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(G) LOCAL STRUCTURE AND STELLAR MOTIONS

The region within about a kiloparsec of the sun contains no globular clusters, and few associations, planetary nebulae, novae, or Cepheids; the interpretation of 21-cm observations is complicated by peculiar motions which are comparable with galactic rotation effects. Nevertheless, this is an extremely important region for the study of galactic structure. Not only are all distance calibrations ultimately based on objects near the sun, but only in this region do we have the resolution necessary to examine the detail of galactic structure and only here can we study the numerous fainter members of the various stellar populations. As elsewhere, the problems are two-fold, the efficient selection of those objects whose study is the most informative and the choice of the methods of obtaining the greatest amount of information about those objects.

(1) *Spectral surveys*

The Kapteyn Selected Areas provide a simple selection of objects for investigation and are small enough to permit a study of all of the stars down to a comparatively faint limiting magnitude. Elvius reported on his investigation [1] of a number of selected areas. He also compared his results with those of other observers. Objective prism spectra were obtained for stars down to about 13·5 photographic magnitude and were classified on the Stockholm system. There is a good correlation between these types and those in the Bergedorfer Spektral Durchmusterung for the brighter stars, but for those fainter than 12th magnitude, the Stockholm classifications appear more accurate. Vyssotsky mentioned that at Virginia they had found that large errors in the Bergedorf Spektral Durchmusterung were usually the result of mis-identifications. Both Virginia and Stockholm classify the K stars a little later than Bergedorf, as a result of using two plates, one for the H and K region and one for the region near λ 4400. Among the F stars, various classification systems differ according to whether they use the intensity of the hydrogen lines or the ratio of $H\gamma$ to the G band. Weak-line stars will be classified later from the former criterion. Elvius also found that relations between various spectral systems vary with the luminosity of the stars compared. The Stockholm system is a consistent one, however, and shows no change with either observer or time. It can be converted to the MK system with an accuracy of three or four tenths of a spectral type. A study of population classes will be made later.

Elvius' investigations were based on the Stockholm magnitudes, which are very close to the international system of pv and pg magnitudes. For the mean of eight or nine plates, the internal accuracies are 0·03, 0·04, and 0·08 magnitudes for the photovisual and photographic magnitudes and the colors, respectively. The intrinsic colors of stars of each spectral type were determined on this system and agree excellently with those determined by Ramberg. Malmquist reported that at the north galactic pole, the spectral classification determines the color of a star within one or two hundredths of a magnitude (determined photo-electrically). His colors for the giants agree well with those of Elvius, but the main sequence stars are between one and two tenths of a magnitude bluer than the Stockholm intrinsic colors. In future programs, ultra-violet magnitudes should also be measured.

For each spectral type in each region, a plot was made of color excess against apparent distance modulus. These plots showed definite deviations from linear relations. While often not significant individually, deviations were usually at the same distance in plots for various groups of stars, indicating that they resulted from true variations in absorption and star density. Moreover, neighbouring regions often showed similar variations at the same height above the galactic plane, even though the line-of-sight distances to the variations were decidedly different. There were rather definite indications of higher star densities over the Orion arm and lower densities in the inter-arm regions. In some regions, extended absorption clouds could be traced to large distances above the galactic plane. The poor location of the selected areas in the direction of the Perseus arm (in regions of high interstellar absorption) made the study of that arm difficult. A ratio of four was used to convert selective absorption to total absorption.

