LPSC – Grenoble

June 5th, 2019

Unveiling the AGN-galaxy connection at high-z with NIKA2 and radio facilities

Ivan Delvecchio

Marie Curie Fellow (CEA-Saclay)
ivan.delvecchio@cea.fr

On behalf of:
V. Smolčić, G. Zamorani, D.J. Rosario, M. Bondi, S. Marchesi,
T. Miyaji, M. Novak, M.T. Sargent, D.M. Alexander, J. Delhaize,
E. Daddi & the COSMOS team

Outline

- AGN-galaxy connection at $z \geq 2$: where do we stand now?

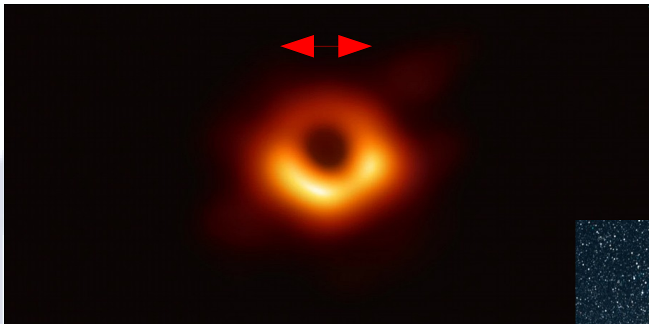
- **NIKA2 + radio** facilities for addressing these issues:

- (1) Impact of radio AGN activity on galaxy SFR at $z>2$;

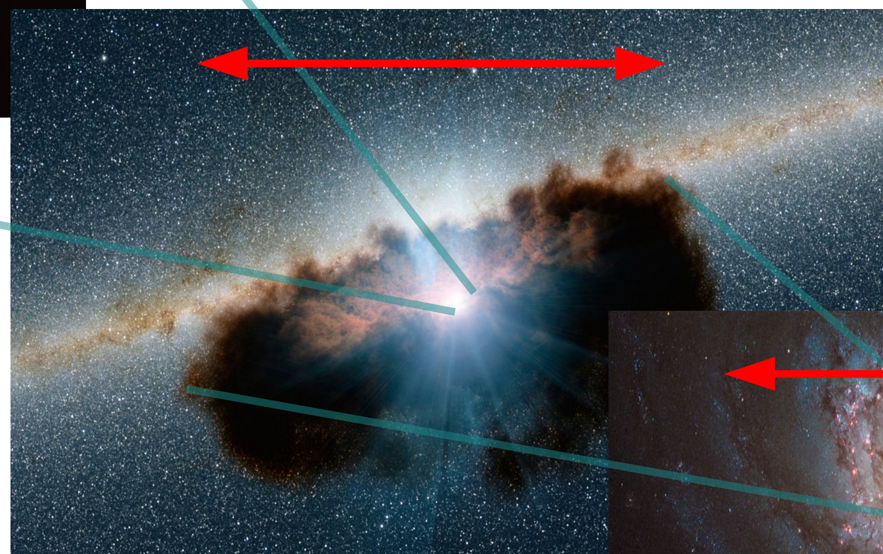
  (2) Calibrating radio and mm emission as SFR tracers at $z>2$

Active Galactic Nuclei (AGN)

0,001 pc

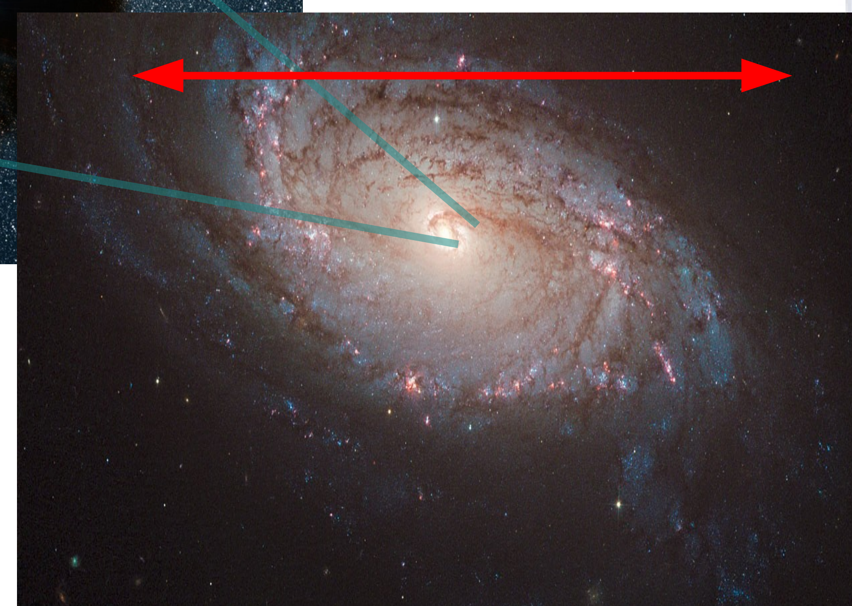


1-10 pc



x 10000

10-100 kpc



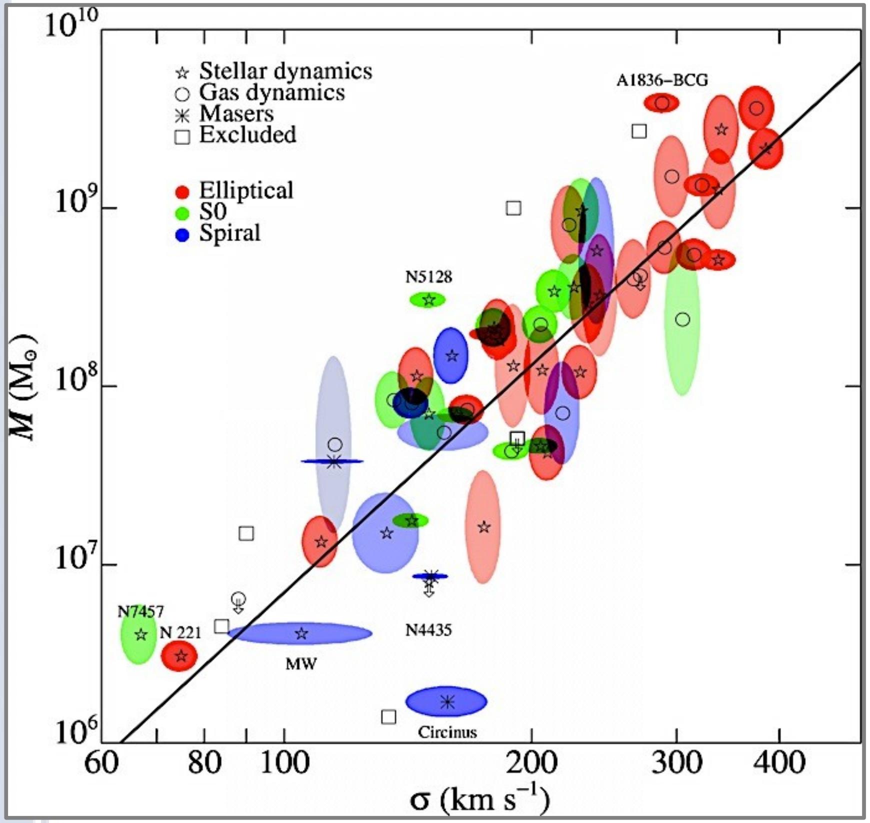
x 1000

MIND THE GAP!

SMBHs are **millions of times** smaller than the galaxies they live in!

Galaxies and SMBHs know each other

Gultekin et al. (2009)



- Black hole masses correlate in nearby spheroidals with galaxy bulge properties:

$M_{BH} - \sigma$ relation

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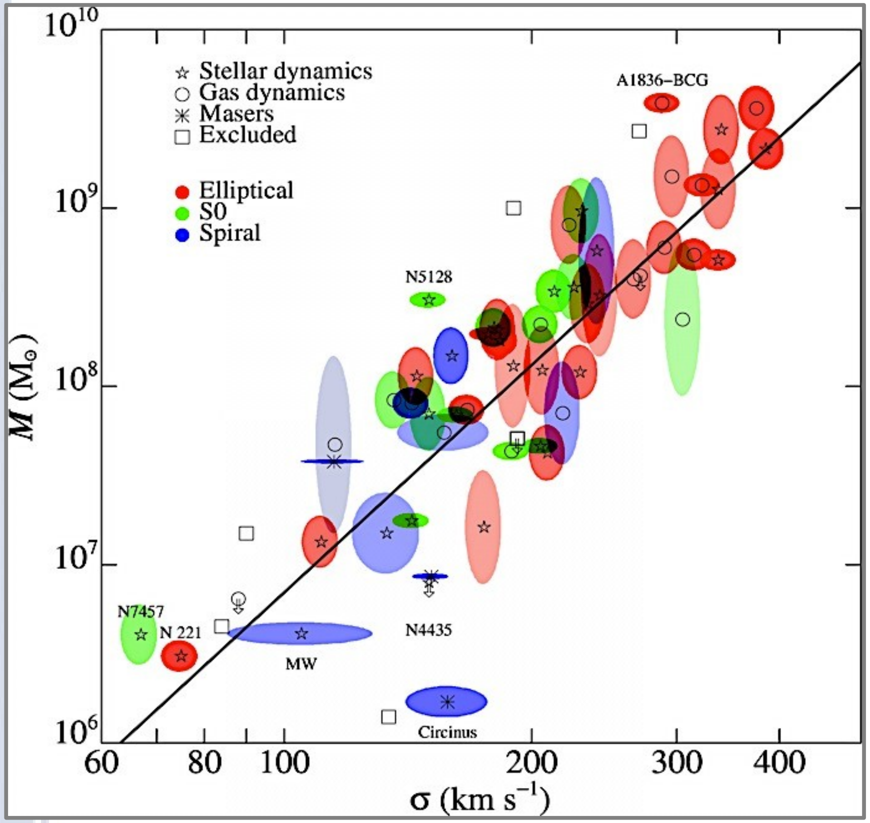
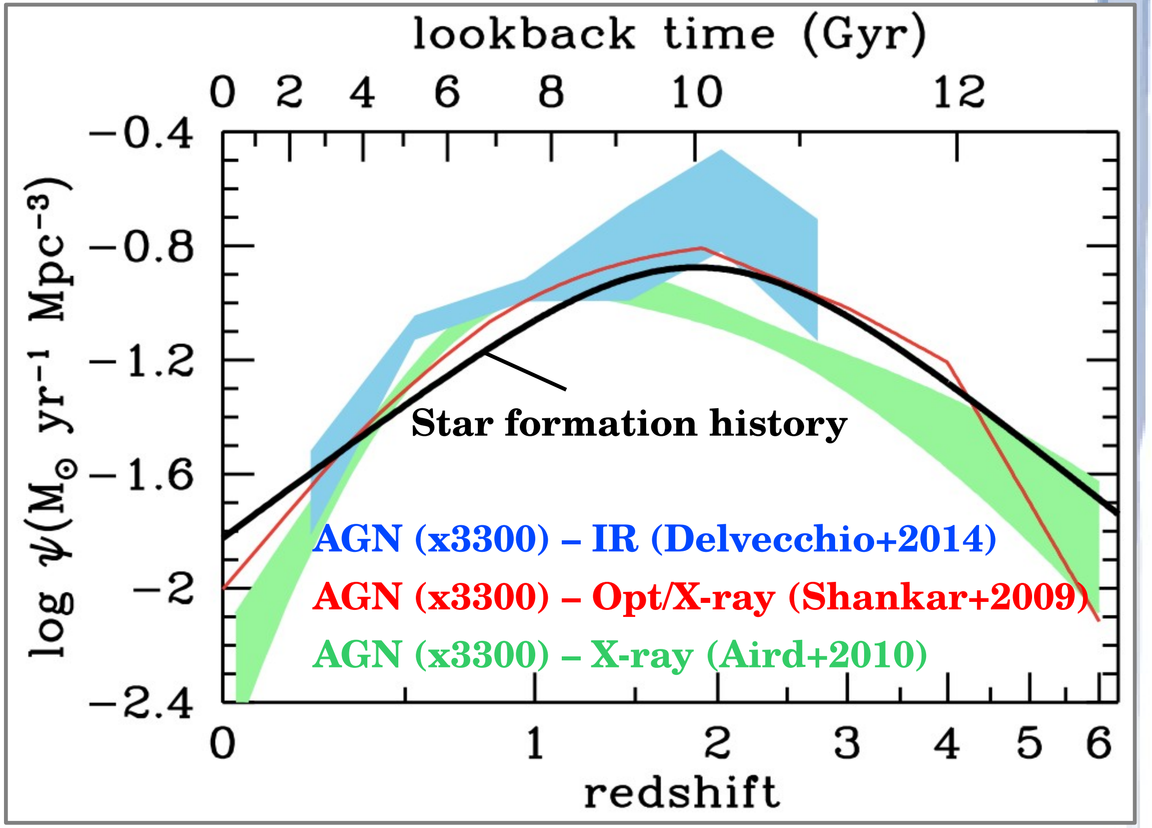


Madau & Dickinson (2014)



- Black hole masses correlate in nearby spheroidals with galaxy bulge properties:

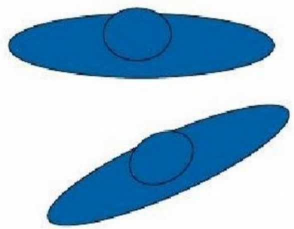
  M_{BH} – σ relation

- Cosmic star formation history and black hole accretion history closely trace each other.

