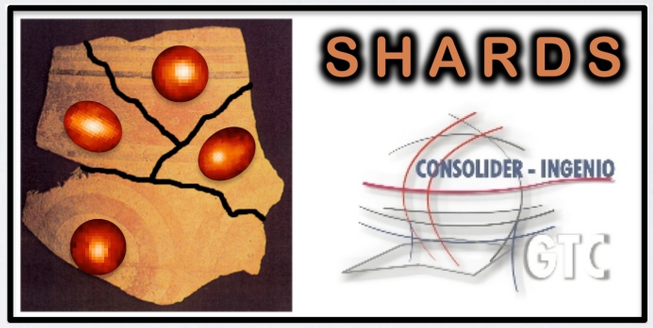
LIVING LA VIDA LOCA: HOW TO ASSEMBLE A MASSIVE DEAD GALAXY BY z=1.0 - 1.5



Helena Domínguez Sánchez

P. G. Pérez-González, P. Esquej, M. C. Eliche-Moral, B. Alcalde + SHARDS team

Dpto. Astrofísica y C.C. Atmósfera, Universidad Complutense de Madrid (UCM)

Bologna, 2nd July 2015

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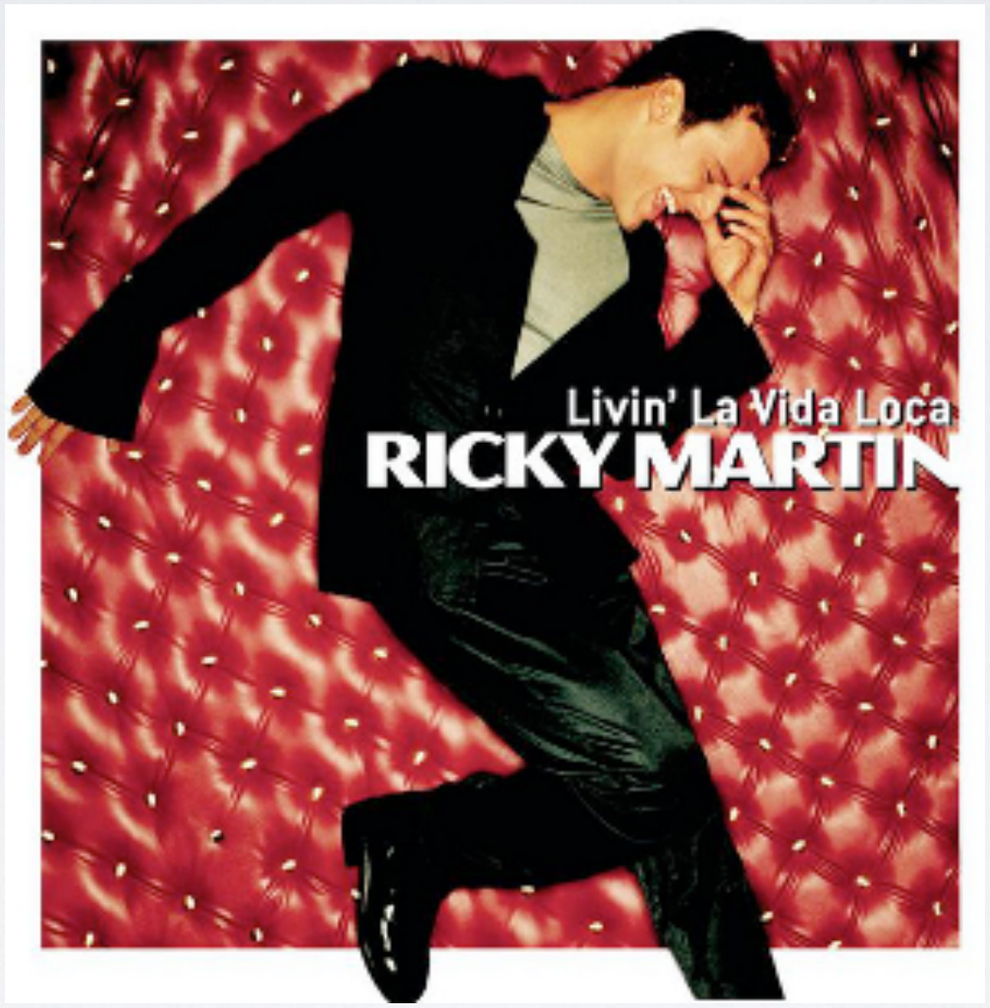

Bologna, 2nd July 2015

OUTLINE

1. Introduction

2. SHARDS data

3. Sample Selection

4. SED-fitting & breaking degeneracies

5. Results: galaxy properties, SFH tracks, MS evolution, number densities

6. Summary & conclusions

INTRODUCTION

- **Quiescent galaxies** dominate the massive end of the local MF: **fundamental** in galaxy formation and evolution

- Existence of massive quiescent galaxies at high z (> 1) in **disagreement with theoretical expectations**

- **Challenge observations**: faint in the optical; important degeneracies using photometry (age-dust-metallicity); spectra very time consuming (~ 12 h per galaxy)

- Up to date works rely on **small samples or stacked spectra** (Cimatti + 2008, Whitaker + 2013, Mendel + 2015)

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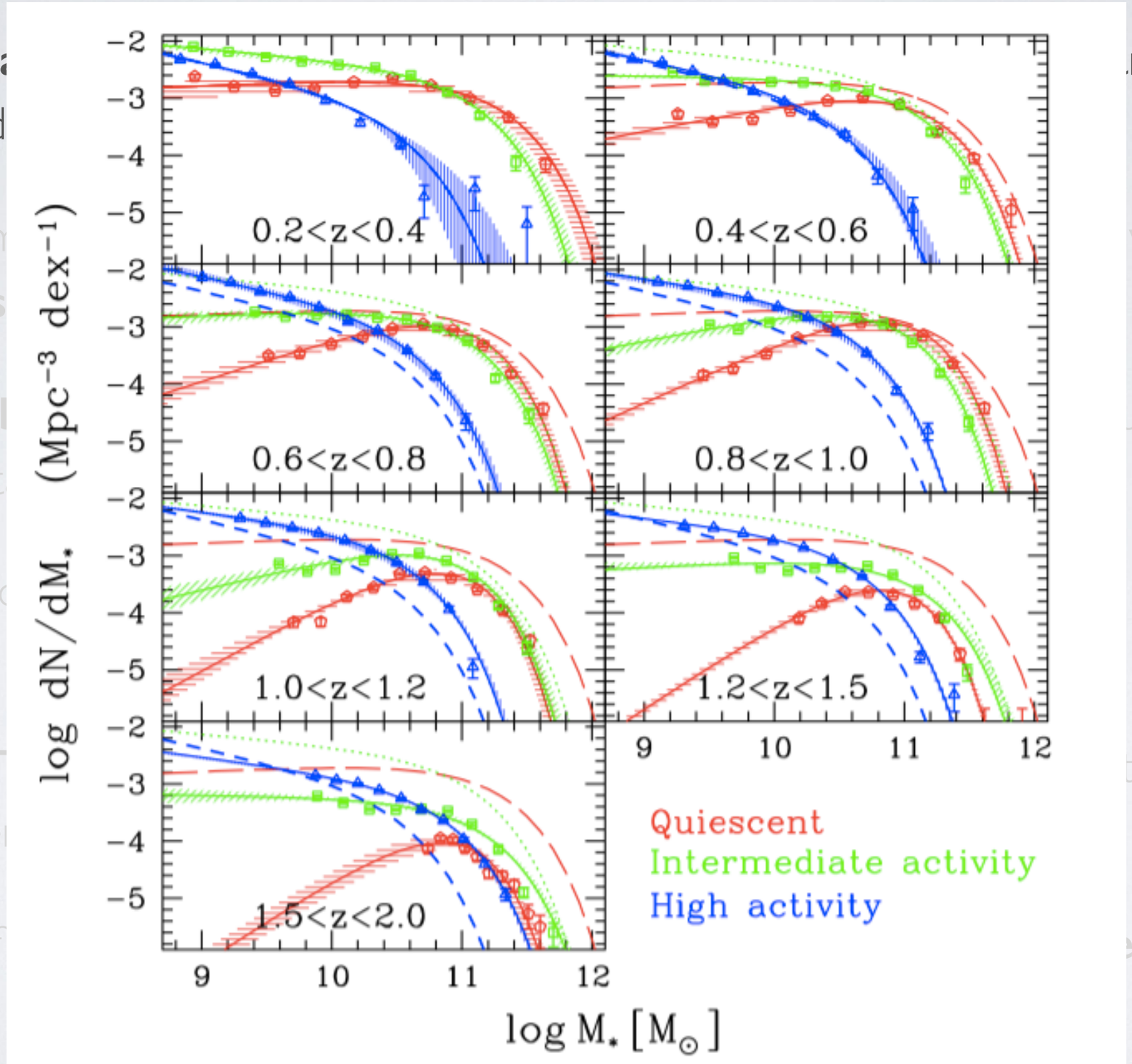

Ilbert+2010

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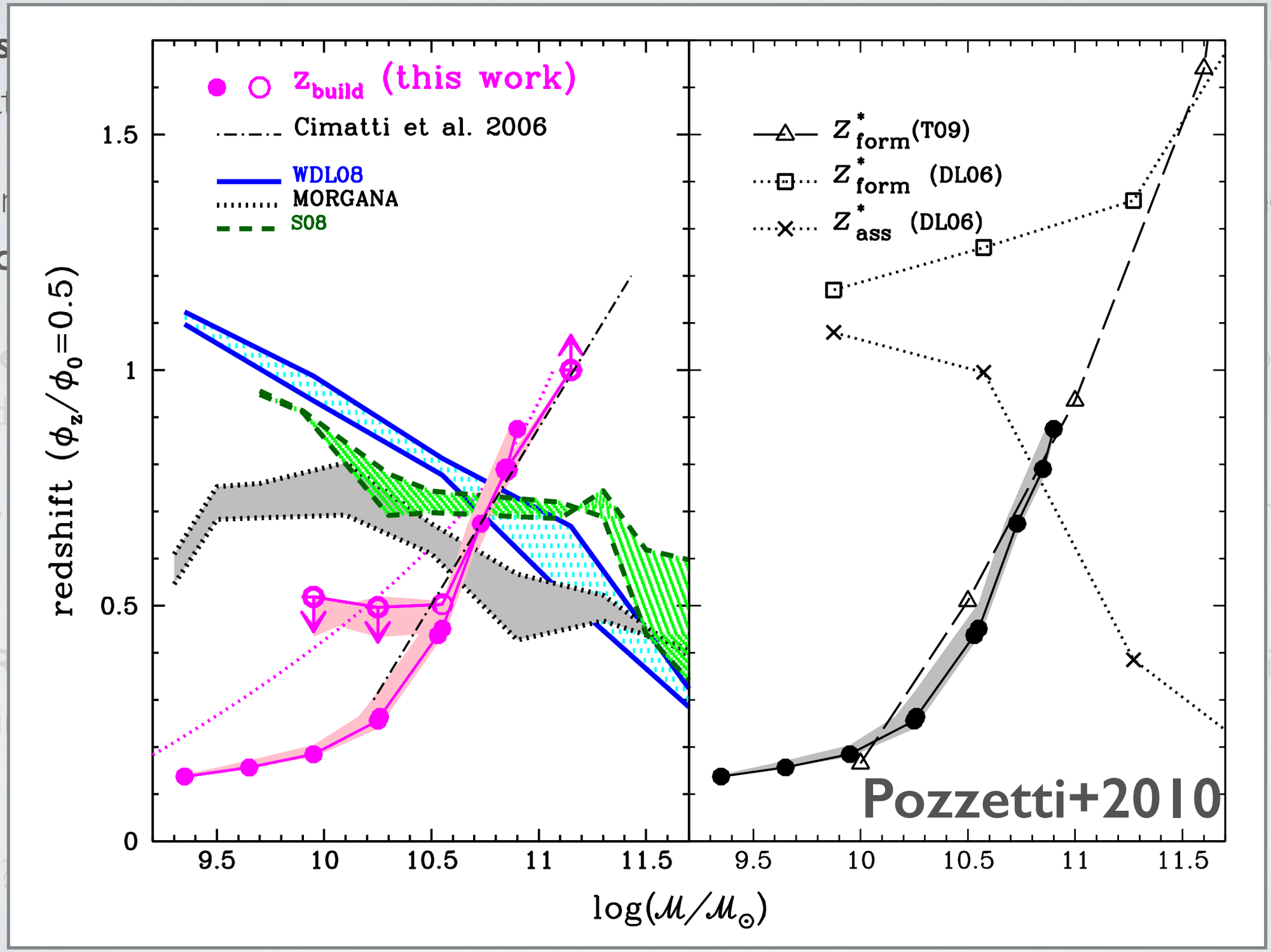

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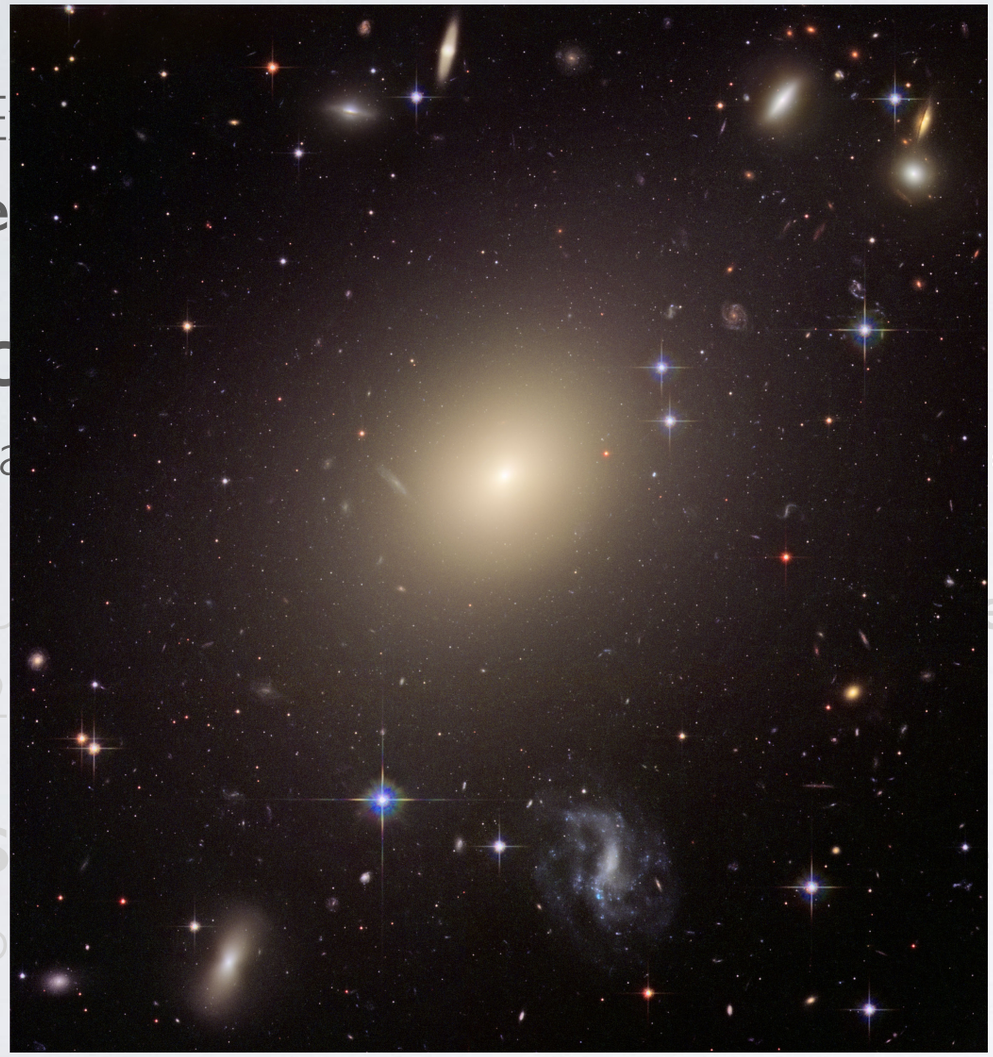

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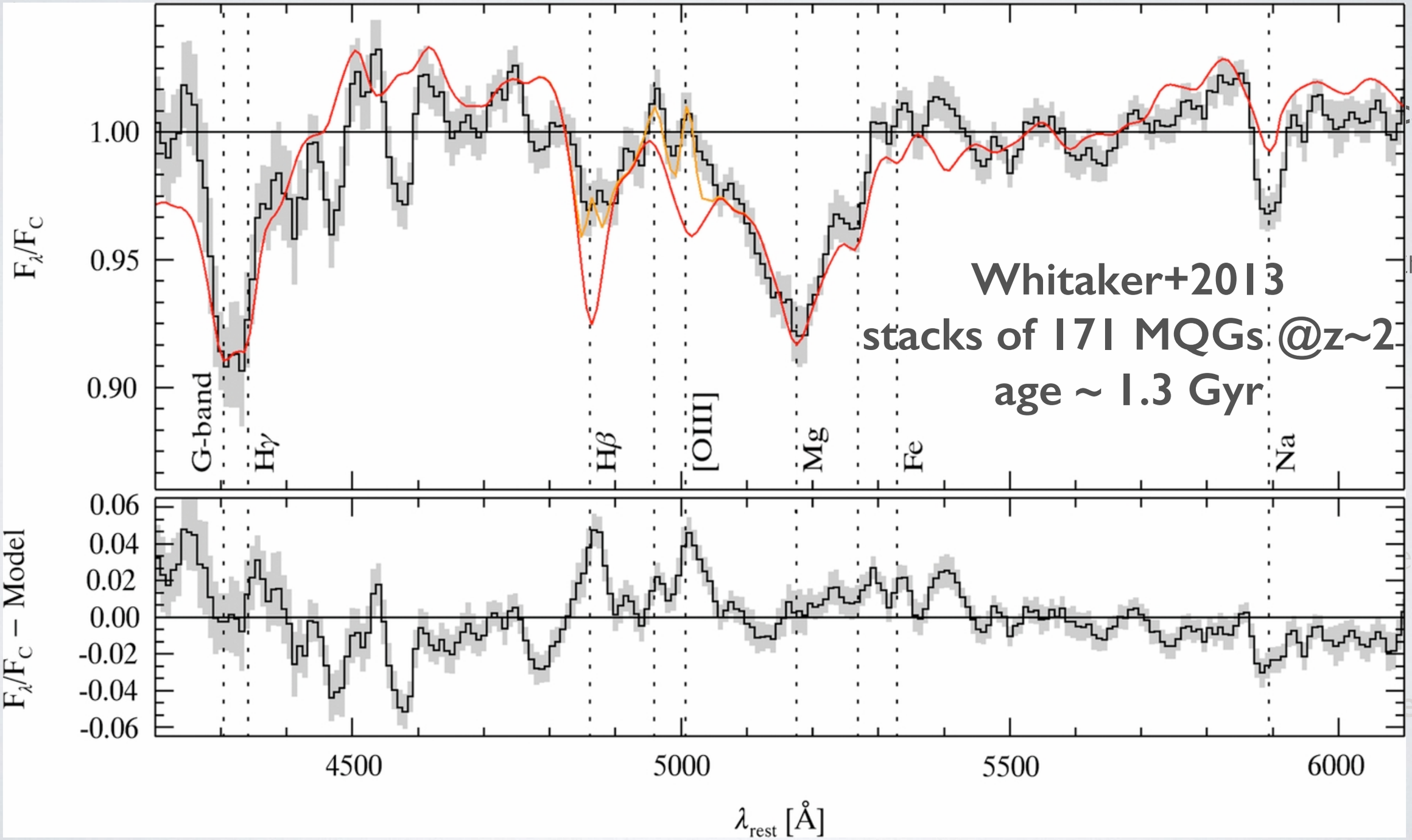

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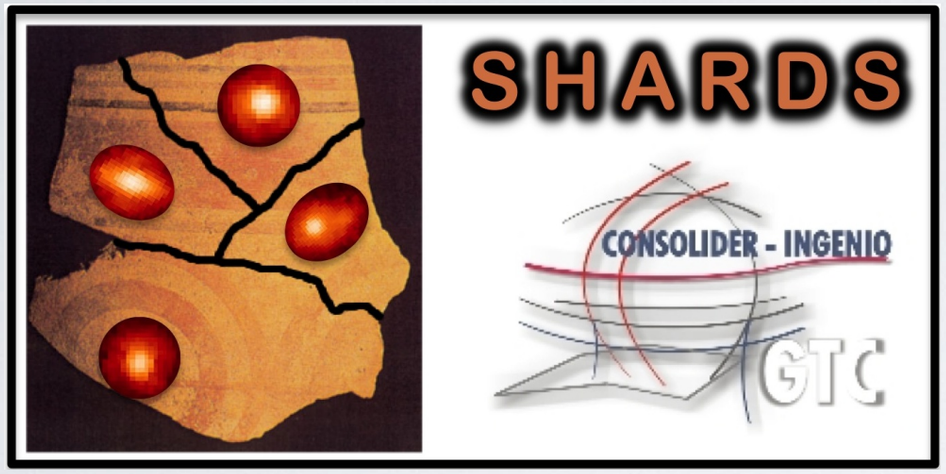
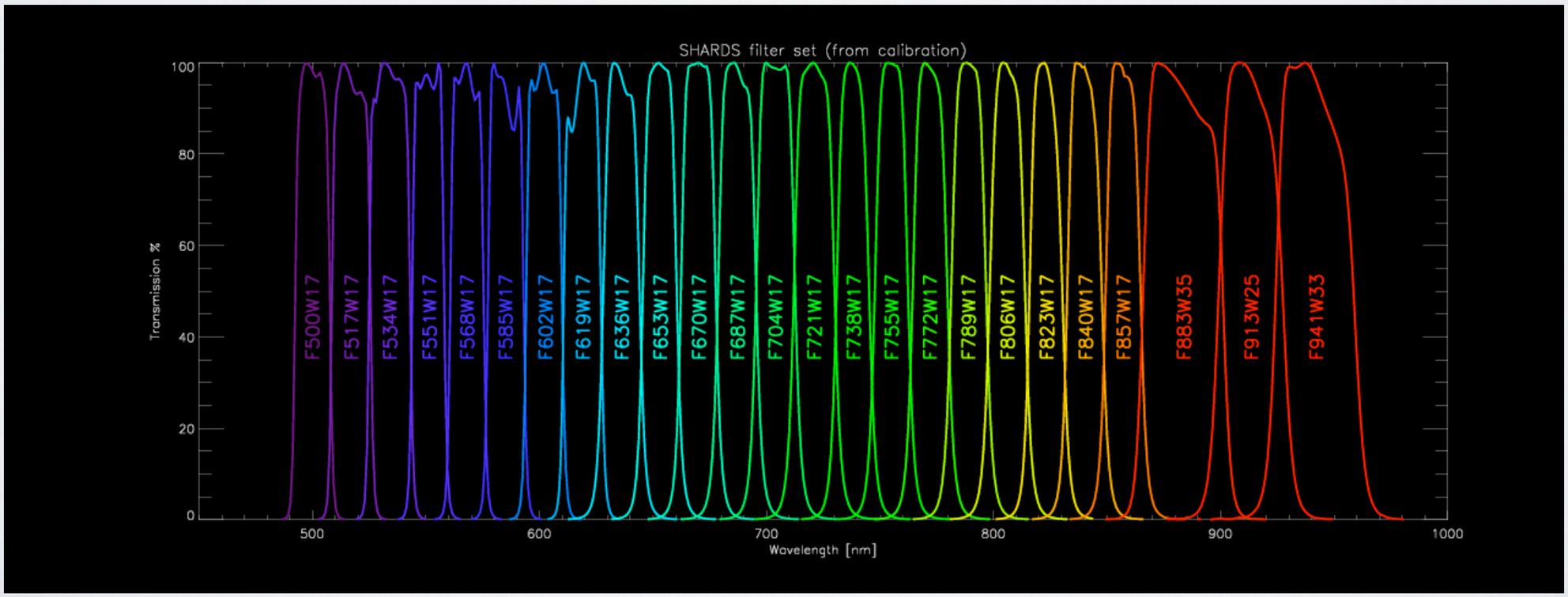
SHARDS

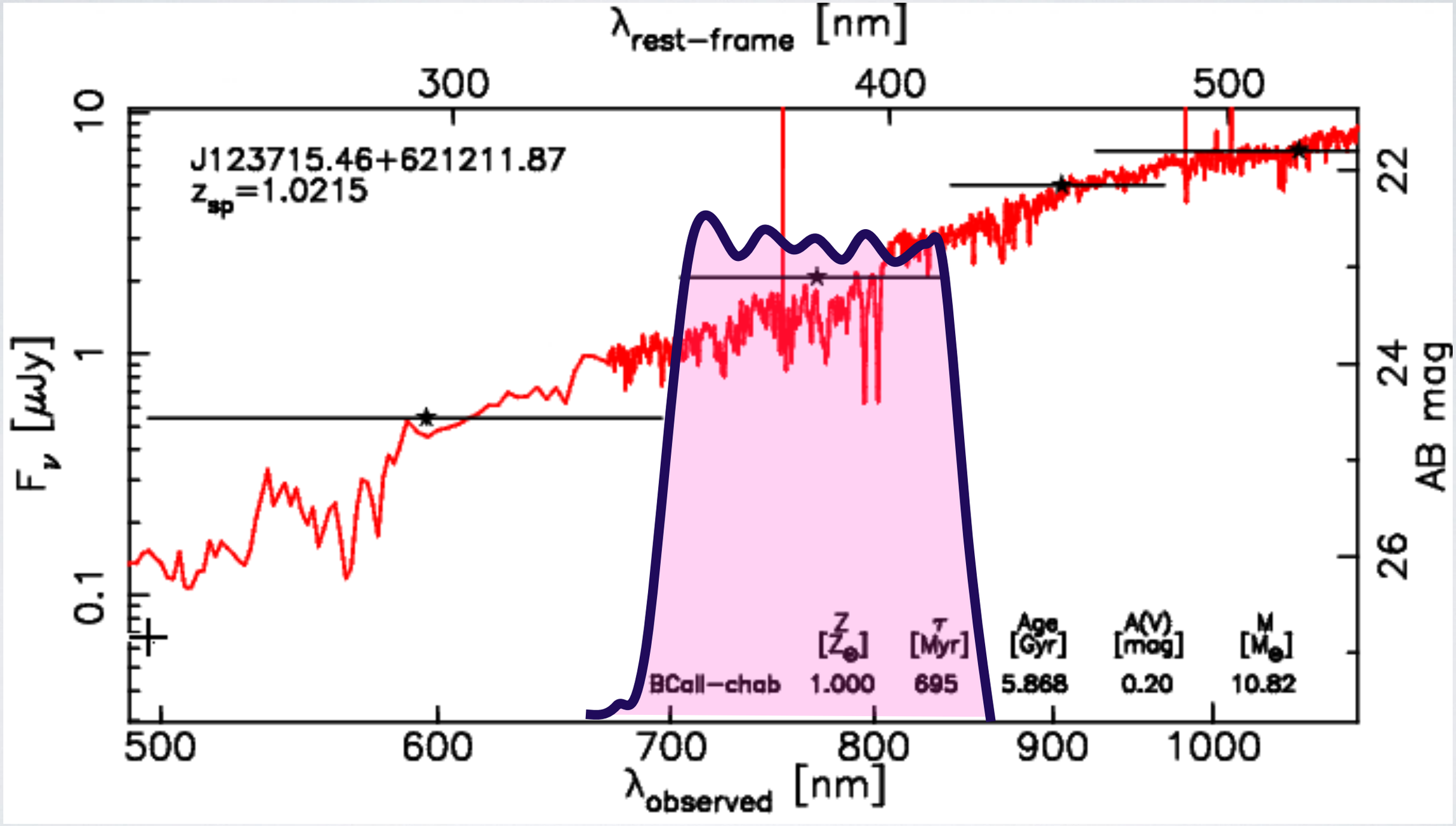
Survey for High-z Absorption Red and Dead Sources



- PI: Pérez-González
- The deepest medium band survey
- ESO/GTC large program
- GOODS-N field
- 25 filters, 500-950 nm, R~50
- 26.5 mag 3σ
- Pérez-González +2013
- http://guaix.fis.ucm.es/~pgperez/SHARDS/



SHARDS: BEYOND CLASSICAL PHOTOMETRY



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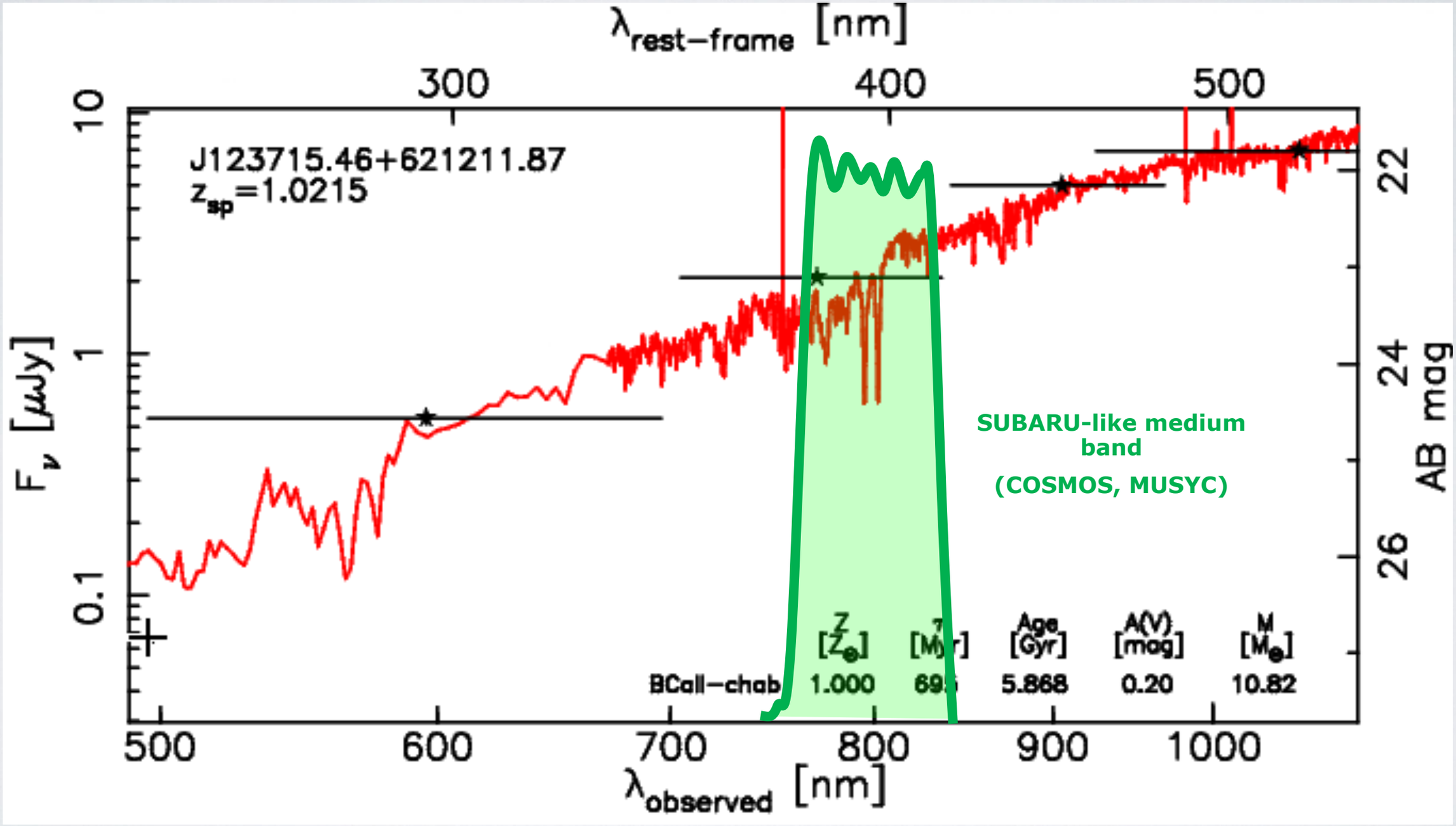

