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

Ionized gas, Magnetic fields

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

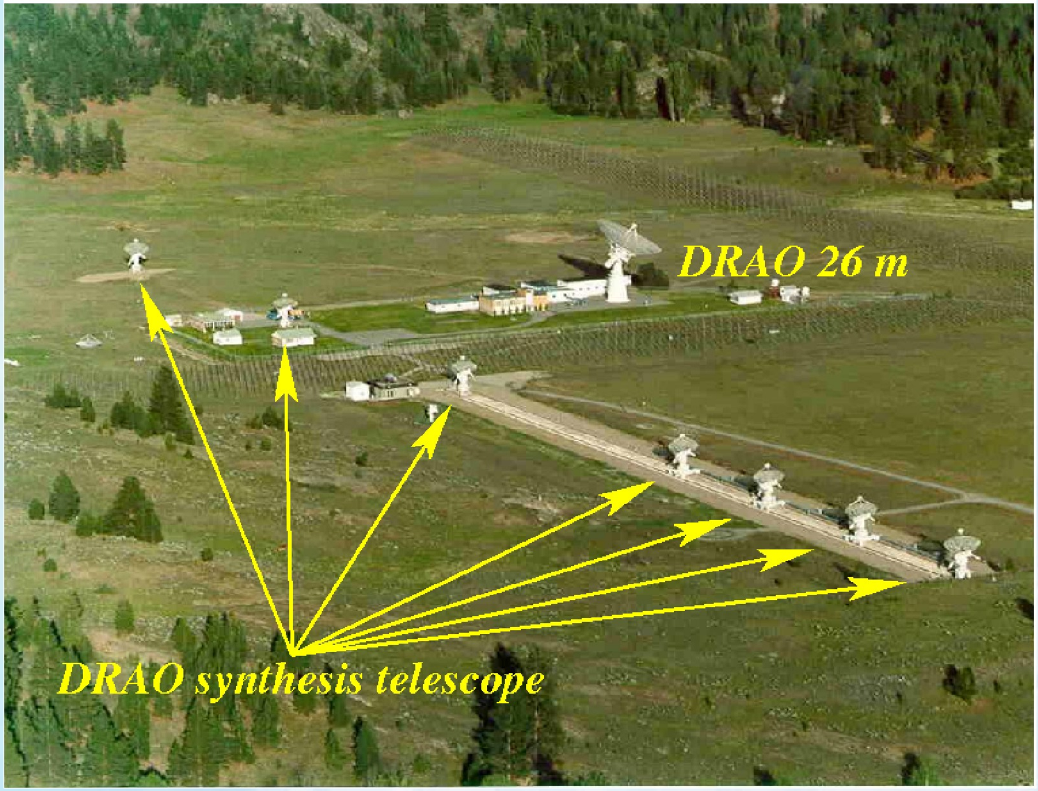
Ionized gas, Magnetic fields

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'x2.8'cosec(DEC)

Spatial frequency coverage:
2.8' to 2.6 deg

System temperature:
105 K + T_{sky}

Continuum sensitivity:
3 mJy/beam (7x12 hrs)

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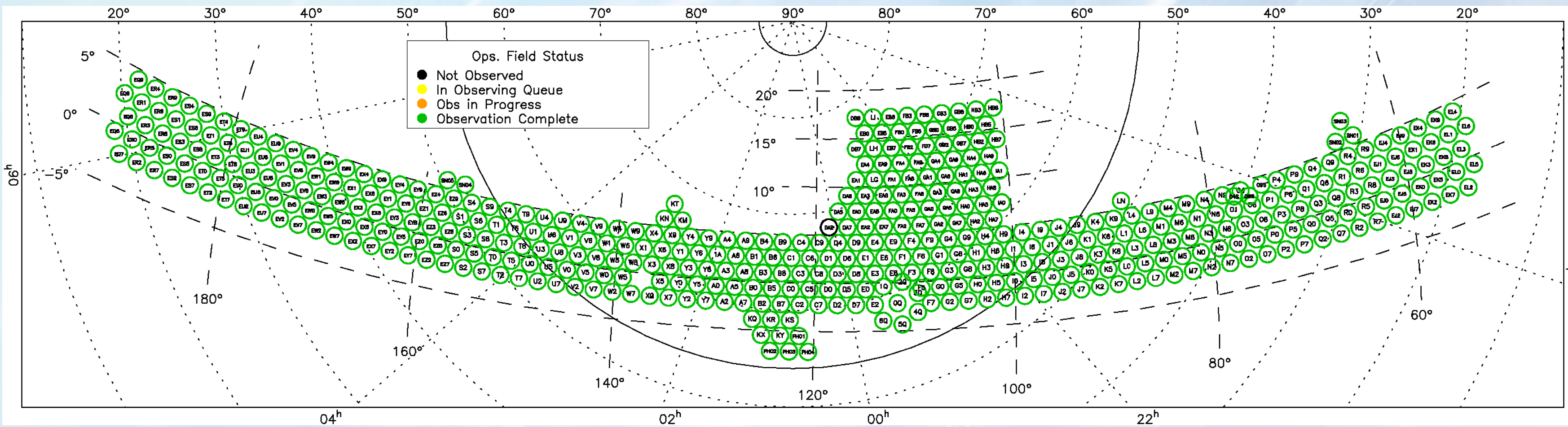
CGPS DRAO ST sky coverage



