Just good friends: The non-causal origin of black hole–galaxy scaling relations

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Galaxy–Black Hole Coevolution

www.mpia.de/coevolution

What drives the growth of black holes?
Durham, 29th July 2010

BH vs. *

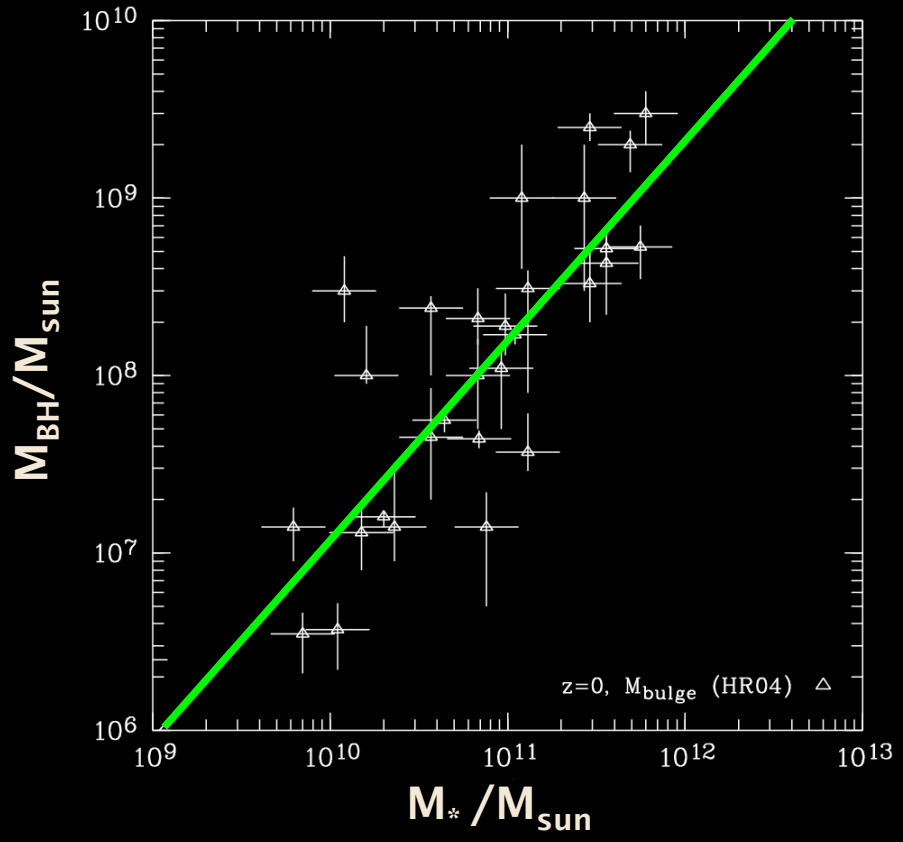
Galaxy growth:

- Growth by star formation → (cold) gas needed
- Gas supply/feeding: major & minor mergers, instabilities
- Growth by assembly → galaxy mergers

Black hole growth:

- Growth by gas accretion → (cold?) gas needed
- Gas supply/feeding: major & minor mergers, instabilities
- Growth by assembly → galaxy mergers

BH vs. *



z=0: Häring&Rix 2004

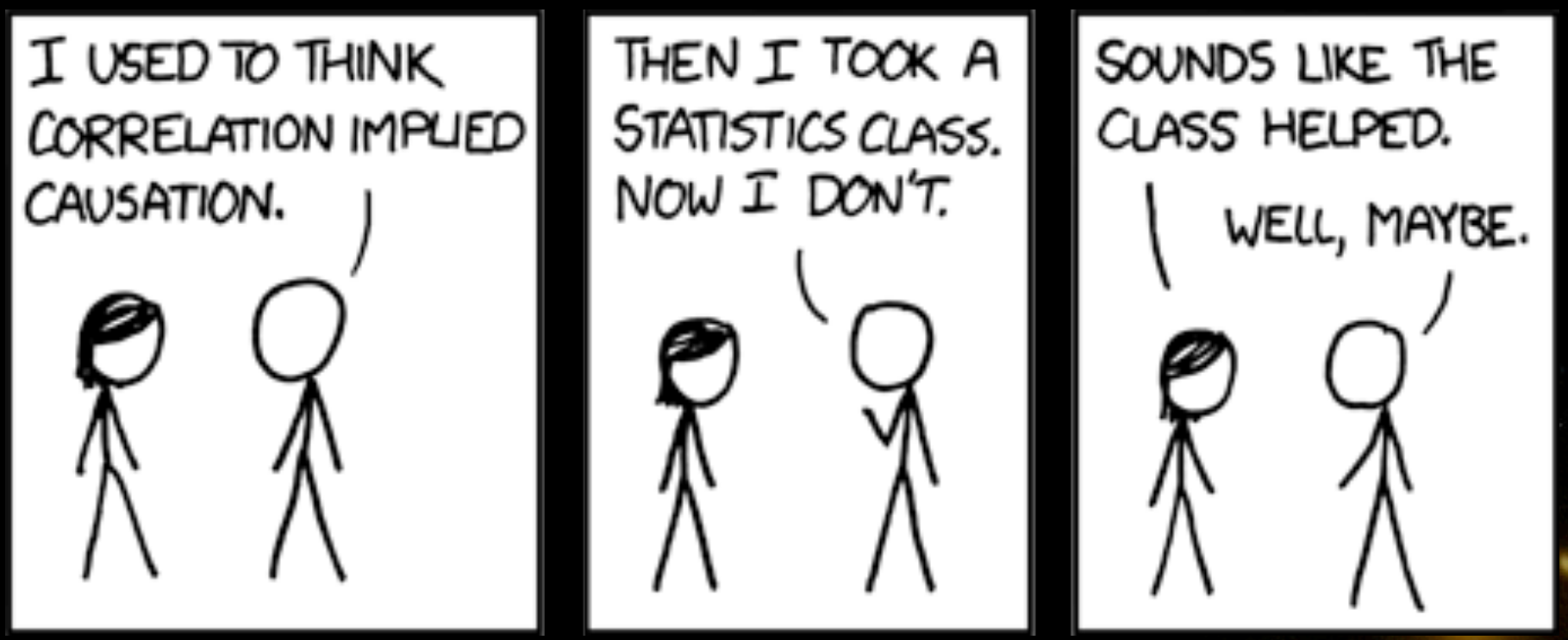
- Tight correlation: BH-bulge, 0.3 dex scatter (measurement or intrinsic?)
- Evolution with z:

