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# Self-Consistently Modelling Galaxy-Supermassive Black Hole Coevolution from z = 0 – 6 within DECODE

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Beyond the Edge - 22nd October 2024

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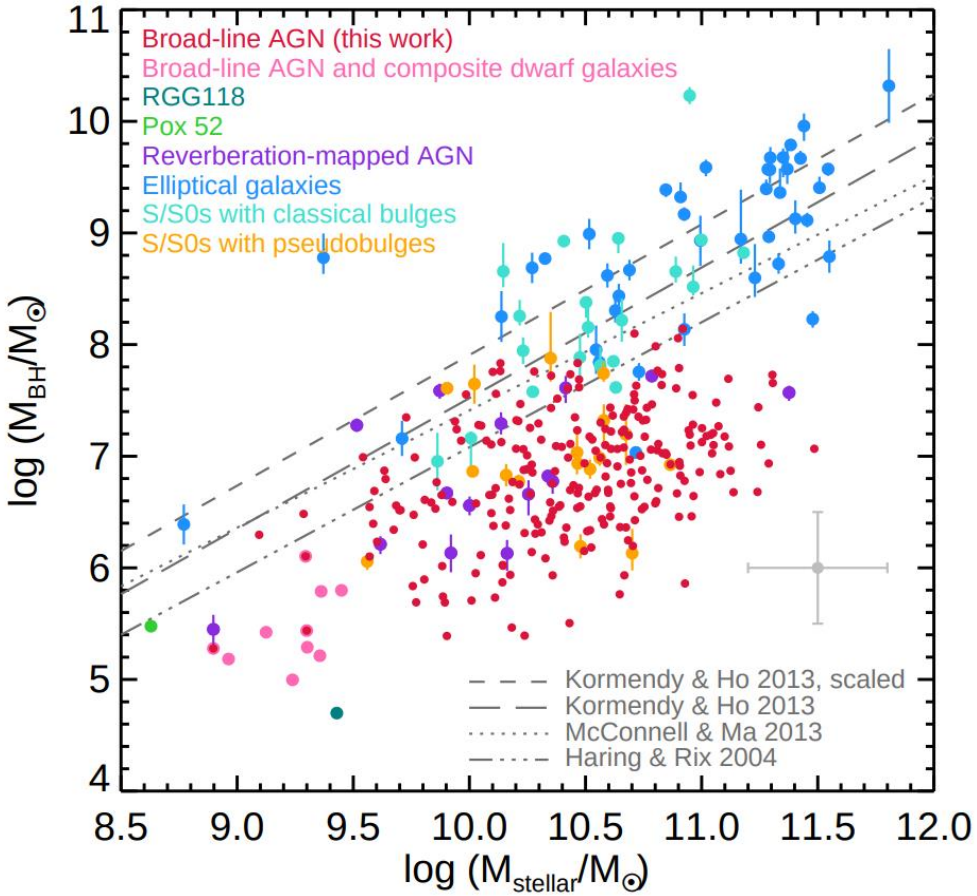
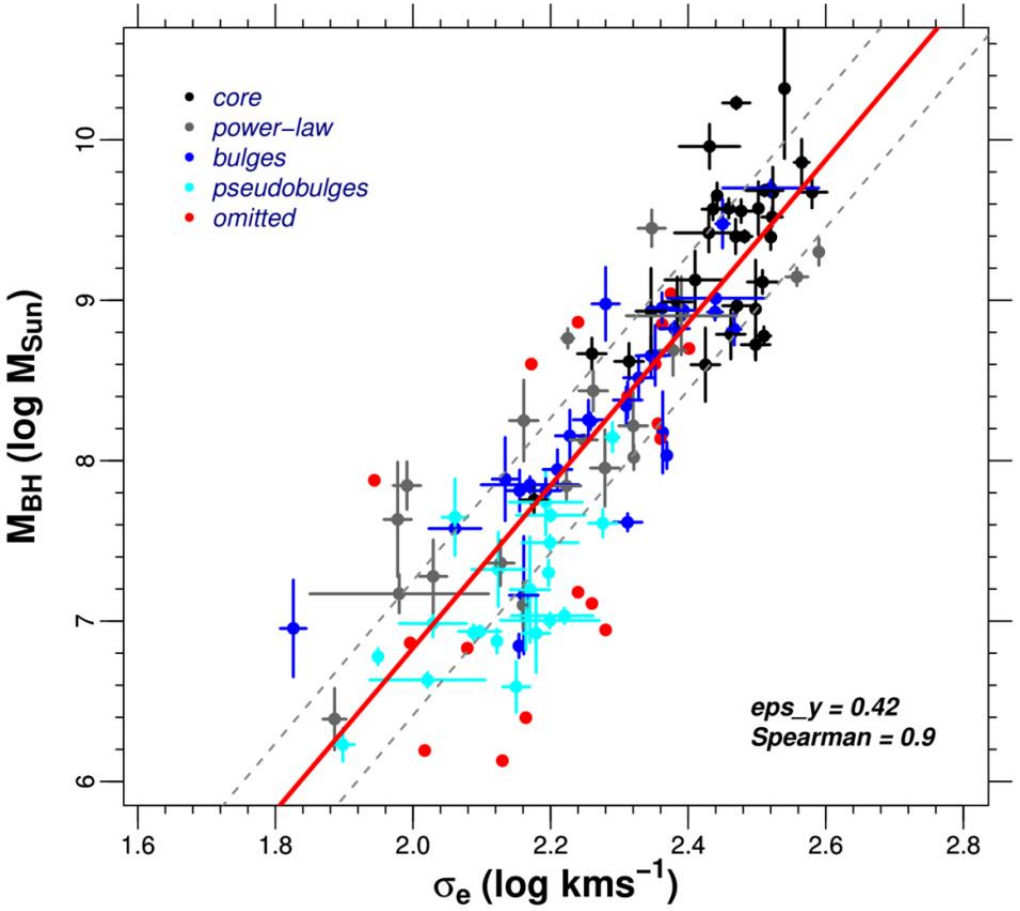
# BH-Galaxy Coevolution via the Observational Evidence

