The Diversity of Growth Histories of Milky Way-mass Galaxies

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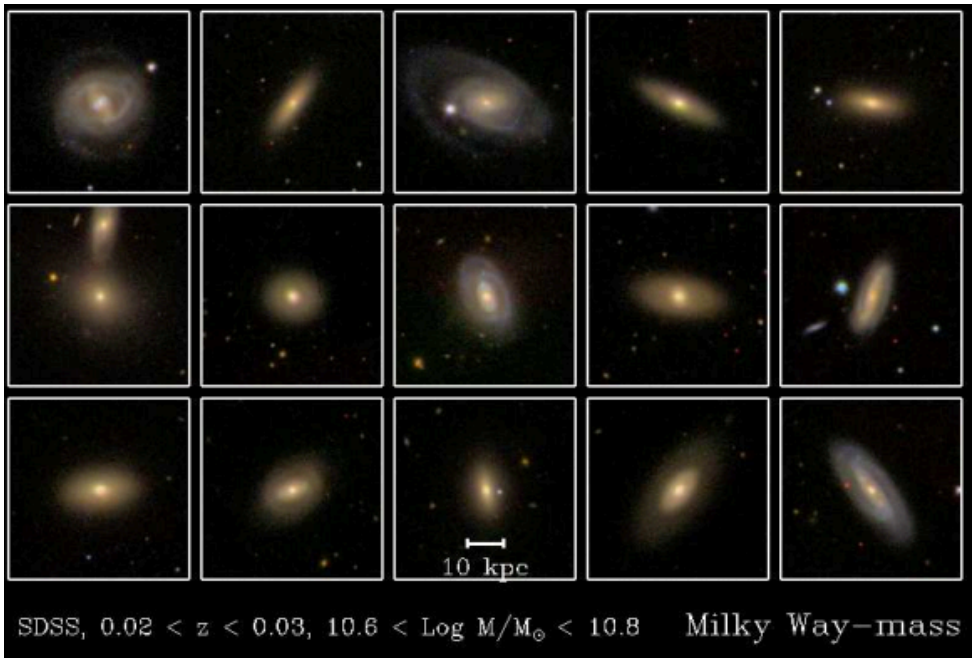
- **We see a large diversity of central galaxies with stellar masses 5-8x10^{10} solar masses at z = 0.**



Papovich et al. 2014

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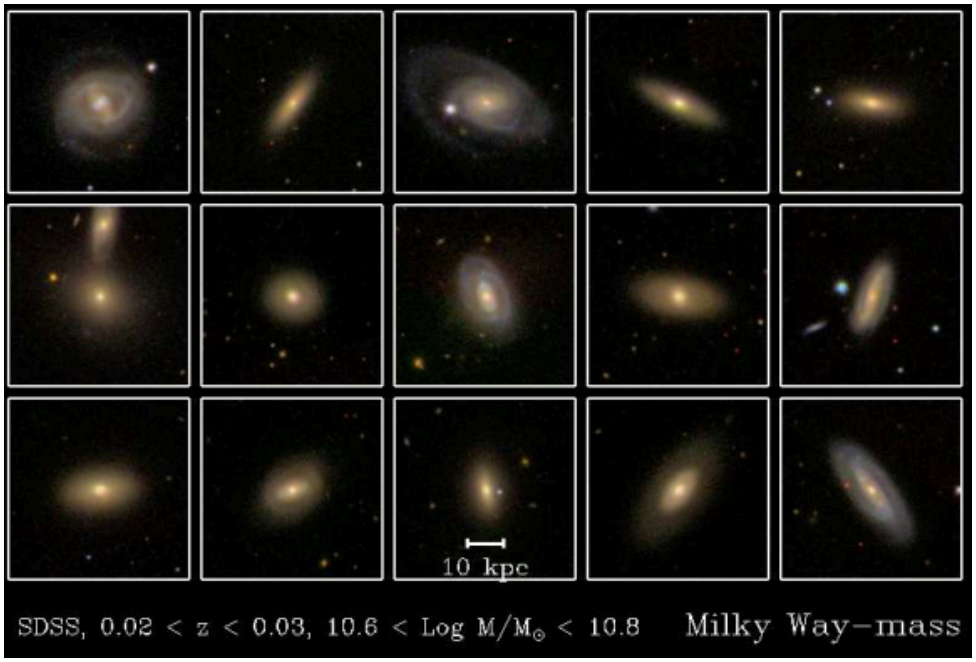
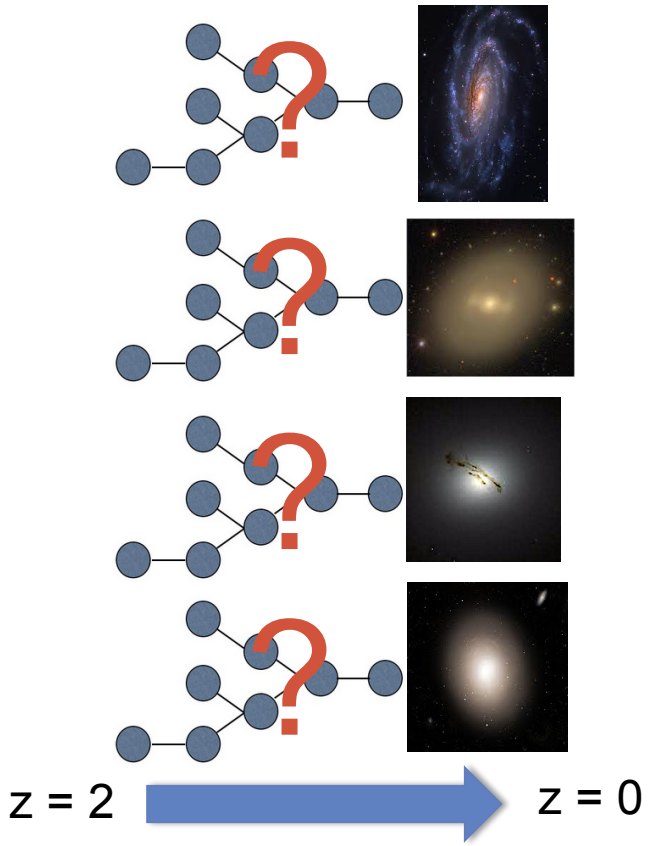


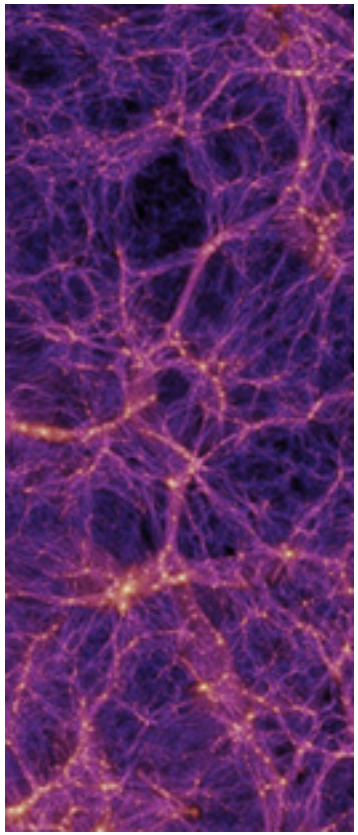
Papovich et al. 2014

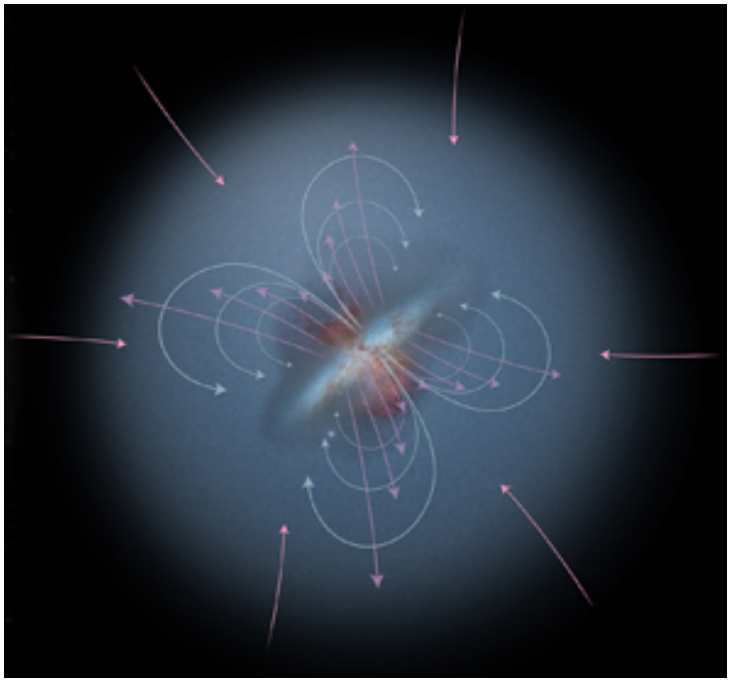


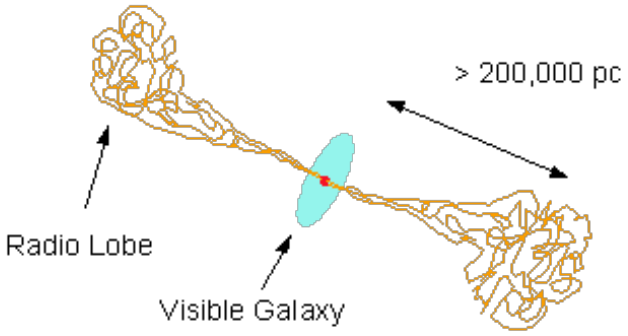
How have these galaxies grown and evolved since z ~ 2?

