Exploring the links between **feedback** and **galaxy SFHs**

Kartheik Iyer @ SIMBA meeting
NHFP Hubble Fellow | Columbia University | 1 May 2023

Columbia University in the City of New York
NHFP
Flatiron Institute
Center for Computational Astrophysics

In collaboration with Tjitske Starkenburg, Chris Lovell, Greg Bryan, Shy Genel, John Wu, Francisco Villaescusa-Navarro, Changhoon Hahn, rachel somerville, Sultan Hassan, Suchetha Cooray, and more!

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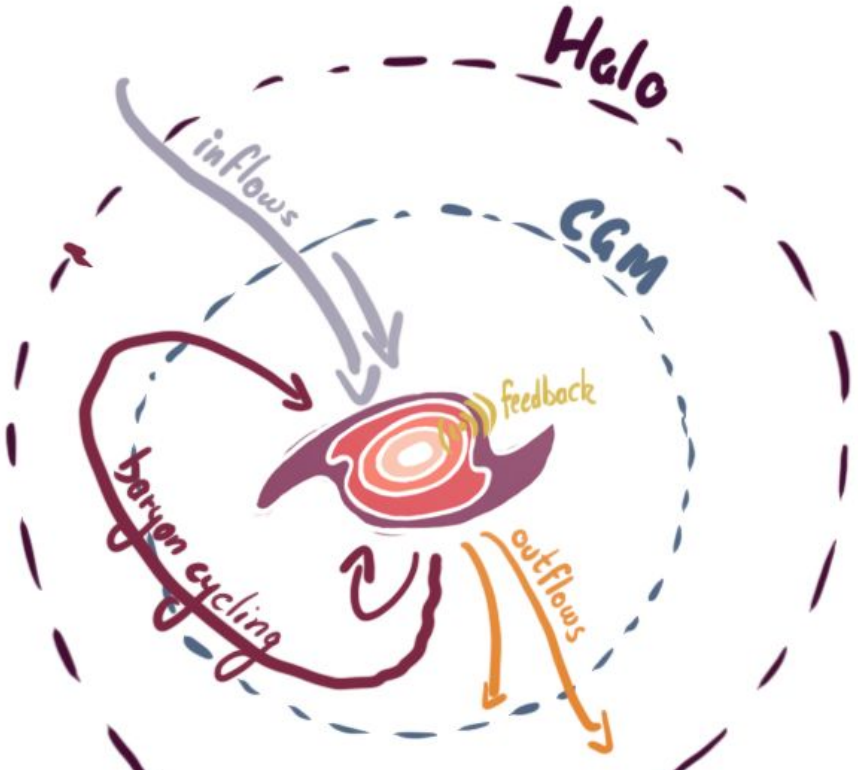

Motivation: Why do we care about **feedback**?

Kartheik Iyer @ SIMBA meeting | Figure based on Iyer & Speagle et al. 2023
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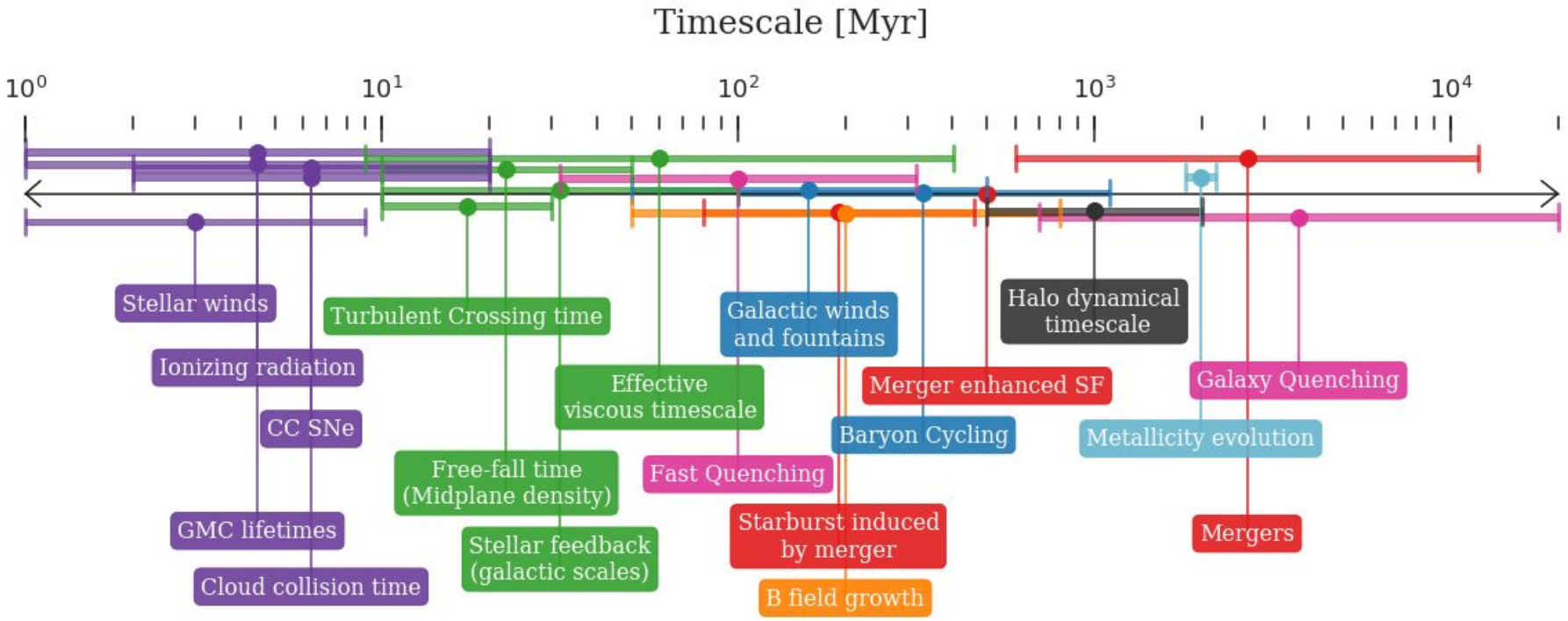

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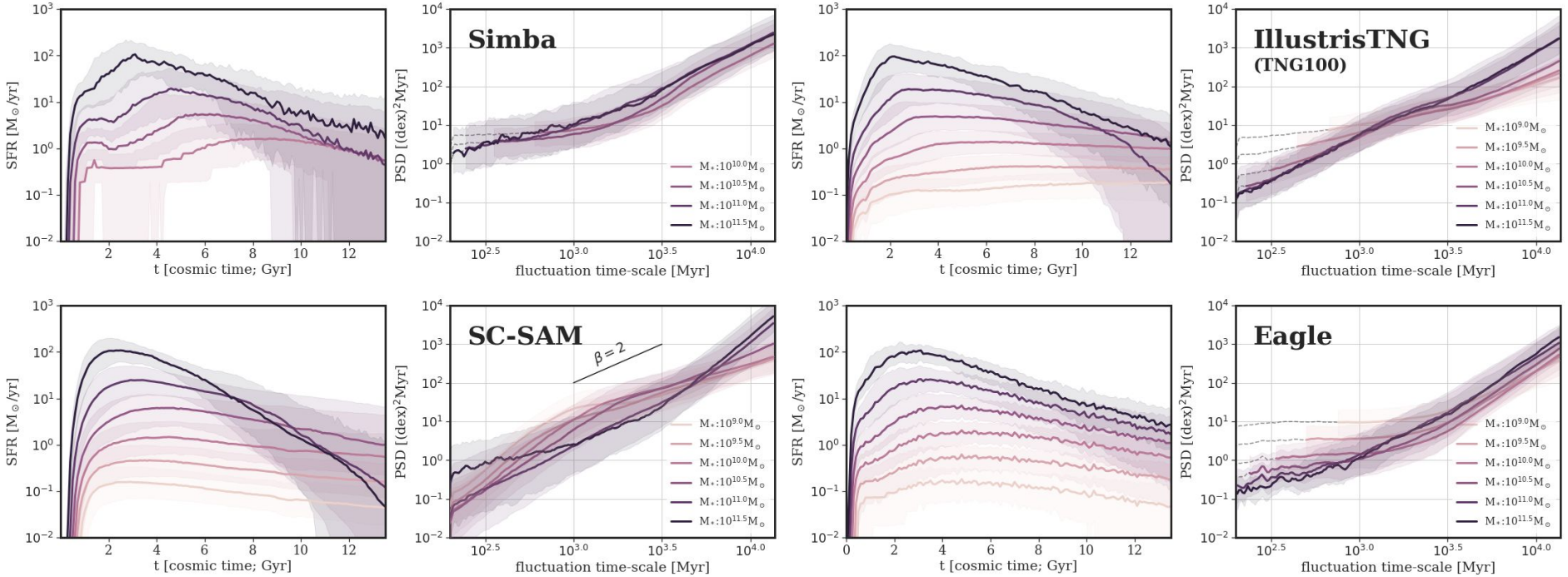
How can we constrain **feedback**?

Kartheik Iyer @ SIMBA meeting |
Exploring the links between **feedback** and **galaxy SFHs**

- **Iyer+20, Tacchella+22:** fluctuations in star formation rates on different timescales (2007.07916, 2006.09382)
- **Keller+22:** spatial decorrelation between molecular gas and SF (2206.06391)
- **Ceverino+22:** elongation, clumps and compaction (2210.15372)
- **Lammers+22:** spatially resolved star formation rate distributions (2212.00762)
- **Breysse+19:** CO intensity mapping (1904.03197)
- **Jo+22:** mass functions / cosmic SFRD + CAMELS (2211.16461)
- **Thiele+22:** thermal Sunyaev-Zel'dovich CMB spectral distortions + CAMELS (2201.01663)
- **Schneider+21:** weak-lensing, X-ray, and kinematic Sunyaev-Zeldovich observations (2110.02228)
- **Gupta+20:** cluster radio AGNs properties (1906.11388)
- **Koudmani+22:** M_*-M_{BH} scaling relations in dwarfs (2206.11274)
- **Heinrich+22:** X-ray power spectra + galaxy clusters (2105.14053)
- and more: morphological features, low-mass galaxies, bursty SF, quenched fractions, reionization, ...

How can we constrain **feedback**?



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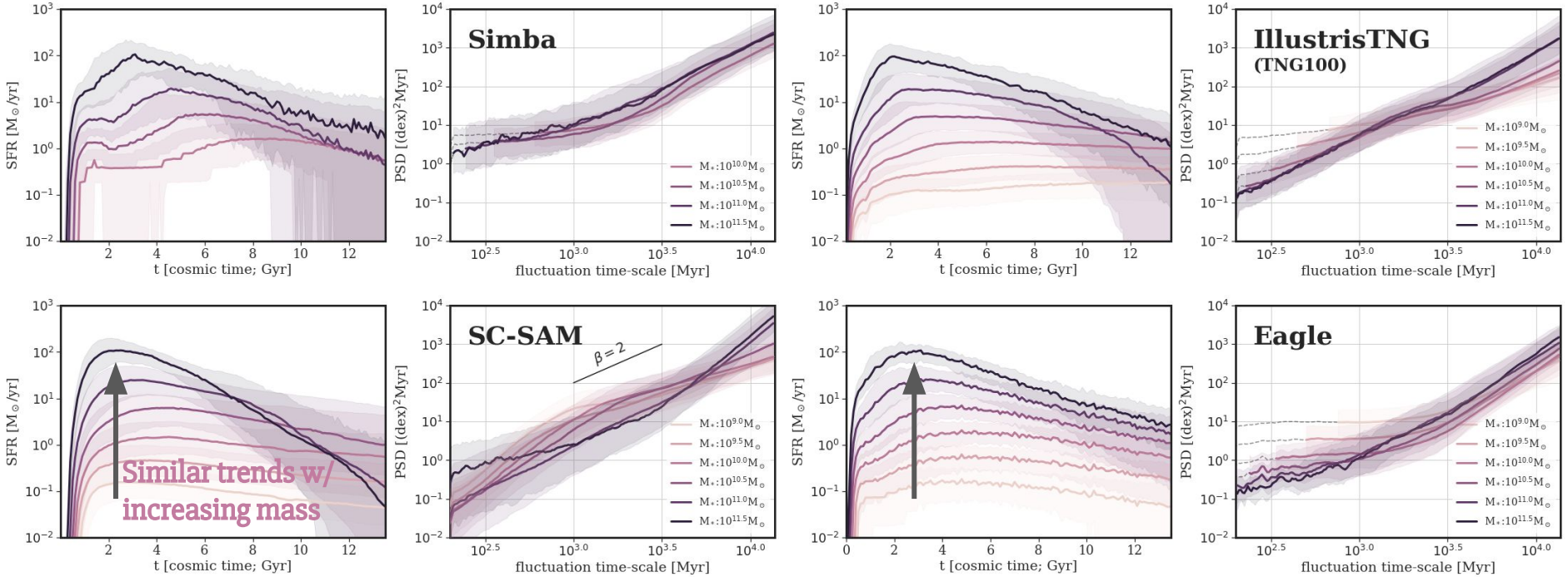

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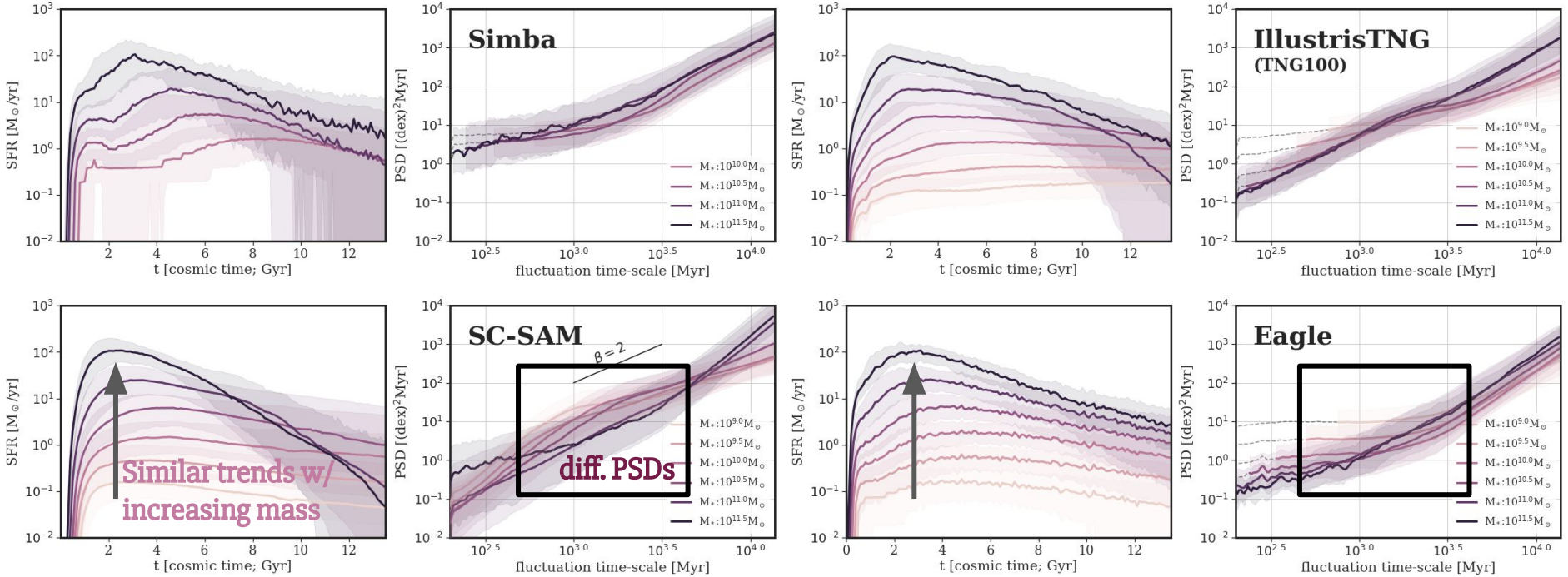

