The evolution of the mass correlation between supermassive Black Holes and their host galaxies

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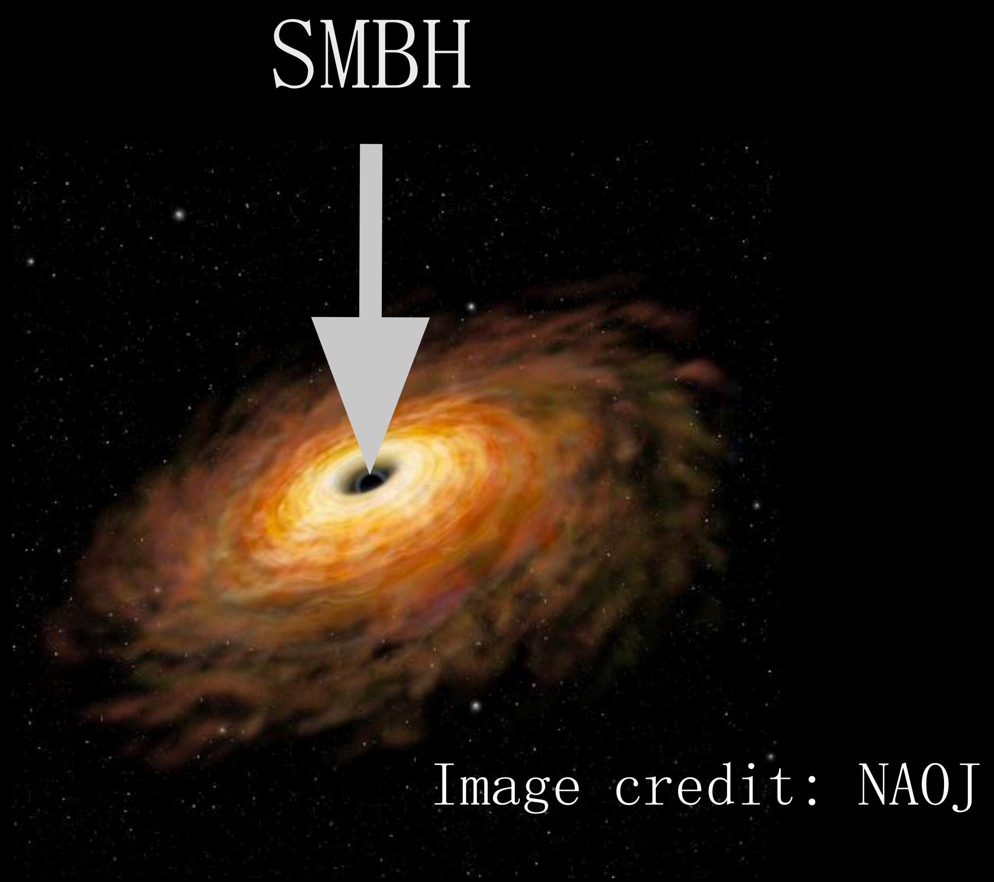
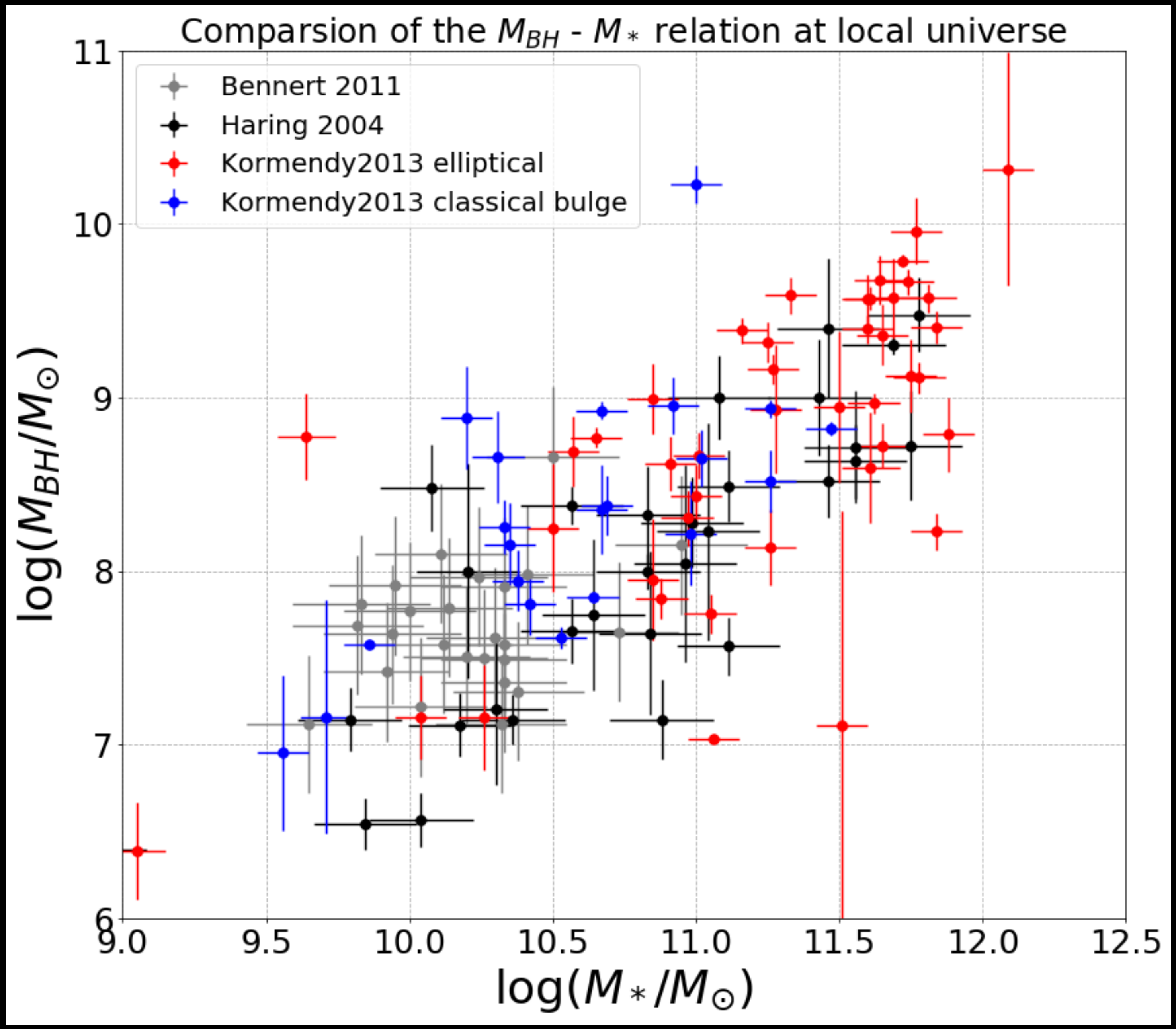
@Kavli IPMU Postdoc Colloquium

11/12th/2021

The BH and host galaxy relation

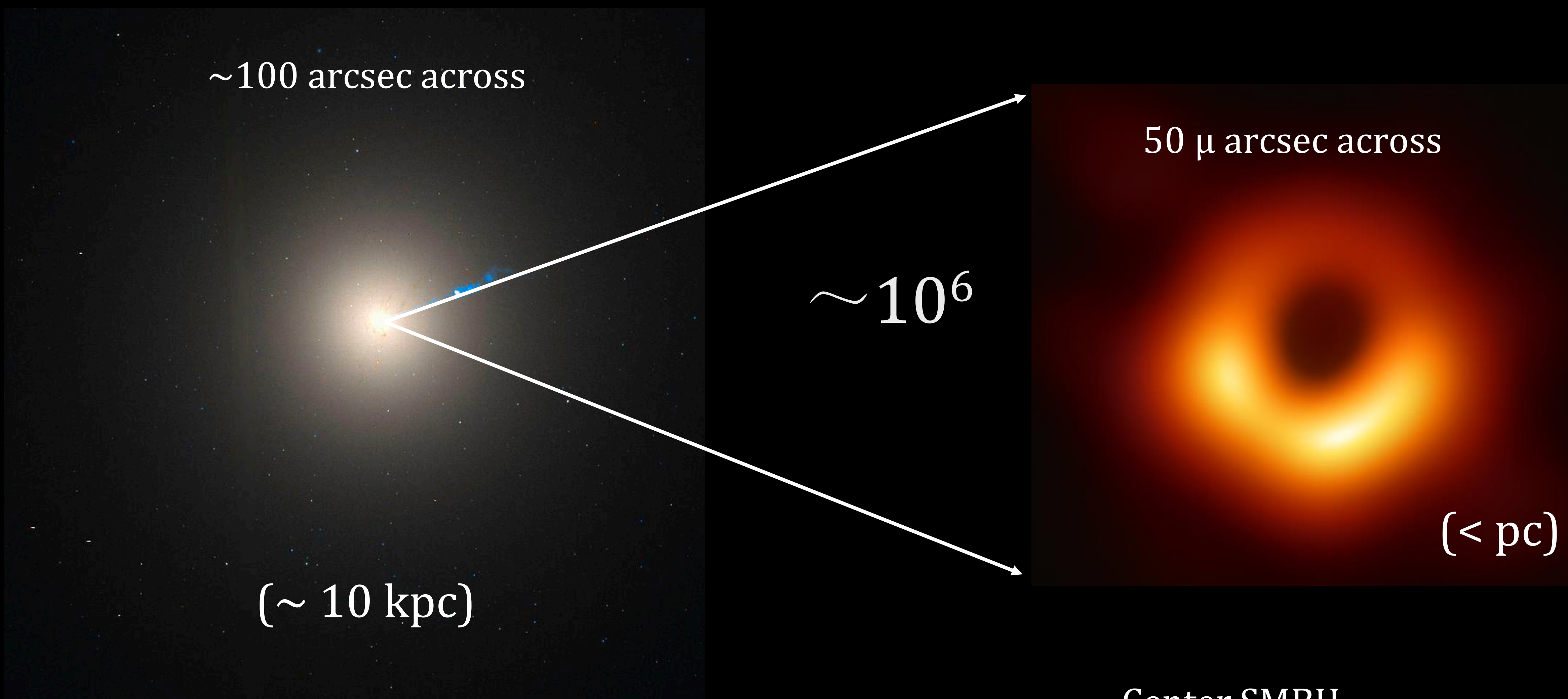
Almost every galactic nuclei harbor a supermassive black hole (SMBH), whose mass is well known to be correlated with the host stellar mass.





