(The Frequency of) Galaxy Mergers in Different Environments

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Layout

Introduction & Methodology

Introduction

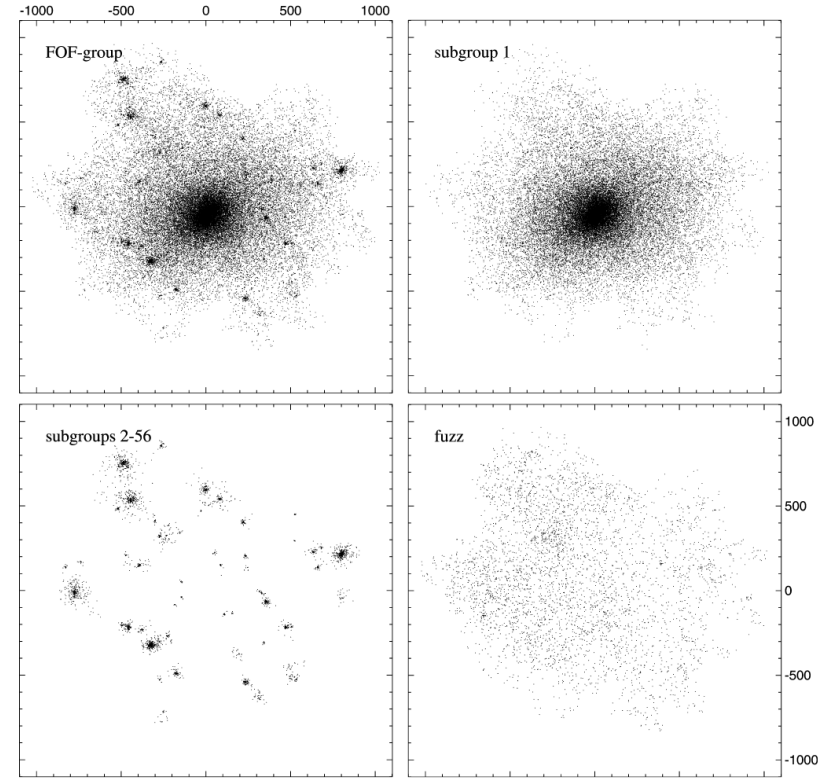
- Galaxy mergers are an essential ingredient in any galaxy formation model.
- Much of our understanding about galaxy mergers comes from *idealized* merger simulations.
- However, hydrodynamic cosmological simulations (Illustris/IllustrisTNG, EAGLE, etc.) are better for studying galaxy mergers in a cosmological context.

Merger examples in the Illustris simulation:

(Figure credit: Annalisa Pillepich)

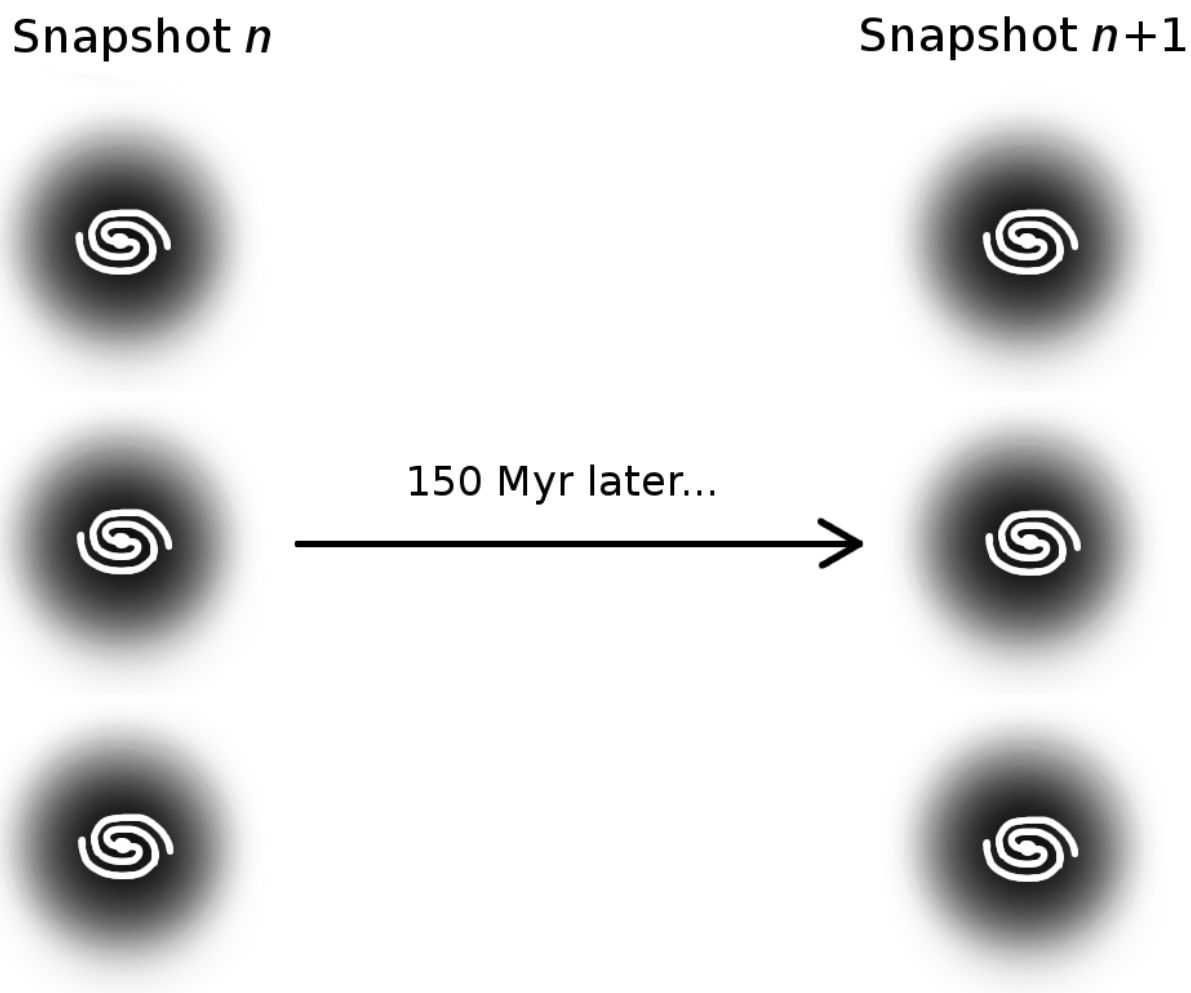
The halo finder

- Bound structures in Illustris are identified using SUBFIND.



(Springel et al. 2001)

Finding the descendants



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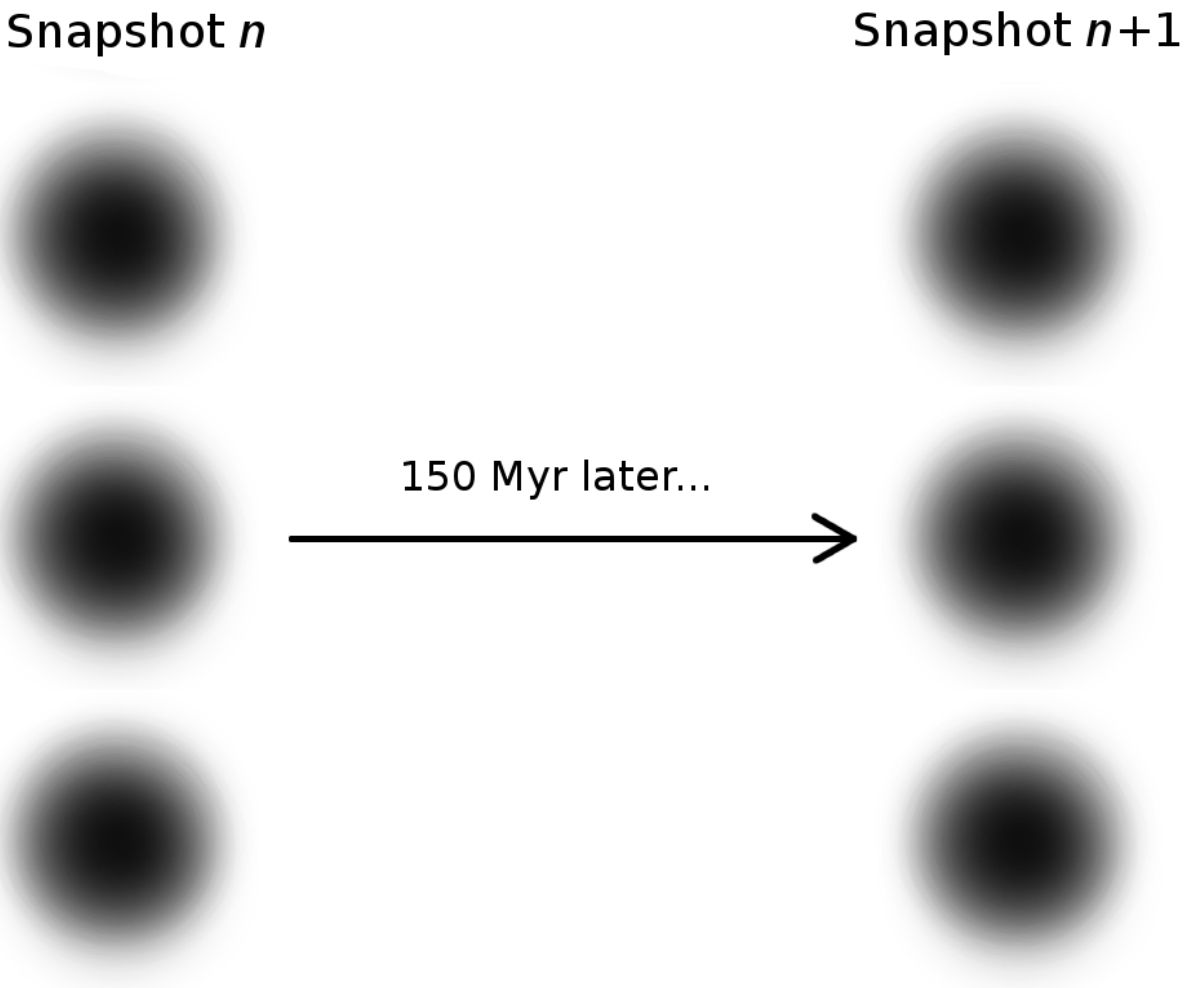

