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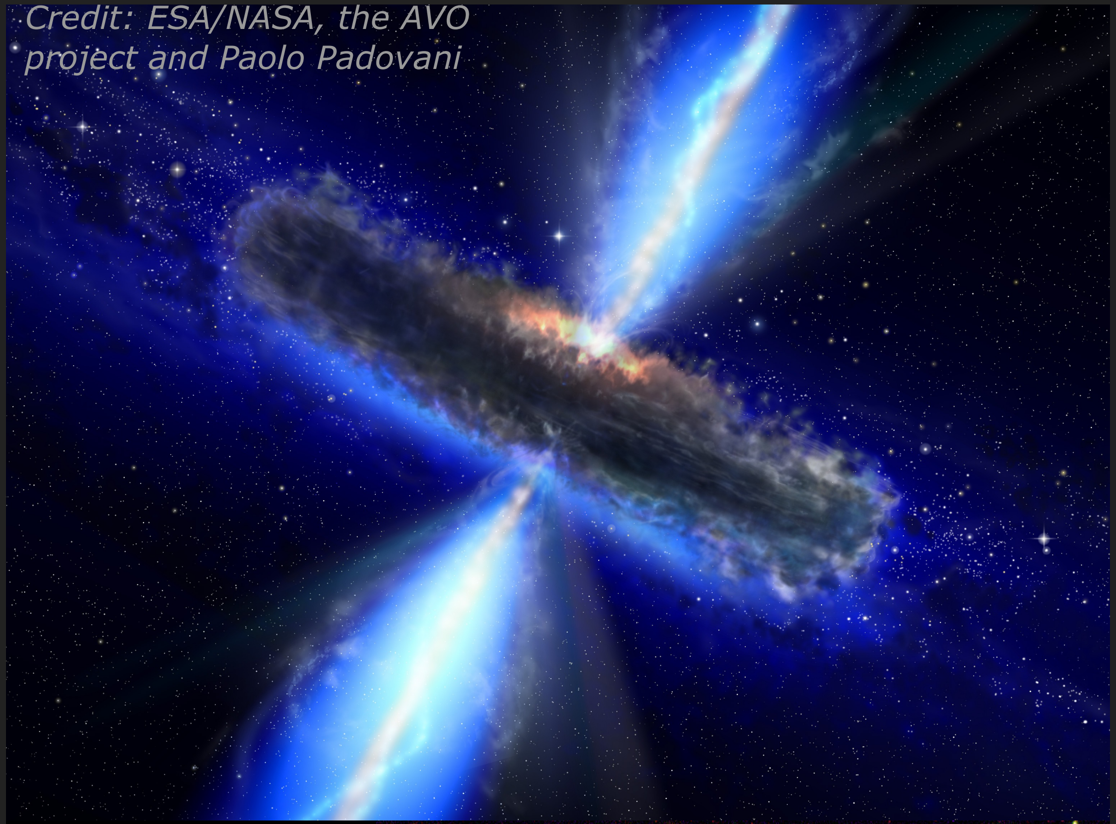
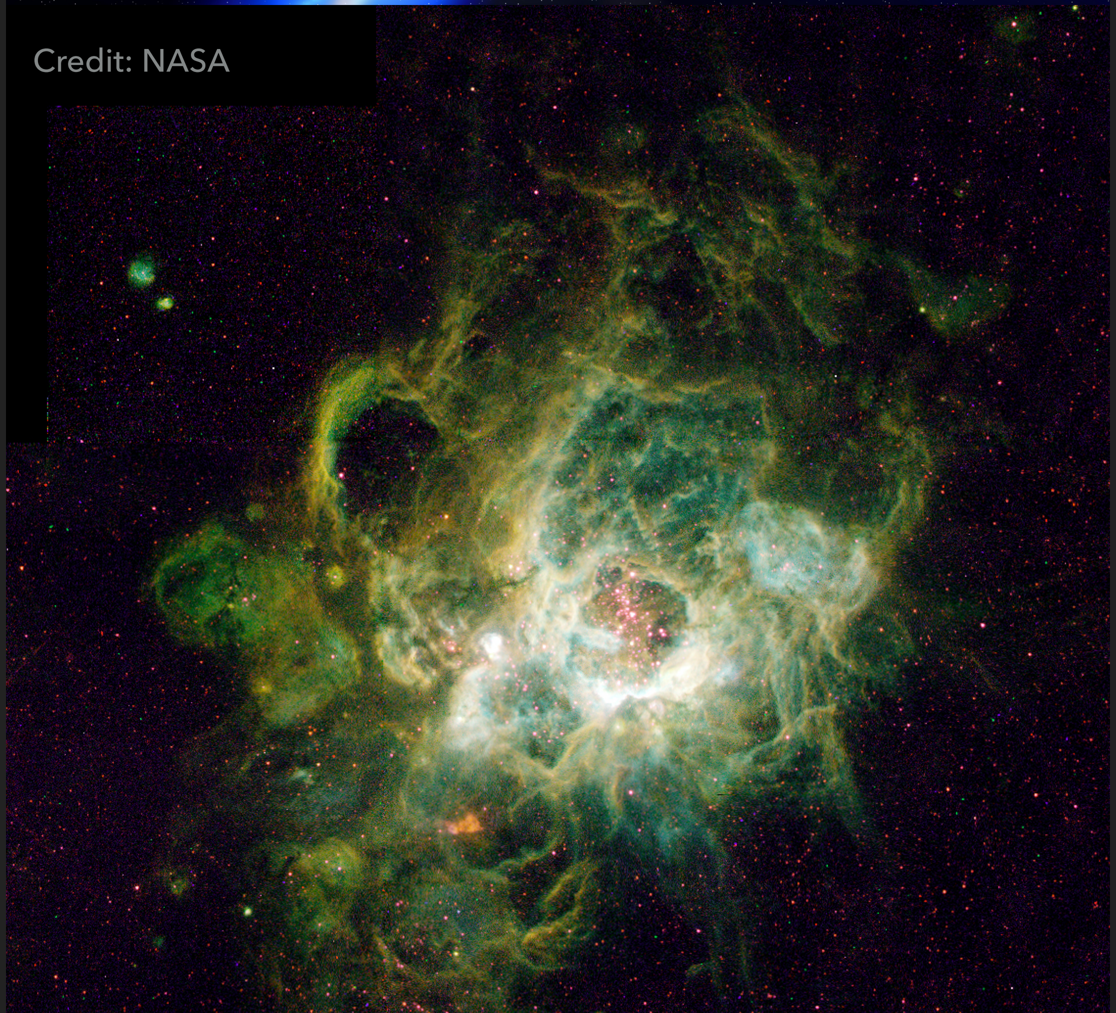
RESULTS FROM Hα, LYα AND CIV/CIII] SELECTED SAMPLES

