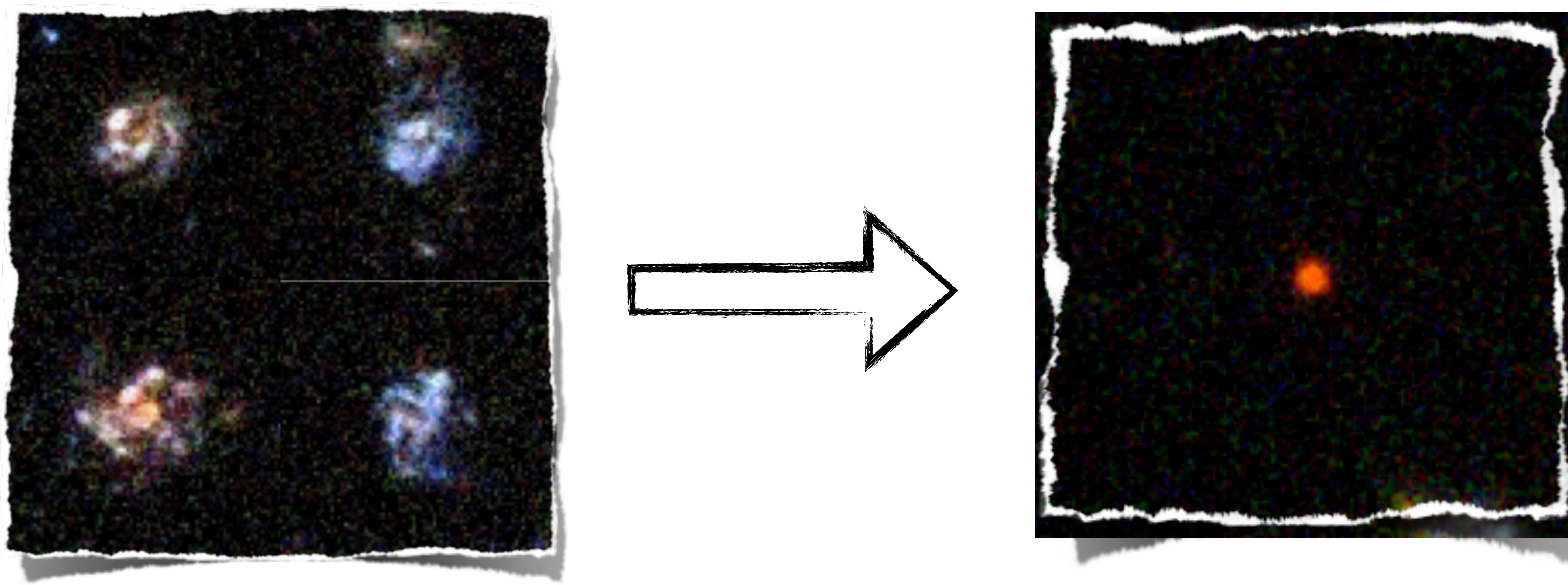
Live fast, die... small:

The progenitors of the first quiescent galaxies

Barro et al., ApJ 2013
Barro et al., ApJ submitted

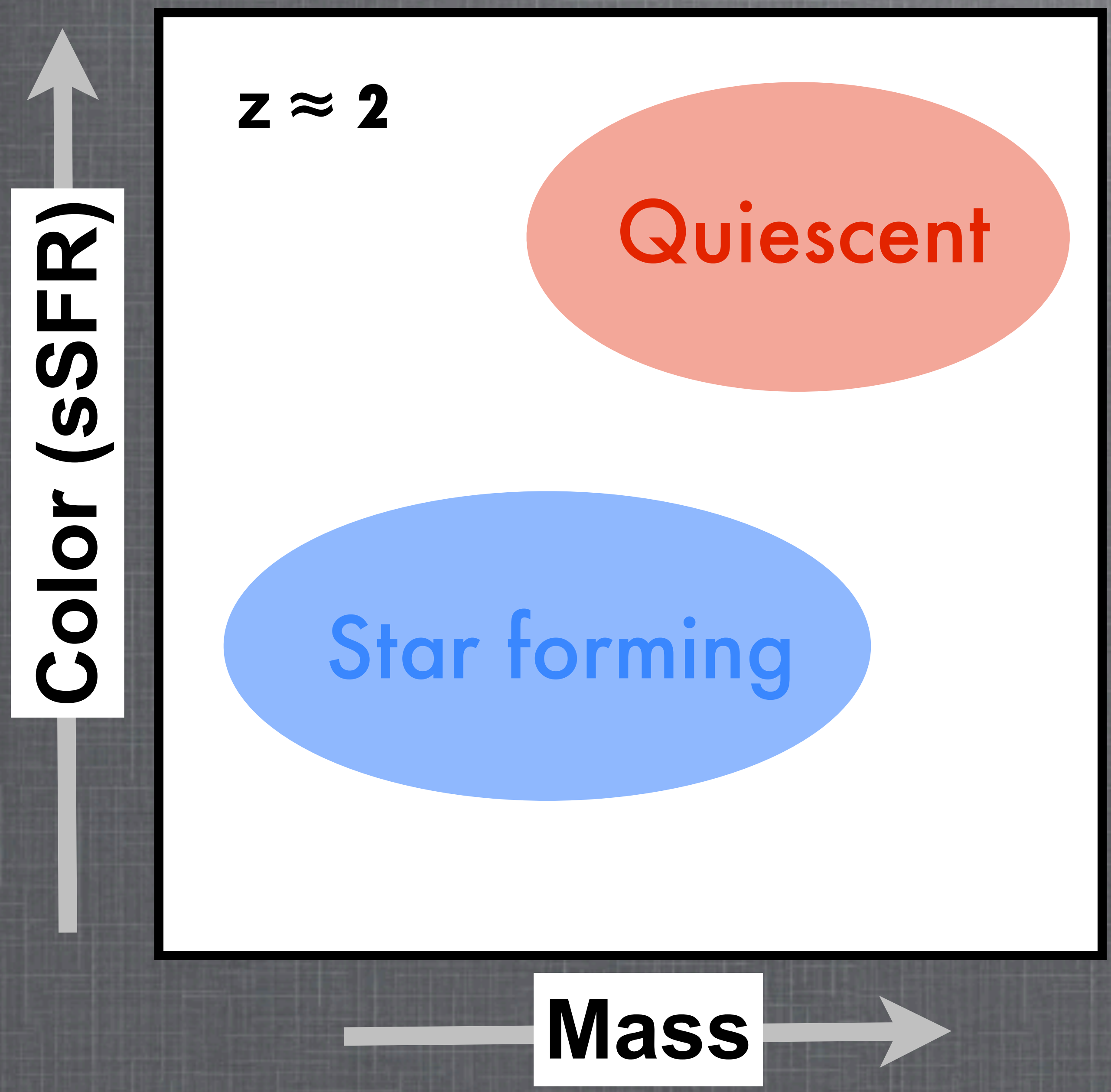


Guillermo Barro (UCSC)

S. Faber, P. Perez-Gonzalez, D. Koo, J. Trump, D. Kocevski, E. McGrath, L. Porter, J. Primack, C. Pacifici, C. Moody, P. Kollipara, A. van der Wel, S. Wuyts + CANDELS

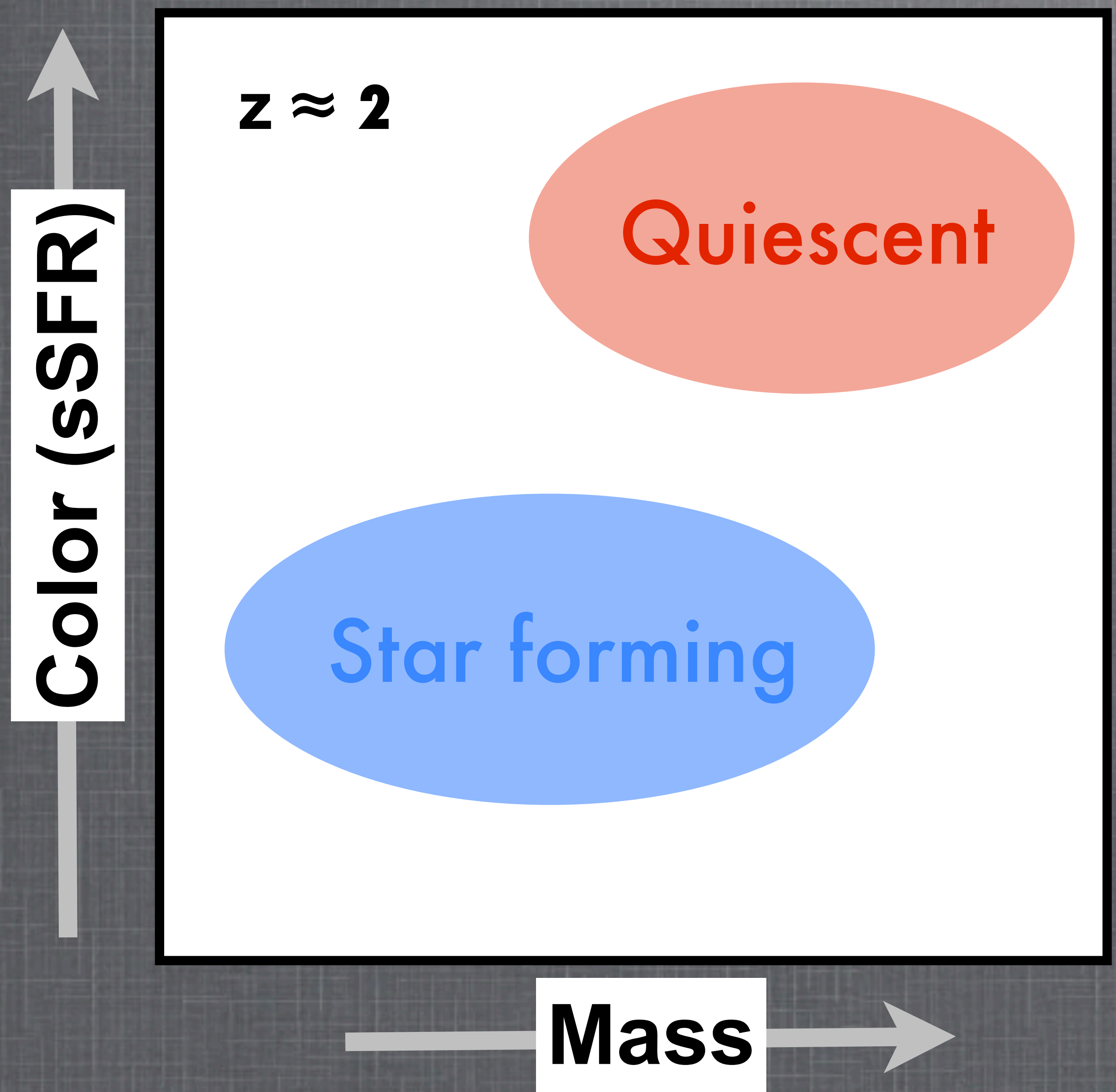
November 19th 2013 - ***ESO Deconstructing galaxies***

Transition regions



(Faber+07; Brammer+09,11; Williams+09; Ilbert +10; Whitaker+11, Wuyts11b, Muzzin+13, etc.)

Transition regions



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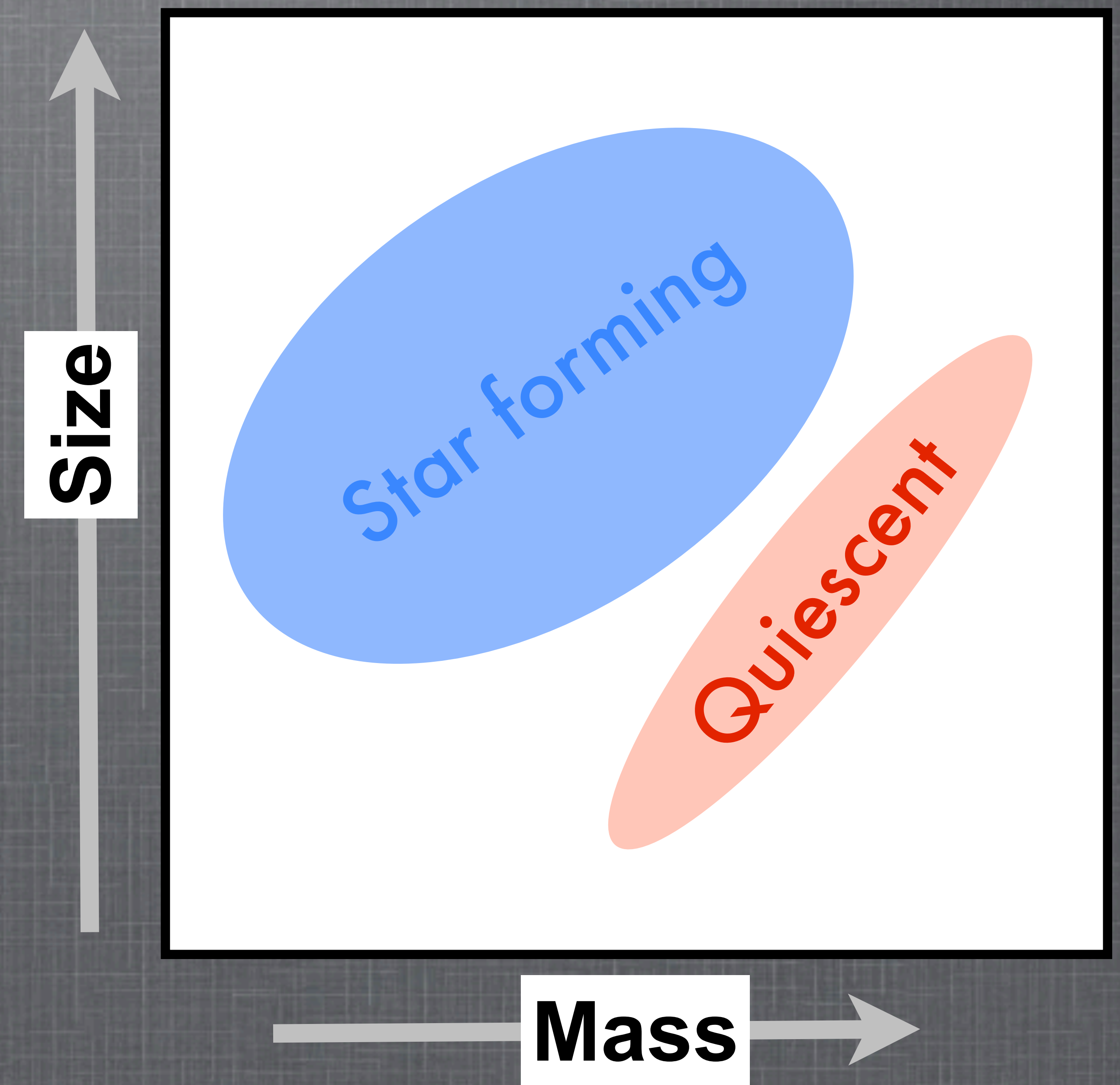
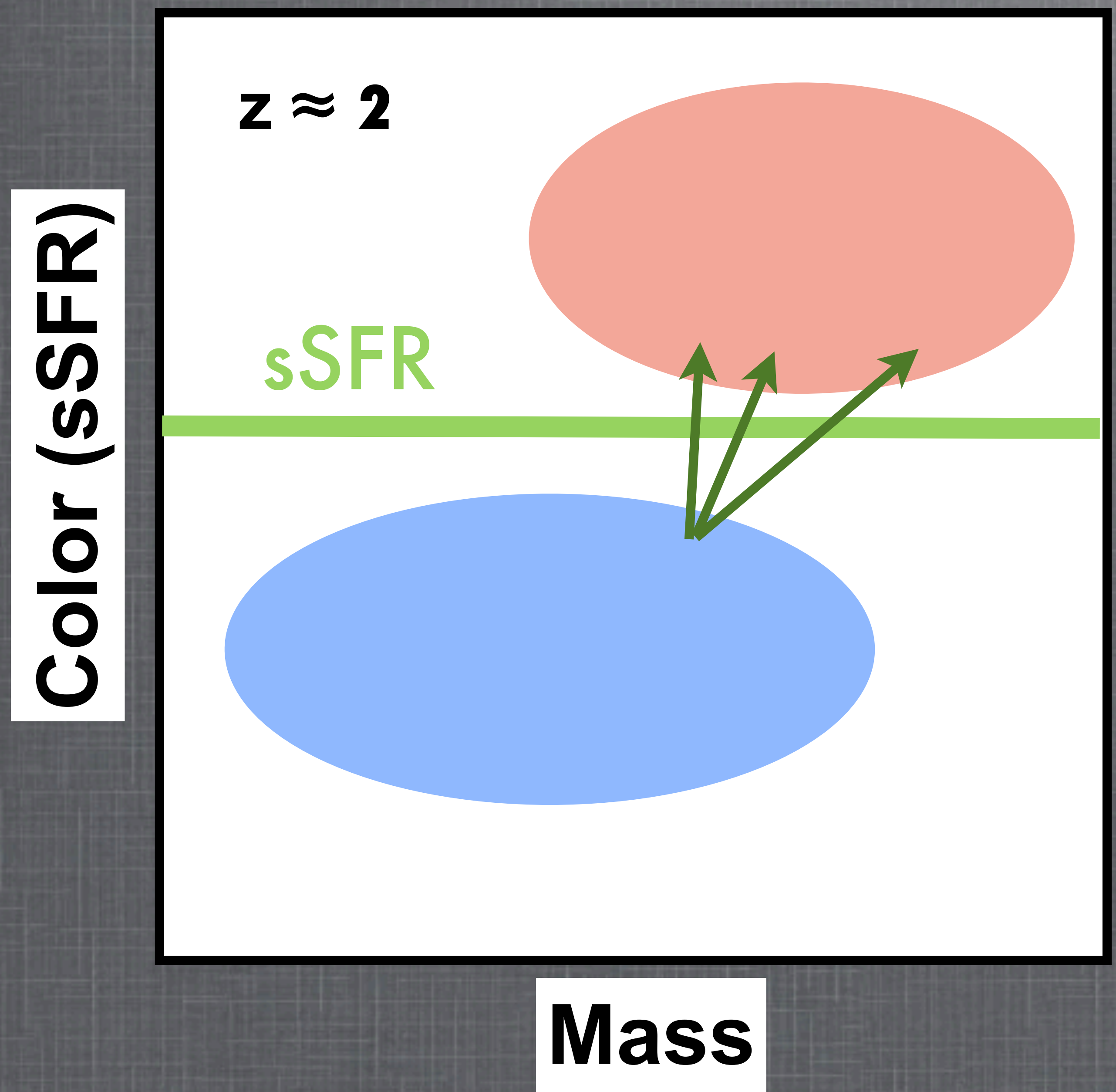
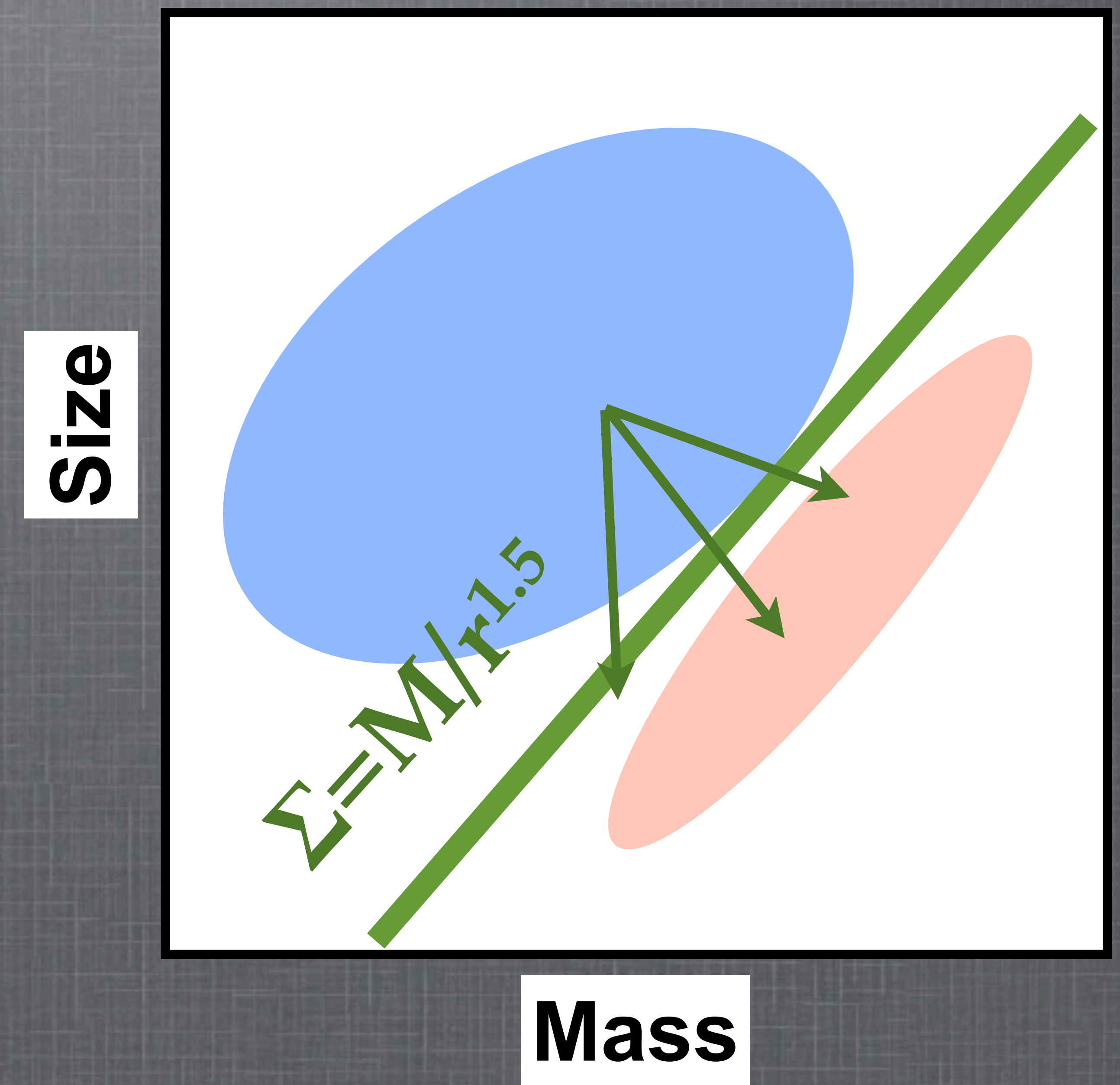


(Trujillo+07; Buitrago+08; van Dokkum +08, Cassata+10; Saracco+10,11; Newman+12, etc.)

Transition regions





(Faber+07; Brammer+09,11; Williams+09; Ilbert +10; Whitaker+11, Wuyts11b, Muzzin+13, etc.)

