A PENCIL-BEAM SURVEY OF THE GALACTIC PLANE AT 3·5 M

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Summary

A survey has been made of the galactic plane region from $l=223°$ through the galactic centre to $l=13°$ between $b=+4°$ and $-6°$ using the 3·5 m wavelength cross-type aerial (beamwidth 50 min of arc) near Sydney. Contour diagrams of brightness temperature have been prepared. The preparation of contours is described in detail, and a detailed discussion of the accuracy of the temperatures is given.

I. Introduction

In an effort to understand the origin of radio-frequency radiation emitted by the Galaxy, numerous surveys of the sky have been carried out in the past at various frequencies. Until 1954, however, there were no aerials operating at metre wavelengths capable of matching the angular resolution obtainable at centimetre wavelengths. The great physical size required of conventional-type aerials made it impracticable to obtain a steerable pencil beam for work at long wavelengths.

That there were features of interest in the distribution of radiation at long wavelengths, especially near the galactic plane, was made quite evident by the interferometer investigations by Scheuer and Ryle (1953) at 1·4 and 3·7 m, and by Bolton *et al.* (1954) at 3 m. The former were able to show the presence of intense radiation originating within a degree or so of the galactic plane, but no decision could be made as to how this radiation was distributed along the plane since the resolution of the aerial in this direction was low. The work of Bolton *et al.* clarified the situation somewhat in that it showed that there were regions of emission closely confined to, and elongated along, the galactic plane. These features were irretrievably lost in the lower resolution surveys.

The investigations noted above indicated, furthermore, that the most satisfactory method of examining the expected complicated distribution of radiation in the vicinity of the galactic plane is by the use of a pencil beam of width preferably less than 1°. That such resolution could be obtained at metre wavelengths by means of a cross-type aerial system was shown by Mills and Little (1953).

The purpose of the present communication is to describe the construction of brightness contours in a strip along a considerable length of the galactic plane using observational material obtained with the 3·5 m cross-type aerial situated at Fleurs, near Sydney. This aerial, which has a beamwidth of 50 min of arc, has been described together with its associated equipment by Mills, Little, *et al.*

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(1958). As this paper will be referred to frequently in the course of subsequent discussion, it will be called paper I.

With such an instrument, detailed comparison between high and low frequency surveys, which had hitherto been restricted to the less complex regions away from the galactic plane and cooler regions near the anticentre, may now be extended right into the galactic plane. A brief preliminary discussion of the more interesting astronomical implications of the present high resolution survey has been given by Mills, Hill, and Slee (1958). More detailed analyses of these and other aspects are now in progress.

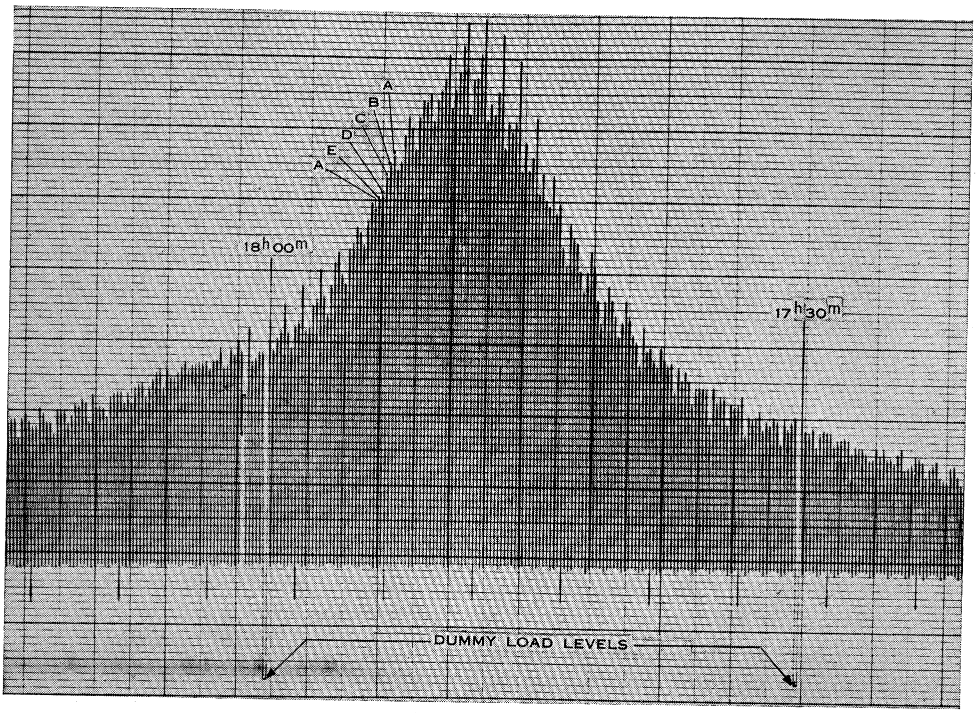


Fig. 1.—A record of the scanning type, described in paper I, used in the reductions of the present survey. This sample covers a period of nearly 1 hr when the beam crosses the galactic plane near $l=330°$. The beam position is *N6* ($\delta=-26°\,30'$) and the record was made on July 4, 1956. The two levels near the base of the record and immediately following the time marks are dummy-load levels. Several deflections indicating temperatures on different subpositions have been marked.

II. Scanning Observations with the 3·5 m "Cross"

For the purpose of the survey, the aerial is used as a meridian transit instrument, so that material is collected from scans across the galactic plane. On each scan the aerial is switched electrically in a time interval of 1 min between five declinations spaced approximately 20 min of arc apart. The individual declination settings of each scan have been denoted by the letters *A*, *B*, *C*, *D*, and *E*, which we shall call subpositions. The declination of the *C* subposition defines the scan, or beam position, *A* and *E* being respectively the most southerly and northerly subpositions.

The range of declinations available to the aerial (from $\delta = +10° 25'$ to $-78° 7'$, corresponding to zenith distances from $+44° 16'$ to $-44° 16'$) is divided into 60 beam positions, 30 on each side of the zenith, labelled *N1* to *N30*, *S1* to *S30*. The zenith angle of each beam position is defined by equation (**28**) in paper I. These beam positions are arranged so that the *A* subposition of any beam position has the same declination as the *E* subposition of the next beam position to the south. This overlap in declination is useful for relating the calibrations of the individual beam positions, and, as noted later, allows the asymmetry in the aerial beam on these subpositions to be removed merely by averaging the two sets of temperatures observed on the adjacent beam positions at these declinations.

With the scanning system in operation, the recorder provides what is called a scanning record. A typical example of such a record during the transit of portion of the galactic plane through the aerial beam is shown in Figure 1. As described in paper I, the length of each sawtooth on the record represents the pencil-beam output at a particular declination and Right Ascension. The temperature of the north-south array, which must be added to the pencil-beam temperature to give brightness temperatures, is given by the deflection between the dummy load levels, two of which appear in Figure 1, and the base of the sawtooth pattern.

III. Instrumental Effects

Prior to describing the survey it will be advantageous to examine some features of the aerial and receiving systems in so far as they influence the interpretation and reduction of records. We consider firstly the aerial directivity effects.

(*a*) *The Aerial Directivity*

A qualitative plan-picture of the aerial pattern when the aerial is switched to a *C* subposition is shown in Figure 2 (*a*). It consists of a central pencil beam, the filled circle, around which is situated the side-lobe pattern. The largest side lobes are to be found distributed along the meridian plane which corresponds to the direction of the fan beam of the east-west array. Here the side lobes, except for several adjacent to the pencil beam, are randomly distributed and their responses average about 2 per cent. of the pencil-beam response. Another important group of side lobes lies along a small circle on the sky about an axis formed by the north-south arm of the cross. This small circle intersects the meridian plane at the declination of the pencil beam, and corresponds to the fan beam of the north-south array. The side-lobe structure here is similar to that on the meridian, but the average response is only about 0·5 per cent. of the pencil-beam response. These two groups of side lobes we call the primary side-lobe pattern, and they are represented by the shaded area in Figure 2 (*a*). The remainder of the diagram is covered by a random distribution of side lobes, whose responses are less than 0·02 per cent. of the pencil-beam response. These side lobes are too small to be of any consequence.

