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A final non-redundant catalogue for the 7C 151-MHz survey

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ABSTRACT

We present a final unified catalogue for the 7C survey at 151 MHz with resolution 70×70 cosec(δ) arcsec^2. This has been constructed by amalgamating the existing catalogues derived from individual fields imaged at this resolution and eliminating redundancy in regions of mutual overlap. This is a non-trivial procedure because the flux in multiple-component sources may be fitted differently on alternative images, owing, for example, to differences in local noise and beam distortion. Separate final catalogues have been published for the 7C Galactic Plane survey (7CG) and the lower-resolution survey of the low-declination strip $9^{\mathrm{h}} <$ RA $< 16^{\mathrm{h}}$, $20^\circ <$ Dec $< 35^\circ$.

Key words: catalogues – surveys – radio continuum: general

1 INTRODUCTION

The 7C survey was performed using the Cambridge Low Frequency Synthesis Telescope (CLFST) operating at 151 MHz with a resolution of 70×70 cosec(δ) arcsec^2. The CLFST is a dual-frequency instrument capable of operating at 151 or 38 MHz; general principles of its operation are described by Rees (1990). Further details specific to methods at 151 MHz are available in McGilchrist et al. (1990), but the methods used to extract sources from the images and the parameters derived for listing in the source catalogue have been modified since that paper. The crux of the algorithm is the beam-set method described by Waldram & McGilchrist (1990), which deals with the distortion of the synthesized beam arising from unavoidable offsets in the E–W alignment of the baselines of the CLFST. Waldram & Riley (1993) describe how this procedure was refined and extended to automate the estimation of integrated fluxes, using methods akin but not identical to those developed by Rees for 38-MHz operations. They include an example of its application to a survey field and a detailed error analysis. This improved algorithm was used in the analysis of the 100 or so individual fields (telescope pointings) which contribute to the catalogue described in this paper.

2 CONTRIBUTING FIELDS AND SKY COVERAGE

The individual catalogues for the fields analysed as above are available in uniform format from the 7C survey web page `http://www.mrao.cam.ac.uk/surveys/7C/`. The data reduction was performed by a number of groups of authors to service the needs of various different projects and so the results were originally released in batches – details of the fields in each batch and any specifics relating to their analysis are given by Lacy et al. (1995), Visser et al. (1995), Pooley, Waldram & Riley (1998), Riley, Waldram & Riley (1999); the final batch of 58 fields was only released electronically – see ftp link `ftp://ftp.mrao.cam.ac.uk/pub/7C/Riley_more/`, accessible under `a further 58 fields` from the web page above. The fields originally reduced by McGilchrist et al. (1990) using an earlier source analysis regime have been reanalysed and now appear in this final batch of 58. The organization of data on the 7C webpage is self-explanatory; for each batch of catalogues, links are provided to the descriptive publication and to a subdirectory containing the catalogue files in ASCII format and a ReadMe file listing the sky coverage, average rms noise, faintest source catalogued and completeness limit for each field.

Fig. 1 shows in equatorial plane projection the sky coverage provided by the ∼100 fields contributing to the main 7C survey at resolution 70×70 cosec(δ) arcsec^2. There are separate final catalogues for the 7C survey of the Galactic Plane (7CG) (Vessey & Green 1998) and the lower-resolution (108×108 cosec(δ) arcsec^2) 7C survey of the low-declination strip $9^{\mathrm{h}} <$ RA $< 16^{\mathrm{h}}$, $20^\circ <$ Dec $< 35^\circ$ (Waldram et al. 1996). There is no intention to incorporate these regions into the present unified catalogue.

3 AMALGAMATING FIELDS AND ELIMINATING REDUNDANCY

As the first step in the unification process, the catalogues from all the individual fields were concatenated into a single

