The influence of environment & its history on galaxy formation

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Growing up at high redshifts: from proto-clusters to galaxy clusters,
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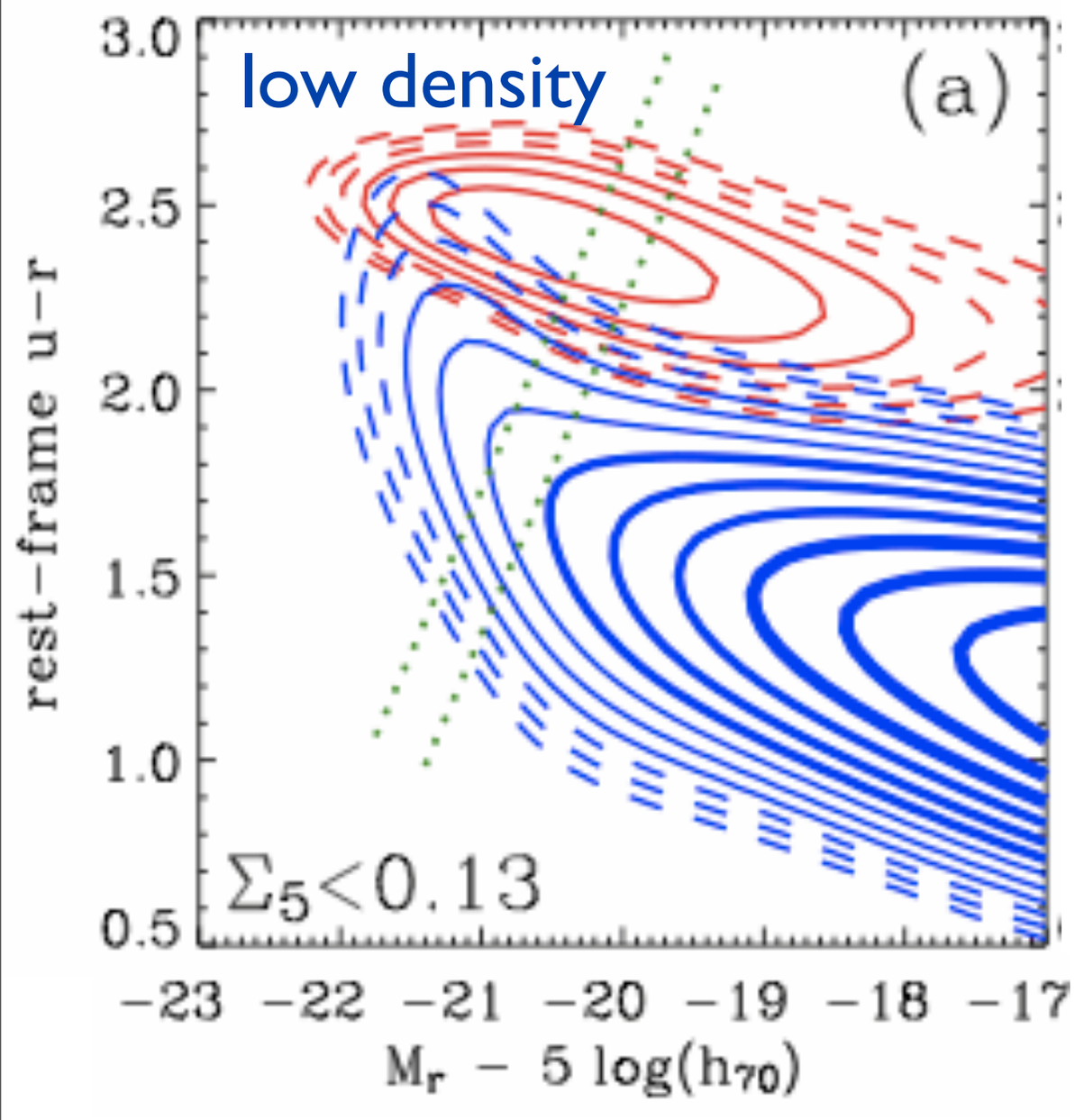
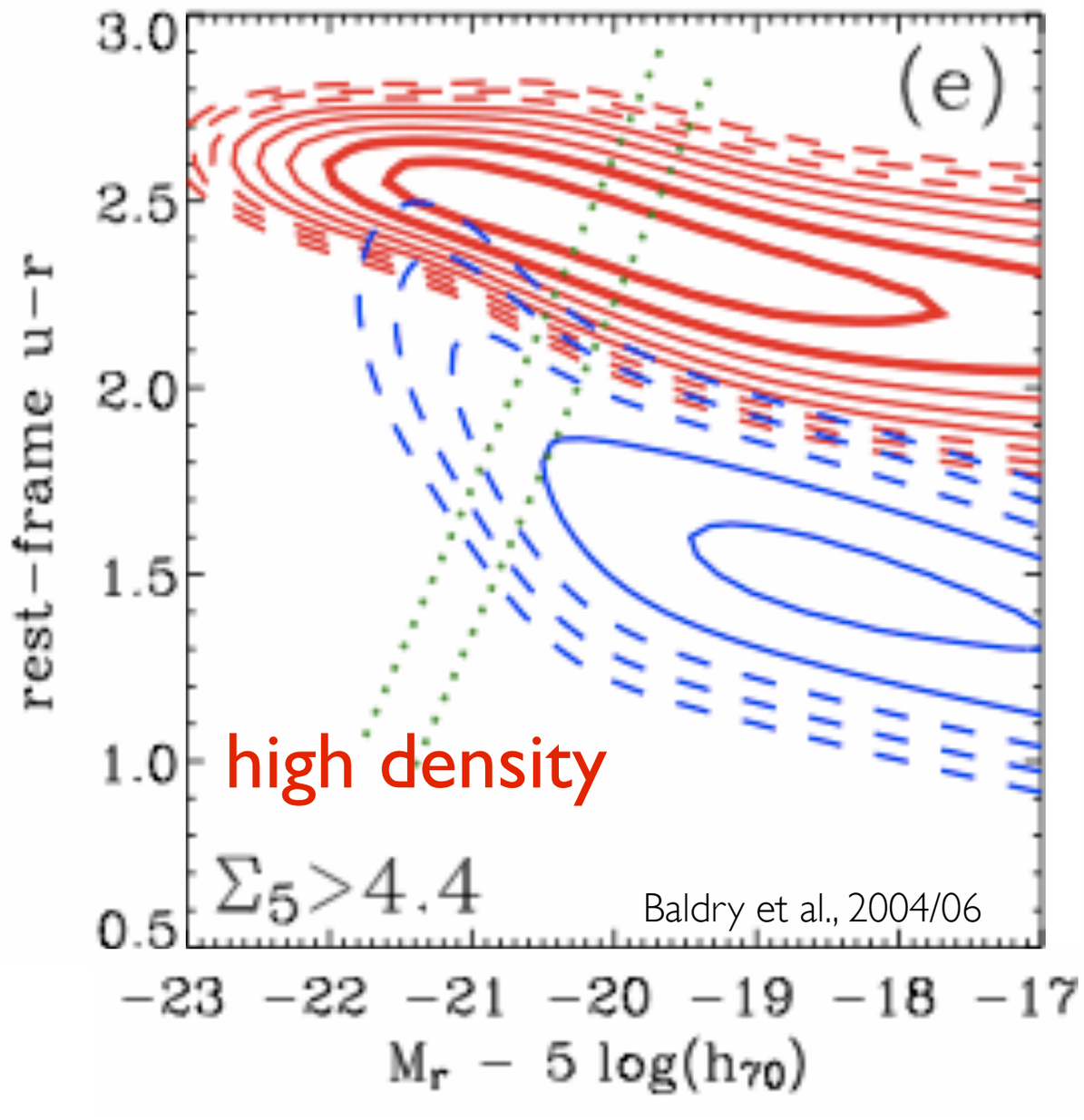
OSSERVATORIO ASTRONOMICO TRIESTE