  z<1.5: ~ low

  z=3: x2-6

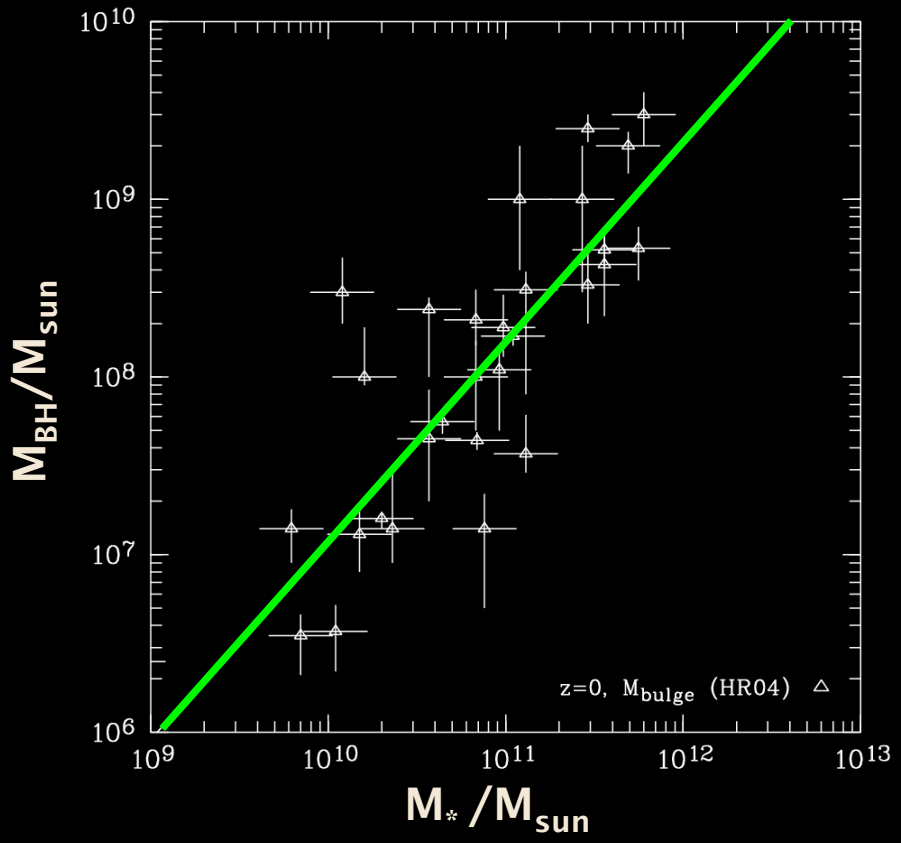
  z=6: x30

Dave A. intro: „somehow the black hole knows about the spheroid it is located in“


I USED TO THINK CORRELATION IMPLIED CAUSATION.
THEN I TOOK A STATISTICS CLASS. NOW I DON'T.
SOUNDS LIKE THE CLASS HELPED.
WELL, MAYBE.

xkcd.com/552

BH vs. *: Correlation or causation?



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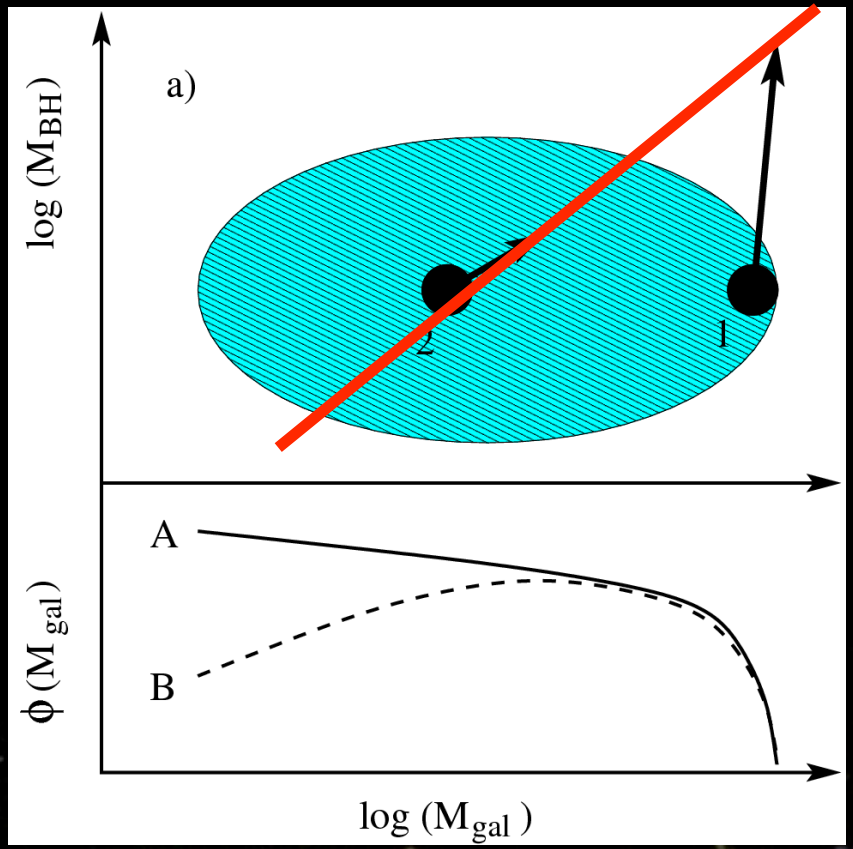
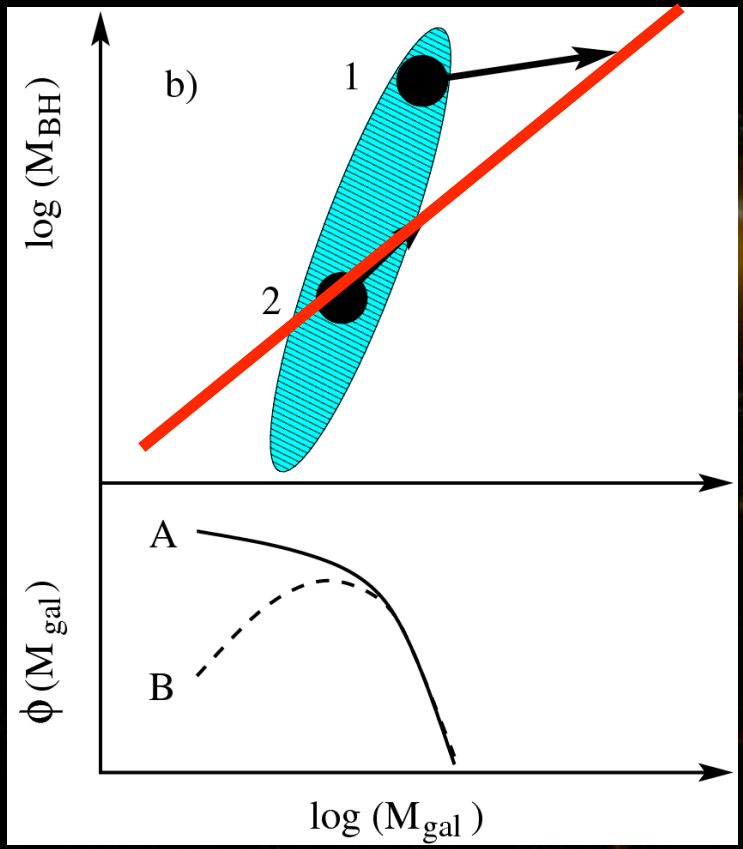
→ Coupled evolution?

BH vs. *: Correlation or causation?

Chien Y. Peng (2007): Galaxy merging averages properties; is M_{BH}-M_* relation due to „central limit theorem“?





