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A radio continuum survey of the Galactic Plane at 11 cm wavelength. I. The area $357°.4 \leqq l \leqq 76°$, $-1°.5 \leqq b \leqq 1°.5$

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Summary. — We show the 11 cm radio continuum radiation of the Galactic Plane in the form of an atlas of contour maps covering the range $357°.4 \leqq l \leqq 76°$, $|b| \leqq 1°.5$. The angular resolution is about 4'.3 and the sensitivity is 50 mK T_B (or 20 mJy/beam area). Additionally we have compiled a catalogue of 1212 small diameter radio sources.

Key words : radio continuum survey — source catalogue — galactic structure.

1. Introduction.

Since 1981 we have used the Effelsberg 100-m telescope to map the Galactic Plane at a wavelength of 11 cm. It is proposed to cover the entire Galactic Plane visible from Effelsberg in the latitude range ± 5° with a much improved sensitivity compared to previous surveys in this wavelength range. A companion 11 cm survey is being observed with the 25-m Stockert telescope covering the latitude range of ± 20°, which will be used to study all large-scale structures.

In this first part we present observations of the narrow Galactic ridge between the Galactic Centre region and the Cygnus complex. In this paper we describe the receiving system and the reduction procedures in some detail which will be the same for subsequent sections of the survey. The observational method, however, of this first part differs somewhat because account has to be taken of the steep intensity gradient in galactic latitude in this region of the galaxy.

2. Observations.

The observations were made with a three-channel receiver installed in the secondary focus of the 100-m telescope. The first two stages of each channel consist of cooled FET amplifiers. A full technical description has been given by Wongsowijoto and Schmidt (1982). Figure 1 shows a block diagram of the receiver. Table I lists some relevant data. We found no linearity errors even for the strongest sources in our survey.

The method of observation was to scan in galactic latitude at a speed of 2°/min and a scan separation of 2'. Except in a few cases each field was scanned at least twice. The scan range in galactic latitude was ± 1°.5 or more in areas where it was already known that strong source complexes are located at the boundary. The observation periods are listed in table I together with the bandwidth used. The expected r.m.s. noise for two coverages is 11 mK T_B or 14 mK T_B for a bandwidth of 80 MHz or 50 MHz, respectively.

In such cases where we found sources at the edge areas preventing an accurate baseline adjustment to be made additional observations of the areas above 1°.3 or below − 1°.3 latitude were made by scanning in galactic longitude. We list all extensions in table II.

A deep antenna pattern of the 100-m telescope at 11 cm wavelength has already been shown by Reich *et al.* (1978). Due to some technical improvements the antenna pattern is now more symmetric in east-west direction. Figure 2 shows the antenna pattern for an area of 30' × 30' obtained by adding several calibration source maps. Further antenna data are listed in table I which have been averaged from all calibration source observations. Calibration of each individual observation was however made by using actual values. The position accuracy and temperature scale of the observations were checked by each day observing several strong point-like sources. 3C 286 was used as a main calibrator. Some other sources served as secondary calibrators and are listed in table I.

3. Reduction.

The first stages of data reduction were made using standard procedures based on the NOD2 reduction library (Haslam, 1974) on the Cyber 172 of the Max-Planck-Institut für Radioastronomie. Calibrated maps were computed and a linear baseline adjustment was

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performed using two data points at each end of a scan. Further reduction steps described below were shared between the Cyber 172 and the VAX 11/780 of the Radioastronomisches Institut of Bonn University.

The maps were improved where required by filtering out spiky data, scans showing jumps in temperature were edited or rejected. Scanning effects were suppressed by using the method of unsharp masking developed by Sofue and Reich (1979). Maps of the same area were compared to look for remaining bad weather effects or interference. For some small regions or scans only one coverage has the required quality, this is noted for individual plates in section 4.2.

We observed the extensions by making longitude scans, and these were reduced in the same manner. However, for longitudes less than ~ 20° ground radiation effects become apparent which were corrected for by fitting polynomials of second order to the lower envelope of each scan. Using this method it is possible that extended structures may have been lost. The baselevels of the maps are therefore corrected for the influence of sources or source complexes at the edge areas only. Table II lists the corrected longitude ranges. Finally, all maps were combined into plates of 2°.2 × 3° in extent having an overlap of 0°.1 at each boundary.

For longitudes greater than 70° the baselevels were further improved by using large-scale information from a first section of the Stockert 11 cm survey (Reif *et al.*, 1984). The Effelsberg data were convolved to the 19′ resolution of the Stockert beam and a difference map was computed. This difference map was set to zero in the area at $l \sim 70°$ and added to the Effelsberg data. This procedure gives a smooth continuation of the data around longitudes 70° and correct relative temperatures between 70° and 76° longitude.

From the observations and the reduction methods it is obvious that the resulting maps do not represent absolute temperatures. The amount of temperature offset may be estimated from the lower resolution 11 cm survey of Altenhoff *et al.* (1970). At ± 1°.5 in galactic latitude the temperatures smoothly increase from ~ 0.5 K T_B at ~ 50° longitude to about 1.5 K in the Galactic Centre region. Another uncertainty for large-scale structures comes from the nonlinear gradients due to the ground radiation for scans observed at low elevations. We have not corrected for this effect. Regions from $l < 20°$ towards the Galactic Centre may be affected. Comparing again with the 11 cm survey of Altenhoff *et al.* we note however that the ground effects are well below 0.5 K T_B, which is the accuracy of that survey.