$M_{BH}$ correlates with several galaxy properties e.g. Stellar Mass (left), Velocity Dispersion (right)




Reines and Volonteri (2015)




de Nicola et al. (2019)

# BH-Galaxy Coevolution via the Observational Evidence

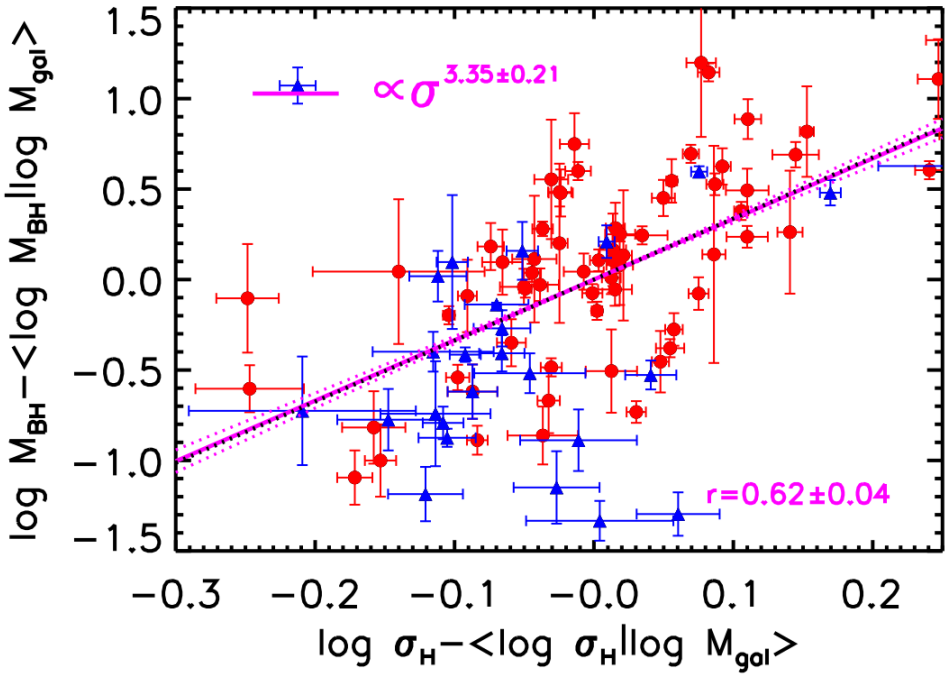
Residuals suggest $M_{BH}$-$\sigma_*$ is the most fundamental relation (Shankar et al. in prep.)

One should not consider the $M_{BH}$-$M_{gal}$ plane alone.

What are the relative contributions of :

- external processes, i.e. mergers
- internal secular processes, i.e. AGN and SNe feedback

in establishing the scaling relations?




Shankar et al. (in prep.)

For this we use DECODE (Fu et al. 22, 24, in prep.)

# DECODE – The Mean Tracks

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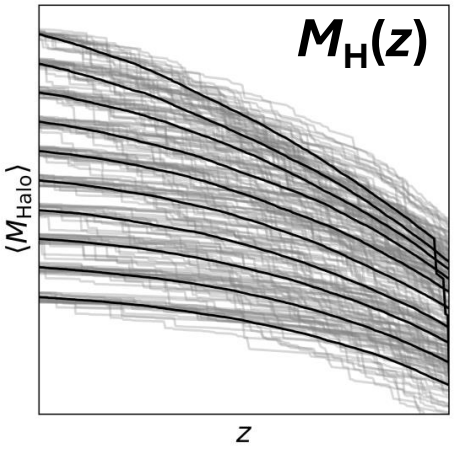
**Halo Mass Histories** → **Stellar Mass Histories** → **SMBH Mass Histories**

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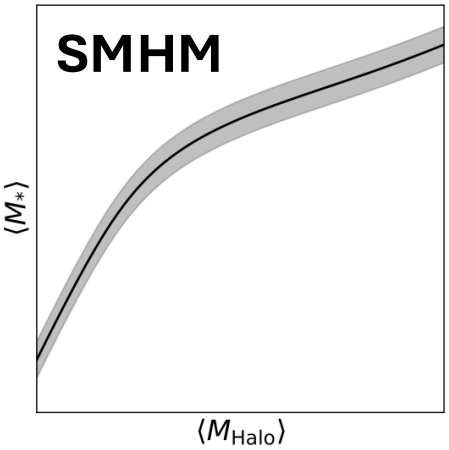