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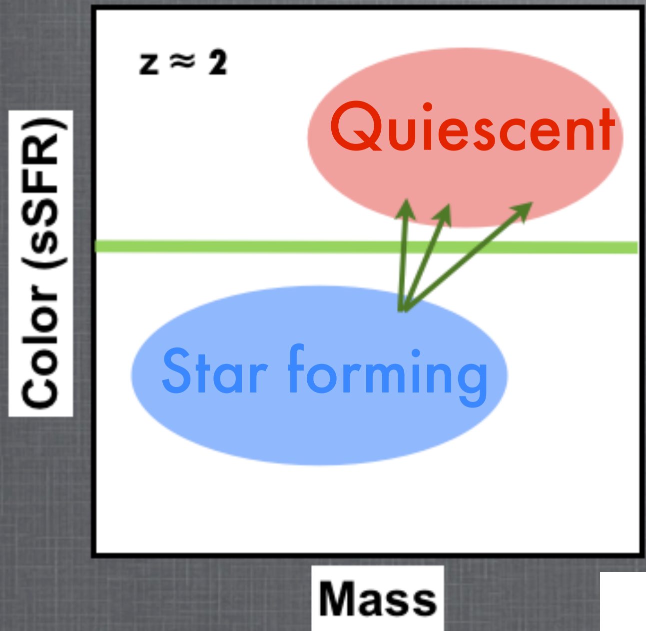
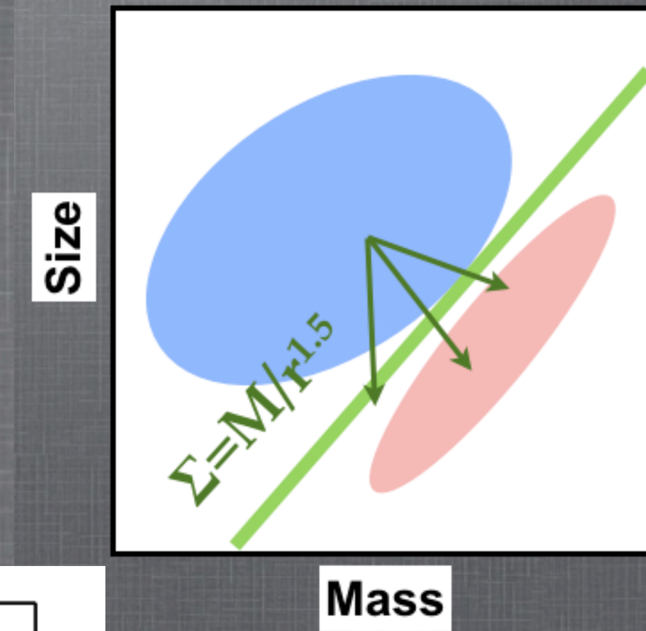
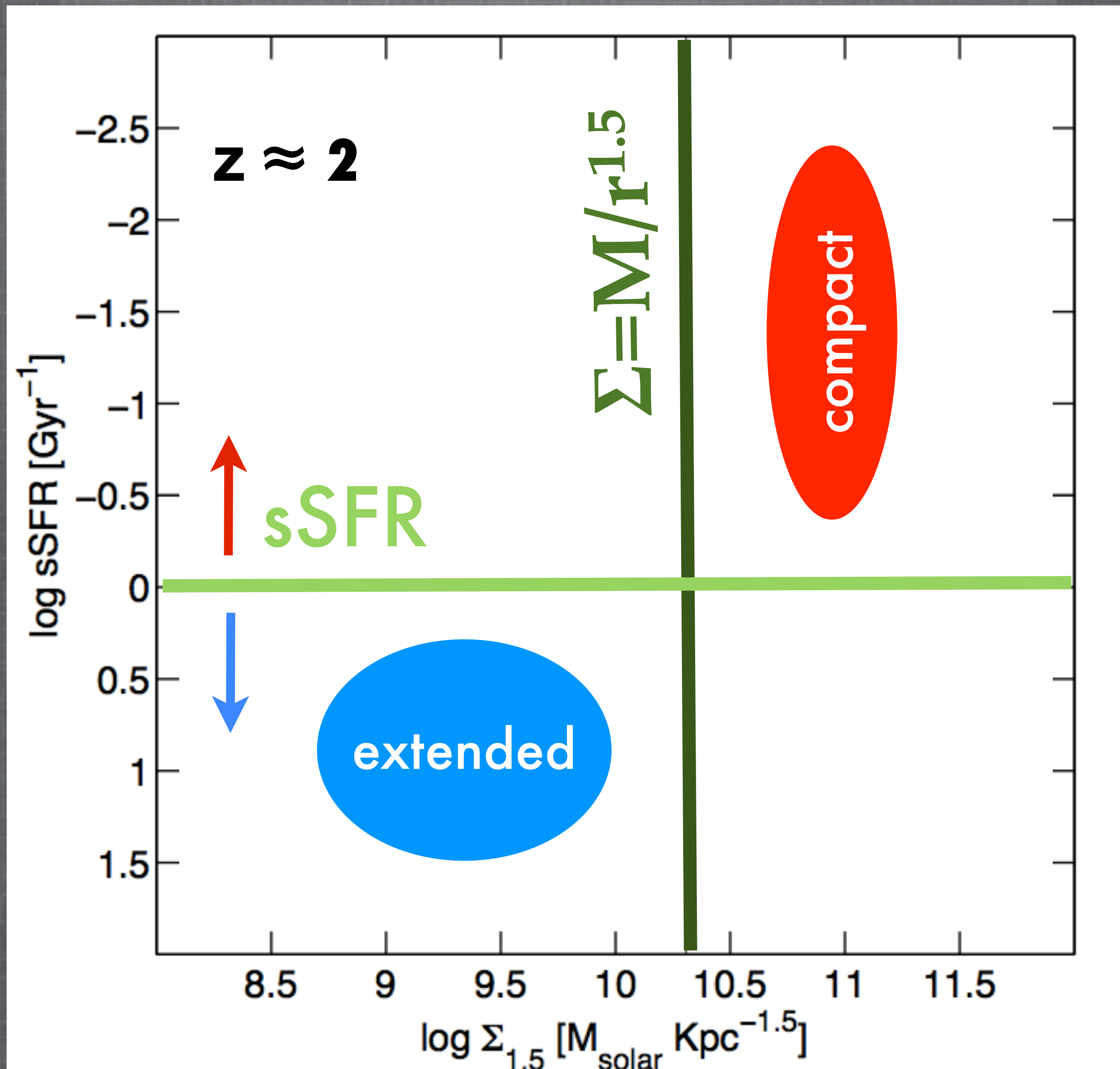


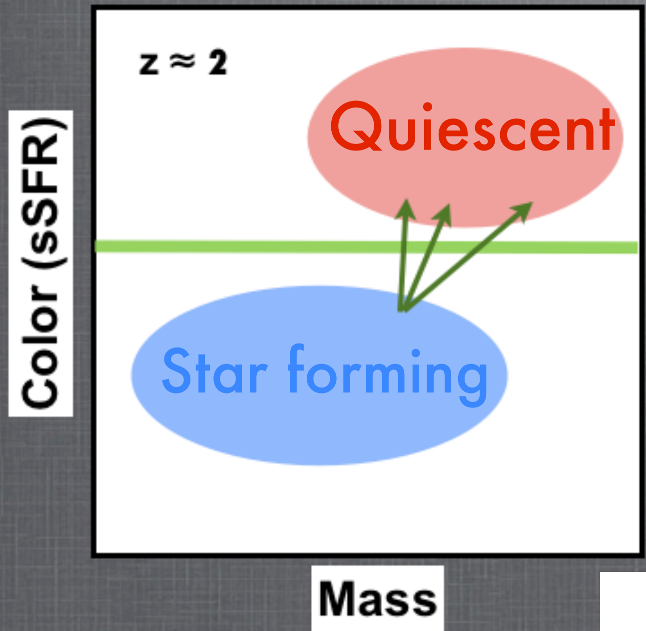
z ≈ 2
Quiescent
Star forming
Color (sSFR)
Mass

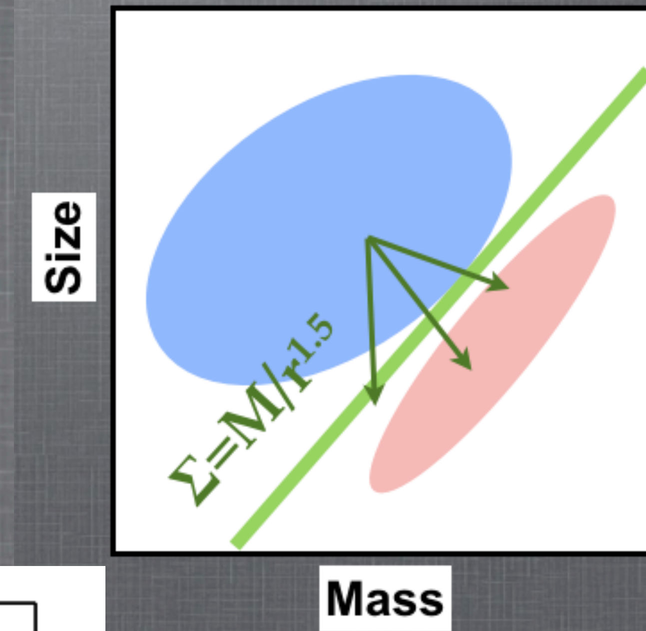


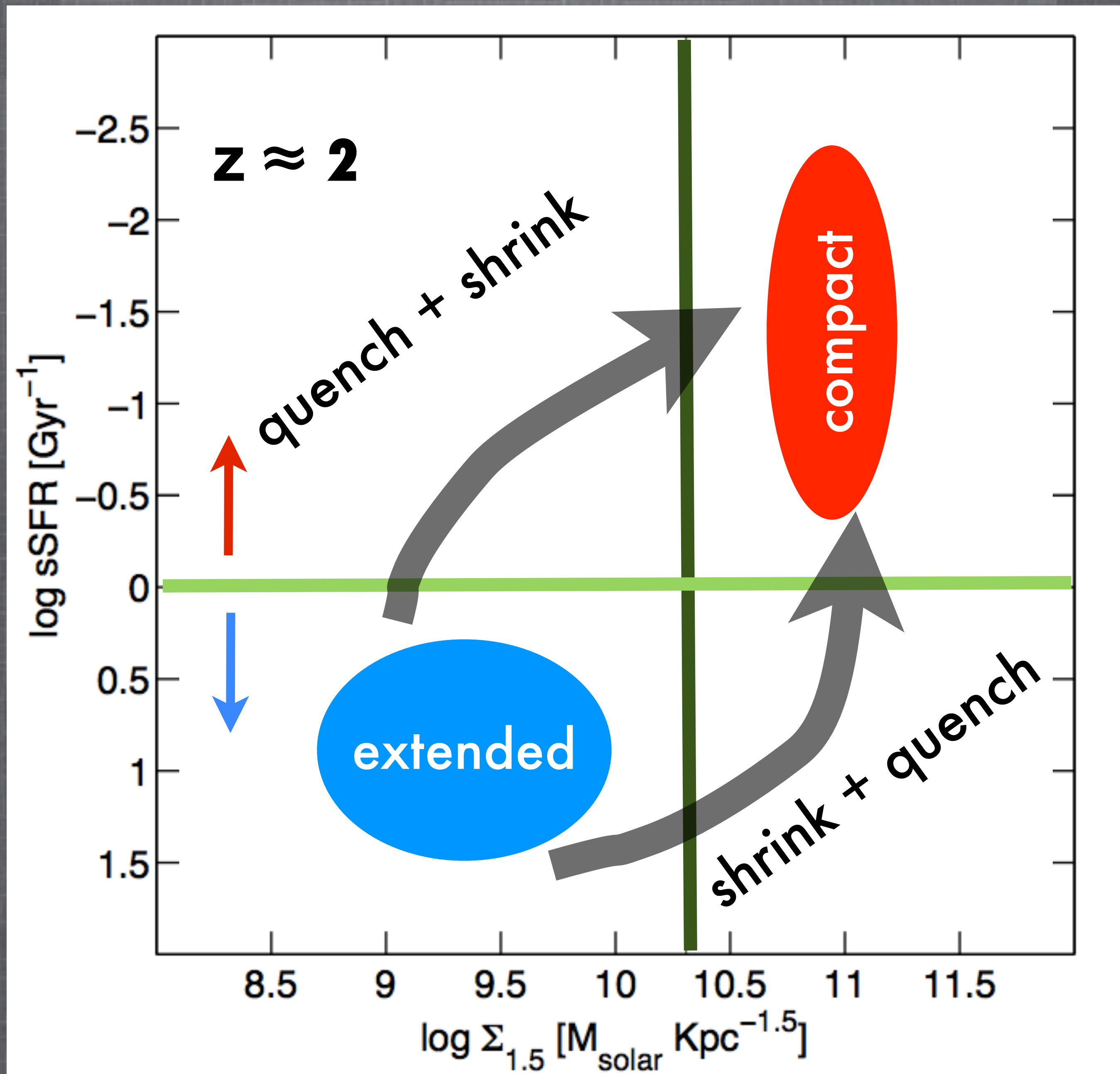
Size
Σ=M/r^1.5
Mass

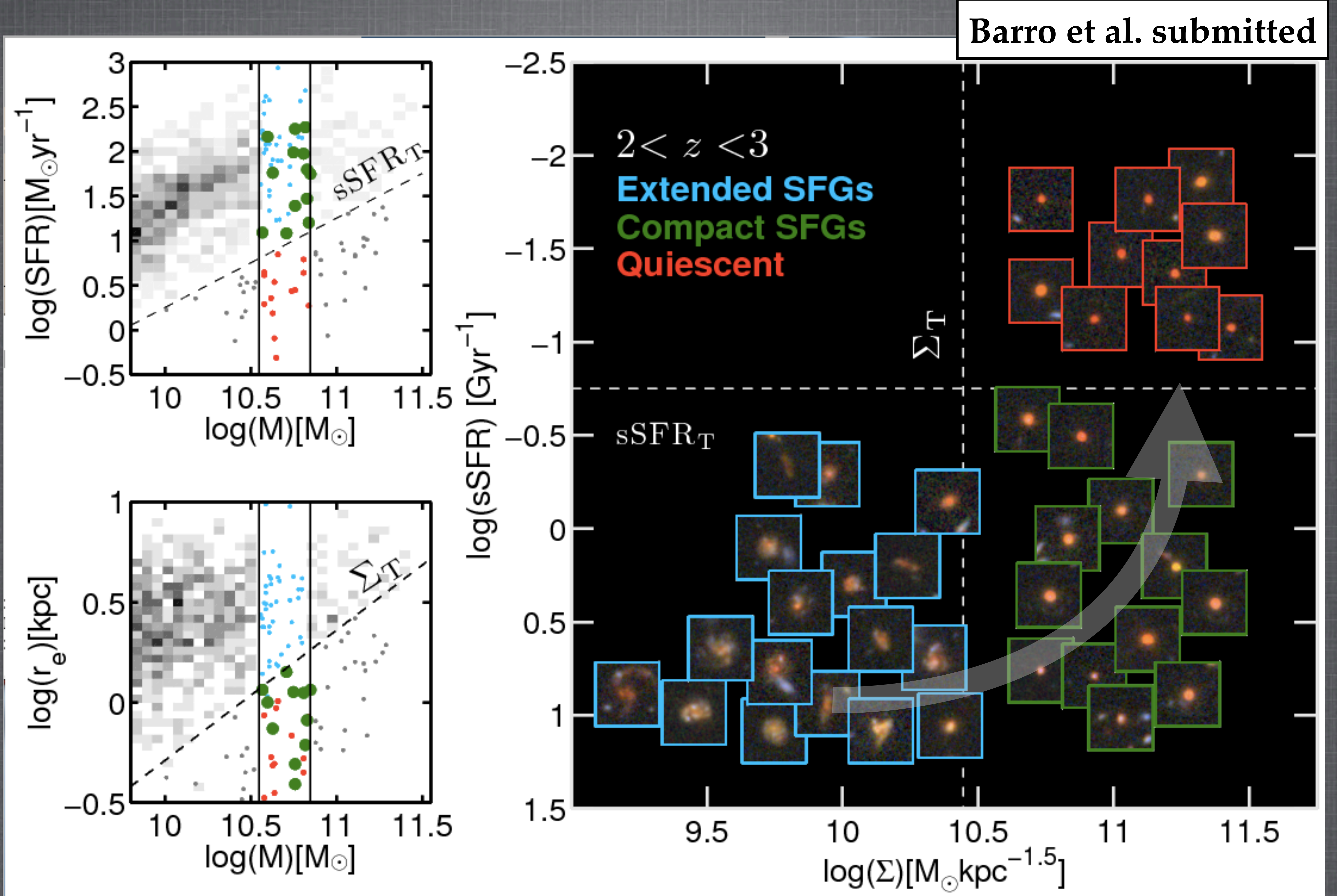


z ≈ 2
Σ=M/r^1.5
compact
sSFR
extended
log sSFR [Gyr^-1]
−2.5
−2
−1.5
−1
−0.5
0
0.5
1
1.5
8.5
9
9.5
10
10.5
11
11.5
log Σ_1.5 [M_solar Kpc^-1.5]


z ≈ 2
Quiescent
Star forming
Color (sSFR)
Mass


Σ=M/r^1.5
Size
Mass


z ≈ 2
quench + shrink
compact
extended
shrink + quench
log sSFR [Gyr^-1]
−2.5
−2
−1.5
−1
−0.5
0
0.5
1
1.5
8.5
9
9.5
10
10.5
11
11.5
log Σ_1.5 [M_solar Kpc^-1.5]



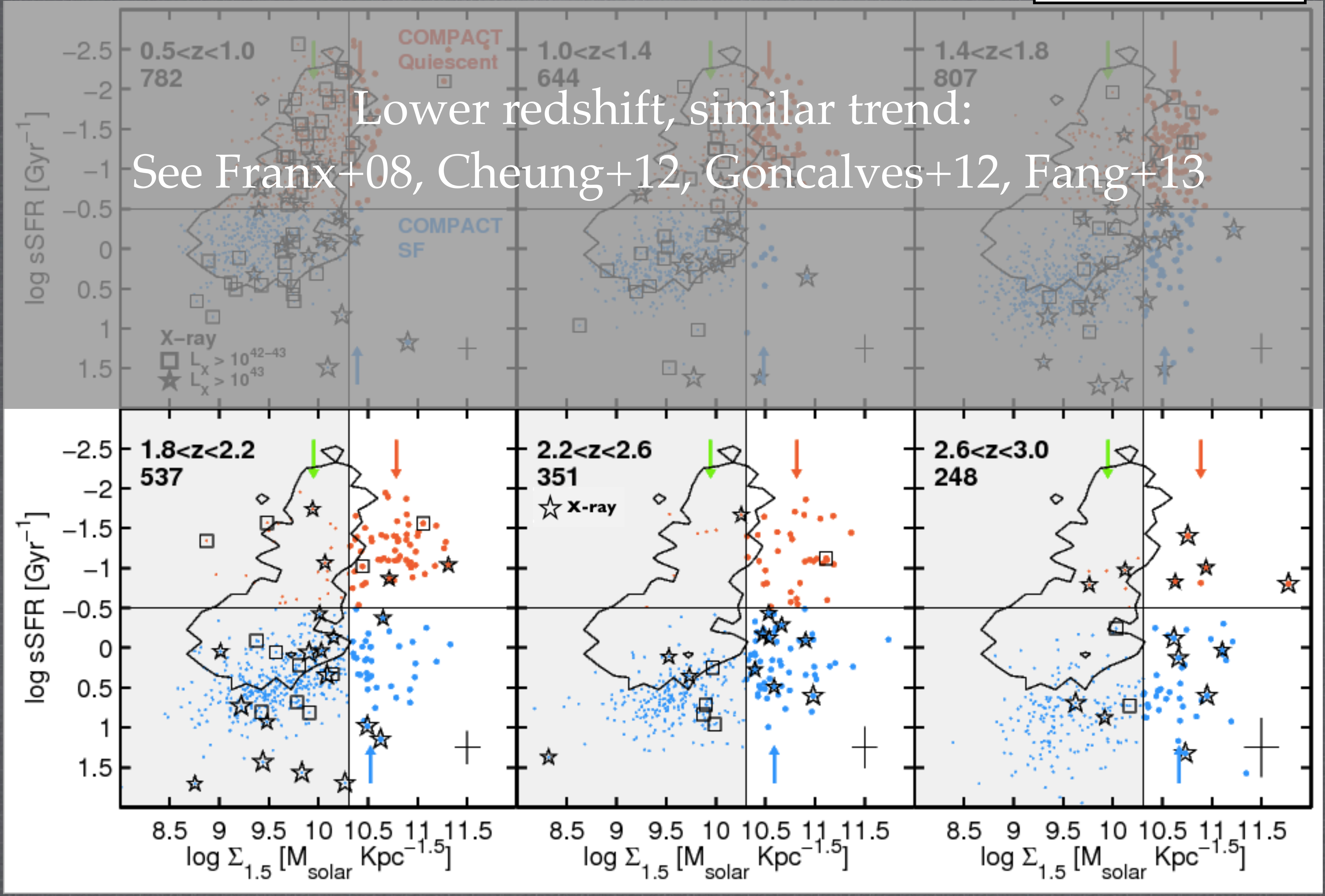
- CANDELS H-band selected in GOODS-S & UDS , log(M)>10
- Photo-z's (spec-z), stellar masses, (UV+IR) SFRs, GALFIT morphologies

Compact quiescent and SFGs

Barro et al. 2013

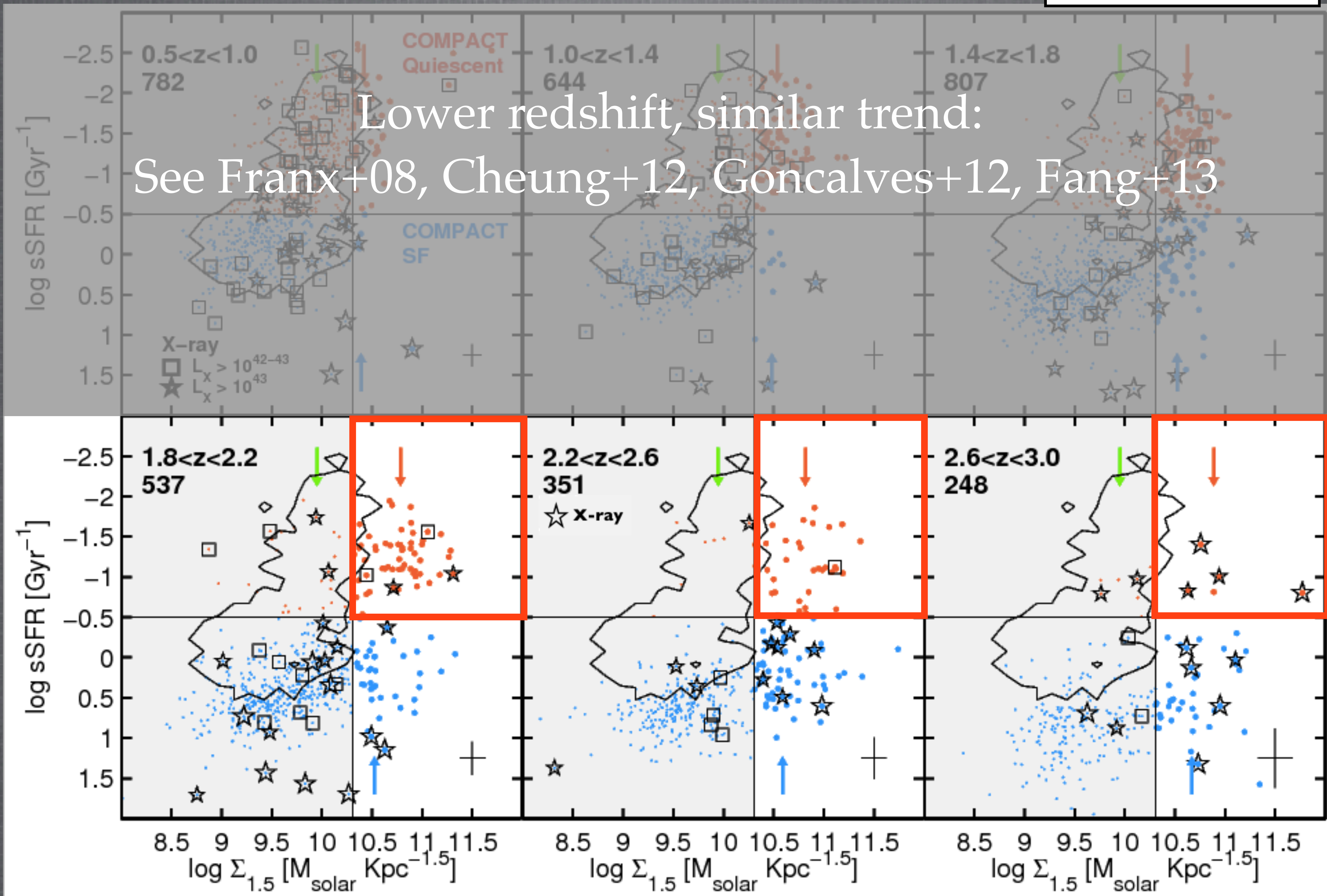
Lower redshift, similar trend:

See Franx+08, Cheung+12, Goncalves+12, Fang+13



Compact quiescent and SFGs

Barro et al. 2013



Lower redshift, similar trend:

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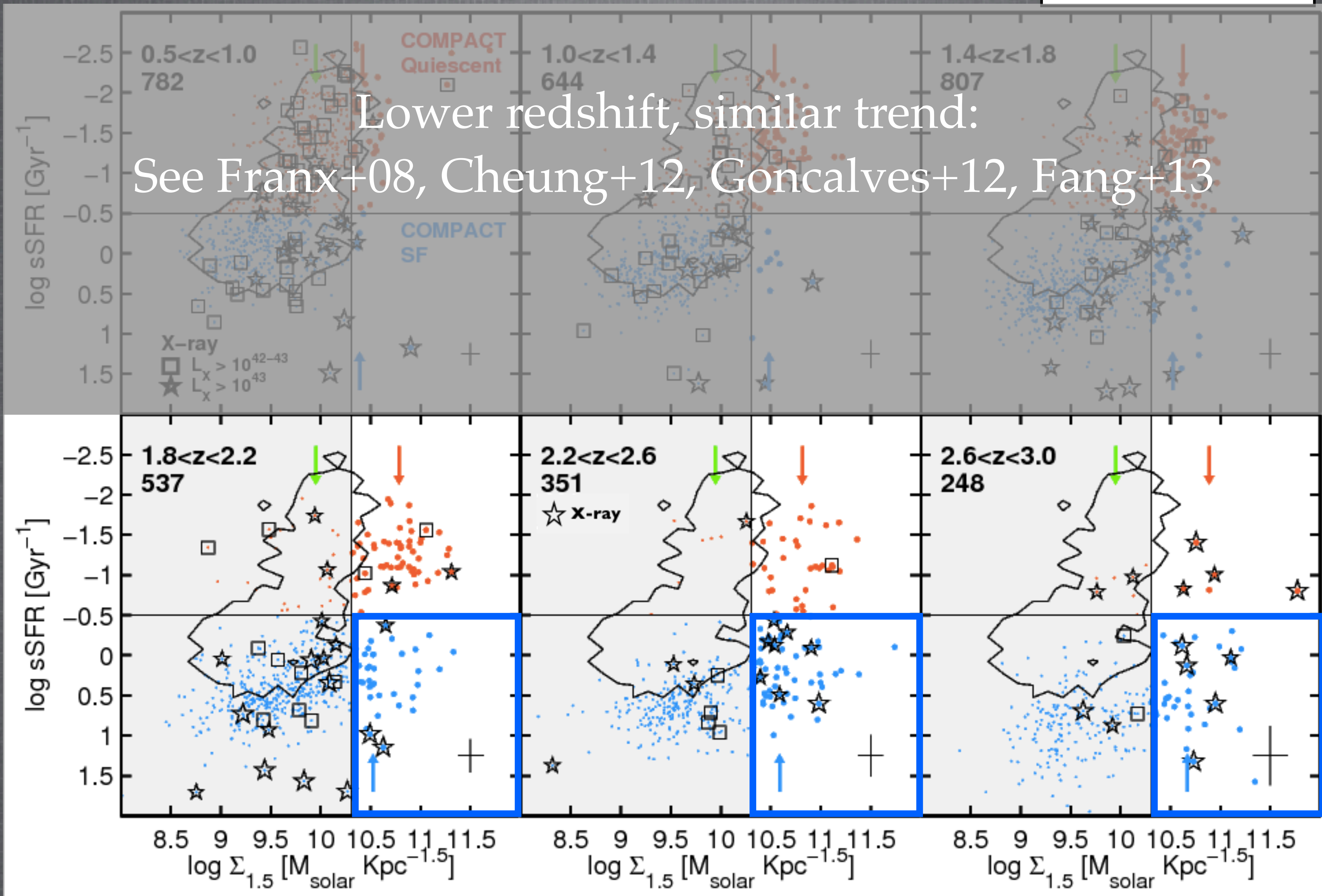
Compact quiescent and SFGs

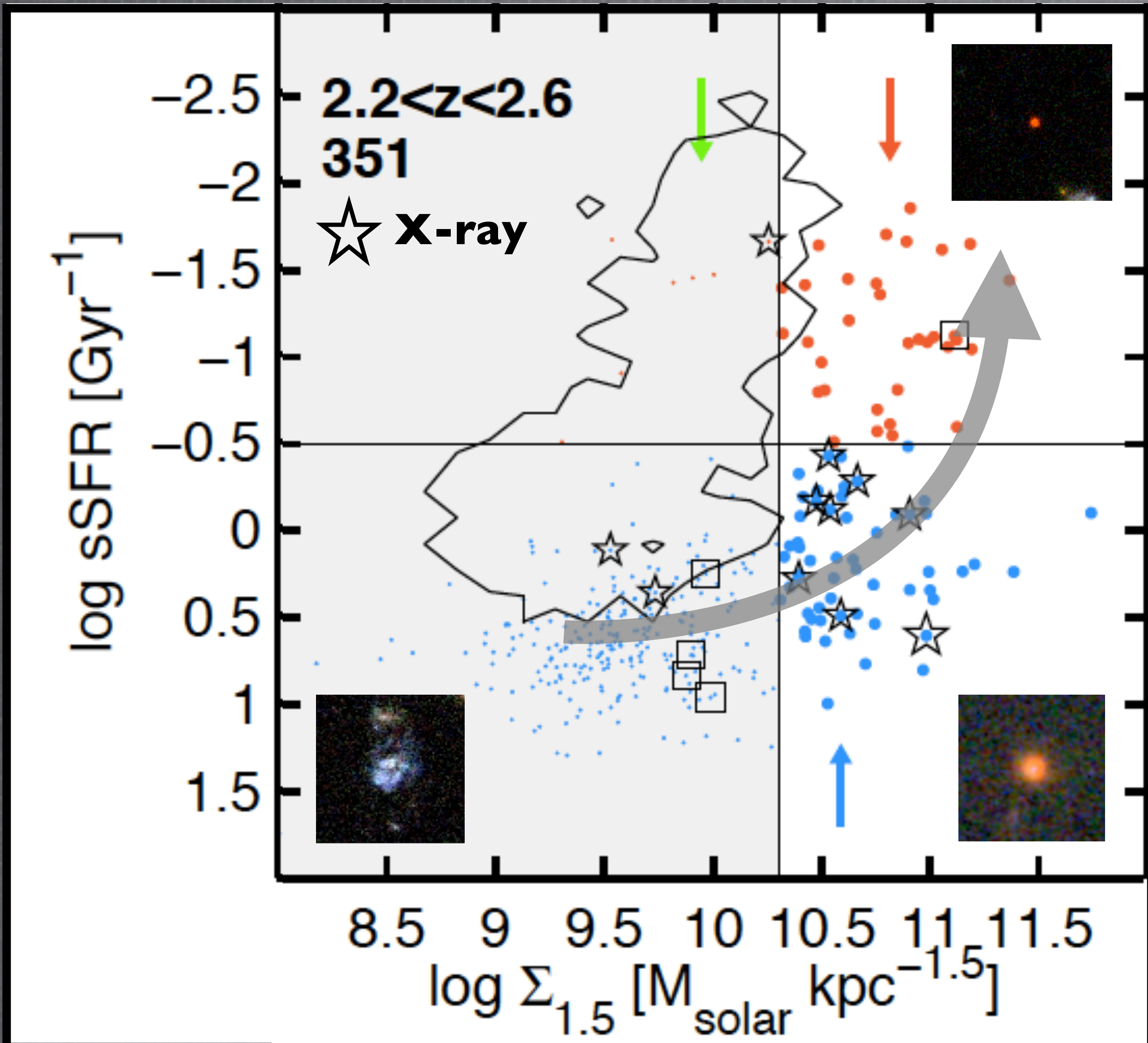
Barro et al. 2013

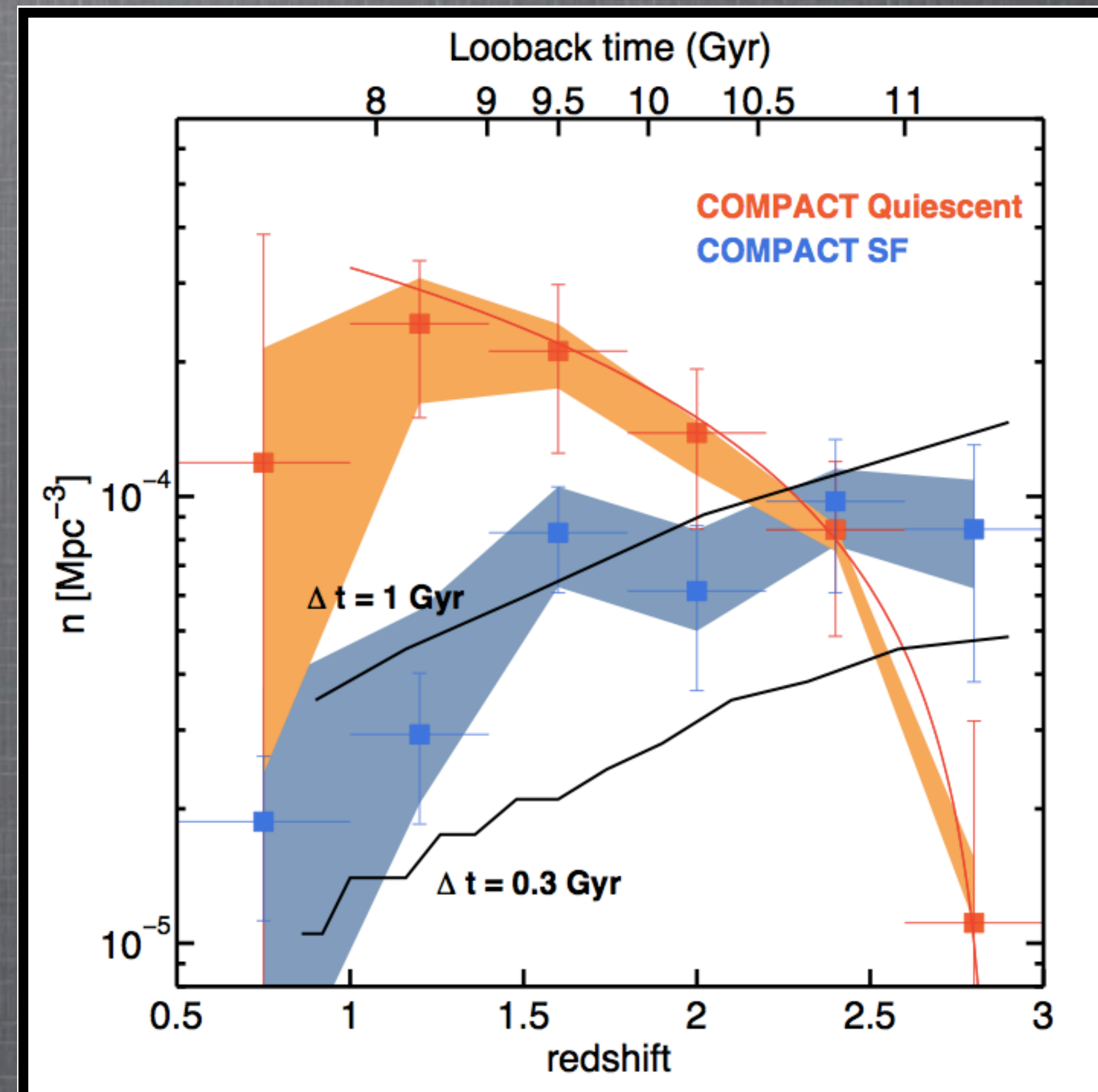


Lower redshift, similar trend:

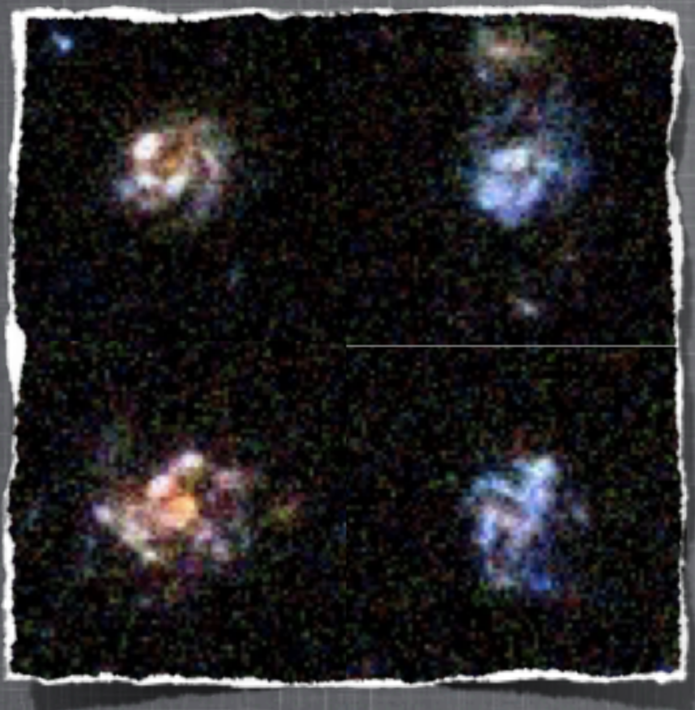
See Franx+08, Cheung+12, Goncalves+12, Fang+13

Fast track to the red-sequence

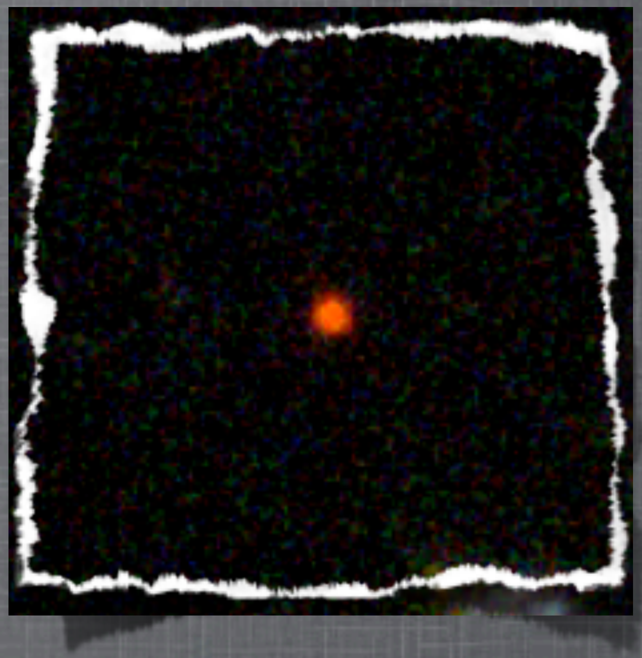


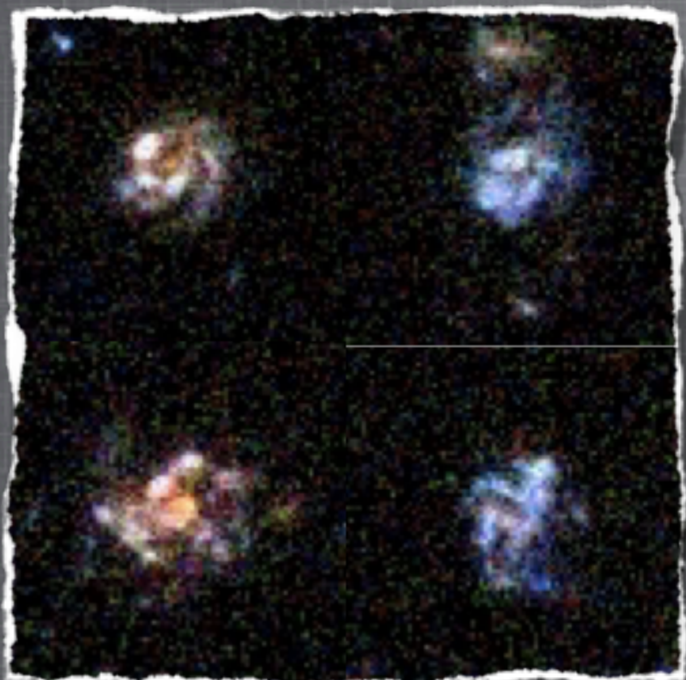


Barro et al. 2013



compact SFGs





compact SFGs

How are these galaxies formed?

Major mergers

- **Dissipational galaxy interaction**
- **Triggers strong starburst**

(Hopkins+06-,08; Naab+06,09; Johansson+09; Wuyts+10; Oser+10,12, etc.)

Disk instabilities

- **Unstable dynamics -> gas inflow**
- **Dissipational SF in the center**
- **Signaled by SF clumps**

(Keres+05,Cox+06,Dekel+09, Hopkin+09,Ceverino+10, etc.)

Life-paths of cSFGs from SAMs

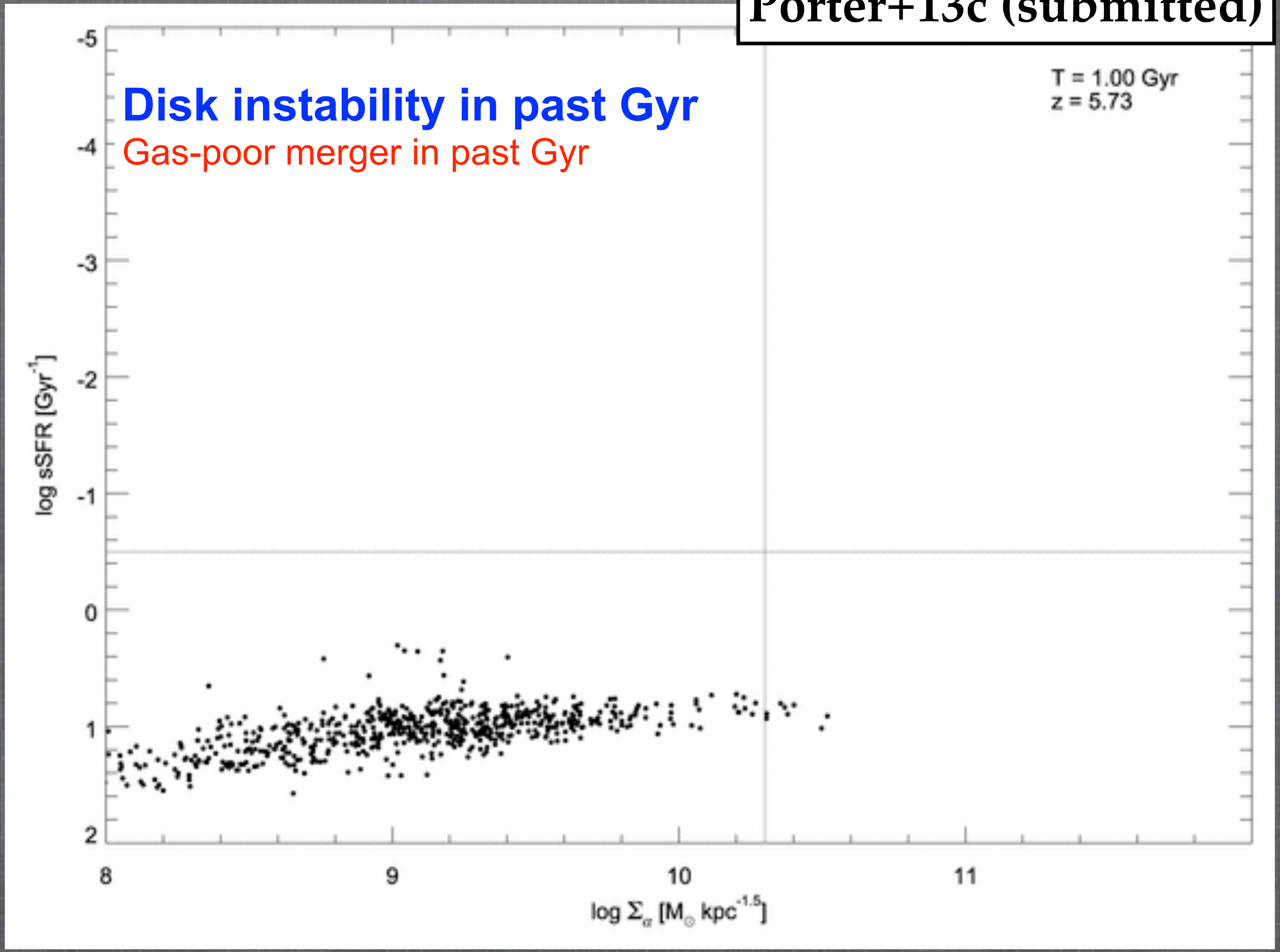
Porter+13c (submitted)

Disk instability in past Gyr
Gas-poor merger in past Gyr

- Compactification by disk instabilities (60% vs. 40% mergers)

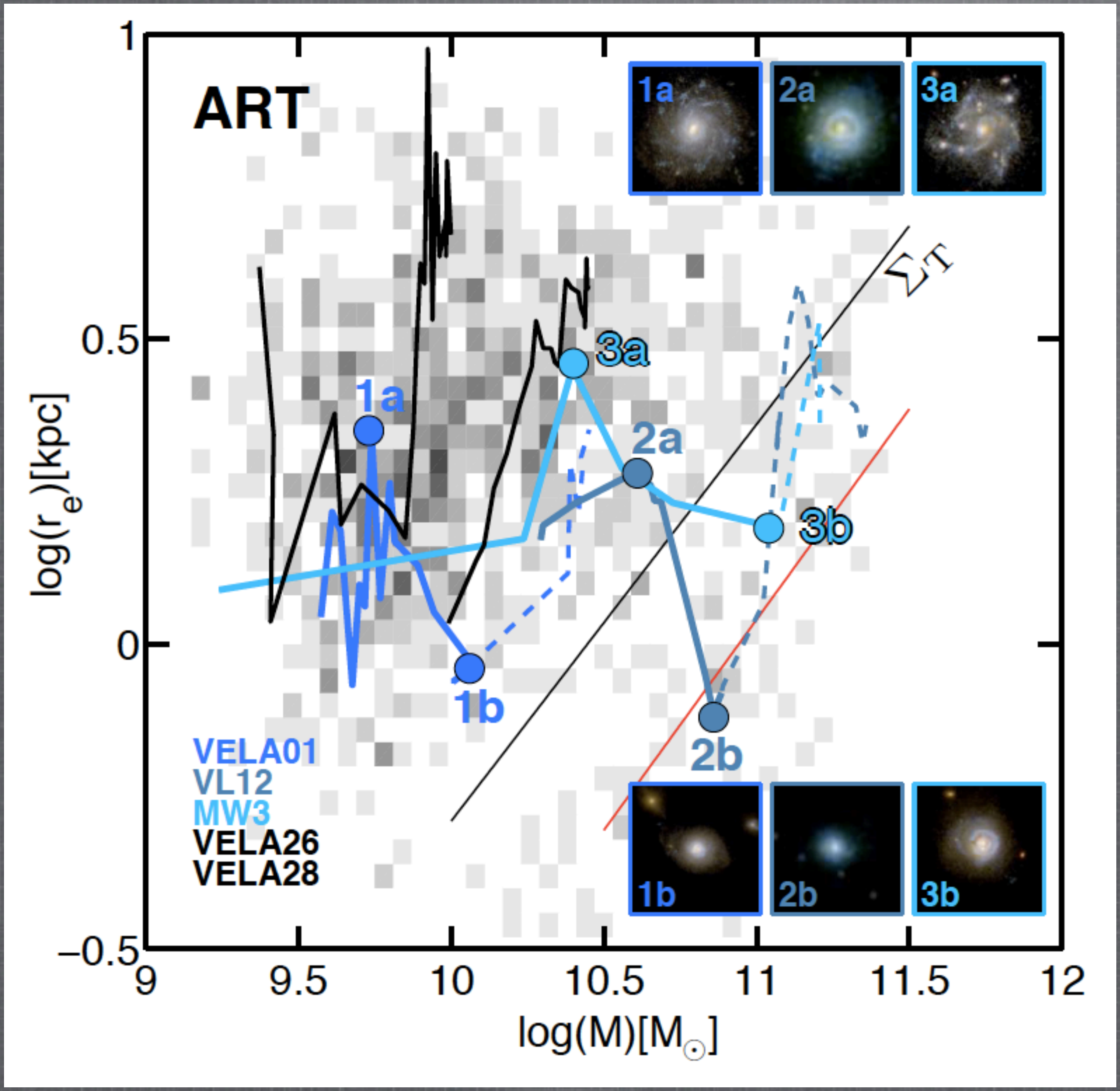
Life-paths of cSFGs from SAMs

Porter+13c (submitted)



