

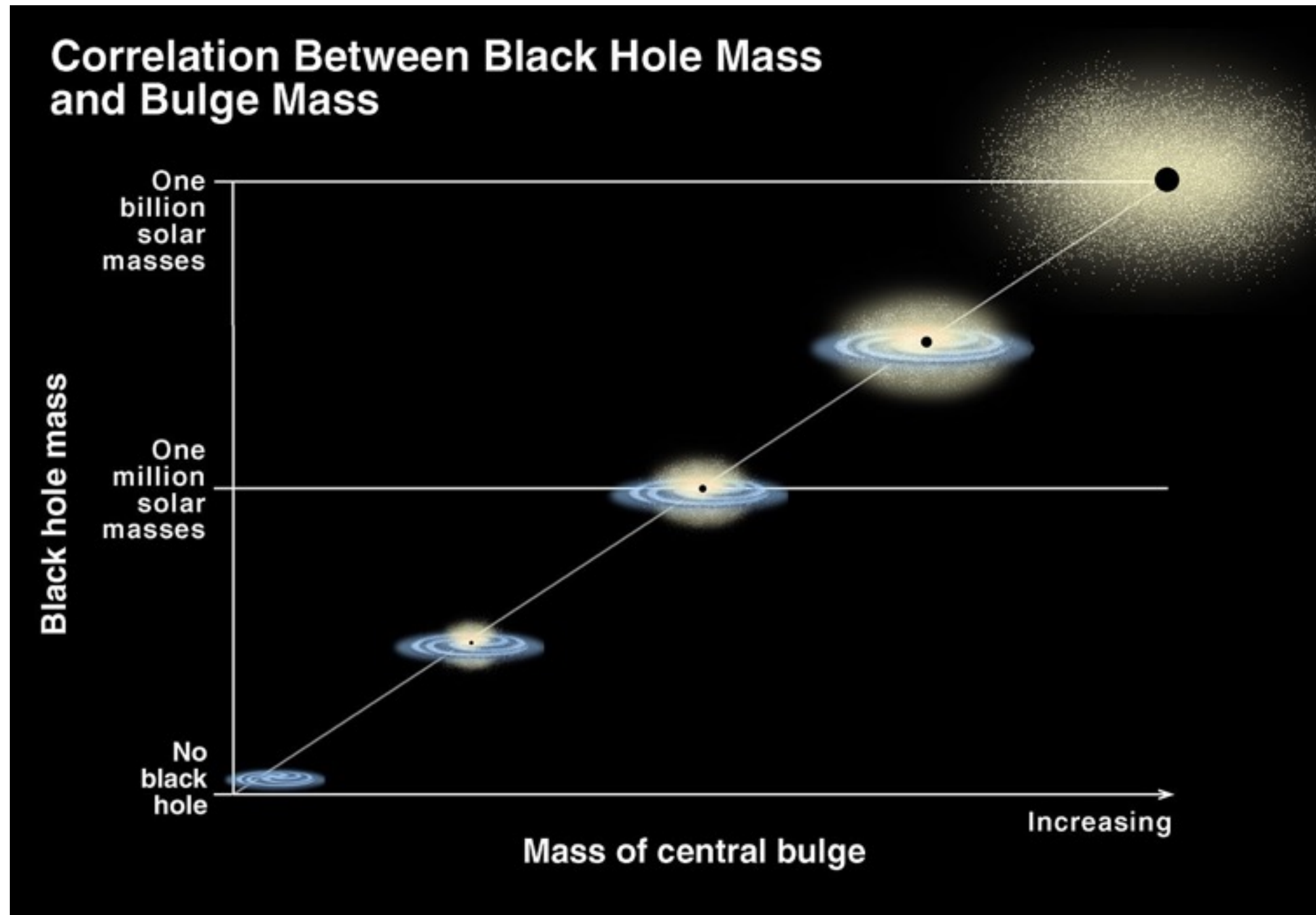
# Linking Black-Hole Growth with Host Galaxies

Guang Yang

2017/11/28 lunch talk

Collaborators: Brandt, W. N.; Vito, F.; Chen, C.-T. J.;  
Trump, J. R.; Luo, B.; Sun, M. Y.; Xue, Y. Q.; Koekemoer, A.  
M.; Schneider, D. P.; Vignali, C.; Wang, J.-X.; Darvish, B.

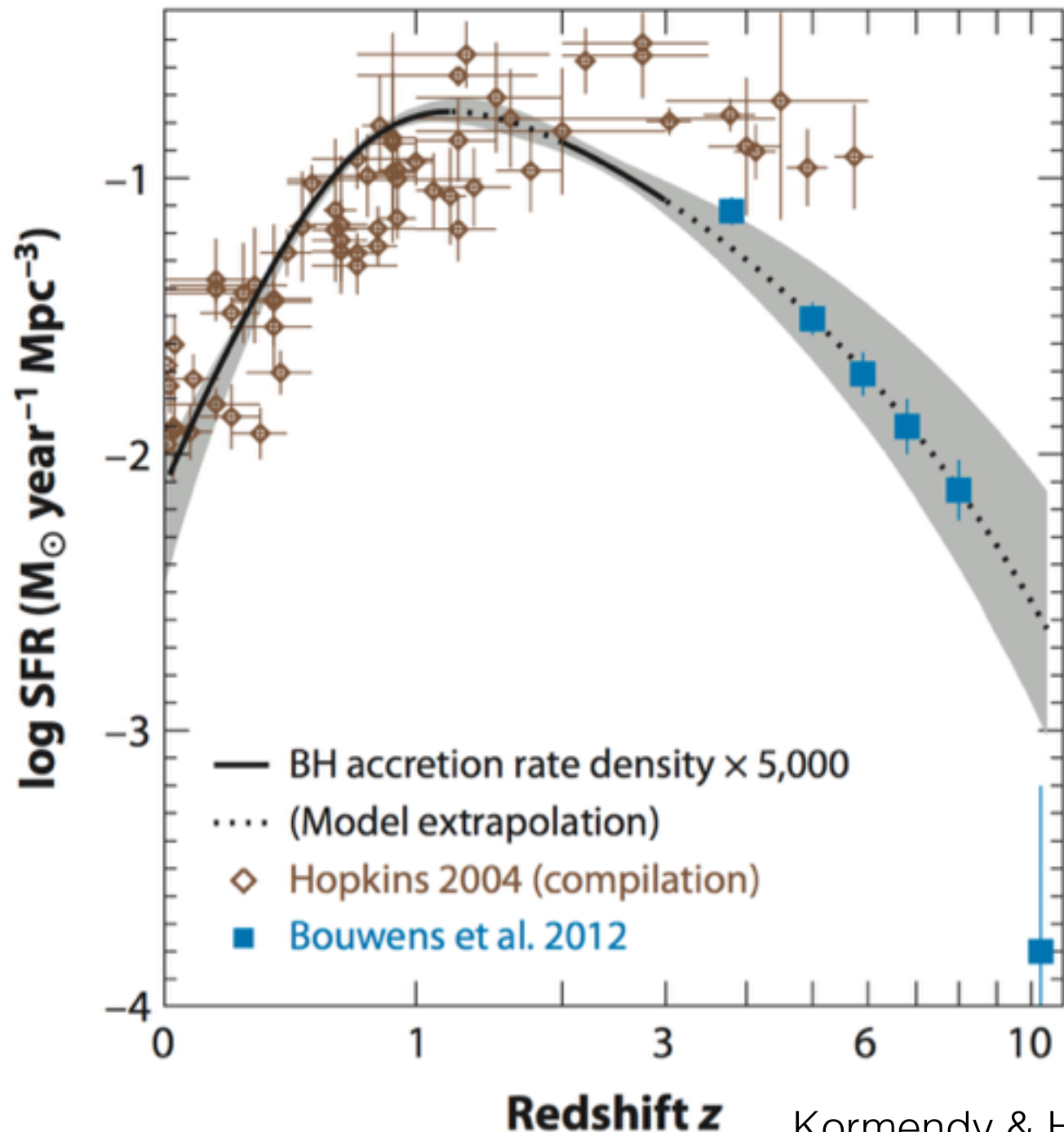
# Local universe: $M_{\text{BH}} \propto M_{\text{bulge}}$



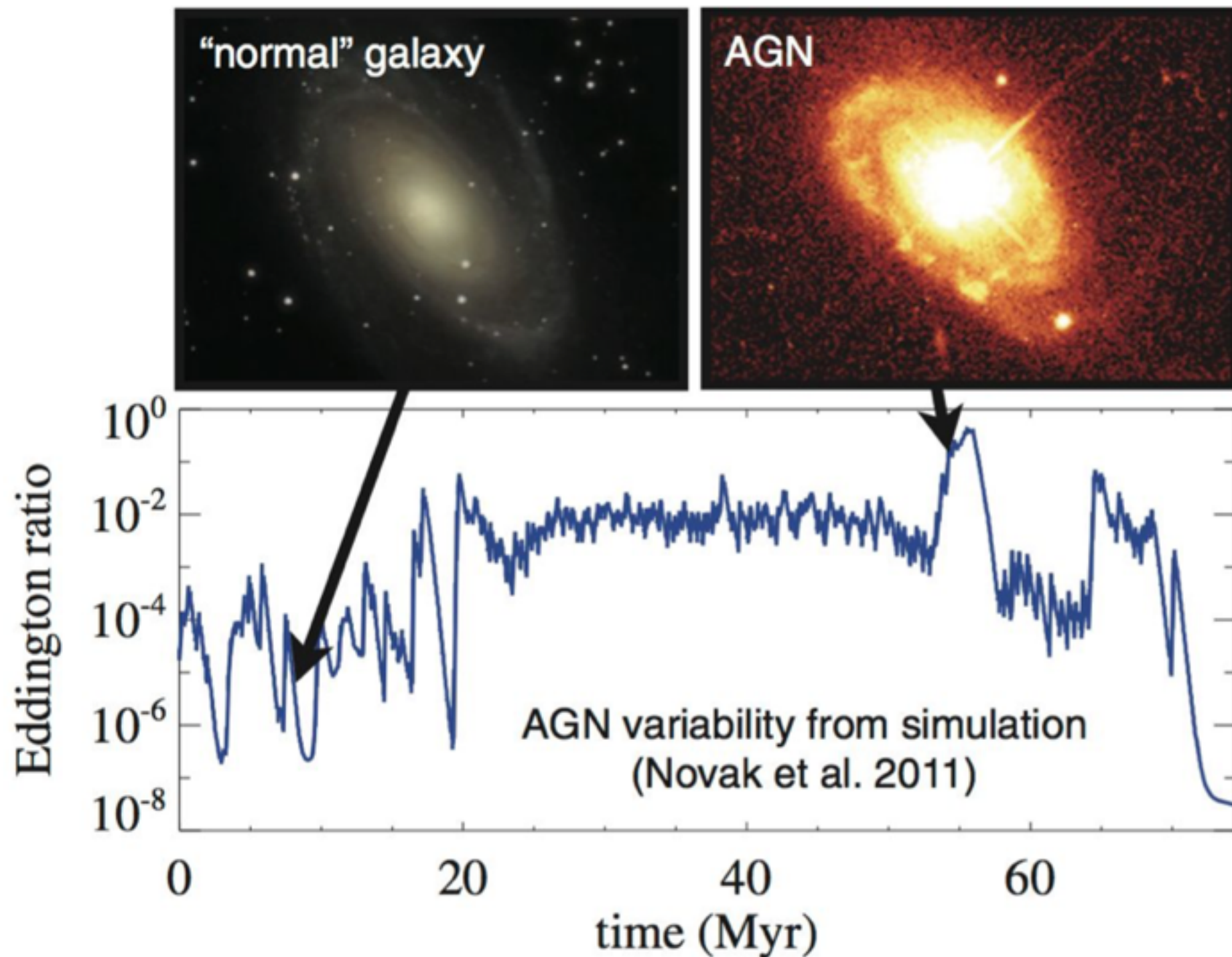
# BH vs galaxy growth

**Total** BH accretion rate ( $\dot{M}_{\text{BH}}$ ) and star-formation rate ( $\dot{M}_{\star}$ ) are **proportional**

**Coevolution?**



# AGN variability: Theory



Hickox et al. (2014)

