III. PROPERTIES OF YOUNG STARS

13. THE DISTRIBUTION OF A AND F STARS NEAR THE GALACTIC PLANE

S. W. McCuskey

(Warner and Swasey Observatory, Case Institute of Technology)

Introduction

Studies of the spatial distribution of the common stars in the vicinity of the Sun have formed a considerable part of the researches undertaken at the Warner and Swasey Observatory during the past 20 years. Spectral types and photometric data obtained with the 24–36 inch Burrell Schmidt-type telescope have been used to survey selected regions near the galactic equator in the longitude range $0° < l^{II} < 210°$. The regions studied, designated as LF-regions, have been selected for a lack of patchy interstellar obscuration. Calculations of the stellar space density in each area as a function of distance have been made. A summary of this work was published some years ago (McCuskey, 1956). Extensions of it are under way at the present time.

The purpose of the present paper is to relate the spatial distributions of the A and the F stars, as far as possible, to the spiral structure of the Galaxy in the solar neighborhood. In essence we ask whether these stars are clearly associated with the young stars such as the O and early B stars, the galactic clusters containing such young stars, and the H I and H II regions. Not only the data from the LF-region survey but also the published results by other investigators concerning the A and F stars will be included.

Table 1 exhibits the surface distribution of these stars as a function of galactic longitude. Entries in the table are numbers of stars per square degree brighter than $m_{pg} = 12{\cdot}2$. Considerable variation in these numbers is evident particularly among the early A stars. Around

Table 1

Distribution of A and F Stars, $m_{pg} < 12{\cdot}2$, in Galactic Longitude
(Entries: no. of Stars per square degree)

Spectral Group	$l^{II}=0°$	15°	44°	47°	54°	65°	74°	102°	113°	116°	129°	136°	146°	165°	197°	214°
B8-A0	11·9	22·9	24·0	13·6	14·6	35·9	19·4	87·5	23·4	14·3	18·0	17·6	18·4	46·6	27·2	47·6
A2-A5	10·8	6·4	6·3	5·5	11·4	24·9	20·6	25·9	11·0	10·2	13·8	6·9	5·3	9·5	8·7	14·9
F0-F5	3·5	4·4	6·7	13·2	12·6	20·5	21·1	20·9	14·1	16·7	9·5	6·4	4·5	9·0	8·5	12·0

$l^{II} = 15°$ to $45°$, $l^{II} = 65°$, $l^{II} = 100°$, $l^{II} = 165°$ and $215°$ there appear to be larger than usual groups of B8–A0 stars. More modest surface fluctuations exist among the later A stars and the F stars. These stars show a marked preference for the region $55° < l^{II} < 110°$. In comparing these surface distributions with the spatial distributions to follow, however, one must bear in mind that the degree of interstellar absorption in a given region has an important bearing upon the calculated space densities. For example, regions at $l^{II} = 15°$ and $44°$ have approximately the same surface distribution of B8–A0 stars but markedly different interstellar absorption. One finds, therefore, a considerable difference in the run of space density as later diagrams will show.

Unfortunately comparable data for the galactic circle from $l^{II} = 214°$ to $360°$ are not available. In Selected Area 193 at $l^{II} = 293°$ Bok, Bok and Basinski (1964) find a region of concentration of B8–A0 stars 54·5 per square degree with $m_{pv} < 11{\cdot}5$. But data on the other spectral groups is not complete.

The A Stars

The distribution of the B8–A0 stars in space is shown in Fig. 1. The numbers are the space density, expressed as the number of stars per 10^5 cubic pc, at various points. Published data from which this figure has been constructed are given by Brodskaya (1955, 1956), Ampel (1959), Brodskaya (1958, 1960, 1961), McCuskey (1956), Pronik (1960), Iwaniszewski (1962), Iwaniszewska (1960). Only the region within 1 kpc of the Sun is shown. Contours and shaded areas indicate, approximately, regions of higher than normal space density. The dashed lines across the diagram represent approximately the position of the local, or Orion, spiral arm of the Galaxy. In all calculations leading to the densities shown the interstellar absorption for the region concerned has been included in the analysis.

