# Highlights from ZFOURGE

FourStar Galaxy Evolution Survey

AAO Gemini, Magellan, and Keck Science Symposium

Michael Cowley, 22nd May 2015

MACQUARIE University
SYDNEY·AUSTRALIA

Australian Government
Department of Industry and Science

AAO

# ZFOURGE

**FourStar Galaxy Evolution Survey**

## What:

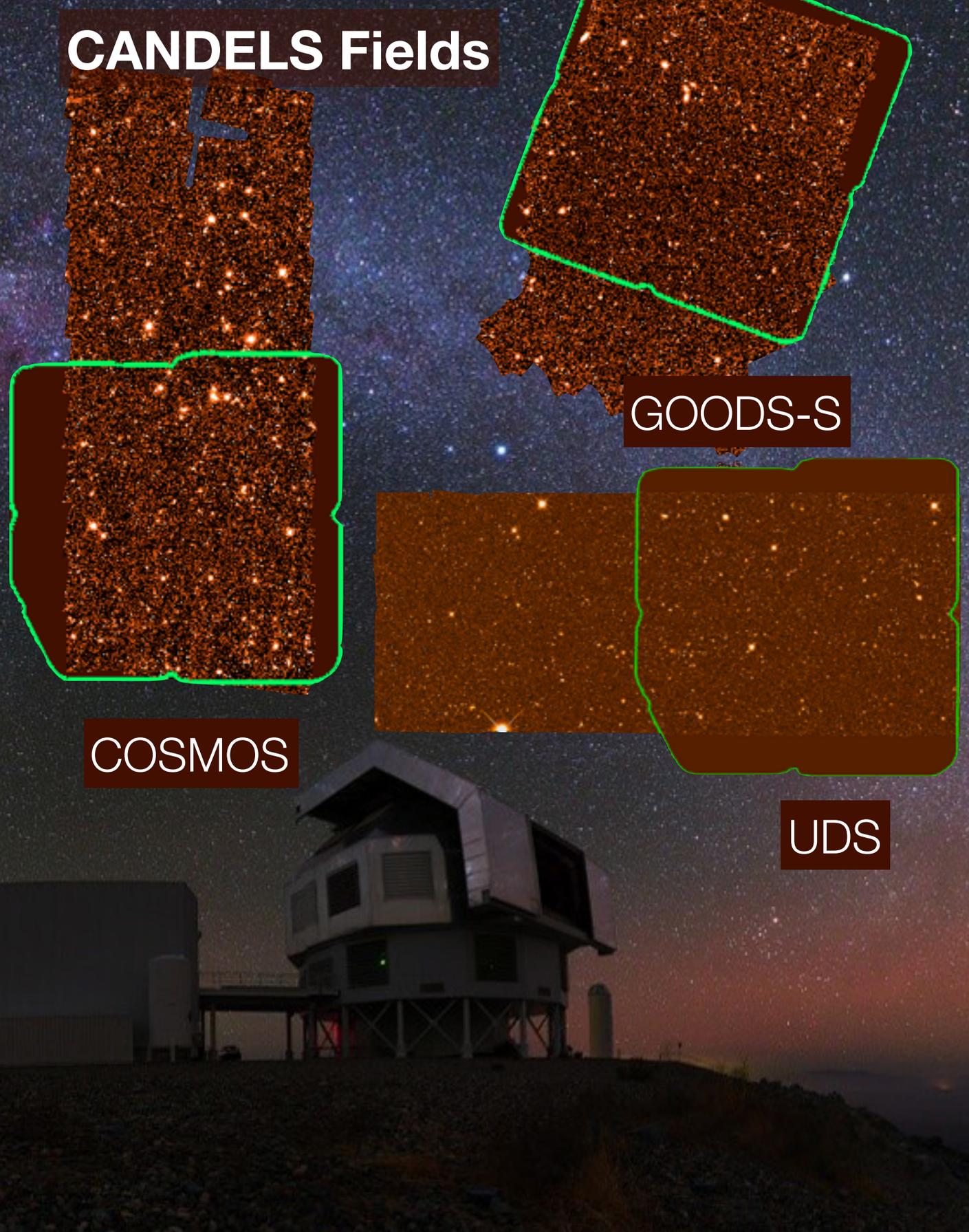
~50 nights on Magellan/
FourStar near-IR camera
5 medium-band filters
Ks broadband

## Primary goal:

Accurate photo-z of ~30,000 galaxies at $z > 1$
Galaxy formation and evolution at $z > 1$

## 3 legacy fields:

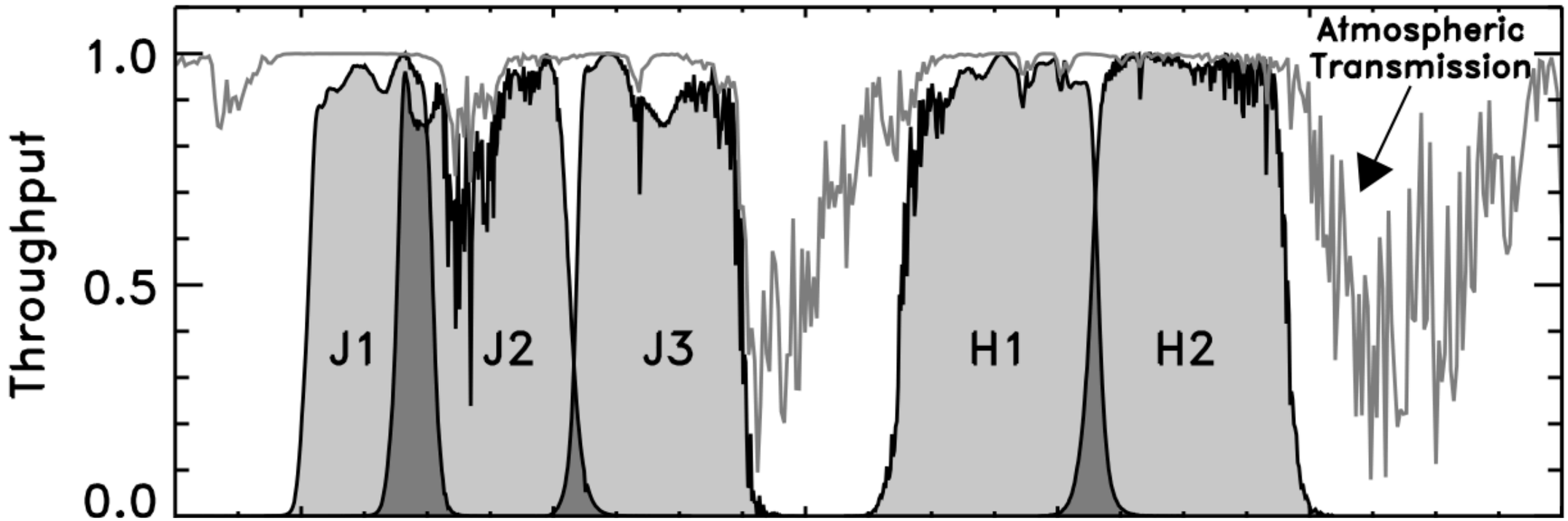
COSMOS, GOODS-S, UDS
11x11 arcmin^2 each



# ZFOURGE

## FourStar Galaxy Evolution Survey

Medium Band Filters




5-sigma: $J_1$ $J_2$ $J_3$ to 26 AB, $H_l$ $H_s$ to 25 AB, $K_s$ to 25 AB

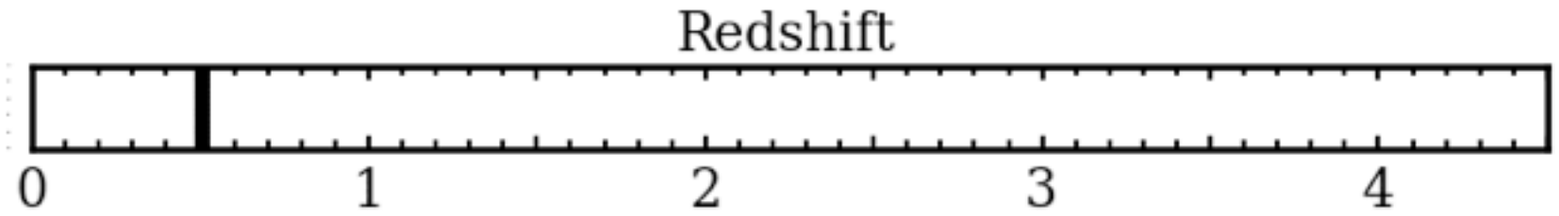
1-2% redshift uncertainties, $\sigma/(z+1)$, at $1.5 < z < 3.5$

