# PRIMUS

## Effects of Galaxy Environment on the Quiescent Fraction at $z < 0.8$

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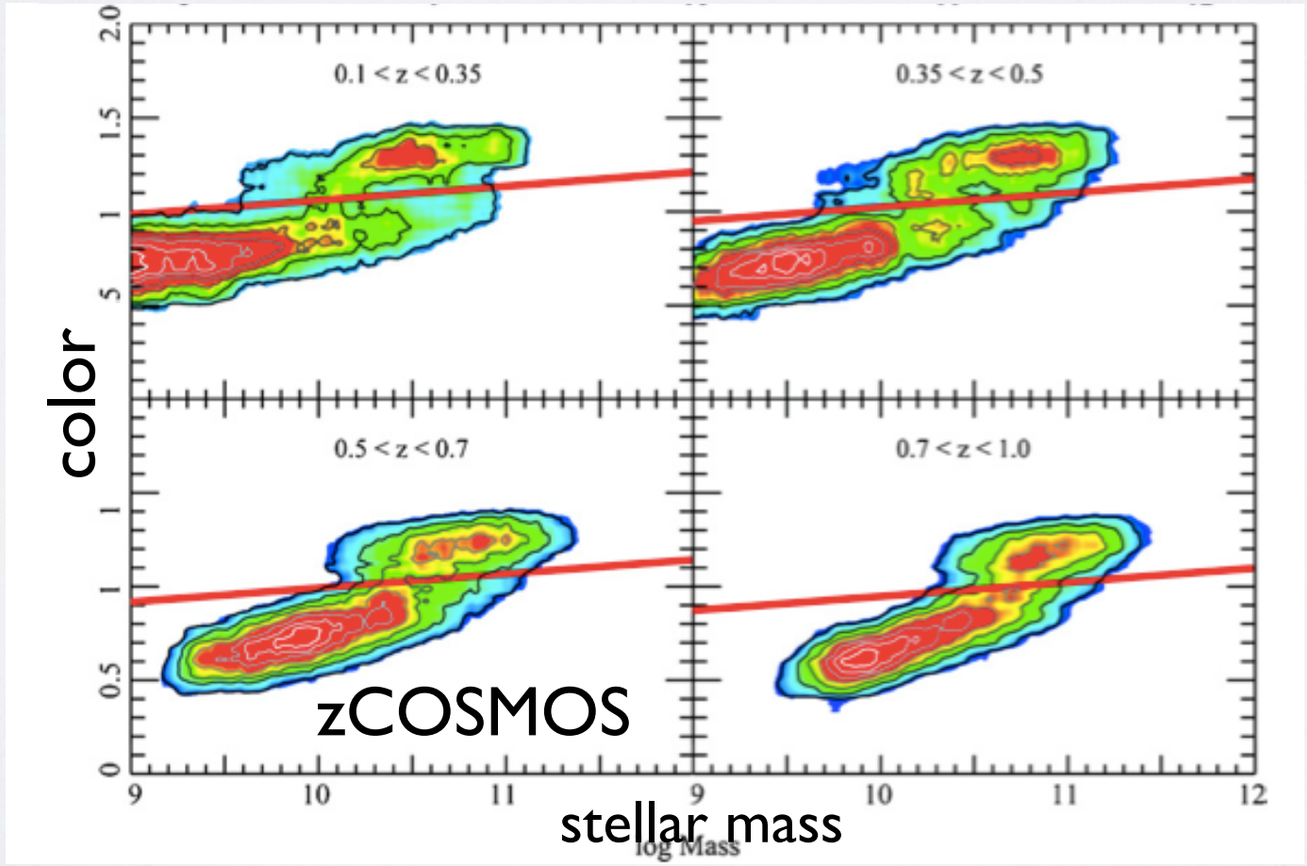
La Palma
March 3, 2015

# Galaxy Evolution through Large Surveys

Large galaxy surveys have revealed many trends in galaxy populations that have helped explain to us how galaxies have been evolving over the last 8 billion years.

- An evolving bimodality in the galaxy population that extends back to z~1.

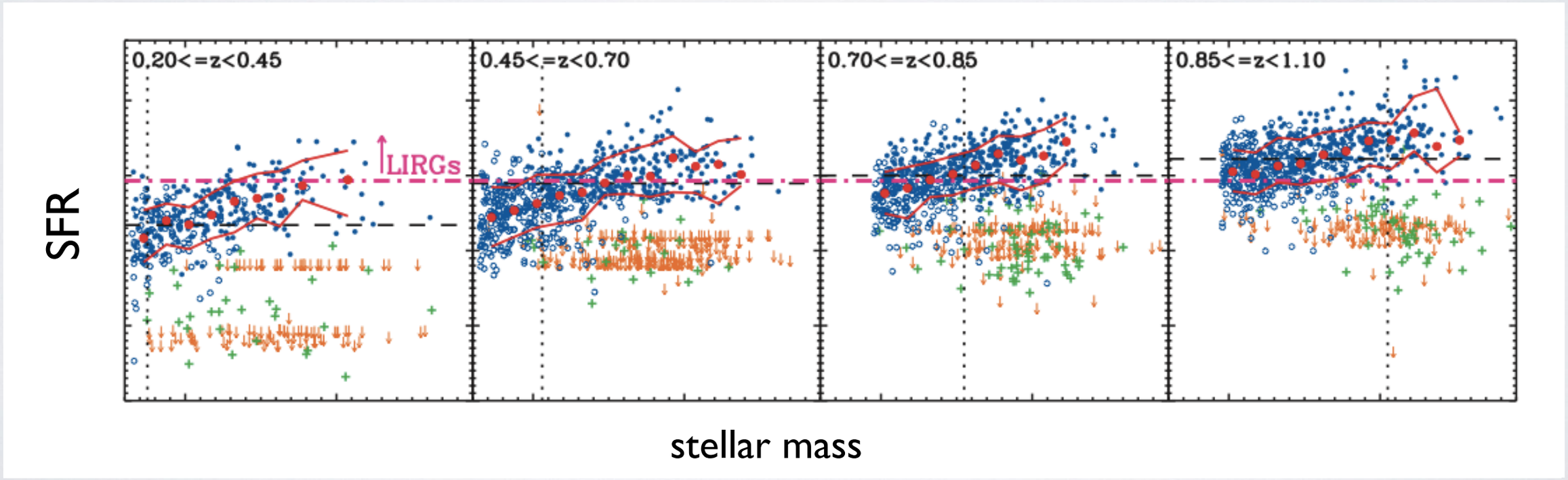



Peng et al. 2010

# Galaxy Evolution through Large Surveys

Large galaxy surveys have revealed many trends in galaxy populations that have helped explain to us how galaxies have been evolving over the last 8 billion years.

- Decline in star-formation of blue, star-forming galaxies fueling the global decline in star-formation.

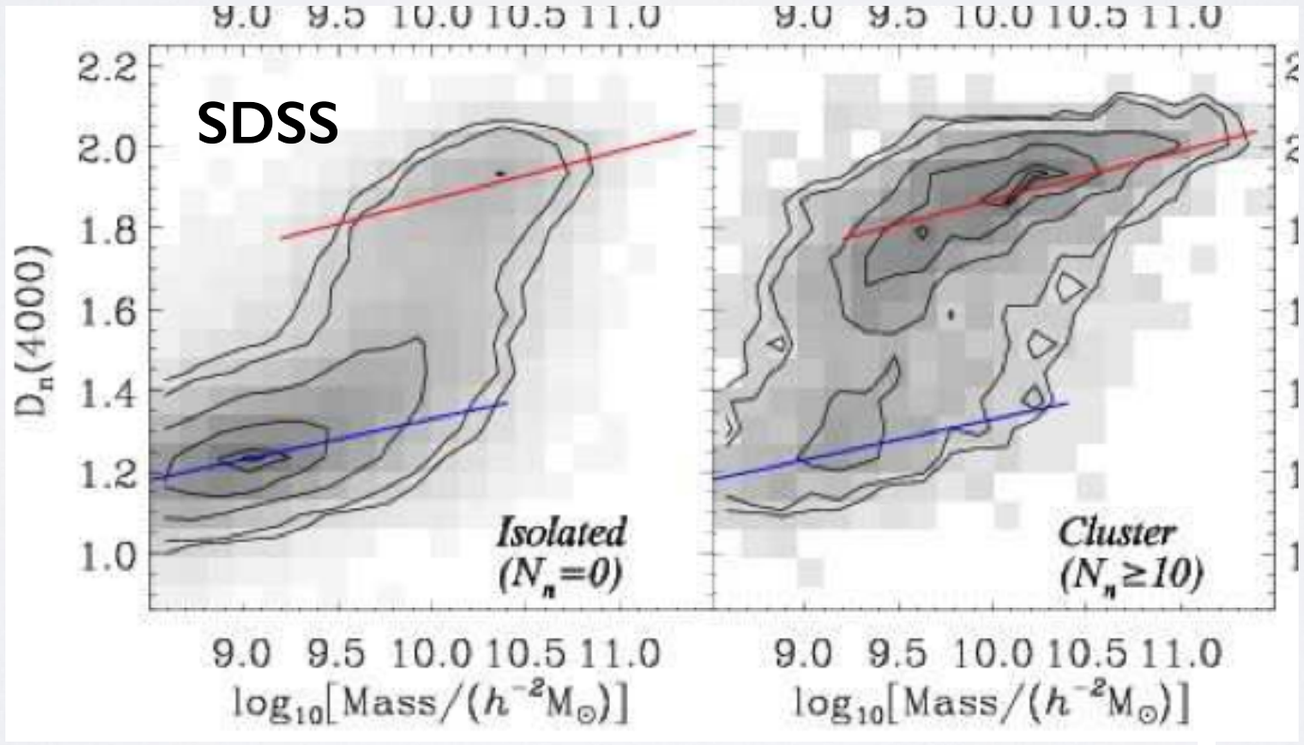



Noeske et al. 2007

# Role of Environment on Galaxy Evolution

*Galaxies in high density environments are redder, more massive and have lower star formation rates*

**Are environment driven quenching mechanisms responsible for stopping star-formation in high density environments?**




Blanton & Moustakas (2009)

# Role of Environment on Galaxy Evolution

*Disentangling the subtle environmental effects from underlying correlations among observable galaxy properties is challenging.*

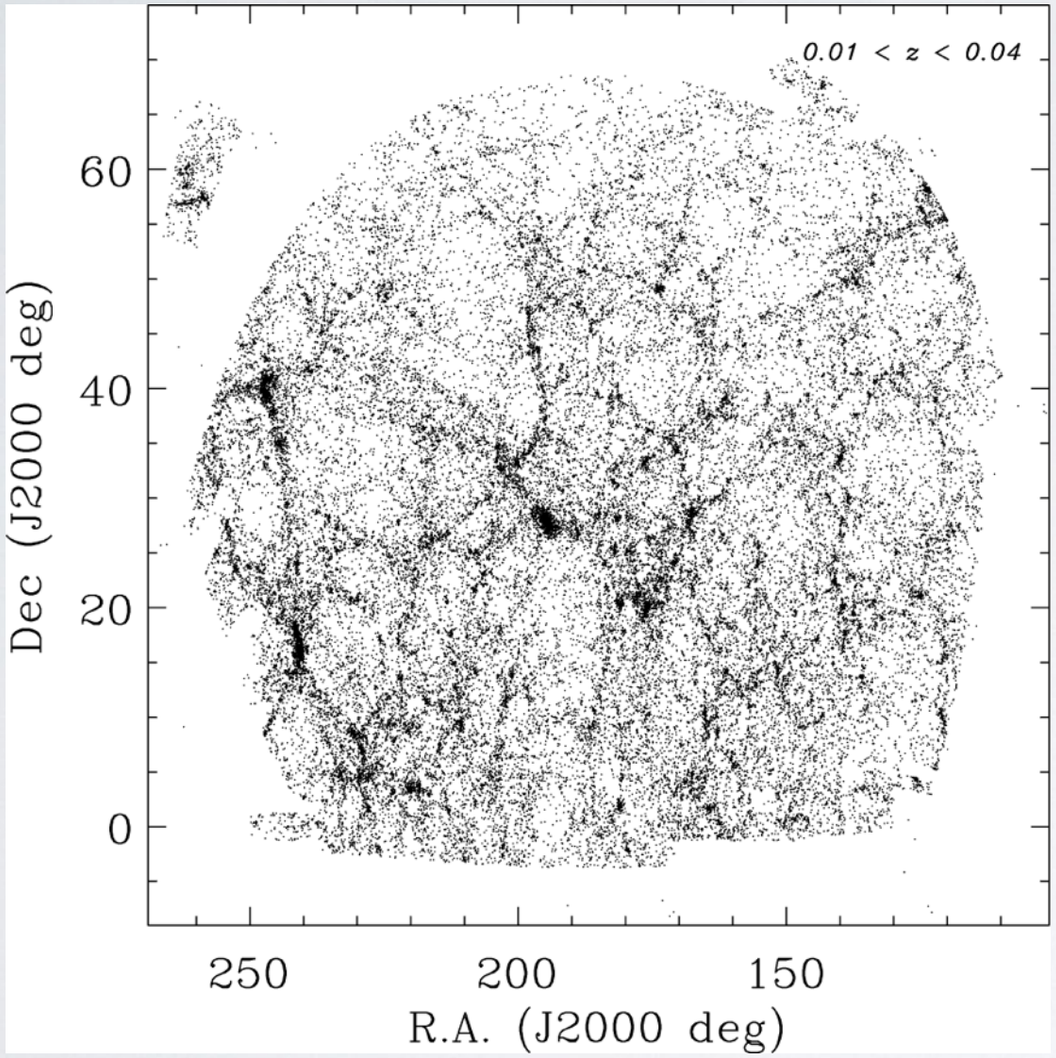
But with the statistics available from **SDSS** and **PRIMUS**…

We evaluate the **quiescent fraction** in bins of ***stellar mass***, ***redshift*** and ***environment***.

$$f_{\rm Q}(\ \mathcal{M}_*,\ z,\ \delta_{\rm env}\ )$$

# NYU Value Added Galaxy Catalog

Blanton et al. (2005)




**NYU-VAGC** galaxies with spectroscopic redshifts between **0.01 < z < 0.2** and ***ugriz* photometry** derived from SDSS Data Release 7.