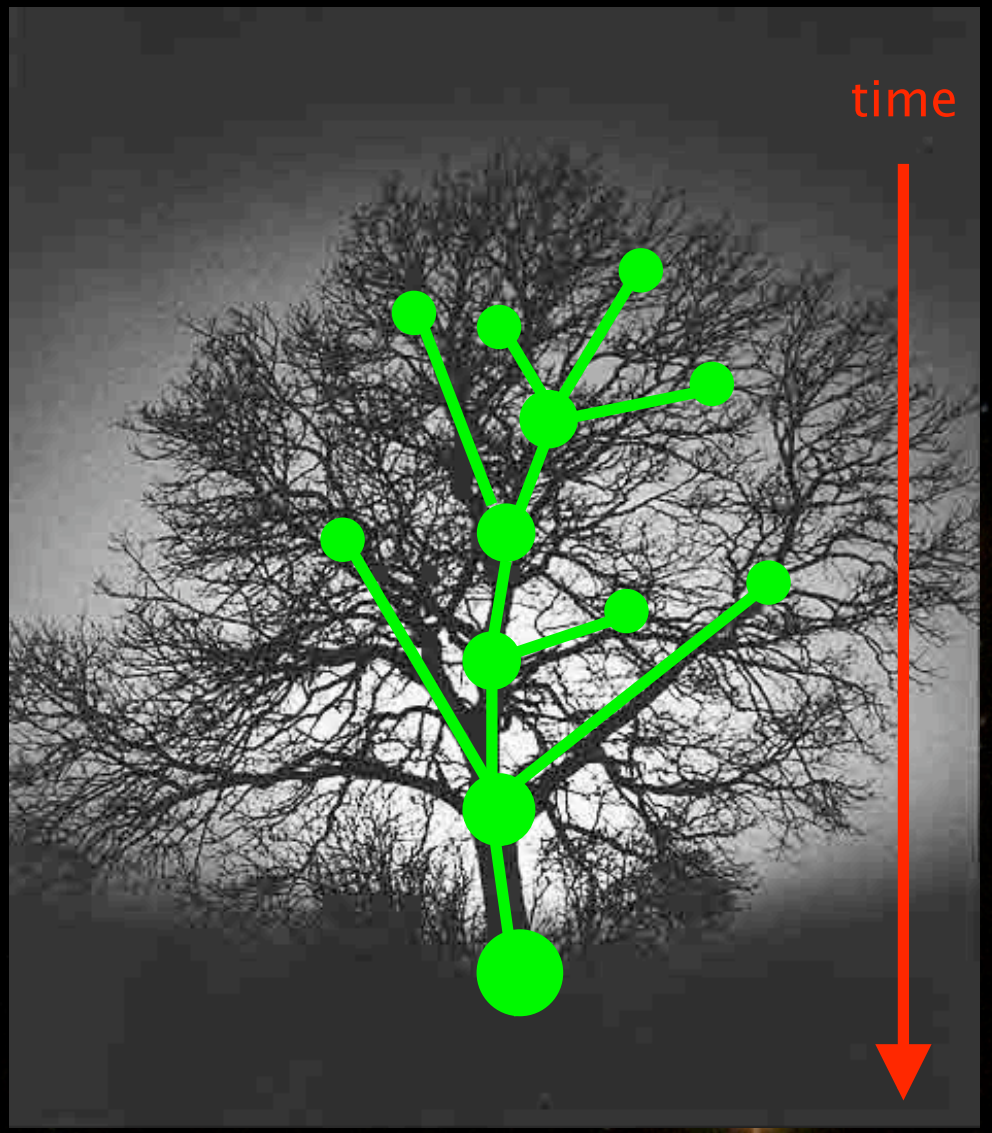
Using a realistic Universe

What about the real Universe?

Use simulated set of DM halos and it's assembly merger tree (*Pinocchio* code, Monaco et al.)

→ BH seeds? M_* seeds?