(2) *Search for sub-giants and M dwarfs*

Except in very small regions of the sky, it is impossible to study all stars in detail; some method must be used to segregate those of special interest. Eggen outlined the method by which sub-giants within 20 pc are being selected for the Greenwich parallax programme. All K 0 stars north of the equator in the Henry Draper Catalogue between magnitudes 5·5 and 8·0 are examined spectroscopically. Stars brighter than this limit have already been classified on slit spectra; fainter sub-giants are too distant. Later, the program will be extended to G stars and late F stars, but these are more difficult to classify accurately. Sandage emphasized that this is a very important program since by studying the faintest sub-giants in the solar neighborhood we will be able to determine theoretically the age of the oldest stars in this region. Vyssotsky described the failure of the McCormick program for determining the parallaxes of sub-giants selected by proper motions. A few of the stars were dwarfs, but most had parallaxes comparable with their errors and it was impossible to determine their luminosities. The Greenwich program will avoid this difficulty by selecting spectroscopically only stars whose parallaxes are greater than $0''.05$. Moreover, Eggen emphasized that parallaxes should always be determined at more than one observatory. Greenwich will remeasure the parallaxes of all stars known to be nearer than 20 pc for which only one parallax determination exists, as well as those stars whose parallaxes measured at two observatories differ by a factor of two or more. A list of the stars on their parallax program will be distributed to anyone interested.

Fricke proposed that very low dispersion spectra, taken, for example, with a small Schmidt telescope and an objective prism, be used to segregate the M stars. In regions near the galactic poles, many of these would be nearby dwarfs, although Nassau pointed out that the 300 square degrees at the pole on the Cleveland survey contain only thirty-five M stars of all luminosities. By using infra-red plates proper motions could be measured for these stars to a limit of 20th photographic magnitude. The scale of the Hamburg Schmidt would be sufficient to provide usable proper motions within a few years. Lindblad pointed out that at 2000 Å/mm, it is possible to distinguish between M giants and M dwarfs, certainly among stars as faint as 15th magnitude and possibly among stars as faint as 17th magnitude.

(3) *High-velocity stars; separation of population groups*

Miss Roman reported on some of the results of her study of high-velocity stars. Most of the six hundred stars which she studied are obviously members of the disk population. Except for two small groups, the average velocity of the stars perpendicular to the galactic plane is little higher than the average Z velocity for all of the weak-line stars near the sun. The two groups excepted are particularly interesting. The F-type sub-dwarfs have very high Z velocities and probably would be found very high above the galactic plane if they were not too faint to be discovered at large distances. The second group, the fifteen high-velocity A stars, is a more surprising one. The velocity of any individual A star is not well determined because it depends on the proper motion and parallax, but many of these stars have very large radial velocities and there is no question that most of them are high-velocity objects. The Z velocities for these stars are almost as high as those for the sub-dwarfs and the A stars are much more concentrated to high-galactic latitudes than are the later F stars.

Further evidence that most of the high-velocity stars and the globular-cluster stars belong to different populations is provided by the spectra and by the color-magnitude diagrams of the two groups. Sandage, on the basis of the trigonometric parallaxes, and Miss Roman, on the basis of spectroscopic parallaxes, both had diagrams which showed that the color-magnitude diagram of the high-velocity stars is similar to that of the old open cluster, M 67, or to that of the field stars near the sun and decidedly different from those of globular-cluster stars. A check on the mean parallaxes for small ranges of spectral type and luminosity showed that the use of spectroscopic parallaxes for the high-velocity stars is legitimate and the similarity of the results from trigonometric and spectroscopic parallaxes substantiates this. A comparison of the spectra of bright red giants in three globular clusters with spectra of the most extreme high-velocity stars indicates that the latter are about a luminosity class fainter. Also other differences indicate that the high-velocity stars are more closely related spectroscopically to the stars near the sun than they are to the globular cluster giants. Parenago's result that the high velocity stars on his diagram obey the color-luminosity relation for the globular clusters does not contradict these results as he was considering an extreme group with large Z-velocity components.

The position of the high-velocity stars on a two-color diagram is also interesting. Johnson and Morgan [2] have shown that on a plot of U-B as ordinate against B-V as abscissa, the normal stars fall on a narrow sequence. The high-velocity stars fill a band about 0·2 magnitude wide extending upwards from the normal sequence to that defined by the stars in M 3. If one defines the height of the star above the normal sequence as its ultra-violet excess, U_{ex}, there is an excellent correlation between this ultra-violet excess and the space velocity of the star in the range of spectral types from F 0 to early K. This correlation is at least as good for each of the components of the total velocity. Both Parenago and Miss Roman emphasized that this indicates a good correlation between U_{ex} and the perigalactic distance. The ultra-violet excess provides a powerful method for selecting members of the disk and halo among faint stars, as well as for segregating dynamically similar groups of stars without biasing the results by using the motion for selection. Either a fourth color or a rough spectral type should be used to correct the measured colors for interstellar reddening, but since the reddening line and the normal star sequence are not far from parallel in this region of the two color diagrams, the ultra-violet excess is not unduly sensitive to reddening.