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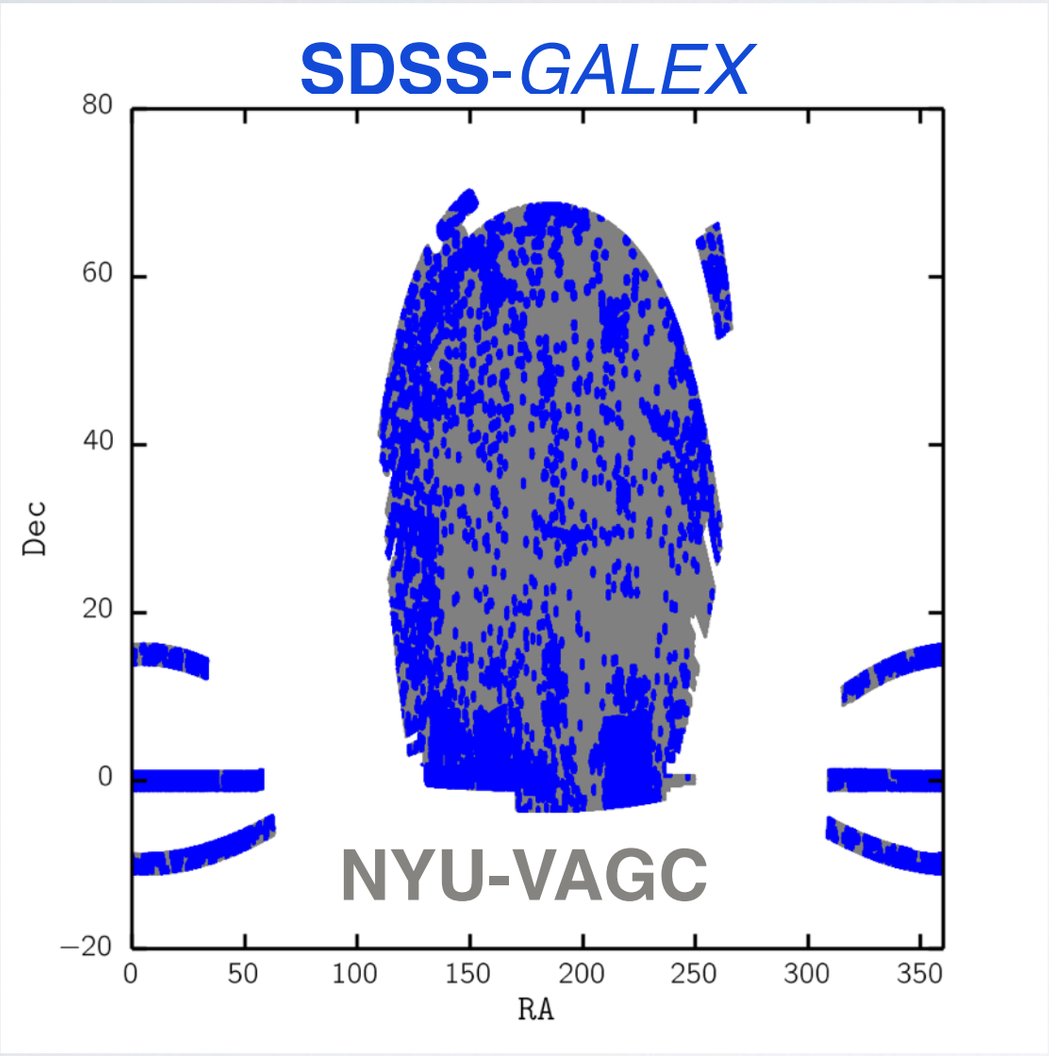



**NYU-VAGC** galaxies with spectroscopic redshifts between **0.01 < z < 0.2** and ***ugriz* photometry** derived from SDSS Data Release 7.

Restrict **NYU-VAGC** data to galaxies with ***GALEX* UV imaging**.

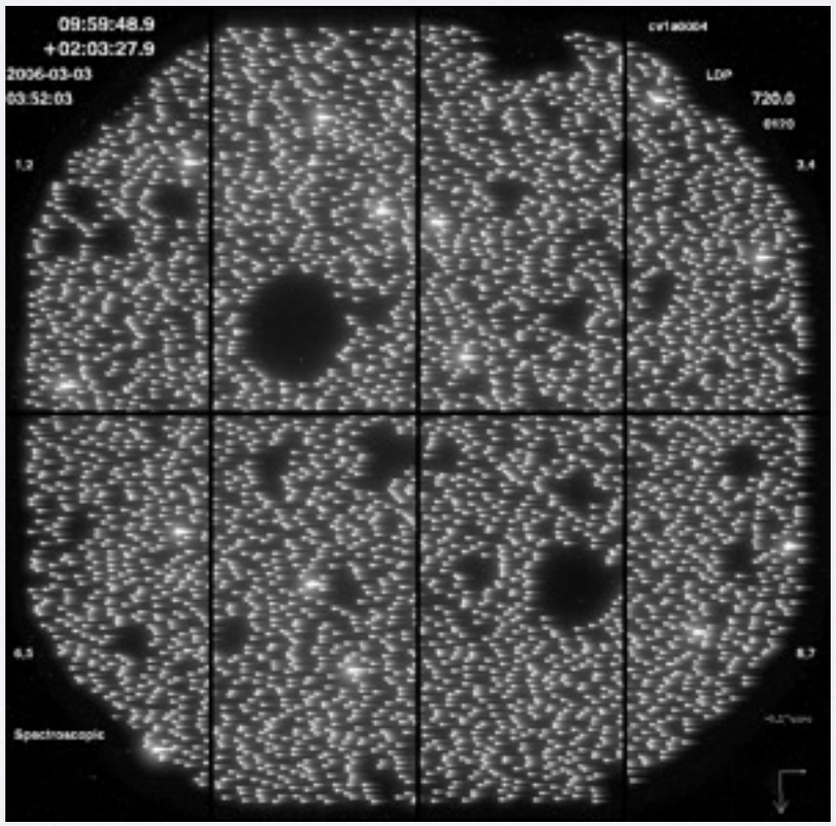
This **SDSS-*GALEX*** data serves as our low redshift anchor in our analysis with …

**169,727 galaxies** over **2,505 deg²**

# **PRI**sm **MU**lti-object **S**urvey (**PRIMUS**)

- **PRIMUS** using the IMACS spectrograph with a custom built **low dispersion prism** on the Magellan I Baade 6.5m telescope to obtain **~120,000 spectroscopic redshift** with $\sigma_z/(1+z) < 0.005$

Coil et al. (2011), Cool et al. (2013)




prism exposure in a PRIMUS field

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- **PRIMUS** Team:

  **Co-PIs**: Michael Blanton, Alison Coil, Daniel Eisenstein, James Aird, Scott Burles, Aaron Bray, Richard Cool, ChangHoon Hahn, Alexander Mendez, John Moustakas, Ramin Skibba, Kenneth Wong, Guangtun Zhu

# **PRI**sm **MU**lti-object **S**urvey (**PRIMUS**)

Upcoming **PRIMUS** publications to look forward to:

- *ΛCDM Halo Models of Galaxy Clustering and Evolution in PRIMUS +DEEP2 at $0.2 < z < 1.2$*
  **Ramin A. Skibba**, PRIMUS Team (in prep.)
- *Clustering as a Function of Star Formation Rate and Stellar Mass*
  **Alexander J. Mendez**, PRIMUS Team (in prep.)
- *Color and Luminosity Dependence of Small-scale Clustering*
  **Aaron Bray**, PRIMUS Team (in prep.)
- *PRIMUS: Effect of Galaxy Environment on the Quiescent Fraction Evolution at $z < 0.8$*
  **ChangHoon Hahn**, PRIMUS Team (Submitted to ApJ)

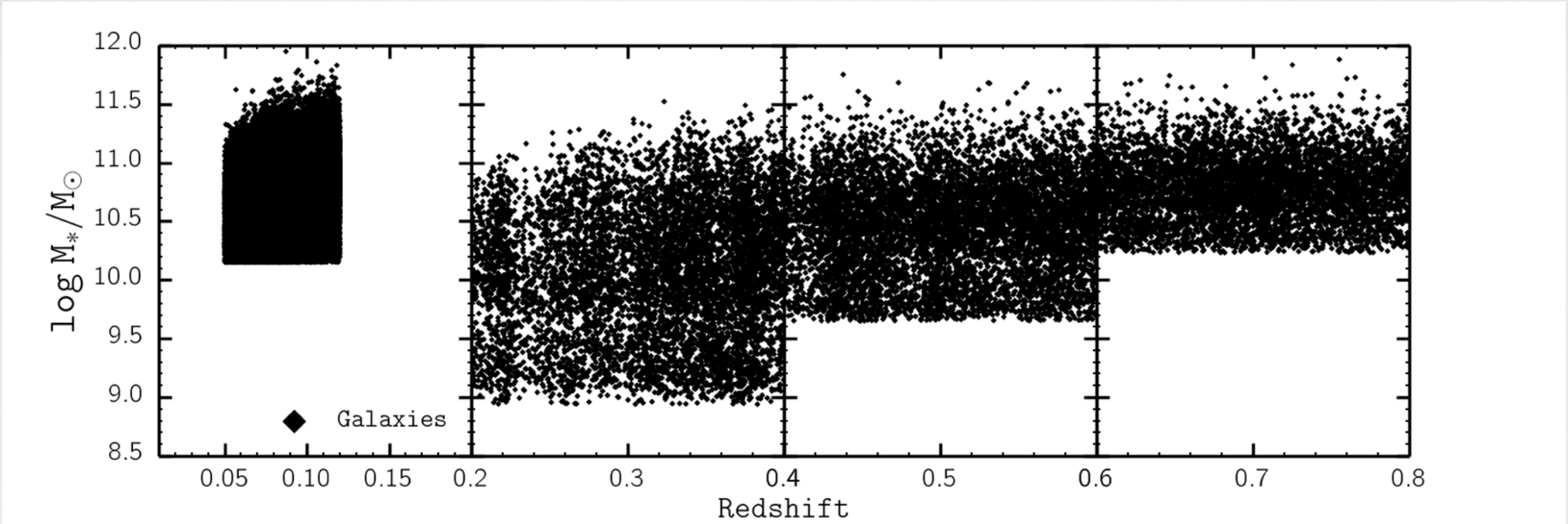
# **PRI**sm **MU**lti-object **S**urvey (**PRIMUS**)

We restrict our **PRIMUS** sample to five fields with ***GALEX* UV** and ***Spitzer*/IRAC imaging** for a total of ~5.5 deg$^2$.

Using the broad wavelength photometry we apply ***iSEDfit*** to calculate **stellar mass and SFR** for our galaxies. (Moustakas et al. 2013)

# Sample Selection

We construct a **stellar mass complete** galaxy sample from the data



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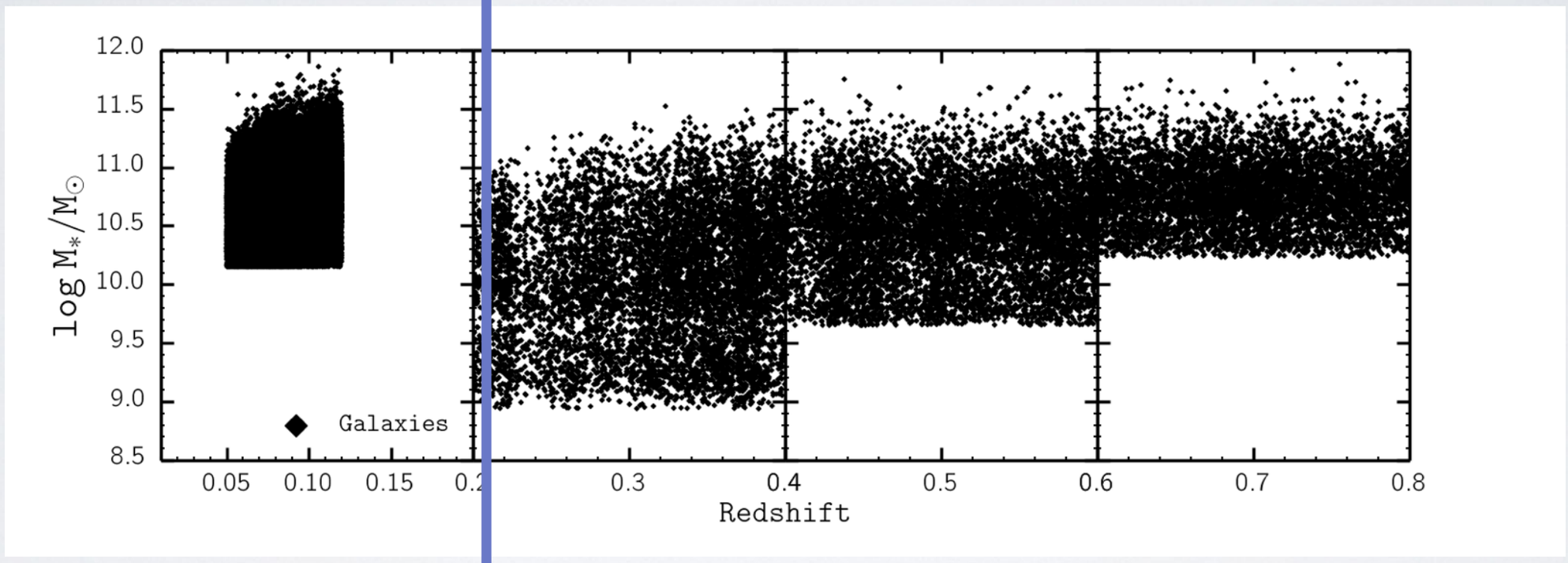


