A COMPARISON OF THE INTENSITIES OF COSMIC NOISE OBSERVED AT 18·3 Mc/s AND AT 100 Mc/s

By C. A. Shain*

[*Manuscript received November* 11, 1953]

Summary

A comparison is made of the intensities of the radiation, from the general background and from the discrete sources, which have been measured at 18·3 Mc/s and at 100 Mc/s.

It is shown that the ratio of brightness temperatures at 18·3 Mc/s and 100 Mc/s is roughly constant (about 120) for different directions of observation except near the galactic equator where low values are generally observed, the ratio being a minimum near the galactic centre. Also, for the discrete sources observed at the two frequencies there is a wide scatter in the ratio of the flux densities at the two frequencies, with a possible grouping of the sources around flux density ratios of 6 and 60.

From these results the following conclusions are drawn : absorption in interstellar gas can account for the variations in the ratio of background brightness temperatures ; extragalactic sources comprise a subclass of Mills's class II and may account for the polar component of the background radiation ; the background radiation is not due to radiation from sources of the type so far observed.

I. Introduction

A previous paper (Shain and Higgins 1954), subsequently referred to as Paper 1, described observations of the intensity of cosmic noise at 18·3 Mc/s. During these observations a broad strip of the sky, centred on Dec. $-32°$, was scanned with an aerial having an overall beam width to half-power of 17°. A number of discrete sources standing out from a comparatively high intensity background was observed. A very similar but more extensive survey was made at 100 Mc/s by Bolton and Westfold (1950) ; with their equipment the discrete sources made no appreciable contribution to the total received power. A survey of the sky at 101 Mc/s, using the interferometer technique, to detect discrete sources has been described by Mills (1952).

It was remarked in Paper 1 that the results of the 18·3 Mc/s observations are generally similar to the results of the observations at 100 Mc/s. Nevertheless there are important differences, and the object of the present paper is to examine the similarities and differences in an attempt to throw some further light on the origin of the radiation. Comparisons of the intensities of cosmic noise as measured at different frequencies have been carried out by a number of authors, particularly Piddington (1951) and Brown and Hazard (1953). Each of these authors considered all the radiation due to discrete sources and interstellar gas, although their conclusions as to the distribution and properties of the constituents of the model galaxies differed considerably. However, all stressed

* Division of Radiophysics, C.S.I.R.O., University Grounds, Sydney.

the importance of low frequency observations and the present comparison is desirable since Paper 1 added considerably to the observational data at 18·3 Mc/s. Section II considers the general background radiation and Section III the discrete sources, while in Section IV the connexion between the discrete sources and the general background is discussed.

II. The Background Radiation

In presenting the results of their 100 Mc/s survey, Bolton and Westfold (1950) gave a map of the equivalent aerial temperatures observed as their aerial scanned the sky, and they then attempted to allow for the smoothing effect of the aerial beam to obtain a closer approximation to the actual brightness distribution. In Paper 1 a map is given of the equivalent aerial temperatures observed at 18·3 Mc/s ; no correction for aerial smoothing was attempted.

Since the main lobe of the aerial used for the observations of Paper 1 had nearly the same shape and size as that used by Bolton and Westfold, the smoothing of the actual brightness distribution by the aerial beams should be nearly the same in the two cases. A comparison of the *observed* distributions should then give results similar to those which would be obtained if the *actual* brightness distributions were compared, although fine details in the comparison would be obscured. However, the details of the side lobes were different for the two sets of observations and it was therefore necessary to correct the observed distributions, at both frequencies, for the different smoothing effects of side lobes.

The correction was carried out by the methods described by Bolton and Westfold, and the results, contours of equal observed brightness temperature corrected for the effects of side lobes, are given in Figure 1.*

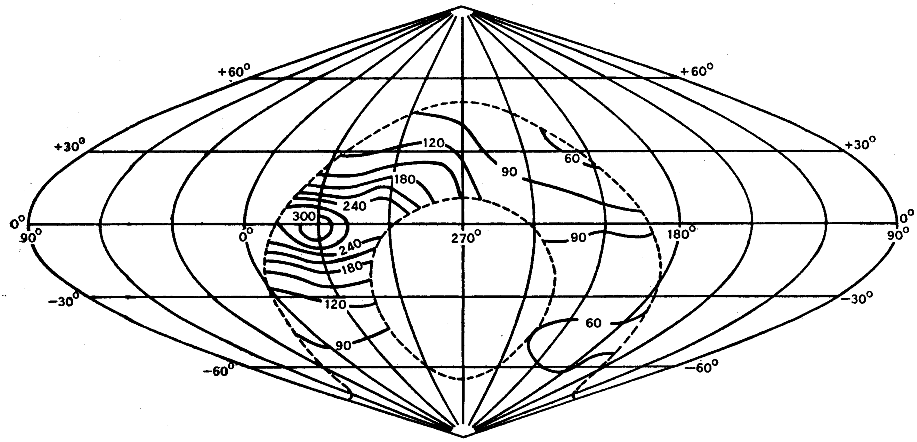
(a) *Ratio of Observed Brightness Temperatures at* 18·3 *Mc/s and at* 100 *Mc/s*

As expected, the form of the contours in Figure 1 is generally similar at the two frequencies, apart from some irregularities on the 18·3 Mc/s contours which can be attributed to the discrete sources. However, the ratio of maximum to minimum temperature at 18·3 Mc/s is only 5·2, whereas the corresponding ratio at 100 Mc/s is 6·7. The difference, 25 per cent. of the mean, is well outside the experimental uncertainty, which in each case is not more than about ± 2 per cent. for relative intensities.

