The LOFAR Snapshot Calibrator Survey

Identifying Calibrators for Long Baseline LOFAR Observations

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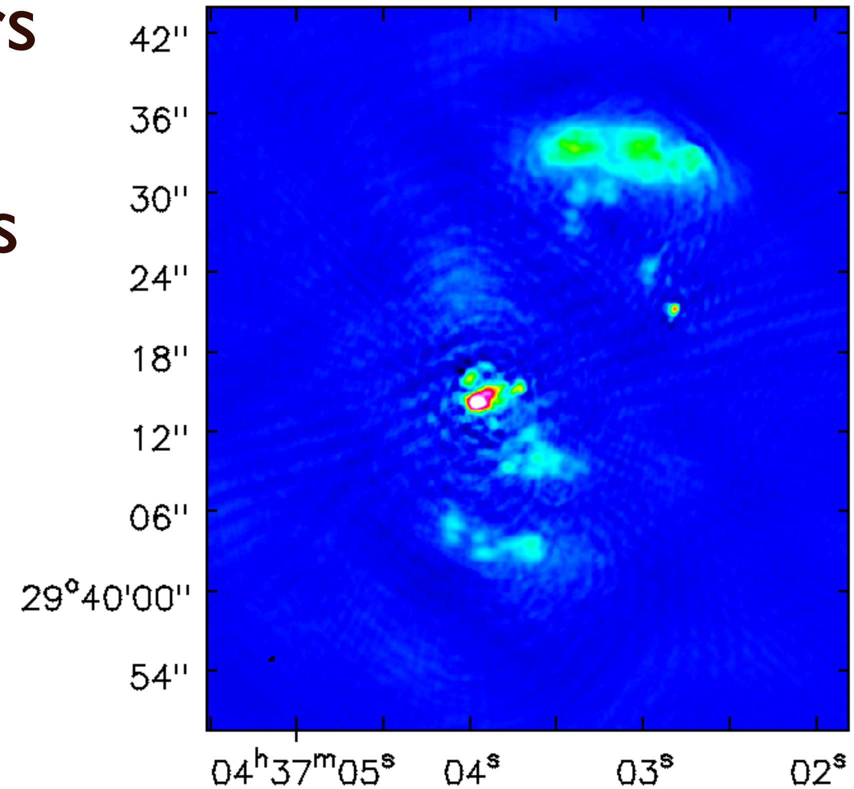


ASTRON

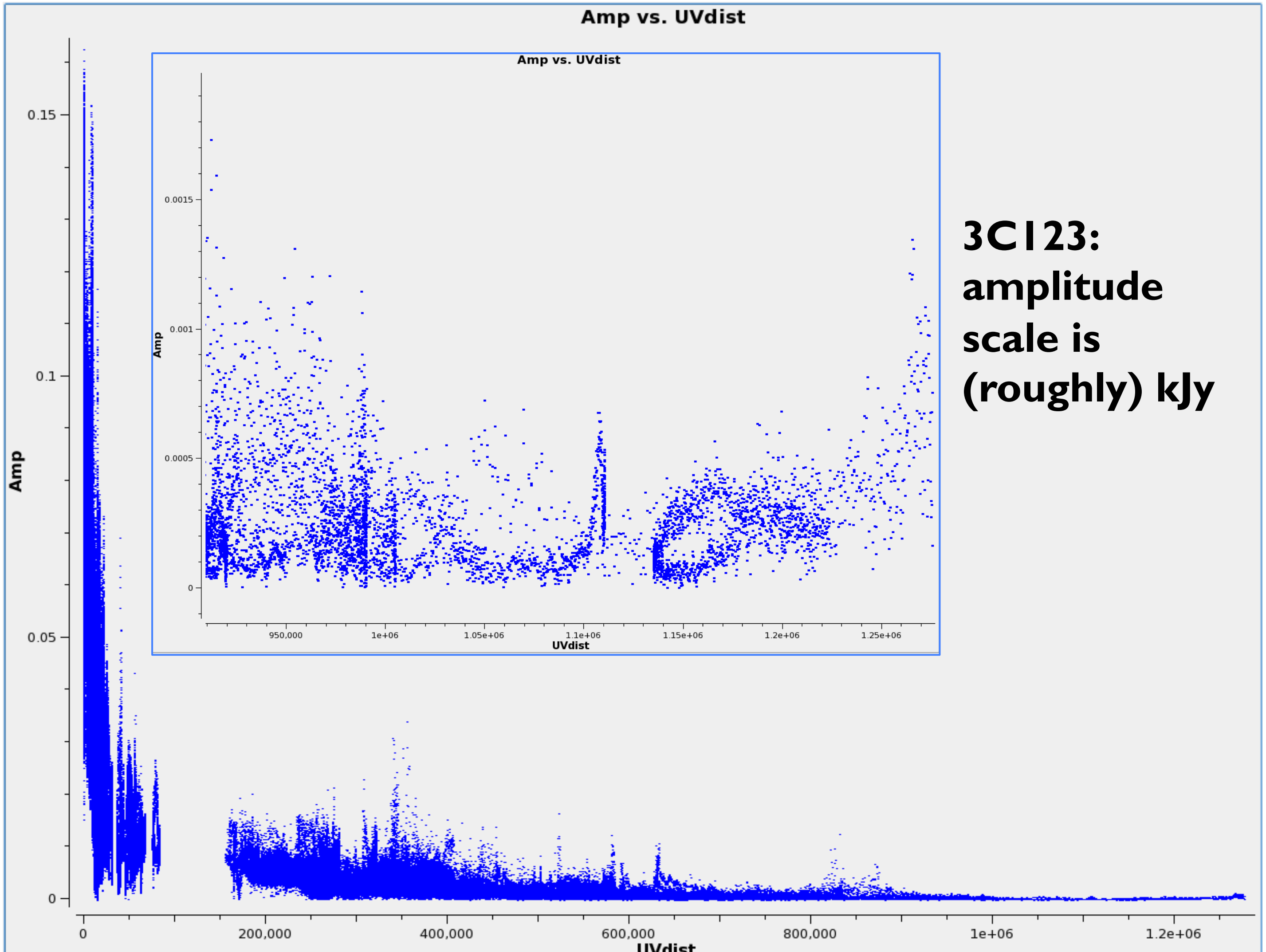
The Long Baseline Situation

The Long Baseline Problem, (1)