**SDSS-*GALEX***

$M_* > 10^{10.2} M_{sun}$

mass-to-light ratio

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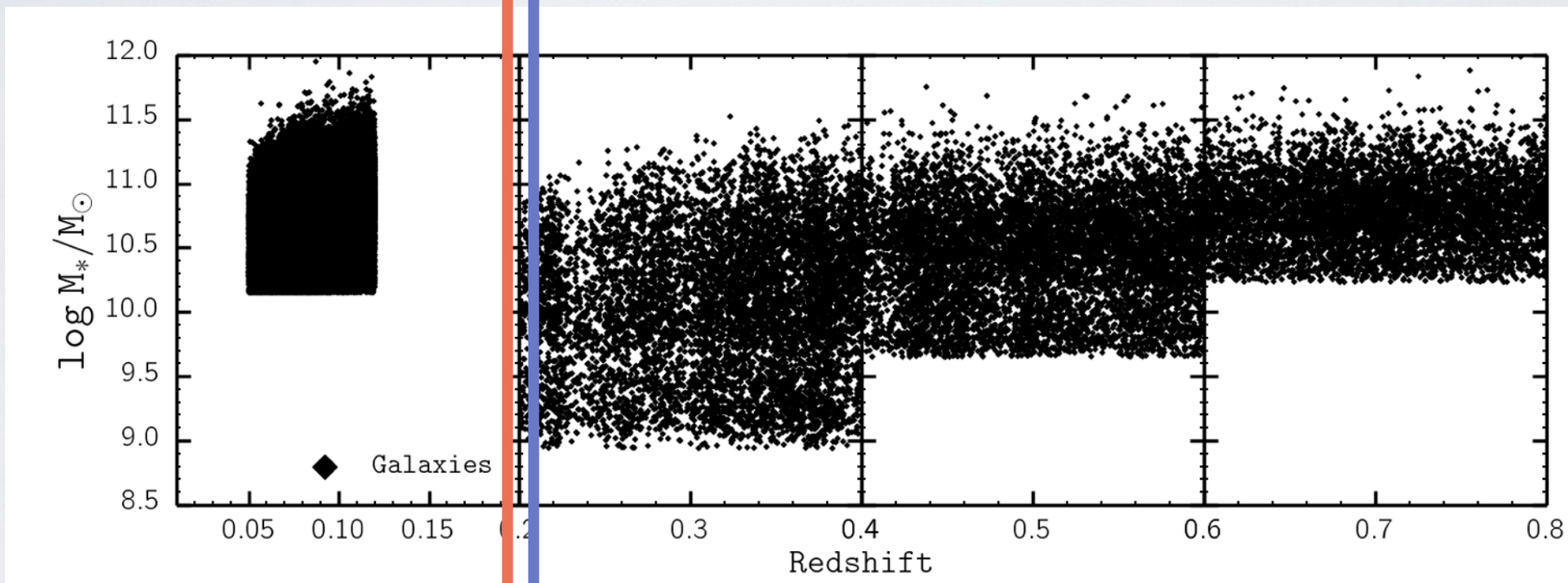


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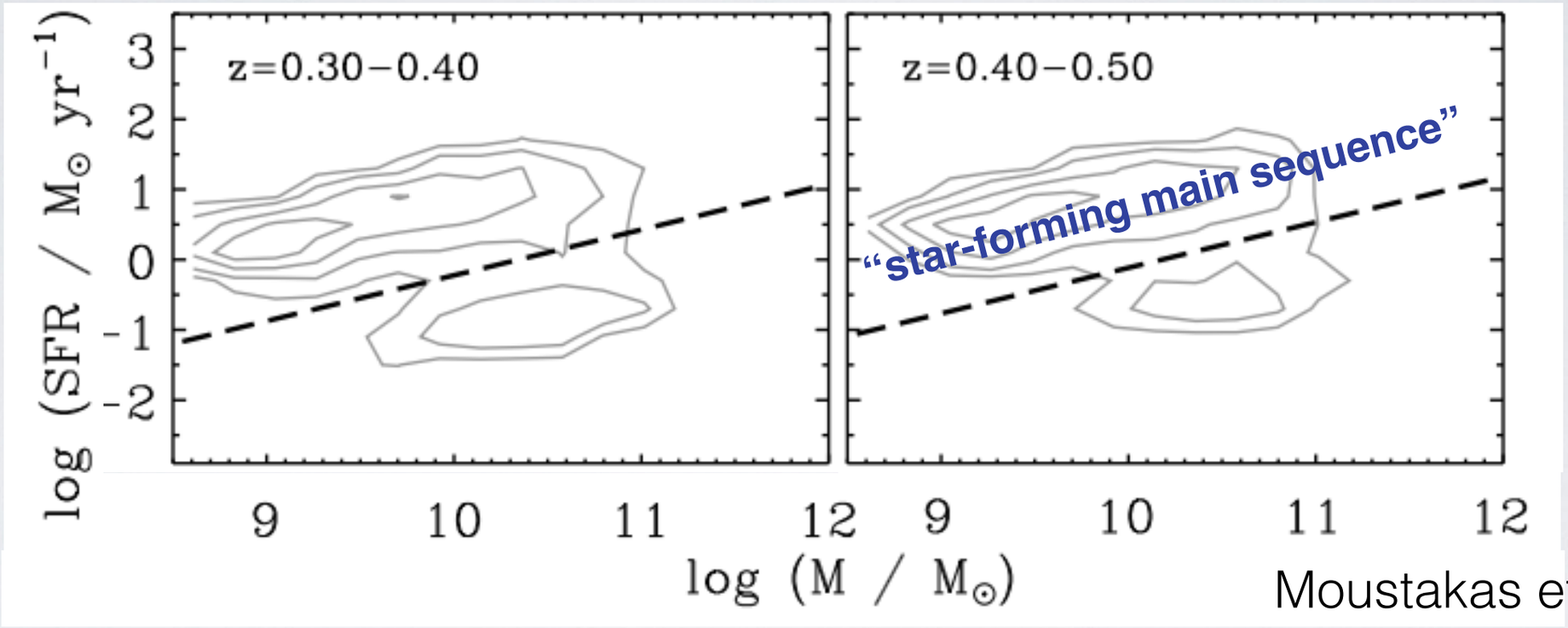
**PRIMUS**

from Moustakas et al.(2013)

| Redshift Range | COSMOS | XMM-SXDS | XMM-CFHTLS | CDFS | ELAIS-S1 |
|---|---|---|---|---|---|
| | | | All | | |
| 0.20 – 0.30 | 8.73 | 8.86 | 8.95 | 9.62 | 9.70 |
| 0.30 – 0.40 | 9.14 | 9.23 | 9.23 | 9.87 | 9.99 |
| 0.40 – 0.50 | 9.51 | 9.58 | 9.51 | 10.10 | 10.26 |
| 0.50 – 0.65 | 9.92 | 9.97 | 9.87 | 10.37 | 10.56 |
| 0.65 – 0.80 | 10.33 | 10.38 | 10.31 | 10.65 | 10.87 |
| 0.80 – 1.00 | 10.71 | 10.78 | 10.83 | 10.94 | 11.17 |

# Classification




Moustakas et al. (2013)

Galaxies are classified as **star-forming** or **quiescent** based on the evolution of the *star-forming main sequence*.

$$log(\mathrm{SFR}) = -0.49 + 0.65\ log(\mathcal{M} - 10) + 1.07(z - 0.1)$$

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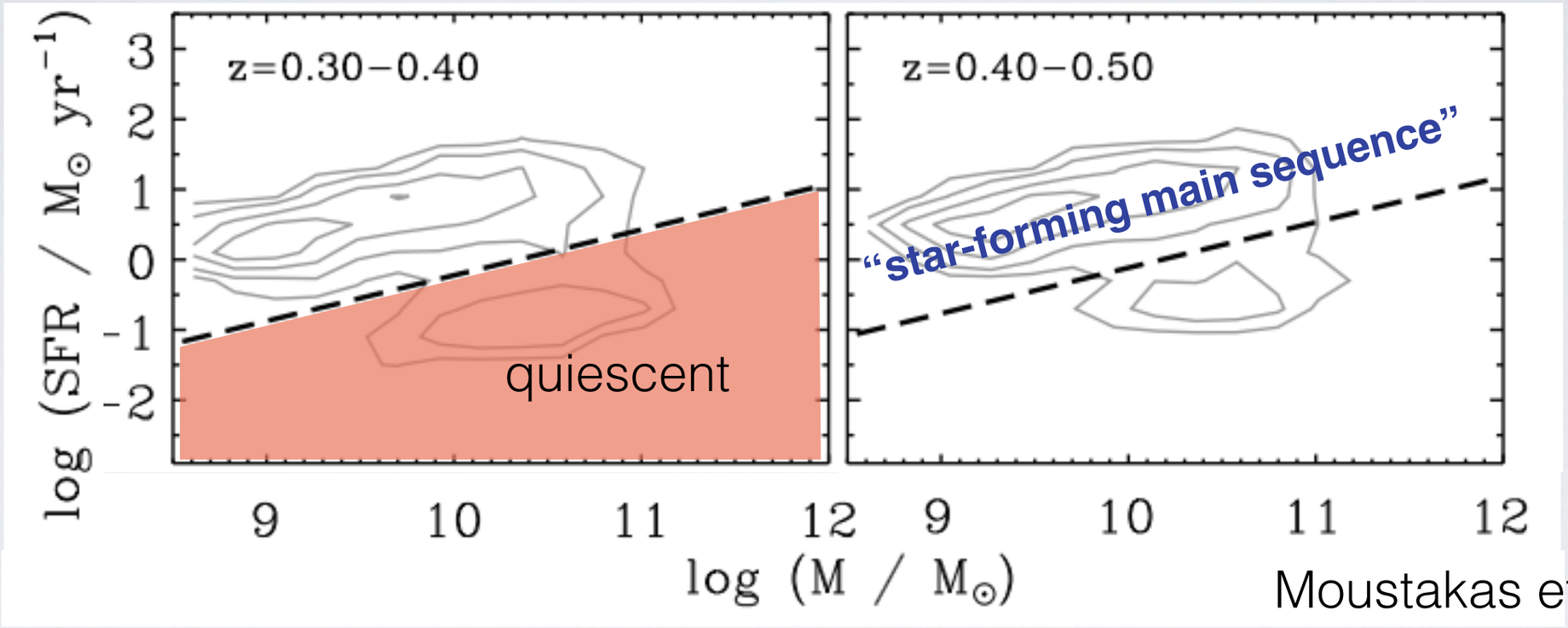


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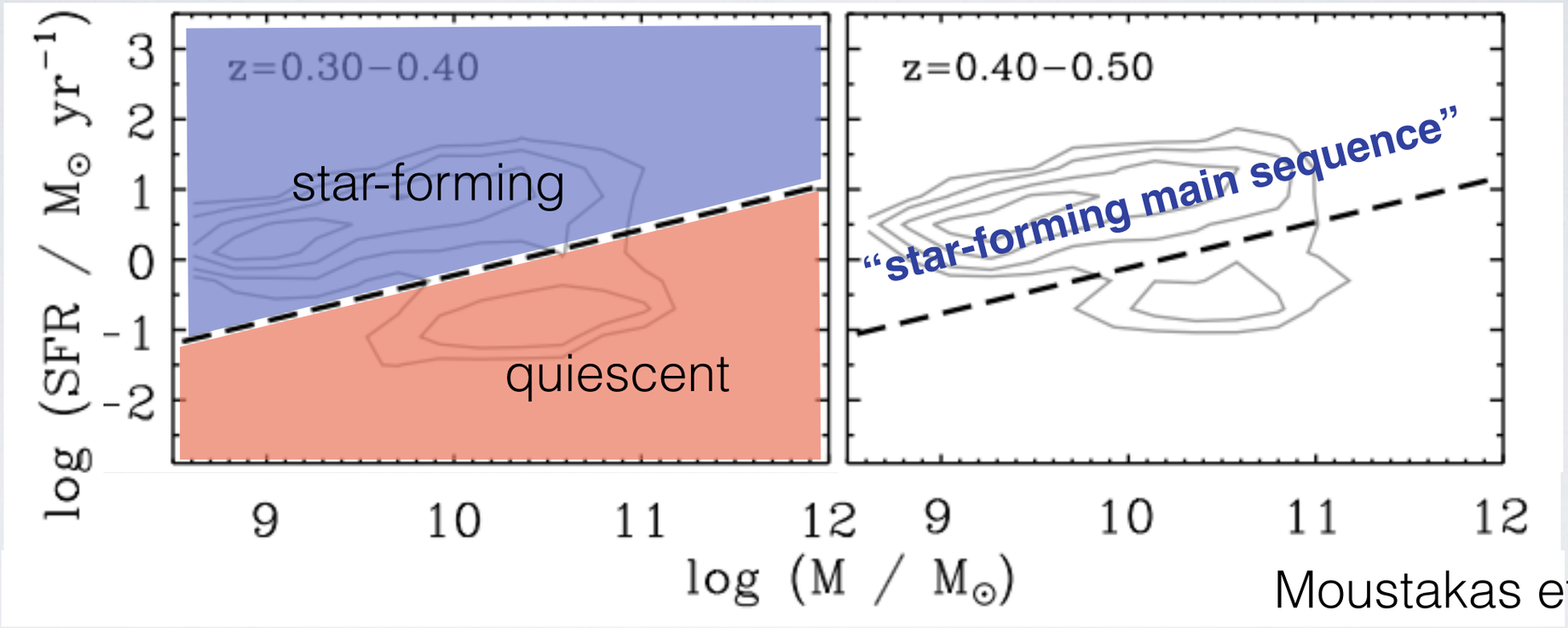


