LBWG memo 34

Calibrating south of 28°

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The problem

The LBCS survey (Jackson et al. 2016, 2022) provides lists of sources which have significant structure on sub-arcsecond scales at HBA frequencies. These sources were all observed at 150 MHz and are classified as 'P', 'S' or 'X' on baselines between the core and each international telescope, according to the signal to noise on those scales at those frequencies. North of 28° there is about one source per square degree with mostly 'P' classifications, although this decreases at the longest baselines.

The sources were selected over ten years ago, when input catalogues were much less extensive than those now available. The main selection used the 78-MHz VLSS from the VLA, together with the 325-MHz WENSS survey. This was done because the low-frequency spectral index was shown in a pilot survey (Moldon et al. 2013) to be a good indicator of compact structure at low frequencies, together with the strength of the source.

WENSS is not available south of 28°, and so a rather ad-hoc selection was done for the LBCS input catalogue. This results in fewer good calibrators being identified, and many fields will not have a good LBCS calibrator. In principle, calibrators can be identified from the observation itself by phase-shifting and searching for structure using `facetselfcal` to provide a phasediff score. Ideally, a southern LBCS would now be done using better input catalogues. However, this document explores the extent to which compactness of structure can be predicted using the now available input catalogues, mainly LoTSS, but also the RFC (Petrov & Kovalev 2025) and the FIRST survey catalogue.

Use of LoTSS

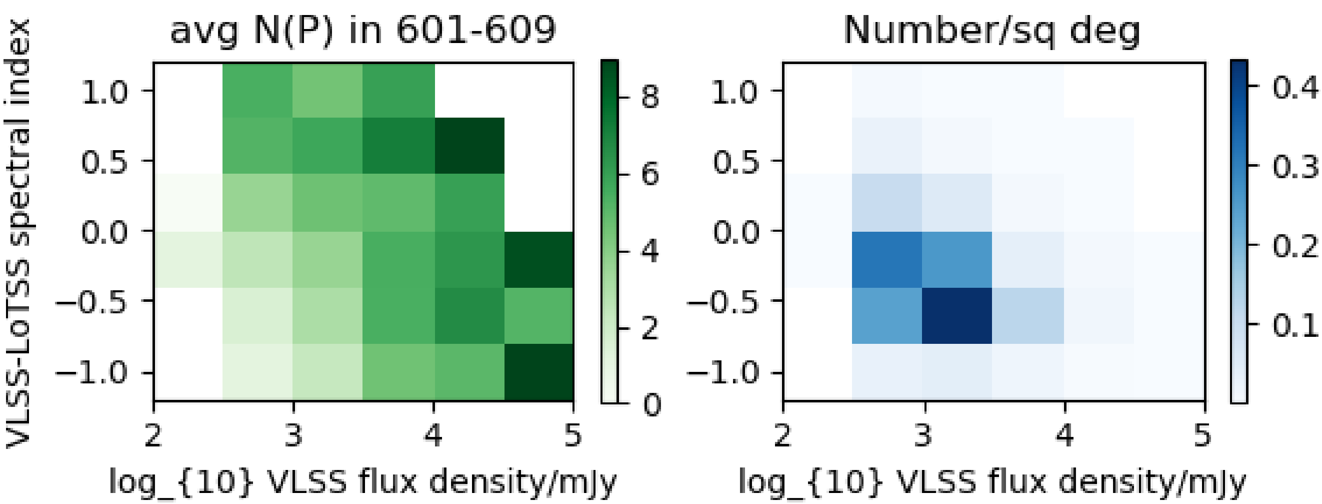

Figure 1: Results from correlating VLSS and LoTSS with LBCS. (Left) Average compactness of common sources, expressed as the average number of 'P' scores in a grid cell of VLSS flux density and low-frequency spectral index, from the first 9 international stations (DE601-DE609). (Right) Density of common sources per square degree.

We begin by correlating VLSS with LoTSS DR2 and examining the sources in common which also have LBCS observations. These are separated by VLSS flux density and by VLSS-LoTSS spectral index (Fig. 1).