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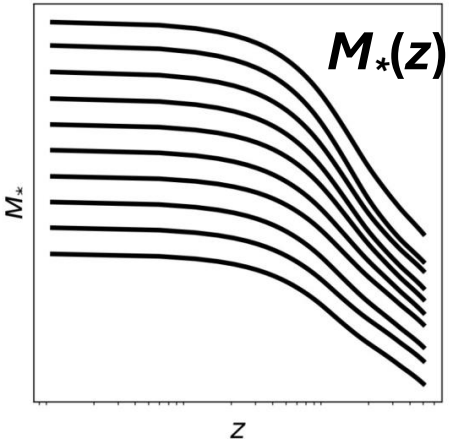
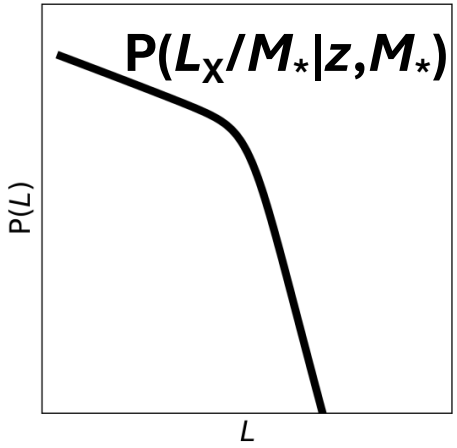
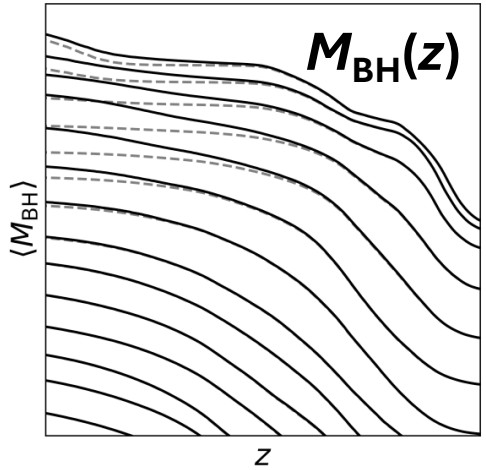


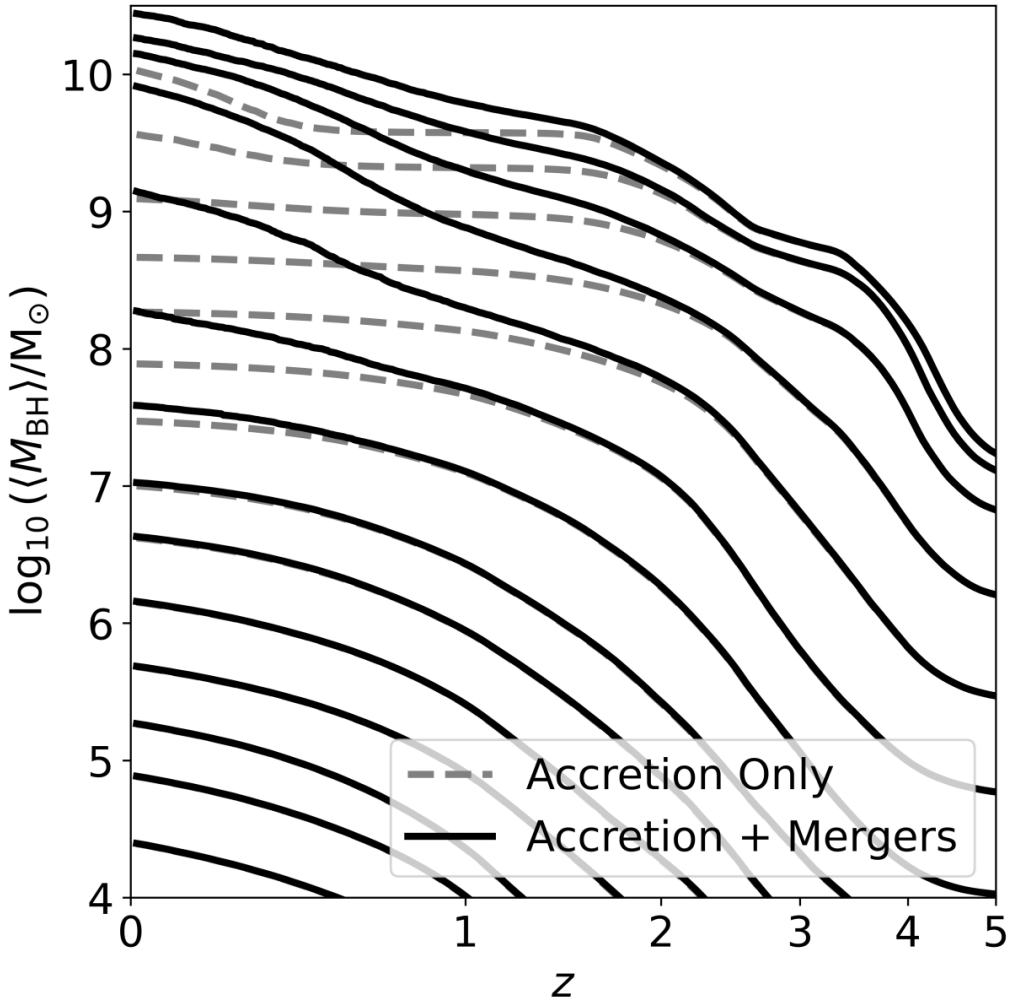

**Accretion** →

**+ Mergers** →



## Mean BH Growth Curves

- Self-consistently derive the growth curves of SMBHs
- These growth curves can be decomposed into the contributions of accretion and mergers
- Mergers have a significant impact at high-$M_{BH}$ for z<2



