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The Molonglo Deep Sky Survey of Radio Sources. II* Declination Zone $-62°$

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Abstract

Results are given for the second zone of a deep survey made at 408 MHz with the Molonglo cross. The catalogue lists positions and flux densities for 95 sources, none of which has been previously catalogued, in a solid angle of $5 \cdot 51 \times 10^{-3}$ sr. The right ascensions covered (with some excluded areas) are $18^h 26^m$–$00^h 06^m$, with a range in declination of $45'$. The lower limit of flux density is 84 mJy. An upper limit of 1000 mJy has also been imposed. The position uncertainties are typically $12''$ at 100 mJy and $6''$ at 250 mJy.

1. Introduction

The first instalment of the Molonglo deep sky survey, made at $-20°$, is given in Part I (Robertson 1977*a*, present issue pp. 209–30), while the number–flux density counts from both instalments are given in Part III (Robertson 1977*b*, present issue pp. 241–9). The present paper gives the second instalment of the deep sky survey, and contains the results from declination zone $-62°$. The sensitivity of the Molonglo cross is greater at declinations well south of the equator, due to the increased time taken for each source to transit through the beams of the telescope. The improvement in sensitivity for this survey relative to that at $-20°$ was, however, not as great as expected (Robertson 1976).

2. Preparation of Catalogue

(*a*) *Observations and Analysis*

Reference should be made to Part I for a description of the observations and the telescope. The discussion here will be limited mainly to those aspects in which the present survey differs from that of Part I. The beamwidth of an individual pencil beam was $2' \cdot 63$ in right ascension and $3' \cdot 19$ in declination. The observations for this survey were made during the same observing session as for the $-20°$ zone, extending over 16 days in September 1973. Observations were made on seven adjacent declination settings, with two independent scans being made on each setting.

The same general procedure was followed for averaging and analysing the data as for the $-20°$ zone. Minor modifications of the source fitting program were required to allow for the greater transit time of sources at southern declinations. The program fitted all responses which had an observed flux density greater than a discrimination level of 60 mJy, but the lower limit finally adopted for the catalogue

* Part I, *Aust. J. Phys.*, 1977, 30, 209–30.

was 84 mJy. The fit to a point source model was again preferred except in the few cases of considerably extended sources. The fully averaged data records were plotted and inspected as for Part I. In contrast to the $-20°$ survey, there were no sources above the lower limit (84 mJy) that were seen on the line scans but not found by the computer program. The same criteria as for Part I were used to make consistent decisions in ambiguous cases of cataloguing, except that an allowance was made for the different beamshape when considering the resolution of two closely spaced responses. Responses were regarded as resolved if they had a separation greater than $4'\cdot0$ for flux density ratios between one and two, while $4'\cdot8$ or more was required if the flux density ratio was between two and five.

Table 1. Right ascensions (1950·0) excluded from catalogue

R.A. range		R.A. range		R.A. range		R.A. range	
h m s	h m s	h m s	h m s	h m s	h m s	h m s	h m s
18 42 08 to	18 50 00	20 15 42 to	20 17 50	21 35 14 to	21 37 14	23 19 33 to	23 21 33
18 53 21	18 55 51	20 19 04	20 23 10	21 49 25	21 56 16	23 25 10	23 26 40
19 06 20	19 10 20	20 26 22	20 31 10	22 04 11	22 06 11	23 30 54	23 32 54
19 11 20	19 17 31	20 40 11	20 42 37	22 08 27	22 10 27	23 36 17	23 39 27
19 18 59	19 23 55	20 53 33	20 56 26	22 22 31	22 26 51	23 49 16	23 51 16
19 30 32	19 39 56	20 58 24	21 03 10	22 37 47	22 40 07	23 52 50	00 00 42
19 43 50	19 45 10	21 17 01	21 19 01	22 52 53	22 56 30	00 02 23	00 04 23
19 52 56	19 55 55	21 20 59	21 22 59	23 06 51	23 08 51		
20 02 20	20 07 03	21 24 37	21 30 26	23 10 58	23 15 24		

