Clues on the evolving infrared-radio correlation towards the SKA era

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On behalf of:

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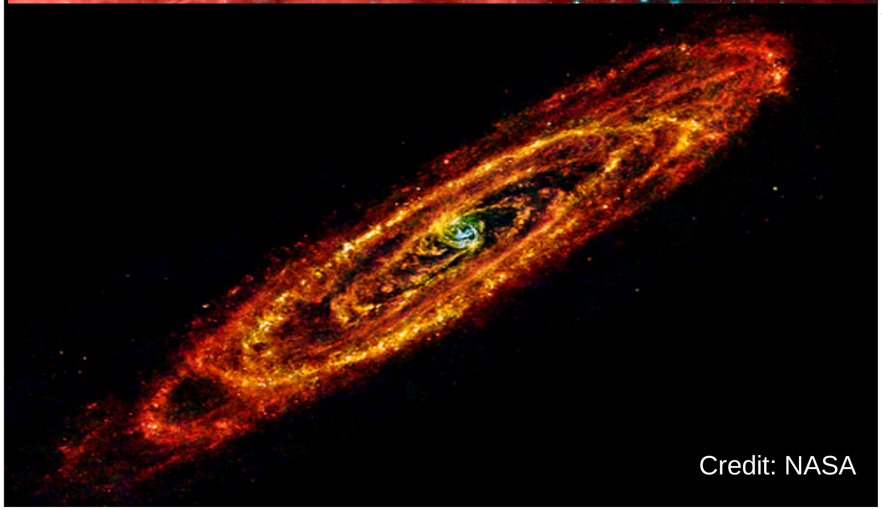
Radio → SFR : The infrared-radio correlation (IRRC)

INFRARED

- thermal emission from dust grains heated by young and fairly massive (>5 M_{sun}) stars → star formation rate (SFR)
  (e.g. Kennicutt & Evans 2012)

RADIO (continuum, ν~GHz)

- Non-thermal synchrotron emission from cosmic ray electrons accelerated by shock waves when massive (>8 M_{sun}) stars explode as SNe



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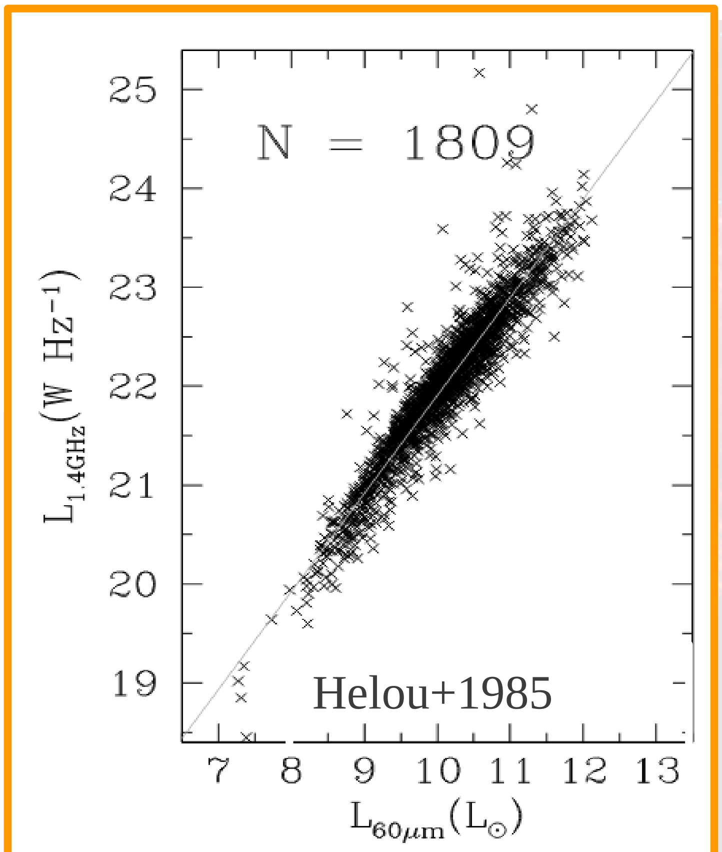
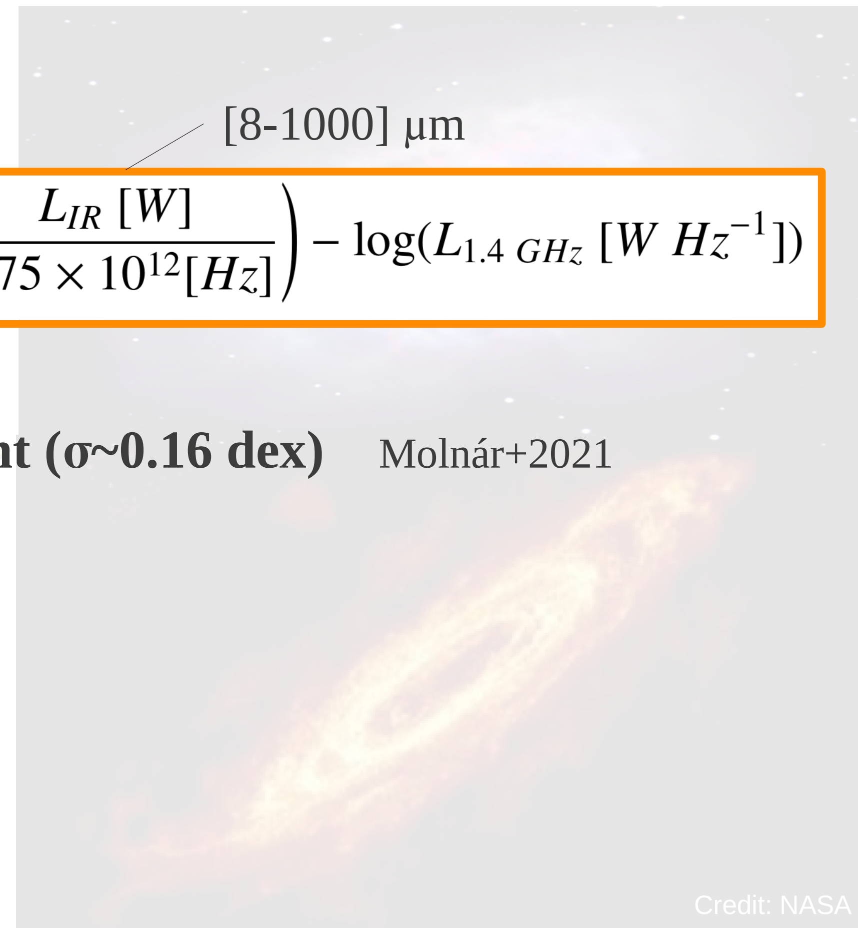


Credit: NASA



[8-1000] μm

$$q_{IR} = \log\left(\frac{L_{IR}\,[W]}{3.75\times10^{12}[Hz]}\right) - \log(L_{1.4\ GHz}\ [W\ Hz^{-1}])$$

- **Very tight (σ~0.16 dex)** Molnár+2021

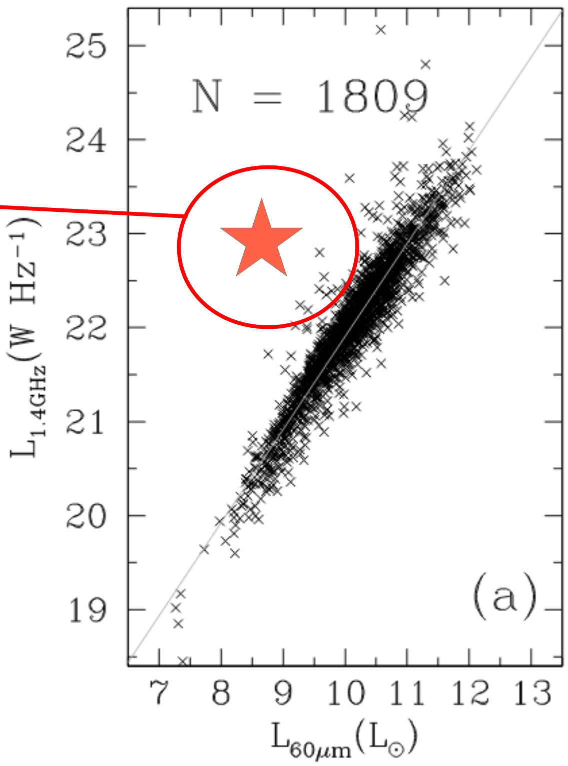
Credit: NASA

Why is the IRRC so important?

