so far except in the McCormick programme. For regions above 15° or 20° galactic latitude the use of extra-galactic reference points, as in the Lick survey, may furnish sufficient accuracy in about 25 years. An attempt is being made at Leiden to obtain some provisional results from old and new plates of clusters of nebulae taken at the Mt Wilson Observatory. In order to improve likewise the motions of super-giant stars in the Milky Way, it would be very important if meridian observers could furnish as strong a connexion as possible between these super-giants and fundamental stars above 20° latitude, which can in turn be tied to the nebulae.

(*b*) For low-latitude stars of the 14th and 18th magnitude, the mean random motions in galactic latitude will average about $\pm 0''.004$ and $\pm 0''.002$ per year, respectively. To obtain significant results, the probable errors of the individual motions should be less than half these amounts. Only *relative* motions are required for this purpose.

(*c*) The mean parallaxes of 14th and 18th magnitude stars in low latitudes may be estimated as $0''.0012$ and $0''.0004$, respectively. The accuracy of the absolute motions needed to determine the corresponding reflected solar motion (about $0''.005$ and $0''.002$) should again correspond to errors smaller than about $0''.0002$ per year.

(*d*) Super-giants are so rare that it is necessary to go to distances of at least 1000 parsecs to find sufficient numbers for calibration.

A similar accuracy will be needed to derive the expanding motions in most B-star clouds.

8. PROBLEMS OF STELLAR ASTRONOMY CONNECTED WITH THE PROPER MOTIONS OF FAINT STARS

By A. Blaauw

Investigations of proper motions of faint stars generally are concerned with either of two problems: the distribution of the peculiar motions of the stars, or the mean parallax of certain groups of stars. In both kinds of investigations the knowledge of absolute proper motions is of fundamental importance. The present paper deals with some of the actual problems.

(1) *The deviation of the vertex of the peculiar motions*

Investigations of bright stars. Various investigations of the motions of the bright stars—i.e. those brighter than $m=8$—have revealed the deviation of the direction of preferential motion from the direction to the galactic centre. The deviation changes with spectral type. Table 1 shows results according to recent investigations, by Delhaye(1) and by Tannahill(2), both based on the proper motions in the *General Catalogue* of 33,342 stars by B. Boss. Delhaye, studying the stars between apparent visual magnitudes 6·0 and 7·5 subdivided into the spectral groups B8–A5, F0–F9 and K0–K2, applied two methods of analysis. The first is the classical one due to K. Schwarzschild, it is based on the ellipsoidal hypothesis. The observational data used are the statistics of the position angles of the proper motions. The size of the proper motions plays no role in this method, but the proper motions have to be in an absolute, fundamental system. The second method, called the dispersion method, uses the dispersion with respect to their mean for the components of proper motion in galactic longitude and latitude. In determining these dispersions it is irrelevant whether the proper motions are given in an absolute or in a relative system. The distribution of the sizes of a component of the proper motions determines the dispersions used in this method.

Tannahill applied Eddington's method of analysis into two streams to the stars of all apparent magnitudes in the GC, subdivided into the spectral groups A5–F5, F8–G5, K0–M. In this method, as in Schwarzschild's method, only the position angles are counted. The results obtained by Delhaye with Schwarzschild's method and those by

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Tannahill confirm the deviation of the vertex towards the higher longitudes found in previous investigations based on proper motions and on radial velocities of bright stars (3). The deviation does not, however, appear in the results based on the dispersion method when applied to the stars of spectral types later than A.

It has been suggested (4) that a difference between the results from the methods based on position angles and on dispersions, applied to the same proper motion data, is an indication that neither the ellipsoidal nor the two-stream hypothesis adequately represents the true distribution of the peculiar motions. More specifically, if we assume that the preferential direction among the low velocities is towards a higher galactic longitude than that among the high velocities, the longitude of the vertex found from the position-angle method should come out higher than the value found from the dispersion method. The deviation of the vertex as represented in the third and the last columns of Table 1 may thus be interpreted in terms of a perturbation of the ellipsoidal or two-streams distribution by a deviating stream among the low velocities.

Delhaye (5) has also discussed the space motions of the bright stars computed by de Vos van Steenwijk, and from these he derived support to the above explanation of the vertex deviation. The projections of the space velocities on the galactic plane, as shown by Delhaye for the various spectral groups, reveal deviations from the smooth elliptical distribution which may be interpreted as a perturbing stream among the low velocities. The fact that the results for the A stars according to the two methods are the same, indicates that this group, for which the motions generally are very small anyhow, largely consists of stars belonging to the perturbing stream. The percentage of stars belonging to the perturbation decreases with advancing spectral type.

