Using Composite Spectral Energy Distributions to Characterize Galaxy Populations at 1<z<4

Ben Forrest

March 21, 2018

University of Melbourne

MITCHELL INSTITUTE
TEXAS A&M UNIVERSITY

ZFOURGE
Fourstar Galaxy Evolution Survey

Acknowledgements

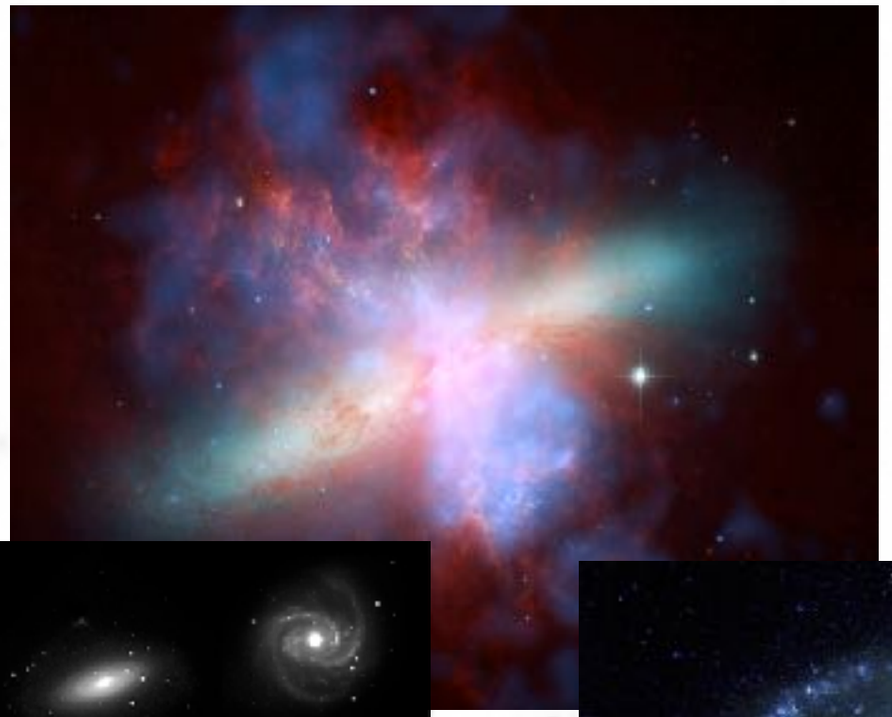
ZFOURGE data gathered at the Magellan Telescopes, Las Campanas Observatory.

Outline

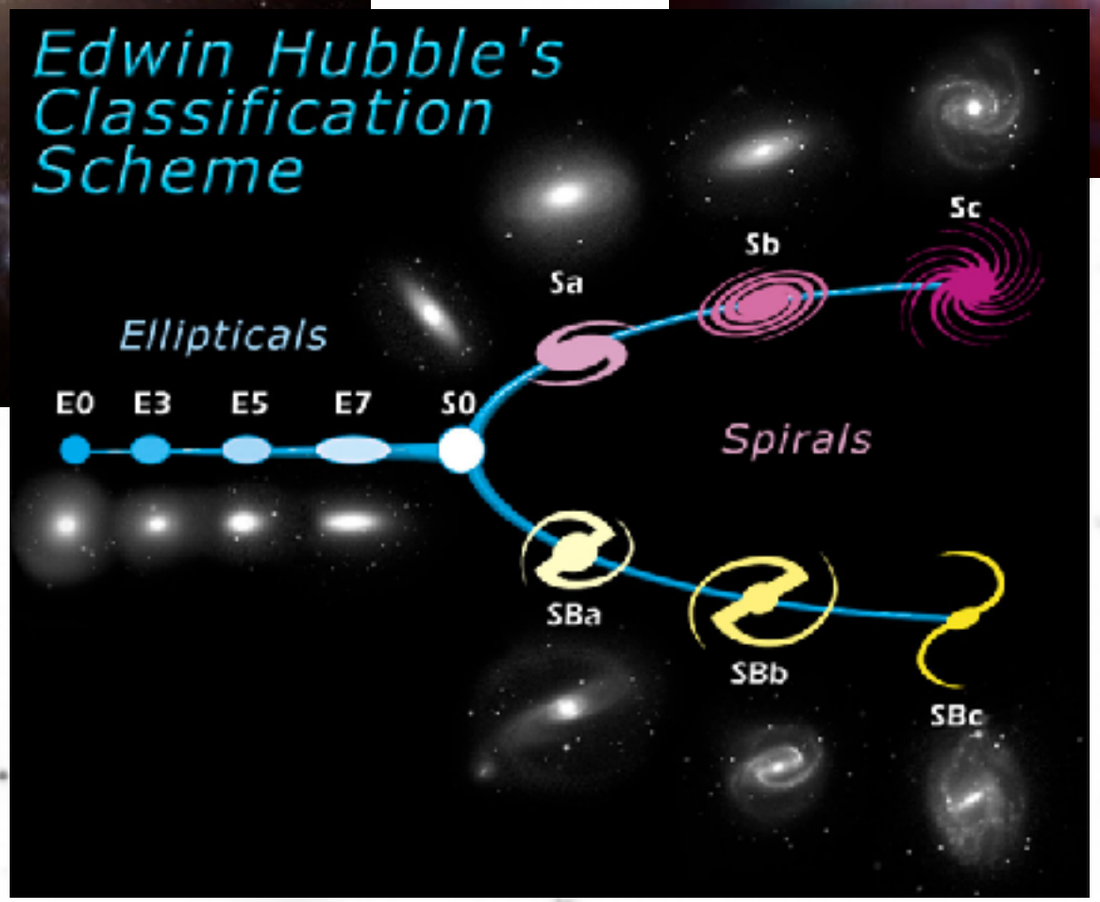
Motivation
Data and Methods
From Star-Forming to Quiescent
Extreme Emission Line Galaxies
Conclusions

