Stellar Mass-Halo Mass Relation

to the second order

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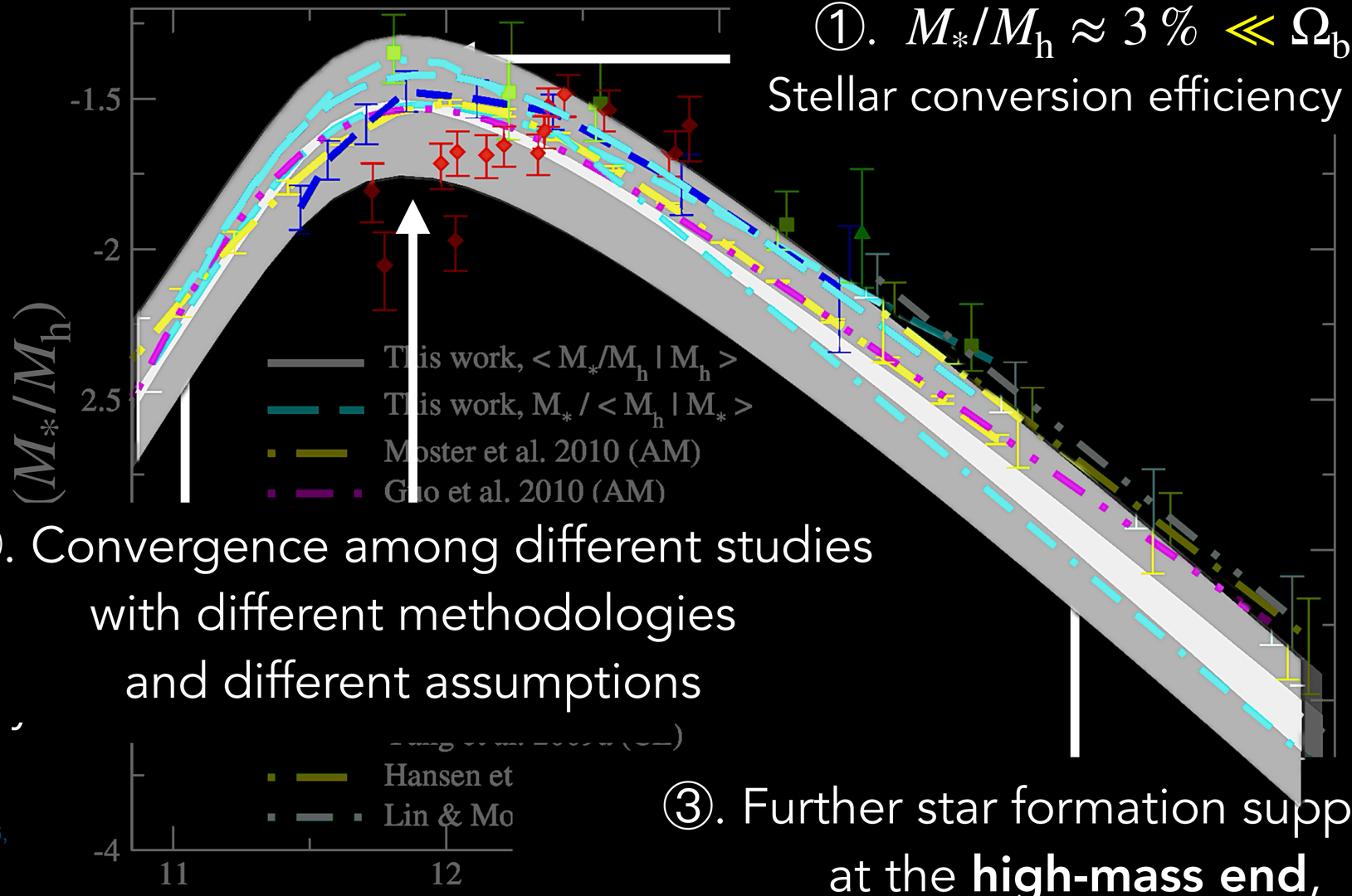
based on

- arXiv: 2304.07189 KW et al. 2023
- arXiv: 2408.07743 KW & Peng 2024

scan me!

20241008 - Mock Barcelona

- **Stellar mass-halo mass relation**



① . $M_*/M_h \approx 3\,\% \ll \Omega_b/\Omega_m \approx 16\,\%$

Stellar conversion efficiency is **LOW** overall.

② . Fu

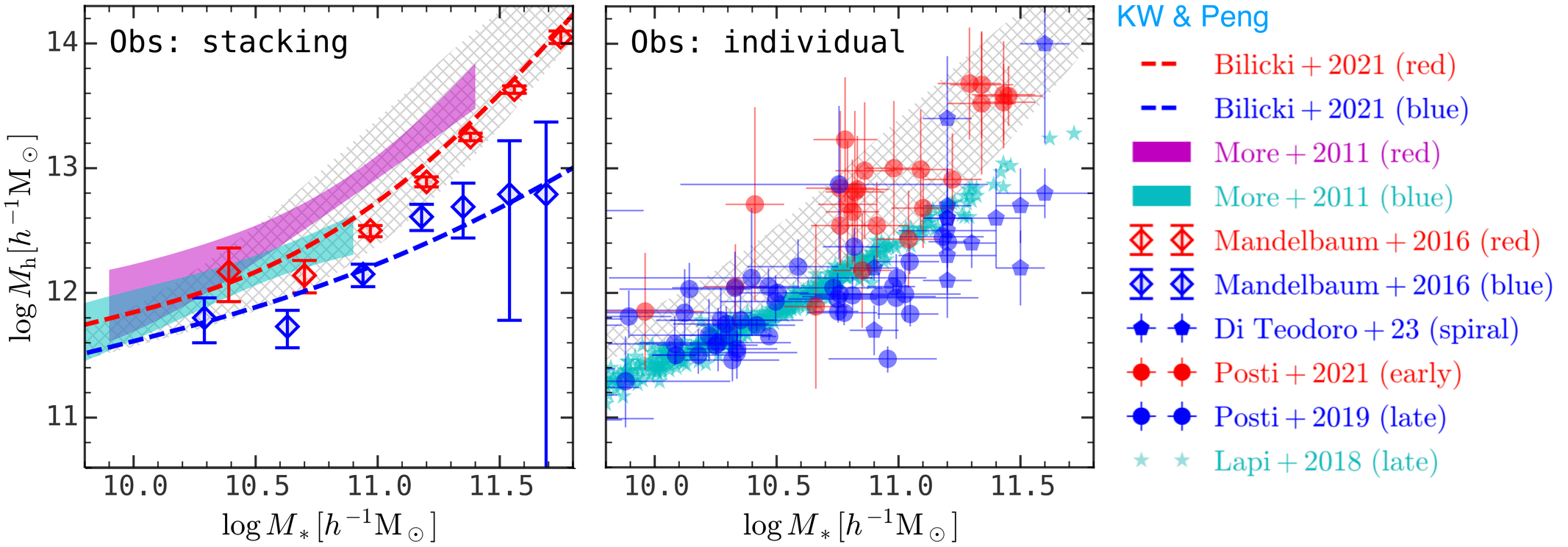
p

④. Convergence among different studies with different methodologies and different assumptions

③. Further star formation suppresion at the **high-mass end**, possibly from *AGN feedback* & *inefficient cooling*

Yang+2003, van den Bosch+2003, Lin&Mohr2004, Mandelbaum+2006, Zheng+2007, Gavazzi+2007, Hansen+2009, Wang&Jing2010, Moster+2010, 2013, 2018, Guo+2010, Klypin+2010, Behroozi+2010, 2013, 2019, Mo+2024 etc.

