Matching LOFAR sources across radio bands

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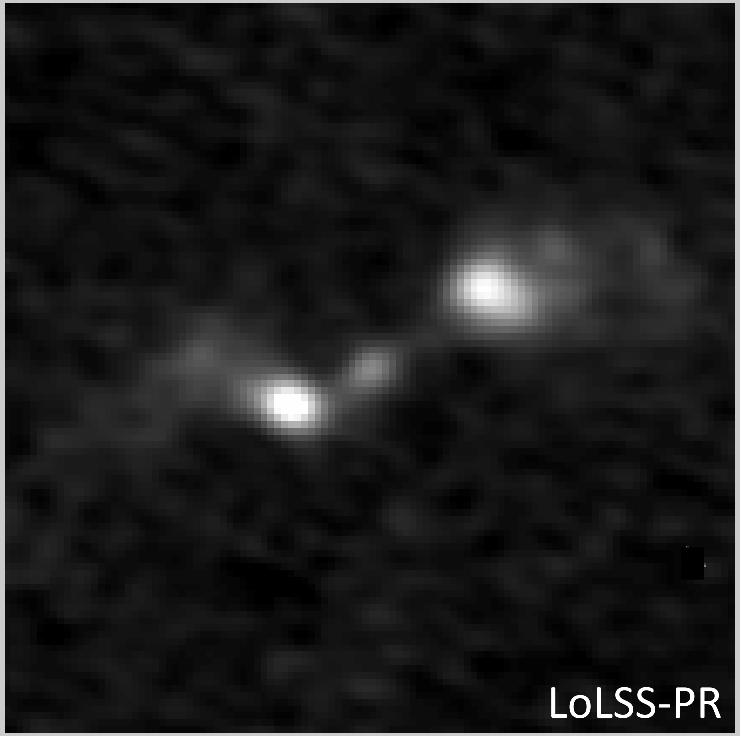
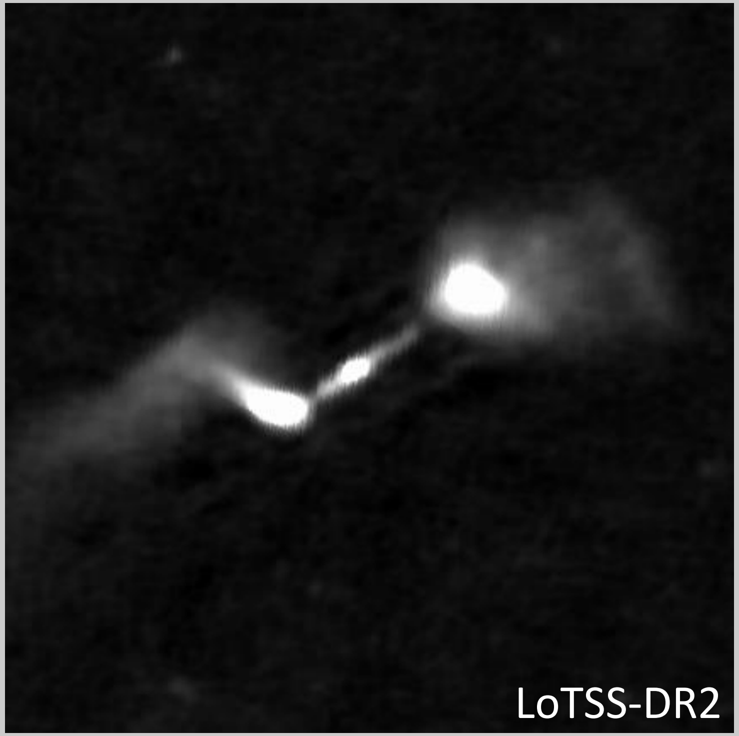
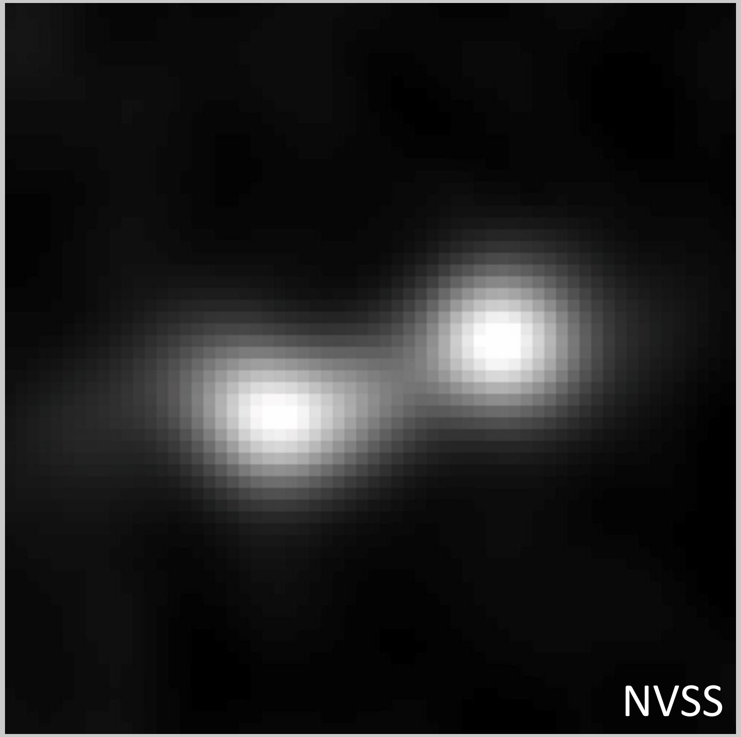
LOFAR Family Meeting 2023



