Mergers, AGN, and the Evolution of Galaxies

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IPMU
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Bimodal Galaxy Distribution

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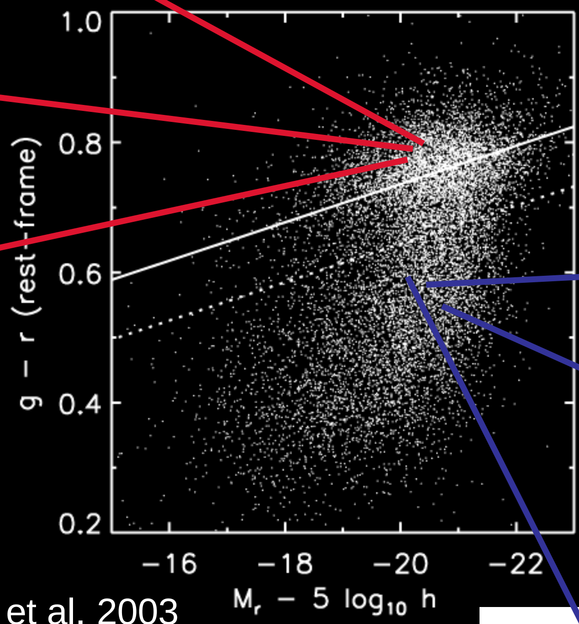

Bell et al. 2003

Star forming
Blue
Late type
Young

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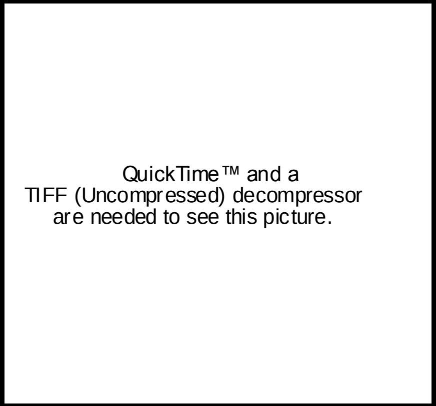
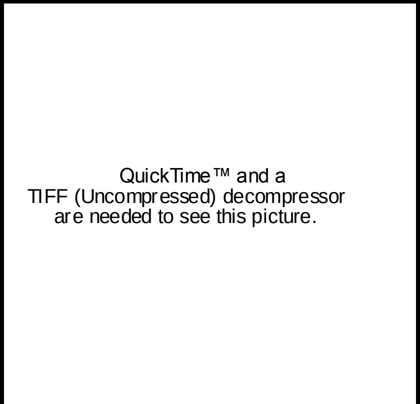
Passive
Red
Early type
Old

- Hubble Sequence - morphology shows dynamically distinct populations
- Gas content/integrated colors - different ages and star formation histories

Downsizing of Star Formation

The sites of star formation appear to shift from including high-mass galaxies at early epochs (z~1-2) to only lower-mass galaxies at later epochs.





Top-Down Formation of Ellipticals

The most massive galaxies transform into ellipticals first, with less massive galaxies following later.

Downsizing of Star Formation

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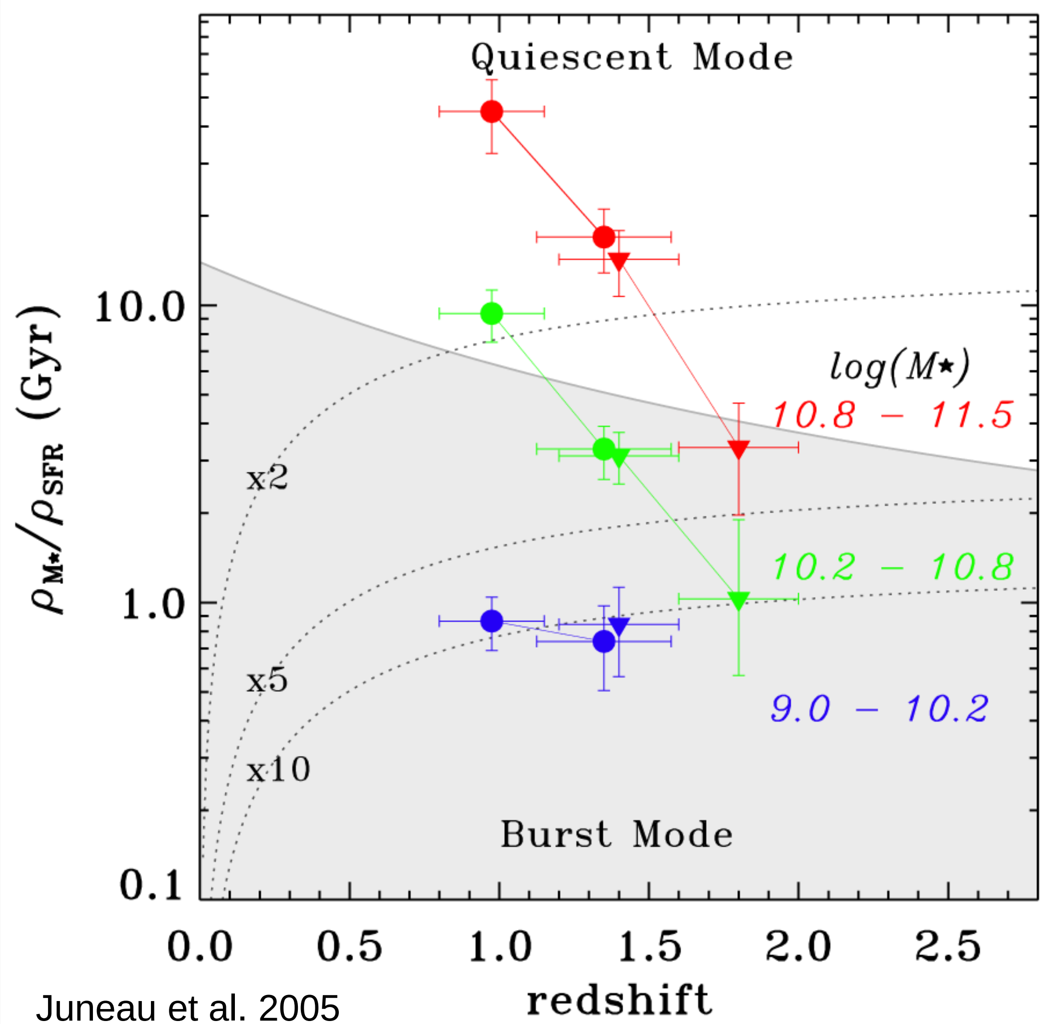

Juneau et al. 2005

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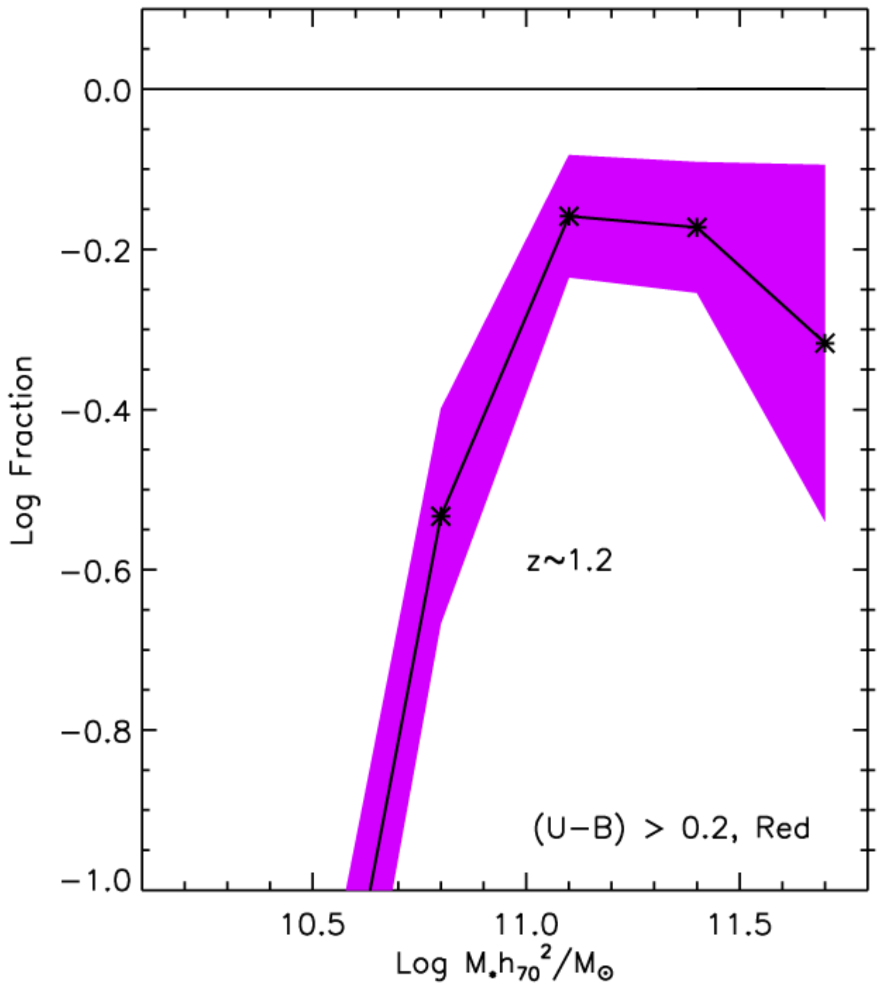
following later

Downsizing: Red Growth

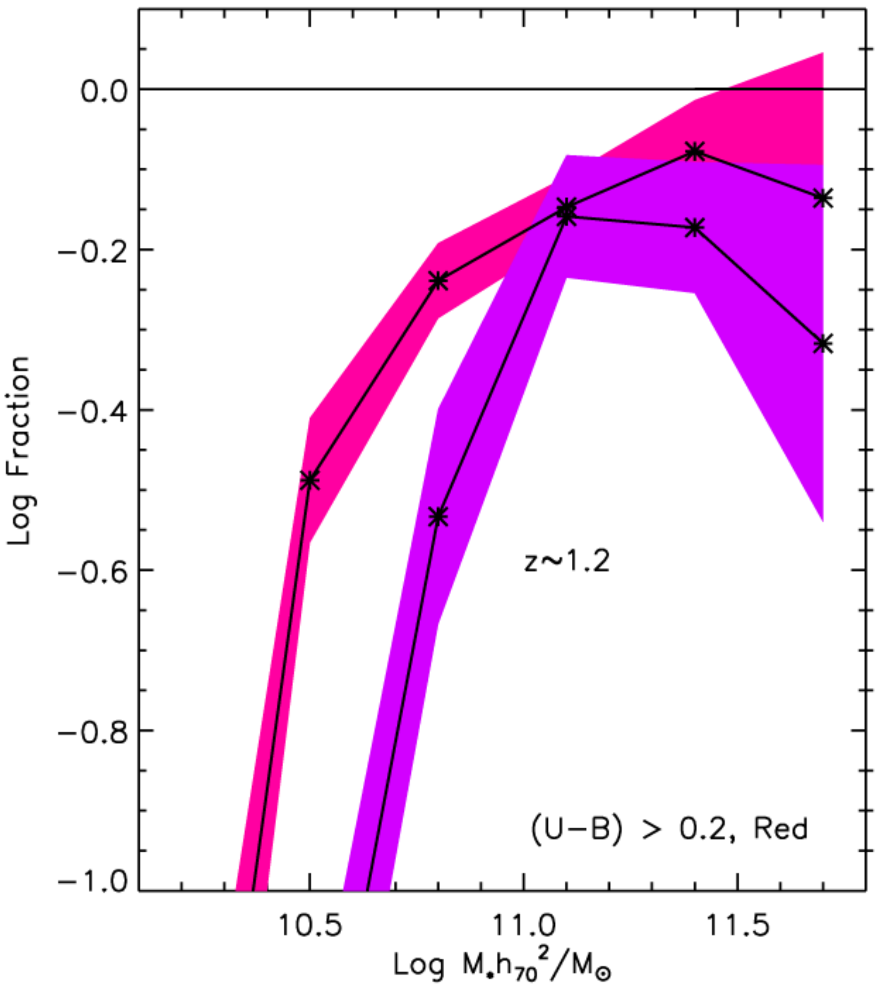


Mass ⟶

Increasing abundance

Bundy et al. 2006

Downsizing: Red Growth



Mass ⟶

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Bundy et al. 2006

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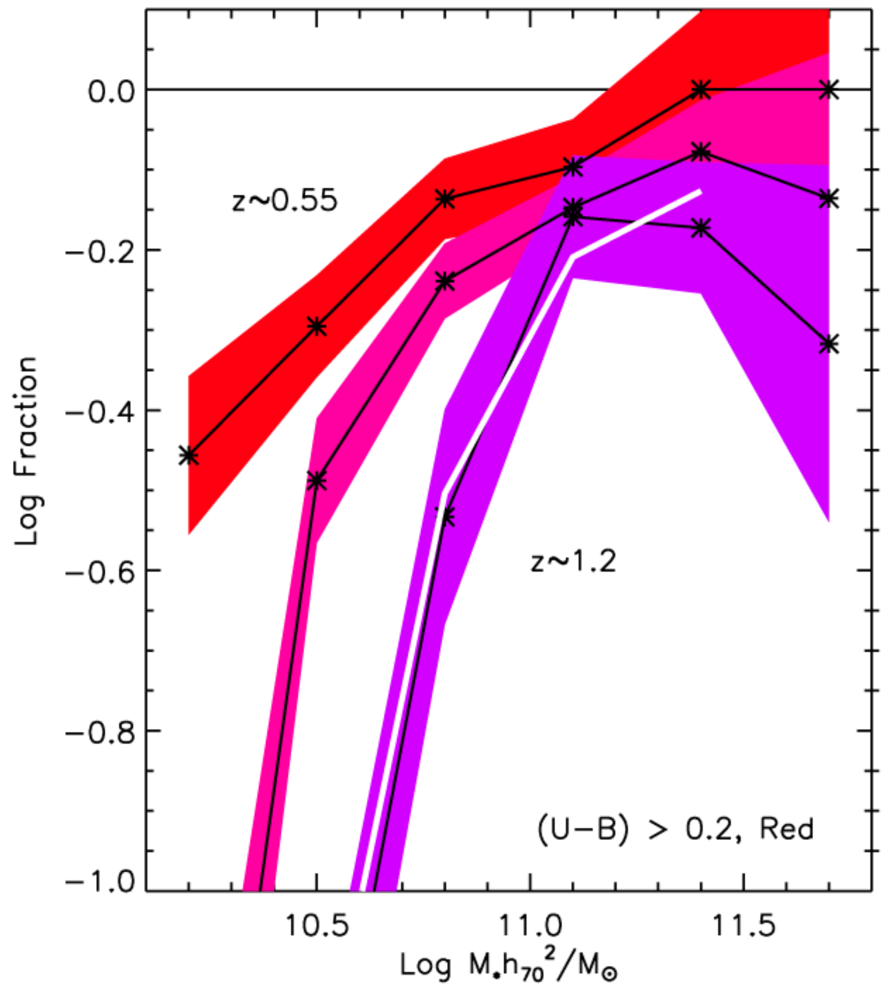