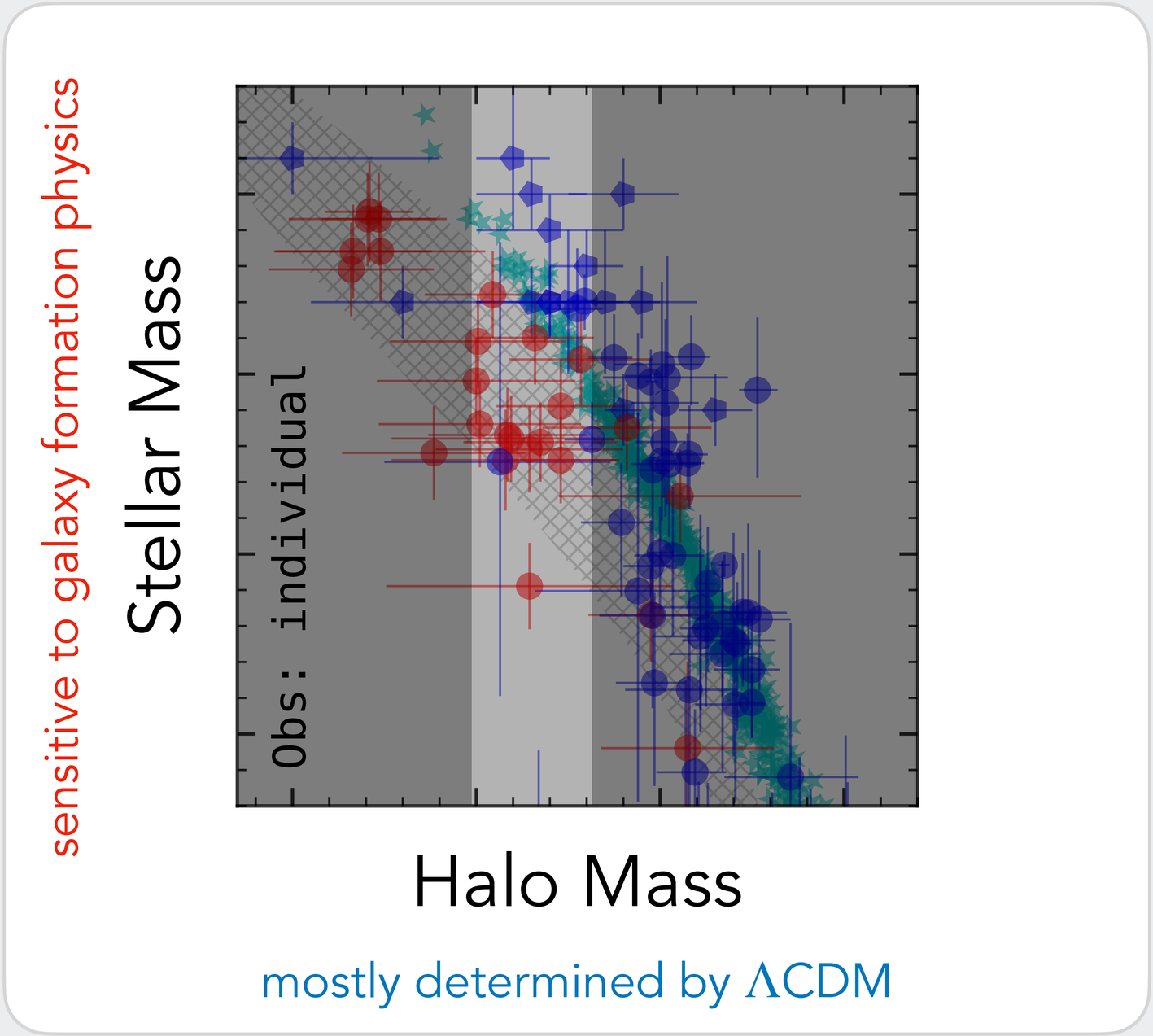
- **Stellar mass-halo mass relation for red and blue galaxies**



Different studies converge to the same qualitative conclusion:

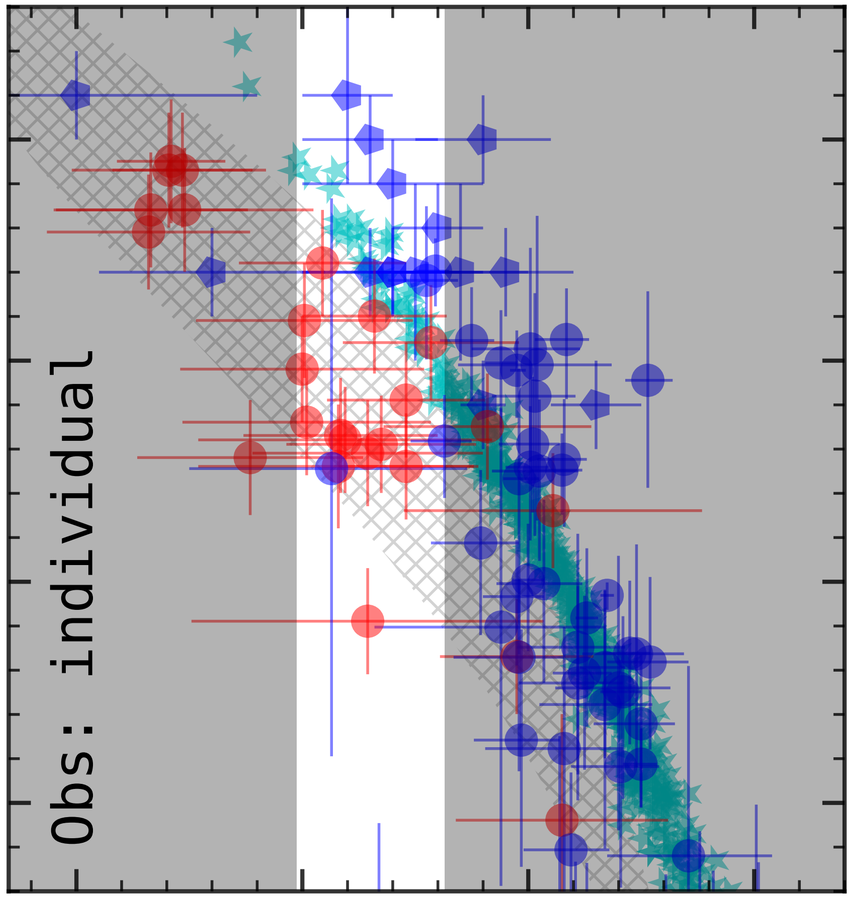
At fixed stellar mass, red galaxies live in *more massive* halos than blue galaxies.