KJ & Macciò, subm. to ApJL
arXiv:1006.0482



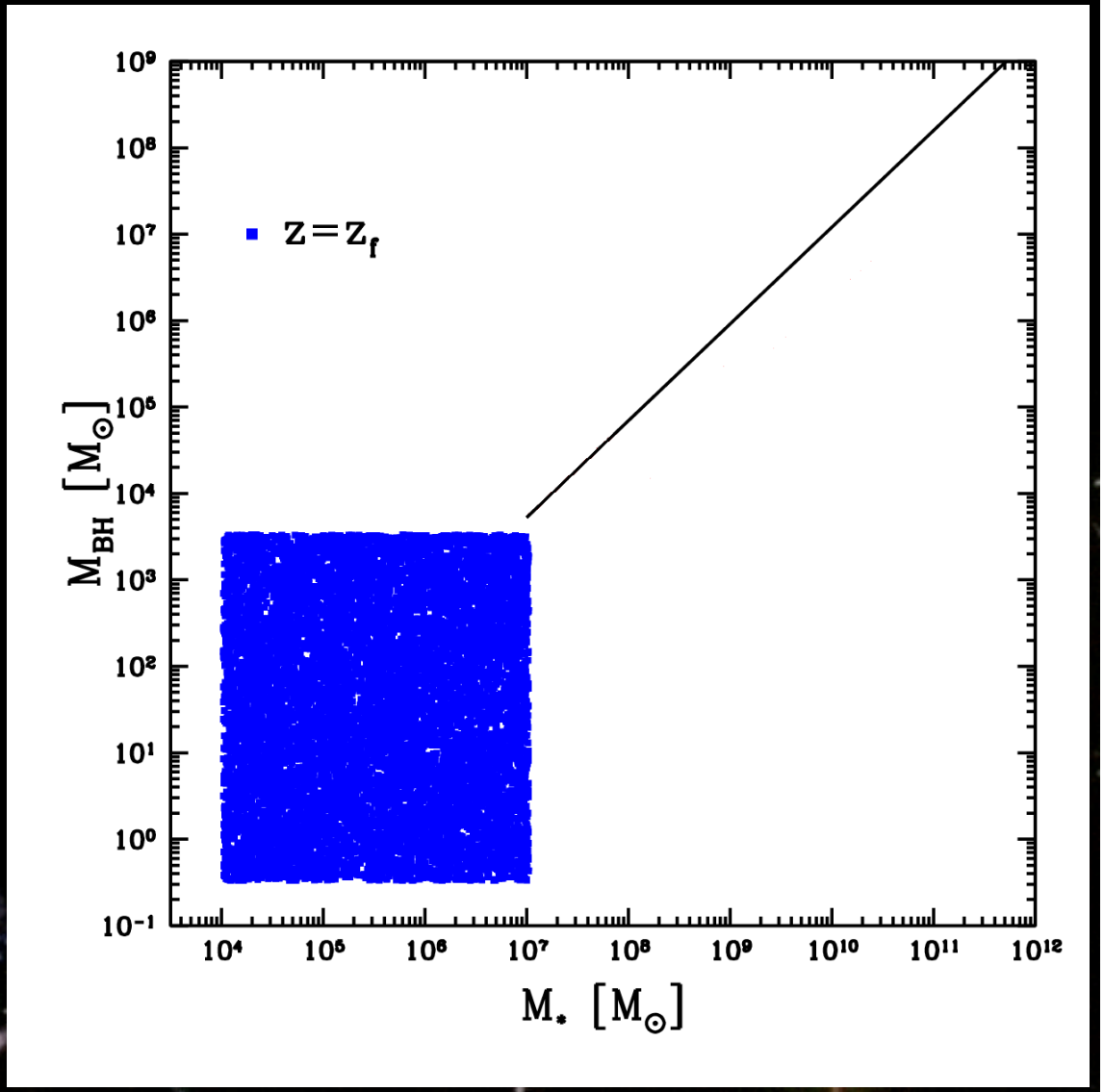
Using a realistic Universe

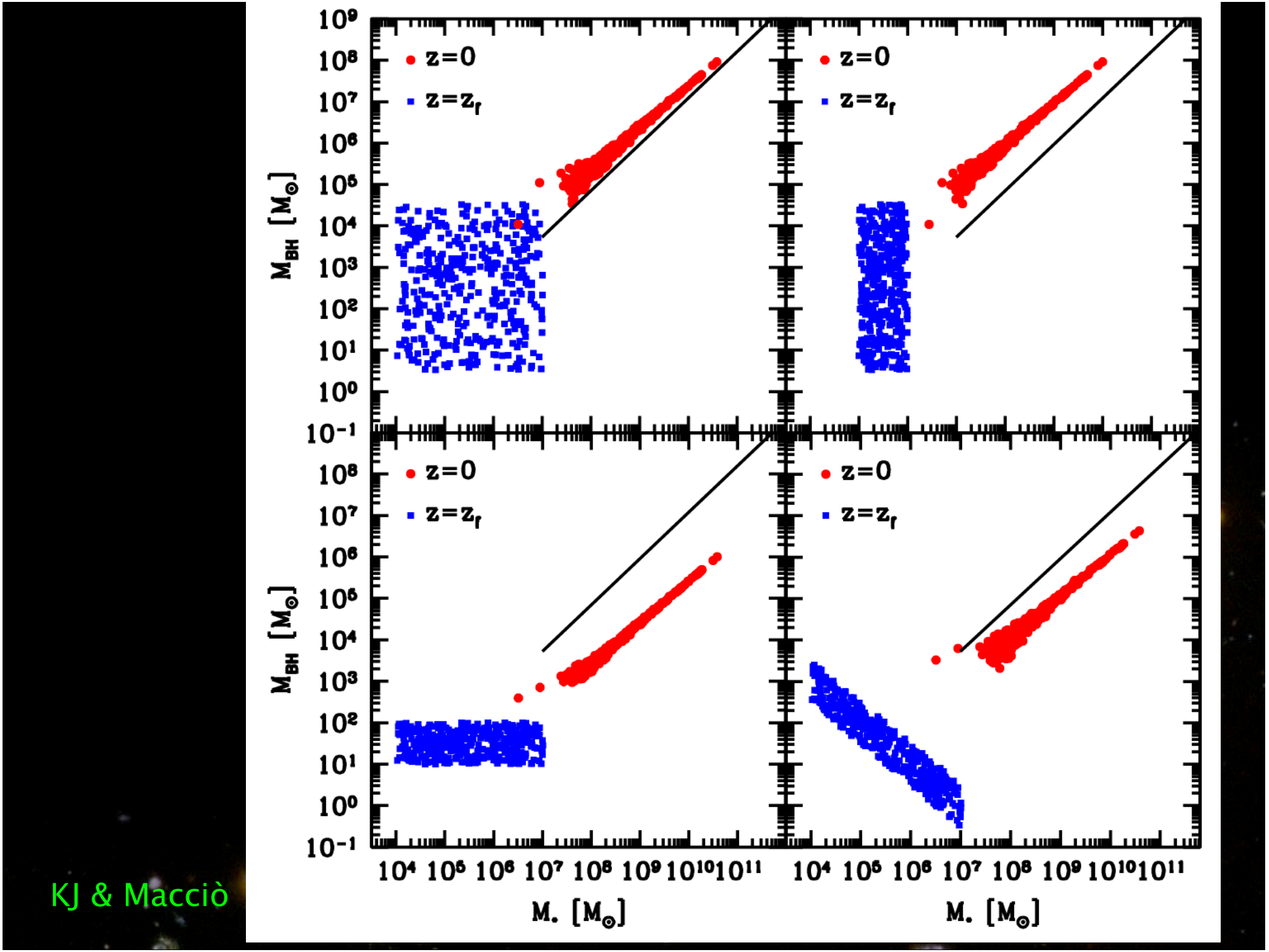
w/ Andrea Macciò (MPIA):

- dark matter merger tree (z=20…0)
- seeded with M_*, M_{BH}
- uncorrelated at large z

→ Produces very tight relation at z=0

KJ & Macciò, subm. to ApJL
arXiv:1006.0482

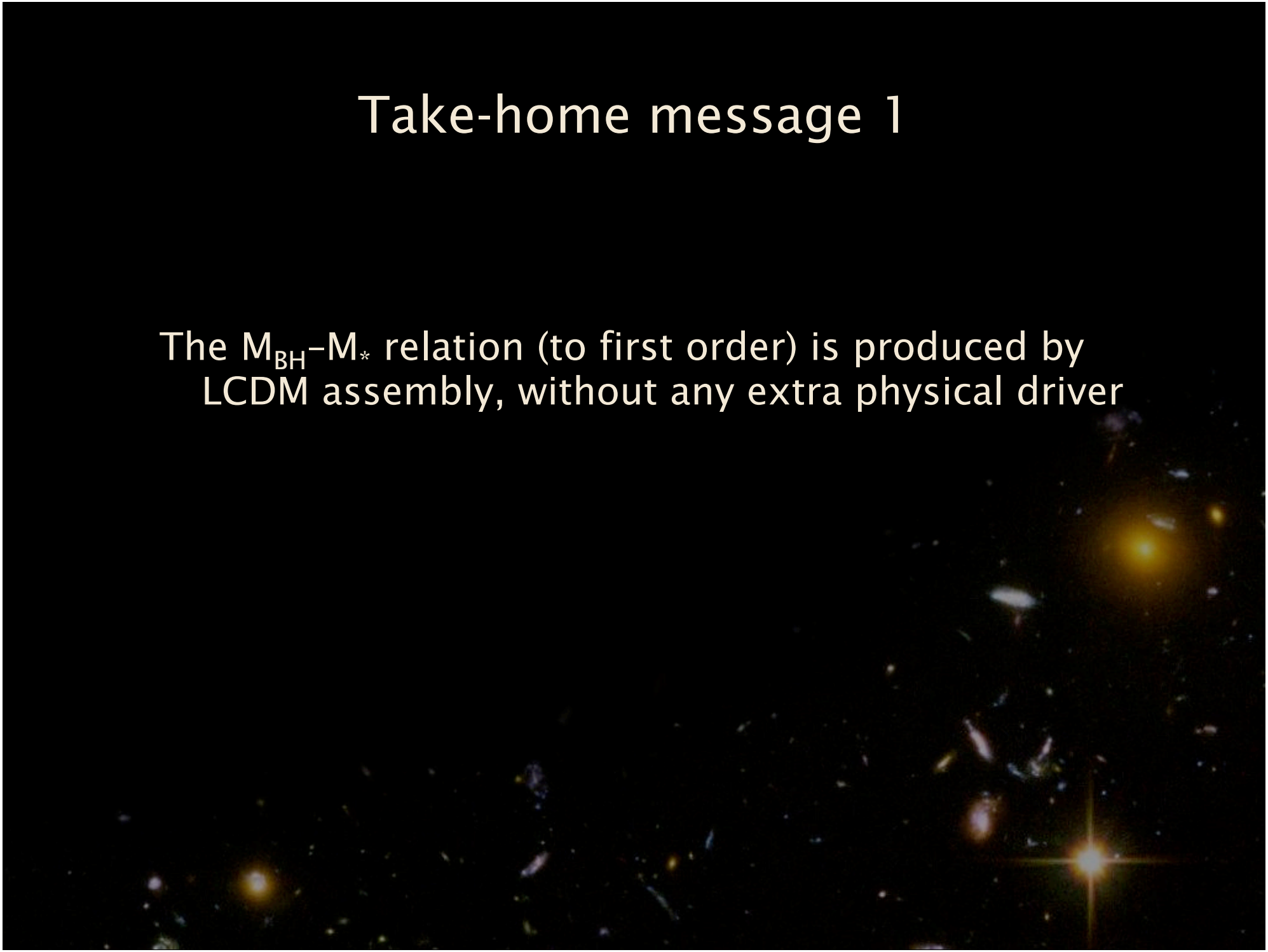



z=0
z=z_f
M_BH [M_⊙]
M. [M_⊙]
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^10
10^11