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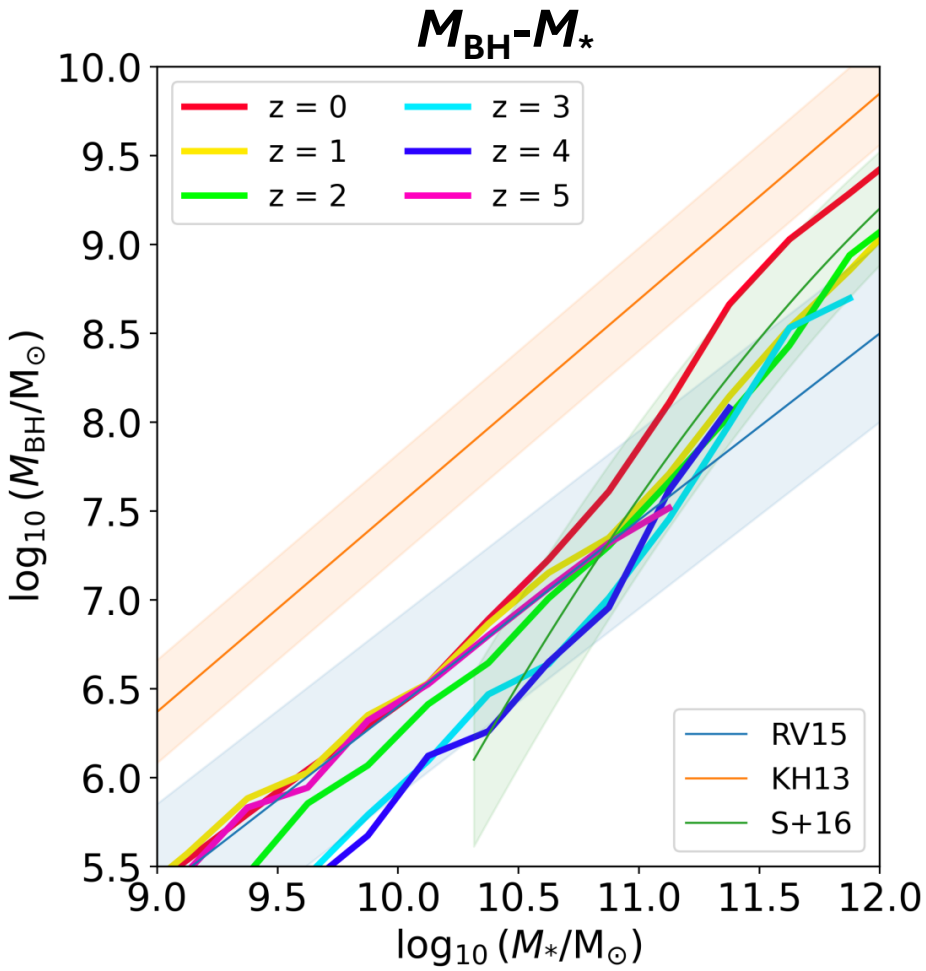
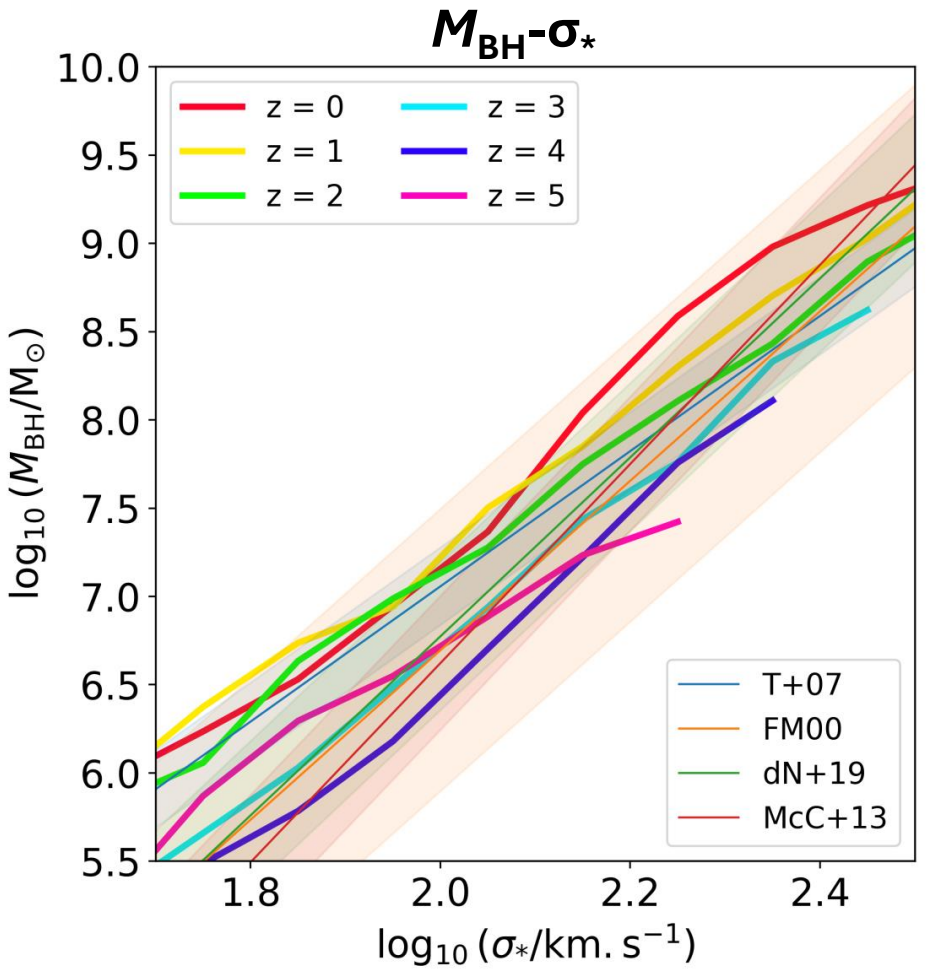
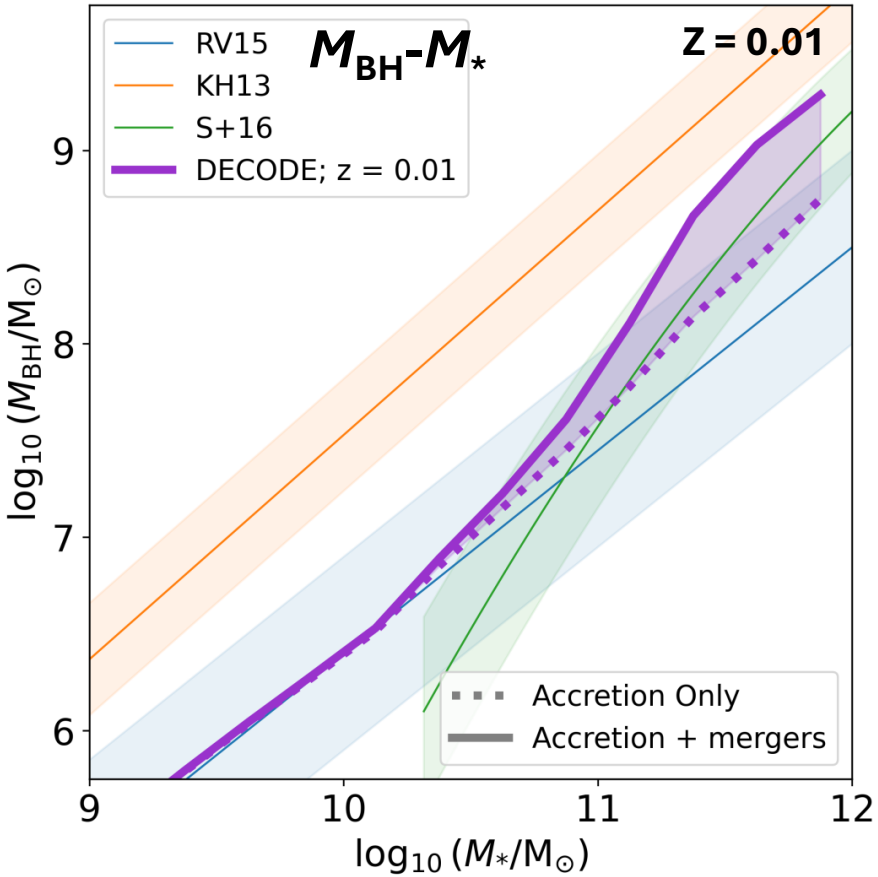
# Evolution of $M_{BH}$-$M_*$ and $M_{BH}$-$\sigma_*$ Relations