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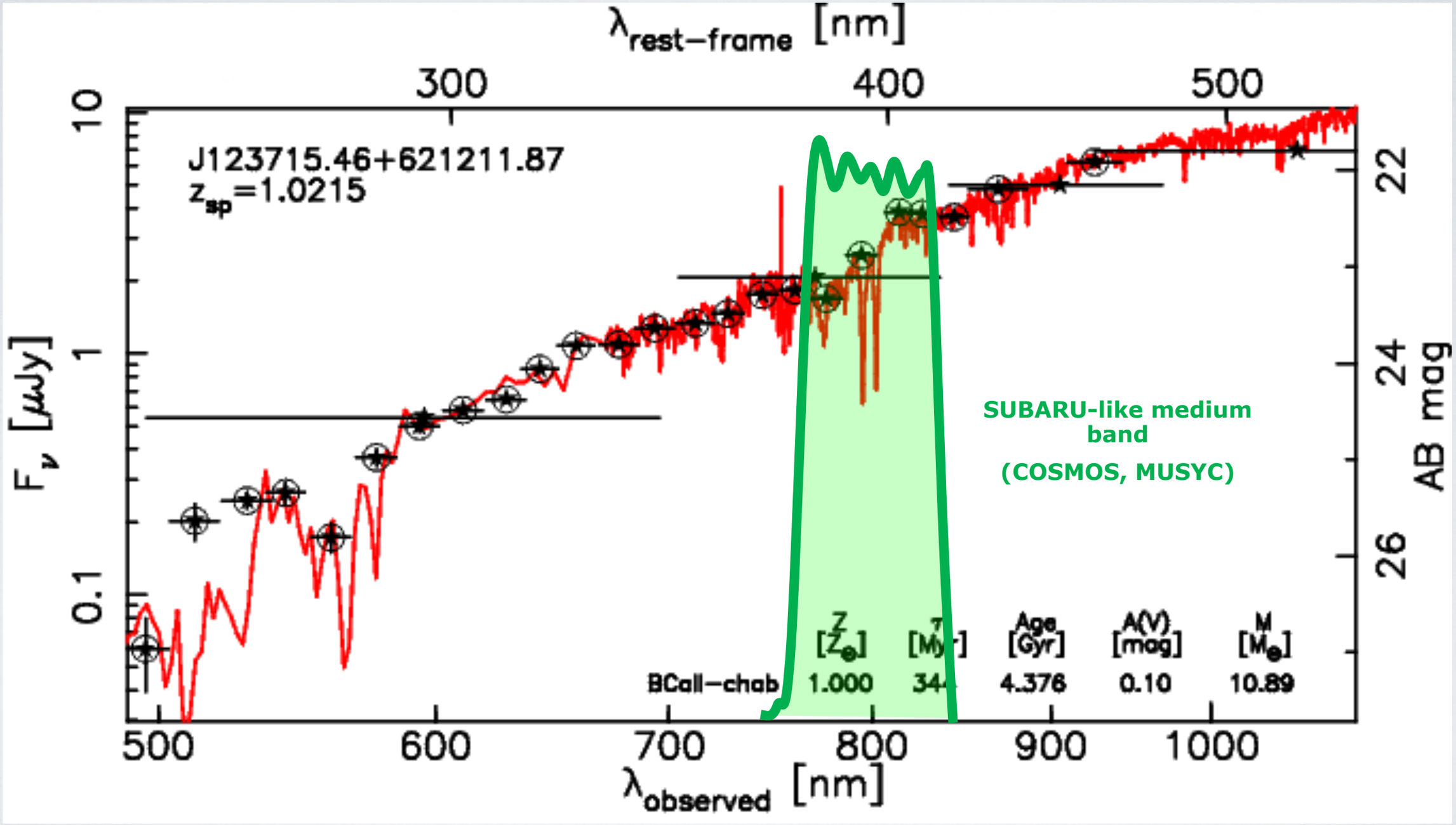

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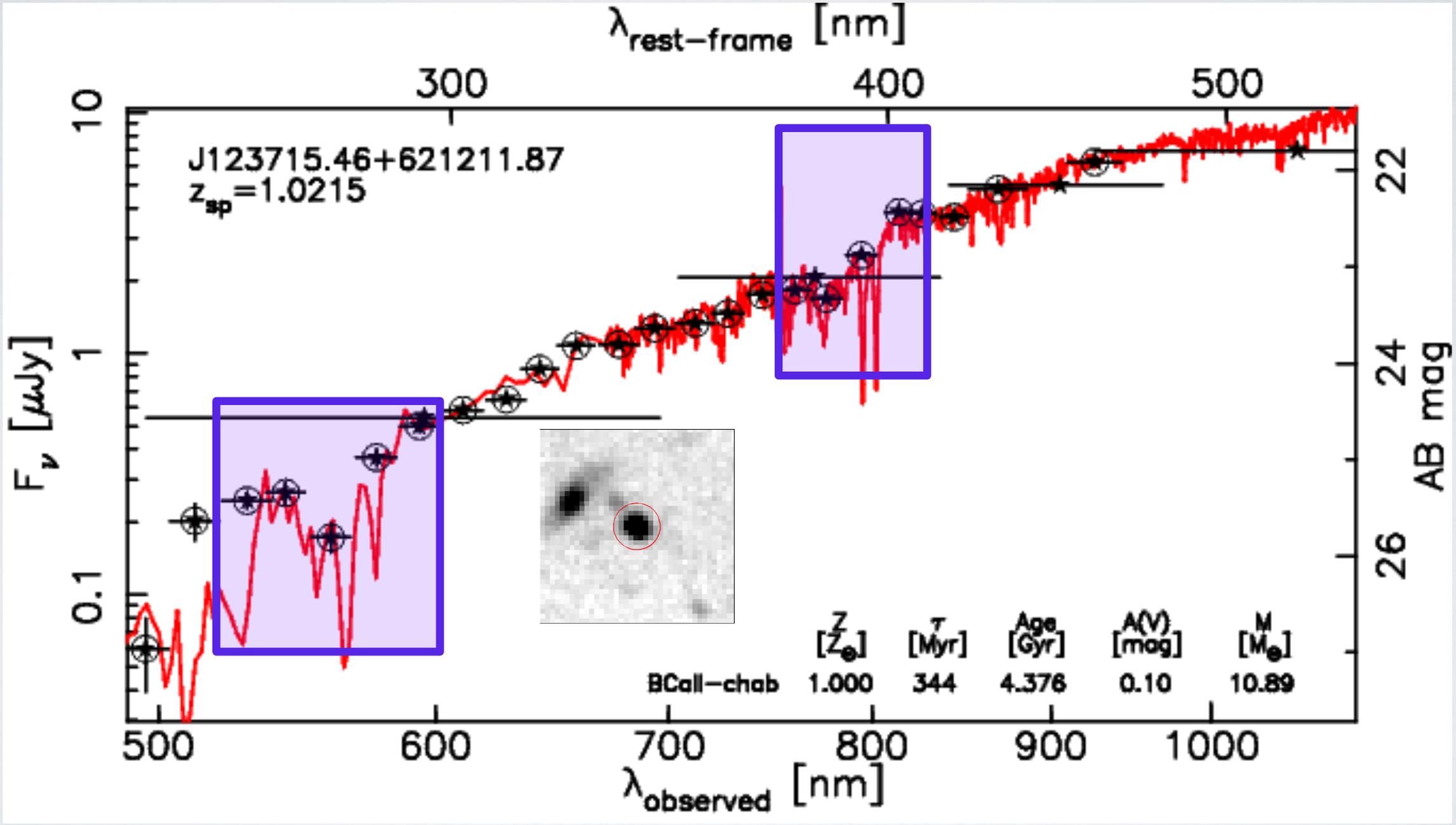
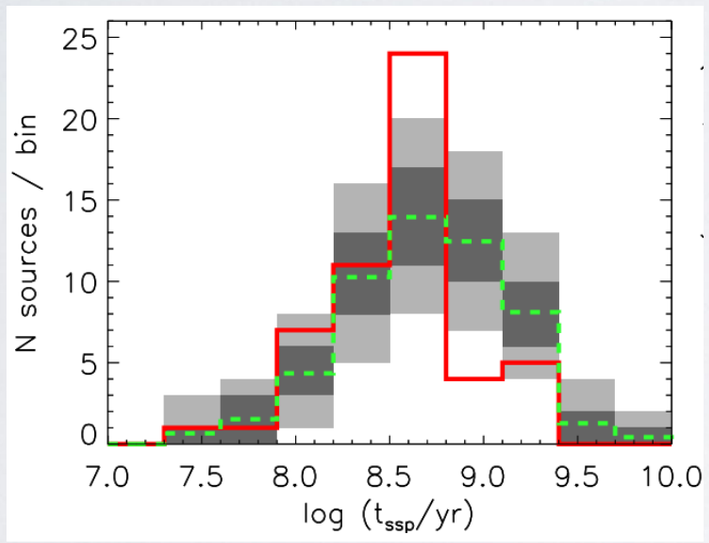
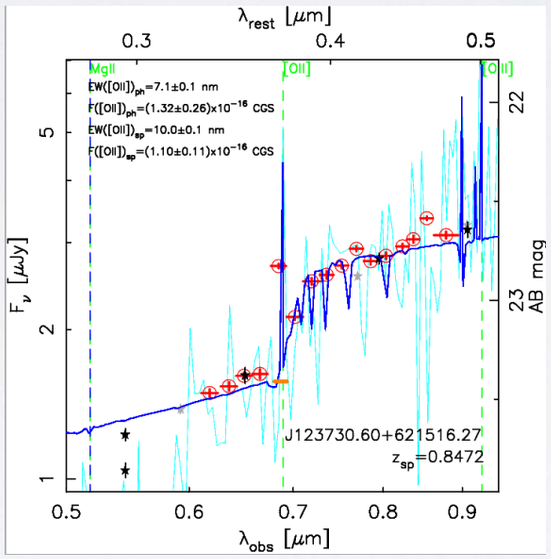
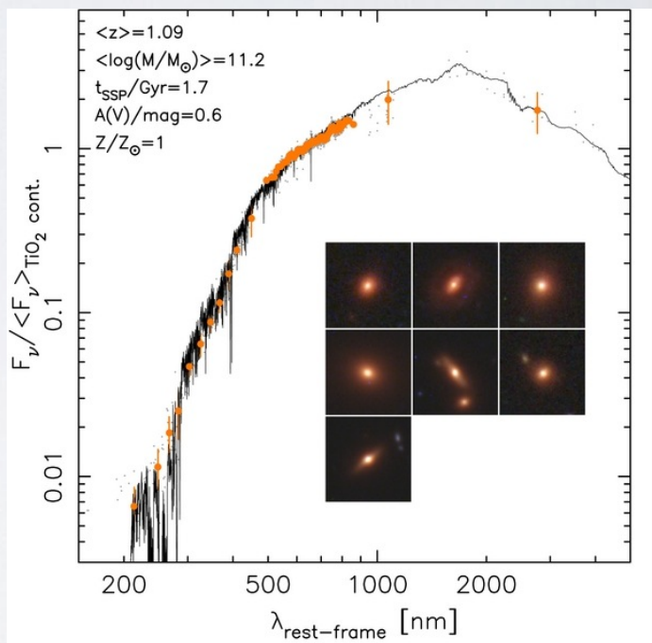


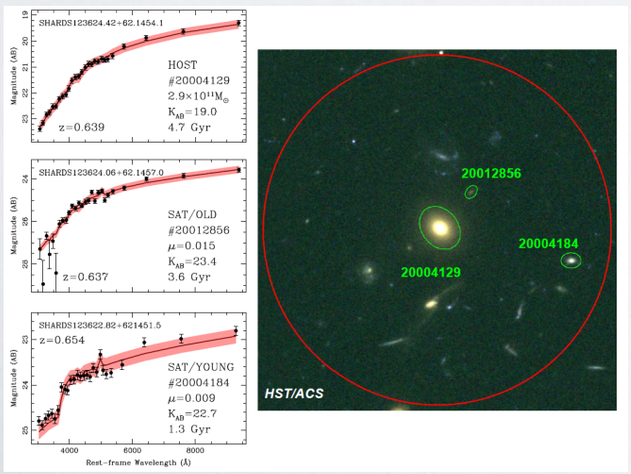
SHARDS: PUBLISHED WORKS

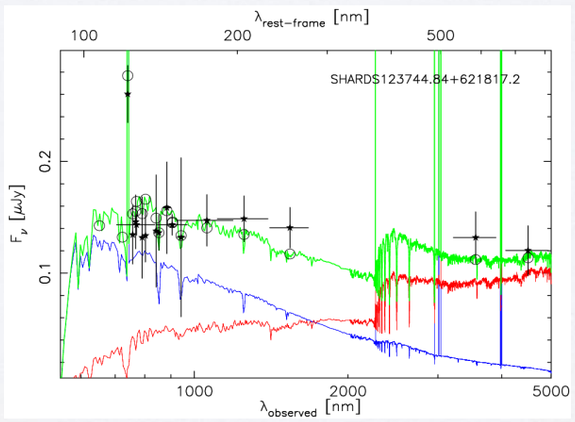
- **AGNs:** Hernán Caballero + 2013, 2014
- **Environment:** Ferreras + 2014
- **Emission line galaxies:** Cava + 2015, submitted
- **Lyα emitters:** Rodríguez Espinosa + 2014
- **IMF:** Martín Navarro + 2015

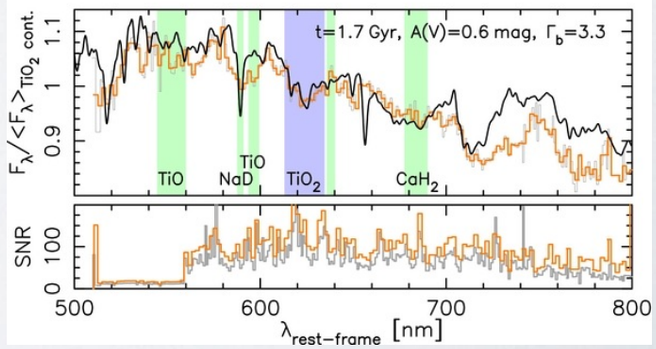












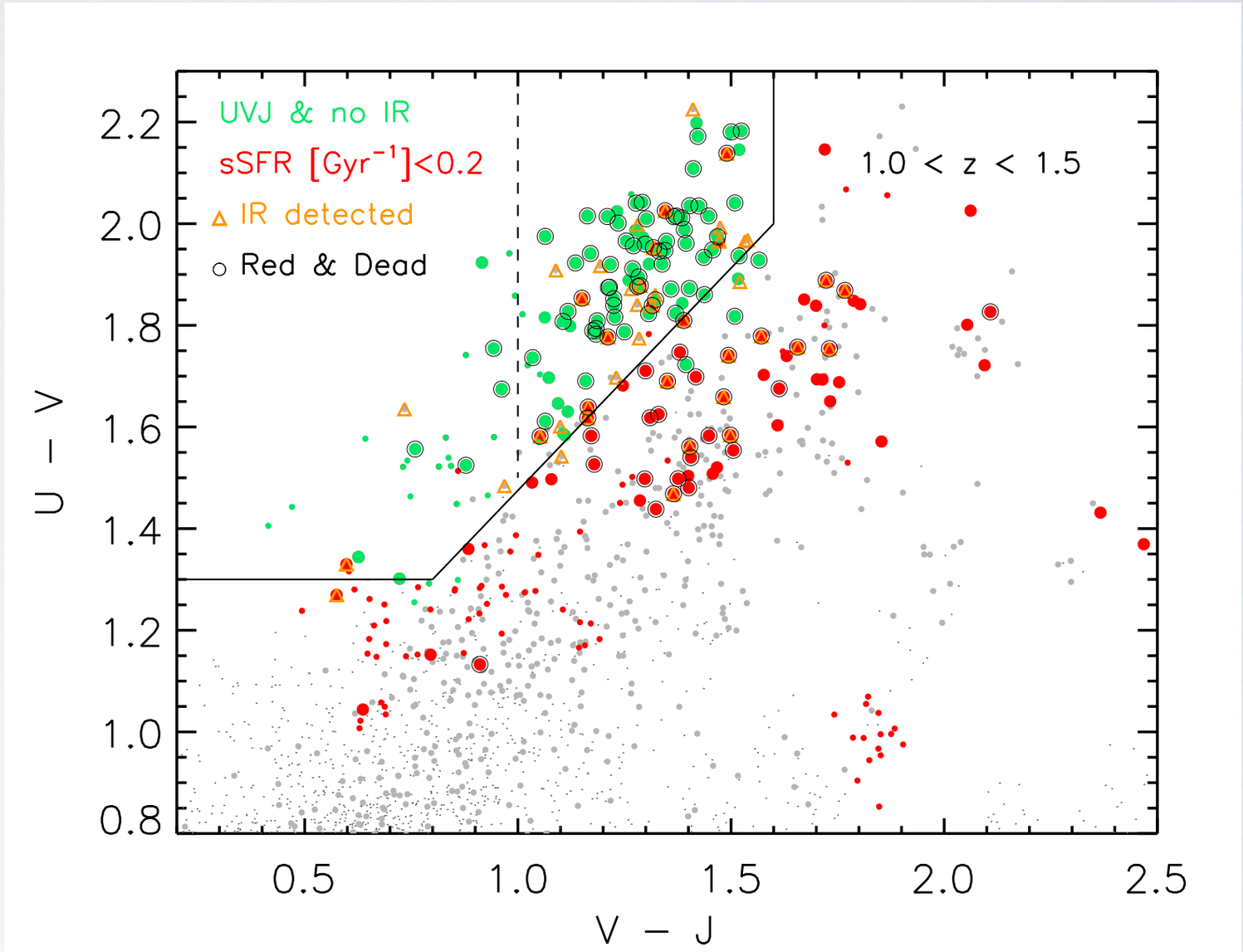
SAMPLE SELECTION

- **GOODS-N, z=1.0-1.5, log M> 10 $M_\odot$** (~ 500 galaxies)
- **UVJ** quiescent region + **No IR** detection (65)
- **sSFR < 0.2 Gyr $^{-1}$** outside UVJ quiescent region (39)

SFR(2800 + IR) or SFR(2800_{corr})

IRX-β relation for low IR emitters:

IRX=8.09 +3.02xβ



Final clean sample: **104 galaxies** (65 UVJ + 39 sSFR)

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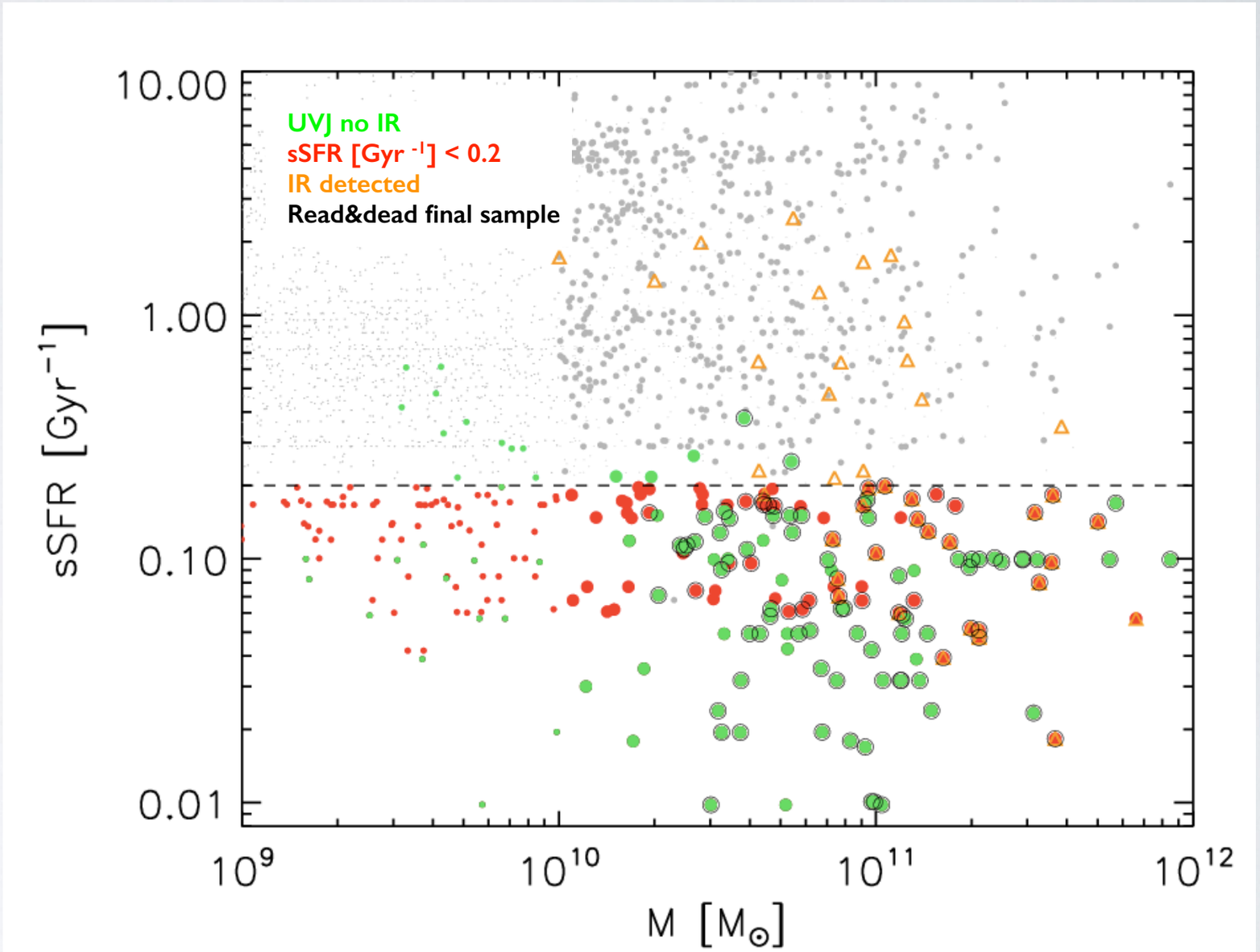

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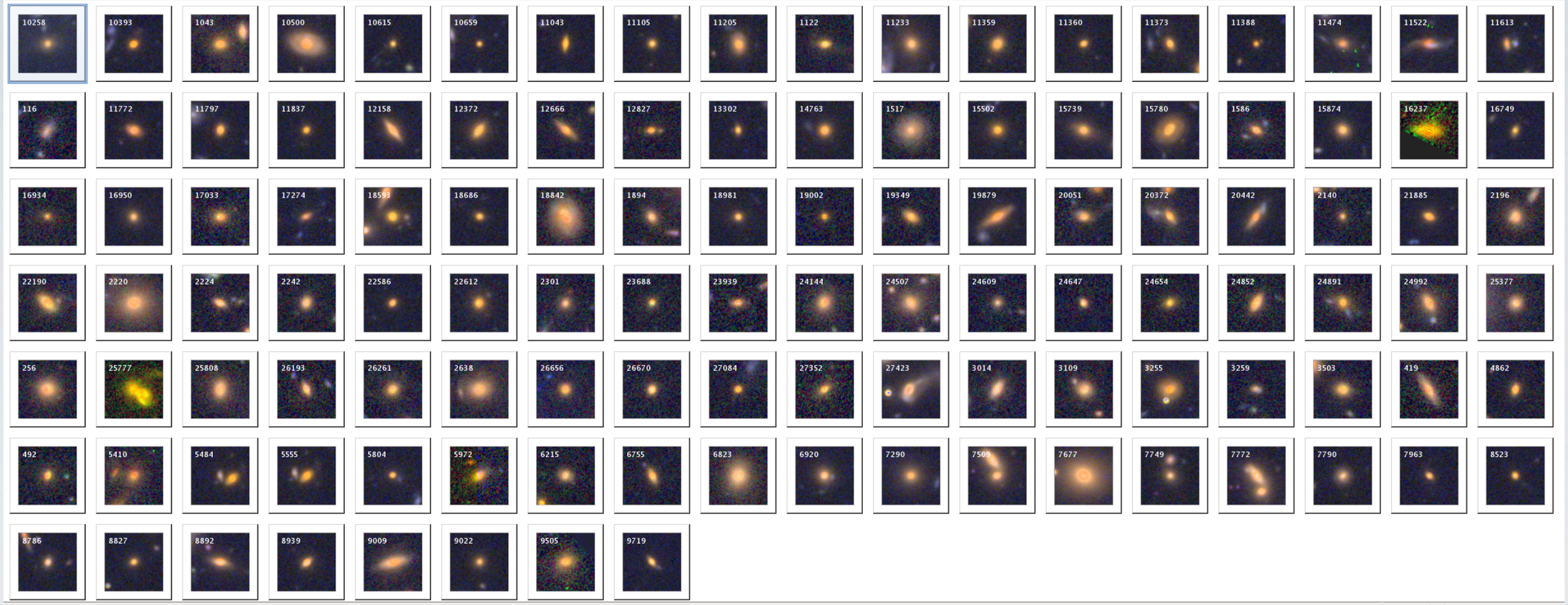

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SED-FITTING

- Construct **best possible SEDs:**

  SHARDS (0.4-0.9 μm**) + WFC3/HST GRISM (**G102, 0.9-1.1 μm, 60%; G141, 1.1-1.6 μm, 70 %) + **Broad Band** (RB-database)

- z-spec/z-phot from RB database ($\Delta z/(1+z)=0.0035$)

- **SFR(t)** $\propto t\, e^{-t/\tau}$

- BC03 models, Calzetti+2000 ext. law, Krou IMF

- **Synthesizer** code: **t (Gyr)** =[0.04 - 6.3] (steps of 0.1 dex)

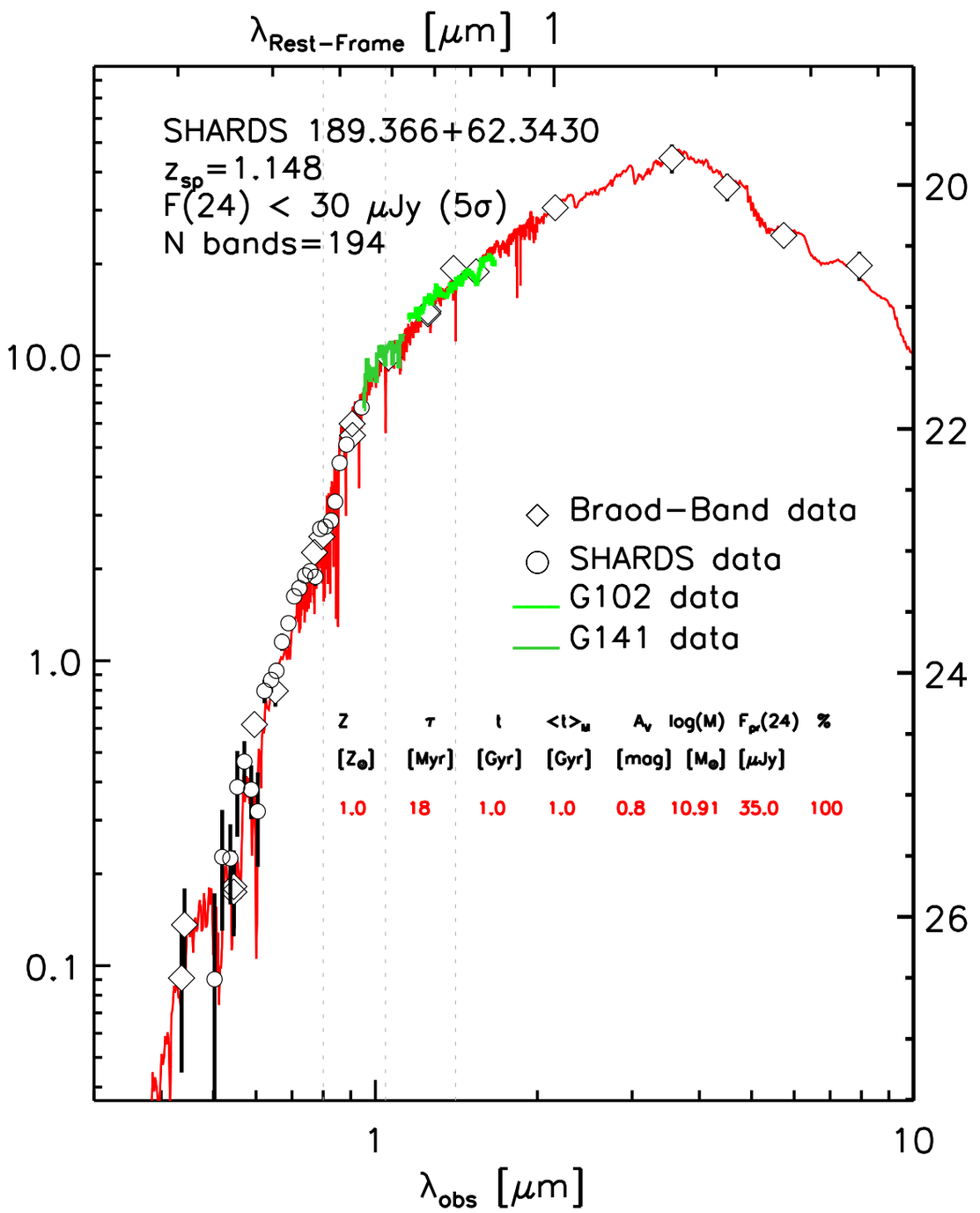
  τ (Myr) =[3 - 10000] (steps of 0.1 dex)

