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THE dB AND gK STARS NEAR THE DIRECTION OF THE GALACTIC CENTER*)

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R I N G K A S A N

Suatu survey dengan prisma obyektip pada arah Palomar-Groningen Variable - Stars Field no. 3 telah diadakan guna menentukan distribusi ruang bintang - bintang dB dan gK. Sebuah konsentrasi bintang-bintang dB ditemukan pada jarak antara 150 sampai 250 pc. Harga Ekses Warna pada arah ini didapati cukup rendah. Ekses tersebut besarnya hanya mencapai $0^{m}_{.}12$ pada $r = 0.5$ kpc dan tidak banyak berubah pada jarak-jarak yang lebih besar.

A B S T R A C T

An objective prism survey of the Palomar-Groningen Variable-Stars Field no. 3 has been undertaken in order to determine the stellar space distribution of dB and gK stars. A concentration of dB stars has been found at the distances between 150 to 250 pcs. The color excess in this direction is found to remain very low. It only reaches $0^{m}_{.}12$ at $r = 0.5$ kpc and remains constant thereafter.

INTRODUCTION

It is a problem of considerable interest in the study of galactic structure, to determine whether the dB (dB8-dA2) and gK (gG8-gK2) stars occupy approximately the same position in space. In the anti-center direction McCuskey (1967) has found

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that the B8-A0 main sequence stars and the G8-K3 giant stars decline in numbers per unit volume beyond 400 pc. from the sun. But the B8-A0 group seems to reach a maximum space density at 300 to 400 pc.

In a preliminary study of the distribution of dB and gK stars in the direction of the galactic center, at b = + 11°, Hidayat (1970) indicated that a correlation between space densities of B8-A2 stars and gG8-gK2 stars may exist.

The present study is aimed at determining the run of stellar space-density of the same groups of stars, in the direction of the galactic-center, at b = - 10°. The results of the present study, when combined with earlier results for approximately the same galactic longitudes should be able to provide the information on the cross sectional distribution of stars in the plane perpendicular to the galactic in the galactic-center direction.

Currently, a study on the distribution of giant M stars is being made. A report on their distribution will be the subject of a subsequent paper.

OBSERVATIONAL DATA

Studied Area

The area of the sky chosen for the study is the Palomar-Groningen Variable-Star Field 3 (R. A. $18^h\ 25^m$; Dec. -33°; ℓ = 0°8; b = - 10°). The total area covered approximately 25 sq. deq. It has been known by Plaut (1968), and by Wehinger and Hidayat (1973) that the area has a low and uniform interstellar absorption. Figure 1 shows the region under study, reprinted from a visual Bosscha-Schmidt Plate.

Spectra

Spectra of the stars were classified on 3 Kodak IIa-O plates taken with a 6° objective prism mounted on the 20-28-in. Schmidt telescope of the Bosscha Observatory. The exposure times were 2, 45 and 60 min. The dispersion of the spectra is 312 Å/min. at Hγ. Spectra were widened 0.20 mm. The criteria used in classifying the spectra are those given by Nassau and Seyfert (1946) and by Nassau and van Albada (1947).

The present authors classified common stars (65 stars) chosen at random at the beginning of the study. The results show that there is no systematic differences between the two classifications, within the spectral ranges included in the present study. An error of ± 1.4 MK subdivisions is estimated from the comparison with catalogued spectra. A limiting mag-