Table 2. Areas (1950·0) excluded due to possible east–west sidelobes

R.A. range		Dec. range		R.A range		Dec. range	
h m	h m	° ′ ″	° ′ ″	h m	h m	° ′ ″	° ′ ″
19 31 to	19 44	−62 14 52 to	−62 20 26*	23 07 to	23 17	−62 22 45 to	−62 25 10*
20 35	20 48	−61 40 07	−61 48 04	23 09	23 20	−61 47 43	−61 55 41
20 55	21 05	−61 38 17	−61 42 15*	23 45	23 55	−62 07 00	−62 14 59
21 52	22 01	−62 13 41	−62 21 41	23 56	00 04	−61 40 46	−61 43 09*

* Exclusion extends to the declination edge of the survey.

(*b*) *Sidelobes and Excluded Areas*

The most prominent sidelobes of the Molonglo cross lie in a north–south line through the source producing them. To eliminate these sidelobes use was made (as in Part I) of the preliminary Molonglo catalogue of all sources in the southern sky above about 1 Jy. Sources were selected which could produce a sidelobe of over 50 mJy in the survey area, for an assumed sidelobe amplitude of 4%. For each such sidelobe-producing source, a strip of sky 2^{m} wide in right ascension was excluded from the survey. Other strips of various widths in right ascension were eliminated owing to the presence of the hourly noise diode calibration signal and some periods of interference. The right ascensions excluded are given in Table 1 (the exact range of the survey being R.A. (1950·0) $18^{h}25^{m}30^{s}$–$00^{h}06^{m}28^{s}$). Eight sources within the survey area were strong enough to require exclusion of the areas affected by their east–west sidelobes. Table 2 specifies the areas removed in this way. Because of these processes of sidelobe removal, it was again necessary to cut off the catalogue at 1·0 Jy. The solid angle included in the survey, allowing for all the excluded areas, is $5 \cdot 51 \times 10^{-3}$ sr. About 39% of the initial area has been excluded. The precise declination limits of the catalogue are $\delta(1973 \cdot 8) = -61° 32' 41''$ and $-62° 17' 21''$.

(c) Calibration

In Part I a description was given of the calibrations of flux density and position for the September 1973 observing session, which included both declination zones of the deep survey. The 16 calibration sources used were spread over the range from $\delta = +10°$ to $-70°$, and thus allowed a determination of the calibrations as a function of declination. For flux density, the form of the gain *v.* declination curve is reasonably well known, and no more than about 5% uncertainty should be introduced by using this curve to predict the gain at one declination from the overall calibration. The declination dependence of the right ascension correction is very small (Hunstead 1972; Robertson 1976) and adds no significant uncertainty to the calibration at the two deep survey declinations. There was some difficulty in establishing the functional form of the declination correction (see Part I and Robertson 1976). However, this should add no more than a few seconds of arc uncertainty to the calibration. A check of this calibration against the declination scale for the preliminary Molonglo catalogue of sources above about 1 Jy was made using nine sources of over 900 mJy which occurred in the area surveyed at $-62°$ (see Robertson 1976). The mean difference in declinations was 2'', which is not significant.

3. Source Catalogue

The catalogue for the present survey is given in Table 3. The Molonglo catalogue number (column 1) is formed as before from the 1950 coordinates. Two sources with the same catalogue number have been distinguished by suffixes A and B in order of decreasing flux density. Columns 2–5 list the position coordinates and their r.m.s. errors, calculated from the relations

$$\sigma_\alpha = \{(162 \cdot 2/F)^2 + 0 \cdot 42^2\}^{\frac{1}{2}} \quad \text{sec. time}, \qquad \sigma_\delta = \{(1302/F)^2 + 3^2\}^{\frac{1}{2}} \quad \text{sec. arc},$$