It is planned to calibrate the Effelsberg 11 cm survey to an absolute temperature scale and to correct large-scale temperature gradients with the help of the Stockert 11 cm data.

4. Results.

We present the results of our survey in the form of an atlas of contour maps and further give a catalogue of small diameter sources. The r.m.s. noise was determined in small flat regions from the final maps. Values between 12 mK T_B and 18 mK T_B were found, which are close to the expected theoretical values.

A discussion of extended sources including polarization and observations in other frequency ranges will be given in subsequent papers together with identifications where possible. Four newly found supernova remnants, G357.7 + 0.3, G359.1 − 0.5, G24.7 + 0.6 and G27.8 + 0.6, have already been discussed (Reich *et al.*, 1984 ; Reich and Fürst, 1984). Another interesting source centred at $l \sim 65°$, $b \sim 0°.1$ was seen in this survey for the first time. It shows a linear extent of ~ 0°.7 and is most likely identified with a giant radio galaxy (Seiradakis *et al.*, 1984).

4.1 SOURCE LIST. — In table III we have listed 1212 radio sources detected in the surveyed area. We have only considered sources smaller than 12′ of maximum size (FWHP) being found by an elliptical Gauss fitting procedure. A single elliptical Gaussian surface was applied to properly selected small areas containing the individual sources.

Sources have been identified generally by temperature peak values ≧ 100 mK T_B above the surroundings. However, very close to the Galactic Plane, particularly at longitudes < 50°, the confusion by diffuse background emission restricts the detection of weaker sources. Consequently, the degree of completeness is not uniform across the surveyed area.

In some cases a very steep gradient in the background emission obscures weak sources, which manifest themselves only in distorting the contours. We have used the values at the four field corners of the selected area around the source to define baselevels by interpolating these values in latitude and longitude direction.

Since we applied only a single Gaussian fit, the results suffer from confusion in cases of closely neighboured sources. Sources affected by confusion due to other sources or complex background emission are marked with « C » in table III. No size and position angle is given in these cases and the quoted flux density should be taken only as an estimate of the source strength.

The position accuracy is generally better than ± 20″ in longitude and ± 35″ in latitude. These values include pointing and Gaussian fitting accuracy and have been checked further with Gaussian fitted sources in the survey at 4.875 GHz by Altenhoff *et al.* (1978).

The following data are included in table III :

Column 1	: sequential number.
Columns 2 and 3	: galactic longitude and latitude.
Columns 4 and 5	: right ascension and declination for Epoch 1950.0.
Column 6	: integrated 2695 MHz flux density in Jy using the source fit parameters of column 7.
Column 7	: a) PL in case of point-like sources : area smaller than 4′.5 × 4′.5. b) WE in case of weak extended sources : area smaller than 5′.0 × 5′.0. c) In case of extended sources : 1. number : large axis, 2. number : small axis, 3. number : position angle of the source ellipsoid. d) No information in case of confused sources.

Column 8 : error class of the fitting procedure :
1. digit : positional error in units of 10″,
2. digit : flux density error in units of 10 % of the quoted flux density value,
3. digit : size error in units of 20″,
4. digit : error of the position angle in units of 5°. « C » denotes confused sources.

4.2 THE CONTOUR MAPS. — The 11 cm survey plates of 2°.2 × 3° are shown in galactic coordinates in figure 3 to figure 42 with a 1° grid of equatorial coordinates (Epoch 1950) superposed. The contour lines are labelled of relative brightness temperature with the following contour intervals above the 0 K contour which is shown dashed :

0	K to	1	K in	50 mK	steps, labelled every	0.25	K
1	K to	1.8	K in	80 mK	steps, labelled every	0.4	K
1.8	K to	3	K in	120 mK	steps, labelled every	0.6	K
3	K to	5	K in	200 mK	steps, labelled every	1	K
5	K to	10	K in	500 mK	steps, labelled every	2.5	K
10	K to	30	K in	1 K	steps, labelled every	5	K
30	K to	80	K in	2 K	steps, labelled every	10	K
80	K to	400	K in	10 K	steps, labelled every	40	K

Arrows on contour lines point towards temperature minima.

Comments to figures 3 to 42 :

Figure 3. — The field 357°.4 ≦ l ≦ 358°, −0°.6 ≦ b ≦ 0°.75 was observed three times and the relative zerolevel was found at b = 0°.75 and b = − 0°.6. It was adjusted to the area l ≧ 358° by adding a planar temperature distribution for a smooth continuation of both maps.

Figures 5, 6. — Small scanning effects at l ~ 2°.4-2°.5. From 1°.6 ≦ l ≦ 3°.266 one of two coverages was observed at a centre frequency of 2675 MHz with 40 MHz bandwidth. Discontinuity at l ~ 5°, b ~ − 1°.5 due to extension limit. Only one useful coverage for 4° ≦ l ≦ 5°.

Figures 13, 14. — Scanning effects at l ~ 17°.2 and probably at l ~ 19°.3-19°.4.

Figures 21, 24. — Discontinuity at l ~ 34°.9, b < − 0°.5 and at l ~ 41°, b < − 0°.7.

Figures 29, 30, 31. — Scanning effects at l ~ 50°.6-50°.7, b < − 0°.6 and l = 52°.5, b ≦ − 0°.4. For the area 52°.5 ≦ l ≦ 54°.5 only one coverage could be used.

Figure 39. — Discontinuity at l ~ 70°.4, b > + 1°.1.

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