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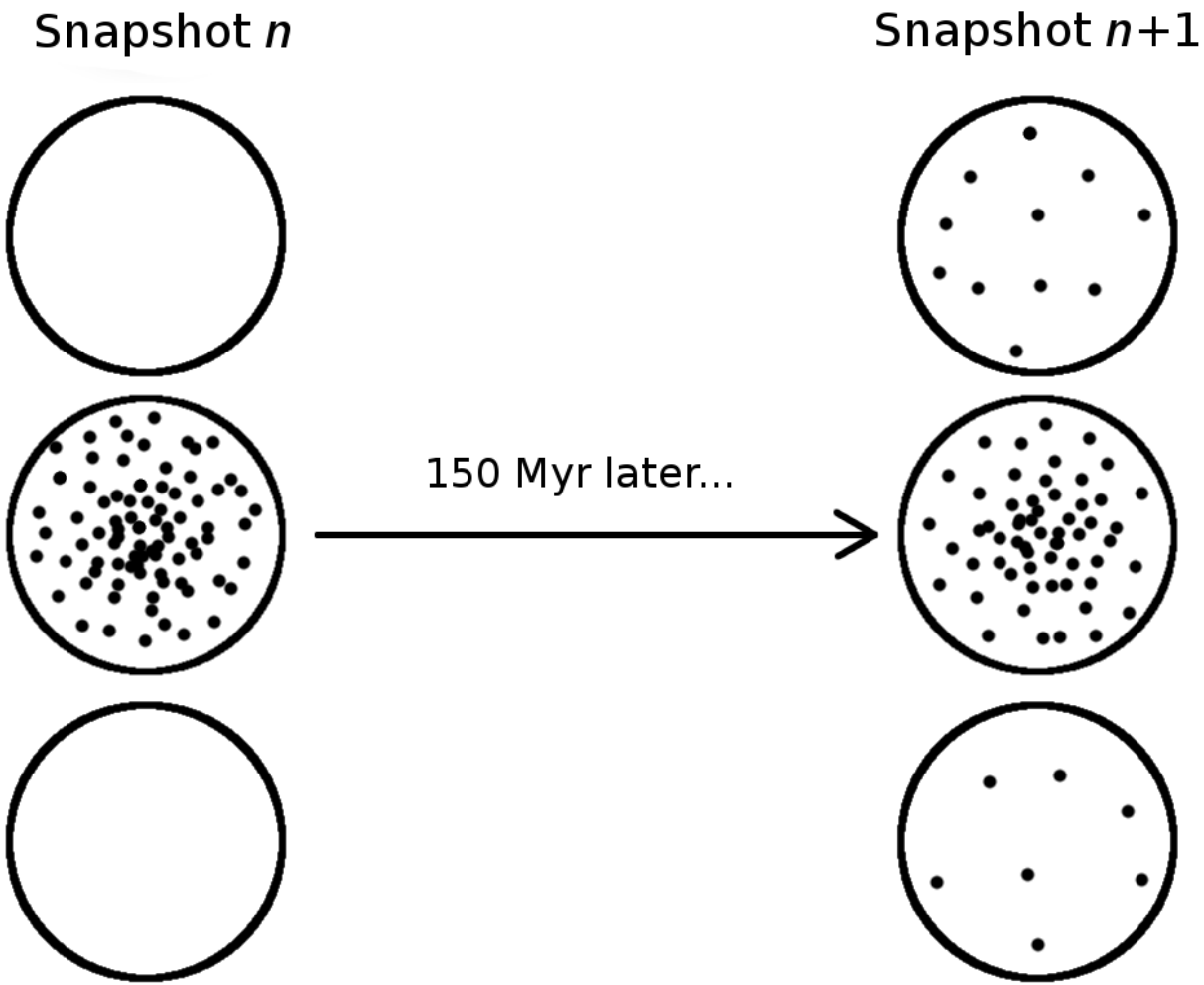

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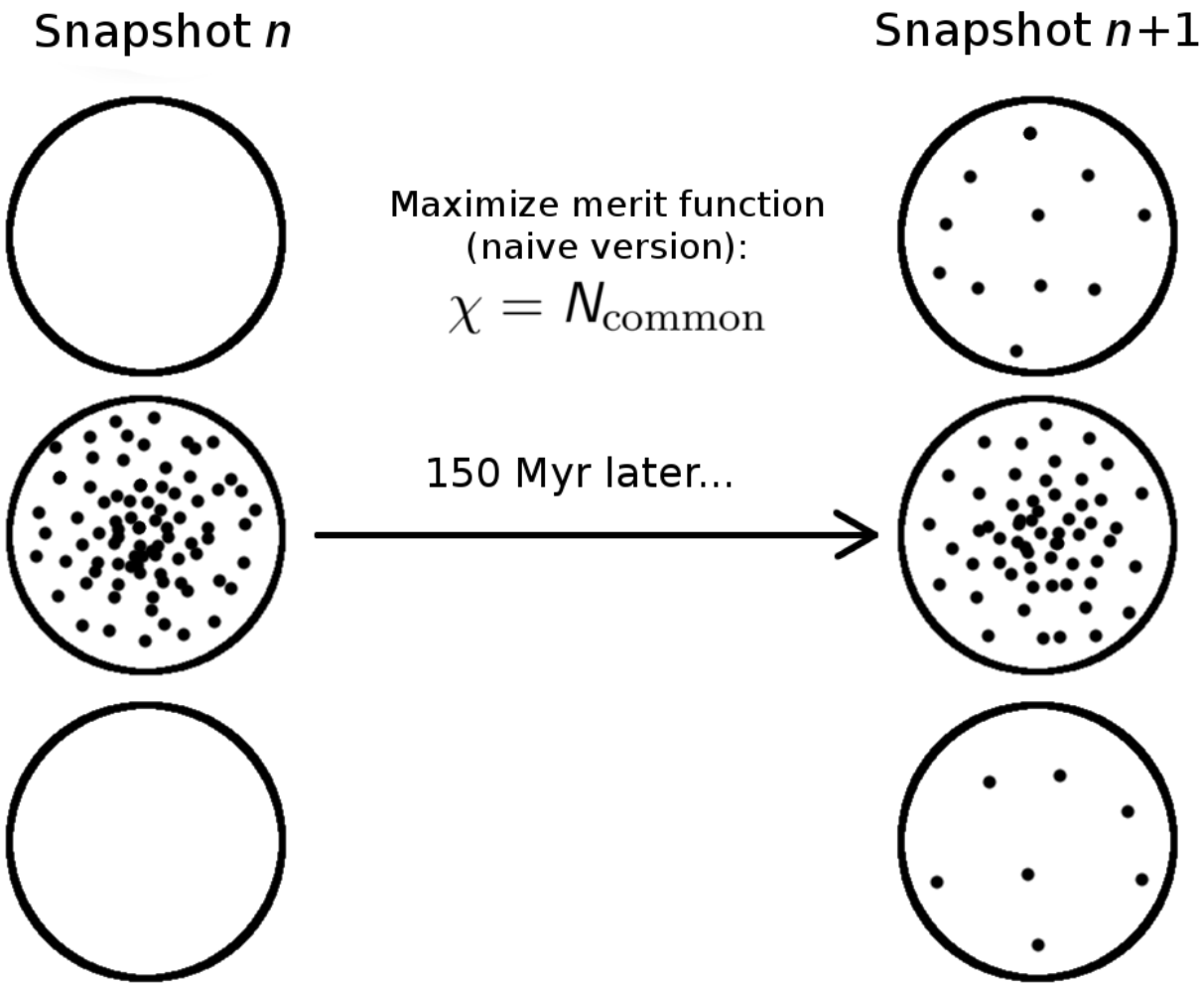
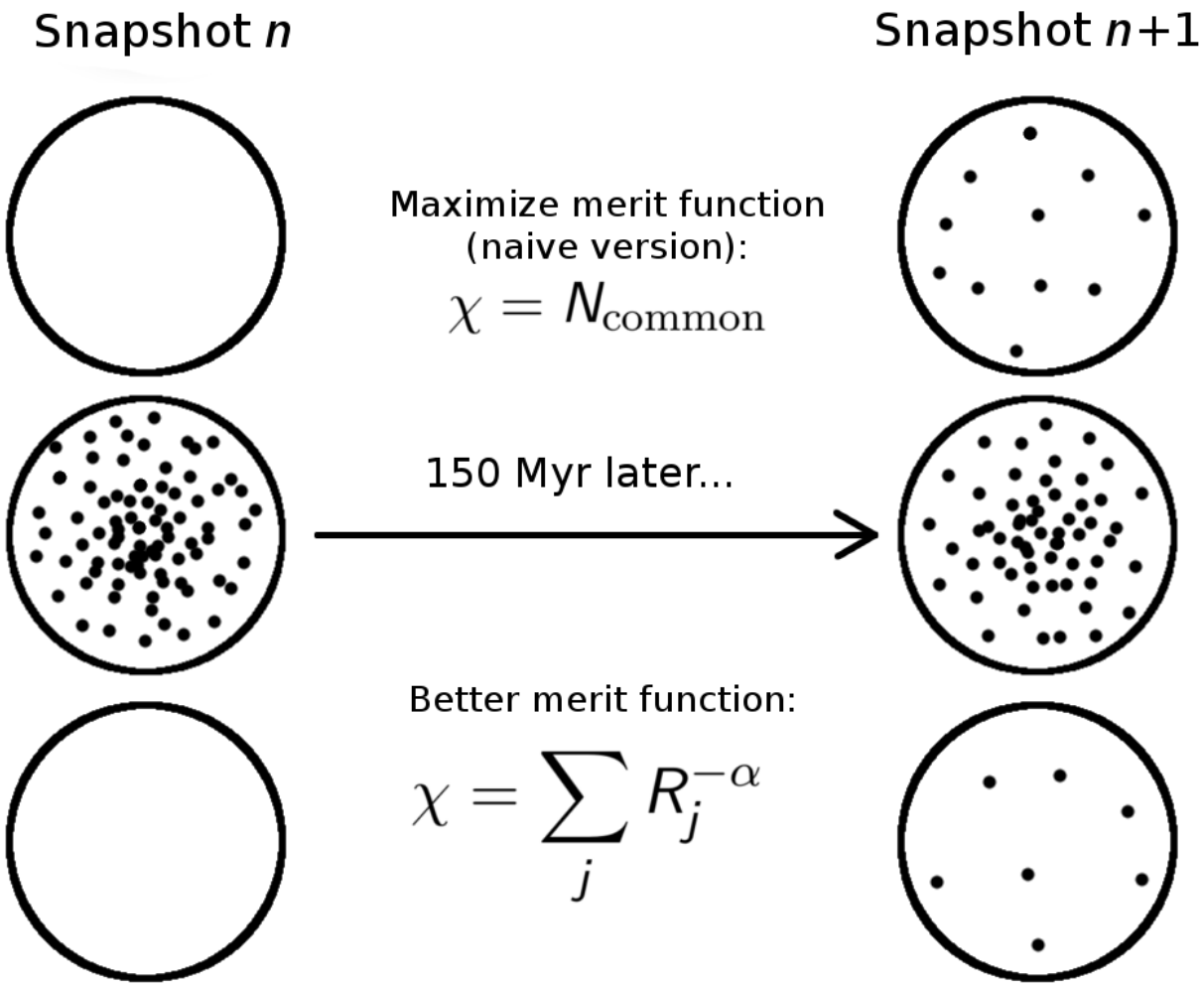
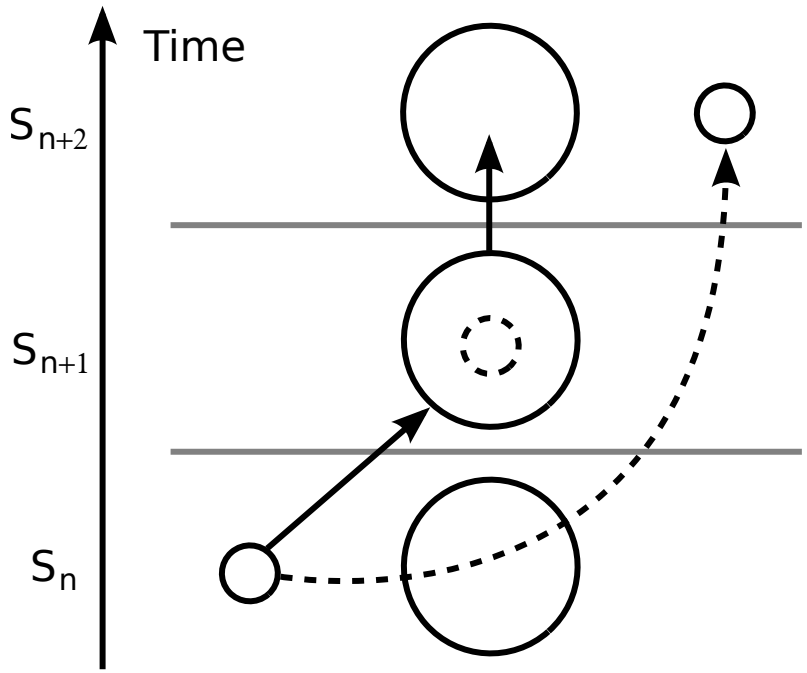


