

# The Effect of Environmental Quenching on Galaxy Evolution to $z < 2$ , measured by ZFOURGE and CANDELS

## Part 1

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CANDELS meeting

2017 Aug 6

# star-formation — density relation out to $z \sim 1.8$

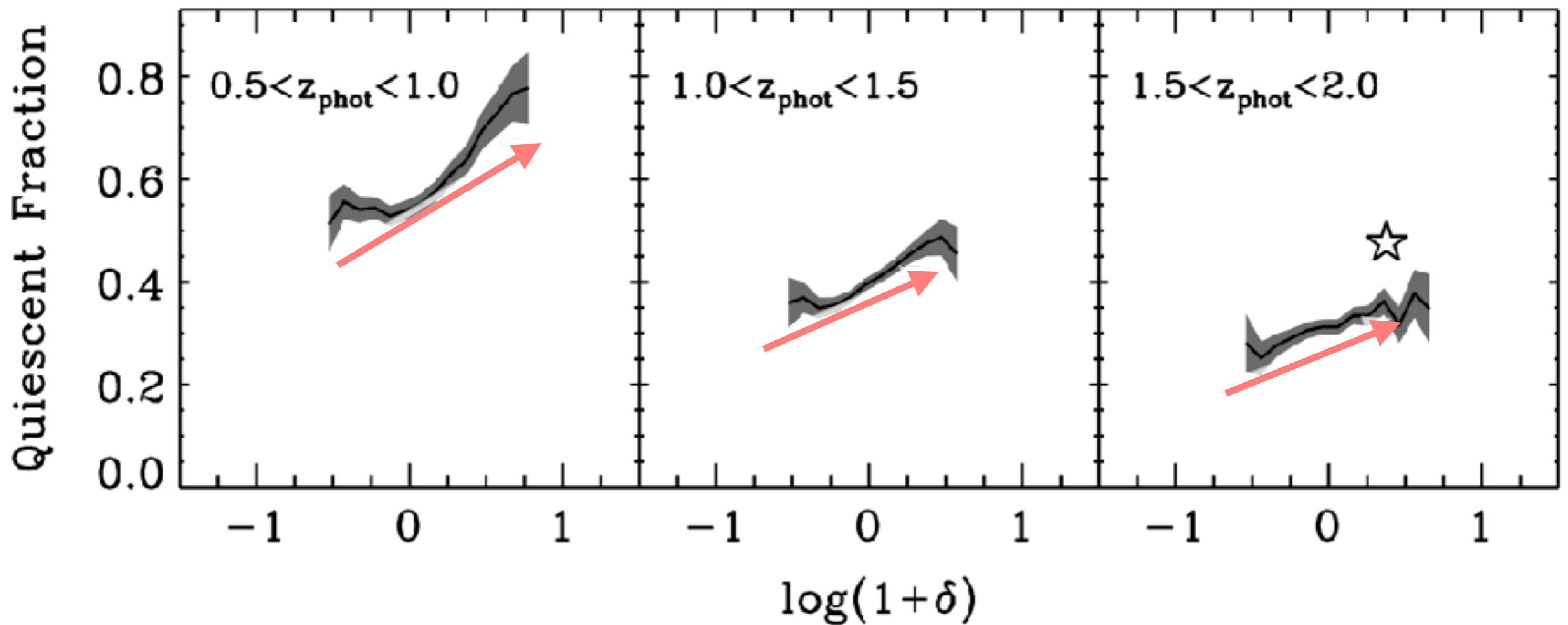
THE ASTROPHYSICAL JOURNAL, 744:88 (12pp), 2012 January 10

