Timing the evolution of galaxies

Camilla Pacifici

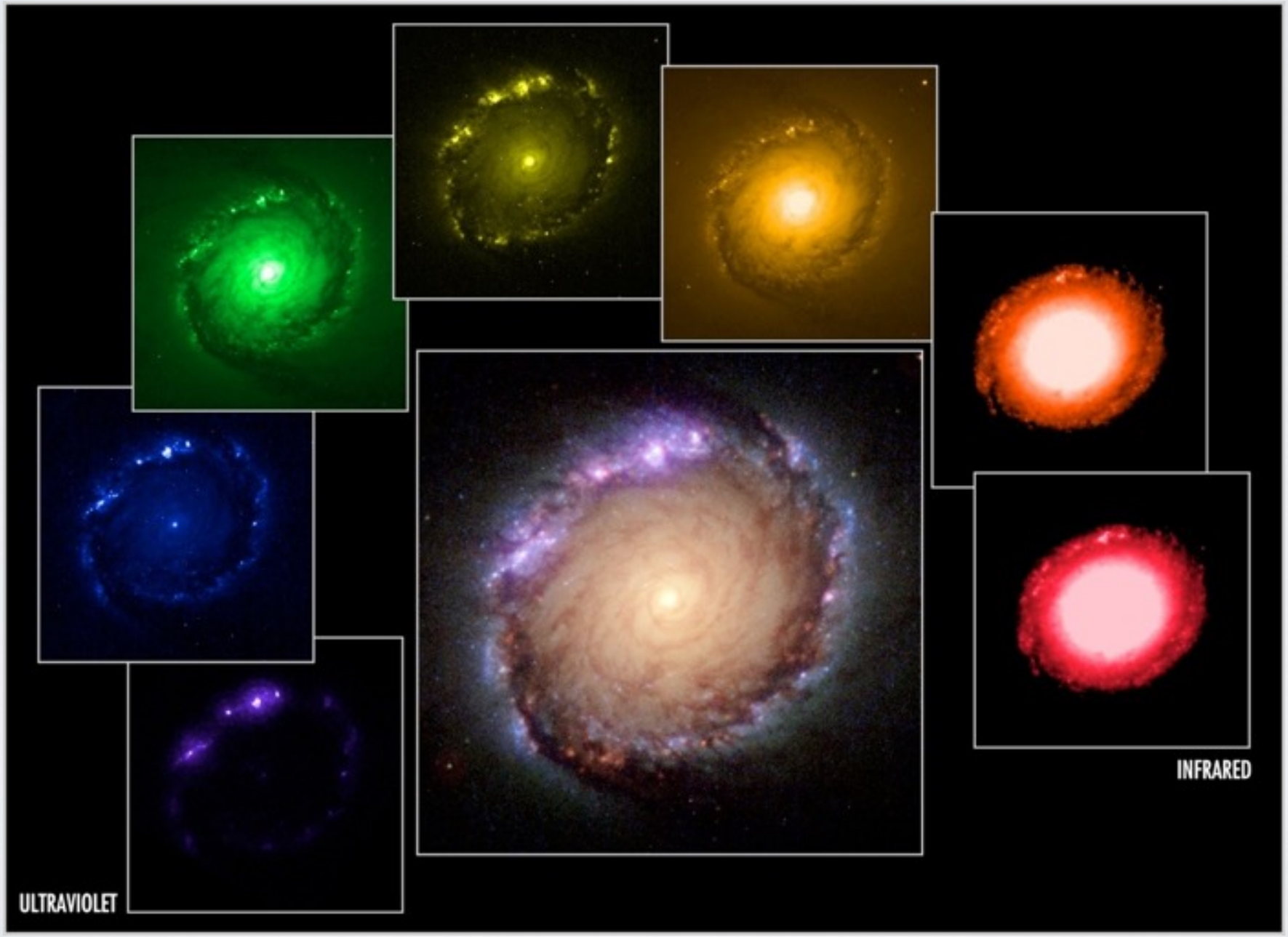
Susan Kassin, Jon Gardner, Harry Ferguson, Guillermo Barro, Sandy Faber, Ben Weiner
Sukyoung Yi, Stephane Charlot, Arjen van der Wel, Aaron Dutton

The early growth of galaxies: The HST, Spitzer and Herschel joint legacy, Sexten, January 12th, 2016