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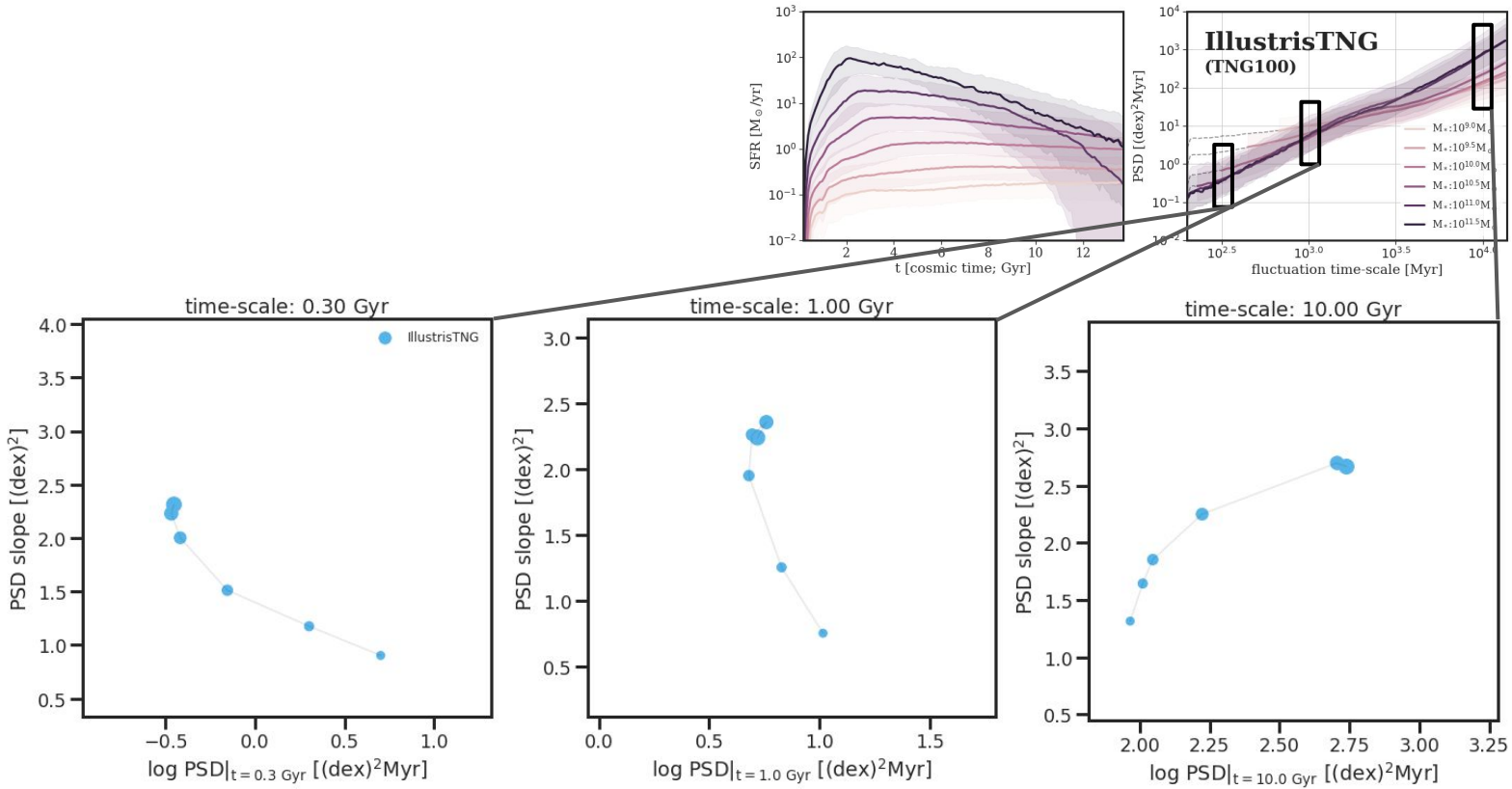

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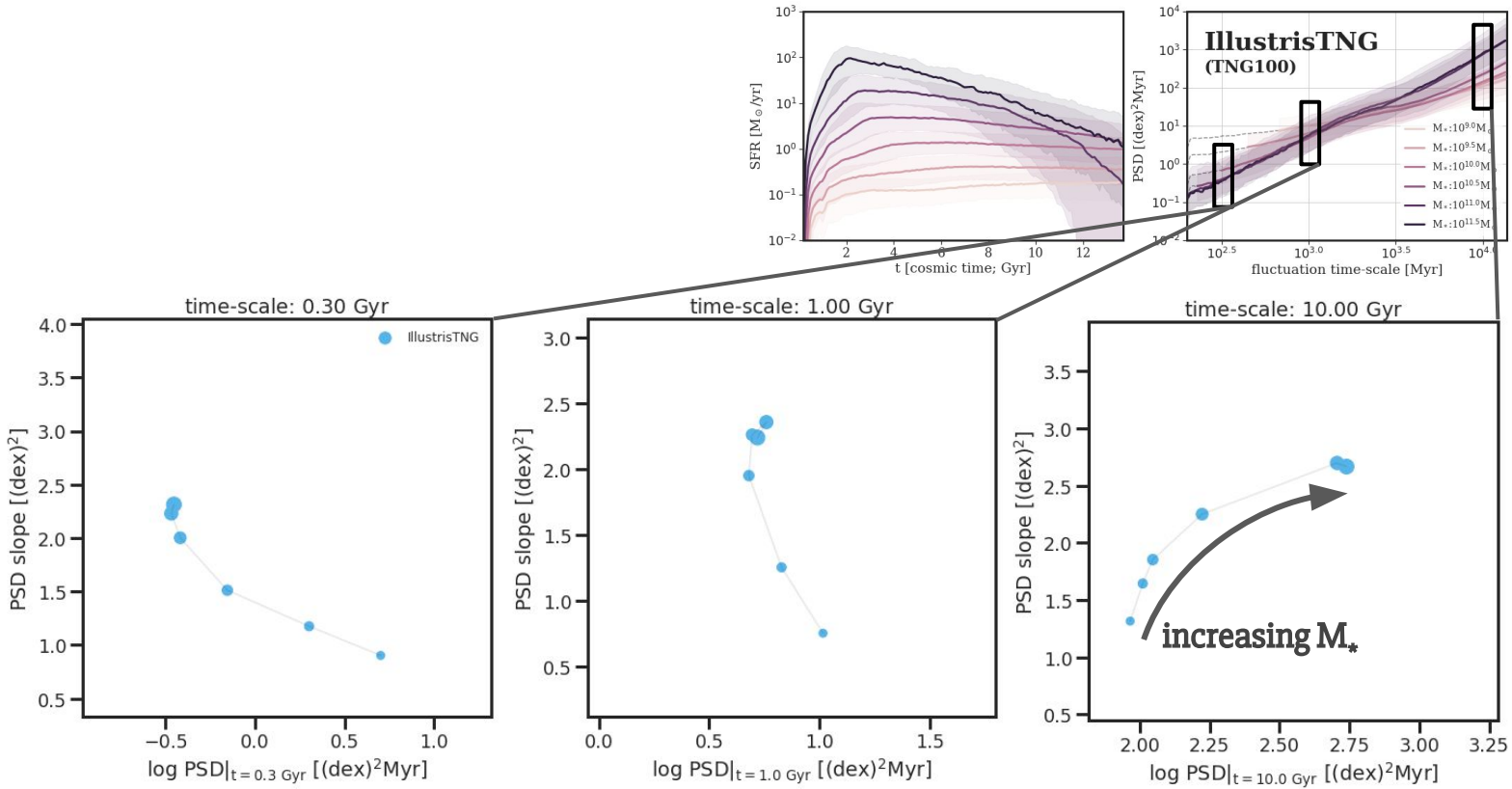

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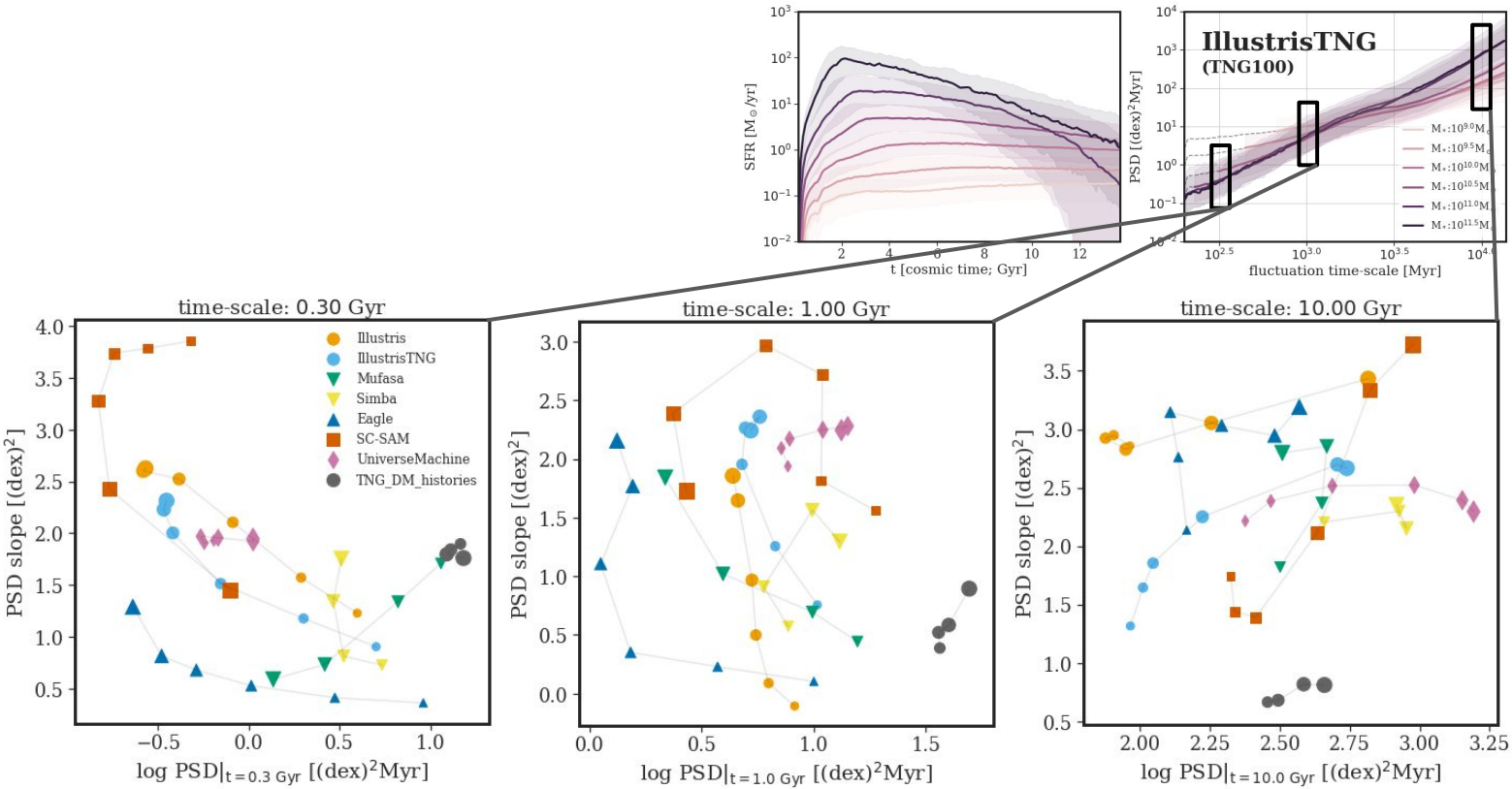

How can we constrain **feedback**?

Observational constraints on **SFHs**

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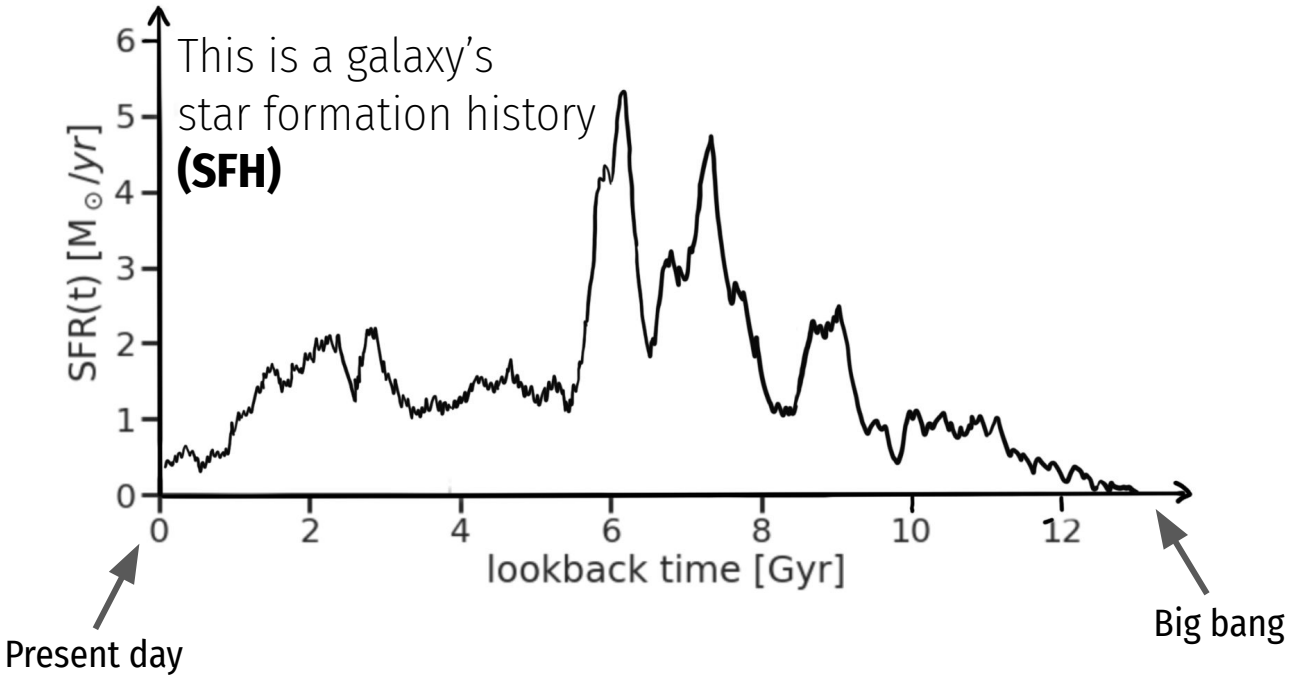
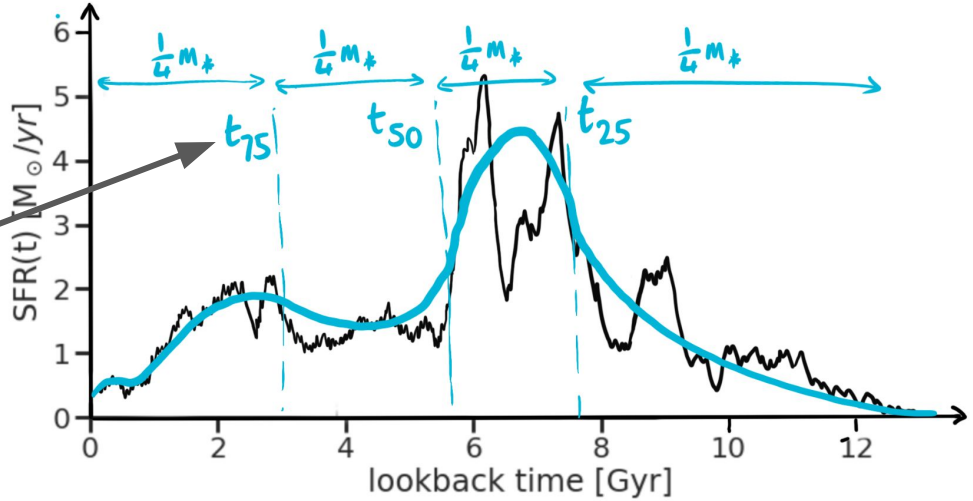


Observational constraints on **SFHs**

SFH = (M*,SFR,{tx})

described with summary statistics



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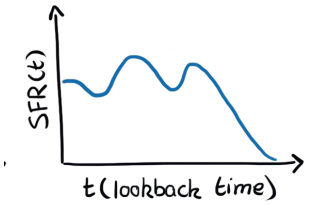


dense-basis.readthedocs.io

Flexible, non-parametric SFHs can be constructed using **GPs*** and an N-tuple such that

