GALACTIC RADIATION AT RADIO FREQUENCIES

VII. DISCRETE SOURCES WITH LARGE ANGULAR WIDTHS

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Summary

Observations with three forms of equipment have revealed the existence of a number of sources of angular width more than 1°.

A rough analysis of the brightness distribution of one source shows that it is elongated along a parallel of galactic latitude. This source appears to be typical of a class that is generally distributed around the galactic equator, and may represent fine structure in the distribution of radiation from the Galaxy.

Of the others, one appears to be associated with the abnormal galaxy NGC 5128, and another has been identified with a network of gaseous filaments in our own Galaxy.

I. Introduction

Up to the present time, surveys of the brightness distribution of galactic noise have been made using either a single aerial of low resolving power or an interferometer consisting of two aerials separated by many wavelengths. The observations have been mainly on metre wavelengths, for which the brightness is sufficiently high to permit measurements over a large part of the celestial sphere.

With such wavelengths, aerials of moderate physical dimensions have beam widths of the order of 10° between half-power points. The observed brightness distributions contain only such major features as the concentration towards the galactic plane with its principal maximum near the galactic centre, and subsidiary maxima in Cygnus and Taurus. The actual brightness distribution can, to some extent, be extracted mathematically from the observed distribution, given the aerial sensitivity pattern, but the manual procedure is most laborious and open to errors. Higher resolution due to the sharp-edged shadow of the Earth can be gained if observations are made with an aerial on a high cliff directed at the horizon.

With the interference techniques the aerial beam is split into a number of closely spaced fringes. As the source passes through the fringe system a sinusoidal pattern is recorded, whose features are determined by the angular distribution of brightness across the source. Most interferometers used so far have aerial spacings of about 50 wavelengths, giving fringe separations of about

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1°. The sources discovered with such systems have angular widths of a few minutes of arc. No appreciable interference pattern is obtained from a source whose angular diameter is of the order of the fringe separation.

No systematic search has yet been made for objects of intermediate size, although a number are known to exist. Mills (1952*a*) found evidence for three such sources from a survey made with two interferometers with different aerial spacings. An extended object in Cygnus has been studied by Brown and Hazard (1951*a*) at 158 Mc/s and by Piddington and Minnett (1952) at 1200 Mc/s.

The present paper describes a survey of the sky for sources whose angular widths are 1° or more. The principal equipment used was a two-aerial interferometer whose fringe spacing could be varied from 3 to 14°. The first observations with the smallest fringe spacings indicated the existence of a few sources which had not been detected with interferometers of fringe spacings of about 1°. If the sources had been sufficiently separated, it would have been possible to gain some idea of the brightness distribution across these sources by observing the amplitudes of the interference patterns at a number of fringe spacings. However, as the fringe spacing was progressively increased, the simple patterns of the smaller spacings gave place to extremely complex patterns, apparently the result of having more than one such source in the fringe pattern at a time. Such complex effects were observed whenever the plane of the Galaxy crossed the fringe system, and may perhaps be attributed to fine structure of the background. Only in relatively few cases has it been possible to suggest a specific interpretation of the observations.

II. Equipment Used in the Investigation of the Sources

Three types of equipment have been used to study the sources. These are a 72-ft diameter fixed reflector, a sea interferometer with automatic control of the receiver gain, and an azimuth interferometer. The last two have been described in a previous paper (Bolton and Slee 1953).

(*a*) *The 72-ft Reflector*

This reflector consists of ½ in. metal strips spaced 1 ft apart on the surface of a paraboloid of revolution, of focal length 40 ft and aperture 72 ft, with its axis vertical. The feed is a rod dipole and parasitic reflector. The aerial beam width is 6° at a frequency of 150 Mc/s and the beam can be directed by tilting the mast supporting the feed. This aerial has about the same ratio of focal length to aperture as the 220-ft reflector at Jodrell Bank, for which Brown and Hazard (1951*b*) found very little distortion in the beam for tilt angles of up to 15°. By tilting up to 15°, a survey was made of the strip of the celestial sphere between declinations −20 and −50° and Right Ascensions 14 and 22 hr ; this includes the galactic equator between longitudes 300 and 335°. The observations were made over a period of only a few months and electrical interference during the day-time prevented satisfactory observations of the other section of the galactic equator. The results of this survey, expressed in the form of contours of equal aerial temperature, are shown in Figure 1.

(*b*) *The Sea Interferometer with Automatic Control of the Receiver Gain*

The aerial of this equipment consists of a 6 by 2 array of Yagis, on an azimuth mounting erected on a 240-ft cliff overlooking the sea. It operates on a frequency of 110 Mc/s and the beam width in azimuth is about 10°. The beam width in altitude is also about 10° but the effect of the Earth's shadow at the horizon greatly improves the resolving power of the aerial, so that a faint source rising above the horizon produces a more marked change in the recorded output of the receiver than it would when crossing the free-space pattern of the aerial. The aerial with its image in the sea forms an interferometer and, if the angular width of a source is smaller than the fringe separation (1°), an interference pattern is observed.