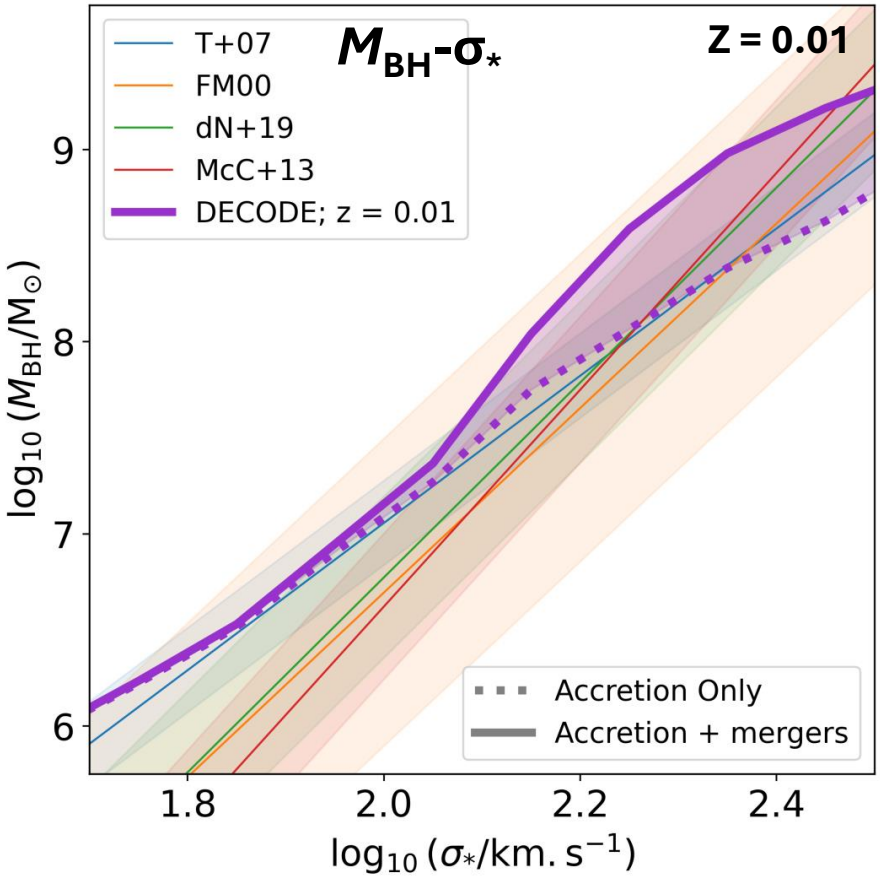



**The $M_{BH}$-$M_*$ and $M_{BH}$-$\sigma_*$ relations display little redshift evolution**

# BH-Galaxy Scaling Relations – Merger Impact




- **Mergers play an important role at z<2**
- **Mergers steepen the high-mass end**