1) It sets a benchmark to use radio-continuum emission as **SFR indicator** (Prandoni & Seymour 2015)

$L_{1.4GHz}$ → q_{IR} → L_{IR} → L_{IR}-SFR → **SFR**

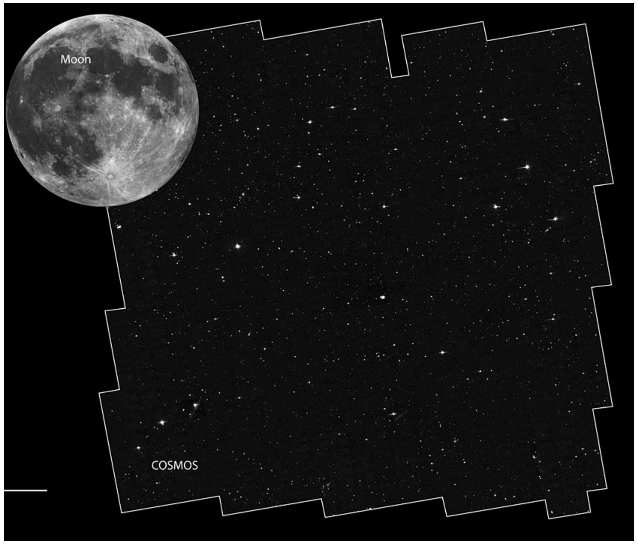
2) It can be used to spot **'radio-excess AGN'**
(e.g. Donley+2005; Del Moro+2013; Bonzini+2015; Delvecchio+2017; Hardcastle+2019)

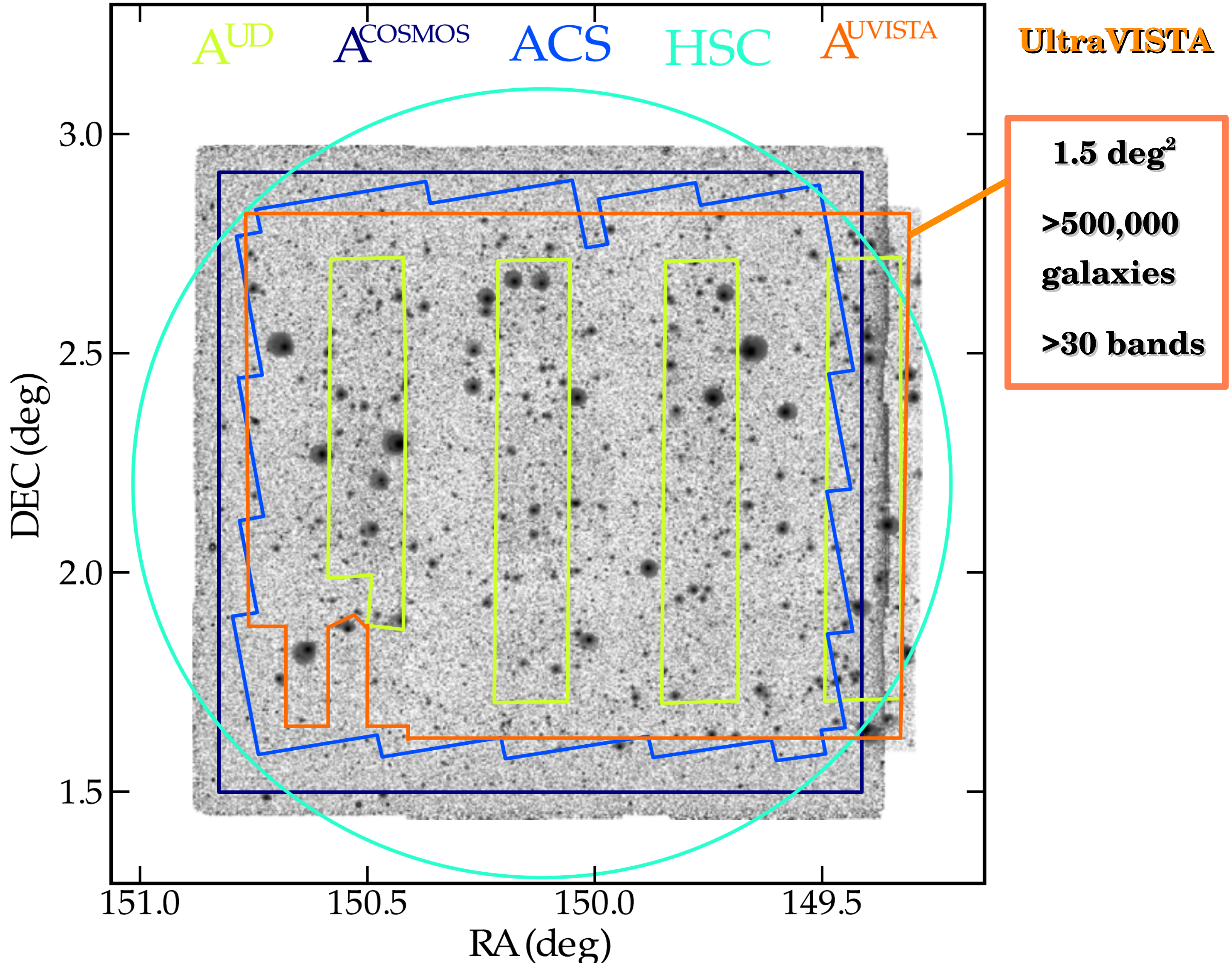


(e.g. Harwit & Pacini 1975; Rickard & Harvey 1984; de Jong+1985; Helou+1985; Hummel+1988; Condon 1992; Garrett 2002; Appleton+2004; Murphy+2008; Jarvis+2010; Sargent+2010; Ivison+2010a, 2010b; Bourne+2011; Smith+2014; Magnelli+2015; Calistro Rivera+2017; Delhaize+2017; Gürkan+2018; Read+2018; Molnár+2018; Algera+2020b; Smith+2021; Molnár+2021; Bonato+2021, ...)

Does the IRRC evolve with redshift and across the galaxy population?

The IRRC from a M_* selected sample in COSMOS





UV/Optical/NIR

MIR

COSMOS2015 catalogue (Laigle+2016) **+**

→

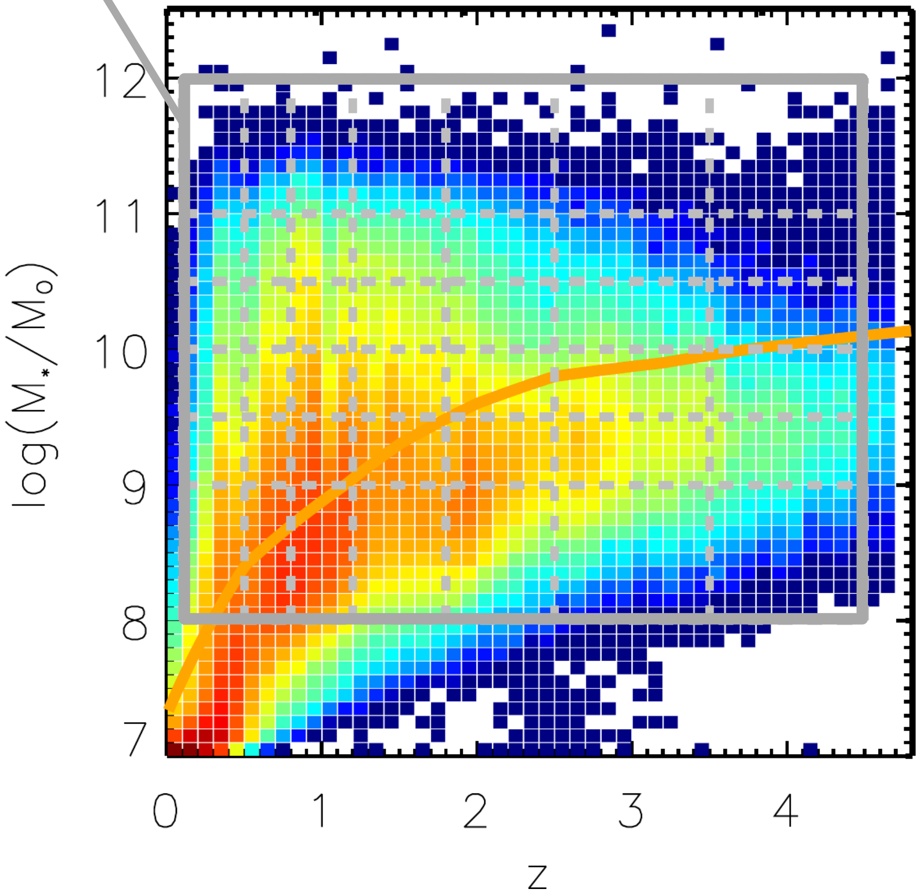
413,768
star-forming galaxies (SFGs) from (NUV-r / r-J) colours

The IRRC from a M_* selected sample in COSMOS

413,768 M_*-selected SFGs

8 < log(M_*/Msun) < 12

0.1 < z < 4.5



Our final sample: infrared and radio ancillary data

413,768 M_*-selected SFGs

8 < log(M_*/Msun) < 12

0.1 < z < 4.5

INFRARED

Herschel+SCUBA+AzTEC

Super-deblended (Jin+2018)