The BH and host galaxy relation

The physical mechanism is still unknown.



Messier 87, credit HST.

Center SMBH

credit Event Horizon Telescope.

Trace the correlation to higher redshift

At high-z, the M_{BH} are determined from the broad-emission line.
The main challenge is to determine the host properties.

$$M_{BH} \simeq G^{-1} R_{BLR} V^2_g$$

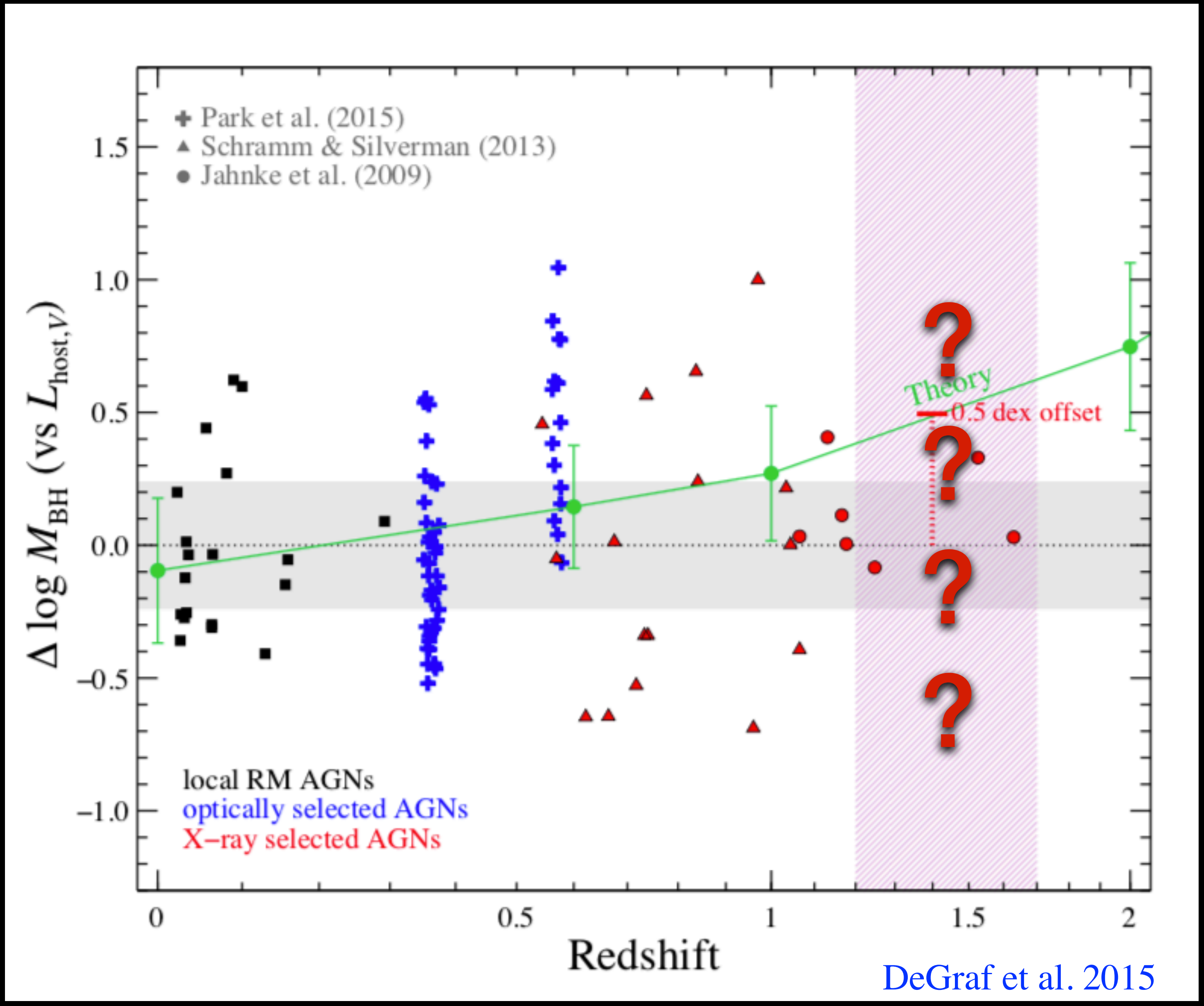
- Galactic nuclei are very bright.
- Cosmological surface brightness dimming as $(1+z)^4$.

bright quasar 3C 273 z = 0.158

credit HST

Trace the correlation to higher redshift

- The simulation has predicted a stronger evolution at z>1.
- However, most studies with photometry are limited within z<1.