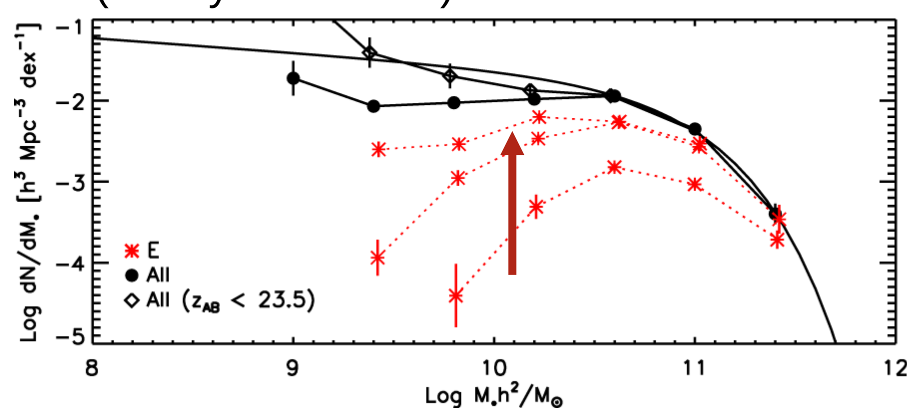
Mass ⟶

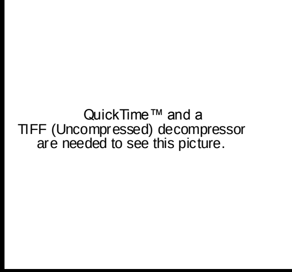
Bundy et al. 2006

Increasing abundance

Morphological spheroidals have a similar formation pattern.

(Bundy et al. 2005)





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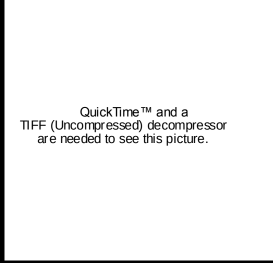
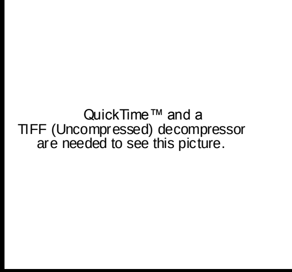


	Trigger	Mechanism	Maintenance
Star formation Quenching (gas)	Major Merger →	Quasar →	 Radio Mode AGN Feedback
Spheroidal Formation (morphology)	Major Merger →	N-body Simulation →	Prevent cold disk formation

Merger Simulations

Springel, Hernquist, Hopkins



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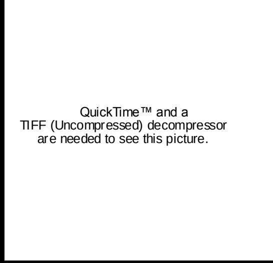


	Trigger	Mechanism	Maintenance

Threshold Halo Mass, ~10^{12} $M_{\odot}$

Star formation Quenching (gas)

Major Merger → Quasar → Radio Mode AGN Feedback

Quenching even at low densities

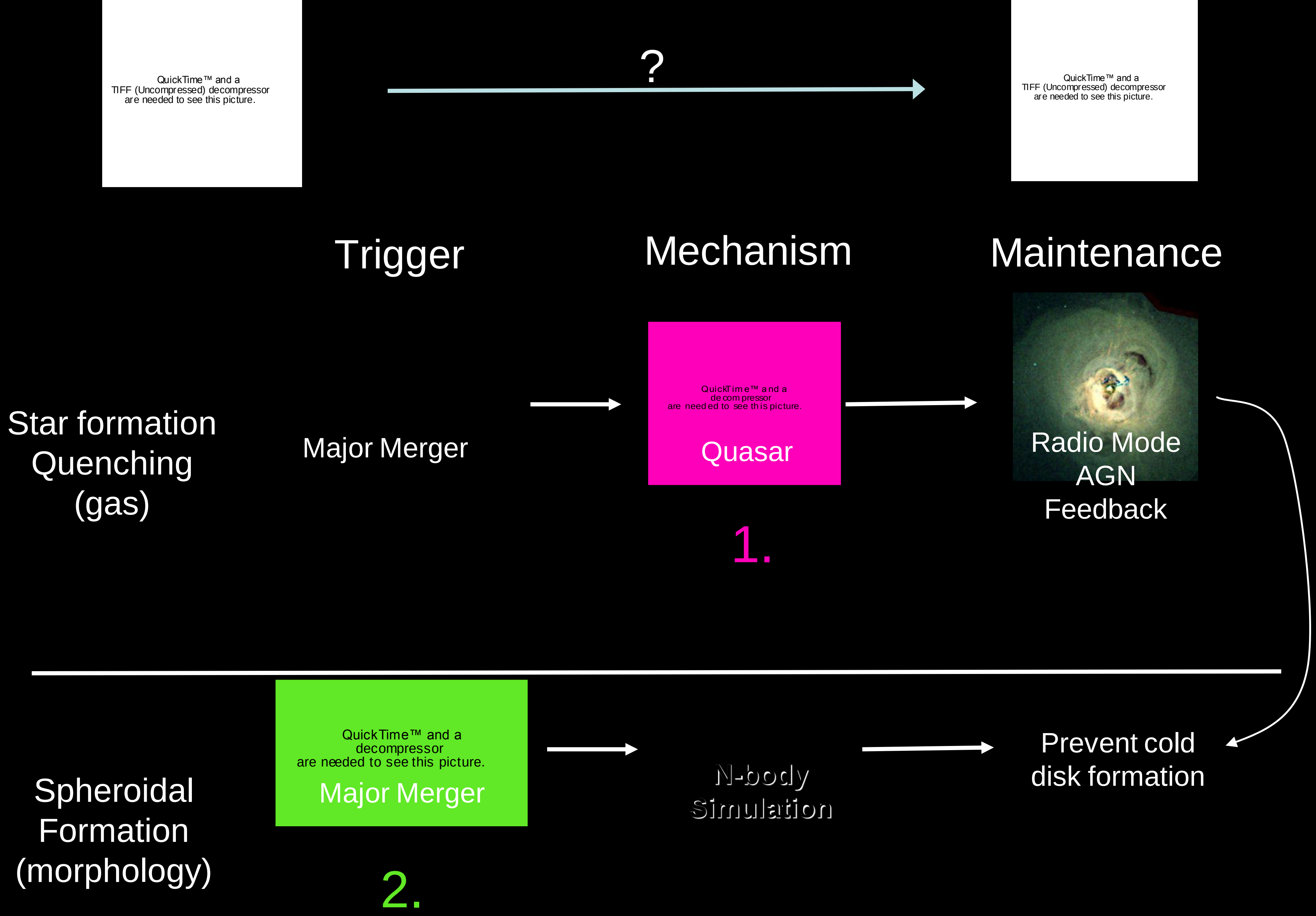
Environment - ram pressure, strangulation?

Spheroidal Formation (morphology)

Major Merger → N-body Simulation → Prevent cold disk formation

How to build S0 bulges?

Environment - S0 formation?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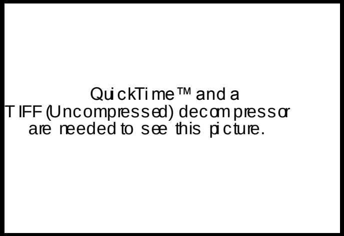
Quasar
Radio Mode AGN Feedback
1.
Spheroidal Formation (morphology)
QuickTime™ and a decompressor are needed to see this picture.
Major Merger
N-body Simulation
Prevent cold disk formation
2.

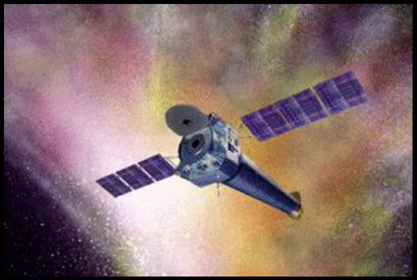
Quenching and AGN (Quasar) Feedback

Does the frequency of AGN activity match the rate of quenching?

AGN Frequency vs. Quenching Rate

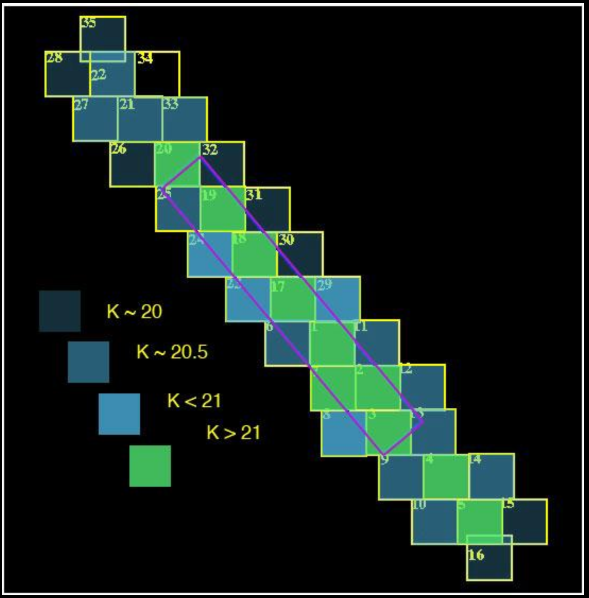
Bundy et al. 2008, ApJ, 681, 931



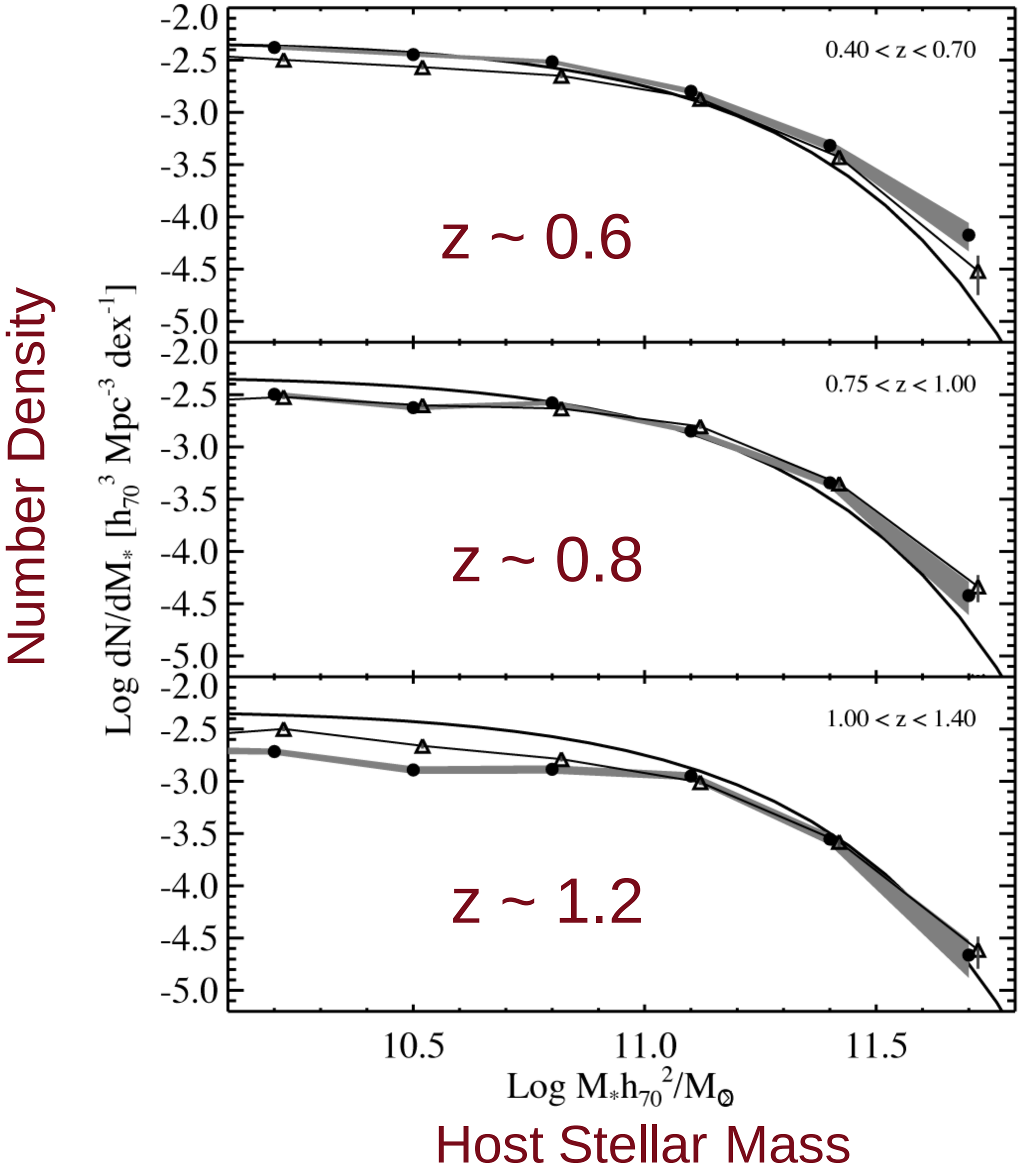


AEGIS: DEEP2 + Palomar + Chandra

- Chandra: 200 ks in EGS, 0.5-10 keV
- 241 X-ray selected AGN hosts, $L_{Xray} > 10^{42}$ erg/s
- ~50% more could be X-ray absorbed.
- Stellar masses and colors mostly unaffected by AGN



