AGN 13

Milan, October 11th, 2018

arxiv: 1809.06363

SMBH accretion properties of radio-selected AGN out to z~4

Ivan Delvecchio

PMF - University of Zagreb
CEA-Saclay (now as Marie Curie fellow)
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On behalf of:
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T. Miyaji, M. Novak, M.T. Sargent, D.M. Alexander, J. Delhaize

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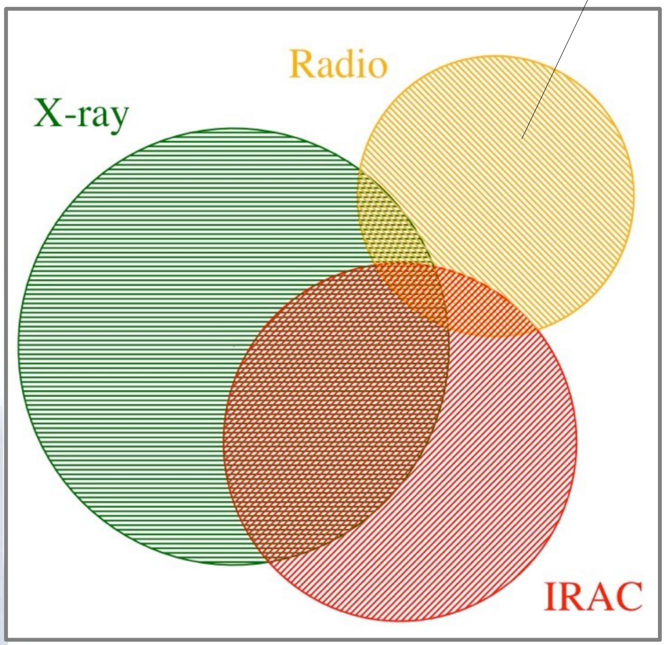
Are *all* radio AGN weakly accreting SMBHs?
If not, does SMBH accretion change with radio power and/or cosmic time?

Radio (bright) AGN at z<1 are special

$L_{1.4} > 10^{24.8}$ W/Hz



Hickox et al. (2009)

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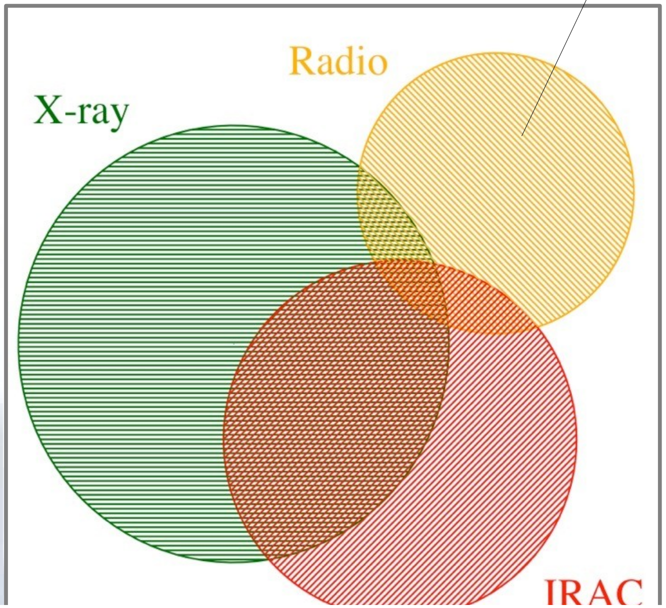

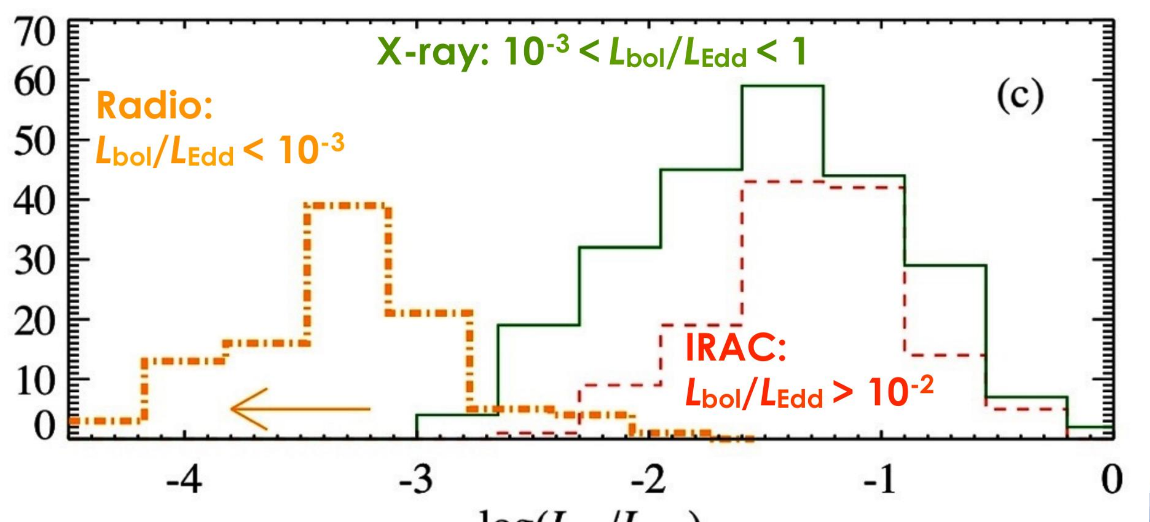

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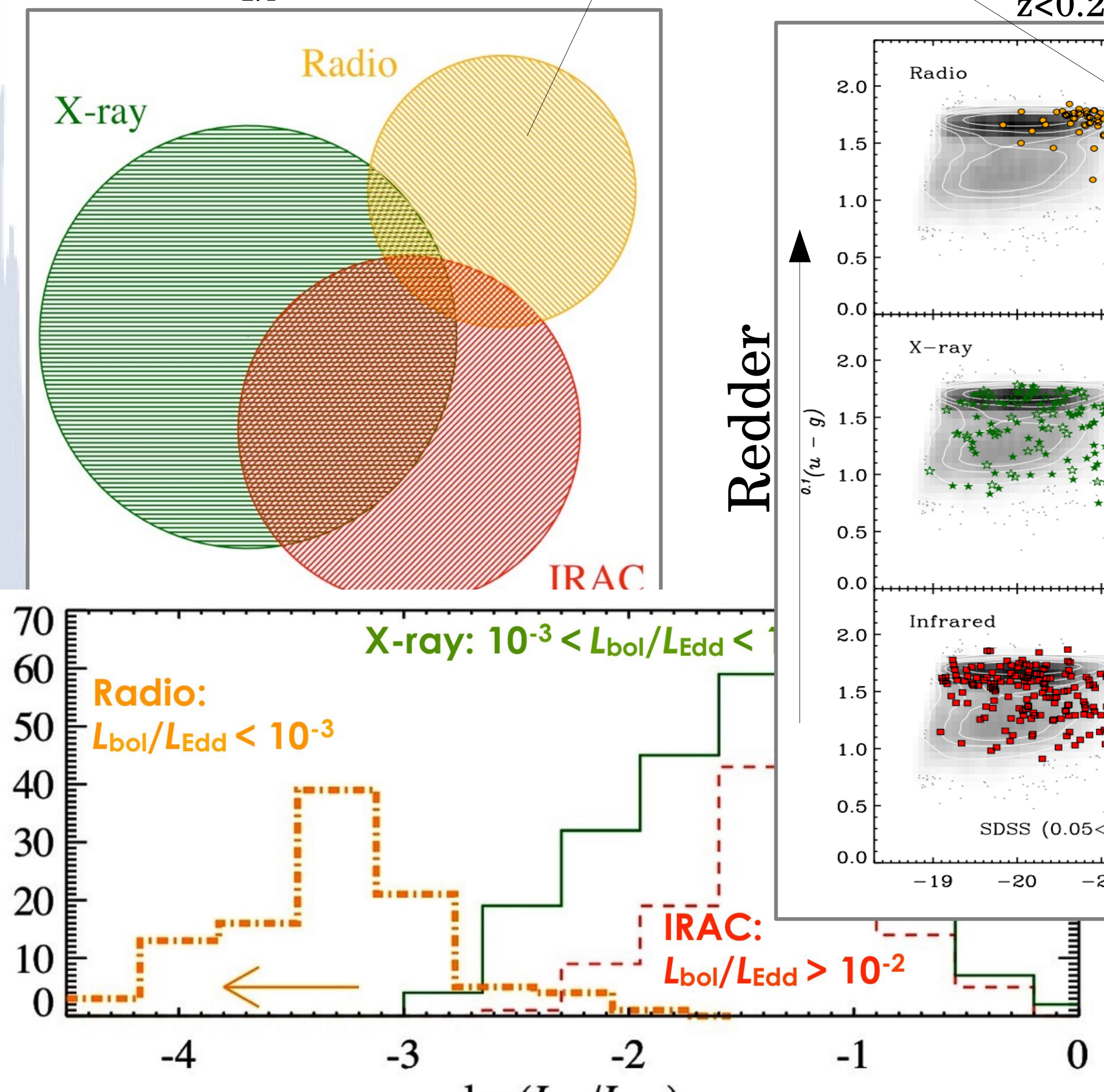

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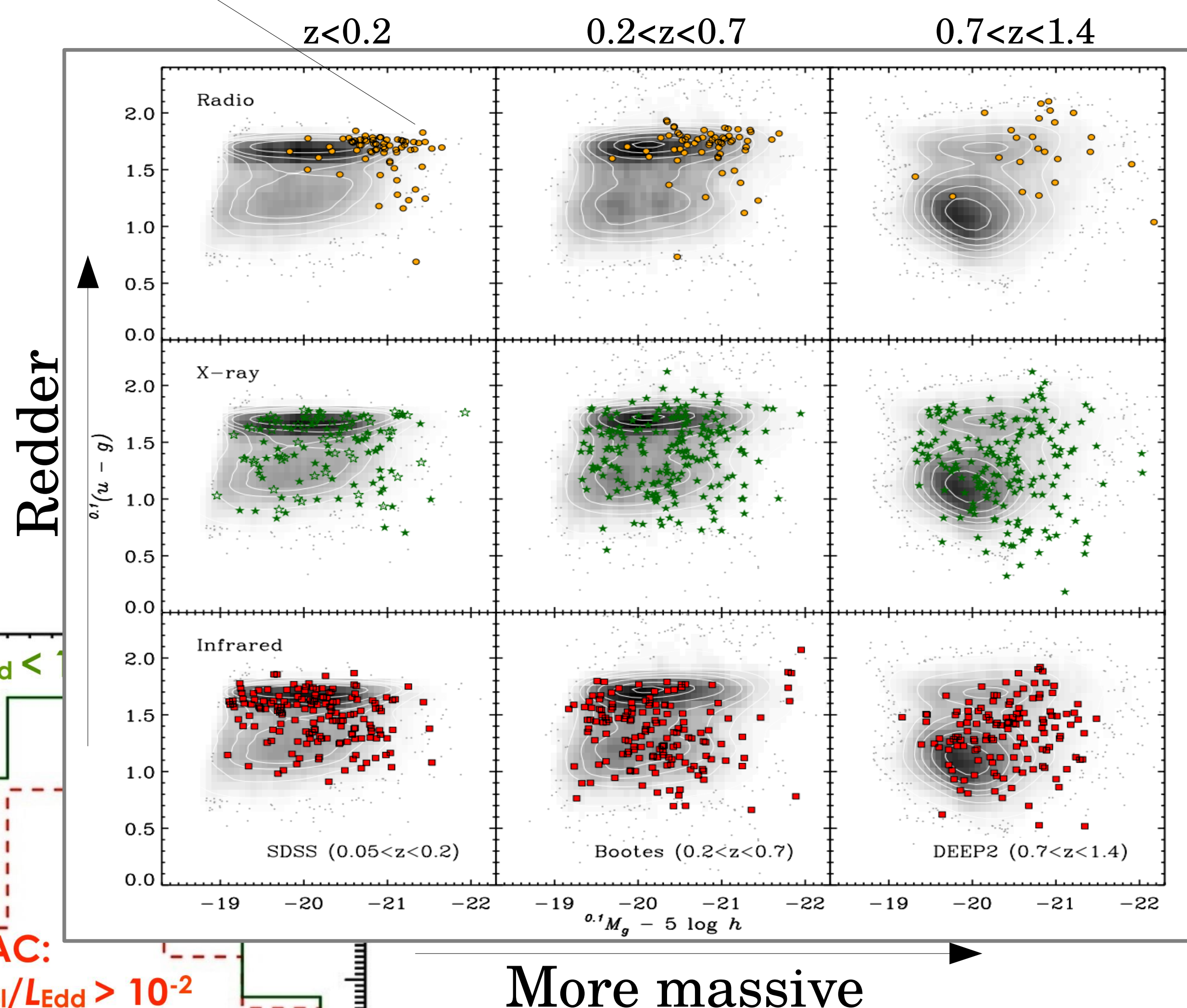

Goulding et al. (2014)