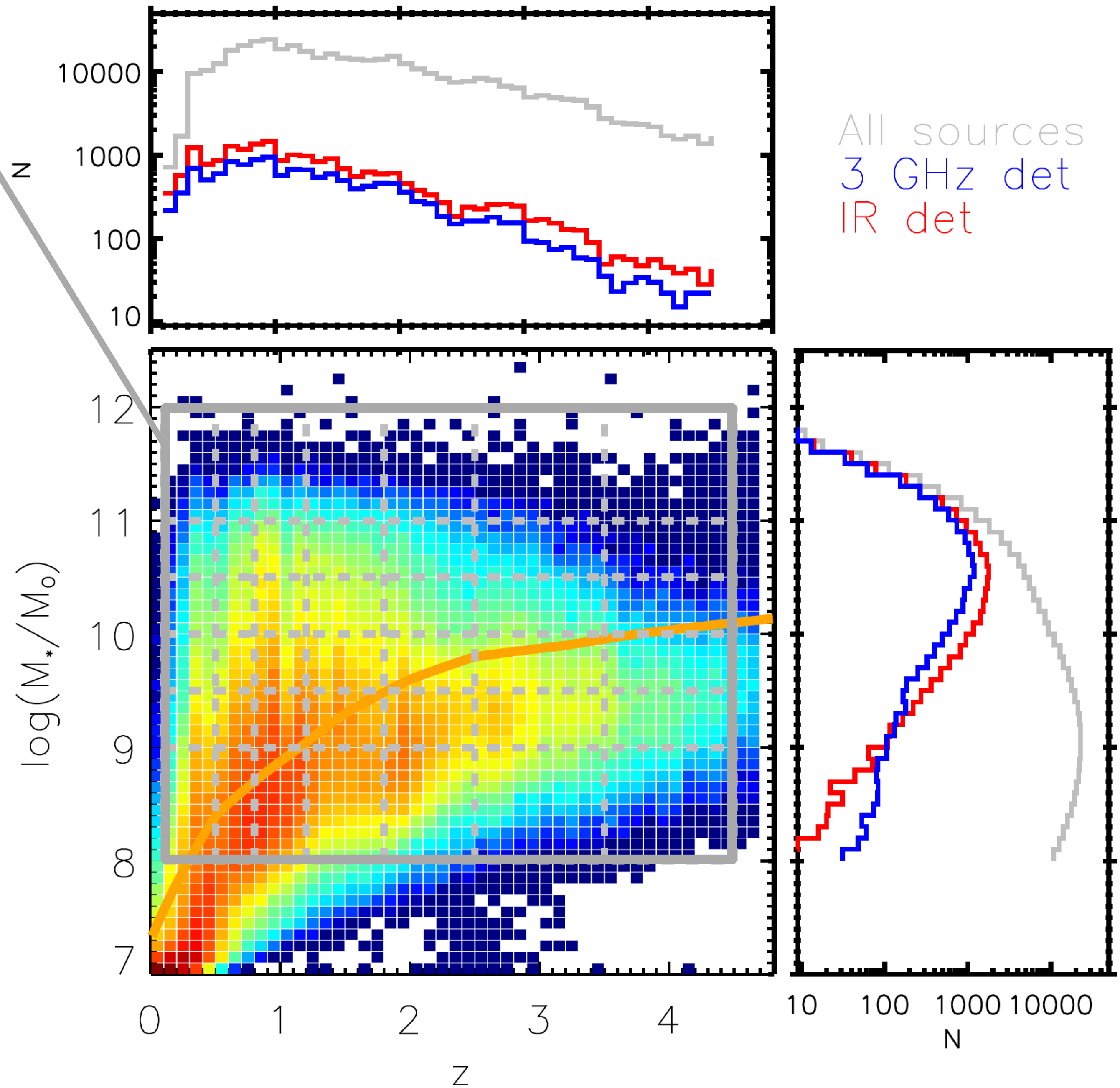
→ **20,777 detections at S/N>3**

RADIO

VLA 3 GHz (Smolcic+2017)

→ **13,808 detections at S/N>3**

& MeerKAT 1.3 GHz (Jarvis+2016)



The IRRC from a M_* selected sample in COSMOS

$q_{IR}\ (M_*, z)$

Multi-band stacking analysis in each M_*-z bin:

INFRARED

Herschel+SCUBA+AzTEC

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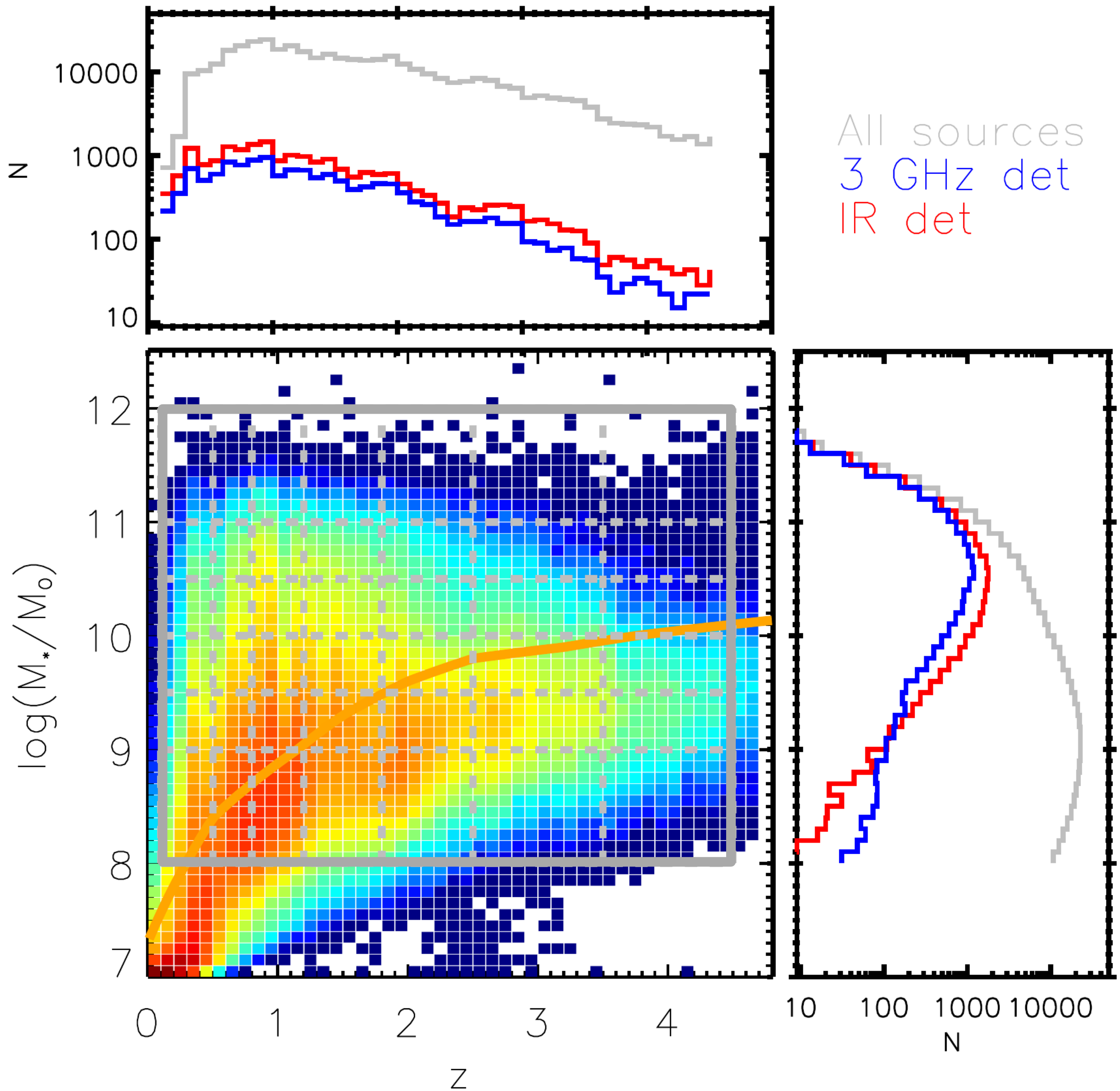
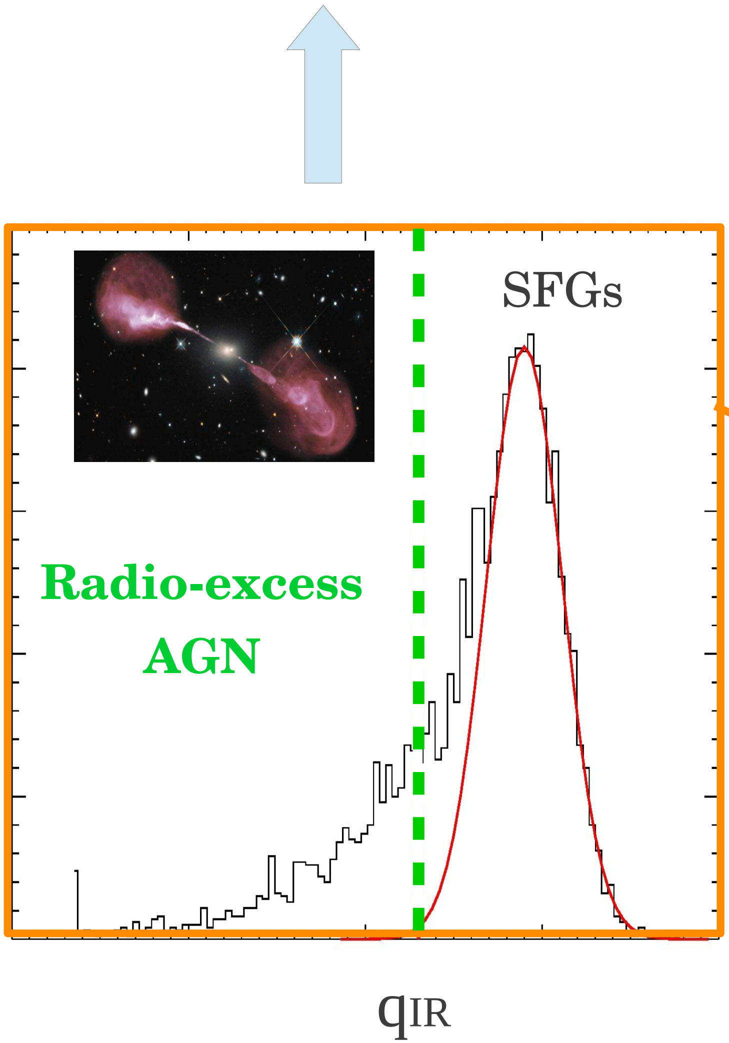
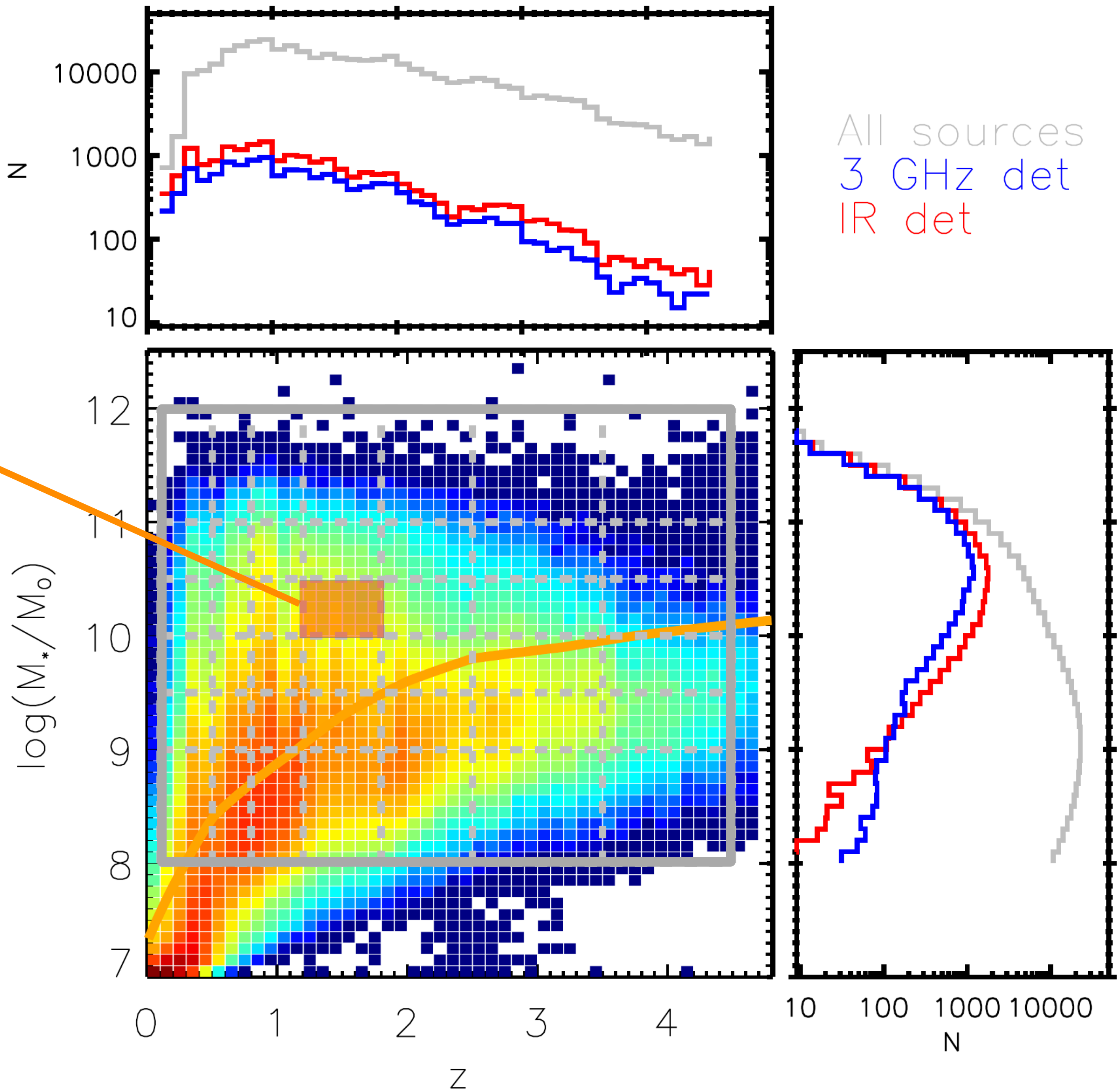