doi:10.1088/0004-637X/744/2/88

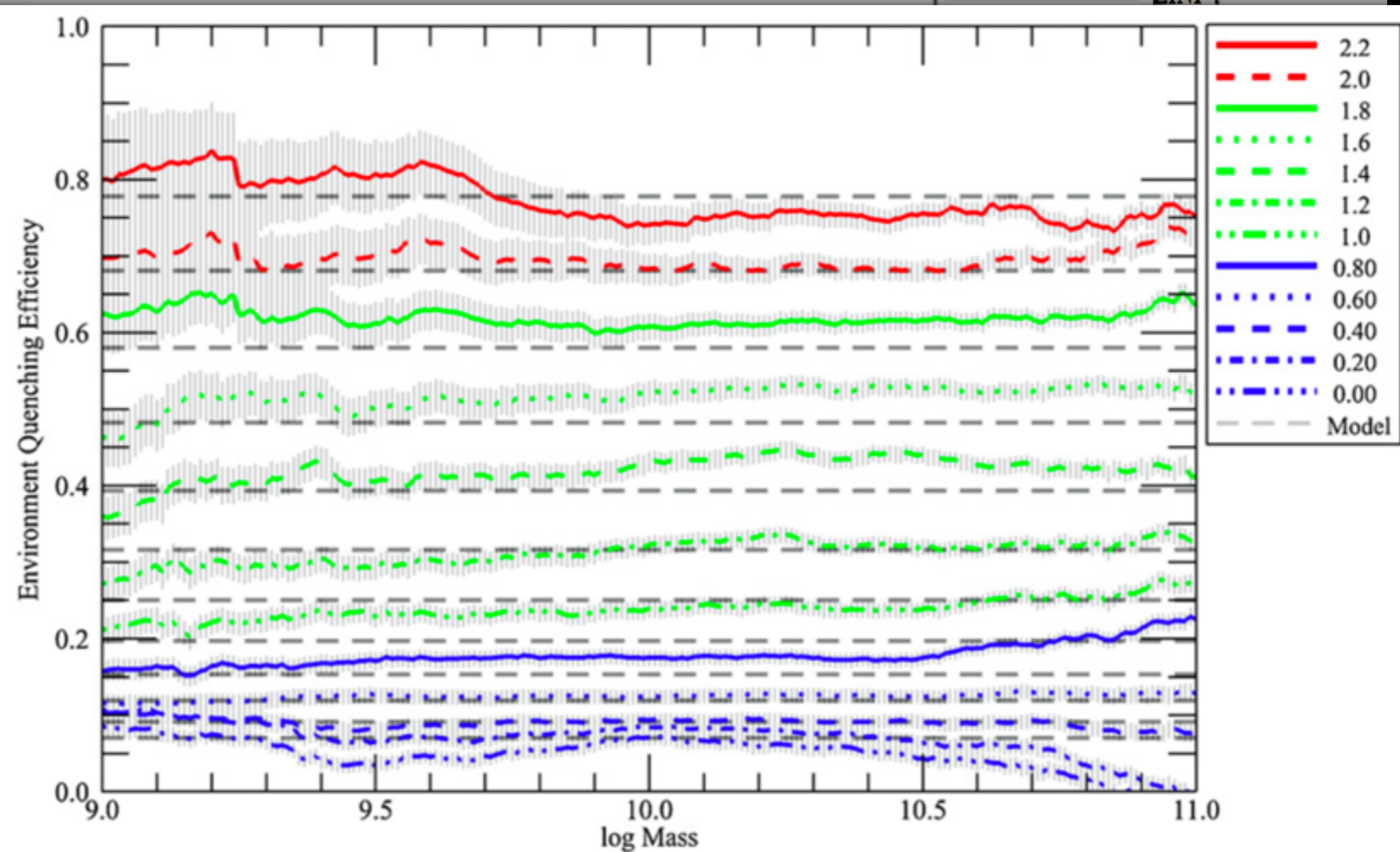
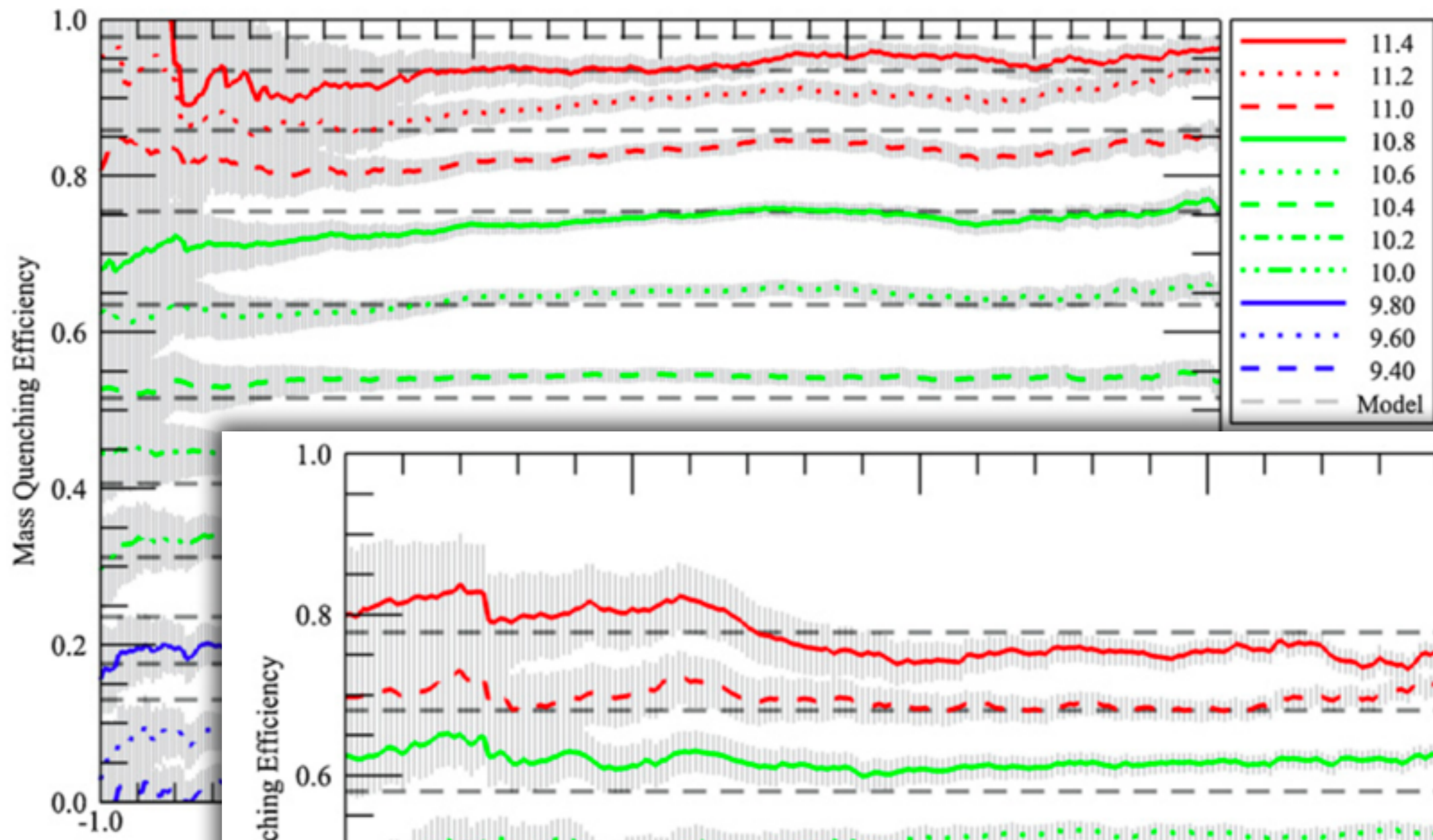
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## TRACING THE STAR-FORMATION-DENSITY RELATION TO $z \sim 2$

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galaxy overdensity  $\longrightarrow$