On a short baseline, the absolute ionospheric path delay difference is small, and the differential spatial gradients are small

On a long baseline, the absolute ionospheric path delay difference is **large** (phase changes rapidly with frequency) and the differential spatial gradients are **large** (phase changes rapidly with direction)

The Long Baseline Problem, (II)



3C123: amplitude scale is (roughly) kJy

The Long Baseline Problem

To summarise:

- Your calibrators are going to be (much) fainter and you can't even average in frequency to (partially) compensate
- Oh, and they need to be close on the sky!
- The standard LOFAR data reduction approach will not work (except for maybe the brightest few sources in the sky)

The Long Baseline Solutions

- Create a "super station" by phasing up all of the core antennas (Σ CS* ➔ TS001)
- Use "VLBI" tools to coherently combine more data (delay/rate search, i.e. linear phase gradient in frequency and time)
  - Imperfect solution, since ionospheric delay is dispersive; ok for small bandwidths

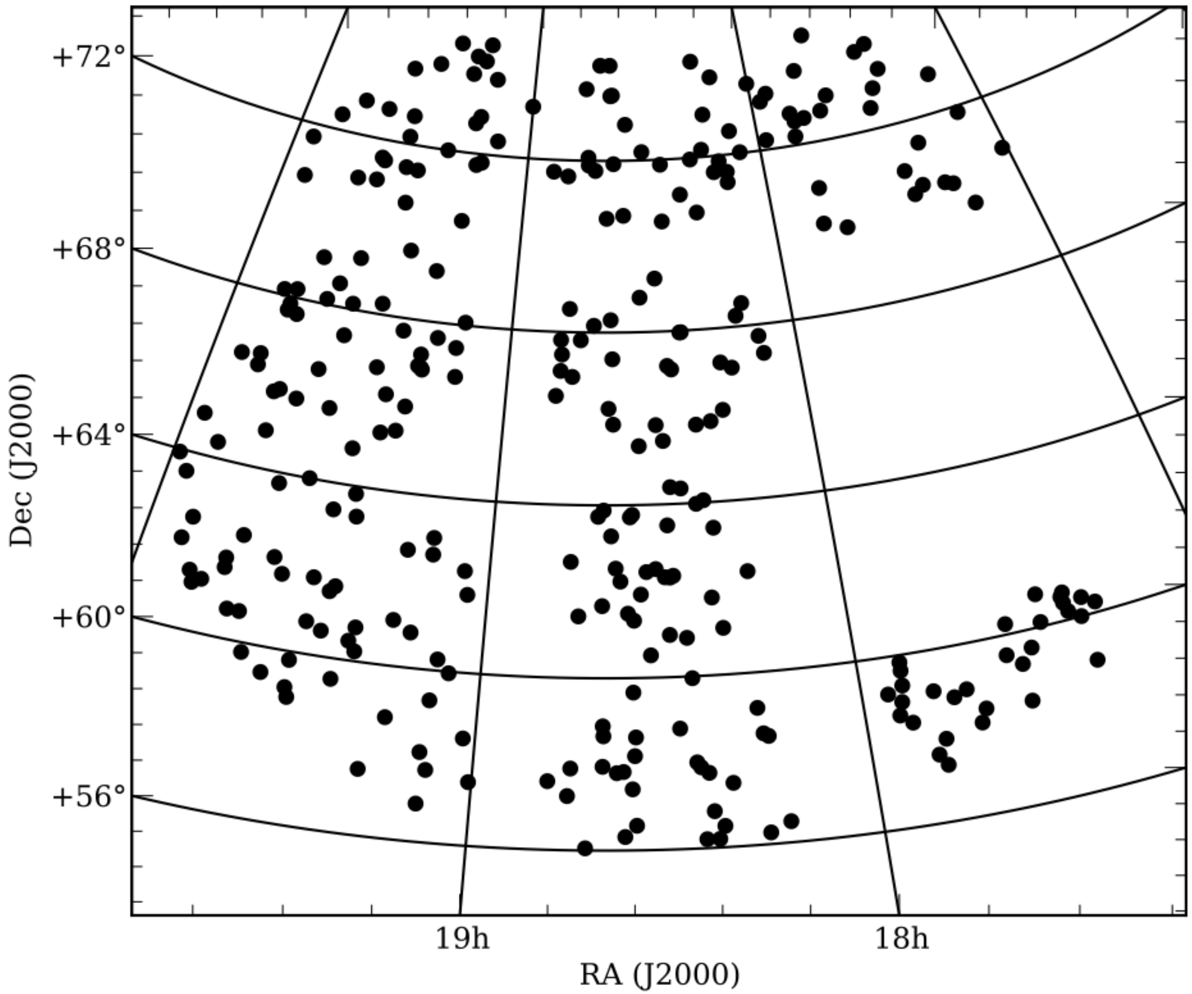
Calibration requirements

- LOFAR theoretical sensitivity suggests a calibrator for our current approach needs ≥100 mJy flux density in a compact component (@150 MHz)
- Experience agrees, and adds that this calibrator should be within ~1 degree
- **The €64,000 question: are there enough bright compact sources?**

LOFAR Snapshot Calibrator Survey

- Designed to answer this question
- Observe sources with S_{150MHz} > 100 mJy
- 16 subbands = 3 MHz / beam
- 30 beams / scan
- 4 minutes / scan
- **360 sources inspected per hour**
- Advantage: No *uv* shifting means simple/ fast processing and smaller data volumes