Since we are using a receiving system which is sensitive to the relative phases of the outputs from the two arms of the cross, side lobes will produce recorder deflections which are of the same or opposite sign as that due to a radio source in the pencil beam. These are called positive and negative side lobes respectively. Randomness in the side-lobe structure arises because there are small departures from the nominal current amplitude and phase distribution along the arrays. However, the innermost primary side lobes are not of a random nature, but depend largely on the current distribution along the array.

As described in paper I, additional side lobes are introduced along the meridian plane when the beam is directed to the A, B, D, and E subpositions. These side lobes arise because displacement of the beam is effected by adjusting the phases of the north-south array dipoles in banks rather than individually; they are called switching side lobes. Near the pencil beam, these side lobes are spaced at intervals of $2^\circ{\cdot}3$ for B and D subpositions, and several such side lobes

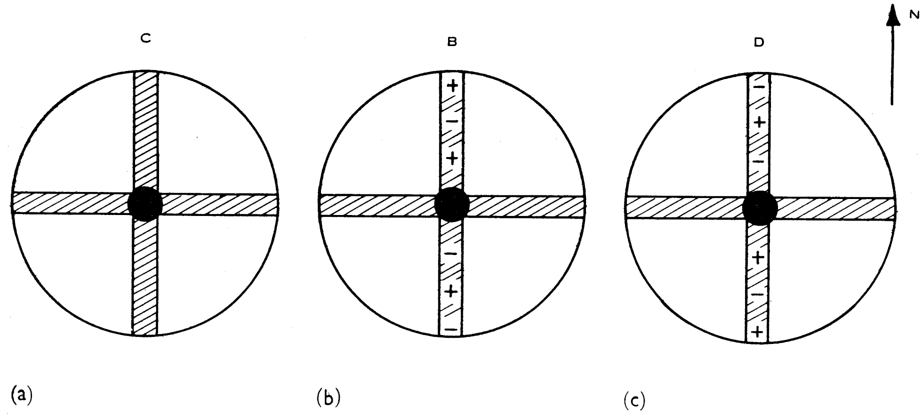


Fig. 2.—Pictorial representations of the aerial patterns of the "cross" on beam subpositions C, B, and D are shown in (a), (b), and (c) respectively. The central circle in each instance represents the pencil beam, whilst the shaded regions in the north-south and east-west directions represent the primary side-lobe pattern. The secondary side-lobe pattern fills the four unshaded sectors in each pattern. For the B and D positions, the positions and phases of switching side lobes are indicated qualitatively by the $\pm$ signs.

in the neighbourhood of the pencil beam are shown in Figures 2 (b) and 2 (c) by $+$ and $-$ signs, which indicate the phases of the side lobes. Responses of switching side lobes diminish rapidly on either side of the pencil beam; the two innermost side lobes on each side of the pencil beam have relative responses 15 and 7 per cent. and provide the most important spurious contributions to brightness temperatures. Aerial patterns for A and E subpositions are similar to those of B and D subpositions, the chief difference being that near the pencil beam the switching side-lobe spacing is about $4^\circ{\cdot}6$.

Switching side-lobe effects are present on all subpositions, except C, whenever the side lobes straddle an area of the sky in which there is a temperature gradient. They are therefore particularly noticeable in the region of the galactic plane. However, due to the fact that A and E subpositions overlap, and, further, that on these positions the switching side-lobe patterns are mirror images of one another, the average of A and E temperatures should contain no trace of their

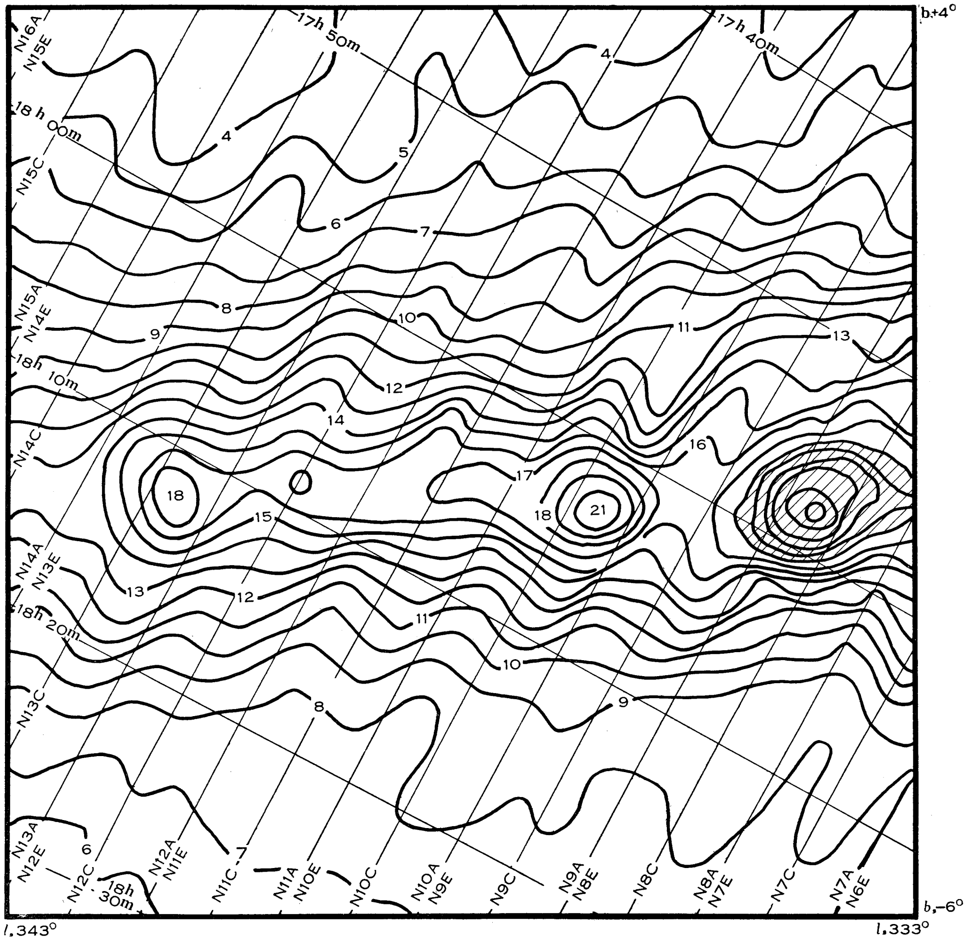


Fig. 3 (*a*).—Contours of brightness temperature for the strip $l=333$ to 343° before removal of beam asymmetry effects. The network of lines across the chart is the Right Ascension and declination grid, the latter being denoted by the beam subposition ; lines marking declinations of *B* and *D* subpositions have been omitted. The contour interval is 1000 °K except in the shaded region, where it is 2000 °K.

effects. On the other hand, all *B* and *D* temperatures require individual corrections on this account. Switching side-lobe effects, which we call asymmetry effects, produce a waviness in the contours as shown in Figure 3 (*a*) for the $l=333°$ to 343°, $b=+4°$ to $-6°$ region. This figure also illustrates the contour distortion effects of a strong source lying in switching side lobes. In the neighbourhood of R.A. $17^{h}\ 58^{m}$ on beam position *N12B*, the effect of source 17–2A (Mills 1952) in one of the 7 per cent. switching side lobes is seen clearly ; stronger spurious responses of the same nature due to this source are seen on *N10 B* and *D* at the same Right Ascension, where it lies in a 15 per cent. switching side lobe. Contours of the same strip of the Galaxy, after correction for beam asymmetry, are shown in Figure 3 (*b*).