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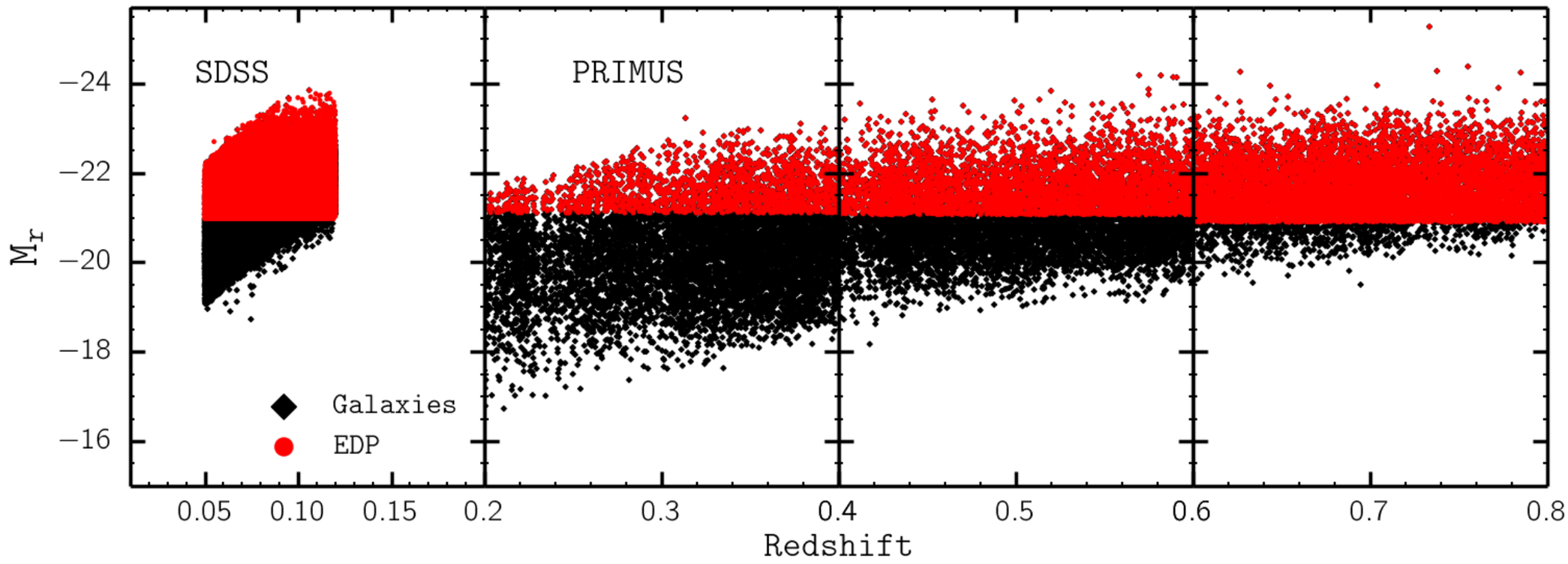
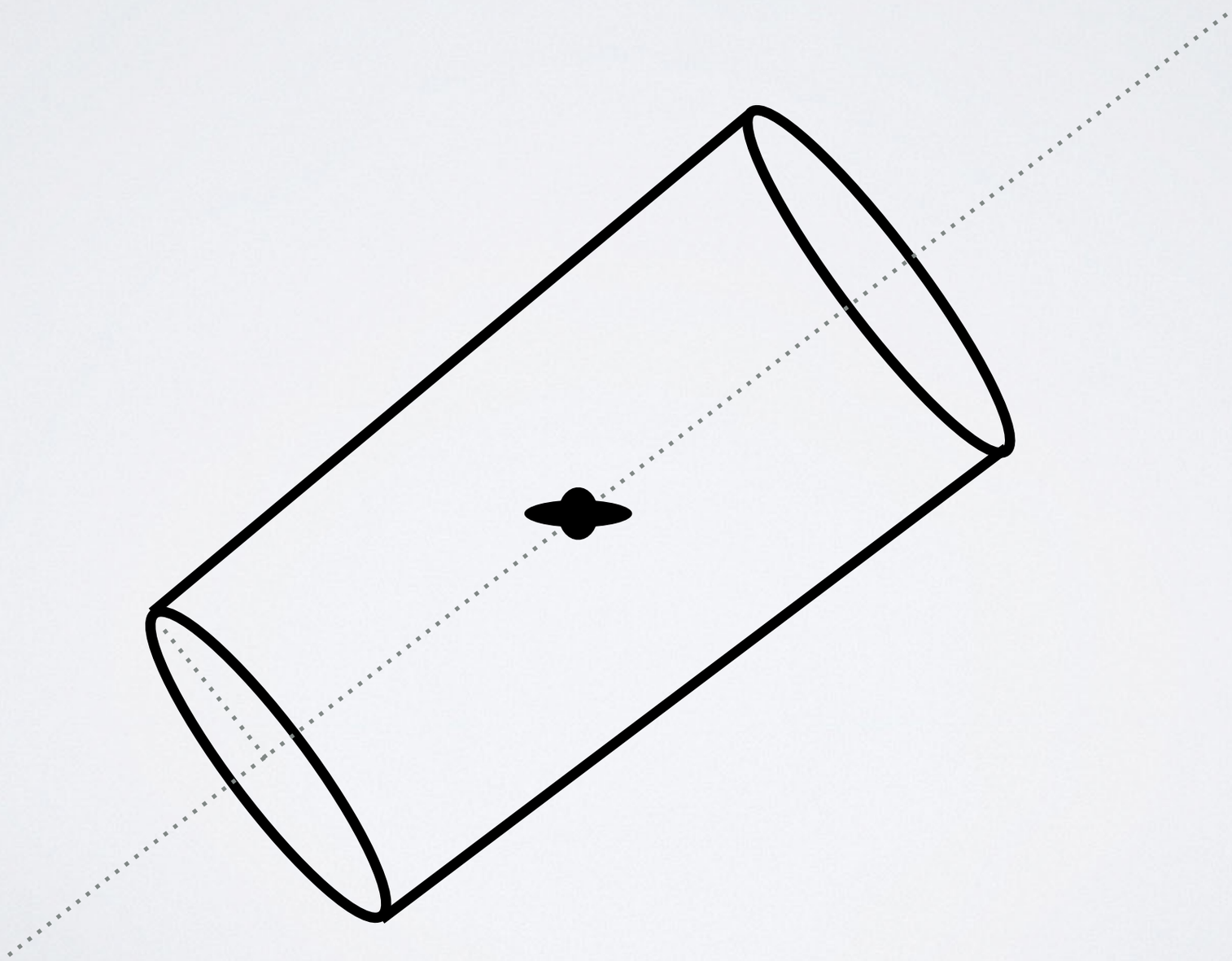
# **E**nvironment **D**efining **P**opulation




- Construct a **volume limited EDP with absolute magnitude ($M_r$) cut-offs** selected so that the number density at all redshift bins are equal. (Behroozi et al. 2013; Leja et al. 2013)

# Galaxy Environment

- Define environment as the number of EDP galaxies within a **fixed cylindrical aperture** around target galaxy.



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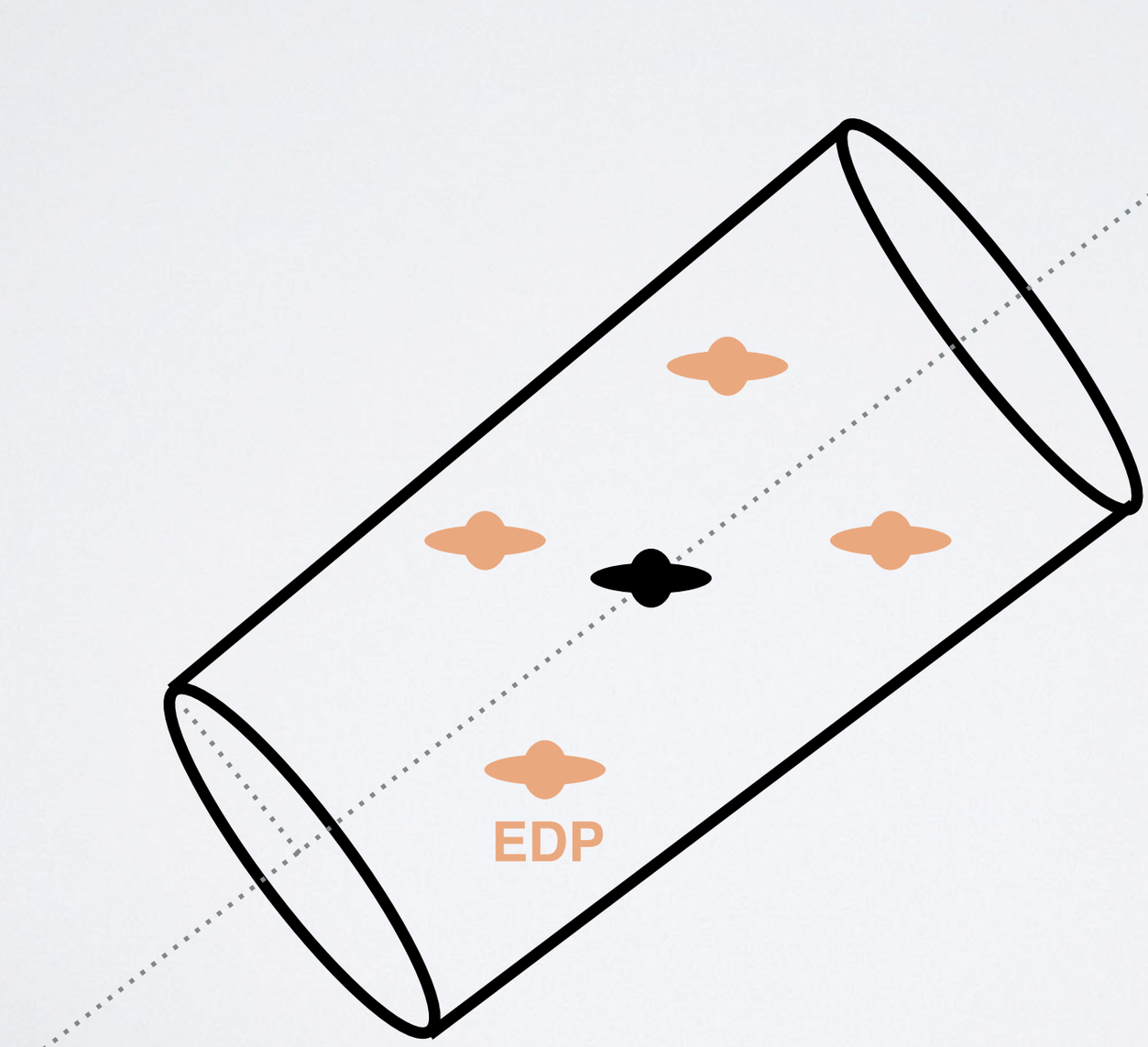

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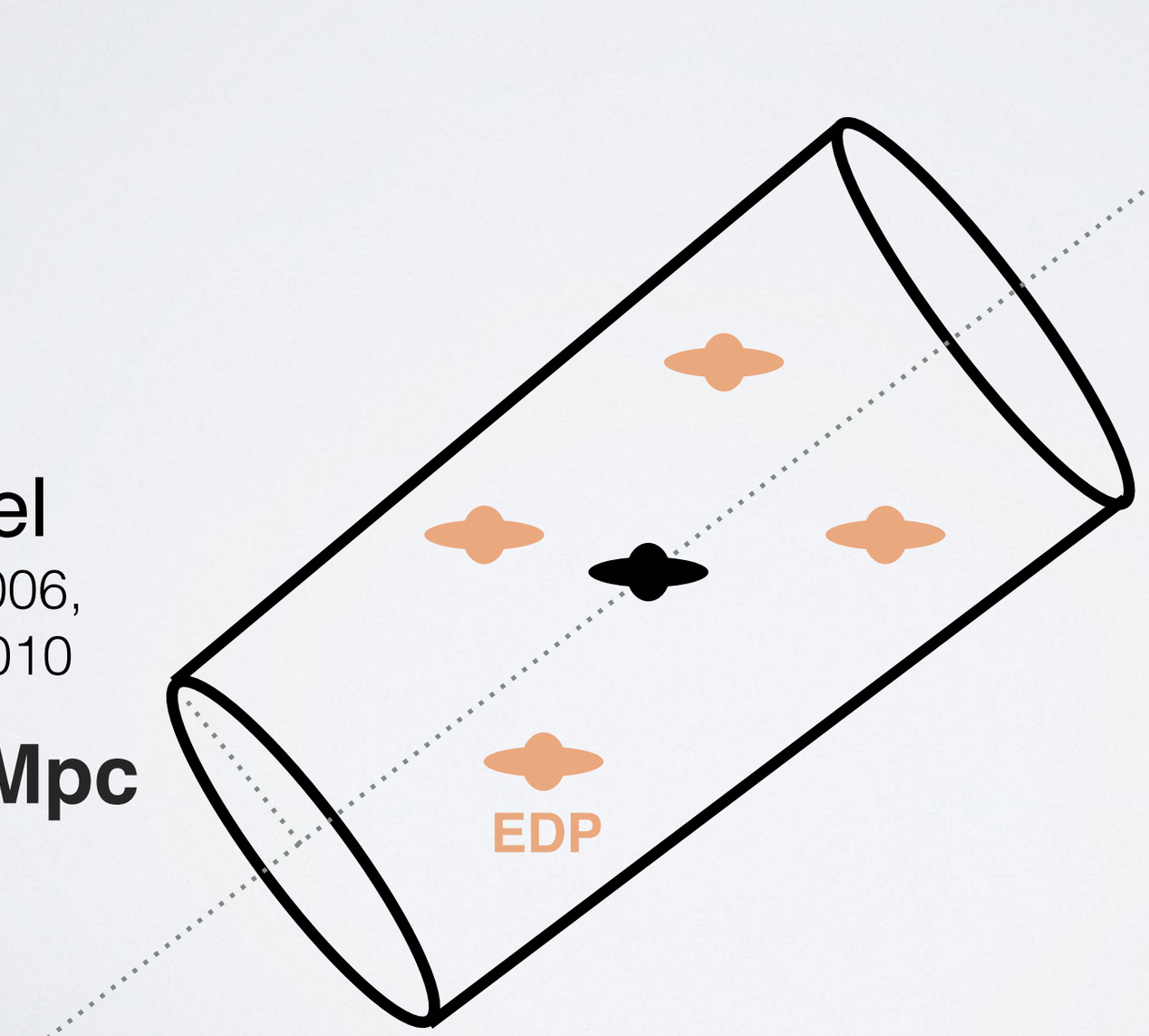