The long discussion which followed this report was primarily restricted to three problems: the physical explanation of the ultra-violet excess, the use of the ultra-violet excess for selecting disk and halo members, and the problem of locating halo stars. The latter are comparatively rare; if the statistics for the halo in general are similar to those for the globular clusters, the K-type halo giants have about the same space density as the RR Lyrae stars. Miss Roman suspects that the ultra-violet excess results from the weakening of the metallic lines and the cyanogen since both features are more prominent in the ultra-violet than they are in the blue region of the spectrum. Chalonge added that in the intermediate types a decrease in the Balmer discontinuity also influences U_{ex} in the same direction and should not be overlooked. At Mount Wilson, high dispersion spectrograms of six normal standard stars and two abnormal high-velocity stars are being studied to determine if the ultra-violet excess can be explained entirely by the weakening of the spectral lines. The equivalent widths of all of the lines between 3200 Å and 6000 Å are being measured.

Miss Roman suggested that one of the Schmidt telescopes be used to select stars in the range A 0 to K 0, or in a narrower range of special interest. Later than K 0, luminosity effects become hard to handle among the giants, and the dwarfs are too close to be interesting. For each of these stars, three-color photo-electric photometry should be obtained. Those stars with U_{ex} (corrected for absorption) greater than 0·08 magnitude will be a relatively small sample of stars from either the halo or the disk. Then, for these, radial velocities and proper motions will be very valuable. In the selected areas we already have proper motions for stars as faint as 14·5 photographic magnitude and radial velocities are being determined by Fehrenbach for stars at least as faint as 12th magnitude. Thus these would be interesting regions in which to begin such a programme. A start is furnished by Miss Roman's work. She has spectra of about 600 stars between 8th and 12th magnitude in the selected areas listed in Table 6. Most of the 'fundamental stars' are BD stars and hence brighter than 10th magnitude. Blaauw pointed out that the accuracy of the proper motions could be increased significantly by a repeat of the Radcliffe photographs. Another related problem is a check on the luminosity calibration of the high-velocity giants. The evidence at present is that the normal luminosity calibration can be used, but this should be checked by trigonometric parallaxes for the most extreme weak-line stars. While individual parallaxes will probably be too small to be meaningful, the mean of several determinations for several stars will be valuable. Miss Roman will be glad to suggest a list of stars for a parallax program.

Oort pointed out that of the stars on Miss Roman's program, only a few will be halo objects; most will be main sequence G stars. To avoid this difficulty, it will be necessary to search over a much larger area and to segregate only the red giants for further study. At 13th magnitude, these giants will be 1000–2000 pc from the galactic plane and many will belong to the halo population, or at least to the high velocity population. Therefore, Oort recommends a systematic survey for K giants in a fairly large region around both the north and the south galactic poles to as faint magnitudes as possible. It is important to have a comparison of these with nearby giants on exactly the same system. There are probably only about 100 halo giants in each of the polar caps so it will be difficult to find a significant number.