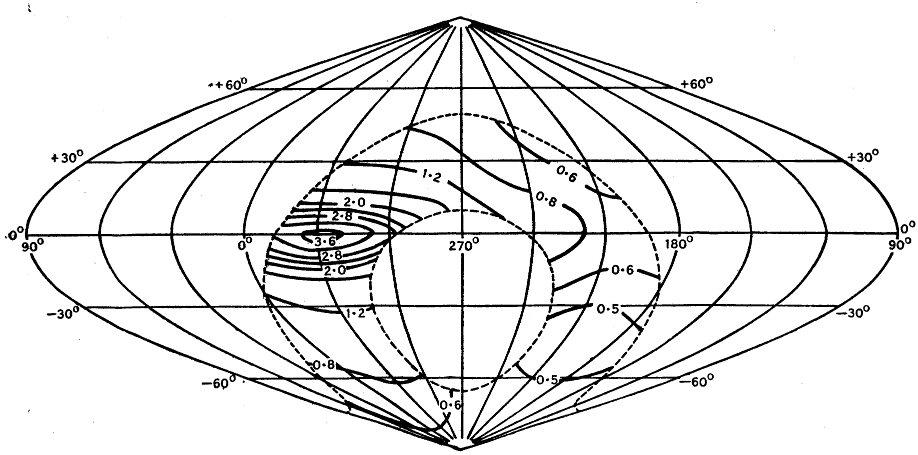
The ratio of the observed brightness temperature at 18·3 Mc/s, T_{18}, to the observed brightness temperature at 100 Mc/s, T_{100}, has been calculated over the region of the sky covered in Figure 1, and contours of equal ratio are plotted in Figure 2. Examination of Figure 2 shows that, again with some irregularities in the contours caused by the presence of discrete sources, the ratio T_{18}/T_{100} is approximately constant (within about 15 per cent.) over about 85 per cent. of the observed strip of the sky, but this ratio is generally low near the galactic

* In the original observations, different systems of galactic coordinates were used (see Paper 1 and also Bolton and Westfold (1951)). The coordinates of Figure 1 are based on the galactic pole at R.A. 12 hr 40 min, Dec. $+28°$ (1900), and appropriate precession corrections were applied to the 100 Mc/s data.

equator from longitude 240° to at least the limit of the observed strip near longitude 350°. There is a marked dip to a ratio of 76 near the galactic centre (in the region of longitude 325°, latitude —1°). It appears that the difference in ratio of maximum to minimum brightness temperature at the two frequencies is associated with this low ratio T_{18}/T_{100} near the galactic centre.



(a)



(b)

Fig. 1.—Contours of observed brightness temperatures (unit 1000 °K). (*a*) 18·3 Mc/s, (*b*) 100 Mc/s. These contours have been derived from published contours as explained in the text and in each case they correspond to the brightness temperatures which would be observed with similar idealized aerials having a single main lobe of beam width 17°.

It will be shown in Section IV that the spectra of the discrete sources differ from the spectrum of the background so that the presence of a discrete source will distort the contours in the sense of increasing the ratio T_{18}/T_{100}. To avoid complications due to this cause, two representative cross sections of Figure 2 have been drawn for restricted ranges of galactic longitude, avoiding as far as possible the known discrete sources. These sections are shown in Figure 3.