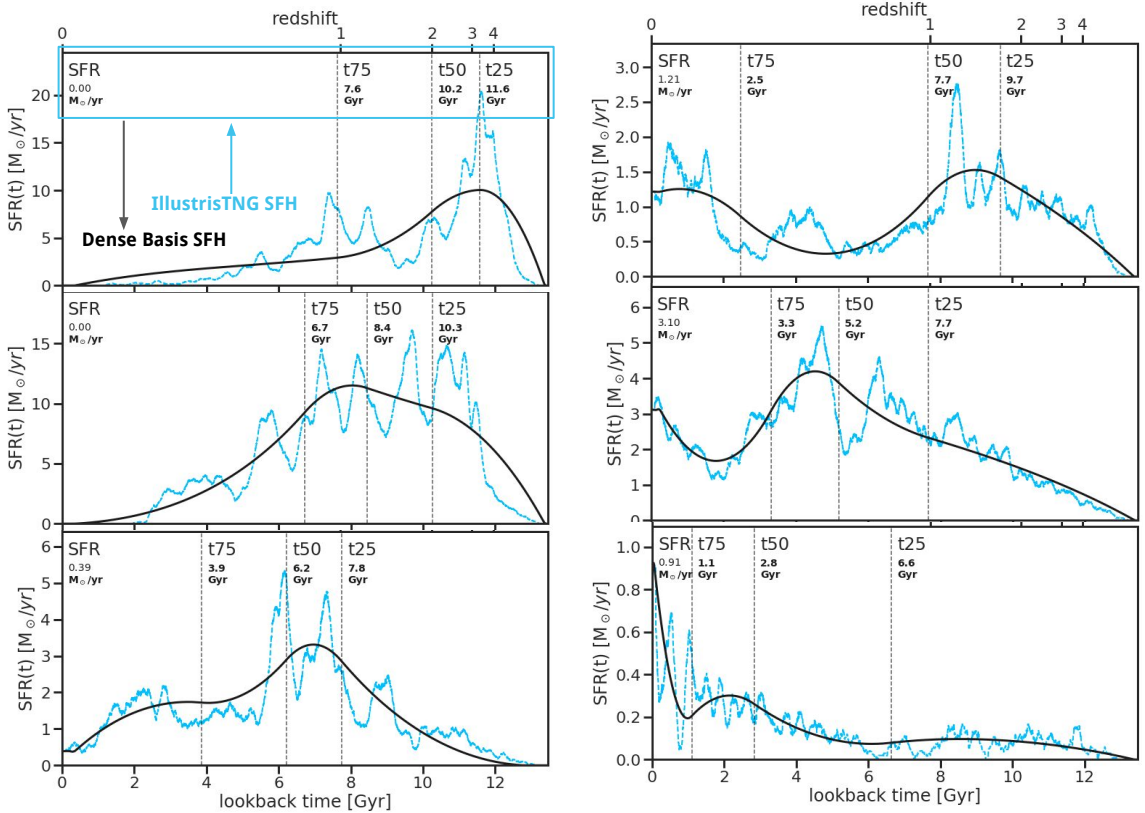
---

SFH≡SFR(t)↔**(M_*, SFR, {tX})**

where {tX} ≡ t25, t50, t75...etc. are lookback times at which a galaxy formed X% of its total mass

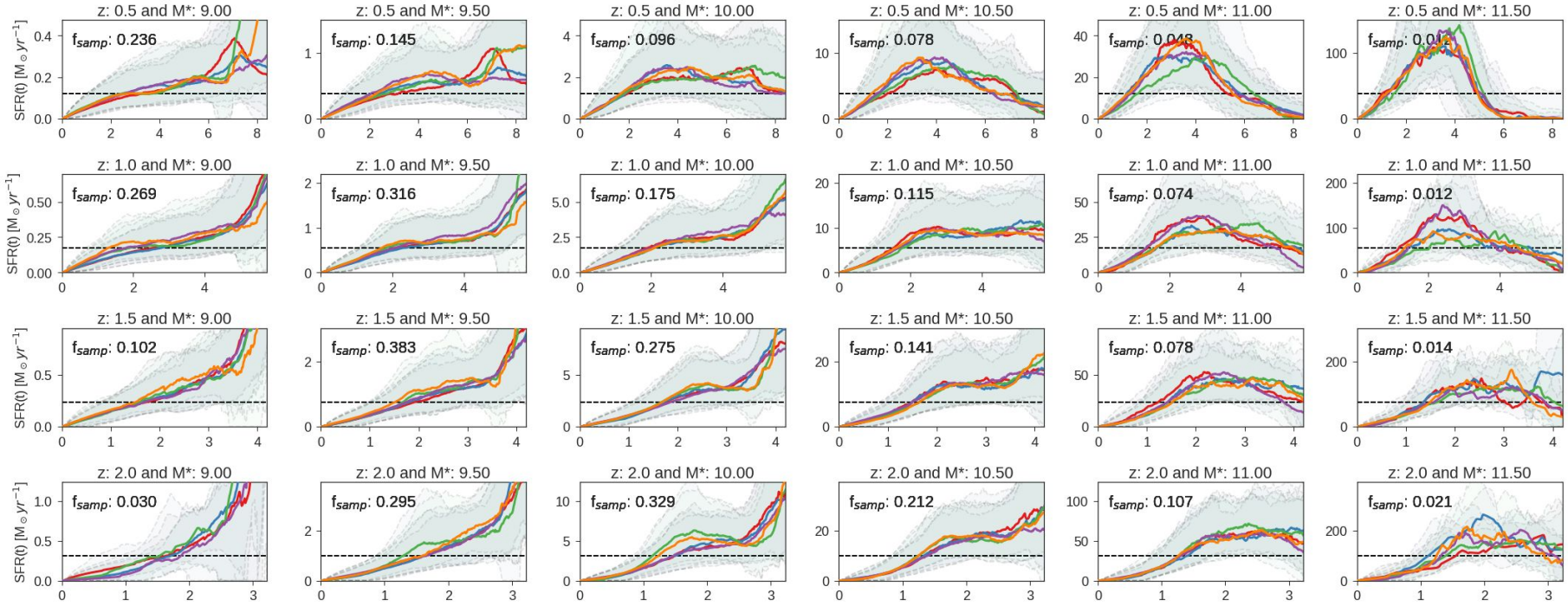
---

***GPs**: **Gaussian Processes**



Observational constraints on **SFHs**

increasing mass



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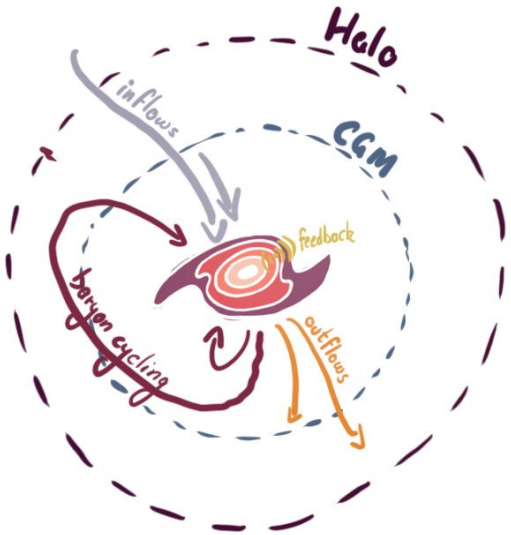

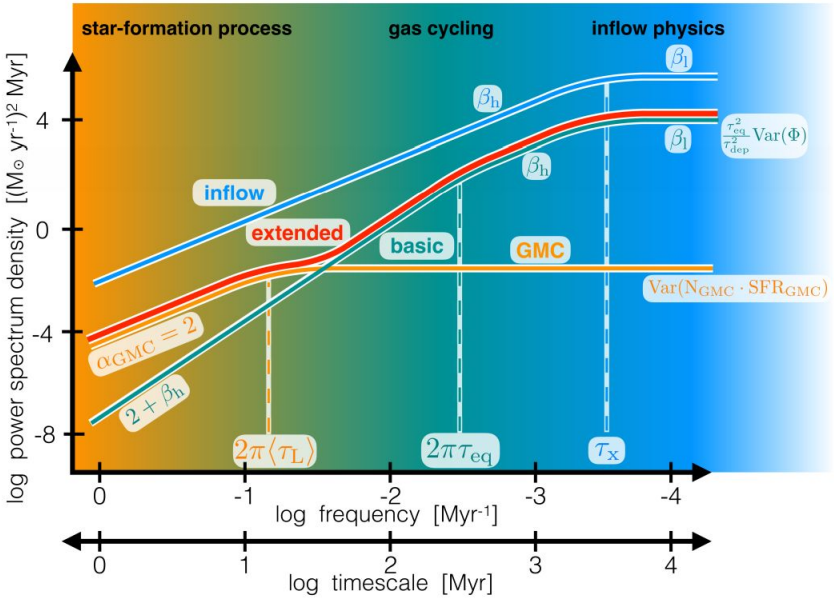

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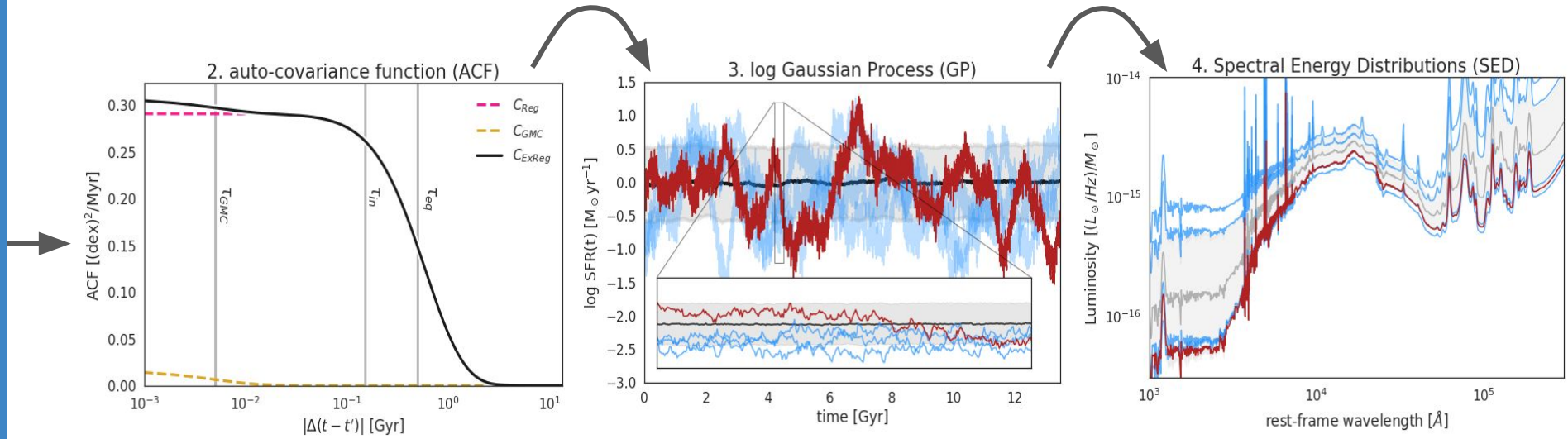

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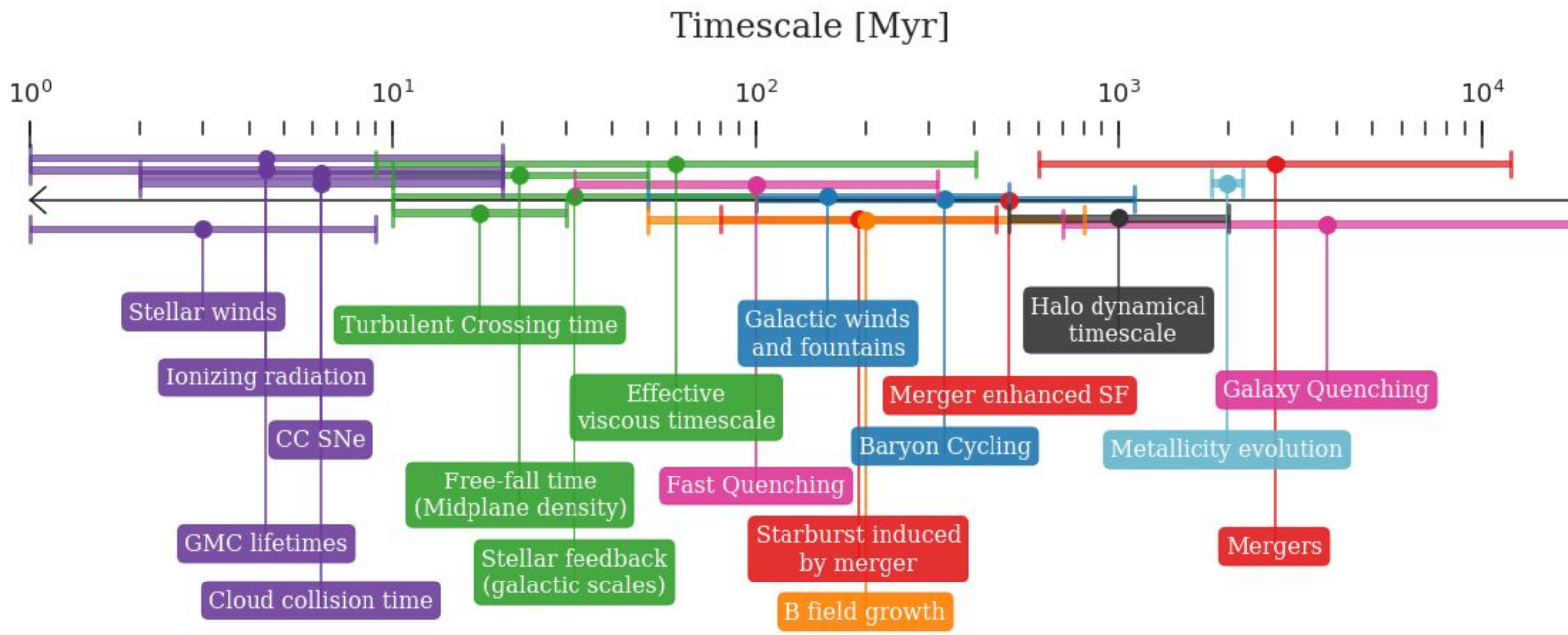

Can **SFHs** constrain feedback/cosmology?

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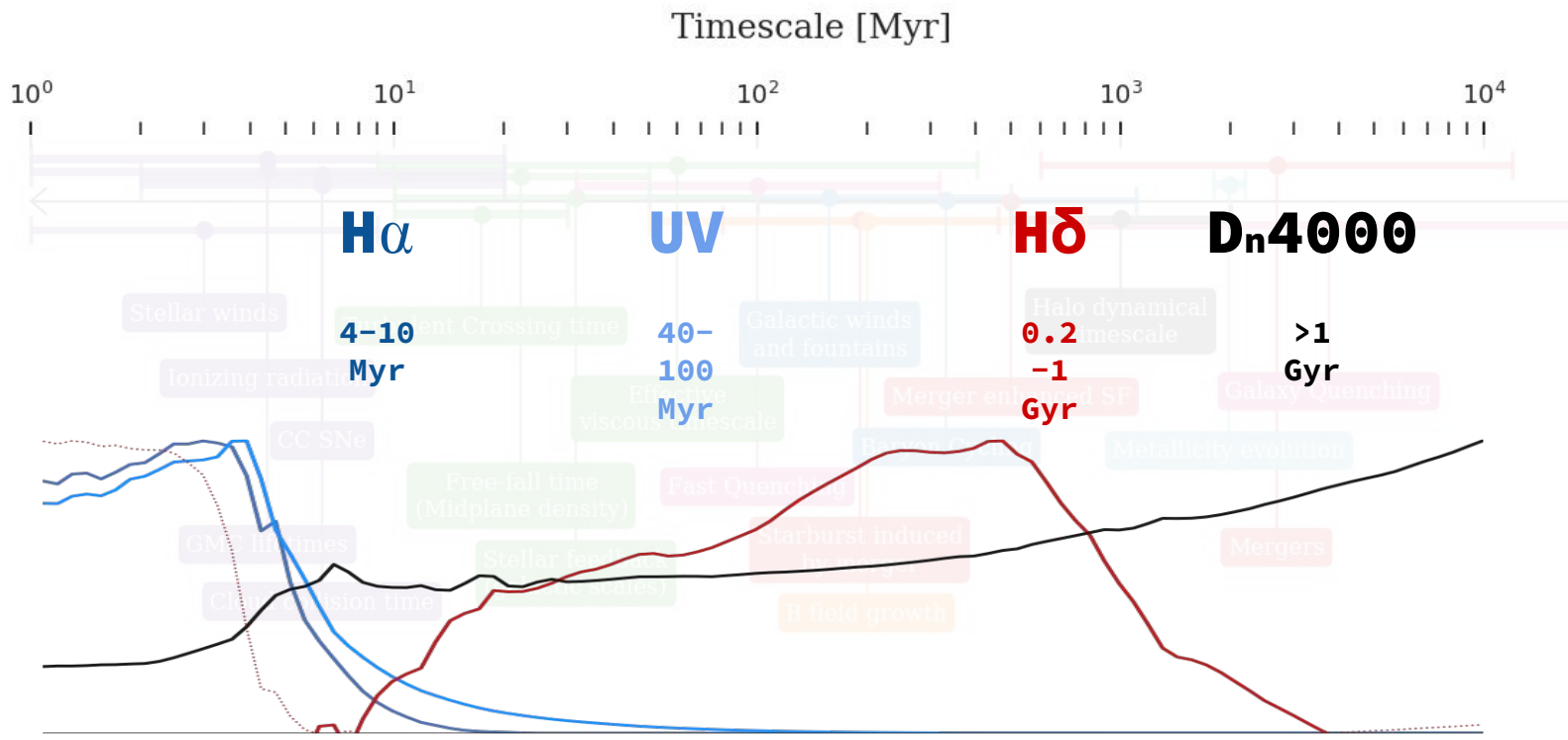