Several studies of giants in the polar regions are in progress. G. Münch has searched plates taken with the Tonantzintla Schmidt for giants fainter than 11th magnitude in high galactic latitudes. Lindblad stated that it is easy to separate giants and dwarfs among stars as faint as magnitude 13·5 with the Stockholm equipment. The weakness of the cyanogen causes no difficulty as the difference between populations is small compared to the difference between giants and dwarfs. Stockholm observers may also be able to measure radial velocities on their plates. Malmquist is investigating about 64 square degrees around the north galactic pole. He has obtained spectra and color indices for stars down to magnitude 13·5 and photo-electric magnitudes and colors for stars brighter than 10th magnitude. There are about 150 K giants in this material and it is obvious that there is a maximum in the apparent distribution at about 10th magnitude. Sandage recommended photo-electric photometry for the fainter stars to segregate those with large ultra-violet excesses. The decrease in the number of K giants for the fainter magnitudes is encouraging since it means that in the range 14th to 16th magnitude, most of the K giants will probably be members of the halo. Edmondson, of Indiana University, has spectra of 700 K stars brighter than 12th magnitude which he has measured for radial velocity. In high latitudes, not more than 7% of these stars are dwarfs and at low latitudes, the percentage drops to 3 or 4%. The stars at high latitudes number only about 80–100 but these have proved useful for the determination of the average velocity of objects at about 1000 pc from the galactic plane. They seem to have larger velocity dispersions than those at lower latitudes although the result is not very definite. However, the average Z velocity is only about 25 km/sec which, while higher than the average for stars near the plane, is not nearly that typical of the halo. The spectra are not suitable for accurate classification but it would be valuable to obtain photo-electric photometry and possibly accurate spectral types for these stars, particularly for those in high galactic latitudes.

Table 6. *Selected areas in which stars have been observed spectroscopically by Miss Roman*

(*a*) Areas in which the 'Fundamental Stars' have been observed. These stars were observed by meridian circle observers as standards for the determination of positions for the remaining area stars. They are listed in *Leiden Annals*, no. 15.

Areas 5, 13–15, 29–35, 53–60, 64, 74, 78–83, 87*, 92, 93, 98*, 102–106, 110, 115–119, 128, 138–143, 162 and 163.

(*b*) Areas in which the observations cover in addition to the 'Fundamental Stars' all of the stars to 12th photographic magnitude in the *Radcliffe Catalogue* of proper motions in Selected Areas or in *Harvard Annals*, no. 102.

Areas 9, 13, 29, 31, 32, 34, 55–58, 64, 74, 80–83, 87, 93, 98, 104, 110, 115, 116, 119, 129* and 138.

* Observations incomplete.

Morgan recommended a spectroscopic survey, star by star, with accuracy equal to that of the MK standards for stars, say from the 10th to the 12th magnitude. This would permit a separation of both spectral and population types and the ultra-violet excess could then be studied as an independent parameter. One should use widened spectra with a dispersion near 100 to 200 Å/mm. These should be compared with exactly similar spectra of standard stars taken with the same equipment. The selection effects should also be carefully studied. Morgan thinks that such a program is feasible but stressed that the main problem is one of high systematic accuracy so that stars in the polar cap can be compared with those in the neighborhood of the sun for which we have much more detailed information. If a slit spectrograph similar to that used for the Yerkes standard stars is employed, the systematic accuracy at K 0 III should be of the order of 0·1 of a class. Under the best conditions, with the best plates, the accidental accuracy should be of the same order. The problem of the intrinsic dispersion in luminosity of the K 0 III stars should also be studied. Halo giants might be extremely rare in a sample of giants between 10th and 12th magnitude, but those which are included would be easily recognized spectroscopically. After the possibilities of this method have been exhausted, one can study the ultra-violet excess and use it, perhaps, to extend the search to fainter stars. Morgan recommended that objective-prism spectra be used for segregating the original group of giants near class K 0.

There was some discussion of the limiting magnitude at which the search for halo stars should be conducted. Sandage thought that the halo giants might outnumber the disk giants at high latitudes in the range between 13th and 16th magnitude, and that therefore the search would be most advantageously conducted among stars of this brightness. Morgan thought that 13th and 14th magnitude stars at a distance of 3000 pc and 5000 pc, respectively, were better objects to start with than stars at 16th magnitude. He also stressed the advantage of studying the brighter stars carefully before going to the faintest ones. It would be possible to pick out 16th magnitude stars with color indices between 0·8 and 1·0 with a micro-Schmidt but one could not separate dwarfs and giants in this way. With a Schmidt, which transmits the ultra-violet, it is possible to separate giants and dwarfs with a dispersion of 500 Å/mm (limiting magnitude near 14th), but otherwise a dispersion of at least 300 Å/mm is needed.