- **Stellar mass-halo mass relation for red and blue galaxies**



- **Stellar mass-halo mass relation for red and blue galaxies**

sensitive to galaxy formation physics

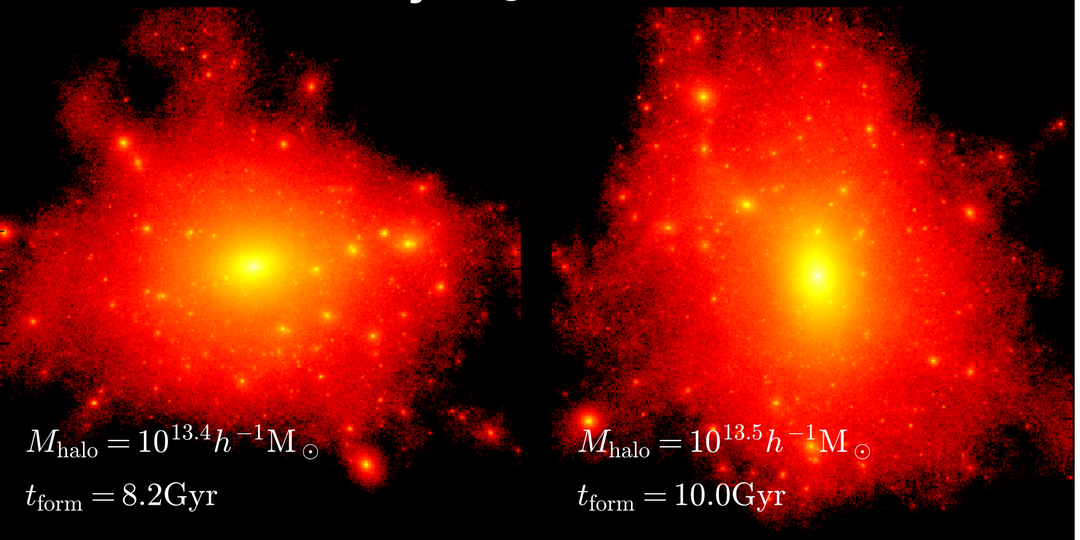


mostly determined by ΛCDM

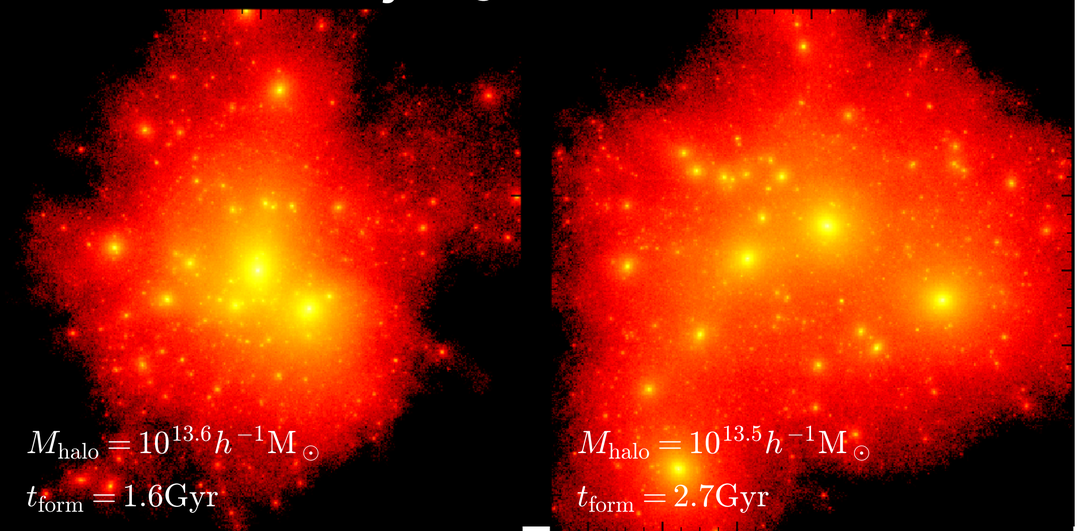
At fixed halo mass,
star-forming galaxies
are more massive than
quiescent galaxies.

• Central stellar mass as a proxy of halo formation time

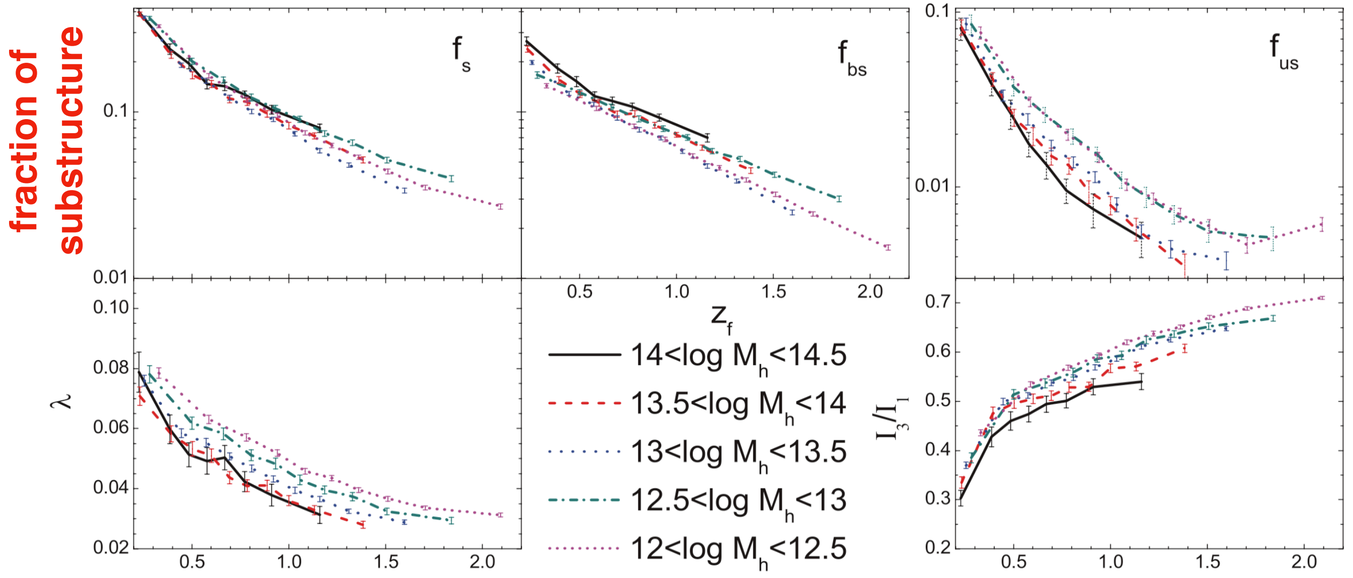
Halos formed ~10 Gyrs ago:



Halos formed ~2 Gyrs ago:



Wang et al. 2011



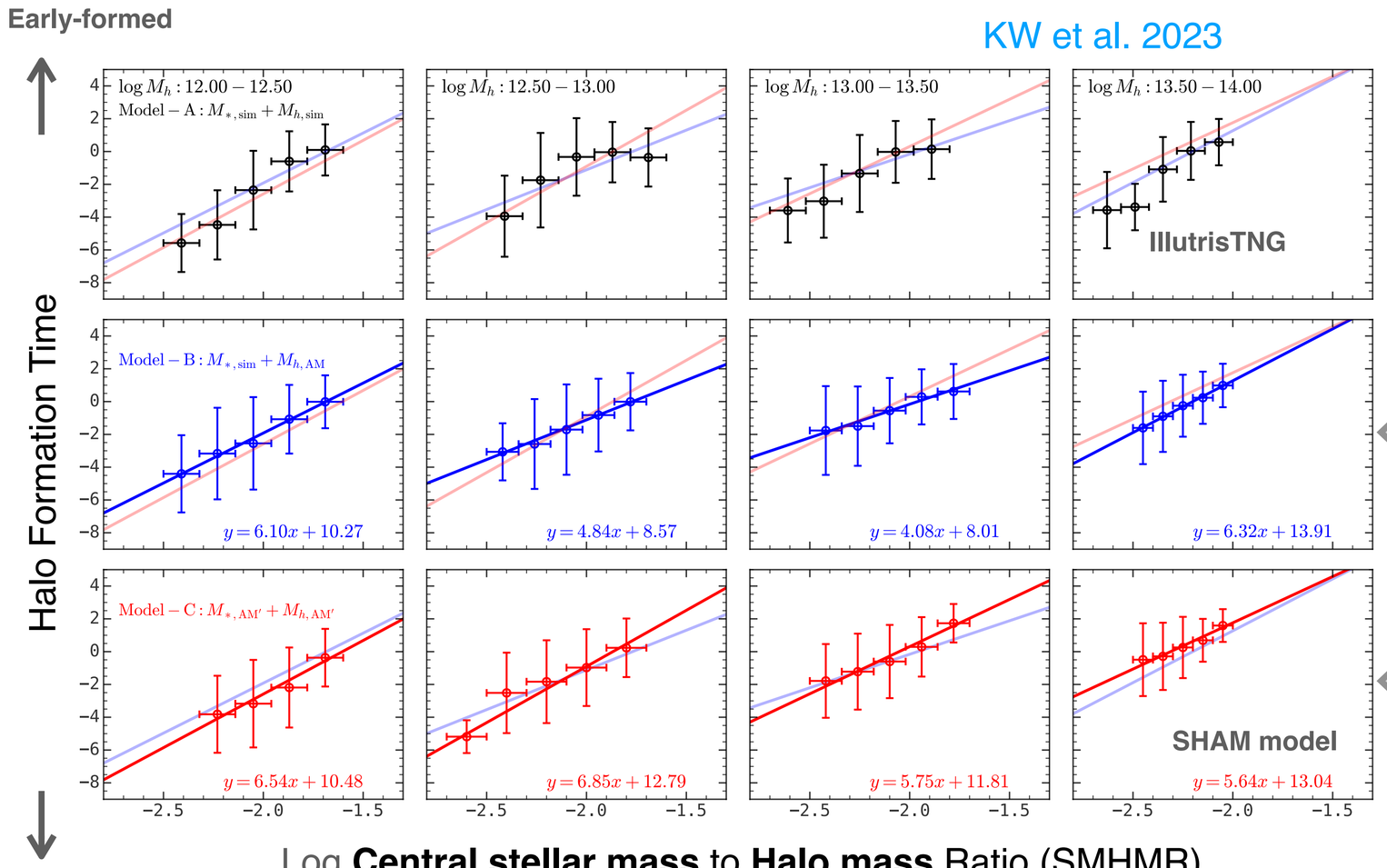
Halo Formation Time in redshift

Early-formed halos

==> have more time to cannibalize their substructures,

==> thus have **less substructures** and **more dominanting**

• Central stellar mass as a proxy of halo formation time



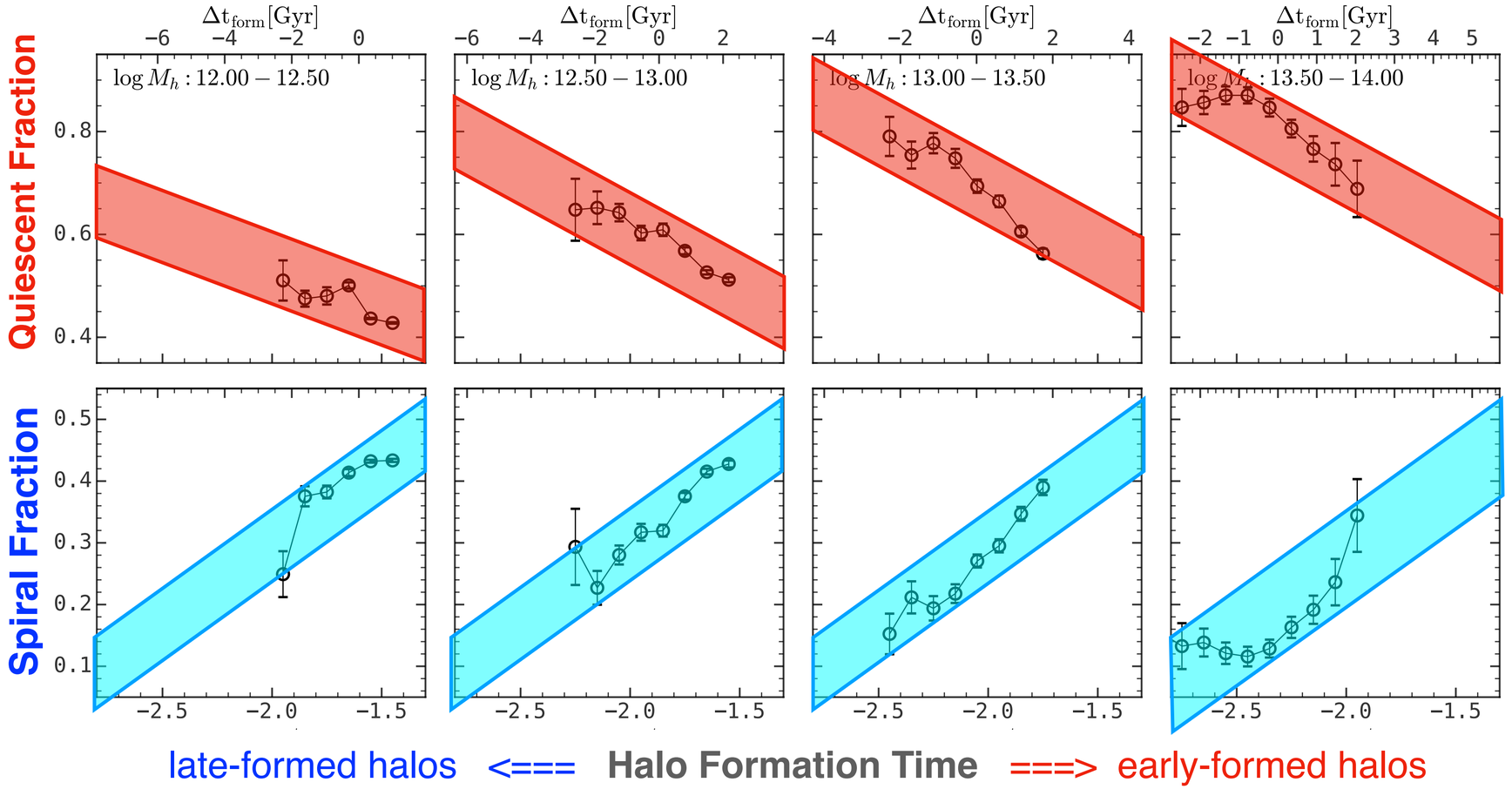
- ✦Halos with **more massive central galaxies** are **formed earlier.**
- ✦**Central SMHMR** is a **valid proxy** for **halo formation time.**