54 MHz



144 MHz

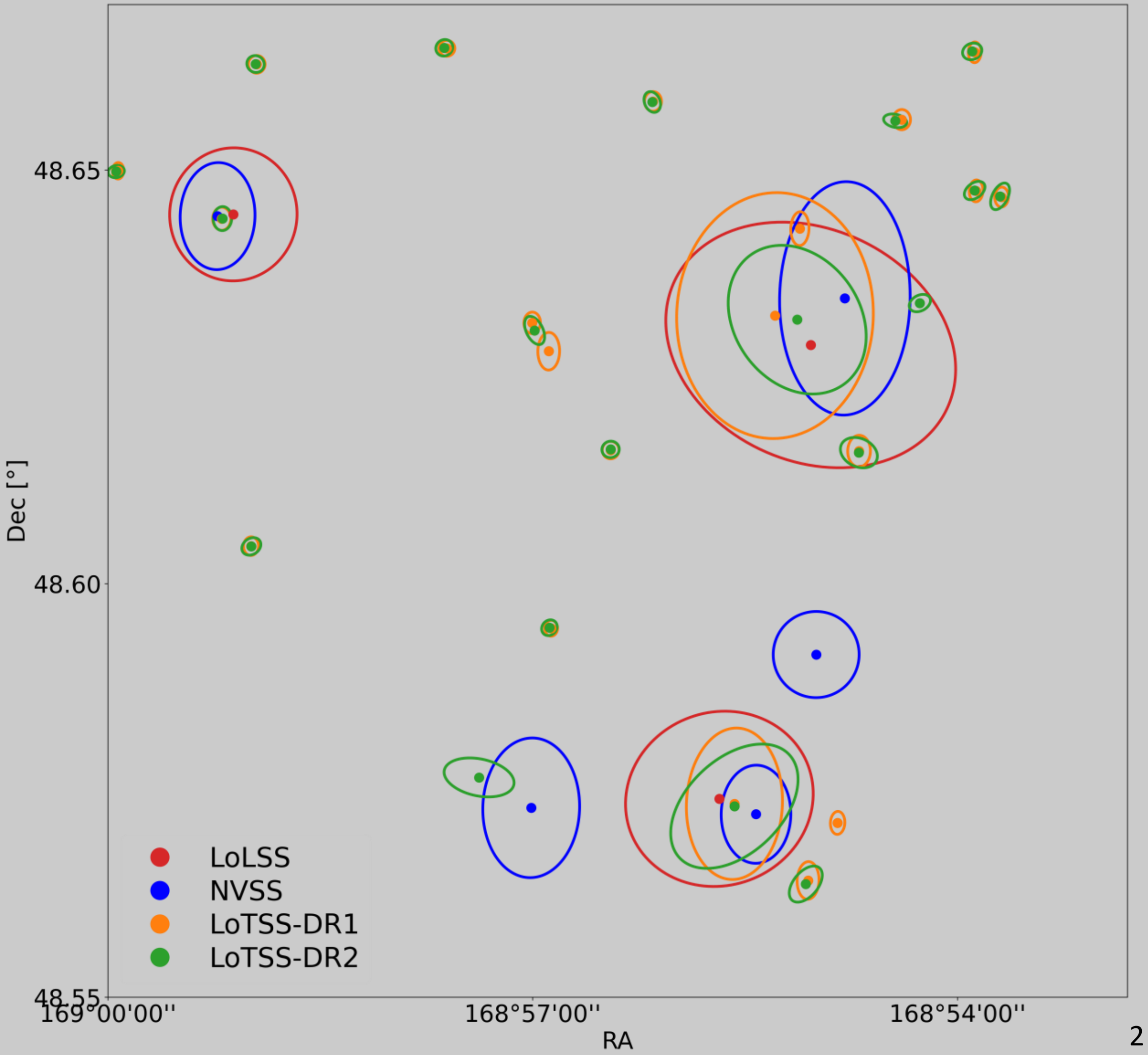


1400 MHz

L. Böhme et al., A&A accepted, arXiv: 2304.14829

Introduction

Motivation | Surveys | Data

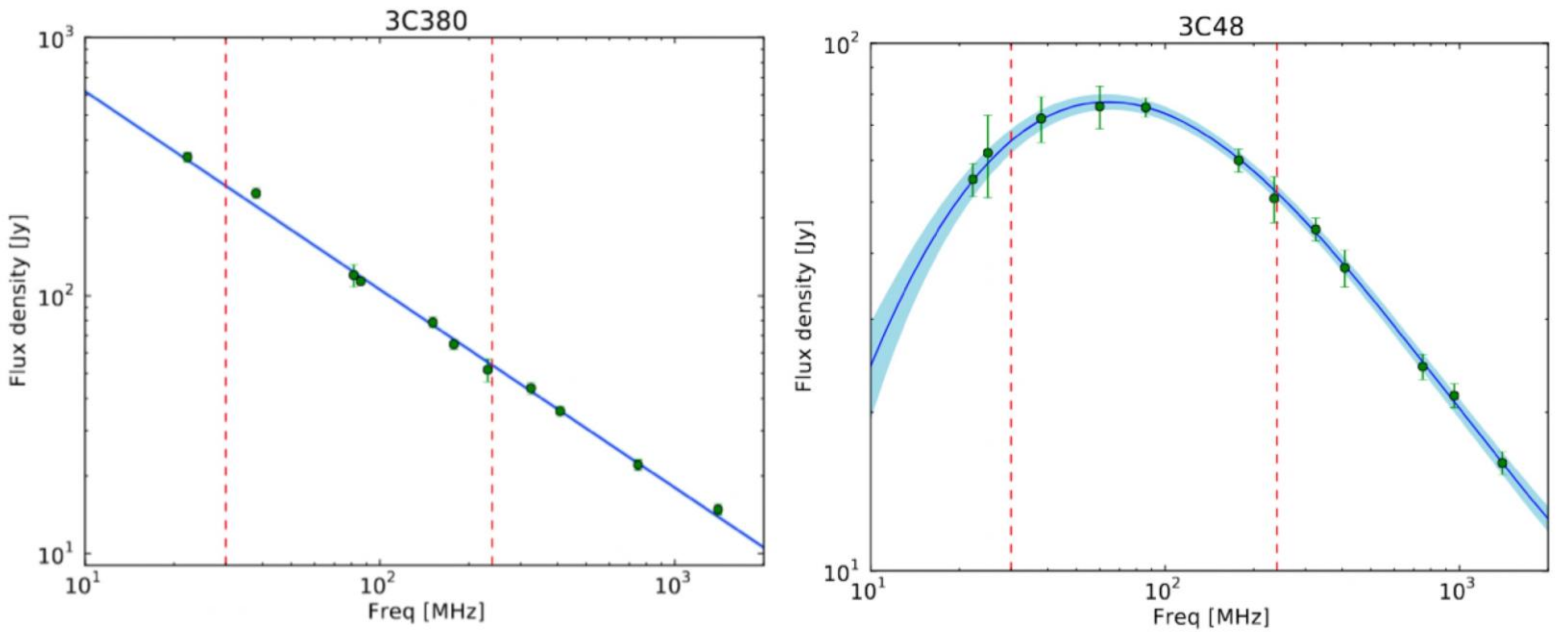


Motivation

LoLSS (LOFAR LBA Sky Survey) has unprecedented data quality at 54 MHz

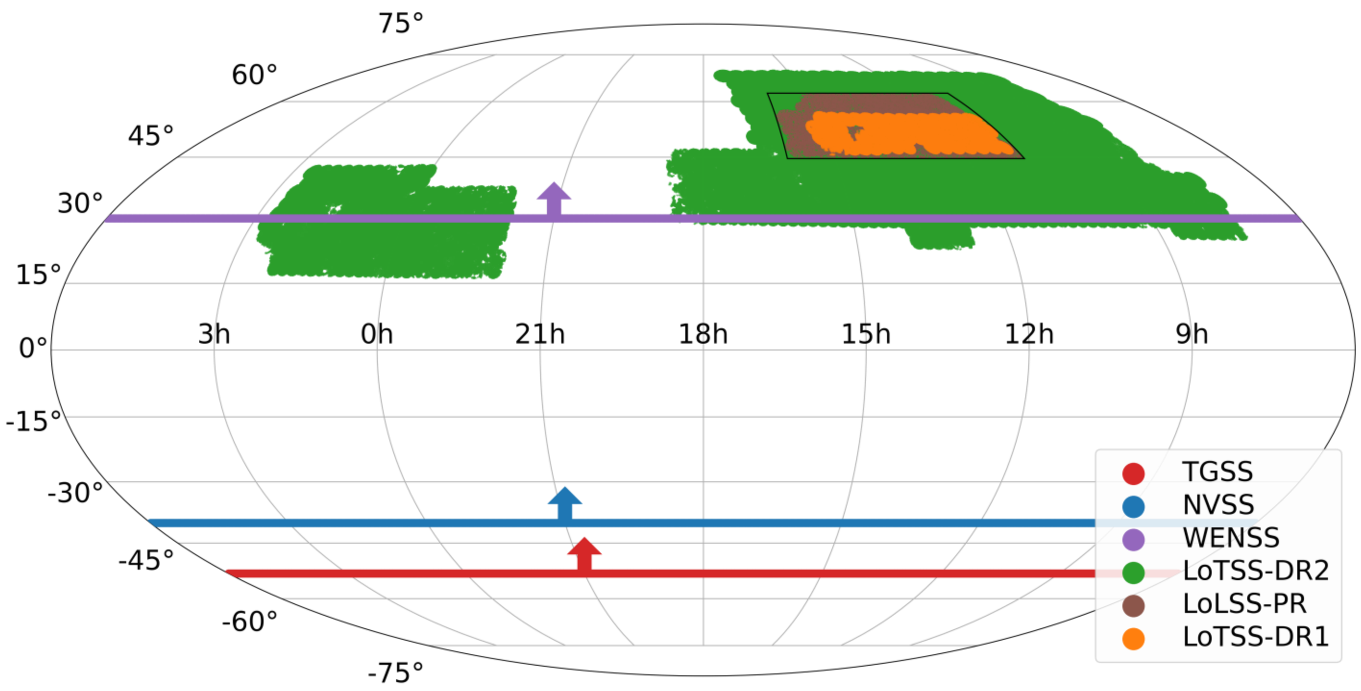
Spectral index: $S_\nu \propto \nu^\alpha$

Study spectral index α at low-frequency in a large sample



Example spectral energy distributions of 3C sources. Source: Scaife & Heald (2012)