LOFAR Snapshot Calibrator Survey

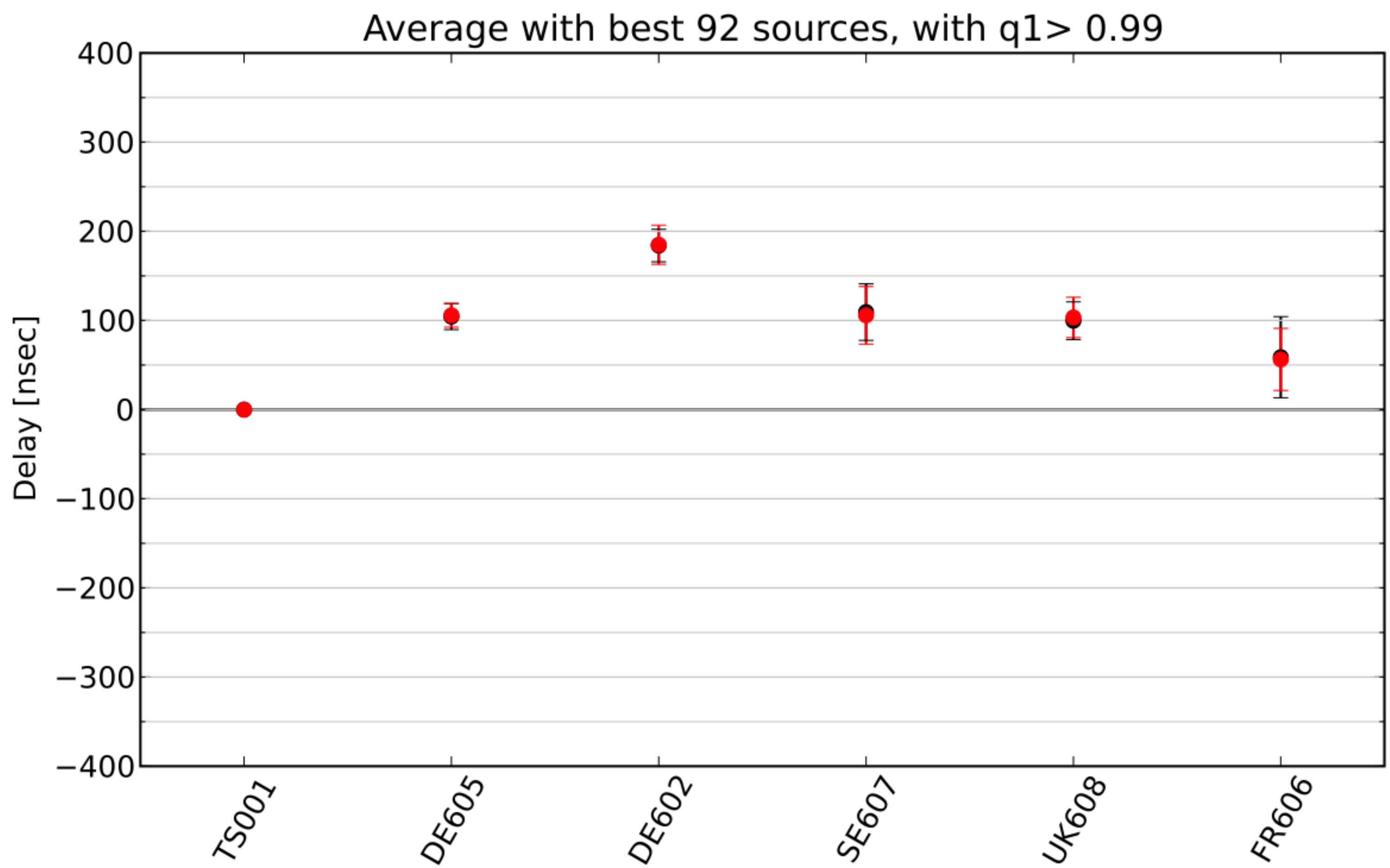


LOFAR Snapshot Calibrator Survey

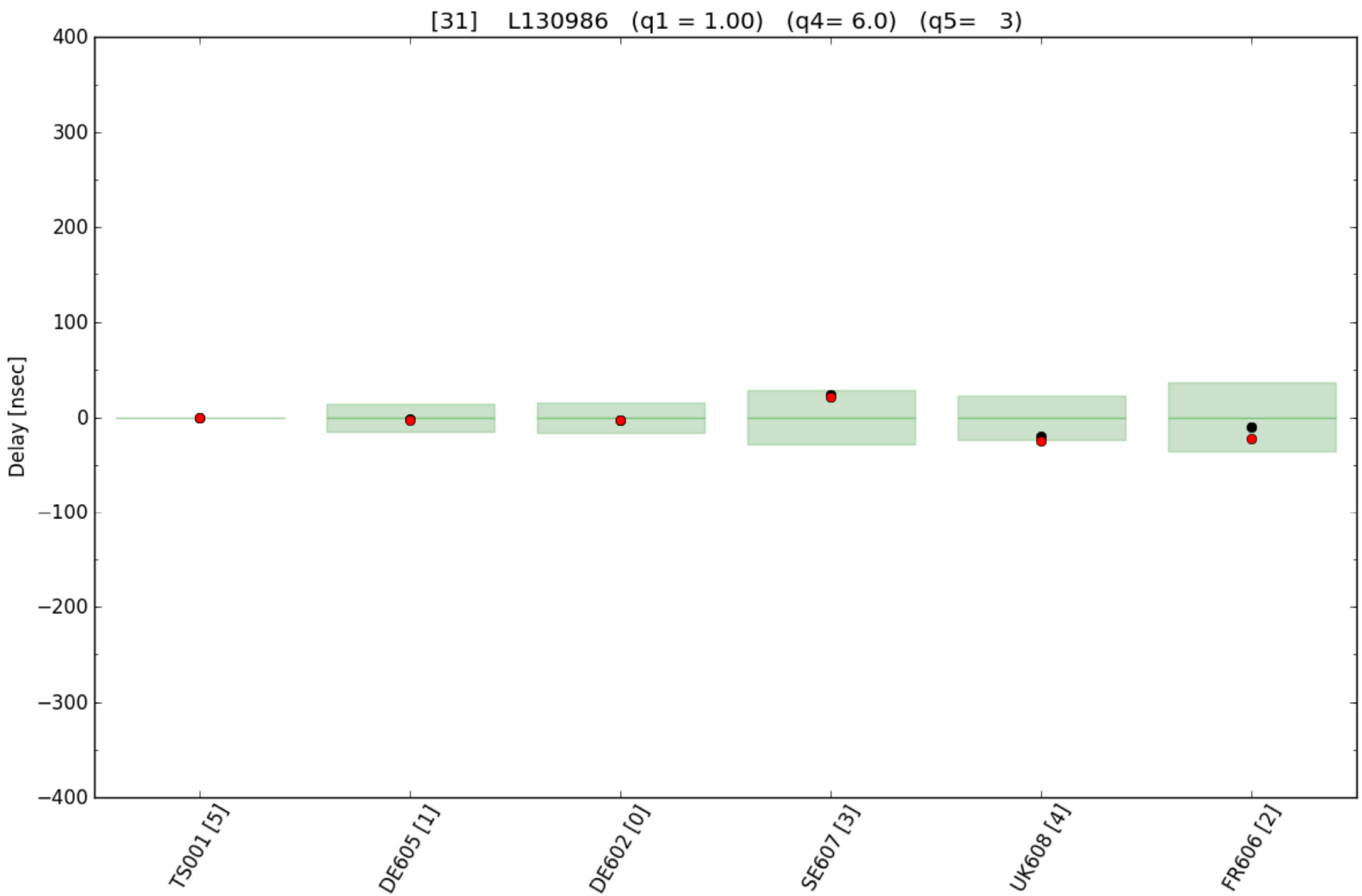
- Two 1-hour observations:
    - 02 May 2013 (targeting sources with 327 MHz flux density > 200 mJy)
    - 07 November 2013 (targeting sources with 327 MHz flux density 80 – 250 mJy)
- Calibrate and phase-up core stations
- Then solve for delay for every target source individually (minimum S/N 8)
- Delay solutions are primary observable

