22/51

"MY THANKS TO OLIVER FOR ENSURING WE MEET THIS BOARD'S QUOTA OF WOMEN."

Low-frequency radio continuum in optically selected quasars

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Energetics and life-cycles of radio sources, March, 2018

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LOFAR ATLAS CSIRO University of Hertfordshire

Outline

- Motivation
- Quasar sample and radio data

  SDSS QSOs

  LOFAR data over the HETDEX and H-ATLAS/NGP regions
- Results

  Radio loudness $(\mathscr{R})$ as a function of redshift (z),

  spectral index (α),
  black hole mass (M_{BH}),
  Eddington ratio (λ_{Edd})

- Future work and conclusions

Motivation

- *Is there a radio loudness dichotomy in QSOs?*
- *Does $\mathscr{R}$ depend on any SMBH parameters?*
- *What is the source of radio emission in optically selected QSOs?*

The classification ratios defined to date are not clear

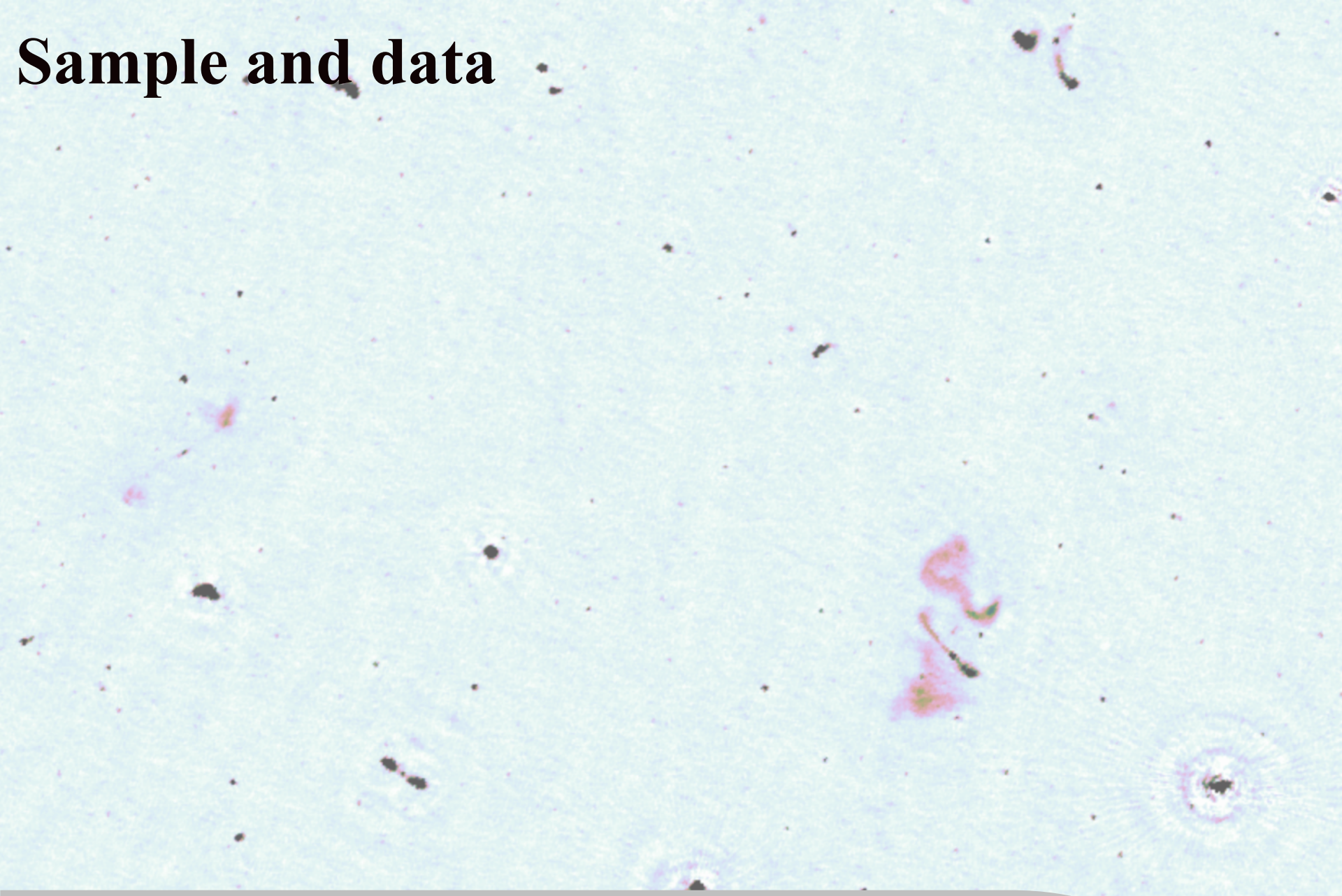
The definition of radio loudness involved using fluxes (or luminosities) at a various optical and radio bands

Construction of the radio loudness definitions to date have been based on samples from different surveys and samples with varying properties