THE GROWTH OF TYPICAL STAR-FORMING GALAXIES AND THEIR SUPERMASSIVE BLACK HOLES ACROSS COSMIC TIME

INTRODUCTION

- Galaxy evolution:
  - Star formation
  - Supermassive Black Hole activity (AGN).
- Galaxies grow by forming stars.
  - AGN and star formation itself condition this process.


Credit: ESA/NASA, the AVO project and Paolo Padovani


Credit: NASA

WHY IS IT IMPORTANT OR HOW DOES THIS WORK, ANYWAY?

- Star formation (Supernovae feedback)
    - Supernova goes off, heats the gas and prevents star formation.
    - On the other hand, shockwaves actually cause the collapse of gas clouds and trigger star formation.
- AGN feedback
  - The energy that the AGN releases can also prevent star formation and an AGN can definitely throw gas out of a galaxy (but we don't know how).

WHY IS IT IMPORTANT OR HOW DOES THIS WORK, ANYWAY?

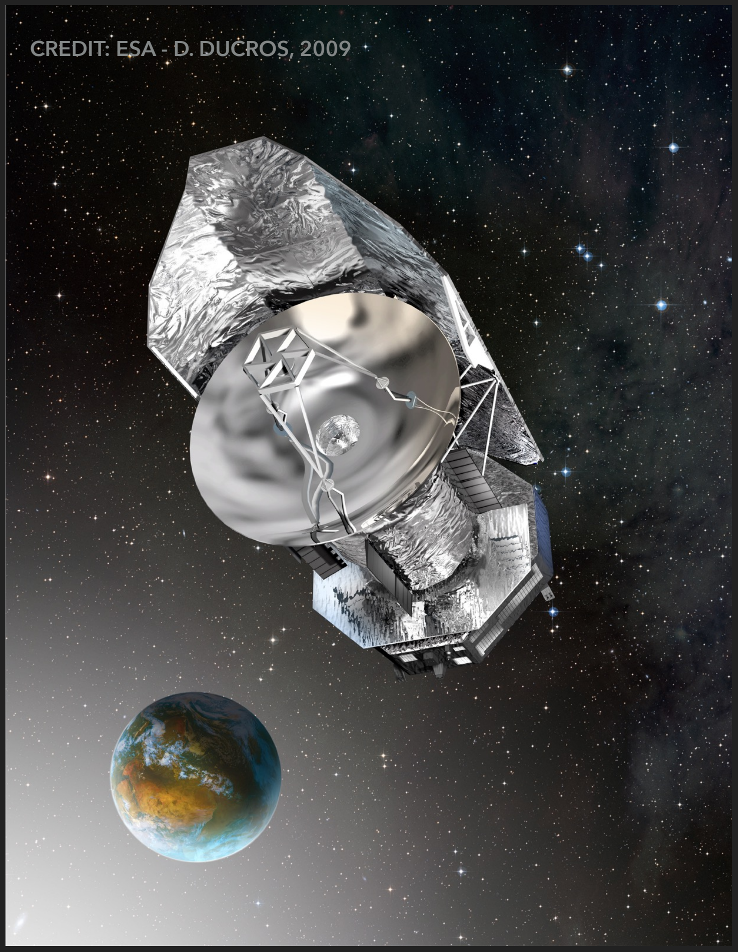
- The general belief is that stellar feedback is dominant in less massive galaxies (Bolatto et al. 2013, Geach et al. 2014)
- AGN feedback reigns in the largest ones (Silk & Rees, 1998; Bower et al 2006).
- Knowing how AGN and SF evolve may shine some light on the life ant times of galaxies.

