The Red Quasar Crisis:

where do they fit into the QSO population?

Quasars in Crisis, ROE, 6 — 9 August 2019

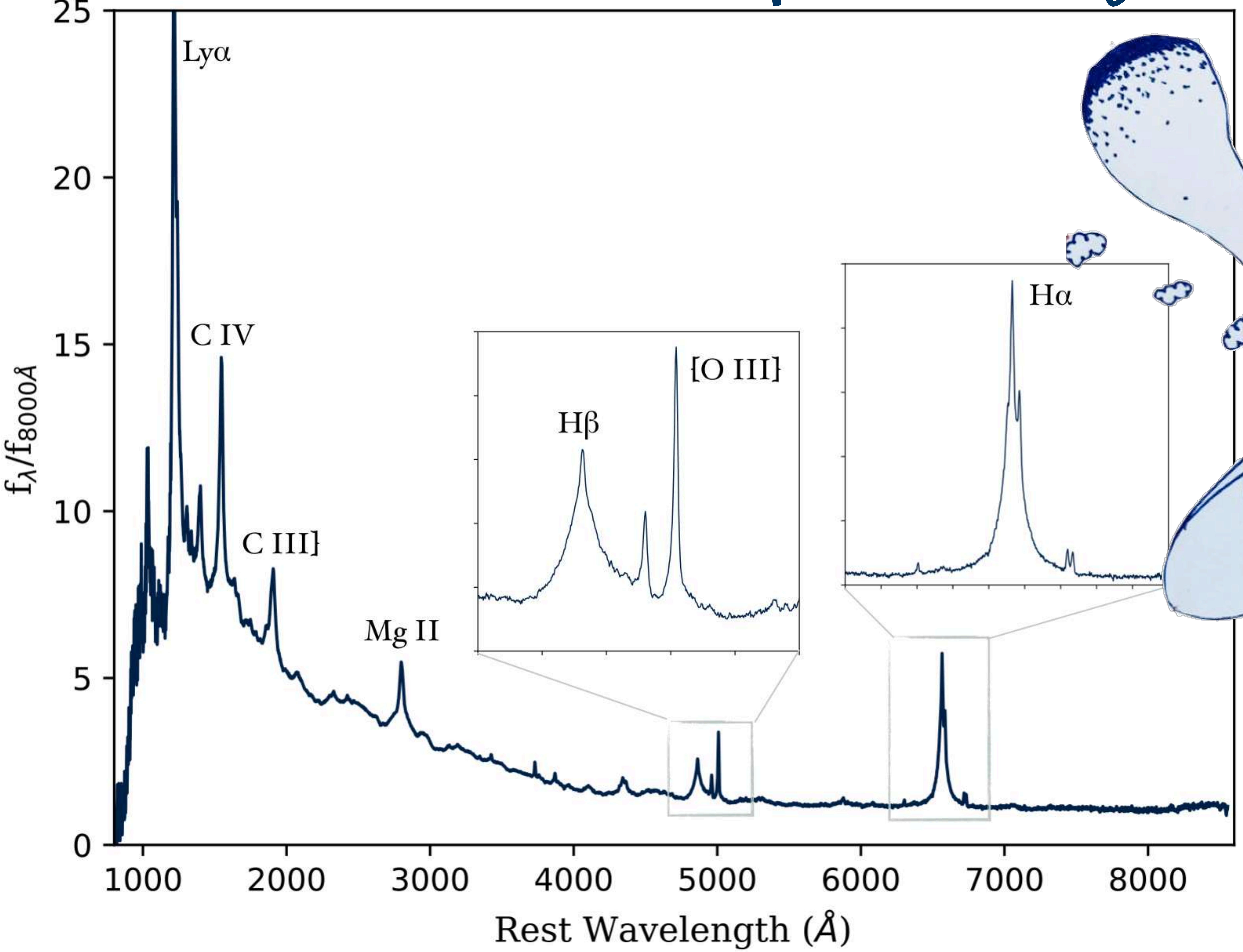
Lizelke Klindt

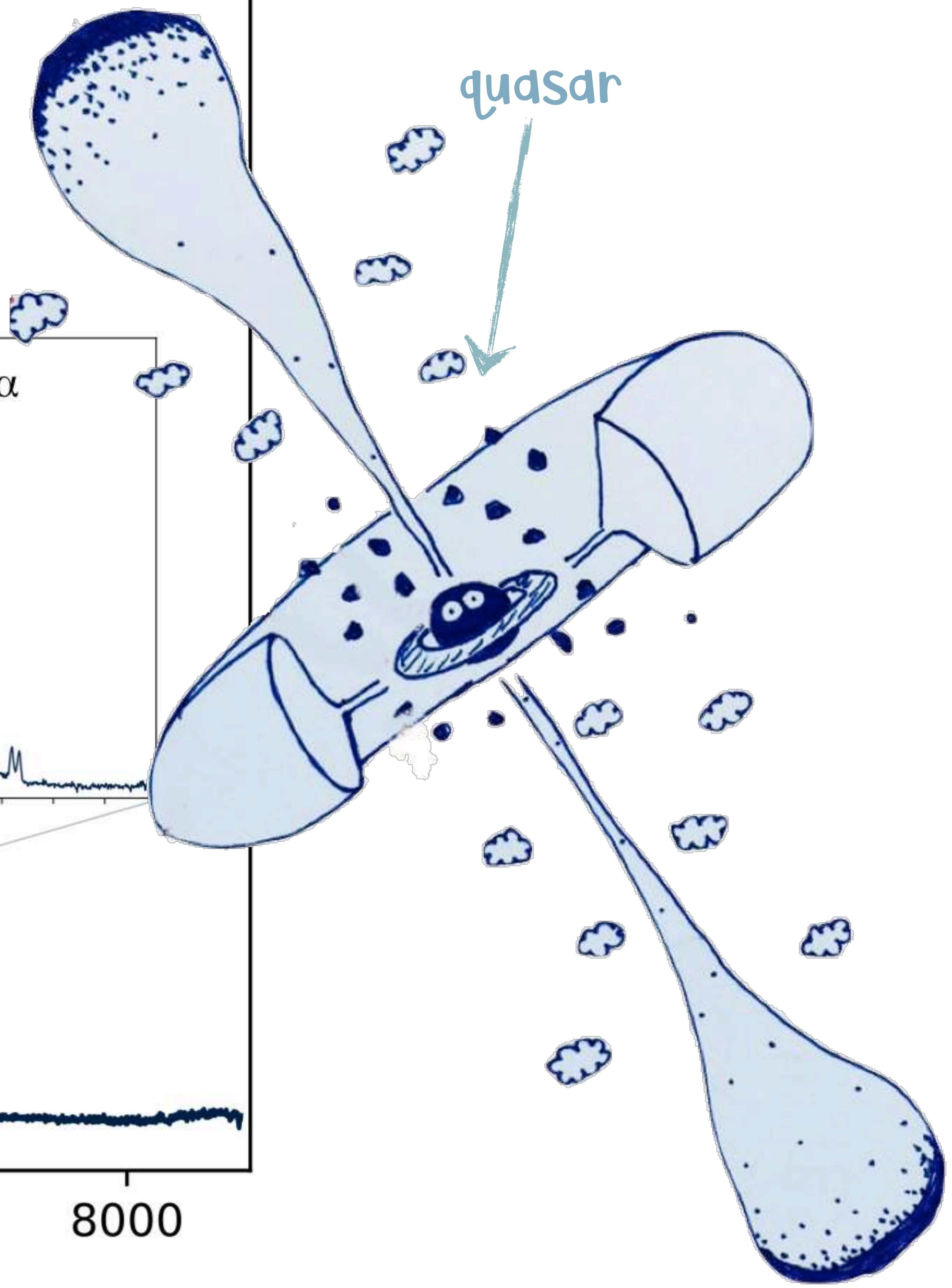
Dave Alexander, David Rosario, Elisabeta Lusso, & Sotiria Fotopoulou

Acknowledge: ***Chris Done, Nicholas P. Ross, Benny Trakhtenbrot****, Manda Banerji, Alastair Edge, Richard McMahon, Andrea Merloni, Adam D. Myers & Gordon T. Richards*

Durham University

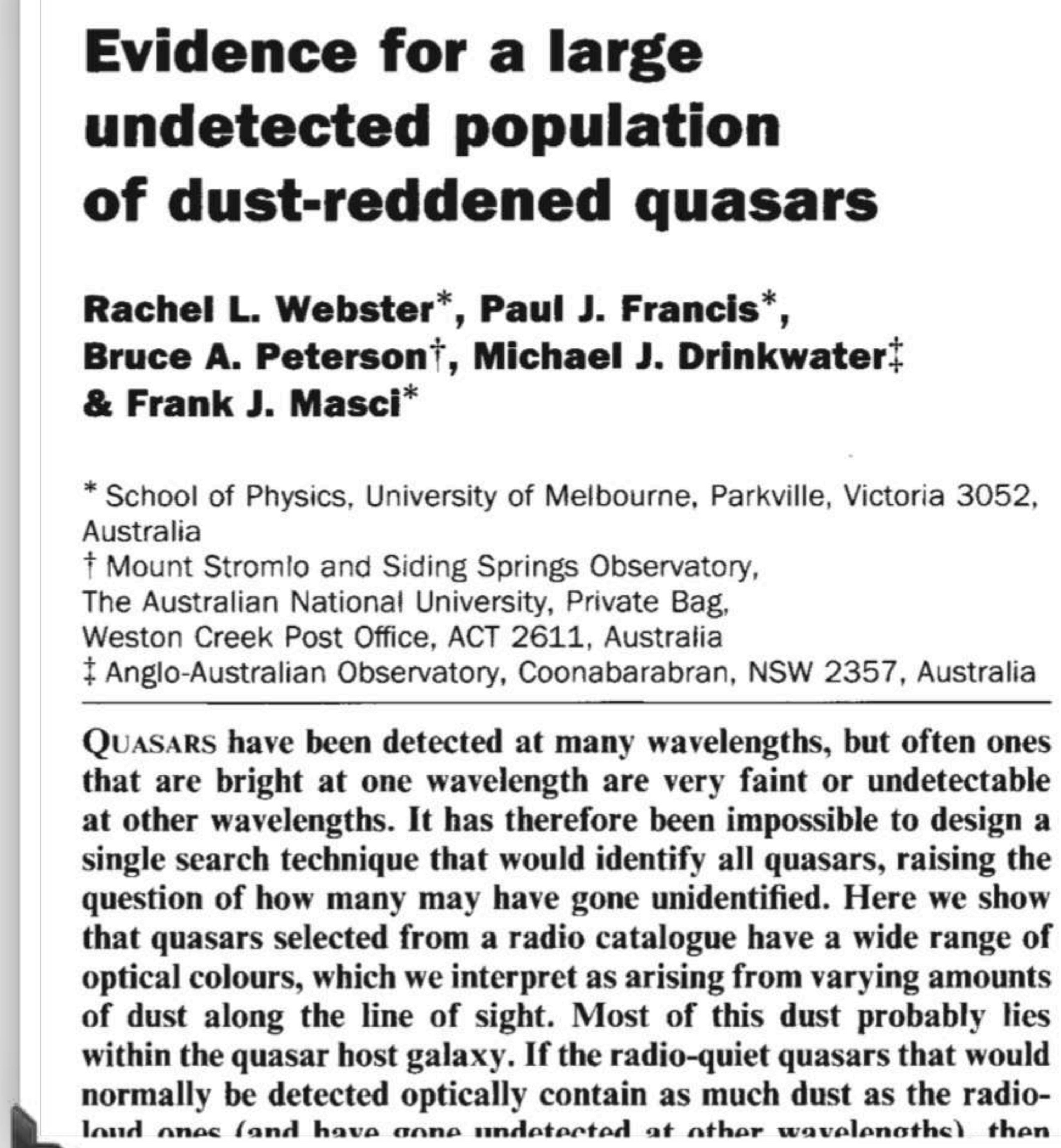
Conventional picture of quasars





Red Quasars: a peculiar subpopulation

Redder colours and spectra: suppressed blue emission.

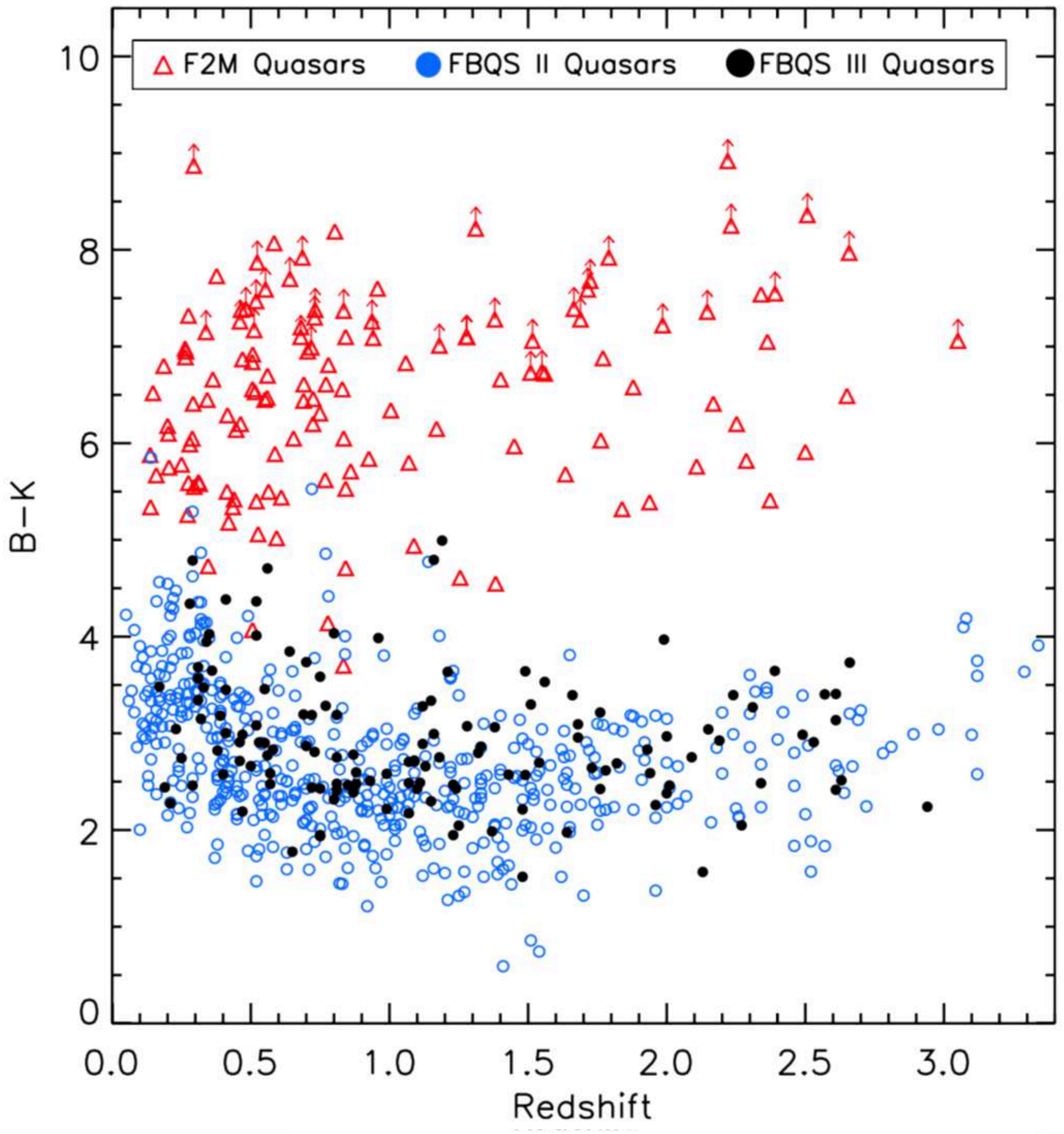


Evidence for a large undetected population of dust-reddened quasars

Rachel L. Webster*, Paul J. Francis*, Bruce A. Peterson†, Michael J. Drinkwater‡ & Frank J. Masci*

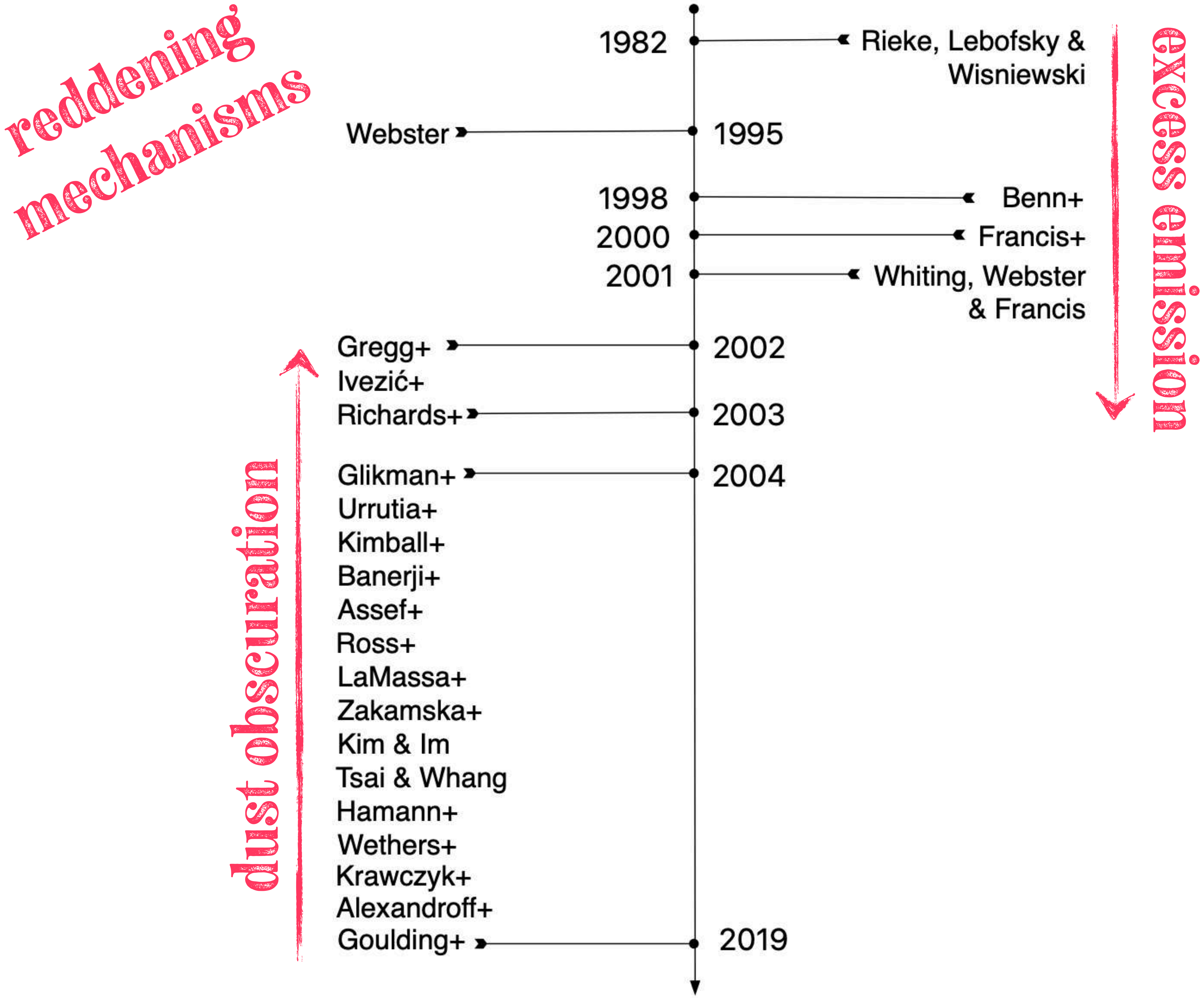
* School of Physics, University of Melbourne, Parkville, Victoria 3052, Australia
† Mount Stromlo and Siding Springs Observatory, The Australian National University, Private Bag, Weston Creek Post Office, ACT 2611, Australia
‡ Anglo-Australian Observatory, Coonabarabran, NSW 2357, Australia

Quasars have been detected at many wavelengths, but often ones that are bright at one wavelength are very faint or undetectable at other wavelengths. It has therefore been impossible to design a single search technique that would identify all quasars, raising the question of how many may have gone unidentified. Here we show that quasars selected from a radio catalogue have a wide range of optical colours, which we interpret as arising from varying amounts of dust along the line of sight. Most of this dust probably lies within the quasar host galaxy. If the radio-quiet quasars that would normally be detected optically contain as much dust as the radio-loud ones (and have gone undetected at other wavelengths), then



e.g., Webster+1995; Glikman+2004; Urrutia+2009; Glikman+2012; +++

Red Quasars: a peculiar subpopulation



Proposed origins of red quasars: Orientation vs. Evolution

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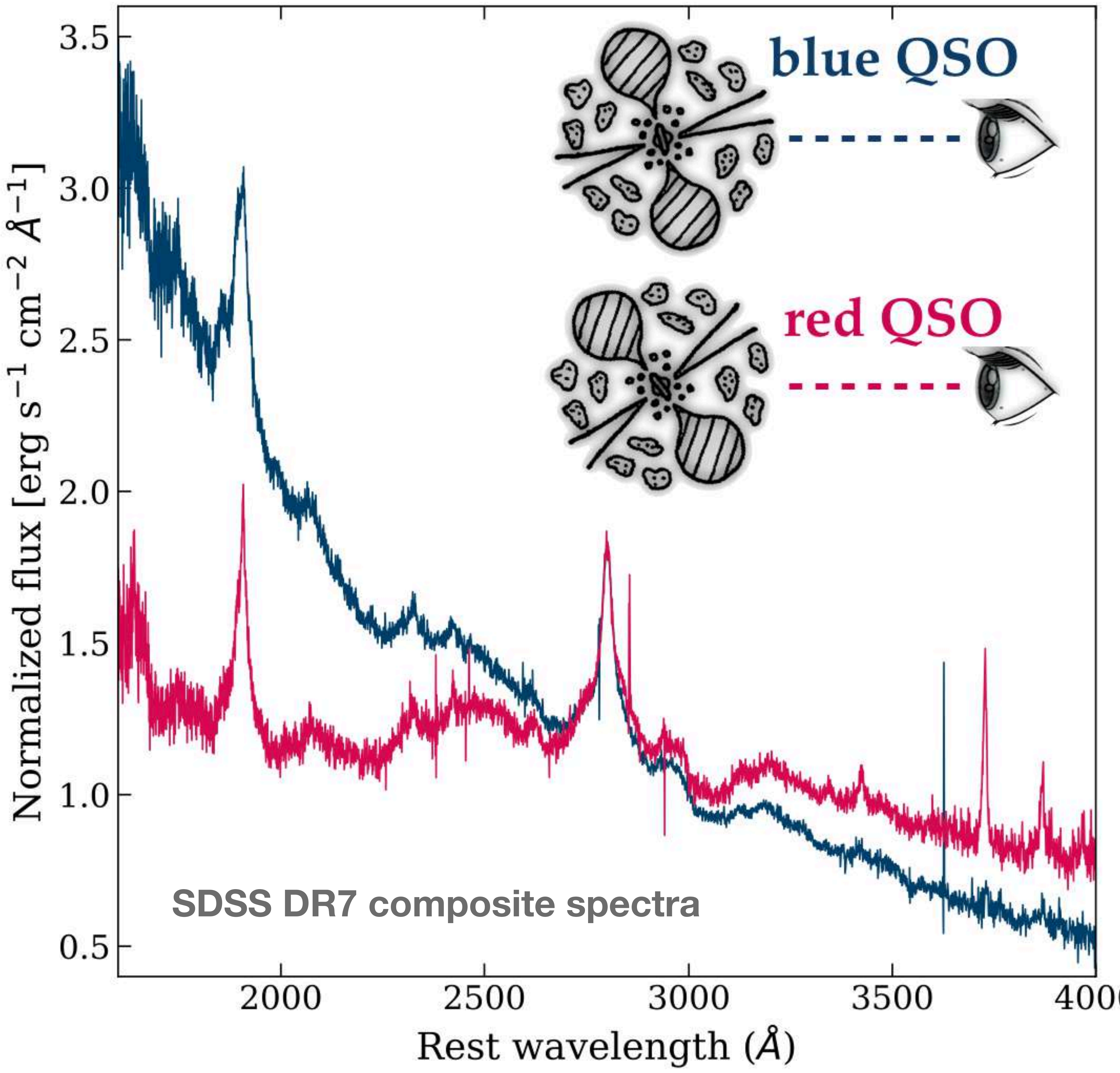
Blue quasar

- Blue unobscured view of BLR
- Broad emission lines superimposed onto continuum that peaks in UV

Red quasar

- Grazing view with additional dust along line-of sight.
- Broad emission lines are still present (Type I), but spectrum is suppressed at shorter wavelengths.



e.g., Antonucci 1993; Urry & Padovani 1995

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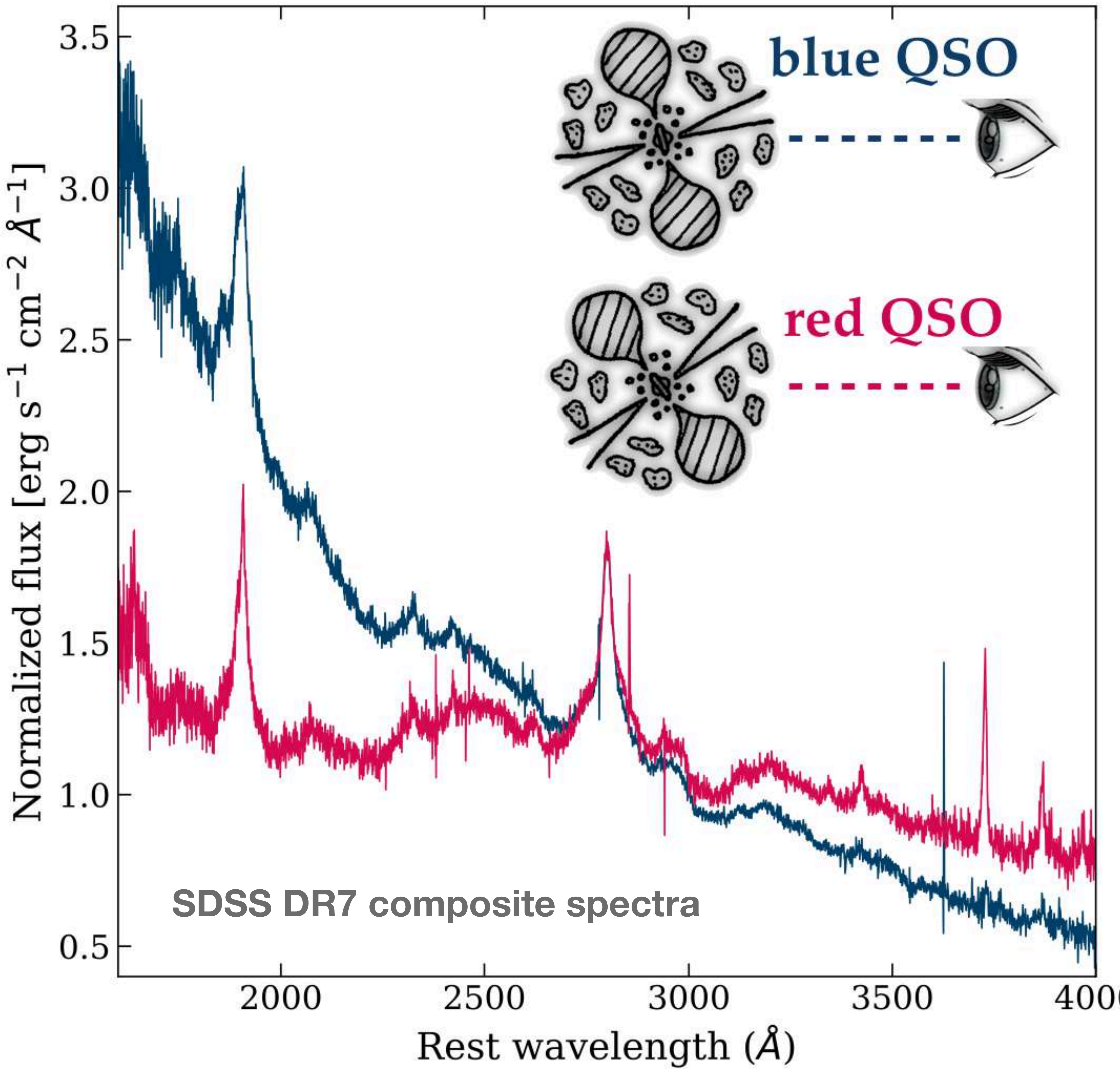
In this scenario red and blue quasars would be expected to be intrinsically similar!