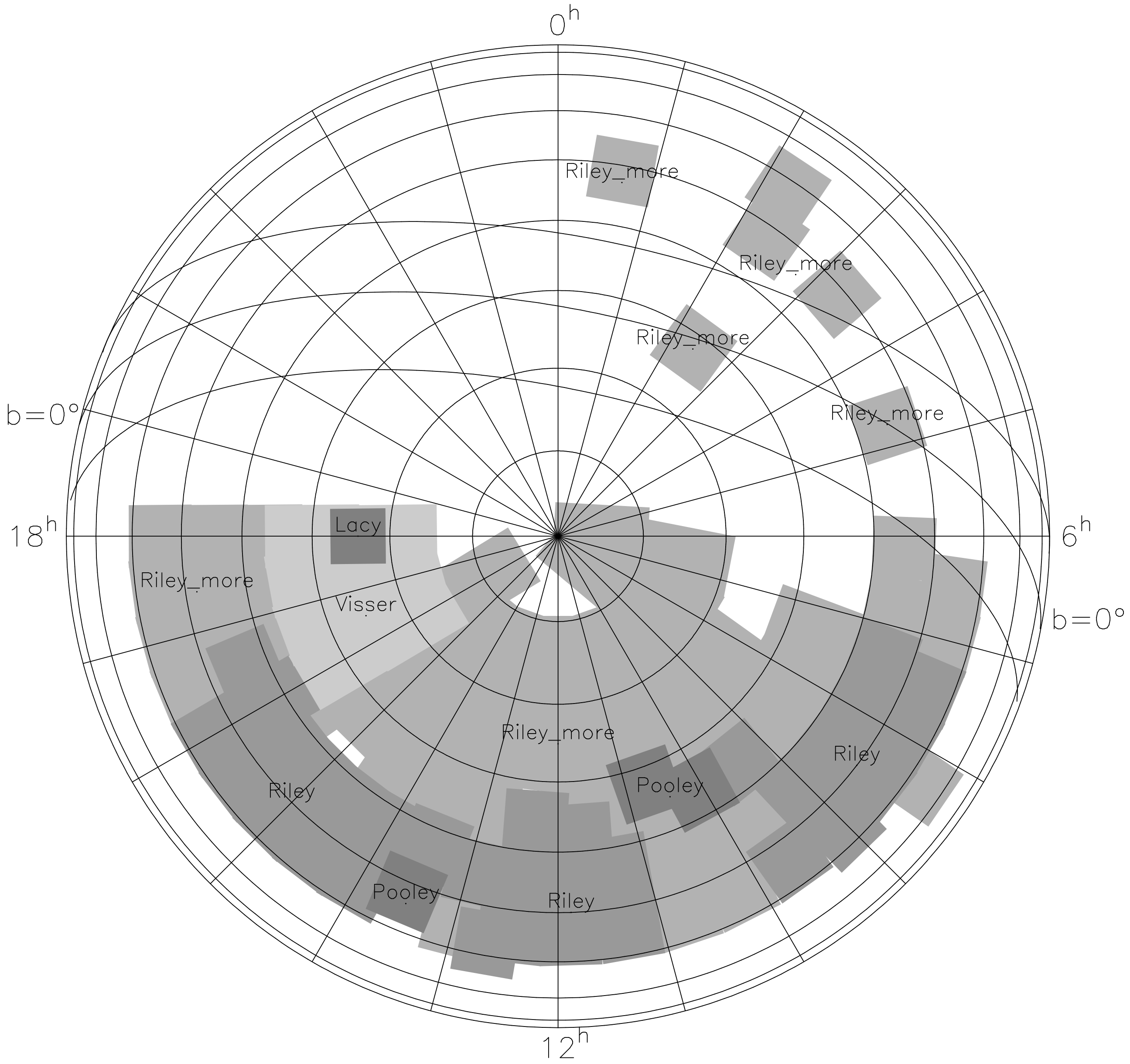

Figure 1. Equatorial plane projection of the northern sky showing the coverage provided by the ∼100 fields contributing to the present 7C survey at resolution 70×70 cosec(δ) arcsec^2. Circles of declination are marked every 10 degrees and lines of RA hourly, with lines of Galactic latitude plotted at $b = -10°, 0°, +10°$. The various depths of grey are used to denote the approximate regions covered by the source lists from the contributing papers as listed in Section 2. The nomenclature follows the names used for the subdirectories in which these data reside under `ftp://ftp.mrao.cam.ac.uk/pub/7C/` – linked from 7C web page `http://www.mrao.cam.ac.uk/surveys/7C/`.

compound catalogue, each having first been assigned an additional column to hold the name of the field from which the data in its constituent rows originated. To eliminate the redundancy due to the overlaps between fields from the compound catalogue, the principal requirements were a method of associating alternative descriptions of the same source and a rule to reduce these to one version to represent that source in the final catalogue. This rule might be a formula for some kind of weighted average or a criterion for selecting one alternative in preference to the others. Signal-to-noise ratio would be a reasonable basis for weighting or for making a selection.

For single isolated sources either possibility would be simple to implement. However, complex sources with multiple components are represented by an integrated flux estimate covering a region containing a number of fitted peaks, each individually listed in the catalogue. They can have radically different appearances and parametrizations from one field to another, owing to differences in local noise, residual artefacts and beam distortion effects; consequently, the regions integrated and overall number of components fitted are not always similar in the two versions, so individual components would not necessarily have one-to-one counterparts. This eliminated the possibility of averaging alternative versions. Moreover, it imposed a requirement that any algorithm for making a selection between alternatives should treat the alternative descriptions of a complex source en bloc rather than component by component, in order to produce a self-consistent description based on data from a single field to represent that source in the final catalogue, rather than a hybrid between results from different fields.

The strategy adopted therefore was to group together end to end the alternative descriptions of corresponding complex areas of flux and to select en bloc that description which contained the component with the highest signal-to-noise. For single isolated sources, the observation with the highest signal-to-noise ratio was used where there was a choice of measurements.