KJ & Macciò

Take-home message 1

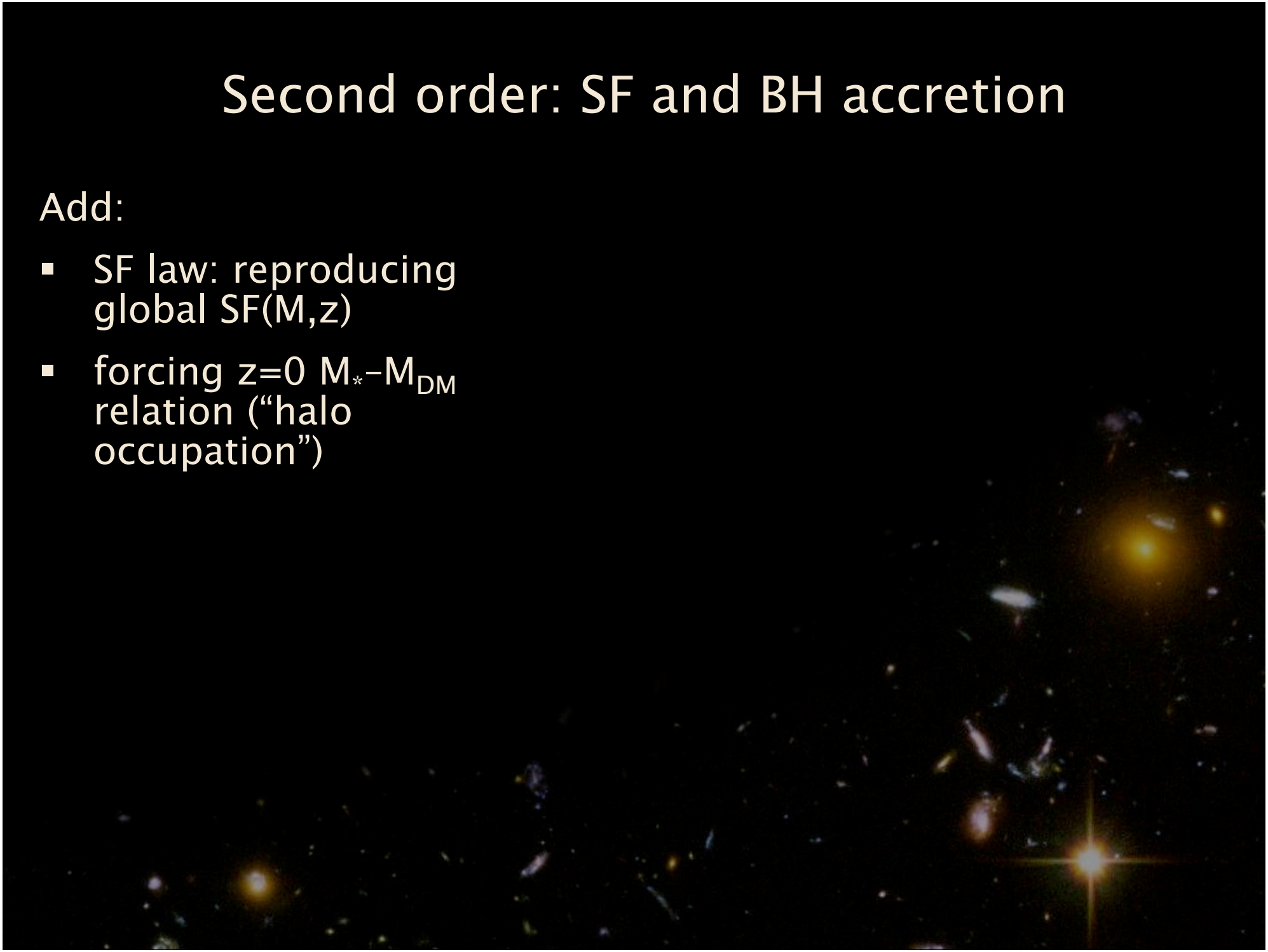
The M_{BH}–M_* relation (to first order) is produced by LCDM assembly, without any extra physical driver



Second order: SF and BH accretion

Add:

- SF law: reproducing global SF(M,z)
- forcing z=0 M_*–M_{DM} relation (“halo occupation”)