Vyssotsky reported on the McCormick study of nearby stars [3]. These included stars between A 0 and A 3 and K stars brighter than $5^{m}5$ as well as the dwarf M stars included in the McCormick survey without regard for parallaxes and proper motions. For the latter either trigonometric or spectroscopic parallaxes are available. These stars were grouped in several ways. First, the maximum Z-velocity observed for any of the A stars was used as a criterion to divide the F- and M-type stars into two groups each. Those with small Z move in orbits near the galactic plane; the orbits of the others are inclined 15° to 20° to this plane. On plots of the velocities of the stars in each of these groups, it was found that for the stars with low orbital inclinations, the vertex of the velocity ellipsoid deviates from the direction to the galactic center by 15° or 20°. Conversely, the velocity vectors for the stars with highly inclined orbits show a much larger dispersion but no deviation of the vertex, which Vyssotsky attributes to the presence of the spiral arms. He also divided the stars into groups according to spectroscopic criteria. For the G stars he used the McCormick data on the relative strength of the Hγ line and the G band. Among the K stars, he used only Miss Roman's material which separated the strong- and weak-line stars. The basis of separation in the M's was whether or not the stars show emission lines. The latter is not as clear a separation as it might be because the spectrograms which were obtained at Mount Wilson tend to be somewhat underexposed. The plots of the velocity vectors for these stars show the same characteristics as the plots for the earlier separation. The A stars, the strong-line stars, and the M dwarfs with emission lines have velocity vectors which show a small dispersion but for which the major axis of the velocity ellipsoid deviates strongly from the direction toward the galactic center. Conversely, the weak-line G and K stars and the M dwarfs without emission lines show a larger dispersion but no deviation of the vertex. It would be useful to do an analysis of this sort of the AG stars in the 20° to 25° zone for which radial velocities have been published by the David Dunlap Observatory [4]. There are also recently improved proper motions for these stars. A separation into strong- and weak-line stars would be necessary in addition.

(4) *Stars with hyperbolic velocities*

According to Perek [5], if the circular velocity near the sun is 216 km/sec and the escape velocity exceeds this by 65 km/sec, then about sixteen stars near the sun have hyperbolic velocities. There are about six sub-dwarfs, three or four RR Lyrae-type stars and the youngest star is AE Aurigae. Also included are the B I IV star BD+28° 4177, van Maanen's star, a white dwarf, AG Aurigae, an RV Tau star, and a globular cluster, NGC 5694. The proper motion of the latter is extremely uncertain but the hyperbolic velocity depends only on the radial component. Three assumptions enter the selection of stars with hyperbolic velocities: the value of the circular velocity, the value of the velocity of escape, and the assumption that the spectral lines really indicate the motion of the center of mass of the star or star system. Oort estimates that the uncertainty in the circular velocity is at least 10% and possibly larger. The velocity of escape is still more uncertain because so little is known about the density in the outer shells of the galactic system.

Perek suggests that a survey for large radial velocities is the most effective way to find stars with hyperbolic orbits. For instance, among thirty-eight stars with radial velocities greater than 250 km/sec there are many hyperbolic velocities but a direct elliptical motion can be established for only one. Fehrenbach already has a program for finding large radial velocities on his objective prism spectrograms. Many stars may well have hyperbolic orbits but the observational data necessary to decide this are lacking. For example, about seven stars need a new determination of the radial velocity, eleven need a new determination of the parallax, and for about forty, new proper motions are desirable. Blaauw emphasized the importance of sub-dividing stars with hyperbolic orbits into those which are apparently very young and have been formed with very high velocities within our Galaxy and other stars which, with reasonable assumptions about their age, must have been formed outside the Galaxy. It is reasonable to expect such interlopers. If we consider a star like AE Aur, we find a velocity of between 120 and 130 km/sec with respect to its origin in the Orion region. This star happens to have a velocity about 30 km/sec larger than the velocity of escape as presently estimated, but if it were formed in a stellar system where the total mass were much smaller, there would be no question but that it would become an intergalactic object. The number of these stars which can be expected depends on the rate of formation, which might be quite large in the Magellanic Clouds, as well as on the gravitational field within the system. Hence, the Magellanic Clouds may well be surrounded by a halo of young high velocity stars.