Finding the descendants



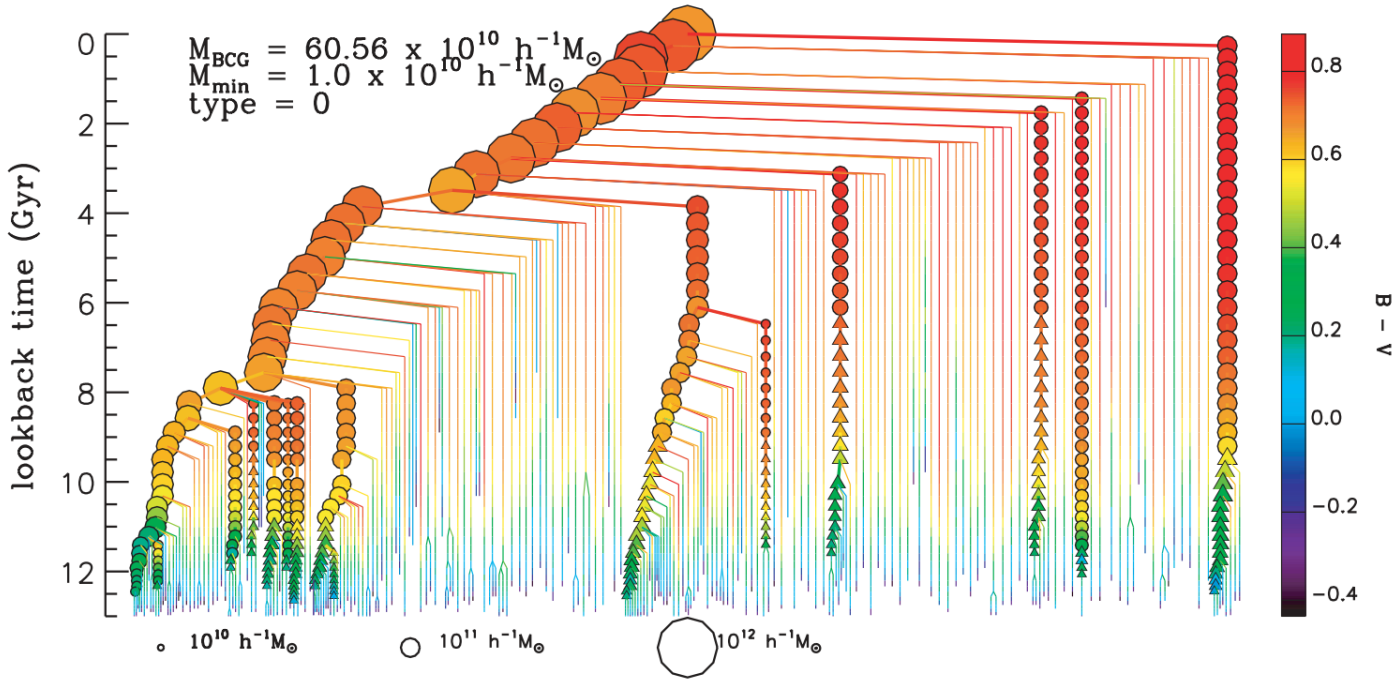
Finding the descendants

- Some small subhalos are allowed to "skip" a snapshot when finding a descendant.



Constructing merger trees

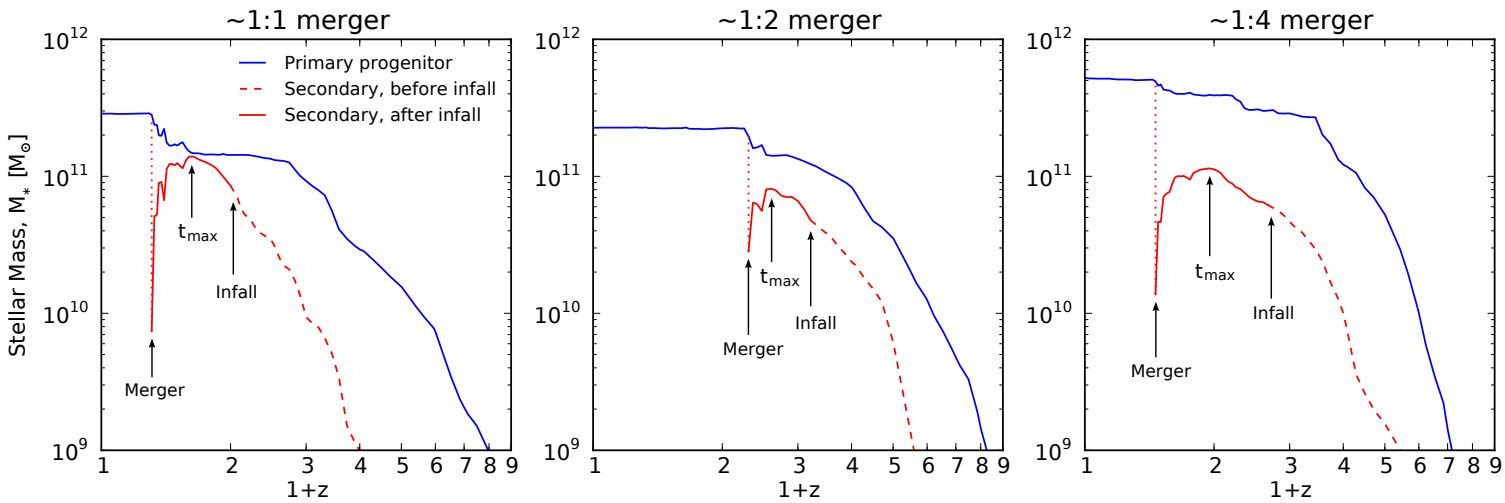
- A merger tree is a data structure that connects subhalos across different snapshots of the simulation.
- A merger takes place when two of the branches join.



