KG Welcome

CIT-SUT Keck renewal

- Agreement in place since 2008
- Now renewed 2018B – 2023A
- 10 nights p.a.

Extras

- $16K (AUD 20K) p.a. reserved for collaborative activities

    Workshops, Exchanges, internships

- CIT researchers get priority access to SUT g3 supercomputer (new in Oct, 4000 cores)

- 1–2 nights reserved p.a. for pilot studies for CIT-SUT collaborative projects (SUT, COO Directors)

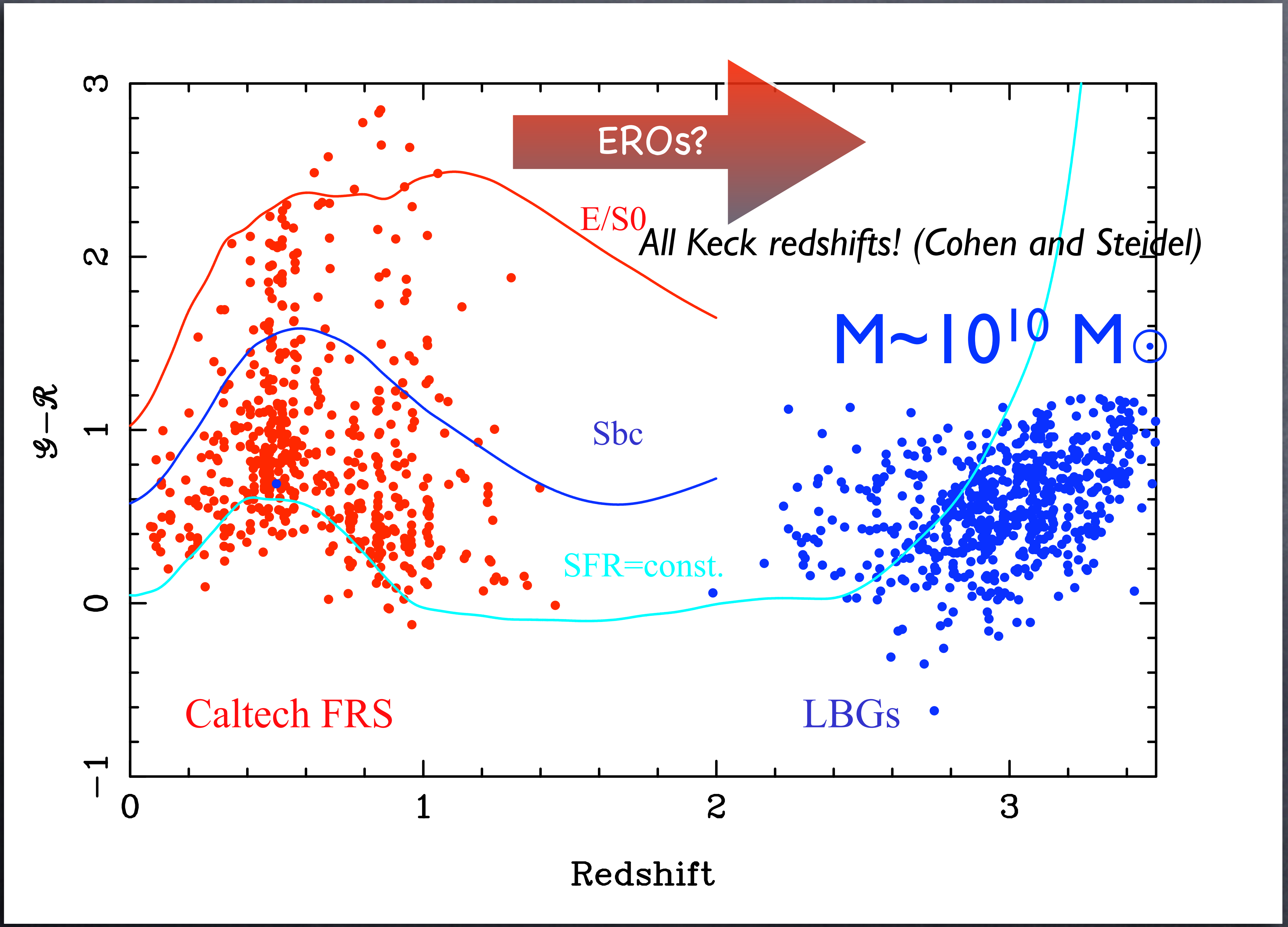
- Annual workshop: 2018 Data Science in Hawaii?


The population of quiescent (or not?) galaxies at z~4.
and the population of red nuggets at z~4
Karl Glazebrook
SWIN BUR NE
CENTRE FOR ASTROPHYSICS AND SUPERCOMPUTING

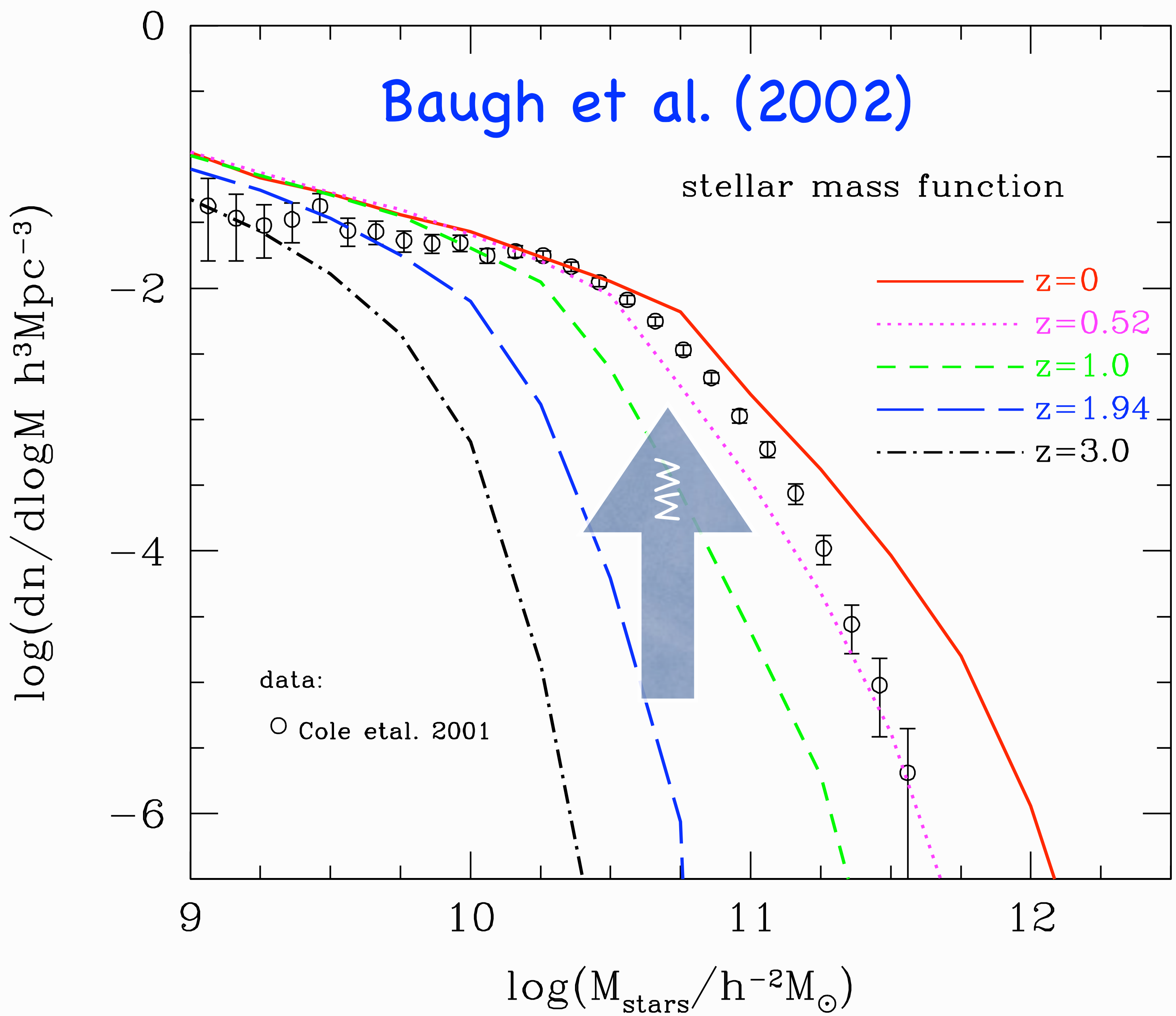
Massive galaxies as probes of ΛCDM: a short history

Back to 2001

COLORS OF HIGH-REDSHIFT GALAXIES



Massive Galaxies as a probe of ΛCDM

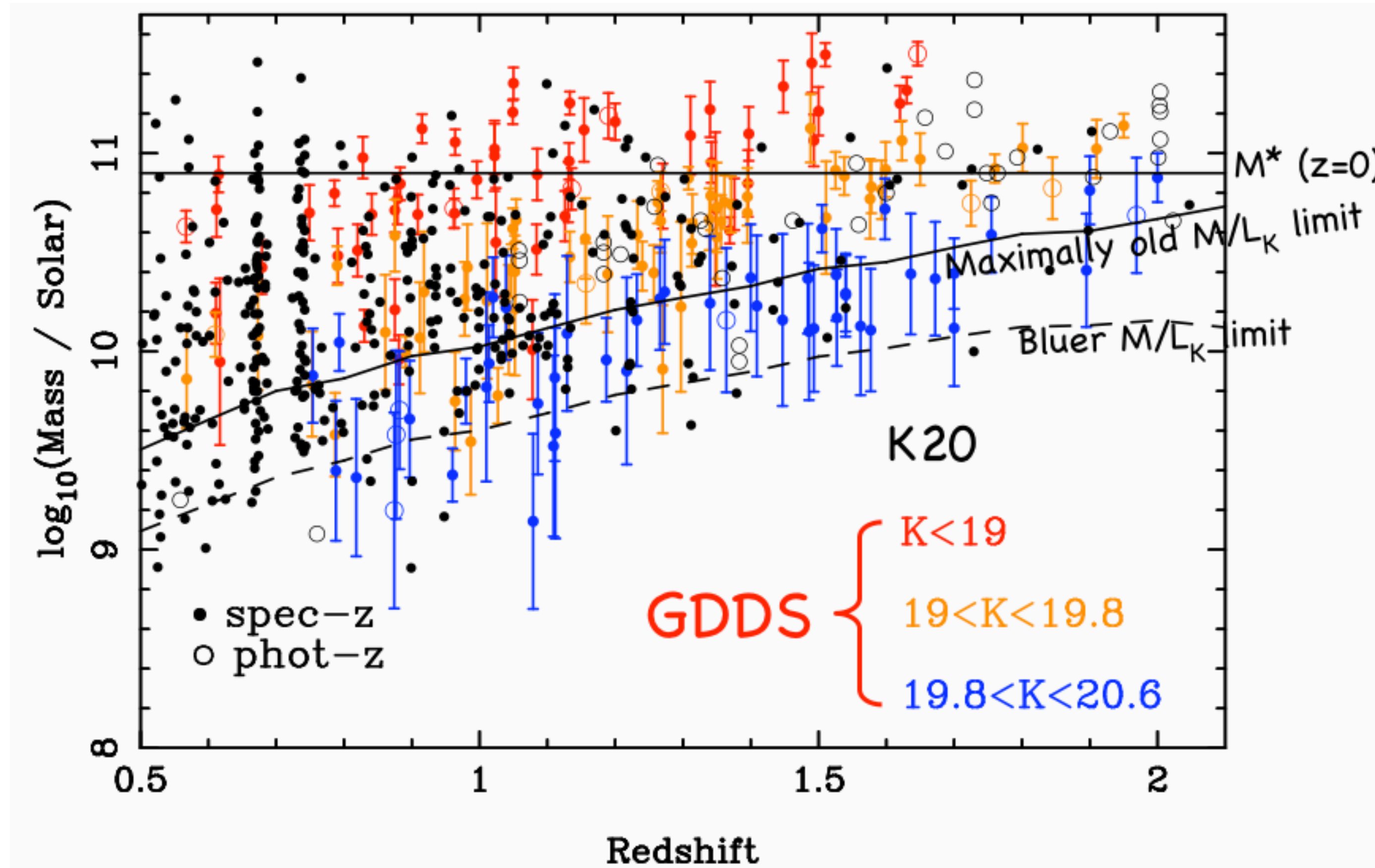


Massive galaxies form last

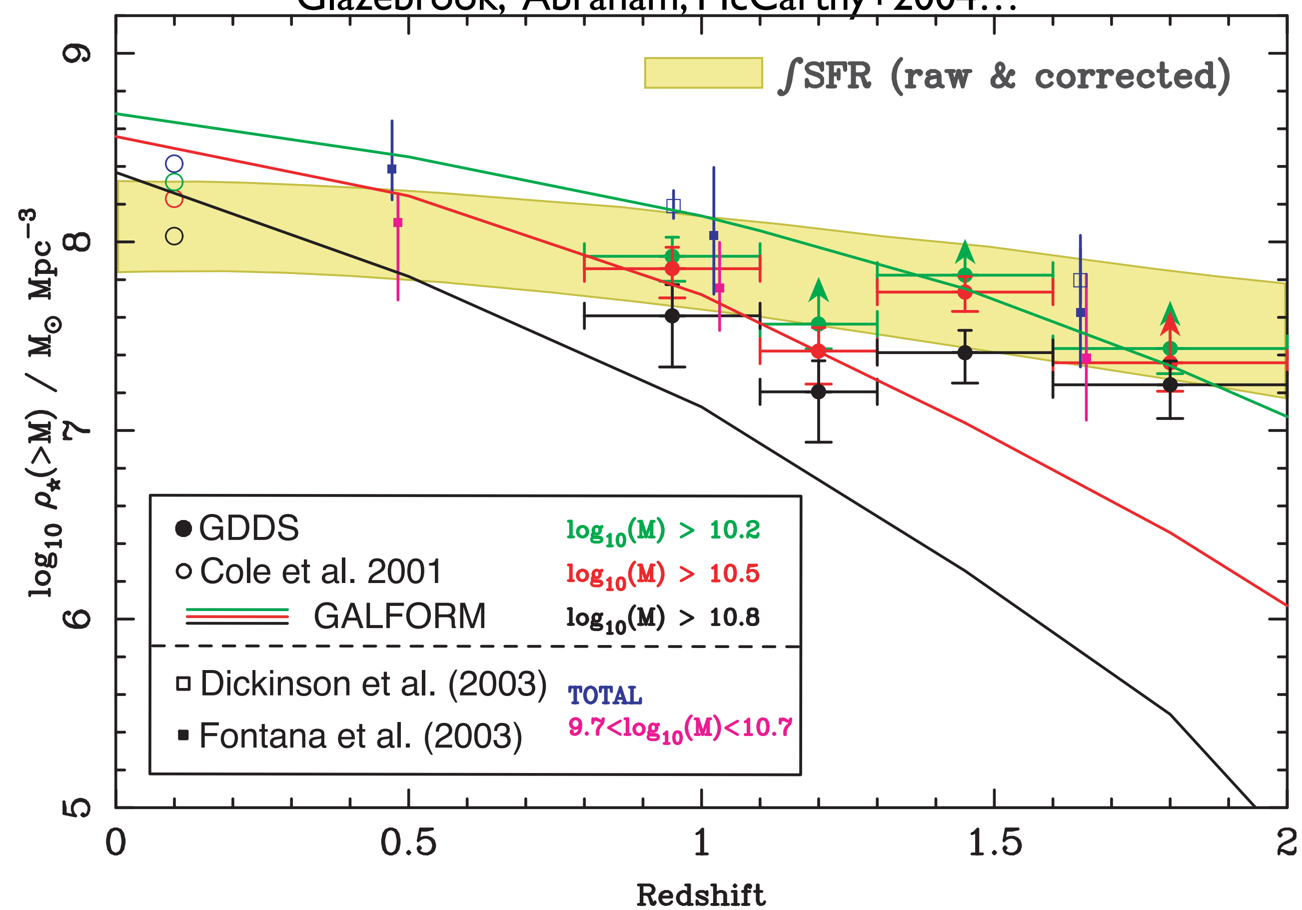
Massive galaxies are rare at high-z

Massive red (and blue) galaxies at z~2

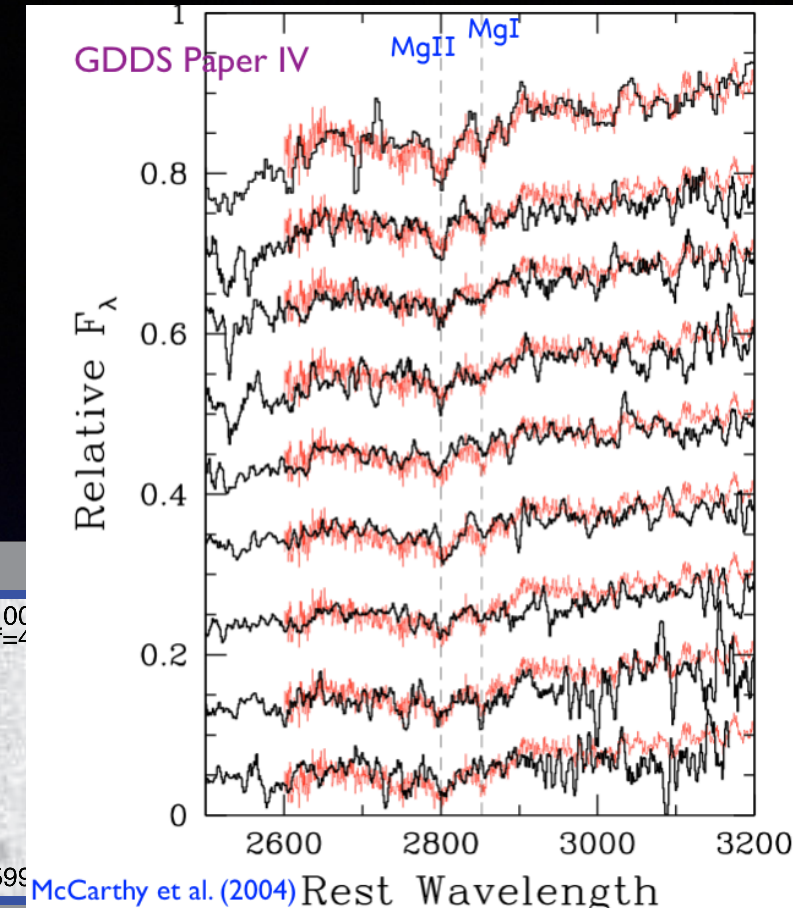
- Franx+2003, Labbé+2003, Glazebrook+2004, Cimatti+2004, McCarthy+2004, van Dokkum+2004,Förster Schreiber+2004, and many others…
- K20, GDDS, MUSYC, …
- DROs, EROs, pBZKs, DRGs

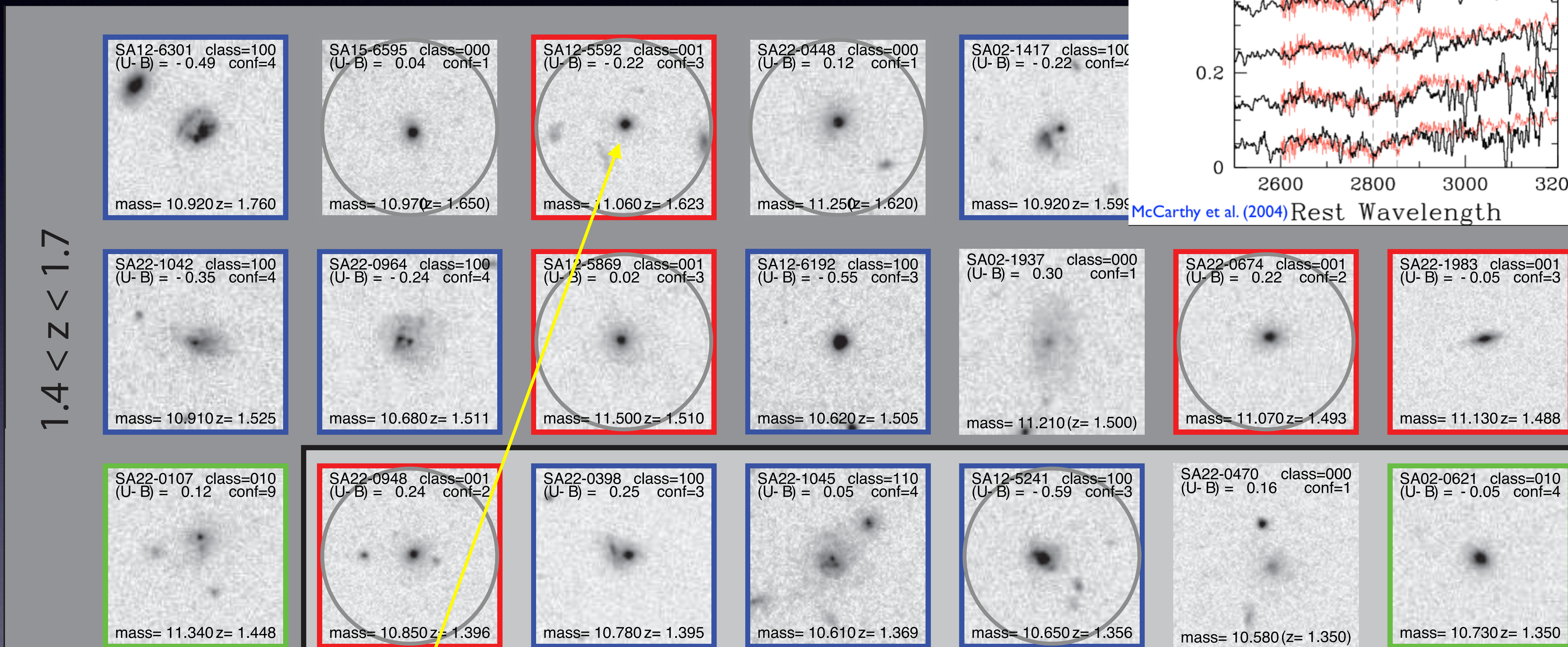


Glazebrook, Abraham, McCarthy+2004…



Age of Universe: 4 billion years
Stellar mass: ~10^{11} M_{sun}





size< 1 kpc ‘Red nugget’

