The mass relations between supermassive Black Holes and their host galaxies at 1<z<2 with HST-WFC3

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Outline

- Motivation
  - The supermassive BH and host galaxy correlation
  - The challenge of tracing to higher redshift
- Methodology
  - Sample selection
  - AGN image decomposition
  - Infer of the host stellar mass
- Results

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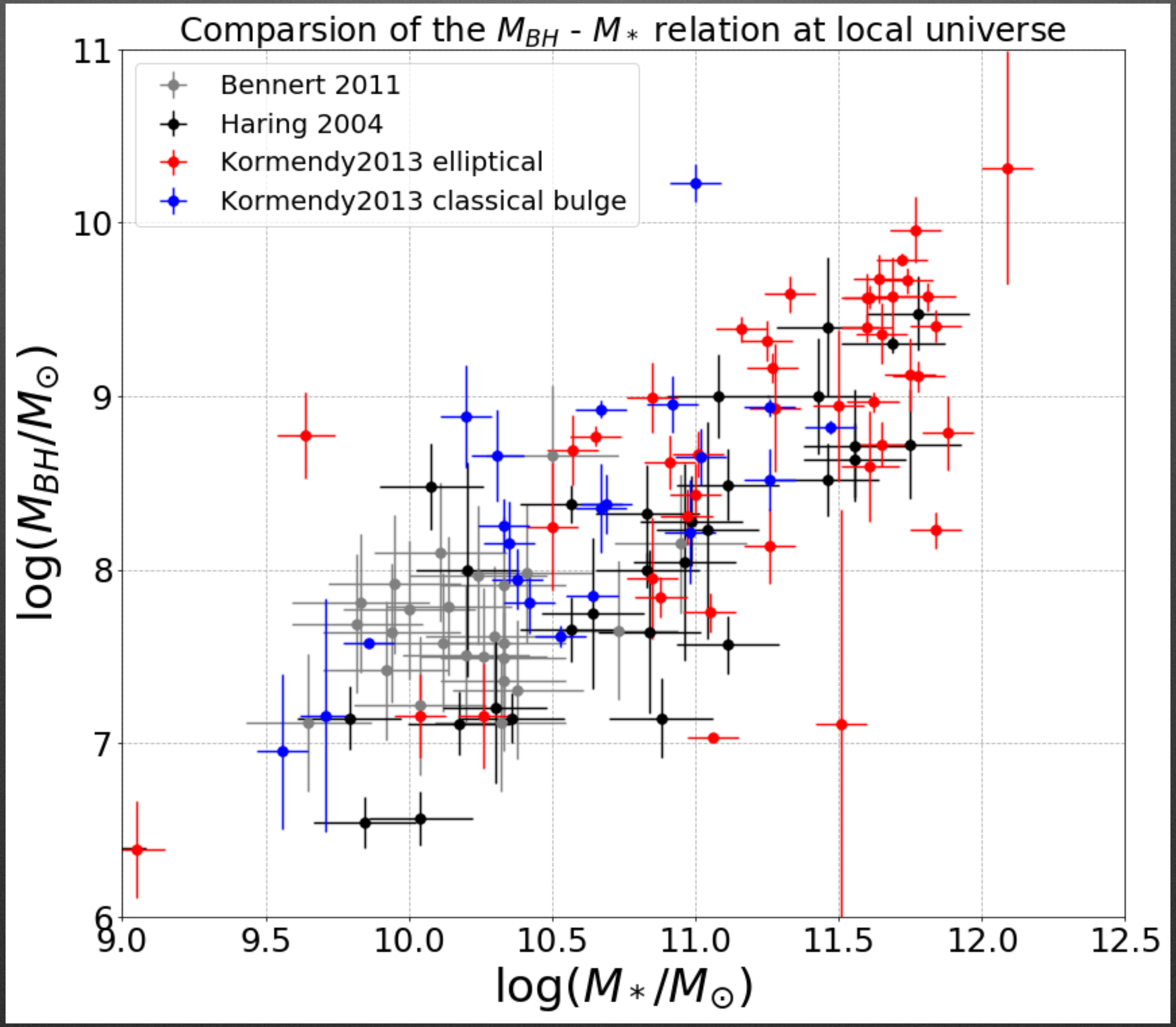
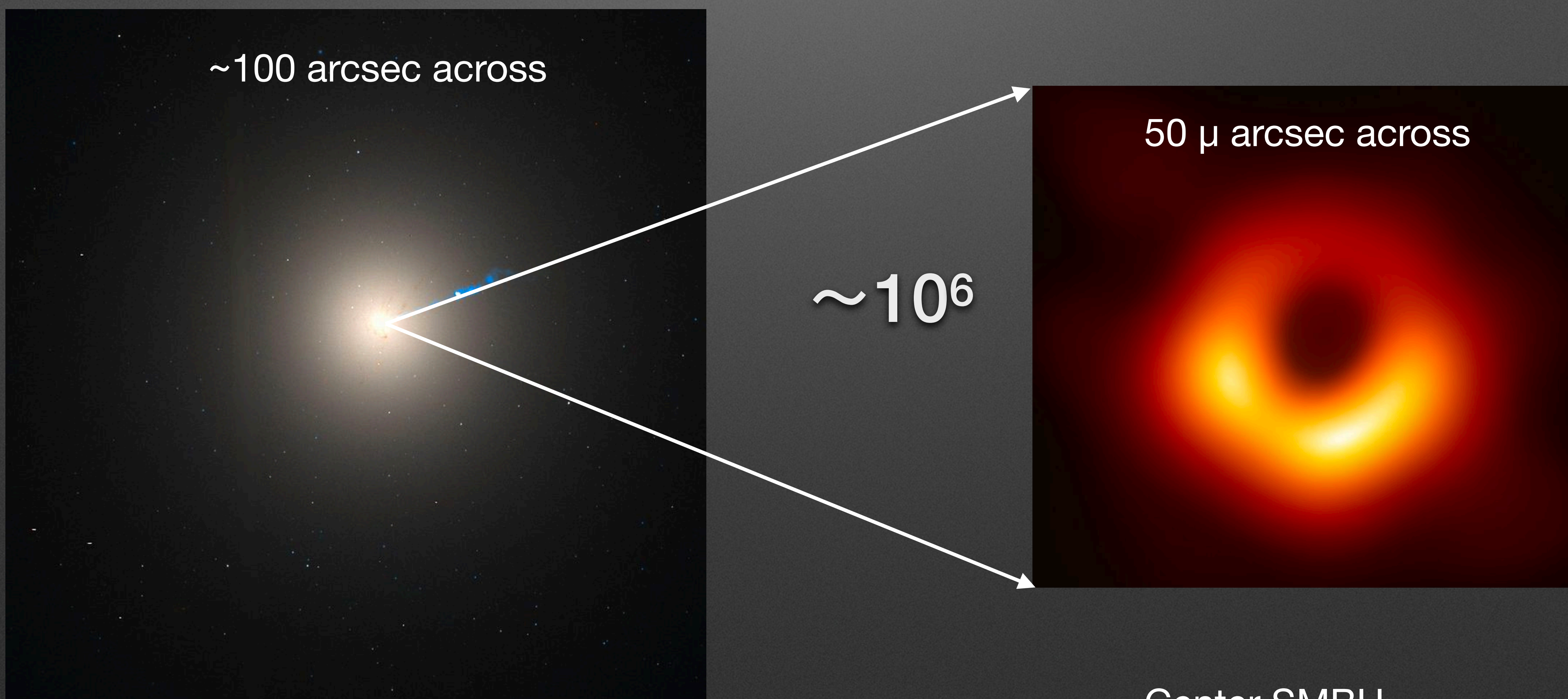
The BH and host galaxy relation

Almost every galactic nuclei harbor a supermassive black hole (BH), whose mass is well known to be correlated with the host properties (including: luminosity, stellar mass, stellar velocity dispersion).



The BH and host galaxy relation

Currently, the physical mechanism that can produce such a tight relationship is unknown, due to the daunting range of scales between the scale of the host galaxy (~ 10 kpc) and center BH dynamical sphere (~ pc).



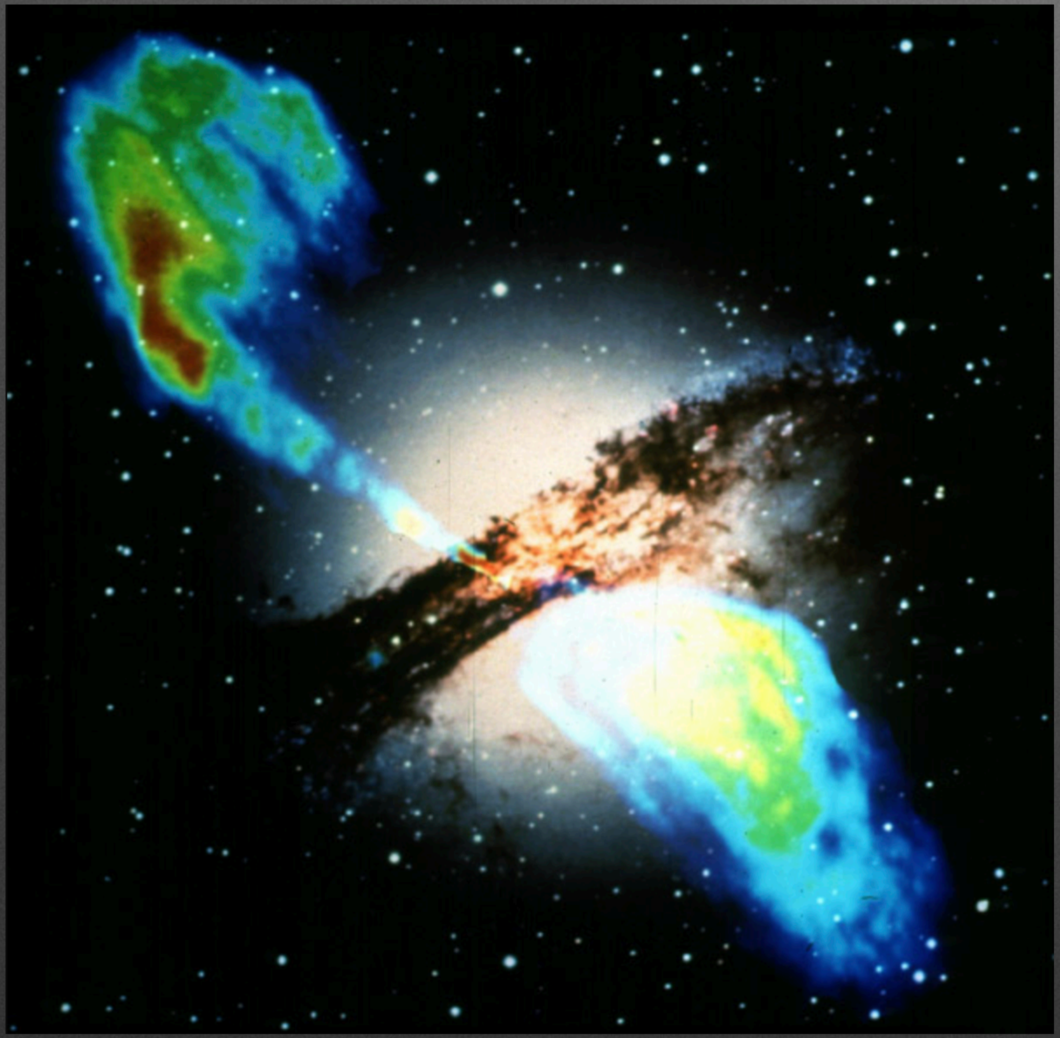
Messier 87, credit HST.

