

DEX XV

EDINBURGH - 2019

The X-ray activity of star-forming galaxies across cosmic time

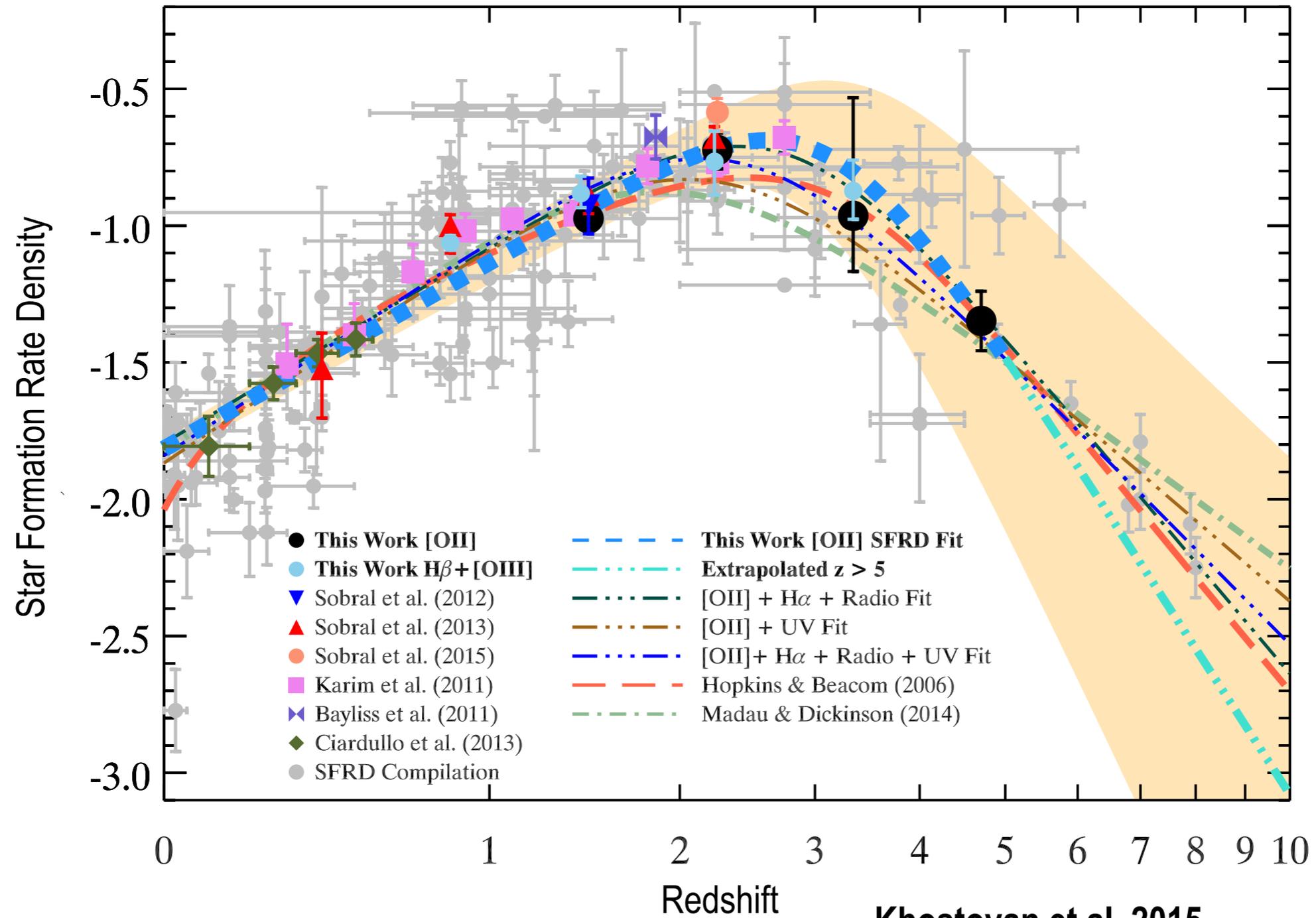
João Calhau

Collaborators: David Sobral, Jorryt Matthee, Sérgio Santos, Andra Stroe, Ana Paulino-Afonso



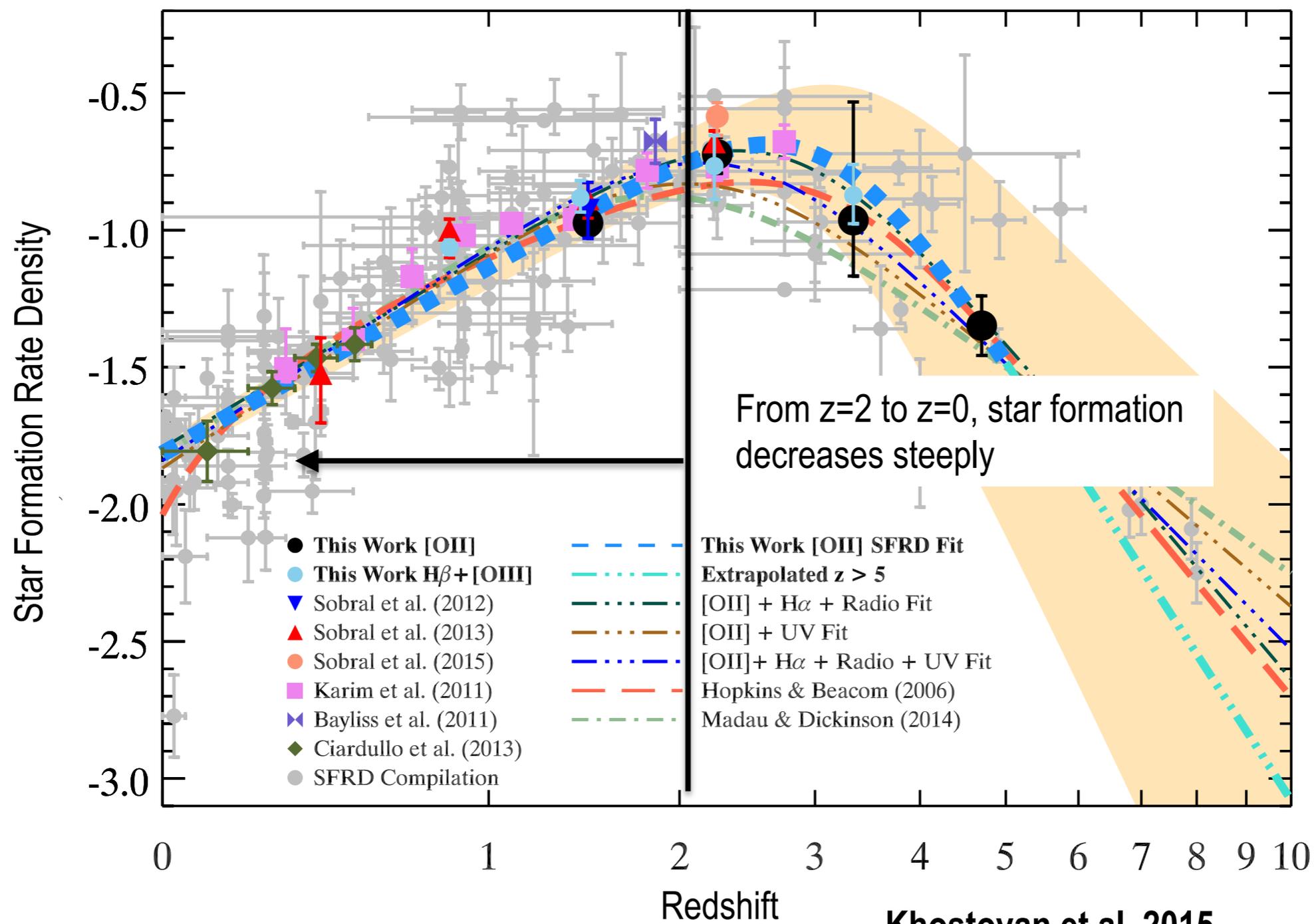
THE STAR FORMATION HISTORY OF THE UNIVERSE

(I'm sorry)