LOFAR Snapshot Calibrator Survey

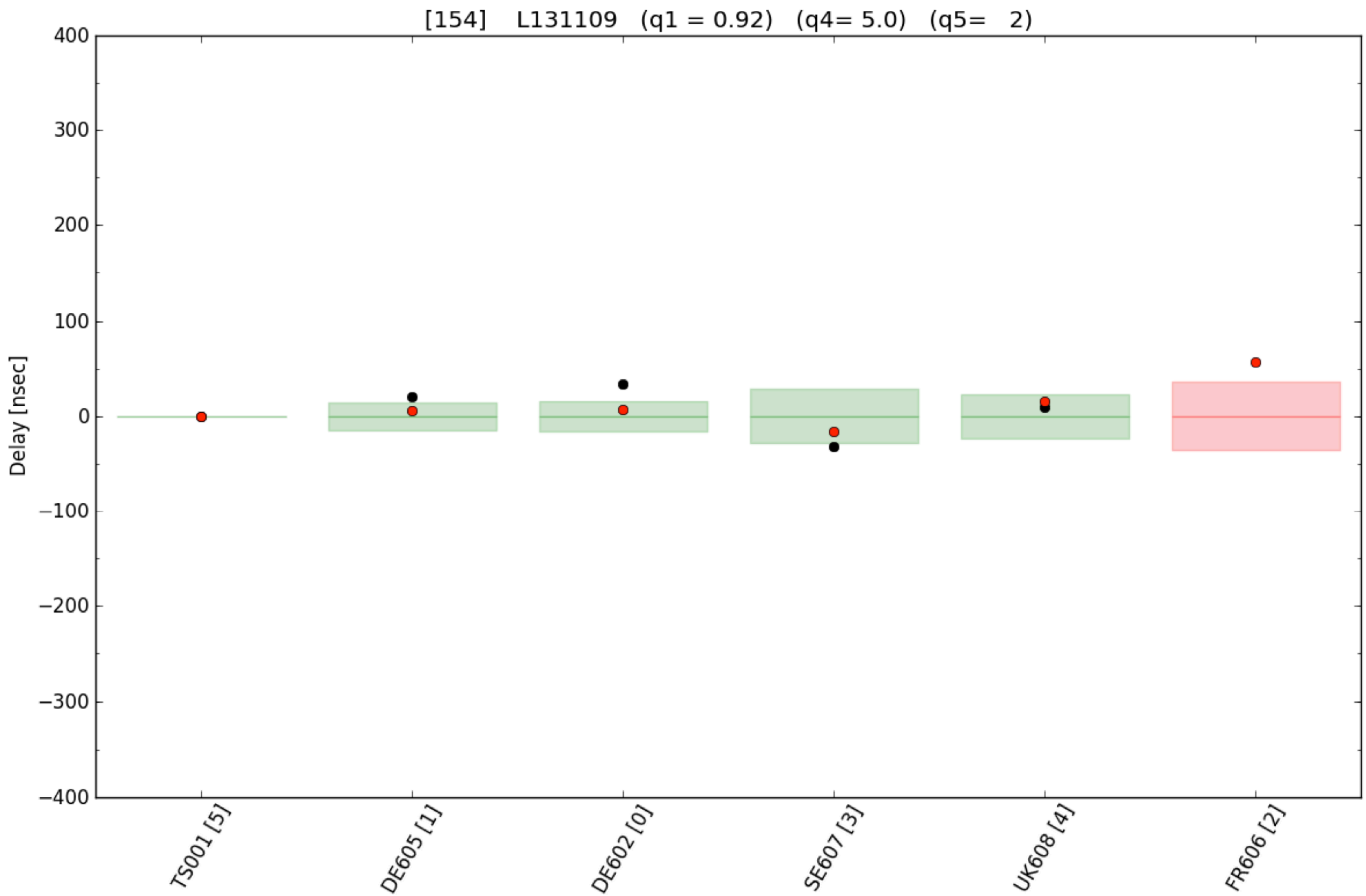
Taking only the best solutions, fit and subtract average delay