Abraham et al. (2004): 30 ksec Gemini observations

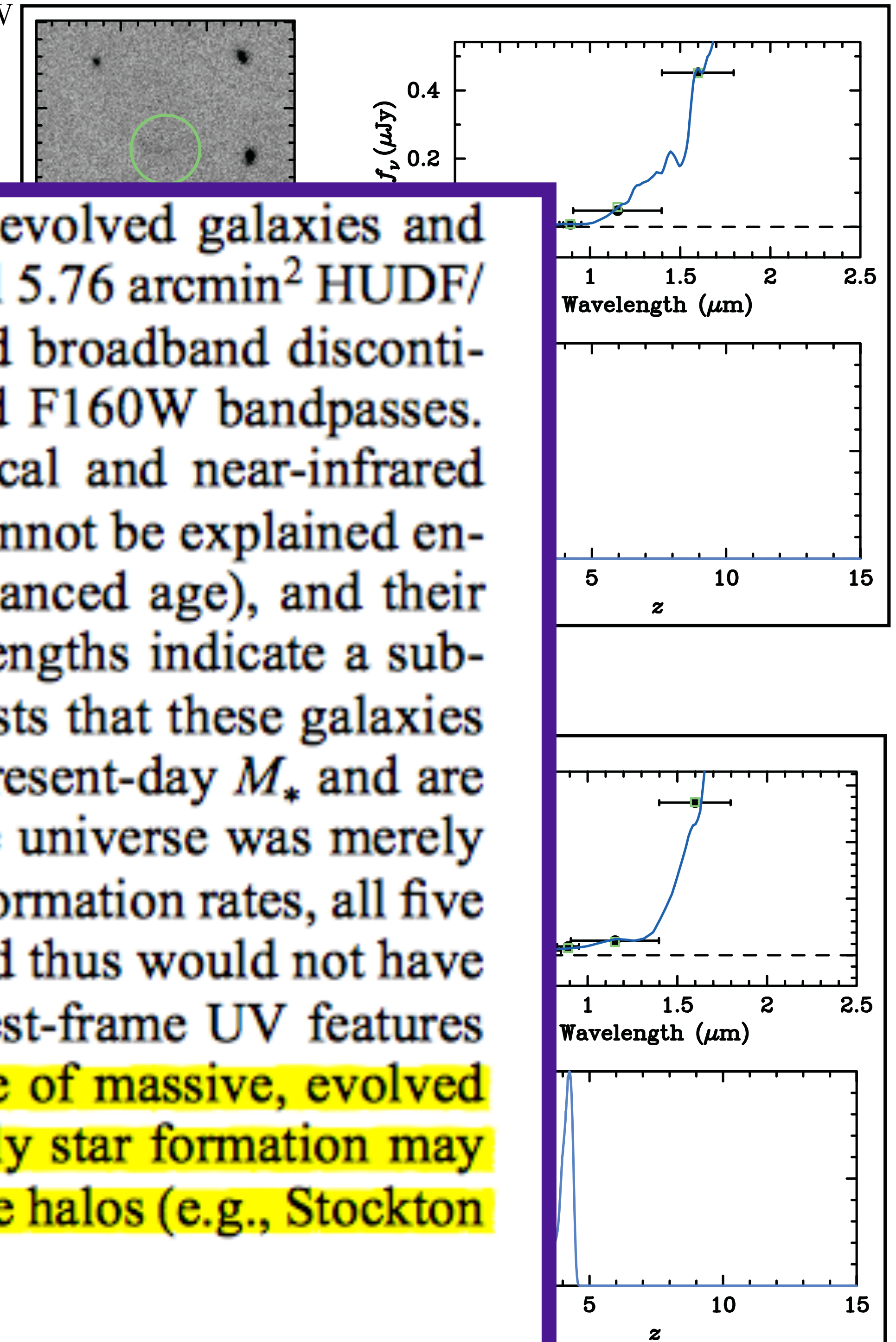
DISCOVERY OF MASSIVE EVOLVED GALAXIES AT $z > 3$ IN THE HUBBLE ULTRA DEEP FIELD[1]

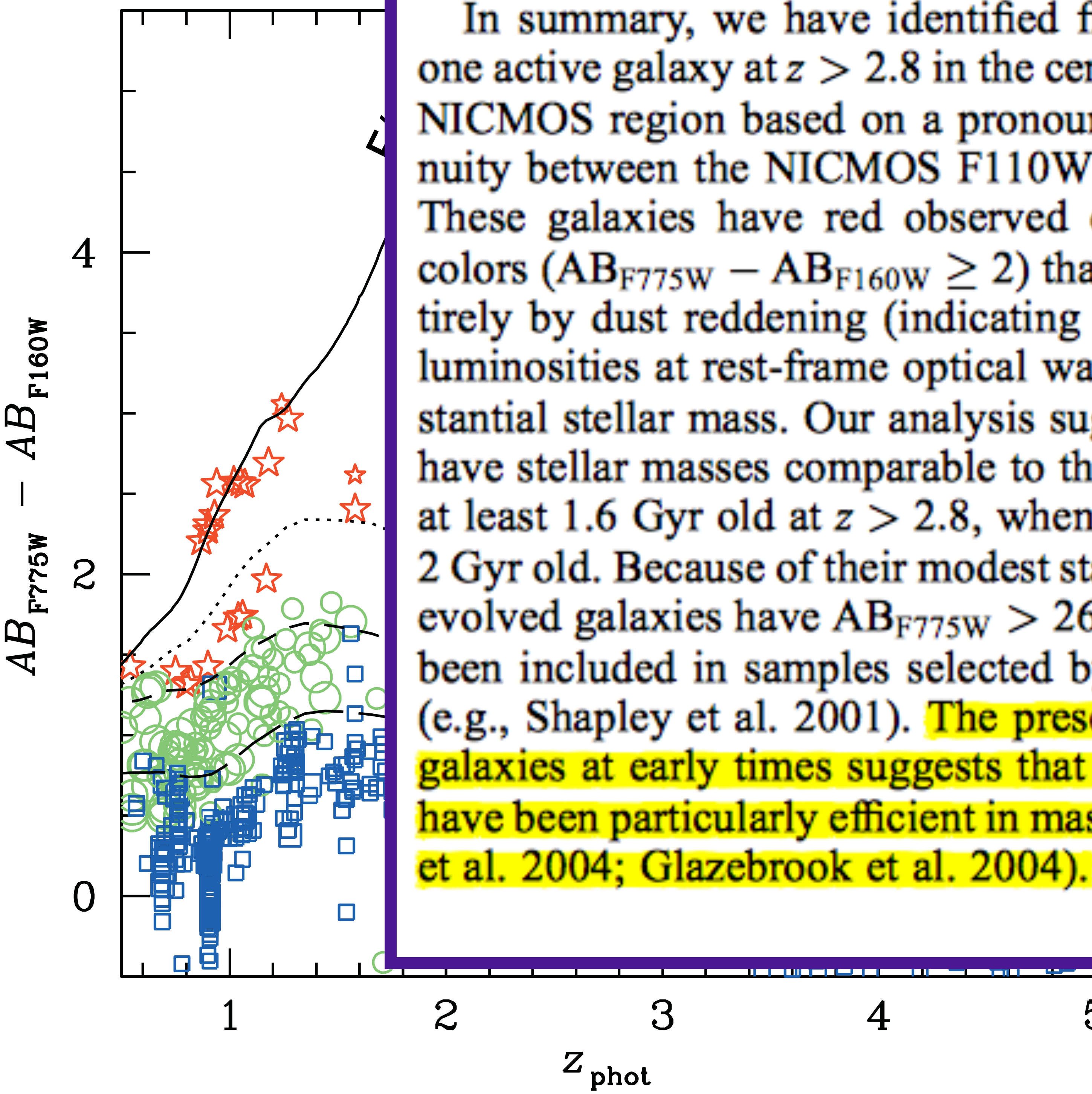
Hsiao-Wen Chen[2,3] and Ronald O. Marzke[4]

Received 2004 May 20; accepted 2004 July 26

ABSTRACT

We have identified six early-type galaxies at $z > 2.8$ in the central 5.76 arcmin^2 Hubble Ultra Deep Field NICMOS region based on a pronounced broadband discontinuity between the NICMOS F110W and F160W

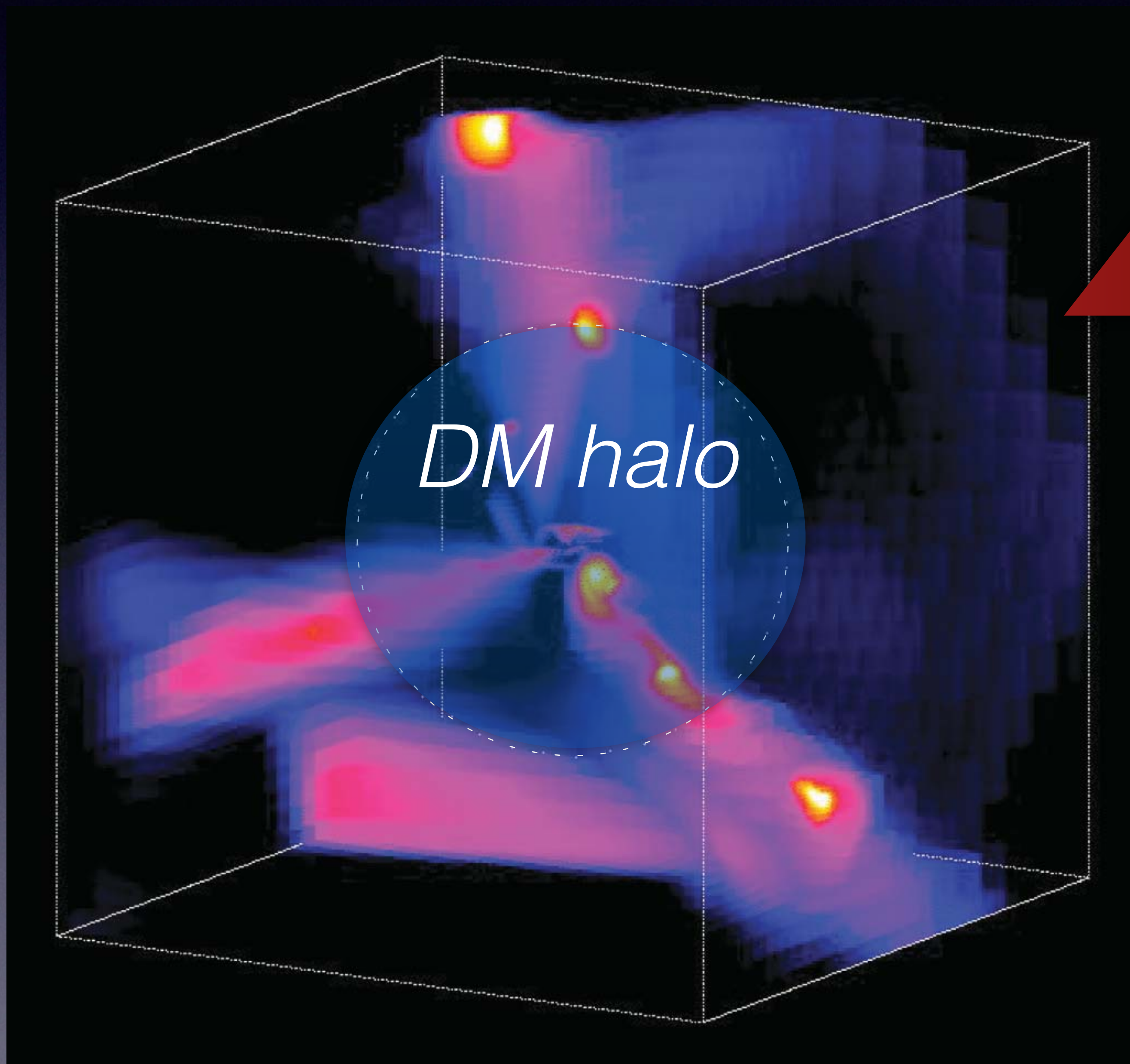


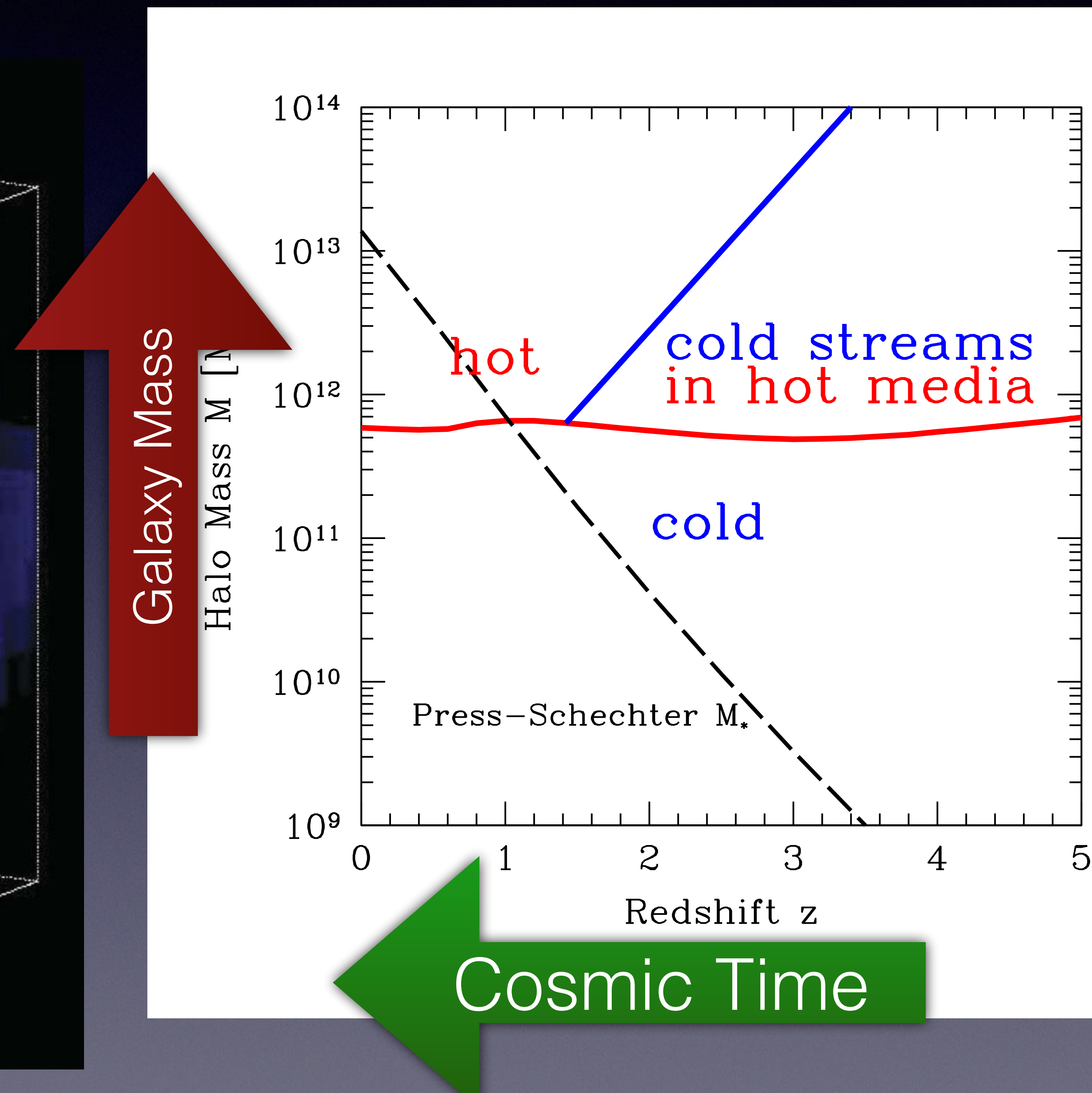


In summary, we have identified five evolved galaxies and one active galaxy at $z > 2.8$ in the central 5.76 arcmin^2 HUDF/NICMOS region based on a pronounced broadband discontinuity between the NICMOS F110W and F160W bandpasses. These galaxies have red observed optical and near-infrared colors ($AB_{F775W} - AB_{F160W} \geq 2$) that cannot be explained entirely by dust reddening (indicating advanced age), and their luminosities at rest-frame optical wavelengths indicate a substantial stellar mass. Our analysis suggests that these galaxies have stellar masses comparable to the present-day M_* and are at least 1.6 Gyr old at $z > 2.8$, when the universe was merely 2 Gyr old. Because of their modest star formation rates, all five evolved galaxies have $AB_{F775W} > 26$ and thus would not have been included in samples selected by rest-frame UV features (e.g., Shapley et al. 2001). The presence of massive, evolved galaxies at early times suggests that early star formation may have been particularly efficient in massive halos (e.g., Stockton et al. 2004; Glazebrook et al. 2004).

#12183

New ideas: ‘cold flows’





Dekel et al. (2009) (see also Keres et al., van der Voorte et al.)

ZFOURGE Survey

A deep mass complete survey at 0.5<z<4

Ivo Labbé, Karl Glazebrook, Kim-Vy Tran, Casey Papovich, Caroline Straatman, Adam Tomczak, Ryan Quadri, Vithal Tilvi, Nancy Kawinwanichakij, Ben Forrest, Rebecca Allen,
Lee Spitler, Glenn Kacprzak, Themiya Nanayakkara, Glen Rees, Michael Cowley, Eric Persson, Pat McCarthy, Andy Monson, Pieter van Dokkum

Ivo Labbé (Leiden)

Lee Spitler (Macquarie Univ.)

How do galaxies assemble in the past 11 Gyr ?

- Stellar Mass Functions
- Star Formation Histories
- Scaling Relations (e.g. size evolution)
- Role of Galactic Environment
- Active Galactic Nuclei

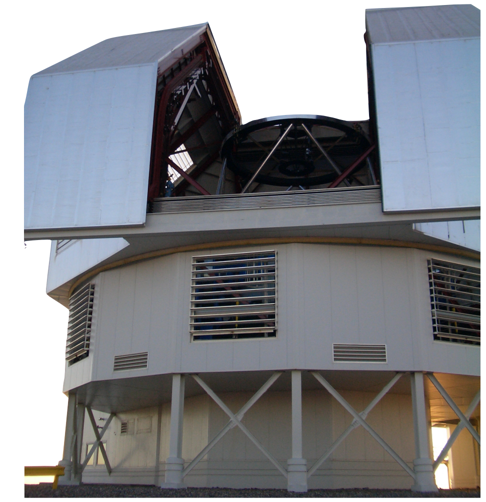
Casey Papovich (TAMU)

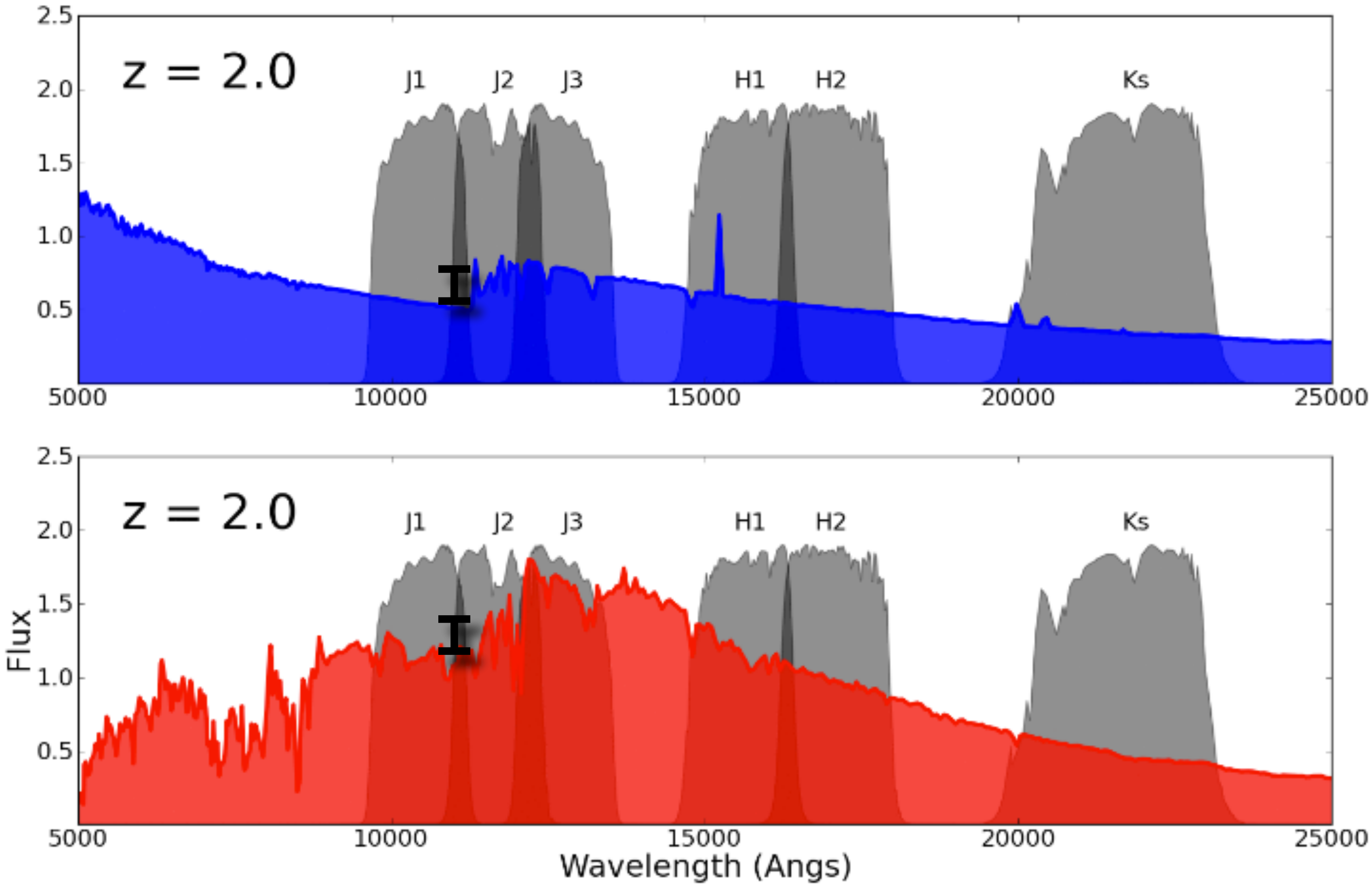
Vy Tran (TAMU/UNSW)

zfourge.tamu.edu

ZFOURGE Survey

Medium Band Near-IR filters⇒ accurate photo-z's including high-z quiescent galaxies



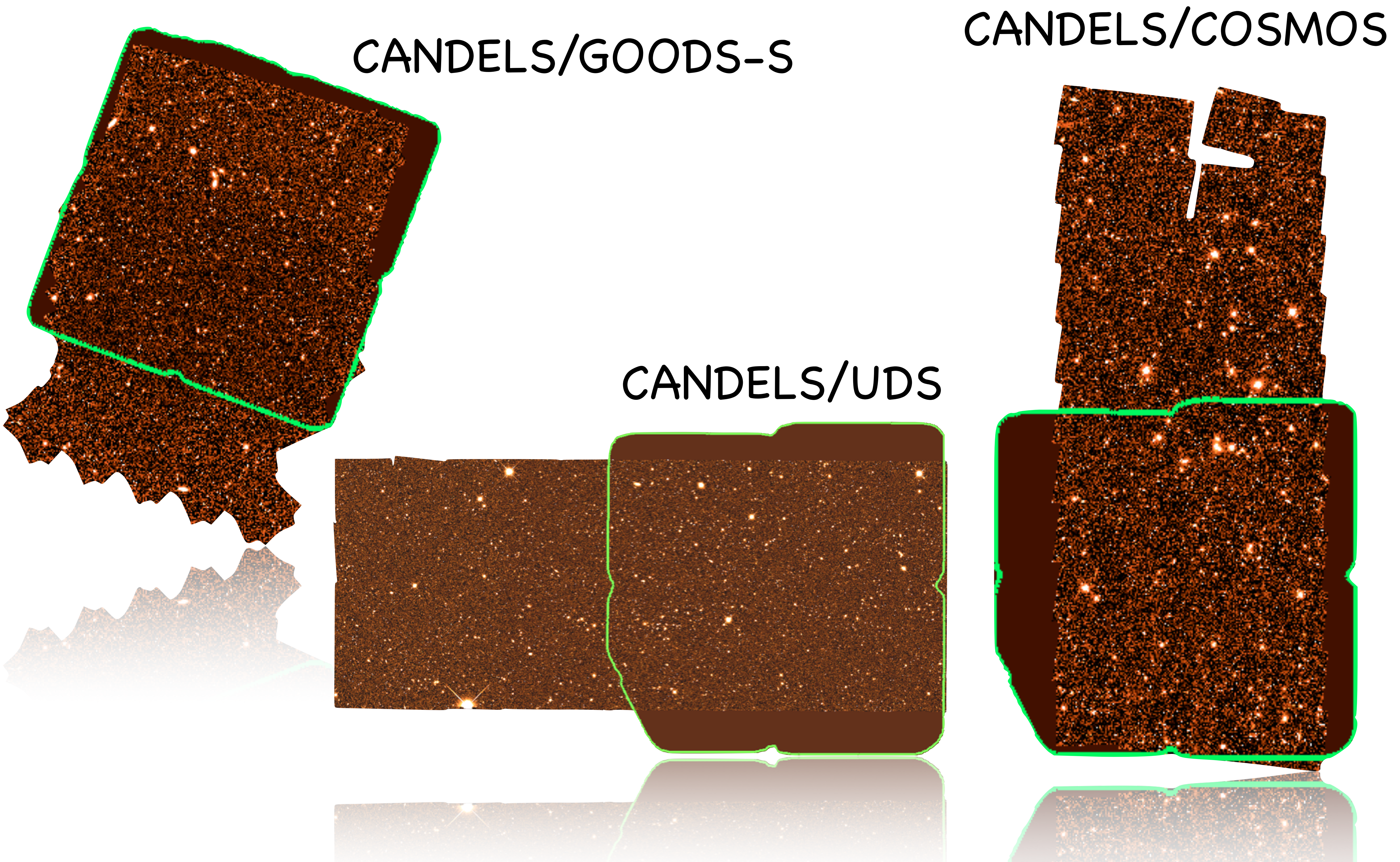


Four-Star:
Near-IR camera on Magellan (11'x11')