(De Lucia & Blaizot 2007)

Identifying mergers

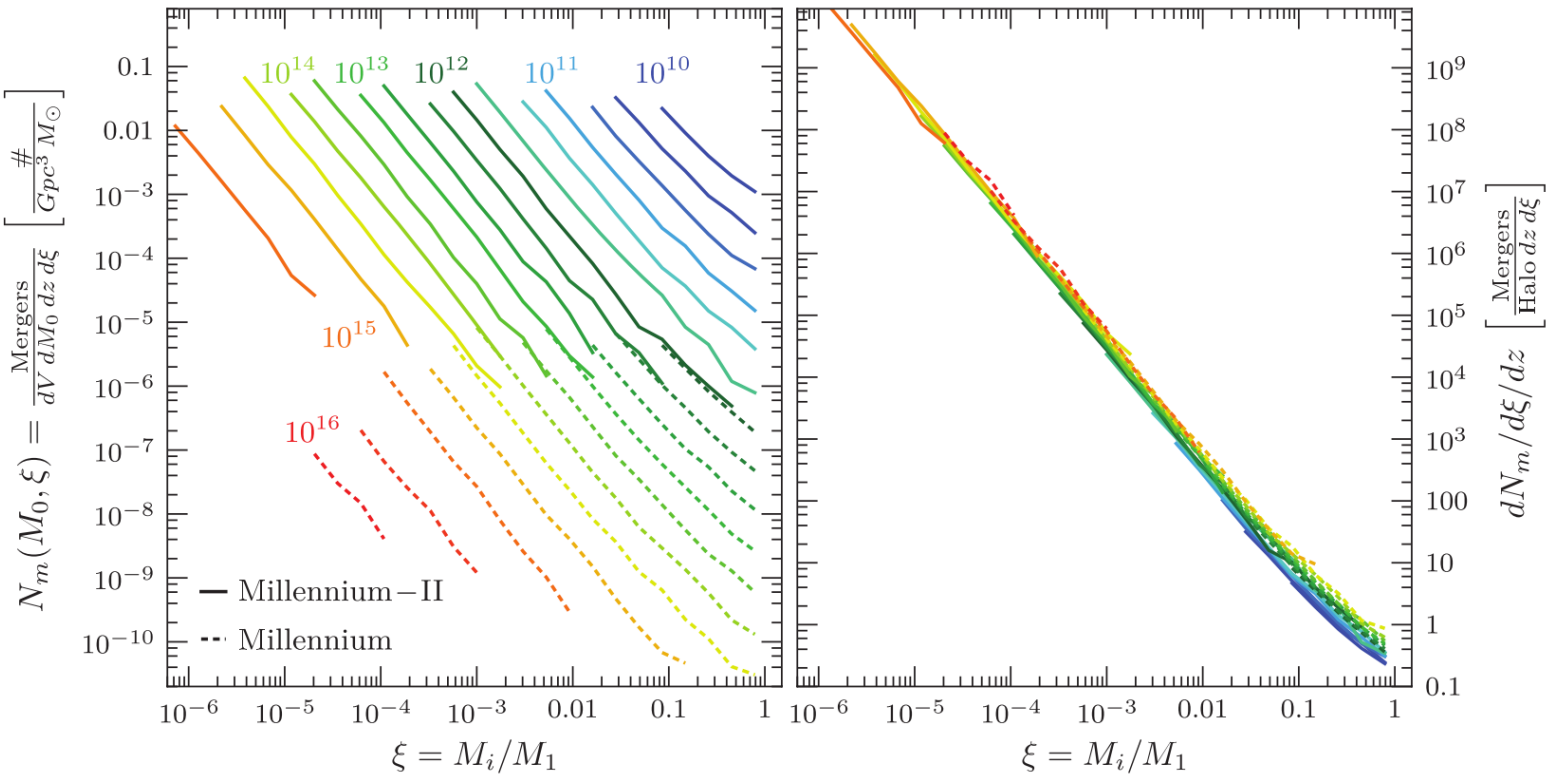
- The merger mass ratio $\mu = M_2/M_1$ is not trivially defined because the galaxy masses right before a merger become unreliable.
- A better choice is to measure the merger mass ratio at $t_{\max}$.



The 'Global' Galaxy Merger Rate

Background

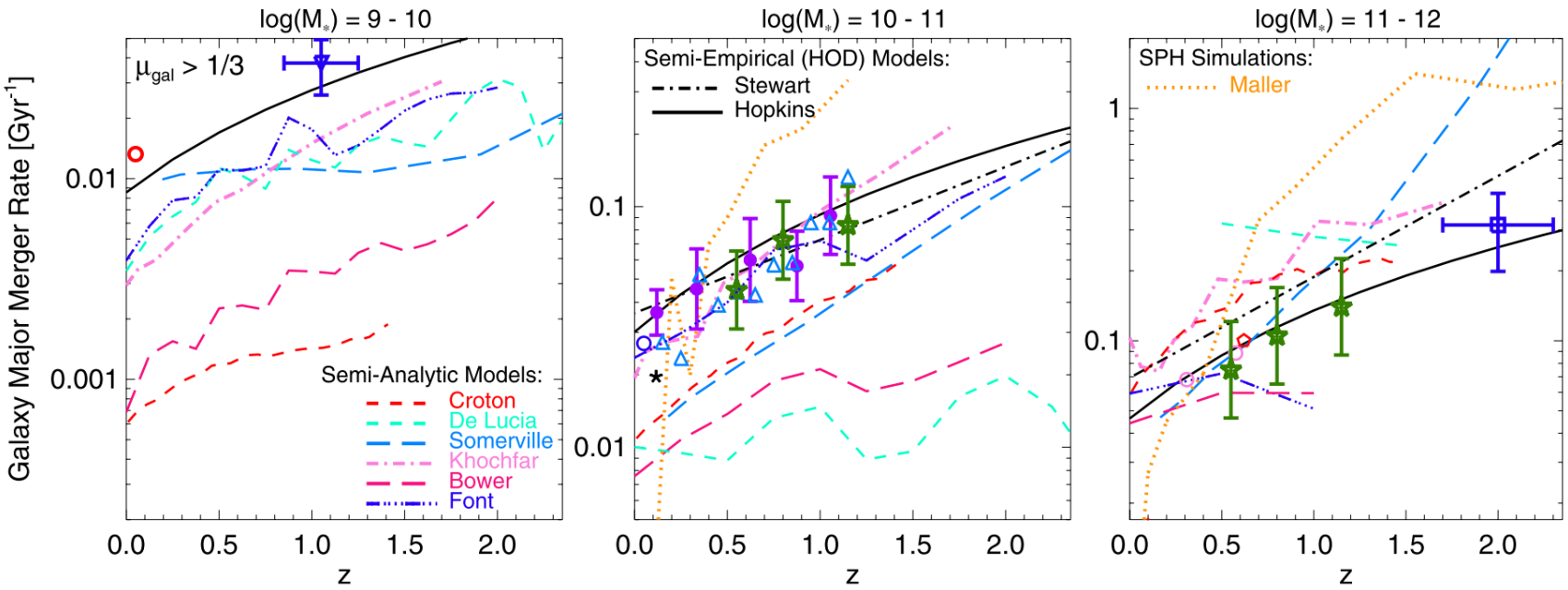
- The merger rate of dark matter *halos* (i.e., FoF groups) is theoretically well constrained.



(Fakhouri et al. 2010)

Background

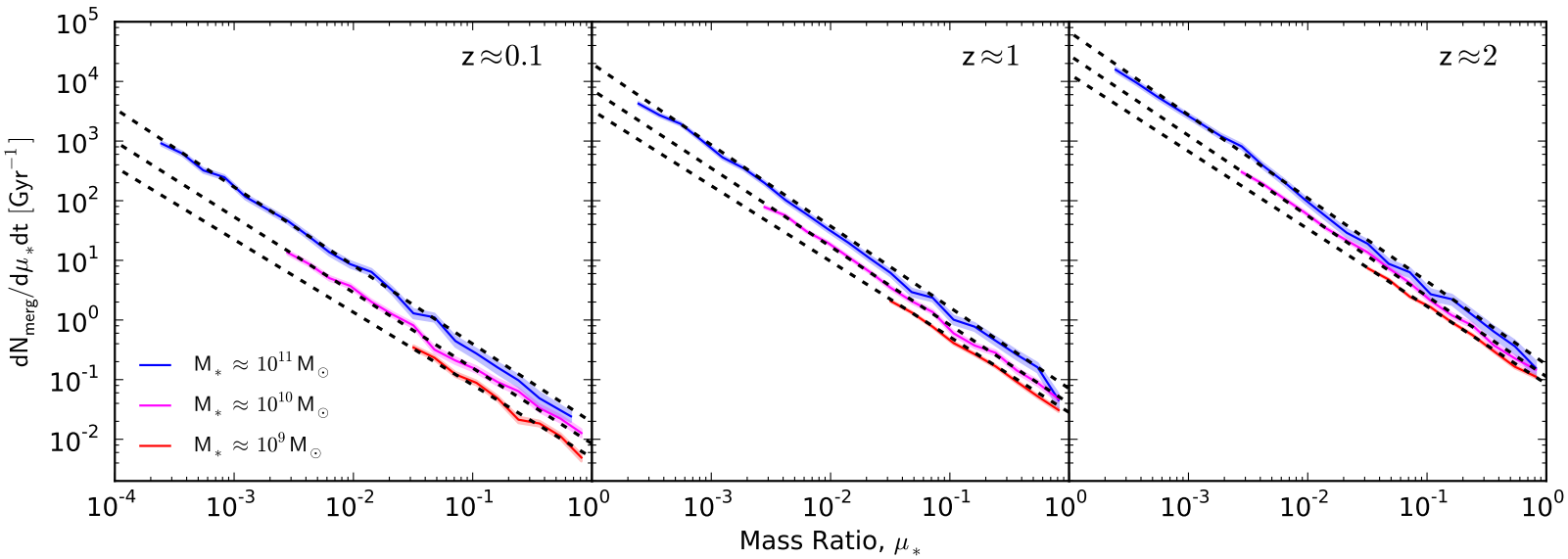
- However, the merger rate of *galaxies* is poorly constrained.
- Observations cannot measure it directly.
- Different theoretical estimates show a scatter of about an order of magnitude.