Henriques et al. 2015 Model

- **We use this model because:**
  - physics-based model
  - best match to SMF and red/blue fractions to date

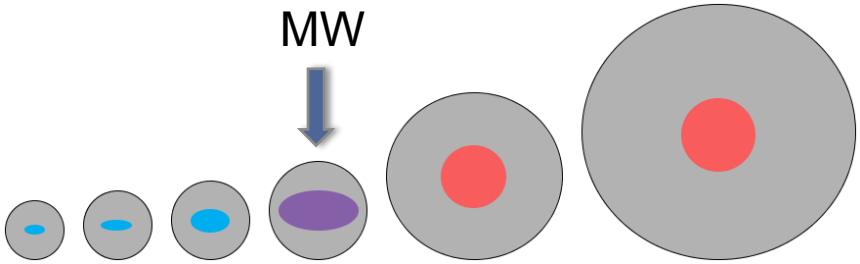




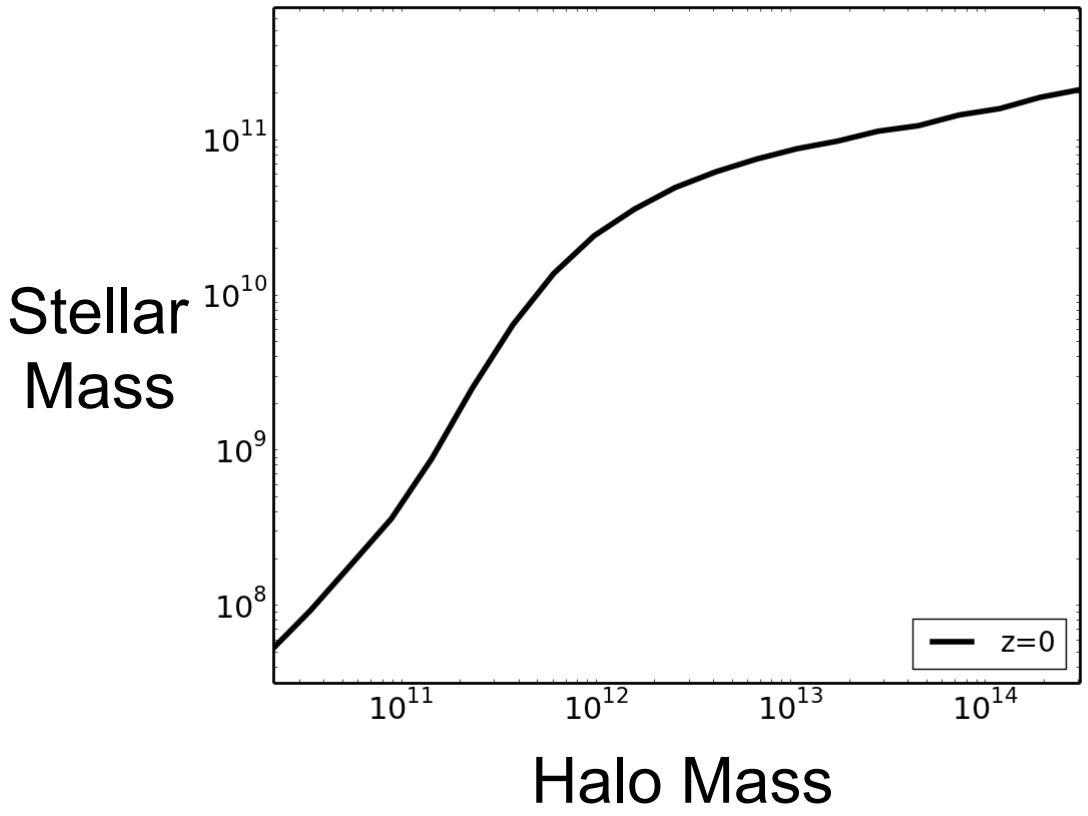


(Only use MR, we've checked with MRII - results are robust!)

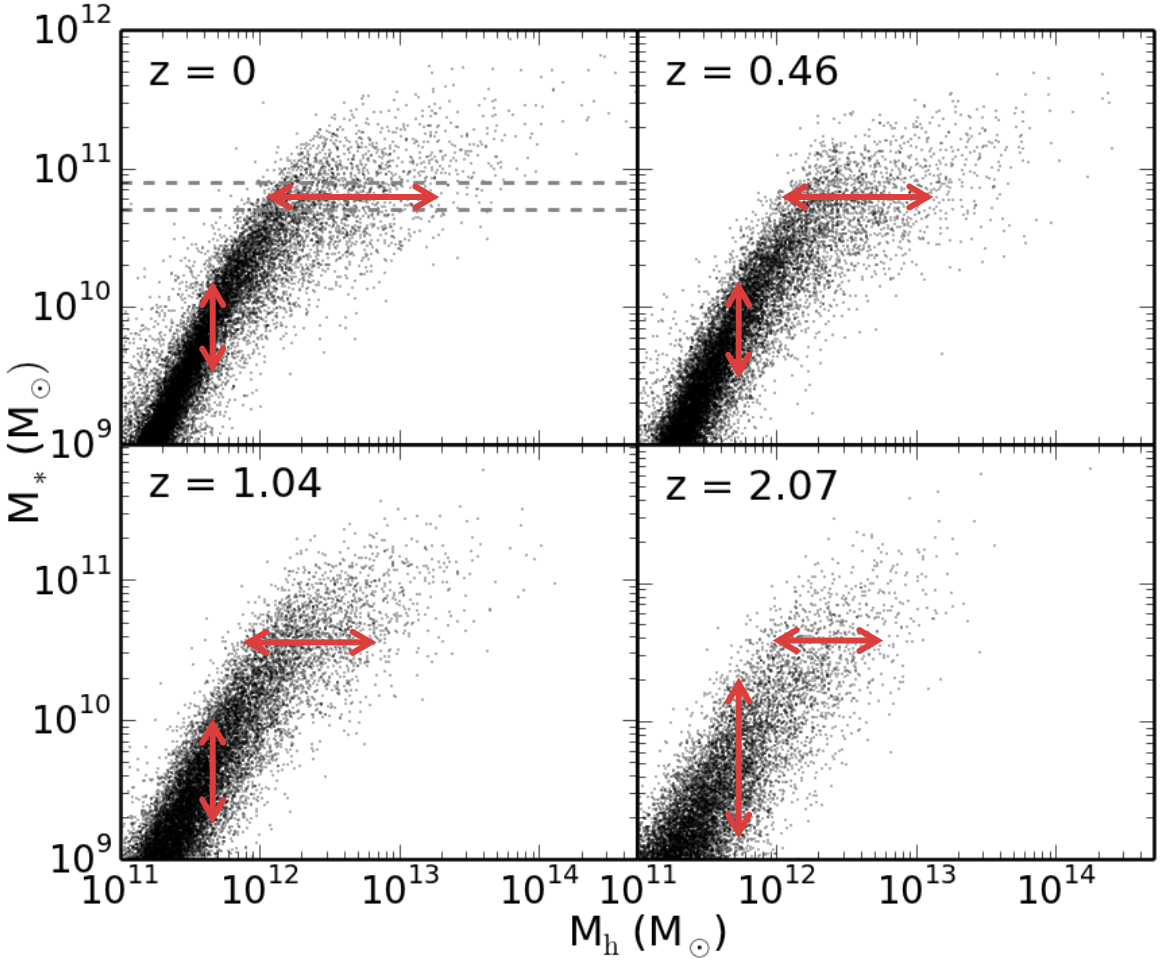
Less massive,
typically star forming



More massive,
typically quiescent



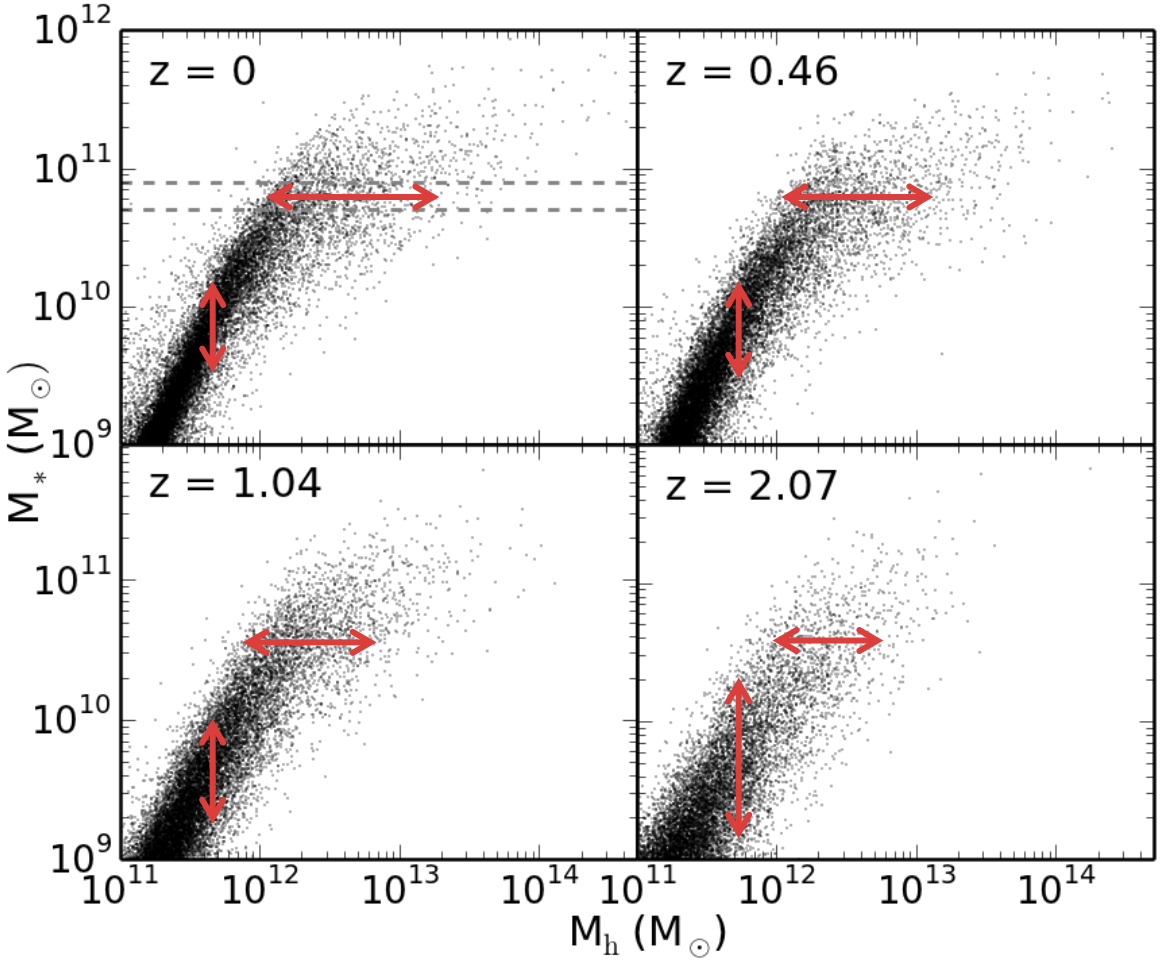
- **Significant scatter in stellar mass-halo mass relation results in no unique relationship between stellar mass and halo mass**