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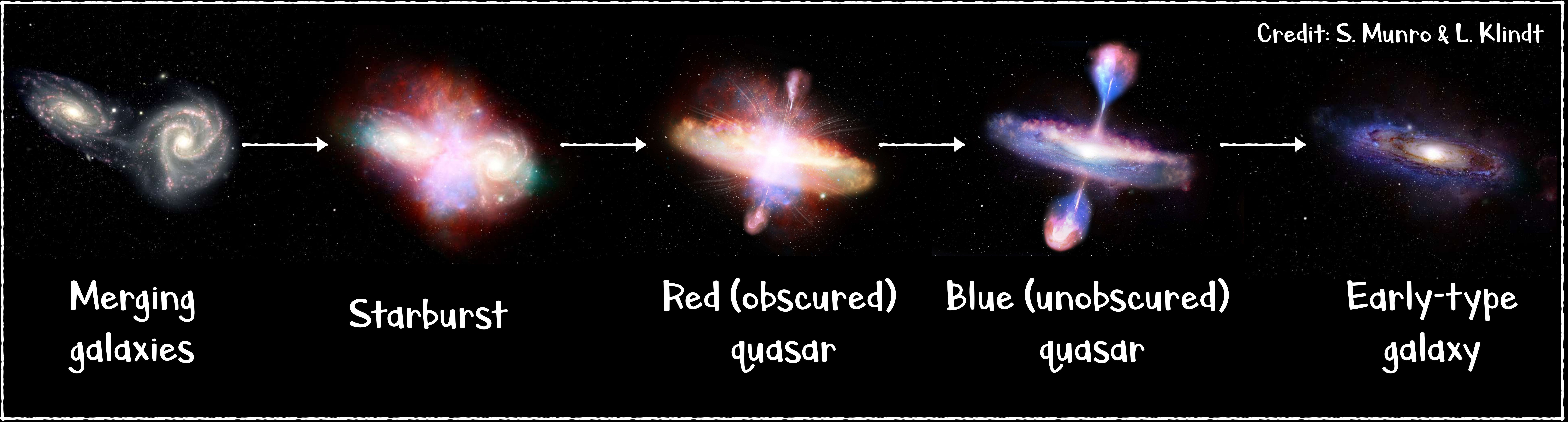
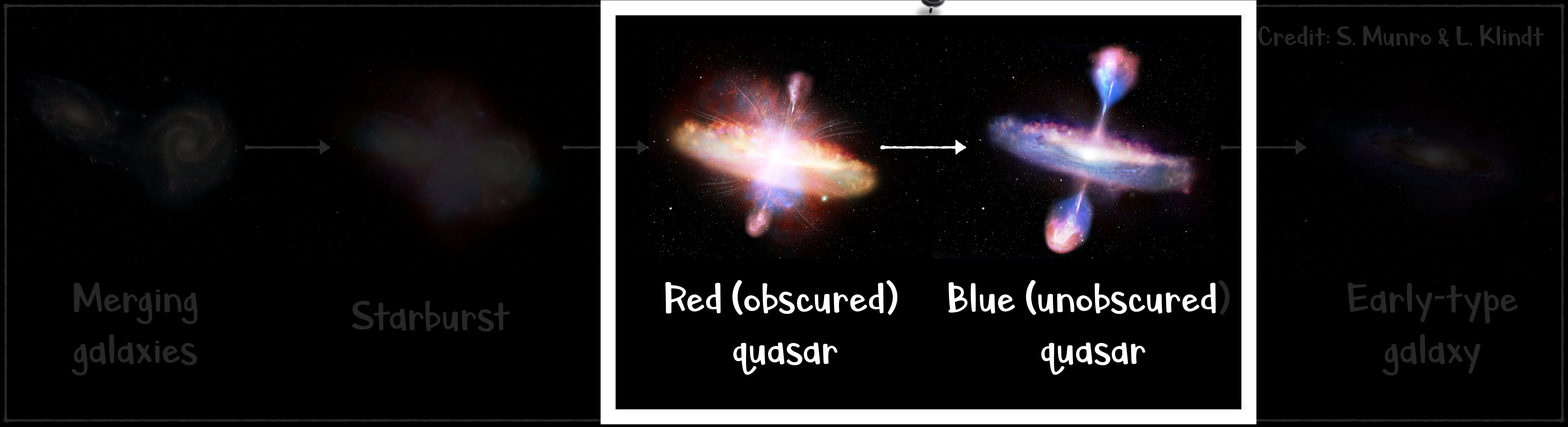


Preferentially obscured

Preferentially unobscured

see e.g., Sanders+1998; Hopkins+2008; Alexander & Hickox 2012; Glikman+2012+++

Proposed origins of red quasars: Orientation vs. Evolution



In this model the "nuclear environments" are effectively different for red and blue quasars

see e.g., Sanders+1998; Hopkins+2008; Alexander & Hickox 2012; Glikman+2012+++

Objectives

- **Test between these two proposed models for the existence of red quasars.**

- **Limitations of previous work is that studies did not uniformly select red and blue quasars from the same parent sample and they were limited in source statistics.**

- **Aim of our study is to address this via a carefully controlled experiment and to ultimately fit another piece to the red quasar puzzle.**

Selecting red and blue quasars

Klindt+2019

SDSS DR7
Schneider+2010
105,783

Selecting red and blue quasars

Klindt+2019

SDSS DR7
Schneider+2010
105,783

➠ Uniform flag
➠ Sole FIRST pre-selected removed

Colour & radio-uniform sample
60,000

Selecting red and blue quasars

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→ W1, W2, W3 detections
→ $0.2 < z < 2.4$

Parent QSO sample
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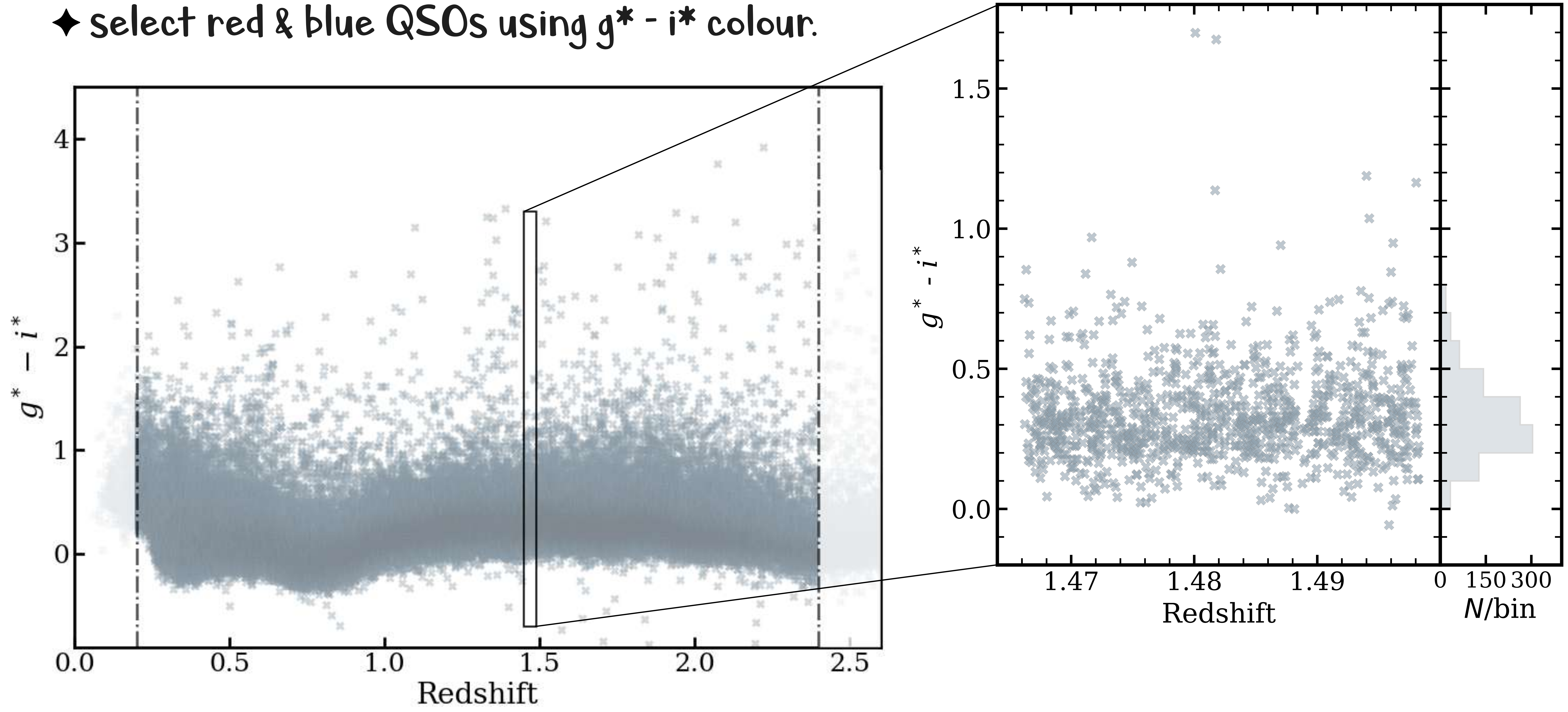
✦ select red & blue QSOs using g* - i* colour.

z-bins of 1000 sources



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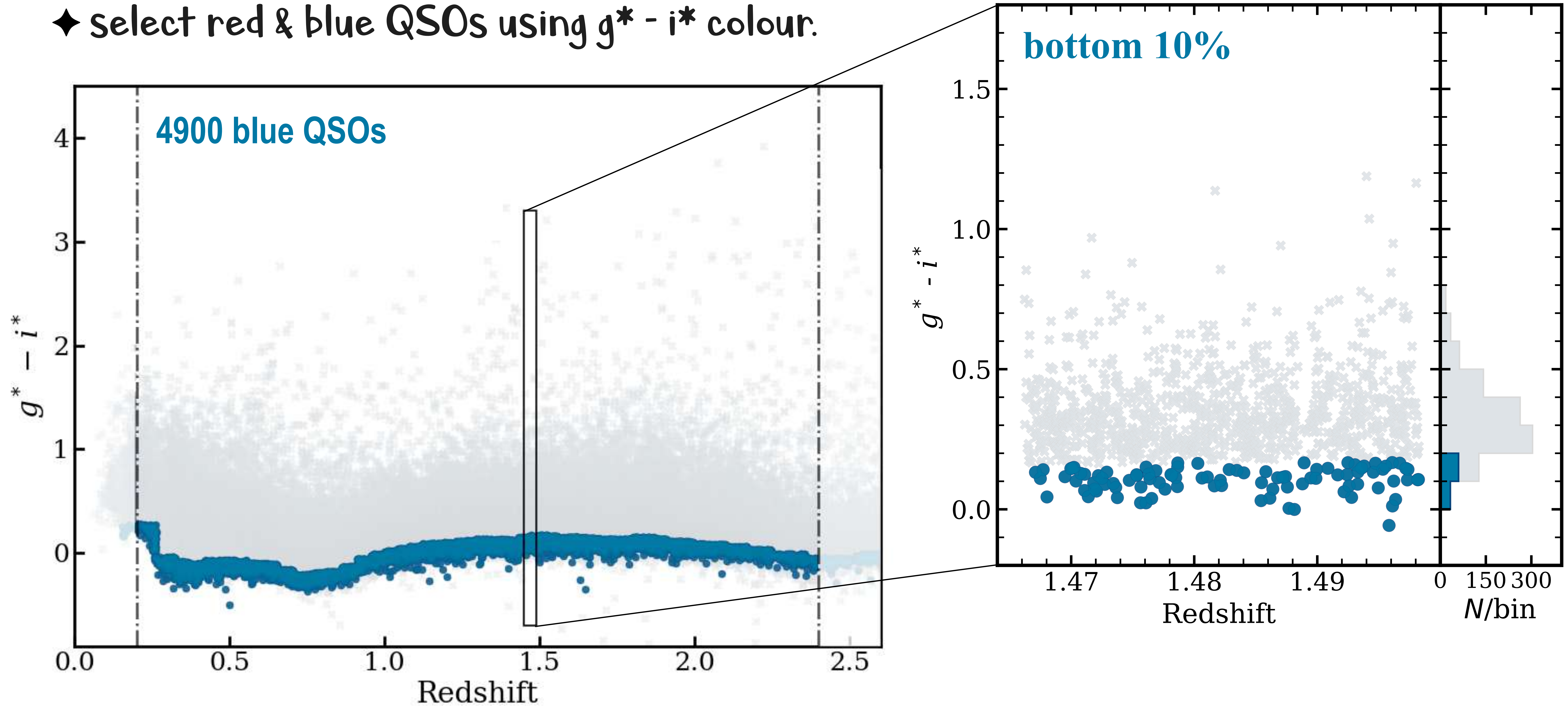

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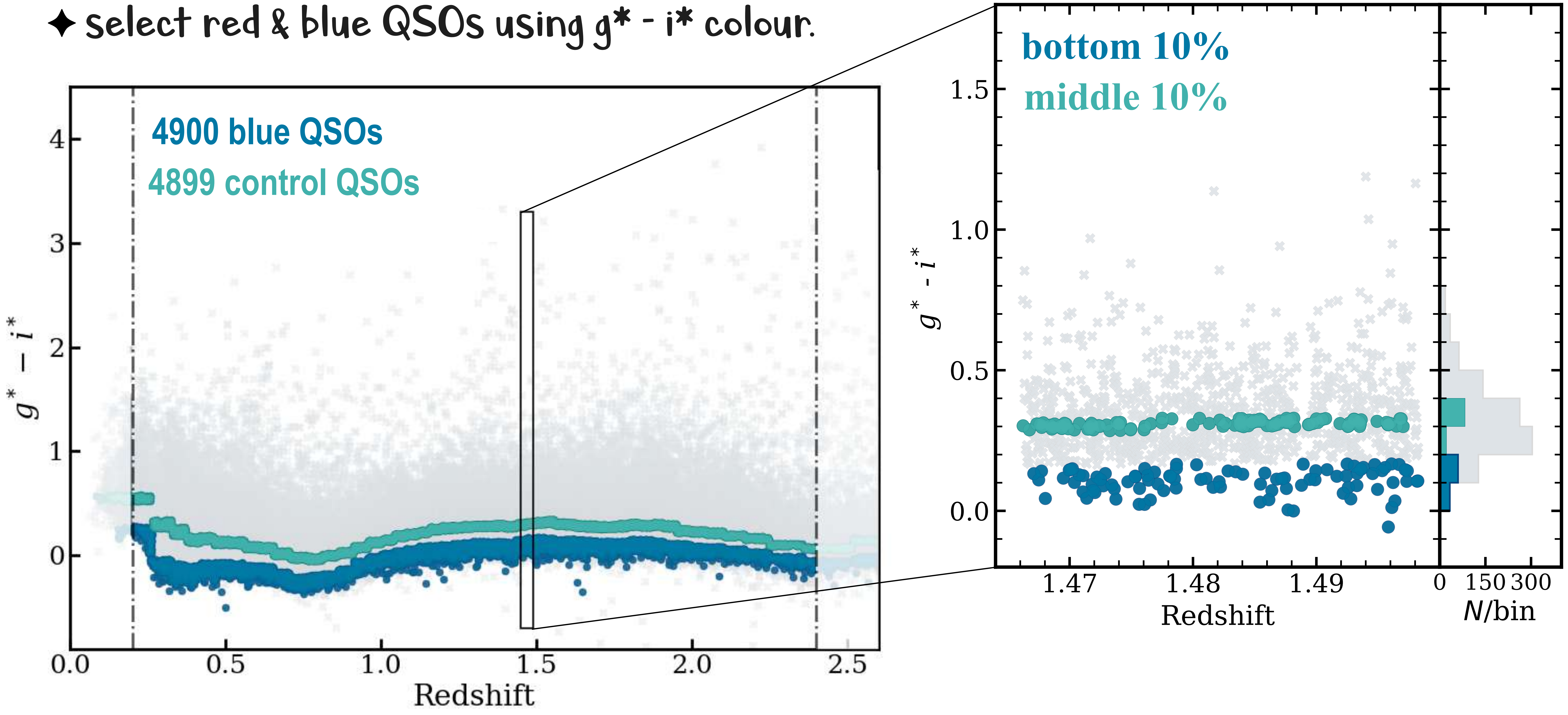

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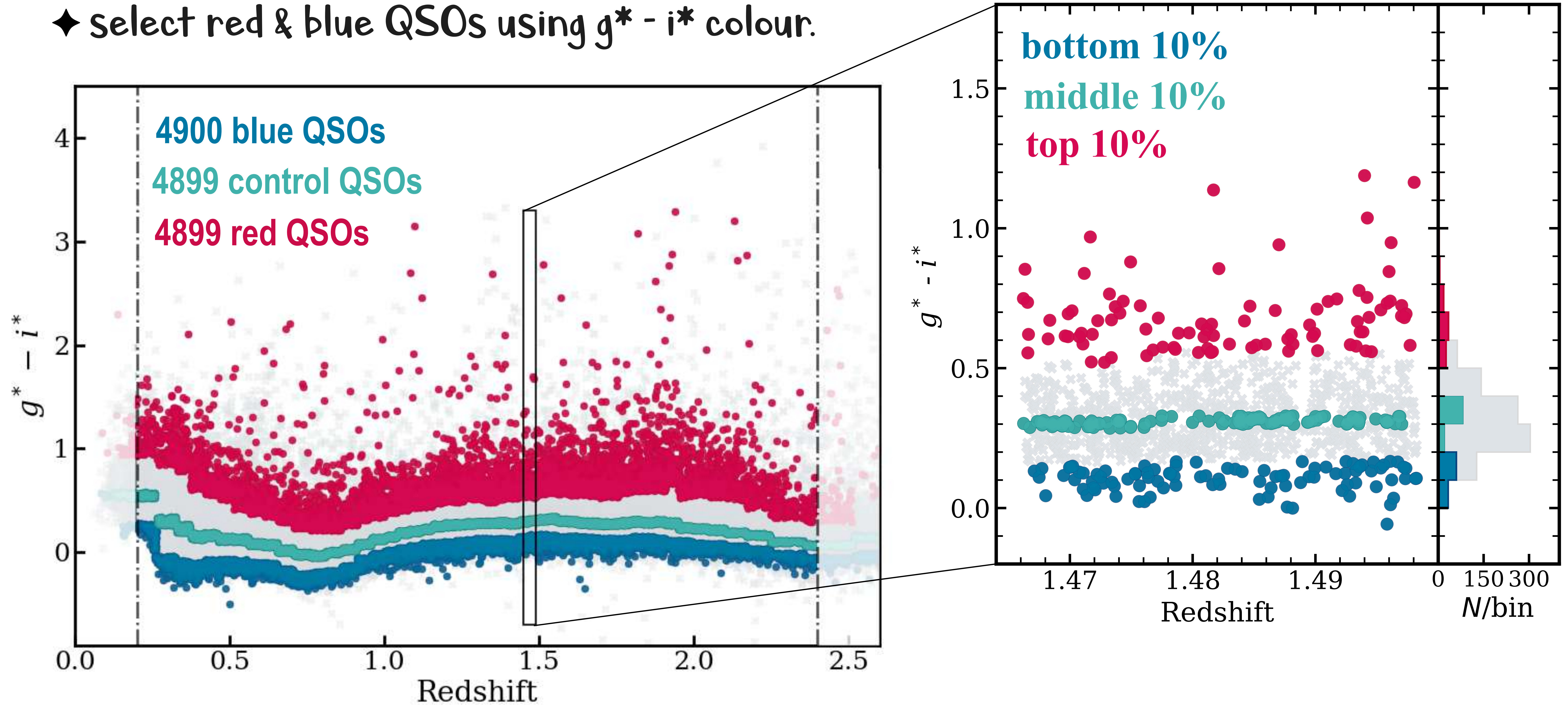
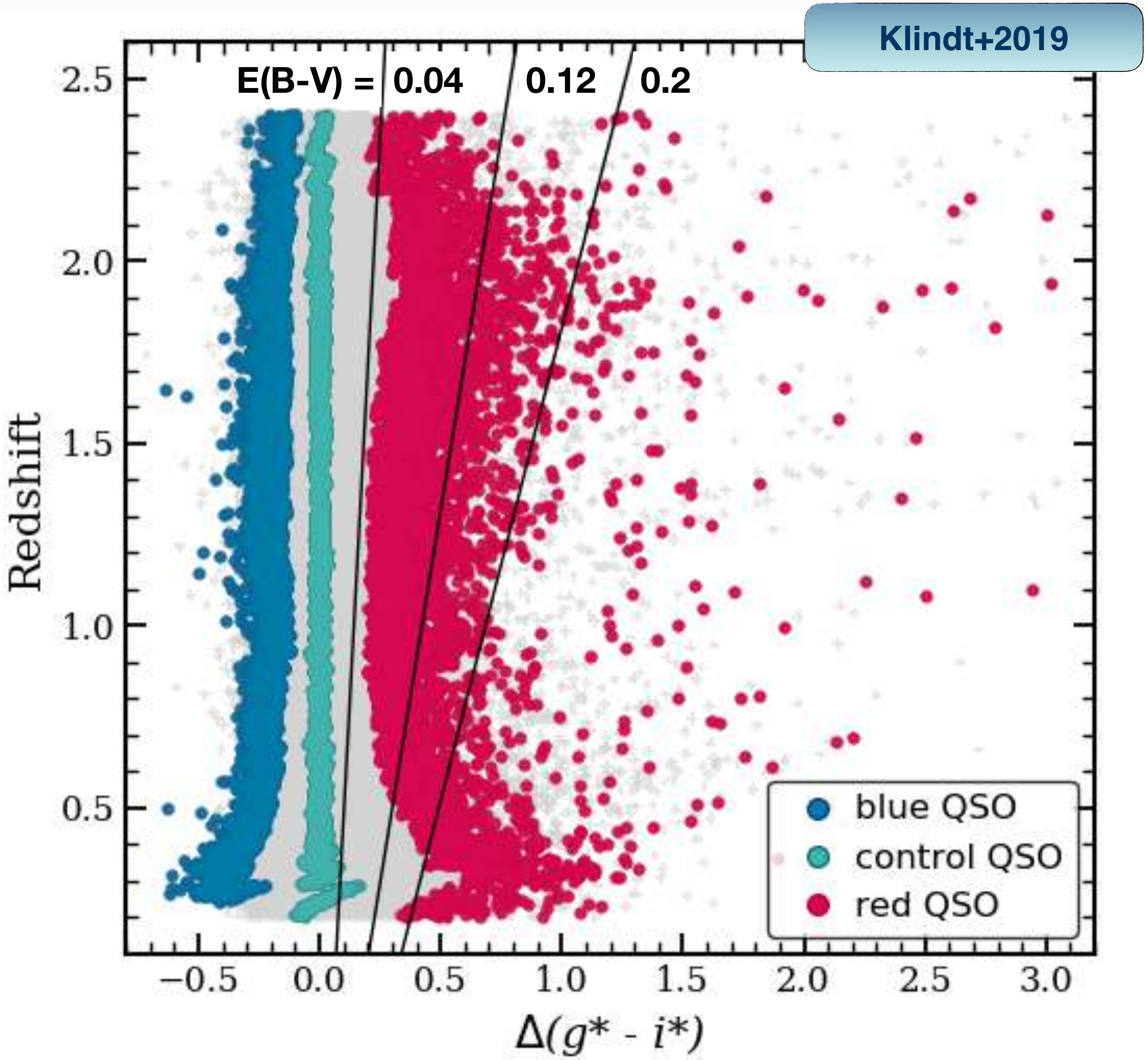


Dust reddening: $\Delta(g^* - i^*)$

Measure of quasar colour relative to median quasar at the same redshift (e.g., Richards+2003).



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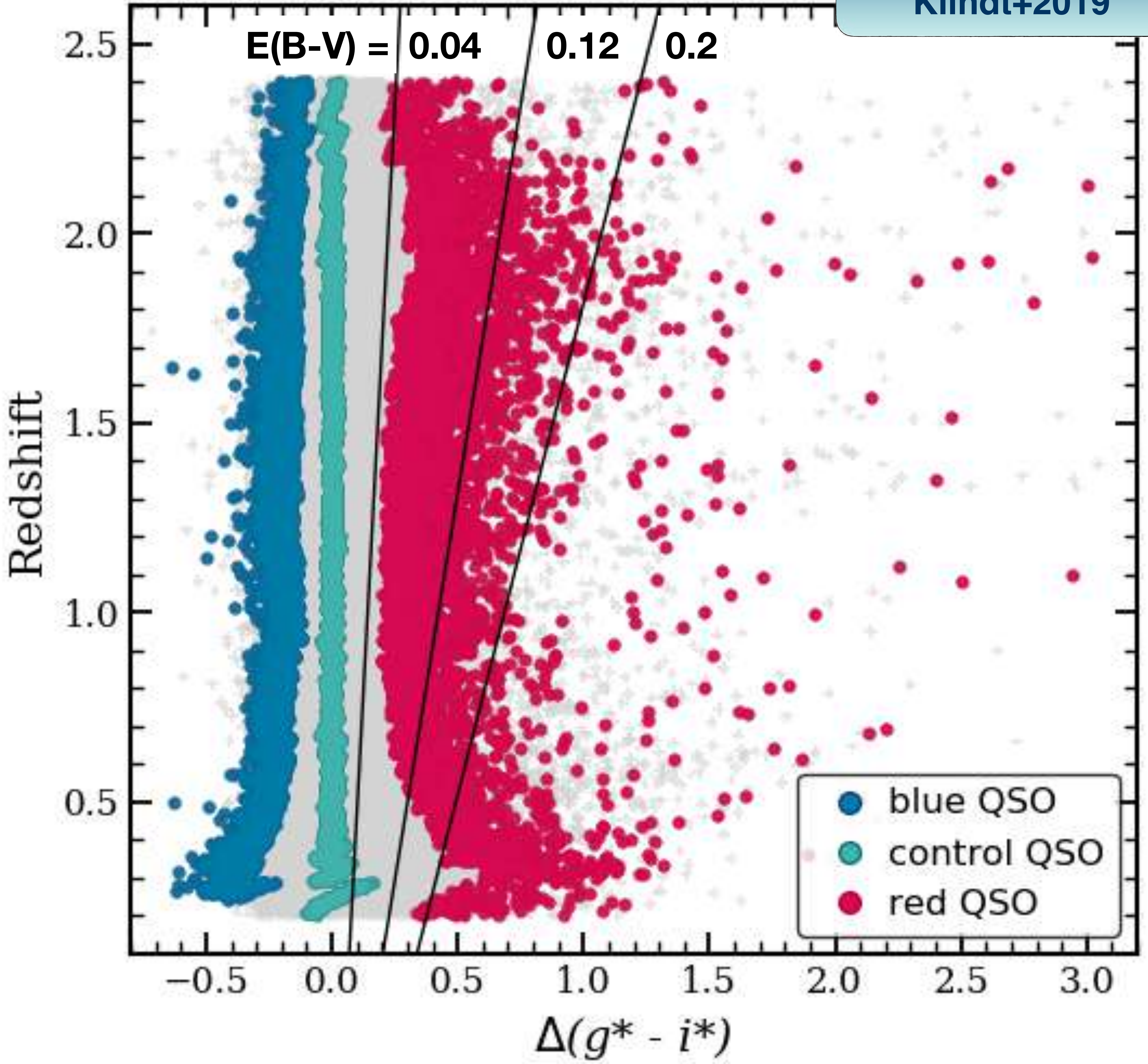
$$\Downarrow$$
$$A_V \sim 0.1 - 0.5 \text{ mag}$$

- On the basis of the evidence we have, the majority of our red quasars are **DUST REDDENED** but not obscured!

Klindt+2019



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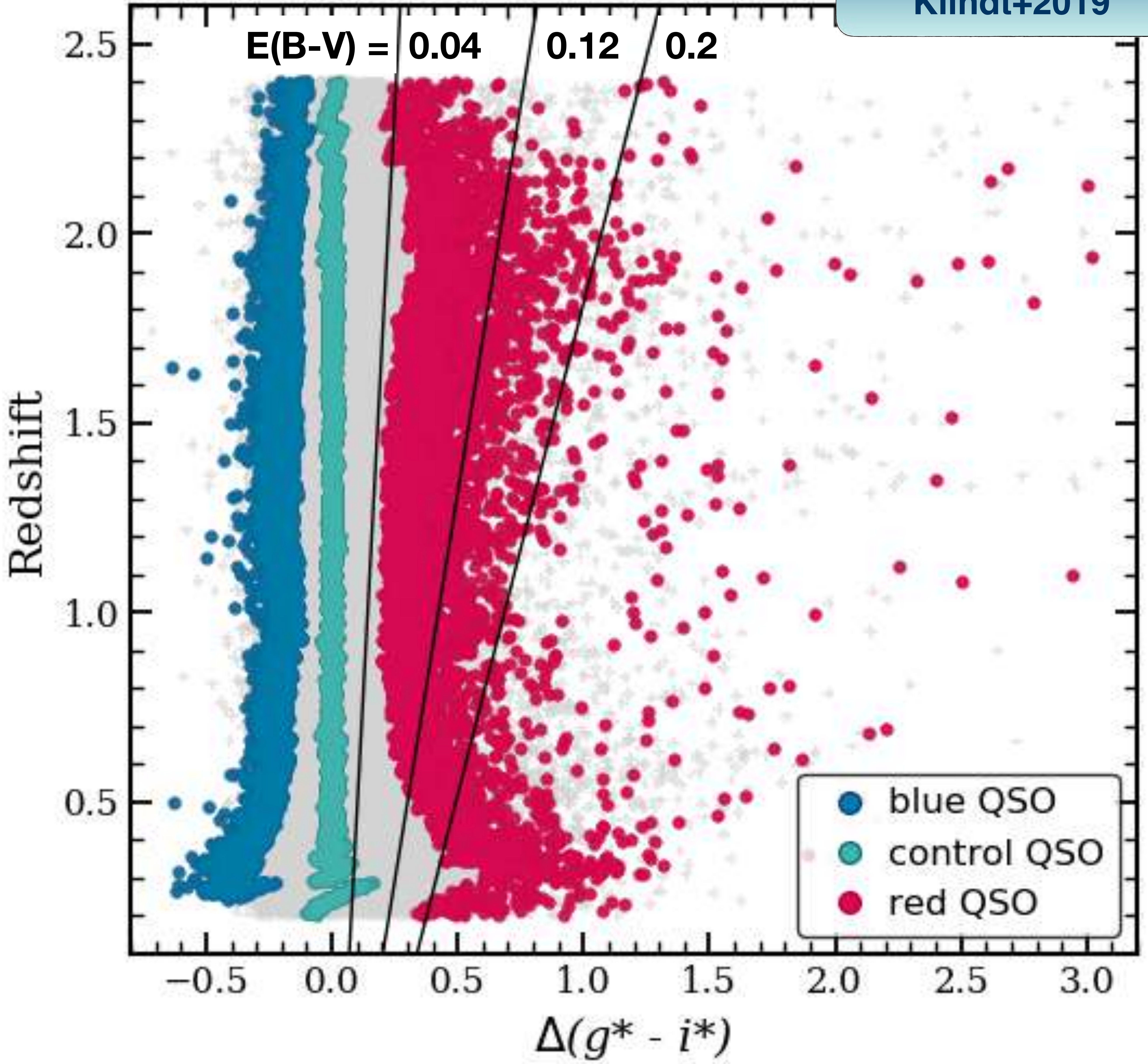
- NIR selected red quasars have dust extinctions of up to $A_V \sim 1 - 6$ mag.