# AGN Variability: Observation

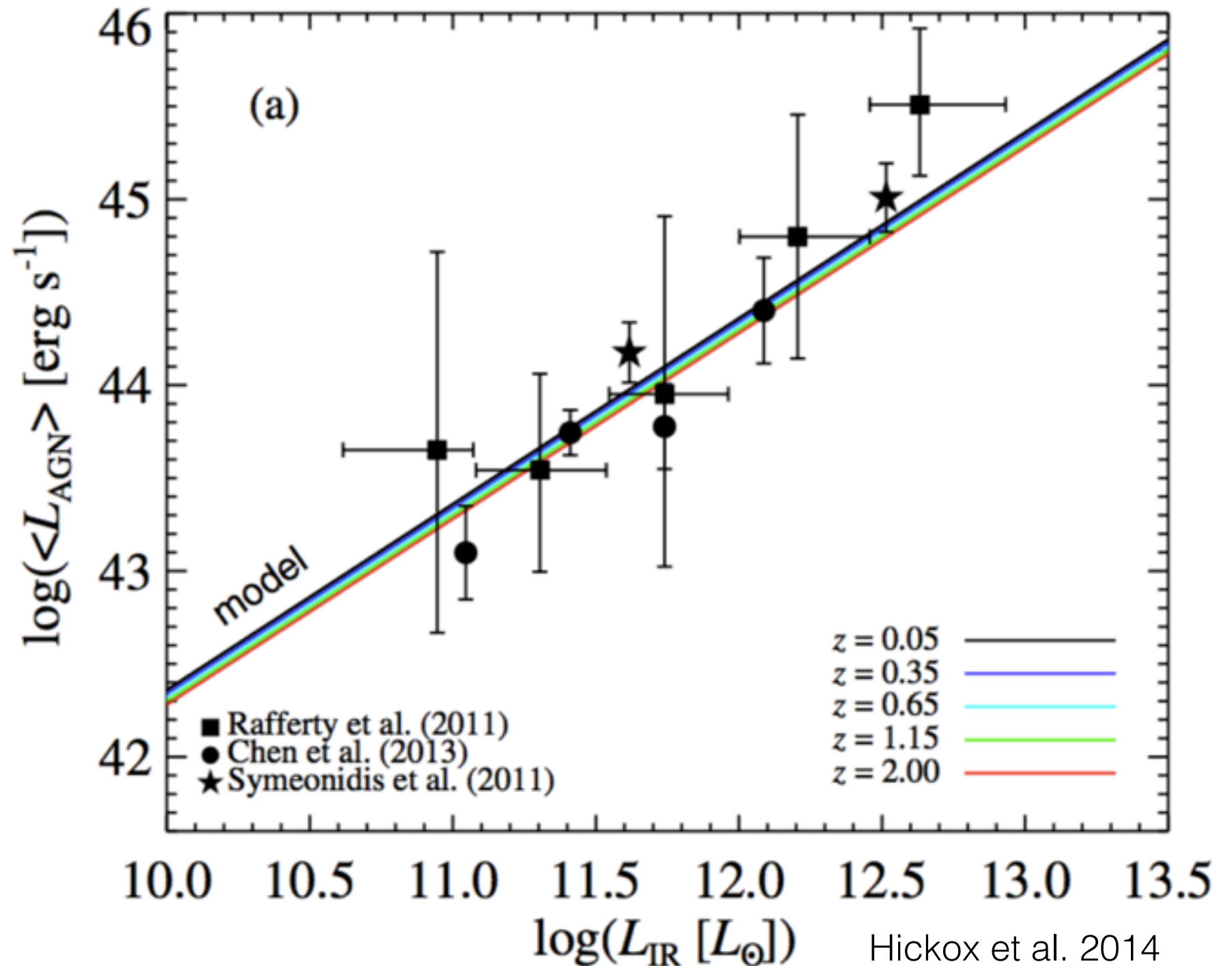


# AGN Variability: Observation



# Overcome variability: Sample average

- Sample average  
~ time average
- Previous work:  
 $\dot{M}_{\text{BH}} \propto \dot{M}_{\star}$

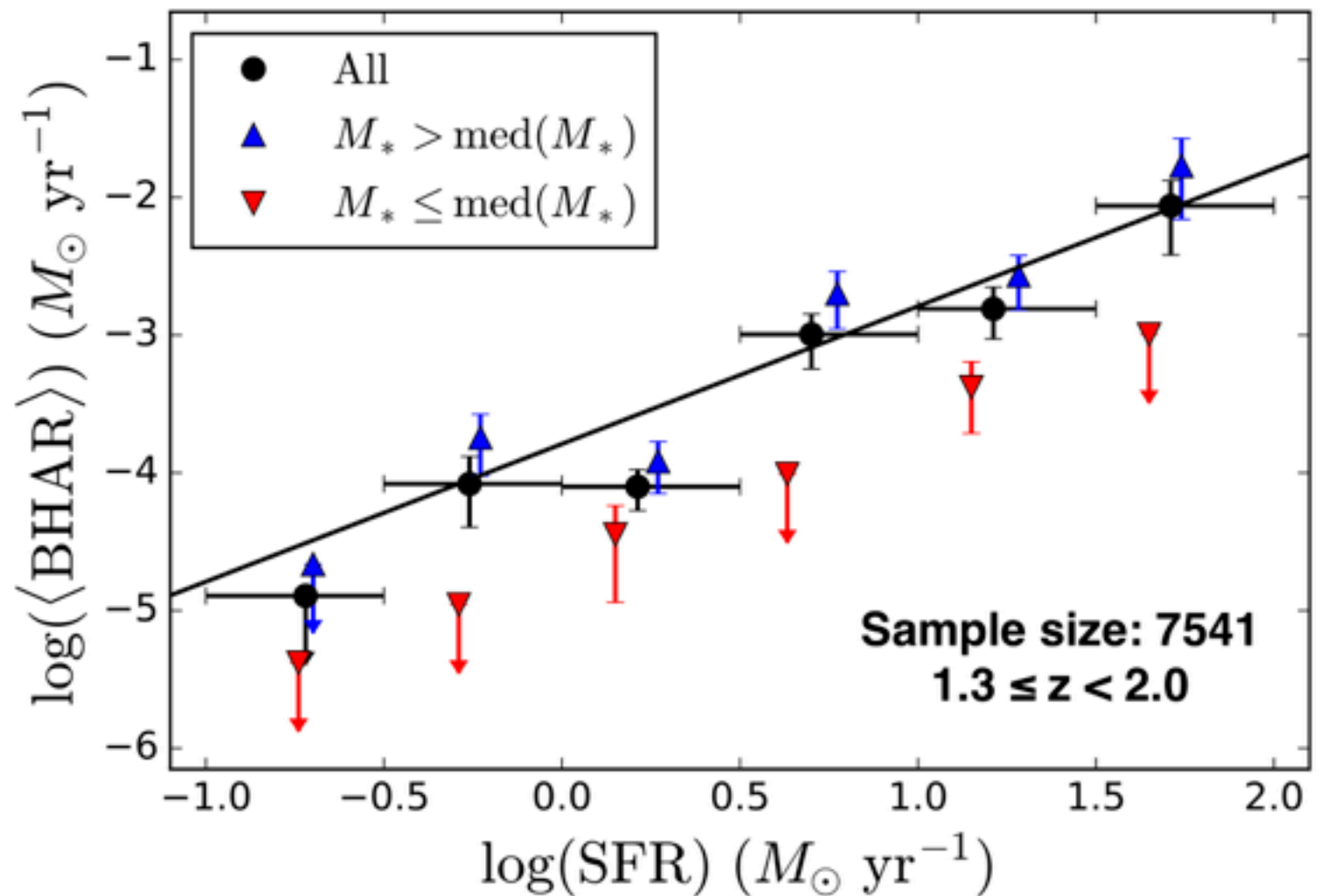




# Is $\dot{M}_{\text{BH}}$ really related to $\dot{M}_{\star}$ ?

Our work:

$\dot{M}_{\text{BH}}$  is more fundamentally related to **stellar mass ( $M_{\star}$ )** rather than  $\dot{M}_{\star}$



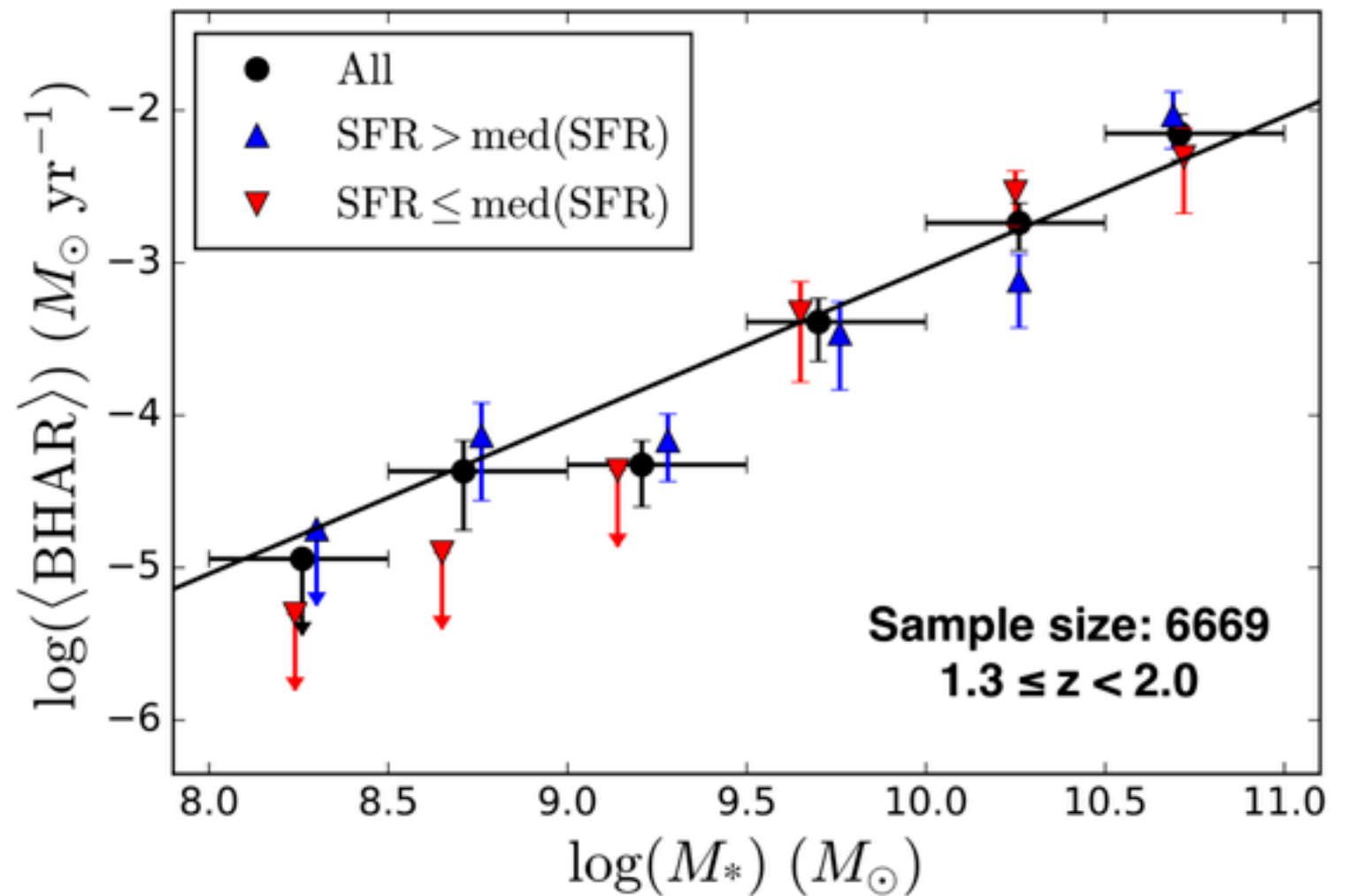
Yang et al. (2017a)