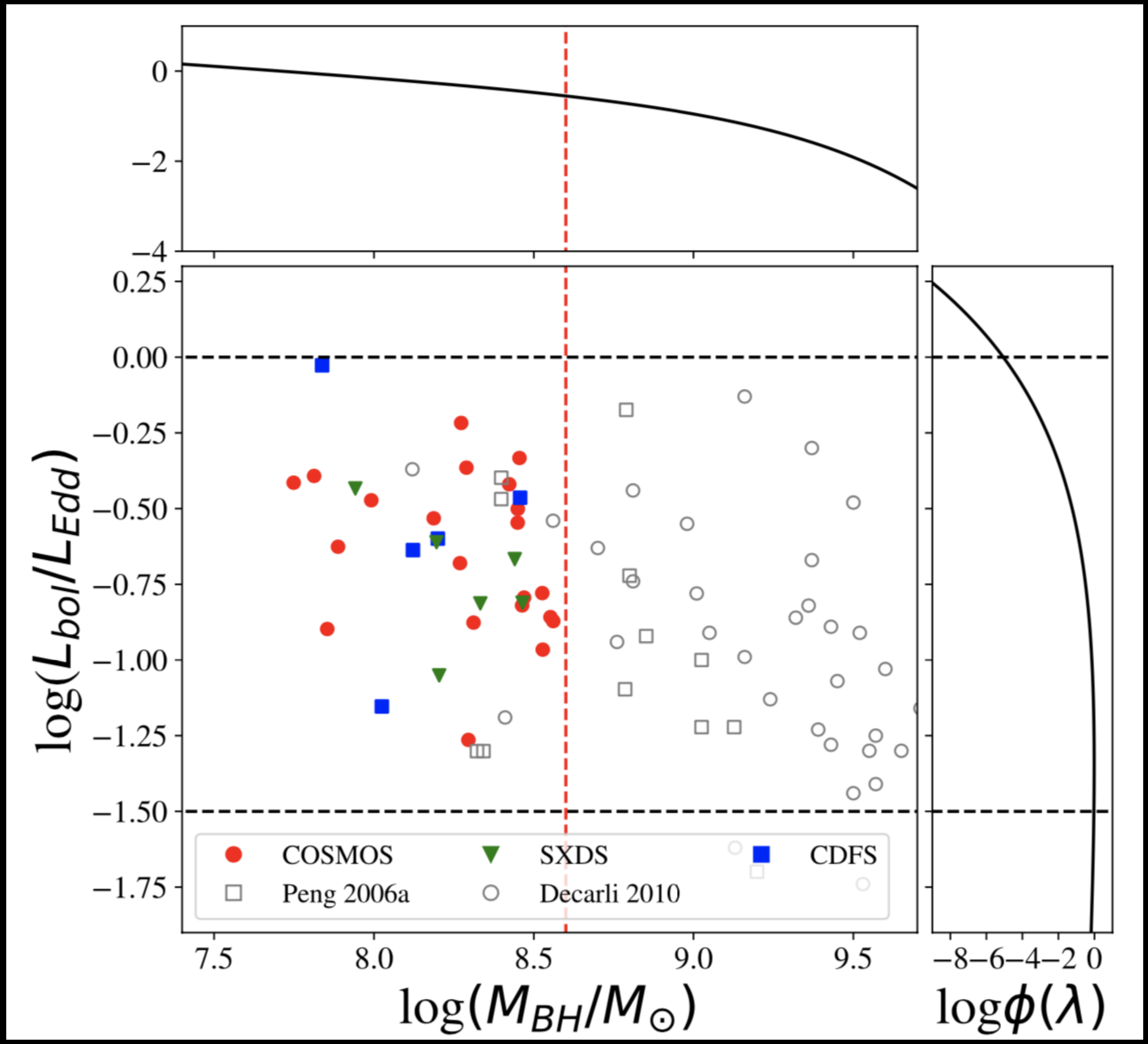


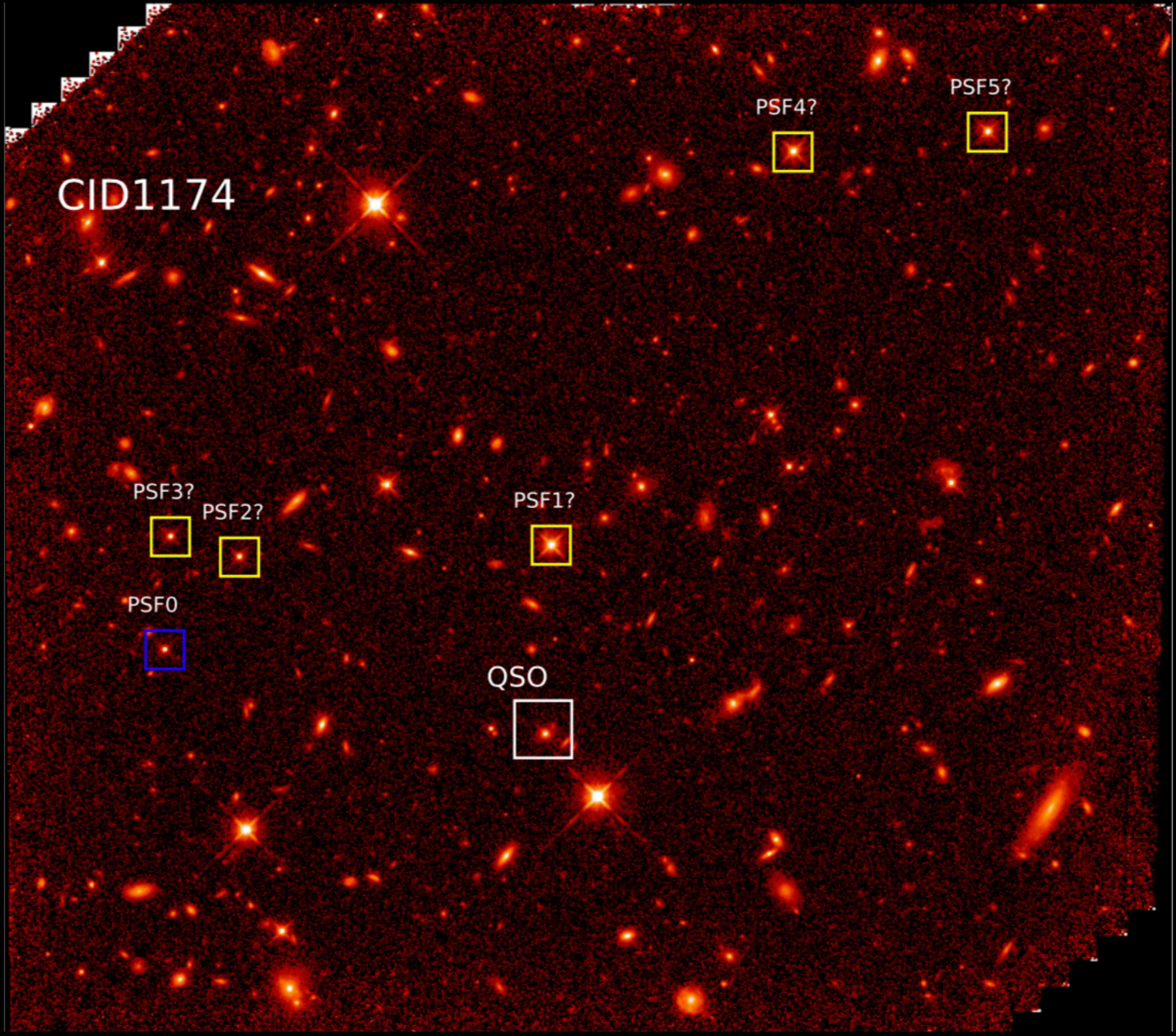
Study the correlations at z>1 using HST/WFC3

We select 32 broad-line AGNs within 1.2<z<1.7 from the catalogs provided by three X-ray coverage fields: COSMOS, (E)-CDFS-S, and SXDS.

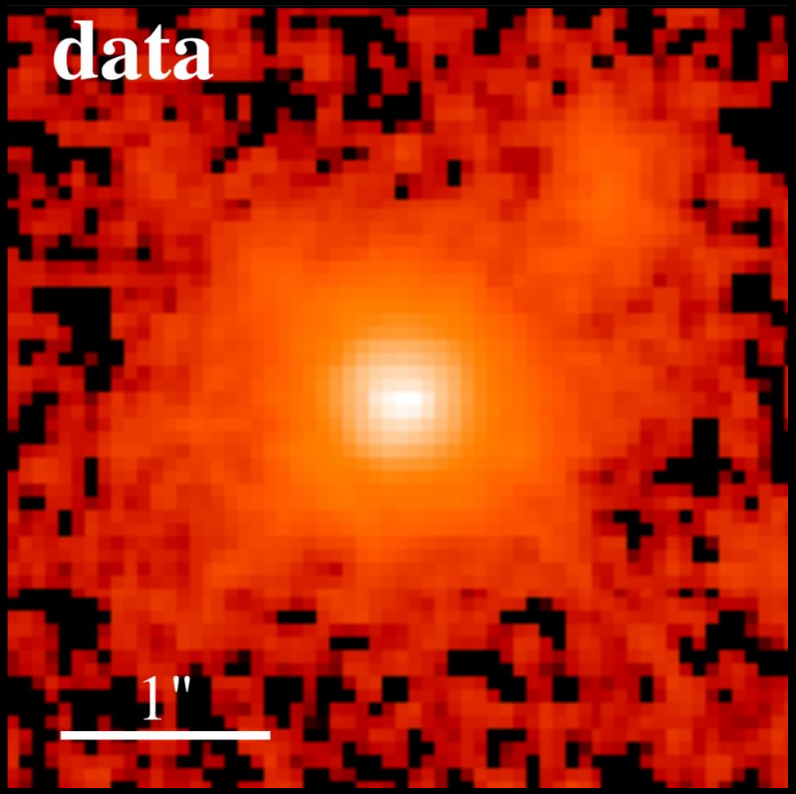
The benefits by our selection:

- MBH estimates are based on Balmer lines (i.e., Hα).
- MBH fall below the knee of the BH mass function. Eddington ratios are above 1%.
- X-ray selected sample have lower nuclear-to-host ratios.
- HST/WFC3 imaging of the host galaxy is above the 4000 A° break and does not include the AGN broad Hα line (6563A°).
- A large fraction of the sample has additional HST imaging (i.e., ACS), providing color information.




CID1174
PSF4?
PSF5?
PSF3?
PSF2?
PSF1?
PSF0
QSO

Infer AGN host properties



Assumptions:

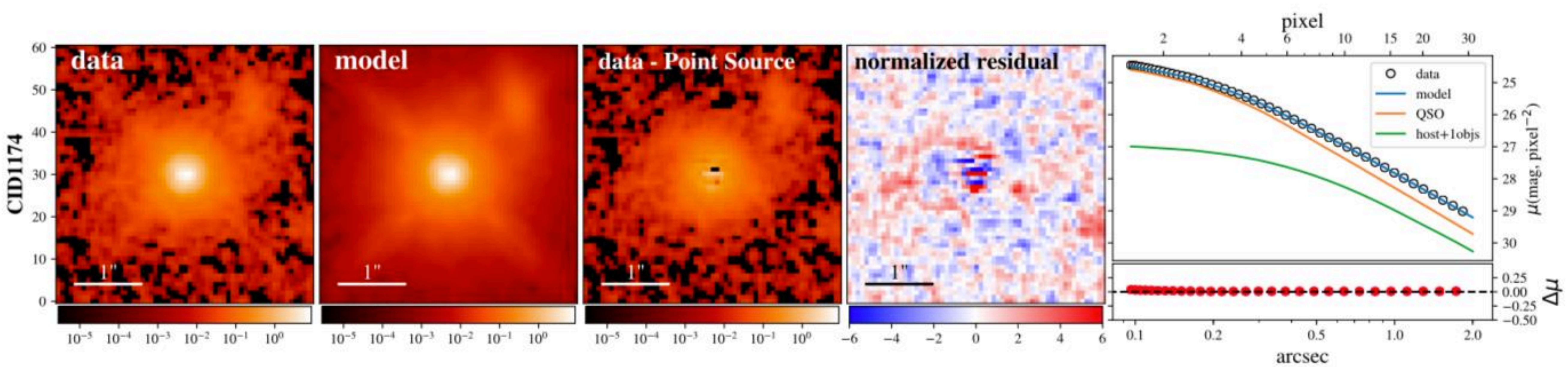
- Host galaxy as a convolved Sersic profile
- Bright nuclei as scaled PSF

