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A 30 MHz Map of the Whole Sky

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Abstract

A 30 MHz map of the whole sky has been produced by combining medium resolution surveys of both hemispheres. The map is useful for studying large-scale galactic features away from the galactic plane.

Introduction

To date, two whole sky maps have been prepared: one at 150 MHz (Landecker and Wielebinski 1970) and one at 85 MHz (Yates 1968). However, these maps are not based on independent data, as both incorporate the 178 MHz data of Turtle and Baldwin (1962) to obtain northern brightness temperatures and the 85 MHz data of Yates *et al.* (1967) to obtain southern brightness temperatures. Recently the results of two northern surveys at medium resolution have been published which are suitable for combining with existing southern data to produce two more independent maps of a large portion of the sky. These new data are from the 38 MHz survey of Milogradov-Turin and Smith (1973) and the 10 MHz survey of Caswell (1976), which have resolutions of $7^\circ \cdot 5$ and 2° respectively. The corresponding southern surveys are the 30 MHz survey of Mathewson *et al.* (1965) and the 10 MHz survey of Hamilton and Haynes (1968), with resolutions of 11° and $4^\circ \times 5^\circ$ respectively.

In the present paper a composite map at 30 MHz is presented. Apart from being new, this map presents the northern data on a galactic grid that is more suitable for the display of large-scale galactic features. A 10 MHz map has also been produced (Cane 1977); the southern half of the map is complete, as the contours of Hamilton and Haynes (1968) have been extended by using 13 MHz data obtained with the Llanherne array (Cane 1975), but a section of the northern data has not yet been analysed. Analysis of the remaining data is in progress (J. A. Galt, personal communication).

Preparation of the Map

The 30 MHz survey of Mathewson *et al.* (1965) was made with an 11° beam and temperatures were measured relative to a region of minimum brightness in the southern hemisphere centred on $l = 230^\circ, b = -45^\circ$. The temperature of this region was taken by the authors as $1 \cdot 48 \times 10^4$ K, and the contour unit of their map is $1 \cdot 8 \times 10^3$ K. From these results a comparison of temperatures at 30 MHz with those at 38 MHz

(Milogradov-Turin and Smith 1973) where the two maps overlap indicates that the 30 MHz temperatures are much greater than the 38 MHz values, even after allowing for the difference in frequency. In order to combine the maps then, a new reference level and contour unit were determined for the southern survey, and the 38 MHz northern temperatures were scaled by a small amount.

The scaling procedure was as follows. Denoting the new 30 MHz brightness temperatures by T and the new reference level and contour unit of the southern survey by Z and C, we have

$$T = nC+Z,$$

where n corresponds to the numbering of the contours in the map of Mathewson *et al.* (1965). It is then assumed that the 38 MHz temperatures T^* can be converted to 30 MHz temperatures T by a scaling factor k, that is

$$T = k\times T^*.$$

The factor k incorporates the conversion arising from the change in frequency and a scaling factor altering the gain of the original map. The zero level of the 38 MHz map is assumed to be correct. If T^* is plotted against n for regions where the two surveys overlap it is possible to determine C, Z and k, provided that the temperature of some particular region of the sky is independently determined.

The region chosen for independent temperature measurement was the south galactic pole. Recently new measurements of the temperatures of the polar regions have been made by the author (results to be published) and these, combined with earlier data, define the galactic polar spectra reasonably well. From these data the temperature of the south galactic pole was determined to be $1\cdot 8\times 10^4$ K at 30 MHz.

For values of n less than about 20 a linear relationship exists between the 38 MHz temperatures and n. For larger values of n (which only occur near the galactic plane) the 38 MHz temperatures increase more rapidly, and this nonlinear effect can probably be attributed to the difference in resolution between the northern and southern surveys. Since an all-sky map is most useful for regions away from the plane, it was considered that a convolution of the higher frequency data to a lower resolution was unwarranted. The straight line fitted to the data was a compromise so that one scaling factor could be applied to all the 38 MHz temperatures.