Sanders et al. (1988); Alexander & Hickox (2012)

The need for AGN feedback

- Early phase



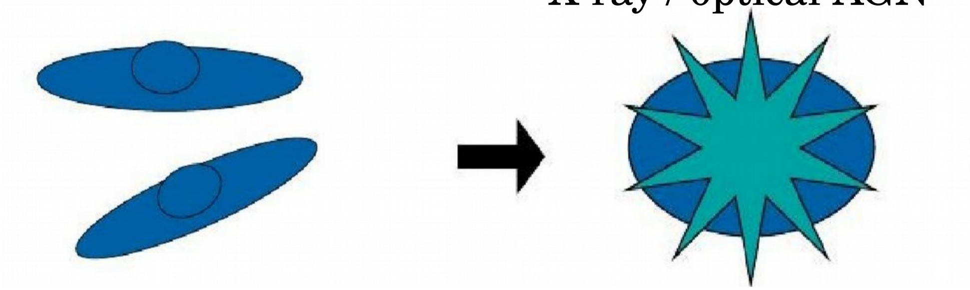
Galaxy mergers /
Stochastic processes

Sanders et al. (1988); Alexander & Hickox (2012)

The need for AGN feedback

- Early phase

- **Star forming** galaxy
- X-ray / optical AGN



Galaxy mergers / Stochastic processes

Gas inflow: SMBH becomes an AGN

"Radiative mode"

t

Sanders et al. (1988); Alexander & Hickox (2012)

The need for AGN feedback

- Early phase

- **Star forming** galaxy
- X-ray / optical AGN

- **Red** and passive galaxy
- Radio AGN

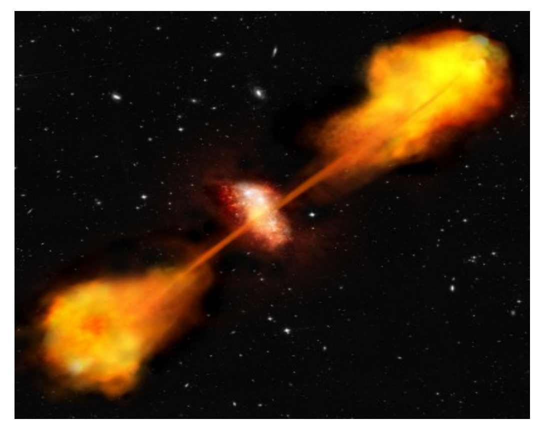
Galaxy mergers / Stochastic processes

Gas inflow: SMBH becomes an AGN

AGN feedback hampers galaxy star formation

"Radiative mode"

"Jet mode"



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The need for AGN feedback

PROs:

- Reproduces the colour bimodality and M* function in the local Universe
- Supported at low-z by the prevalence of radio AGN in red & massive galaxies

"Radiative mode"

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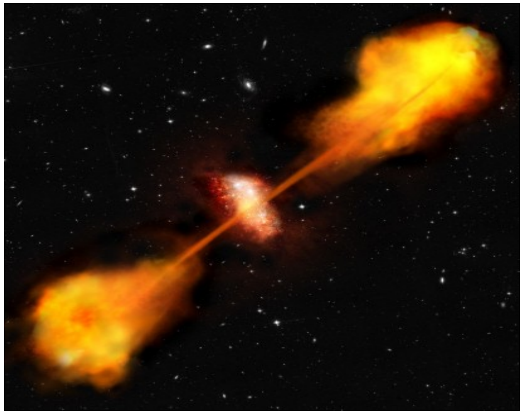

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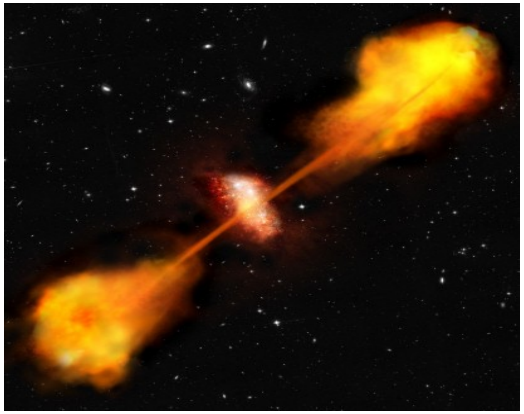

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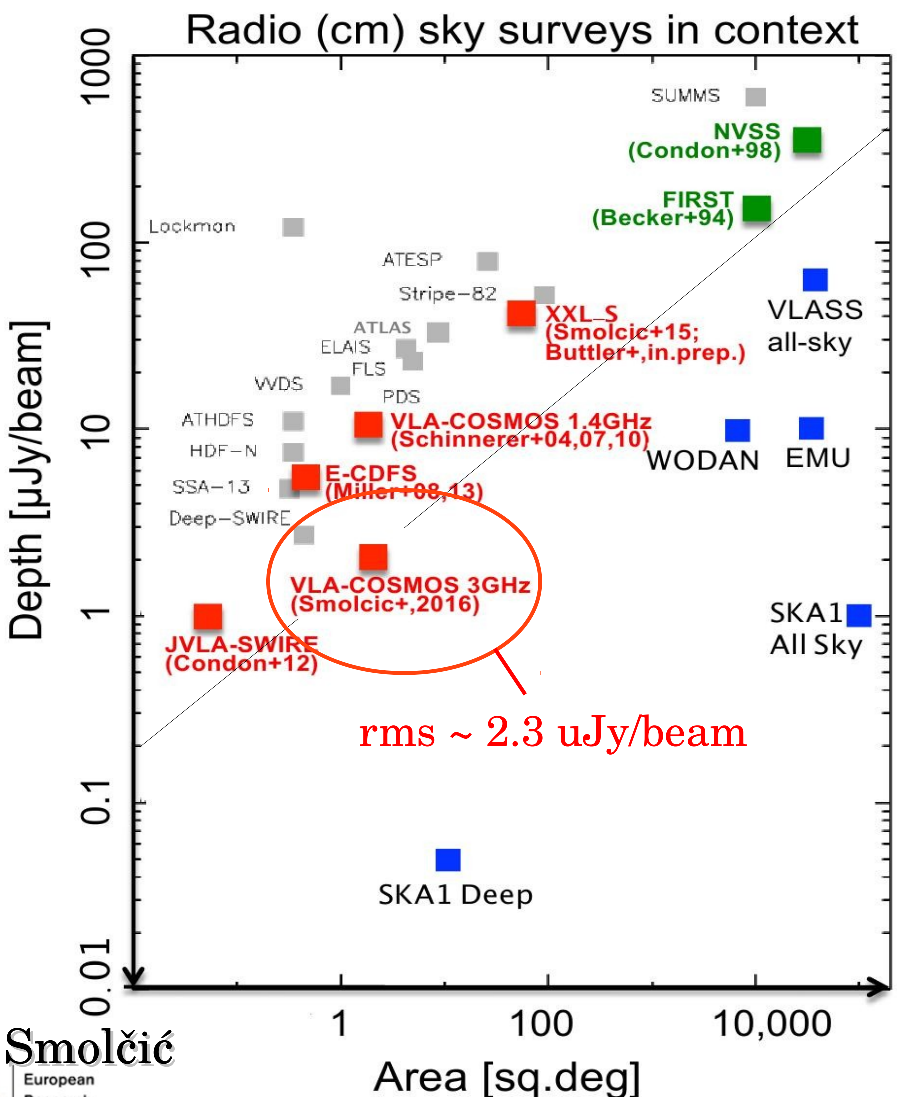
Q: Does AGN feedback change across cosmic time?

Radio AGN out to z~4:

The VLA-COSMOS 3 GHz Large Project



PI: V. Smolčić

European Research Council

Credit: M. Novak

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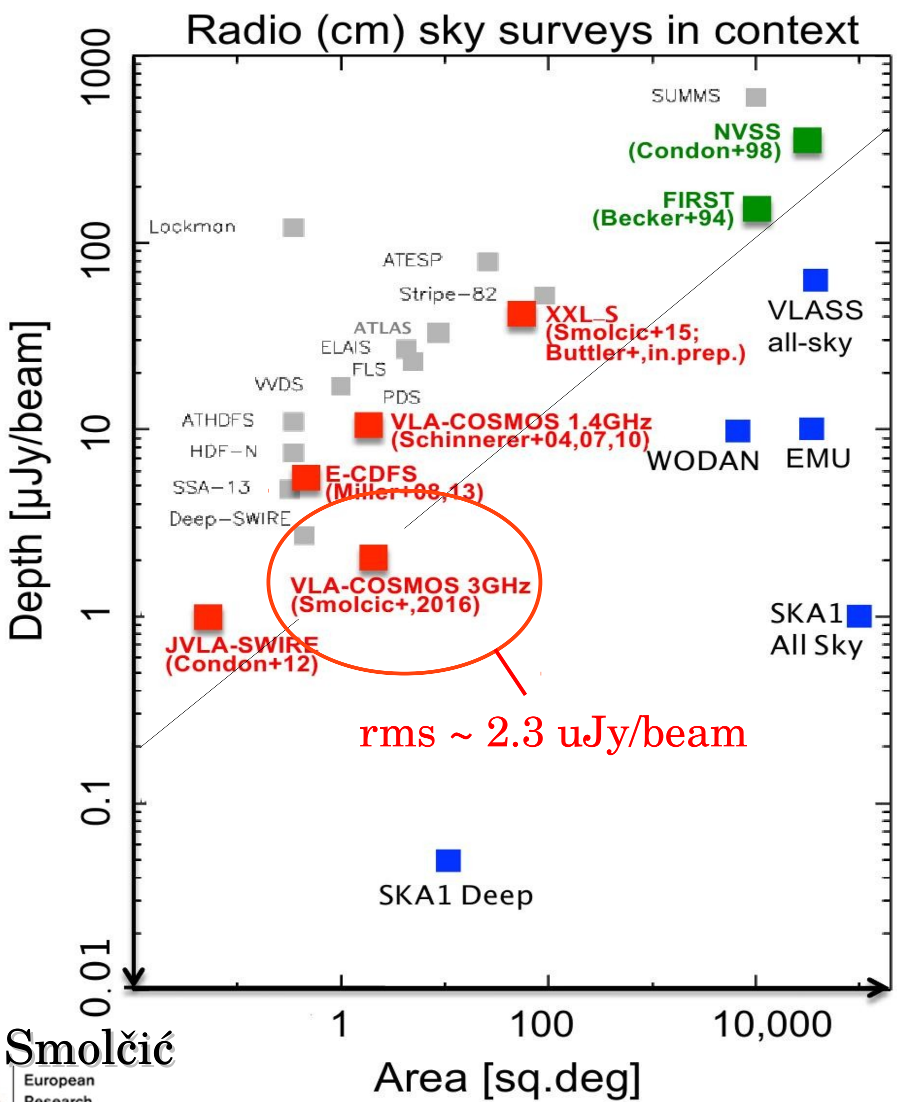

- 7729 radio sources selected at 3 GHz (10 cm) at 0.75“ resolution, with optical/NIR counterpart in the COSMOS2015 catalogue (Smolčić, ID et al. 2017b).
- Press release on A&A special issue: http://cosmos.astro.caltech.edu/news/52

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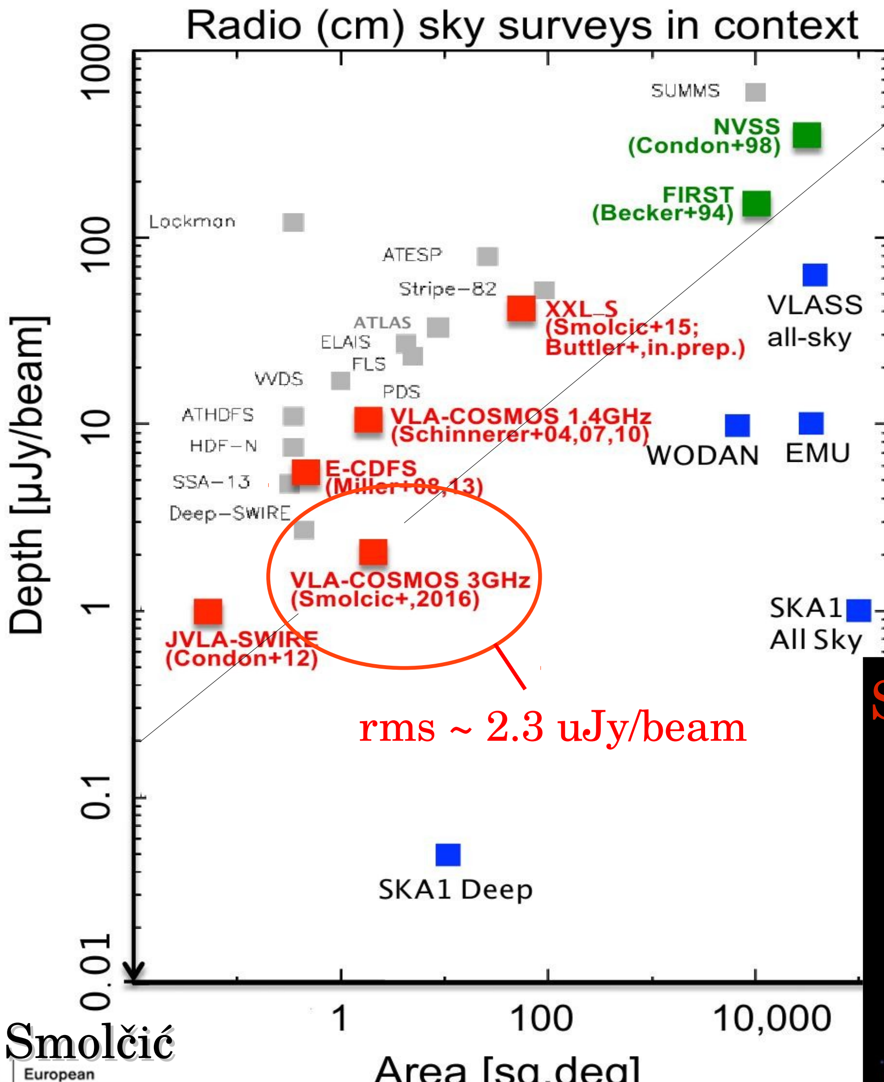

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European Research Council

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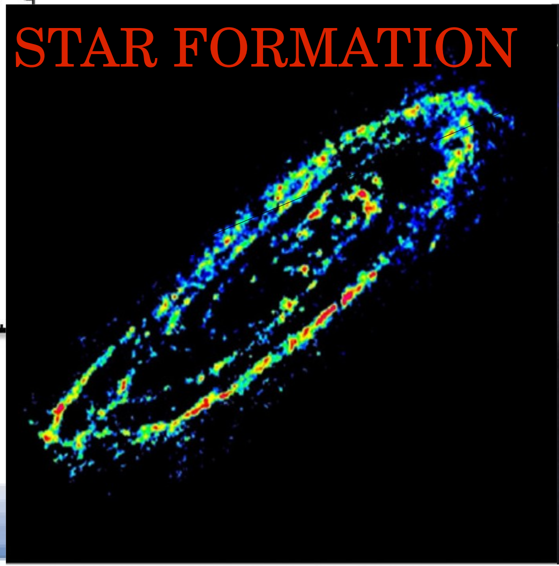
Radio emission:



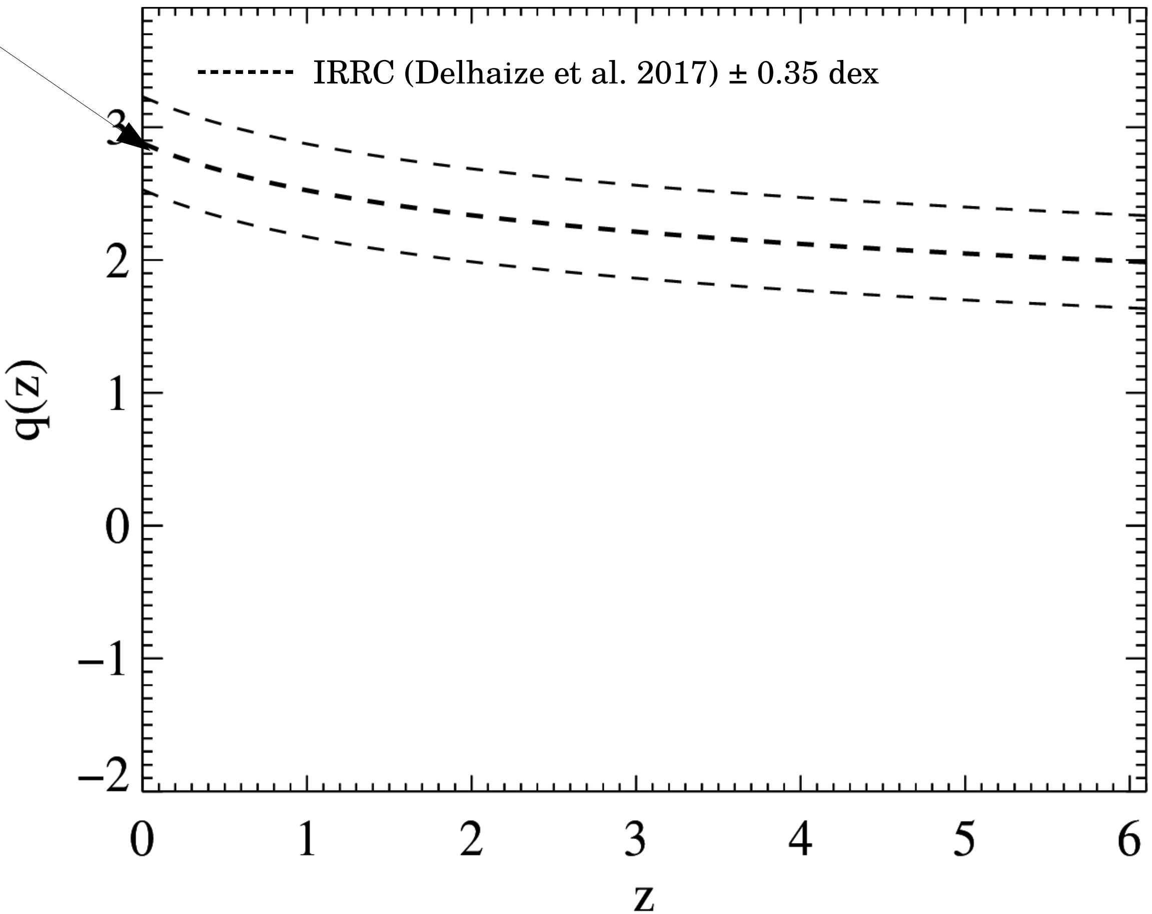
The infrared-radio correlation

- $q = log(L_{IR} \ / \ L_{radio})$

In our VLA sample:

L_{IR} decontaminated from AGN contribution (SED3FIT, Berta et al. 2013)

L_{radio} comes from AGN+SF



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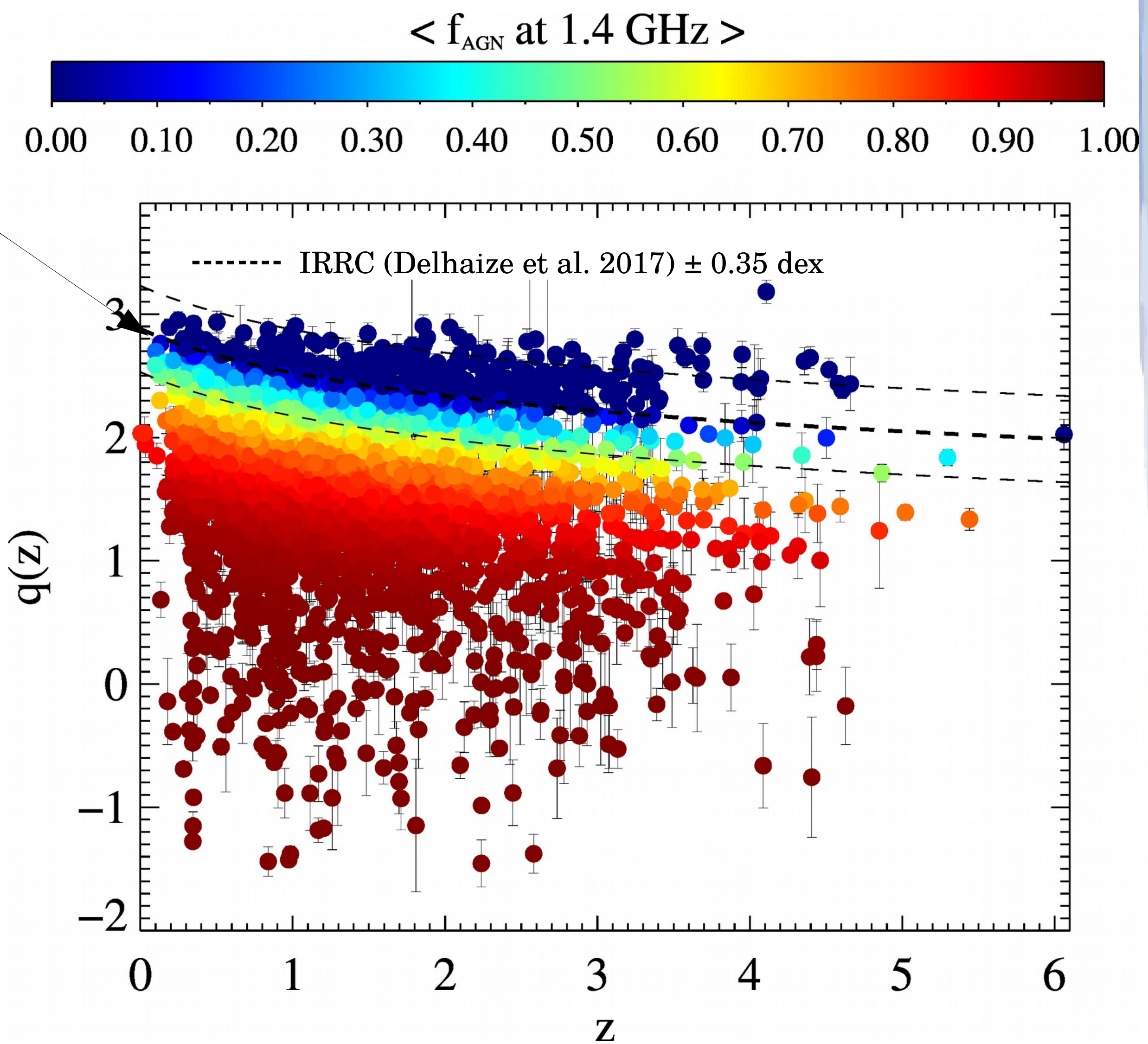
- We measure the q-offset from the IRRC as a proxy for the **radio AGN** emission

(Delhaize, Smolčić, ID et al. 2017)



(see also Bell et al. 2003; Ivison et al. 2010; Magnelli et al. 2015; Calistro Rivera et al. 2017)

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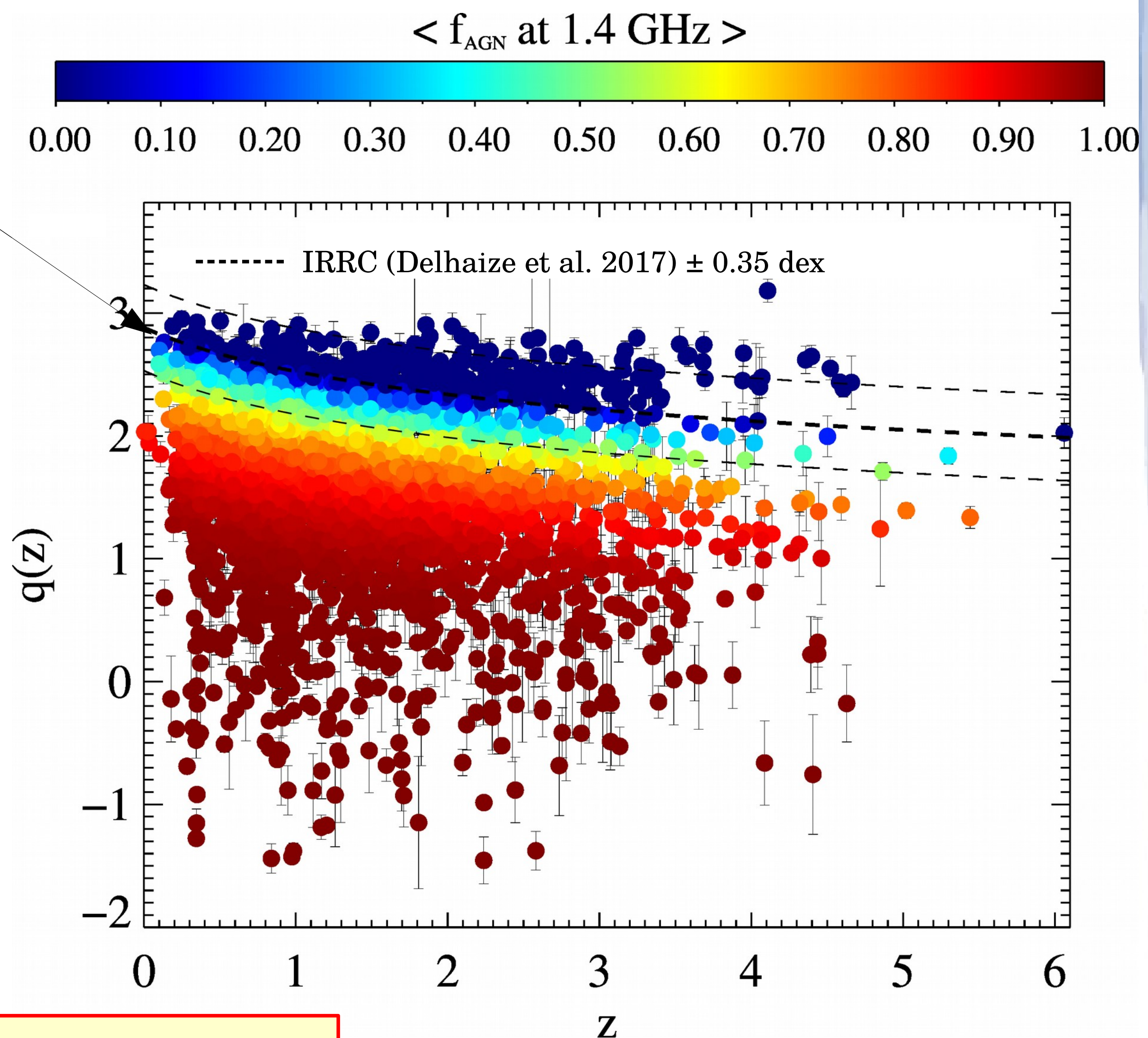
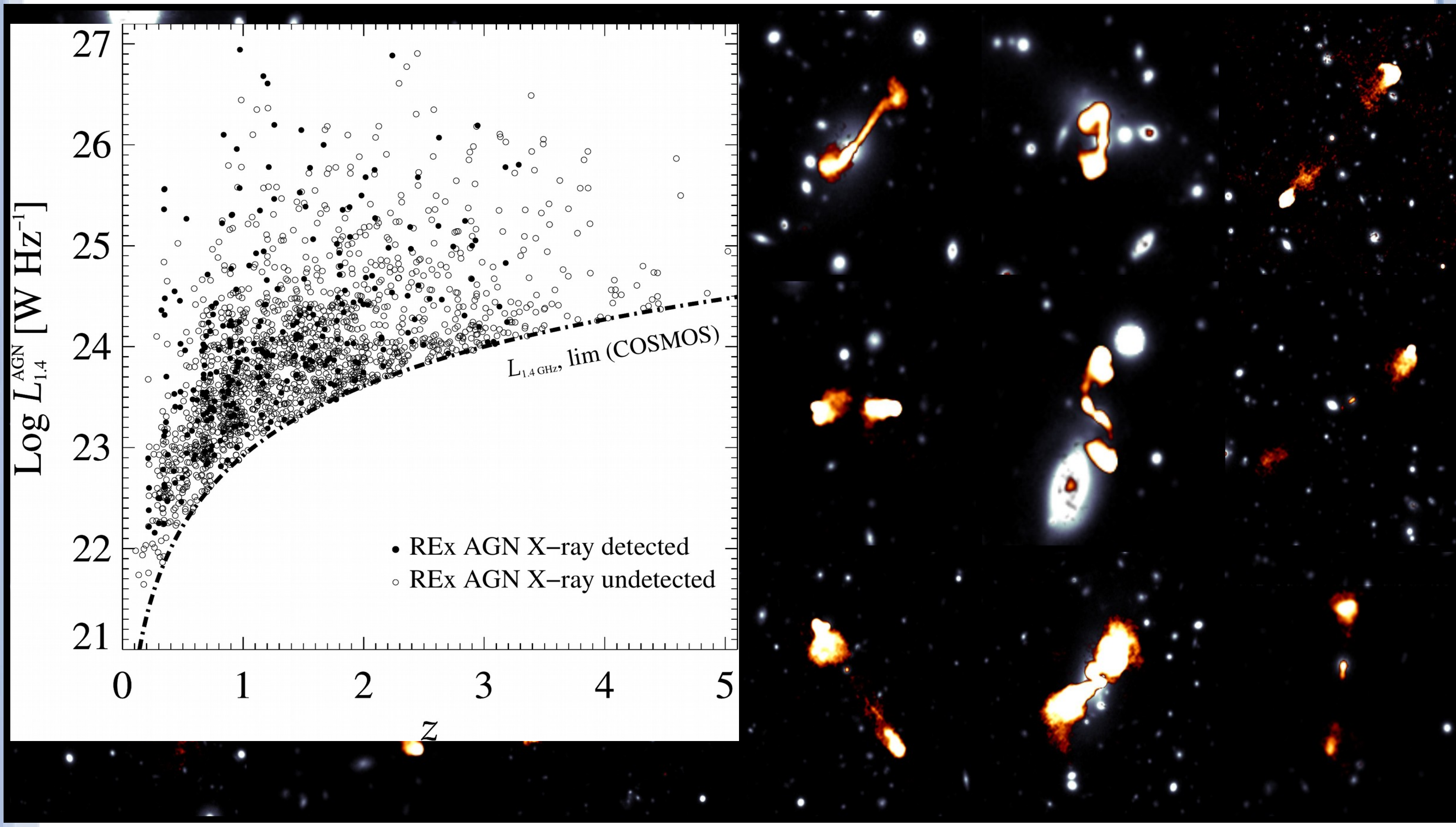


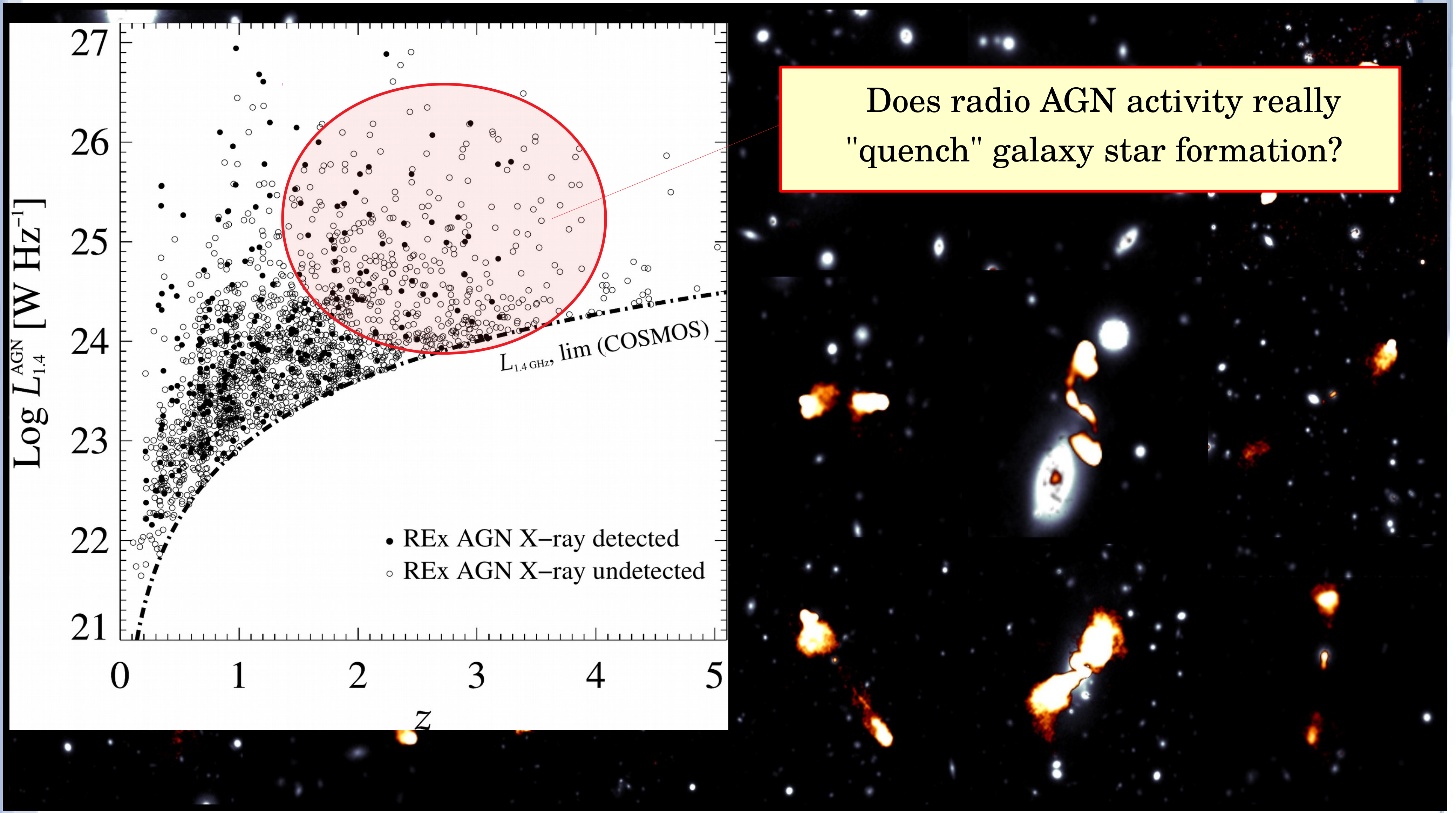
(>2σ) 5x radio excess → **1800 radio AGN**