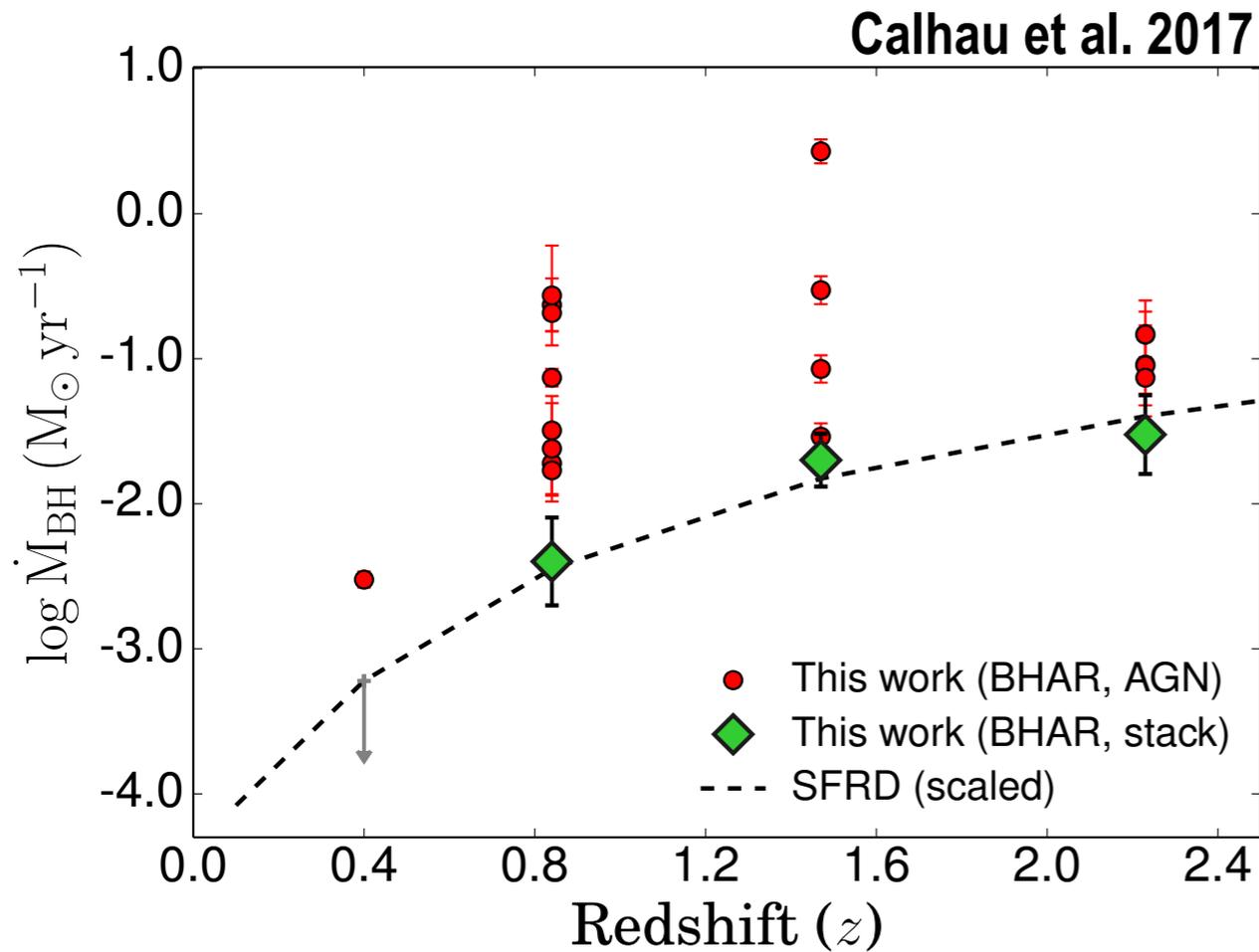
Khostovan et al. 2015

THE STAR FORMATION HISTORY OF THE UNIVERSE



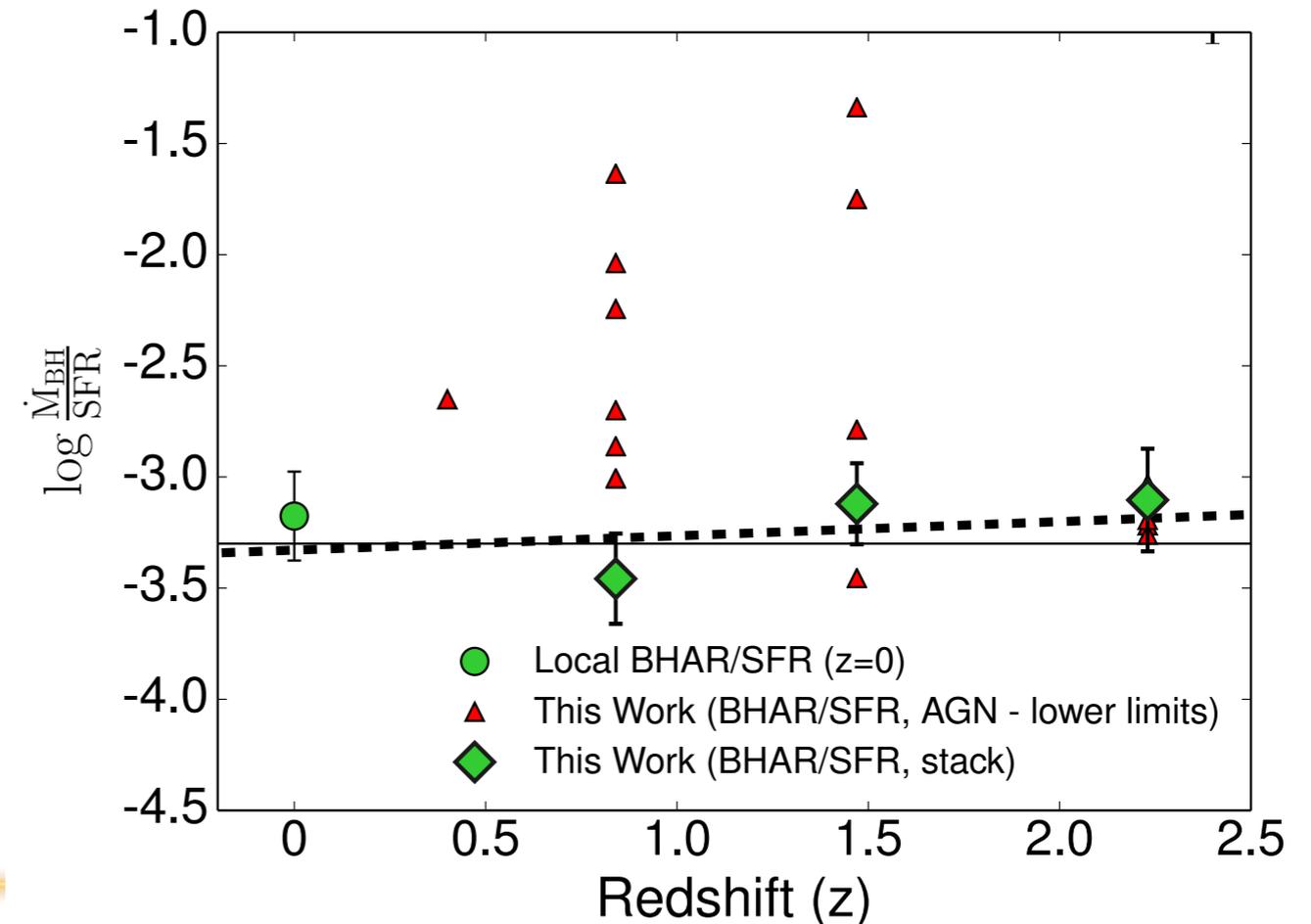
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THE BLACK HOLE ACCRETION RATE OF STAR FORMING GALAXIES

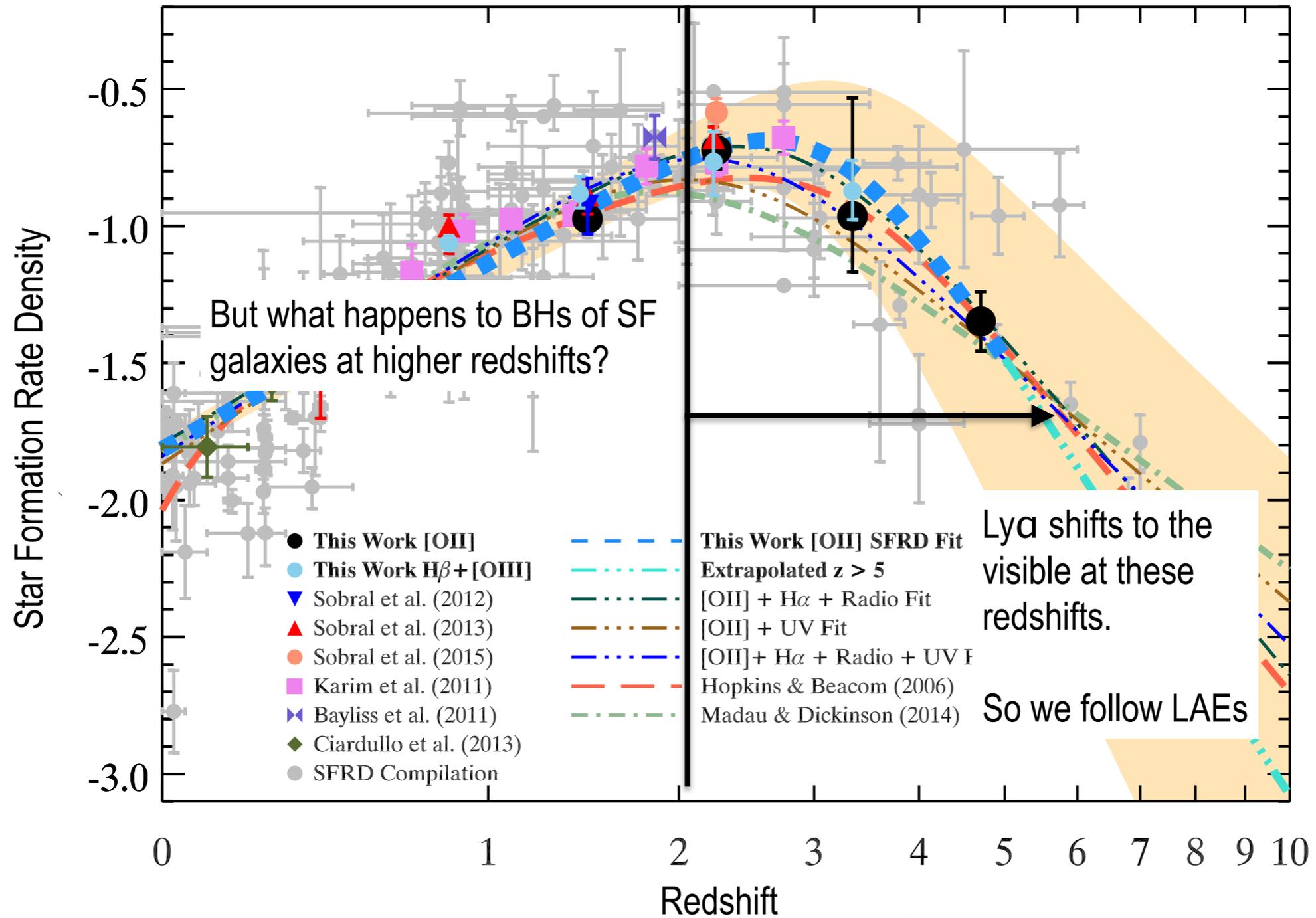


With the ratio between the two remaining constant - same feeding mechanism?