Center SMBH
credit Event Horizon Telescope.

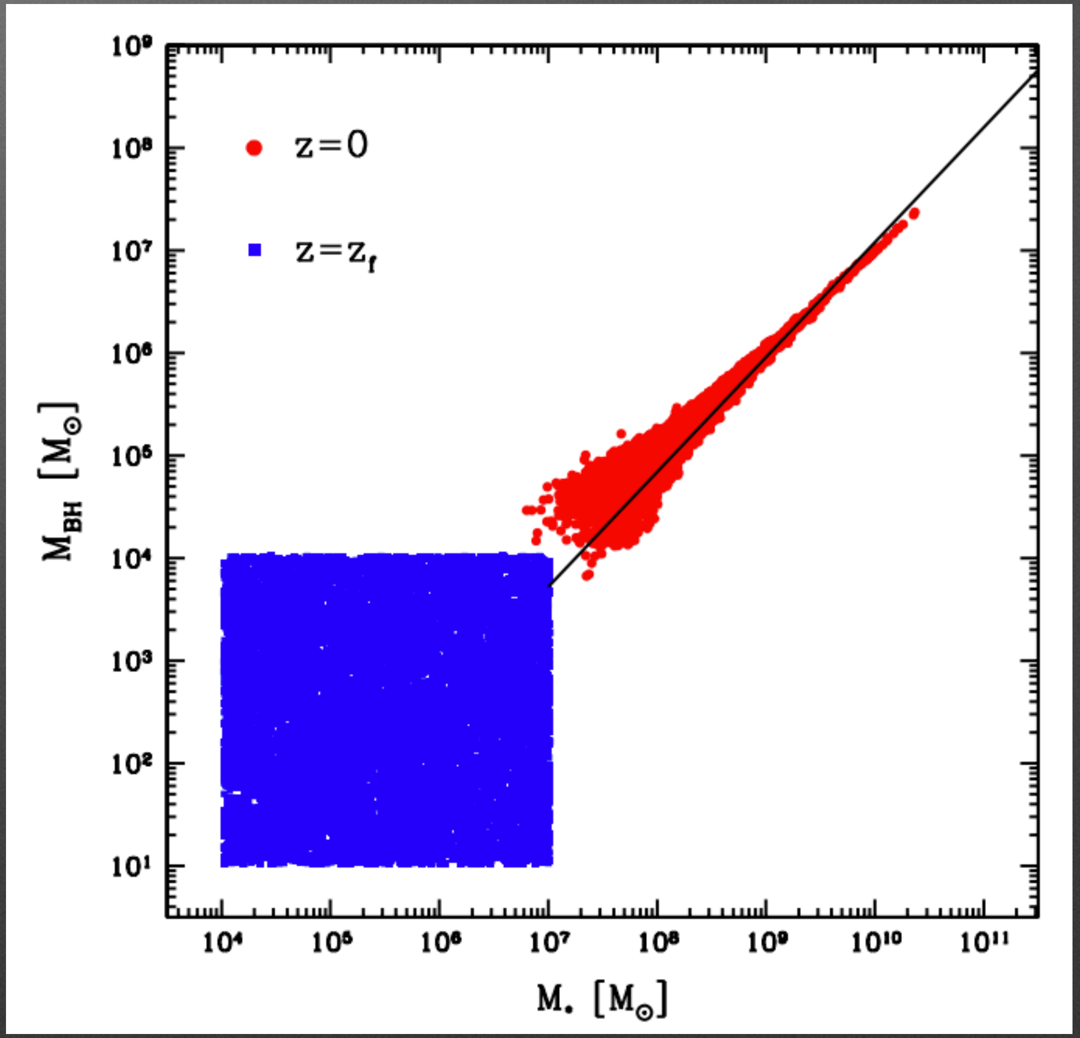
Possible origins

1. Physical coupling? (e.g. AGN feedback? fixed feeding rate?)

2. Merger of Galaxies?



Centaurus A,
credit HST + VLA.



Jahnke & Maccio 2011

Trace the correlation to higher redshift

One key to this study is tracing their correlation to higher redshift.

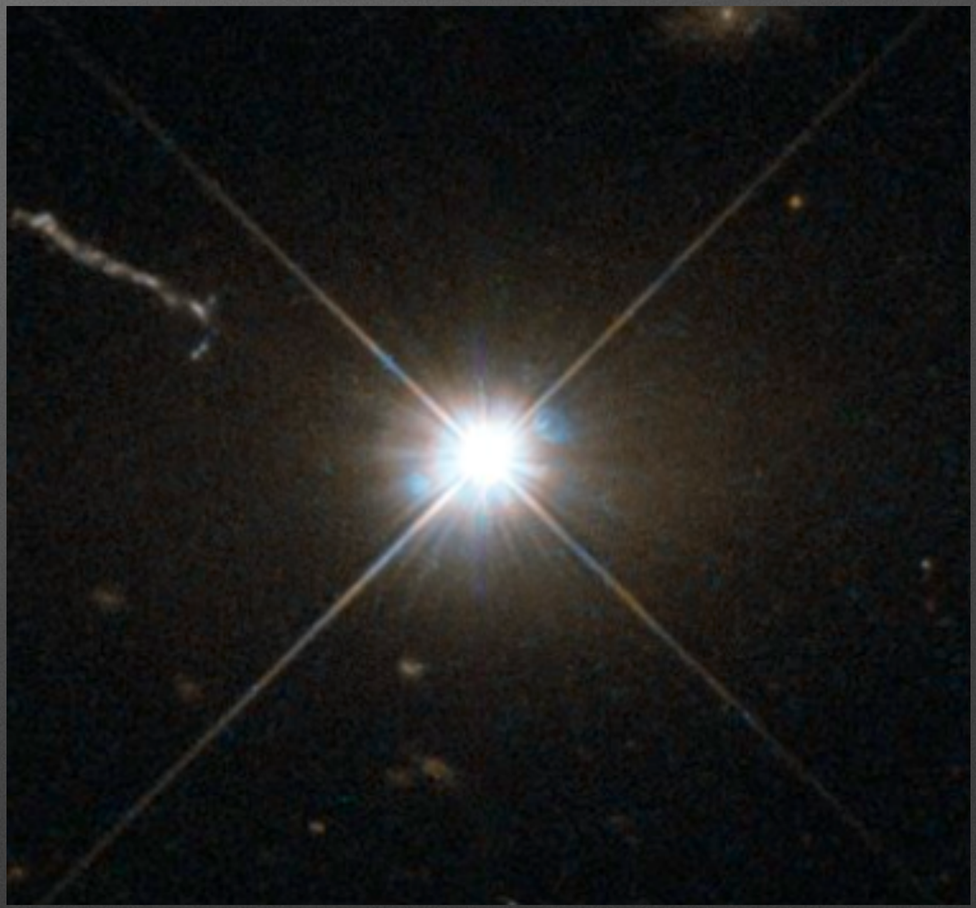
However, direct dynamical determinations of MBH are not feasible at distance universe. The only approach so far is to inferred MBH from the AGN emission line using virial method.

$$\mathrm{M_{BH}} \simeq \mathrm{f}\, R_{\mathrm{BLR}} V^2{}_{\mathrm{g}}$$

Trace the correlation to higher redshift

The main challenge is to determine the host properties.

- AGNs are very bright.
- Cosmological surface brightness dimming as $(1+z)^4$.