- Compactification by disk instabilities (60% vs. 40% mergers)

Life-paths of cSFGs from ART-Hydro

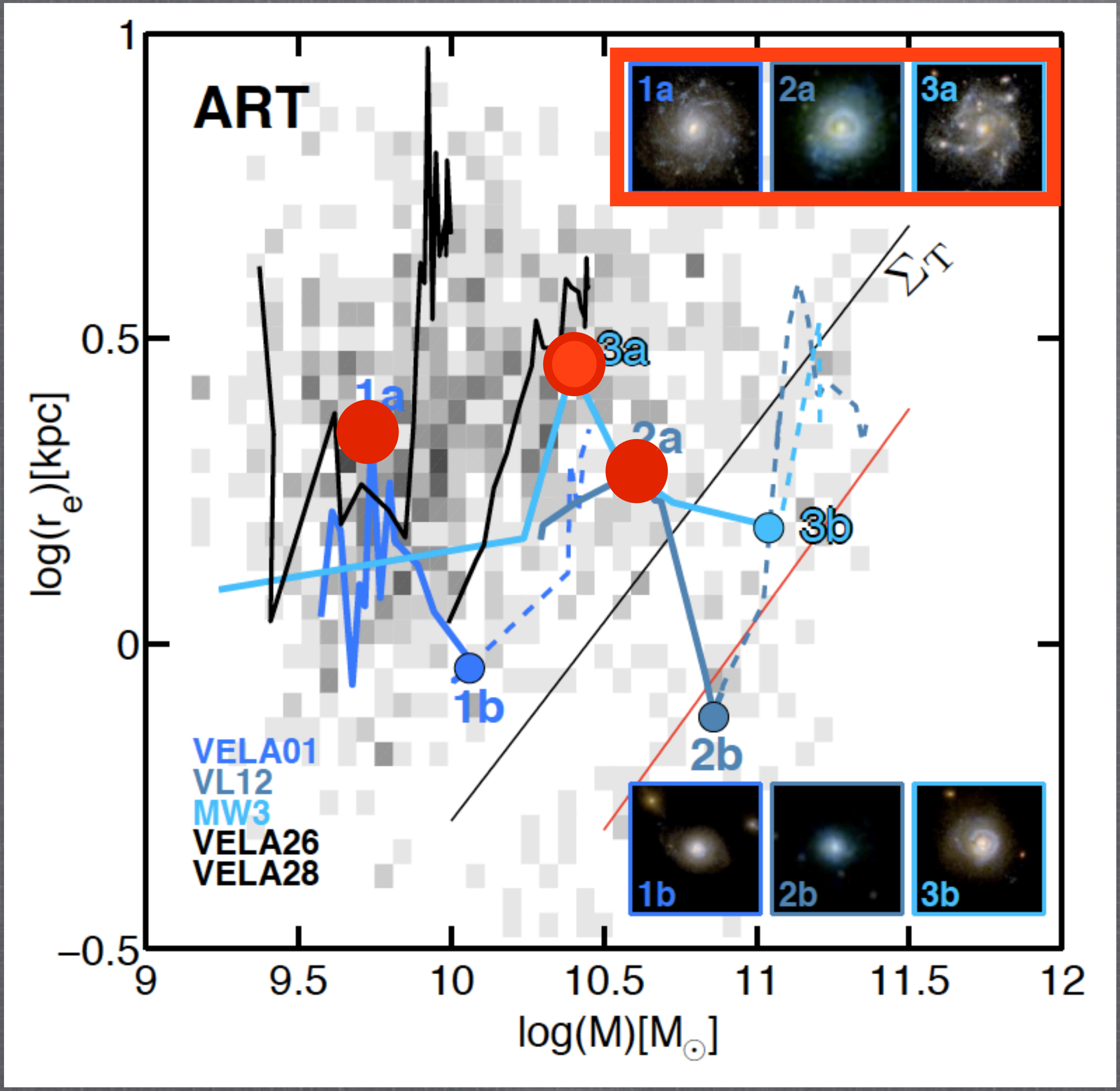


- 20-30 ART-Hydro simulations (Ceverino+10,12; Dekel+13b)

- Violent disk instabilities, gas infall & bulge growth (ceverino, Zolotov in prep).

Barro et al. submitted

Life-paths of cSFGs from ART-Hydro



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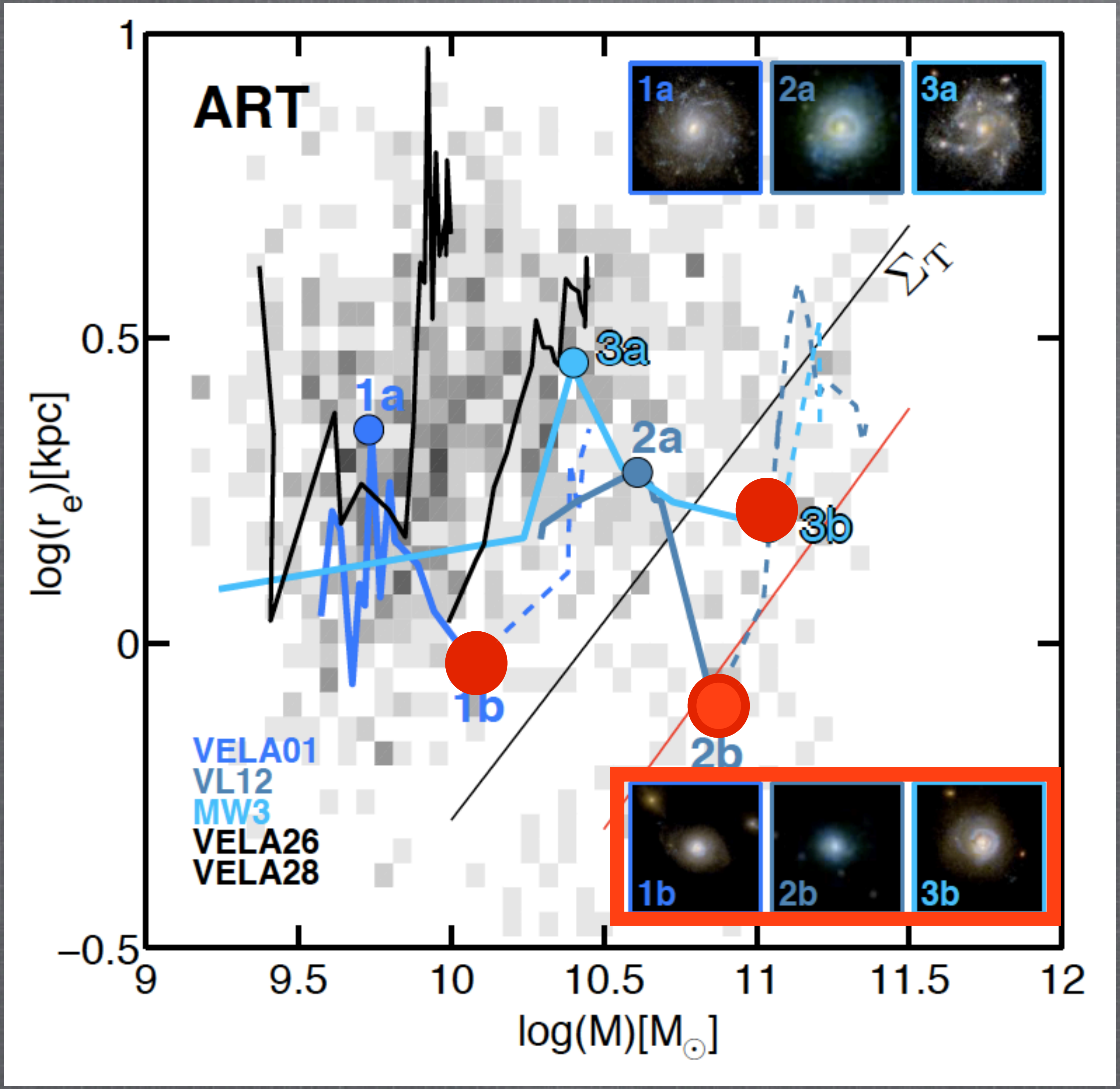

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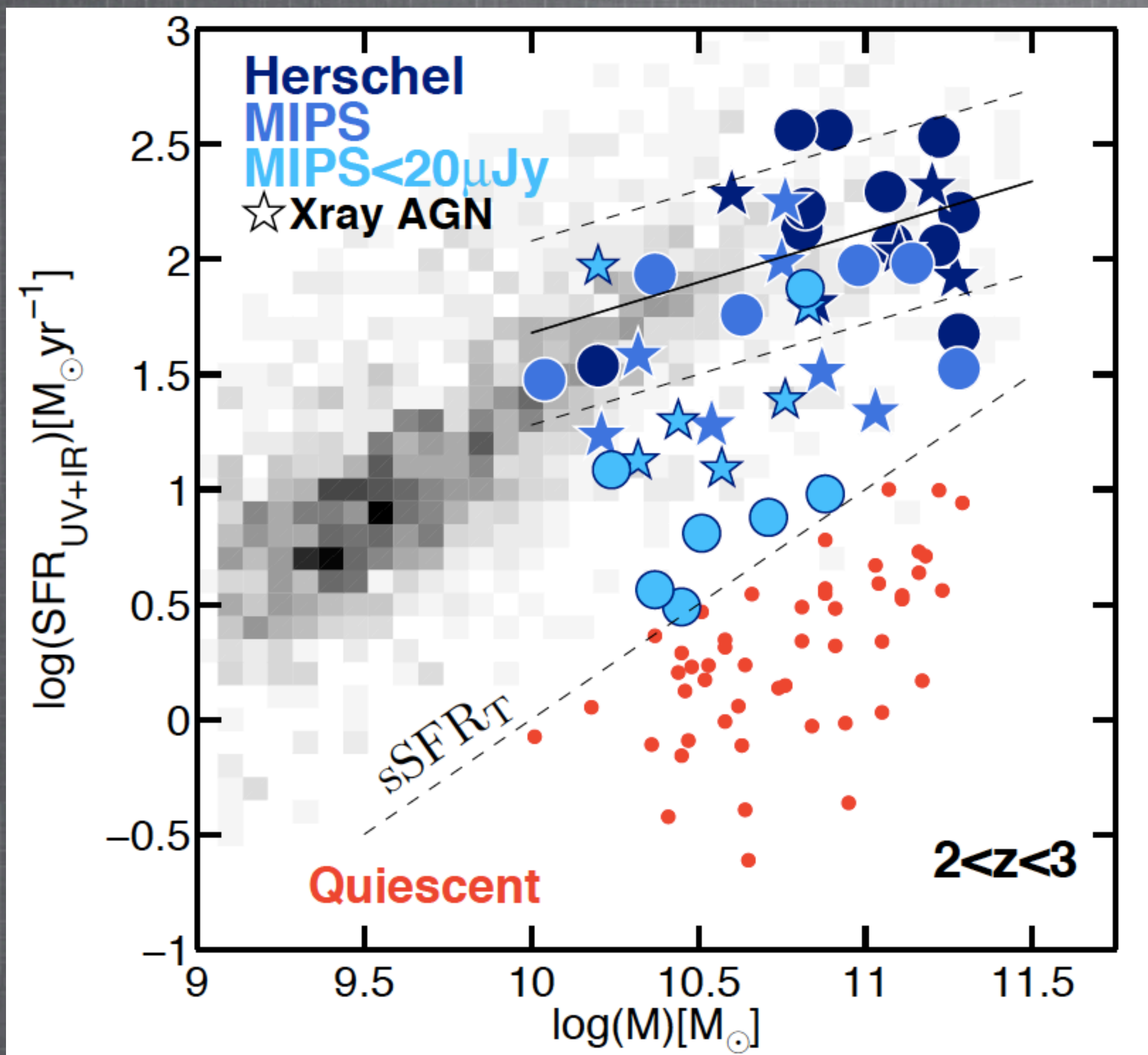
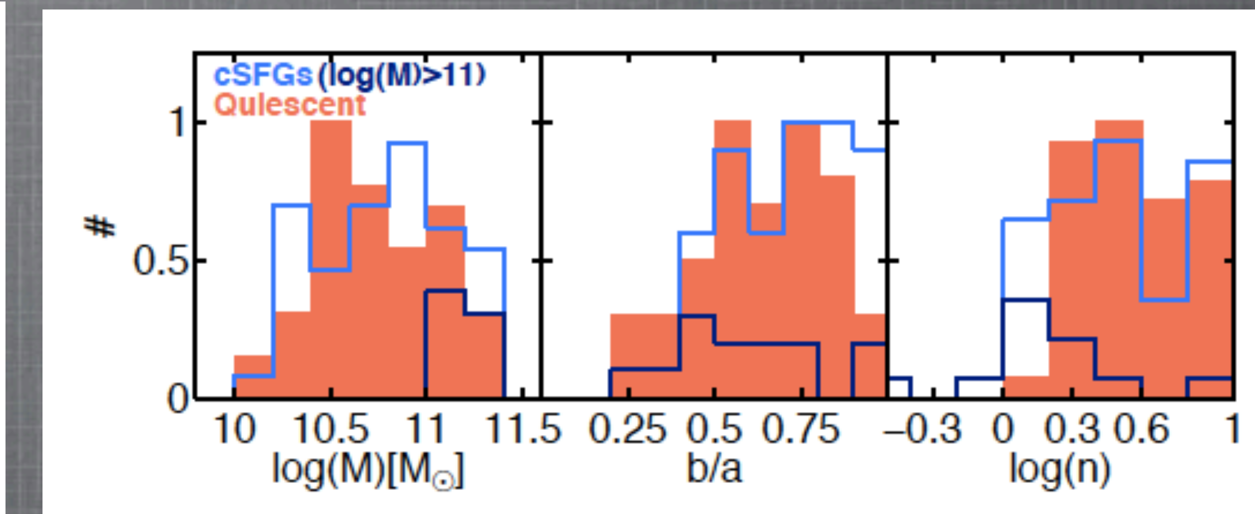
Barro et al. submitted

SFRs and dust properties of compact SFGs 2<z<3



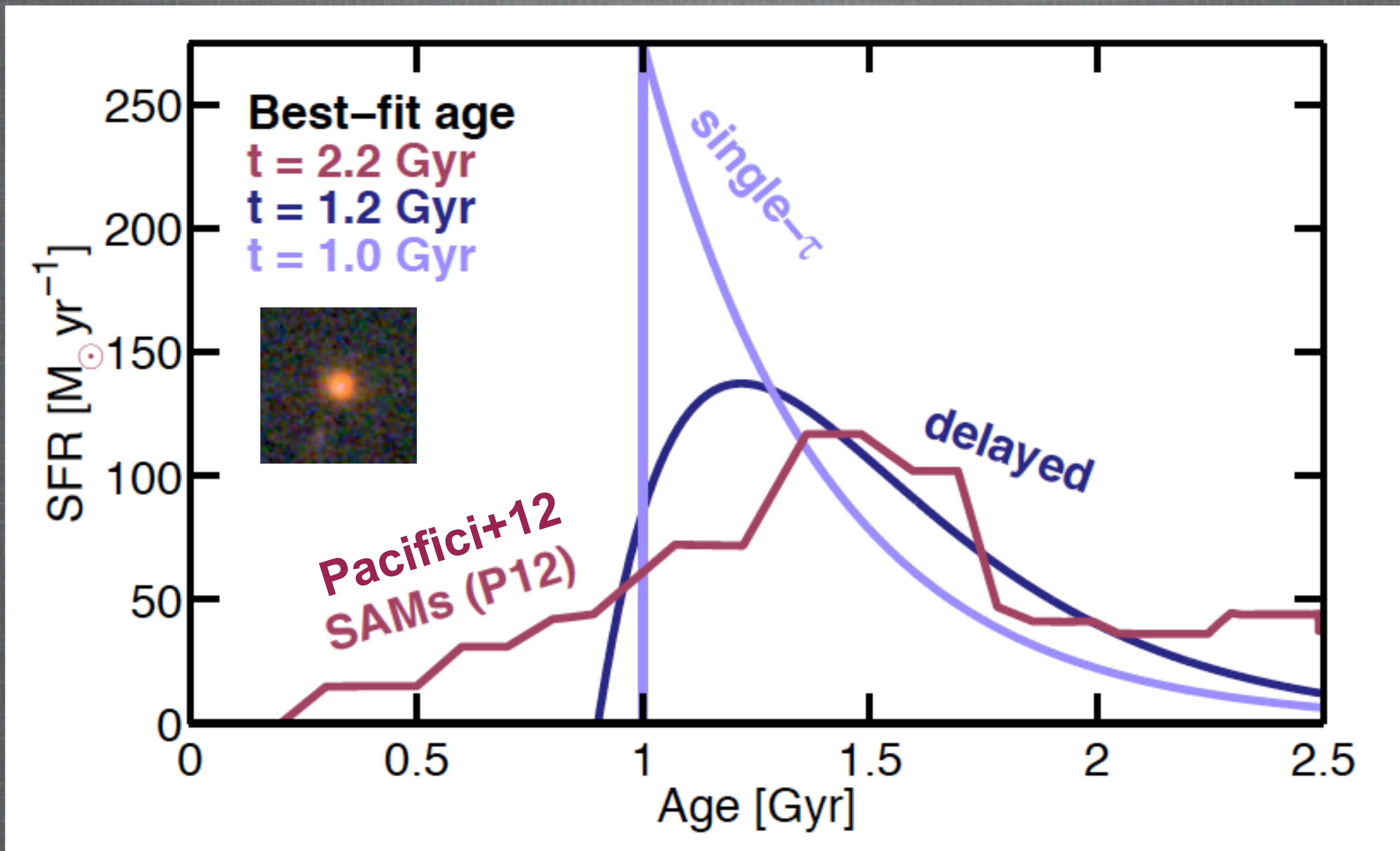


Barro et al. submitted

- 70% are dusty (far-IR)
- 50% are AGNs
- Only 2 *starburst*
- Range in sSFR

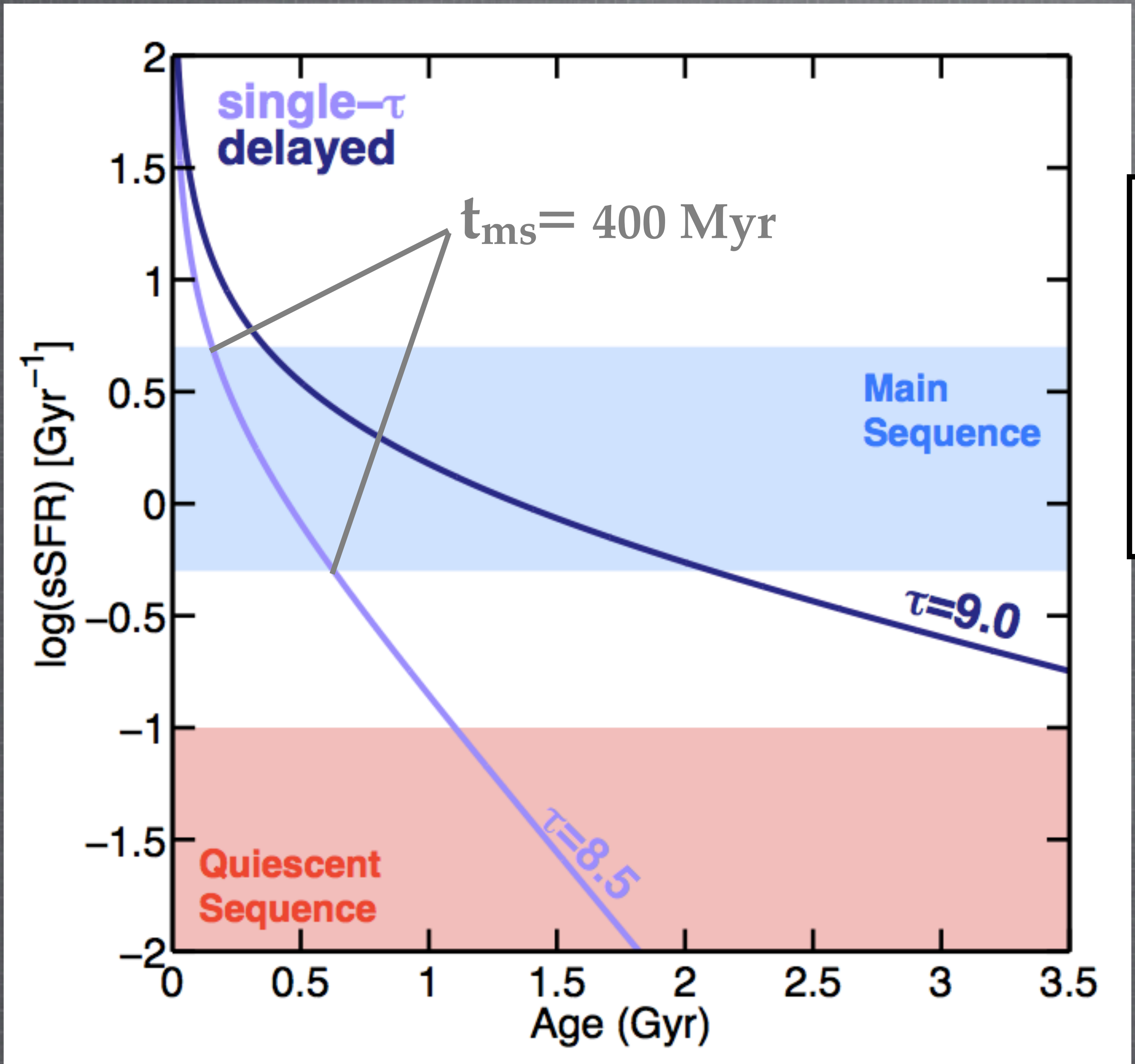
Consistent w/ quiescent:
- Mass range
- Sersic index
- axis ratio

SED modeling with different SFHs



- The 3 models provide equally good fit χ^2
- SAM-SFHs predict longer formation timescales by x2

SED modeling with different SFHs



BEST FIT AGES [Gyr]

