# OBSERVATIONS OF THE SOUTHERN SKY AT 10·02 MHz

By P. A. HAMILTON* and R. F. HAYNES*

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*Summary*

The brightness distribution of cosmic radio noise has been surveyed at 10·02 MHz between declinations $-2°$ and $-65°$ with an aerial beam of 4° by 5°. The galactic plane appears as a region of low brightness. Spectra of sources observed are discussed.

## I. INTRODUCTION

Recent low frequency surveys of the sky have shown the galactic plane in absorption as a region of low brightness. The results to date are consistent with the existence of a general ionized atmosphere within the galactic disk with an r.m.s. electron density of 0·1–0·2 $cm^{-3}$. While this conclusion is not inconsistent with other astronomical measurements, it may represent the first positive evidence on the nature of the interstellar intercloud medium.

It is therefore of some interest to obtain high resolution maps of sky brightness at a number of low frequencies in order to map the distribution of ionized hydrogen. A programme of such observations has been in operation in Tasmania since 1962 at frequencies of 2·1 MHz (Reber 1968), 4·7 MHz (Ellis and Hamilton 1966*a*), and 10·02 MHz reported here. Construction of a new radio telescope for the range 7–20 MHz has commenced and a higher frequency reference survey at 153 MHz has been completed (Hamilton and Haynes, in preparation).

## II. OBSERVATIONS

### (*a*) *Aerial System and Receiver*

The antenna consisted of a plane rectangular array of 24 by 15 half-wave dipoles at a height of a quarter-wave above the ground. The resulting beam to the half-power points was 4° by 5°. A plan of the array and the computed aerial space factors are given in Figure 1. The aerial system was situated at latitude 42·9° S. and longitude 147·0° E.

The receiver was a mutichannel instrument, using a variable intermediate frequency and delay cables to give six simultaneous beams. A detailed description of the receiver is given elsewhere (Hamilton 1968).

Considerable difficulty was experienced in finding channels free from transmitting-station interference, and the observing technique that has become standard

* Department of Physics, University of Tasmania, G.P.O. Box 252 C, Hobart, Tas. 7001.

in Tasmania for low frequency measurements was adopted: The receiver centre frequency is swept over a frequency range of five to six times the passband. A transmitting station within this range then appears as a periodic impulse at the second detector. If the second detector is followed by a minimum reading d.c. amplifier (Ellis 1960), this impulse is ignored and the final record is free from the interference. This permits continuous automatic operation of the telescope without re-tuning as other stations appear. The success of this method depends on the separation of stations being greater than the receiver bandwidth, and a careful choice of sweep rate and second-detector time constant. The final i.f. bandwidth of the receiver was $2\cdot 1$ kHz ($-6$ dB) and the receiver centre frequency was swept through 10 kHz five times a second. Approximately two-thirds of the records were reasonably clear of transmitting-station interference.

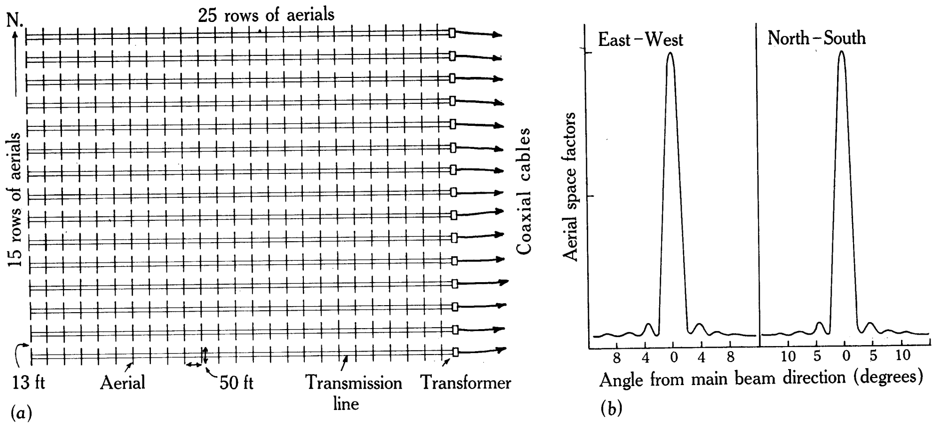


Fig. 1.—Details of the receiving system showing (*a*) a plan of the dipole array and feeds and (*b*) computed aerial space power factors (normalized).

