Exploring the origin of the connection between supermassive black holes and galaxies with advanced approaches

Xuheng Ding (Kavli IPMU)

Collaborators: J. Silverman (IPMU), M. Onoue (KIAA)

@Kavli IPMU Postdoc Colloquium

Oct/13th/2022

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 stellar mass.

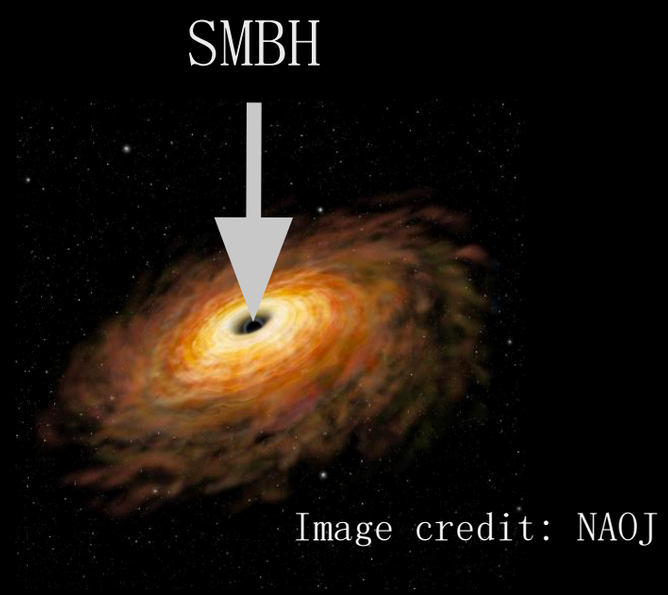
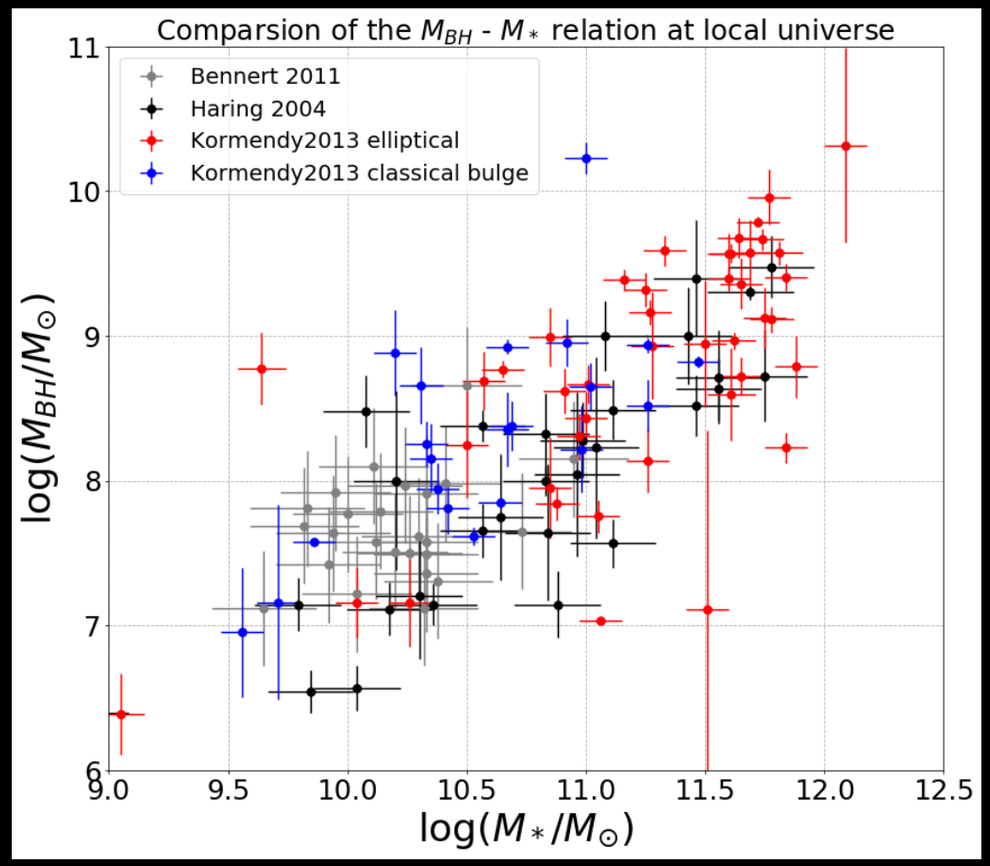


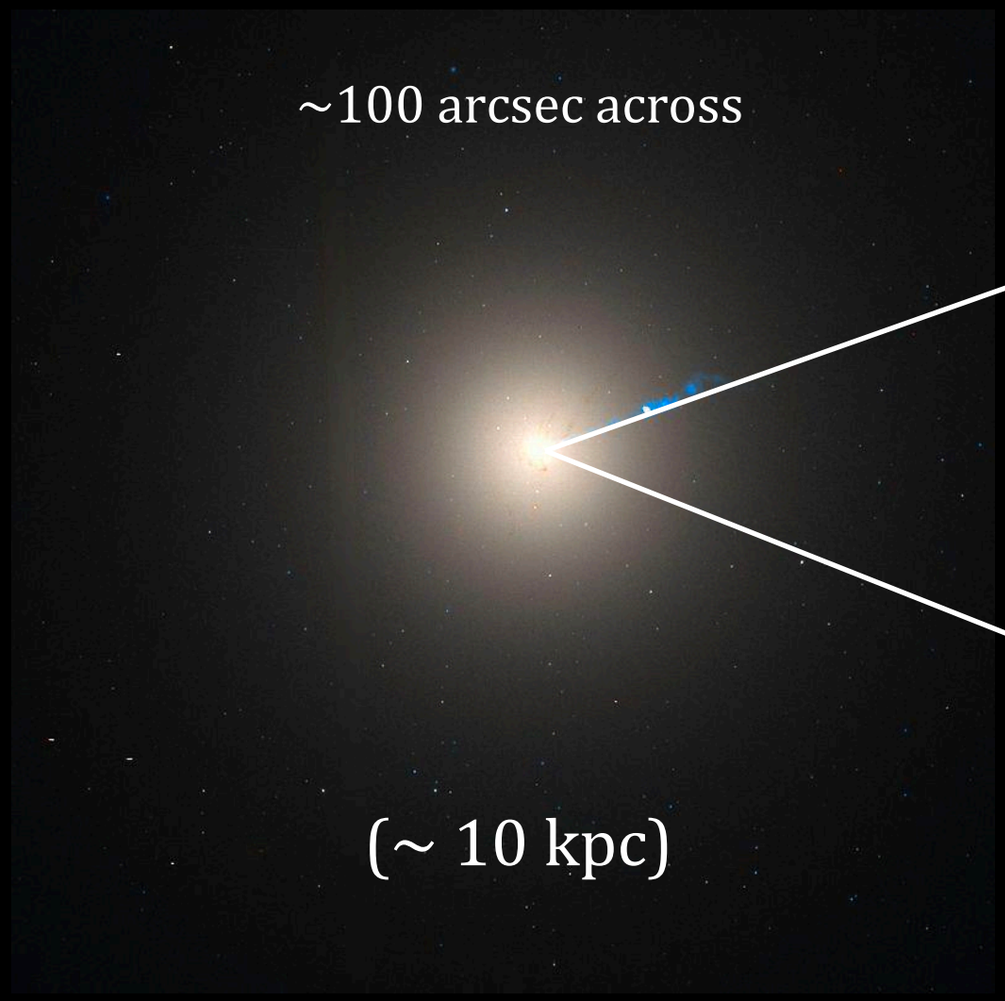
Image credit: NAOJ



The origin of this connection is still an open question.