Correcting for radio-excess AGN contamination

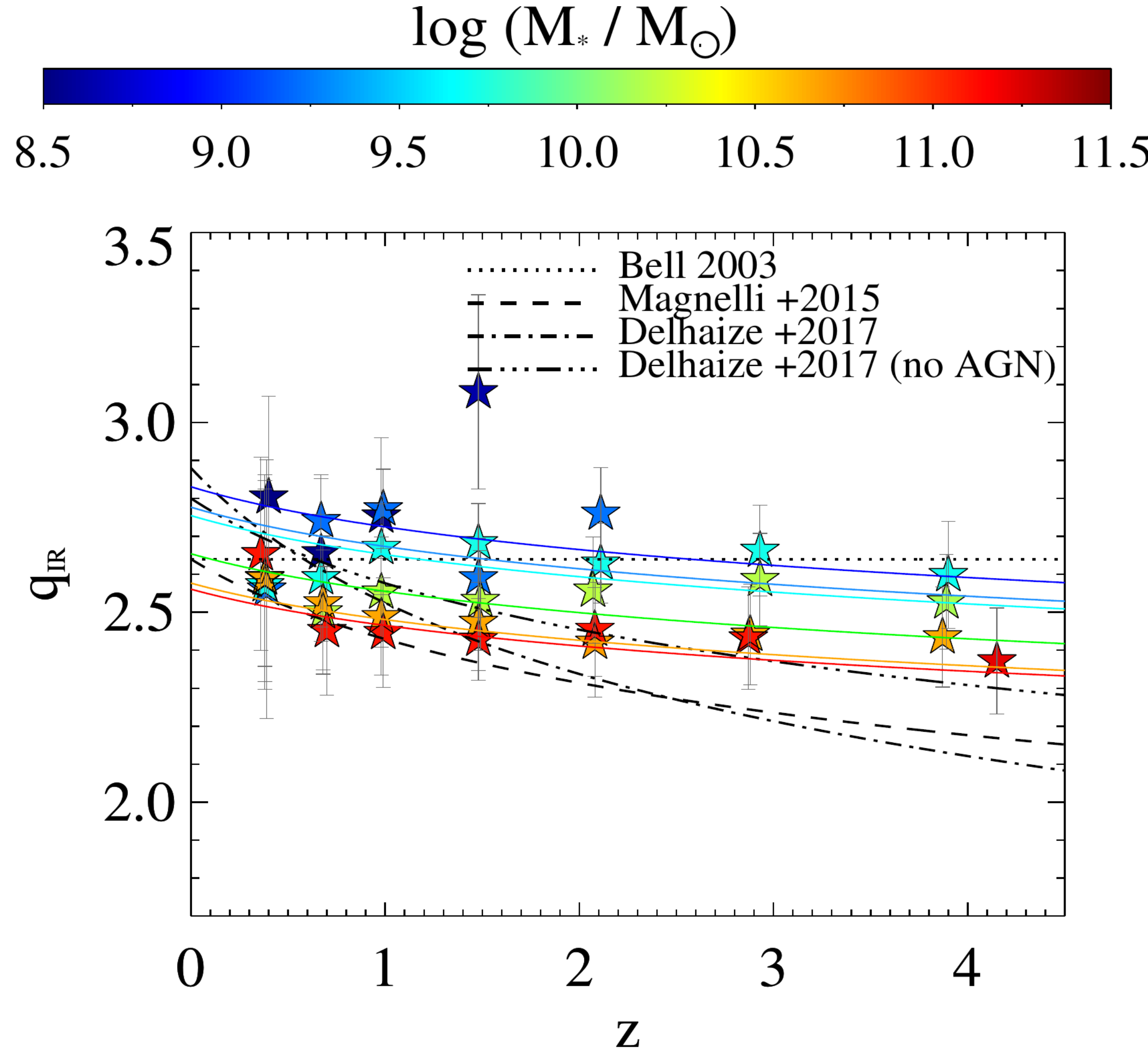
$q_{IR}\,(M_*, z)$





IRRC after removing radio AGN

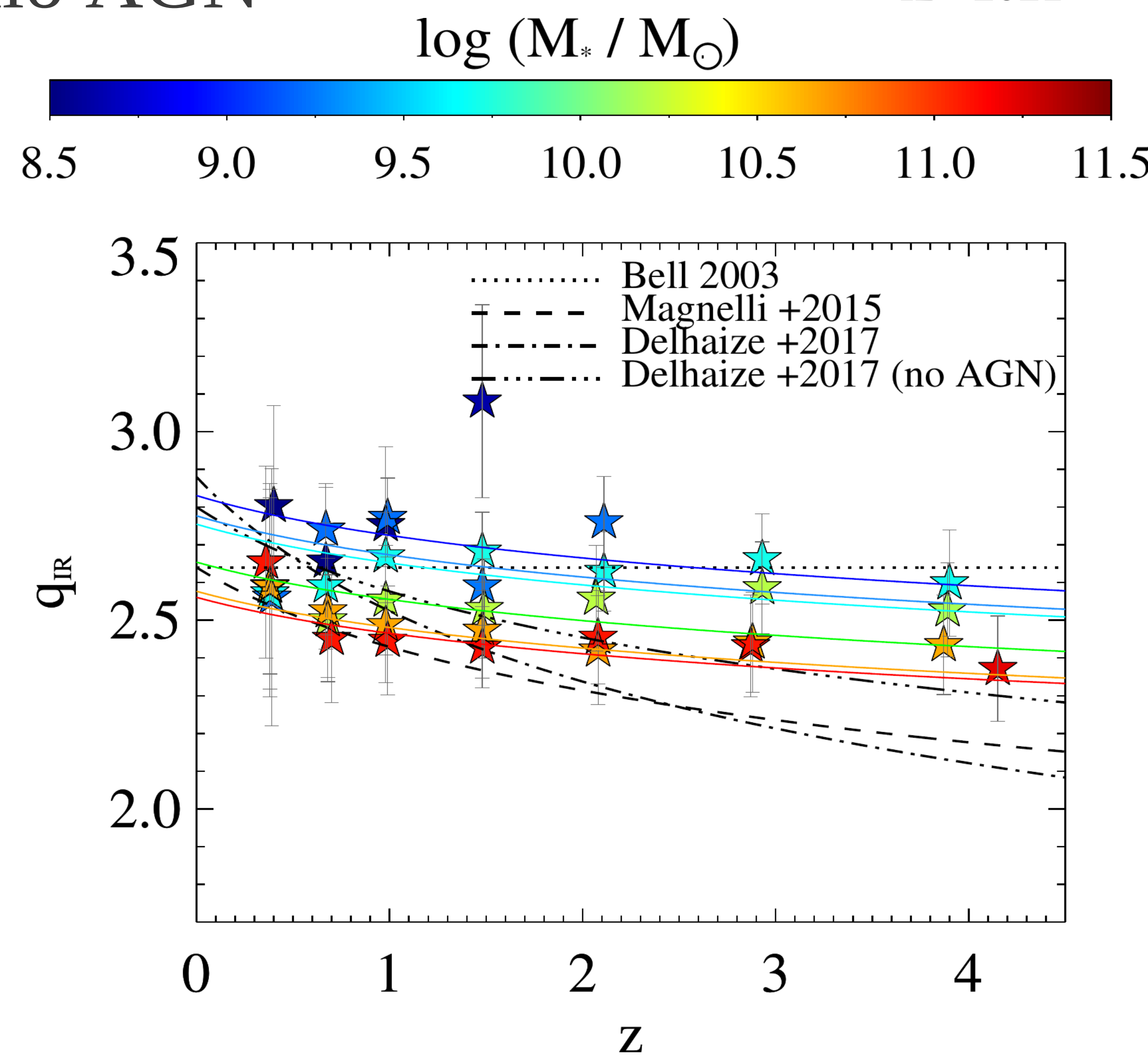
ID+2021



IRRC after removing radio AGN

ID+2021

The IRRC is nearly redshift-invariant and evolves primarily with M_*