Survey overview

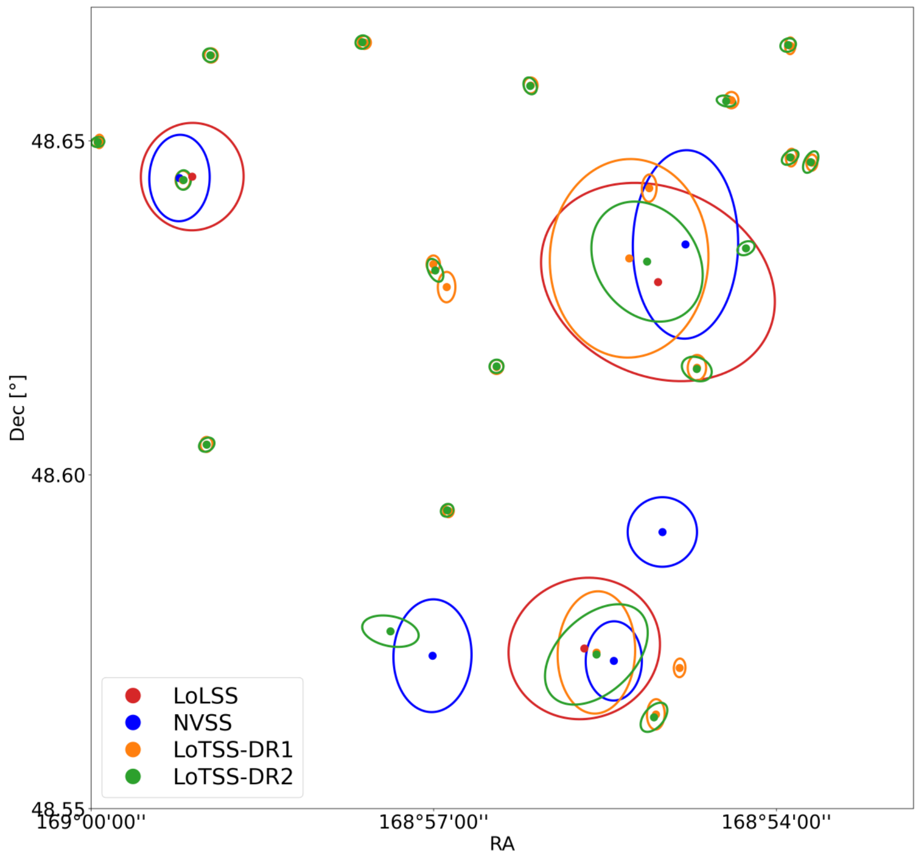


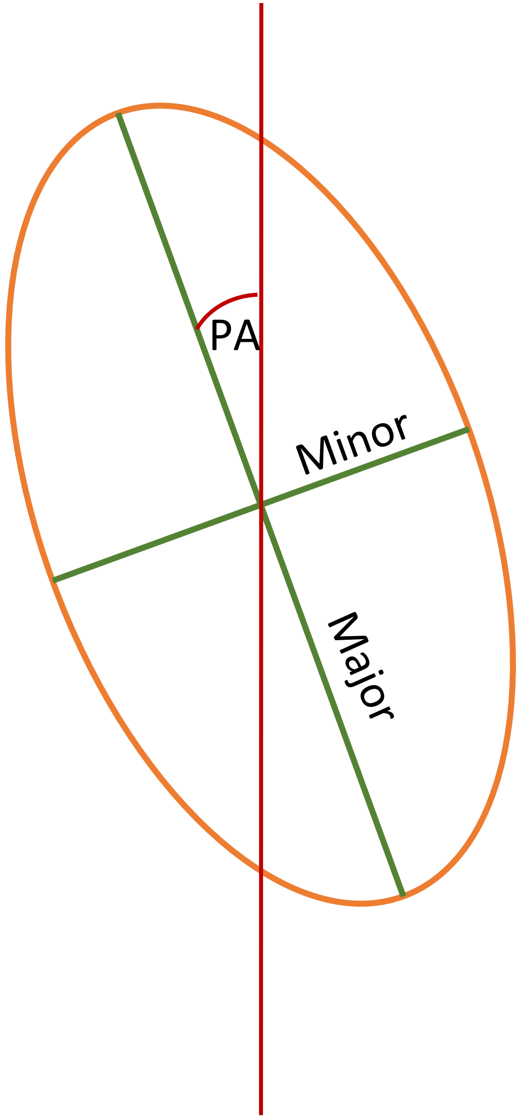
Survey name	Frequency [MHz]	Resolution	Source density $[\mathrm{deg}^{-2}]$
LoLSS-PR (de Gasperin et al. 2021)	54	47’’	34.1
LoTSS-DR2 (Shimwell et al. 2022)	144	6’’	780.2
NVSS (Condon et al. 1998)	1400	45’’	53.7
LoTSS-DR1 (Shimwell et al. 2019)	144	6’’	765.6
TGSS-ADR1 (Intema et al. 2017)	150	25’’	16.9
WENSS (Rengelink et al. 1997)	325	54x54/cos(δ)	22.5

Data

Gauss fits for every source:

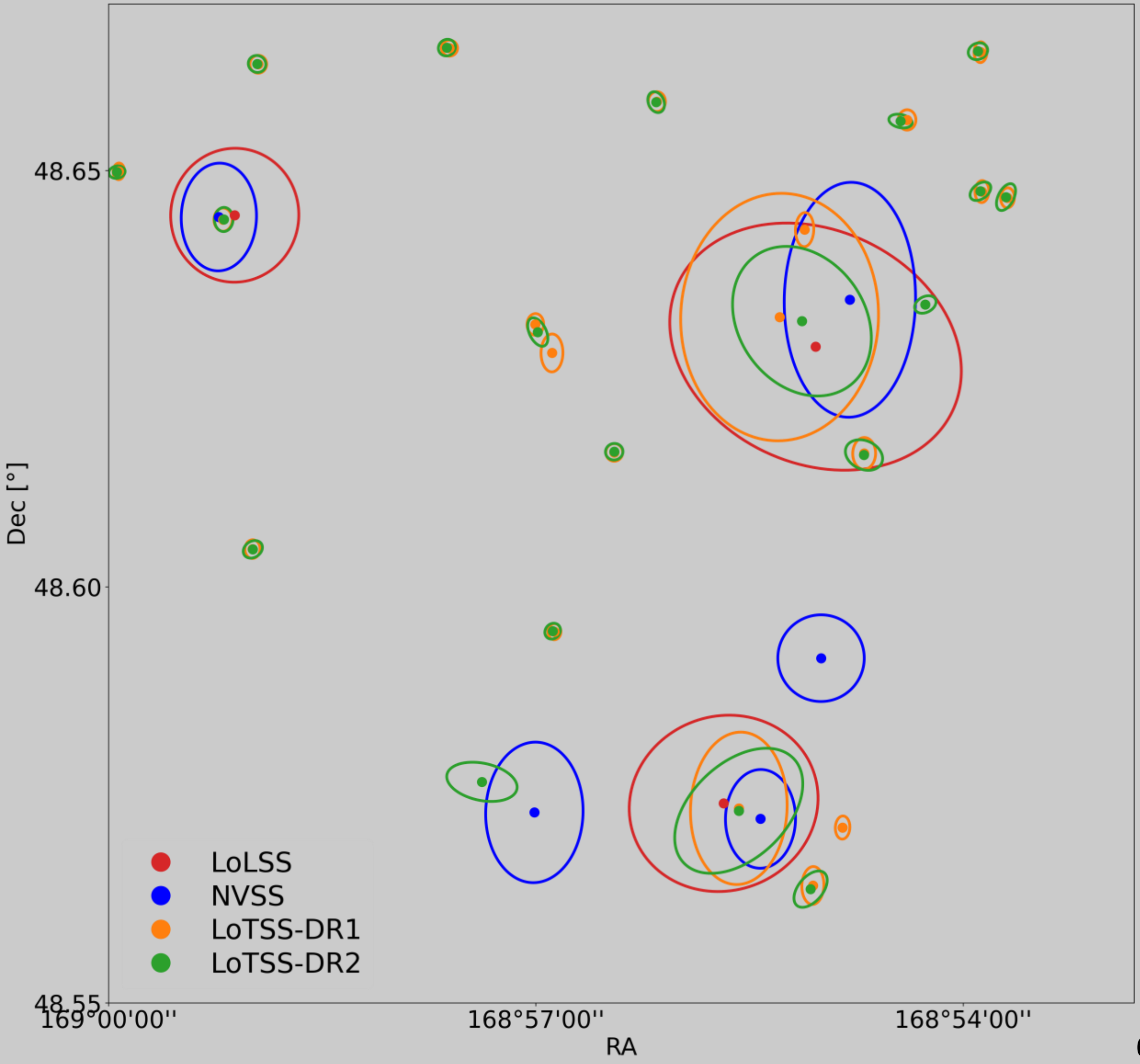
- Major axis
- Minor axis
- Positional angle PA





Cross-matching

Method | Artefacts | Result



Cross-matching

For every LoLSS source:

- Check for potential counterparts in 205’’
- Create Gaussian function with peak = 1.

Matching Step 1:

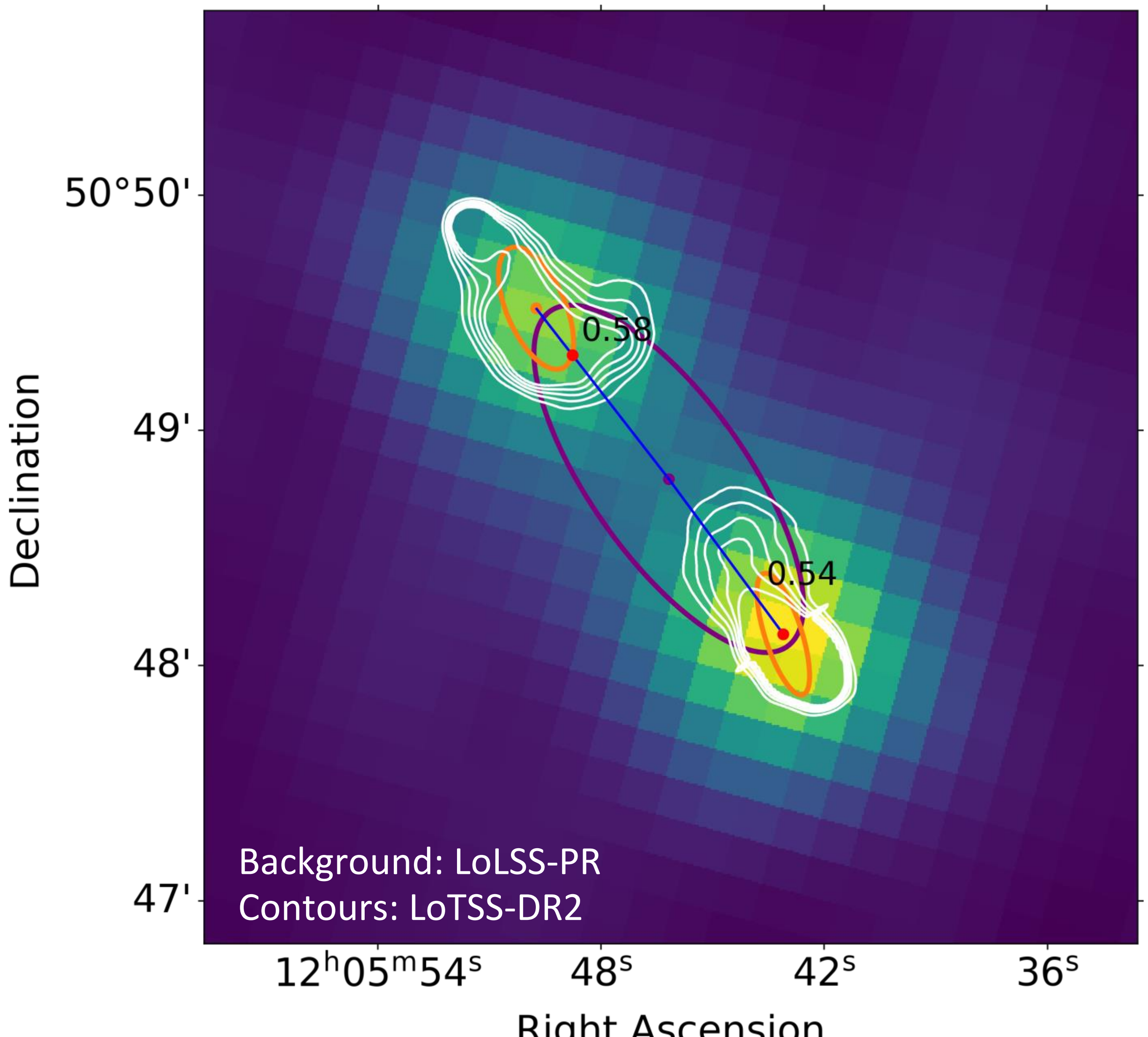
- Calculate value at each counterpart center