(5) *Radial velocity programs*

Fehrenbach reported on the objective-prism radial velocity program carried on at the observatories at Haute-Provence and Marseille. So far, nearly 1300 plates have been taken, the first 400 of which were 9×12 cm across. This size is no longer used as it has been found that the usable field is actually much larger. It was first replaced successively by 13×18 cm plates (about 700 of which were taken) and, during the past year, by 16×16 cm plates corresponding to a $4^\circ \times 4^\circ$ field. With the small objective prism of 15 cm diameter, magnitude 10 can be reached with an exposure of twice 2 hours. In a field of $4° \times 4°$ near the Milky Way, between 80 and 120 stars are well measurable.

So far, fifteen fields have been measured in galactic latitudes near zero and at longitudes, separated by 15°, between 345° and 180°. Four fields containing 240 stars have been published [6], and nine fields containing 800 stars are ready for publication. In addition there is a field in Coma Berenices with about fifty stars. In each field three plates are taken with twice 2 hours exposure covering the range $7^{m}.8$ to 10^{m}, and 3 plates with twice 40 minutes exposure covering the magnitudes down to $8^{m}.5$. Thus there is an overlap between $7^{m}.8$ and $8^{m}.5$ on both sets of plates to insure a homogeneous system.

The scarcity of well determined slit radial velocities in these fields is a serious problem which has been brought to the attention of the I.A.U. sub-commission on Standard Velocity Stars. In the B and A stars and the F stars earlier than F 6, usually only Hγ and Hδ are measured, but in the later stars, types F 6 to M, about eight lines, spread over the spectral region, are used. The latter were chosen after a preliminary study similar to that which is carried out for the choice of lines on slit spectra. The mean error per star for radial velocities based on about six plates is ± 4.8 km/sec for types B, A, F and ± 3.1 km/sec for types G, K, M. Some of the errors seem to be due to displacements of the gelatine on the plates. For this reason the Mount Stromlo announcement of a new development technique was a welcome one [7].

In each of Fehrenbach's fields, spectral classes on the MK system are being determined, partially with the collaboration of Kourganoff at Lille. A large number of the stars which seem particularly interesting are being measured photo-electrically on the U-B-V system at Toulouse.

In addition to these programs, twenty plates covering the P Cygni association have already been classified and the measuring is well advanced. Two regions in Cygnus are being studied, one with P Cygni as its center and the other near 28 Cygni. Further, ten fields have been selected in regions of the Milky Way with low absorption. Selected were those rich in O- and B-type stars on the basis of the classifications by Nassau and Morgan. So far thirty plates have been taken and the measurements are well under way. Finally, plates have been taken in nine additional galactic fields. For the future, a general study of all Selected Areas is planned. About thirty plates have already been taken.

High-velocity stars are searched for, by a special rapid procedure, on each field observed so far.

A new objective prism, with a diameter of 40 cm and a dispersion a little smaller than that which has been used, has been constructed. If used with a Grubb and Parsons triplet objective the limiting magnitude will probably be about 13. This combination will cover a $2° \times 2°$ field and will be sufficient to pick out stars in the Magellanic Clouds; these stars will have a Doppler displacement of the order of 40μ which is easily visible provided the spectra are well exposed.

There is no dependence of the accuracy or of the zero-point of the velocity measurements on the length of the exposure.

Woolley mentioned that Greenwich is obtaining a radial-velocity objective prism for use with the 10-inch Astrograph at the Royal Observatory. He is primarily interested in studying the nearby stars.