1.8

637X/721/1/193

AND THE

ZINI<sup>3</sup>

in 30%–70%

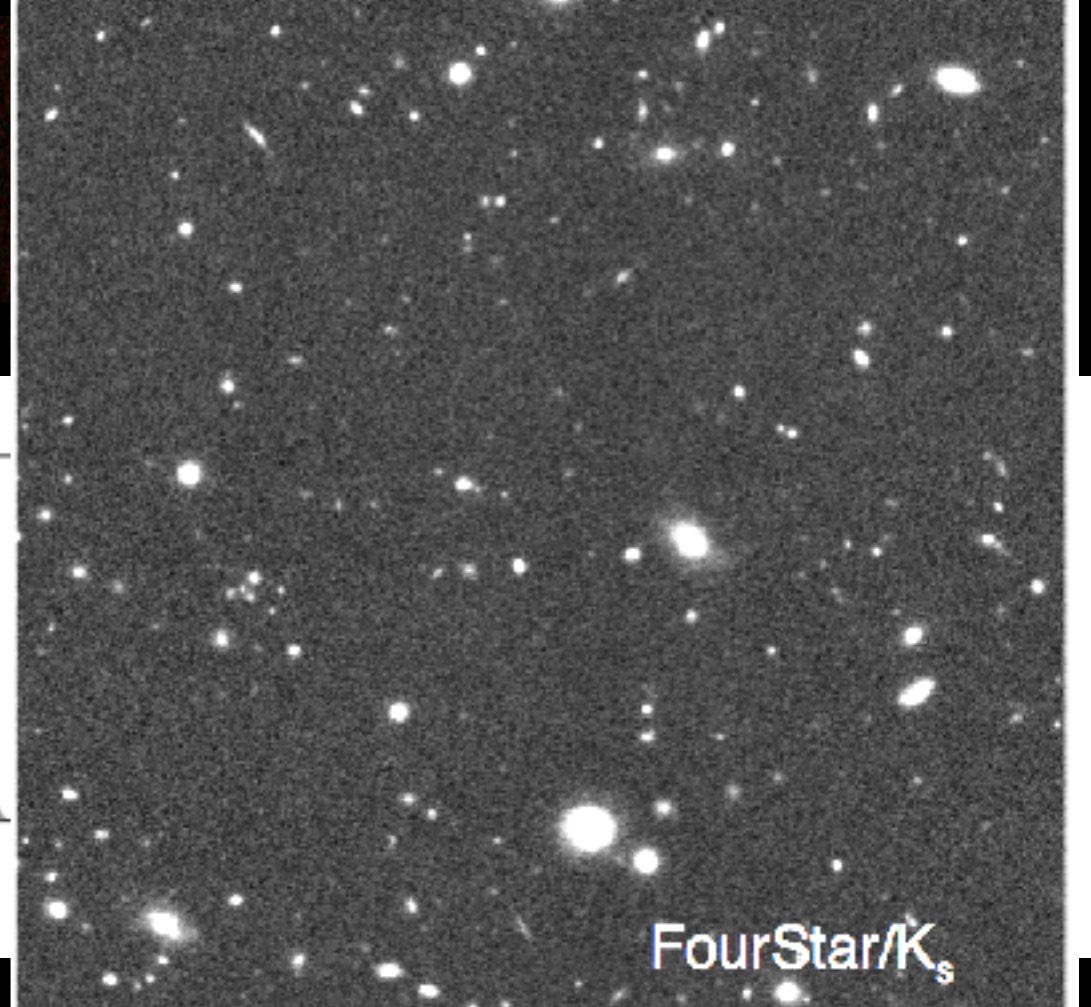
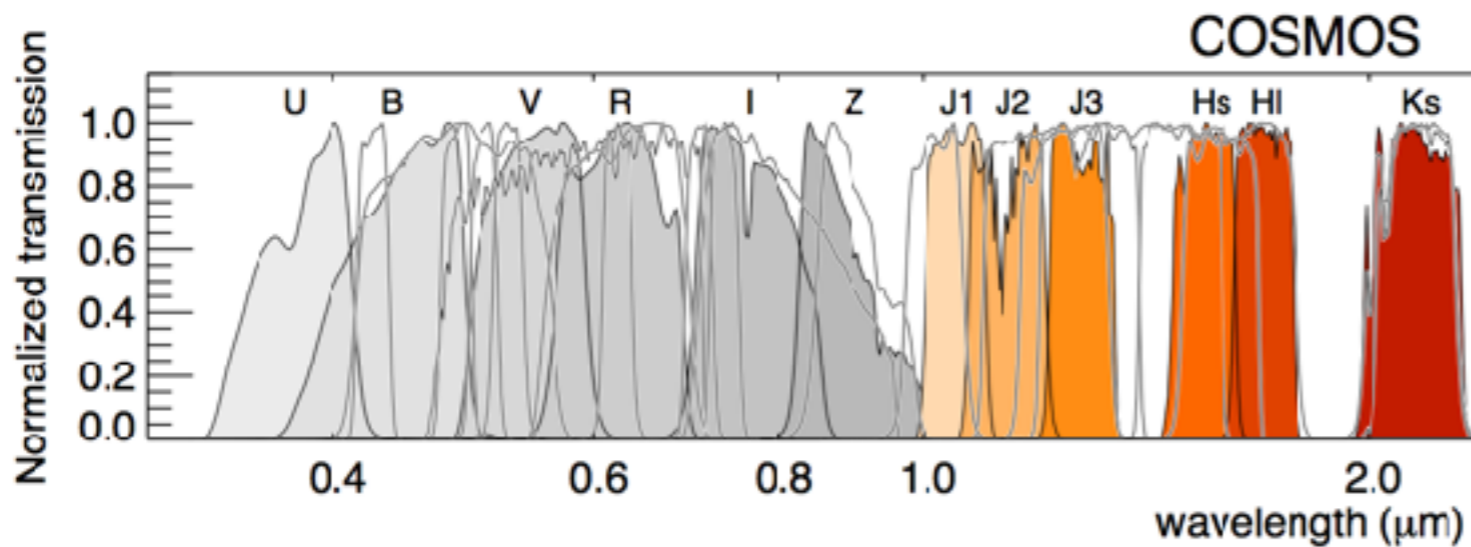
