Exploring the faint source population at 15.7 GHz

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Abstract: We have combined the Tenth Cambridge (10C) survey at 15.7 GHz with several lower-frequency radio catalogues and a wide range of multi-wavelength data (optical, near- and far-infrared and X-ray) to investigate the properties of the faint, high-frequency source population. We find a significant increase in the proportion of flat spectrum sources at flux densities below 1 mJy – the median radio spectral index between 15.7 GHz and 610 MHz changes from 0.75 for flux densities greater than 1.5 mJy to 0.08 for flux densities less than 0.8 mJy. The multi-wavelength analysis shows that essentially all ($\geq$ 97 percent) of the 10C sources are radio galaxies; the populations of star-forming galaxies and radio-quiet AGN predicted to be present by recent models, such as the SKADS Simulated Skies, are not found in the 10C sample.

1) Data used

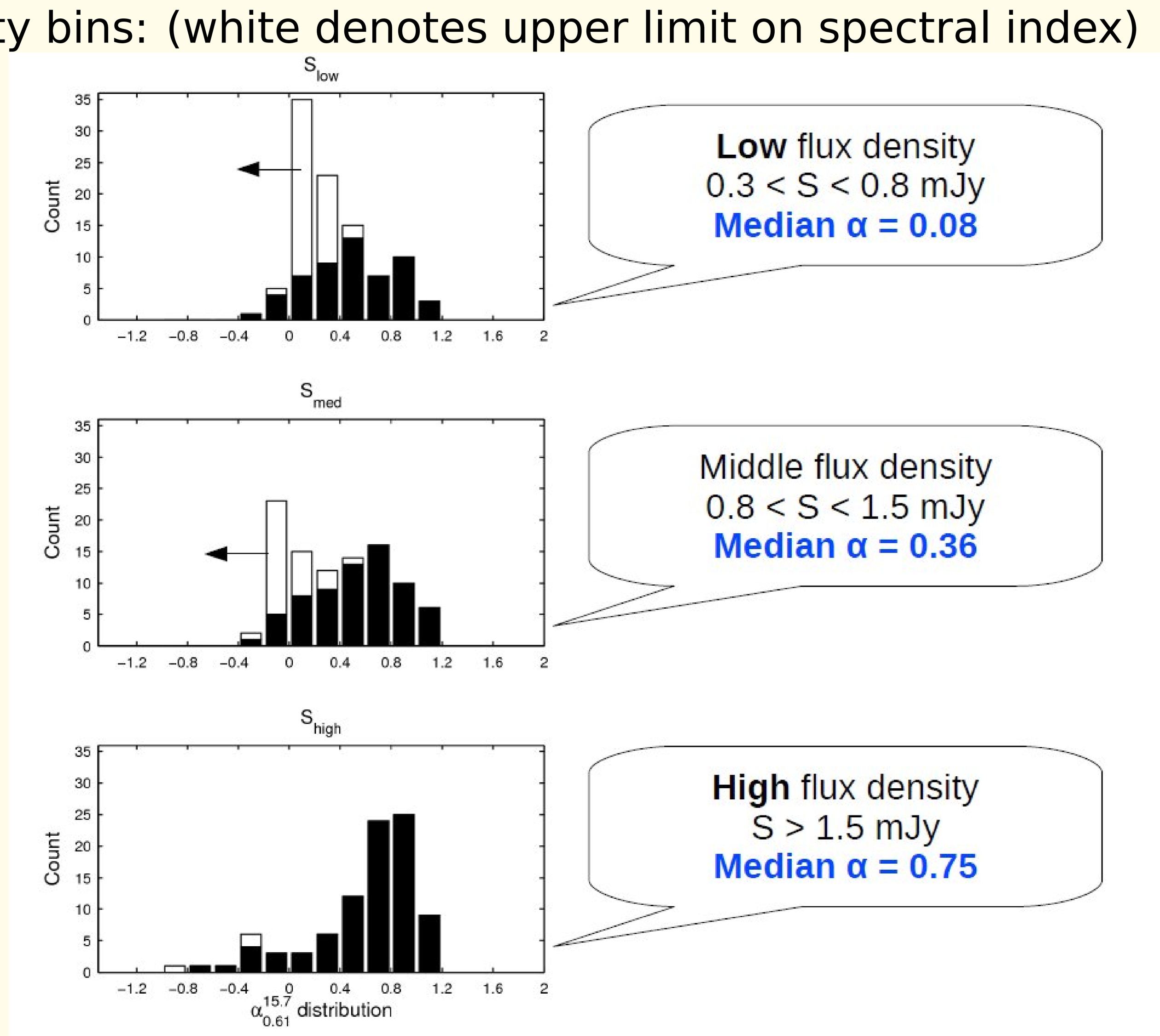
The AMI Large Array in Cambridge.

