A new 408 MHz compact source catalogue

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CGPS data set

DRAO Synthesis Telescope:

408 MHz
Continuum Stokes I

7.5 MHz at 1407 MHz (A)
Continuum I, Q, U and V

7.5 MHz at 1414 MHz (B)
Continuum I, Q, U and V

256 channels of 4 MHz at 1420 MHz
HI
Atomic hydrogen

7.5 MHz at 1427 MHz (C)
Continuum I, Q, U and V

7.5 MHz at 1435 MHz (D)
Continuum I, Q, U and V

Accompanied by observations at other wavebands and matching resolutions (far-IR, $^{12}$CO survey and X-ray etc.)

Dust Molecular gas Ionized gas Taylor et al. 2003
DRAO Synthesis Telescope

408 MHz characteristics:

Field of view: 8.2 deg

Angular resolution: 2.8' x 2.8' cosec(DEC)

Spatial frequency coverage: 2.8' to 2.6 deg

System temperature: 105 K + T_{sky}

Continuum sensitivity: 3 mJy/beam (7x12 hrs)
Galactic plane coverage @ 408 MHz: $52 < l < 192; -6.7 < b < 8.7$
Area coverage: $\sim 2500 \text{ deg}^2$ (fairly uniform noise; extended area with degraded sensitivity)
1.4 GHz continuum and HI data taken simultaneously
## 408 MHz catalogues

<table>
<thead>
<tr>
<th>Suvey Name</th>
<th>Frequency (MHz)</th>
<th>Sky Coverage</th>
<th>Catalog Flux Limit (mJy) (5σ)</th>
<th>Source Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Third Bologna Sky Survey</td>
<td>408</td>
<td>37°15'&lt;δ&lt;47°37' (epoch 1978.0)</td>
<td>100</td>
<td>13354</td>
</tr>
<tr>
<td>Molonglo Reference Catalog</td>
<td>408</td>
<td>-85°&lt;δ&lt;18.5°,</td>
<td>1000</td>
<td>7347</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b</td>
<td>&gt; 3° (7.85 sr)</td>
</tr>
<tr>
<td>Fifth Cambridge Survey</td>
<td>408 (1407)</td>
<td>13 Pencil beams of diameter 4° (@ 408 MHz)</td>
<td>10</td>
<td>3220</td>
</tr>
</tbody>
</table>
Re-calibration of 408 MHz data

Need for re-calibration: Automatic Level Control System to ensure an almost stable sensitivity for digitized correlation; voltages are not recorded → absolute amplitude calibration from synchronized source observation not applicable

- Selection of calibration sources: spectrally well-behaved sources; used VLSS, 7C, Texas, WENSS, NVSS
- Derivation of calibration factors: comparison of map extracted flux with predicted flux from spectral fitting.
- In case of calibration sources shortage: utilization of adequate sources in overlapping neighbouring fields.
Calibration source selection
Spectral complexity

Spectral fitting: \[ \log S(\nu) = a + \alpha_1 \log \nu + (\alpha_2 \log^2 \nu + \alpha_3 \log^3 \nu) \]

Evaluation of spectral complexity: \[ \text{BIC} = \chi^2 + k \ln(n) \]

Discriminate against spectral complexity; select sources with power law spectra
Calibration factors

- Calibration factors derived from flux density extrapolation
- Selection of calibration sources by spectral simplicity and signal-to-noise ratios of catalogued flux densities.
- All source flux values are brought onto the same absolute flux scale.
Source extraction
Algorithm

• Tools:
  • The algorithm is based on DRAO Export Package routines
    – FINDSRC: Provides estimates on source coordinates and fitting parameters
      • Matched "point-source" wavelet filter to enhance point-like sources
      • Removal of point-source responses from the filtered image by Clark-like clean method
    – FLUXFIT: Source extraction using fitting boxes and parameters
      • computing flux densities, fitting Gaussians, correcting for beam shape, etc.
  
• Step-wise Procedure and iterations
  • Step 1: Iterative application of FINDSRC/FLUXFIT
  • Step 2: Iterative application of Tiling/FLUXFIT to go deep

DRAO export package: Higgs et al. 1997
Source extraction
At work

Positions of extracted compact sources (different styles indicate extraction step):

Residual image (extended emission and sources, noise):

5°x5°
Complex morphologies of radio sources → resolved into two or more closely separated components. Majority of sources in CGPS 408 MHz (resolution: ~3 arcminute) are unresolved -> Simplification of extraction. Otherwise multiple component sources can produce spurious clustering signal on small scales. However, this complicates matching with other catalogues of higher resolution.
Completeness and Contamination:

• Estimation by simulations: Introducing compact sources at various flux densities into the data.

• Estimation by extrapolation: Using other catalogues to extrapolate and derive expectations for source numbers and locations in the survey data.
Radio source counts

Differential source count:

\[ \frac{dN}{dS} = AS^{-\gamma} \]

Power law behaviour for \( S_{\text{lim}} = 15 \text{ mJy} \)

Flattening and turn over due to incompleteness for \( S < 15 \text{ mJy} \)
Spectral index for sources from CGPS 408 MHz catalogue matched with NVSS 1.4 GHz catalogue (source at the 5σ flux density limits of catalogues with $\alpha > 1.13$)

\[ S(\nu) = S_{1.4\text{GHz}} \left(\frac{\nu}{1.4\text{GHz}}\right)^{-\alpha} \]
Spectral source classification

Flux limits:

\( S > 15 \text{ mJy} \)

\( S > 200 \text{ mJy} \)

\( S > 500 \text{ mJy} \)

Probability of extragalactic source increases with flux density limit.
Final catalogue properties forecast:

- Expect to achieve a catalog of high completeness ($\geq 90$ percent) above a flux limit of $5\sigma_{\text{rms}}$ (15 mJy)
- At the detection limit of 15 mJy, we expect to obtain a contamination rate of < 10 percent
- Estimated total number: $\geq 40000$
- Majority extra-galactic radio galaxies
Compact source clustering
Angular correlation function

Flux limit:
15 mJy

Caution:
Likely includes extra-galactic radio galaxies and Galactic sources.

Reliable separation of source origin necessary

Employed estimator of Landy & Szalay 1993
Summary and future work

The CGPS catalogue provides a new window on the radio source population at 408 MHz (so far the largest catalogue established at this frequency)

Further characterization of sources (nature, radio spectral behaviour)

Cross-matching with other catalogues and data sets (e.g. FIRST (for position accuracy), Herschel, WISE, Planck, X-ray etc.)

Extension of this work to other data sets (e.g. SPIDER field; for comparison and to study complications in the Galactic plane)