AGN Host Mass Function



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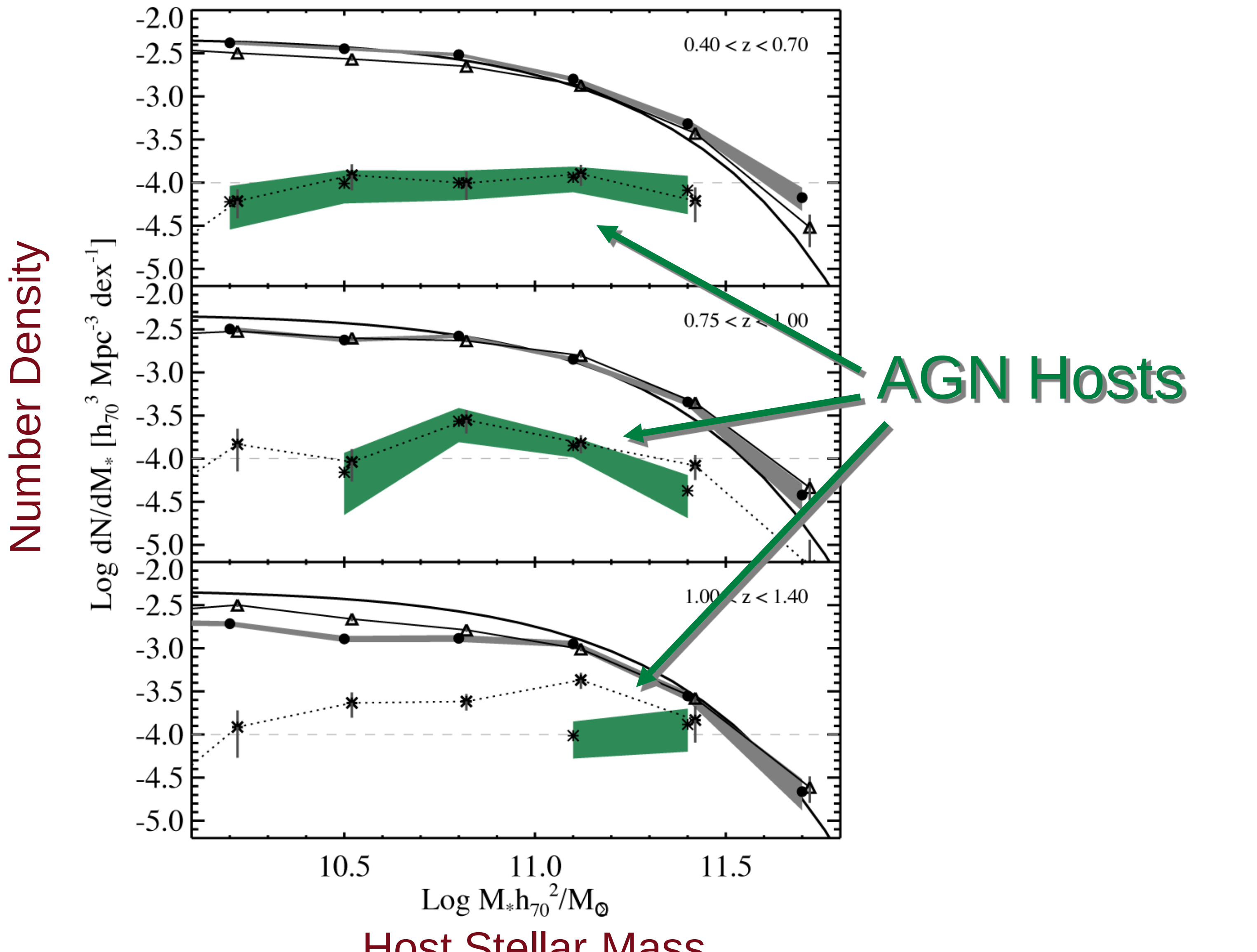

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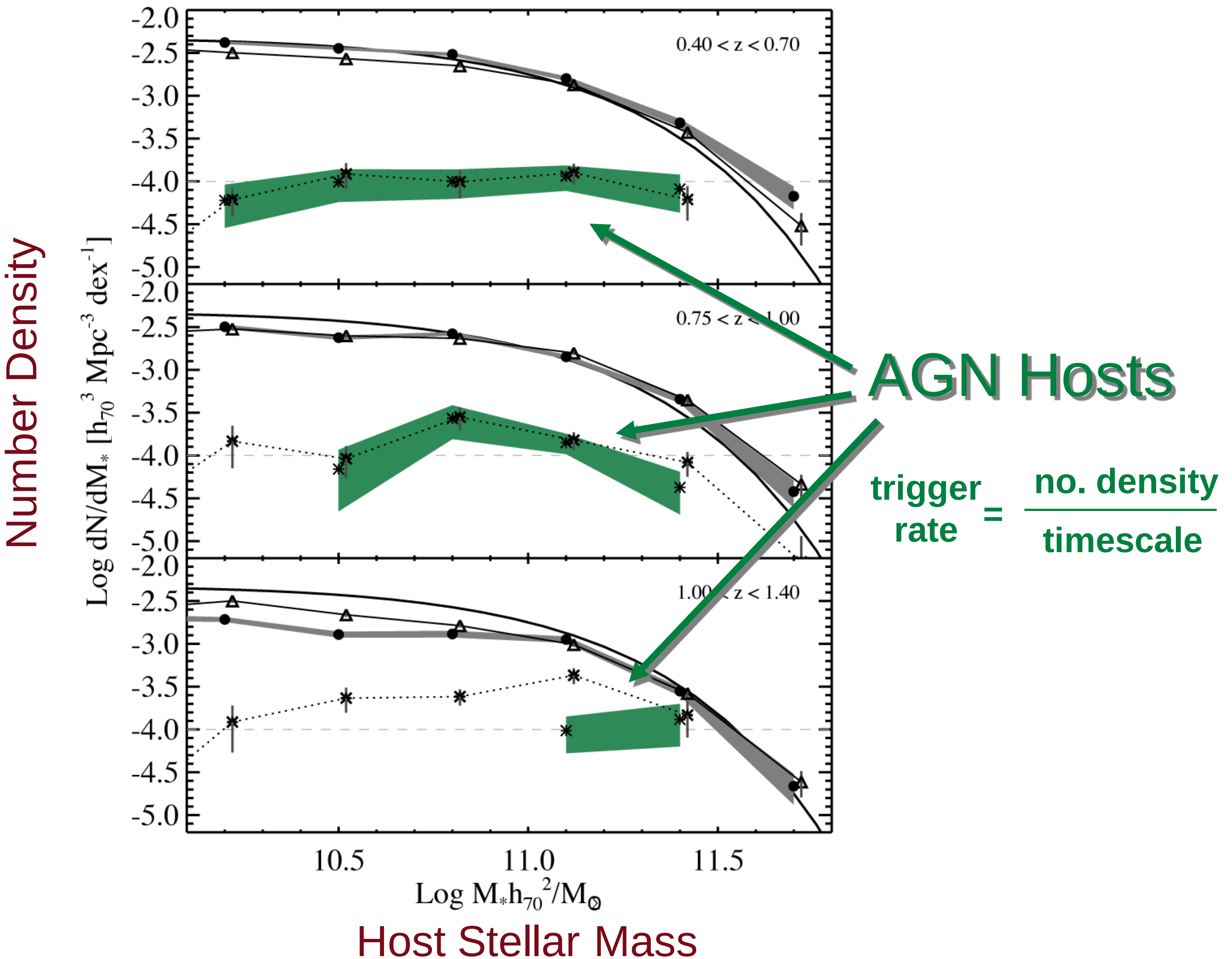
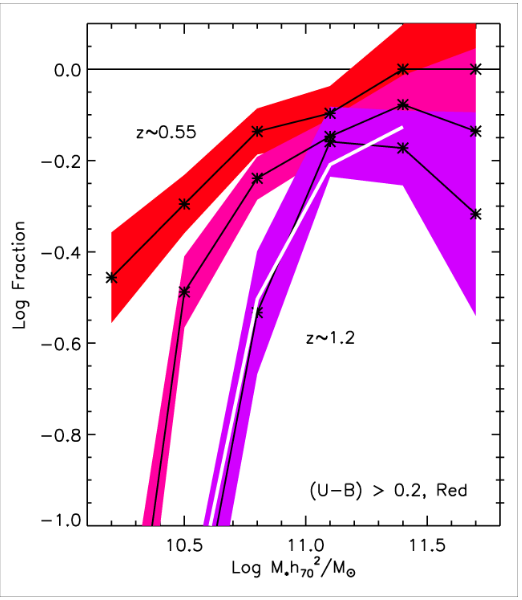


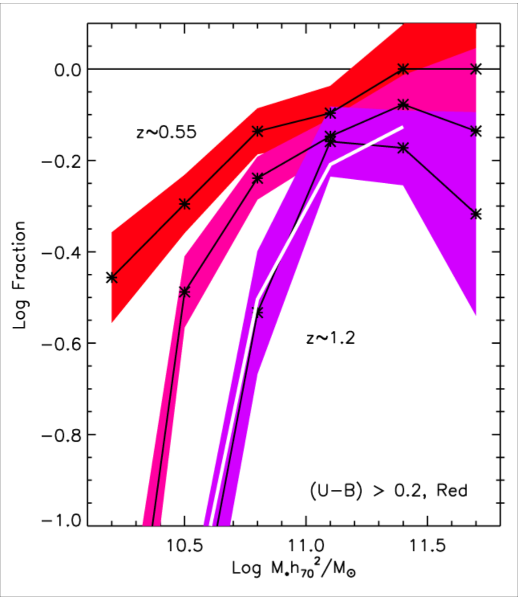
Bundy et al. 2008

Quenching Rate

Quenching Rate



Red Fraction



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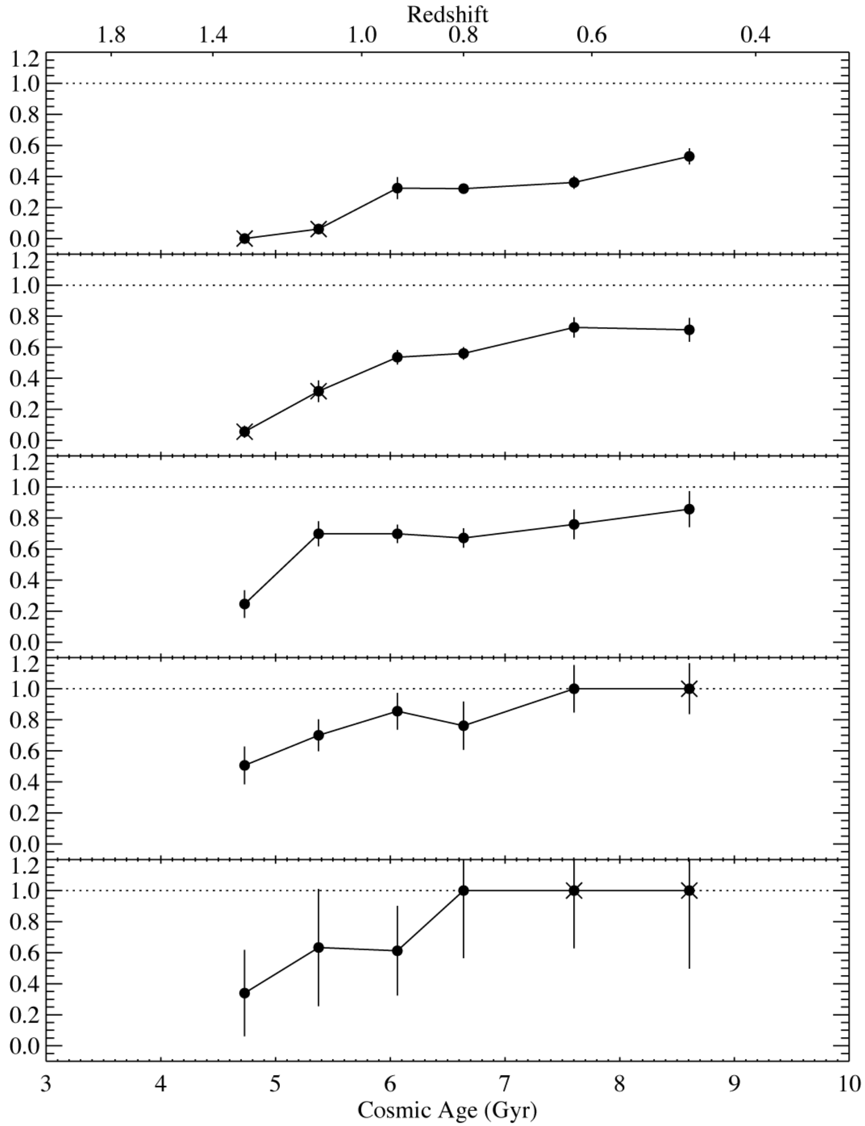
Quenching Rate



Lowest M*

Log M* ~ 10.5

Log M* ~ 10.8

Log M* ~ 11.1

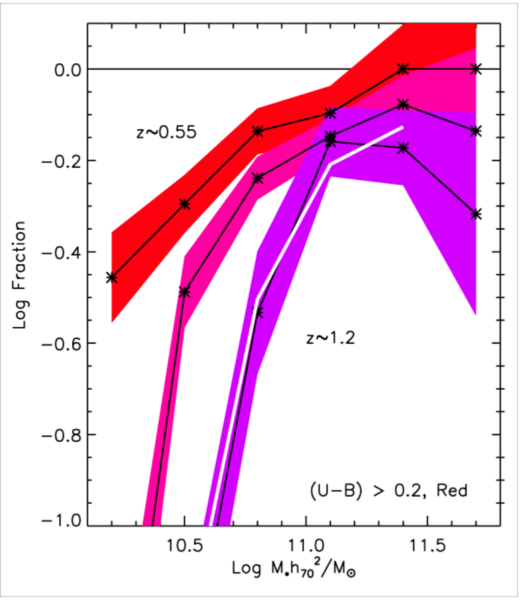
Log M* ~ 11.4

Log M* ~ 11.7

Highest M*

Cosmic Age (Gyr)