The Life of Galaxies

ESO 325-G004; NASA



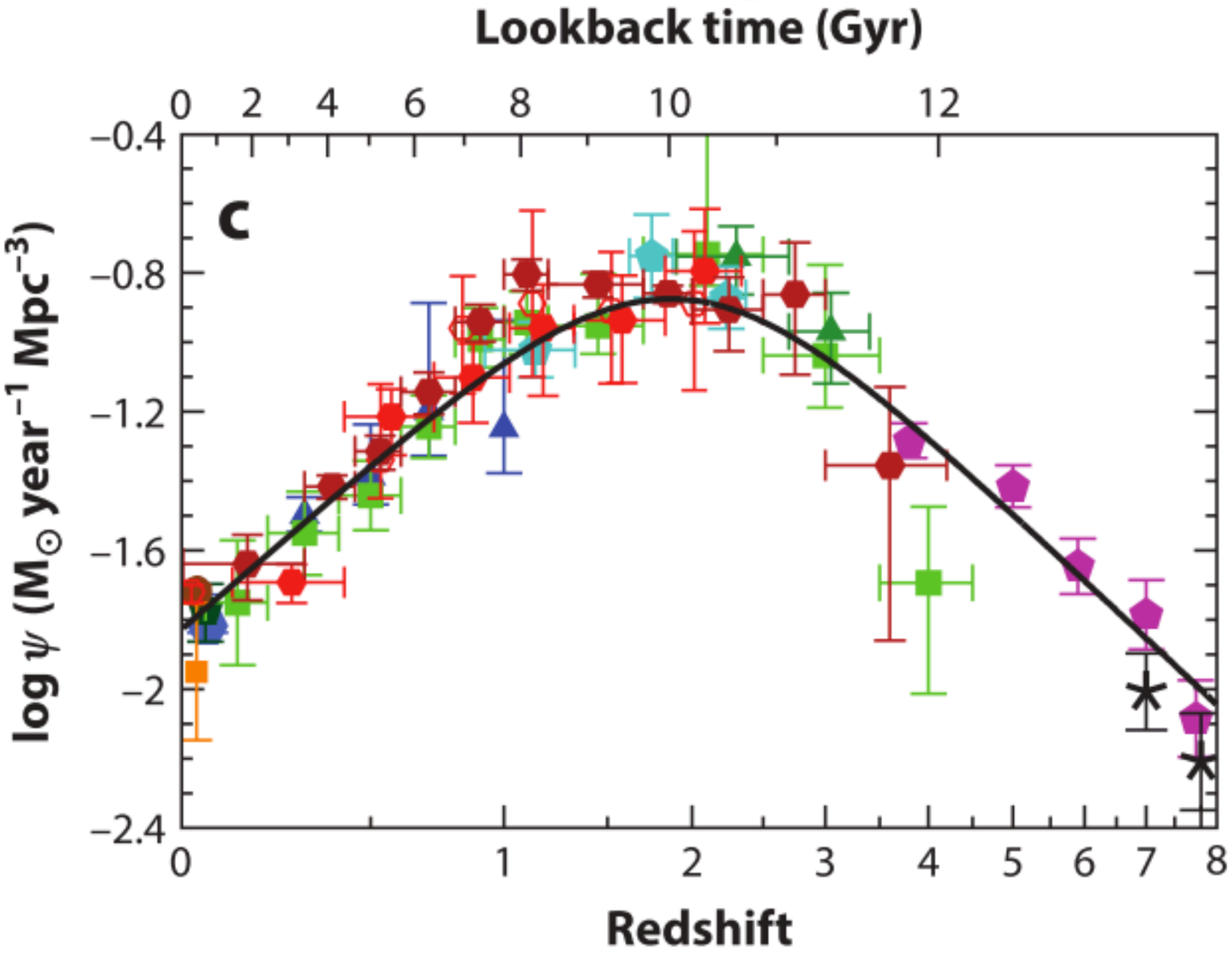
M82; NASA



STSCI

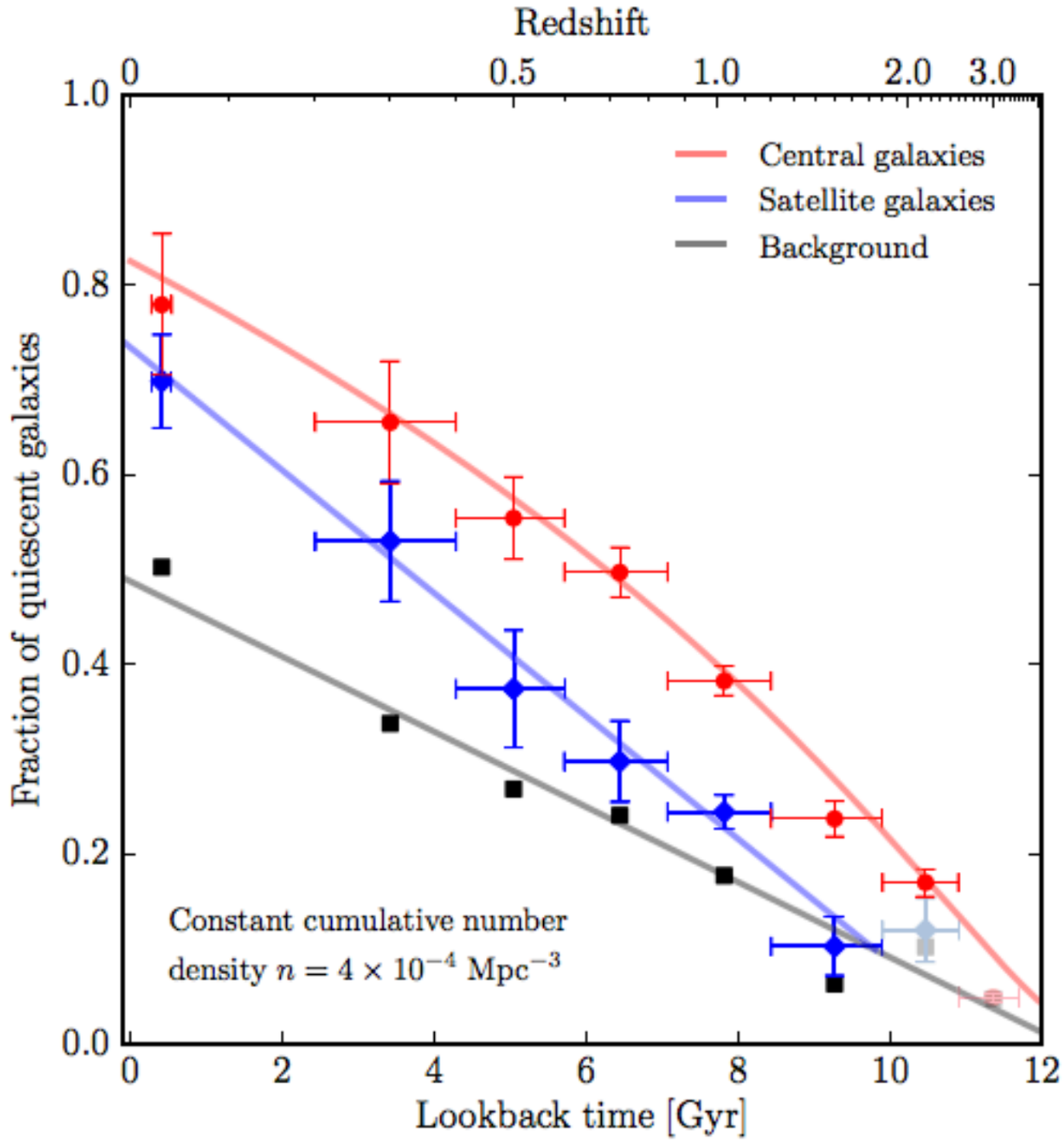
NGC 1232; ESO

The Star-Forming History of the Universe



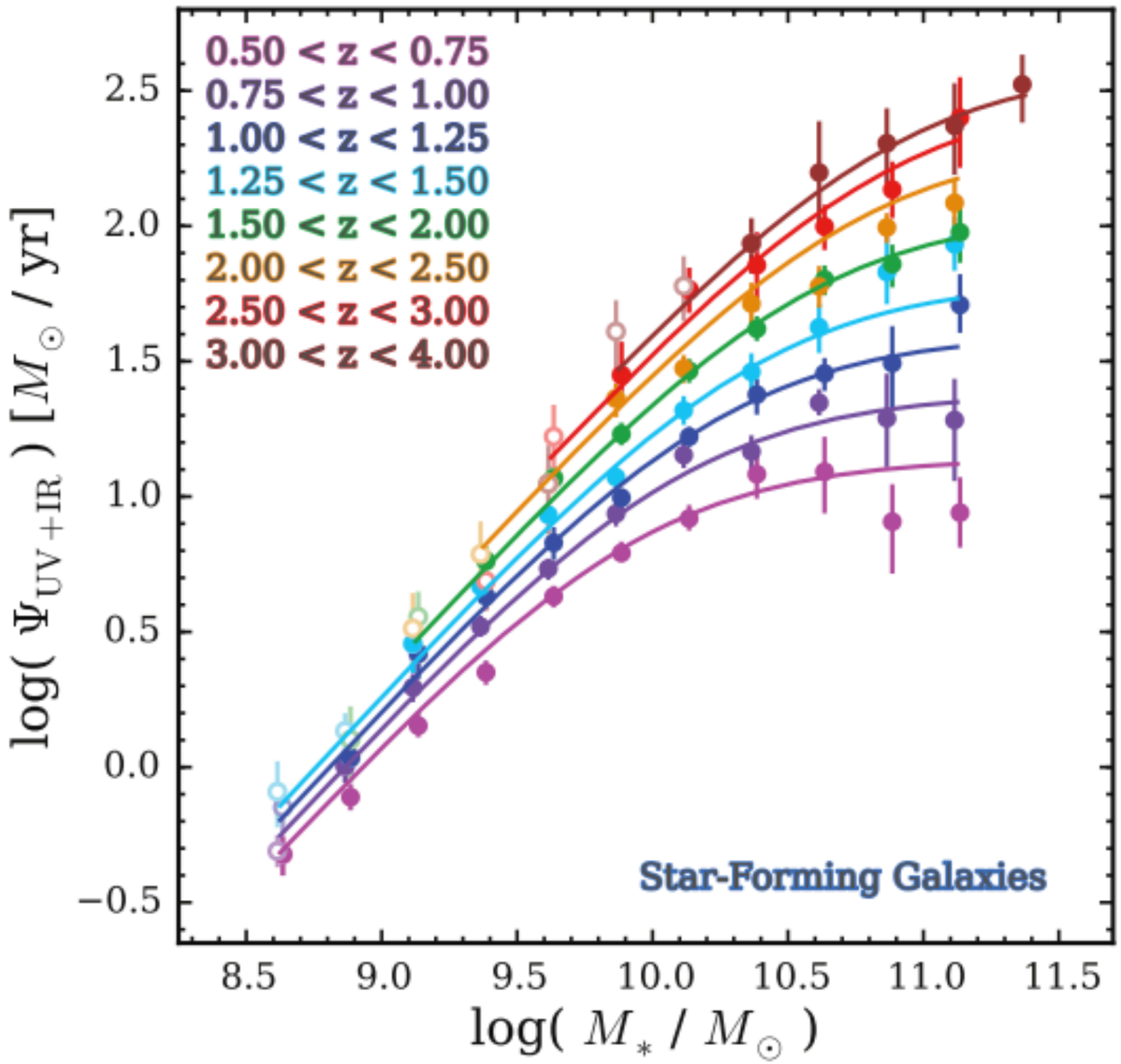
Madau+2014

Galaxies are Quenching



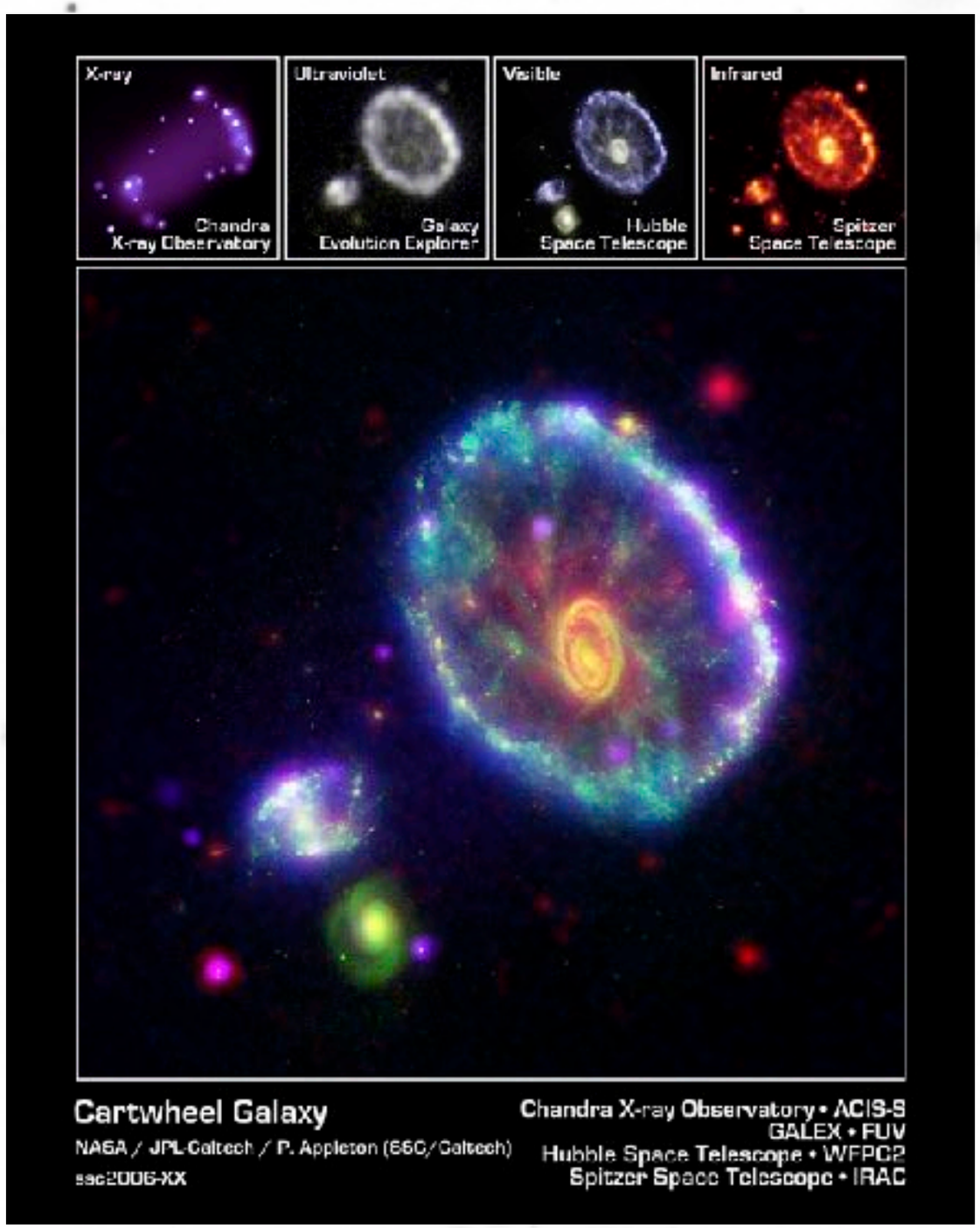
Tal+2014

The Star Formation - Stellar Mass Relation

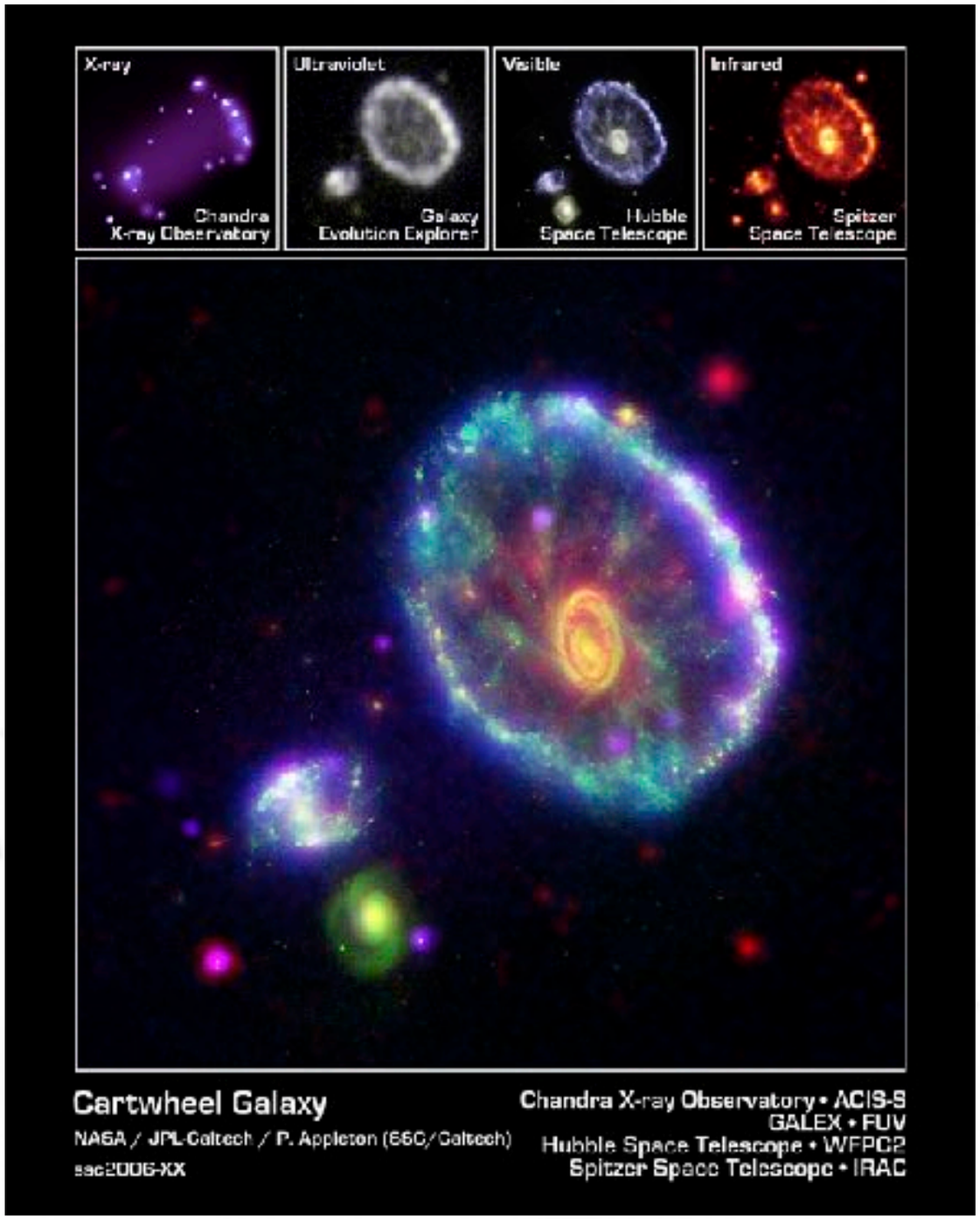


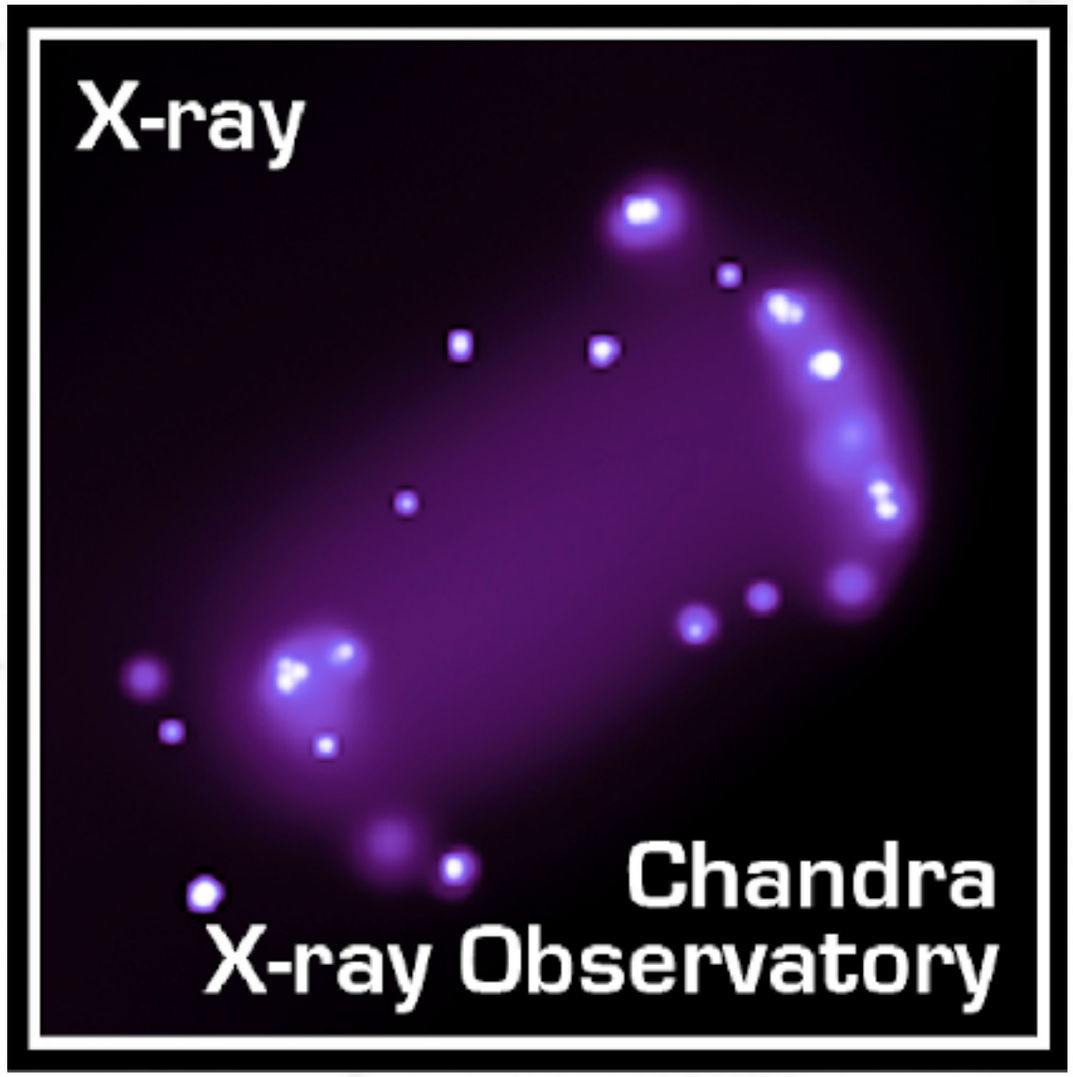
Tomczak+2016

Galaxy-Galaxy Interactions

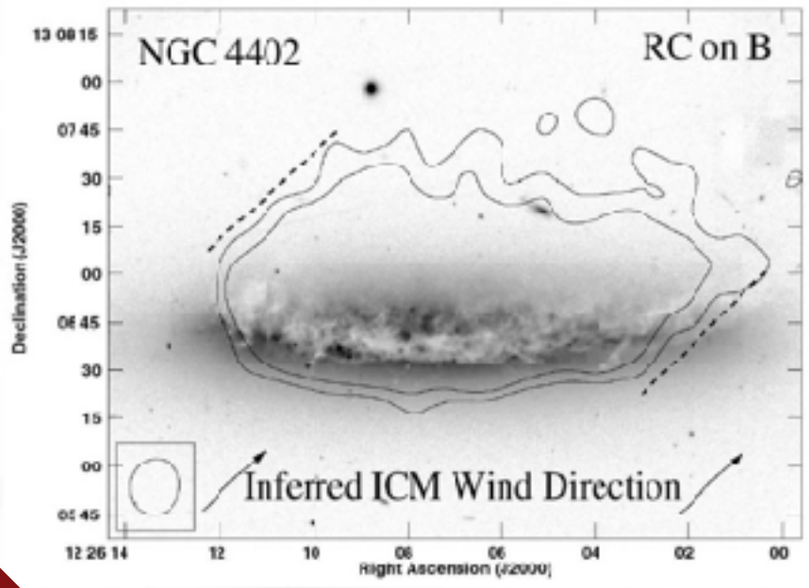