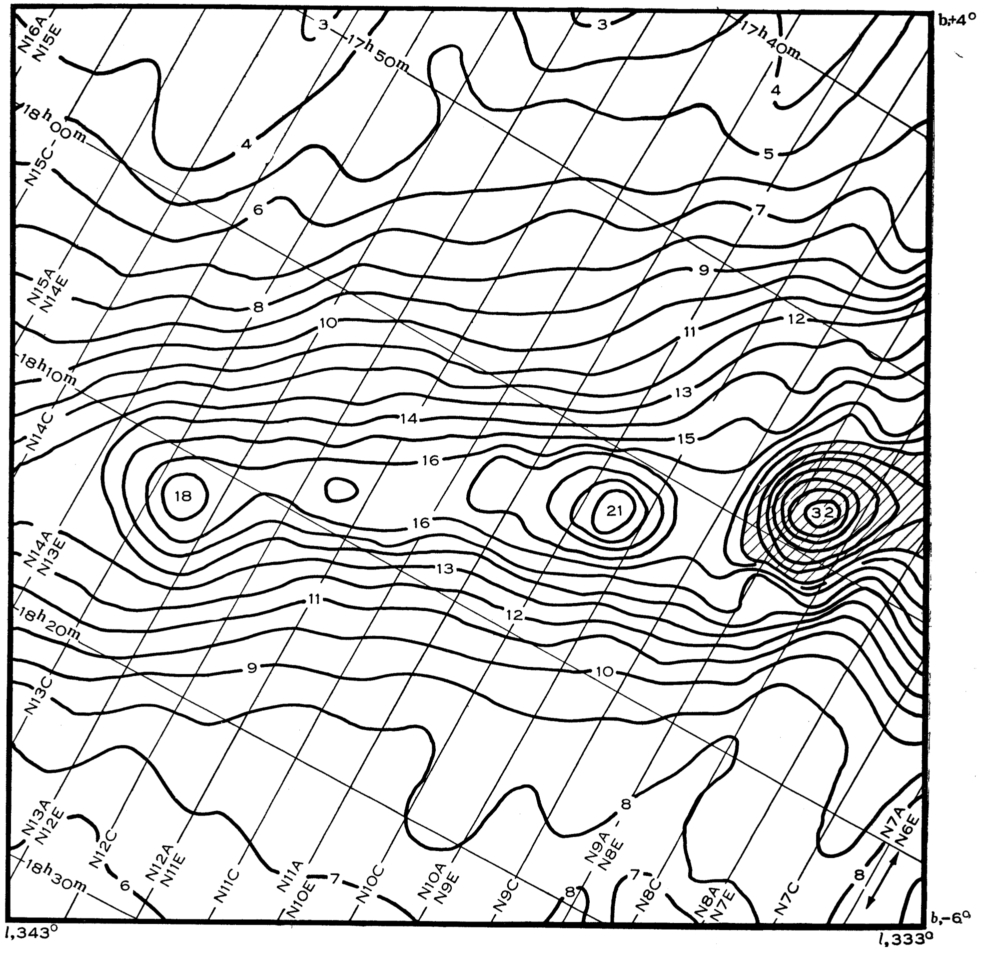


Fig. 3 (*b*).—Contours of brightness temperature for the strip l=333 to 343° after removal of beam asymmetry effects. Network and contour intervals as in Figure 3 (*a*).

For the determination of the switching side-lobe pattern, the reader is referred to paper I. There, it was shown that adequate corrections to B and D subposition temperatures are given by

$$\Delta T_{nB}=0\cdot 13(T_{(n-2)C}-T_{(n+2)E})-0\cdot 06(T_{(n-4)D}-T_{(n+3)D}),$$
$$\Delta T_{nD}=0\cdot 13(T_{(n+2)E}-T_{(n-2)E})-0\cdot 06(T_{(n+4)B}-T_{(n-3)B}),$$

where suffixes nB and nD are the subpositions of beam position n at which temperatures are being corrected.

Finally, a strong source in one of the primary side lobes may affect brightness temperature measurements. The most serious of such effects is due to the intense central source of I.A.U. 13S4A (Centaurus-A) when it lies on the meridian. Adopting the average relative response of these side lobes, ±2 per cent., this source could produce a modification of ±1100 °K to the real brightness temperature. Other bright sources in the field of the aerial could only produce effects up to ±300 °K. Since the amplitudes and phases of the currents in the individual dipoles are not known sufficiently well to determine the side-lobe pattern, it is not possible to correct for these influences on measured temperatures. We will have cause to consider this effect in discussion of the contours (Section V).

(*b*) *Calibration Changes*

We have considered effects arising as the result of the reception of radiation in unwanted directions. The remaining instrumental effects are those related to variations in sensitivity or zero level as functions of time or beam position.

In order to obtain the brightness temperature of any region of the sky it is necessary, as described in paper I, to include a temperature derived from the north-south arm of the cross alone. But, as the aerial is switched between the five subpositions, small changes occur in the impedance presented by the north-south array to its receiver; their most serious effect is to cause changes in the zero level of the power output. Variations of this kind are responsible in part for the slightly irregular heights of the lower ends of the scans in Figure 1. When the north-south beam is directed close to the zenith the impedance changes become very marked because, as discussed in paper I, the standing-wave ratio along the feed line becomes high and needs special arrangements for cancellation; the degree of cancellation varies between different subpositions. For the two beam positions closest to the zenith (*S1* and *N1*), variations in zero level of up to 600 °K occur. Distortion in the contours arising in this manner have been neglected in the present survey. Since the brightness temperature always exceeds 5000 °K when the impedance changes are largest, the maximum possible error in the temperatures of two adjacent subpositions of the beam due to this cause is about 10 per cent., and over most of the area surveyed the error is very much less.

Absolute temperature measurements depend also on the stability of the receiver gain, which may be studied by means of the record calibration measurements. Although the calibration of the temperature scales was performed only at the beginning and end of each day's recording, lasting on the average 17 hr, a continuous check could be kept on the zero of the temperature scale by noting the variation of the dummy-load levels at half-hourly intervals. A study of the calibrations and dummy-load levels showed that the average change in sensitivity over this time interval was approximately 6 per cent., the change being essentially of a systematic nature. Hence we may conclude that the maximum receiver calibration error is unlikely to exceed 6 per cent. and, by making use of linear interpolations, this error was probably substantially reduced.

For the galactic plane studies a considerable amount of observational data was accumulated over the period from October 1955 to November 1956. In this interval two series of observations from beam positions *N30* to *S30* were carried out, yielding, after records free of obvious solar interference had been sorted out, one complete and another almost complete set of observations over the 60 beam positions. In each series the procedure was to observe firstly beam positions *N1* to *N30*, in that order, followed by adjustments to the arrays, if necessary, after which observations were continued with southern beam positions *S1* to *S30*.

The lengthy period of observation has meant that consideration has to be given to the magnitude of long-term changes in the calibration. An estimate of such changes alone has not been attempted, but intercomparison of temperatures from duplicate records of the same beam position has been used to estimate the combined effects of short- and long-term changes. A detailed description of these investigations would be too tedious to give here, but the nature of the considerations involved will be indicated.