Fitting ingredients:

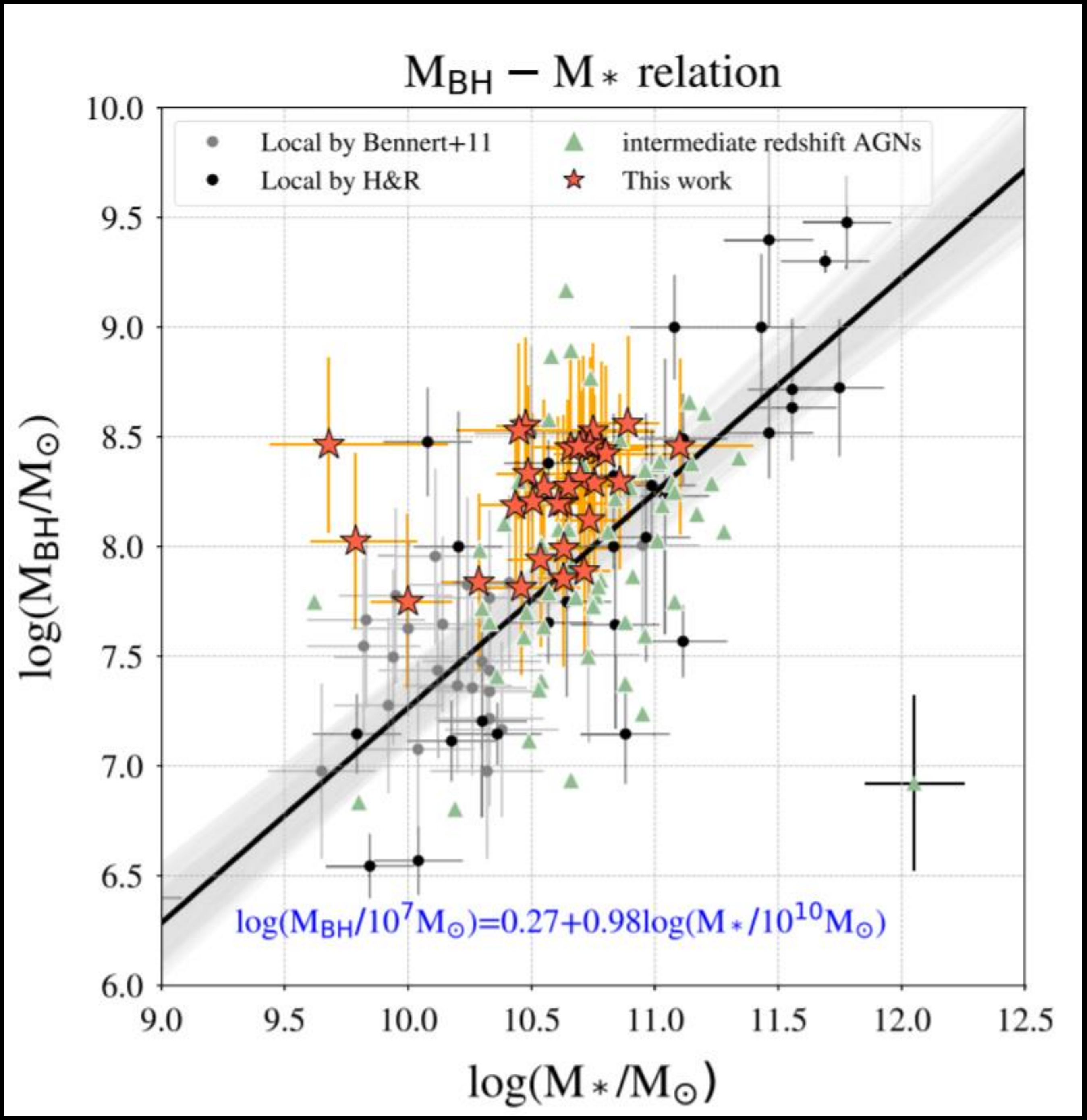
- AGN imaging data
- Noise level map
- **PSF**

Infer AGN host properties

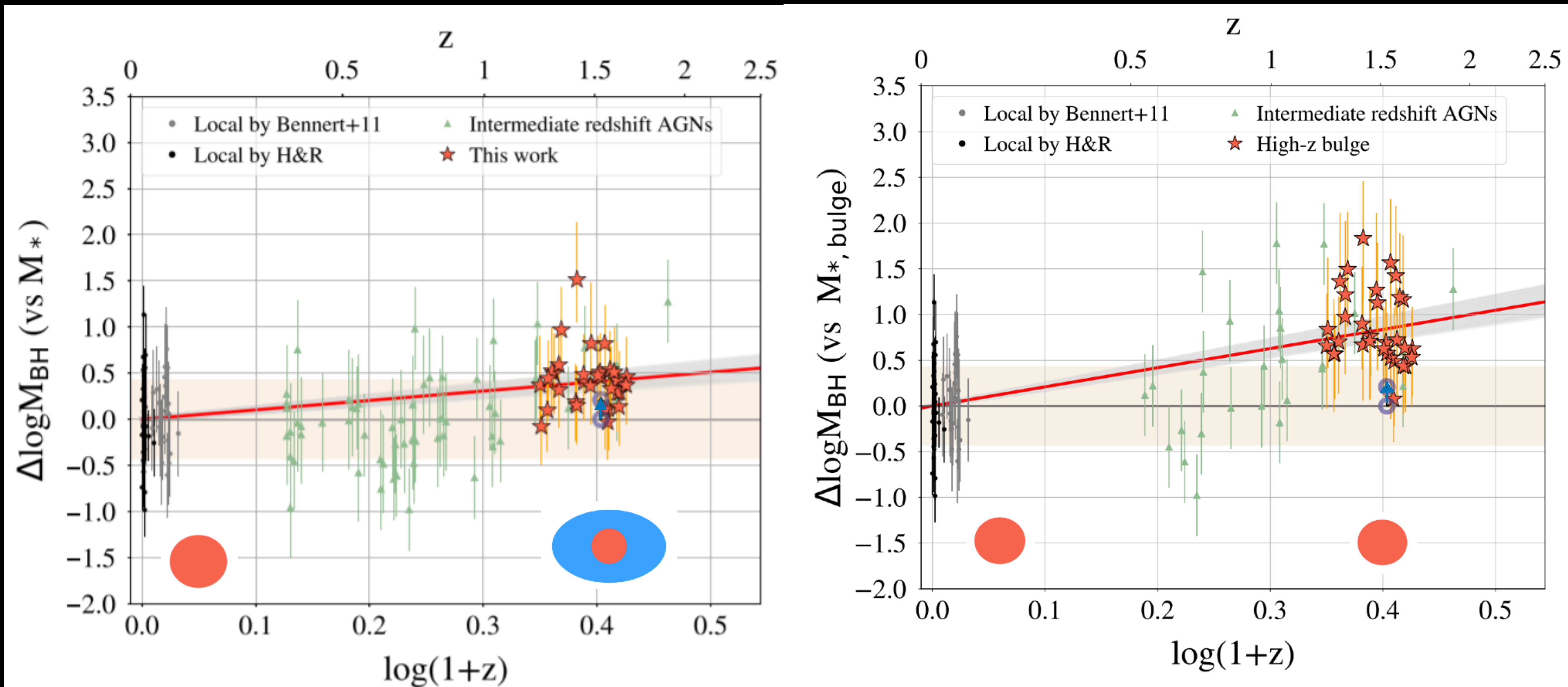
I develop a python package based on the imaging modelling tool LENSTRONOMY to decompose the AGN image.



The M_*—M_{BH} relation and its evolution.