(Hopkins et al. 2010)

Results

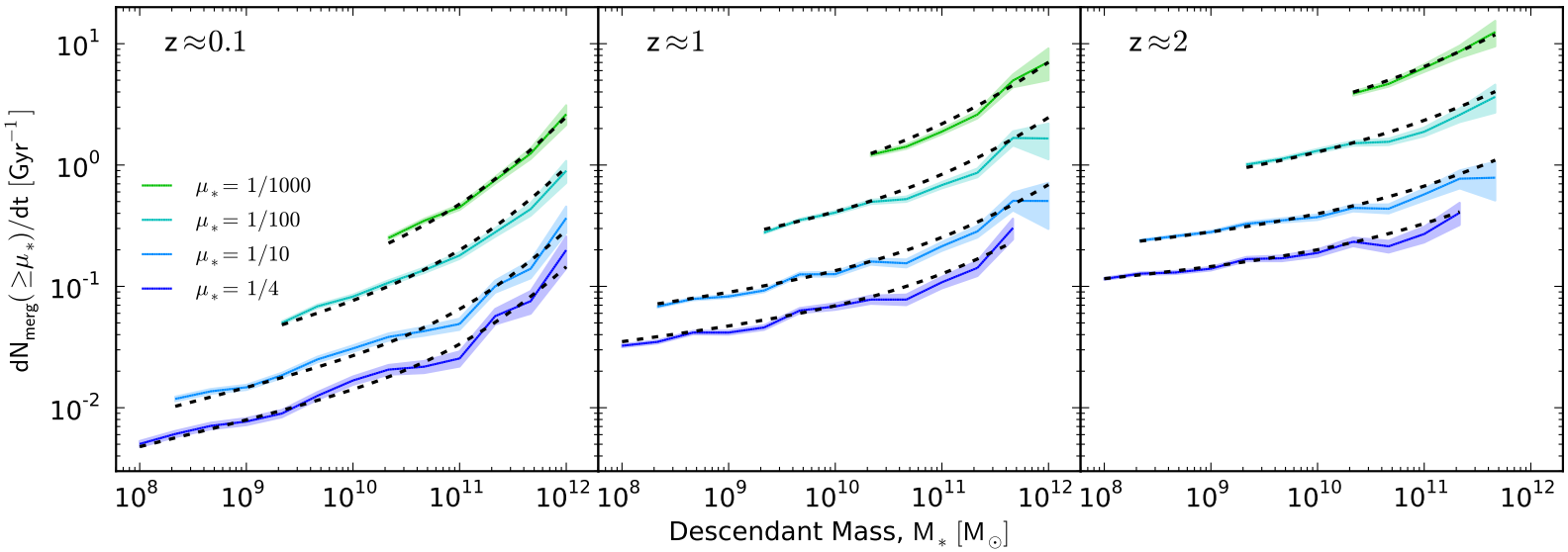
- Dependence on mass ratio is a power law (similar to the halo-halo merger rate):



(Rodriguez-Gomez et al. 2015)

Results

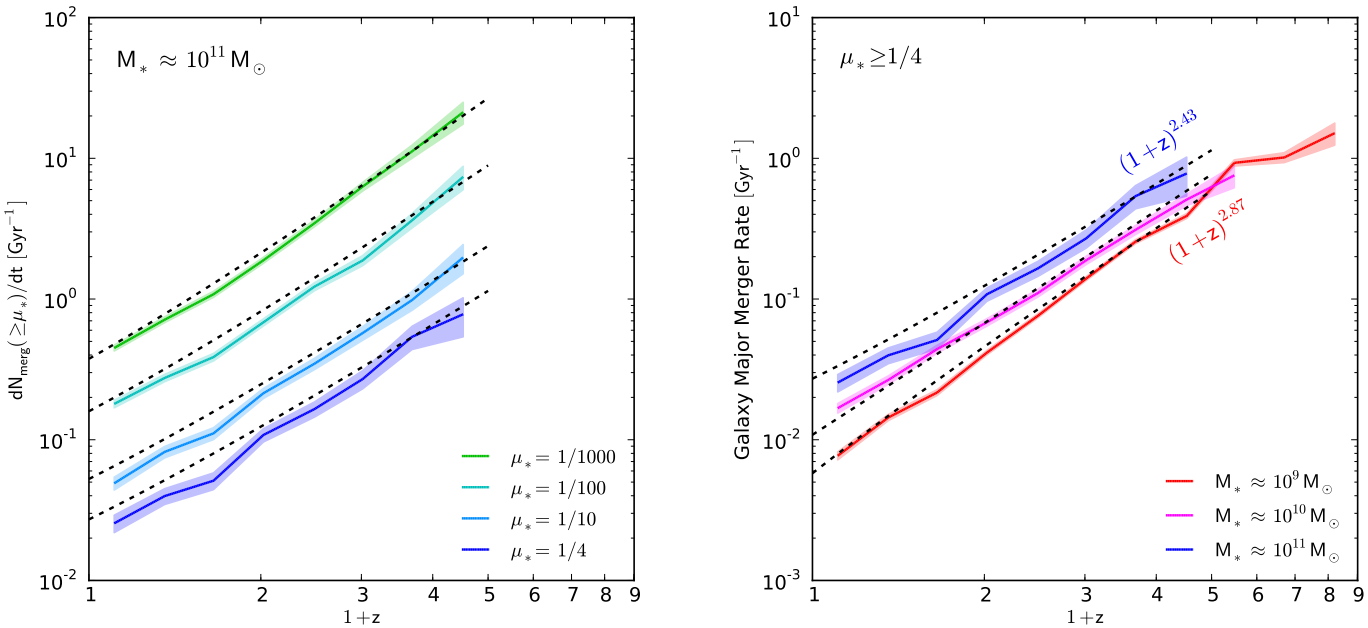
- Dependence on descendant mass is a double power law (more massive galaxies have higher merger rates):



(Rodriguez-Gomez et al. 2015)

Results

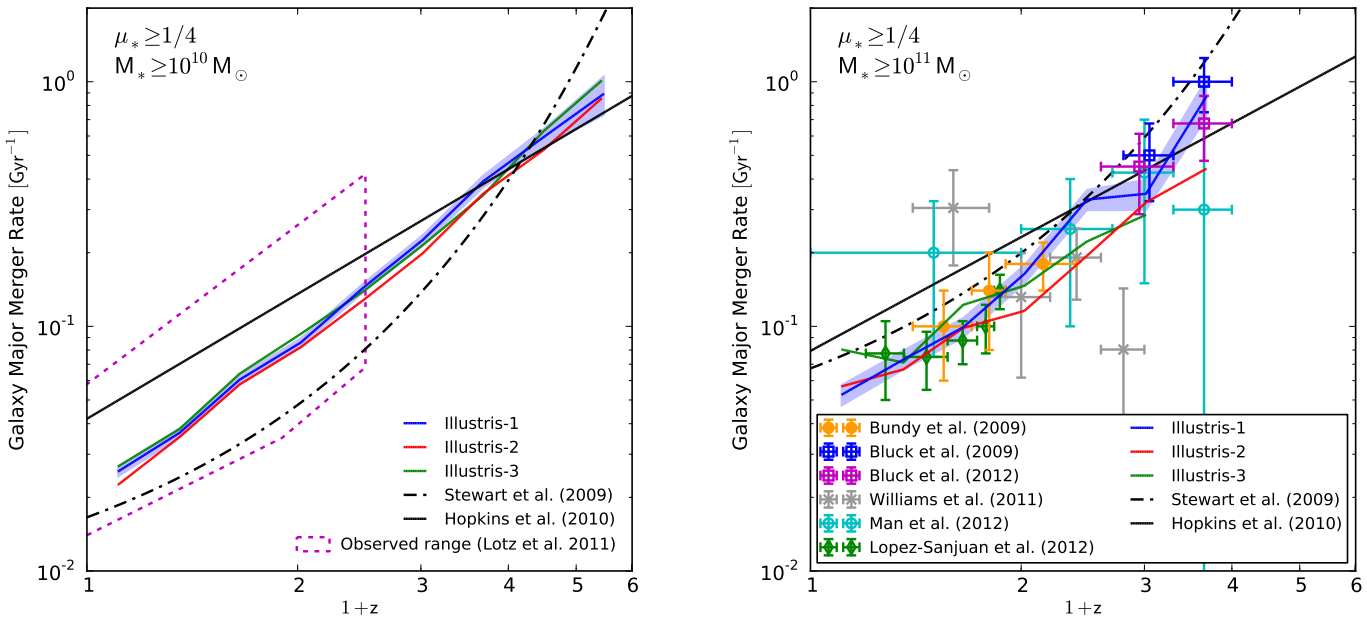
- Dependence on redshift is a power law (the merger rate was higher at earlier times):



(Rodriguez-Gomez et al. 2015)