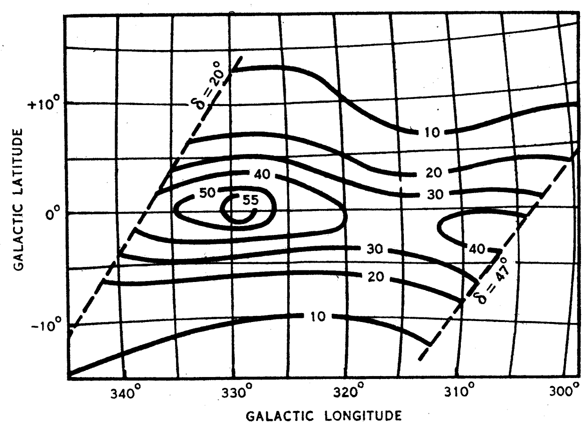

Fig. 1.—Contours of aerial temperature of the region about the galactic centre as seen on the 72-ft reflector at 160 Mc/s (aerial beam width 6° between half-power points). The units are not accurately known owing to uncertainty in the reflection coefficient of the aerial, but the contour interval is approximately 20 °K.

Normally, with the sea interferometer it is difficult to distinguish the effects of faint sources against the large, but slowly varying, changes in the output of the receiver as the regions near the galactic plane cross the aerial beam. However, with a receiver modification described by Bolton and Slee (1953) this disadvantage has been largely overcome. In this modification, which is a form of automatic gain control, the output of the receiver is fed into an integrator, the output of which is in turn used to control the gain of the input stages of the receiver. The result of this arrangement is to suppress almost entirely the slowly varying components in the receiver output. Sources of angular width less than the fringe spacing appear as an interference pattern, and those of angular width somewhat greater than the fringe spacing as a small " hump ", on the record. Such sources were roughly located by the sidereal time at which they first appeared, the estimated time at which they were fully risen, and a knowledge of the aerial diagram in azimuth.

(c) *The Azimuth Interferometer*

This equipment and some of its uses have been described in a previous paper (Bolton and Slee 1953). It consists of two aerials, whose spacing can be varied, on the top of a cliff overlooking the sea. The frequency used was 100 Mc/s. The aerial beam is split into a double system of interference fringes, due to the spacing of the two aerials and their images in the sea. The present observations were made with aerial spacings along the cliff top of between 4 and 20 wavelengths. The spacing between the aerials and their images was 50 wavelengths. Some of the observations were made with a stationary fringe system, and in others the fringe system was swung backwards and forwards through one fringe width per minute. The fringe swinging was found particularly useful with small aerial spacings where the movement of a source through the fringes, due to the Earth's rotation, is comparatively slow.

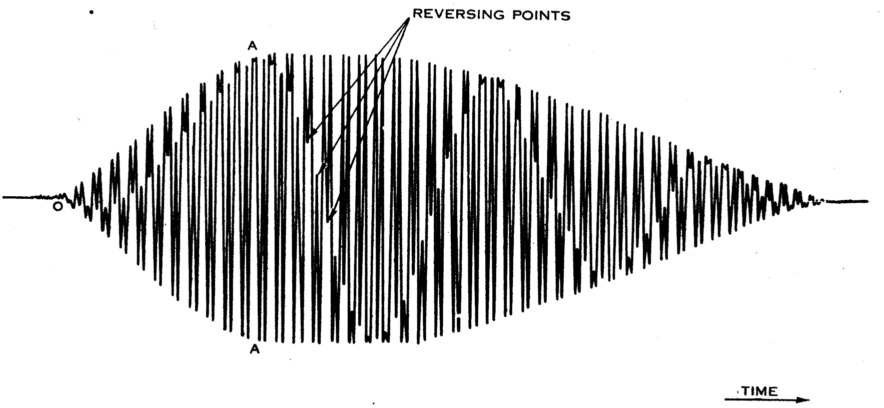

Fig. 2.—Idealized pattern due to an extended source rising above the horizon and through the fringe system of the azimuth interferometer. The fringe system is swung backwards and forwards through 1 fringe-width/min. The points at which the direction of the fringe swing is reversed can be clearly seen. From O to A the amplitude of the pattern increases as the source rises above the horizon, and then slowly decreases as the source passes out of the aerial beam. Due to phase switching of the aerials the pattern is distributed about a central zero line. Note also the change in the period of the pattern drawn by the reversing points; this is due to the motion of the instantaneous centre of the source during and after rising.