The implementation employed the STARLINK application TopCat, operating on the concatenation of catalogues from the individual fields. It was used first to associate the components of each complex region via their identical centroid positions and to flag them with a unique serial number denoting that region; it was then used a second time to associate alternative measurements of the components via their individual beam-fitted positions. Using a specially written computer program the flagged catalogue was sorted into a hierarchy of complex regions, by considering each complex in turn and writing out its rows en bloc followed by the rows comprising any alternative descriptions. The starting complexes for each of these considerations were treated in order of decreasing multiplicity; any other complex or single sources which contributed to the ensuing list of alternative descriptions were then discounted from all later considerations, in order to avoid accounting for the same flux twice. This may be best illustrated by means of an example: if a complex of multiplicity four had as a counterpart a complex of multiplicity three and a singleton, these lower multiplicity sources would then be discounted as starting points for potential groups of alternatives lower down in the hierarchy, since their flux was already represented in the earlier group. The hierarchical list was then read to select en bloc, from all available alternatives, the description of each complex source associated with the highest signal-to-noise detection for inclusion in the final catalogue. Those complexes which had no alternative description were automatically selected. All the remaining single sources not considered so far were then similarly treated. Any simple single counterparts were grouped together and, where there was a choice, the version with the highest signal-to-noise ratio was selected for inclusion in the final catalogue. Additionally those single sources which had no counterparts gained automatic entry. Overall, the method ensured that no flux was accounted for more than once in the final catalogue and that any sources not in overlap regions were automatically included.

4 THE FINAL CATALOGUE

The original partially-redundant catalogue of 57462 sources was thus reduced to a non-redundant final unified catalogue of 43683 sources. It is available together with a ReadMe file, in the format prescribed by the CDS Strasbourg in its Standard for Documentation of Astronomical Catalogues (`http://vizier.u-strasbg.fr/doc/catstd.htx`), via the 7C website `http://www.mrao.cam.ac.uk/surveys/7C/`. The columns are fully described in the ReadMe file and are summarized in Table 1. As well as the columns present in the original catalogues for the individual fields, two additional columns appear in this final catalogue. ICOMP is a serial number for each complex source; it can be used in conjunction with the multiplicity NMAX to associate the entries corresponding to the individual components of that complex. For single sources ICOMP is set to zero. MAPCEN is the name of the field from which the data for a particular source listed in the final catalogue originates. We should emphasize that the rms noise and hence the limiting flux density of the survey varies both within any one field and between different fields owing to beam distortion, primary beam and ionospheric effects. The ReadMe file lists by name MAPCEN all the fields which contributed to the final catalogue, summarizing the average rms noise, faintest source catalogued and completeness for each field. The user can, if required, refer to this information for a particular source in the catalogue which will have its MAPCEN specified therein; more importantly, it may be accessed for guidance in the case where the catalogue lists no explicit detection within acceptable proximity to a target position specified by the user.

Table 1. Columns of the final non-redundant 7C catalogue. The nomenclature of columns here is the same as that used in the ReadMe file accompanying the final catalogue, in accordance with the Standard for Documentation of Astronomical Catalogues prescribed by the CDS, Strasbourg. This convention labels the principal spherical coordinate pair as (RA,DE), and adds suffices to these root names for any additional spherical pair, such as (RAI,DEI) below. All coordinates in this paper are B1950, but a J2000 version of the final catalogue will be released in due course. Expressions for errors on the positions and flux densities are given in Appendix A.

RAh	Beam-fitted position RA (hours)
RAm	Beam-fitted position RA (minutes)
RAs	Beam-fitted position RA (seconds)
DE-	Beam-fitted position Dec (sign)
DEd	Beam-fitted position Dec (degrees)
DEm	Beam-fitted position Dec (arcmin)
DEs	Beam-fitted position Dec (arcsec)
RAIh	Centroid of integrated region, RA (hours)
RAIm	Centroid of integrated region, RA (minutes)
RAIs	Centroid of integrated region, RA (seconds)
DEI-	Centroid of integrated region, Dec (sign)
DEId	Centroid of integrated region, Dec (degrees)
DEIm	Centroid of integrated region, Dec (arcmin)
DEIs	Centroid of integrated region, Dec (arcsec)
S	Beam-fitted flux density (Jy/beam)
SINT	Integrated flux density (Jy)
SNR	Signal-to-noise ratio
EXTENT	Extent of the source (in local beam areas)
NMAX	Number of local maxima within integrated region
ICOMP	Serial number of complex source (0 if NMAX is 1)
MAPCEN	Name of the field from which data originates

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APPENDIX A: ERRORS

The following expressions give approximate estimates for the rms (1σ) errors on the positions and flux densities in the catalogue.

For the beam-fitted positions (RA, DE):

$$\sigma_{RA}(arcsec) = \sqrt{1^2 + (32/\ \mathrm{SNR})^2}$$

$$\sigma_{DE}(arcsec) = k\ \mathrm{cosec}(\delta)\sqrt{1^2 + (32/\ \mathrm{SNR})^2}$$

where k is a declination-dependent constant with value approximately 1.0 around $\delta = 70^\circ$ increasing to about 1.3 below $\delta = 50^\circ$.

For the flux densities (S, SINT):

$$\sigma_S(Jy/beam) = \ \mathrm{S}\sqrt{0.03^2 +\ \mathrm{SNR}^{-2}}$$

$$\sigma_{SINT}(Jy) = 1.5\ \ \mathrm{SINT}\sqrt{0.03^2 +\ \mathrm{SNR}^{-2}}$$