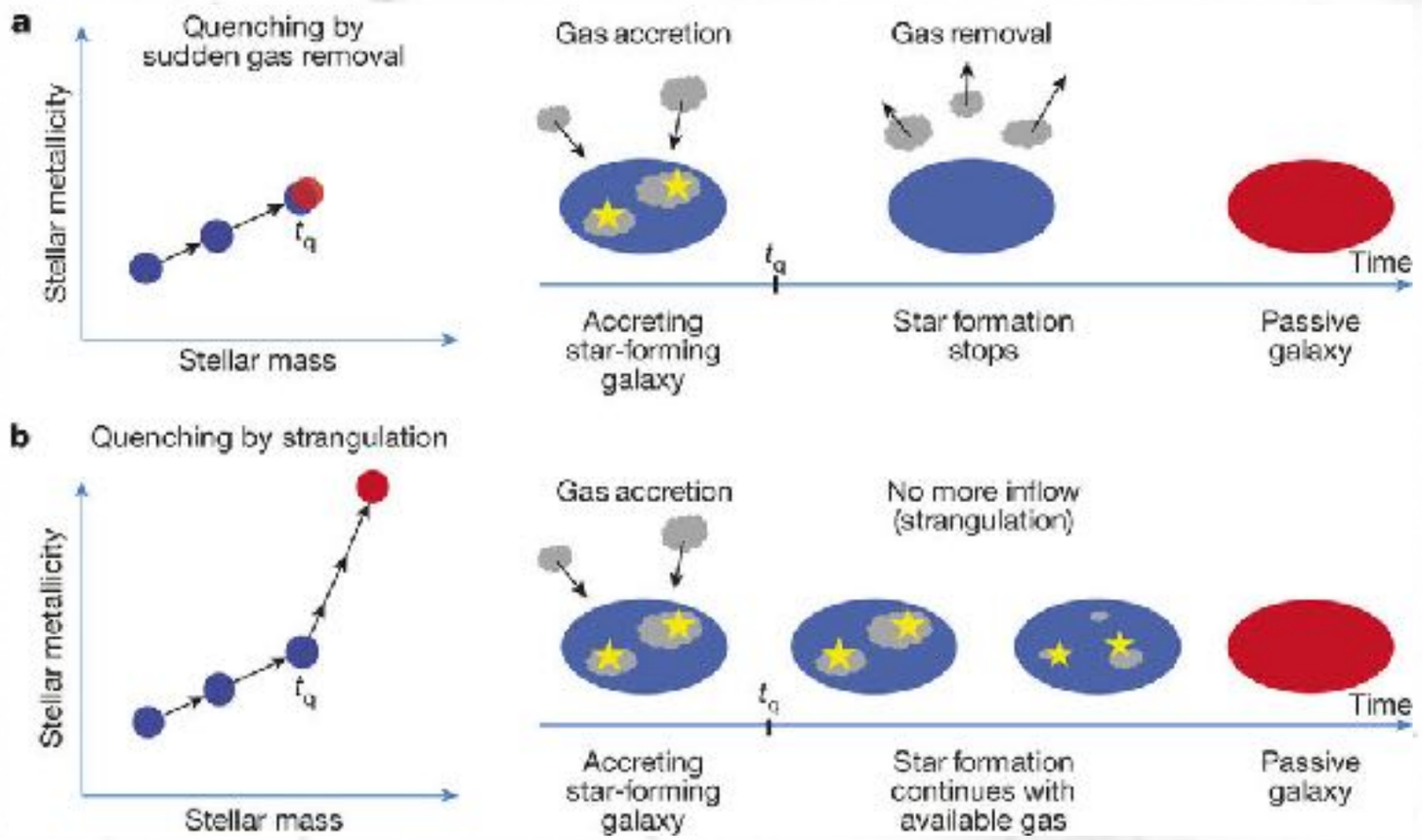
Galaxy-Galaxy Interactions





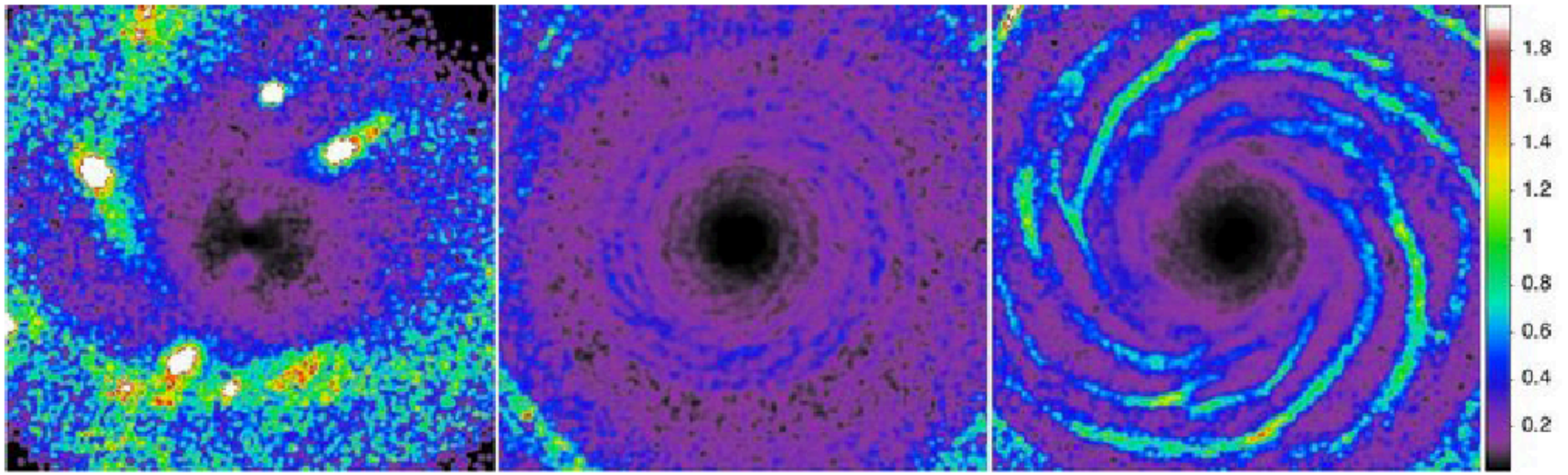
Galaxy-Cluster Interactions





Crowl+2005

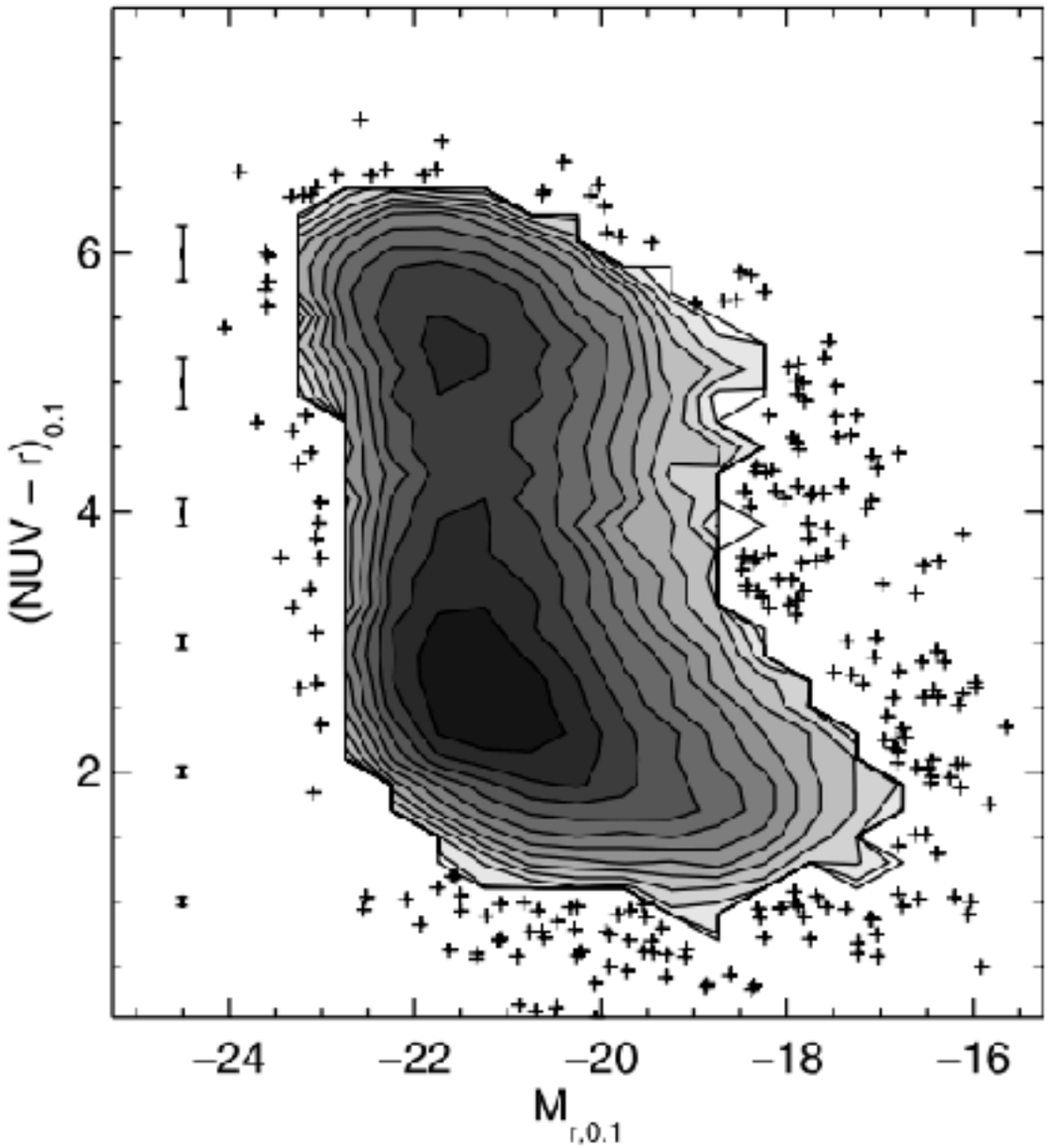
Morphological Quenching

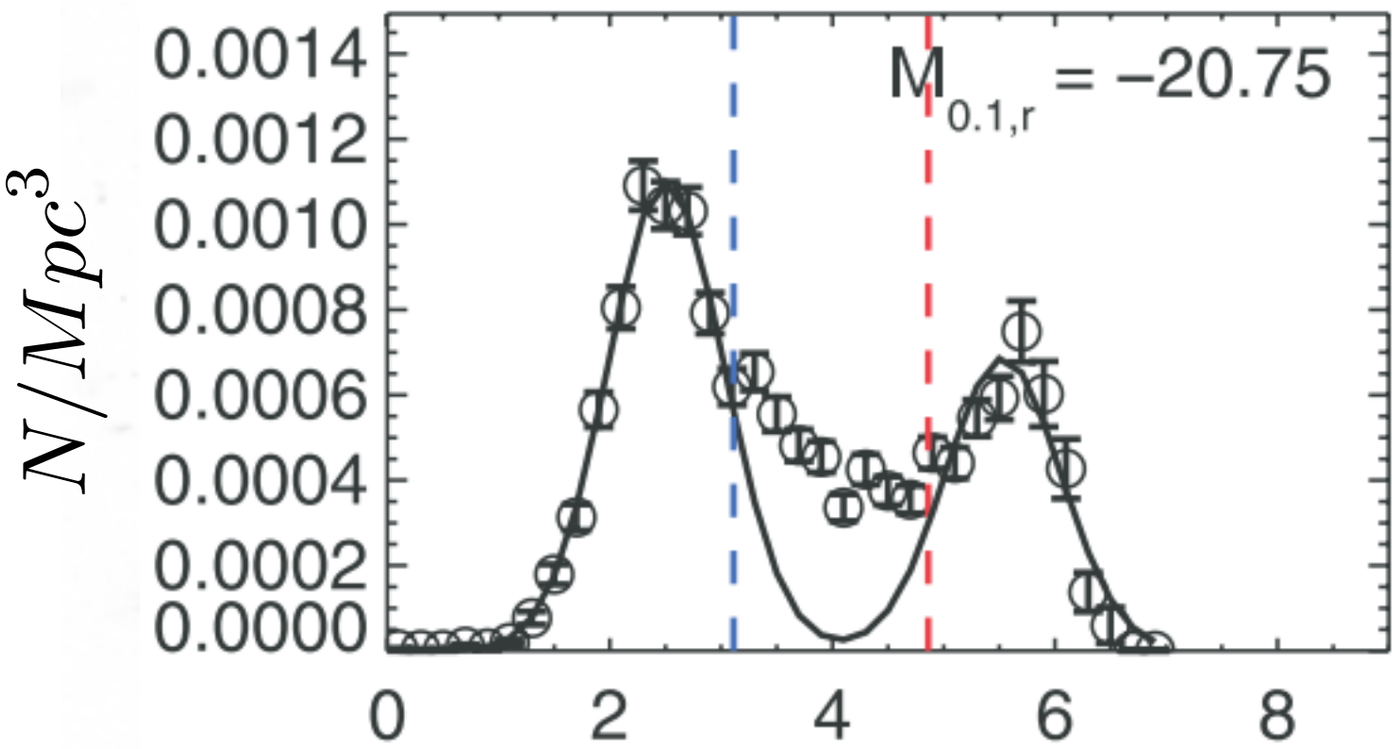


Colored by ratio of gas density to tidal density

Martig+2009

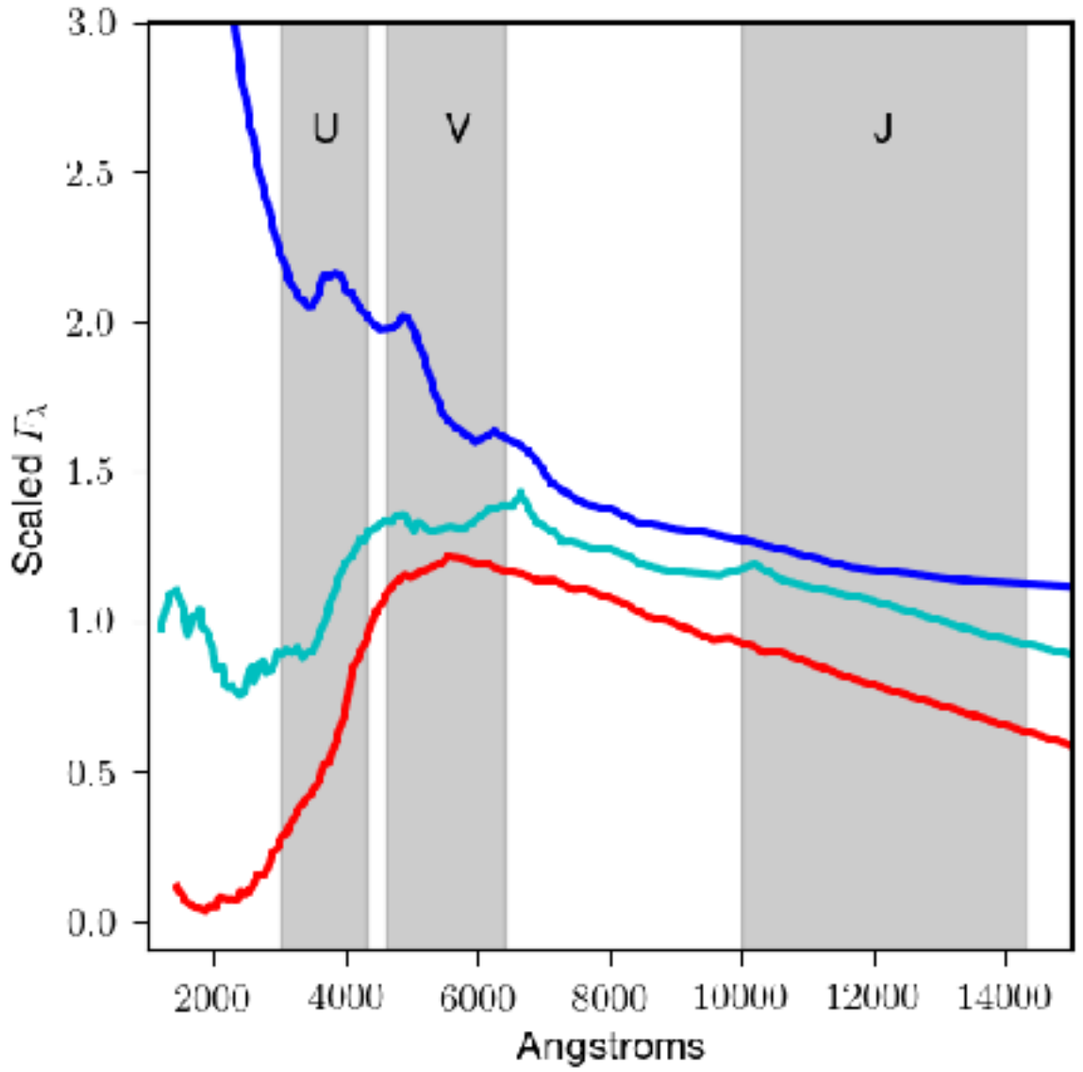
The Green Valley

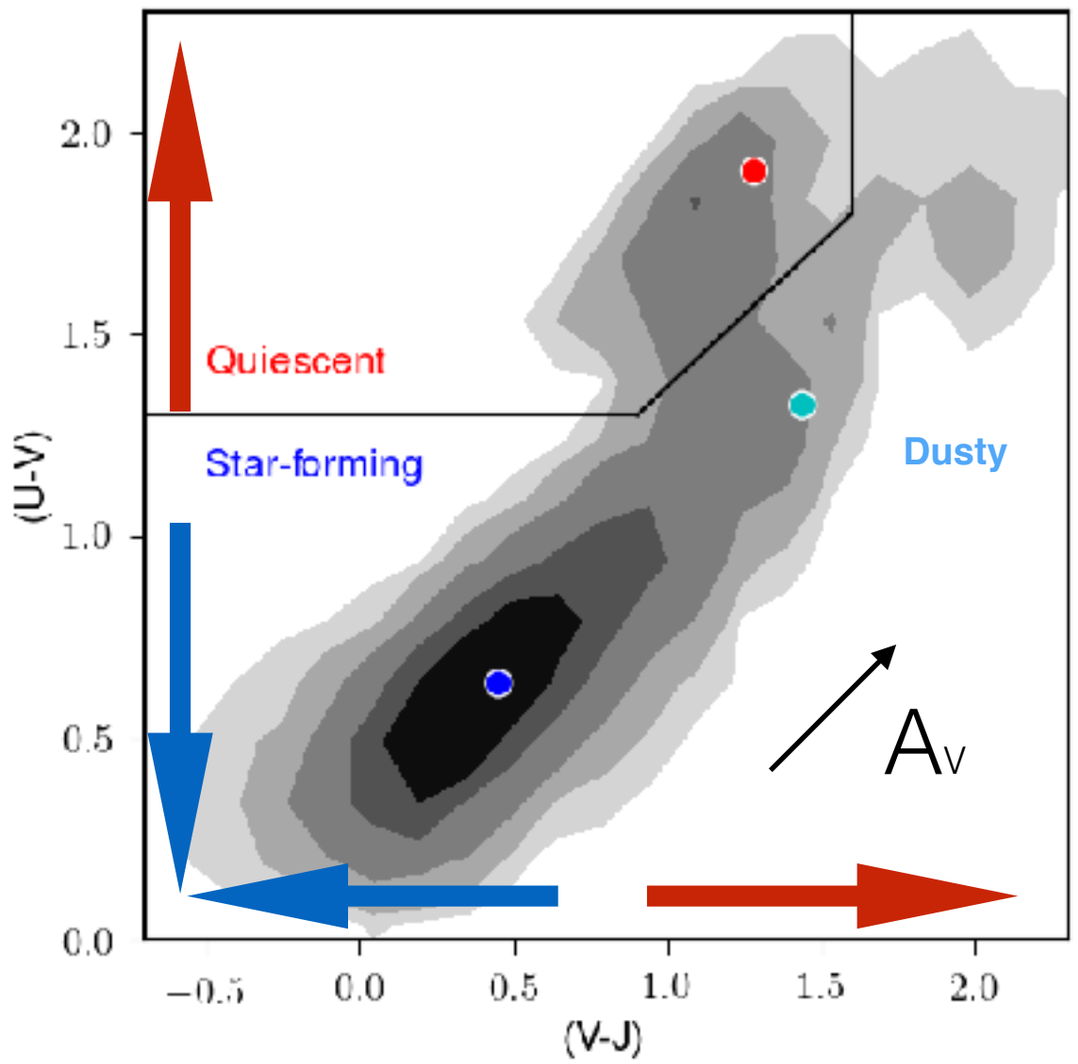




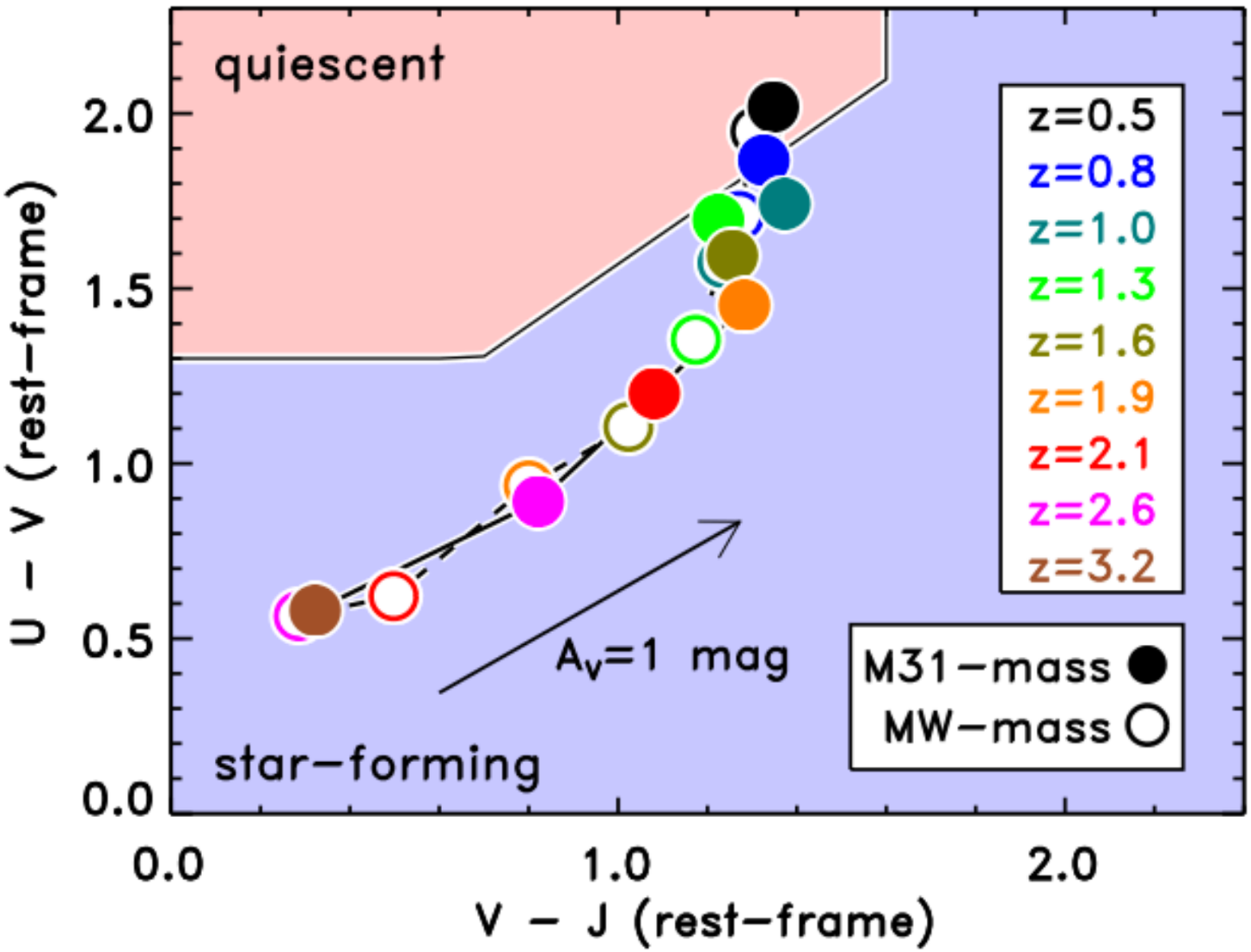
Wyder+2007

The UVJ Diagram



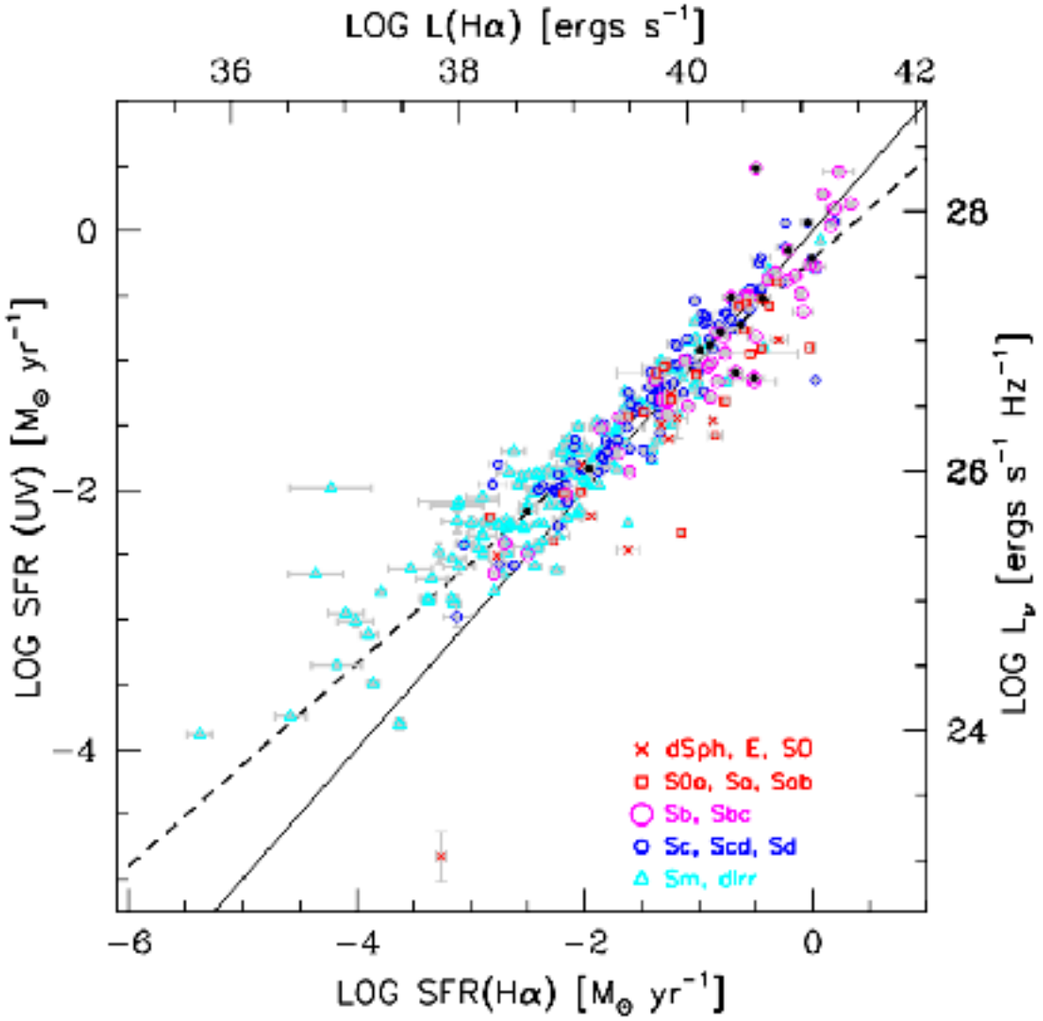


The UVJ Diagram