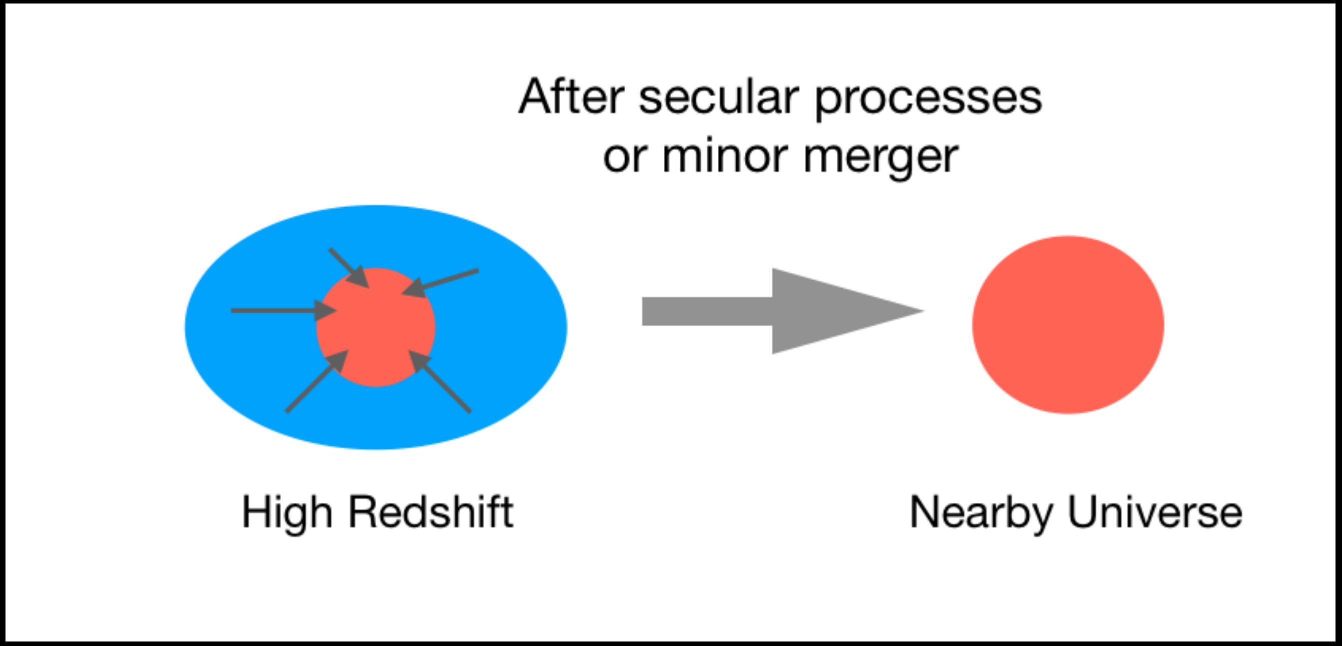
The M_*—M_{BH} relation and its evolution.



- There is an *apparent* evolution of MBH as positive.
- Most of the evolution can be explained by the selection effect.
- Local sample is bulge dominated galaxy and bulge mass is adopted. However, for high-z sample, it is the M* of the entire galaxy inferred.
- The evolution must be significant if consider bulge only.

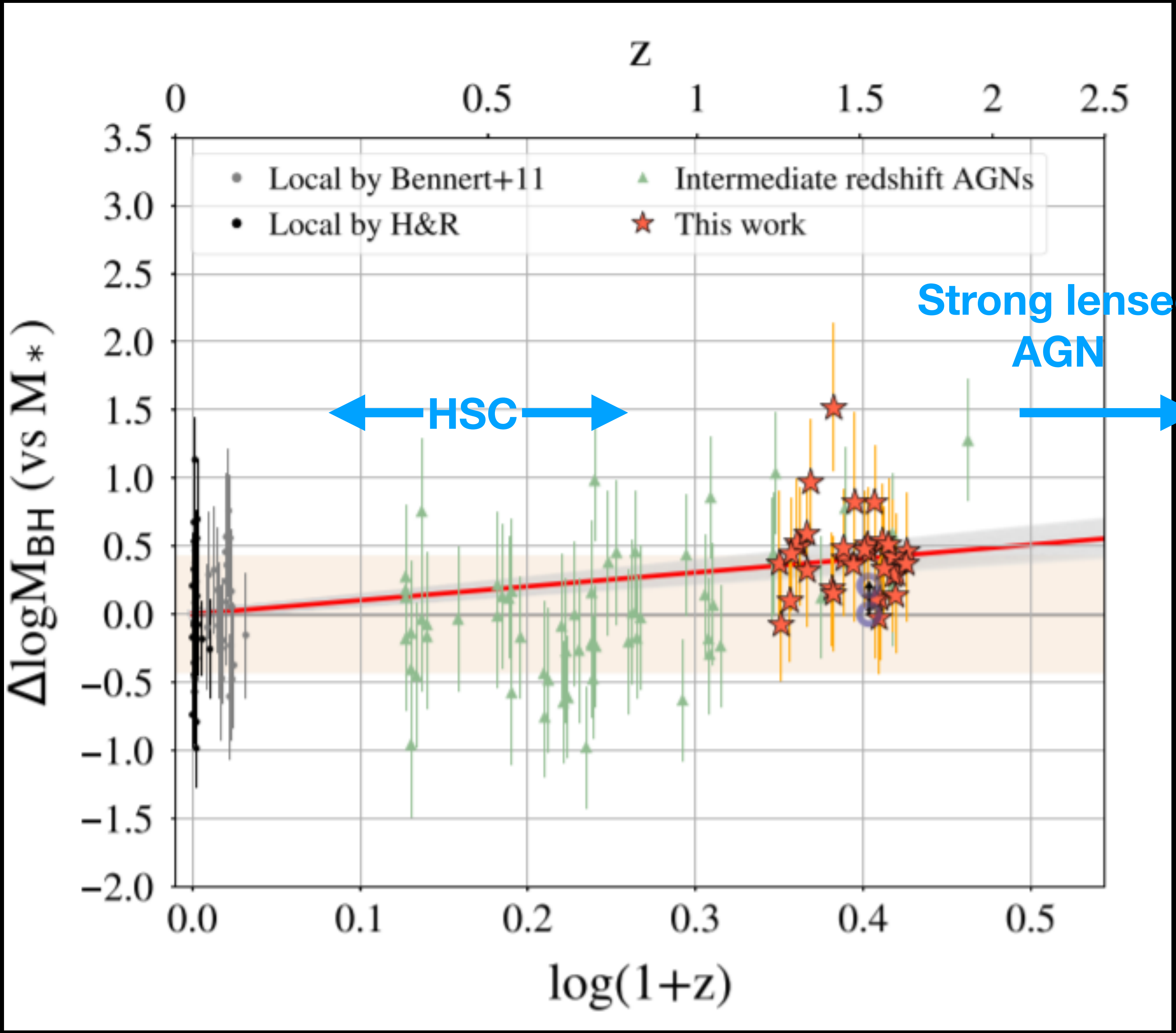
The interpretations based on the results

1. Taking supermassive BH mass as reference, the evolution of stellar mass of the entire galaxy is little.
2. Stellar mass is transferred from the disk to bulge (e.g., minor merger process) at a faster rate than mass accretion of the SMBH.

