culating space densities we have, however, retained the correction factor $10^{-1 \cdot 6E}$ throughout.

Figure 2 shows the central part of the cluster system projected upon the galactic plane. Some absorption regions near the Milky Way are easily recognized. Moreover, the hemisphere behind the galactic centre contains only a few known low-latitude objects.

The observed and theoretical distributions of the clusters over $r = \sqrt{\varpi^2 + z^2}$ are compared in Figure 3. The theoretical numbers have been computed for a line making an angle of 28° with the galactic plane; it was assumed that these would give a good approximation for the average distribution. The value $\nu_0 = \cdot 0048$ has been chosen so as to make the two distribution functions coincide at $\varpi = 8$ kps. Only the clusters on the solar side of the centre have been considered. The slopes of the curves are well alike near their intersection point. Nearer to the centre, however, the theoretical numbers appear to be very sensitive to the model chosen, smaller ϖ-dimensions of the central mass yielding larger numbers. The data in the figure have been calculated with the model corresponding to the third assumption (cf. Table 2), from which a total number of 2000 clusters within a sphere of 8 kps radius would follow.

Until a better knowledge of the gravitational field up to the centre will be obtained, no significant estimate of the number of occulted clusters seems to be possible.

It is a pleasure to thank here Professor OORT for his kind help and encouragement throughout this investigation.

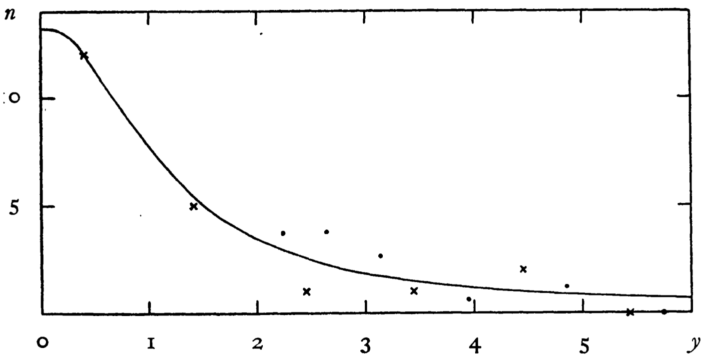
Note on the structure of the inner parts of the galactic system, by *J. H. Oort.*

In the present note I wish to consider the question in how far the distribution of globular clusters may give useful information on the distribution of mass in the inner parts of the galaxy. From the discussion in the preceding article it appeared that with a "central" ellipsoid with semi-axes of 4·2 and 1·4 kps and a density of about 12 times that near the sun the calculated numbers of clusters within 5 kps of the centre so greatly surpass the numbers known that this model may be considered as incompatible with observations. We may ask ourselves whether we can construct a model of the galactic system in which the calculated numbers of clusters bear some resemblance to the observations, and which at the same time agrees with the dynamical data of which we dispose.

The most serious difficulty is that we have no trustworthy information as to the true concentration of globular clusters towards the centre. It is well-known that the clusters within roughly 3° of the galactic plane are practically all blotted out by absorption, and there is every reason to assume that even at considerably higher latitudes, due to this absorption a certain fraction of the globular clusters have remained undiscovered. Moreover, because of the absorption and of uncertainties in the distance criteria, the distances of many clusters must be regarded as quite uncertain. If there exists a strong concentration of clusters towards the centre this is likely to be largely masked in the observed space distribution.

Another, less important, difficulty is that in order to compute the distribution of clusters for a given gravitational field we have to assume that the velocity distribution is approximately Maxwellian, or, what comes to the same, that the average peculiar velocity of the clusters is the same in different parts of the galaxy. From the scant radial velocity observations available there is no evidence of serious deviations from this assumption.

In order to avoid the absorption troubles as far as possible we might consider the distribution of clusters in a zone between, say, 5° and 10° galactic latitude. It might be expected that in such a zone the distribution in longitude would not have been strongly influenced by the absorption, and would, in so far as we consider only the distribution projected on the sky, be entirely free from the uncertainties in the distances. In order to simplify the computations I have not considered this distribution on the sky, but the distribution in ordinary projection on a plane through the centre of the galactic system and perpendicular to the line joining the sun with the centre (the yOz-plane). As long as we consider directions not too far from the centre this projection will not differ very much from the projection on the sky.