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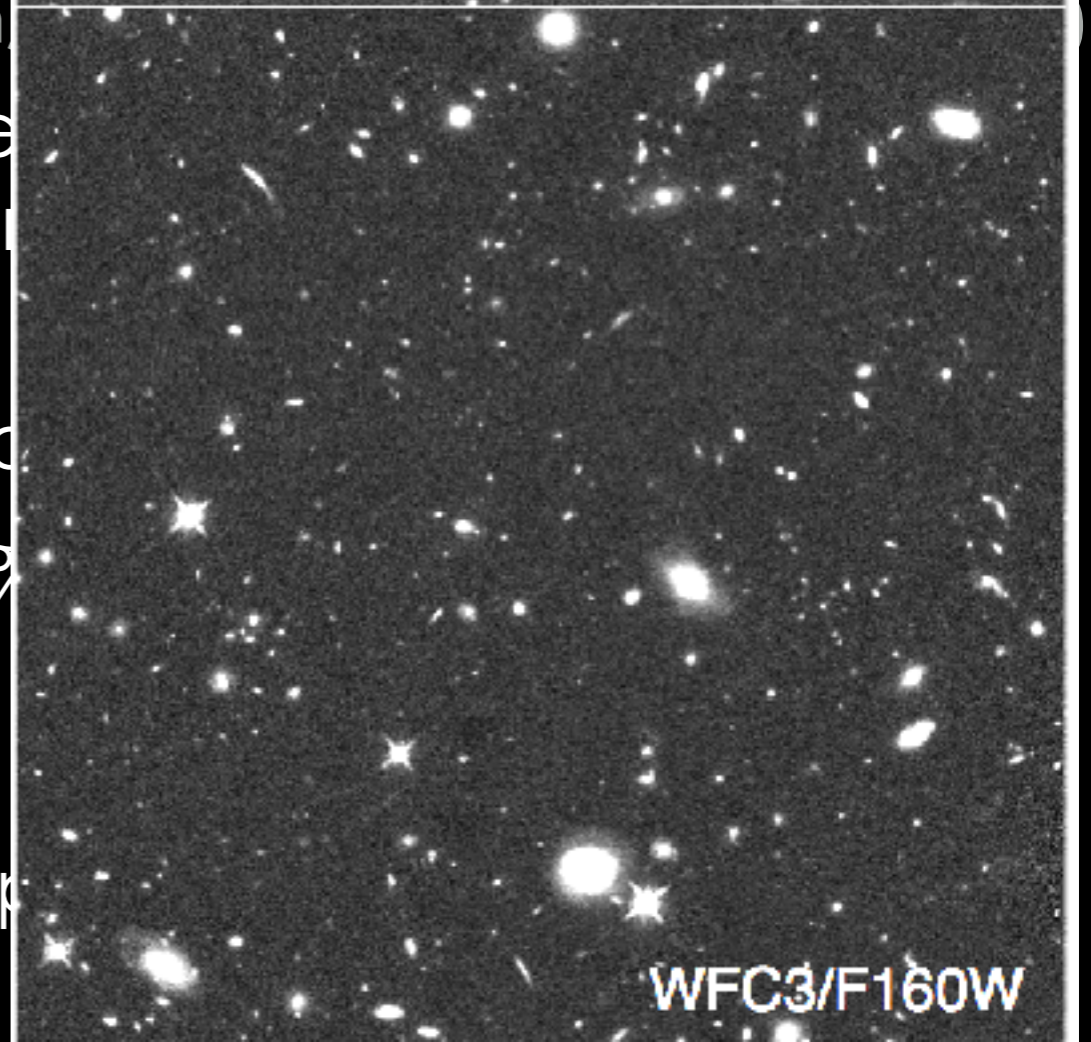
## Nomenclature:

- We are measuring the effects of quenching as a function of:
  1. Stellar Mass:  $\text{Luminosity} \times M/L(\text{SED})$
  2. Local Overdensity (“environment”): local density of galaxies
- “Mass Quenching”: quenching processes internal to the galaxy (scales with stellar mass?)
- “Environmental Quenching”: externally driven quenching processes (scales with over density? Halo mass of central?)



### Stratman

- Deep ( $K > 25$  AB mag) imaging in three (COSMOS, CDFS, UDS) w/Medium-band provide  $R \sim 10$  "spectroscopy".
- Stellar mass limit,  $\text{Log } M/M_{\odot} = 9$  (9.5) and
- Measure precise redshifts ( $\Delta z/1+z = 1\%$ )  
\*\*\*  $dv < 3000 \text{ km s}^{-1}$
- Combine with CANDELS HST imaging environmental effects on galaxy morph

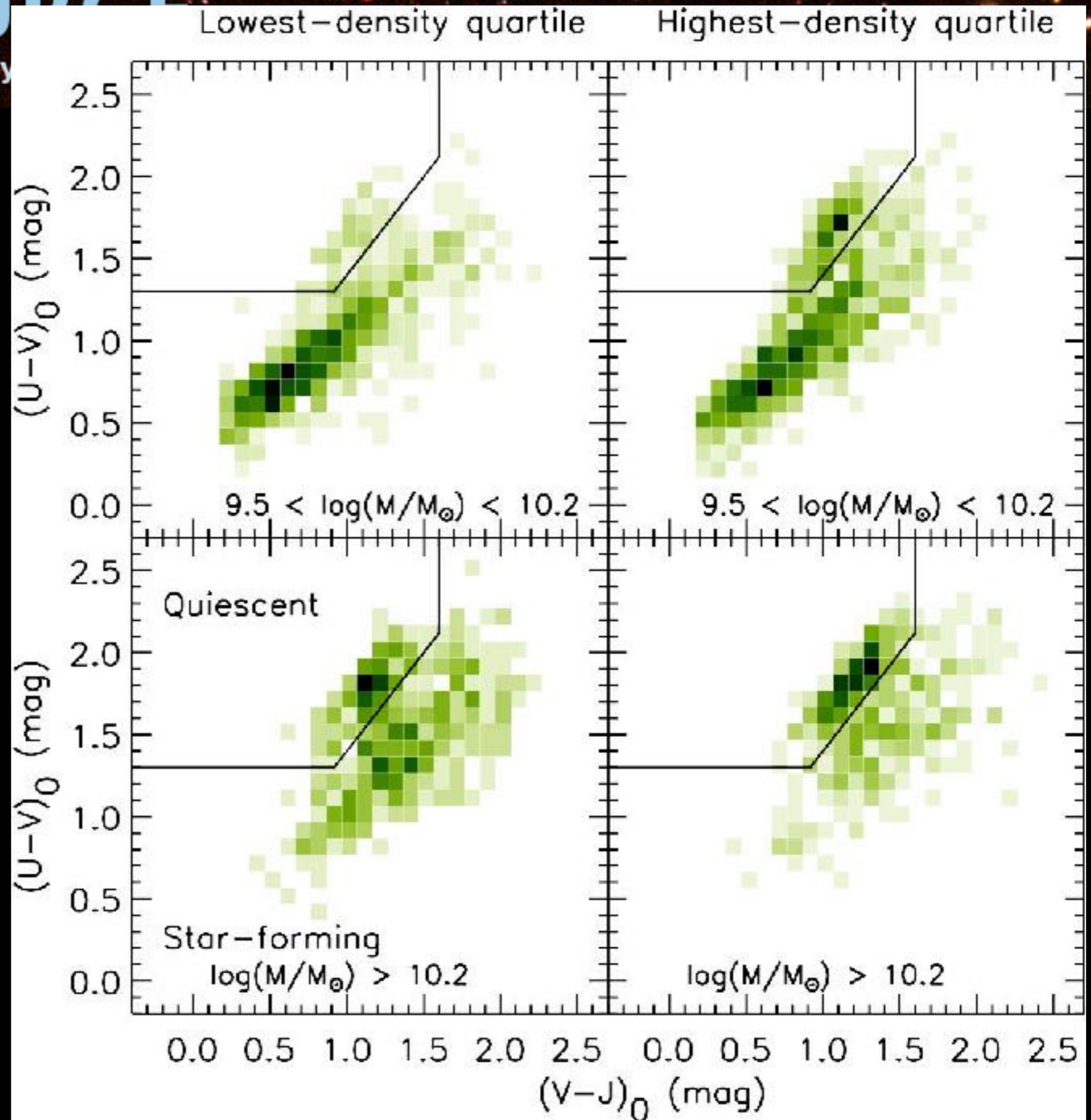


Overdensities  
from a Bayesian-  
motivated 3rd  
nearest neighbor  
method.

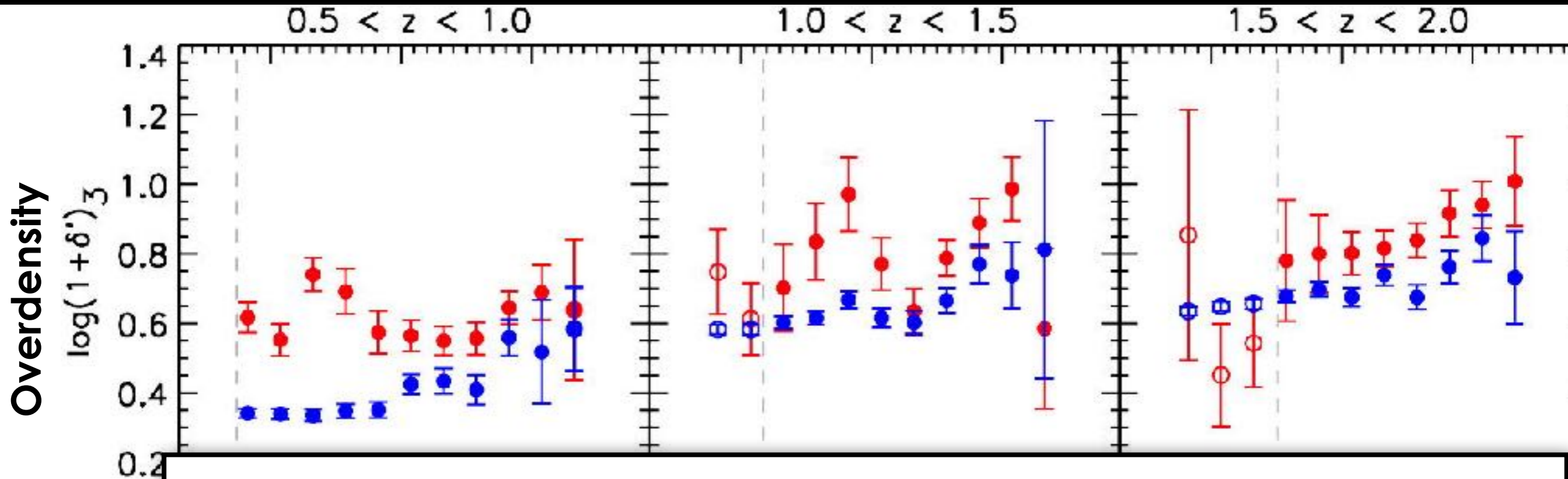
(Cowan & Izevic  
2008)



Nancy Kawinwanichakij, CP,  
et al 2017, ApJ,  
submitted, arXiv:  
1706.03780



## evolution of mass quenching and environmental quenching efficiency



*Quiescent galaxies are found in denser environments at all redshifts and stellar masses (Kawinwanichakij, CP, +17)*