LOFAR Snapshot Calibrator Survey



LOFAR Snapshot Calibrator Survey



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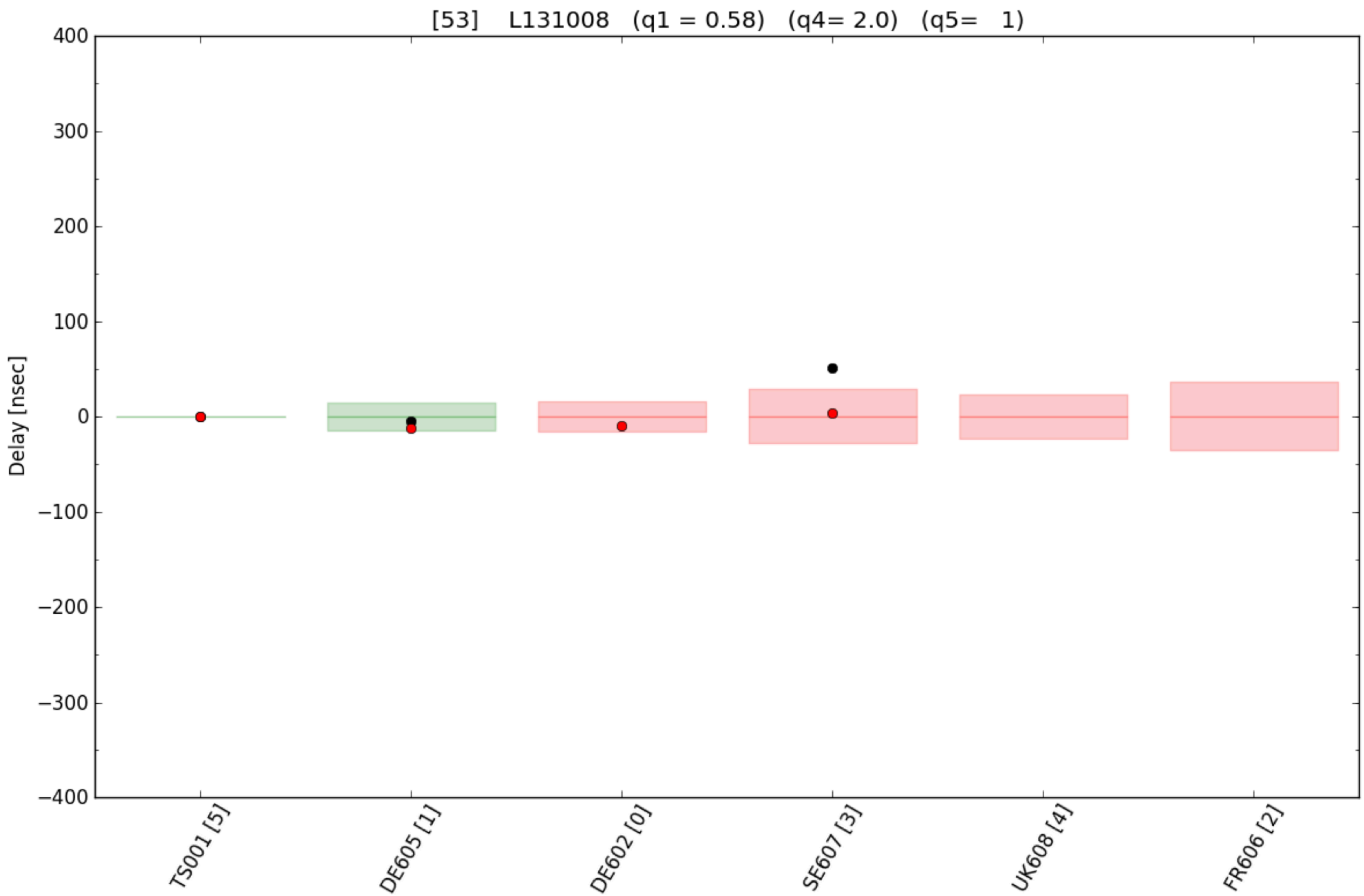

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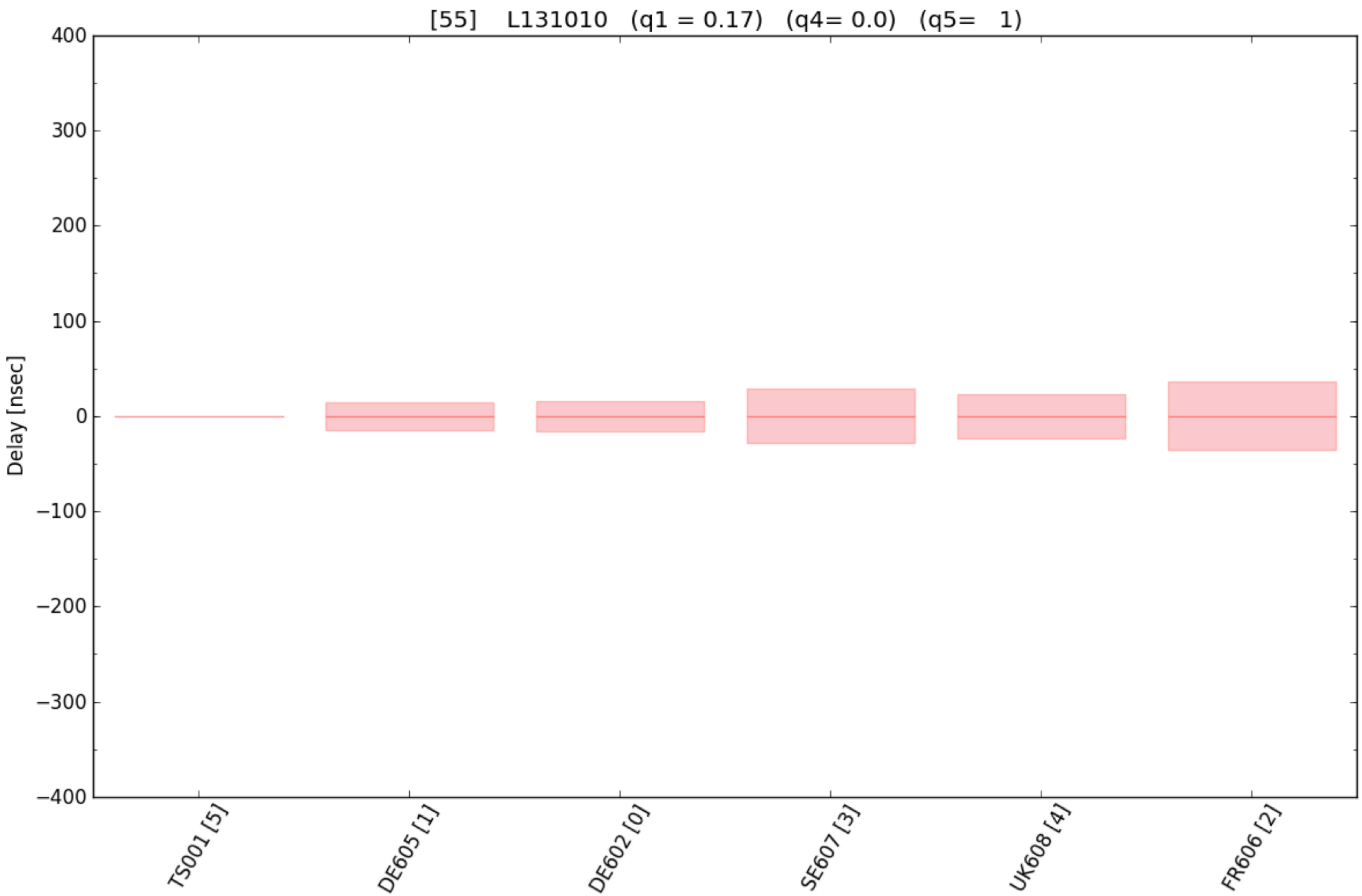