The comparison of the first and second series of observations has been restricted to the high temperature ridge lying near the galactic plane, principally because it is in this interesting region that an estimate of precision is most desirable. Therefore, for each record the average pencil-beam and north-south temperatures from the five consecutive beam subpositions giving the largest average brightness temperature were computed. The ratio of the average pencil-beam temperatures, and average north-south temperatures were then deduced from the two records generally available for each beam position.* Plots of these ratios are shown in Figures 4 (*a*) and 4 (*b*) as a function of beam position and the galactic longitude of the region where temperatures were measured. For some beam positions these figures indicate two ratios—in these instances the open circles identify the ratios with which we are concerned at present.†

Adopting the average of the two mean temperatures for each component as the basis for comparison of the two series of observations, it is found that the average deviation of the temperatures, both pencil-beam and north-south, is 5 per cent. The largest deviation is 15 per cent. This would indicate that averages of brightness temperature available for the area surveyed constitute a satisfactory combination of available observations. However, it was considered that a better compromise could be obtained near the galactic ridge by applying corrections to pencil-beam calibrations corresponding to points of Figure 4 (*a*) showing relatively large deviations. By so doing, it was hoped that the considerable fine structure apparent along and near the ridge-line would be defined more accurately. It should be noted that no weight was given to the north-south temperature ratios in deciding at what beam positions calibration adjustments were necessary, since the north-south contribution to the brightness temperature at the ridge is relatively small.

Closer scrutiny was therefore given to the original records showing the most serious discrepancies between the two measurements, namely, beam positions *N10* and *S1* to *S12*, and to their neighbouring beam positions. Since the pencil-beam temperatures for galactic crossings on *S13* to *S21* between galactic

* Since there were no records among the second series of observations covering the galactic crossings around $l=270$ to $295°$ on beam positions *S16* to *S20*, there are no temperature ratios in this range of longitudes.

† The fact that the more southerly declination circles cross the strip of the galactic plane with which we are concerned on two occasions explains the two sets of ratios possible for the more southerly beam positions.

longitudes 240 and 265° are for the most part too low to be corrected reliably, no attempt was made to modify their calibrations. By examining particularly the peak pencil-beam temperatures on the overlapping *A* and *E* subpositions in the vicinity of *S1* to *S12* it was found that much better continuity prevailed amongst the first series of observations on *N1A-S1E*, and *S12A* and *S13E* overlaps. Thus the systematic difference apparent on Figure 4 (*a*) appears to be due to some, as yet untraced, effect which caused the second series of temperatures on *S1* to *S12* to be about 20 per cent. too low. This disagreement has been removed by adding 20 per cent. to all the second survey pencil-beam and north-south temperatures on these beam positions—the latter temperatures being

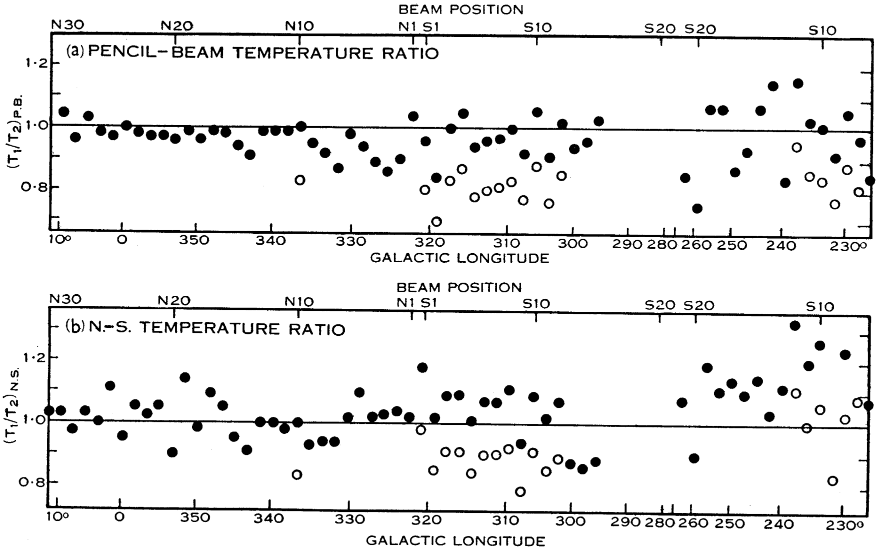


Fig. 4.—These diagrams depict the comparison of temperatures on the galactic ridge from the two observations available for nearly every beam position. (*a*) shows the ratio of the second to the first series of pencil-beam temperatures, (*b*) shows the similar ratio for the north-south temperatures. On beam positions *N10* and *S1* to *S12*, where calibration adjustments were made, the filled circles are based on the adjusted temperatures. Temperature ratios on these 13 beam positions, prior to calibration modifications, are shown by open circles.

included only because it was more convenient to correct total brightness temperatures than the pencil-beam contribution alone. The beam position *N10* was similarly treated—in this instance it was found that the first series of measurements was discordant. For all these 13 beam positions the ratio of second to first series observations, after the corrections just considered, have been indicated by the dots. It will be noted that in applying the corrections to north-south temperatures, the agreement between the two measurements for *N10* and *S1* to *S12* (from l=300 to 320°) has been improved. On the *S1* to *S12* (l=227 to 238°) crossings the agreement between the two series of north-south temperatures has deteriorated. This is not considered serious, since the average north-south temperature is only about 1500 °K.

To summarize, it has been found that for all beam positions, other than *N10* and *S1* to *S12*, an average of the two sets of observations is quite adequate. On the remaining 13 beam positions, for which agreement between our two series of measurements was not quite so good, appropriate corrections have been made to measurements of one series or the other to produce more suitable averages of the observations.

As a result of these corrections the average uncertainty in the relative brightness temperatures combined in the above manner should be less than 5 per cent. However, in respect to the absolute accuracy of brightness temperatures, the accuracy of the aerial gain measurements must be considered. Little (1958) considers that the uncertainty in the aerial gain is 10 per cent.; this means that the absolute accuracy of the survey temperatures would be somewhat better than 15 per cent.

Finally, it might be mentioned that, although the investigations outlined above have been restricted to the neighbourhood of the galactic ridge, the conclusions regarding the accuracy of brightness temperatures will apply all over the area of sky considered. The principal reason for this is that for the most part the aerial scans across the galactic plane region between $b=+4$ and $-6°$ in so short a time that there is little chance of significant variation from the values taken at the crossing itself.

IV. Reduction of Data for the Survey

As was mentioned earlier, the region of the galactic plane to be considered comprises the strip between latitudes $+4$ and $-6°$ and stretches from $l=223°$ through the galactic centre to $l=13°$.*

In collecting material for this area, brightness temperature measurements were made from tracings of the original records prepared in a manner described in paper I. As in the preliminary analysis described in Section III (*b*), only records not obviously affected by solar interference have been used. Temperature scales for the north-south and pencil-beam components were obtained by linear interpolation from the calibrations at the beginning and end of each record. Temperatures were measured to within ± 150 °K at intervals of 2 min in Right Ascension on every subposition of the beam. In complex regions of the sky, temperatures were measured at 1 min intervals. After the corrections indicated by the preliminary comparison (see Section III (*b*)) were applied to these measurements, the results of the two series of observations were averaged. In regard to this averaging it might be added that not only are instrumental effects reduced, but any less obvious effects of solar interference on the records is also diminished. Further, averaging of *A* and *E* subposition temperatures removed beam asymmetry effects at these declinations.

* No data are obtainable for longitudes from 13 to 167°, since these regions lie to the north of the normal operating declination range of the aerial. Here the aerial efficiency is a rapidly decreasing function of zenith angle and the relative importance of spurious responses increases. The strip from $l=167$ to 223° has been subjected to a preliminary investigation which showed that this comparatively low temperature region would require special methods of reduction if features present were to be described accurately. We have consequently deferred consideration of this region until a later date.

