UNIVERSITY OF Southampton

Probing black hole-galaxy co-evolution from de-biased scaling relations

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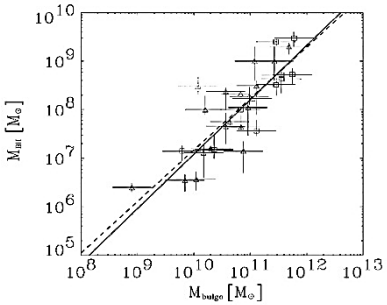
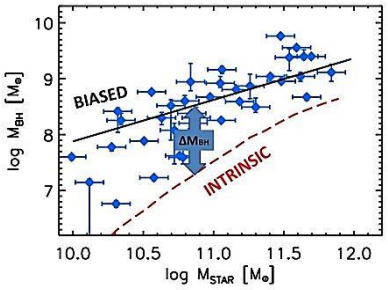
WHAT I WILL DISCUSS:

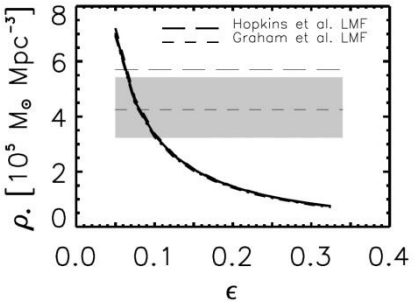
Local Scaling Relations:
Slopes, Normalizations, Scatters



Discussion of biases:
Observed vs '*Intrinsic*' relations



Consequences:
Basic models, AGN feedback, Accretion, Gravitational waves

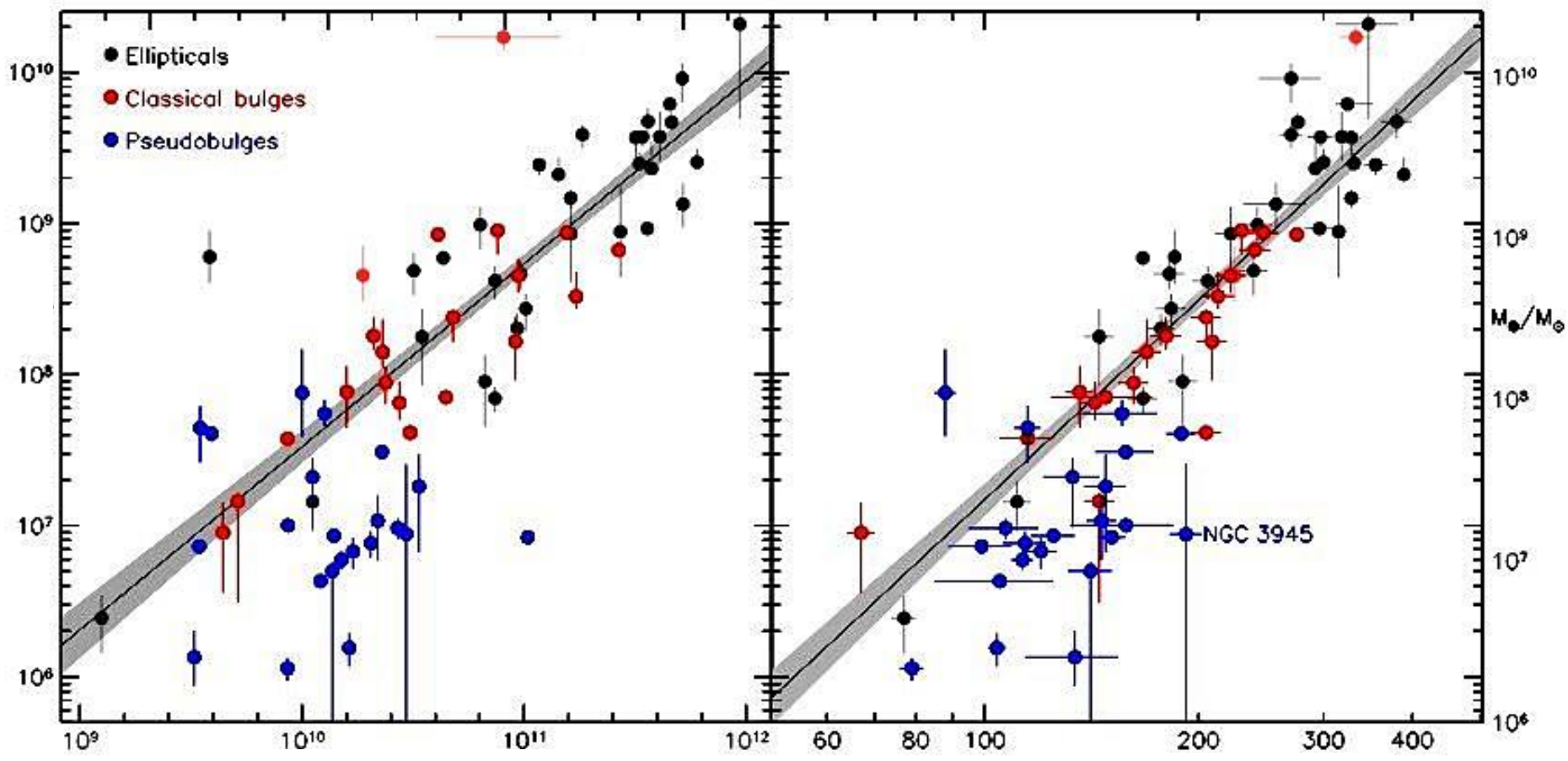


Local Scaling Relations:
Slopes, Normalizations, Scatters

BH-galaxy scaling relations

$M_{BH} \sim M_{star}$

$M_{BH} \sim \sigma^{4-5}$

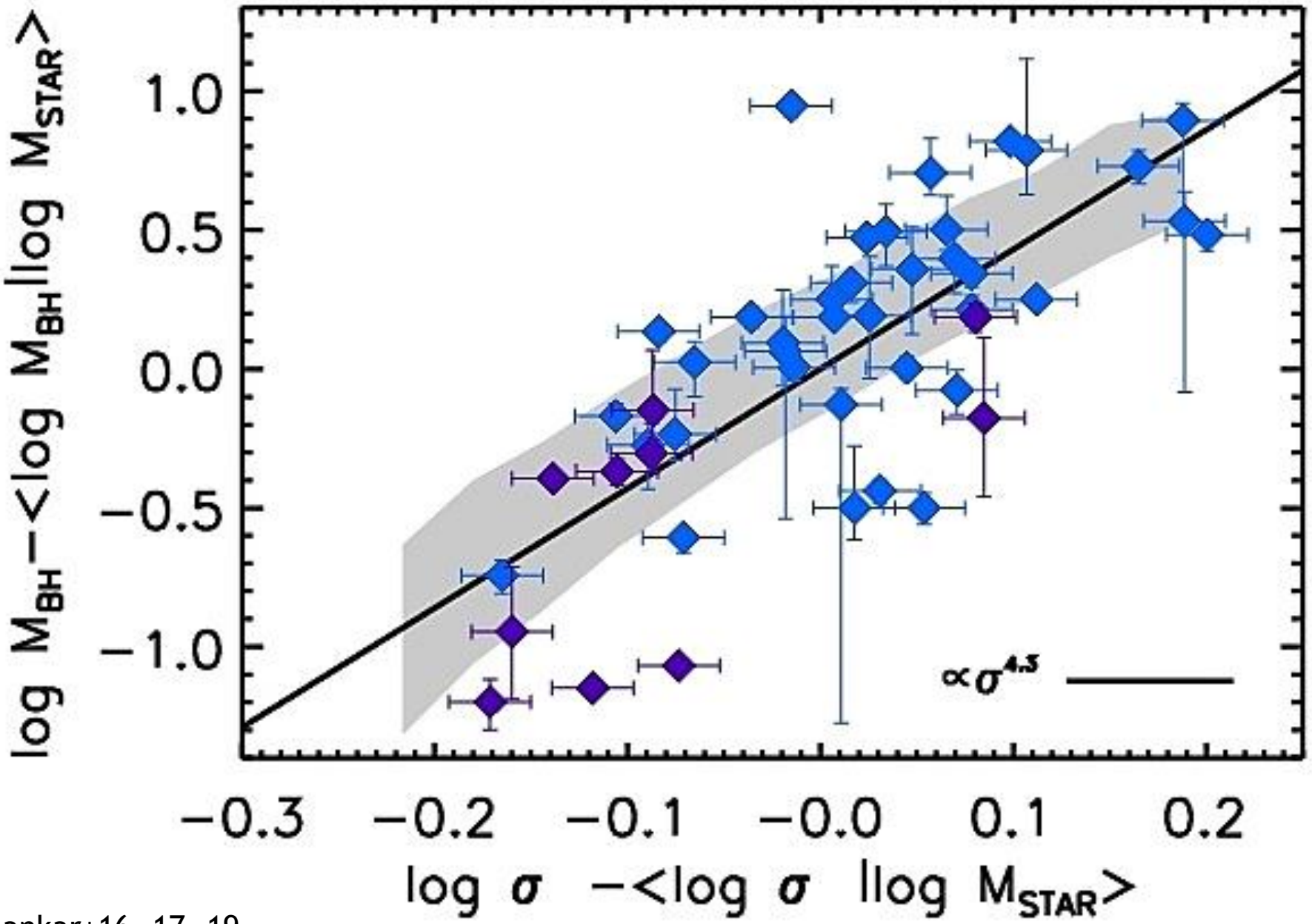


$L_{K,bulge}$ (Lsun)

σ (km/s)