- ✦Similar results in
  - EAGLE (Matthee et al. 2017, Correa et al. 2020)
  - IllustrisTNG (Bose et al. 2019, Martizzi et al. 2020)
  - SAM (Zehavi et al. 2018)
  - UniverseMachine (Bradshaw et al. 2020)

- **Halo assembly history relates to central quenching and morphology**

Apply to **SDSS MGS**
with **Yang's Group Catalog**
with **GSWLC M⋆ and SFR**
with **Galaxy Zoo morphology**

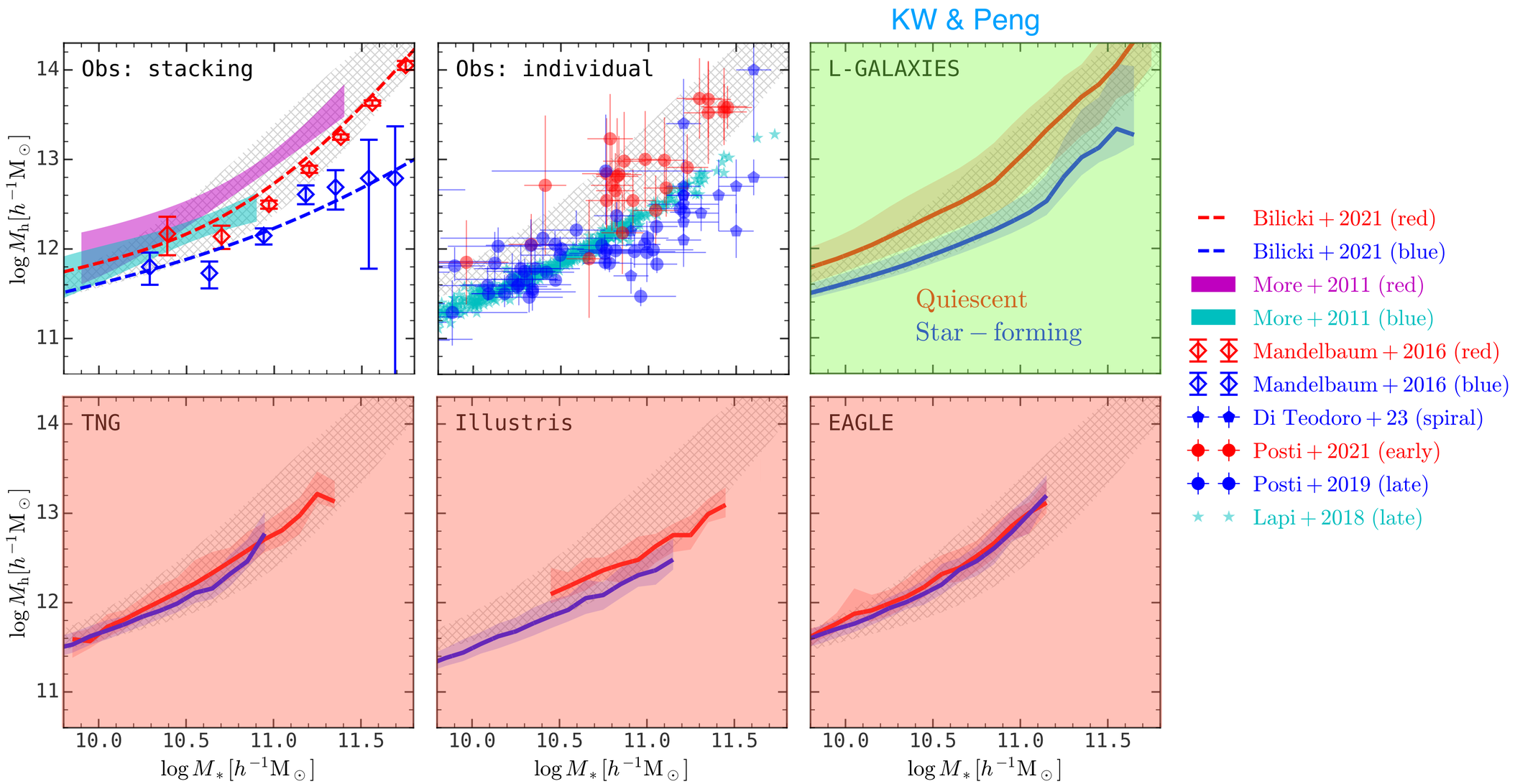
In different halo mass bins:

KW et al. 2023

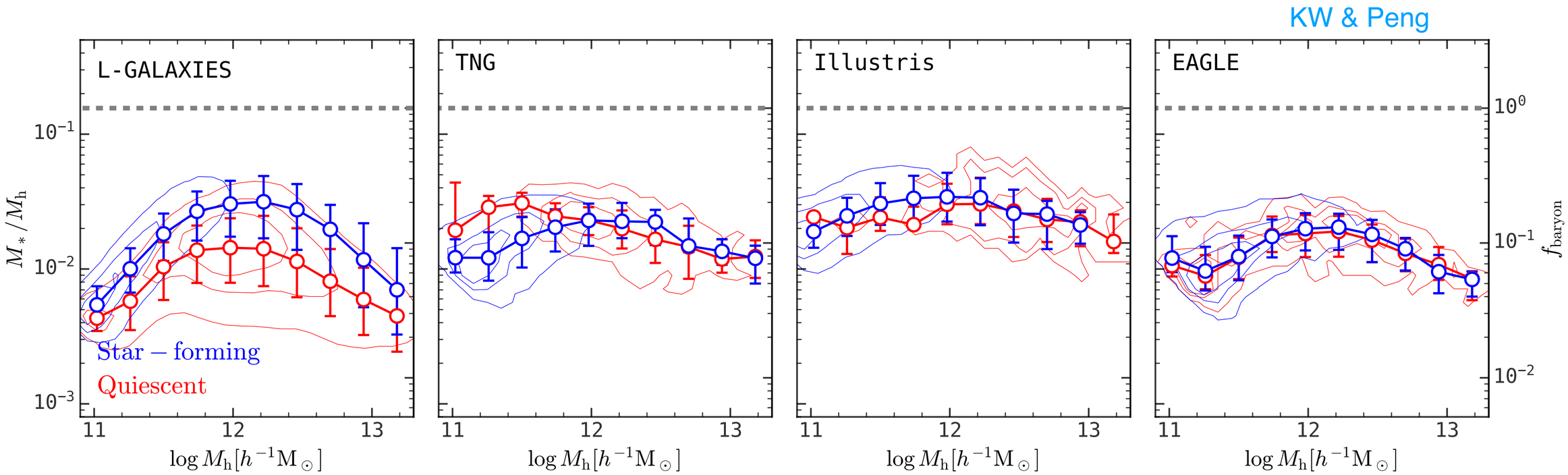


Central galaxies in **early-formed halos** are **more star-forming** and **more spiral-like.**

- **Comparison with galaxy formation models**



- **Stellar conversion efficiency in galaxy formation models**

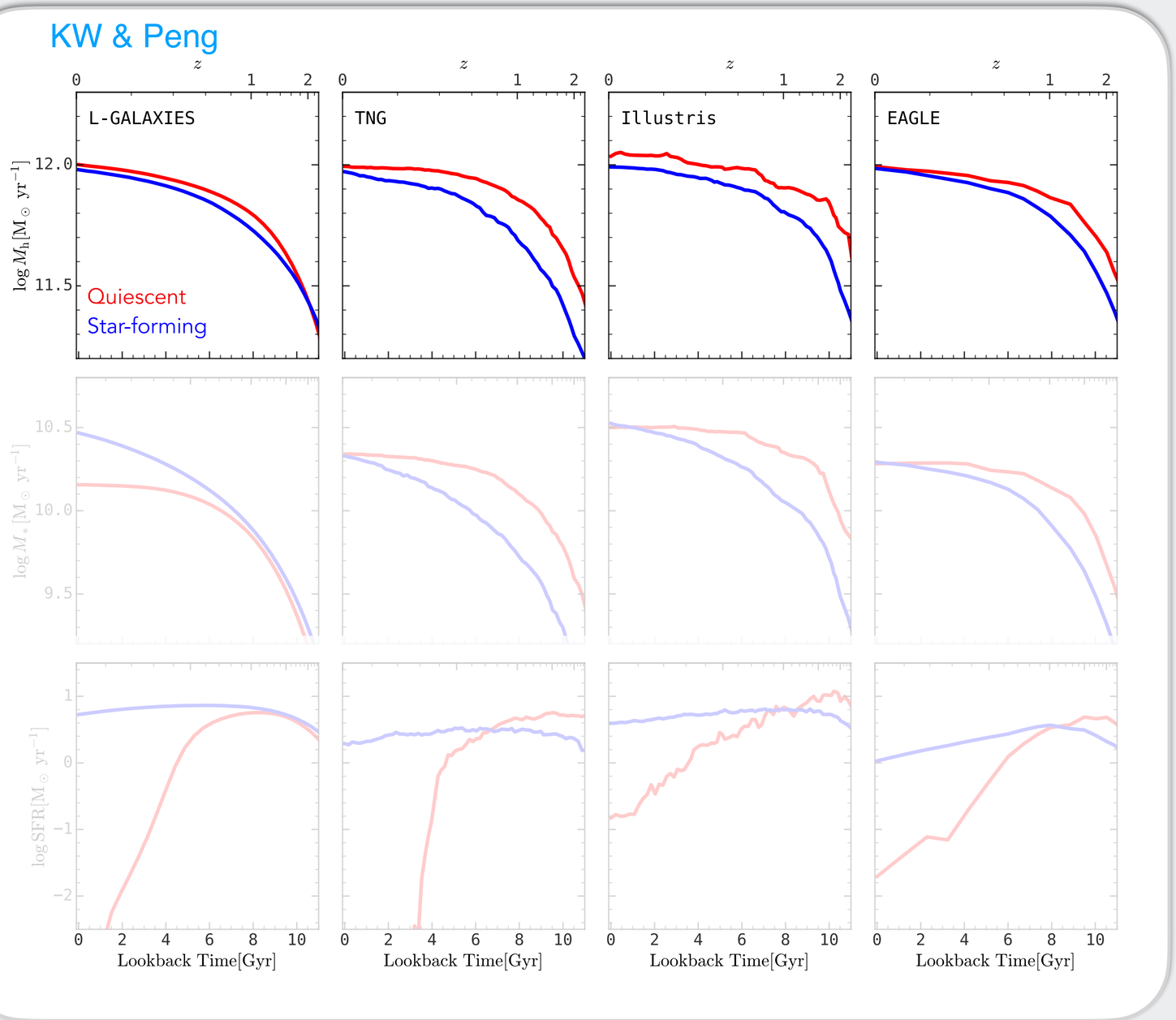


✓ All models reproduce the same halo distribution and assembly history.

✓ All models reproduce the stellar mass function and SFR distribution.

✗ The relation betweem halo assembly and star formation must be different!