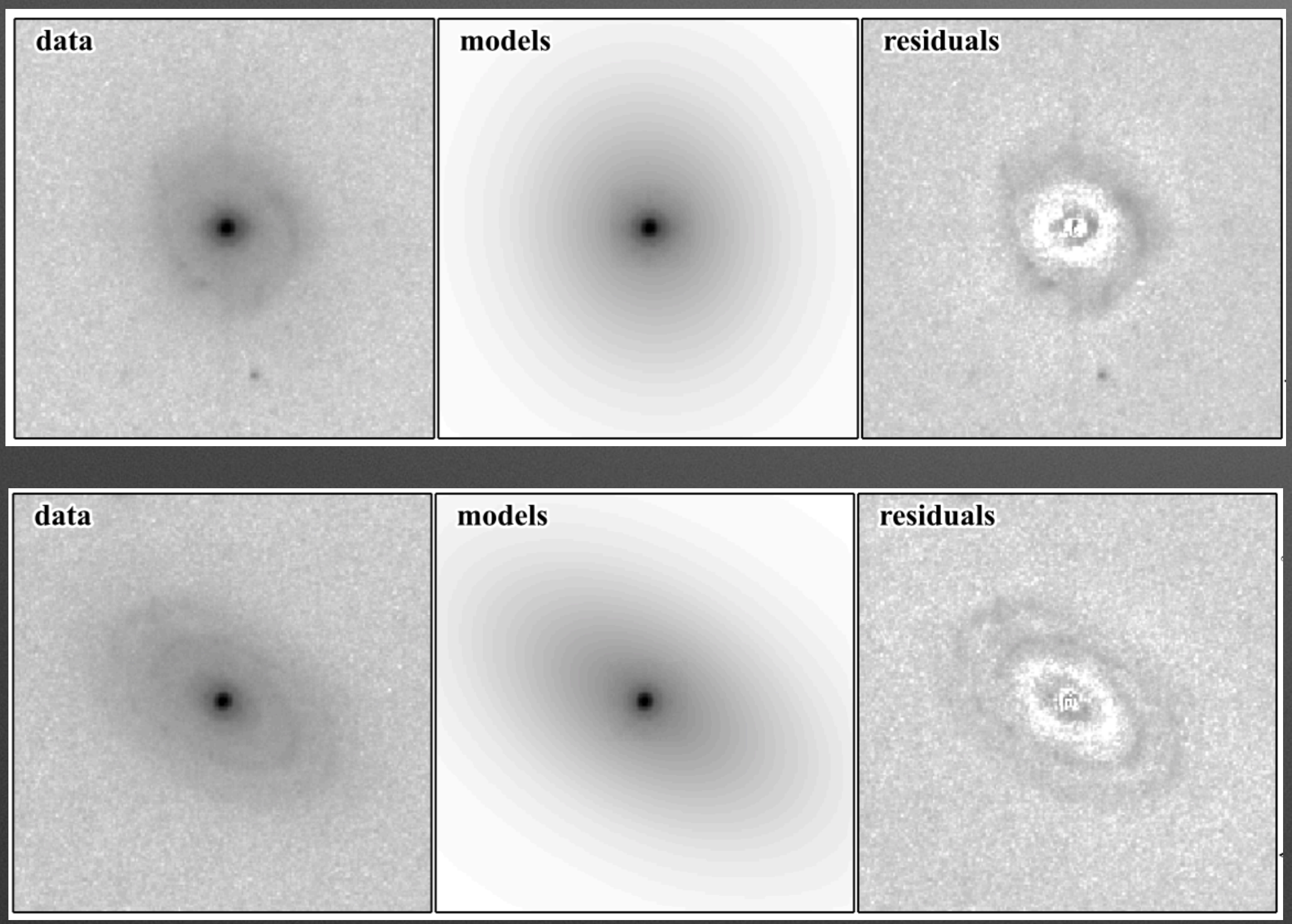


bright quasar 3C 273

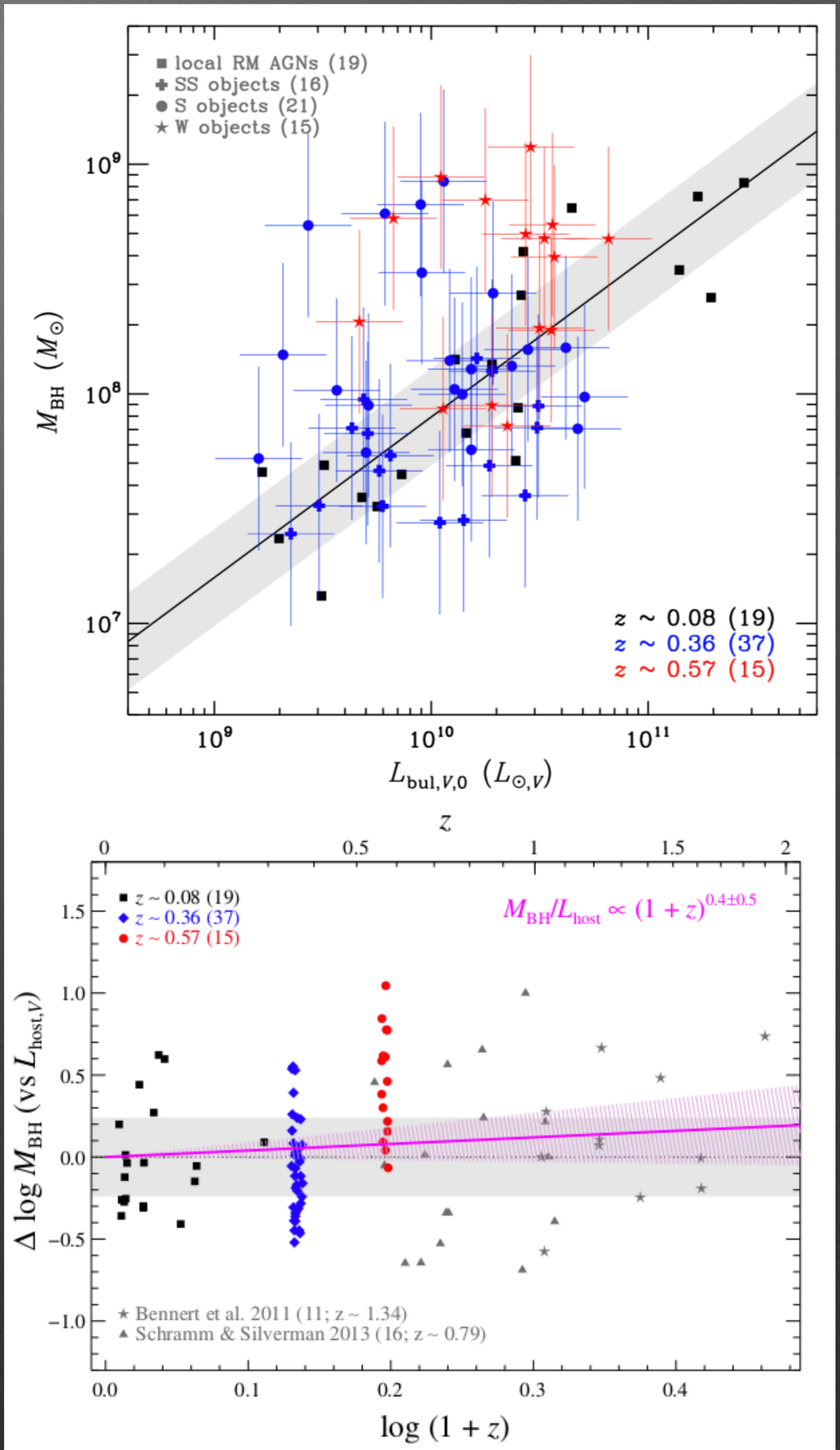
$z = 0.158$

credit HST

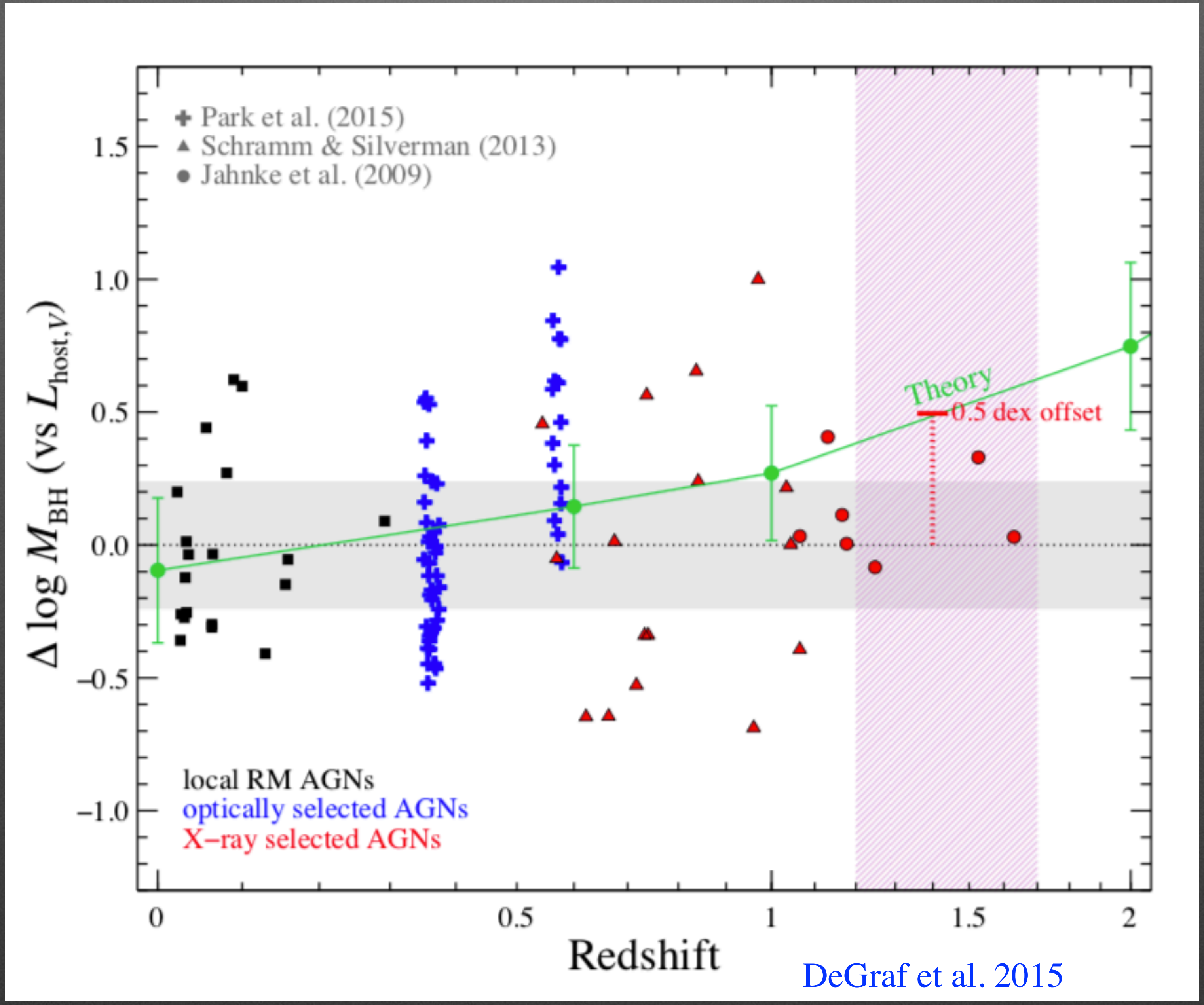
Infer host galaxy properties using 2D decomposition



Park et al. 2015



However, most of these studies are limited within z<1.



The simulations predict a strong evolution with SMBHs more massive by 0.5 dex at z~1.4 as compared to z=0.