Quenching Rate



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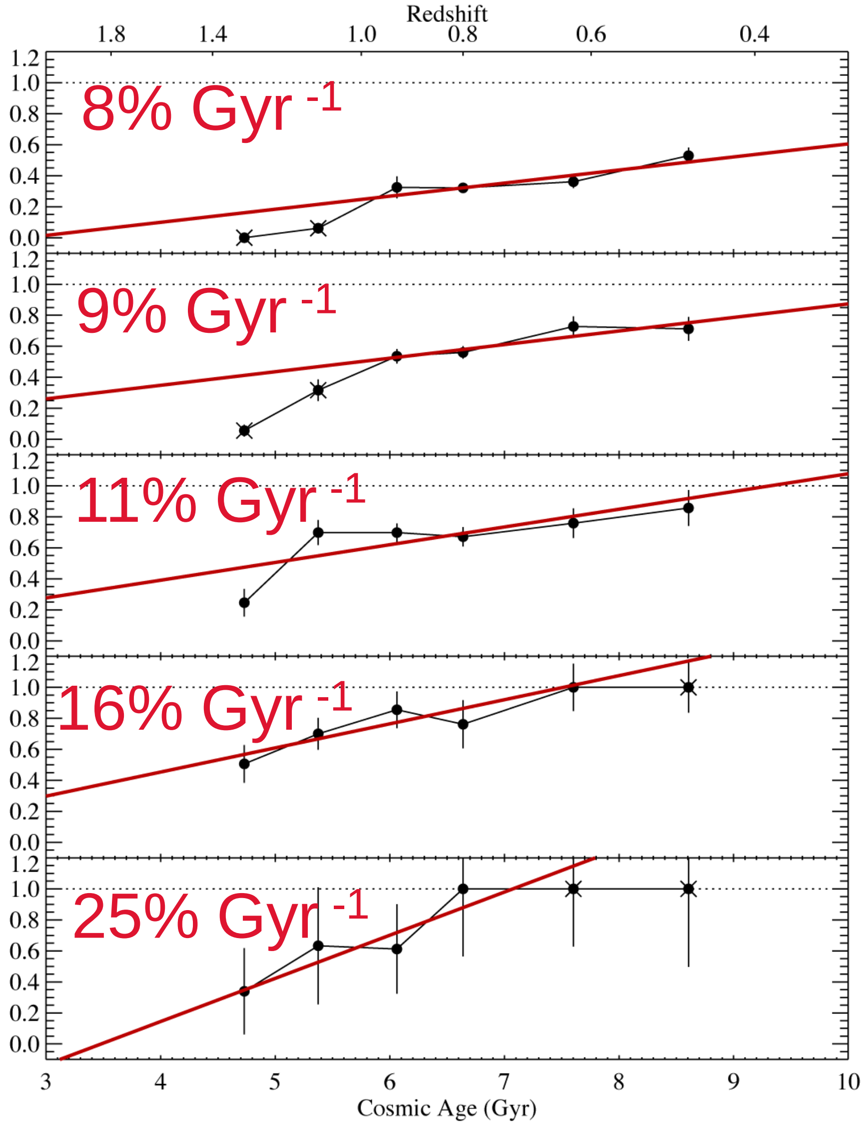

Lowest M_*

Log M* ~ 10.5

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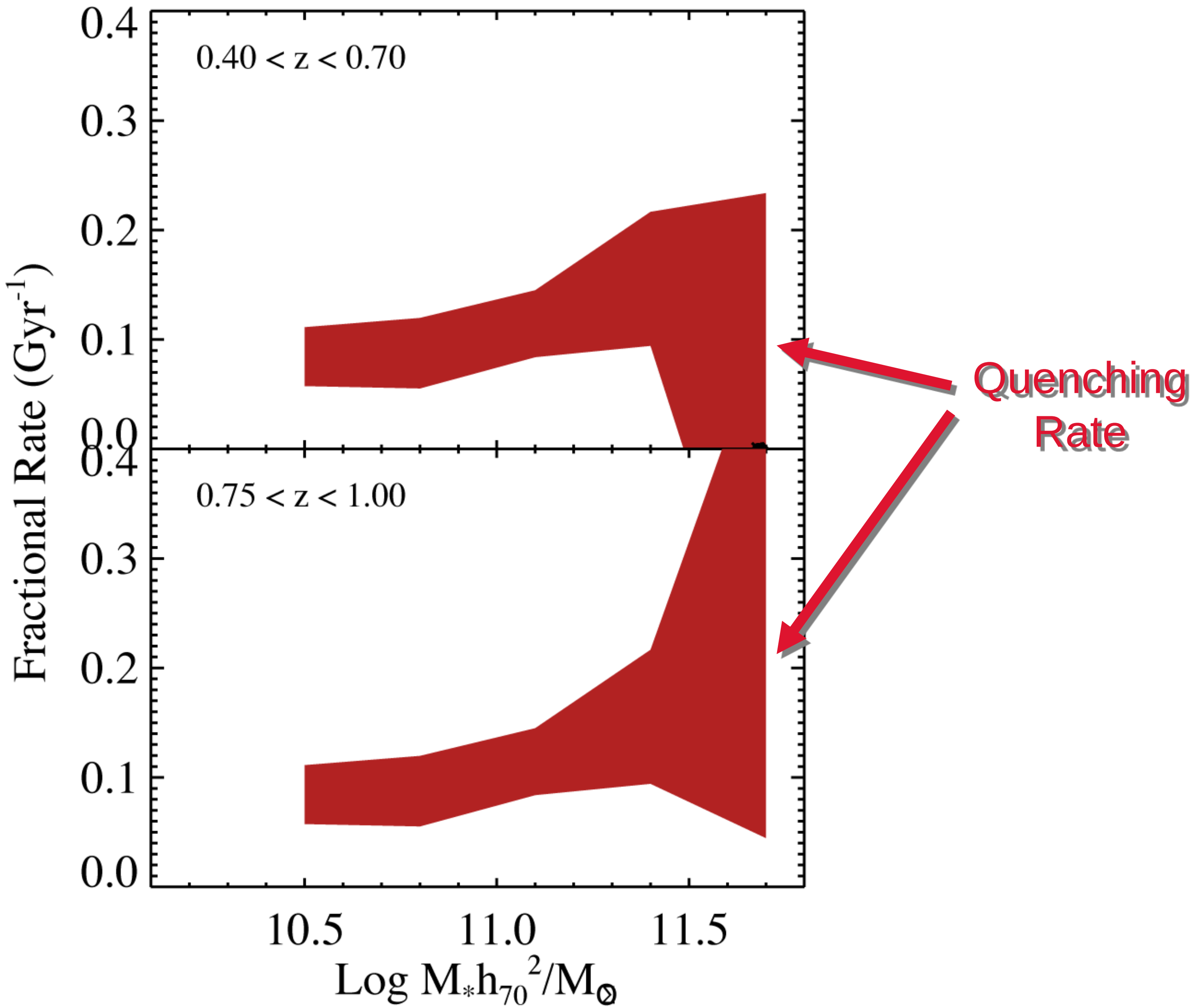
Highest M_*

Cosmic Age (Gyr)

Bundy et al. 2008

Quenching vs. AGN Triggering



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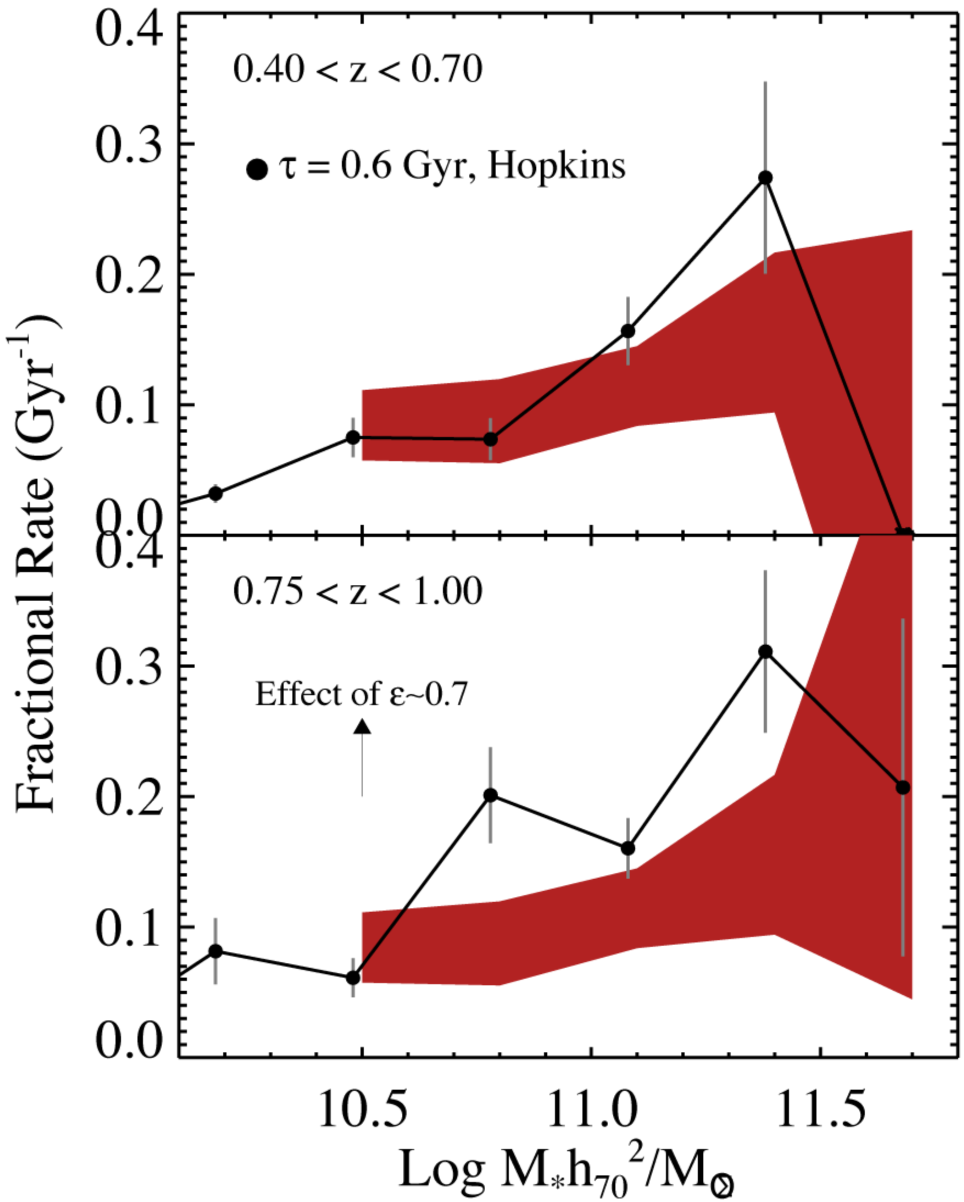

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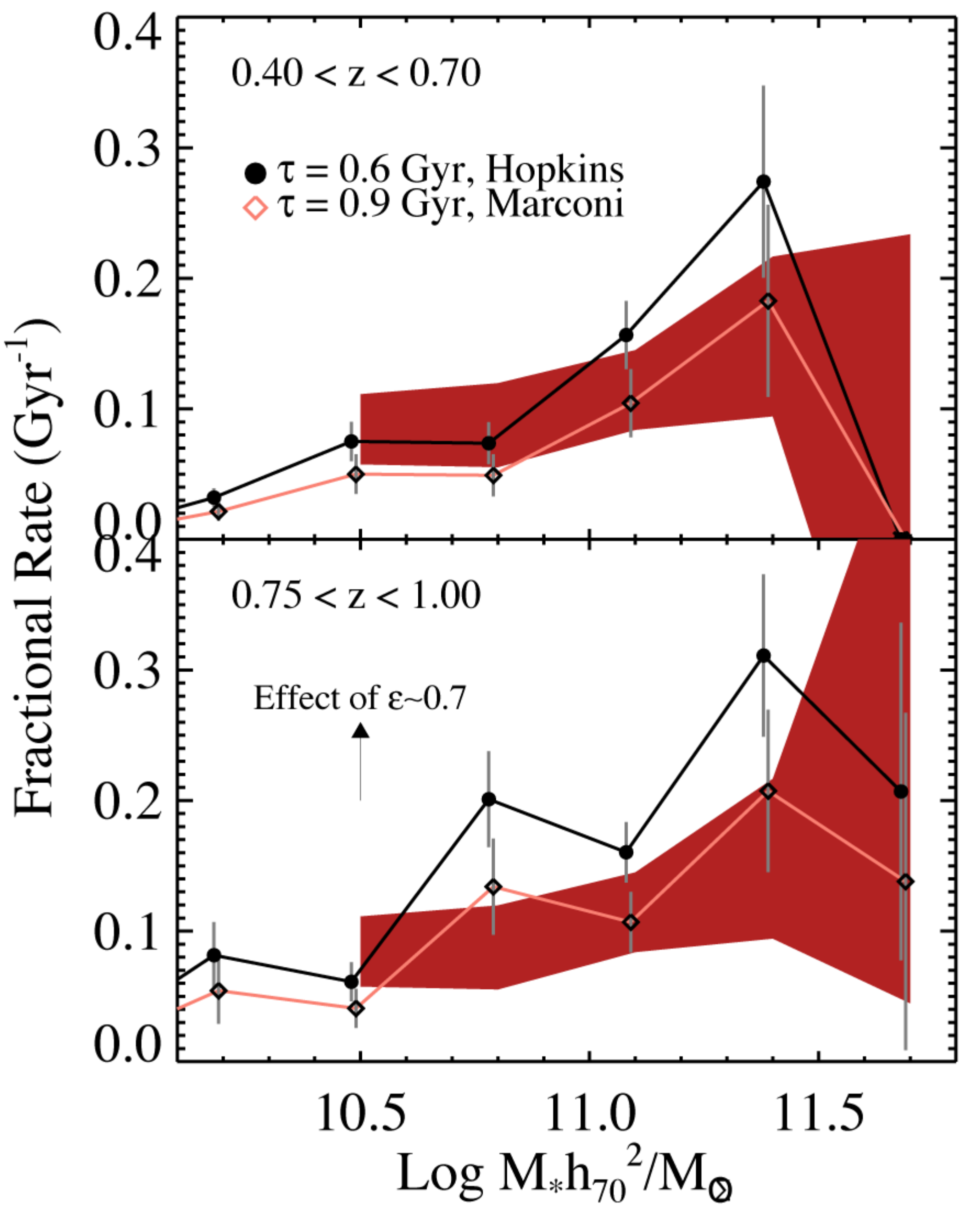