where F is the catalogued flux density in mJy (see Section 4*c* below). The flux density in mJy is given in column 6, and its r.m.s. error calculated from

$$\sigma = \{(17 \cdot 84)^2 + (F/25)^2\}^{\frac{1}{2}} \quad \text{mJy}$$

is given in column 7. No account has been taken here of the variation of the r.m.s. flux density error with flux density (see Section 4*a*). A plus sign following any of the r.m.s. errors indicates that the error should be increased, in a few cases substantially, due to extension of the source or for some other reason. In these cases, further information is given in the notes following the table. The remarks used in column 8 are: *Integ.* shows that an integrated flux density is given; *Fig. N* indicates that a contour map of the source is given in Fig. *N*. For other notes a reference is given in column 8 to the footnotes to the table.

Seven contour maps (Figs 1–7) are given of sources showing extensions or close companions. These include the majority of suitable sources. The effective half-power beamshape is shown by the ellipse in the insert to each map. Uncertainties in the background levels as assessed by the contouring program again render the contour maps unsuitable for obtaining integrated flux densities.

4. Error Analysis

(a) Flux Density Errors

The method of error analysis was similar to that for Part I, which should be referred to for details and notation. In the present survey, synthetic Monte Carlo sources were added to the fully averaged data and analysed, in the following numbers: 494 at 100 mJy, 245 at 150 mJy and 498 at 200 mJy. Fig. 8 shows the distribution of values of F obtained from the Monte Carlo sources of S = 100 mJy. This is (within statistical uncertainties) the function $P(F\,|\,S)$ for S = 100 mJy. A gaussian function

Table 3. Molonglo deep sky survey at −62°

(1) Molonglo catalogue number	(2) R.A. h m s	(3) Position (1950·0) RMS error	(4) Dec. ° ′ ″	(5) RMS error	(6) S_{408} (mJy)	(7) RMS error	(8) Notes
1825−616	18 25 52·5	0·9	−61 40 07	7	199	20	
1825−615	18 25 59·1	1·1	−61 35 04	9	160	19	
1827−616	18 27 12·2	1·4	−61 40 43	11	120	18	
1827−622	18 27 44·3	1·2	−62 16 20	9	149	19	
1829−619	18 29 05·9	1·4	−61 55 32	11	123	19	
1829−620	18 29 40·6	0·6	−62 00 54	4	456	26	
1831−618	18 31 28·0	1·1	−61 50 27	9	162	19	
1832−617	18 32 29·2	1·3	−61 46 11	10	133	19	
1835−615	18 35 30·8	0·5	−61 34 47	4	663	32	
1835−620	18 35 32·0	0·5+	−62 05 26	4+	591	30+	Integ., Note 13
1835−619	18 35 39·4	0·7	−61 55 06	5	314	22	
1837−618	18 37 11·8	1·0	−61 51 48	8	180	19	
1837−619	18 37 14·2	1·7	−61 59 26	13	101	18	
1839−615	18 39 13·9	0·6	−61 35 47	5	337	22	
1859−621	18 59 10·1	0·9	−62 07 01	7	204	20	
1902−623	19 02 10·0	0·8	−62 18 01	6	241	20	
1902−618	19 02 52·5	0·7	−61 49 07	6	265	21	
1905−621	19 05 04·0	0·8	−62 06 43	6	243	20	
1910−616	19 10 29·7	0·9	−61 39 47	7	213	20	
1910−621	19 10 36·3	0·7+	−62 10 29	5+	285	21+	Integ., Fig. 1
1918−618	19 18 40·7	1·0+	−61 52 53	8+	169	19+	Integ., Fig. 2, Note 16
1930−623	19 30 15·4	1·5	−62 18 55	12	110	18	
1940−618	19 40 03·3	1·9	−61 53 32	15	86	18	
1945−621	19 45 45·1	1·7	−62 09 03	14	98	18	
1949−622	19 49 45·9	1·4+	−62 14 42	12+	117	18+	Fig. 3, Notes 4, 5
1951−616	19 51 40·8	1·1	−61 39 44	9	161	19	
1952−619	19 52 17·5	0·5	−61 55 21	4	520	27	
1958−621	19 58 00·8	1·2	−62 10 09	10	140	19	Note 5
2008−618	20 08 11·5	0·5+	−61 51 33	4+	556	29+	Integ., Fig. 4, Note 13
2009−616	20 09 16·6	1·5	−61 38 40	12	113	18	
2023−623	20 23 27·1	0·5	−62 18 12	3	995	44	
2032−617	20 32 48·5	0·9	−61 43 43	7	215	20	
2033−618	20 33 33·7	0·5	−61 52 03	4	715	34	
2034−621	20 34 03·7	0·7	−62 07 57	6	269	21	
2035−617	20 35 02·3	1·7	−61 45 22	14	97	18	
2039−620	20 39 33·2	1·2	−62 04 14	10	142	19	
2044−619	20 44 32·9	1·7	−61 59 09	14	97	18	
2046−621	20 46 02·0	0·8+	−62 08 30	6+	242	20+	Integ., Fig. 5, Note 13
2048−622	20 48 44·7	1·3	−62 15 50	11	127	19	
2053−621	20 53 10·8	1·7	−62 09 25	14	98	18	
2104−619	21 04 57·0	1·9	−61 54 42	15	89	18	
2104−622	21 04 57·9	1·3	−62 17 35	11	128	19	
2107−622	21 07 01·6	1·2	−62 12 42	10	144	19	
2109−618B	21 09 30·0	1·1+	−61 48 11	9+	155	19	Fig. 6, Note 13
2109−618A	21 09 35·0	0·7+	−61 52 50	6+	266	21	Fig. 6, Note 13