Galactic plane coverage @ 408 MHz: 52<l<192; -6.7<b<8.7
Area coverage: ~2500 deg^2 (fairly uniform noise; extended area with degraded sensitivity)
1.4 GHz continuum and HI data taken simultaneously

408 MHz catalogues

Suvey Name	Frequency (MHz)	Sky Coverage	Catalog Flux Limit (mJy) (5σ)	Source Number
Third Bologna Sky Survey	408	37°15'<δ<47°37' (epoch 1978.0)	100	13354
Molonglo Reference Catalog	408	-85°<δ<18.5°, |b| > 3° (7.85 sr)	1000	7347
Fifth Cambridge Survey	408 (1407)	13 Pencil beams of diameter 4° (@ 408 MHz)	10	3220

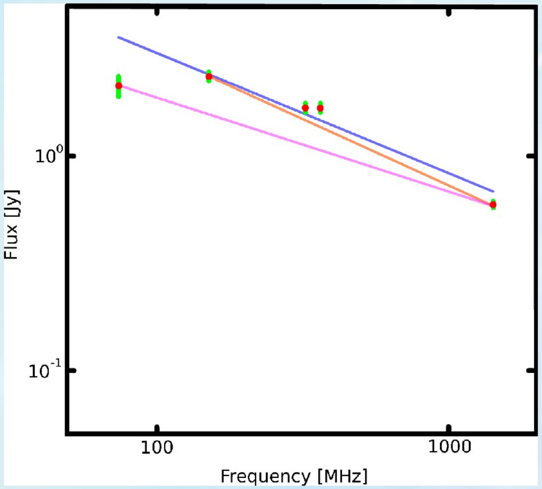
Re-calibration of 408 MHz data

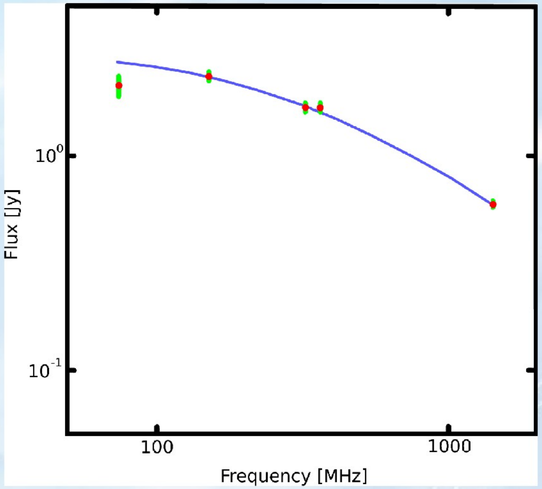
Need for re-calibration:
Automatic Level Control System to ensure an almost stable sensitivity for digitized correlation; voltages are not recorded → absolute amplitude calibration from synchronized source observation not applicable

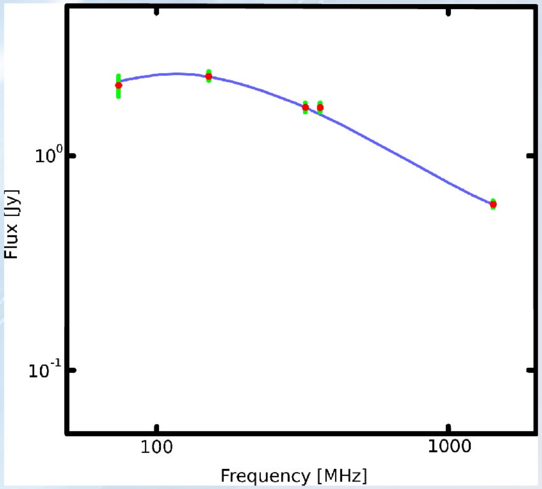
- Selection of calibration sources: spectrally well-behaved sources; used VLSS, 7C, Texas, WENSS, NVSS
- Derivation of calibration factors: comparison of map extracted flux with predicted flux from spectral fitting.
- In case of calibration sources shortage: utilization of adequate sources in overlapping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