Let z represent the distance from the galactic plane in kps and y the other co-ordinate in the plane just defined. The crosses plotted in the accompanying figure show the numbers of clusters counted in the projection between z $\pm$·7 and $\pm$1·5, and between y $-$·5 and $+$·5, as function of y. For these counts I have used the co-ordinates obtained by means of the distances tabulated in Table 4 of the preceding article by Mr DE KORT. Beyond $y = 2$ kps the data have been supplemented by counts in the zone from z $\pm$1·6 to $\pm$2·9, which, after reduction to the interval $\pm$·7 to $\pm$1·5, have been plotted as dots at the y corresponding to the same distance from the centre as where the counts were made. A smooth curve has been drawn through the observed points; the numbers in the second column, marked Obs., in Table 3 have been read from this curve.

The columns marked A, B, C show the calculated numbers. The schematic model of the galactic system used in these calculations is the same as that employed by Mr DE KORT as far as the "outer" ellipsoids are concerned. The dimensions, masses and densities of the "central" spheroids, assumed in the three cases A, B, C are shown in Table 1; a is the semi-major axis. The masses were so chosen that the total gravitational force was sufficient to balance a rotational velocity of 271 km/sec near the sun, which was assumed to be at a distance of 8 kps from the centre. In case C the central spheroid has the same dimensions as in case A, but a point-mass of 10^{10} solar masses has been superposed in the centre. Calculations have also been carried out for a model D in which the central spheroid had a semi-major axis of 7 kps as in case A, but with an axial ratio of 10:1 instead of 3:1 (no central point-mass has been superimposed in this case). The values of the potential in the latter model are practically the same as in case A.

The potential $V(\varpi,z)$ computed for these various

TABLE 1.

Case	a (kps)	a/c	Mass of spheroid	Density (g/cm³)	Density in units of dens. near sun
A	7	3	·82 × 10^{11} ☉	1·17 × 10^{-23}	1·98
B	5	3	·98 ,,	3·81 ,,	6·46
C	7	3	·75 ,,	1·06 ,,	1·80
D	7	10	·78 ,,	3·68 ,,	6·24

models is tabulated below. The first line of Table 2 gives the potentials due to the outer ellipsoids, while the lines A, B, C, D give the sum of the potentials due to outer ellipsoids and "central" mass. The potential is zero at infinity. The numbers in the second column refer to a point coinciding with the sun, the other points have been chosen in the plane $z = 1$, except for the last three which are in the axis of rotation at larger distances from the galactic plane.

With the aid of these potentials the density distribution of the clusters in the plane $z = 1$ has been computed from the formula

$$\log \nu\,(\varpi, z) - \log \nu_0 = 2\,c_1 \operatorname{Mod}\,(V - V_0),$$

in which ν_0 and V_0 represent the density and poten-

TABLE 2.
Potential in different schematic models of the galactic system (unit 10^{12} cm²/sec²).

	$\varpi=8$ $z=0$	$\varpi=0$ $z=1$	$\varpi=2$ $z=1$	$\varpi=4$ $z=1$	$\varpi=6$ $z=1$	$\varpi=8$ $z=1$	$\varpi=10$ $z=1$	$\varpi=0$ $z=2$	$\varpi=0$ $z=4$	$\varpi=0$ $z=6$
"Outer ellipsoids"	161	205	201	191	175	152	122	187	155	129
A	641	1161	1124	1012	827	624	490	1055	793	619
B	706	1751	1638	1297	911	691	548	1461	1013	746
C	651	1506	1233	1042	839	635	500	1192	843	646
D	624	1153	1112	989	801	606	474	988	747	588

tial near the sun, and $1/2\,c_1$ is the mean of the squares of the velocities in one co-ordinate. In accordance with the preceding article I have taken $2\,c_1 = 6{\cdot}29 \times 10^{-15}$ cm²/sec². In Table 4 of that article there are three clusters within 3 kps from the sun, and four between 3 and 4 kps, giving a density ν_0 of ·027 and ·026, respectively, per kps³; I have adopted $\nu_0 = {\cdot}026$. This is roughly five times larger than the value of ν_0 found by VAN DE KAMP [1] and by DE KORT [2] for the average density in a spherical shell with a radius of 8 kps around the centre of the galactic system. The difference is due in part to the flattening of the system of clusters, and for another part probably to incompleteness and observational dispersion of the distances.

By summation of the densities over a column perpendicular to the yOz-plane I obtained the projected densities shown in the columns A, B, C of Table 3.