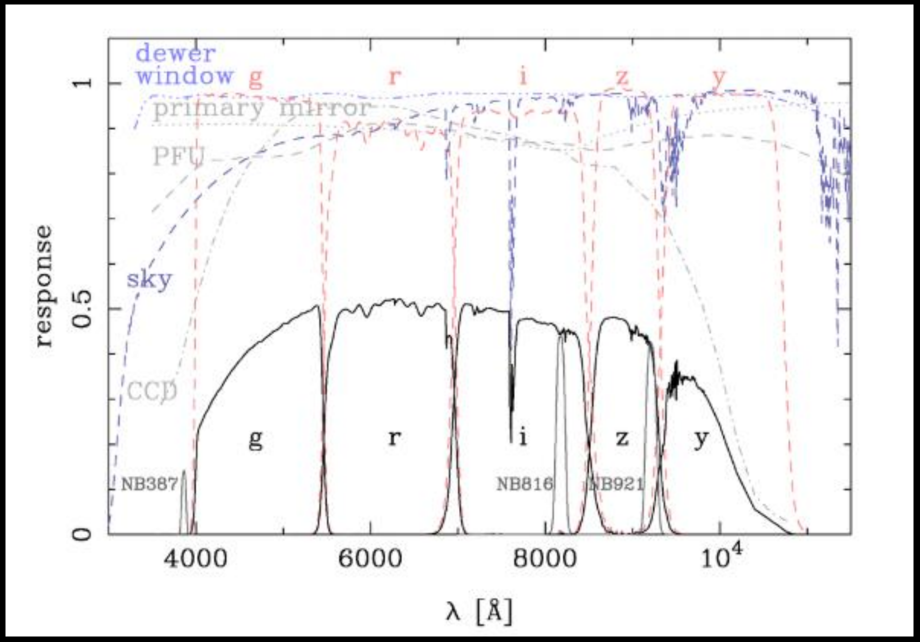


X. Ding et al. 2020, 888, 37D

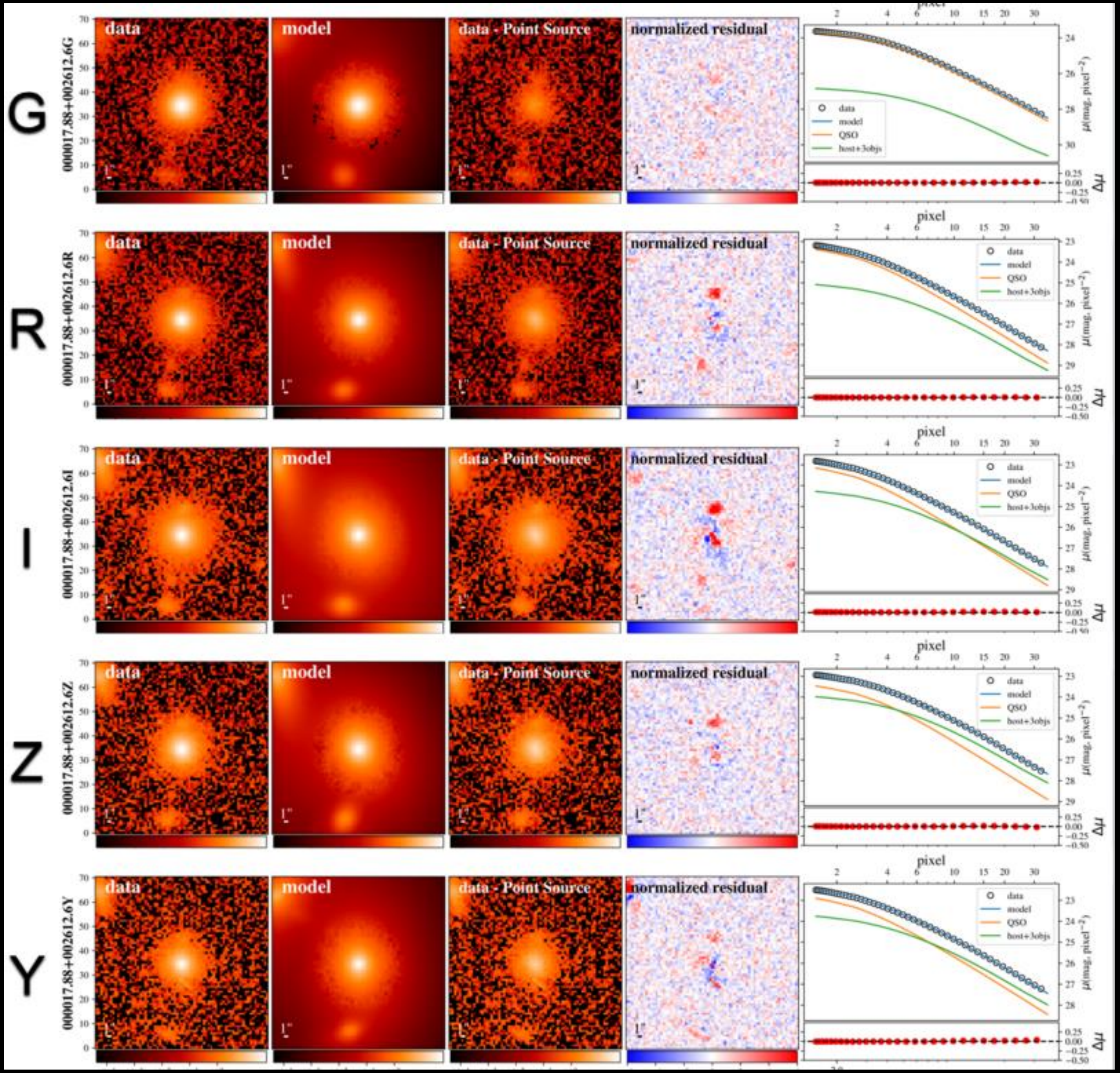
Extend the study to different redshift range

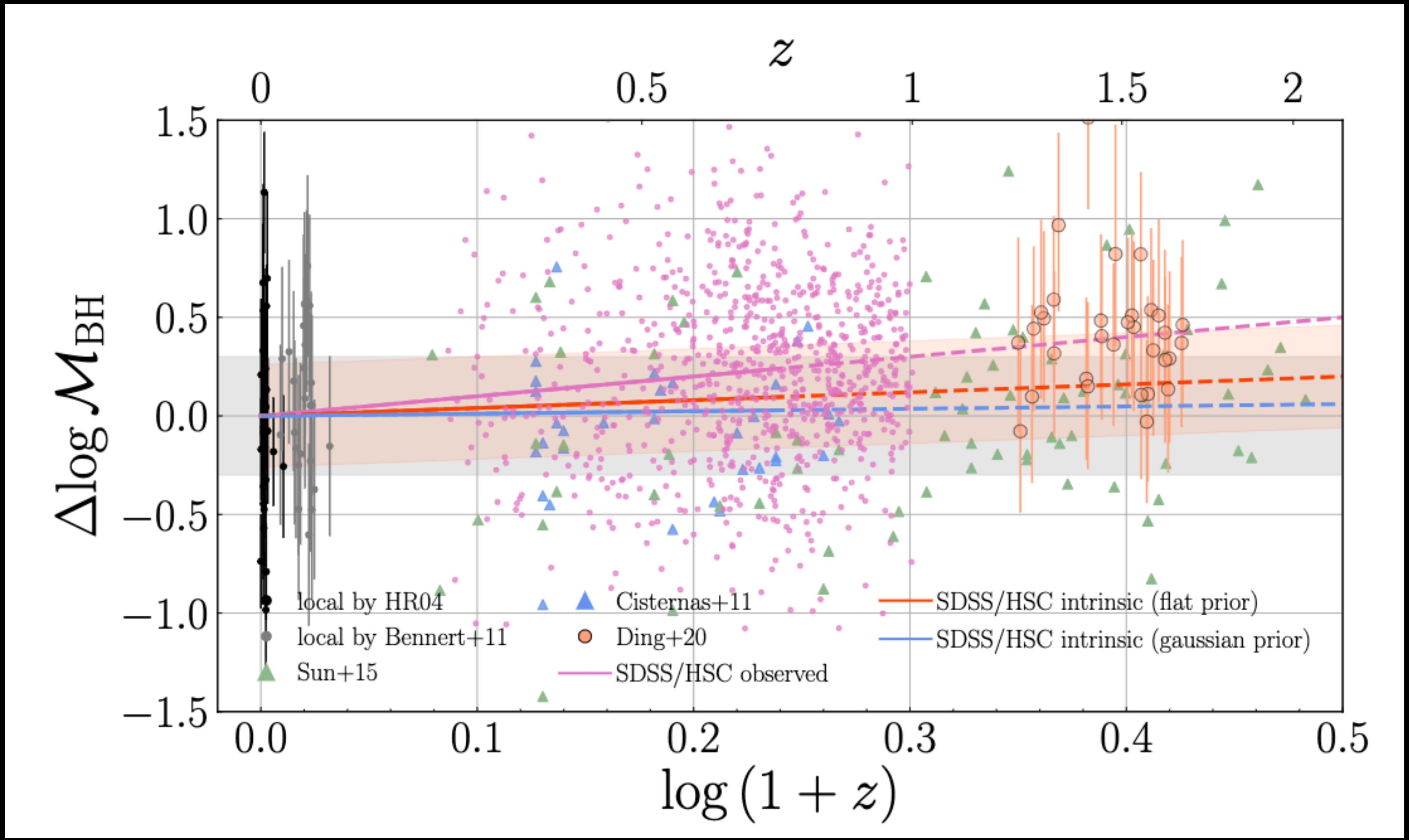


Hyper Suprime-Cam Subaru Strategic Survey



Over thousands of SDSS confirmed QSOs has been observed with HSC multi-band (grizy) which can be included as intermediate redshift (0.2-0.8) sample.