Calibration source selection

Spectral complexity







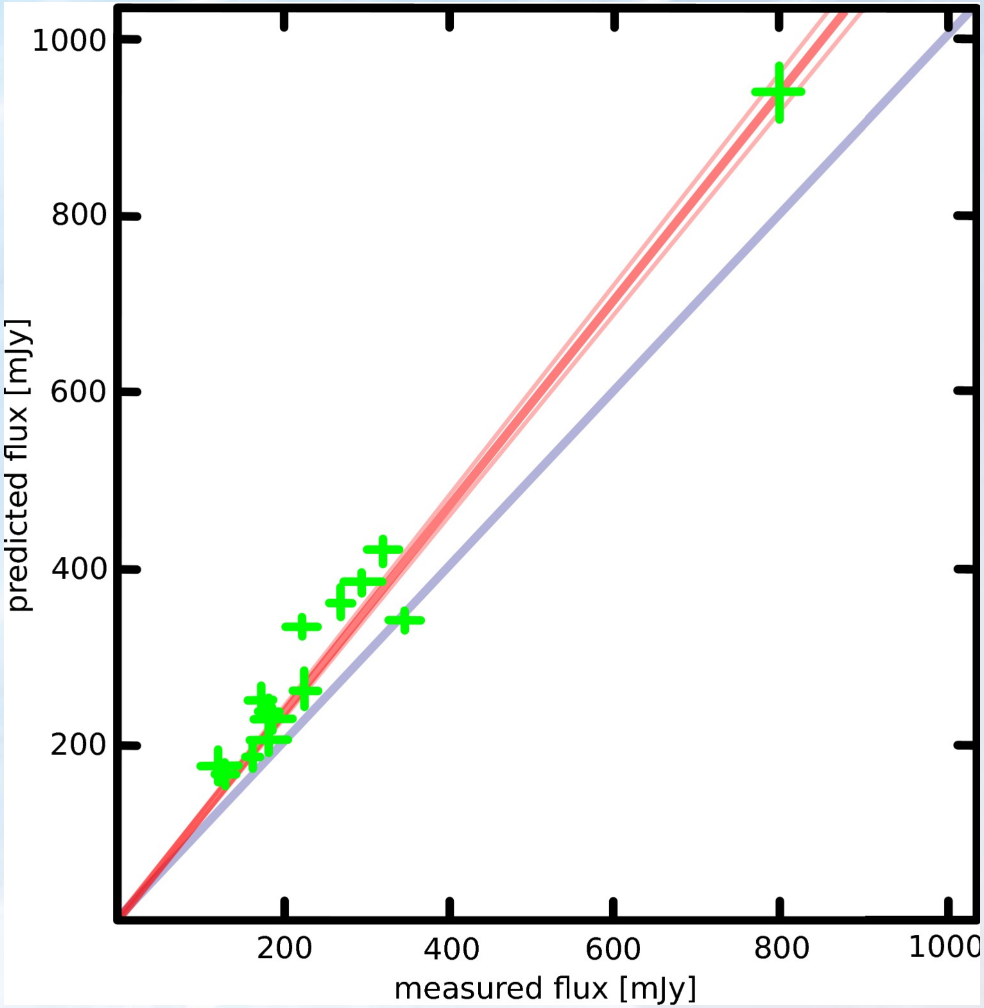
Spectral fitting: $$\log S(\nu) = a + \alpha_1 \log \nu + (\alpha_2 \log^2 \nu + \alpha_3 \log^3 \nu)$$

Evaluation of spectral complexity: $$\mathrm{BIC} = \chi^2 + k \ln(n)$$

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.