OBJECTIVE

- Most works focus on AGN-selected samples when studying SFR and/or BHAR (e.g. Stanley et al, 2015).
- We are interested in understanding how BH and SF processes influence each other in a typical star forming galaxy and in particular,
  - How do the SFR and BHAR change and evolve relative to each other (see also, e.g. Delvecchio et al. 2015)?

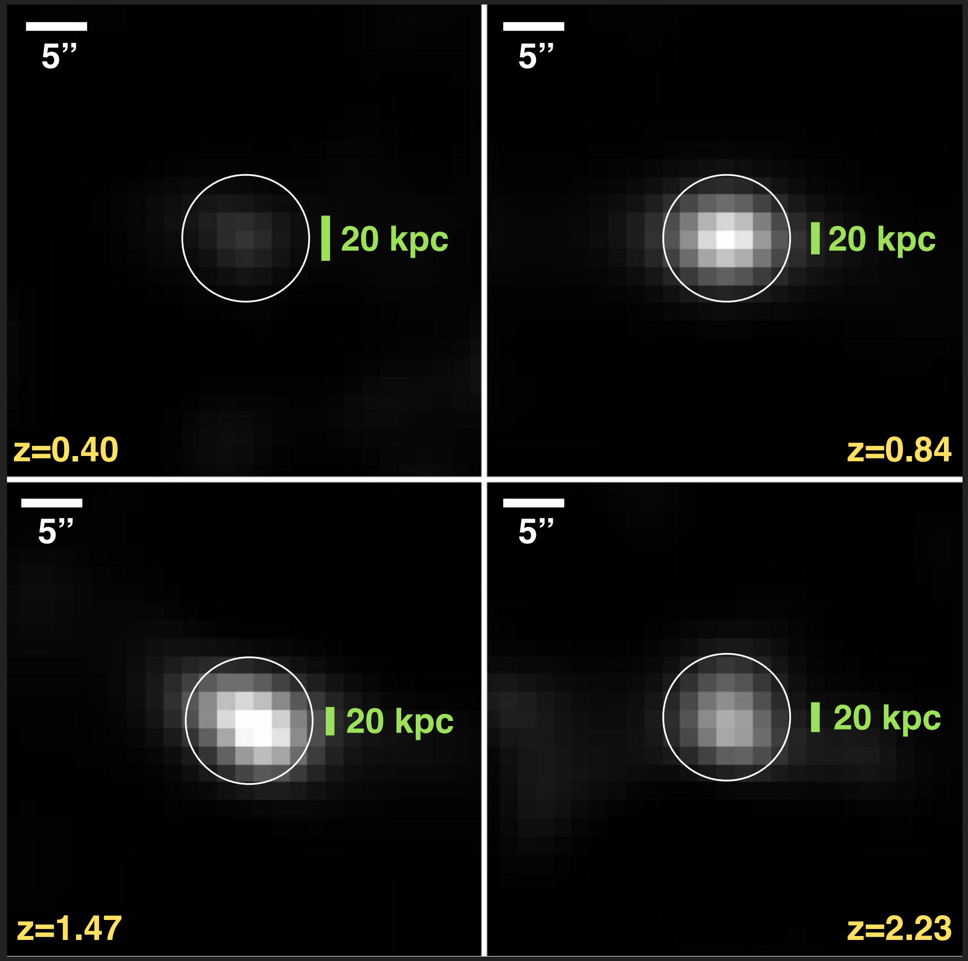
DATA - Hα SELECTION

- Sources taken from HiZELS, for z=0.4, 0.8, 1.47 and 2.23.
- COSMOS field (Scoville et al. 2007).
- C-COSMOS (Elvis et al. 2009) for the X-ray data.
- HERMES (Oliver et al. 2012), PEP (Lutz et al. 2011) and SCUBA2 (Geach et al. 2013, 2016) for the far-infrared.



DATA - Hα SELECTION

- Hundreds of star-forming galaxies per redshift with four different redshift bins.
- Stellar mass ~ $10^{9.6}$ $M_\odot$
- Hα SFR ~ 4-25 $M_\odot$
- Radio SFR ~ 2-60 $M_\odot$