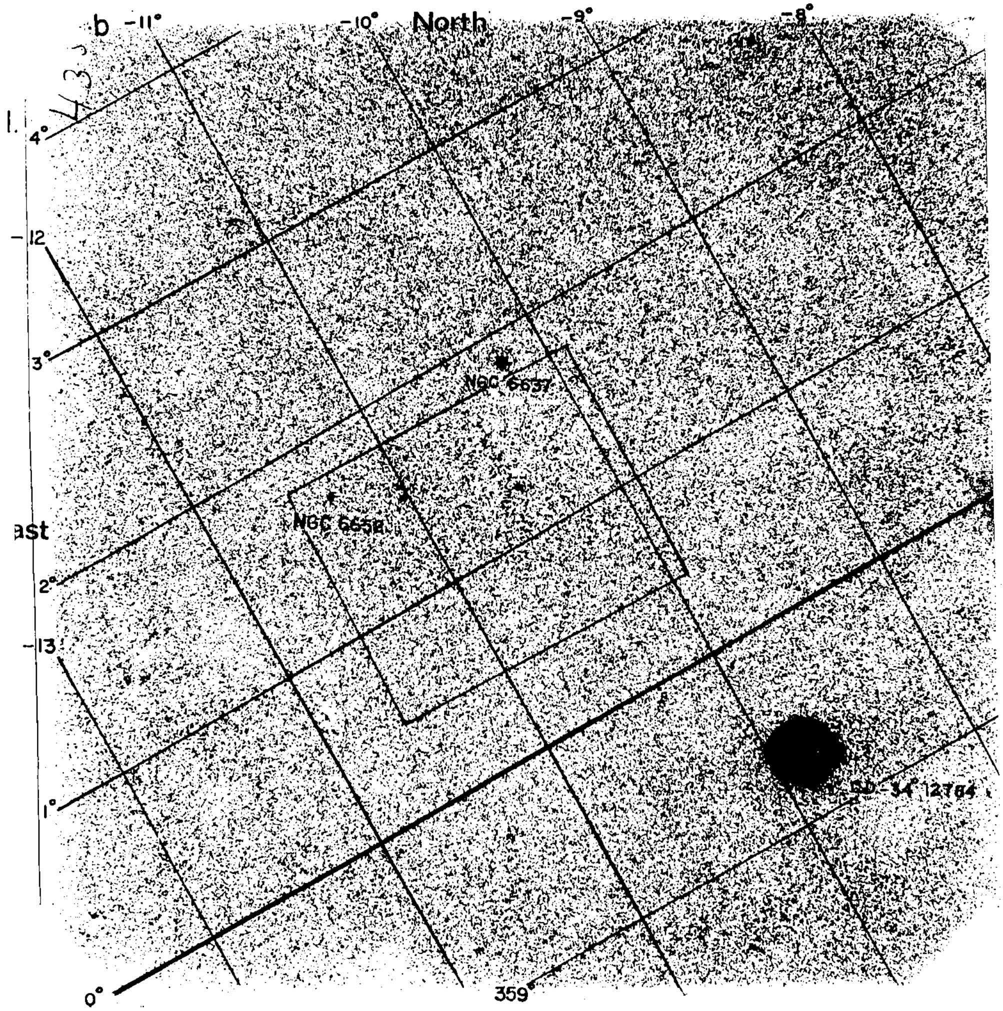

Figure 1. Palomar-Groningen Field No. 3. Reproduced from a visual plate obtained with the Bosscha Schmidt Telescope. Grids show galactic longitude and latitude.

nitude of approximately m_{pg} = 12.8 was reached. 348 dB and 314 gK stars have been classified.

Photometry

V and B magnitudes on the system of Johnson and Morgan (1953) were obtained from three Kodak 103a-D plates taken through a Schott GG 11 filter and three Kodak IIa-O plates taken through a Schott GG 13 filter. All the plates were obtained with the Bosscha Schmidt Telescope in 1966. All stars for which spectra had been classified were measured on each of the plates with Eichner Astrophotometer of the Bosscha Observatory.

The photoelectric sequence used to calibrate the astrophotometer readings for each plate, is the sequence established by Wehinger and Hidayat (1973). These stars have been carefully photographed in the center of the field under study.

In the present study attempt has not been made to study the radial effect of the magnitude determinations. For each plate the astrophotometer readings were fitted to the observed magnitudes by a curv· of a third degree polynomials.

The ranges of the magnitude measurements of the program stars were used to estimate the error according to the method described by Schlesinger (1937). In the final catalogue of magnitude of stars of the present study a probably error of $\pm 0^m.09$ and $\pm 0^m.10$ for V and B-V respectively are attached.

INTERSTELLAR ABSORPTION

An inspection on the deep red blue Bosscha Schmidt photometric plates of the area does not show any appreciable patchiness of surface distribution of interstellar material. We therefore assume that the same variation of interstellar absorption with distance is applicable throughout the area. The evaluation of the interstellar reddening has been made from photoelectric data given by Wehinger and Hidayat (1973).

For each photoelectric sequence stars MK spectral types have been assigned. These spectra have been determined from the spectral plates obtained with the Bosscha Schmidt telescope. An assumption that the stars are of luminosity class V was made. Using absolute visual magnitudes and instrisice colors calibrated by Blaauw (1963) and Fitzgerald (1970) the color excesses for each stars can readily be calculated. The resulting values of E_{B-V} are then plotted as a function of the distance modulus.