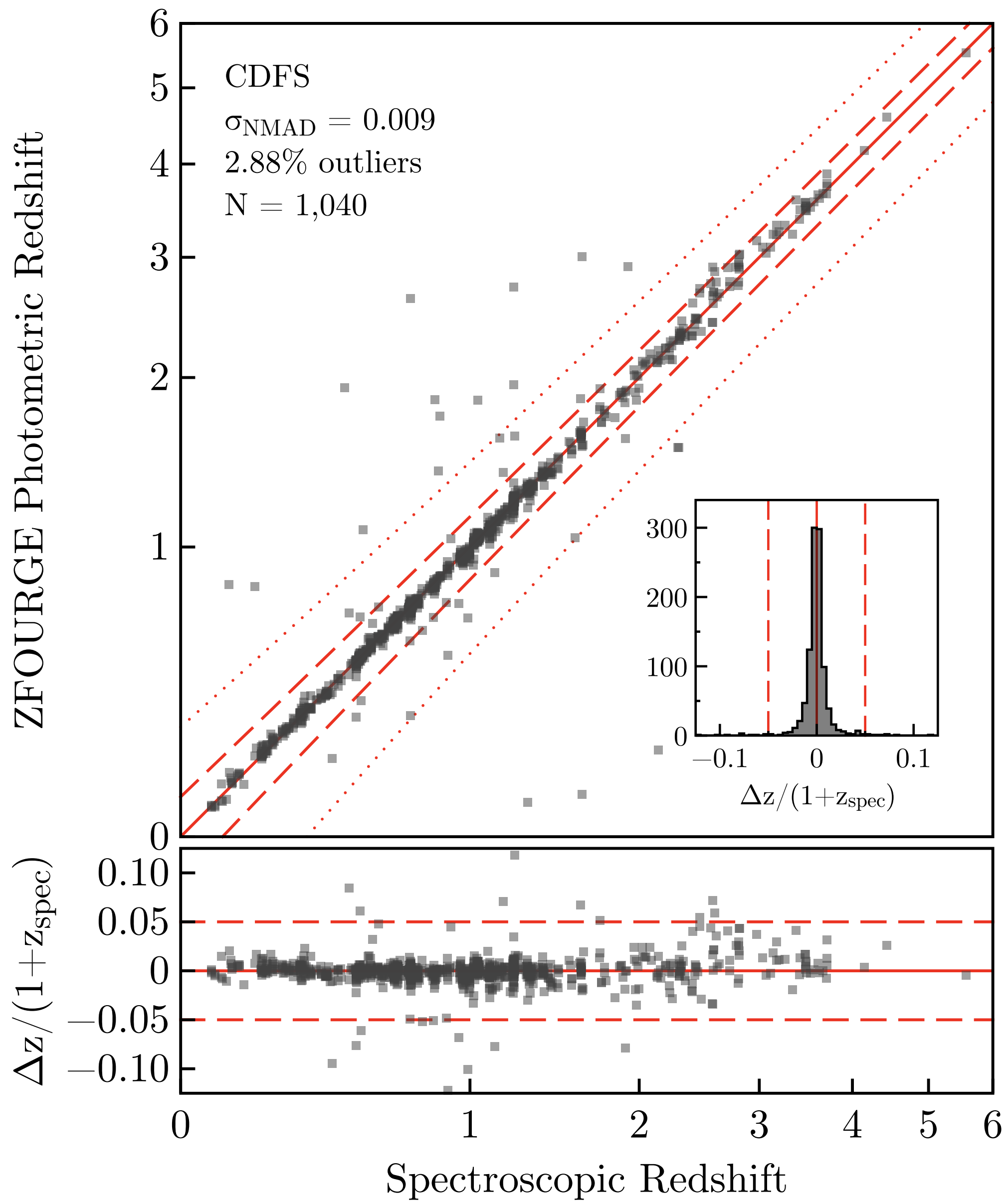
$J_1 J_2 J_3$~25.5
$H_l H_s$~25
K_s~25.5

Builds on ideas pioneered by NEWFIRM Medium Band Survey (PI van Dokkum)

ZFOURGE Survey

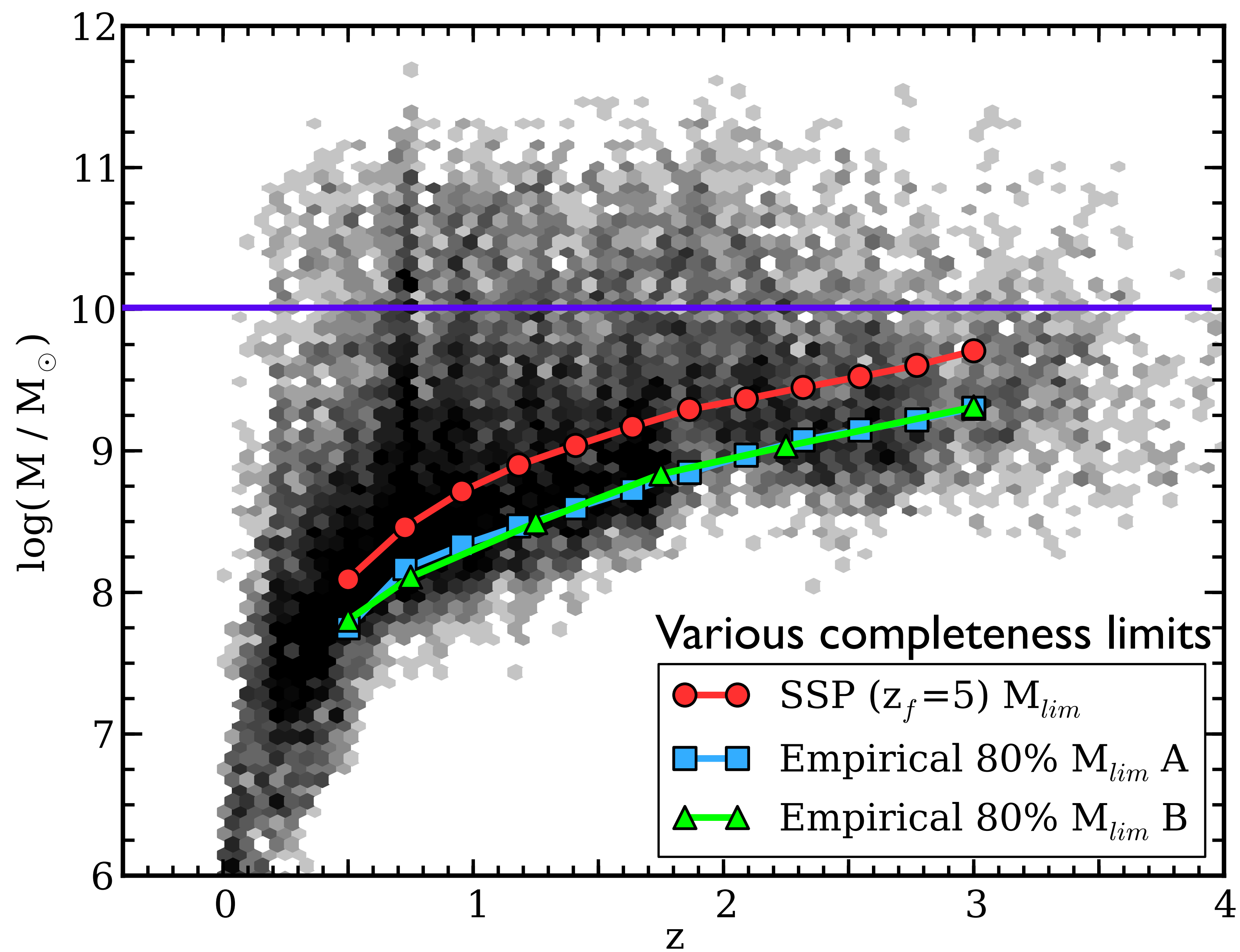


Excellent ~1% photo-z's!



Straatman et al. (2016)

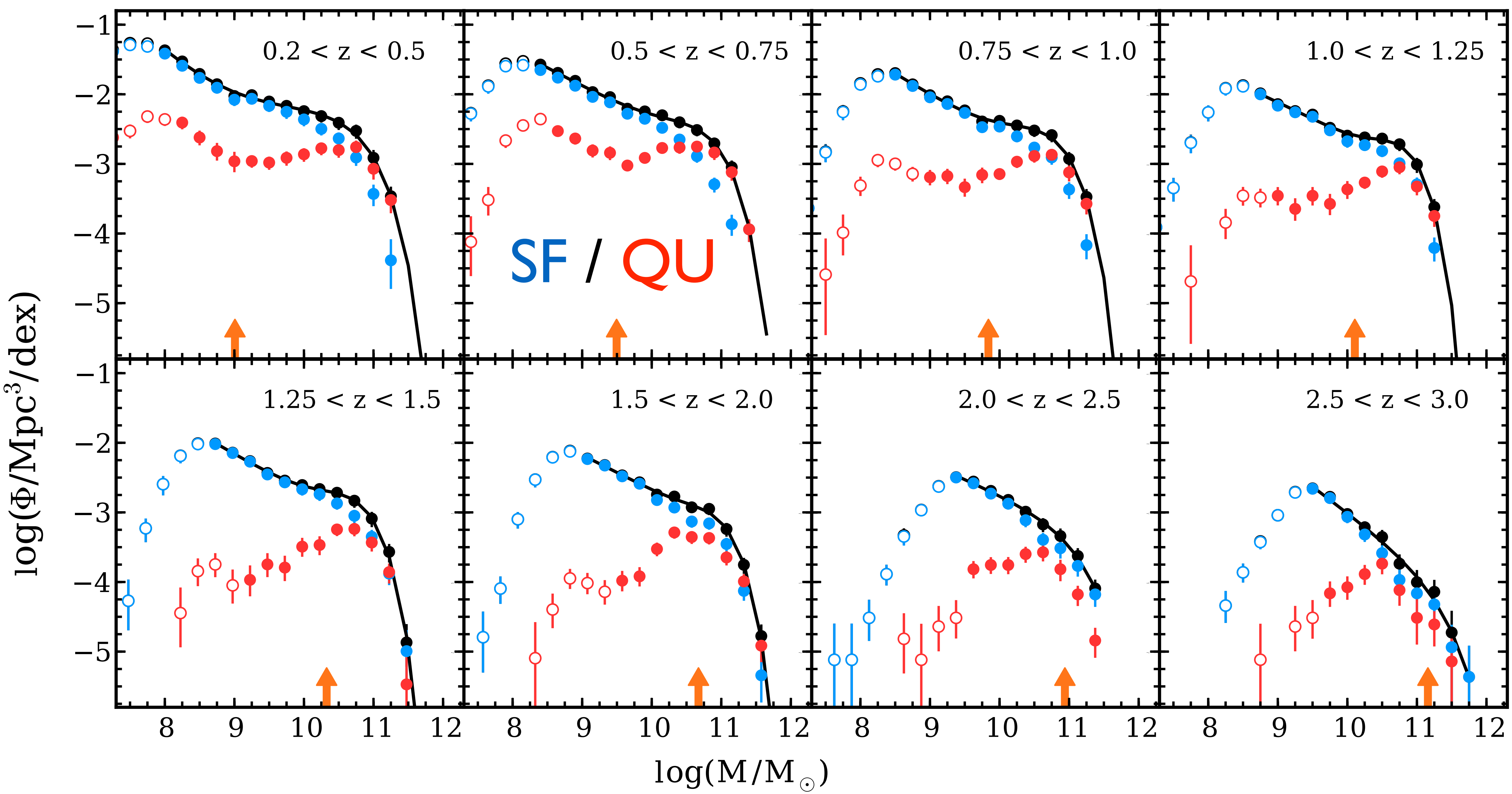
Stellar mass - redshift



Tomczak et al. (2014)

Stellar Mass Function (UVJ class)

ZFOURGE+NMBS

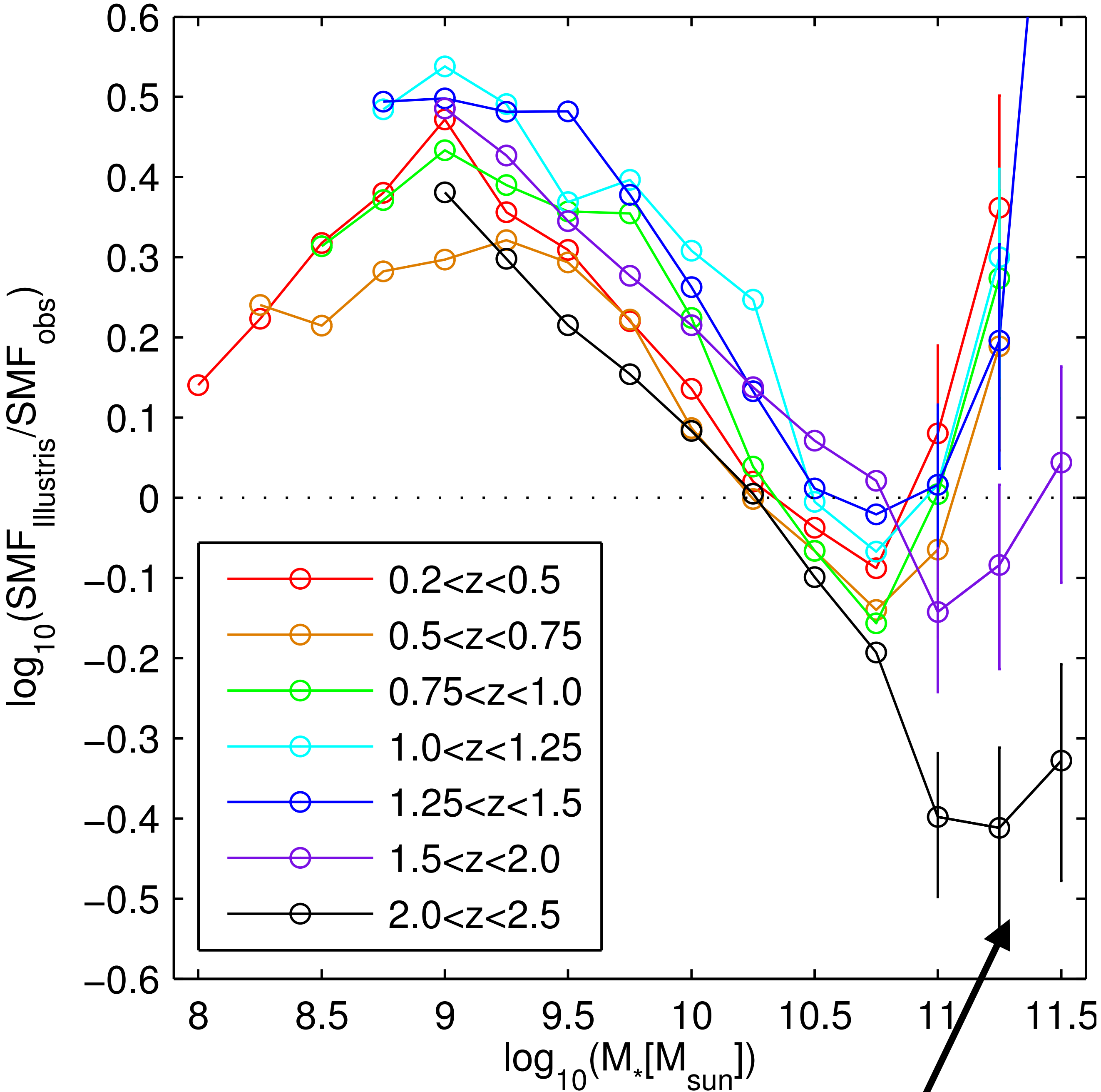


Tomczak+2014

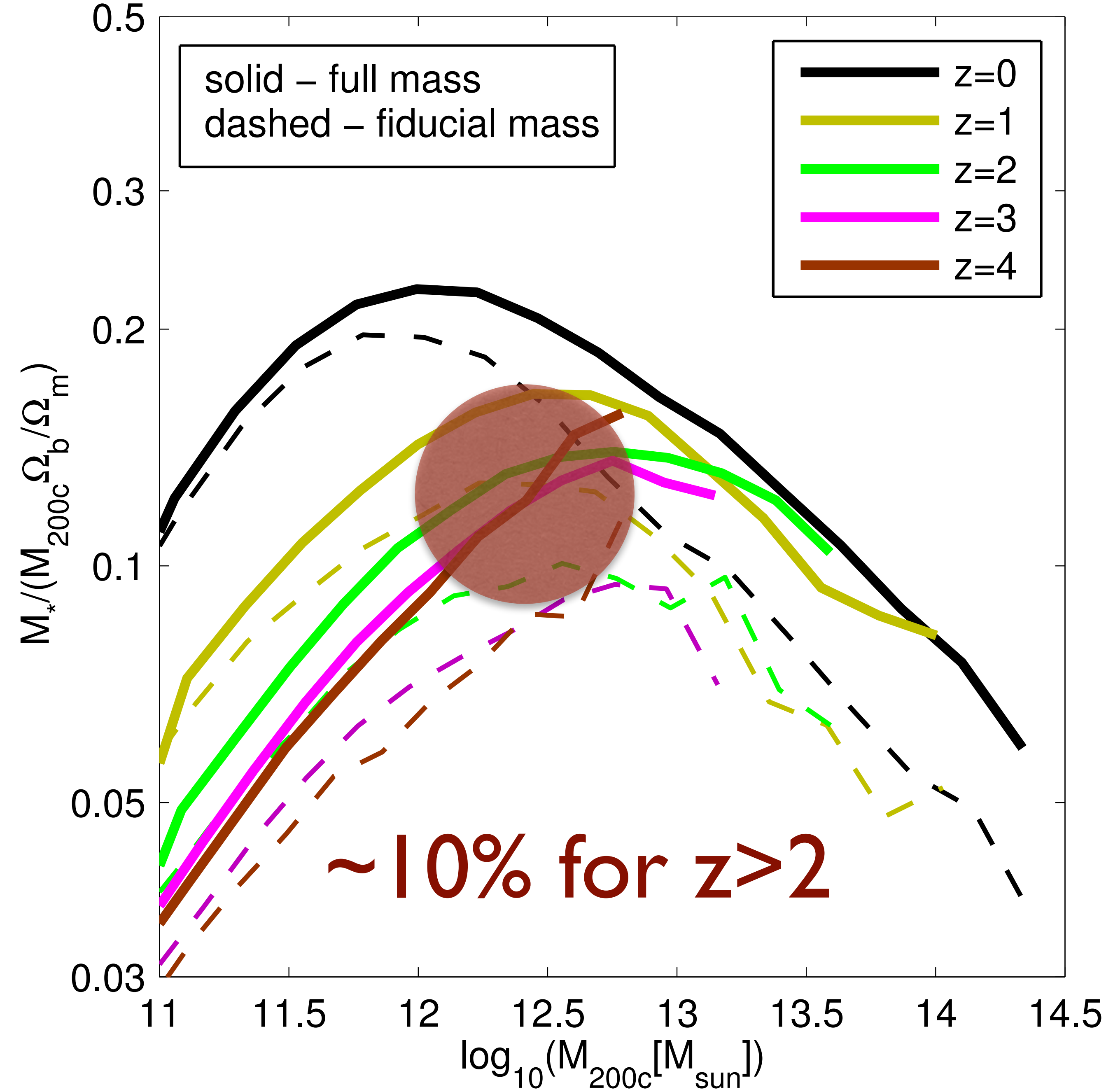
Illustris comparison

(Genel+2014)