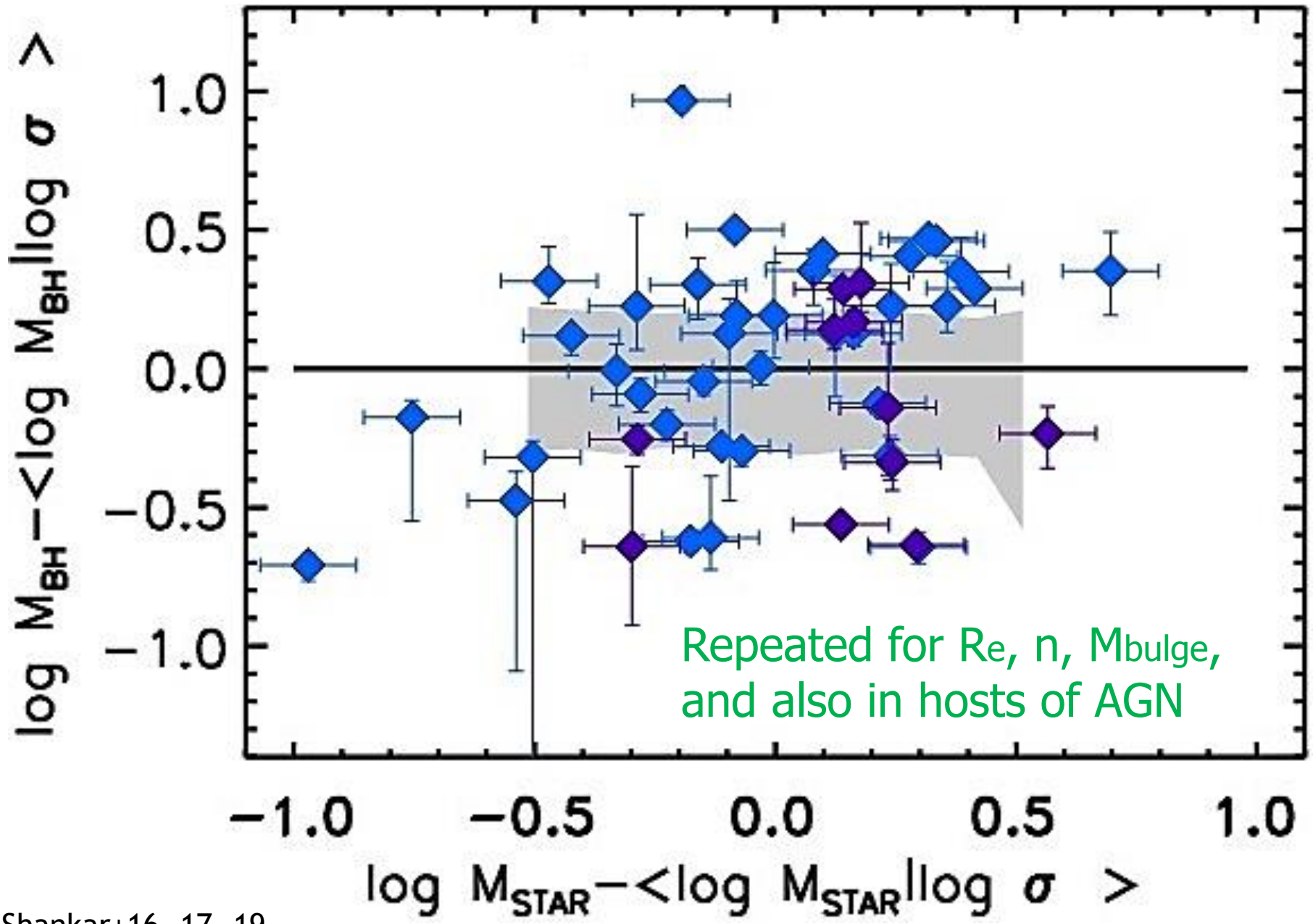
Kormendy & Ho 13

The M_{BH}-σ: The most fundamental?



Shankar+16, 17, 19

The M_{BH}-σ: The most fundamental?



Shankar+16, 17, 19

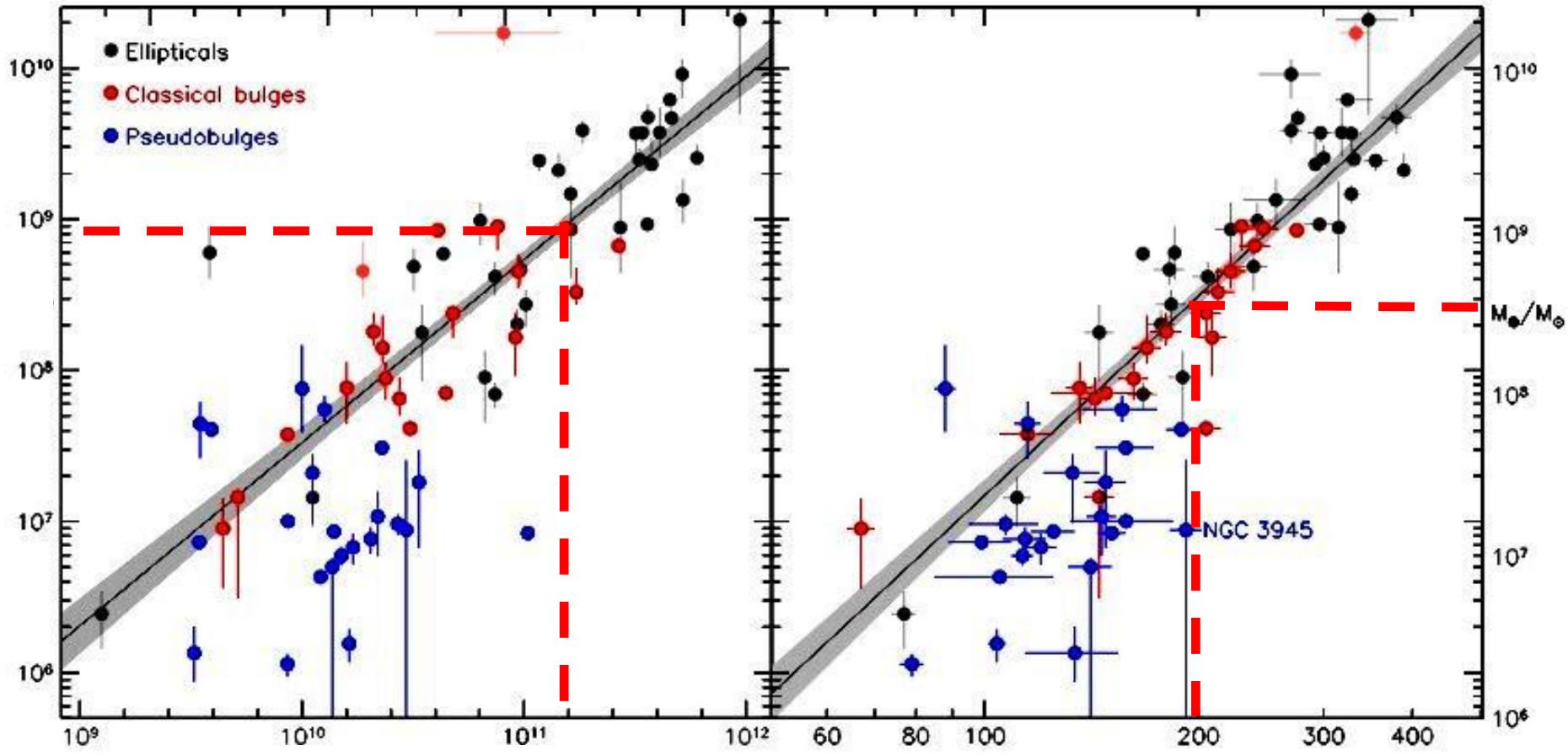
Take-home message I:

Stellar velocity dispersion is more fundamental!

Discussion of biases:
Observed vs '*Intrinsic*' relations

One major problem!

M_{BH}/M_{sun}

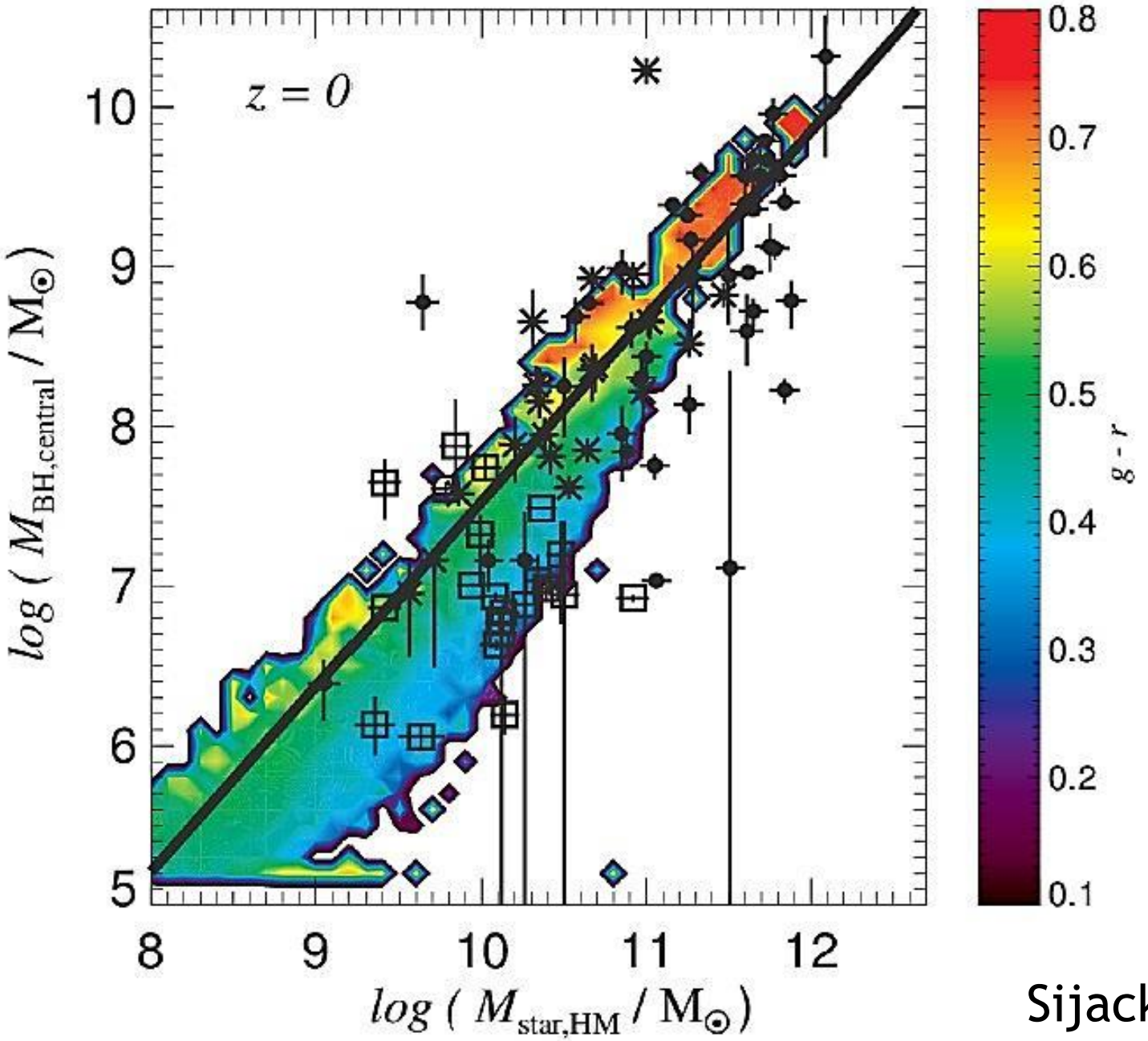


$L_{K,bulge}$ (Lsun)