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Our work:

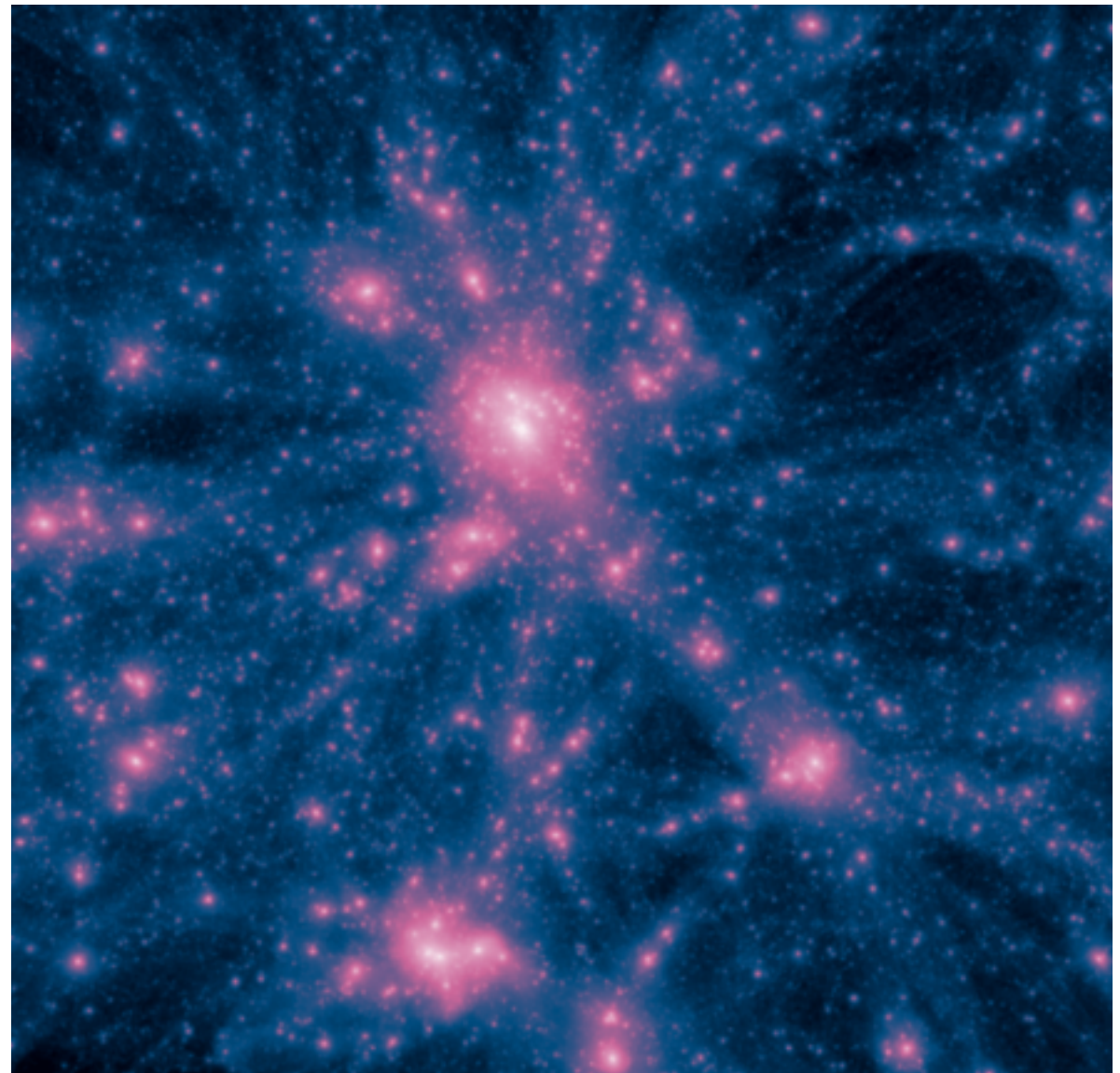
$\dot{M}_{\text{BH}}$  is more fundamentally related to **stellar mass ( $M_{\star}$ )** rather than  $\dot{M}_{\star}$



Yang et al. (2017a)

# Does $\dot{M}_{\text{BH}}$ depend on cosmic environment?

- Galaxy evolution is related to cosmic environment, i.e., "environmental quenching"
- The effects of cosmic environment on BH growth is poorly understood.



Illustris simulation: Vogelsberger et al. (2014)

# Does $\dot{M}_{\text{BH}}$ depend on cosmic environment?

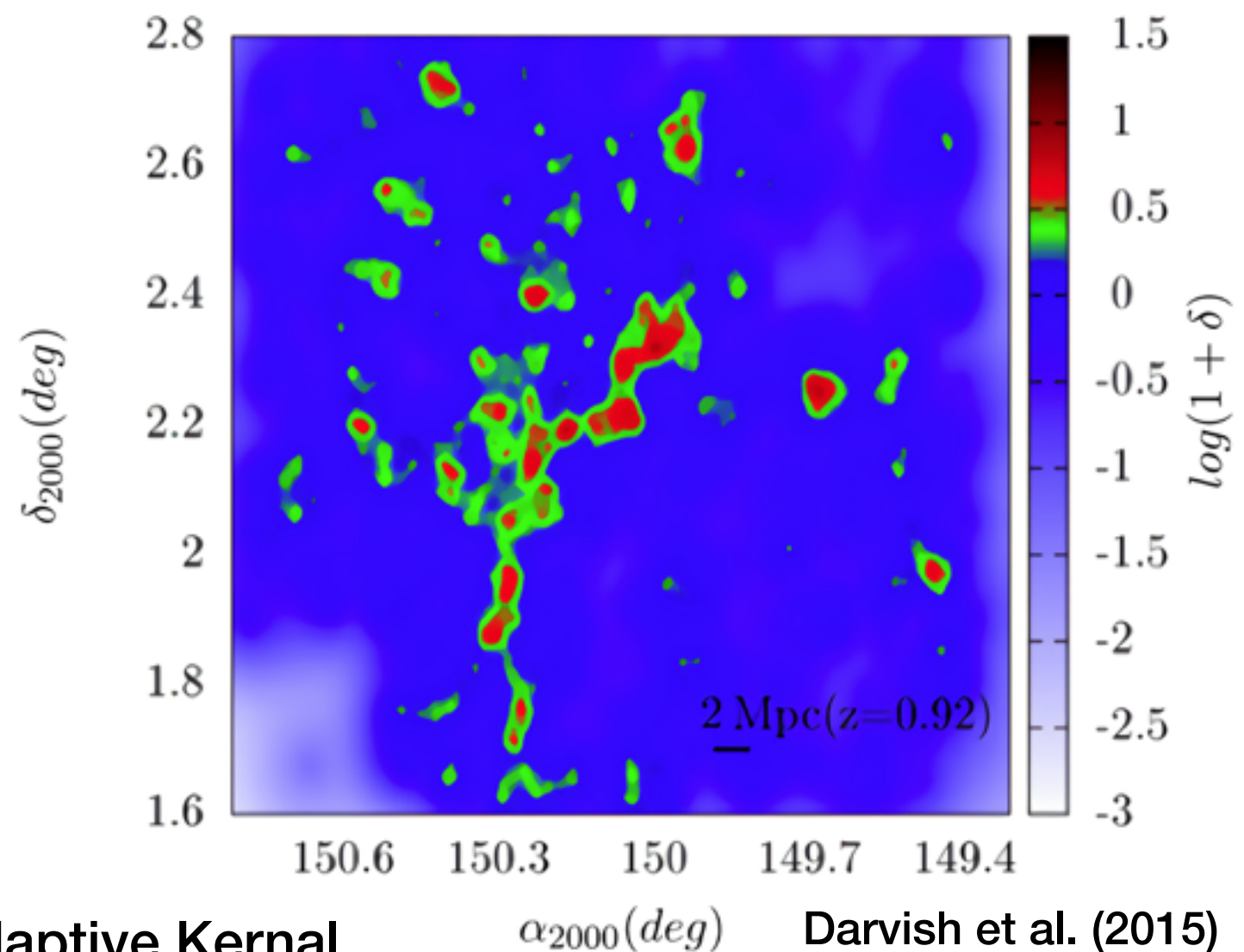
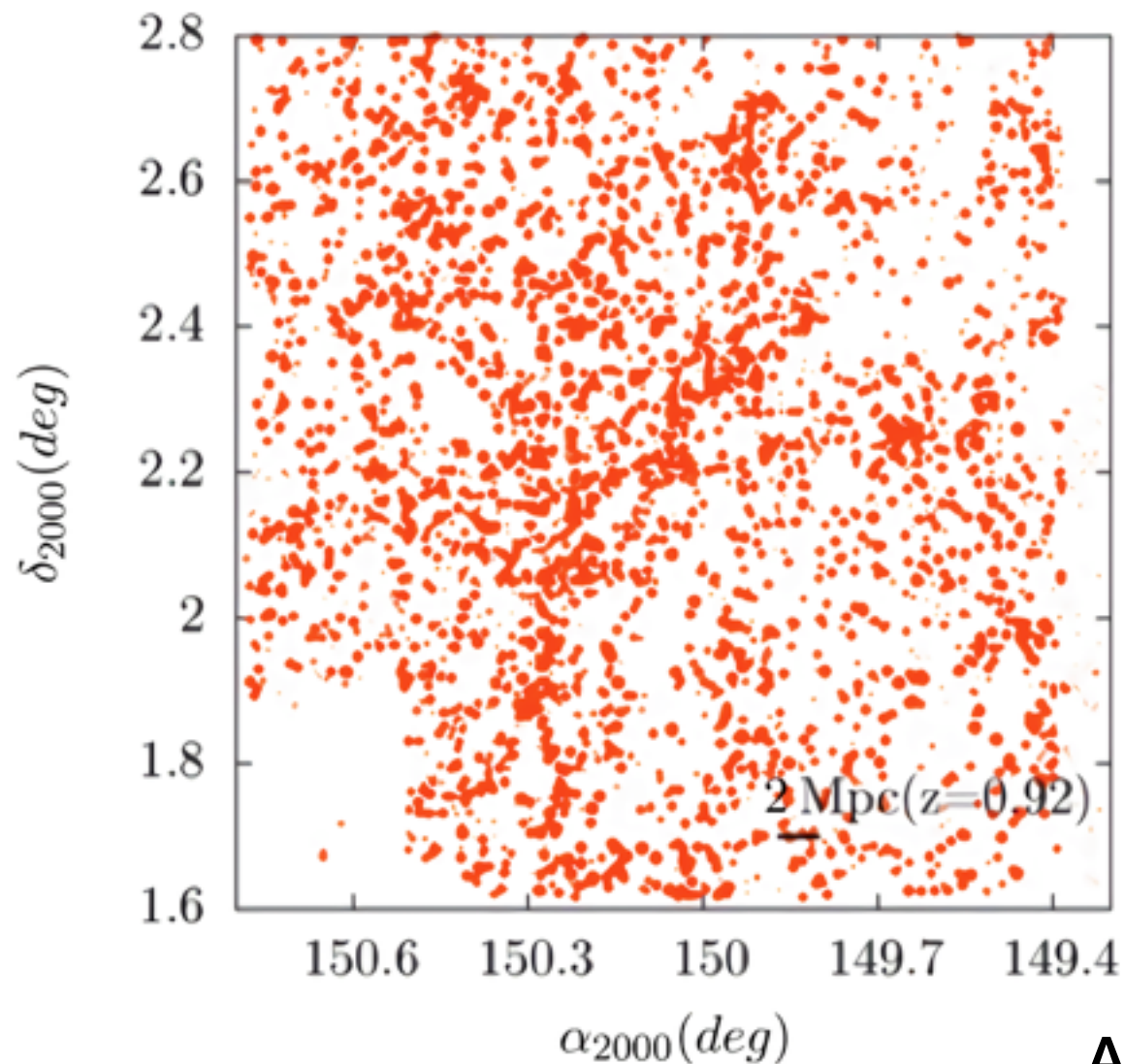
- Galaxy evolution is related to cosmic environment, i.e., "environmental quenching"
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Abell 1689; CREDIT: NASA, ESA, B. SIANA, AND A.