stellar MF ratio



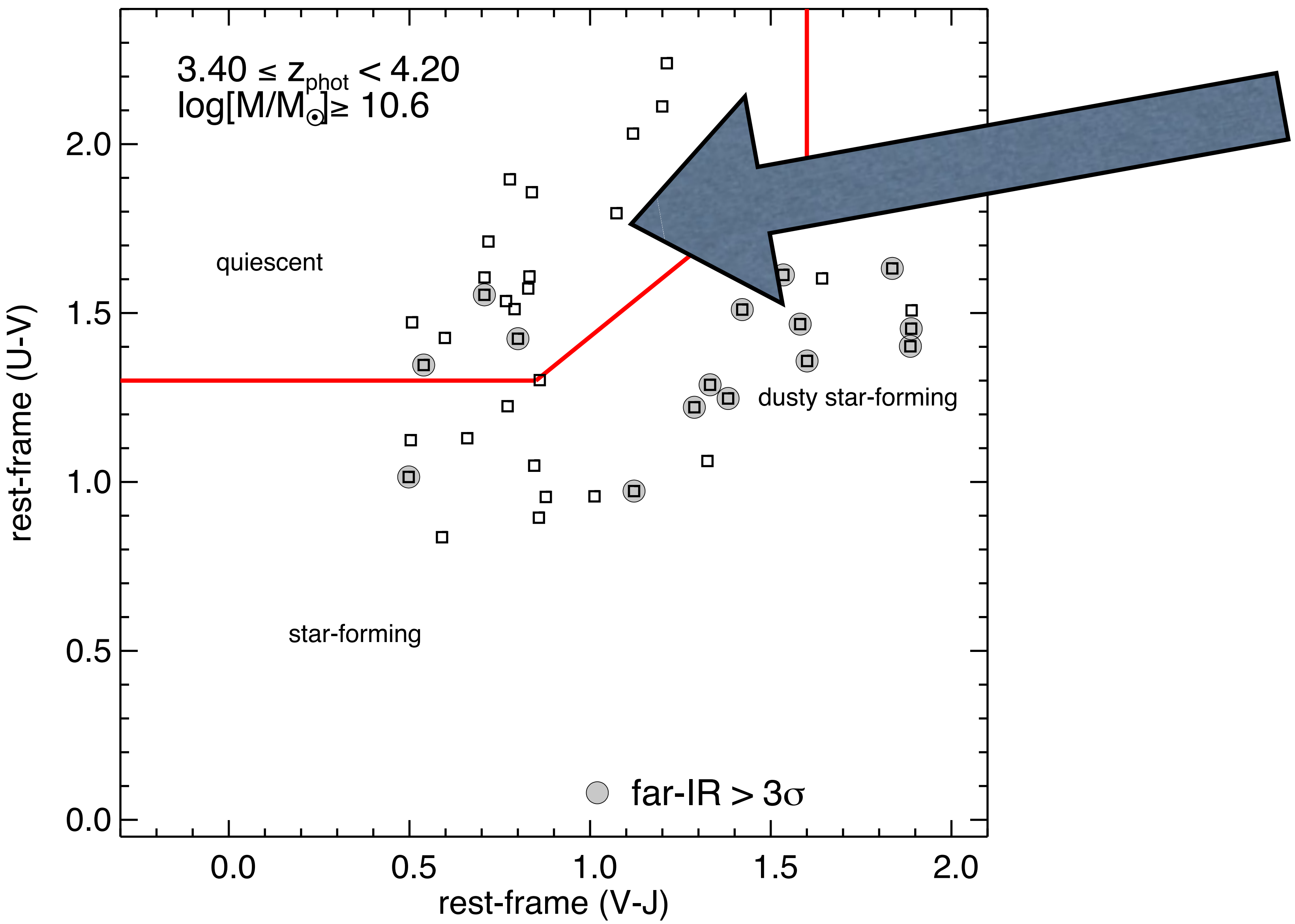
baryon conversion efficiency

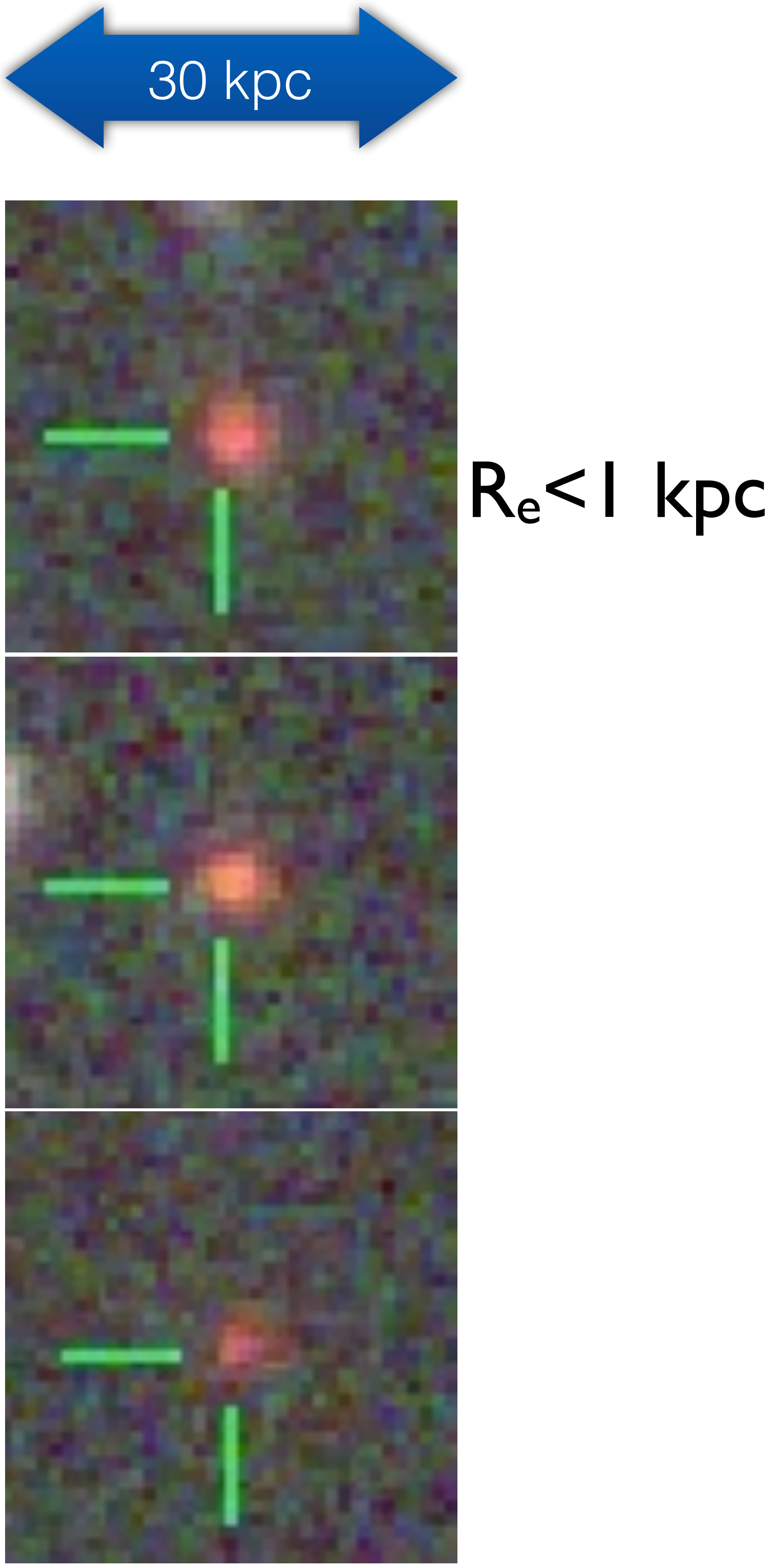


Sims under predict z>2

Massive quiescent galaxies & their halos at z~4

'rest-frame UVJ classification' z>3.5 massive galaxies



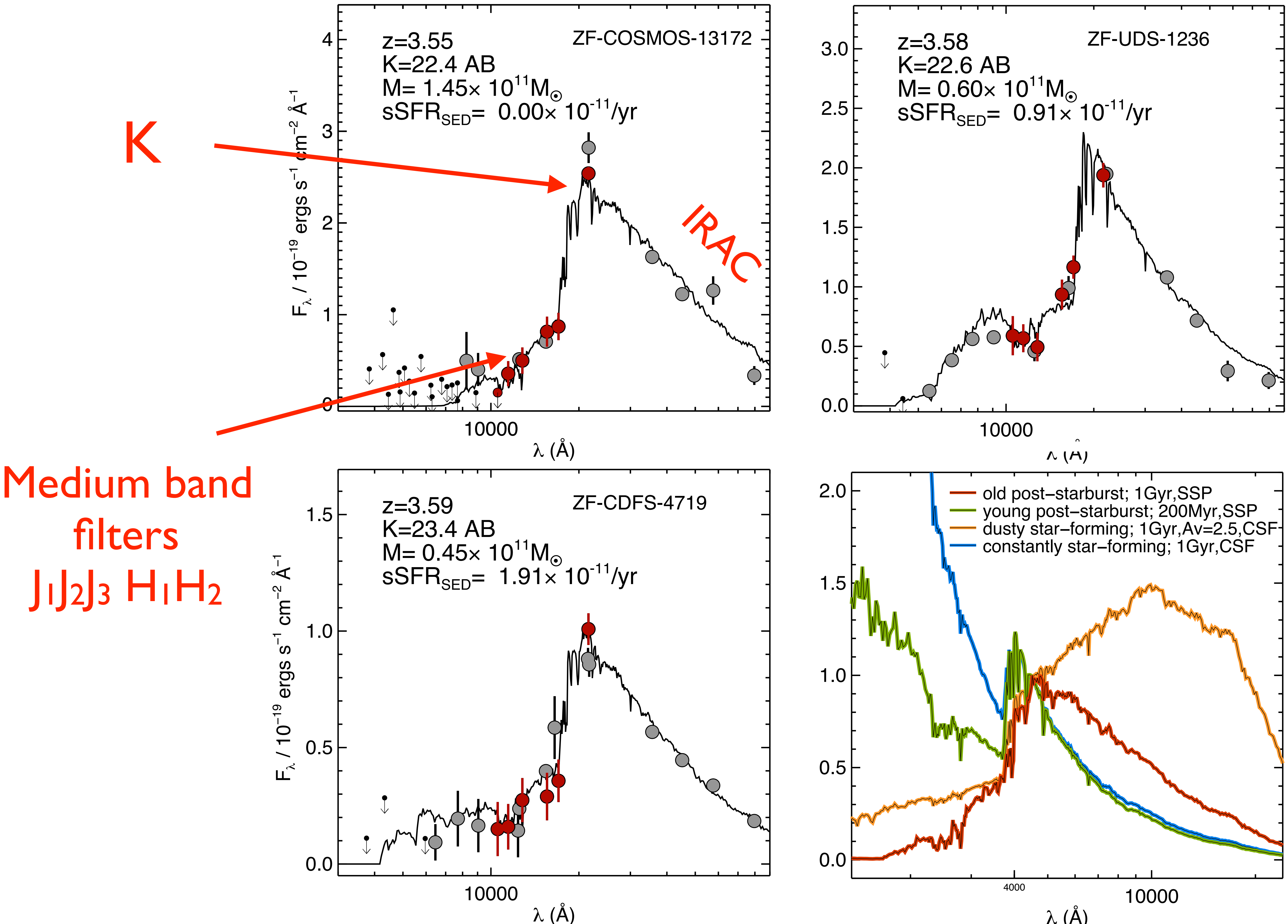


Straatman et al. (2014)

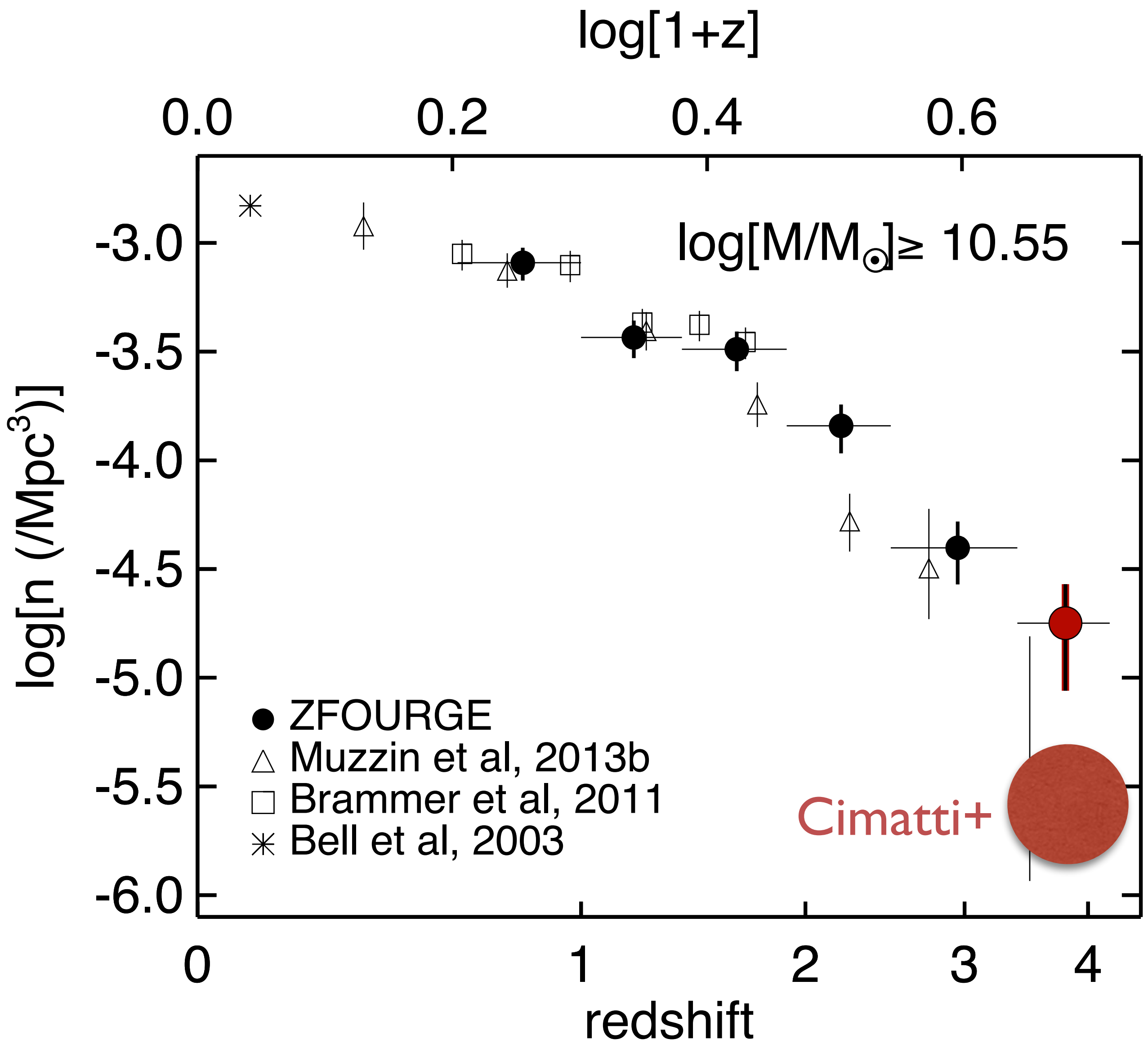
14 galaxies

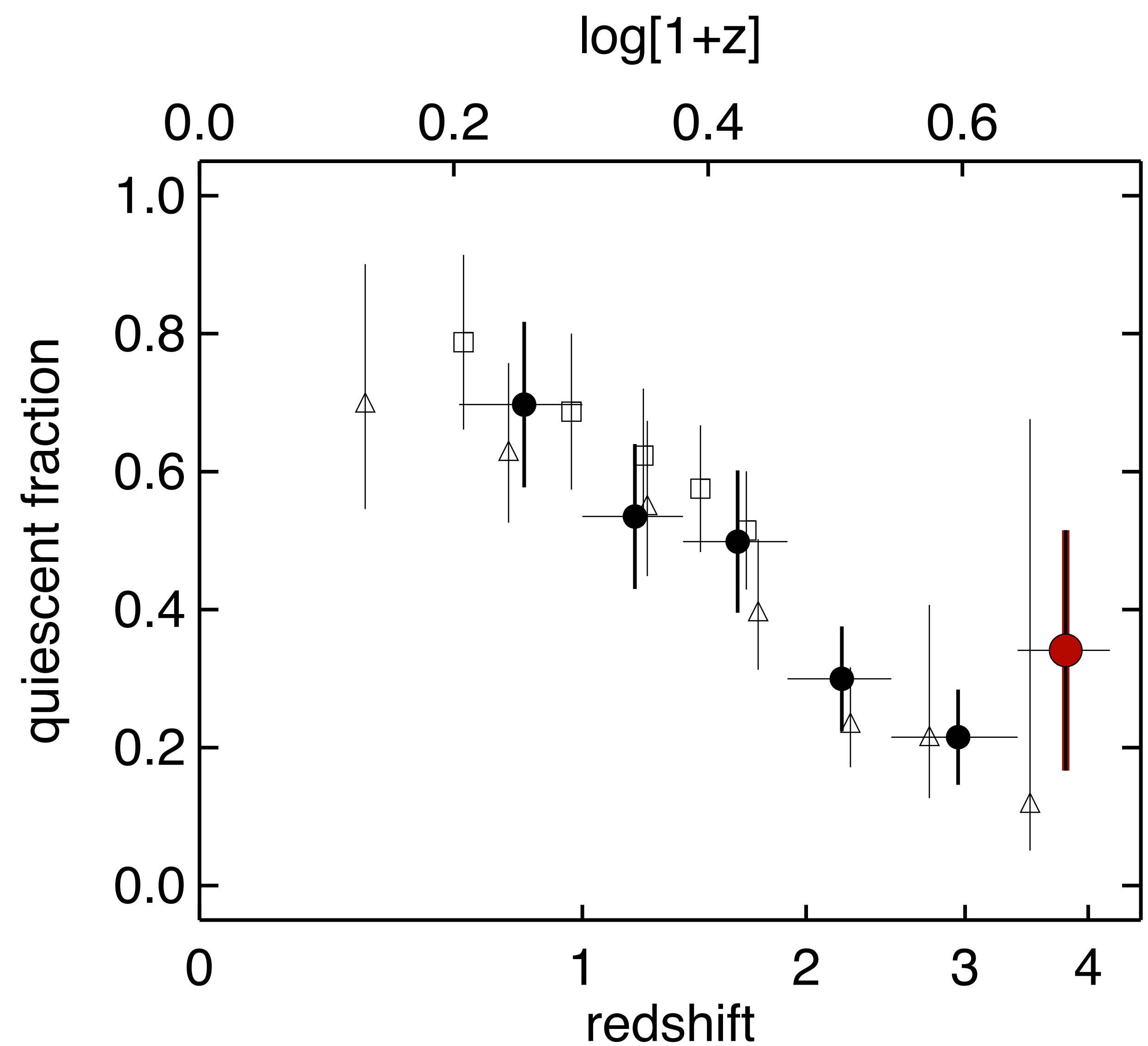
Colour Filters 1.5 1.7 2.1 μm

‘K-band peaks’ = Quiescent SEDs. ***Dust free.***



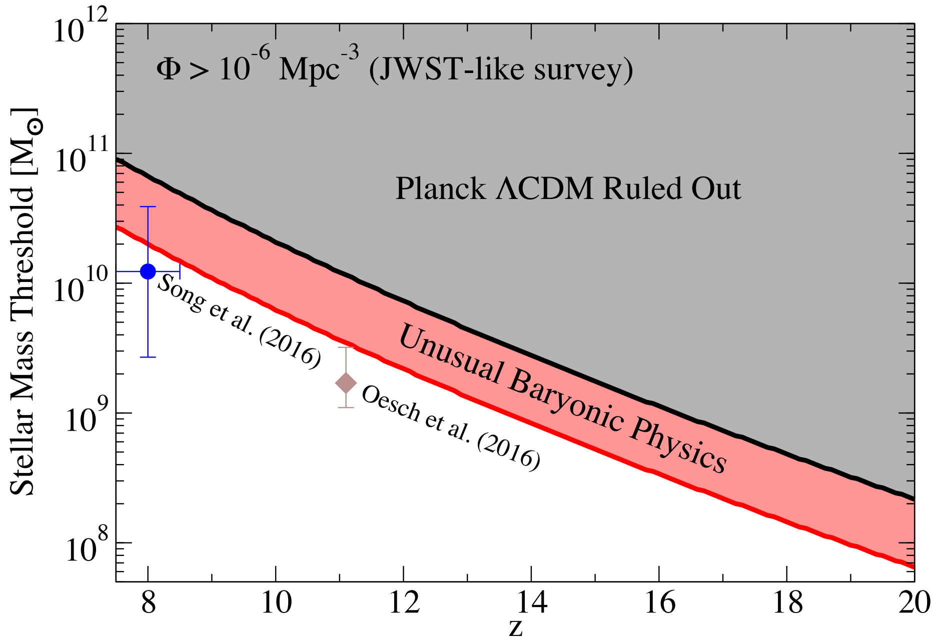
Declining quiescent galaxy abundance



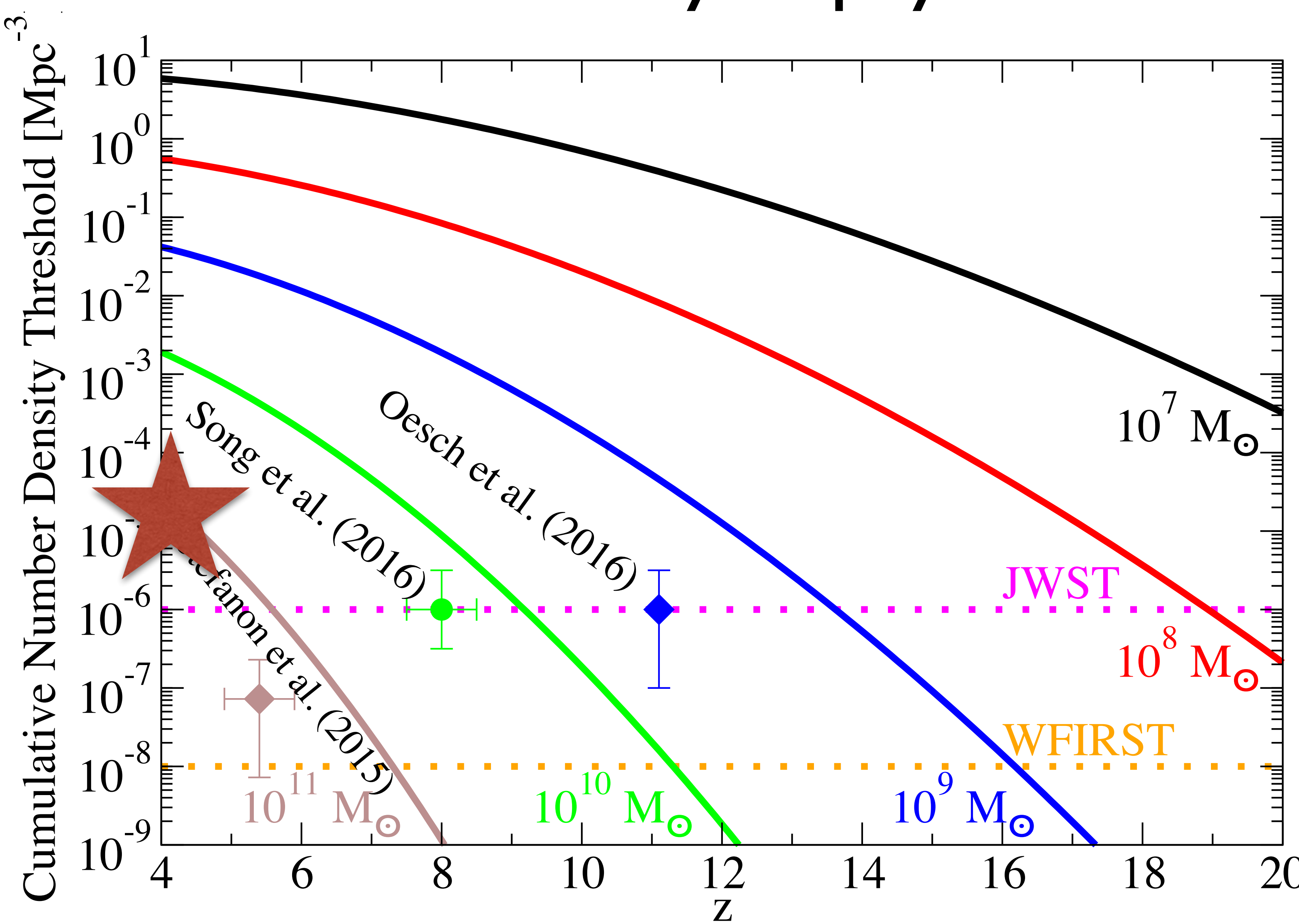


Straatman+2014 (see also Davidzon+2017)

What about DM halos?