$$q_{IR}(M_\star,z)=(2.646\pm0.024)\times(1+z)^{(-0.023\pm0.008)}-(0.148\pm0.013)\times(\log\ M_\star/M_\odot-10)$$

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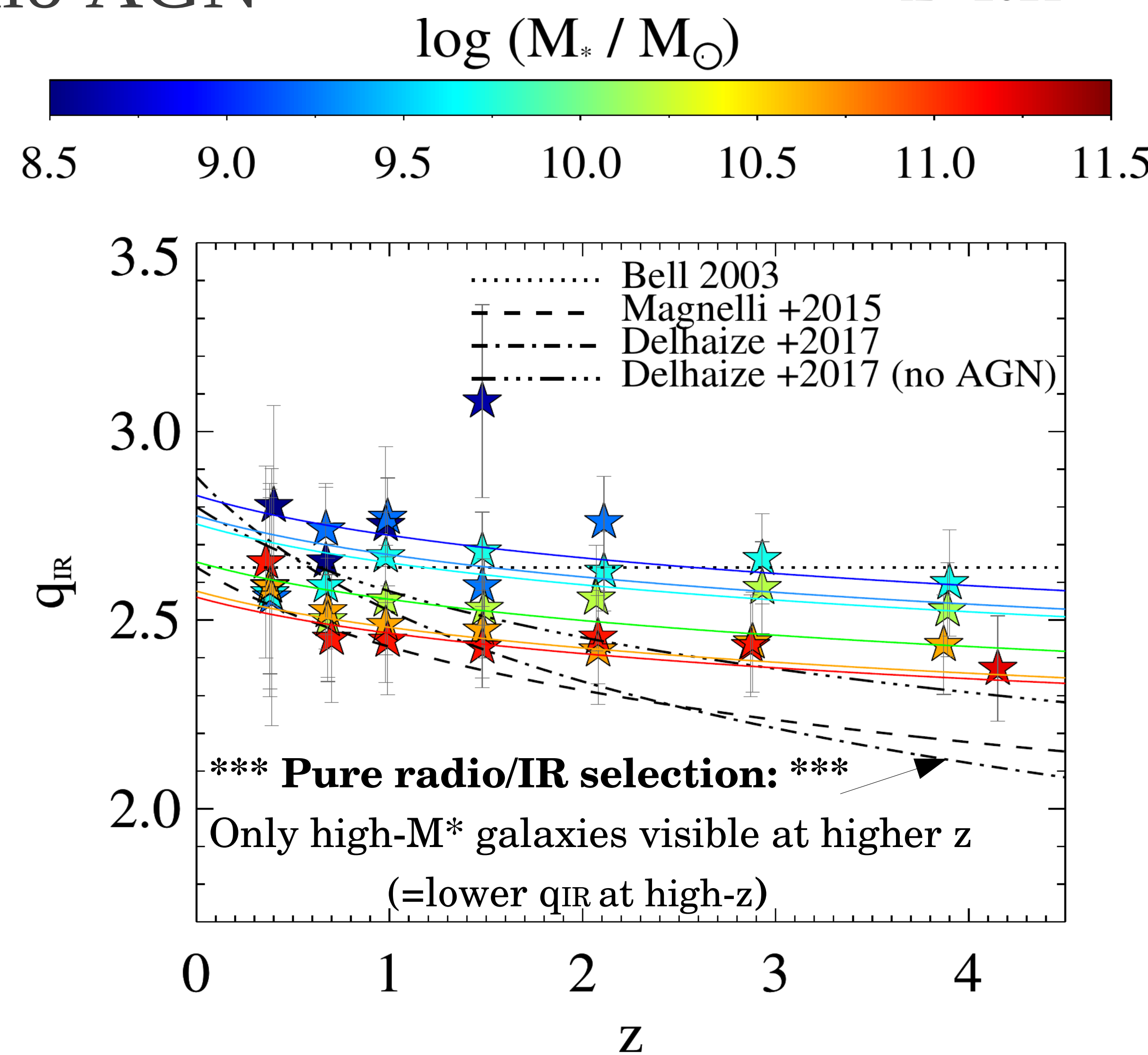

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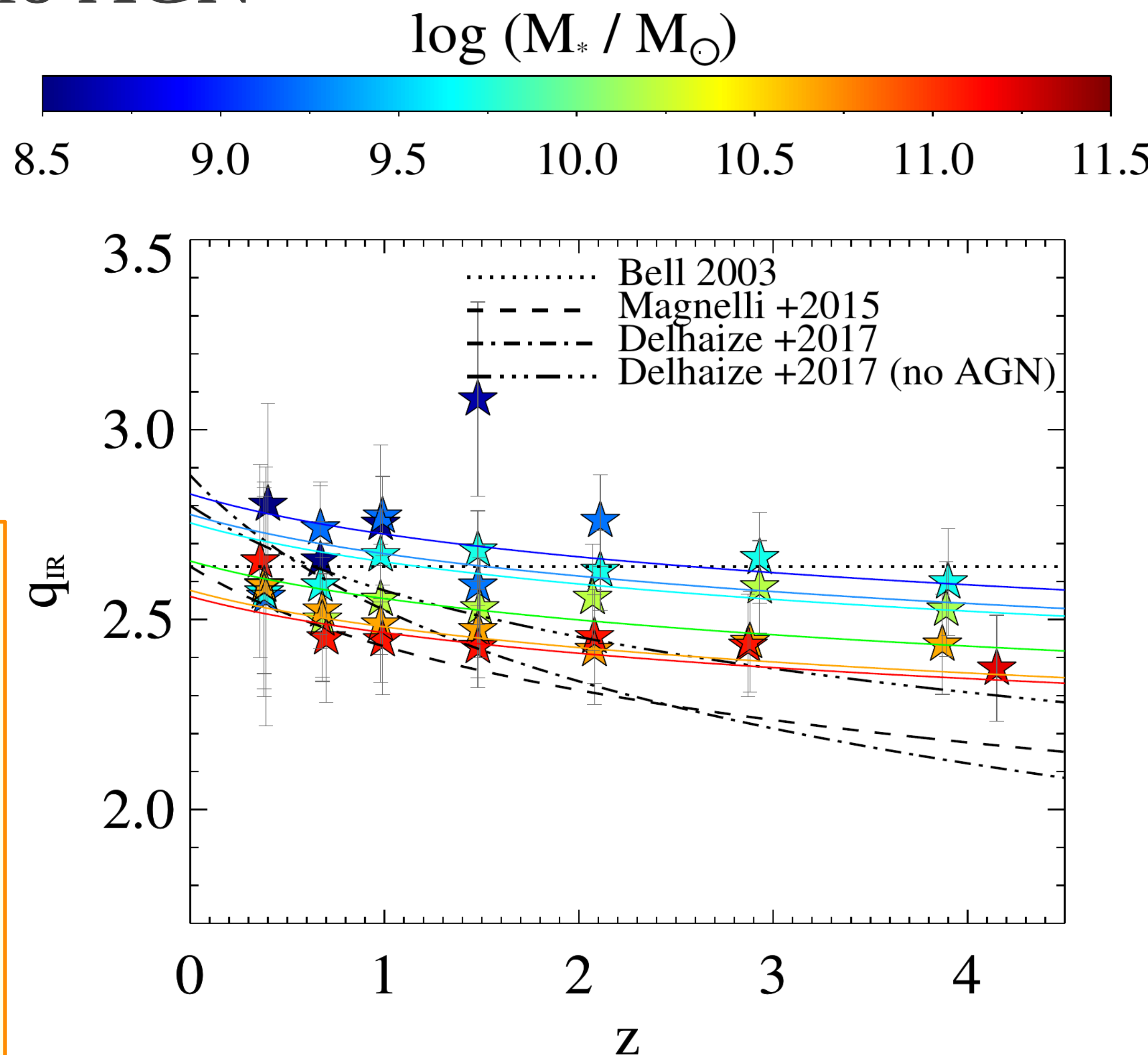