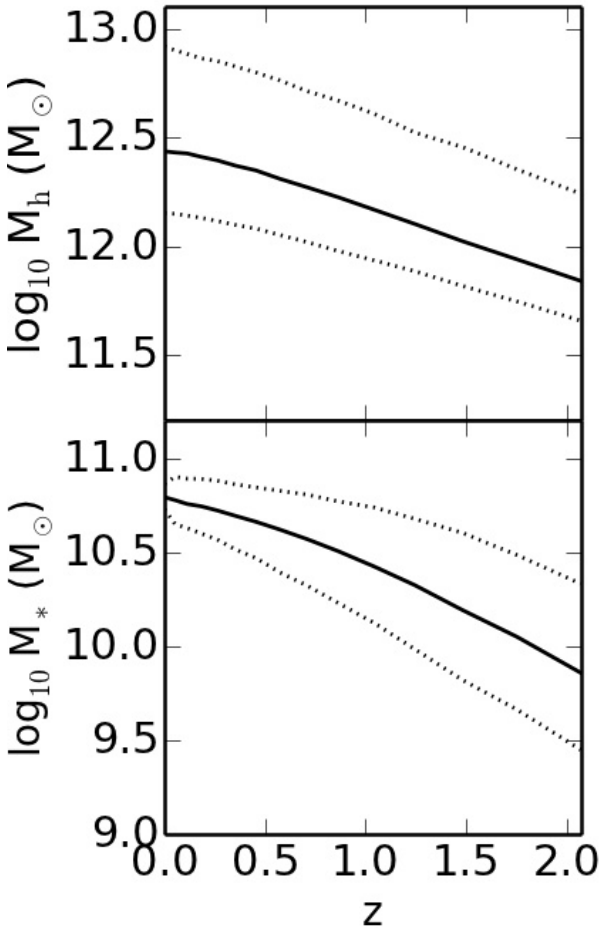


Henriques et al. 2015 model

- **Significant scatter in stellar mass-halo mass relation results in no unique relationship between stellar mass and halo mass**

→ Real consequences for growth histories

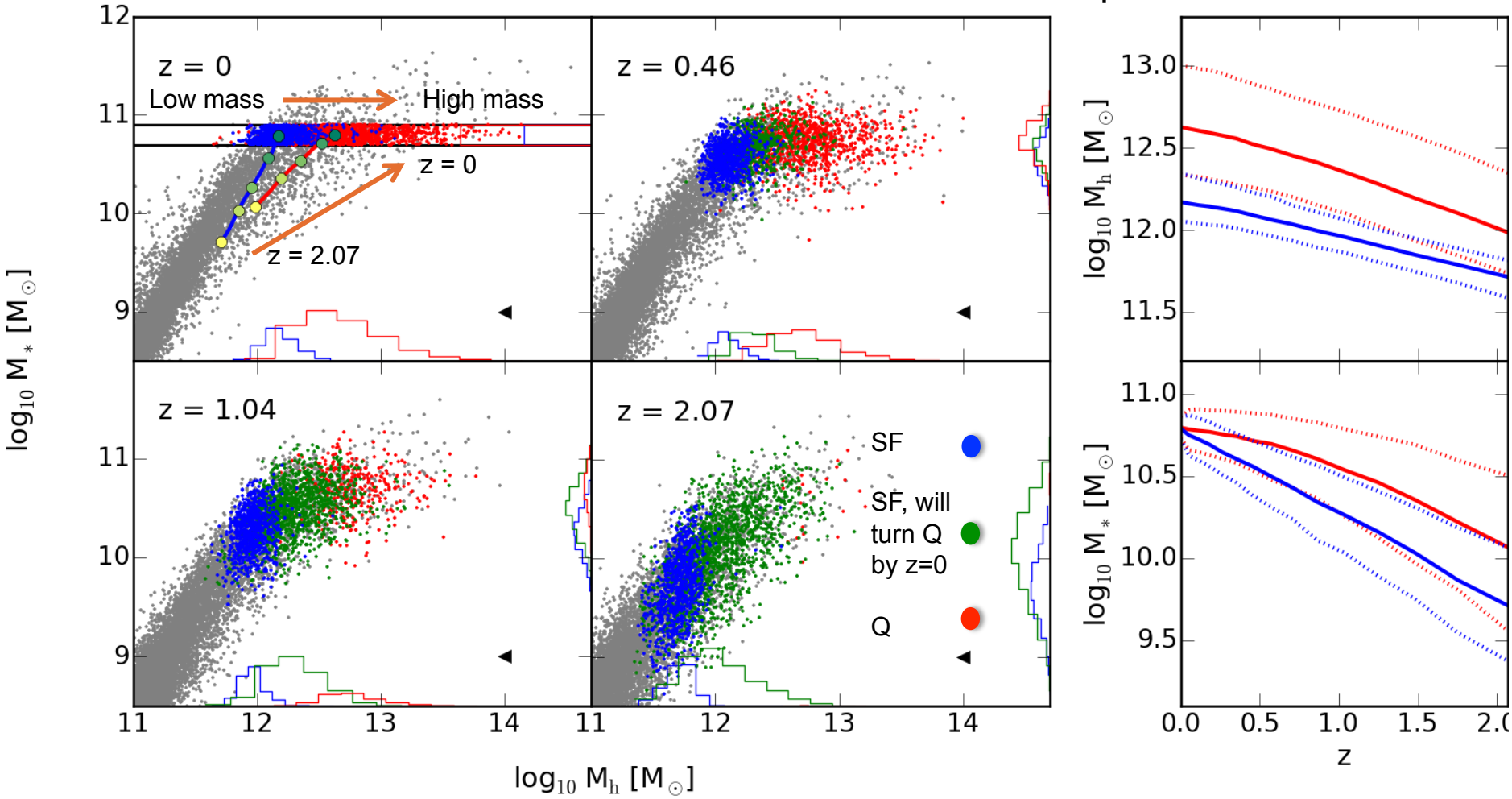




Henriques et al. 2015 model

- **Milky Way-mass galaxy progenitor tracks split by sSFR at z = 0.**

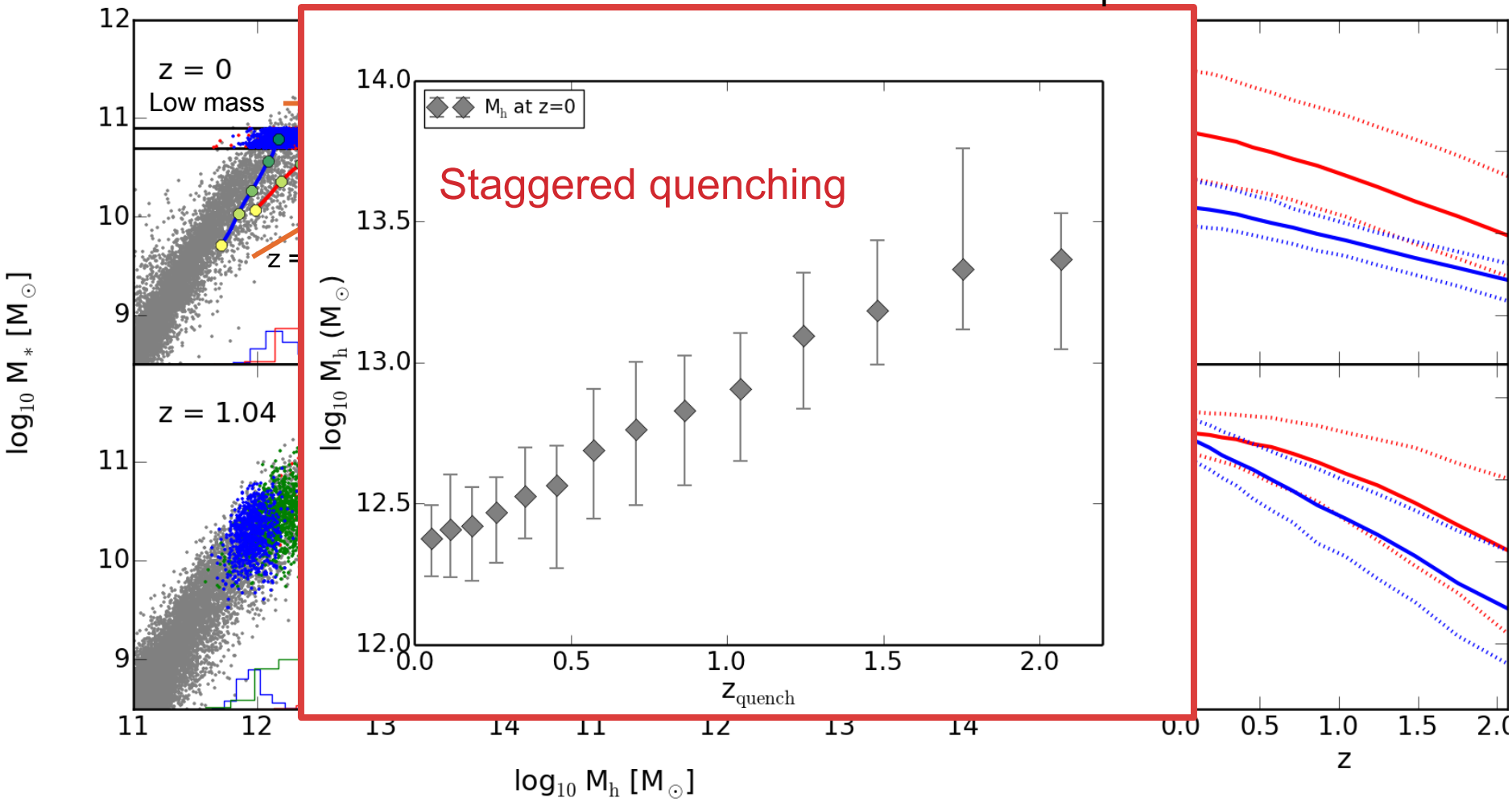
Henriques et al. 2015 model



- **Quiescent galaxies have different mass tracks than star-forming galaxies → contributes to scatter in growth histories**