halo model

Blanton et al. 2006,
Wilman et al. 2010

**R = 2.5 Mpc**

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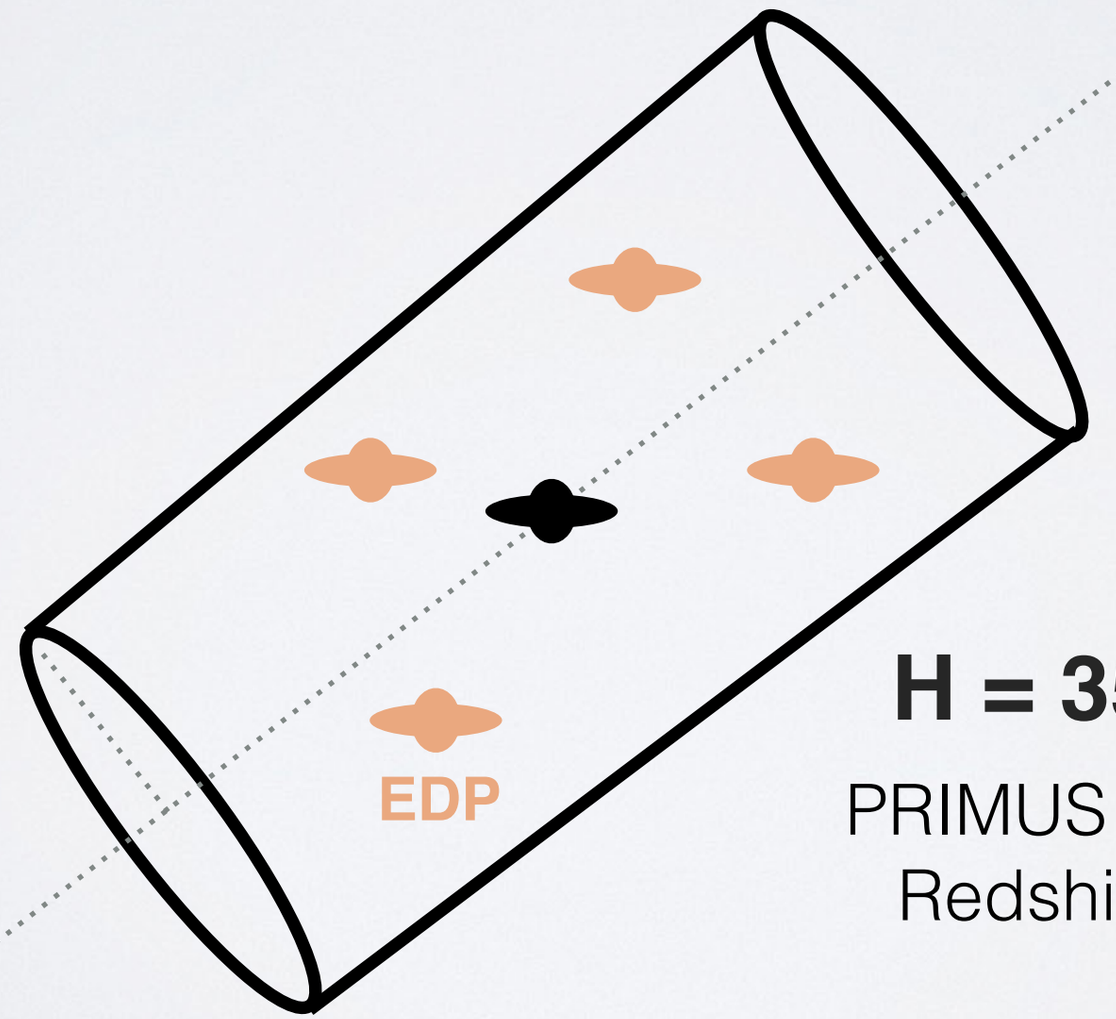



halo model

Blanton et al. 2006,
Wilman et al. 2010

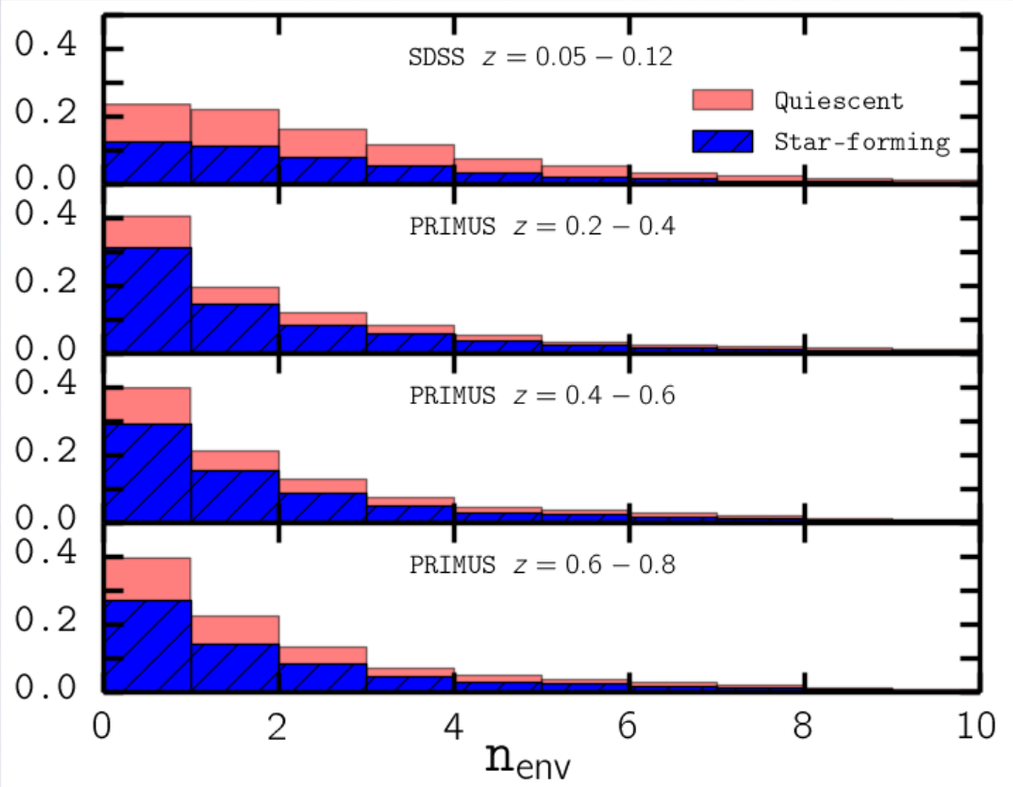
**R = 2.5 Mpc**

**H = 35 Mpc**

PRIMUS redshift uncertainties
Redshift Space Distortions

# Final Sample

- After the stellar mass completeness limits and the edge-cuts we have …




| | $n_{env}$ | $N_{gal}$ Quiescent | $N_{gal}$ Star-Forming |
|---|---|---|---|
| $0.05 < z < 0.12$ | all | **63,417** | |
| $0.2 < z < 0.4$ | all | 1668 | 2964 |
| $0.4 < z < 0.6$ | all | **13,734** | |
| $0.6 < z < 0.8$ | all | | |
| Total | | 77151 | |

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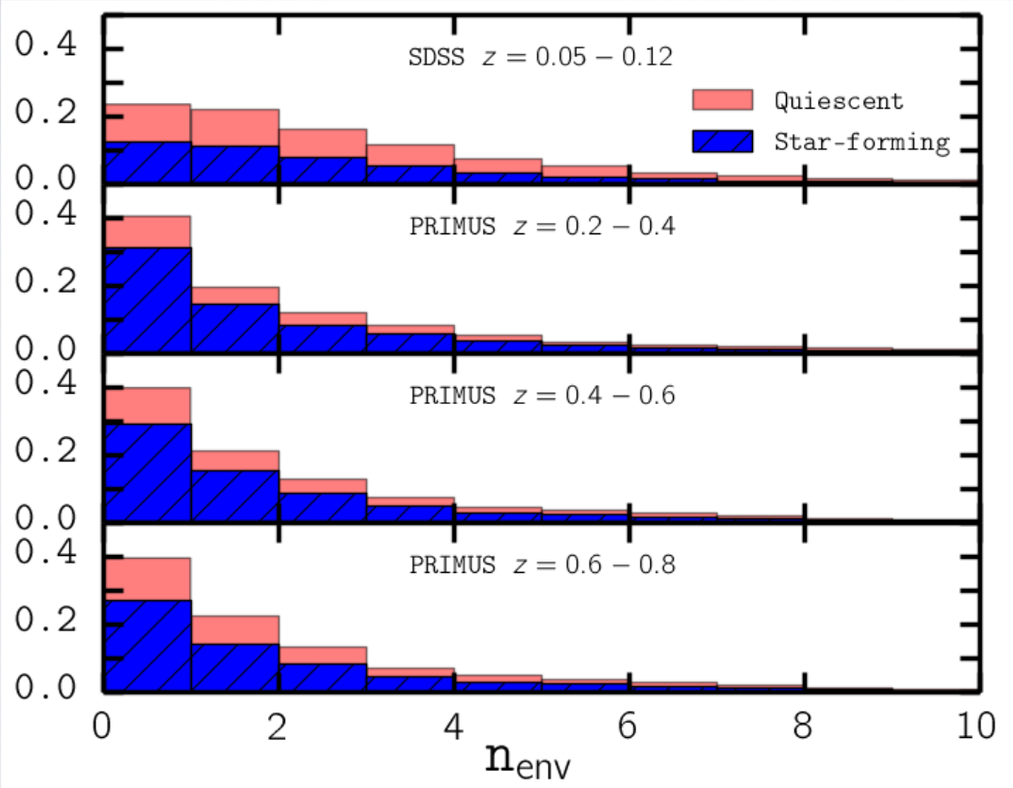


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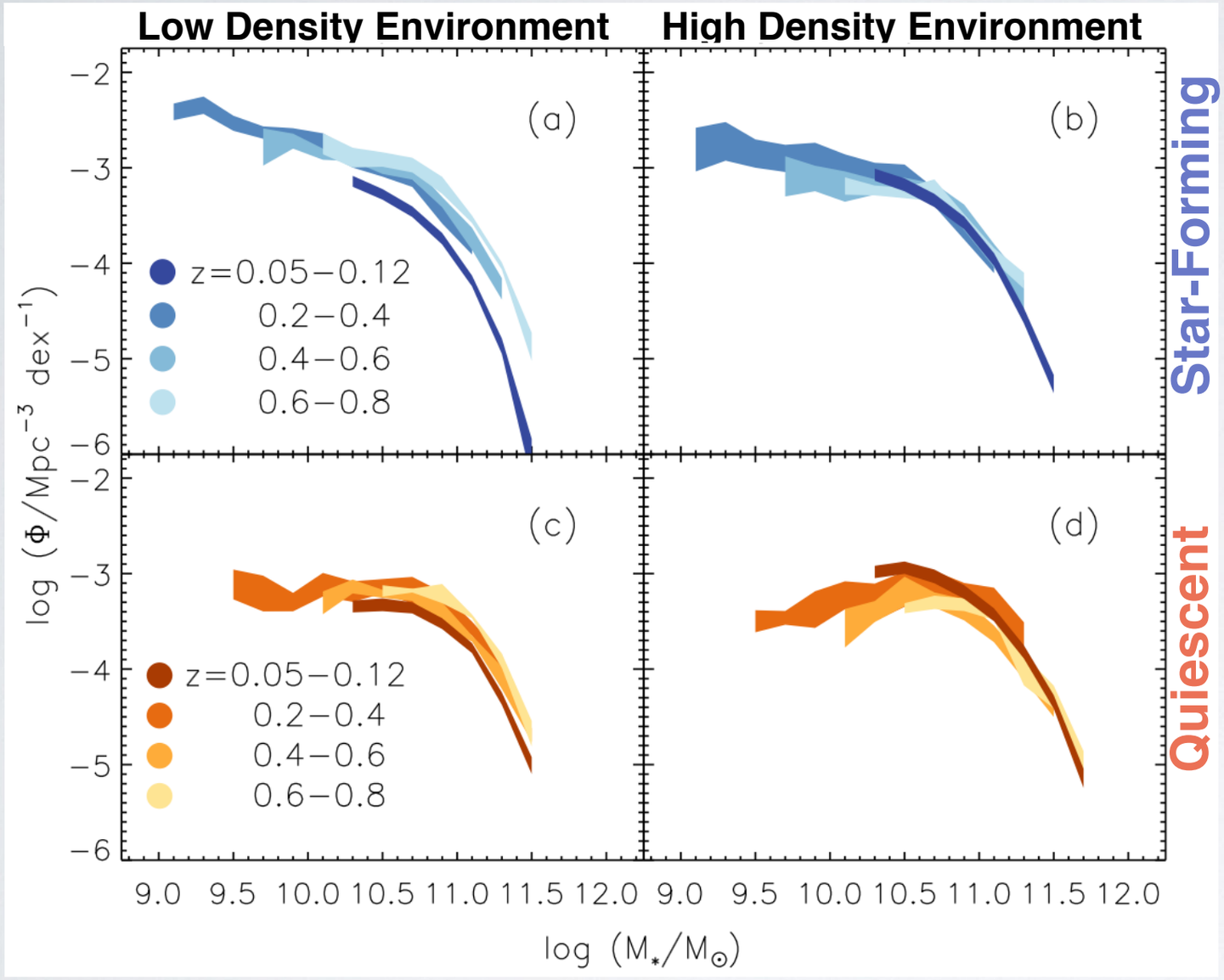
Using the