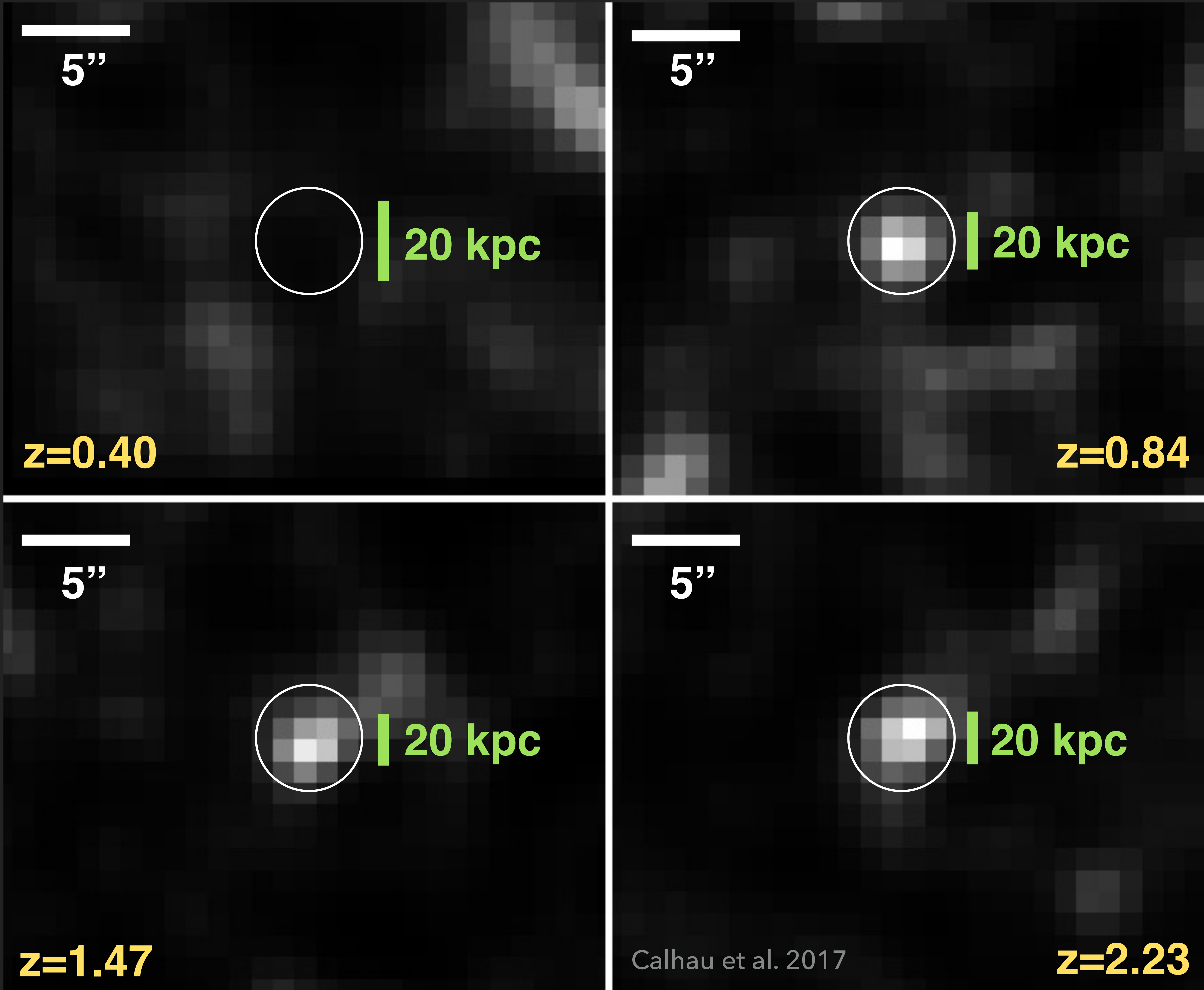
Calhau et al. 2017 - Radio stacking

X-RAYS ARE FOR BLACK HOLES

- X-ray Luminosity → Black hole accretion rates (Lehmer et al. 2013, Ranalli et al. 2003)
  - Direct detections - source matching between HiZELS and C-COSMOS.
  - Stacking of the entire sample.

$$\mathrm{L_X} = 4\pi \mathrm{d_L}^2 \mathrm{f_X} (1+\mathrm{z})^{\Gamma-2}\ (\mathrm{erg\,s^{-1}})$$