- **10C survey[1,2]:** Observed with the Arcminute Microkelvin Imager (AMI) in Cambridge at 15.7 GHz, bandwidth 4.3 GHz, synthesised beam 30 arcsec.
- Deepest high-frequency radio survey to date.
- Ten fields covering a total of 27 deg^2 complete to 1 mJy and a further 12 deg^2 complete to 0.5 mJy.
- This work – complete sample of 96 sources in the Lockman Hole, flux densities $0.5 < S_{15\text{GHz}} < 45$ mJy.

- 10C sources were matched to several lower frequency catalogues – a GMRT survey at 610 MHz[3,4], a WSRT survey at 1.4 GHz[5], deep VLA surveys at 1.4 GHz[6,7], NVSS[8] and FIRST[9].
- All 96 sources have at least one match to a lower frequency catalogue.
- Radio sources were matched to multi-wavelength catalogues available in the field; SERVS[10], SWIRE[11], UKIDSS[12] and optical[13] and X-ray[14,15] catalogues.
- 80 out of 96 sources have at least one multi-wavelength counterpart.

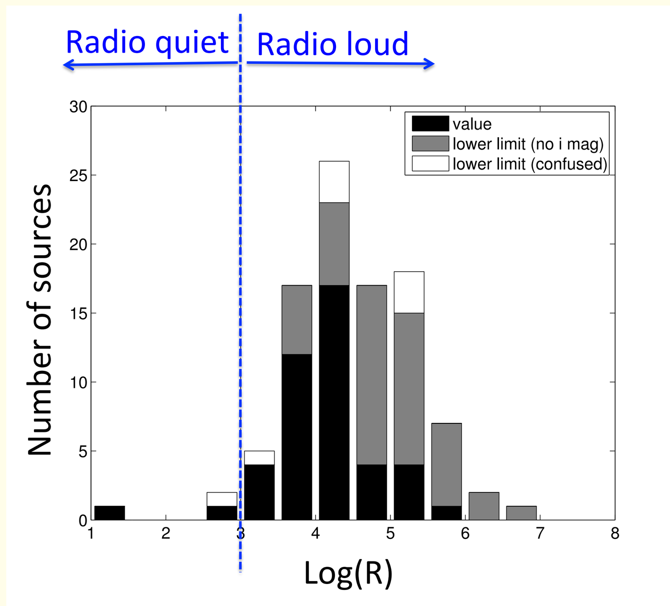
2) Variation in spectral index with flux density

- Spectral index ($S \propto \nu^{-\alpha}$) distribution in three different 15.7-GHz flux density bins: (white denotes upper limit on spectral index)



- Clear change in spectral index with flux density.
- Population of flat-spectrum sources emerging below 1 mJy.
- Spectral index indicates the balance between core and lobe emission – these faint, flat spectrum sources are likely the cores of FRI sources.

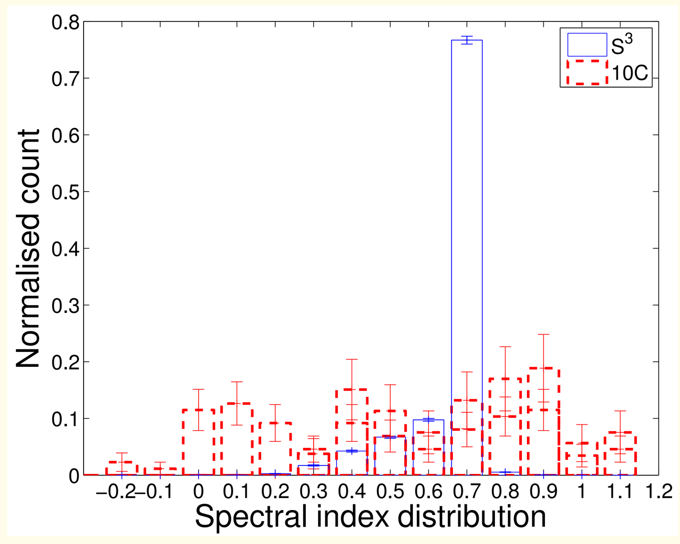
3) Radio to optical ratios



- Radio to optical ratio $R = S_{1.4\text{ GHz}} \times 10^{0.4(m-12.5)}$.
- Used to split radio loud and radio quiet sources.
- 93 out of 96 sources are radio loud.
- Rules out possibility that star-forming sources or radio-quiet AGN contributing to the population – essentially all sources in this sample are radio galaxies.

4) Comparison with SKADS Simulated Sky (S^3)

- Wilman et al. (2008, 2010)[16,17] produced a semi-empirical simulation of the radio continuum sky which contains over 320 million sources down to 10 nJy at 151, 610 MHz, 1.4, 4.86 and 18 GHz.
- We have selected a sub-sample of sources with flux densities > 0.5 mJy at 18 GHz – comparable to the 10C sample studied here.