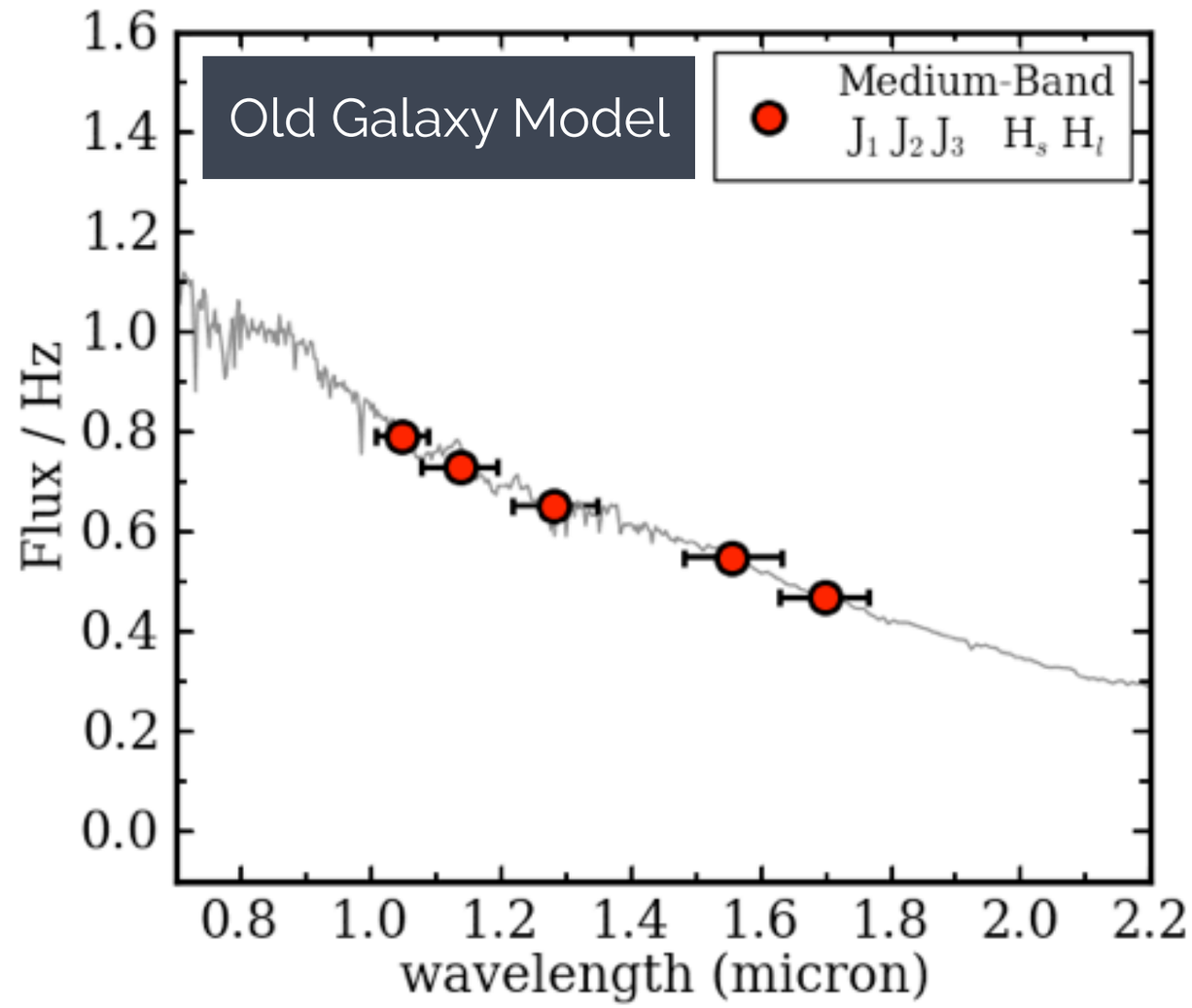
NEWFIRM 1.2”
K 12 hours
NMBS

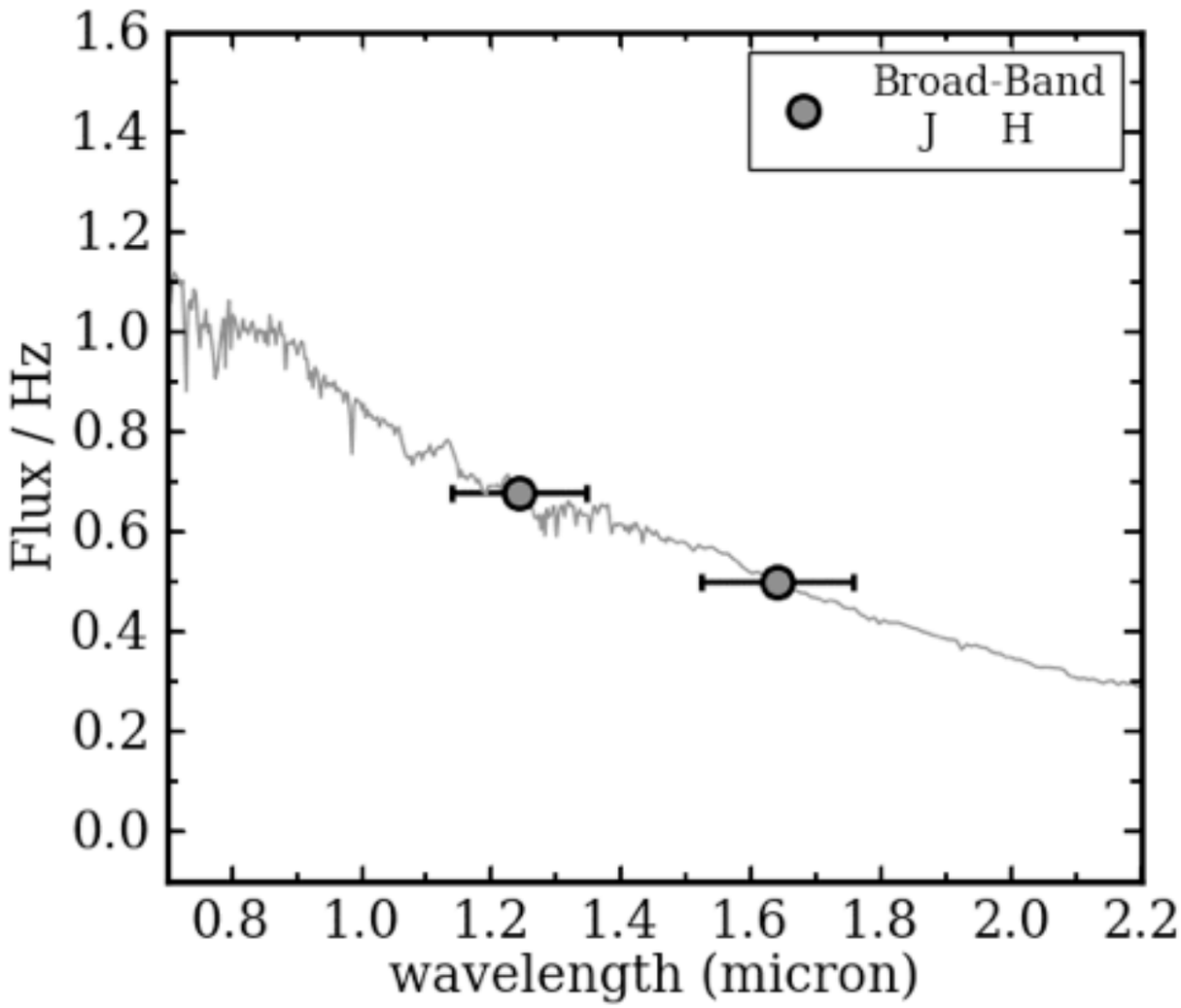
Four-Star 0.4”
K 30 minutes
ZFOURGE

# ZFOURGE

**FourStar Galaxy Evolution Survey**



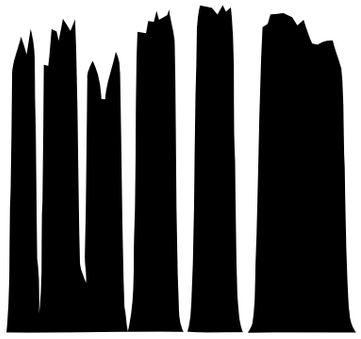




ZFOURGE Filters

Traditional Filters

Animation: A.Tomczak



# ZFOURGE

## FourStar Galaxy Evolution Survey

zfourge.tamu.edu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Glenn Kacprzak
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Ivo Labbé (PI)
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Andy Monson
Themiya Nanayakkara
Casey Papovich
Eric Persson
Ryan Quadri
Glen Rees
Lee Spitler
Caroline Straatman
Vithal Tilvi
Adam Tomczak
Kim-Vy Tran
Pieter van Dokkum