'Unusual baryon physics'



z~4 nuggets:

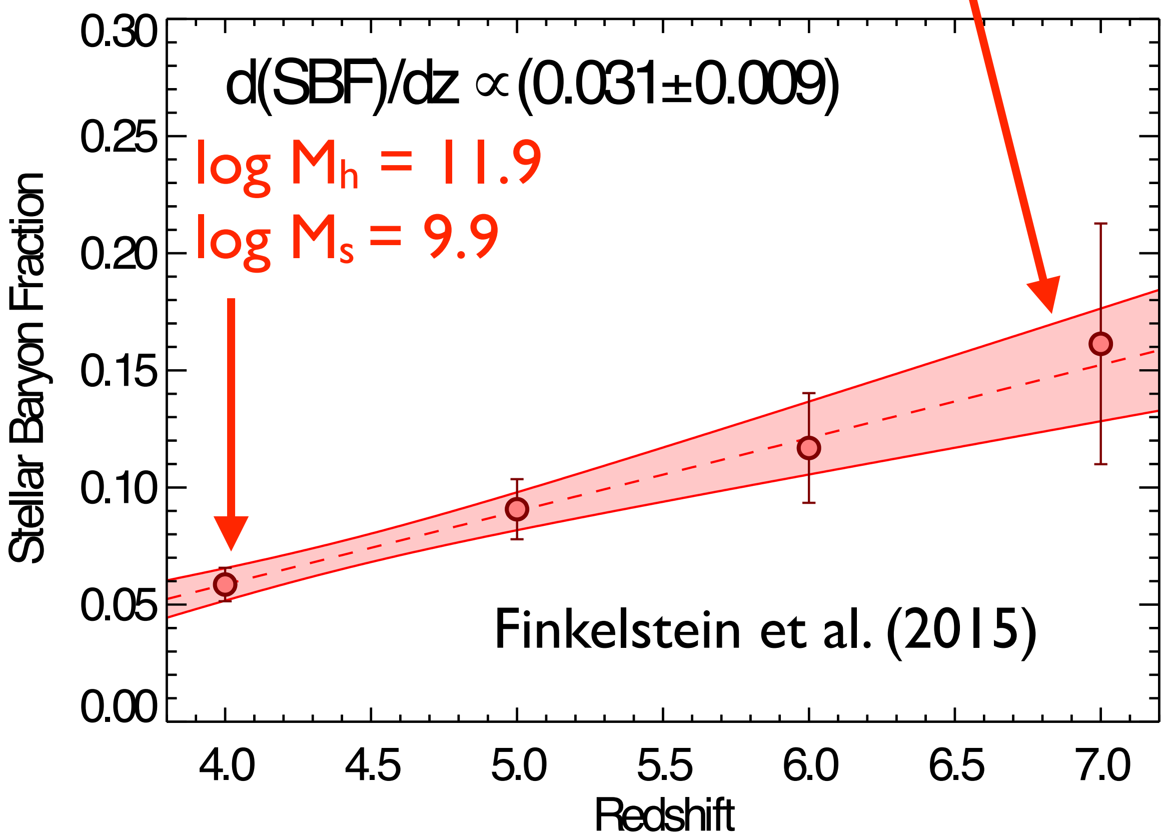
Log(Halo mass) = 12.5 (matching number density) gives **19%** stellar baryon conversion eff. (!)

Behroozi & Silk (2016)

Karl Glazebrook, SUT

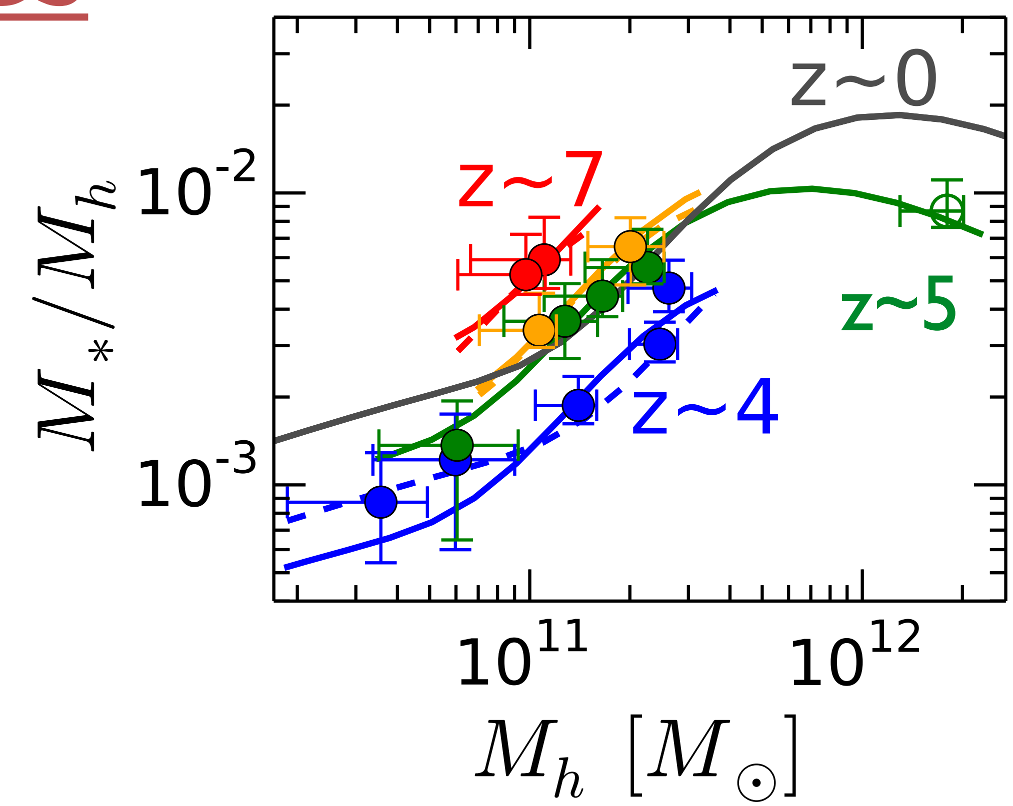
UV selected z>4 galaxies show the same trends

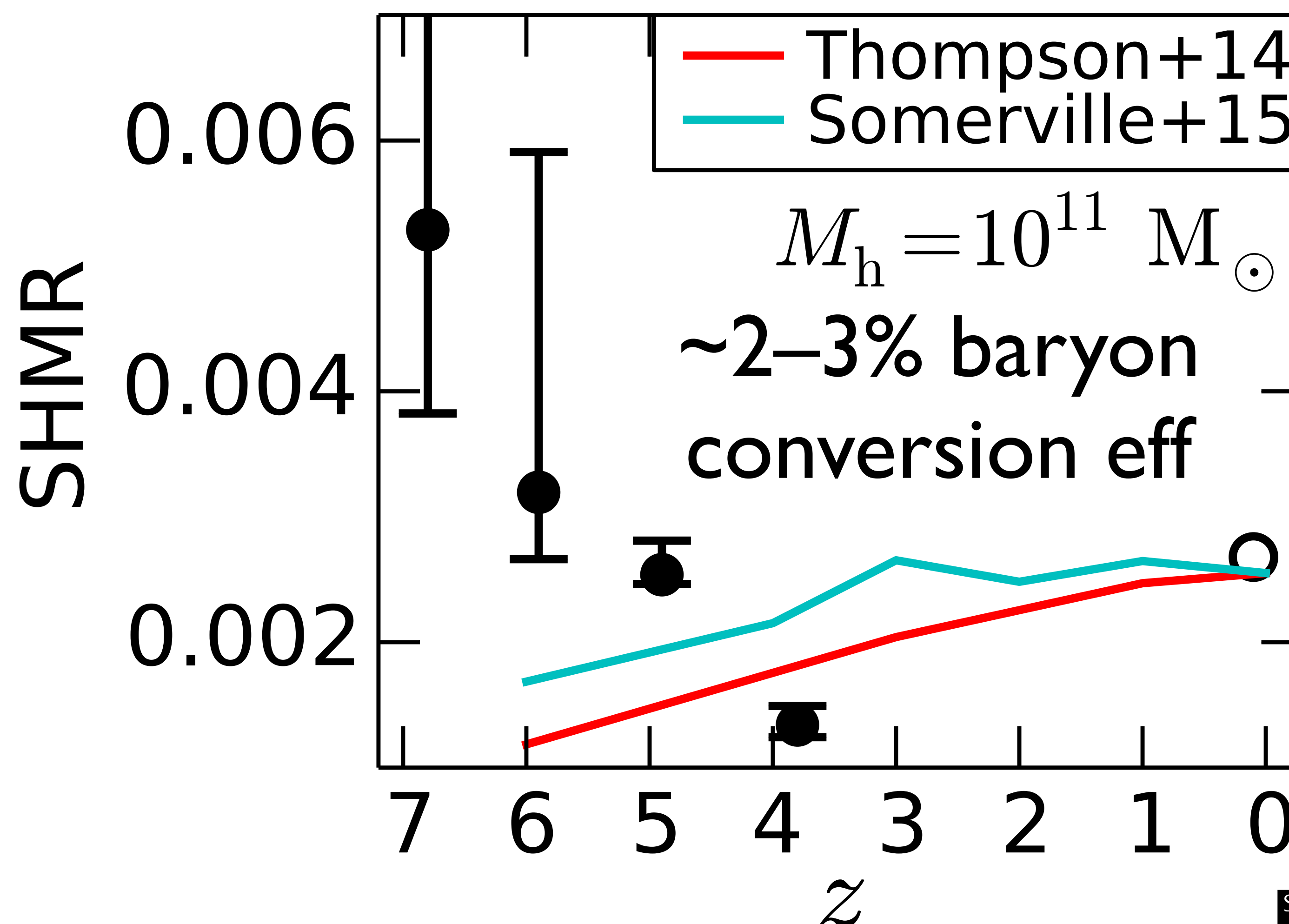
log M_h = 11.4
log M_s = 9.8



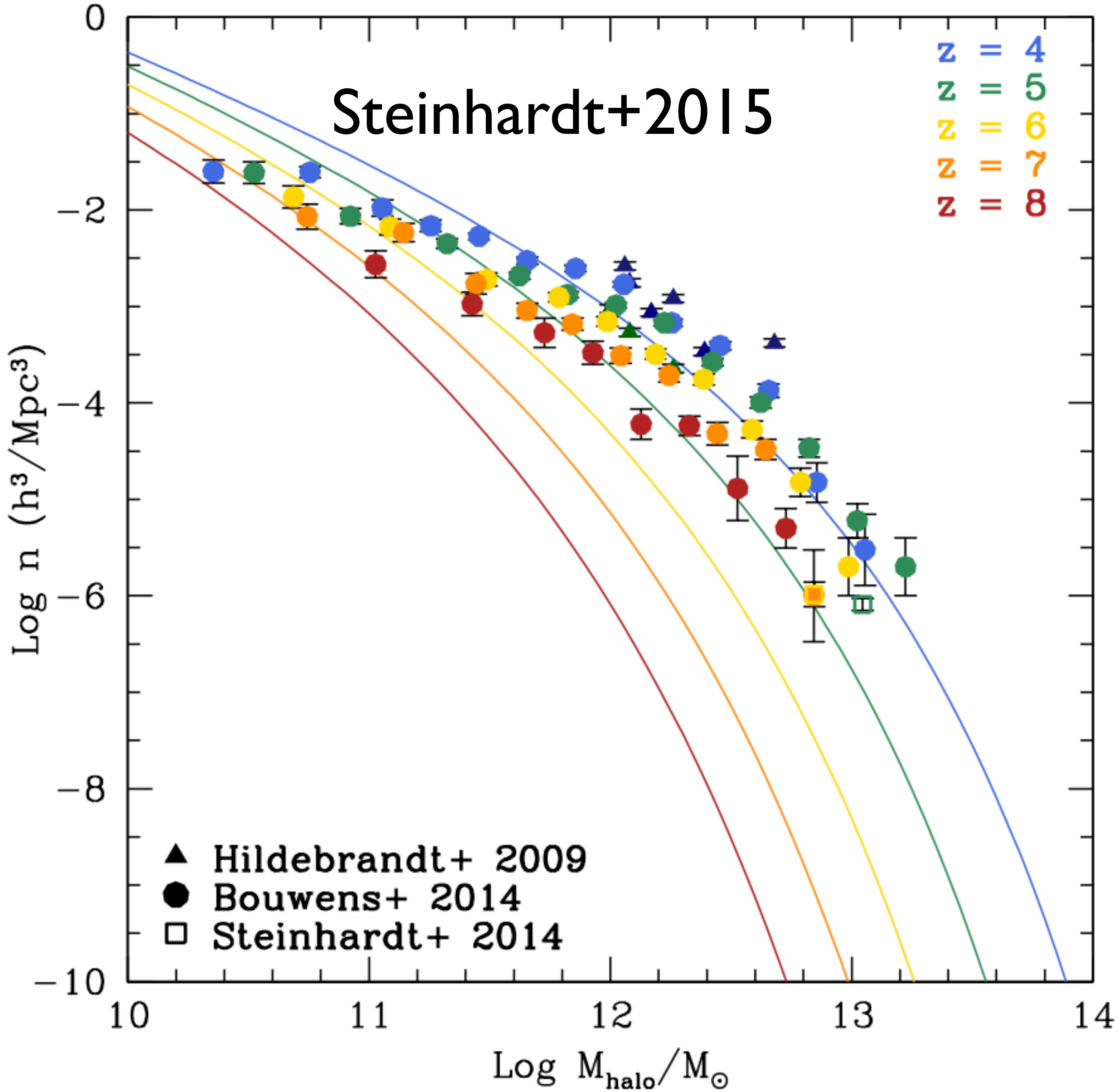
z>4 UV-selected LBGs:
M(1500) < –21

Harikane+2016

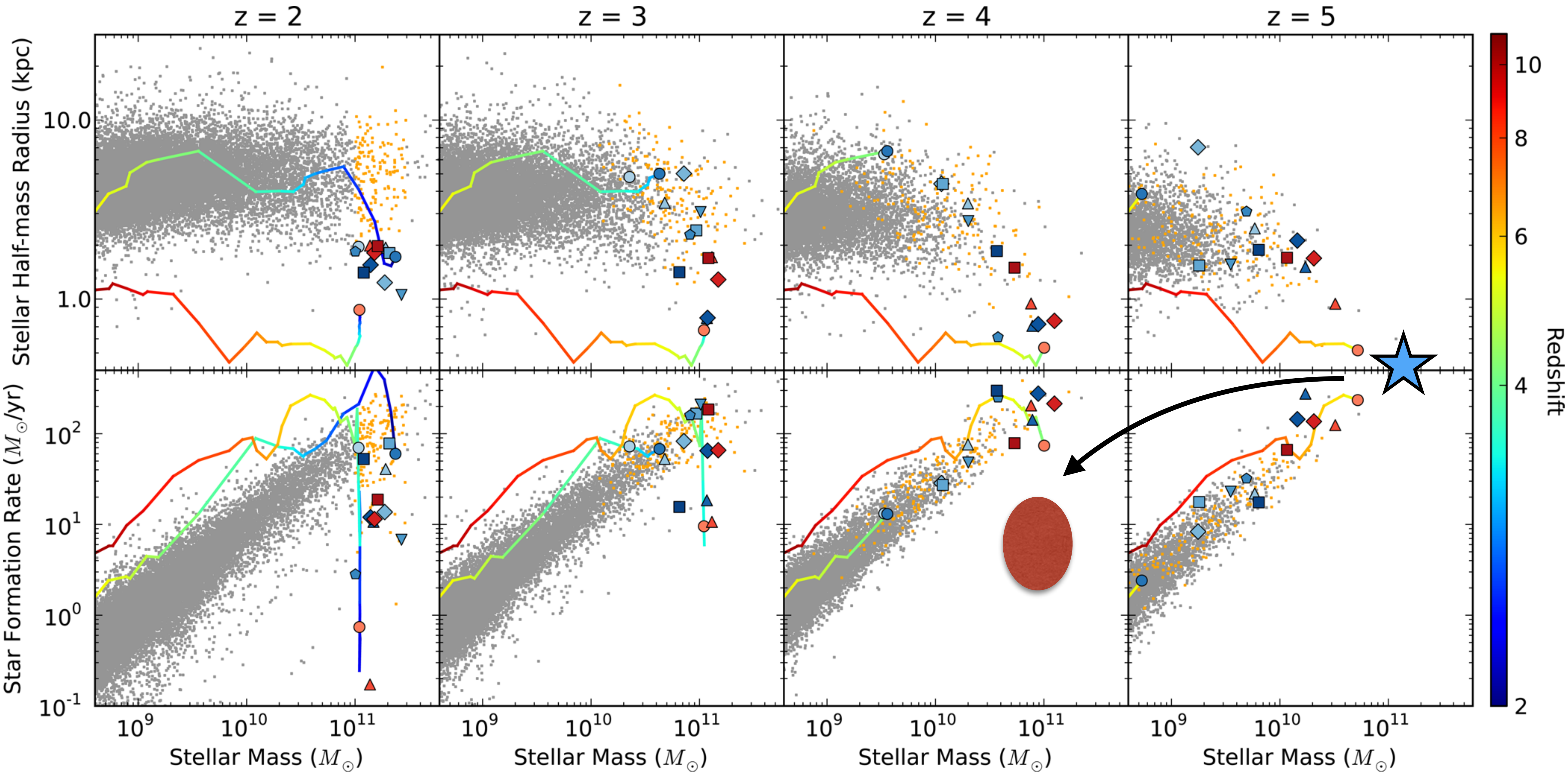




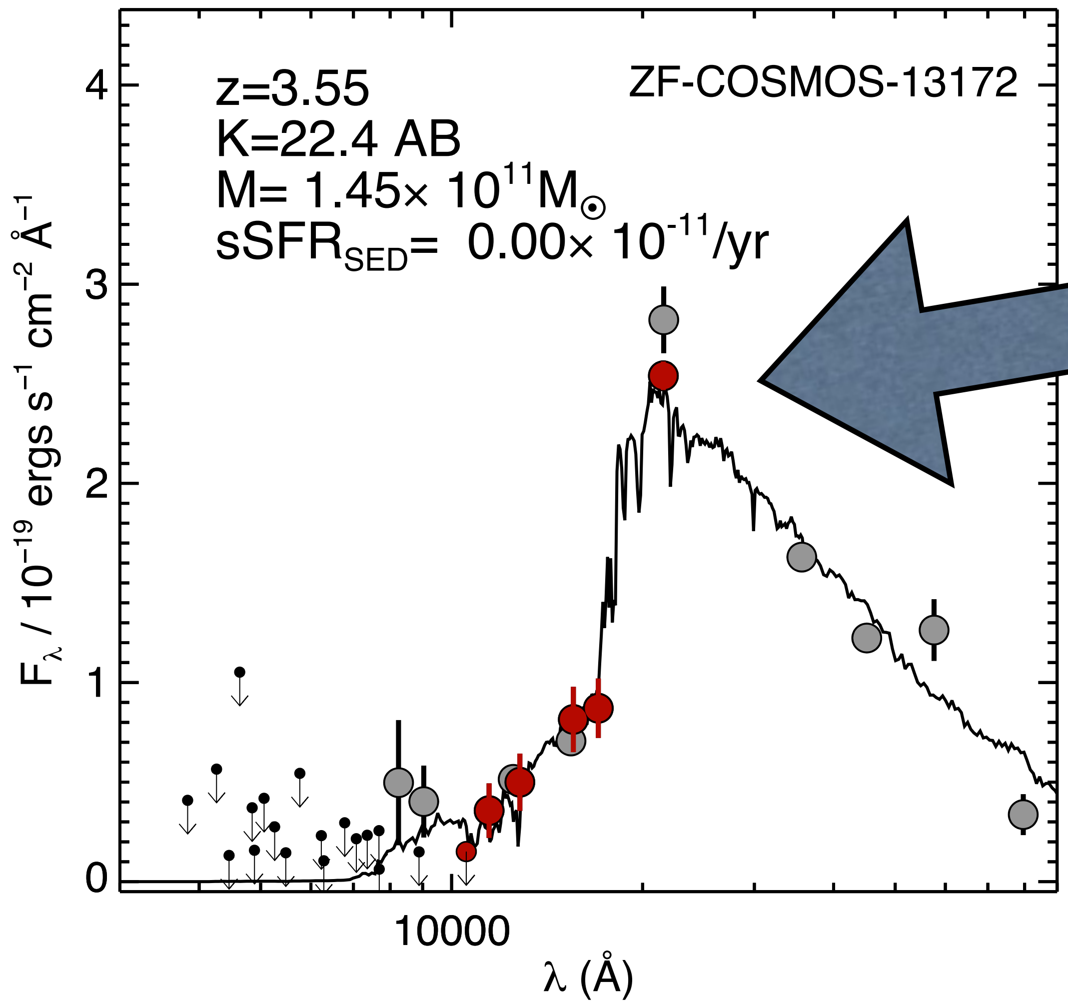
Number of z>4 UV galaxies stays high



z~4 QGs: A challenge to models?



Wellons+15 (Illustris simulation)



Strong emission line?

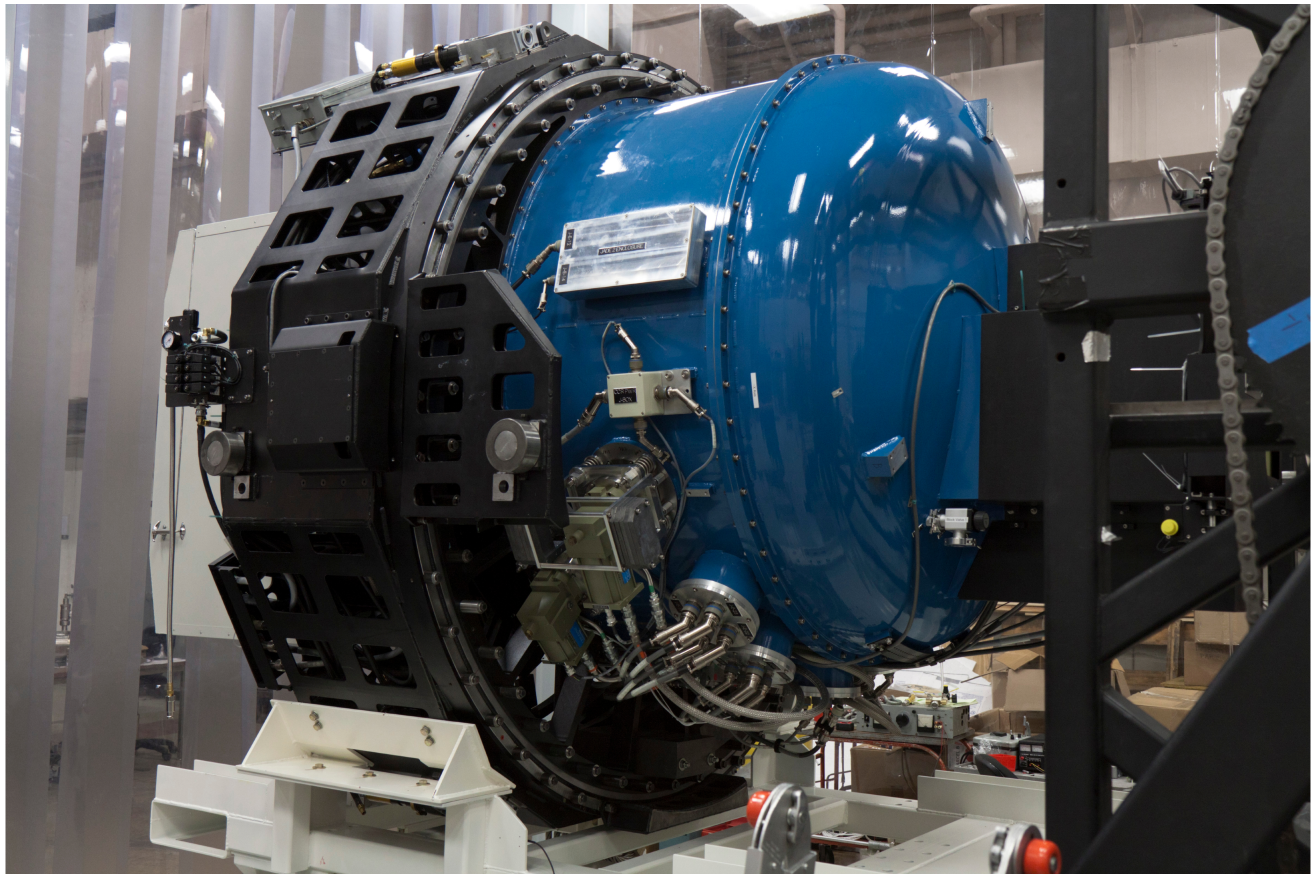
Are they *really* at z~4?