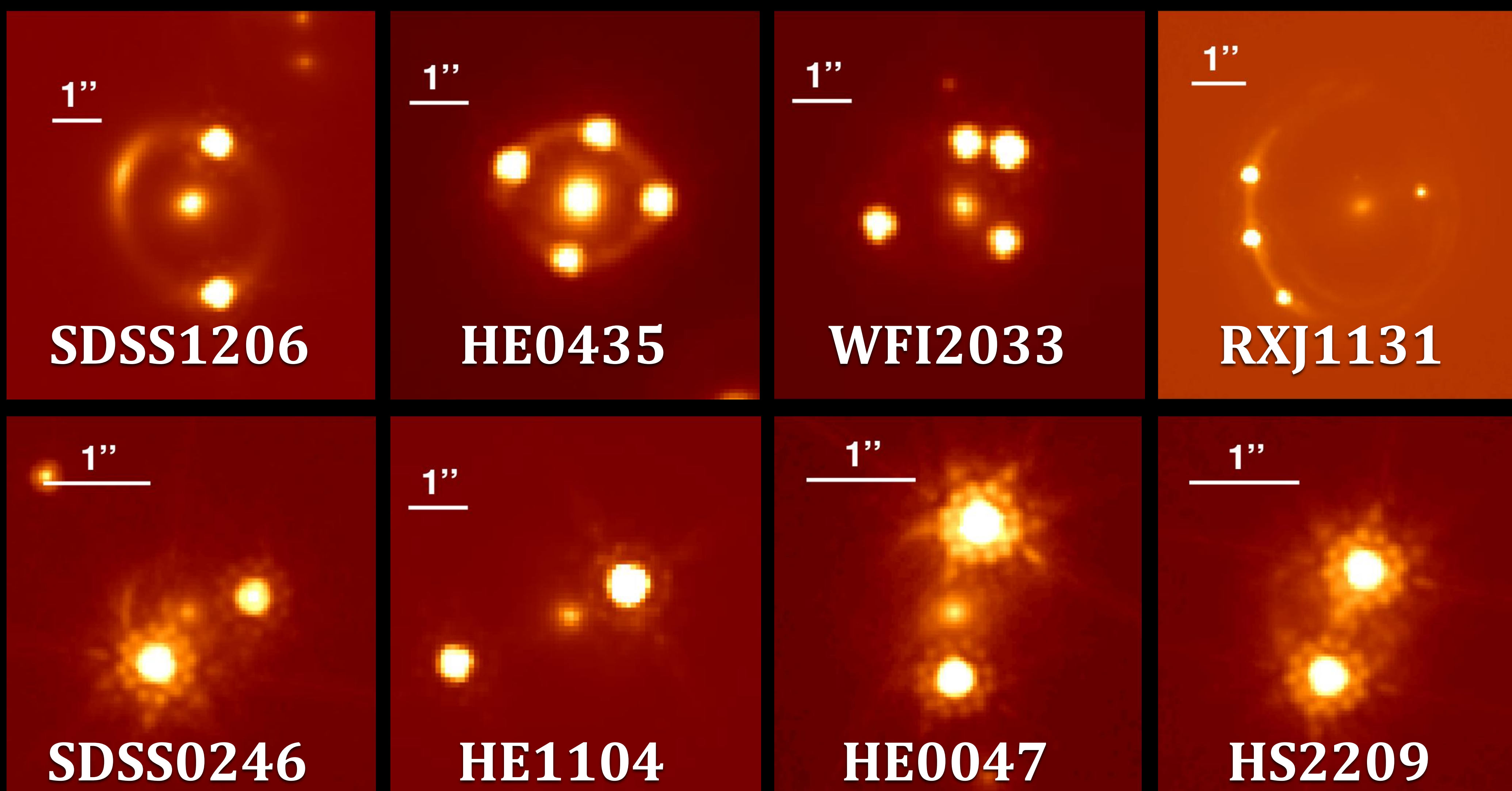


Li J., Silverman J., Ding X., et al., 2021 ApJ, accepted, arxiv: 2109.02751

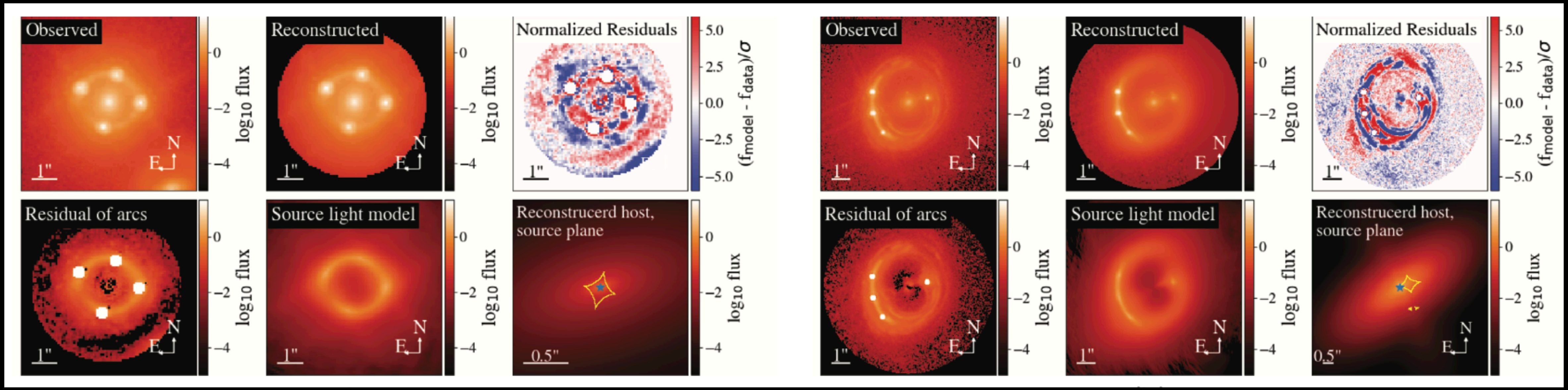
SMBH vs host galaxy

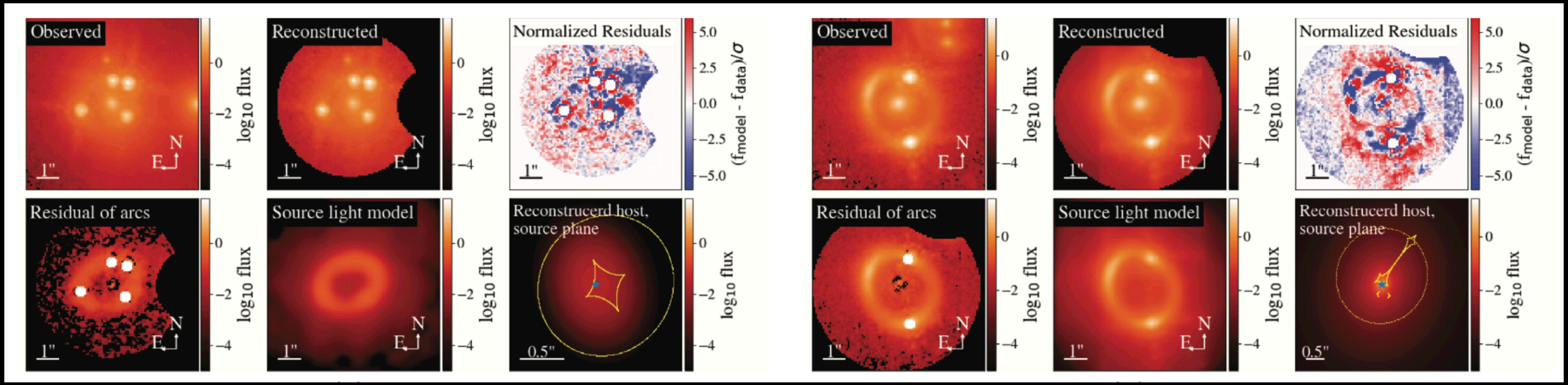
Strong gravitational lensed AGNs can help to trace to even higher redshift.

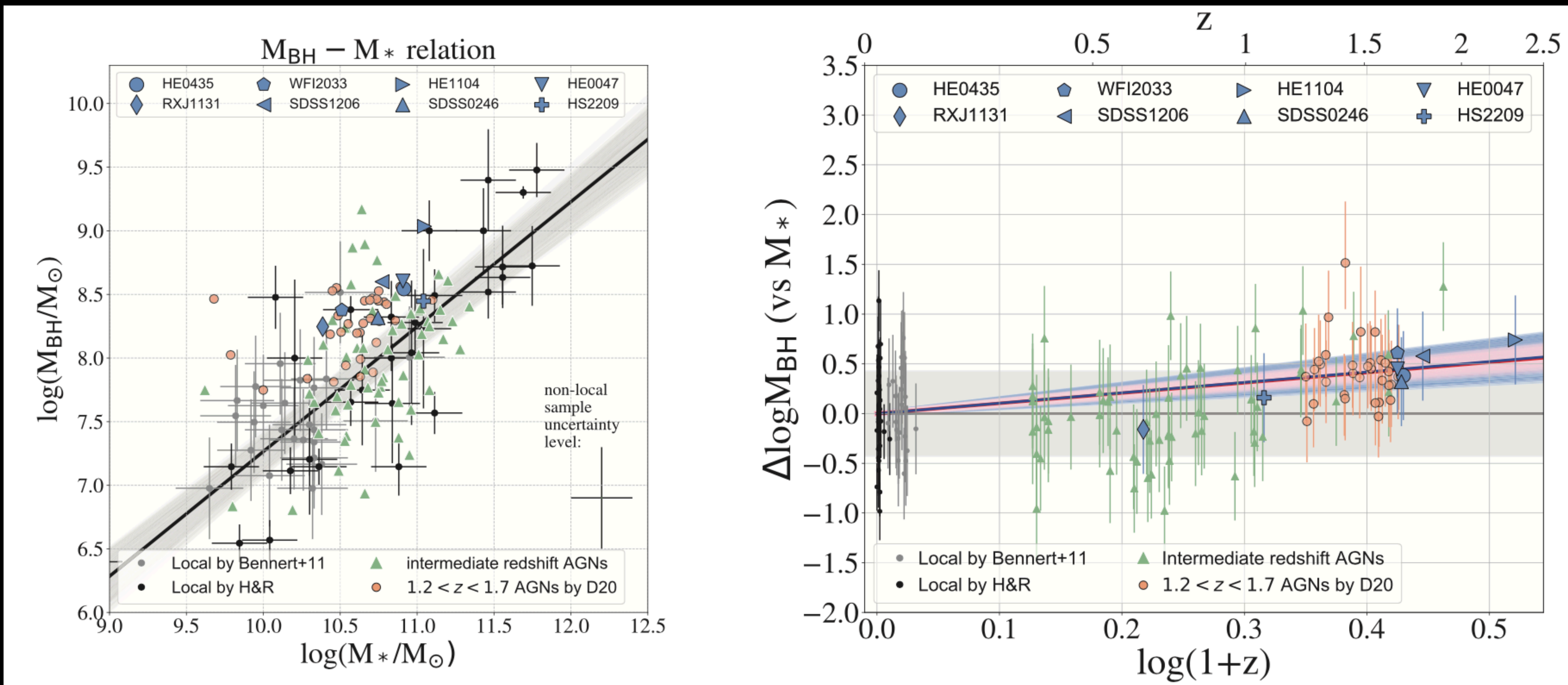
Name	z_s	Camera	Filter
HE0435−1223	1.69	WFC3-IR	F160W
HE1104−1805	$\boxed{2.32}$	WFC3-IR	F160W
SDSS1206+4332	1.79	WFC3-IR	F160W
WFI2033−4723	1.66	WFC3-IR	F160W
HE0047−1756	1.66	WFC3-UVIS	F814W
SDSS0246−0825	1.68	WFC3-UVIS	F814W
HS 2209+1914	1.07	WFC3-UVIS	F814W
RX J1131−1231	0.65	ACS	F814W



Using strong lensing modelling technique, the host flux of the lensed QSOs can be obtained.