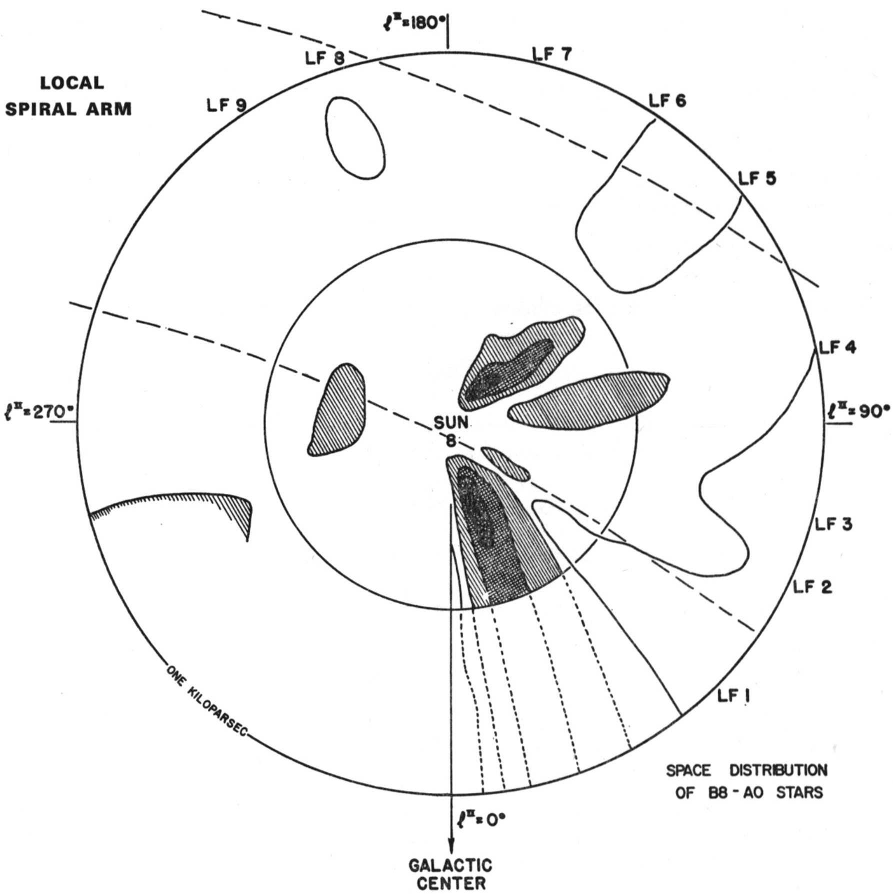

Fig. 1. The space distribution of B8-A0 stars in the galactic plane within 1 kpc of the Sun. Near the Sun, the density is 8 stars per 10^5 cubic pc. Contours of equal density have been drawn at 10, 20, 30, 40 and 50 stars per 10^5 cubic pc. An approximate position of the local spiral arm is shown. Circles denote 500 and 1000 pc distances from the Sun.

https://doi.org/10.1017/S0251107X00019349 Published online by Cambridge University Press

Several concentrations of B8–A0 stars are shown by the shaded areas. Two of these lie within the Orion spiral arm and one appears to be between the local arm and the Sagittarius arm. In both of these areas the interstellar absorption sets in very near the Sun and is quite strong. For instance, in the regions LF5 and LF6 the value of A_{pg} at 250 pc is 1·0 mag. In the region at $l^{II} = 15°$ the absorption at 250 pc is 1·5 mag. The obscuration appears to be highly localized, however, since in the directions of LF1 and LF2 it is negligible, $A_{pg} < 0·2$ mag at 250 pc.

Although the high concentrations appear to be real, one must always bear in mind the influence of uncertainties in the calculations due to the variable nature of the interstellar absorption. For example, Pronik (1960) has obtained space densities for the region at $l^{II} = 15°$ which are lower by a factor of 4 than those derived here from his data. One, therefore, may question somewhat the large concentration at this point. A check calculation made from Pronik's counts for the B8–A0 group as a function of corrected distance modulus seems to confirm the high space density. More data are required to clarify the discrepancy.

The present lack of observational data of this type for the range in l^{II} observable from the southern hemisphere is conspicuous. Recently Bok, Bok and Basinski (1964) have reported anew on the high concentration of B8–A0 stars in the direction of Selected Area 193 at $l^{II} = 293°$. Their results were not available when Fig. 1 was drawn. They find an extended region of relatively high density, 32 to 35 stars per 10^5 cubic pc, between 500 and 1000 pc from the Sun at this longitude. This is a region between the local and the Sagittarius arms of the Galaxy.