• Tracing the evolution of galaxies in galaxy formation models



✦ Selecting $\sim 10^{12}h^{-1}\mathrm{M}_{\odot}$ halos

① Halo assembly history

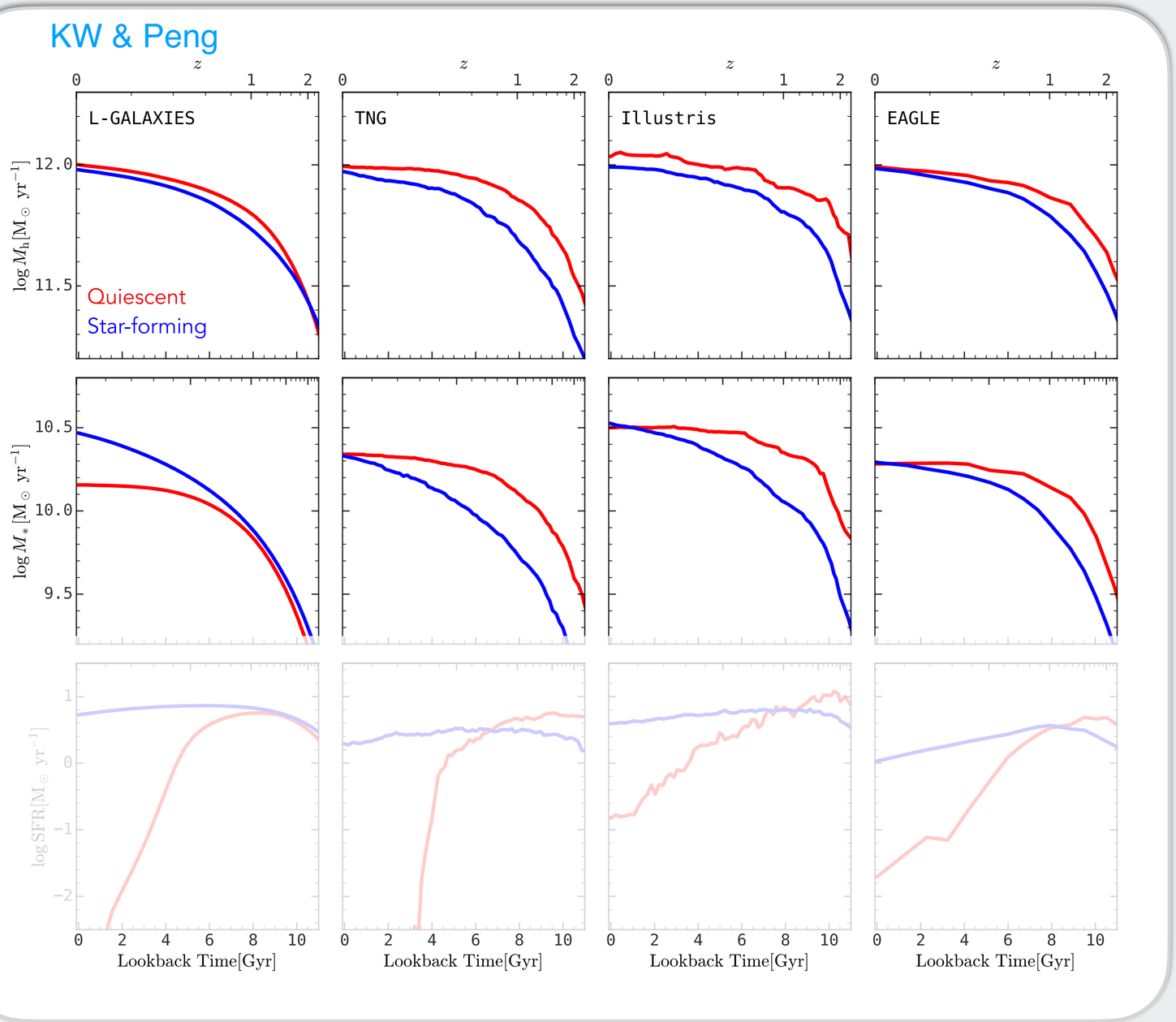
② Stellar growth history

③ Star formation history

✳ L-GALAXIES:
Weak correlation between quenching and halo assembly history

✳ TNG/Illustris/EAGLE:
Quenched galaxies prefer to live in **early-formed halos**