# Environment (density field) can be measured for distant galaxies!



Adaptive Kernel  
Smoothing



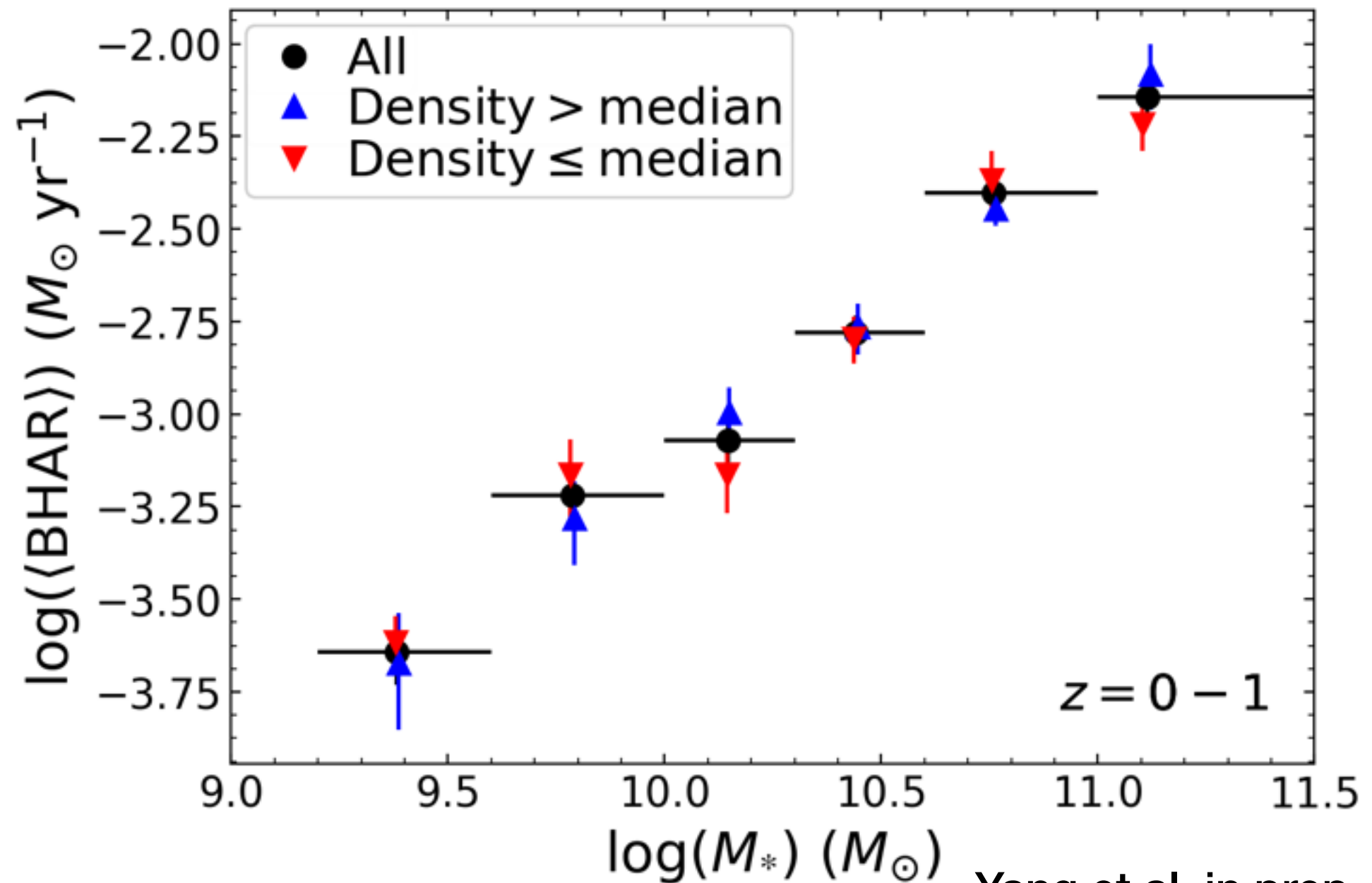
Density field

Observed galaxy  
spatial distribution

Darvish et al. (2015)

# $\dot{M}_{\text{BH}}$ vs. Environment

BHs **do not know** their environment

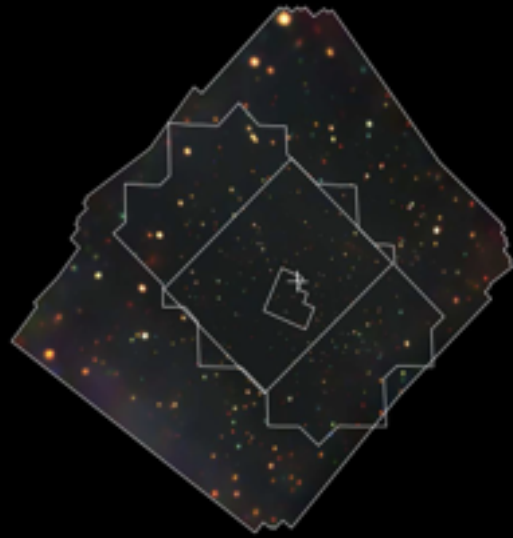


# $\dot{M}_{\text{BH}}-M_{\star}$ : the key

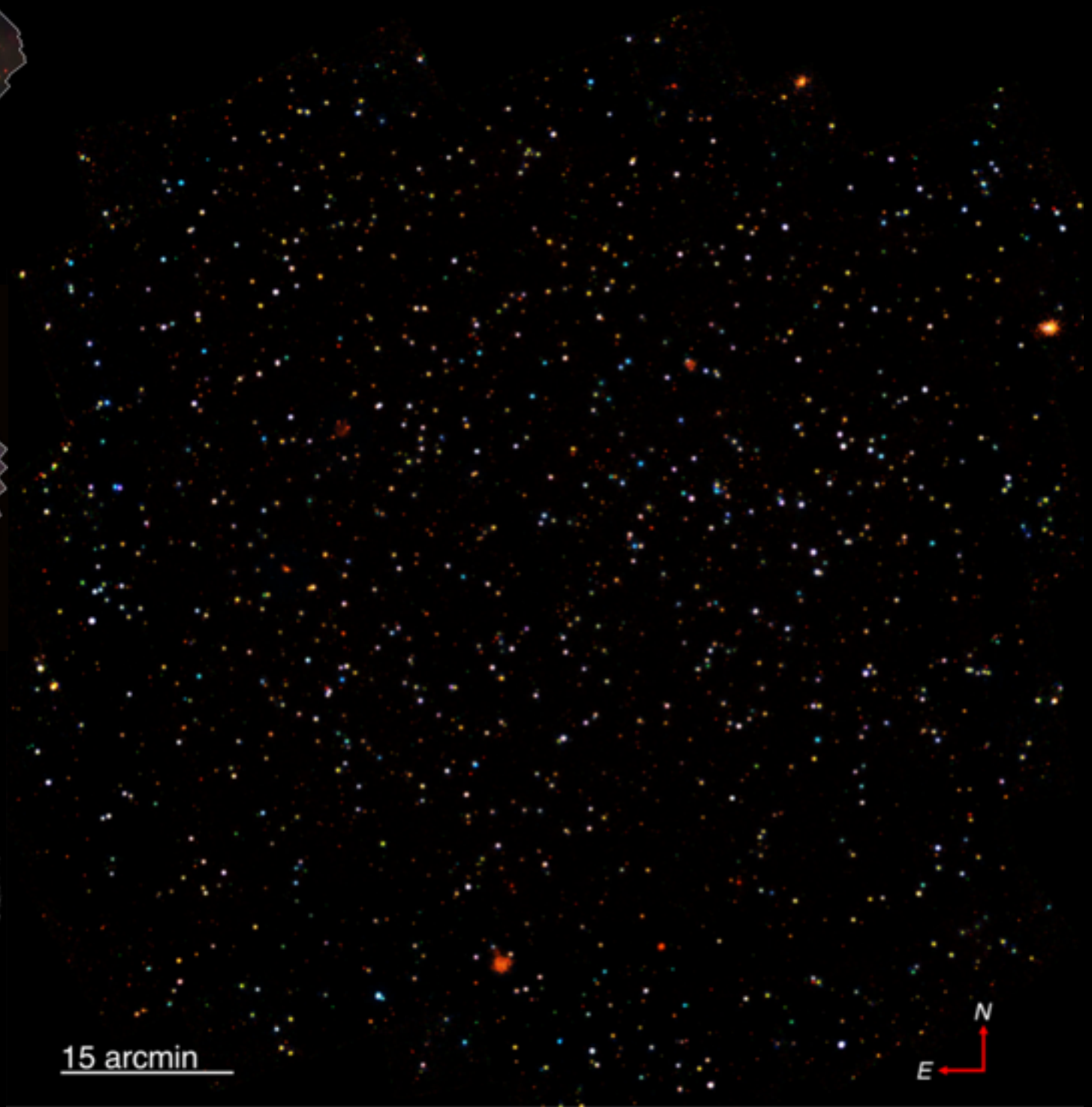
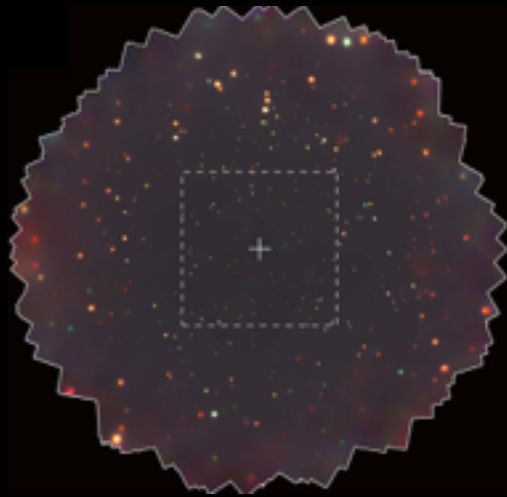
- $\dot{M}_{\text{BH}}$  vs.  $\dot{M}_{\star}$  ✗ (Yang et al. 2017a)
- $\dot{M}_{\text{BH}}$  vs. environment ✗ (Yang et al. in prep.)
- $\dot{M}_{\text{BH}}$  vs.  $M_{\star}$  ✓ (quantified in Yang et al. 2017b)