Other studies under way at the Mount Stromlo Observatory and by various investigators with the ADH telescope in Bloemfontein, South Africa, should materially aid in filling the gap in data for the southern hemisphere in the near future.

The results of space density analyses for the B8–A0 stars are shown on a smaller scale and to 3 kpc from the Sun in Fig. 2. Here the spiral structure as outlined by galactic clusters (W. Becker, 1963) and H II regions (W. Becker and Fenkart, 1963) is also shown. A conspicuous concentration of early A stars appears between 1 and 2 kpc from the Sun in longitudes $l^{II} = 180°$ to $200°$. Again this is an inter-arm region. But the region does coincide with the so-called 'Orion spur', which appears to connect the local spiral arm with the Perseus arm.

Little can be said about the space distribution of these stars beyond 2 kpc.

From these diagrams, and from a study of the distributions of O and early B stars as exhibited by Beer (1961), Whiteoak (1963) and others we draw the following conclusions:

1. Corresponding to our concentration of B8–A0 stars in Cepheus at $l^{II} = 100°$ to $110°$ there is a large number of early B stars. But they appear to be within 300 pc of the Sun whereas the early A stars lie between 200 and 700 pc.

2. In the region of LF5, $l^{II} = 129°$, the A star concentration between 100 and 400 pc of the Sun falls in a void in the distribution of early B stars.

3. Corresponding to the early A star concentration at $l^{II} = 15°$ at $r < 500$ pc there is a small but inconspicuous grouping of B stars.

4. The concentration of B8–A0 stars at $l^{II} = 293°$ (SA 193) between $r = 500$ and 1000 pc has no counterpart in the distribution of OB stars. Here the O and early B stars are distributed more or less evenly between distances of 1 and 4 kpc from the Sun (Hoffleit, 1960).

5. The high population of B8–A0 stars between 1 and 2 kpc at $l^{II} = 200°$ does not coincide with a similar clustering of O and B stars. In this longitude the great density of O and B stars, Orion and Monoceros, lies at distances less than 500 pc. Beyond that distance the OB stars are scattered thinly.

https://doi.org/10.1017/S0251107X00019349 Published online by Cambridge University Press