• Tracing the evolution of galaxies



✦ Selecting $\sim 10^{12}h^{-1}\mathrm{M}_{\odot}$ halos

① Halo assembly history

② **Stellar growth history**

③ Star formation history

Quenching

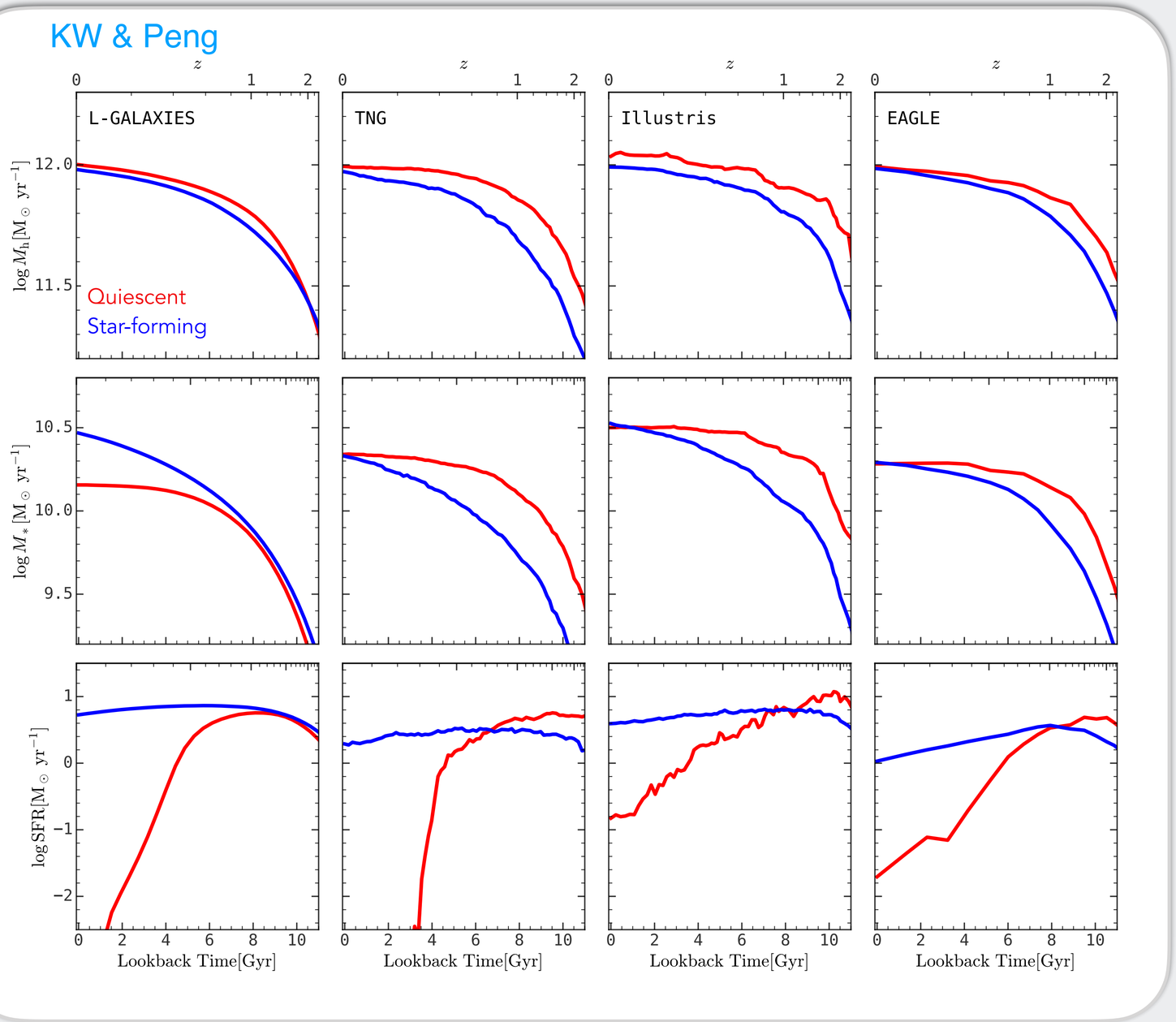
↓

Stellar growth suppression

✳ L-GALAXIES:
Star-forming galaxies are more massive.

✳ TNG/Illustris/EAGLE:
Star-forming galaxies are equally massive as quiescent galaxies.

• Tracing the evolution of galaxies



✦ Selecting $\sim 10^{12}h^{-1}\mathrm{M}_\odot$ halos

① Halo assembly history

② Stellar growth history

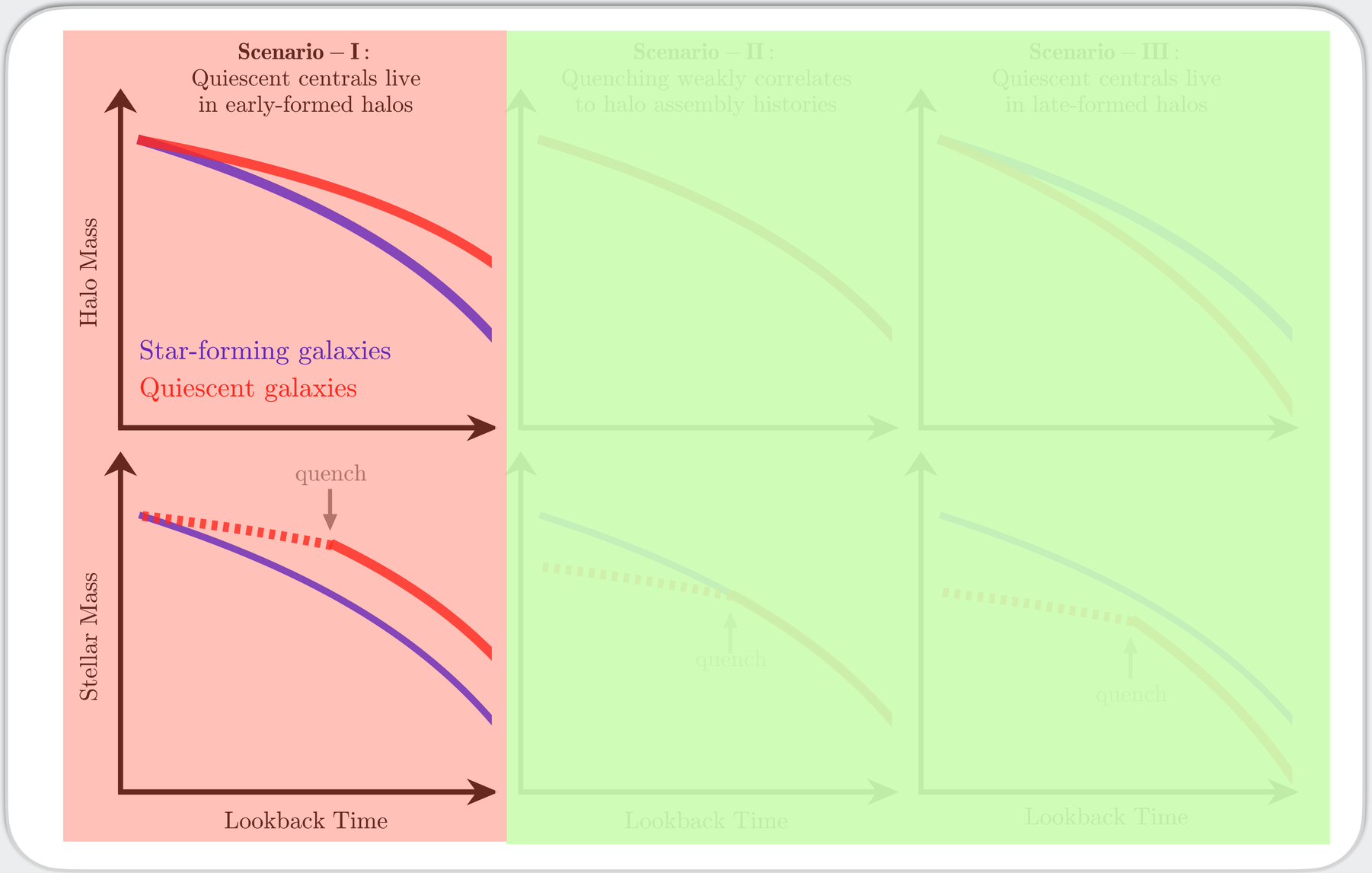
③ Star formation history

early-formed halos

↓

higher progenitor SFR

- **Implications for galaxy-halo co-evolution**



KW & Peng

SUMMARY: Stellar Mass-Halo Mass Relation to the second order

- The stellar mass-halo mass relation has taught us a lot on galaxy formation and evolution, and we expect to learn more from **the secondary relation**.
- Converging obervational evidences show that star-forming galaxies **convert baryons into stars more efficiently** than quiescent galaxies, at fixed stellar mass/halo mass.
- Different theoretical models all suggest that early-formed halos host more massive centrals, making the **central stellar-to-halo mass ratio** a robust **proxy for halo formation time**.
- **Early-formed halos** prefer to host **star-forming** and **spiral-like central galaxies**, with the stellar-to-halo mass ratio as a proxy of halo formation time.
- EAGLE, Illustris & TNG **fail to reproduce observation** since they let *quiescent galaxies more likely to live in early-formed halos*.