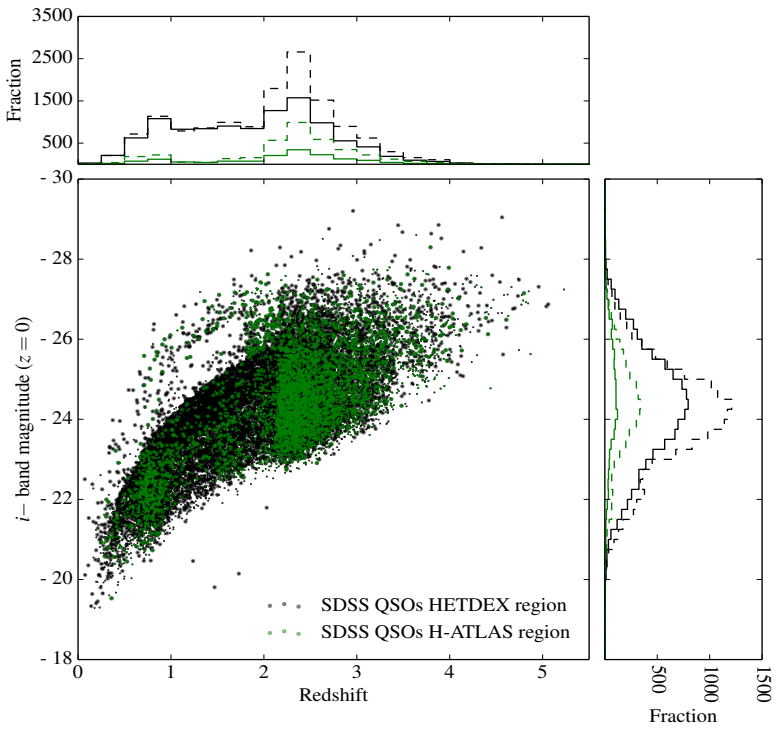
It is still not known which definition is statistically significant

A good fraction of QSOs classified as RL and RQ in the literature might present similar properties

Sample and data



Sample and data



Radio data:

Low Frequency Array (LOFAR)

– LOTSS *[Shimwell +18 in prep.,Williams+18 in prep., Duncan+18 in prep.]*

~ 100 μJy sensitivity and 6 arcsec resolution

– H-ATLAS/NGP *[Hardcastle +16]*

~ 100 μJy sensitivity and 6 arcsec resolution

Optical data:

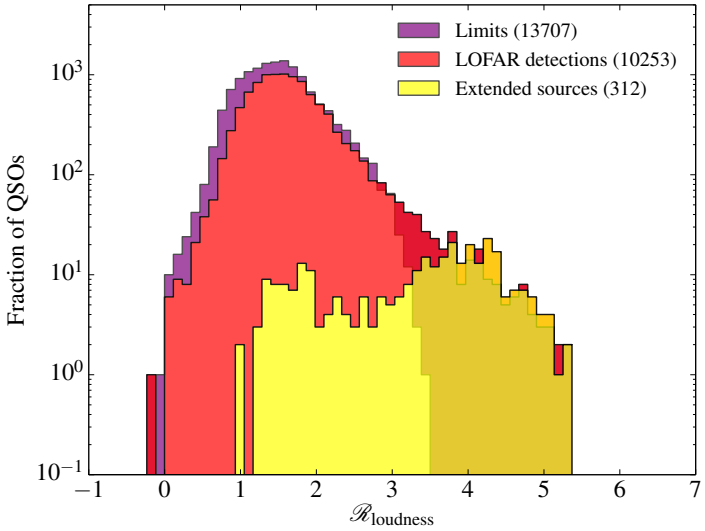
Sample ⟶ SDSS-BOSS DR12 *[Alam et al. 2015, Ross et al. 2012, Paris et al. 2014]*

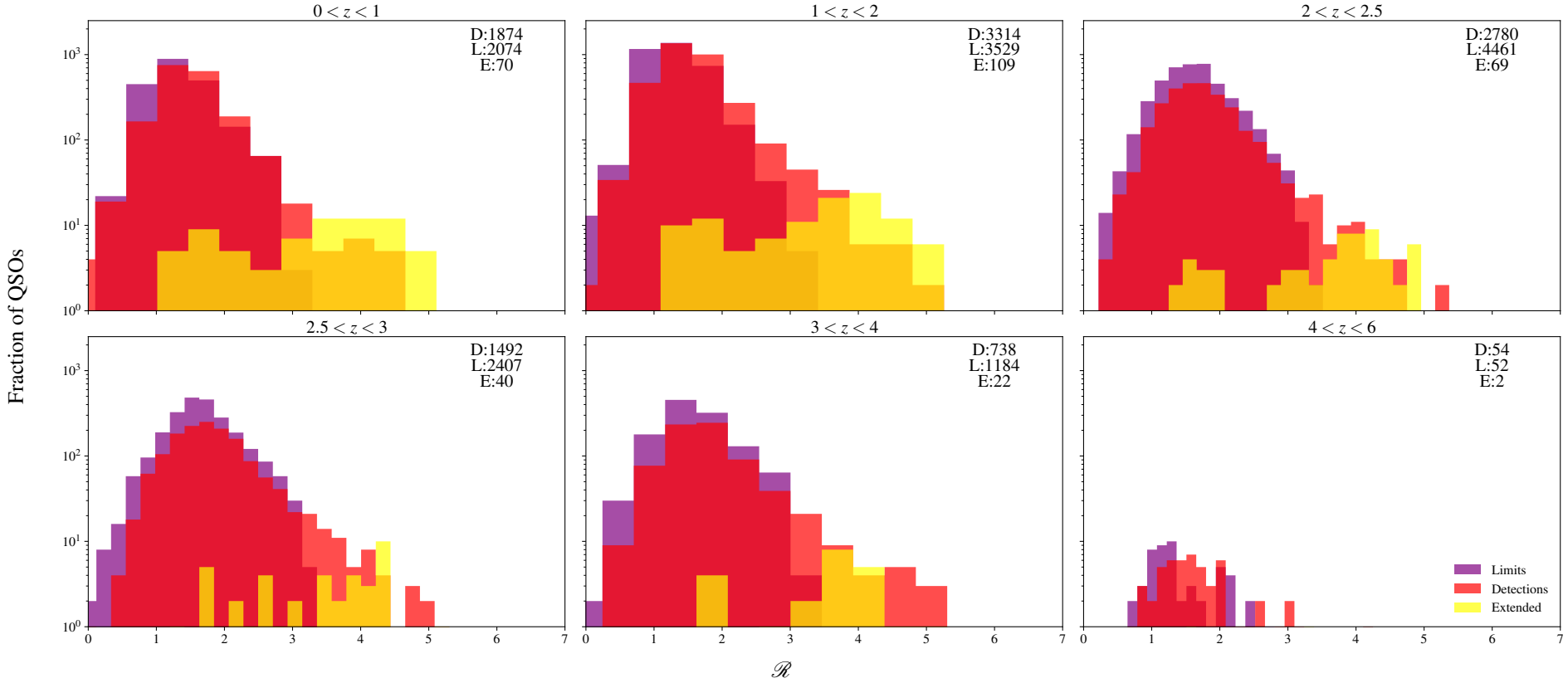
Redshifts *(0 < z < 6)*, SDSS band magnitudes *(u,g,r,i,z)*

