expected increase with distance. The effects are presumably caused by systematic peculiar motions of groups of stars and might well be investigated by means of additional observations.

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Discussion

See Discussion on Paper No. 14.

14. FAINT SOUTHERN B STAR VELOCITIES

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At the Radcliffe Observatory, Dr. Feast and I have recently compiled a third list of radial velocities of O and B stars which was designed primarily to push our optical knowledge of the dynamics of the Galaxy to great distances from the Sun (Feast and Thackeray 1963). This program was preceded by the determination of distance moduli of 248 O and B stars in cooperation with Dr. Stoy of the Royal Observatory, Cape, and Dr. Wesselink at the Radcliffe Observatory (Feast *et al.* 1961). As a result of this work we now have radial velocities for a very considerable number of southern stars at distances greater than 2 and even 3 kpc. It is quite possible that many of these distances are overestimated and it is highly desirable that the distances should be improved by the Walraven multicolour method or by some other technique. In the meantime it can certainly be claimed that our knowledge of radial velocities of these distant stars is considerably better in the southern than in the northern hemisphere.

There are three southern directions where radial velocities are of especial interest:

(1) The node near $l^{II}=270°$, from which a determination of R_0 can be made;
(2) the region of $l^{II}=\pm 30°$, where according to the Leiden $\omega(R)$ curve the velocities increase almost linearly with distance out to 5 or 6 kpc;
(3) the direction to the centre, where it is specially important to compare velocities of stars and gas with the 21-cm results.

Determination of R_0

In the predicted galactic rotation curve near the node at $l=270°$ for stars at distance 2·0, 3·2, and 5·0 kpc, there is of course a progressive shift of the node from 270°. It is also of interest that between 290 and 300° the change in velocity predicted for stars from 2 to 5 kpc is less than the intrinsic velocity dispersion of B stars.

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For comparison with the theoretical curves we have radial velocities of 104 stars with distances greater than $1\frac{1}{4}$ kpc with southern stars carrying two-thirds of the weight. One hundred and four stars have been averaged in six groups of approximately equal weight. A linear fit to the six means by least squares gives a fully significant shift of the node amounting to $7^\circ.6$. With a mean distance of $2 \cdot 38$ kpc for all 104 stars this would correspond to $R_0 = 9 \cdot 0$ kpc (assuming circular orbits as usual). However, there are three factors of uncertainty which make this determination quite unreliable; taken in increasing order of importance they are:

(1) Presence of stream motions among the stars. Stars near η Carinae tend to give a negative residual which places them in a region of "forbidden" radial velocities unless R_0 is taken very large.

(2) The distance scale depends directly on the latest Johnson calibration of MK standards.

(3) Any determination of R_0 by this method depends on the adopted solar motion in a way that needs stressing. The result quoted above corresponds to velocities corrected for Vyssotsky's basic solar motion. If the standard solar motion is used (as for reduction of 21-cm velocities), R_0 is increased by a factor of over 2.

Milne and Edmondson have pointed out how the solar motion derived from distant stars may be distorted by second order effects of galactic rotation. But it does not seem to have been realized how accurately the solar motion must be known in order to derive R_0 from the shift of the node. It is a disappointing conclusion that an error in the solar motion affects a determination of R_0 by this method in almost exactly the same way whether one uses the northern node in Cygnus or the southern node in Carina. In either case, the larger the solar motion adopted (particularly the Y component which is the least well-determined component), the larger will be the value of R_0 derived from the shift of the node.

It might be argued that the most appropriate solar motion to apply to distant B stars would be that from coudé measures of interstellar lines of the nearest OB stars, but even these may be sufficiently distant to produce a value distorted by galactic rotation. Dr. Blaauw (private communication) has suggested that 21-cm observations in intermediate latitudes, which show a small amount of galactic rotation, but must refer to relatively nearby gas, might give the most appropriate value; and I understand that the value found is close to the standard solar motion.

To sum up, a preliminary analysis of the material to hand suggests that the value of R_0 is certainly greater than $8 \cdot 2$ kpc with any reasonable value of the solar motion; but that if the standard solar motion is adopted, a value considerably exceeding 10 kpc is indicated. The analysis could undoubtedly be improved in various ways, particularly in a more rigorous selection of stars with accurate velocities, or grouping stars in clusters or associations as one velocity, and such refinements are planned.

Region $l^{\mathrm{II}} = 324$ *to* 336°

Figure 1 shows the variation of radial velocity predicted by the Leiden model for $l^{\mathrm{II}} = 24$, 30, and 45°. The variation is remarkably the same out to great distances.