Comparison to observations

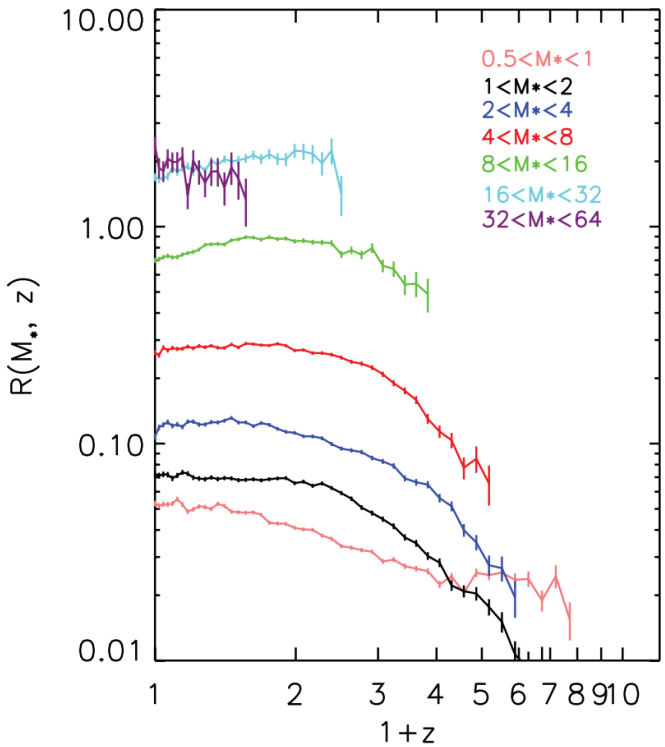
- Assuming a constant merger "observability" timescale (Lotz et al. 2011), the redshift evolution of the major merger rate is consistent with observations at $z \lesssim 1.5$:



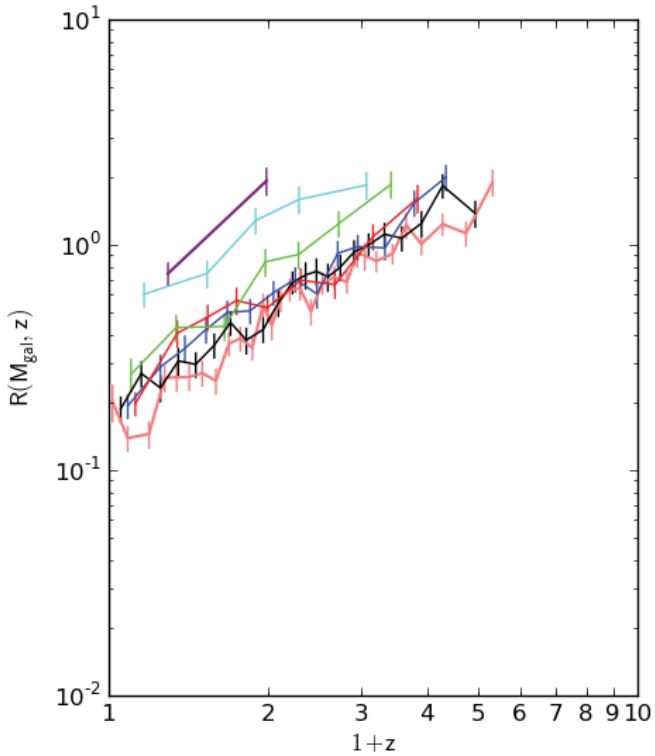
(Rodriguez-Gomez et al. 2015)

Comparison to previous theoretical models

However, our results are in stark contrast with some predictions based on semi-analytic models:



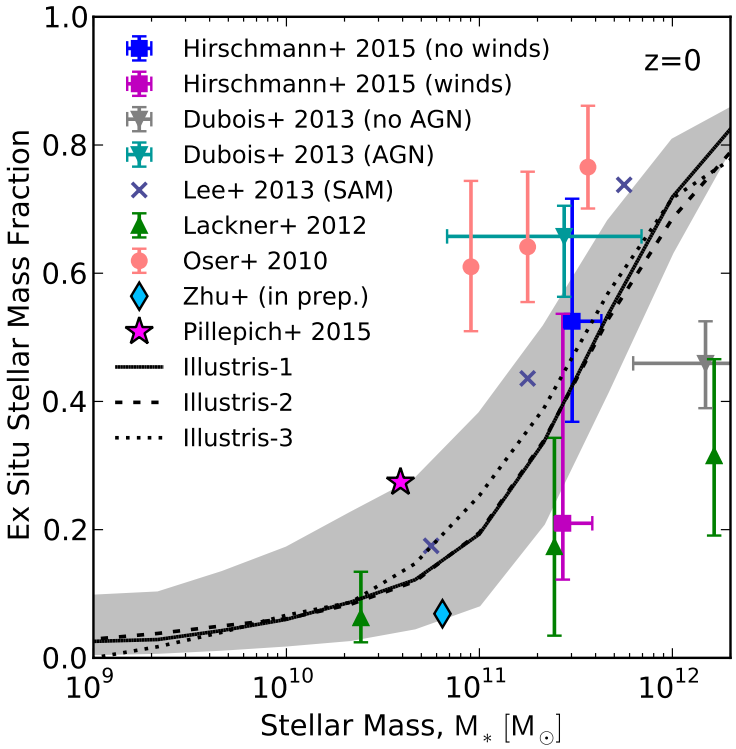
(Guo & White 2008)



(Rodriguez-Gomez et al. 2015)

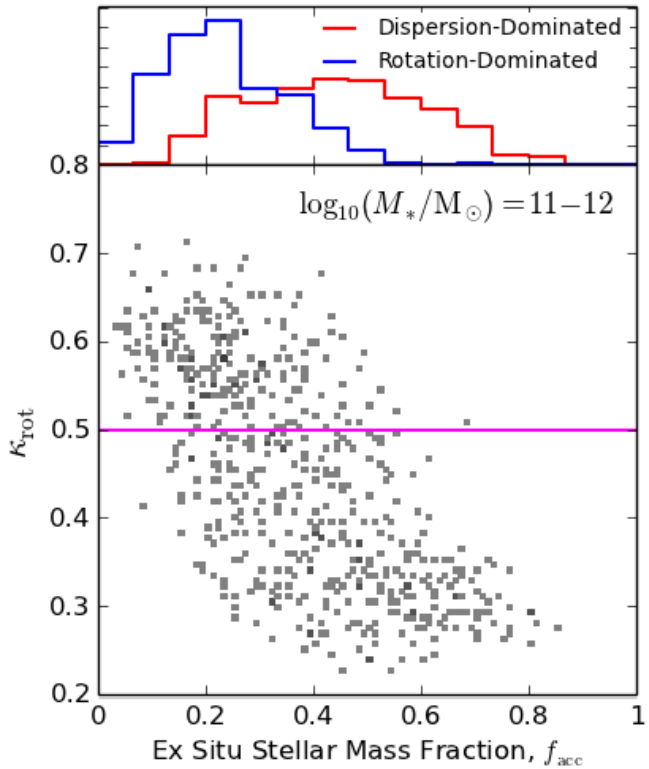
Some consequences of galaxy mergers

Stellar mass assembly:



(Rodriguez-Gomez et al. 2016)

Mergers and morphology:



(Rodriguez-Gomez et al. 2017)

Dependence on Environment

Motivation

- How common are satellite-satellite mergers?
- Are galaxy mergers more or less frequent in cluster environments?
- Are galaxy mergers more or less frequent in protocluster environments?
- How does the galaxy-galaxy merger rate depend on different measures of environment?
- Insights into the assembly of BCGs, the establishment of the morphology-density relation, etc.

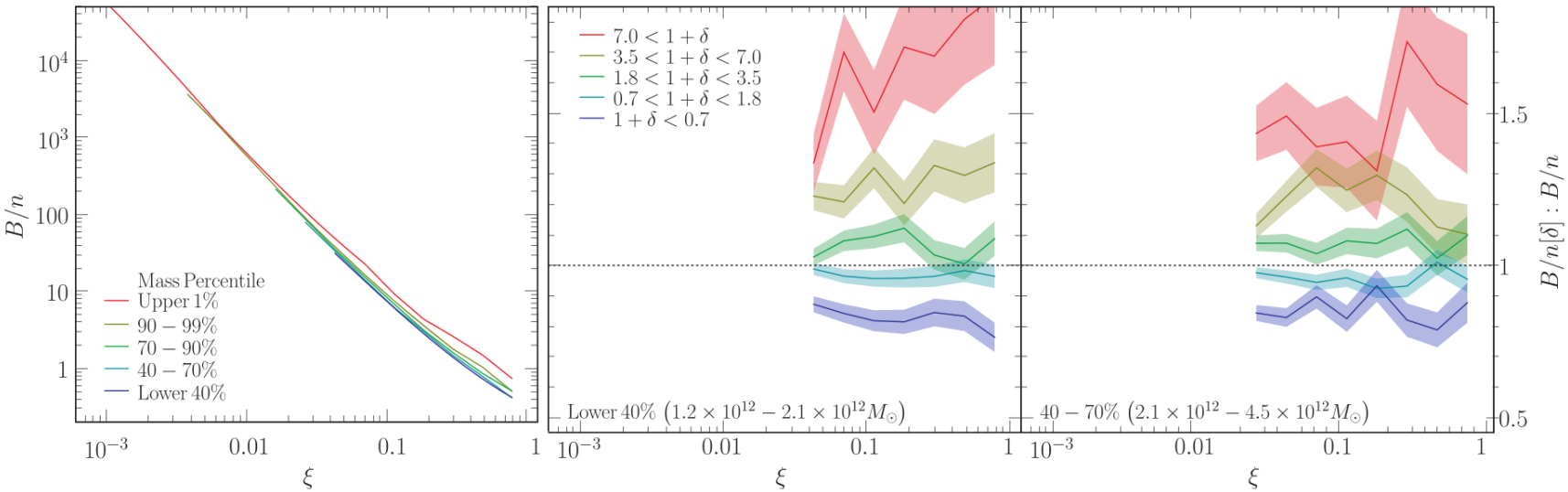
Measuring environment

Many ways to quantify environment:

- Large-scale overdensity (e.g., within a few Mpc)
- Local overdensity (e.g., within the distance to the Nth nearest bright galaxy)
- Host halo mass
- Halocentric distance
- Central/satellite/splashback galaxies

Previous work

- The merger rate of dark matter *halos* (i.e., FoF groups) is higher in denser environments.