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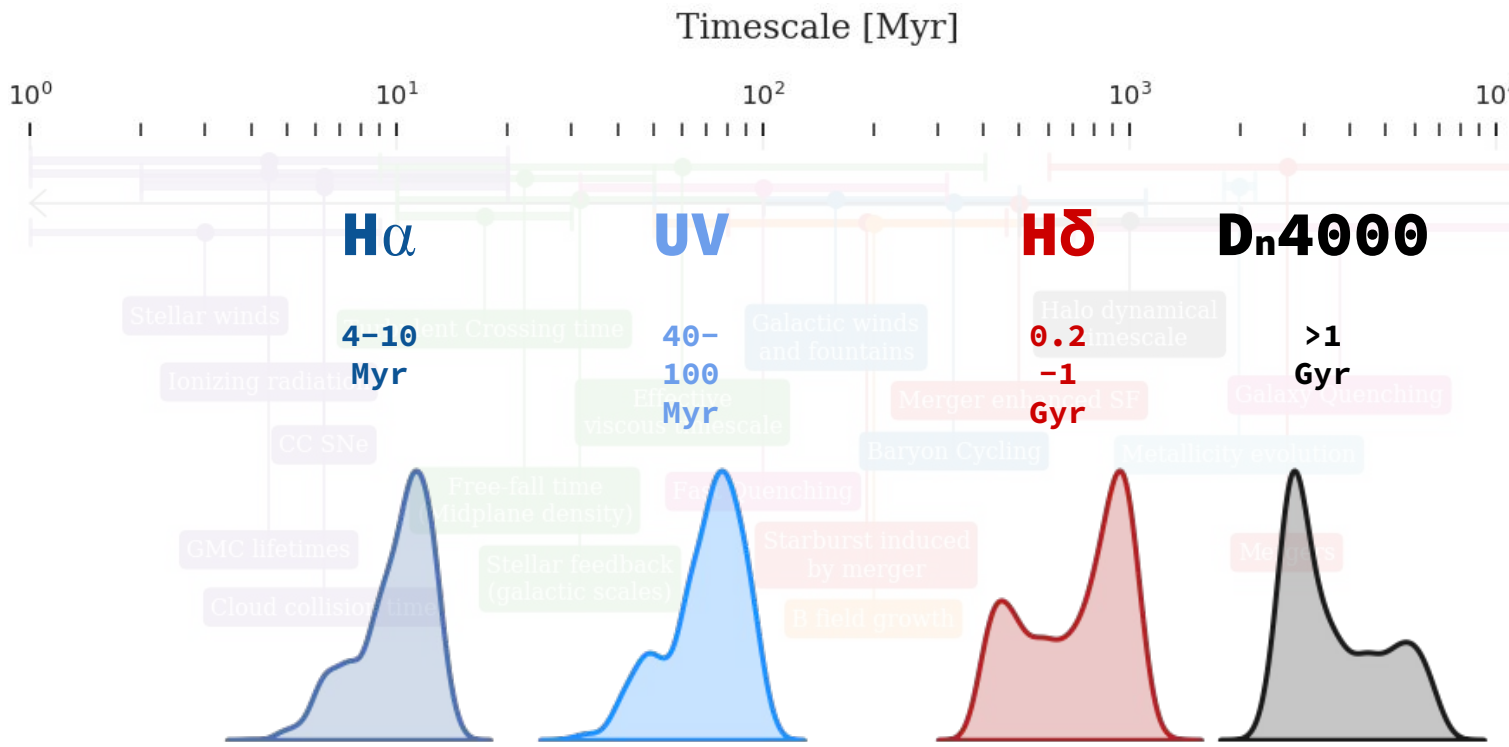

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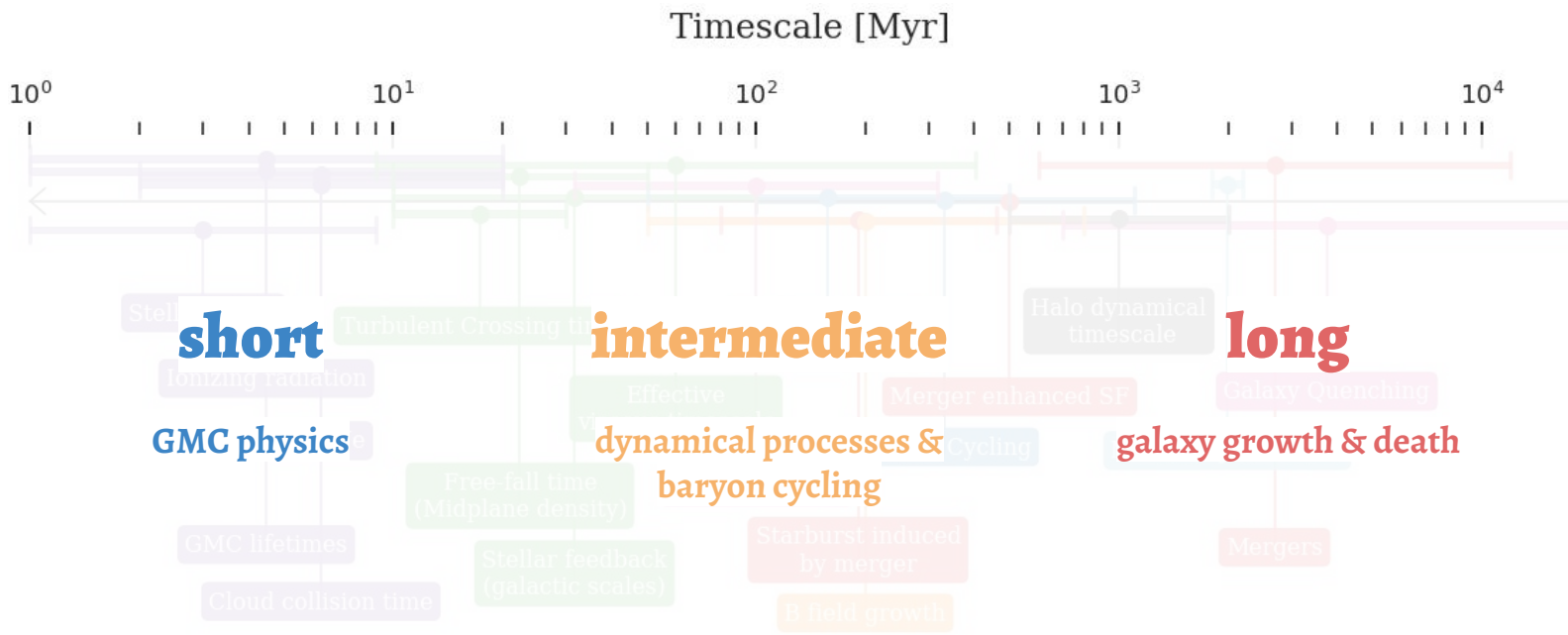

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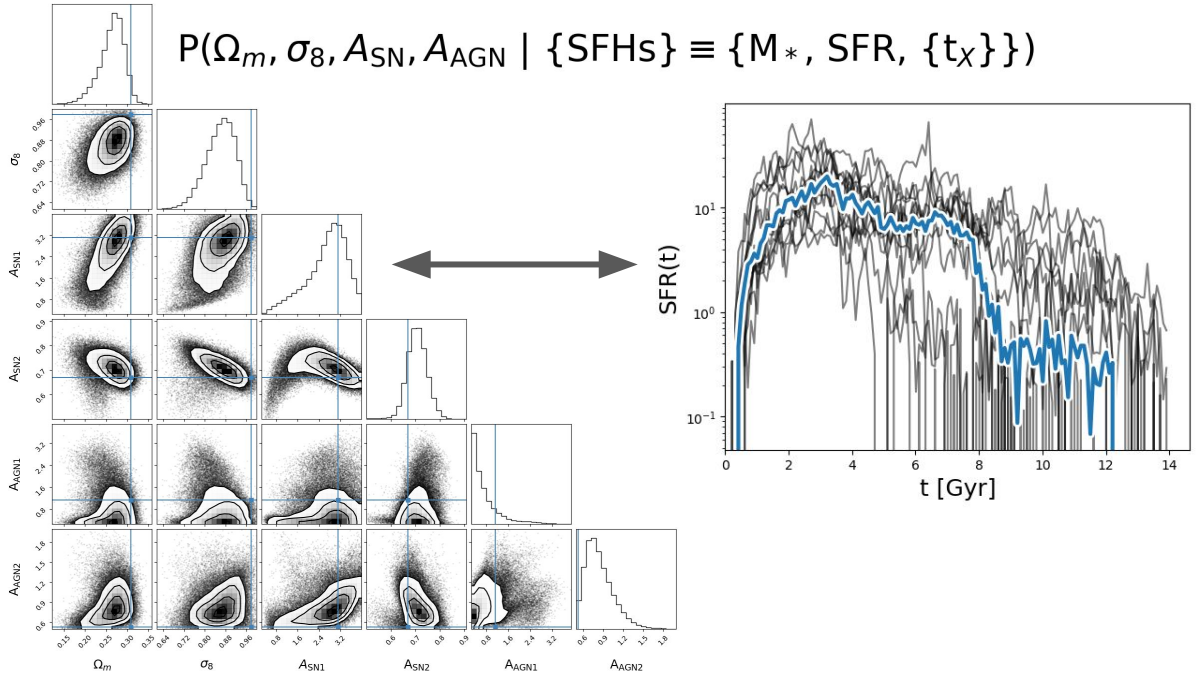

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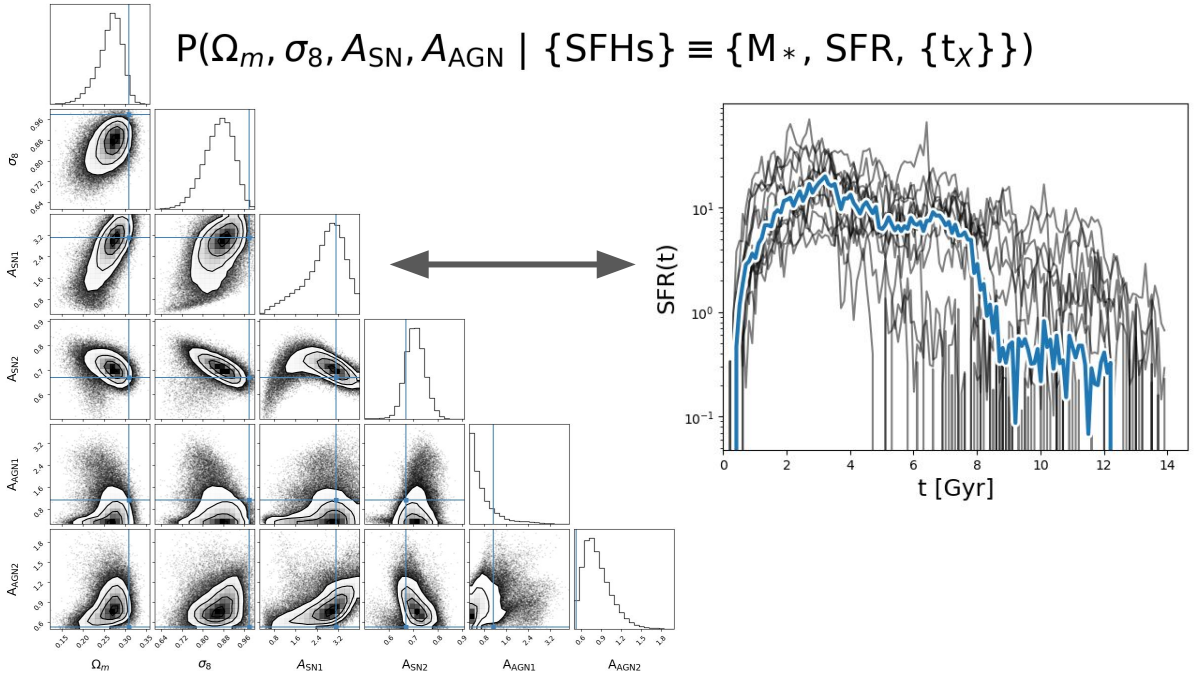
Yes.



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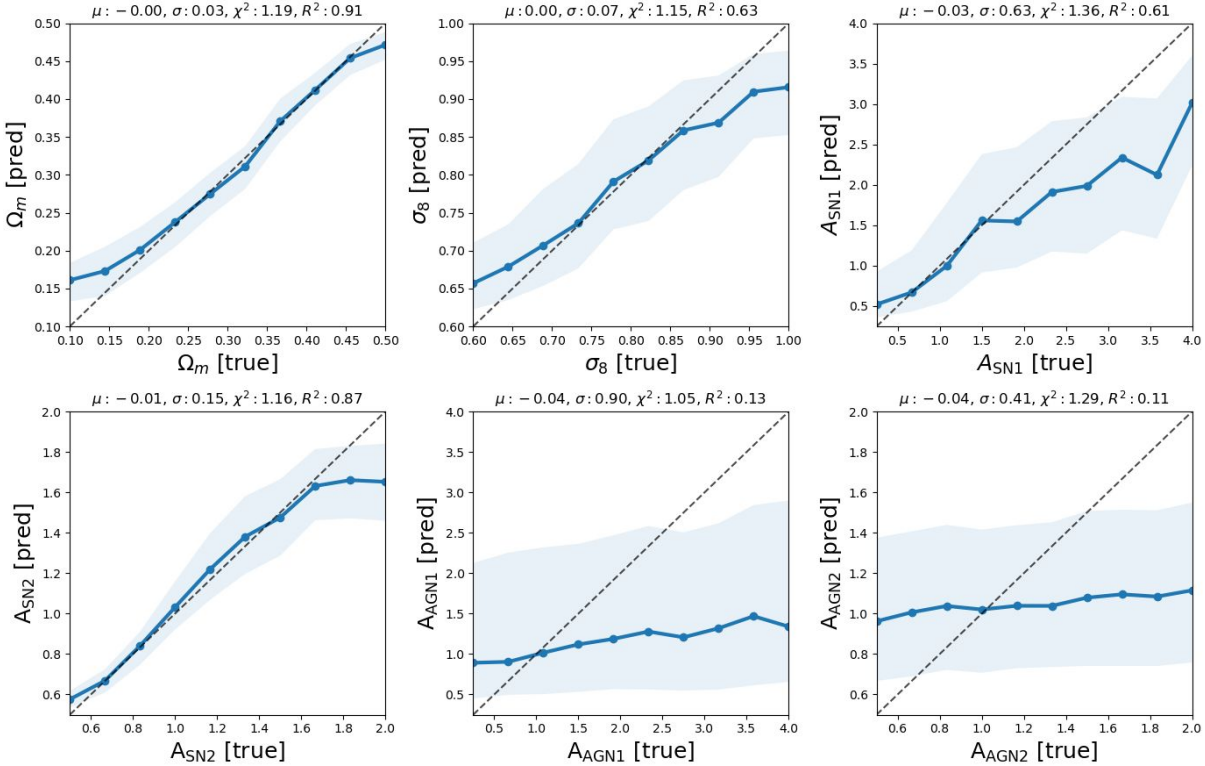
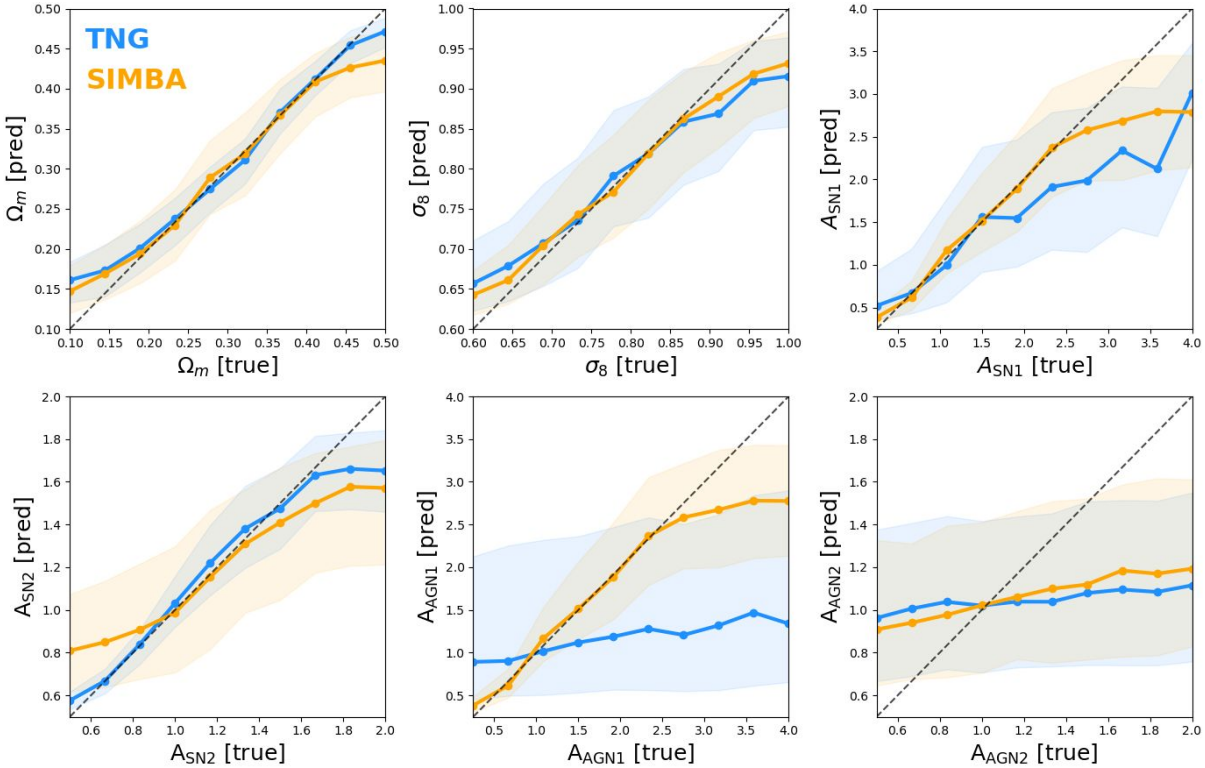
Yes.
(sort of)



left: CAMELS/TNG
100 galaxies, $10^{9.5}<M_*<10^{11.5}$

Can **SFHs** constrain feedback/cosmology?