## BH-Galaxy Scaling Relations – Initial Conditions

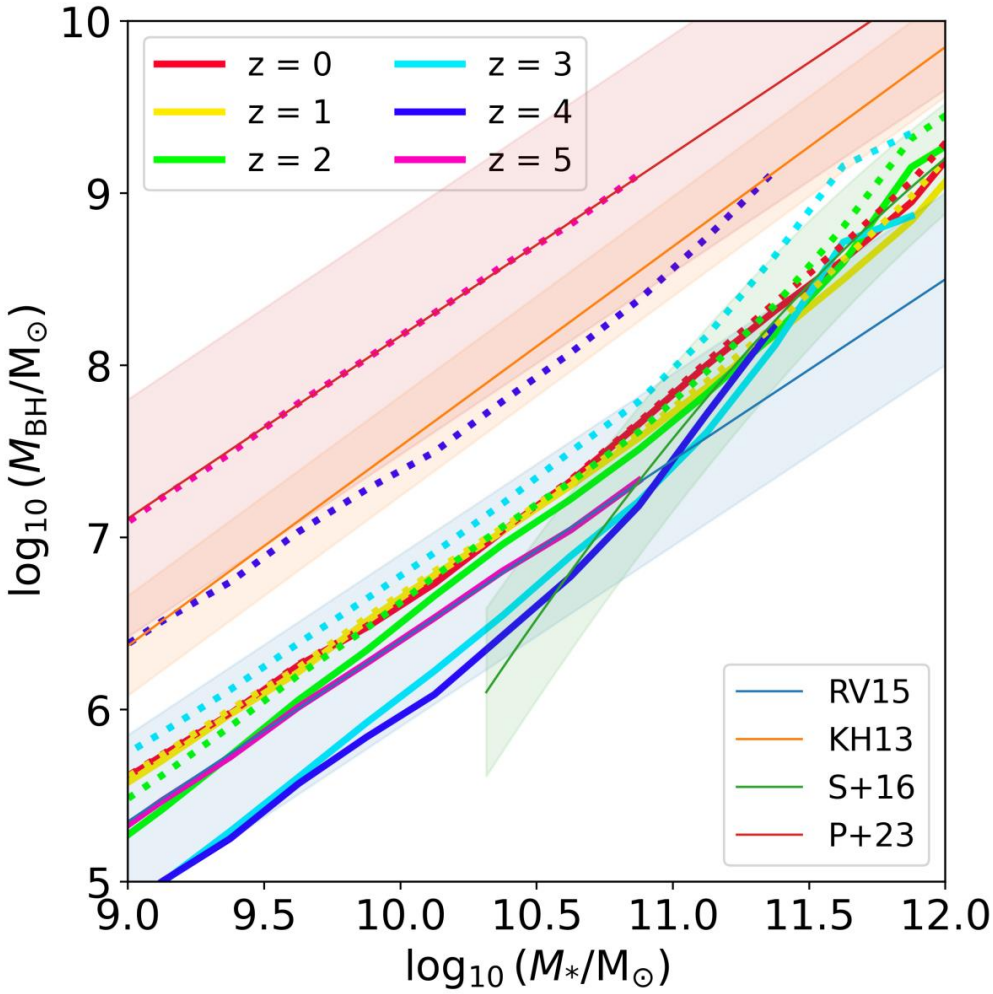
Whether seeded with the $M_{BH}$-$M_*$ relations of:

- Reines & Volonteri (2015), **solid** lines
- Pacucci et al. (2023), **dotted** lines

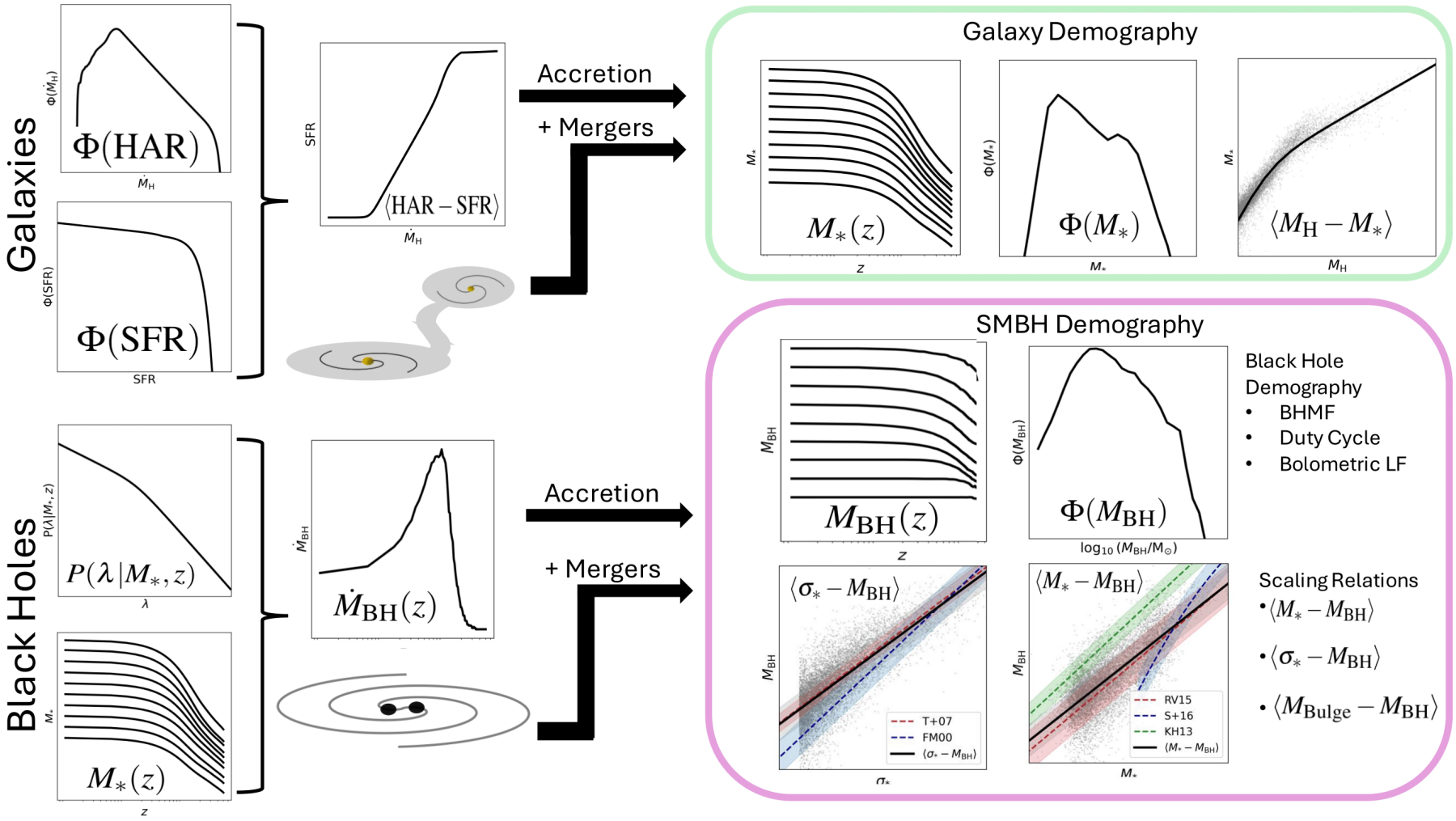
the $M_{BH}$-$M_*$ relations converge by $z = 2$