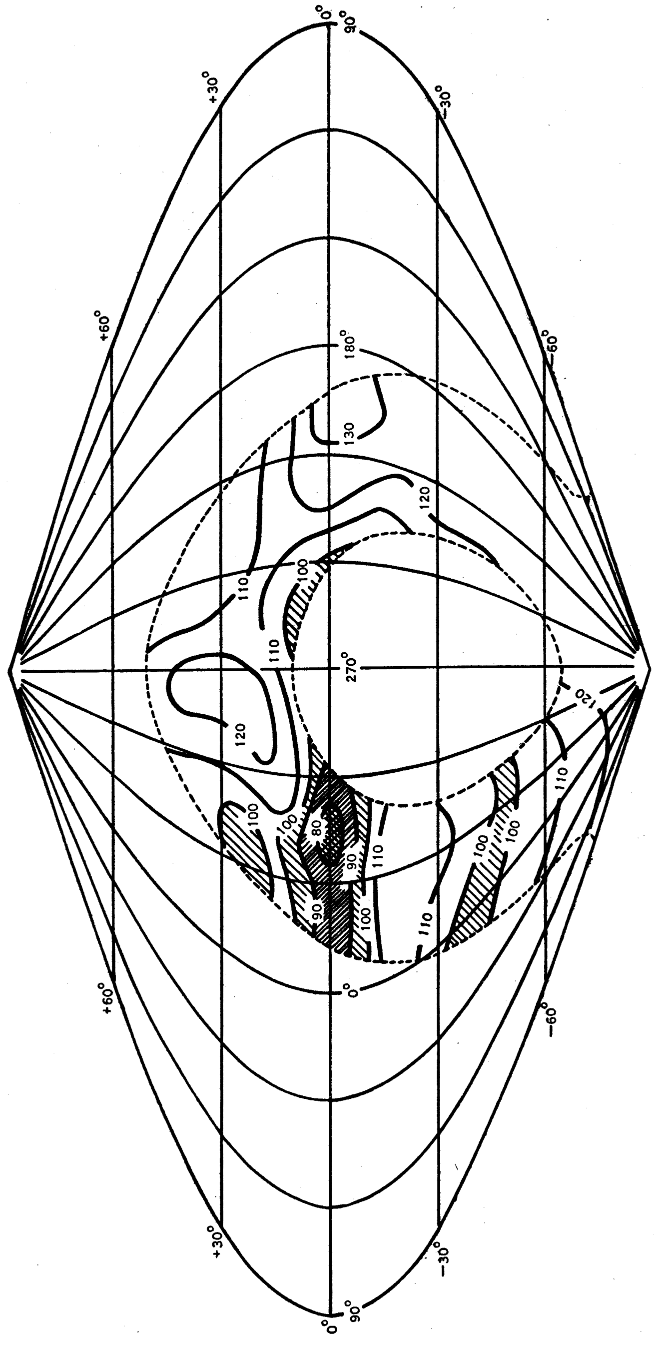


Fig. 2.—Contours of the ratio T_{18}/T_{100} derived from Figure 1.

It is seen that for longitudes between 205 and 215° the ratio is approximately constant around a mean value of about 124, while for longitudes 305–330° the maximum value occurs at the pole and there is a sharp dip for latitudes less than about 20°. There are subsidiary minimum and maximum values near latitudes —50 and —25° respectively.

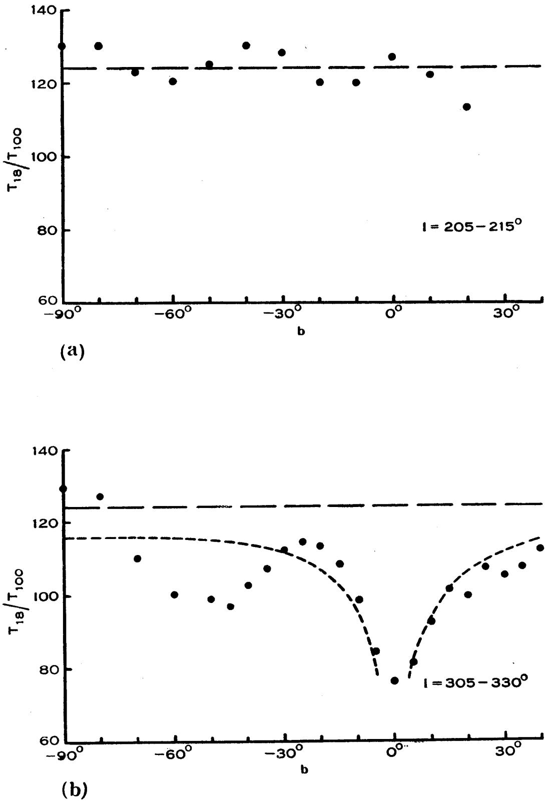


Fig. 3.—Representative sections of Figure 2, avoiding as far as possible the known discrete sources. All the points were obtained in either of two restricted ranges of galactic longitude. (*a*) Longitudes 205–215°, (*b*) 305–330°. The dashed line in (*b*) is a theoretical curve showing the variation to be expected due to absorption in interstellar gas.

The sharp dip in the ratio T_{18}/T_{100} near the galactic centre extends over only a fairly small range of latitudes. This suggests that it is due to some feature of the Galaxy which is confined to regions near the galactic plane. Interstellar gas is thought to extend over such a comparatively thin region near the galactic plane and, since absorption in the gas would be relatively greater at 18·3 Mc/s than at 100 Mc/s, its effect would be in the direction observed. At the frequencies concerned emission from the gas can be neglected (Westerhout and Oort 1951); therefore, as a possible explanation of the dip in T_{18}/T_{100} towards the galactic centre, the effect of interstellar absorption on the ratio T_{18}/T_{100} will now be considered.

