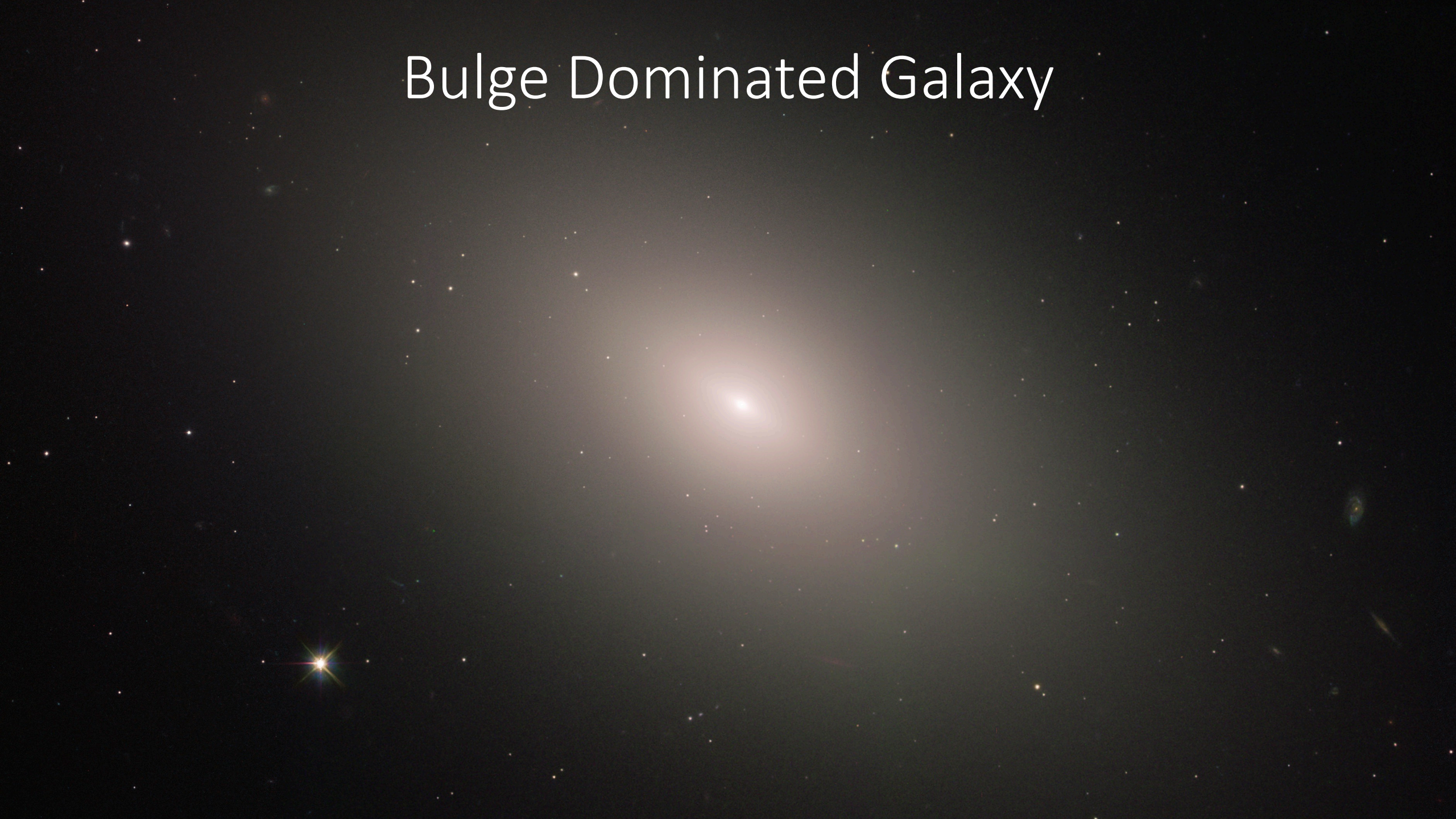
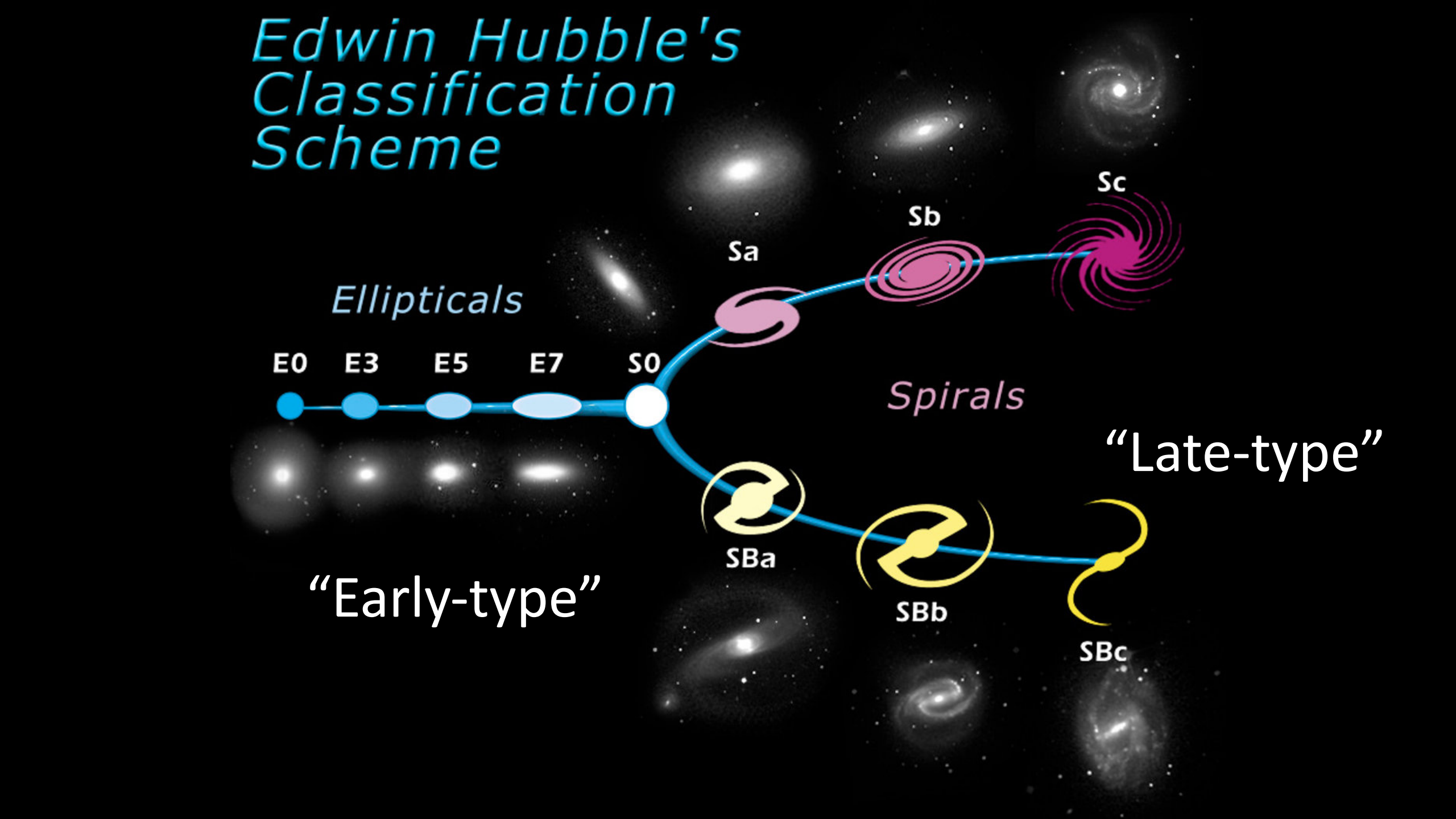
Quenching and morphological evolution of galaxies at $z \approx 3$

Peter Lustig

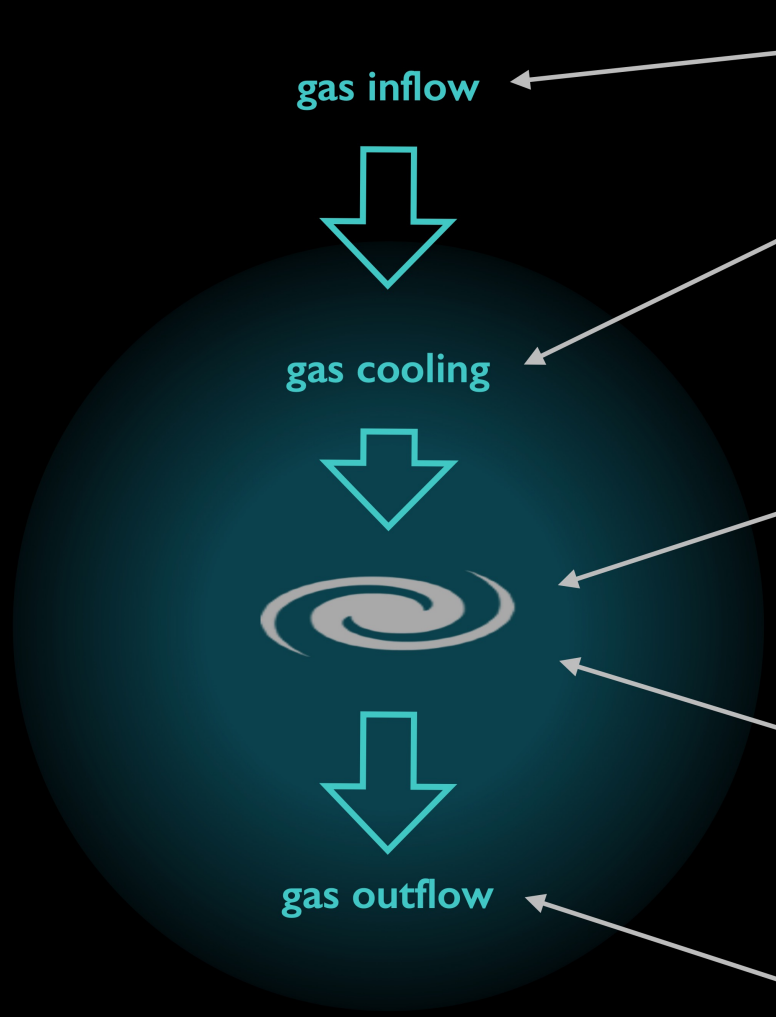
Disk Dominated Galaxy

Bulge Dominated Galaxy




Edwin Hubble's Classification Scheme
Ellipticals
E0
E3
E5
E7
S0
Sa
Sb
Sc
Spirals
SBa
SBb
SBc
"Early-type"
"Late-type"

How can star-formation be suppressed?