Motivation

Observations: Color-density-relation





Luminous, blue galaxies dominate low density regions

Less luminous, red galaxies preferentially reside in high density regions

Motivation

Open questions:

- What is the *origin of the color-density-relation*?
- Which role does the *environment* play *in quenching galaxies i.e. in the transition from blue, star-forming to red, passive galaxies*?

How a galaxy can get quenched:

A) Internal processes (**nature**) feedback from SN and AGN in central & satellite galaxies

⟷

B) External processes (**nurture**) merger events/*environment(strangulation, ram-pressure, harassment...)*

↓

Aim: Better understanding of environmental quenching in satellites

When and where are galaxies quenched by environmental processes?

Quenching Time-scales?

1. How well do recent models reproduce the observational trends
2. Investigating the modeled environmental history of galaxies

Method

Observational data

- ***Density catalogue*** of *Wilman et al. (2010)* using SDSS (DR8):
  $z = 0.015\text{-}0.08$, $M_r < -18$,
  $\Delta v = +/-1000\text{km/s} + V_{max}$ correction

- ***Cross-correlated*** with *Brinchmann et al. (2004) & Yang et al. (2007)*:
  Estimates for stellar masses, SFRs (Halpha emission lines), galaxy types

Theoretical models

- ***Millennium-Simulation*** (*Springel at al. 2005*):
  512^3 particles in a $(500\text{Mpc/h})^3$ box, merger trees & spatial distribution of the halos

- ***Semi-analytic models*** (*DeLucia & Blaizot, 2007; Guo et al., 2011*):
  Populate dark matter halos with galaxies, same selection criteria as in observations

Quiescent galaxies:

$$\mathrm{sSFR} \equiv \frac{\mathrm{SFR}}{M_{\mathrm{stellar}}} < \frac{0.3}{t_{\mathrm{Hubble}}}$$

see *Franx et al. 2010*

Density estimation:

$$\Sigma_{r_i, r_a} = \frac{N_{\mathrm{gal}}}{\pi(r_a^2 - r_i^2)}$$

see *Wilman et al. 2010*

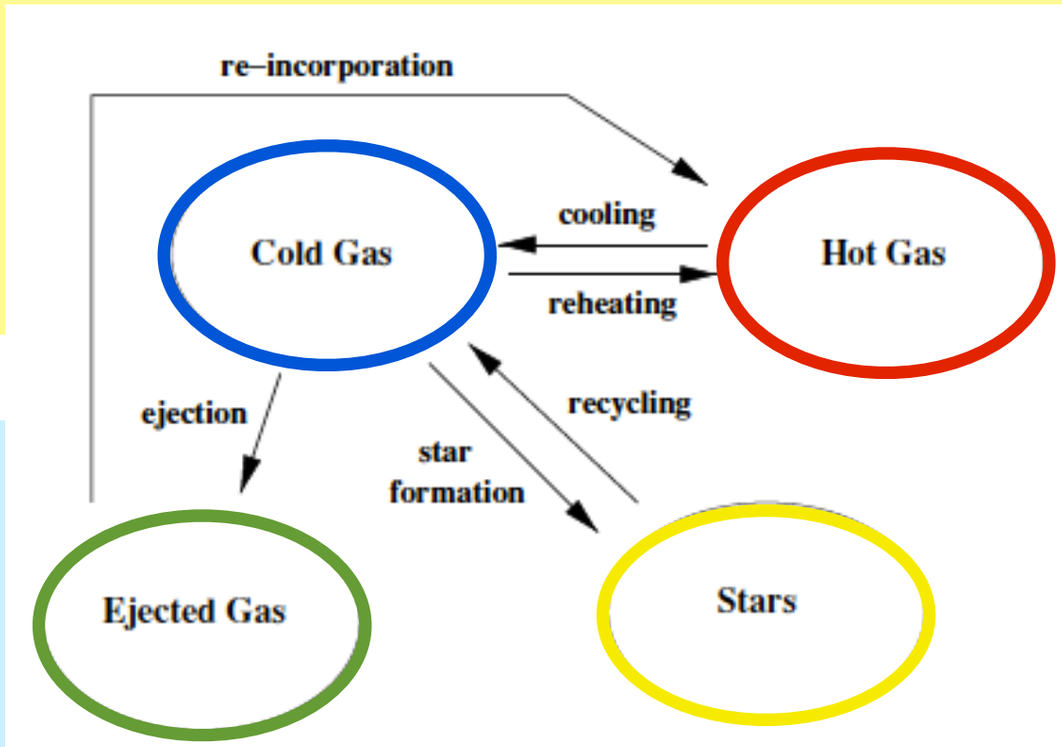
with: $r_i = 0$ Mpc, $r_a = 1$ Mpc

Semi-analytic models

De Lucia et al. 2007 ⟷ *Guo et al. 2011*

Basic recipes for cooling, star formation & BH growth are similar

✦ ***SN feedback***: *constant efficiency* for reheating and ejection of gas



✦ ***Stronger SN feedback***: reheating & ejection *efficiency dependent* on halo circular velocity

✦ ***Instantaneous strangulation*** of the hot gas reservoir when a galaxy becomes a satellite galaxy ⟷

✦ ***Gradual strangulation*** of the hot gas reservoir by the same rate as the dark matter halo gets stripped

1. How well do recent models reproduce the observed trends?

Quenched galaxy fraction

...versus mass

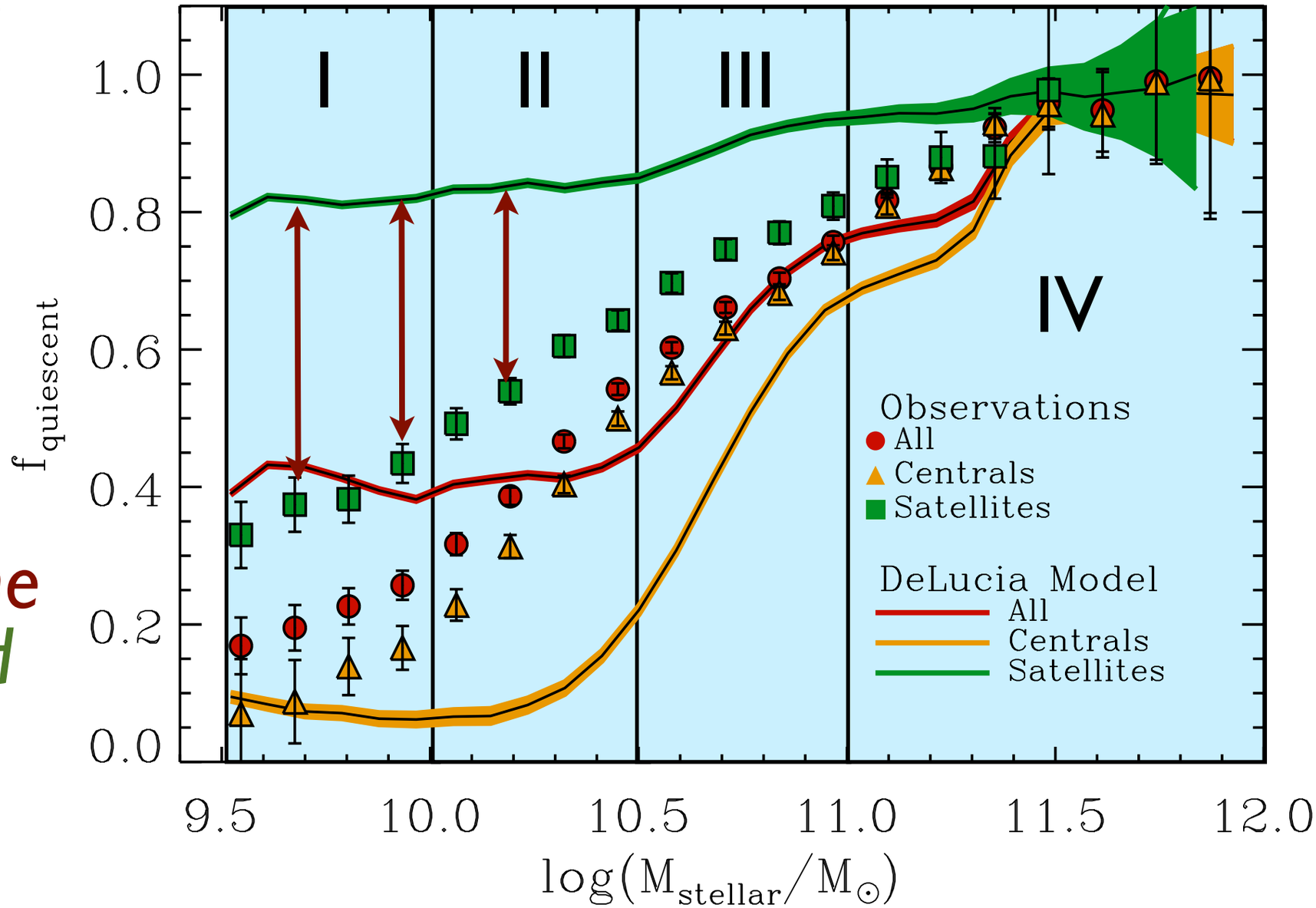
DeLucia07: *Instantaneous strangulation* of the hot gas reservoir of satellite galaxies