See e.g., Glikman+2004; Banerji+2012

Klindt+2019



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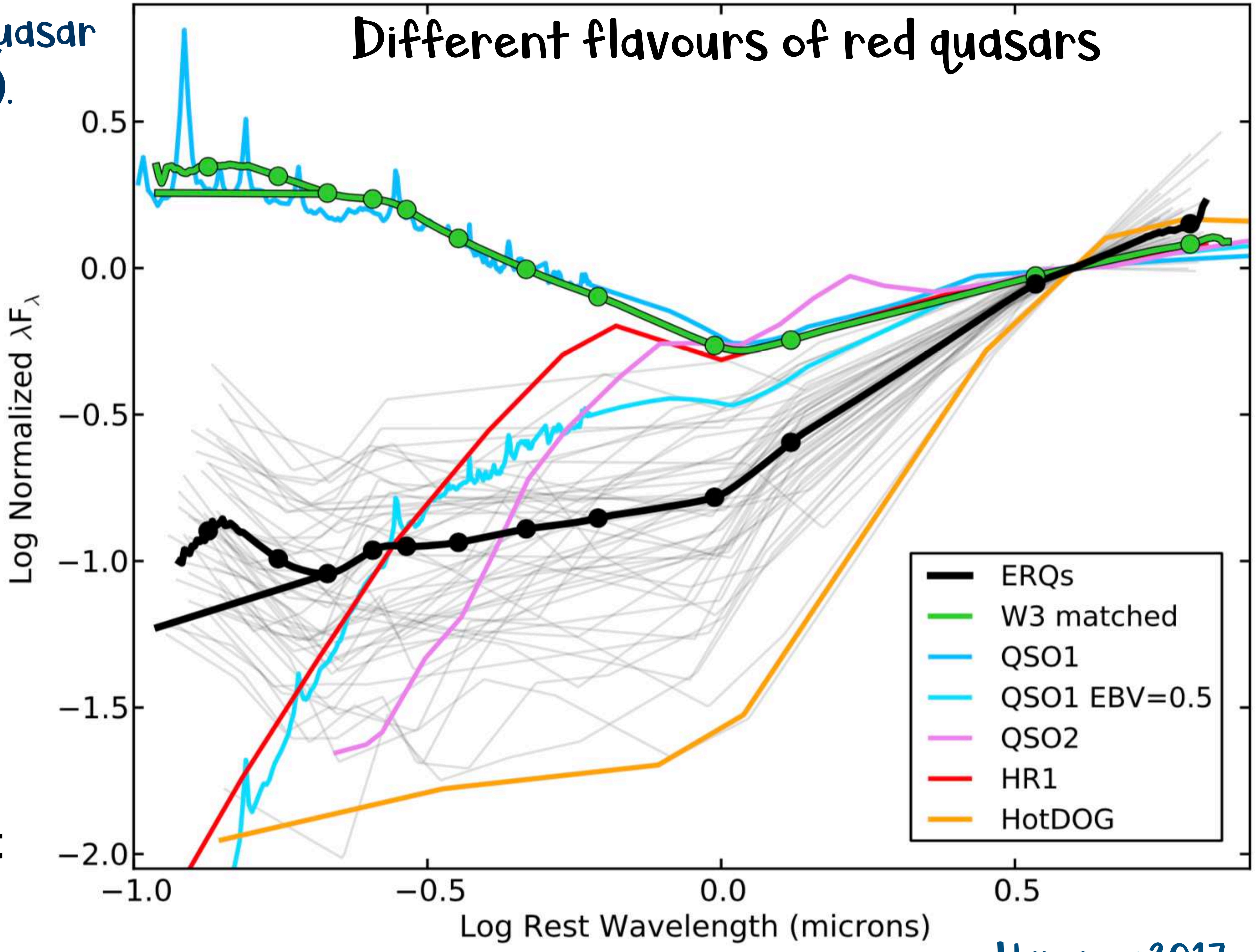

Hamann+2017

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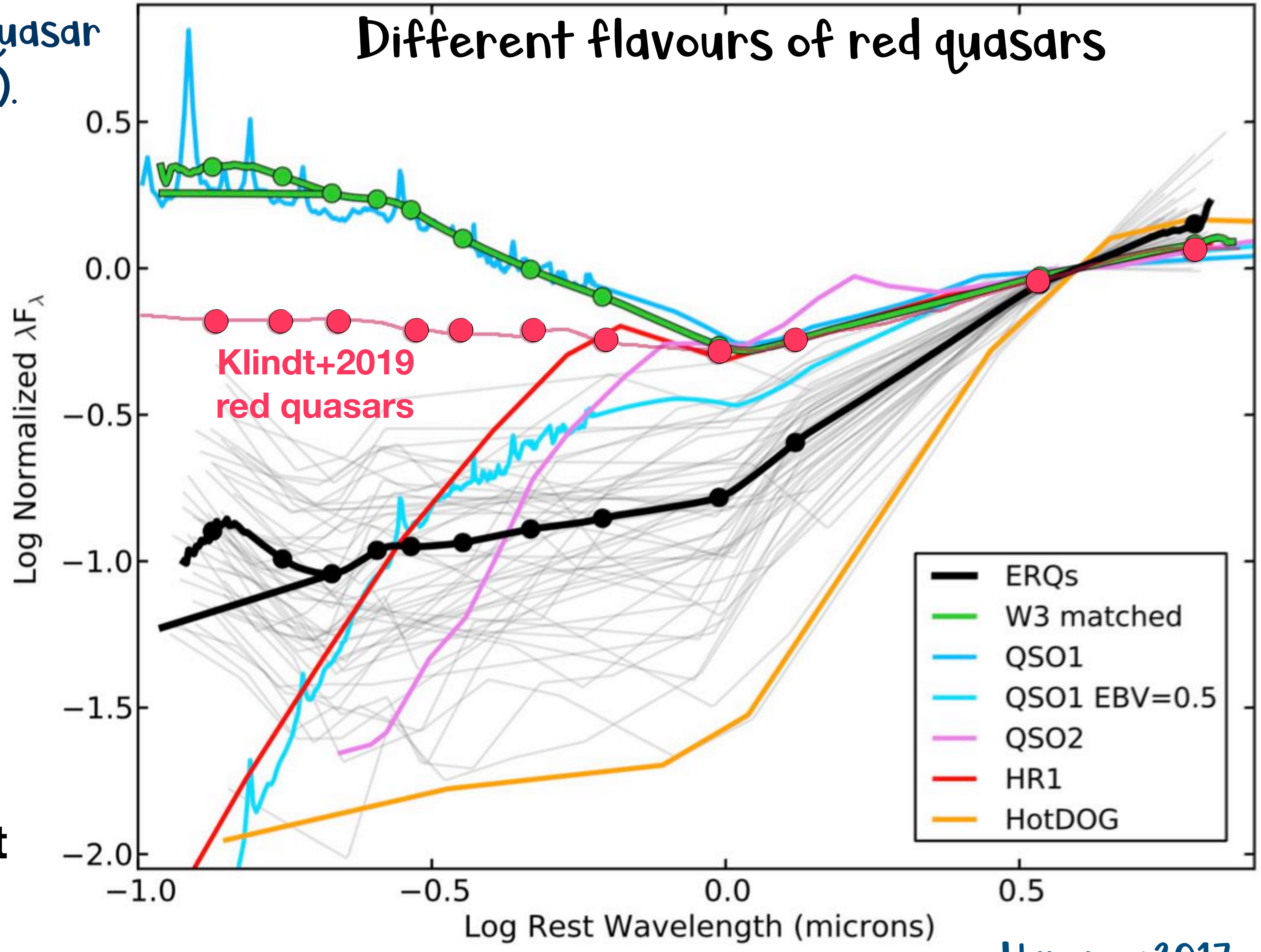

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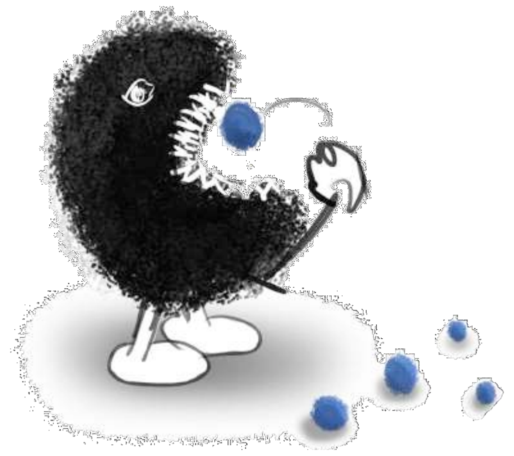
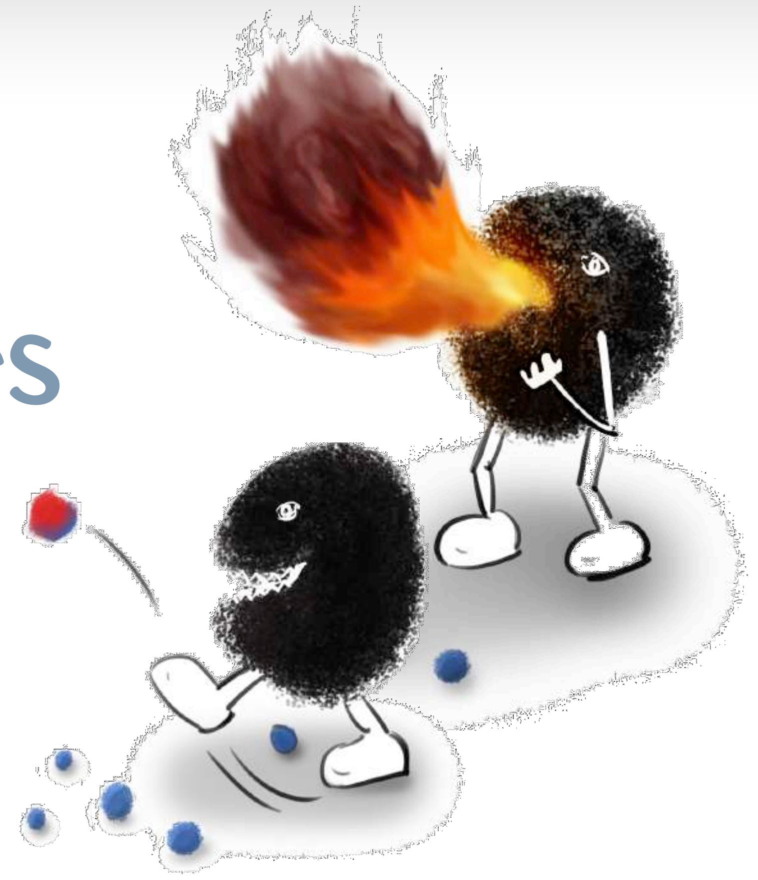


Radio emission — FIRST 1.4 GHz

Faint Images of the Radio Sky at Twenty-centimeters



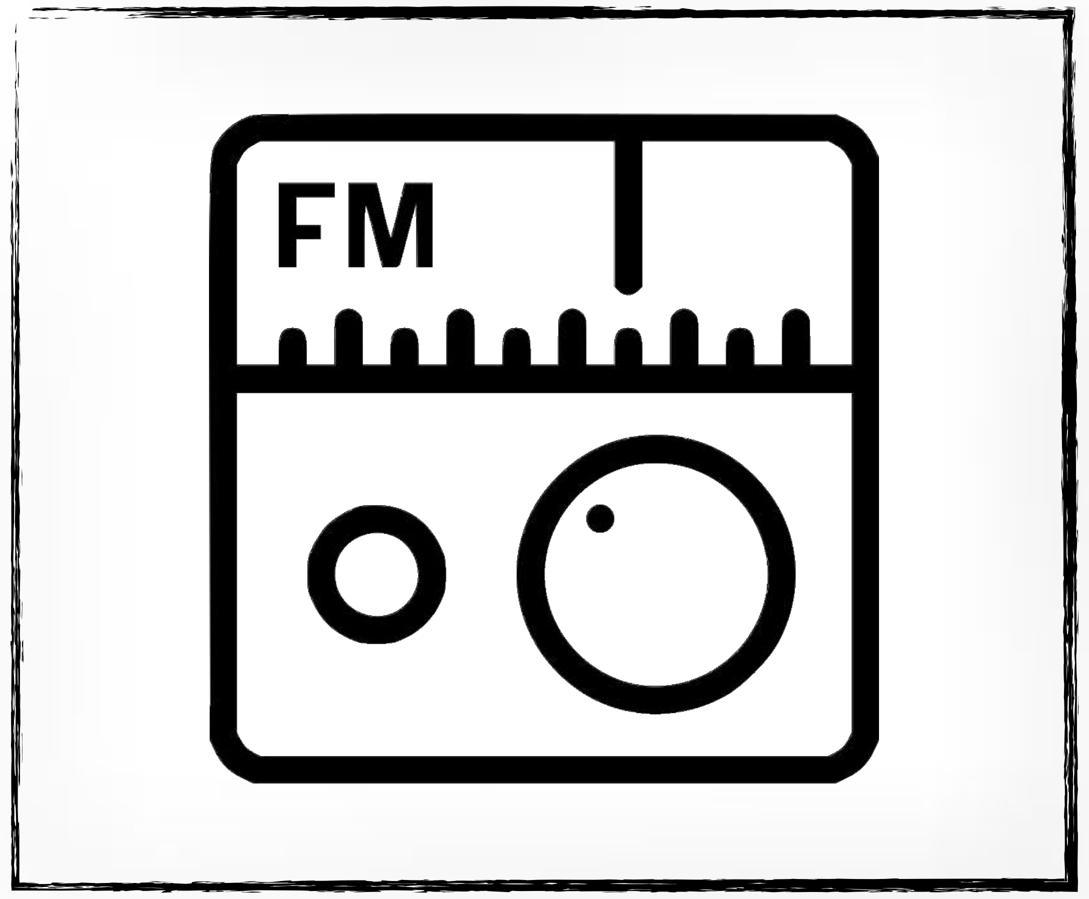
frequency = 1.4 GHz

resolution = 5"
projected sizes = 43 kpc at z = 1.5

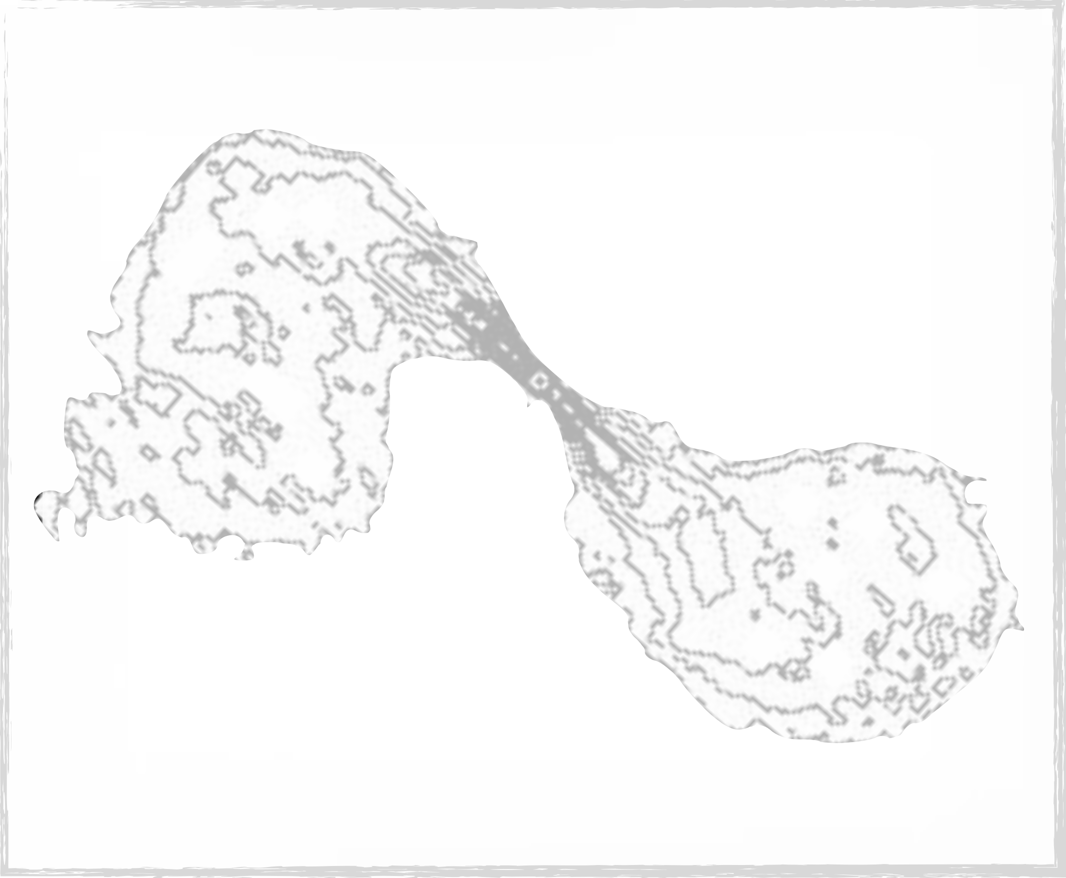
detection threshold = 1 mJy

Radio emission — FIRST 1.4 GHz

radio-detection rate



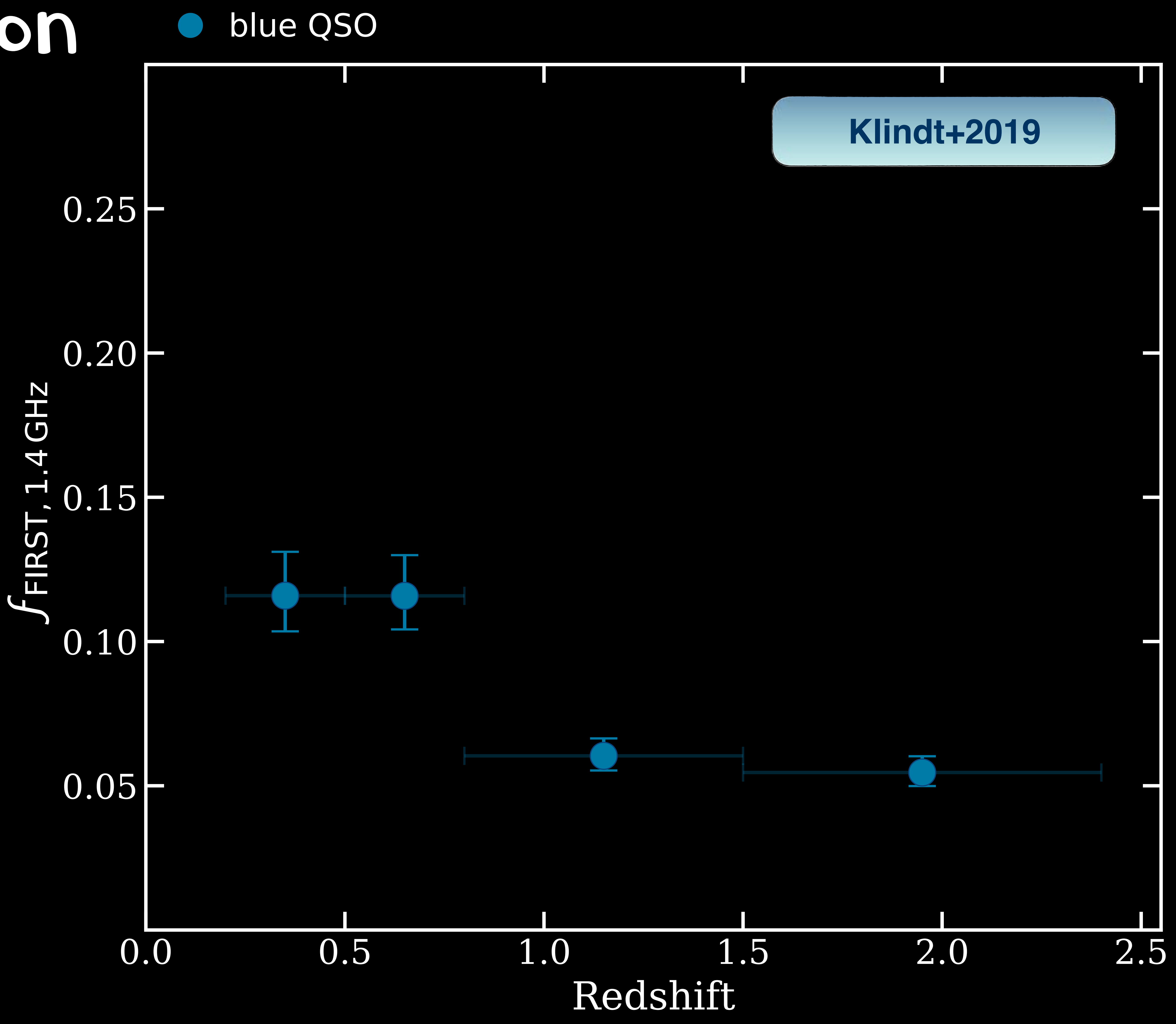
radio morphologies



radio loudness

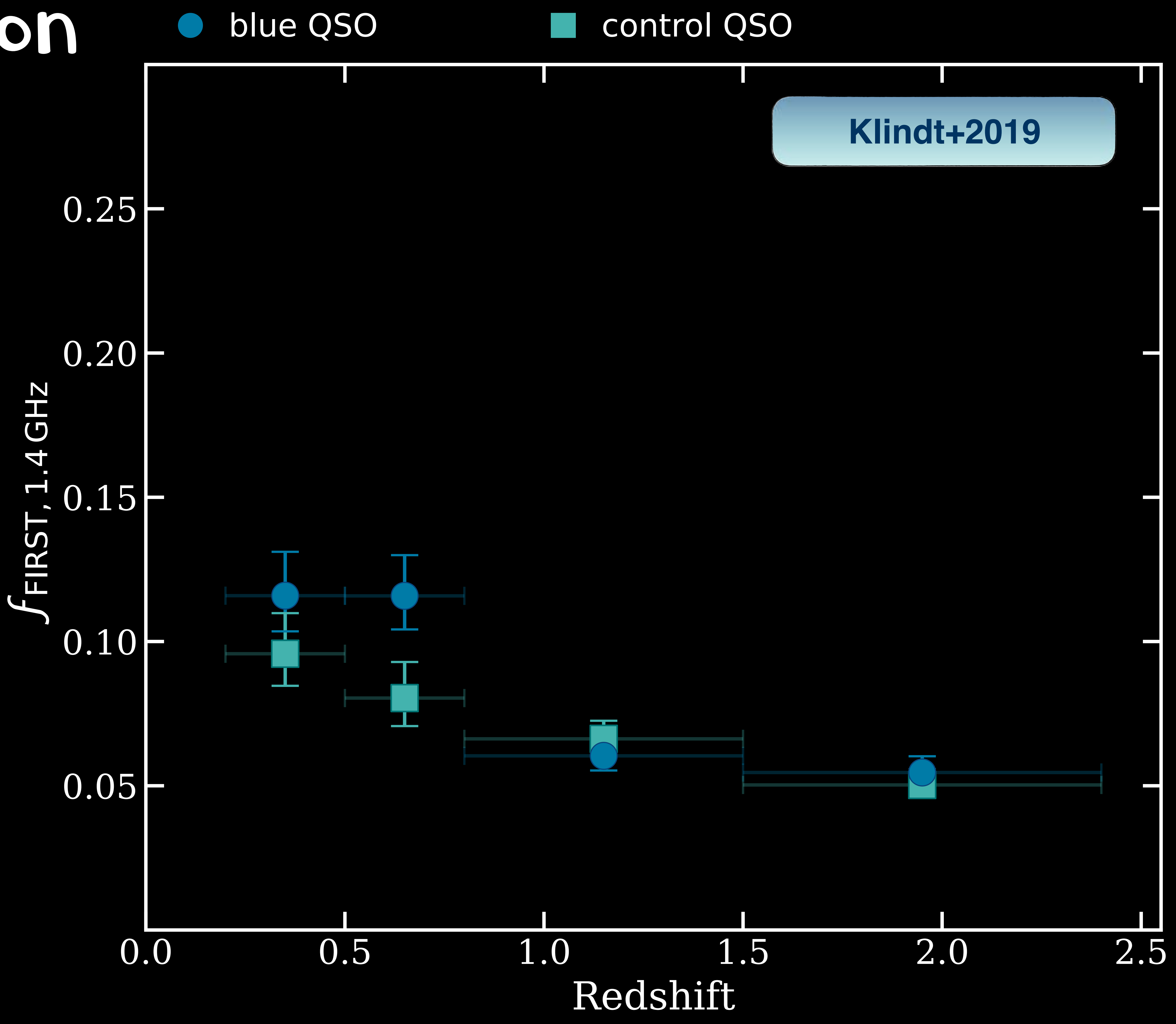
FIRST-detection fraction

■ blue QSO 5 — 10%



FIRST-detection fraction

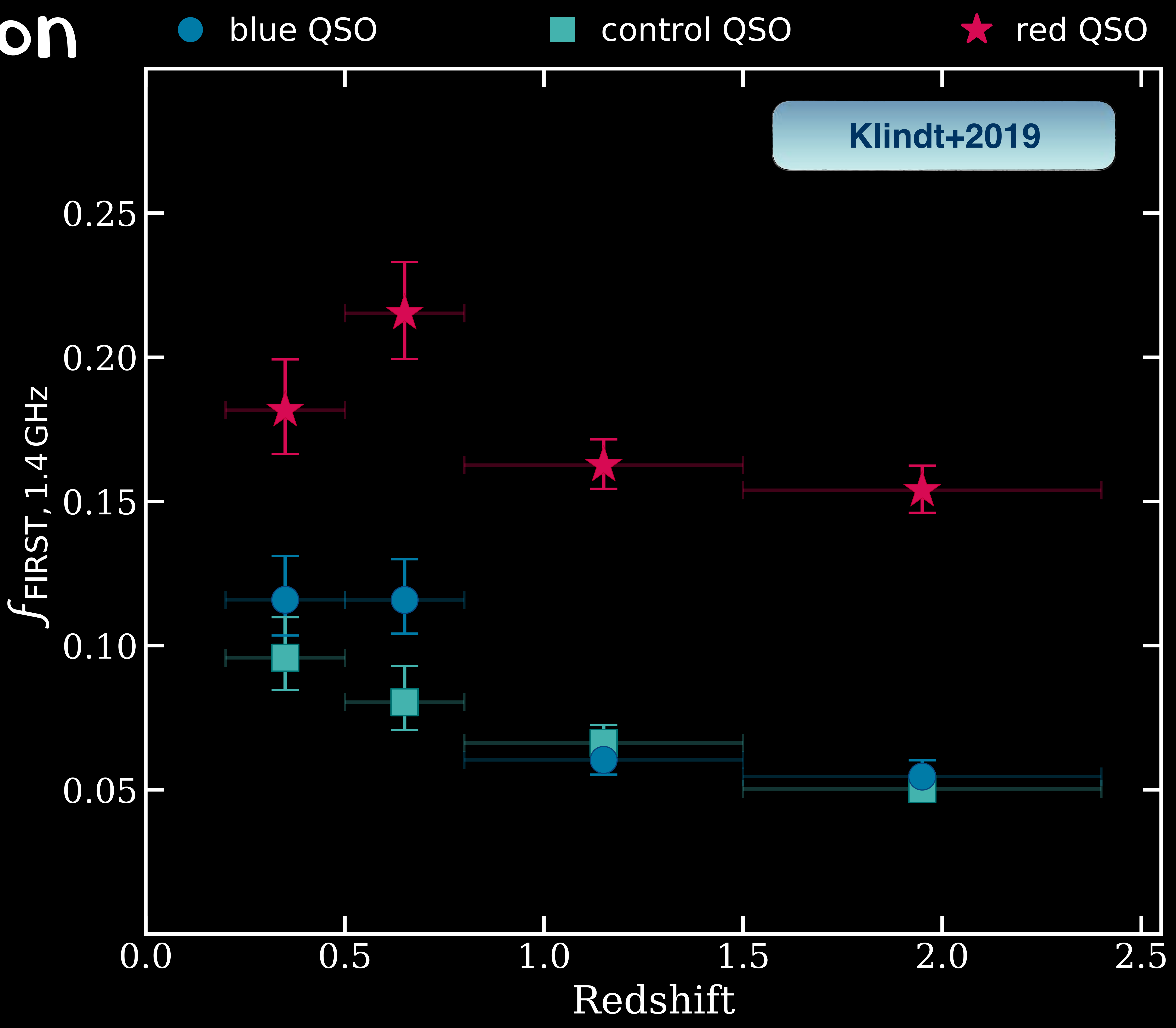
blue QSO	5 — 10%
control QSO	5 — 10%



FIRST-detection fraction

■	blue QSO	5 — 10%
●	control QSO	5 — 10%
★	red QSO	17 — 22%

* **We see a significant enhancement in the detection rate of red quasars across all redshifts.**



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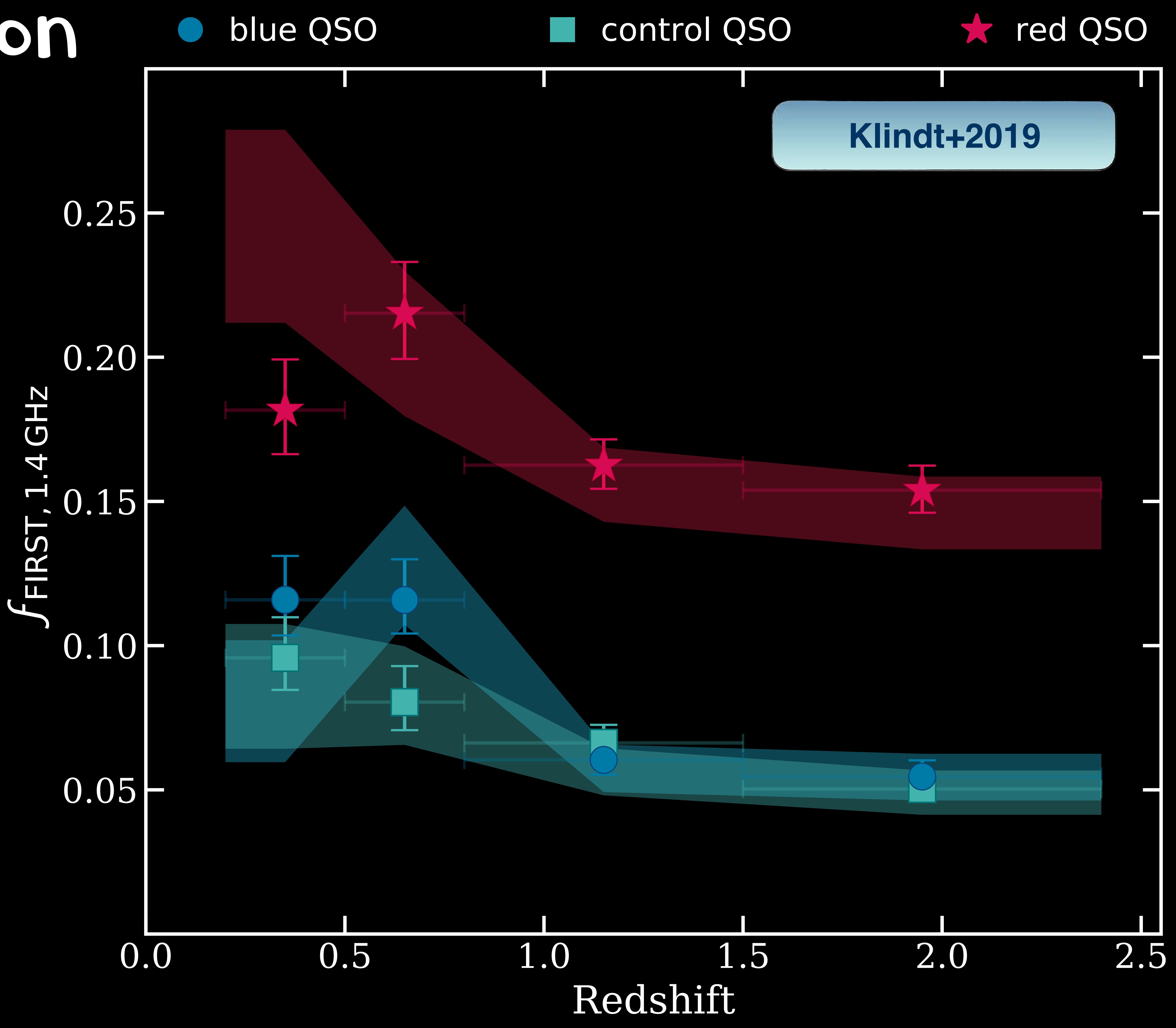
* We see a significant enhancement in the detection rate of red quasars across all redshifts.

* Match in rest frame 6 μm luminosity and redshift.

Result holds !



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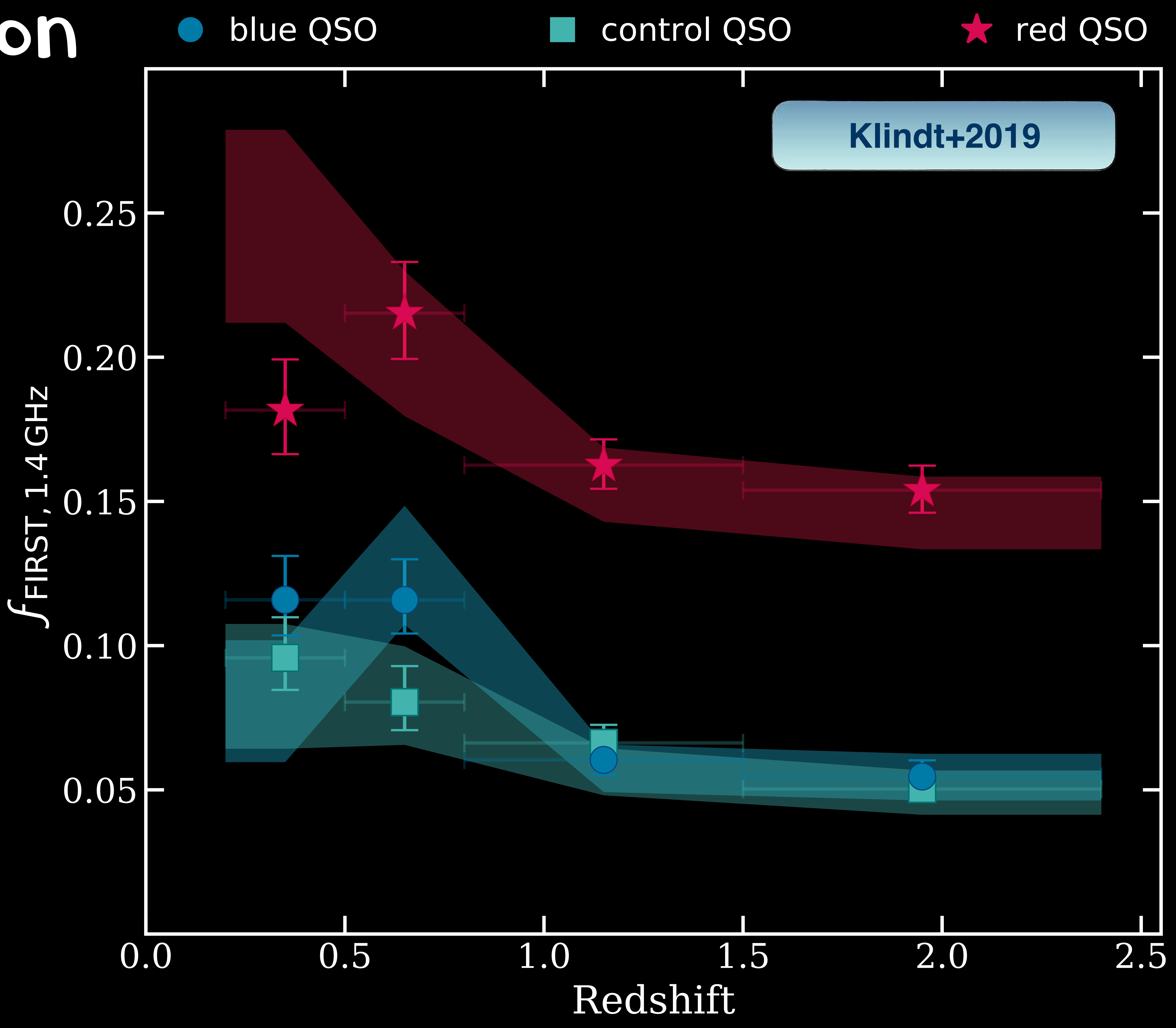
Result holds !