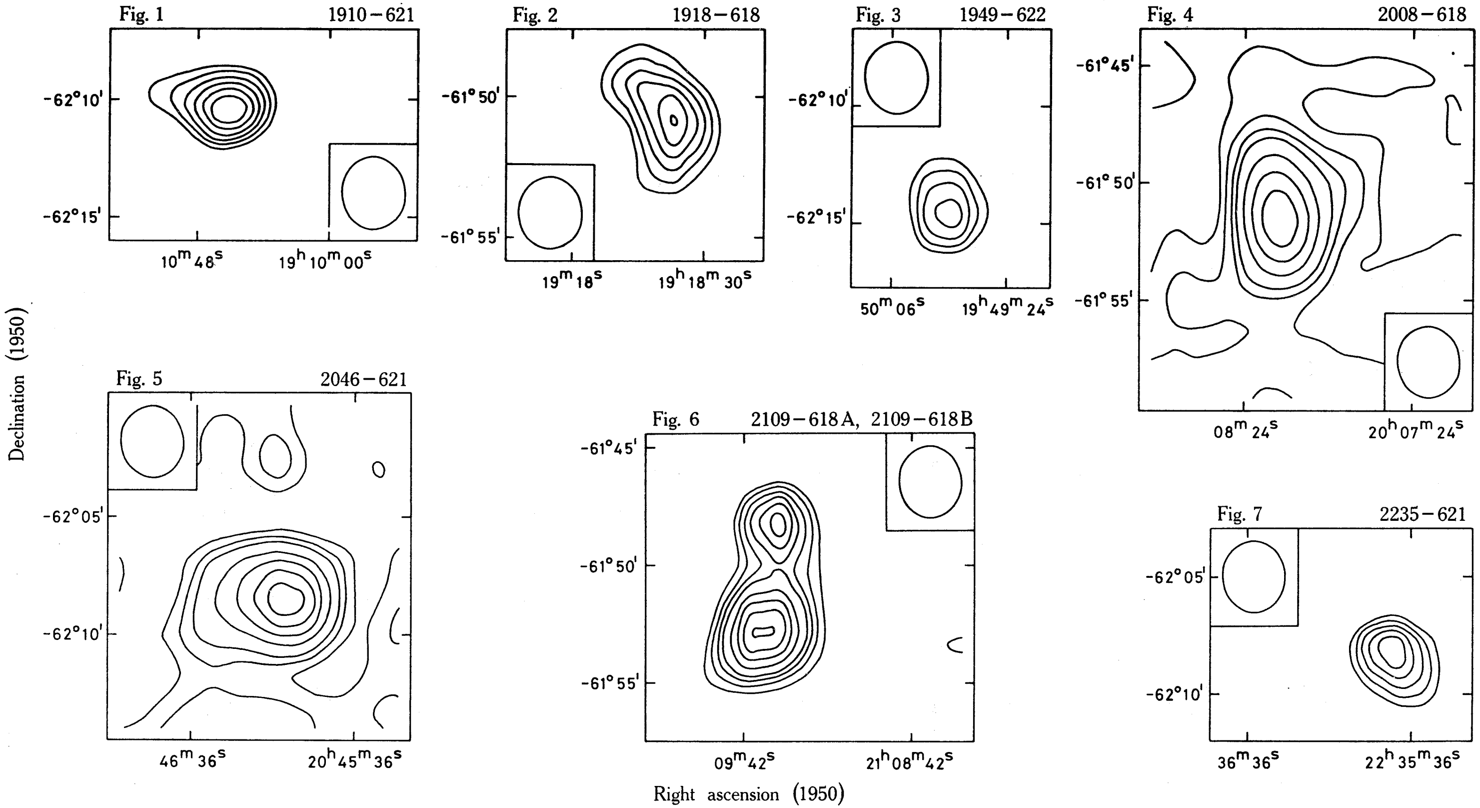
Table 3 (*Continued*)