- **Milky Way-mass galaxy progenitor tracks split by sSFR at z = 0.**

Henriques et al. 2015 model



- **Quenching time correlates with present day halo mass**

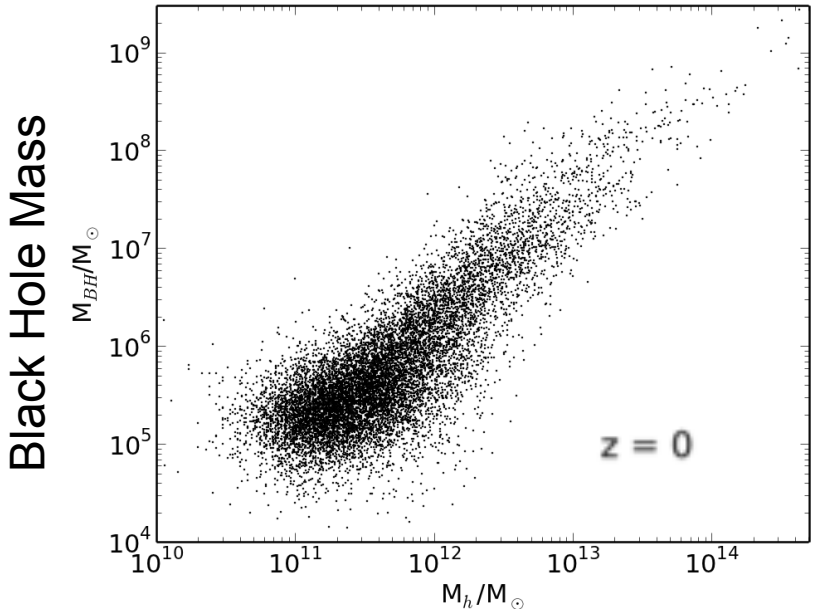
The Quenching Mechanism in H15

Heating

AGN >> function of M_h and M_{BH}

Cooling

2 cooling regimes >> function of M_h



Henriques et al. 2015 model

- **Quenching is a function of black hole mass and halo mass!**

The Quenching Mechanism in H15

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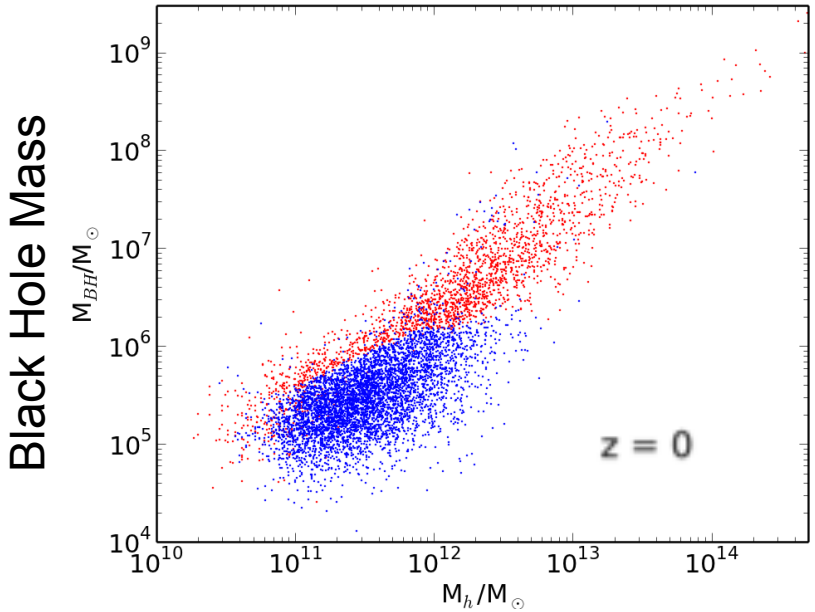

Henriques et al. 2015 model

- **Sharp division between star-forming and quiescent galaxies**

The Quenching Mechanism in H15

Heating

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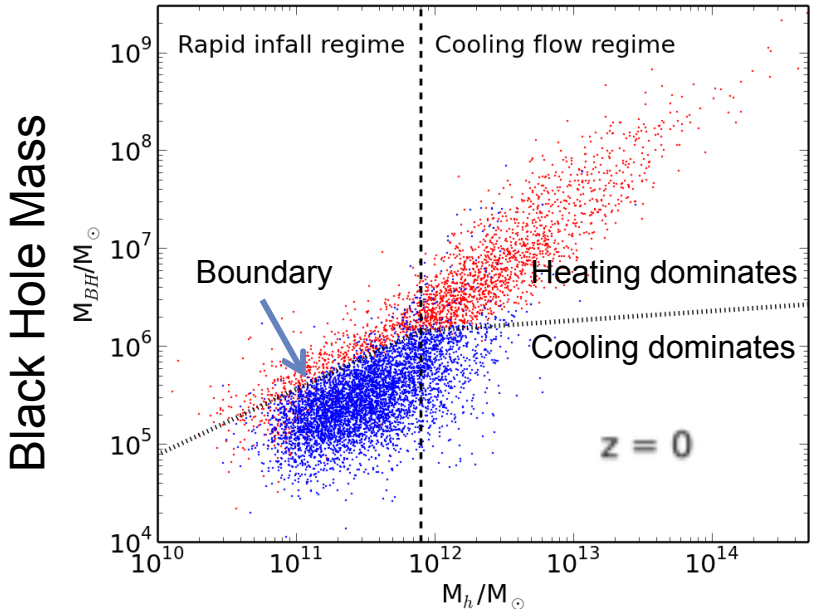
2 cooling regimes >> function of M_h



Halo Mass

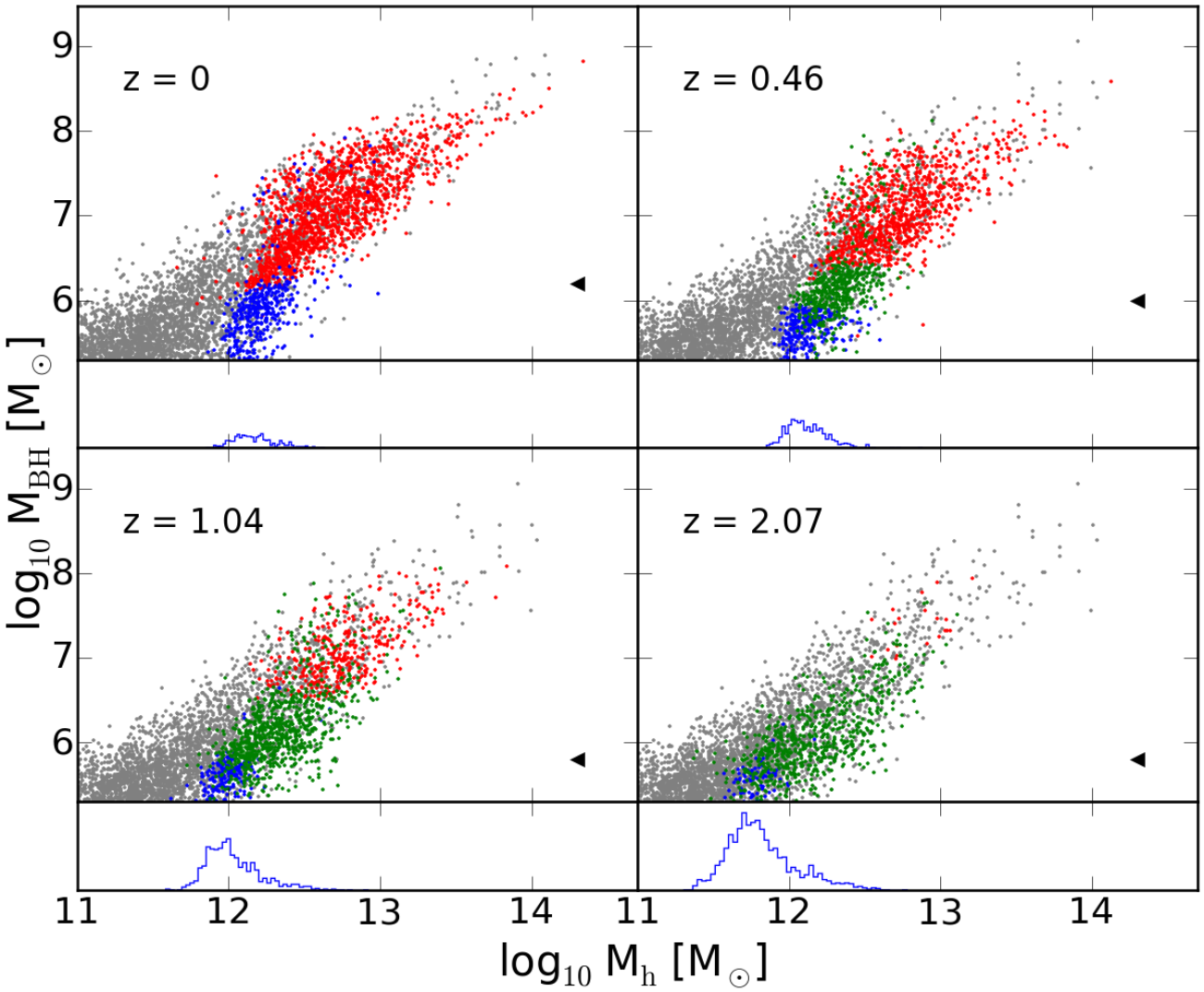
Henriques et al. 2015 model

- **Joint consideration of halo and black hole mass is necessary in order to account for quenching**