# 4.6 Ms COSMOS-Legacy

2 Ms  
CDF-N



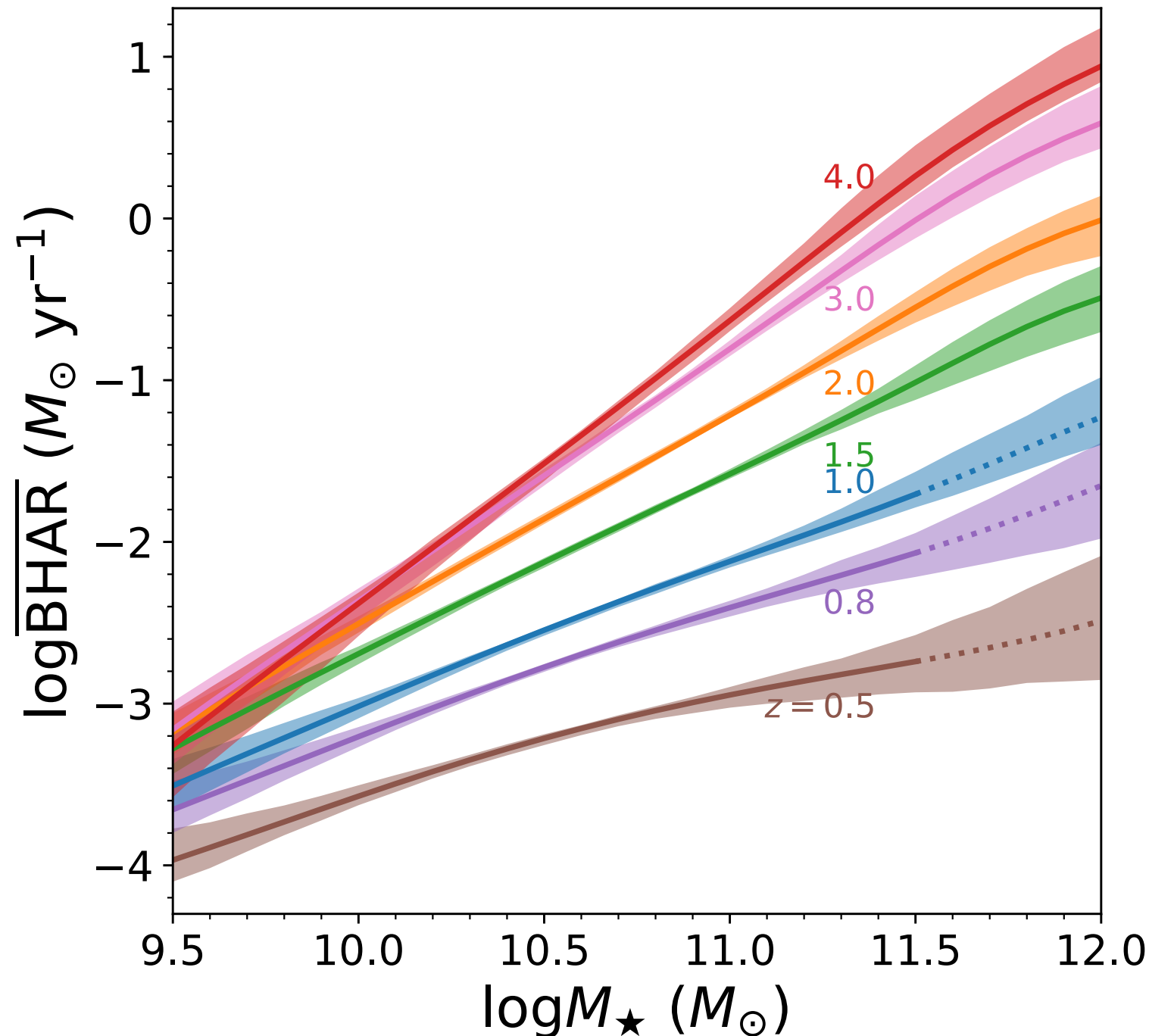
7 Ms  
CDF-S



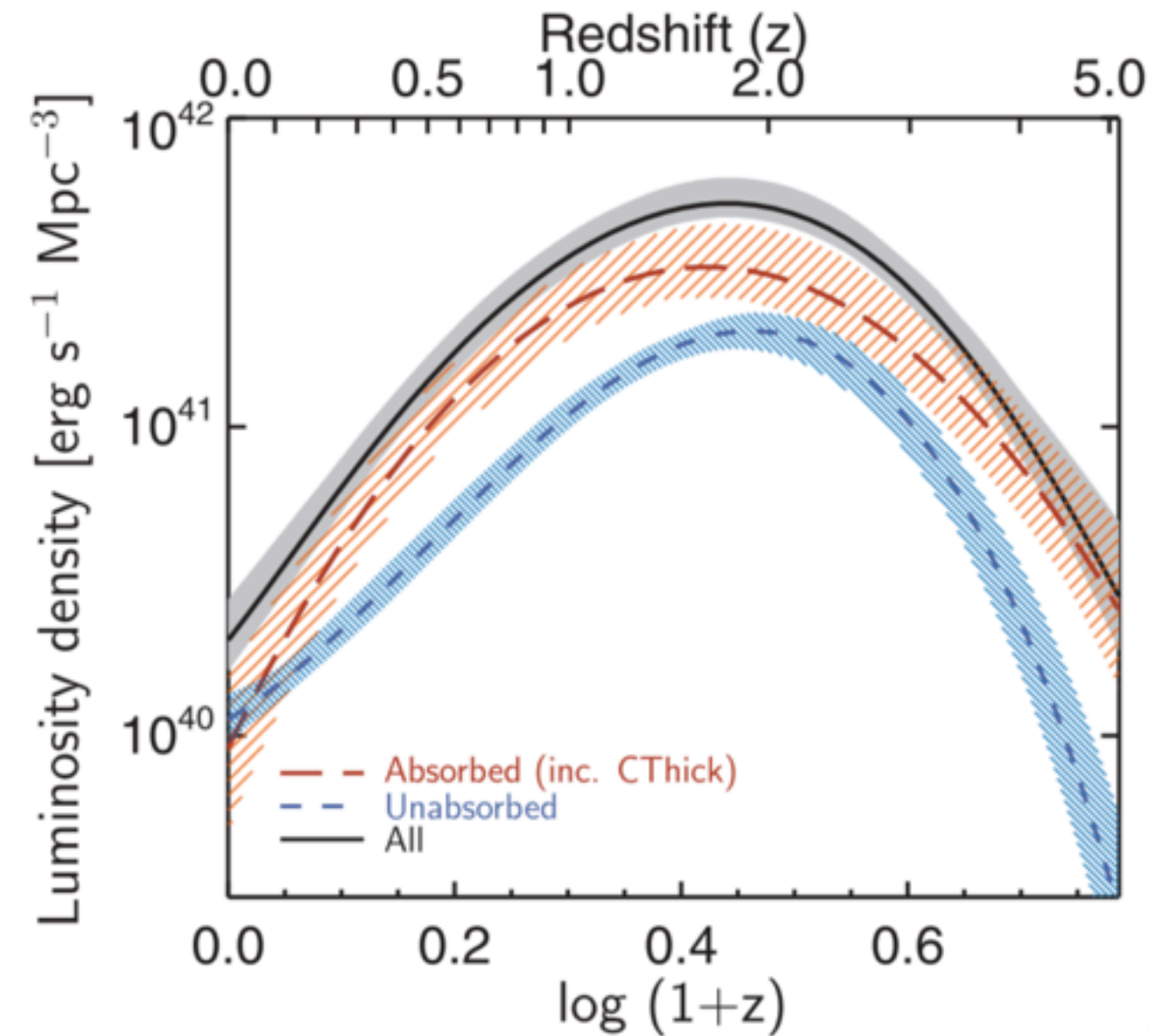


# $\dot{M}_{\text{BH}}-M_{\star}$ : and its cosmic evolution (up to $z=4$ )

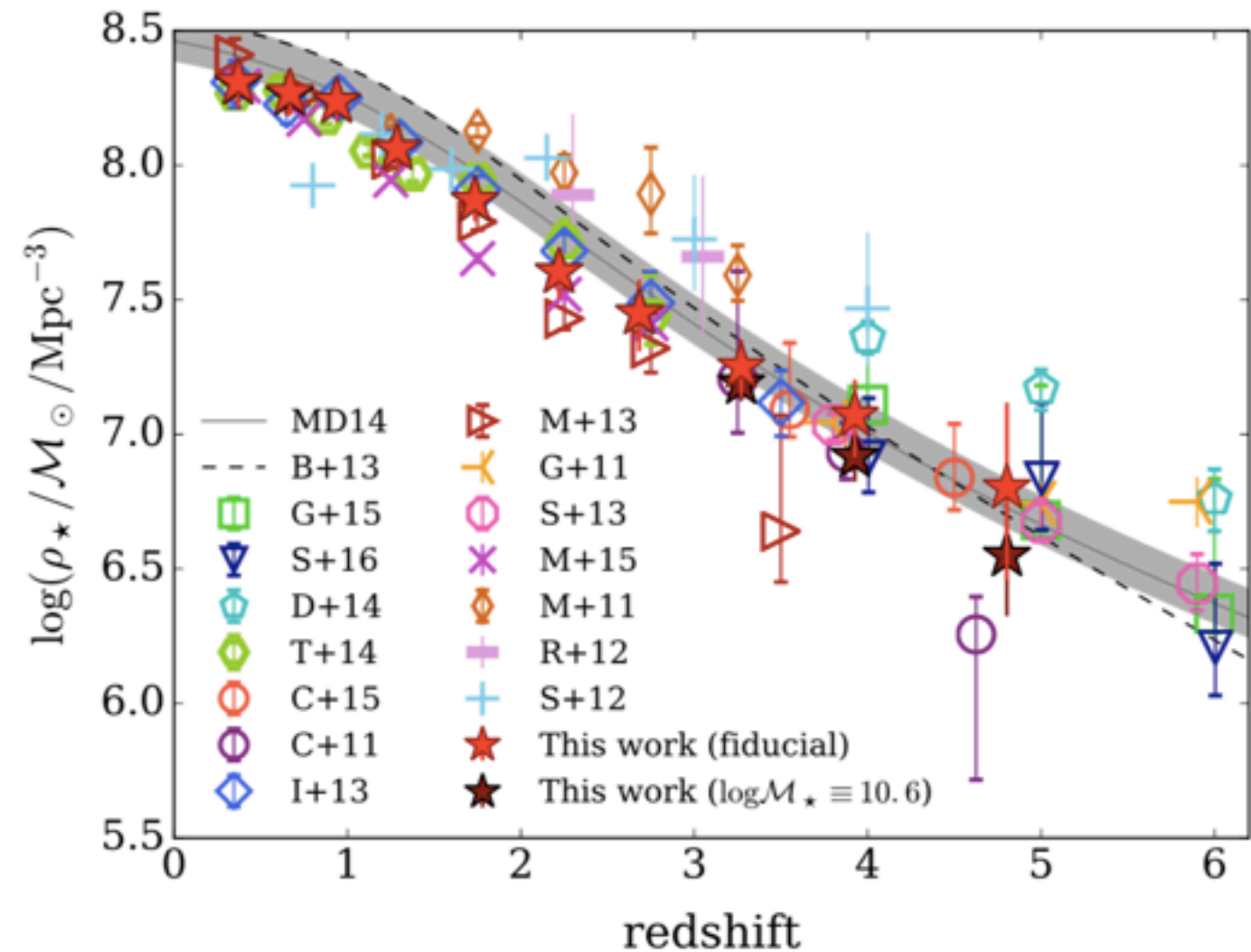
At a given  $M_{\star}$ :  $\dot{M}_{\text{BH}}$   
**always rises** toward  
high  $z$