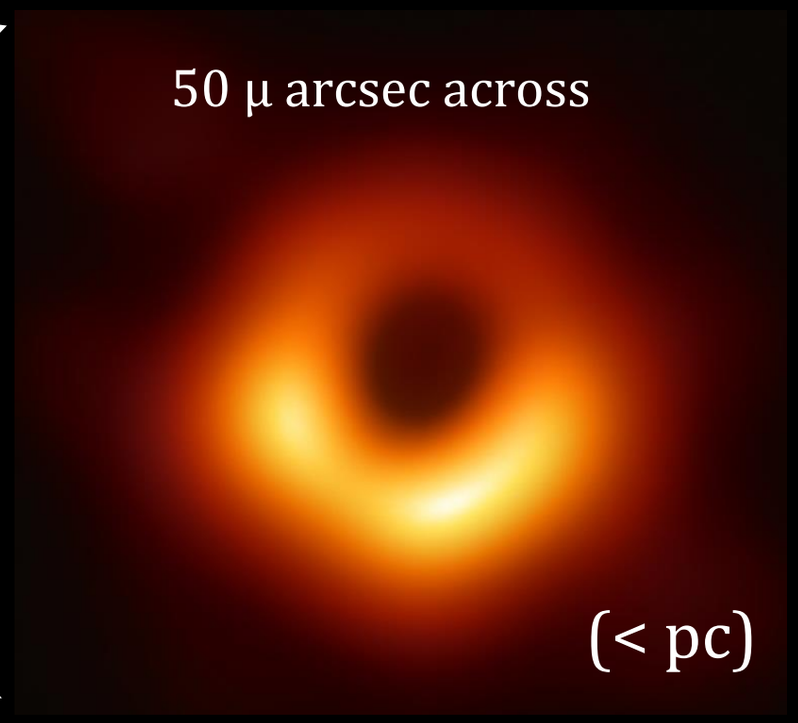
The BH and host galaxy relation

The physical mechanism is still unknown.



Messier 87, credit HST.

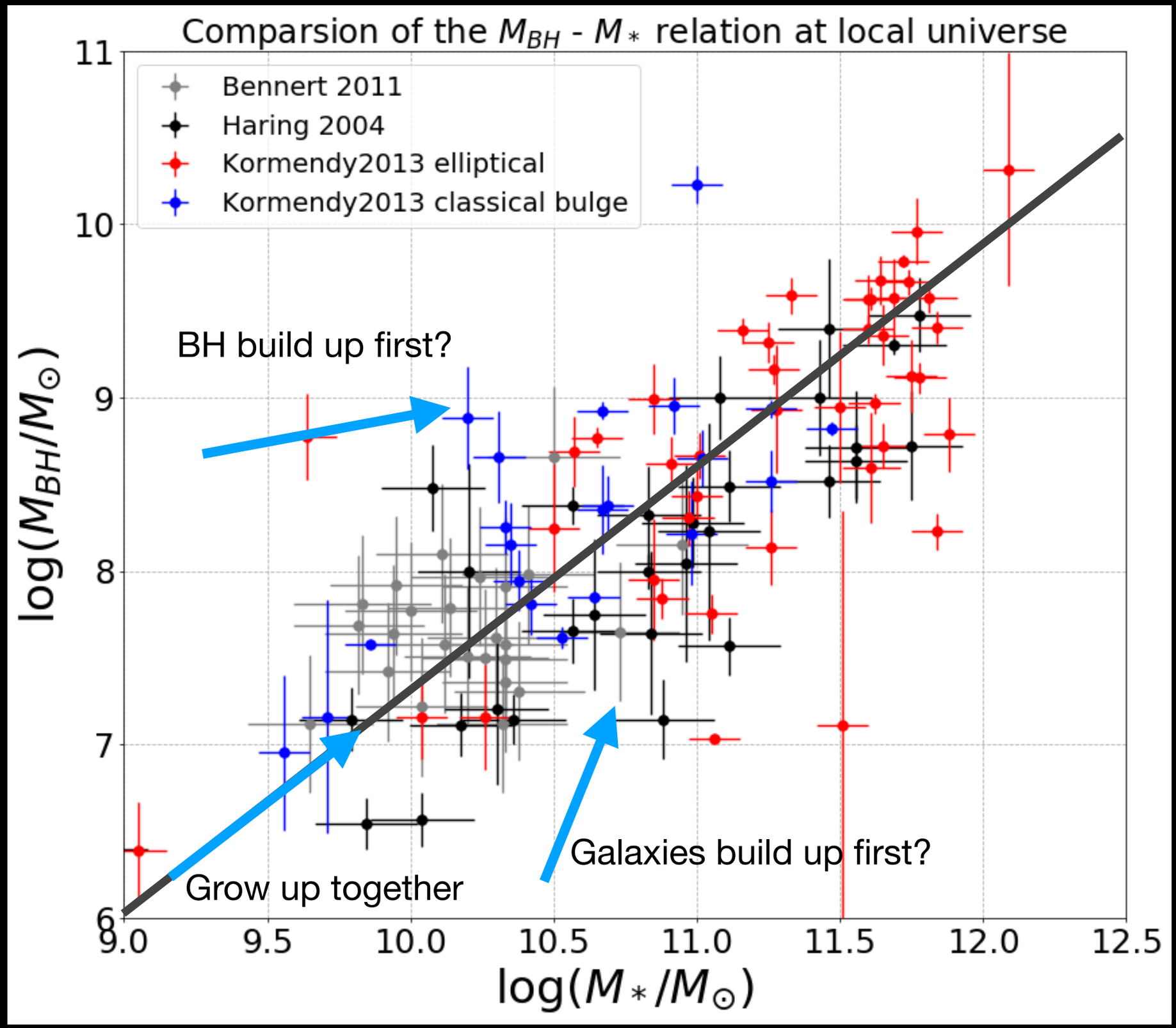
$\sim 10^6$



Center SMBH

credit Event Horizon Telescope.

Trace the correlation to high-z is the key



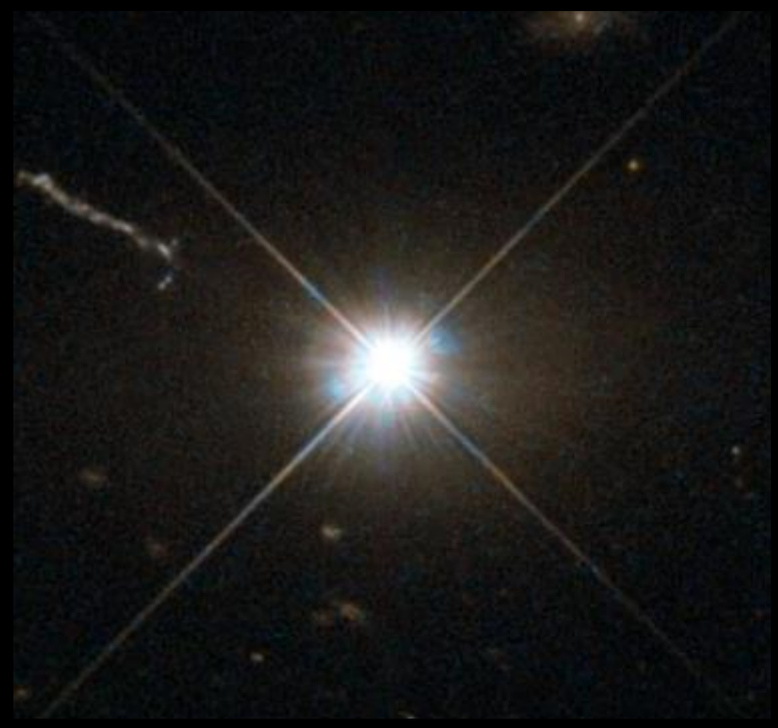
However, it's difficult at high redshift

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 $(1+z)^4$.