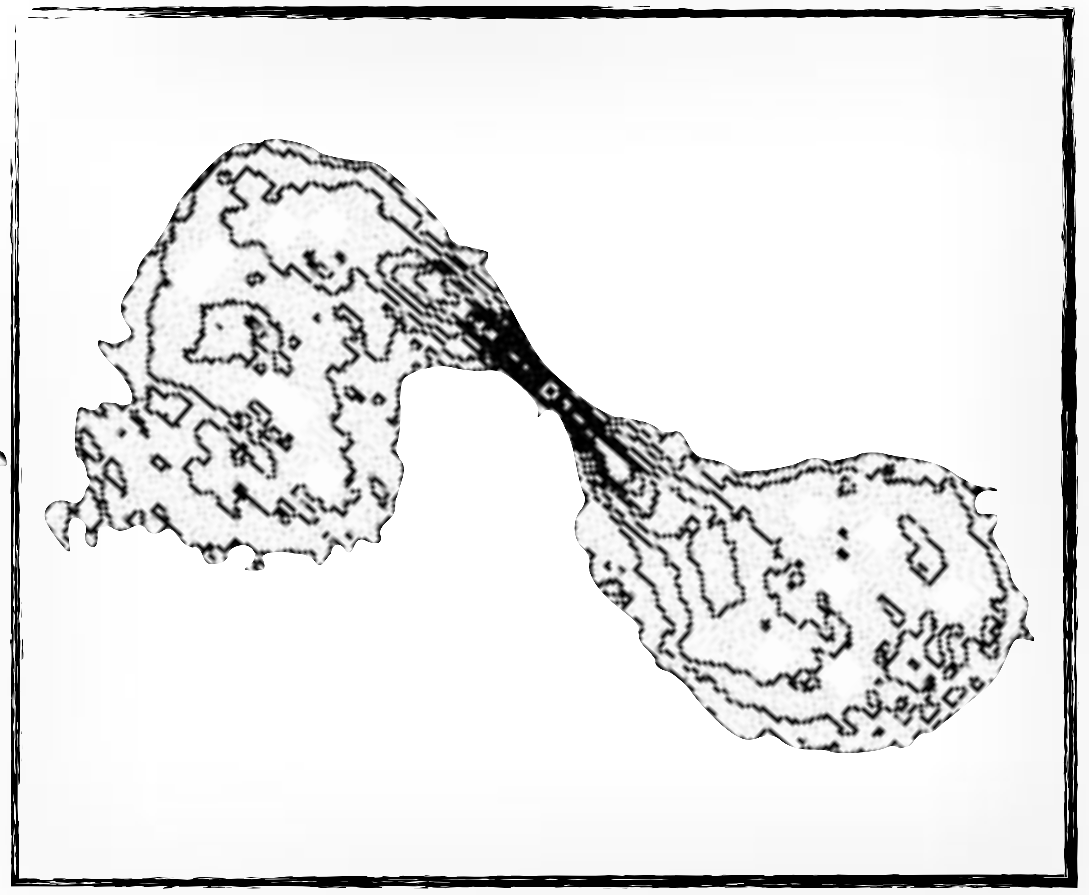
* Note we don't see significant differences in BH mass and Edd ratio after matching in $L_{6\mu m}$ and z.



Radio emission — FIRST 1.4 GHz

radio-detection rate

radio morphologies



radio loudness

Radio emission — FIRST 1.4 GHz

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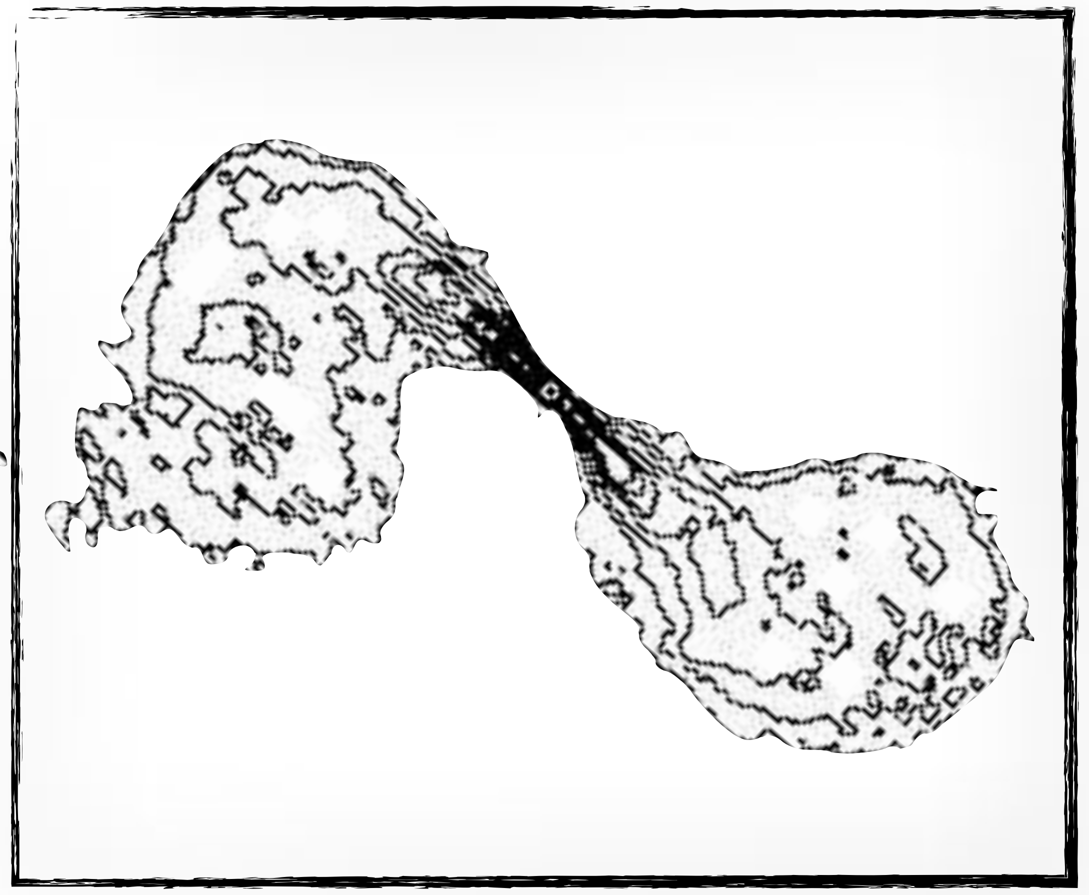

radio loudness

Visually assessed ~1400 FIRST cutouts to classify radio-detected quasars

Radio emission — FIRST 1.4 GHz

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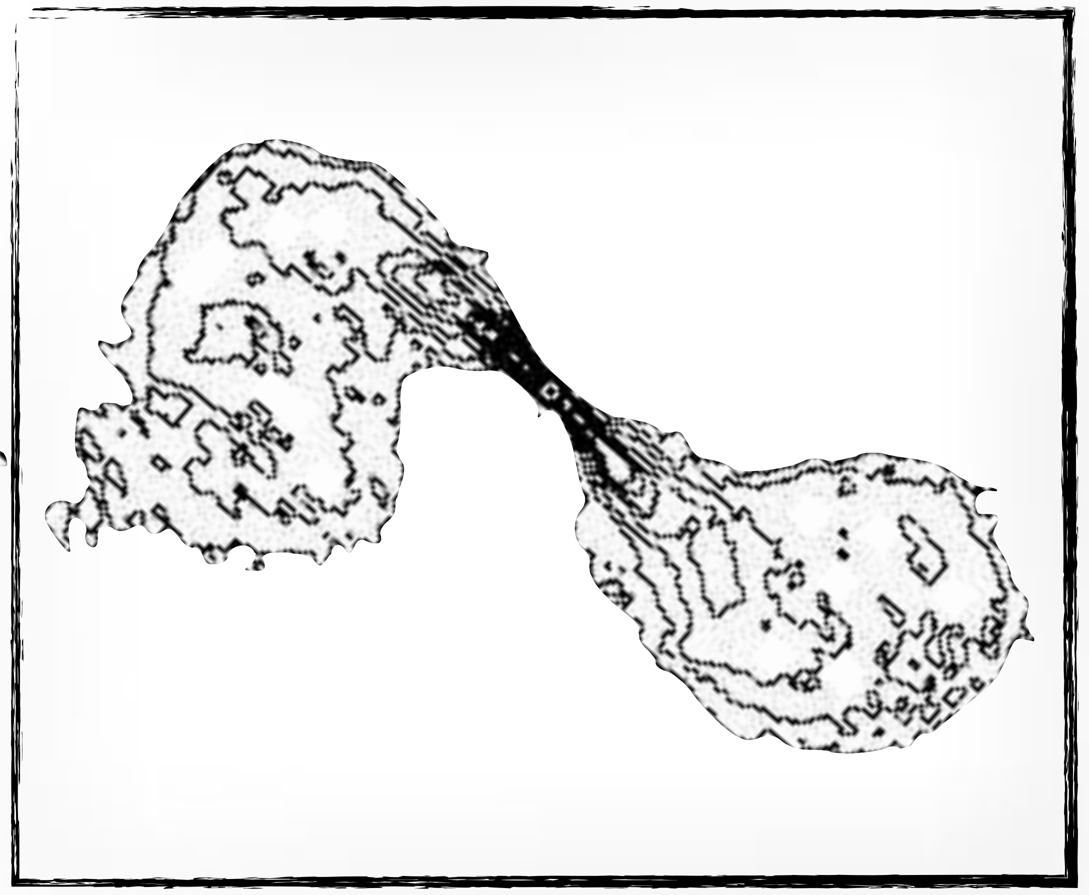

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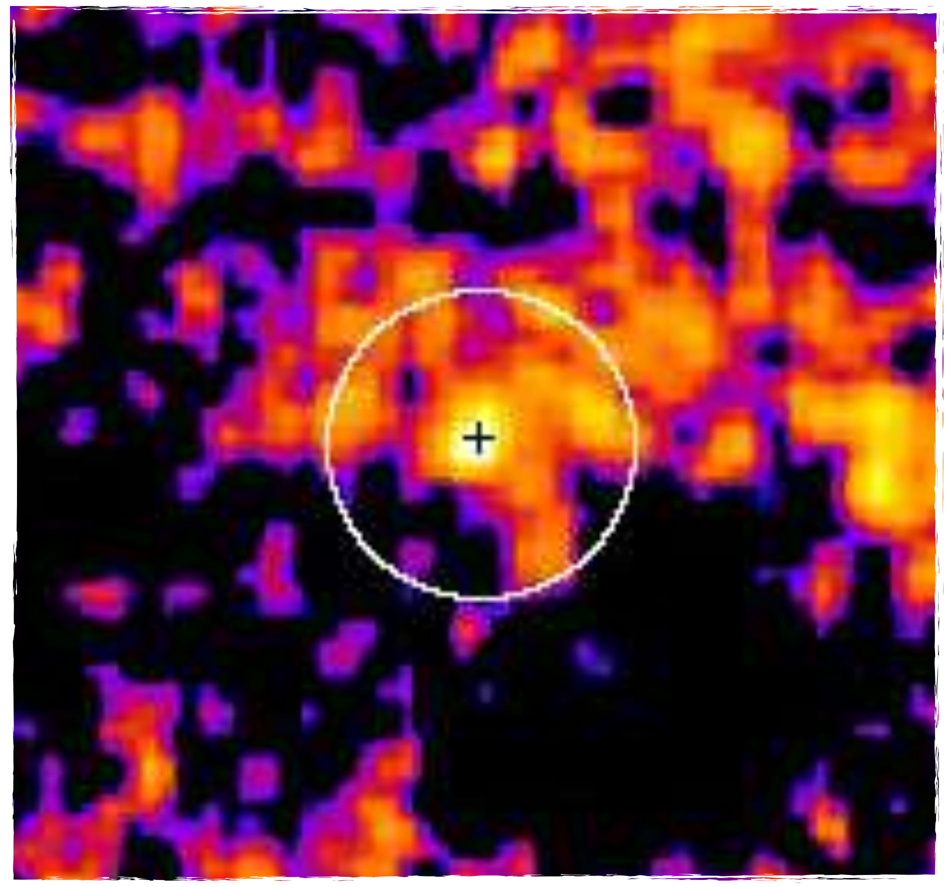
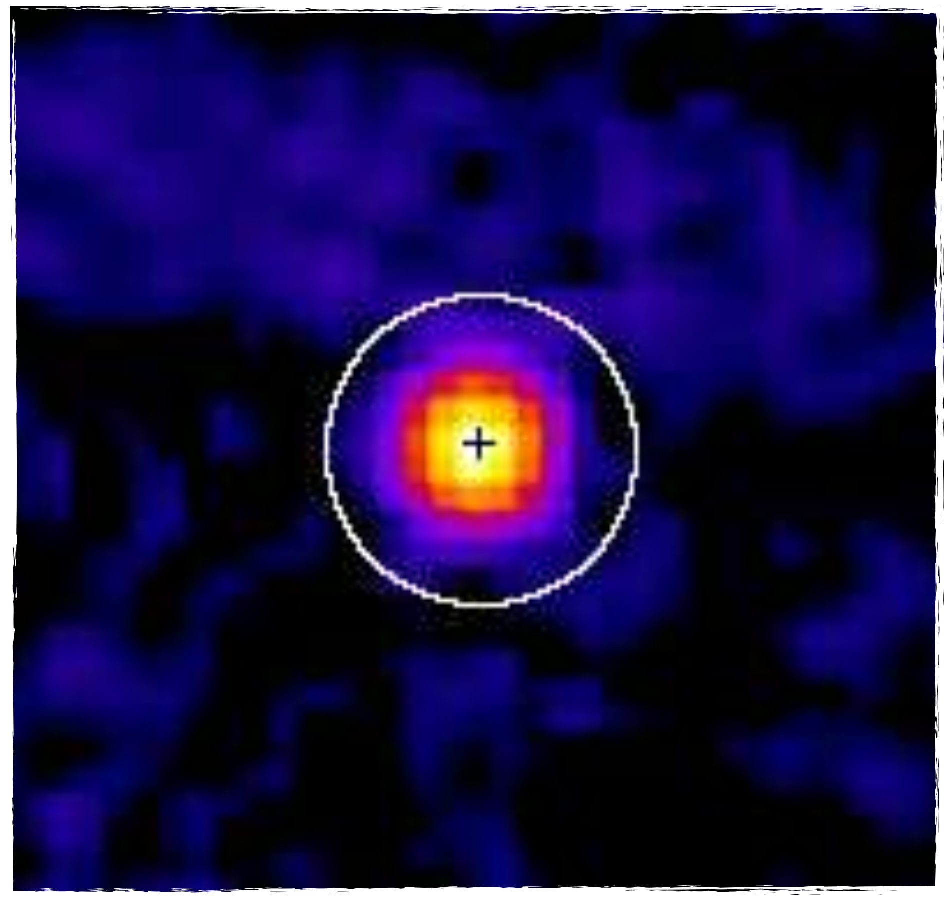
Faint



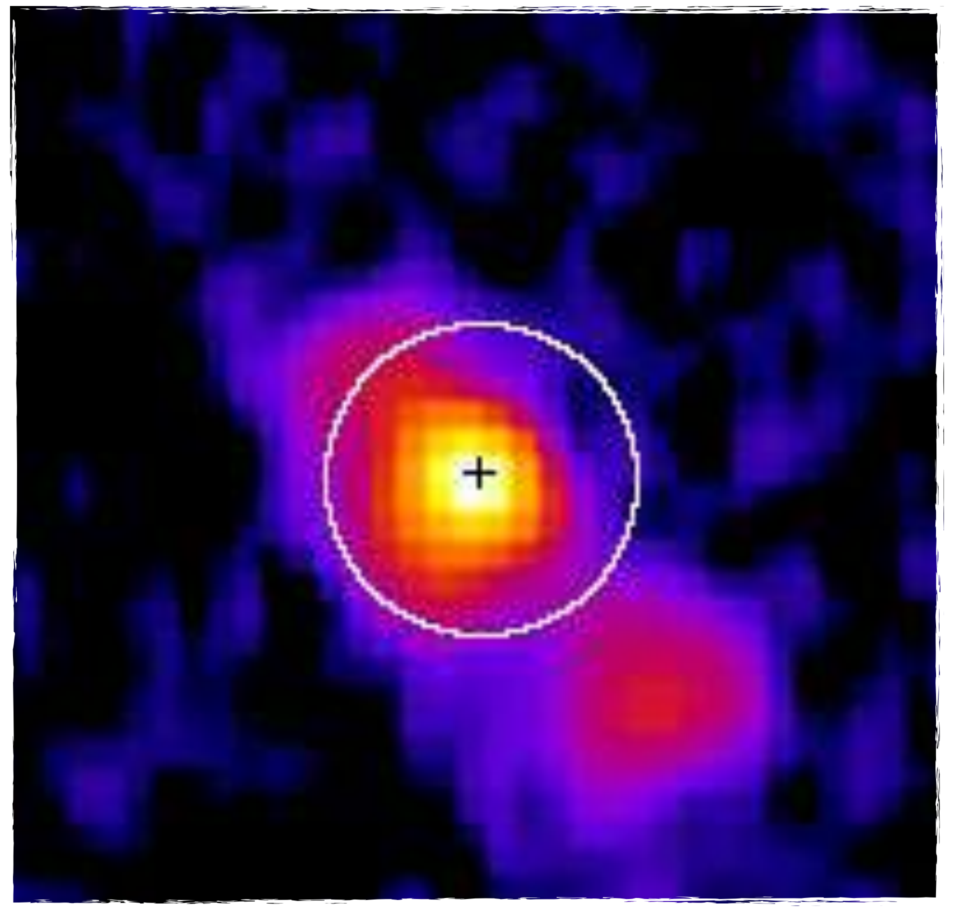
F_{peak} < 3 mJy

Compact

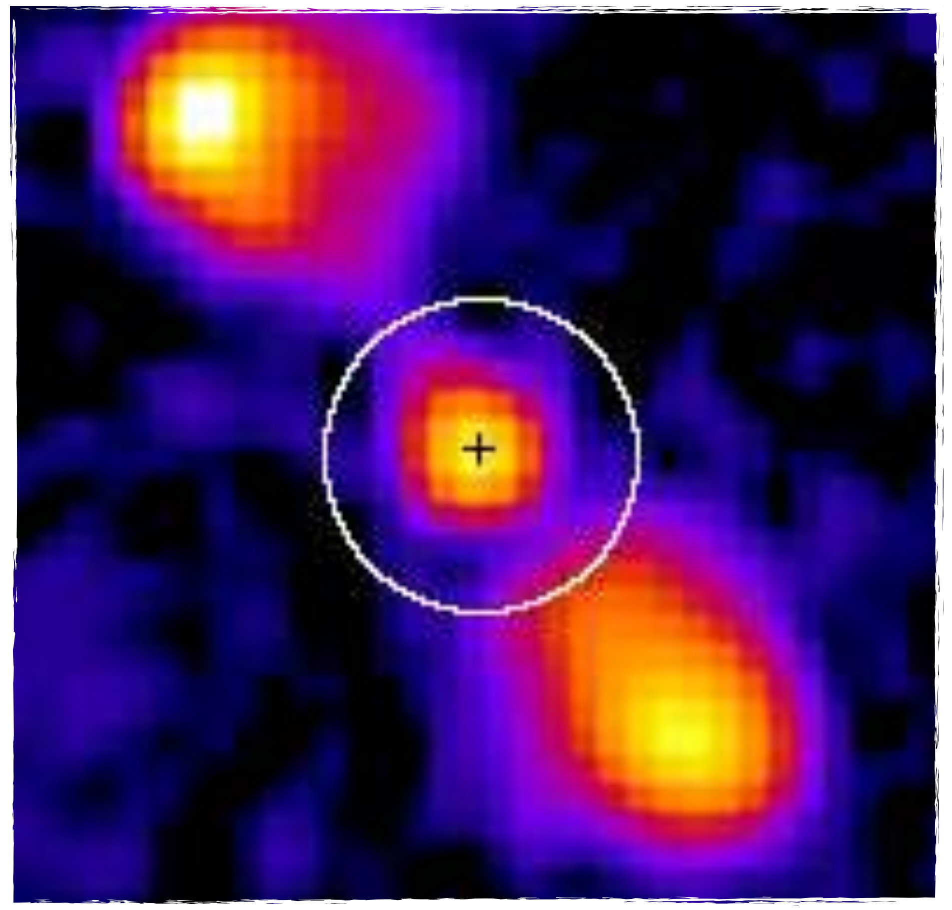


Maj < 5”

Extended



FR II



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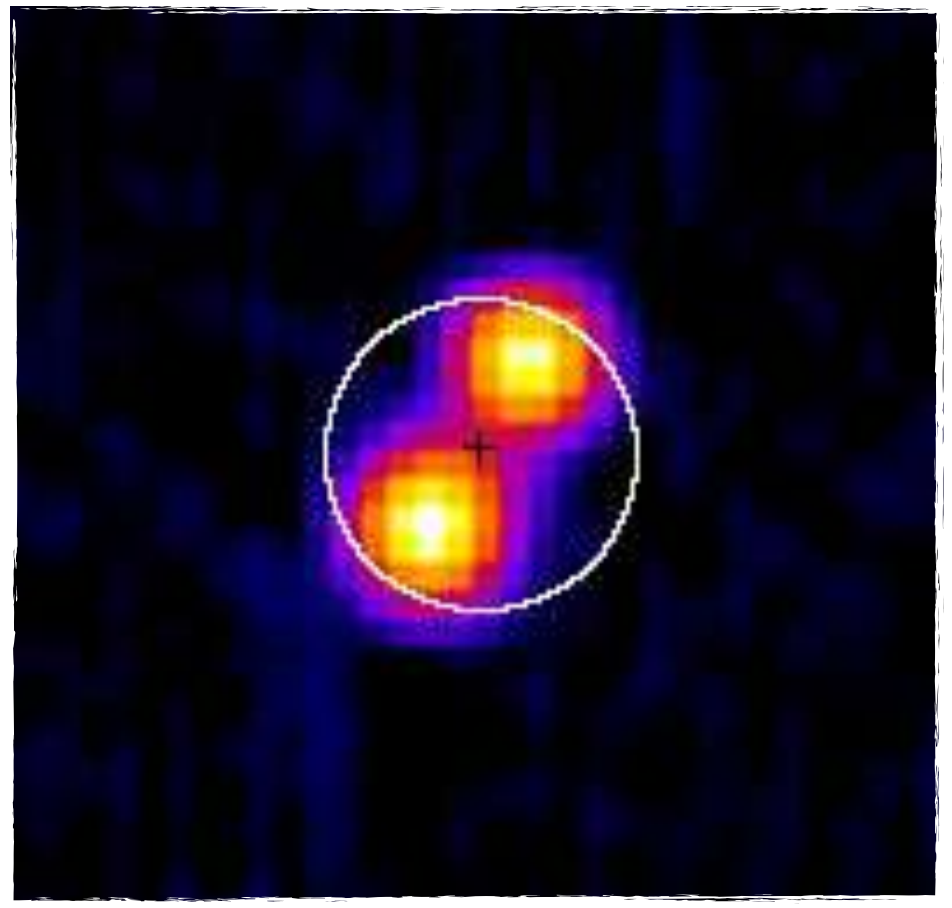
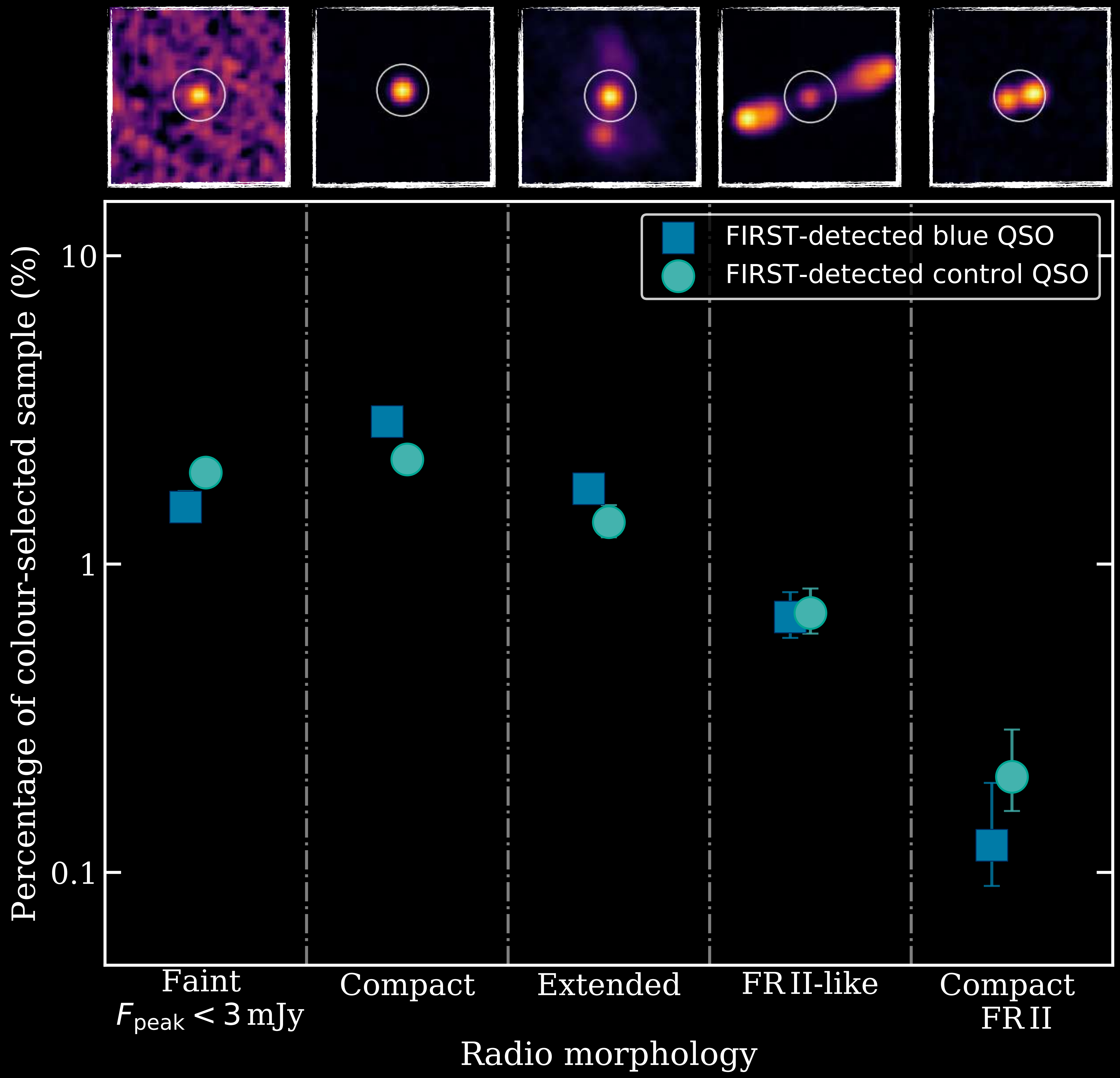


Radio morphologies

- **Blue & control QSOs have similar fractions in all morphology classes.**



Klindt+2019

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- Blue & control QSOs have similar fractions in all morphology classes.

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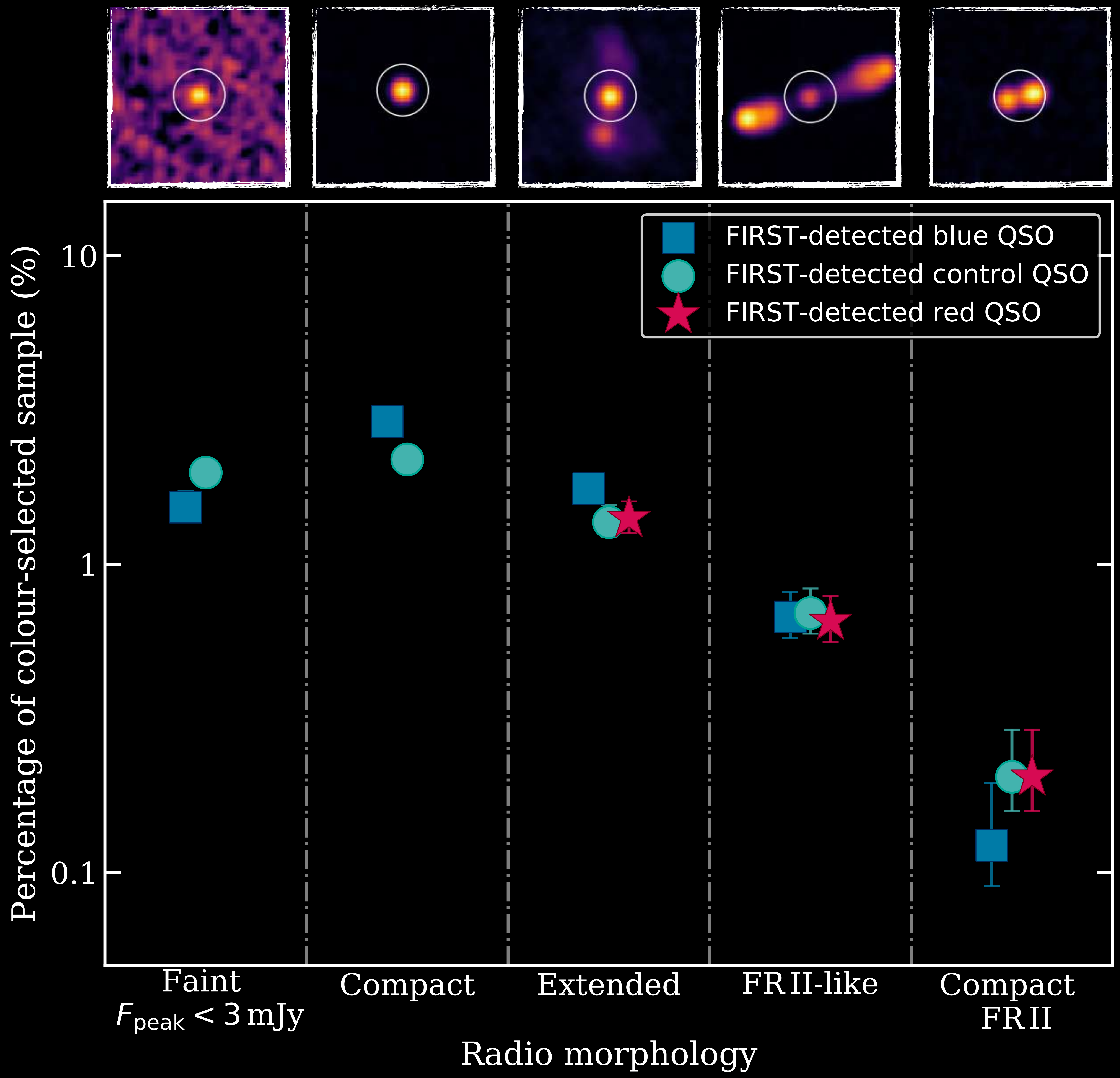
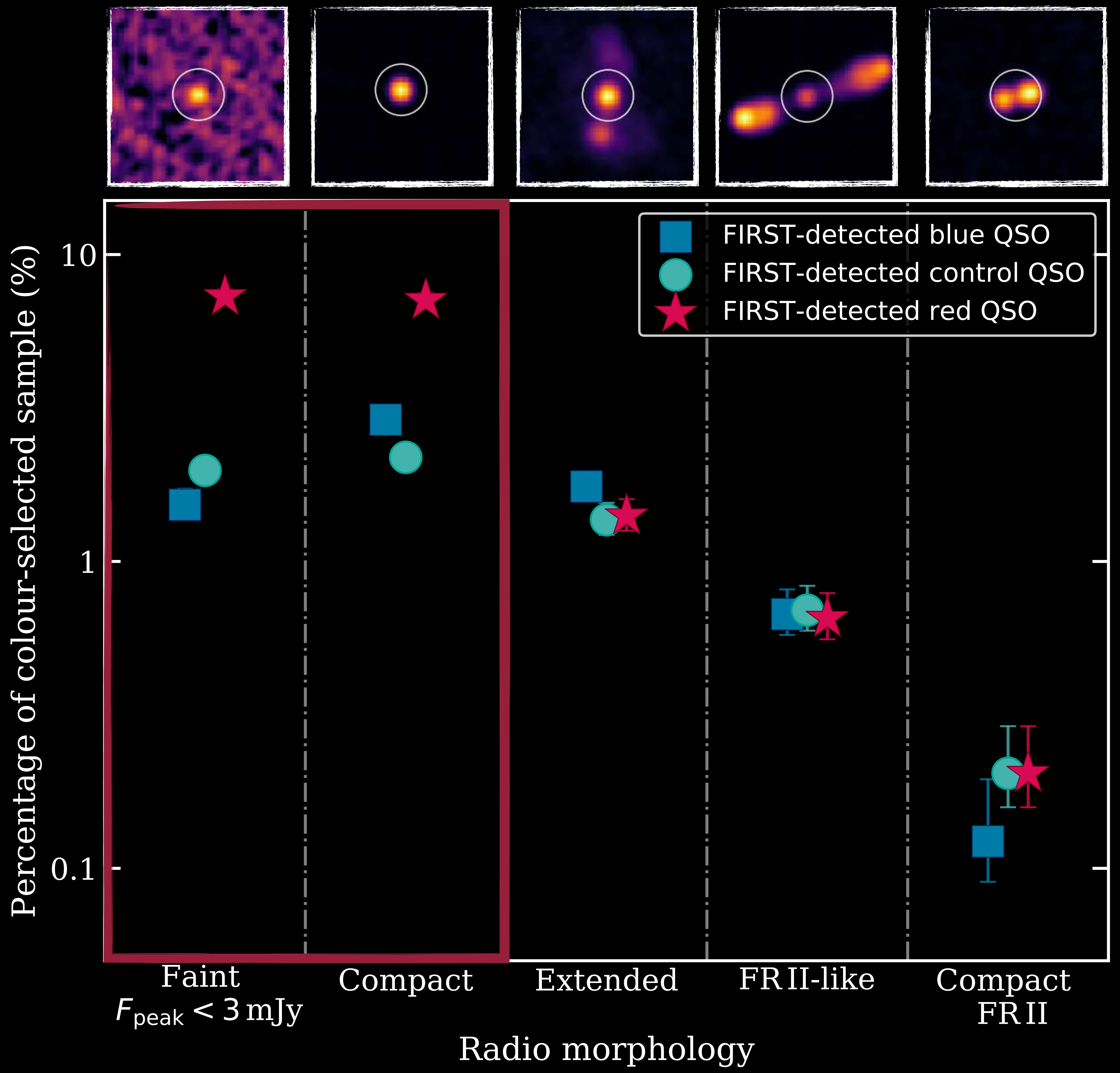