Gas does not accrete

Gas does not cool

Cold gas does not form stars

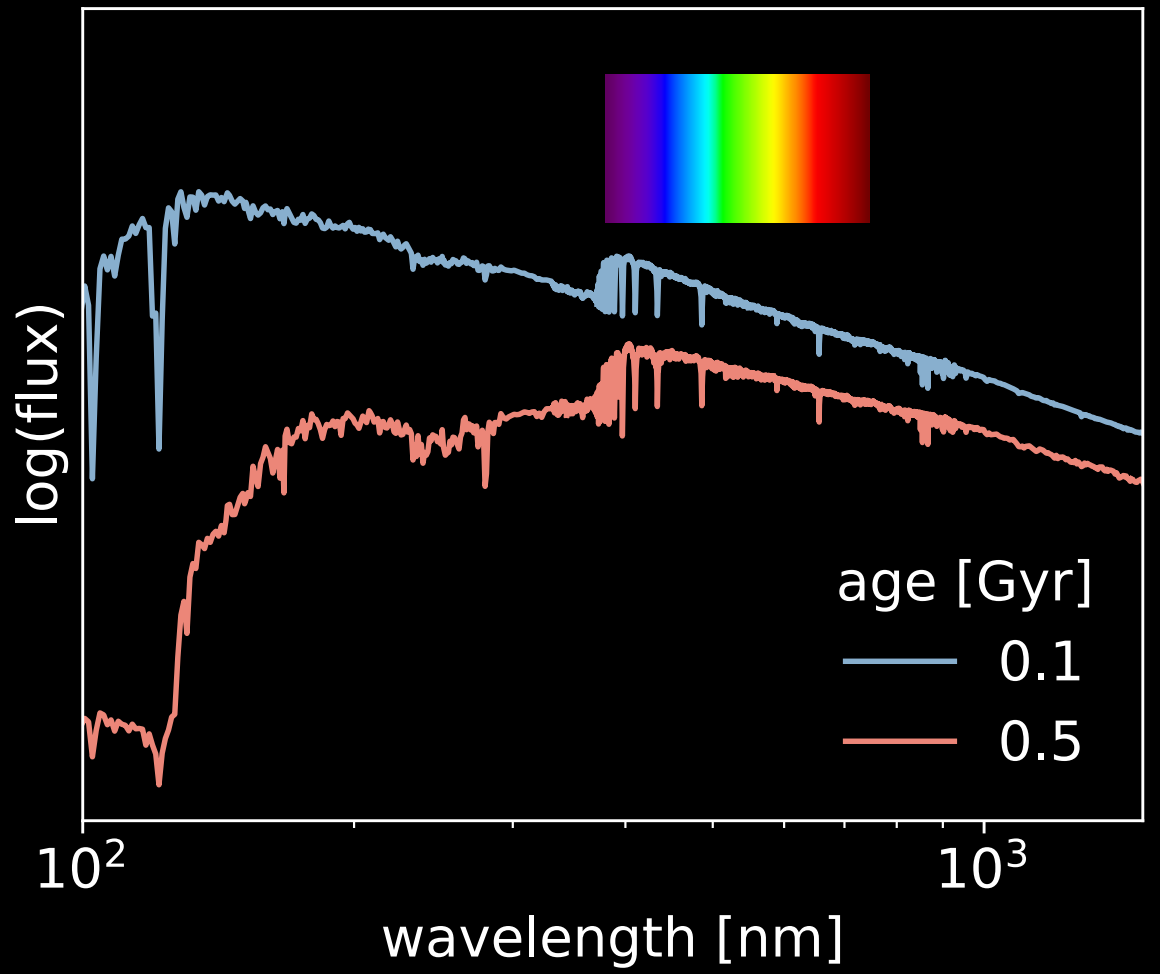
Cold gas is rapidly consumed

Gas is removed

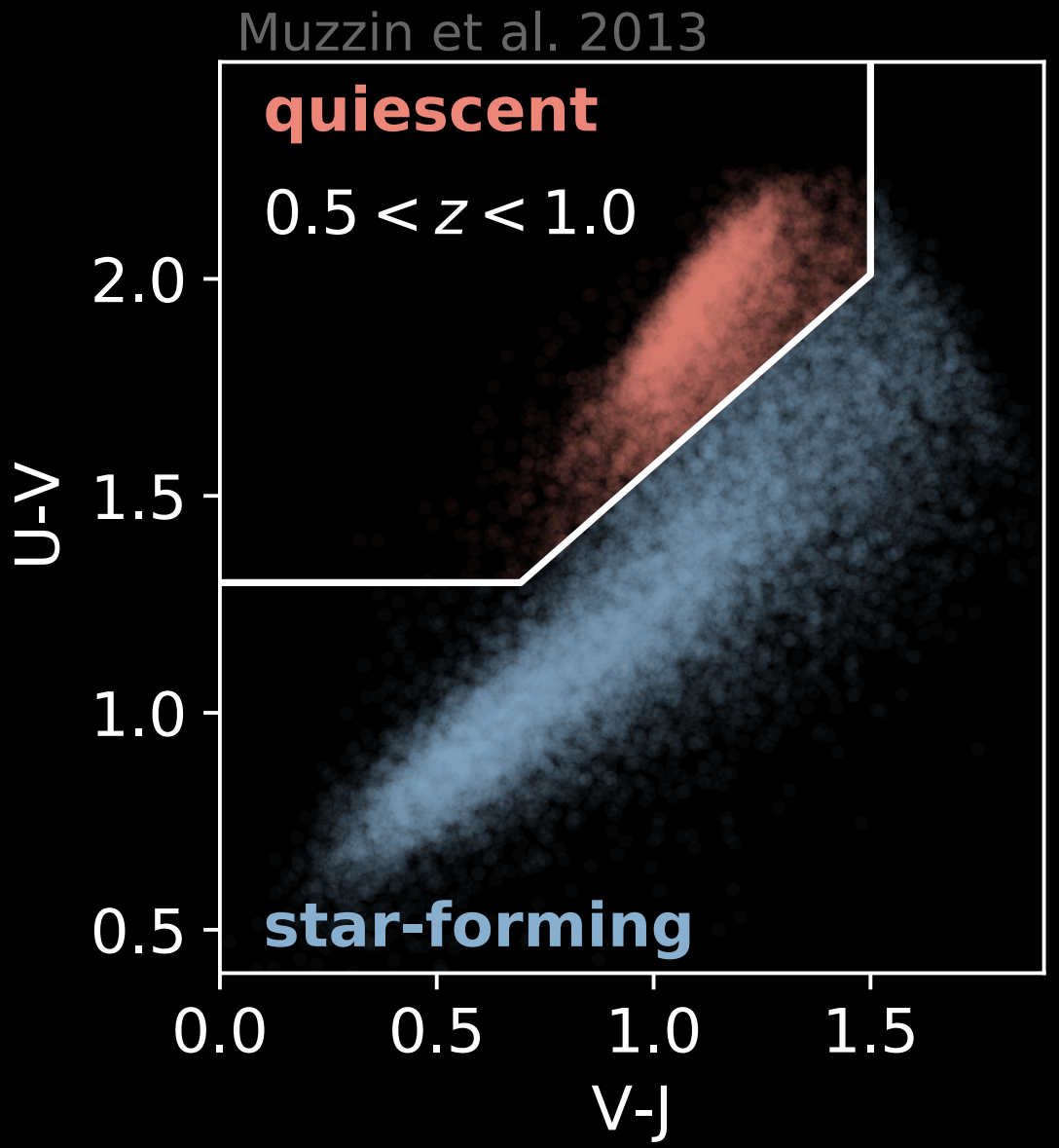
Man, Belli 2018

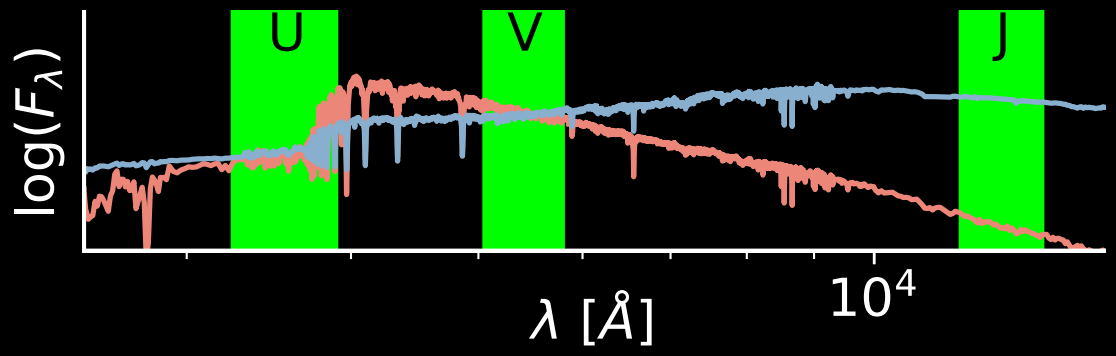
Colors of Star-Forming and Quiescent Galaxies

Younger Stellar populations are bluer



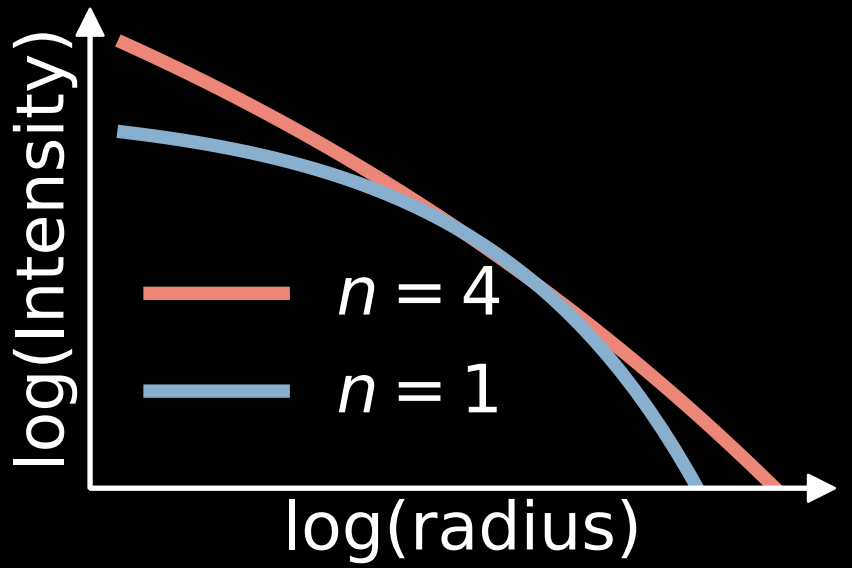
Photometric Classification of Galaxies





UVJ rest-frame colors are routinely used to classify star-forming and quiescent galaxies photometrically.