(*b*) *The Effect of Interstellar Gas*

(i) *Expected Ratio of Brightness Temperatures for Two Frequencies.*—Consider the case in which interstellar gas is distributed roughly uniformly in a thin disk, symmetrical about the galactic plane. The radiation is assumed to come from some sources more widely distributed throughout the Galaxy than the gas. (The " sources " of the background radiation considered here should not be identified with the discrete sources which have been observed. It will be shown later, by consideration of the spectra of the discrete sources, that it is unlikely that these sources could account for more than a small part of the background radiation.) Let T' be the brightness temperature that would be observed, for a particular direction, in the absence of the absorbing gas. Then in directions for which the path length in the emitting region is much greater than the path length in the gas (that is, for directions more than, say, 6° from the galactic plane) it may readily be shown that the actual observed brightness temperature T is given closely by

$$T=T'e^{-\alpha h \operatorname{cosec} |b|},$$

where α is the absorption coefficient per parsec,

h is the semi-thickness of the gas disk,

b is the galactic latitude in which the observations are made.

The absorption coefficient will vary inversely as the square of the frequency f Mc/s. Hence we may put

$$\alpha=af^{-2},$$

where a will be the absorption coefficient per parsec for a frequency of 1 Mc/s. Therefore

$$T=T' \exp(-af^{-2}h \operatorname{cosec} |b|).$$

Let T_1 and T_2 be the brightness temperatures observed at frequencies f_1 and f_2 Mc/s respectively. Then

$$T_1/T_2=(T_1'/T_2') \exp\{-ah(f_1^{-2}-f_2^{-2}) \operatorname{cosec} |b|\},$$

and, taking logarithms,

$$\ln(T_1/T_2)=\ln(T_1'/T_2')-ah(f_1^{-2}-f_2^{-2}) \operatorname{cosec} |b|.$$

To the present no restrictions have been put on the spectra of the sources of the radiation, that is, on T_1'/T_2'. We will now make the tentative assumption that all the sources have the same spectra so that the ratio T_1'/T_2' does not depend on galactic latitude. In this case a graph of $\ln(T_1/T_2)$ against $\operatorname{cosec} |b|$ should be a straight line, from which T_1'/T_2' and ah, the optical depth in the direction of the pole, may be found.

For a given direction, T_1 and T_2 are strictly the temperatures that would be observed with infinitely narrow beamed aerials whereas the observed temperatures are the averages over a fairly wide cone of angles with the axis in the direction considered. However, if only directions not too close to the galactic plane are considered, and this restriction has already been introduced, the ratio of the observed temperatures for a particular direction of the aerial maximum should be very nearly equal to T_1/T_2 for that direction.

(ii) *Comparison with Experimental Results.*—The values of the ratio T_{18}/T_{100} for galactic latitudes between 6 and 40° were taken from Figure 3 (*b*) and for each latitude the values of the ratio for the northern and southern hemispheres were averaged. Figure 4 shows ln (T_{18}/T_{100}) plotted against cosec $|b|$ and it is seen that the points lie reasonably close to a straight line. This result supports the assumptions that there is an absorbing layer in the form of a thin disk about the galactic plane and that the spectrum of the sources of the radiation is independent of galactic latitude. The dotted curve in Figure 3 (*b*) shows the variation of T_{18}/T_{100} with latitude corresponding to the line in Figure 4.

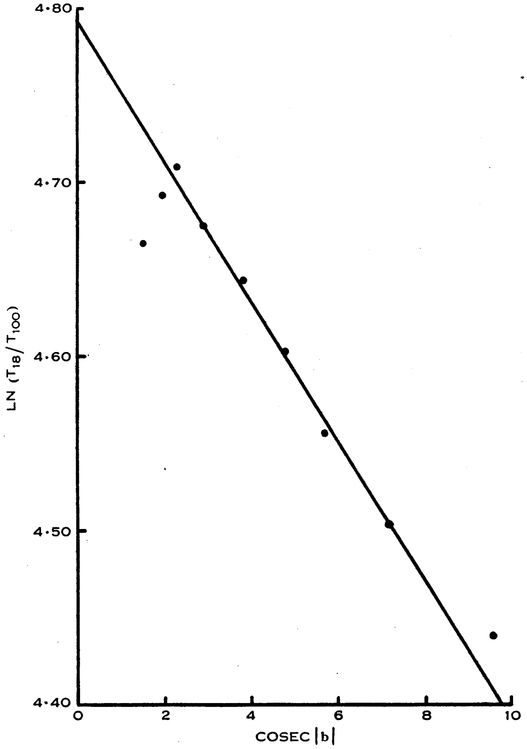


Fig. 4.—Ln (T_{18}/T_{100}) as a function of cosec $|b|$ for the points of Figure 3 (*b*).

The intercept on the ln (T_{18}/T_{100}) axis (Fig. 4) is 4·79, corresponding to a ratio T_{18}'/T_{100}' equal to 120, and the slope of the line is $-0\cdot04$, giving $ah=14$.