(see also Bell et al. 2003; Ivison et al. 2010; Magnelli et al. 2015; Calistro Rivera et al. 2017)

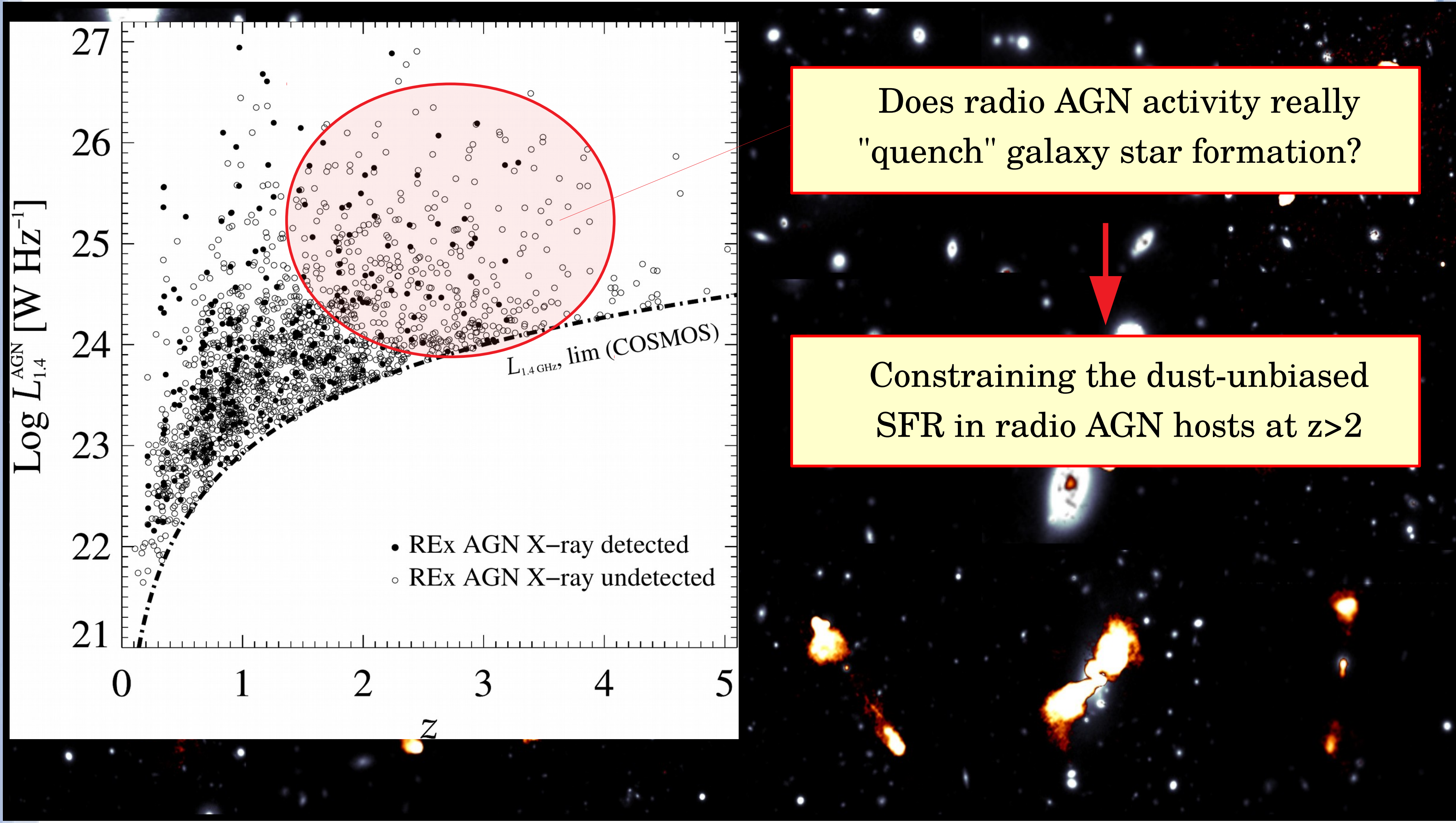
Radio-selected AGN in COSMOS



Radio-selected AGN in COSMOS



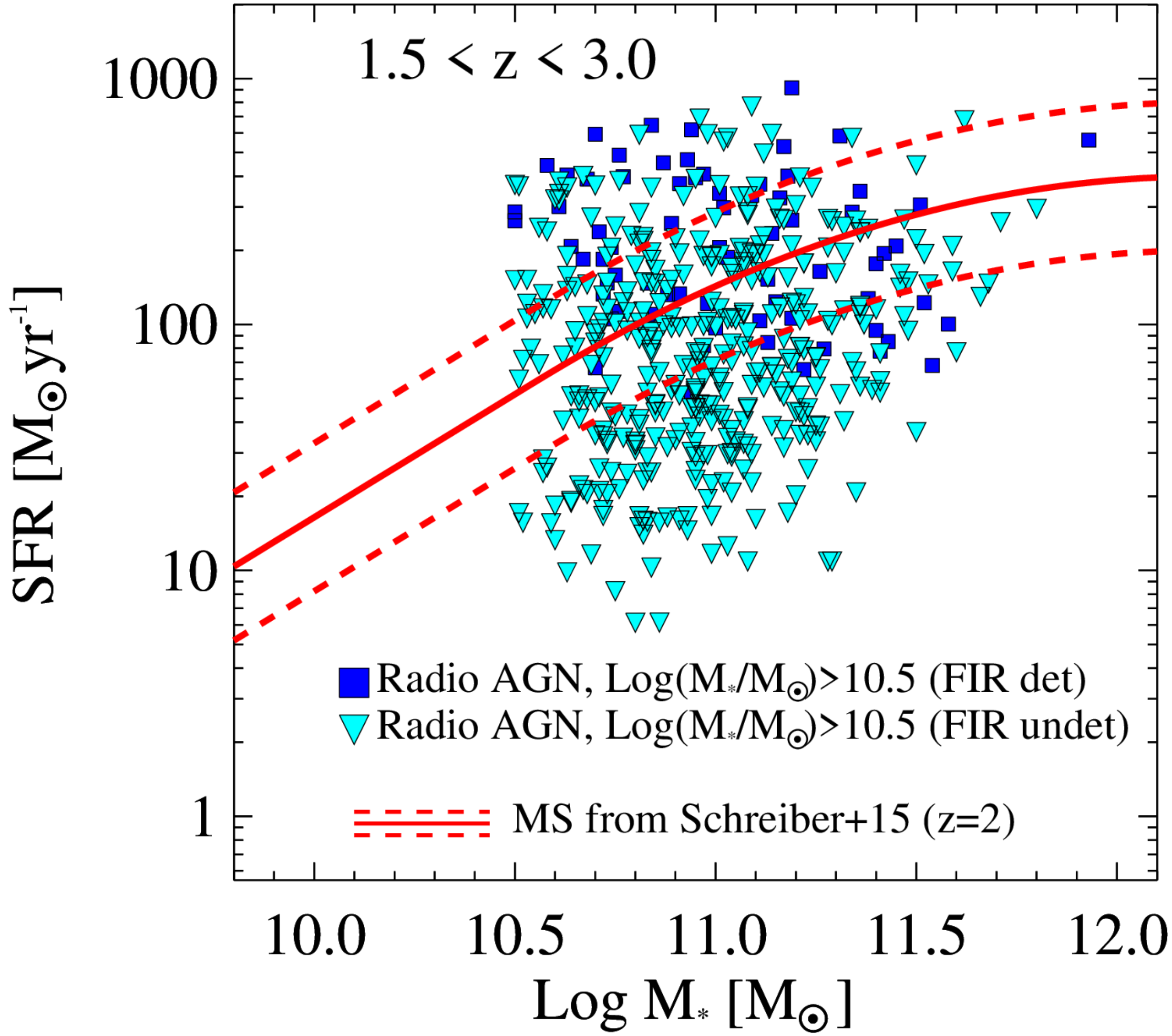
Radio-selected AGN in COSMOS



Does radio AGN activity really "quench" galaxy star formation?

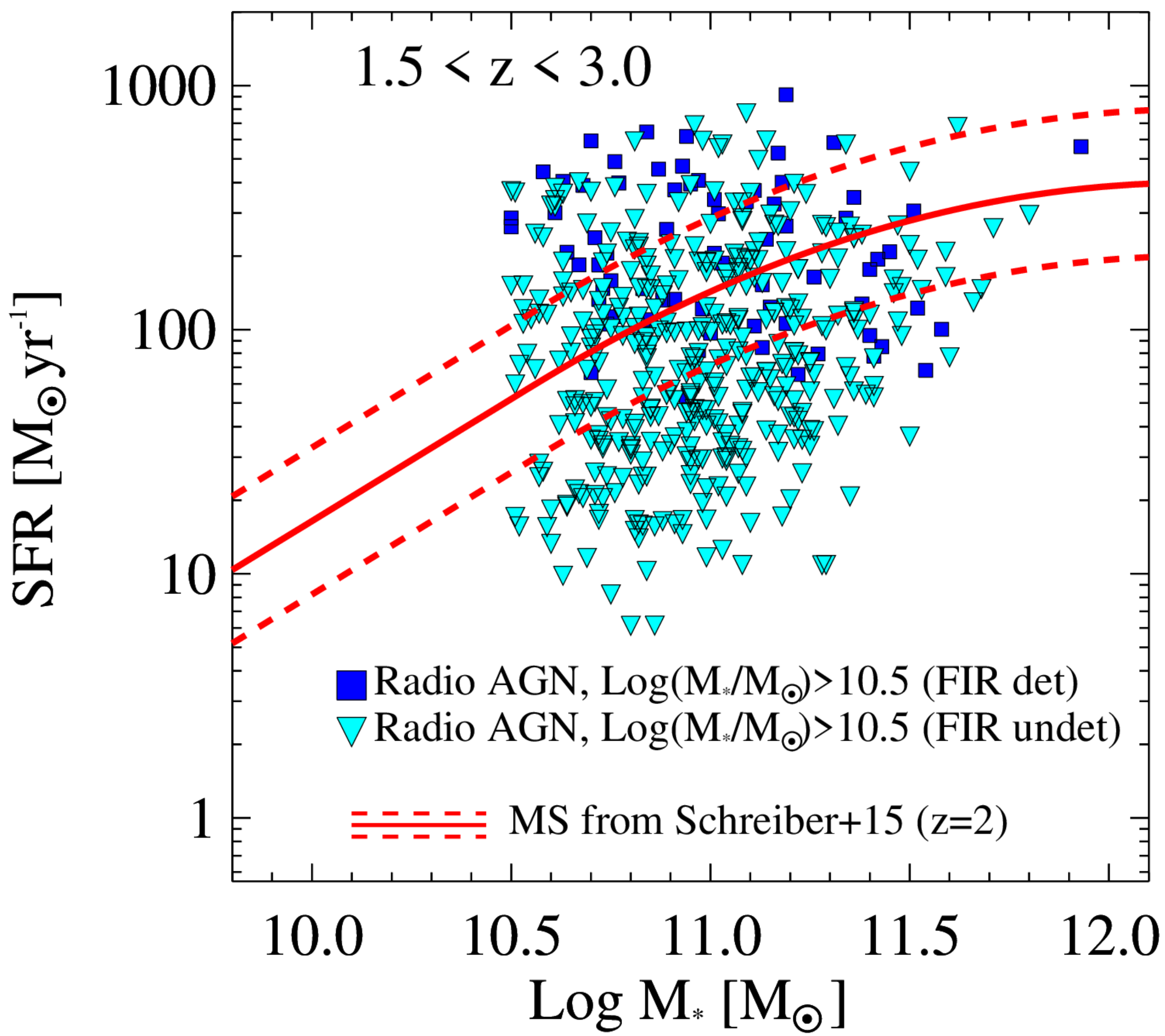
Constraining the dust-unbiased SFR in radio AGN hosts at z>2

Radio AGN hosts at z~2



Radio AGN hosts at z~2

- 85% radio AGN at z~2 and $M_* > 5x10^{10}$ Msun are **undetected by *Herschel***
- SFR limits (5σ) are consistent with Radio AGN being around the main sequence (same with *UVJ*)



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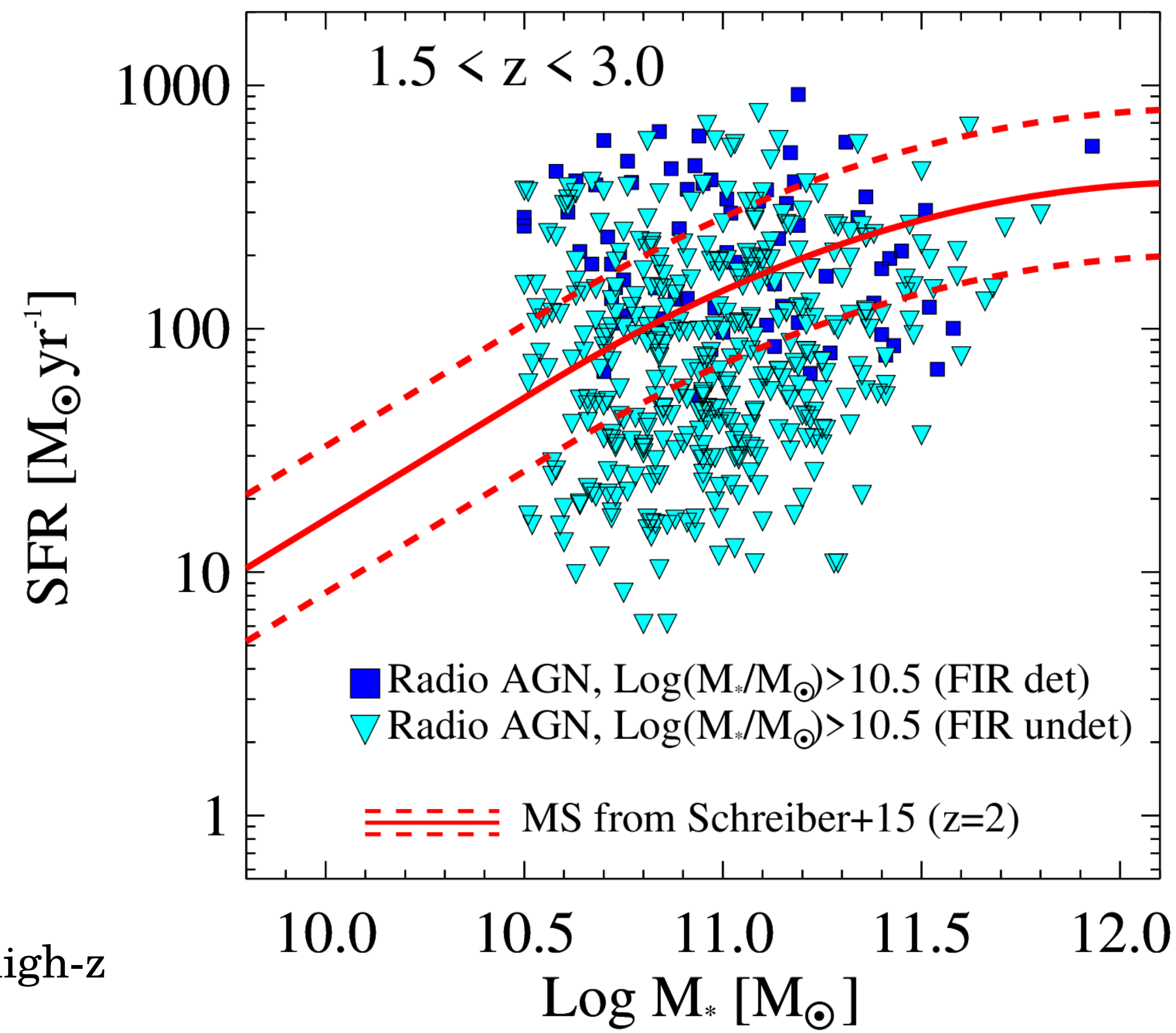
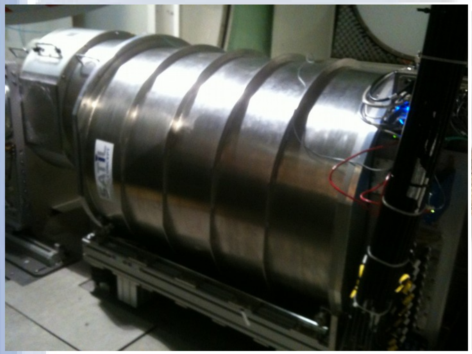
- 85% radio AGN at z~2 and M_*>5x10^{10} Msun are **undetected by *Herschel***
- SFR limits (5σ) are consistent with Radio AGN being around the main sequence (same with *UVJ*)
- Deep mm surveys are needed for:

  (1) measuring their SFR
  (2) testing the AGN-driven quenching paradigm at high-z



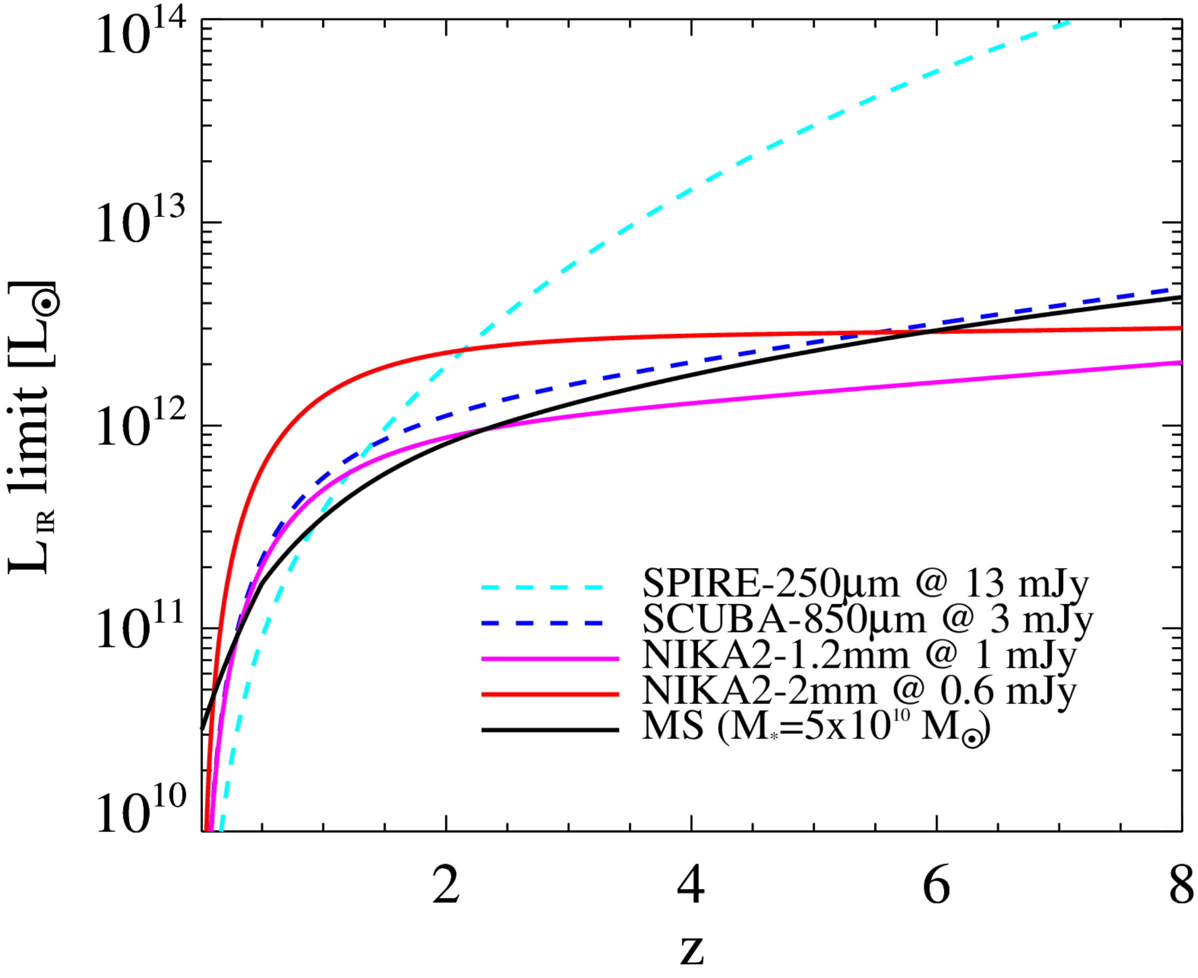
The synergy NIKA2 - radio

(1) Constraining the impact of radio AGN activity on galaxy SFR at z>2;

(2) Calibrating radio and mm emission as SFR tracers at z>2

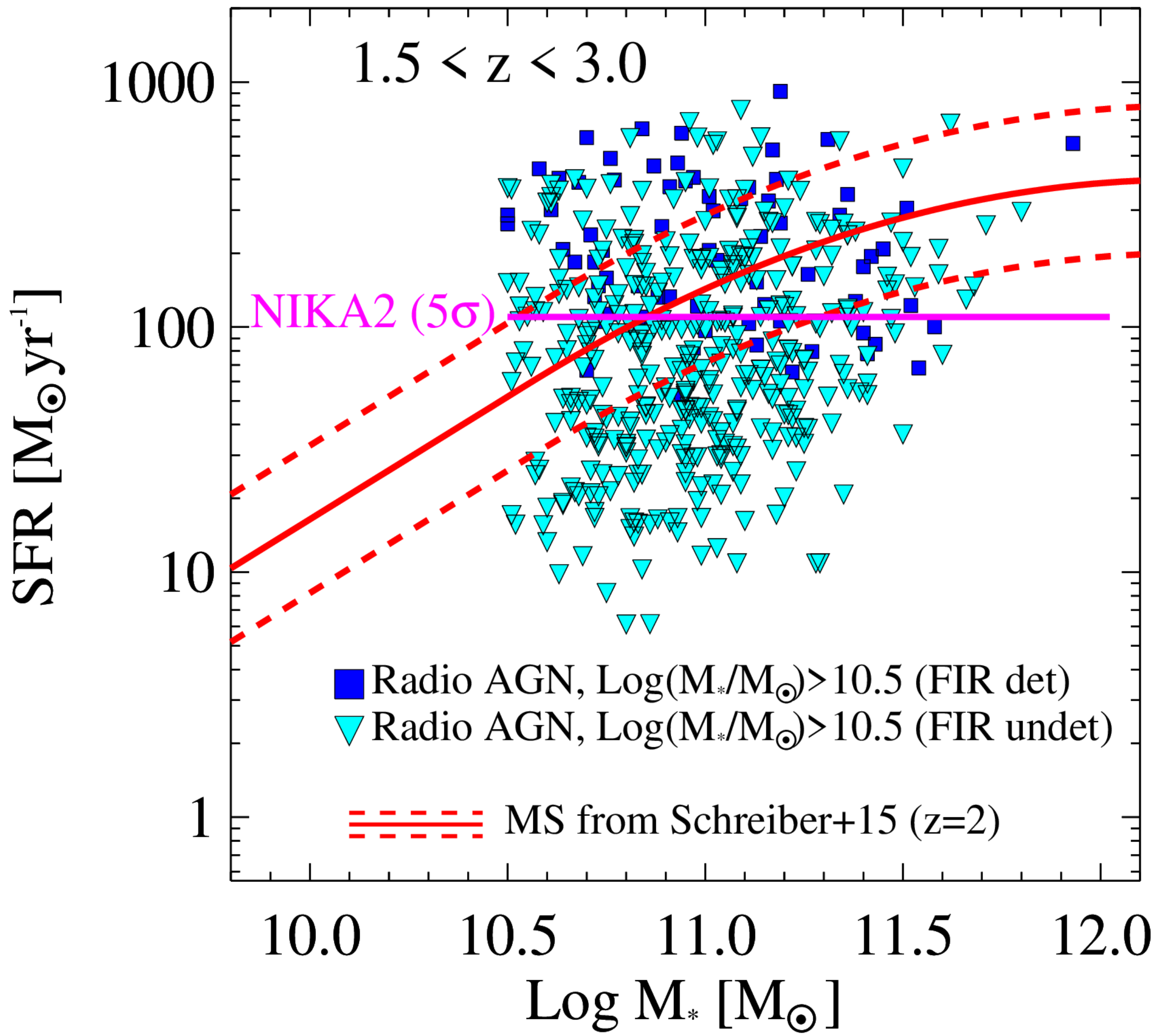
NIKA2: a deep view of normal high-z galaxies

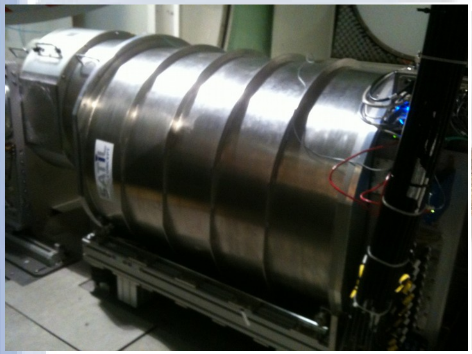
- Large survey (0.5 deg^2) of COSMOS at 1.2 and 2 mm
- Looking at massive MS galaxies at z>2 down to 10^{12} Lsun (= 100 Msun/yr)



NIKA2: a deep view of normal high-z galaxies

- Large survey (0.5 deg^2) of COSMOS at 1.2 and 2 mm
- Looking at massive MS galaxies at z>2 down to 10^{12} Lsun (= 100 Msun/yr)
- Potentially able to detect up to **50%** FIR-undetected radio AGN at z~2
- SED-fitting and stacking will infer first crucial constraints on the SFR distribution of radio AGN





The synergy NIKA2 - radio

(1) Constraining the impact of radio AGN activity on galaxy SFR at z>2;

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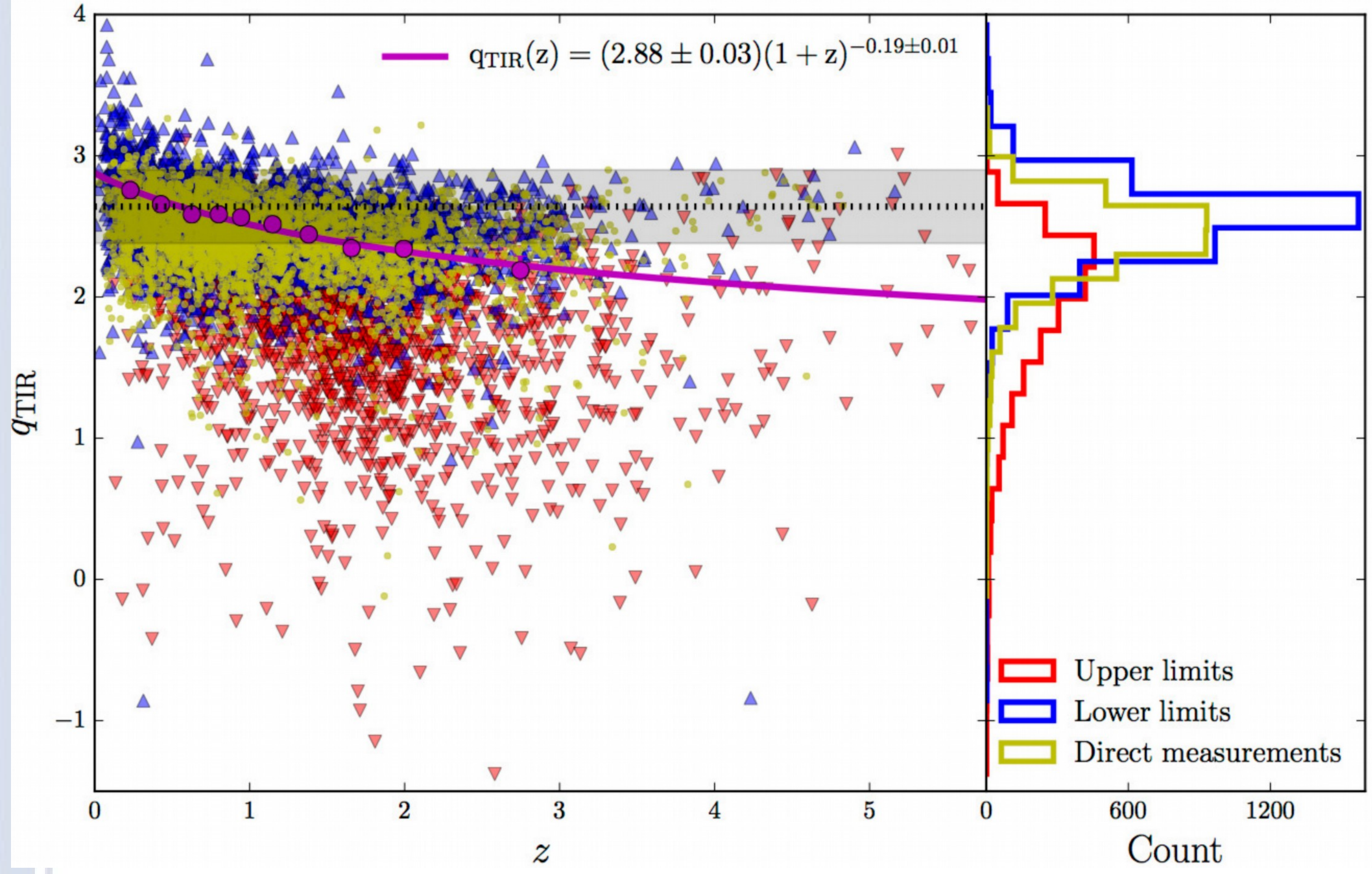
Calibrating mm & radio as SFR tracers