Sérsic Profile

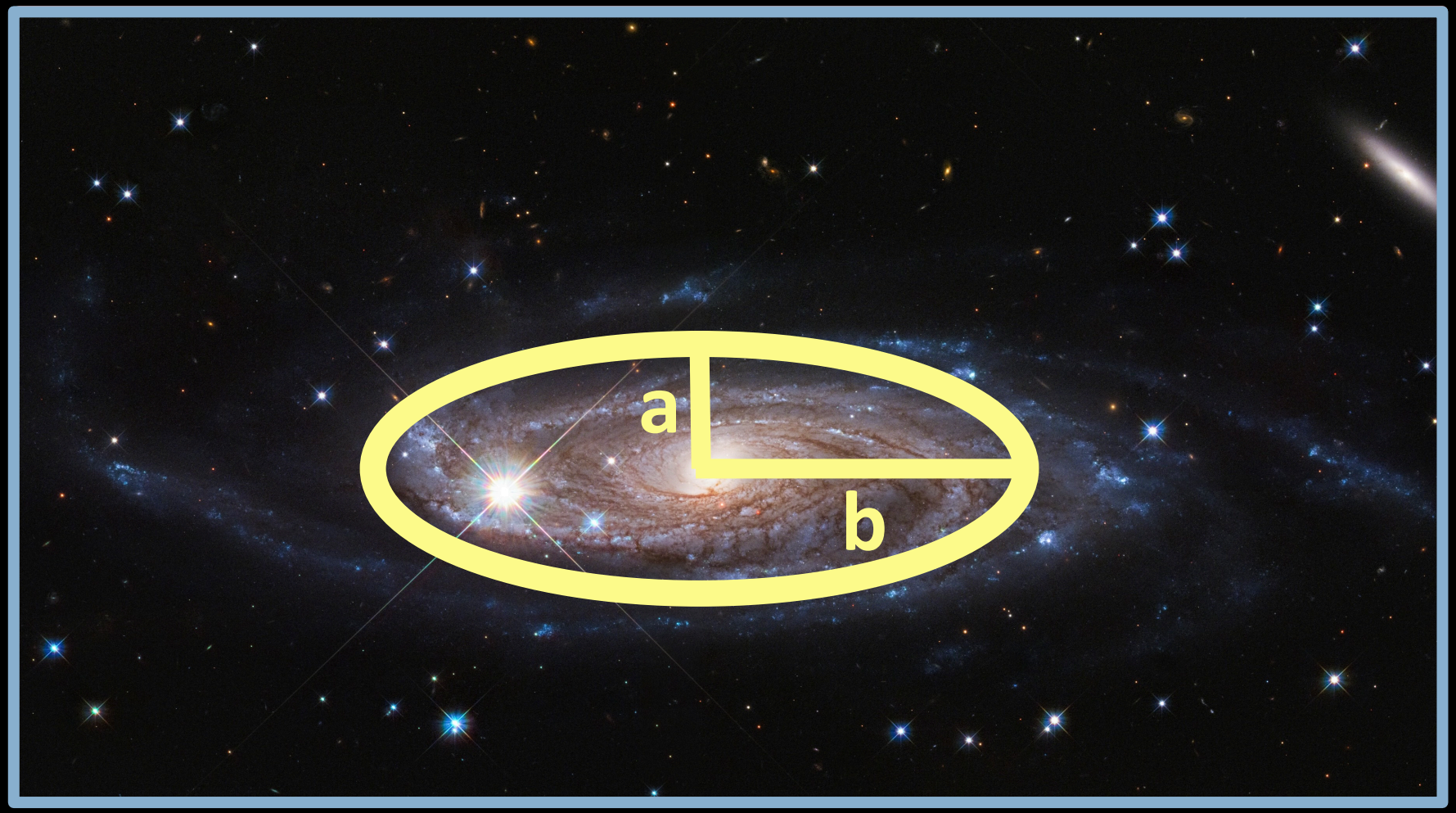


$$\log\left(\frac{I(r)}{I_e}\right) = -b_n\left[\left(\frac{r}{r_e}\right)^{\frac{1}{n}} - 1\right]$$

Sérsic Index “n”: central concentration

Effective ratius “r_e”: galaxy size

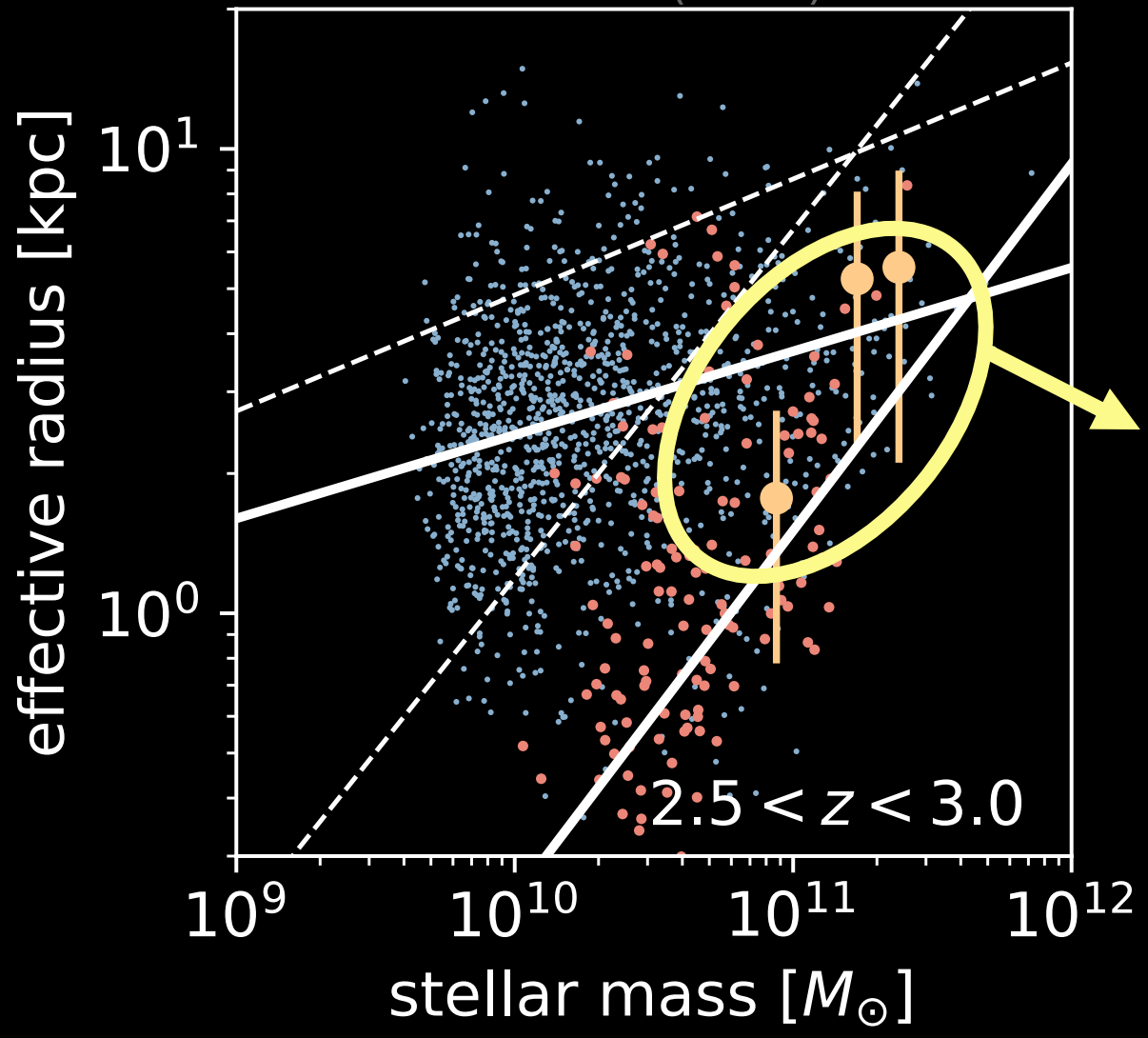
Projected Axis Ratio



$$q = \frac{a}{b}$$

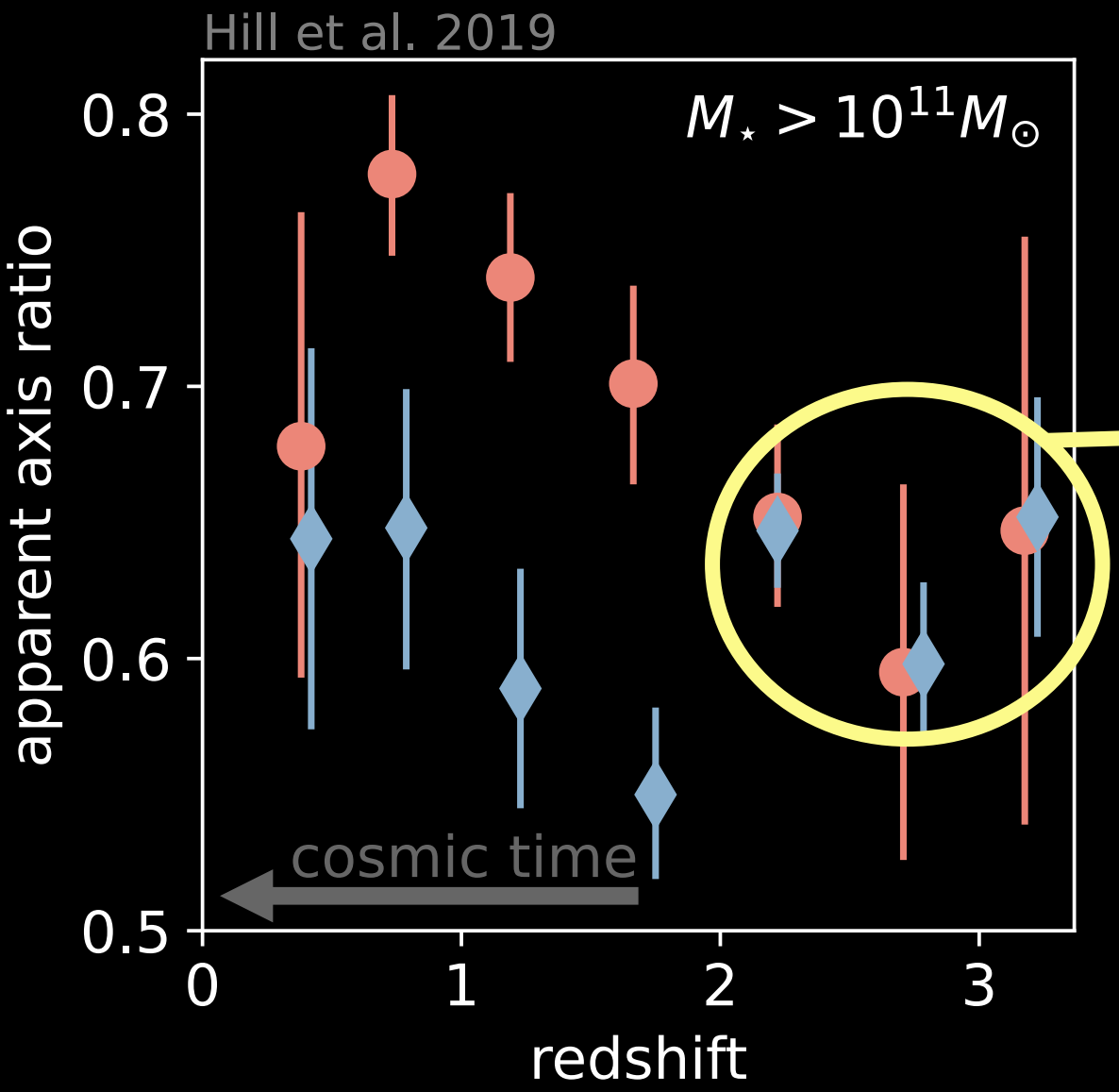
The Mass-Size Relation

Marsan et at. (2019)
van der Wel et al. (2014)