For sources whose angular widths in altitude exceed the separation of the sea-interference fringes, the effect of the azimuth fringe system only is observed. An idealized record with fringe swinging, due to such a source, is shown in Figure 2. The instantaneous amplitude of the pattern between the points marked O, when the source starts to appear above the horizon, and A, when it is fully risen, represents the total flux density from that part of the source above the horizon. The subsequent decrease in the amplitude of the pattern is due to the source passing out of the aerial beam. Apart from a small effect as the rising edge of the source enters the aerial beam, the envelope of the pattern from O to A gives the flux density per unit altitude from the source, along a line perpendicular to the horizon. The flux density per unit azimuth, along a line parallel to the horizon, can be deduced from the variation of the pattern amplitude with aerial spacing.

The points at which the fringe swing is reversed at each end of the cycle are clearly shown on Figure 2. The locus of these points represents one of the interference patterns that would be obtained with the stationary fringe system. The period of this pattern is due to the azimuth motion of the effective centre of the source and, ideally, it can be used to determine its declination. However, while the source is rising, the period of the locus is often different from that when it is fully above the horizon. This effect is due to the motion of the instantaneous centre of the visible part of the source. For a source rising

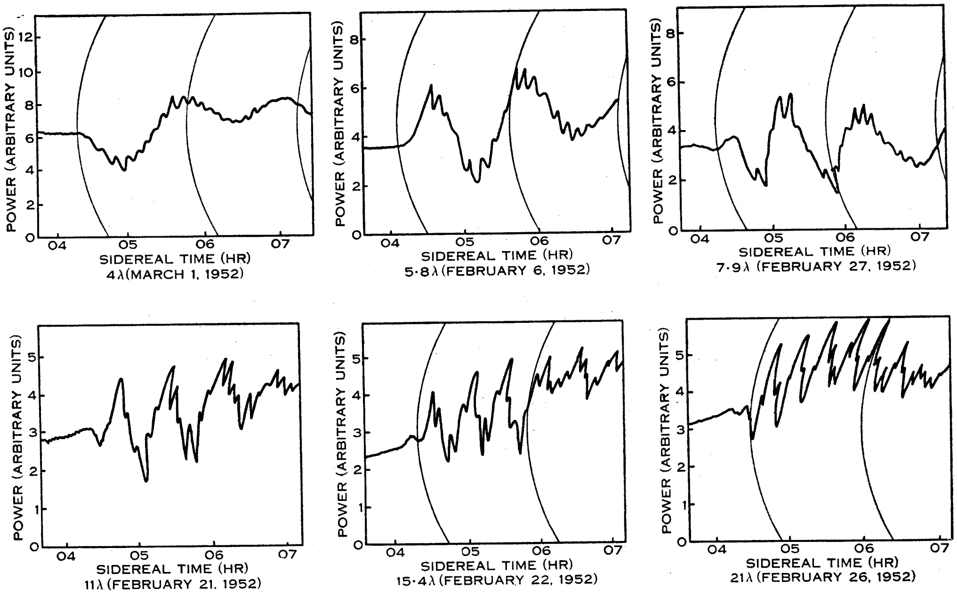

Fig. 3.—Records obtained with the azimuth interferometer (fixed fringes), at six different aerial spacings, of the point and extended sources in Centaurus. The rapid sinusoidal variation is due to the point source passing through the sea-interference fringes, the slower one to the azimuth fringe system. The amplitude of the sea-interference fringes due to the point source provides a calibration. Note that the amplitude of the azimuth pattern due to the extended source increases as the aerial spacing decreases (it is zero for a spacing of 21 wavelengths). The aerials were directed towards an azimuth of 40 ° E. of S.; the hour angle for a source on the horizon at this azimuth is approximately 08 hr 20 min.

with its central line vertical, the period of the locus does not change. In other cases the period of the locus during rising is shorter or longer than in the remainder of the record, according as the instantaneous centre moves north or south in azimuth relative to the azimuth of a fixed point on the celestial sphere. The change in period of the locus as the source rises would, in principle, enable the inclination of its central line to be determined.