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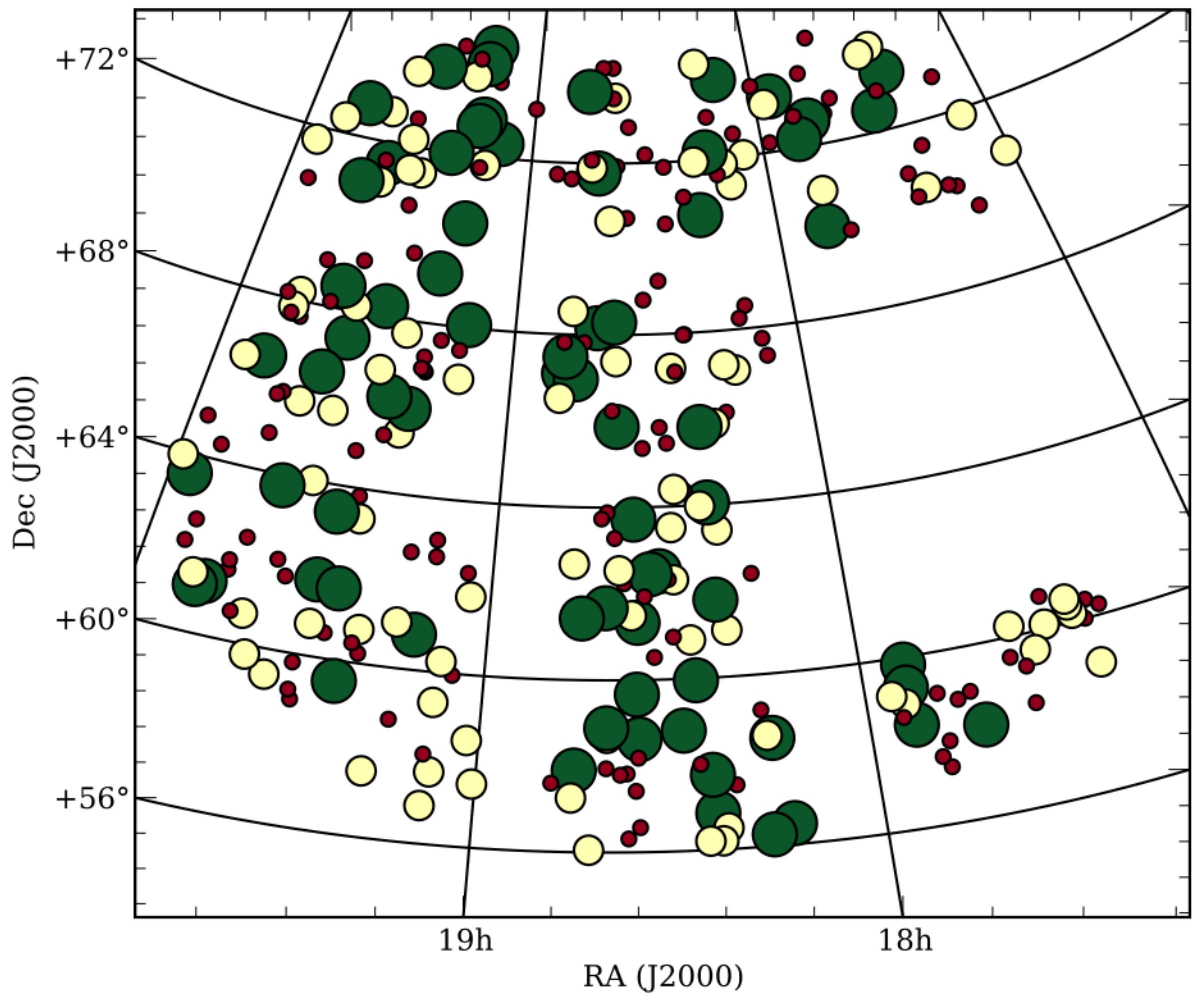

