THE POSITION OF THE GALACTIC CENTRE

(PAPER V)

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Summary

The direction to the radio source Sagittarius A is found to be within 0°·03 of the direction to the galactic centre as determined from a number of precise optical and radio observations, including the recently discovered rapidly rotating disk of neutral hydrogen around the centre. This, together with the fact that the source is unique among the known sources, makes it highly probable that Sgr A is situated at the centre. Additional evidence comes from the observation of 21-cm absorption lines, which indicate that the distance of Sgr A is equal to or greater than the distance to the galactic centre.

Objects of Baade's Population II show a very strong concentration towards the centre of the Galaxy. Observations of RR Lyrae variables in a field centred at $l^{I}=328°{\cdot}7$, $b^{I}=-5°{\cdot}3$* show that at a distance of 600 pc from the centre the density of these variables is about 700 times that in our vicinity (Baade 1958). Similar concentrations are observed for the planetary nebulae, which form a typical old disk population. The density near the nucleus must in this case be at least 1000 times that near the Sun.

The actual centre is hidden by absorbing clouds which must have a very large optical depth. If we were able to penetrate through this matter, we would probably see a well-defined small nucleus, such as is shown by spirals of comparable type. In the Andromeda nebula, for example, a dense nucleus is observed, with a diameter of about 2″·5, or 7 pc (Baade 1955). So far, no optical observations have succeeded in distinguishing a sharp nucleus in the Galaxy. It would seem very important to search for this at a wavelength around 2 microns, where the penetrating power should be sufficient.

For finding the direction of the centre from optical observations we must, for the present, rely on regions more than 2° away from the centre, where the absorption has become sufficiently small to show planetary nebulae. The best value for the *longitude* at present available is that derived from surveys of planetary nebulae. Minkowski (unpublished; for a preliminary discussion cf. Minkowski 1951) finds $l^{I}=327°{\cdot}7$. The uncertainty may be of the order of 0°·5; it is mainly caused by the unevenness of the absorption. The result agrees well with the less accurate value obtained previously from globular clusters, viz. $l^{I}=327°\pm2°$ (estimated probable error) (Shapley 1930).

Because of the absorption the *latitude* cannot be determined with much accuracy from these objects. It can, however, be derived with considerable precision from the situation of the layer of neutral hydrogen gas as found from 21-cm line measurements. From the data in Paper II, the centre of the H I principal plane is found to be at $b^{I}=-1°{\cdot}44$. It can also be determined from

* The galactic coordinates used in this paper are the old system.

the continuous radiation in the region within 50° or 60° from the longitude of the centre. The mean value of the latitude of the continuum "ridge lines" in the centre direction, derived from the data in Table II of Paper III, is $b^{\mathrm{I}} = -1°{\cdot}40$.

A still greater precision might possibly be obtained by using only the hydrogen in the region within 3 kpc from the centre, which can, at least in part, be recognized by its high velocity; but the discussion of this has not yet been finished.

The authors have recently adduced evidence (Rougoor and Oort 1960) of a concentration of neutral hydrogen quite close to the centre (within about 500 pc), which forms a thin disk rotating at a high velocity. The discussion of the extensive observational material obtained at Dwingeloo is not yet entirely completed. A provisional reduction has given a mean latitude of $b^{\mathrm{I}} = -1°{\cdot}48 \pm 0°{\cdot}03$ (estimated probable error) for the central plane of the small disk, which is likely to contain the mass centre of the Galaxy. The same disk gives also independent accurate information on the *longitude* of the centre of rotation, which is found to be $l^{\mathrm{I}} = 327°{\cdot}70 \pm 0°{\cdot}10$ (estimated probable error).

Other dynamical evidence concerning the longitude of the centre, such as may be derived from stars in the neighbourhood of the Sun, or from the motions of globular clusters, is consistent with the above evidence, but is of so much lower accuracy that there is no point in considering it further for the present purpose.

The dynamical evidence from the small rotating disk at the centre agrees very well with that given by the planetary nebulae. Independently from the evidence furnished by the radio source Sagittarius A—which we shall consider below—we may adopt, from the data discussed above, the following position for the mass-centre of the Galaxy: $l^{\mathrm{I}} = 327°{\cdot}70 \pm 0°{\cdot}10$, $b^{\mathrm{I}} = -1°{\cdot}46 \pm 0°{\cdot}05$, the errors being estimated probable errors.

The position of Sagittarius A has been discussed in Paper III and the values of the coordinates finally adopted are $l^{\mathrm{I}} = 327°{\cdot}68$, $b^{\mathrm{I}} = -1°{\cdot}45$. This position agrees so precisely with the direction of the galactic centre as found above, that this by itself makes it almost certain that Sgr A is situated *at* the centre of our Galaxy. For Sgr A is not only one of the five brightest sources, but it is also unique among the known sources, consisting, as it does, of a small, apparently thermal core surrounded by a more extensive non-thermal envelope (Westerhout 1958). It would be an extremely improbable coincidence if this unique source should accidentally lie within 0°·1 of the centre without being connected with it. The interesting recent discovery by Drake (1959) that the thermal source is in reality multiple, does not make any difference to this conclusion.

Though the evidence for the connection between Sgr A and the galactic centre provided by the positions in the sky is sufficiently convincing, it remains of some interest to inquire whether there is direct evidence that also the *distance* of Sgr A is of the right order.

That Sgr A is situated at a large distance from the Sun is shown by the 21-cm absorption lines observed in the spectrum of this source. The most striking evidence comes from a spiral arm whose distance from the centre is estimated to be about 3 kpc (van Woerden, Rougoor and Oort 1957; Oort and Rougoor 1958; Rougoor and Oort 1959). This arm, which has been named the "3-kpc expanding arm", passes between us and the centre. It has a remarkable outward motion in addition to partaking in the general rotation of the Galaxy. At the point where it passes Sgr A it shows a strong absorption line at a velocity which coincides with the emission velocities observed in the "3-kpc expanding arm" on either

side of the longitude of the centre. The occurrence of this absorption shows that Sgr A lies behind the arm and that it is, therefore, further than 5 or 6 kpc from the Sun. There are also absorption lines at higher negative velocities which may be due to the small rotating disk at the centre. If this interpretation is correct it would indicate that the distance of the radio source is equal to that of the centre, or greater.

In view of the evidence given it seems fairly safe to assume that Sagittarius A can be identified with the galactic centre.

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References

Baade, W., 1955, *Mitt. Astr. Ges.*, 51–59.
Baade, W., 1958, *Stellar Populations*, edited by D. J. K. O'Connell, S.J., Specola Astr. Vaticana, Ric. Astr., **5**, 310.
Drake, F. D., 1959, *A.J.*, **64**, 329.
Minkowski, R., 1951, *Publ. Obs. Univ. of Michigan*, **10**, 25.
Oort, J. H., and Rougoor, G. W., 1958, *Acad. Sci. Amsterdam Versl.*, **67**, 139.
Rougoor, G. W., and Oort, J. H., 1959, *I.A.U. Symposium No.* 9, 416 (Paris Symp. on Radio Astronomy).
Rougoor, G. W., and Oort, J. H., 1960, *Proc. Nat. Ac. Sci. Washington*, **46**, No. 1.
Shapley, H., 1930, *Star Clusters*, McGraw-Hill, New York, 22.
van Woerden, H., Rougoor, G. W., and Oort, J. H., 1957, *C.R.*, **244**, 1691.
Westerhout, G., 1958, *B.A.N.*, **14**, 215 (No. 488).