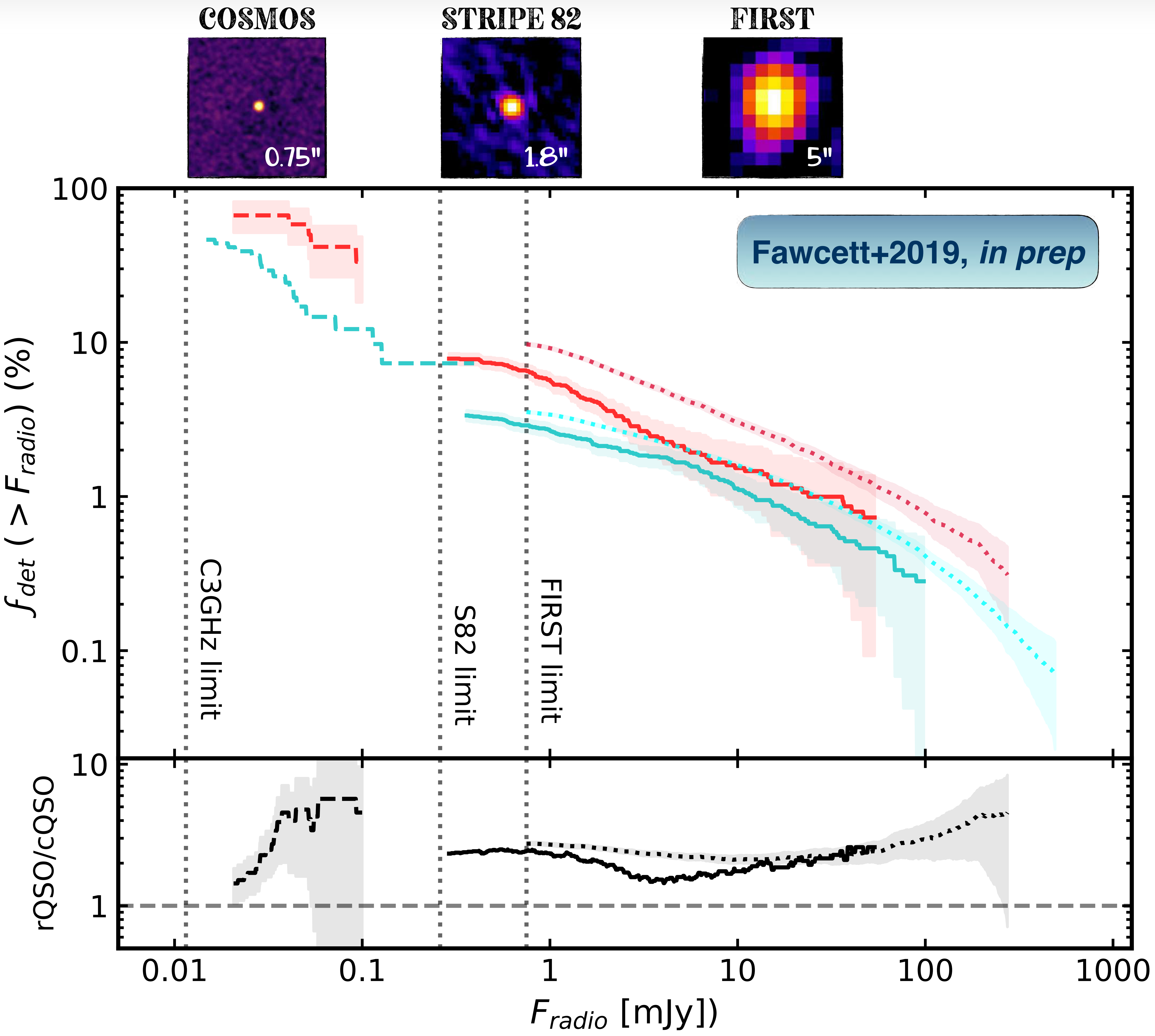
Klindt+2019

Radio morphologies

- Blue & control QSOs have similar fractions in all morphology classes.
- Red QSOs have similar FIRST detection fractions to the blue and control QSOs in the extended classes.
- A factor of 2–6 more rQSOs have either compact radio emission or are radio faint, in comparison to blue quasars.



Klindt+2019



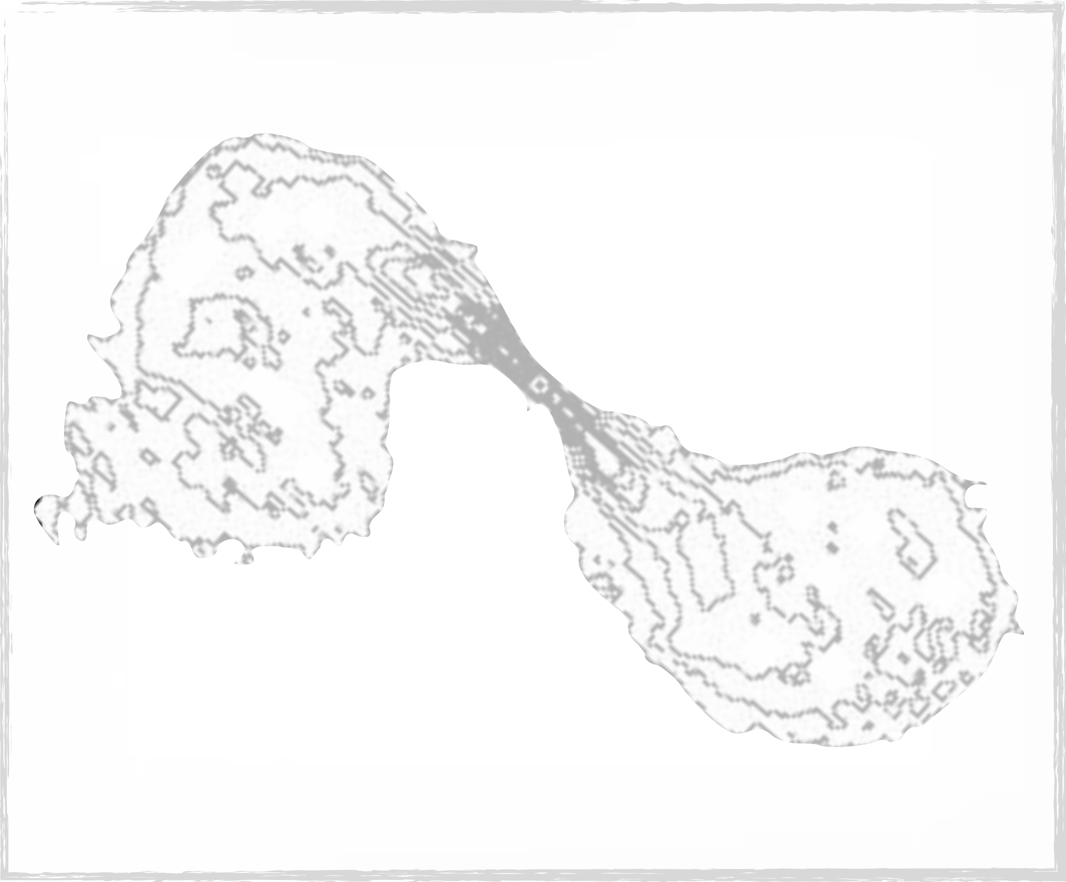
Going deeper & resolving smaller scales

- **SDSS DR14 — half a million QSOs**
- **Even when going 2 orders of magnitude deeper we see an enhancement in the radio-detection rate of red quasars.**
- **Starting to see radio differences at the host galaxy scale.**

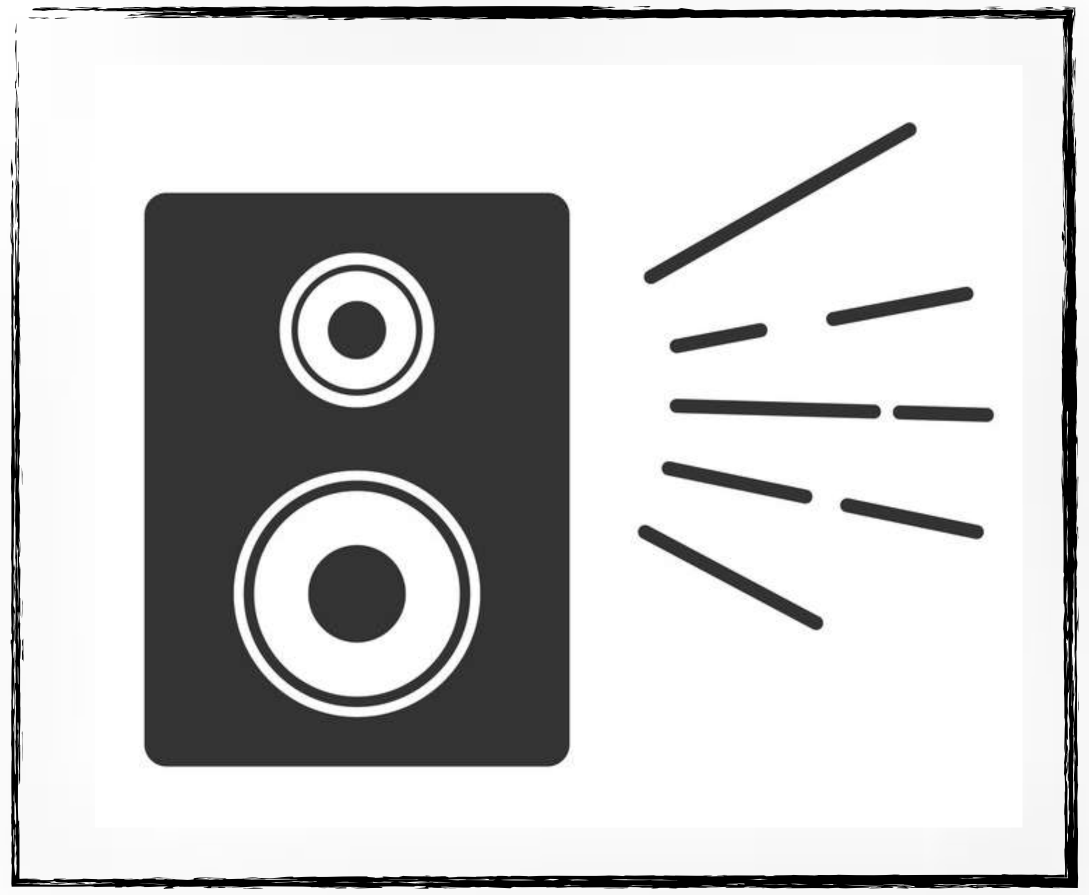
Radio emission — FIRST 1.4 GHz

radio-detection rate

radio morphologies

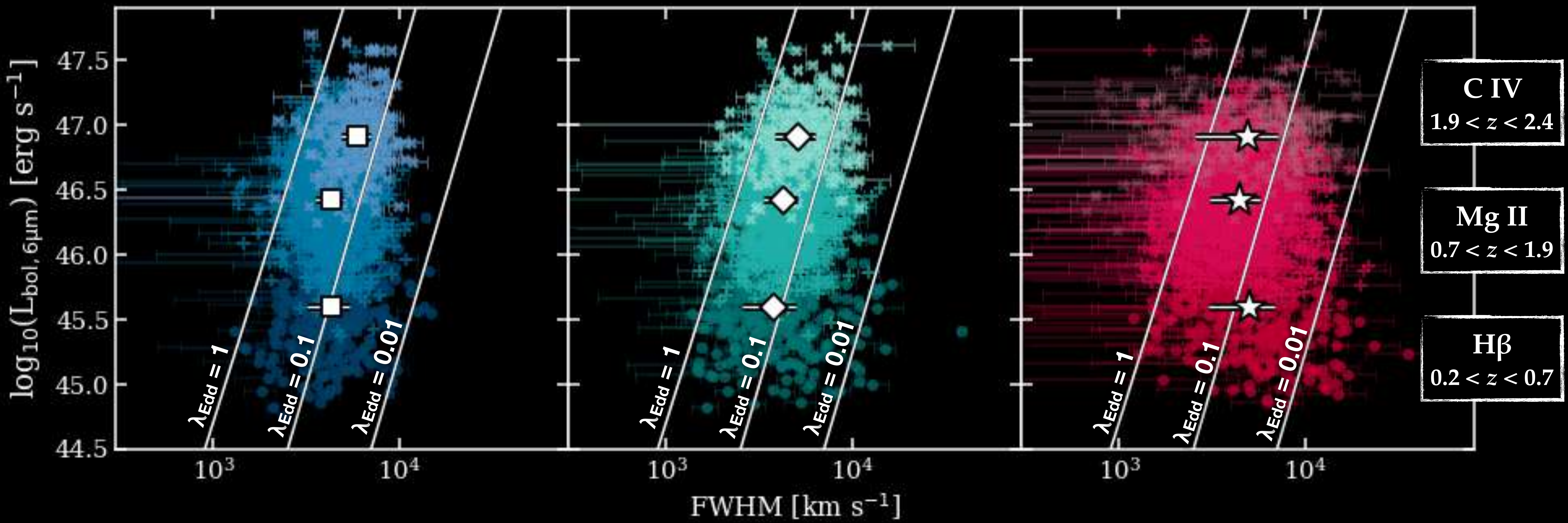


radio loudness



Excess of red radio-detected quasars near the detection limit.

footnote: do red quasars have different accretion rates?



* NIR selected QSOs have higher accretion rates (e.g., Richards+2003, Urrutia+2012 & Kim+2015).
* No strong differences in the ***average* accretion rates** between red and blue quasars.
* Further explore this with our X-shooter sample!

Klindt+2019

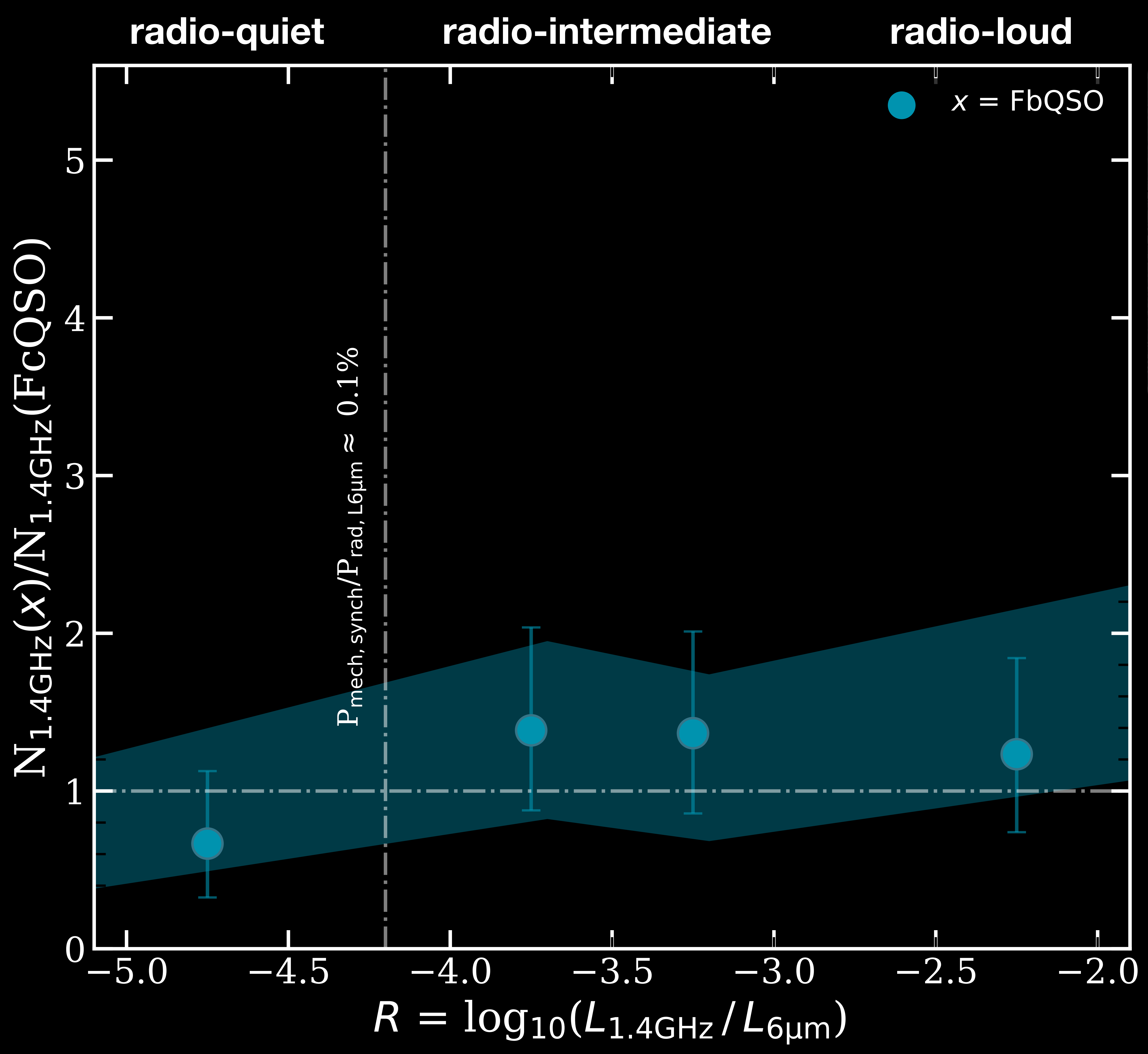
Radio loudness

$R = f_{radio} / f_{optical}$

- Relative ratio of the quasar in the radio band to the overall accretion power.

$$R = \log_{10}(L_{1.4GHz}/L_{6\mu m})$$

- No excess of blue quasars relative to control quasars.



Klindt+2019

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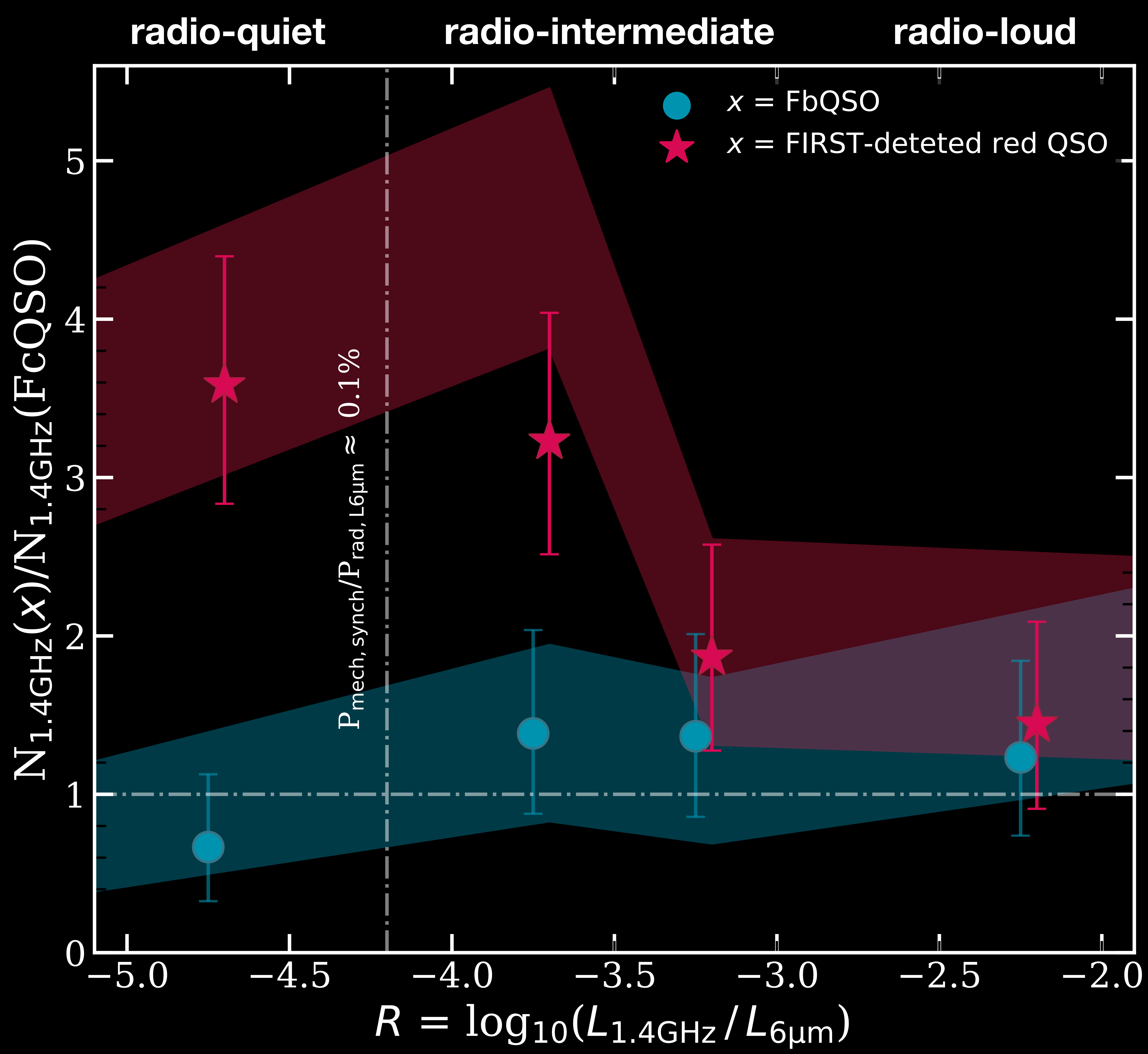
$$R = \log_{10}(L_{1.4GHz}/L_{6\mu m})$$

- No excess of blue quasars relative to control quasars.
- No excess of red quasars relative to control quasars at radio-loud end.
- Excess of red quasars which are radio-quiet or radio-intermediate.



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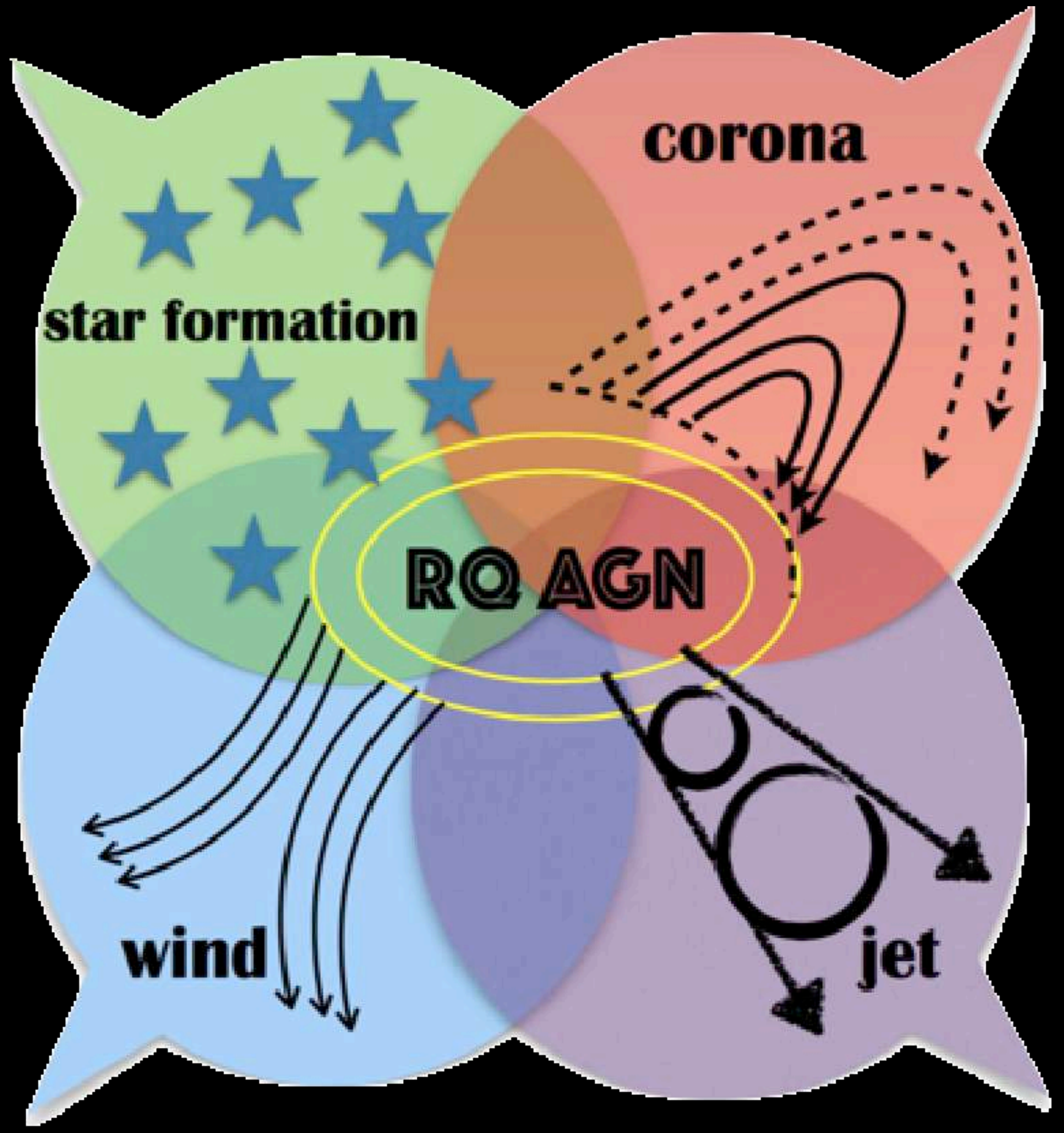
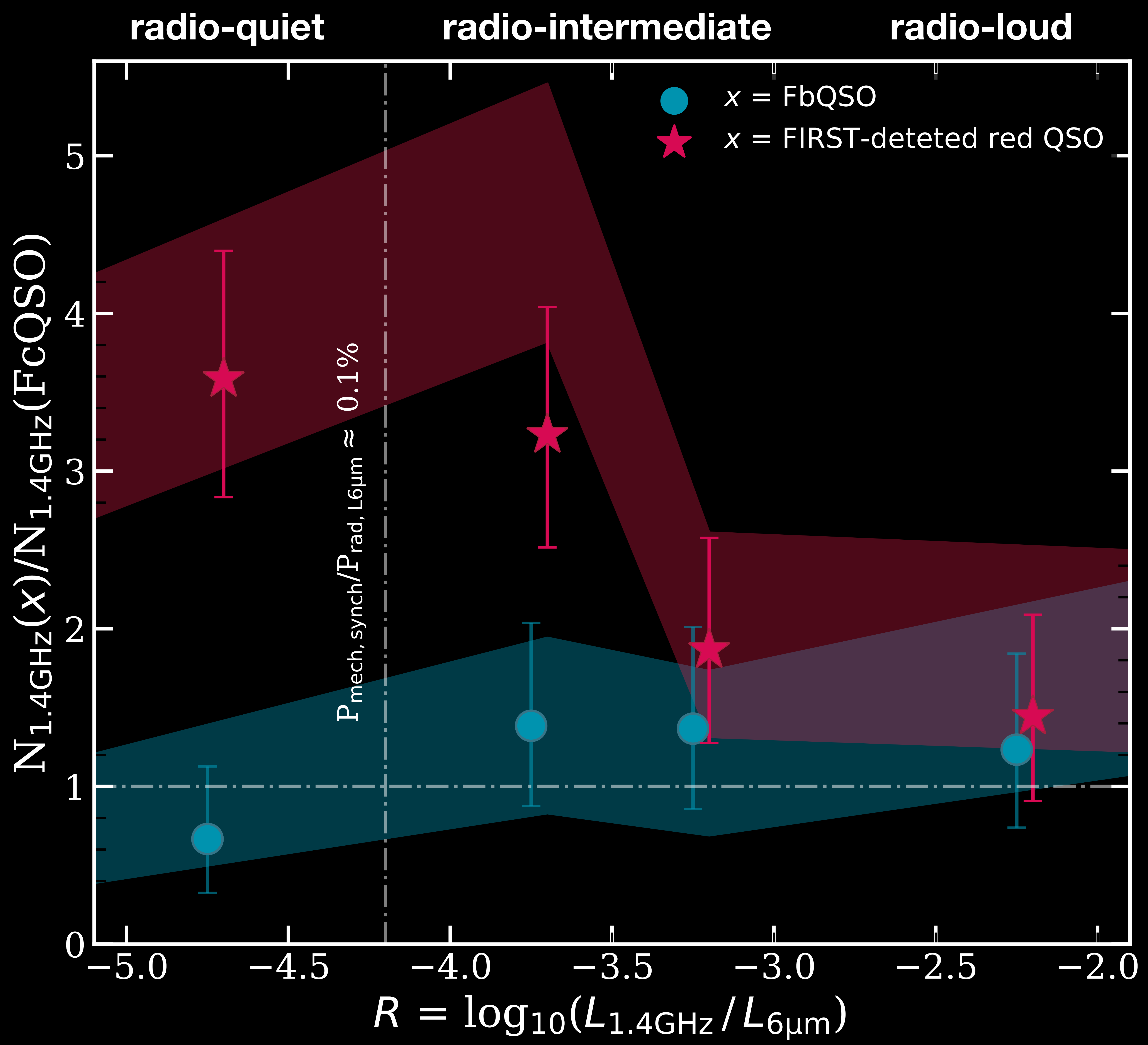
Radio loudness