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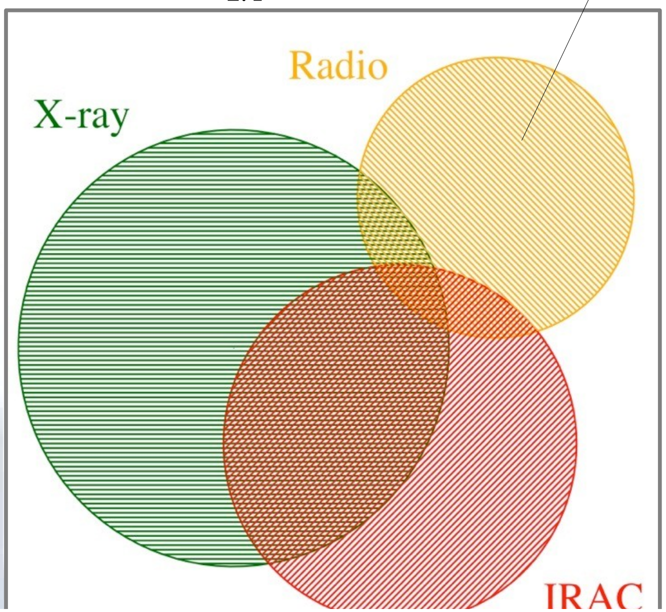
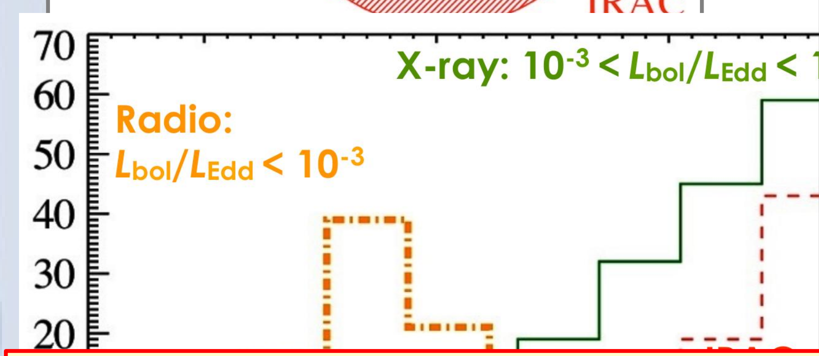
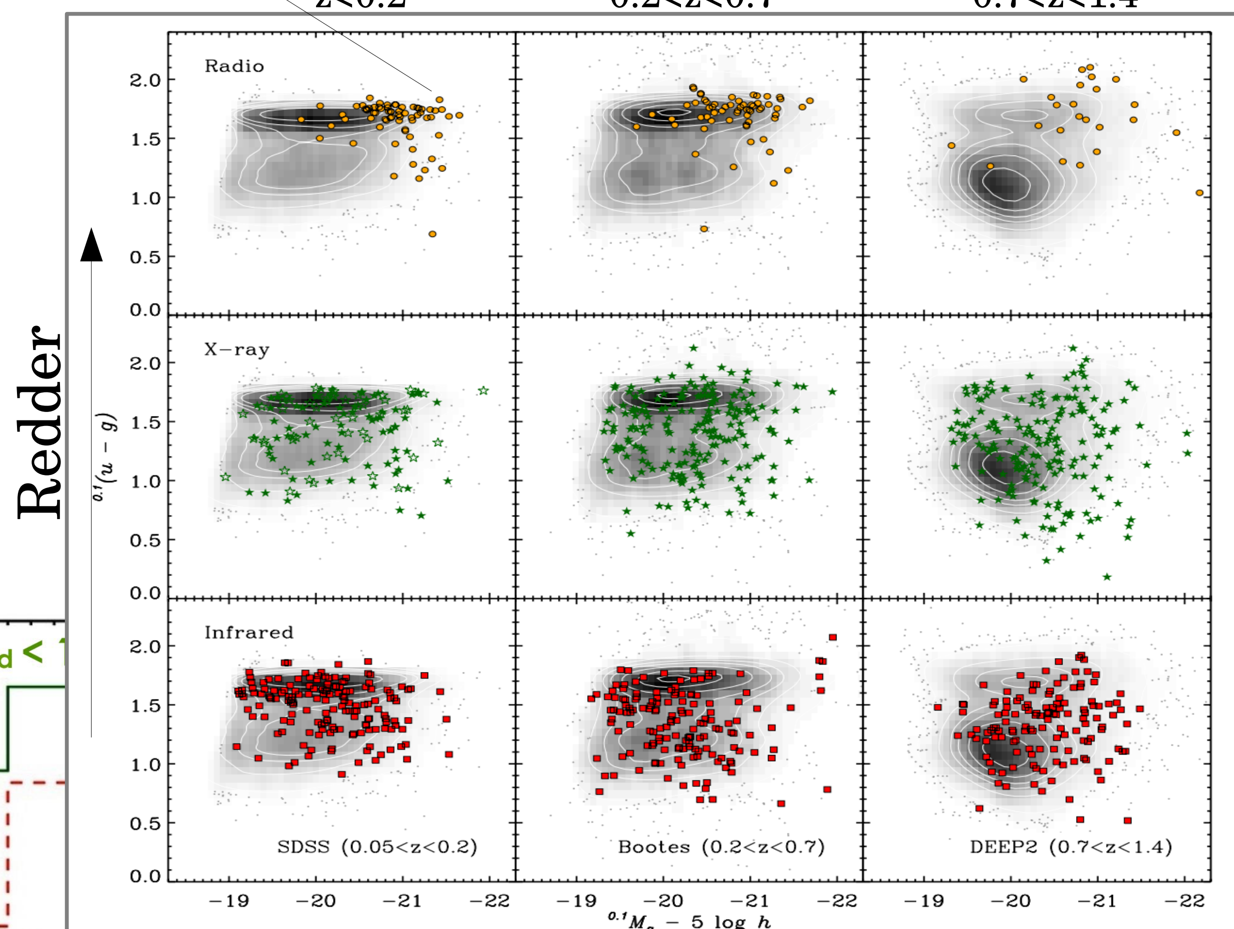
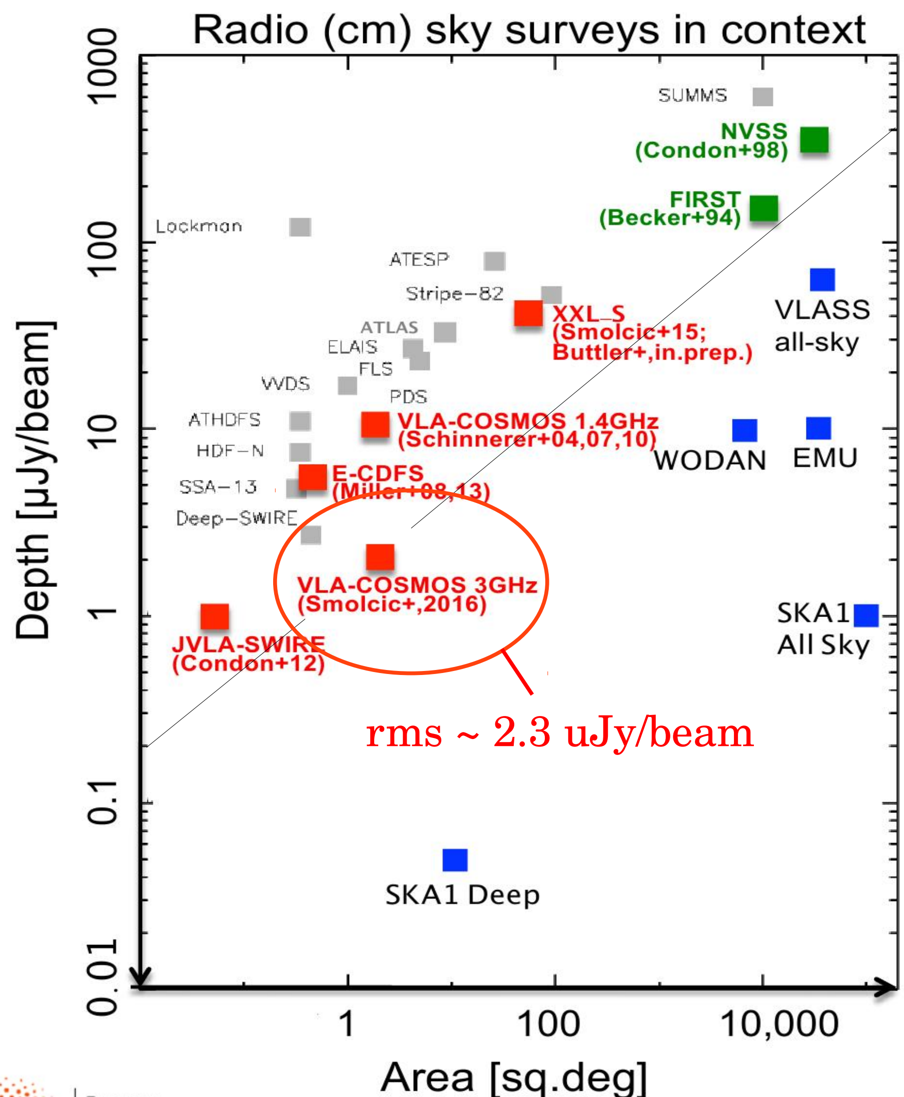






Radio bright (or loud) AGN at z<1 are mostly weakly accreting SMBHs hosted within massive and passive galaxies

Going deeper and further back in time: The VLA-COSMOS 3 GHz Large Project



European Research Council

PI: V. Smolčić

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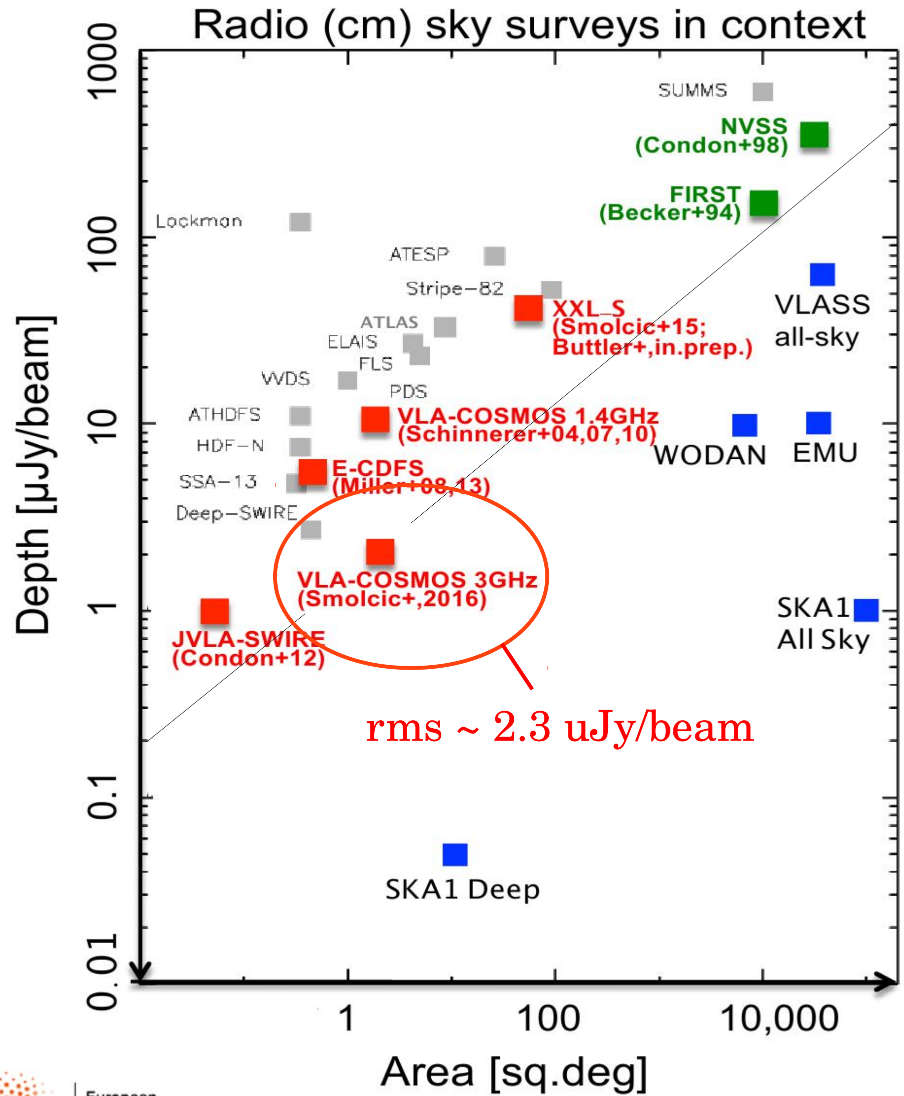

- 7729 radio sources selected at 3 GHz (10 cm) with optical/NIR counterpart in the COSMOS2015 catalogue (Smolčić et al. 2017b).
- Press release on A&A special issue: http://cosmos.astro.caltech.edu/news/52

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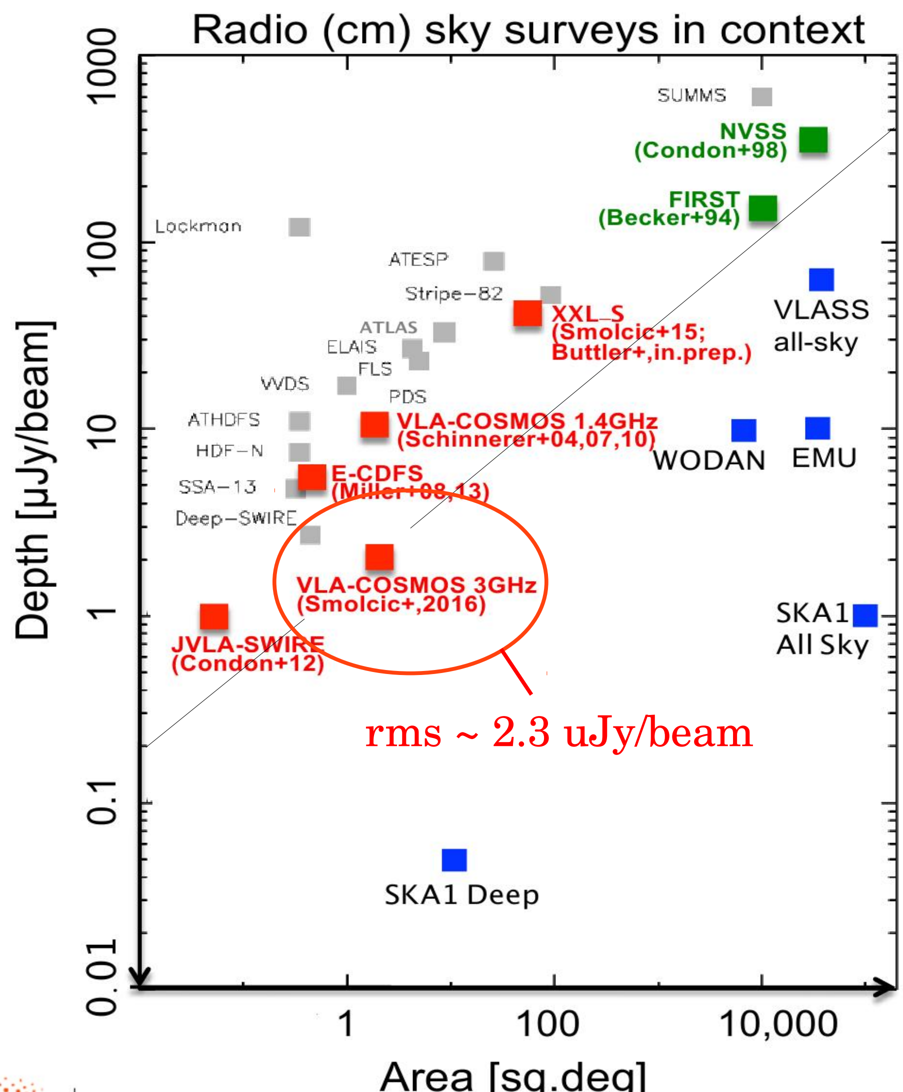

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> 1800 radio AGN: identified via a significant (>2σ) excess in radio emission, relative to the IRRC of star-forming galaxies (Delhaize et al. 2017)