- Strong dependence of quenching on stellar mass for **centrals** & **satellites**
- A *fundamental problem* of many current galaxy formation models:

Over-estimation of the fraction of quenched satellites

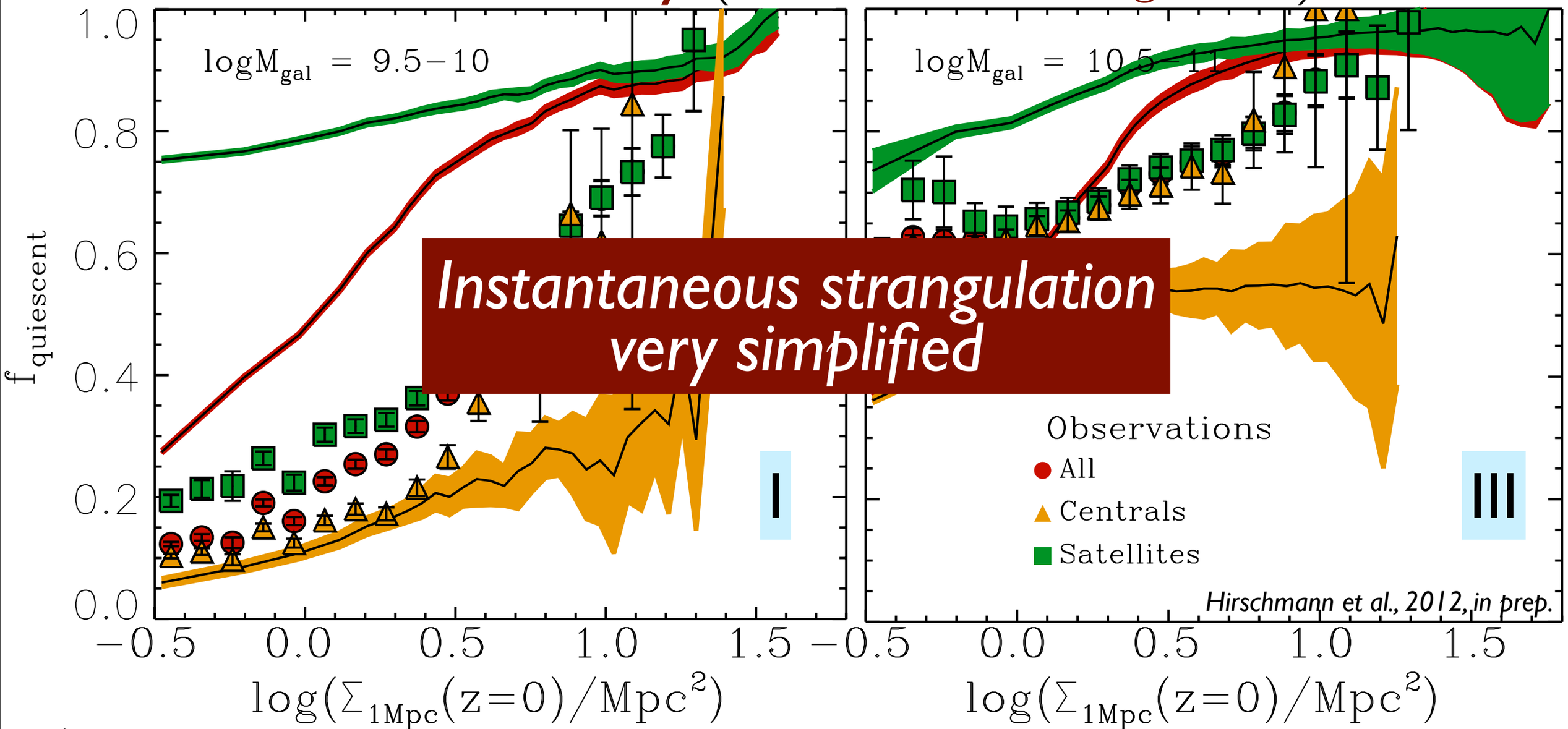
Qualitative agreement with e.g. Kimm et al. 2009

Hirschmann et al., 2012, in prep.