If not accepted: *Matching Step 2:*

- Calculate at line intersections with FWHM.

Accept matching if:

- $f_{center} \geq 0.5$ or
- $f_{intersect} \geq 0.55$



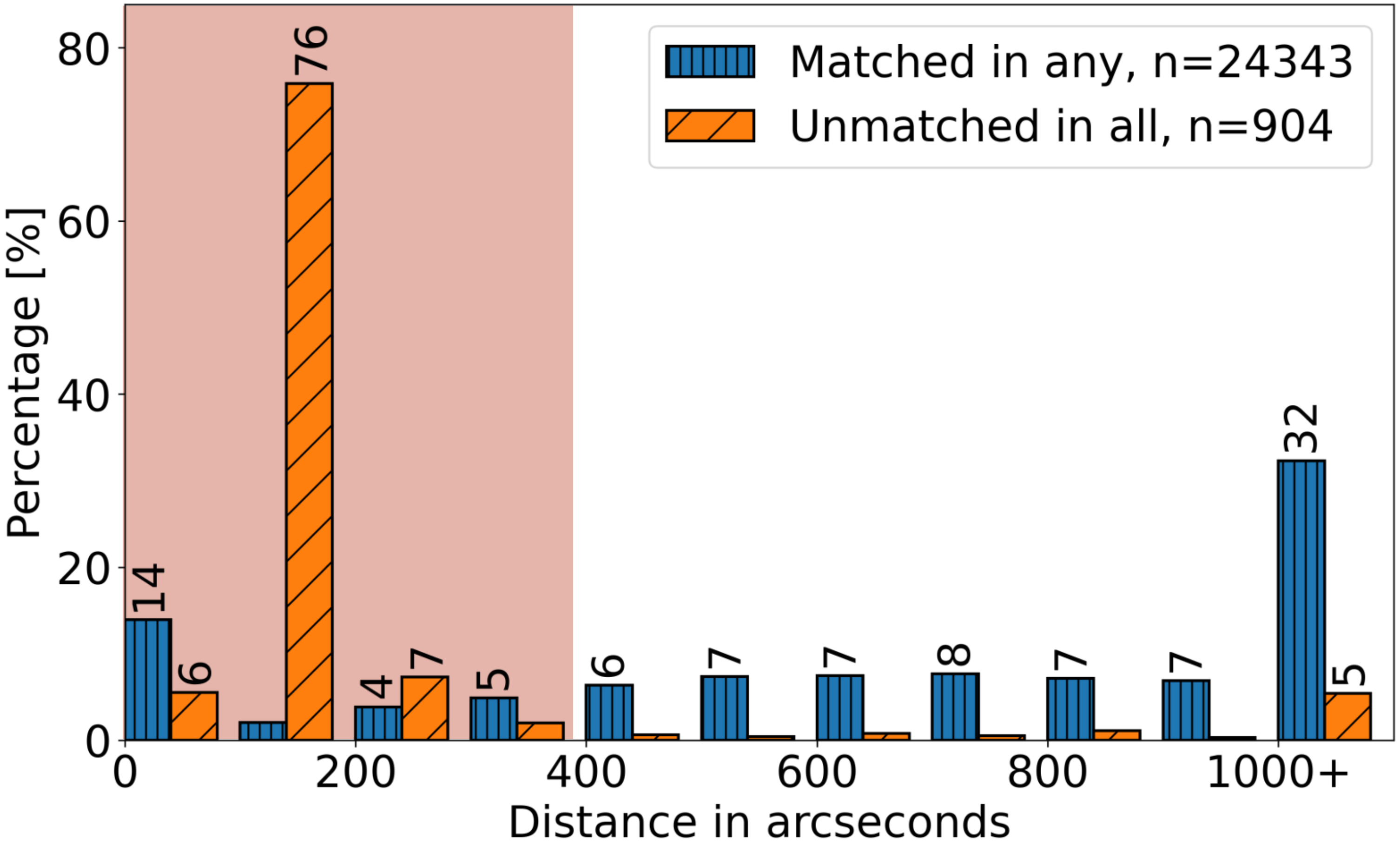
Cleaning

Bright source: $S_{54} \geq 0.5$ Jy

≈90% of unmatched sources are in vicinity to bright sources

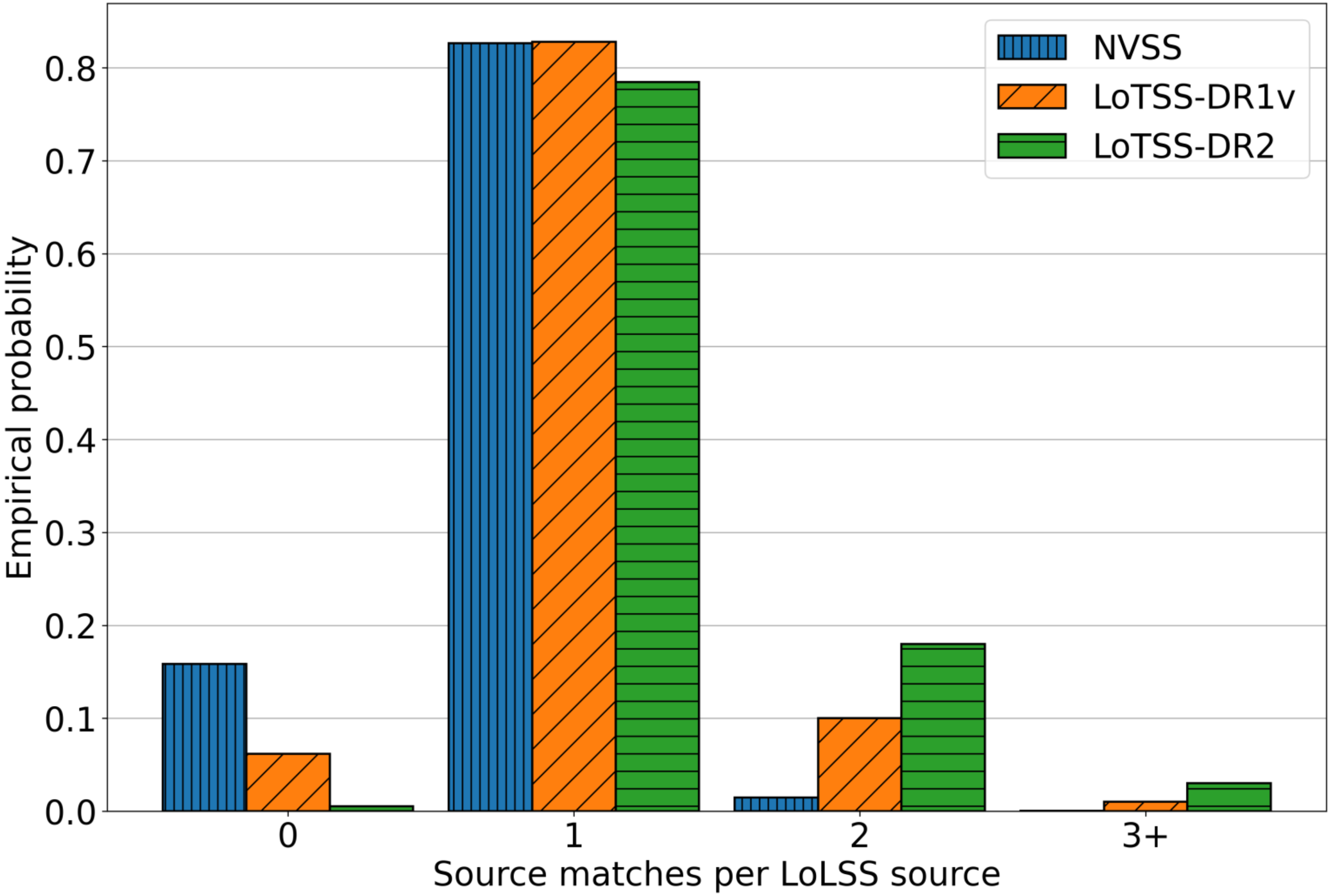
=> Remove all sources closer than 300'' from bright sources