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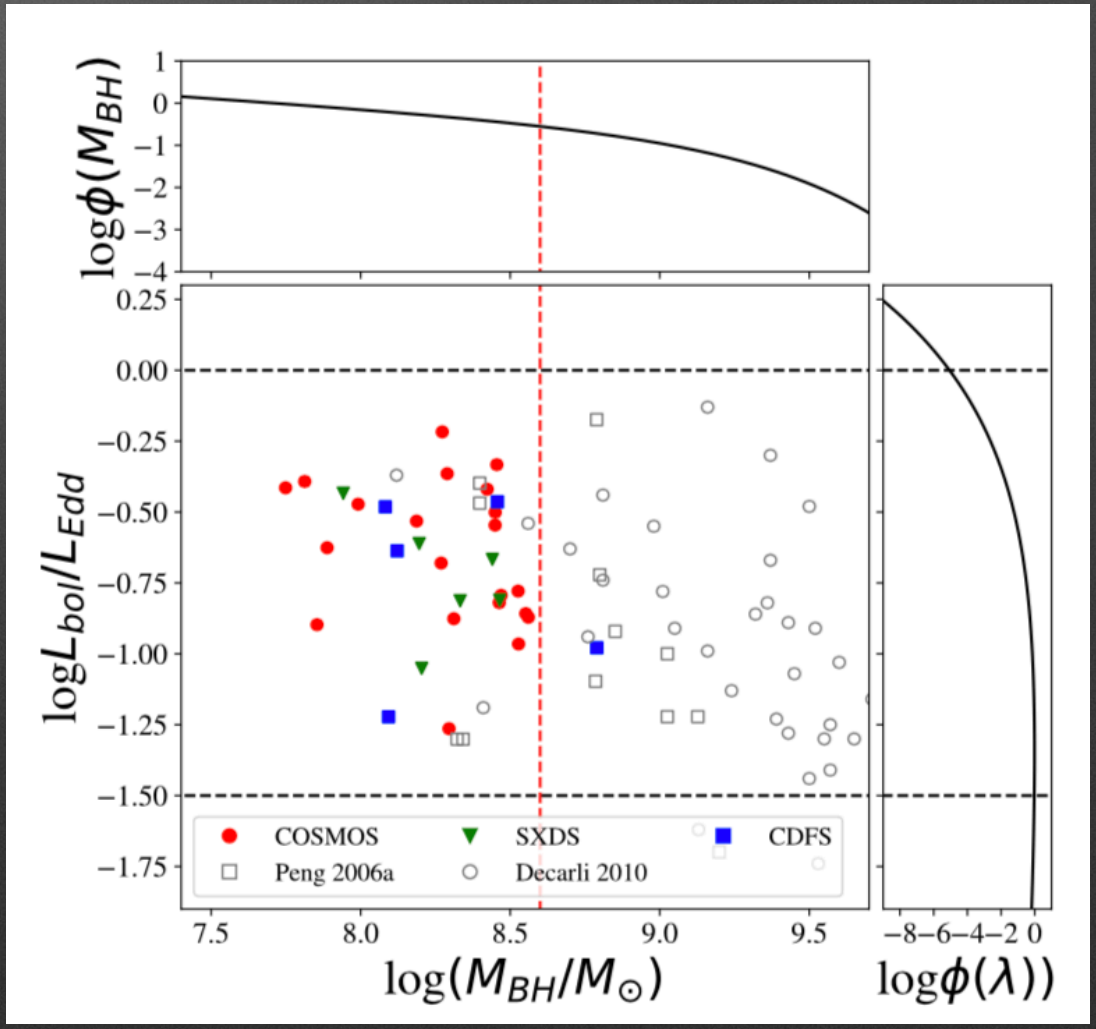
Study the correlations up to z>1 using HST/WFC3

We selected 32 broad-line AGNs uniformly within 1.2<z<1.7 from a catalog provided by the X-ray coverage of COSMOS, (E)-CDFS-S, and SXDS fields.

The HST filter WFC3/F125w and WFC3/F140W are adopted, for samples at z~1.2–1.44 and z~1.44–1.7, respectively.

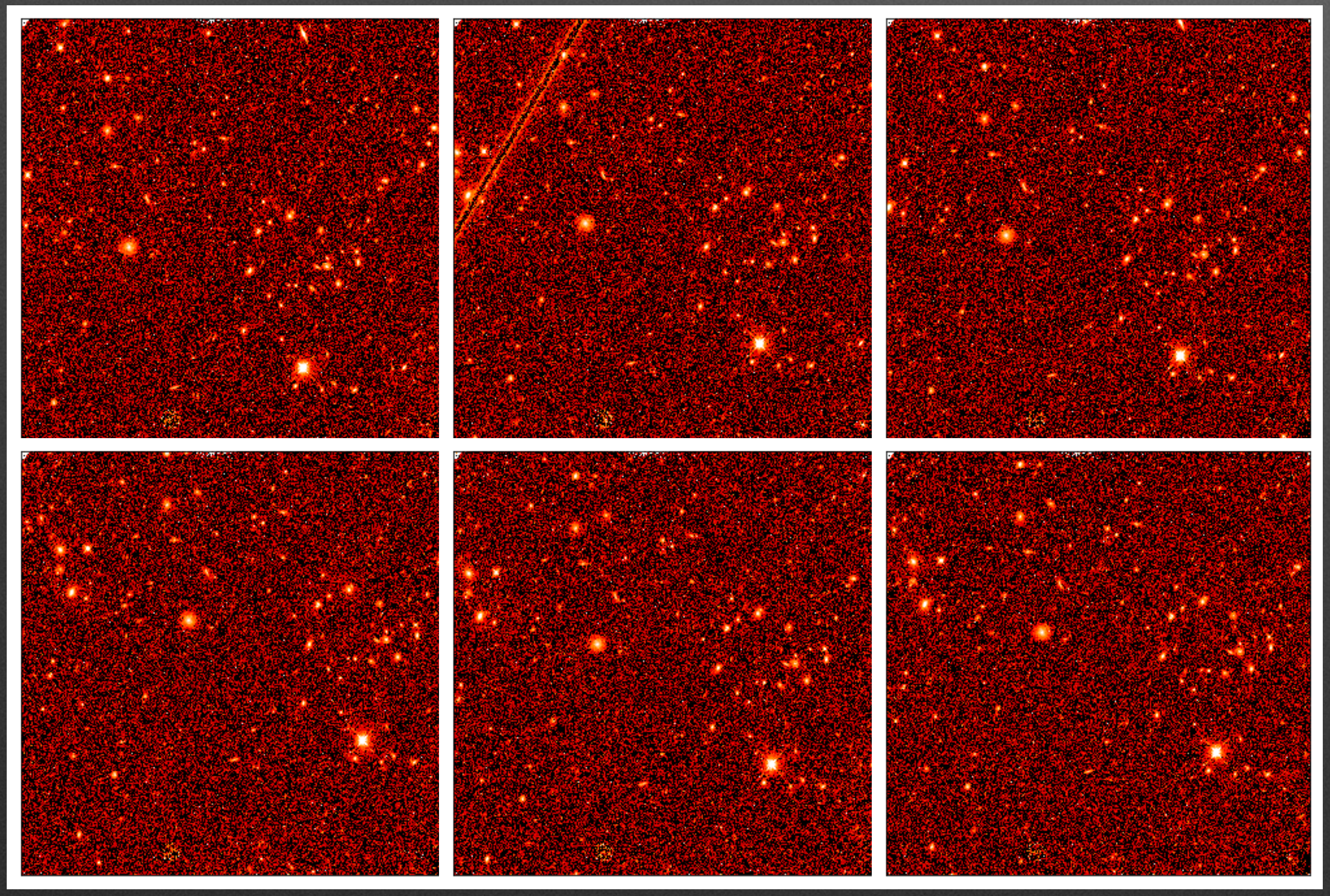
The benefits by our selection:

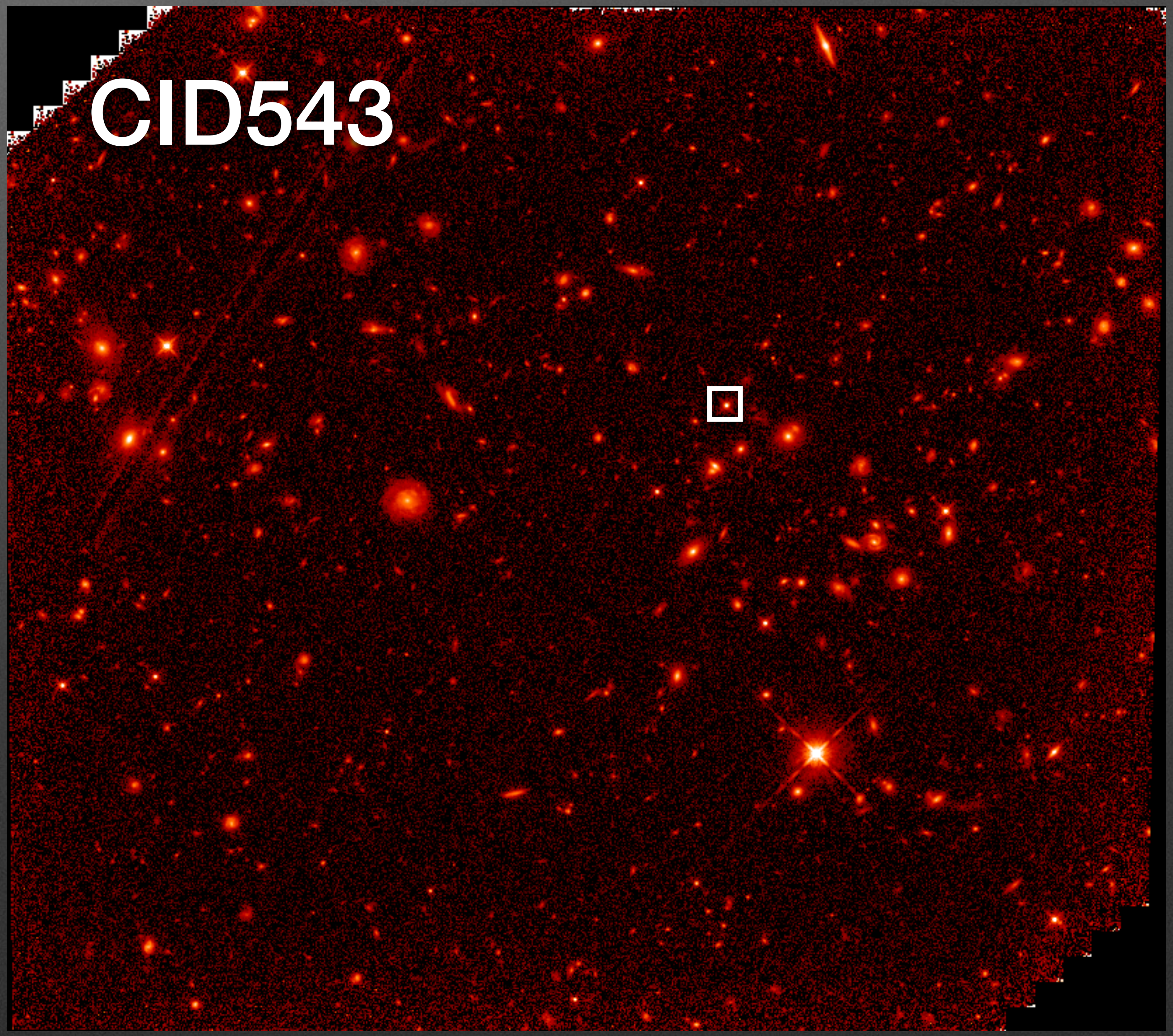
- AGNs fall below the knee of the black hole mass function.
- BH masses measured using Balmer lines (i.e., Hα) to remove systematics with Mgii, Civ. (by Schulze et al. 2018).
- Imaging the host galaxy above the 4000 A break and below the broad Hα line (6563 A).
- X-ray selected AGN have higher host-to-total flux.
- The multi-band information (HST/ACS images and ground-based photometry).