Yes.
(sort of)



left: CAMELS/TNG+SIMBA
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Why are **SFHs** able to constrain feedback?

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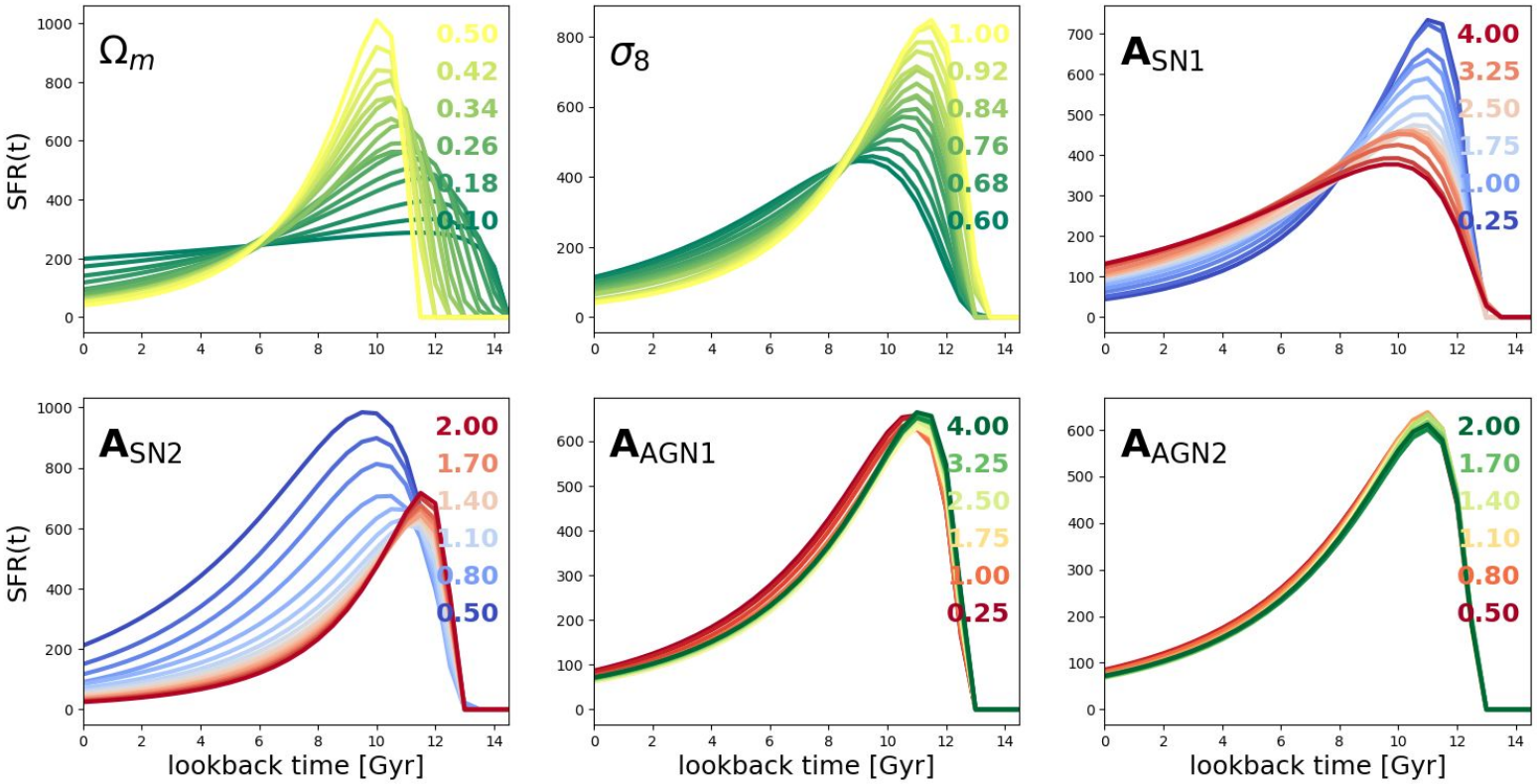

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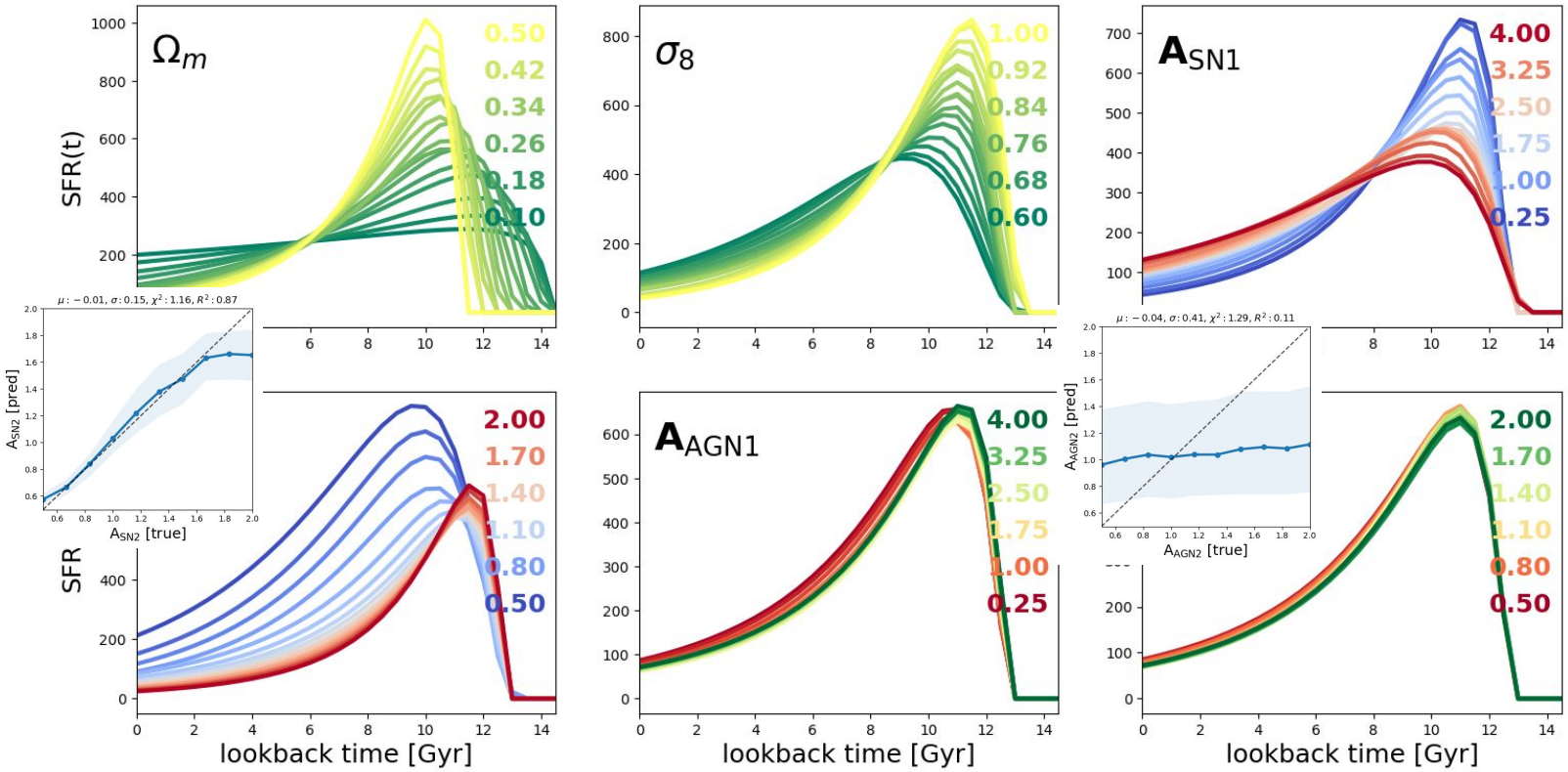

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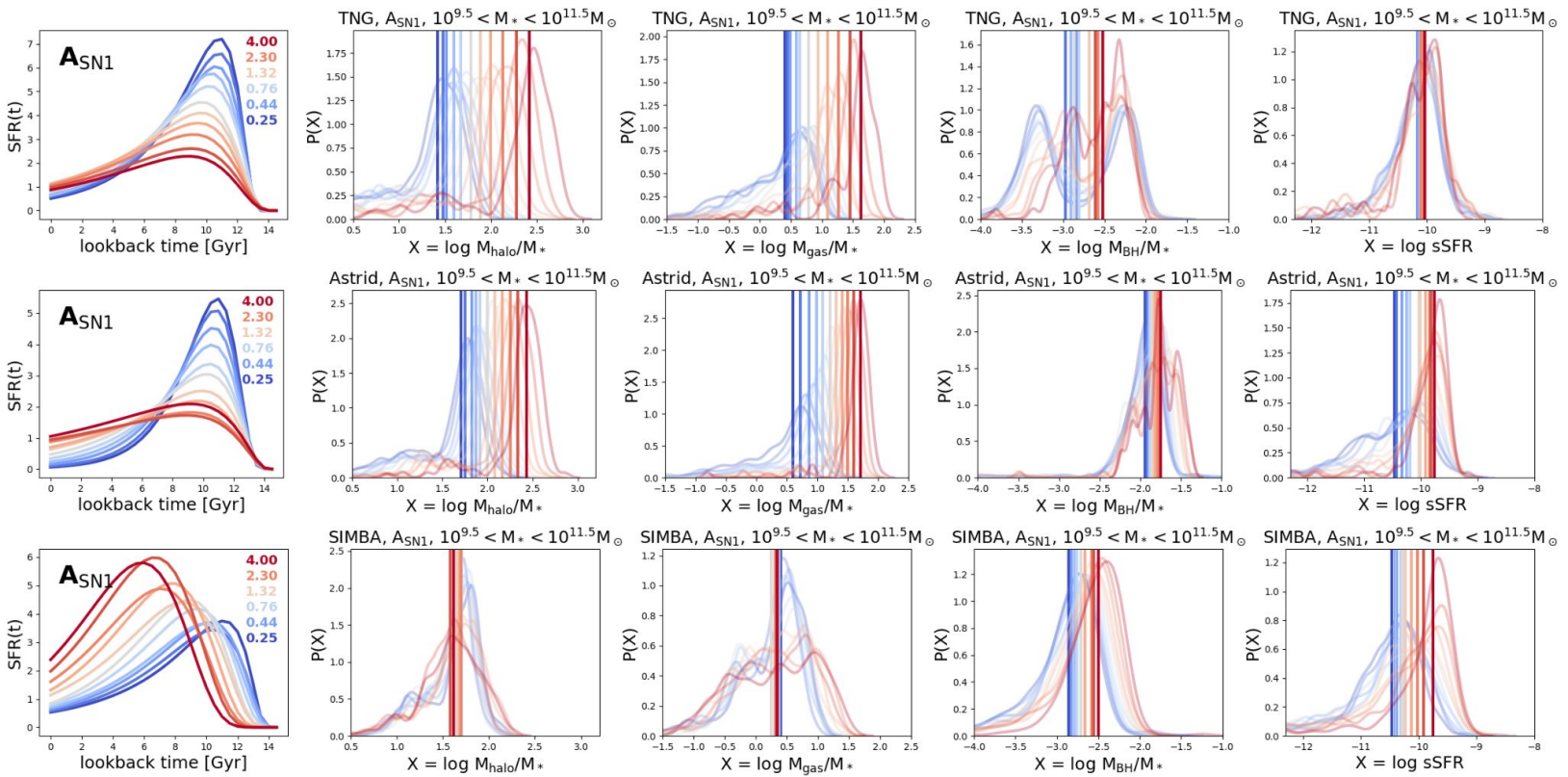
Simulation	A_{SN1}	A_{SN2}	A_{AGN1}	A_{AGN2}
ASTRID	Galactic winds: energy per unit SFR [0.25 - 4.00]	Galactic winds: wind speed [0.50 - 2.00]	Kinetic mode BH feedback: energy per unit BH accretion [0.25 - 4.00]	Thermal mode BH feedback: energy per unit BH accretion [0.25 - 4.00]
TNG	Galactic winds: energy per unit SFR [0.25 - 4.00]	Galactic winds: wind speed [0.50 - 2.00]	Kinetic mode BH feedback: energy per unit BH accretion [0.25 - 4.00]	Kinetic mode BH feedback: ejection speed / burstiness [0.50 - 2.00]
SIMBA	Galactic winds: mass loading [0.25 - 4.00]	Galactic winds: wind speed [0.50 - 2.00]	QSO & jet-mode BH feedback: momentum flux [0.25 - 4.00]	Jet-mode BH feedback: jet speed [0.50 - 2.00]

Table 1. This table summarizes the physical meaning of the four astrophysical parameters (A_{SN1}, A_{SN2}, A_{AGN1}, A_{AGN2}) in the ASTRID, TNG, and SIMBA suites. The fiducial parameter value in each simulation is normalized to $A_{SN1} = A_{SN2} = A_{AGN1} = A_{AGN2} = 1$. The variation of each parameter is also shown in each cell. We note that the range of A_{AGN2} in the ASTRID suites is different from TNG and SIMBA, as A_{AGN2} in the ASTRID suite represents energy flux, similar to A_{AGN1}.