Most MWs quench at cooling flow regime (not rapid infall)

Evolving heating-cooling boundary + Black hole growth → Quenching

Henriques et al. 2015 model



SF

SF, will turn Q by z=0

Q

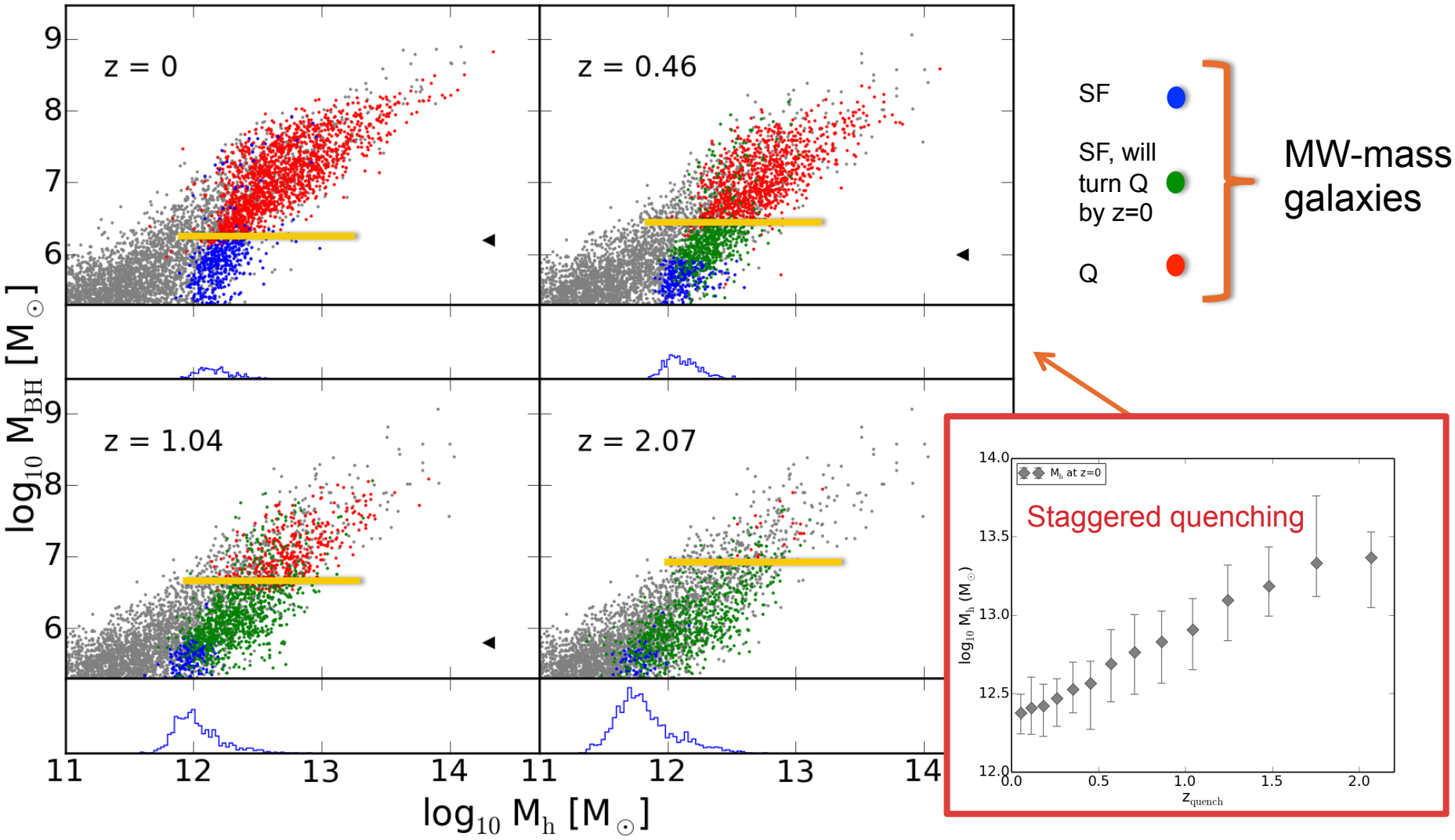
MW-mass galaxies

Zero-mass black holes

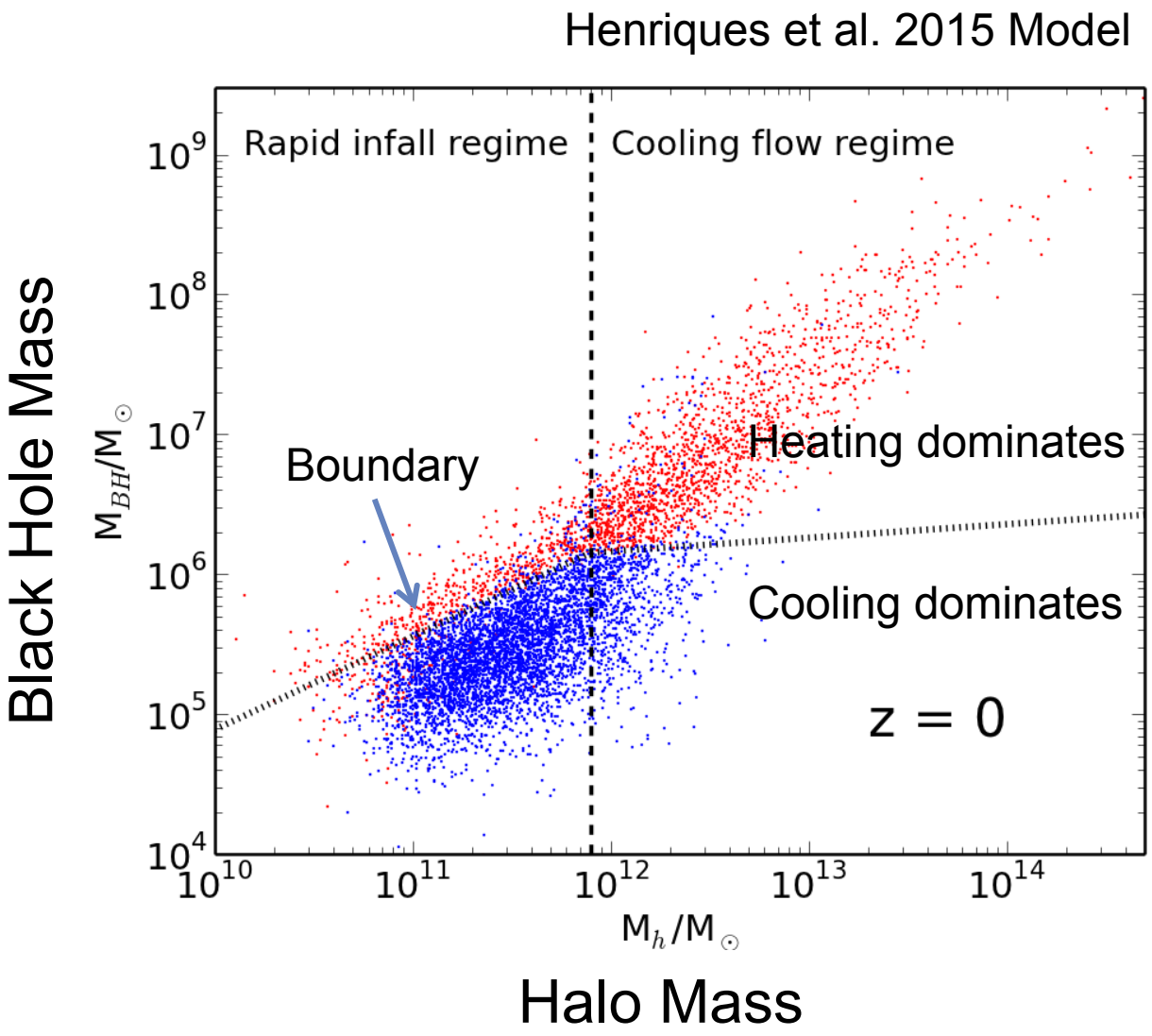
Most MWs quench at cooling flow regime (not rapid infall)

Evolving heating-cooling boundary + Black hole growth → Quenching

Henriques et al. 2015 model



Question: Is this heating-cooling boundary observed?