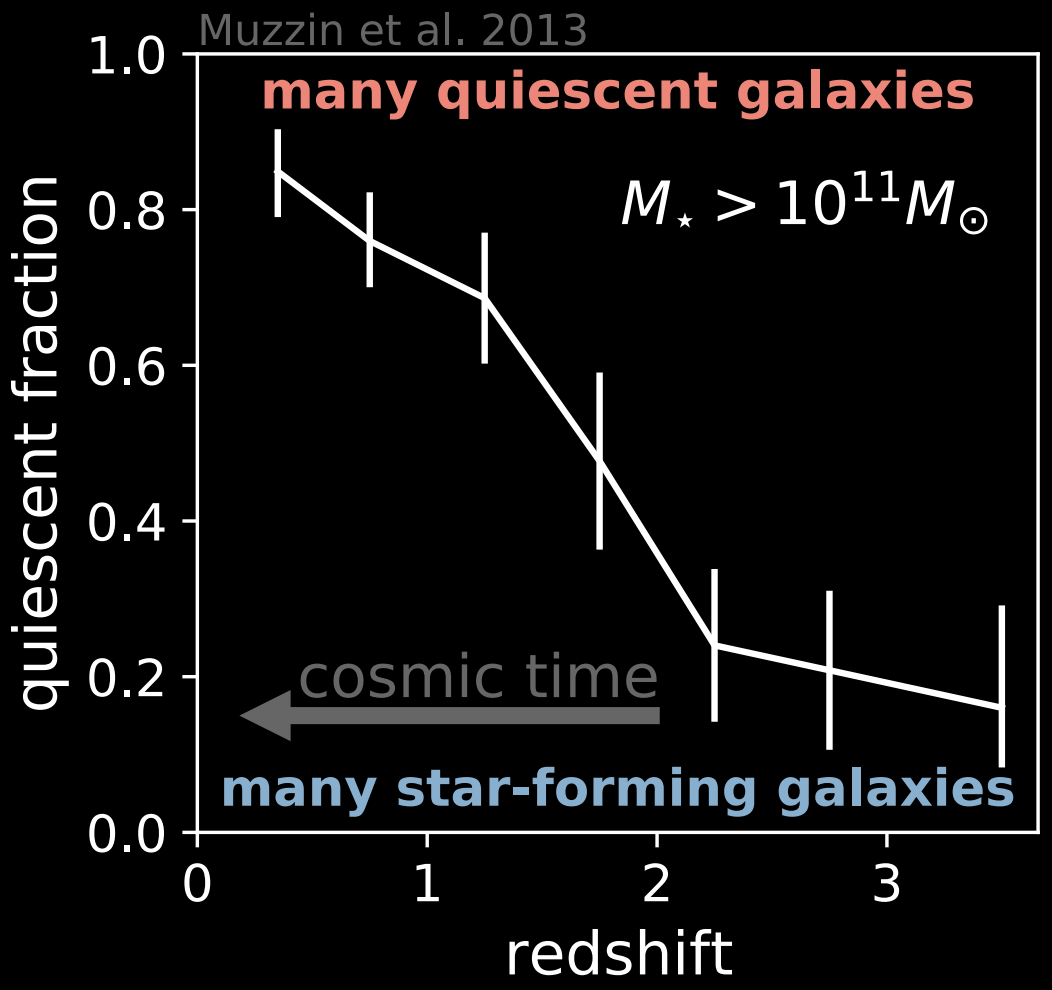
Are the most massive quiescent galaxies at high redshift larger than extrapolated from previous mass-size relation determinations?

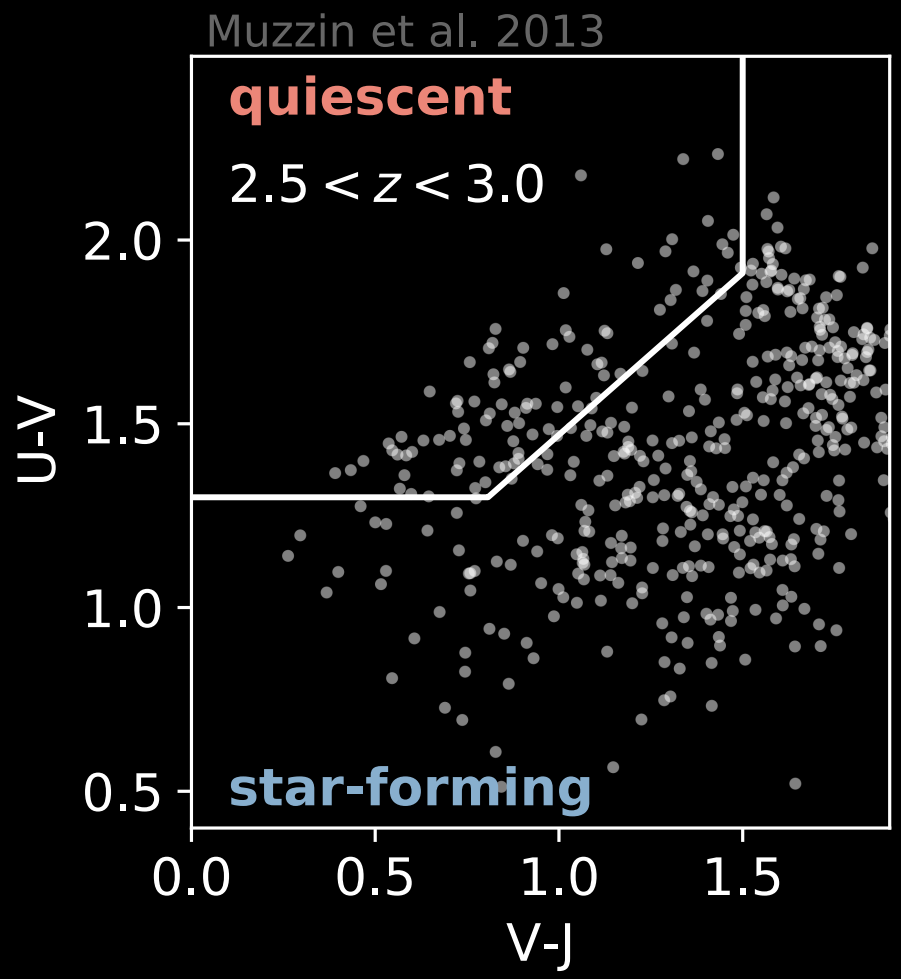
Broad Structural Properties



Are quiescent galaxies disks at high redshift?

Difficulties at high redshift



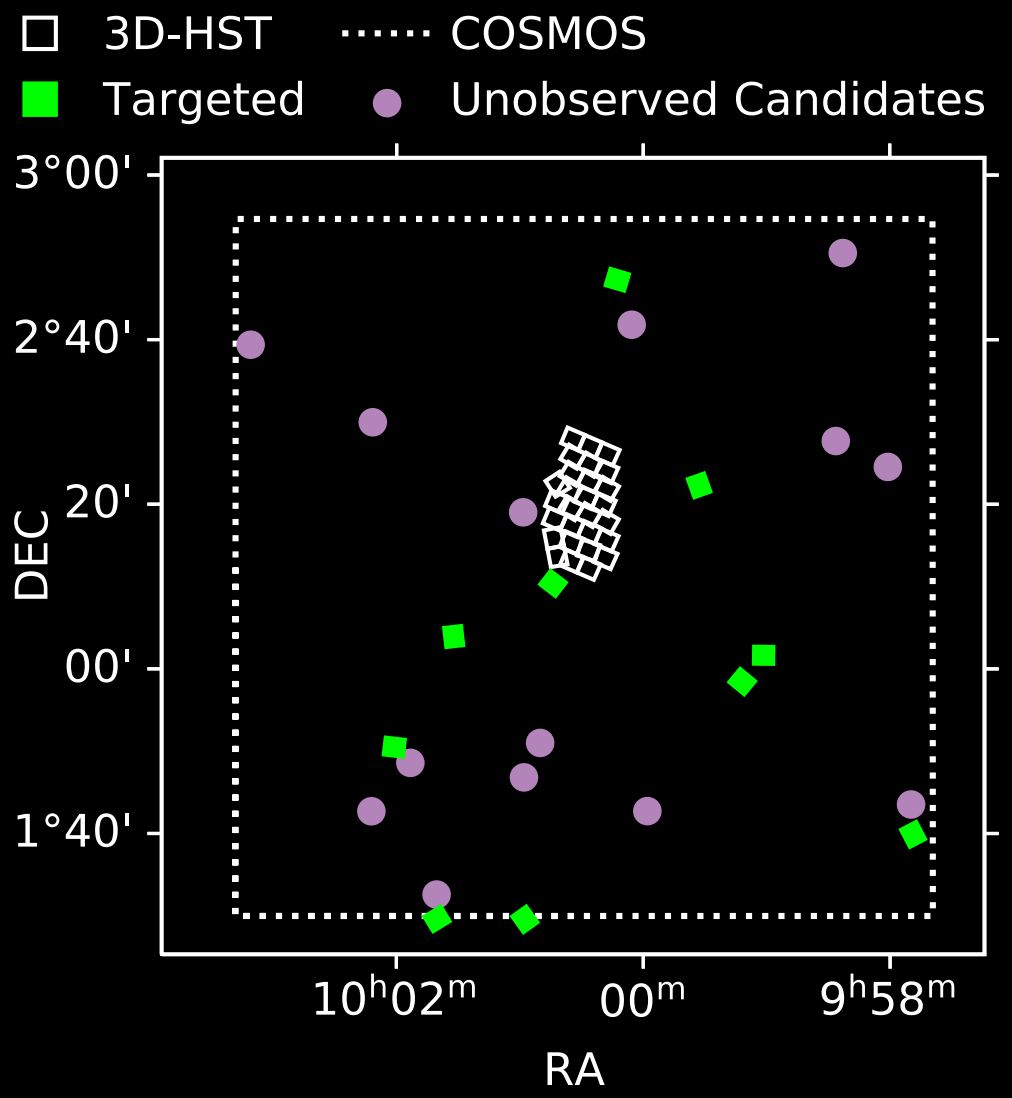


Quiescent galaxies are rare at high redshift

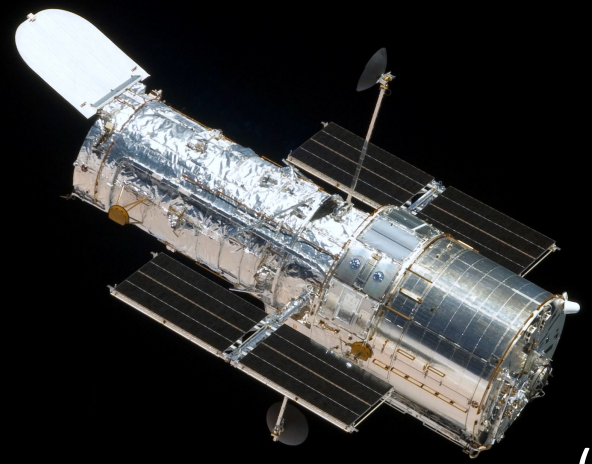
The photometric classification is uncertain.

Spectroscopy is more accurate, but expensive.