σ (km/s)

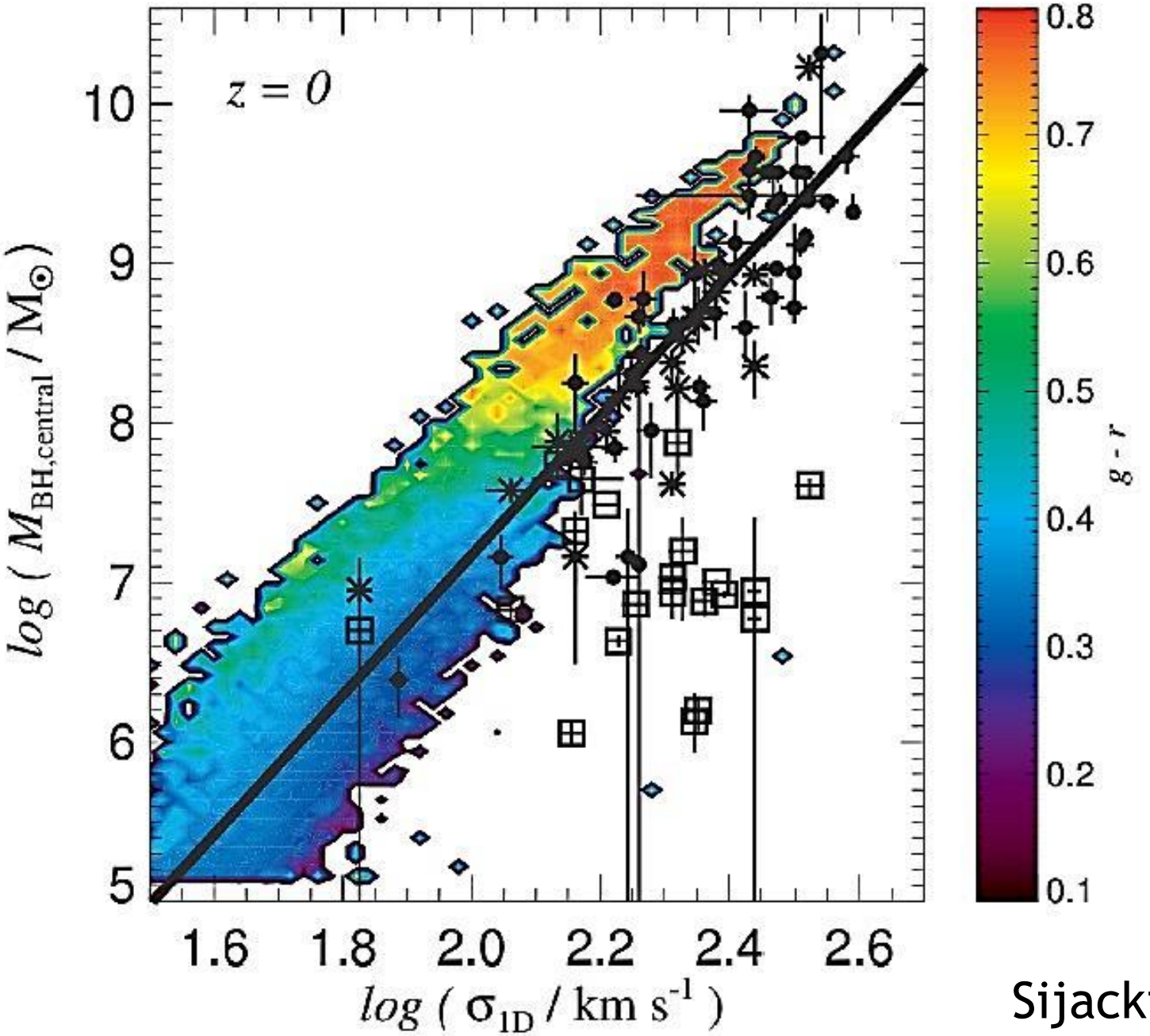
Kormendy & Ho 13

A case study: The Illustris simulation (Horizon also!)



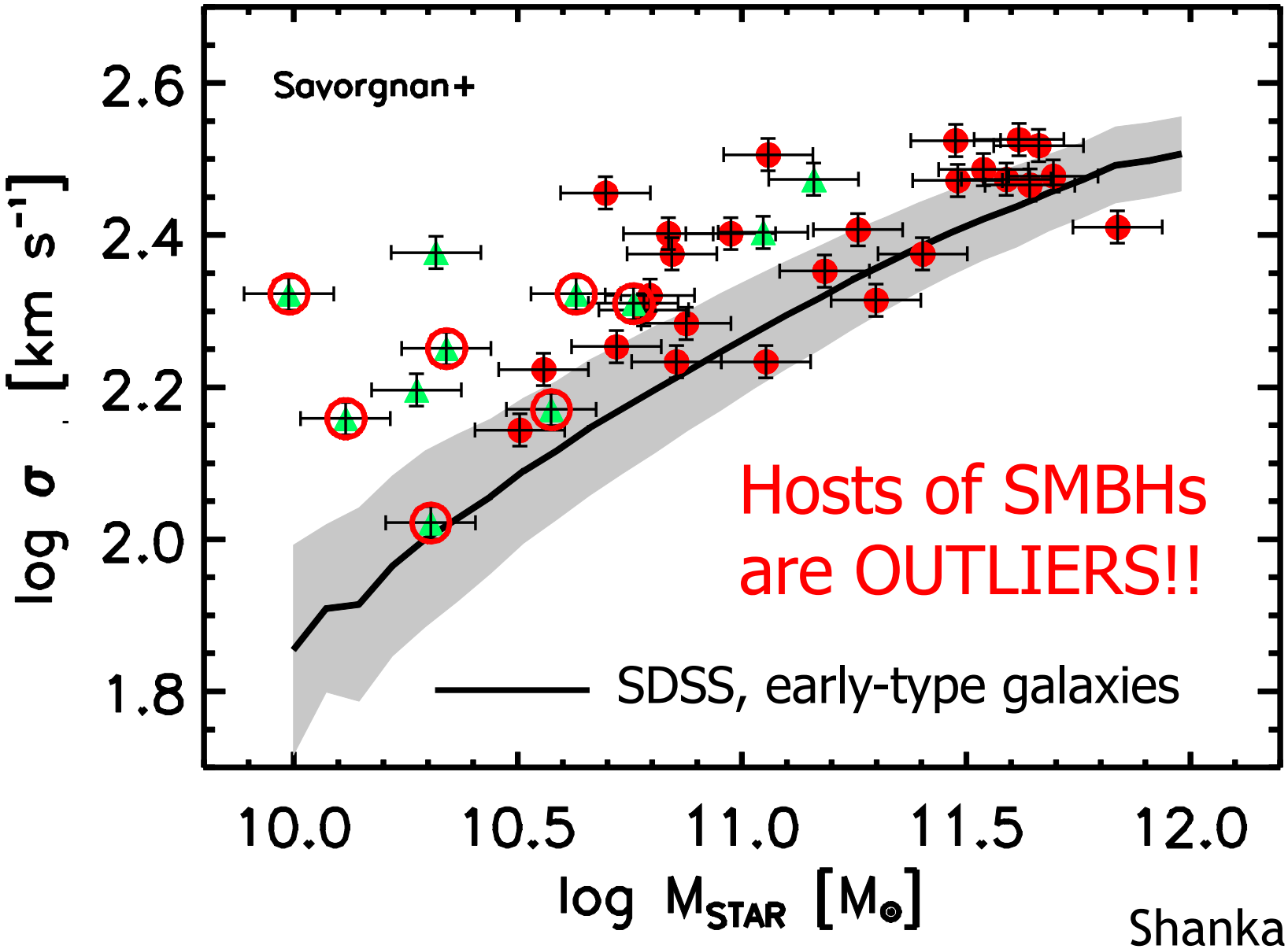
Sijacki+15

A case study: The Illustris simulation (Horizon also!)



Sijacki+15

Another major problem!