# AGN activity decreases in the early universe? Probably not



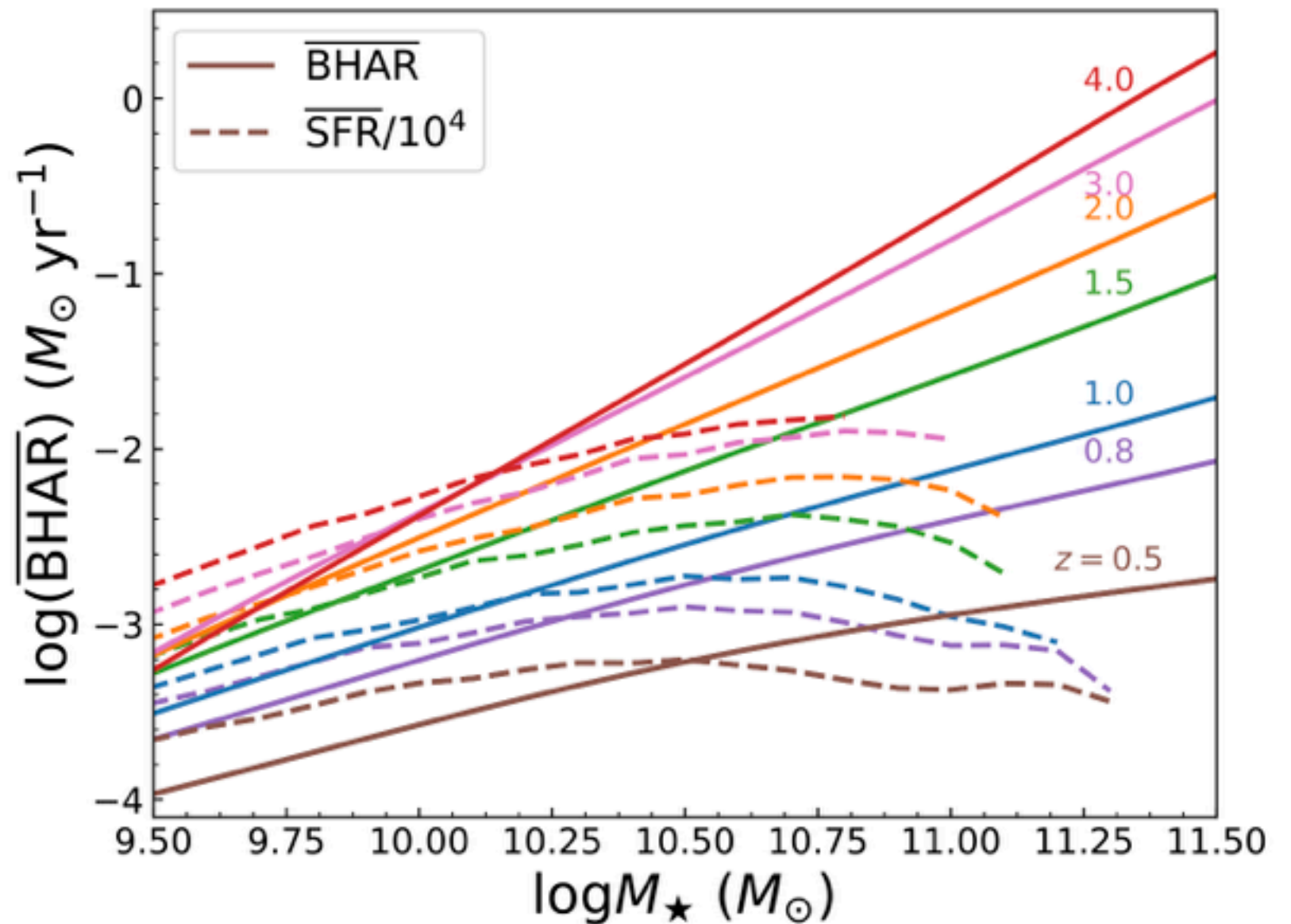
Aird et al. (2015)



Davidzon et al. (2017); also see Vito et al. (2017)

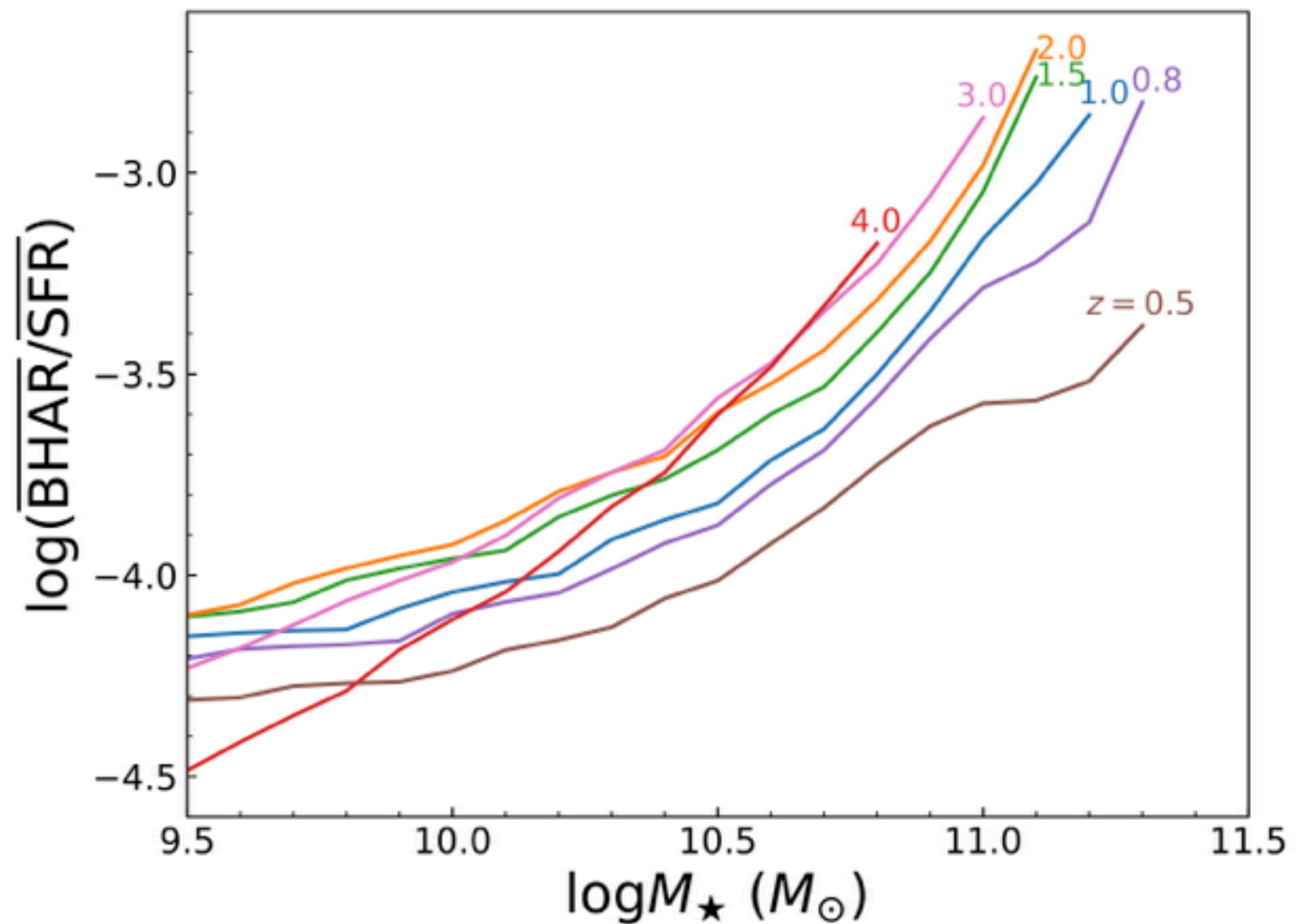
# BH & galaxy growth are **not** strongly coupled

- $\dot{M}_{\text{BH}}$  rises more steeply toward high mass than  $\dot{M}_{\star}$
- Massive systems are **more effective** in growing BHs



# BH & galaxy growth are **not** strongly coupled

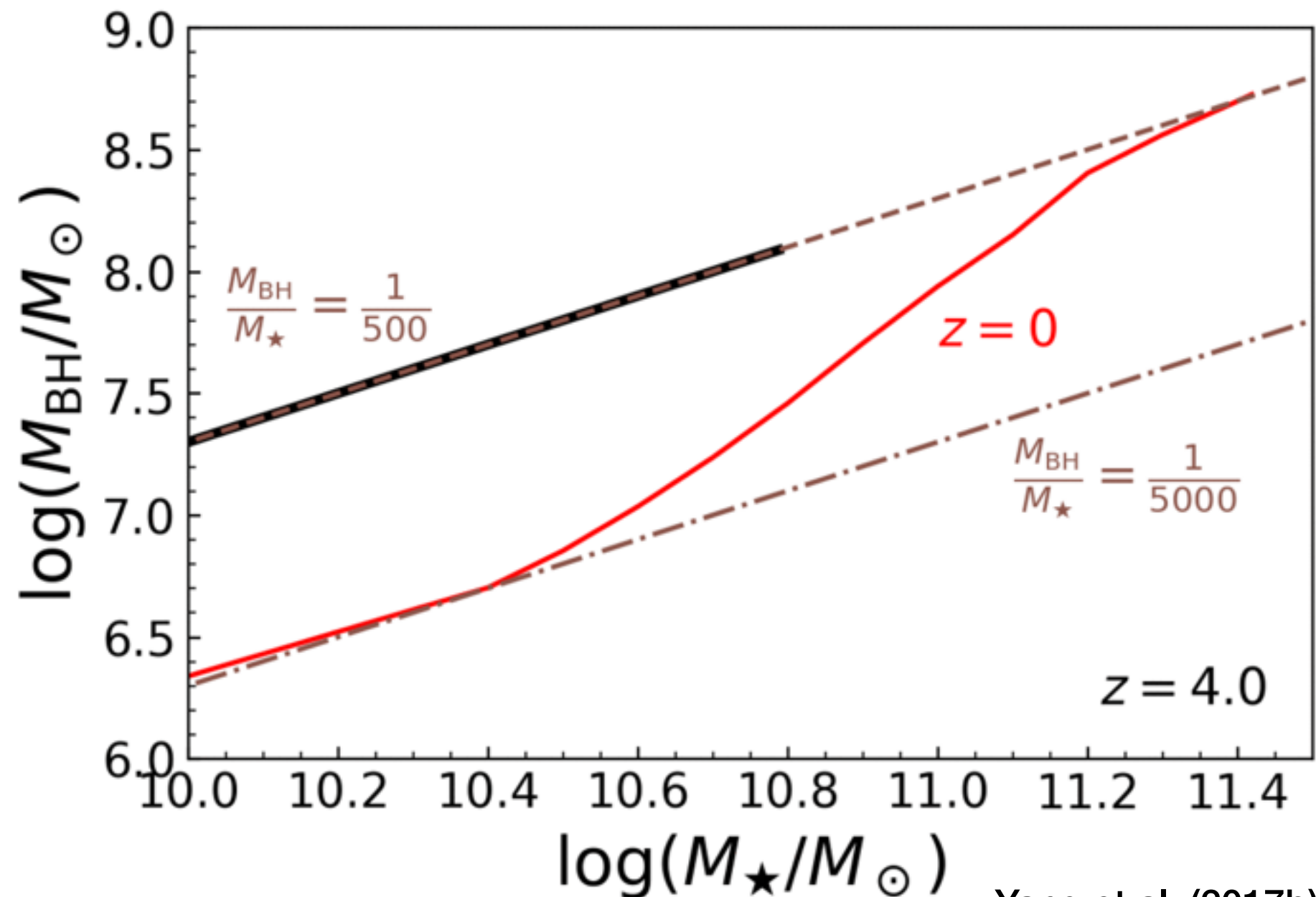
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# The $M_{\text{BH}}-M_{\star}$ relation: evolution

$$M_{\text{BH}}(z) = \int_4^z \overline{\text{BHAR}}(M_{\star}(z'), z') \frac{dt}{dz'} dz' + M_{\text{BH}}|_{z=4}$$