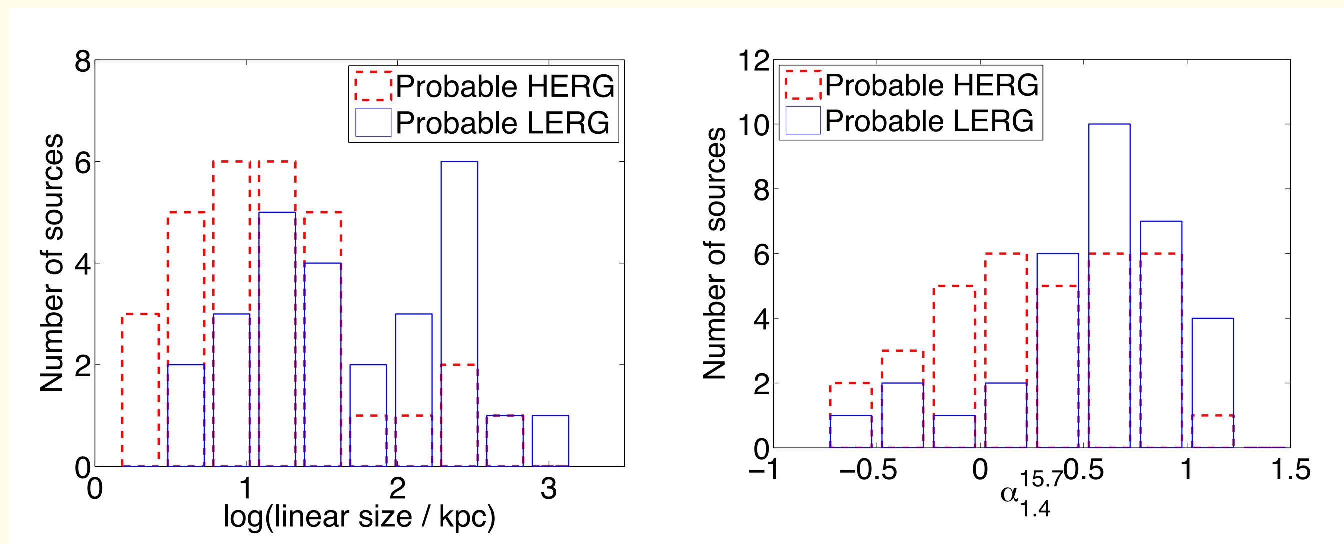


- Simulation clearly fails to reproduce the observed spectral index distribution – complete absence of sources with $\alpha < 0.3$ in the simulation.
- This is probably because the flat-spectrum cores of the radio galaxies are far more dominant than the model predicts.

- Simulation also predicts that 10% of the sample are radio-quiet AGN or star-forming galaxies – these are not found in the observed sample.

5) High-excitation and low-excitation radio galaxies

We classified the 10C radio galaxies as HERGs and LERGS:



- HERGs have flatter spectra and smaller linear sizes than LERGS.
- Suggests they are dominated by emission from their cores.
- May lack the powerful extended emission typical of FRI/IIs.

Conclusions

- The properties of 96 sources selected at 15.7 GHz with flux densities $0.5 < S_{15\text{GHz}} < 45$ mJy are investigated.
- A significant change in median spectral index with flux density is found – source spectra are significantly flatter below $\approx$ 1 mJy.
- Radio-to-optical ratios show that > 97 percent of the population are radio galaxies.
- The observed faint, flat-spectrum sources are therefore likely to be the cores of radio galaxies.
- Populations of radio-quiet AGN and star-forming galaxies predicted to be present by recent models, such as the SKADS simulated skies, are not present in the 10C sample.
- HERGs in this sample have flatter spectra and smaller linear sizes than the LERGS – suggests they are dominated by core emission.
- For more details see Whittam et al. (2013)[18] and Whittam et al. (in prep).

References: [1] AMI Consortium: Davies et al., 2011, MNRAS, 415, 2708, [2] AMI Consortium: Franzen et al., 2011, MNRAS, 415, 2699, [3] Garn T. et al., 2008, MNRAS, 387, 1037, [4] Garn T. et al., 2010, BASI, 38, 103, [5] Guglielmino G. et al., 2012, rsri, id22, [6] Owen F. N., Morrison G. E., 2008, AJ, 136, 1889, [7] Biggs A. D., Ivison R. J., 2006, MNRAS, 371, 963, [8] White R. L. et al., 1997, AJ, 475, 479,[9] Condon J. J. et al., 1998, AJ, 115, 1693, [10] Mauduit J.-C., et al., 2012, PASP, 124, 714, [11] Lonsdale C. J., et al., 2003, PASP, 115, 897, [12] Lawrence A., et al., 2007, MNRAS, 379, 1599, [13] GonzÃąlez-Solares E. A., et al., 2011, MNRAS, 416, 927 [14] Wilkes B. J., et al., 2009, ApJS, 185, 433, [15] Brunner H., et al., 2008, A&A, 479, 283 [16] Wilman R. J. et al., 2008, MNRAS, 388, 1335, [17] Wilman R. J. et al., 2010, MNRAS, 405, 447, [18] Whittam I. H. et al., 2013, MNRAS, 429, 2080.