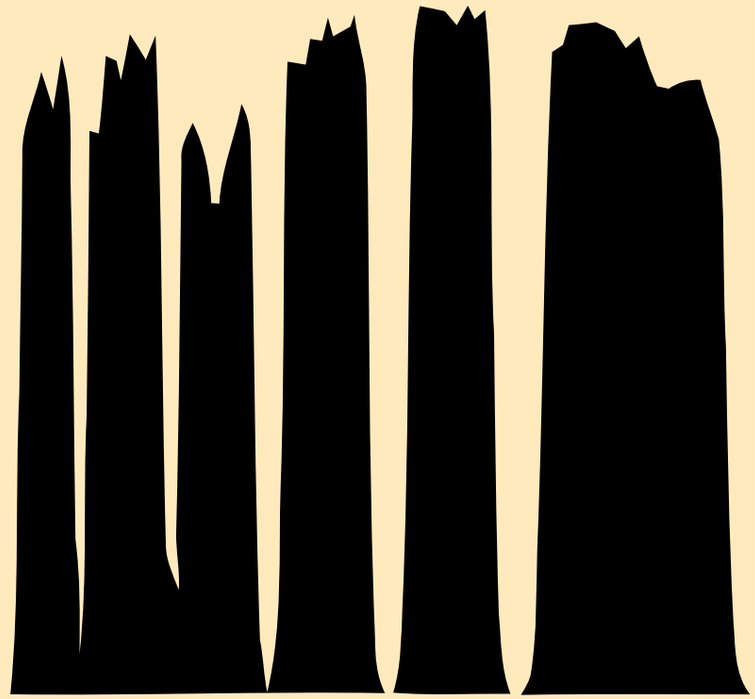




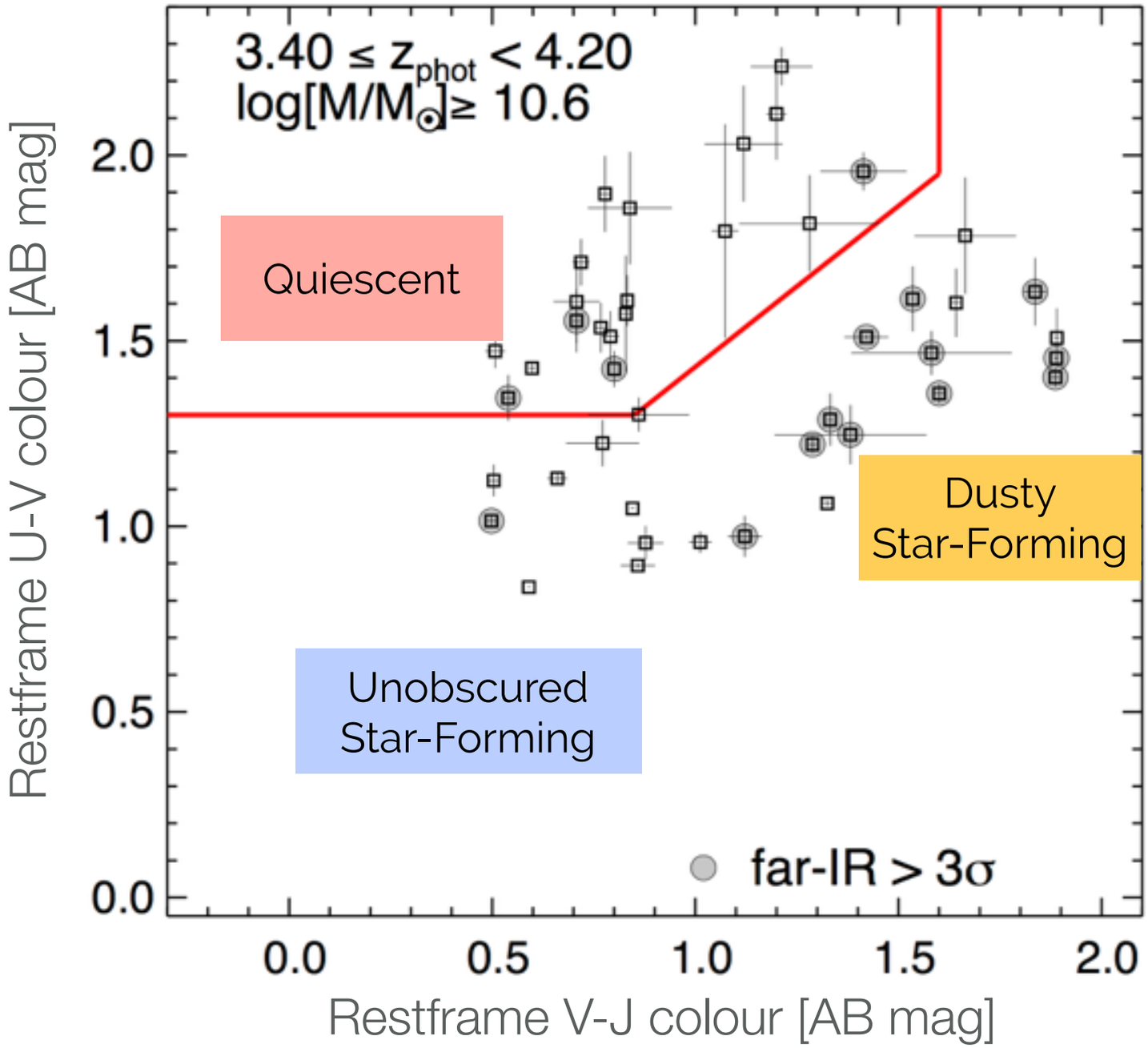


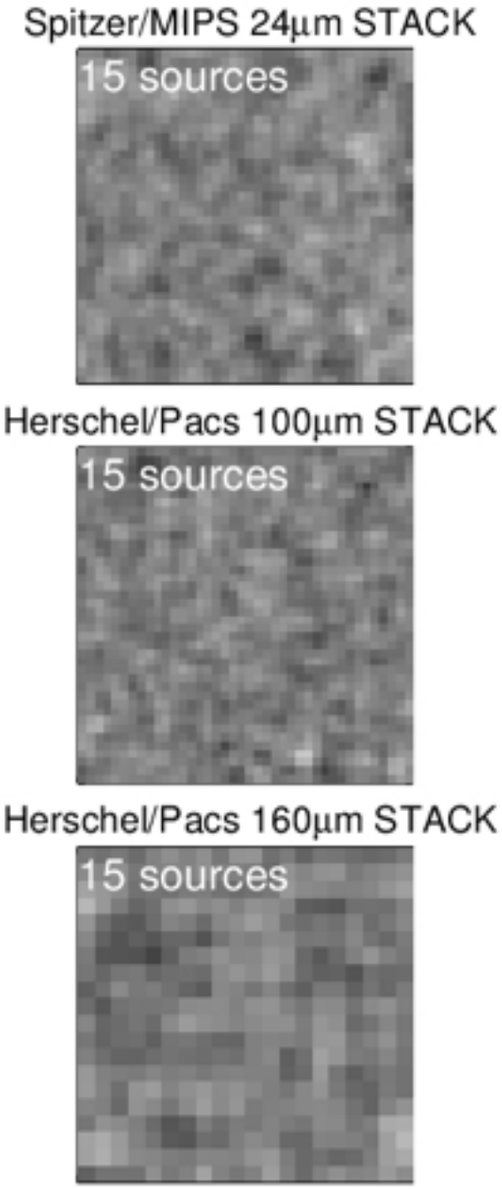
A substantial population of massive quiescent galaxies at z~4 from ZFOURGE

**Straatman et al. 2014**



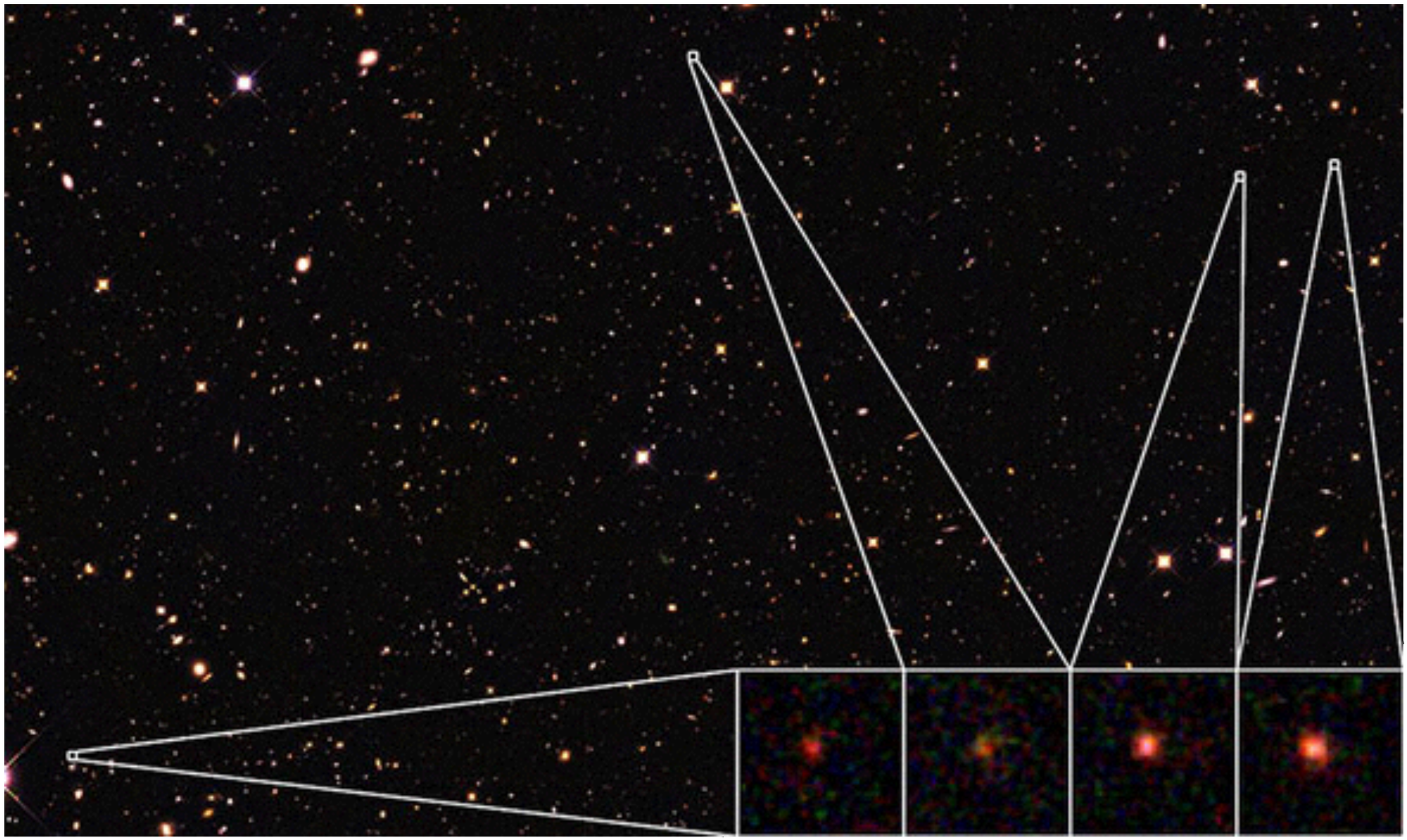
# UVJ Diagram - a HR diagram for galaxies



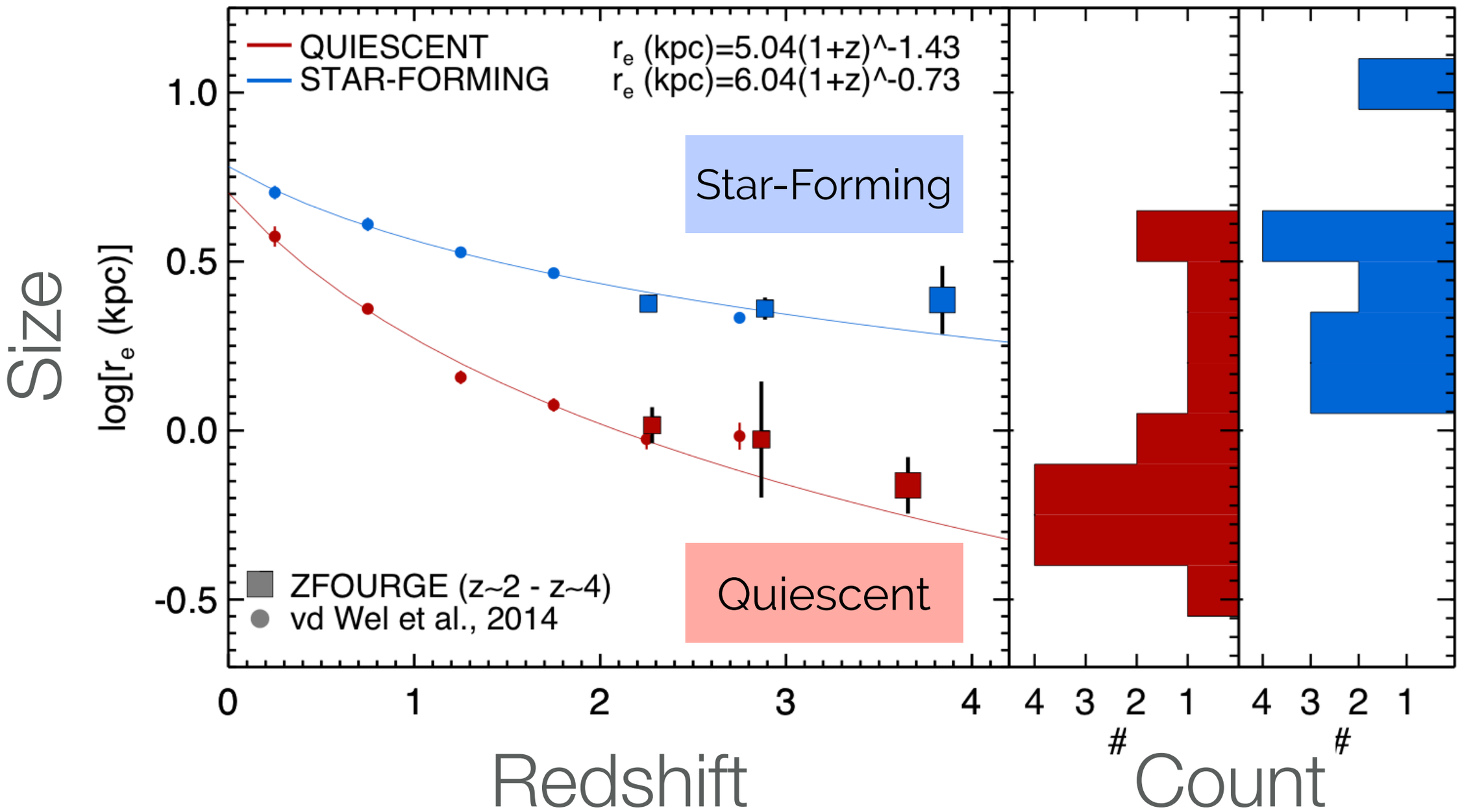




Straatman et al. 2014

# Massive Quiescent Galaxies at z = 4



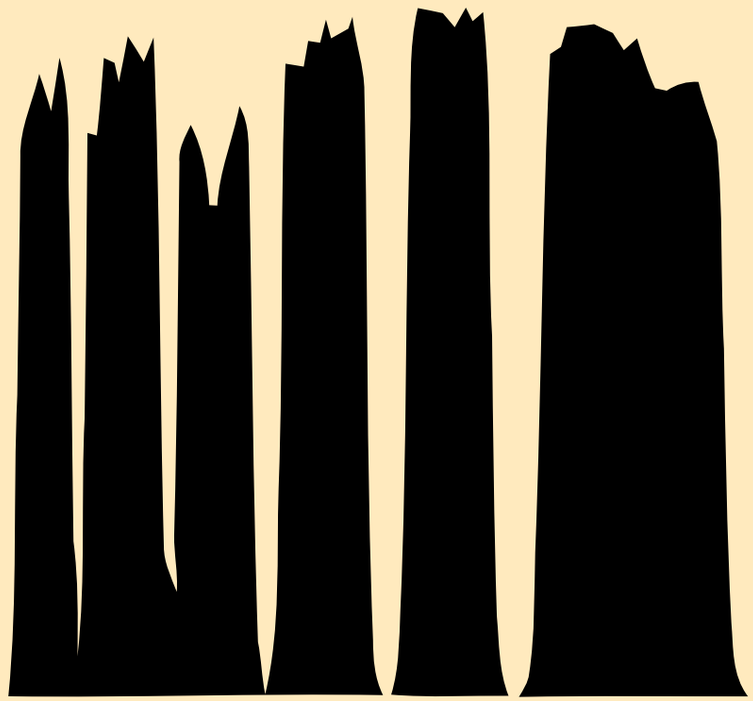
# Sizes of Massive (~0.8 × $10^{11}M_{\odot}$) z=4 galaxies