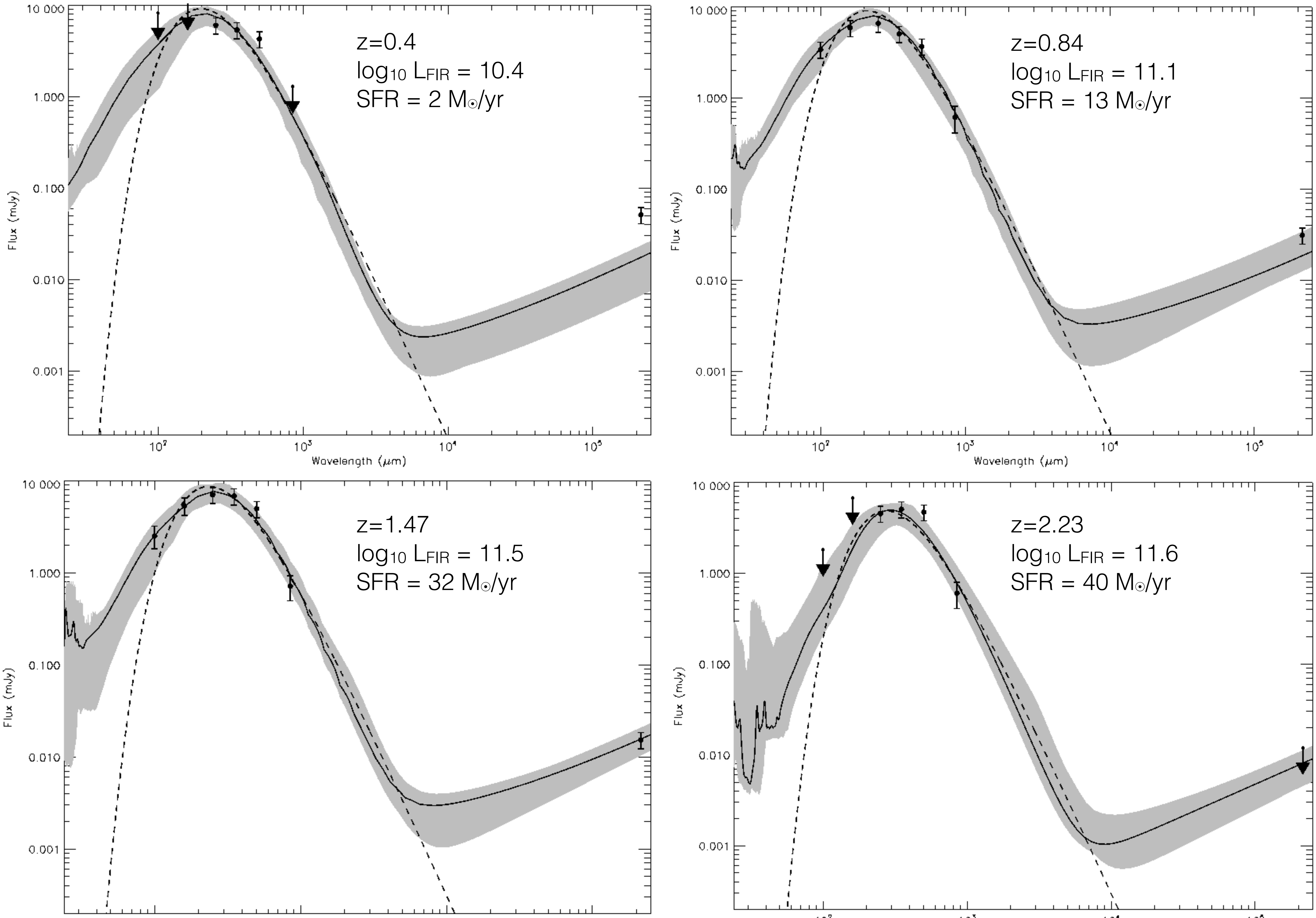
$$\dot{M}_{\mathrm{BH}} = \frac{(1-\epsilon)L_{bol}^{AGN}}{\epsilon c^2} (\mathrm{M_\odot\,yr^{-1}})$$



5''
20 kpc
z=0.40
5''
20 kpc
z=0.84
5''
20 kpc
z=1.47
5''
20 kpc
Calhau et al. 2017
z=2.23

FAR-INFRARED IS FOR STARS

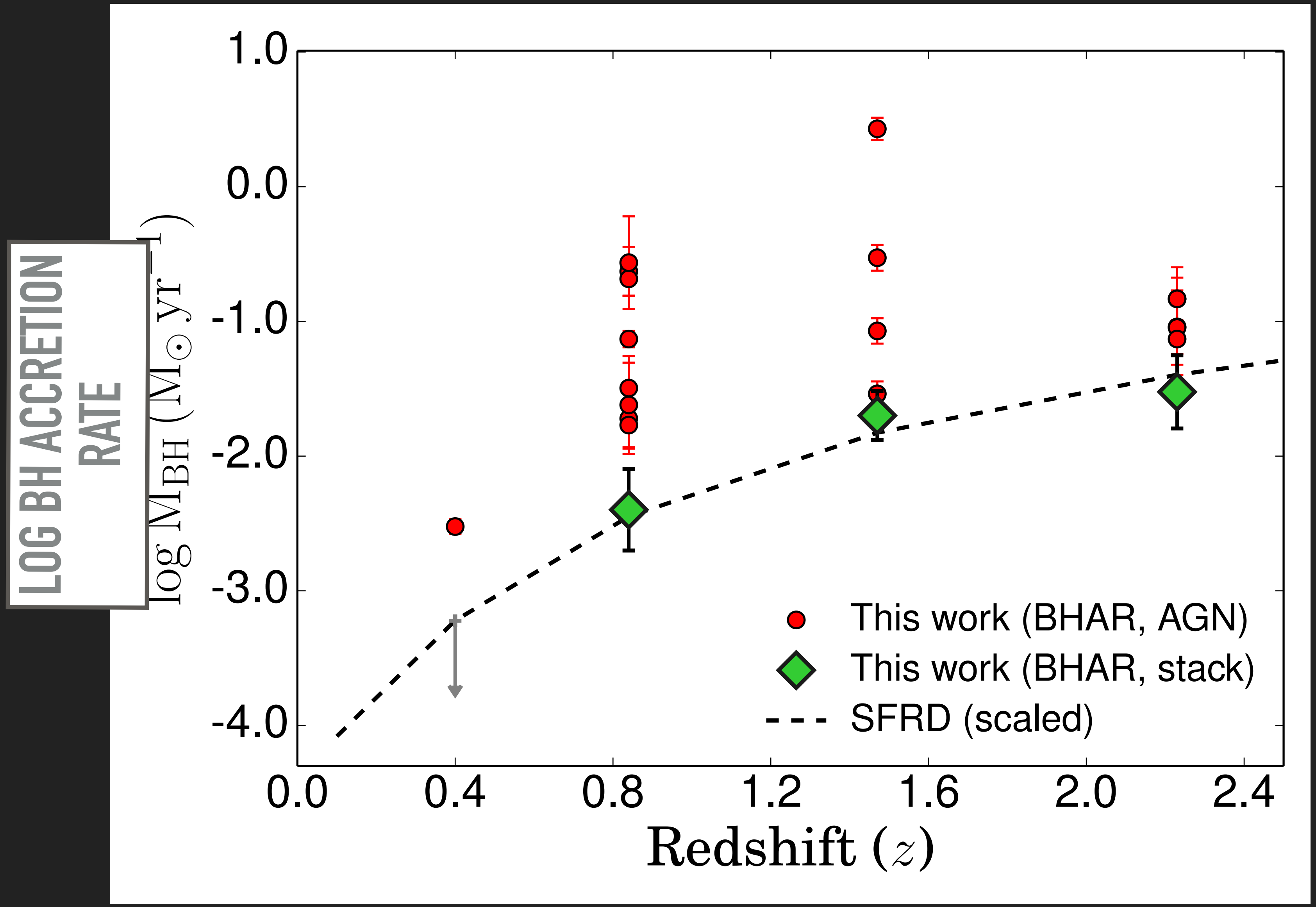
- Using far-infrared we avoid contamination from AGN that may still influence Hα and Radio.
- Far-Infrared luminosity ⟶ Star formation rates (Kennicutt, 1998)
  - Direct detection - source matching between HiZELS and HerMES, PEP and SCUBA2.
  - stacking of the entire sample.
  - SED fitting.