The new reference level and contour unit for the southern data are $1\cdot 05\times 10^4$ K and $1\cdot 27\times 10^3$ K respectively. The corresponding value for k is $1\cdot 98$ which, if we assume a temperature spectral index of $2\cdot 55$, means that we have raised the 38 MHz temperatures by 8%.

The composite map was prepared by redrawing the scaled contours of both surveys on a galactic grid. Northern contours were used in preference to southern contours if they differed in the overlap region, although no extra contours were included that were not on the original southern survey. Thus some of the detail near the galactic centre provided by the 38 MHz survey was not included.

The complete sky map is shown in Fig. 1. For the northern region not covered by the 38 MHz survey, contours have been closed with broken lines in a manner consistent with the features seen in the 178 MHz survey of Turtle and Baldwin (1962). The estimated probable error in the brightness temperatures is 10%.

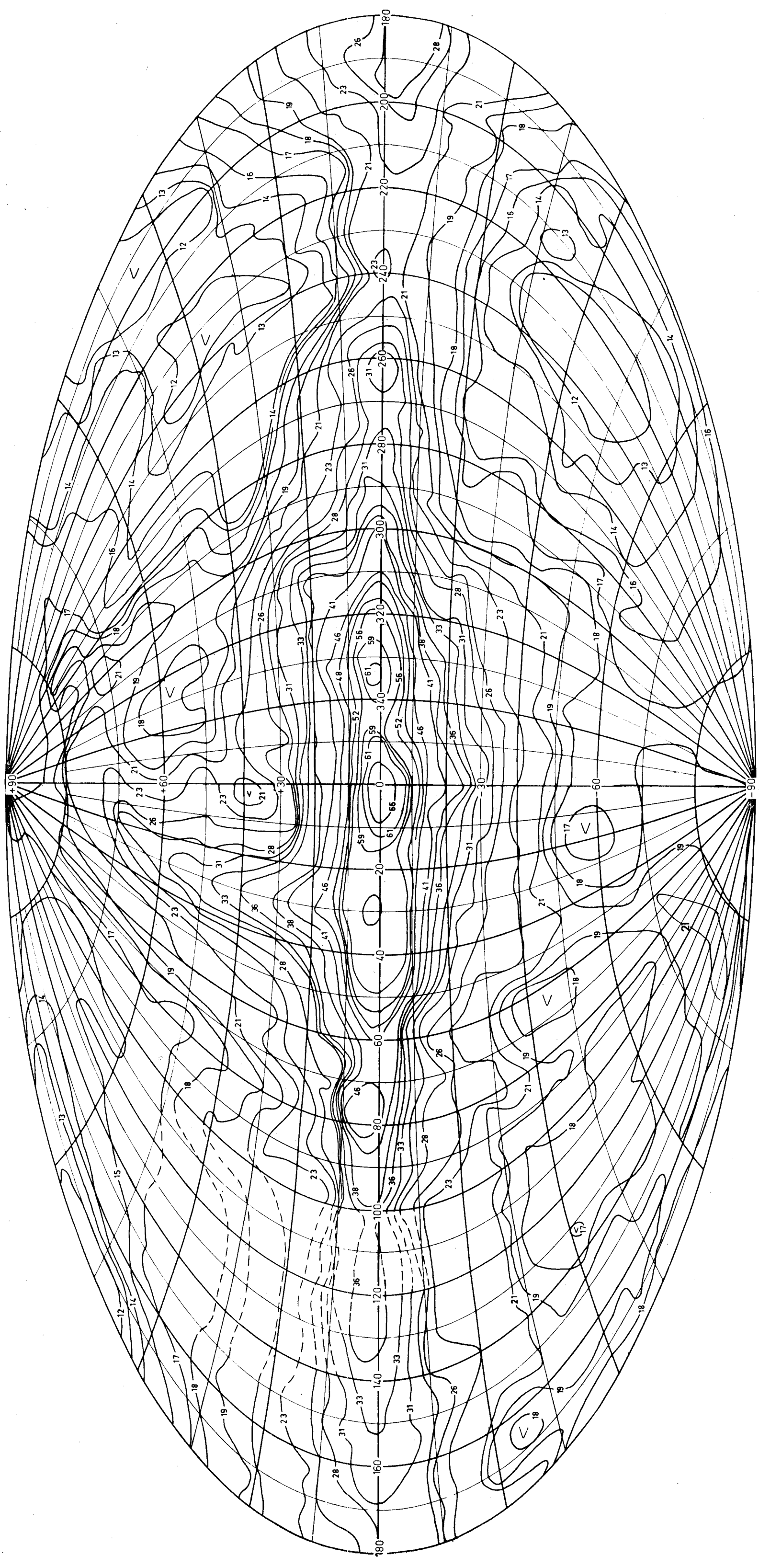

Fig. 1. Contour map of 30 MHz brightness temperatures plotted on a Hammer equal-area projection in galactic coordinates. The contour unit is 1000 K.

Discussion

The distribution of emission presented by the 30 MHz map varies little from that at 150 MHz. The detail along the galactic plane is slightly different because of the broader beams used at the lower frequencies and because of the effects of absorption by ionized hydrogen. Although no discrete HII regions are seen in absorption (cf. the high resolution 29·9 MHz survey of Jones and Finlay 1974), there is evidence of absorption along the plane in the longitude range $l = 340°–350°$. A large region of absorption in this longitude range is seen on the low frequency surveys of Cane and Whitham (1977).

Away from the galactic plane there is still considerable emission and most of this can be attributed to the loops. As pointed out by Milogradov-Turin and Smith (1973), all the loops delineated by Large *et al.* (1962) and other workers are distinct on their 38 MHz map. On the southern 30 MHz map there is evidence of the Southern Spur at $l = 0°$, $b = -20°$ extending out to $l = 290°$, $b = -55°$. It is worth noting that the southernmost part of Loop II ($l = 60°–160°$, $b = -80°$) is seen on the 38 MHz survey. This region of the sky was not mapped by Yates *et al.* (1967) and hence this section of Loop II is absent from the 85 MHz whole sky map (Yates 1968).