Straatman et al. in prep

# Exploring the z=3-4 massive galaxy population with ZFOURGE: the prevalence of dusty and quiescent galaxies

**Spitler et al. 2014**

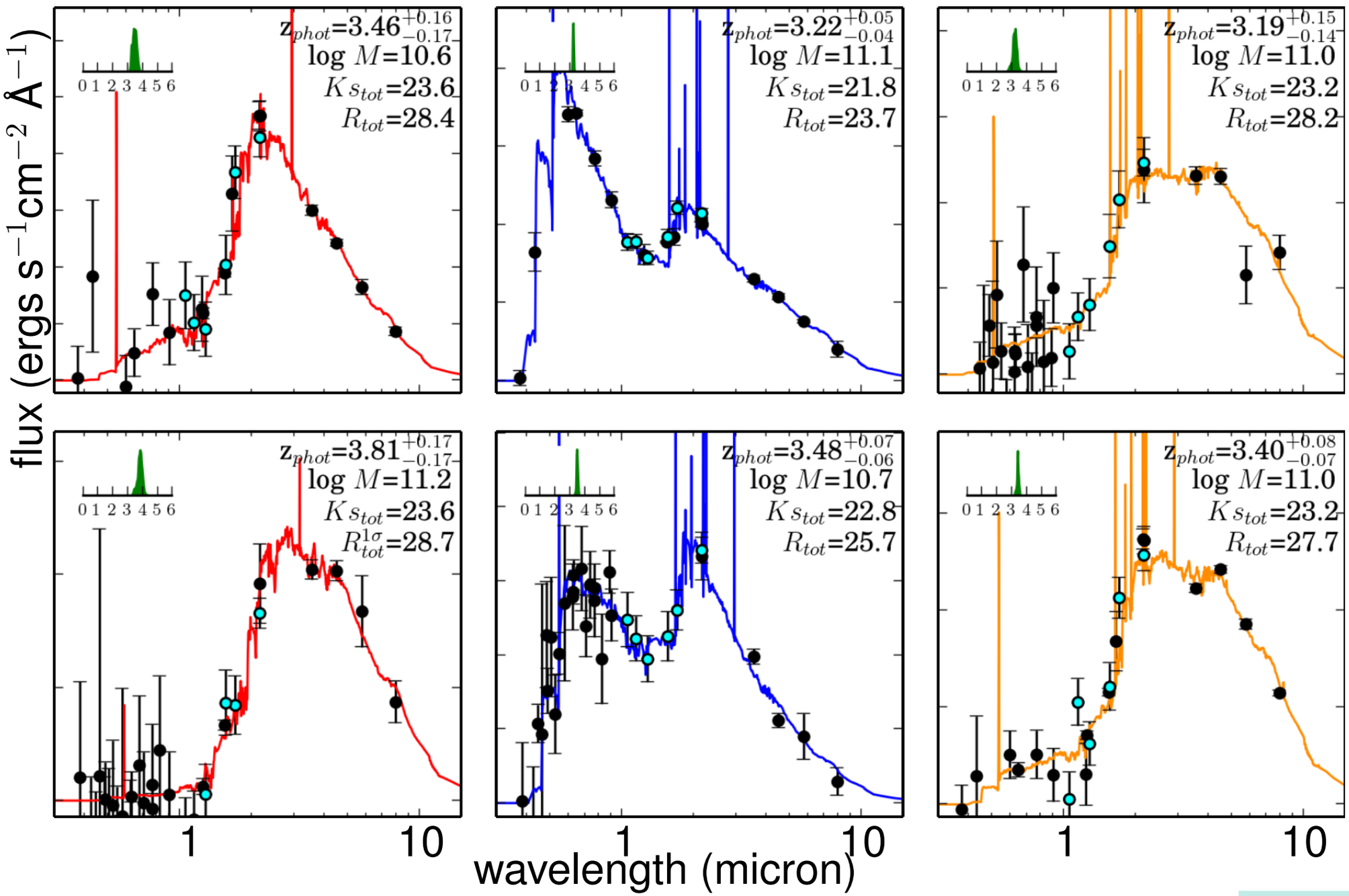


# A mass-limited census at z=3-4

Quiescent

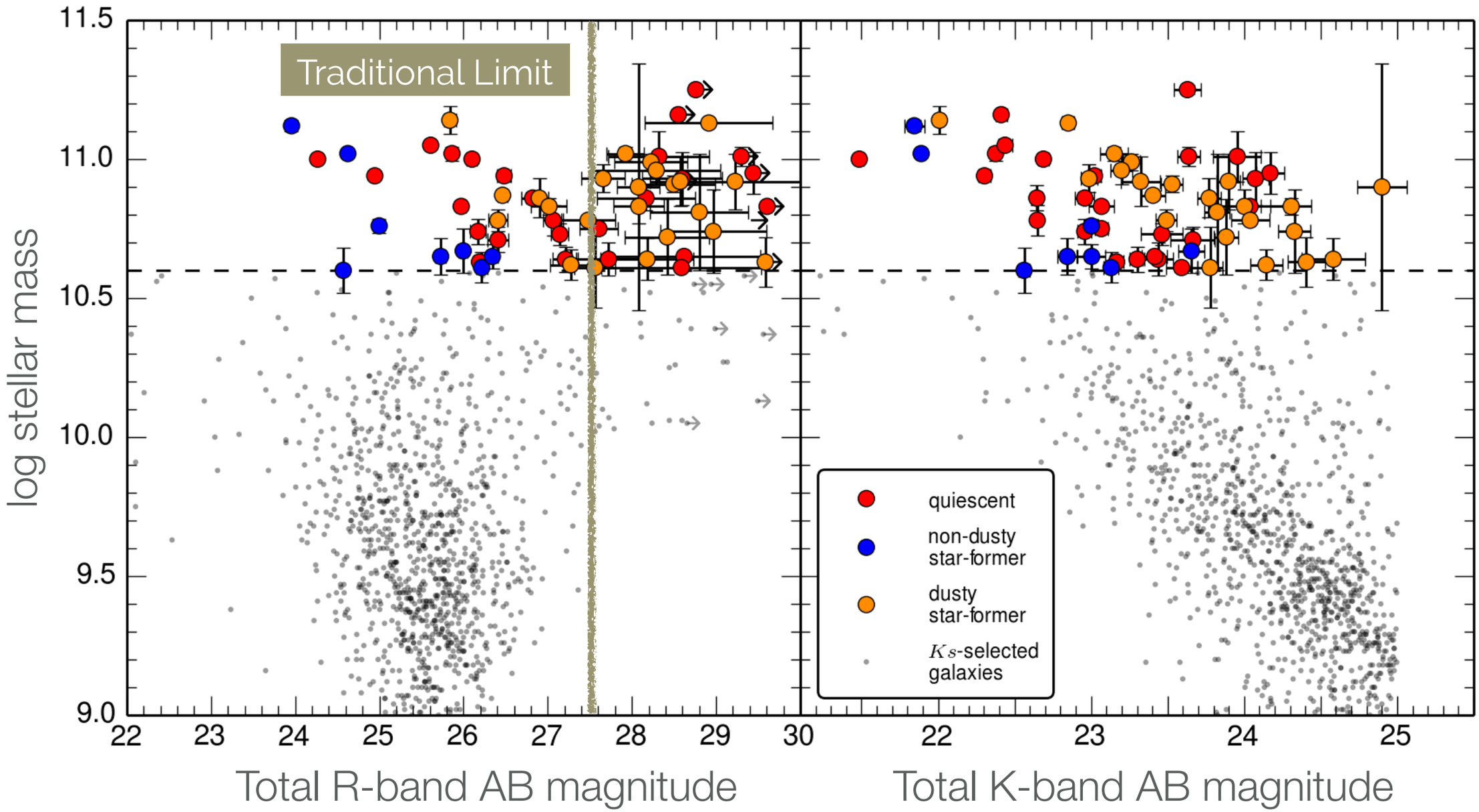
Unobscured Star-Forming

Dusty Star-Forming




Spitler et al. 2014

# A mass-limited sample at z=3-4

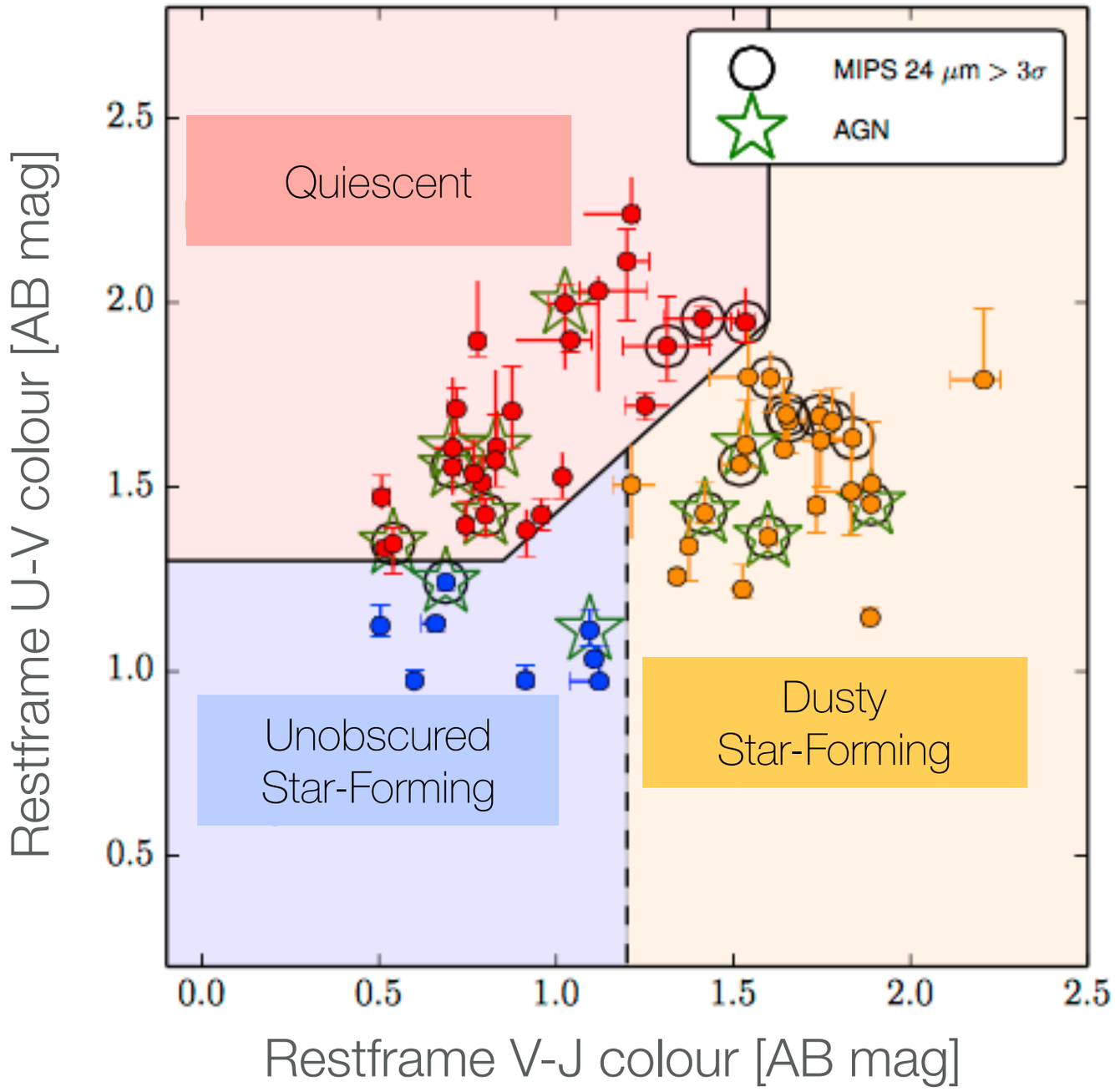



Traditional Galaxy Selection

ZFOURGE Galaxy Selection

Spitler et al. 2014