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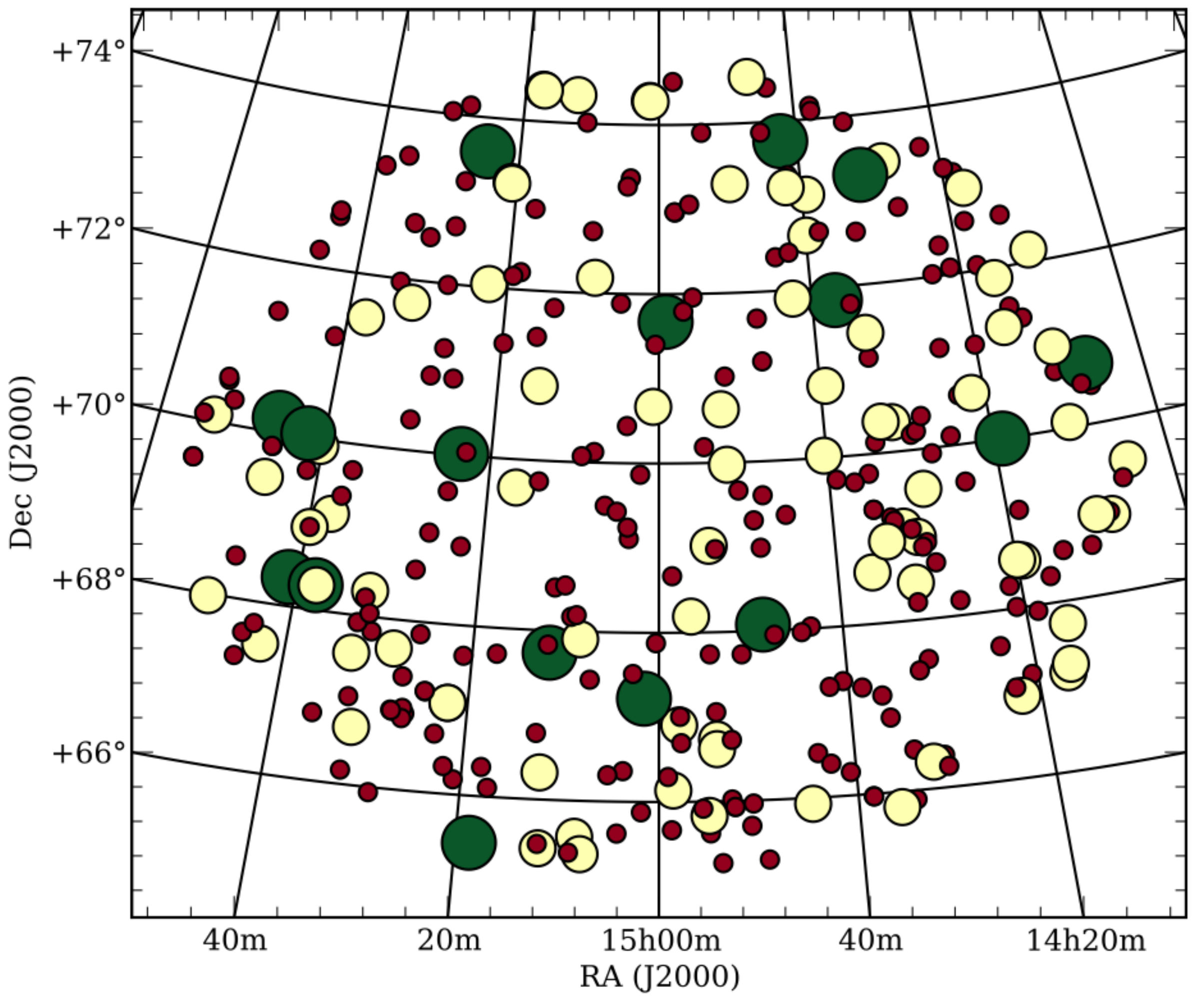
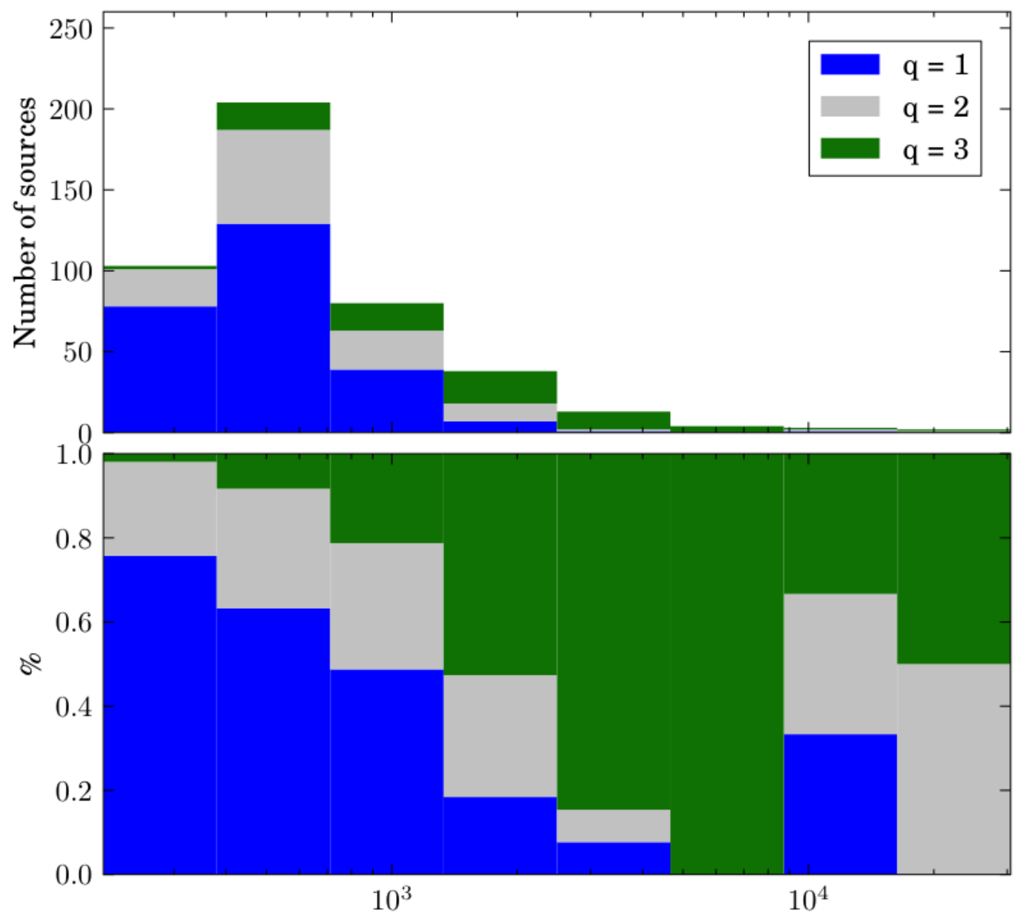