**The initial conditions at z≥4 do not impact the local SMBH demography**

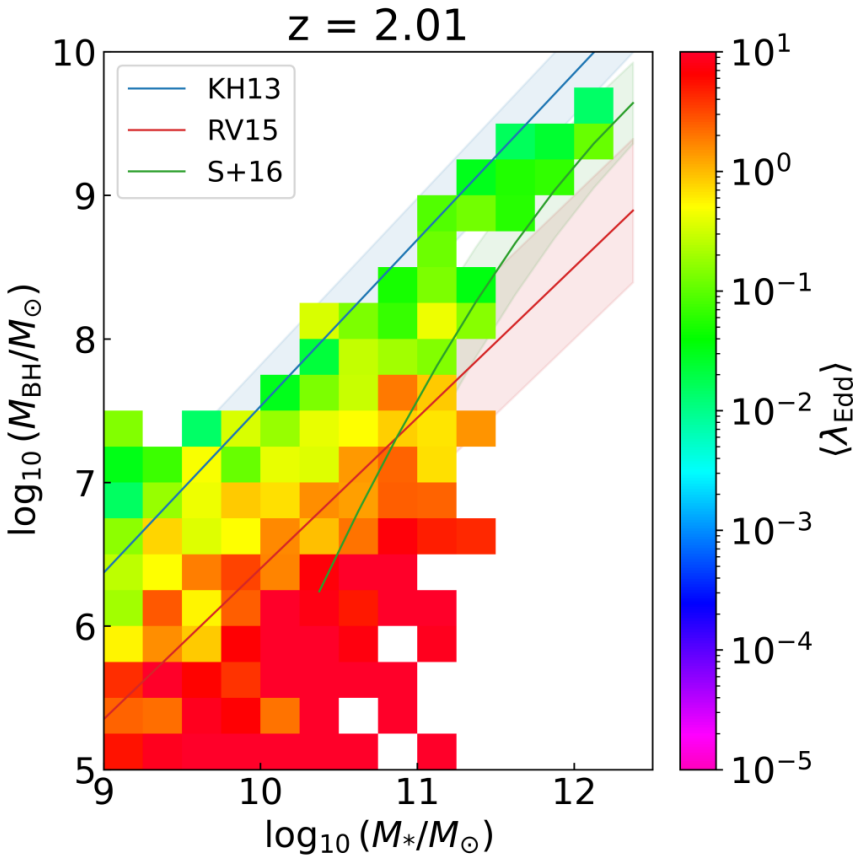
**Radiative Efficiencies of ~0.1 are consistent with local AGN relations**