III. Observations of the Sources

The existence of more than 20 sources has been inferred from the observations with the three aerial systems. Of these, one has been observed with all three equipments, three with two, but the majority with the azimuth interferometer only. The survey with the 72-ft reflector revealed only those with high flux density within the small region covered. With the sea interferometer and receiver with automatic gain control, sources whose dimensions in the vertical plane at rising are small compared with the aerial beam were discerned. Objects of angular width smaller than 2° could be studied satisfactorily using the azimuth interferometer at aerial spacings of more than 10 wavelengths. With this instrument, as the aerial spacing was reduced, the number of sources observed increased, but so also did the confusion due to the effects of more than

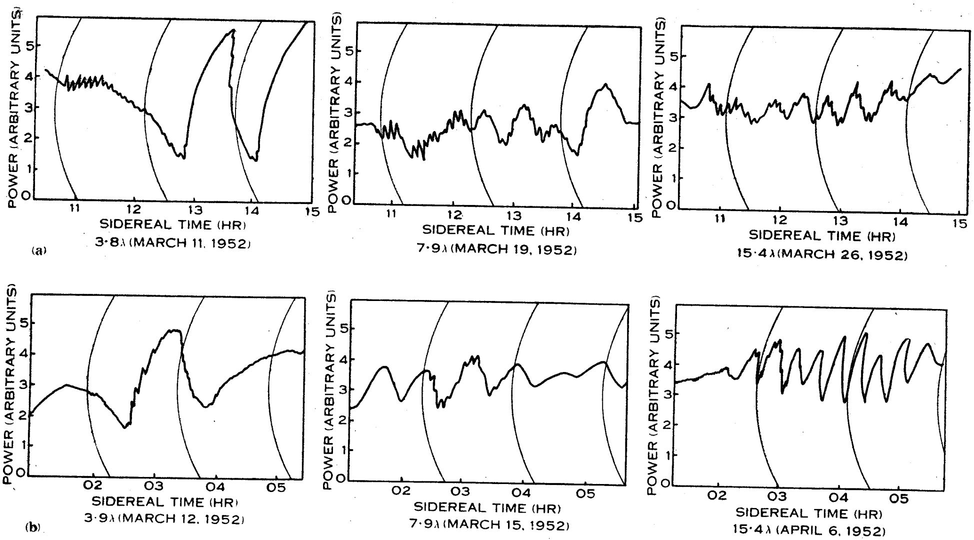

Fig. 4.—Records, illustrating the high degree of confusion of the effects due to a number of sources in the fringe system at the one time, obtained with the azimuth interferometer at three different aerial spacings. (*a*) A region close to the galactic plane. All records have the same scale of sensitivity, as can be seen from the amplitudes of the sea-interference patterns due to two point sources. The aerials were directed towards an azimuth of 110° ; the hour angle for a source on the horizon at this azimuth is approximately 05 hr 20 min. (*b*) A region well away from the galactic plane. All the records have the same scale of sensitivity, as can be seen from the amplitudes of the sea-interference patterns due to a point source. The aerials were directed towards an azimuth of 70° ; the hour angle for a source on the horizon at this azimuth is approximately 06 hr 40 min.

one source in the fringe system at a time. For aerial spacings of four wavelengths (fringe separation 15°) interference patterns were observed whenever the plane of the Galaxy crossed the fringe system.

A case where there is little confusion is illustrated in Figure 3 which shows records, obtained with the azimuth interferometer with a stationary fringe system, of an extended source surrounding the " point " source Centaurus–A. At the 21-wavelength spacing only the pattern due to the point source passing through the sea and azimuth fringe systems can be seen. At smaller spacings this pattern is superimposed on the azimuth pattern due to an extended source. The scales of these records are not all the same, but the pattern due to the point source provides a calibration. It can be seen that the amplitude of the pattern due to the extended source, relative to that of the point source, increases as the aerial spacing is decreased. The azimuth patterns due to the point and extended sources are in phase, suggesting that the two sources are concentric.

Figures 4 (*a*) and 4 (*b*) are records, obtained with the same equipment, showing cases with a high degree of confusion, in regions respectively close to and away from the galactic plane. It is not possible to say with any certainty where a source rises on these records. Both the amplitude and period of the pattern at any aerial spacing change in an irregular manner and there is no systematic change in the amplitudes of the patterns for different aerial spacings. Figure 5 is a 24-hr record obtained with the fringe-swinging system. It shows an almost continuous complex pattern due to many extended sources, and sea-interference patterns due to the point sources Taurus–A and Virgo–A.

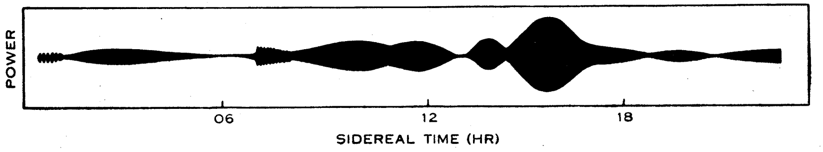

Fig. 5.—A 24-hr record obtained with the azimuth interferometer with the fringe-swinging system. The envelope is filled in by the rapid movement of the recorder pen as the fringe system is swung backwards and forwards. The complex effects due to a number of extended sources passing through the fringe system and the sea interference patterns of two point sources, Taurus–A and Virgo–A, can be seen. The aerials were directed towards an azimuth of 116° ; the hour angle for a source on the horizon at this azimuth is 05 hr.