Comparing trends: **TNG, SIMBA & Astrid**



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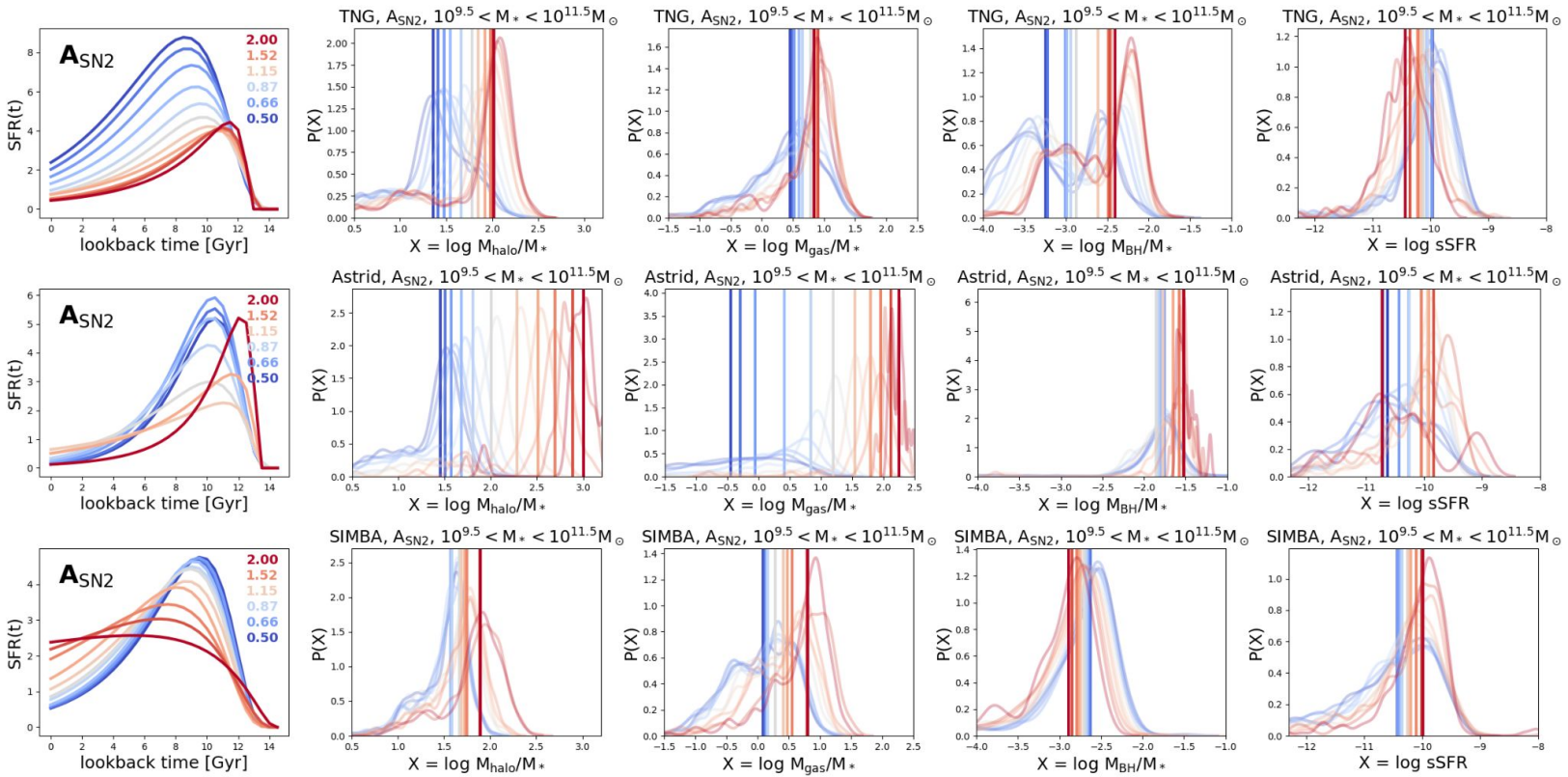

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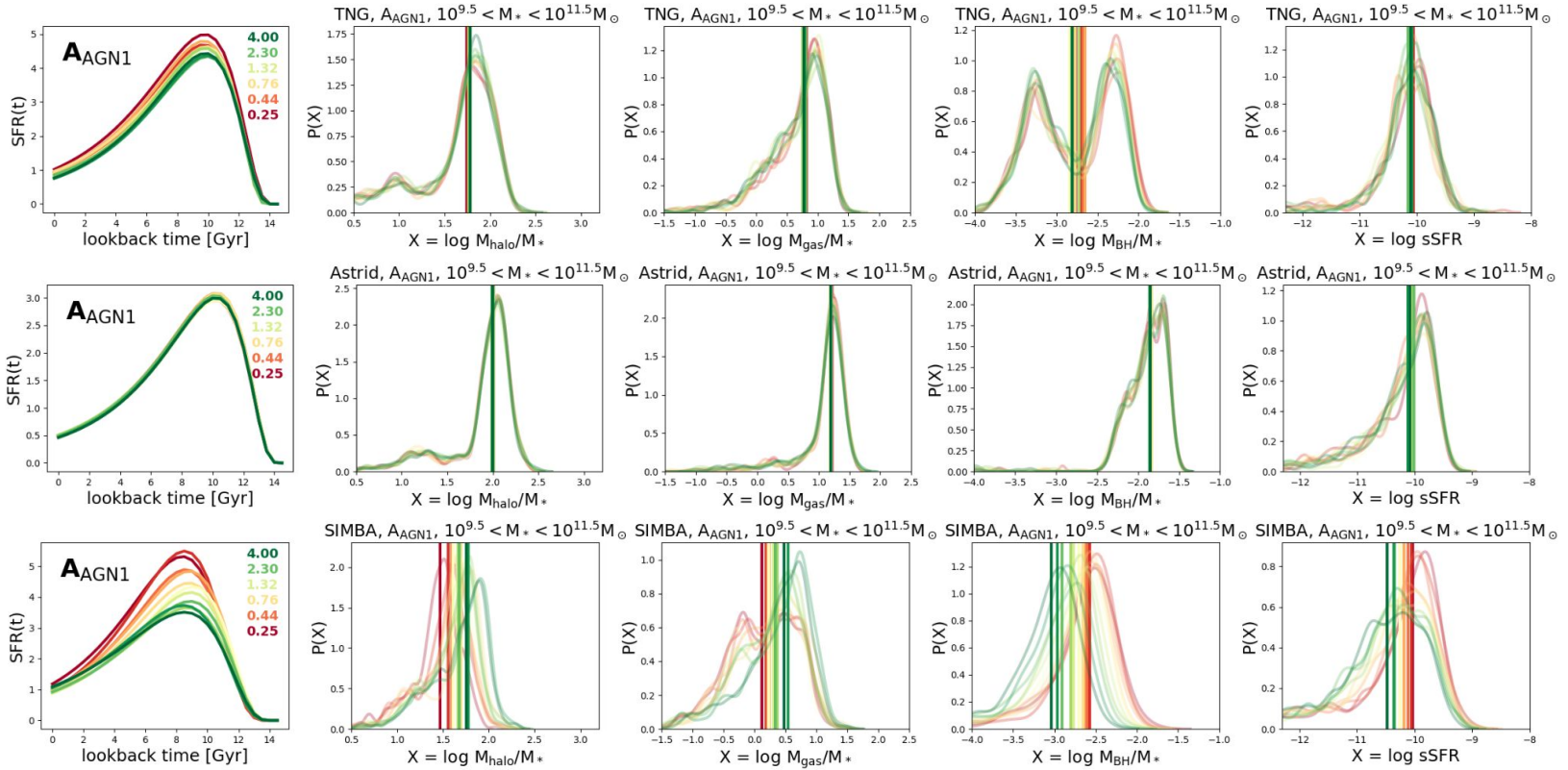

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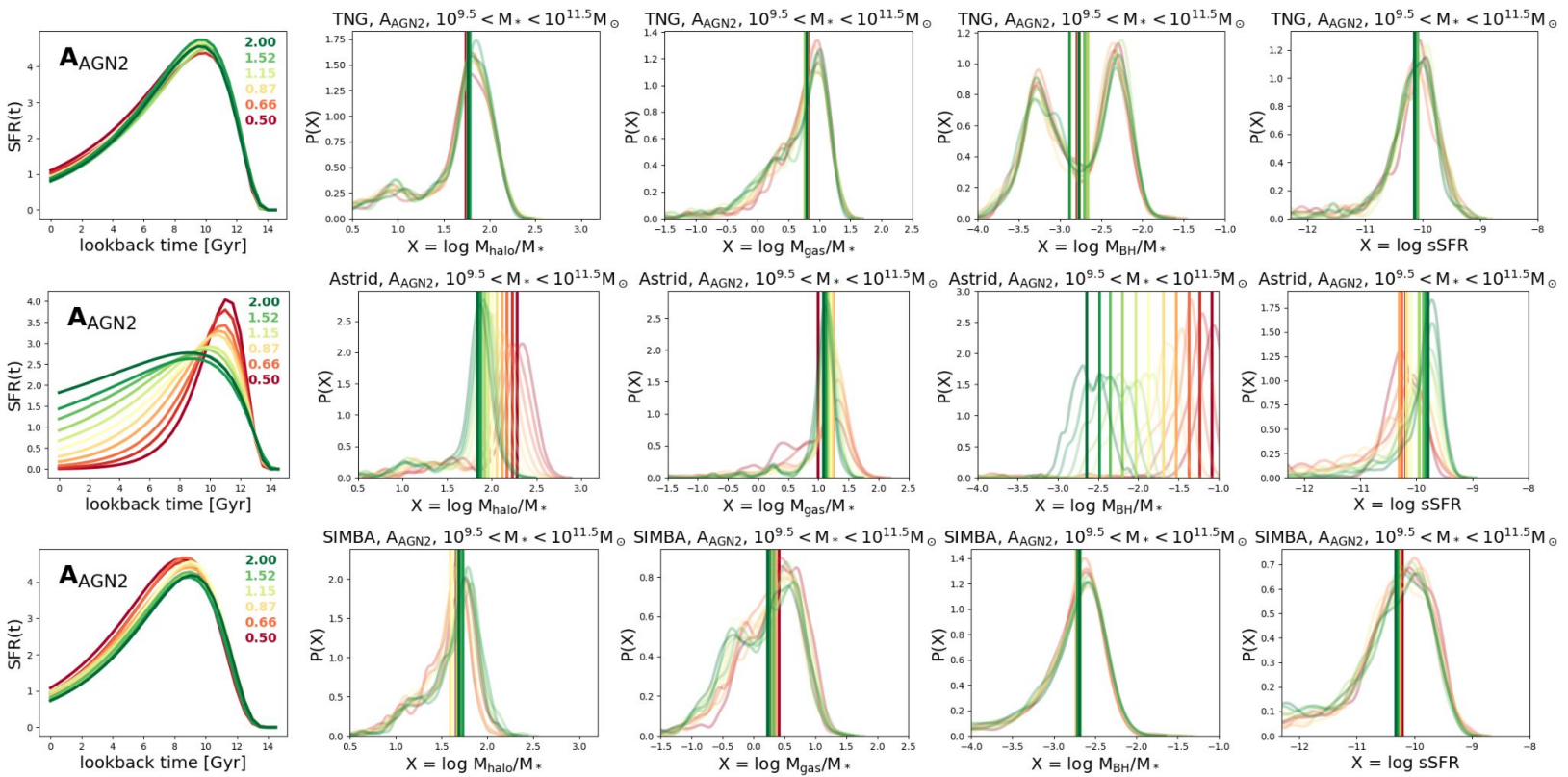

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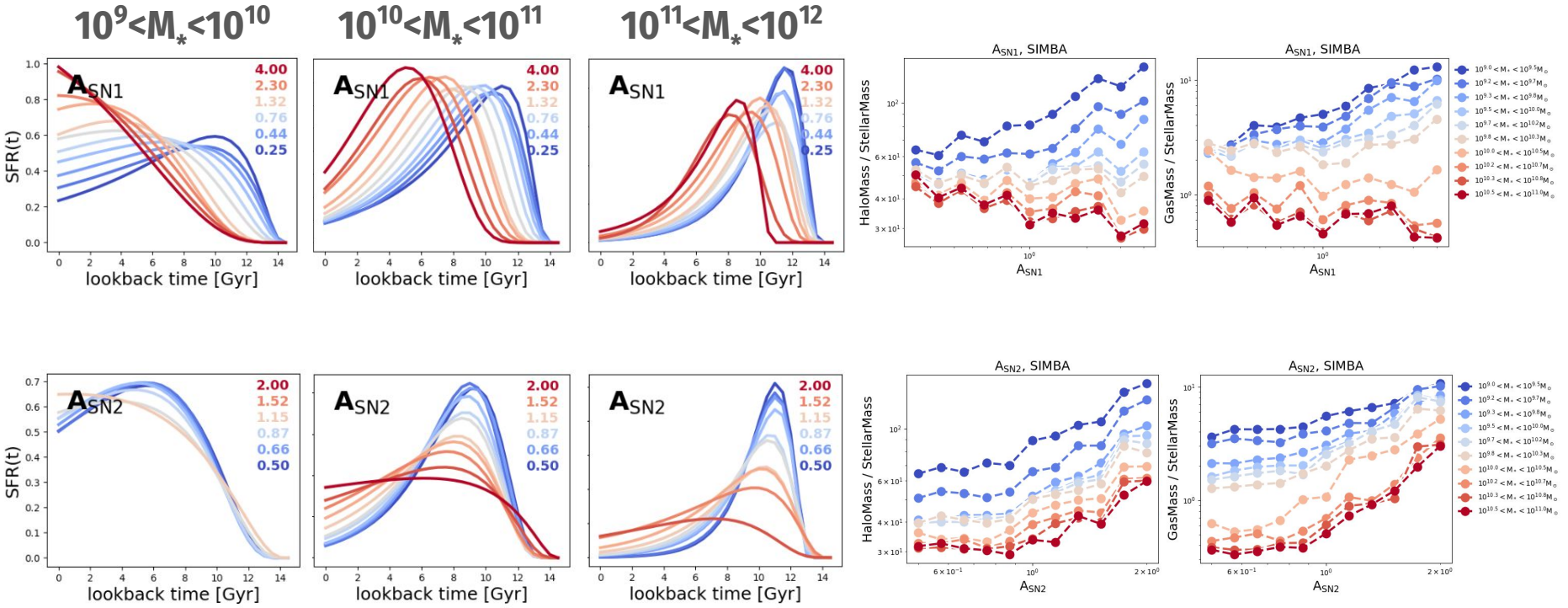

Comparing trends: **fdbk at diff. masses**

Kartheik Iyer @ SIMBA meeting | Preliminary figures based on Iyer et al. *in prep.*
Exploring the links between **feedback** and **galaxy SFHs**

- **The overall shapes of galaxy SFHs** contain information about the processes that regulate star formation
- **Large datasets like CAMELS + SBI** can quantify the relations between SF at different epochs & masses as a function of the strength of SNe and AGN feedback
- **Propagating this to observational space,** we can use distributions of SFHs from local + HST/JWST observations to constrain feedback for diff. Galaxy populations across a range of epochs!
- **Questions?** Any more tests? Summary stats to check? Methods?

Thank you!

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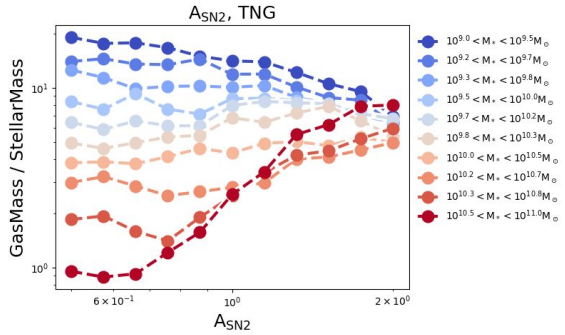
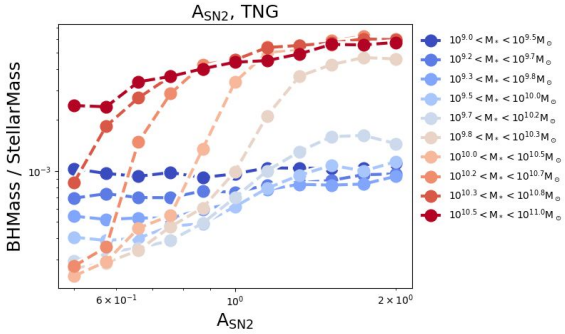
kgi2103@columbia.edu