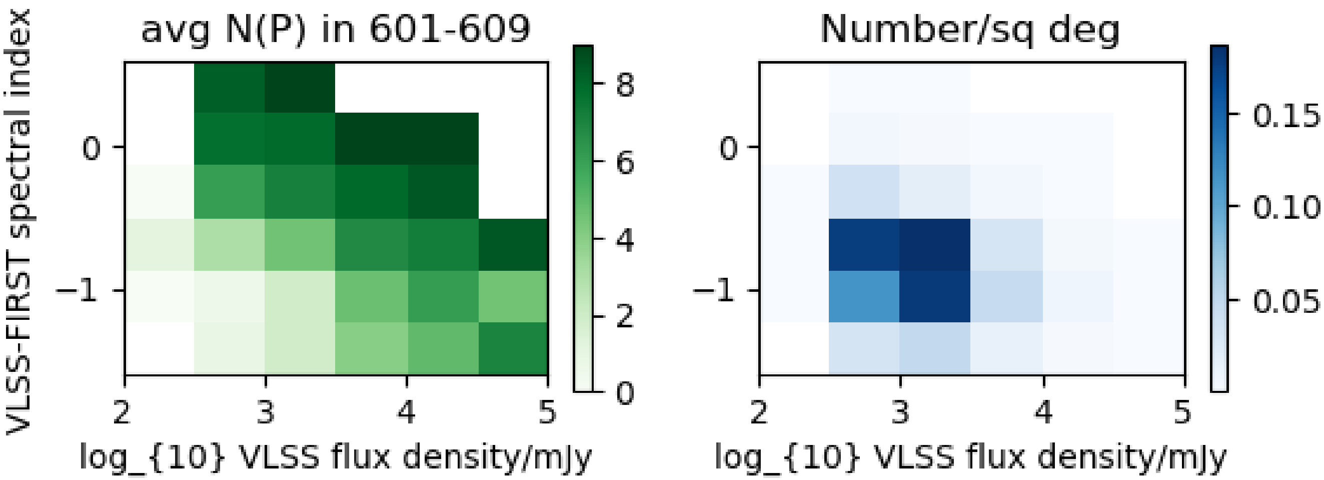

Figure 2: Results from correlating VLSS and FIRST with LBCS. (Left) Average compactness of common sources, expressed as the average number of 'P' scores in a grid cell of VLSS flux density and low-frequency spectral index, from the first 9 international stations (DE601-DE609). (Right) Density of common sources per square degree.

There is a trend for stronger VLSS sources to be better calibrators, and also for flatter-spectrum sources to be better. However, the good calibrators are found reliably only for very strong sources, or for relatively strong (10 Jy at 78 MHz) which have inverted spectra. The space density of such sources is very low, probably less than 0.1 per square degree. These combinations of input catalogues cannot therefore be relied on to identify good calibrators.

Fig. 2 shows the effect of repeating this process with VLSS and FIRST. Again the trend with flux density and spectral index is apparent. However, the density of calibrators which can be reliably predicted to have 8 or more 'P' entries is very small (only about 20 sources in the sky).

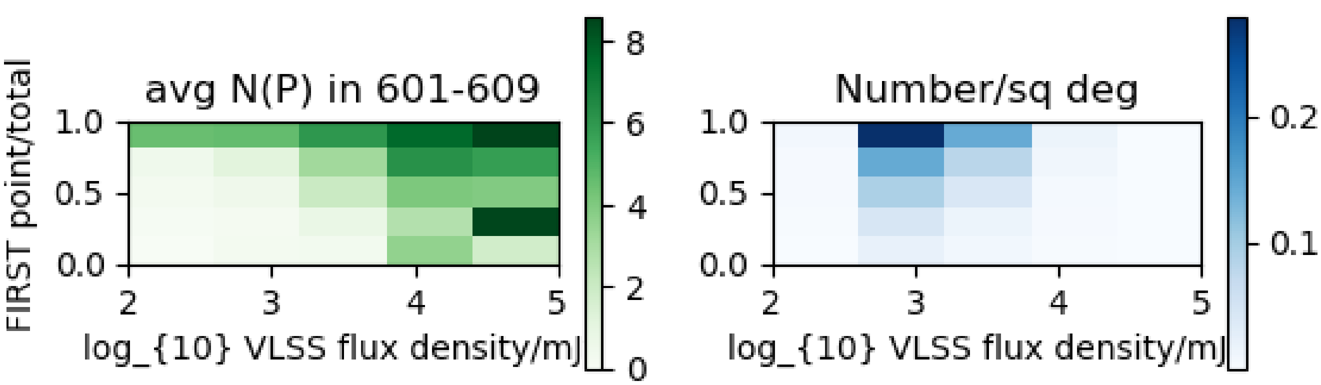

Figure 3: Calibrator goodness (out of 9) against VLSS flux density and FIRST compactness.