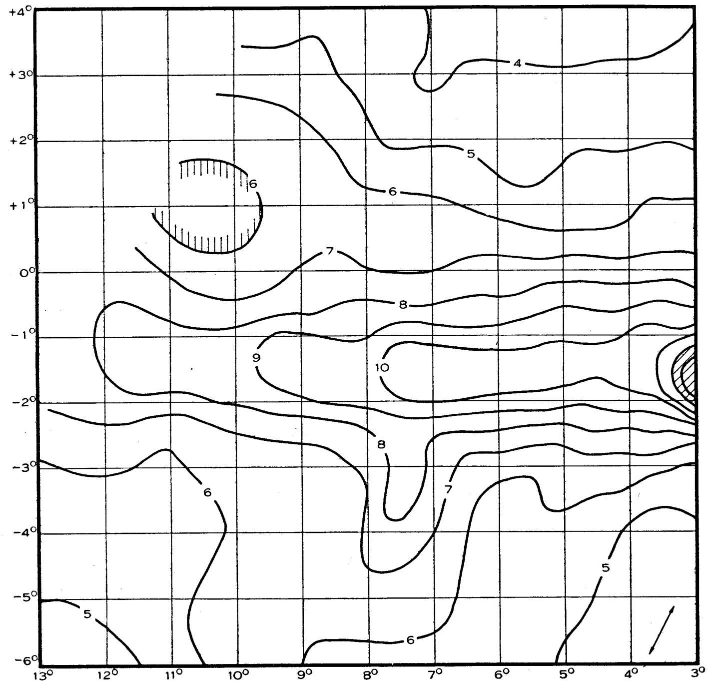


Fig. 5 (*a*).—For explanation, see Section V.

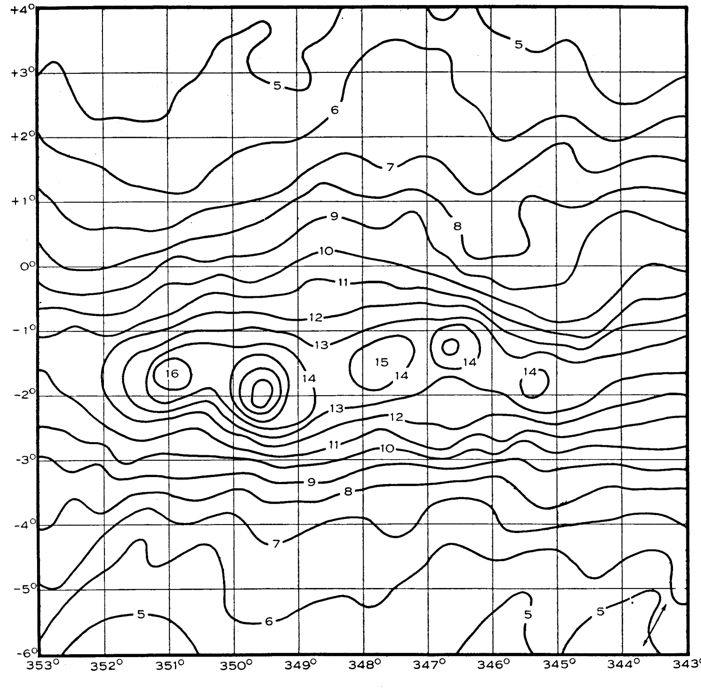
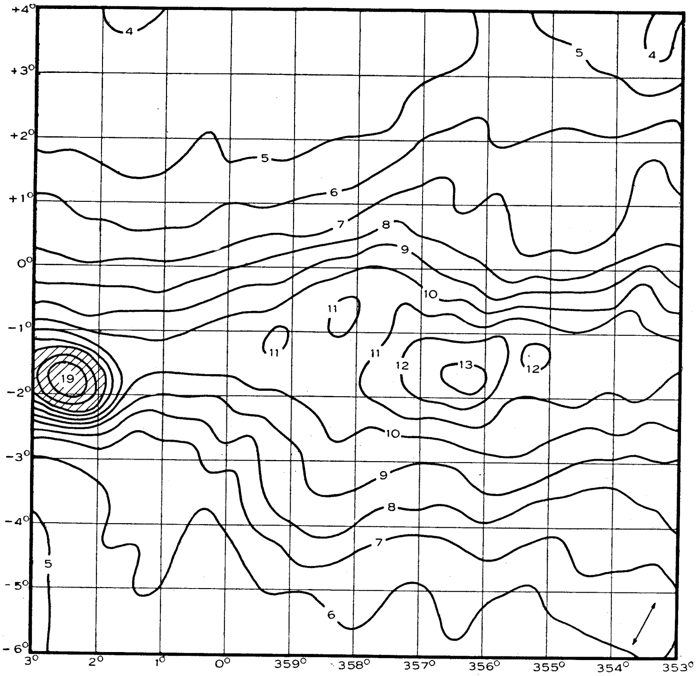


Fig. 5 (*c*).—For explanation, see Section V.



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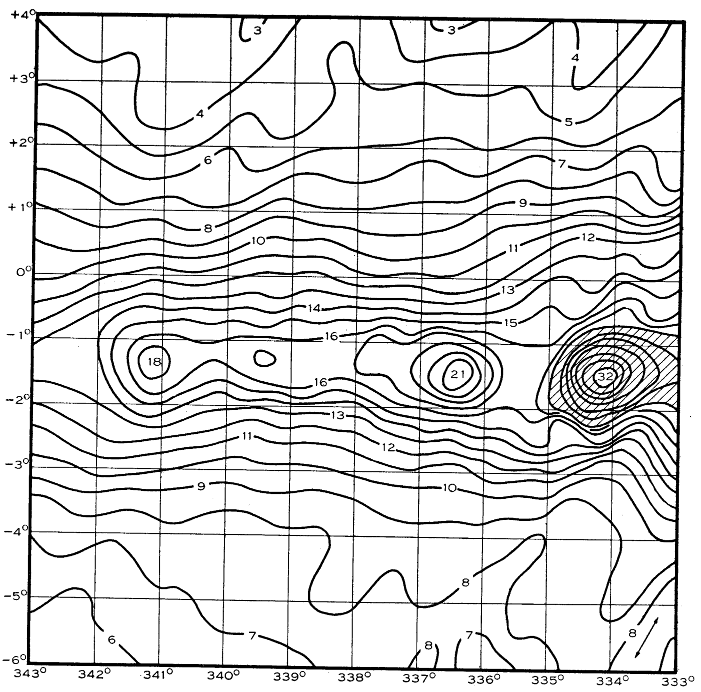

Fig. 5 (*d*).—For explanation, see Section V.

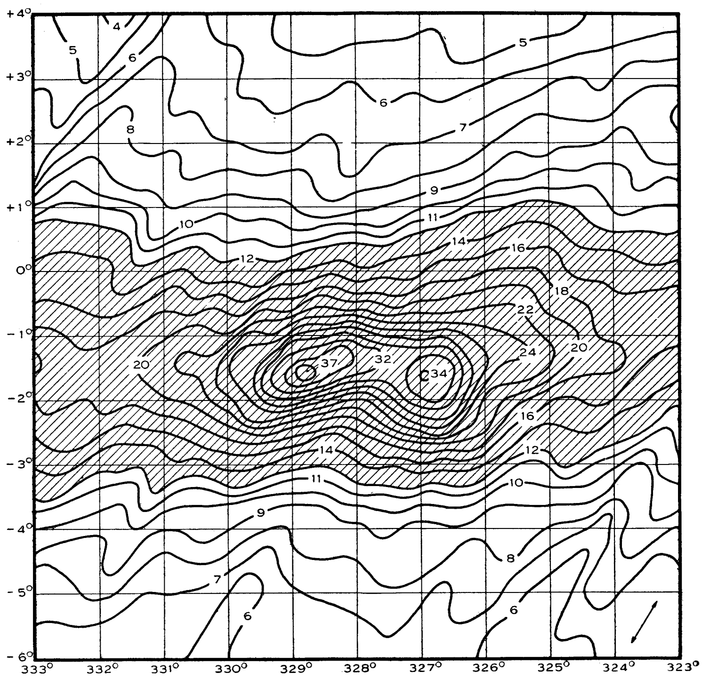

Fig. 5 (*e*).—For explanation, see Section V.