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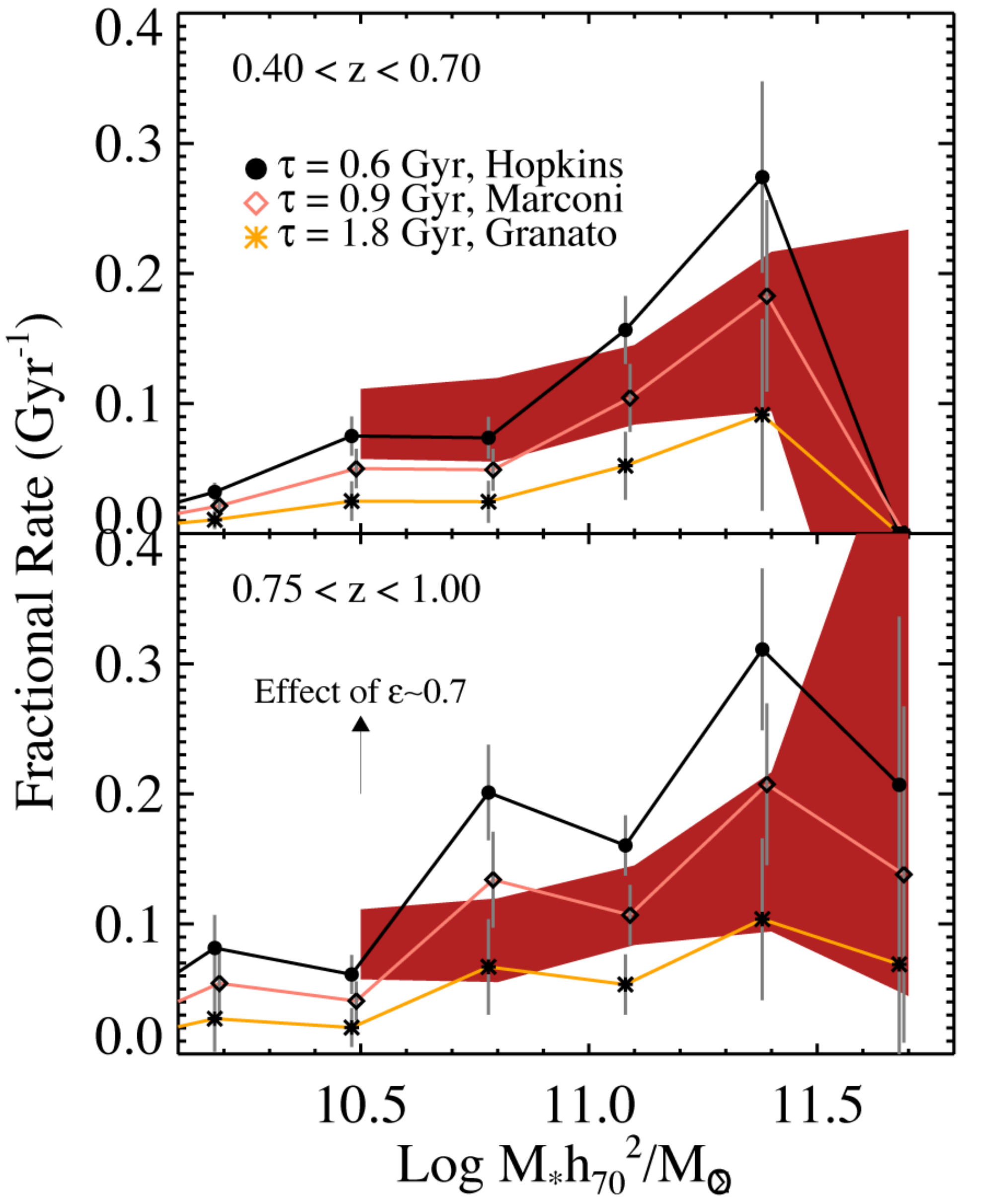


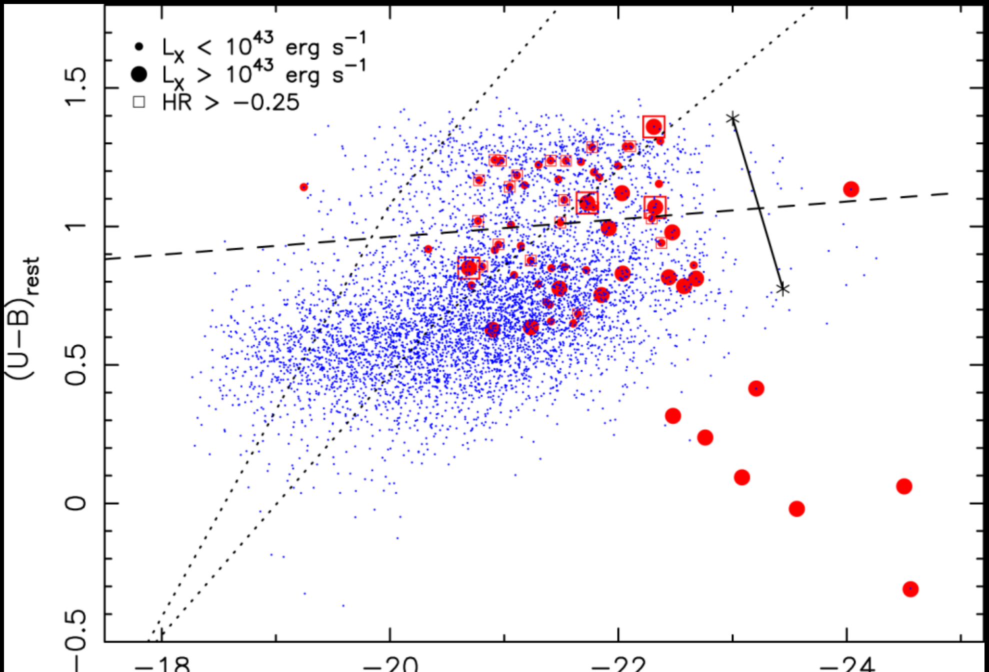
Bundy et al. 2008

Quenching and AGN (Quasar) Feedback

- Does the frequency of AGN activity match the rate of quenching?

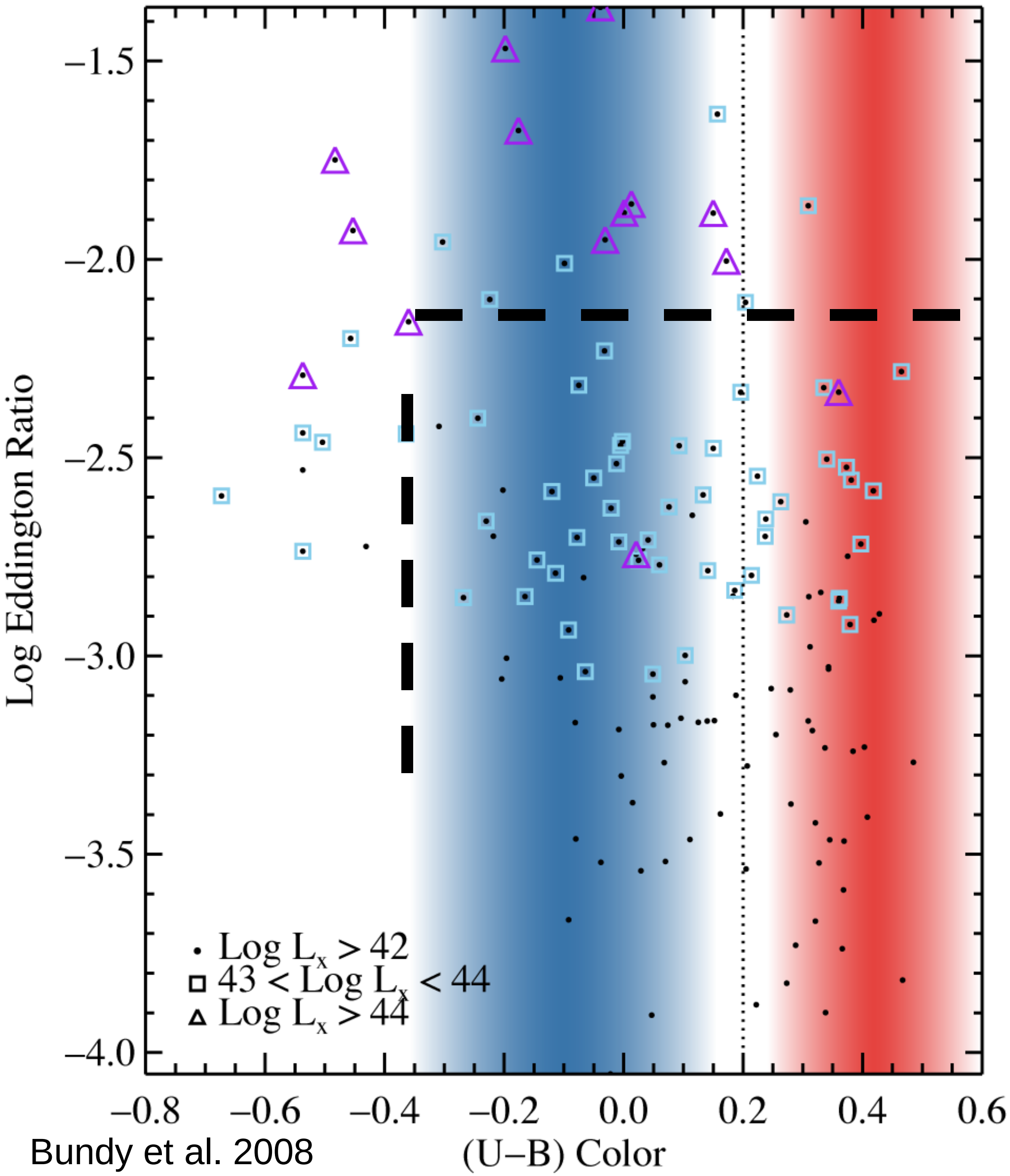
Yes

- Do AGNs live in quenched or at least quenching galaxies?



Nandra et al. 2006

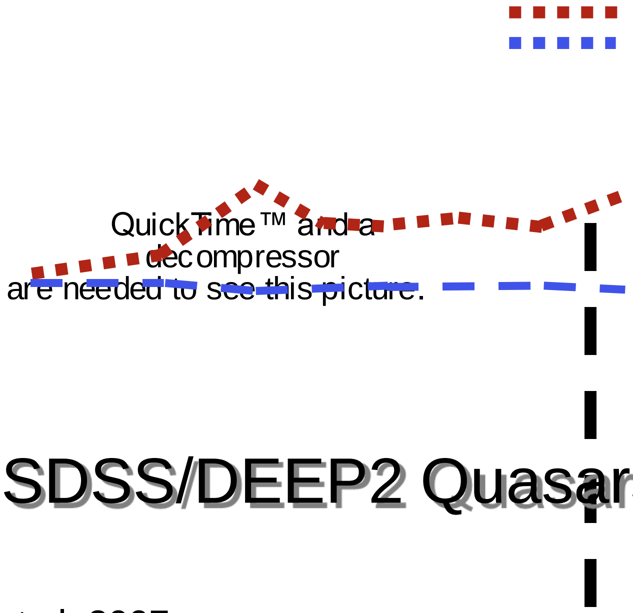
Accretion Efficiency



Bundy et al. 2008

Also see Silverman et al. 2008

Alison Coil's DEEP2 Clustering Measurements



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decompressor
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SDSS/DEEP2 Quasars

X-ray AGN

Coil et al. 2007

Coil et al., in prep
Also see Georgakakis et al. 2008.

Quasars cluster like blue galaxies, X-ray AGN like red ones.

Quenching and AGN (Quasar) Feedback

- Does the frequency of AGN activity match the rate of quenching?

Yes

- Do AGNs live in quenched or at least quenching galaxies?

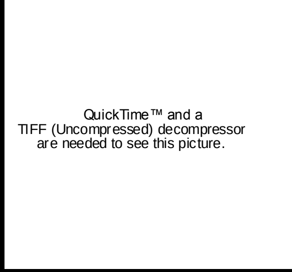
Not always…

- Is this physics correct?

Probably not…

AGN activity is associated with quenching, but probably not the cause.

Stellar winds, outflows, starbursts are observed (Crystal Martin's work., Weiner et al. 2008, Erb 2008) and likely can do the job (e.g., Murray et al. 2005).



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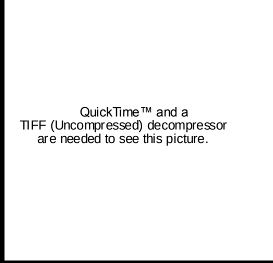
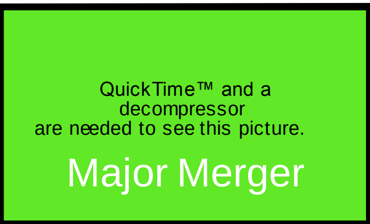


	Trigger	Mechanism	Maintenance
	Threshold Halo Mass, ~10^{12} $M_\odot$		
Star formation Quenching (gas)	Major Merger	AGN? / Starburst	Radio Mode AGN Feedback
Spheroidal Formation (morphology)	Major Merger	N-body Simulation	Prevent cold disk formation



2.

Are there enough mergers to make spherdoial galaxies?

Merger Rate?