Westerhout and Oort (1951), considering the 100 Mc/s emission from interstellar gas, took the semi-thickness of the gas disk to be 100 parsecs. Also, taking the characteristics of the gas suggested by Stromgren (1948), they found an optical depth of 0·017 per kiloparsec at 100 Mc/s. This corresponds to a value for a of 0·170 per parsec, giving $ah=17$, in good agreement with the value found above, although there is considerable uncertainty in the value deduced from optical data.

From the value of ah derived above, and taking h equal to 100 parsecs, it is found that 100 Mc/s radiation in the galactic plane would be very little absorbed between the Sun and the centre of the Galaxy, whereas 18·3 Mc/s radiation would reach optical depth unity within 3 kiloparsecs. Any source of radiation near the galactic centre would be " visible " at 100 Mc/s but obscured at 18·3 Mc/s. It will be seen from Figure 1 that the maximum observed temperature at 100 Mc/s is close to the galactic plane, whilst the maximum at 18·3 Mc/s is several degrees to the south and at a different longitude. It is probable that there exists a region of high brightness near the galactic centre, perhaps the source " K " observed by Bolton *et al.* (1954), of which the brightest portion is obscured by gas absorption at 18·3 Mc/s so that at this frequency the position of the apparent maximum is displaced from the position of the 100 Mc/s maximum.

The above discussion applies to latitudes greater than about 6°. If the gas disk is only of the order of 100 parsecs thick, the radiation never travels more than a few kiloparsecs through the gas to the earth. Therefore no conclusions may be drawn as to whether the gas is in the form of a complete disk extending from the centre of the Galaxy to the Sun or in the form of an annulus with little gas in the central regions of the Galaxy. However, if the thin layer of gas extended uniformly round the Sun even for only a few kiloparsecs, there should be little change with longitude for a given latitude and in particular there should be the sharp dip near the equator for all longitudes. Examination of Figure 3 (*a*) shows that this is not so. It follows that there must be irregularities in the distribution of the gas with longitude.

In this connexion, the observations of Morgan, Sharpless, and Osterbrock (1952) are of interest. These workers found that Hα emission regions in the northern Milky Way are confined to two lines, believed to represent two spiral arms of the Galaxy. The nearer arm extends from galactic longitude 40 to 190° and passes at its nearest point about 300 parsecs distance from the Sun in a direction opposite to that of the galactic centre. Similar observations for the southern Milky Way have been commenced by Bok, Bester, and Wade (1953), but the results for longitudes 180–250° have not yet been published. Christiansen and Hindman (1952), from their study of 1420 Mc/s hydrogen line radiation, also found evidence for the concentration of hydrogen to two spiral arms which would fit the results of Morgan, Sharpless, and Osterbrock.

The optical and 1420 Mc/s results confirm the generally held hypothesis that interstellar gas is mainly confined to the spiral arms of galaxies, and it is possible that in observing cosmic noise in longitude 210° we may be looking between two spiral arms, in which case there would be little interstellar gas for a considerable distance from the Sun. The absorption of 18·3 Mc/s radiation near the galactic plane for this longitude would then be small. It is probable that a similar situation occurs in visual astronomy. Bok (1937, p. 85) states that there is a notable absence of obscuring clouds of interstellar dust (generally associated with the gas) from longitudes 190 to 230°. It is also of interest that the low values of T_{18}/T_{100} in the region around $l=330°$, $b=+20°$ cover about the same region of the sky as the large, dark nebula in Ophiuchus. This obscuring cloud of dust extends over most of the region between longitudes 320–0° and latitudes 0 to +30° (Bok 1937, p. 83, 1944, p. 91). Recently Sharpless and Osterbrock (1952) have detected in this region a large Hα emission region, about 10° in diameter, near l=330°, b=+23° surrounding ζ Ophiuchi. Similarly, although there is at present no optical evidence for heavy obscuration or Hα emission in this high latitude region, the comparatively low values of T_{18}/T_{100} around l=330°, b=−50° may possibly be due to the effect of a large gas cloud somewhat below the galactic plane.

If the high values of T_{18}/T_{100} near longitude 210° are associated with a lack of absorbing gas in this direction, in a gap between spiral arms, it follows that the actual sources of the background radiation cannot be confined to spiral arms. These sources must then be either extragalactic sources or galactic sources distributed more like Population II than Population I.

The analysis of the effects of absorption assumed that in the absence of absorption the ratio T_{18}/T_{100} would be the same in all directions. An alternative explanation of the variations in the observed values of T_{18}/T_{100} is that the actual sources of radiation in regions near the galactic centre have spectra intrinsically different from the sources of radiation in other regions of the Galaxy. However, although source spectral variations are not excluded, it appears that at present the variations of T_{18}/T_{100} can be best accounted for in terms of absorption in interstellar gas, the radio observations being consistent with optical evidence concerning the characteristics of the gas.