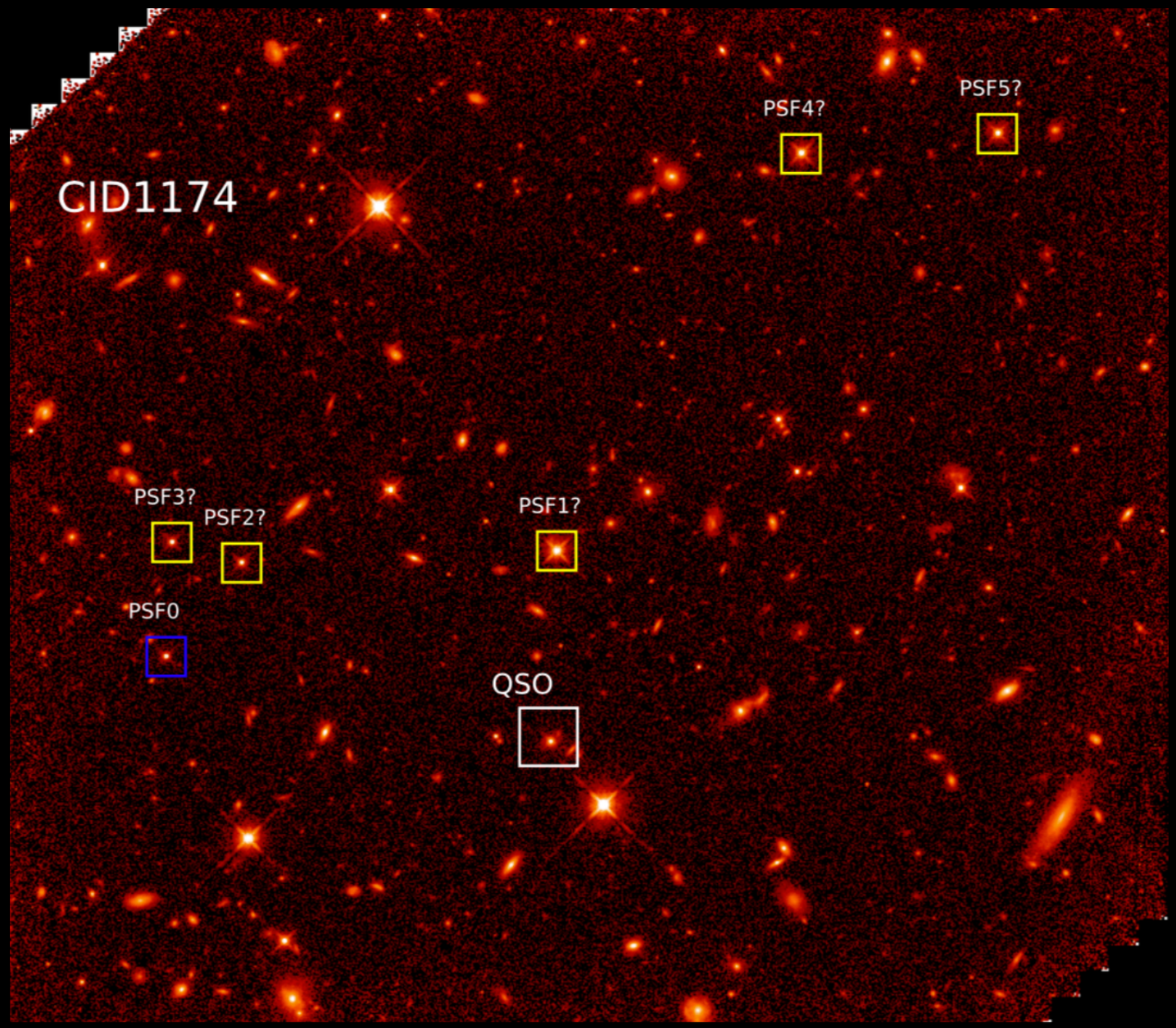


bright quasar 3C 273 z = 0.158

credit HST

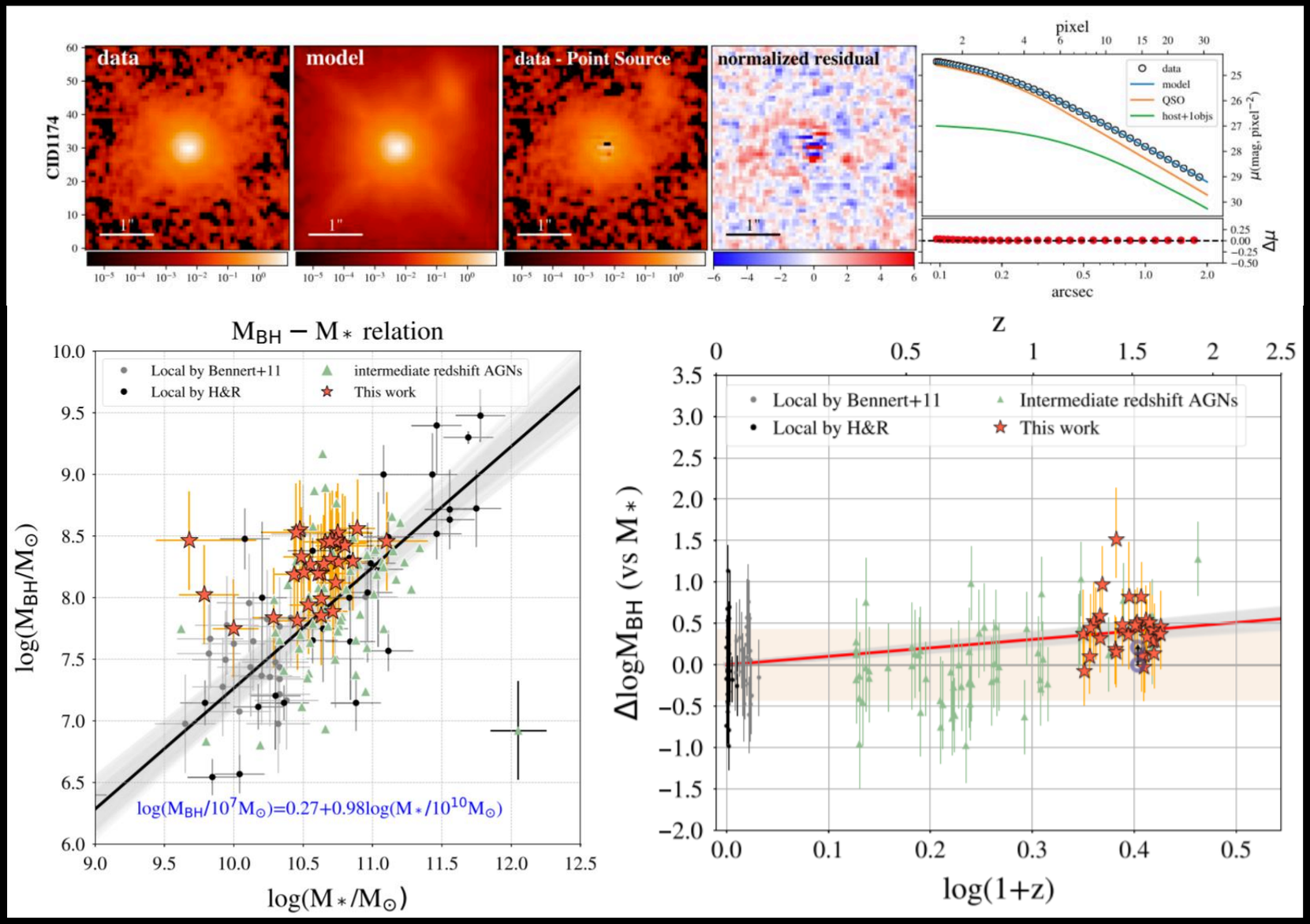
Given these challenges, most previous studies were below z<1.

The first effort beyond z>1



We first extended the study of this correlation at at z>1 using a statistical sample with 32 quasars (z~1.5), using HST.

Infer AGN host and study the coevolution



We developed *Galight* from this study

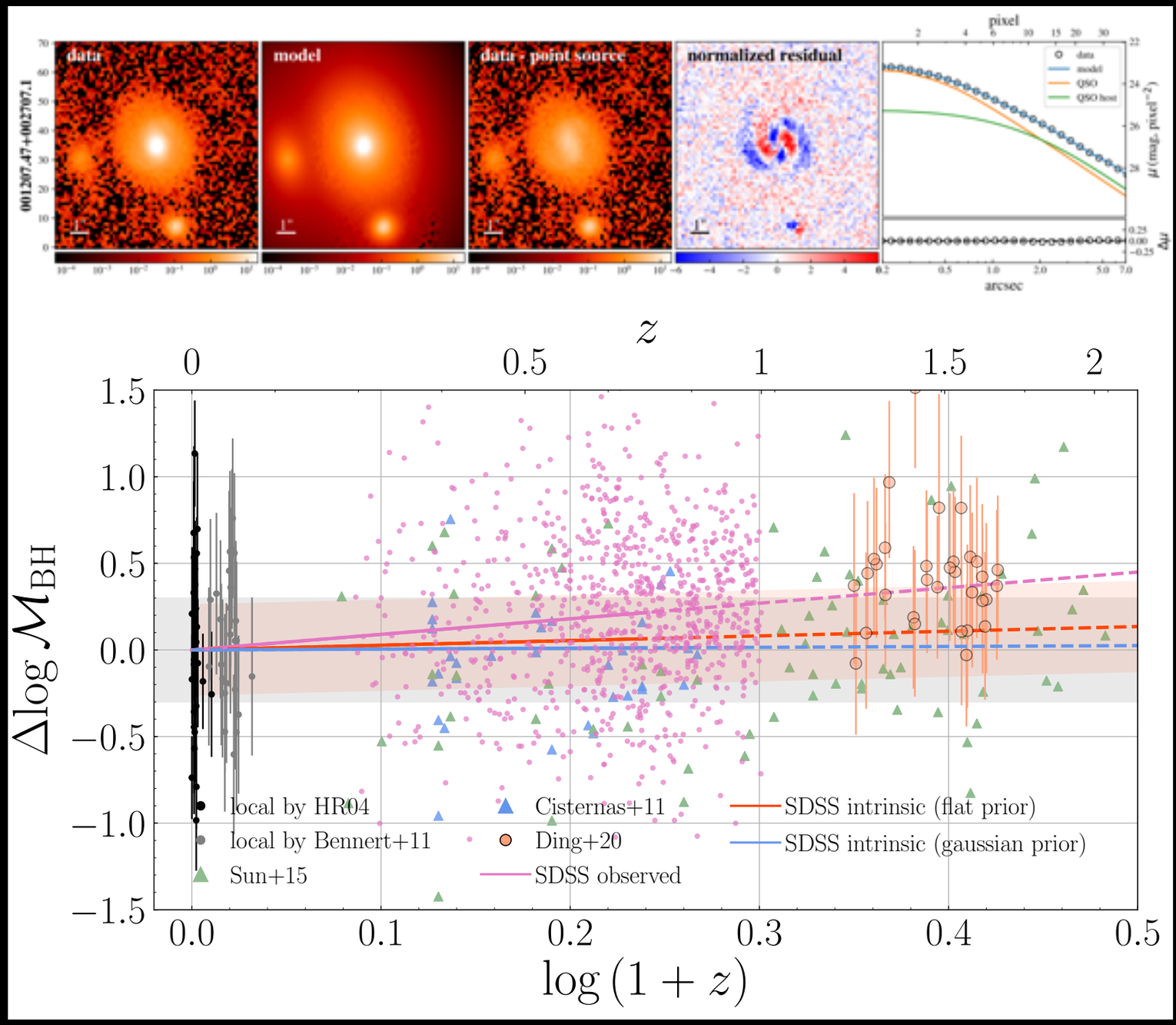
Our final conclusion indicate: stellar mass is transferred from the disk to bulge during the evolution, which is at faster rate than SMBH mass accretion.