Black hole accretion rate seems to follow the evolution of star formation



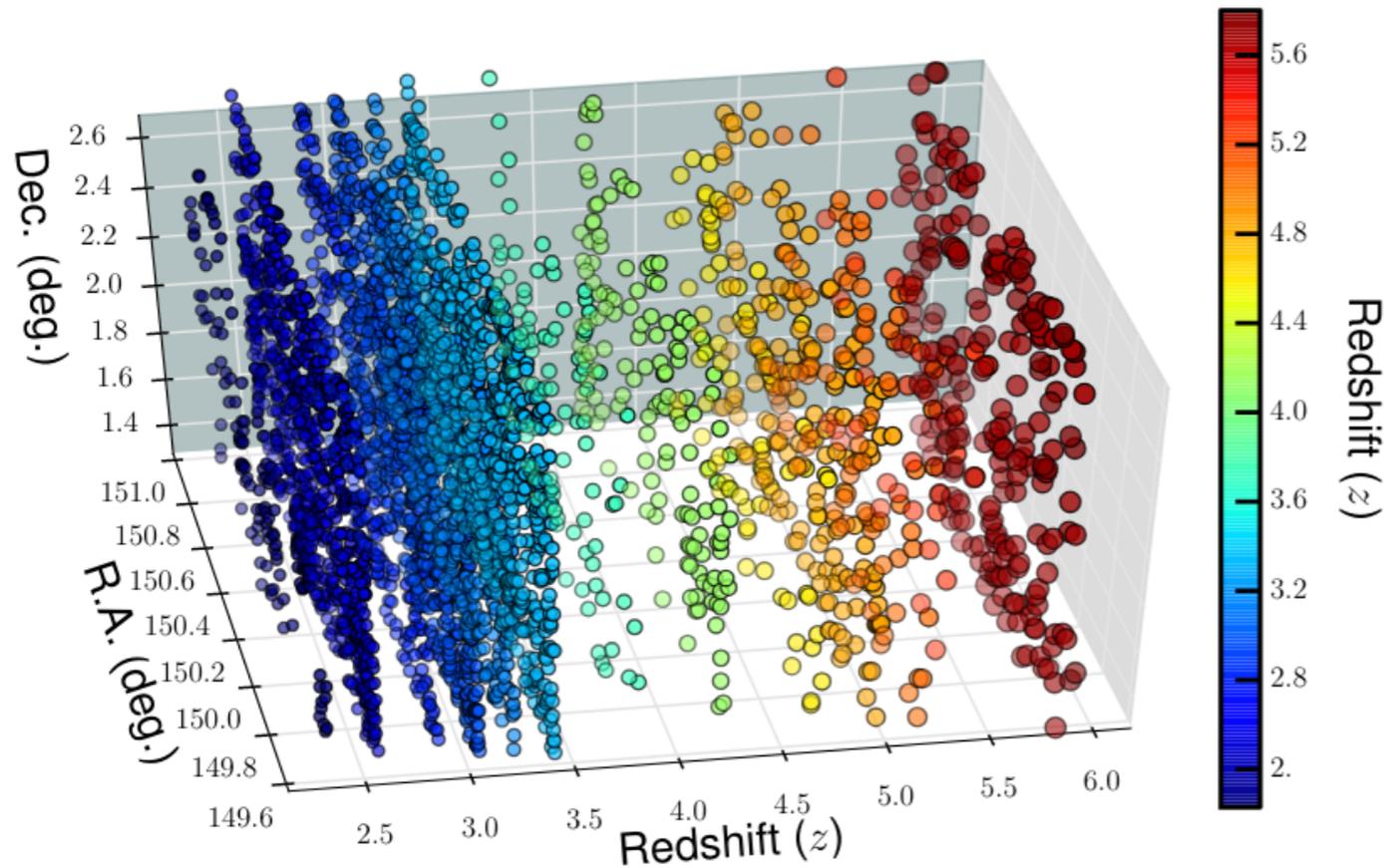
THE BLACK HOLE ACCRETION RATE OF STAR FORMING GALAXIES



Khostovan et al. 2015

ENTER SC4K - SLICING COSMOS FROM Z=2 TO Z=6

Sobral et al 2018a - ArXiv:1712.04451



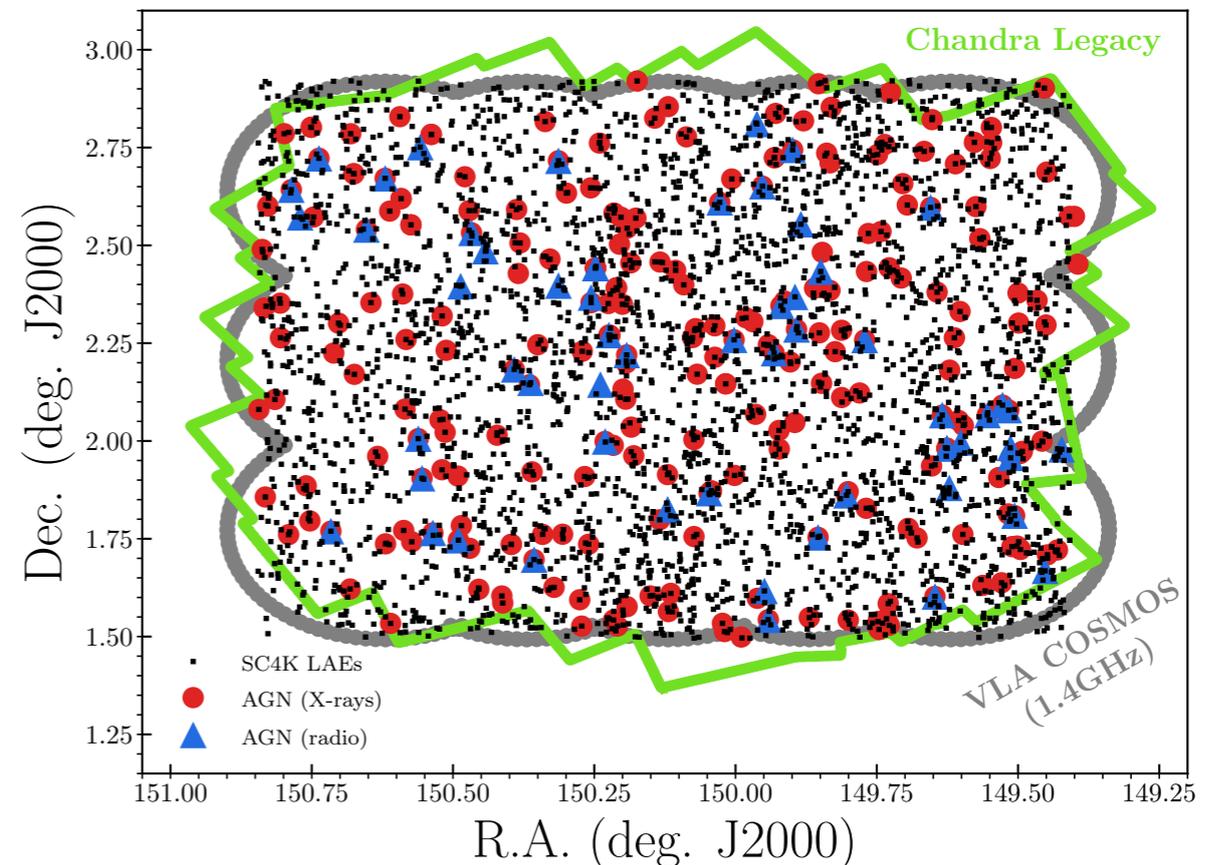
~4000 LAEs spanning a redshift range of $z \sim 2 - 6$ in the COSMOS field.

Total volume of $\sim 6 \times 10^7 \text{ Mpc}^3$

Publicly available

In the COSMOS field (Scoville et al. 2007).

Numerous available bands: X-rays, Radio, Infrared and more



Calhau et al. submitted

X-RAY ACTIVITY FOR LAES

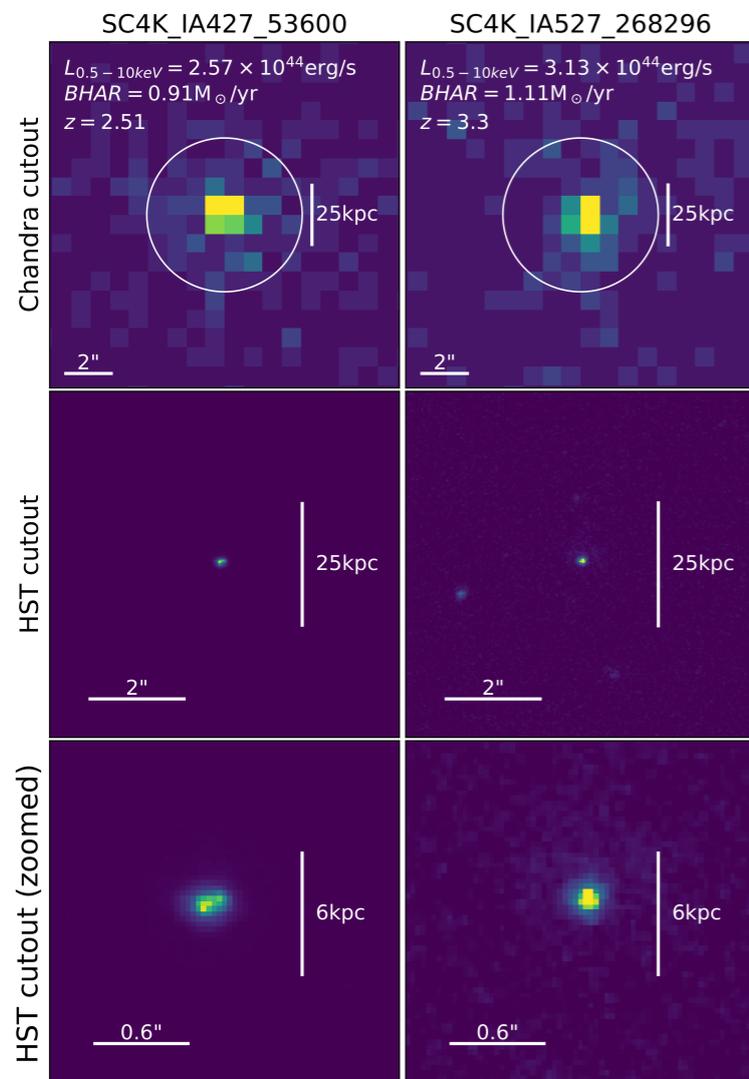
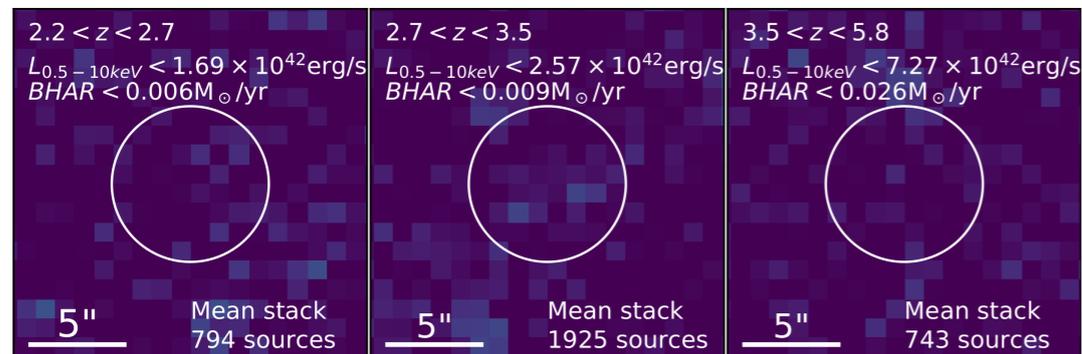
Radio emission from
synchrotron radiation.

Inverse-Compton effect:
X-ray emission

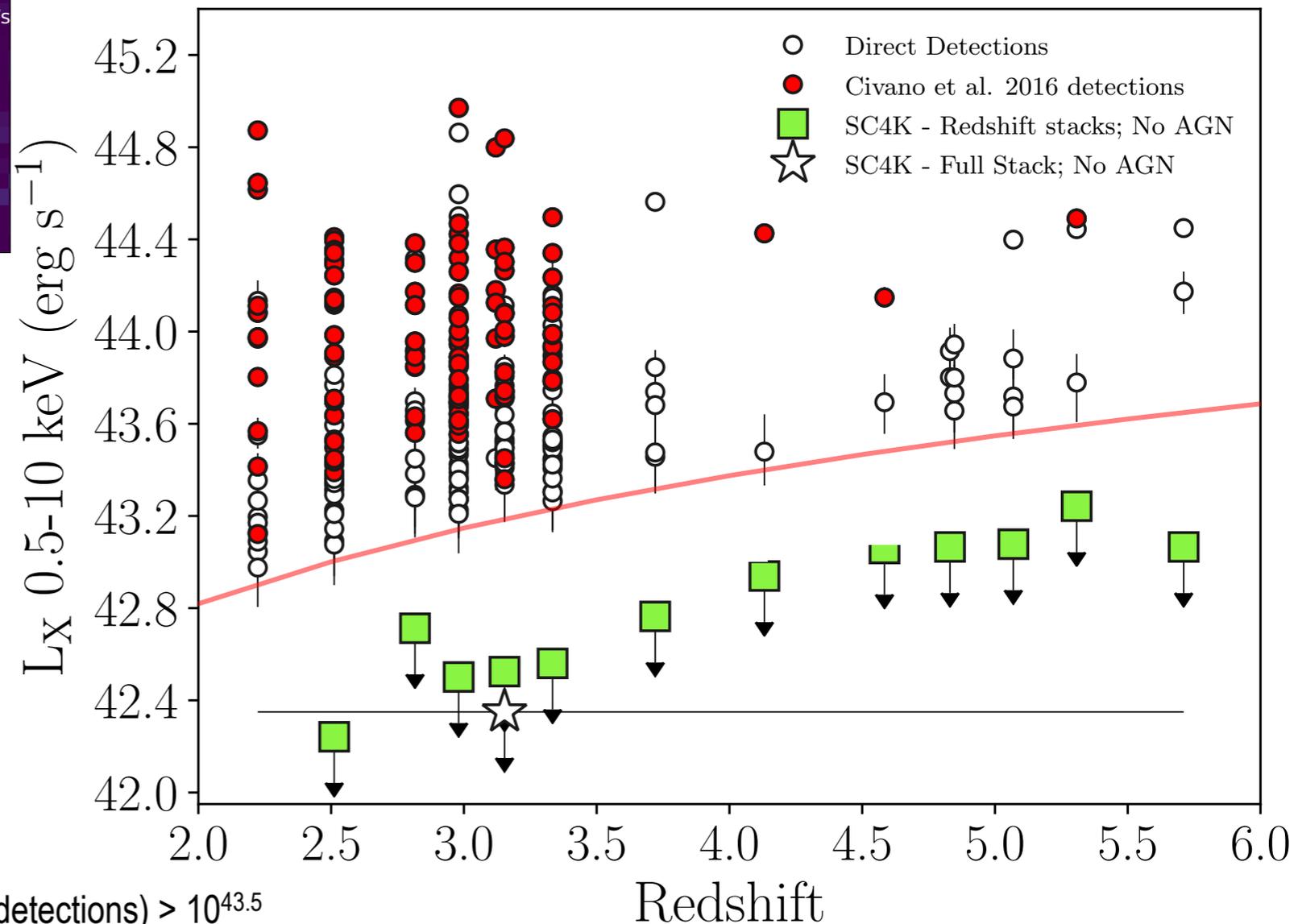
Directly related to the
rate of accretion.