(Fakhouri & Ma 2009)

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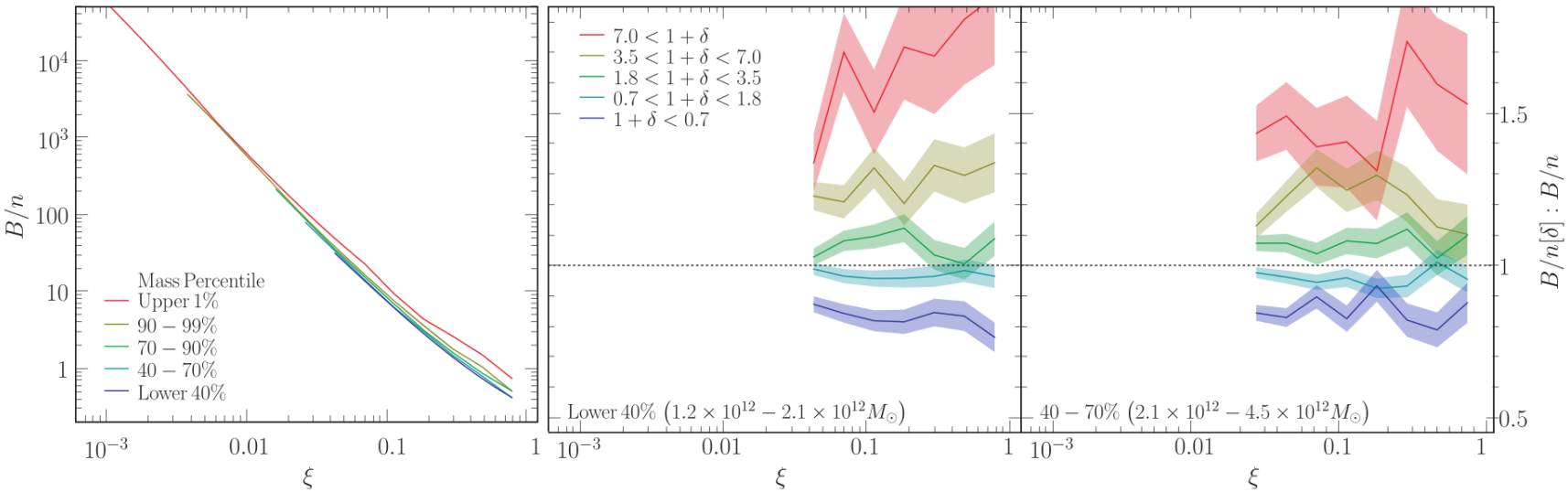


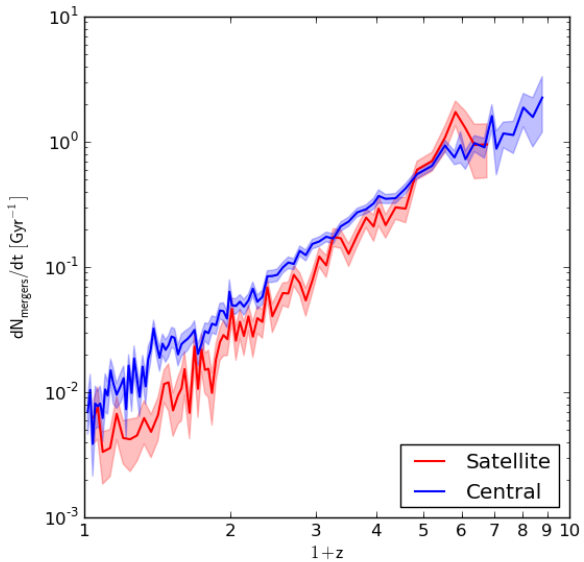
(Fakhouri & Ma 2009)

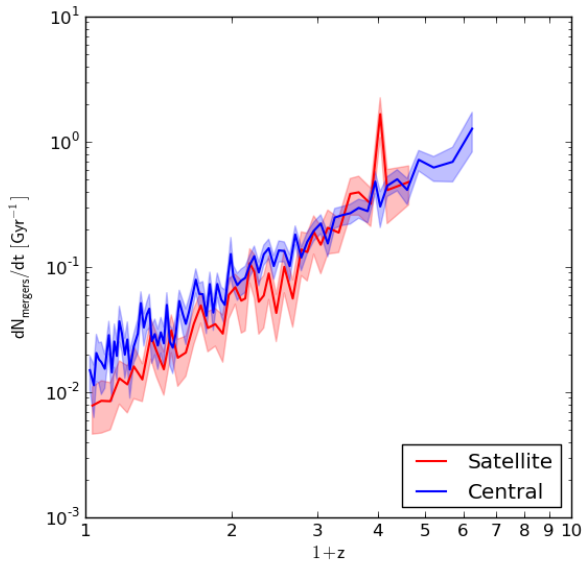
- But what about galaxies?

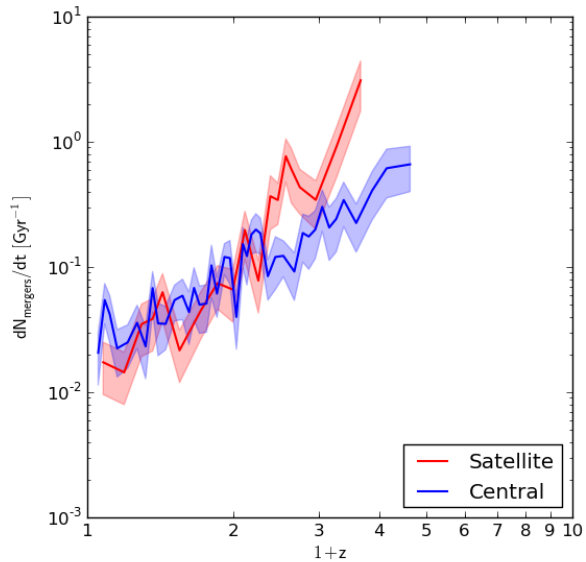
Results (preliminary)

The major merger rate of *satellite* galaxies (i.e., mergers in which the descendant is a satellite) is comparable to that of *central* galaxies (i.e., mergers in which the descendant is a central) across all redshifts and descendant stellar masses:

$M_* \approx 10^9\,\mathrm{M}_\odot$ $M_* \approx 10^{10}\,\mathrm{M}_\odot$ $M_* \approx 10^{11}\,\mathrm{M}_\odot$



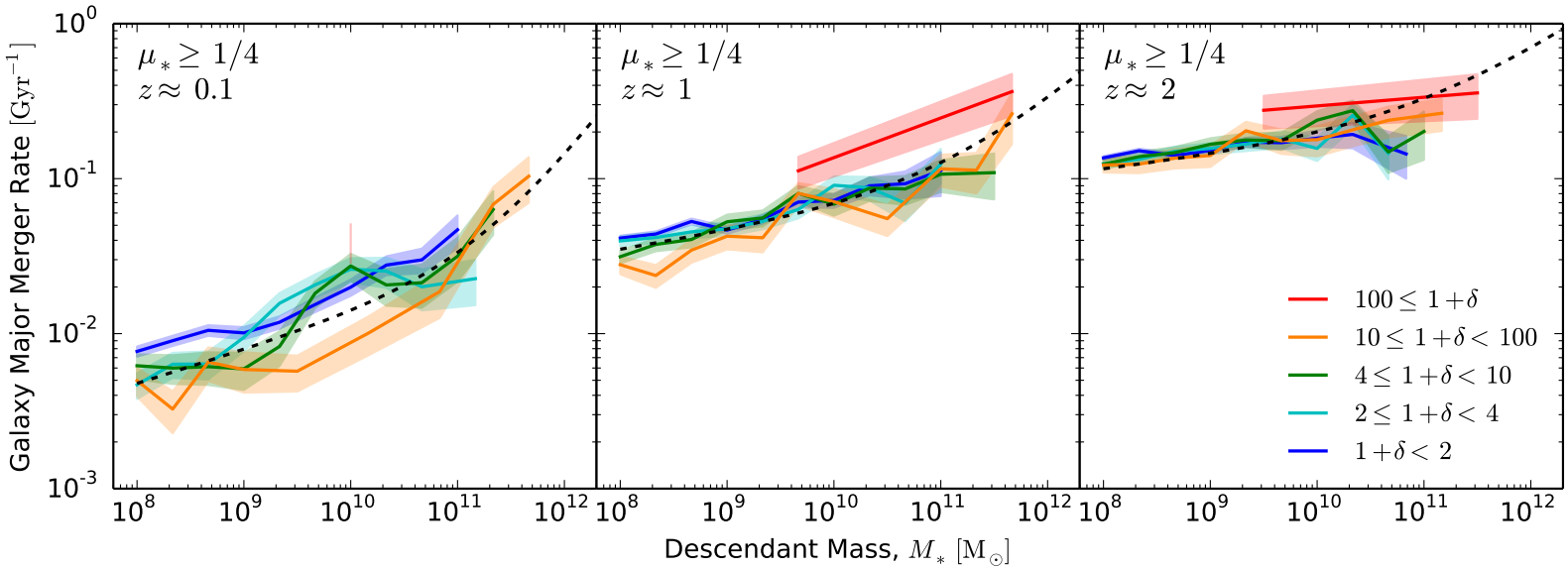




Results (preliminary)

However, the major merger rates of satellites and centrals display qualitatively different trends with environment (here quantified by the local overdensity δ).