III. The Discrete Sources

Of 37 discrete sources detected at 18·3 Mc/s and listed in Paper 1, 22 coincide in position,* within the limits of error (up to about 5°) with sources observed at 101 Mc/s by Mills (1952). These sources are listed in Table 1, with Mills's values for the galactic coordinates of each source, these being more accurate than the 18·3 Mc/s values. The sources are identified using Mills's nomenclature which gives the hour of the Right Ascension followed by the sign and tens of degrees of the declination. Sources listed in Paper 1 and by Mills are prefixed by S and M respectively. In the few cases where the designations do not correspond exactly (e.g. S03−4, M03−3), the source is close to one of the grid lines which define the designation.

In Table 1 the intensities of the sources are specified logarithmically by their " levels ". The level, L_f, at a frequency f, of a source having a flux density at the earth $S_f \times 10^{-25}$W m^{-2} (c/s)$^{-1}$ is defined by $L_f=\log_{10}S_f$. The table gives the level of each source at 18·3 Mc/s, L_{18}, and at 101 Mc/s, L_{101}, together with the " level difference " $L_{18}-L_{101}$ which corresponds to the ratio of the flux densities at the two frequencies. For two of the sources (M08−4 and M13−4) which have appreciable angular size, Mills gave values of flux density for two spacings of the interferometer aerials. In Table 1 the greater values have been given. Bolton *et al.* (1954) have shown that the sources M13−4, M03−3, and

* The source called S20+x, which may probably be identified with the source M19+4, Cygnus–A, has been omitted owing to the great uncertainty in its position and intensity (see Paper 1).

M05—4, or perhaps sources associated with them, have considerable angular size. The total intensities measured by Bolton are such that the values of L_{101} for these sources should be increased by about 0·3, 0·4, and 0·8 respectively. The corresponding values of L_{101} and of $L_{18}-L_{101}$ are shown in brackets in Table 1. The uncertainties in the levels vary from source to source. They are generally less than 0·1 in L_{101} (corresponding to an uncertainty in S_{101} of ± 25 per cent.) and less than 0·2 in L_{18} (± 50 per cent. in S_{18}).

Table 1

SOURCES OBSERVED AT BOTH 18·3 Mc/s AND 101 Mc/s

Designation		Position (Mills) l	Position (Mills) b	L_{18}	L_{101}	Level Difference (L_{18}–L_{101})
S01—2	M01—2	163	—73	3·0	0·9	2·1
S03—4	M03—3	206	—55	2·5	1·4 (1·8)	1·1 (0·7)
S04—2	M04—1	189	—36	2·8	1·2	1·6
S05—4	M05—4	219	—31	2·5	1·4 (2·2)	1·1 (0·3)
S06—1	M06—1	191	—17	3·0	0·8	2·2
S06—3	M06—3	206	—15	2·5	1·0	1·5
S06—5	M05—5	231	—29	2·9	1·2	1·7
S07—1	M07—2	200	— 4	3·1	1·0	2·1
S08—4	M08—4	229	0	2·8	1·7	1·1
S09—1	M09—1A	212	+28	2·6	1·4	1·2
S09—3	M09—3	227	+15	2·8	0·9	1·9
S10—1	M10—0	217	+41	2·9	0·7	2·2
S12+1	M12+1	260	+74	3·0	2·1	0·9
S13—2	M13—2	282	+39	3·3	1·0	2·3
S13—4	M13—4	278	+18	3·7	2·4 (2·7)	1·3 (1·0)
S13—5	M13—6	276	0	(3·5)	1·9	(1·6)
S15—6	M16—6	293	— 9	(3·8)	1·9	(1·9)
S19+0	M19+0	7	— 2	3·0	1·5	1·5
S20—4	M19—5	316	—30	2·5	0·7	1·8
S21—2	M21—2	356	—53	2·7	0·9	1·8
S21—3	M21—3	341	—43	2·9	0·9	2·0
S21—5	M22—5	308	—51	2·4	0·7	1·7

A comparison of the intensities observed at the two frequencies is made in Figure 5 where, for each source listed in Table 1, L_{18} is plotted against L_{101}. For each of the sources M13—4, M03—3, and M05—4 two circles are shown corresponding to the pair of values of L_{101}. There is a considerable scatter of the points, but there is a general tendency for the intensities measured at the two frequencies to increase together.

Mills has proposed that the discrete sources be divided into two classes on the basis of spatial distribution. The class I sources would comprise intense sources distributed thinly throughout the Galaxy and hence generally close to the galactic plane; the class II sources, more or less randomly distributed, may be either weak galactic objects near the Sun or extragalactic sources. In case the spectra of these classes may be different, the sources will be divided into two groups, one having latitudes less than 12° (" equatorial " group) and the other having latitudes greater than 12° (" non-equatorial " group). This is the division used by Mills in his analysis. In general the class I sources would be expected to fall in the equatorial group while most of the class II sources would be non-equatorial, although the separation would not be clear-cut.