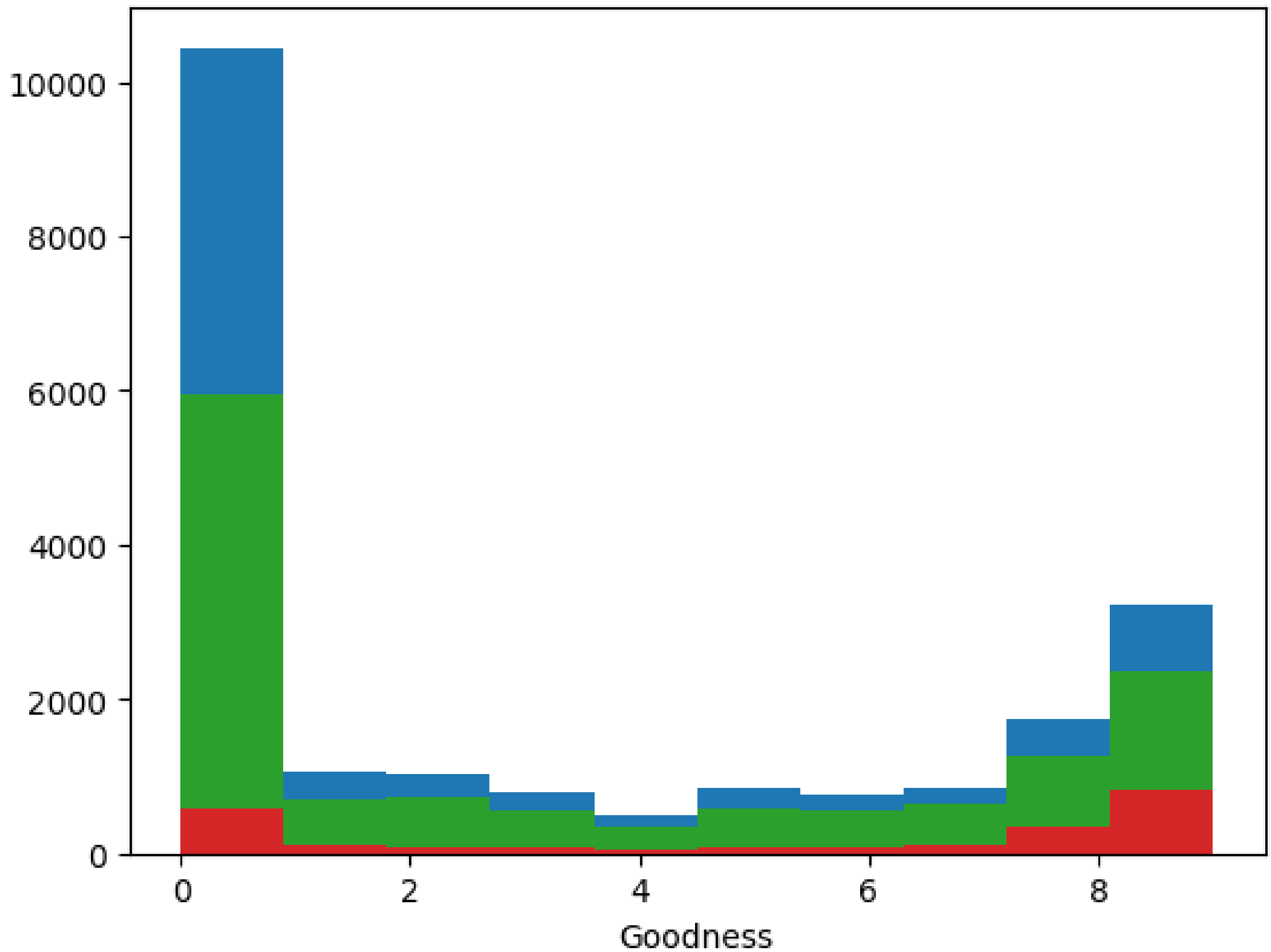

Figure 4: Coincidences of the VLSS, Radio Fundamental Catalogue (Petrov & Kovalev 2025) and LBCS. Blue: VLSS and LBCS only. Green: VLSS and LBCS sources which also appear in the RFC. Red: as before, but with the additional constraint that the VLSS flux density is >1Jy.

Fig. 3 shows the effect of separating sources by FIRST compactness (defined as the ratio of peak to total flux). Unsurprisingly, non-compact FIRST sources are less good calibrators, although the statistics are very poor at the high-flux end. Reliable calibrators are only found for compact, very strong (VLSS flux density >10 Jy) sources for which the numbers are very small, certainly much less than 1 source per field.

Finally, Fig. 4 shows the effect of correlation with the catalogue of VLBI sources collated by Petrov & Kovalev (2025). These have all been observed at GHz frequencies, from L-band and higher. Correlation of the VLSS sources with this catalogue produces a histogram with a noticeably relatively lower peak at low LBCS value, and using strong VLSS sources (> 1Jy) improves this further, but again at the cost of the resulting source population being of low enough density to be only marginally useful for calibration purposes.

Conclusion

If you are lucky enough to have a very strong, flat-spectrum source in the field of the observation, it can be used as a calibrator. However, most good calibrators are hidden among the general population in a way that is hard to find without observing them explicitly with high resolution and at LOFAR frequencies.

References

Jackson N. et al. 2016, A& A 595, 86

Jackson N. et al. 2022, A&A 658, A2

Moldon J. et al. 2015, A&A 574, 73

Petrov L., Kovalev Y.Y., ApJS 276, 38