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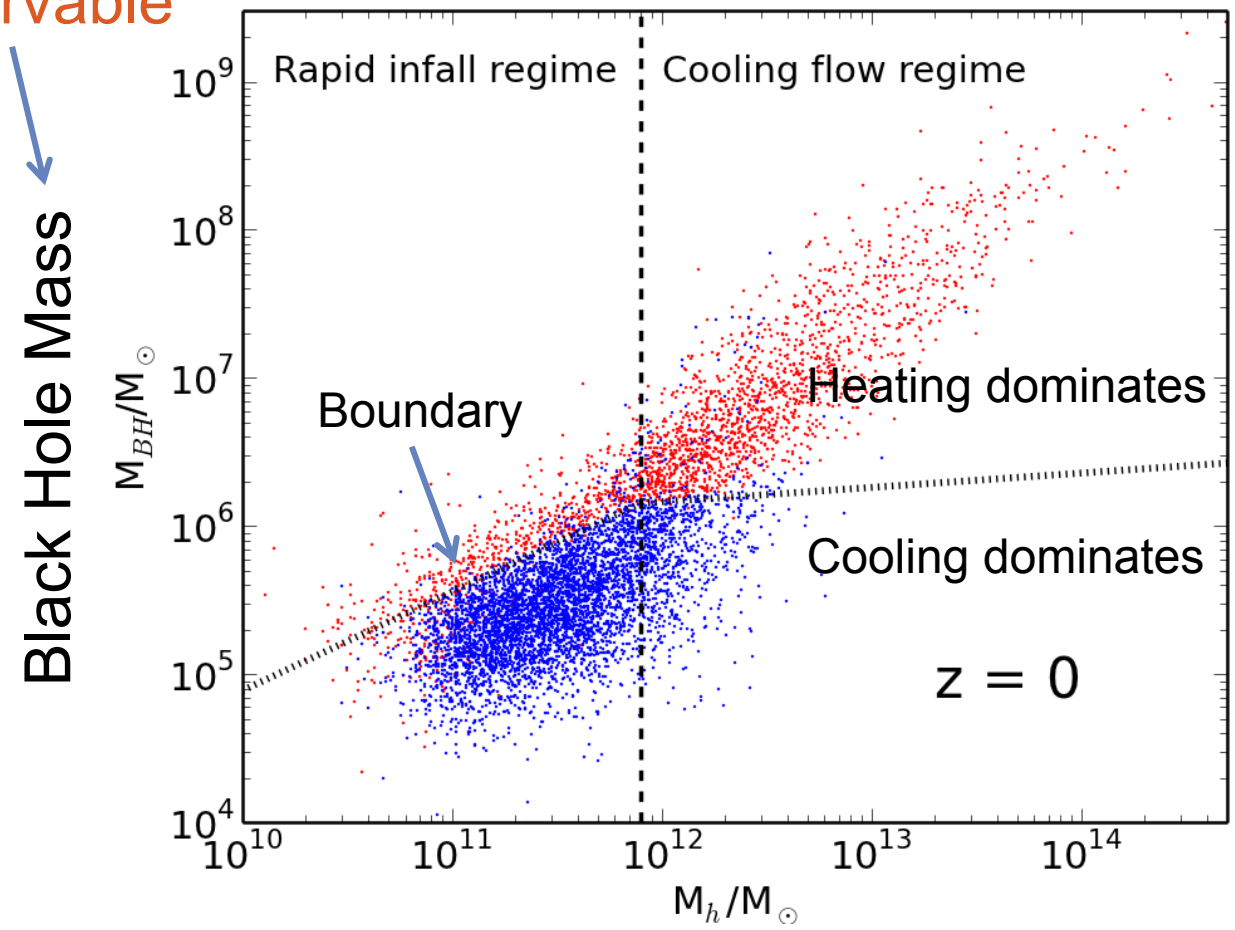
Henriques et al. 2015 Model

Observable

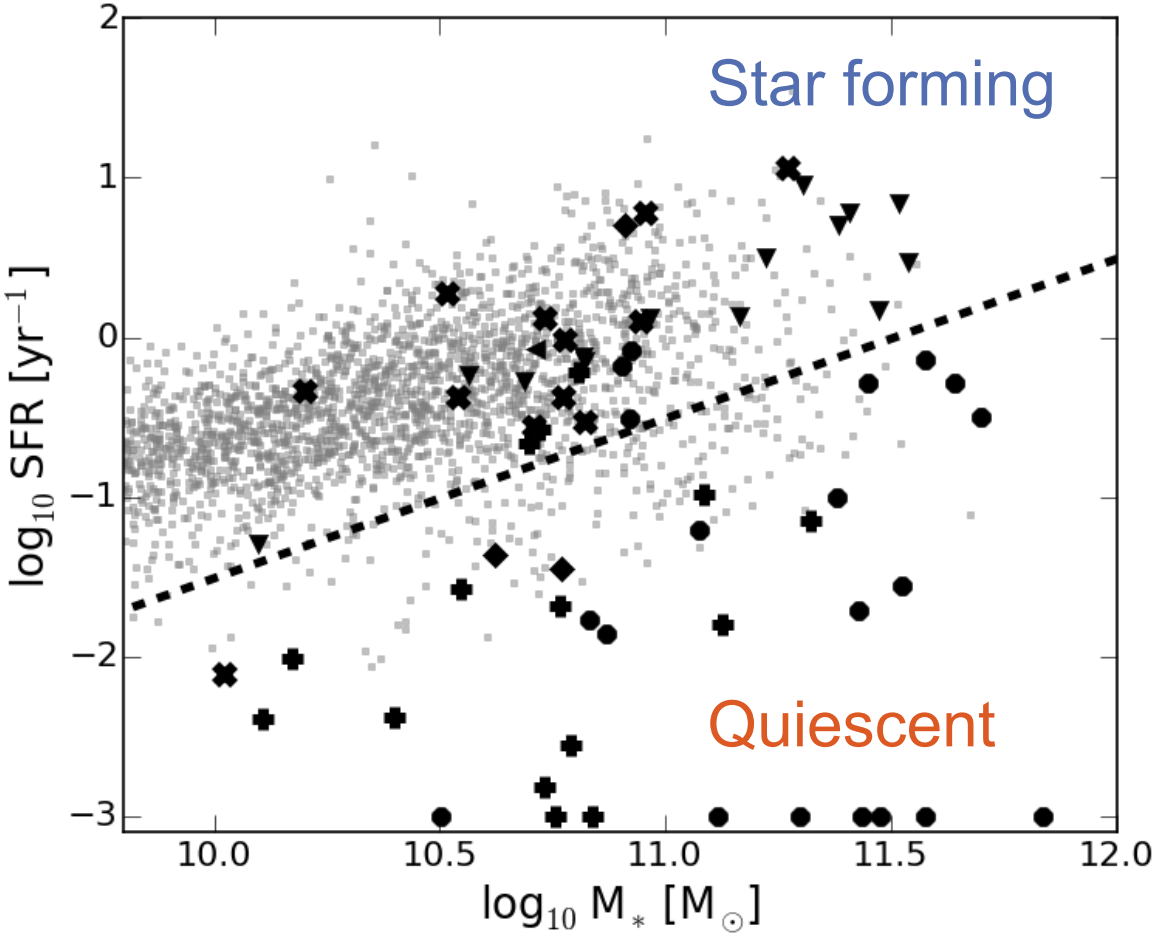


Halo Mass

Not very observable

Compiled:

- **K band 2MASS luminosities => Stellar Mass**
- **Black hole masses => Dynamically detected, masers, reverberation mapping**
- **60 micron IRAS luminosities => SFR**