***M**, *z*, environment and star-forming/quiescent classification**

of our galaxies, we construct …

# Stellar Mass Function




Over cosmic time …

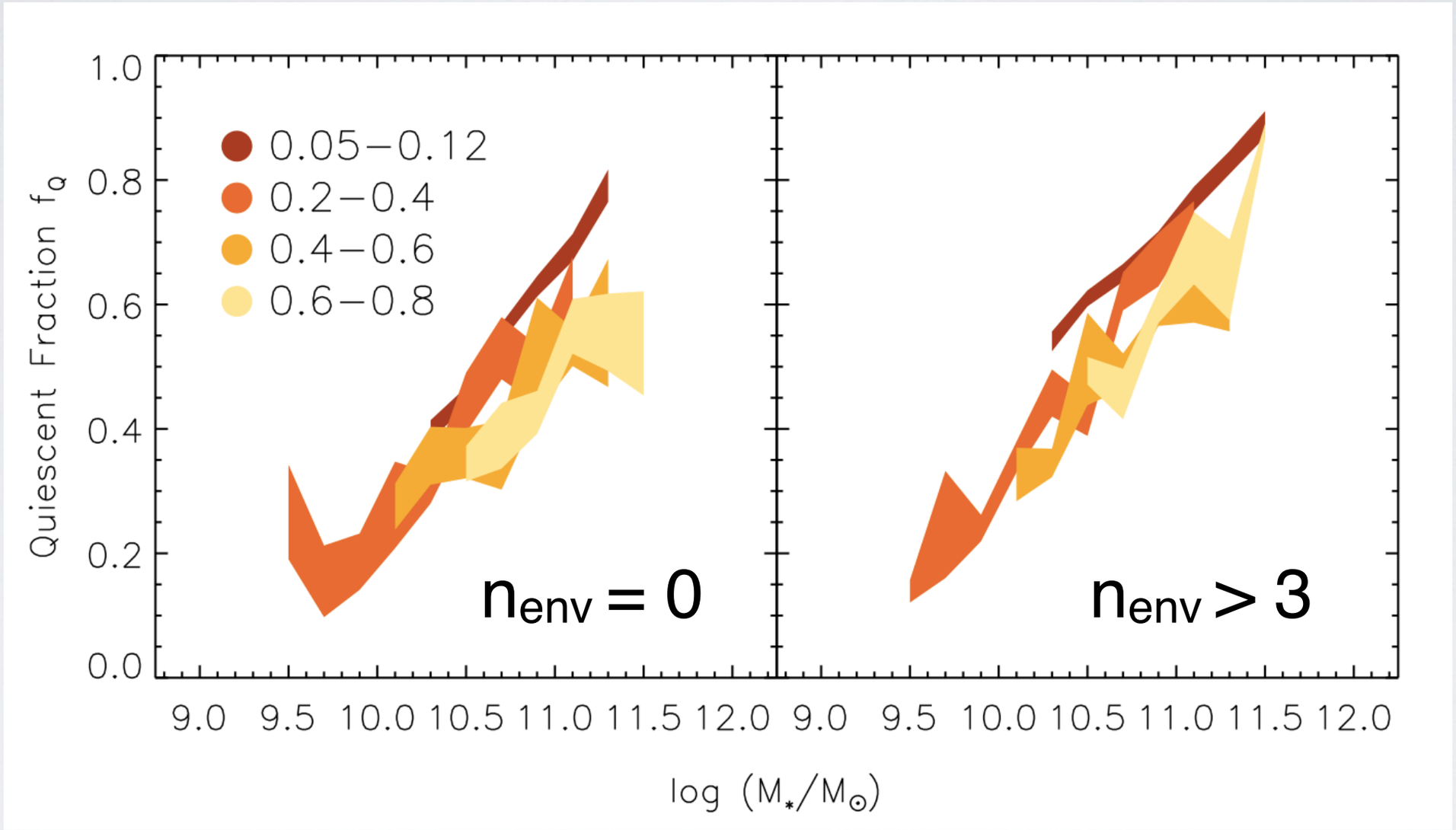
- **Star-Forming + Low Env** decreases significantly in the high mass end
- **Star-Forming + High Env** increases in SMF below the knee
- **Quiescent + Low Env** decreases at higher masses
- **Quiescent + High Env** increases significantly at lower masses

$$\Phi(log\ \mathcal{M})\Delta(log\ \mathcal{M}) = \sum_{i=1}^{N} \frac{w_i}{V_{\mathrm{max,avail},i}}$$

From **SMFs** we calculate

$f_Q$( ***Mass***, ***Redshift***, ***Environment*** )

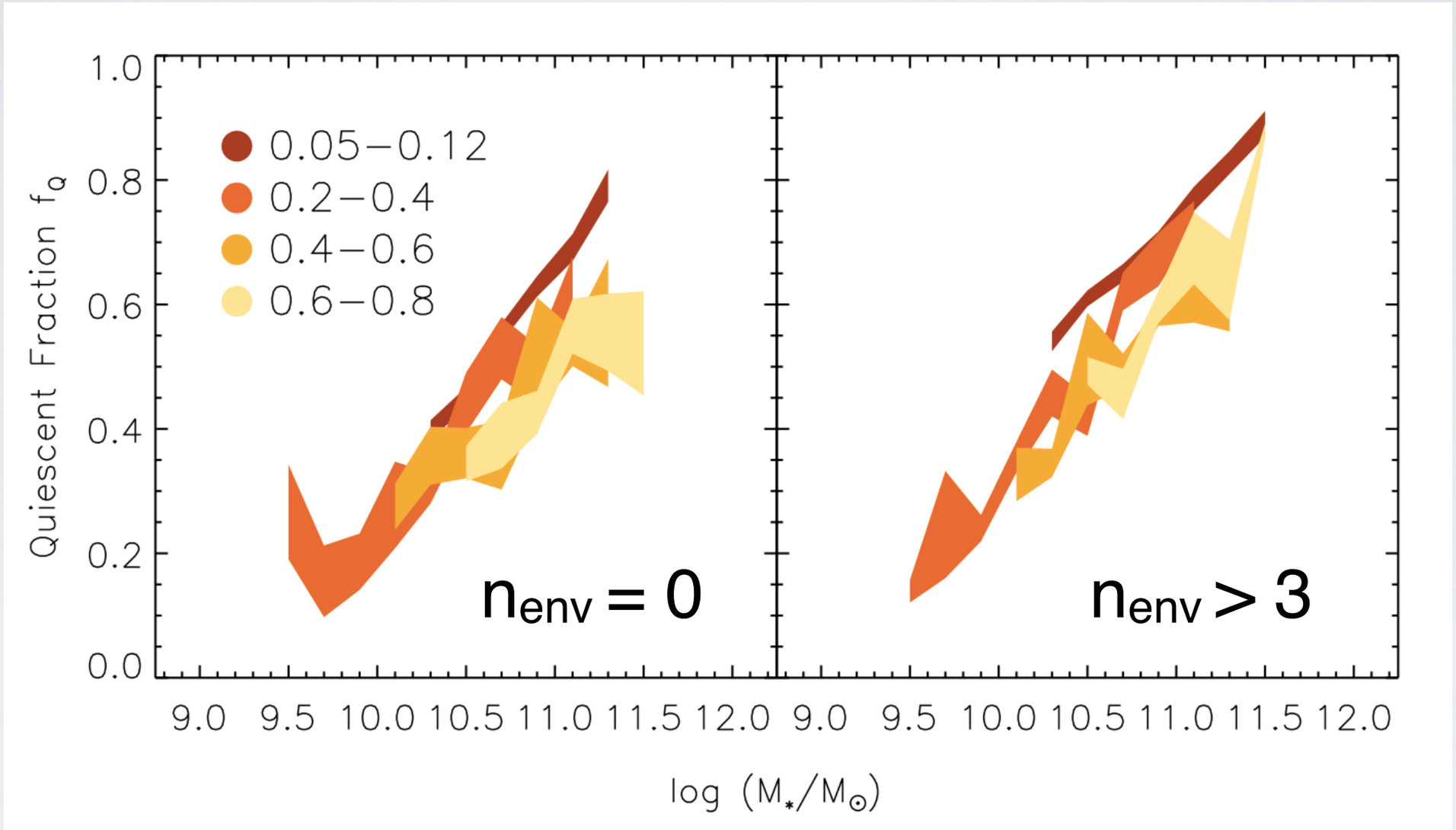
**Low Density Environment** **High Density Environment**



From **SMFs** we calculate

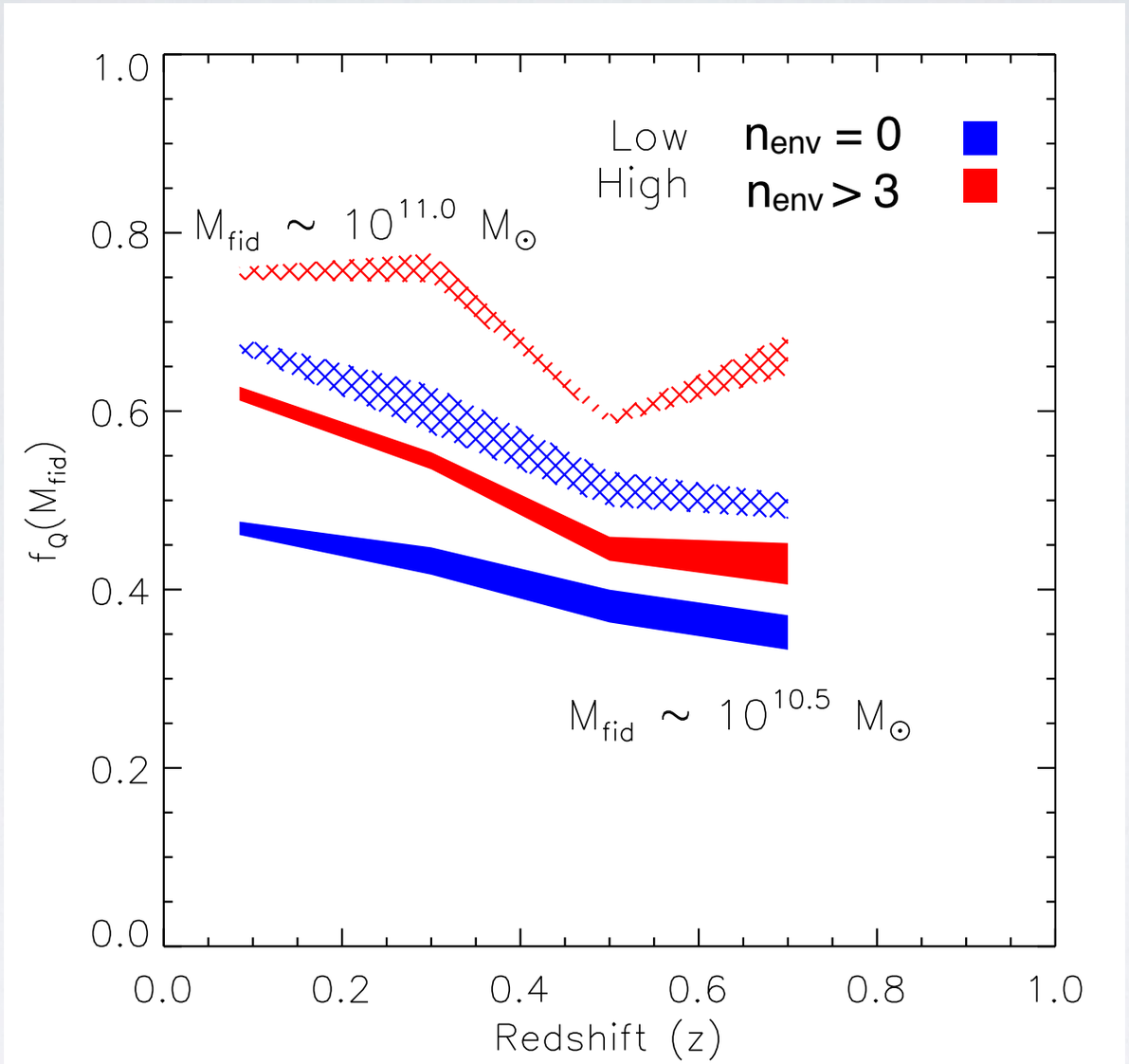
# $f_Q$( *Mass*, *Redshift*, *Environment* )