Central Descendants:



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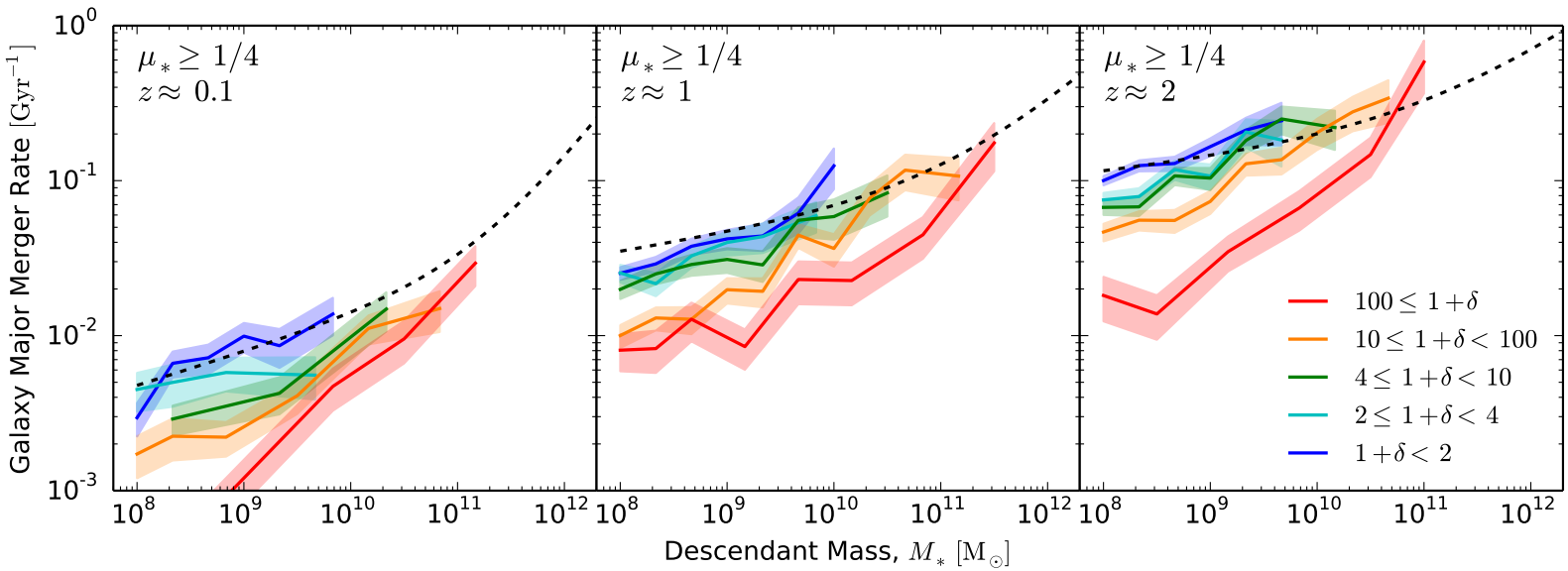
Satellite Descendants:



Results (preliminary)

Such trends become even more different when quantifying 'environment' with the mass of the host halo.

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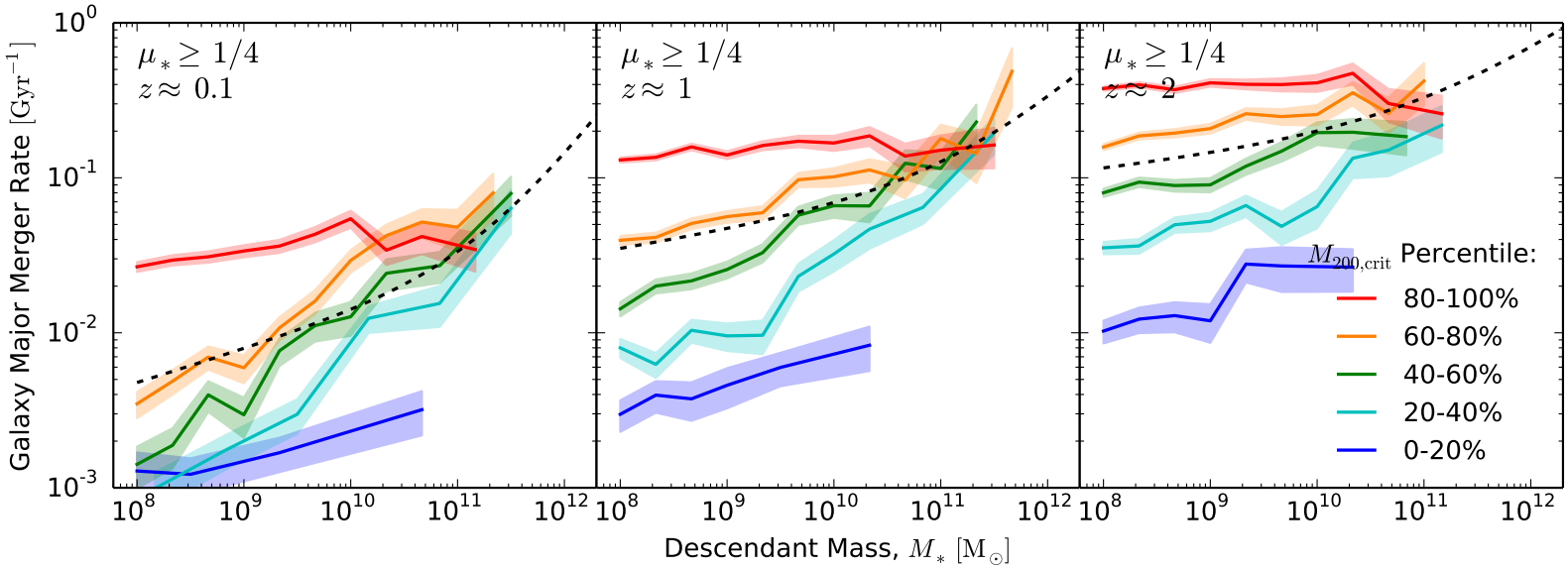

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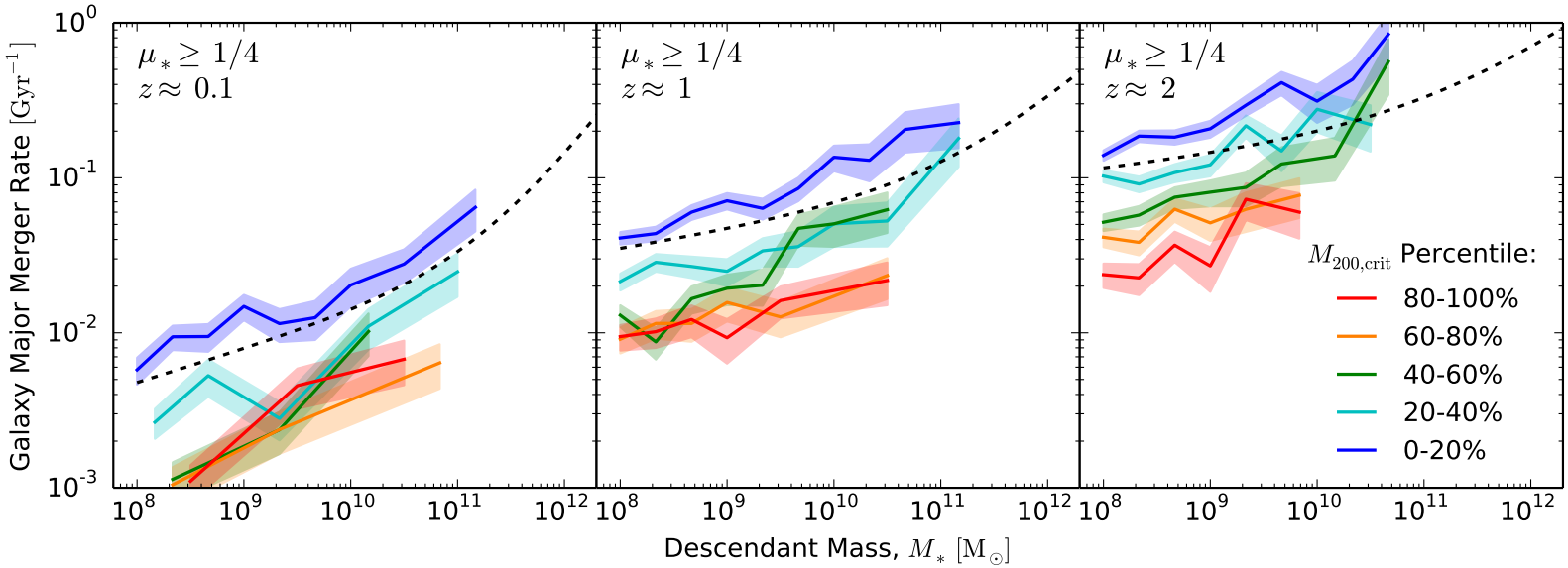
Satellite Descendants:



Conclusions

Conclusions

- We have developed a theoretical framework for constructing and analyzing merger trees, which we applied to the Illustris simulation.
- We have provided a determination of the 'global' galaxy-galaxy merger rate (Rodriguez-Gomez et al. 2015), finding that it has a simple mathematical form.
- The merger rates of centrals and satellites are comparable in magnitude across all stellar masses and redshifts.
- Mergers between *satellite* galaxies are less likely to happen in denser environments / more massive host halos.
- On the contrary, *central* galaxies tend to have more mergers when located in more massive host halos.
- Further measures of environment will be explored.