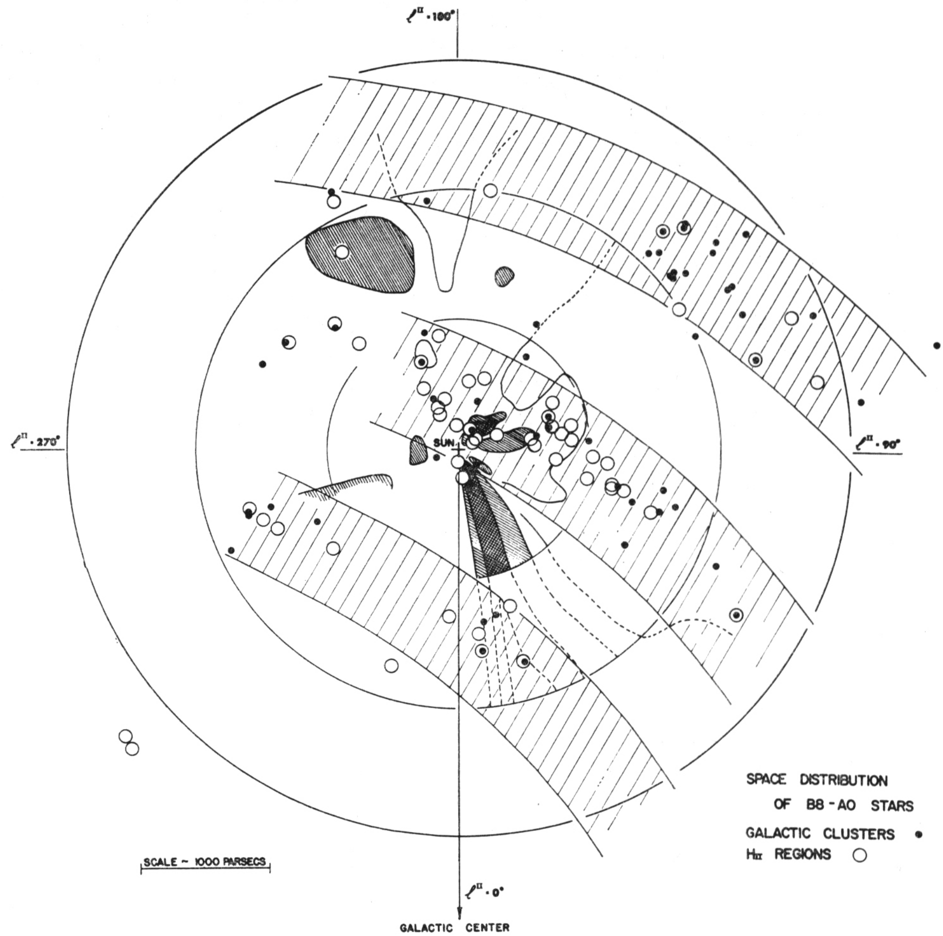

Fig. 2. The space relationship of the B8–A0 stars in the galactic plane to the galactic spiral structure. Filled circles represent galactic clusters; open circles represent H II regions. Circles denote 1, 2, and 3 kpc distances from the Sun. Contours as in Fig. 1.

In this connection it should be mentioned that the high density of a A stars here (l^{II} = 180° to 200°) coincides with a region of reasonably high density of H I as shown by Oort, Kerr and Westerhout (1958). Furthermore the relatively low space density of these stars at l^{II} = 110° to 130° at distances of 1 to 2 kpc coincides with a region of low H I density. But, as accurately as can be determined with the present data, there appears to be no increase in the population of A stars between 2 and 3 kpc in these same longitudes comparable to the high density of H I within the same distance interval.

The space density distribution of the A2–A5 stars in the vicinity of the galactic plane is shown in Fig. 3. The pattern resembles that of the early A stars with one notable exception. Around the Sun in all longitudes the space density is high. Such a tendency towards a concentration around the Sun becomes even more conspicuous among the F stars. The region of

https://doi.org/10.1017/S0251107X00019349 Published online by Cambridge University Press

