The mass-luminosity relation for the stars falling in the region of the (U, V)-plane occupied by the B-type stars and the A*p* stars bluer than $B - V = -0^m.1$ (which is also the region occupied by the Hyades and Pleiades groups and by stars showing no ultra-violet excess with respect to the Hyades) is displaced from the mass-luminosity relation followed by other stars. This displacement may be caused by a large difference in the hydrogen to helium ratios.

These results indicate that the Hyades and Pleiades group stars, and all objects with the same chemical composition may have been formed from the same gas cloud and have not wandered more than 1000 pc from the distance from the galactic center at formation. All other stars which are now in the solar neighborhood but spend most of their lifetime at greater distances from the galactic center, have an appreciably different hydrogen to helium ratio. These later stars include the Sirius and Coma Berenices groups, as well as the Sun.

15. PREVIOUS REGIONS OF STAR FORMATION DERIVED FROM STELLAR MOTIONS

B. Strömgren

For several years it has been a goal of investigations of young stars to derive, for individual stars, the places of formation from the combination of knowledge of space motions with that of stellar ages.

Properties of the space motions of young stars have been discussed in the previous paper by O. J. Eggen. I would like to discuss questions of age determination for main-sequence B and A stars, particularly with a view to the application of the ages to the calculation of places of star formation.

For B stars, the combination of *UBV* photometry and hydrogen-line photometry yields relatively accurate determinations of the location in the Hertzsprung-Russell diagram. Extensive hydrogen-line photometry for B stars has been carried out in recent years—photographically by Petrie at Victoria, and photo-electrically by Crawford and collaborators at Kitt Peak National Observatory. For A stars later than A1 four-color photo-electric photometry in bands of intermediate widths serves the purpose satisfactorily in the case of unreddened stars, while reddened A stars are dealt with through the combination of four-color photo-electric photometry and Hβ photometry. For A0 and A1 stars the situation is at present somewhat less favorable. However, relatively accurate location in the Hertzsprung-Russell diagram is possible on the basis of Hβ photometry combined with determinations of $(B - V)_0$, either from measures of $B - V$ in the case of unreddened stars, or for reddened stars from MK classification or measures of further photometric indices.

The theoretical investigations of tracks of evolution through the hydrogen-burning phase for B and A stars which were carried out by Kushwaha, Henyey LeLevier and Levee, Haselgrove and Hoyle, and others, led to a calibration of the Hertszprung-Russell diagram in terms of stellar mass and stellar age. In collaboration with Mr T. Kelsall, I have recently reconsidered the age-calibration problem on the basis of evolutionary tracks computed by Kelsall using improved tables of opacity and energy generation. I would like to summarize some of the results which have a bearing on the accuracy of age determination for B and A stars.

It is well known that the curves of equal age in the Hertzsprung-Russell diagram lie relatively close together in the part of the main-sequence band which is near the zero-age line, while they open up in a way favorable to the accuracy of age determination in the upper half of the main-sequence band. My remarks today pertain to the case of B and A stars in this part of the Hertzsprung-Russell diagram.

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In the investigation by Kelsall and myself the age calibration was carried out for six different assumptions regarding the initial chemical composition so that the effect of changes in the helium-hydrogen ratio or in the heavy element-hydrogen ratio upon the determined ages could be ascertained. The changes are quite noticeable, though not very large.

Photometric investigations of young population I stars by Harold Johnson and Knuckles, by myself, and during the last year by Crawford and myself have shown that the initial heavy-element-hydrogen ratio varies appreciably from star to star even in this group. An r.m.s. deviation of Z from an average value less than or equal to 0·01 is indicated. The results just referred to then lead to the conclusion that the Z-variations contribute an uncertainty in the determined ages measured by a probably error inferior or equal to 7 per cent of the age.

Recent investigations by Eggen of the mass-luminosity relation in galactic clusters belonging to the category of young population I stars suggest that the initial helium-hydrogen may vary appreciably from star to star. Assuming the r.m.s. deviation of X from the average value to be 0·05 we find that the corresponding age-uncertainty is 2 per cent of the age.

The uncertainty contributed by photometric errors in the case of the ages determined on the basis of Crawford's $(U-B)_0-\beta$ photometry is measured by a probable error of about 4 per cent of the age. For ages determined from the $c_1-(b-y)$ diagram the situation is quite similar.

An estimate of the accuracy of the age determinations can be obtained through comparison of the values obtained for different stars belonging to the same galactic cluster. An analysis of results obtained for the Hyades and Coma clusters suggests probable errors of less than 10 per cent. The scatter is presumably due to the variations in stellar parameters other than mass and age, such as rotational velocity and magnetic field strength, and perhaps rate of mass loss. It should be emphasized that strongly peculiar stars were excluded from the discussion. This appears to be quite essential. It is very desirable to extend this type of analysis of the accuracy of age determination to many more galactic clusters, and an extension of the work in this direction is planned.