Quenched galaxy fraction

...versus density (*Instantaneous strangulation*)



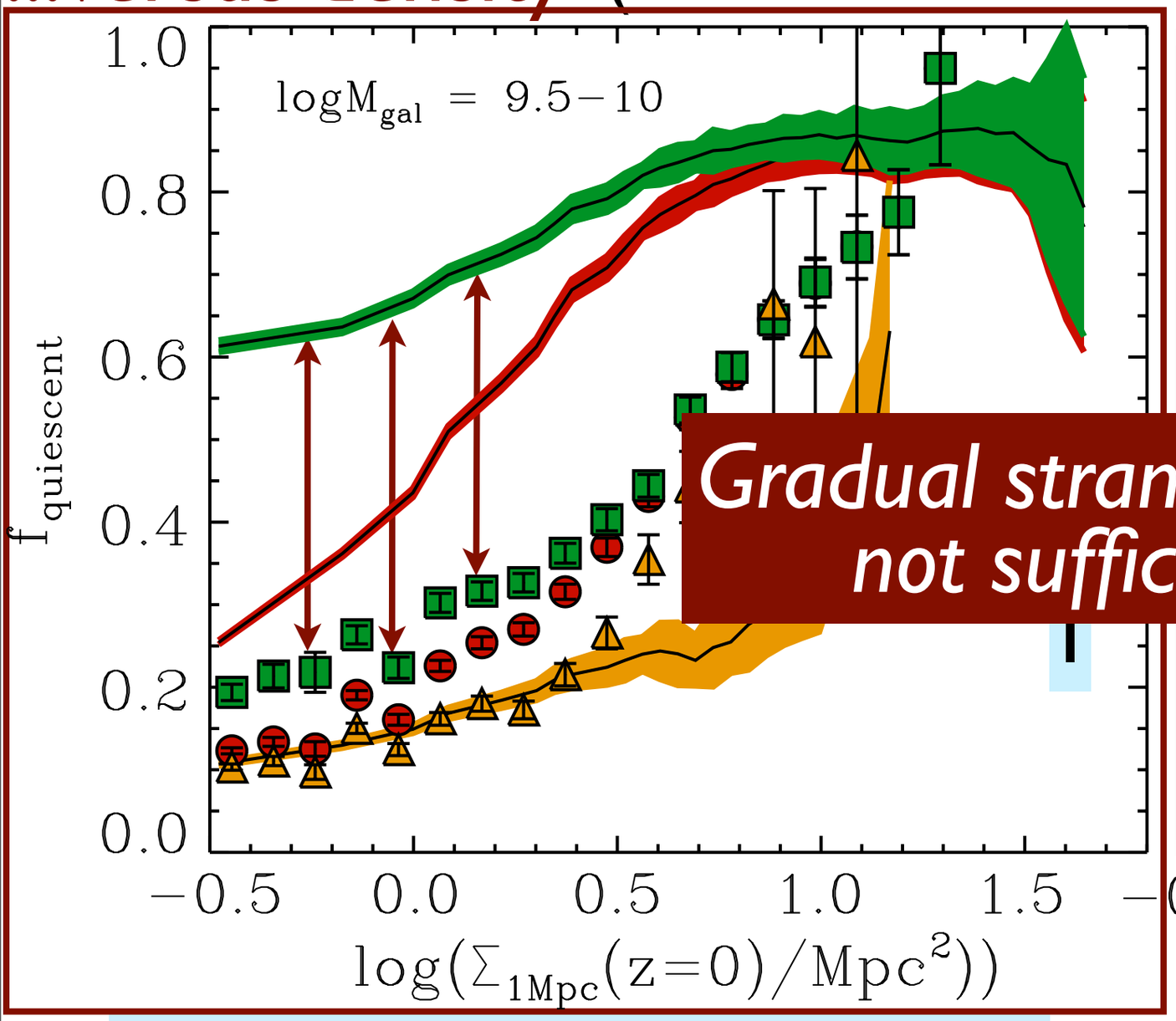
Instantaneous strangulation very simplified

- ***Observations***: *similar behavior of* ***centrals*** & ***satellites*** & *quenching strongly dependent on density*
- ***Models***: centrals & satellites behave ***very differently***