No attempt has been made to sort out many of the sources from these complex patterns. The accuracy of the results would not warrant the labour involved and the observations must ultimately be superseded by surveys made with pencil-beam aerials.

In Table 1 are listed a number of sources which could be delineated without too much difficulty. The observations on these sources were such that the times of rising above the horizon could be confidently estimated and, with the azimuth interferometer, the changes in amplitude of the patterns with aerial spacing behaved in a regular manner. Table 1 includes the estimated positions, flux densities, and angular extents of the sources, and the equipments with which they were observed. Further details are given in the following notes.

Source A.—This source is clearly seen on the azimuth-interferometer records with aerial spacings less than 15 wavelengths, but its effects are obscured by confusion at smaller spacings. It appears to be the source Fornax–A (Stanley and Slee 1950) and the position given is a new determination from sea-interference measurements.* The declination agrees with that given by Mills (1952*b*) for this source, but the Right Ascension differs by 2 min from Mills's value, a discrepancy which cannot be resolved. Mills also considers that this source has

* These measurements will be reported in a later paper.

TABLE 1

LIST OF SOURCES

Source	Approximate Position of Apparent Centroid				Estimate of Flux Density at 100 Mc/s (Both Polarizations) (10^{-24} Wm^{-2} (c/s)$^{-1}$)	Estimate of Angular Size (To Approx. 20% of Central Brightness)	Equipment Used in Observations*	Remarks
	Celestial Coordinates (Epoch 1950)		Galactic Coordinates					
	R.A. (hr min)	Dec.	Longitude	Latitude				
A	03 17	—37¼°	206°	—56°	6	½—1°	Az.I	Probably source Fornax-A
B	04 36	20°	145°	—16°	20	10×5°	A.G.C.	Lies along a parallel of galactic latitude
C	05 10	—43½°	215°	—35°	15	1—2°	Az.I	Possibly source Pictor-A
D	05 42	0°	173°	—14°	15	10×5°	A.G.C.	Lies along a parallel of galactic latitude
E	08 20	—42¼°	227°	— 2°	15	1—2°	Az.I	Source Puppis-A
F	08 24	—44°	230°	— 2°	70	5°	72-ft reflector Az.I, A.G.C.	
G	09 15	—10°	210°	+27°	>10	—	Az.I	Position may be in error by several degrees
H	12 40	7°	270°	+69°	25	4°	Az.I	Position may be in error by several degrees
J	13 22	—43°	274°	+20°	50	2°	A.G.C. Az.I	Concentric with Centaurus-A
K	16 51	—45°	309°	— 2°	350	10×6°	Az.I 72-ft reflector	Lies along a parallel of galactic latitude
L	17 41	—27½°	329°	0°	⩾300	12×2°	Az.I 72-ft reflector	Lies along the galactic equator

* The azimuth interferometer is denoted by Az.I and the sea interferometer with automatic gain control by A.G.C.

an angular diameter of about ½°. The difference in the two values of the Right Ascension may be due to its angular extent, but no definite suggestion can be made as to a brightness distribution which would reconcile the two results.

Sources B and D.—These sources were seen only with the sea interferometer with automatic control of the receiver gain. They are objects of low surface brightness and rise with their central lines nearly parallel to the horizon and the galactic equator. The positions given may be in error by 1 or 2°. The sources were not observed with the azimuth interferometer, presumably because of their extent in azimuth.

Source C.—This source is clearly seen with the azimuth interferometer with aerial spacings greater than 15 wavelengths, but its effects are obscured by confusion at smaller spacings. It may be associated with the source Pictor–A (Stanley and Slee 1950).

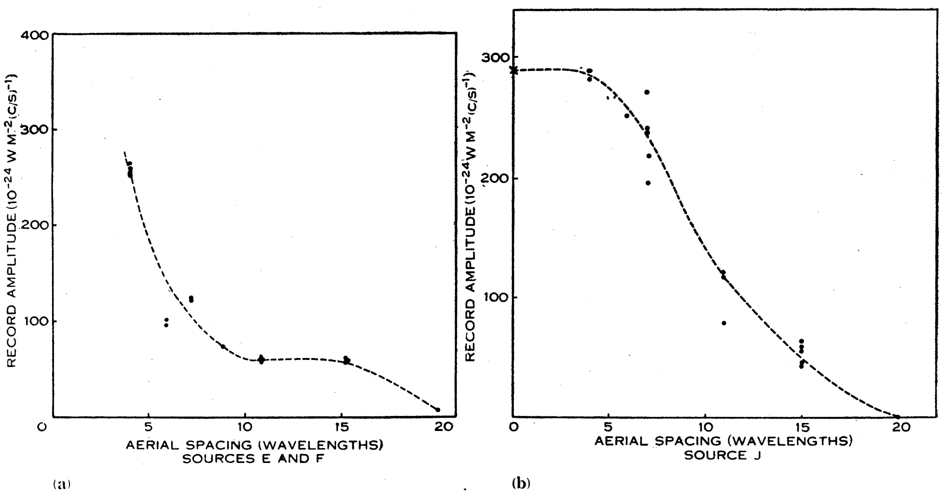

Fig. 6.—Curves showing the variation of the amplitudes of the azimuth-interferometer patterns with aerial spacing. (*a*) Sources E and F. The effects of source F begin to show for aerial spacings of less than 10 wavelengths. (*b*) Source J.