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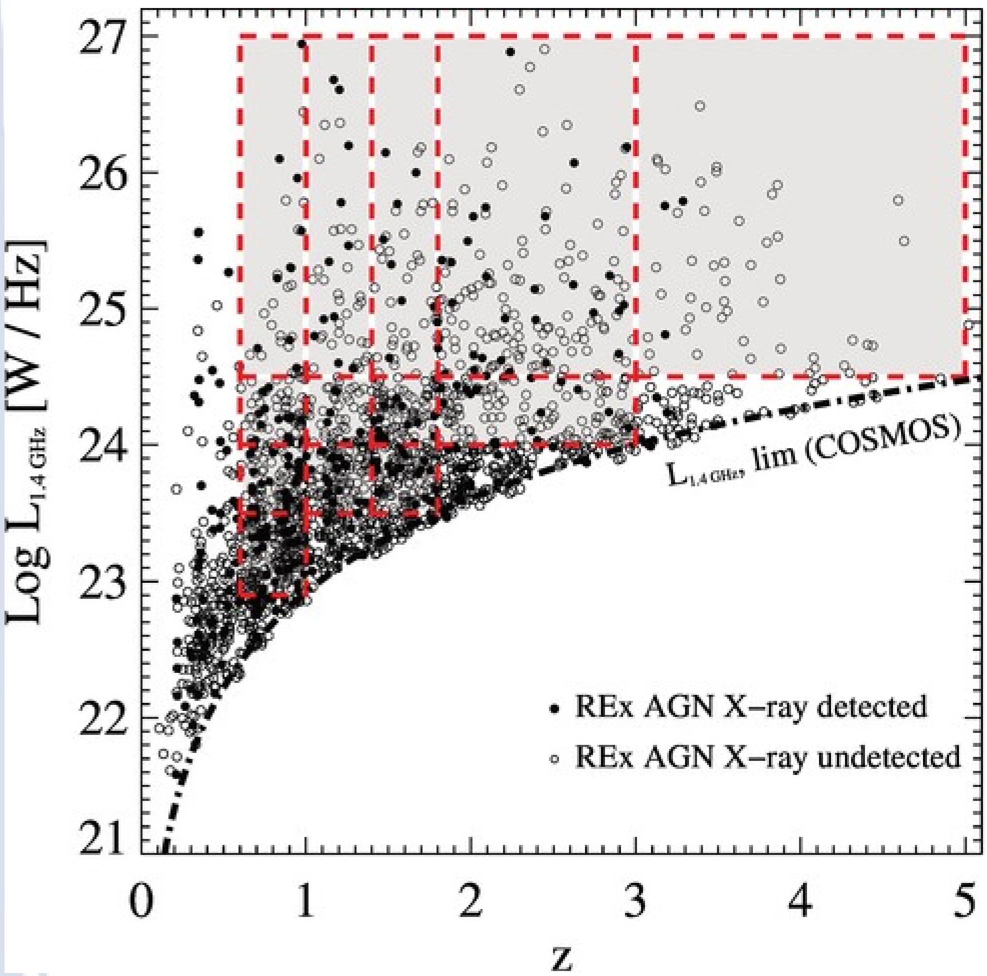
Radio-excess AGN out to z~4



- Selecting a $L_{1.4}$-complete subset of **>1200 radio-excess AGN** out to z~4

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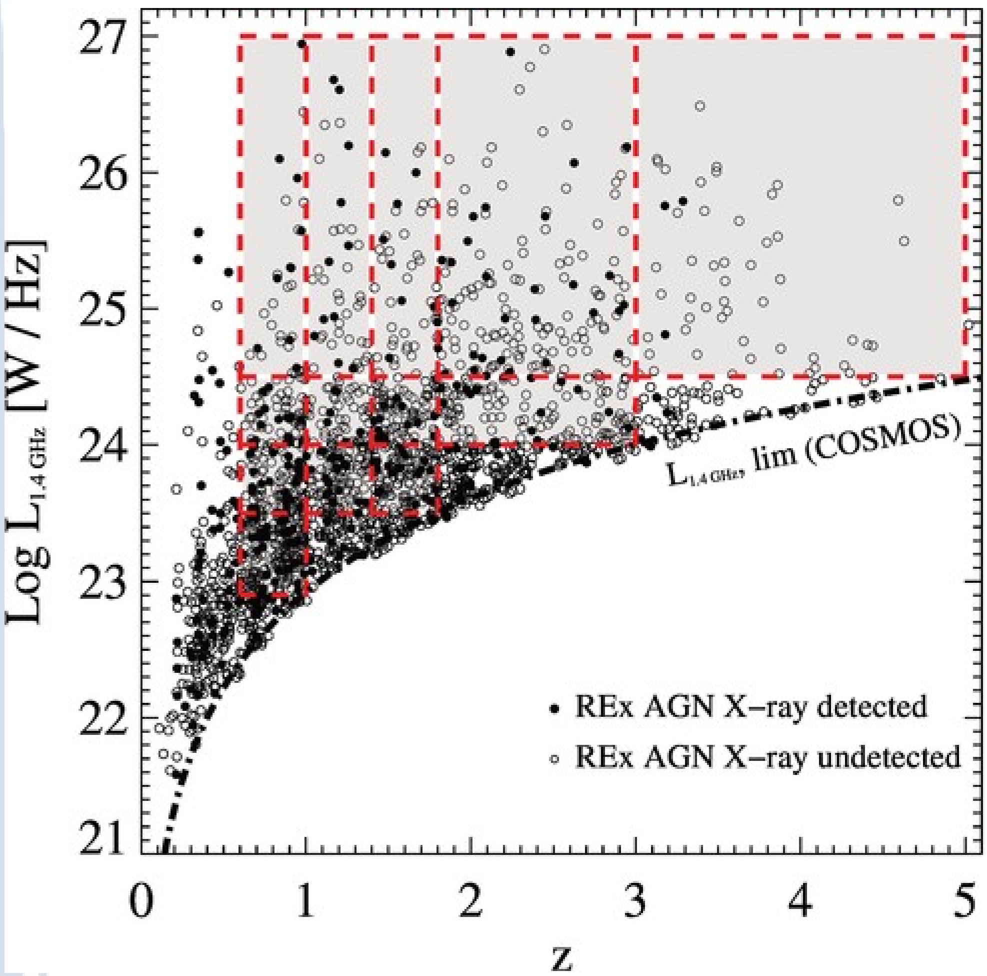

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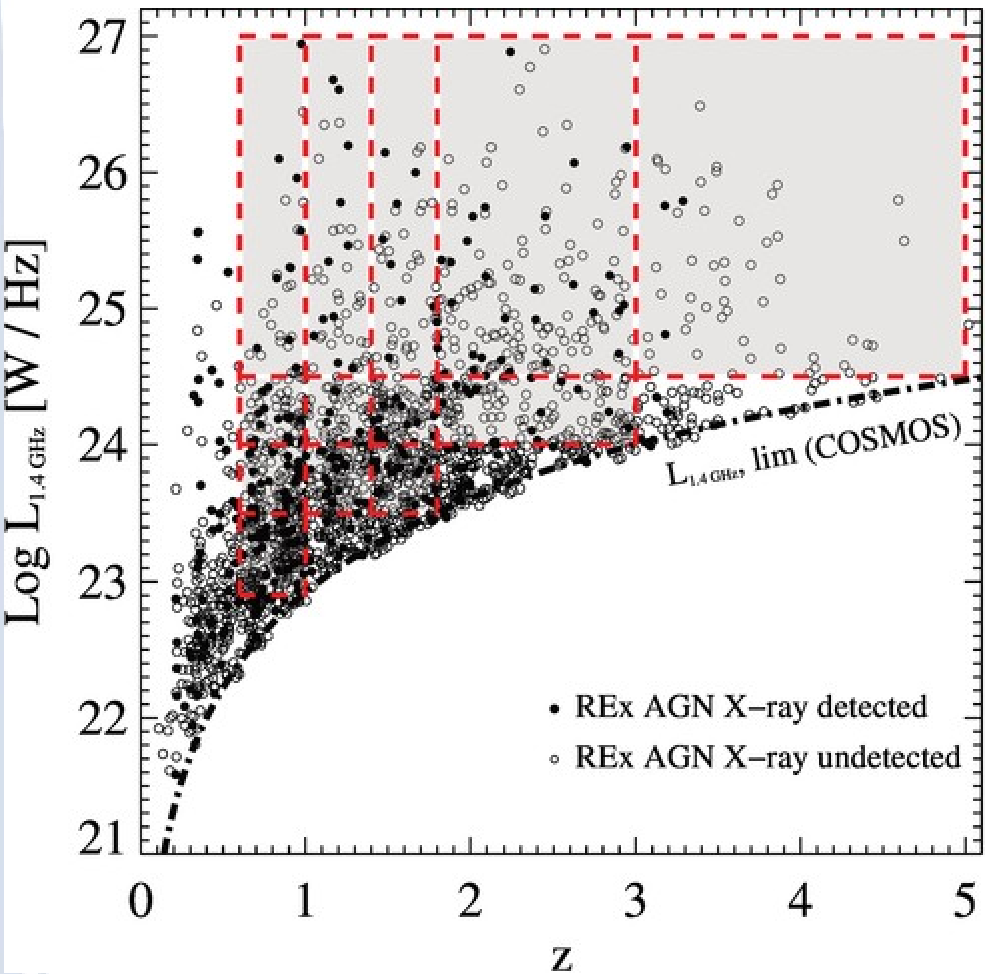

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* http://lambic.astrosen.unam.mx/cstack/

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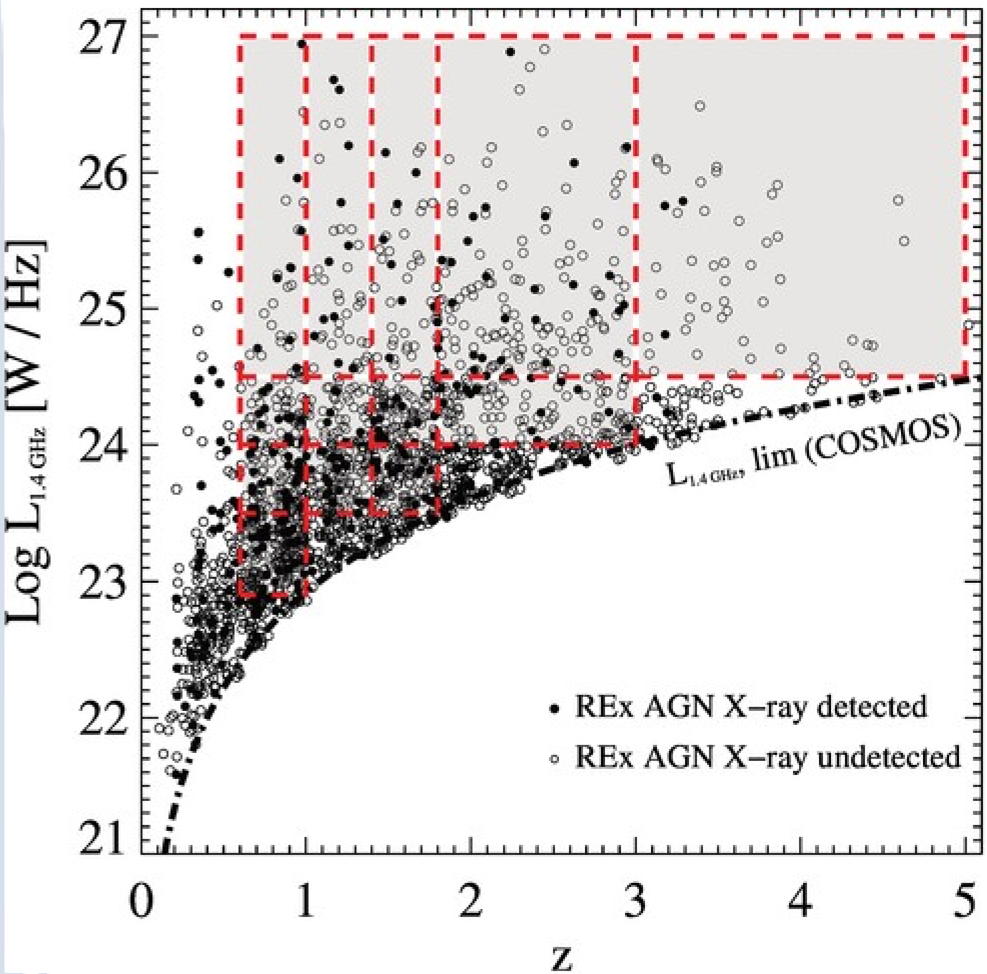

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- **Lx** ⟶ specific BH accretion rate (**s-BHAR** ~ Lx/M*)
- **s-BHAR** ⟷ **Edd. Ratio** (if fixed M*/MBH)

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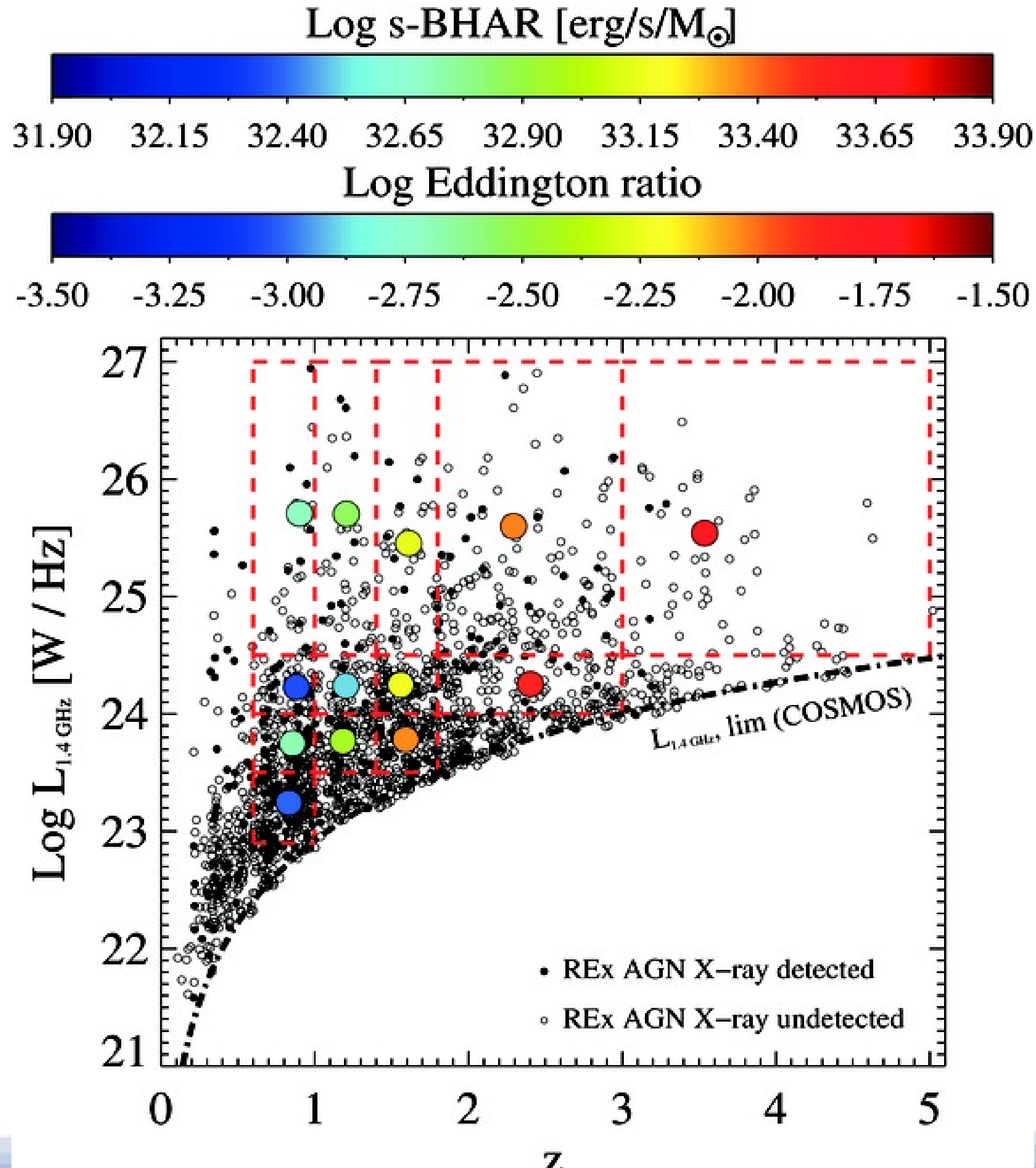
Average s-BHAR as a function of $L_{1.4}$ and z