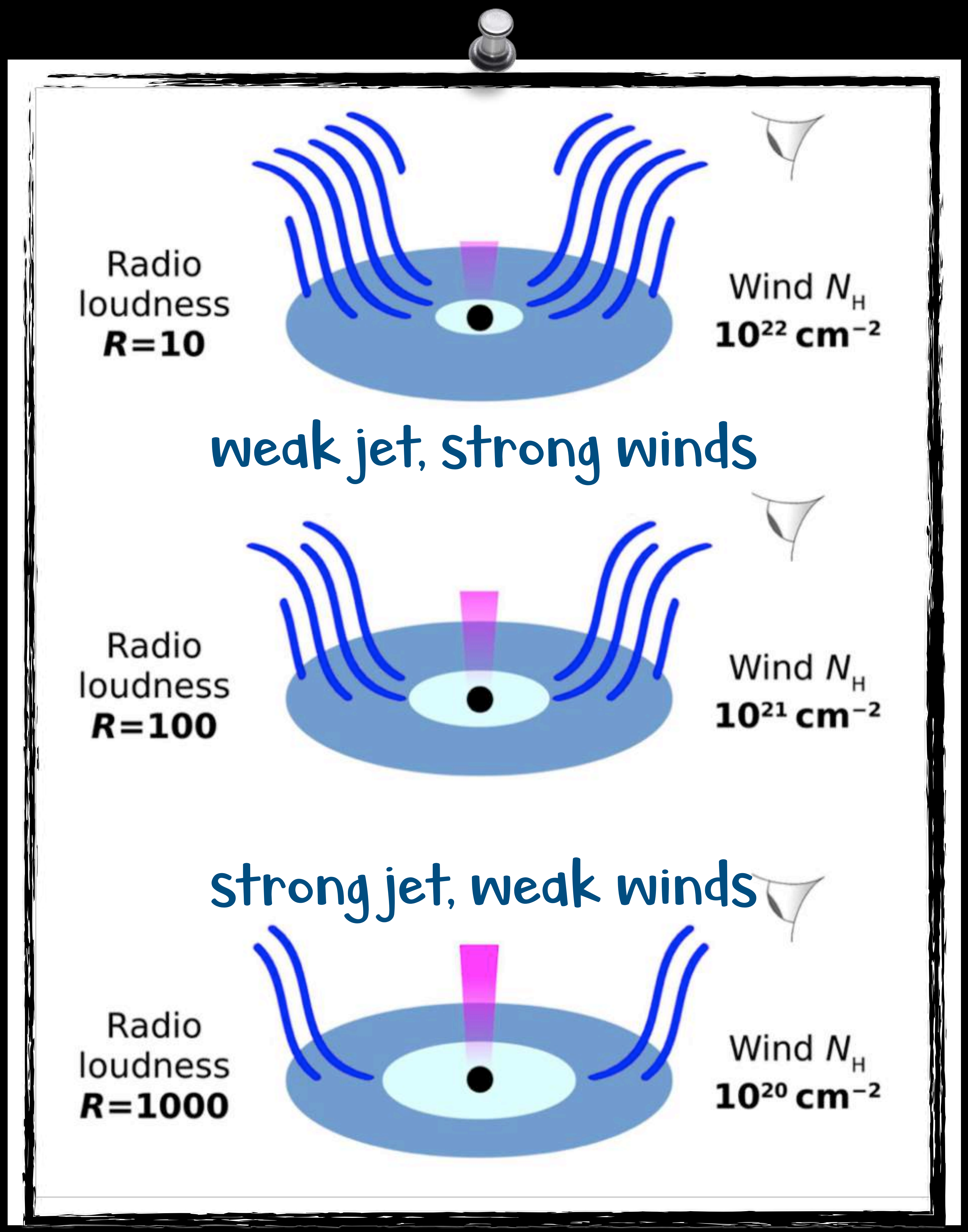


Panessa+2019
see also Zakamska & Greene (2014); Hwang+2018

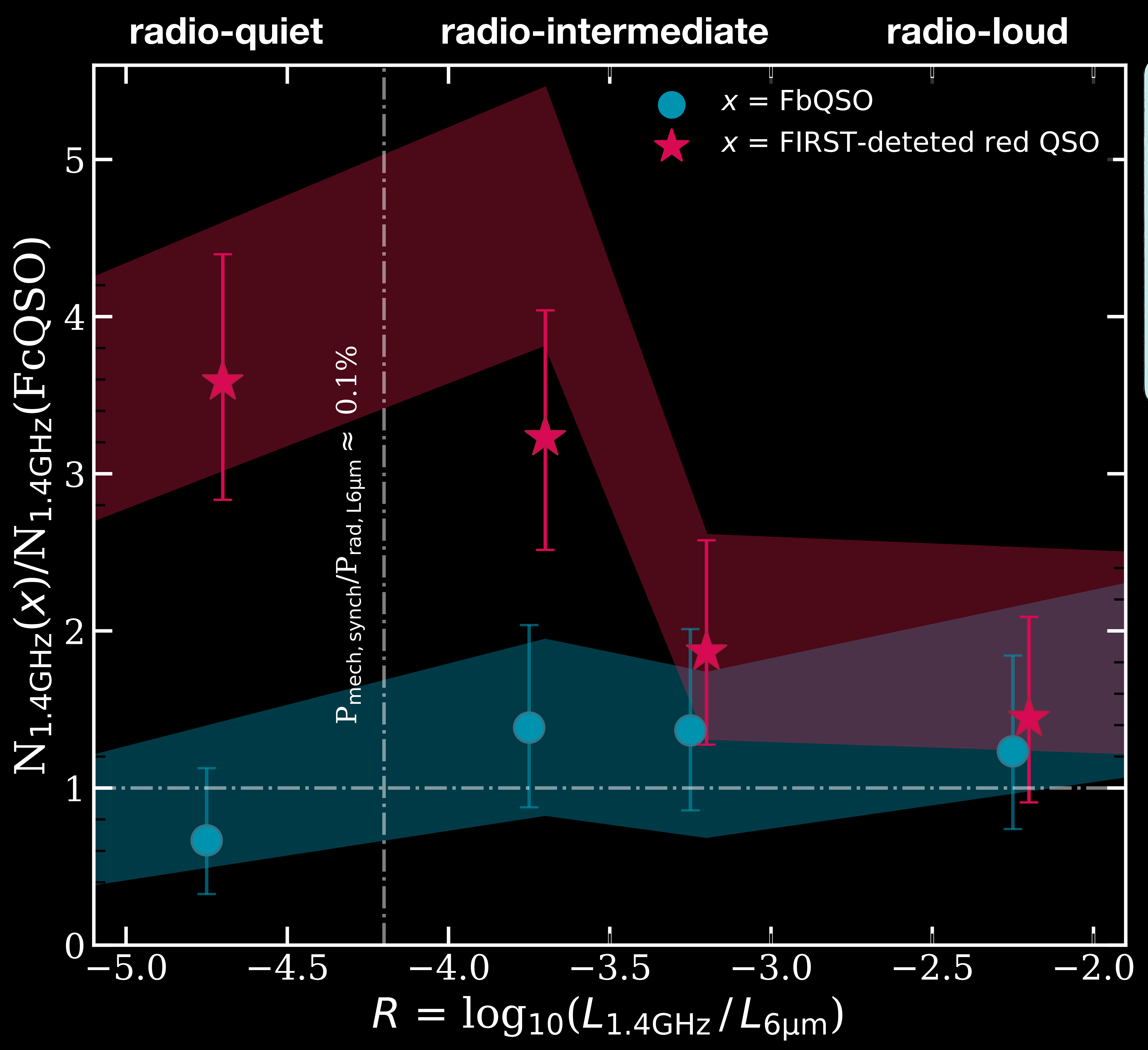


Klindt+2019

Radio loudness



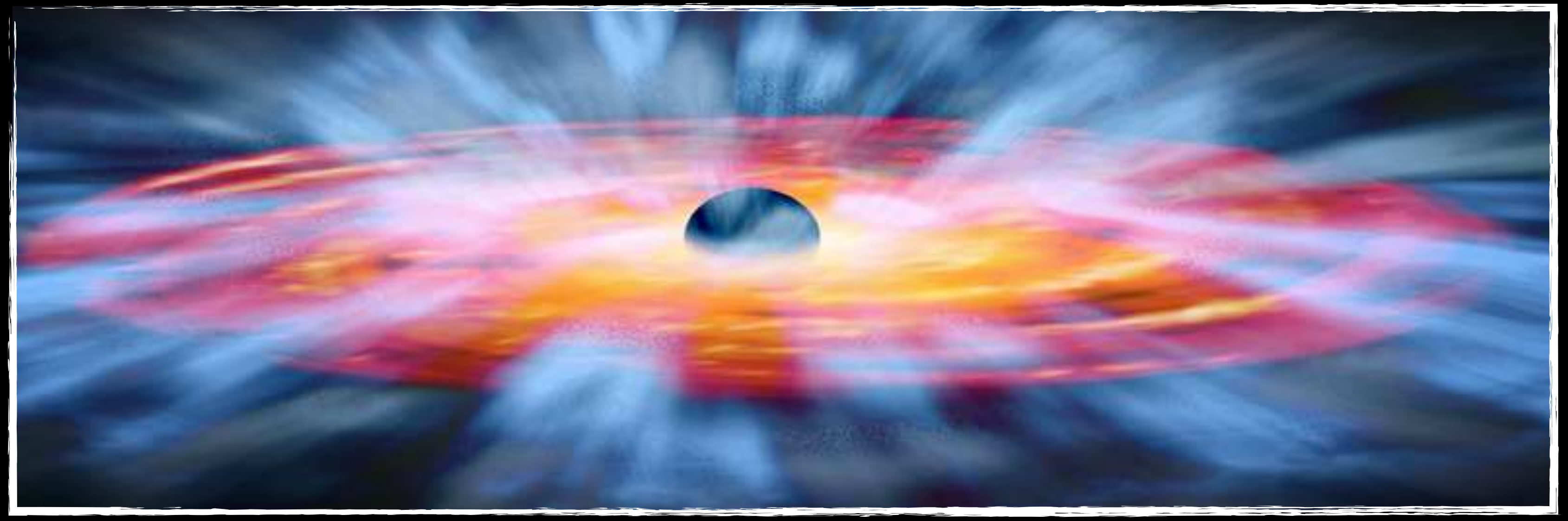
Anti-correlation between ionised winds and the radio loudness parameter (Mehdipour+2019).

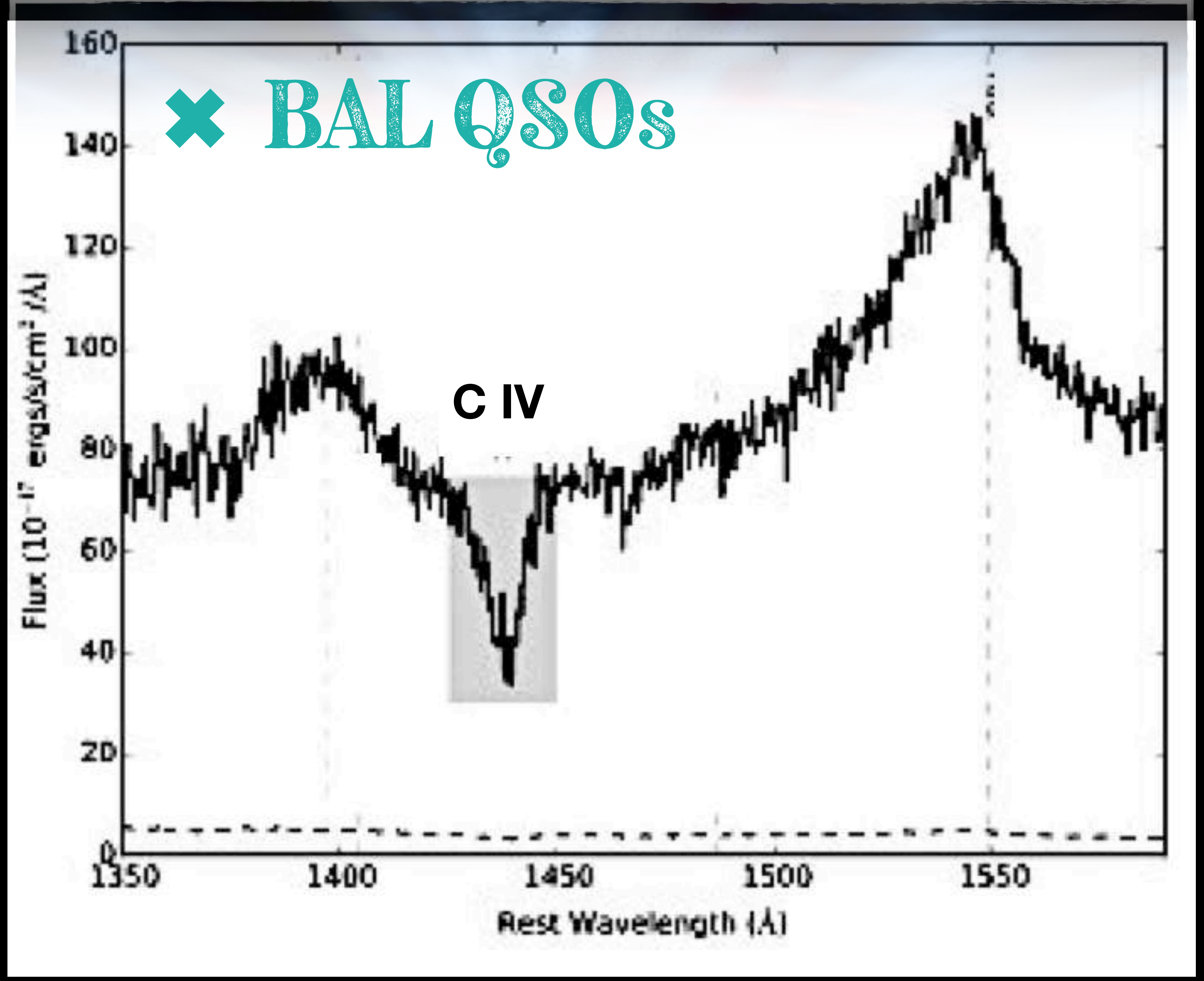


Klindt+2019

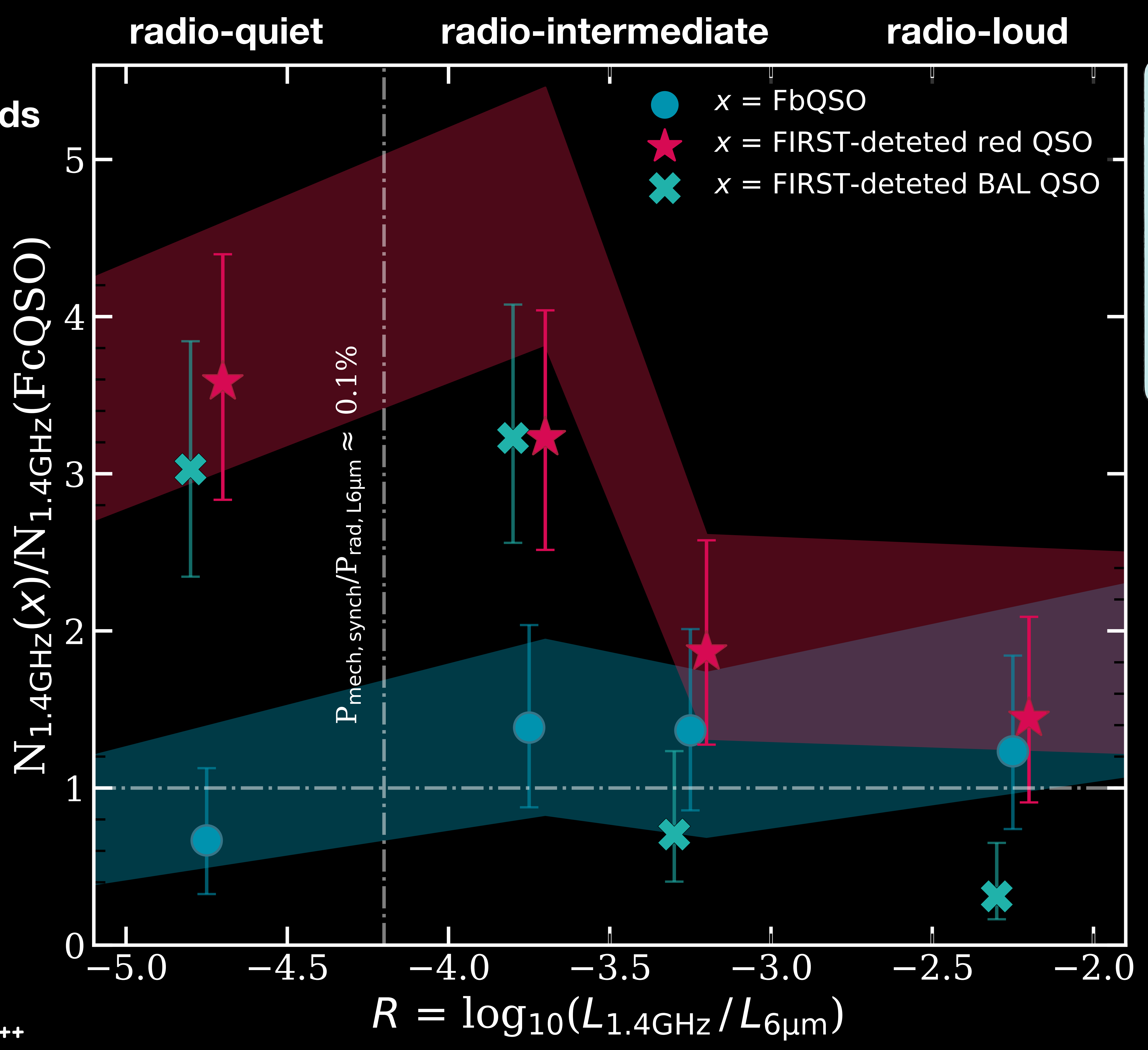
Radio loudness

Explore whether the radio emission comes from winds

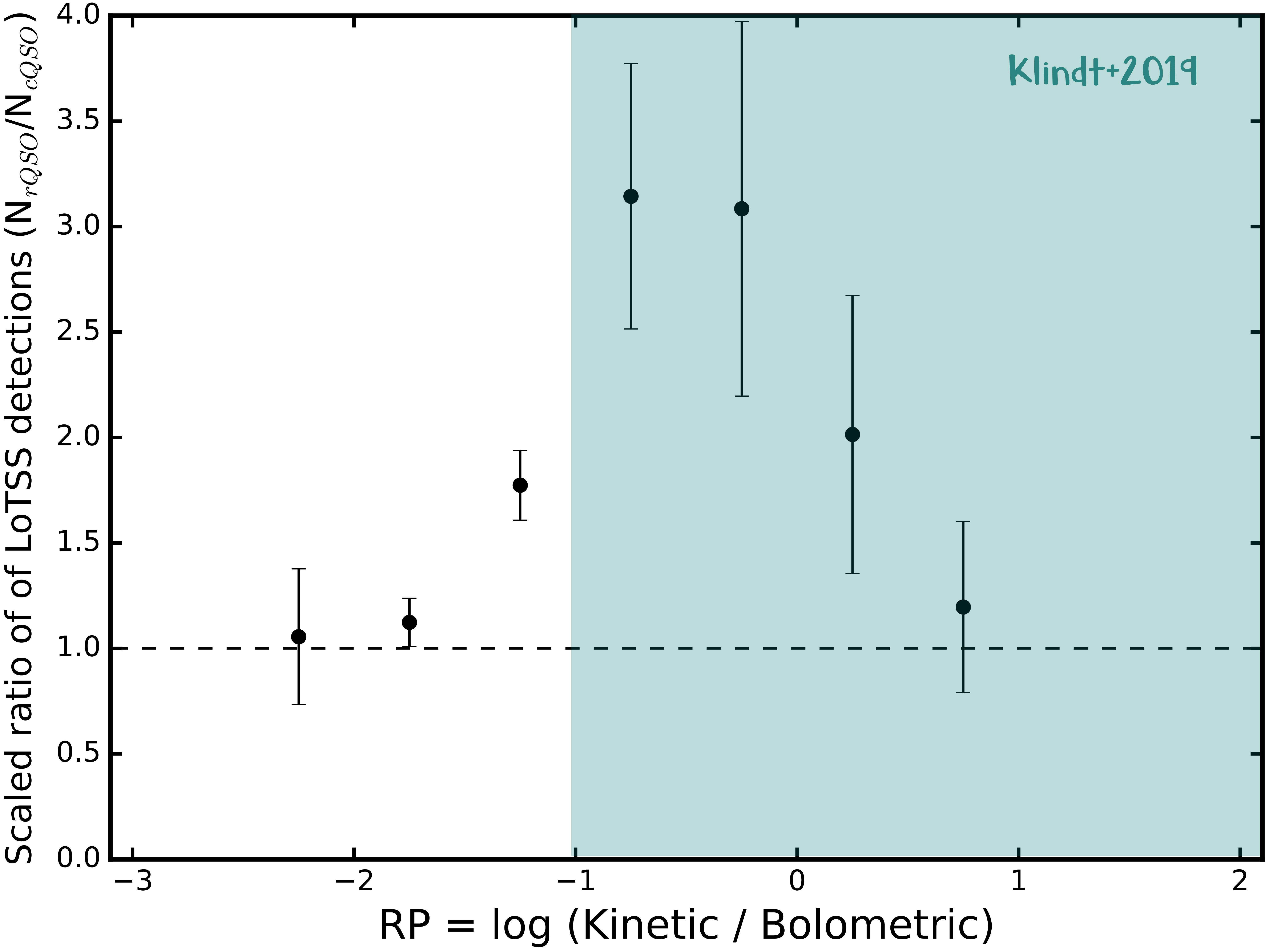




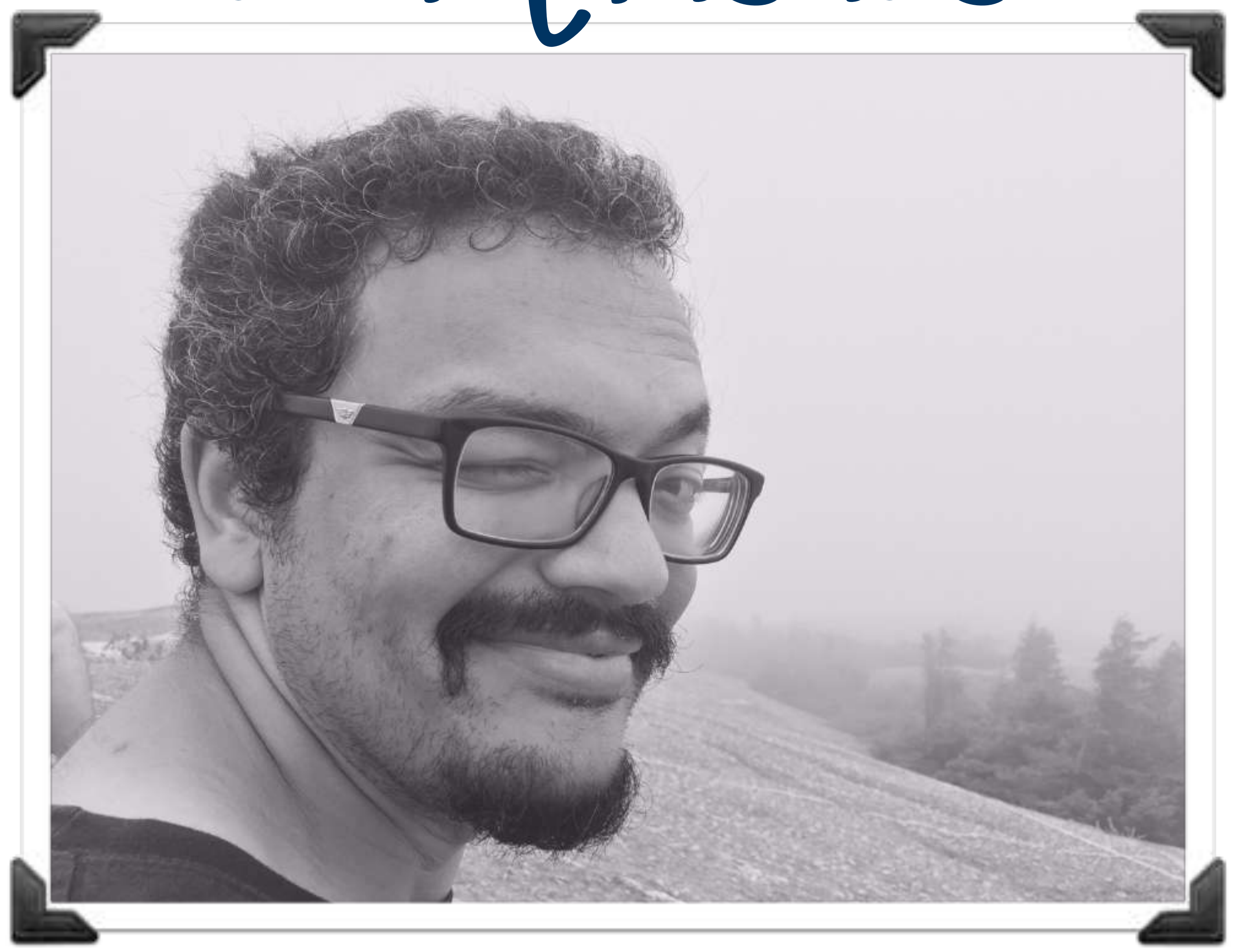
e.g., Najita+2000; Ross+2015; Hamann+2017; Morabito+ 2018; +++



Klindt+2019

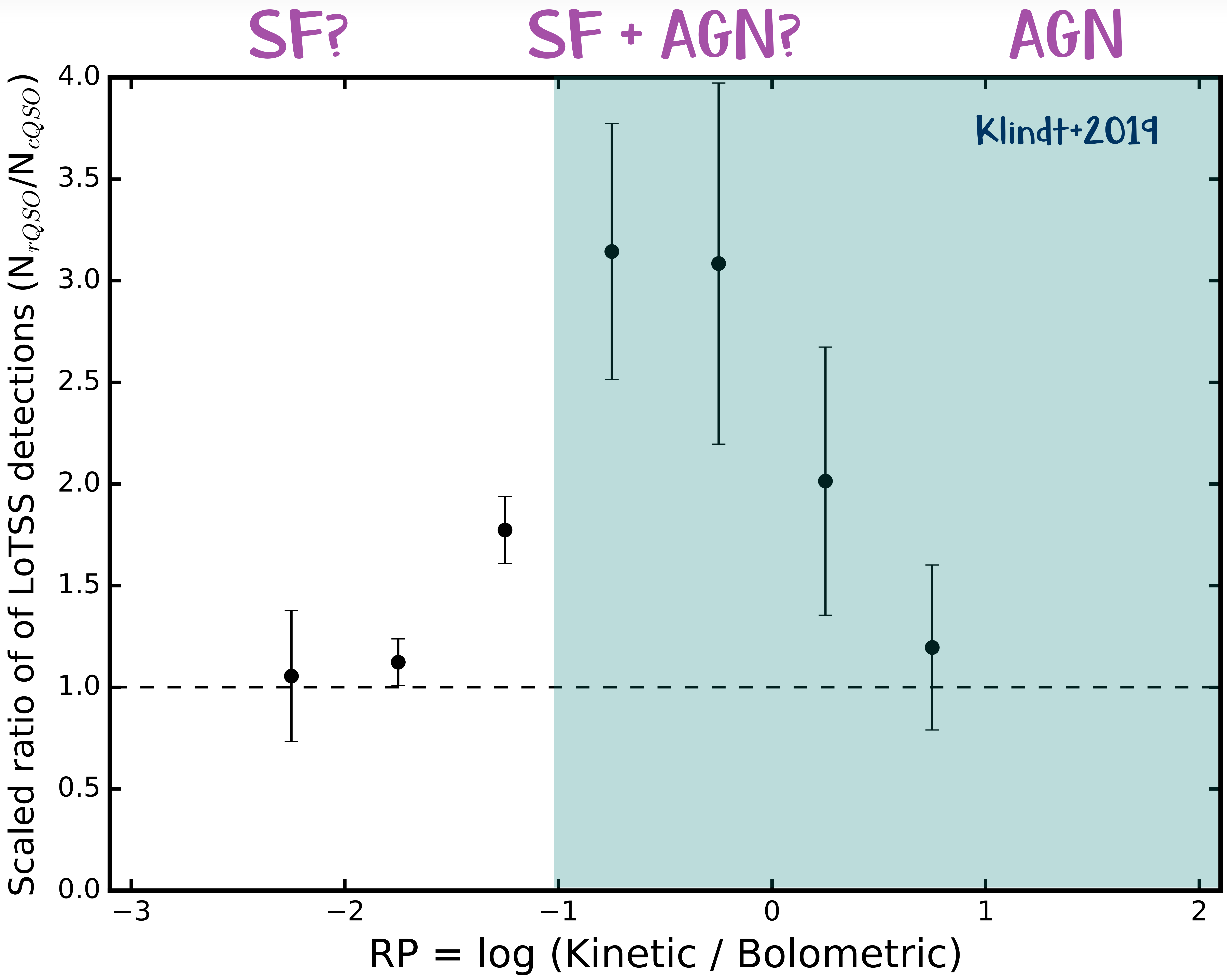


The LOFAR view of red quasars

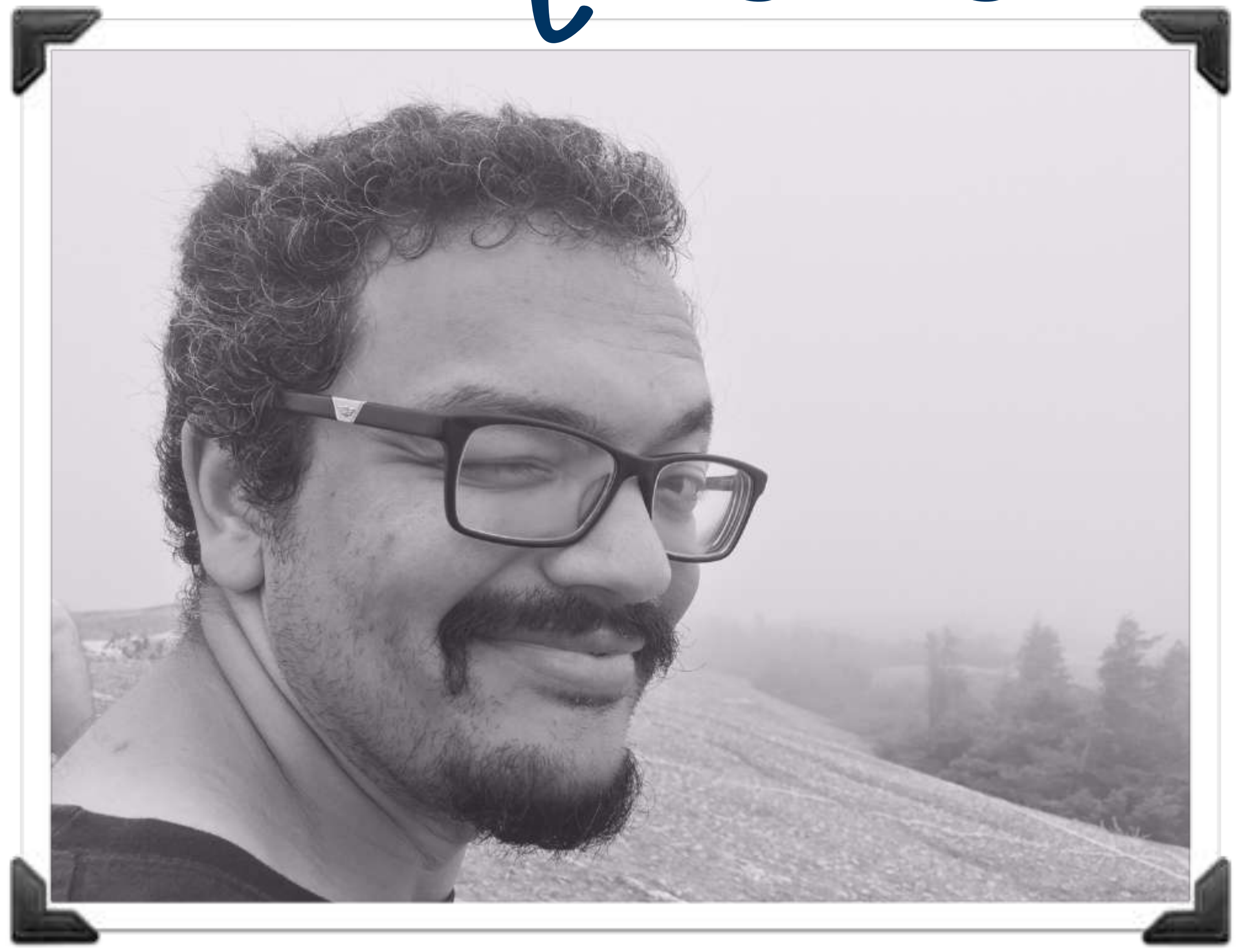


- LoTSS: image entire northern sky @ 120—168 MHz with 6” resolution.
- Confirmation of enhanced radio emission in the red QSO population.