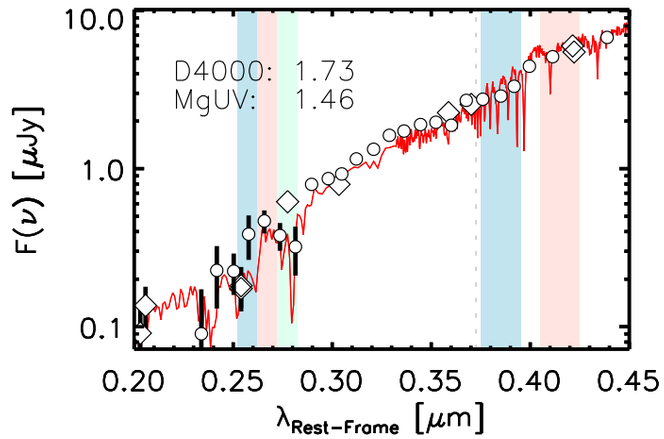
  A_V (mag) =[0 - 1.5] (step of 0.1 mag)

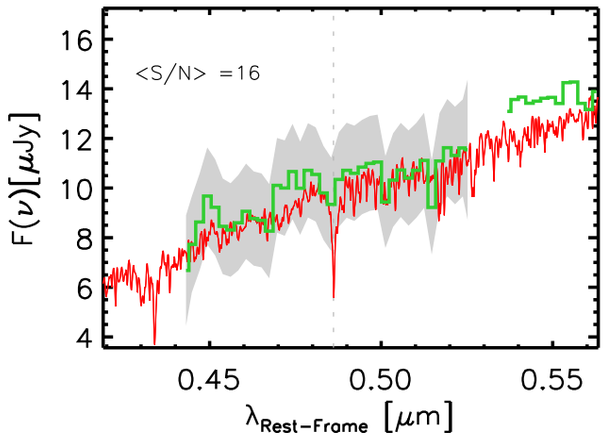
  $Z/Z_\odot$ = [0.4, 1.0, 2.5]

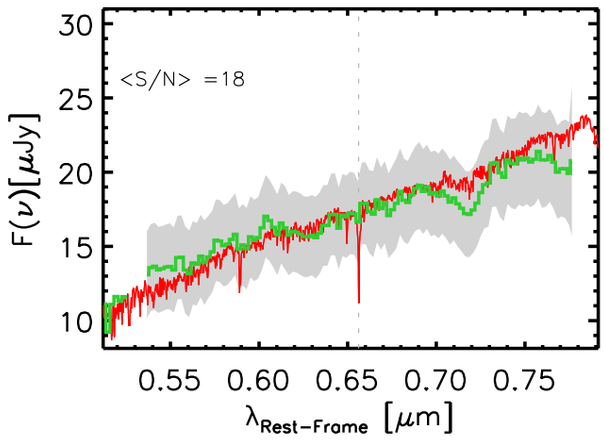
- 1000 **Montecarlo simulations & clusters** in **t-τ** parameter space with k-means method

SED-FITTING RESULTS









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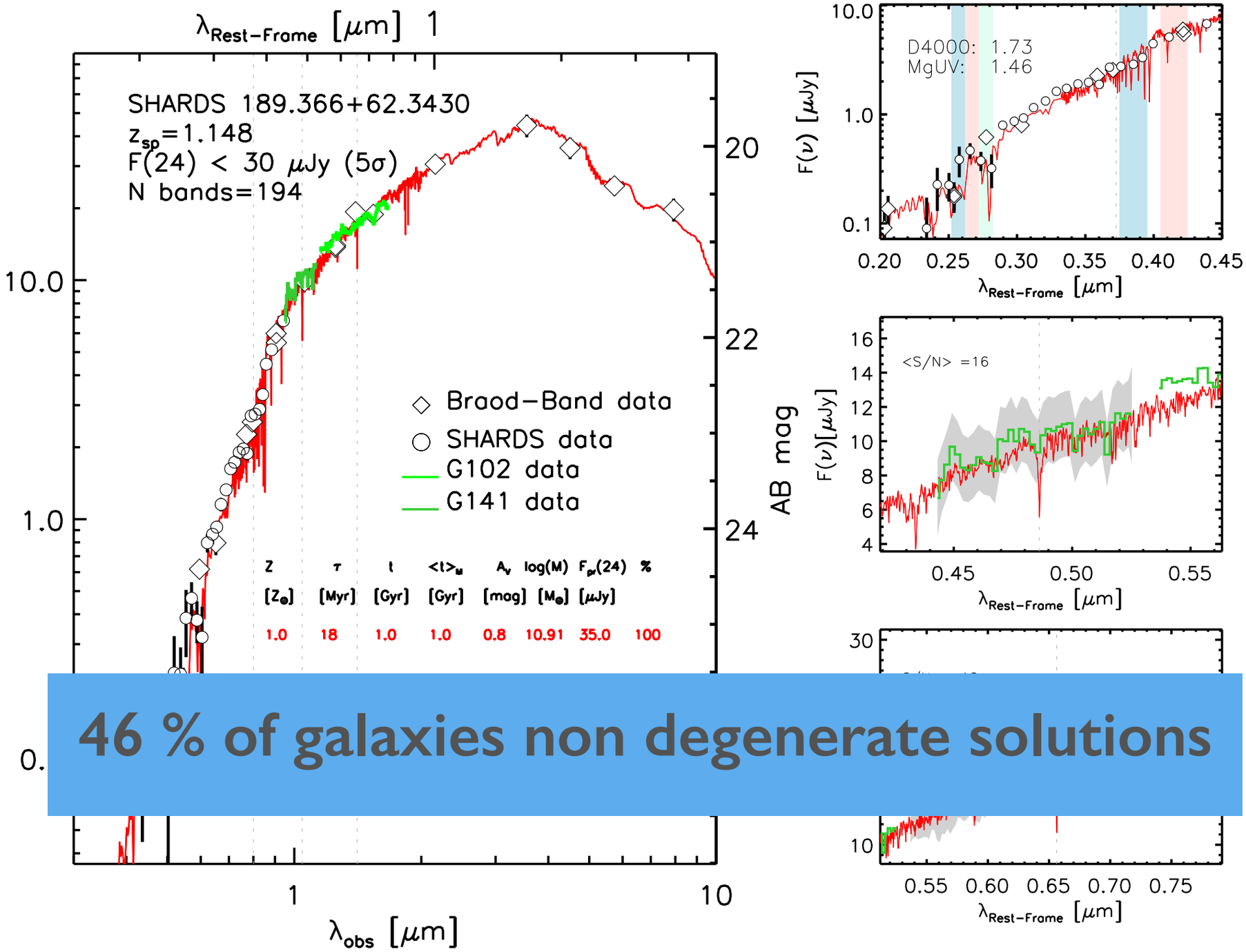

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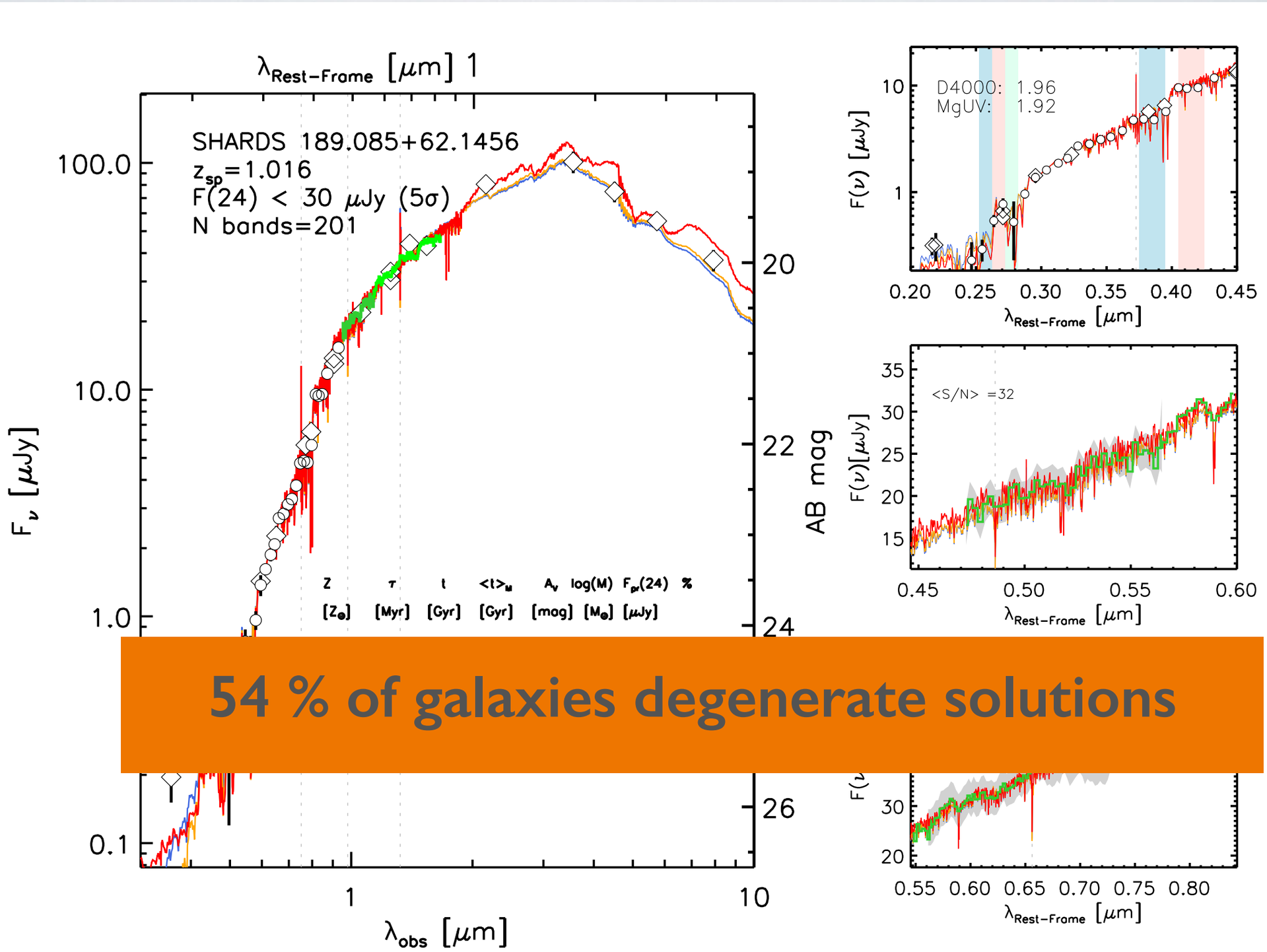

54 % of galaxies degenerate solutions

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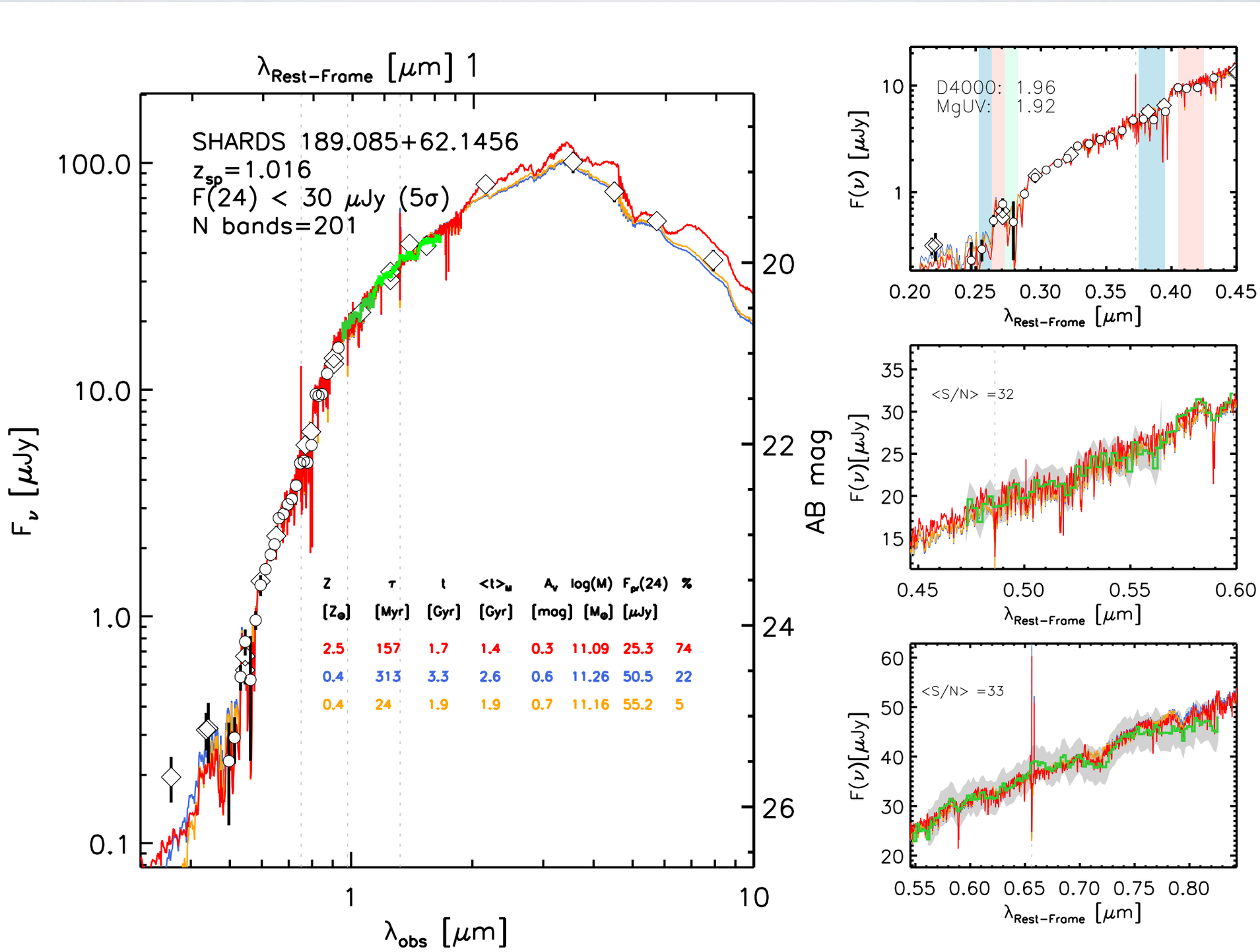
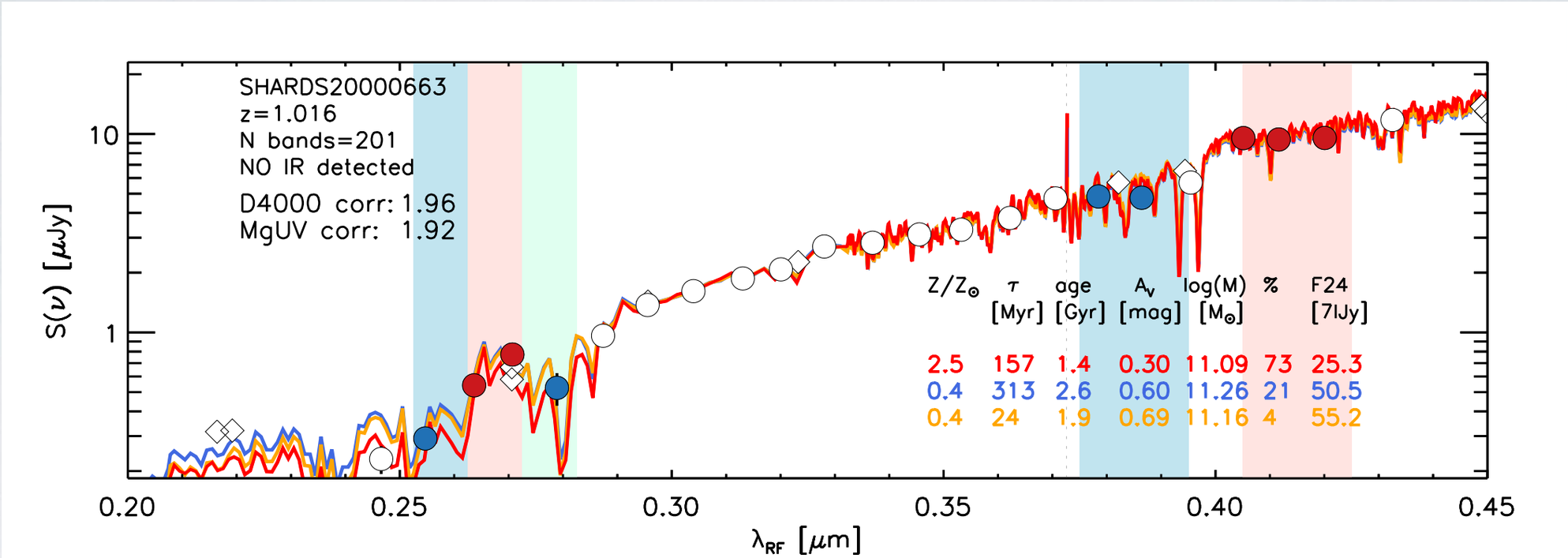
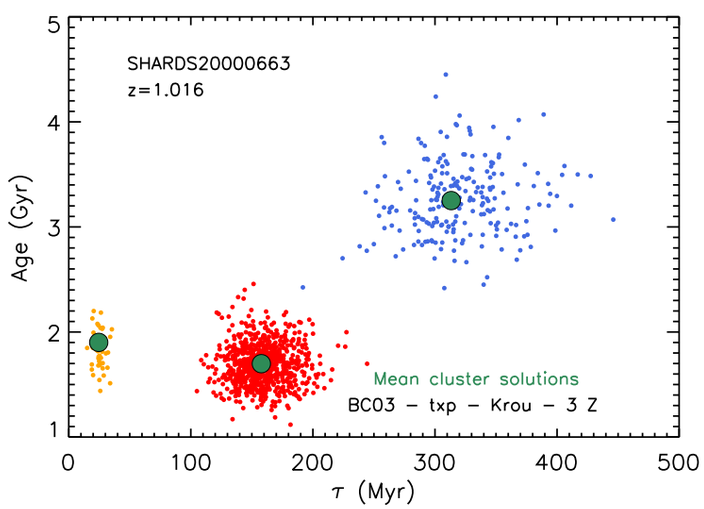
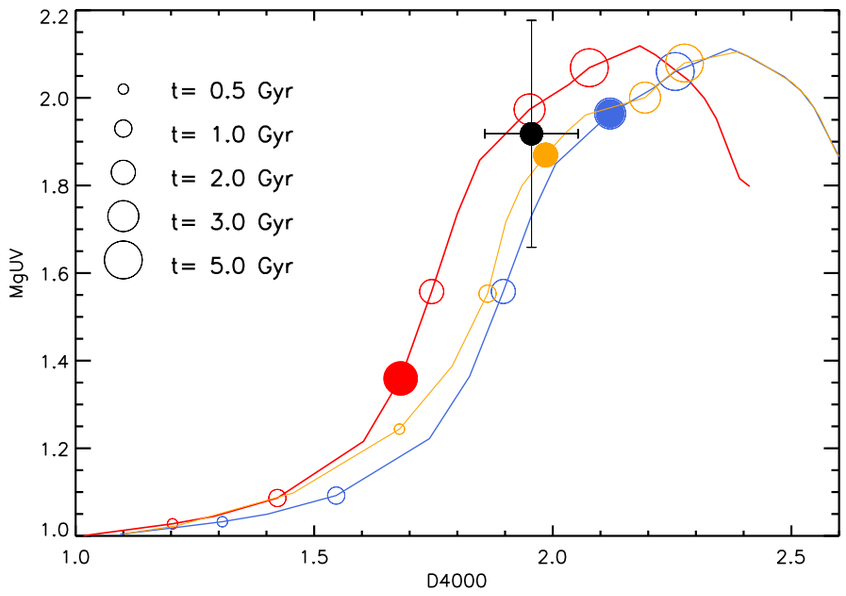


BREAKING DEGENERACIES:
D4000 & MGUV, THE POWER OF SHARDS DATA







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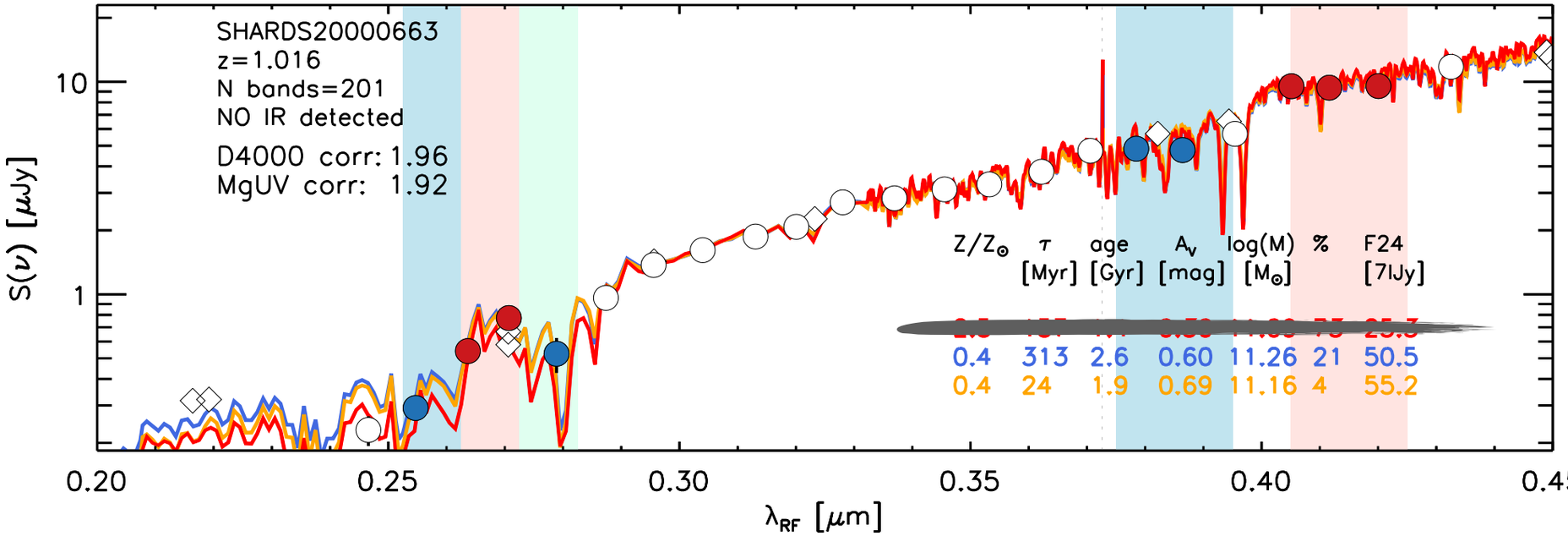

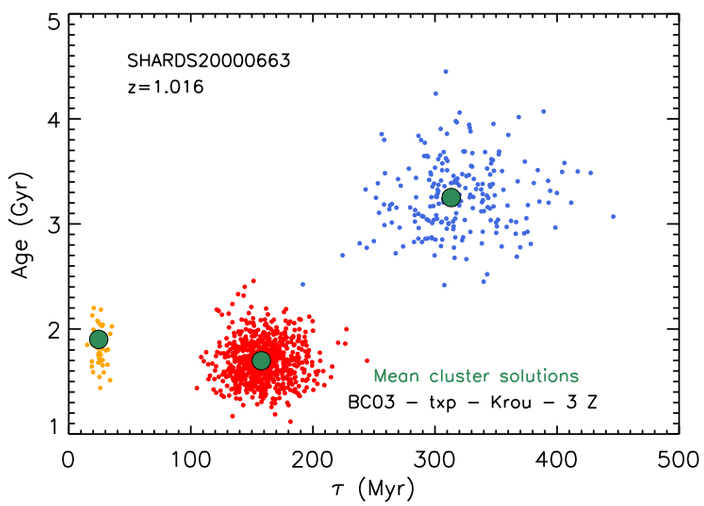

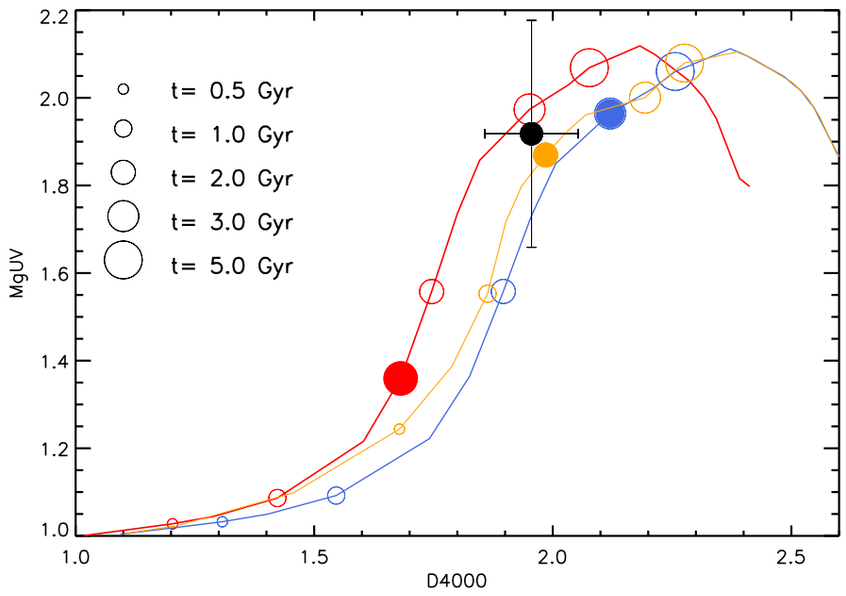

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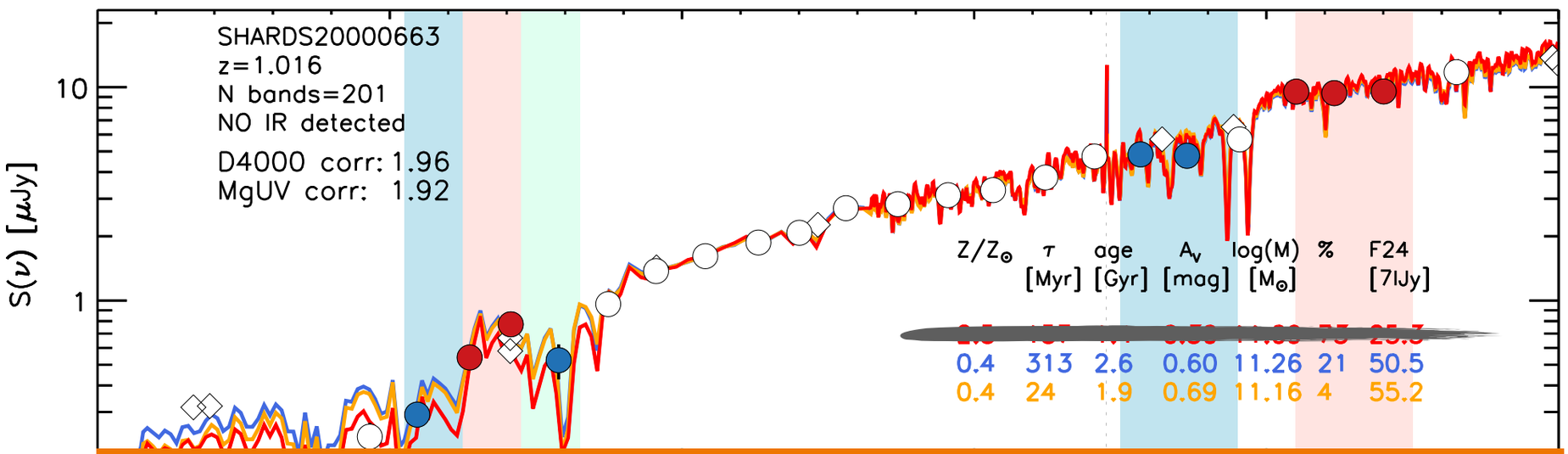
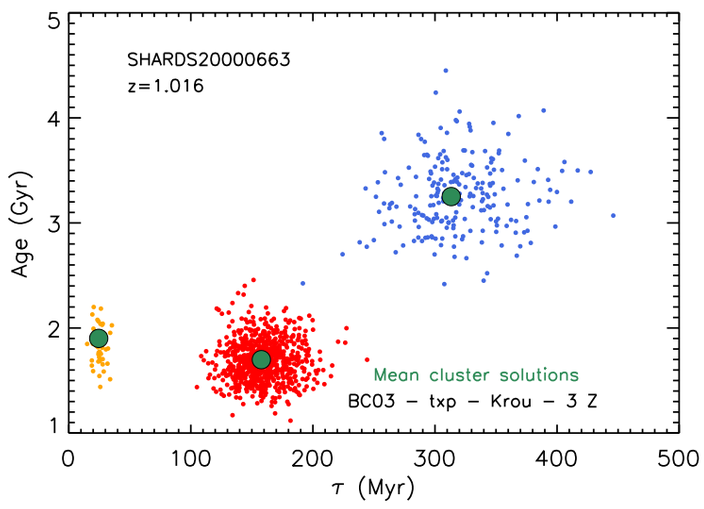
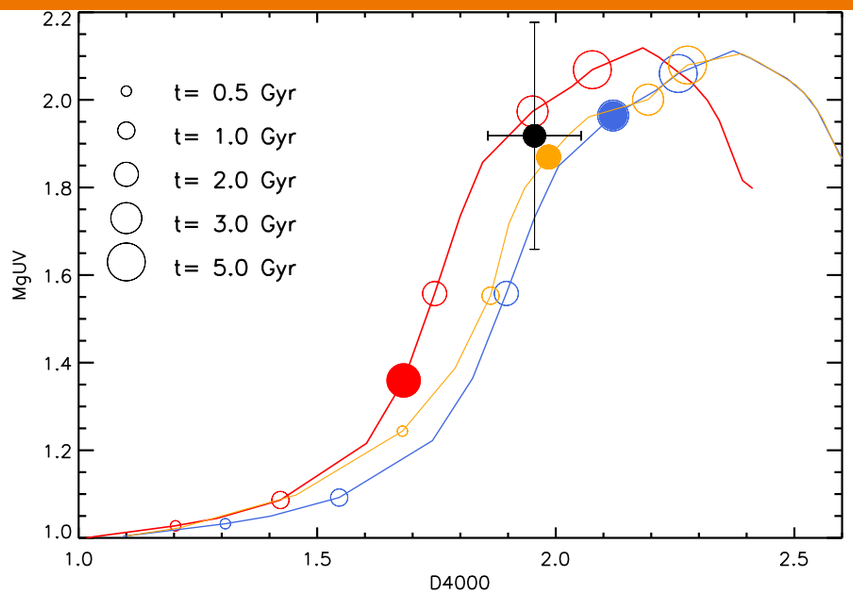