Shankar+16

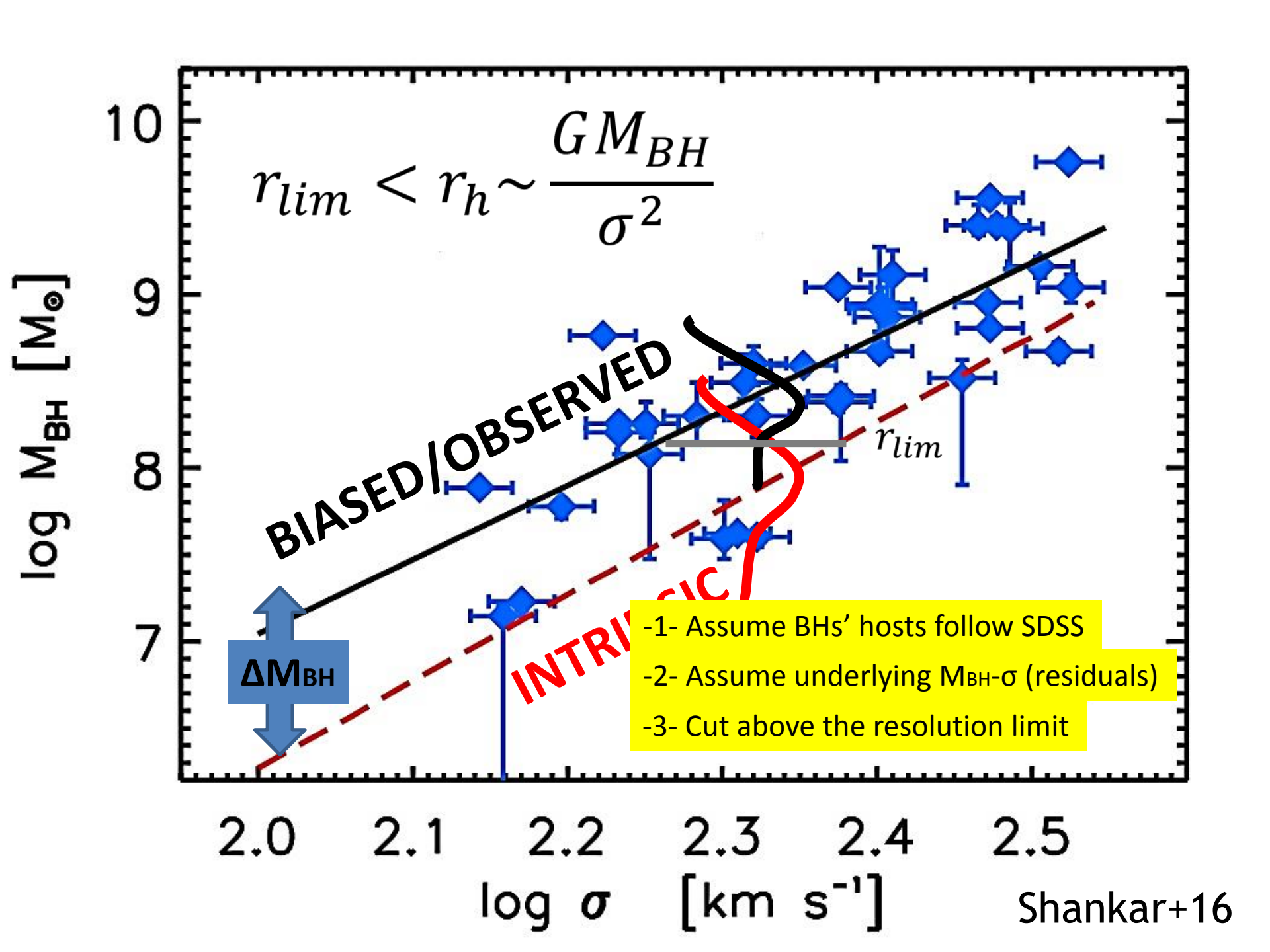
The 'sphere of influence' of a SMBH

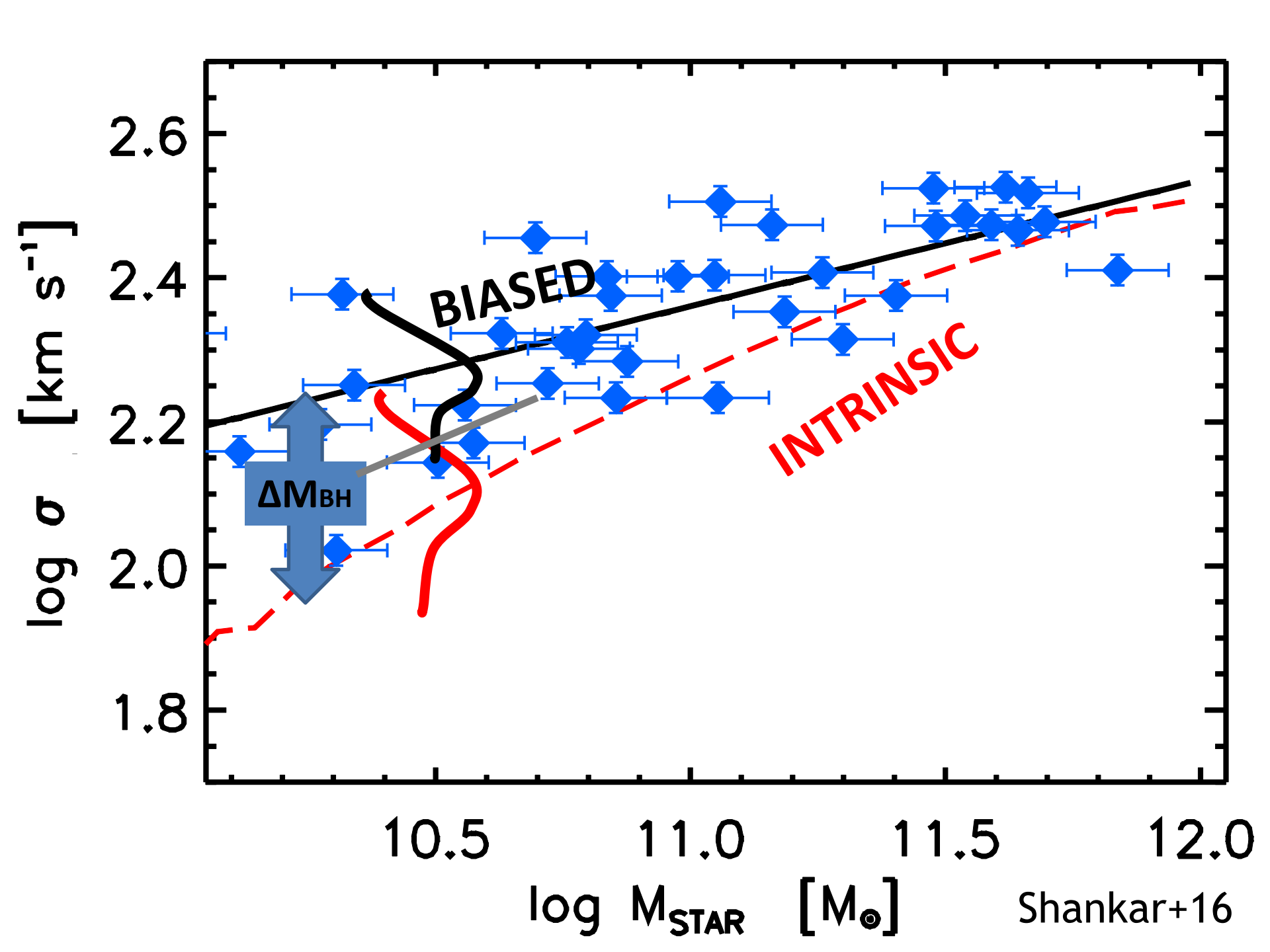
$$r_h \sim \frac{GM_{BH}}{\sigma^2} \sim 11 \left(\frac{M_{BH}}{10^8 M_{sun}}\right) \left(\frac{\sigma}{200\ km/s}\right)^2 \quad \text{pc}$$

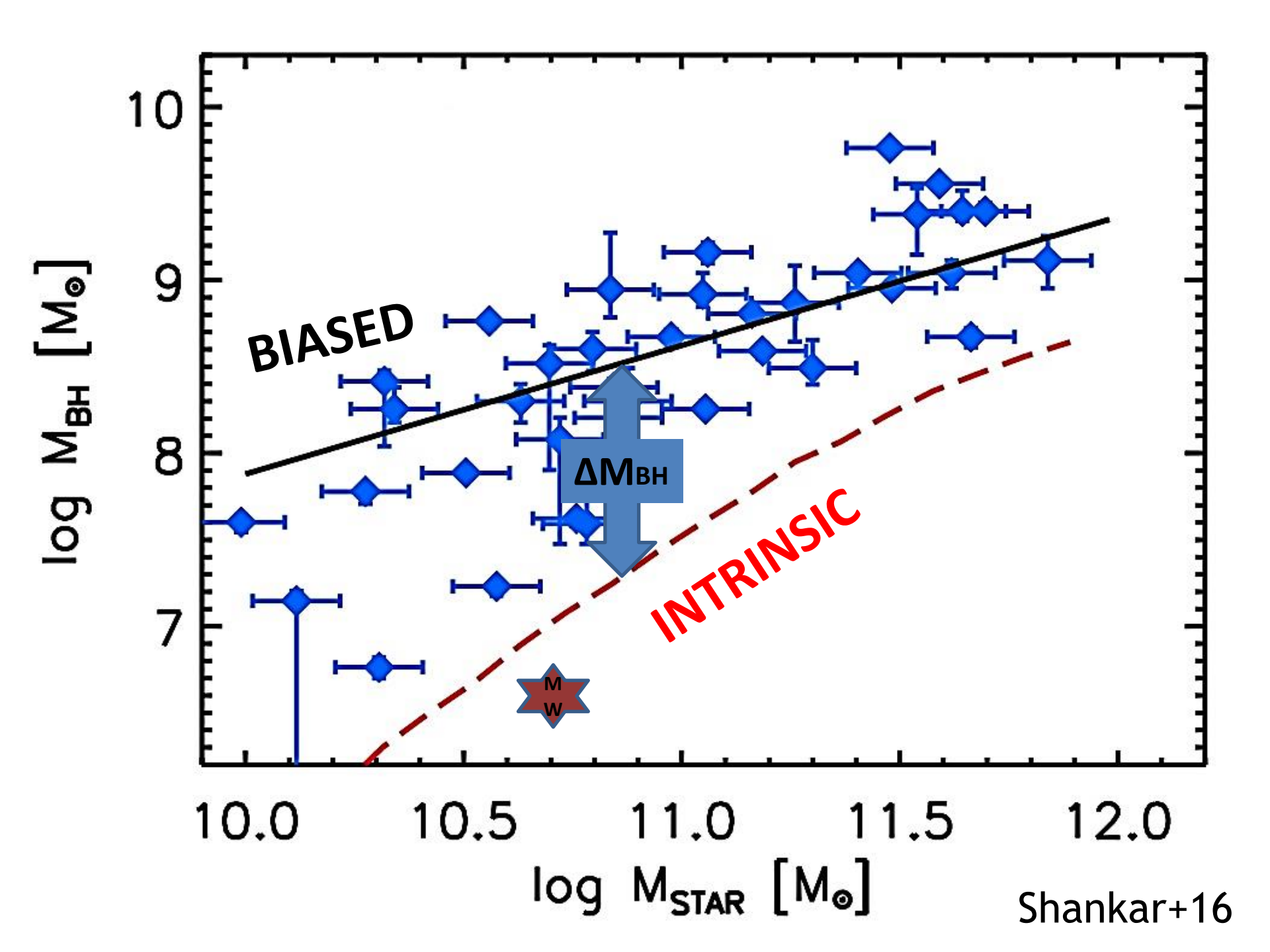
"...*defined as the region of space within which the gravitational potential of the SMBH dominates over that of the surrounding stars.*"

Implications?
As an example, a SMBH of $M_{BH} \sim 3 \times 10^7$ M_{sun} placed at the distance of the Virgo cluster (~15 Mpc), would shrink to a projected radius of 0.07", beyond the reach of even HST (~0.1")!