THE X-RAY ACTIVITY OF STAR FORMING GALAXIES AT Z=2-6

Direct detections in the X-rays possess moderate to high luminosity, but stacking non-X-ray sources results in non-detections.



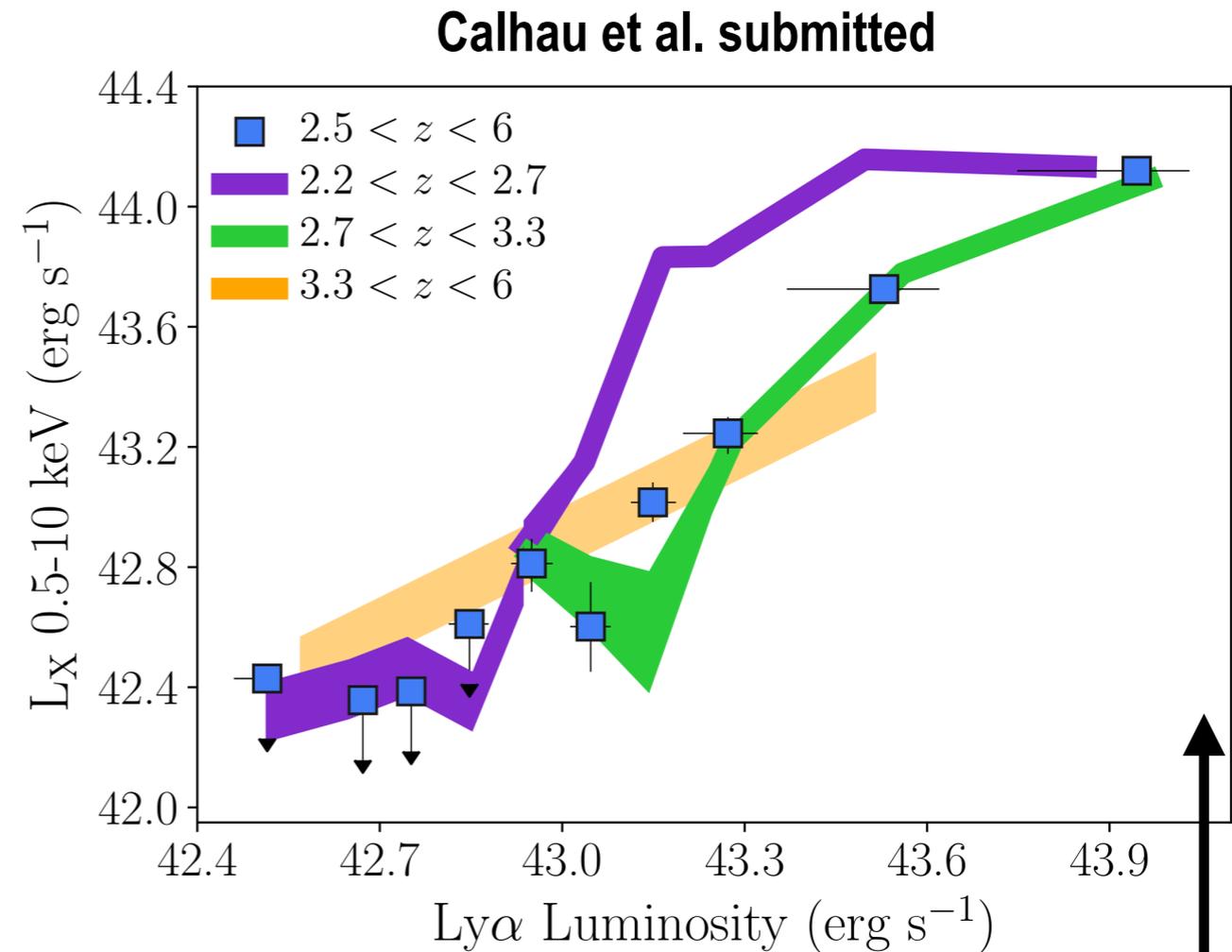
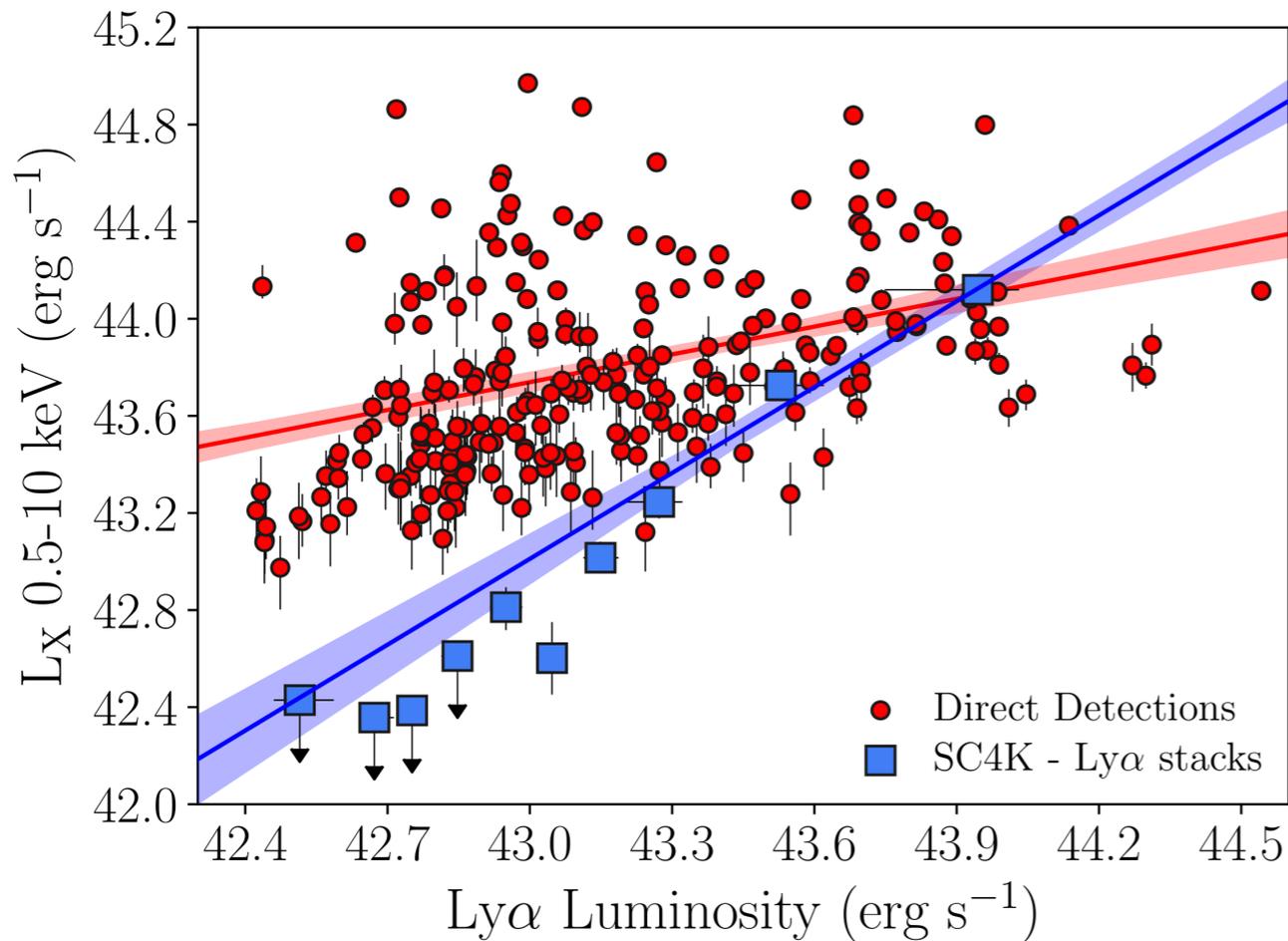
Calhau et al. submitted