Sources E and F.—The observations with the azimuth interferometer in this region were very good. The variations of the amplitude of the interference patterns with aerial spacing are shown in Figure 6 (*a*). It is believed that for spacings greater than 10 wavelengths the curve is due to source E alone and, at smaller spacings, to the two sources. The position of the centre of source F is difficult to estimate, but from observations with the sea interferometer it appears to be slightly south of E, which is the source Puppis–A (Stanley and Slee 1950). The position of the latter is a new determination.* It disagrees with the position published by Mills (1952*a*, source 08 –4) but Mills has informed the authors (personal communication) that his results on this source are ambiguous and that an alternative interpretation would agree with the present results.

* These measurements will be reported in a later paper.

Sources G and H.—These sources are clearly seen with the azimuth interferometer with aerial spacings between 8 and 15 wavelengths but their effects are lost in confusion at smaller spacings. The positions may be in error by several degrees.

Source J.—The azimuth interferometer results in the region of this source are very good and clear of confusion for aerial spacings of more than five wavelengths. The amplitudes of the patterns for various aerial spacings are shown in Figure 6 (*b*), the value at zero spacing being a direct observation with the sea interferometer. This source overlaps the source Centaurus–A, which has been identified with the galaxy NGC 5128 (Bolton, Stanley, and Slee 1949).

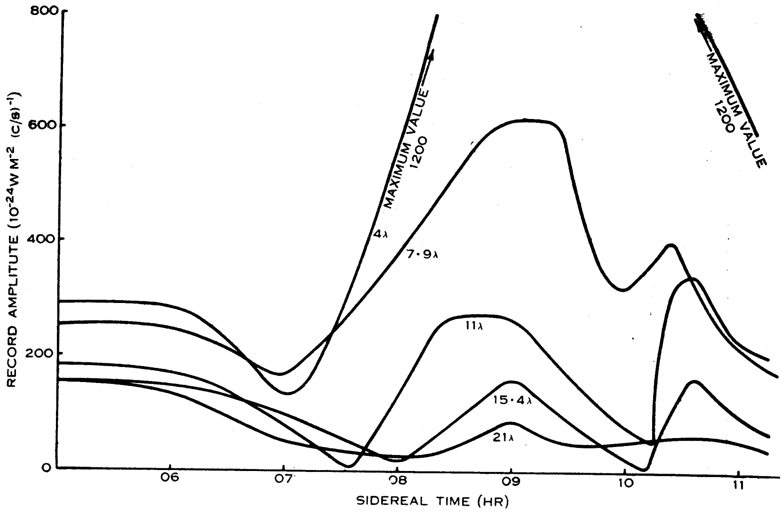

Fig. 7.—Variation in amplitude of the azimuth-interferometer patterns for five aerial spacings. The aerials were directed towards an azimuth of 40° ; the hour angle for a source on the horizon at this azimuth is approximately 08 hr 20 min.

Source K.—This is the second brightest of the extended sources observed. It appears in the contours of the 150 Mc/s survey and is clearly observed at all aerial spacings with the azimuth interferometer. The observations indicate that it rises with its central line nearly vertical, along the parallel of galactic latitude $b = -2°$. It is therefore particularly suitable for analysis of its brightness distribution.

As the source rises, the variation in amplitude of the azimuth-interferometer pattern, for any spacing, determines the distribution along its length of flux density per unit galactic longitude. In the present circumstances, it is approximately given by the rate of change of amplitude with altitude of the leading edge of the source. In Figure 7, the amplitude due to the sources J, K, and L is plotted against sidereal time. At 07 hr, J is passing out of the aerial beam and K is rising into it ; at 10 hr, K is passing out of the beam and L is rising into it ; at 09 hr, K is fully risen and is making practically the full contribution to the power received. In the interval between about 07 hr 30 min and

08 hr 30 min the curves are almost rectilinear. Thus, for a rough analysis, we may consider the flux density per unit galactic longitude of the source K to be uniform over its extent of approximately 10°.