Ding, Silverman, Treu et al. 2020

Larger quasar sample by HSC

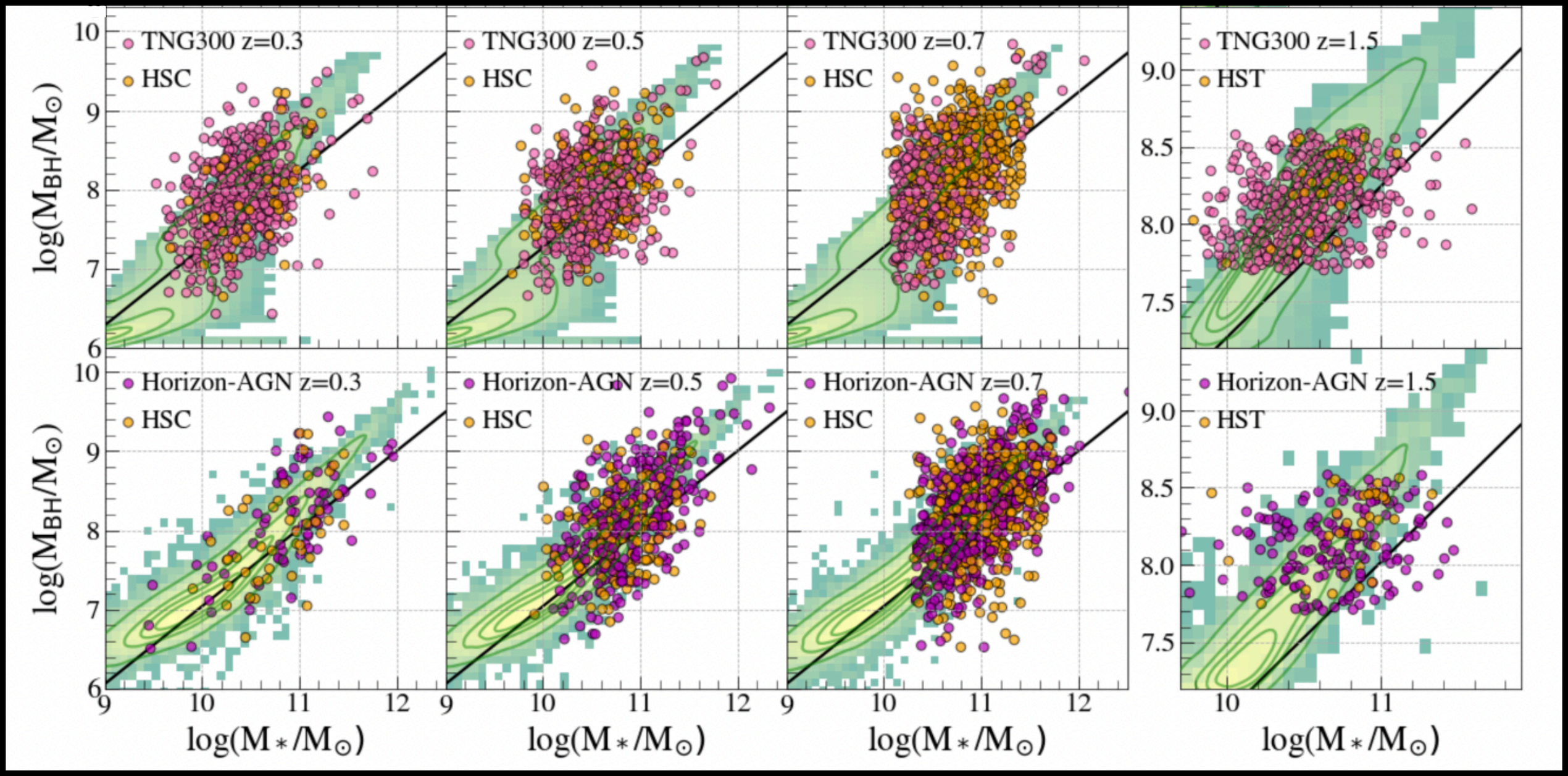
We also measure the correlation using ~600 quasars at 0.2<z<0.8 that observed by HSC. The consistent results are obtained.

Combining HSC and HST, we build up a sample from redshift range 0.2 to 1.5.