Stars that are members of the same cluster are expected to vary less in initial chemical composition than samples of field stars. However, combining the information on cluster stars with the results of the discussion of the influence of variation of chemical composition upon age determination we may conclude that the accuracy—in the part of the Hertzsprung-Russell diagram considered—is about 10–15 per cent (probable error).

If indeed we can determine ages of B and A stars in the upper half of the main-sequence band with an accuracy of 10–15 per cent of the age, then it appears possible to utilize the ages together with space motions for calculation of places of formation for individual field stars when the age is less than about 600 million years.

For stars with ages less than 100–200 million years the uncertainty of the ages is small enough for the results to be significant in the discussion of the role of star formation in associations.

The actual application of the method to B stars is only in its very beginnings. However, D. L. Crawford and his associates at Kitt Peak National Observatory have nearly completed a program of *uvby* photometry, *UBV* photometry and $H\beta$ photometry of all B0-B5 stars brighter than $V = 6^{m}.5$ and north of declination −20°. A catalogue of *UBV* photometry and $H\beta$ photometry for B8 and B9 stars brighter than $V = 6^{m}.5$ has already been published by D. L. Crawford. This photometric material will be utilized for the determination of space motions and ages. Galactic orbits and places of formation are to be determined in collaboration with G. Contopoulos.

For the age range 200–600 million years corresponding to the spectral range B9-A8 for upper-main-sequence stars the uncertainties in the computed places of origin are such that the information gained is of little value in discussions of the role of associations in galactic star formation. Here, what one would hope to gain is information on the role of the spiral arms, and in particular on the possible role of regions in spiral arms that are temporarily active in star formation—a problem discussed by Lindblad, Oort, Eggen and Woolley.

In this connection, I should like to comment on one particular problem. Delhaye and Blaauw in studies of space motions of A stars as well as G and K giants have shown that these stars occur in a ridge in the $U - V$ plane which is not populated by the youngest population I stars. This ridge contains the stars of the Ursa major stream. The interpretation of this phenomenon is being considered on the basis of space velocities and ages for the stars in question.

Although some of the conclusions regarding the possibility of age determinations of sufficient accuracy for the use in discussions of places of origin of the stars are encouraging, I wish to emphasize again the many difficulties, and also the fact that applications of the method on a large scale have not yet been made. I believe, however, that is worth while to try method out by pursuing the various programs outlined.

16. STELLAR DISTRIBUTION AT HIGH GALACTIC LATITUDES

B. J. Bok

In recent years much work has been done on the problems of stellar distribution in the north and south galactic polar caps. Most of the relevant papers have been summarized in the Report of Commission 33 and we shall soon have available T. Elvius's summary in Chapter 3 of Compendium, Volume 5. Because of the likely close approach to the steady state (equivalent to the well-mixed state) in the directions of the two galactic poles, the continuing emphasis must be on related studies of stellar distributions and velocity distributions perpendicular to the galactic plane for homogeneous groups of stars differentiated on the basis of spectral or colour characteristics. Spectral data have become available through the researches carried on at the Warner and Swasey, the Hamburg-Bergedorf, the Uppsala and Lick Observatories. In recent years valuable additional radial velocity material has been contributed by the Dominion Astrophysical Observatory, by the Hamburg-Bergedorf Observatory and through the combined efforts of the Royal Greenwich Observatory and the Cape Observatory. Much additional information on the distribution of faint dwarf-stars, including white dwarfs and subdwarfs, continues to accumulate through the surveys of W. J. Luyten, G. Haro and F. Zwicky. Colour data are now being gathered through the work of J. M. Basinski and myself and that of W. Becker and associates in Basel. In recent years the most extensive analyses have been carried out by J. H. Oort and E. R. Hill, by A. R. Upgren, by T. E. Elvius, by I. I. Kuzmin, by J. E. E. Einasto and by R. v. d. R. Woolley.

There are two reasons why these researches must be continued and extended during the next few years. The first is that from related radial velocity and density distribution studies for stars relatively near the galactic plane, one obtains precise information for the mass density in the galactic plane near the Sun. Most workers seem agreed that 0·15 solar masses per cubic parsec represents the best value, but Kuzmin and Einasto favour 0·09 as the best solution. If the majority is right, then a total mass density of 0·05 solar masses per cubic parsec remains unaccounted for, but there would be no such excess of unknown stars, and possibly molecular hydrogen, if the quoted value of Kuzmin and Einasto proves to be correct. The second reason for studying stellar and velocity distributions perpendicular to the galactic plane is that through such work we can learn much about the nature of the general galactic field of force—which affects the functions predicted for large distances from the plane.

In the years to come, studies of the related distributions of $(U - B)$ and $(B - V)$ colour indices will probably assume increased significance, especially since these quantities can be measured with precision for much fainter stars than are within reach of spectral classification

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