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THE SPHERICAL COMPONENT OF THE GALACTIC RADIO EMISSION

J. E. BALDWIN
Cavendish Laboratory, Cambridge, England

As part of the programme of observations with the large Cambridge radio telescope, a survey of the integrated radio emission has been made using one of the four elements of the interferometer. At a wave-length of 3·7 metres this aerial has beam-widths to half-power points of 2° in right ascension and 15° in declination. The use of a long wave-length makes it possible to obtain accurate measurements of the brightness temperature of the sky in regions away from the galactic plane. It is with the radiation from these regions that this paper is primarily concerned.

Westerhout and Oort (1951) [1] showed, from a study of previous surveys, that the background radio emission could be conveniently divided into two main components: (*a*) a distribution similar to that of the distribution of mass in the Galaxy, and (*b*) an almost isotropic distribution which might arise from the integrated radiation from extra-galactic sources. Distribution (*a*) contributes the greater part of the radiation at latitudes less than 30°, whilst at higher latitudes (*b*) is the principal source of radiation. On the basis of this classification, the areas of minimum brightness of the sky should lie within a few degrees of the galactic poles. An examination of the present survey shows that these areas lie at latitudes of ±45° between longitudes 100° and 215°, i.e. in directions away from the galactic centre. This suggests immediately that much of the radiation at high galactic latitudes may be galactic in origin. Shklovsky (1952) [2] has already proposed that the source of most of the radiation from the Galaxy is distributed throughout a large spherical region and this suggestion has received support from observations of the Andromeda nebula made at Cambridge (Baldwin, 1954) [3] which showed the existence of such a distribution in M31.

In order to investigate in detail this distribution in the Galaxy, a comparison has been made between the observed distribution of radiation at latitudes greater than 30° and that expected on the basis of a simple model. We shall first take one in which

(1) there is no contribution from extra-galactic sources,

(2) the distribution is spherical in form, of radius R, centred on the Galaxy, and having

(3) uniform emission per unit volume, σ, throughout the sphere.

The observed distribution of brightness at latitude +50° as a function of galactic longitude is shown in the form of a polar plot in Fig. 1, together

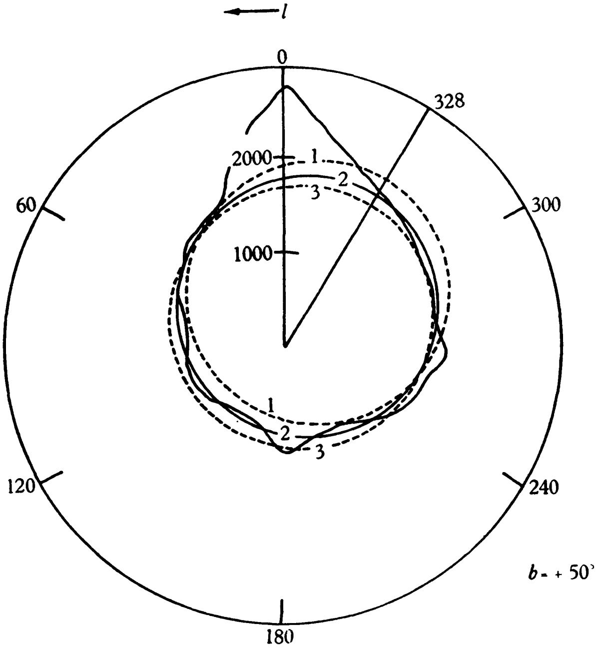

Fig. 1. The distribution of radio emission at $b = +50°$. The observations are shown in comparison with the computed curves for three spherical models having different values of R: (1) 12 kiloparsecs, (2) 16 kiloparsecs, (3) 20 kiloparsecs.

with the calculated curves for three different values of the radius R of the spherical model—12, 16 and 20 kiloparsecs. In each case the value of σ has been adjusted to give the best fit to the experimental curve. It may be seen that a value of R of 16 kiloparsecs gives the best agreement with the observations. The corresponding value of σ is $1{\cdot}8 \, . \, 10^8$ watts ster.$^{-1}$ (c./s.)$^{-1}$ parsecs^{-3}. Using these figures, the distributions of brightness expected at other galactic latitudes have been calculated and are shown in comparison with the observed distributions in Fig. 2. The fit is good except in the neighbourhood of $l = 0°$ where a bright arm of radiation

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exists extending from the equator towards the pole, a feature which has been observed in several previous surveys.