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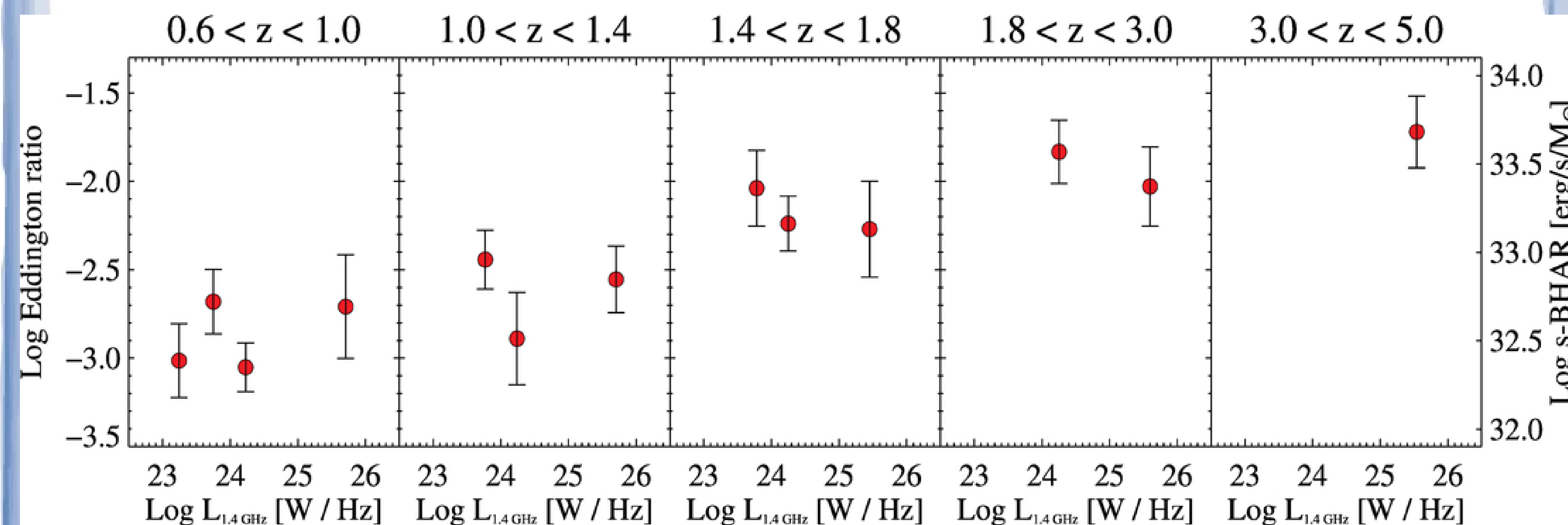
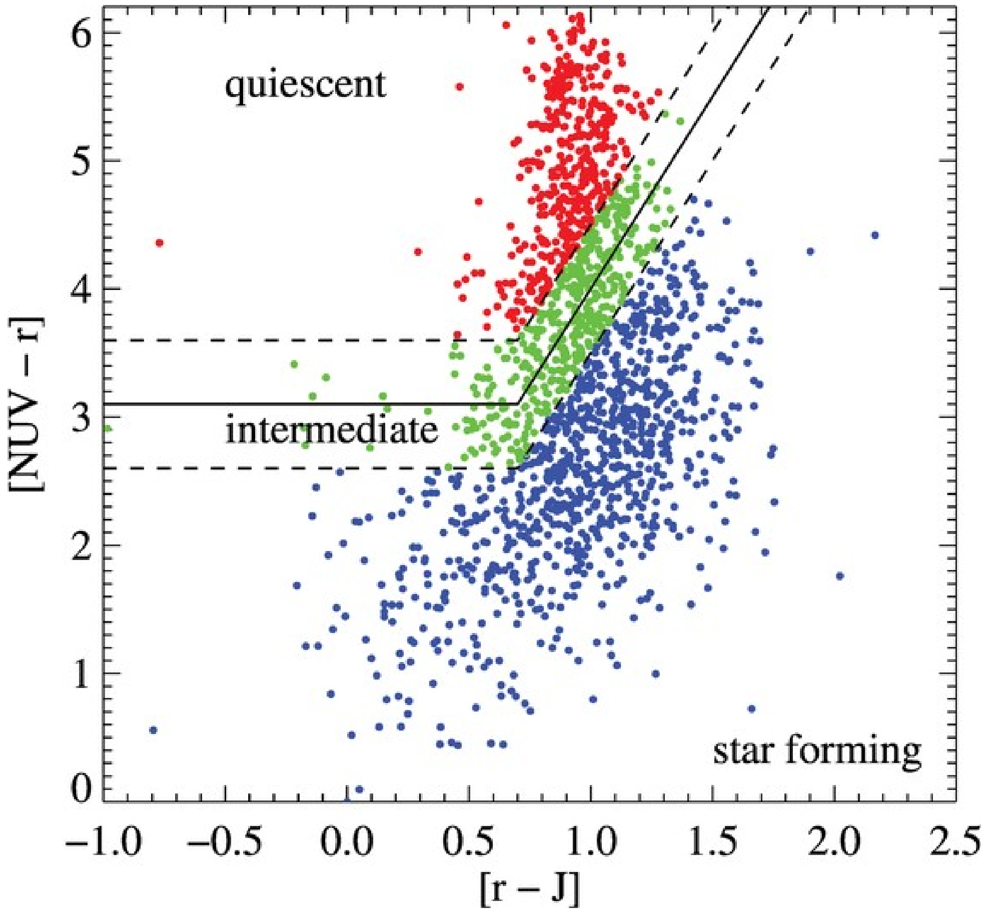


- The average s-BHAR increases by a factor of **10** from z~0.7 to z~3.5
- Radio and X-ray emission are not strongly correlated
- The Edd ratio exceeds 1% (=**radiatively efficient** BH accretion) at z>2. The high-z Universe seems to facilitate radiative AGN activity: **cold gas** ←→ **SMBH accretion**

(Aird et al. 2018)

How do *radio AGN* hosts evolve?

- *(NUV-r)* / *(r-J)* locus to identify **blue** (=star forming) radio AGN hosts (Ilbert et al. 2013; Davidzon et al. 2017)



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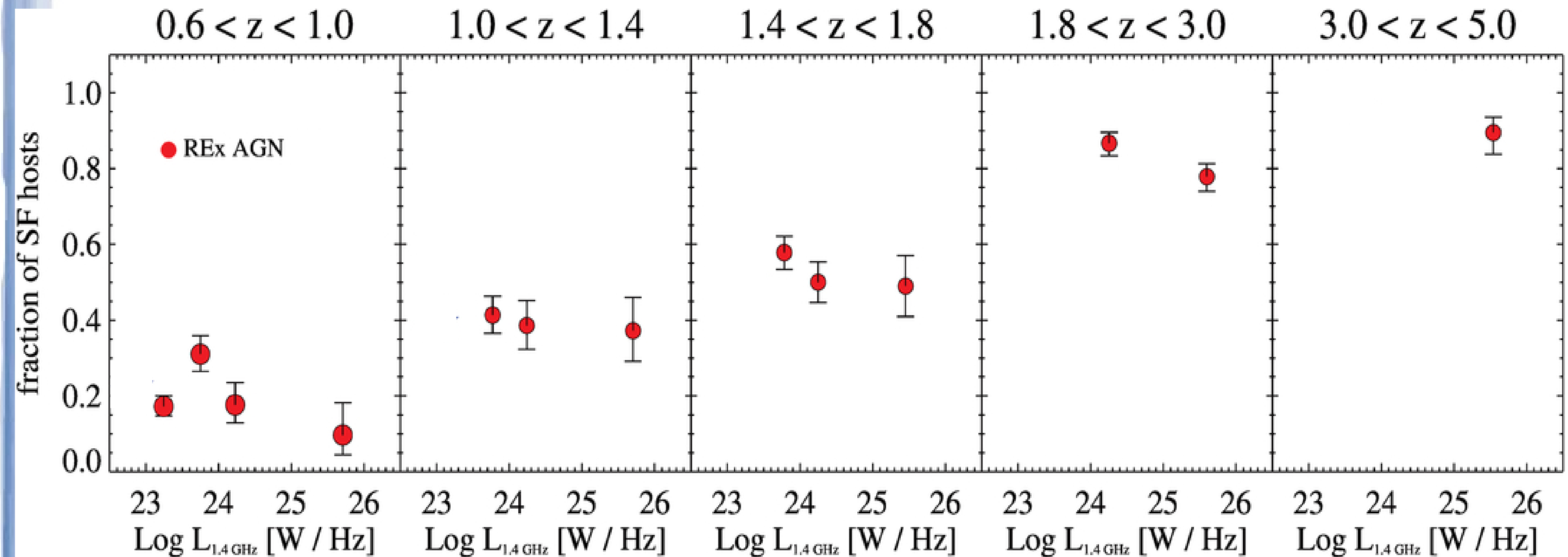

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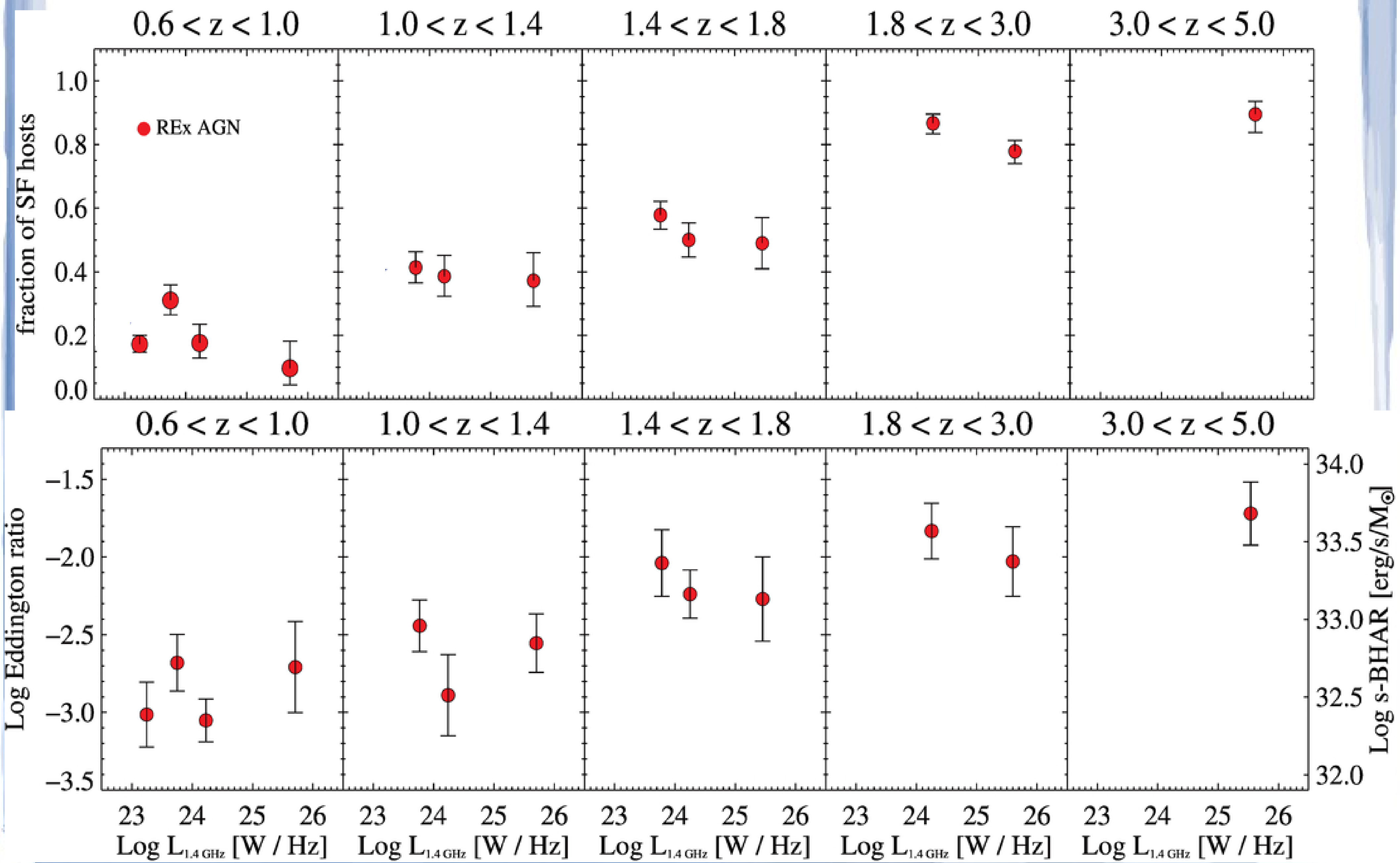

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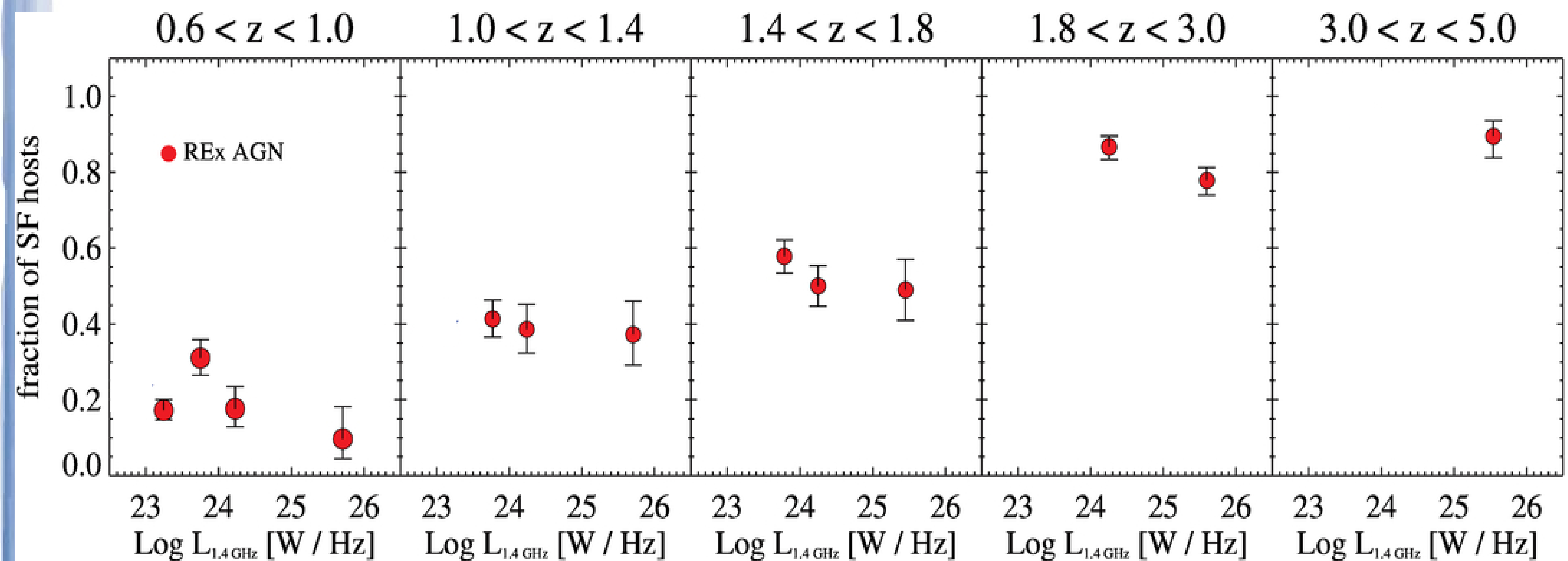