## (*b*) *Operation of Equipment*

The aerial phasing system required that all the r.f. amplifiers be adjusted to have identical phase shifts and gains, and so the whole receiver was re-aligned weekly, although the tests made on these occasions indicated that this was unnecessarily often. The gain of the system was held constant to within 5% by this method.

The telescope was operated in 1965 and 1966; observations were terminated prematurely in February 1967 when the array was destroyed in a bush fire.

## (*c*) *Results*

Final records were chosen from night-time observations only, when ionospheric effects were negligible (Ellis 1965; Ellis and Hamilton 1966*a*). Sample records at eight declinations are given in Figure 2. The best records at each declination were selected for smoothness of trace, reproducibility, and absence of transmitting-station interference. Final profiles were then obtained by the method of Ellis and Hamilton, which assists the rejection of ionospheric effects.

The distribution of sky brightness is given in Figure 3 in galactic coordinates. The contour interval is chosen to bring the temperature of the featureless region in the vicinity of the south galactic pole into agreement with low resolution observations of the same region. We have taken the temperature of this region to be $6\cdot3\times10^5$ °K, as obtained by Higgins and Shain (1954) and independently by Ellis (1965). This makes the contour interval equal to $2\times10^5$ degK.

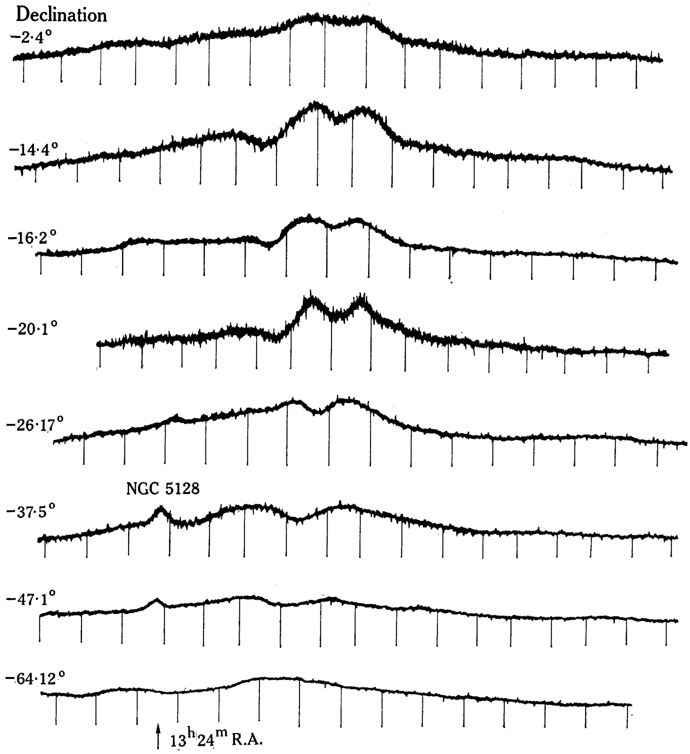


Fig. 2.—Sample records at eight declinations.

## III. Discussion of Results

### (a) *Background Survey*

The striking feature of all sky surveys at frequencies below 20 MHz is the band of low brightness lying along the galactic plane, reaching a minimum at the galactic centre. A preliminary analysis of low frequency surveys (Ellis and Hamilton 1964) has suggested that the Sun is embedded in a region of ionized hydrogen that is uniform to an angular scale of 1° as seen from the Earth. The absorption coefficient $\tau$ is given by

$$\tau \simeq 0\cdot2\,E/T^{3/2}f^2,$$

where $T$ is the electron temperature, $f$ the wave frequency, and the emission measure