Optical bolometric luminosities, black hole masses and Eddington ratios ⟶ Kozlowski +17

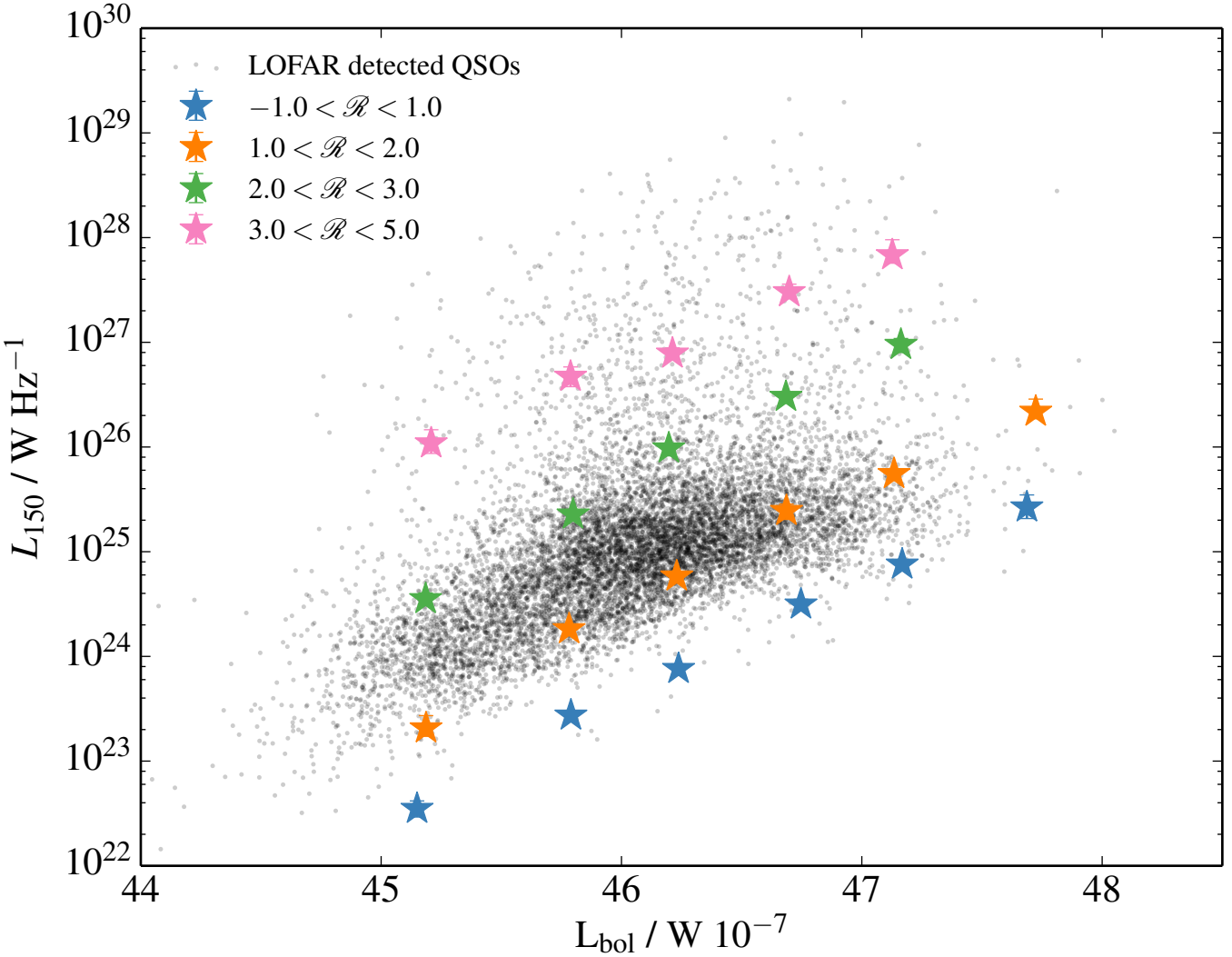
Results – Radio loudness ($\mathscr{R}$)