HST Follow-up Observations



Photometric selection of bright $z \approx 3$ quiescent galaxy candidates for targeted HST follow-up observations



GRISM + WFC3
($\approx$ 4000 Å Restframe)

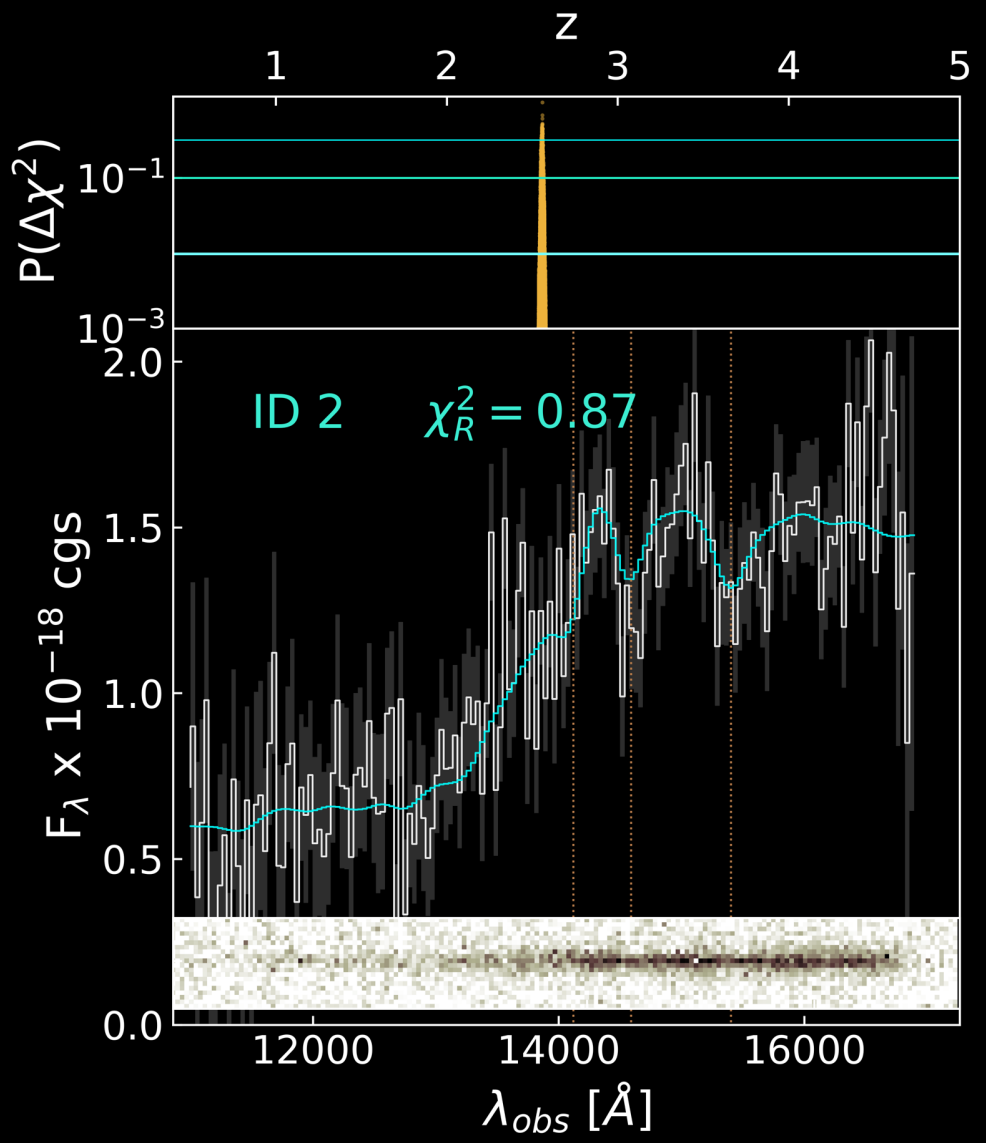
Stellar Population Properties

Quiescence is confirmed for all 10 targets.

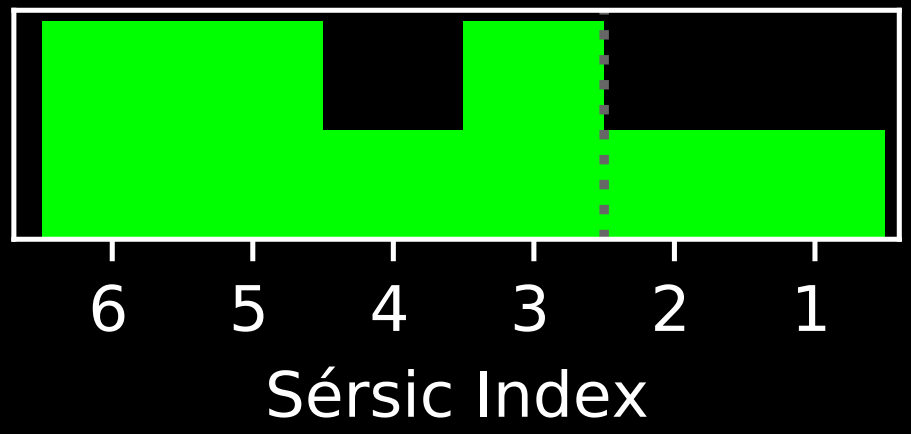
Spectroscopic redshifts are $2.4 < z < 3.2$.

Spectro-photometric modeling reveals young ages (median 0.5 Gyr).

The sample is very massive with $M_{\star} \gtrsim 10^{11}\ M_{\odot}$.

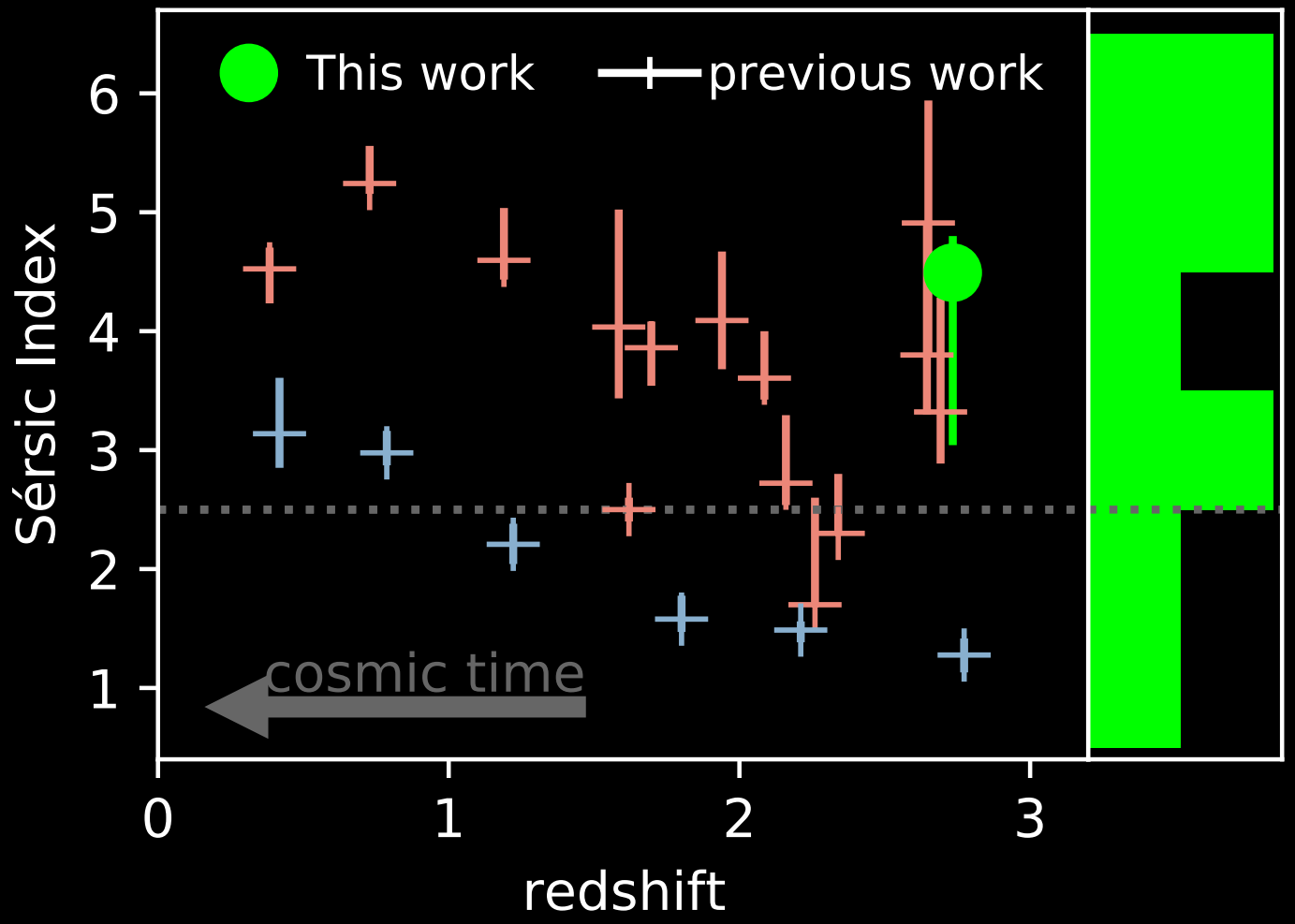


Broad Structural Properties



High fraction of bulge-dominated systems

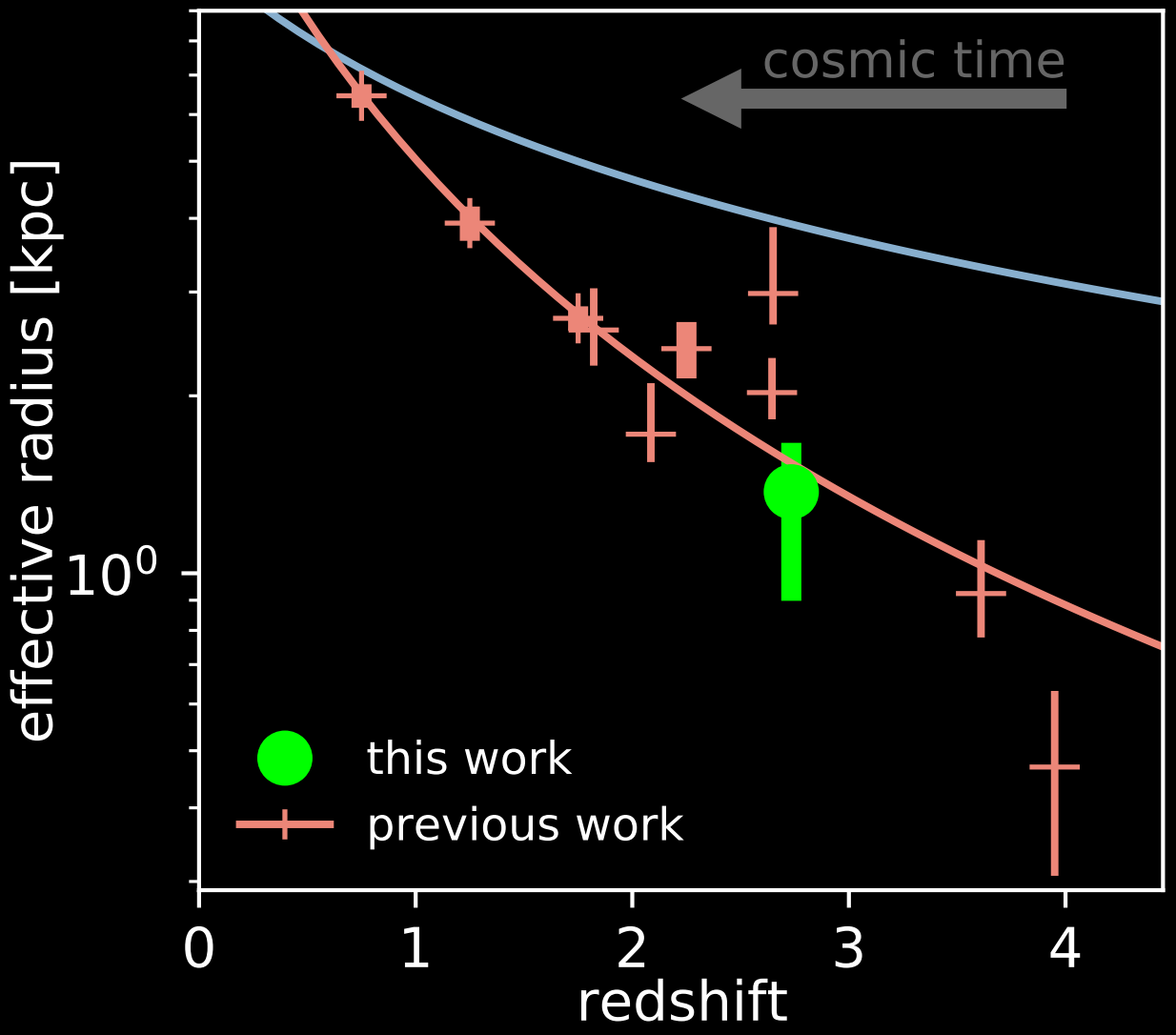
Broad Structural Properties



High fraction of bulge-dominated systems

Median Sérsic index is similar to lower-redshift massive quiescent samples

Size Evolution



Average massive quiescent galaxy sizes decrease by ≈ 1 mag since $z \approx 3$

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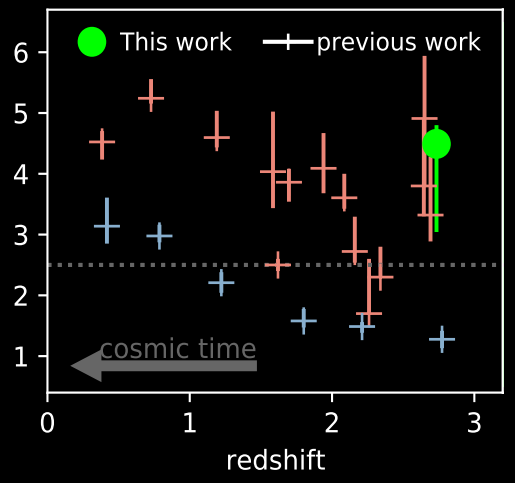
ROYAL ASTRONOMICAL SOCIETY

