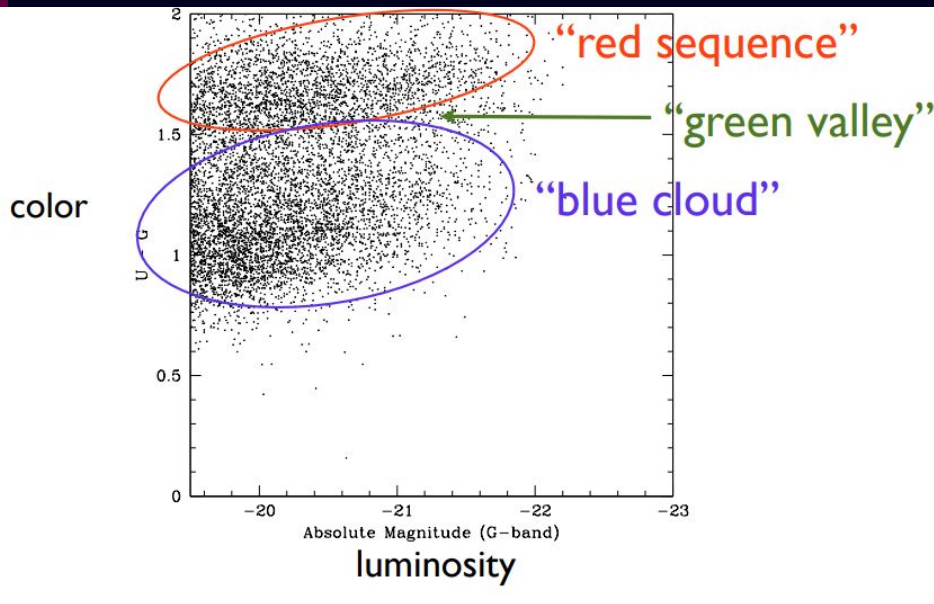


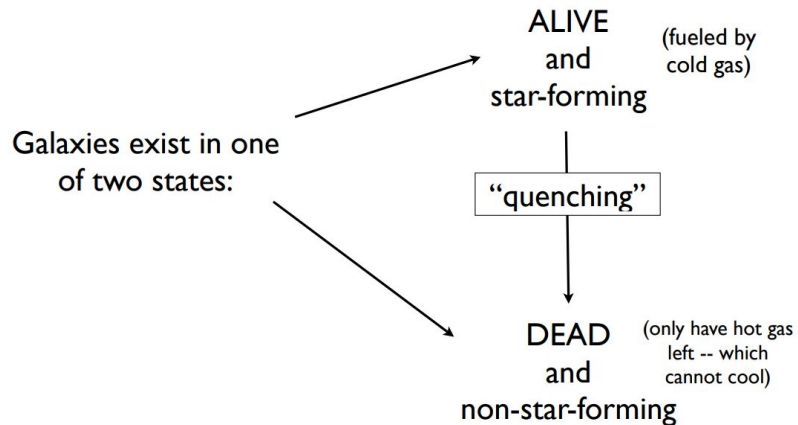
# Mass and Environmental Quenching in Galaxies

By Sanne van Beek & Naomi Schutte

# Recap: What is quenching?



Why is there a bimodality?





# Paper 1

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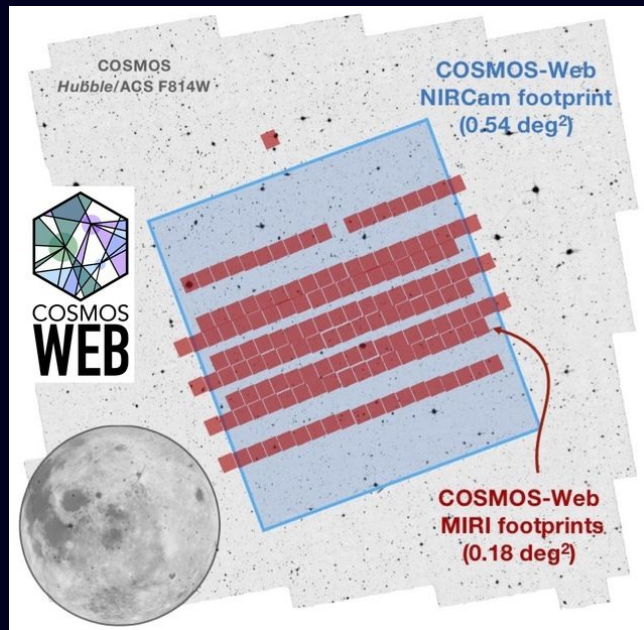
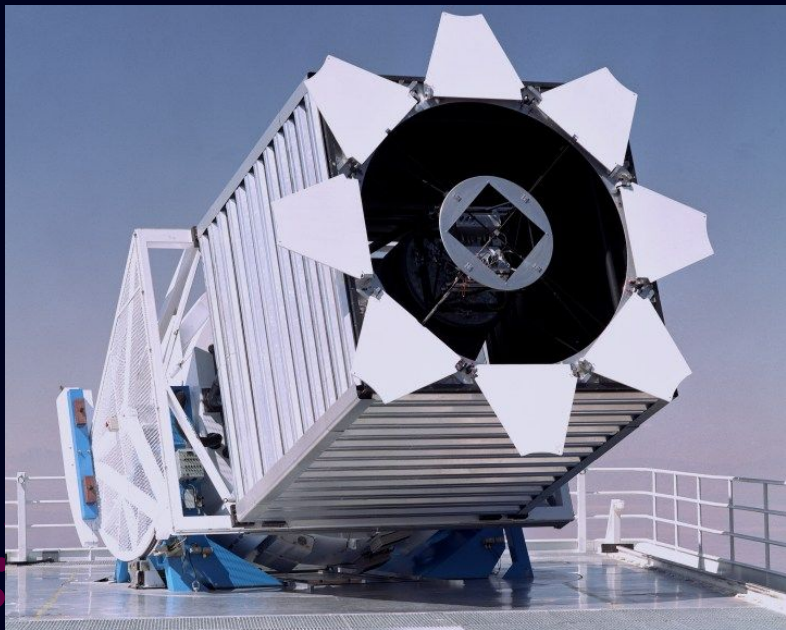
Mass and environment as drivers of Galaxy evolution in SDSS and zCOSMOS and the origin of the Schechter function