$$\mathscr{R} = \frac{L_{150}(W/Hz)}{L_{i-band}(W/Hz)}$$

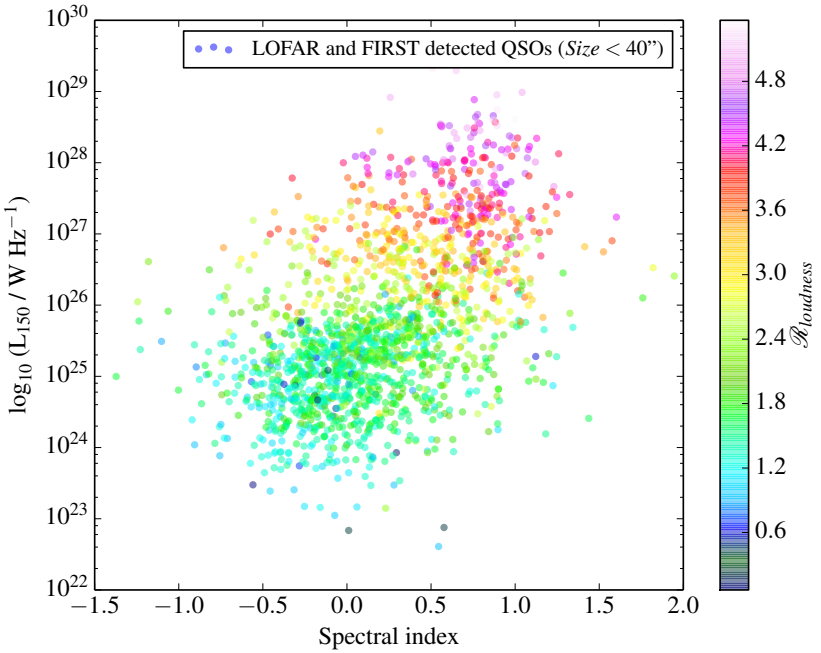


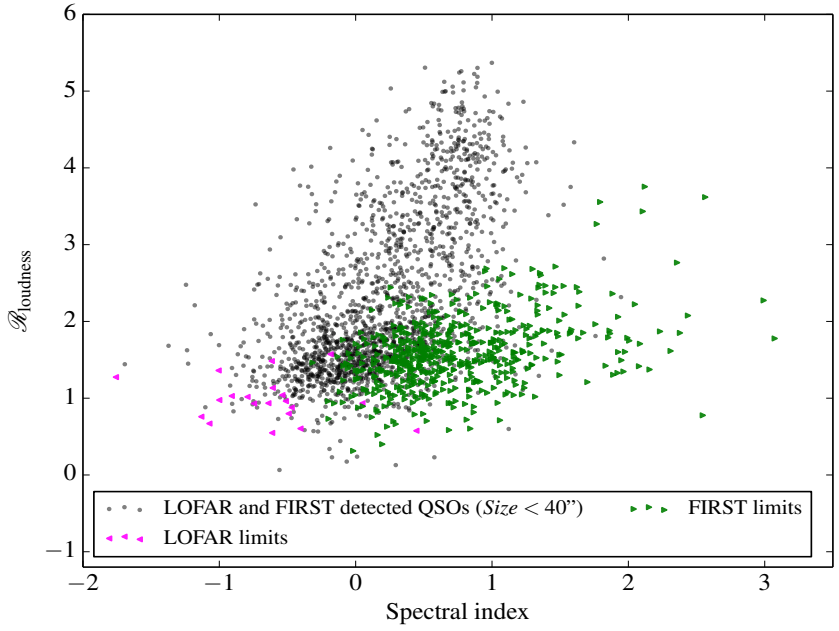


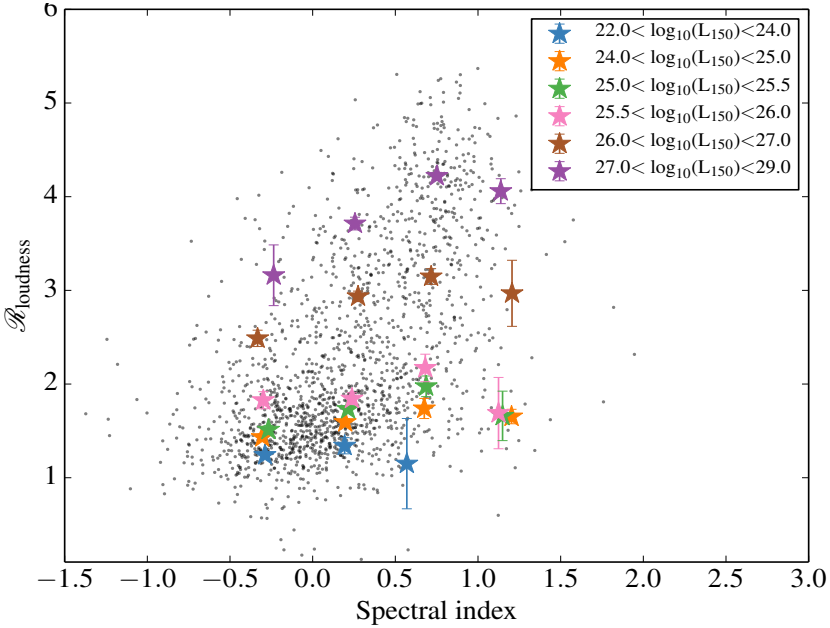
Results


LOFAR detected QSOs
$-1.0 < \mathscr{R} < 1.0$
$1.0 < \mathscr{R} < 2.0$
$2.0 < \mathscr{R} < 3.0$
$3.0 < \mathscr{R} < 5.0$
10^{30}
10^{29}
10^{28}
10^{27}
10^{26}
10^{25}
10^{24}
10^{23}
10^{22}
L_{150} / W Hz^{-1}
44
45
46
47
48
L_{bol} / W 10^{-7}