# UVJ Diagram: Galaxy Classification




Spitler et al. 2014

# A mass-limited census at z=3-4

Quiescent

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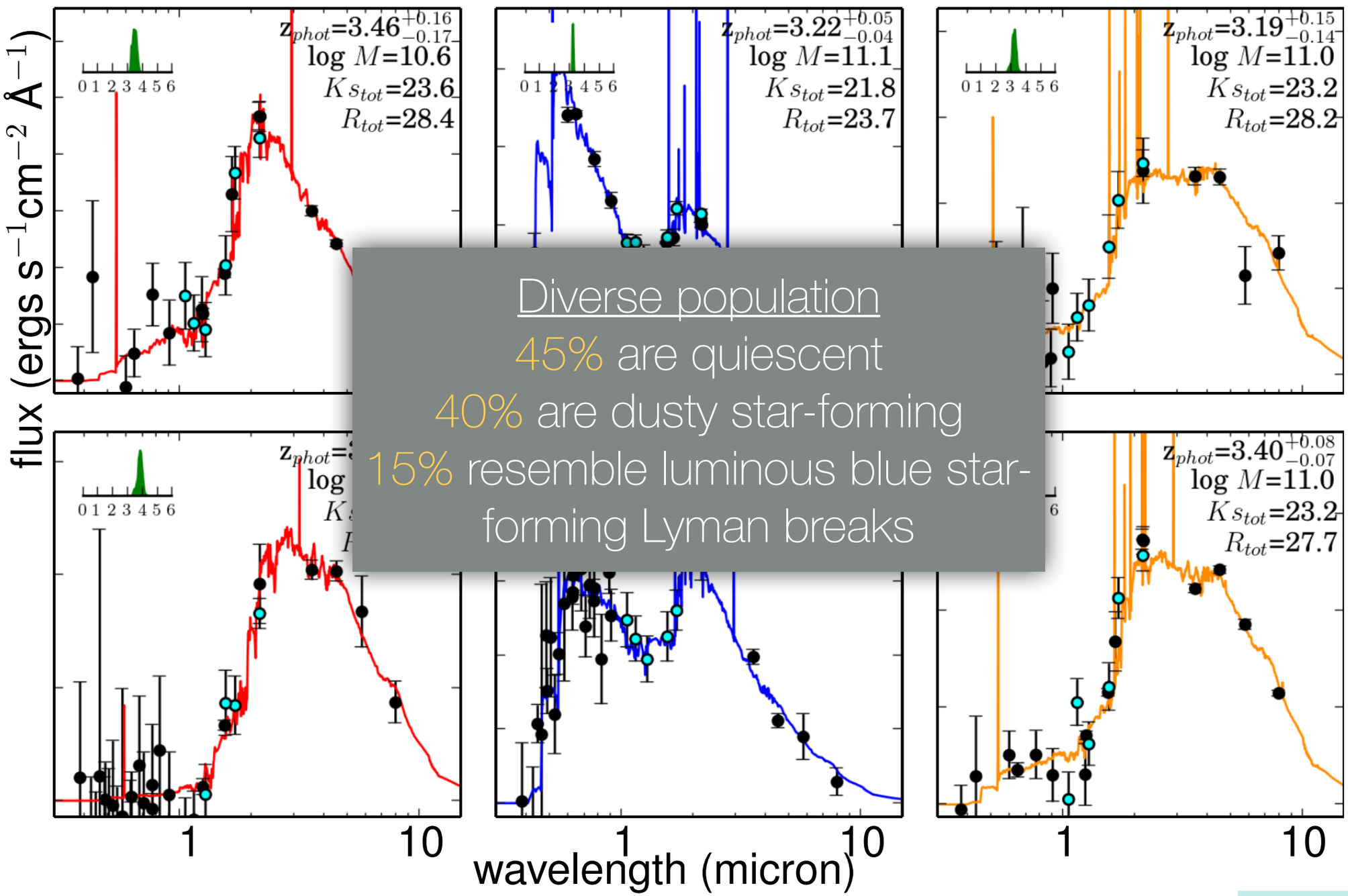



Diverse population

45% are quiescent

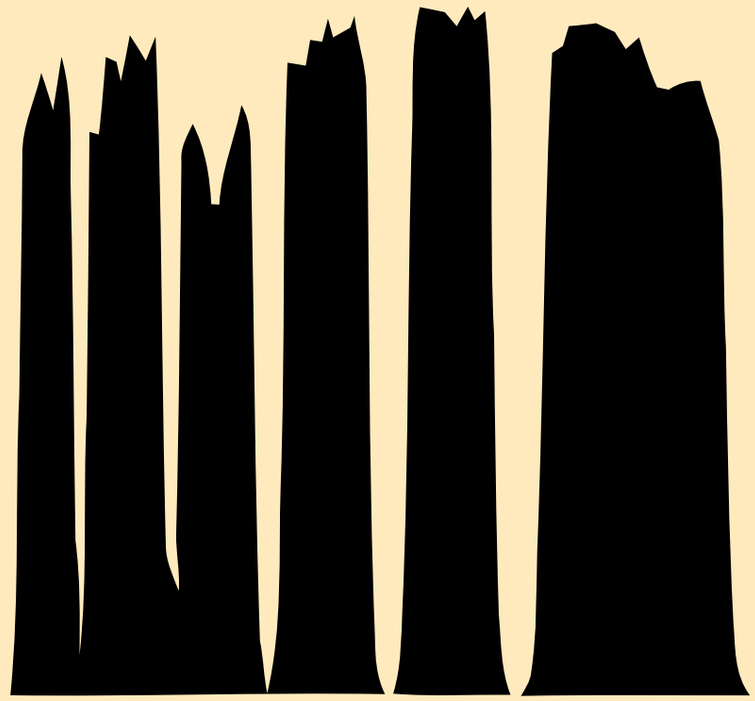
40% are dusty star-forming

15% resemble luminous blue star-forming Lyman breaks

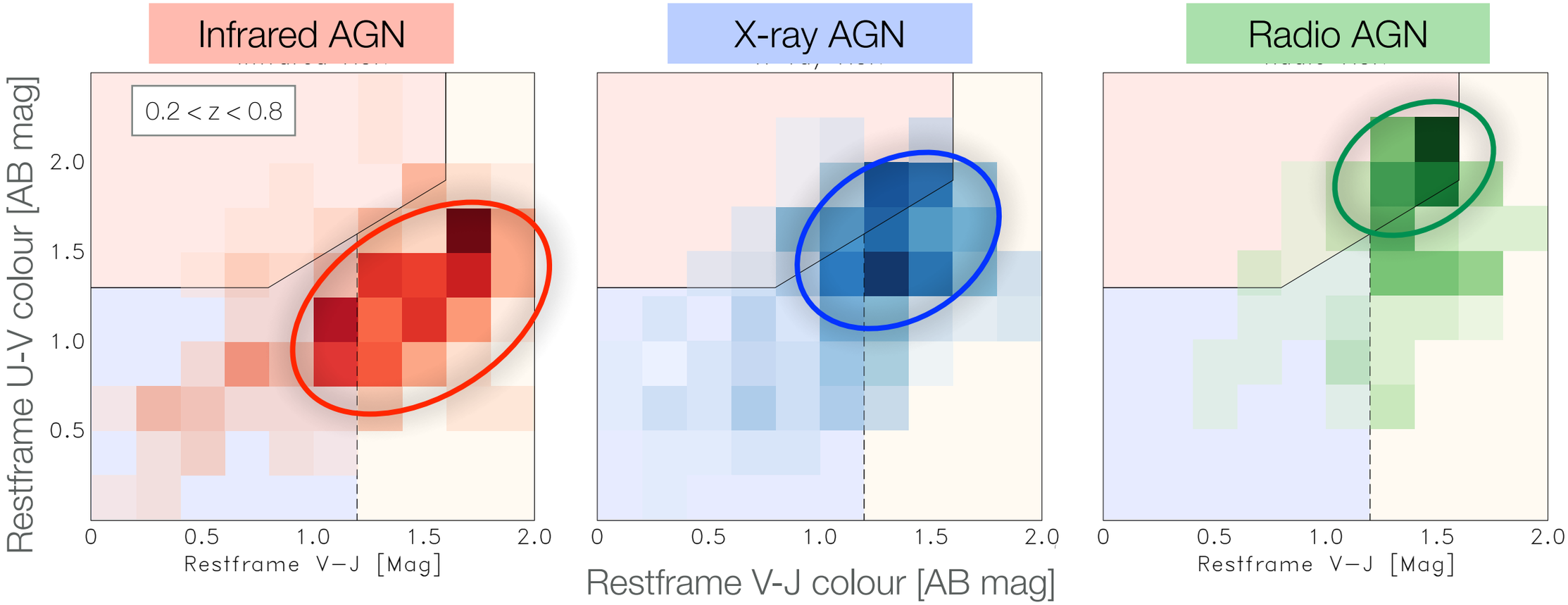
Spitler et al. 2014

ZFOURGE Catalogue of AGN Candidates: A Comparison of Star-Formation Activity in Active and Non-active Galaxies