(1) Molonglo catalogue number	(2) R.A. h m s	(3) Position (1950·0) RMS error	(4) Dec. ° ′ ″	(5) RMS error	(6) S_{408} (mJy)	(7) RMS error	(8) Notes
2110−621	21 10 50·0	1·5	−62 09 42	12	113	18	
2111−622	21 11 44·2	1·3	−62 14 39	10	134	19	
2114−617	21 14 21·8	0·7	−61 46 21	5	311	22	
2119−619	21 19 32·9	1·4	−61 59 42	11	124	19	
2120−622	21 20 04·9	1·5	−62 15 03	12	111	18	
2131−622	21 31 28·7	0·5	−62 17 48	4	529	28	
2133−621	21 33 01·1	1·1	−62 11 56	8	164	19	
2133−619	21 33 57·6	0·8	−61 58 39	6	231	20	
2137−617	21 37 16·4	1·9	−61 43 32	15	86	18	
2139−623	21 39 23·1	0·7+	−62 21 03	5+	292	21+	Integ.
2139−616	21 39 27·3	1·7	−61 40 17	14	98	18	
2141−619	21 41 49·4	1·7	−61 58 19	13	100	18	
2142−621	21 42 36·5	1·7	−62 06 23	14	97	18	
2148−623	21 48 16·8	1·9	−62 18 27	15	88	18	
2156−617	21 56 22·0	0·5	−61 42 22	4	699	33	
2200−617	22 00 26·8	0·8	−61 44 59	6	227	20	
2200−620	22 00 29·8	0·9+	−62 00 42	7+	194	19	Note 5
2207−623	22 07 19·9	0·6	−62 19 40	5	353	23	
2207−620	22 07 26·3	0·7	−62 02 16	6	280	21	
2211−620	22 11 03·3	0·9	−62 01 09	7	216	20	
2216−616	22 16 15·0	1·2	−61 41 08	10	139	19	
2216−620	22 16 21·1	1·8	−62 02 08	14	94	18	
2226−620	22 26 55·2	1·4	−62 02 50	11	124	19	
2228−622	22 28 53·1	0·6	−62 15 49	4	456	26	
2229−621	22 29 02·8	0·6	−62 08 36	5	387	24	
2229−619	22 29 15·7	0·5	−61 58 52	3	724	34	
2231−621	22 31 55·0	0·8	−62 08 37	6	236	20	
2233−617	22 33 40·6	1·4	−61 47 33	11	126	19	
2234−619	22 34 13·4	0·9	−61 59 50	7	191	19	
2235−618	22 35 19·8	1·1	−61 53 26	9	159	19	
2235−621	22 35 42·7	1·5+	−62 08 05	12+	109	18+	Fig. 7, Notes 4, 13
2241−623	22 41 46·5	0·9	−62 23 29	7	209	20	
2245−619	22 45 34·1	1·3	−61 55 11	10	131	19	
2246−622	22 46 10·0	1·5	−62 16 49	12	109	18	Note 11
2259−616	22 59 22·8	0·8	−61 41 44	7	223	20	
2303−617	23 03 56·1	1·7	−61 45 11	14	96	18	
2303−618	23 03 59·5	0·6	−61 51 24	5	367	23	
2306−619	23 06 03·0	0·8	−61 56 31	6	244	20	
2315−619	23 15 48·7	0·5	−61 55 41	4	545	28	
2322−620	23 22 39·0	0·8	−62 04 43	6	226	20	
2322−617	23 22 49·7	0·8	−61 44 22	6	248	20	
2324−621	23 24 39·9	0·7	−62 11 22	6	266	21	
2330−620	23 30 08·4	0·5	−62 00 35	3	791	36	
2330−619	23 30 50·8	1·1+	−61 59 31	9+	162	19+	Note 4
2335−620	23 35 54·3	1·6	−62 00 55	12	108	18	
2340−617	23 40 40·4	1·3	−61 42 56	11	128	19	
2341−622	23 41 23·8	1·5	−62 16 54	12	111	18	
2346−618	23 46 52·9	1·3	−61 51 10	10	130	19	
2351−620	23 51 57·7	1·2+	−62 04 37	9+	147	19	Note 5
2351−622	23 51 58·1	1·6	−62 14 59	13	105	18	