The possibility that the perturbation is related to inequalities in the density distribution of the stars in the galaxy in the region around the sun has been discussed by Oort (6) and by Vyssotsky (7). A point of primary interest is, whether this perturbation is a local phenomenon or whether it is present also among the faint, distant stars.

Faint stars. Let us first consider the faintest, most distant stars that have been studied. The dispersion method has been applied by Hins and Blaauw (8) to the McCormick proper motions ($m_{pv}=10$–13) published by Van de Kamp and Vyssotsky (9) and to the proper motions in the northern selected areas ($m_{pg}=11{\cdot}5$–$14{\cdot}5$), in both cases only to the stars below 20° galactic latitude. The selected area proper motions had been obtained (10) by combining the proper motions in the Radcliffe Catalogue (11) with those measured at Poulkovo (12). The longitude of the vertex, l_v, was in both cases found to be close to that of the galactic centre; the average value being $l_v=323^\circ{\cdot}5 \pm 1^\circ{\cdot}8$ (p.e.). In a still unpublished study, Hins has found that the proper motions of the selected-area stars at higher latitude, when analysed according to the dispersion method, confirm this low value of l_v. It thus appears that at least the large motions among these faint stars do not show the vertex deviation.

It is not quite clear whether the perturbation is present among the smaller proper motions. Schwarzschild's method has been applied to the selected-area stars by Knox-Shaw and Scott Barrett (11) and by Deutsch (13), and to the McCormick proper motions by Van de Kamp and Vyssotsky (9). These investigations gave high values of l_v, particularly for the low-latitude stars, $|b|<20^\circ$, viz. $l_v=340^\circ \pm 3^\circ$ according to Knox-Shaw and Scott Barrett and $l_v=348^\circ \pm 2^\circ$ according to Van de Kamp and Vyssotsky (see Table 5.3 of the latter authors' paper). However, the suitability of Schwarzschild's method when applied to these faint low-latitude stars has been questioned in the paper by Hins and Blaauw. In this method there is an ambiguity in the determination of the direction toward the vertex from the individual areas near the vertex, and this may have led to an erroneous value of l_v. A slightly modified procedure avoiding this ambiguity was applied to the same proper motion data; the results (see Table 4 of *B.A.N* No. 391)—also based on the position angles—give a low value of l_v. Thus, there would seem to be no deviation of the vertex even among the small motions of these faint, distant stars. The probable errors are large, however, and therefore these latter results cannot be considered to be entirely conclusive.

Stars of intermediate brightness. Stars of apparent magnitudes intermediate between the GC stars studied by Delhaye and by Tannahill, and the McCormick and selected-area stars, have been investigated by various authors. Among the investigations which deal with separate spectral classes are those by Jackson (14) based on the Cape Zone proper motions (decl. $-40°$ to $-52°$) and Smart and Tannahill's analysis (15) of these same data, and the study of the Cambridge proper-motion stars by Stenquist (16). Both discussions of the Cape proper motions are based on the position-angle methods; Jackson used the ellipsoidal hypothesis, while Smart and Tannahill used the two-stream hypothesis. The results for separate spectral classes are in Table 2.

Stenquist applied a method developed by Charlier and Wicksell to the tangential velocities obtained with his spectroscopic parallaxes. His results are given in the last column of Table 2. Distant groups discriminated by Stenquist within each spectral class have been combined here. (The most distant group for spectra B8 to A3 has been omitted; for this group the results given by Stenquist obviously cannot have much significance because of the large ratio of the accidental errors of the proper motions and the peculiar motions.) The method used by Stenquist gives relatively high weight to the large proper motions, somewhat similar to the dispersion method.

Comparison of Stenquist's results with those in the left-hand part of Table 2 suggests the same phenomenon as was noticed in Table 1. For the A stars l_v is high, but for the later types the position-angle methods show high l_v, whereas Stenquist's analysis indicates lower values of l_v. This shows that among these intermediate stars the perturbation among the low velocities is still present. The real nature of the perturbation and more precise knowledge of the region of the galaxy over which it extends are interesting problems, the solution of which will depend on the precision with which absolute proper motions will become available.

From Delhaye's diagram of the projected space-velocity distribution we can roughly estimate that the perturbing streaming is in the direction of about galactic longitude 10°, and that the velocities in the perturbation are of the order of 10 km./sec.

The mean distances of the stars studied by Delhaye are about 180, 90 and 140 parsecs for types A, F and K. Studies of 10th magnitude stars give information about the perturbing stream at distances of about 500 parsecs. The velocity of 10 km./sec. mentioned above then corresponds with 0".004 per year, if it is perpendicular to the line of sight. We can only hope to obtain knowledge about the region of the galaxy over which the perturbation extends by regional studies of the distribution of the proper motions, particularly of the small proper motions. To identify the perturbation the proper motions will have to be free from systematic errors larger than half this amount of 0".004. This means that we will need absolute proper motions with systematic errors below 0".002.