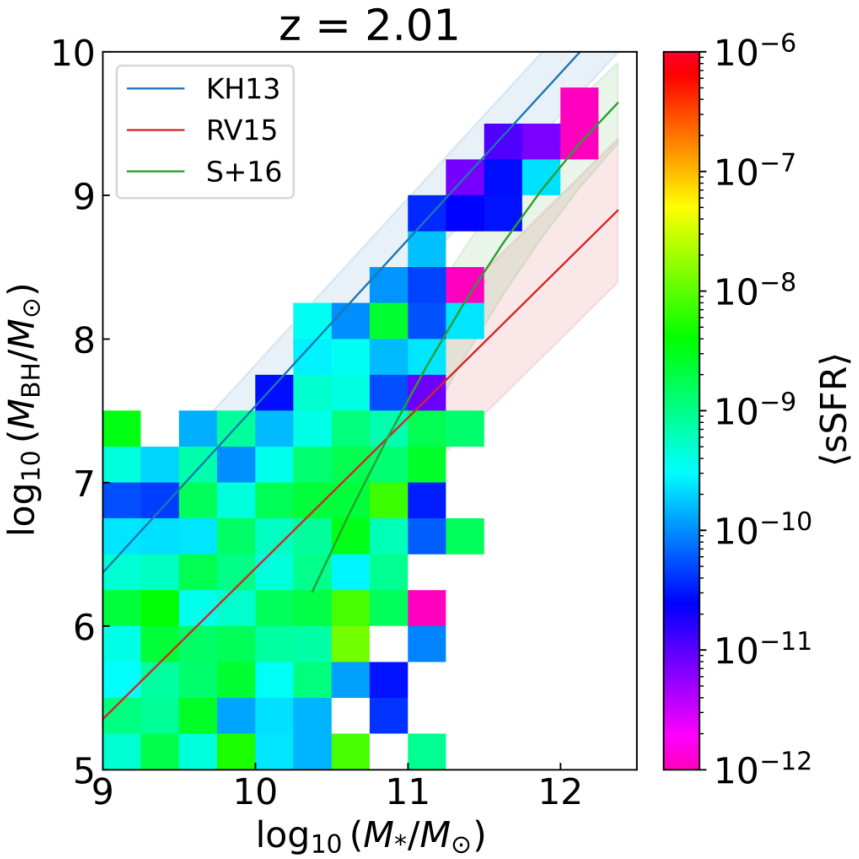
# DECODE2 - A halo-by-halo approach



# DECODE2 – Trends in the scatter



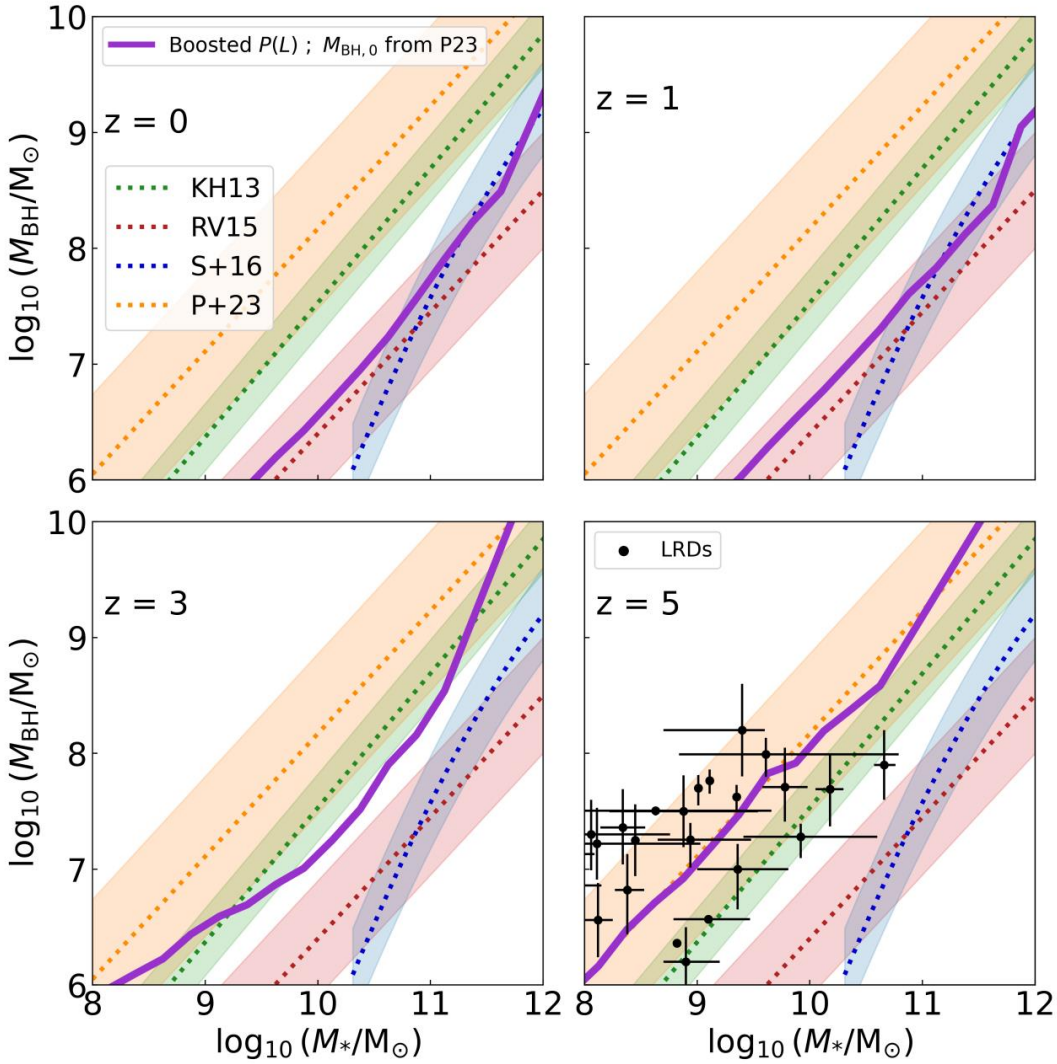

Under-massive BHs have higher Eddington Ratios in DECODE.




The sSFR distribution displays the impact of the observed quenched fraction.

## Forward Modelling the LRDs

- Seed with the JWST Pacucci et al. (2023) $M_{BH}$-$M_*$
- Boost the P($L$) to match LRDs' bolometric LF
- The accretion from cosmic-noon washes away any memory of the ICs
- $M_{BH}$-$M_*$ relations converge by $z$~1
- BHMF at $z$~0 is almost identical



## Conclusions

- **Within DECODE we can self-consistently predict the growth of BHs to:**
- Derive the BH-galaxy relations which
  - Agree well with the observed relations
  - Display little redshift evolution
- Mergers play an important role since cosmic-noon
- Initial conditions at $z \geq 4$, do not impact the local SMBH demography in our model

**We are using / will use DECODE to:**

- Investigate mechanisms driving the observed quenched fraction
- Predict the SMBH merger rates and GW background
- Break the degeneracy of Eddington ratio and radiative efficiency



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