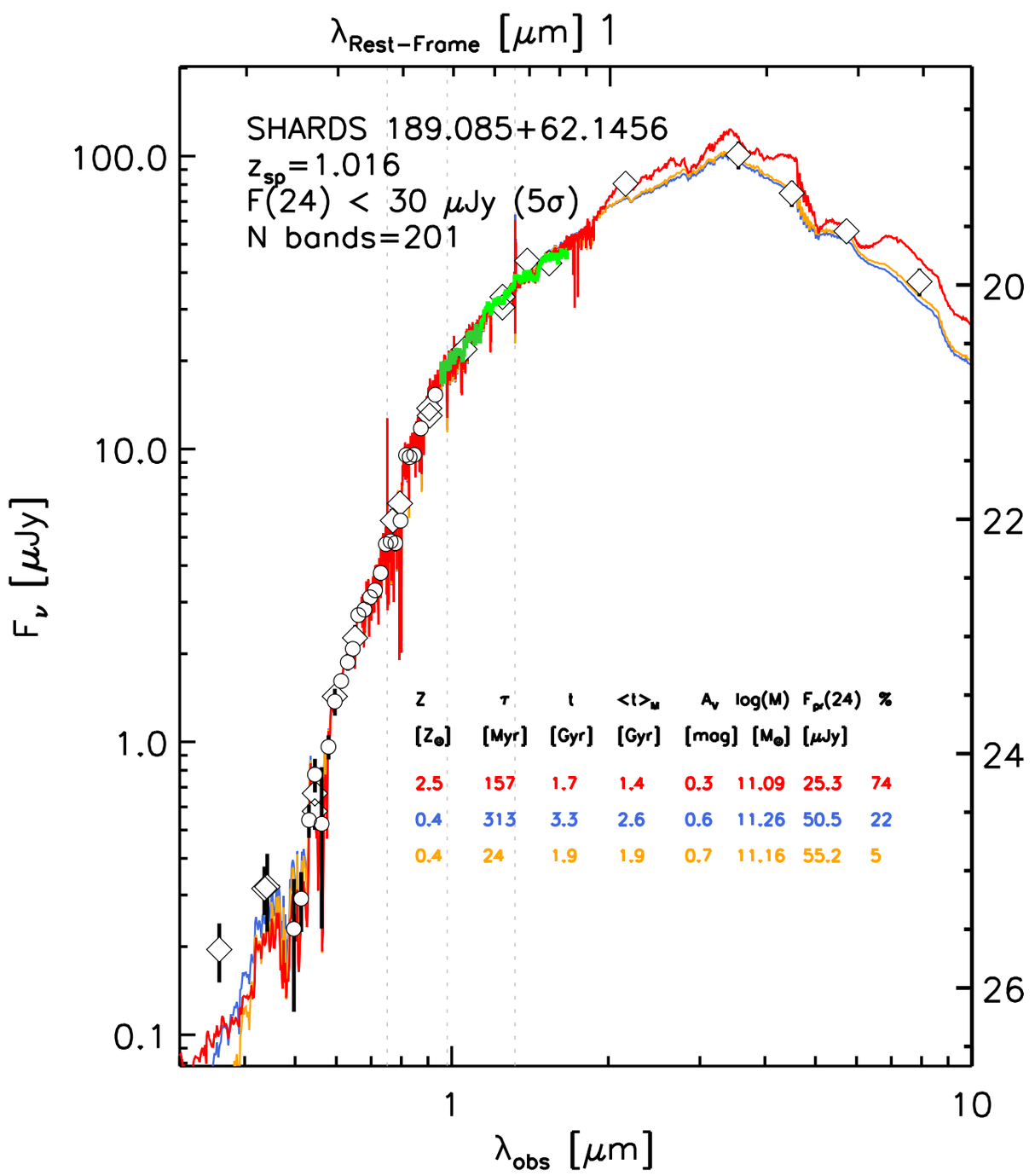
disentagles 32 % of degenerate solutions

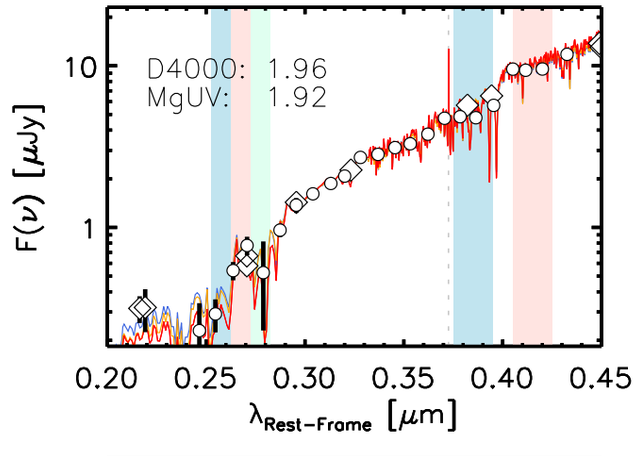


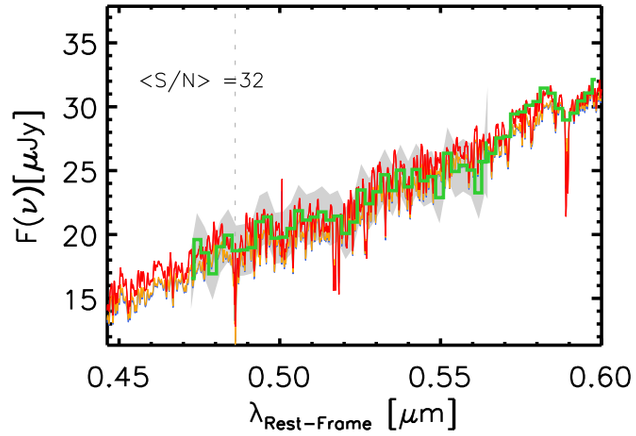


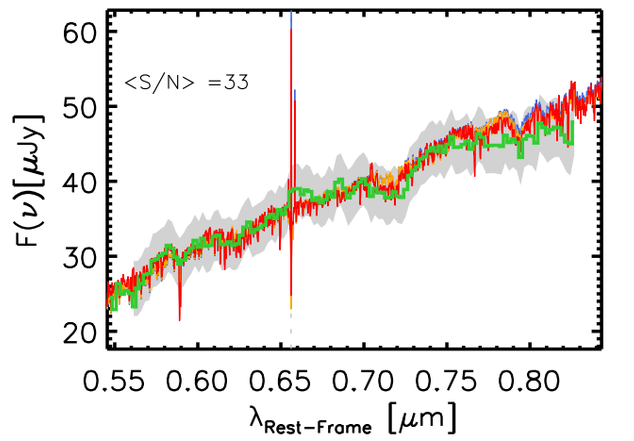
BREAKING DEGENERACIES:

FIR DETECTION & ENERGY BALANCE









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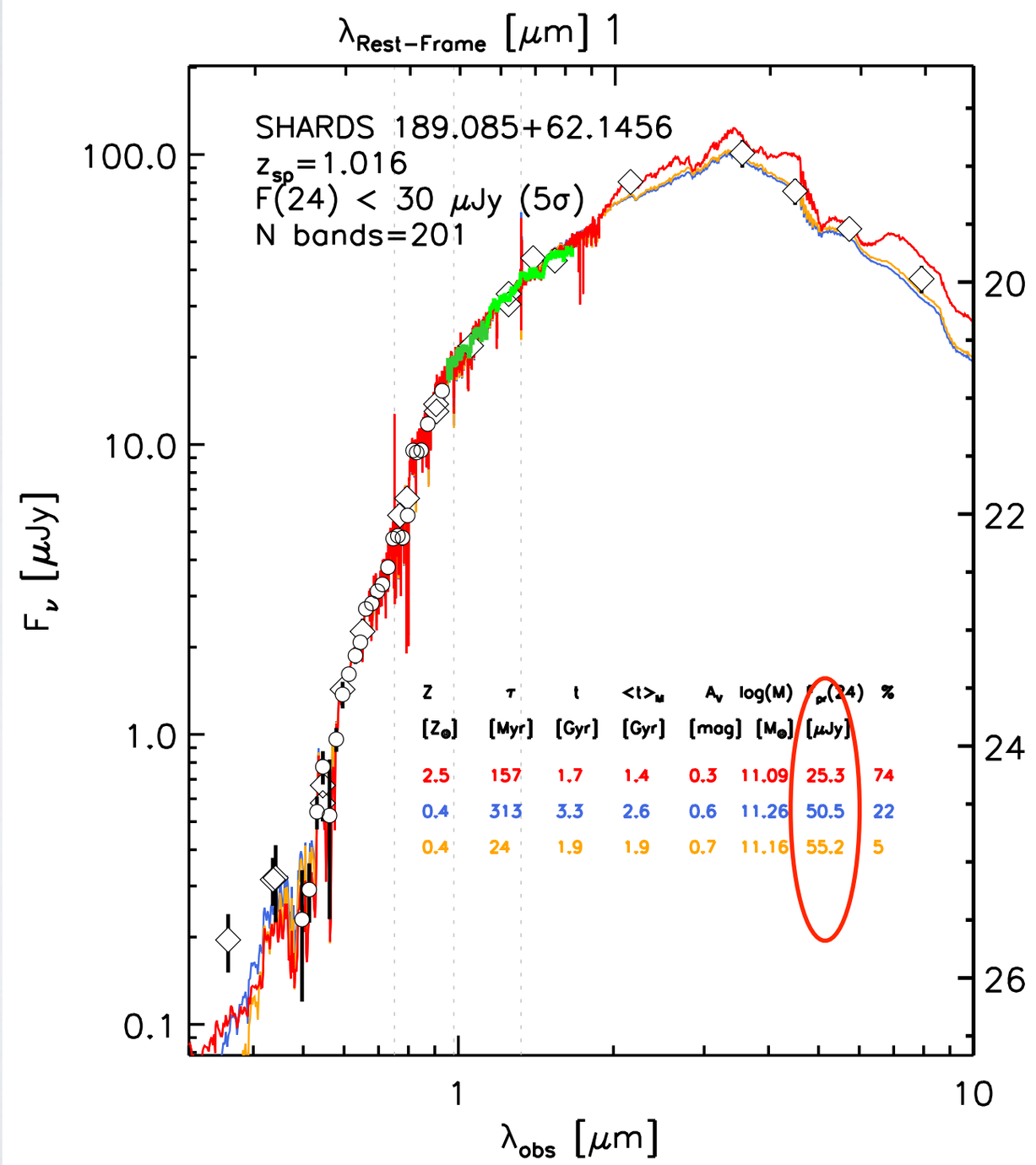
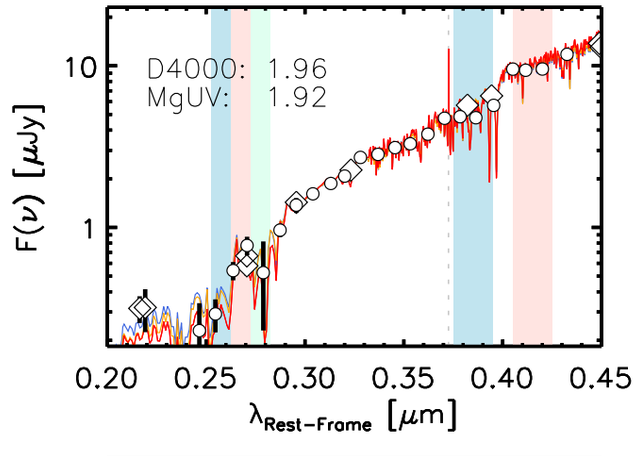
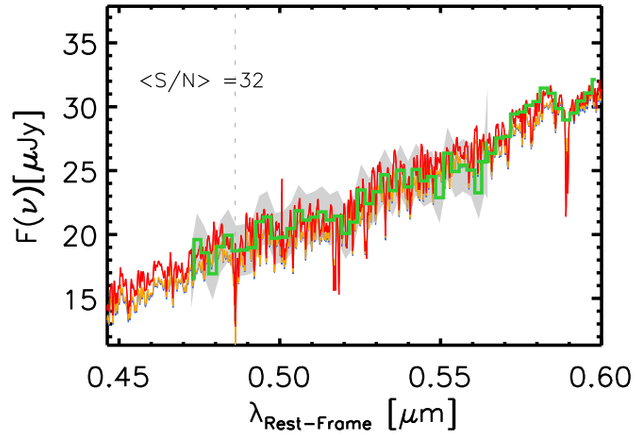
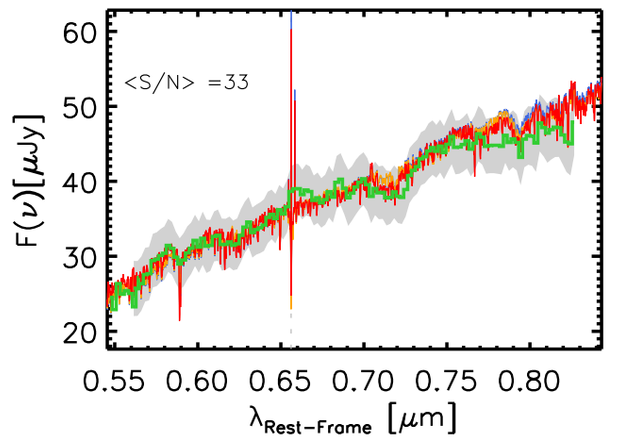
FIR DETECTION & ENERGY BALANCE



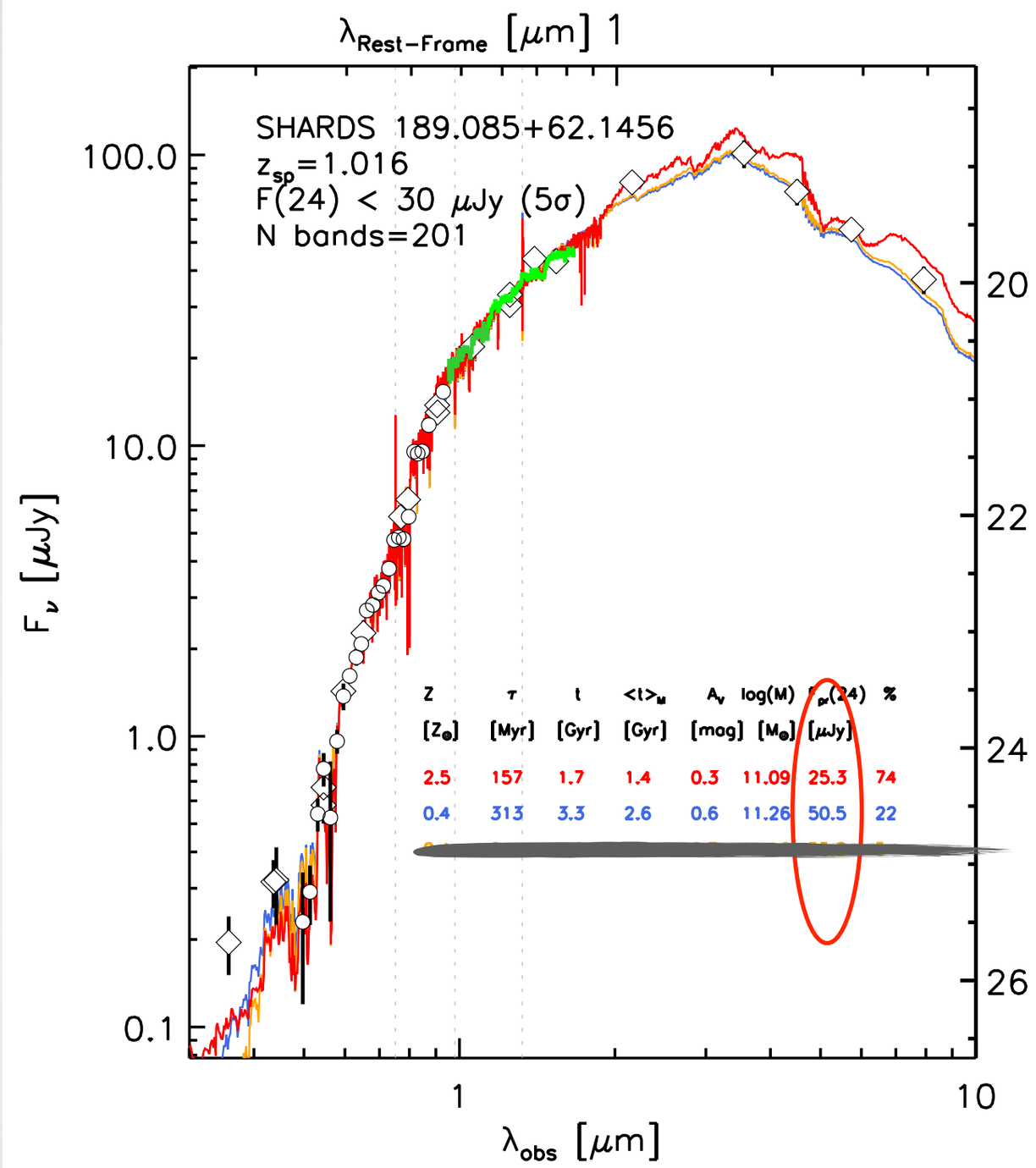


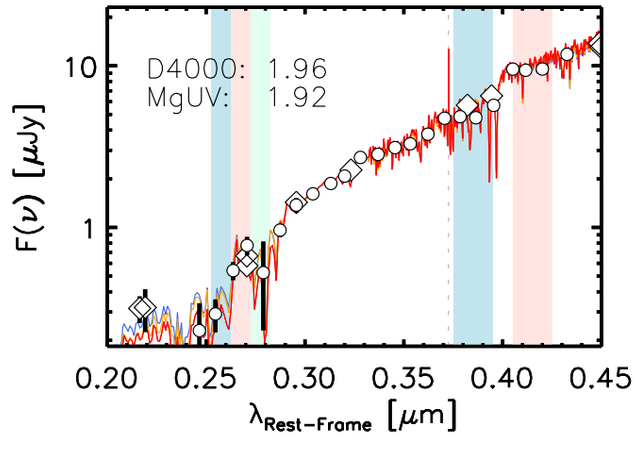


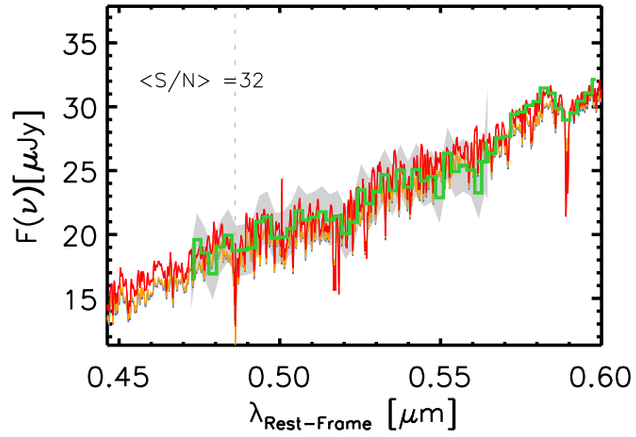


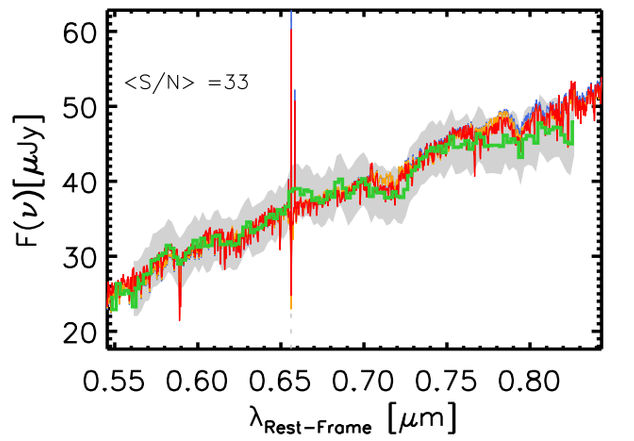
BREAKING DEGENERACIES:

FIR DETECTION & ENERGY BALANCE



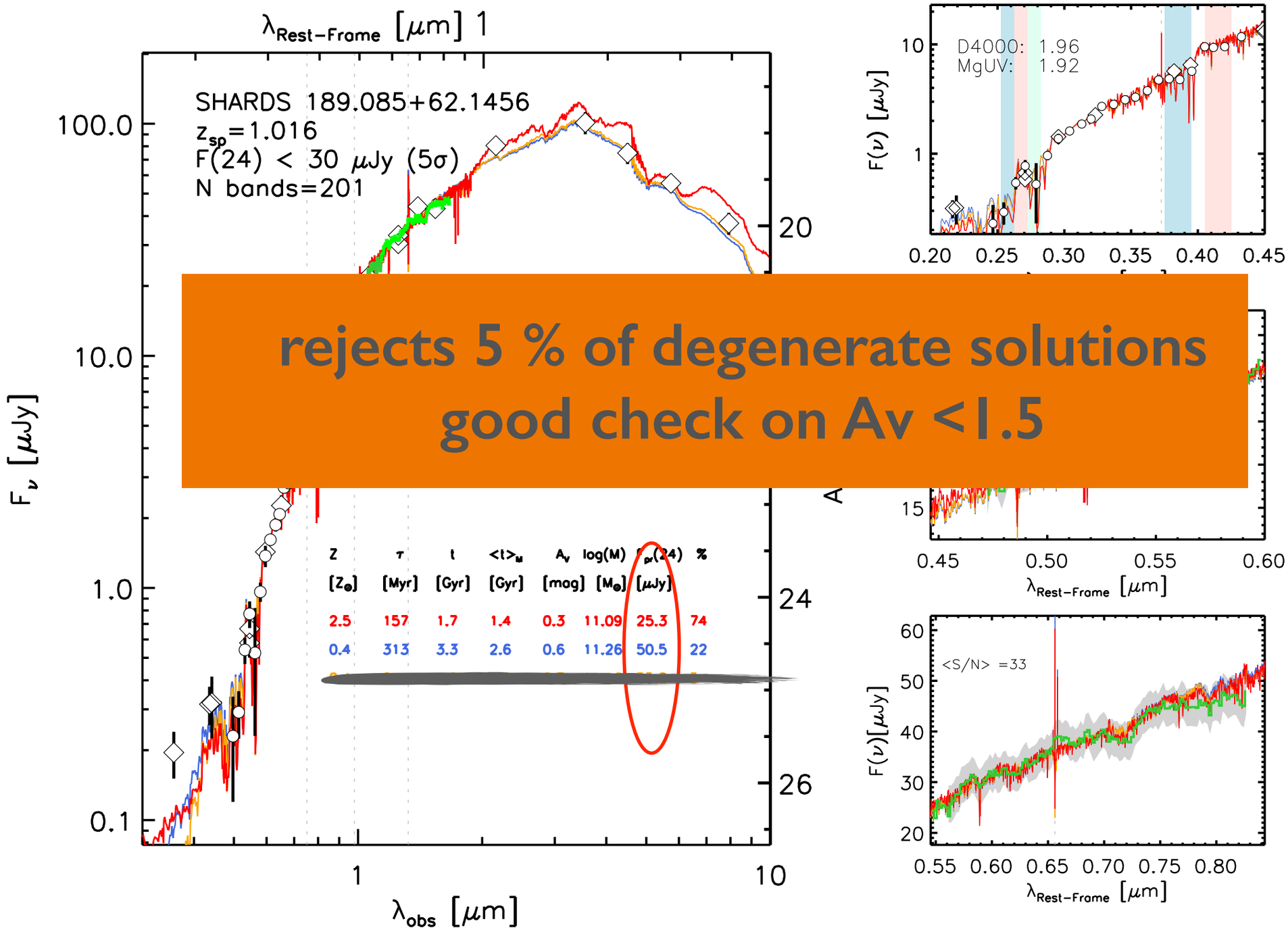






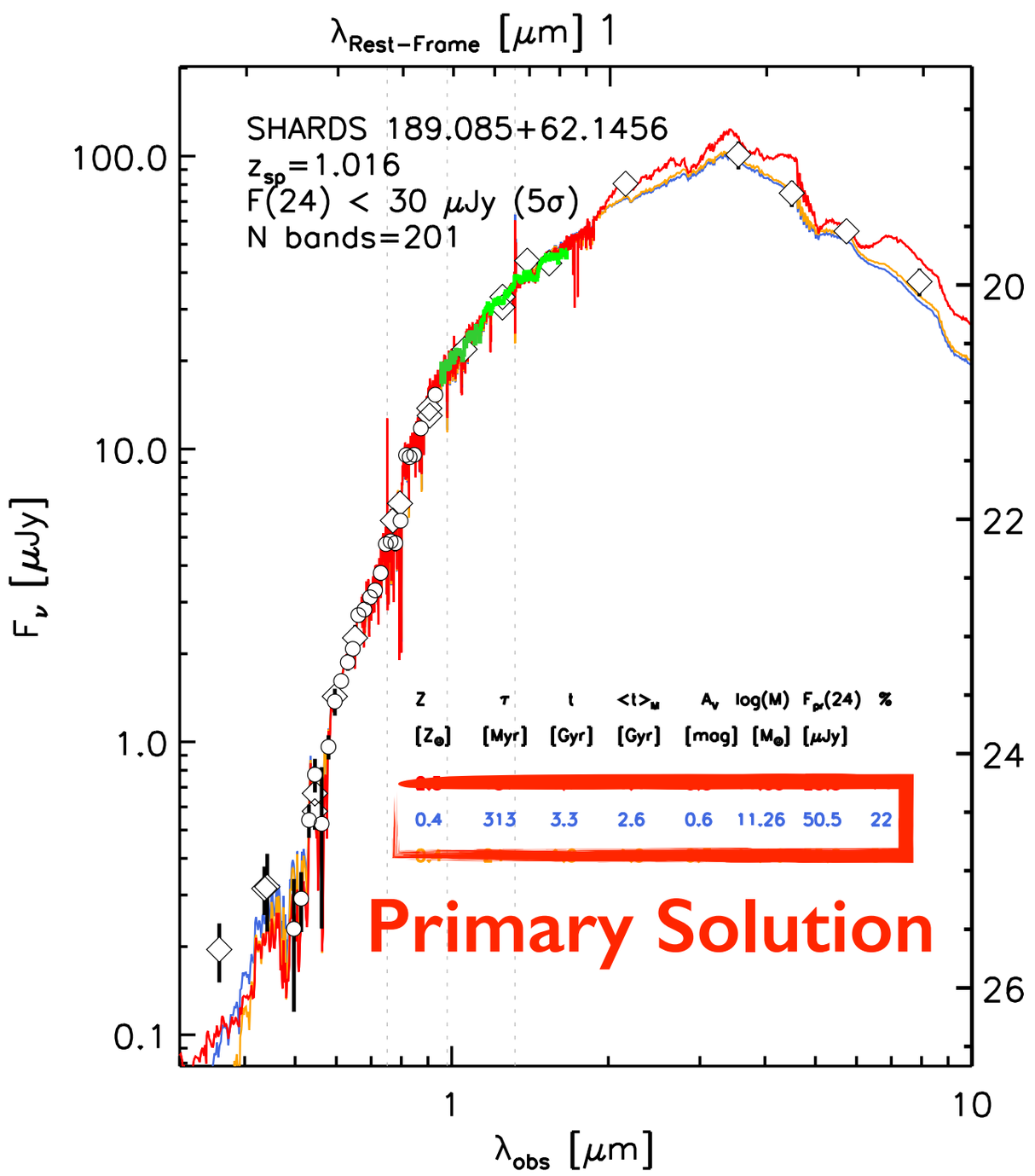
BREAKING DEGENERACIES:

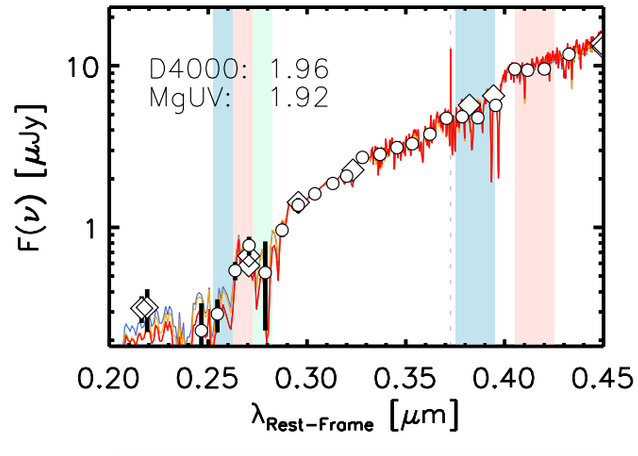
FIR DETECTION & ENERGY BALANCE

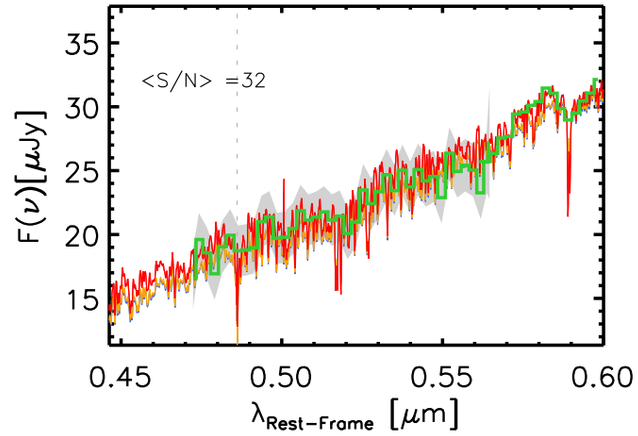


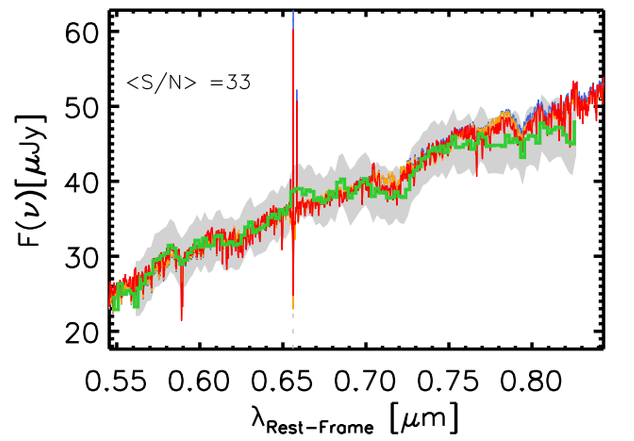
BREAKING DEGENERACIES:

FIR DETECTION & ENERGY BALANCE





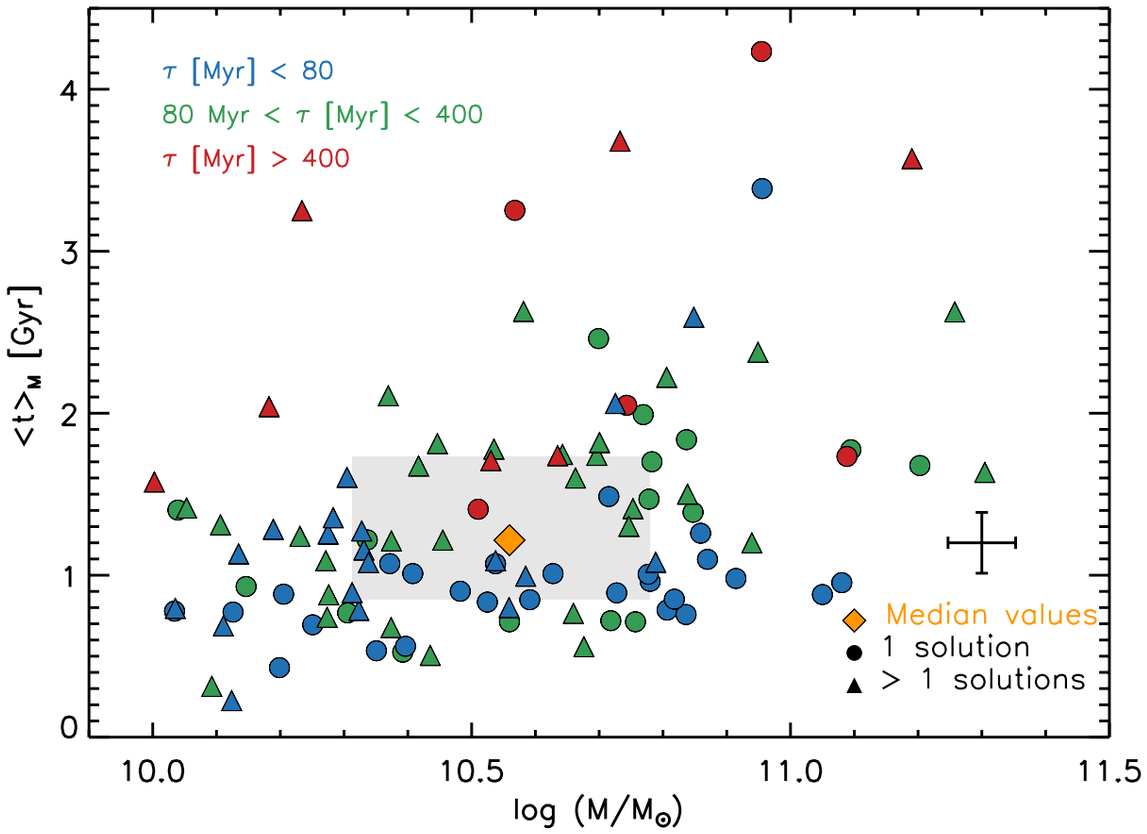


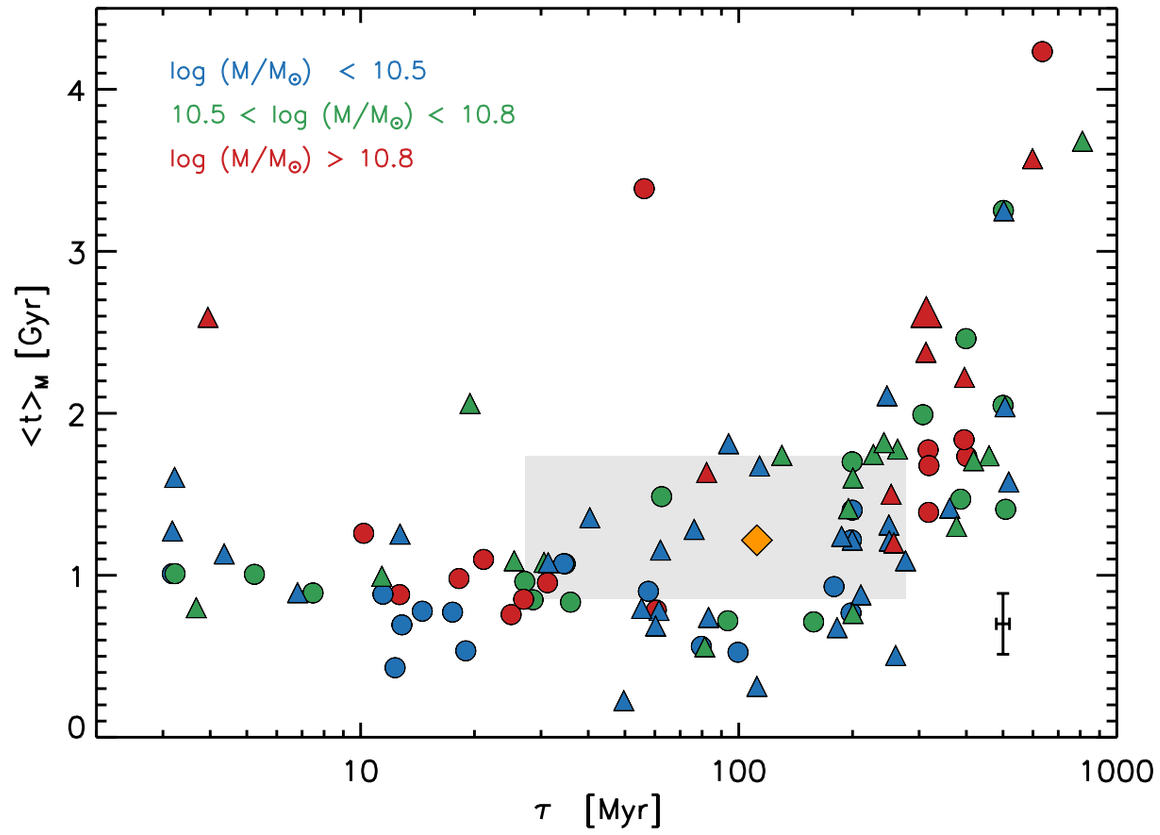


GALAXY PROPERTIES

Degenerate solutions

One cluster solution



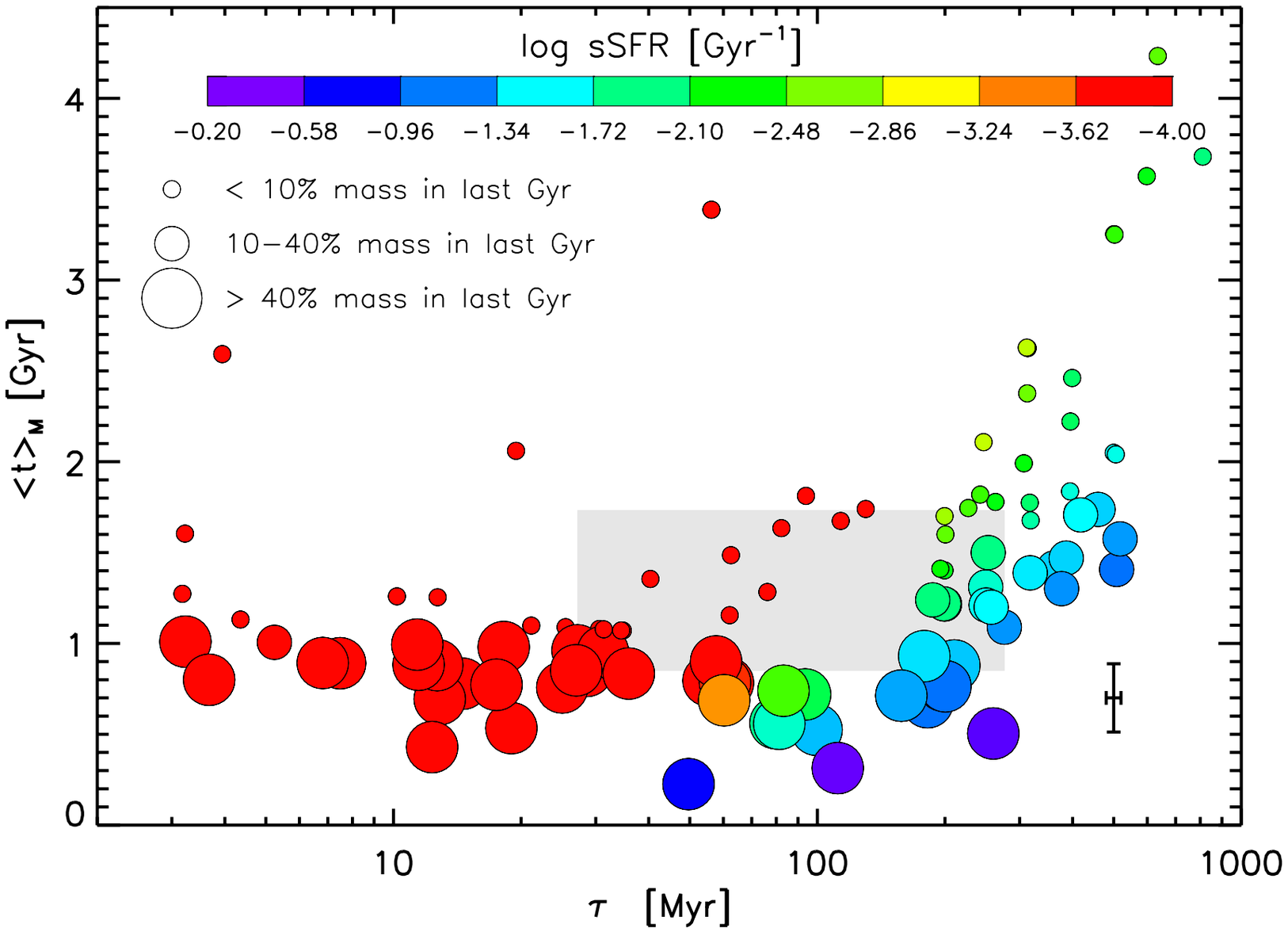


85 % galaxies **t ~ 1 Gyr,** shorter SF-timescales

15 % galaxies **t > 2 Gyr,** larger SF-timescales

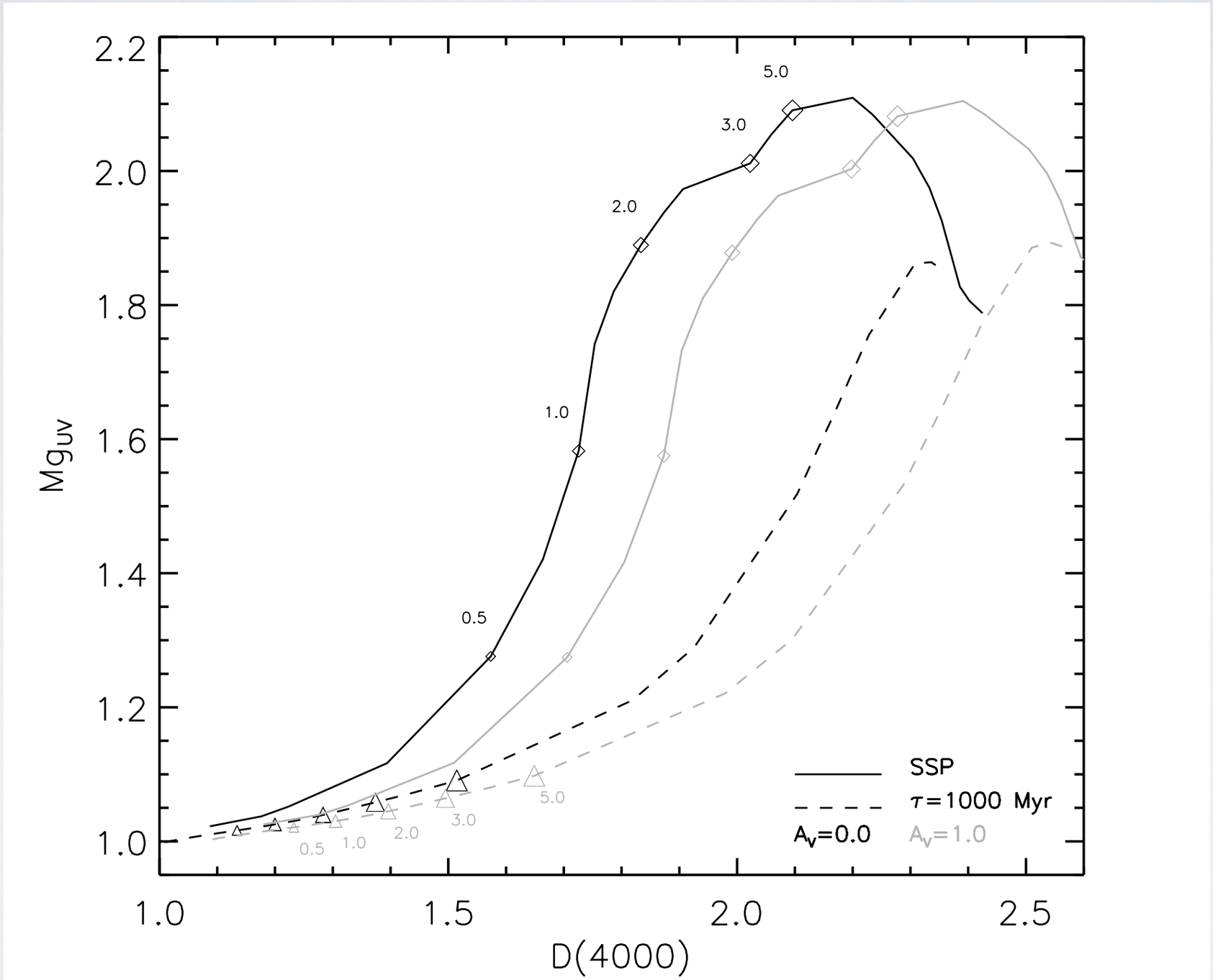
GALAXY PROPERTIES:

OLD vs QUIESCENT

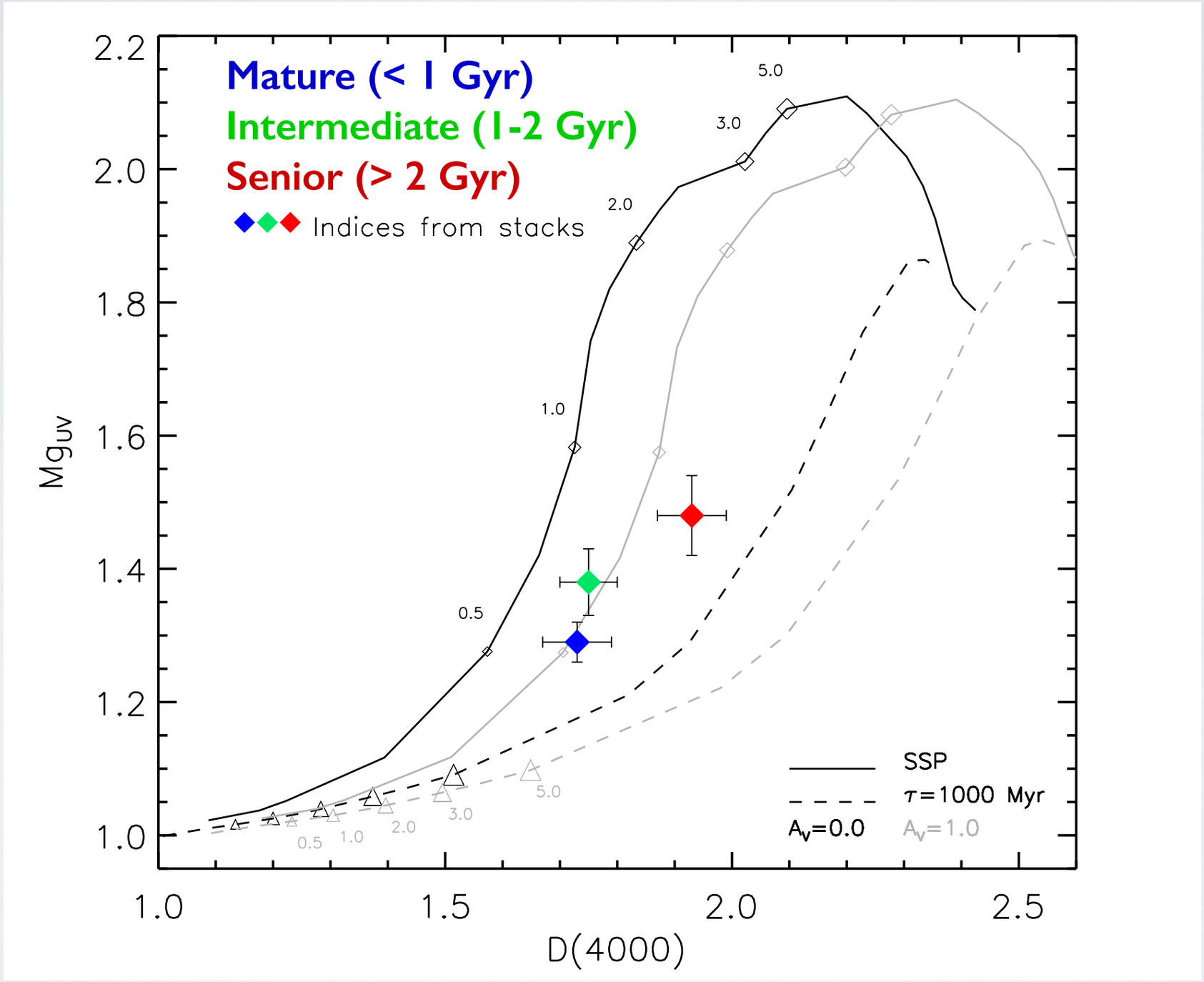


BREAKING DEGENERACIES:

D4000 & MGUV

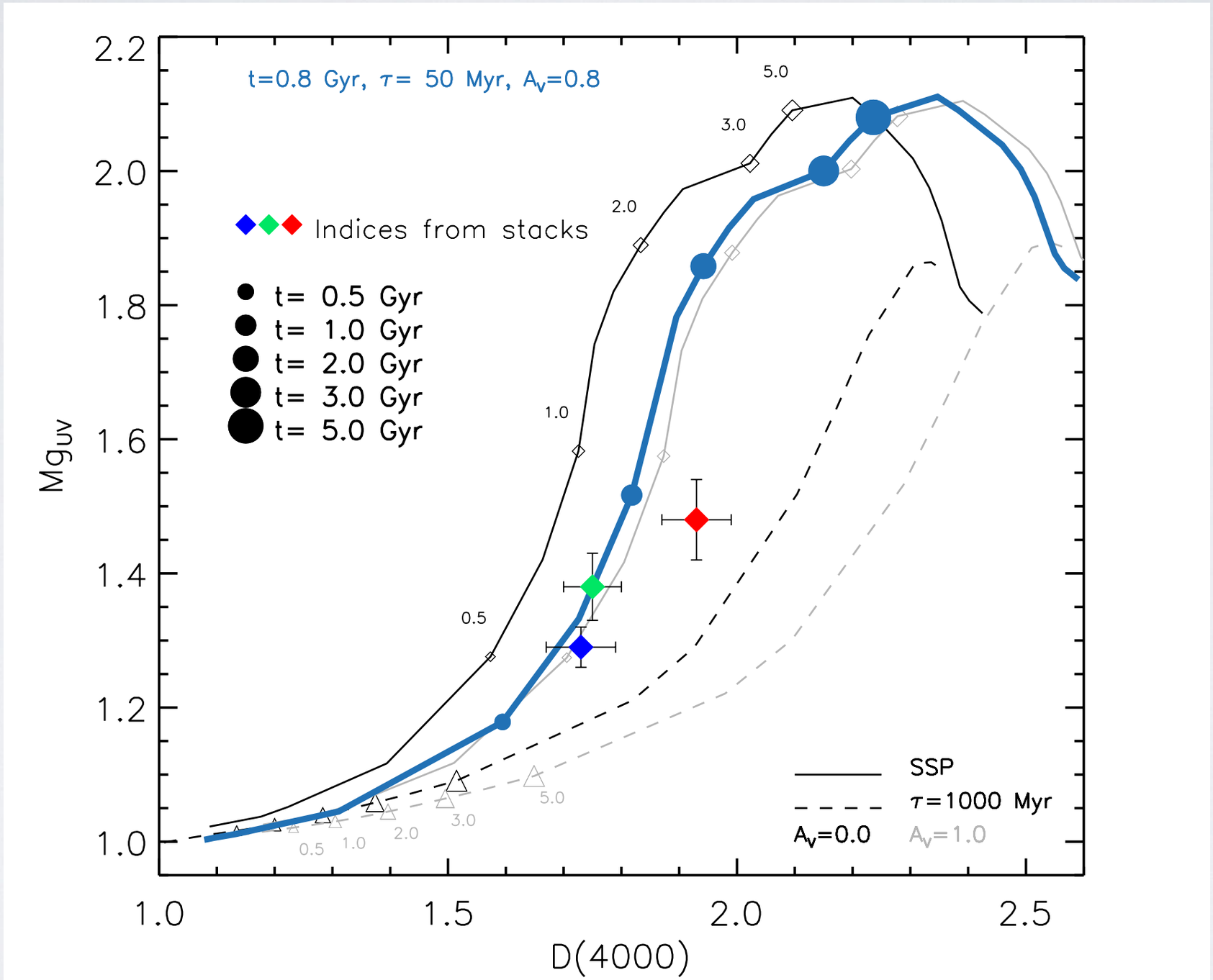


BREAKING DEGENERACIES:
D4000 & MGUV

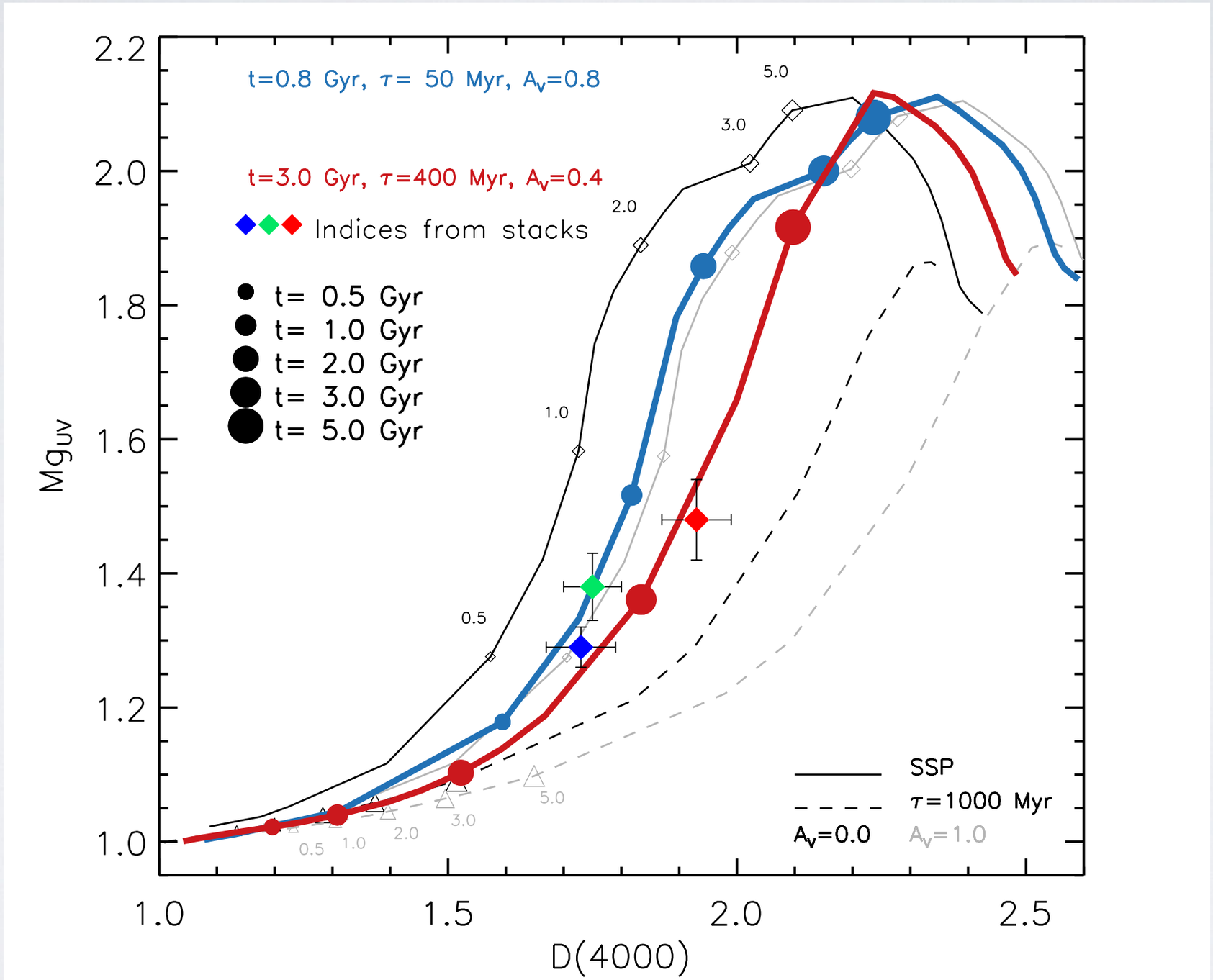


BREAKING DEGENERACIES:

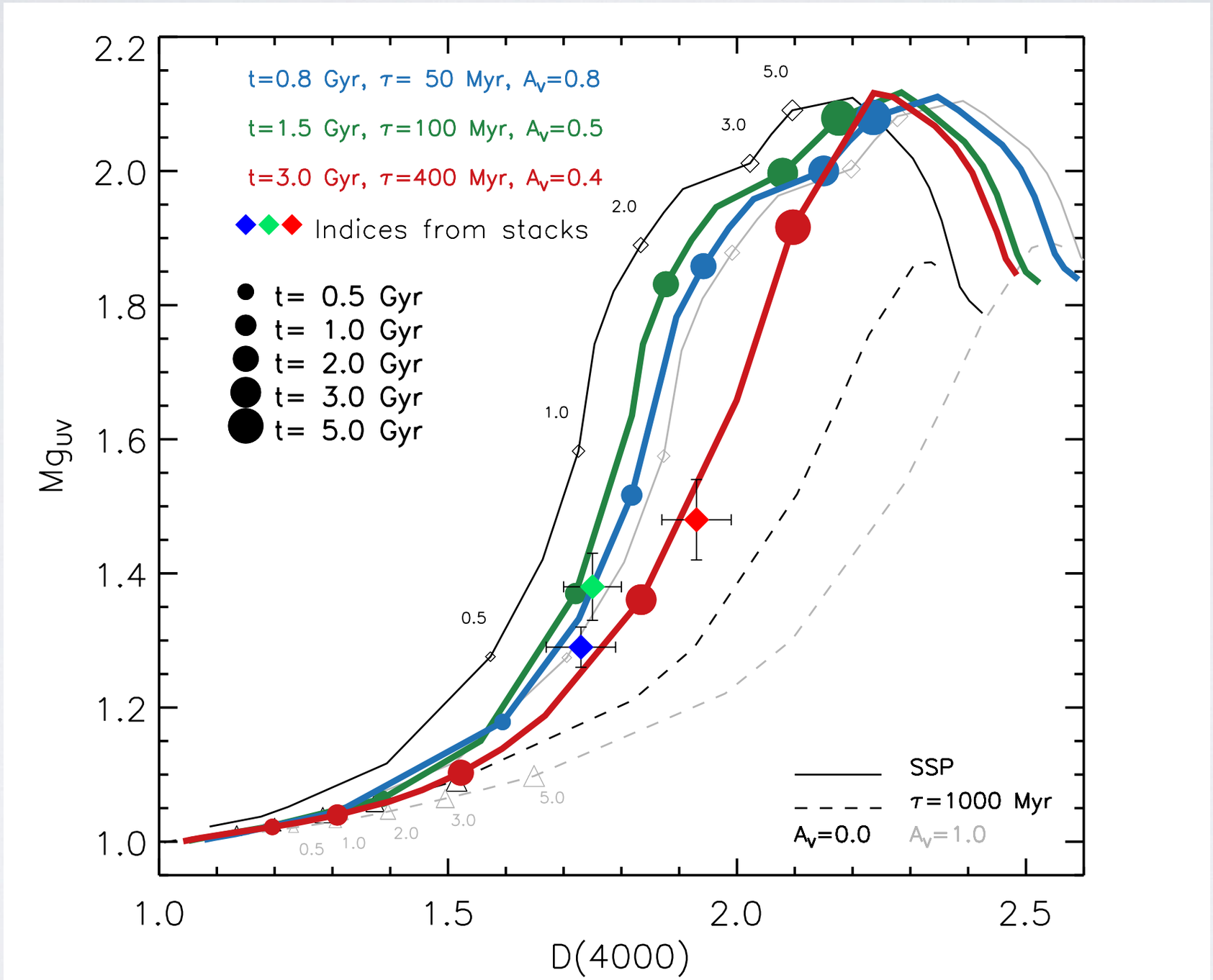
D4000 & MGUV



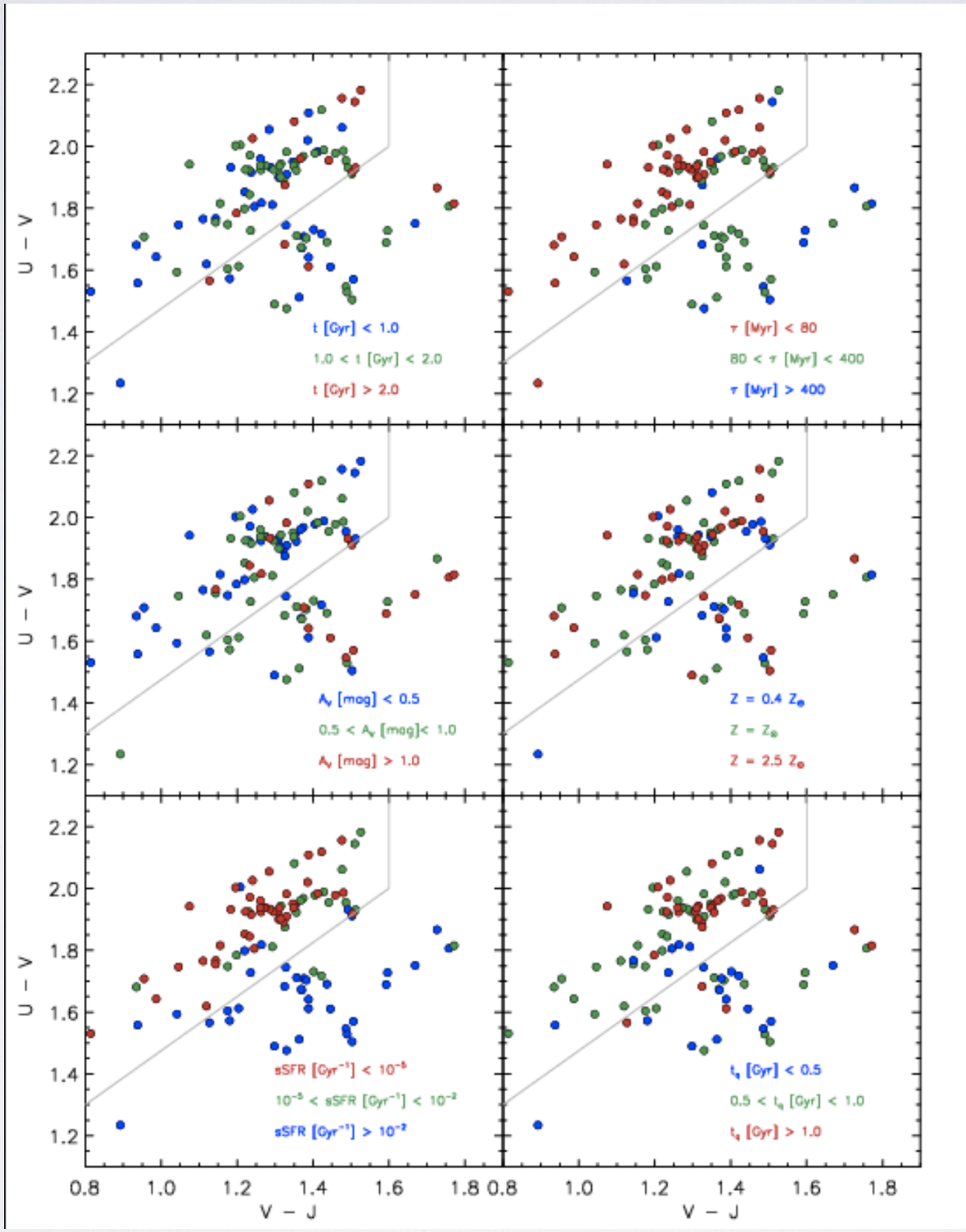
BREAKING DEGENERACIES:
D4000 & MGUV



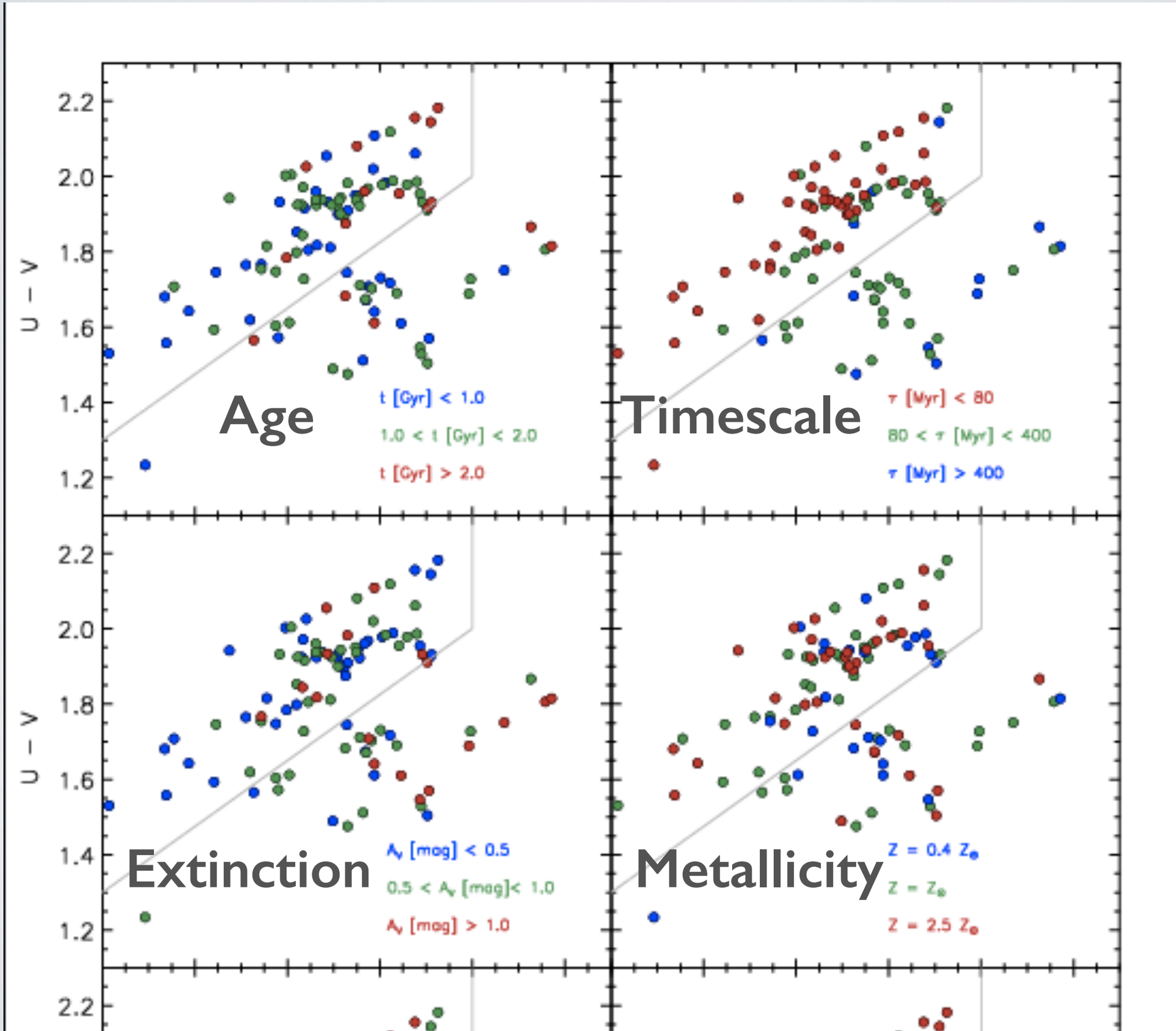
BREAKING DEGENERACIES:
D4000 & MGUV



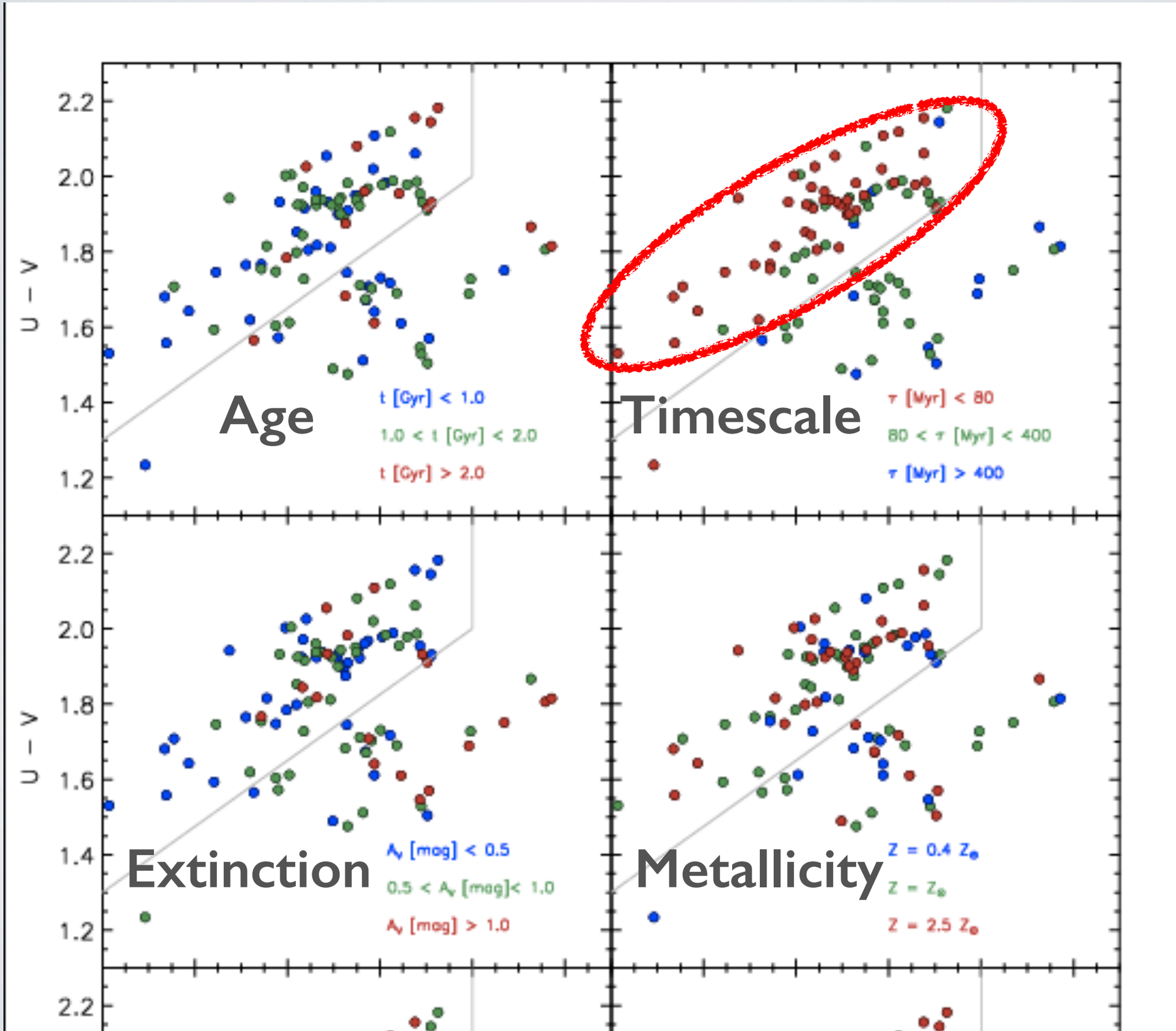
GALAXY PROPERTIES IN UVJ PLOT



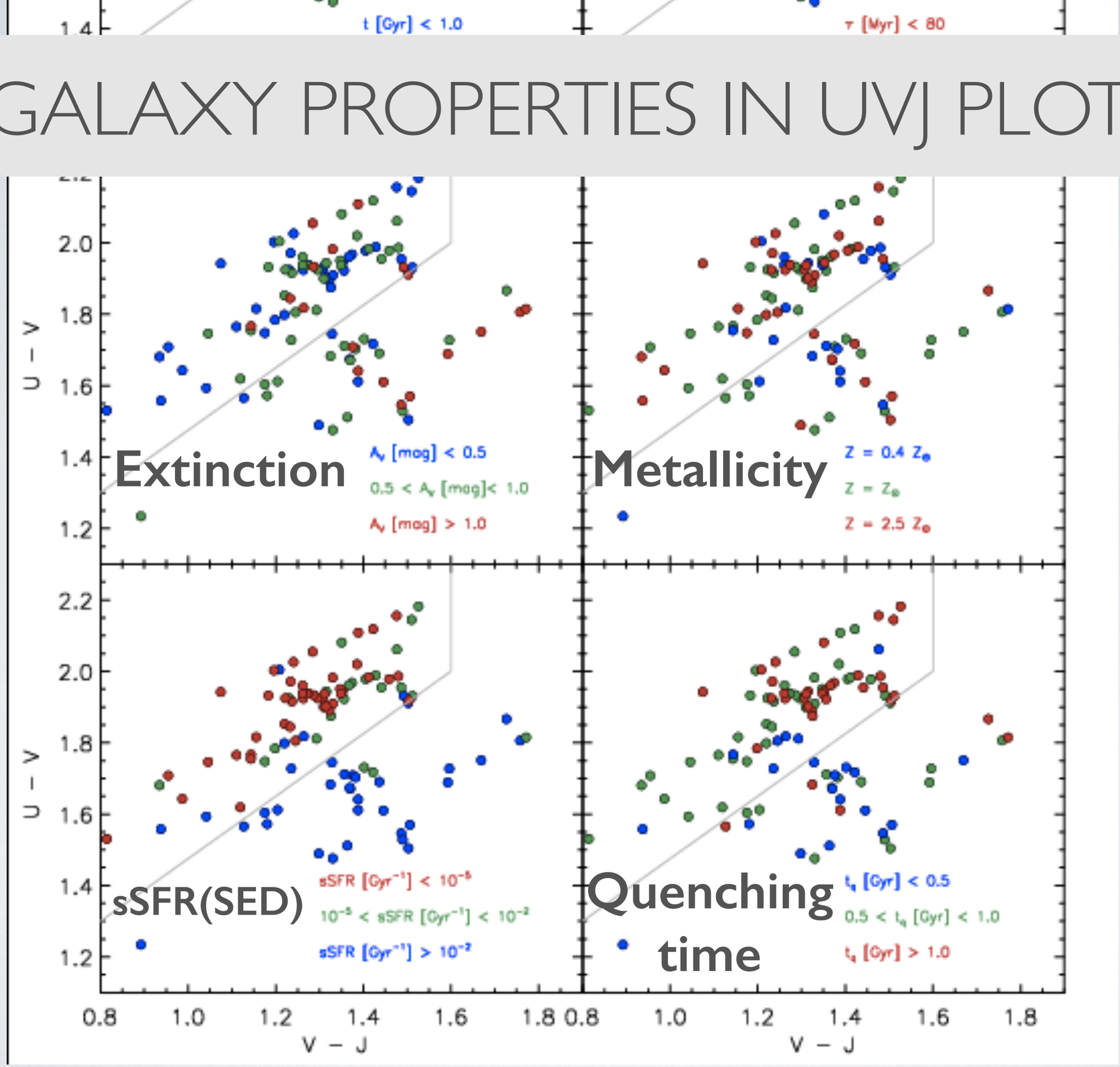
GALAXY PROPERTIES IN UVJ PLOT



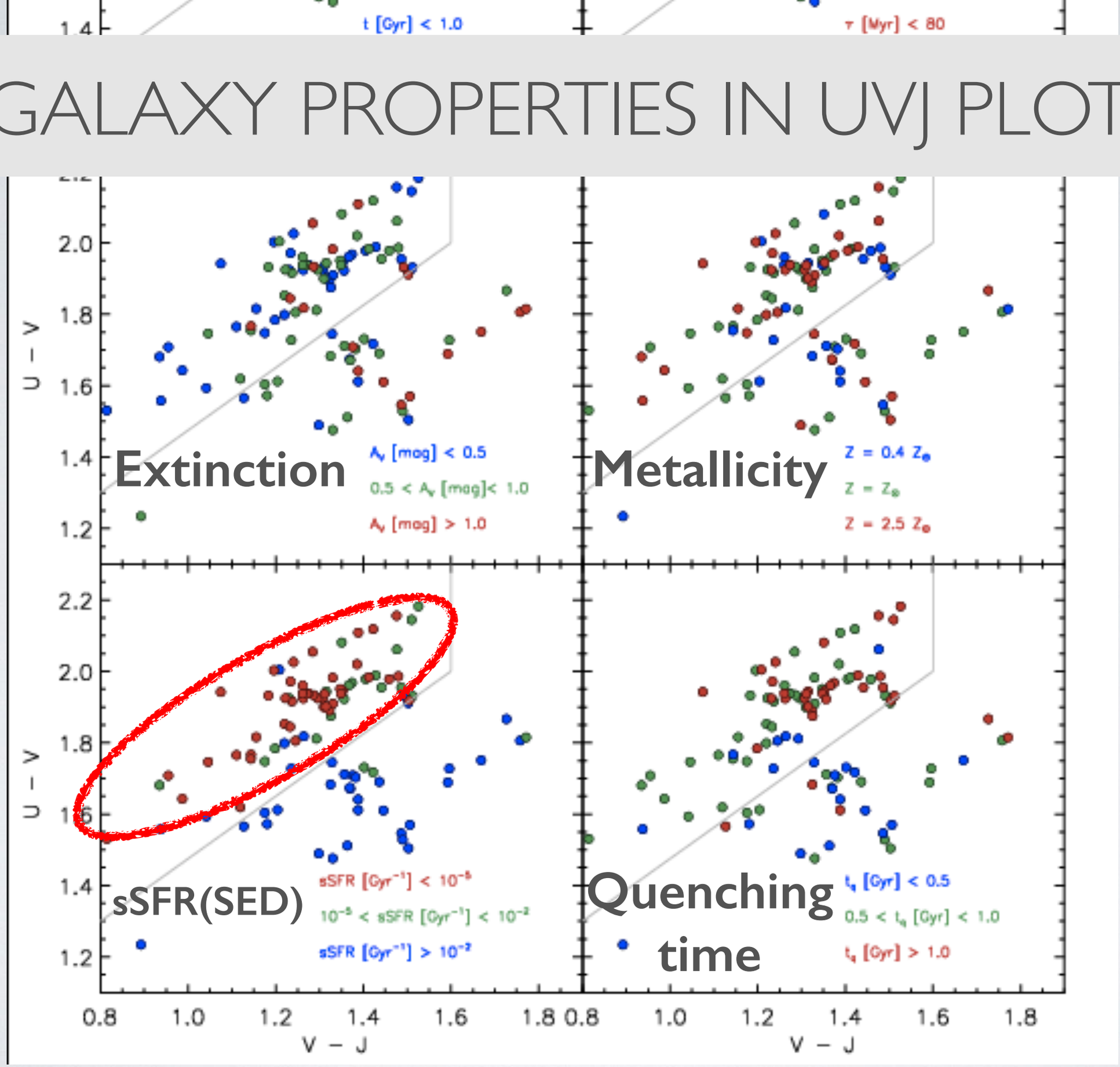
GALAXY PROPERTIES IN UVJ PLOT



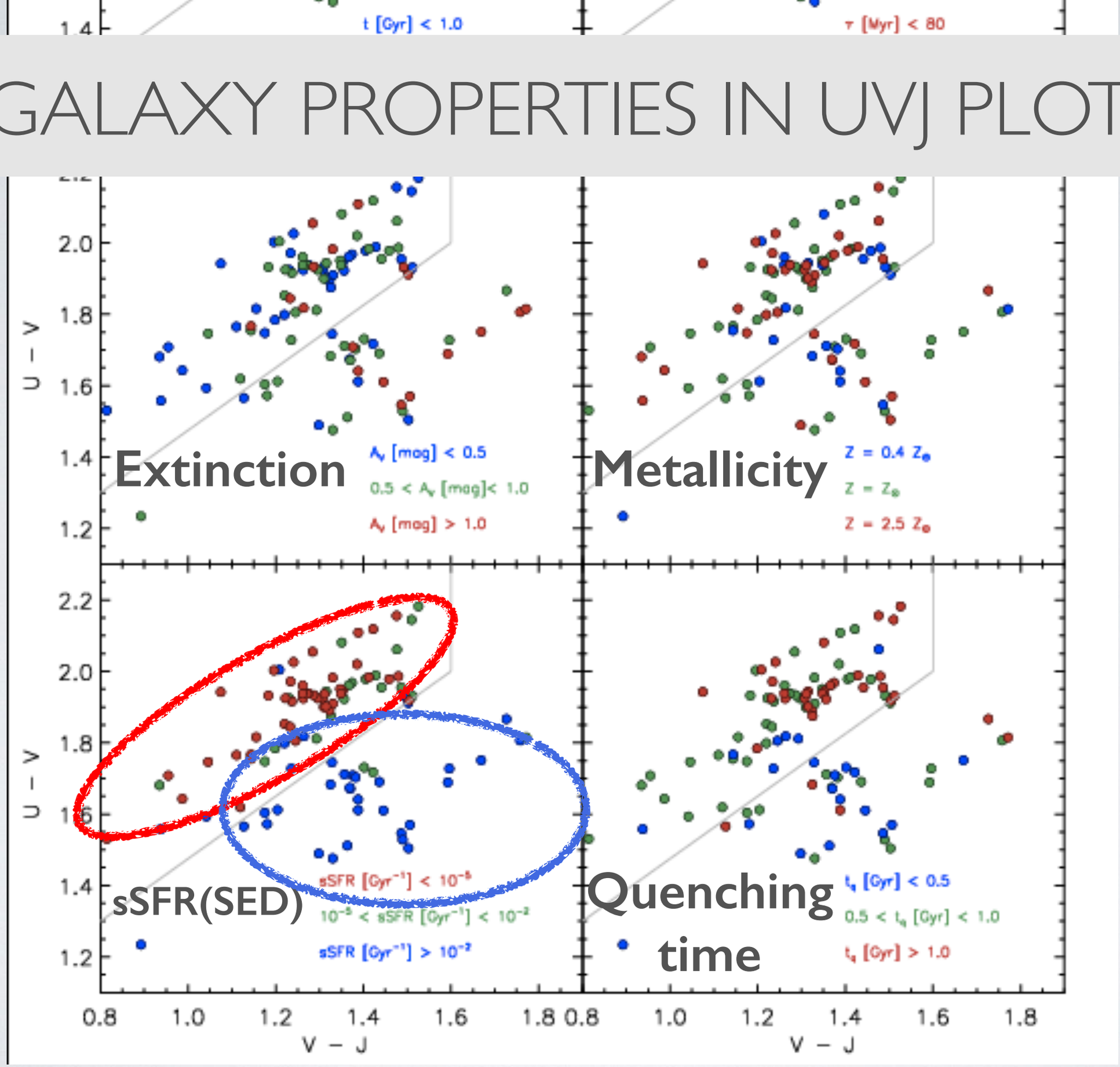
GALAXY PROPERTIES IN UVJ PLOT



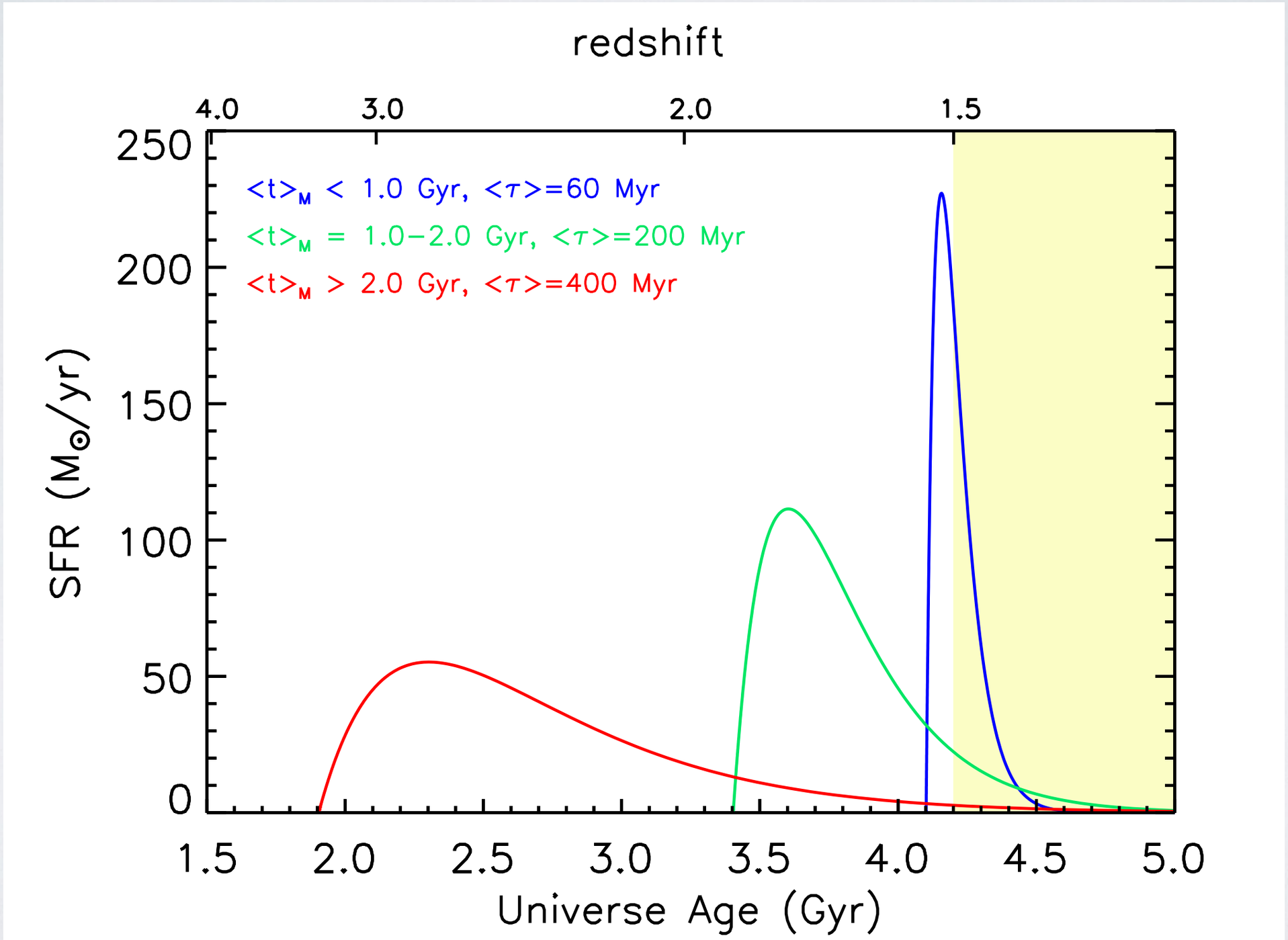
GALAXY PROPERTIES IN UVJ PLOT



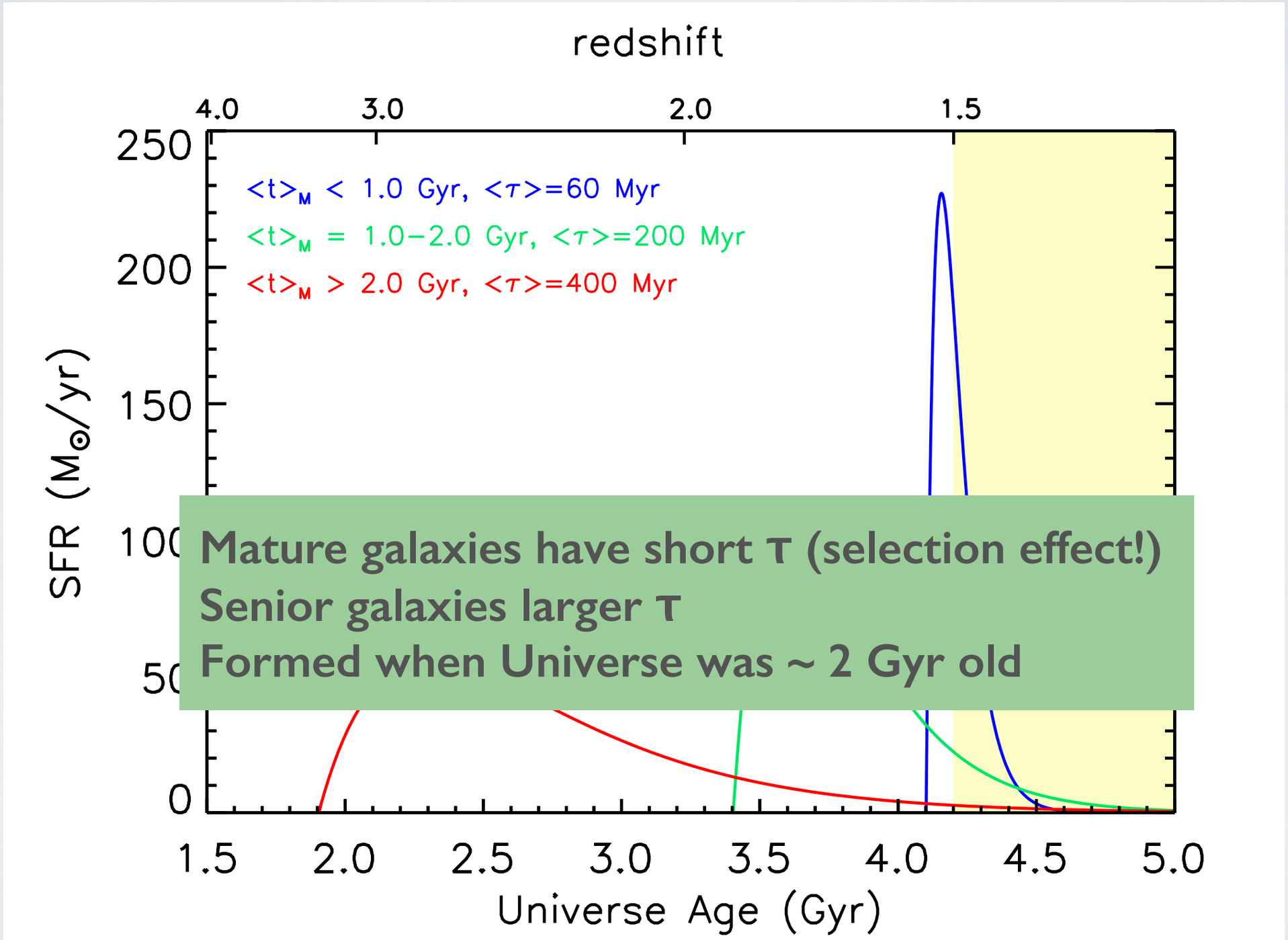
GALAXY PROPERTIES IN UVJ PLOT



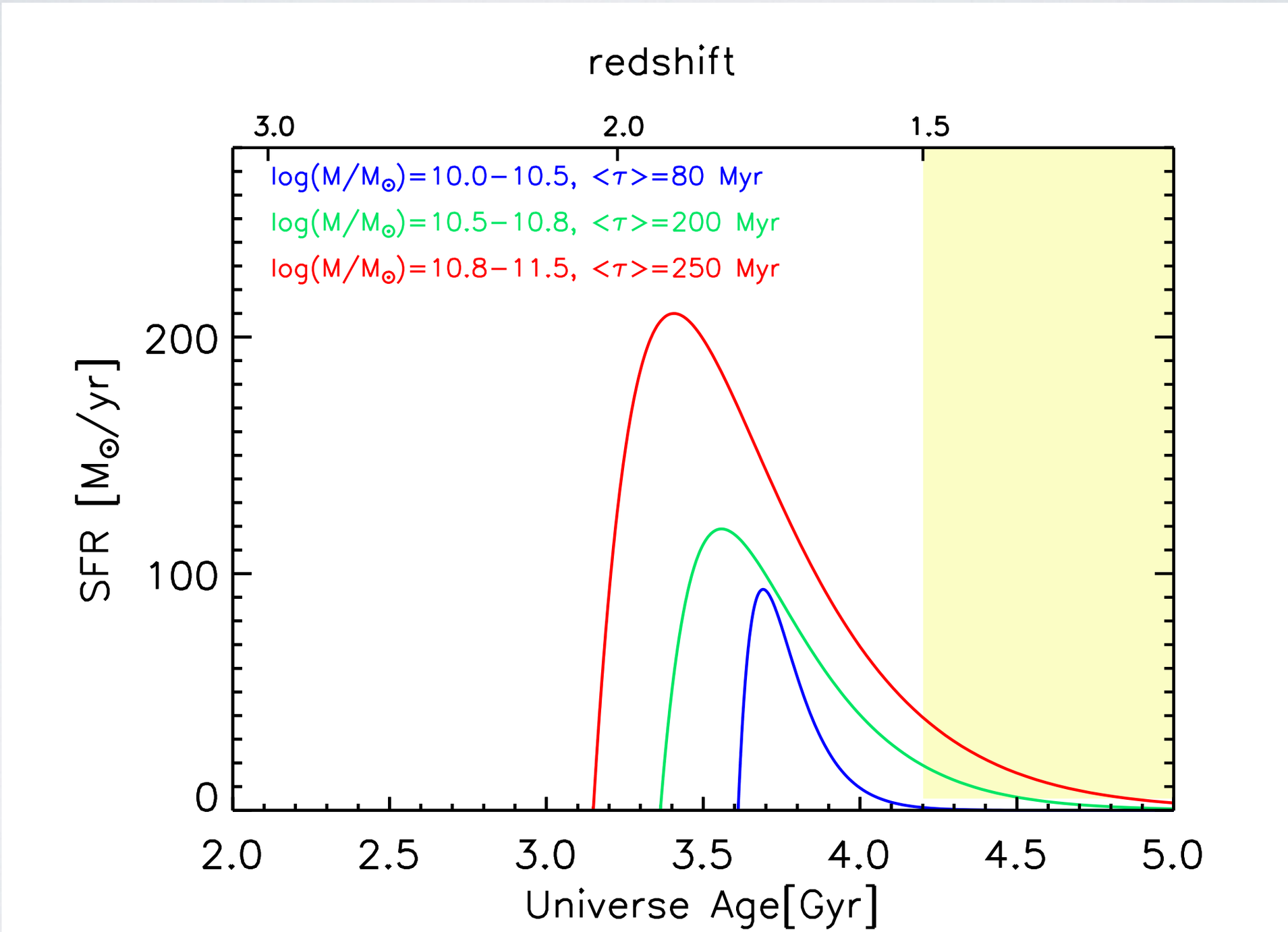
MEDIAN SFH BY AGE



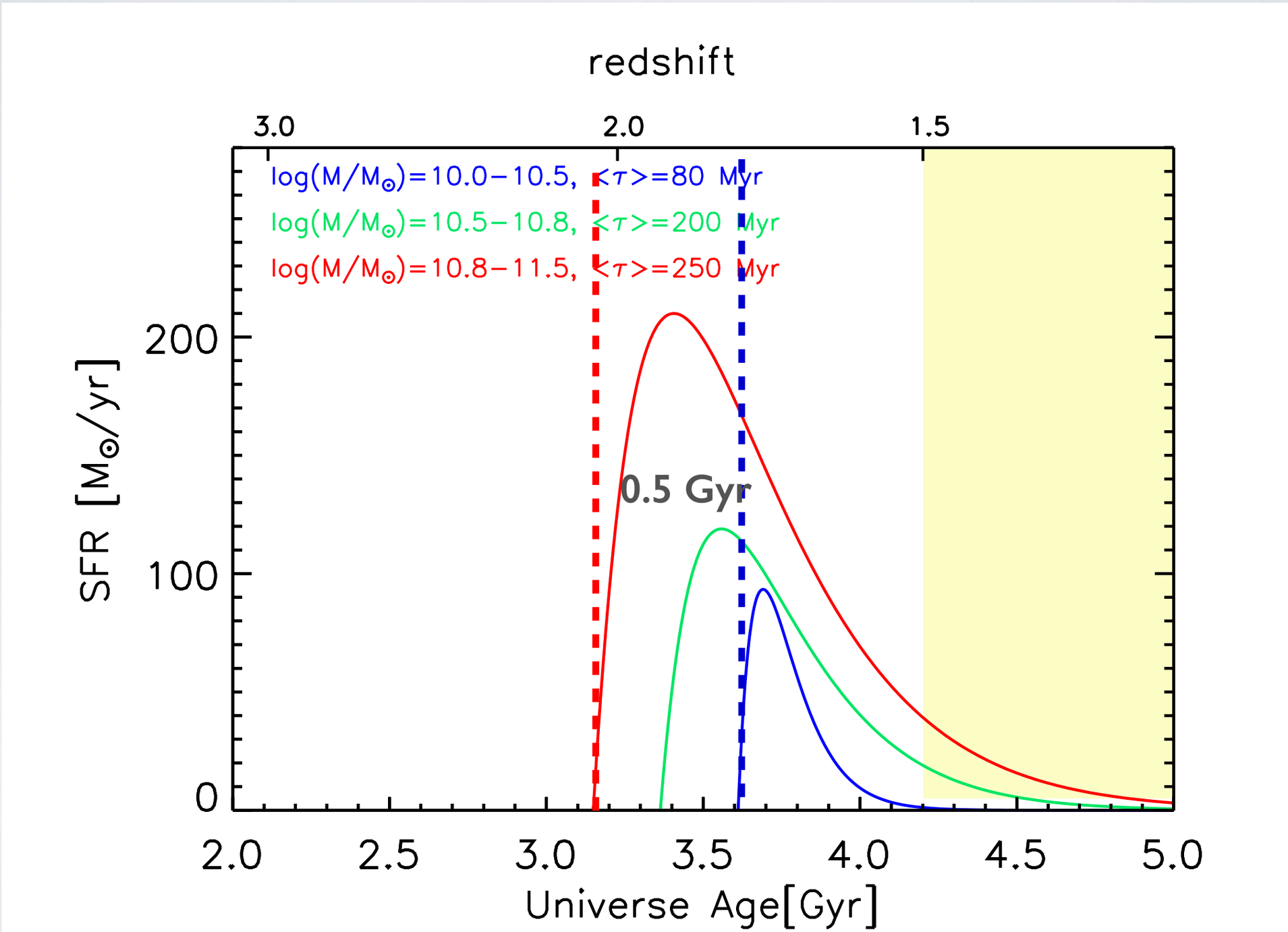
MEDIAN SFH BY AGE



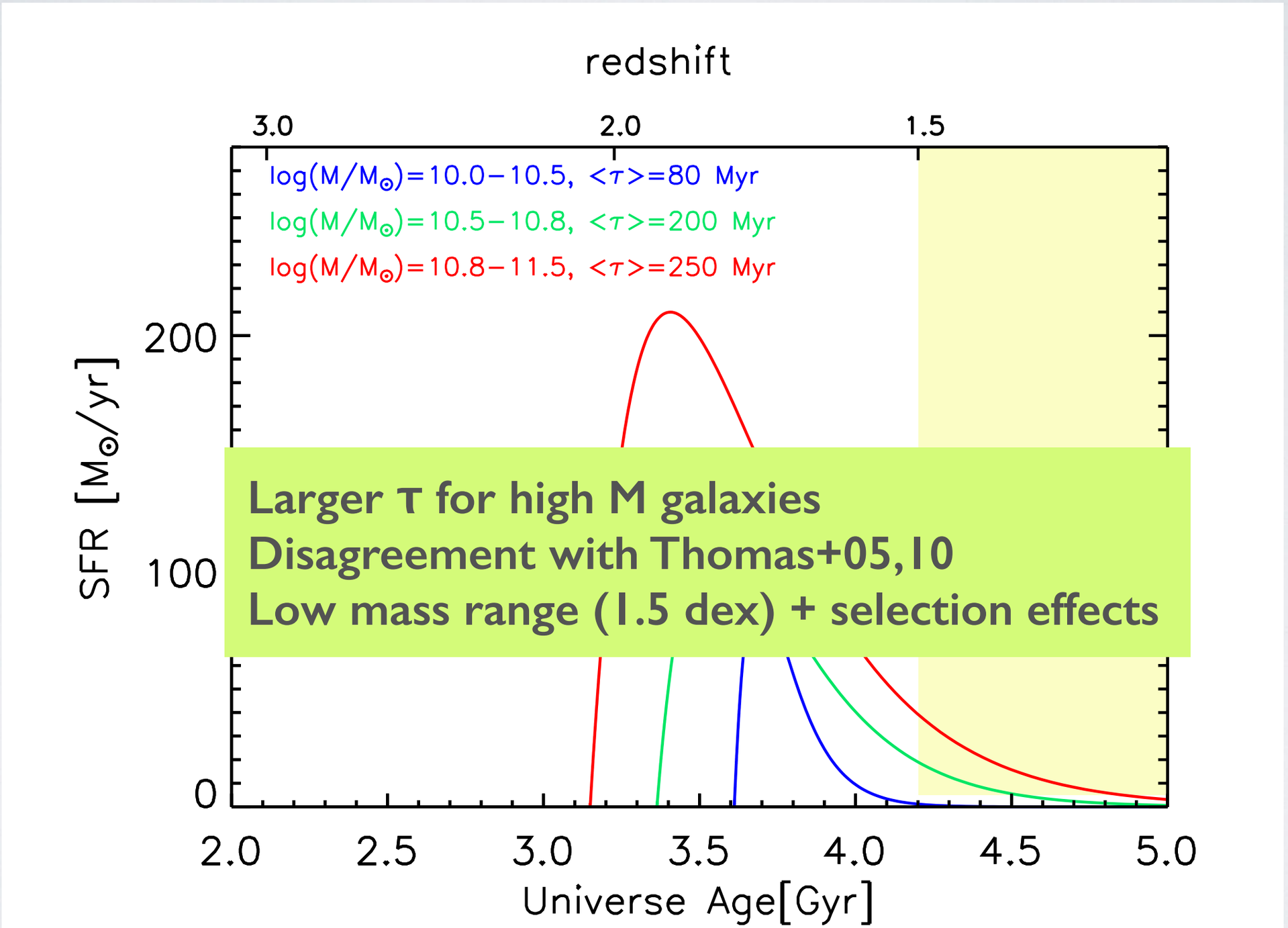
MEDIAN SFH BY MASS



MEDIAN SFH BY MASS



MEDIAN SFH BY MASS



SFH TRACKS

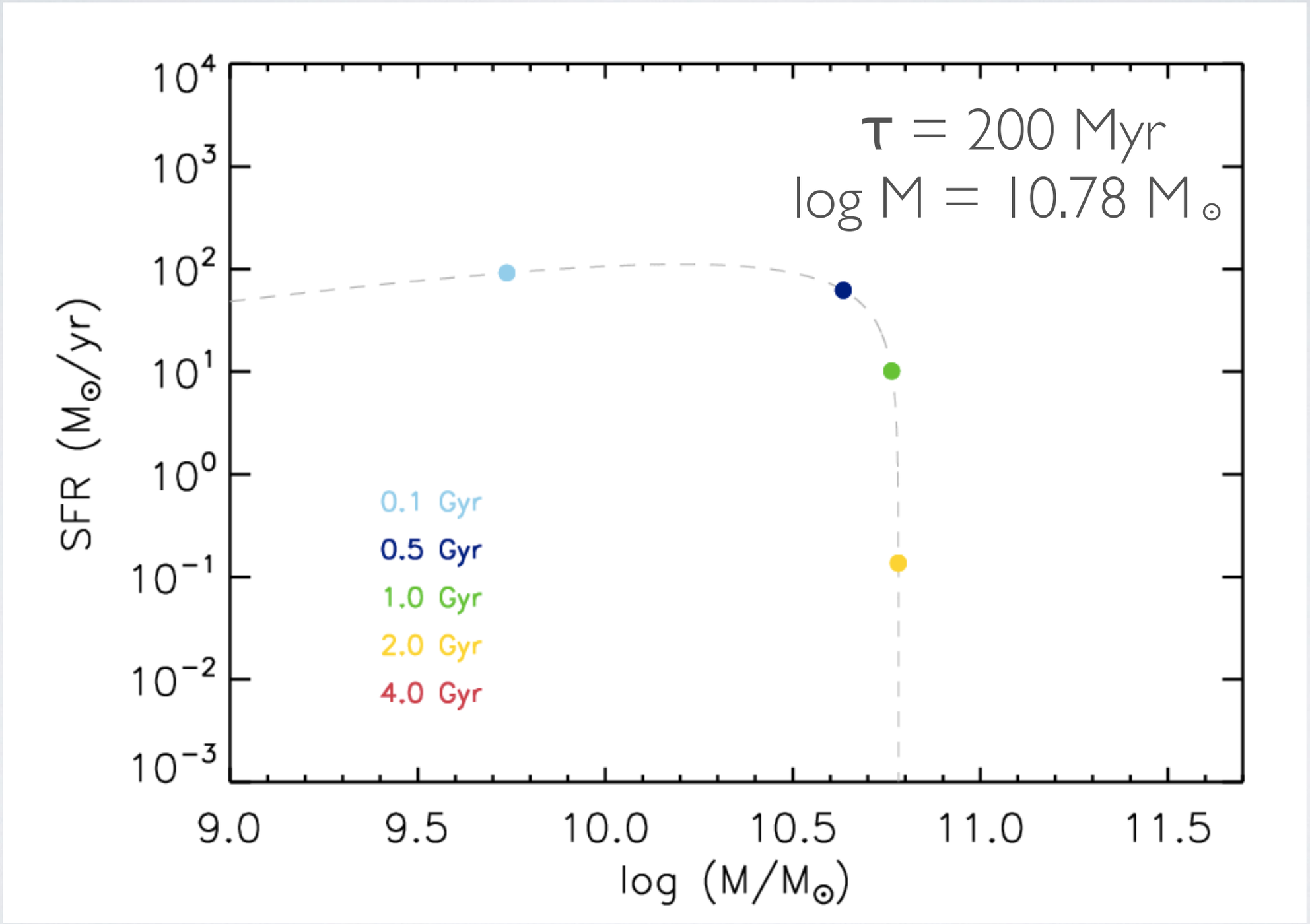
$$\mathbf{SFR(t) \propto \tau^{-2} t\, e^{-t/\tau}}$$

SFH TRACKS

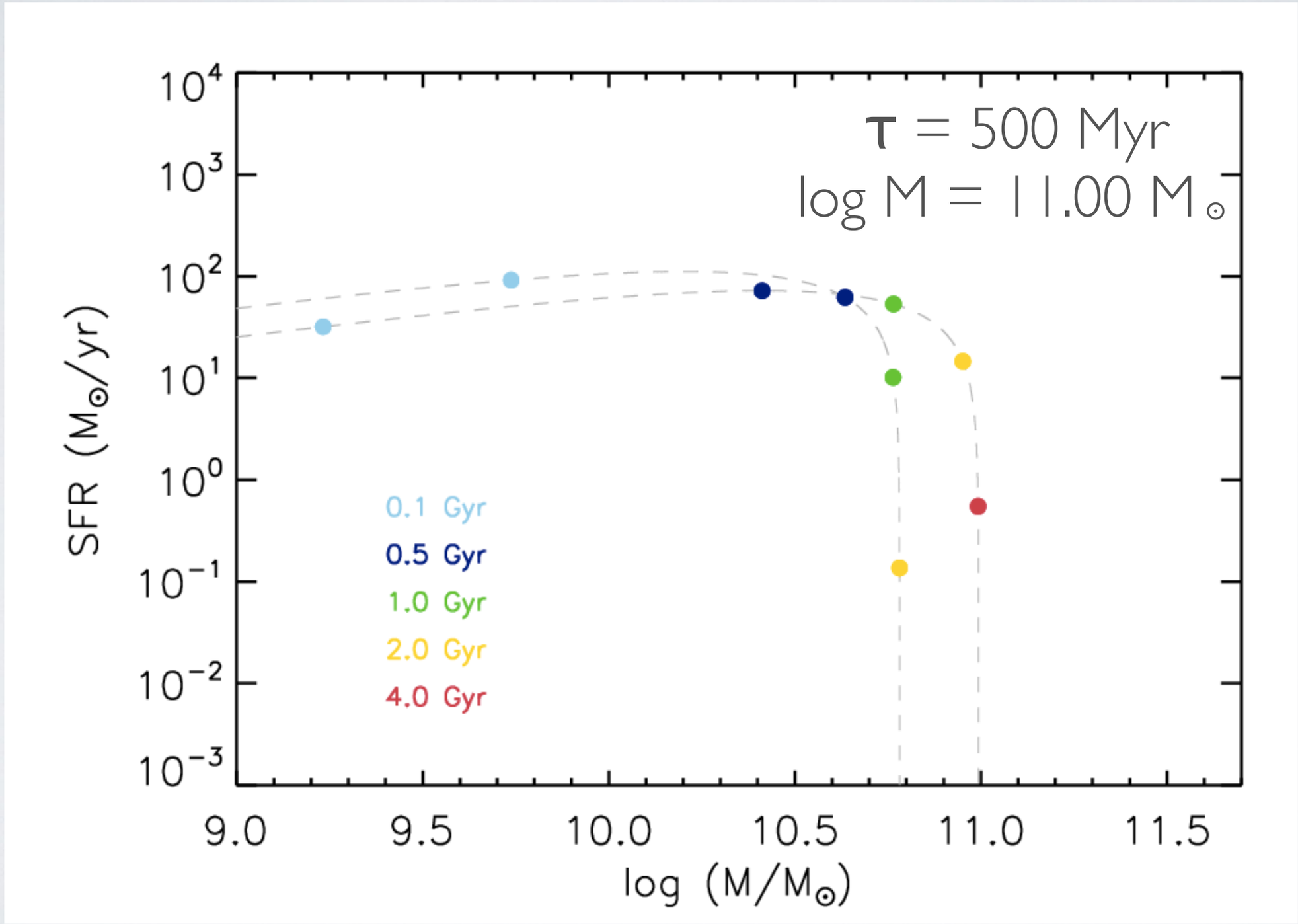