Extra slides





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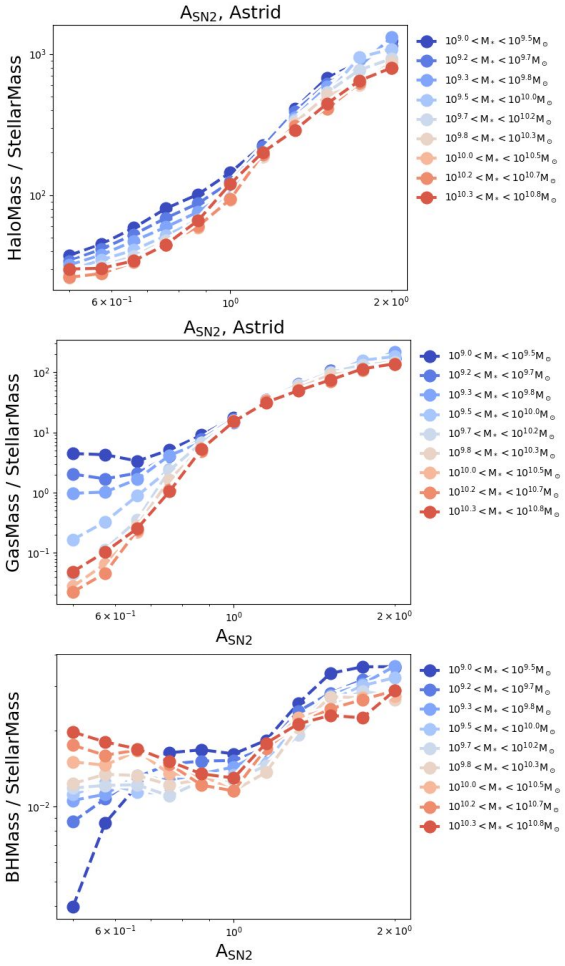
Comparing



at diff. masses

Kartheik Iyer @ SIMBA mee

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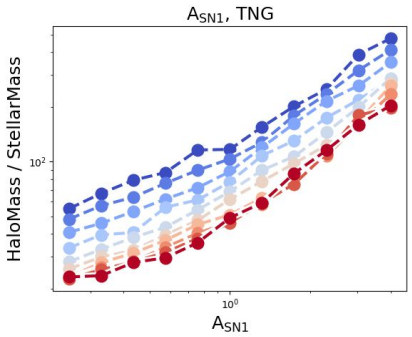
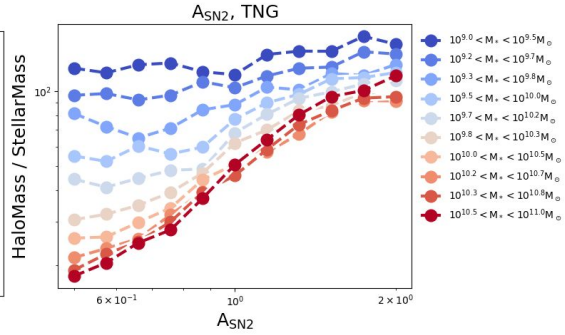
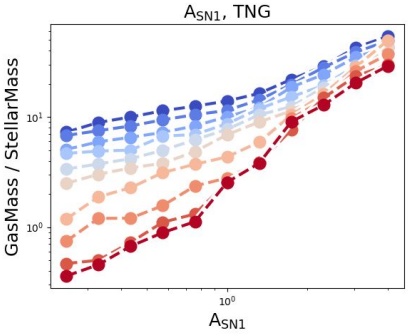
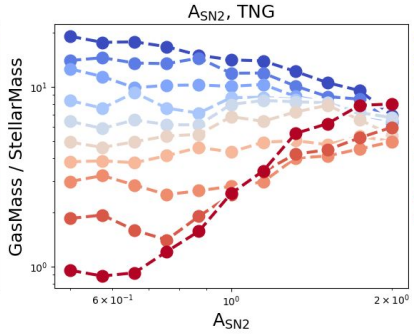
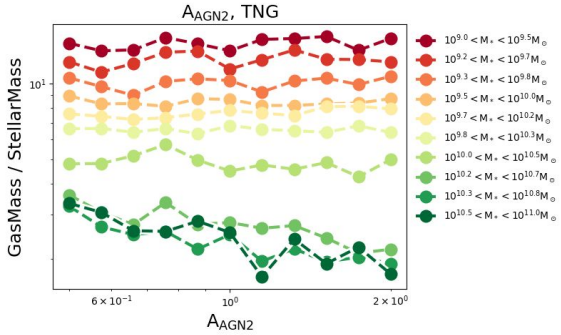

A_{SN1}, TNG
HaloMass / StellarMass
10^2
10^0
A_{SN1}


A_{SN2}, TNG
HaloMass / StellarMass
10^2
6×10^{-1}
10^0
2×10^0
A_{SN2}

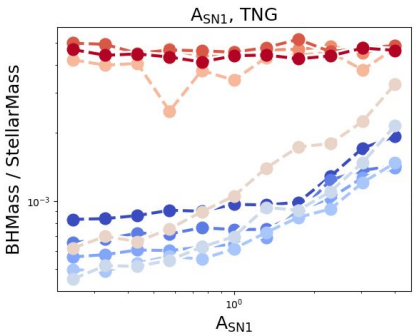
$10^{9.0} < M_* < 10^{9.5} M_\odot$
$10^{9.2} < M_* < 10^{9.7} M_\odot$
$10^{9.3} < M_* < 10^{9.8} M_\odot$
$10^{9.5} < M_* < 10^{10.0} M_\odot$
$10^{9.7} < M_* < 10^{10.2} M_\odot$
$10^{9.8} < M_* < 10^{10.3} M_\odot$
$10^{10.0} < M_* < 10^{10.5} M_\odot$
$10^{10.2} < M_* < 10^{10.7} M_\odot$
$10^{10.3} < M_* < 10^{10.8} M_\odot$
$10^{10.5} < M_* < 10^{11.0} M_\odot$

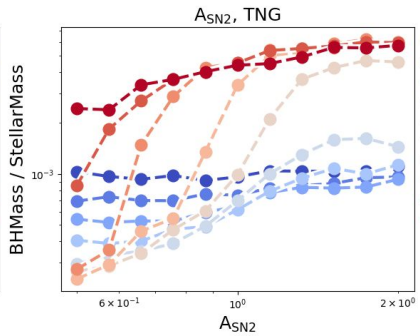

A_{SN1}, TNG
GasMass / StellarMass
10^1
10^0
A_{SN1}

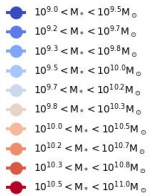

A_{SN2}, TNG
GasMass / StellarMass
10^1
10^0
6×10^{-1}
2×10^0
A_{SN2}

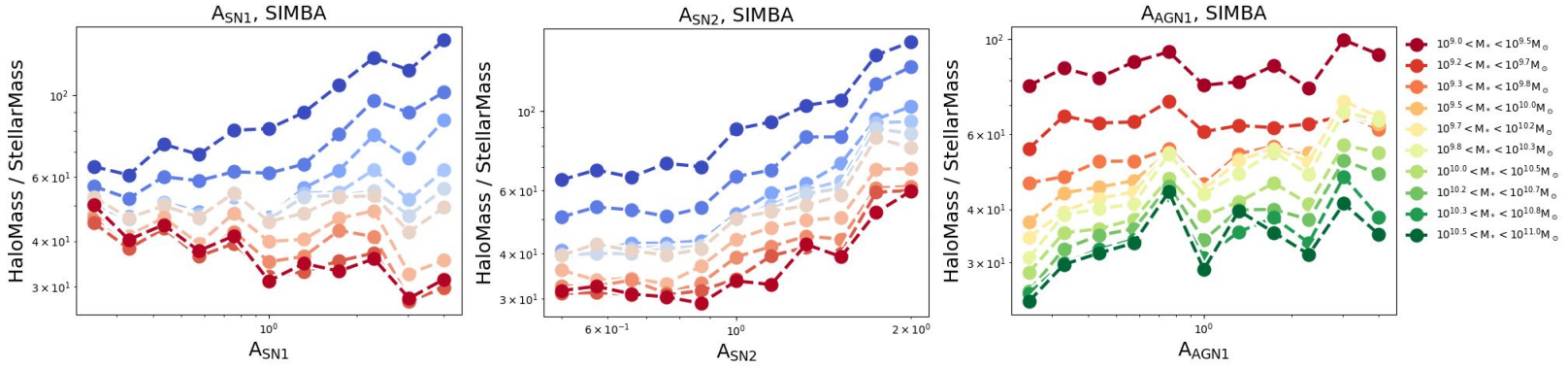

A_{AGN2}, TNG
GasMass / StellarMass
10^1
6×10^{-1}
10^0
2×10^0
A_{AGN2}

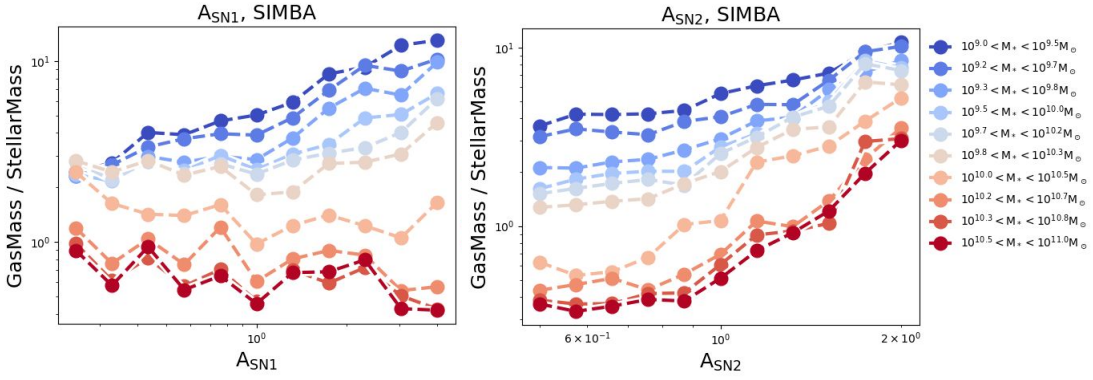
$10^{9.0} < M_* < 10^{9.5} M_\odot$
$10^{9.2} < M_* < 10^{9.7} M_\odot$
$10^{9.3} < M_* < 10^{9.8} M_\odot$
$10^{9.5} < M_* < 10^{10.0} M_\odot$
$10^{9.7} < M_* < 10^{10.2} M_\odot$
$10^{9.8} < M_* < 10^{10.3} M_\odot$
$10^{10.0} < M_* < 10^{10.5} M_\odot$
$10^{10.2} < M_* < 10^{10.7} M_\odot$
$10^{10.3} < M_* < 10^{10.8} M_\odot$
$10^{10.5} < M_* < 10^{11.0} M_\odot$