Calhau et al. 2017

RESULTS

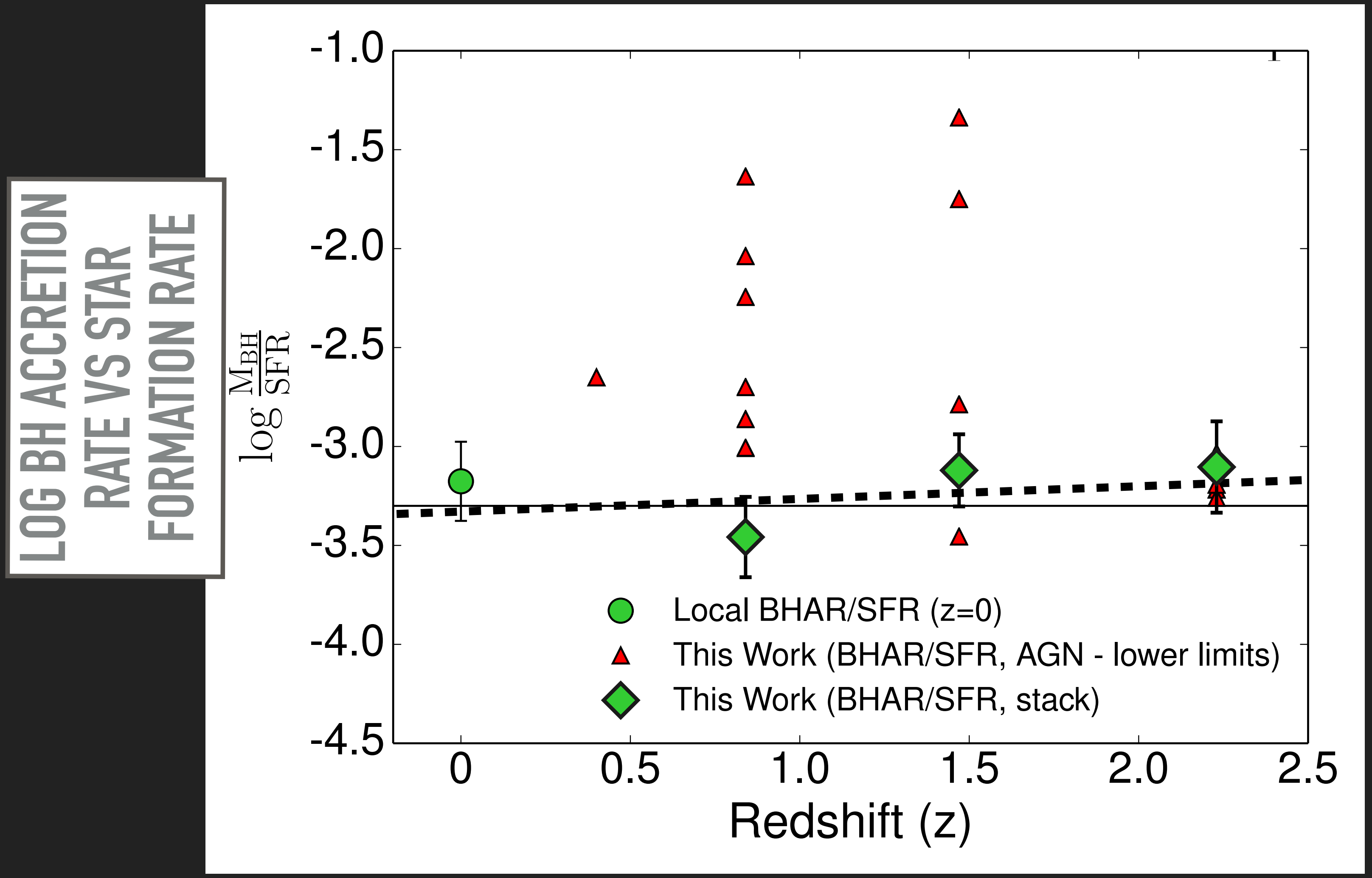
- The evolution of the BHAR follows the evolution of the star formation rate density.