- Radio AGN hosts were predominantly **star forming** at z>1.5

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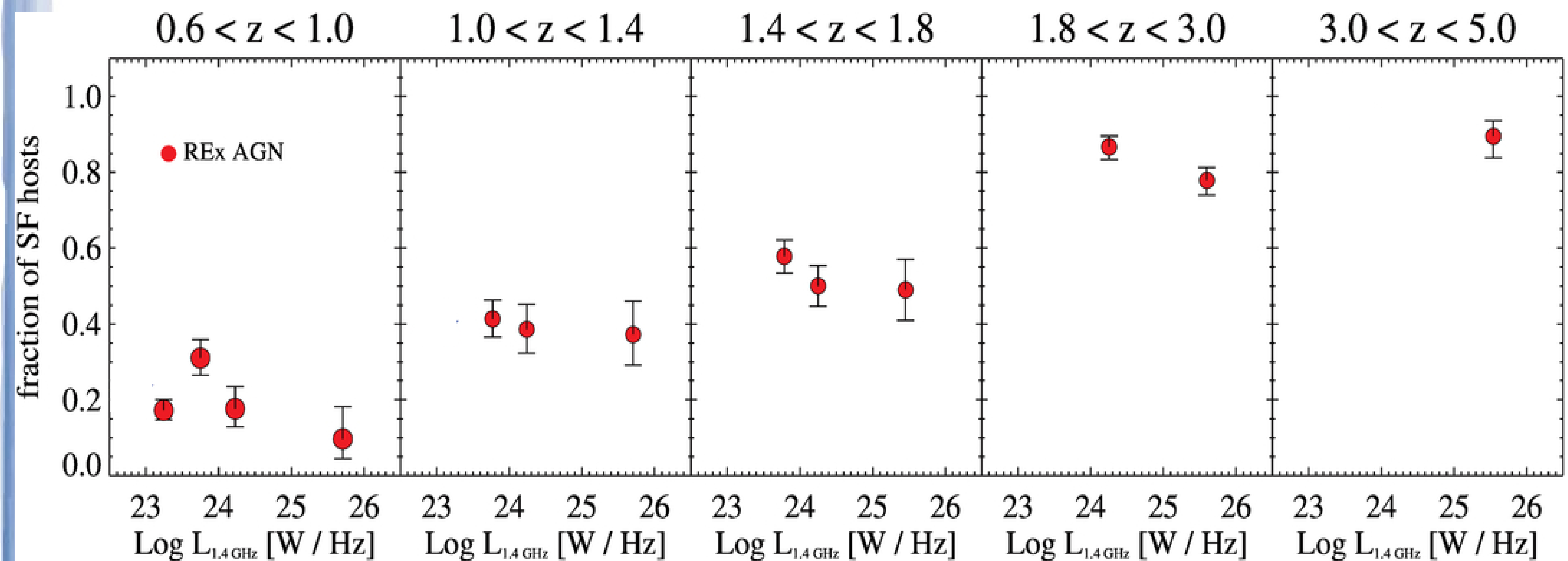

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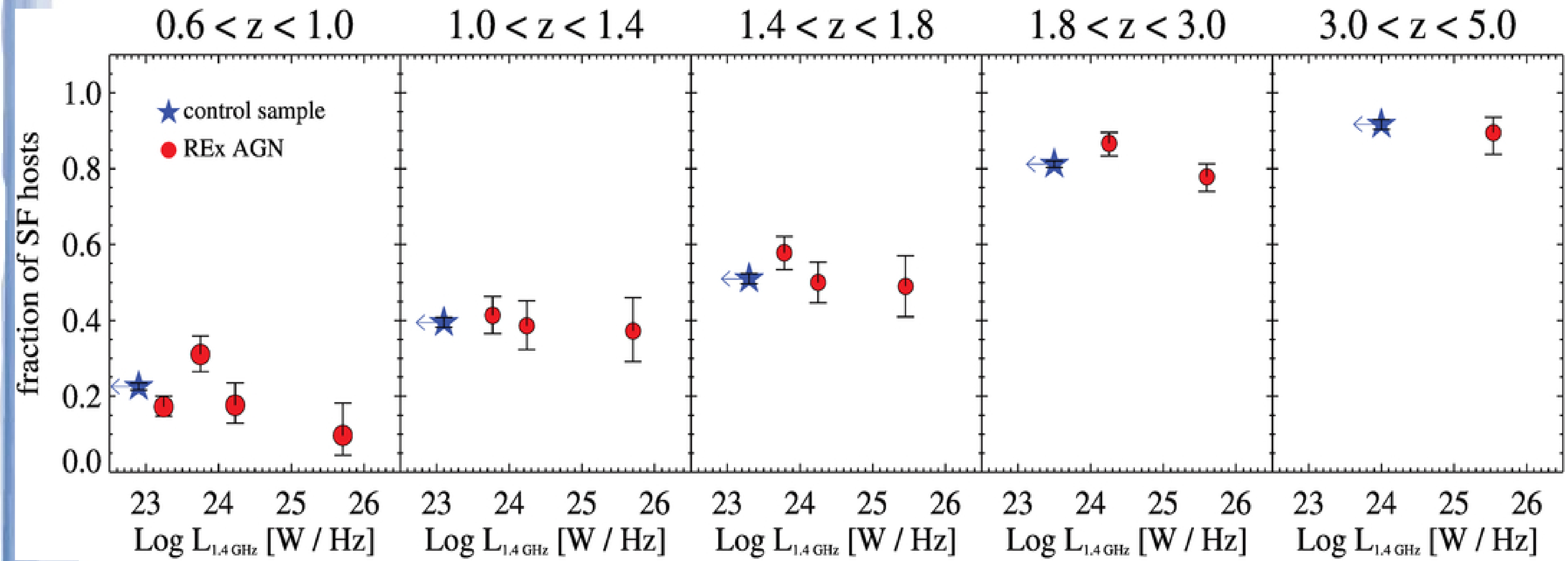

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- A control sample of non-AGN galaxies (matched in M*-z) shows similar %SF hosts and similar redshift evolution

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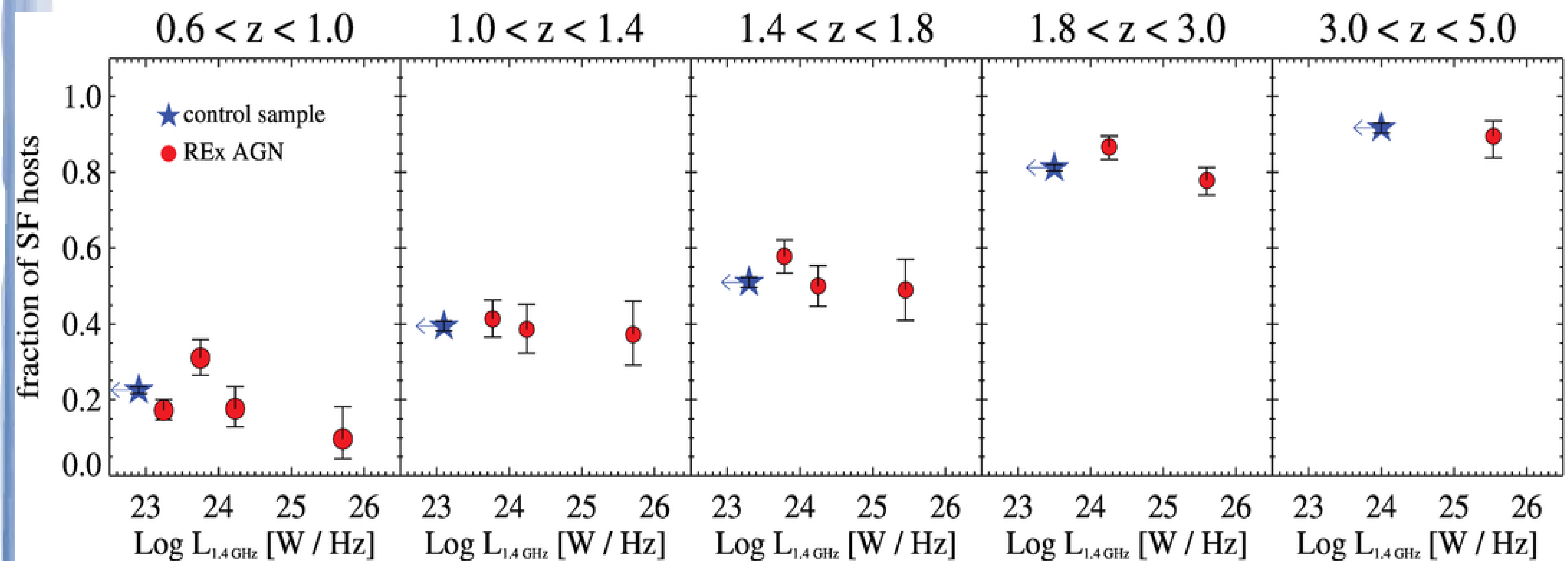

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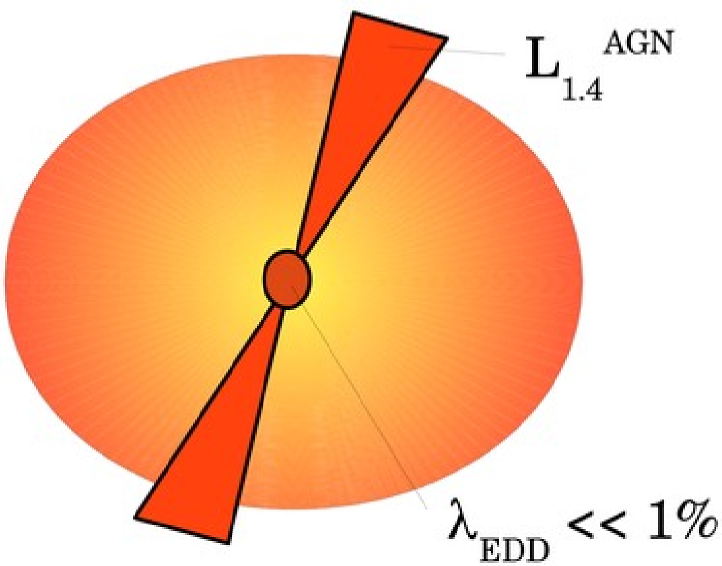
- Does it imply that "jet-mode" feedback is less efficient at higher redshift?
- A control sample of non-AGN galaxies (matched in M*-z) shows similar %SF hosts and similar redshift evolution

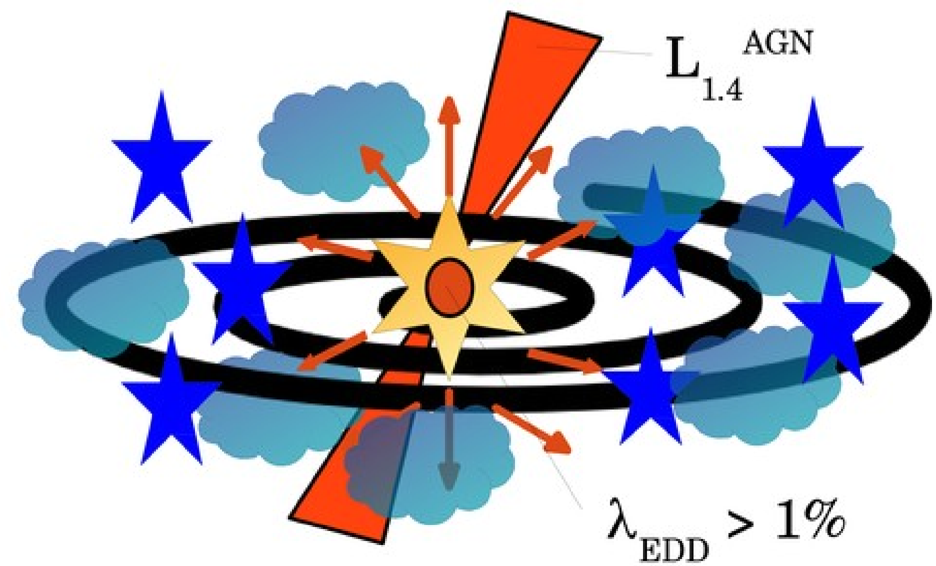
The overall galaxy population becomes more SF with z, while the possible presence of a *radio AGN does not seem to influence its evolution*.