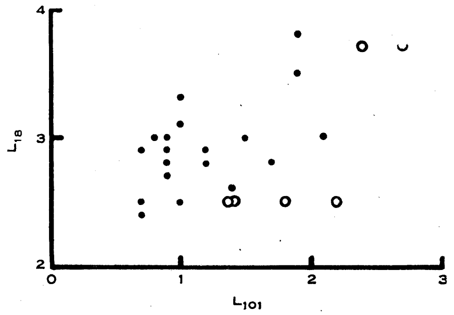


Fig. 5.—L_{18} *v.* L_{101} for all the sources listed in Table 1. For each of three sources two circles are given, instead of points, corresponding to values of L_{101} observed under different experimental conditions.

The values of level difference range from 0·3 to 2·3, corresponding to ratios of flux density of between 2 and 200. The variations in the spectra of the sources are shown in more detail in Figures 6 and 7. Figure 6 is a histogram of the frequency of occurrence of values of level difference. For those sources for which two values of level difference are given in Table 1, the smaller has been

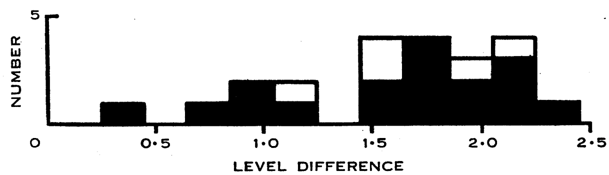


Fig. 6.—Histogram of the frequency of occurrence of level differences. The shaded portion of the histogram corresponds to the non-equatorial sources, the unshaded portion to the equatorial sources.

used. That part of the histogram which corresponds to the equatorial sources has been left unshaded, the shaded portion corresponding to the non-equatorial sources. Figure 7 shows plots of level difference against (*a*) L_{18} and (*b*) L_{101}. Circles and points correspond to the equatorial and non-equatorial sources respectively. Level difference shows no significant correlation with L_{18}, but the inverse correlation with L_{101} is statistically significant.

The histogram in Figure 6 is markedly skew. With a scatter of level differences from 0·3 to 2·3 the mode is at 1·75, the mean being at 1·6 and the standard deviation 0·5. Since the observational uncertainty in level difference would be expected to be, at most, not more than 0·3, corresponding to an uncertainty in the ratio of flux densities of a factor of 2, it would appear that some factors other than the random errors of measuring L_{18} and L_{101} from the records must be affecting the shape of the histogram.

Two effects which must be considered as possibly affecting the shape of the histogram are angular sizes of the sources and absorption along the paths between the sources and the Earth. Besides the sources mentioned earlier, it is probable that others have angular sizes sufficiently great to give a low value of intensity with Mills's interferometer. For example, from a study of the scintillations of some sources, it was suggested in Paper 1 that the source S10 −1 (M10 −0) might have an angular size of between 0·5 and 1·0°. However, source size effects, which would tend to increase the values of level differences, could cause the observed skewness of the histogram only if the intensities of a moderately large

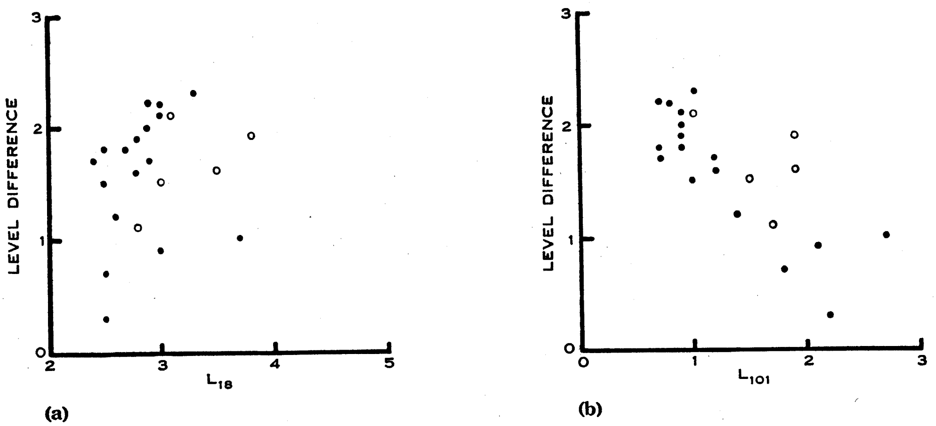


Fig. 7.—Level difference *v.* (*a*) L_{18}, (*b*) L_{101}. Points and circles relate to the non-equatorial and equatorial sources respectively.

number of sources had been affected. At present there is little evidence on which to decide whether such a possibility is reasonable, but Bolton (personal communication) considers that the percentage of sources with large angular sizes is fairly small (say 10 per cent.).

Absorption would be expected to be greatest (and hence the level differences lowest) for the sources in lowest latitudes. However, Figure 6 shows that the level differences for the sources within 12° of the galactic plane are no smaller than those for the sources outside that range of latitudes. A plot of level difference against galactic latitude (not reproduced) showed no significant correlation. Also, if absorption were markedly affecting the observed intensities of the sources, any correlation between level difference and L_{101} would be expected to be direct rather than inverse (Fig. 7 (*b*)). The conclusion that interstellar absorption is inappreciable for the relatively inaccurate observations of the intensities of the discrete sources is consistent with the results of the previous section.