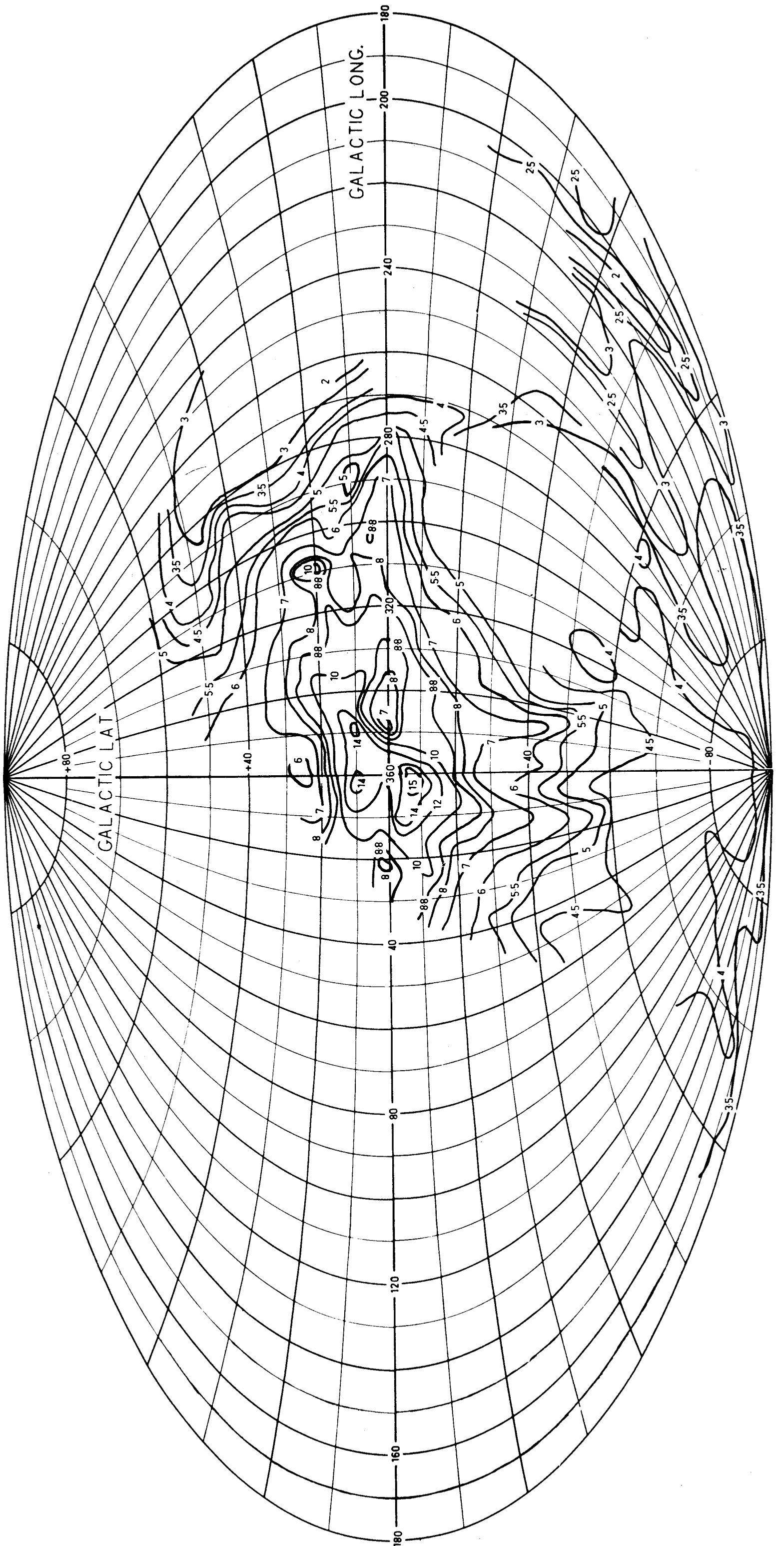


Fig. 3.—Background survey at 10·02 MHz (contour intervals of $2 \times 10^5$ degK).

$E$ is given by

$$E=\int_0^L N^2\,\mathrm{d}l\,,$$

with $N$ the electron density, and $L$ the path length in the absorber. A single scan at declination $-37°$ has been analysed in detail (Ellis and Hamilton 1966*b*) for a model in which the observed radiation is the sum of the radiation from distant sources that has passed through this absorption together with radiation from within the ionized hydrogen region itself. Electron densities in the range 0·1–0·2 $\mathrm{cm}^{-3}$ were obtained for this model.