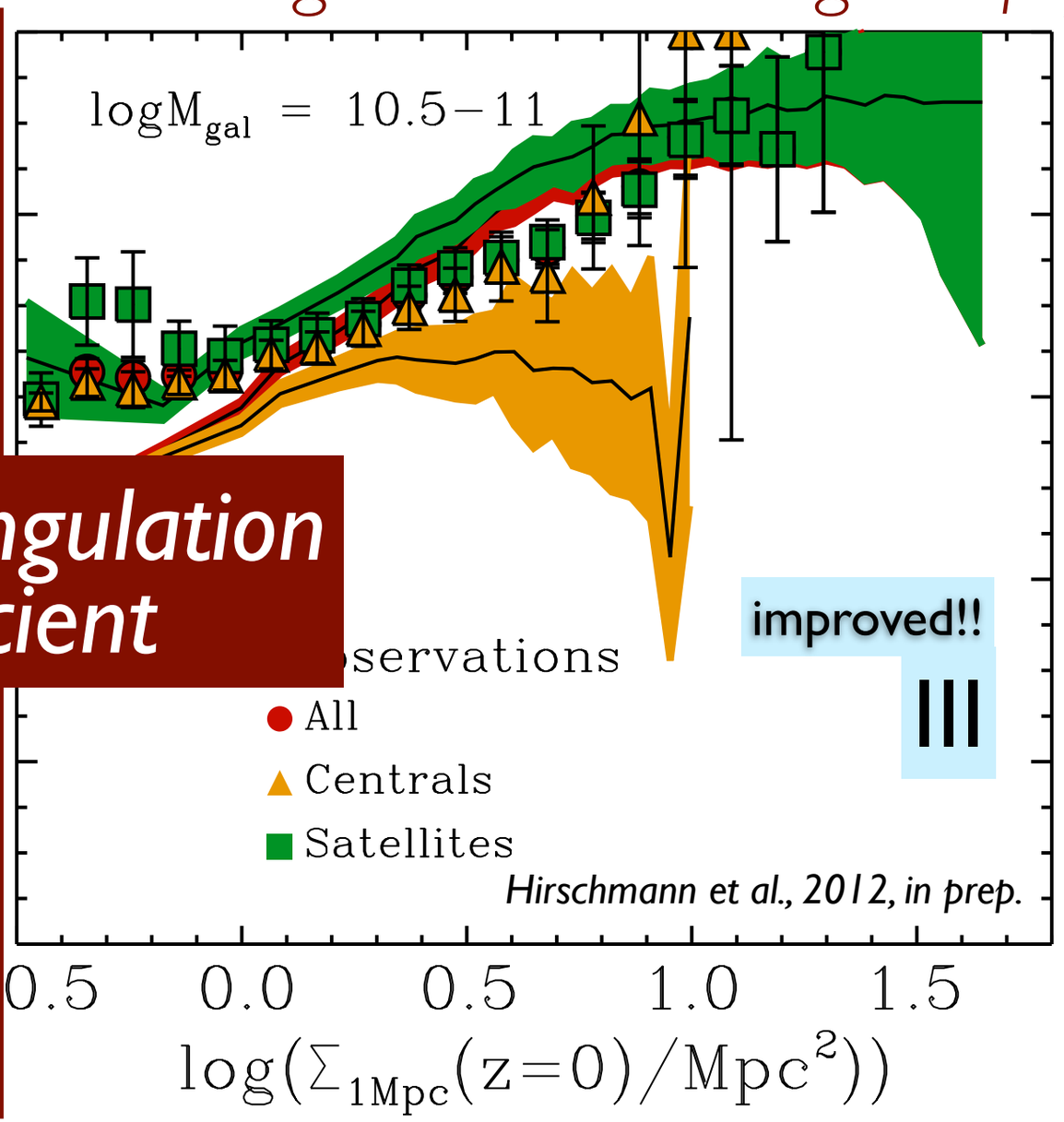
⇨ Over-estimating *quenched satellites* & under-estimating *quenched centrals*

Quenched galaxy fraction

...versus density (Guo model: *Gradual strangulation & strong SN fb*)



Gradual strangulation not sufficient



Quenched *satellite fractions get reduced*, quenched *central fractions increased*, but still:

Over-estimation of the fraction of quenched satellites for low-mass galaxies

2. Investigating the modeled environmental history

Environmental history

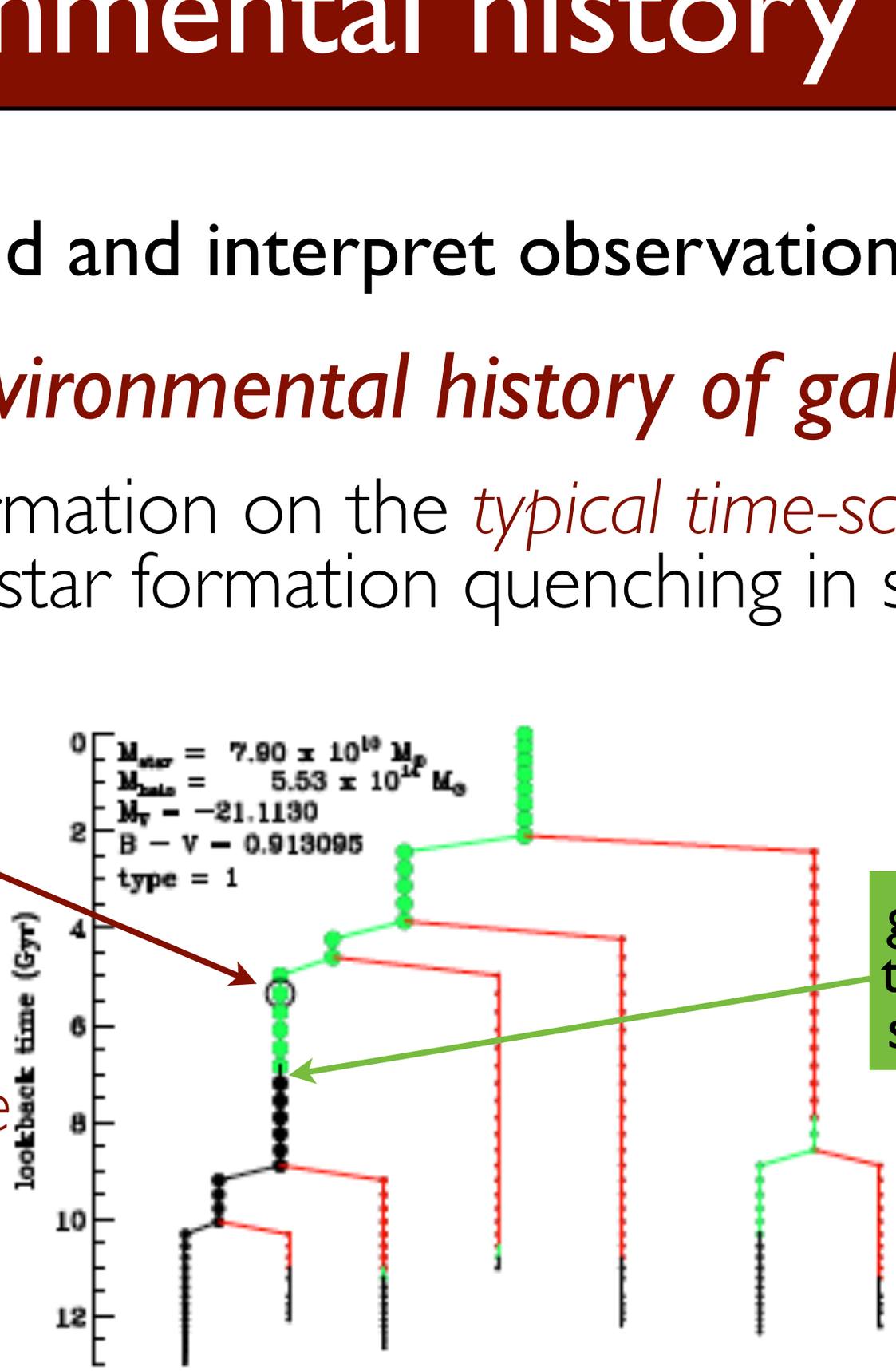
To better understand and interpret observational data:

Investigate the environmental history of galaxies...

Can we gain any information on the *typical time-scale* & the *typical environment* of star formation quenching in satellites??

galaxy was accreted onto the final parent halo

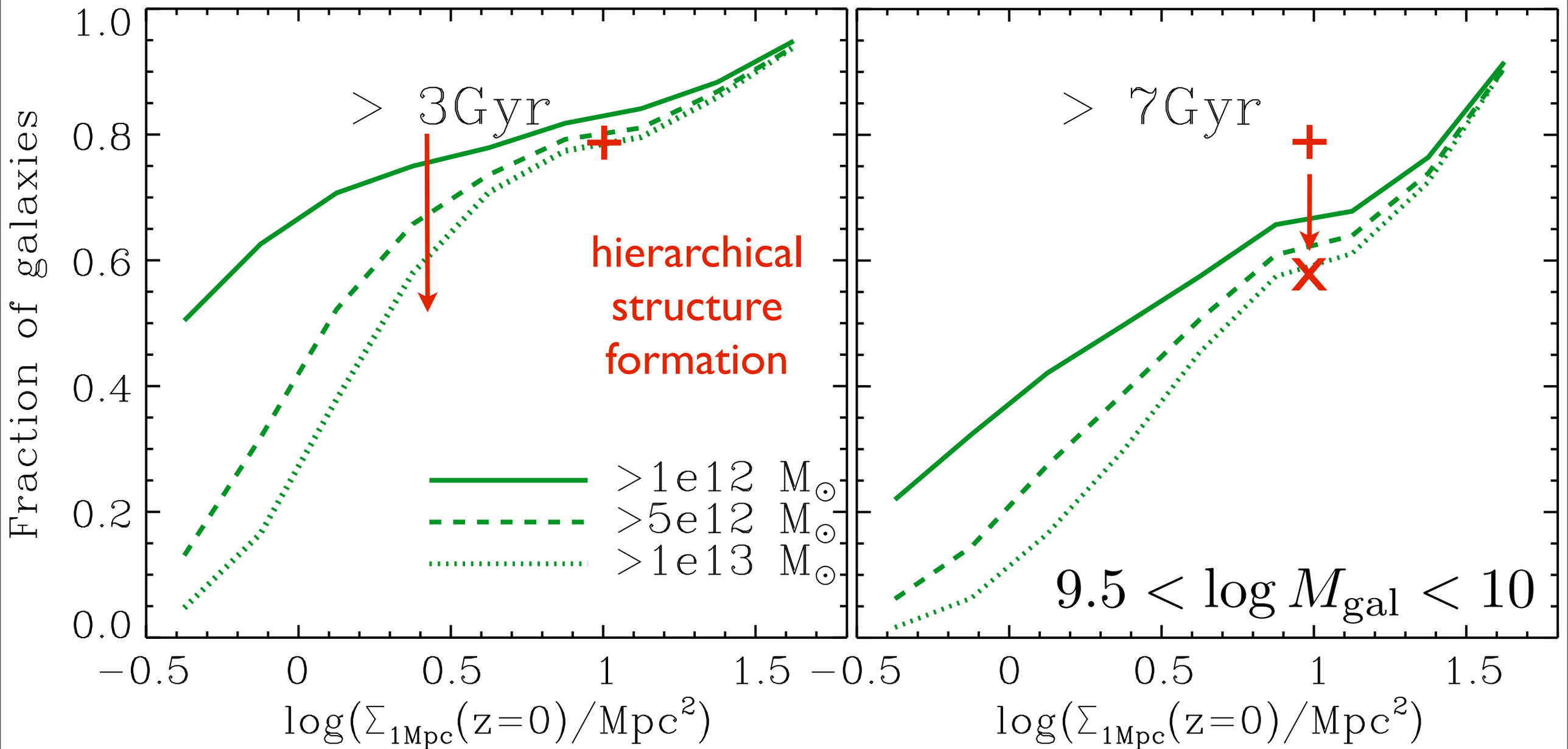
- Using galaxy merger trees
- *How long has a satellite galaxy been living in a parent halo of a certain mass?*