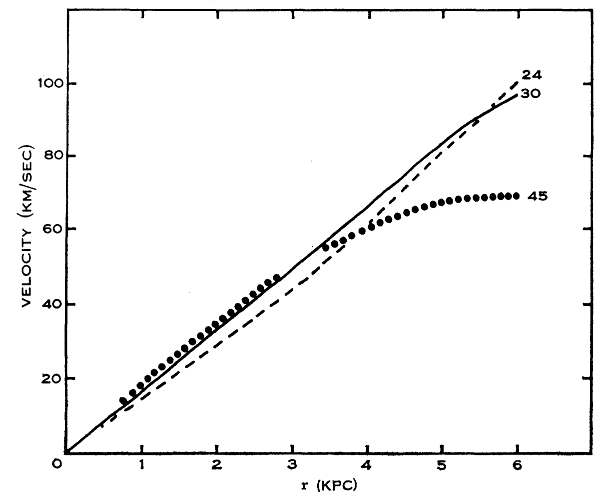

Fig. 1.—Radial velocity as function of distance in longitudes $l^{II}=24$ to $45°$ (based on Leiden $\omega(R)$).

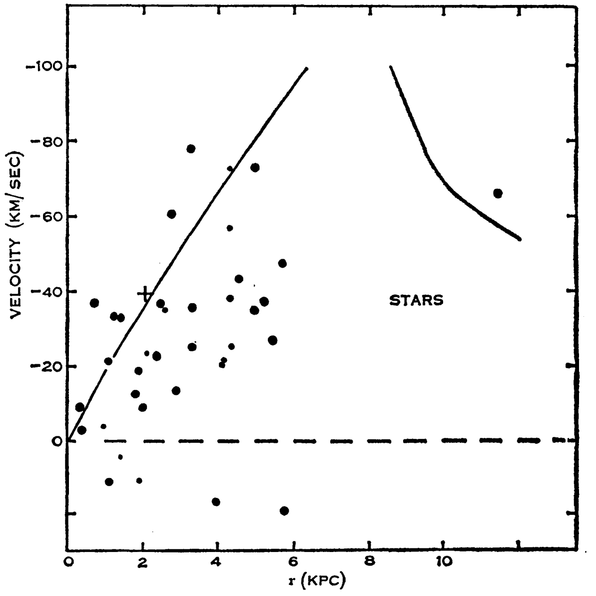

Fig. 2.—Observed radial velocities of stars in longitudes $l^{II}=324$ to $336°$, against spectroscopic distance. Small circles carry half weight. The cross corresponds to NGC 6067. The curve is the prediction from the Leiden $\omega(R)$ variation.

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Figure 2 shows the stellar velocities plotted directly against spectroscopic distance for stars in the highly restricted longitude range 324 to 336°. It will be noticed that there are a considerable number of stars believed to be as distant as 4 to 6 kpc. The curve shows the predicted variation of velocity (at $l^{II}=330°$) from the Leiden model.

While errors exist in both coordinates, the larger uncertainty is (in my opinion) likely to be associated with distance and it is quite possible that some distances are overestimated by a factor 2. Even so, the plot definitely suggests a value of the Oort constant A considerably smaller than that appropriate to the Leiden model. (The cross refers to the cluster NGC 6067.) The star on the extreme right with distance 11·5 kpc calls for special mention. It lies at latitude $+7^{\circ}.6$ and must thus be regarded as a halo object, even if the distance is overestimated. Two stars with positive velocities depart by nearly 100 km/sec from the theoretical curve; strong interstellar lines with negative velocities rule out the possibility of their being nearby subluminous stars. It is intended to reobserve some of these discrepant cases for velocity and it is

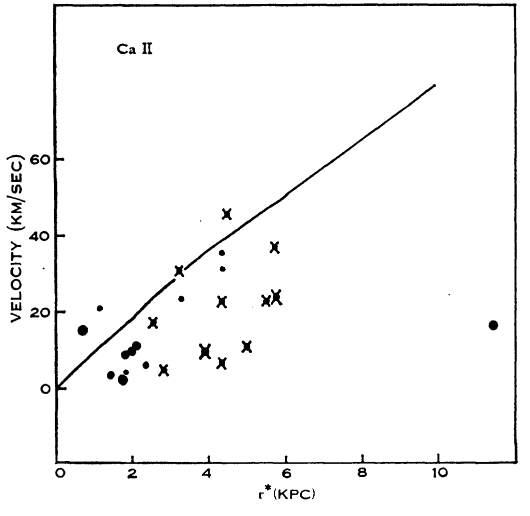

Fig. 3.—Observed CaII velocities in longitudes 324 to 336° against stellar distance. The curve corresponds to the velocity predicted by the Leiden $\omega(R)$ curve for half these distances. Crosses refer to data for stars with the most discrepant velocities in Figure 2. (Two large crosses correspond to stars with positive stellar velocities.)

hoped that better determinations of distance will become available. An attempt has been made to see whether the greatest discrepancies could be attributed to an abnormal ratio of total to selective absorption in these longitudes, but this has not proved to be a very hopeful solution.

Figure 3 shows a similar plot for interstellar CaII velocities. Here the stellar distance is plotted against the theoretical velocity for a point halfway to the star.

Crosses refer to the most discrepant stars in Figure 2, the large crosses referring to the stars already mentioned with positive velocities. It would appear that overestimated distances could account for many but not all of these discrepancies.