Karl Glazebrook, SUT

SWIN BUR NE

MOSFIRE as a null detector…

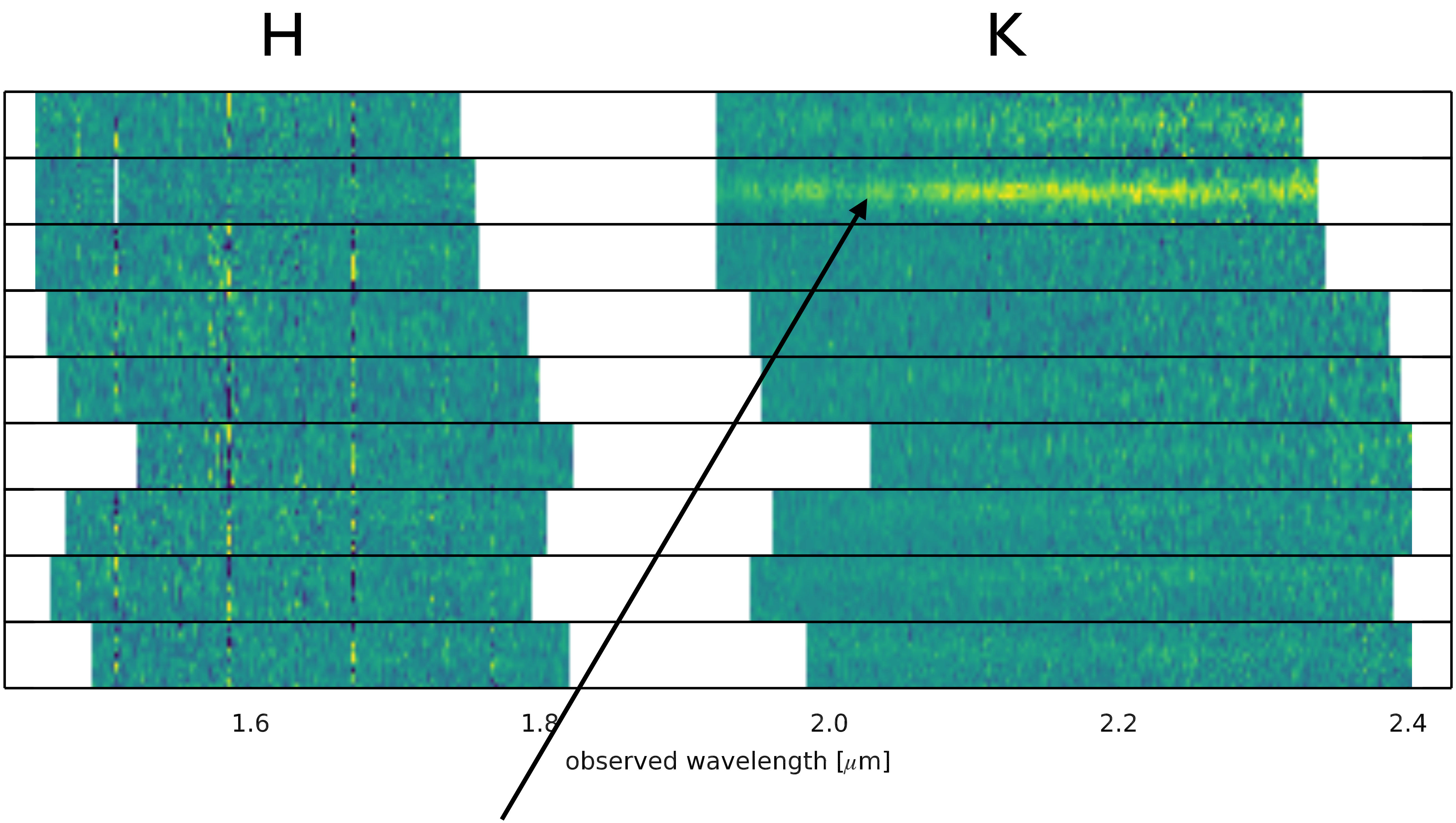
4–8 hrs NIR spectra on sample of massive z~4 quiescent galaxies in EGS, UDS & COSMOS.



Deepest COSMOS Mask: 8 hrs

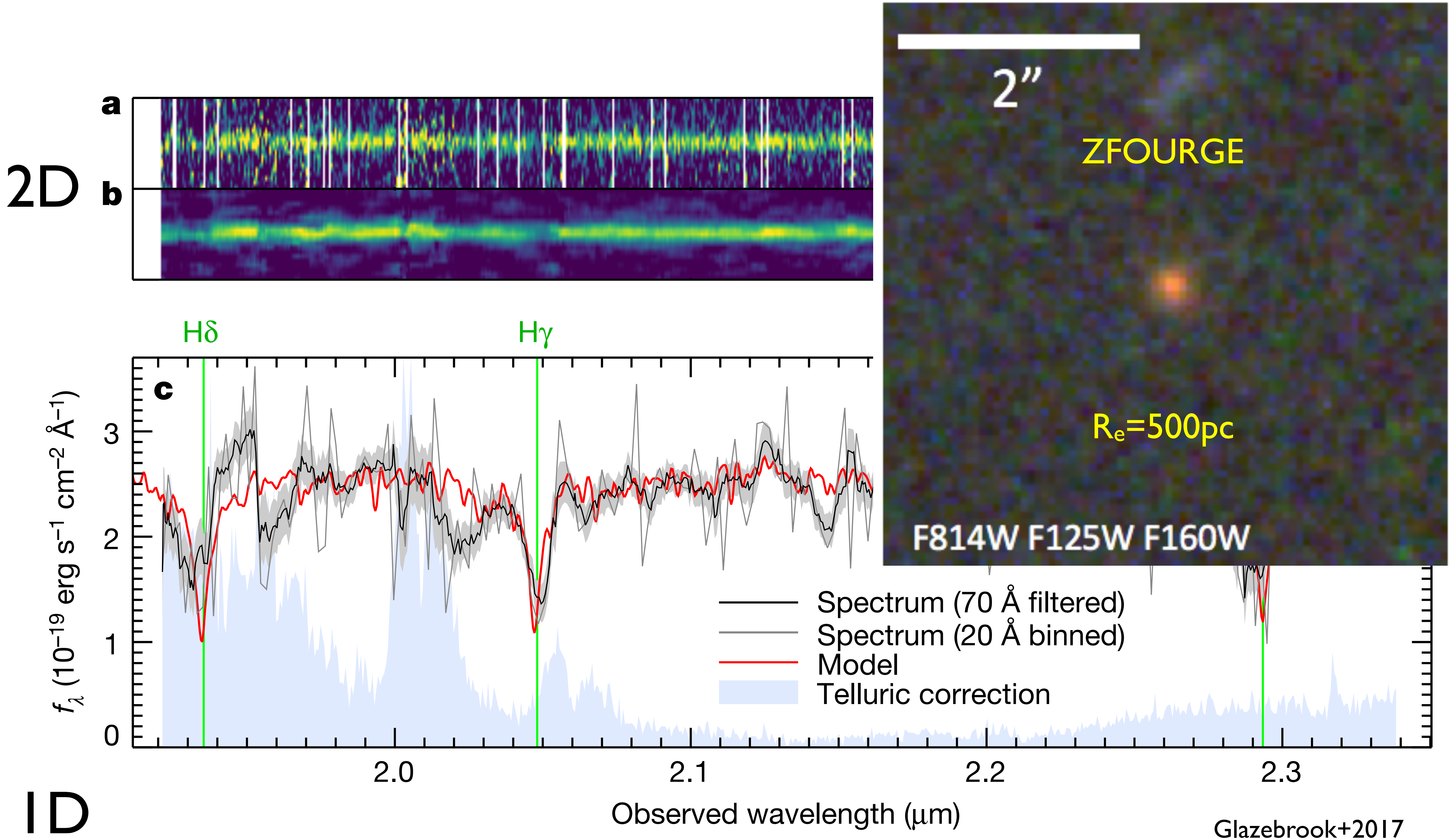
Plan: rule out huge emission lines in K band

Nine z~4 Quiescent Galaxies



z_{photo}=3.55 K=22.4 M=$1.45 \times 10^{11} M_{\odot}$

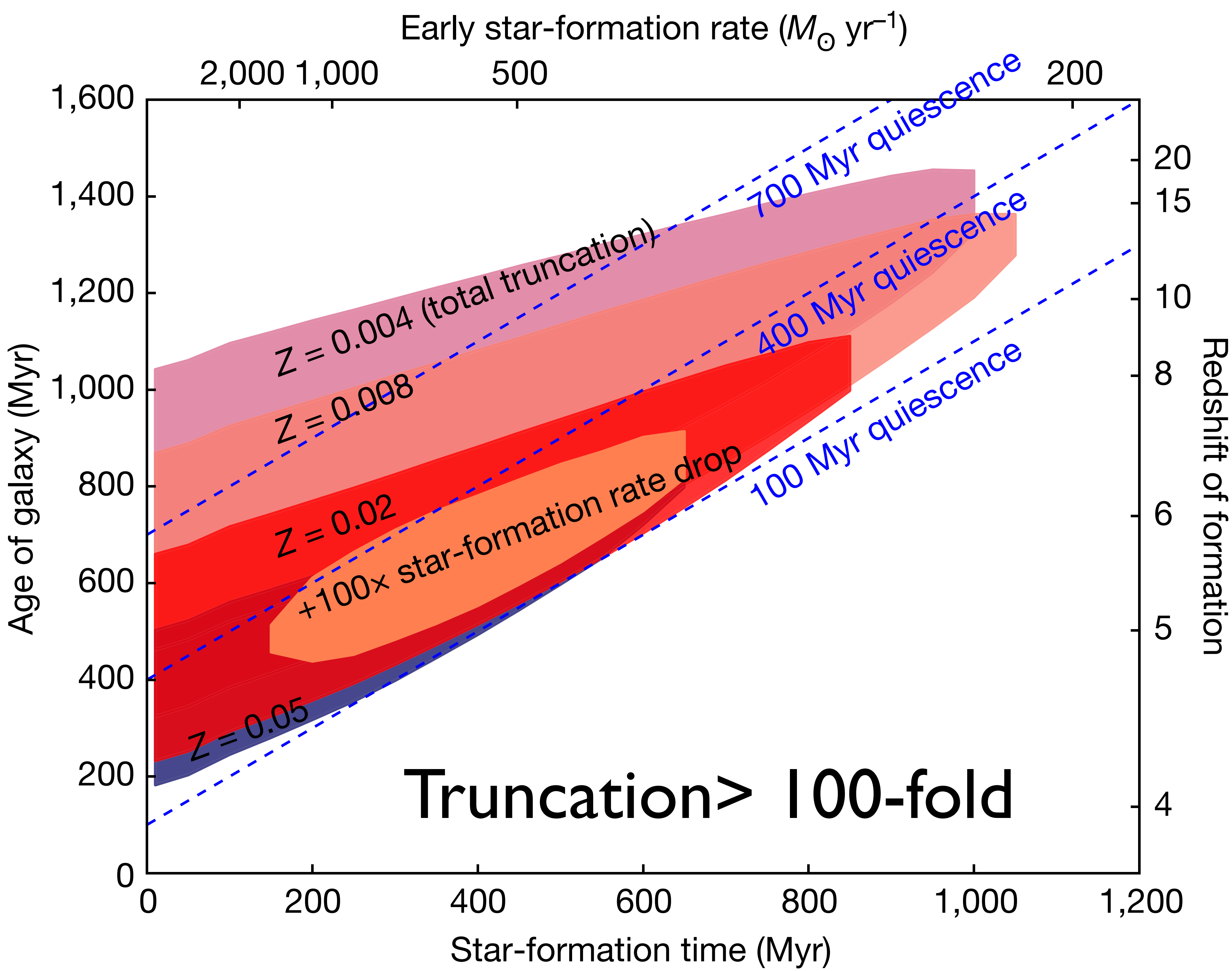
Optimum binning & extraction…



Glazebrook+2017

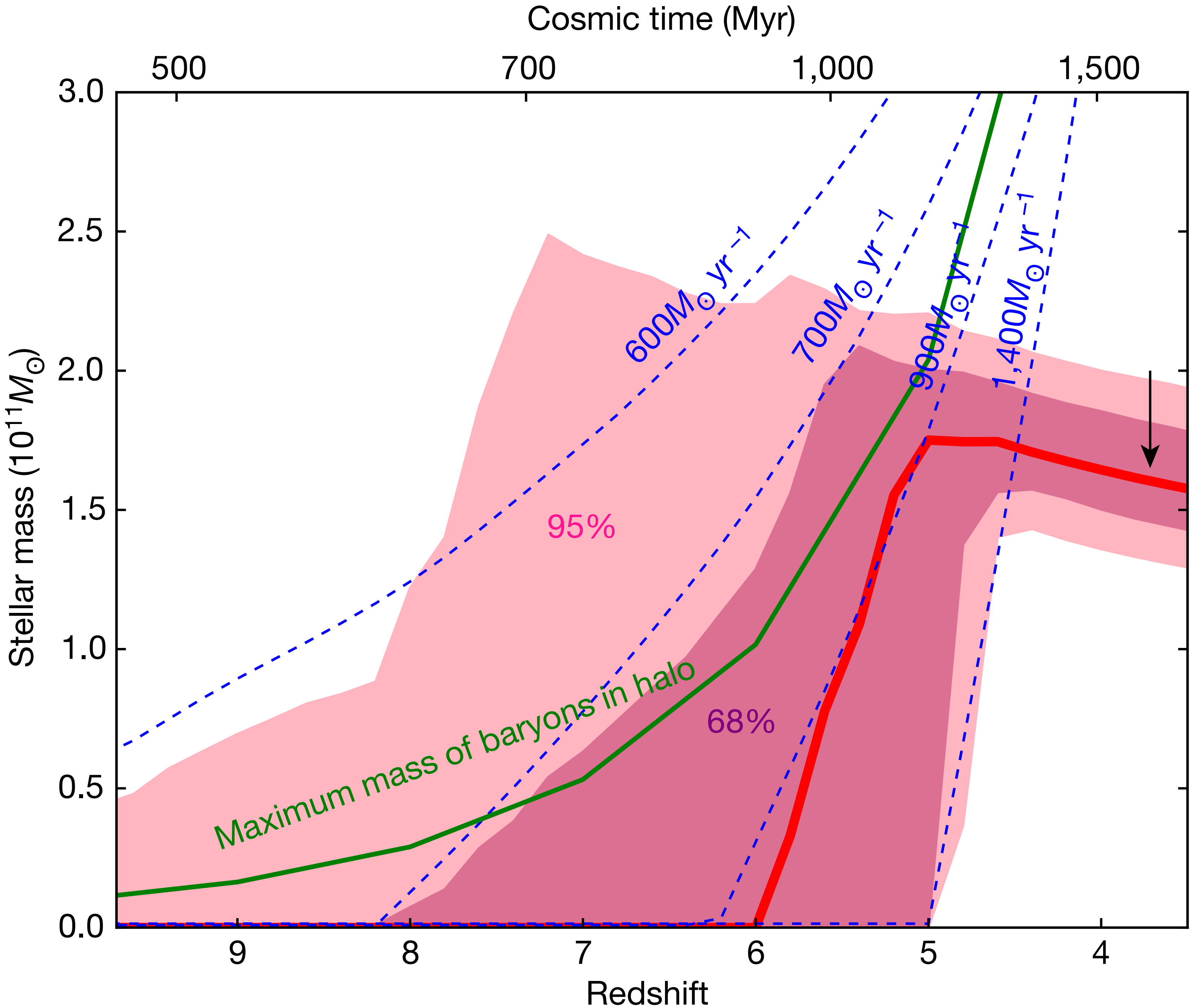
z_{spec}=3.717 – PSB spectrum! K(AB)=22.4

Strength of Balmer lines: quiescent & 200–1000 Myr old

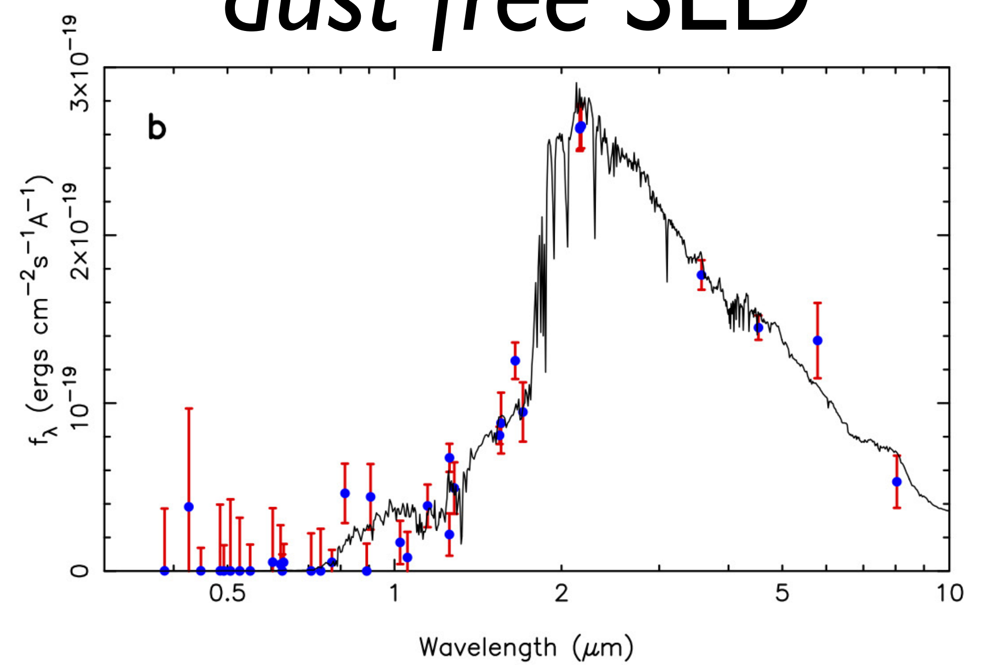


Glazebrook+2017

Full SED+spectrum SFH



dust free SED



30–35% of baryons in halo in ZF-20115?

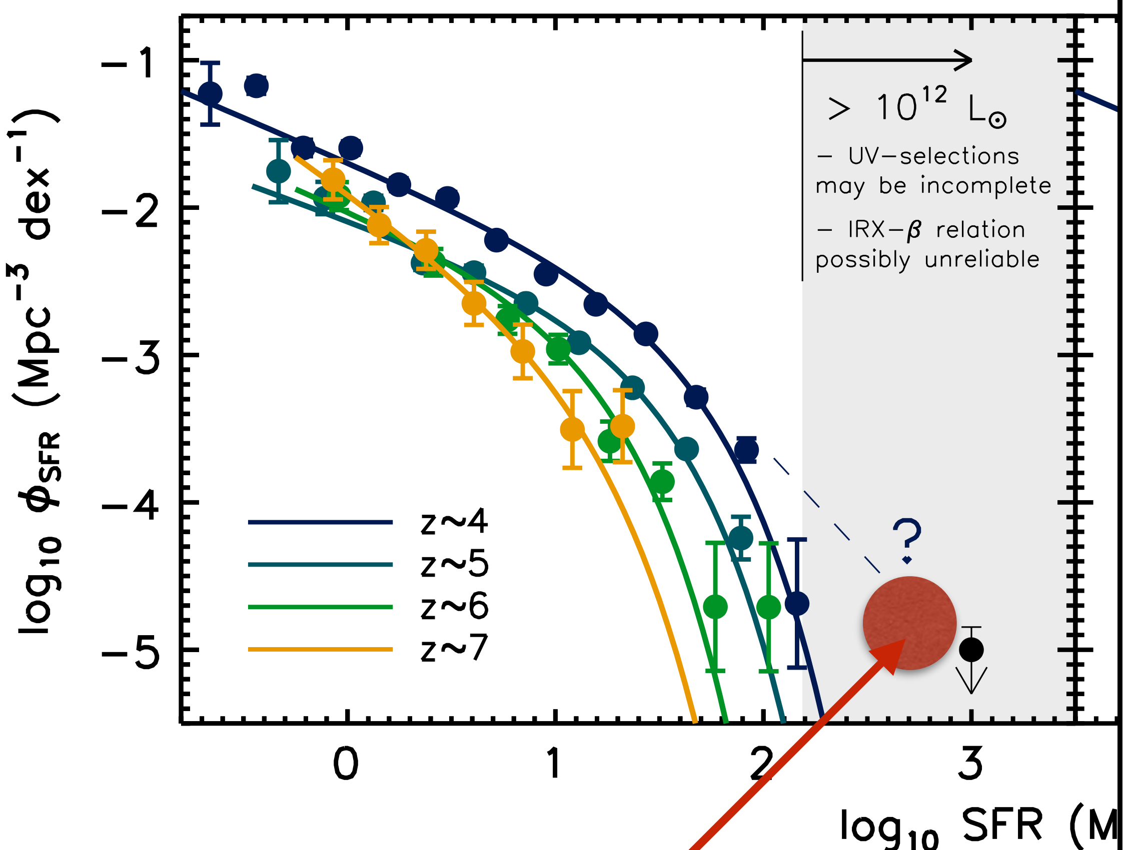
Karl Glazebrook, SUT

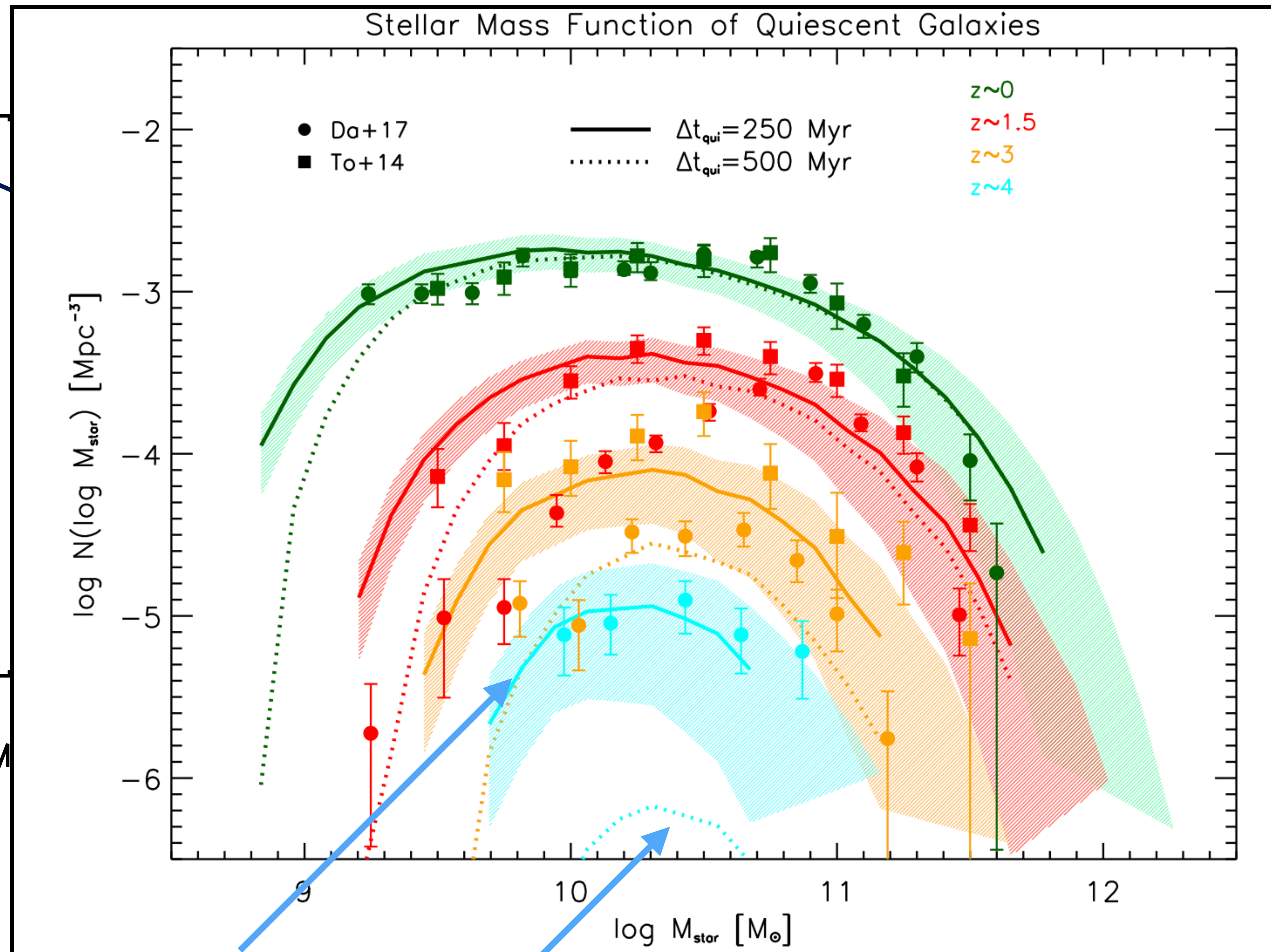
Glazebrook+2017

Empirically: enough QG ancestors?