**Low Density Environment** **High Density Environment**




To better compare the $f_Q$ evolution we fit a power-law parameterization

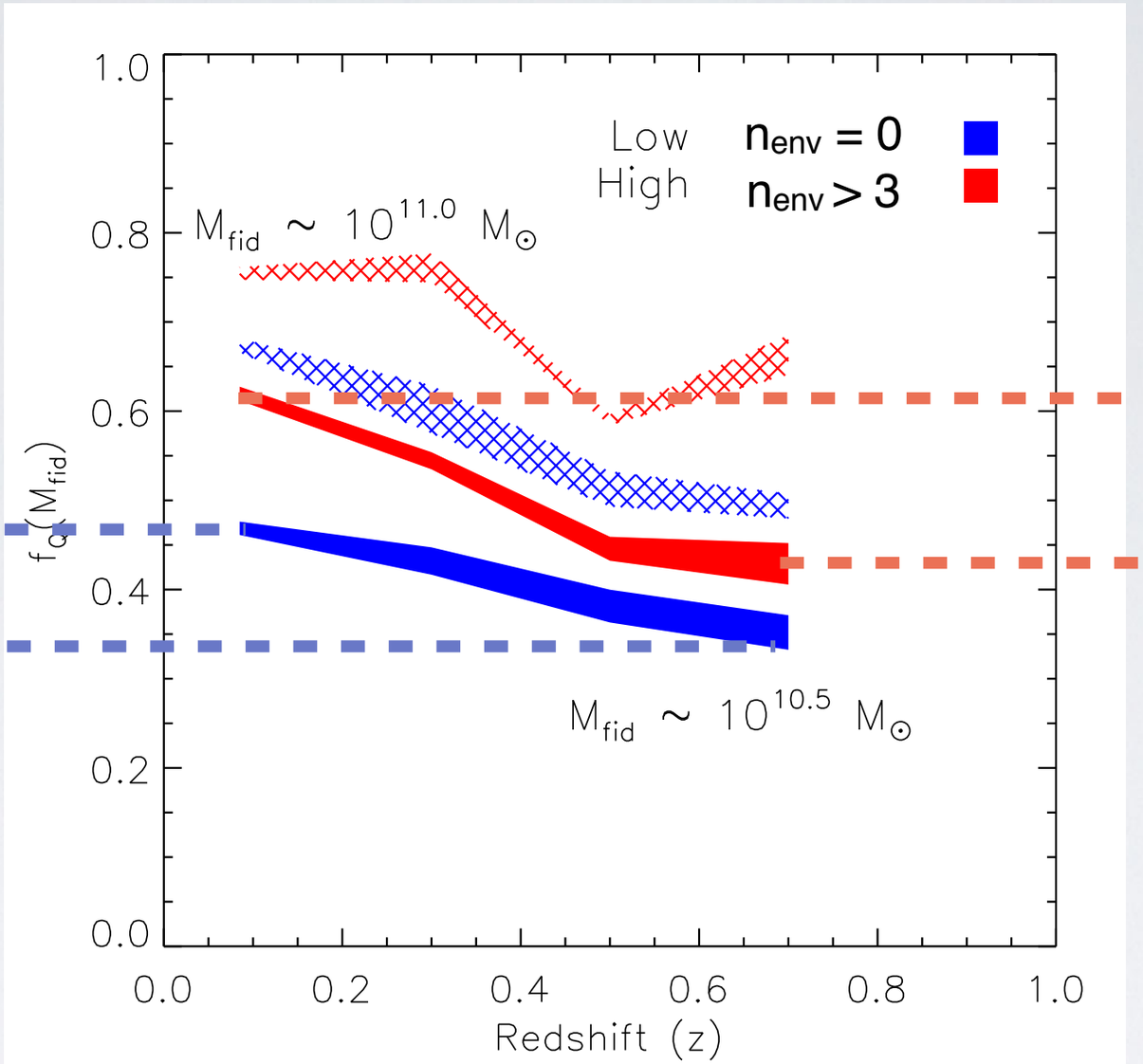
$$f_Q(\mathcal{M}_*) = a \log(\frac{\mathcal{M}_*}{\mathcal{M}_{\rm fid}}) + b$$




Even at low density environments, $n_{env} = 0$, there is ***significant $f_Q$ evolution*** over cosmic time.

**There are environment independent internal mechanisms that are responsible for ending star-formation.**

$\Delta f_{Q,\mathcal{M}_{\rm fid}}^{\rm low} \approx 0.1$




$\Delta f_{Q,\mathcal{M}_{\rm fid}}^{\rm high} \approx 0.12$

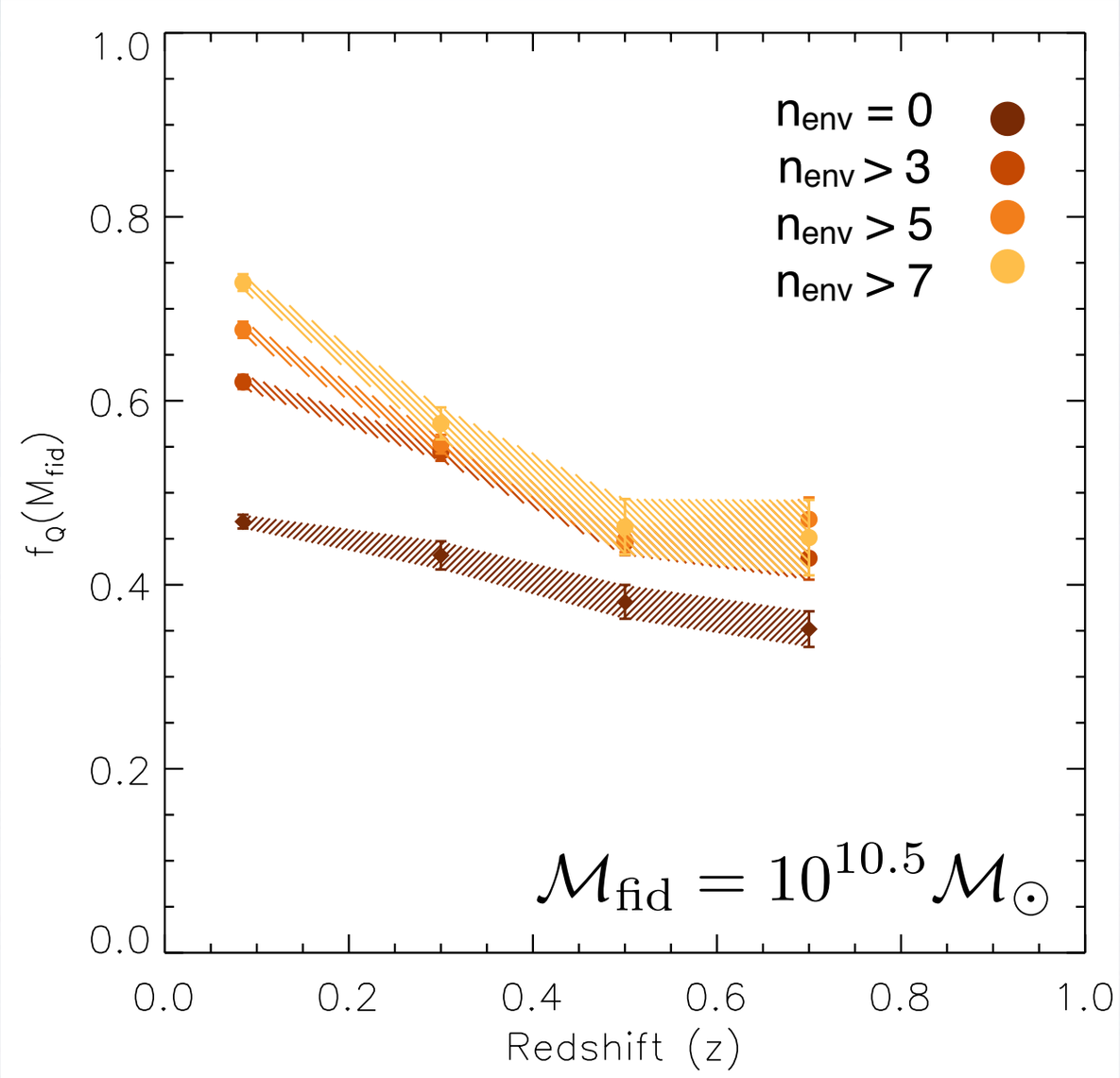
Environmental dependence in the $f_Q$ evolution?

*Is there a significant difference in $f_Q$ evolution between low and high density environments?* ***Possibly ...***

More stringent high environment classifications *increase the overall $f_Q$*

More importantly, purer high environment classification reveals

***evidence for environmental dependence in the $f_Q$ evolution.***




For purest high density environment sample

$$\Delta f_{Q,\mathcal{M}_{\rm fid}}^{\rm high} - \Delta f_{Q,\mathcal{M}_{\rm fid}}^{\rm low} \sim 0.1$$

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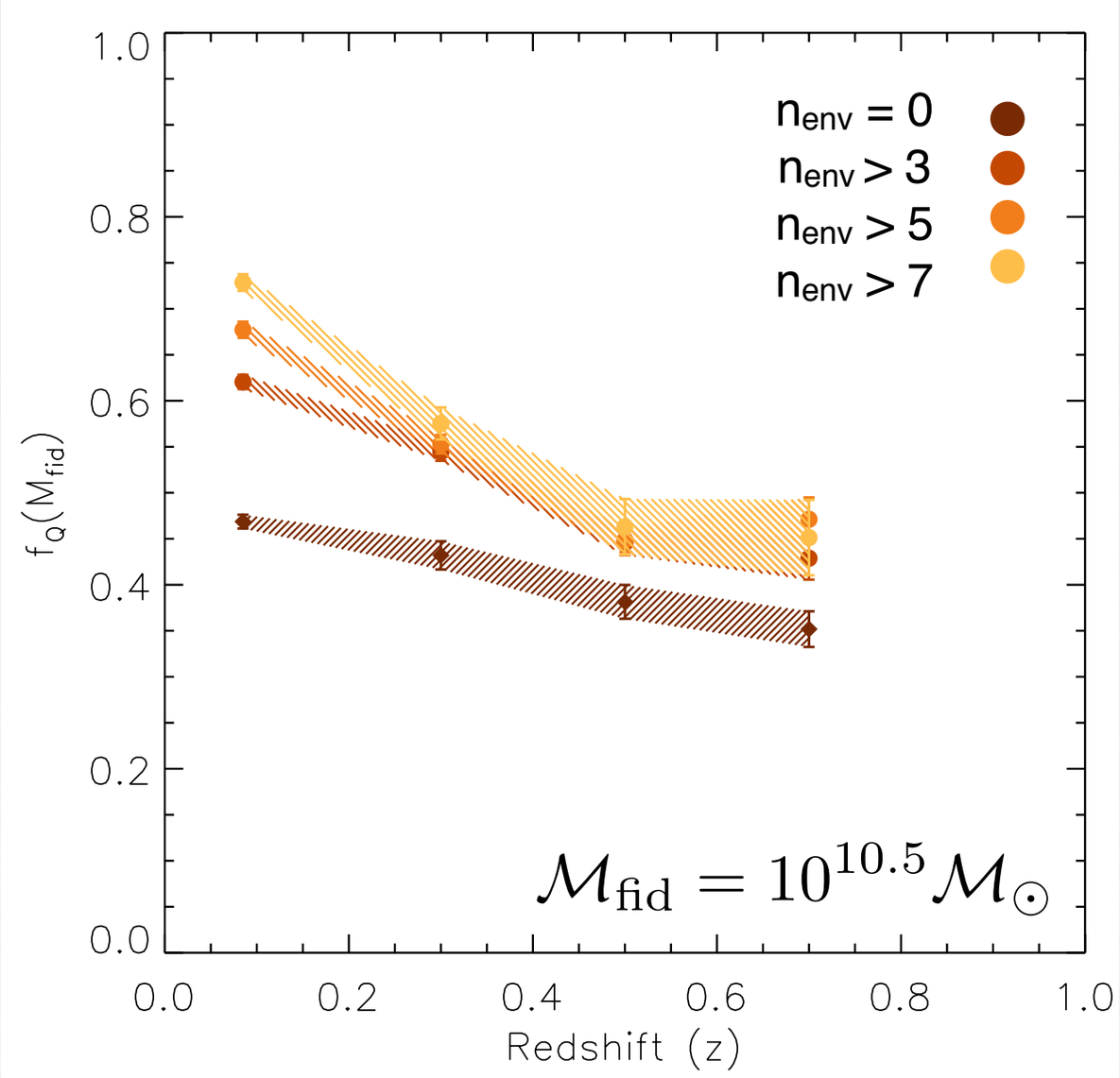
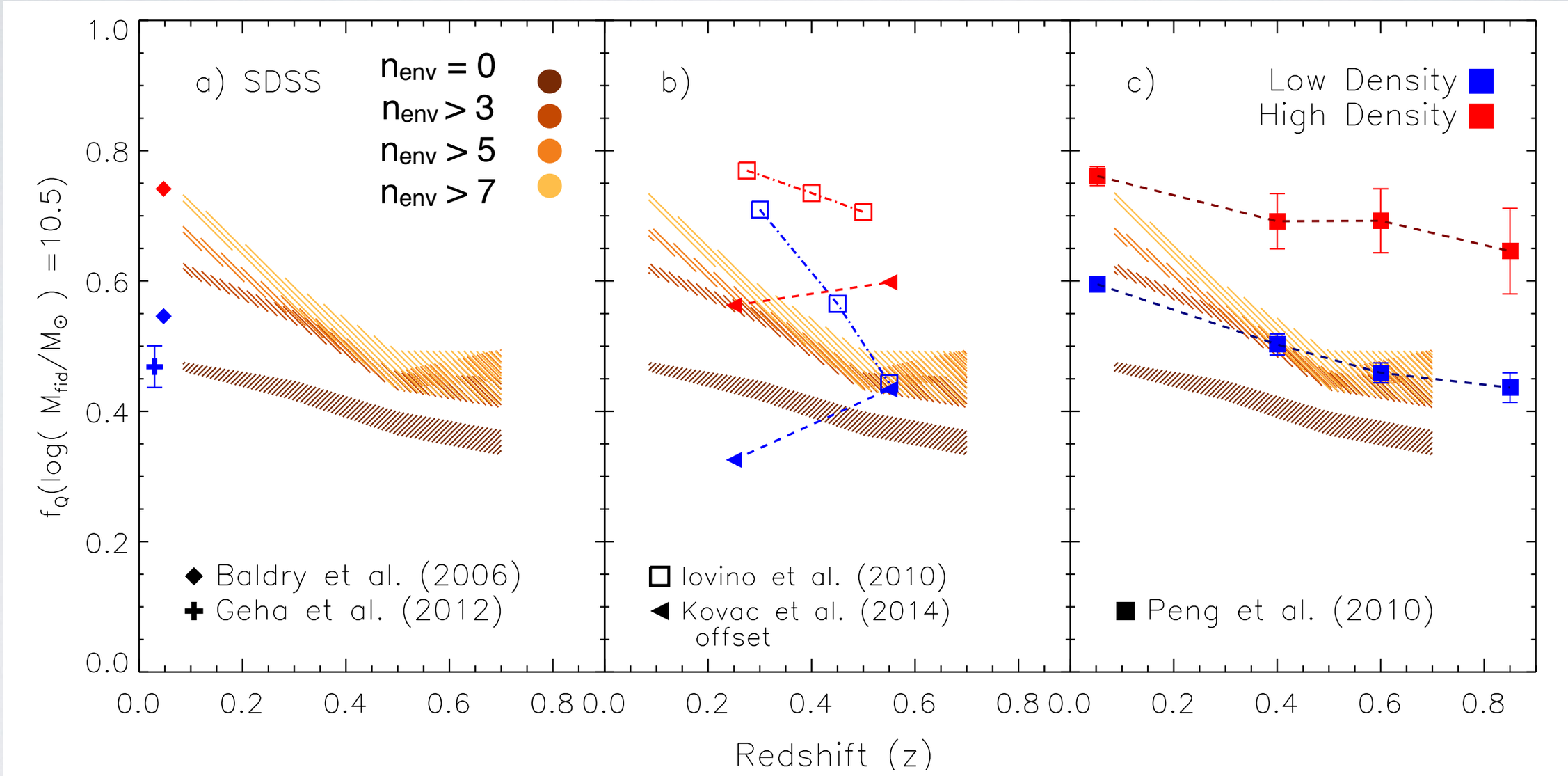