Rosario+2019, *in prep*



The LOFAR view of red quasars

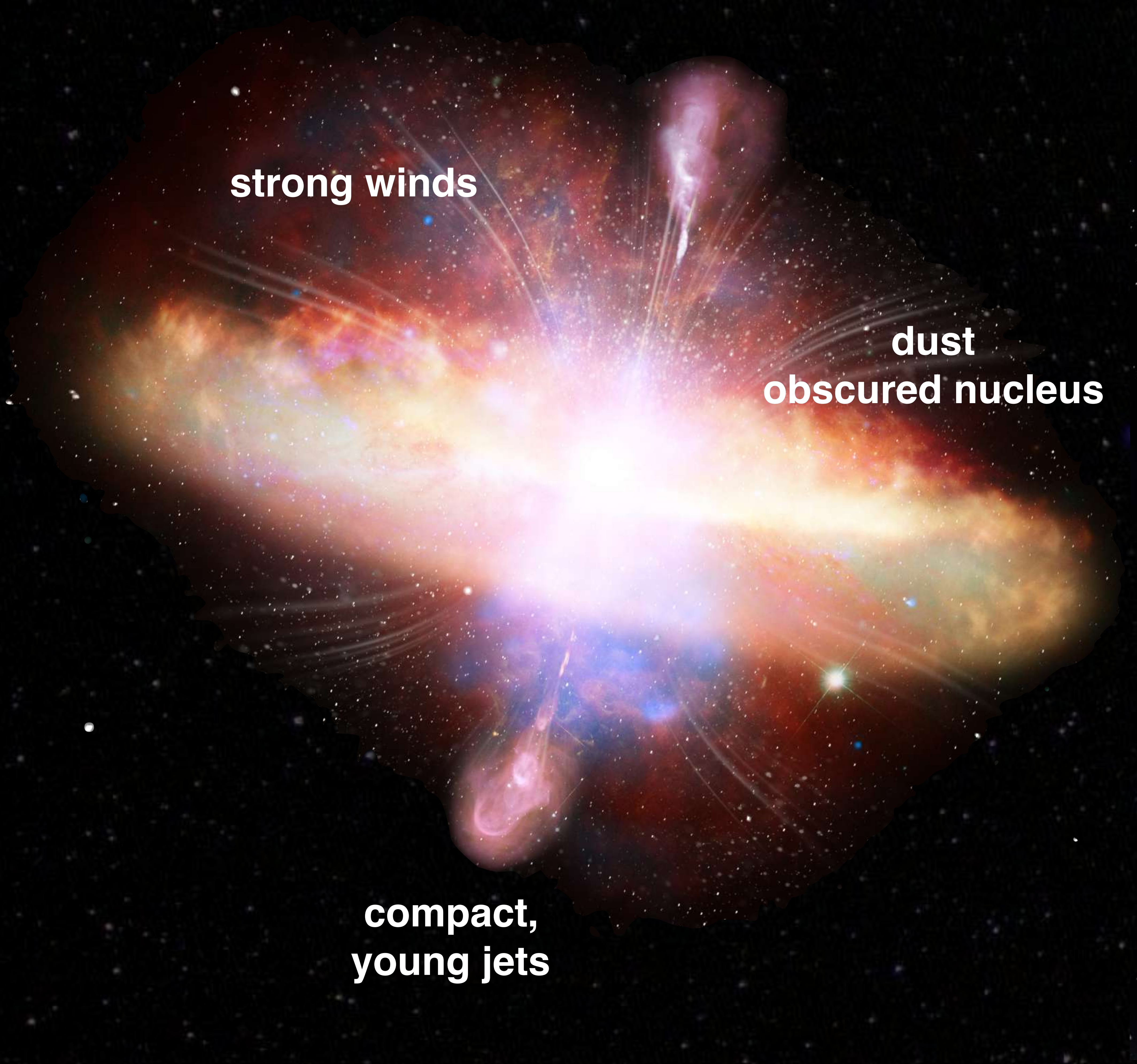


* LoTSS: image entire northern sky @ 120—168 MHz with 6” resolution.
* Confirmation of enhanced radio emission in the red QSO population.
* At lower R values the enhancement drops.
* Enhancement is due to AGN processes?

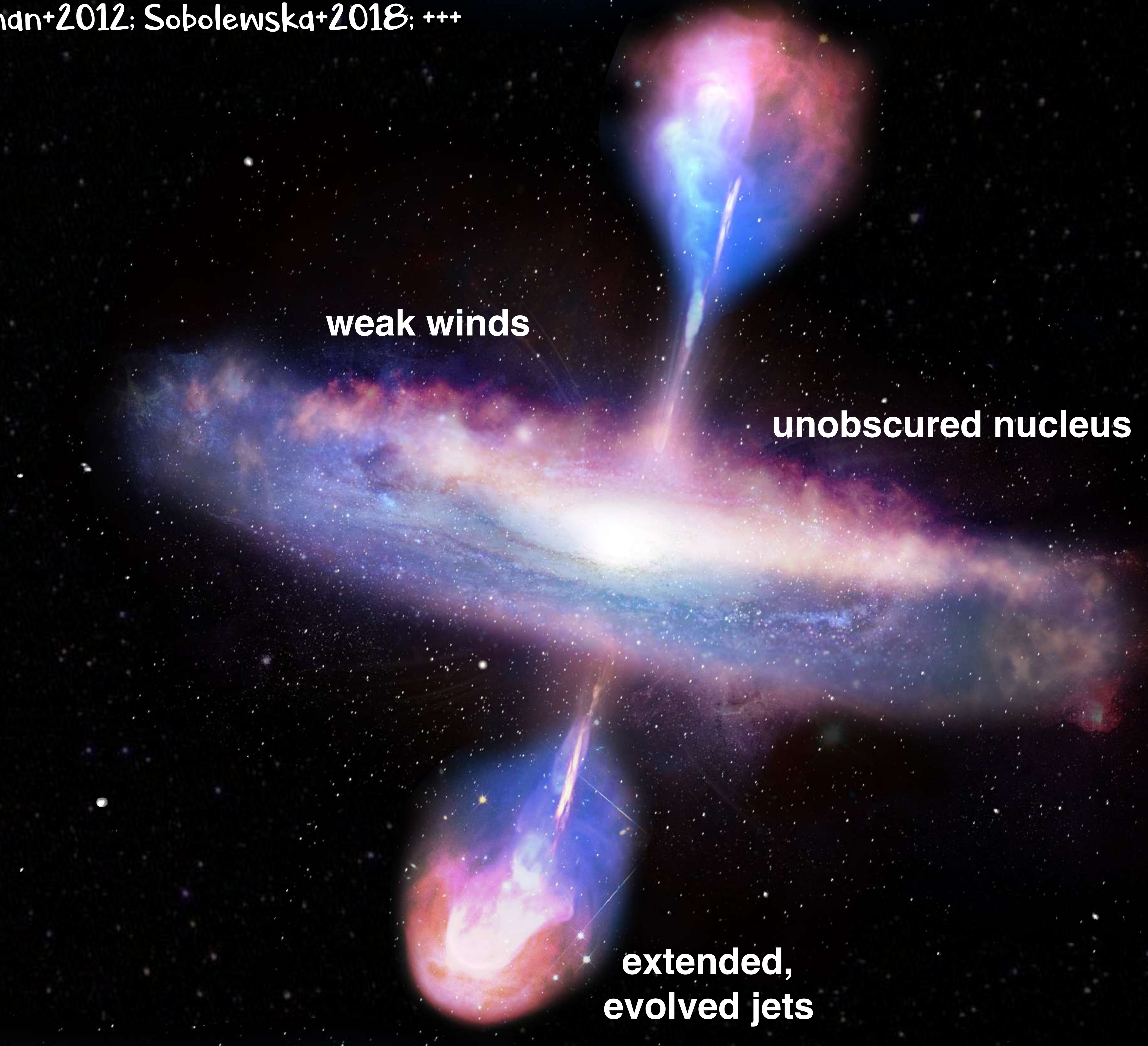
Rosario+2019, *in prep*

We think that the majority of red quasars are younger systems...

see also Georgakakis+2012; Glikman+2012; Sobolewska+2018; +++

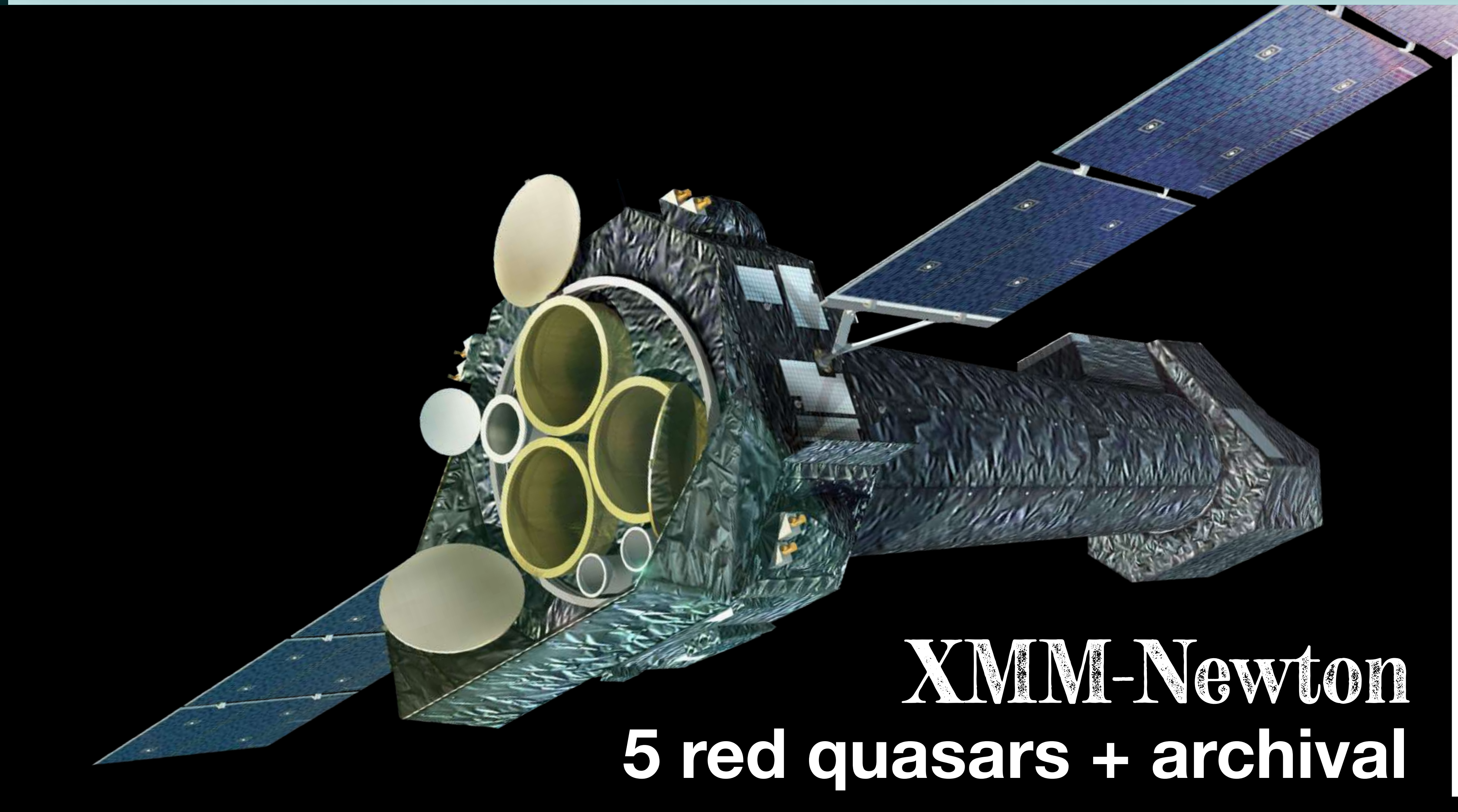


Red Quasar



Blue Quasar

Future work


XMM-Newton
5 red quasars + archival


VLT/X-SHOOTER
60 quasars

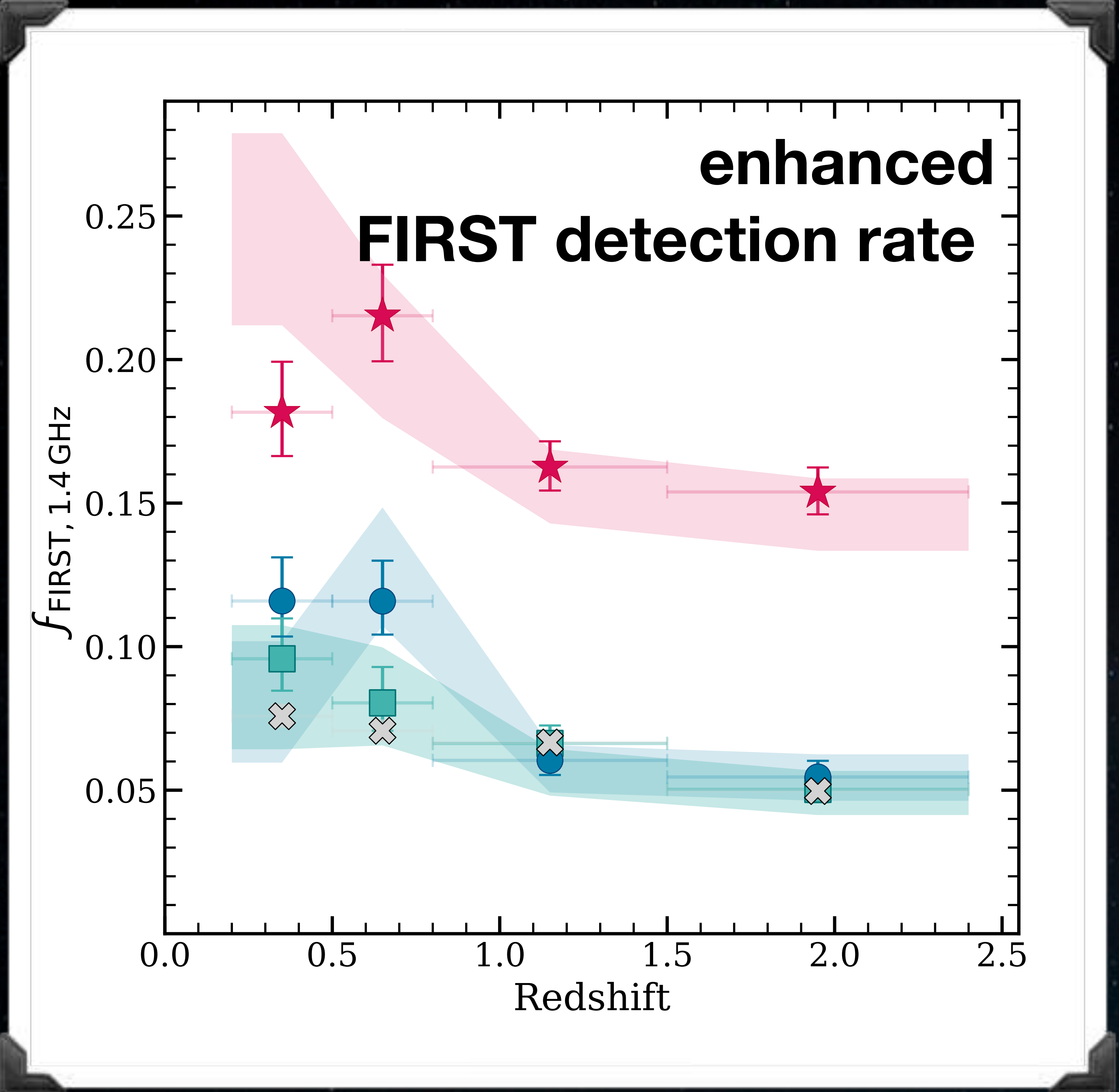

eMERLIN
40 quasars
0.1"

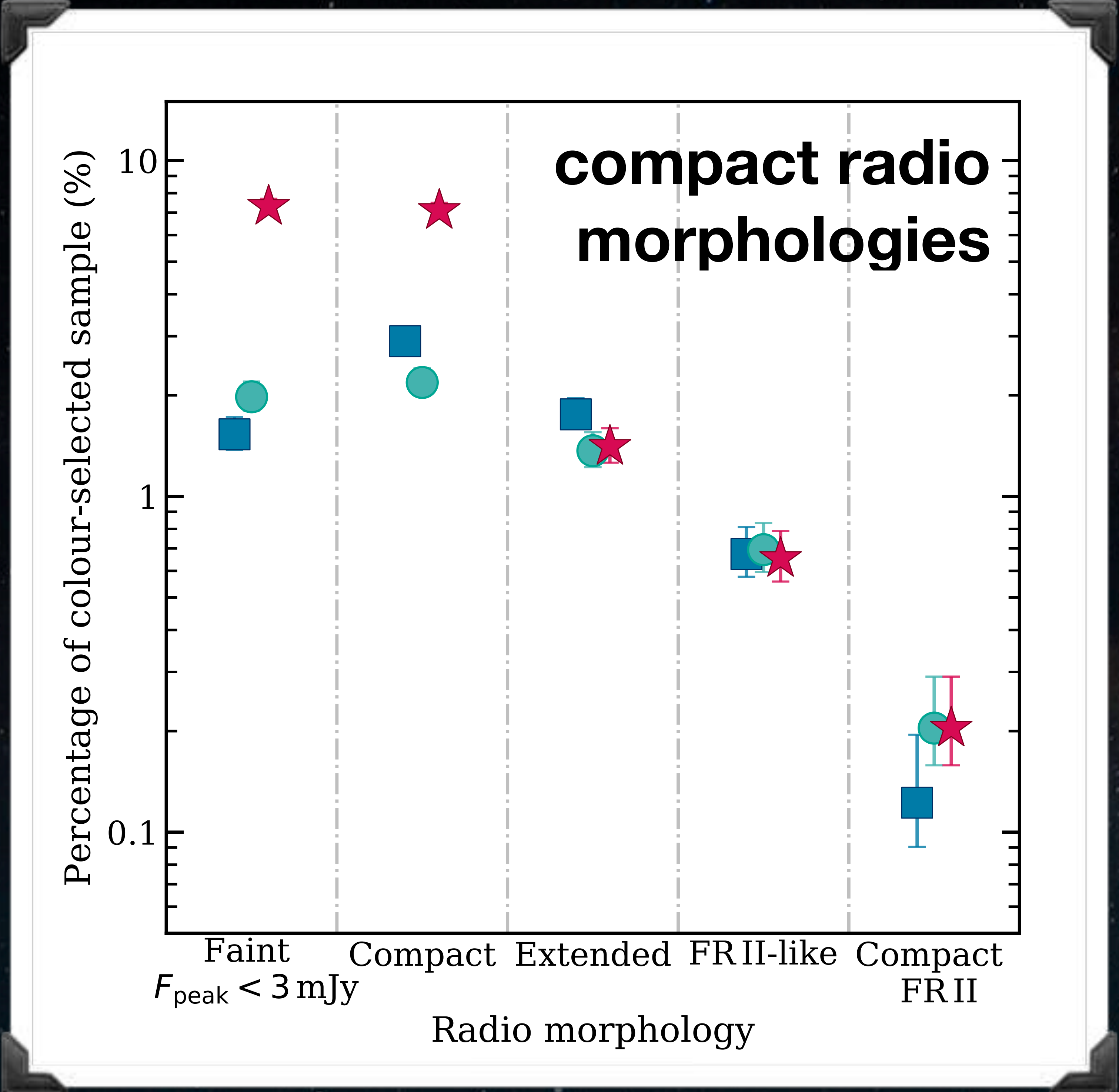

JVLA
38 quasars
0.3"

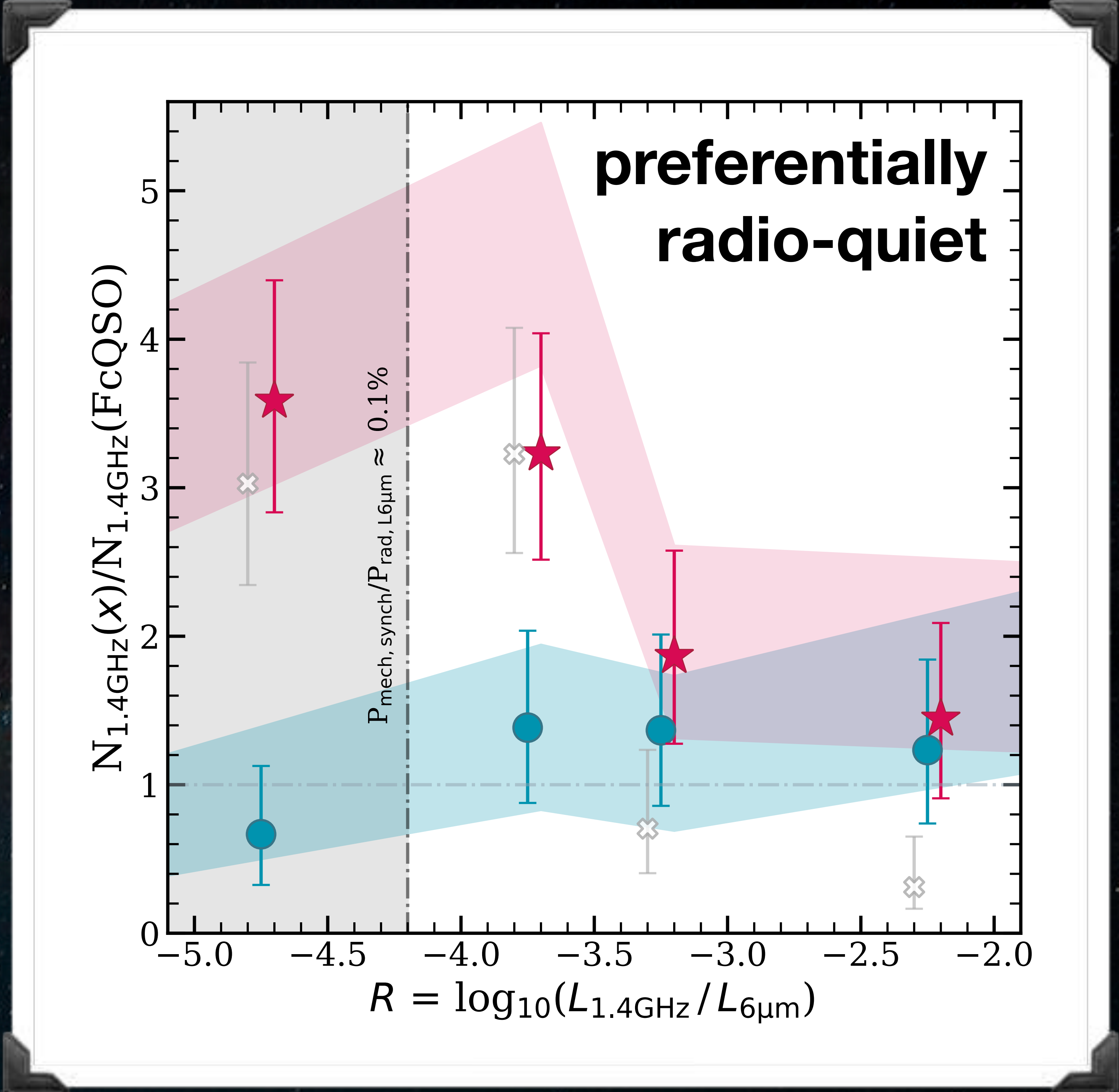

ALMA
90 quasars

Take home message

* Optically selected red quasars have an enhanced radio-detection fraction.
* These red quasars are preferentially compact and radio-quiet.
* Our results favour evolution over orientation.





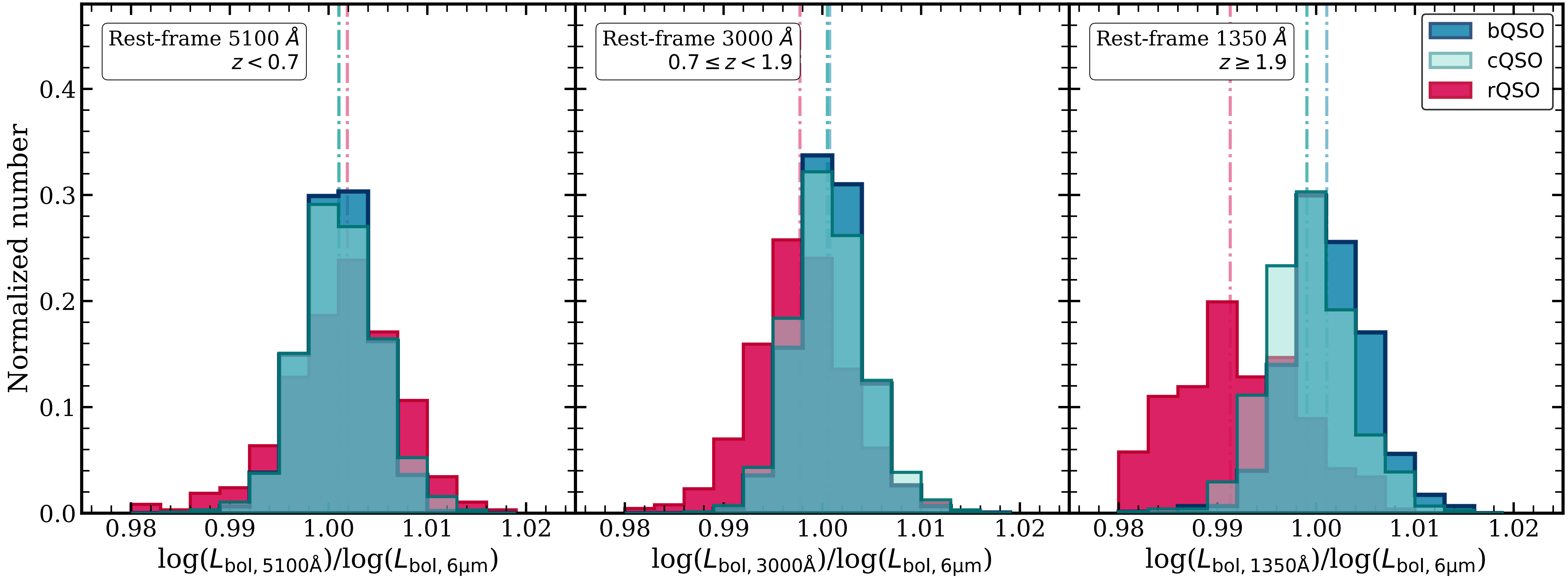


"Look up into the heavens. Who created all the stars? He brings them out like an army, one after another, calling each by its name. Because of his great power and incomparable strength, not a single one is missing." — Isaiah 40:26


Thank you
Questions?
Credit: S. Munro & L. Klindt

BackupS...

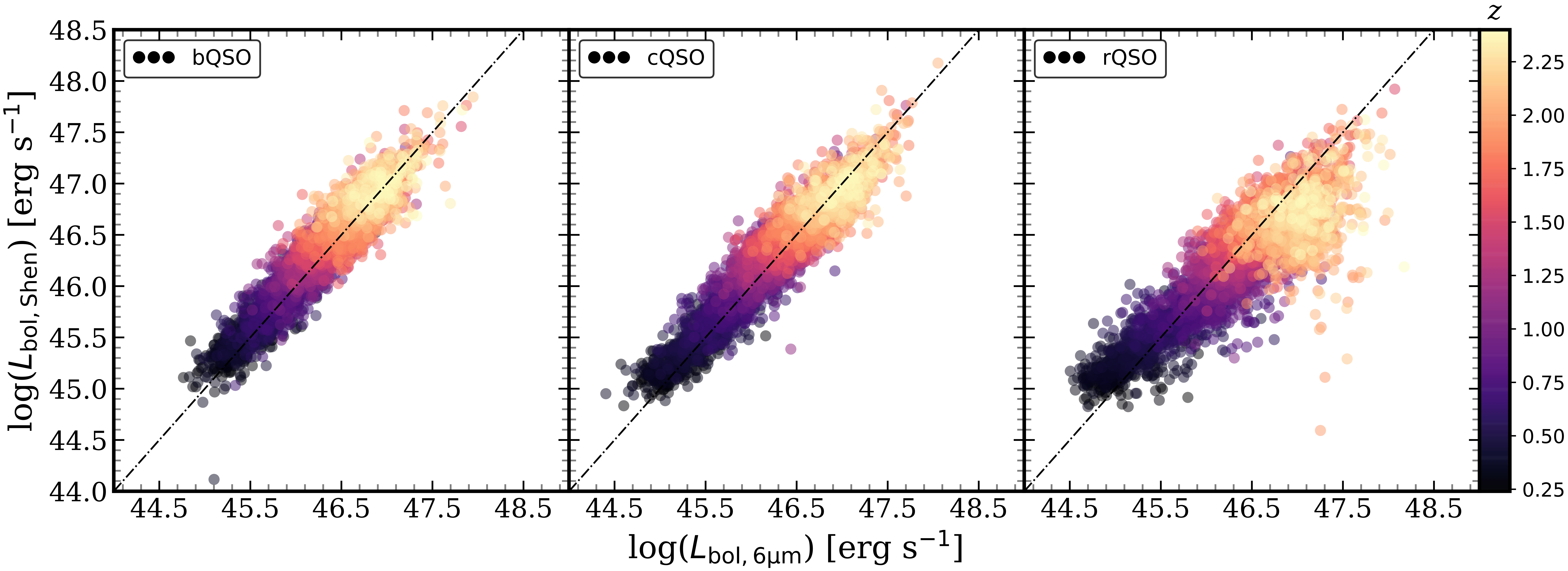
Rest-frame $L_{6\mu m}$ vs. redshift



❒ This is the signature that we would expect for dust reddening as the shorter wavelength emission will be more suppressed for a fixed amount of obscuration than longer wavelength emission.

MIR is a more reliable measurement of the intrinsic AGN power !