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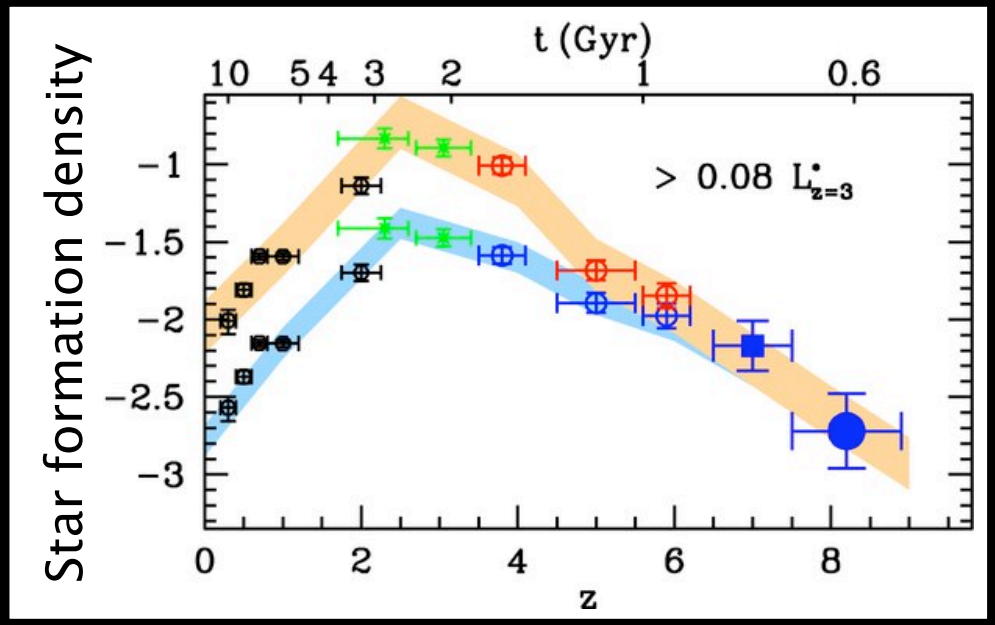
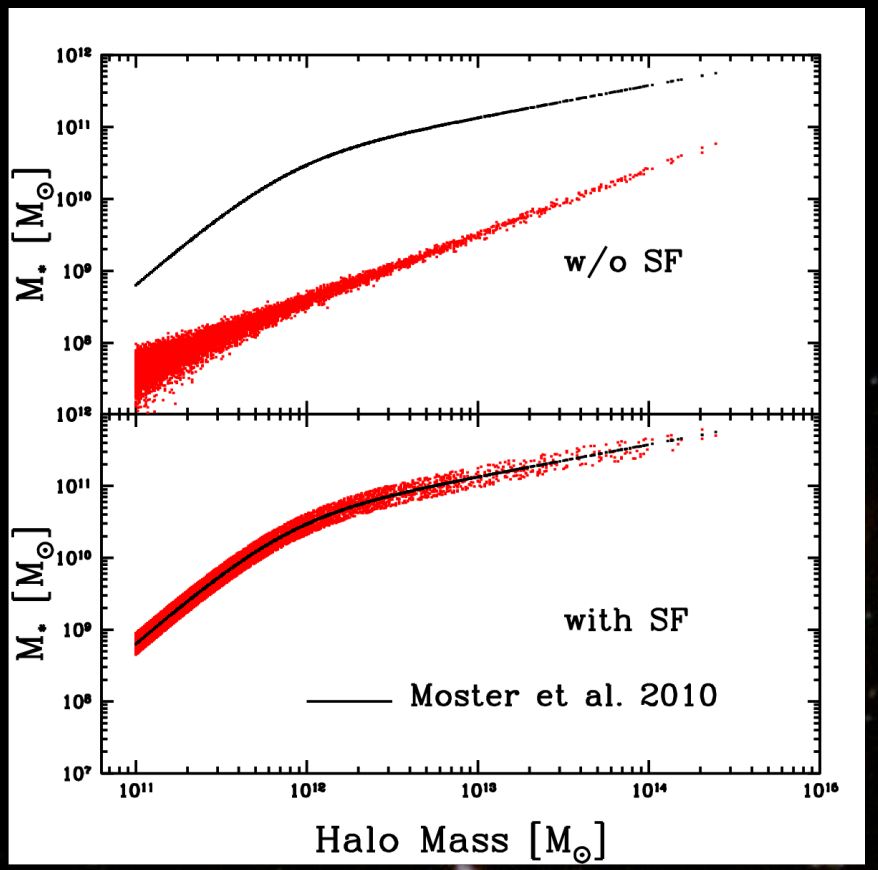


$dM_*(z)$ from star formation

Bouwens+ 2010b



Halo occupation distribution

Moster+ 2010

Second order: SF and BH accretion

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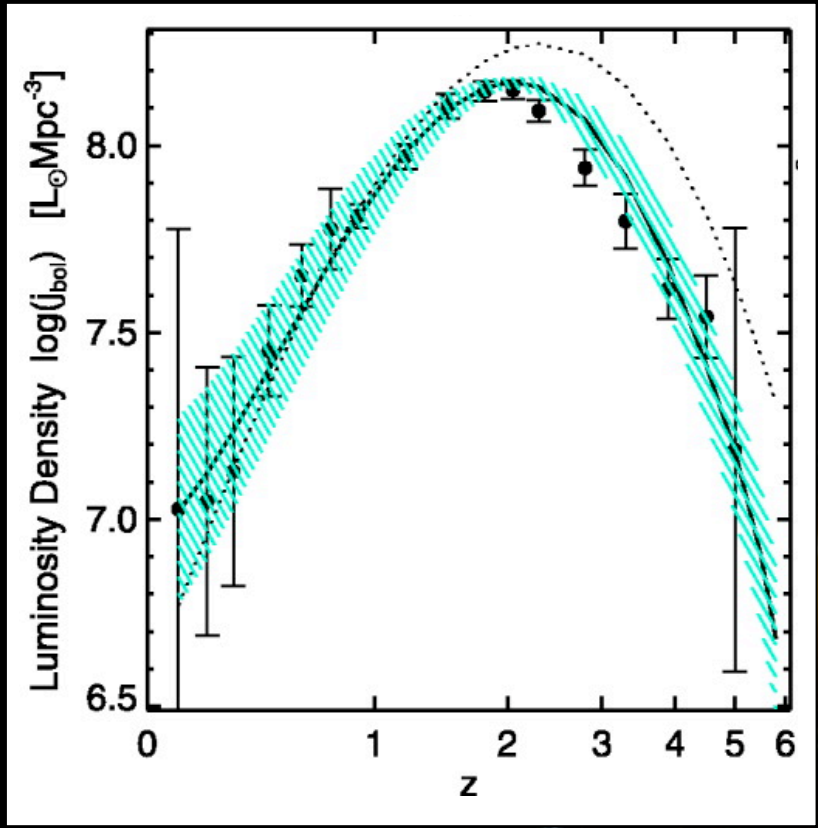
- BHA law: global BHA(z) + random doubling events (matching z=0 normalization)



$dM_{BH}(z)$ from BH accretion

Hopkins+ 2007

The origin of the BH-galaxy scaling relations

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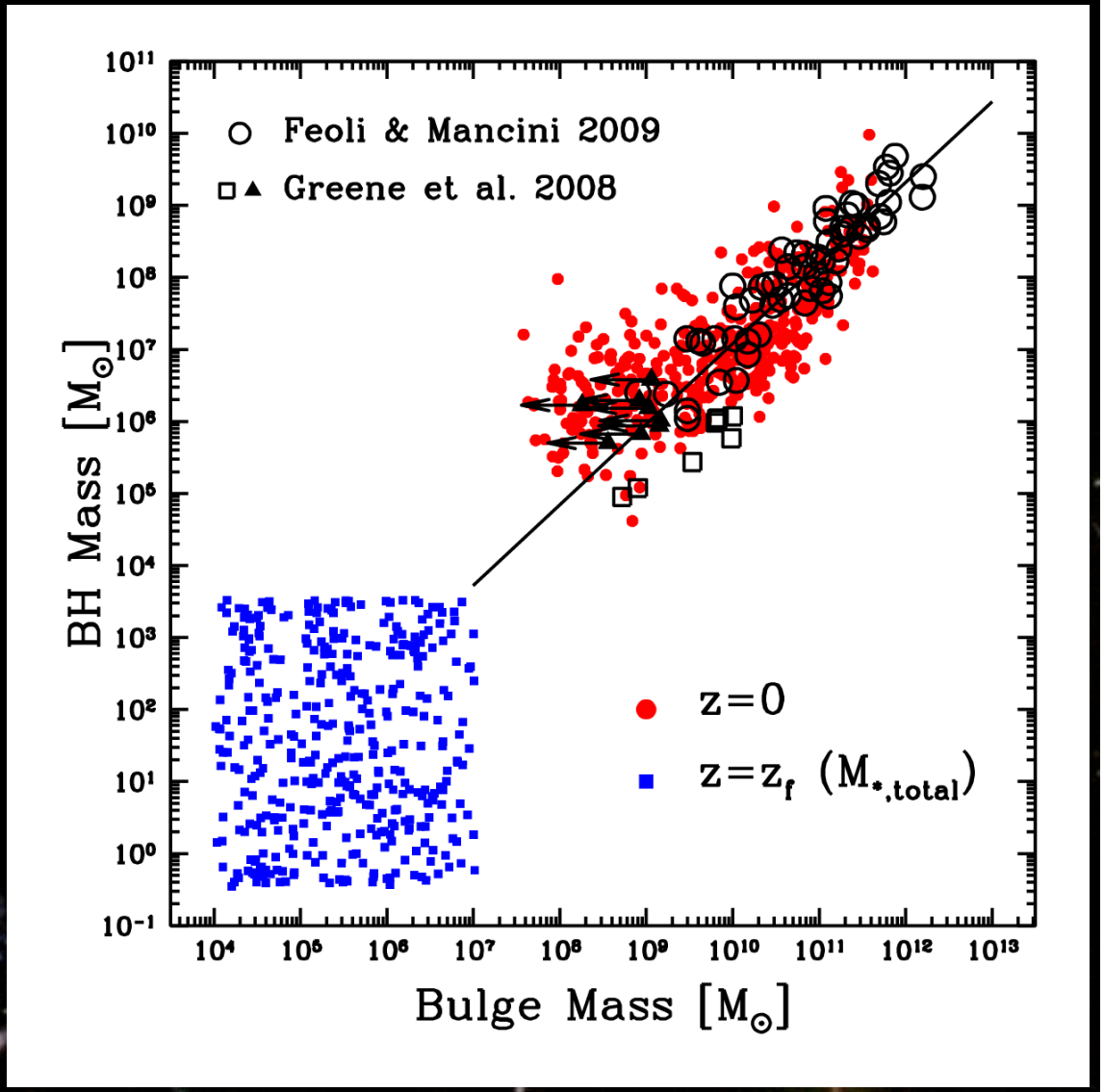
- disk → bulge mass conversion when merging