Take-home message

$z << 1$ $\longleftarrow$ $z > 1.5$

(independently of $L_{1.4}^{AGN}$)

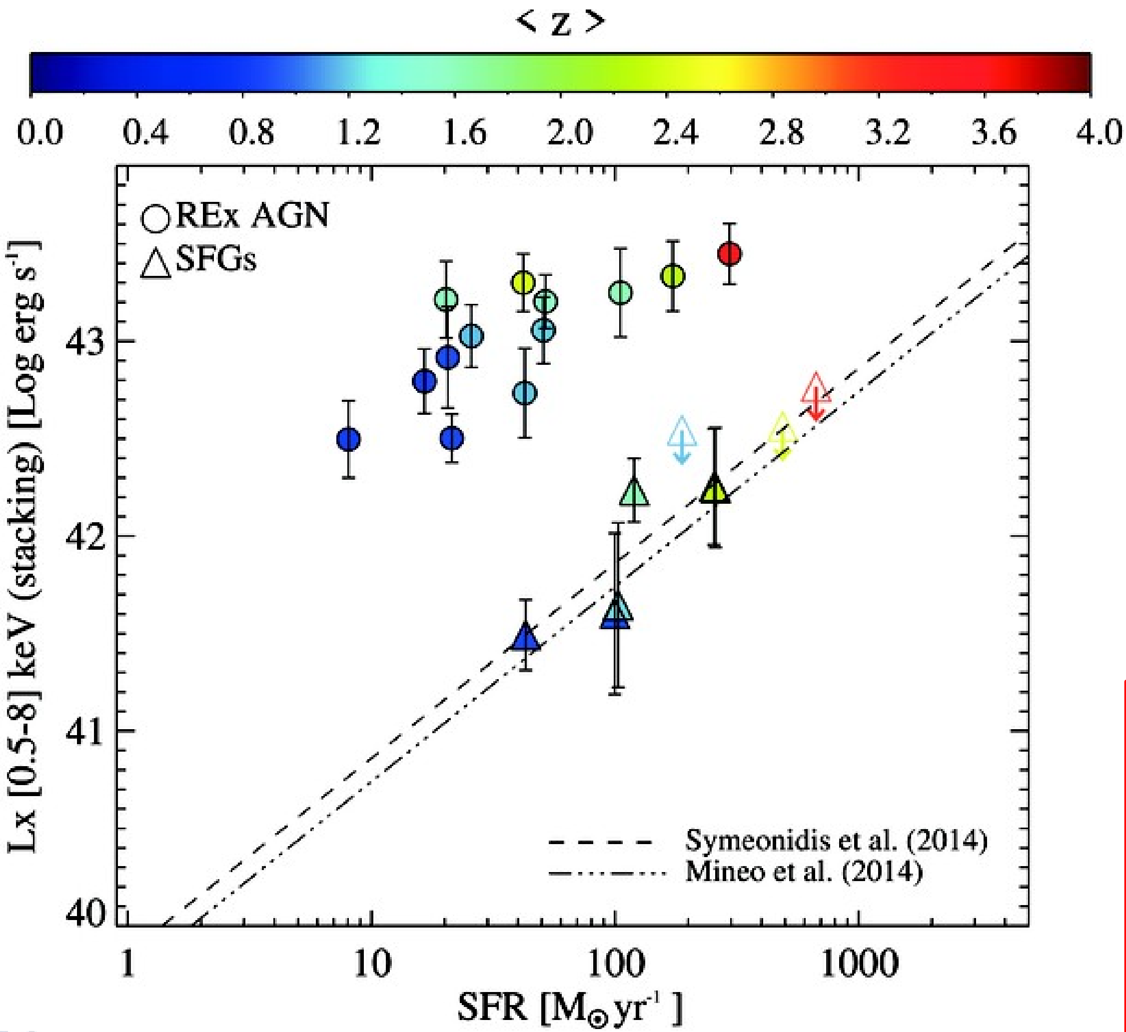




Red and passive galaxy	RADIO (AND NON) AGN HOST	Blue and highly star-forming galaxy
Weakly accreting SMBH ($\lambda_{EDD} << 1\%$)	RADIO AGN	Highly accreting SMBH ($\lambda_{EDD} > 1\%$)

Supplementary slides

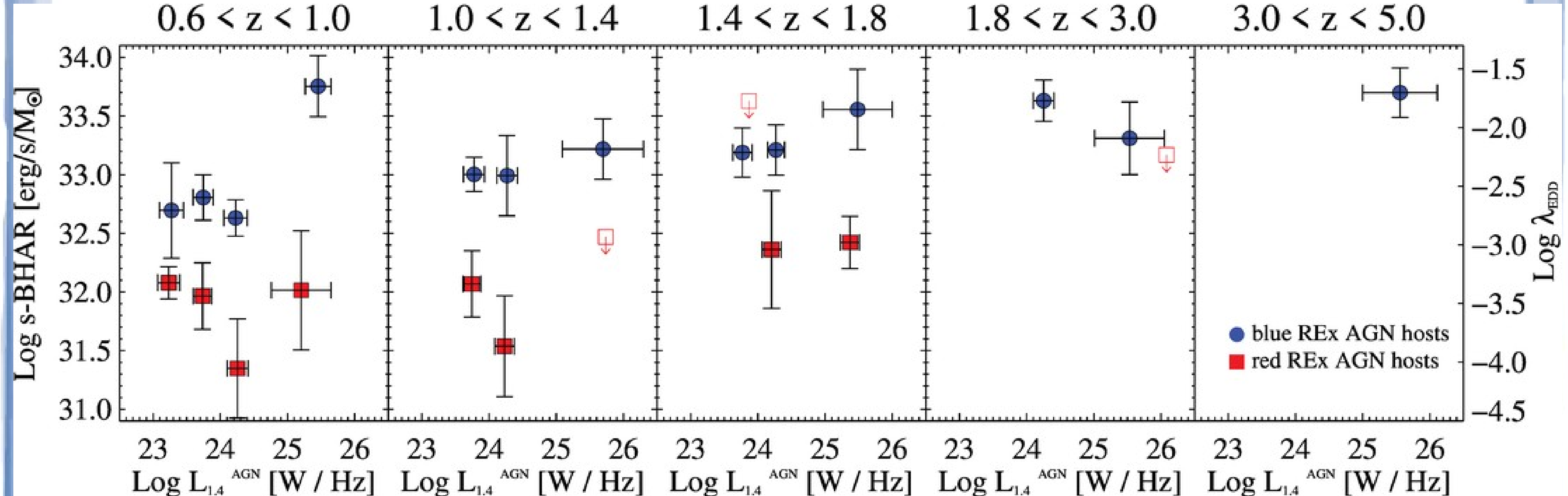
Average Lx of radio-excess AGN



- X-ray stacking of radio-excess AGN within each $L_{1.4}$-z bin (*CSTACK*, T.Miyaji)
- Comparison with X-ray emission expected from star formation (Symeonidis et al. 2014; Mineo et al. 2014)

The mean Lx derived from stacking is systematically higher than that expected from star formation

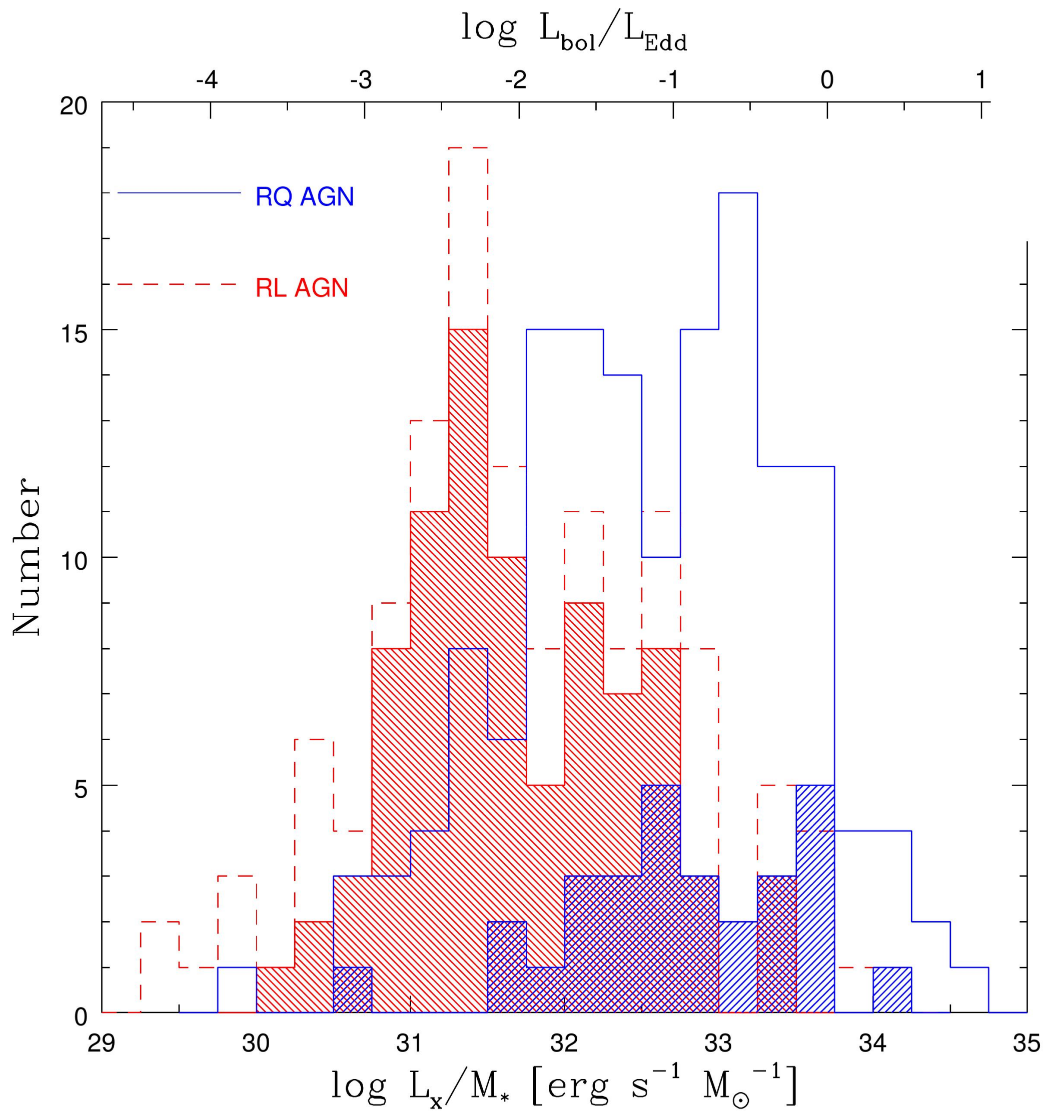
How do *radio AGN* hosts evolve?



- The average s-BHAR is significantly higher in **blue** radio AGN hosts, at fixed L1.4 and z

Literature: s-BHAR of radio AGN

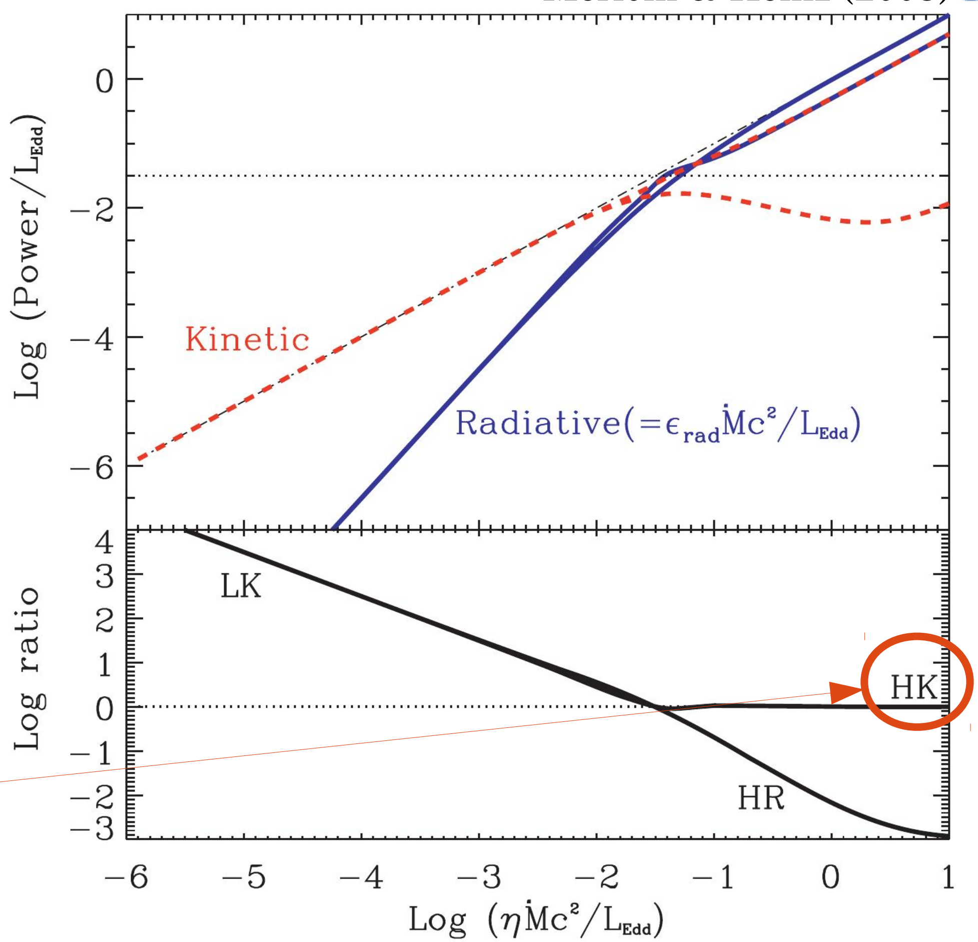
- Best & Heckman (2012) used multi-wavelength information to distinguish radio loud AGN between HERGs & LERGs
- Padovani et al. (2015) used deep VLA 1.4 GHz data in the E-CDFS to identify radio AGN down to the "radio quiet" regime
- SMBHs accretion rates are mostly limits (shaded areas) due to the large fraction of non-detections.



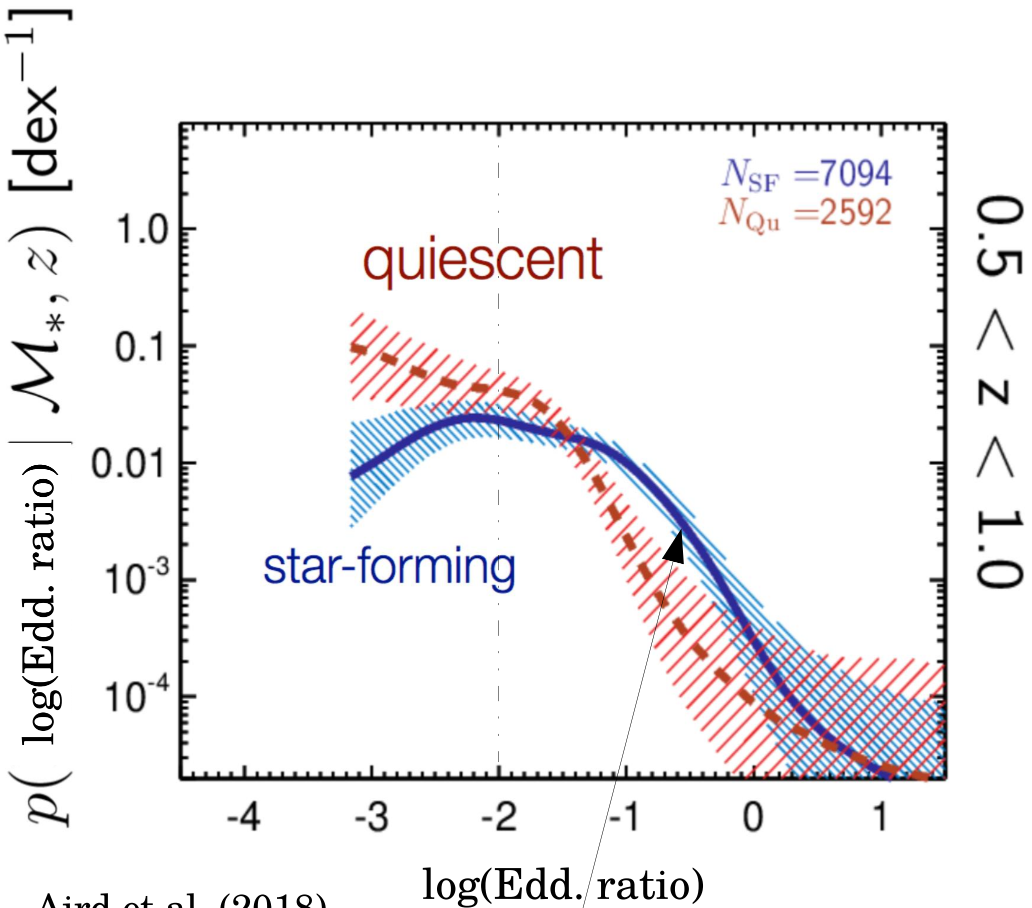
Take-home messages

- All galaxies become typically bluer with redshift, incuding radio AGN hosts
- The qualitatively similar trends between s-BHAR and % SF hosts are plausible if cold gas drives radio AGN activity
- No correlation between X-ray and radio emission processes might explain the non-trend between s-BHAR and $L_{1.4}$
- Radio jet emission at z>1.5 traces also radiative AGN activity (**High-Kinetic mode**?)