By Peng et al. (2010)



# Data

## SDSS and zCOSMOS



# Defining relative quenching efficiencies

Environment:

$$\varepsilon_{\rho}(\rho, \rho_0, m) = \frac{f_{\text{red}}(\rho, m) - f_{\text{red}}(\rho_0, m)}{f_{\text{blue}}(\rho_0, m)}.$$

Mass:

$$\varepsilon_m(m, m_0, \rho) = \frac{f_{\text{red}}(m, \rho) - f_{\text{red}}(m_0, \rho)}{f_{\text{blue}}(m_0, \rho)}.$$

Recall:

## 1. Mass Quenching

Some factor related to the mass of a galaxy causes star formation in a galaxy to shut off (perhaps due to heat produced from a supermassive black hole in galaxies? which is proportional to the stellar mass)

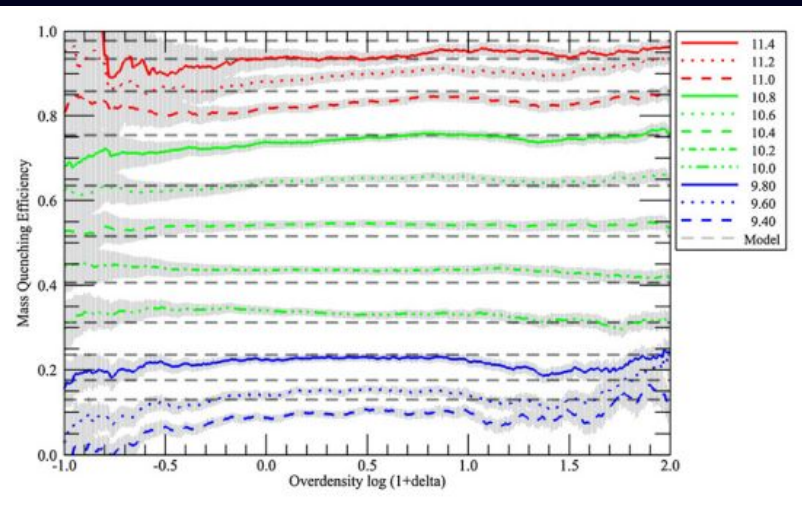
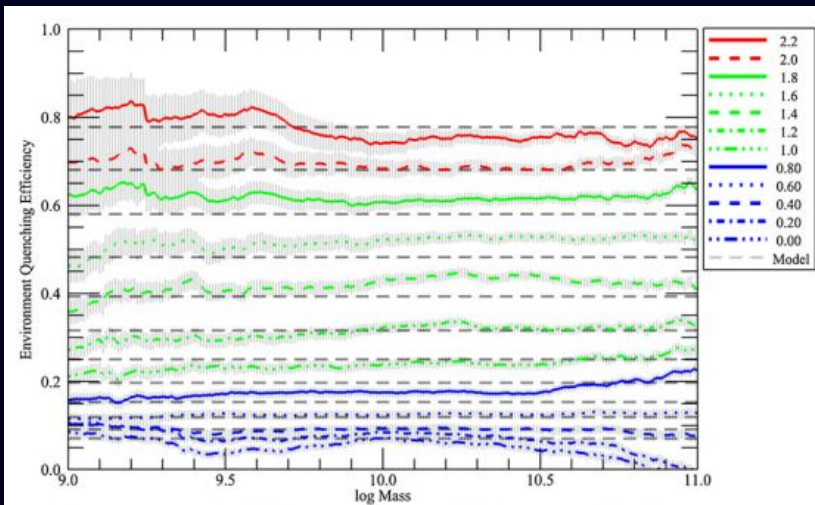
## 2. Environmental Quenching

Some factor related to the environment of a galaxy is found causes star formation in a galaxy to shut off (perhaps due to the fact that galaxies in dense environments will not be fed by cold gas and thus the star formation would shut off?)

# Dependence of quenching efficiencies

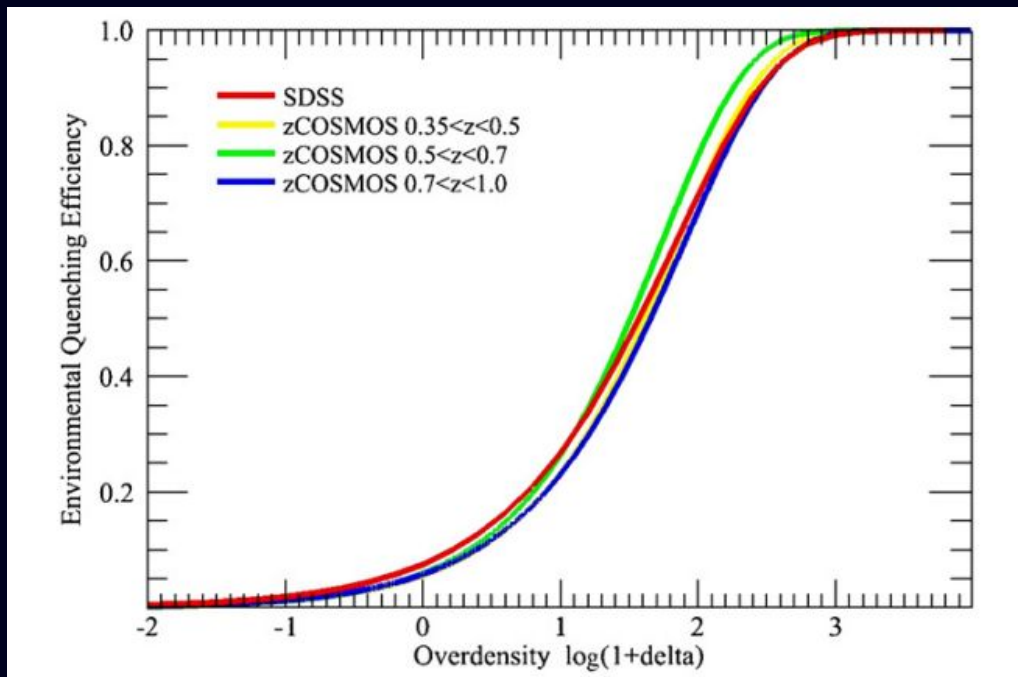
$\varepsilon_{\rho}$  is independent of mass