Context

Galaxies

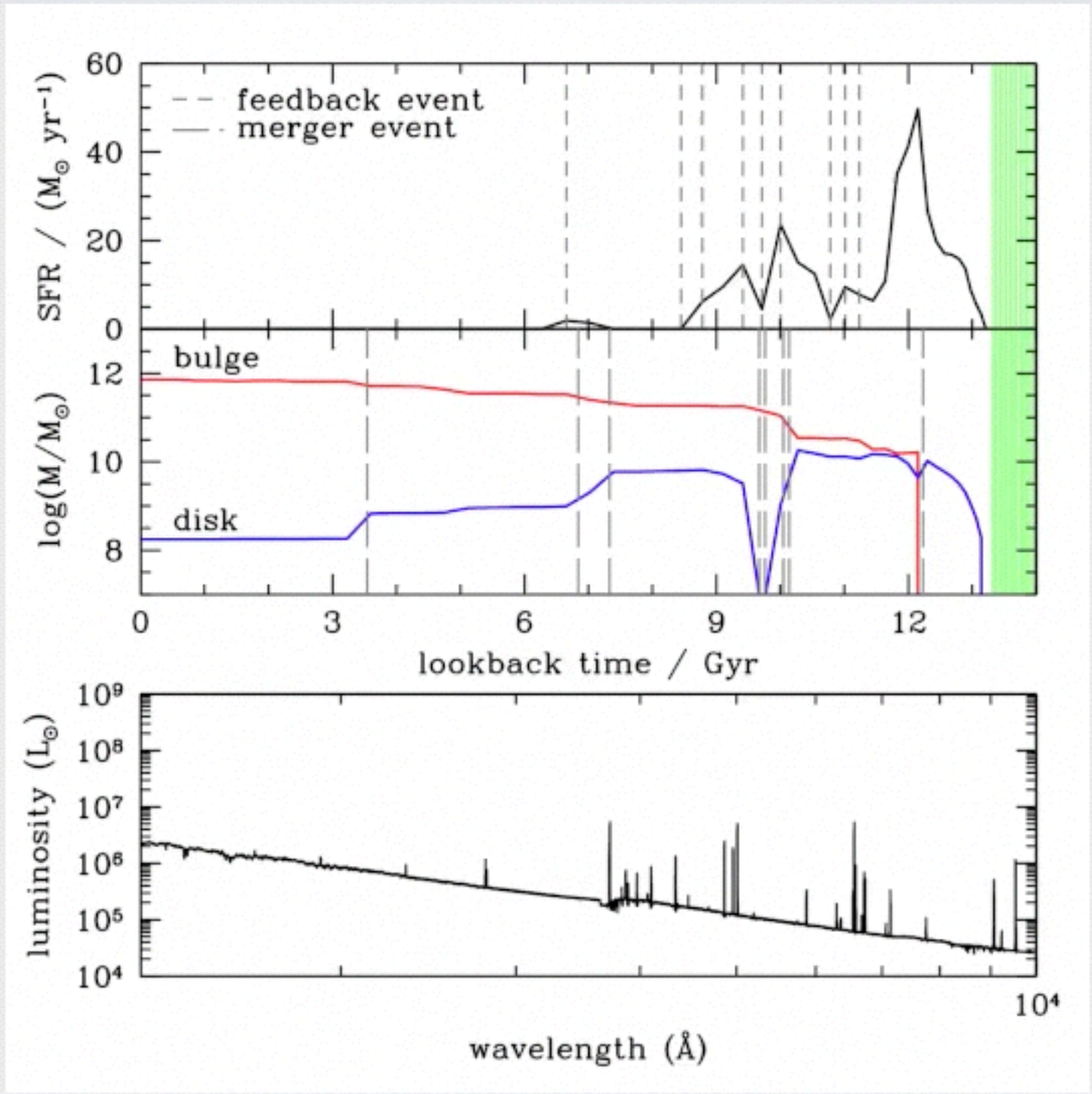
- how do they form?
- how do they evolve?
- what are they made of?



Connecting Theory and Observations

Simulated SFH

Model SED



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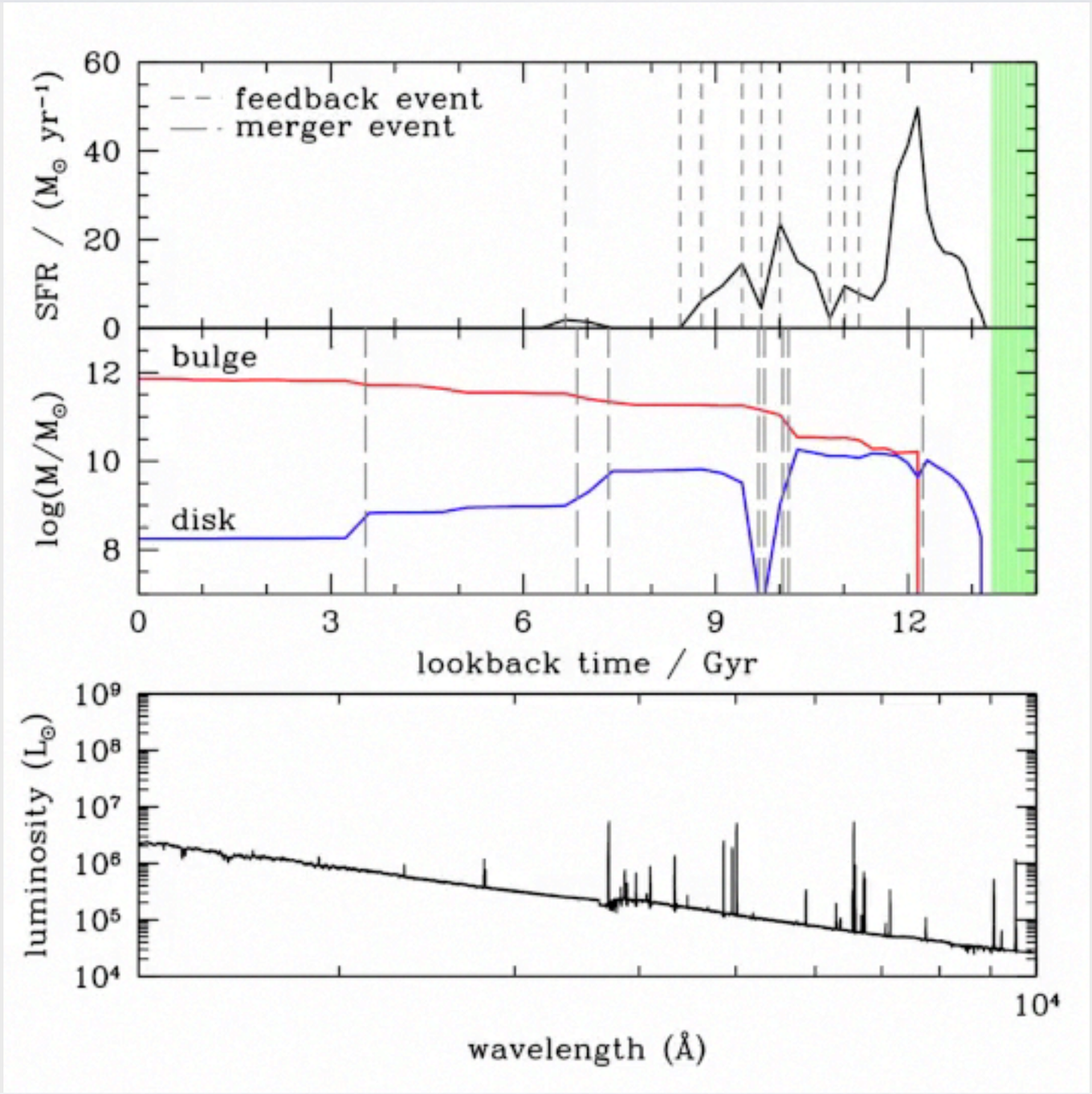