Results

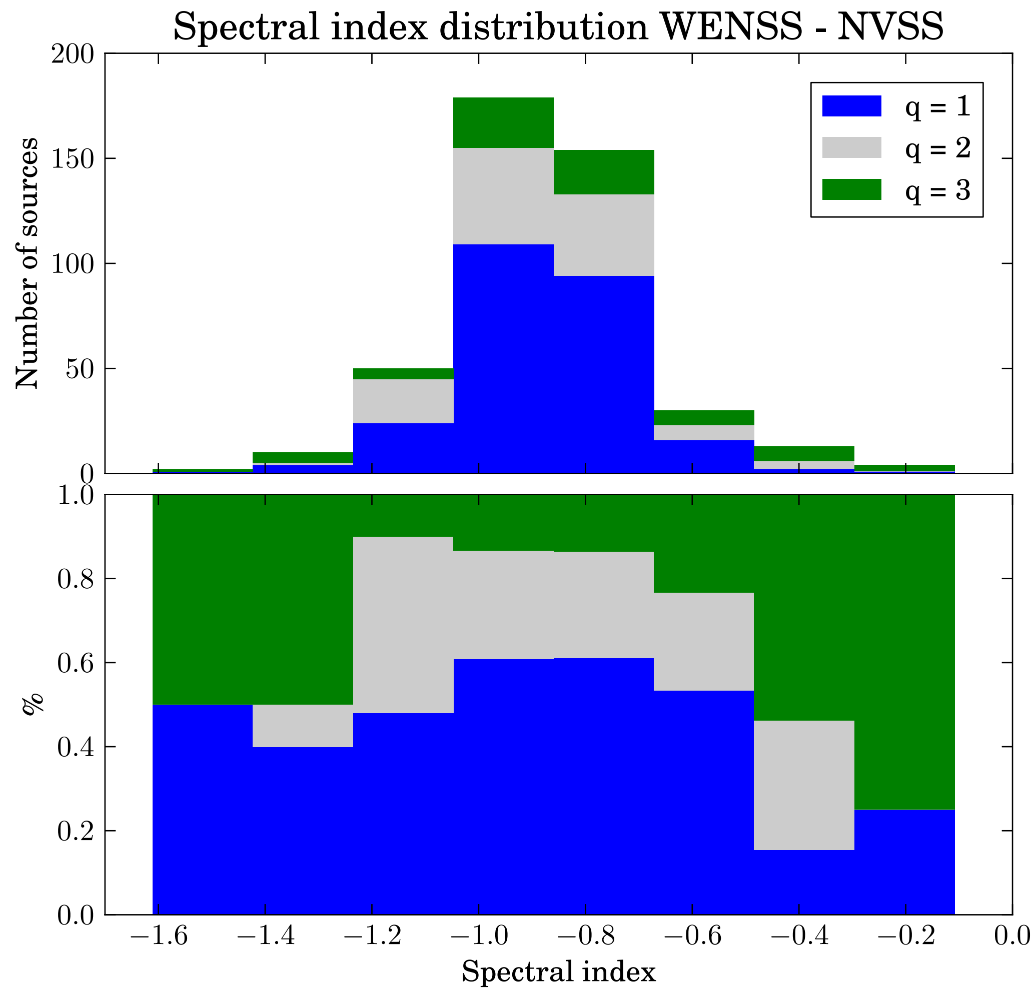
- Preliminary! Analysis shown here was finished yesterday.
- Much more information than I can present here in the time available

Results

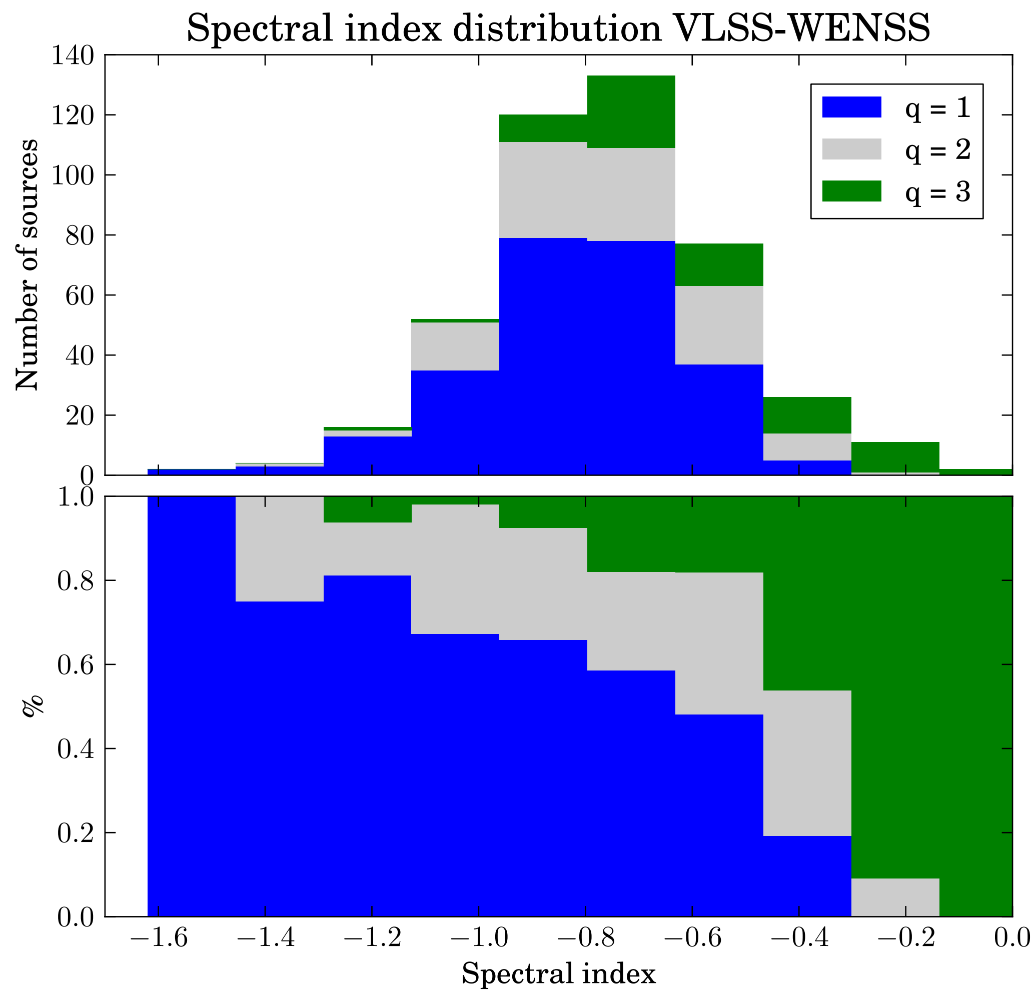


Predicted LOFAR flux density (mJy)

Results


Spectral index distribution WENSS - NVSS
Number of sources
200
150
100
50
0
q = 1
q = 2
q = 3
%
1.0
0.8
0.6
0.4
0.2
0.0
−1.6
−1.4
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
Spectral index

Results



Spectral index distribution VLSS-WENSS
Number of sources
140
120
100
80
60
40
20
0
q = 1
q = 2
q = 3
%
1.0
0.8
0.6
0.4
0.2
0.0
−1.6
−1.4
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
Spectral index

Results

- We classified 86 out of 620 sources as "good", from total area of ~400 sq. deg.
  - But search was not exhaustive, not every source >100 mJy in those 400 sq. deg. was inspected (in fact only about ¼ were)
  - Controlling for selection effects, we find the effective search area was 89 sq. deg.
  - So: density of good calibrators ~1 per sq. deg.

Conclusions

- **Enough calibrators:** density ~1/sq deg, enough to calibrate virtually anywhere at 150 MHz. Bright sources with a spectral turnover most likely to be compact.
- **We can find them:** observing technique + pipeline can identify suitable long baseline LOFAR calibrator in ~15 minutes
- **Looking ahead:** Our pipeline to be developed into observatory pipeline for general long baseline reduction