Kawinwanichakij, CP, et al 2017, ApJ, submitted, arXiv:1706.03780

SDSS/zCOSMOS from Peng+2010, Kovač+2014



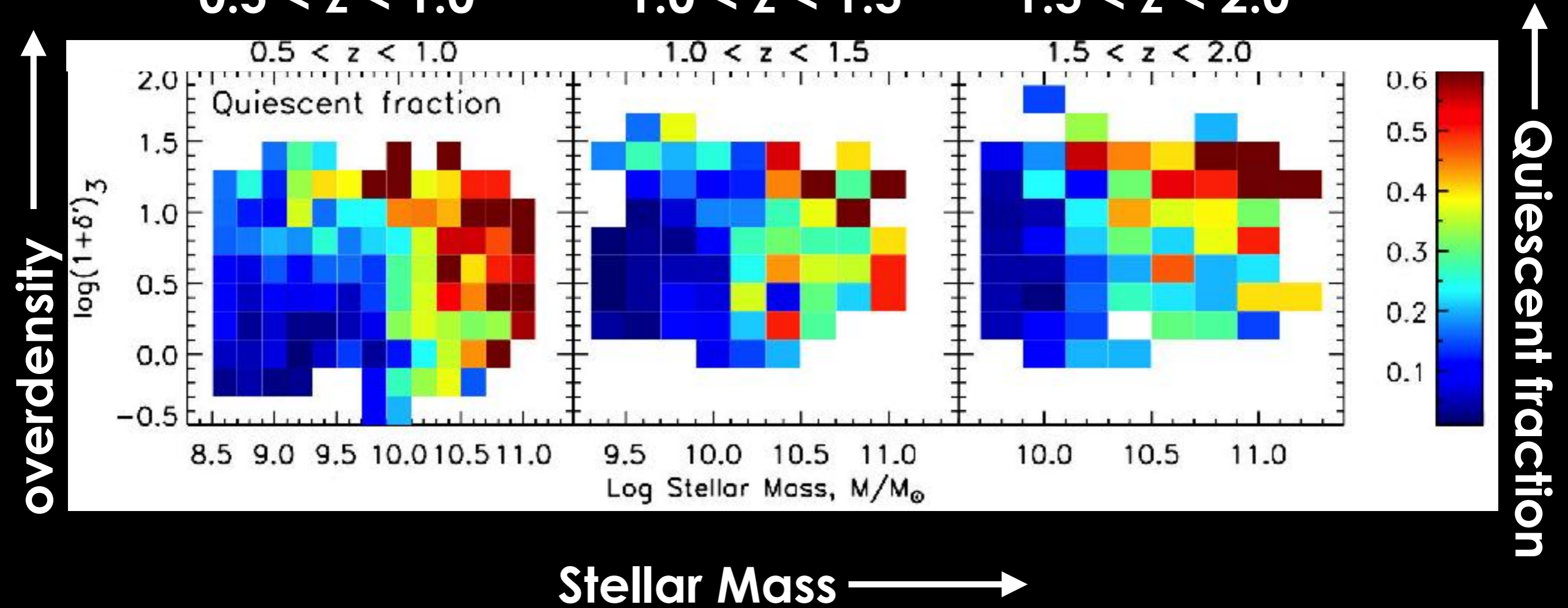
# ZFOURGE

Fourstar Galaxy Evolution Survey

$0.5 < z < 1.0$

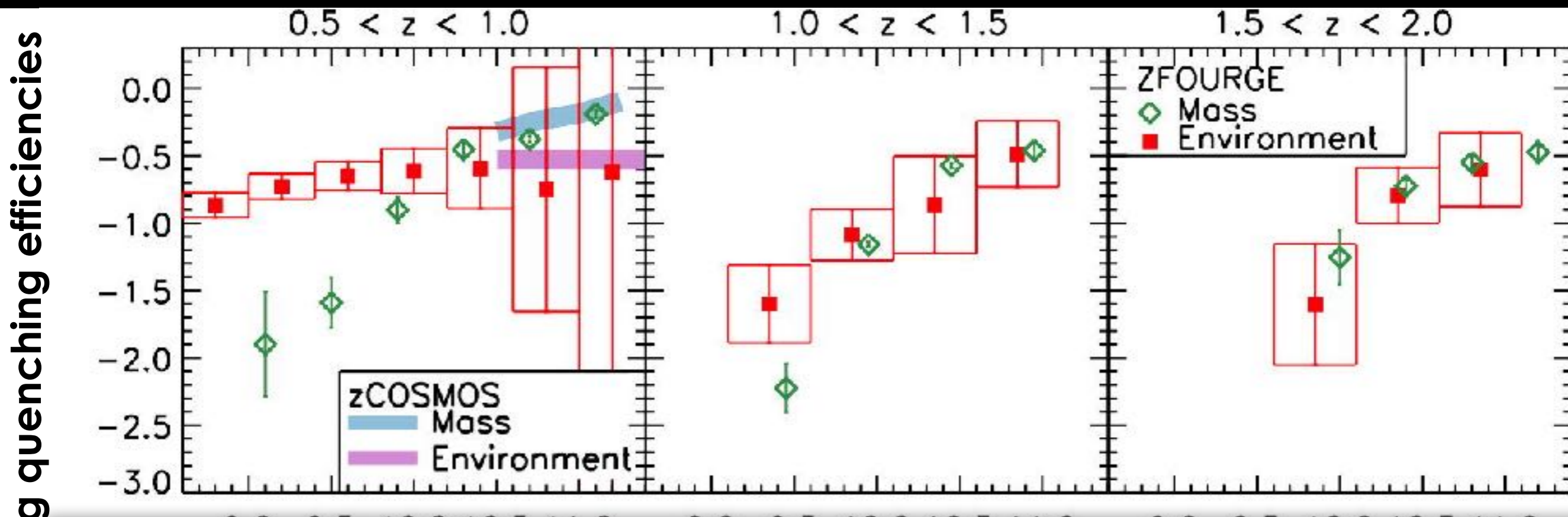
$1.0 < z < 1.5$

$1.5 < z < 2.0$





## evolution of mass quenching and environmental quenching efficiency in ZFOURGE



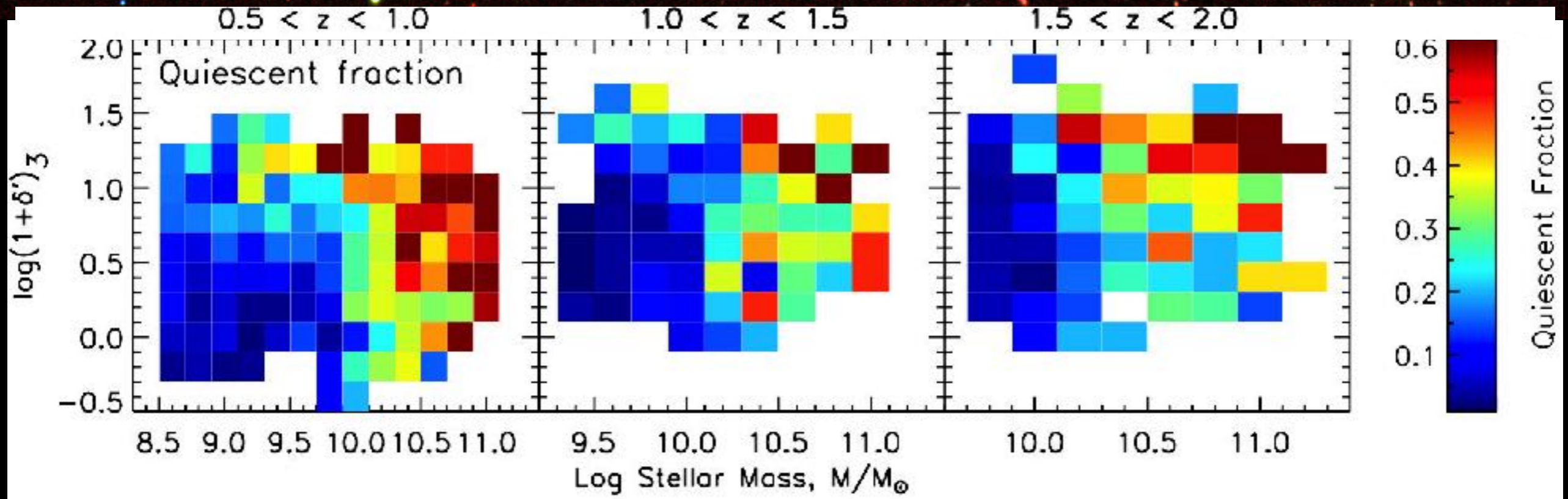
*At  $z > 0.5$ , environmental quenching efficiency correlates with stellar mass. Environmental quenching mechanism must scale with stellar mass. (Kawinwanichakij, CP et al. ApJ, submitted).*