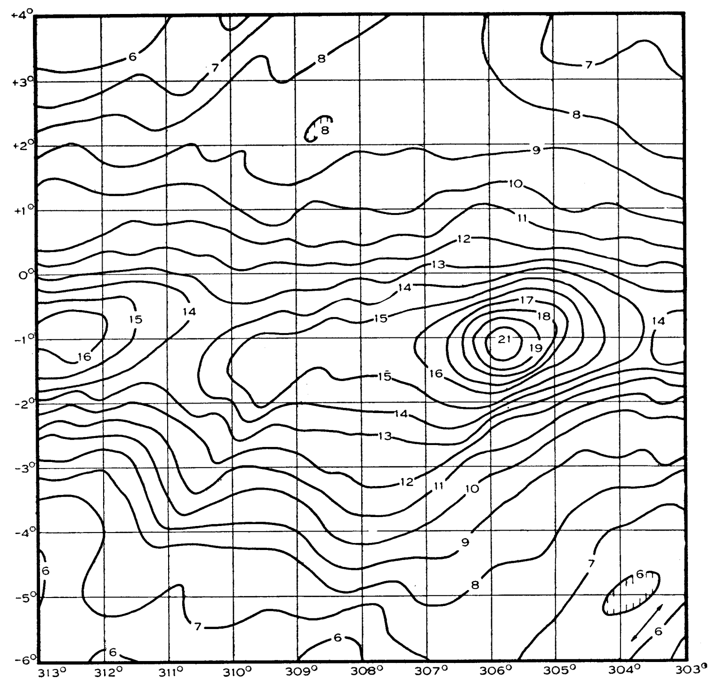

Fig. 5 (*g*).—For explanation, see Section V.

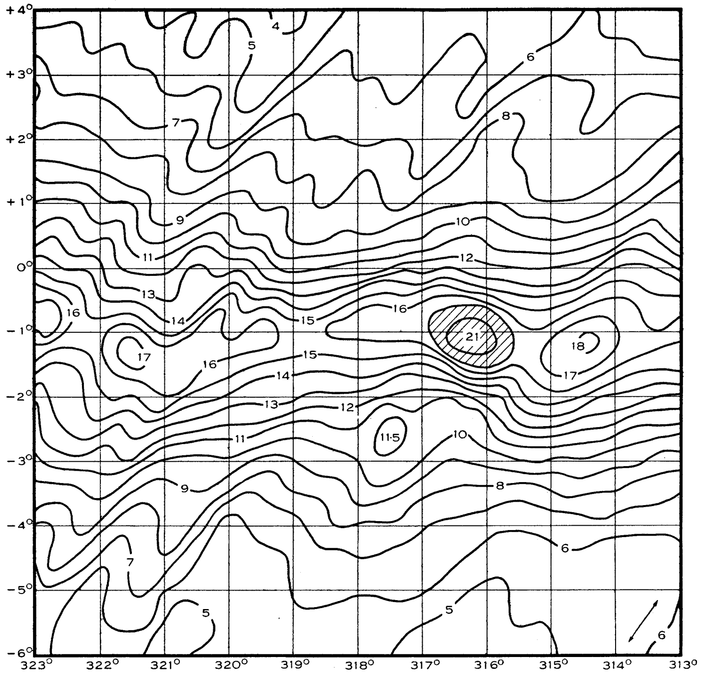

Fig. 5 (*f*).—For explanation, see Section V.

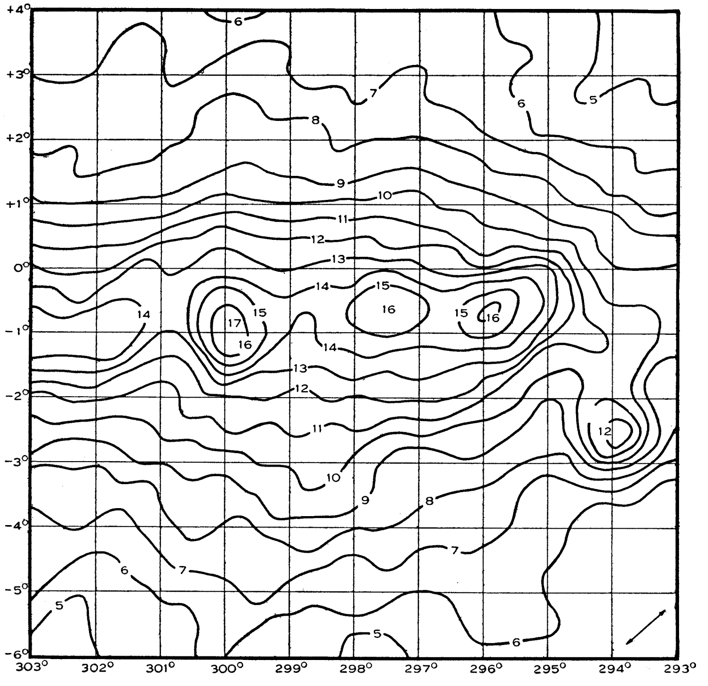

Fig. 5 (*h*).—For explanation, see Section V.

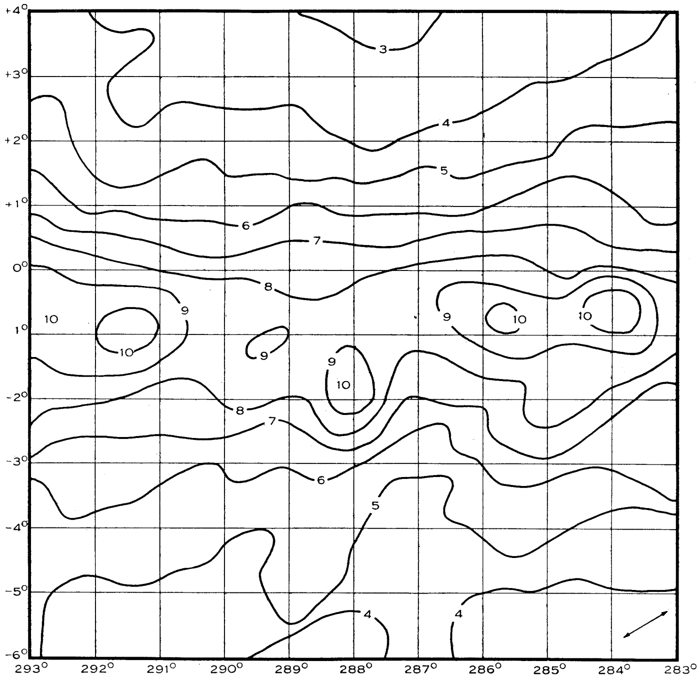

Fig. 5 (*i*).—For explanation, see Section V.