$\varepsilon_m$  is independent of density



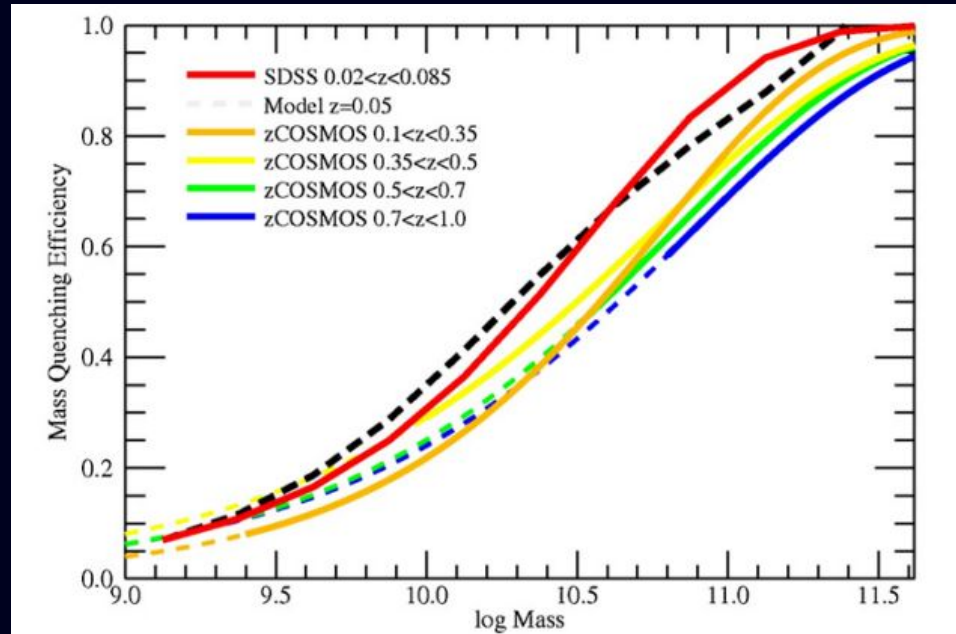
# Environmental quenching

- ★ No mass and time dependence
- ★ Satellite quenching
- ★ Ram pressure stripping
- ★ Strangulation



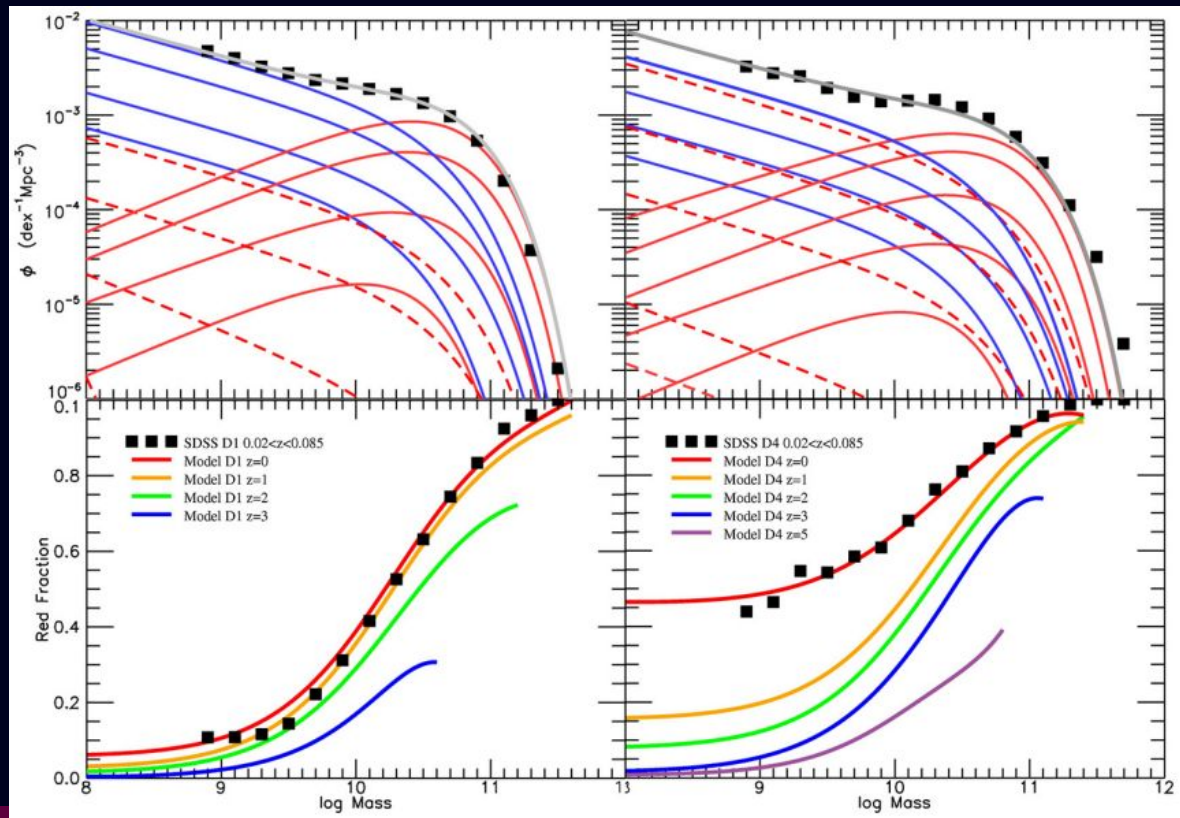
# Mass quenching

- ★ Time dependence
- ★ Continuous process
- ★ SFR dependent
- ★ Supernovae feedback
- ★ AGN feedback