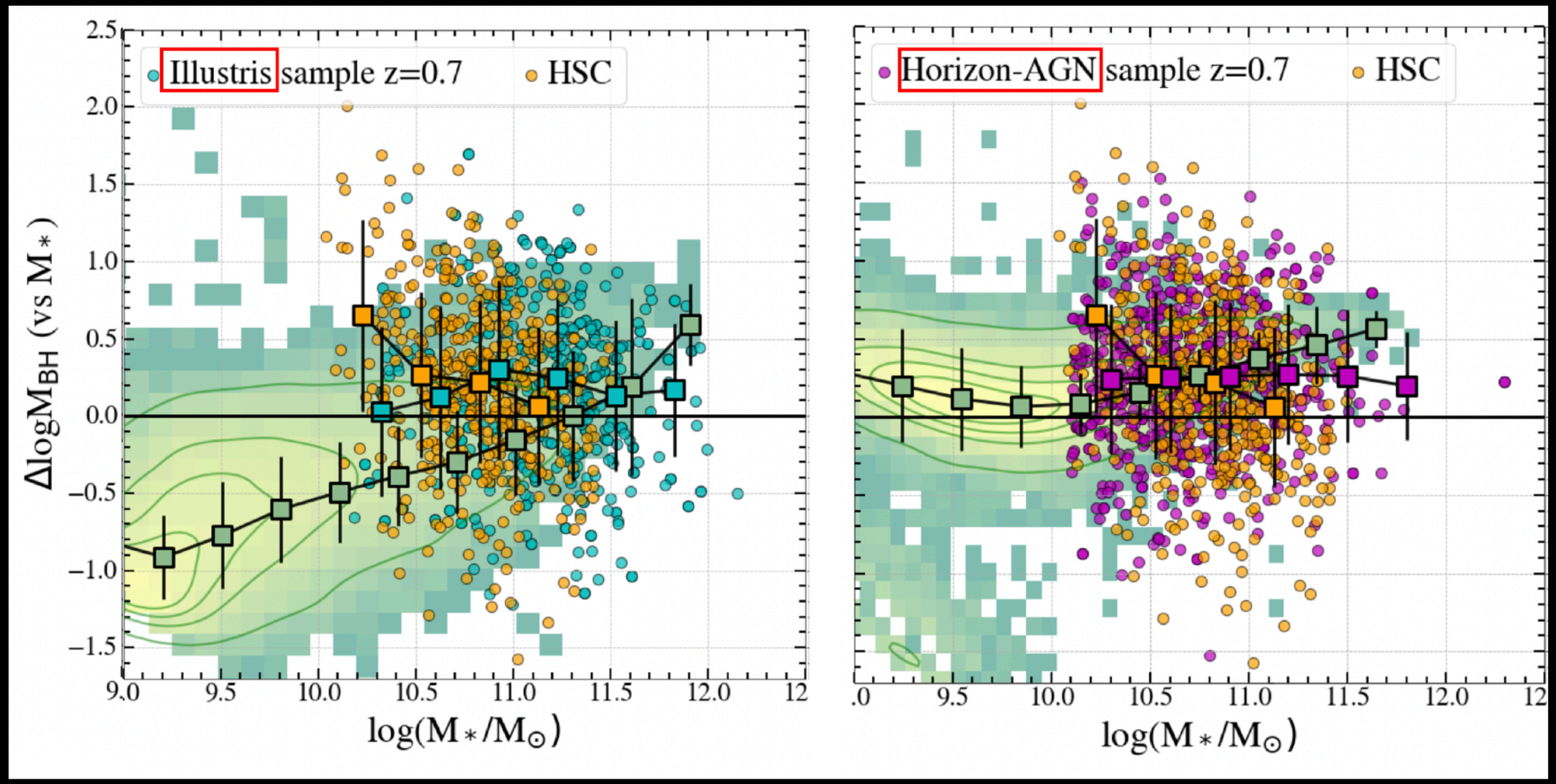
Li, Silverman, Ding et al. 2021

Concordance between simulations and observations



Ding, Silverman, Treu et al. 2022

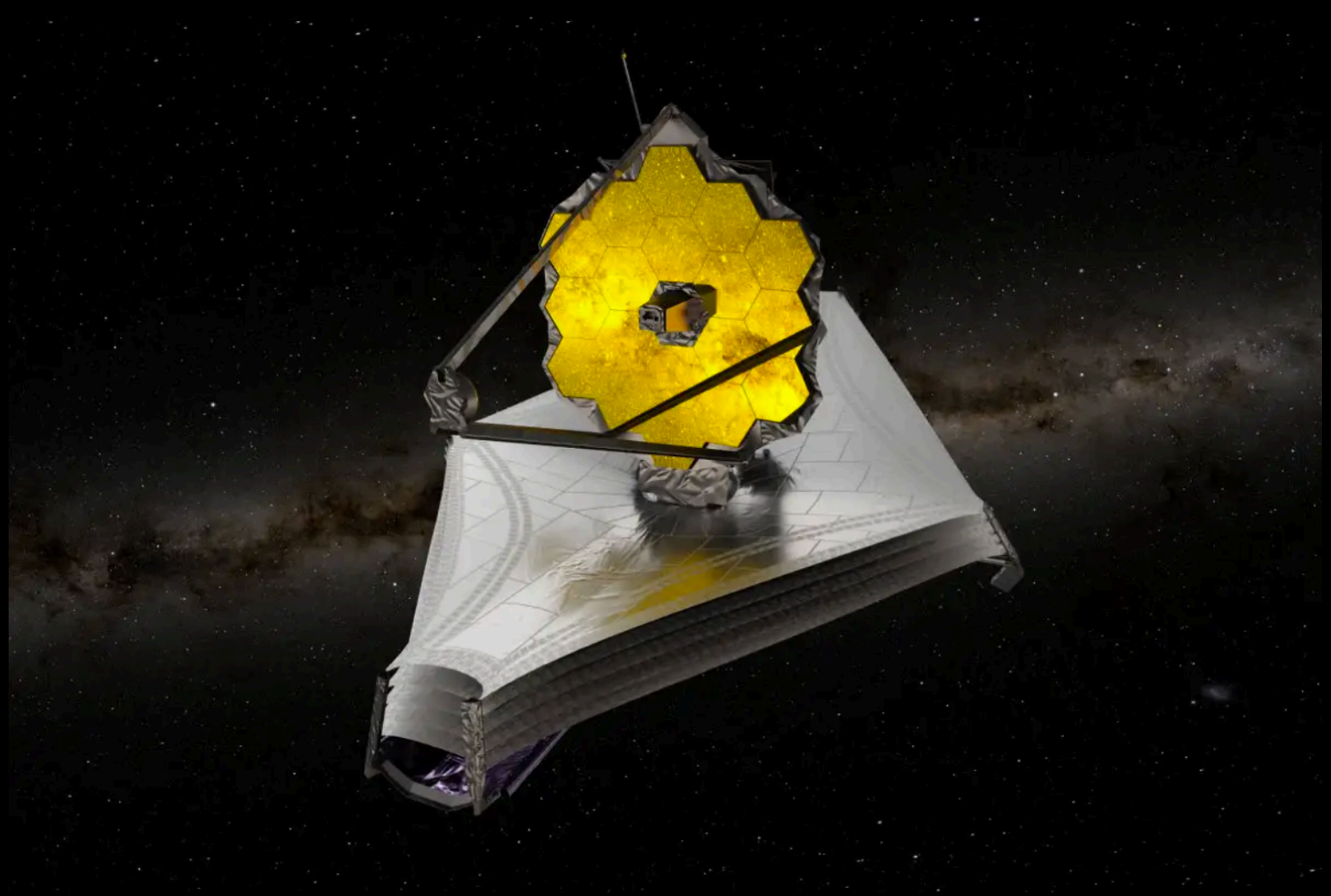
Concordance between simulations and observations



Extending the study to low mass end is also the key to role out the theoretical model.

Ding, Silverman, Treu et al. 2022

Until July 2022, our studies were still limited within z<2 at the high stellar mass end (logM*> 10)



July/12/2022

Welcome to the era of JWST!

JWST will soon obtain a sample of 12 high redshift quasars for us

A census of supermassive black holes and host galaxies at z = 6

PIs: Masafusa Onoue (MPIA->IPMU; 2023) Yoshiki Matsuoka (Ehime), John Silverman (IPMU), Xuheng Ding (IPMU)

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

Investigators for JWST program 1967

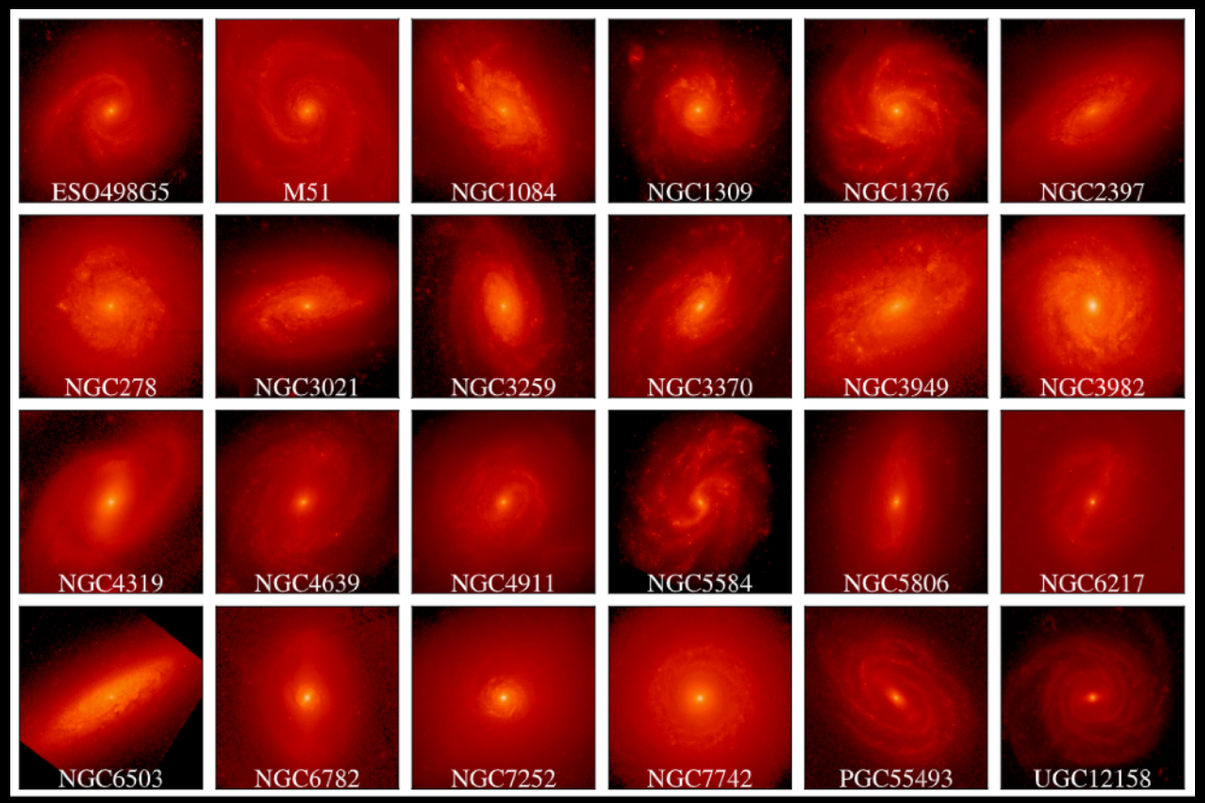
PI Contact	Masafusa Onoue
	Max Planck Institute for Astronomy
Co-PI	Xuheng Ding
	Institute for Physics and Mathematics of the Universe
Co-PI	John David Silverman
	University of Tokyo
Co-PI	Takuma Izumi
	National Astronomical Observatory of Japan (NAOJ)
Co-PI	Yoshiki Matsuoka
	Ehime University