Notes to Table 3

The numbering scheme of Part I has been adopted.

4, Probably extended, but integrated flux density not used (see Section 2*a*)
5, Flux density obtained manually from the line scans (see Section 2*a*)
11, Declination obtained manually from the line scans
13, Position obtained manually from the contour map
16, Right ascension obtained manually from the contour map



Figs 1–7. Contour maps of the indicated Molonglo sources. (See Table 4 for details of the maps.)

was fitted to the peak region, while an empirical fit was used in the tail region of larger F. The distributions for $S = 150$ and 200 mJy were fitted similarly. The gaussian fits to the three distributions gave an average bias of 2·2 mJy underestimation. Unlike the results for the $-20°$ survey, the resulting standard deviations varied significantly for the different values of true flux density. The values were 15·6 ±0·6 mJy at $S = 100$ mJy, 20·4 ±1·0 at $S = 150$ and 17·6 ±0·6 at $S = 200$ mJy.

Table 4. Details of contour maps

Fig. No.	Sources contained	Contour interval (mJy)	Comments
1	1910–621	15	zero level contour omitted
2	1918–618	15	zero level contour omitted; declination scale uncertain due to computer fault
3	1949–622	20	zero level contour omitted
4	2008–618	30	alternate contours omitted above fourth plotted
5	2046–621	15	alternate contours omitted above third plotted
6	2109–618A 2109–618B	20	alternate contours omitted above fourth plotted in the stronger component
7	2235–621	15	zero level contour omitted