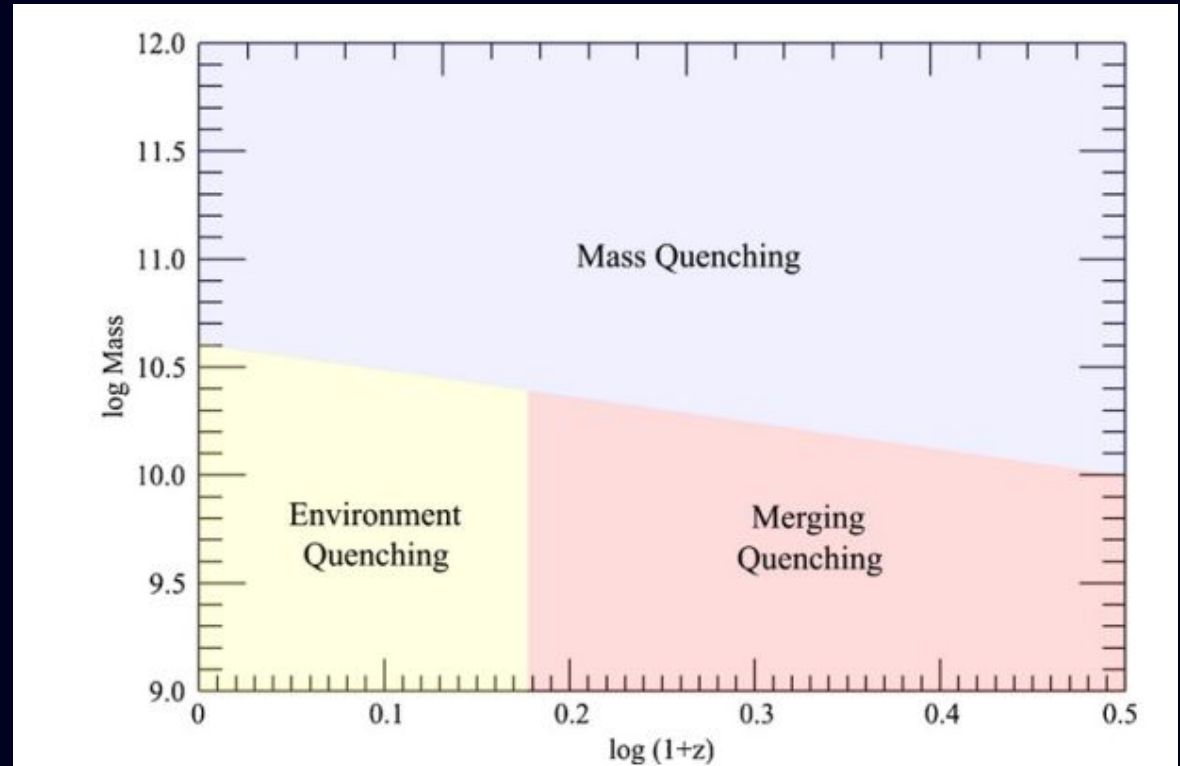
# Model for galaxy evolution

- ★ Simple model: based on combined quenching rates
- ★ Shows good agreement



# Dominant modes

- ★ Mass versus redshift
- ★ Merging quenching important at earlier times
- ★ Merging quenching important at earlier times





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## Main points of Peng et al.

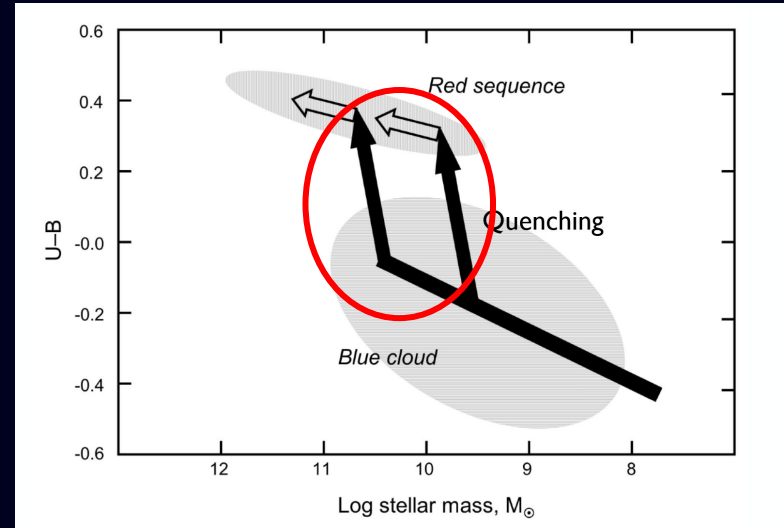
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- ★ Environmental and mass quenching are separable
- ★ Environmental quenching is time and mass independent
- ★ Mass quenching is dependent on SFR
- ★ A simple model can be made which makes good prediction for mass functions
- ★ Above a certain galaxy stellar mass, mass quenching is dominant

## Paper 2:

# Galaxy evolution in groups and clusters: satellite star formation histories and quenching time-scales in a hierarchical Universe

Examining the star formation history and quenching time-scales for galaxy satellites





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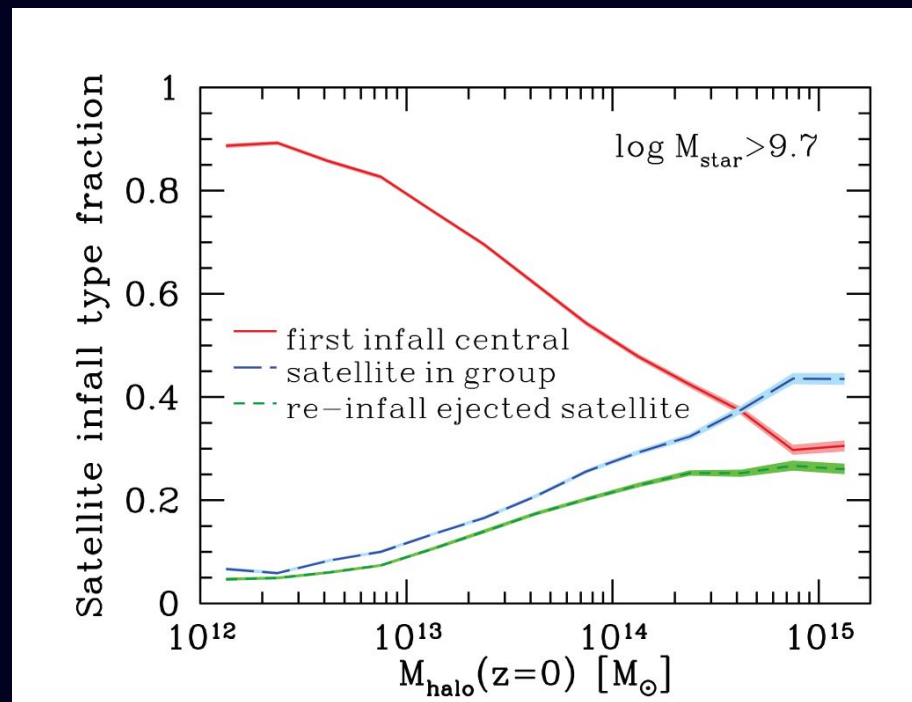
# Satellite simulation