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Source extraction

Algorithm

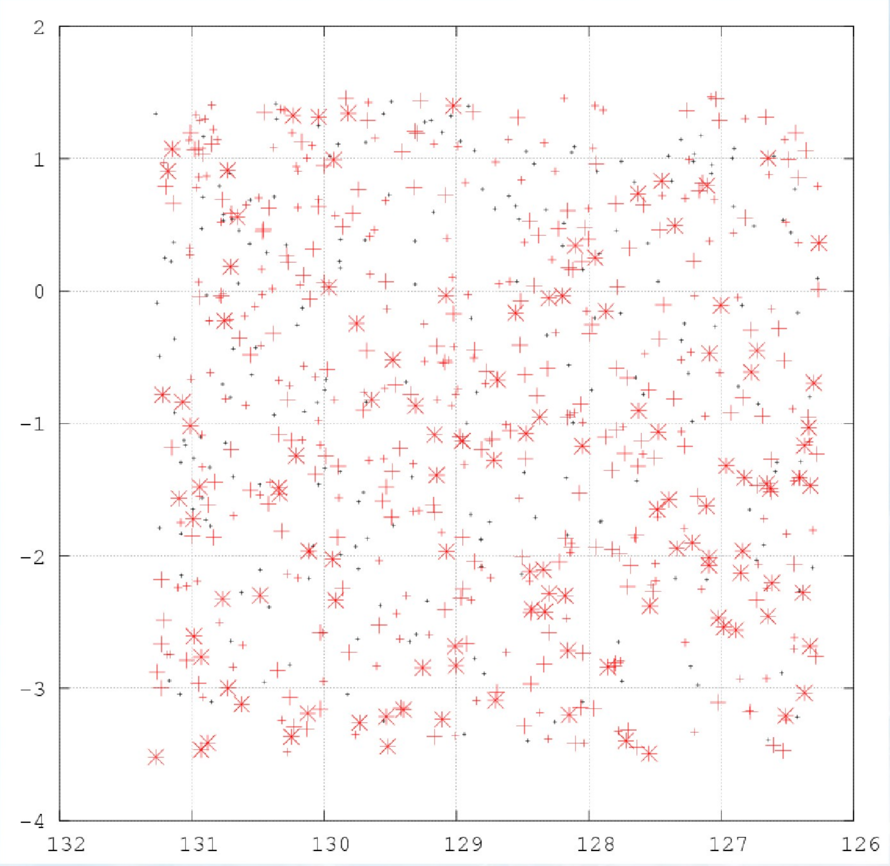
- Tools:
  - The algorithm is based on DRAO Export Package routines
    - ***FINDSRC***: Provides estimates on source coordinates and fitting parameters
      - Matched "point-source" wavelet filter to enhance point-like sources
      - Removal of point-source responses from the filtered image by Clark-like 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

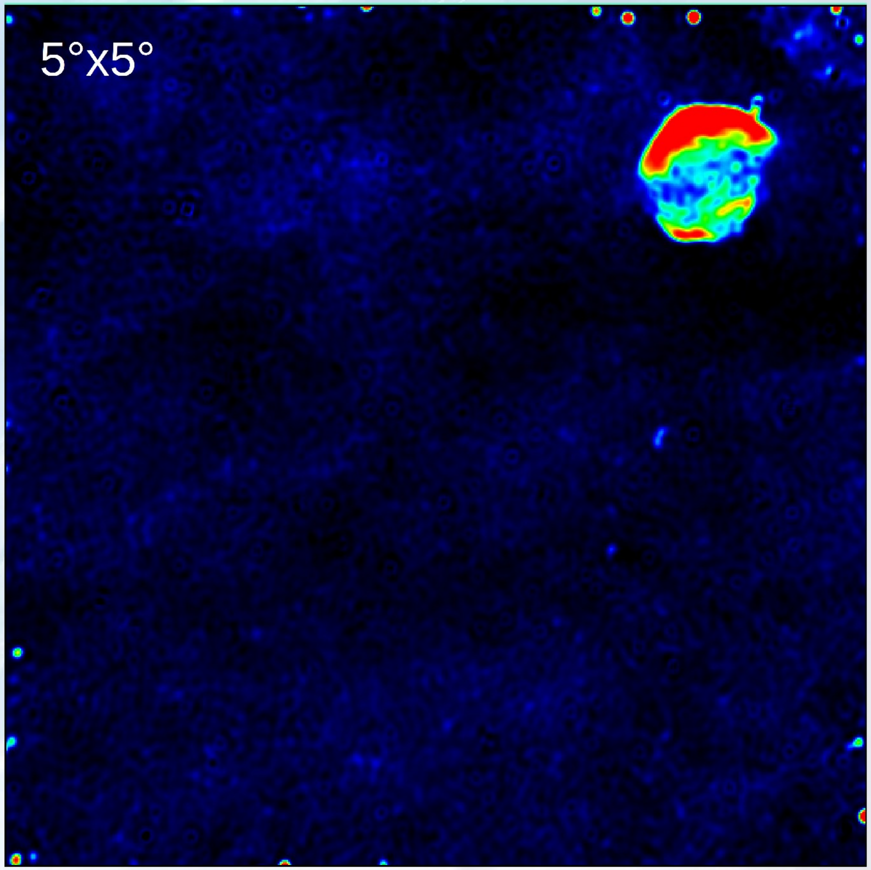
Source extraction

At work

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



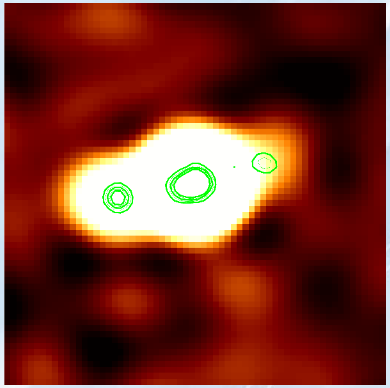
Residual image (extended emission and sources, noise):



Source extraction

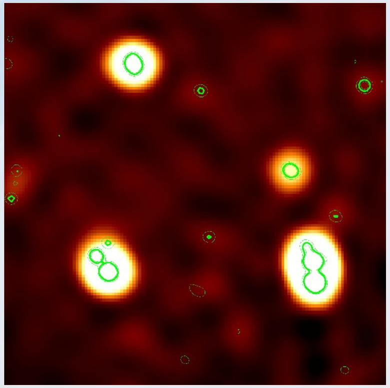
Caveats

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.