At low frequencies the absorption coefficient is a rapid function of frequency. Comparison of the present survey with other low frequency surveys would not therefore be expected to give good agreement. In fact only the broad features agree with those seen at 19·7 MHz (Shain, Komesaroff, and Higgins 1961) and 4·7 MHz

TABLE 1

FLUX DENSITIES OF SOURCES

| PKS Catalogue Number | Position (1950·0) R.A. h m s | Dec. ° ′ | $S_{4\cdot7}$ | $S_{10\cdot02}$ | $S_{85\cdot5}$ | $S_{408}$ | $S_{1410}$ | Remarks |
|---|---|---|---|---|---|---|---|---|
| 0821−43 } 0834−46 } | | | 3600 | 2800 | 690 1100 | | | Puppis A not resolved |
| 1322−42 | 13 22 24 | −42 45·0 | 51000 | 43000 | 8700 | | | Centaurus A |
| 1343−60 | 13 43 19 | −60 10·0 | | 1500 | 795 | 242 | 130 | IAU 13S6A |
| 1549−56 | 15 49 01 | −56 01·0 | 2000 | 1400 | 270 | 144 | 130 | Nonthermal |
| 1648+05 | 16 48 42 | +05 04·5 | | 7800 | 890 | 161 | 46·0 | Herc. A |
| 1711−38 | 17 11 18 | −38 24·0 | 1500 | 1600 | 300 | 196 | 77 | Nonthermal |

(Ellis and Hamilton 1966*a*), and agreement is poor with the survey at 2·1 MHz (Reber 1968). At frequencies above 20 MHz the absorbing region becomes transparent and a resolution of 1° or better at 30 MHz is required before the galactic plane can be seen in absorption. The surveys at 30 MHz (Mathewson, Broten, and Cole 1965) and 85 MHz (Yates, Wielebinski, and Landecker 1967) were made with resolutions too low to enable direct comparison with the 10 MHz survey. However, these surveys can be used in an analysis of the type made by Ellis and Hamilton (1966*b*), and such a detailed analysis of the low frequency maps is in progress.

### (*b*) *Discrete Sources*

#### (i) *Measurements*

Problems of transmitting-station interference mentioned earlier led to the combination of narrow bandwidth and short second-detector time constant. The resulting fluctuation in record levels was therefore rather high, making measurement of discrete sources difficult. The smallest observable flux density was calculated to be in the range 800–1400 f.u.,* depending on the background. The minimum reading

* 1 flux unit $= 10^{-26}\,\mathrm{W\,m^{-2}\,Hz^{-1}}$.

d.c. amplifier caused further difficulty if the source was scintillating due to ionospheric irregularities.

The flux densities of those sources whose records reproduced accurately a sufficient number of times are given in Table 1, together with their flux densities at 4·7 MHz (Ellis and Hamilton 1966*a*), 85·5 MHz (Mills, Slee, and Hill 1960), and 408 and 1410 MHz (Parkes catalogue: Bolton, Gardner, and Mackey 1964; Price and Milne 1965; Day *et al.* 1966; Shimmins *et al.* 1966).

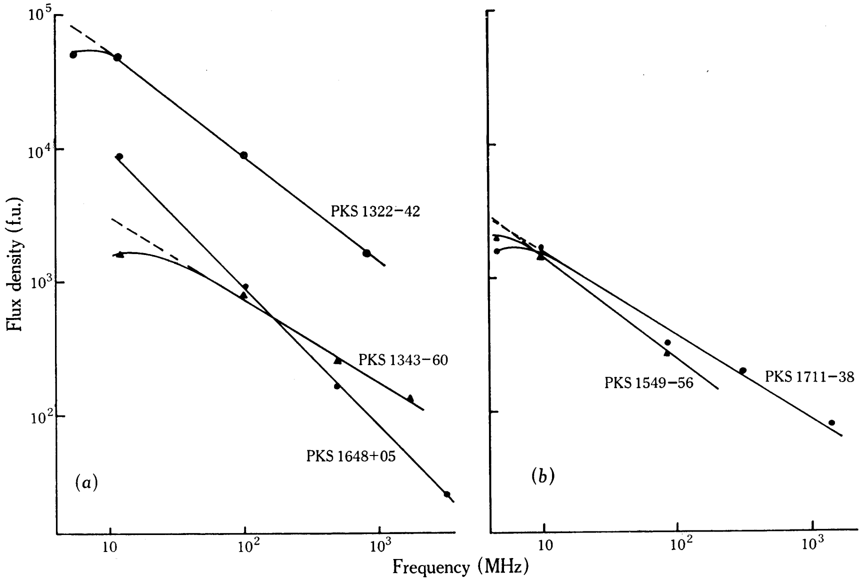


Fig. 4.—Spectra of sources measured at 10·02 MHz.