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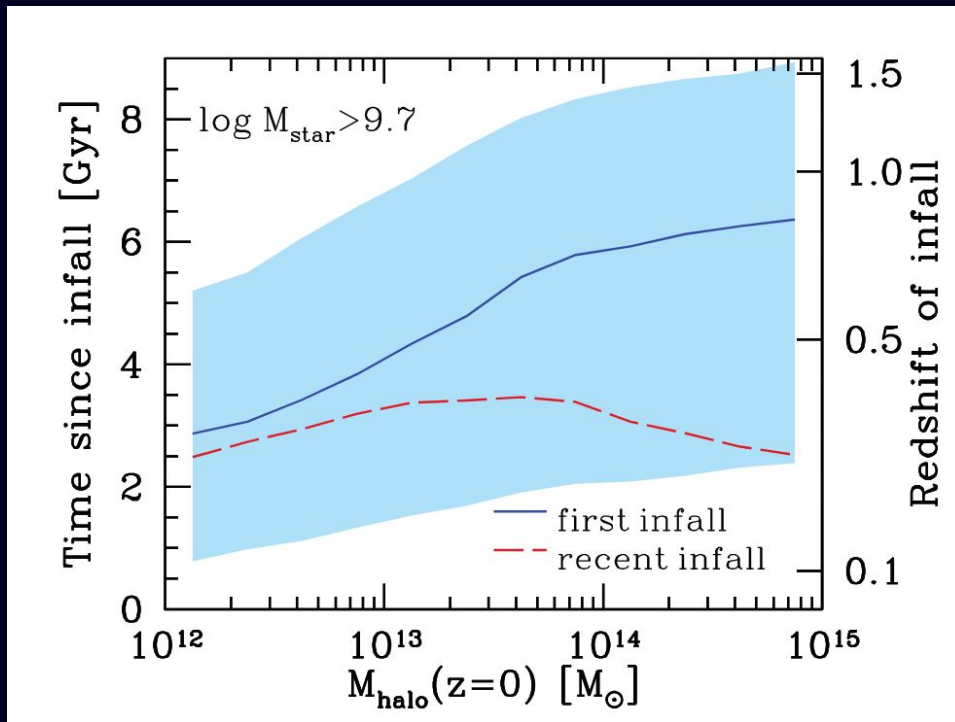
- ★ Flat
- ★ CDM cosmology
- ★  $\Omega_m = 0.274$ ,  $\Omega_b = 0.0457$ ,  $h = 0.7$ ,  $n = 0.95$ ,  $\sigma_8 = 0.8$
- ★ N-body
- ★ FoF (6D)

# Satellite infall types

- ★ First infall and  $M_{\text{max}}$
- ★ Re-infall



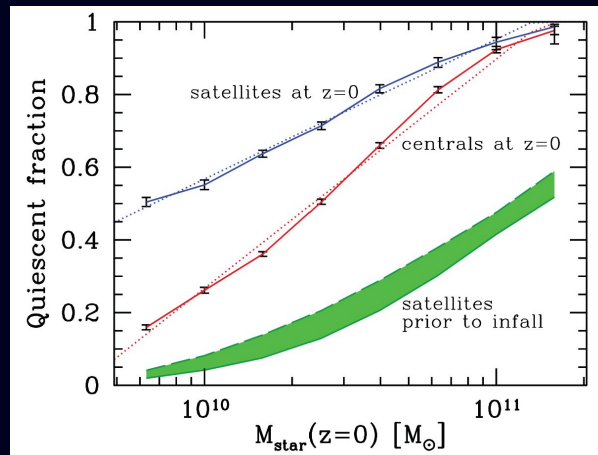
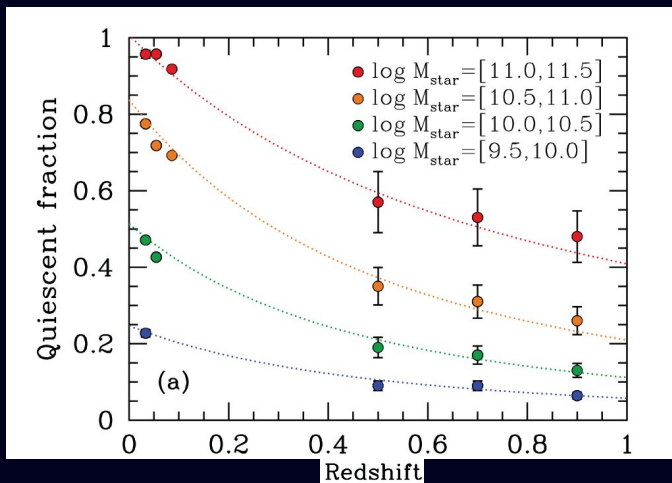
# Satellite infall times