- Jointly-selected radio (VLA) and FIR (*Herschel*) samples



Calibrating mm & radio as SFR tracers

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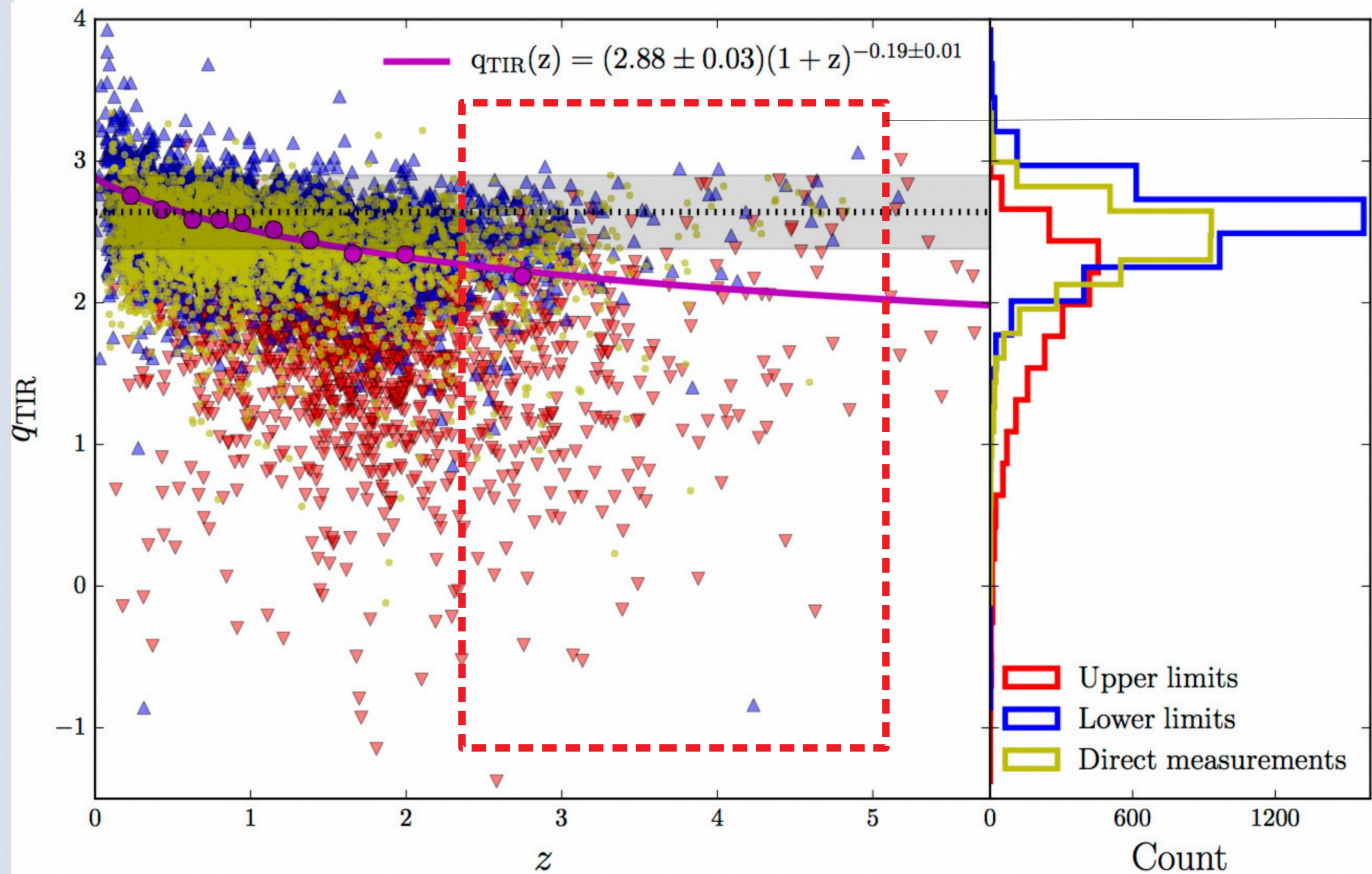
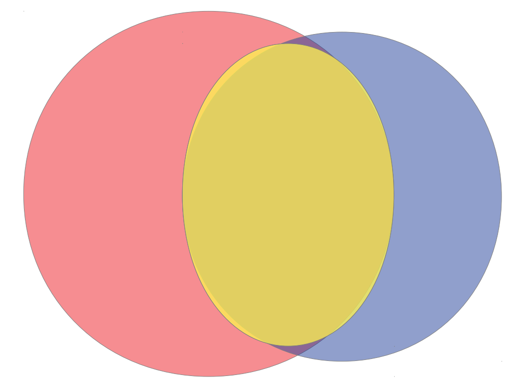


At z>2:



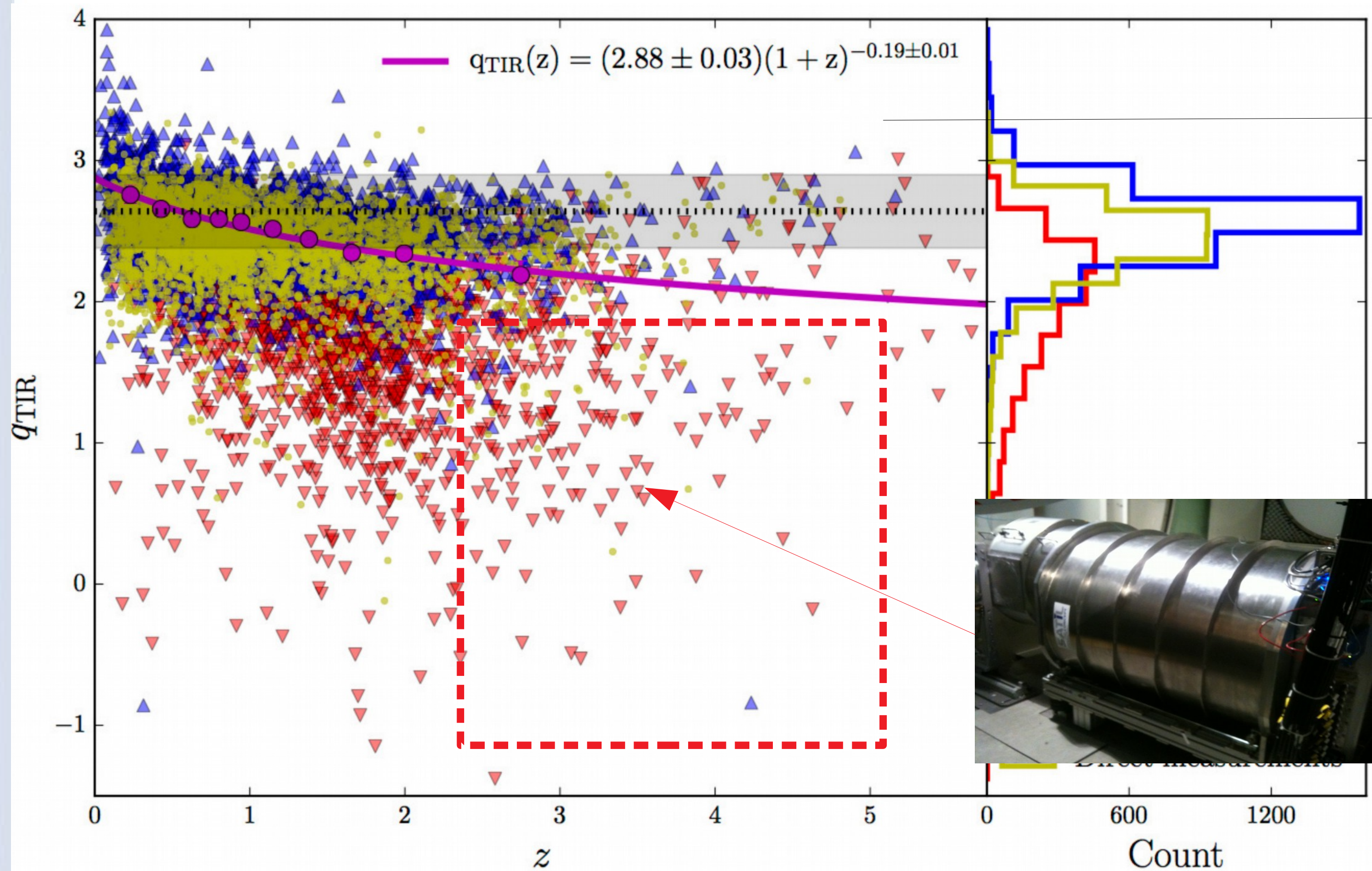
FIR not radio = 25%

Radio not FIR = 40%

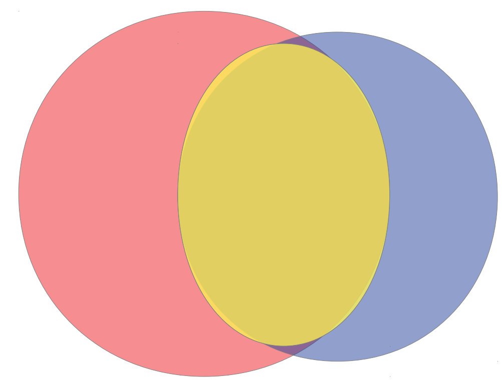
Radio & FIR = 35%

Calibrating mm & radio as SFR tracers

- Jointly-selected radio (VLA) and FIR (*Herschel*) samples



At z>2:



FIR not radio = 25%

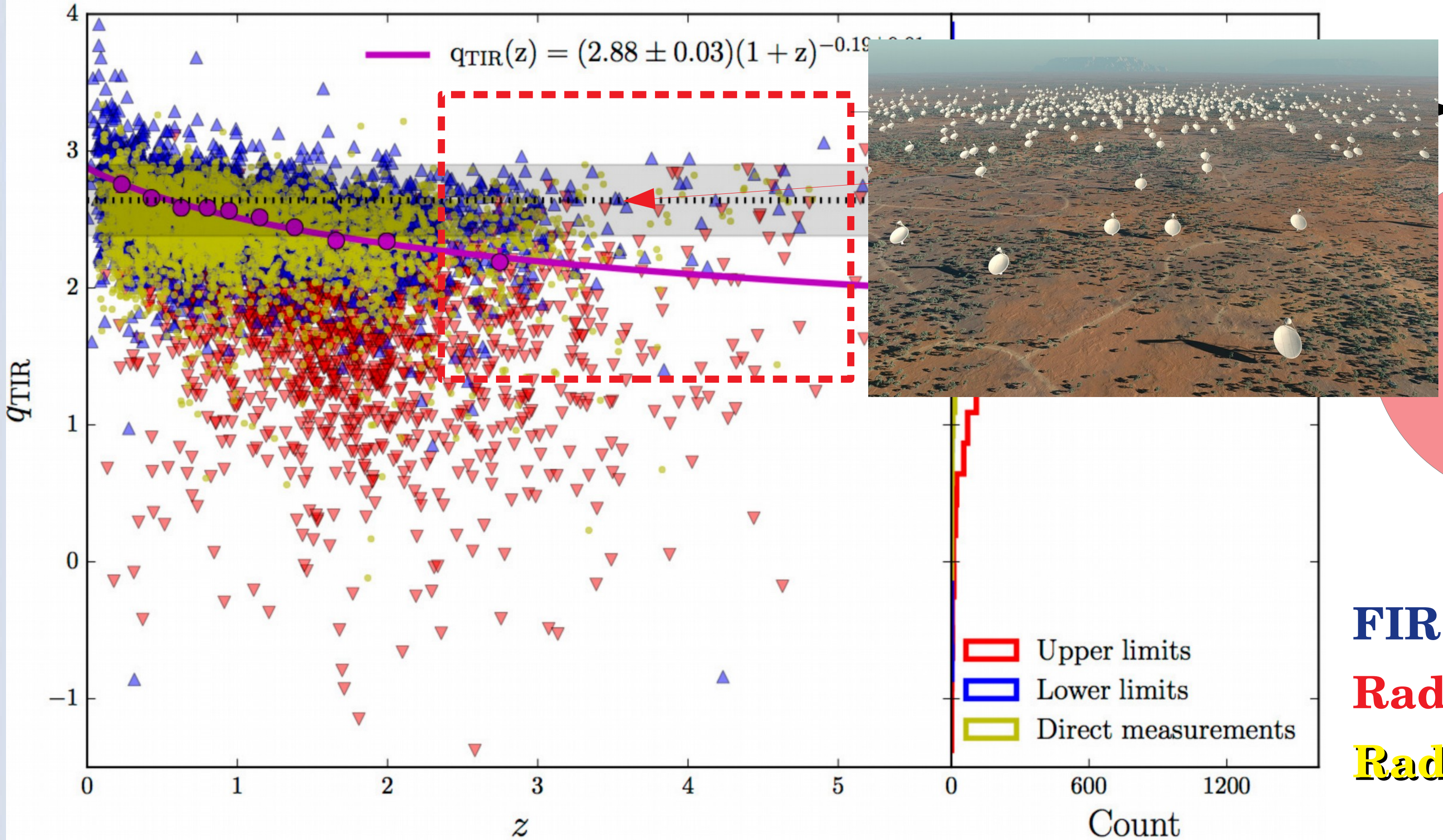
Radio not FIR = 40%

Radio & FIR = 35%

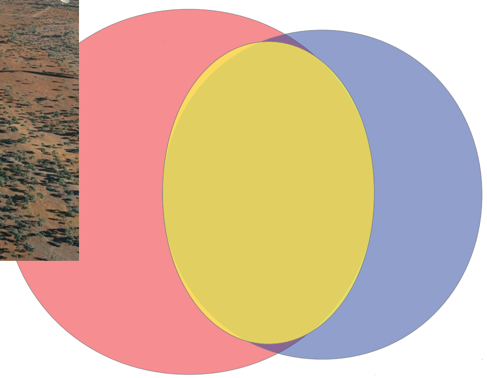
- **NIKA2** will double the number of FIR-detected MS galaxies at z>2
- Accurate galaxy SFRs and AGN parameters from SED-fitting decomposition and deblended IR-mm photometry (Jin, Daddi, …, ID et al. 2017)

Calibrating mm & radio as SFR tracers

- Jointly-selected radio (VLA) and FIR (*Herschel*) samples



At z>2:



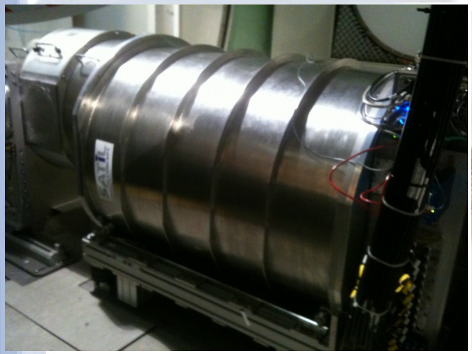
FIR not radio = 25%

Radio not FIR = 40%

Radio & FIR = 35%

SKA-MID1 will reach 1 μJy rms at ~10 mas resolution (<100 pc) in only 1 hour!