**Cowley et al. in prep**



# UVJ colours of AGN hosts




**INFRARED AGN**: Dusty, young, late-type galaxies

**RADIO AGN**: Old, early-type galaxies

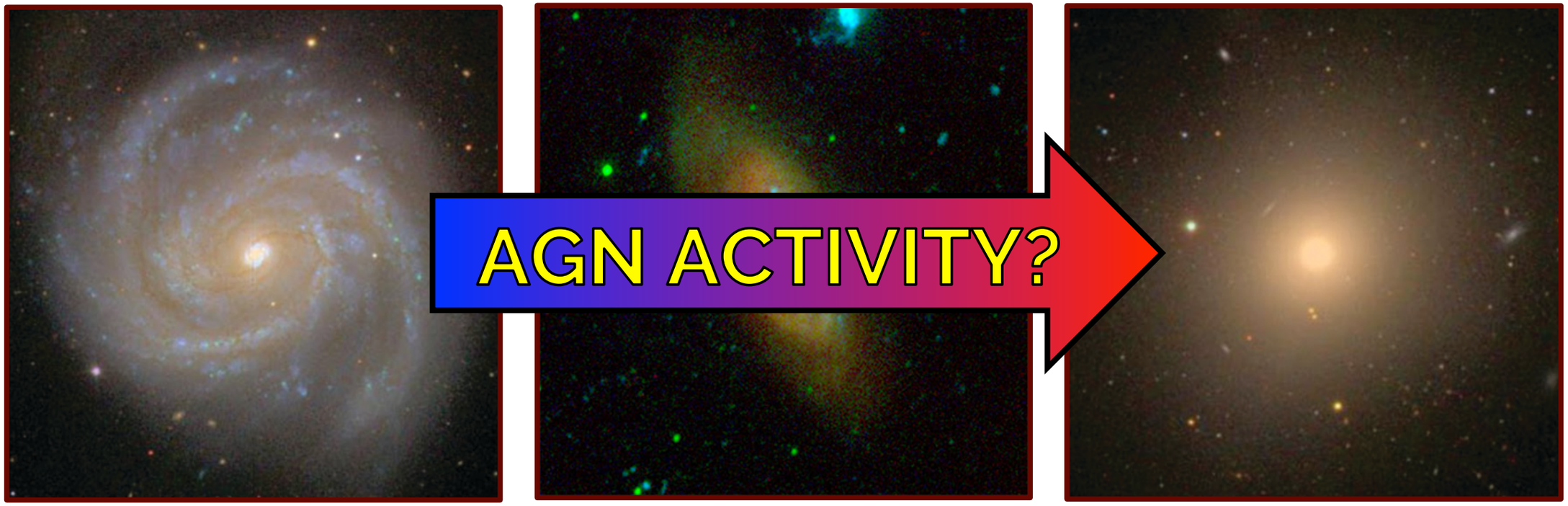
**X-RAY AGN**: Straddle between the two

Cowley et al. in prep

Infrared AGN

X-ray AGN

Radio AGN




Younger Galaxies

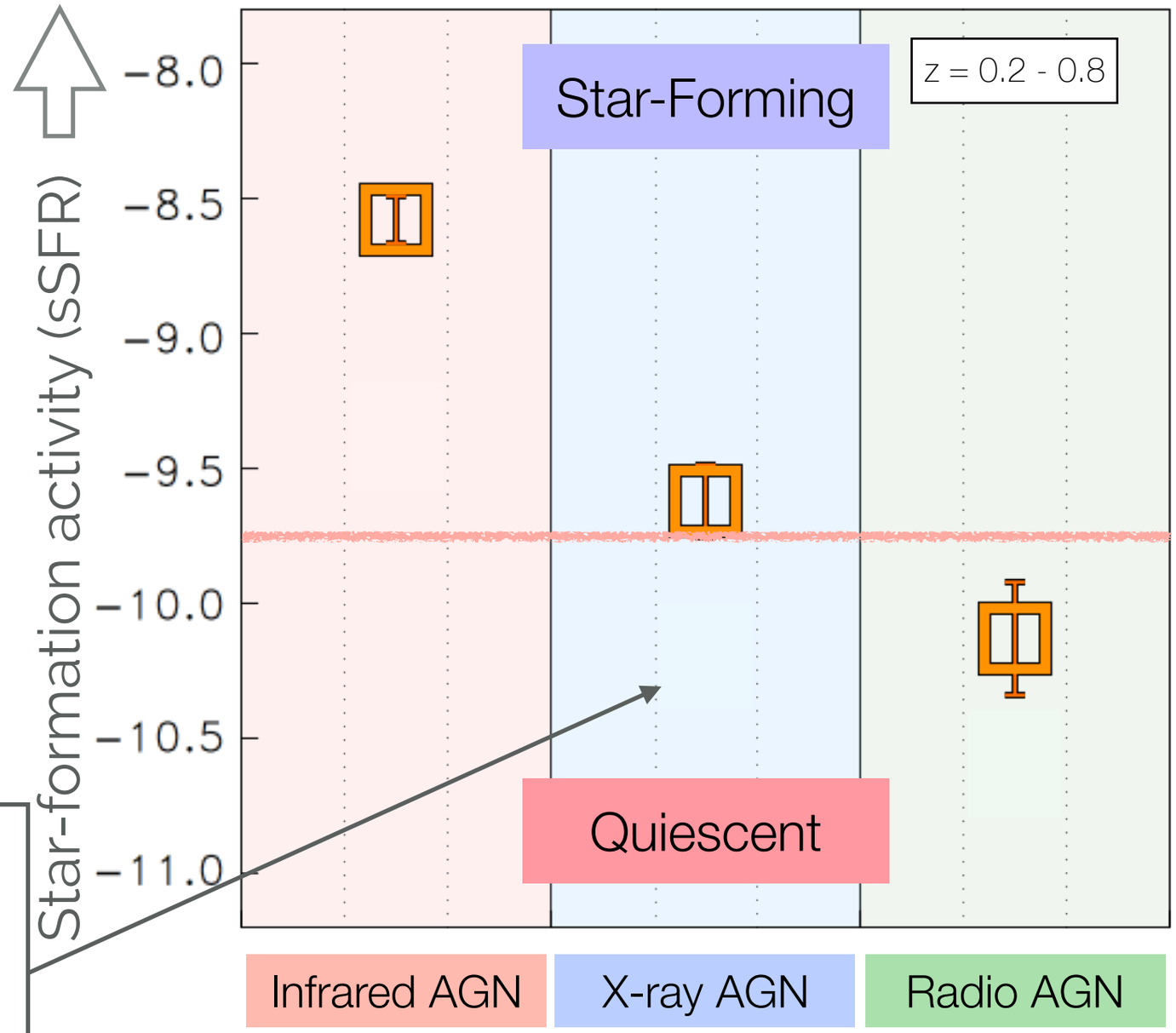
Middle-Aged Galaxies

Old Galaxies

# SF activity of AGN hosts

**INFRARED AGN**:
Star-forming
**RADIO AGN**:
Quenched
**X-RAY AGN**:
Straddle the two

Control sample of mass-matched, non-active galaxies

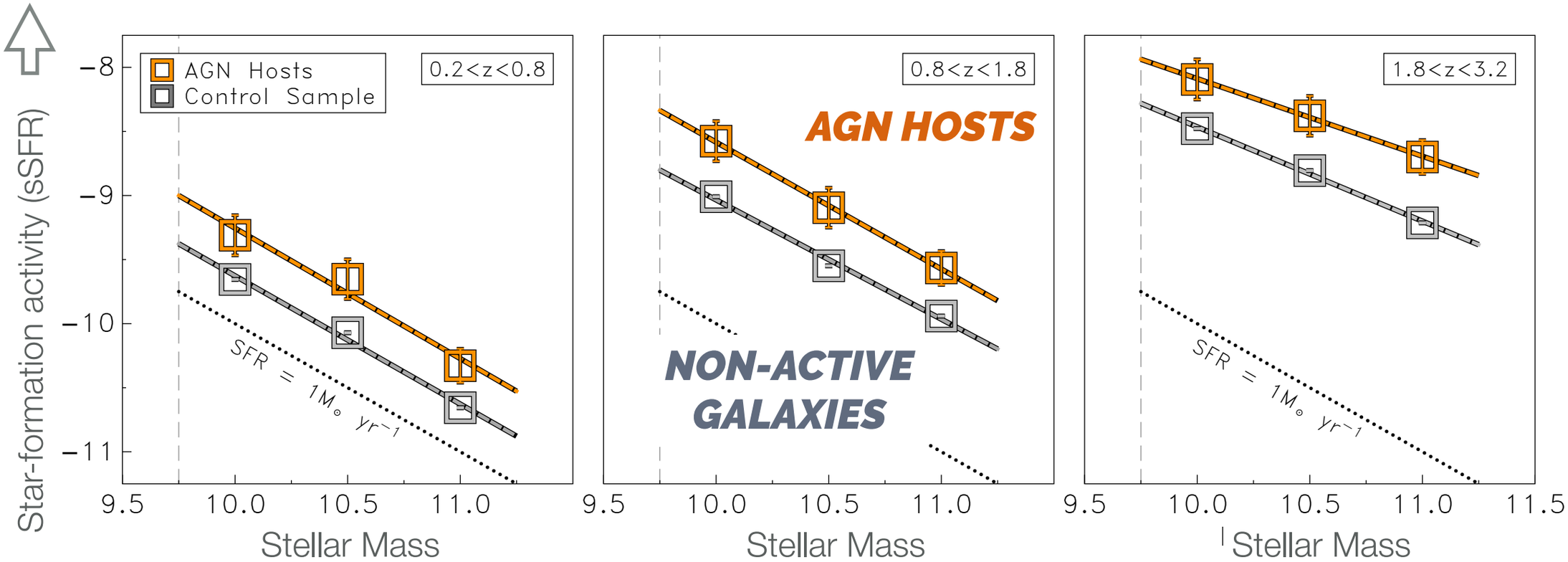



SFRs derived from FIR (Spitzer+Herschel)

Cowley et al. in prep

# Star-formation Activity in AGN Hosts

All AGN hosts exhibit an  elevated level of star-formation activity when compared to a control sample of mass-matched non-active galaxies