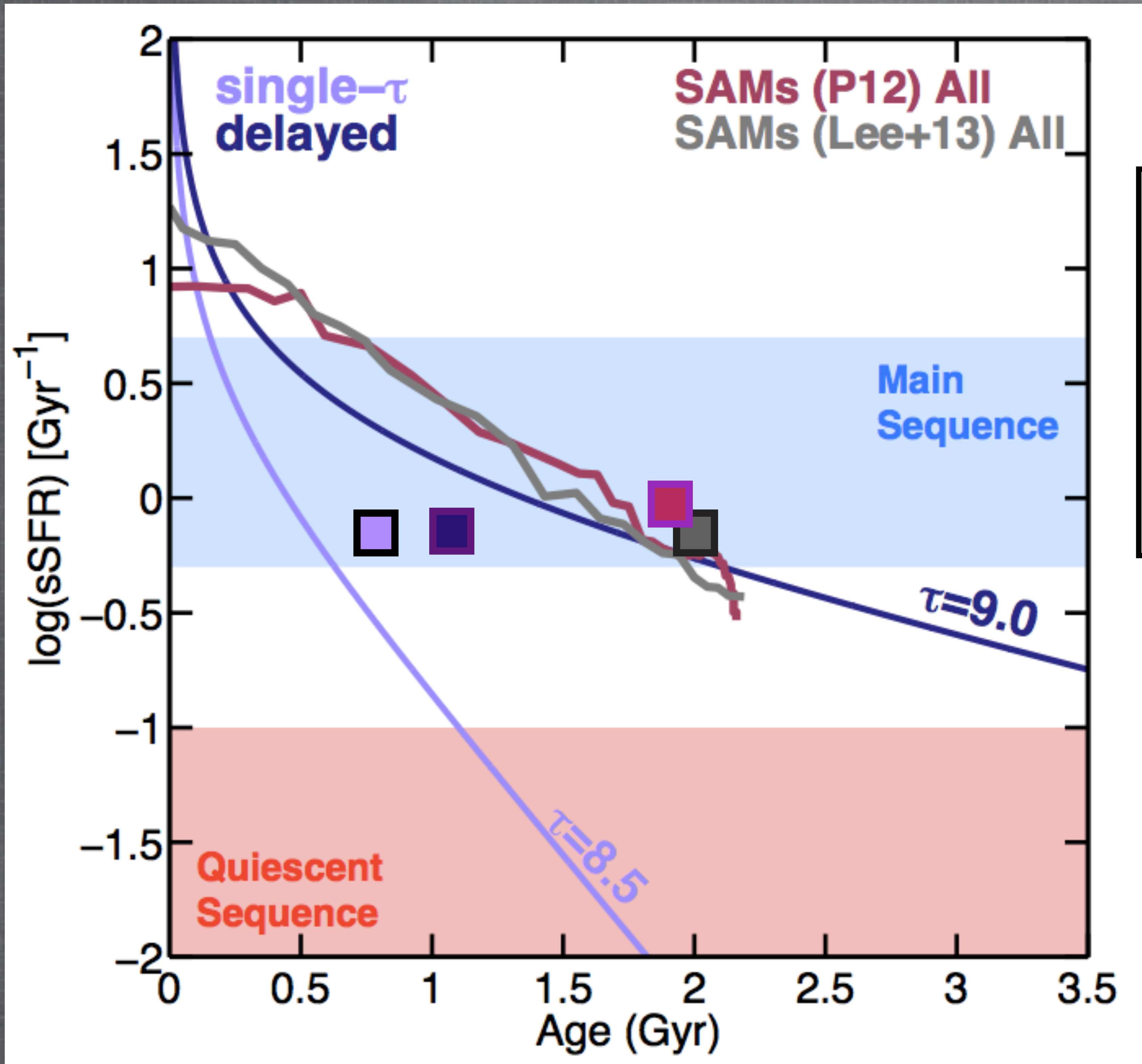
single / delayed

t ≈ 0.8 / t ≈ 1.1

Formation redshift

z ≈ 3.5 - 4

SED modeling with different SFHs



BEST FIT AGES [Gyr]

single / delayed / SAMS

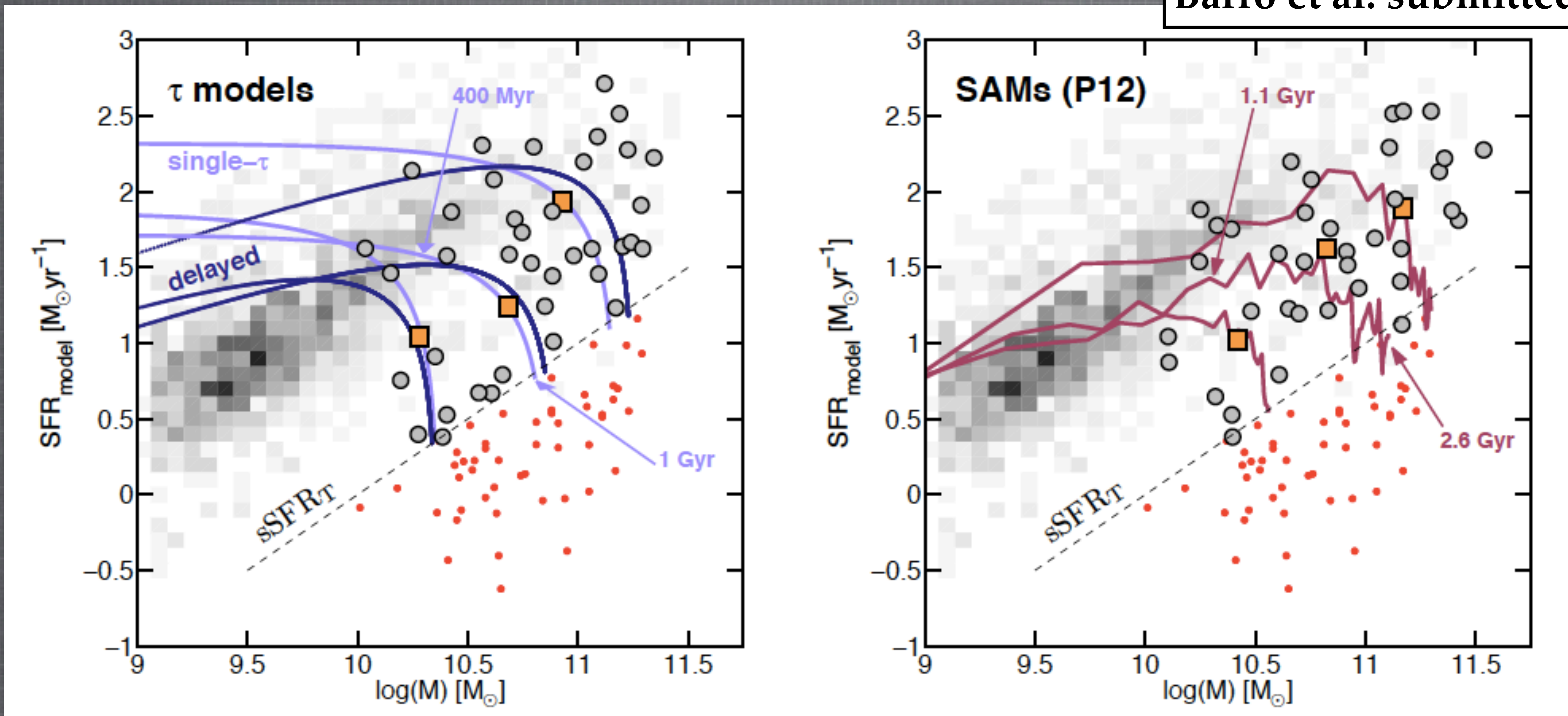
t ≈ 0.8 / t ≈ 1.1 / t ≈ 2

Formation redshifts

z ≈ 3.5-4 / z ≈ 6-7

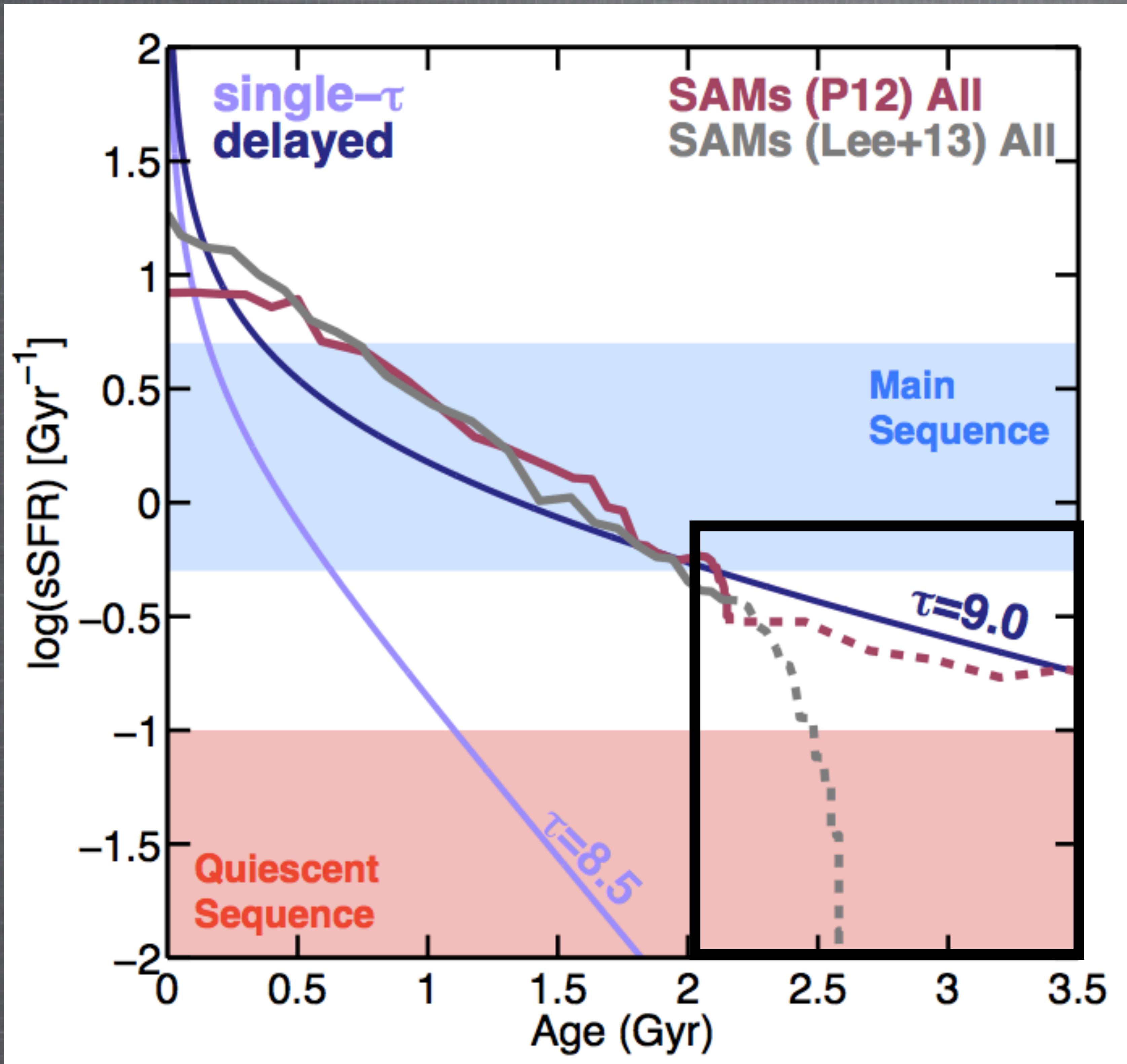
Star-formation histories in the MS

Barro et al. submitted



- SAMs match better the slope and normalization of the MS
- Predict a longer MS phase consistent with the secular (gas-fed) mode (Dekel+09, Bouche+10, Magnelli+12, Sargent+13)

SED modeling with different SFHs

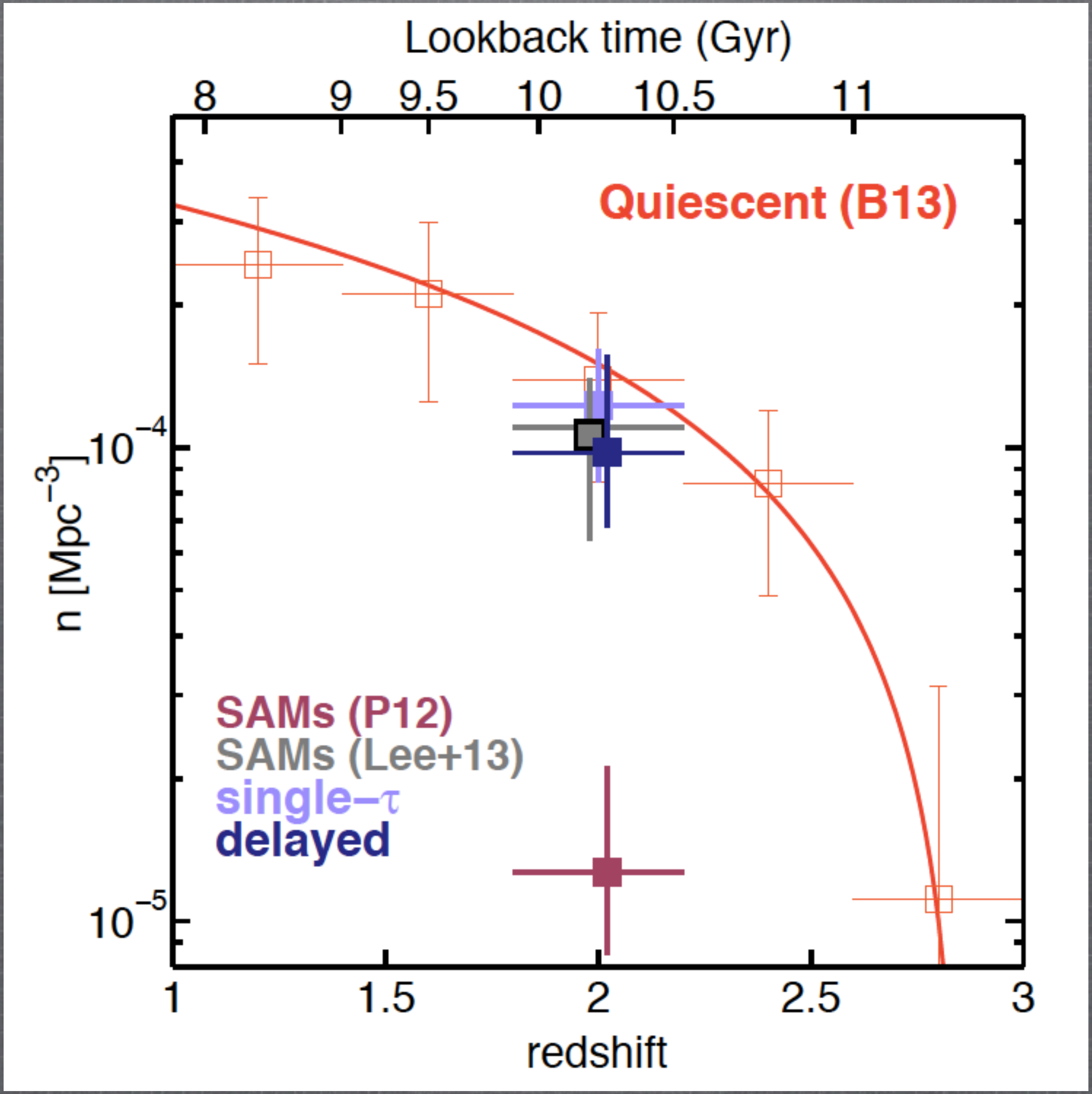


Quenching times [Gyr]

SAMs (P12) / SAMs (Lee+13)

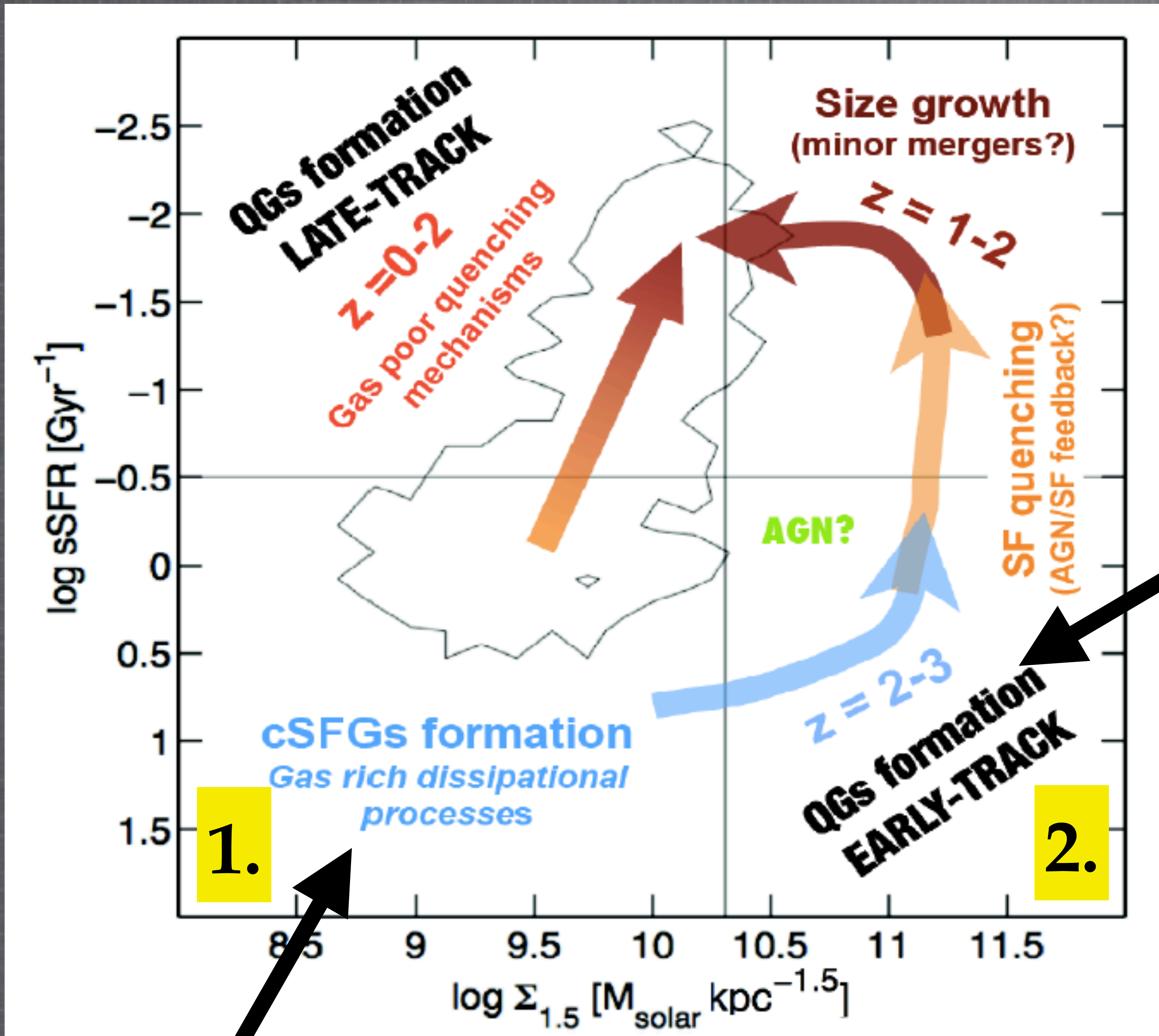
$t \approx 1.5$ / $t \approx 0.4$

Predicted number densities



- To match observations SAM-SFHs require short quenching times

Conclusions



Compact SFGs properties 2.

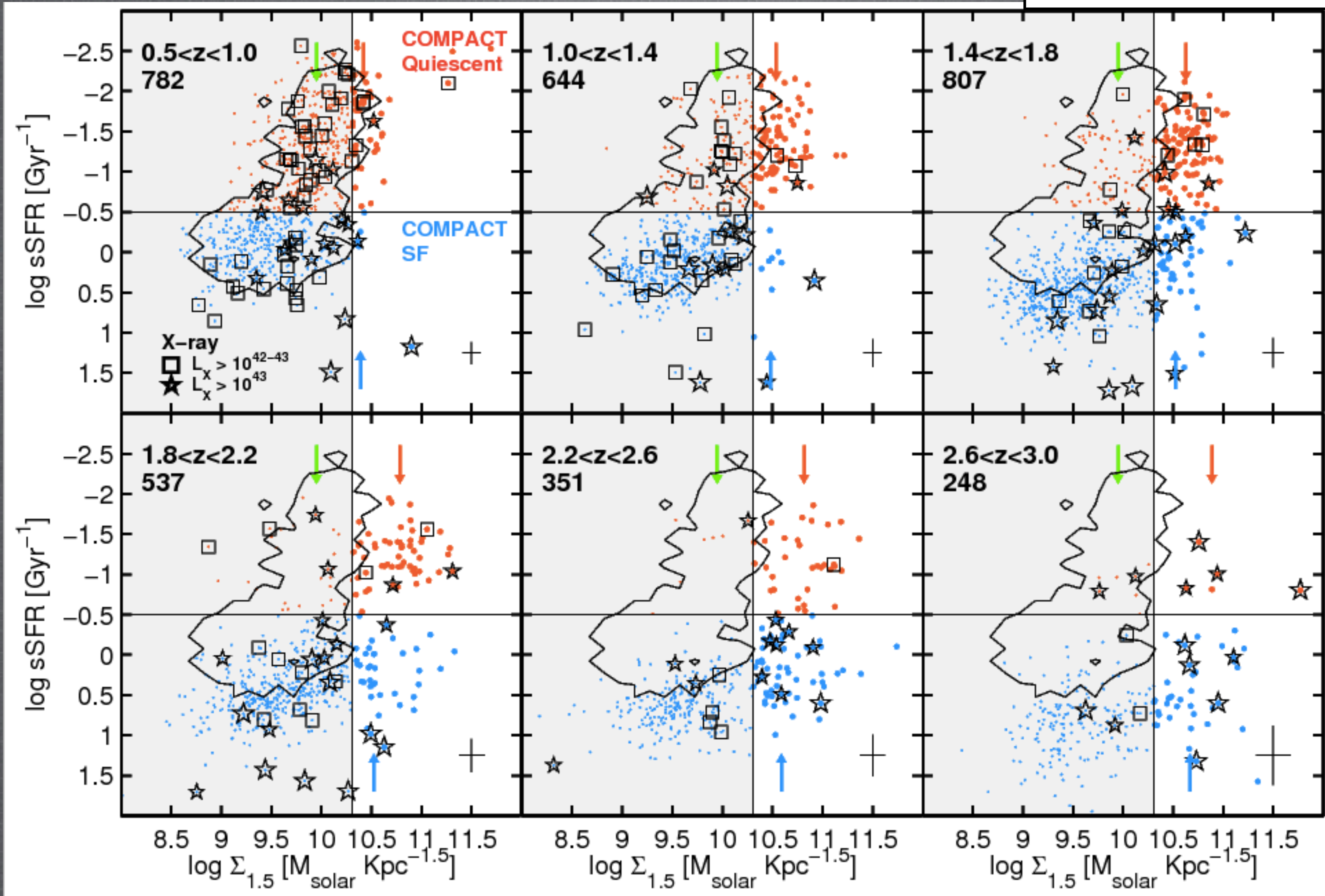
- 70% dusty (IR-) star-formation.
- high-sersic, undisturbed sph.
- 50% AGN det. fraction.
- 0.3 -1 Gyr quenching time.
- Age ~ 1- 2 Gyr.
- AGN/SF feedback (outflows?)

Compact SFGs formation 1.