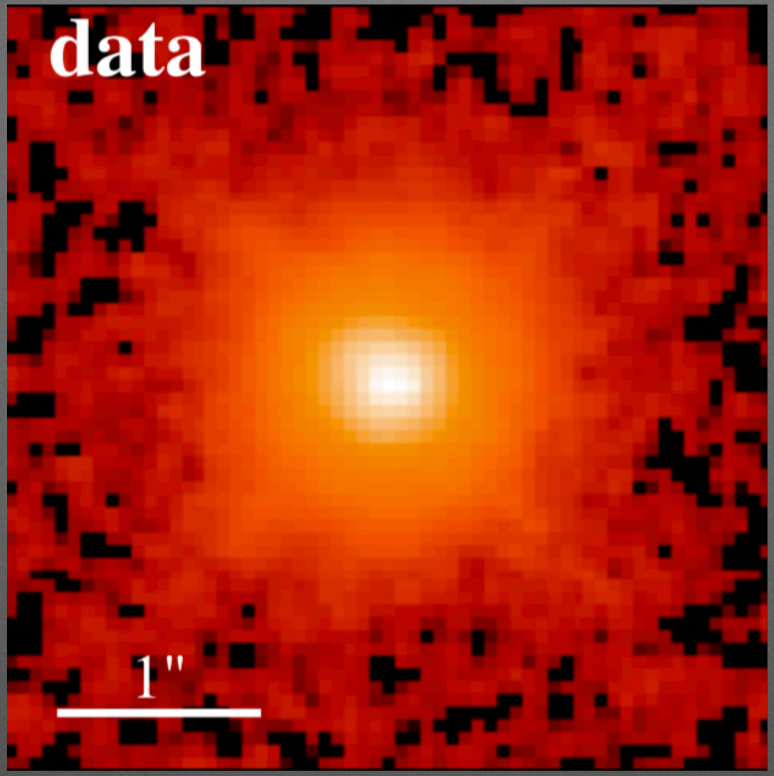
AGN imaging data

We obtain six separate exposures ~400s/frame. (i.e. ~2400s in total) and use astrodrizzle software to co-add the image with an output pixel scale of 0."0642.





Decompose the AGN 2D image



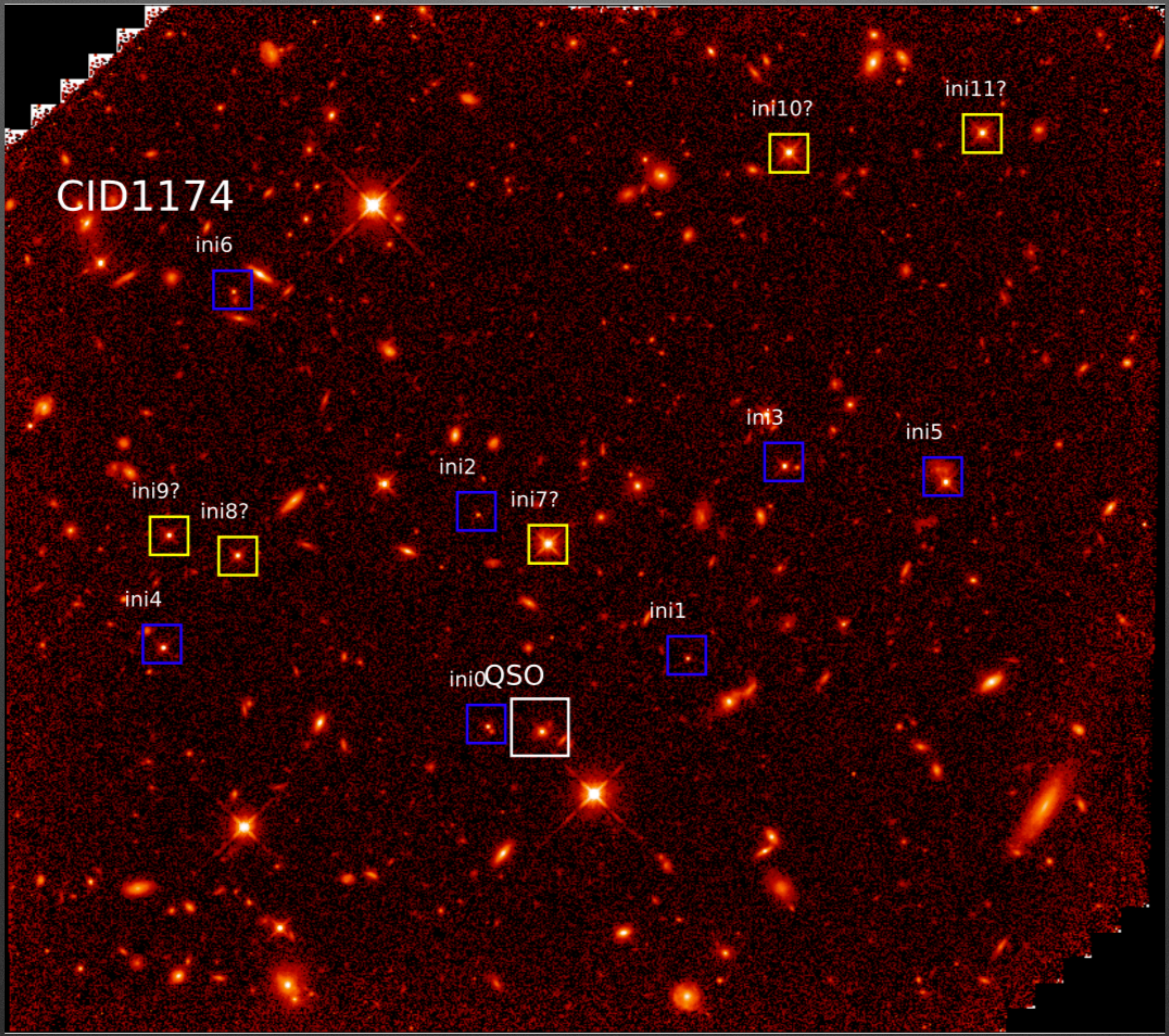
Assumptions:

- Host galaxy as a convolved Sersic profile
- Bright nuclei as scaled PSF

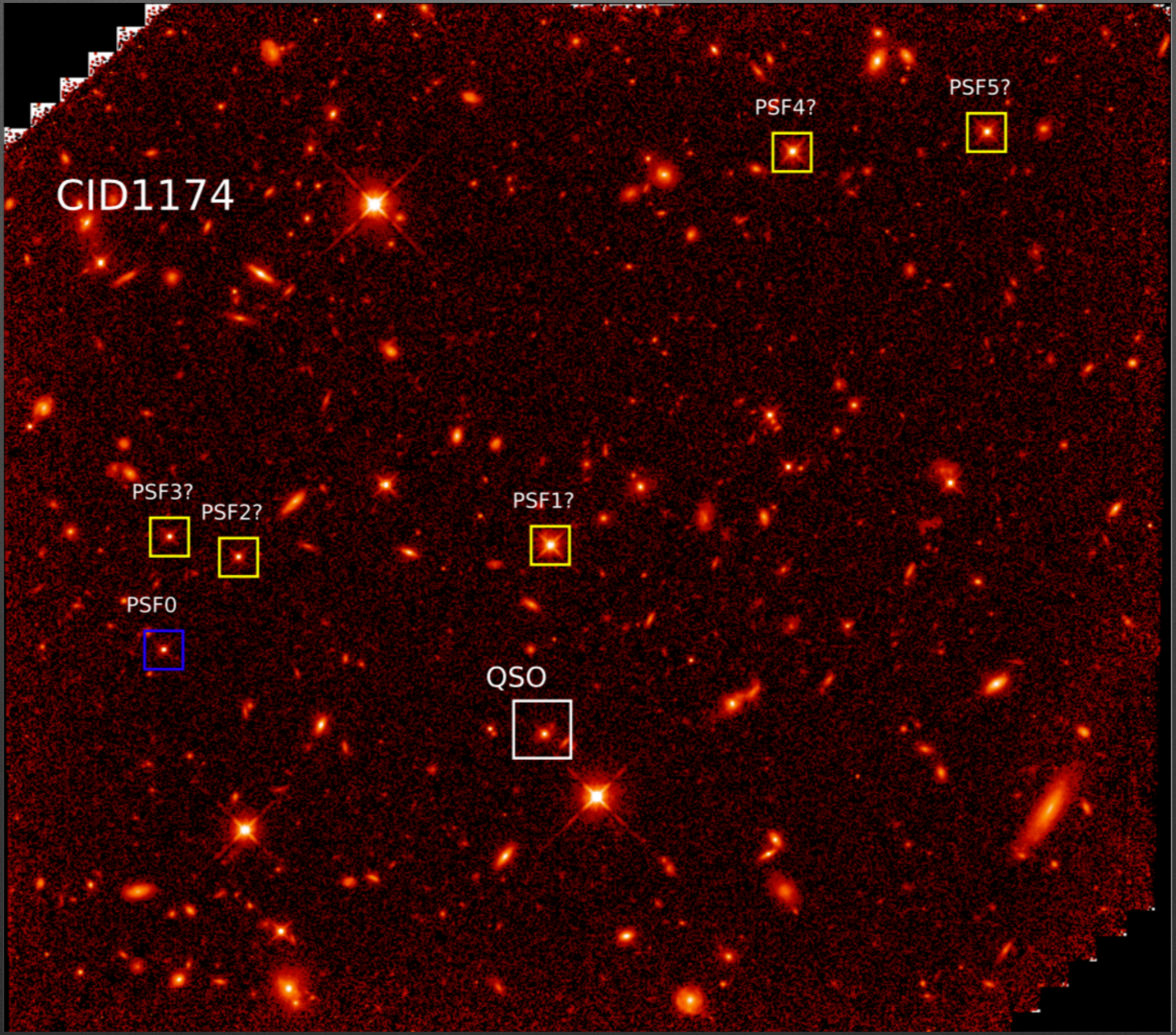
Fitting ingredients:

- AGN imaging data
- Noise level map
- **PSF**

Build up PSF library



Build up PSF library



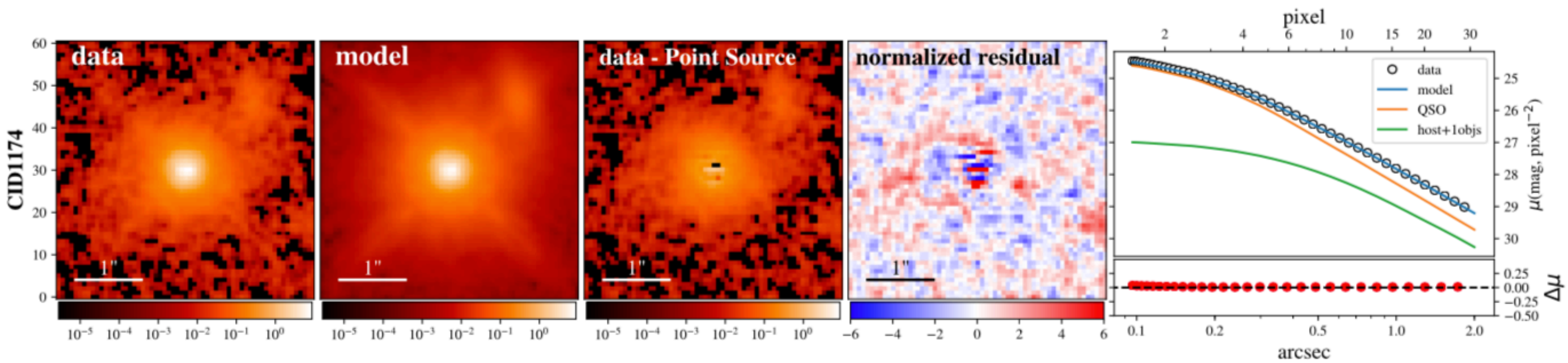
Build up PSF library

The sample includes 20 systems by WFC3/F140W and 12 WFC3/F125W. In total, I collect 78 PSFs for F140W and 36 PSFs for F125W.

We carry out the AGN decomposition using each PSF, one by one, in the library. We ranking the performance of each PSF based on the goodness (i.e. Chisq), to infer the host properties by weighting the results from the top ranked PSFs.

Weight the inference using top ranked PSF

I adopt the imaging modeling tool LENSTRONOMY to perform the decomposition of the host and nuclear light.

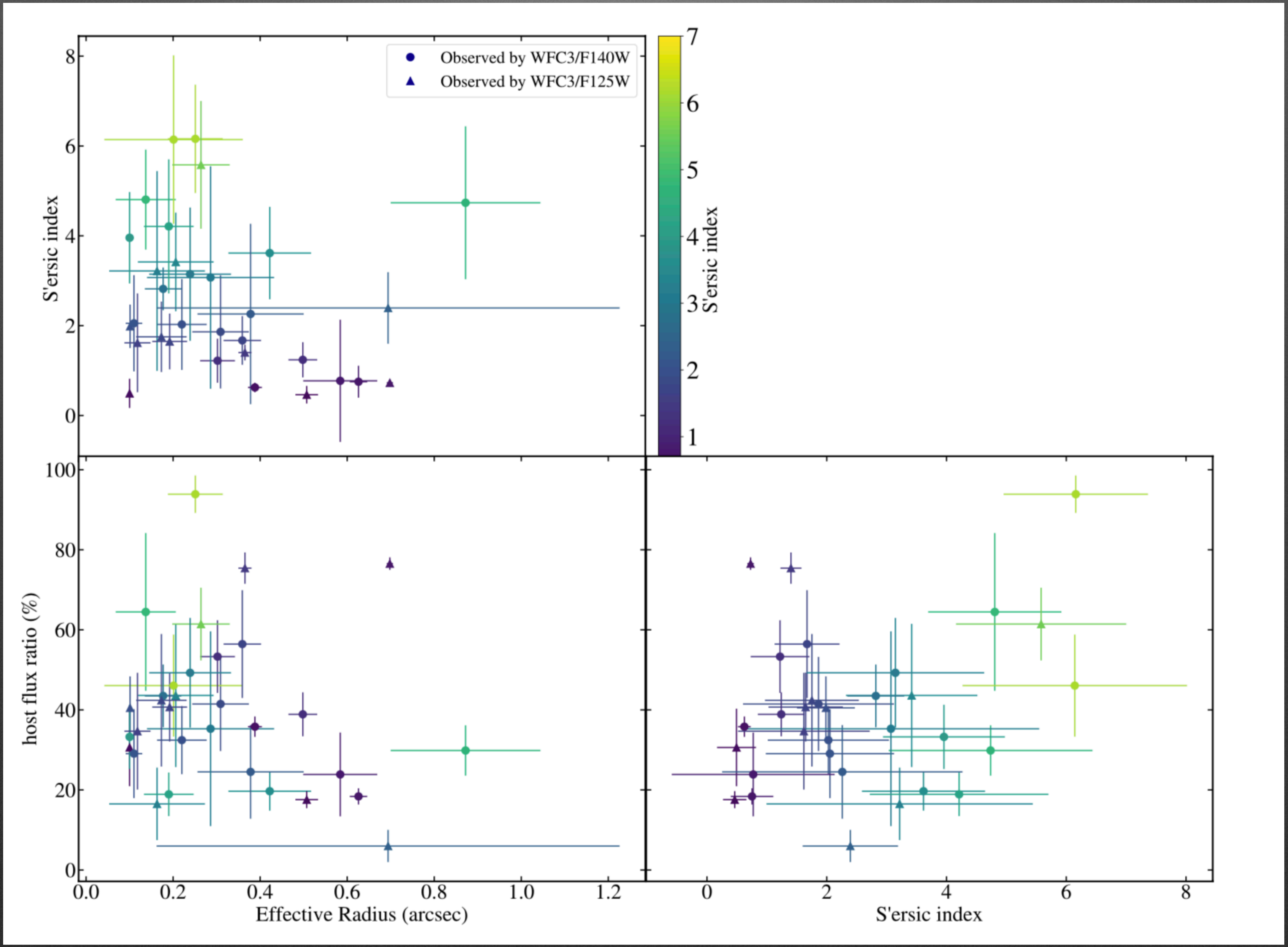


PSF rank (1)	total χ^2 (2)	weights w_i (3)	host flux (counts) (4)	host flux ratio (5)	$R_{\rm eff}$(arcsec) (6)	Sérsic n (7)
1	8584.429	1.000	82.209	35.4%	0.″345	1.114
2	8646.711	0.920	99.102	41.9%	0.″298	1.932
3	8816.947	0.734	76.74	33.0%	0.″365	1.102
4	9304.841	0.383	128.618	54.7%	0.″231	2.78
5	9652.575	0.241	187.498	79.0%	0.″116	6.175
6	9917.101	0.170	100.166	42.3%	0.″287	2.066
7	10018.324	0.148	75.061	32.3%	0.″365	1.226
8	10087.456	0.135	79.835	34.3%	0.″358	1.195
Weighted value			97.322 ± 28.336	$41.5\% \pm 11.7\%$	$0.''309 \pm 0.''065$	1.862 ± 1.26

$$w_i = exp(-\frac{(\chi^2_i - \chi^2_{best})}{2\alpha\chi^2_{best}}),$$

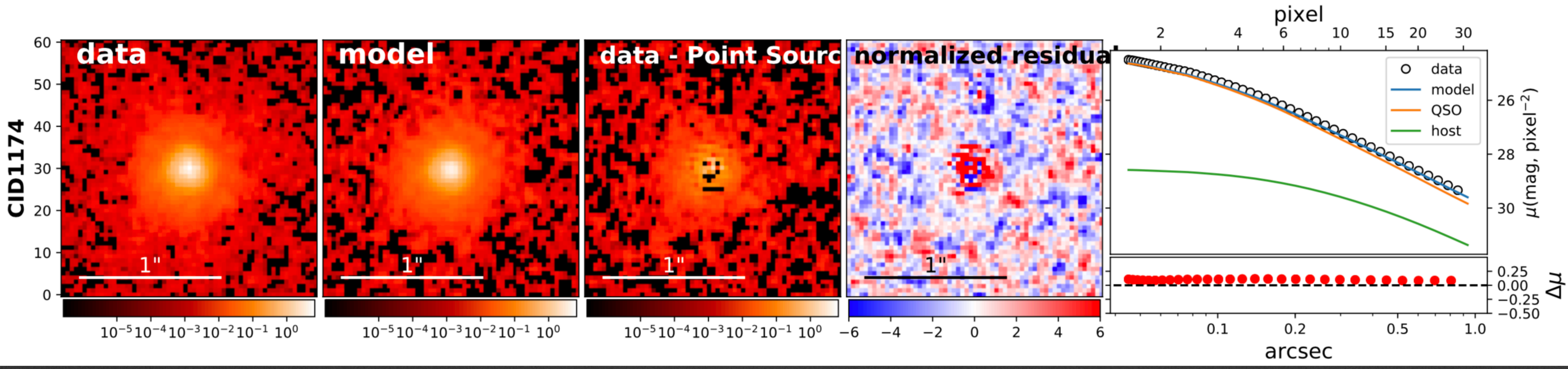
$$\alpha\frac{\chi^2_{i=8} - \chi^2_{best}}{2\chi^2_{best}} = 2$$