- $M_{\text{BH}}-M_{\star}$  has **weak evolution since  $z \sim 2$**
- Massive systems have higher  $M_{\text{BH}}/M_{\star}$

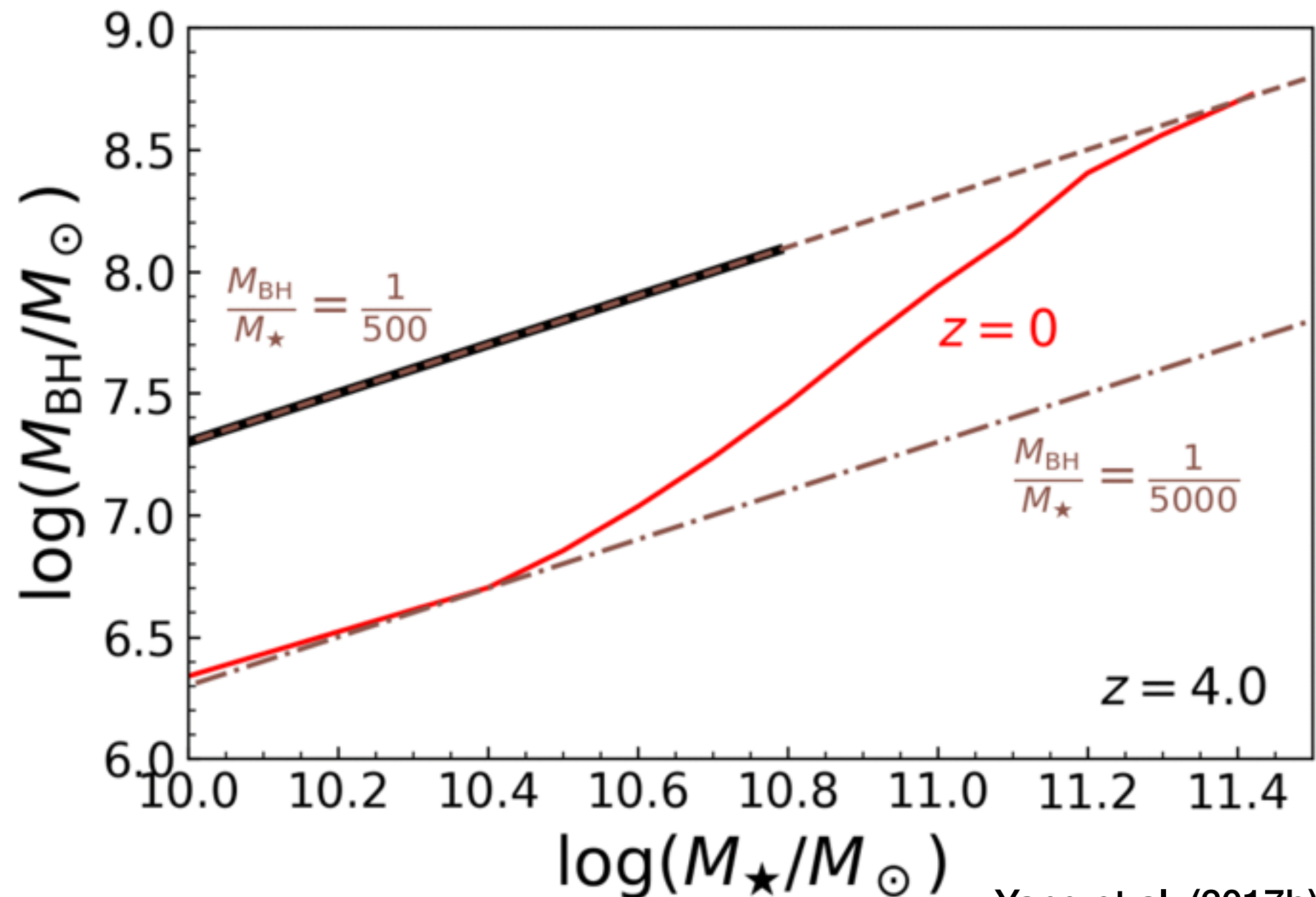




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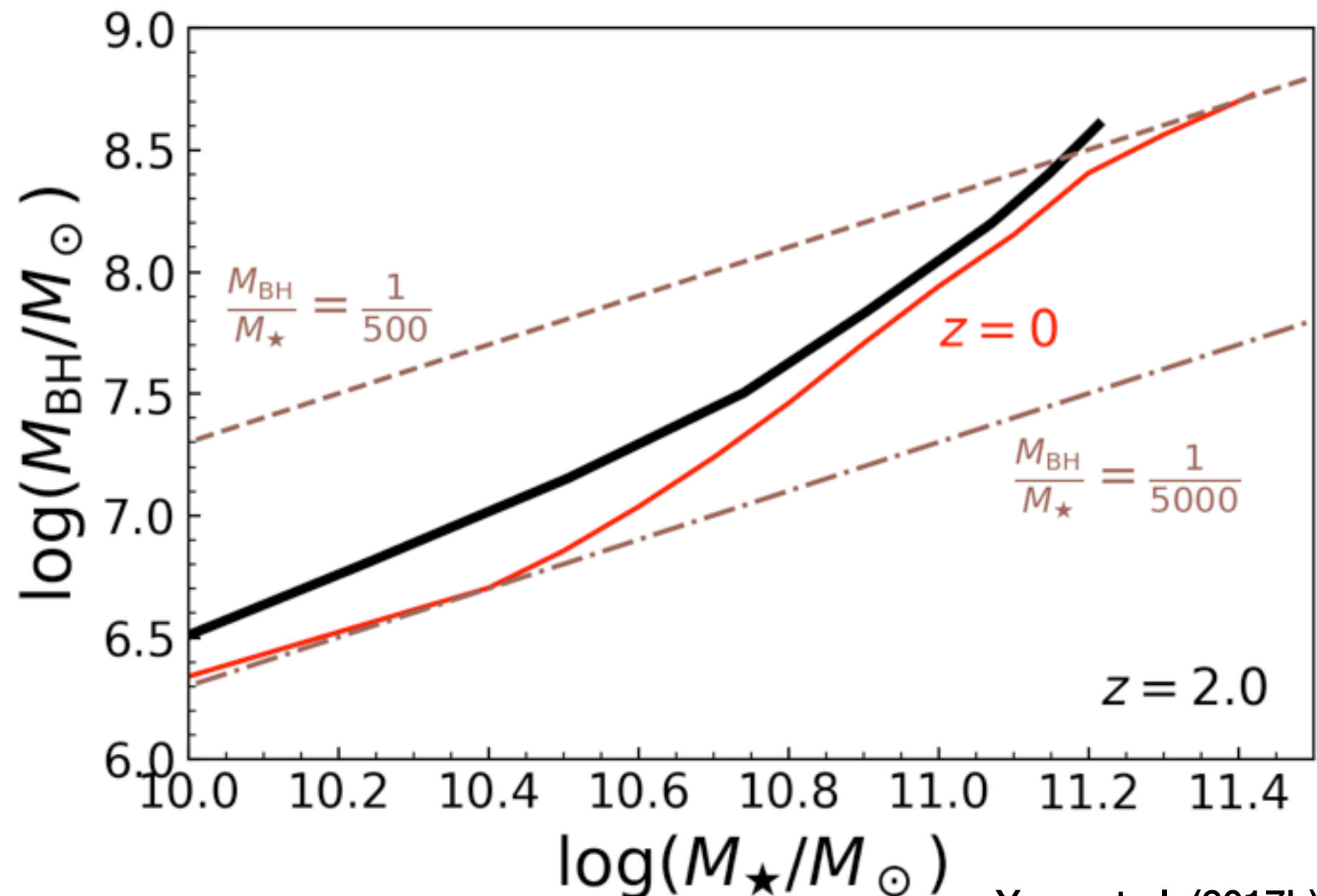
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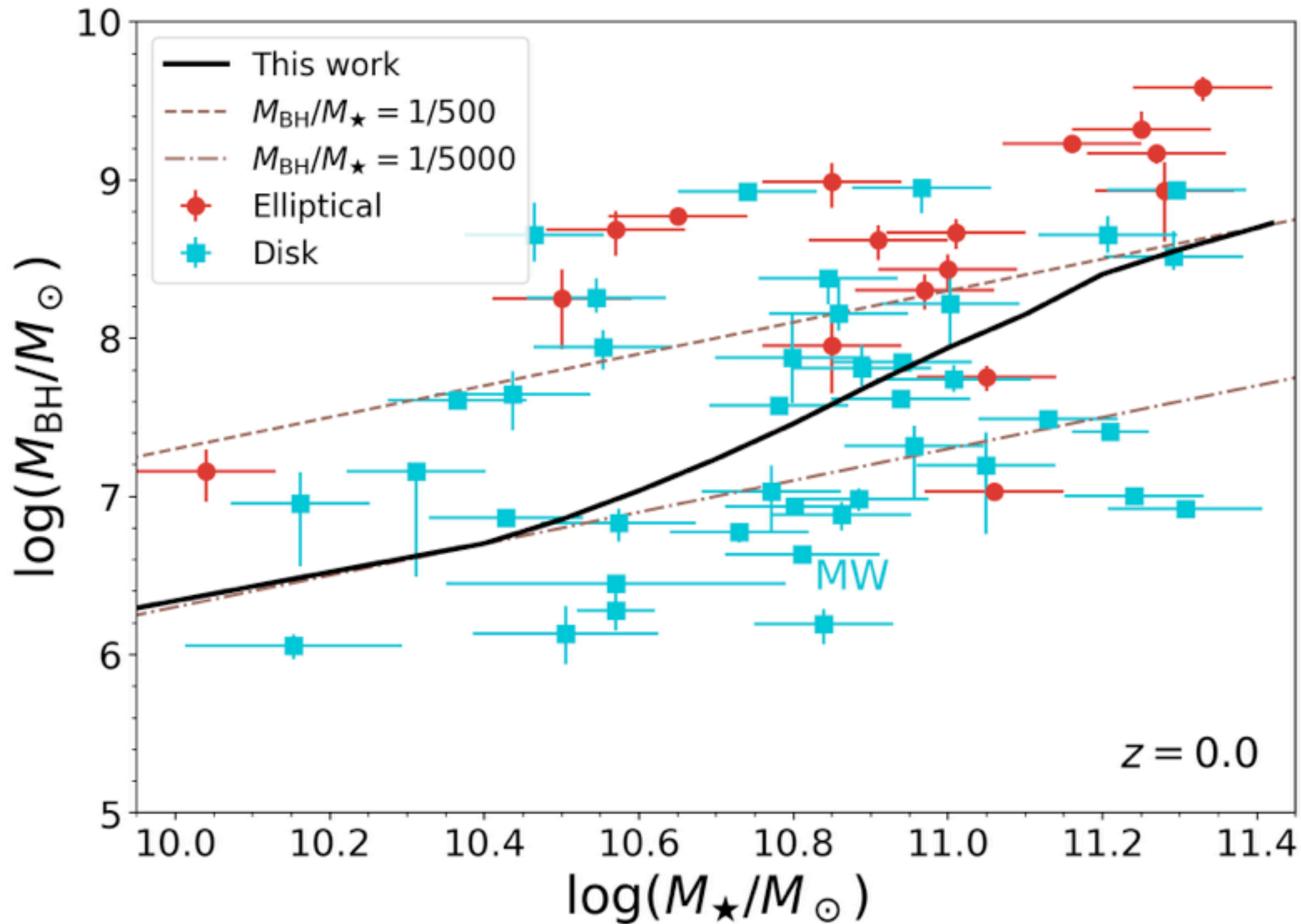
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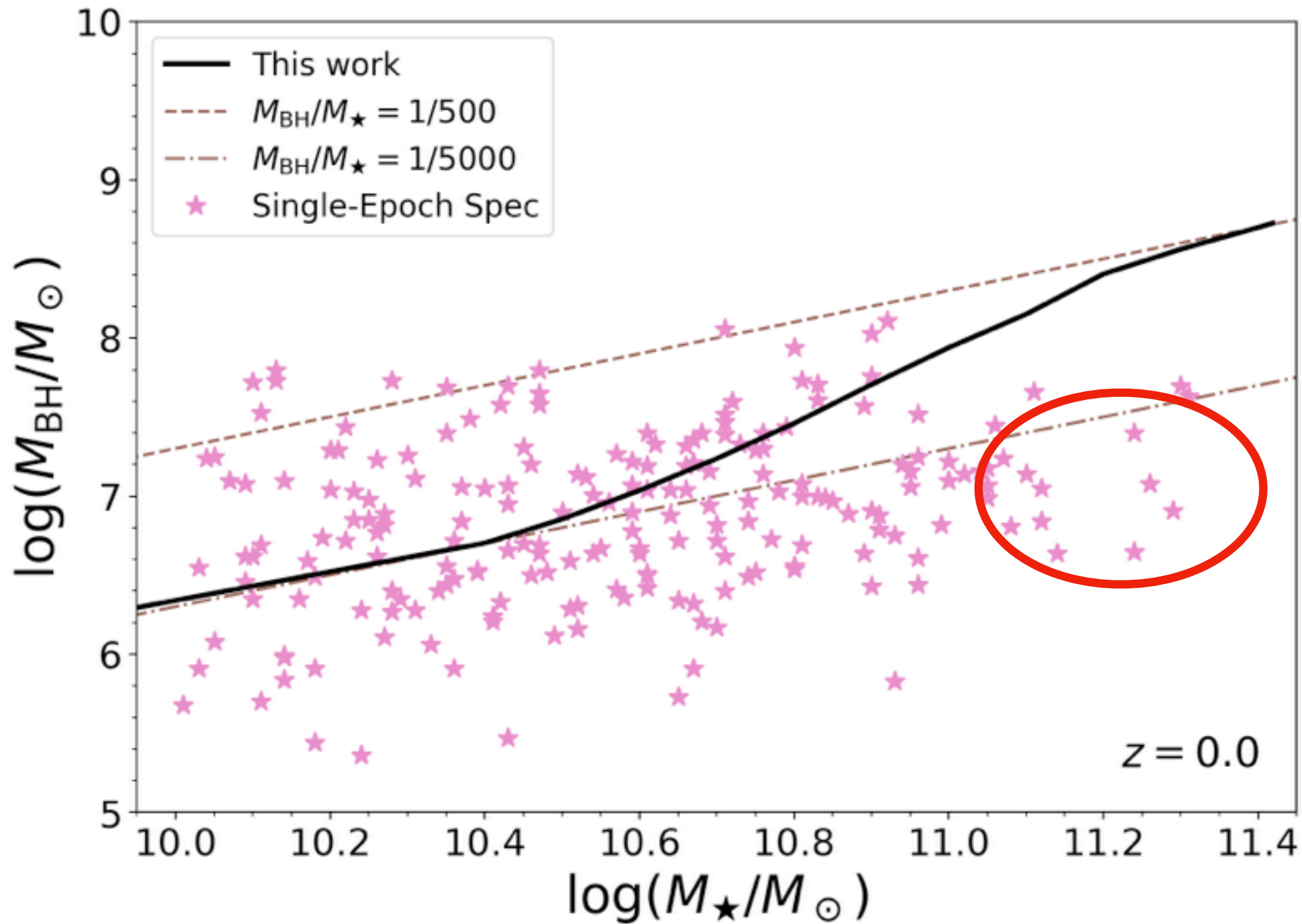