Calhau et al. submitted

THE X-RAY ACTIVITY OF STAR FORMING GALAXIES AT Z=2-6

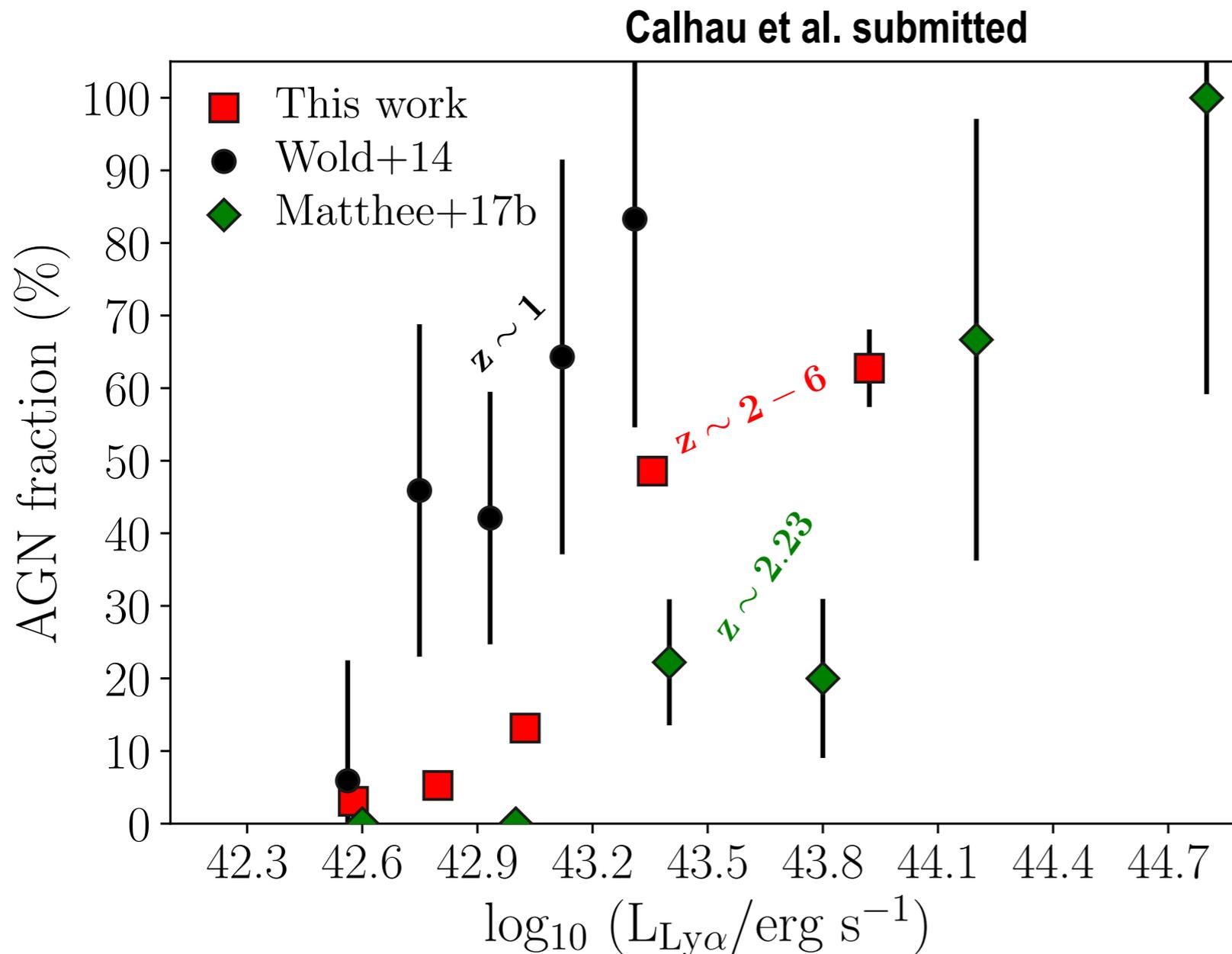
There seems to be a relation between Ly α luminosity and X-ray luminosity - Ly α becomes a tracer for black hole accretion.



This relation differs for different redshift bins. For low redshift sources, the same x-ray luminosity results in fainter Ly α emission - low-z LAEs less dusty than higher-z counterparts?

THE AGN FRACTION OF LAES

Only ~4% of our sources are detected in either x-rays or radio and classified as AGN.

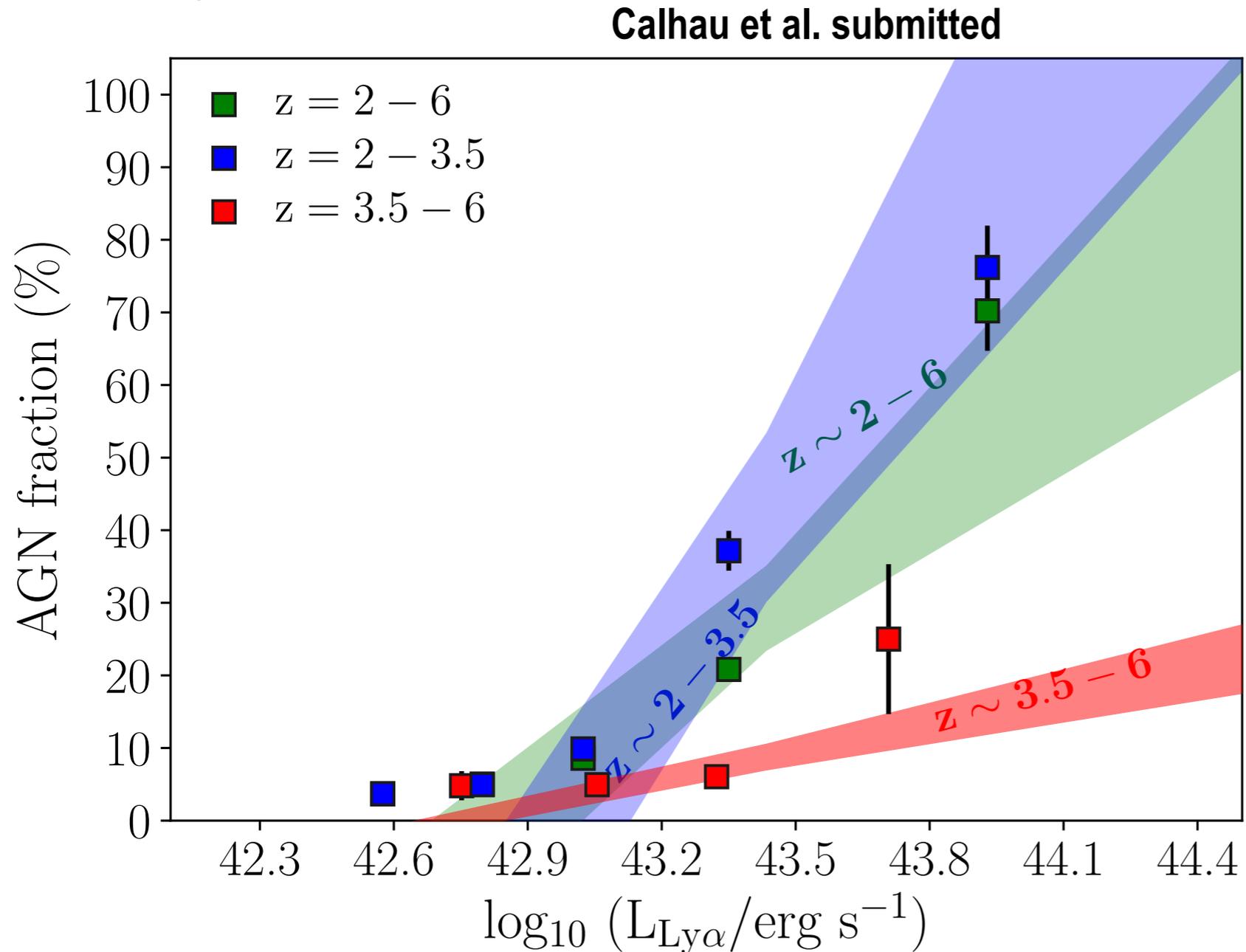


The total AGN fraction (x-ray + radio) rises with Ly α luminosity.

At higher luminosity bins, this fraction approaches 100%.

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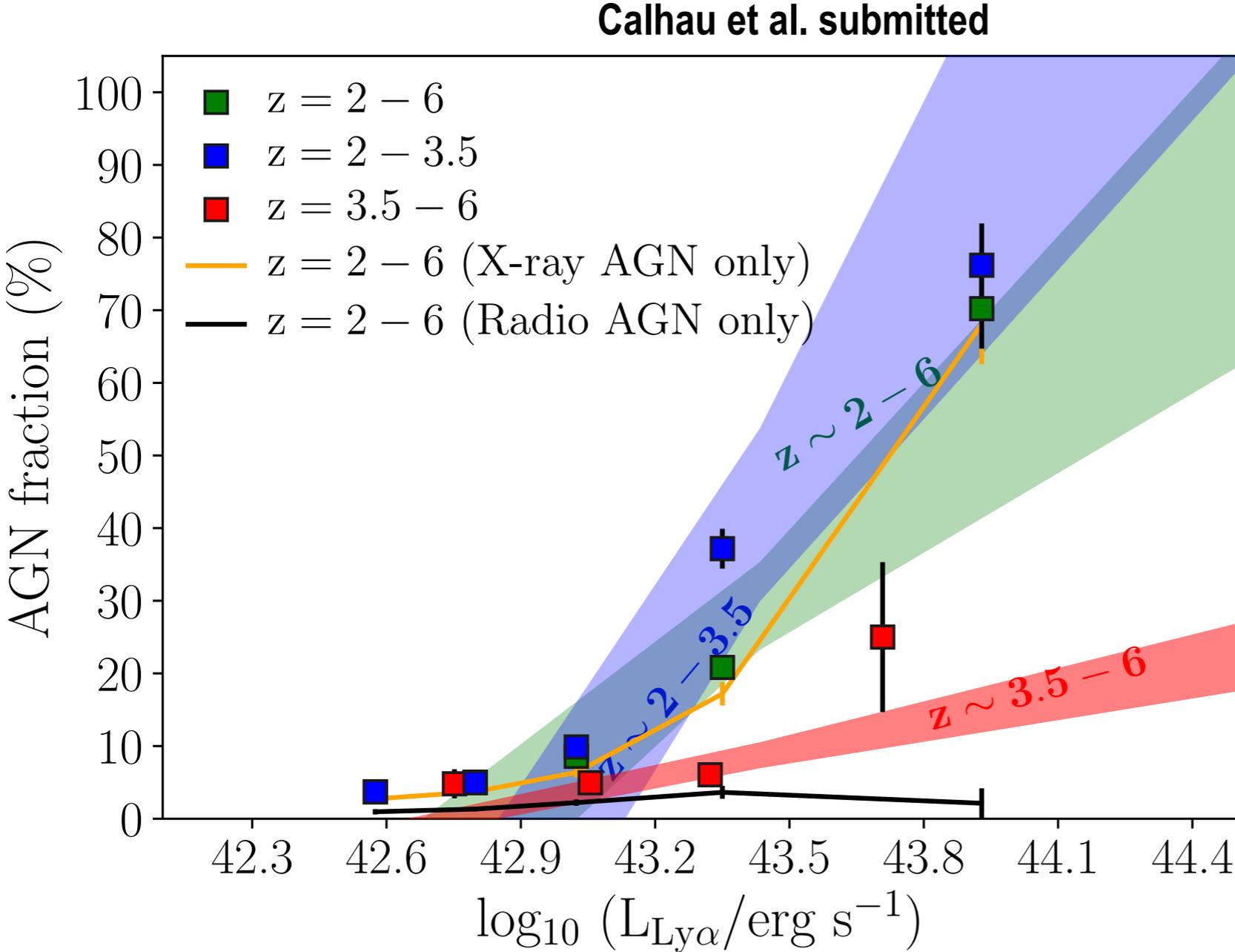
The total AGN fraction (x-ray + radio) rises with Ly α luminosity.

At higher luminosity bins, this fraction approaches 100%.

The AGN fractions also appears to show evolution with redshift.