# Right before infall

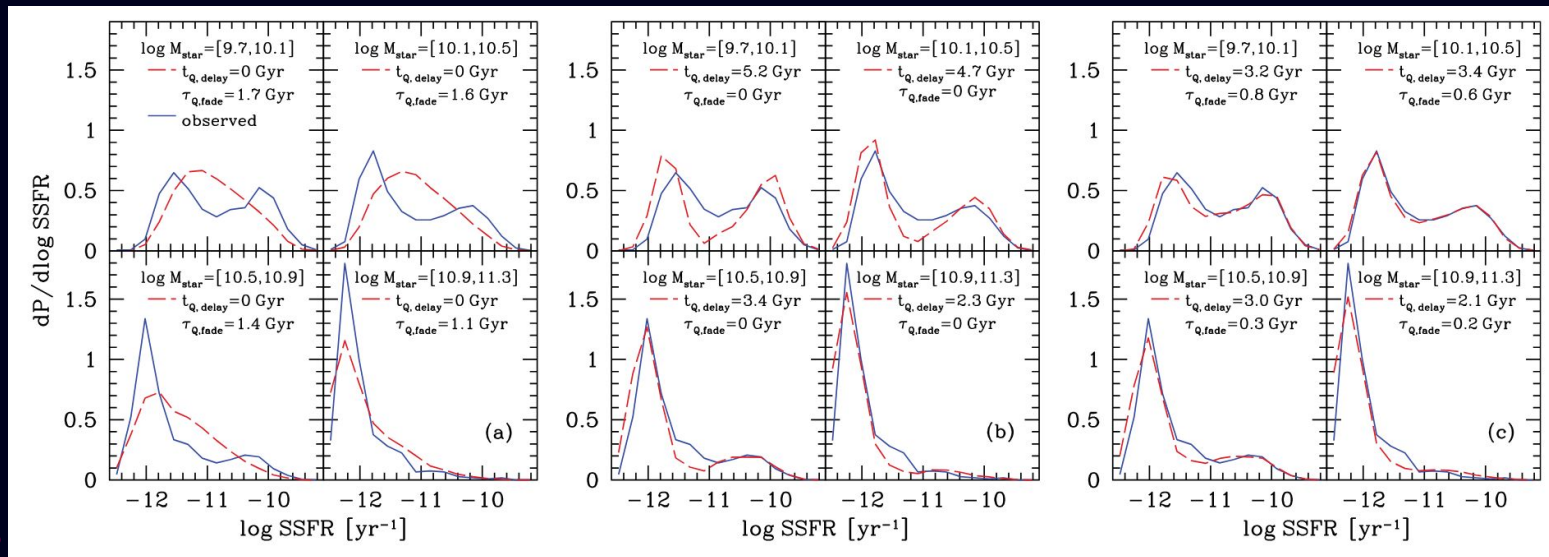
- ★ Initial conditions for SFR of the satellite through empirical parameterization:

$$f_Q^{\text{cen}} = \frac{f_Q^{\text{all}} - f_Q^{\text{sat}} f_{\text{sat}}}{1 - f_{\text{sat}}},$$



# Specific Star Formation Rate comparison

- ★  $SSFR = SFR/M_{\text{star}}$
- ★ SDSS group catalogue vs simulation group catalogue



# Satellite and central SFR

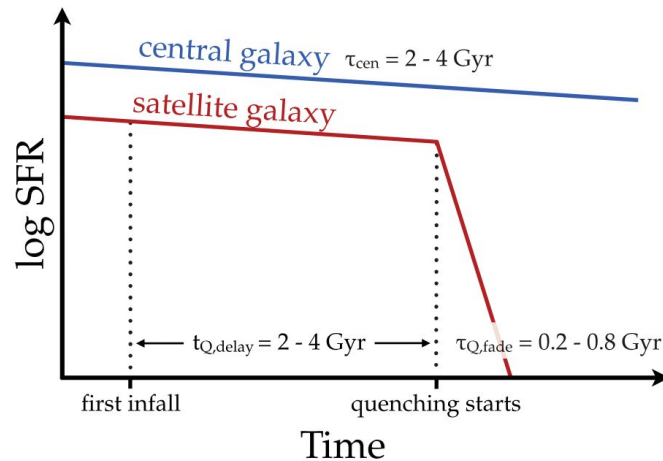
$$\text{SFR}_{\text{cen}}(t) \propto (t - t_f) \exp\left\{-\frac{(t - t_f)}{\tau_{\text{cen}}}\right\}$$

$$M_{\text{star}}(t) = f_{\text{retain}} \int_{t_f}^t \text{SFR}(t) dt$$

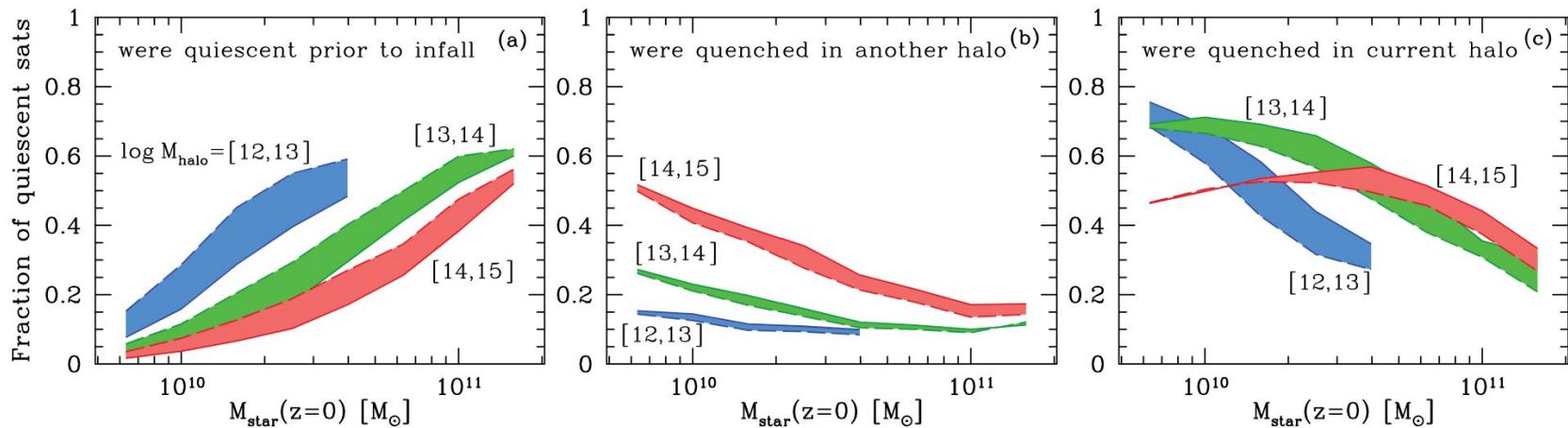
$$t_{Q, \text{start}} = t_{\text{inf}} + t_{Q, \text{delay}}$$

$$\text{SFR}_{\text{sat}}(t) = \begin{cases} \text{SFR}_{\text{cen}}(t) & t < t_{Q, \text{start}} \\ \text{SFR}_{\text{cen}}(t_{Q, \text{start}}) e^{\left\{-\frac{(t - t_{Q, \text{start}})}{\tau_{Q, \text{fade}}}\right\}} & t > t_{Q, \text{start}} \end{cases}$$