ID	z	M_{1450} (mag)	$y_{\rm AB}$ (mag)	$\lambda_{\rm obs,H\beta}$ (μm)	$T_{\rm NIRSpec}$ (hr)	$T_{\rm NIRCam}$ (hr)
J223644.58+003256.9	6.4	–23.8	23.2	3.60	1.5	1.8
J225538.04+025126.6	6.34	–23.9	23.0	3.57	1.4	2.3
J152555.79+430324.0	6.27	–23.9	23.5	3.53	2.2	1.8
J114648.42+012420.1	6.27	–23.7	23.8	3.53	1.8	1.9
J084431.60–005254.6	6.25	–23.7	23.1	3.52	1.5	1.8
J021721.59–020852.6	6.2	–23.2	23.5	3.50	1.8	2.3
J091833.17+013923.4	6.19	–23.7	23.2	3.50	1.4	1.9
J151248.71+442217.5	6.18	–23.1	24.2	3.49	3.3	1.9
J084408.61–013216.5	6.18	–24.0	23.7	3.49	1.8	2.3
J142517.72–001540.8	6.18	–23.4	23.4	3.49	1.4	2.3
J114658.89–000537.7	6.3	–21.5	24.8	3.55	4.1	1.8
J091114.27+015219.4	6.07	–22.1	24.6	3.44	3.8	1.8

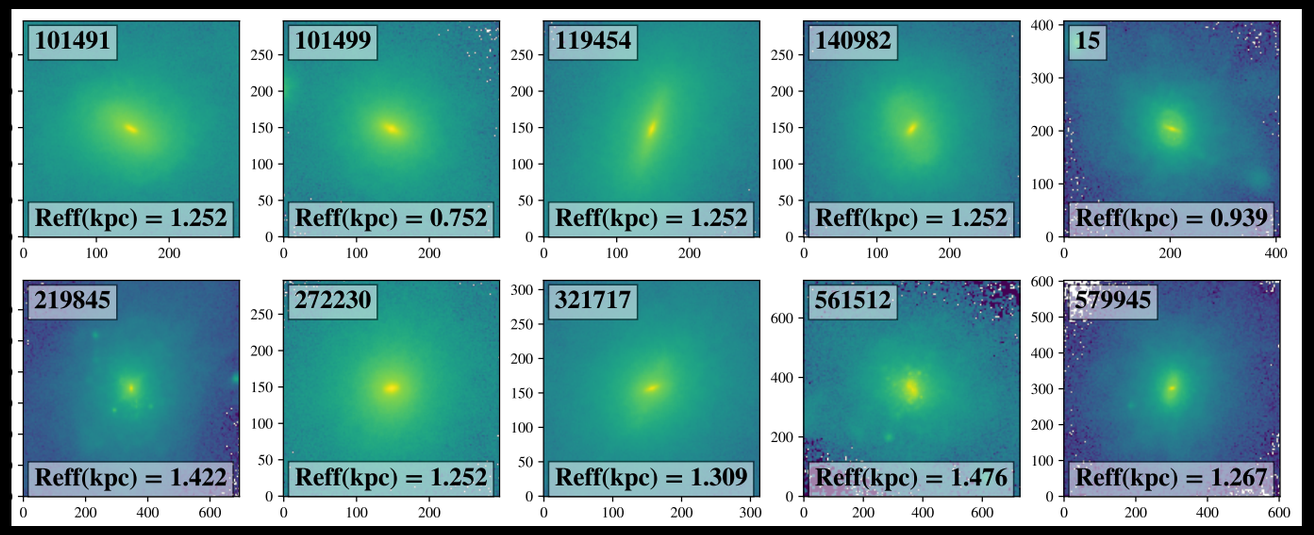
First part of the data is coming later this month!

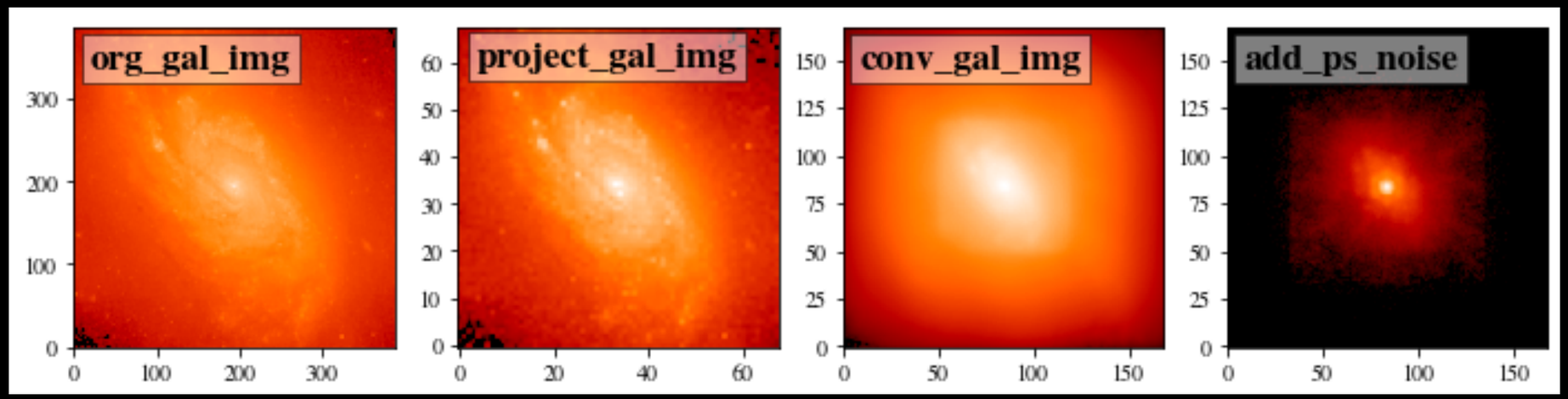
To get prepared, I performed extensive simulation tests