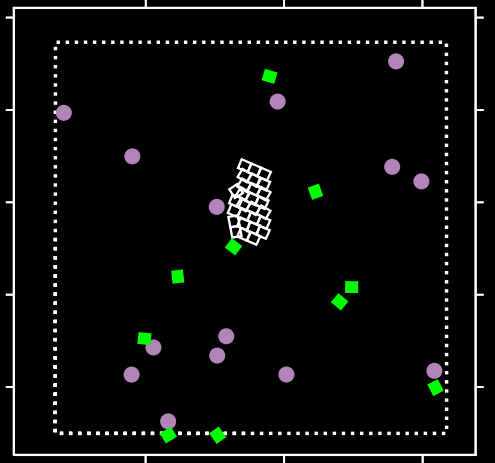
MNRAS **501,** 2659–2676 (2021)
Advance Access publication 2020 December 5

doi:10.1093/mnras/staa3766

Compact, bulge-dominated structures of spectroscopically confirmed quiescent galaxies at $z \approx 3$

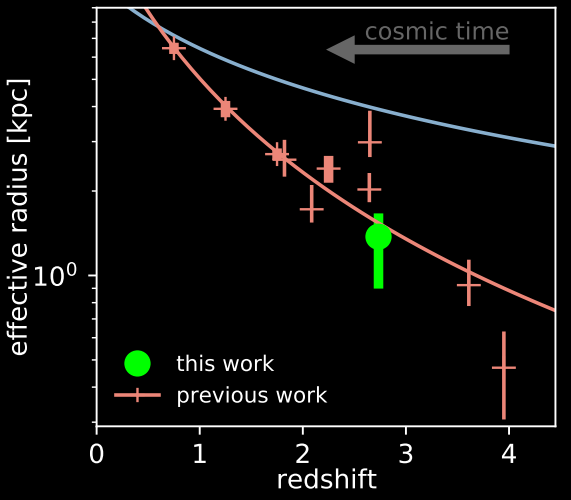
First homogeneous morphological analysis of 10spectroscopically confirmed massive, quiescent galaxies at $z \approx 3$.



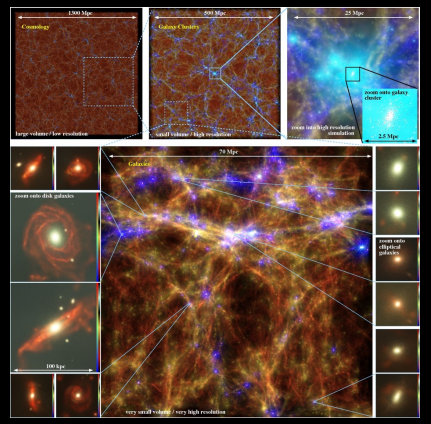


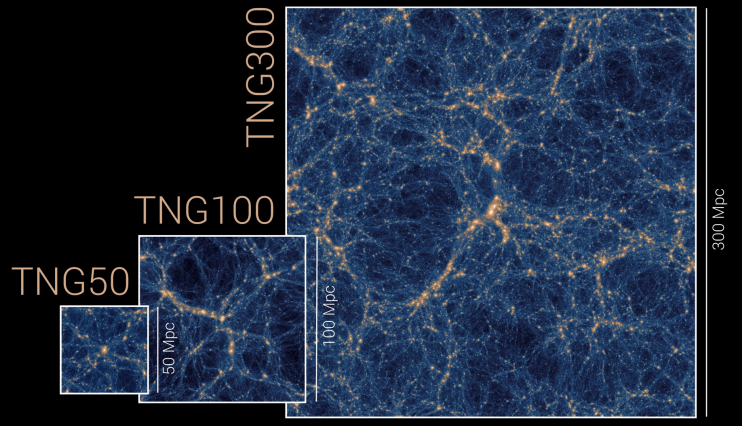
Large bulge dominated fraction already at $z \approx 3$.

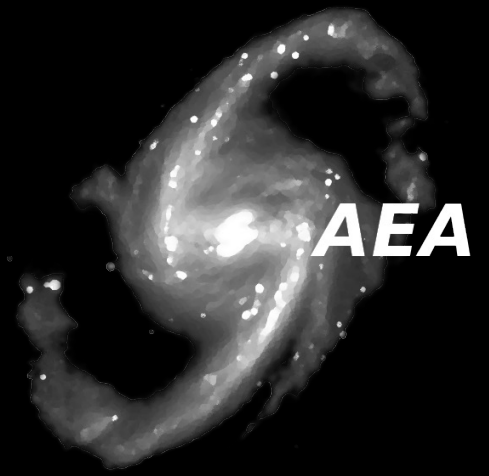
Sizes are consistent with size evolution by nearly an order of magnitude since $z \approx 3$.



Comparison with Simulation Predictions at $z \approx 2.7$

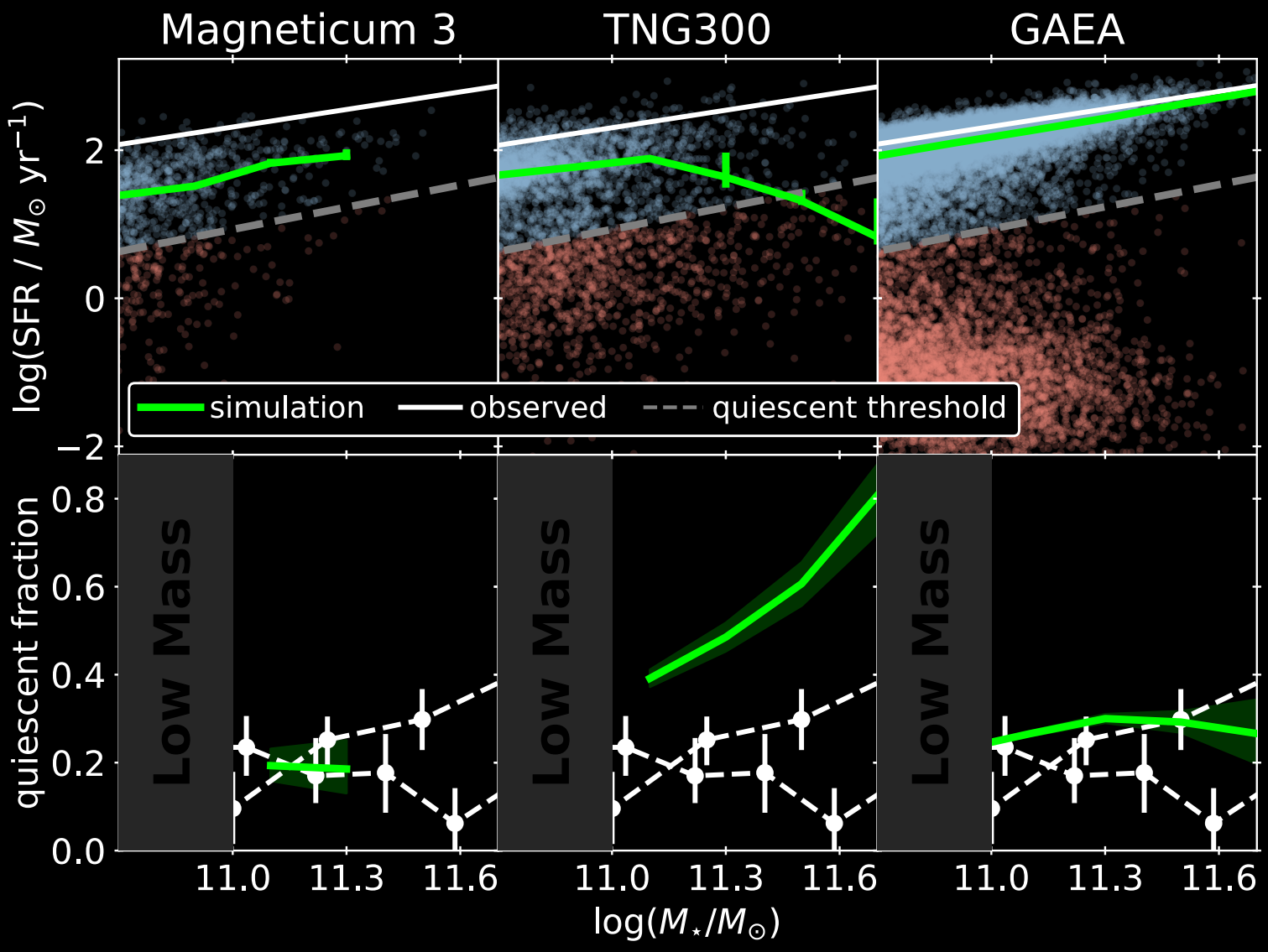






	Hydrodynamical Simulations		Seminanalytical Model
	Magneticum 3	**IllustrisTNG 300**	**GAEA**
Volume [Mpc^3]	182	303	685
Galaxies	166	993	9339