TABLE 3.

y (kps)	Obs.	A	B	C
0	13	18·4	292	53·4
2	3·5	14·6	140	20·7
4	1·3	7·4	18·5	8·0
6	·7	2·4	2·4	2·4

In comparing the calculated distributions with the observed numbers in the second column we note, first, that hypothesis B yields numbers which are so much in excess of those observed that we may safely conclude that the mass of the galactic system is much less concentrated towards the centre than would correspond to the model B. For, although absorption may have blotted out a certain fraction of the clusters in the region considered, the known clusters in this region are mostly such striking and easy objects that it is difficult to conceive that only less than 5% of the clusters between 5° and 20° latitude would have been discovered. Hypothesis A, in which the "central" spheroid extends to 7 kps from the centre, with a density of only twice that found near the sun, gives numbers which seem to be of a more correct order. However, this model fails to reproduce the concentration of clusters near the longitude of the centre which is such a fairly pronounced feature of the observed distribution. This concentration may be explained by assuming that about 10% of the "central" mass is concentrated very near the centre while the rest is evenly distributed over the large ellipsoid. Consequently, the densities were calculated for a model like A but with an extra point-mass of 10^{10} solar masses near the centre, the density of the large central spheroid being at the same time reduced by 9% in order that the model give the same circular velocity near the sun. This model has been denoted by C in the above tables. It will be seen that it reproduces approximately the concentration of the clusters near $y = 0$. But the total numbers are about four times higher than those observed, which indicates that, if such models as we have been considering bear any resemblance to the real system (and it seems difficult to think out a model which would yield the necessary central concentration and at the same time much lower total numbers) [1], the blotting out effect of the absorption would have been very considerable at the latitudes considered.

All three hypotheses appear to give a somewhat steeper drop in the numbers between y 4 and 6 kps than that observed; this difference becomes even stronger at still larger values of y. But for a discussion of these larger distances a general treatment of the entire material of globular clusters seems preferable. Such an investigation has been made previously [2], and has indicated that the observed drop in the density of the clusters at a distance from the centre comparable to that of the sun conforms well with the gravitational force as computed from any such model as considered in the present note.

Near the sun the derivative with respect to ϖ of the acceleration K_ϖ corresponding to the potential field of the model C is equal to $2{\cdot}46 \times 10^{-30}$ sec⁻². This derivative may also be computed from the constants of differential rotation, A and B, by the formula

$$\partial K_\varpi / \partial \varpi = (A - B)\,(3A + B).$$

Inserting $A = +{\cdot}018$ km/sec.ps, $B = -{\cdot}013$ km/sec.ps we obtain ·00129 (km/sec.ps)² $= 1{\cdot}36 \times 10^{-30}$ sec⁻²; this value is much smaller than that found from model C. Though the constants A and B have a considerable uncertainty it does not seem possible to vary them to such an extent as to bridge this large discrepancy; only a minor part of it could be removed by choosing a more concentrated model. With models of the kind we have been considering the only manner in which the value of $\partial K_\varpi / \partial \varpi$ can be much reduced

[1]) *A.J.* **42**, 161, 1933.
[2]) Preceding article.

[1]) It should be noted that the above computations were made on the supposition that the cluster system has no rotation; with rotation the computed numbers might come out somewhat smaller. On the other hand, part of the discrepancy might be due to the uncertainty of ν_0.
[2]) *M.N.* **99**, 375, 1939; see also the preceding article by Mr DE KORT.

is by assuming a lower velocity of rotation and a smaller distance of the sun to the centre. We thus have an indication that the rotational velocity should be lower than 270 km/sec and the distance to the centre less than 8 kps.

The main conclusions of the above note are:

1. The "central mass" needed to explain the observed circular motions near the sun must extend almost up to the sun, and exhibits no central concentration, except for about 10% of this mass which seems to be concentrated very near the centre [1]).

2. There is a strong indication that even well outside the 6° wide "zone of avoidance" of the globular clusters the major part of the clusters are hidden from our view.

3. The constants of differential rotation indicate that the rotational velocity near the sun is probably rather less than 270 km/sec.

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[1]) At first sight it might seem that this practical lack of central concentration contrasts with what is found in the extragalactic nebulae, most of which show a very pronounced concentration of light towards and inside their nuclear regions. Spectroscopic observations seem to show, however, that, for instance, in the elliptical nebula NGC 3115, in which the light is strongly concentrated towards the nucleus, the mass density is practically constant, at least beyond 10″ from the centre. A somewhat similar contrast between the distribution of light and mass is indicated in a few other extragalactic nebulae which have been observed for rotation.