Ferrarese 06


$r_{lim} < r_h \sim \frac{GM_{BH}}{\sigma^2}$
BIASED/OBSERVED
INTRINSIC
r_{lim}
ΔMBH
-1- Assume BHs' hosts follow SDSS
-2- Assume underlying MBH-σ (residuals)
-3- Cut above the resolution limit
log MBH [M⊙]
10
9
8
7
2.0
2.1
2.2
2.3
2.4
2.5
log σ [km s⁻¹]
Shankar+16


2.6
2.4
2.2
2.0
1.8
log σ [km s-1]
BIASED
INTRINSIC
ΔMBH
10.5
11.0
11.5
12.0
log MSTAR [M⊙]
Shankar+16


10
9
8
7
log M_{BH} [$M_\odot$]
BIASED
ΔM_{BH}
INTRINSIC
M
W
10.0
10.5
11.0
11.5
12.0
log M_{STAR} [$M_\odot$]
Shankar+16

Take-home message II:

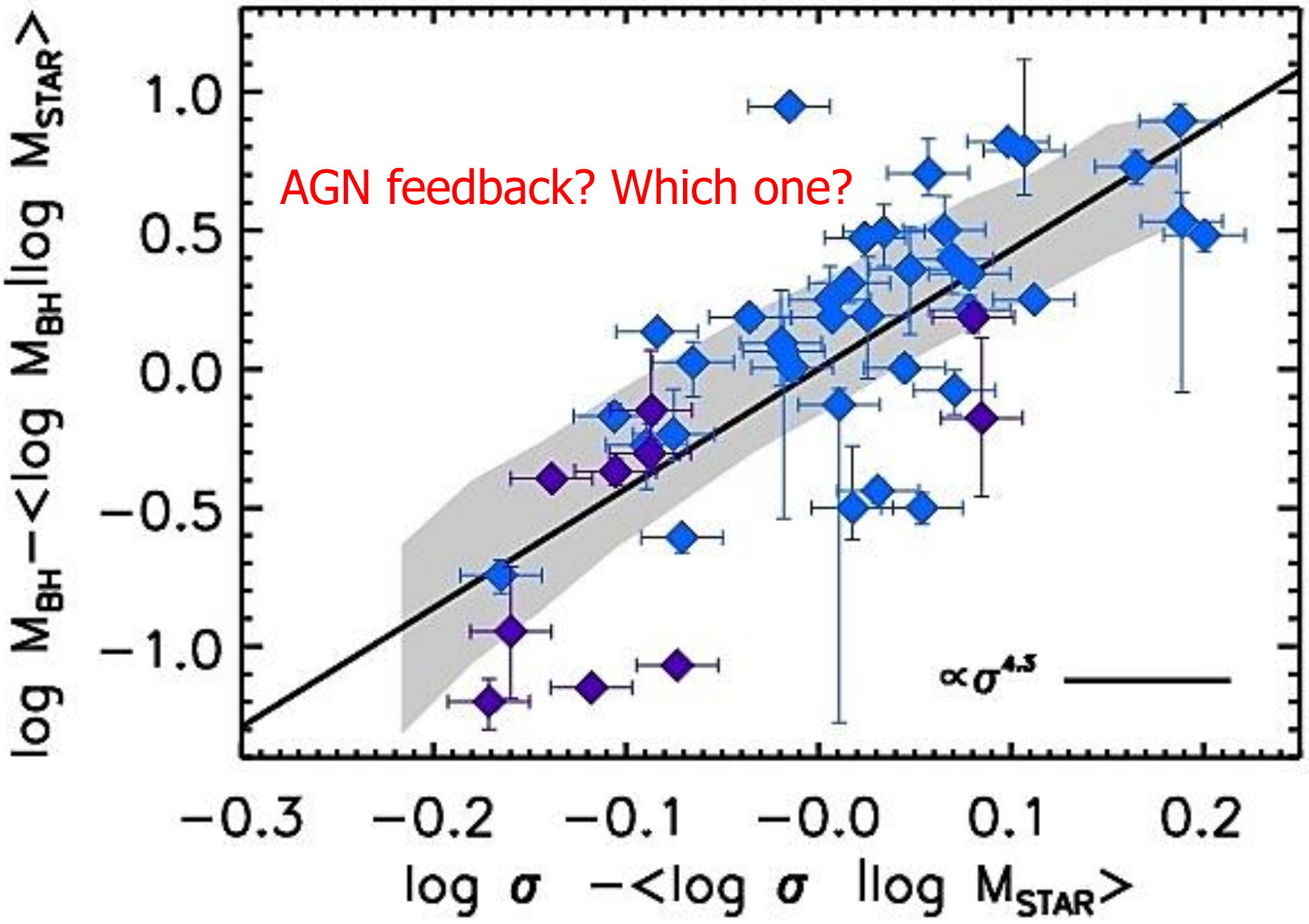
Be cautious with 'raw' scaling relations!

Consequences:

Basic models,

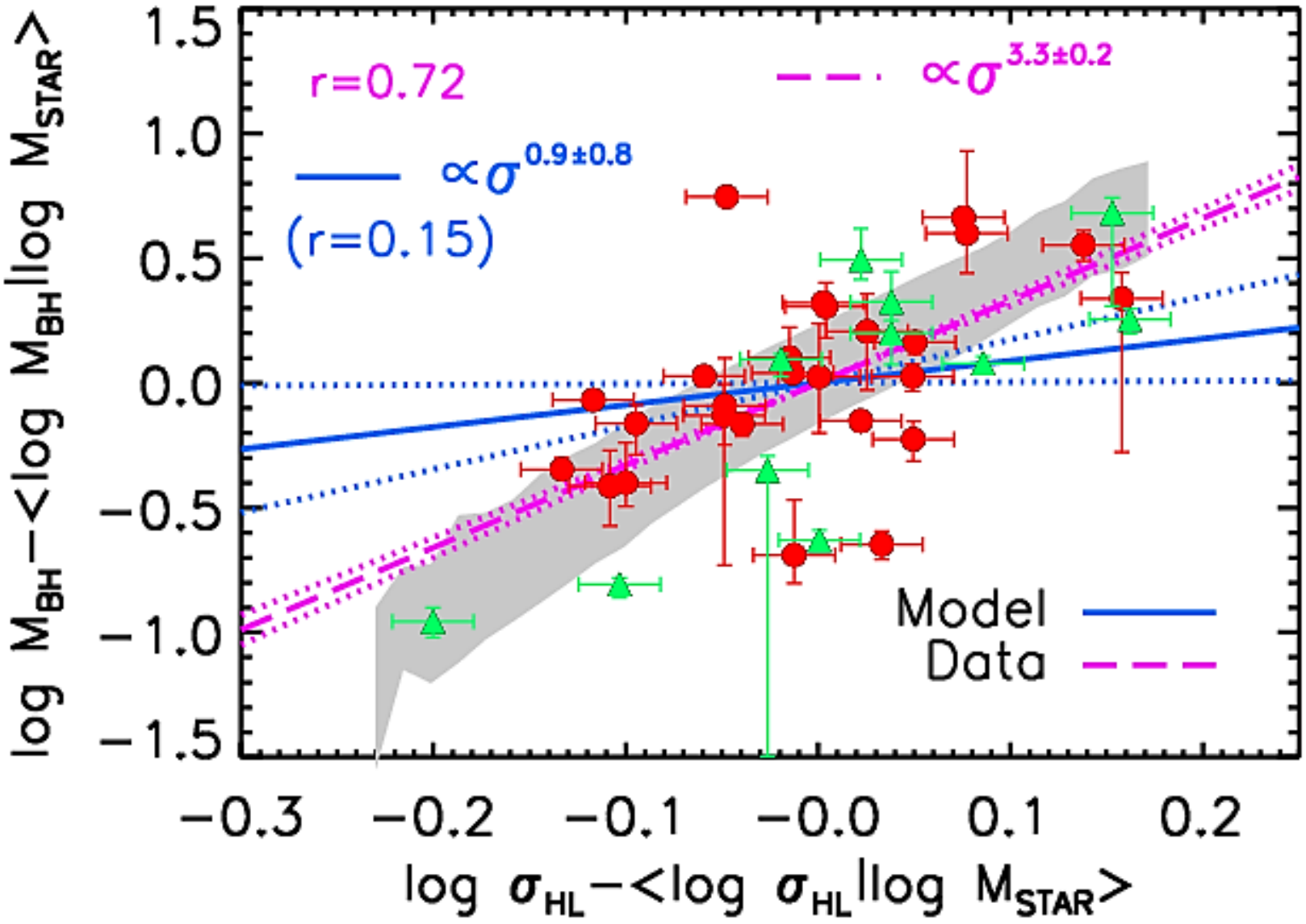
AGN feedback, Accretion,

Gravitational waves

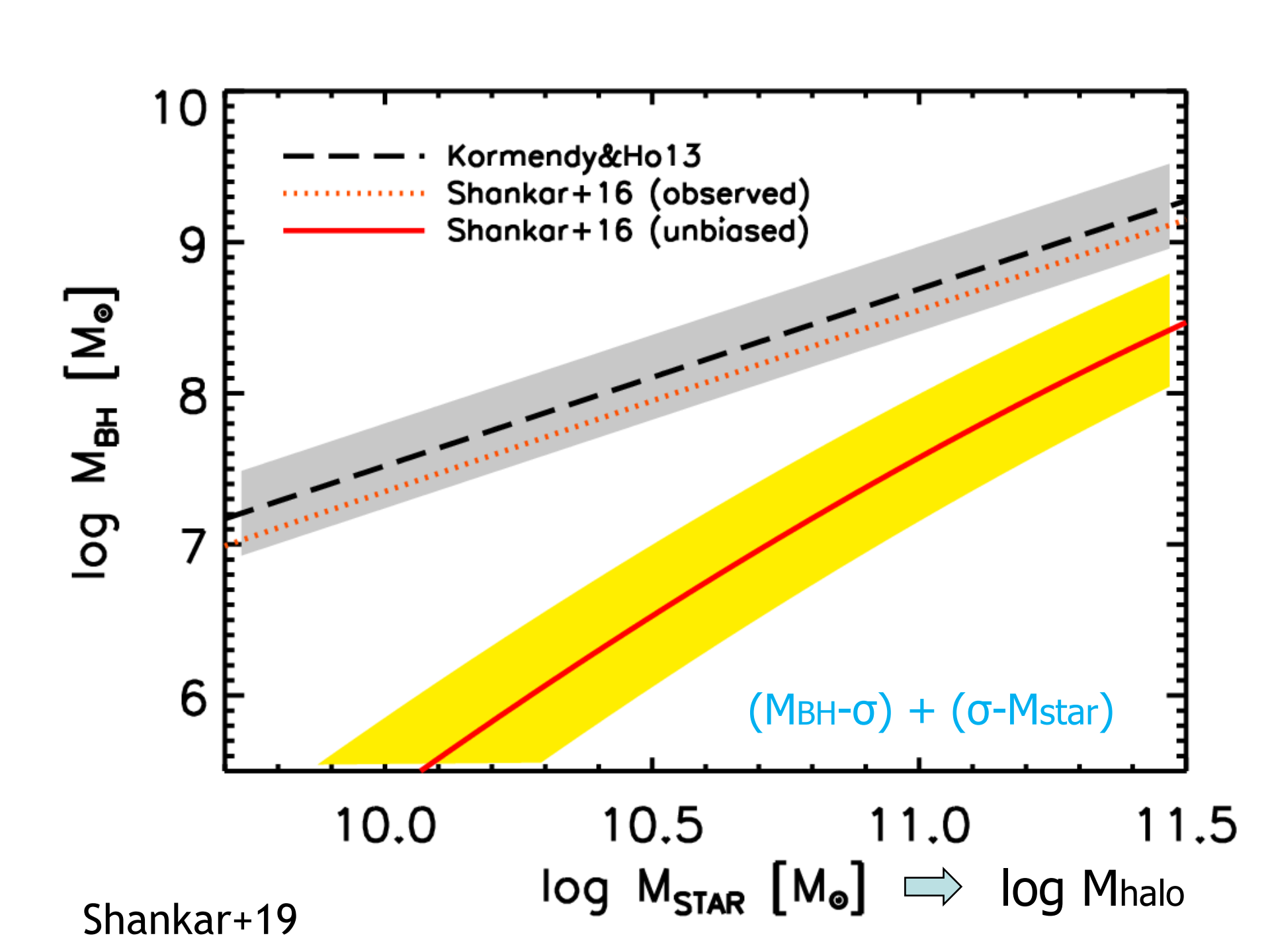

AGN feedback? Which one?
log M_{BH} − <log M_{BH} |log M_{STAR}>
log σ − <log σ |log M_{STAR}>
1.0
0.5
0.0
−0.5
−1.0
−0.3
−0.2
−0.1
−0.0
0.1
0.2
$\propto \sigma^{4.5}$

Shankar+16

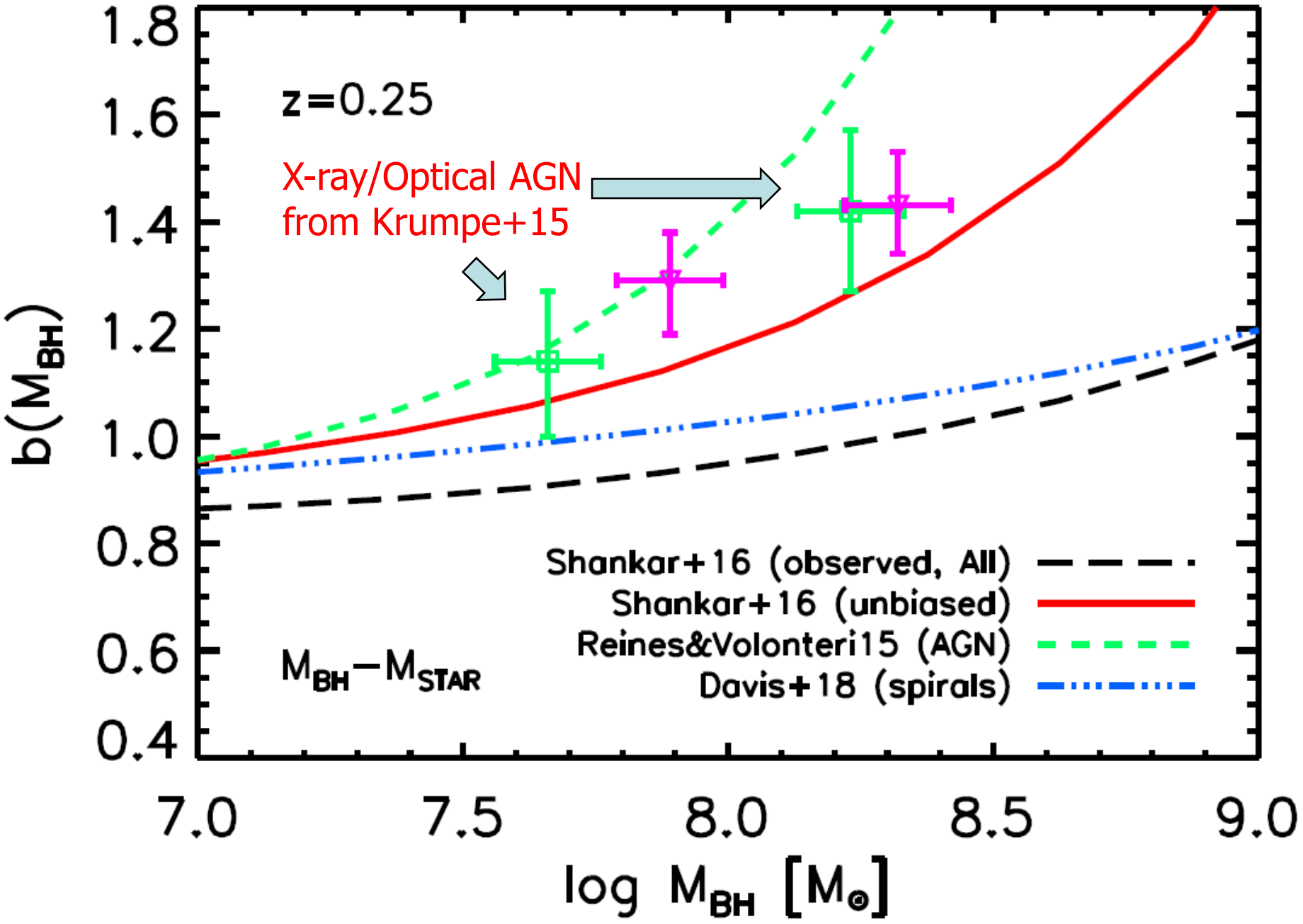
Thermal AGN feedback does not work!



Barausse, FS, et al. 2017

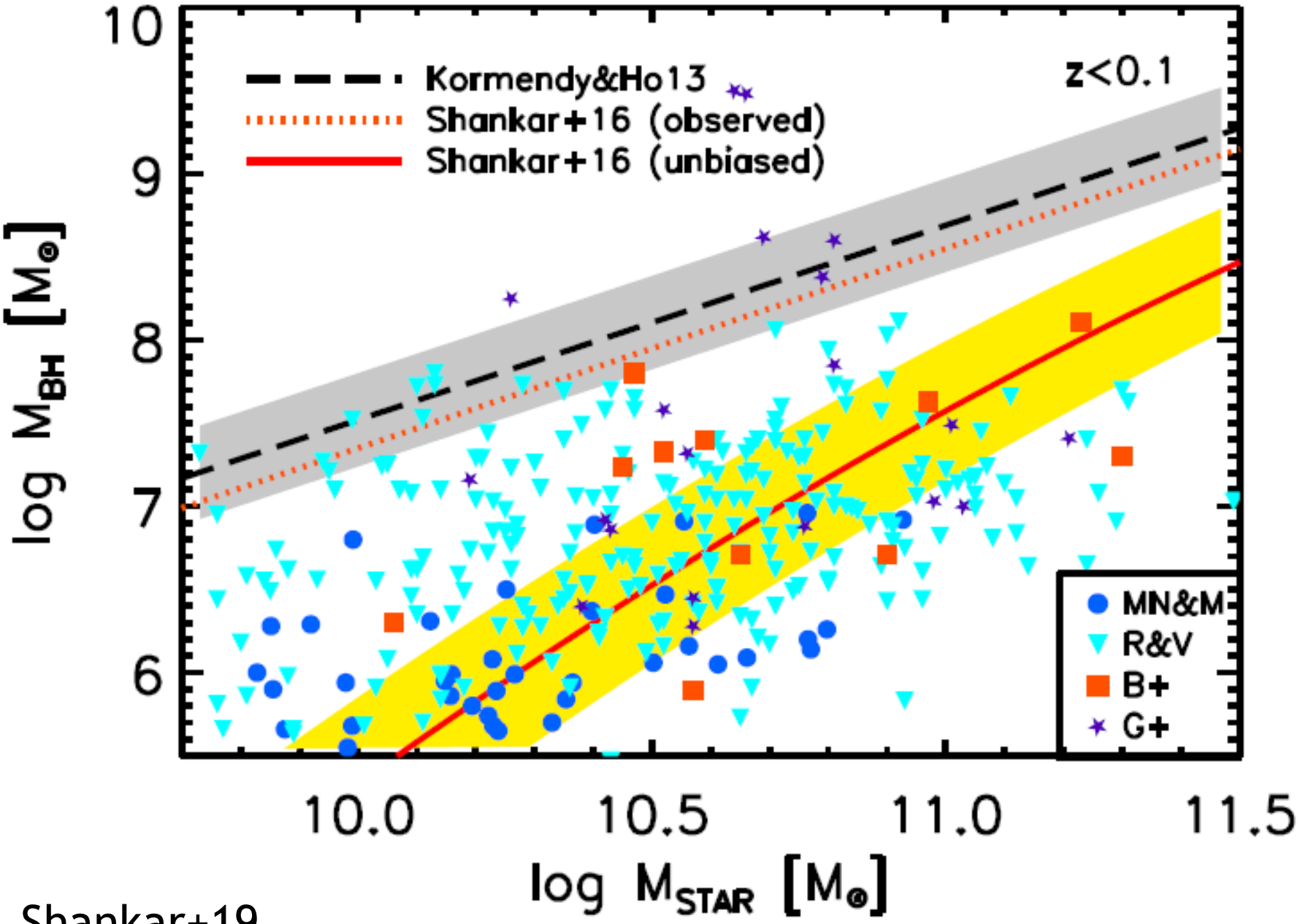

Kormendy&Ho13
Shankar+16 (observed)
Shankar+16 (unbiased)
(MBH-σ) + (σ-Mstar)
log MBH [M⊙]
log MSTAR [M⊙] ⇨ log Mhalo
10
9
8
7
6
10.0
10.5
11.0
11.5