Lin et al. 2004, 2008 (DEEP2); de Ravel et al. 2008 (VVDS), Kartaltepe et al. 2007 (COSMOS), Bell et al. 2006 (COMBO17), Lotz et al. 2007 (morph.), Patton & Atfield 2008 (SDSS)

Challenges

- Must distinguish major mergers.
- Must probe the mass dependence.
- Need complete, mass-limited samples.

Observed Near-IR Galaxy Merger Rate

Subaru K~22 Observations in GOODS-N + ISAAC in GOODS-S

Bundy, Fukugita, Targett, Ellis, Belli, Kodama

Method 2:

Observed Near-IR Galaxy Merger Rate

Subaru K~22 Observations in GOODS-N + ISAAC in GOODS-S

Bundy, Fukugita, Targett, Ellis, Belli, Kodama

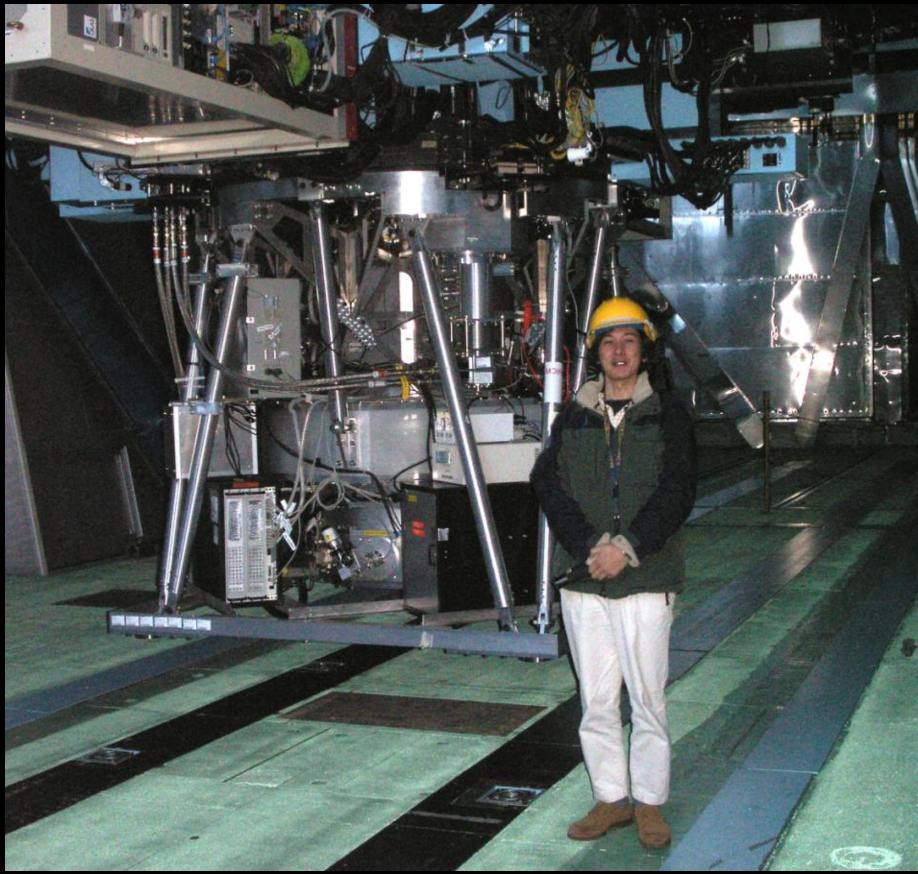
Observations

• MOIRCS K~22 (Vega), 0.5'', GOODS N+S, 0.08 deg^2

• K Catalog (17155 sources) matched to ACS data and spec-z surveys.

• ~3000 hosts (60% spec-z), $M_* > 10^{10} M_\odot$, $0.4 < z < 1.4$

• Additional GOODS-S photo-zs from Grazian et al. 2006 (dz/1+z ~ 0.03). BPZ in GOODS-N (dz/1+z ~ 0.09).



Iichi Tanaka and MOIRCS

Pair Fraction

Count the fraction of galaxies with a fainter companion.

Companion Criteria:

- $5 < r_{sep} < 20$ kpc
- no fainter than $K_{host} + 1.5$, ensures major mergers defined as $M_{comp}/M_{host} > 1/4$

Contamination Correction

Correction 1:

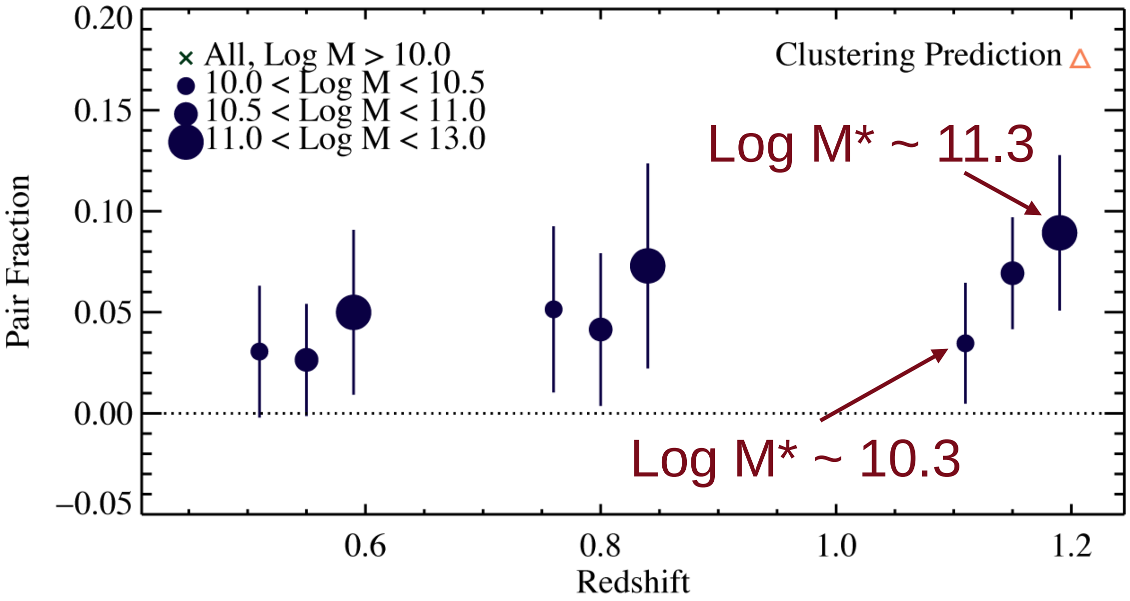
Subtract background number density.

Correction 2:

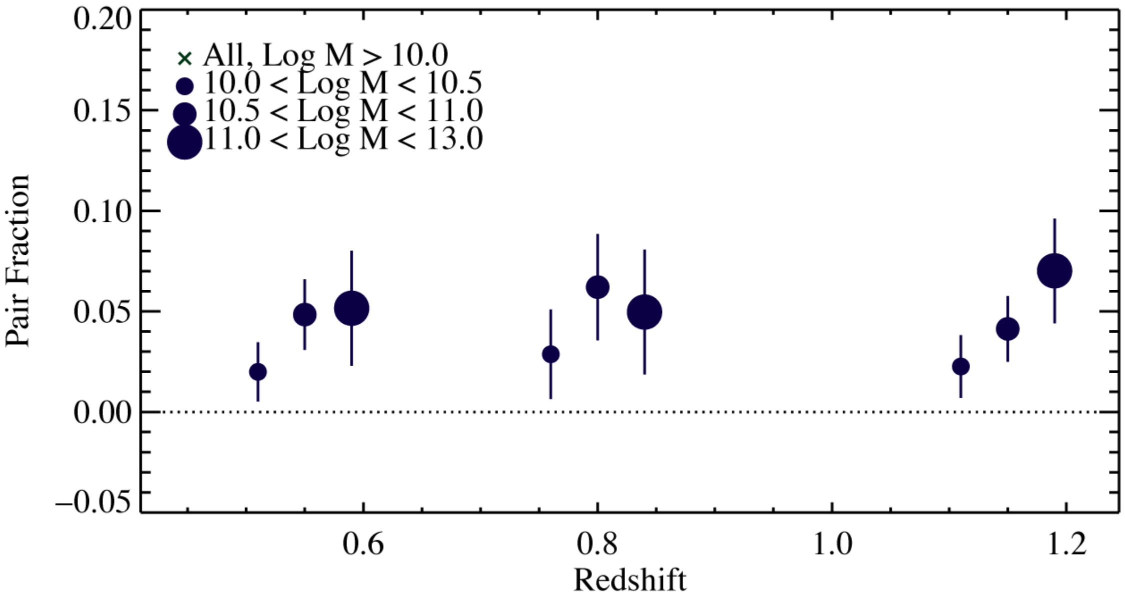
Use redshift information, $\Delta z^2 < \sigma_{host}^2 + \sigma_{comp}^2$.

Then randomize the x,y positions 100 times, subtract the average remainder.

Mass Dependent Pair Fraction

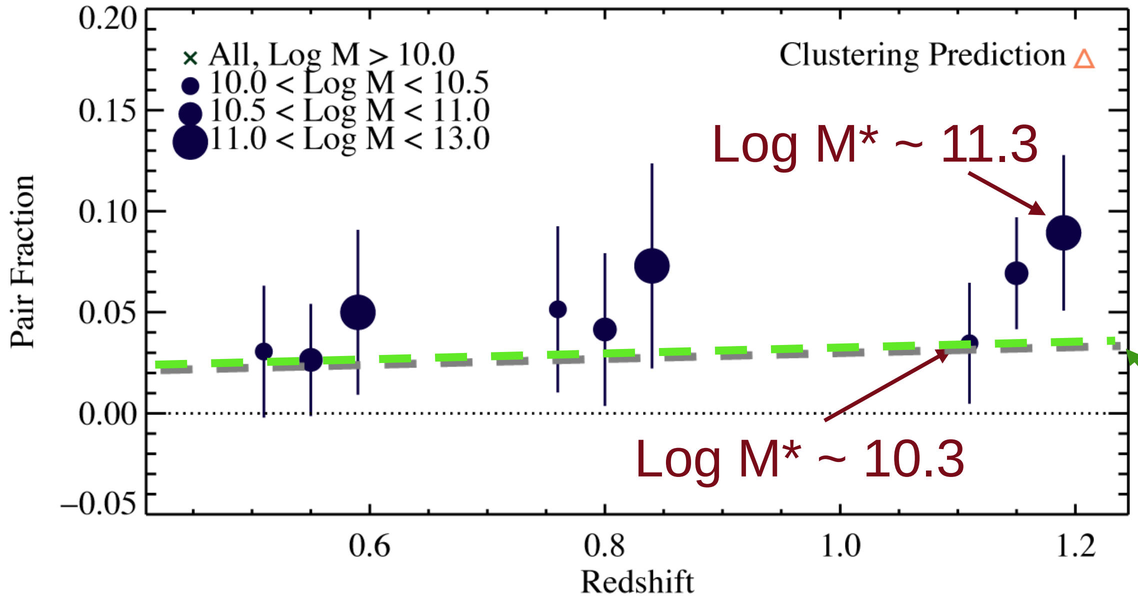


Background field correction



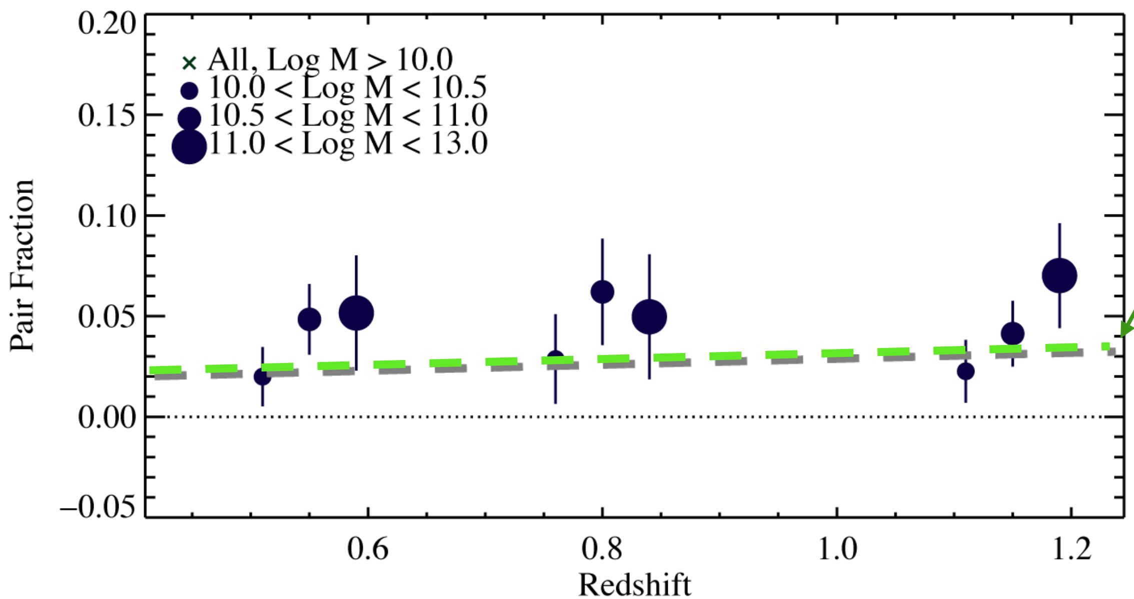
Redshift pair correction.