Radio galaxies: AGNs, jets and lobes

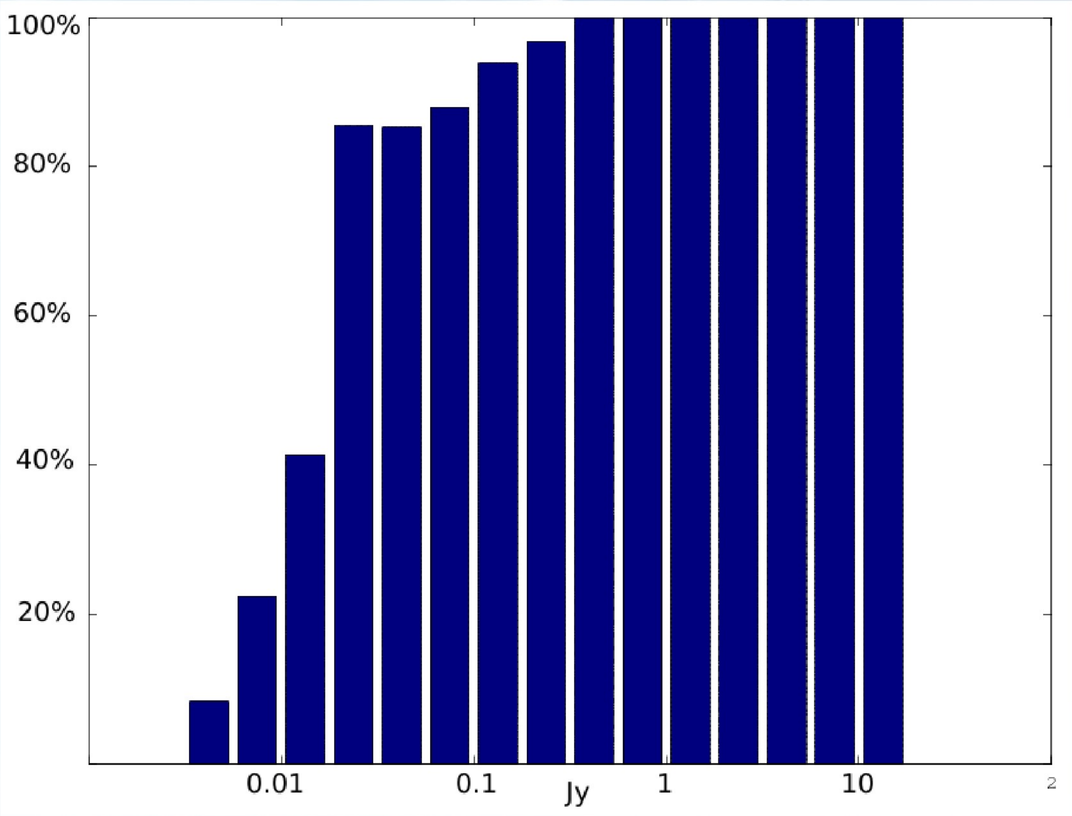
Contours: 1.4 GHz CGPS continuum data



Catalogue properties

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.