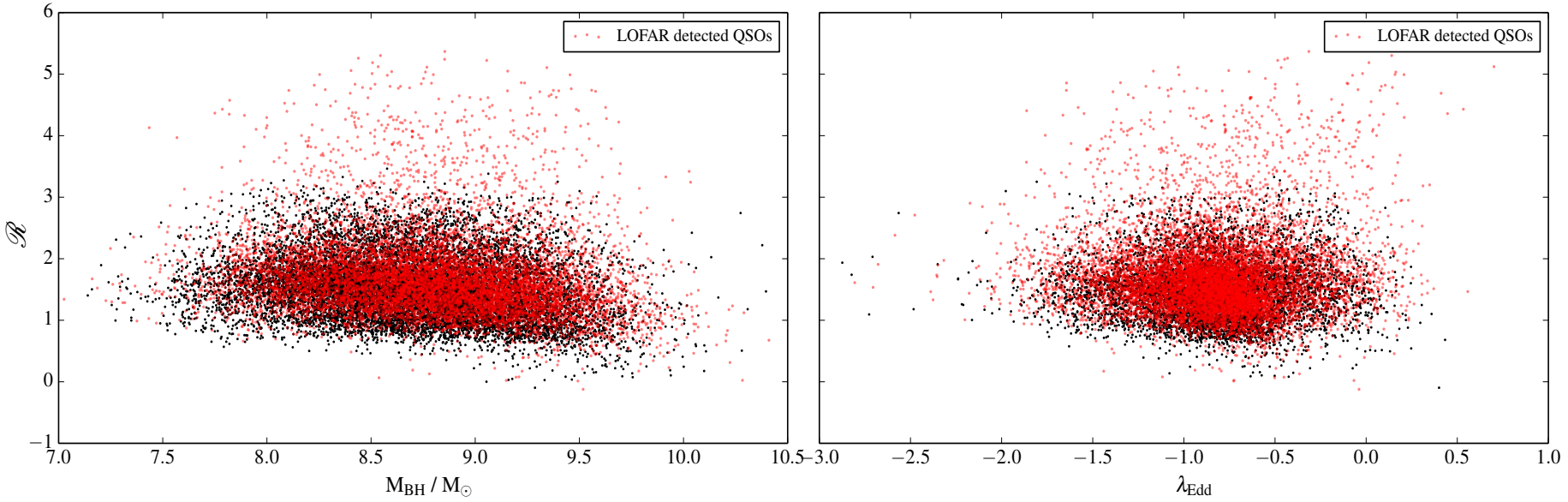
Results – $\mathscr{R}$ and spectral index