- subtraction of radio faint AGN emission
- dust-unbiased SFRs from synchrotron emission



Summary

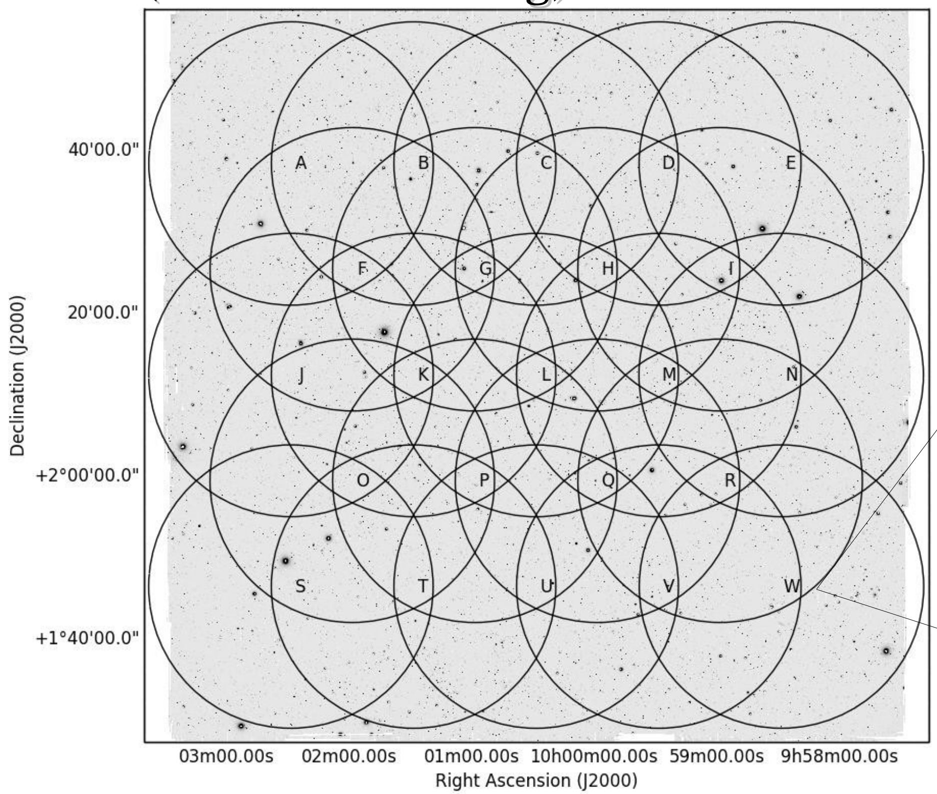
- NIKA2 will constrain up to 50% FIR-undetected radio AGN at z~2, providing a useful benchmark for testing the AGN-driven quenching scenario

- The synergy between NIKA2 and SKA will allow us to calibrate mm and radio emission as SFR tracers at high redshift

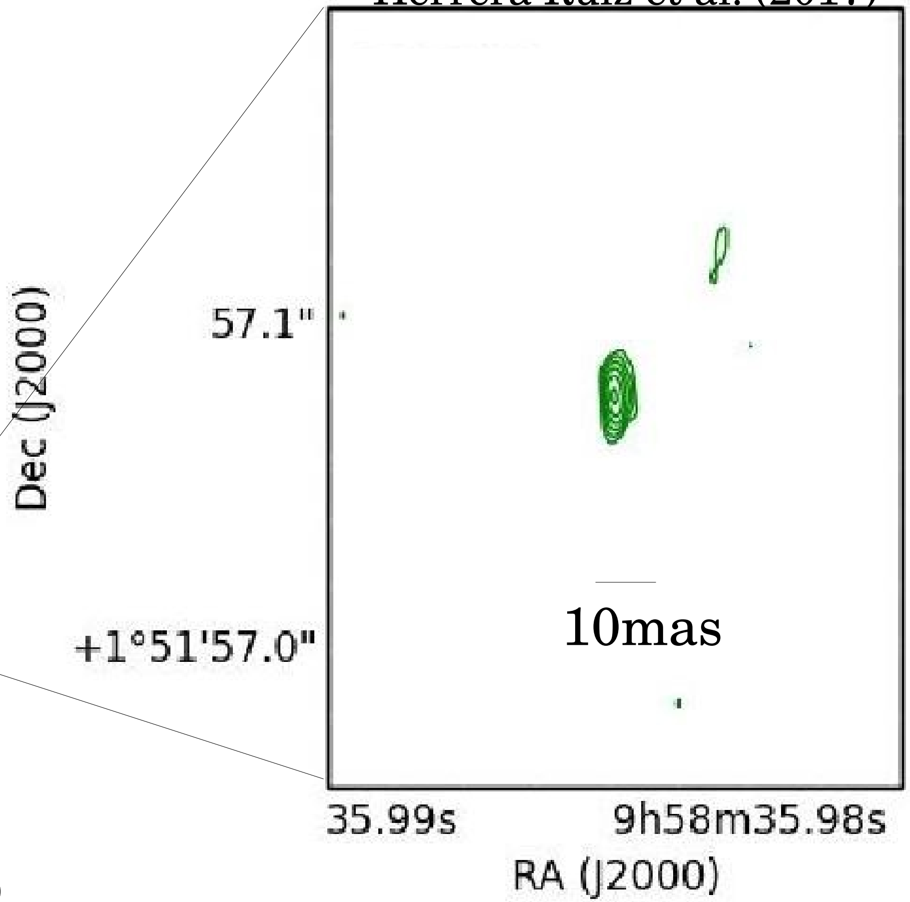
Supplementary slides

Overcoming host-galaxy dilution: VLBI interferometry

(PI: E. Middleberg)

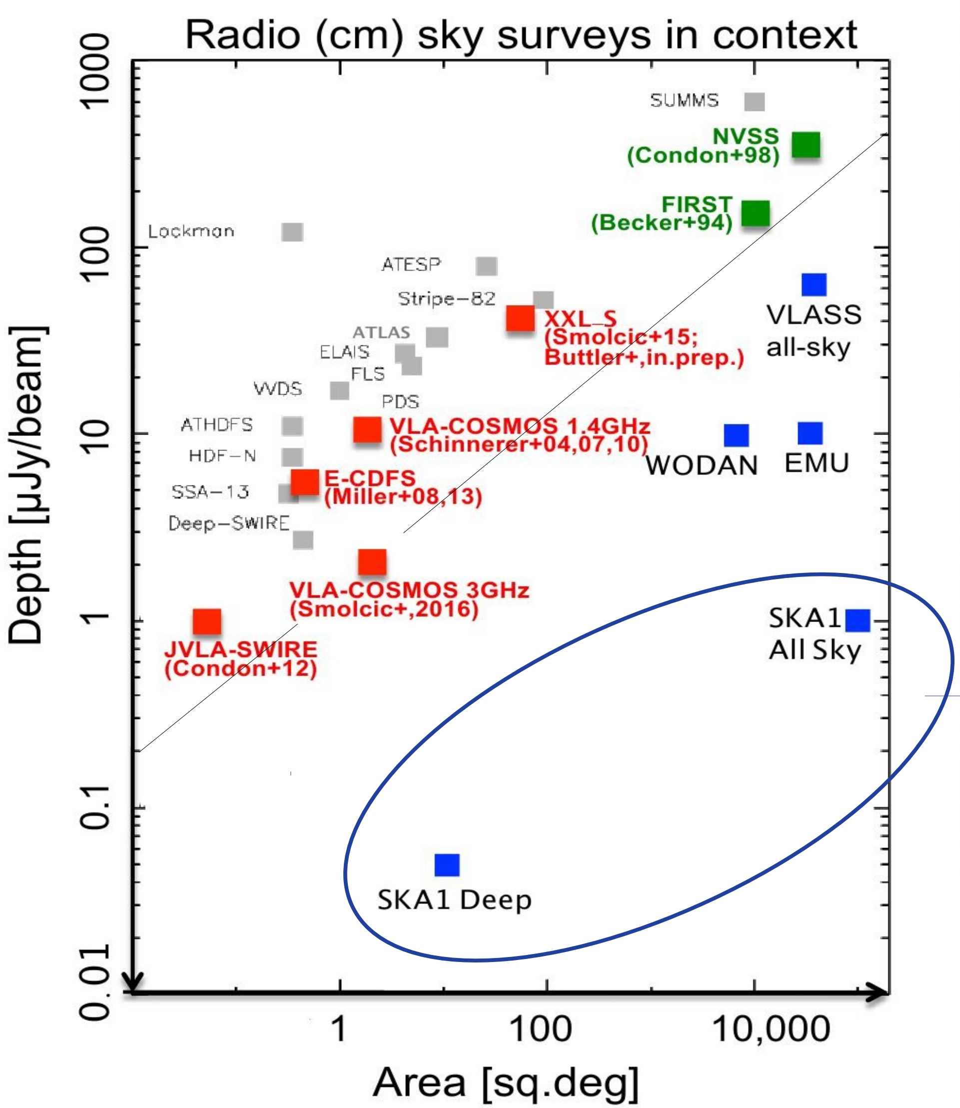


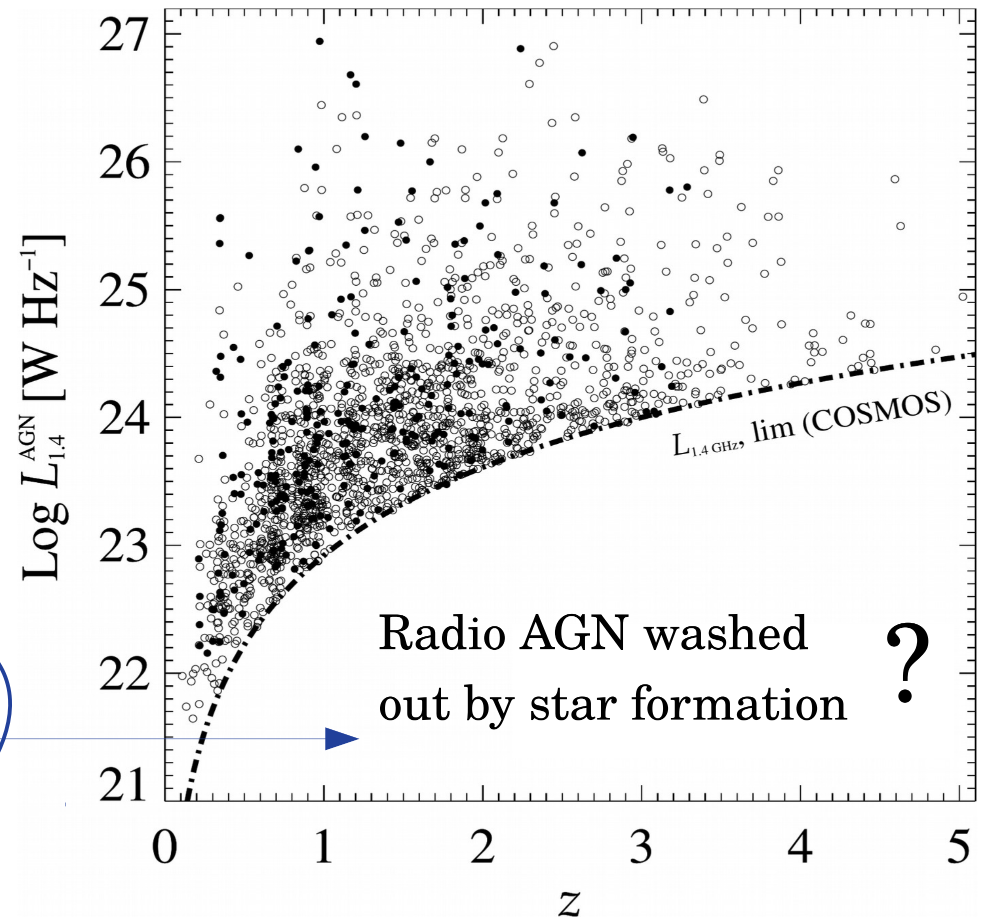
Herrera Ruiz et al. (2017)



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

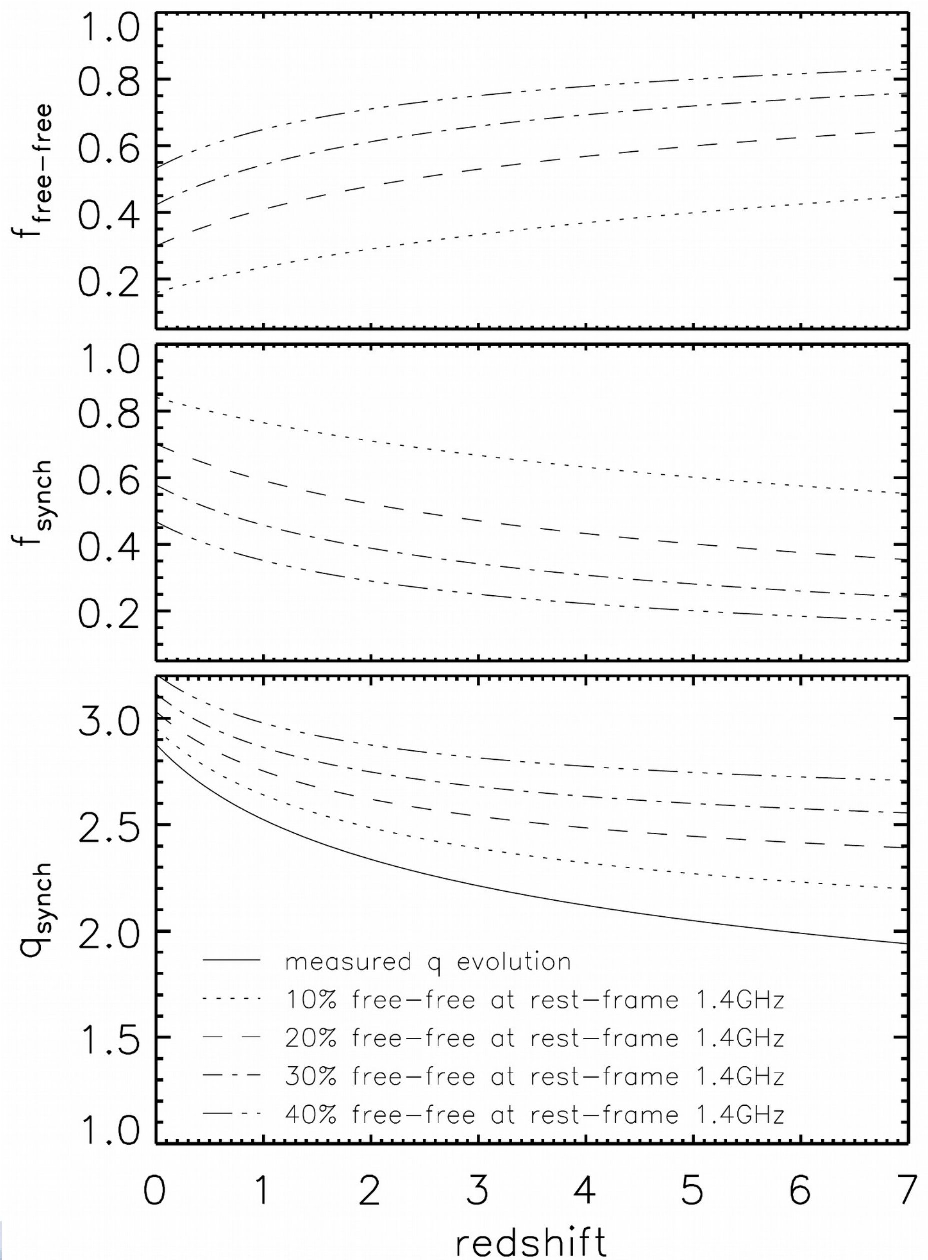
SKA: towards a full census of star formation

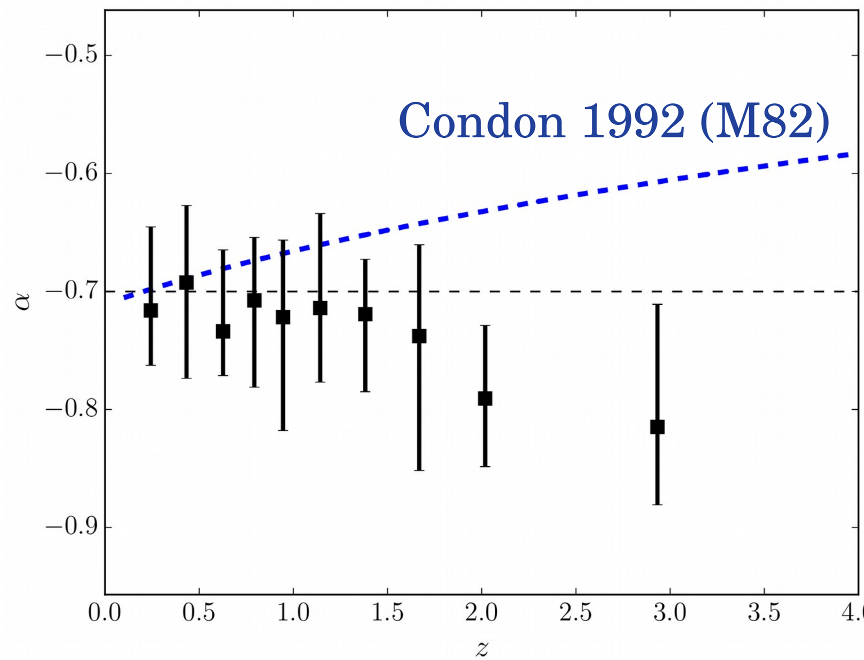




- Overcoming the host-galaxy dilution
- Pin down the AGN jet position at mas resolution (few pc)