Merloni & Heinz (2008)



The high-z Universe facilitates (radiative) AGN activity(*)



Aird et al. (2018)

Typical Edd. Ratio increases with z,

(*) especially in star-forming galaxies

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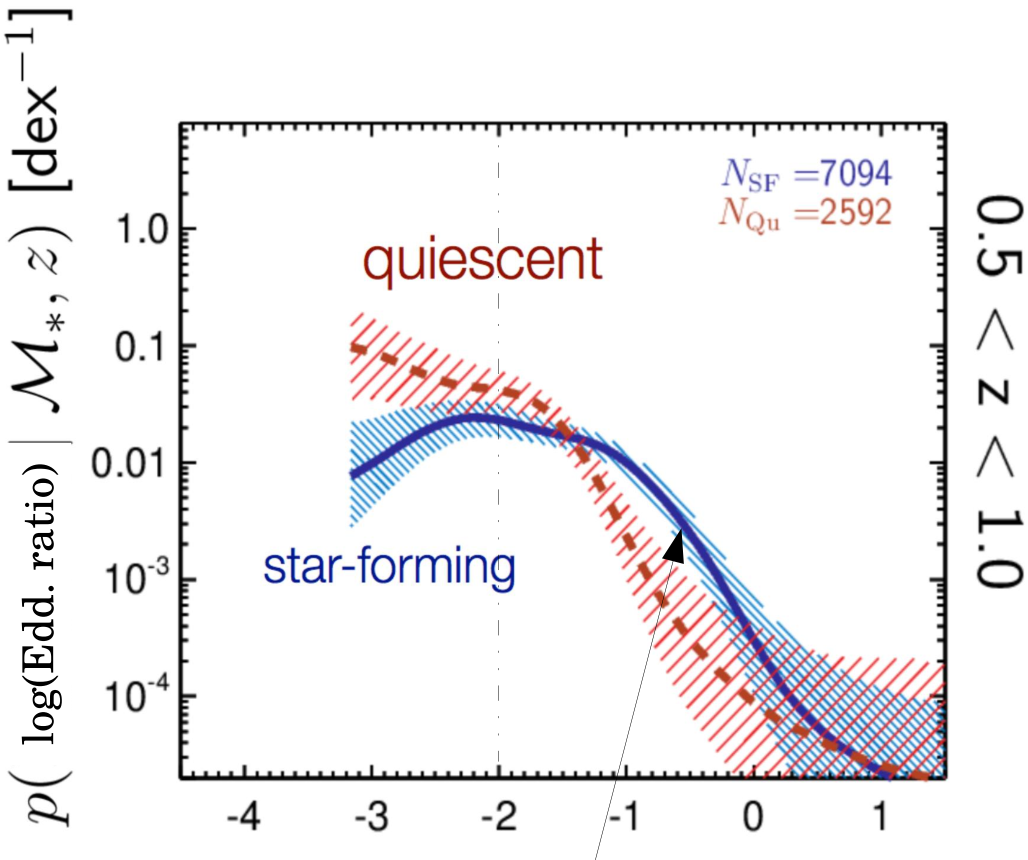

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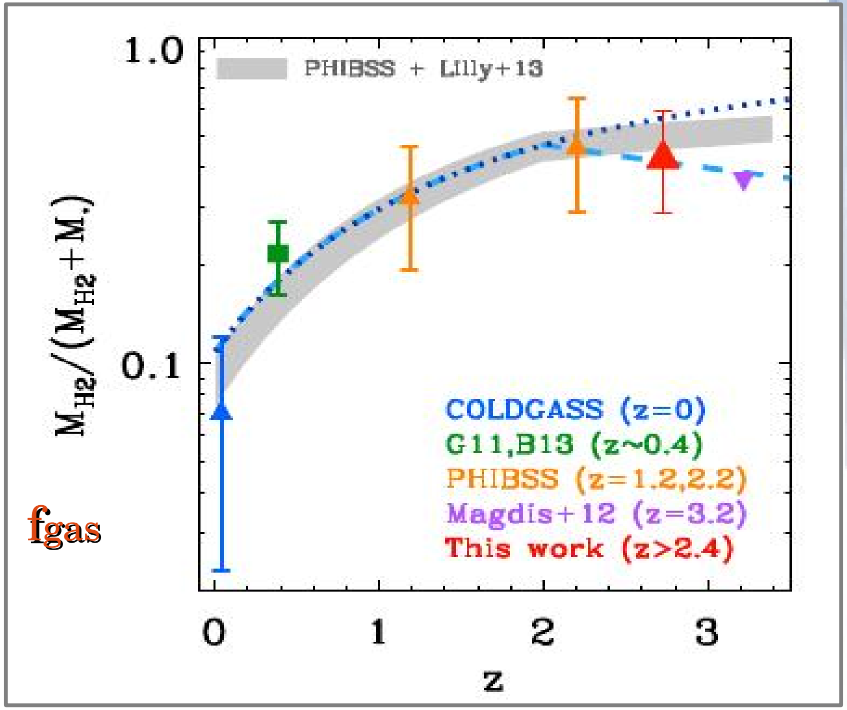


Saintonge et al. (2012)

The cold gas fraction fgas increases in main-sequence galaxies out to z~2-3

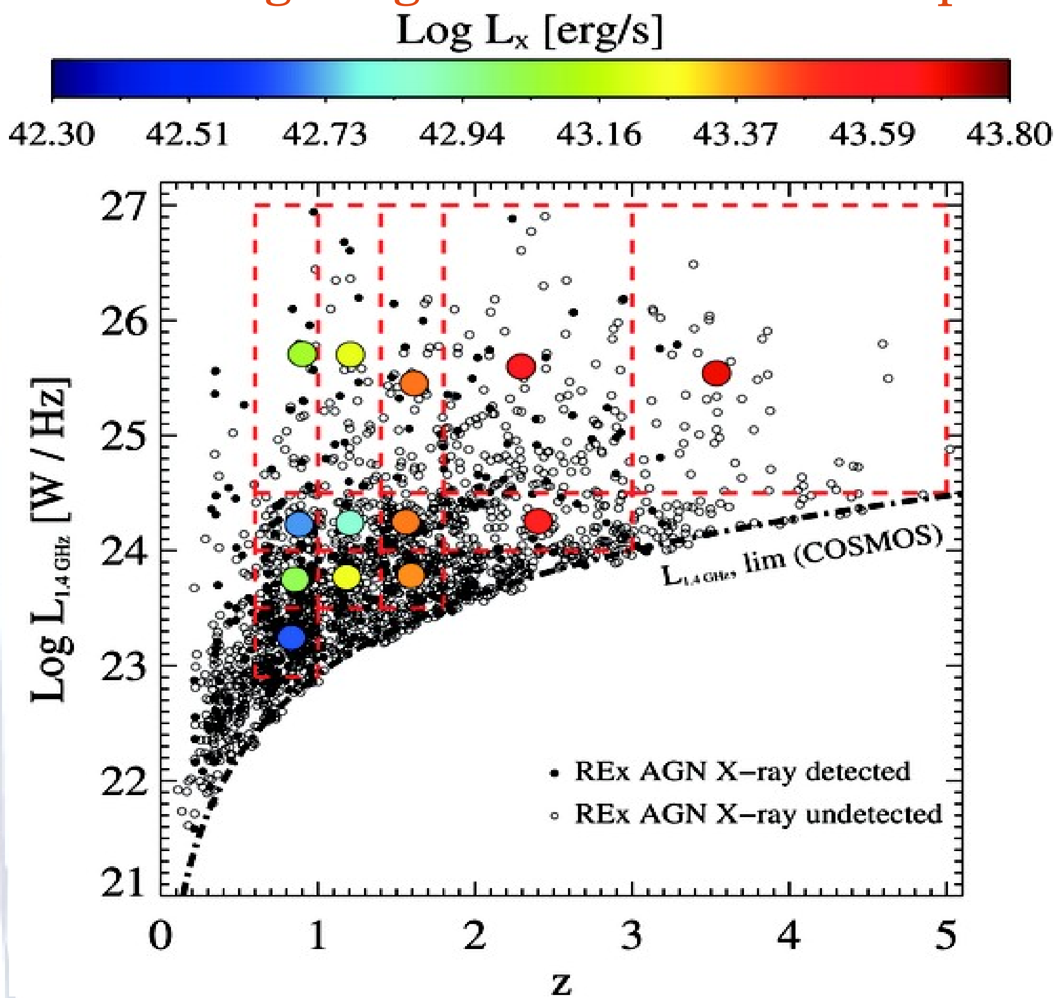
Typical Edd. Ratio increases with z,

(*) especially in star-forming galaxies

SMBH accretion ⟷ **cold gas supply**

Average Lx of radio-excess AGN

Investigating the simultaneous dependence of Lx on *both* L1.4 and redshift



- X-ray stacking of radio-excess AGN within each L1.4-z bin (*CSTACK*, T.Miyaji)
- Combining X-ray detections and non-detections together
- Boostrapping to mitigate the effect of bright outliers
- Comparison with X-ray emission expected from star formation (Symeonidis et al. 2014; Mineo et al. 2014)

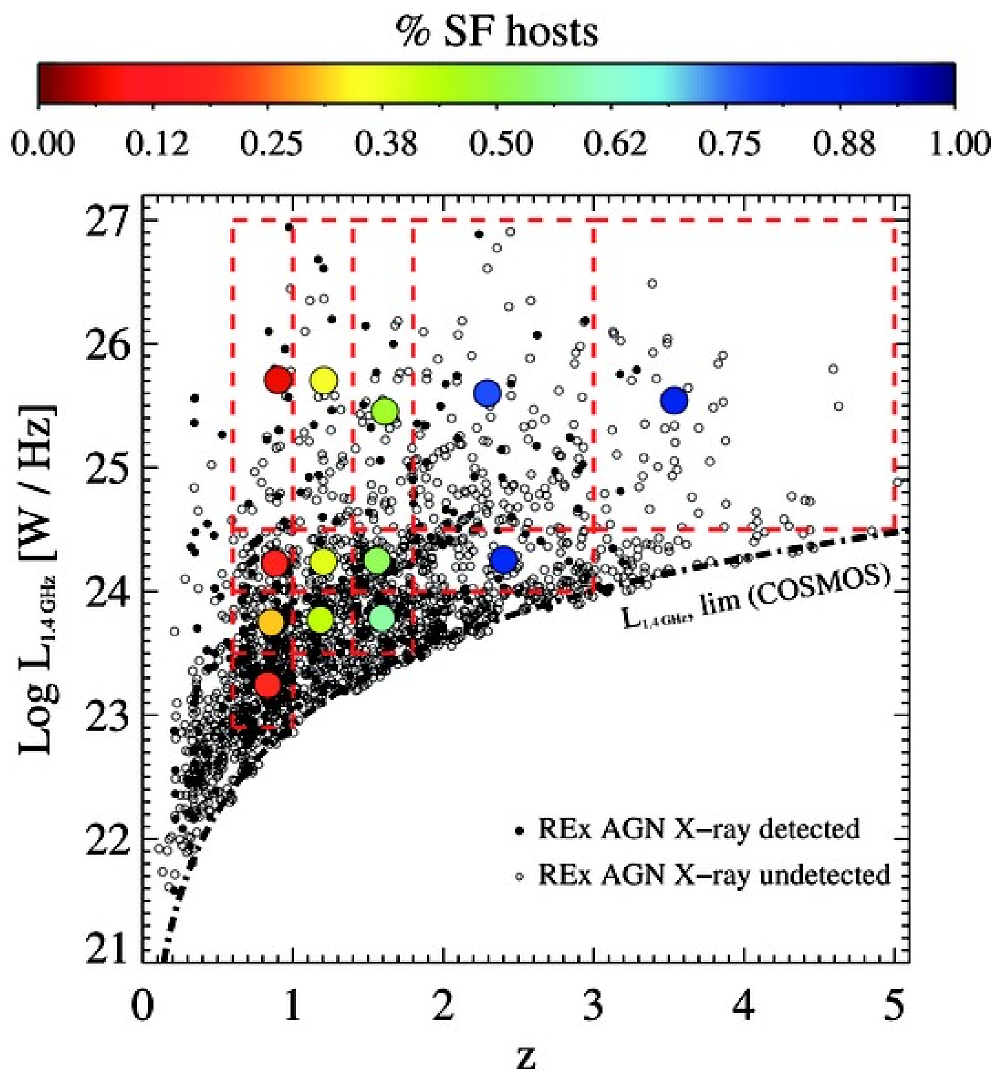
The *average* Lx does not show a significant trend with L1.4 at fixed z, while it increases with redshift, at fixed L1.4

How do *radio AGN* hosts evolve?

