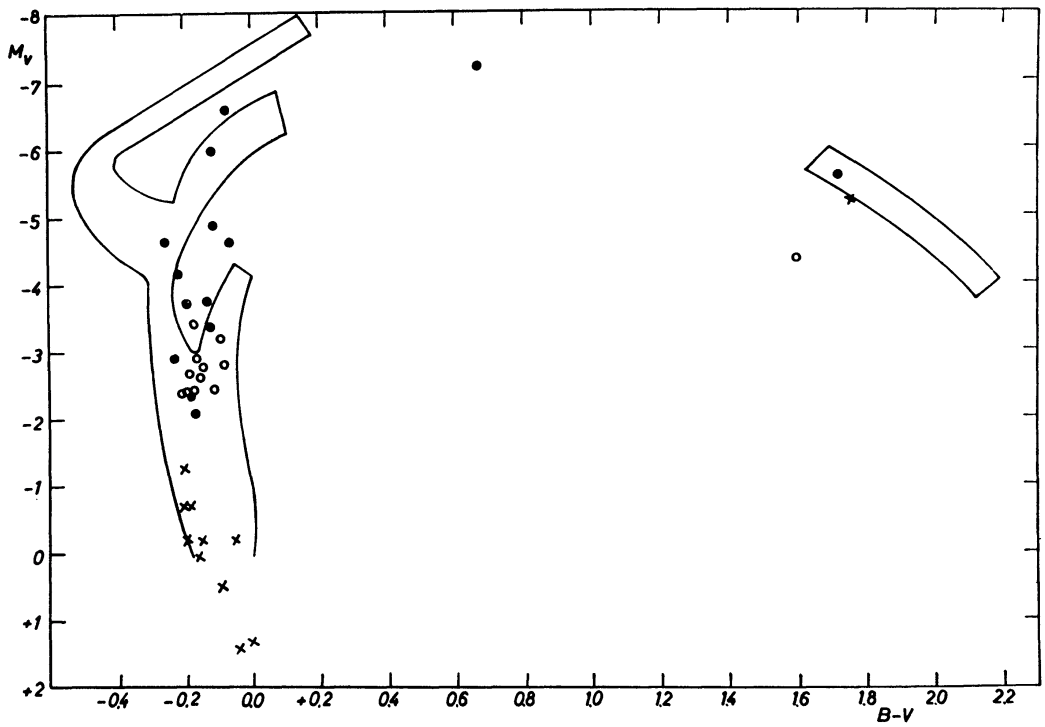


FIG. 5.—Color-absolute magnitude diagram of all the stars which are supposed to be members of Cr 121. For comparison the schematic drawing made by Wildey (1964) of h and χ Persei is shown.

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red star, whose membership is uncertain, is about 1 mag below this giant red sequence; (*e*) one very bright star, δ CMa ($M_v = -7.2$, $B - V = 0.67$) is in the gap.

Taking into account all the uncertainties involved in judging the membership of some of the stars it seems that Cr 121 is very similar to the double cluster in Perseus.

VII. CONCLUSION

What is called Cr 121 is a concentration of a red supergiant and some main-sequence B stars in a circle of 1° diameter in Canis Major, but we found that some supergiants of types B, F, and M in a circle of about 10° are related to the group. Some fainter stars around may also be connected to it.

The relations of the early-type supergiants in Canis Major with Cr 121 may explain the existence of these young stars as apparent field stars.

I am very much indebted to Dr. W. Buscombe for calling my attention to the probable connection between the apparent bright stars in Canis Major with the cluster Cr 121. I am also thankful for the comments and suggestions made by Dr. C. Jaschek in the preparation of the paper. Finally I should like to record my appreciation to Dr. J. Stock for permission to use the facilities of the Cerro Tololo Inter-American Observatory.

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