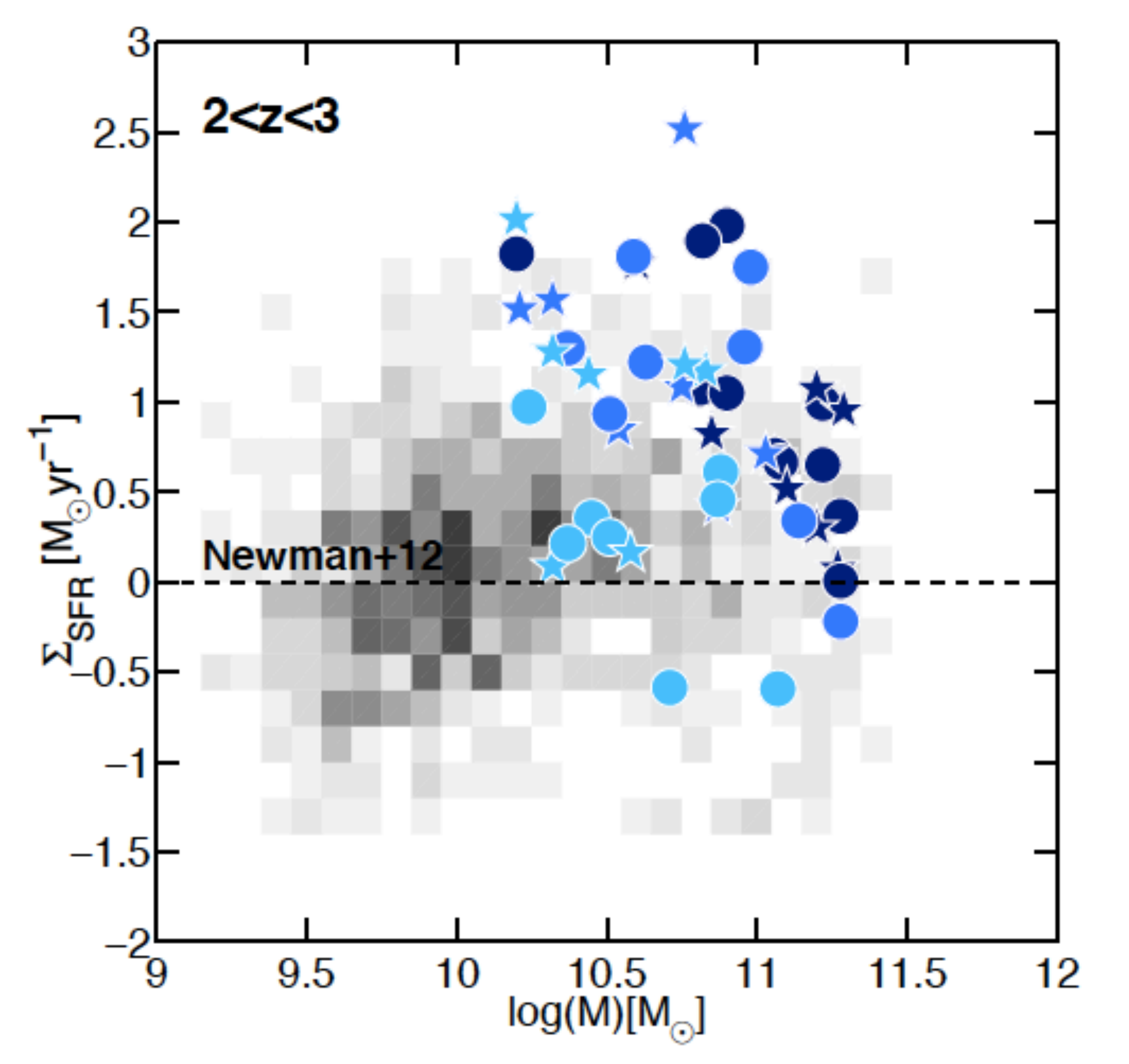
- SAMs - DI (60%) , wet mergers (40%)
- SAMs - Compactification of ~x2
- ART-hydro - VDI time-scale 300 - 500 Myrs.

Compact quiescent and SFGs

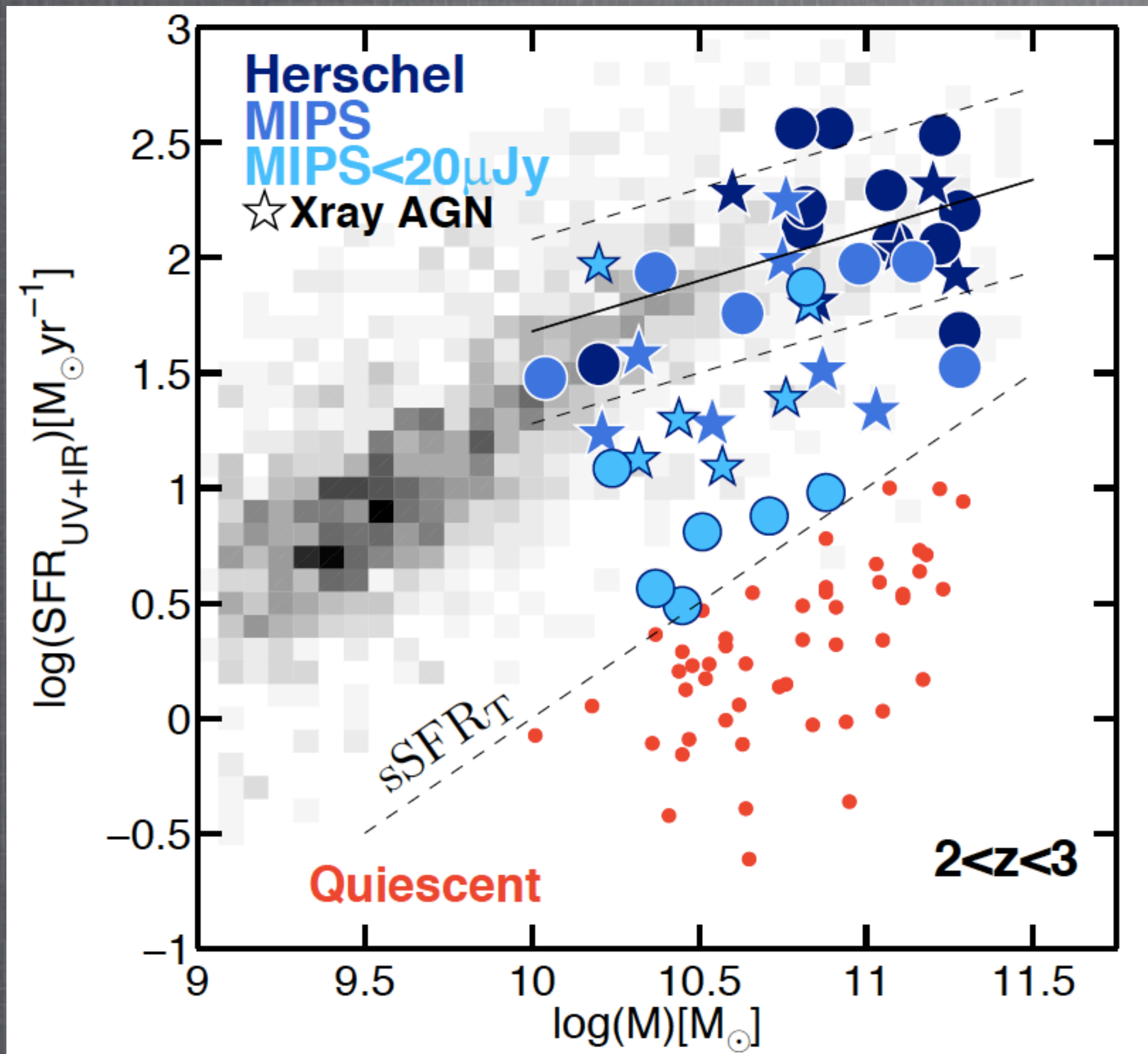
Barro et al. 2013

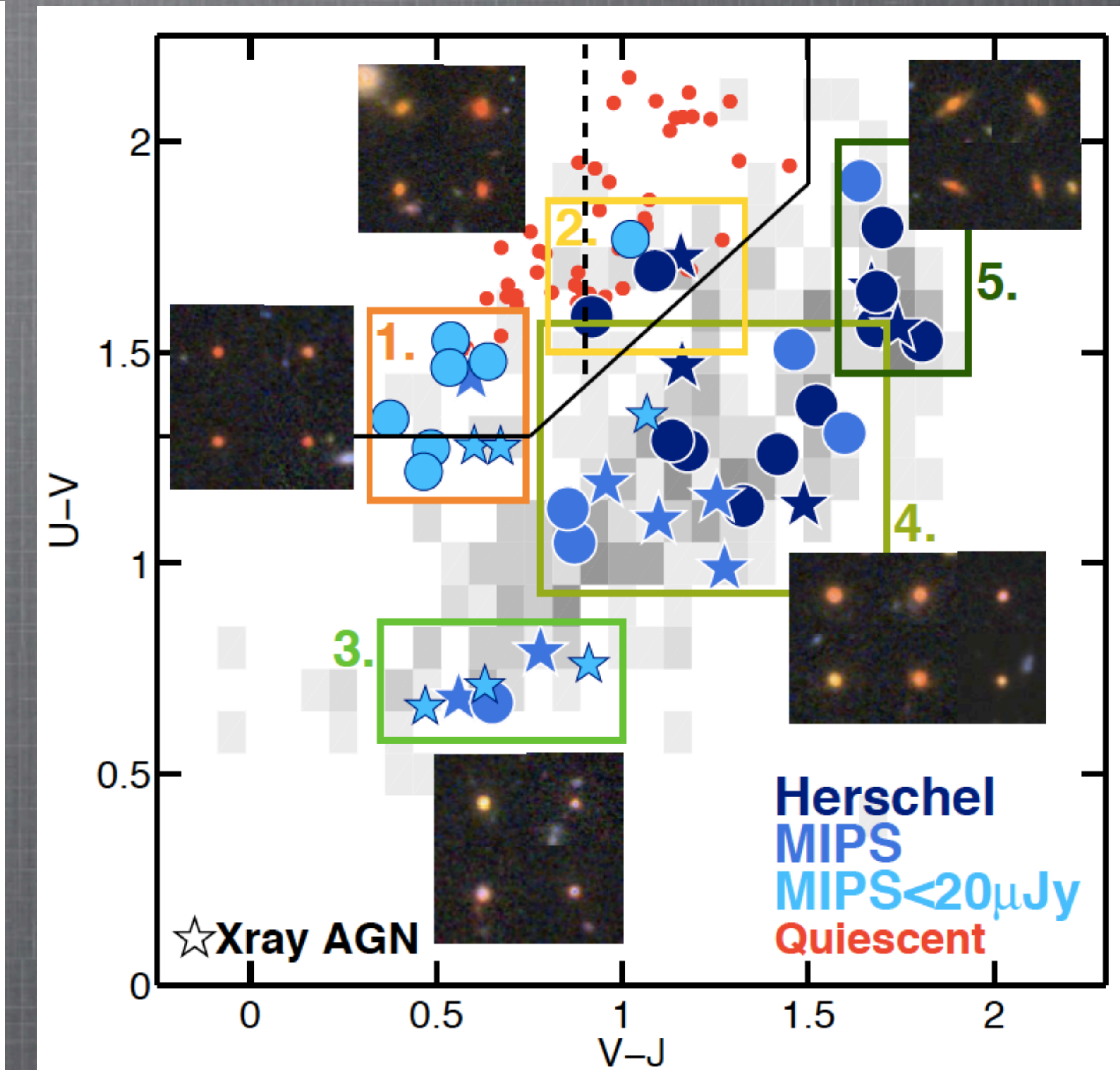


Galaxy scale outflows



SFRs and dust properties of compact SFGs 2<z<3

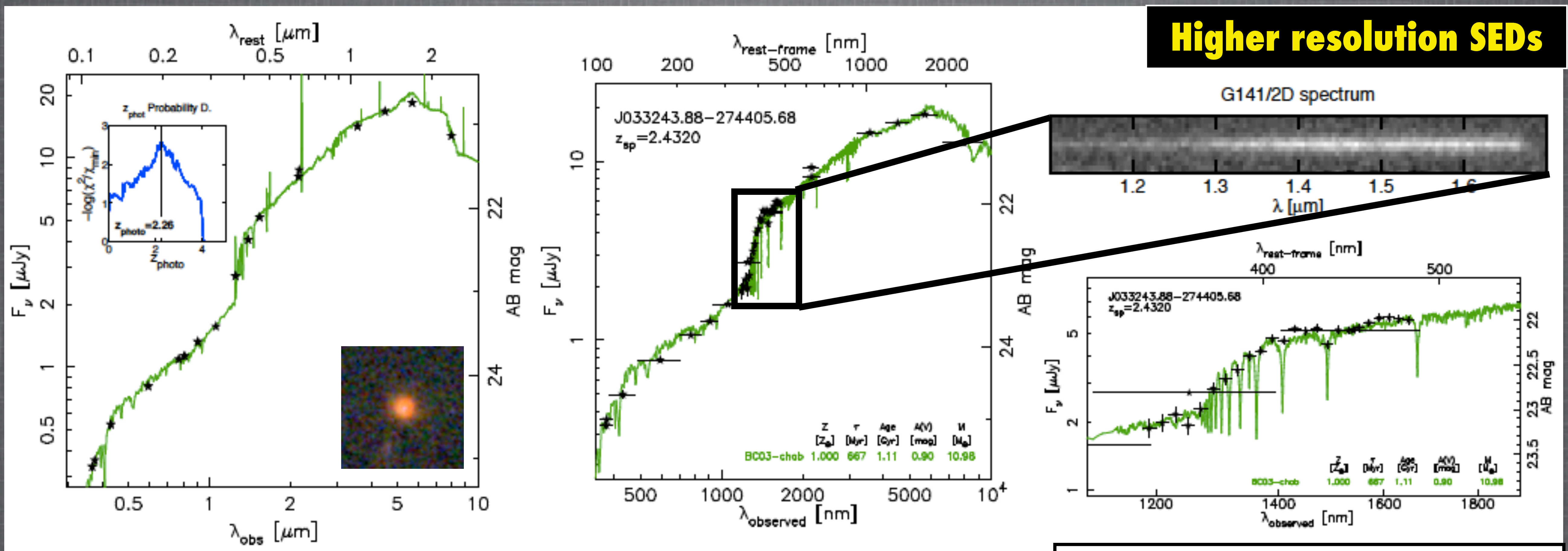




70% are dusty (far-IR) SF
50% are AGNs
Mass range consistent w/ QGs

Barro et al. submitted

SED modeling of cSFGs



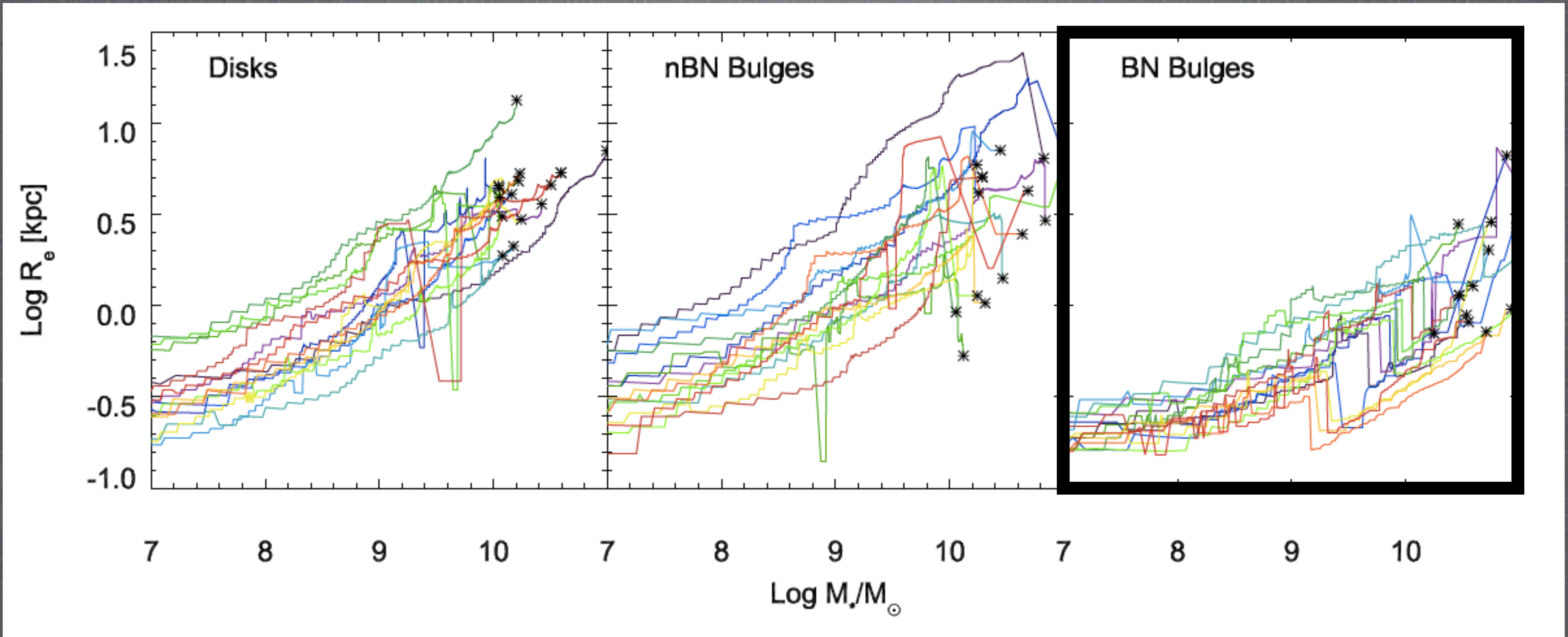
Barro et al. submitted

SED-based stellar properties for 2 < z < 3 cSFGs

3D-HST (Brammer+12), NIR (1.1-1.7microns) grism spectroscopy

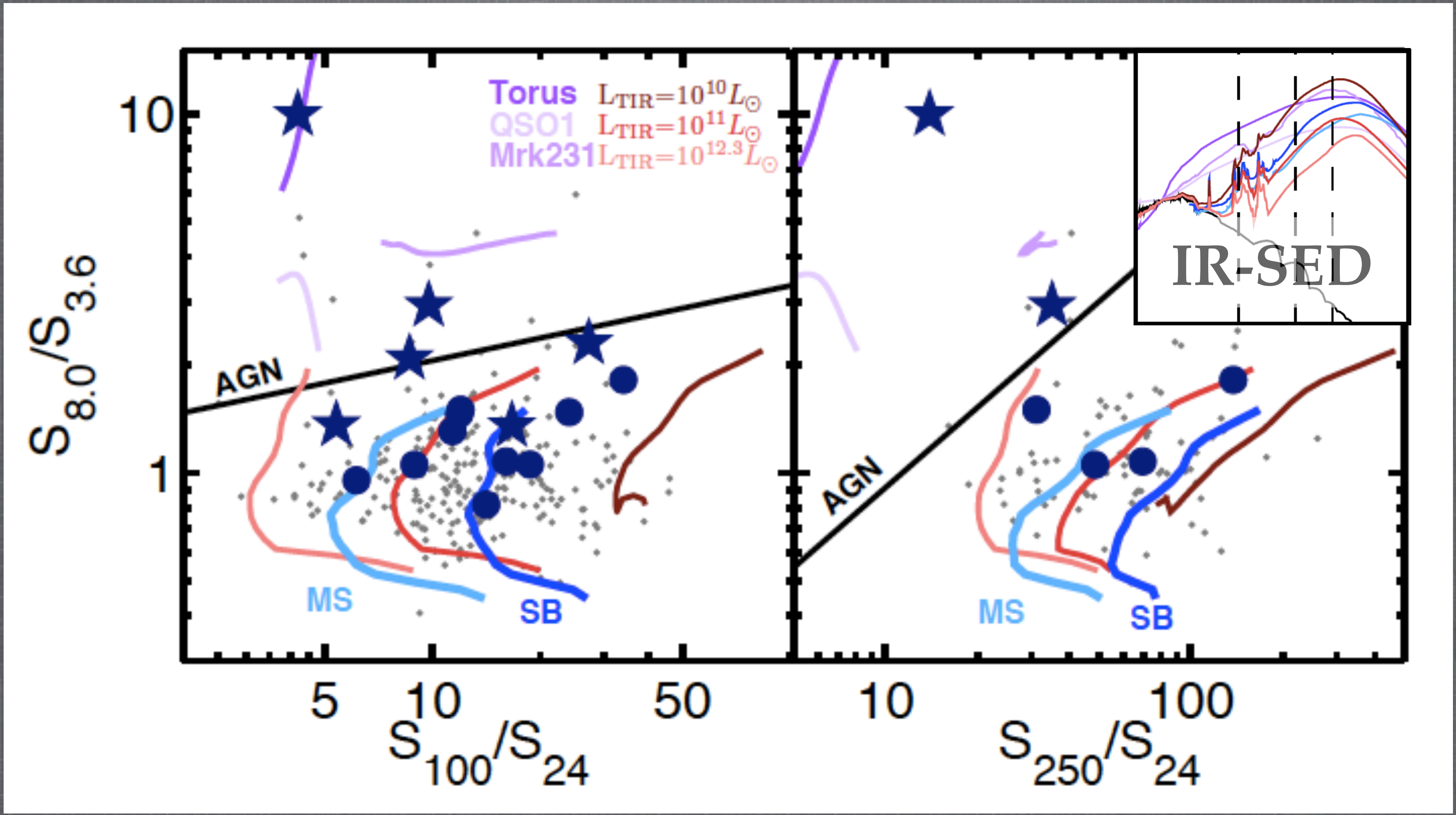
Life-paths of cSFGs from SAMs

Porter in prep.