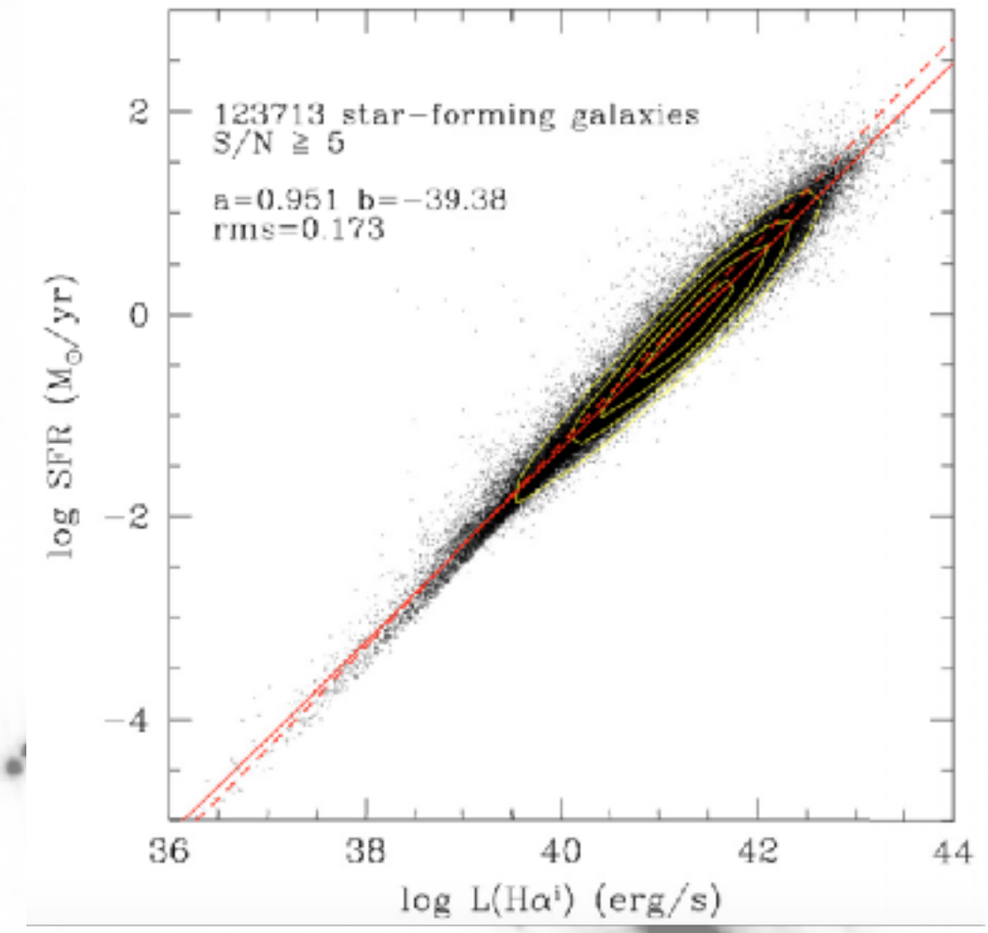


Papovich+2015

Hα Emission

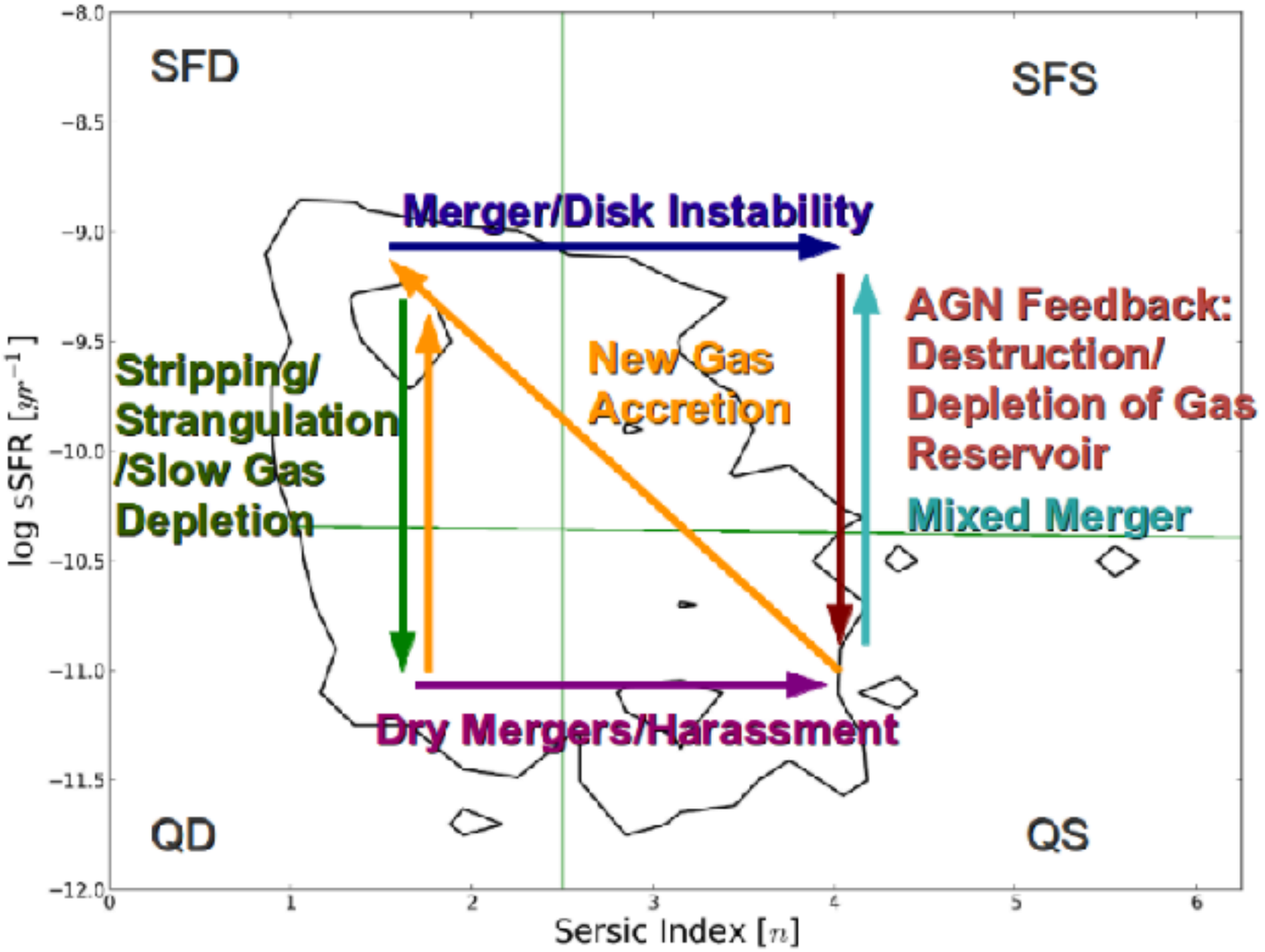


Lee+2009
Local Dwarf Galaxies



Argence+2009
SDSS

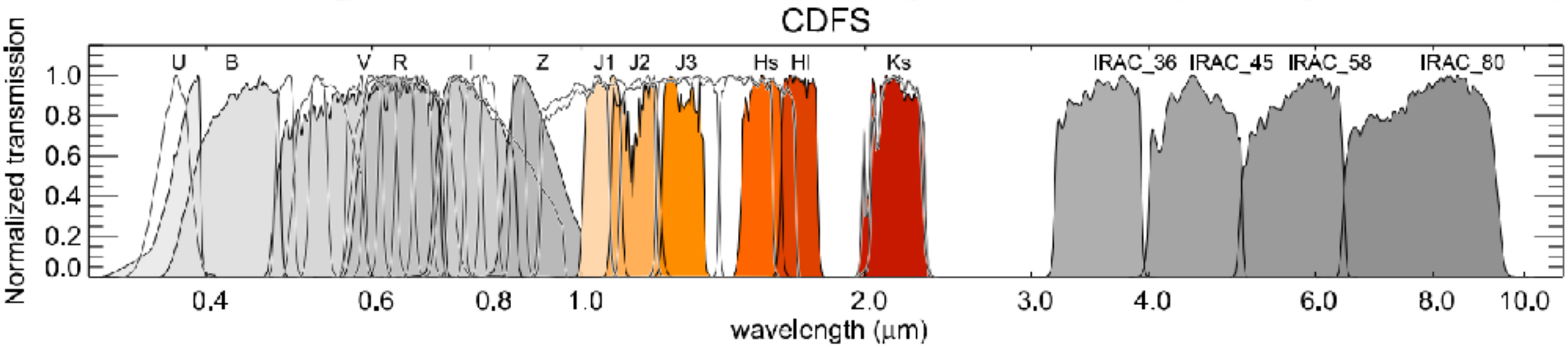
Morphological Changes



Brennan+2015

Data

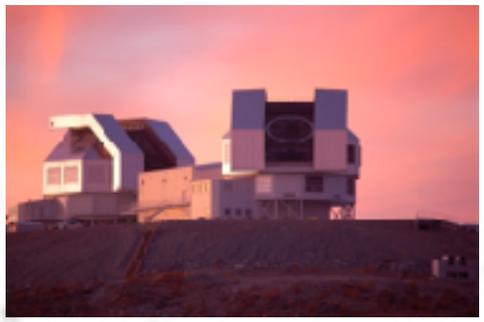
The FourStar Galaxy Evolution Survey (ZFOURGE)



~400 arcminutes in CDFS, COSMOS, and UDS

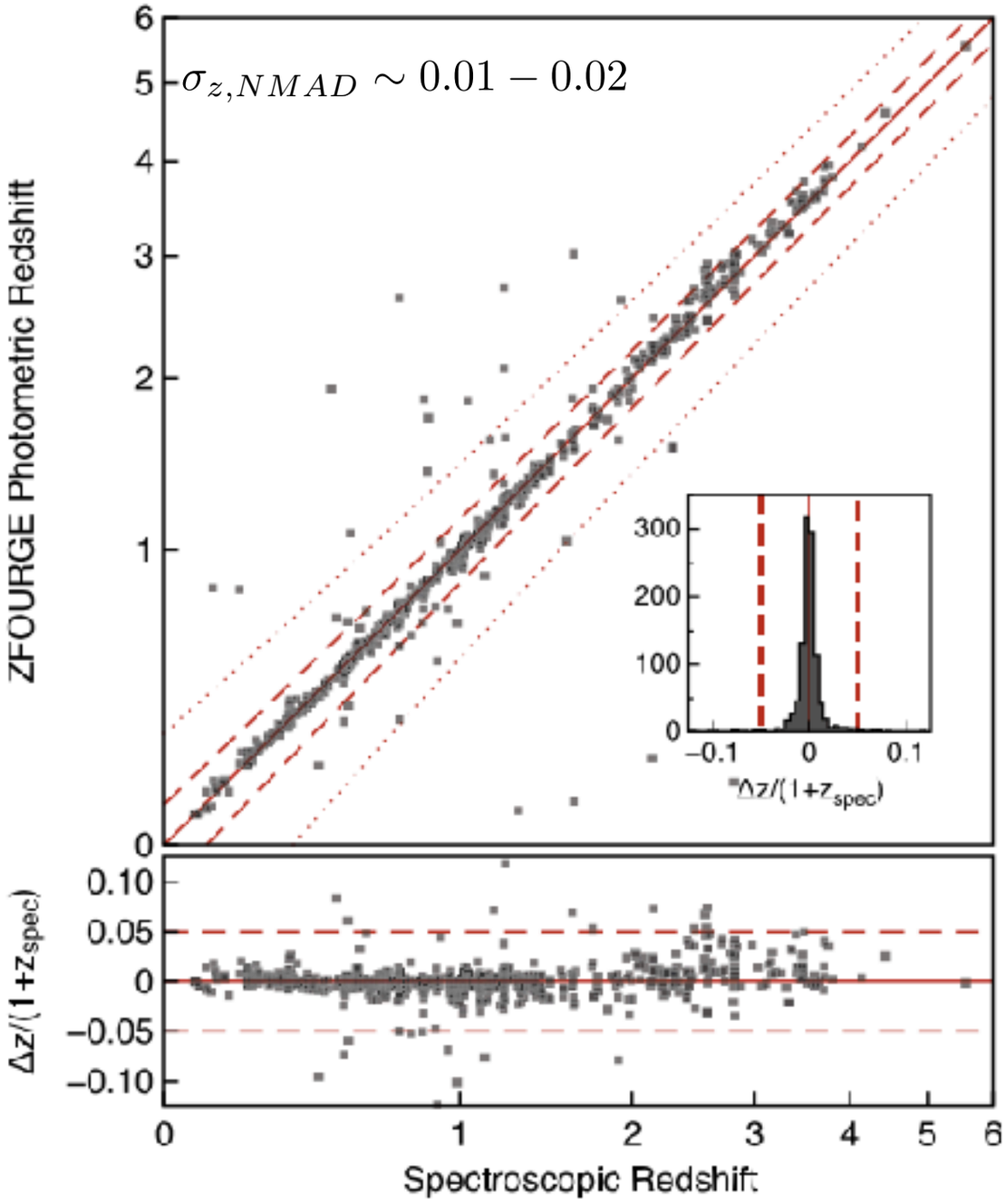
80% completeness K_s~26

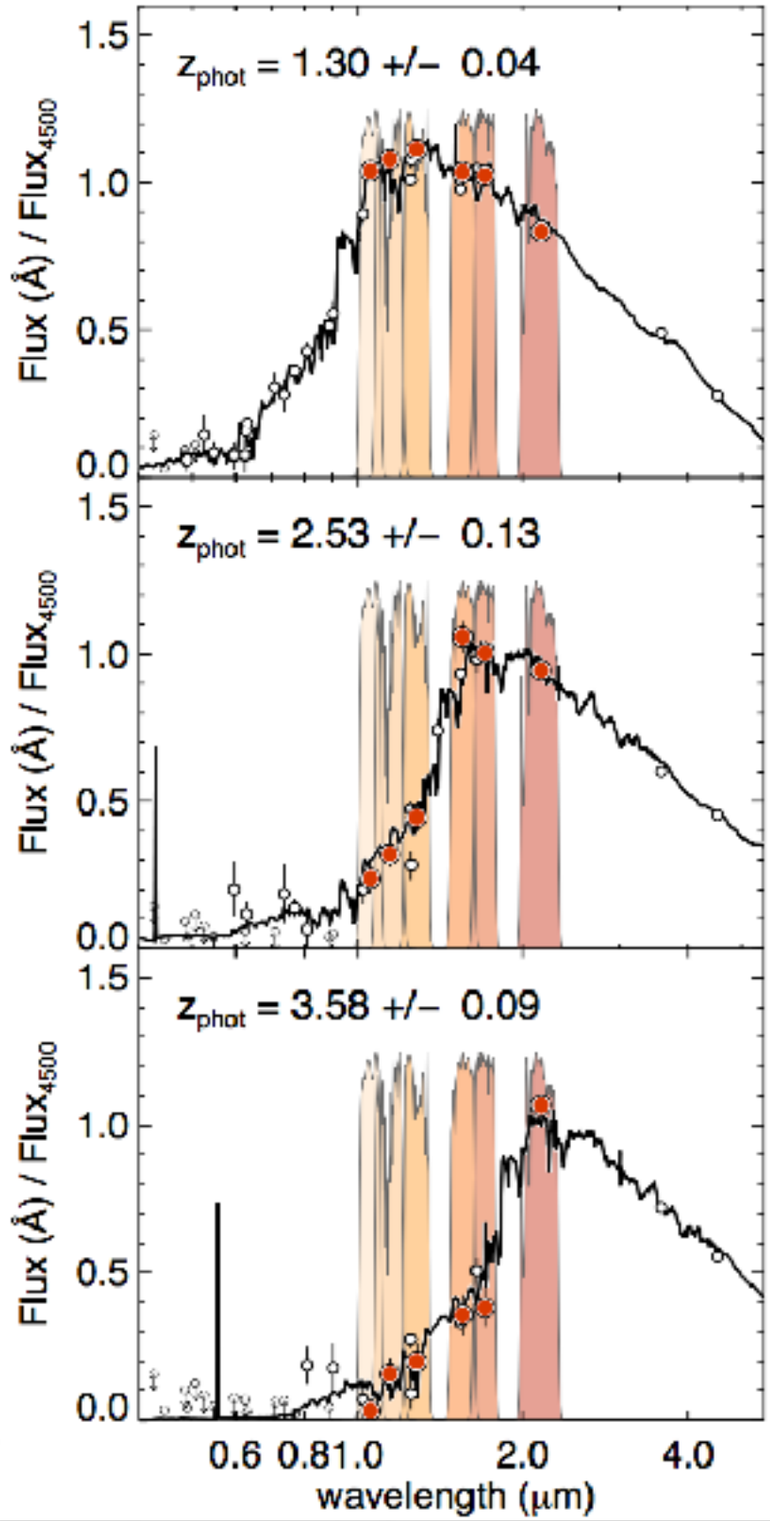
Up to 40 photometric observations from 0.3-8 micron