Results – $\mathscr{R}$ and SMBH parameters



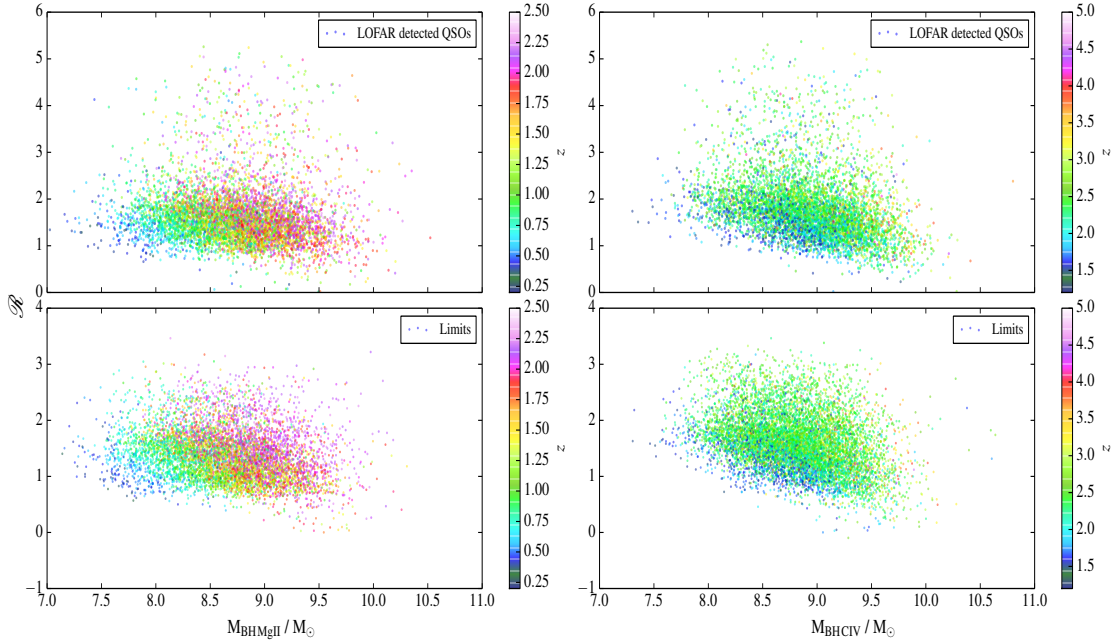
Black hole masses

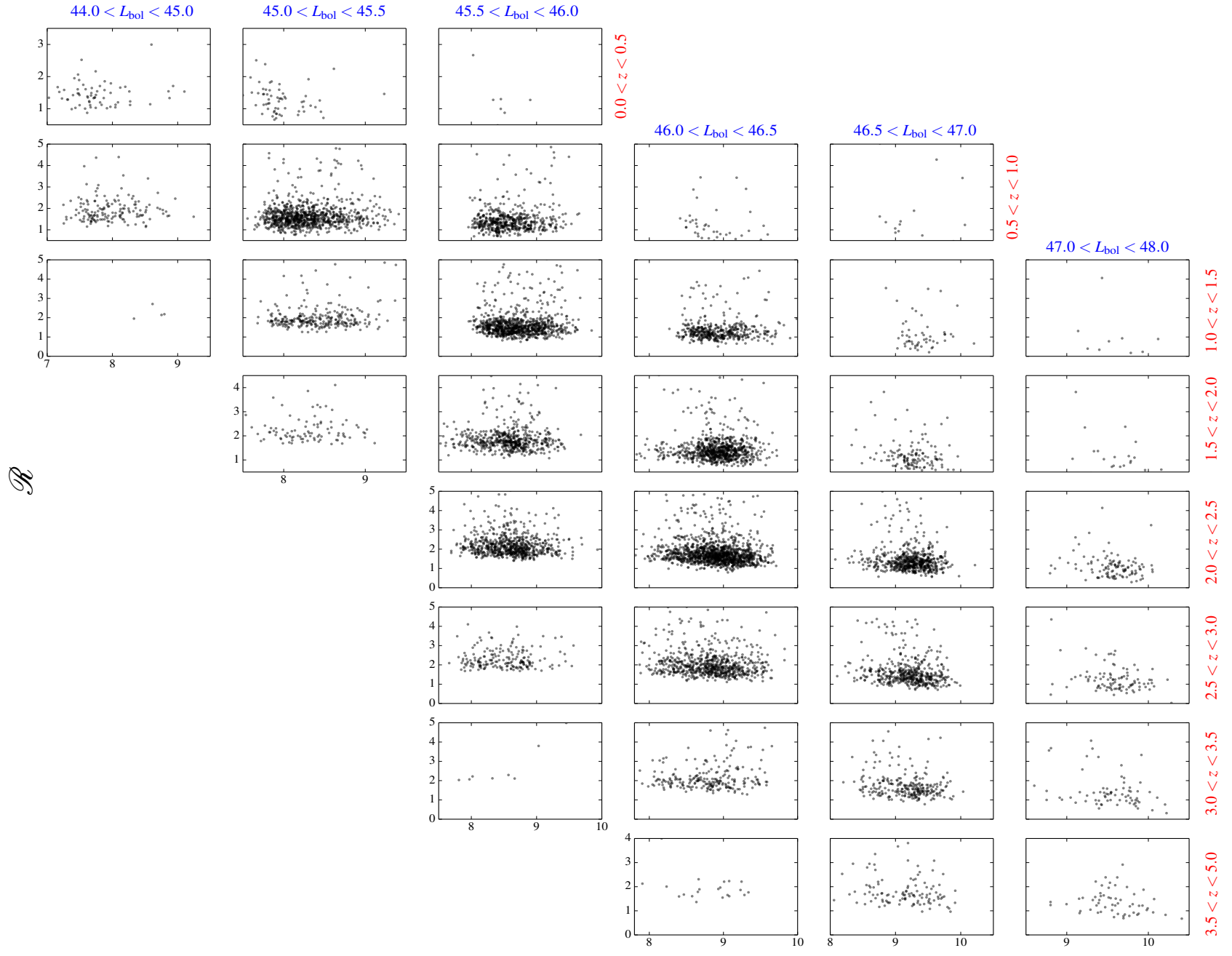
M_{BH} using MgII line

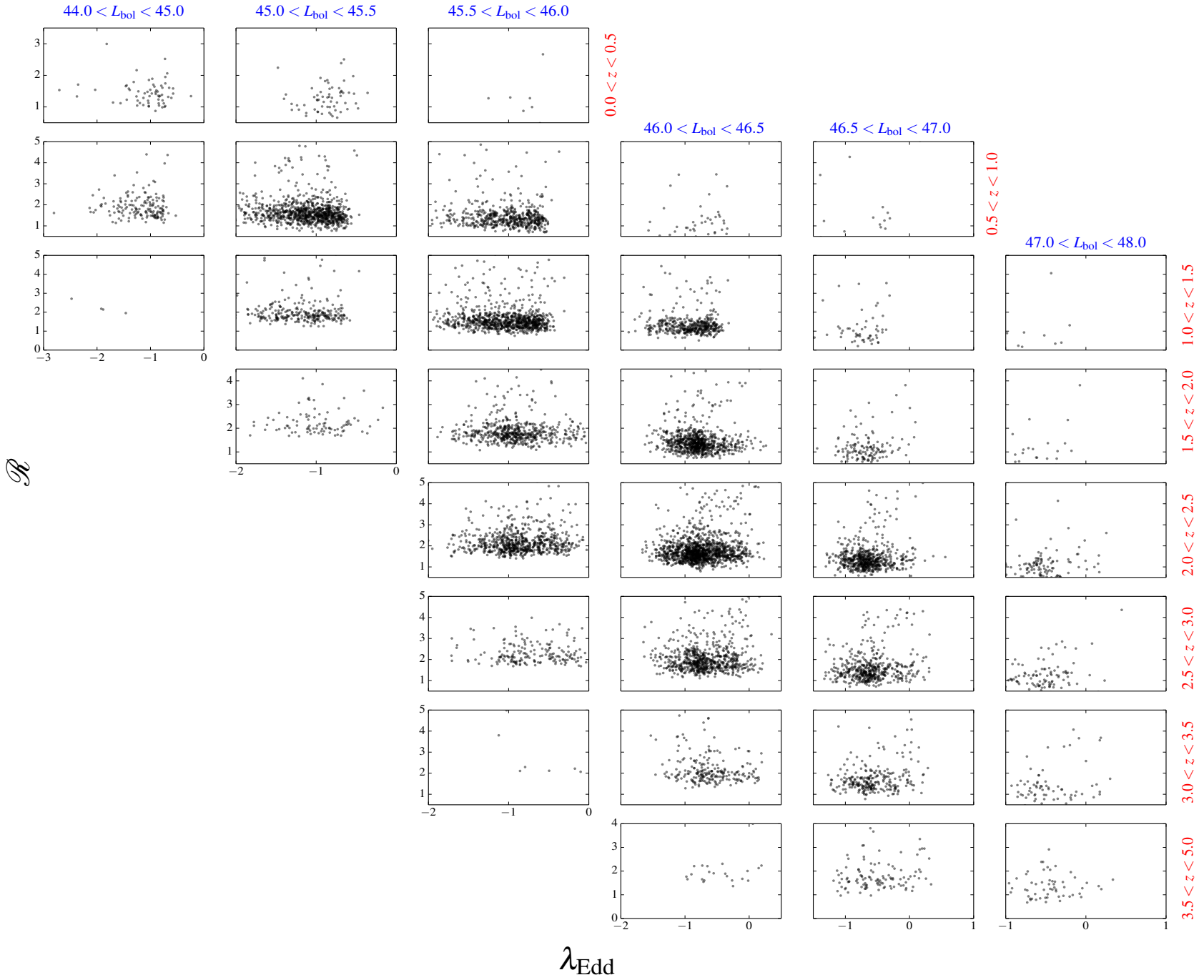
QSOs z<1.5

M_{BH} using CIV line

QSOs z>1.5




44.0 < L_{bol} < 45.0
45.0 < L_{bol} < 45.5
45.5 < L_{bol} < 46.0
46.0 < L_{bol} < 46.5
46.5 < L_{bol} < 47.0
47.0 < L_{bol} < 48.0
0.0 < z < 0.5
0.5 < z < 1.0