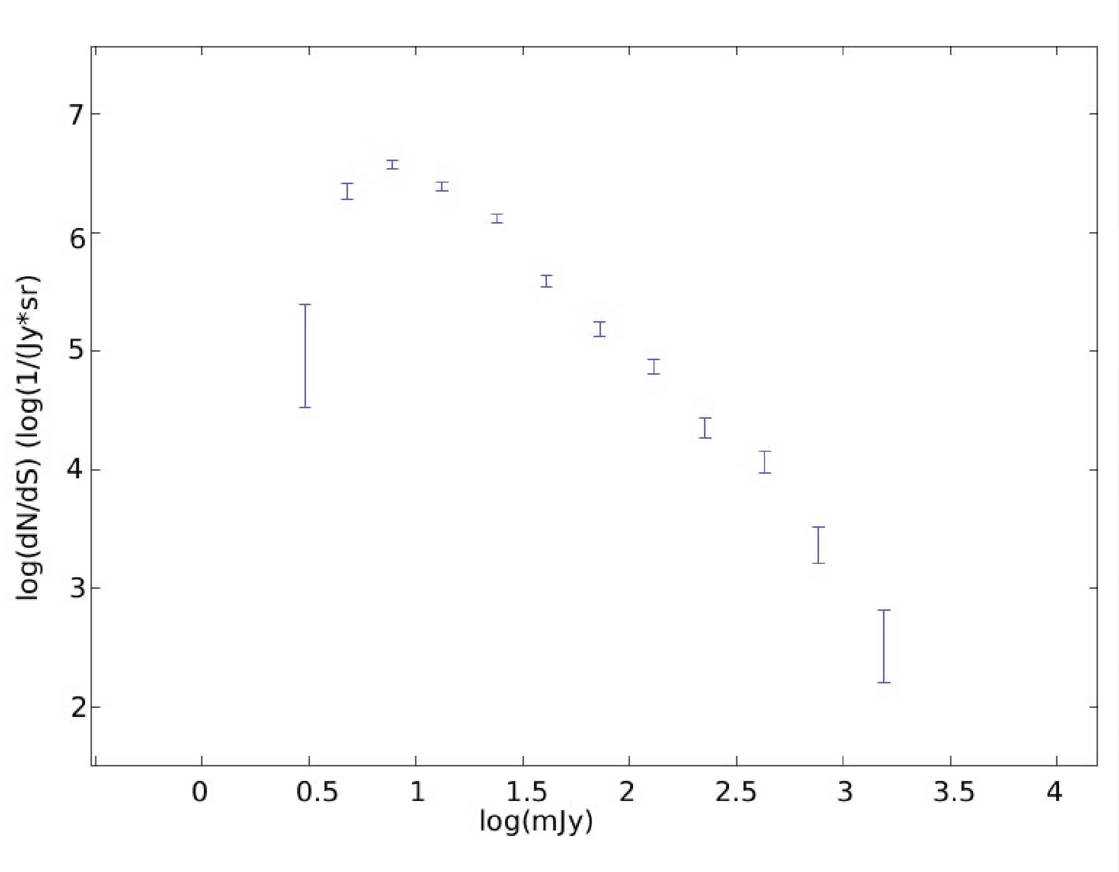
Radio source counts

Differential source count:

$dN/dS = AS^{-\gamma}$

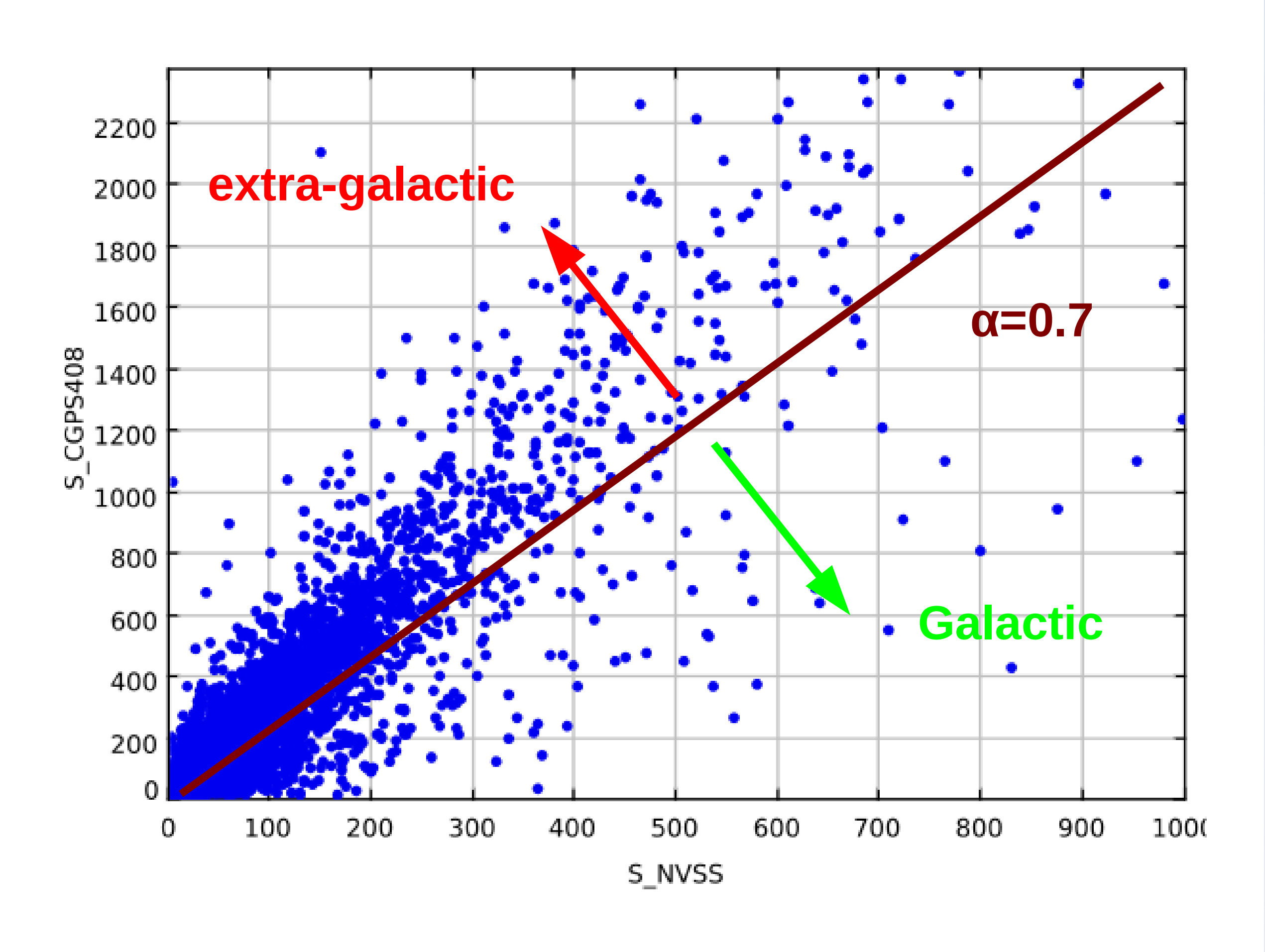
Power law behaviour for S_{lim}=15 mJy

Flattening and turn over due to incompleteness for S<15mJy



Spectral source classification

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 α > 1.13)



$$S(\nu)=S_{1.4GHz}(\nu/1.4GHz)^{-\alpha}$$

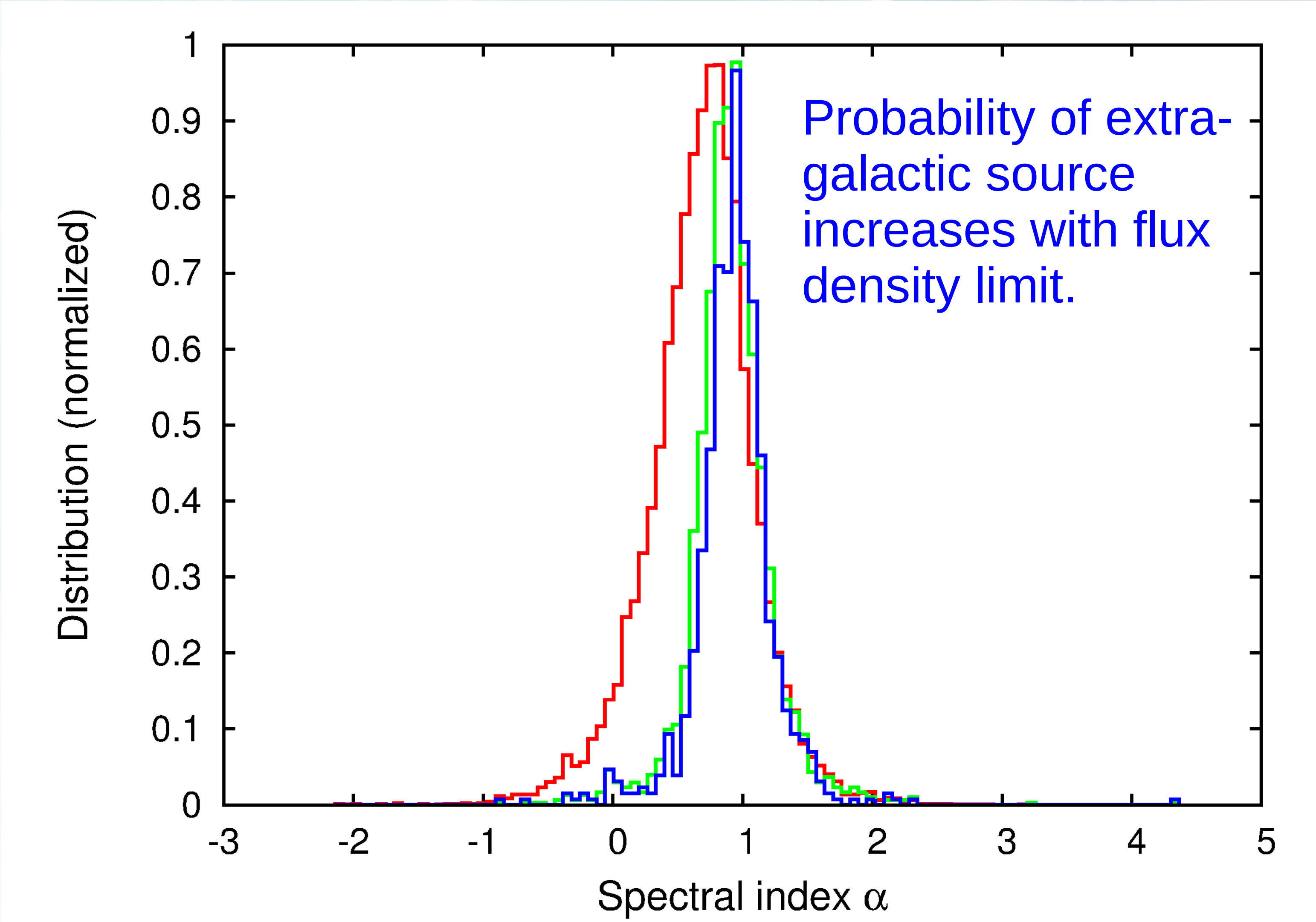
Spectral source classification

Flux limits:

S>15 mJy

S>200 mJy

S>500 mJy



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Catalogue properties

Summary

Final catalogue properties forecast:

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

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Compact source clustering

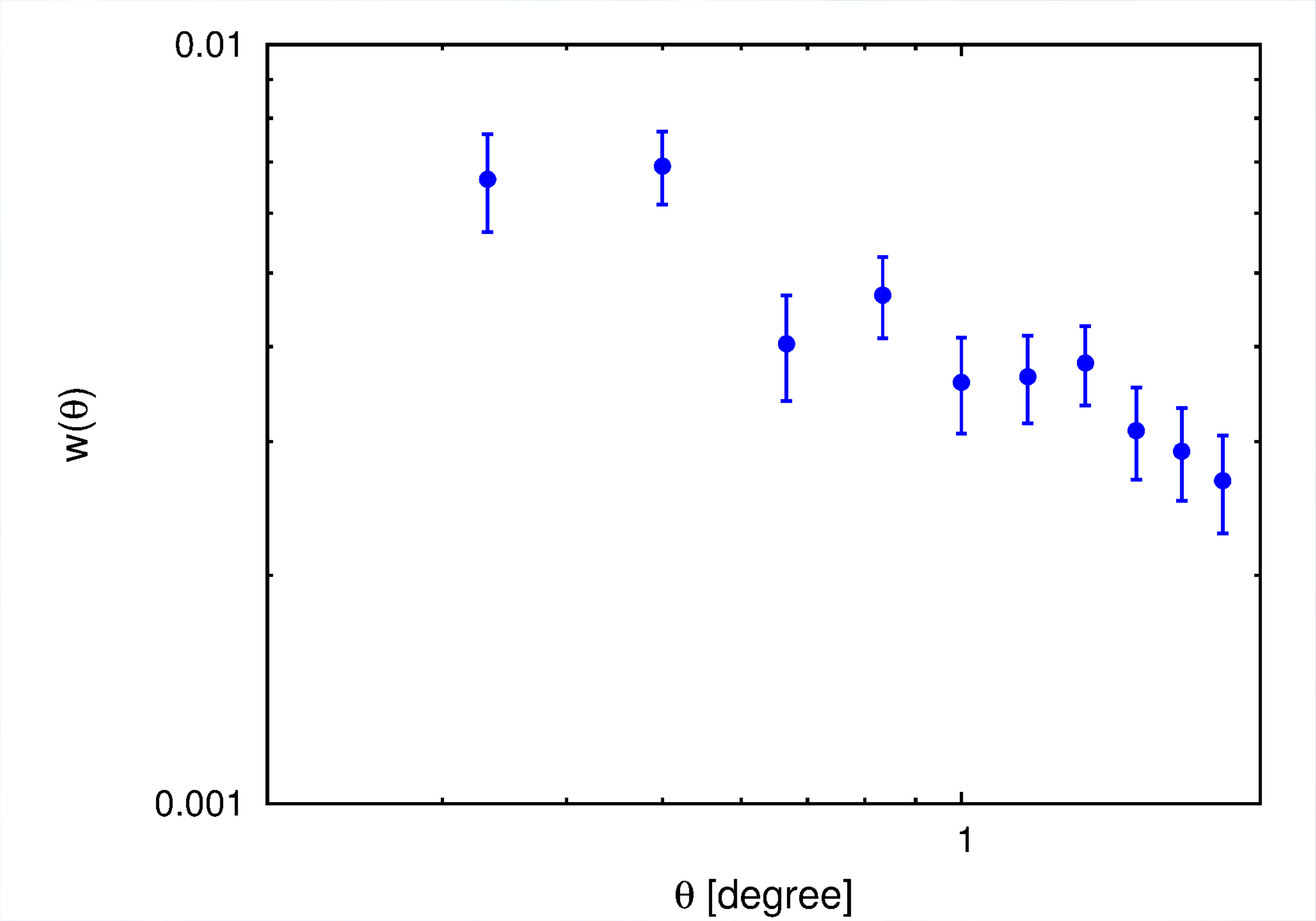
Angular correlation function

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)