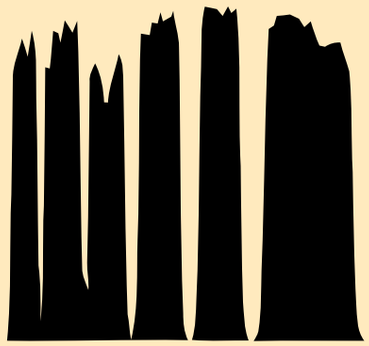


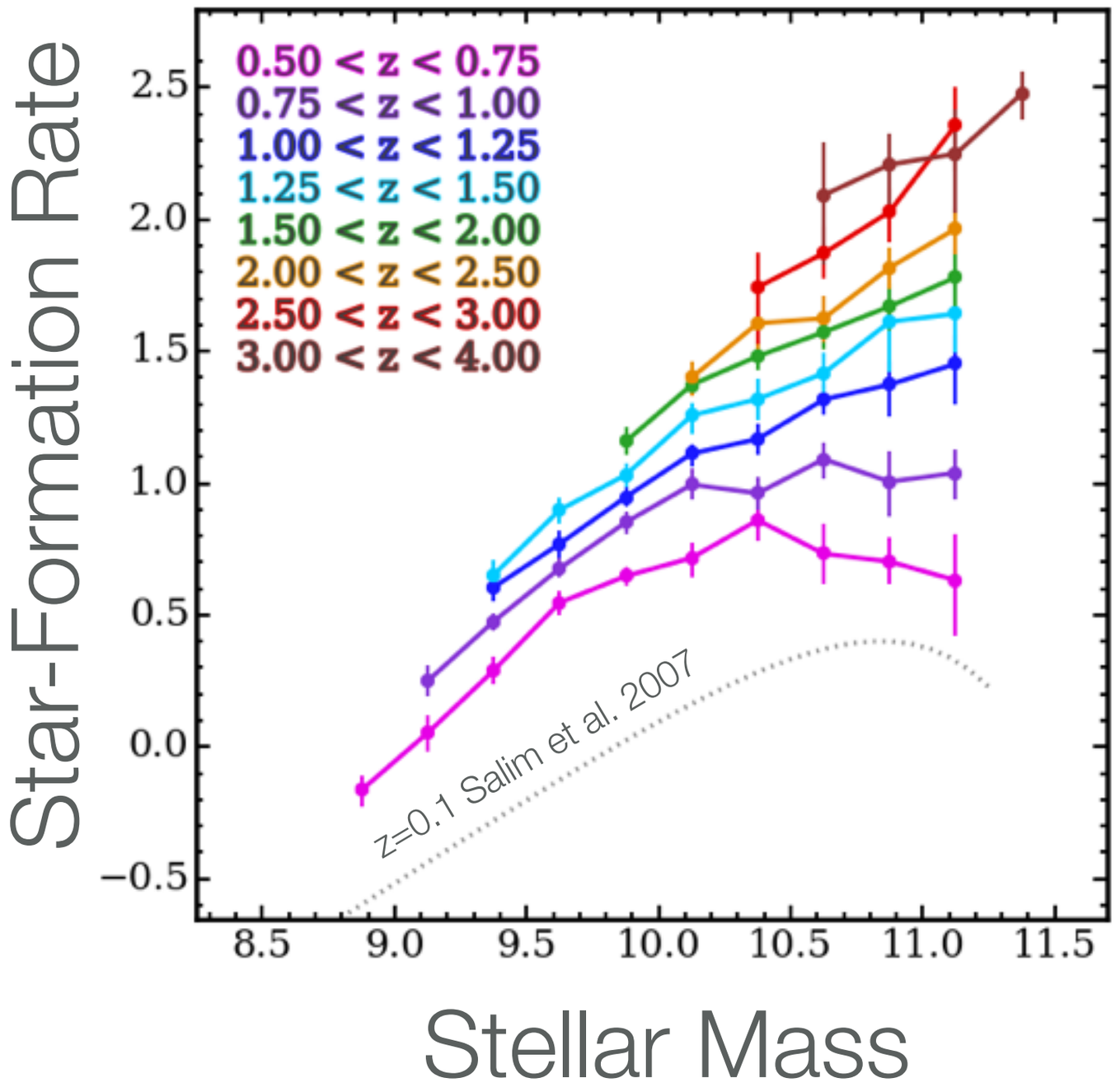

SFRs derived from FIR (Spitzer+Herschel)

Cowley et al. in prep

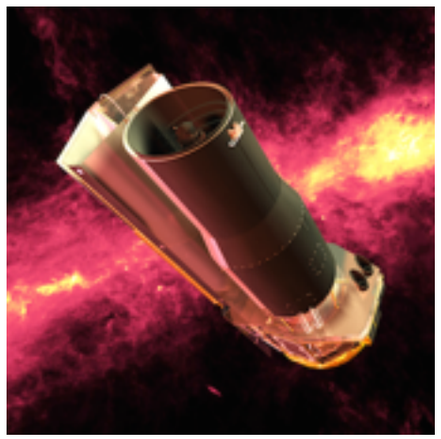
# The SFR–$M_*$ Relation and Empirical Star-Formation Histories from ZFOURGE

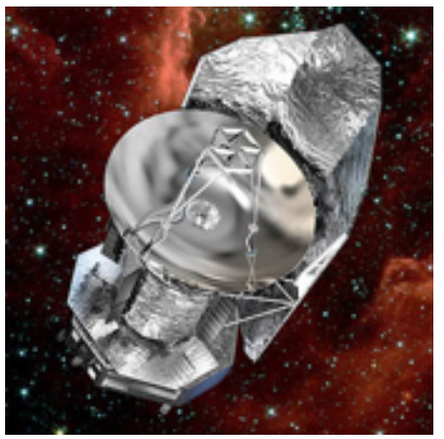
**Tomczak et al. in prep**






ZFOURGE + Spitzer + Herschel

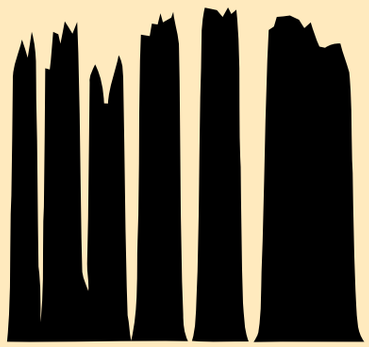


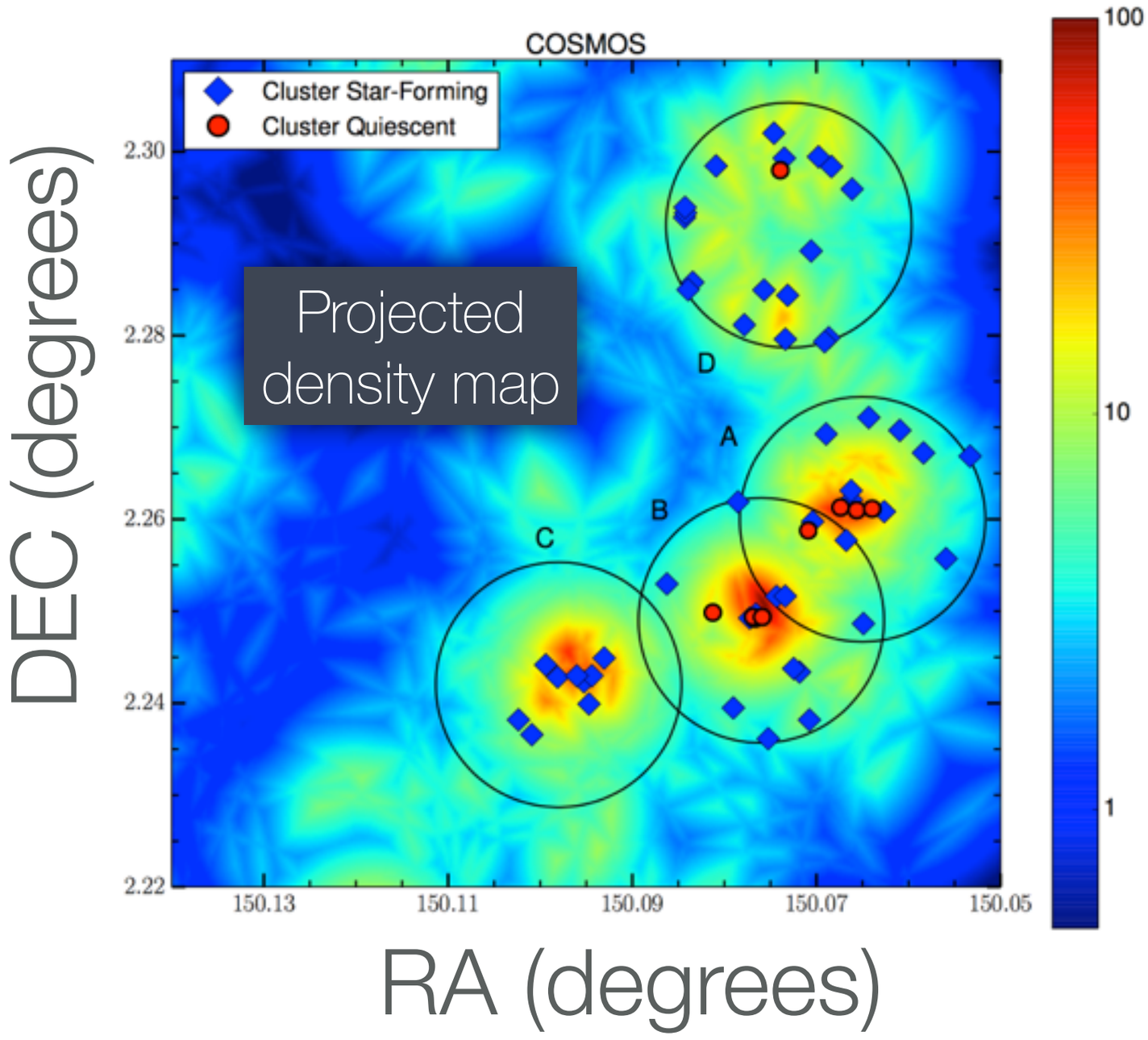


SFRs are roughly proportional to stellar mass at low masses, but this trend flattens at higher masses at z<1

Tomczak et al. in prep

The Differential Size Growth
of Field and Cluster Galaxies
at z = 2.1 in ZFOURGE
**Allen et al. in press**





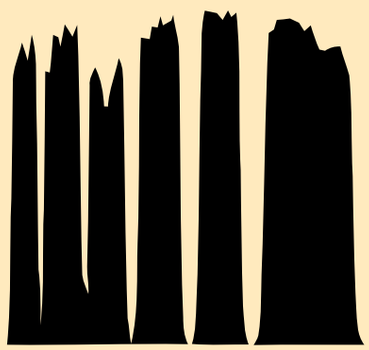

Investigate the differences in star-forming and quiescent galaxy properties as a function of environment