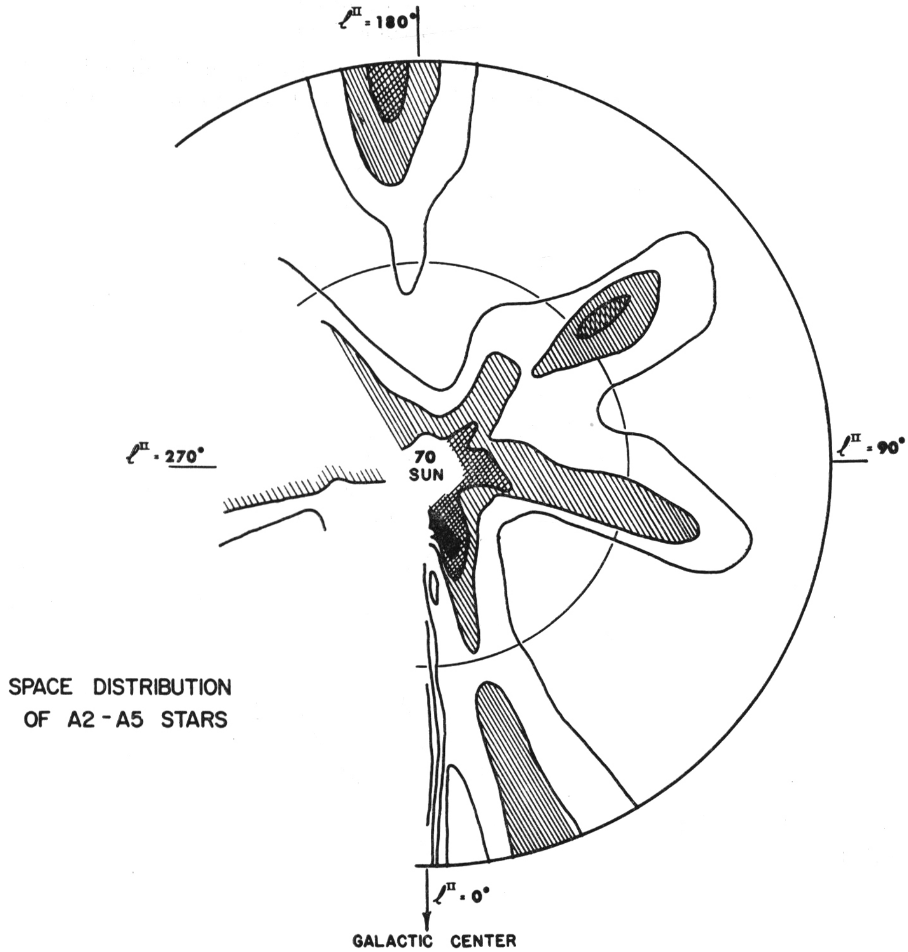

Fig. 3. The space distribution of A2–A5 stars in the galactic plane within 1 kpc of the Sun. Contours as in Fig. 1.

relatively high space density near the galactic anticenter remains to be confirmed by a study now under way at the Warner and Swasey Observatory.

From the data available at present we can only conclude that there is little evidence for systematic coexistence in space between the A stars, the OB stars and the neutral hydrogen. Further studies in depth both in northern and southern hemispheres are required. Such a study in the northern sky based upon spectra taken with a new thin (1°5) prism on the Burrell Schmidt-type telescope of the Warner and Swasey Observatory is planned.

The F Stars

Fig. 4 shows the space density distribution of the F0–F5 stars in the galactic plane. As in Figs. 2 and 3 the numbers give the numbers of stars per 10^5 cubic pc. Contours and shading indicate regions of high density. One of these occurs in the longitude range $l^{II} = 110°$ to $140°$

https://doi.org/10.1017/S0251107X00019349 Published online by Cambridge University Press

at a distance of about 500 pc. This is somewhat more distant than the localization of B8–A0 stars in the same longitude range and more nearly coincides with the A2–A5 group.

A second concentration occurs between distances of 200 and 500 pc in the direction of LF 3b, $l^{II} = 74°$. Here again the F stars and the late A stars appear to coexist in space while there is