Models of galaxy spectral energy distributions

build library of galaxy spectra which can best reproduce a wide range of observables

star formation and chemical enrichment histories

+

emission by the stars

+

emission by the gas

+

effect of the dust

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use models as priors to interpret the observations

The need for physically motivated models

The need for physically motivated models

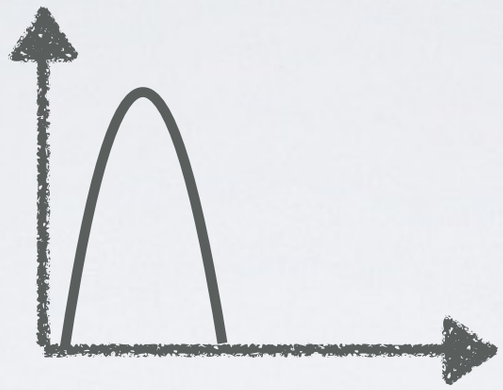
Data

Pacifici et al. (2015)

The need for physically motivated models

Data

Prior



Pacifici et al. (2015)

The need for physically motivated models

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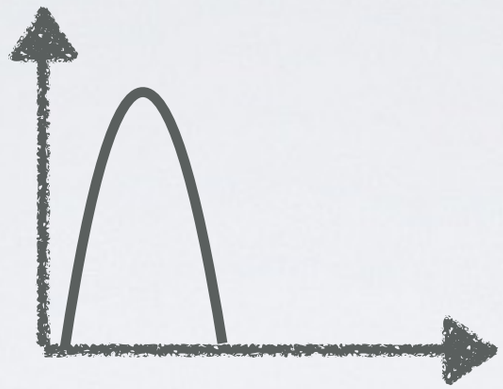
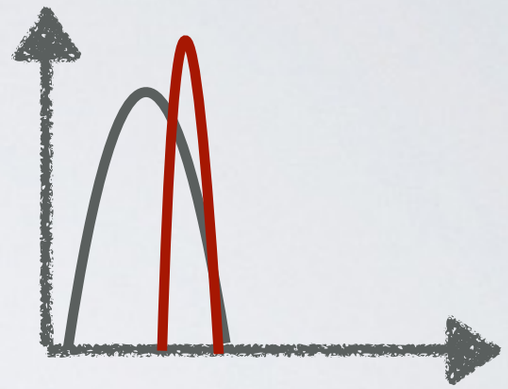


Result



Pacifici et al. (2015)

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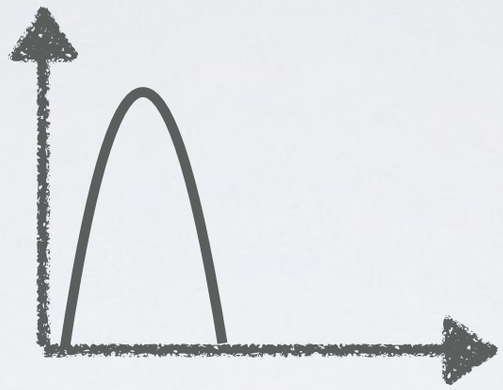

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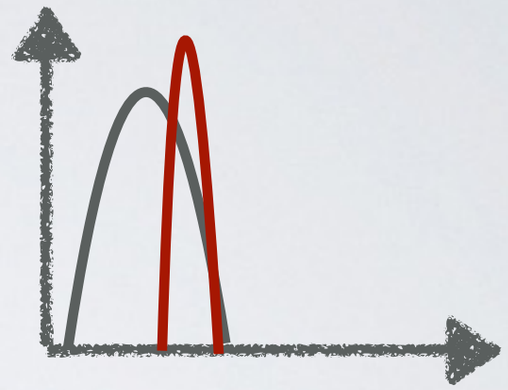

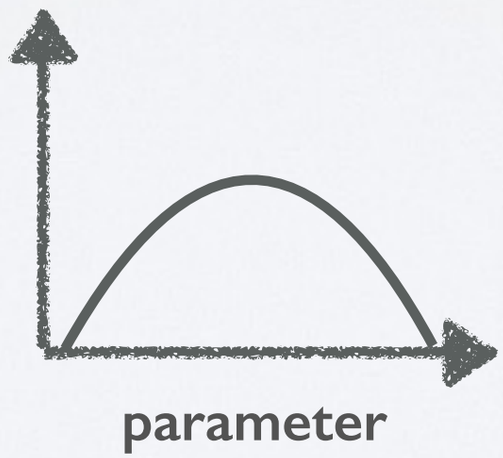

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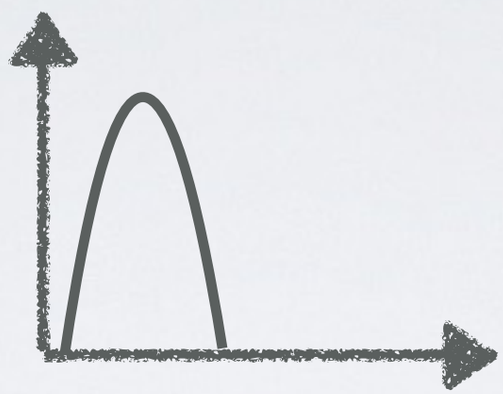