Ding X., et al., 2020, MNRAS 501 269D

Outlook to even higher redshift

We proposed, JWST accepted in cycle 1, NIRSpec Fixed-Slit + NIRCam broad-band observations of 12 of the lowest-luminosity quasars known at z~6 to obtain the first full census of the black holes and host galaxies of the earliest quasars.

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Investigators for JWST program 1967

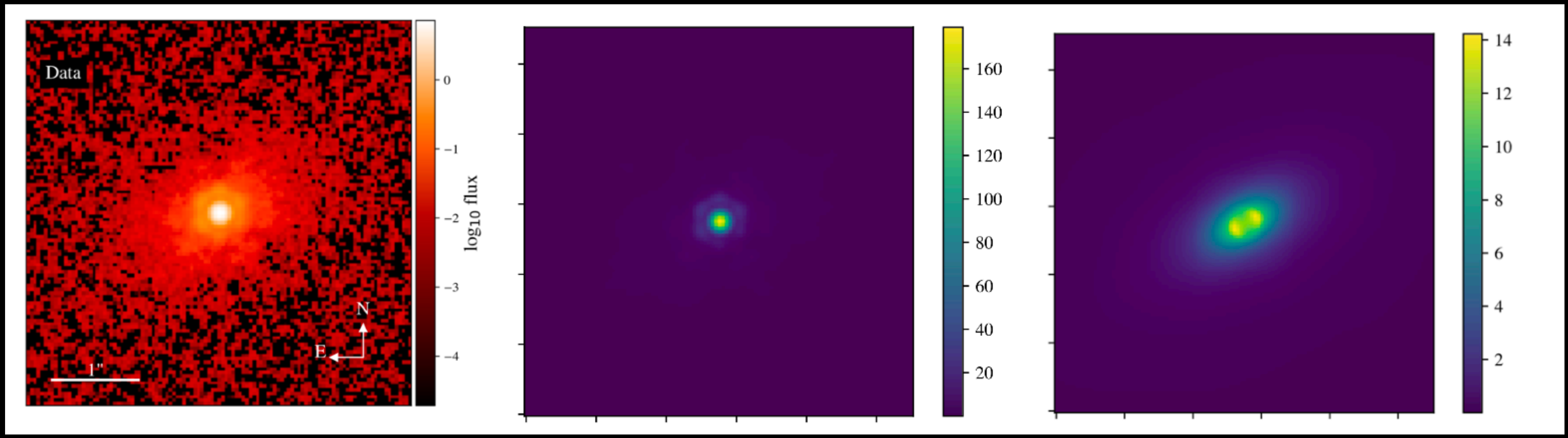
PI Contact	Masafusa Onoue	Max Planck Institute for Astronomy
Co-PI	Xuheng Ding	Institute for Physics and Mathematics of the Universe
Co-PI	Takuma Izumi	National Astronomical Observatory of Japan (NAOJ)
Co-PI	Yoshiki Matsuoka	Ehime University
Co-PI	John David Silverman	University of Tokyo

Simulation setting

- JWST/NIRCam PSF based on STSCI/webPSF package
- Noise level and zeropoint using: STSCI/ETC (Exposure Time Calculator)
- Mimic the Drizzling (Ding 2017, Fig. 2), then use iraf to drizzle image:
  1. For SW (F150W and F200W): drizzle 0.031” to 0.029”
  2. For LW (F356W and F444W): drizzle 0.063” to 0.04”

one example simulation based on F444W for ID1:

SCI image: AGN SNR: AGN host galaxy SNR:

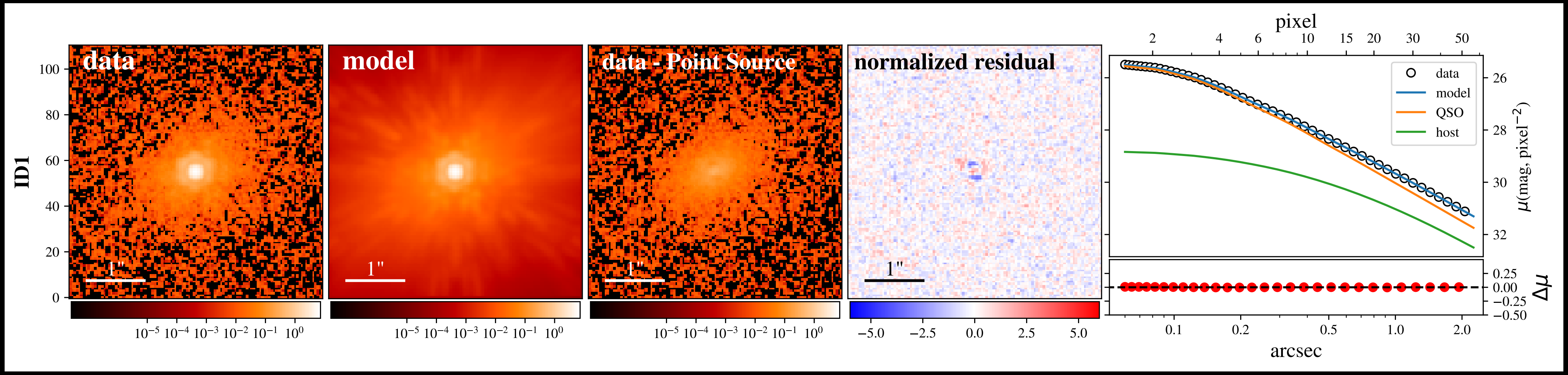


- Using simulations, we can study the reliability of the host inference as a function of 1) exposure time; 2) host flux ratio; 3) Host size; 4) Sersic n.

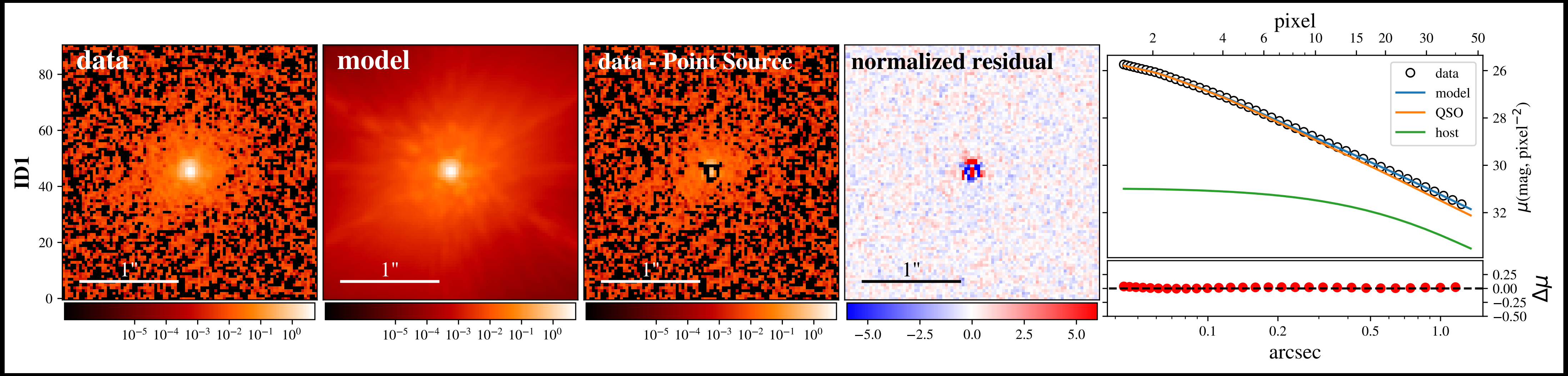
Fitting inference

- Examples of the modeling image (assume 5000s exposure time):

ID1
F356W:



ID1
F150W:



One more thing …

The modelling software — GaLight

galight
latest

Search docs

- Installation
- Usage
- galight package
- Contributing
- Credits
- History

» galight - Galaxy shapes of Light   Edit on GitHub

galight - Galaxy shapes of Light

pypi package 0.0.0 | build unknown

A python package that analyze and model the imaging data of galaxies, QSOs and duals.

Installation

```
$ pip install galight --user
```

Alternatively, the package can be installed through github channel:
https://github.com/dartoon/galight

Requirements

Running `galight` requires the following packages to be installed.

- `lenstronomy` https://github.com/sibirrer/lenstronomy
- `astropy` https://github.com/astropy/astropy
- `photutils` https://github.com/astropy/photutils
- `regions` https://github.com/astropy/regions

and related ones to be installed...

https://galight.readthedocs.io/en/latest/

Benefits of this software:

1. Determine a suitable cutout size for the image frame.

2. Search PSFs in the FOV.

3. If needed, a noise map can be generated using the exposure time and the background noise level from empty regions.

4. Neighboring sources can be masked or simultaneously modeled.

5. By default, the parameter settings for all the fitting sources will be assigned automatically.

6. Output data products are generated for full assessment of the goodness-of-fit with the ability to share across different platforms.