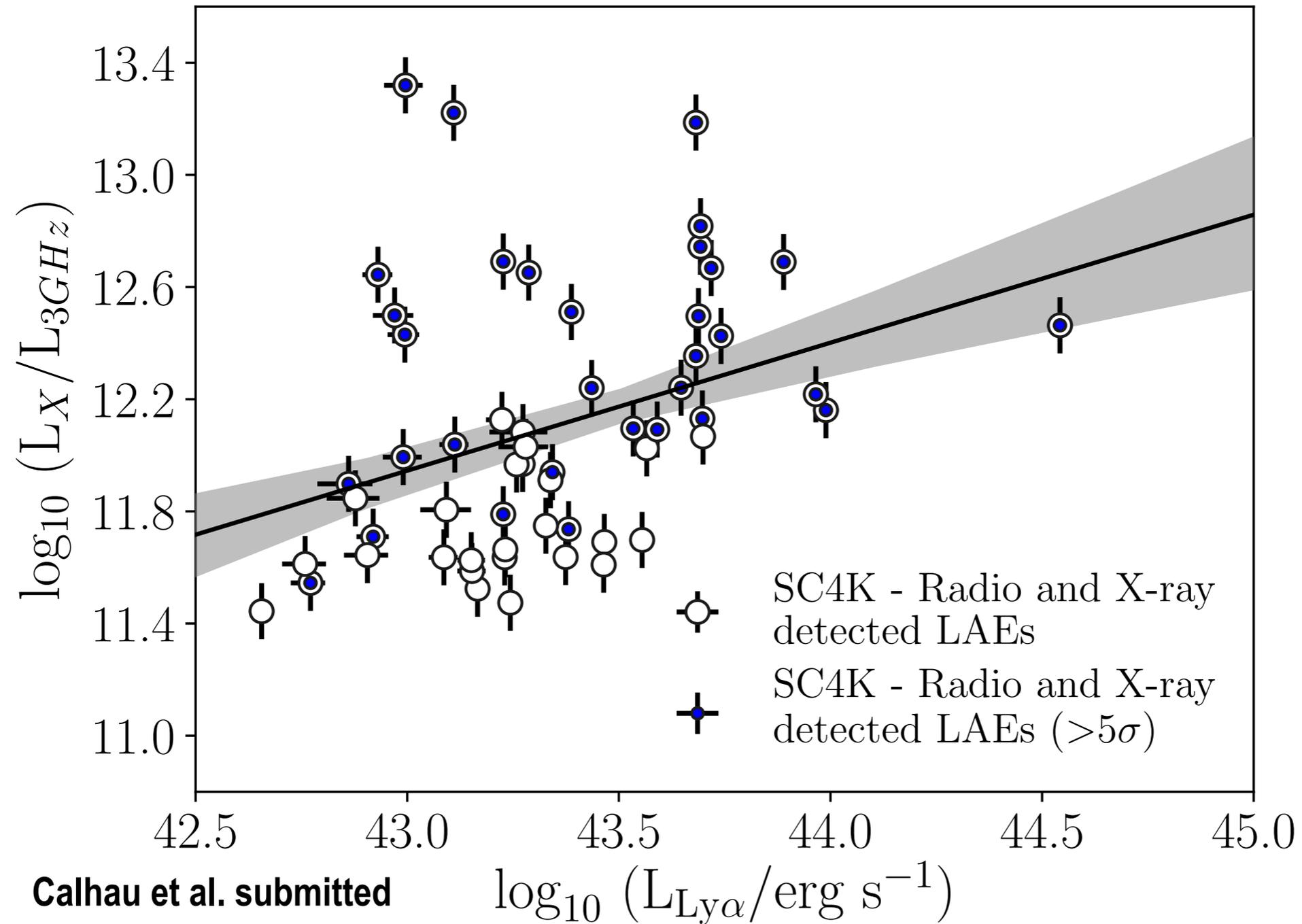
BUT

THE AGN FRACTION OF LAES

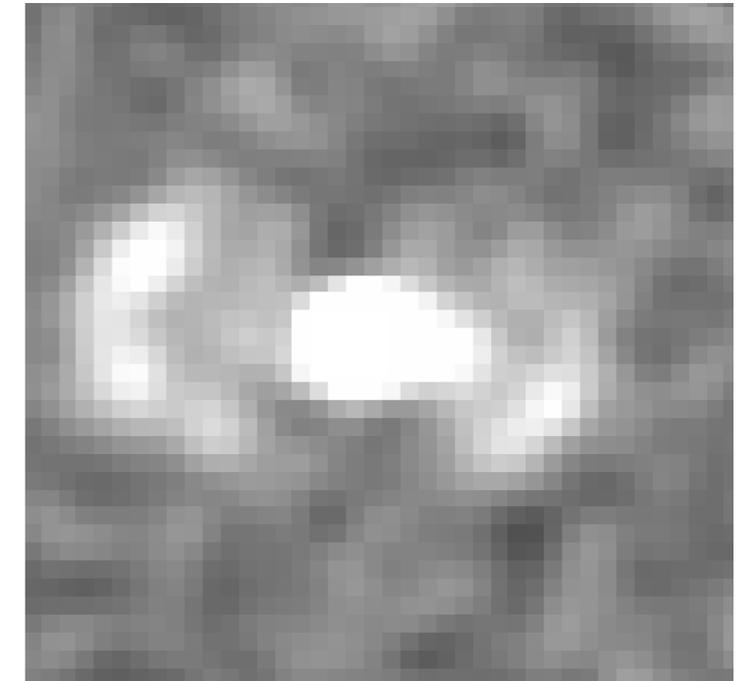
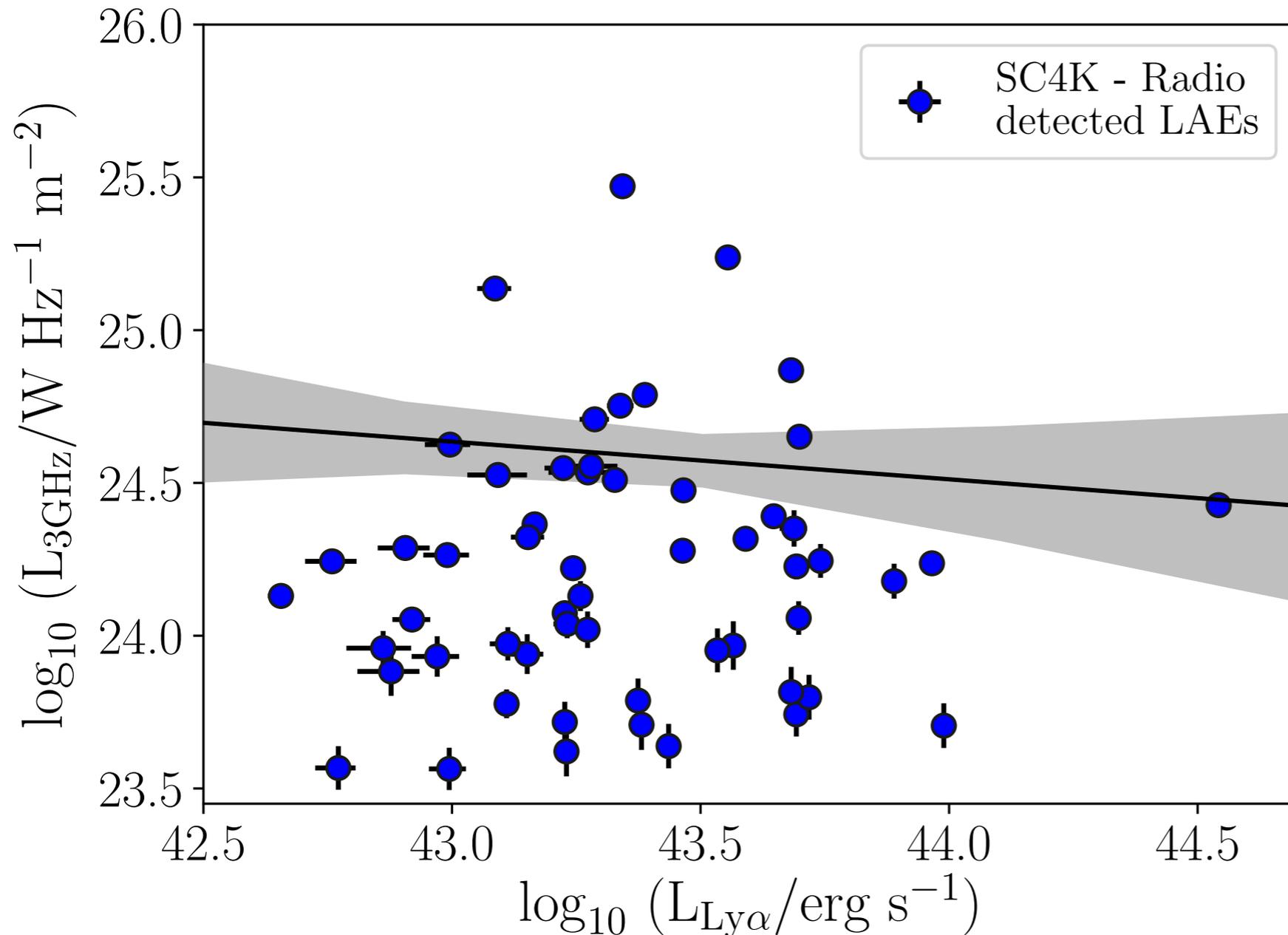


Only x-ray sample shows signs of evolution. Radio AGN are constant across Ly α luminosity.

Radio and X-rays correlate with $\text{Ly}\alpha$ luminosity?



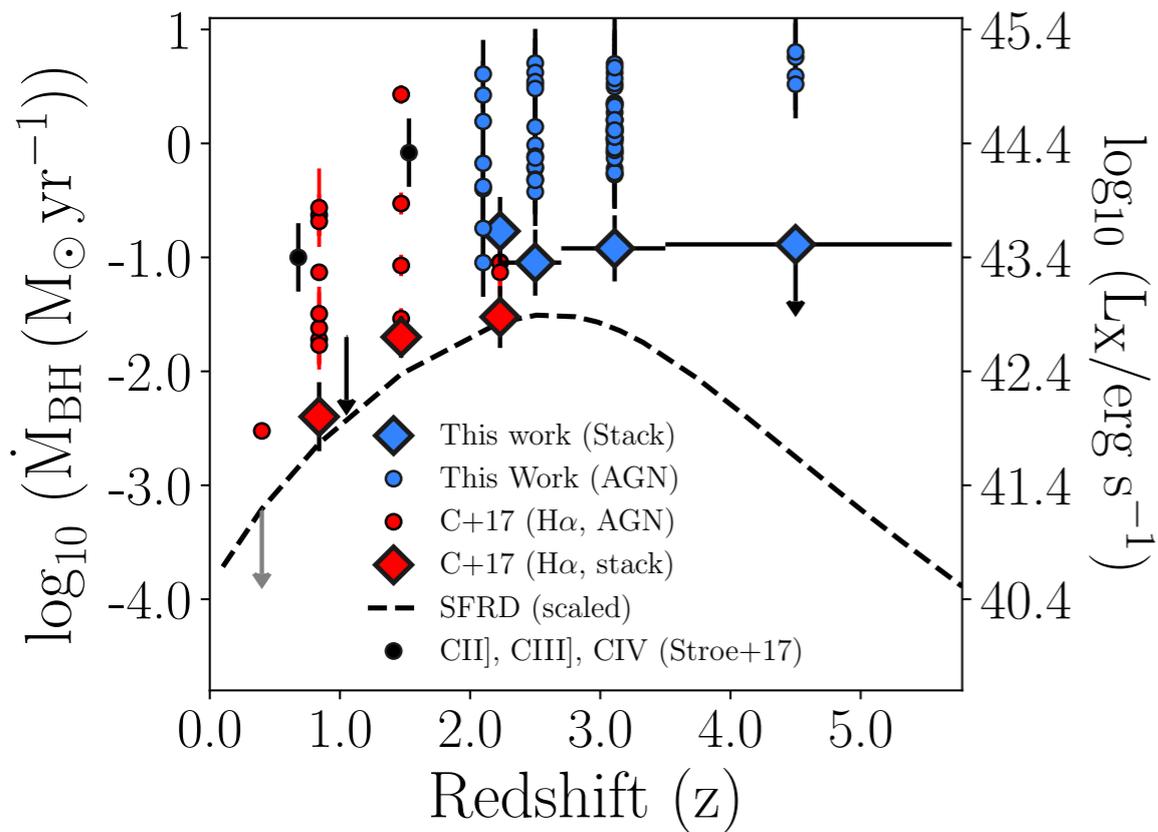
L_X/L_{RADIO} RELATION WITH $\text{Ly}\alpha$ LUMINOSITY?