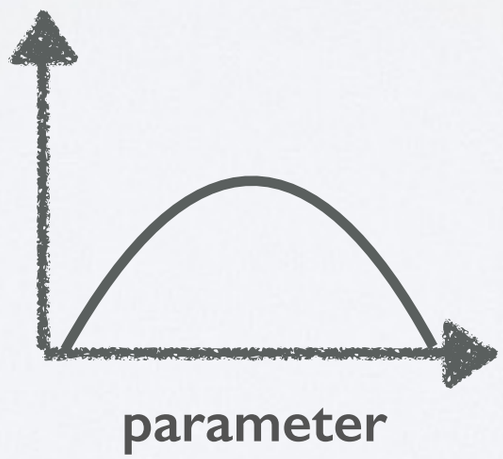

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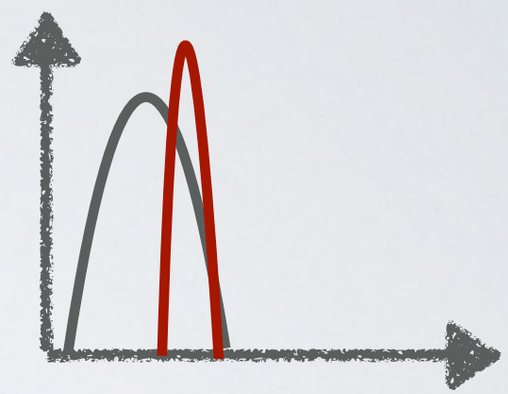

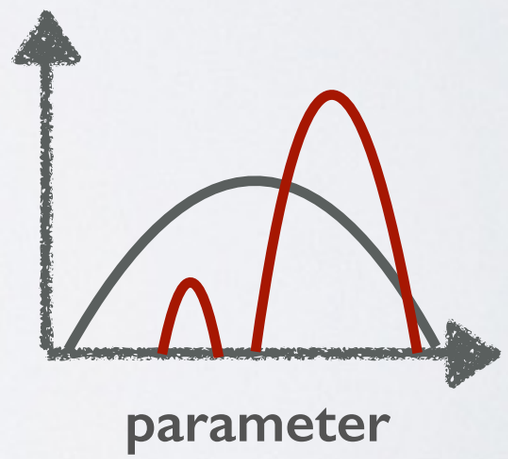

Pacifici et al. (2015)

Models of galaxy spectral energy distributions

Appeal to state-of-the-art models to include:

- physically motivated SF and chemical enrichment histories (from simulations)
- latest progress in the spectral modeling of stellar populations
- contamination of stellar emission by nebular emission
- comprehensive prescriptions for attenuation by dust

(large range of parameters to account for uncertainties in the models)

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(large range of parameters to account for uncertainties in the models)

build large library of "as realistic as possible" SEDs to estimate physical parameters from multi-wavelength observations

Pacifici et al. (2012)

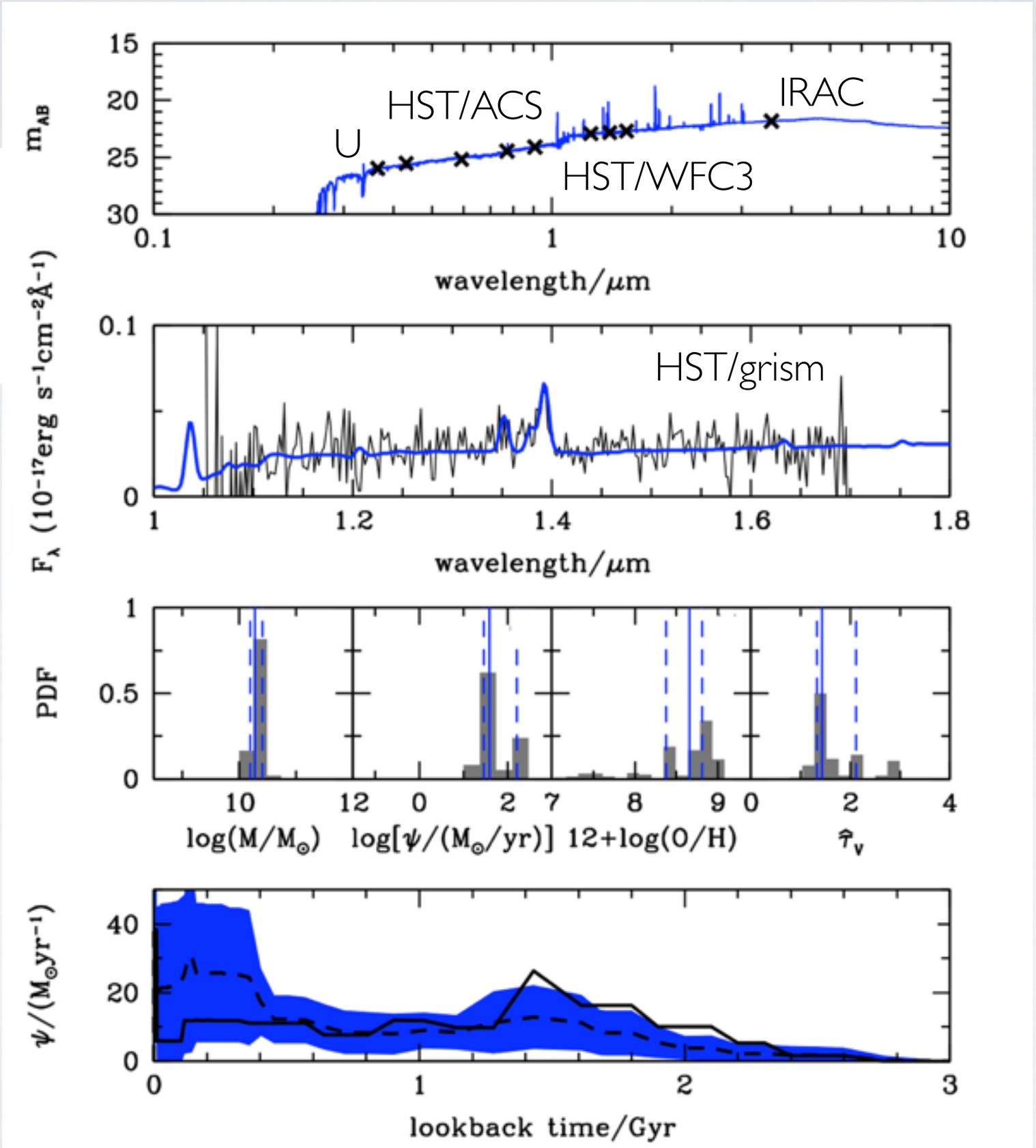
Interpreting observations

3D-HST data

z=1.781

✱ data

— model



best-estimate SFH

extract:
stellar mass
SFR
oxygen abundance
dust

Pacifici et al. (2015)