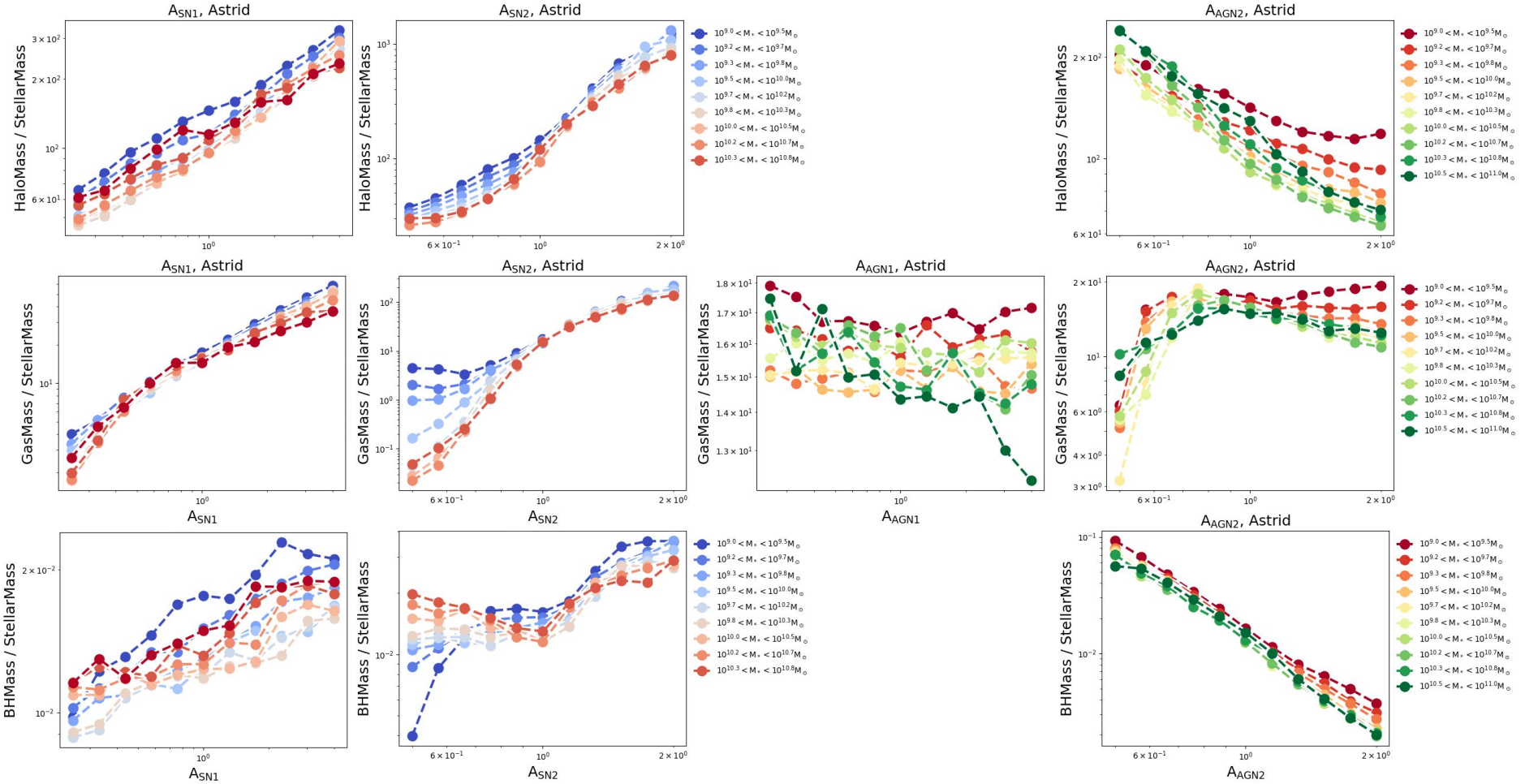

A_{SN1}, TNG
BHMass / StellarMass
10^{-3}
10^0
A_{SN1}

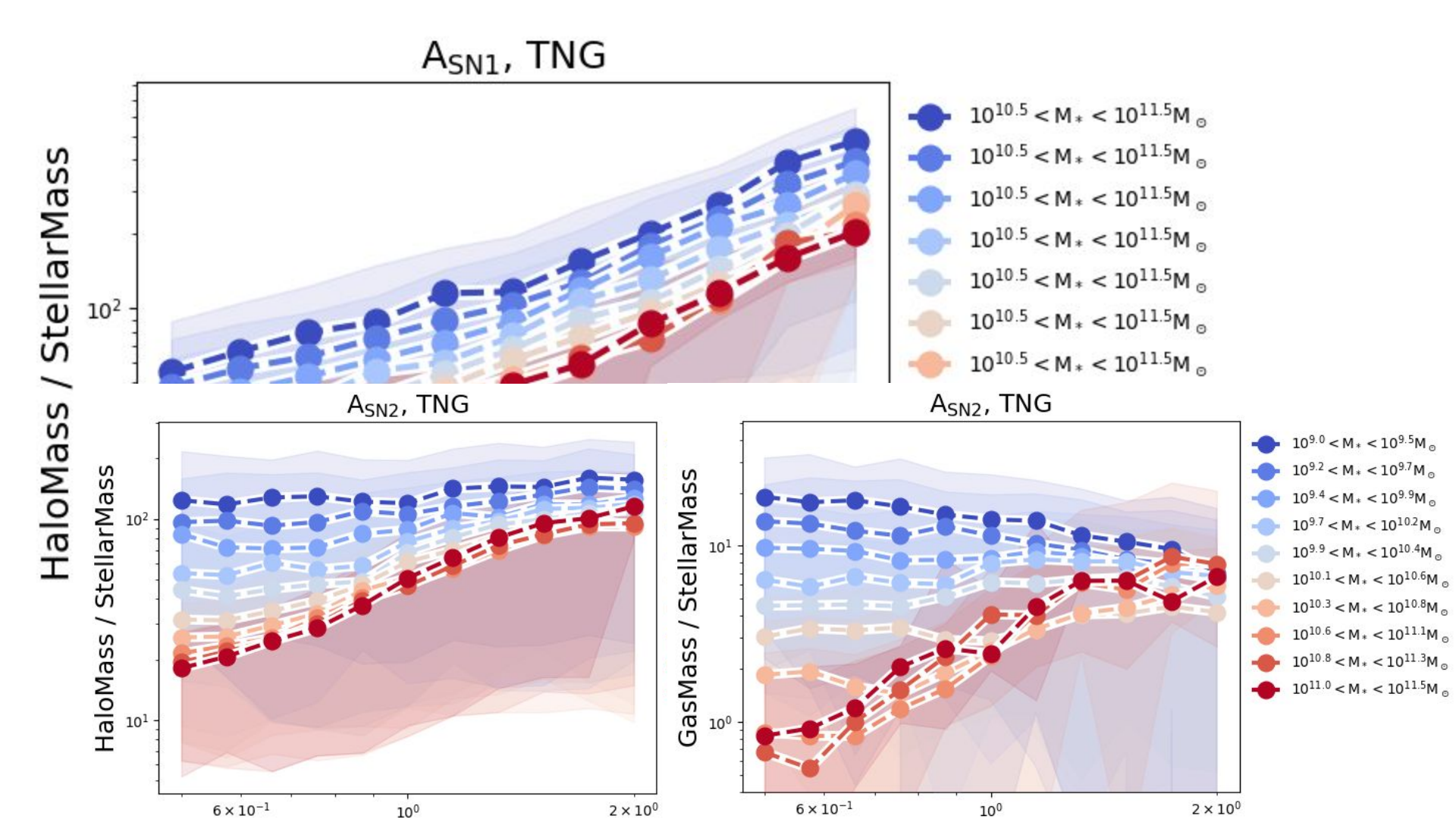

A_{SN2}, TNG
BHMass / StellarMass
10^{-3}
6×10^{-1}
10^0
2×10^0
A_{SN2}

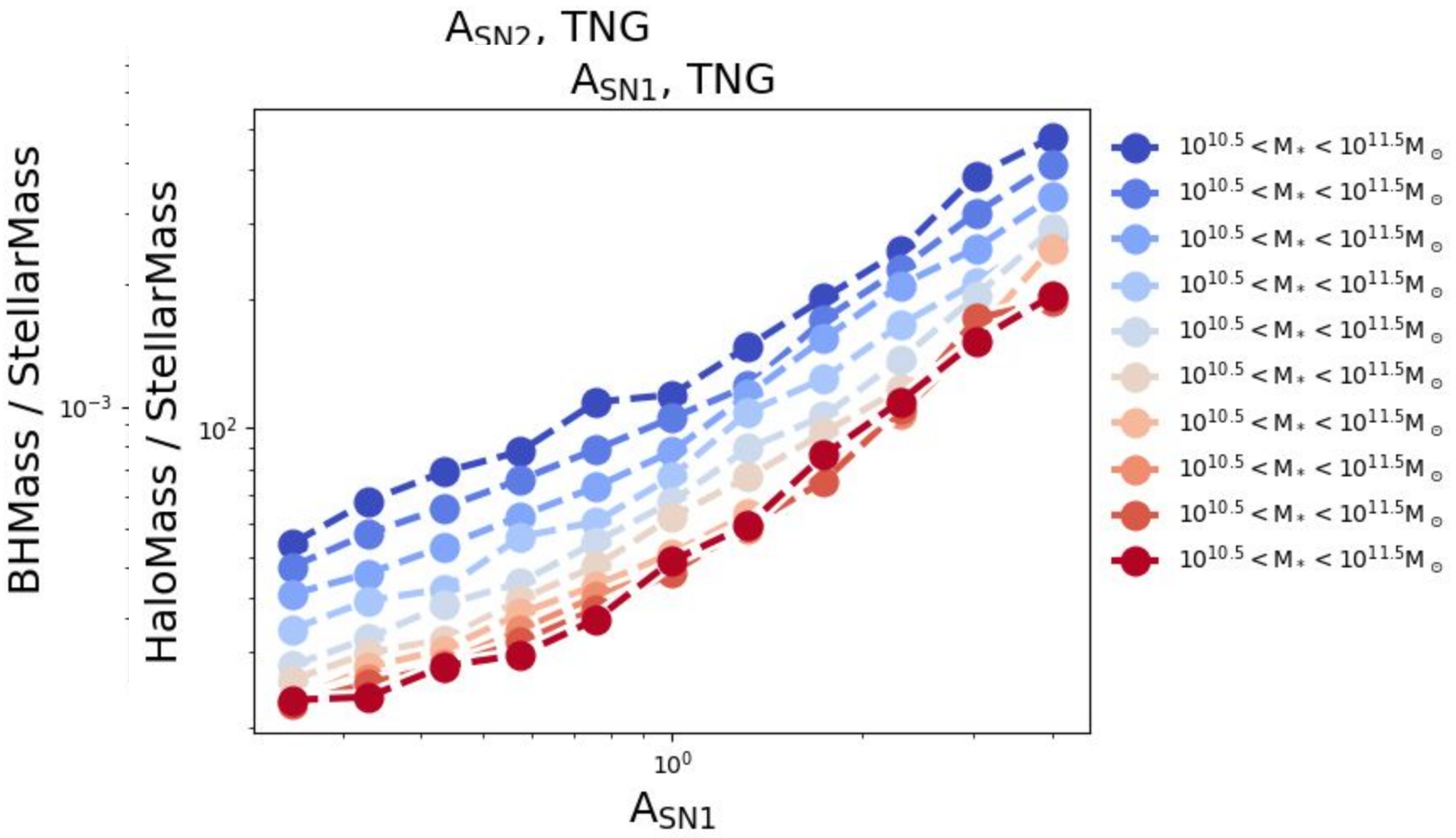

$10^{9.0} < M_* < 10^{9.5} M_\odot$
$10^{9.2} < M_* < 10^{9.7} M_\odot$
$10^{9.3} < M_* < 10^{9.8} M_\odot$
$10^{9.5} < M_* < 10^{10.0} M_\odot$
$10^{9.7} < M_* < 10^{10.2} M_\odot$
$10^{9.8} < M_* < 10^{10.3} M_\odot$
$10^{10.0} < M_* < 10^{10.5} M_\odot$
$10^{10.2} < M_* < 10^{10.7} M_\odot$
$10^{10.3} < M_* < 10^{10.8} M_\odot$
$10^{10.5} < M_* < 10^{11.0} M_\odot$

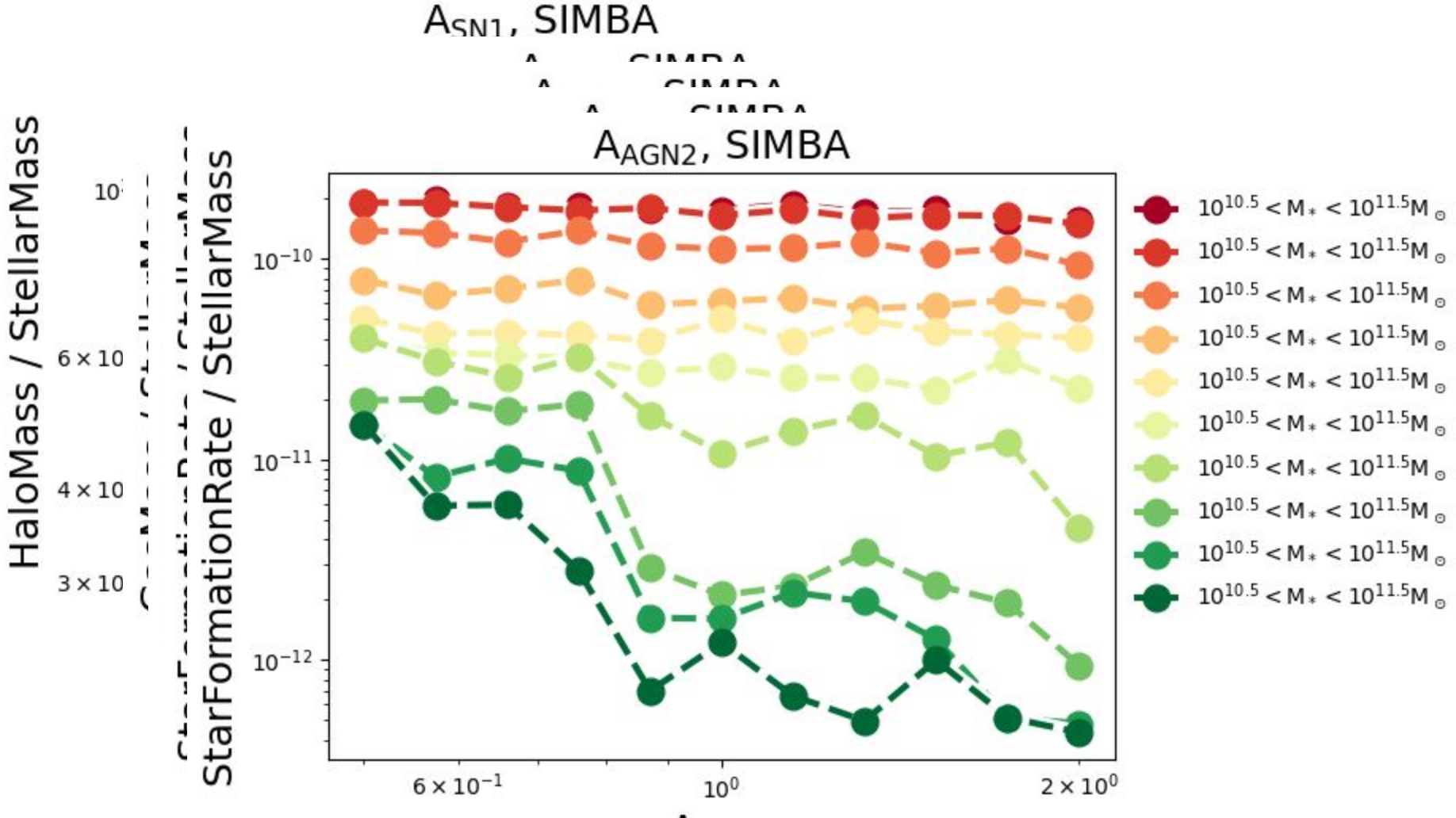

A_{SN1}, SIMBA
HaloMass / StellarMass
A_{SN1}
A_{SN2}, SIMBA
HaloMass / StellarMass
A_{SN2}
A_{AGN1}, SIMBA
HaloMass / StellarMass
A_{AGN1}
$10^{9.0} < M_* < 10^{9.5} M_\odot$
$10^{9.2} < M_* < 10^{9.7} M_\odot$
$10^{9.3} < M_* < 10^{9.8} M_\odot$
$10^{9.5} < M_* < 10^{10.0} M_\odot$
$10^{9.7} < M_* < 10^{10.2} M_\odot$
$10^{9.8} < M_* < 10^{10.3} M_\odot$
$10^{10.0} < M_* < 10^{10.5} M_\odot$
$10^{10.2} < M_* < 10^{10.7} M_\odot$
$10^{10.3} < M_* < 10^{10.8} M_\odot$
$10^{10.5} < M_* < 10^{11.0} M_\odot$

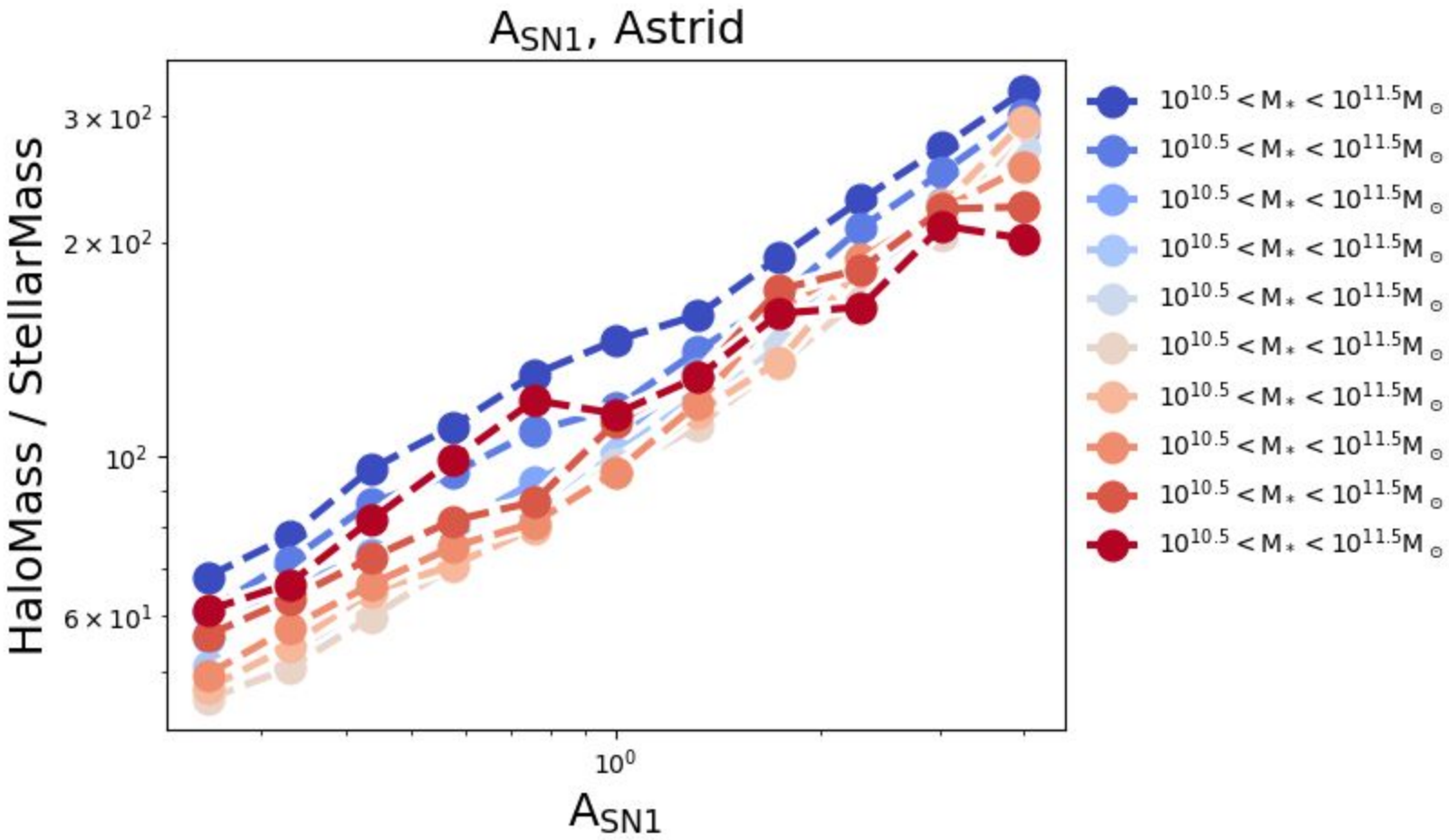

A_{SN1}, SIMBA
GasMass / StellarMass
A_{SN1}
A_{SN2}, SIMBA
GasMass / StellarMass
A_{SN2}
$10^{9.0} < M_* < 10^{9.5} M_\odot$
$10^{9.2} < M_* < 10^{9.7} M_\odot$
$10^{9.3} < M_* < 10^{9.8} M_\odot$
$10^{9.5} < M_* < 10^{10.0} M_\odot$
$10^{9.7} < M_* < 10^{10.2} M_\odot$
$10^{9.8} < M_* < 10^{10.3} M_\odot$
$10^{10.0} < M_* < 10^{10.5} M_\odot$
$10^{10.2} < M_* < 10^{10.7} M_\odot$
$10^{10.3} < M_* < 10^{10.8} M_\odot$
$10^{10.5} < M_* < 10^{11.0} M_\odot$


A_{SN1}, Astrid
A_{SN2}, Astrid
A_{AGN2}, Astrid
A_{SN1}, Astrid
A_{SN2}, Astrid
A_{AGN1}, Astrid
A_{AGN2}, Astrid
A_{SN1}, Astrid
A_{SN2}, Astrid
A_{AGN2}, Astrid
HaloMass / StellarMass
GasMass / StellarMass
BHMass / StellarMass
A_{SN1}
A_{SN2}
A_{AGN1}
A_{AGN2}
$10^{9.0} < M_* < 10^{9.5} M_\odot$
$10^{9.2} < M_* < 10^{9.7} M_\odot$
$10^{9.3} < M_* < 10^{9.8} M_\odot$
$10^{9.5} < M_* < 10^{10.0} M_\odot$
$10^{9.7} < M_* < 10^{10.2} M_\odot$
$10^{9.8} < M_* < 10^{10.3} M_\odot$
$10^{10.0} < M_* < 10^{10.5} M_\odot$
$10^{10.2} < M_* < 10^{10.7} M_\odot$
$10^{10.3} < M_* < 10^{10.8} M_\odot$
$10^{10.5} < M_* < 10^{11.0} M_\odot$


A_SN1, TNG
HaloMass / StellarMass
10^2
10^10.5 < M* < 10^11.5 M⊙
A_SN2, TNG
HaloMass / StellarMass
10^2
10^1
6 × 10^-1
10^0
2 × 10^0
A_SN2, TNG
GasMass / StellarMass
10^1
10^0
6 × 10^-1
10^0
2 × 10^0
10^9.0 < M* < 10^9.5 M⊙
10^9.2 < M* < 10^9.7 M⊙
10^9.4 < M* < 10^9.9 M⊙
10^9.7 < M* < 10^10.2 M⊙
10^9.9 < M* < 10^10.4 M⊙
10^10.1 < M* < 10^10.6 M⊙
10^10.3 < M* < 10^10.8 M⊙
10^10.6 < M* < 10^11.1 M⊙
10^10.8 < M* < 10^11.3 M⊙
10^11.0 < M* < 10^11.5 M⊙


A_{SN2}, TNG
A_{SN1}, TNG
BHMass / StellarMass
HaloMass / StellarMass
10^{-3}
10^{2}
10^{0}
A_{SN1}
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$


A_{SN1}, SIMBA
A_{AGN2}, SIMBA
HaloMass / StellarMass
StarFormationRate / StellarMass
10^{-10}
10^{-11}
10^{-12}
6×10^{-1}
10^{0}
2×10^{0}
$10^{10.5} < M_* < 10^{11.5} M_\odot$


A_{SN1}, Astrid
HaloMass / StellarMass
3×10^2
2×10^2
10^2
6×10^1
10^0
A_{SN1}
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$
$10^{10.5} < M_* < 10^{11.5} M_\odot$