Calhau et al. 2017

RESULTS

- Typical star-forming galaxies grow their stellar mass much quicker than their black holes (BHAR/SFR ~ 0.0001).
- There is little evolution of the BHAR/SFR ratio across cosmic time for star-forming galaxies.



Calhau et al. 2017

RESULTS

- These results seem to support the possibility that BH accretion and SF evolve at equivalent rates across cosmic time, and
- Central supermassive black holes and star formation mechanism likely work in conjunction for regulation of galaxy evolution.

LET'S GO FARTHER: LY-ALPHA AND CARBON SELECTED SAMPLES

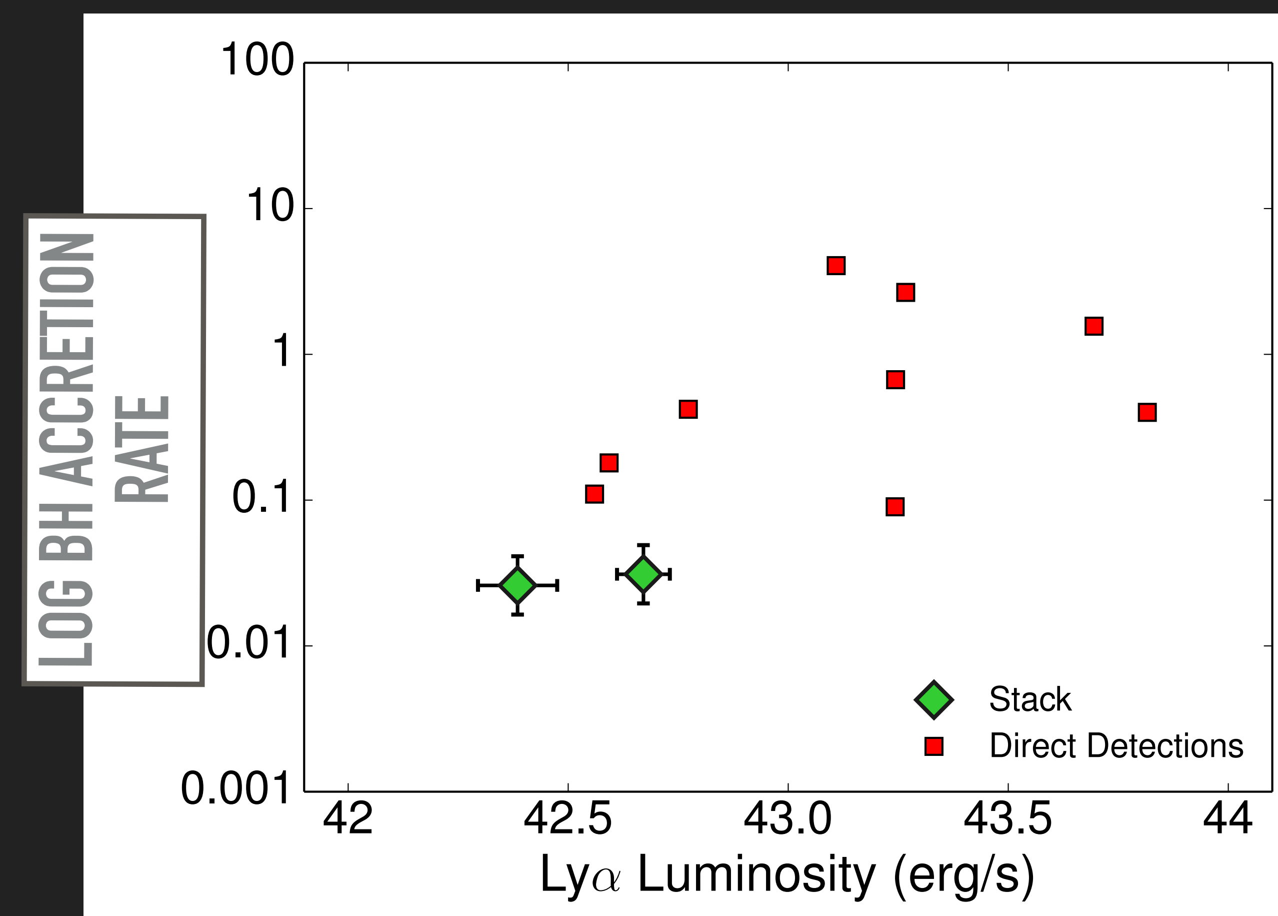
- At higher redshift Hα is currently not available.
    - Need alternatives.
- Lya is the most notable option but,
- CIII] and CIV emitters are also available (e.g. Stark et al. 2017)
    - Problem: We do not know their nature.
    - Studying them at lower redshifts might help us understand them.