Qualitatively, this perturbation may perhaps also explain the differences in the solar motion for stars of different spectral types. The solar motion increases from about 16 to 20 km./sec. with advancing spectral type from A to K (17). Such a change is to be expected if the percentage of stars pertaining to the perturbation decreases from A to K, and if we assume that the solar motion with respect to the undisturbed distribution is about the standard solar motion (20 km./sec. toward $l=23°$, $b=+22°$).

Vyssotsky and Janssen (18) have proposed a value for the basic solar motion (the Sun's motion with respect to the circular velocity around the galactic centre) very close to the Sun's motion with respect to the A stars, viz. $=15{\cdot}5$ km./sec. towards $l=12°{\cdot}4$, $b=+22°{\cdot}3$. A serious objection against this view is, that the stars from which this motion was derived (A stars and K giants) do not represent more than 3% of the total mass present in the neighbourhood of the Sun, whereas for the interstellar matter, which represents almost half of the total mass, we find a solar motion very close to the standard solar motion, viz. 20·1 km./sec. $\pm 0{\cdot}7$ (p.e.) towards $l=19°$, $b=+23°$ (19). This is also close to the value found from O and B stars. It is true that these represent only 0·1% of the total mass, but their radial velocities have been measured over a wide region of space, up to 1500 parsecs from the Sun, so that local streamings cannot have had as much influence in the determination as in the case of the A stars.

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Table 1

The galactic longitude of the vertex for GC stars according to recent investigations by Delhaye and Tannahill

Spectral group	No. of stars	Delhaye: Schwarzschild method °	Delhaye: Dispersion method °	Tannahill two-stream hypothesis °
B8–A5	5098	351·5 ± 3·3	350·8 ± 3·2	...
A5–F5	4310	...	...	348·6 ± 1·1
F0–F9	2748	341·1 ± 2·8	325·9 ± 3·0	...
F8–G5	5112	...	...	341·7 ± 1·4
K0–K2	4439	335·7 ± 2·6	327·3 ± 3·1	...
K0–M	8531	...	...	342·4 ± 1·4

Table 2

The galactic longitude of the vertex from stars of intermediate brightness

Spectral group	No. of stars	Cape Zone Catalogue: Jackson ellipsoidal hypothesis °	Cape Zone Catalogue: Smart and Tannahill two-stream hypothesis °	Cambridge proper motions (Stenquist) °
B–A3	5927	353·1:	...	...
B8–A3	300	...	...	341 ± 9
A5–F5	3261	348·1	344·5	...
F2–F8	469	...	...	336 ± 5
F8–G5	3973	342·1	340·2	...
G0–K6	802	...	...	328 ± 4
K0–M	4216	340·3	340·6	...

(2) *Mean parallaxes of δ Cephei variables and OB stars*

Mean parallaxes of faint stars may be derived either from the υ components of the proper motions, the average of which is supposed to reflect the mean tangential component of the solar motion, or from the dispersion in the τ, υ, or other components. The latter dispersion can be related to the dispersion of the linear velocities in the corresponding directions, thus giving the mean parallaxes.

Which method is the most profitable one depends on whether we deal with stars whose peculiar motions are large or small compared with the solar motion. An example of the first category, large peculiar motions, are the RR Lyrae variables; an example of the second category, small peculiar motions, are the cepheids of population I. It is especially in connexion with the latter kind of stars, that knowledge of the proper motions in an accurate absolute system proves to be important. I shall discuss two of the special groups of stars which play an important role in the study of galactic structure and extra-galactic distances.

δ Cephei variables. The importance of accurate knowledge of the zero-point of the period luminosity relation of the classical cepheids need not be stressed. It forms the basis of all distance determinations of extra-galactic objects containing population I stars and hence of the scale of the universe. There are two methods in determining the luminosities of these cepheids.

One method depends on the derivation of distances from the effect of differential galactic rotation. This method can be used, with the constant A accurately determined

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from the B stars and from proper motions, as soon as observations of magnitudes, colour excesses and radial velocities have been accumulated for a large number of cepheids. This constitutes an extensive observational programme but its important bearing on our knowledge of distances in the universe will warrant the effort. Provisional estimates show that it may be possible to determine the zero-point of the period-luminosity curve in this way with a probable error of the order of one or two tenths of a magnitude.