1.0 < z < 1.5
1.5 < z < 2.0
2.0 < z < 2.5
2.5 < z < 3.0
3.0 < z < 3.5
3.5 < z < 5.0
$\mathscr{R}$
M_{BH} / $M_{\odot}$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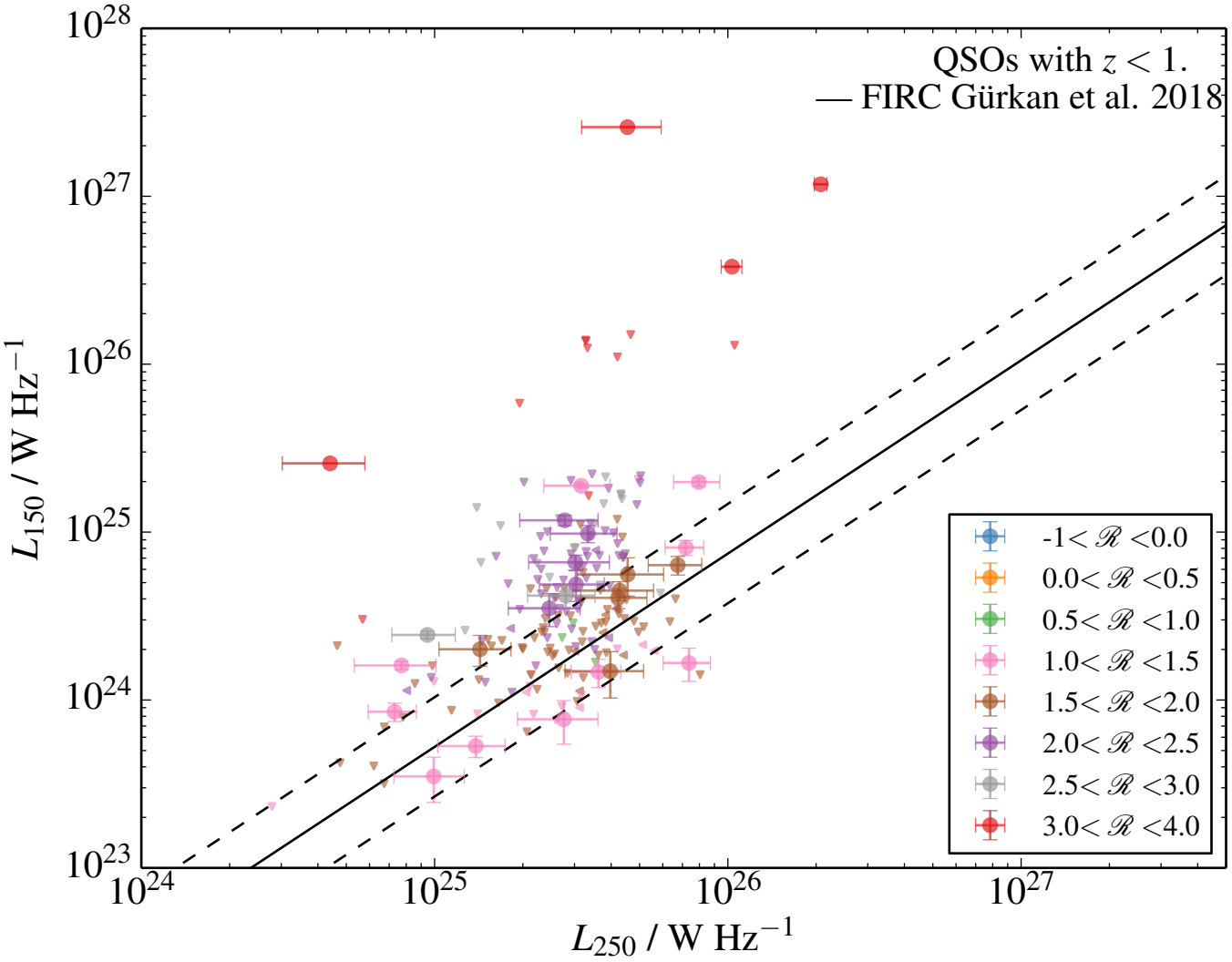
45.5 < L_{bol} < 46.0
46.0 < L_{bol} < 46.5
46.5 < L_{bol} < 47.0
47.0 < L_{bol} < 48.0
0.0 < z < 0.5
0.5 < z < 1.0
1.0 < z < 1.5
1.5 < z < 2.0
2.0 < z < 2.5
2.5 < z < 3.0
3.0 < z < 3.5
3.5 < z < 5.0
$\mathscr{R}$
λ_{Edd}