The star formation histories of galaxies

The star formation histories of galaxies

Applying the modelling approach to different samples:

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- Photometric and spectroscopic observations at z<1.4 (DEEP2)
- Timing the evolution of local galaxies (SDSS)
- Towards high redshift with CANDELS

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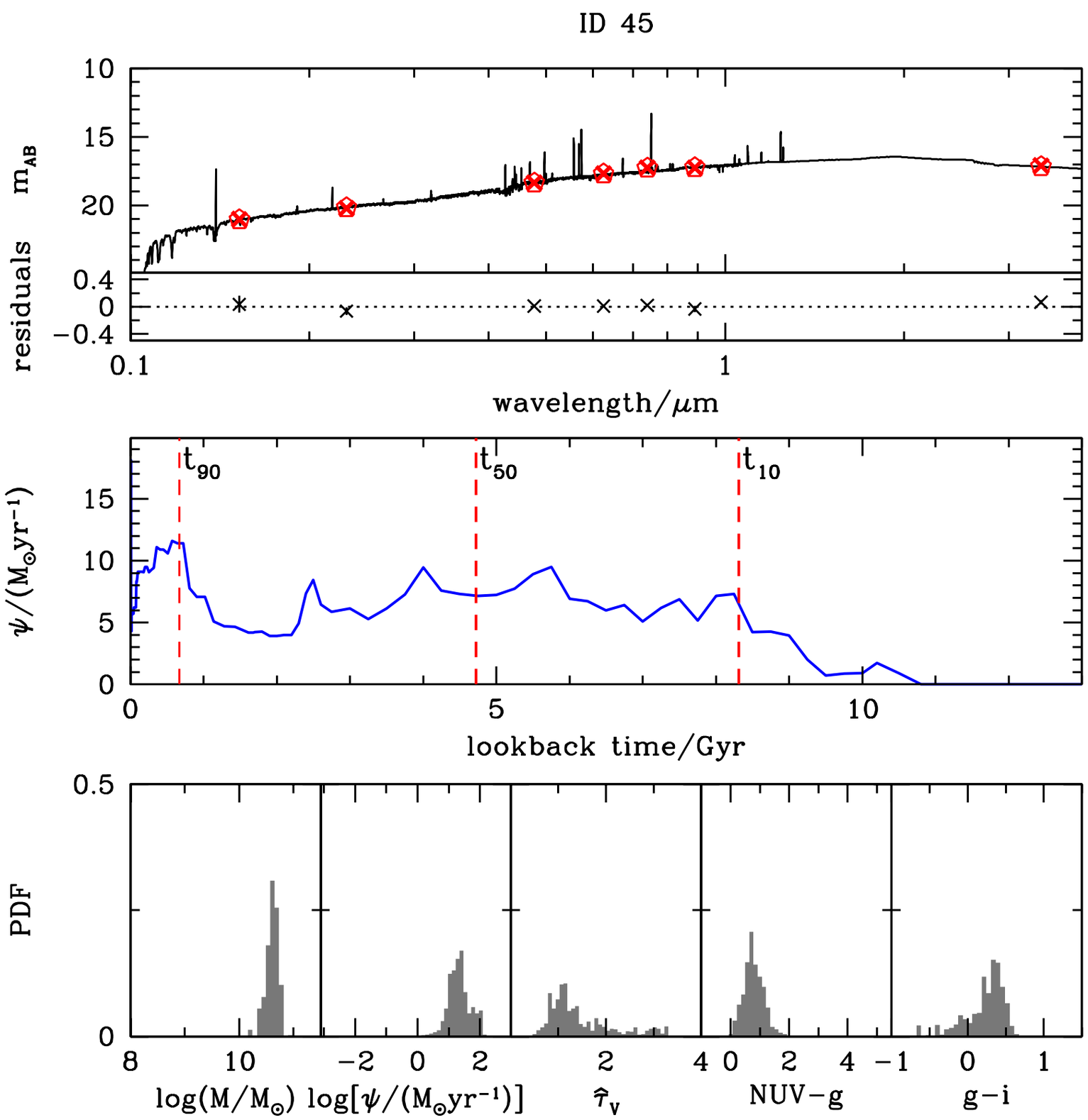