galaxy became the first time a satellite galaxy

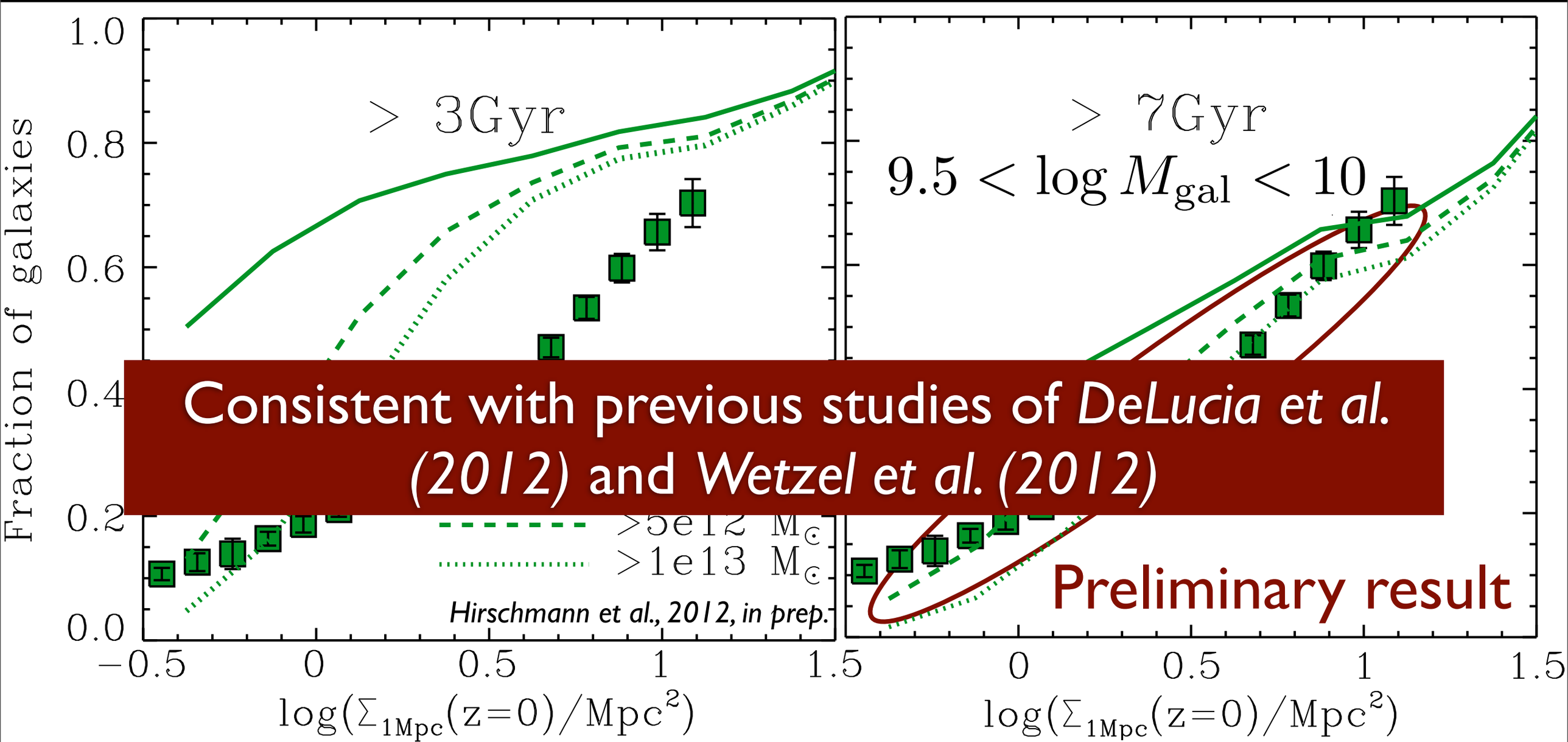
Central
Type I satellite
Type II satellite

Environmental history



Lines: ***'Environmental'*** fraction: fraction of ***model satellite galaxies*** having resided in halos more massive than X for a longer time than Y, versus the ***present-day density***

Environmental history



Consistent with previous studies of *DeLucia et al. (2012)* and *Wetzel et al. (2012)*

Lines: ***'Environmental'*** fractions of ***model satellite galaxies***
Symbols: ***Observed, transition fraction*** with a large systematic error

Preliminary conclusion:
Long quenching time-scales for satellites: **7Gyrs**

Summary

1. Recent models *do not reproduce observed trends* concerning the quenched fractions very well
2. *Environmental history* points towards
   - ⇨ *Long quenching time-scales (7Gyrs)* in low-mass satellites
   - ⇨ *Satellites* need to behave more *like centrals*
3. *Color-density relation is mainly set by structure formation*
   - ⇨ *No need for cluster-specific processes*

OUTLOOK

- ✦ *Where* do satellites get quenched? Look at radial distribution
- ✦ How can we *improve our galaxy formation models* particularly achieve long quenching time scales for satellites
  - ⇨ *Fundamental change in recipes for SF and feedback?*