$$\mathbf{SFR(t) \propto \tau^{-2} t\, e^{-t/\tau}}$$

M(t), SFR(t)

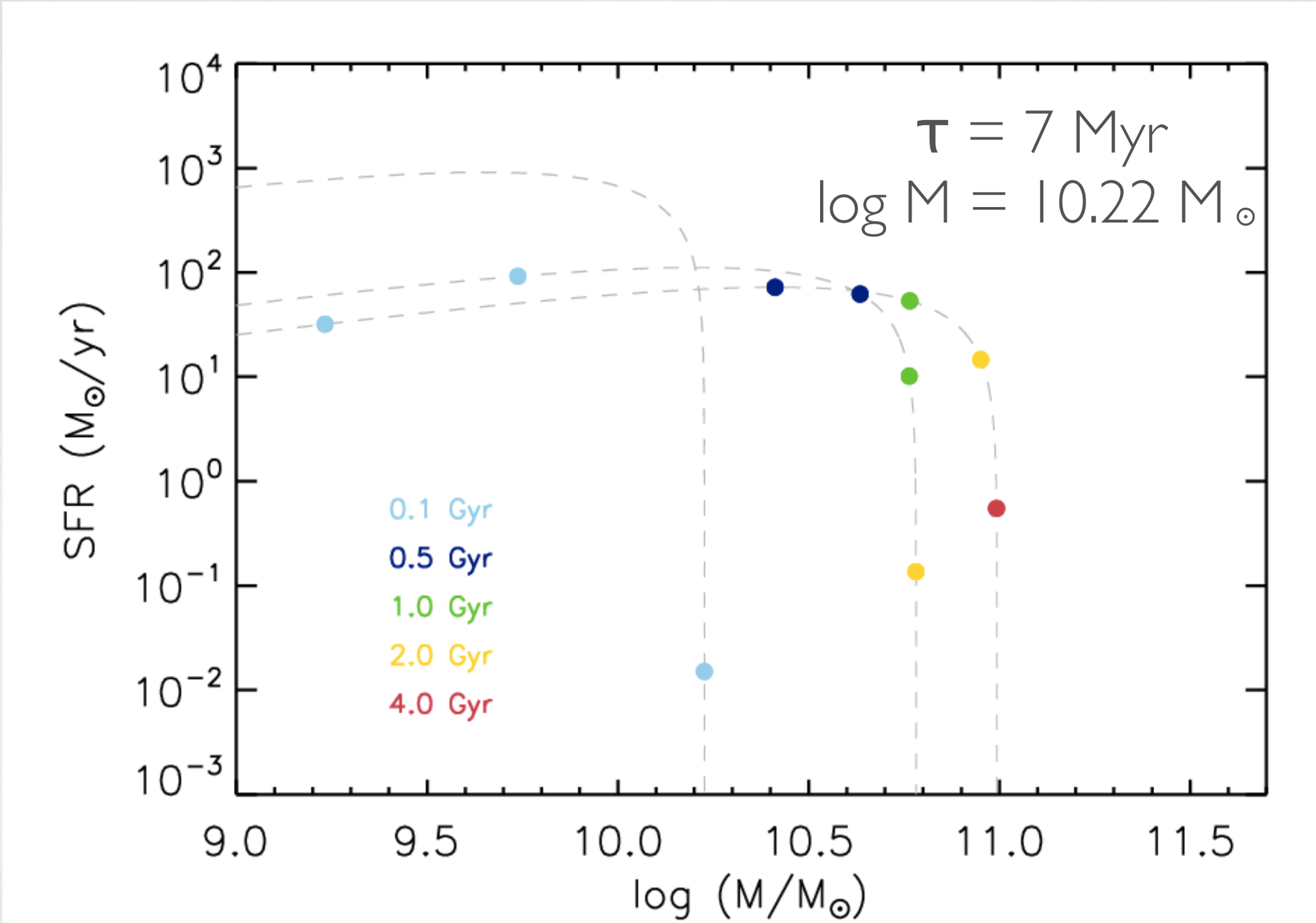
SFH TRACKS


τ = 200 Myr
log M = 10.78 M⊙
0.1 Gyr
0.5 Gyr
1.0 Gyr
2.0 Gyr
4.0 Gyr
SFR (M⊙/yr)
log (M/M⊙)
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
9.0
9.5
10.0
10.5
11.0
11.5

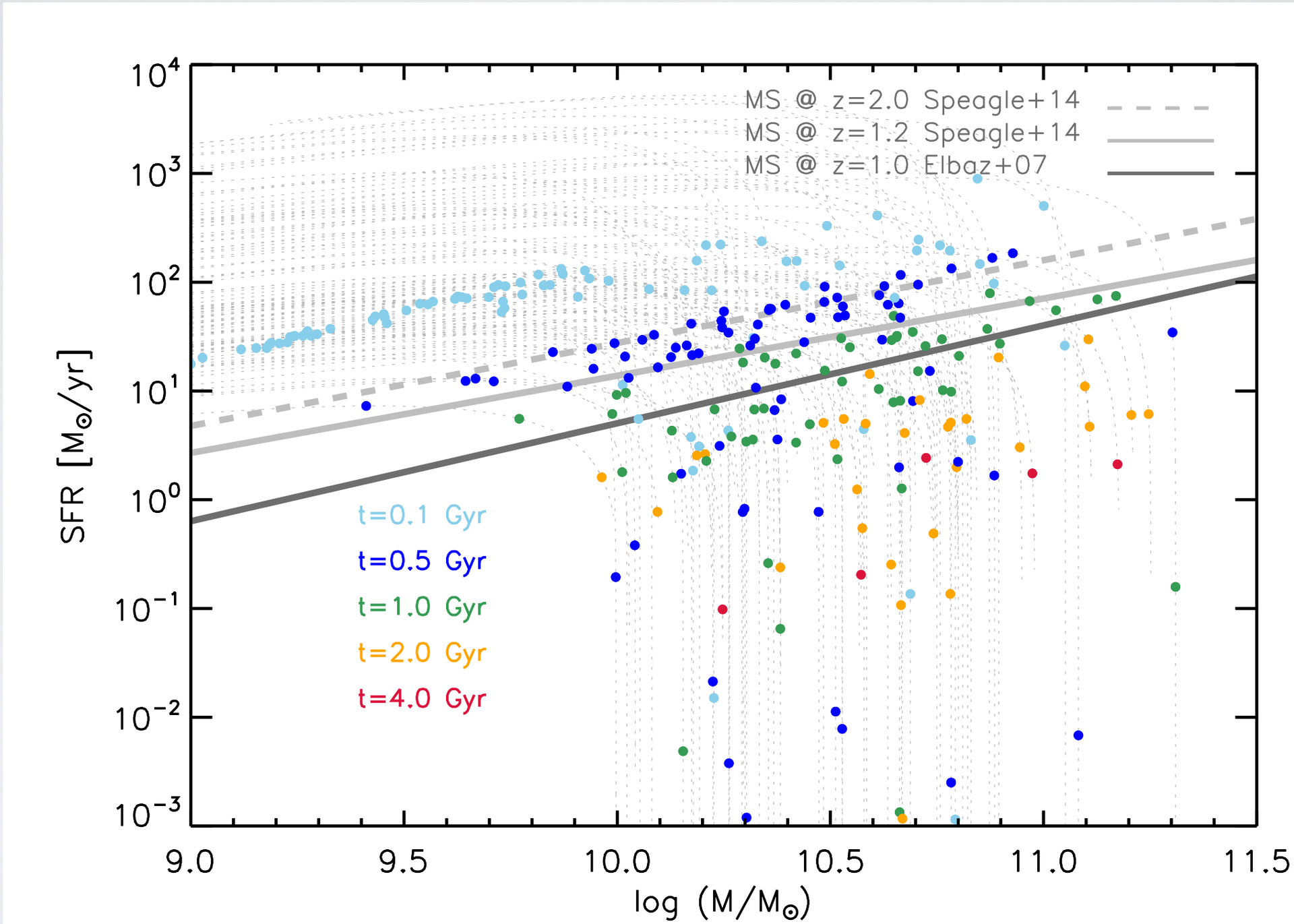
SFH TRACKS


τ = 500 Myr
log M = 11.00 M⊙
SFR (M⊙/yr)
10^4
10^3
10^2
10^1
10^0
10^−1
10^−2
10^−3
0.1 Gyr
0.5 Gyr
1.0 Gyr
2.0 Gyr
4.0 Gyr
9.0
9.5
10.0
10.5
11.0
11.5
log (M/M⊙)

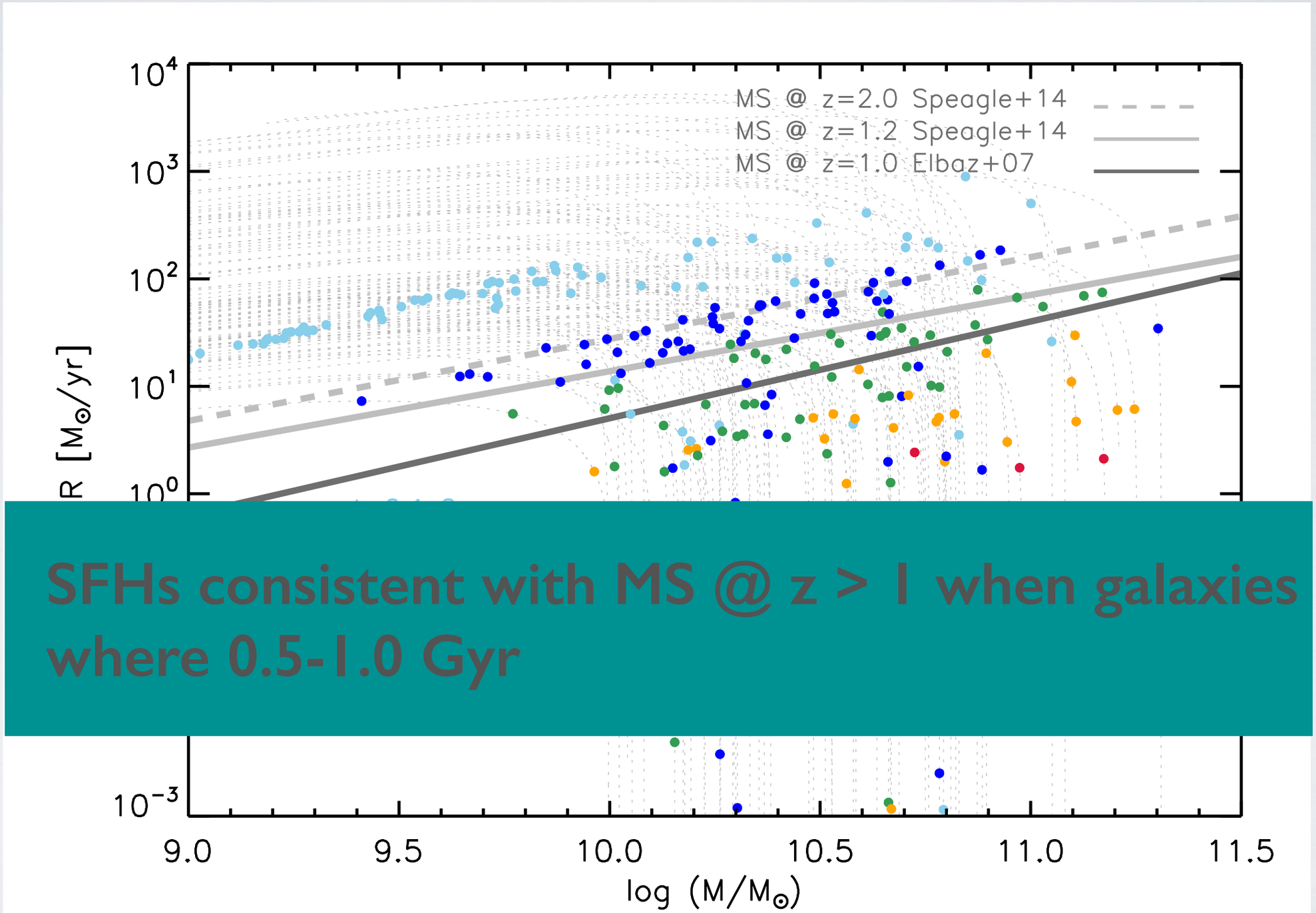
SFH TRACKS


τ = 7 Myr
log M = 10.22 M⊙
0.1 Gyr
0.5 Gyr
1.0 Gyr
2.0 Gyr
4.0 Gyr
SFR (M⊙/yr)
log (M/M⊙)
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
9.0
9.5
10.0
10.5
11.0
11.5

SFH TRACKS

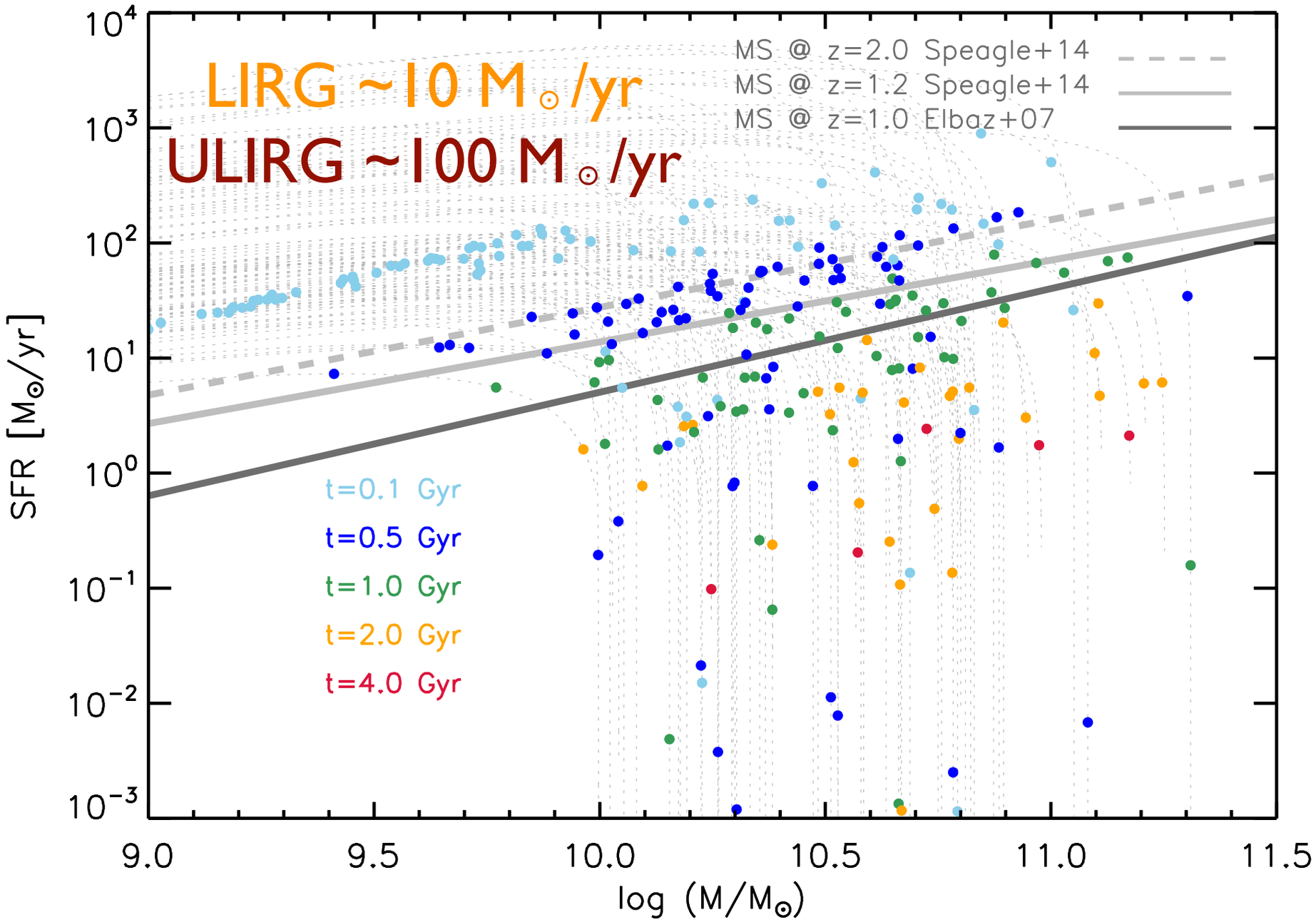

MS @ z=2.0 Speagle+14
MS @ z=1.2 Speagle+14
MS @ z=1.0 Elbaz+07
t=0.1 Gyr
t=0.5 Gyr
t=1.0 Gyr
t=2.0 Gyr
t=4.0 Gyr
SFR [M⊙/yr]
log (M/M⊙)
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
9.0
9.5
10.0
10.5
11.0
11.5