The most noticeable difference between the 30 and 150 MHz whole sky maps is the position of the region of minimum brightness in the southern hemisphere. At 30 MHz the minimum is centred on $l = 230°$, $b = -40°$ compared with $l = 250°$, $b = -30°$ at 150 MHz. This section of the 150 MHz map is based on 85 MHz contours and is not consistent with the 153 MHz contours of Hamilton and Haynes (1969). The position of the minimum at $l = 230°$, $b = -40°$ is confirmed by the 153 MHz map and the 10 MHz composite map. The small ridges in the 30 MHz contours at $l = 312°$, $b = +18°$ and $l = 270°$, $b = +78°$ are caused by the incomplete removal of the effects of the sources Centaurus A and Virgo A respectively.

A more detailed comparison of the map is obtained by dividing the 30 MHz temperatures by 150 MHz temperatures at corresponding positions across the sky. The scatter in the ratio is approximately $\pm 20\%$ about the mean value. This scatter is partially caused by the inaccuracies in temperature scales of the various surveys combined together, but also reflects variations in spectral index. Determinations of spectral index from the two maps can only be approximate because the 30 MHz temperatures have not been corrected for side-lobe responses of the aerials.

The distribution across the sky of the ratio of 30 to 150 MHz temperatures indicates that the section of Loop II at $l = 50°$, $b = -50°$ has a steeper spectral index than the section at $l = 160°$, $b \approx -30°$ to $-50°$ and the North Polar Spur. This is consistent with the results of other workers, as discussed by Berkhuijsen (1971). The section of Loop II at $l = 155°$, $b = -35°$ has a very low temperature ratio, which is attributed to free–free absorption. This is confirmed by the 10 MHz map of Caswell (1976) where it can be seen that this section of the loop (near R.A. $02^h 50^m$, Dec. $+20°$) exhibits a small depression. The position of the depression corresponds to that of the nebulosity observed by Meaburn (1967).

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