Shankar+19

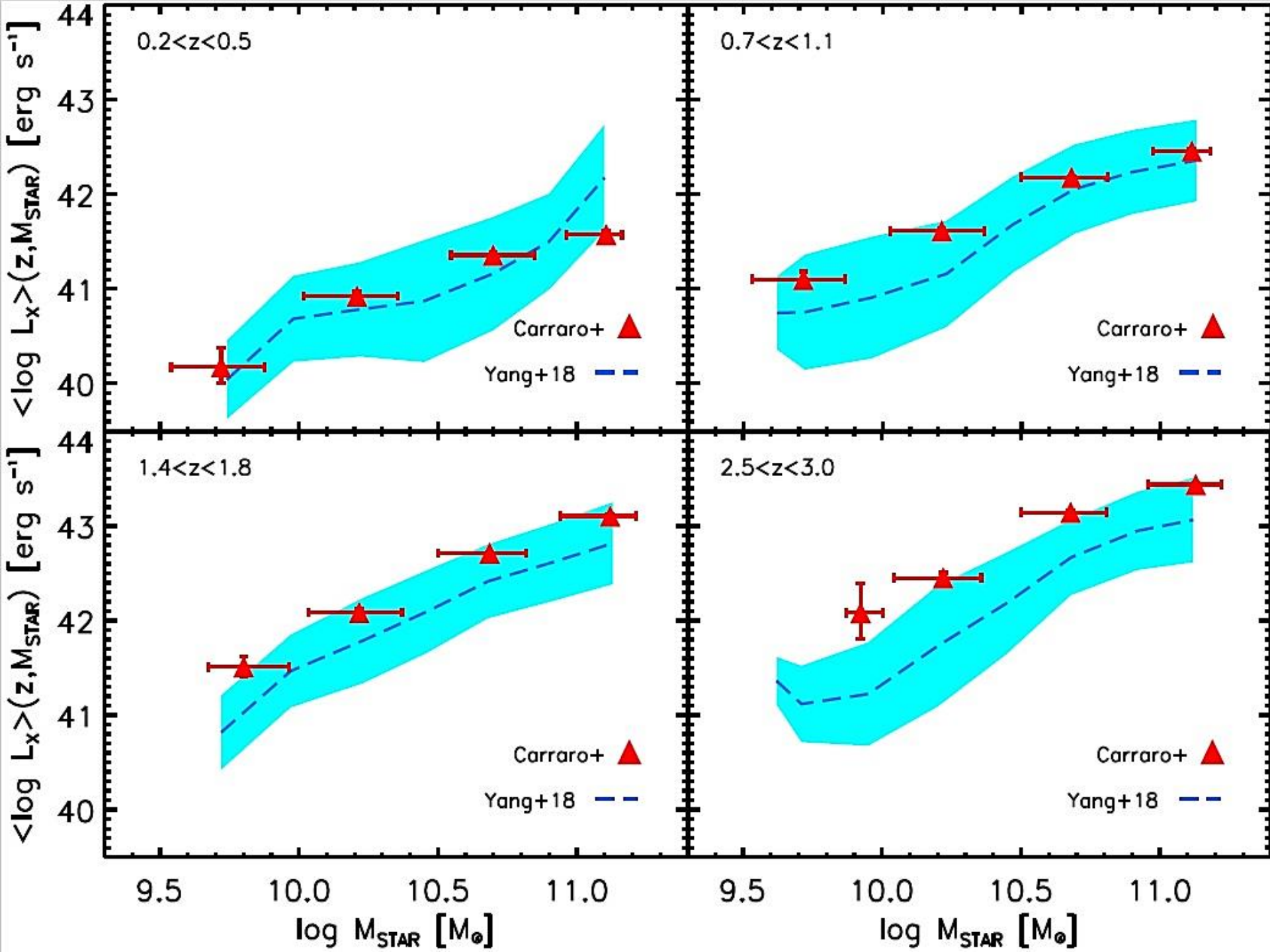


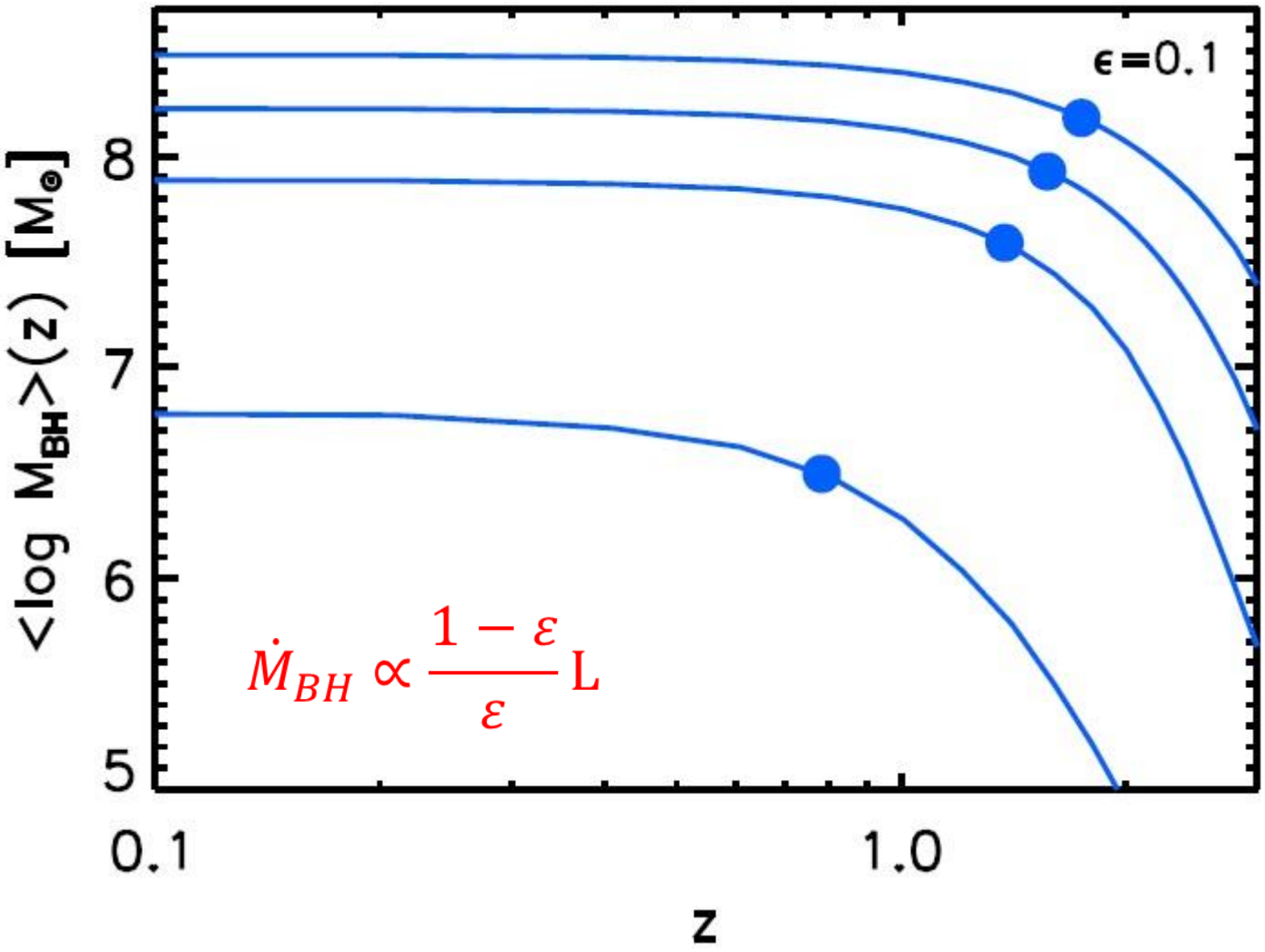
Shankar+19b, Nature Astronomy, resubmitted

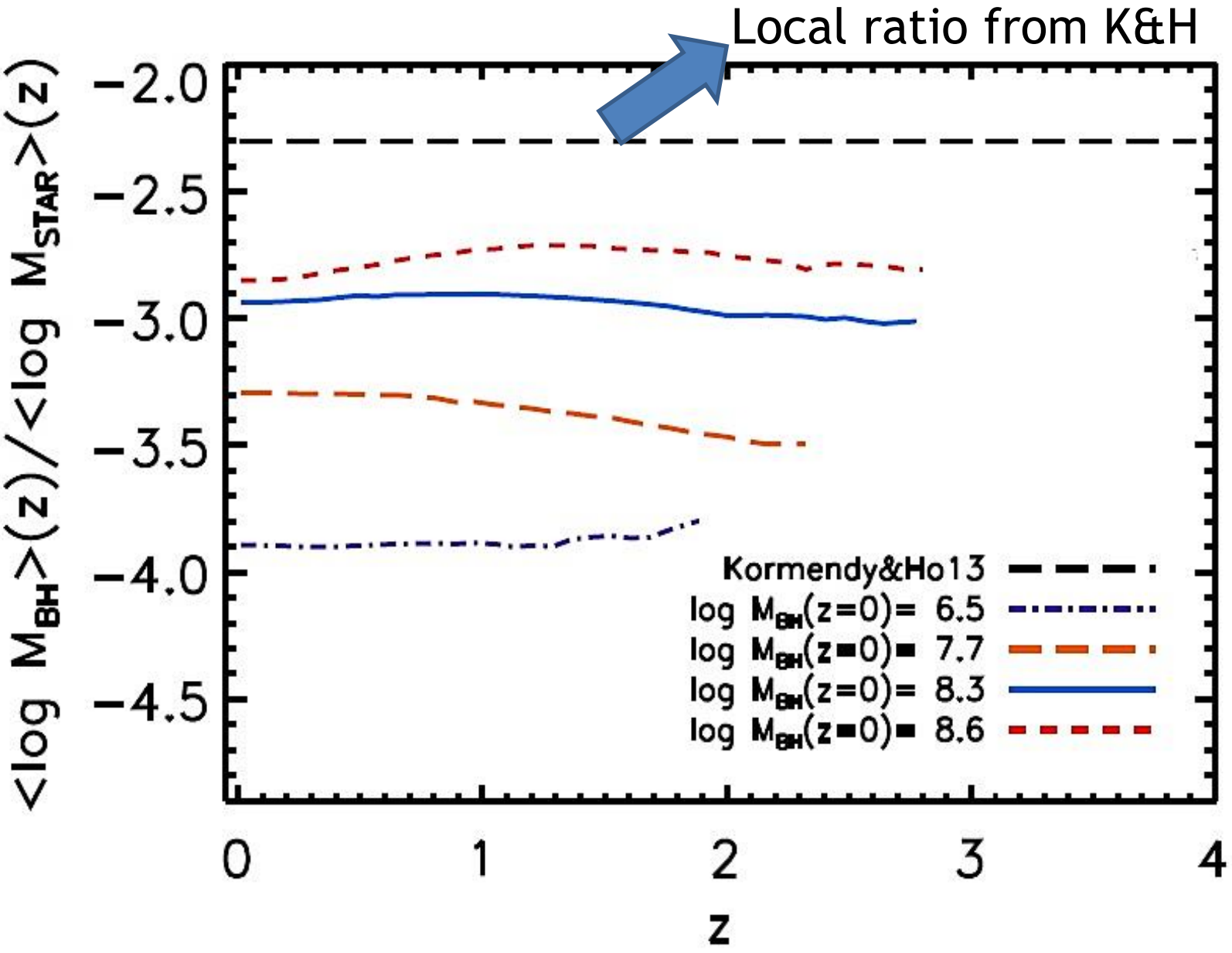
AGN ARE NOT (GRAVITATIONALLY) BIASED!!