SFH TRACKS

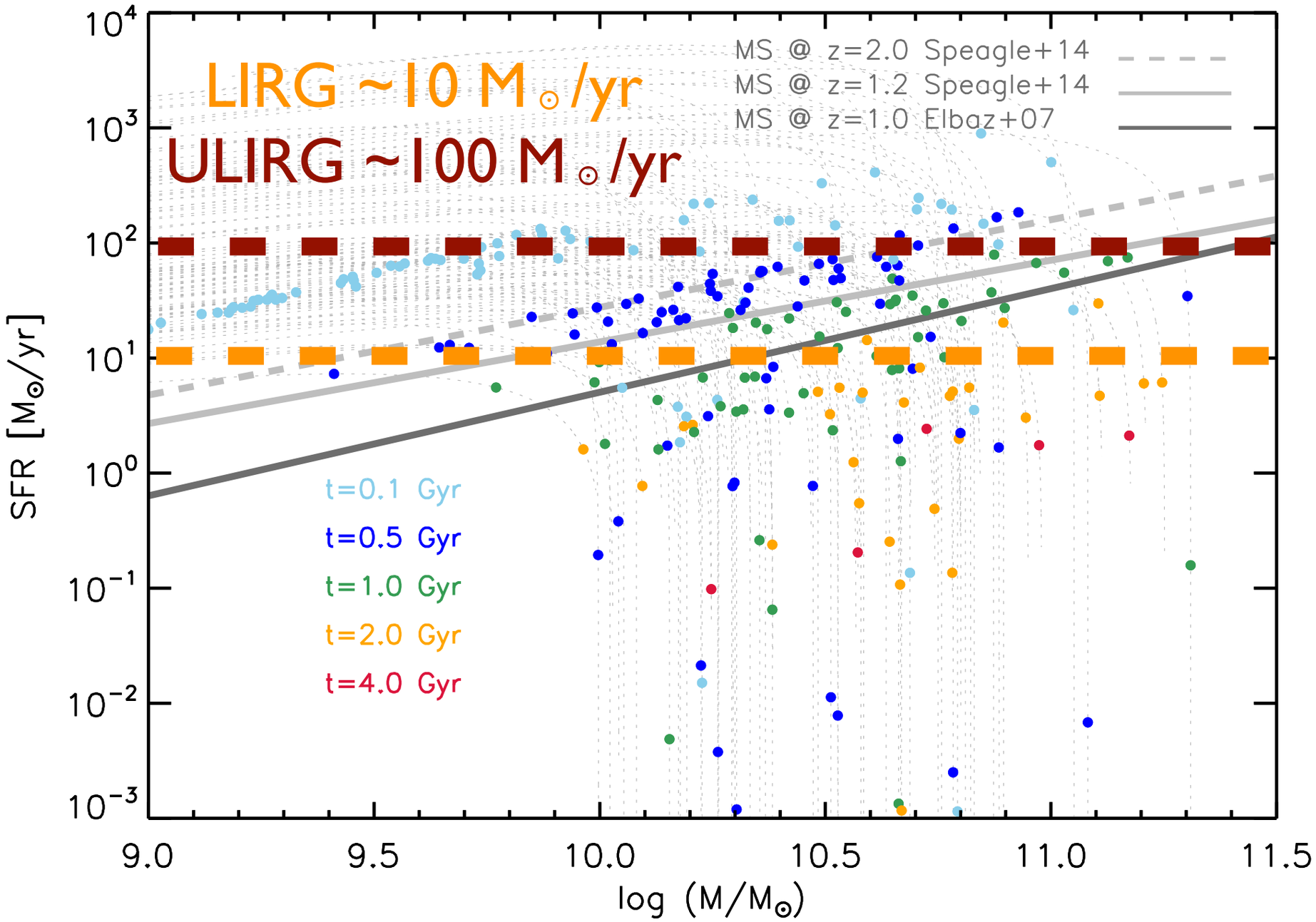


SFHs consistent with MS @ z > 1 when galaxies where 0.5-1.0 Gyr

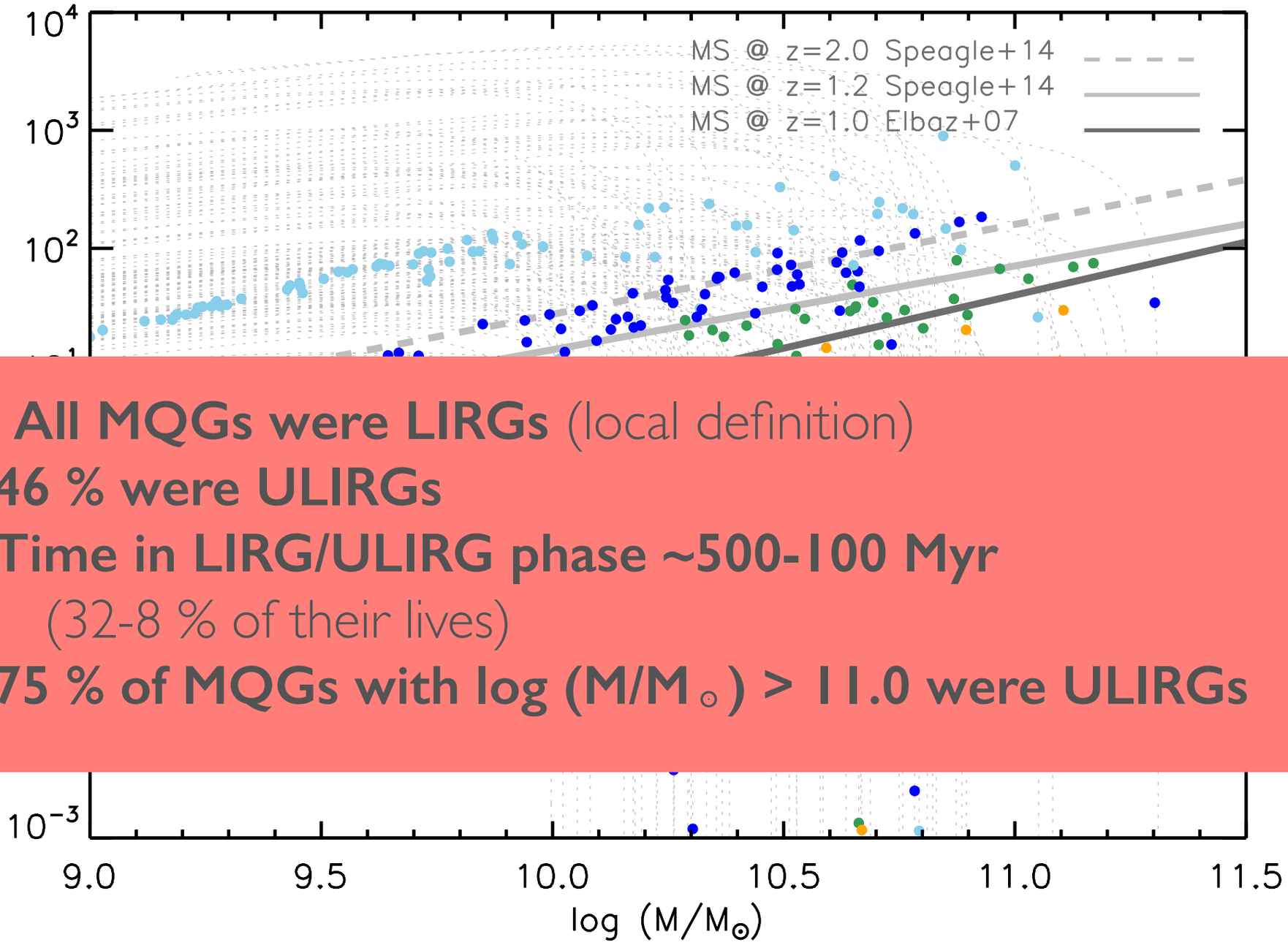
SFH TRACKS


LIRG ~10 M⊙/yr
ULIRG ~100 M⊙/yr
MS @ z=2.0 Speagle+14
MS @ z=1.2 Speagle+14
MS @ z=1.0 Elbaz+07
t=0.1 Gyr
t=0.5 Gyr
t=1.0 Gyr
t=2.0 Gyr
t=4.0 Gyr
SFR [M⊙/yr]
log (M/M⊙)
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
9.0
9.5
10.0
10.5
11.0
11.5

SFH TRACKS

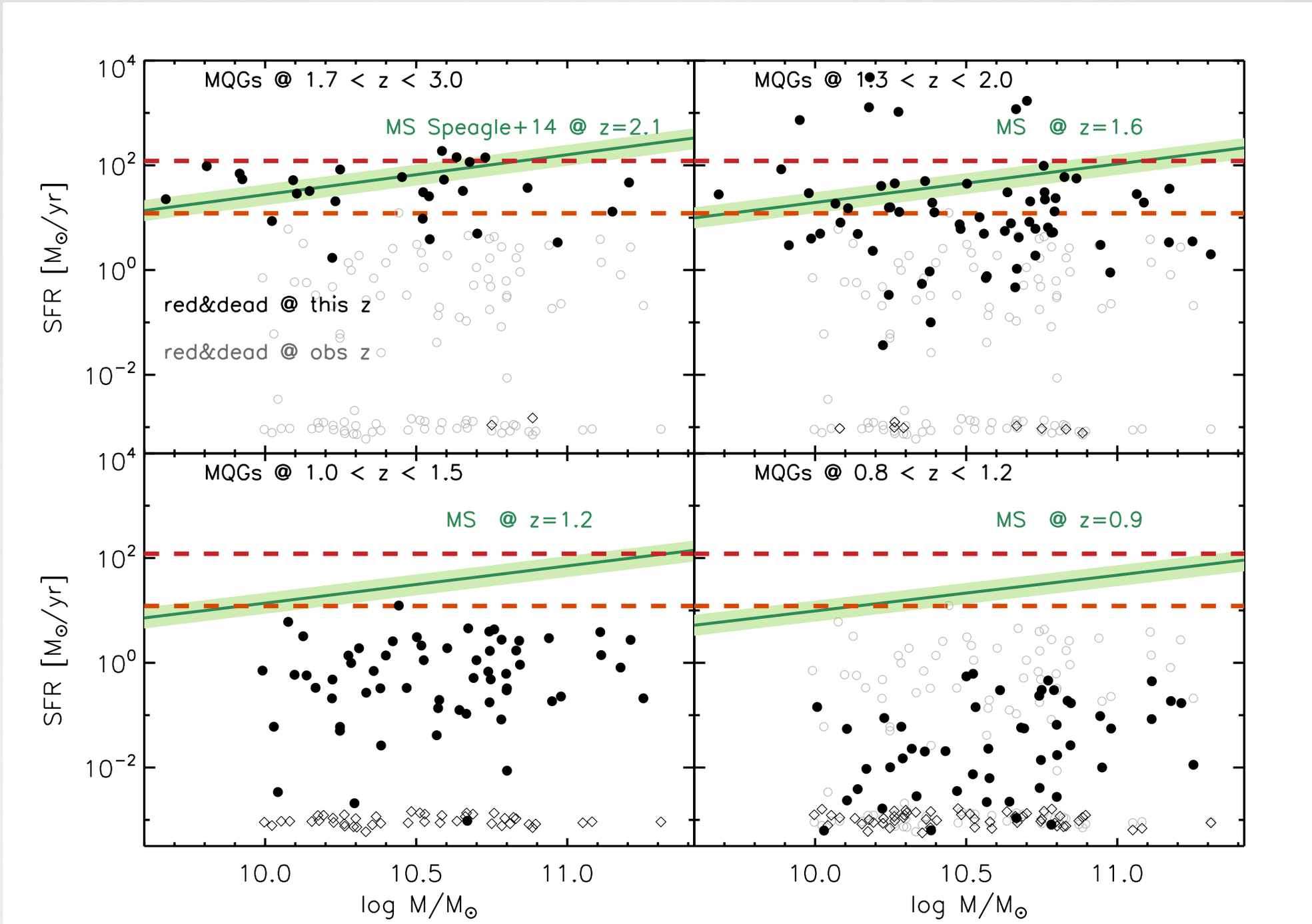

LIRG ~10 M⊙/yr
ULIRG ~100 M⊙/yr
MS @ z=2.0 Speagle+14
MS @ z=1.2 Speagle+14
MS @ z=1.0 Elbaz+07
t=0.1 Gyr
t=0.5 Gyr
t=1.0 Gyr
t=2.0 Gyr
t=4.0 Gyr
SFR [M⊙/yr]
log (M/M⊙)
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
9.0
9.5
10.0
10.5
11.0
11.5

SFH TRACKS

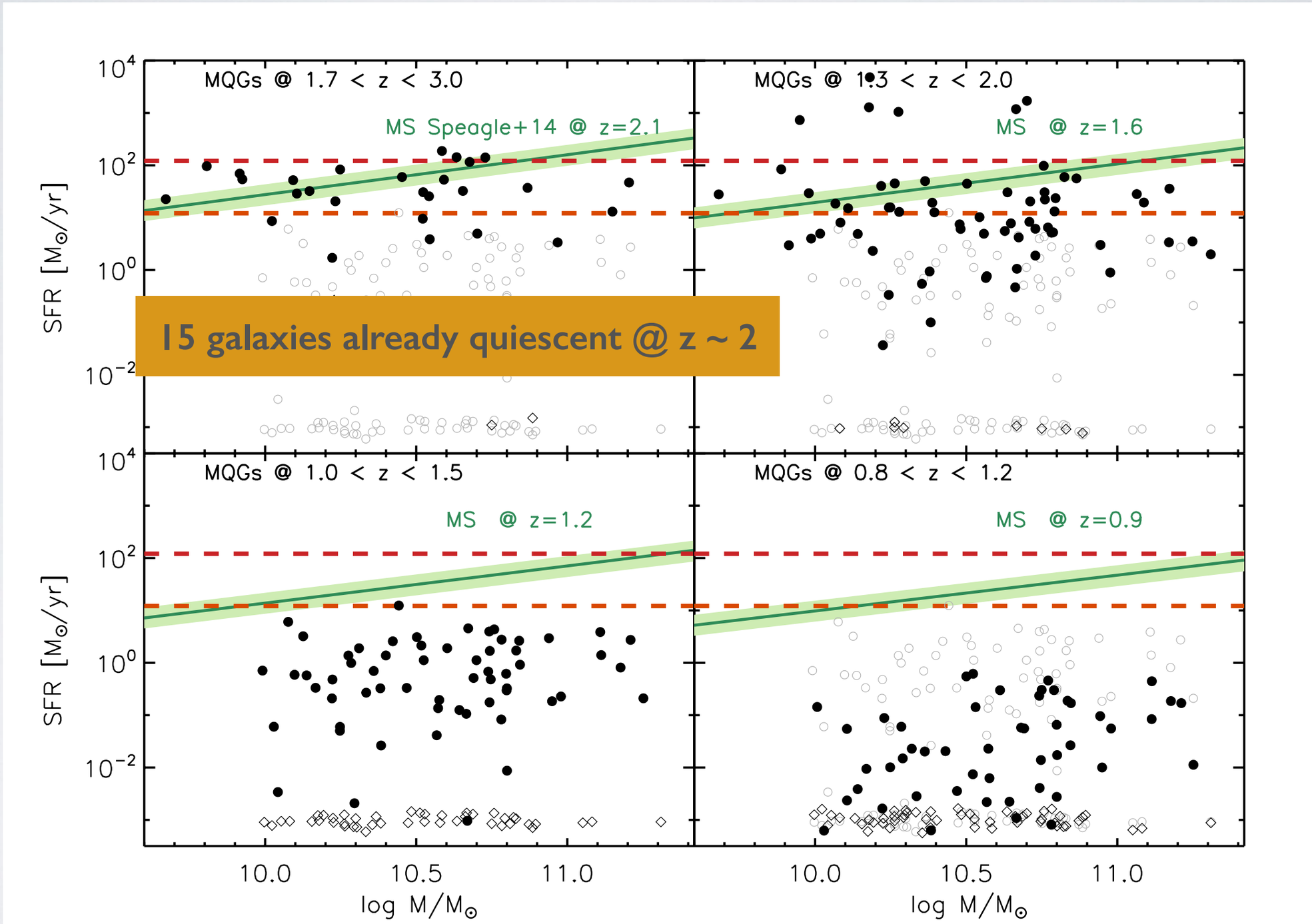


- **All MQGs were LIRGs** (local definition)
- **46 % were ULIRGs**
- **Time in LIRG/ULIRG phase ~500-100 Myr**
  (32-8 % of their lives)
- **75 % of MQGs with log (M/M$_\odot$) > 11.0 were ULIRGs**

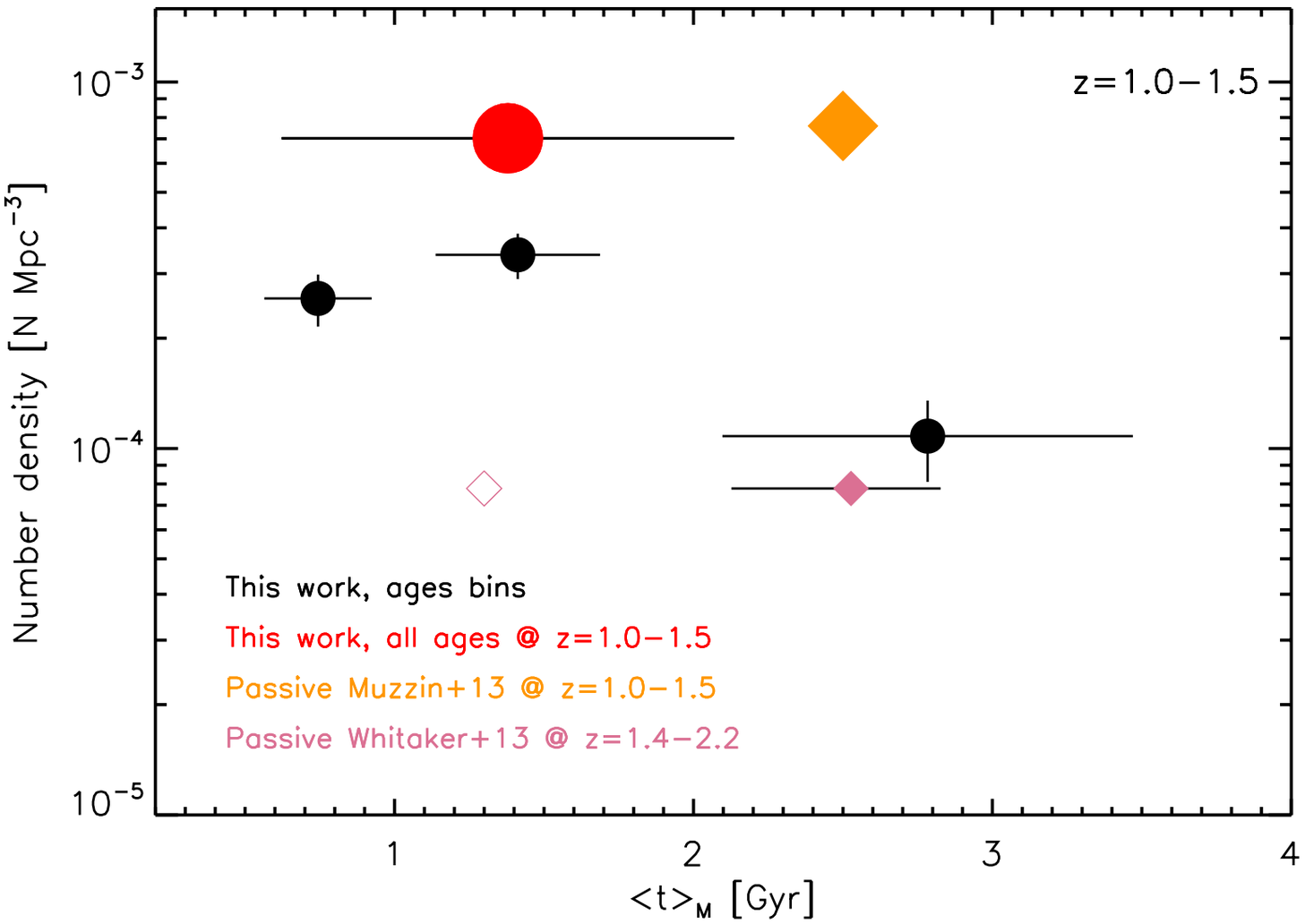
MAIN SEQUENCE EVOLUTION



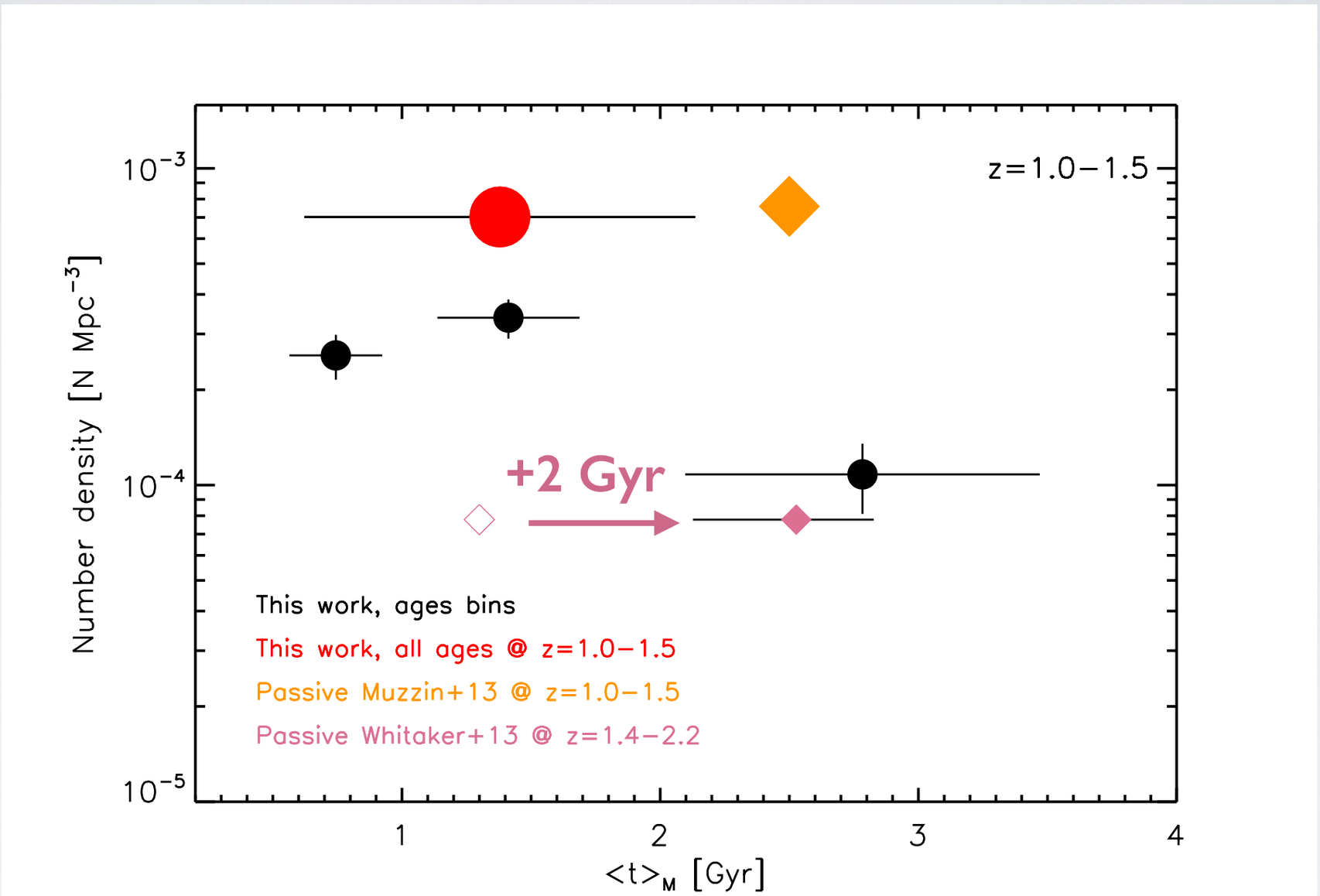
MAIN SEQUENCE EVOLUTION



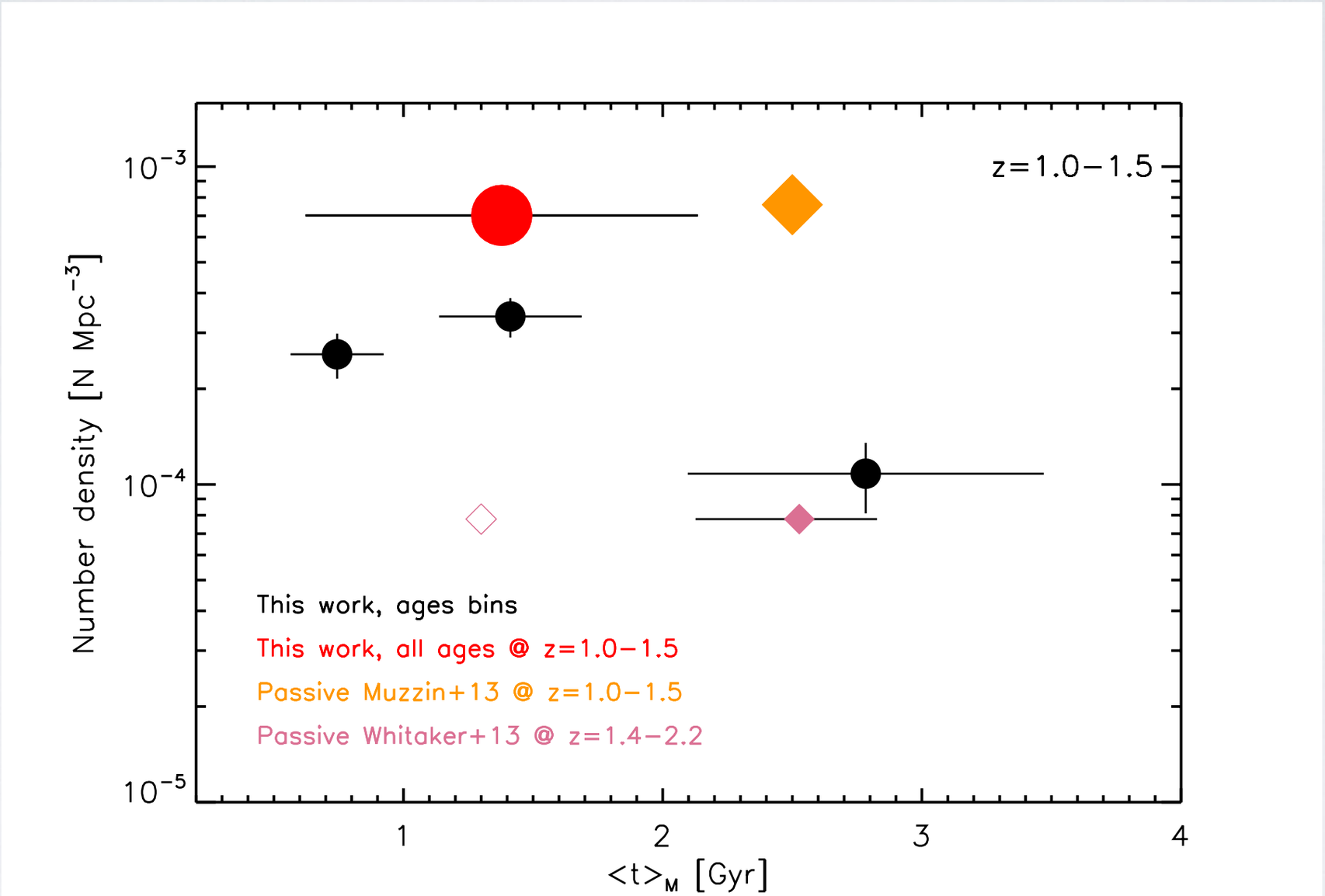
NUMBER DENSITY



NUMBER DENSITY



NUMBER DENSITY



Number density of dead galaxies consistent with:
Muzzin +13 @ z=1.0-1.5 (all sample)
Whitaker + 13 @ z=1.4-2.2 (t > 2.0 Gyr)

CONCLUSIONS

- Combination of **SHARDS + GRISM** data fundamental for **constraining galaxy properties** of massive quiescent galaxies at z > 1.0
- MQGs @ z=1.0-1.5 **dominated by "new arrivals"** (~1 Gyr old galaxies).
- The average age of a massive quiescent galaxy at 1.0<z<1.5 is **1.5 Gyr**, and the typical timescale is **100 Myr.**
- A **small fraction (16%) is older (2 Gyr, τ ~ 400 Gyr),** so they were already dead by z~2 (cf. Whitaker +13).
- According to the SFHs we derived, MQGs @ z=1.0-1.5 **lived on the observed main sequence at z=1.5-2.0,** following closely its slope and location
- The **SFR peak** in the SFHs of our sample lies **typically at the LIRG level.** The SFH for some (**46 %**) galaxies are consistent with a fraction of their lifetime time experiencing a **ULIRG phase**.
- Most massive galaxies (**log M > 10.8 $M_\odot$**) were **formed first** (t_U ~ 3 Gyr) in very intense SF processes (> 200 $M_\odot$/yr)

More data coming!

GTC Large program SHARDS Frontier Fields approved

Thank you!!