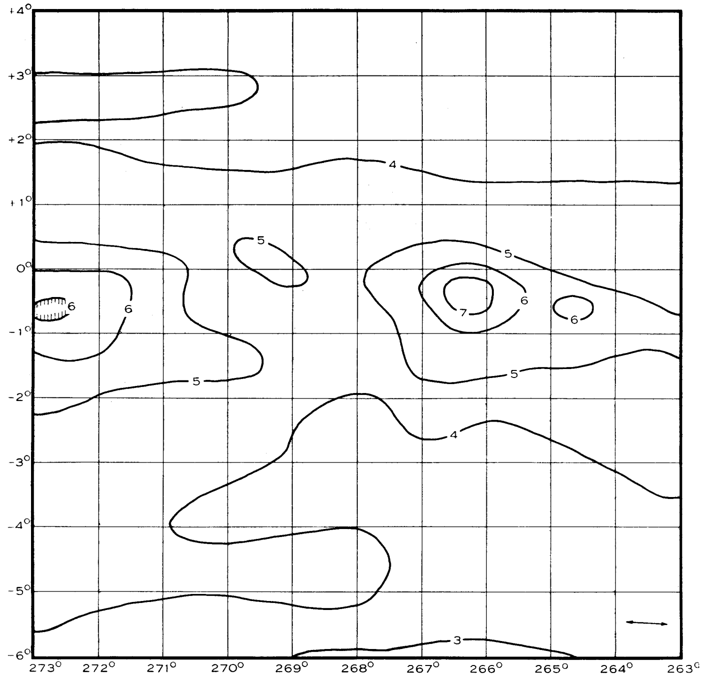

Fig. 5 (*k*).—For explanation, see Section V.

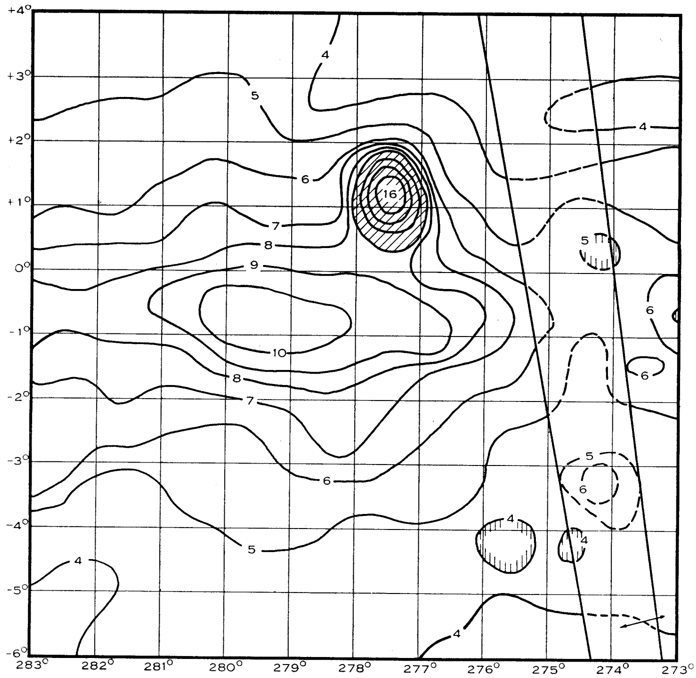

Fig. 5 (*j*).—For explanation, see Section V.

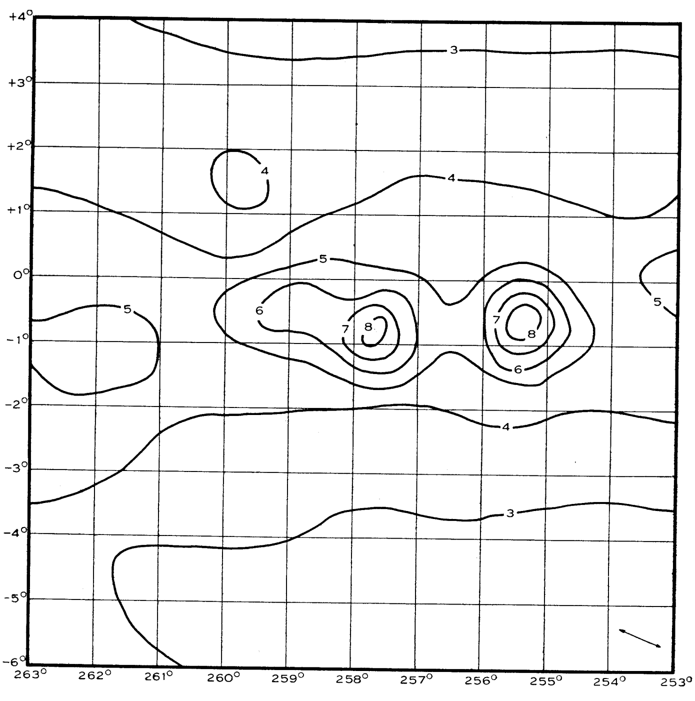

Fig. 5 (*l*).—For explanation, see Section V.

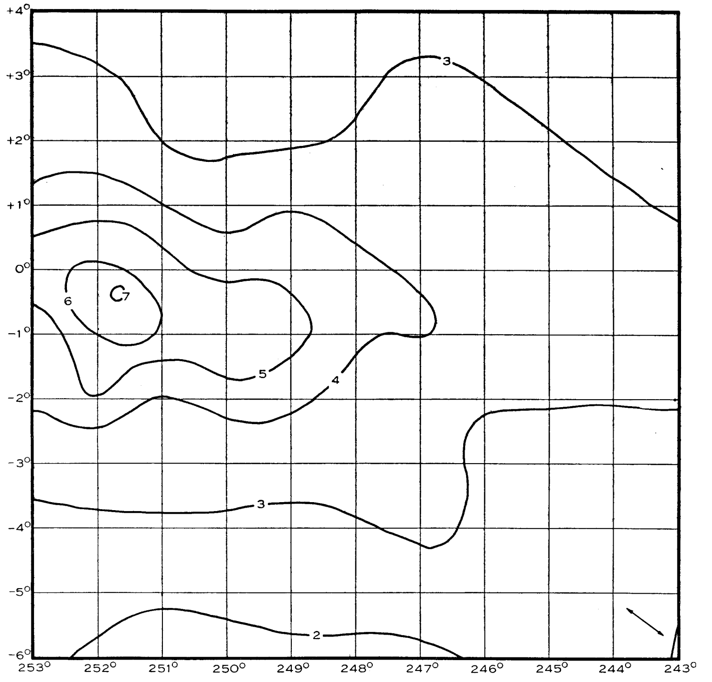

Fig. 5 (*m*).—For explanation, see Section V.

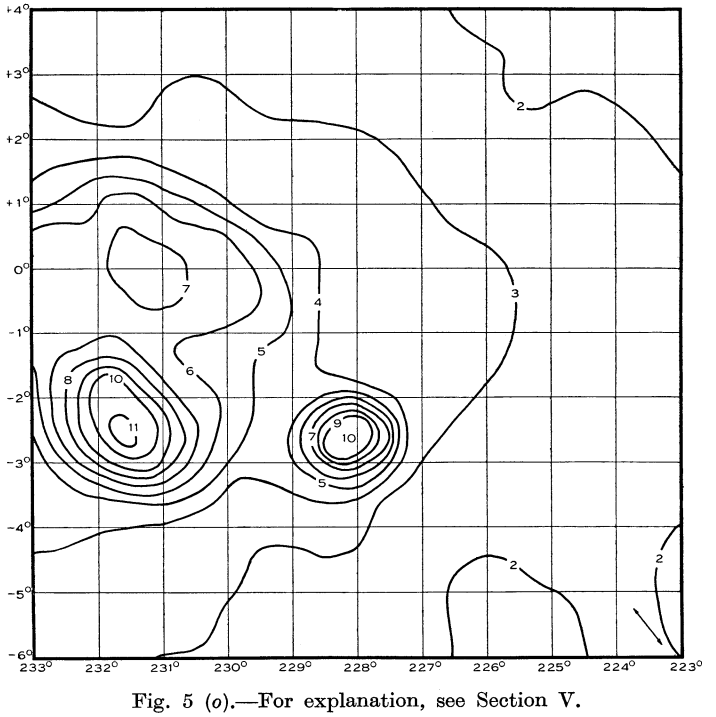

Fig. 5 (*o*).—For explanation, see Section V.