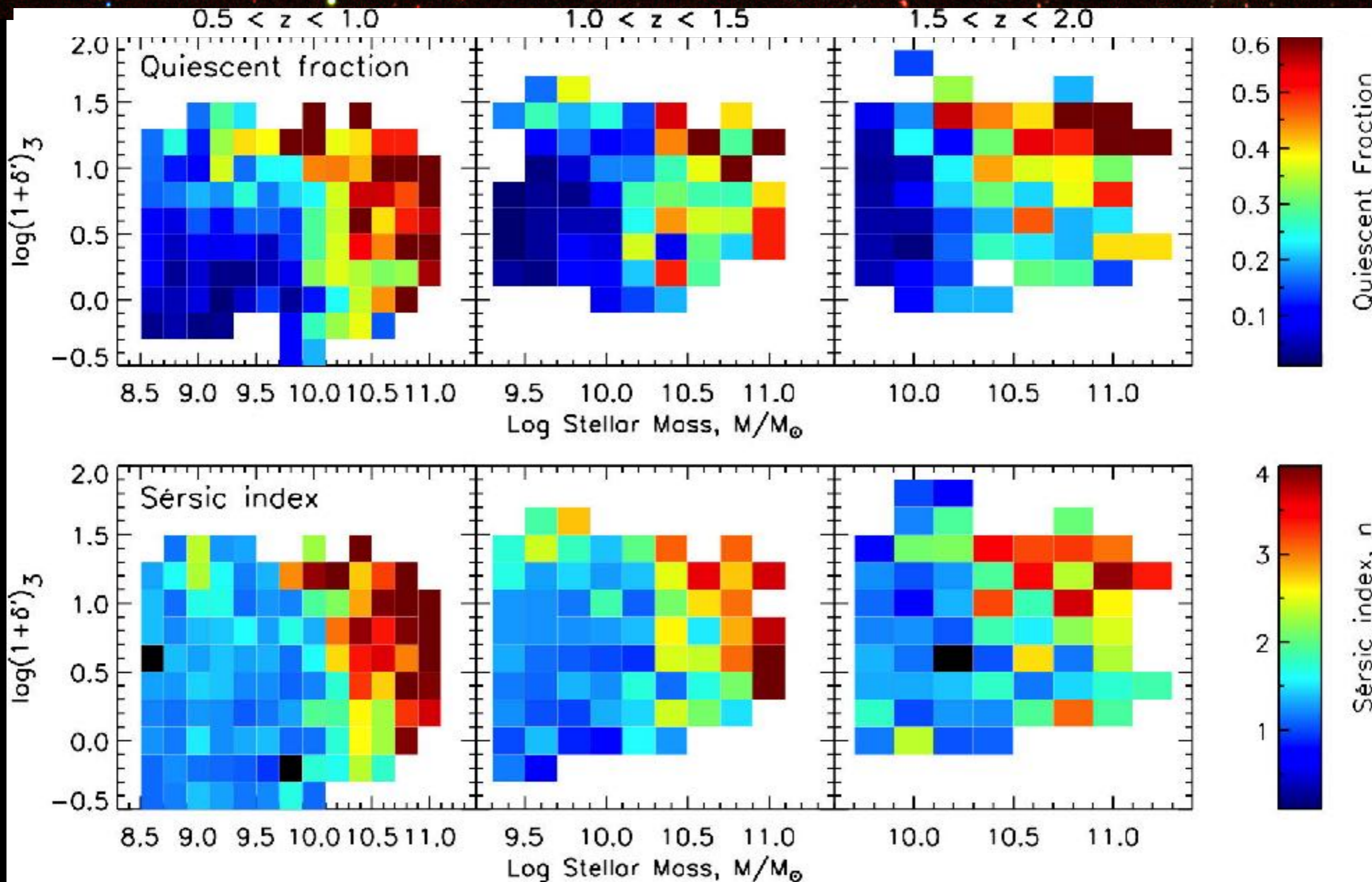


# ZFOURGE

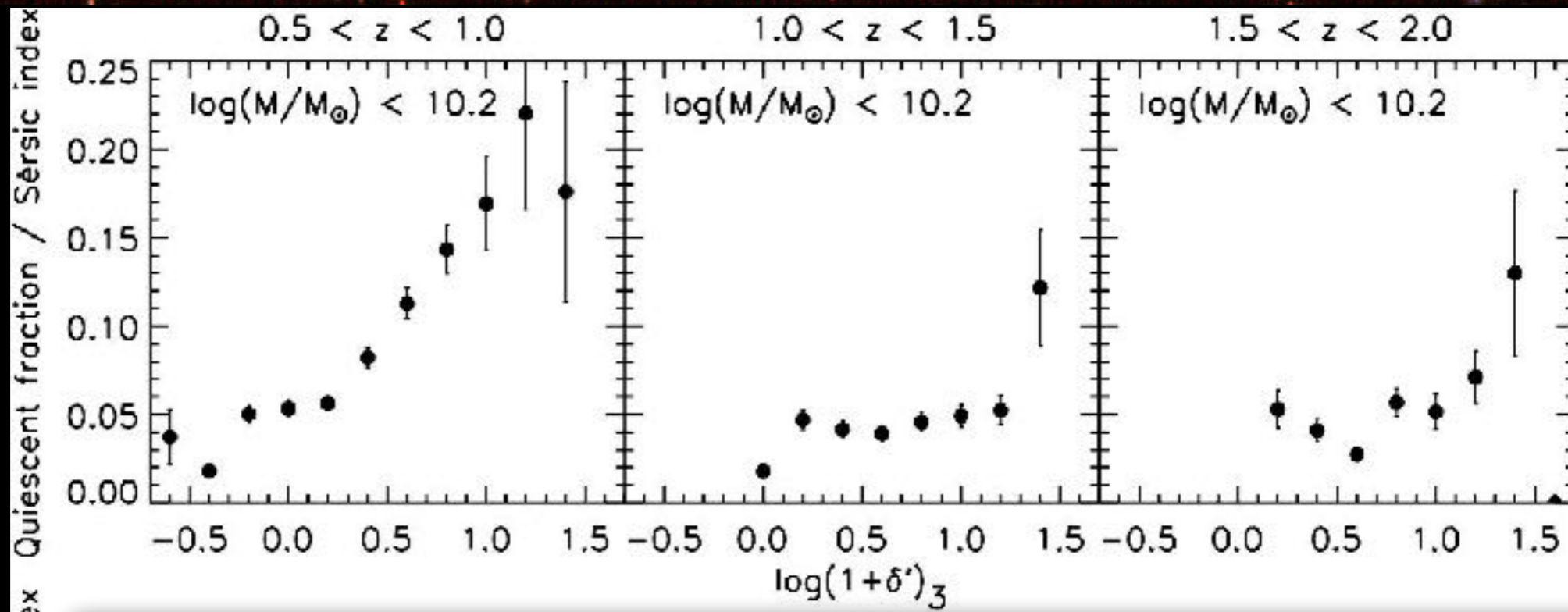
Fourstar Galaxy Evolution Survey

# CANDELS





**Ratio of quiescent fraction to Sersic Index**



**Lower mass galaxies**

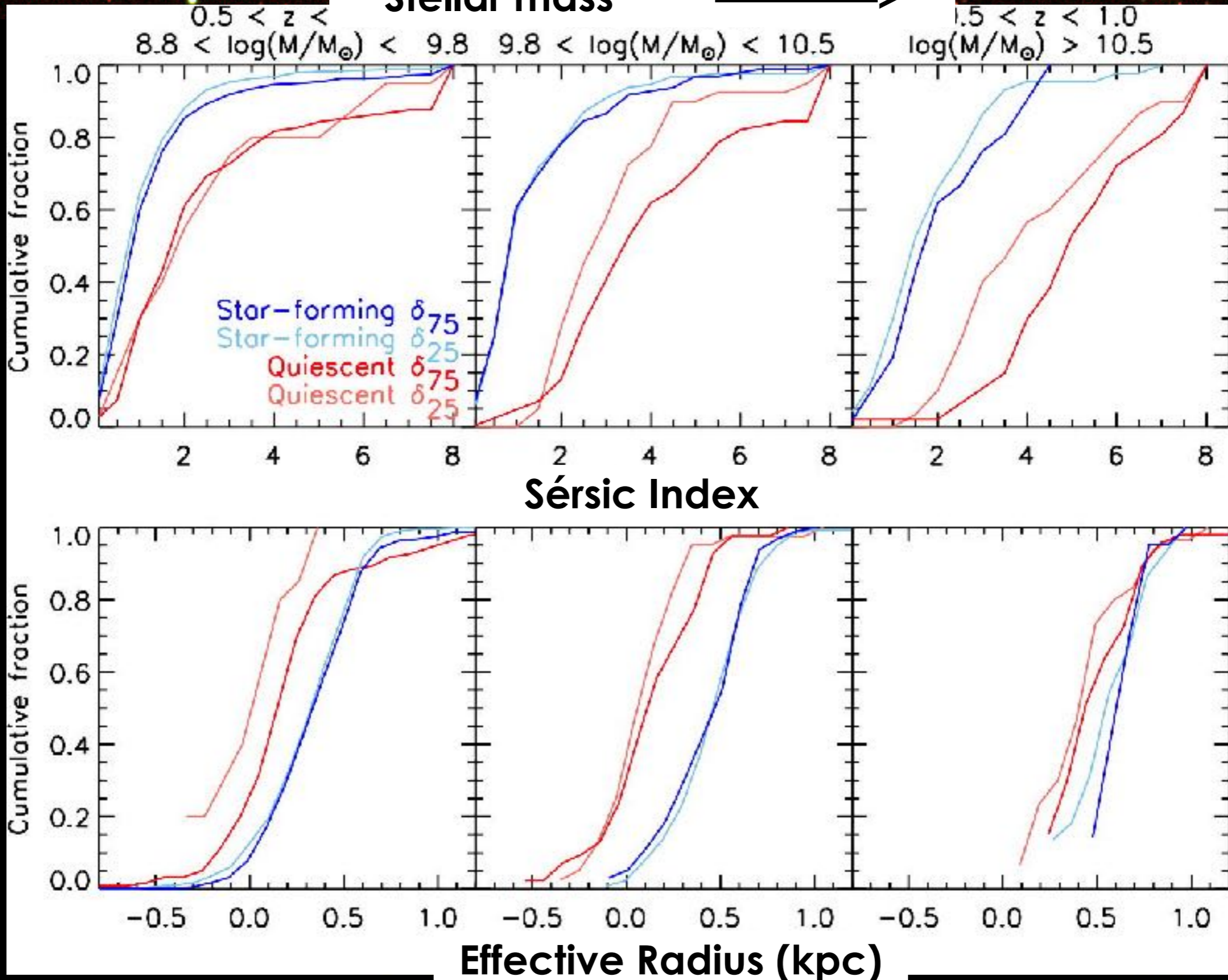
*For lower mass galaxies, change in quiescent fraction is faster than change in morphology...*

*But... there is no statistical difference in morphologies of quiescent galaxies in lowest and highest densities (environment must erase any differences...)*

(Kawinwanichakij, CP et al. ApJ, submitted)

0.5 < z < 1.0  
Stellar mass →

Cumulative fractions



## **Environmental Quenching observed to $z < 2$ in ZFOURGE/CANDELS**

- Quiescent galaxies reside in overdense regions out to  $z \sim 2$  (Kawinwanichakij+17)
- Mass quenching: increases with stellar mass, and decreasing redshift (Kawin+17)
- Environmental quenching: clear dependence on stellar mass at  $z > 0.5$ ; quasi-constant at lower redshift ( $z < 0.5$ )? (Kawin.+17)
  - *(Part II, tomorrow:) must be true or SMF would be very different at high*
  - *(Part II, tomorrow:). All the evolution in the quiescent galaxy SMF results from environmental quenching (in overdense regions)*
- **Environmental quenching appears to change morphologies (Kawin.+17)**
  - *Environmental change in quiescent fraction faster than change in morphology (Sersic Index), but...*
  - *Statistically, distributions of quiescent galaxy morphologies in low-density regions are identical to those in high-density regions (nor do quiescent galaxies look like star-forming galaxies in any environment).*
- *(Part II, tomorrow:). Favors environmental mechanisms at high redshift that scale with (stellar) mass (e.g., “overconsumption”, McGee+14; Balogh+16).*