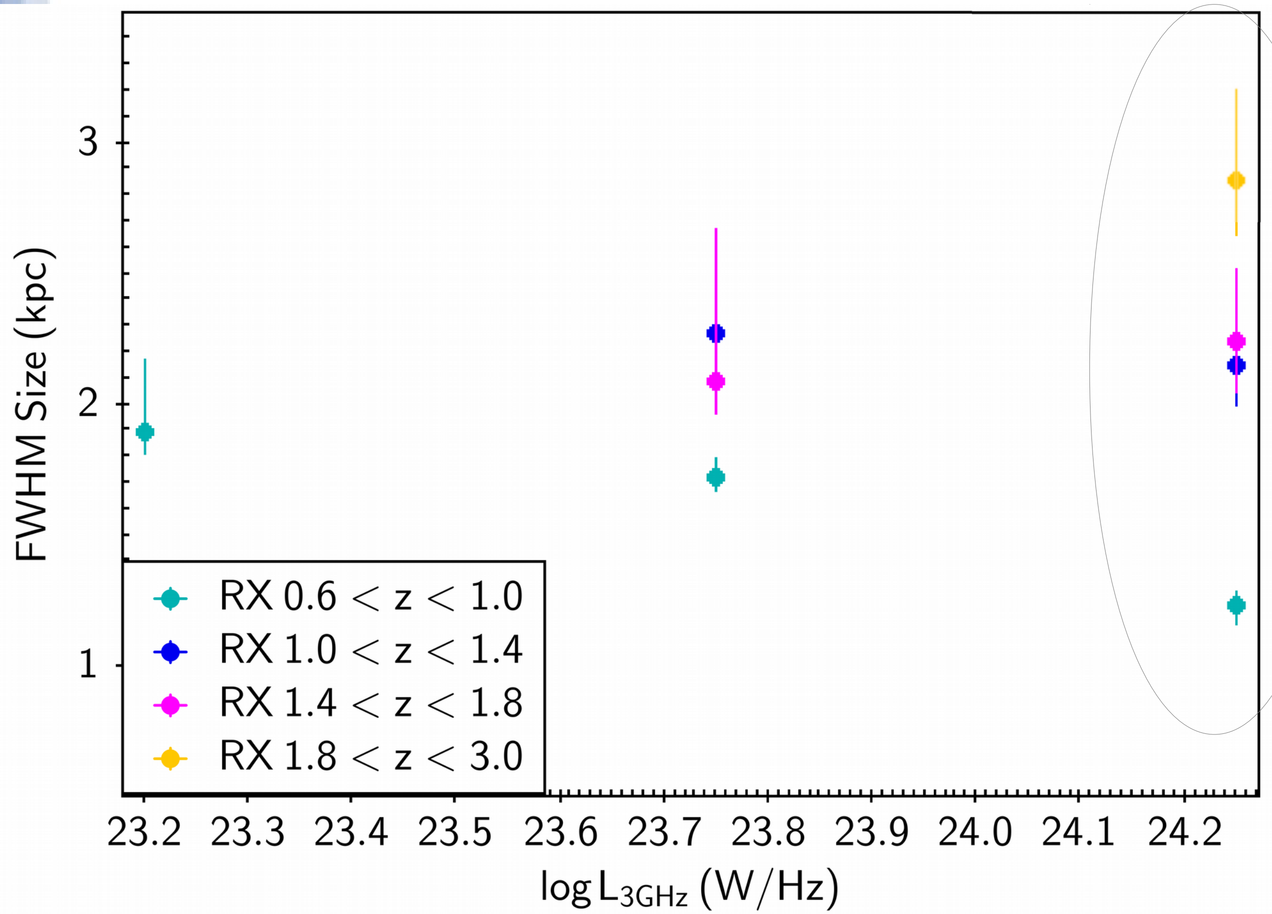
- *(NUV-r)* / *(r-J)* locus to identify **blue** (=star forming) radio AGN hosts
  (Ilbert et al. 2013; Davidzon et al. 2017)

- The average fraction of SF hosts increases with redshift, at fixed L1.4, but does not depend on L1.4

- Radio AGN hosts were predominantly **star forming** at higher redshifts



3 GHz sizes of radio-excess (RX) AGN

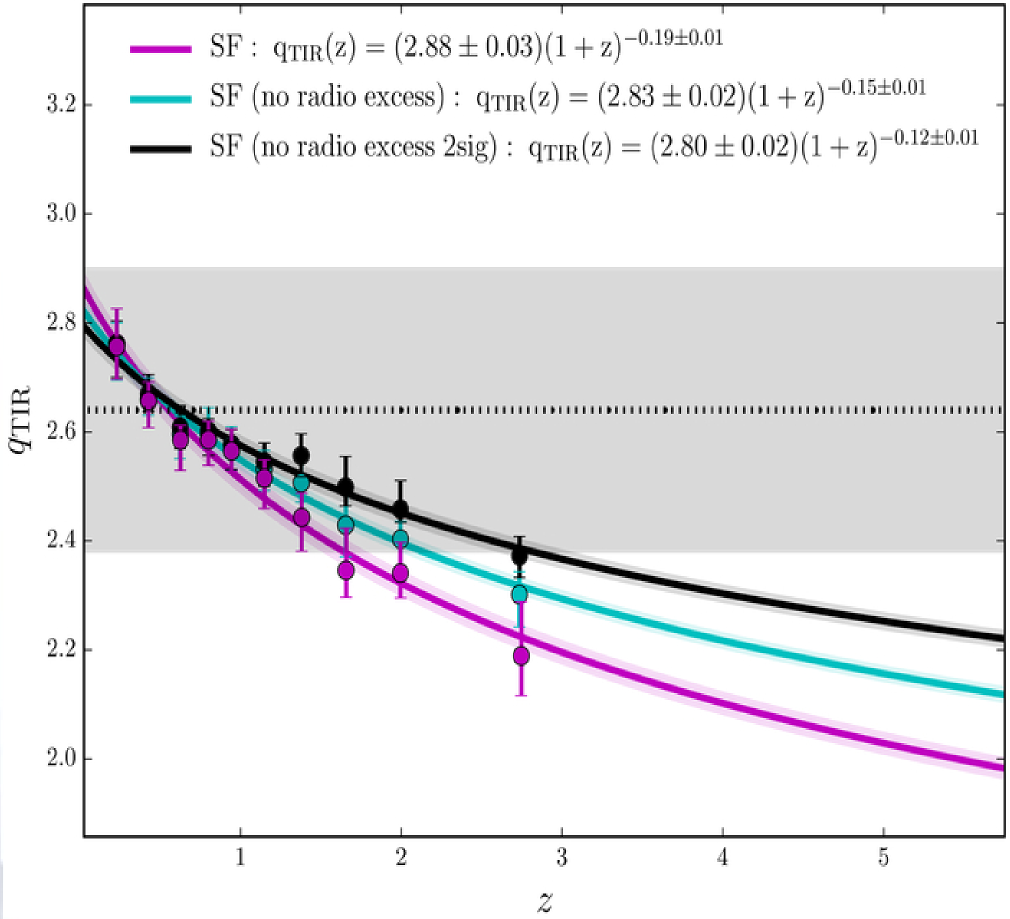


(Bondi et al., 2018.)

Radio-excess AGN of a given $L_{1.4}$ show increasing 3 GHz sizes with redshift

- Rad. inefficient AGN accretion is associated with a compact radio core
- Larger sizes might hint at a switch in the SMBH accretion mechanism?

The infrared-to-radio correlation



(Courtesy of J. Delhaize)

- Delhaize et al. (2017)

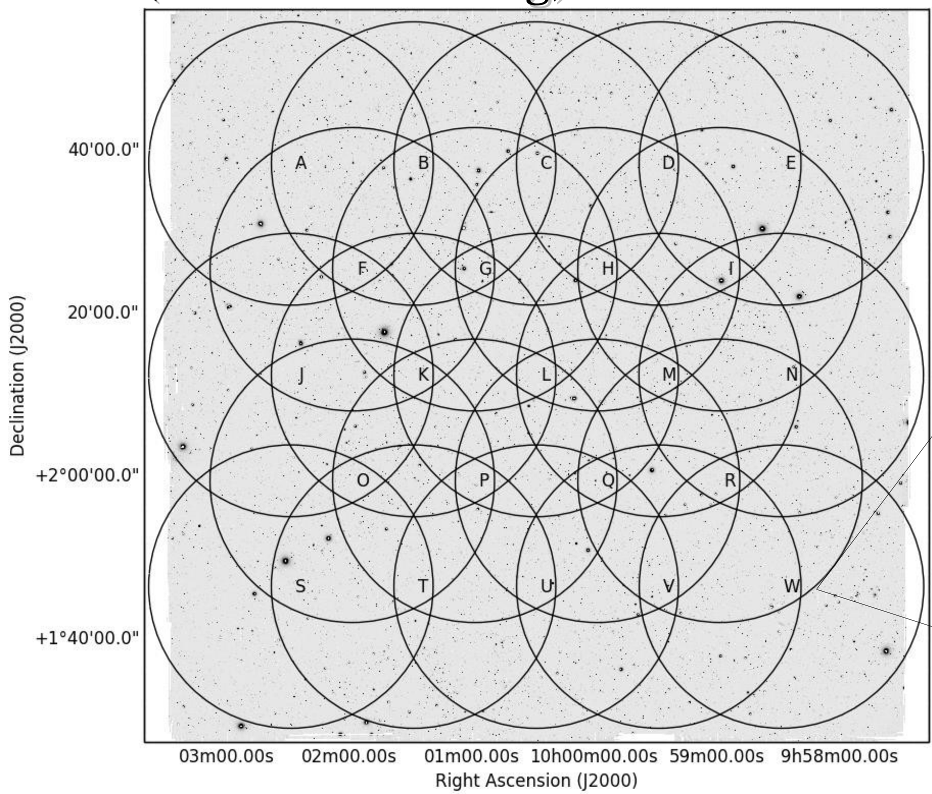
- Delhaize et al. (2017) removing 3σ outliers

- Delhaize et al. (2017) removing 2σ outliers
(flatter than that published in D17, but largely consistent with literature)

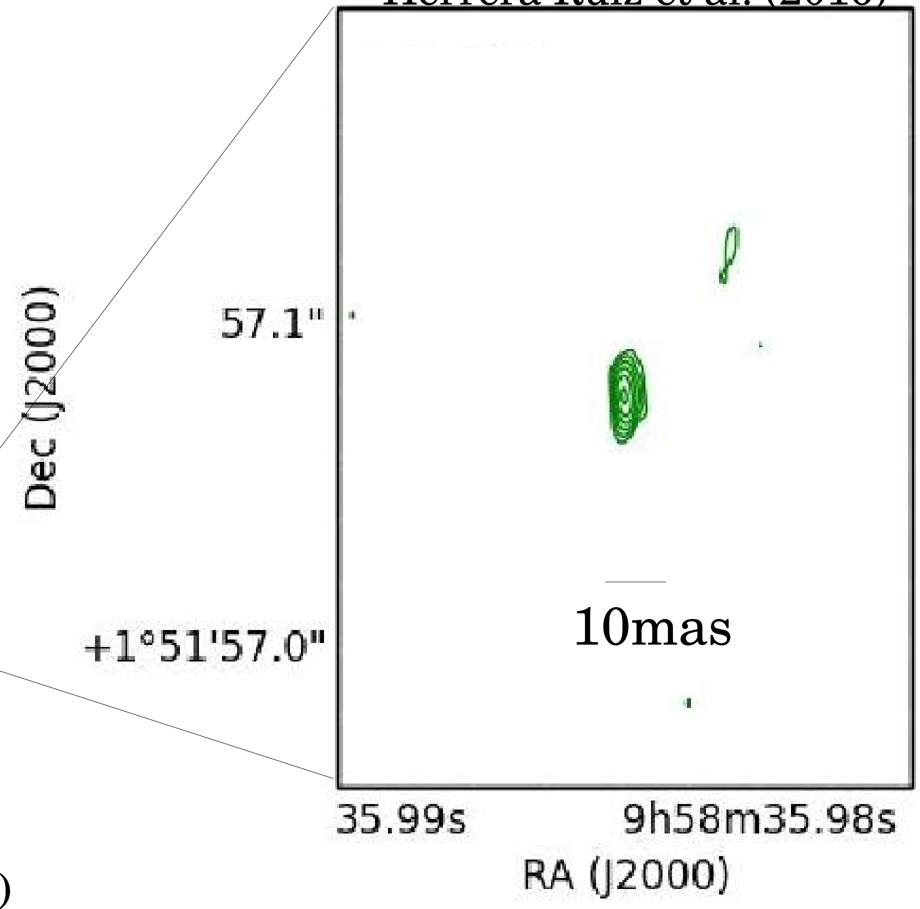
Used in this work for consistency with our definition of radio-excess AGN

Overcoming host-galaxy dilution: VLBI interferometry

(PI: E. Middleberg)

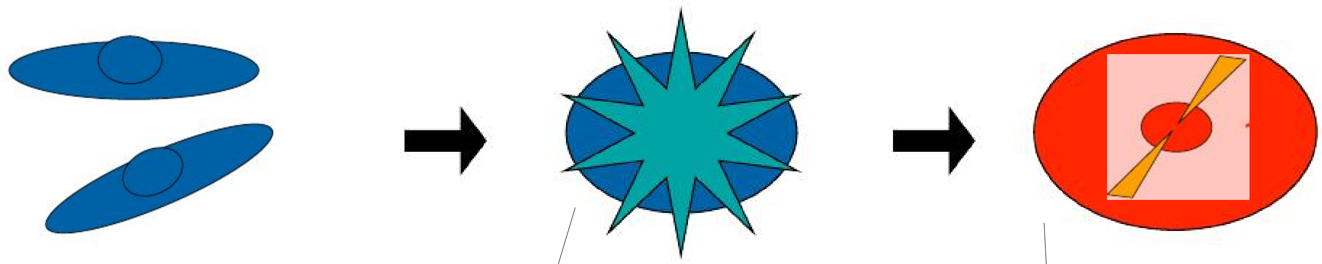


Herrera Ruiz et al. (2016)



(Courtesy of E. Middleberg and N. Herrera Ruiz)

AGN feedback: two flavours



Alexander & Hickox 2012

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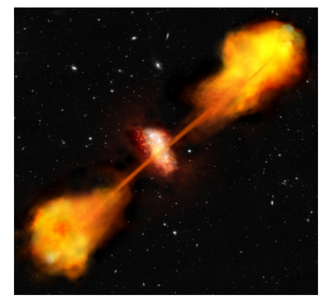
"Radiative mode"



"Jet mode"

- Cleaning mode
- Moves the galaxy from "blue" to "red"
- Radiatively efficient ($L / L_{edd} > 1\%$)

- Mainteinance mode
- Keeps the galaxy "red"
- Radiatively inefficient ($L / L_{edd} << 1\%$)

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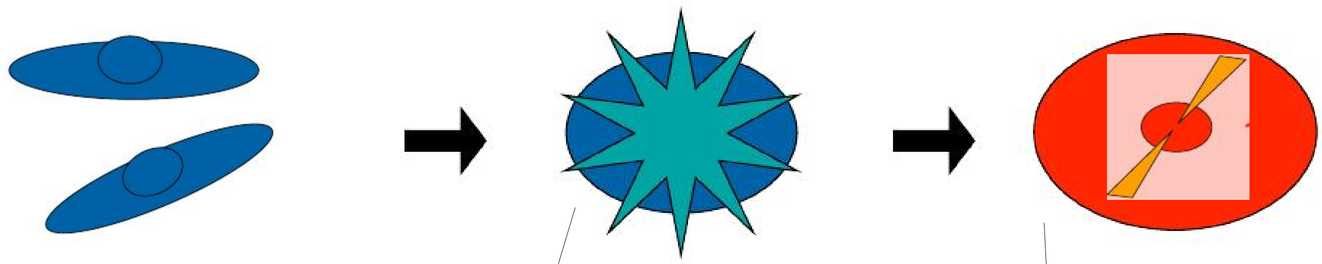

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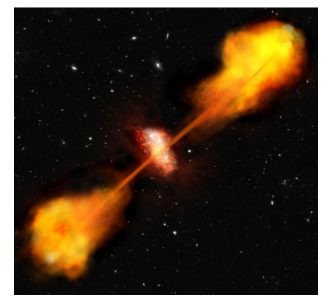

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Radio samples of AGN are crucial to probe the "Jet mode" phase of AGN feedback