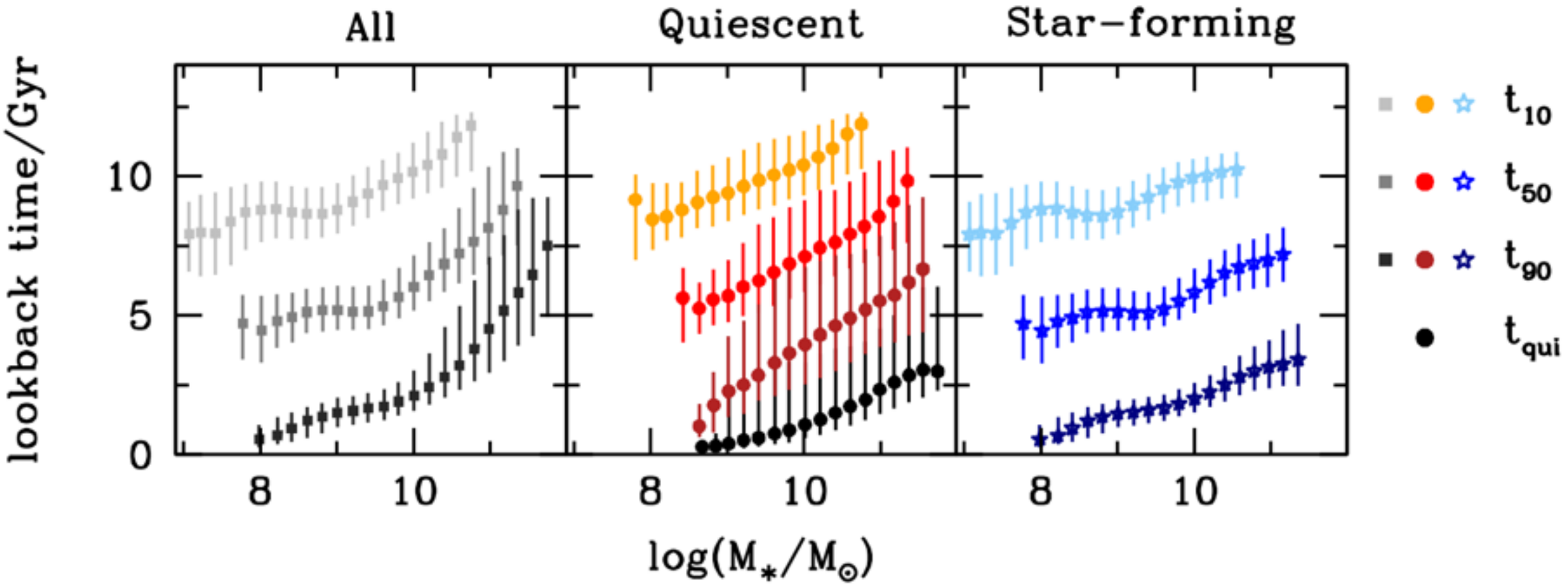
GALEX+SDSS+WISE

best-estimate SFH

stellar mass
SFR
dust
colors

Pacifici et al. (submitted)

The star formation histories of galaxies



- From observations we can measure the evolutionary stages of galaxies
- Quiescent and star-forming galaxies evolve differently
- We can use similar plots to calibrate simulations

Pacifici et al. (submitted)

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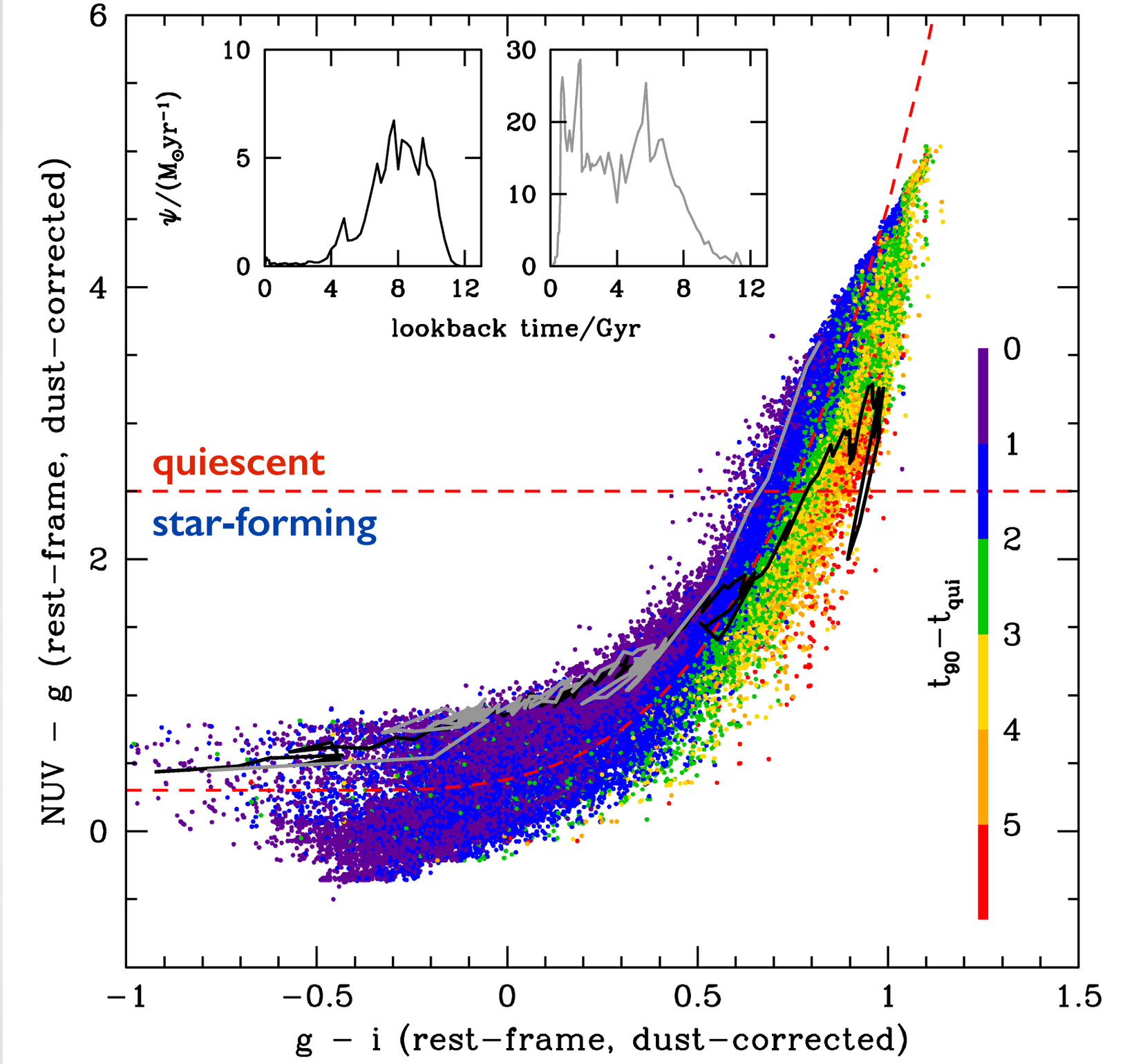