z

Smit+2012 cosmic SFR functions





z~4 QG ancestors

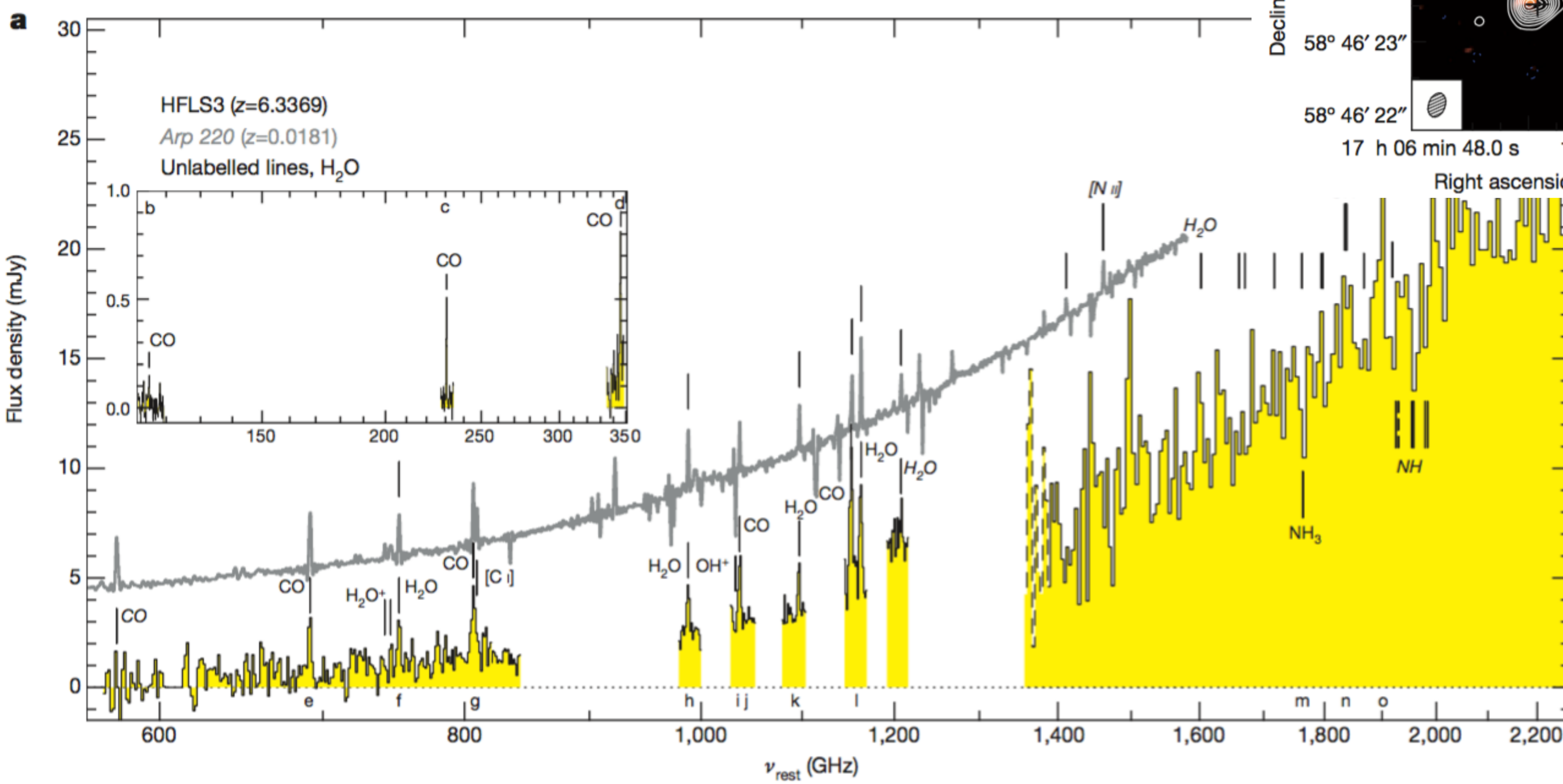
form at z=4.6

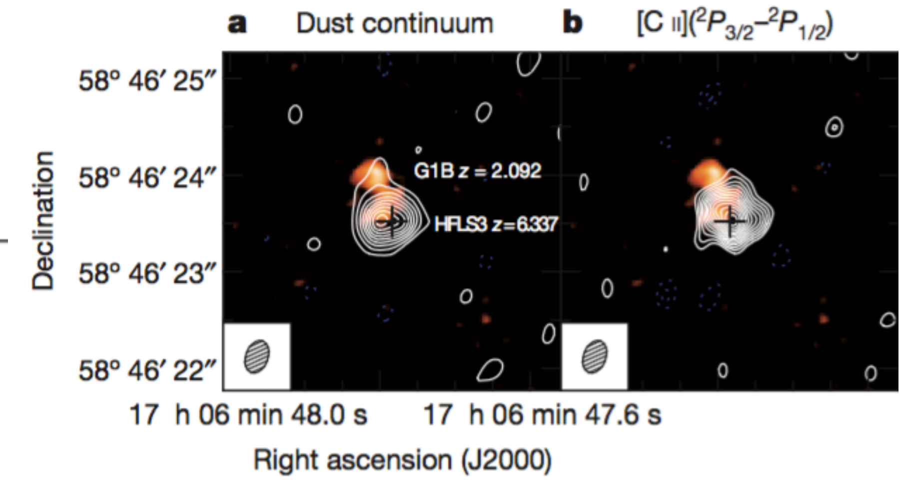
form at z=5.5

Karl Glazebrook, SUT

Observed ancestors?

Need SFR > 1000 M⊙yr^{-1} at z>5



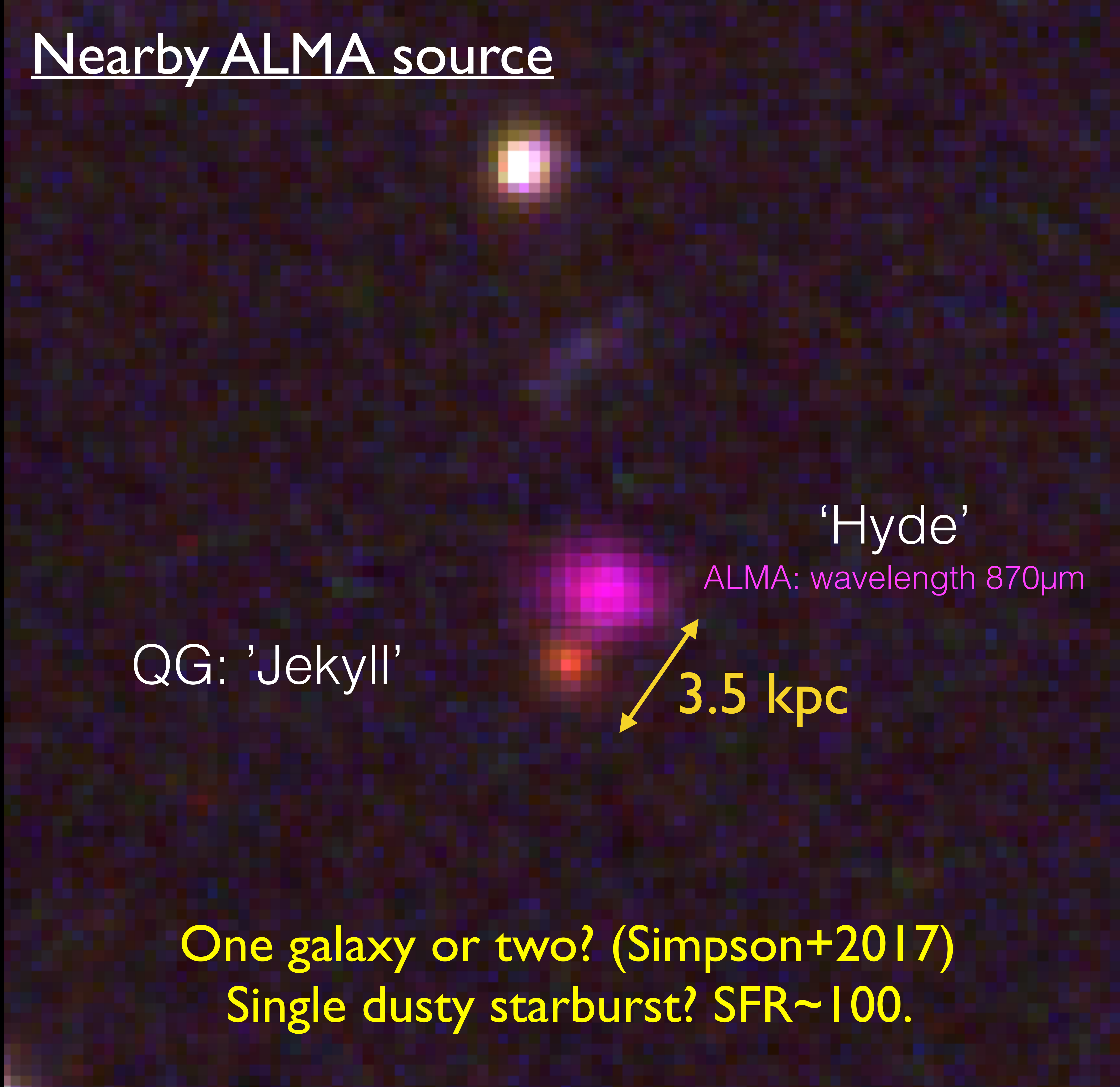


ALMA detection (Reichers et al. 2016), z=6.3

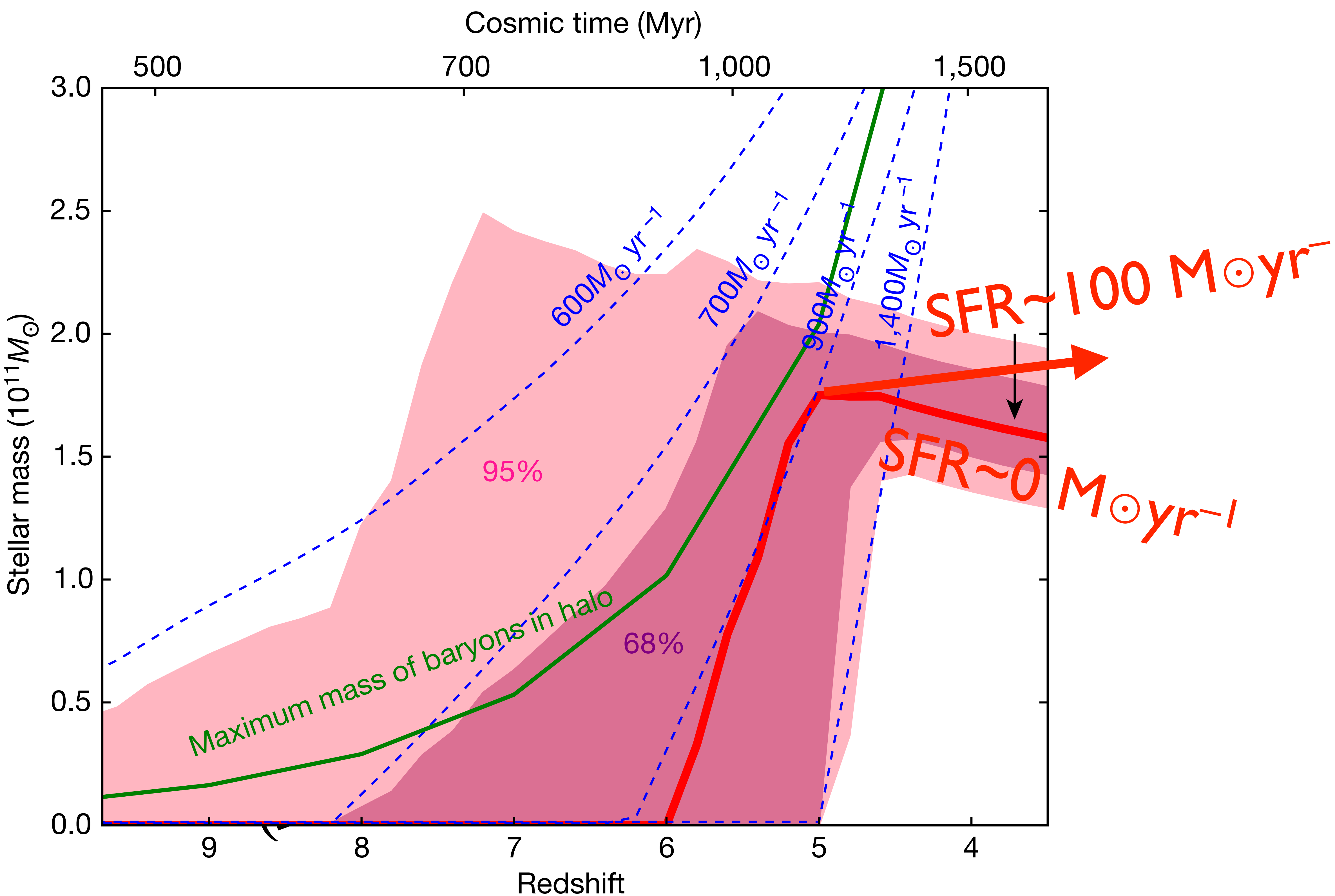
SFR = 2900 M⊙yr^{-1} *Stellar* mass 3.7x10^{10} M⊙