Satellite SFR Evolution: Delayed-then-Rapid Quenching



# Where were satellites when they quenched?






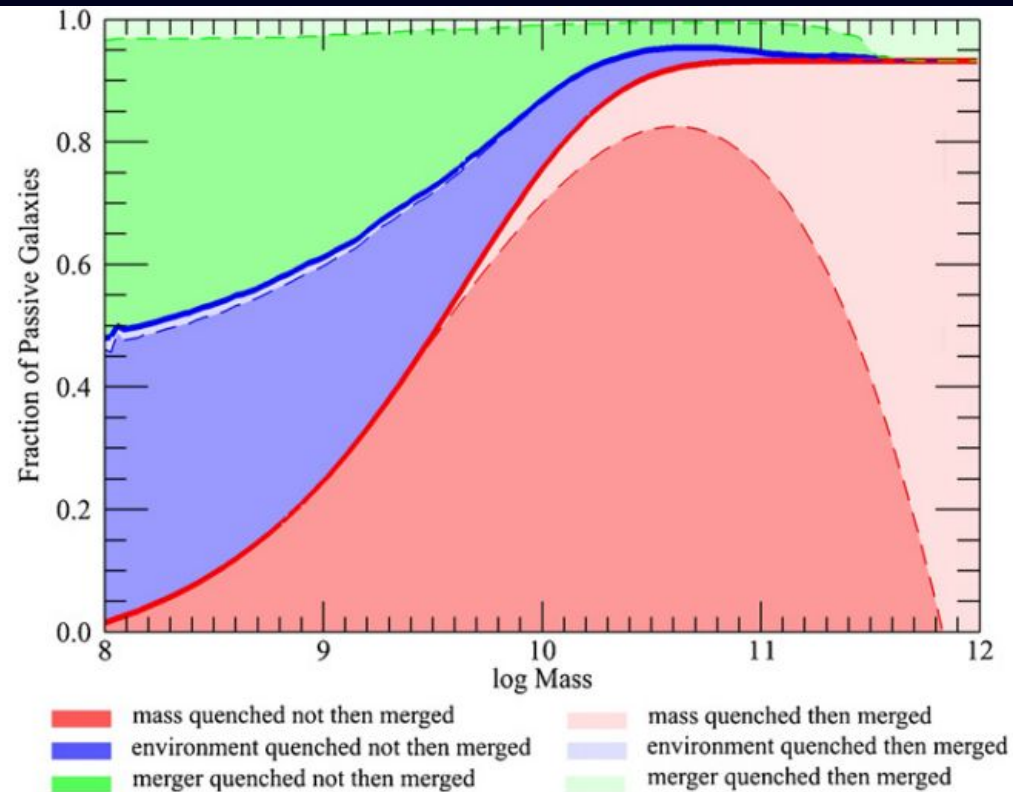
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## Main points of Wetzel et al.