Central galaxies only

x – pseudobulges
+ – bulges
o – ellipticals
} Kormendy & Ho 2013

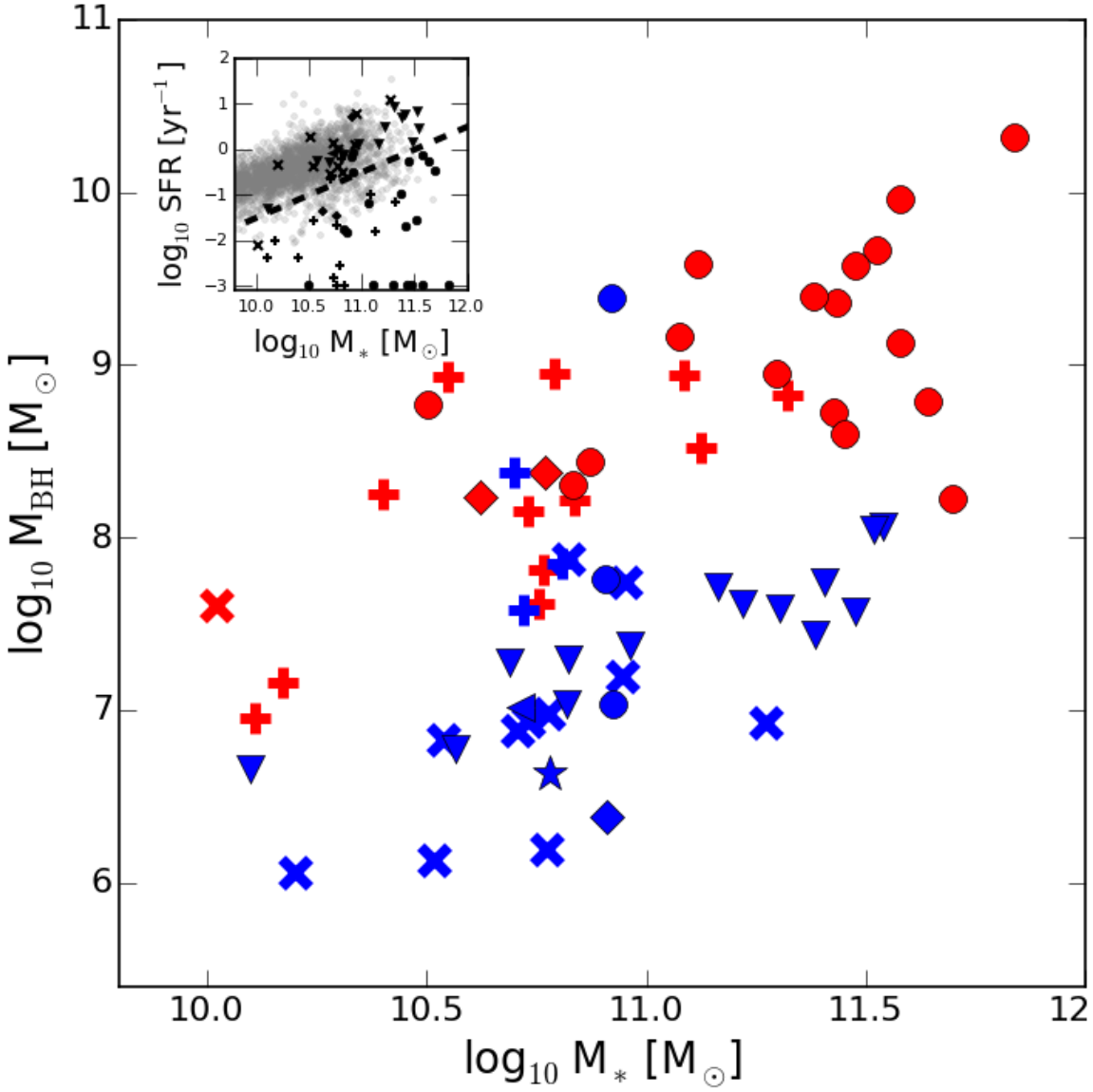
v – reverb. Mapped } Bentz & Katz 2015

< – masers } Kuo et al. 2011

diamonds – dynamically detected } Graham & Scott 2013

. – other galaxies

66 galaxies



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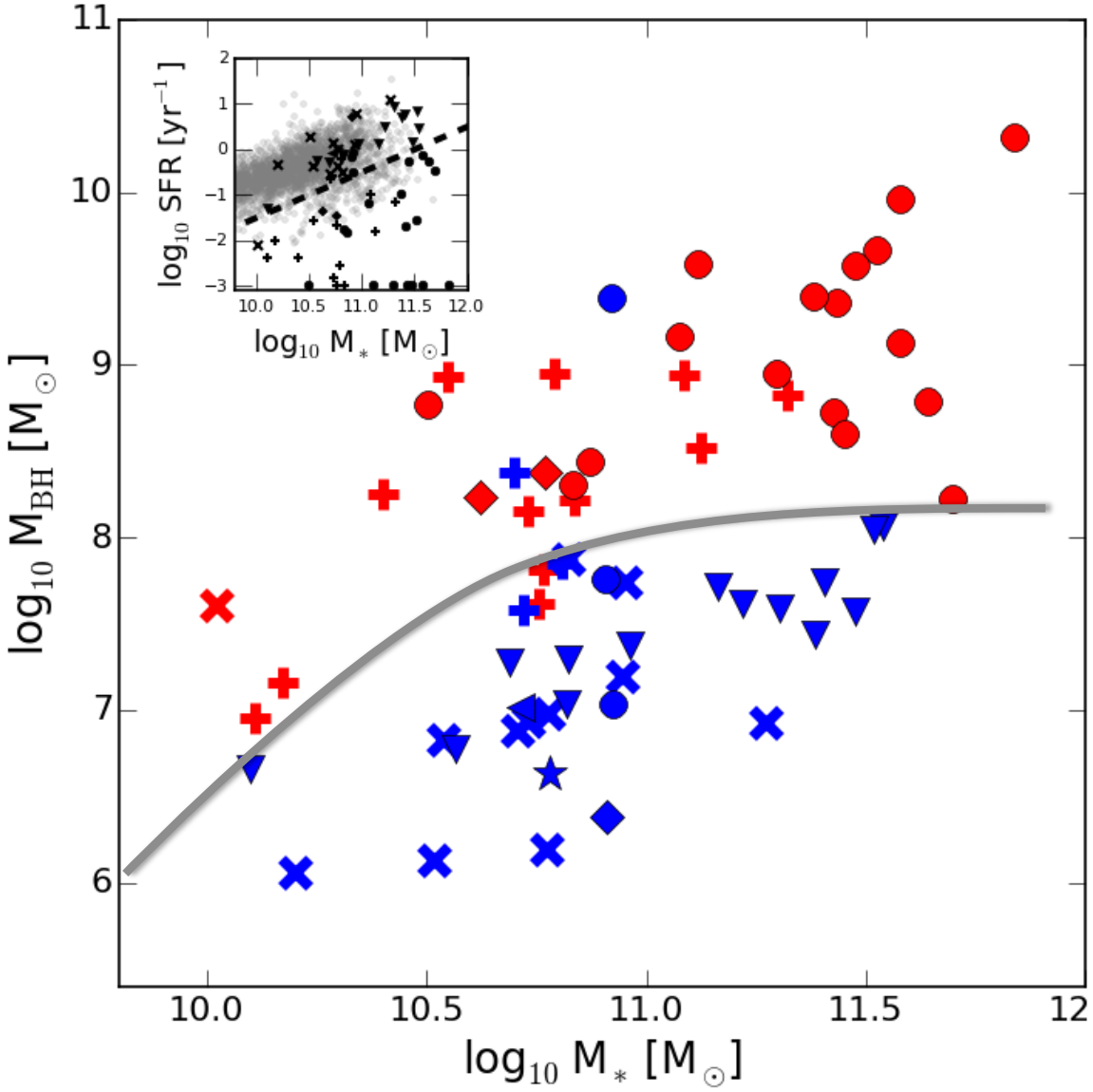

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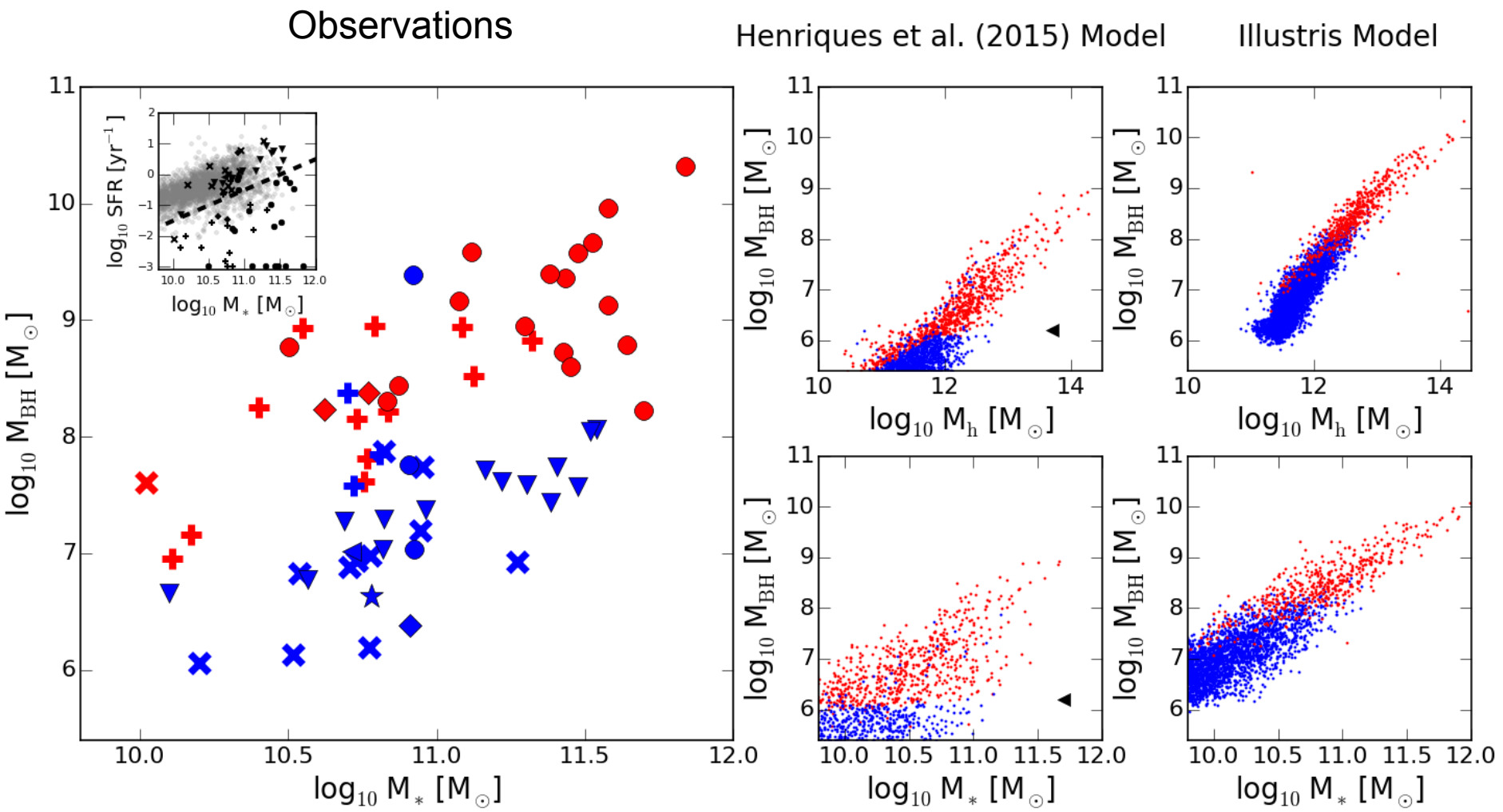
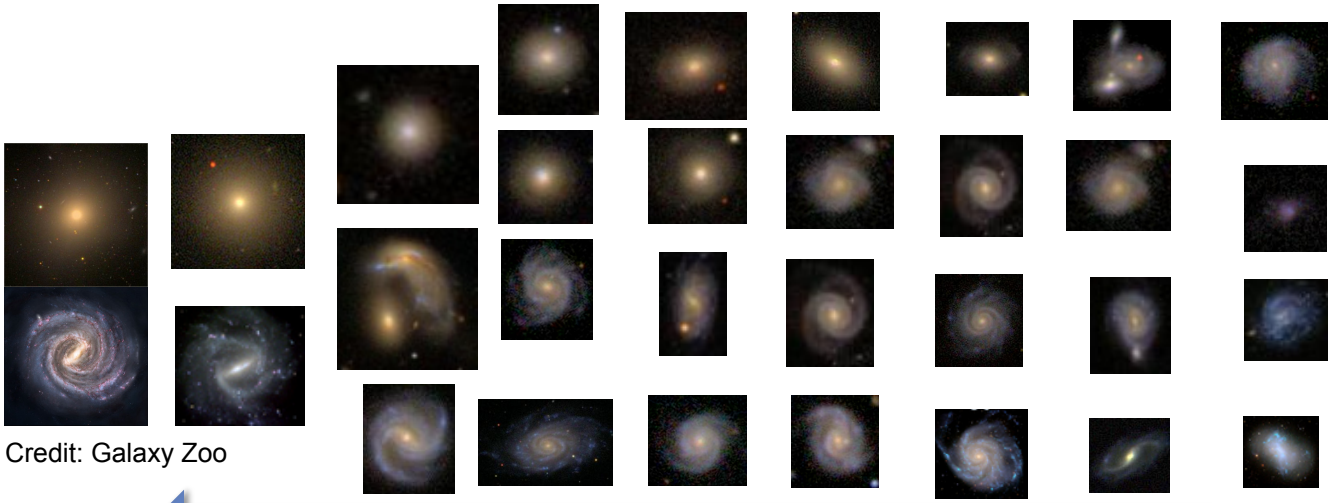