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Agreement with SFR-L_{radio} relations:

- Smith+2021
(IRAC sample + LOFAR@150MHz, z<1)
- Bonato+2021
(only LOFAR@150MHz, z≤2) *[Next talk]*

Consistent with local derivations:

- Molnár+2021 (z<0.2)
- Matthews, Condon+2021

$$q_{IR}(M_\star,z)=(2.646\pm0.024)\times(1+z)^{(-0.023\pm0.008)}-(0.148\pm0.013)\times(\log M_\star/M_\odot-10)$$

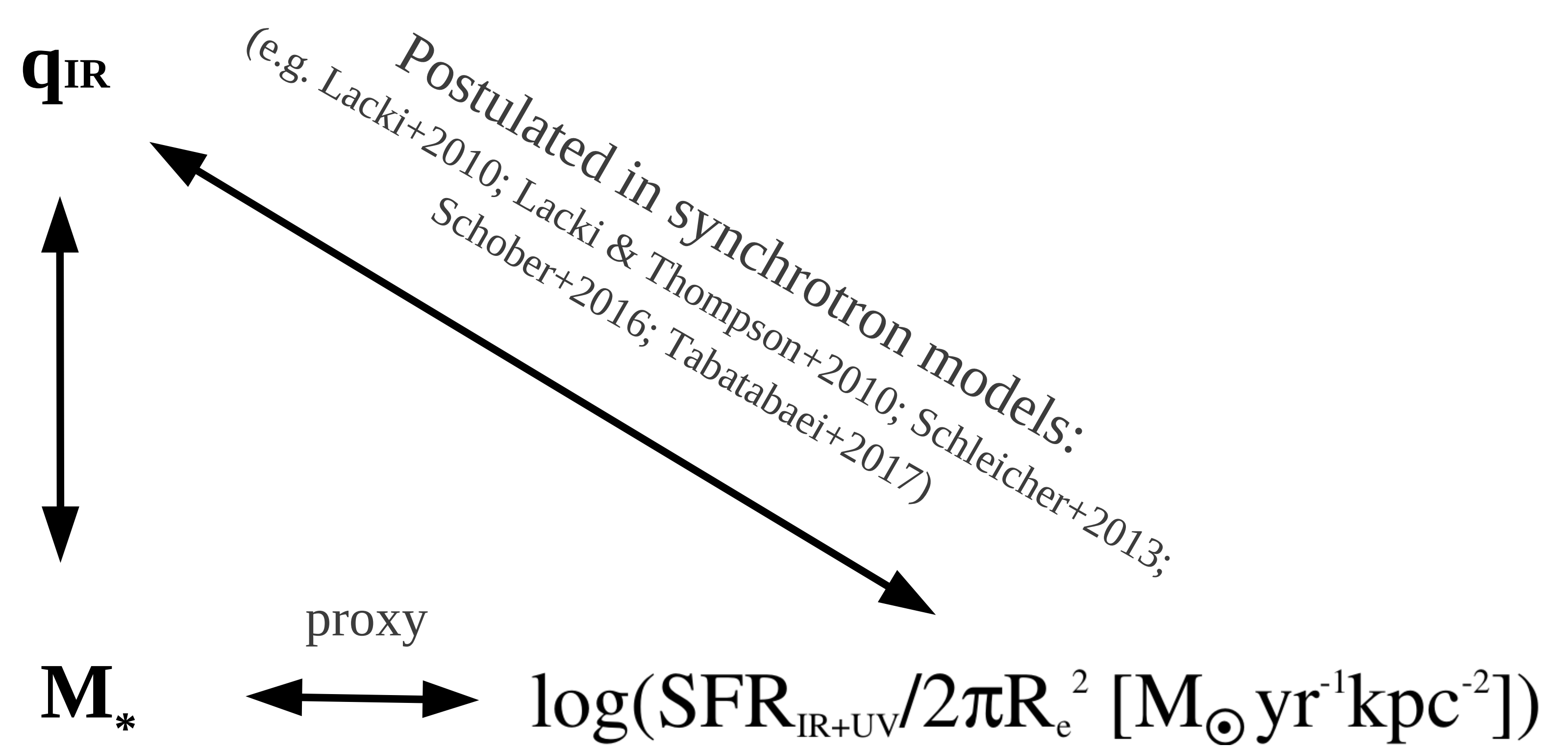
Data vs models

$\mathbf{q_{IR}}$

↕

$\mathbf{M_*}$

Data vs models: the role of SFR surface density (Σ_{SFR})



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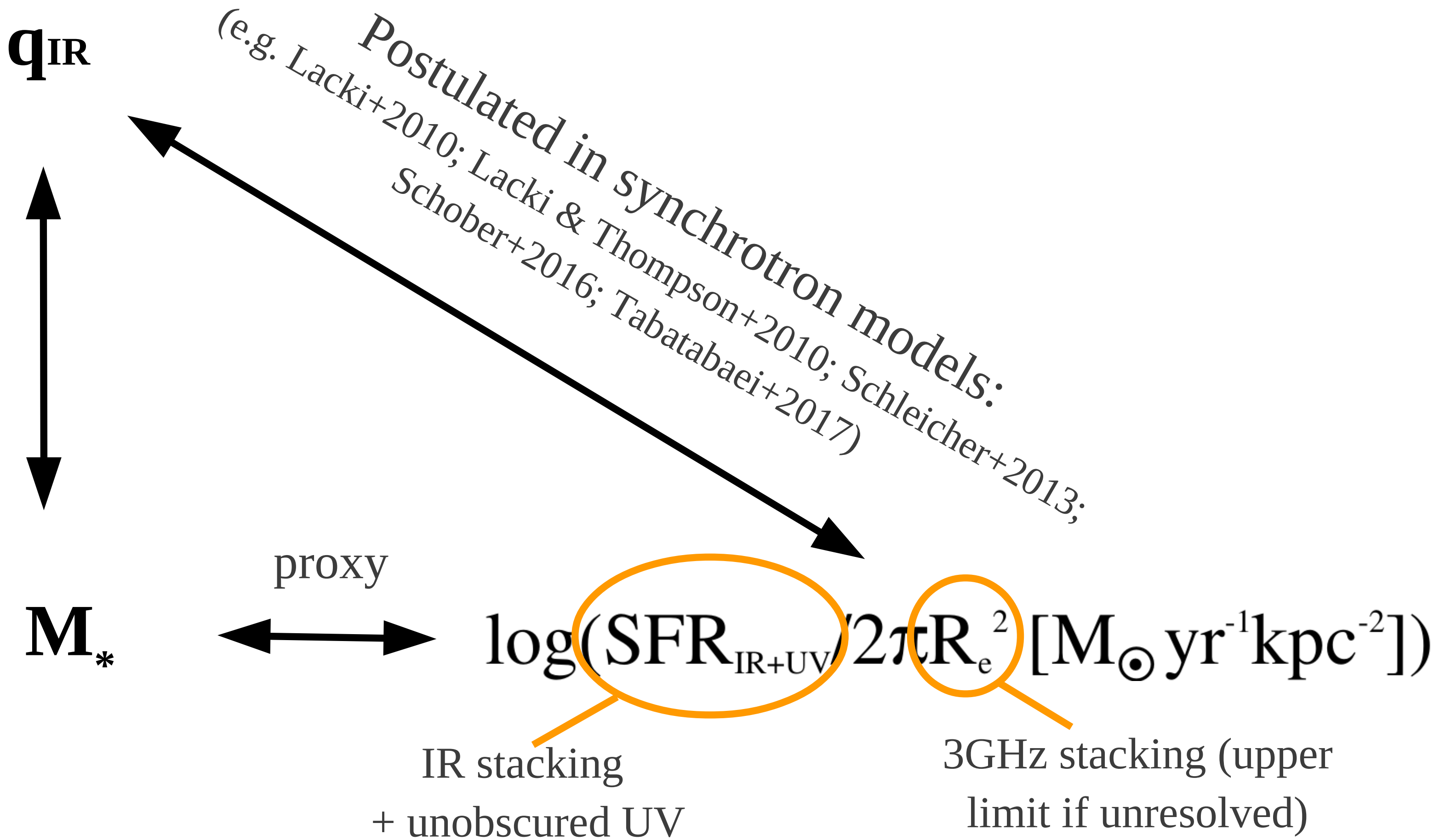