(6) *Photometric spectral classifications of high accuracy*

Strömgren has developed a photo-electric method of spectral classification. He uses interference filters to isolate wavelength regions of the order of 35 to 40 Angstroms in width near important spectral features such as the hydrogen lines, particulary $H\beta$, the Balmer discontinuity, the break in the spectrum at the G band, and the cyanogen absorption [8]. Comparison regions are also measured near each of these wavelengths to correct for both interstellar and atmospheric extinction. These measures define the main sequence well but some scatter remains after allowance for photometric errors; this is undoubtedly due to a third dimension, or population variation, in the spectra.

An instrument is now in use with which the narrow band intensity in $H\beta$ and the intensity in the comparison band are measured simultaneously, which completely eliminates variations in sky transparency. Other line strengths are also measured with different filter pairs. The limiting magnitude with this method, the 82-inch reflector, and an integration time of about 1 minute is near 12th magnitude; with the 200-inch and a longer integration time it should be possible to reach stars of 17th magnitude. At present, the classification of 2000 B and A stars in clusters and associations is in progress as well as the observation of B 8 to F 1 stars within 1000 pc of the sun. The purpose of the latter program is a determination of the dust distribution near the sun; this spectrophotometric method can be used to compute and to eliminate color excesses as well as to determine spectral types and luminosities of the stars. A similar program is planned for determining the dust and star distributions to greater distances in particular Milky Way areas.

Chalonge has obtained extremely high accuracy in spectral classification using a more conventional spectrophotometry of photographic spectra [9]. He measures three criteria in each spectrum. They are: the spectrophotometric gradient in the blue region of the spectrum, the wavelength, λ_1, at which the apparent continuum is half-way between the extensions of the blue and ultra-violet continua, and the magnitude of the Balmer discontinuity. On a three-dimensional diagram defined by these parameters, the normal main sequence population I stars fall on a well-defined surface. From the position of a star on this surface, the spectral type and luminosity can be predicted with more accuracy than the MK classification and on the same system.

It is interesting to compare the F stars in the Hyades and the Coma clusters. The Coma main sequence stars seem to have lower luminosities than the Hyades stars. This also explains the color excess observed for the Coma stars since, having lower luminosities, they also have smaller Balmer jumps and hence are brighter in the ultra-violet than the somewhat more luminous stars in the Hyades. This comparison stresses the importance of the Balmer jump in determining the ultra-violet excess of stars in addition to the importance of the metallic lines. Sandage agreed as to the importance of the Balmer jump difference between the two clusters. He believes that the Coma cluster is a younger cluster and is in a slightly different stage of evolution than the Hyades. For this reason the F stars in Coma have slightly higher surface gravities than those in the Hyades.

Compared to the normal stars, the F-type sub-dwarfs of the same gradient have decidedly smaller Balmer discontinuities and slightly smaller λ_1's. Conversely, the metallic-line stars have larger Balmer jumps and larger λ_1's. There is a continuous distribution of stars from the most extreme sub-dwarfs through the normal F-type stars to the most pronounced metallic-line stars. Moreover, the spectrophotometric indication of the degree of peculiarity in these stars is in agreement with estimates from other methods. For example, the high-velocity stars which have not been classified as sub-dwarfs seem to be intermediate between the extreme sub-dwarfs and the normal main-sequence stars. The very small Balmer discontinuities observed in the sub-dwarfs explain the strong ultra-violet excesses of these stars almost completely. There is also a small difference between the shapes of the visible continuum in the sub-dwarfs and in the main sequence stars. The normal stars show a small discontinuity which the sub-dwarfs do not have.

Although the surface, in Chalonge's representation, is well defined for the normal stars it is not infinitely narrow. Probably the spread near the surface corresponds to an intrinsic spread in the character of the stars corresponding, for example, to Miss Roman's division of stars into strong-and weak-line groups. This has been partially tested by observing some of Miss Roman's stars, and the preliminary results agree with this interpretation. The weak-line stars fall on the side of the surface with the sub-dwarfs and population II stars while the strong-line stars, for the most part, fall on the opposite side. It would be interesting and important to study the B stars in the same way but this is more difficult because of the effects of interstellar absorption.