- Sharp truncations are caused by disk instabilities more often (62%) than mergers

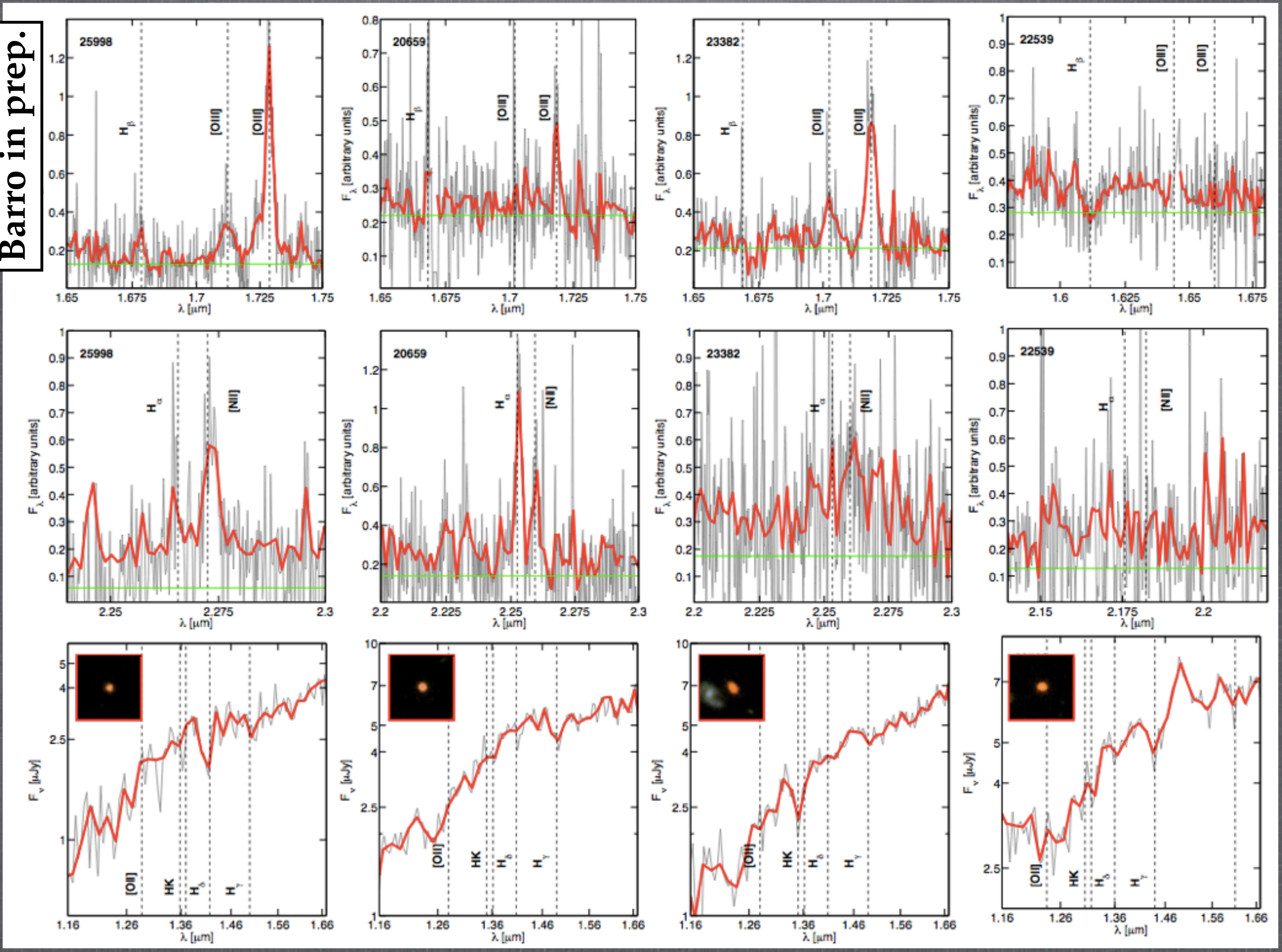
Far-IR Spitzer/PACS/SPIRE colors



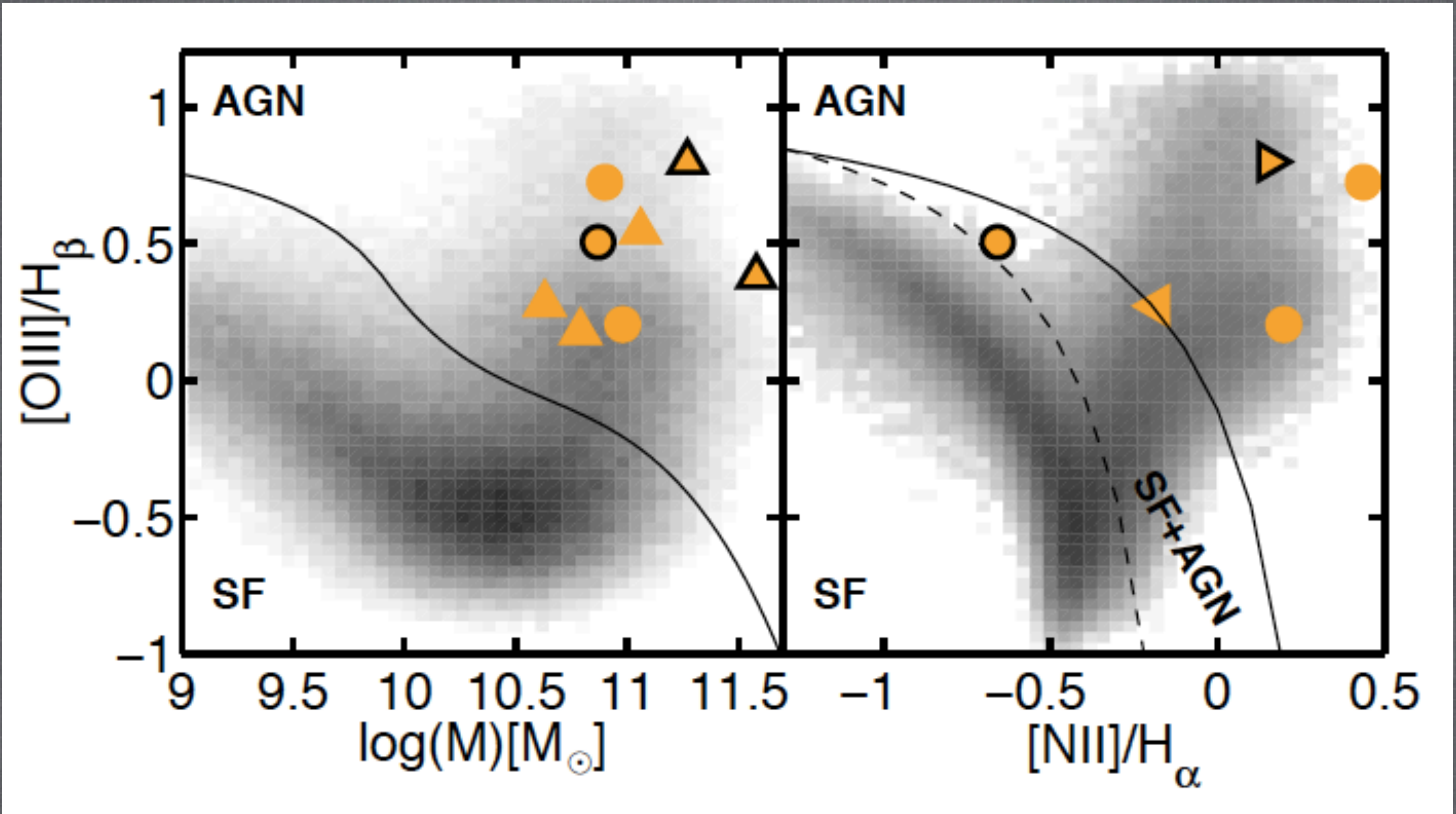
Colors consistent with SF even in most X-ray galaxies
Color distribution betwee MS and SB w/ few exceptions

NIR - spectroscopy of compact SFGs

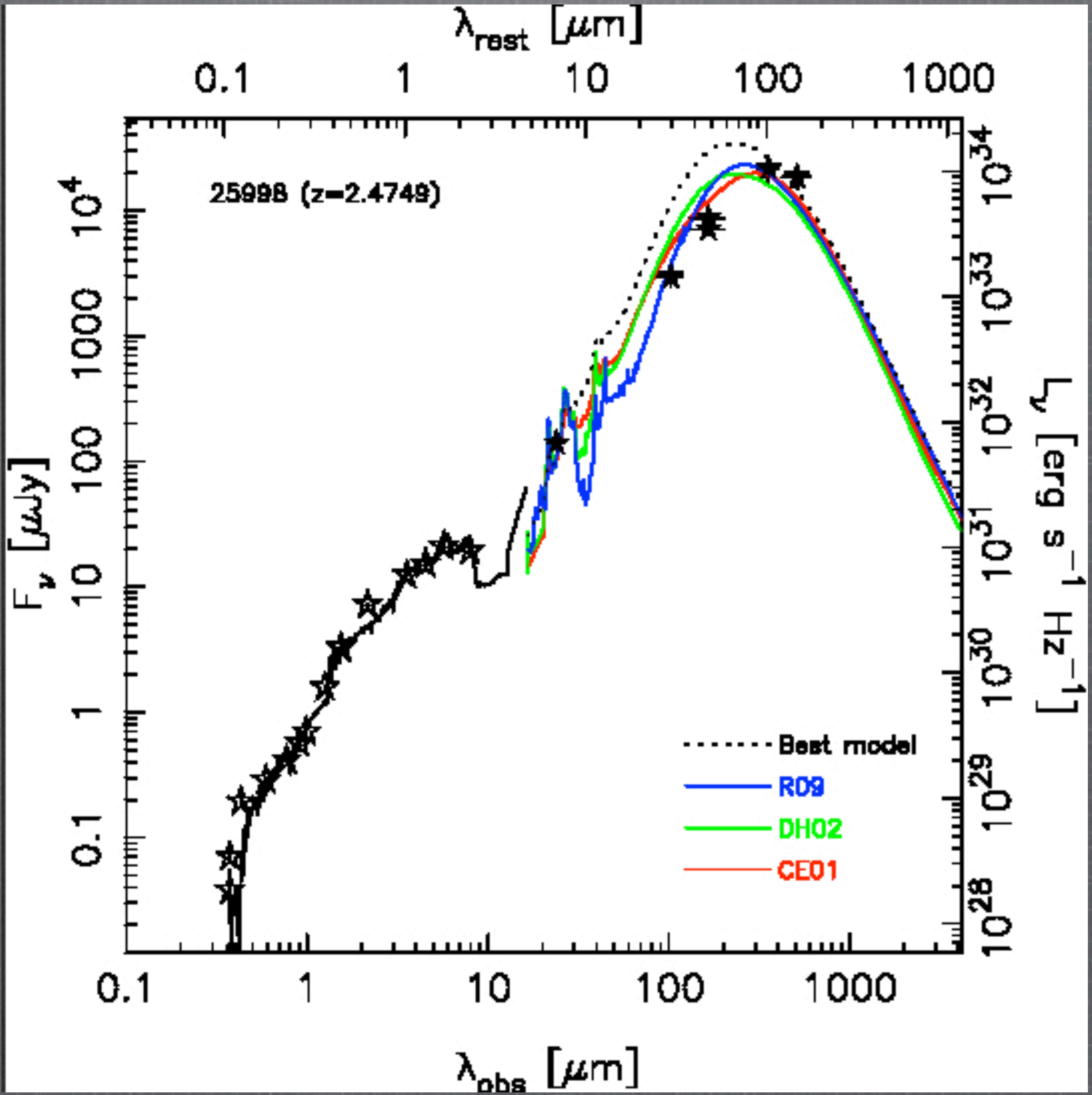
Barro in prep.



Emission line diagnostic

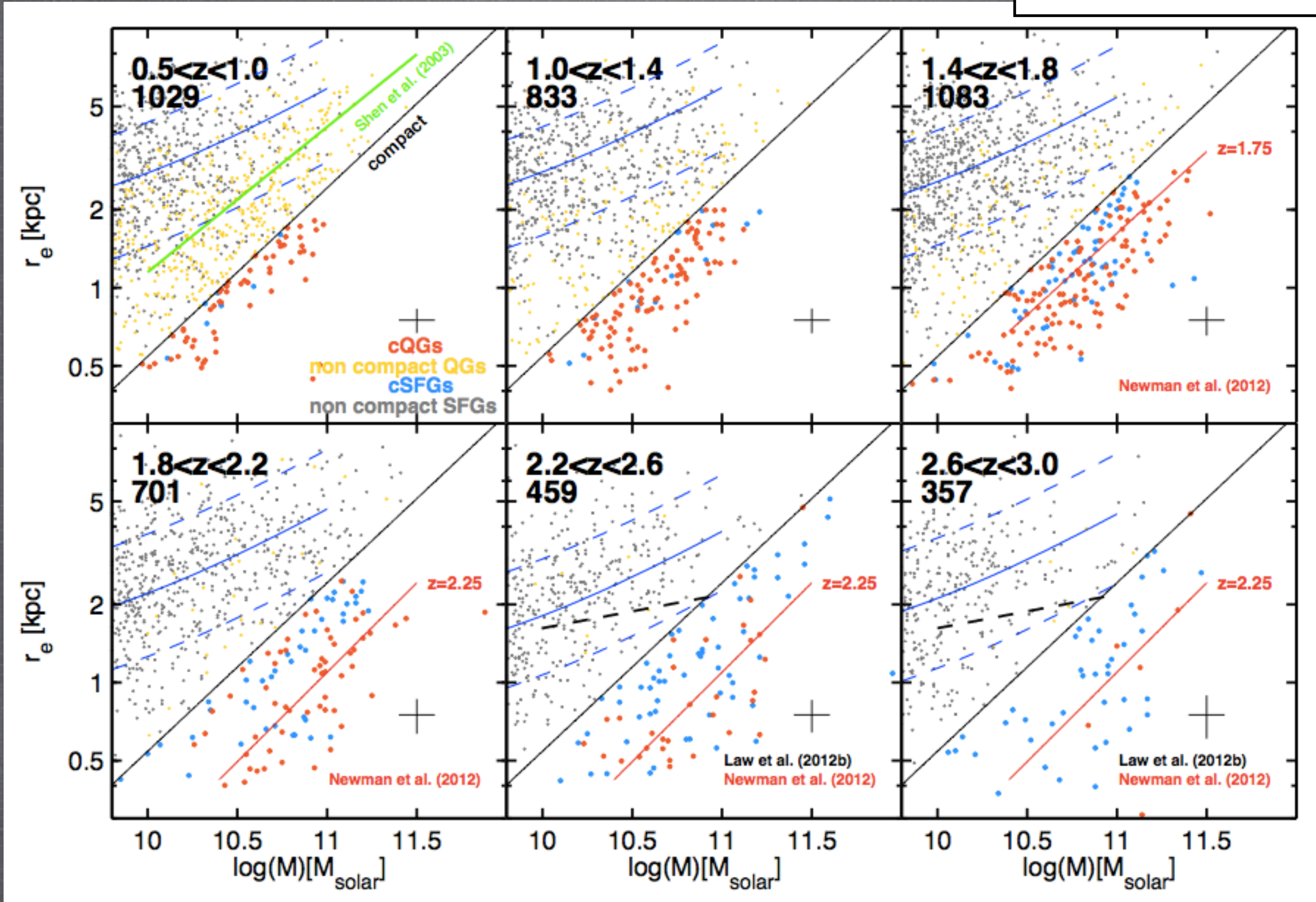


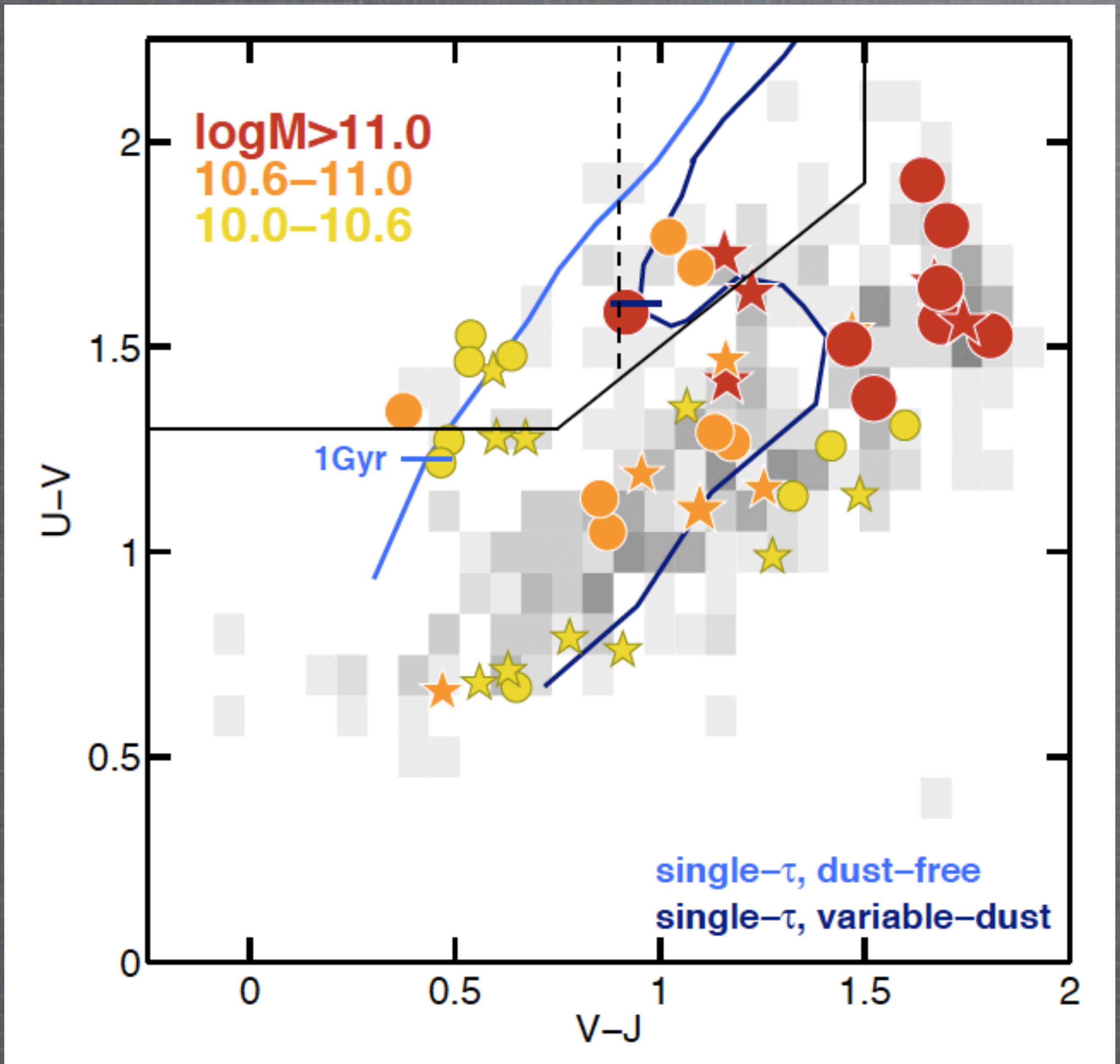
Spitzer/Herschel IR-SFRs



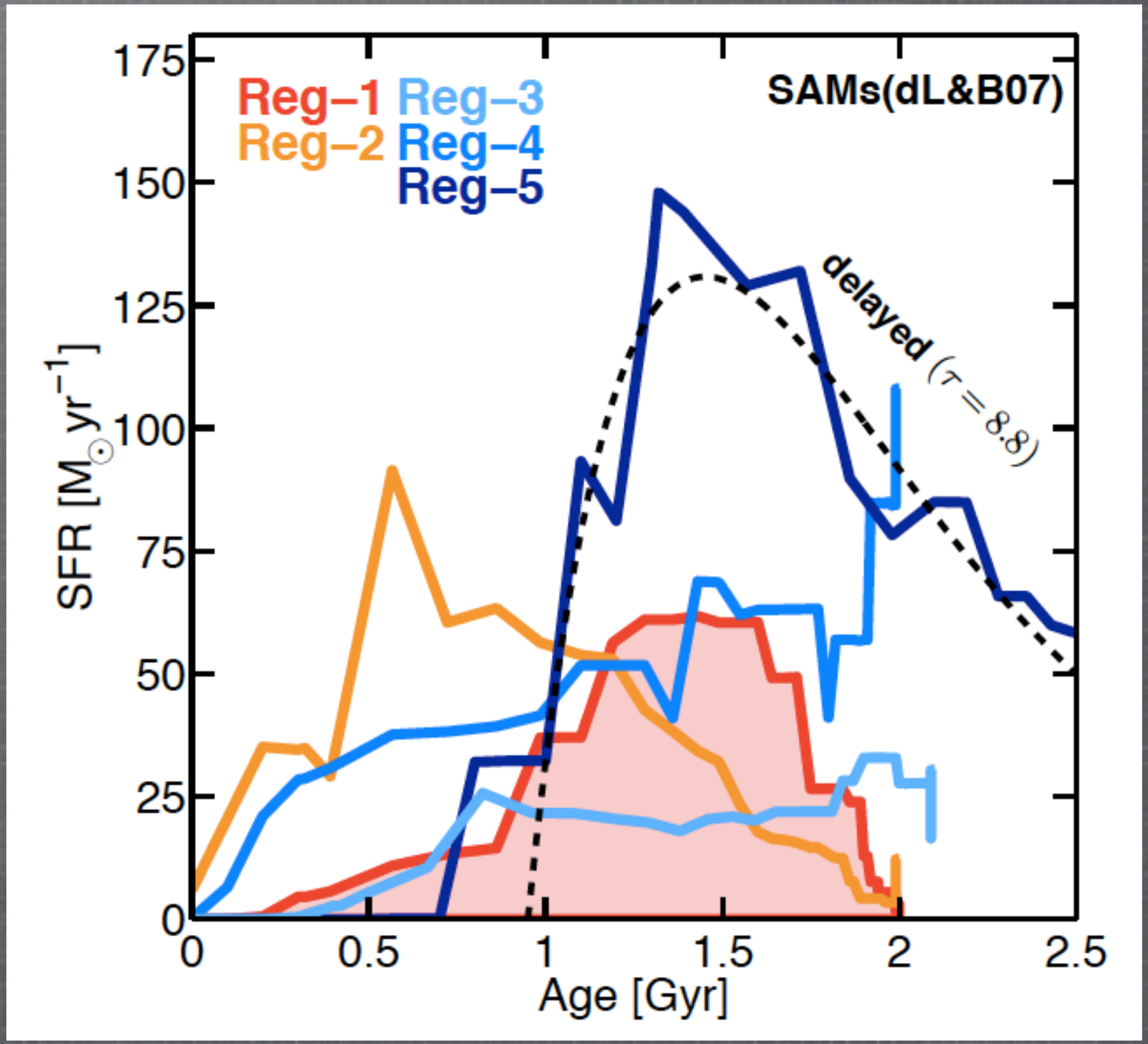
Compact quiescent and SFGs

Barro et al. 2013





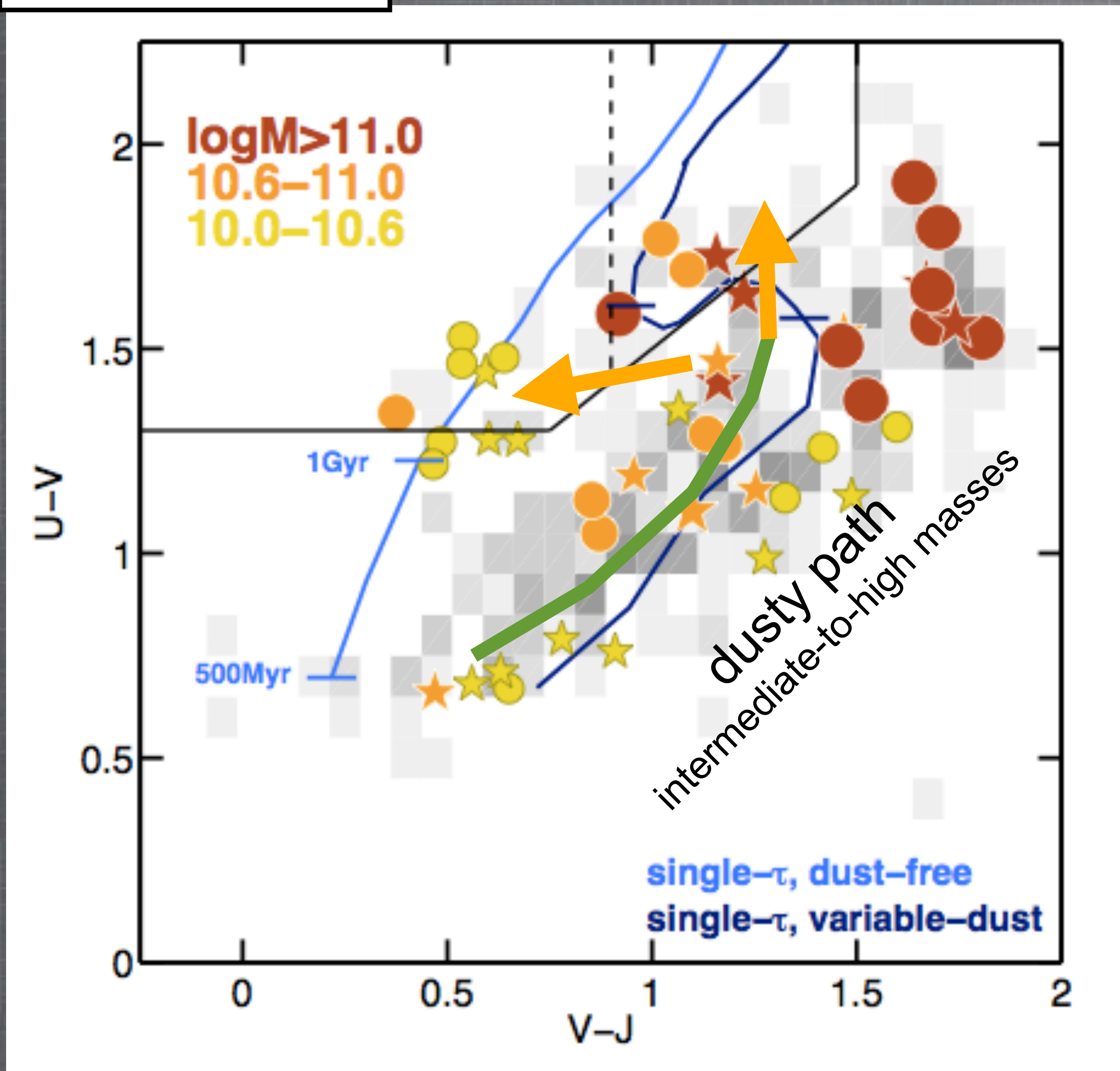
logM>11.0
10.6–11.0
10.0–10.6
1Gyr
single–τ, dust–free
single–τ, variable–dust
U–V
V–J