Figure 2 shows the run of the color excess versus the uncorrected distance modulus of the photoelectric sequence

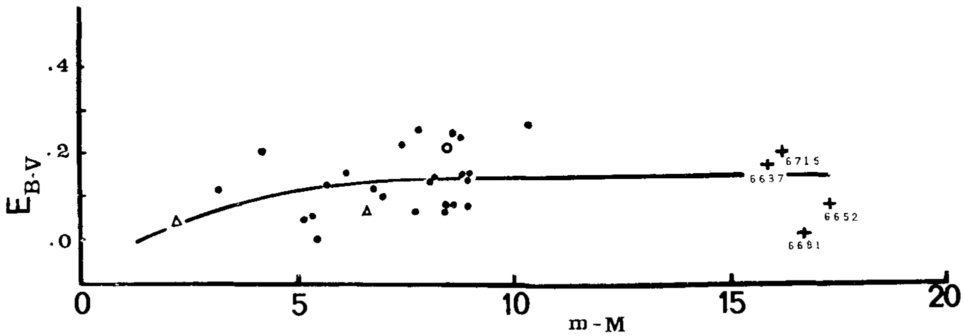

Figure 2. The run of interstellar reddening as the function of uncorrected distance modulus (sec text).

stars. In order to delineate the absorption at large distances the data for the cluster NGC 6637, 6652 and 6681, given by Kron and Mayall (1960) have been incorporated. It can be seen from Fig. 2 that the color excess increases slowly from almost zero in the solar neighborhood to approximately $0^m.1$ at uncorrected distance modulus of 5. Beyond this point the reddening remains constant at $E_{B-V} = 0^m.12$. Fitzgerald (1968) in his study of distribution interstellar reddening material has found $E_y \sim 0^m.13$ at least up to r = 3 kpc for areas close to the field of the present study. In the following discussions a ratio of 3 between the total visual absorption to the excess in B-V was adopted. Table I gives the variation of absorption as the function of distance.

Table I

Total absorption in the direction of Field 3

r (kpc)	A_V
0.05	$0^m.34$
0.20	0.36
0.30	0.37
0.40	0.38
0.50	0.39
1.00	0.39

DISTRIBUTION OF STARS

A summary of the star counts for each $0^m.5$ intervals in the surveyed area is represented in Table II. The lack of bright gK stars is rather obvious. But the drop in number beyond m = 12.5 may be due to the incompleteness of the survey, fainter than m_{pg} = 12.5. Variation in the surface distribution of dB stars (B8-A0) has been noted by McCuskey (1965). The surface density found in the present study is approximately 14 B8-A2 stars per square degree. In the direction of ℓ = 0, the surface density of B8-A0 alone, according to McCuskey (1965), reaches 14 stars per square degree. It is, therefore, expected that the surface density of B8-A2 stars would be larger than

Table II

Observed distribution of dB and gK stars

m_B	dB	gK
6.25	3	-
6.75	3	-
7.25	8	-
7.25	6	1
8.25	15	8
8.75	23	10
9.25	32	18
9.75	48	26
10.25	48	36
10.75	55	49
11.25	40	55
11.75	40	43
12.25	21	36
12.75	5	26
13.25	-	6

that detected in Field 3. In his study of SA 158 (ℓ = $3^\circ.9$, b = -9°) McCuskey (1970) found a surface density of approximately 13 stars per square degree down to a limiting magnitude of $12^m.5$. Assuming there exist a systematic difference in the spectral classification, the numbers of stars found in the two surveys are comparable.

From the frequency distribution shown in Table II, the ratio of the numbers of gK to dB stars can be shown to increase with increasing apparent magnitude. Due to the absence of gK stars brighter than m = 8.00, the ratio at the bright-end of the survey for these groups of stars was not computed. In logarithmic scale the ratio of the number of gK stars (N gK) to the number of dB stars (N dB) is shown in Figure 3, together with the results obtained by McCuskey (1963) for SA 158 and by Weaver (1970) for Lacerta OB 1-Association. In absolute number the results for Field 3 of the present study is comparable to that of SA 158. However, they are being smaller than the value found in Lacerta OB 1. The fact that in Weaver's analysis (1970) the K3 and A3 stars were included in N (K) and N (B) may explain part of the difference. Another reason may be caused by a "latitude-effect". There seems to be no difference in the trend of increase of the ratio of N (gK) to N (dB) in both galactic latitudes discussed here.

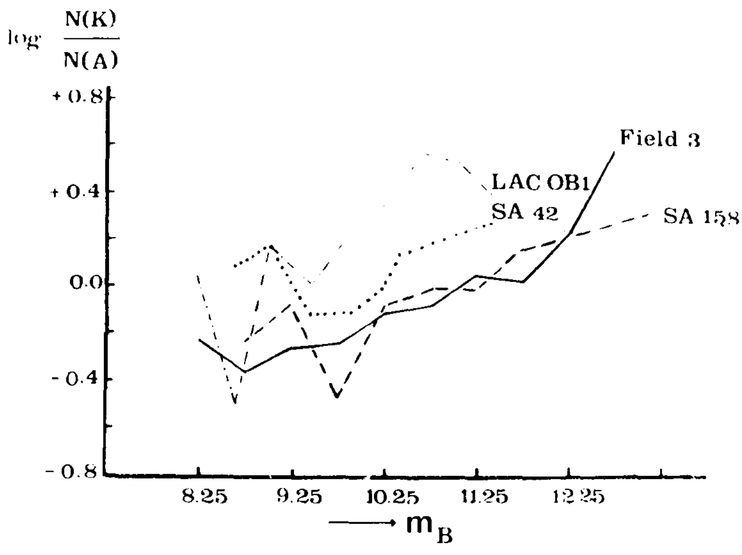

Figure 3. The ratios of giant K stars to B stars in various galactic longitudes. The result of the present study is superposed on the results obtained by Weaver (1970).