1. HST high res. image

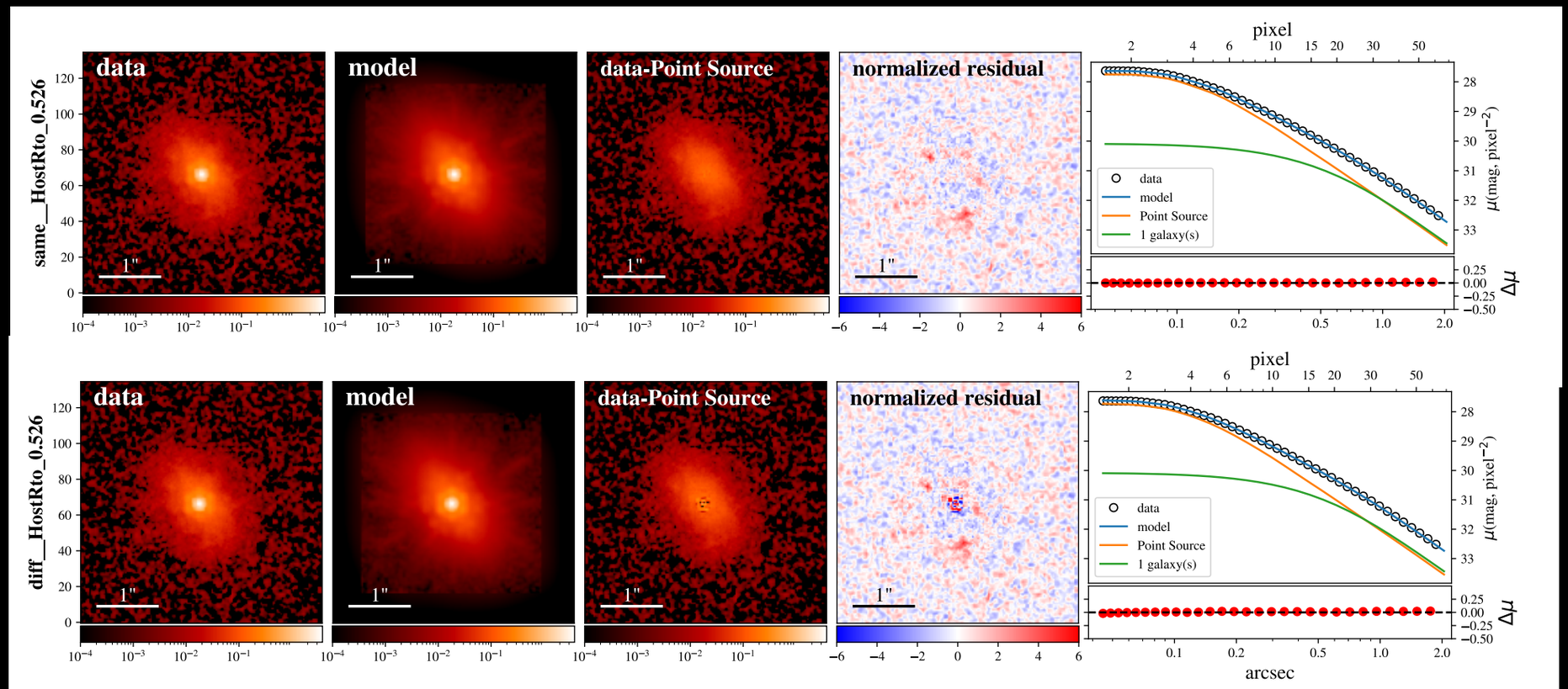


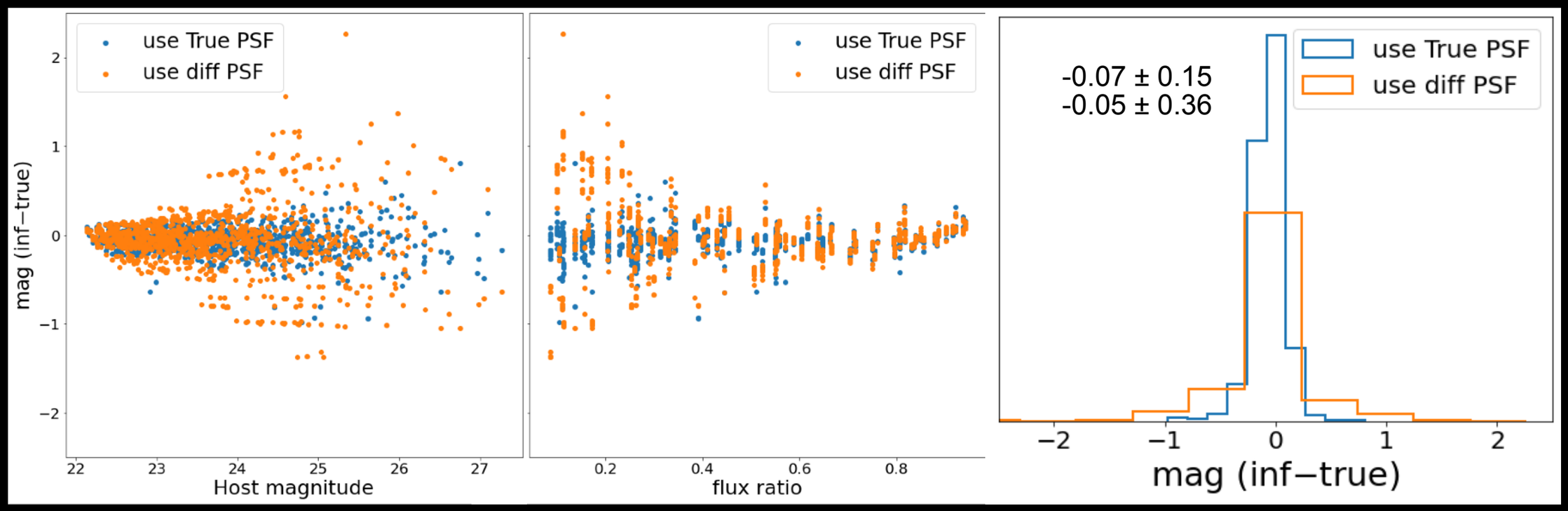
2. TNG50 high-res image





A thousand times realizations

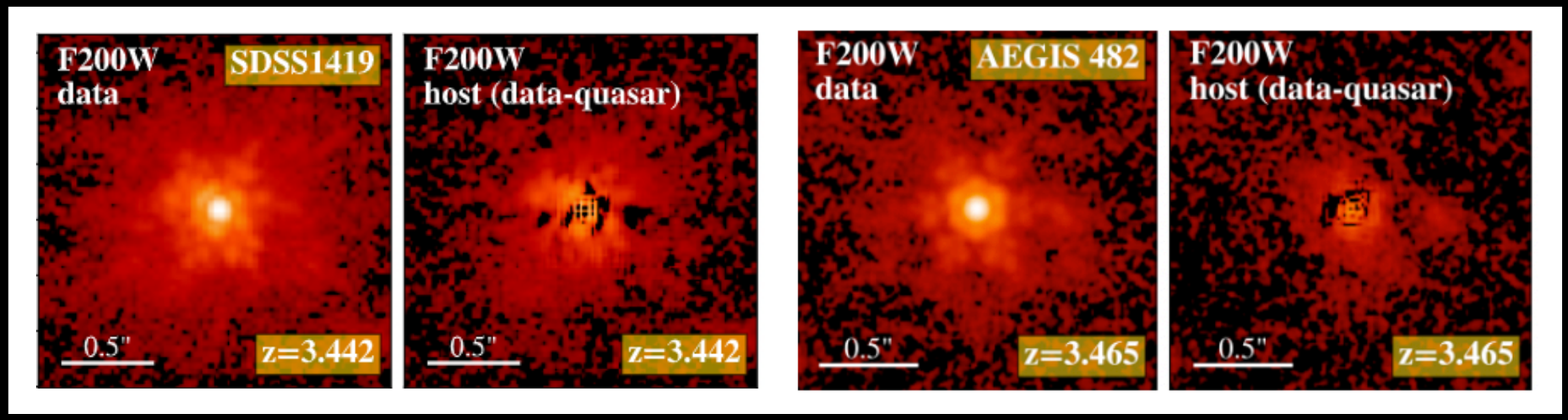




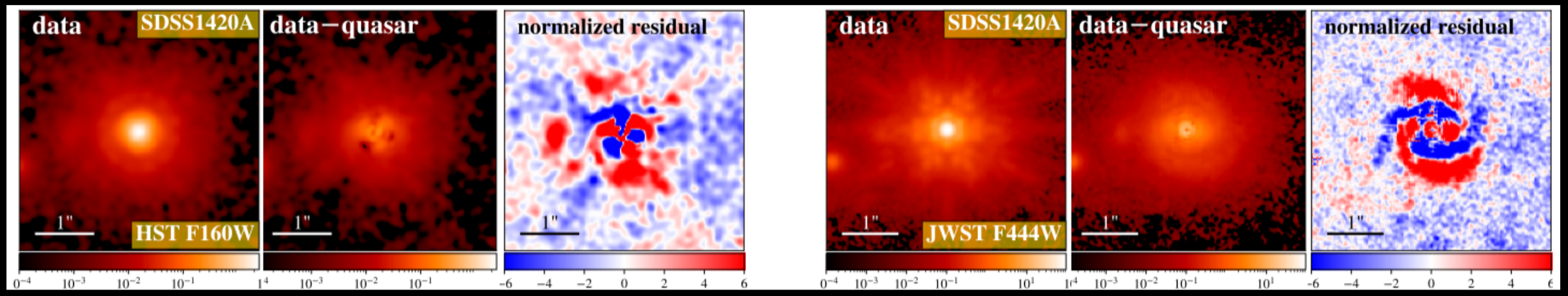
First touch on real JWST data

Using the first month JWST data from CEERS program, I have performed the QSO image analysis using 5 quasars at 1.6<z<3.5.