Distribution of fitted the Sersic parameters

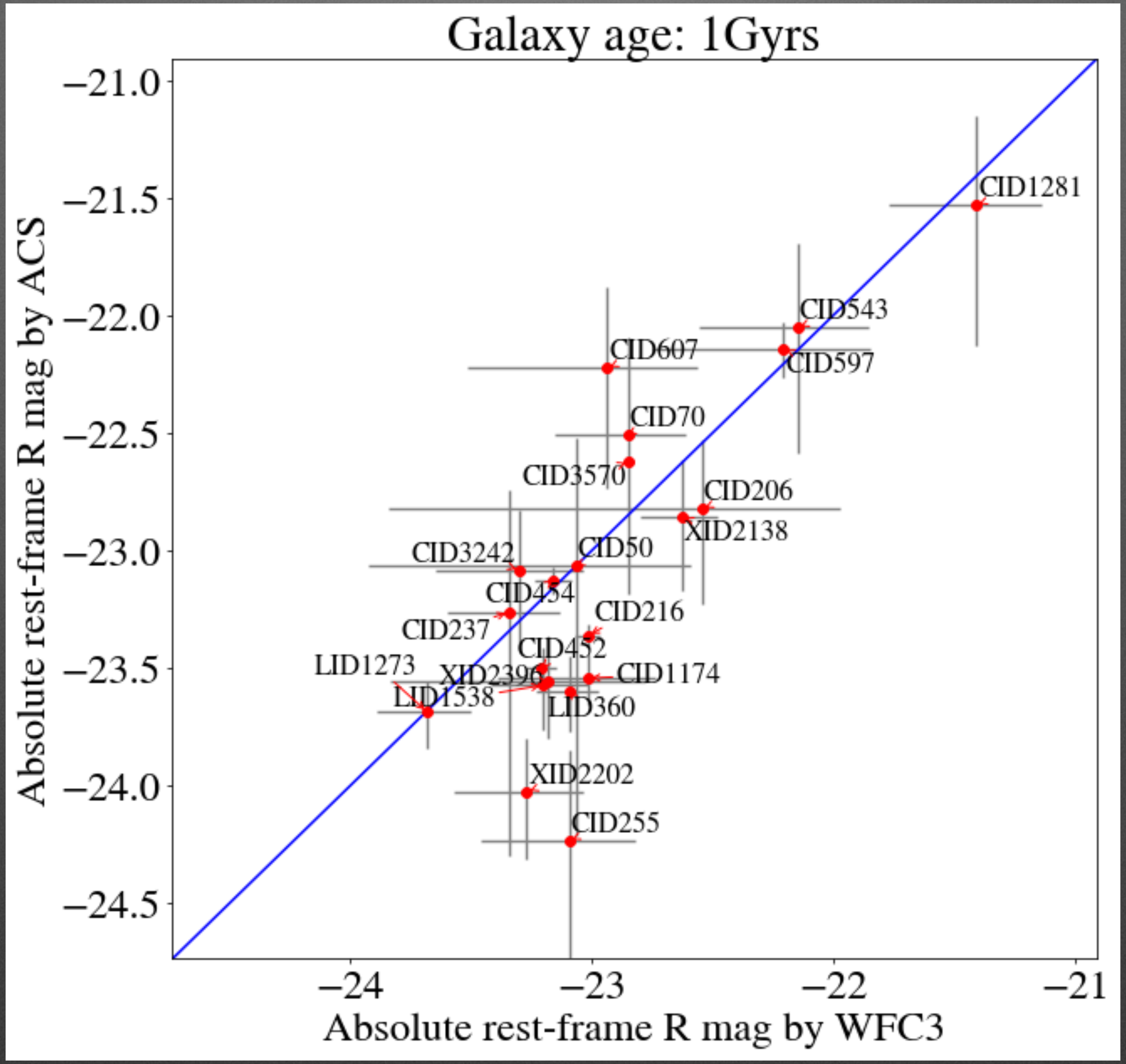


Decompose the AGN at ACS band

21/32 systems in COSMOS field have ACS/F814W images. Following the same approach, I derived the host flux in ACS band using the build up the PSFs library in ACS.



Adopt stellar template



I find that the 1 Gyrs galaxy template is very consistent for the colors between WFC3 and ACS. We thus adopt this stellar template to derive the rest-frame R band luminosity (L_R) and the stellar mass (M_*).

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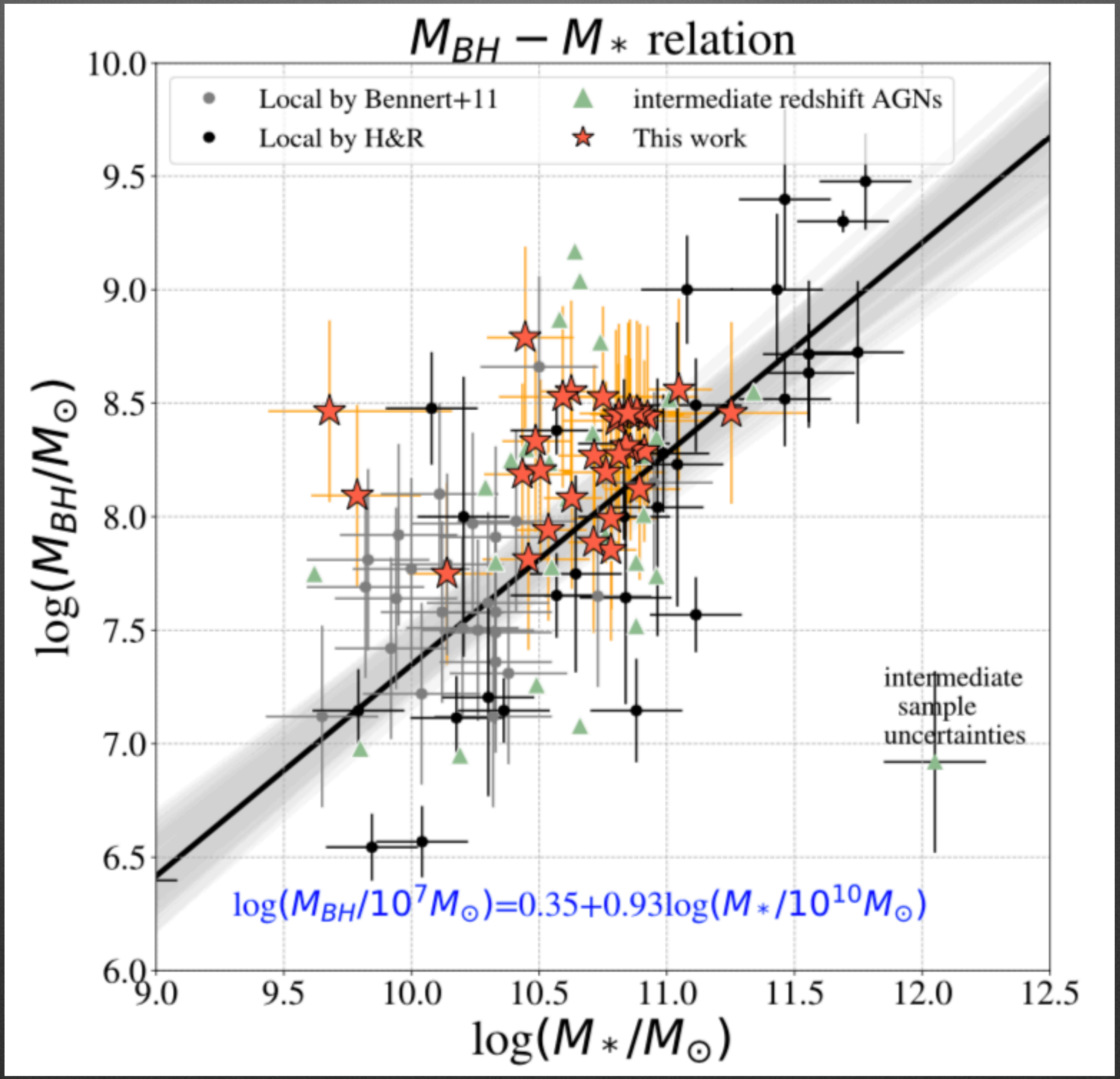
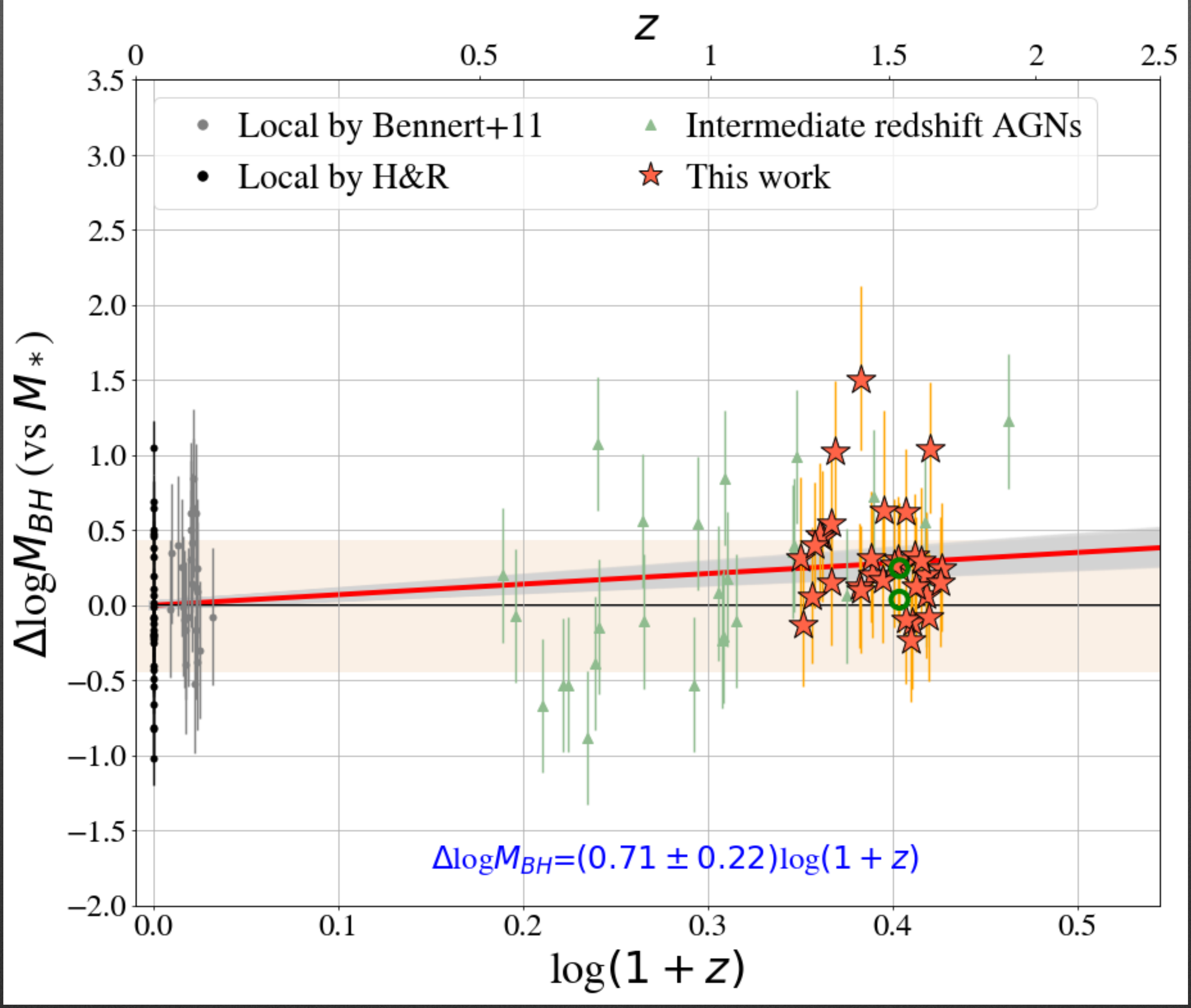
Combining with MBH to infer the relation