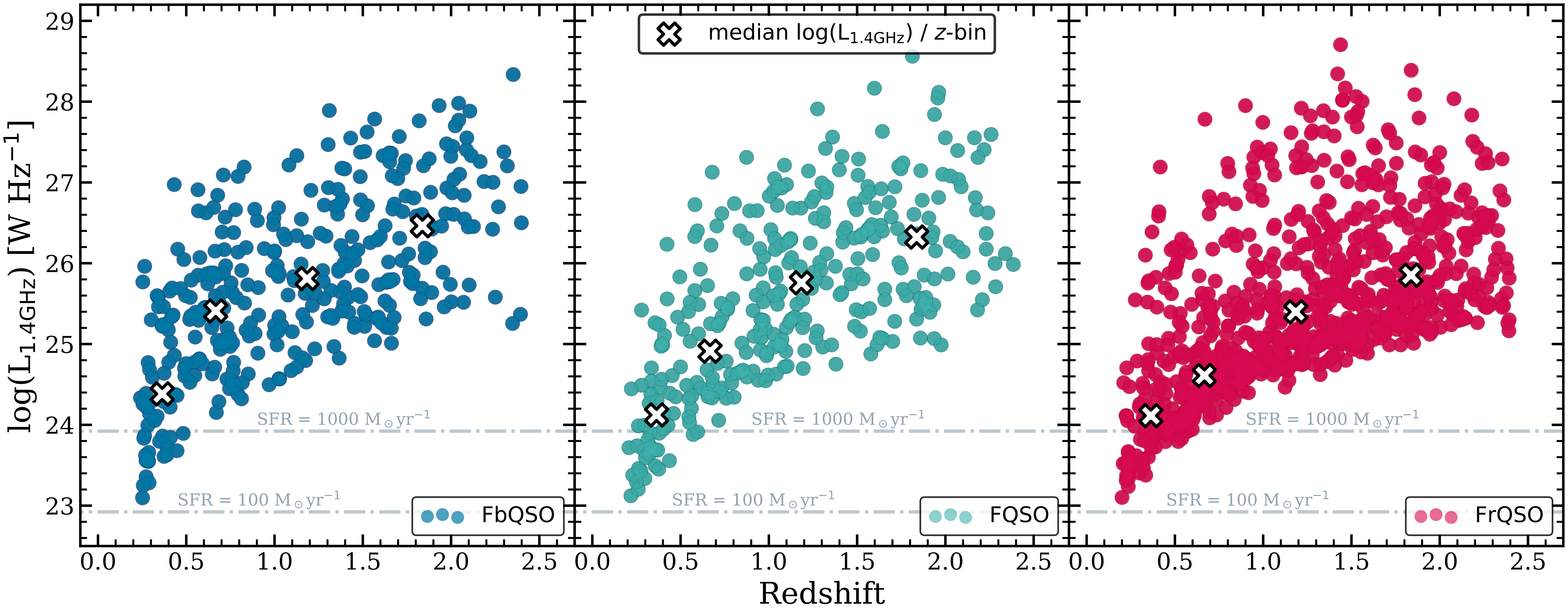
Rest-frame $L_{6\mu m}$ vs. $L_{bol,Shen}$



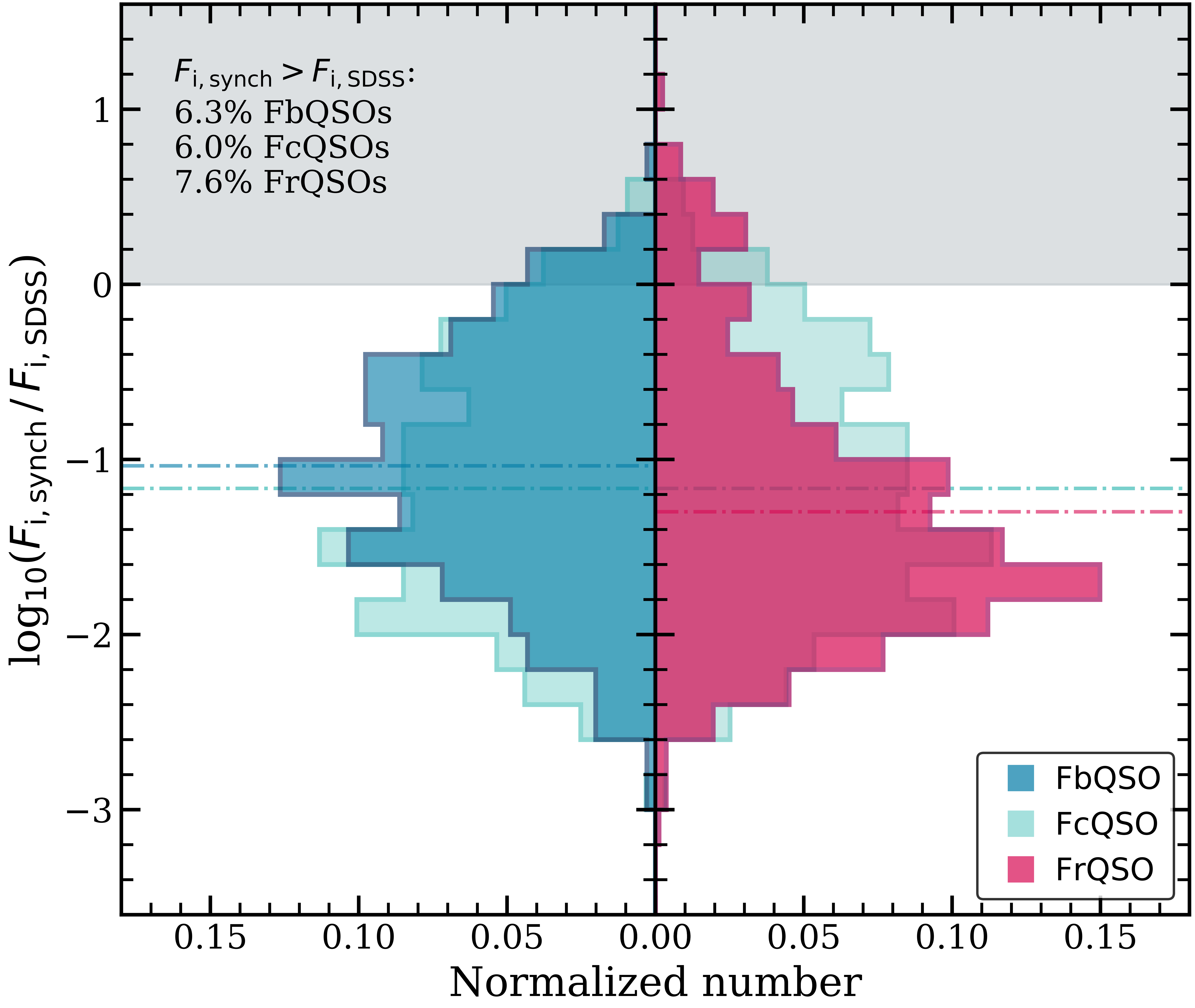
MIR is a more reliable measurement of the intrinsic AGN power !

Klindt+ 2019

L1.4GHz vs redshift



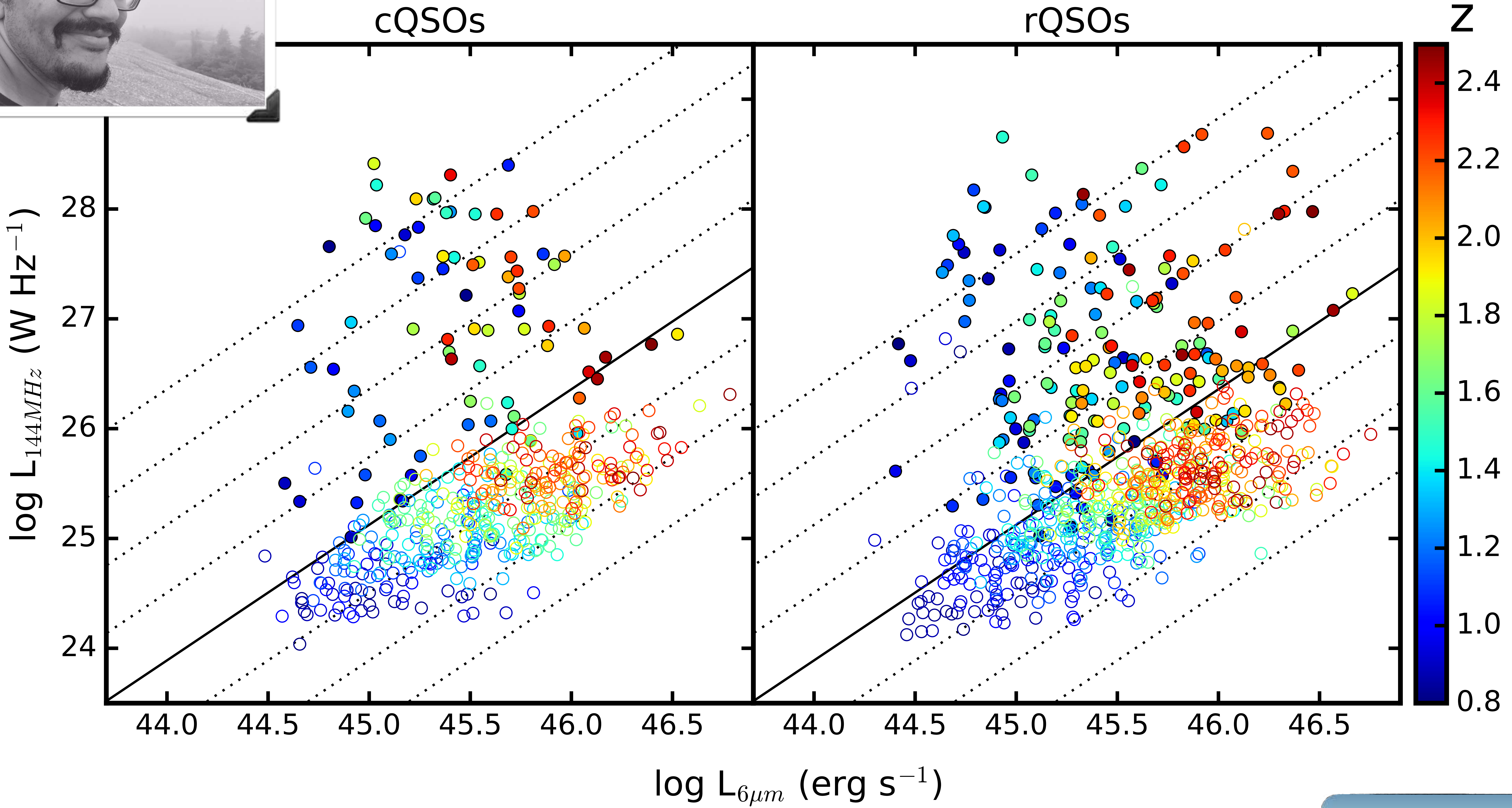
Klindt+ 2019



Red synchrotron component?

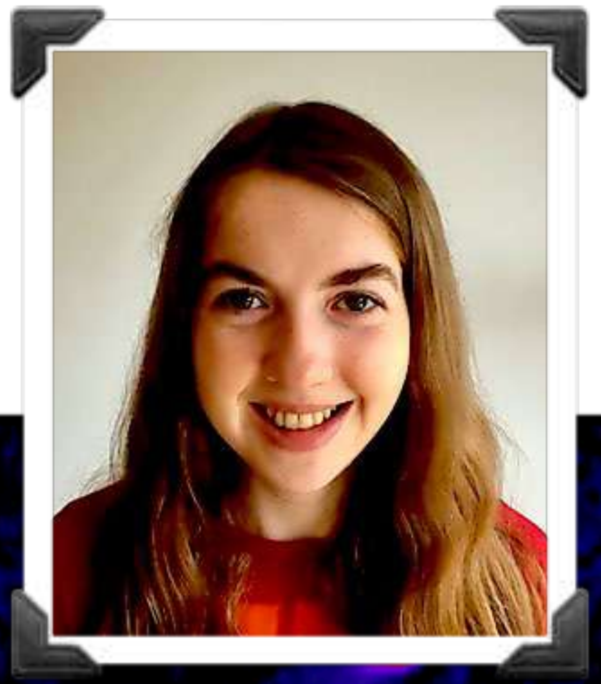
Klindt+ 2019

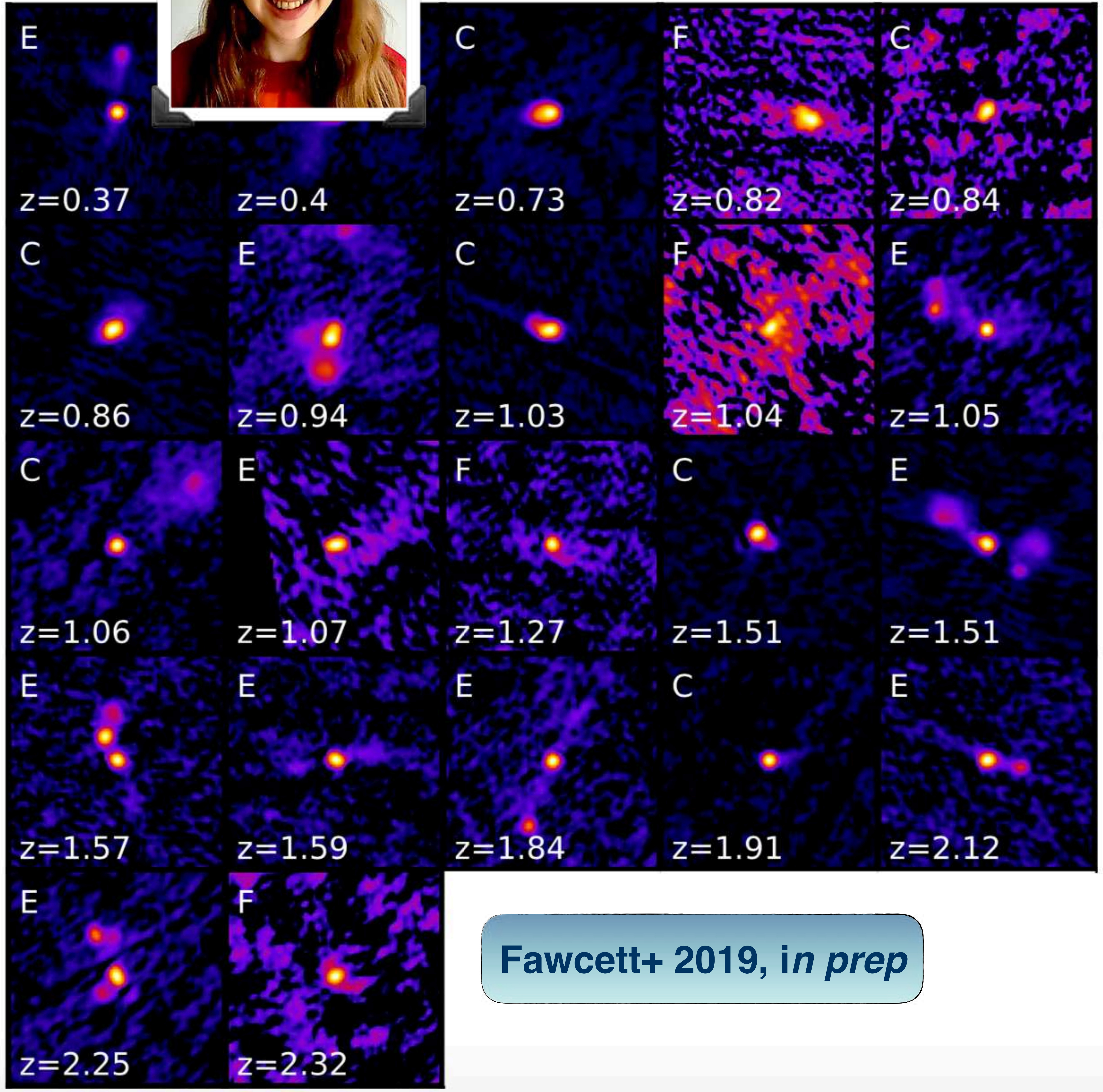
The LOFAR view of red quasars



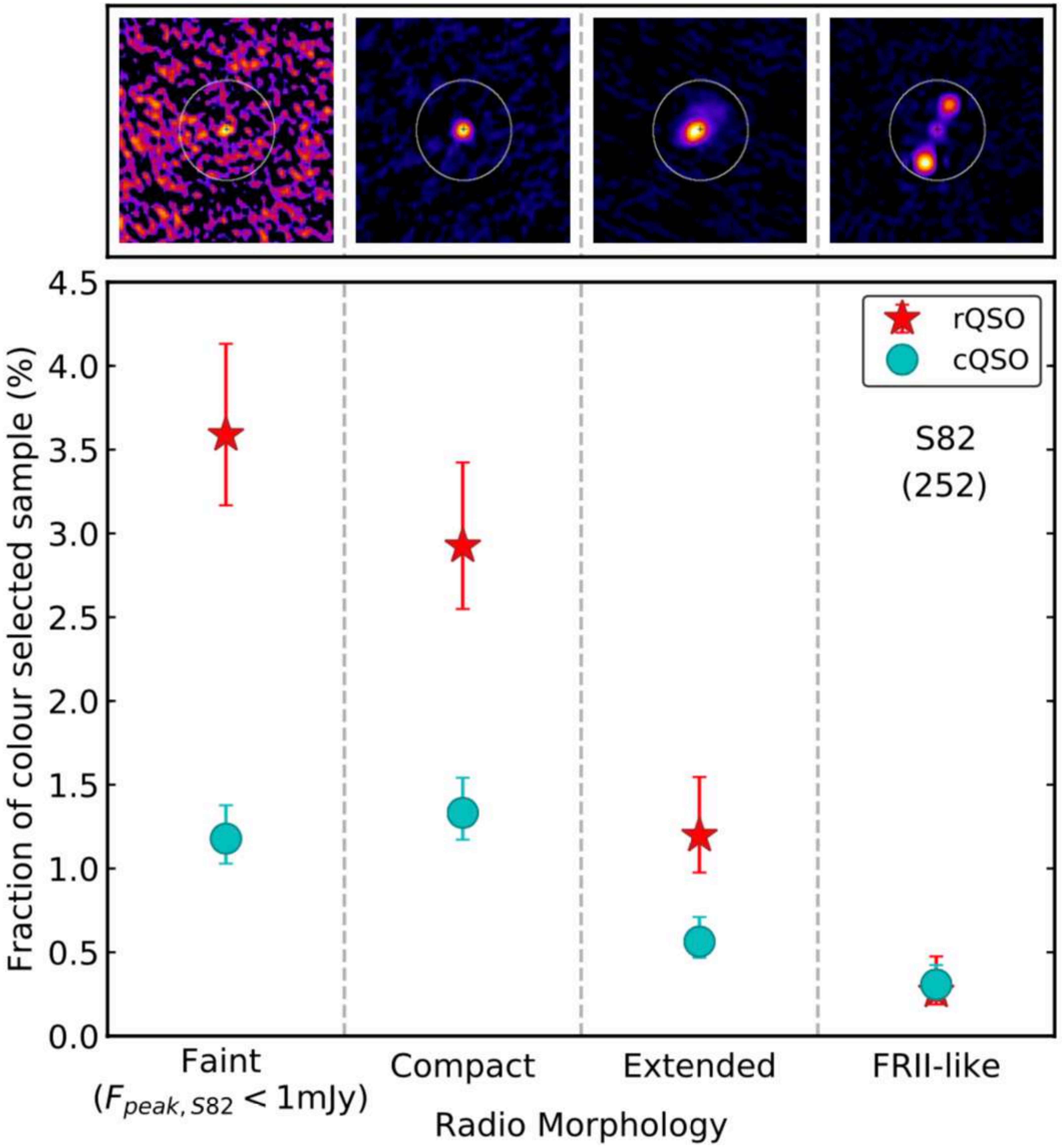
Rosario+ 2019, *in prep*

Going deeper & resolving smaller scales



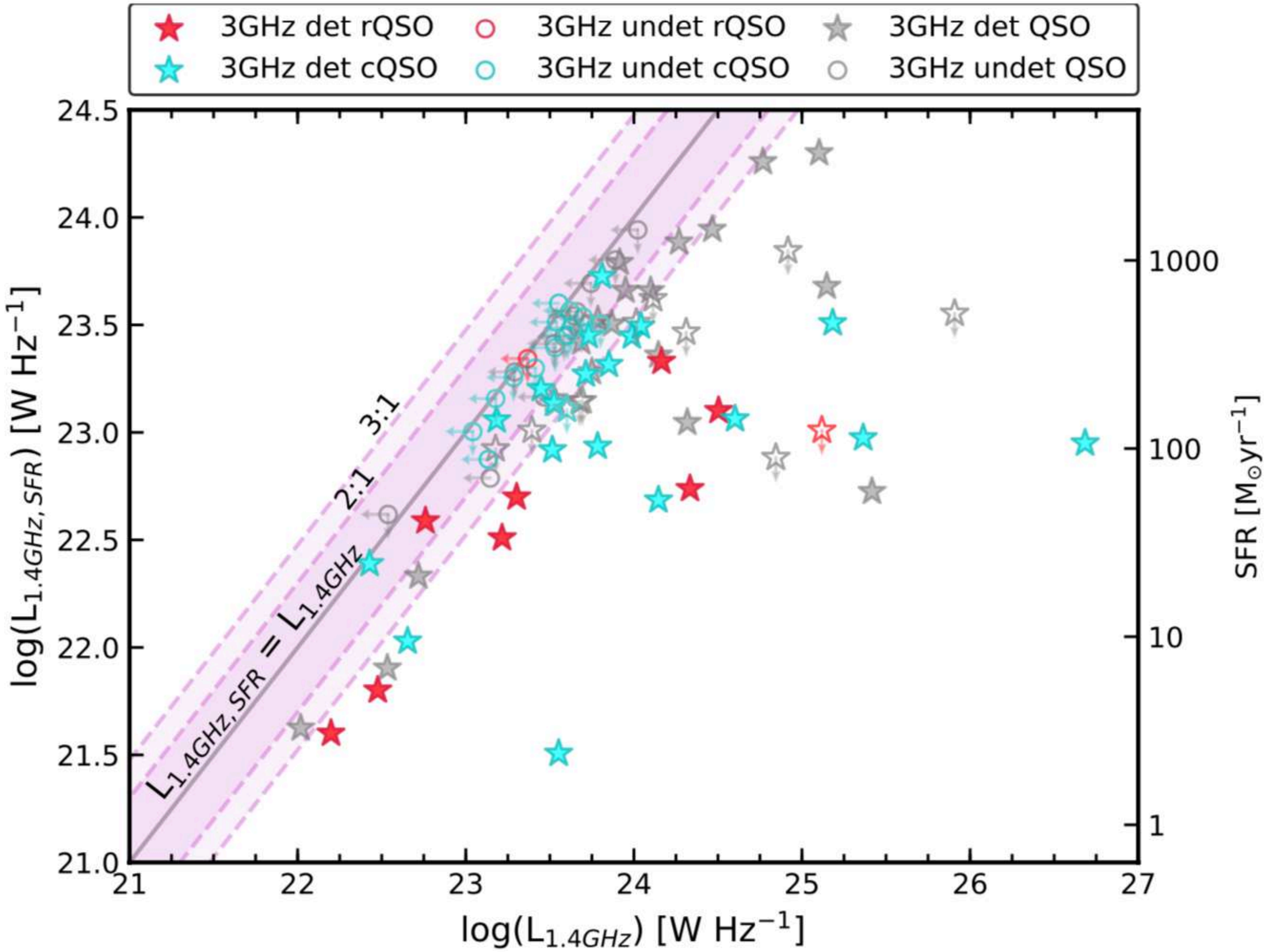


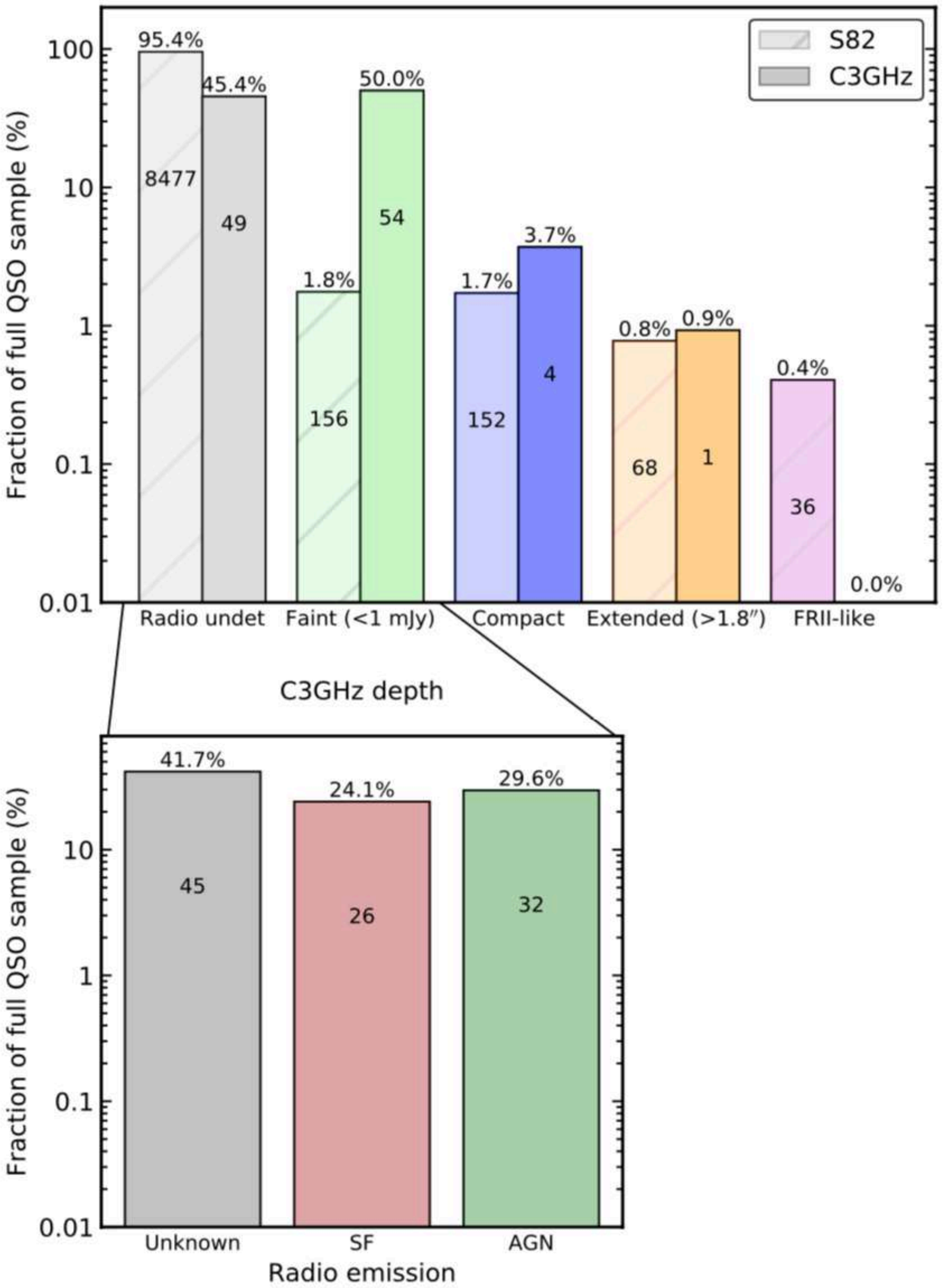
Fawcett+ 2019, *in prep*



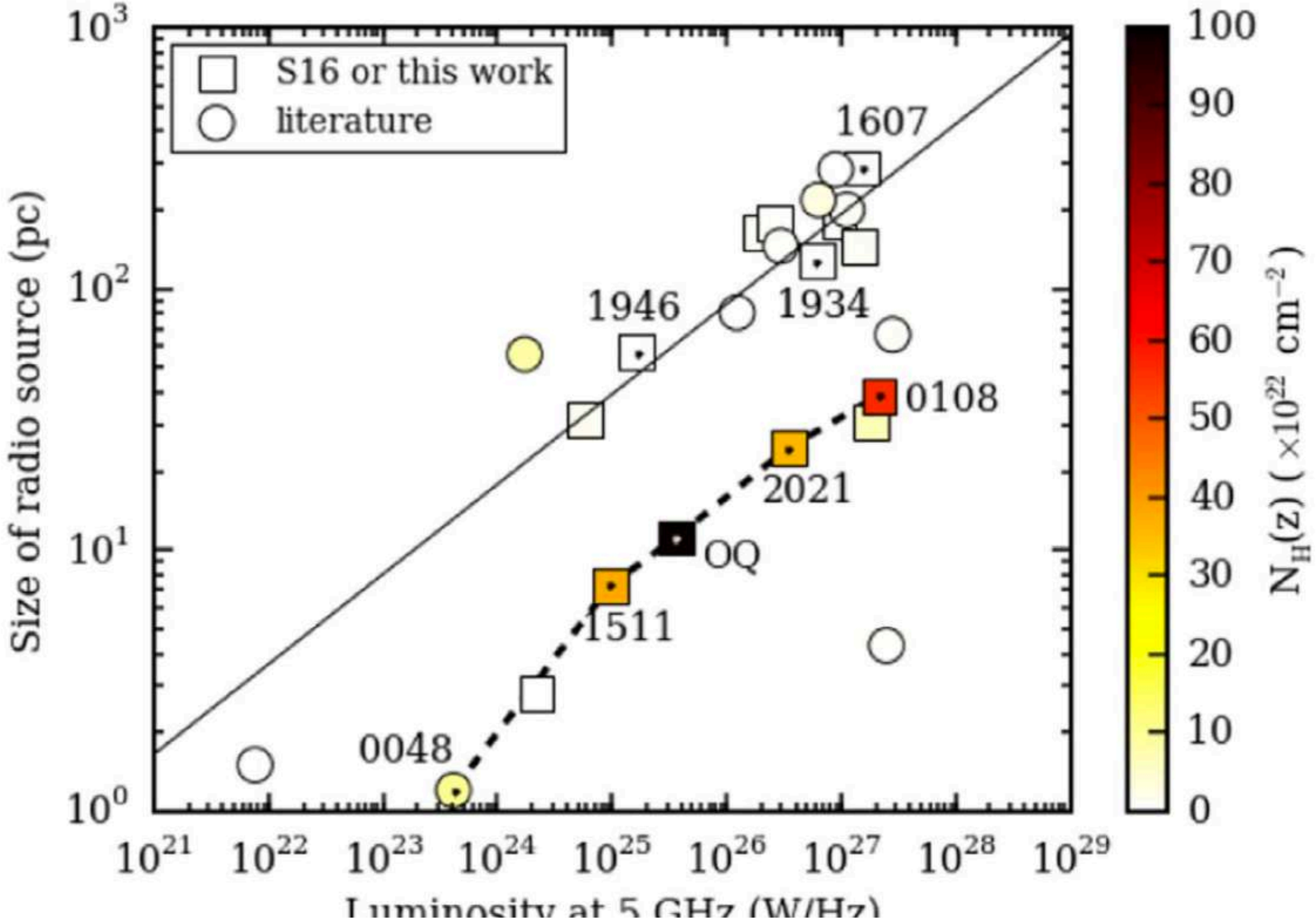
Going deeper & resolving smaller scales

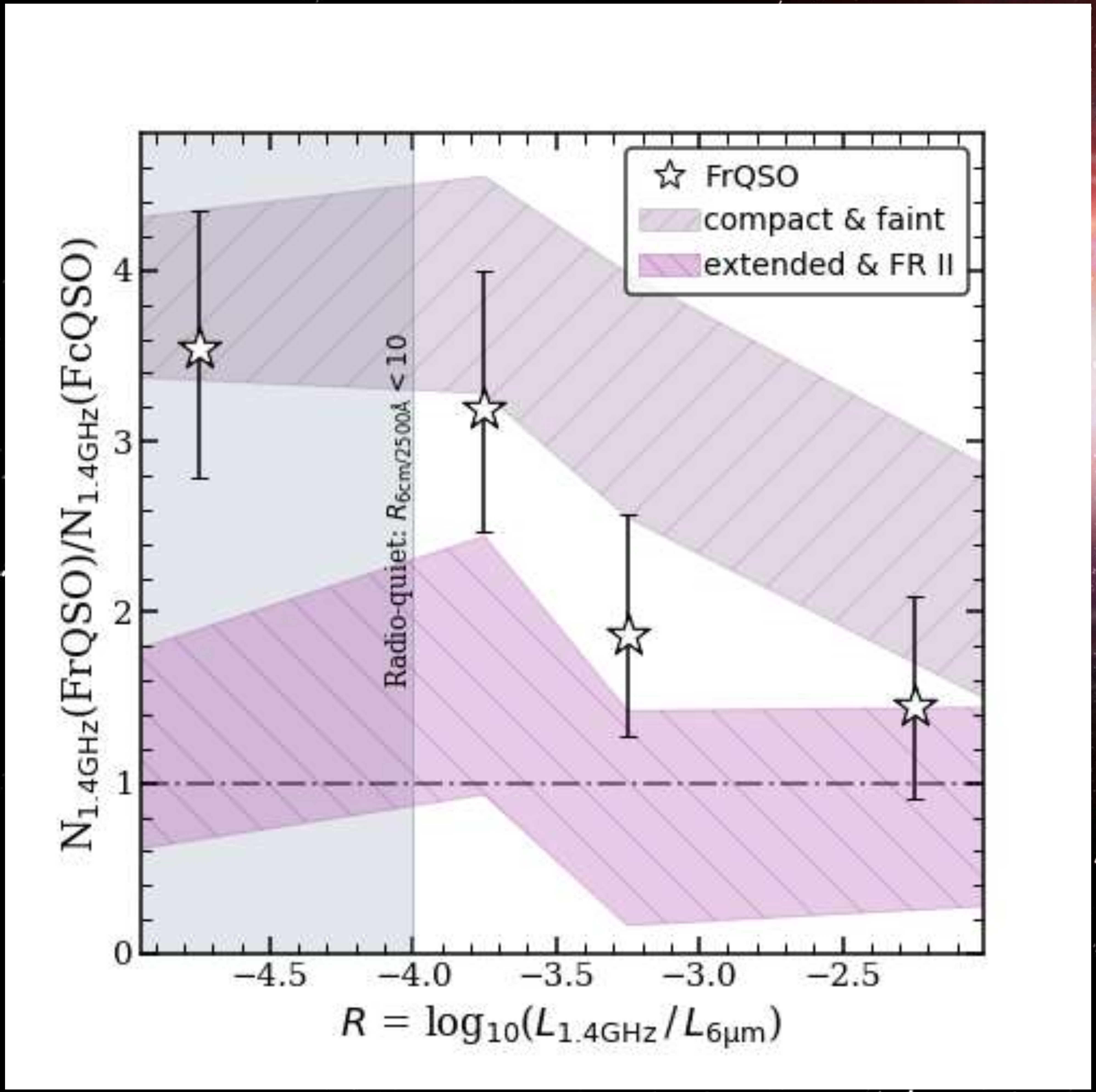
Fawcett+ 2019, *in prep*





Sobolewska+2019




FrQSO
compact & faint
extended & FR II
Radio-quiet: $R_{6cm/2500Å} < 10$
$N_{1.4GHz}(FrQSO)/N_{1.4GHz}(FcQSO)$
$R = \log_{10}(L_{1.4GHz}/L_{6\mu m})$
0
1
2
3
4
−4.5
−4.0
−3.5
−3.0
−2.5


radio loudness vs.
radio morphologies