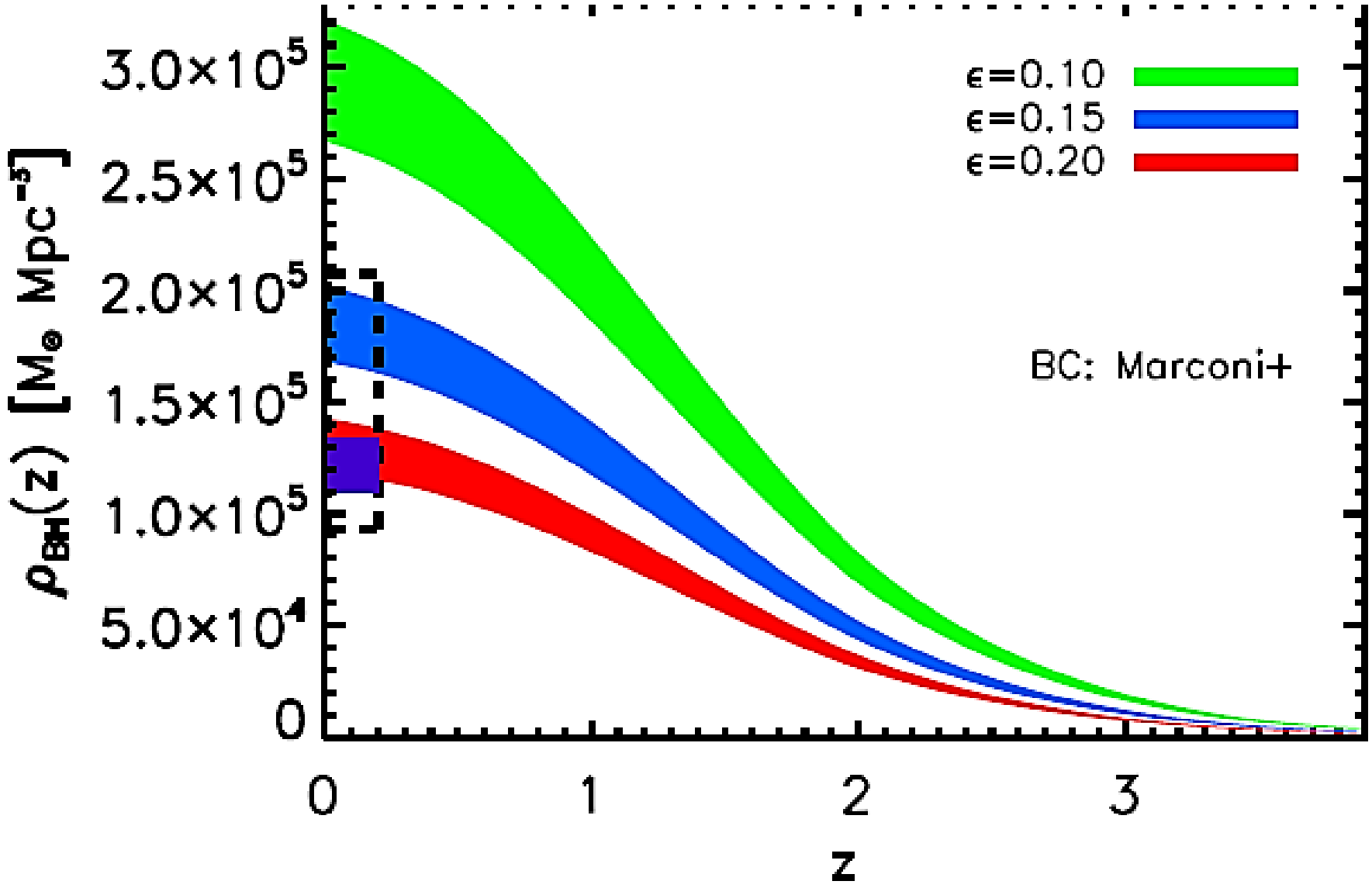
Shankar+19


0.2<z<0.5
0.7<z<1.1
1.4<z<1.8
2.5<z<3.0
Carraro+
Yang+18
<log Lx>(z,MSTAR) [erg s-1]
log MSTAR [M⊙]
44
43
42
41
40
9.5
10.0
10.5
11.0


ϵ=0.1
<log M_BH>(z) [M⊙]
8
7
6
5
0.1
1.0
z
$\dot{M}_{BH} \propto \frac{1-\varepsilon}{\varepsilon} \mathrm{L}$

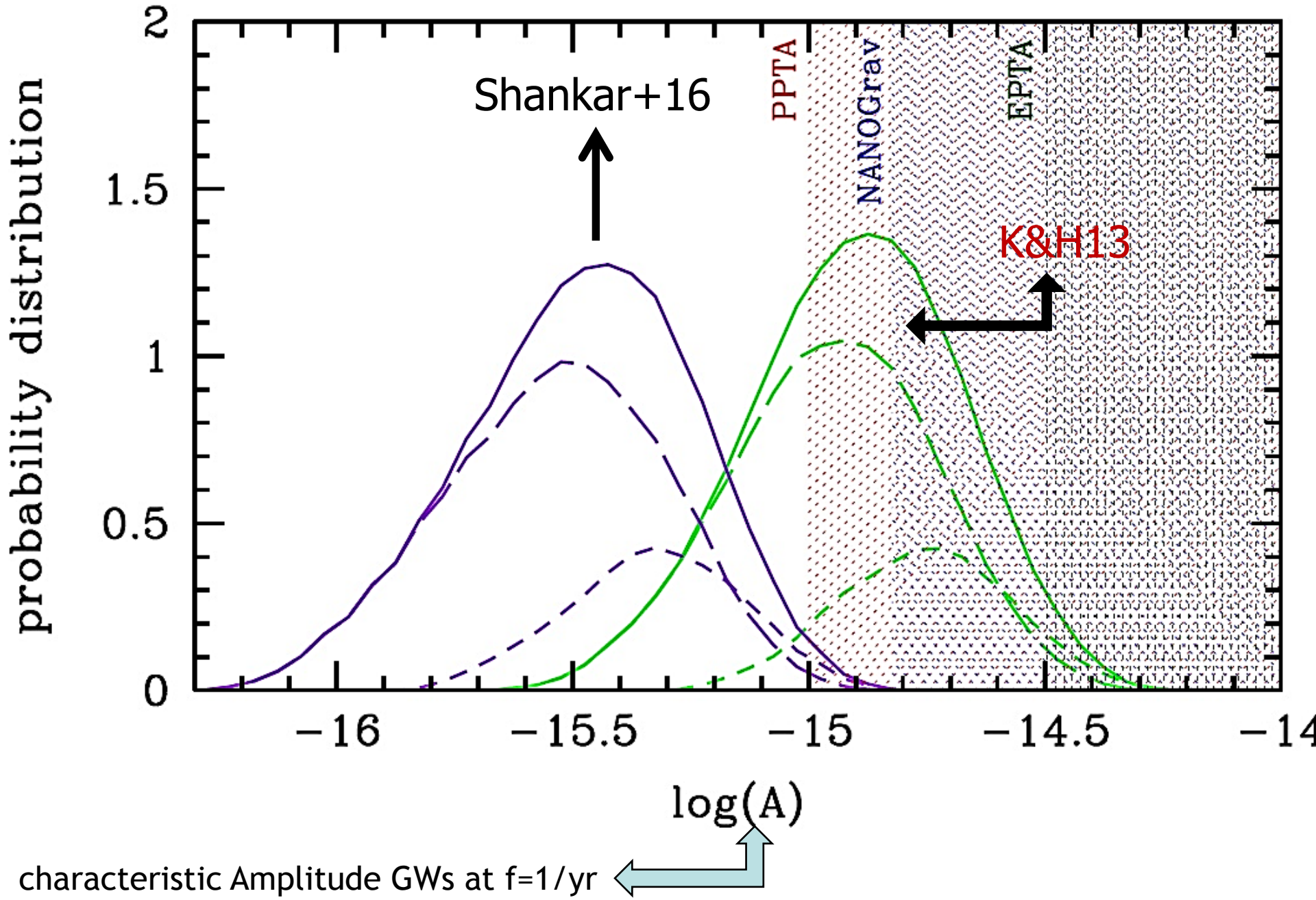


Shankar+19 in prep, Suh+19 submitted, Carraro+19 submitted, ...



Shankar+19, NatAstro, resubmitted

Sesana, FS, et al. 2016



characteristic Amplitude GWs at f=1/yr

Take-home message III:

From de-biased scaling relations more radiative efficiency, less evolution, less GWs!