Does not seem like Radio correlates with Ly α luminosity. Radio emission originates from different processes than X-rays and Ly α .

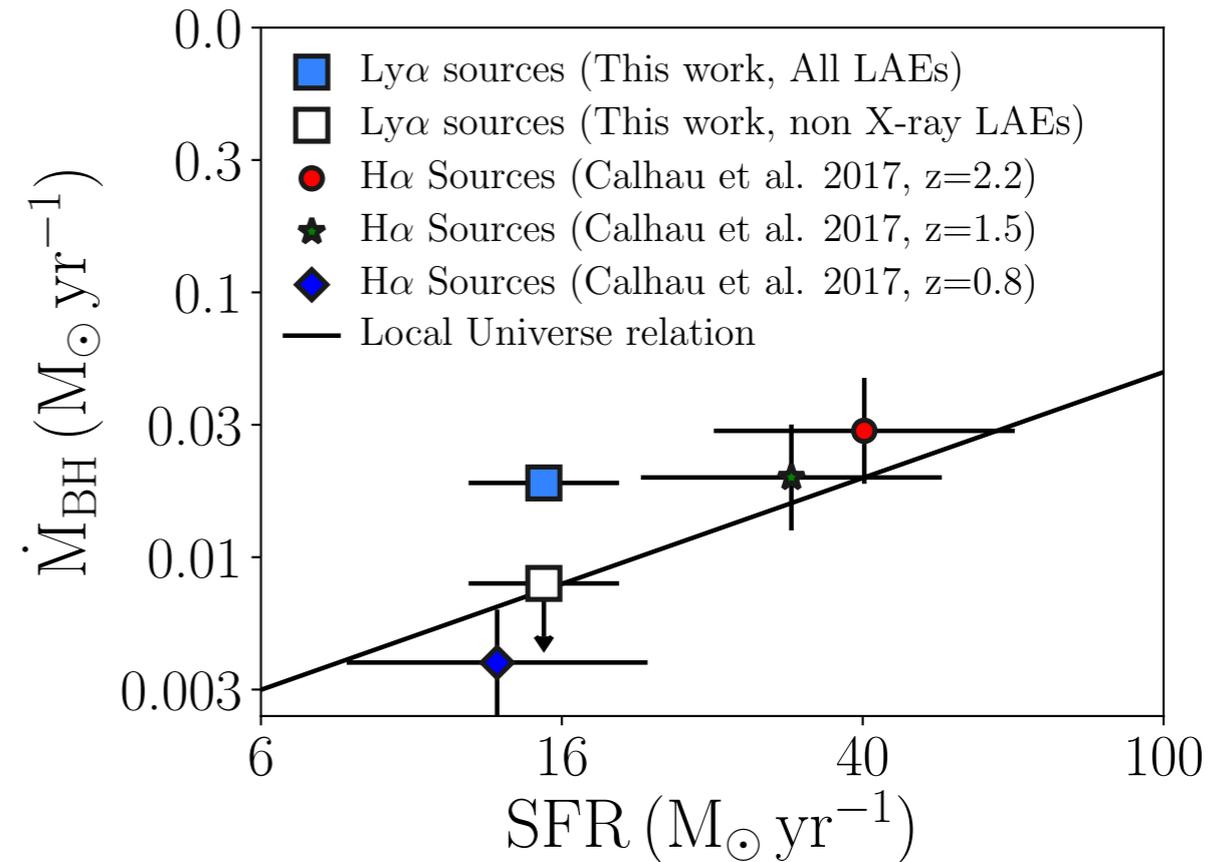
THE EVOLUTION OF BHAR ACROSS COSMIC TIME

Ly α -selected samples yield high accretion black holes.



The evolution of BHARs is consistent with SFRD up to $z=3$, but beyond that we cannot be sure.

Calhau et al. submitted

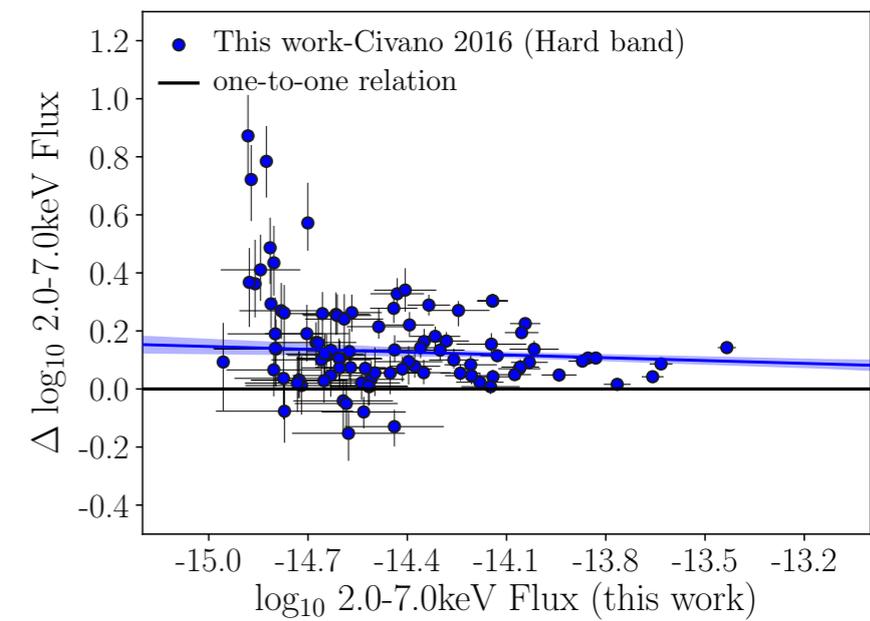
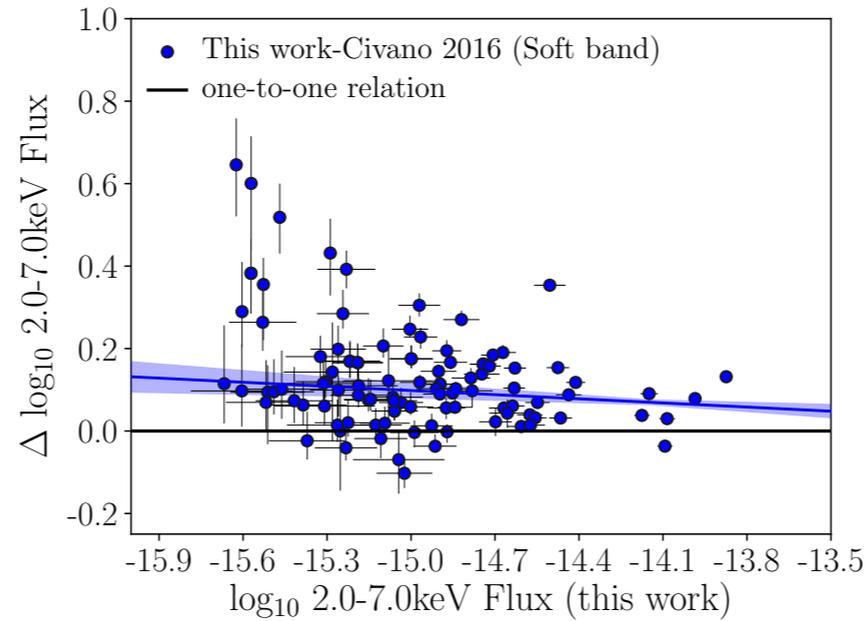
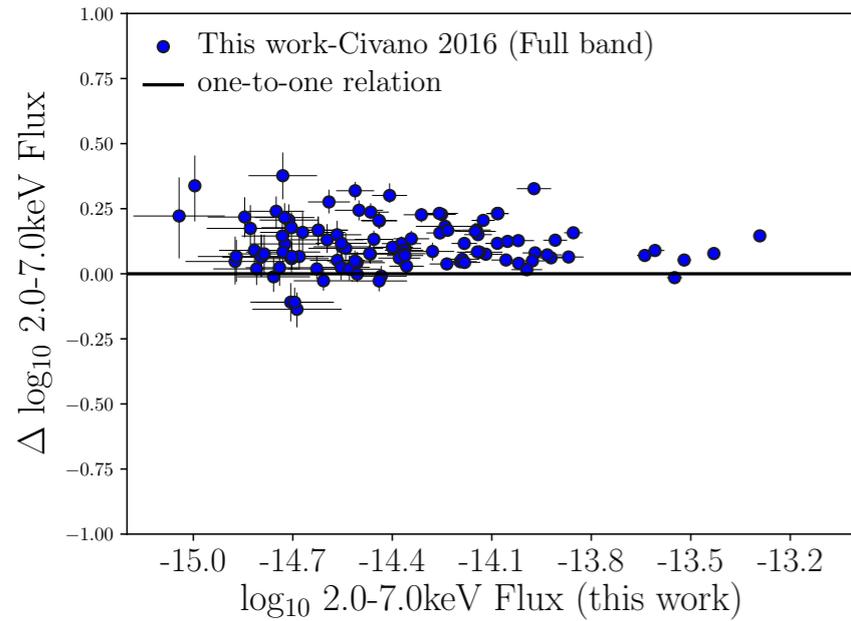


The black hole to galaxy growth ratio (BHAR/SFR) is <0.001 , consistent with typical star forming galaxies that can easily lead to establishing the local BHAR/SFR relation.