The AGN host galaxies are detected at z~3.5 for the first time:



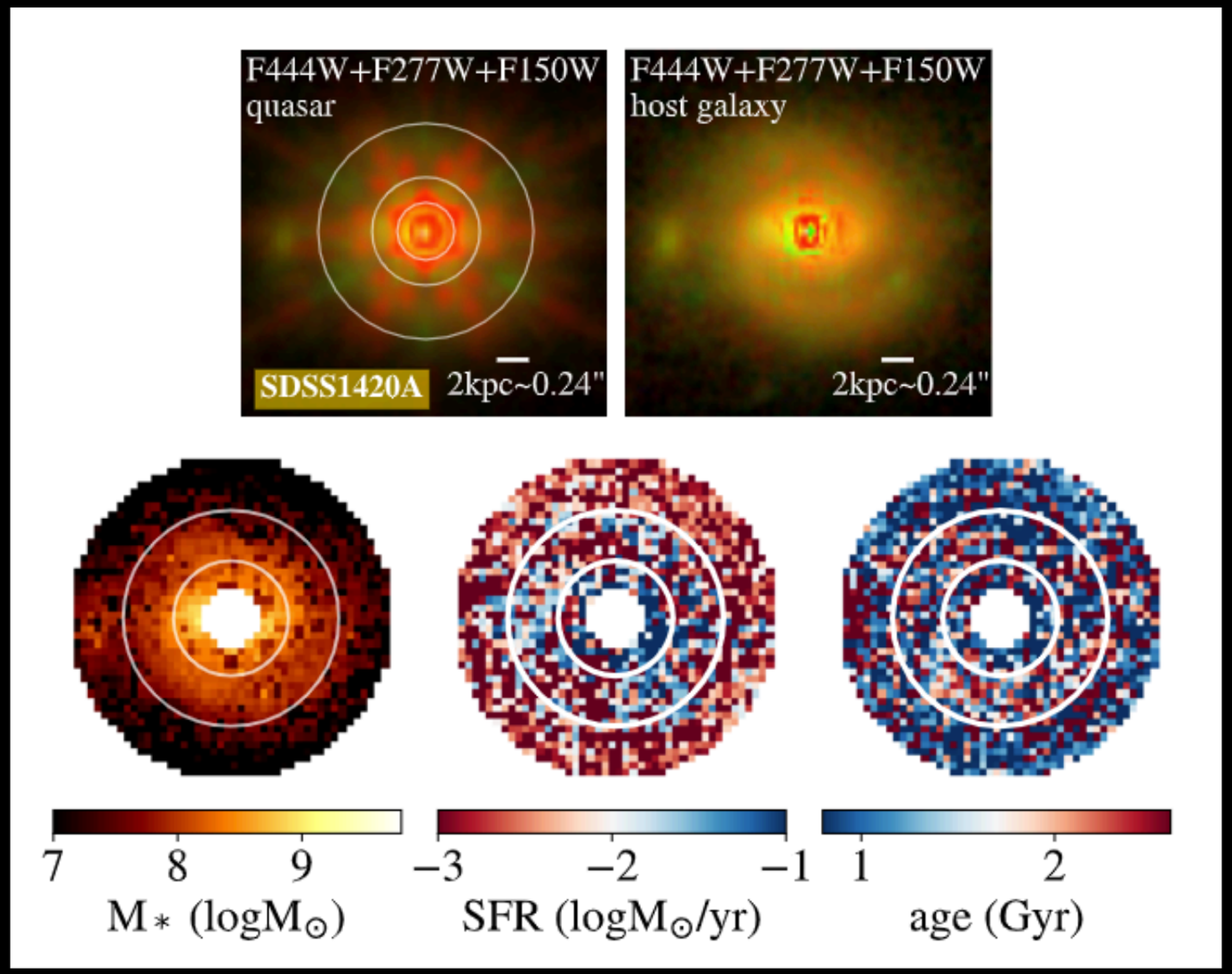
Measure the morphological structures of a quasar (z~2) not possible with HST:



HST JWST

Ding, Silverman, Onoue et al. 2022, ApJL re-submitted

The first touch on real JWST data



The inner region have higher SFR and younger age, than the outskirts.

Ding, Silverman, Onoue et al. 2022, ApJL re-submitted

Dual quasar — a remarkable laboratory

During structure formation, galaxies sometime experience a merger with another galaxy that rapidly accelerates their SFR and the growth of the central SMBH.

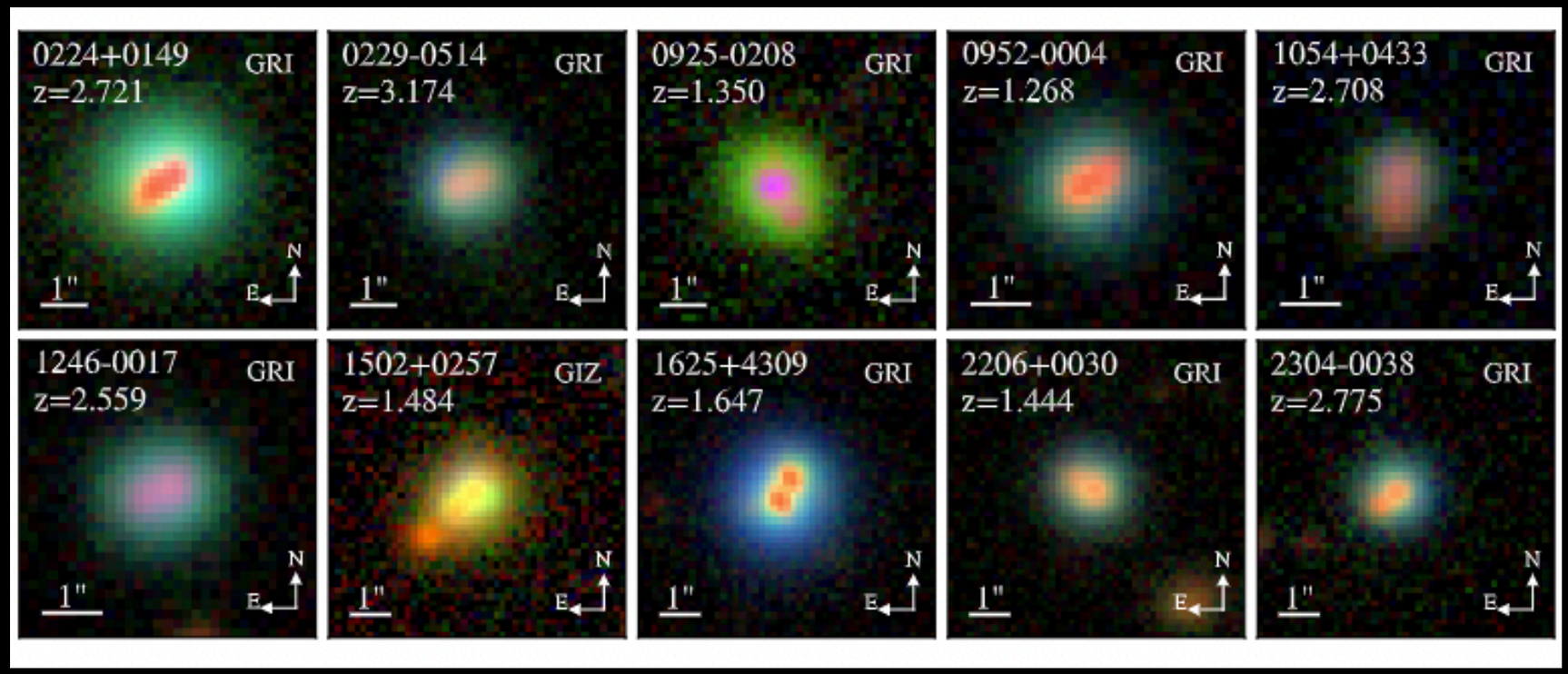
Artist’s impression of the merging galaxies
credit: NAOJ

The dual quasar provide a unique laboratory to study the fueling process to the growth of galaxy and its central SMBH.

However, to date, only a handful examples have been discovered at z>1, due to the limitation of the spatial resolution and the challenge of disentangling AGNs spectrum.

Dual quasar — a remarkable laboratory

Using on deep multi-band (grizy) optical imaging from HSC survey, I used galight to identified a unique sample with 11 dual candidates to be confirmed as dual quasars.



We have proposed to use HST to confirm their nature (Program #17143, PI: Xuheng Ding).

The first of HST grim spectrum data will come in this November.

Key notes

- Extend the correlation study to high-z and low mass is the key.
- We have use HST and HSC to build up a well established sample at 0.2<z<1.7.
- The new era is just opened by JWST and the future is promising.
  - Using first month data, we already achieved a z~3.5 study
  - We will soon extend the study to z~6
- 11 dual quasars searched by HSC will soon identified by HST.

Stay tuned!