This removes 2640 LoLSS sources (10.5%)



Cross-matching Result

80% single component
20% doubles



Results

Catalogue | Spectral Index

Three small catalogues

1. Steep spectrum:

   292 sources with $\alpha_{54}^{144} < -2$

2. High redshift, steep spectrum:

   9 sources with $z > 2, \alpha_{54}^{144} < -1$

3. High-redshift radio galaxies (HzRGs) candidates:

   46 compact (Maj$< 10''$, $\frac{\text{Peak}}{\text{Total}} > 0.8$), single comp., steep ($\alpha_{54}^{144} < -1.3$) sources

Overall catalogue completeness > 99%

Whole catalogue provides:

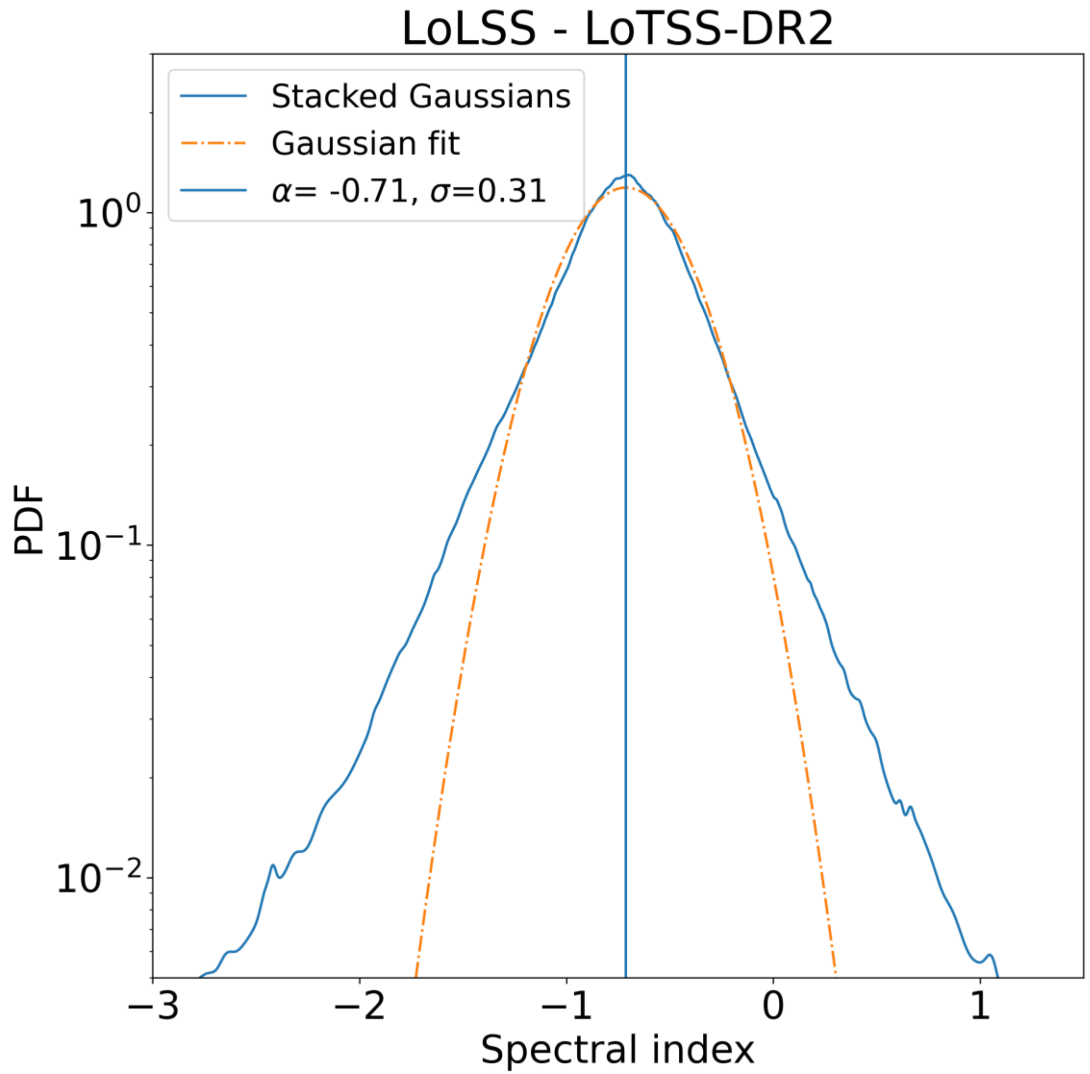
22 607 (89.5%) LoLSS sources with at least one cross-match

Spectral index

Calculated by bootstrapping the flux density values 1000 times

Sources matched in LoLSS-LoTSS-DR2:

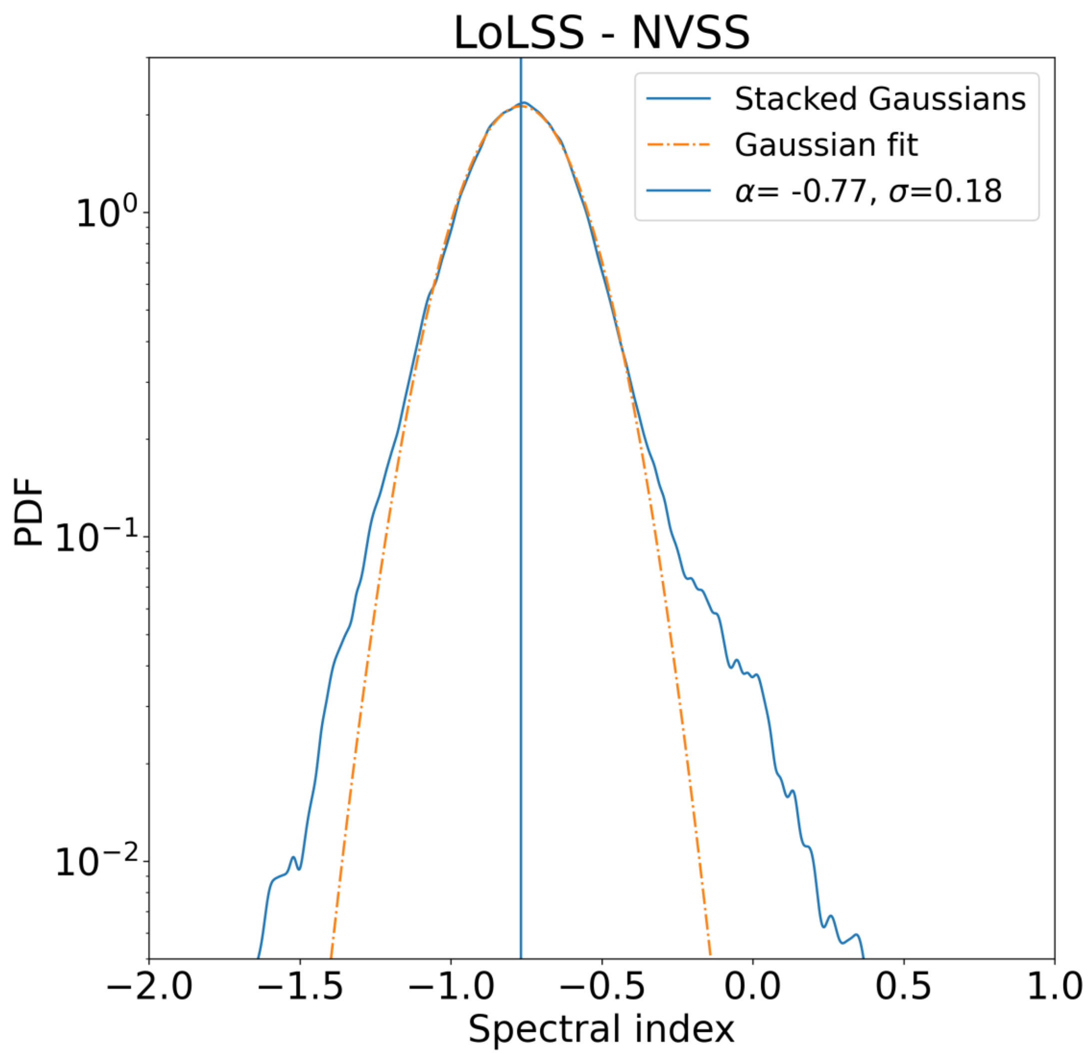
$$\alpha_{54}^{144} = -0.71 \pm 0.31$$



Spectral index

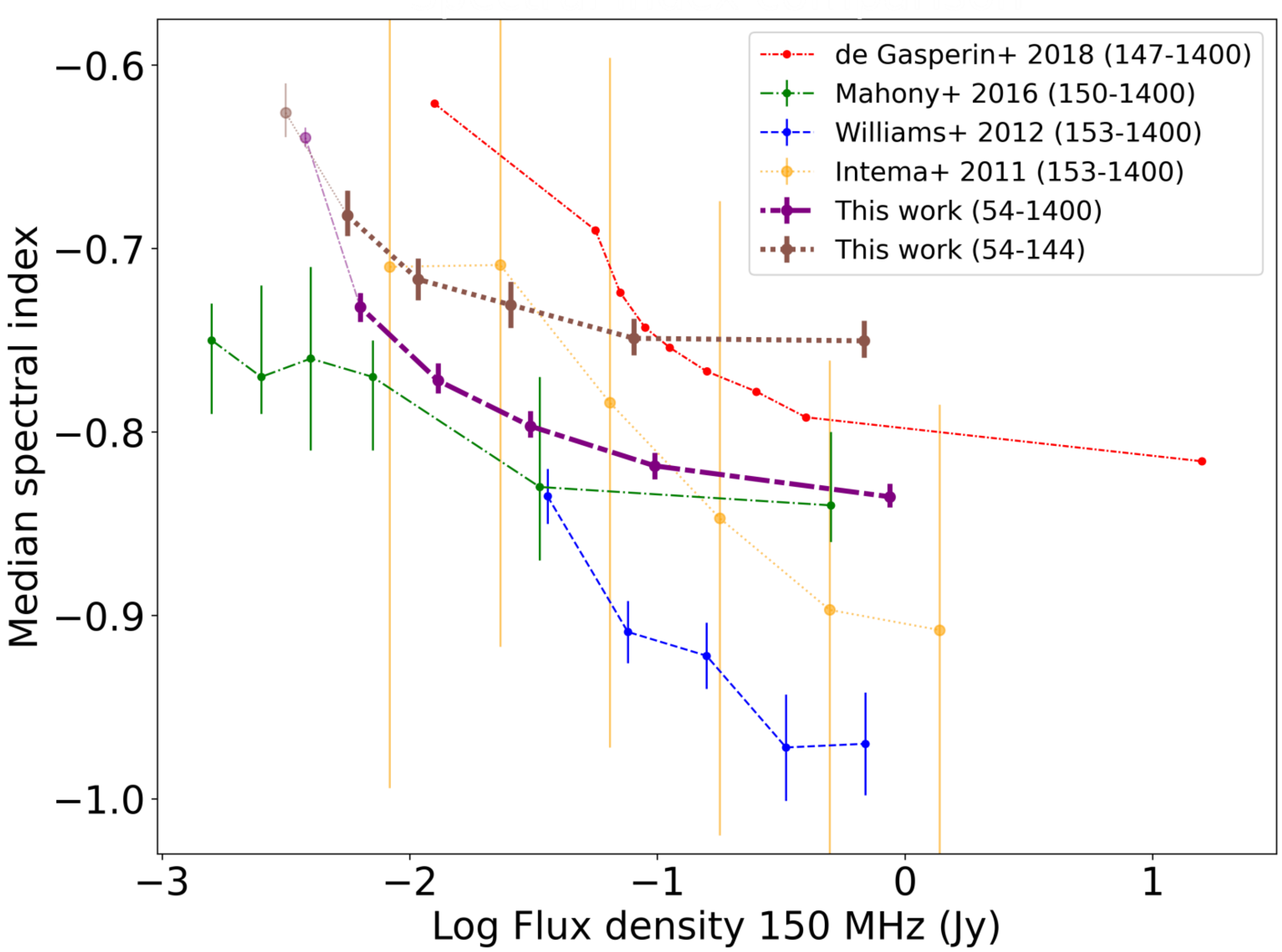
For sources matched in LoLSS-NVSS:

$$\alpha_{54}^{1400} = -0.77 \pm 0.18$$



Spectral index comparison

Similar trend in several studies



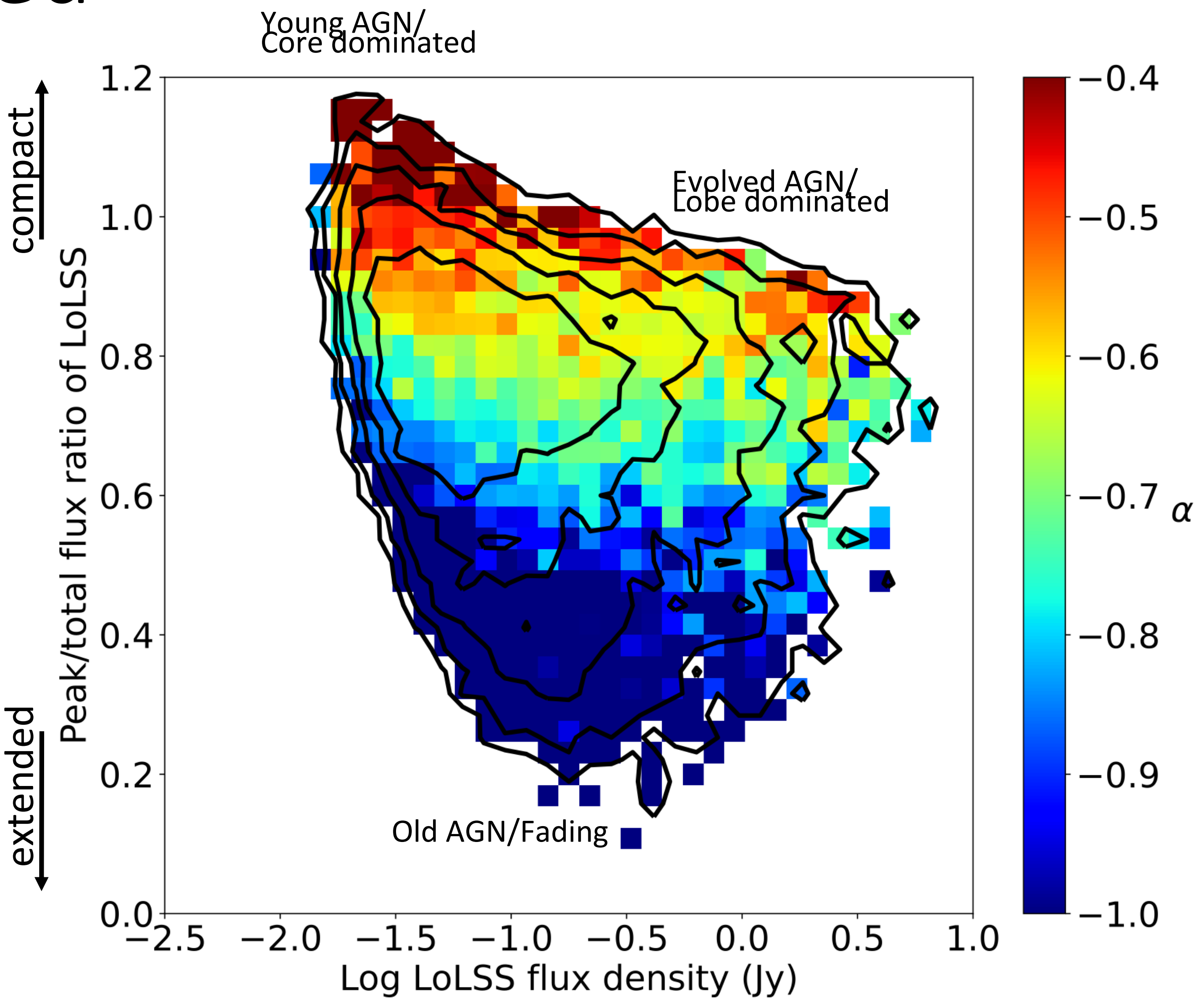
Compact and extended

A rough estimate of source size is Peak/Total flux density

Compact + Faint = Flat

Extended or bright = Steep(er)