Although the method described is very time consuming it does permit a very accurate classification and it may be a useful way to give some indication of the physical and chemical properties of various stars. Chalonge is willing to study any star brighter than 10th magnitude provided it is sufficiently early in type to have a Balmer discontinuity. The success of this method stresses particularly the importance of using the Balmer discontinuity and the ultra-violet region of the spectrum for the study of classification problems. Madam Hack in Italy is experimenting with the use of photo-electric techniques for this type of classification. She has substituted the intensity of $H\beta$ for the measurement of λ_1 so that her system is also somewhat similar to that of Strömgren. Strömgren's and Chalonge's methods are not too different and Strömgren's measurement of the total intensity of groups of lines will give a third parameter which will be even closer to Chalonge's.

(7) *The luminosity function*

Recent investigations by Sandage and Salpeter, reported on p. 18 of this volume, have revived interest in the luminosity function. Published luminosity functions such as those by van Rhijn and Luyten include not only main sequence stars but also giants and a few super-giant stars. Different portions of the luminosity function have been determined in different ways. For the fainter stars trigonometric parallaxes have been used; in the region of somewhat brighter stars statistical analyses of proper motions have been valuable; and the brightest end, which is the most uncertain, has been determined primarily from the statistics of stars in the Magellanic Clouds. Blaauw emphasized that the present problem is to redetermine accurately the luminosity function for main sequence stars only. In the region near the sun trigonometric parallaxes can be used to give sufficient statistics for stars fainter than about +6. Thus an extension of the trigonometric parallax program is needed. For the brightest stars, say brighter than about +2, the best procedure might be a careful redetermination of spectroscopic absolute magnitudes. Such a program should include the stars brighter than about 7·0 and hence an extension of the

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present classification from 5·5 to 7 would be extremely valuable. In the intermediate region of absolute magnitudes, between +2 and +4, the best course for future study is less obvious. Perhaps Wilson's method of determining absolute magnitudes as a function of the width of the reversal of the H and K line (see p. 59 of this volume) may be the most powerful method for locating stars in the region above the main sequence. This should also be done for all stars brighter than 7·0.

Weaver pointed out that the luminosity function which Blaauw had described referred to different volumes of space in different regions of luminosity. At Berkeley there is an interest in determining the luminosity function for small volumes as, for example, in clusters. These luminosity functions have been determined purely by counting procedures. That is, the number of stars in a cluster has been counted as the excess over the background distribution. In he cluster NGC 7160, a 1b2 cluster on Trumpler's classification, the diagram starts at about absolute magnitude 0 and extends to about +8. There are no detectable faint stars, which may mean that their number is less than the number predicted on the basis of the van Rhijn luminosity function. The 1b6 cluster NGC 7243 extends a little fainter in luminosity but is also comparatively lacking in faint stars.

Heckmann was willing to admit that there may be well established differences in the luminosity functions between a cluster and the region near the sun but he felt that it is important to be very cautious in stating that there are no faint stars in some open clusters. He thinks that there is greater reason to believe that there are some faint stars—many more than can be detected by Weaver's method. For example, when stars are selected by proper motions as in Hyades, Praesepe, Pleiades, Coma and the alpha Persei cluster one can say with certainty that the luminosity function seems to be constant down to an absolute magnitude near +10 and that limit is the limit of the proper motions, not of the stars themselves (see also p. 9 of this volume). However, Baade commented that the luminosity function in star clusters, and in the general field need not be the same. An excellent example is the τ Canis Majoris cluster. Both on Schmidt plates and in more careful investigations, the main sequence of this cluster seems to stop near B8. It is absolutely certain that there is not a large number of faint stars. This is a very young cluster and B8 is very near the point at which the main sequence would be expected to end on evolutionary theories.

Walker has observed three clusters in which the luminosity functions seem to be nearly the same as the 'Initial Luminosity Function' of stars near the sun. These are the Orion cluster, NGC 2264 and NGC 6530 or

M8. McCuskey's investigations [10] of selected Milky Way fields indicated that the luminosity function is quite uniform in general but there are certain regions in which there are too few stars in small intervals of absolute magnitude.

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