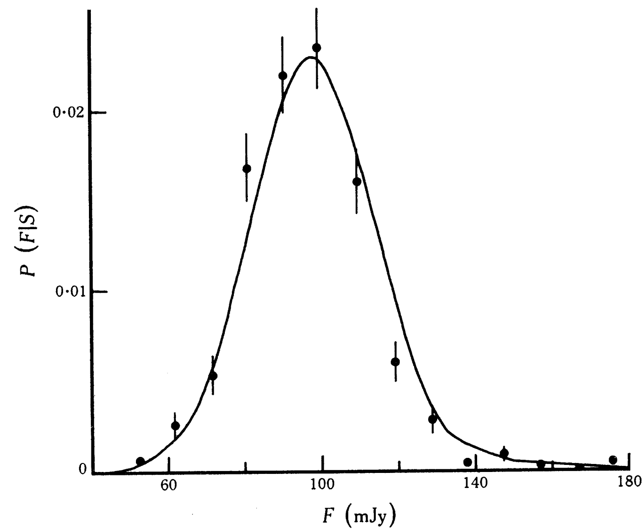


Fig. 8. Distribution of noise and confusion errors as obtained by analysis of Monte Carlo sources with a true flux density of 100 mJy. (See text for discussion of the fitted curve.)

Some increase of the component of the r.m.s. error due to confusion is expected with increasing flux density of the source, but the large value of the standard deviation at $S = 150$ mJy is almost certainly a chance fluctuation. The method used in Part III to calculate corrections to the counts takes account of the empirical variation of the standard deviation. The lower limit of the survey (84 mJy) is at or above five times the r.m.s. error for any reasonable fit to the observed standard deviations as a function of S.

The contribution of noise alone to the r.m.s. error was examined by inserting a further 247 Monte Carlo sources into records formed by subtraction of the independent scans, thus removing the effects of confusion. This gave an r.m.s. noise error of $13\cdot1 \pm 0\cdot7$ mJy. The contribution due to confusion is $12\cdot4 \pm 1\cdot1$ mJy for $S = 200$ mJy, although this value refers only to the gaussian part of the distribution, and its uncertainty is purely formal because of the variation of the total error with flux density. The analysis of flux density errors using comparisons of two independent observations of each source in the survey was not made for the $-62°$ catalogue, but it is expected that the random calibration errors of $\sim4\%$ derived in this way for the $-20°$ survey will apply here also.

(*b*) *Completeness and Reliability of Catalogue*

The definitions for completeness and reliability that are used in this work are given in Part I. The completeness has been calculated for the present survey using the error distributions obtained from the Monte Carlo analysis. For a lower limit of 84 mJy, the completeness is $89\cdot7\% \pm 1\cdot0\%$, allowing for noise, confusion and obscuration; while it is $93\cdot3\% \pm 0\cdot2\%$, allowing for noise and confusion only. For a flux density limit of 120 mJy, the respective values are $92\cdot6\% \pm 0\cdot7\%$ and $95\cdot0\% \pm 0\cdot2\%$. The values at the lower limit of 84 mJy are slightly higher than for the $-20°$ catalogue at 88 mJy ($87\cdot6\%$ and $92\cdot2\%$), thus providing further evidence for the safety of the present lower limit (88 mJy represents five times the r.m.s. error at $-20°$). With regard to reliability, the statements made in Section 7 of Part 1 apply here also, and the catalogue is expected to be highly reliable.

(*c*) *Uncertainties in Source Positions*

Position uncertainties were assumed to have the form

$$\sigma^2 = A^2/F^2 + B^2,$$

where the first term is due to noise and confusion, and the second to random calibration errors. The Monte Carlo sources showed that noise and confusion alone give $\sigma_\alpha = 11''\cdot5 \pm 0''\cdot6$ and $\sigma_\delta = 13''\cdot0 \pm 0''\cdot7$ at 100 mJy. The r.m.s. calibration errors can again be taken as 3″ in both coordinates. The method of comparing independent fits to the same survey source was used to assess the r.m.s. error due to noise alone. It showed that noise and confusion make comparable contributions to the overall uncertainties.

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