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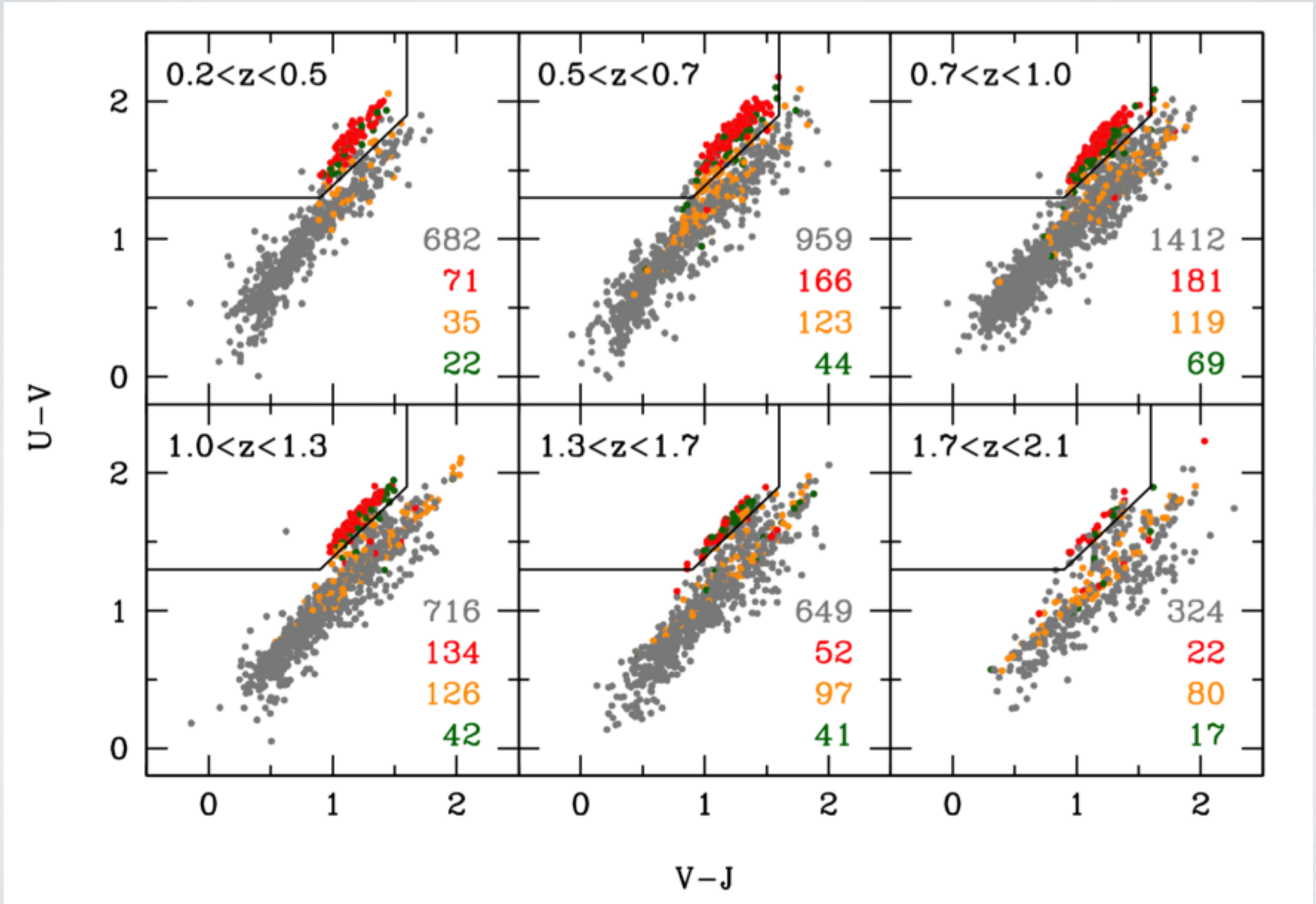