Although the assumption of a model with uniform emission per unit volume leads to good agreement between theory and observation, there

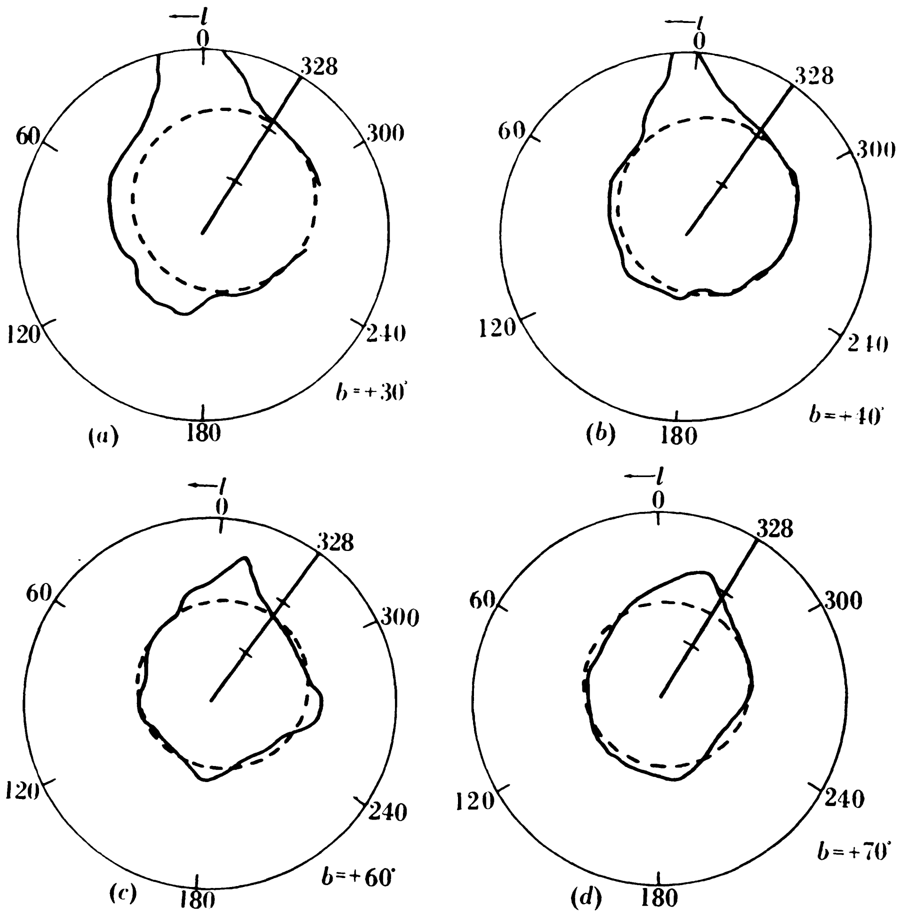

Fig. 2. The distribution of radio emission at $b = +30°$, $+40°$, $+60°$ and $+70°$. Full line: observed curve. Dotted line: computed curve for a spherical model having a radius of 16 kiloparsecs.

are two regions in which appreciable variations in the value of σ would be undetectable.

(1) The region within 4 kiloparsecs of the galactic centre. This region lies at galactic latitudes less than 30° where the radiation associated with the disk of the Galaxy is superimposed on that from the spherical distribution.

(2) Beyond 10 kiloparsecs from the centre of the Galaxy. The difficulty of interpretation in this region is that a spherical shell of emission 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 neighbourhood of the sun. It is thus not possible to determine the variation of the spatial density of the source of emission with radius in the outer parts of the sphere, and in the limit it is impossible to distinguish between emission from a very large galactic shell and that from extra-galactic sources.

A range of models may therefore be derived containing different contributions from extragalactic sources, all of which fit the observations equally well. The essential constants of these models are given in the first three columns of Table 1.

Table 1

Assumed extragalactic radiation (° K.)	R (kps.)	σ watts ster.$^{-1}$ (c./s.)$^{-1}$ ps.$^{-3}$	Axial ratio
0	16		> 0·75
150	14·5	$1{\cdot}8\times10^8$	> 0·7
300	13		> 0·6
500	11		> 0·5

In the previous discussion only spherical models having a uniform emission per unit volume have been considered. An investigation has been made of distributions in the form of flattened ellipsoids of revolution, their minor axes lying perpendicular to the galactic plane, and of the effect of assuming the emission per unit volume to be a function of the radial distance from the centre. None of these models fit the observations as closely as do the simple spherical models. From these calculations it has been possible to place a lower limit on the axial ratio of the ellipsoid appropriate to any assumed value of the extragalactic emission and these limits are given in the last column of Table 1. It has also been shown that the value of σ cannot vary by more than a factor of 2 between 4 and 10 kiloparsecs from the centre of the Galaxy.

The range of models may be narrowed still further by using estimates of the extra-galactic emission derived in other ways. The recent survey of radio stars has provided evidence that the extragalactic component must be at least 150° K. at this frequency. The radius of the sphere must therefore lie in the range 11–14·5 kiloparsecs. This radius is comparable with the radius of 18 kiloparsecs found for the similar distribution in M31. In this latter case too, the value of σ is sensibly constant throughout the spherical region, although its actual value is some six times smaller in M31 than in the Galaxy. The respective values are

Galaxy	$1{\cdot}8 \times 10^8$ watts ster.$^{-1}$ (c./s.)$^{-1}$ ps.$^{-3}$
M31	$0{\cdot}24$–$0{\cdot}35 \times 10^8$ watts ster.$^{-1}$ (c./s.)$^{-1}$ ps.$^{-3}$

For M31 it has been shown that at least two-thirds of the total radiation originates in the spherical distribution and this fraction could be much greater. The range of values of σ quoted for M31 correspond to this uncertainty.

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