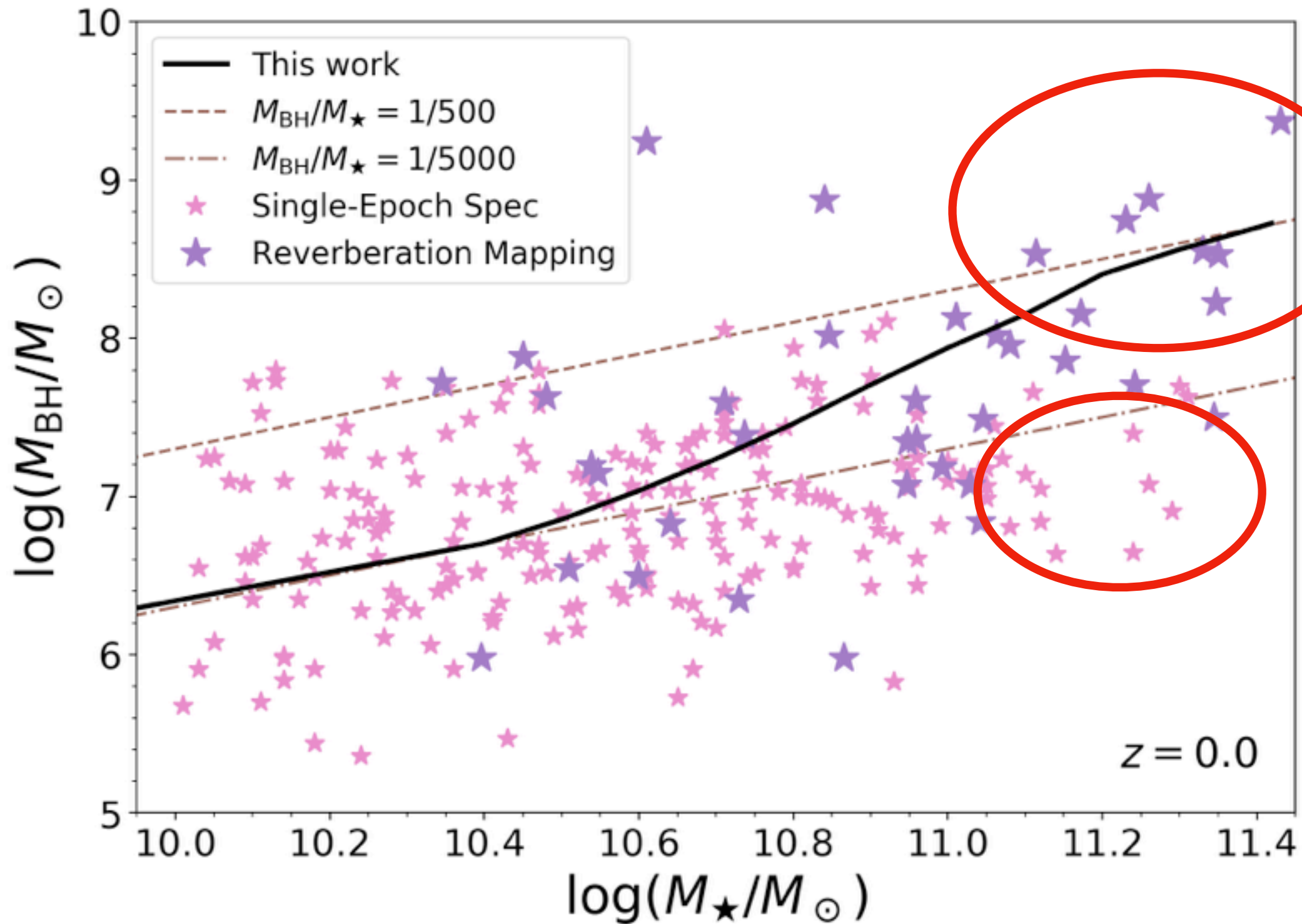
# The $M_{\text{BH}}-M_{\star}$ relation: $z=0$



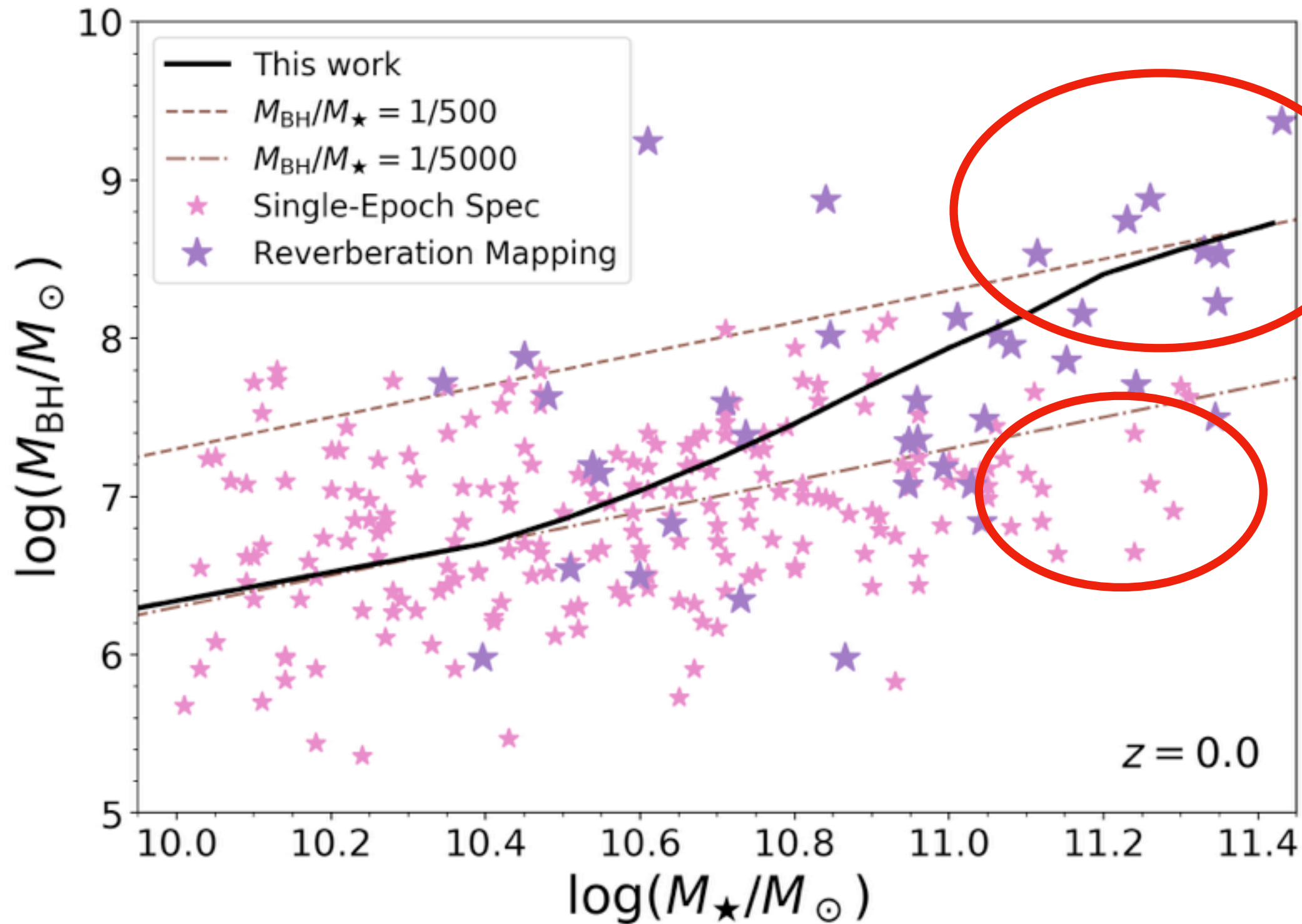
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**More observations needed!**

# Outstanding questions

- $\dot{M}_{\text{BH}}$  vs. galaxy morphology?
- $M_{\text{BH}}$  growth from mergers?
- $\dot{M}_{\text{BH}}$  from Compton-thick AGNs?