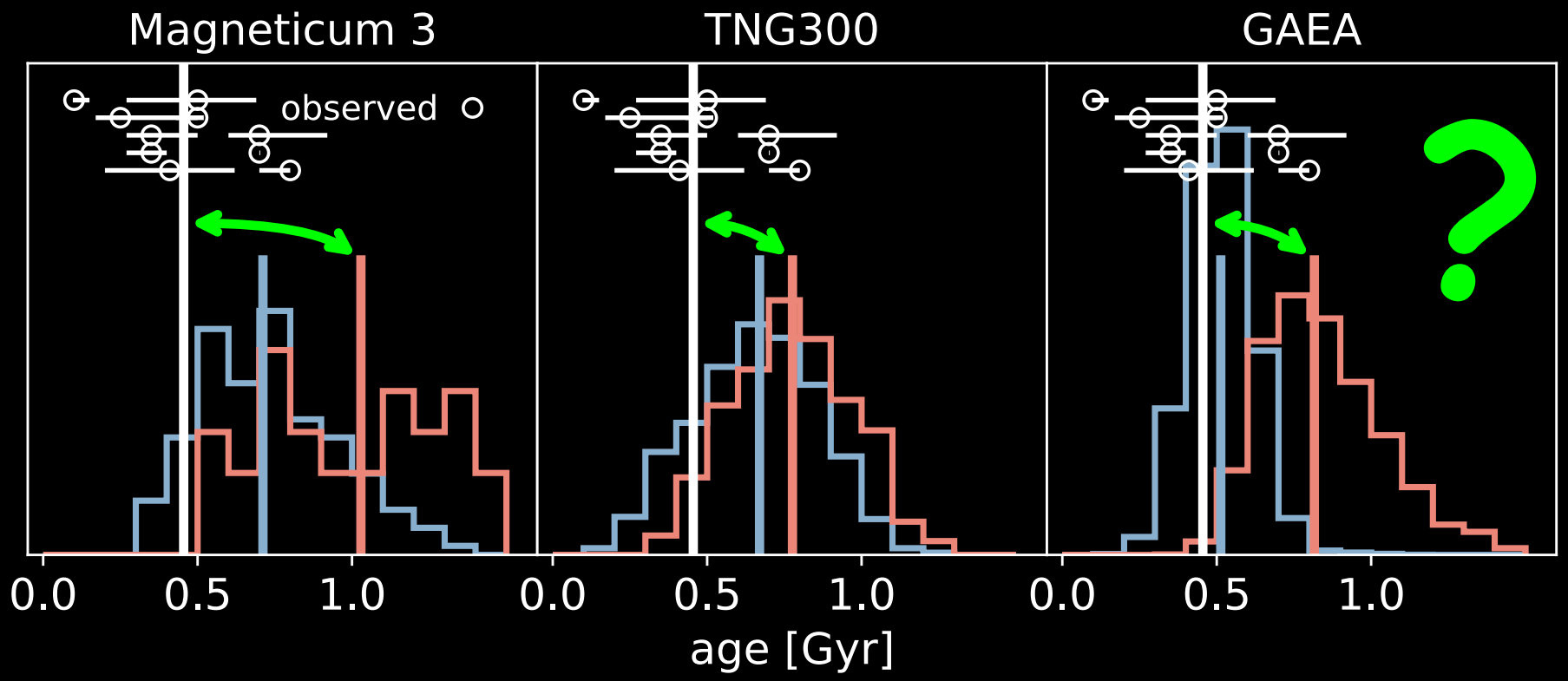
Simulated Quiescent Galaxies at $z \approx 3$



Quiescent if:

$$\frac{\text{star formation rate}}{\text{stellar mass}} < 0.3 \times H(t)$$

Stellar Ages

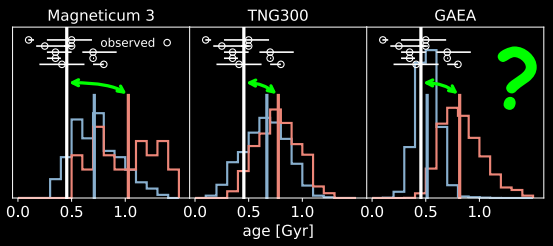


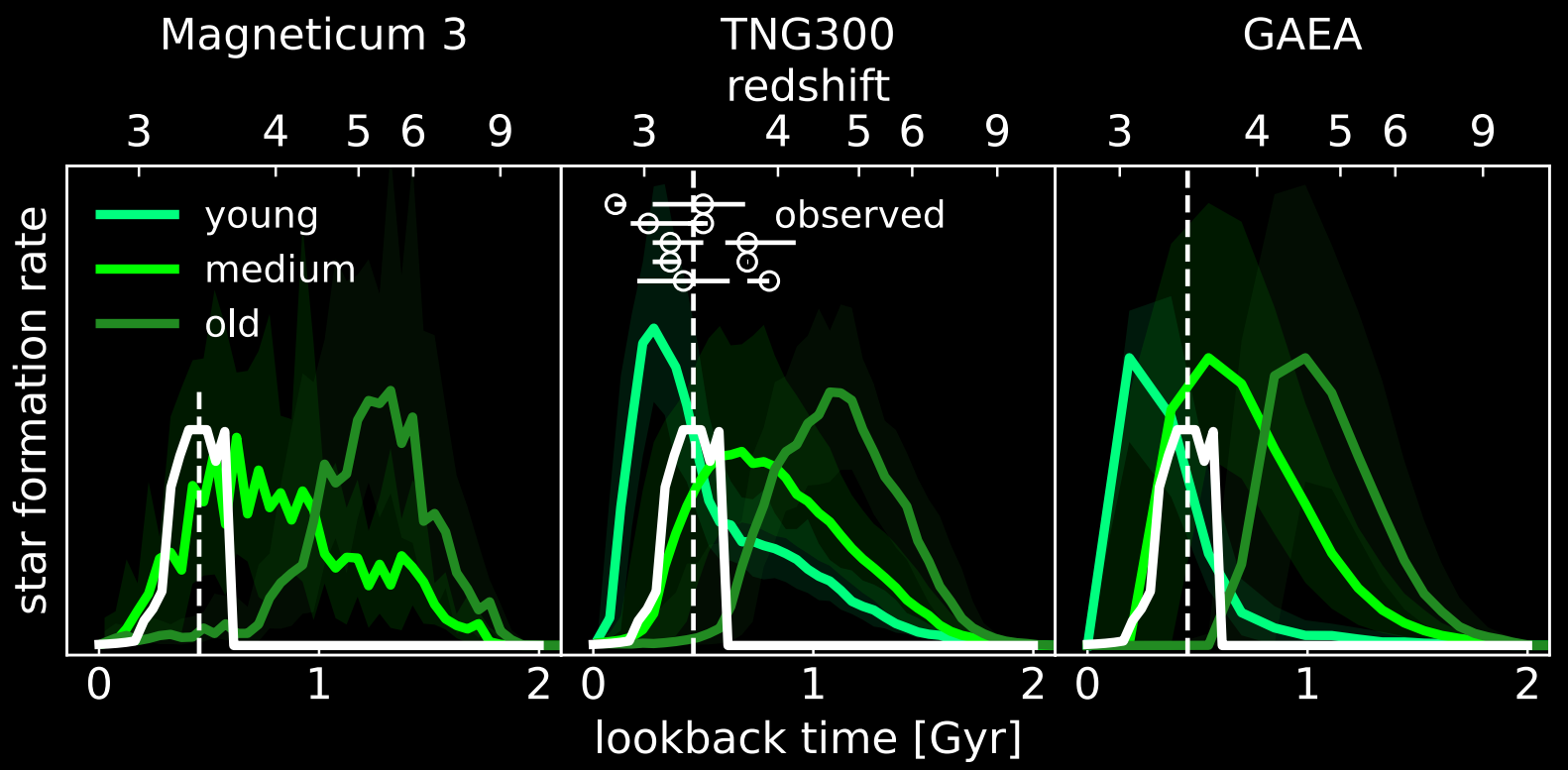
Observed galaxies are younger than simulated galaxies

Are galaxies in simulations too old?

Observational bias?

Star Formation Histories



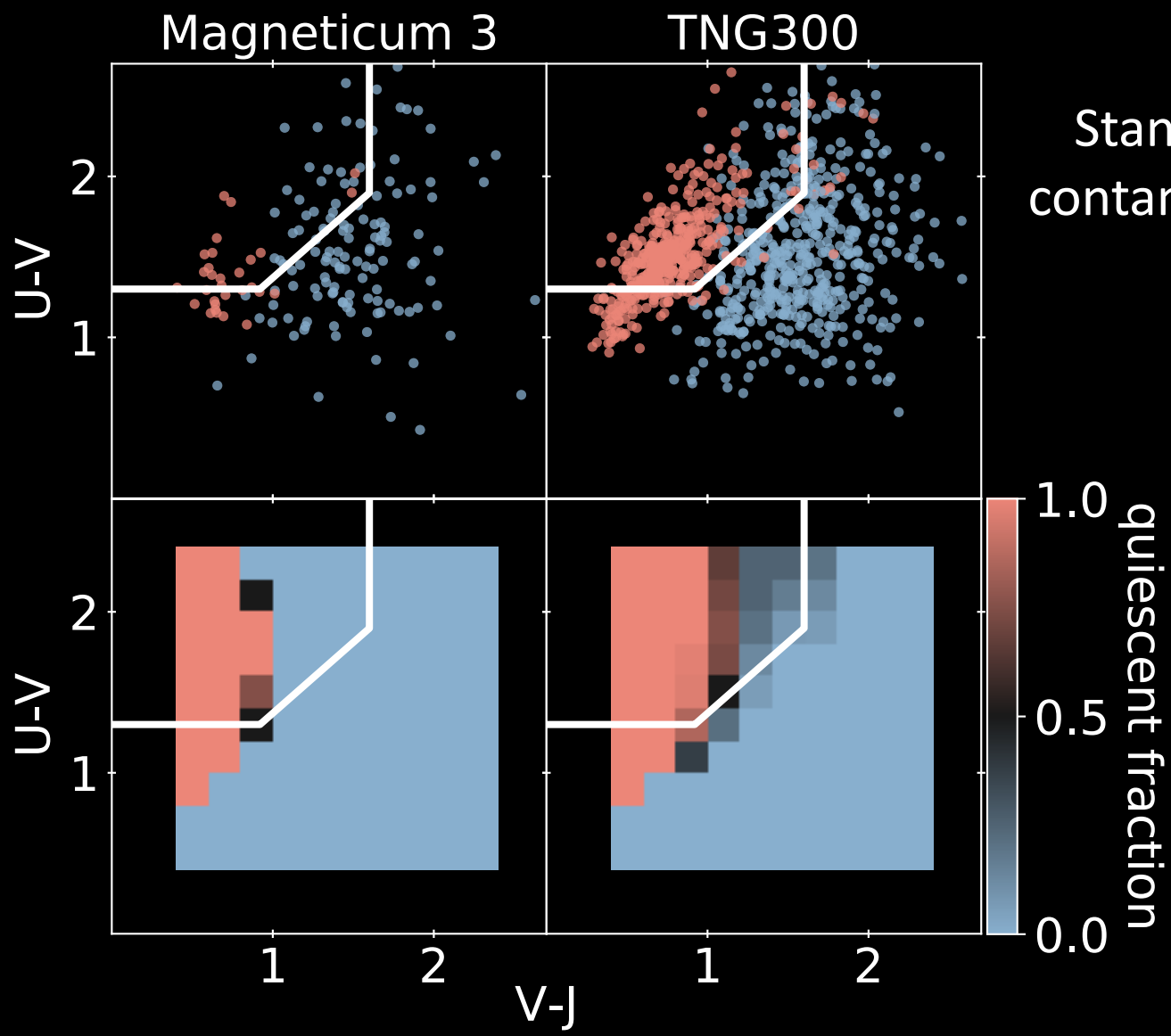


Observed star-formation starts later and stops faster.