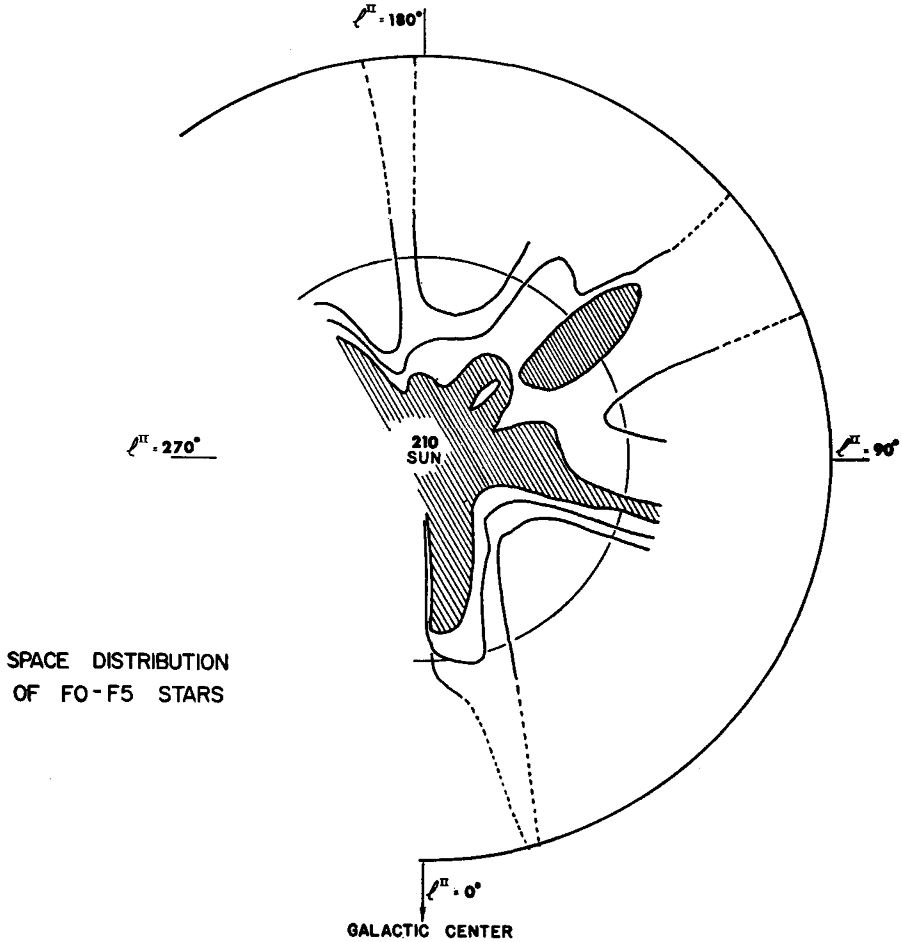

Fig. 4. The space distribution of the F0–F5 stars in the galactic plane within 1 kpc of the Sun. Contours as in Fig. 1.

no corresponding concentration of early A stars. At $l^{II} = 15°$ there is no grouping of F stars corresponding to that of the A stars.

An unusual feature of the spatial distribution of the F stars is their apparent concentration near the Sun. No matter what the direction in the galactic plane, the space density of these objects appears to decrease with distance. This is shown in Fig. 5. Each histogram indicates the number of stars per 1000 cubic pc at distances of 100, 200, 400, and 600 pc. A histogram appears for each galactic longitude for which comparable data are available. The negative

https://doi.org/10.1017/S0251107X00019349 Published online by Cambridge University Press

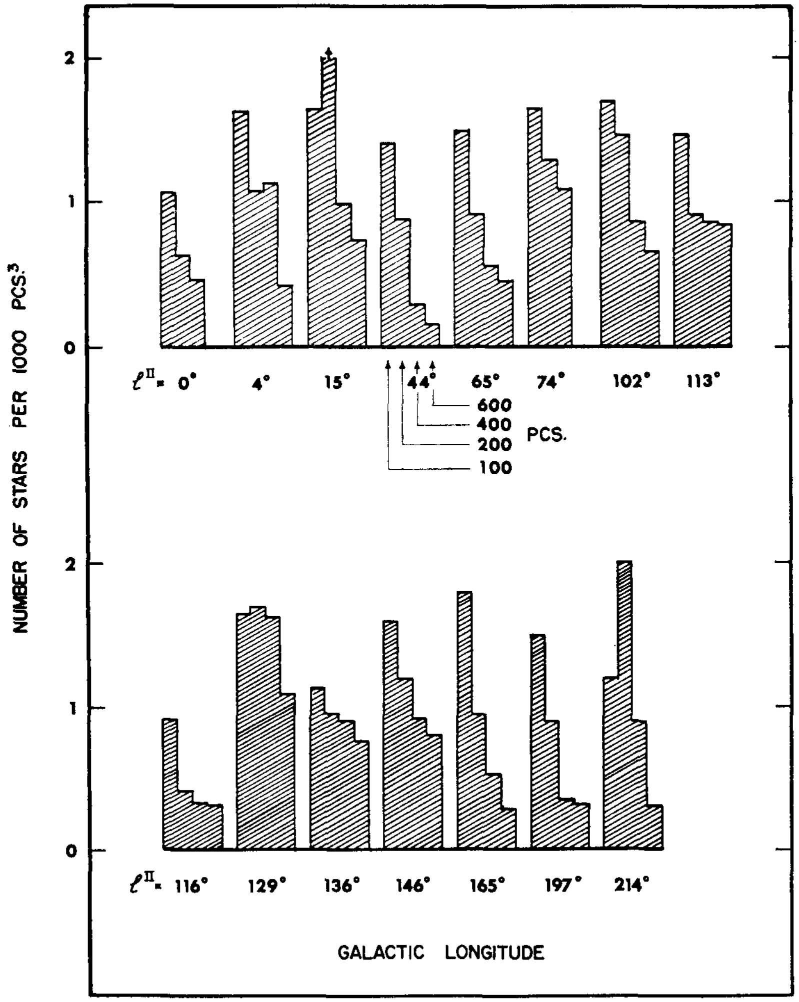

Fig. 5. Histograms showing the decrease in space density of the F0–F5 stars with distance from the Sun.

density gradient is apparent in every case. The reason for this is obscure. Perhaps the Sun is in a localized cluster of these objects.