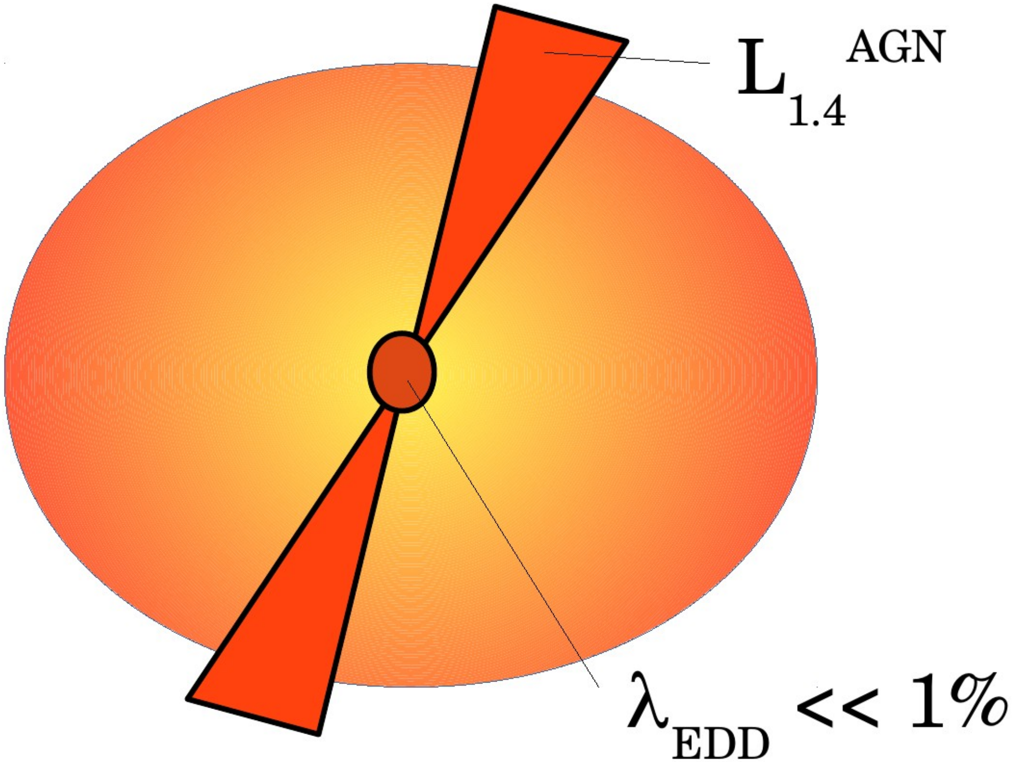
Free-free emission in the radio





An increasing free-free contribution at 1.4 GHz would imply flatter radio spectra and flatter q(z) than that observed.

Radio AGN: the picture at z<<1

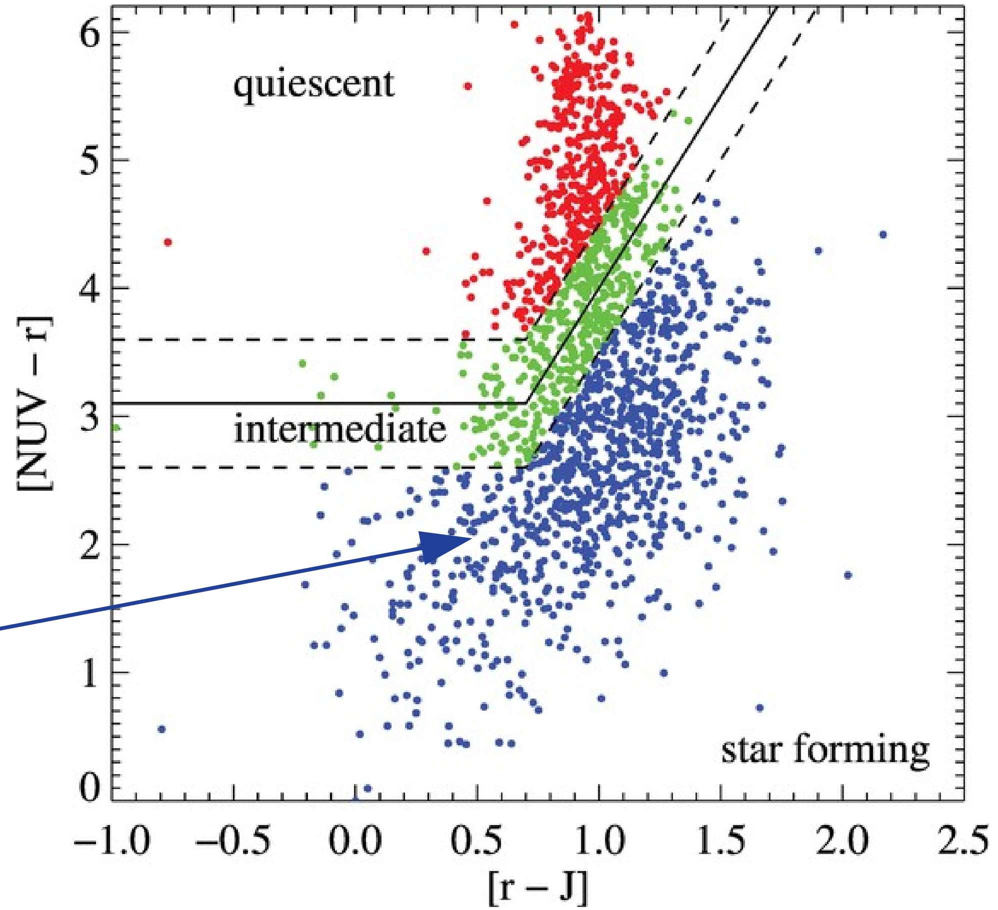


Radio AGN at z<1 are weakly accreting SMBHs predominantly hosted by massive and passive galaxies

Star formation in radio AGN hosts

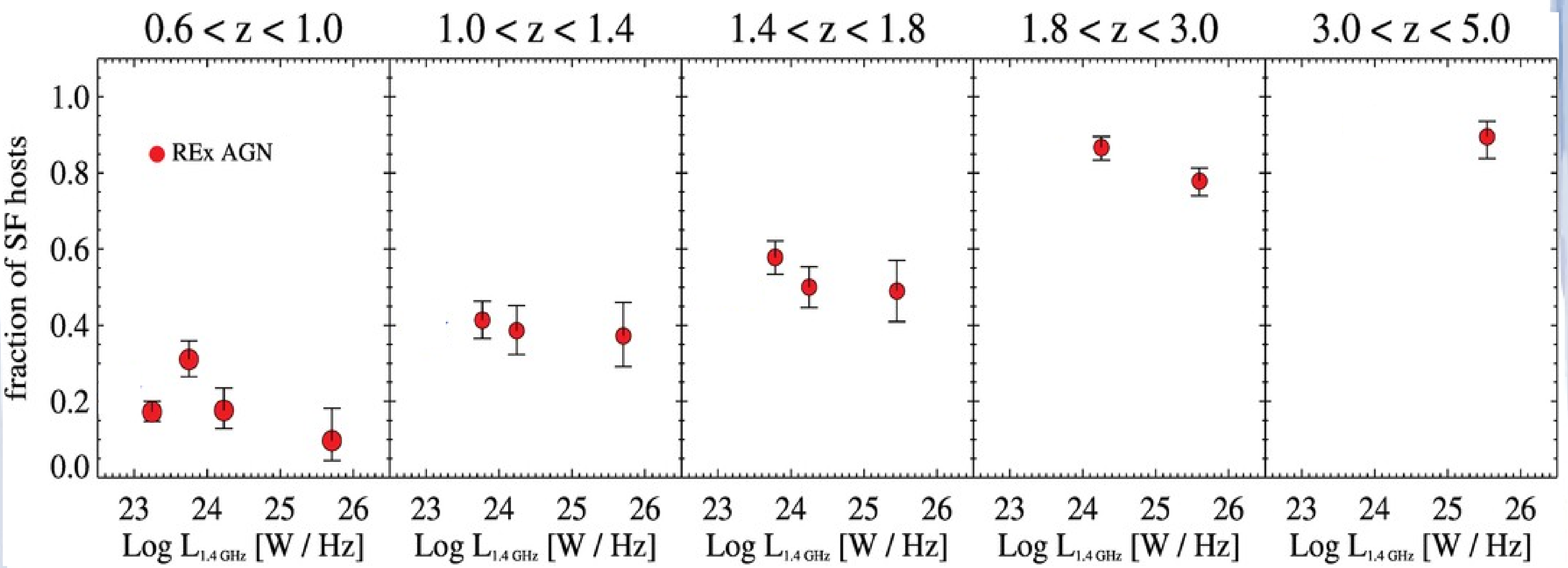
- *(NUV-r)* / *(r-J)* locus to identify **blue** (=star forming) radio AGN hosts
  (Ilbert et al. 2013; Davidzon et al. 2017)

$$f_{SF} = \frac{\#\ \text{SF Radio AGN hosts}}{\#\ \text{Radio AGN hosts}}$$



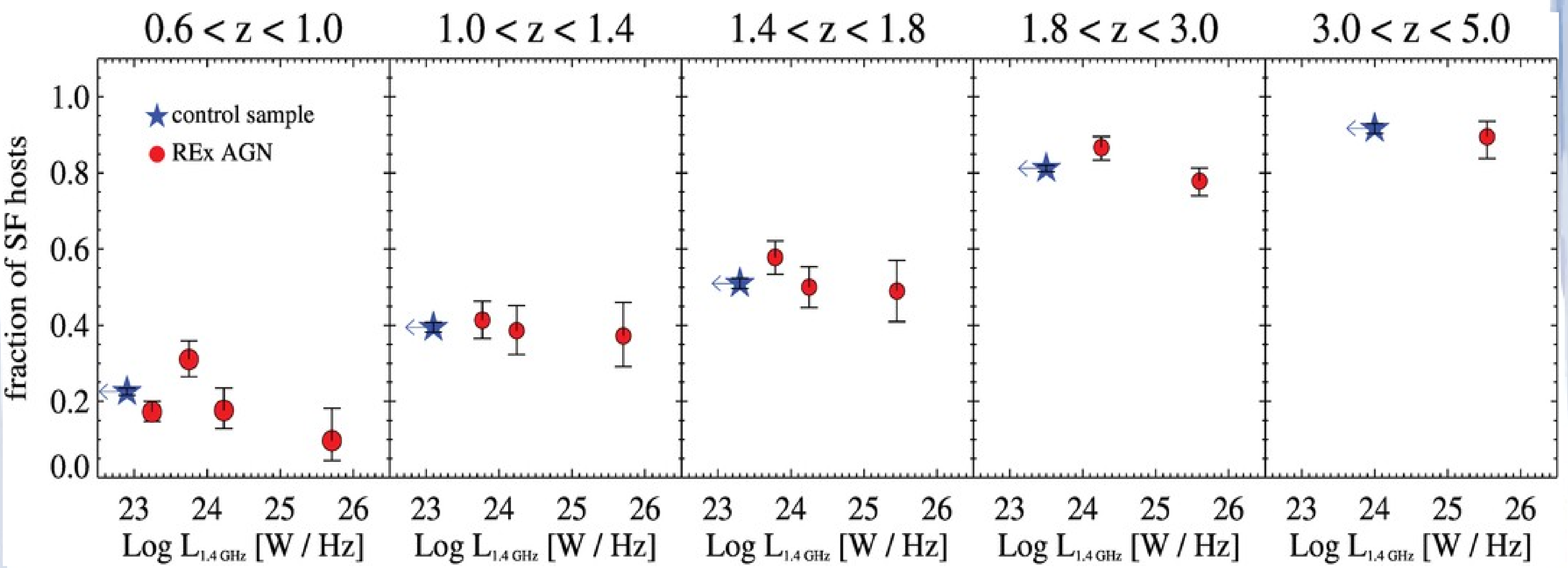
(qualitative proxy for star-forming content)

Star formation in radio AGN hosts



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

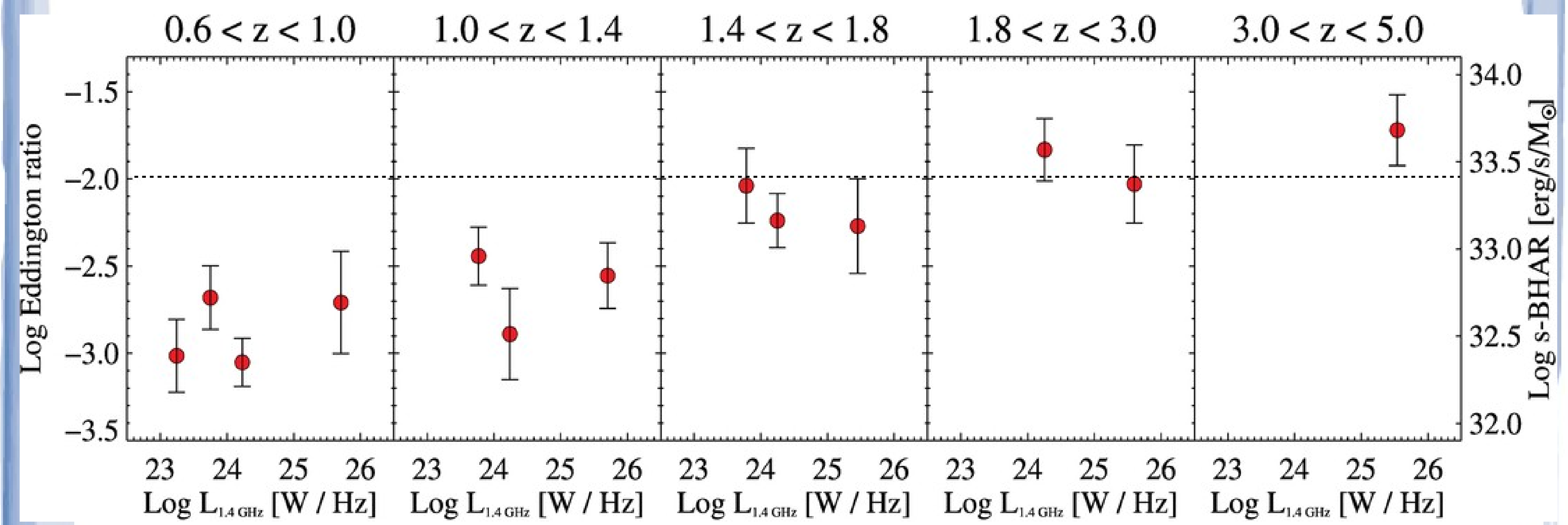
Star formation in radio AGN hosts



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

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

Average s-BHAR as a f($L_{1.4}$, z)



- The average s-BHAR increases by a factor of **10** from z~0.7 to z~3.5
- The Edd ratio exceeds 1% (=**radiatively efficient** BH accretion) at z>1.5 (Aird et al. 2018)