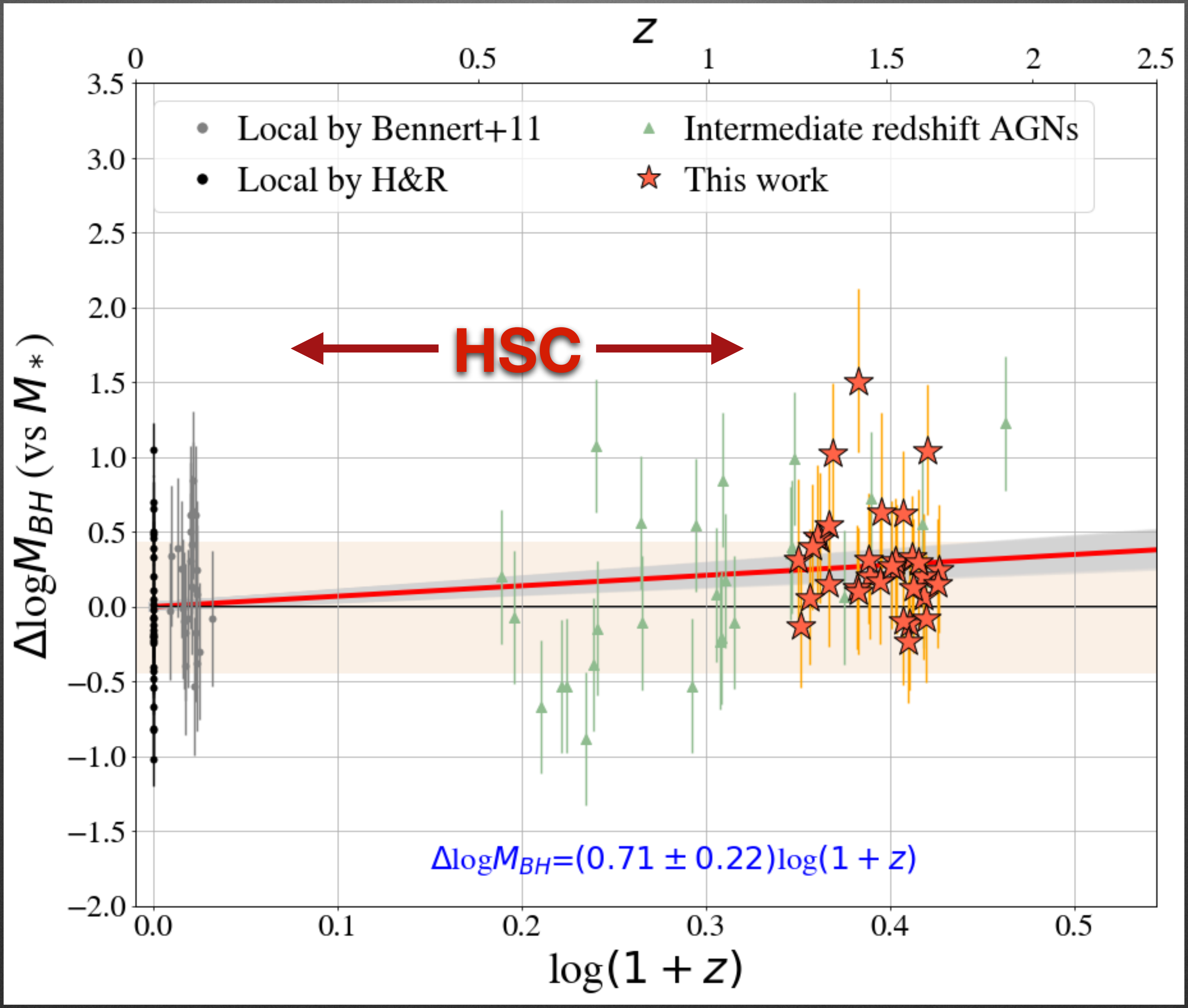
We combining the inference of the host properties can study their relation with their BH mass.

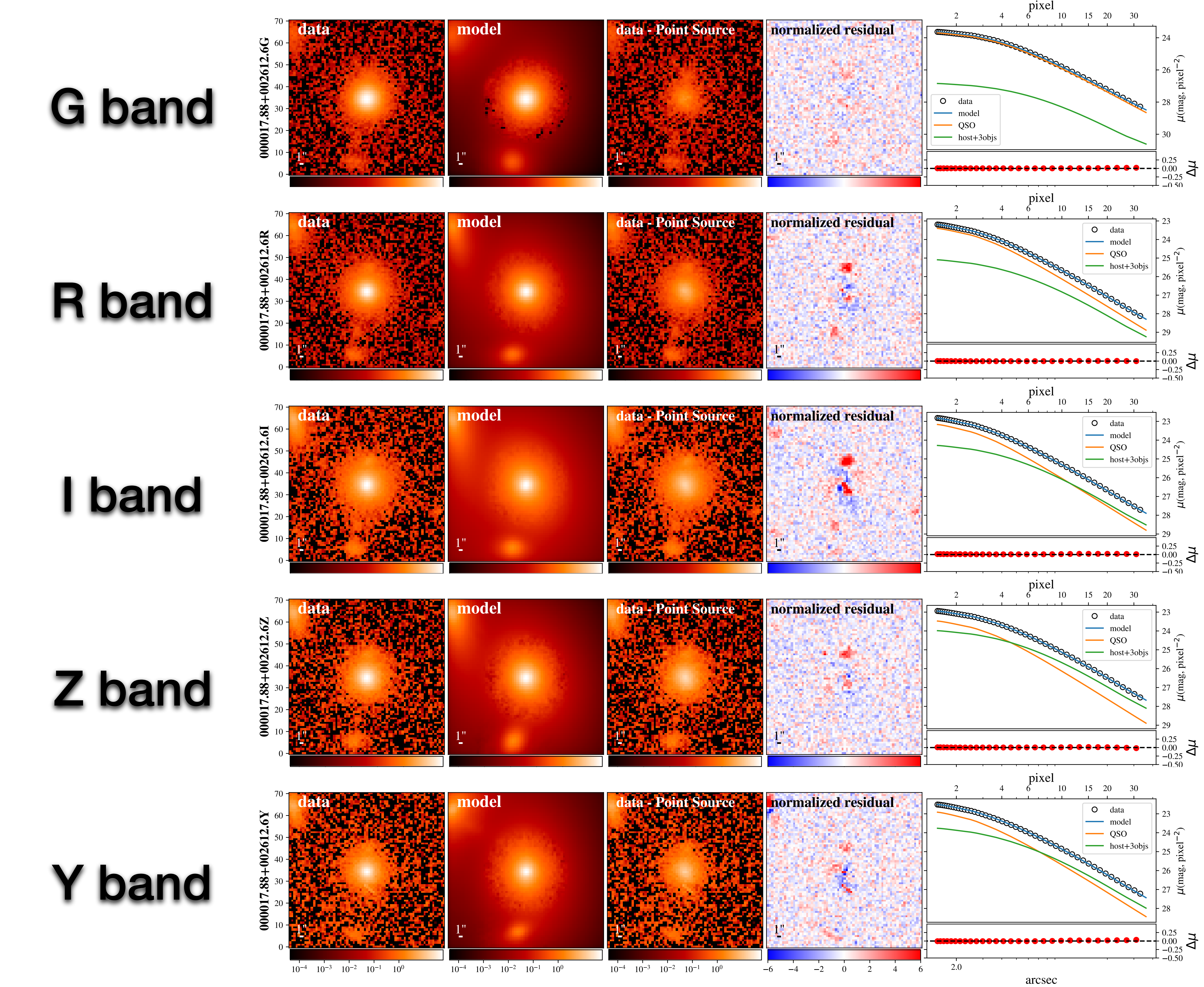


The evolution of M_{BH}-M*



Extension the with HSC at redshift desert





G band
R band
I band
Z band
Y band
data
model
data - Point Source
normalized residual
000017.88+002612.6G
000017.88+002612.6R
000017.88+002612.6I
000017.88+002612.6Z
000017.88+002612.6Y
pixel
arcsec
data
model
QSO
host+3objs
μ(mag, pixel^{-2})
$\Delta\mu$

Thanks!