Mass Dependent Pair Fraction



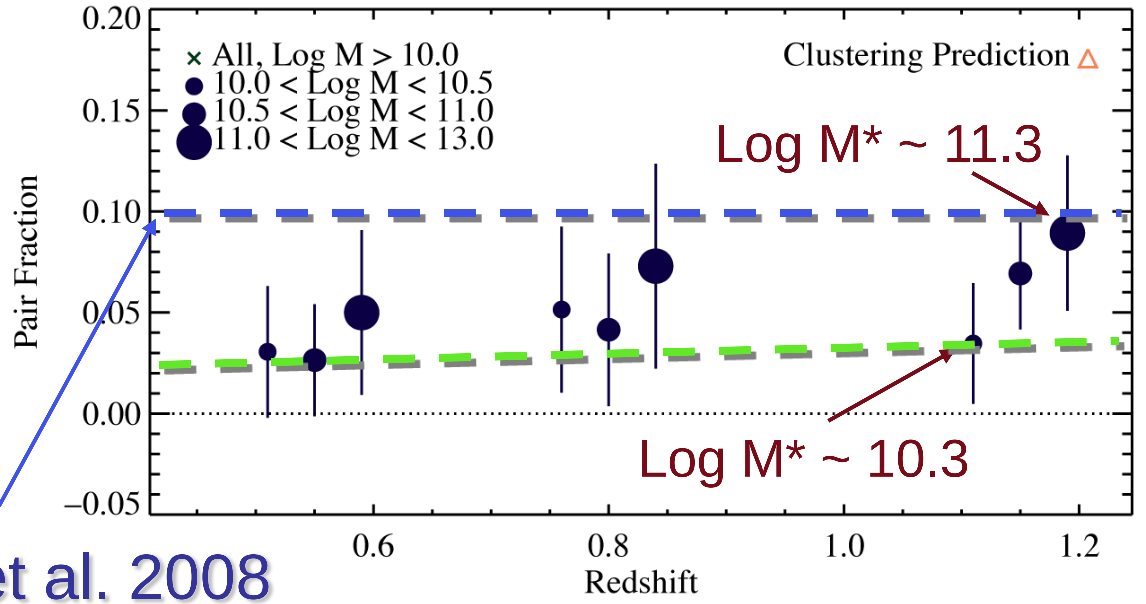
Background field correction

Lin et al. 2008



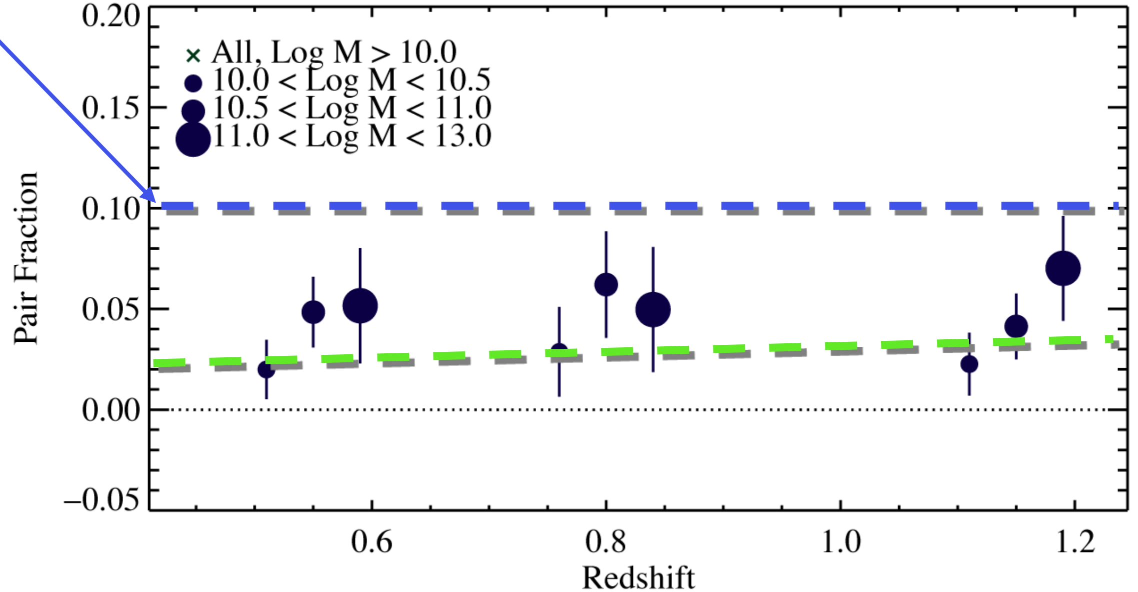
Redshift pair correction.

Mass Dependent Pair Fraction



Background field correction

Lotz et al. 2008



Redshift pair correction.

Deriving the Merger Rate

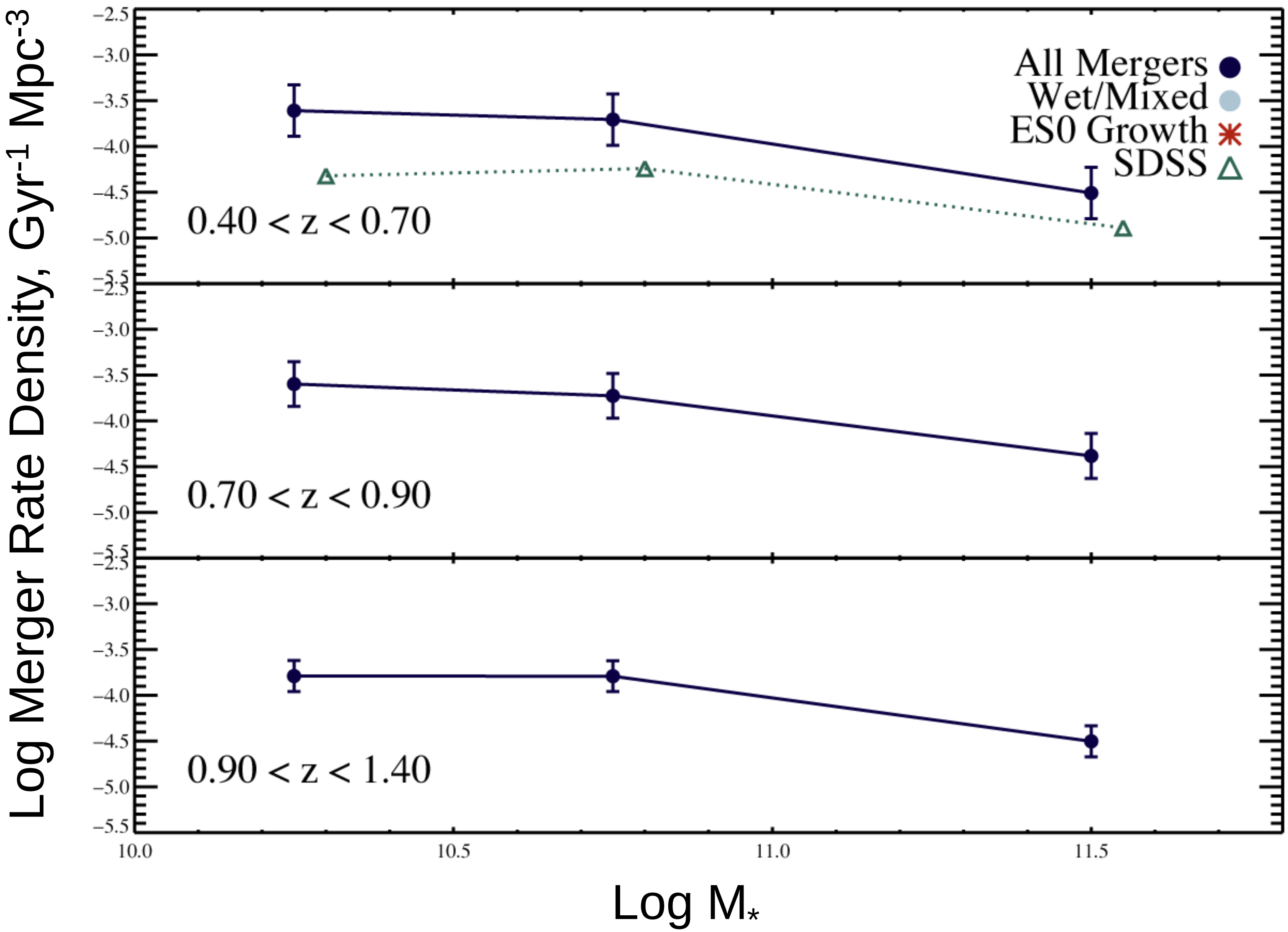
Merger efficiency and timescale.

Kitzbichler & White 2007. Find τ decreases as $M_*^{-0.3}$

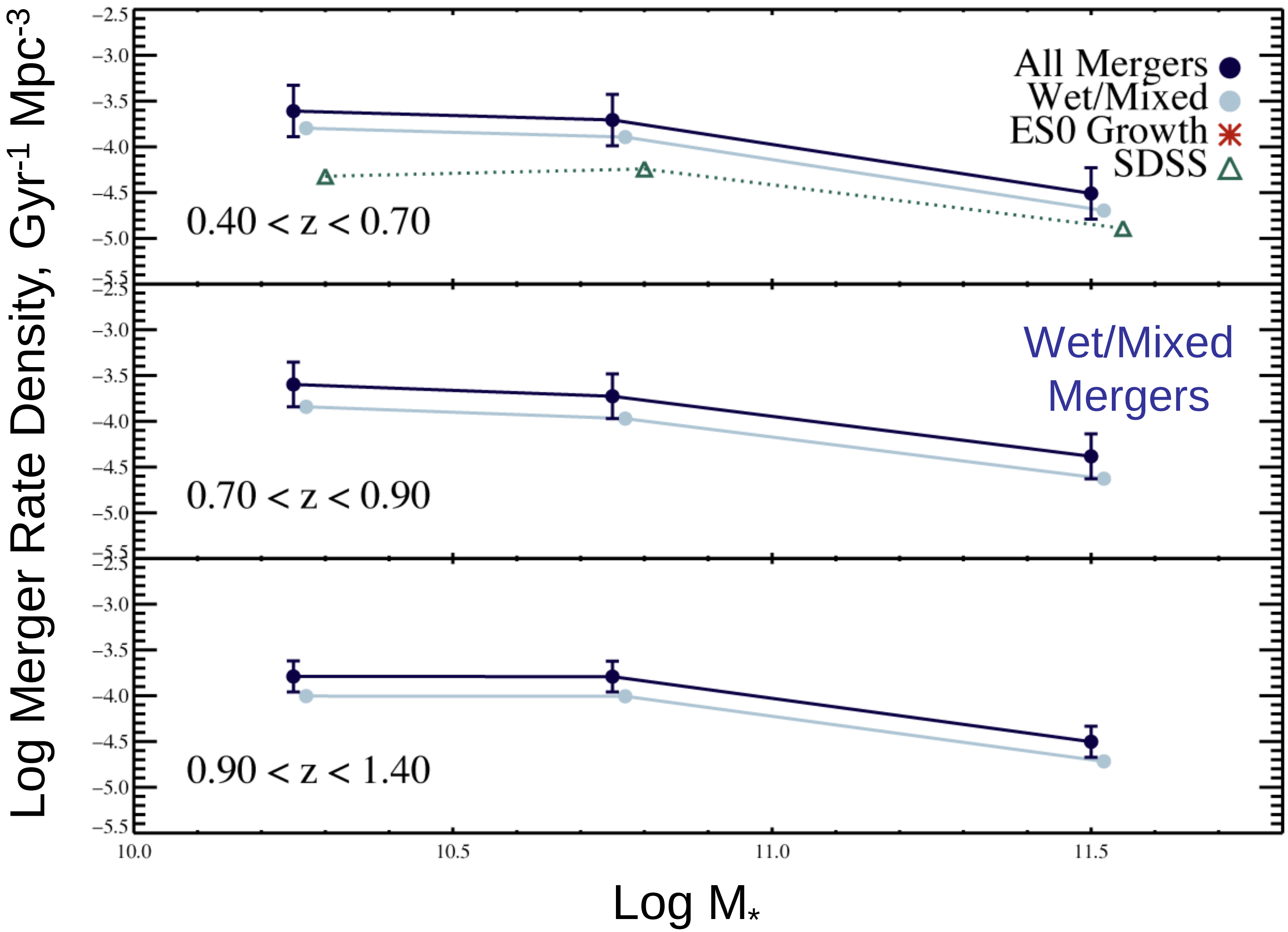
Patton & Atfield 2008. τ = 0.5 Gyr, less efficient at high M^*

We use our sample to determine volumetric merger rate.