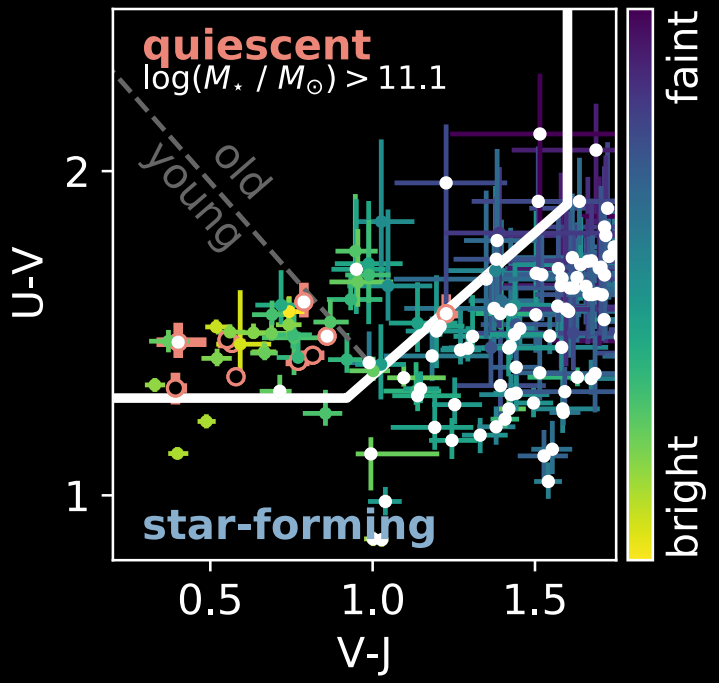
Estimating ages of simulated galaxies with observational methods produces younger ages

⇒ **observational bias likely contributes to tension between observed and simulated ages**

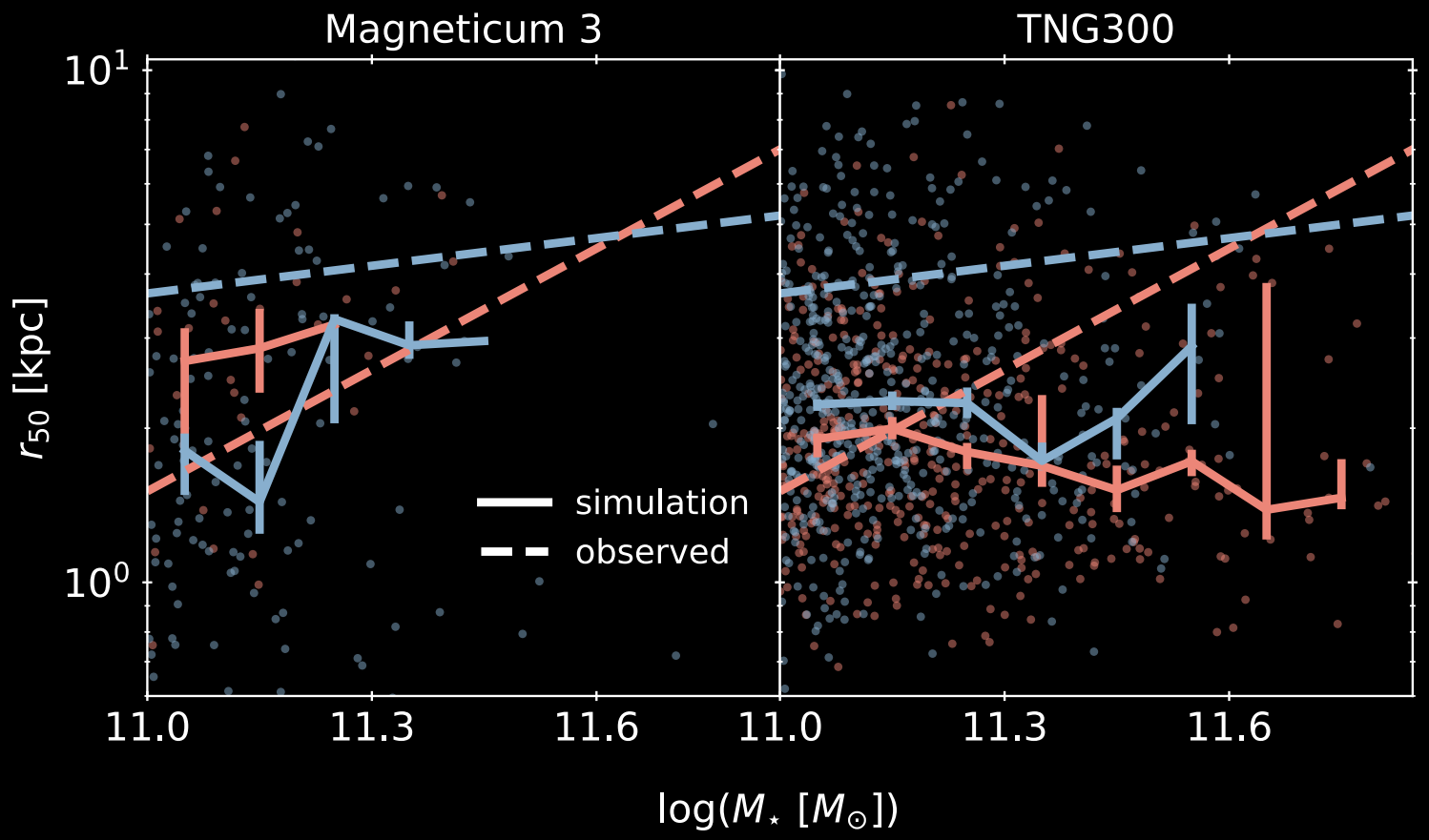
Photometric Selection of Quiescent Galaxies



Standard UVJ selection yields incomplete and contaminated quiescent samples at high redshift.



Morphological Properties

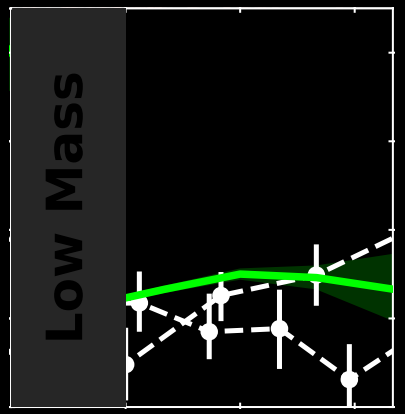


The observed mass-size relation is not well reproduced

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

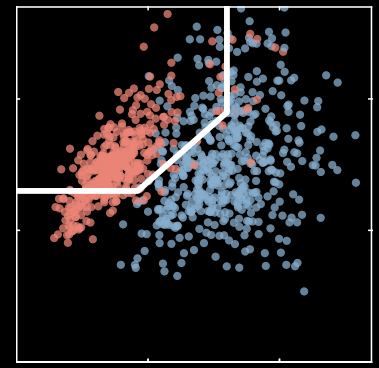
MNRAS **518,** 5953–5975 (2023) https://doi.org/10.1093/mnras/stac3450
Advance Access publication 2022 November 28

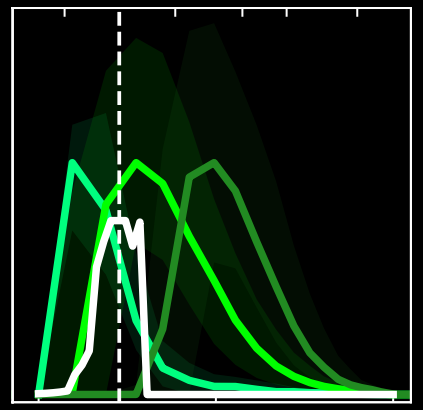
Massive quiescent galaxies at $z \sim 3$: A comparison of selection, stellar population, and structural properties with simulation predictions



Quiescent fractions in Magneticum and GAEA are in good agreement with observations, and a bit higher in IllustrisTNG

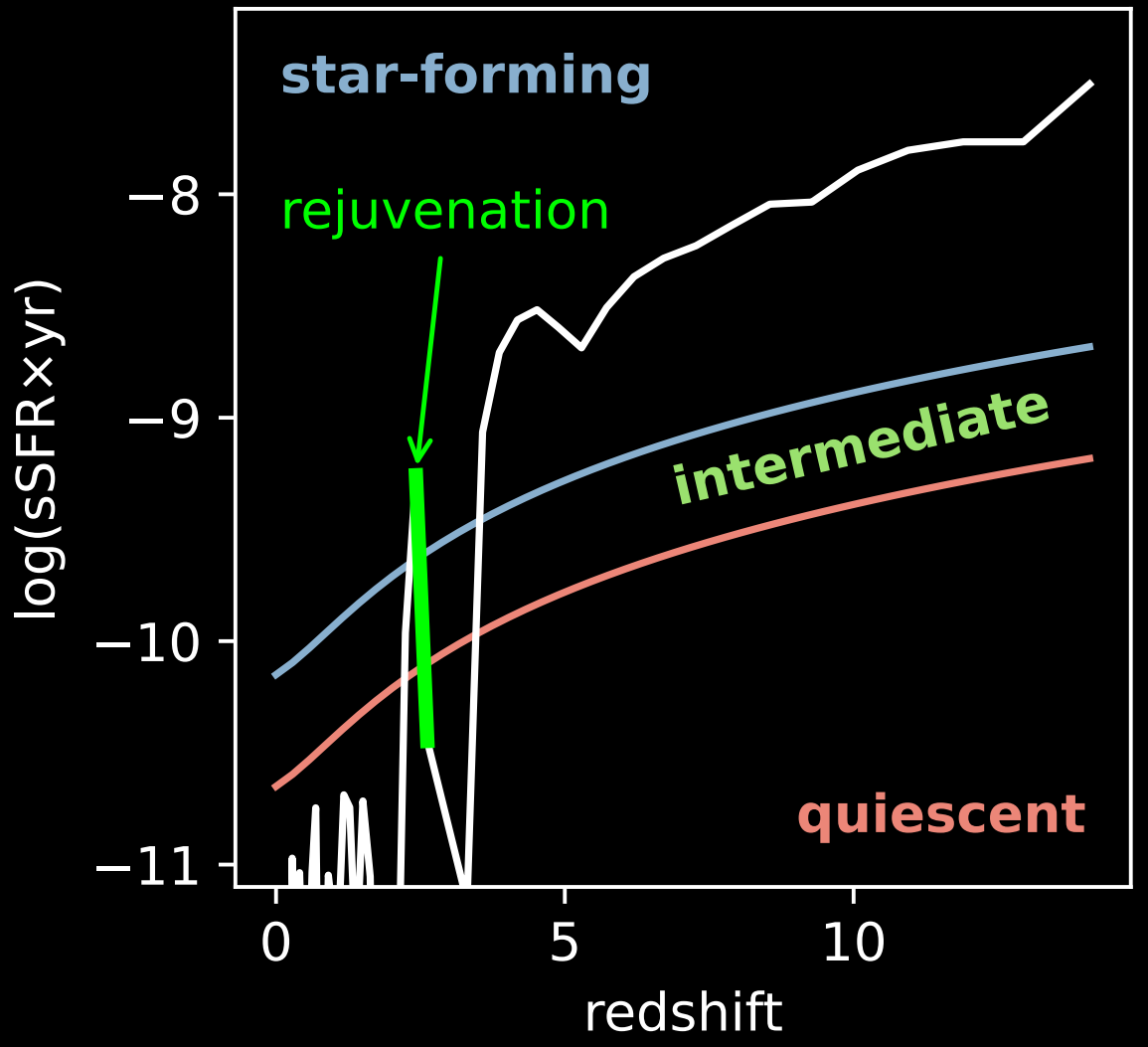
At high redshift standard photometric **selection criteria** lead to **incomplete and contaminated quiescent samples**: bias in characterisation





Mismatch between star formation histories in simulations and observations: **observational estimates appear biased towards younger ages and shorter quenching timescales**

Definition of Rejuvenation



Rejuvenation: the Role of Mergers

Preliminary