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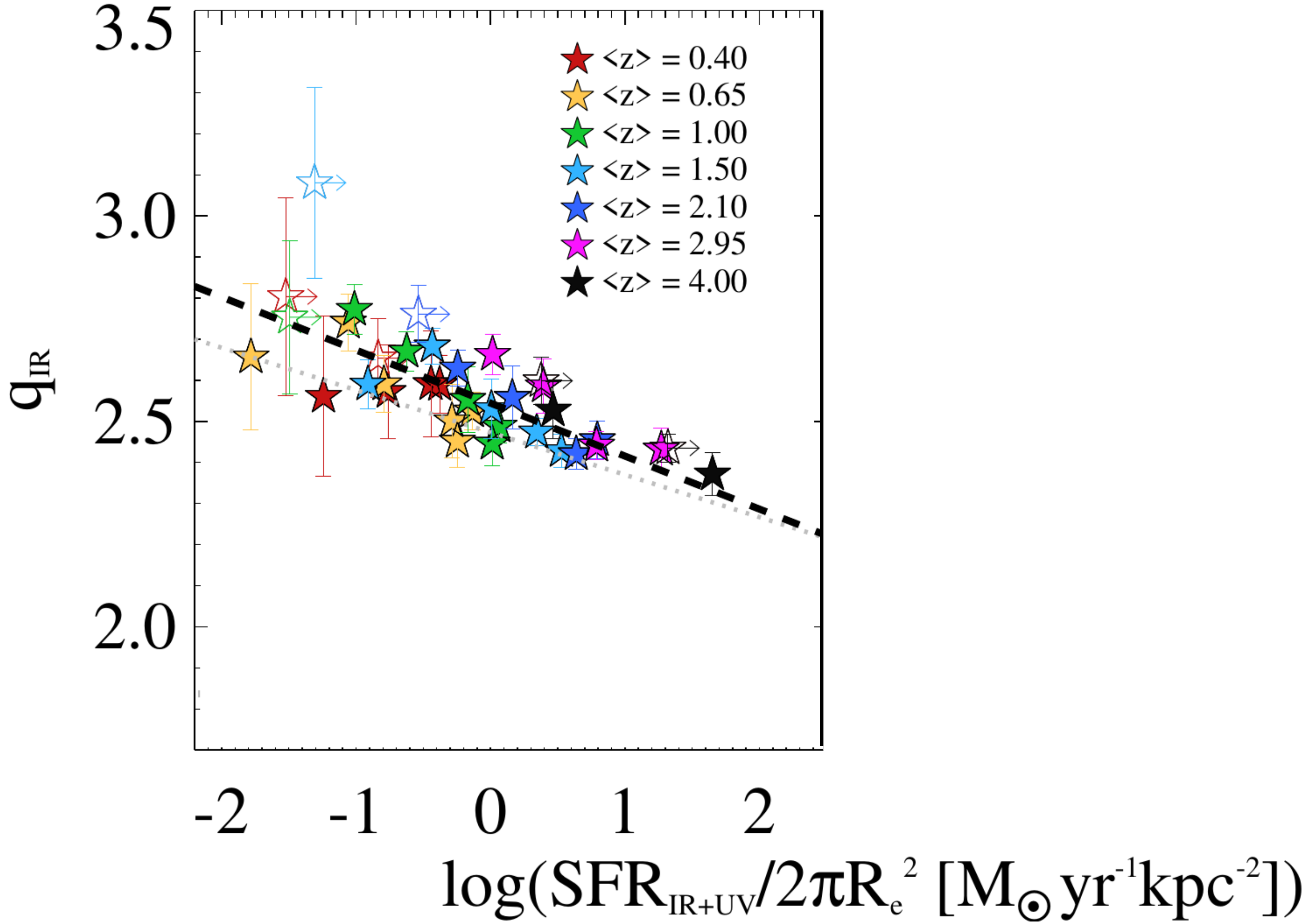
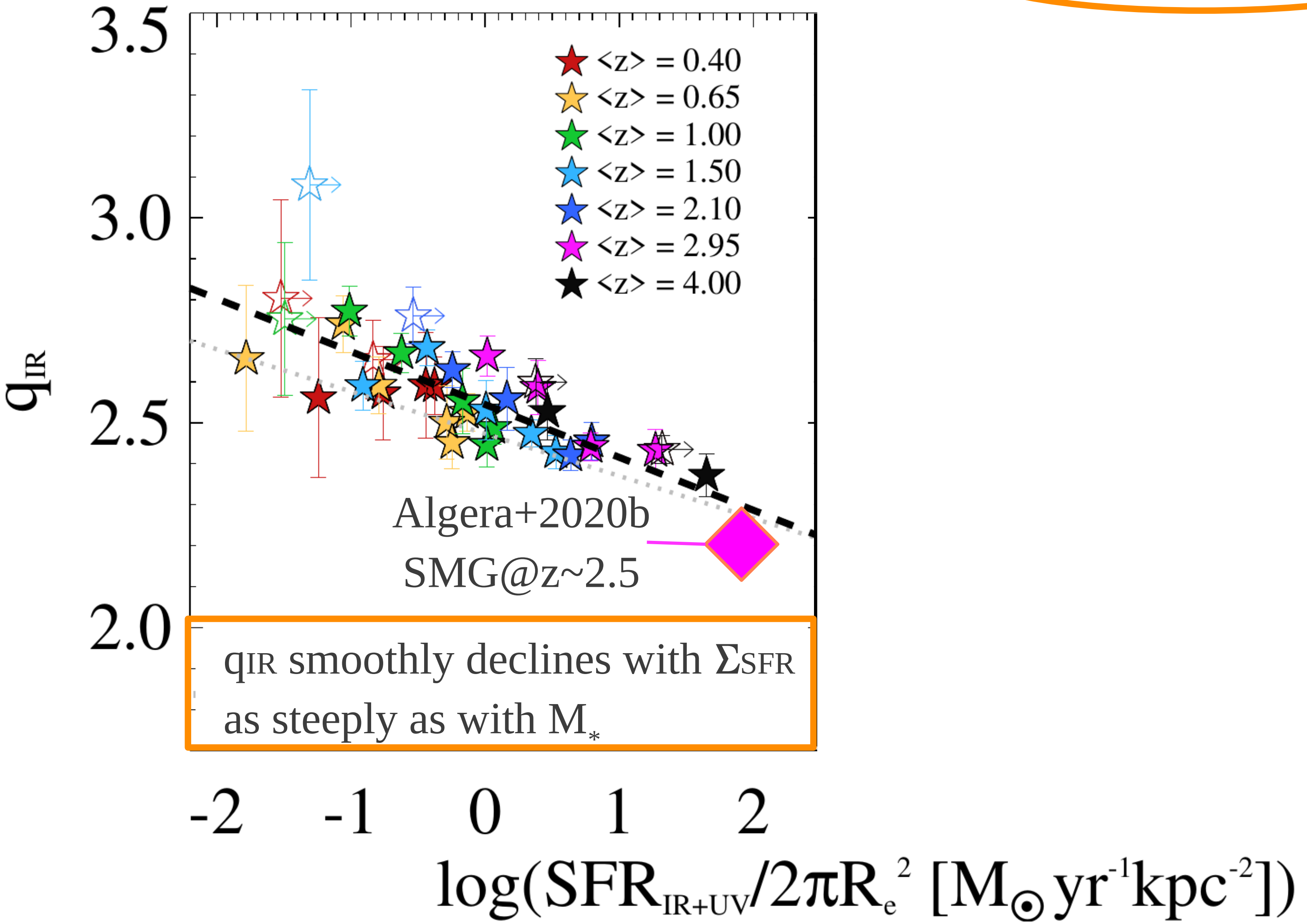