When fully risen, the variation in amplitude with aerial spacing enables the flux density per unit galactic latitude, in the transverse direction, to be determined by Fourier analysis similar to that used by Stanier for the Sun (see Ryle 1950). Figure 8 (*a*) is a plot of amplitude against the parameter $2\pi s/\lambda$, where s is the spacing and λ the wavelength ; the curve is extrapolated to meet the amplitude axis at right angles. The derived distribution, assumed symmetrical about the central line, is given in Figure 8 (*b*). The effect of adopting a higher value for the amplitude at $s=0$ would be to raise all the values of flux density per unit latitude, and thus enhance the " skirt " of the distribution.

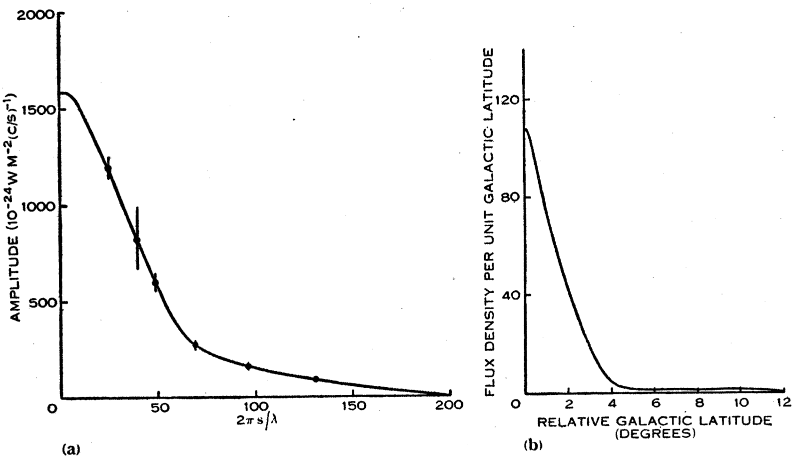

Fig. 8 (*a*).—Curve representing amplitude as a function of $2\pi s/\lambda$ for the source K. Experimental points are shown as dots, with vertical lines denoting the estimated probable errors. (These decrease with increasing s/λ.) The value at $s=0$ is obtained by extrapolation.

Fig. 8 (*b*).—The flux density per unit galactic latitude across the source K. Latitude is measured from the central line $b=-2°$. The estimated extent of the source in galactic longitude is 10°, giving a maximum brightness temperature of 12,000 °K.

However, it is possible that the values of amplitude for the smaller spacings are too high because of contributions from the background. If the background distribution is not symmetrical about $b=-2°$, it will have the effect of broadening the apparent distribution in latitude of the source. Taking the extent in longitude as 10°, we obtain 12,000 °K. for the mean brightness temperature along the central line of the source.

Source L.—This source, in the region of the galactic centre, is the brightest of the extended sources. Observations with the azimuth interferometer show that it has a strong central concentration, as interference patterns are obtained with the largest aerial spacings (fringe separation 3°). It is not easy to make an analysis of the azimuth-interferometer results as the patterns of this source overlap with those of source K and also the inclination of its axis is unfavourable.

Some idea of its shape may be gained from the results of the 150 Mc/s survey in this region, although the 6° beam of the aerial cannot resolve all the detail.

Observations of the brightest sources K and L were also made with simple azimuth interferometers consisting of two single-Yagi aerials at 100 and 160 Mc/s. It was observed that the ratio of the amplitudes of the interference patterns to the total background noise received by the aerials was approximately the same on the two frequencies, at each of three fringe separations (3, 7, and 14°). These observations suggest that in this frequency range the spectra of the sources are the same as that of the background radiation in their neighbourhoods.

IV. Discussion

The observations described in this paper have revealed the existence of a large number of objects having angular widths of 1° or more. Some of these, for example, sources B, D, K, and L, which are elongated along parallels of galactic latitude, may represent fine structure in the distribution of the background radiation ; the remainder appear to form no one distinct physical class. However, sources E and J are of particular interest.

Source E, Puppis–A (08 hr 20 min, −42° 15′).—The new determination of position and observation of angular width have led to the identification of this source by Baade and Minkowski (personal communication) with a network of gaseous filaments similar to that which coincides with the Cassiopeia source. The filaments are in an area 1·25 by 0·75°, position angle 135°, centred at 08 hr 20 min, −42° 48′. The radio position is slightly different, but this was determined from sea-interference measurements, which refer to a bright concentration rather than the optical centre. Moreover, this position coincides with the most outstanding filament. The filaments show no sign of organized motion, but the velocity dispersion within individual filaments ranges from +120 to −30 km/sec. This is the second of a new type of galactic nebulosity discovered through radio observations. The velocity dispersion in the filaments of this source is only about one-tenth, its brightness about one-fifth, but its angular diameter is about 10 times that of the Cassiopeia source. The identification provides another example of a high ratio of radio to optical emission, associated with a violent gas velocity dispersion.