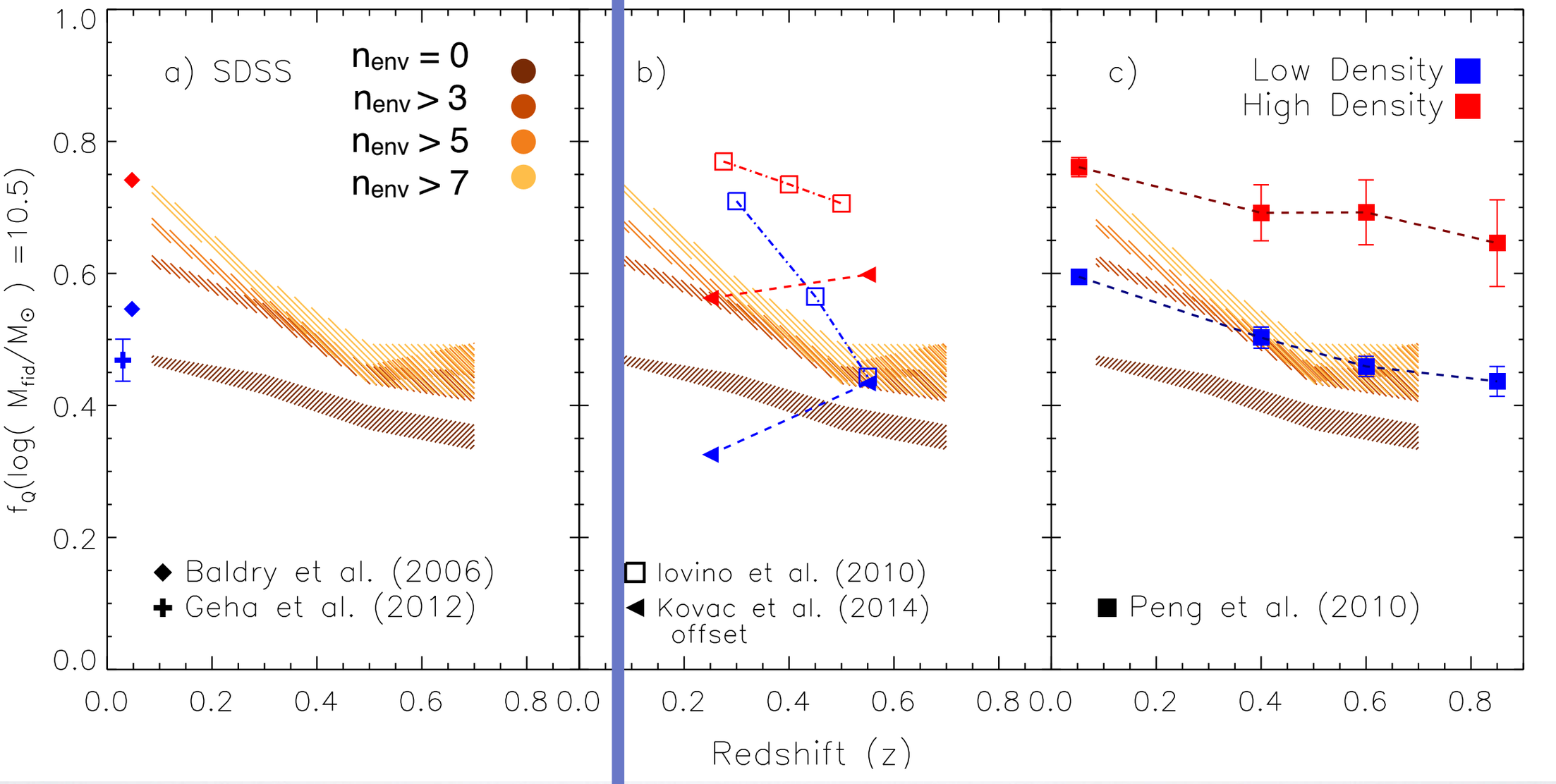

For purest high density environment sample

$$\Delta f_{Q,\mathcal{M}_{\rm fid}}^{\rm high} - \Delta f_{Q,\mathcal{M}_{\rm fid}}^{\rm low} \sim 0.1$$

In addition to internal mechanisms, **in groups and clusters environment-dependent effects contribute to end star-formation**.

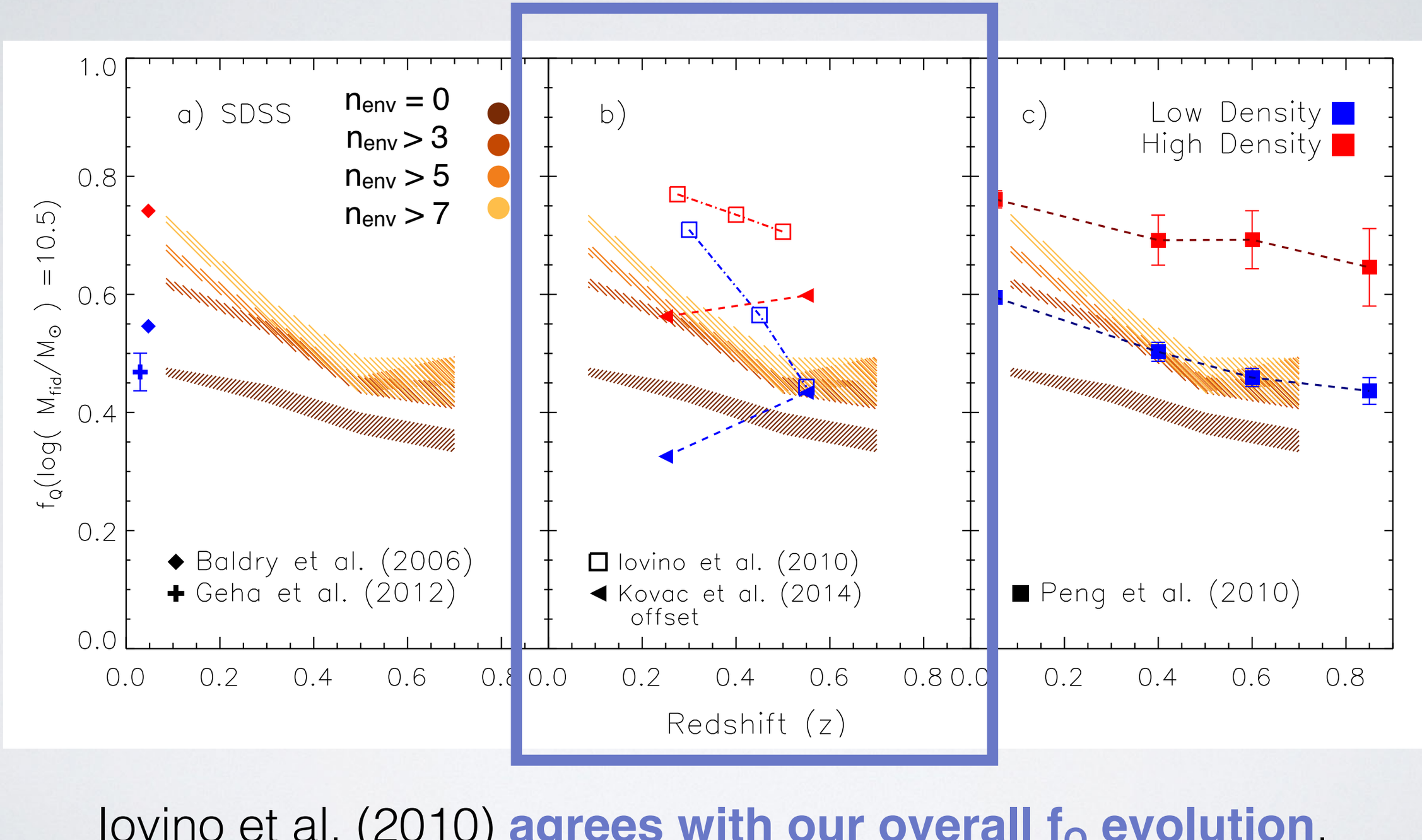

a) SDSS
b)
c)
$n_{env} = 0$
$n_{env} > 3$
$n_{env} > 5$
$n_{env} > 7$
Low Density
High Density
Baldry et al. (2006)
Geha et al. (2012)
Iovino et al. (2010)
Kovac et al. (2014)
offset
Peng et al. (2010)
$f_Q(\log(M_{fid}/M_\odot) = 10.5)$
Redshift (z)
0.0
0.2
0.4
0.6
0.8
1.0

# SDSS




$f_Q$ values show **good agreement** with other SDSS results that use different environment classifications

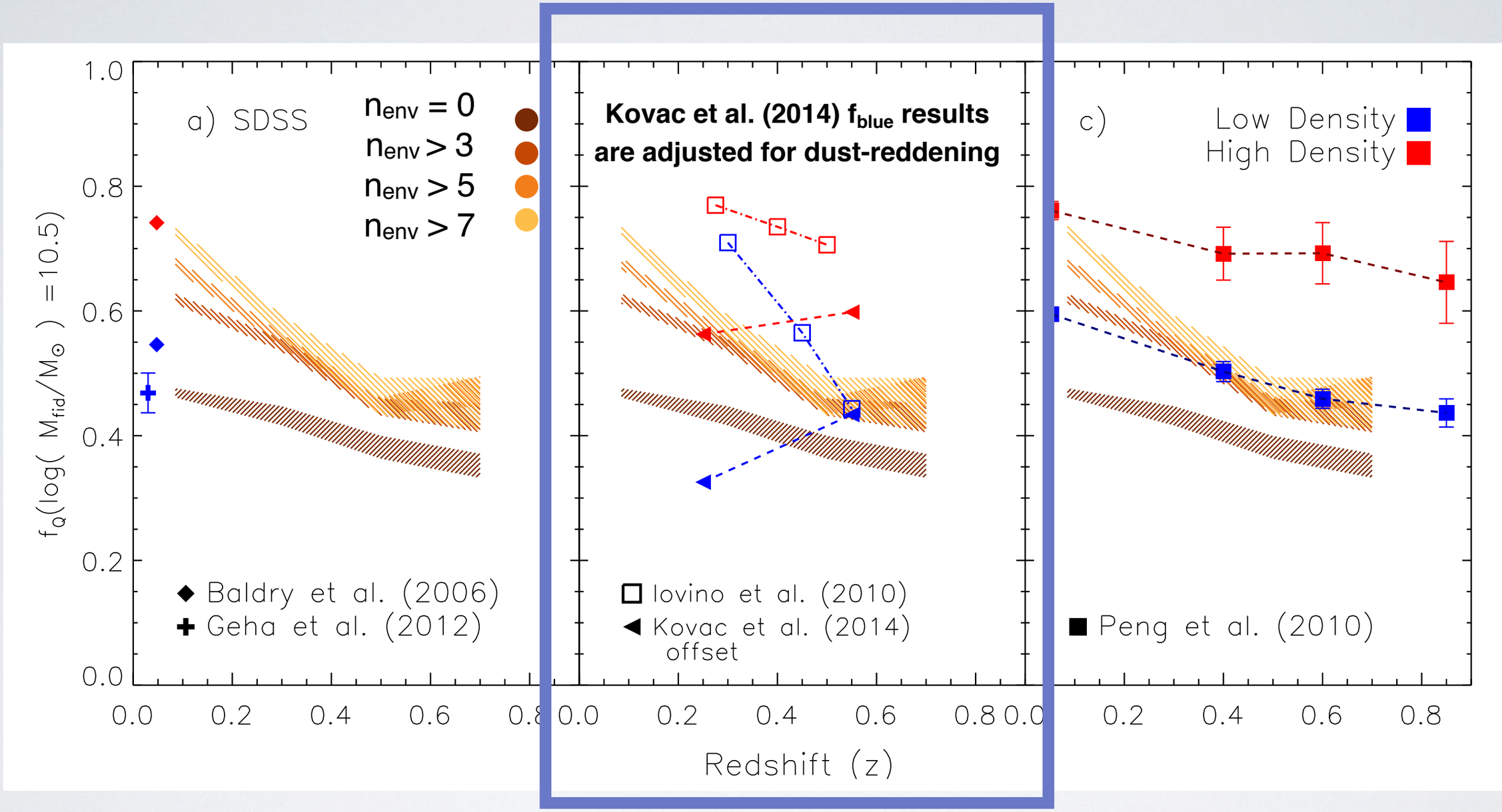
# zCOSMOS




Iovino et al. (2010) **agrees with our overall $f_Q$ evolution**.

But, their **environment dependence is in the opposite direction**.

# zCOSMOS




Kovac et al. (2014) **disagrees with our overall $f_Q$ evolution**.

But, their **environment dependence is in the same direction**.

# Summary

We use a **stellar mass complete sample of 63,417 galaxies from SDSS and 13,734 galaxies PRIMUS** with consistently measured galaxy environments from robust spectroscopic redshifts to calculate

$$f_Q(\ \textit{Mass}, \textit{Redshift}, \textit{Environment}\ )$$

Based on our results,

- ***Environment-independent internal mechanisms are responsible for the cessation of star-formation.***
- ***In groups and clusters, environment dependent effects contribute to the end of star-formation.***

Hahn et al. (submitted) arXiv:1412.7162