Clearly there appears to be no traceable relationship of the F stars to the early A stars or to the other objects normally assignable to spiral arm populations. The later A stars seem to form a link between the F star population and the early A star population. We conclude further that any spatial correspondence between these A and F stars and the spiral arms of the Galaxy remains to be demonstrated.

DISCUSSION

Bok. (*a*) Am I correct that Dr McCuskey's data show that the highest A-star concentrations within 1000 pc of the Sun are in the Northern Milky Way and that the concentration in Carina-Centaurus at 500 to 1000 pc from the Sun is only a minor one by comparison?

(*b*) I should warn against the temptation to draw the spiral arms of our Galaxy within 3 kpc of the Sun. For the time being I would prefer to plot spiral concentrations without putting in the arms.

McCuskey. The density of early A-stars in longitudes l^{II} 120° to 130° amounts to about 0·4 per 10^3 cubic pc; in the Carina region it is only about 0·3 per 10^3 cubic pc. There is, therefore, a higher concentration near 300 to 500 pc in $l^{II} \sim 125°$ than in Carina at 500 to 1000 pc.

Schmidt-Kaler. I have noted in my picture a segregation of objects of different type. It seems to me that a similar segregation can be noted for the late B-stars and the A-stars in Dr McCuskey's picture. This segregation is in the same sense, the youngest objects being at the outer edge of the spiral feature for the local arm as well as for the Orion-Puppis spur. The results of F. Becker and Bok in Carina confirm this.

REFERENCES

Ampel, R. *Bull. astr. Obs. Toruń* no. 20, 1959.
Becker, W. *Z. Astrophys.*, **51**, 117, 1963.
Becker, W., Fenkart, R. *Z. Astrophys.*, **56**, 257, 1963.
Beer, A. *Mon. Not. R. astr. Soc.*, **123**, 191, 1961.
Bok, B. J., Bok, P. F., Basinski, J. M. Private Communication, 1964.
Brodskaya, E. S. *Izv. Krym. astrofiz. Obs.*, **14**, 3, 1955; *ibid.*, **16**, 162, 1956; *ibid.*, **20**, 299, 1958; *ibid.*, **24**, 160, 1960; *ibid.*, **26**, 375, 1961.
Hoffleit, D. *Astrophys. J.*, **124**, 161, 1960.
Iwaniszewska, C. *Bull. astr. Obs. Toruń* no. 24, 1960.
Iwaniszewski, H. *Bull. astr. Obs. Toruń* no. 30, 1962.
McCuskey, S. W. *Astrophys. J.*, **123**, 458, 1956.
Oort, J. H., Kerr, F. J., Westerhout, G. *Mon. Not. R. astr. Soc.*, **118**, 379, 1958.
Pronik, I. I. *Izv. Krym. astrofiz. Obs.*, **23**, 46, 1960.

14. MOVING GROUPS AMONG YOUNG STARS

O. J. Eggen

The space motions of several hundred A-type stars brighter than visual magnitude 5·5 clearly show the presence of four or five moving groups of stars among stars younger than about 5×10^8 years and in the solar neighborhood. The values of V (i.e. the vector of the space motion directed with galactic rotation) for members of a group have a dispersion of only 1 or 2 km/sec but the values of U (i.e. the vector of the space motion directed away from the galactic center) show a spread of nearly 20 km/sec.

The peculiar A-type stars (A*p*), have been divided into two classes; (1) those bluer than $B - V = -0^m.10$, which are all 'Mn' or 'Si' stars and (2) those that are redder than $B - V = -0^m.10$, which are mainly 'Cr-Eu' or 'Sr' stars. These two classes of stars populate almost mutually exclusive halves of the (U, V)-ellipse with the stars in class 1 being mostly members of the Hyades and Pleiades groups and many of the class 2 stars belonging to the Coma Berenices and Sirius groups. The F and G type stars in clusters containing A*p* stars of the 'Mn' or 'Si' types show no ultra-violet excess with respect to the Hyades cluster stars whereas those in clusters containing 'Cr-Eu' or 'Sr' stars show an ultra-violet excess of $0^m.03$ or more. F and G type companions to A*p* stars confirm this result.

The B-type stars near the Sun populate the same region of the (U, V) diagram as the A*p* stars bluer than $B - V = -0^m.10$ ('Mn' and 'Si' stars).

https://doi.org/10.1017/S0251107X00019349 Published online by Cambridge University Press