Angular Velocity Curve

Finally, Figure 4 shows the angular velocity curve $\omega(R)$ as a function of galactocentric distance. R is calculated for each star assuming $R_0 = 8 \cdot 2$ kpc. This

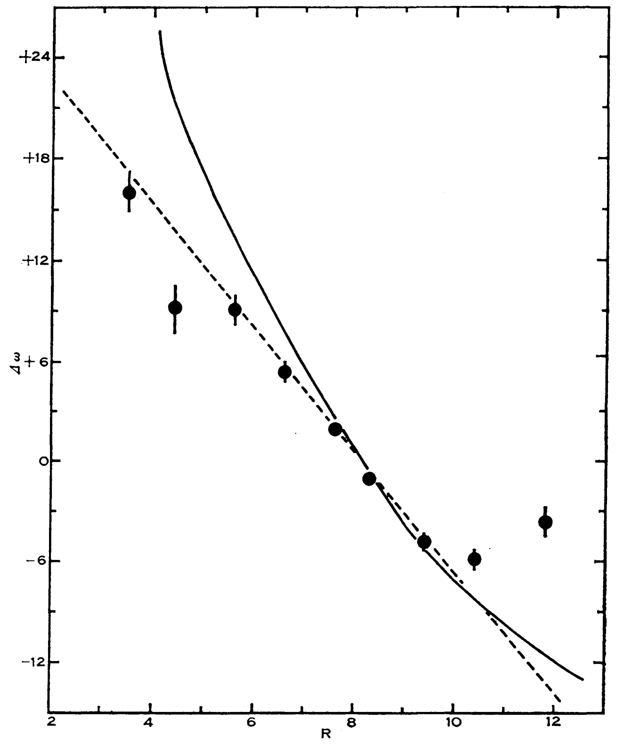

Fig. 4.—Angular velocity of B stars as function of galactocentric distance R (computed from $R_0 = 8 \cdot 2$). The continuous curve shows the Leiden $\omega(R)$ variation. The dashed straight line corresponds to $A = 15 \cdot 0$ km/sec.kpc.

plot (compiled by Dr. Feast and Mrs. Shuttleworth) includes stars from all longitudes (northern and southern). The weights of individual stars vary widely with longitude; also the means grouped according to R carry very different weights, the extreme values of R naturally carrying least weight.

It is clear now that the radial velocities of OB stars in the inner part of the Galaxy depart systematically from the Leiden model. A constant $A = 15 \cdot 0$ over a considerable range in R fits the observations reasonably satisfactorily. It should be mentioned that, although our new observations add considerable weight, particularly at large distances, compared with the material used by Feast and myself in an earlier

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analysis in deriving $A = 17 \cdot 5$, the lower value derived here approximately may be largely attributed to the greater distances implied by using Johnson's latest calibration of the MK scale. Basic solar motion has been used for reducing these observations, but clearly this has a negligible effect on the value of A compared with its effect on the determination of R_0 previously described.

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Discussion

Kerr: Have you found any systematic differences between southern and northern velocities?

Thackeray: No extensive analysis combining the two has been attempted. However, there is no clear-cut evidence of any expansion term between the north and south from what has been done.

Blaauw: In both papers the question of the relative motions of groups of stars arose. In the local system (Gould Belt) the relative motions seem to have a systematic pattern rather than a random character. See, for instance, Eggen's and my own plots for the local system. It would be most interesting to pursue the study of these relative motions in order to understand the large-scale properties of systems like the local system.

Dr. Thackeray's analysis was hampered by these relative motions because they render the determination of the solar motion uncertain. One might next look for the solar motion of the nearby hydrogen which should be rather alike — although then the problem enters of the differences between its systematic motion and the circular velocity around the galactic centre.

Buscombe: An ultraviolet colour index is more sensitive for luminosity discrimination of early-type stars than the $B-V$ index.

Perek: Up to what distances was the linear formula for galactic rotation used? Were any higher order corrections applied?

Heard: Petrie did not include higher terms of the Oort analysis since the data he used here did not go beyond 1800 pc. The stars in his program not yet used in analysis will include many at greater distances for which he is now obtaining *UBV* data.

Arp: In a paper to be published in the forthcoming Kuiper volume on "Structure of the Galaxy" I have derived a distance to the centre of $R_0 = 9 \cdot 9 \pm 0 \cdot 5$ kpc (for M_B RR Lyrae $= +0^{\mathrm{m}}.5 \pm 0 \cdot 1$). Fernie, in a recent *A.J.* **67**: 769–74 (1962), gets $9 \cdot 7$ kpc for the same RR Lyrae absolute magnitude. This confirms that the accuracy of this R_0 determination is almost completely that of the RR Lyrae zero point. Assuming this to be accurate, a very satisfactory independent check with the R_0 derived by Kraft and Schmidt is obtained. I would like to ask Dr. Thackeray if it would be fruitful to adopt the solar motion which results?

Thackeray: Yes, as the two are tied together. But one feels that it should be possible to observe a good value of the solar motion locally, and derive R_0.