TAKE AWAY POINTS

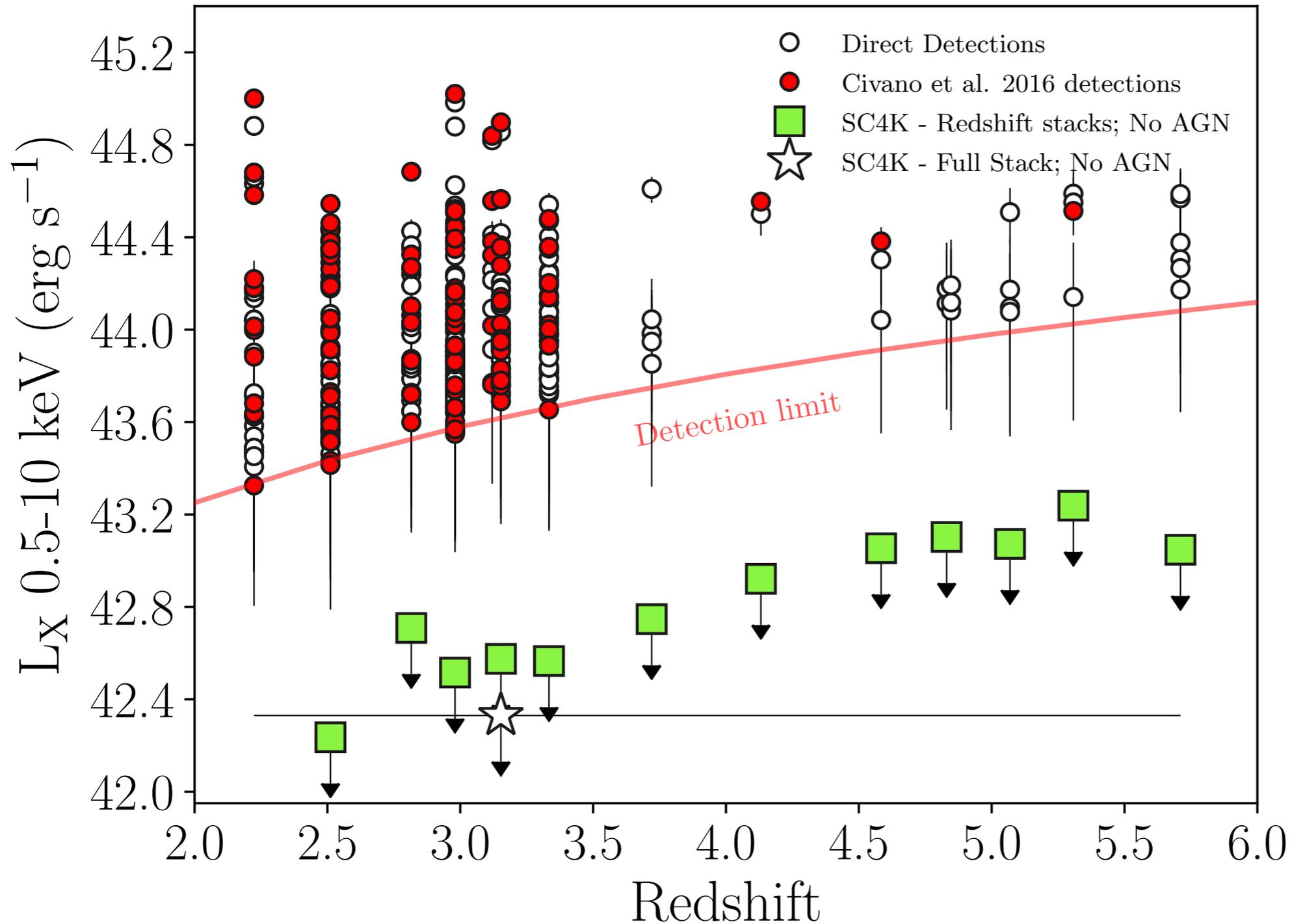
- ~96% of the LAEs are likely star forming galaxies. Only 4% are AGN candidates.
 - Very bright AGN in the X-rays ($\log(L_{X\text{-rays}}) > 43.5$; average BHAR $\sim 0.46 M_{\text{solar}}/\text{yr}$)
 - No relation between X-ray and Ly α luminosities found when stacking without the AGN, but -
 - Positive relation when including X-ray detections.
- ↓
- Ly α emission in X-ray detected galaxies is likely tracing BH activity.
 - AGN fraction rises with Ly α luminosity and shows signs of evolution with redshift.
 - LAEs present a variety of different HR values, but there is no evolution with redshift.
 - Radio emission does not correlate with Ly α \longrightarrow likely originates from different processes than Ly α and X-rays.
 - Evolution of BHAR consistent with SFH up to $z \sim 3$. BHAR/SFR comparable to lower redshift star forming galaxies suggesting a trend across cosmic time.

FLUX CORRECTIONS FOR THE X-RAY MEASUREMENTS



Correction of a factor of +0.1 (log scale) based on the median difference between the logs of our fluxes and Civano et al. 2016

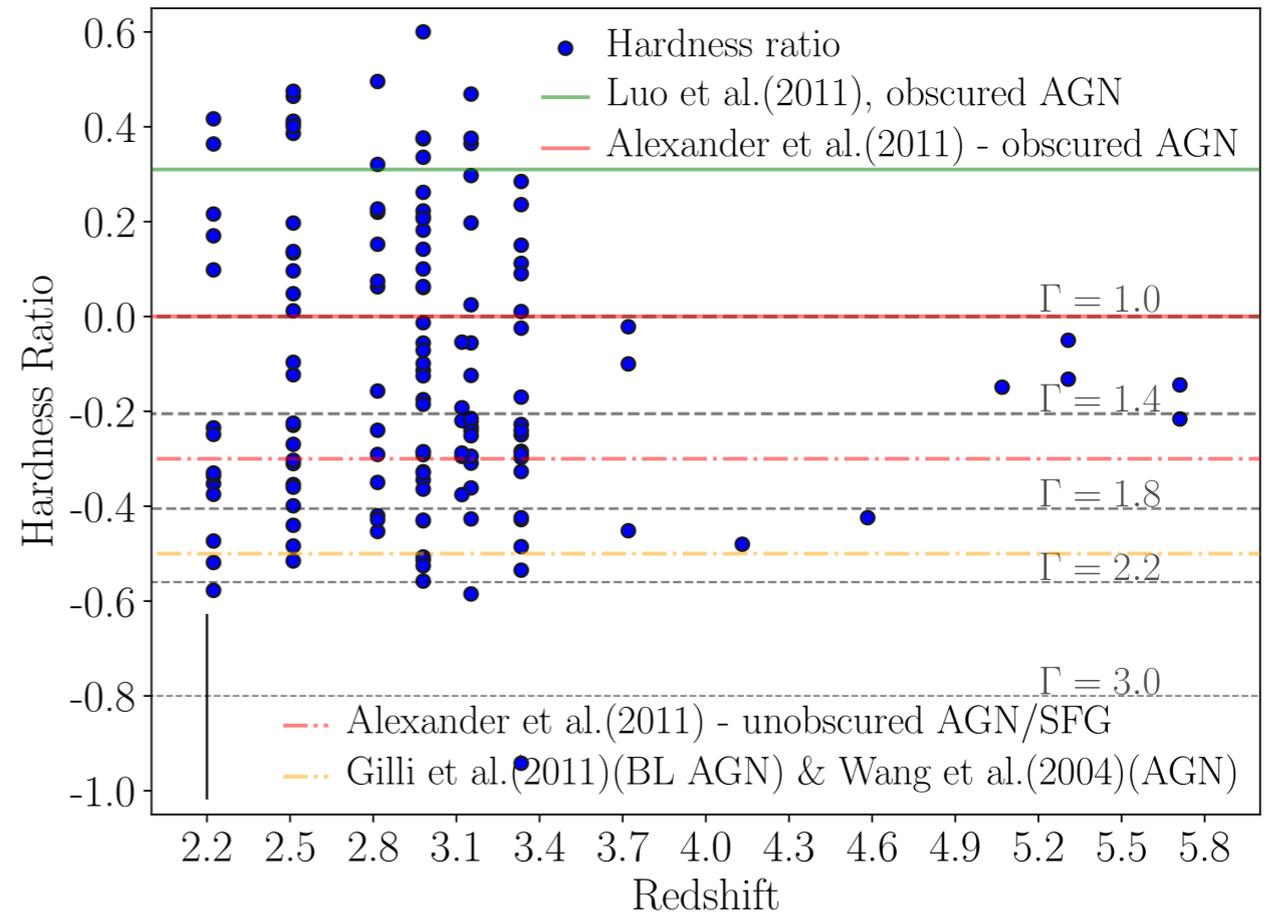
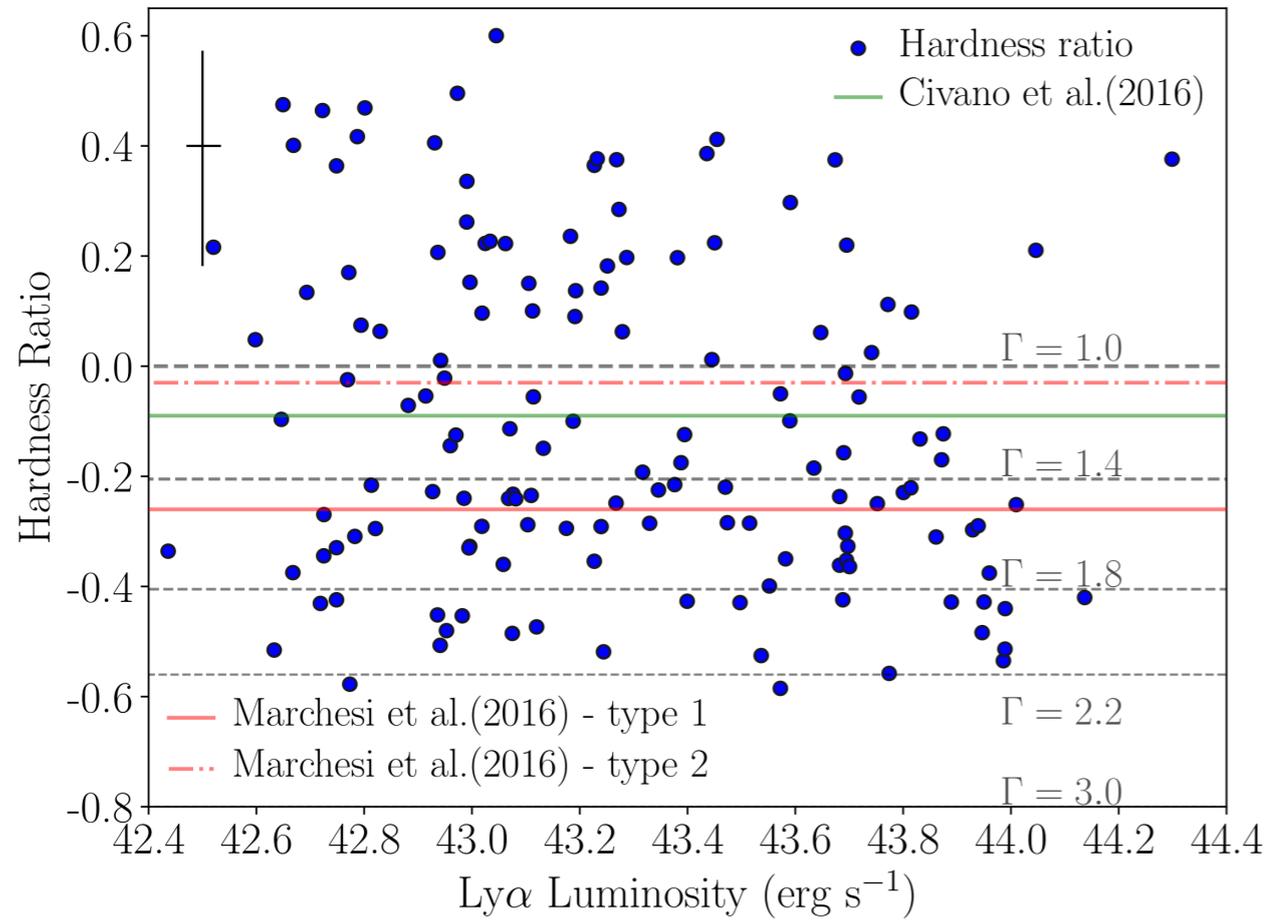
X-RAY FLUX CORRECTION



Flux correction to our X-ray fluxes to make them comparable to Civano et al. 2016's fluxes.

Correction taken as the median of the difference of the logarithm of the fluxes.

HARDNESS RATIO



LYMAN-ALPHA EMISSION

- Photon emission from the passage of an electron from the energy level $n=2$ to $n=1$ in an Hydrogen atom.
- Wavelength 1216 angstrom.
- VERY easily absorbed by gas.
- Has a very distinct shape.
- Shifts to optical at $z>2$ and is the most luminous line in SF regions.
- May also come from AGN activity.