The proposed explanation of the skewness of the histogram and of the apparent dependence of level difference on L_{101} but not on L_{18} is that these are due to differing spectral characteristics of the sources themselves. It is suggested that the sources may be divided into two groups on the basis of their spectra, the first having level differences clustered about 0·8 and the second about 1·8, the division coming at about level difference 1·2. Five of the six sources having level differences 1·2 or less are in the non-equatorial group and this may imply a subdivision of Mills's class II into two subclasses. Two of these five sources, M12+1 and M13−4, have been identified with peculiar extragalactic nebulae, and, since none of the other sources has been so identified, the subclass having low level differences, and comprising the five strongest non-equatorial sources, may be tentatively assumed to be extragalactic objects. On this assumption it will be shown in the next section that a class of such sources could account for the general background radiation observed near the poles. The second group of non-equatorial sources have spectra not significantly different from those of the equatorial sources (level differences about 1·8). It is possible that a large group of class II sources and the class I sources are the same type of galactic objects, the more powerful emitters being concentrated towards the galactic plane.

Since the number of sources for which level differences are available is comparatively small, these suggestions must be considered as provisional until more data are available.

IV. The Discrete Sources in Relation to the General Background

If the general background radiation is made up of the radiation of a large number of similar discrete sources, the variation with frequency of the flux density at the Earth from an individual source should be the same as that of the brightness of the background radiation. This relation would be modified by severe interstellar absorption, but it has been shown in Section II that absorption is important only over a comparatively small area of the sky. The background brightness at a wavelength λ is proportional to $T\lambda^{-2}$ where T is the brightness temperature.

It has been shown that over most of the sky the ratio of brightness temperatures of the background at 18·3 Mc/s and at 100 Mc/s is about 120, although somewhat lower values are observed near the galactic centre. The corresponding ratio of brightness is 4. It has been shown also that the average values of the level difference for the discrete sources, taken all together, is 1·6, while if the group of sources with low level differences are omitted this would be raised to about 1·8. These level differences correspond to ratios of flux densities of 40 or 60 respectively. Although the values for some sources may be reduced as the effects of source size are overcome in further observations, it is hardly likely that these average values should be in error by a factor as great as 10; the probable errors of the averages for the sources studied correspond to a factor of 2. The variation with frequency of the source flux densities is therefore quite different from that of the background brightness and it appears that the background radiation cannot be made up of the radiation from discrete sources similar to the bulk of those so far observed.

However, the level differences for the possible extragalactic subclass of the class II sources are about 0·8, corresponding to a flux density ratio of 6. This is close to the brightness ratio for the general background and it is possible that these sources could be responsible for at least some part of that radiation. Since the class II sources, and especially any extragalactic sources, are distributed homogeneously whereas the general background shows a marked galactic concentration, the contribution from these sources must be small. They could be responsible for the "residual" background of Bolton and Westfold (1951) and Westerhout and Oort (1951) which is the apparent reason for the high brightness temperatures observed near the galactic poles.

Mills (1952) suggested that all the class II sources might be extragalactic objects, and in some rough calculations he showed that the total radiation from all such sources would be of the right order of magnitude to account for the "residual" radiation. The restriction of Mills's calculation to the sources of the suggested subclass does not invalidate the result, since for his estimate of the density of the sources he took as the typical source M12+1, which has been included in this subclass.

V. Conclusion

The most important conclusion to be drawn from the comparisons of the intensities at 18·3 Mc/s and 100 Mc/s of the background and of the discrete source radiation is that the background radiation cannot be made up of the radiation from sources of the type so far observed, although a small polar component may be due to the extragalactic sources. This conclusion makes the possible identification of the sources of the background radiation even more difficult than has been thought up to the present.

It has been shown that absorption in interstellar gas must have a considerable effect on the intensity variations with direction of the background radiation observed at 18·3 Mc/s. This effect will presumably be even more pronounced in any observations made at lower frequencies. It has been also shown that the considerable scatter in the ratio of flux densities of the discrete sources at 18·3 Mc/s and at 101 Mc/s suggests a grouping of the sources in terms of their spectra, certain sources probably comprising a class of extragalactic objects. The remaining sources, including probably sources of both of Mills's classes, all have higher flux density ratios which do not differ significantly amongst themselves.

Further observations at comparatively low and high frequencies should make possible a more detailed study of the structure of the "radio Galaxy" and of the absorbing effects of interstellar gas. It is apparent that future work on the discrete sources requires the accumulation of data on flux densities and angular sizes at several frequencies for many sources so that firm statistical conclusions may be drawn concerning possible methods of classification.

VI. Acknowledgments

The author is indebted to Mr. F. J. Kerr and to Mr. B. Y. Mills of the Division of Radiophysics for useful discussions during the preparation of this paper.

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