Dynamical mass 2.7x10^{11} M⊙

Nearby ALMA source

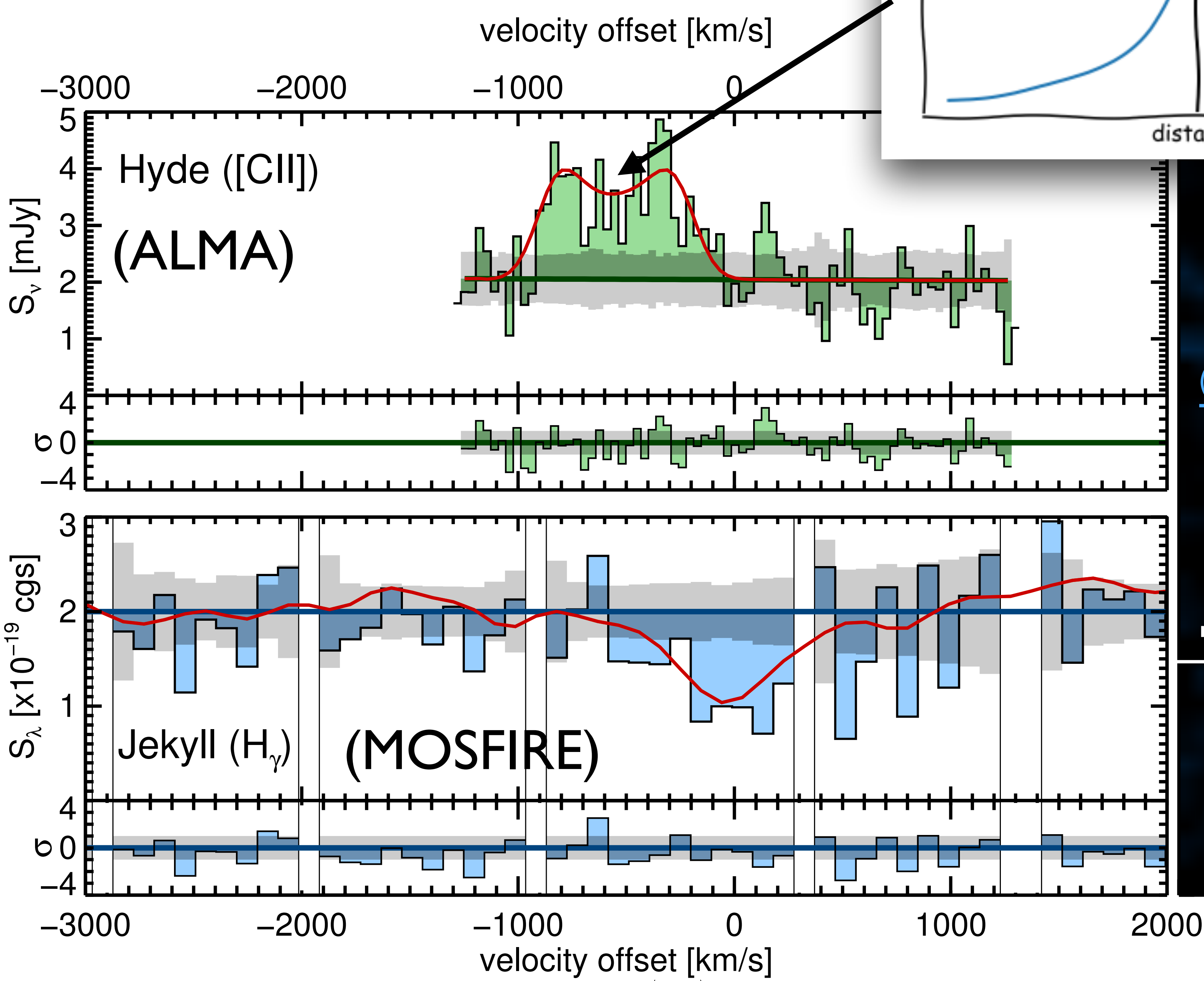


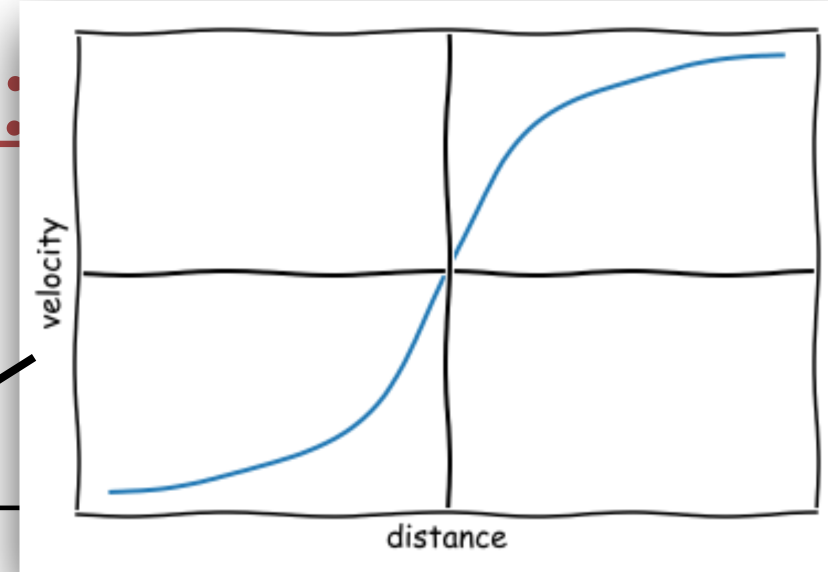
Minor effect on SFH



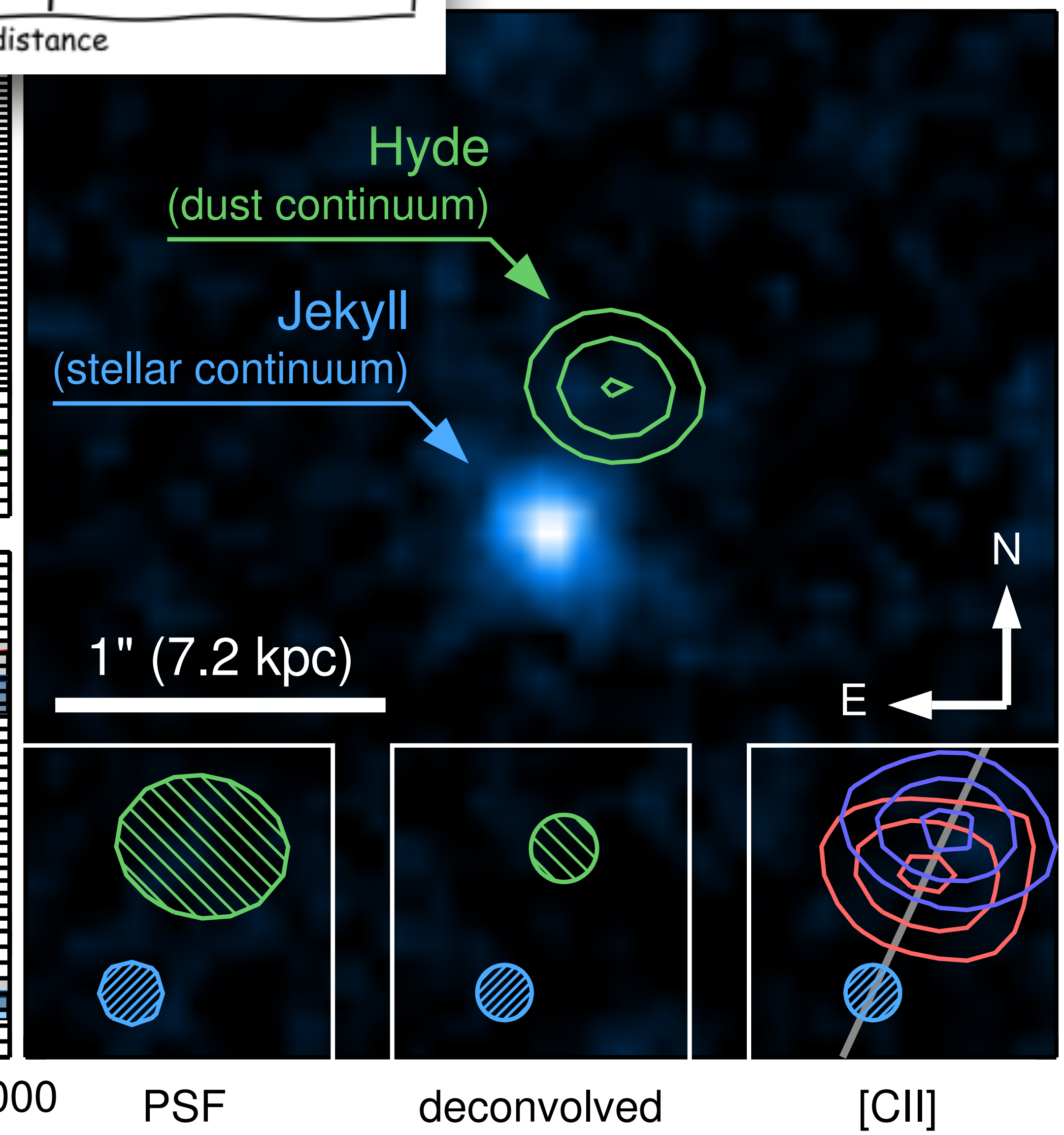
Glazebrook+2017

ALMA DDT follow-up: TWO galaxies





Separate galaxy with own DM halo

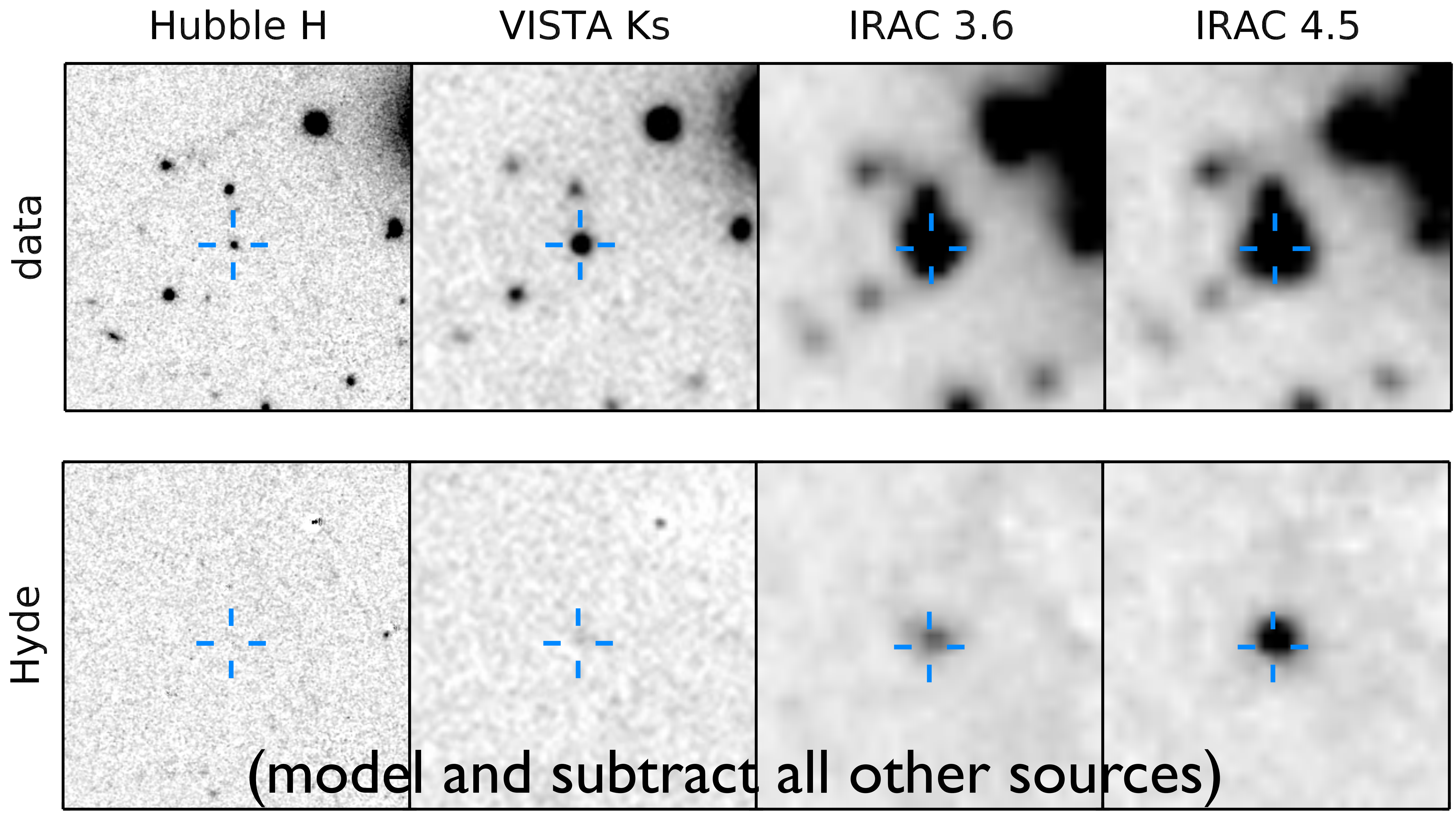


550 km/s

Hyde: dusty starburst.

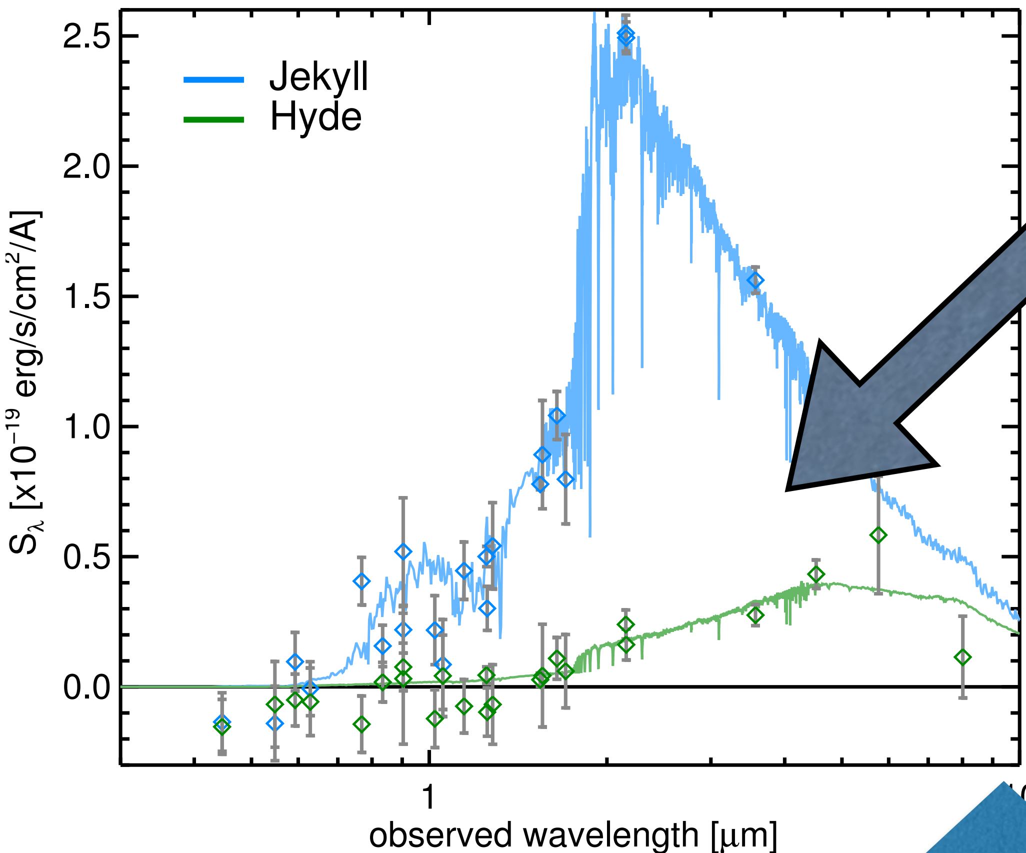
M~10^{11}M⊙ from dynamics

O/IR Deblending!

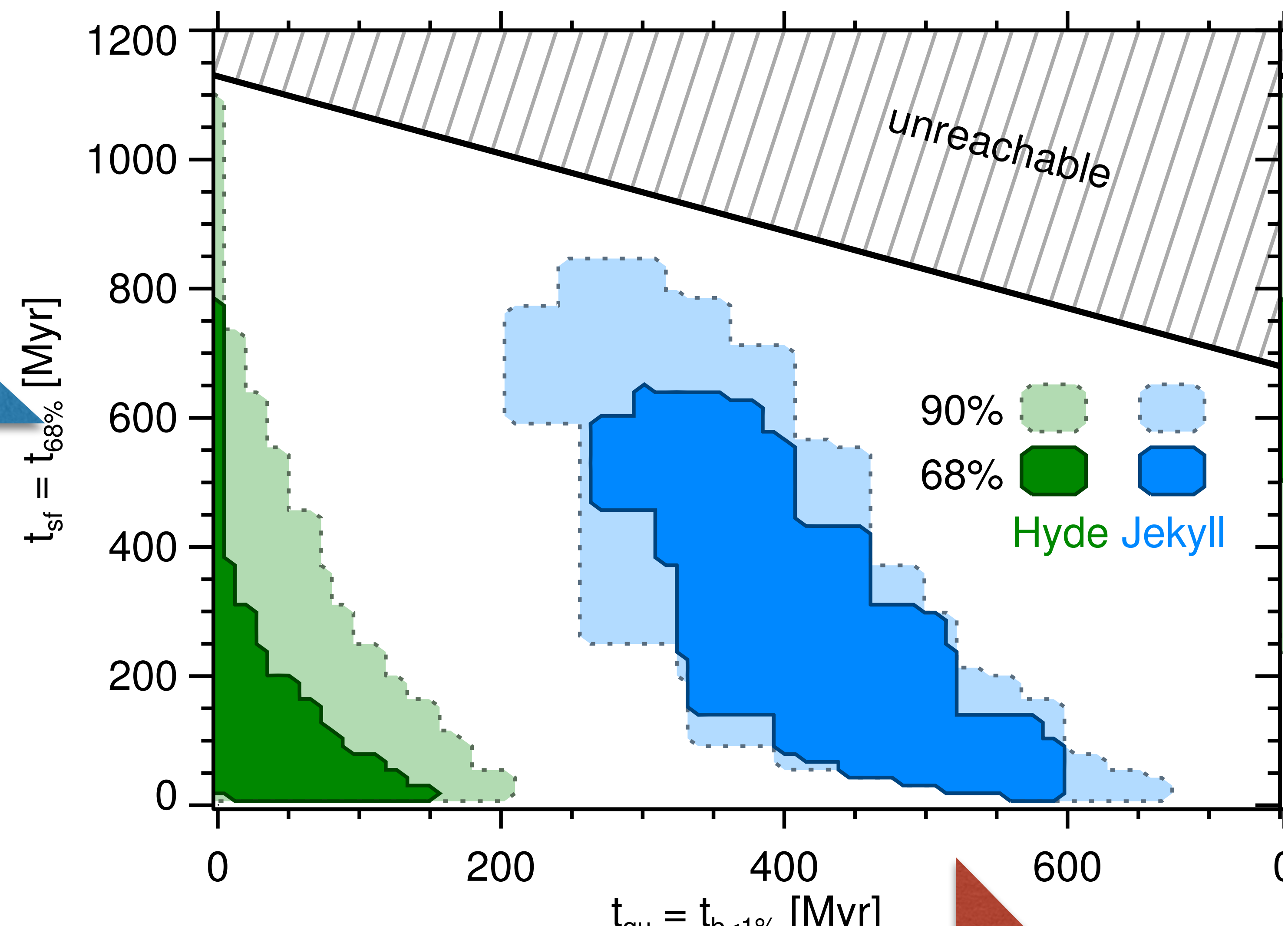


Cross=Jeckyll

SED modeling + L(FIR) + spectrum



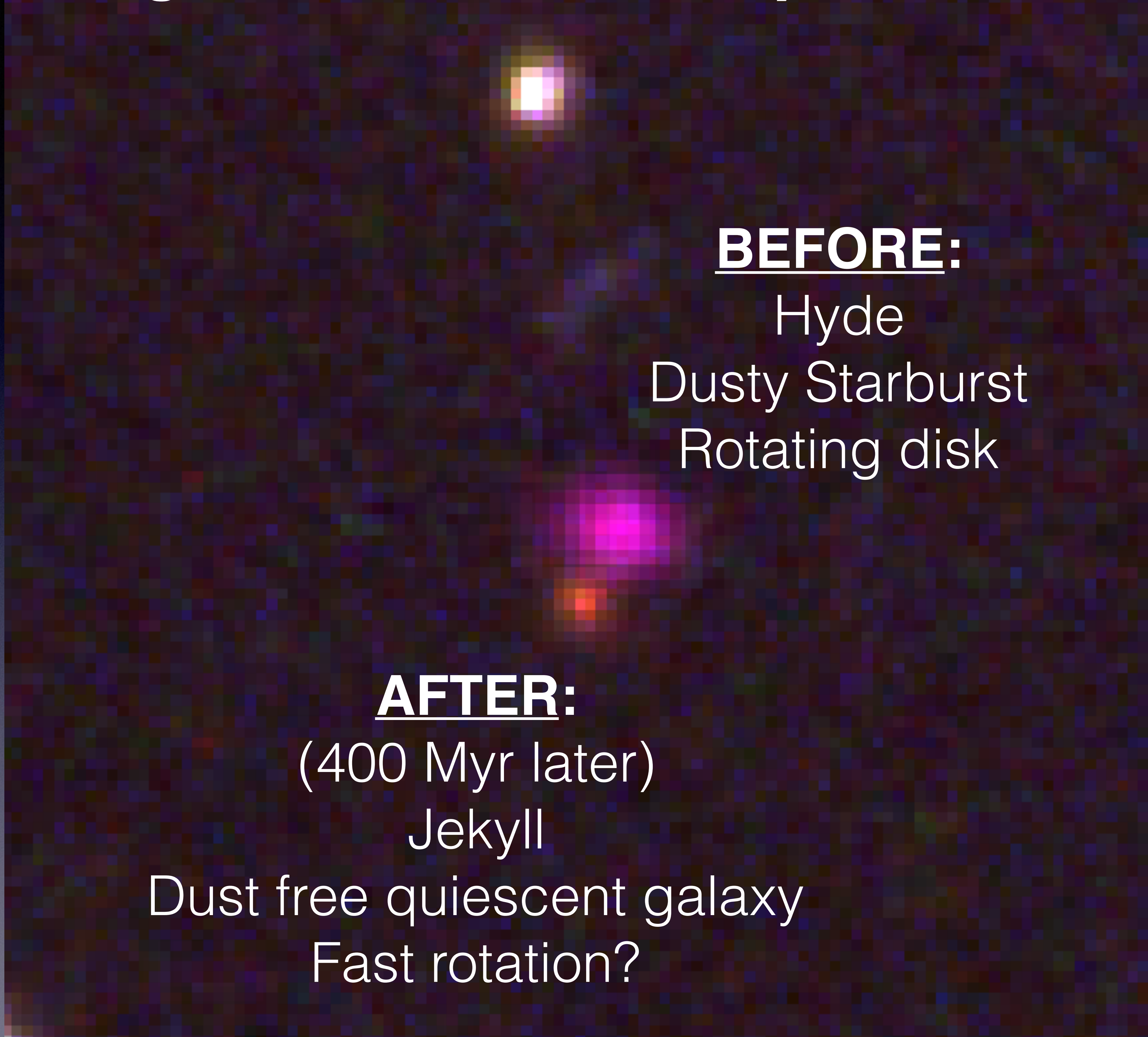
Deblending O/IR using ALMA prior CRITICAL



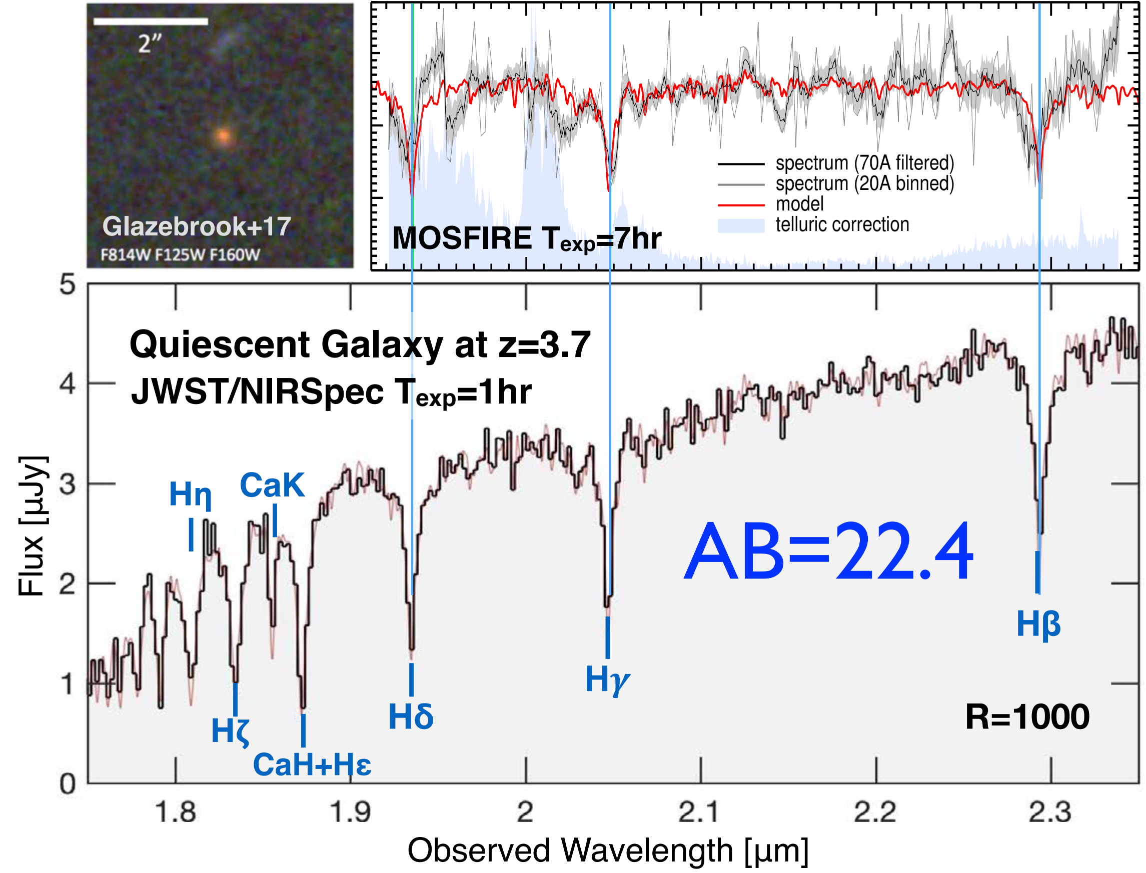
Timescale of initial SF burst

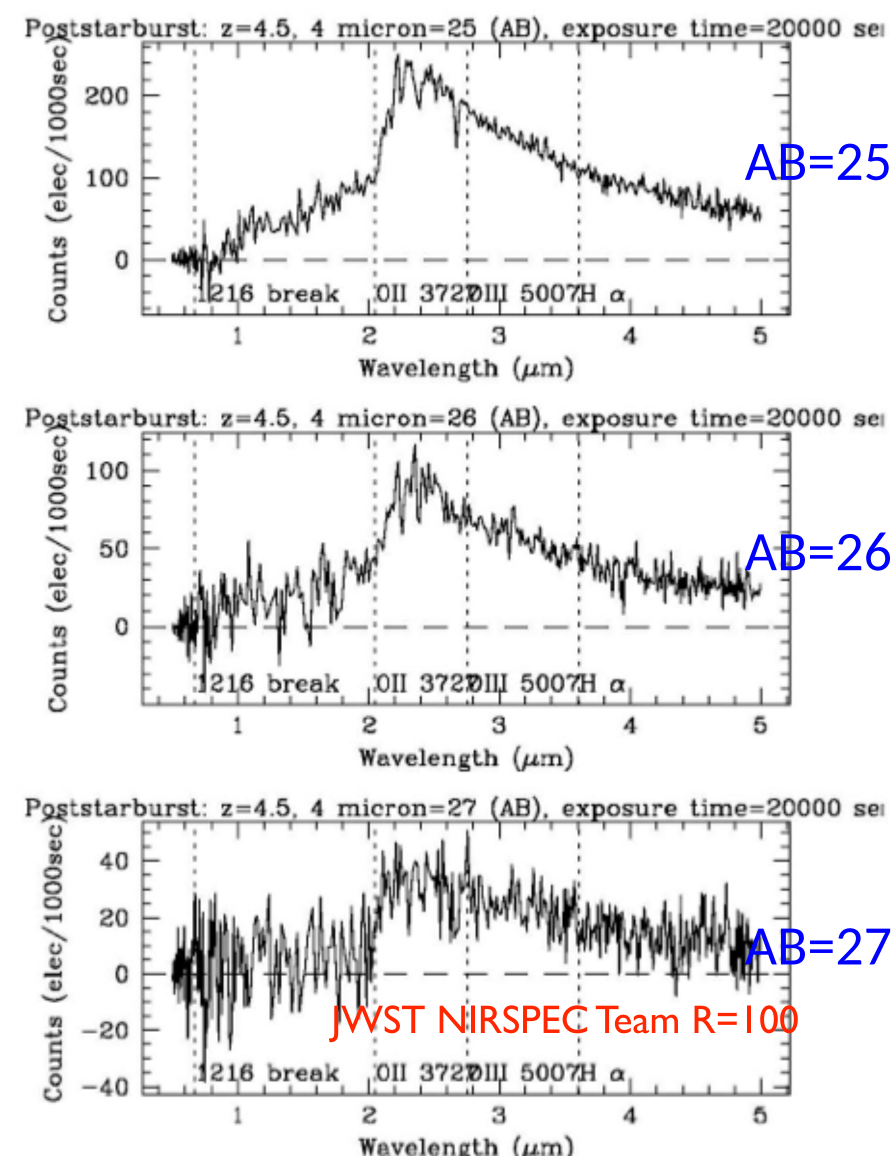
Time since SF

Two galaxies at z~4 with very similar mass




LOW RH


2"
Glazebrook+17
F814W F125W F160W
MOSFIRE T$_{exp}$=7hr
spectrum (70A filtered)
spectrum (20A binned)
model
telluric correction
Quiescent Galaxy at z=3.7
JWST/NIRSpec T$_{exp}$=1hr
Hη
CaK
Hζ
CaH+Hε
Hδ
Hγ
Hβ
AB=22.4
R=1000
Flux [μJy]
Observed Wavelength [μm]


Poststarburst: z=4.5, 4 micron=25 (AB), exposure time=20000 se
AB=25
Poststarburst: z=4.5, 4 micron=26 (AB), exposure time=20000 se
AB=26
Poststarburst: z=4.5, 4 micron=27 (AB), exposure time=20000 se
AB=27
JWST NIRSPEC Team R=100
Counts (elec/1000sec)
Wavelength (μm)
1216 break
OII 3727
OIII 5007
H α

Summary

- Can now probe massive galaxies to z~4 in complete samples, and low mass to z~2.5
- quiescent 'red nuggets' at z~4:

  too abundant for comfort.
  NOT emission-line contaminants

  one definitive spectroscopic confirmation

  not enough massive halos: require very high baryon conversion efficiencies. Are there enough ancestors? Obscured?

  what is going on in SF at z>5? Or halo growth?