Observations
Henriques et al. (2015) Model
Illustris Model
log10 MBH [M⊙]
log10 M* [M⊙]
log10 Mh [M⊙]
log10 SFR [yr−1]

Summary



We have shown that:

- **Milky Way-mass galaxies have a diversity of growth histories.**

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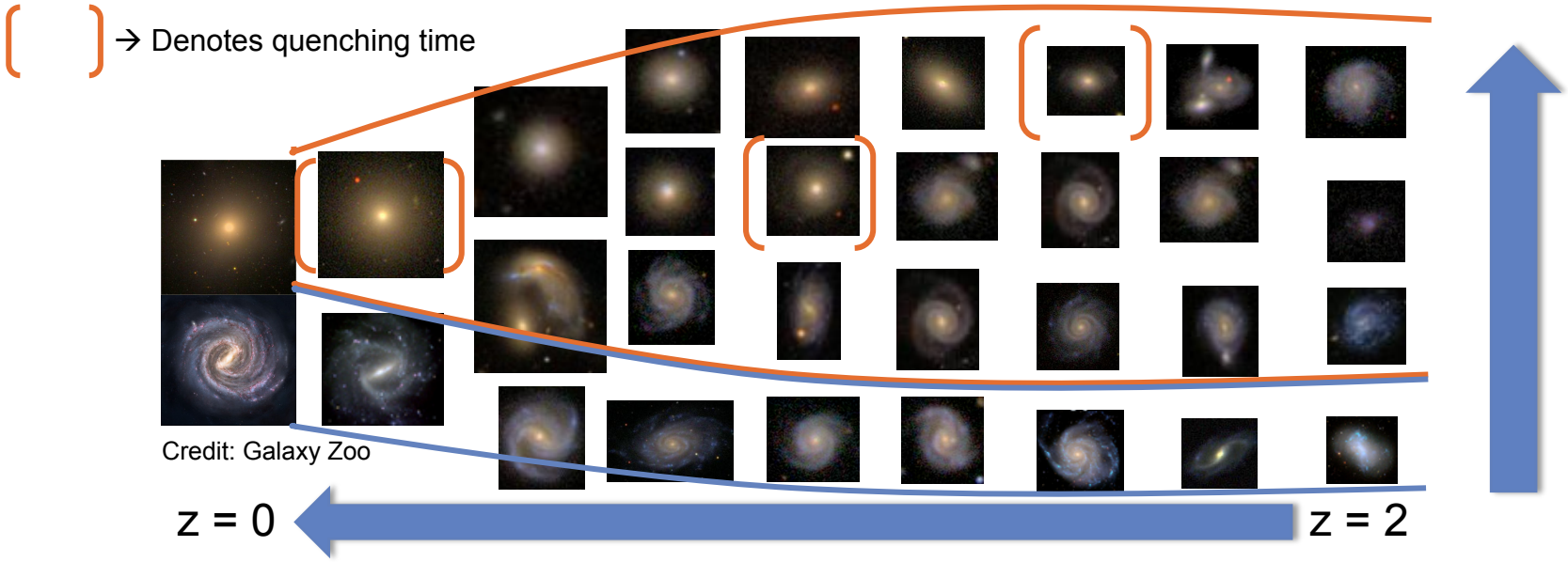

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- **Quenching accounts for much of the physical scatter in growth histories.**

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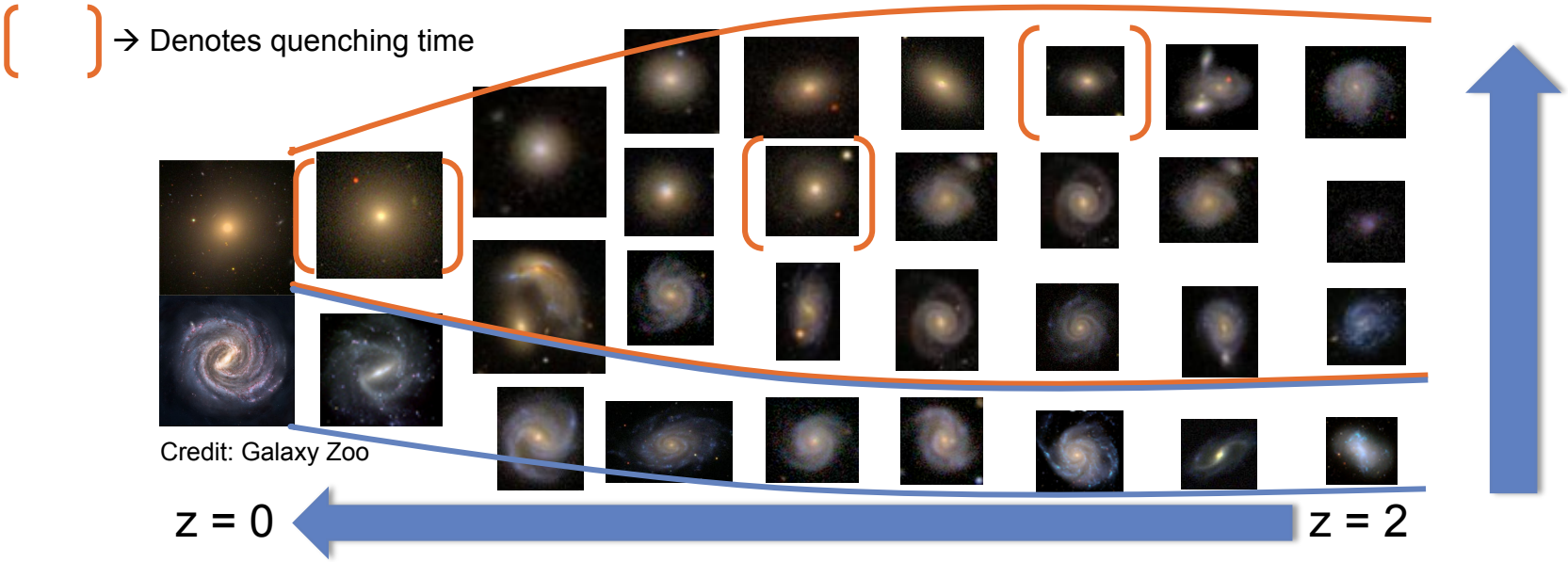

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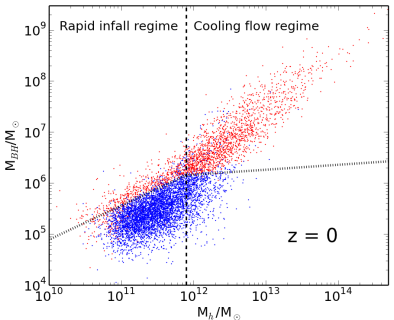
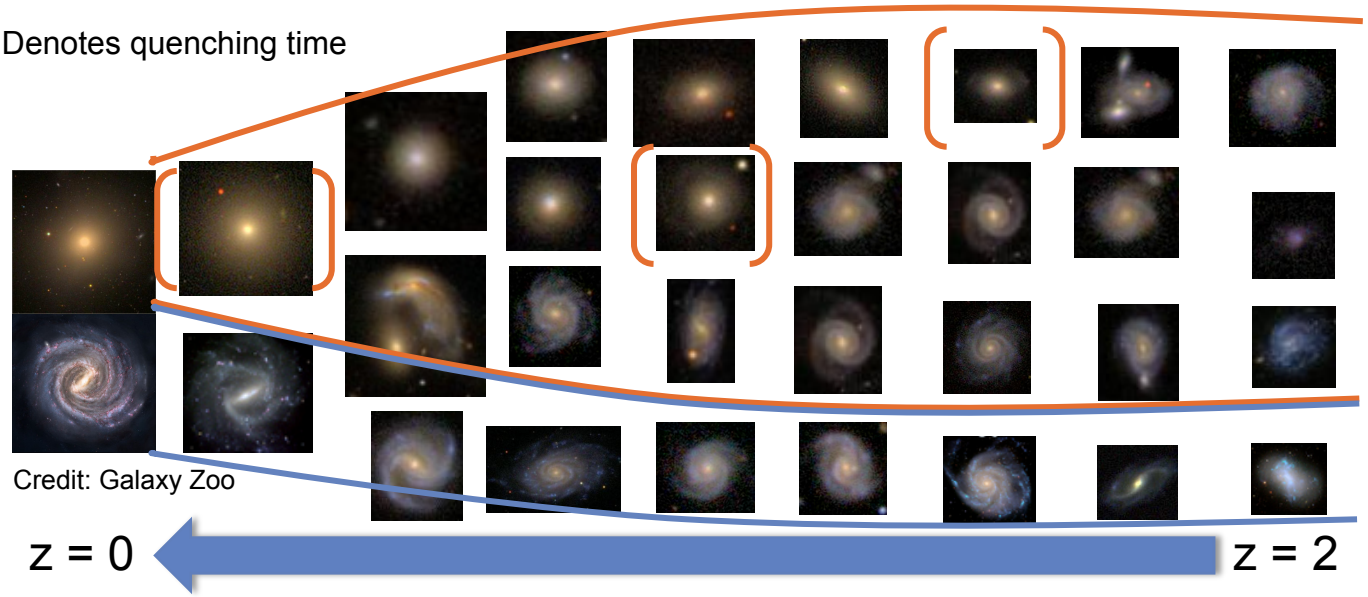
- **Milky Way-mass galaxies have a diversity of growth histories.**
- **Quenching accounts for much of the physical scatter in growth histories.**
- **Quenching depends on the balance between heating and cooling : this manifests itself in a heating-cooling boundary on a black hole mass-halo mass plot in the model.**



Summary

[ ] → Denotes quenching time



We have shown that:

- **Milky Way-mass galaxies have a diversity of growth histories.**
- **Quenching accounts for much of the physical scatter in growth histories in H15.**
- **Quenching depends on the balance between heating and cooling in H15 : this manifests itself in a heating-cooling boundary on a black hole mass-halo mass plot in the model.**
- **There is strong evidence that this heating-cooling equilibrium boundary exists in observational data for central galaxies.**