LET'S GO FARTHER: LY-ALPHA SELECTED SAMPLES

- We are still in the COSMOS field.
- Sample from CALYMHa (CAlibrating LYMan-alpha with H-alpha) survey (Sobral, et al 2016) at z=2.23.
- X-rays → black hole accretion rates.
- Far-infrared shows no detection when stacking.
- Hα → star formation rates

LET'S GO FARTHER: LY-ALPHA SELECTED SAMPLES

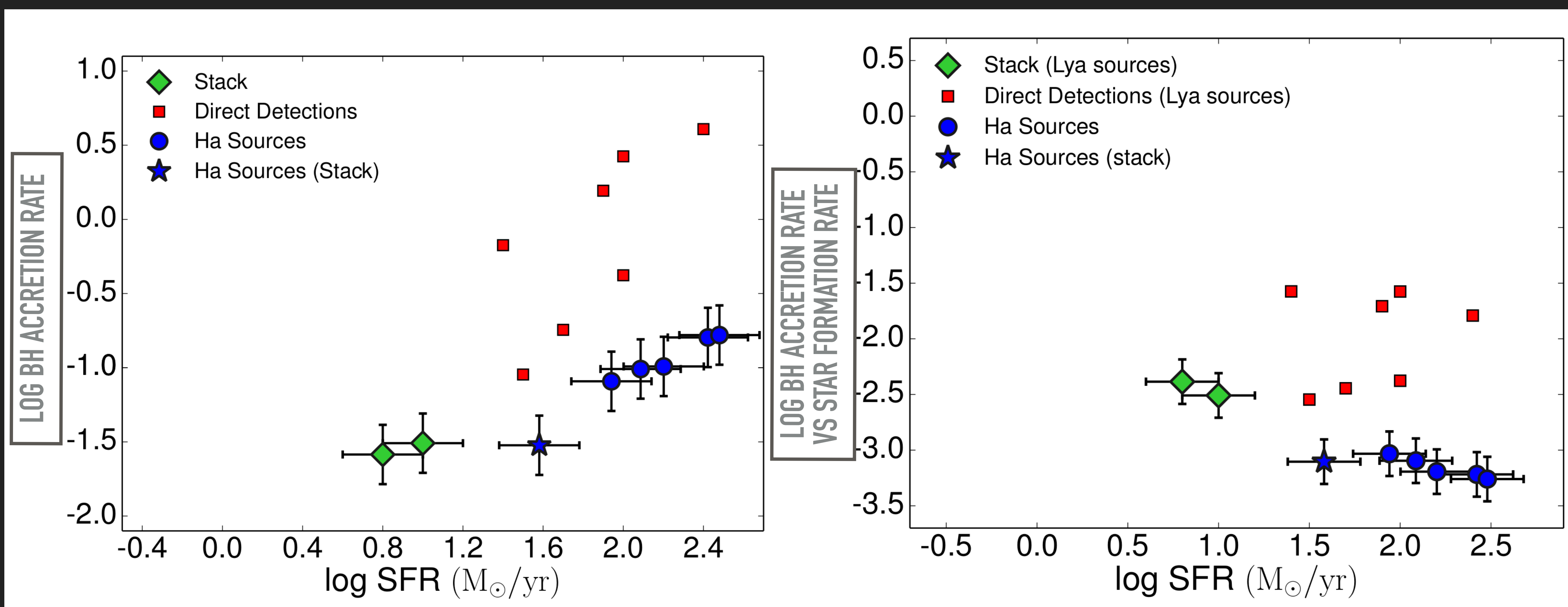
- Direct detections are very powerful (~10^{45} erg/s)
- There seems to be a correlation between the Lya luminosity of CALYMHa sources with their X-ray luminosity - but not very strong.
- Outflows or due to the AGN activity?



Calhau et al. in prep.

LET'S GO FARTHER: LY-ALPHA SELECTED SAMPLES

- Star formation still seems to be stronger than the black hole activity, despite the strength of the AGNs.
- However, once again, the two quantities seem to grow together.



Calhau et al. in prep.

LET'S GO FARTHER: CARBON SELECTED SAMPLES – CIV

- Sample from Stroe et al. (in prep.)
- Redshift ~ 1.53
- 45% are candidates for CIV emitters.

↓

- 45% are candidates for AGN even if not detected by Chandra.
- Very powerful: some sources with luminosities of ~10^{45} erg/s for CIV emitters in the X-rays.

Calhau et al. in prep.

LET'S GO FARTHER: CARBON SELECTED SAMPLES – CIV

- Sample from Stroe et al. (in prep.)
- Redshift ~ 1.05
- 40% are candidates for CIII] emitters.
- 40% are candidates for Star forming galaxies.
- Still powerful: some sources with luminosities of ~10^{42}-10^{43}erg/s for CIII] emitters in the X-rays.
- Undetected AGN?

Calhau et al. in prep.

CONCLUSION

- Galaxies grow their stellar mass quicker than their black holes.
- There seems to be no evolution of the relative growth of stellar mass and black hole mass.
- The two quantities seem to grow together even within the same redshift - common feeding processes?

THANK YOU FOR YOUR TIME