Results – the source of radio emission in QSOs



Conclusions & future work

- *Is there a radio loudness dichotomy in QSOs?*

Optically selected QSOs show a wide continuum of radio properties.

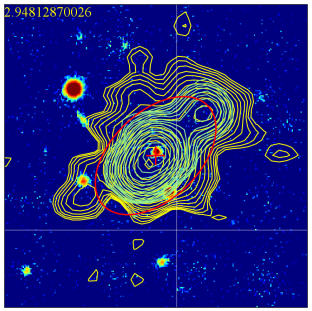
- *Does $\mathscr{R}$ depend on any BH parameters?*

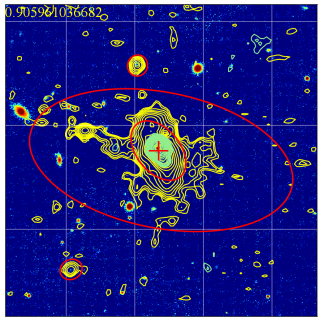
We do not observe any dependency of $\mathscr{R}$ on either black hole mass or Eddington ratio.

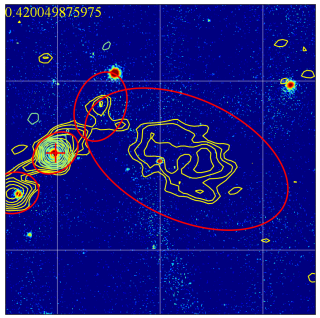
- *What is the source of radio emission in optically selected QSOs?*

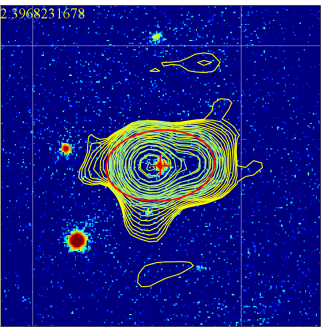
Contribution from star-formation?

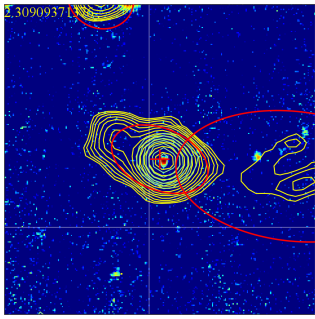
Gurkan+18 in prep.



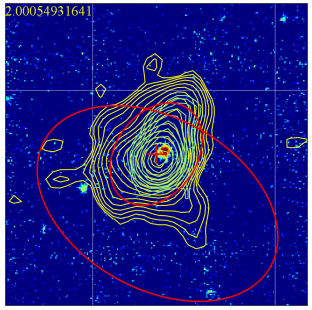


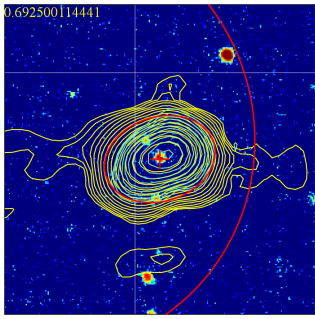


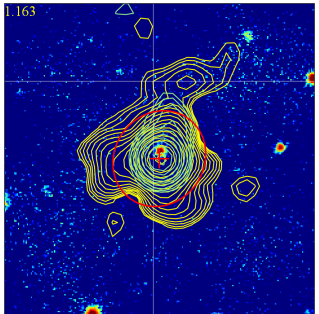


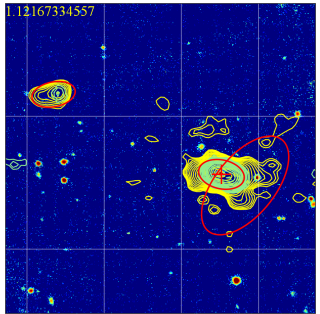


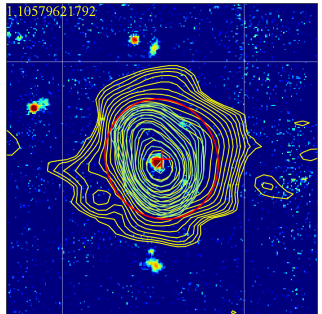
How about FRI QSOs?











Thank you

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