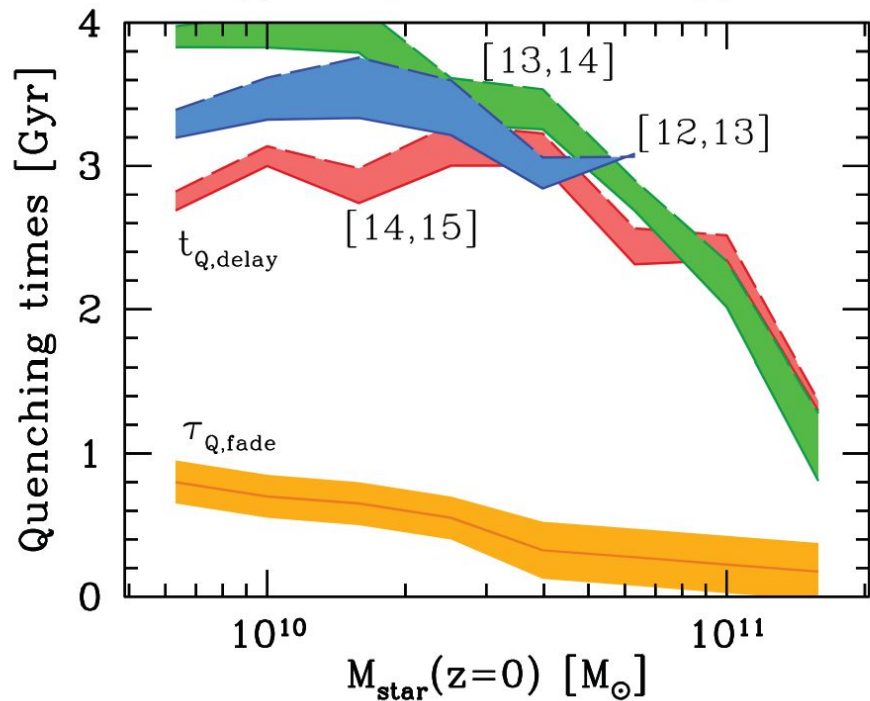
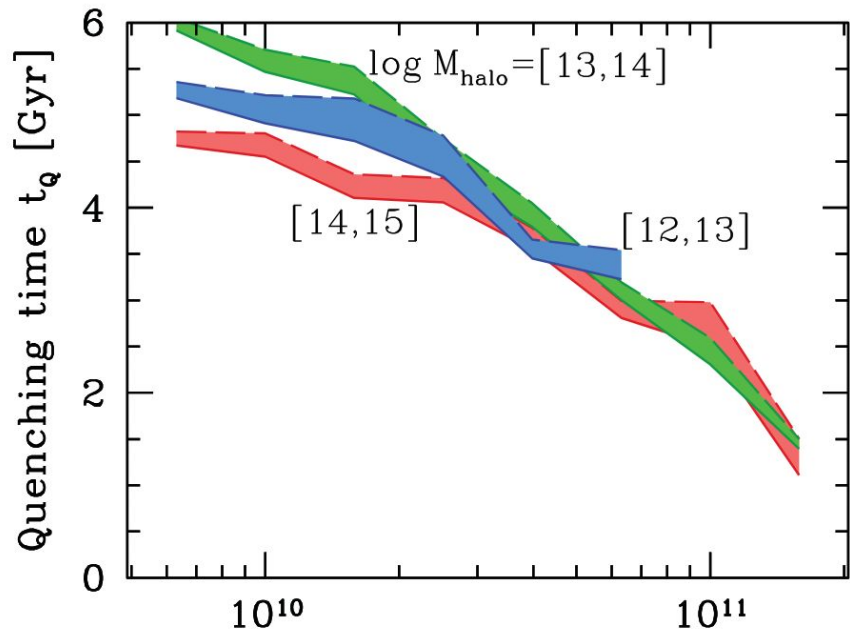
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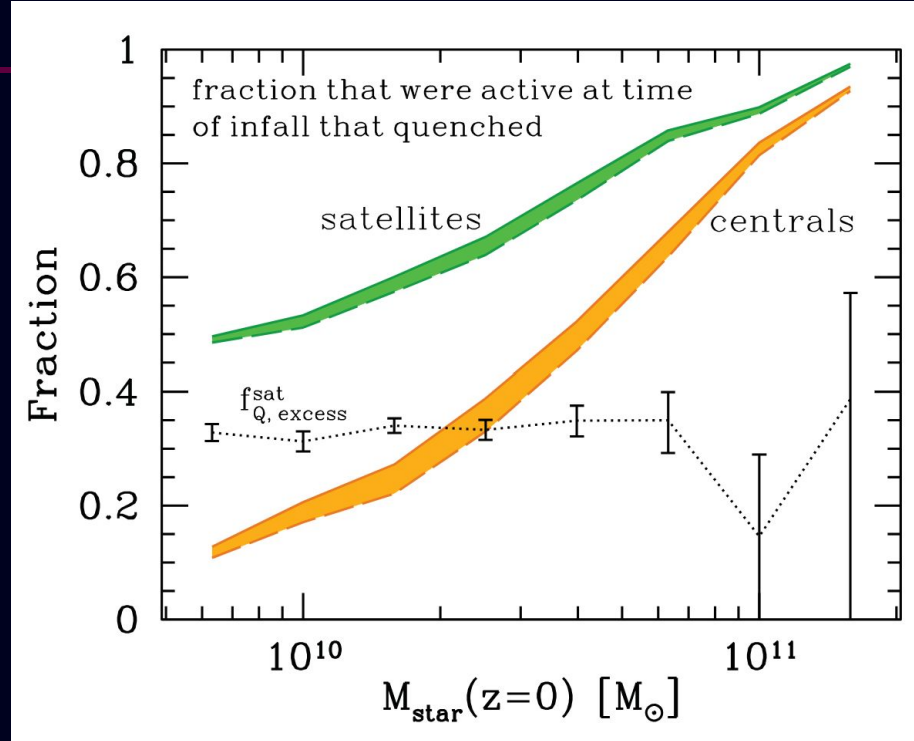
- ★ Quenching is a critical process in galaxy evolution
  - ★ Satellite quenching is delayed after infall, but when it happens it is rapid
  - ★ Satellite quenching time-scales are shorter at higher stellar mass, but independent of host halo mass
  - ★ Satellite quenching barely impacts stellar mass growth
- 

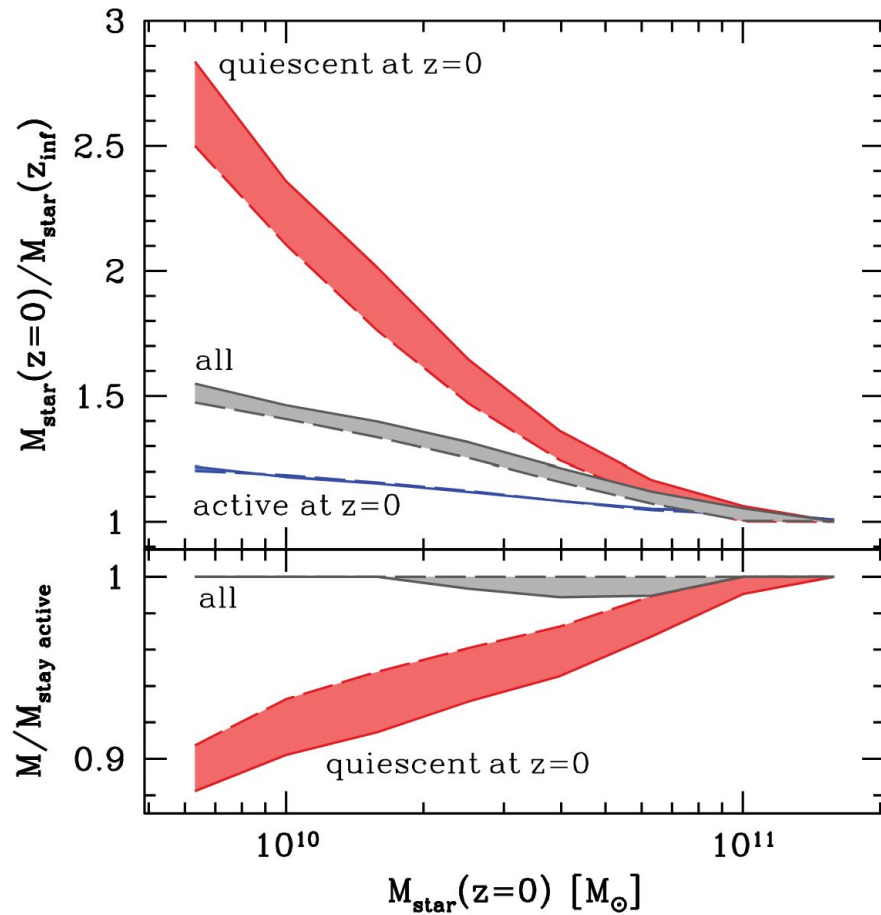
# Bonus slide



# Bonus slide









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# The quench that stole christmas

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