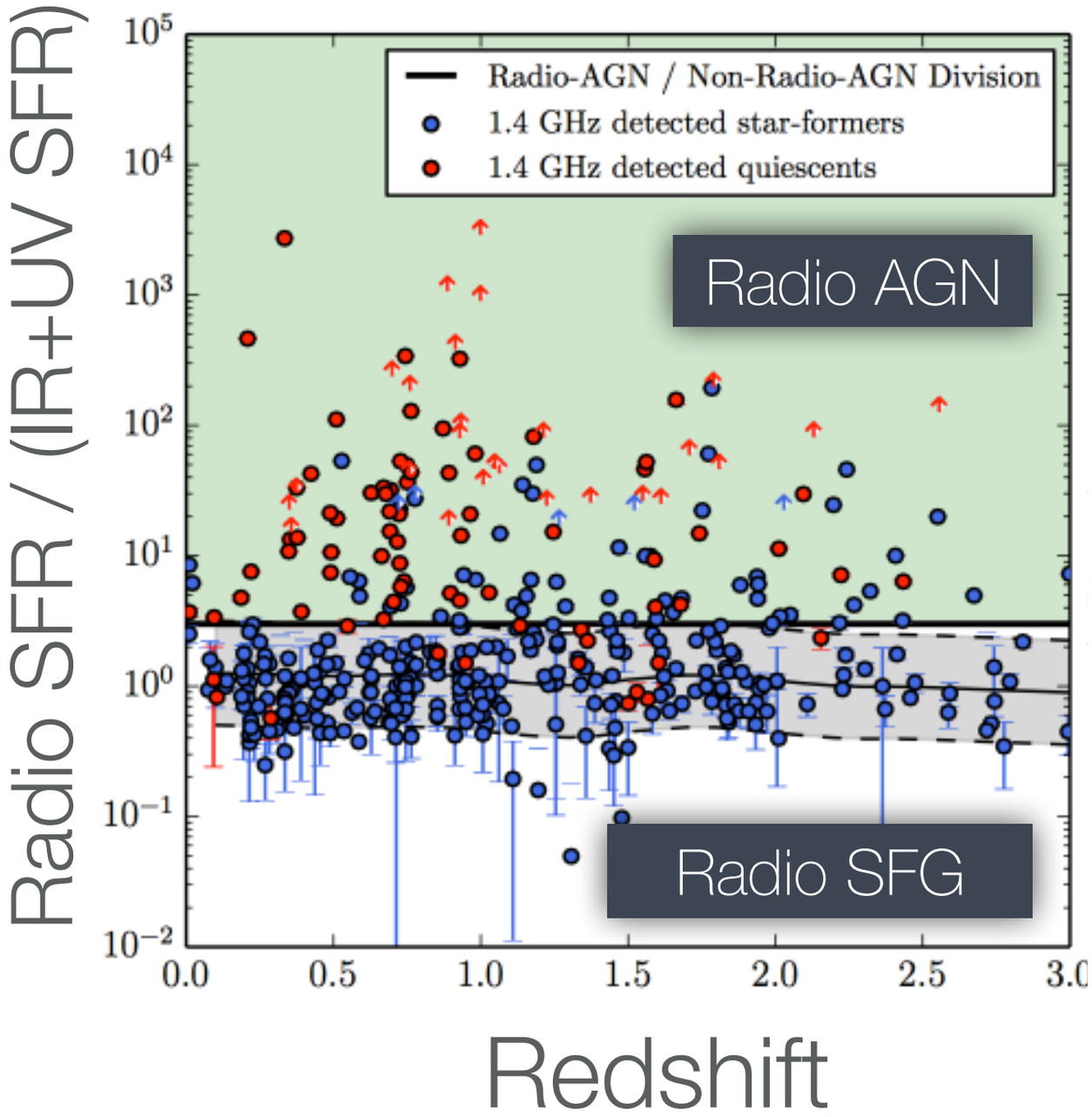
SF cluster galaxies
12% larger and 20% redder
than SF field galaxies
Little difference between
quiescent cluster and field
galaxies

Allen et al. in press

Radio galaxies in ZFOURGE/ NMBS: no difference between radio-AGN and non-radio-AGN hosts to z=2.25

**Rees et al. submitted**






Investigate the host galaxy properties of a high-luminosity ($L_{1.4} > 10^{24}$ W $Hz^{-1}$) sample of radio-loud AGN to z = 2.25

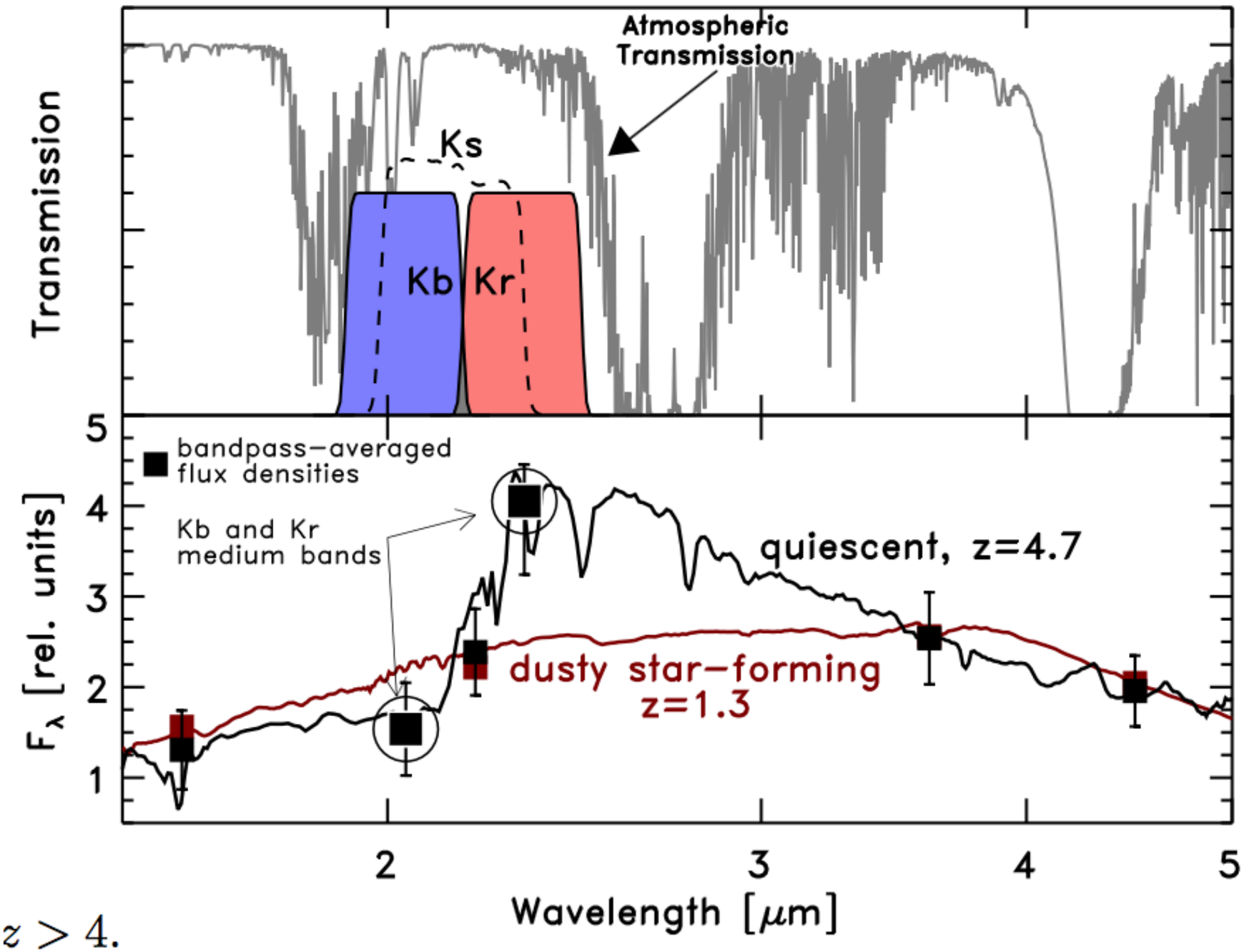
The stellar populations of radio-AGN are found to evolve with redshift in a manner that is consistent with the non-AGN mass-similar galaxy population

Rees et al. submitted

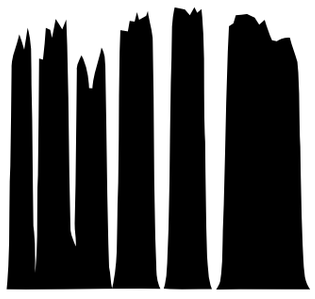

ZFOURGE
FourStar Galaxy Evolution Survey
2.0

# ZFOURGE 2.0

**FourStar Galaxy Evolution Survey**




$z > 4.$



# ZFOURGE

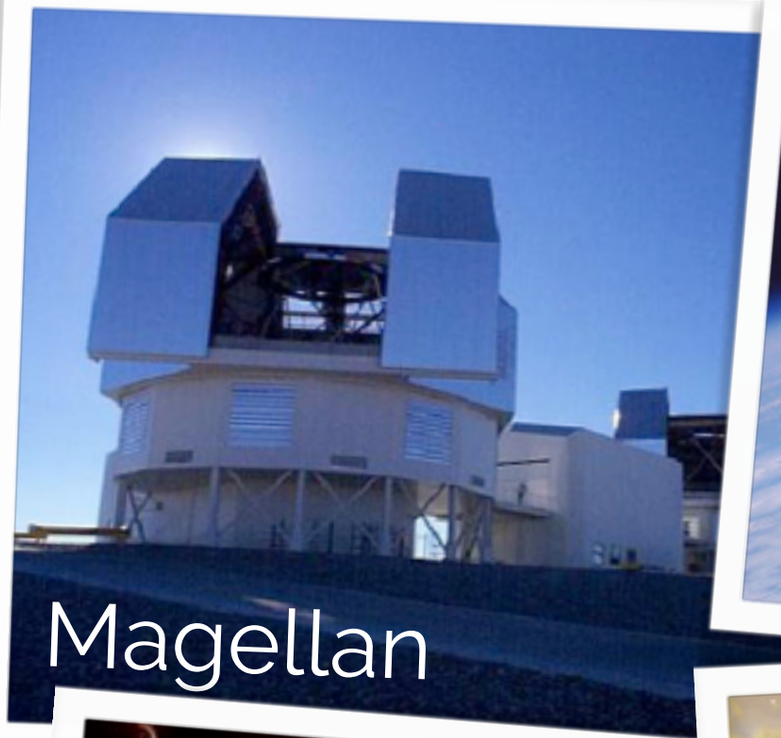
## FourStar Galaxy Evolution Survey

Lots of interesting results, **more to come in 2015 !**

- Sizes : quiescent galaxies at z~4 (Straatman, submitted)
- Star formation histories since z~3 (Tomczak, in prep)
- Radio Galaxies (Rees, submitted)
- Multi-wavelength AGN (Cowley, in prep)
- Enviro of cluster and field galaxies at z~2 (Allen, in press)
- Satellite galaxies at 1<z<3 (Kawinwanichakij, in prep)
- Composite SEDs for 1<z<3 (Forrest, in prep)
- ZFOURGE survey paper (Straatman, in prep)

zfourge.tamu.edu

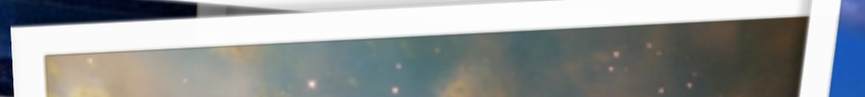
# Thanks Magellan! …and other observatories













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FourStar Galaxy Evolution Survey

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