# 9. THE RADIO EMISSION FROM THE GALAXY AND THE ANDROMEDA NEBULA

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Although the sources responsible for the radio emission from the Galaxy are unknown, it may nevertheless be valuable to make a comparison between the magnitude and distribution of the emission observed in our Galaxy and that of other nebulae. Analyses have already been made to relate the total emitted power from nearby nebulae with that from the Galaxy [1], and by considering the integrated radiation from well-defined clusters attempts were made to extend the comparison to the average emission from fainter nebulae.

The results of this work indicated that there was a reasonably constant relationship between optical and radio magnitudes for nebulae of types Sb and Sc down to magnitude +10. The extension to fainter magnitudes by considering the integrated radiation of clusters has been shown to be unreliable by the observation of Baldwin and Elsmore of the Perseus cluster [2]; in fact nearly three-quarters of the total emission from this cluster originates in NGC 1275, which is a source of very much greater luminosity than the nearby galaxies and which is now thought to be the result of a collision between a spiral and an elliptical nebula [3]. Owing to the much greater probability of such encounters in clusters, it seems likely that similar difficulties may arise in using the observations of other dense clusters.

Although it has been possible in this way to make certain deductions about the relationship between the optical and radio emission from certain extra-galactic nebulae, a further difficulty arises when a comparison with the Galaxy is attempted. In early investigations, the relative importance of the contributions to the integrated radiation from extra-galactic sources and from sources inside the Galaxy was unknown; it was therefore impossible to predict the intensity which would be expected for other nebulae on the supposition that they were similar to the Galaxy.

The first detailed model of the galactic radio emission was proposed by Westerhout and Oort [4], who showed that the observed contours of brightness of the integrated radiation could be explained on the supposition that the sources responsible for the radio emission were distributed in the same way as the distribution of mass in our Galaxy. They found that the computed values of radio brightness showed good general agreement with the observations except in one important respect: the observed temperatures showed a fairly uniform excess, over those calculated, of about 600° K (at a wave-length of 3·0 m) in all parts of the sky. They suggested that this emission might originate in extra-galactic sources or in some widely extended population of galactic sources.

Recent observations at Cambridge have enabled a new map of the radio isophotes at a wave-length of 3·7 m to be made. Using this new data it has been possible to show conclusively that the greater part of the integrated radio emission is due to a very extended distribution of galactic sources; a similar suggestion has already been made by Shklovsky [5]. The new data not only provide a good estimate of the total power radiated by the Galaxy, but also give a much more reliable model of its spatial distribution.

More detailed measurements have shown that a similar extended distribution of radio emission exists in the Andromeda nebula. Using the new data, a detailed comparison of the radio emission from the Galaxy and the Andromeda nebula has been made.

The new observations of the integrated radiation were made with one section of the Cambridge radio telescope [6]. An examination of the contours of brightness shows that the areas of minimum brightness lie at galactic latitudes of $\pm 45°$ between longitudes 100° and 210°. This result suggests immediately that an appreciable fraction of the radiation at high latitudes may be galactic in origin.

A study was then made of the emission at latitudes greater than 40° where the contribution from the Westerhout and Oort population is less than one-tenth of the total emission. A series of models was constructed each of which was ellipsoidal and of uniform emission per unit volume. An investigation was made of the effects of varying the size and axial ratio of the ellipsoid and also the effect of assuming different values of the extra-galactic radiation. In each case the model was compared with the observations by plotting, as a function of galactic longitude, the intensity at latitudes of $+40°$, $+50°$, $+60°$, and $+70°$. The figures were also derived for $b = +30°$, but in this case agreement cannot be expected since the Westerhout and Oort distribution here makes a significant contribution to the total radiation. One example of these diagrams is shown in Fig. 1; in this model the extra-galactic radiation was taken to be zero. It can be seen that, apart from the arm of radiation running up to the galactic pole along $l = 0°$ which is a feature seen in many previous surveys, a radius of 16 kpc gives good agreement with the observations.

So far a uniform emission per unit volume has been assumed, but, in the region beyond 10 kpc from the centre of the Galaxy, appreciable variations in the value of the emission per unit volume ($\sigma$) would be undetectable. The interpretation of this region is difficult because a spherical shell of sources whose radius is appreciably greater than the distance of the sun from the centre gives a brightness distribution over the sky which is almost isotropic as seen from the earth. It is thus not possible