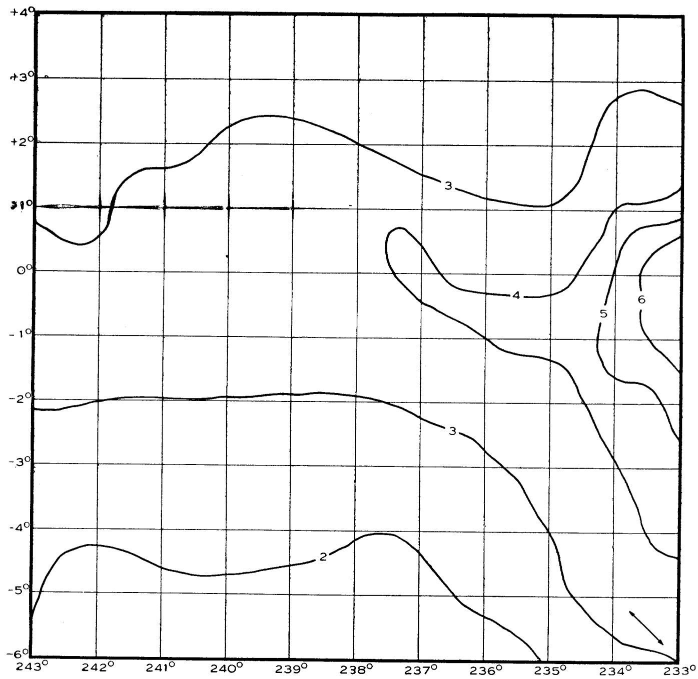

Fig. 5 (*n*).—For explanation, see Section V.

Charts, each 10 by 10° in galactic latitude and longitude, were then prepared with a Right Ascension and declination grid such that each intersection of the grid corresponded to a direction in which temperatures had been measured from the tracings. The construction of the grid was based on data prepared in the Laboratory by Martha Stahr Carpenter from the Lund tables with precession corrections necessary to render the conversion valid for epoch 1955. This being only about a year and a half from the mean epoch of observation meant that, since the grid was intended to be accurate to 0·1° in l and b, adjustment of the grid to make it appropriate for the mean epoch of observation was not warranted. Average temperatures as deduced above were then inserted at their appropriate Right Ascension-declination grid junction.

The beam asymmetry corrections for all B and D subpositions were then computed from the relations noted earlier (Section III (*a*)) using the average temperatures inserted on the charts. Although this involved in many cases using uncorrected B and D temperatures, the effects produced in doing so are of minor importance and were neglected. Beam asymmetry corrections around $b=+4$ and $-6°$ were always less than several hundred degrees, irrespective of galactic longitude. Around the galactic plane, however, larger corrections occur because of the greater background temperature gradients. This is especially so about the galactic centre where ± 1000 °K corrections were common, whilst in small areas in this locality corrections of up to ± 2000 °K have been necessary. Generally, however, the asymmetry corrections were less than ± 1000 °K.

From the final temperature grid on the charts, contours were constructed—these are shown in Figures 5 (*a*) to 5 (*o*).* No use has been made of Bracewell's (1956) process of filtering out artificial high frequency components since the method is too laborious for manual reductions and, moreover, the uncertainties in the data do not warrant such a detailed analysis. Finally, no correction has been made to the contours for the finite width of the pencil beam.

V. Discussion of Contour Diagrams

Contours of brightness temperature in Figures 5 (*a*) to 5 (*o*) constitute the results of the survey. Temperatures marked on these diagrams are in units of 1000 °K, which is also the interval of the contours except in the diagonally shaded regions where the interval is 2000 °K. Contours enclosing cool regions have vertical shading on the low temperature side of the contours. Where the contour system is inadequate for the purpose of illustrating peak temperatures of sources, or in extended bright areas, extra temperatures have been added. These temperatures are not embraced by contour lines. In the lower right-hand square of the l–b grid on each chart the average direction of the aerial scan is indicated by the double-headed arrow.

A general inspection of the diagrams indicates that the beam asymmetry corrections have successfully removed most of the spurious waves in the contours. There are traces of asymmetry effects remaining, for example, around the galactic centre region $l=323$ to 333°, but they do not influence the interpretation sufficiently to warrant more precise correction.

There are several spurious effects remaining in the contours to which attention should be drawn. Firstly, there is the region wherein the effects of Centaurus-A in the north-south part of the primary side-lobe pattern may produce significant distortion of the contours. The narrow strip which is affected occurs around $l=274$–275°. This strip has been indicated on Figure 5 (*j*) and contours within it have been broken. In this uncertain region, there is at $l=274\frac{1}{4}°$, $b=-3\frac{1}{3}°$ a temperature of about 2000 °K above the surroundings. Whether this is a real source, or whether it is one of the rare examples of a relatively large primary side lobe cannot be ascertained. The side lobe would be required to have a response of 4 per cent. of the primary beam to produce this effect as compared with an estimated r.m.s. primary side-lobe response in the north-south direction of 1·7 per cent.

Another area where spurious effects occur lies close to the zenith in a strip lying diagonally across the charts between $l=323°{\cdot}1$ and $326°{\cdot}2$ at $b=-6°$, and $l=316°{\cdot}4$ and $319°{\cdot}7$ at $b=+4°$. Here the impedance effects, mentioned earlier, have their maximum influence and introduce spurious detail into the contours.

A map of contours obtained with this instrument in the region of the galactic centre, the area corresponding to our Figure 5 (*e*), has been published by Mills (1956). Although many of the records used in these two maps were the same,

* A large diagram, measuring 6 by 90 in., in which the contents of Figure 5 are combined into one continuous chart, has been prepared, and a limited number of copies are available on request.

there are some differences in the published results, the most notable being the higher brightness temperatures obtained now. These result from a recalibration of the equipment as described in paper I. Other small and relatively unimportant differences in the shapes of the contours arise from the use of different reduction processes and the use of additional observational material in the present map. While this map is, in general, more reliable, the source at the galactic centre was treated more carefully in the earlier investigation, using extra records at intermediate beam positions: these were not used in the present reduction as the aim was to produce a uniform and more or less standardized treatment of the whole area covered by the maps.

Another and much larger area has been treated more carefully in an independent investigation by H. Rishbeth (1958); this includes the bright regions around longitude 230° as well as adjacent areas at higher latitudes not included in our maps. It is probable that other localized areas will also receive special treatment in subsequent analyses.

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VII. References

Bolton, J. G., Westfold, K. C., Stanley, G. J., and Slee, O. B. (1954).—*Aust. J. Phys.* **7**: 1.
Bracewell, R. N. (1956).—*Aust. J. Phys.* **9**: 297.
Little, A. G. (1958).—*Aust. J. Phys.* **11**: 70.
Mills, B. Y. (1952).—*Aust. J. Sci. Res.* A **5**: 266.
Mills, B. Y. (1956).—*Observatory* **76**: 65.
Mills, B. Y., Hill, E. R., and Slee, O. B. (1958).—*Observatory* **78**: 116.
Mills, B. Y., and Little, A. G. (1953).—*Aust. J. Phys.* **6**: 272.
Mills, B. Y., Little, A. G., Sheridan, K. V., and Slee, O. B. (1958).—*Proc. Inst. Radio Engrs., N.Y.* **46**: 67.
Rishbeth, H. (1958).—*Aust. J. Phys.* **11**: 550.
Scheuer, P. A. G., and Ryle, M. (1953).—*Mon. Not. R. Astr. Soc.* **113**: 1.