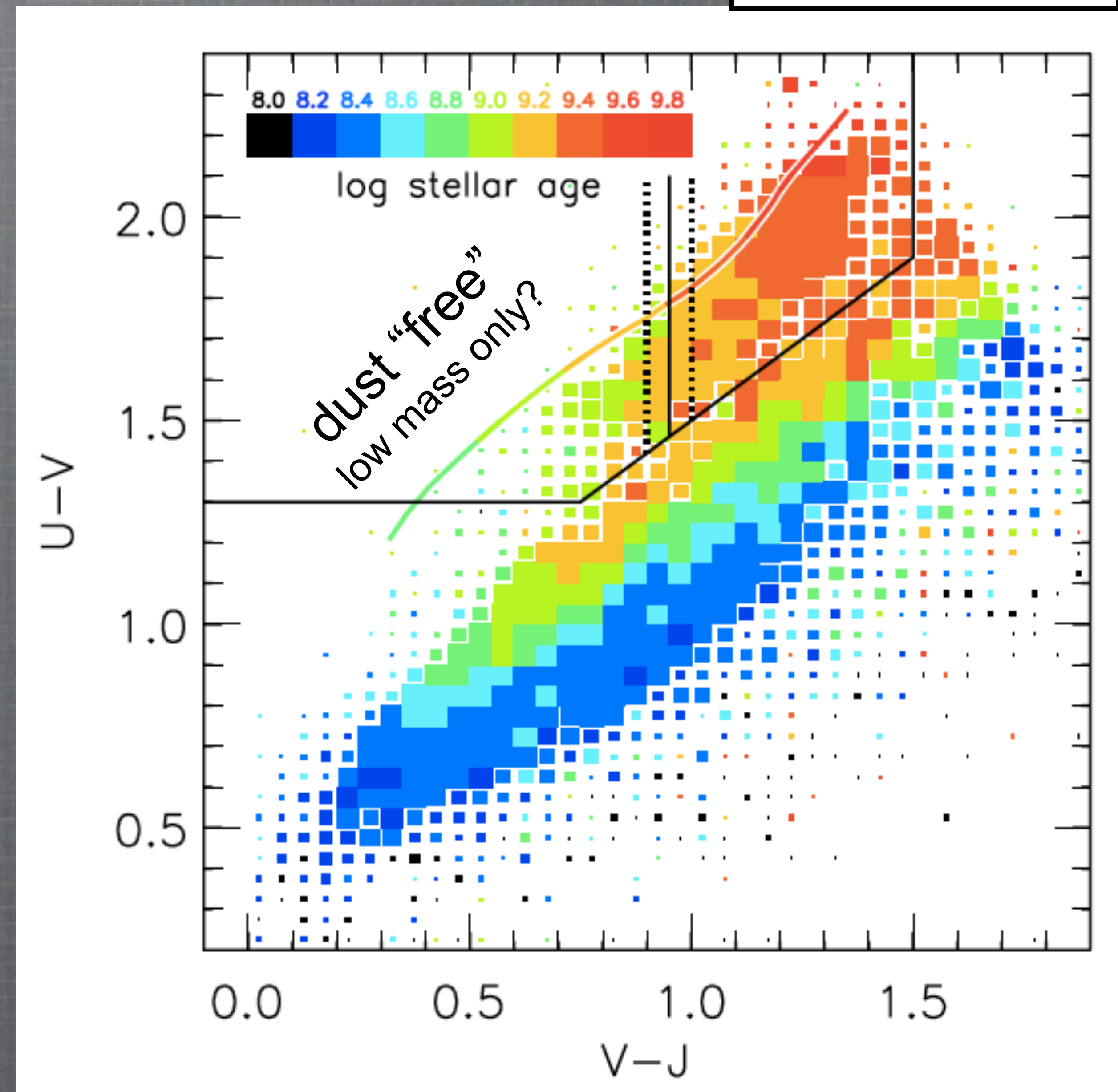
Reg–1 Reg–3
Reg–2 Reg–4
Reg–5
SAMs(dL&B07)
delayed (τ = 8.8)
SFR [M⊙ yr−1]
Age [Gyr]

The dusty path to the red-sequence

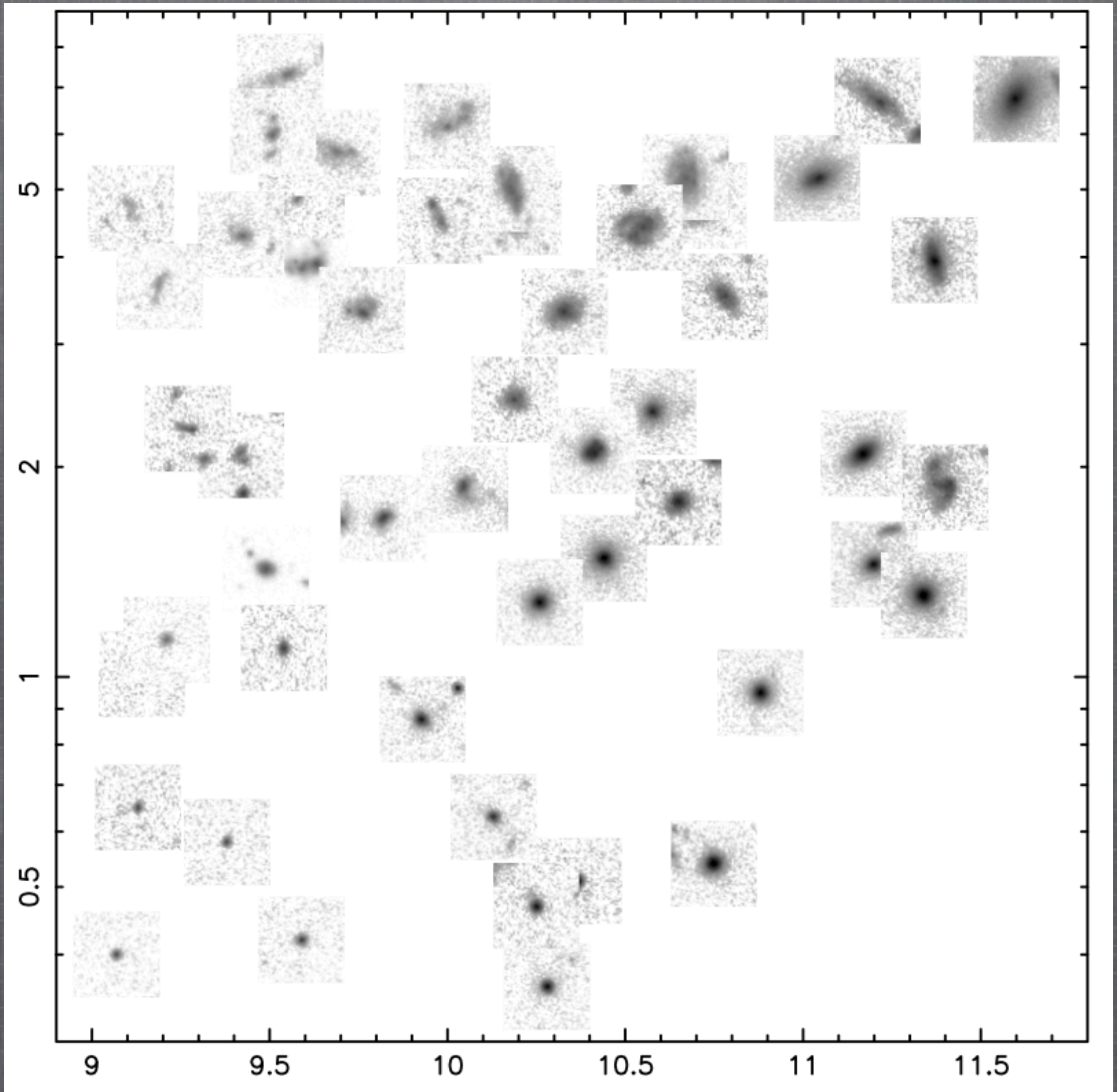
Barro in prep



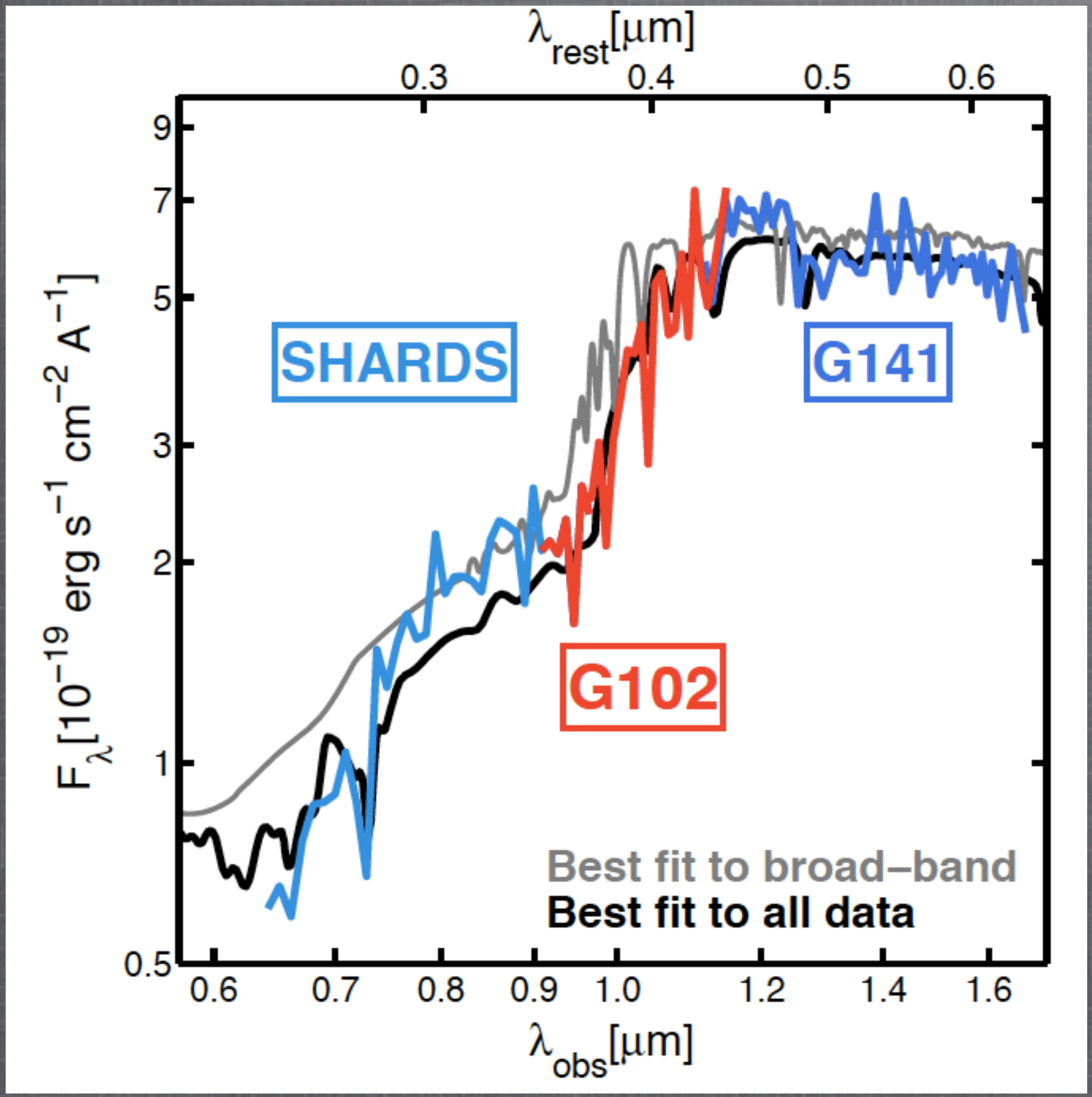
Whitaker+11

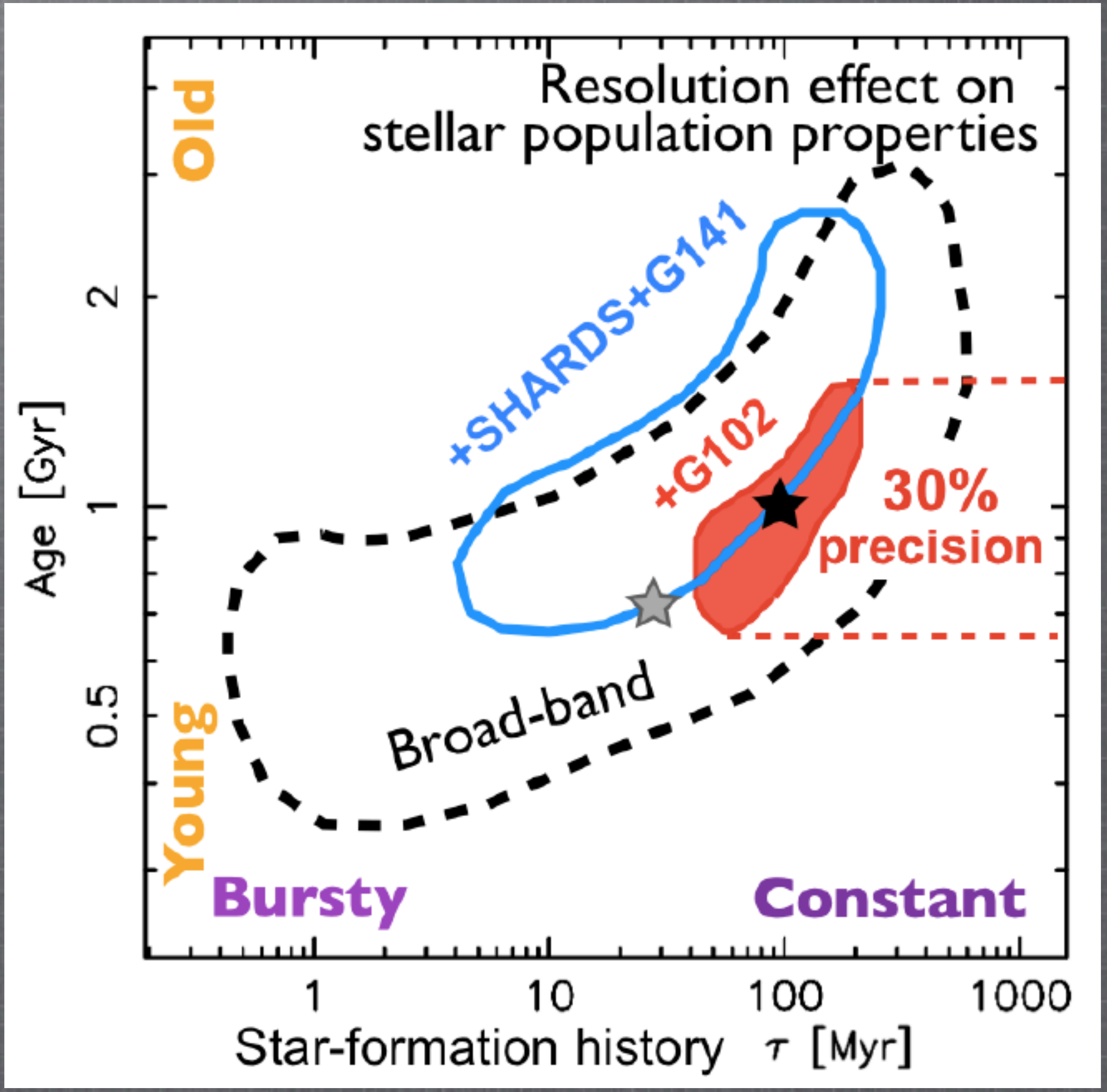


Mass vs. Size 1.4 < z < 3.0



SHARDS + HST/GRISM at 1<z<2





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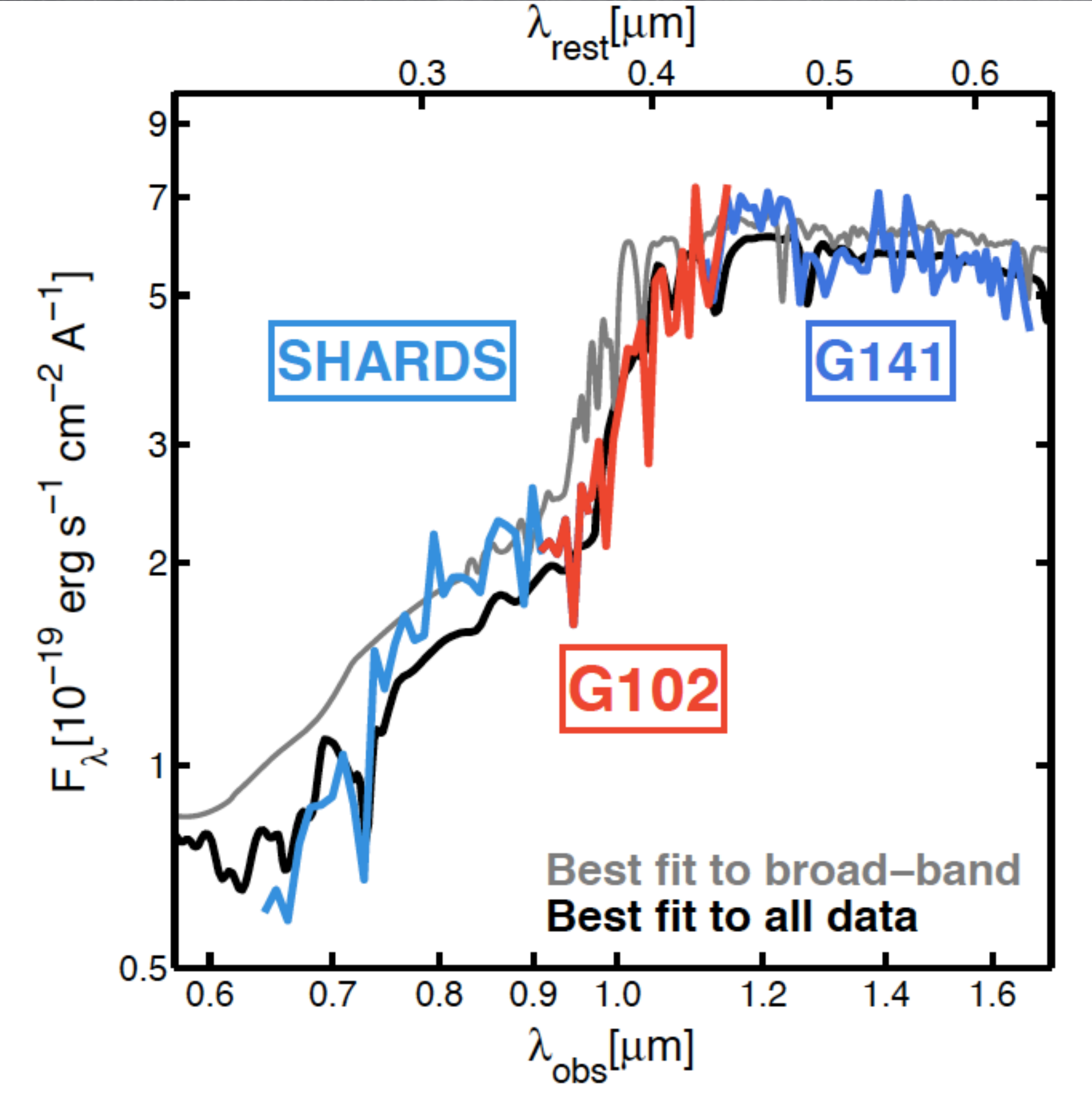

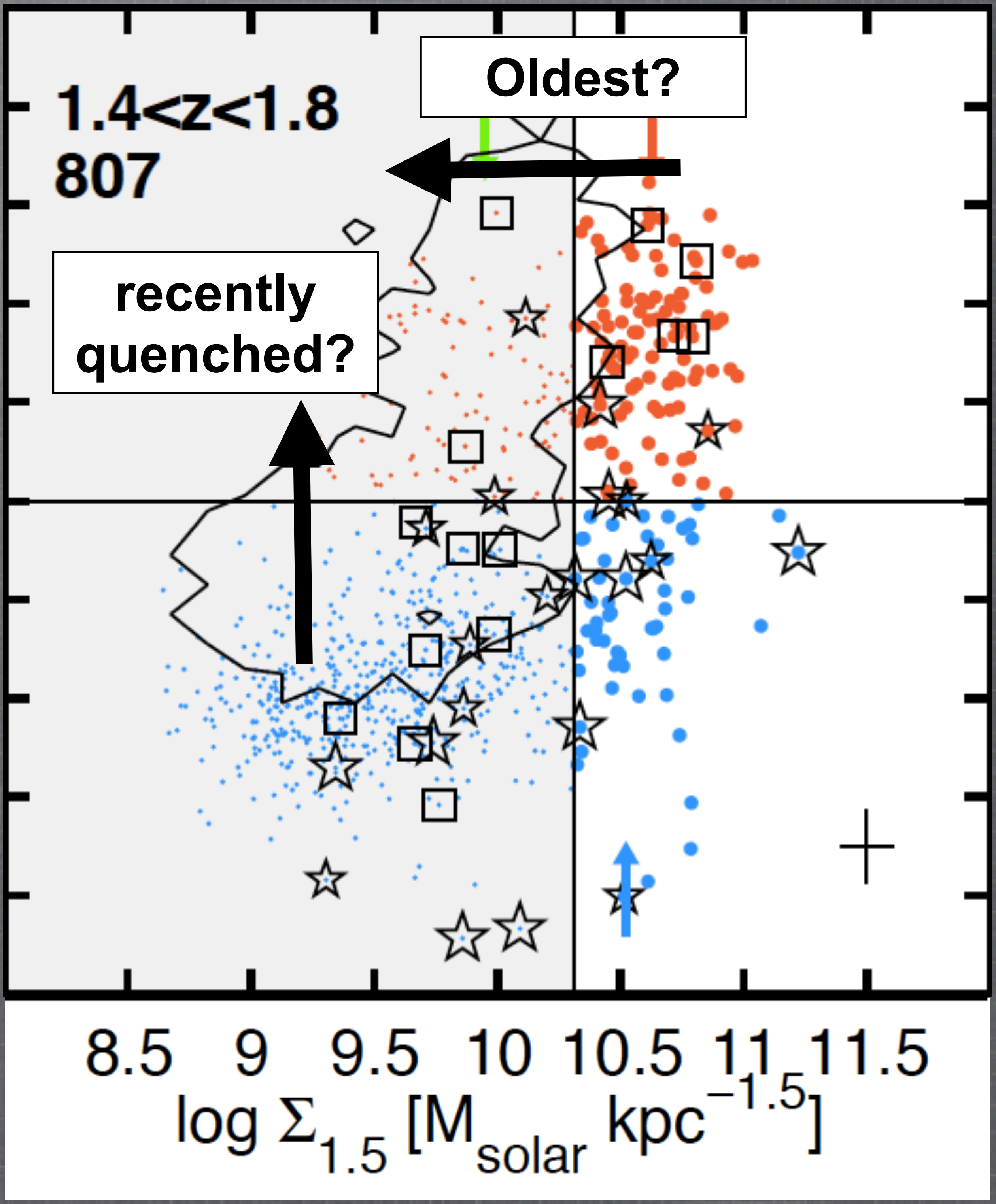

- Precision ages
- Correlation with structural properties/visual appearances

Conclusions from Barro+13

- ✦ We find a population of compact star-forming galaxies co-existing with compact quiescent galaxies at $1.5<z<3$.
- ✦ Both populations present similar properties: sizes, masses, surface mass densities, Sersic profiles.
- ✦ As the number density of cQGs increases since $z=3$, the number of cSFGs decreases in a similar amount suggesting an evolutionary connection if quenching times are 0.3-1Gyr.
- ✦ A surprisingly high fraction of cSFGs are X-ray detected suggesting that AGNs may play a role in quenching the SF.

Conclusions

- We find a population of compact star-forming galaxies co-existing with compact quiescent galaxies at 1.5<z<3.
- As the number density of cQGs increases since z=3, the number of cSFGs decreases in a similar amount suggesting an evolutionary connection if quenching times are 0.3-1Gyr.
- SED-modeling estimated ages for exponentially declining SFHs (or short last event of SF) roughly consistent with elapsed times to quiescence of 0.3-1Gyr.
- Low-mass (low extinction) cSFGs present the shortest SFHs, more massive (dusty) longer SFHs and reduce their extinction in the quenching process?.