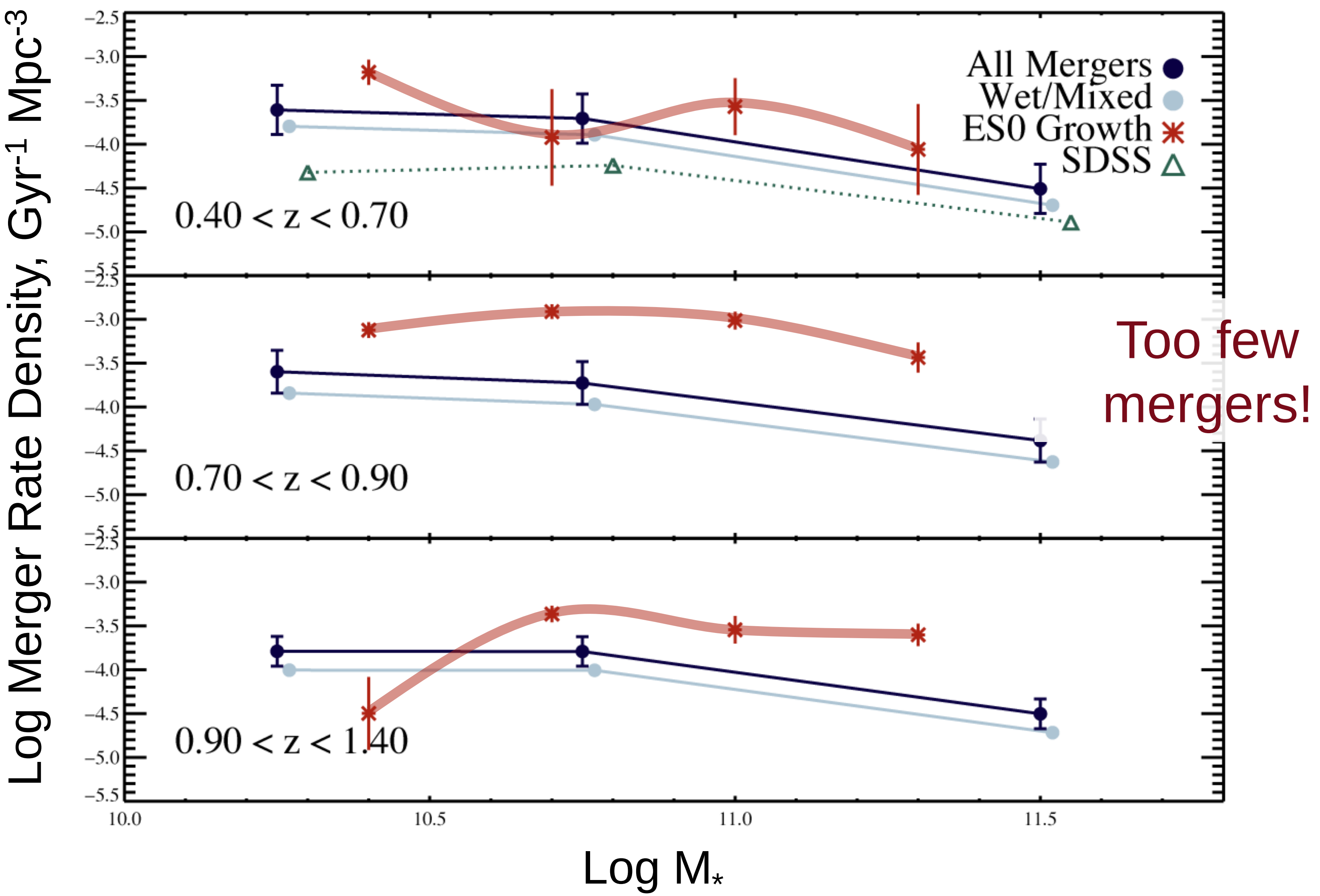
Volumetric Merger Rate



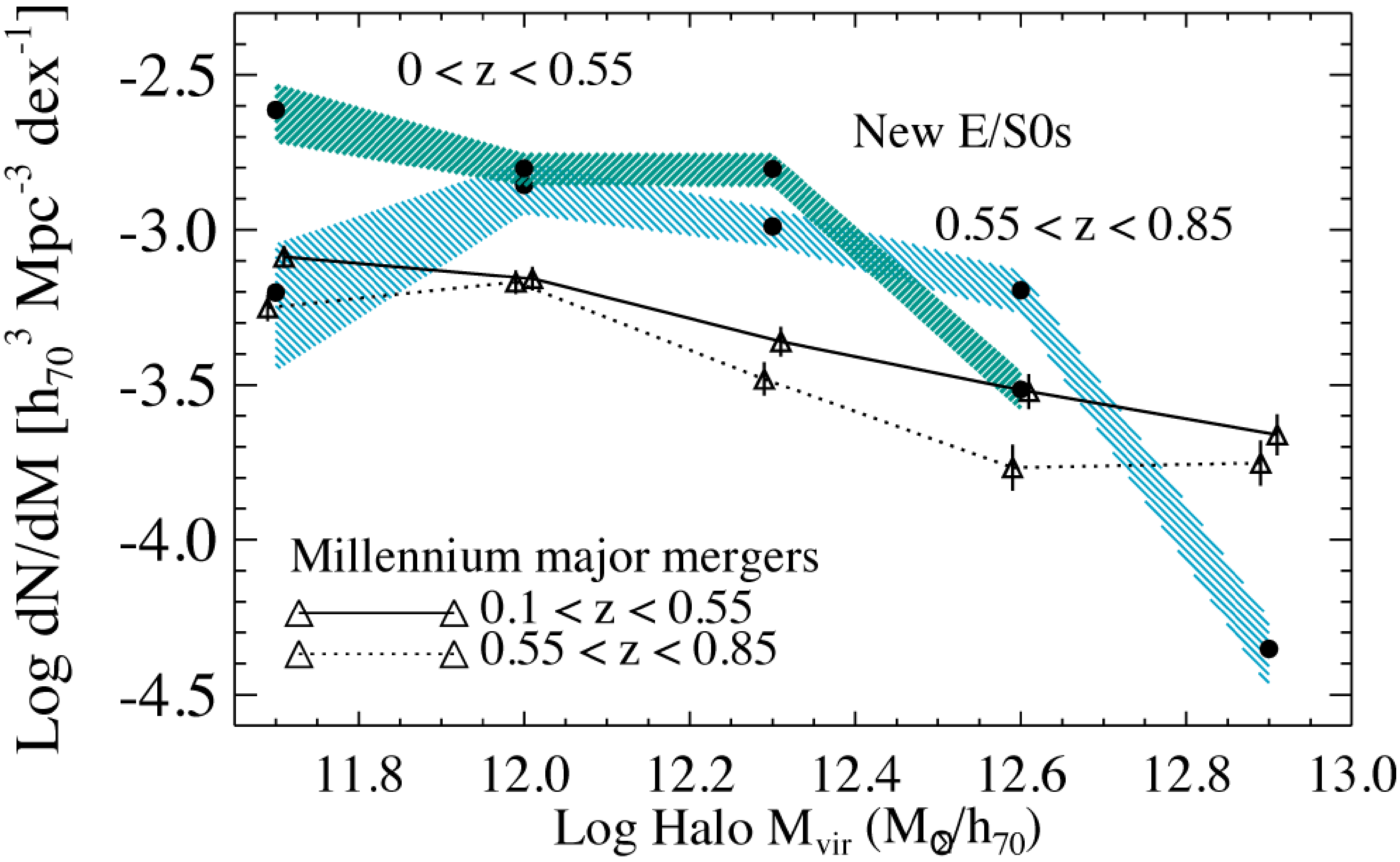
Volumetric Merger Rate



Volumetric Merger Rate

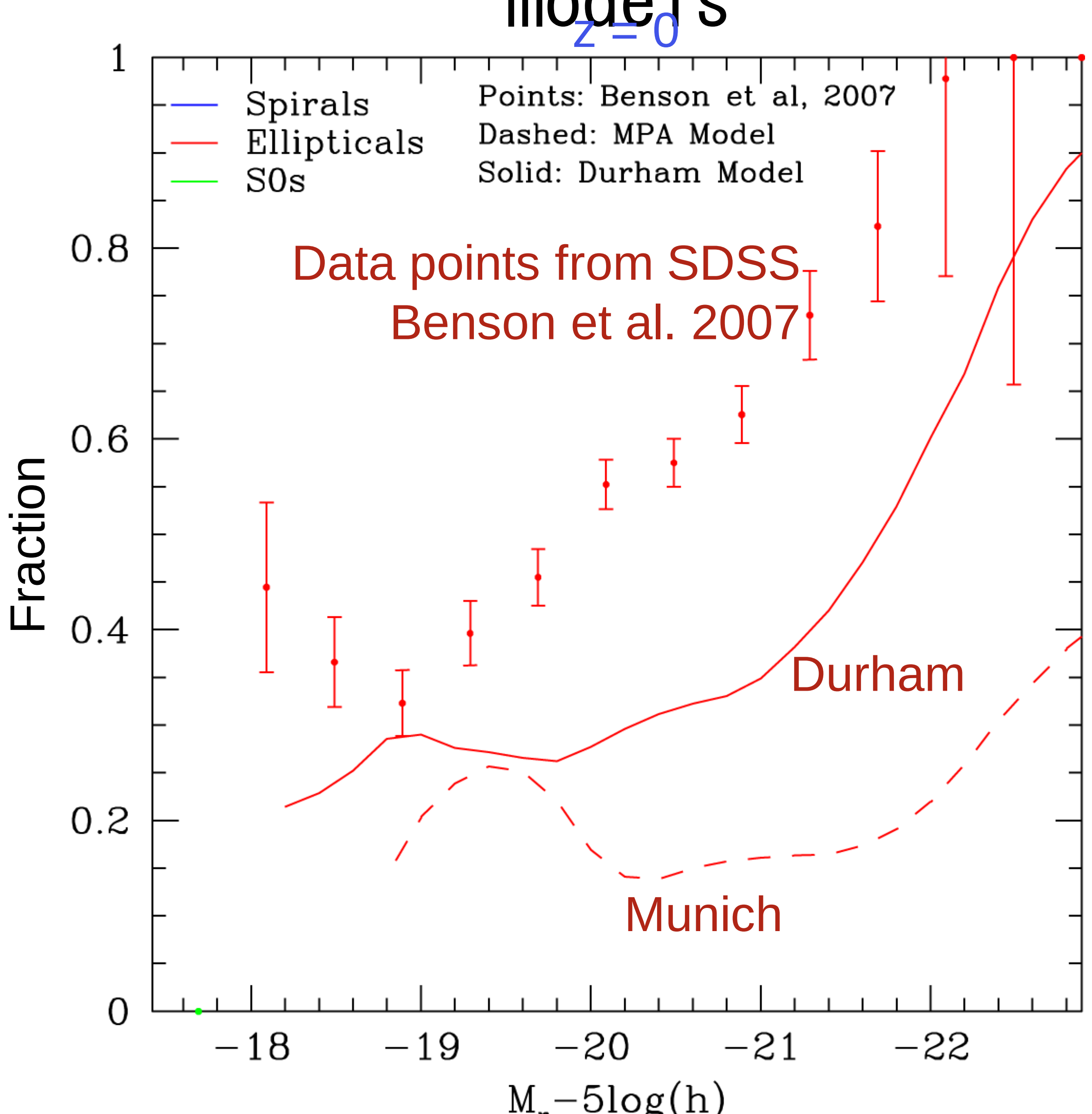


Halo Mergers from Millennium



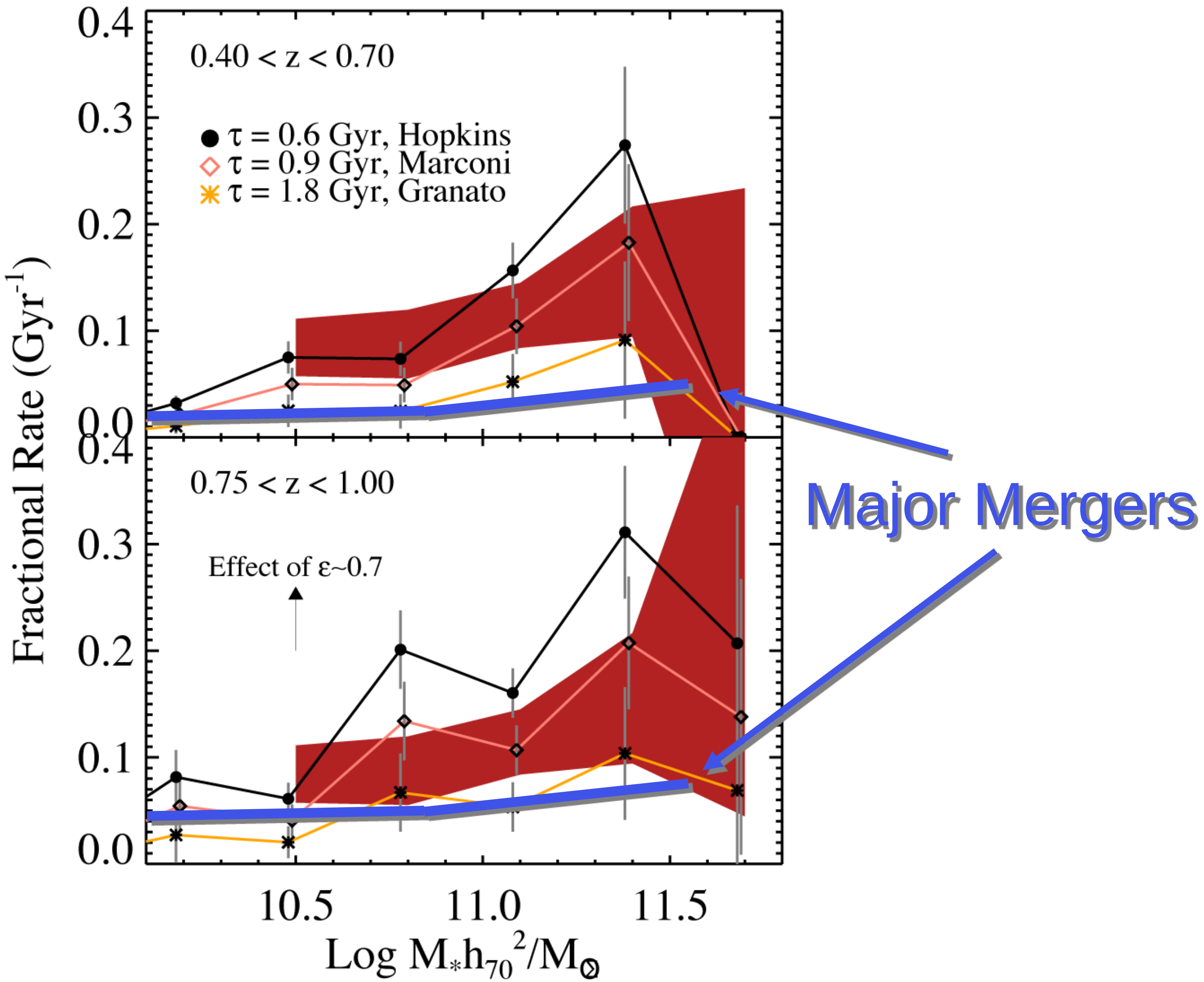
Bundy et al. 2007

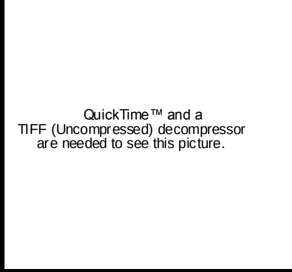
Elliptical Fraction in semi-analytic models



Parry et al. 2008

Mergers vs. quenching and AGN





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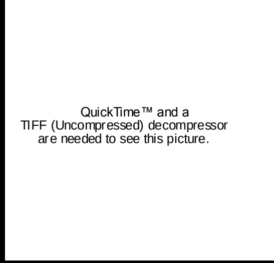

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Star formation Quenching (gas)	Major Merger	AGN?	 Radio Mode AGN Feedback
Spheroidal Formation (morphology)	Bombardment?	Starburst (winds, outflows)	Prevent cold disk formation
		N-body Simulation	Size growth??
	Disk Instability Pseudobulges?		

Summary and Conclusions

- AGNs seem to be associated with quenching but are not the cause… Stellar feedback instead?
- There are too few major mergers to understand morphological evolution, quenching, or AGN triggering.
- New triggers are needed: disk instabilities, minor mergers, bombardment…??