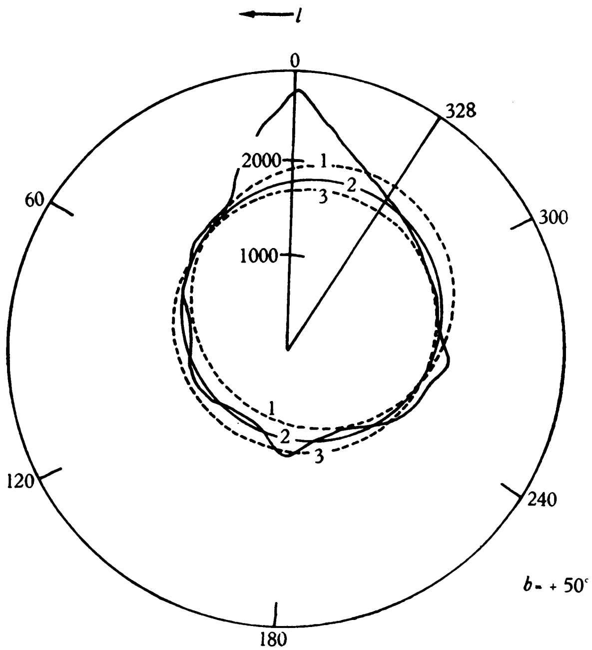


Fig. 1. The variation of brightness temperature with galactic longitude at $b = +50°$. The three circles are the calculated distributions for models having values of $R$ of (1) 12 kpc, (2) 16 kpc, and (3) 20 kpc respectively.

to determine the radial distribution in the outer parts of the sphere; there might, for example, be a significant contribution from extra-galactic sources.

A wide range of satisfactory models may be constructed based on the assumption of different values of the extra-galactic emission; however, it is impossible to account for the observations if this component exceeds 500° K. In every case the best agreement is obtained with a spherical model, but slightly ellipsoidal models would also be permissible. The range of models consistent with the observations is shown in Table 1.

The range of possible models may be narrowed still further if an independent estimate of the extra-galactic emission can be made. It seems probable that this radiation is at least 150° K (at a wave-length of 3·7 m). We may therefore conclude that the greater part of the radio emission from the Galaxy is due to an almost spherical distribution whose radius lies between 11 kpc and 14·5 kpc and that in this region the emission per unit volume is sensibly constant, with a value of $1{\cdot}8 \times 10^8$ watts ster$^{-1}$ (c/s)$^{-1}$ pc$^{-3}$.

Table 1

| Assumed extra-galactic radiation (° K) | $R$ (kpc) | Emission per unit volume ($\sigma$) watts ster$^{-1}$ (c/s)$^{-1}$ pc$^{-3}$ | Axial ratio |
|---|---|---|---|
| 0 | 16 | $1{\cdot}8 \times 10^8$ | $>0{\cdot}9$ |
| 250 | 13·5 | $1{\cdot}8 \times 10^8$ | $>0{\cdot}8$ |
| 500 | 11 | $1{\cdot}8 \times 10^8$ | $>0{\cdot}65$ |

At galactic latitudes less than 30° the contours of brightness are consistent with a distribution of radio emission similar to the distribution of mass in the Galaxy, as suggested by Westerhout and Oort. However, this population contributes only about a fifth of the total radiation from the Galaxy.

These results may now be compared with the observations of the Andromeda nebula. It was shown [7] that in this case also, most of the radiation originates in an approximately spherical region; the observations were not sufficiently accurate to determine precisely the contribution of the Westerhout and Oort population, but it was shown that at least two-thirds of the total emission is due to the spherical population; the proportion could, however, be as great as in the Galaxy. The distribution of brightness across the nebula was shown to be consistent with a spherical distribution having a uniform emission per unit volume and an apparent angular radius of 100′ of arc. Using the most recent determination of the distance of M 31, 610 kpc [8], the actual radius becomes 18 kpc.

In Table 2 a comparison is made between the spherical distribution in the Andromeda nebula and the two limiting models of this component in the Galaxy. The two values of $\sigma$ quoted for M 31 refer to the cases in which (i) the spherical distribution contributes only two-thirds of the total emission, and (ii) the spherical distribution is responsible for the whole of the radiation.

Table 2

| | $R$ (kpc) | Total emission watts ster$^{-1}$ (c/s)$^{-1}$ | $\sigma$ watts ster$^{-1}$ (c/s)$^{-1}$ pc$^{-3}$ |
|---|---|---|---|
| M 31 | 18 | $0{\cdot}8 \times 10^{21}$ | $0{\cdot}24$–$0{\cdot}35 \times 10^8$ |
| Galaxy | 14·5 | $2{\cdot}3 \times 10^{21}$ | $1{\cdot}8 \times 10^8$ |
| | 11 | $1{\cdot}0 \times 10^{21}$ | $1{\cdot}8 \times 10^8$ |

It is interesting to note that, although the limitations of the present analysis lead to an uncertainty of more than a factor of two in the total emission from the Galaxy, the derived emission per unit volume is much more accurately known. The existence of extended distributions of radio emission have been found in both M 31 and the Galaxy; in the case of the Galaxy the radius is appreciably smaller than that in M 31, but the emission per unit volume is about six times greater.

## REFERENCES


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### *Discussion*

Schmidt: What is the explanation of the excess radiation at longitude 0°?
Baldwin: We do not know, but it has been observed in several surveys.
Schmidt: Are the minima observed at latitudes $\pm 45°$ clearly represented?
Baldwin: Yes.