(ii) *Discussion*

Comparing the results at 10·02 MHz with the other observations given in Table 1 (see Fig. 4), it can be seen that none of the measured sources show any increase in spectral index at low frequency. (The spectral index $\alpha$ is defined by the relation $S = Af^{-\alpha}$, where $S$ is the source flux density, $f$ the frequency, and $A$ a constant.)

Four of the sources (PKS 1322−42, 1343−60, 1549−56, and 1711−38) show definite curvature at low frequencies, some of which is due to absorption within the galactic disk. The preliminary work of Ellis and Hamilton (1966*b*) suggests that the low frequency absorption results from a layer of ionized hydrogen within the disk. The observed flux density $S$ is then related to the emitted flux density $S_0$ by

$$S = S_0 \exp(-\zeta E/T^{3/2}f^2),$$

where $T$ is the electron temperature within the absorber, $f$ is the wave frequency, $E$ is the emission measure along the line of sight within the absorber, and $\zeta$ is a factor that $\simeq 0{\cdot}2$ at these frequencies (Ginzburg 1964). Ellis and Hamilton found that the emission measure was approximately proportional to cosec $b$ (where $b$ is the galactic latitude) for $30° \leqslant b \leqslant 90°$, while it increased at a somewhat faster rate as $b \to 0$. They obtained emission measures of $8 \cdot 1$ cm$^{-6}$ pc for $b = 60°$ and 165 cm$^{-6}$ pc for $b = 5°$.

Taking these results it is possible to obtain the spectrum for PKS 1322−42 as seen outside the galactic disk, since for $b \simeq 21°$ we would expect the emission measure along the line of sight to be $\sim 30$ cm$^{-6}$ pc. This spectrum is shown as the dashed line in Figure 4(*a*), and it is apparent that the emission spectrum of the source is linear down to 4·7 MHz. The emission is consistent with synchrotron radiation from a region with an electron energy distribution of the form

$$N(E)\,\mathrm{d}E = KE^{-\gamma}.$$

The spectral index of 0·7 gives $\gamma = 2 \cdot 4$.

The three remaining sources showing curvature in their spectra are all at galactic latitudes of 2° or less. Ellis and Hamilton were unable to give emission measures at such low galactic latitudes because of the limited resolution of the surveys on which their calculations were based. However, it can be asserted that the emission measures along these three lines of sight to the edge of the galactic disk are all well in excess of the value of 165 cm$^{-6}$ pc given for $b = 5°$. If we assume that the emission spectra of these sources are linear to 10 MHz and that the observed curvature is the result of interstellar absorption, we can calculate the emission measures required to produce this absorption, and these results are given below.

| Source | Coordinates $l^{\mathrm{II}}$ | $b^{\mathrm{II}}$ | Emission Measure ($N^2L$ cm$^{-6}$ pc) | $L$ for $N = 0 \cdot 2$ cm$^{-3}$ (pc) |
|---|---|---|---|---|
| PKS 1343−60 | 309·8 | 2·1 | 93 | 2300 |
| PKS 1549−56 | 326·3 | −1·7 | 31 | 760 |
| PKS 1711−38 | 349·2 | 0·6 | 49 | 1240 |

The emission measures obtained indicate that either the sources are galactic objects or the emission spectra have sharp increases in spectral index at low frequencies. If the emission measures are correct and the sources are galactic, we can estimate the distances from these sources to the Sun. Taking $N = 0 \cdot 2$ cm$^{-3}$ (Ellis and Hamilton 1966*b*), we obtain the distances shown above. The source PKS 1343−60 (IAU 1356A) has been identified by Shlovsky as a supernova remnant but no distance estimate has been made from optical measurements. The other sources have not been identified with optical objects.

## IV. Acknowledgments

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