Straatman+ 2016

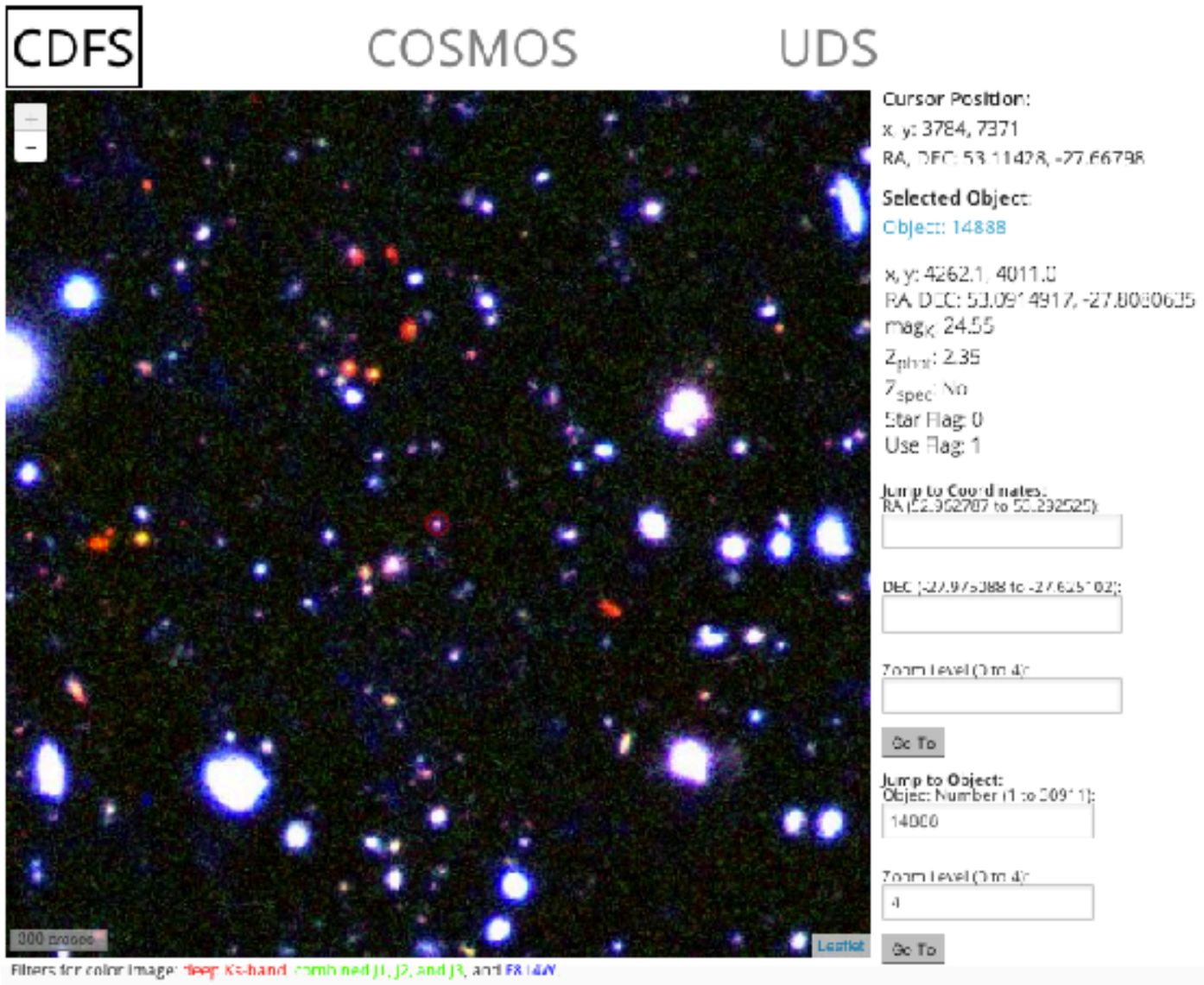
ZFOURGE





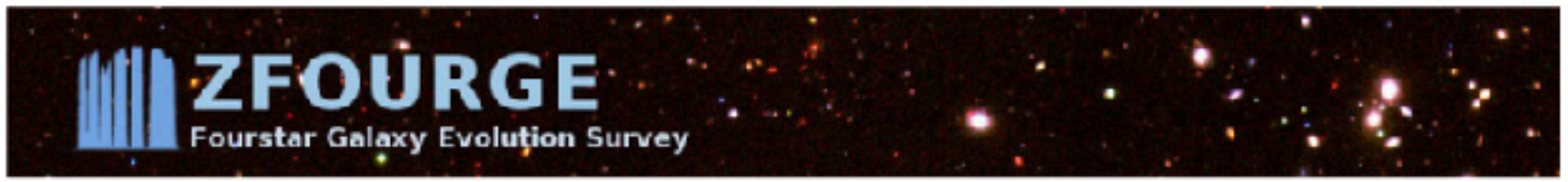
Straatman+ 2016

ZFOURGE



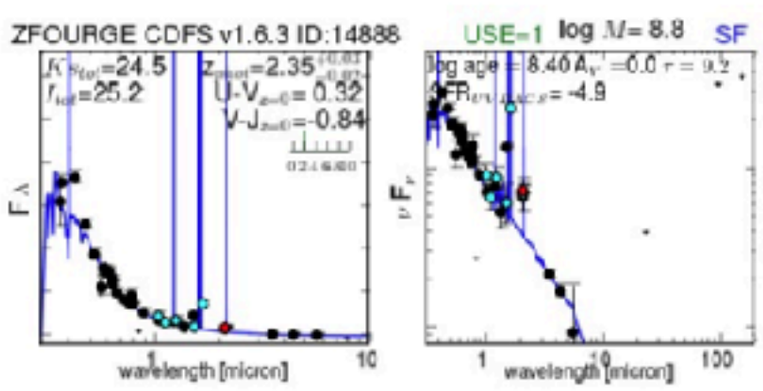
ZFOURGE.TAMU.EDU
Fourstar Galaxy Evolution Survey

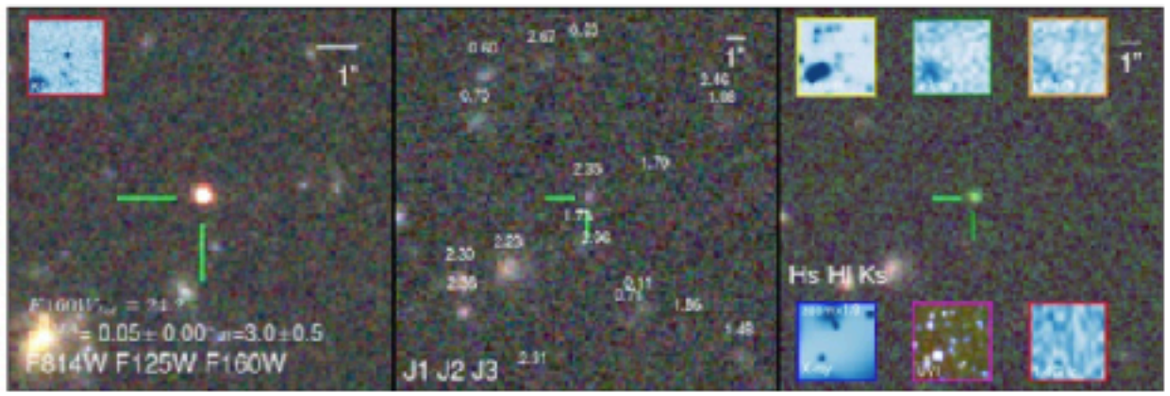
ZFOURGE



CDFS Object ID: 14888

X (pixels)	4262.1	Y (pixels)	4011.0
RA (degree)	53.0914917	DEC (degree)	-27.8080635
mag_K	24.55	mag_i	25.21
z_{phot}	2.35	z_{spec}	No
Star flag	0	AGN flag	No
Use Flag	1	Log Stellar Mass (M_{Sun})	8.85
SFR_{UV+IR} (M_{Sun}/year)	-3.661	Log Specific Star Formation Rate	-99
$(U-V)_{Rest}$	0.319	$(V-J)_{Rest}$	-0.84





Warning: these values are for inspection only. If you would like to do actual science with these objects, please download the catalogs.

Methods

Grouping Galaxy SEDs

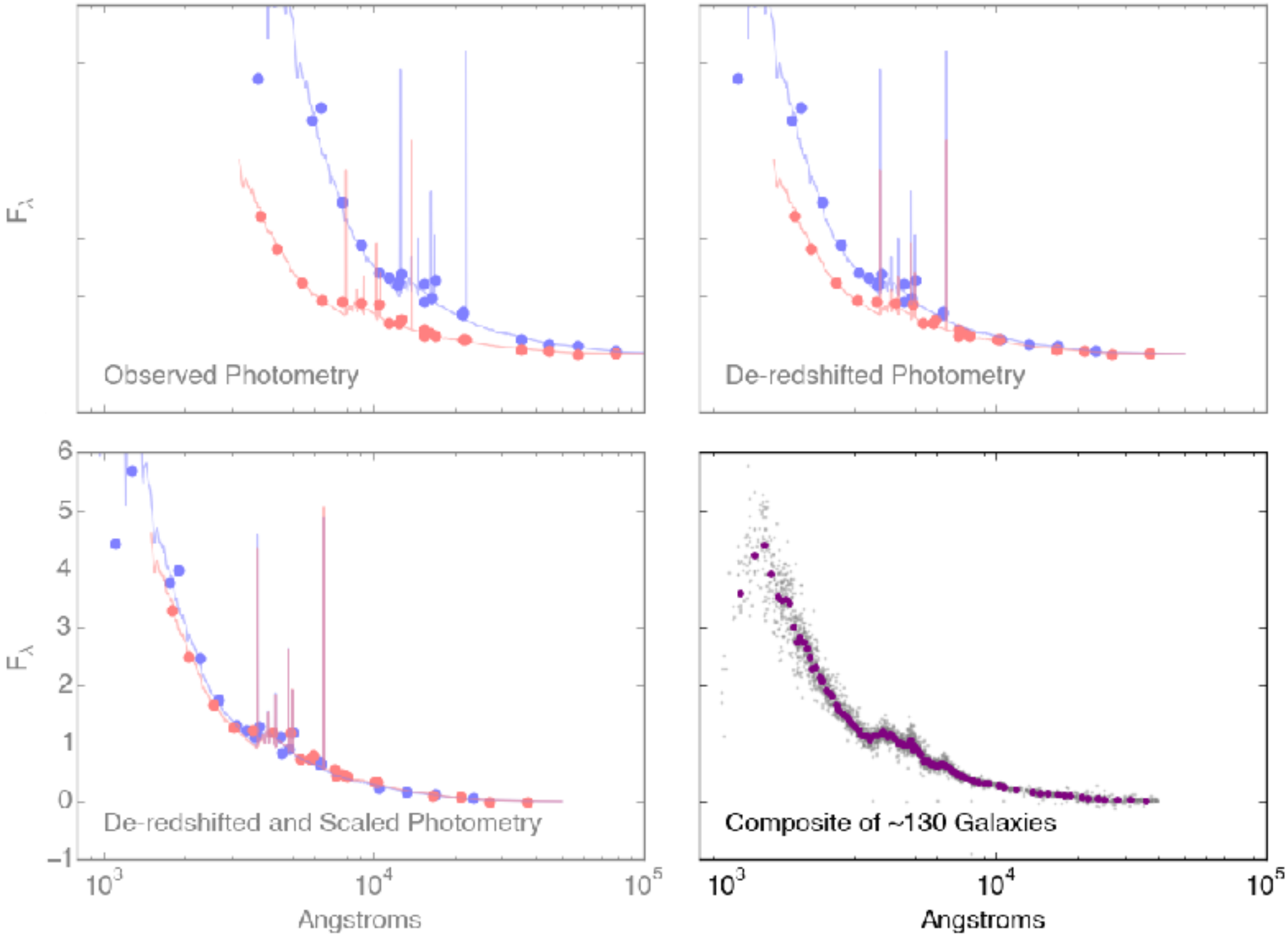
$$b_{12} = \sqrt{\frac{\Sigma(f_\lambda^{ob1} - a_{12} f_\lambda^{ob2})^2}{\Sigma(f_\lambda^{ob1})^2}}$$

$$a_{12} = \frac{\Sigma f_\lambda^{ob1} f_\lambda^{ob2}}{\Sigma(f_\lambda^{ob2})^2}$$

Method pioneered in Kriek, et al. 2011

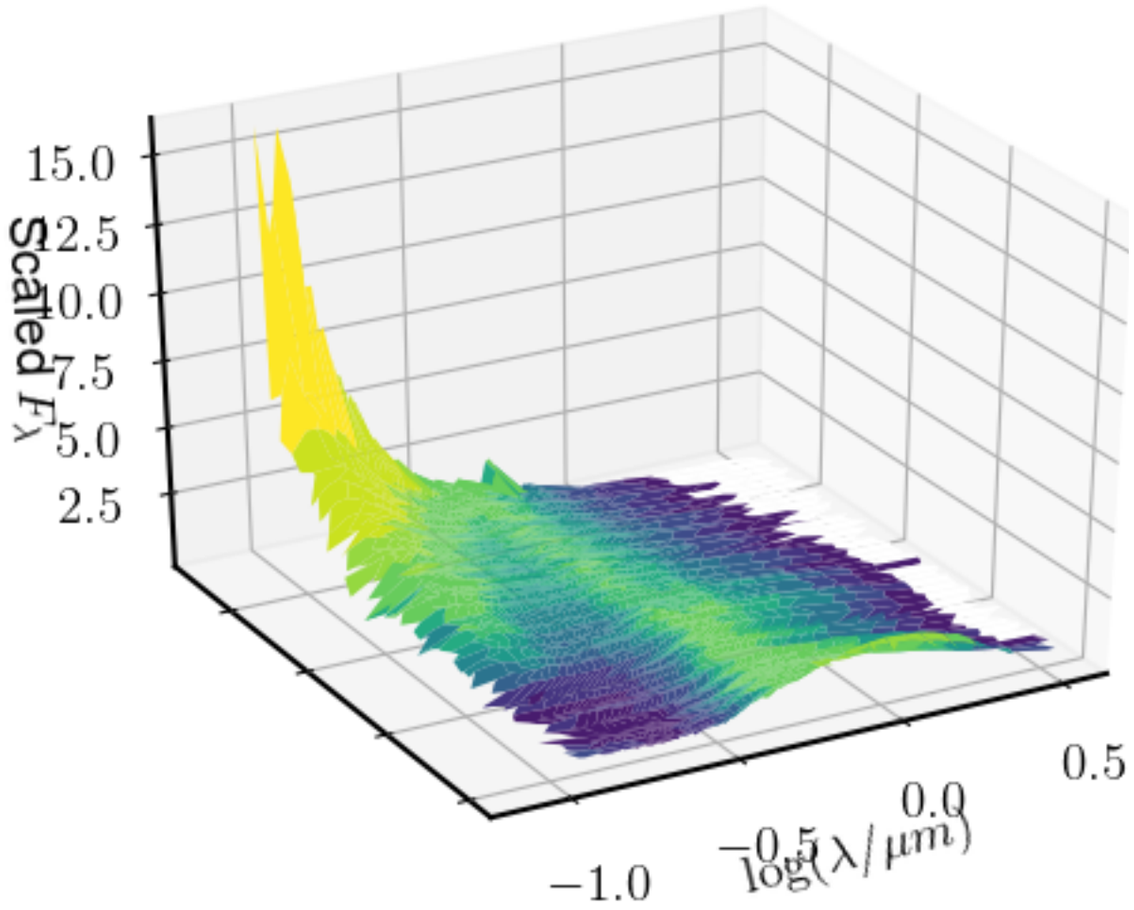
- Compare rest-frame photometry of SNR>20 galaxies.
- The smaller the value of *b*, the more similar the photometry of the two SEDs.
- Galaxies are grouped according to which other galaxies they are the most similar.