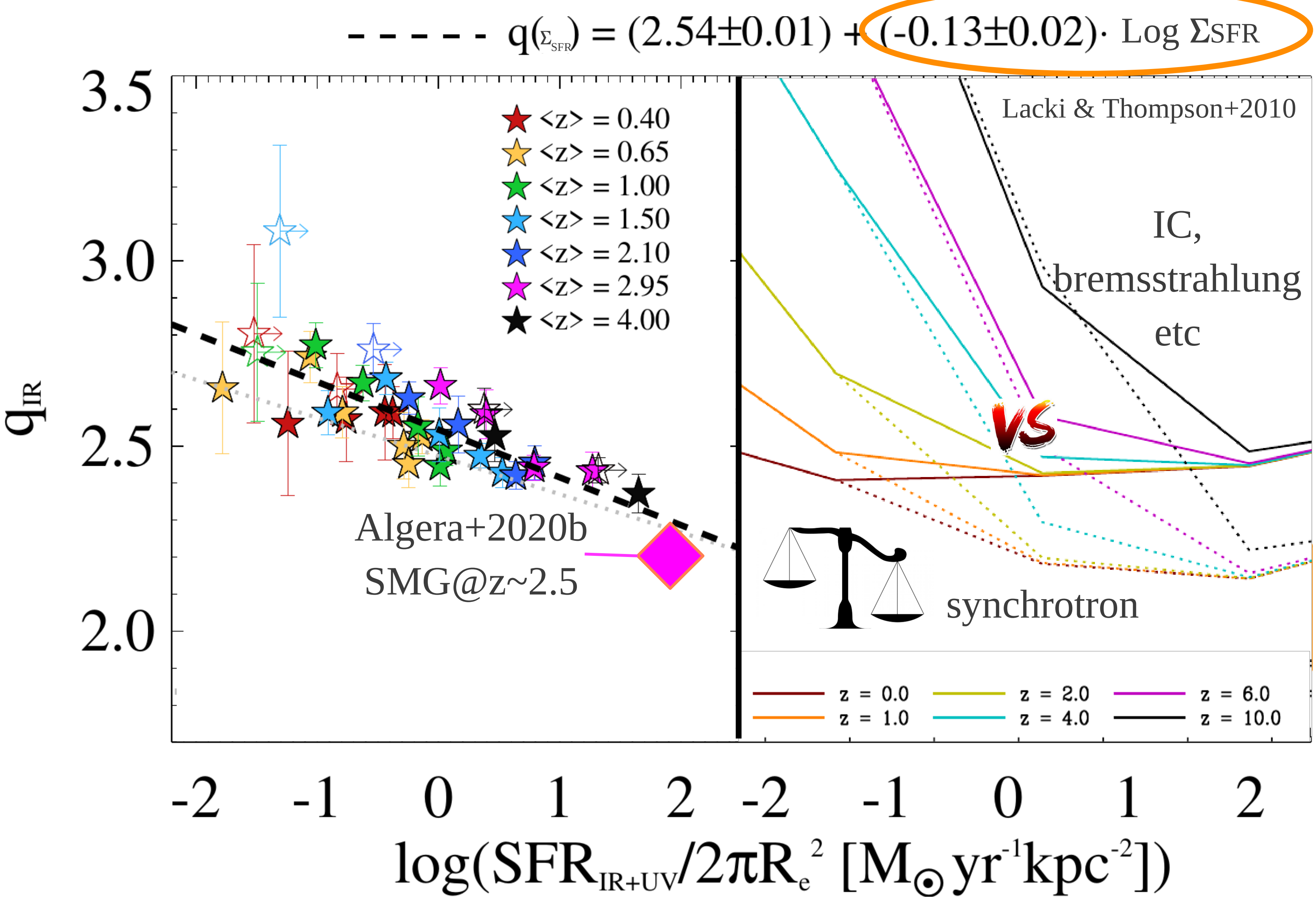
Data vs models: the role of SFR surface density (Σ_{SFR})

$q(\Sigma_{SFR}) = (2.54 \pm 0.01) + (-0.13 \pm 0.02) \cdot \mathrm{Log}\, \Sigma_{SFR}$



q_{IR} smoothly declines with Σ_{SFR} as steeply as with M_*

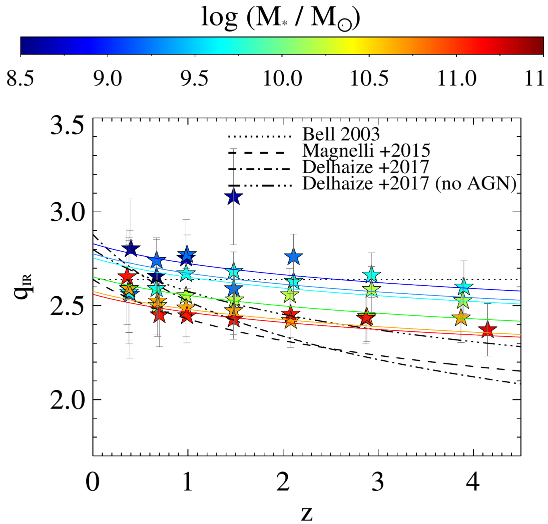
Data vs models: the role of SFR surface density (Σ_{SFR})

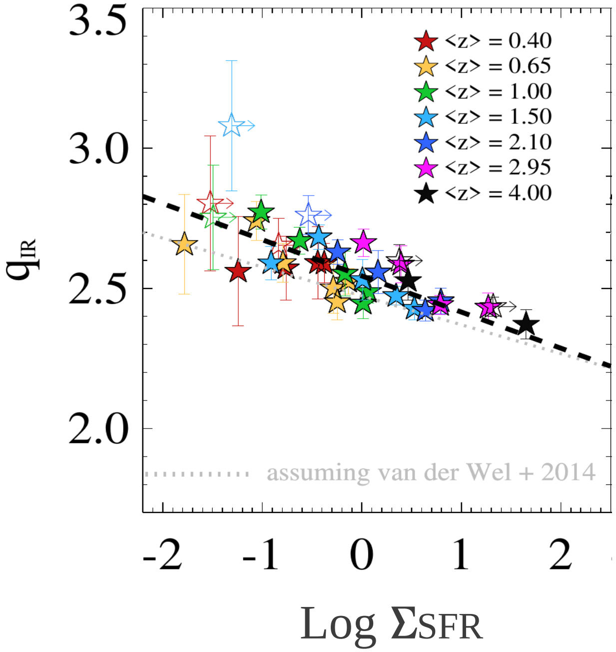


- Flattening of q_{IR} due to high-Σ_{SFR} conspiracy
- Highly redshift-dependent → IC losses scale with CMB energy density ~ $(1+z)^4$

Take-home points

- The IRRC of typical SFGs is significantly M_* dependent and nearly redshift-invariant, in agreement with recent literature

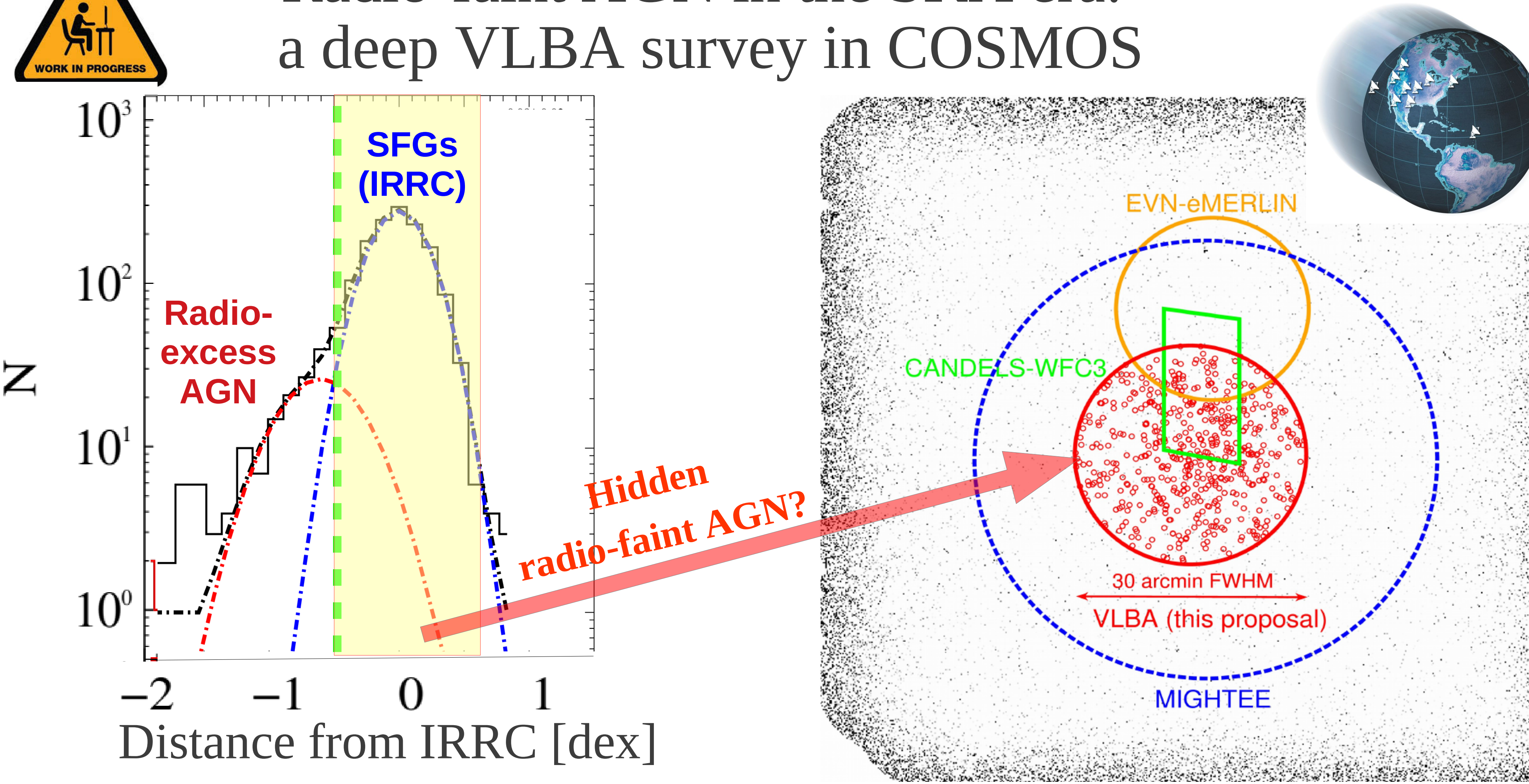




- The M_* dependence of q_{IR} could be linked to Σ_{SFR}, but our data do not fully support synchrotron model predictions

- M_*-dependent relations are required to convert future SKA-MID1 detections into accurate SFR measurements

Radio-faint AGN in the SKA era: a deep VLBA survey in COSMOS



- **120h** @ VLBA-1.4GHz (PI: Delvecchio)
- rms ~ **3.7 μJy/beam** (θ_{beam} ~ 0.01")
- **>500** star-forming galaxies (0.5<z<4.5) within the IRRC

- *Separating AGN vs SF on a source-by-source basis in "normal" galaxies*
- *Constraining incidence of radio AGN at few μJy* → *SKA-MID1*