The other method is based on secular parallaxes. The accuracy of the determination depends on the number and precision of the absolute proper motions of the cepheids. A paper by R. E. Wilson (20) on the zero-point of the period luminosity relation shows the data available at present. It contains 86 cepheids with an average photographic magnitude of 8·0; the probable errors of the proper motions of which range from $\pm 0''.001$ to $\pm 0''.015$.

For these 86 stars the average υ component is $0''.0059 \pm 0''.0010$ and the mean parallactic motion $q = h/\rho = 0''.0079 \pm 0''.0013$. The average probable error of a proper motion is $0''.008$. The average peculiar velocity probably is between 5 and 10 km./sec., corresponding to about $0''.003$. Let us be optimistic and suppose that new meridian observations—which evidently are extremely desirable—may reduce the probable errors of the proper motions of the stars listed by Wilson to this same value of $\pm 0''.003$. The total 'probable error' including the cosmical error is then about $0''.004$ and as far as observational and cosmical accidental errors are concerned, the probable error of q will be $\pm 0''.0006$, or 1/13 of q itself. This corresponds to a probable error of $0^{m}.15$ in the mean luminosity and is of the same order of magnitude as the uncertainty expected for the determination from the differential effect of galactic rotation. It is clear, however, that we shall be able to reach this precision of the second method only if there are no serious systematic errors in the proper motions affecting the value of q. Although systematic errors in the fundamental system in different regions of the sky may partly compensate each other in the components υ, one may say that these errors should be less than $0''.002$ in order that the error of q be less than the fraction 1/13 mentioned above.

OB stars. Considerations similar to those for the classical cepheids hold for the O- and B-type giants and super-giants, the category called OB by W. W. Morgan. Although here an additional way of deriving their absolute magnitudes is presented by referring the luminosities to those of the main-sequence B stars when both types are observed in clusters or aggregates, the determination of absolute proper motions for the faint objects must be considered as equally important as in the case of the cepheids. Absolute magnitudes derived from υ components will be a much-desired check of the values obtained by the other methods. Moreover, the proper motions of these stars form one of the best means for the determination of the constants of galactic rotation. It may therefore strongly be recommended that absolute proper motions be determined for the faint O and B stars in the *Henry Draper Catalogue* and for those found in the recent surveys by Nassau and Morgan (21).

These proper motions may also serve for the study of two recently discovered phenomena among the O and B stars: the expansion of some of the aggregates and the high-velocity O stars. The first one is discussed elsewhere during this meeting. As to the second, it may be recalled that high velocities (up to 100 km./sec.) are found for the O-type stars AE Aurigae and ζ Ophiuchi. This proves that exceptionally high space velocities do occur among these, in general, slowly moving stars, and it confirms an earlier suspicion based on the radial velocities. As most of the O stars are very distant (>1000 parsecs), tangential velocities of even 50 km./sec. correspond to only $0''.011$ at most. The detection of these interesting stars therefore requires very accurate proper motions.

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Drs Mineur and Oort discussed briefly the question of the velocity distribution of stars in the vicinity of the Sun.

Prof. Zverev expressed the opinion that it would be advisable for Messrs Oort, Ambartsumian and others to form a small consulting committee to make immediate recommendations regarding a definite selection of stars to be observed by meridian instruments, and which would be important for problems of stellar statistics and cosmogony.

Dr Heckmann requested permission at this time to discuss the question of the necessary number of reference stars required on one plate. A short discussion ensued between Drs Brouwer, Jackson and Nemiro.

M. Mineur recalled a suggestion made by him in 1932, to use O and B stars from the HD catalogue to get a distant reference system. He also outlined a two-step method to refer stars to galactic clusters.

Dr Schatzman spoke in favour of undertaking a programme of observations of various types of stars useful in the study of stellar evolution.

9. UTILISATION DES OBJETS EXTRA-GALACTIQUES POUR L'ETABLISSEMENT D'UN SYSTEME ABSOLU DES MOUVEMENTS PROPRES DES ETOILES

Par A. N. Deutsch

1. Dans le domaine de l'astrométrie avec ses applications pratiques, ainsi que dans les problèmes de l'astronomie stellaire concernant la structure et l'évolution de la Galaxie, l'étude des mouvements propres des étoiles tient une place importante.

La méthode photographique permet de déterminer avec une grande exactitude les mouvements propres d'un nombre énorme d'étoiles, y compris les plus faibles. L'erreur systématique essentielle, dont on doit tenir compte en ce cas, est l'erreur dépendant de la magnitude de l'étoile.

Cependant, sur la plaque photographique ne peuvent être mesurés que les mouvements propres relatifs, c'est-à-dire, des mouvements qui ne contiennent pas le mouvement propre moyen des étoiles de repère, de caractère systématique ou accidentel. Ces

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