Building Composite SEDs

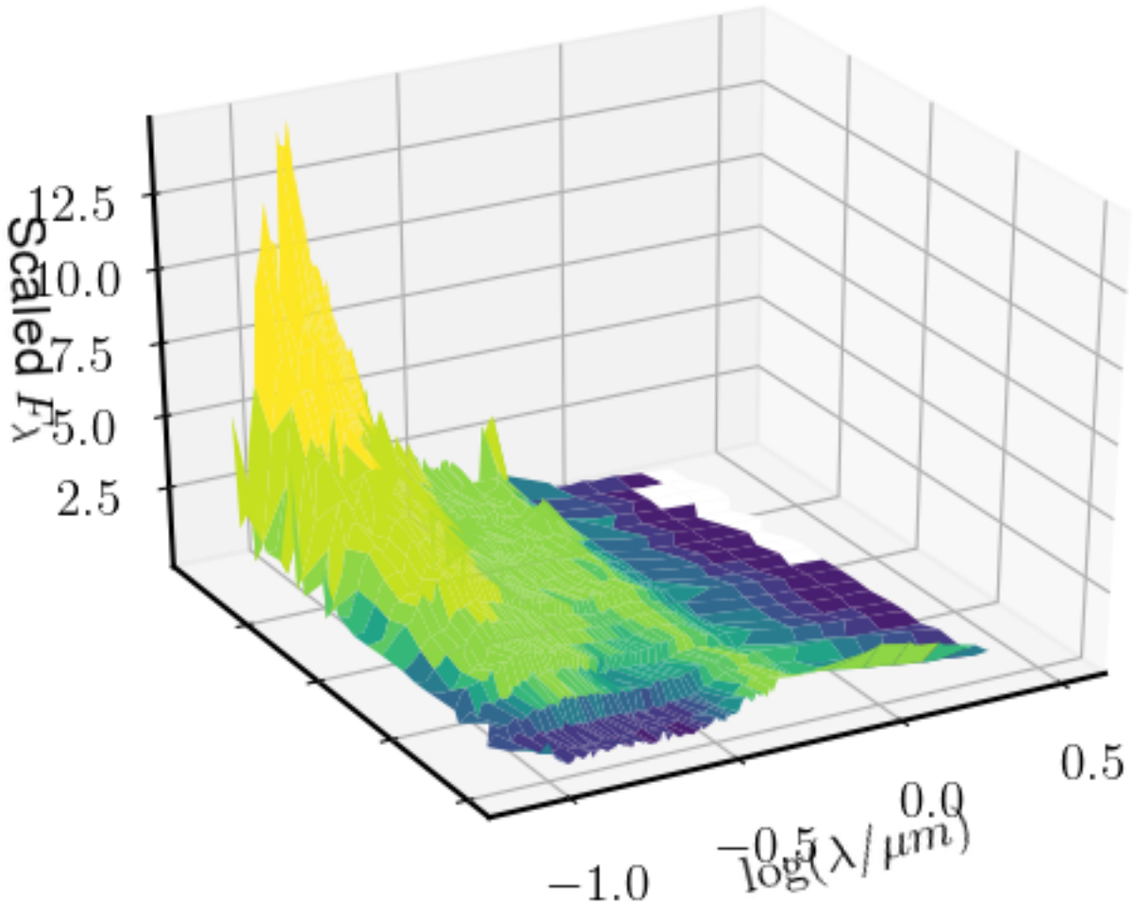


Composite SEDs

$1 < z < 3$

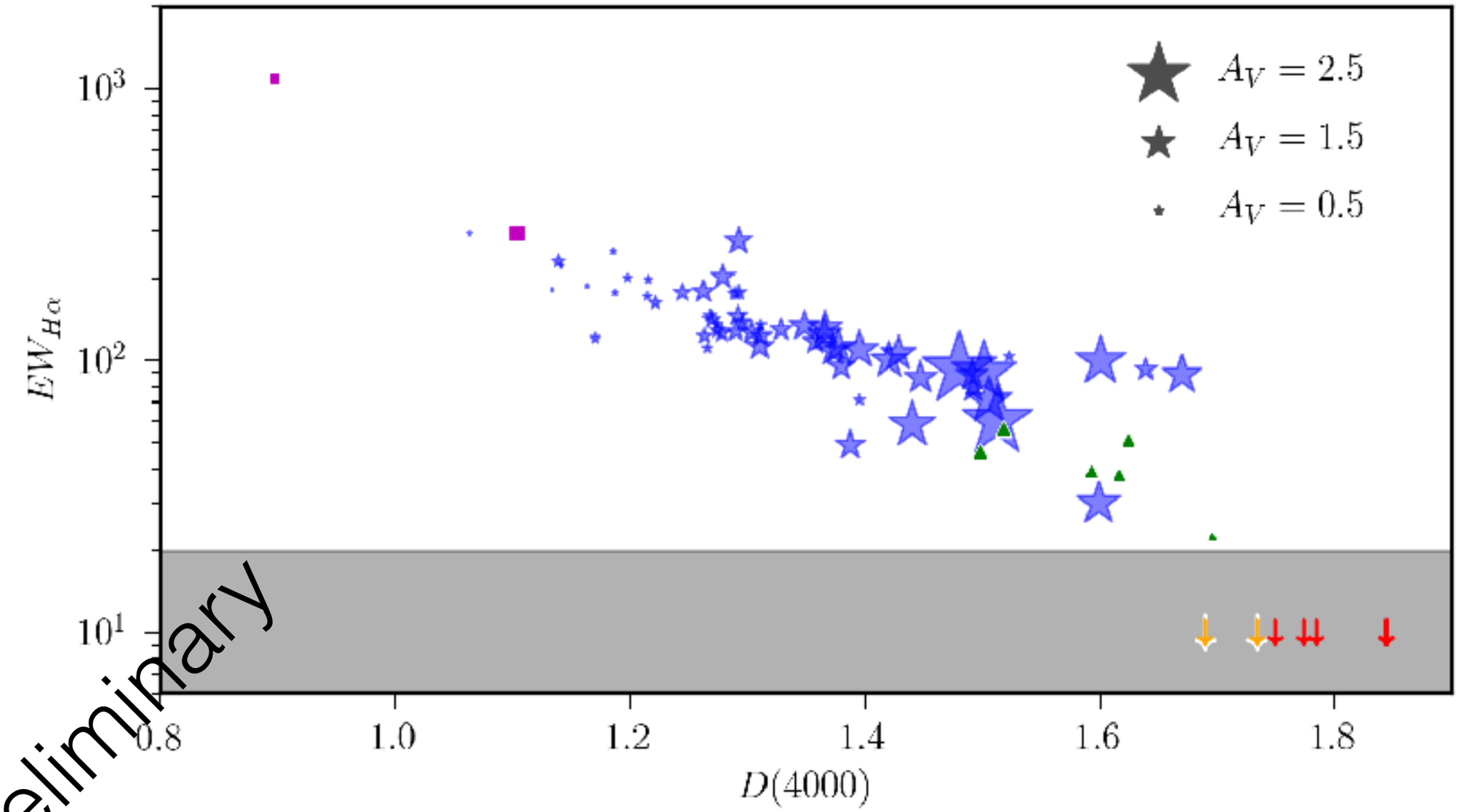


$2.5 < z < 4$



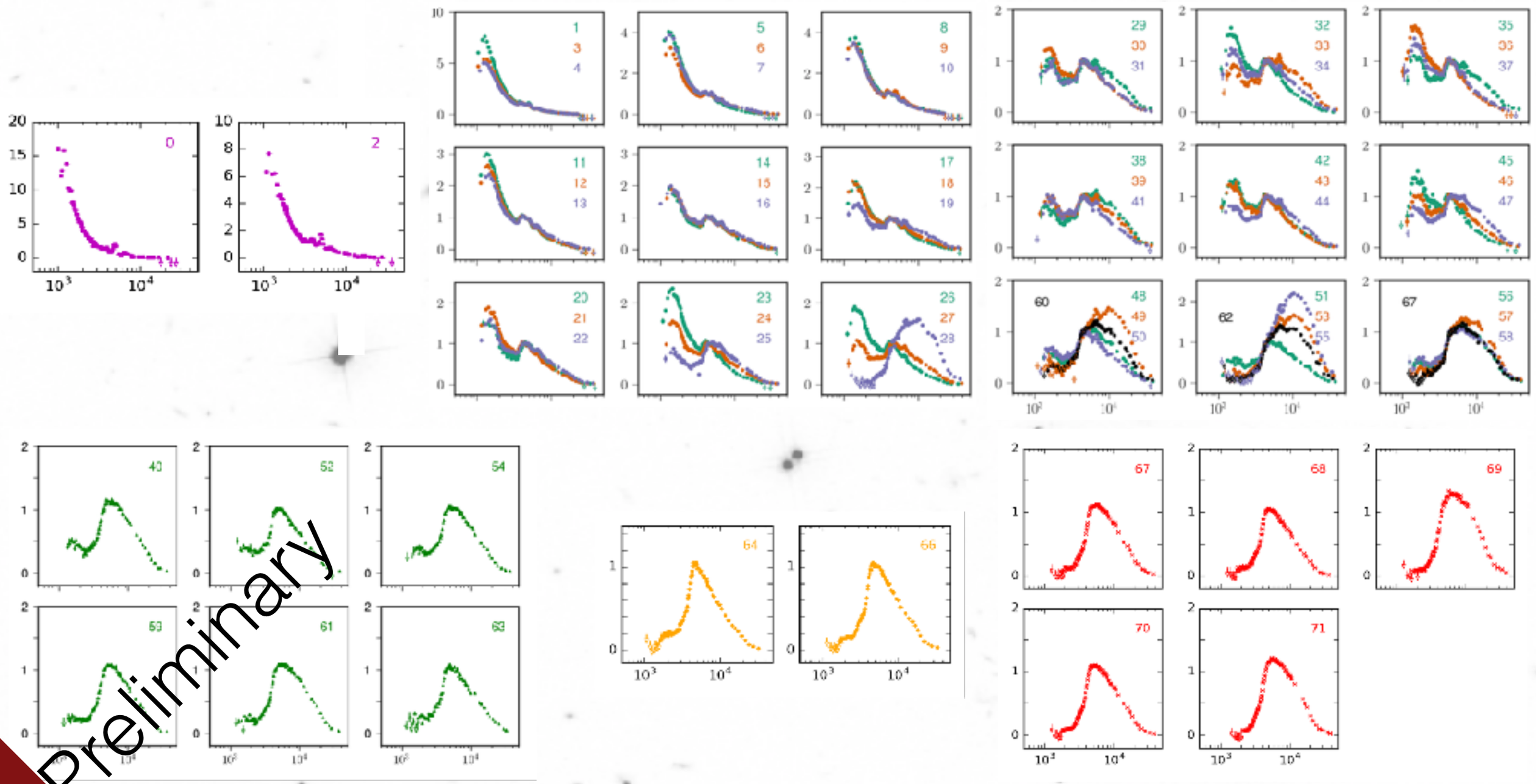
From Star-Forming to Quiescent

Classification



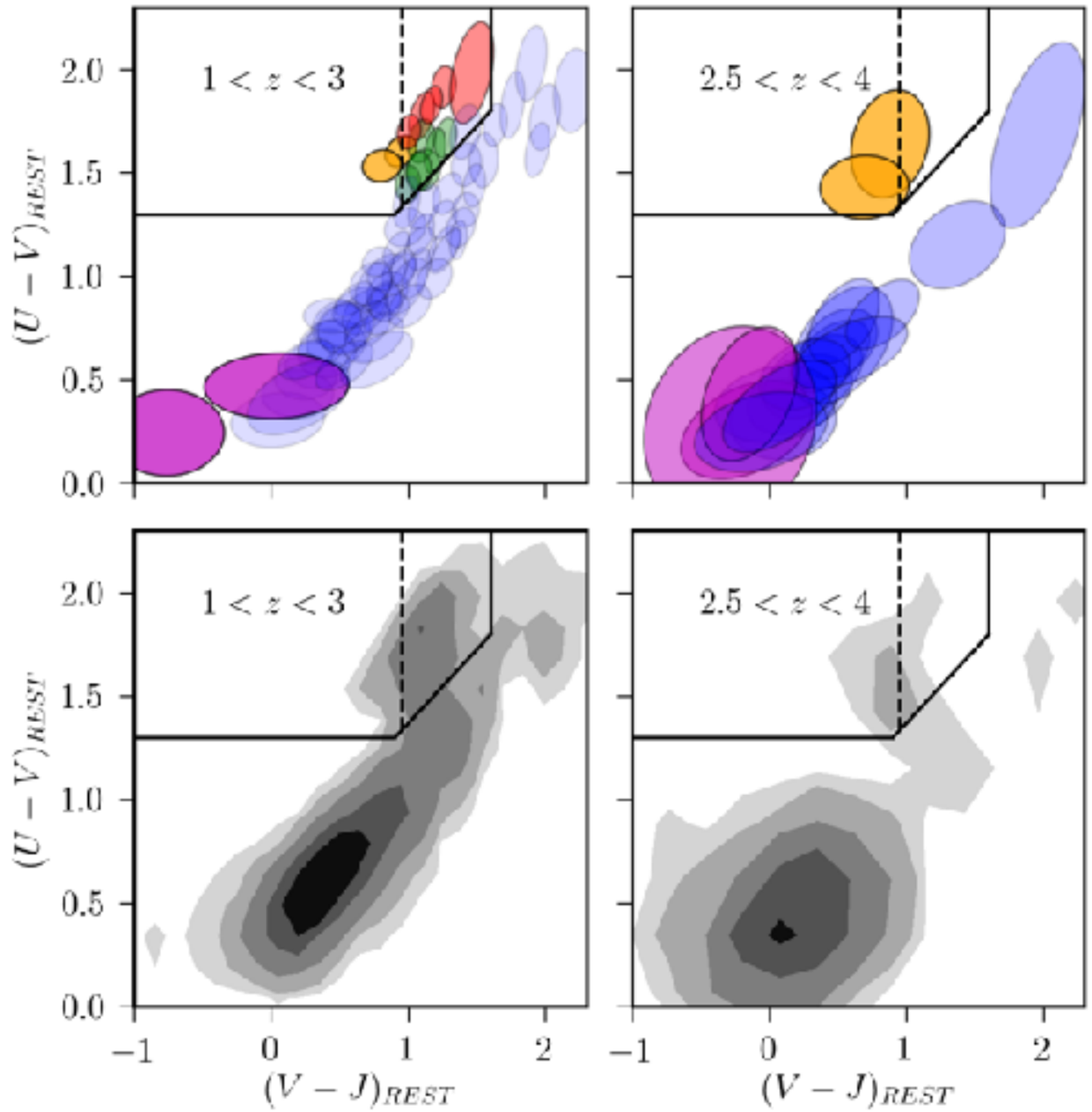
Preliminary

Composite SEDs



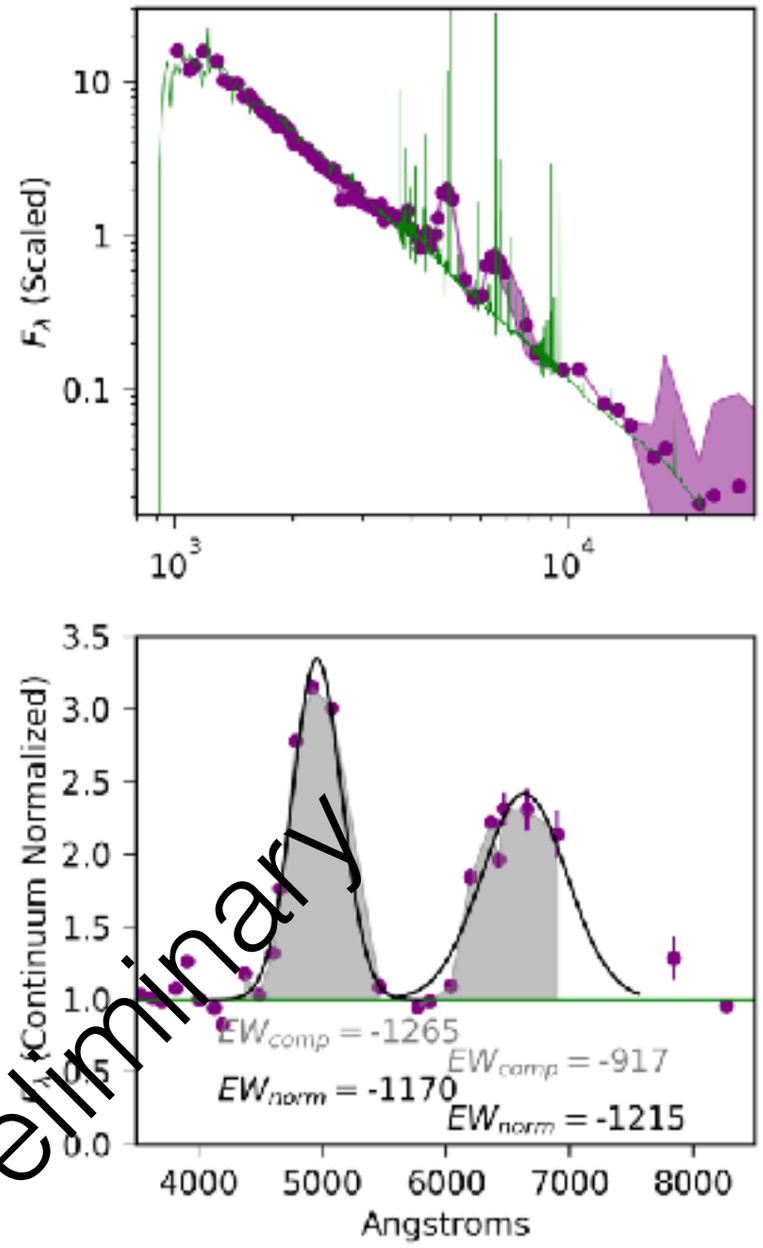
Preliminary

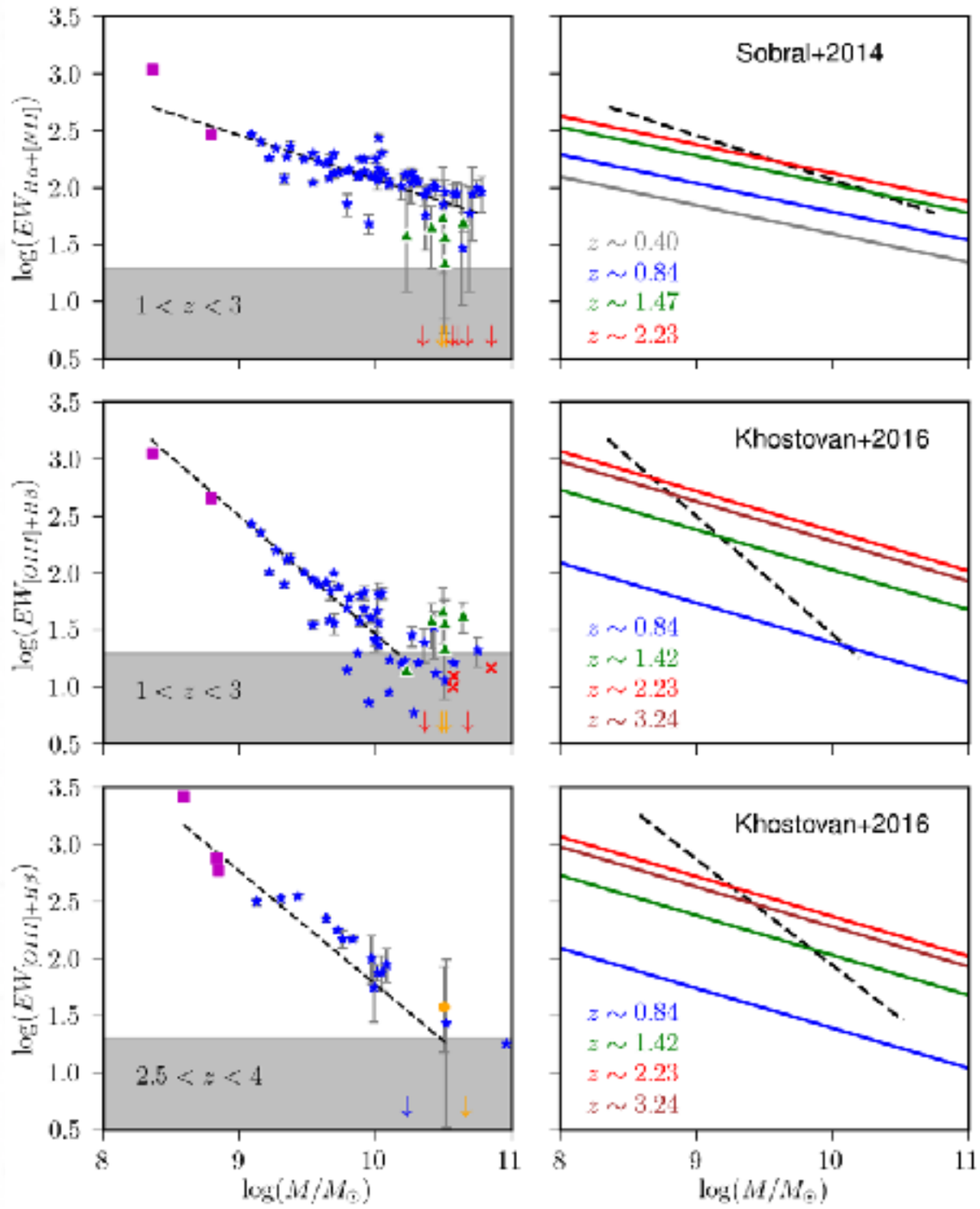
Composite SED Colors



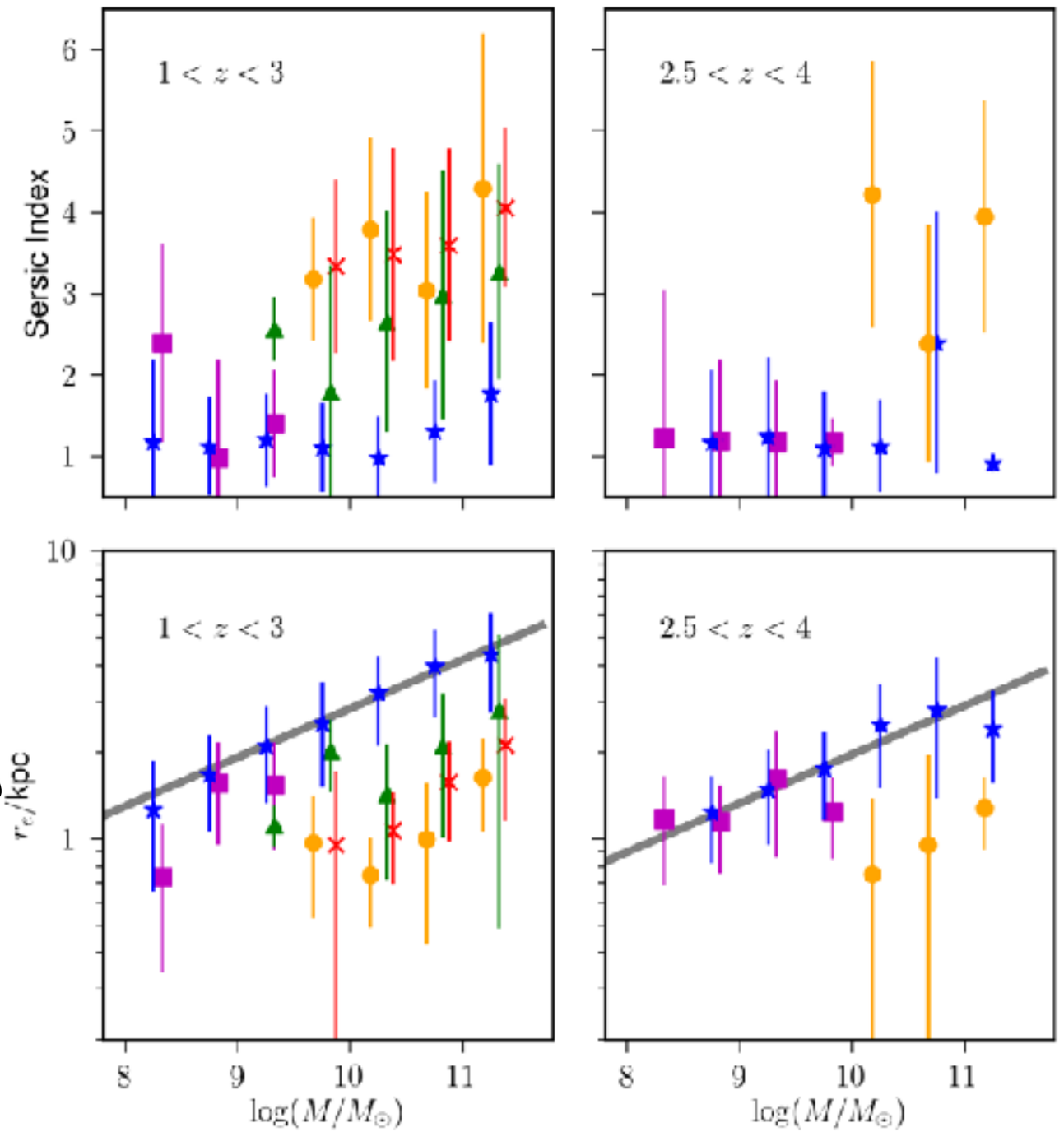
Preliminary

Equivalent Widths



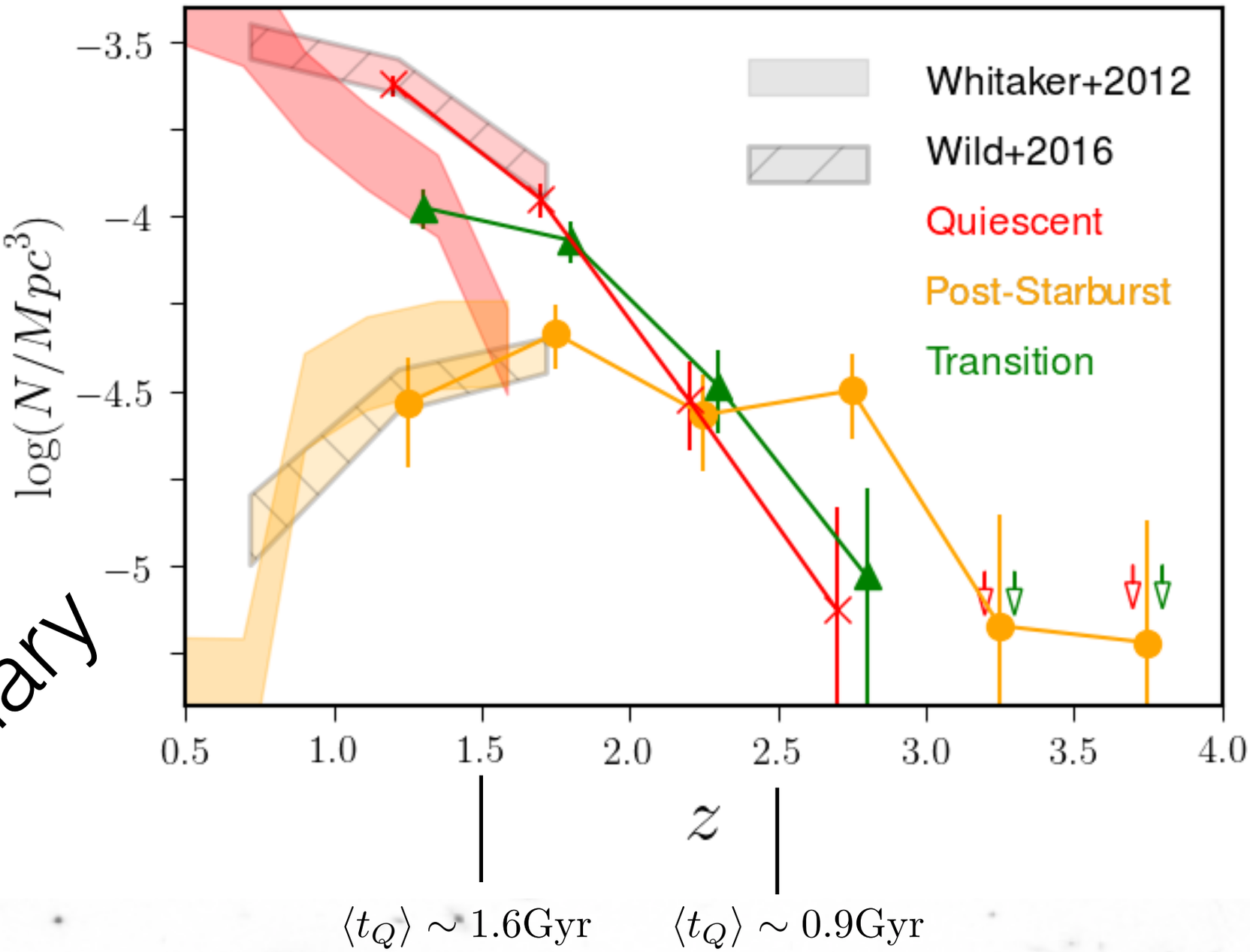


Morphologies



Preliminary

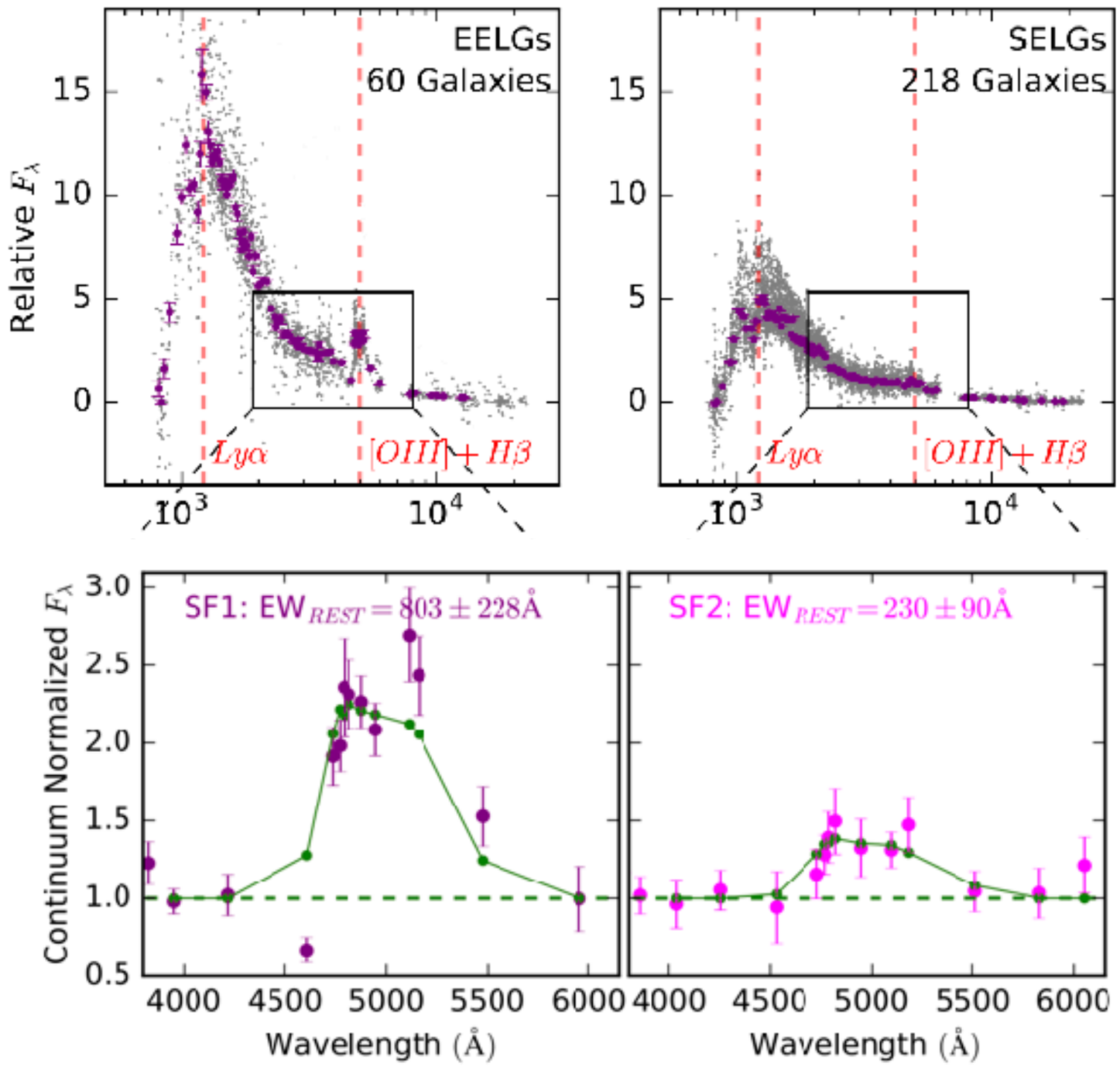
Number Density Evolution



Preliminary