Source J (13 hr 22 min, −43°).—The angular diameter of this source is about 2½°. It overlaps the source Centaurus–A, which has been identified with the galaxy NGC 5128. Centaurus–A is known to have an angular diameter of less than 7′ (Stanley and Slee 1950 ; Mills 1952*c*), which is less than the visible extent of the galaxy. It is possible that the small source is associated with the nucleus of the galaxy and the extended object with its outer regions. It would be a remarkable coincidence if these two bright sources had no physical connection.

Of the sources that may be associated with galactic structure, K and L are deserving of further comment.

Source K (16 hr 51 min, −45°).—Observations of this source provide the best example of the type of pattern observed whenever the plane of the Galaxy crosses the fringe system of the azimuth interferometer. It is inferred that there is a general distribution of similar objects around the galactic plane, which may prove to be fine structure of the background radiation. The analysis of the flux density per unit galactic latitude across source K then indicates a far greater concentration about the plane of the Galaxy than has hitherto been inferred. The half-width deduced from Bolton and Westfold's (1950) 100 Mc/s survey with a low-resolution aerial was 15°, which gave rise to the supposition that the sources of the background radiation were distributed in a manner similar to the stars of Population II. The present value of 3° (see Fig. 8 (*b*)) is rather to be associated with the objects of Population I, such as early-type stars and interstellar gas and dust. It is possible that the background radiation originates in the interstellar gas, although it is generally agreed that some non-thermal process must be responsible.

Source L (17 hr 41 min, $-27\frac{1}{2}°$).—The observations indicate that this source provides the greatest flux density and has the most peaked brightness distribution in both longitude and latitude of all the extended sources. The position of its centre is close to the accepted position of the galactic centre.

It is difficult to believe that its high flux density is due to the fortuitous superposition of radiation from a number of objects in the line of sight. We are left with the inference that there is an extended physical object at the centre of the Galaxy, which is an unusually intense source of radio noise.

V. Limitations of Interference Techniques

The extended sources have been found by the use of interferometers of much smaller aerial spacing, that is, much greater fringe separation, than normally employed. They were not previously discovered in surveys of the general background because of the low resolving powers of the aerial systems used, and, in spite of their high flux densities, were not observed with other interferometers because the fringe separations of those instruments were less than the angular dimensions of the sources. Although the present observations have been of some value, they have also served to emphasize some of the fundamental limitations of interference techniques.

It has been claimed that an interferometer has a resolving power equal to that of a single aerial whose physical dimensions in one direction are equal to the spacing between the individual aerials forming the interferometer. This resolving power can, however, only be realized in the study of a single isolated object. An interferometer consisting of two aerials has a theoretical resolving power determined only by the ratio of the wavelength and the aerial spacing, but in practice it is more often limited by the width of the primary beam of the individual aerial and the distribution of the sources whose angular dimensions are less than the fringe separation within that primary beam.

A source may be regarded as *effectively isolated* under certain circumstances, e.g. when its flux density far exceeds that of any other source within the primary aerial beam; examples are the Sun at centimetre wavelengths and the bright sources in Cygnus and Cassiopeia at short metre wavelengths when the primary aerial beam is fairly small. Two other factors tend to isolate sources in the case of interferometers with very narrow fringe separations; firstly, the instrumental effect of a finite receiver bandwidth reduces the visibility of high-order (off-axis) fringes and so effectively decreases the primary beam of the aerial, helping to isolate a source; secondly, as the fringe separation is reduced below the angular dimensions of most of the sources within the beam, these no longer contribute to the output and leave one source effectively isolated.

Under normal conditions, where there is no isolation, the output of the interferometer represents the sum of the effects of a distribution of sources within the primary beam. If the sources can be considered as widely separated points, the actual distribution can be reconstituted from the observed patterns, provided observations are taken with a number of fringe separations and a number of different interferometer axes. Such reconstitution presents far greater difficulty where the individual sources cannot be considered as points, that is, when their angular dimensions are of the order of the fringe separation and their isophotes are of irregular shape.

The observations described in this paper have shown that the actual distribution of the extended sources is too complex to be delineated by interferometers of moderate primary beam width, since in general there are several of them in the primary aerial beam at a time. It might be argued that some improvement could be gained by reducing the beam width of the individual aerials. This, however, has the effect of reducing the already small number of fringes within the primary beam and, although it might reduce the confusion between a number of sources in the beam at one time, it also introduces the complication of a change in shape from one fringe to the next within the primary beam. It is clear that a detailed study of the extended sources can be made satisfactorily only with pencil-beam aerials whose beam widths are less than the angular dimensions of the sources.

VI. References

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