$$\alpha_{core} \approx -0.4$$
$$\alpha_{lobe} \approx -0.7$$



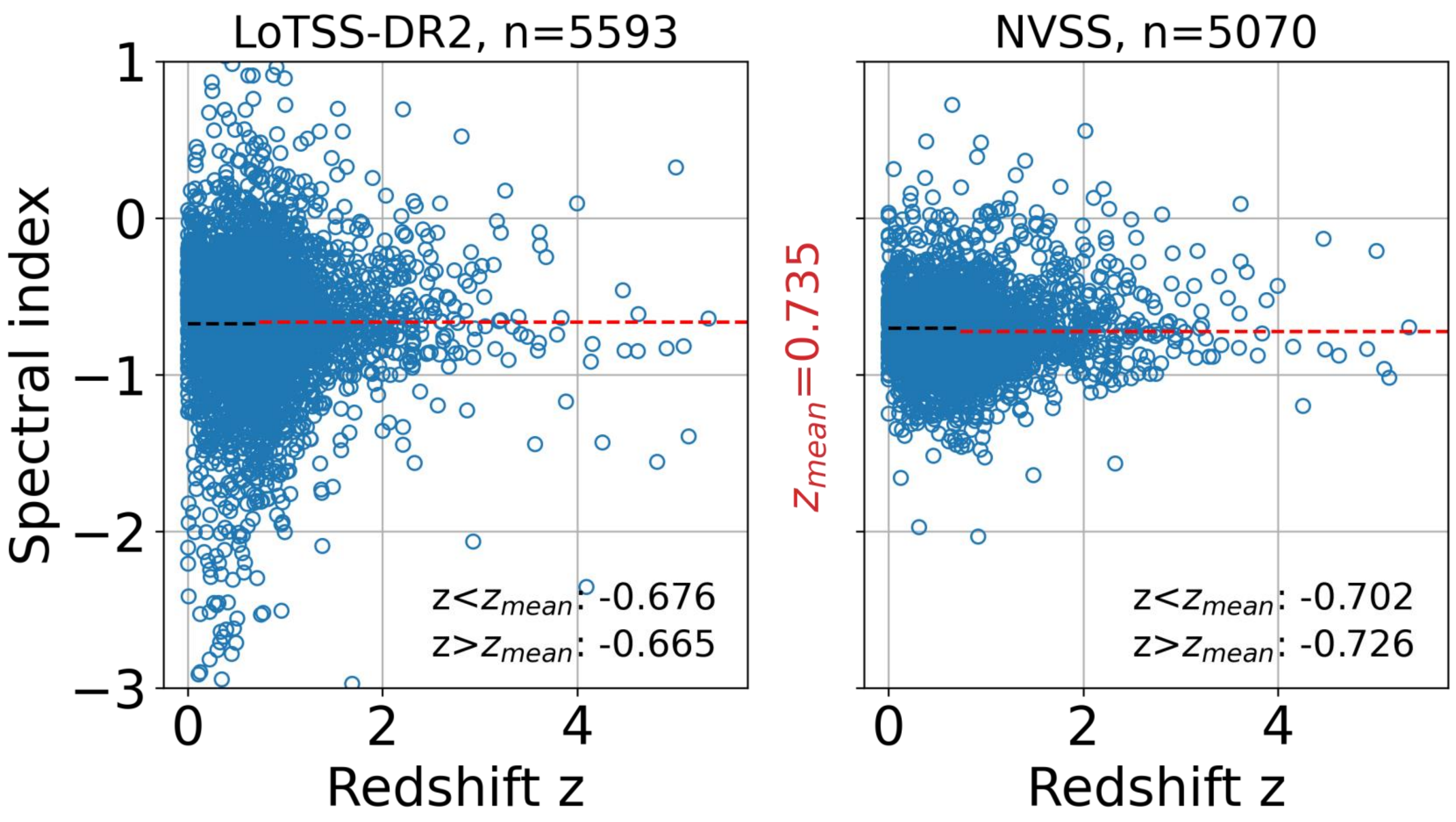
Spectral index and redshift

Photo-z from LoTSS-DR1v

Mean redshift z_{mean}= 0.73

No significant difference:

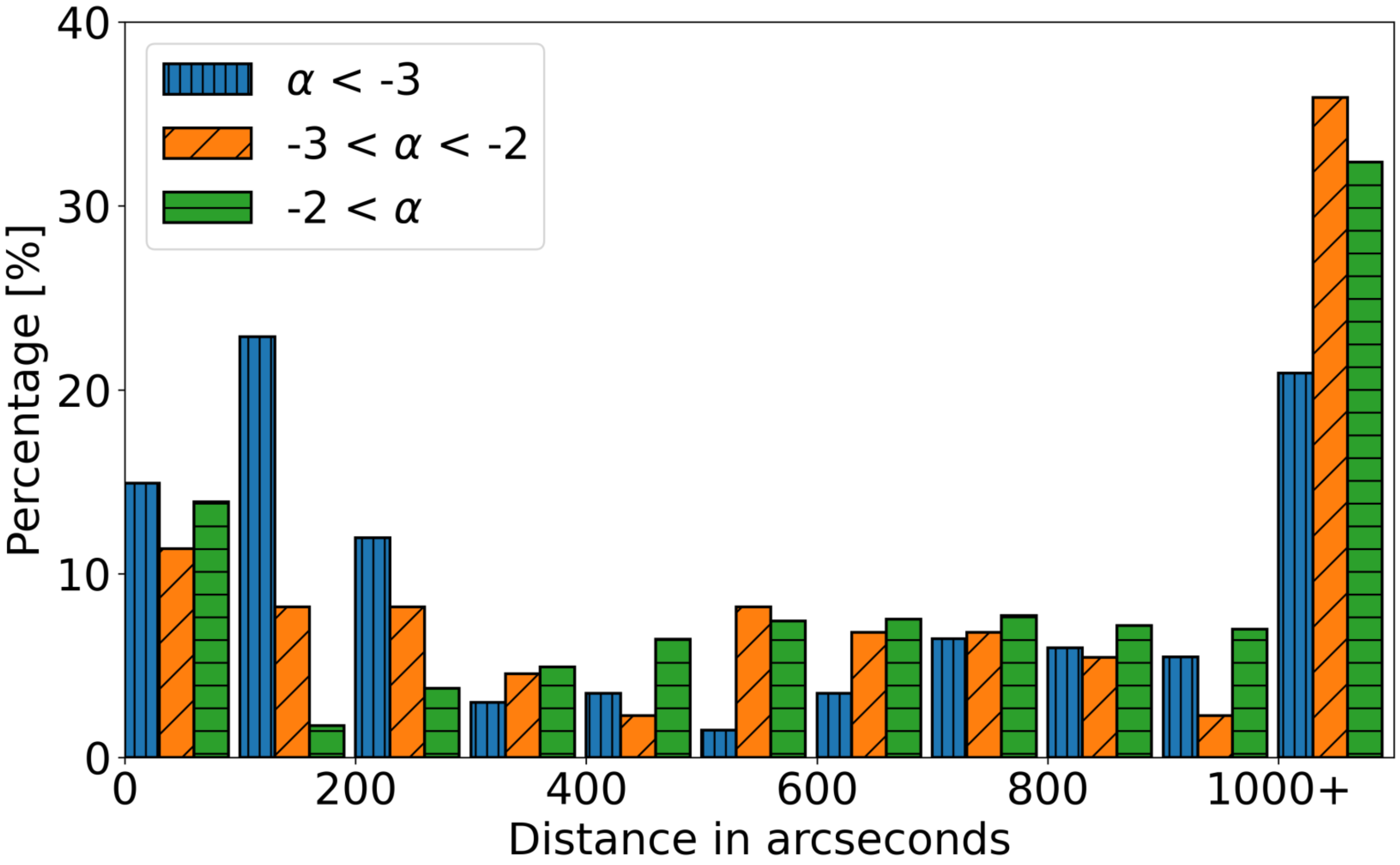
$$\alpha_{z<z_{mean}} \approx \alpha_{z>z_{mean}}$$



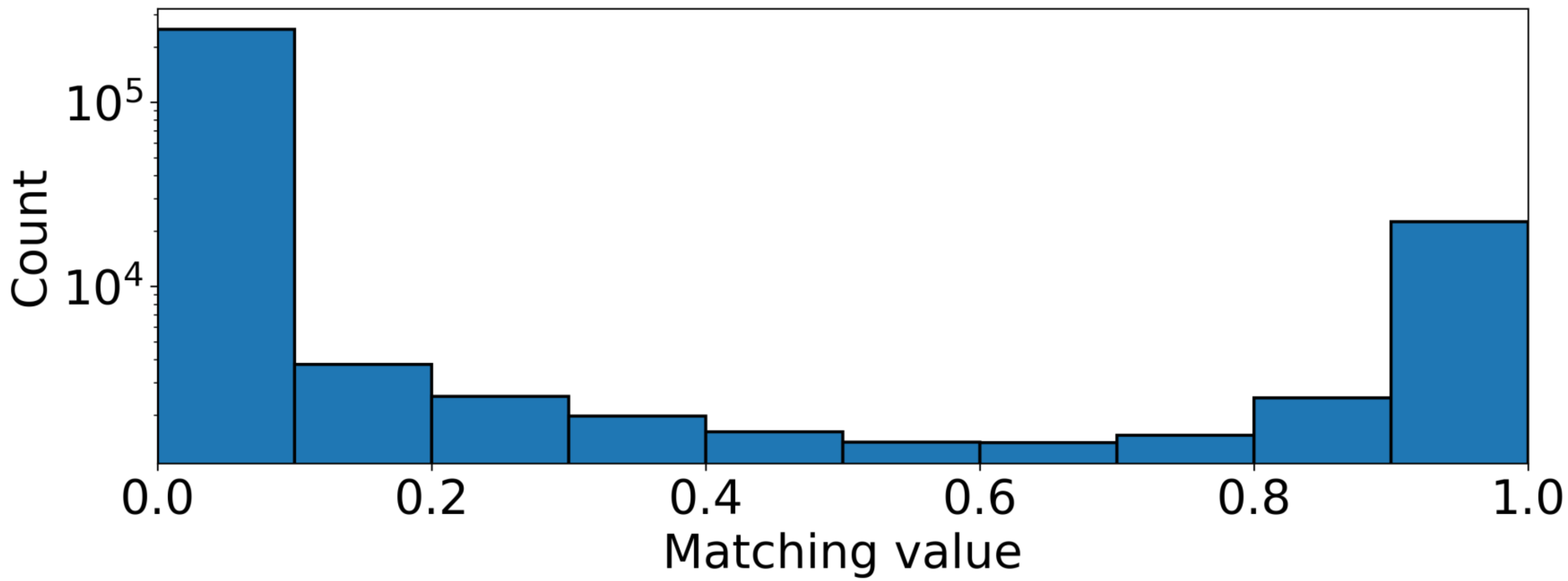
Summary

- 80% of LoLSS sources are single component
- About 20% are doubles
- An average spectral index of:
  - $\alpha_{54}^{1400} = -0.77 \pm 0.18$ and
  - $\alpha_{54}^{144} = -0.71 \pm 0.31$ is found
- No evolution of α with redshift is found