The space densities of dB and gK stars were evaluated using the Malmquist method. In the space-density calculation the mean absolute visual magnitudes of 0.7 and 0.8 for dB and gK groups, respectively, were adopted. In both cases a dispersion in absolute magnitude of $\sigma_M = 0.8$ was used. The absolute visual magnitude for dB stars adopted here is fainter than the newly published results by McCuskey and McMillan (1973).

The resultant space-dencities, corrected for interstellar absorption, the run of which is shown in Table I, is given in Table III. The correction was carried out in the manner described by Seeliger.

For the purpose of comparison, the results for Field 2 and SA 158 are given in Table III. The data suggest that, if the result for r = 100 ps in the direction of Field 3 can be considered accurate, a large concentration of dB and gK stars may exist at the distances between 150 - 250 pc. Earlier, high concentration of dB stars has also been detected at approximately the same distance range by McCuskey (1946) in SA

Table III

Space densities for dB and gK stars in Field 3, shown with other results (expressed in stars per 10^5 pc^3).

r	Field 3 - 10°		Field 2[(1)] + 11°		G. Center direction[(2)] - 9°
(pc)	dB	gK	dB	gK	B8 - A0
100	41	21	-	-	20
150	59	40	-	-	26
200	49	42	42	64	28
250	44	40	25	49	25
300	33	35	19	32	19
350	27	30	16	28	-
400	23	26	14	25	16
500	15	18	9	19	-
750	8	11	7	16	-
1000	4	6	7	19	3
1500	1	3	4	(16)	2

(1) obtained by Hidajat (1970)
(2) " by McCuskey (1970).

158 and by Hidayat (1970) in Field 2. A rather steep decline in the space density function is observed beyond the distance of 250 pc.

In order to exhibit the density variation with respect to the distance from the galactic plane, the r-values in Table III were transformed into z-values. Here z is the distance from the galactic plane. The density variation with z is shown in Table IV. Again the results obtained by McCuskey (1964) for B8-A0 stars in the direction of SA 158 is smaller.

Table IV

Space-density variation with distance from the galactic plane (expressed in stars per 10^5 pc^3).

Z (pc)	Field 3 $\ell = 0^\circ.8$, $b = -10^\circ$		Field 2 $\ell = 4^\circ$, $b = -10^\circ$		SA 158 $\ell = 4^\circ$, $b = -9^\circ$
	dB	gK	dB	gK	B8 - A0
50	39	38	25	40	19
75	21	26	14	27	15
100	13	17	9	19	10
125	10	15	7	17	6
150	7	9	7	16	4
175	5	-	6	-	3
200	3	-	6	-	2

This difference can probably be accounted for not including the A2 stars in McCuskey's analysis.

DISCUSSION

Regions of high stellar concentrations have been detected by several authors. Stegman and Fitzgerald (1972) found a marked increase of the density of B8-A0 stars in Vela (ℓ = 268°, b = - $0^\circ.3$), between the distances of 500 to 800 pcs. The maximum density found by Stegman and Fitzgerald is 30 stars per 10^5 pc^3, as compared to 49 stars for the same unit ov volume found in the direction of Field 3. It would be interesting to compare the run of the ratio of gK to dB stars in these two galactic longitudes.

Another region with high stellar density distribution was found by Drilling (1968), between 500 to 1000 pcs in the direction of LF 15 ($\ell = 329^{\circ}\!.8$, $b = -2^{\circ}\!.2$). Similarly, Bok (1956) a high density zone in the direction of $\ell = 293^{\circ}$, which is thought to be a bridge between the local and the Sagittarius arms. The results presented above, if compared to the results for the LF regions (Drilling 1968) suggest that probably the densities in the southern latitudes are larger compared to the densities in the corresponding northern latitudes. Again the result for the field under the present study indicate that less B8-A2 stars are found in the solar neighborhood, as compared to that in the zone of 150-250 pc. This result is not in contradiction with the assertion that older stars are located in the inner part of the arm, which is delineated by gas.

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