The origin of the BH-galaxy scaling relations

Add:

- SF law: reproducing global SF(M,z)
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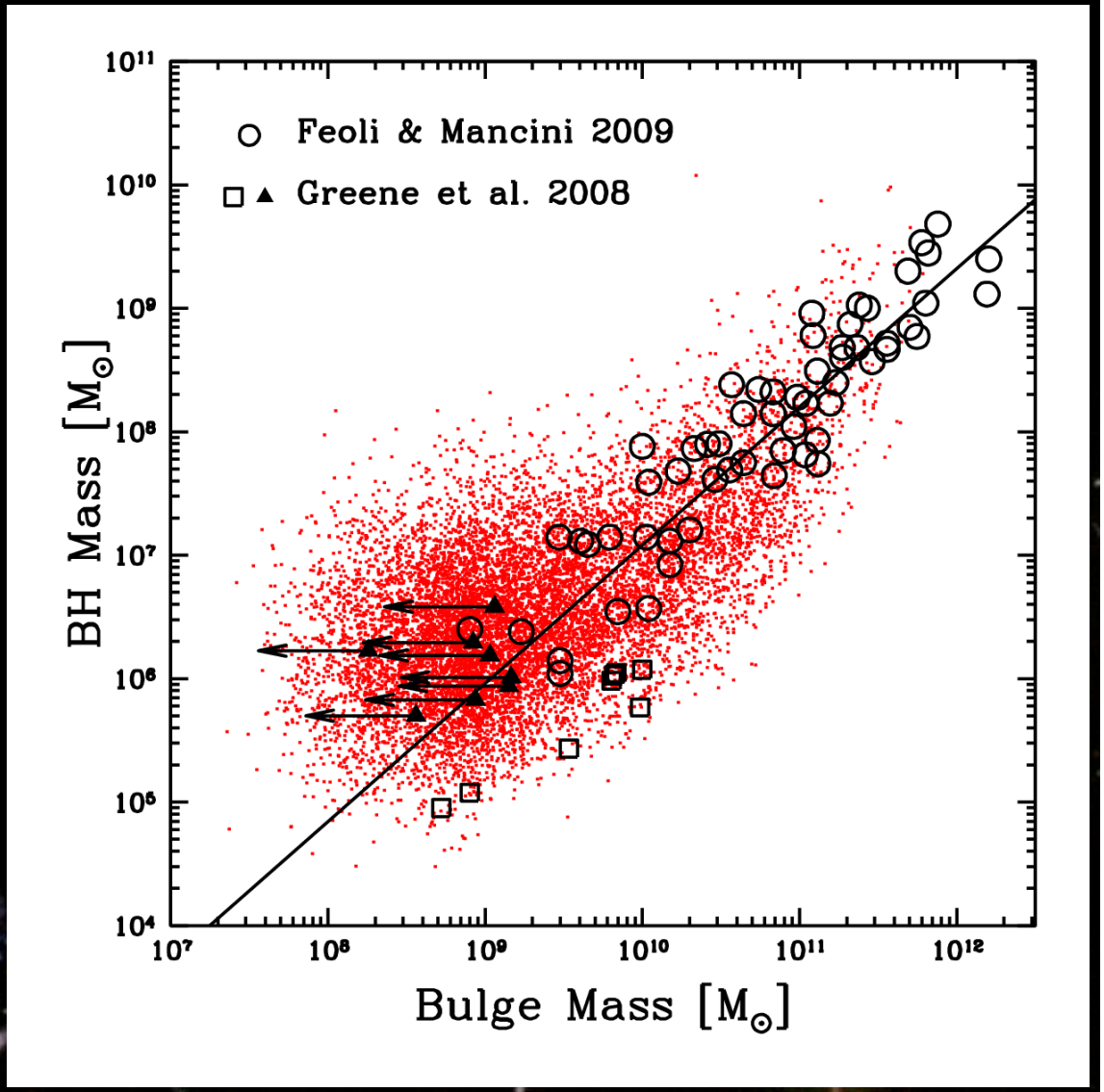
(6.5×10^6 → ~10.000 halos)