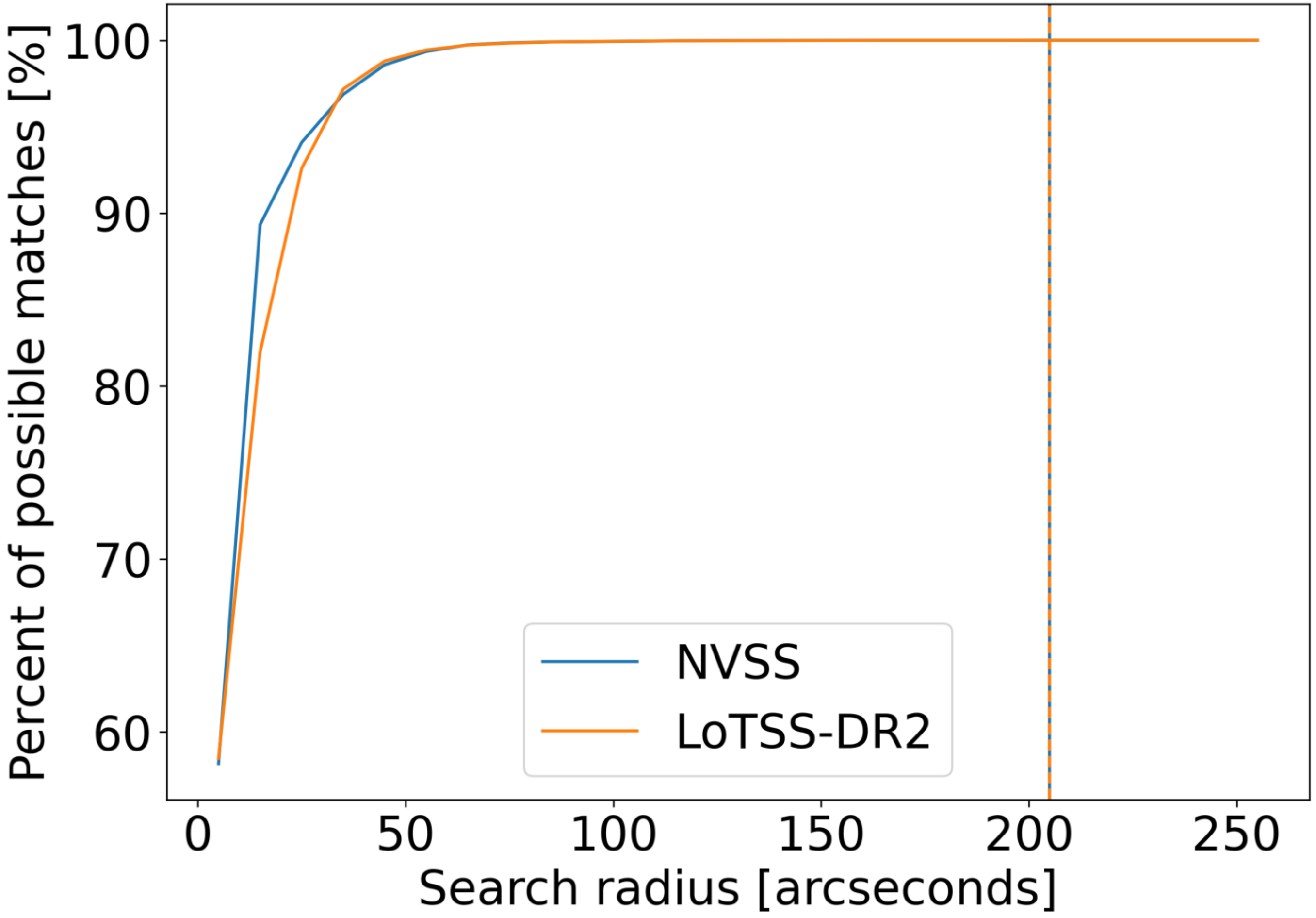
Thank you!

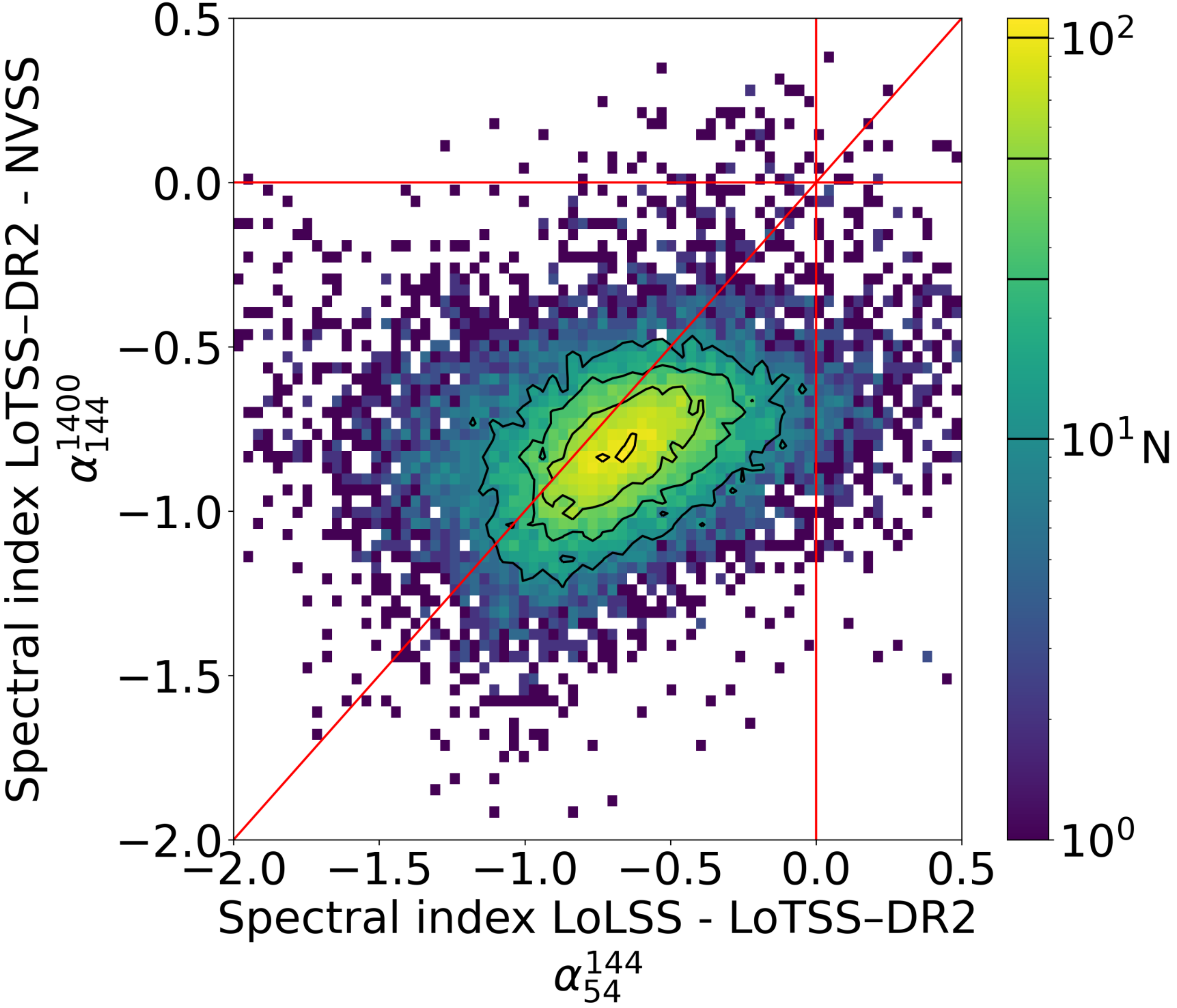


40
30
20
10
0
Percentage [%]
0
200
400
600
800
1000+
Distance in arcseconds
α < -3
-3 < α < -2
-2 < α



Count
10^5
10^4
0.0
0.2
0.4
0.6
0.8
1.0
Matching value


Percent of possible matches [%]
100
90
80
70
60
0
50
100
150
200
250
Search radius [arcseconds]
NVSS
LoTSS-DR2



Spectral index LoTSS–DR2 - NVSS
α_{144}^{1400}
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.0
−1.5
−1.0
−0.5
0.0
0.5
Spectral index LoLSS - LoTSS–DR2
α_{54}^{144}
10^2
10^1
N
10^0