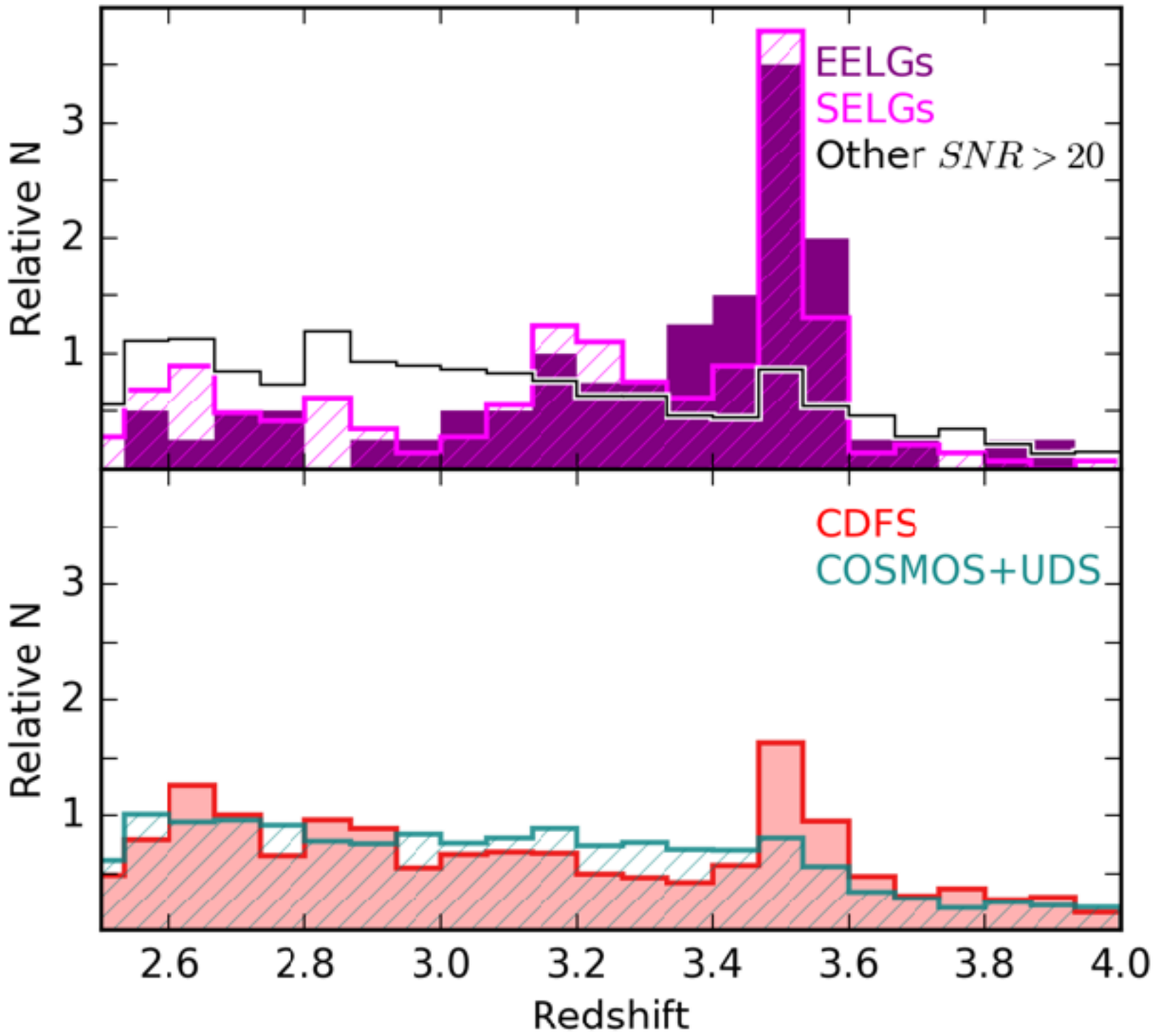
Extreme Emission Line Galaxies

Emission Lines



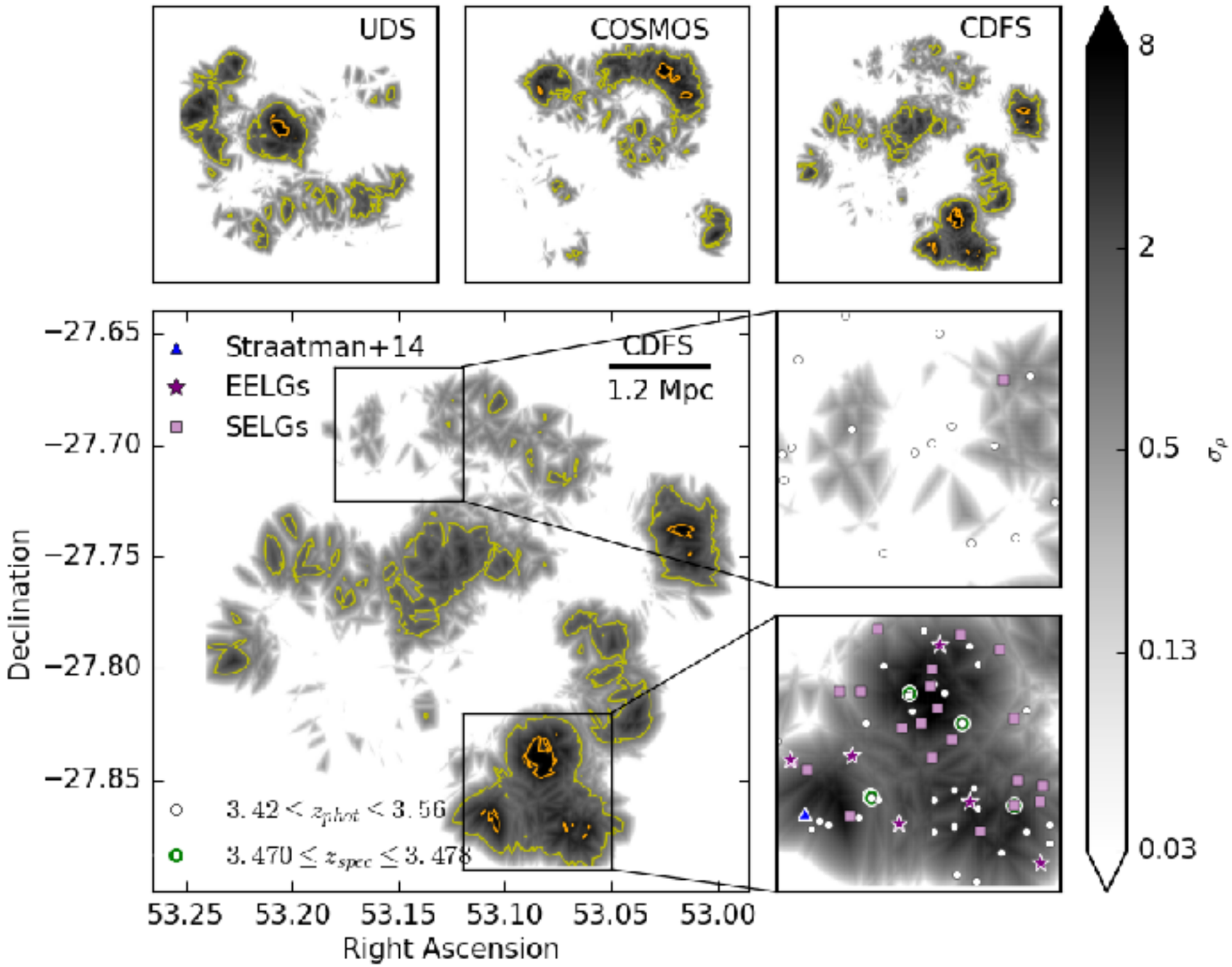
Forrest+2017

Excessive Galaxies at z~3.5



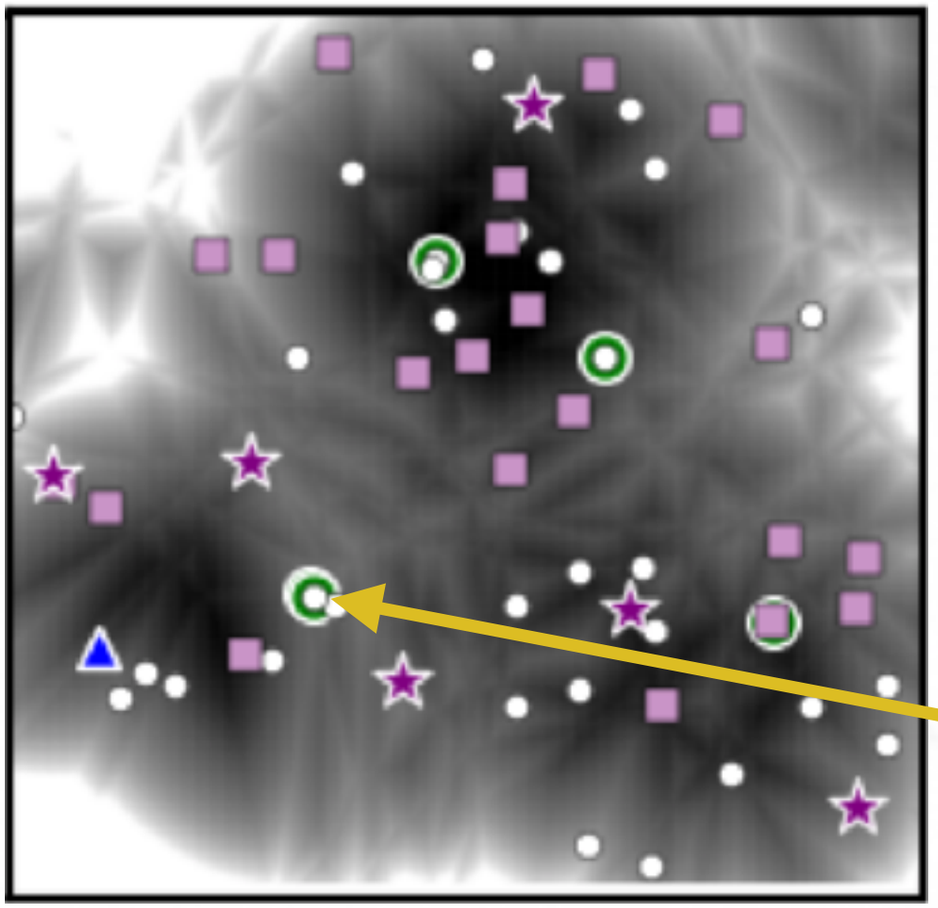
Forrest+2017

Galaxy Overdensity

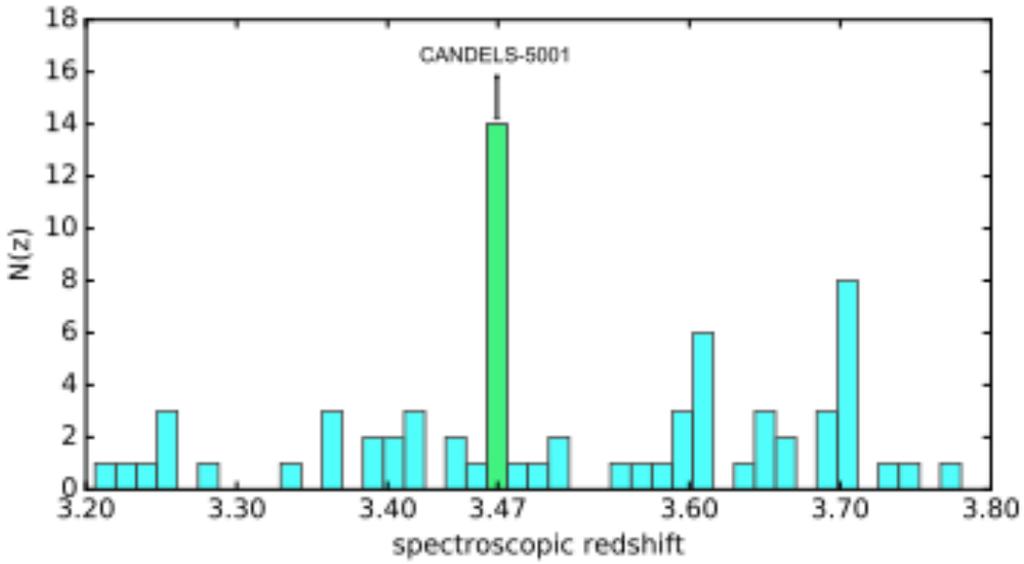


Forrest+2017

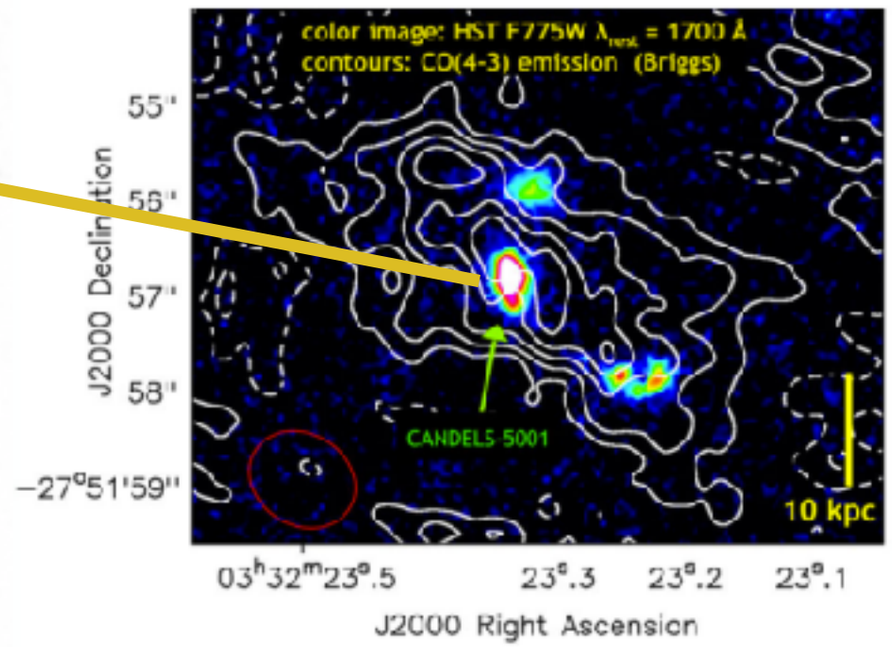
Structure in CDFS at z~3.5



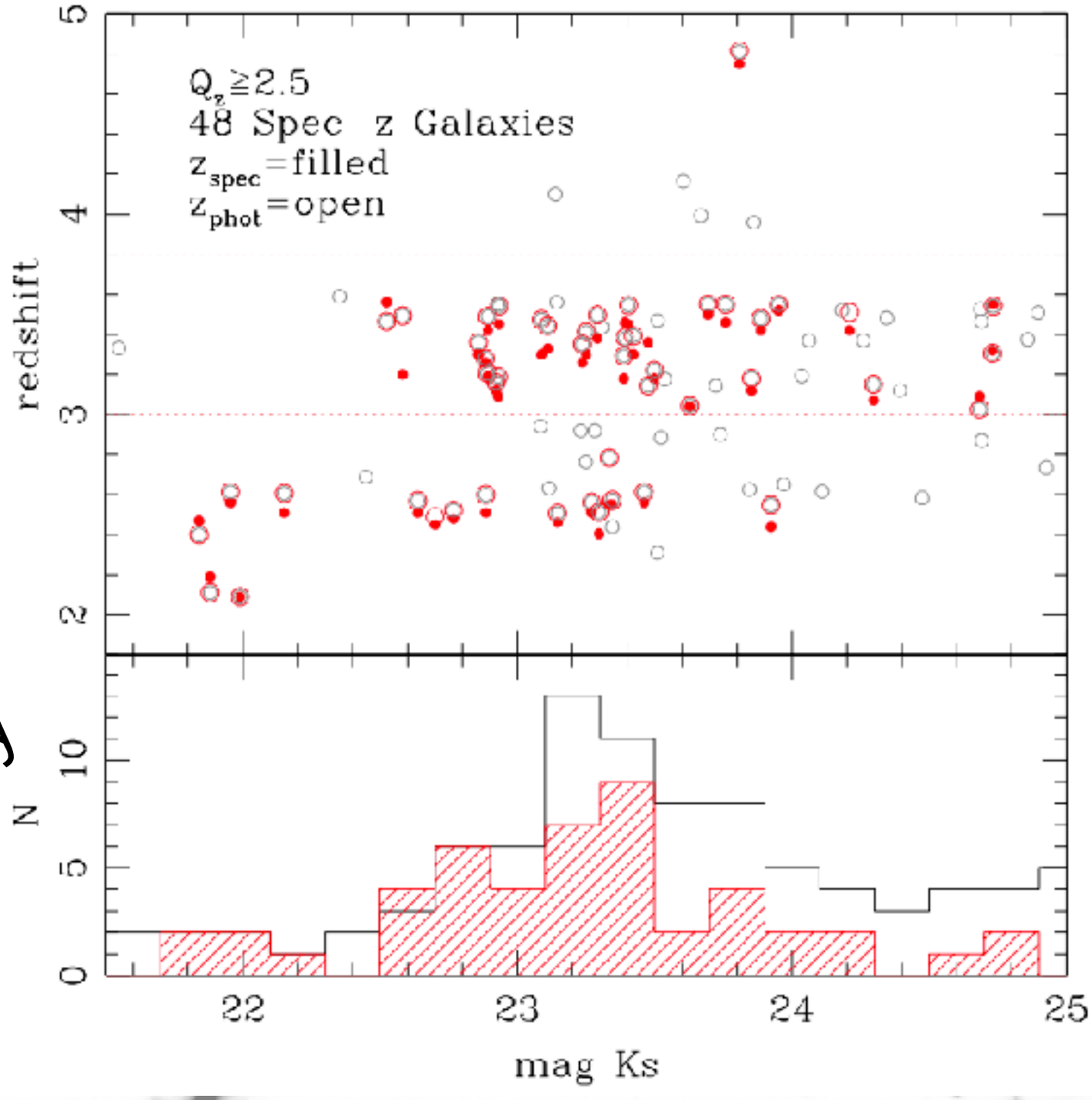
Forrest+17



Ginolfi+17



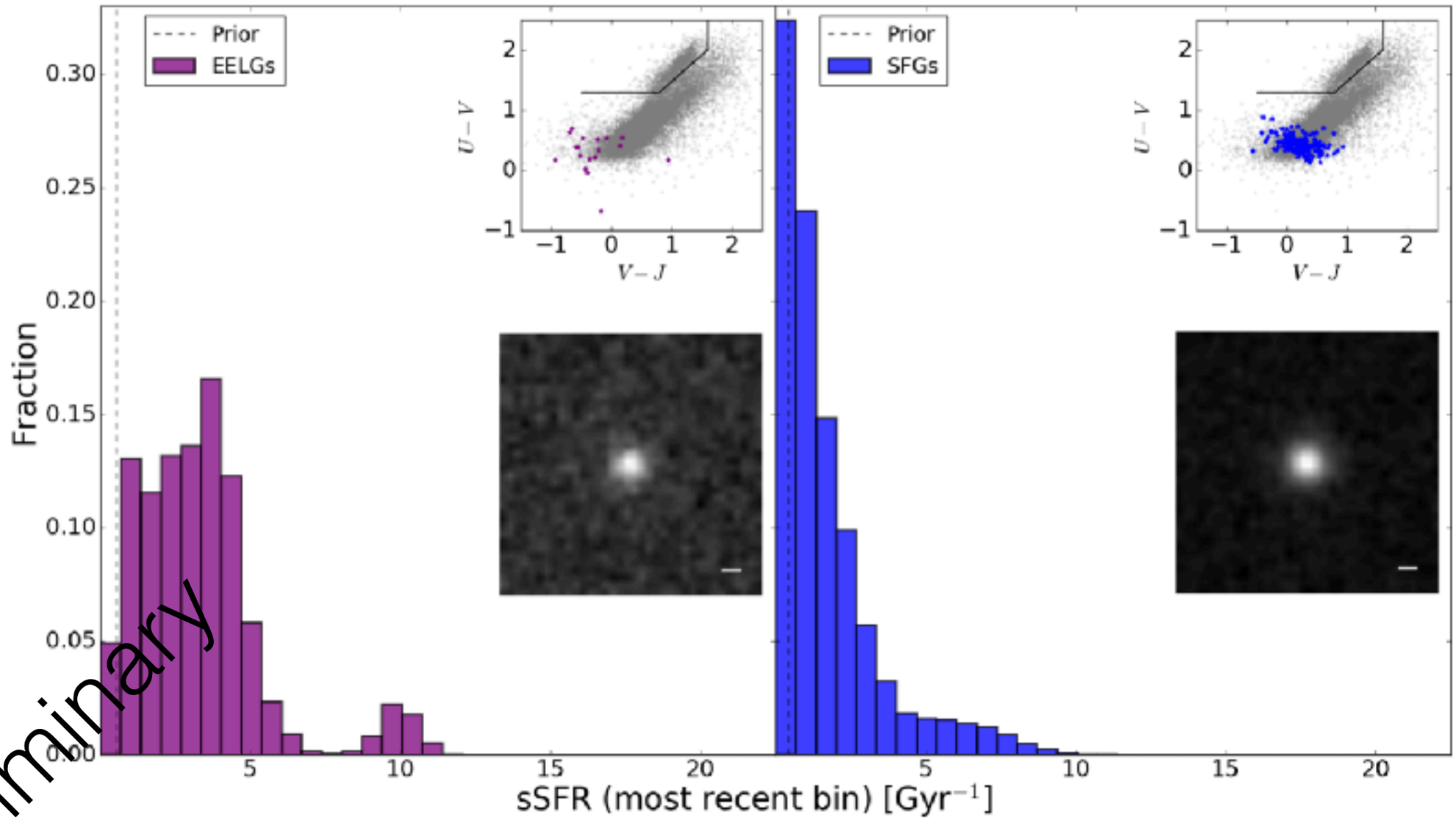
Follow-Up: MOSEL



Preliminary

Tran, B.F.+, in prep

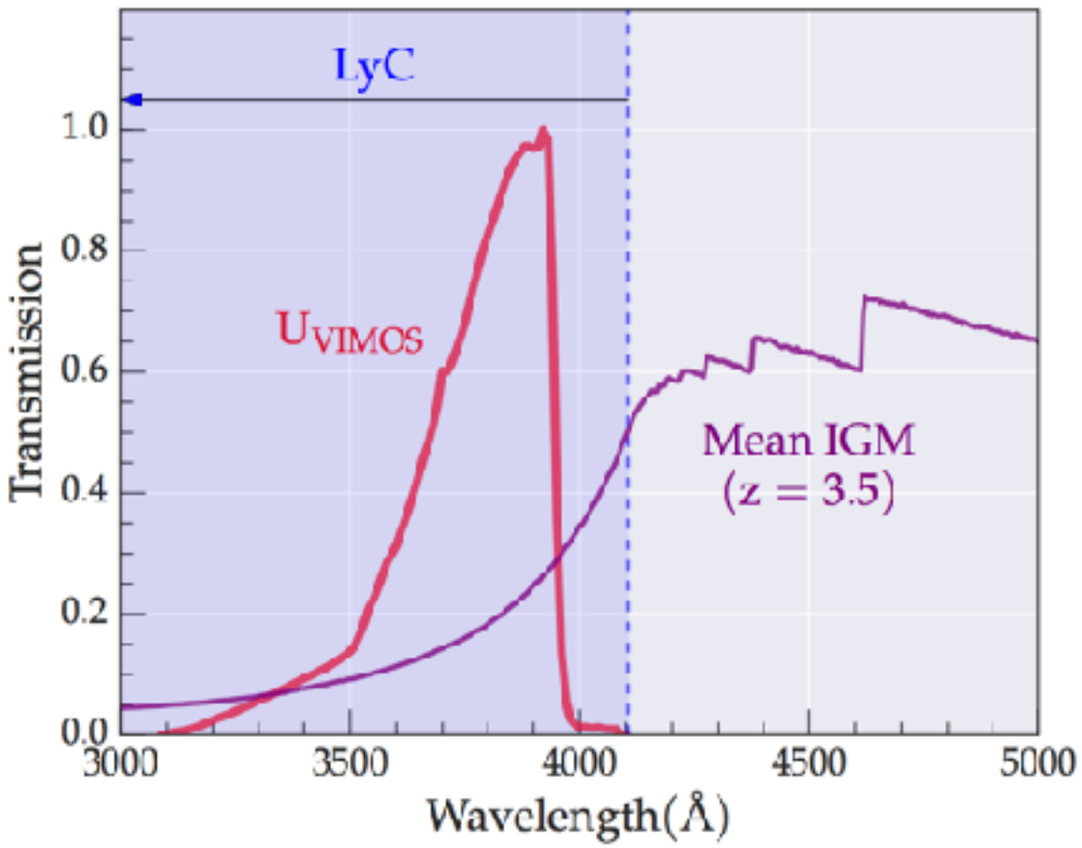
Follow-Up: Prospector

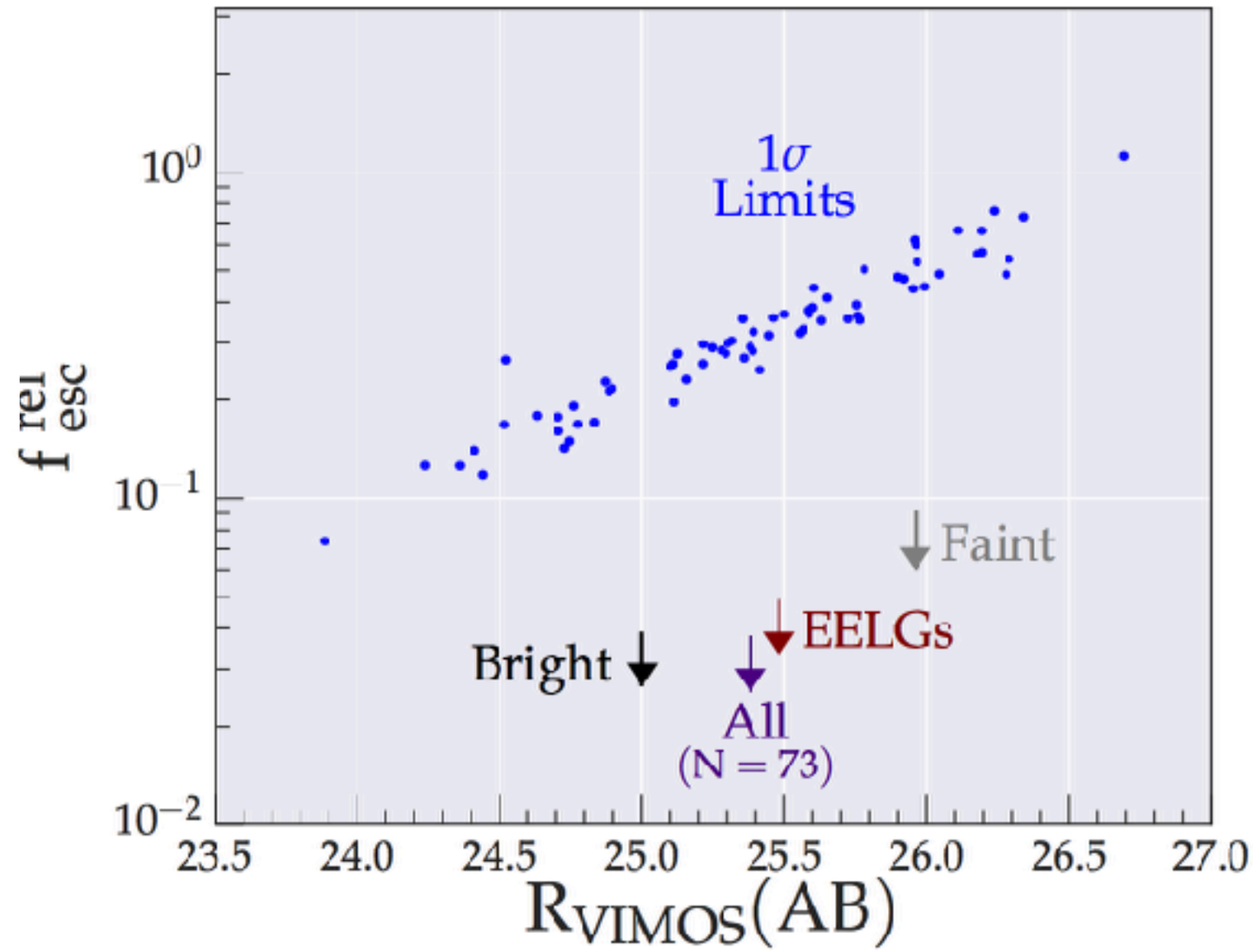


Preliminary

Cohn, B.F.+, in prep

Follow-Up: Escape Fractions





Preliminary

Naidu, B.F.+, submitted

Conclusions

- The average galaxy in the process of shutting off star formation has recently undergone a morphological change, consistent with mechanisms such as morphological quenching.

- These galaxies have become more common from z=4 to z=1, in tandem with the number density of quenched galaxies.

- Galaxies with large amounts of nebular emission are increasingly common at high redshift.
  - ✳ The most extreme of these galaxies are likely undergoing their initial bursts of star formation.
  - ✳ Similar galaxies at higher redshifts will need larger escape fractions to contribute significantly to cosmic reionization.