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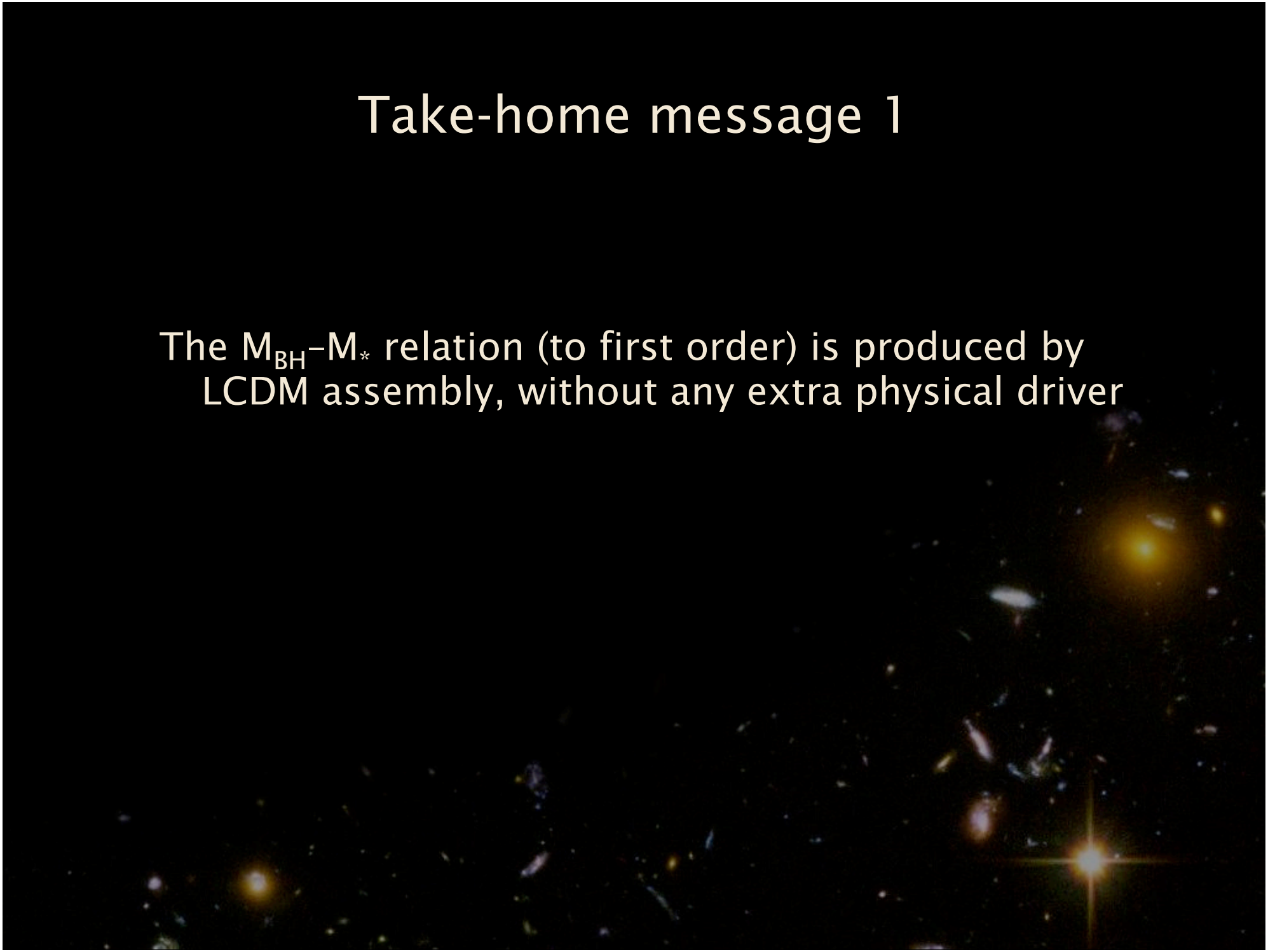
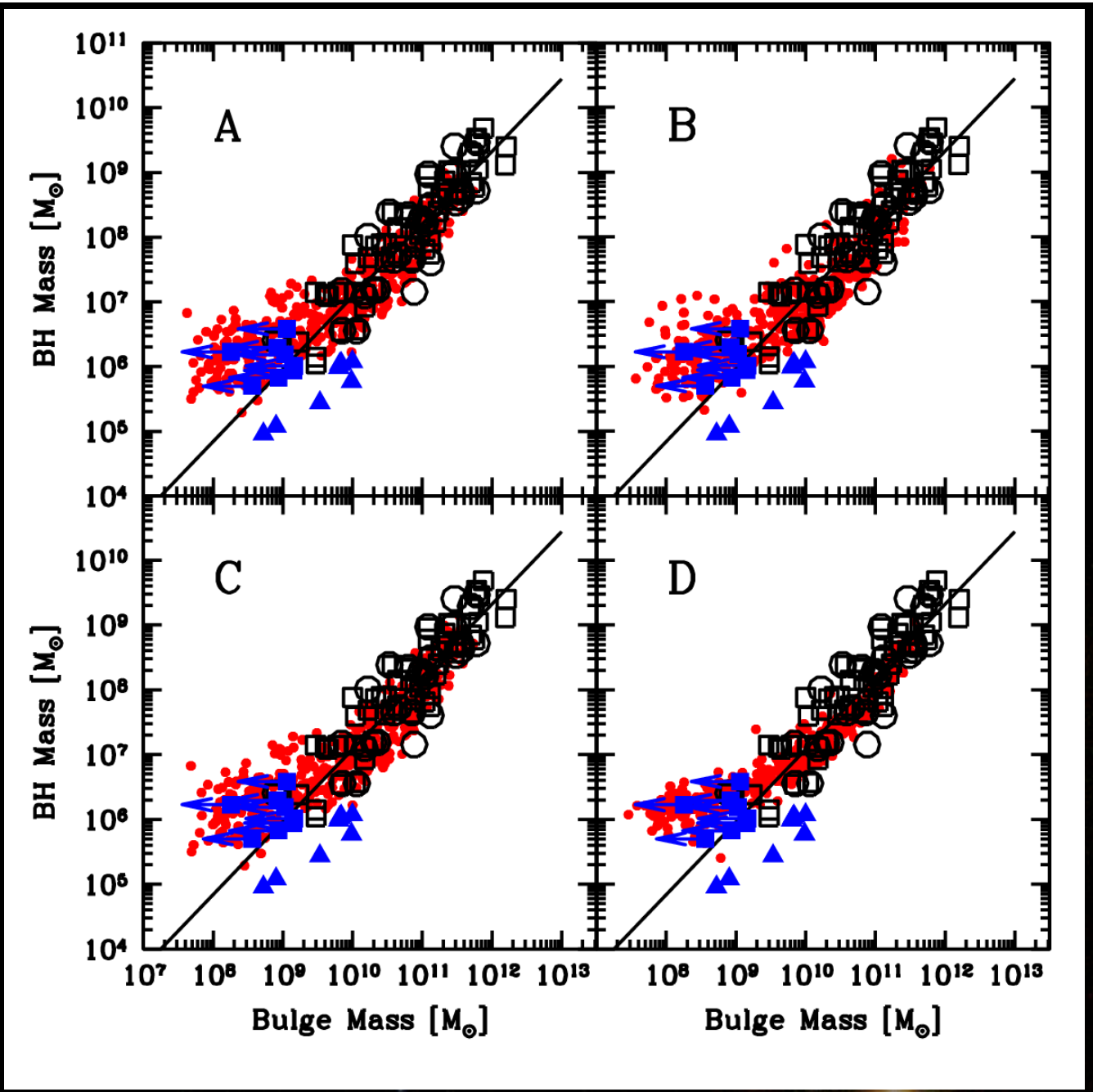


Take-home message(s) 2

- Exact shape/deviation from slope=1 due to 2nd order effects (SF cutoff at massive end → halo occupation)
- AGN feedback not needed (for scaling relations!), but possibly for 2nd order (on par to grav. heating, modified SN feedback)
- Evolution in M_{BH}/M_{bulge} at z>1: yes → early growth of BHs → so SF and BHA not strictly parallel
- Scatter evolution interesting diagnostics for seed BHs

~the end~

A: reference
B: SF(z) = const.
C: SF(z) = const. &
BHA(z) = const.
D: no random
component in BHA



Finer consequences

Merger assembly/averaging path:

- Correlation with BH applies to all components taking part in merger assembly (bulge, halo,…)
- Hopkins: Correlations of BH with bulge but not central stellar/gas density → not necessarily taking part in this assembly process
- Automatic: more massive BHs → more luminous AGN live in more massive halos (Alison Coil and others)

Batcheldor 2010: „M-sigma is only limiting case, upper limit“ → only if mergers not taken into account

Ric Davies: 40% of gals without mergers since z=2 → different mode of bulge formation, so not properly represented in our sims

Hidden parameters: short/mid-term merger history not modelled, has influence on morphology and extra parameters (radius, compactness, binding energy, etc.)