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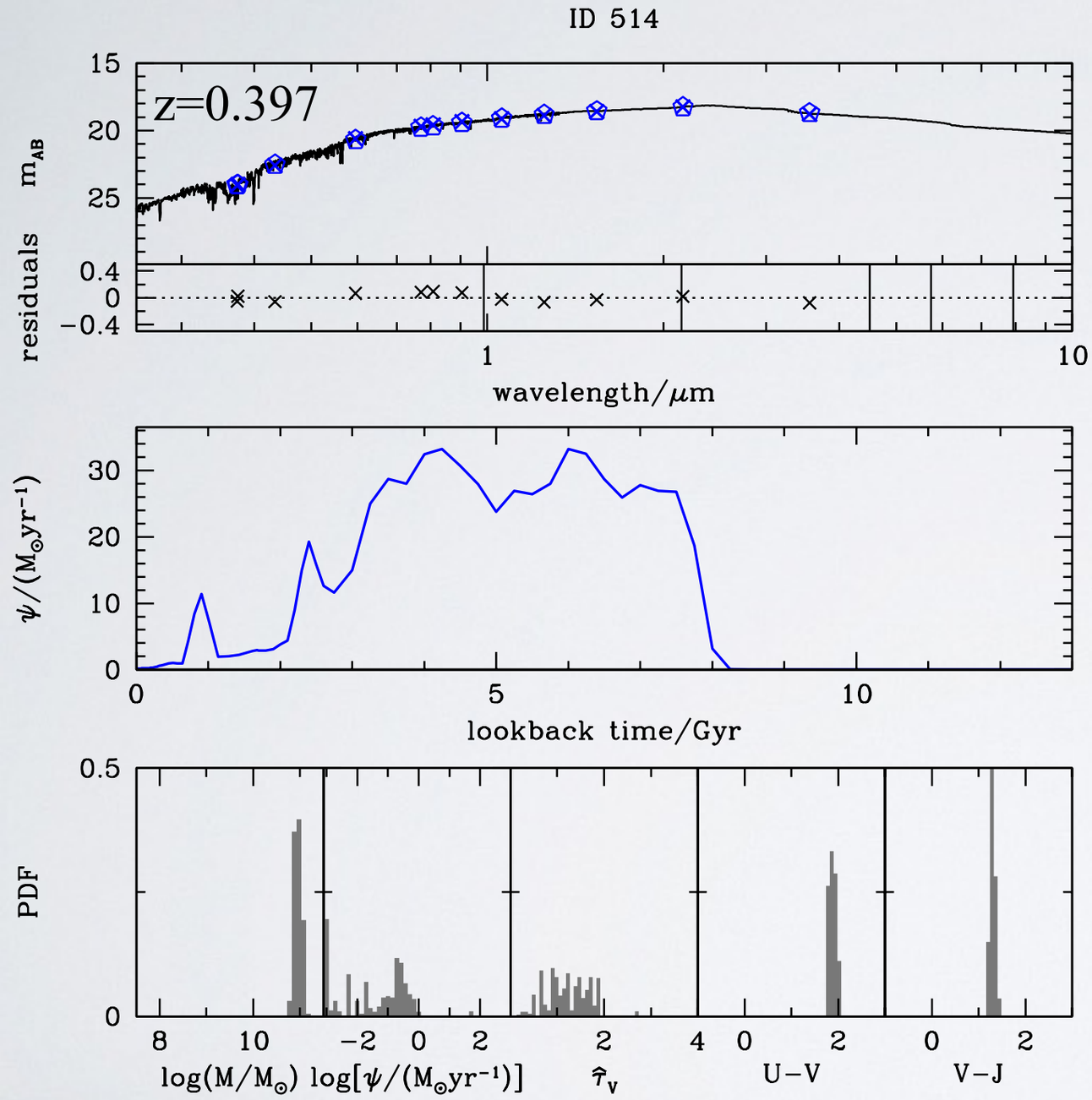

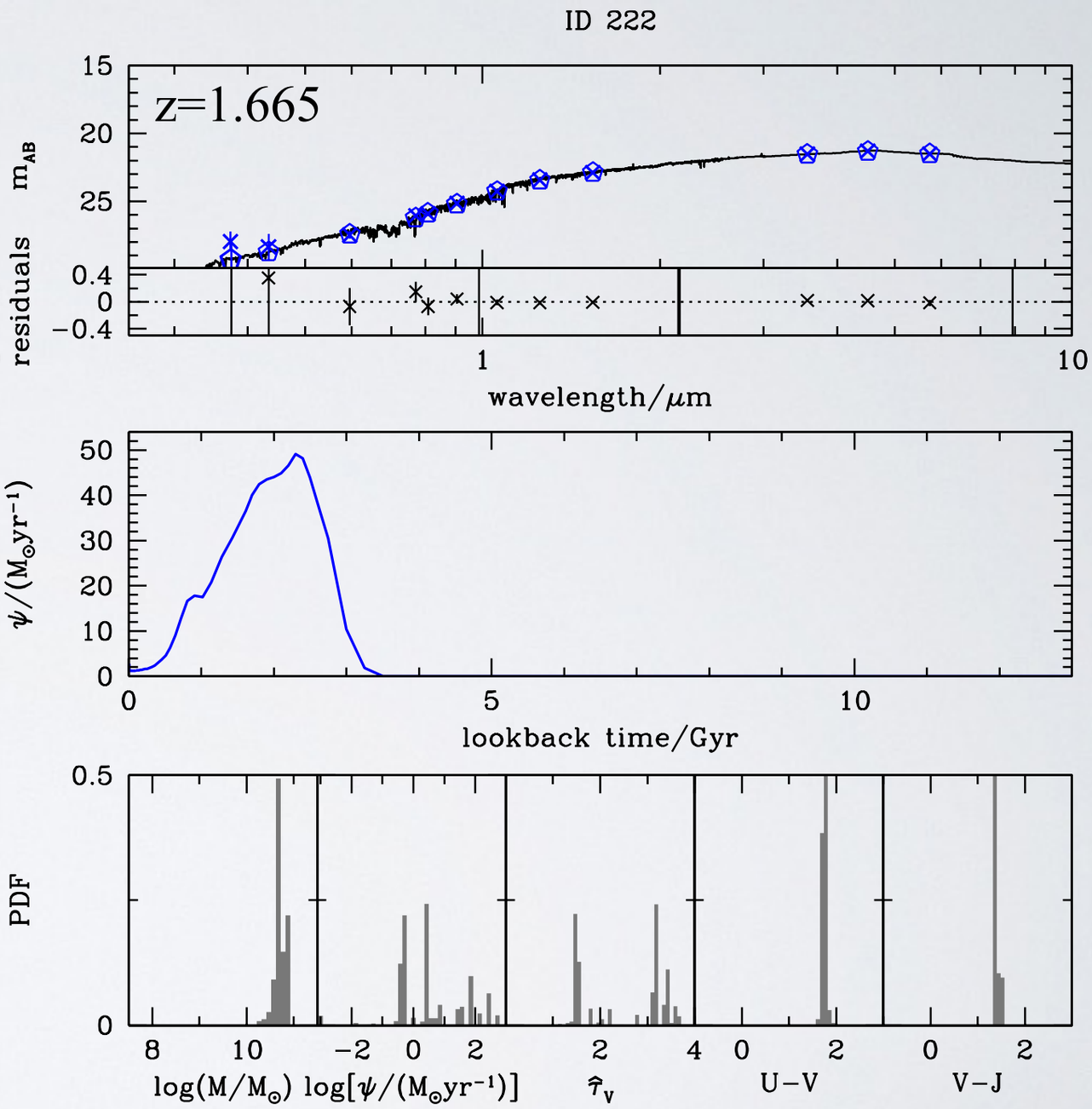

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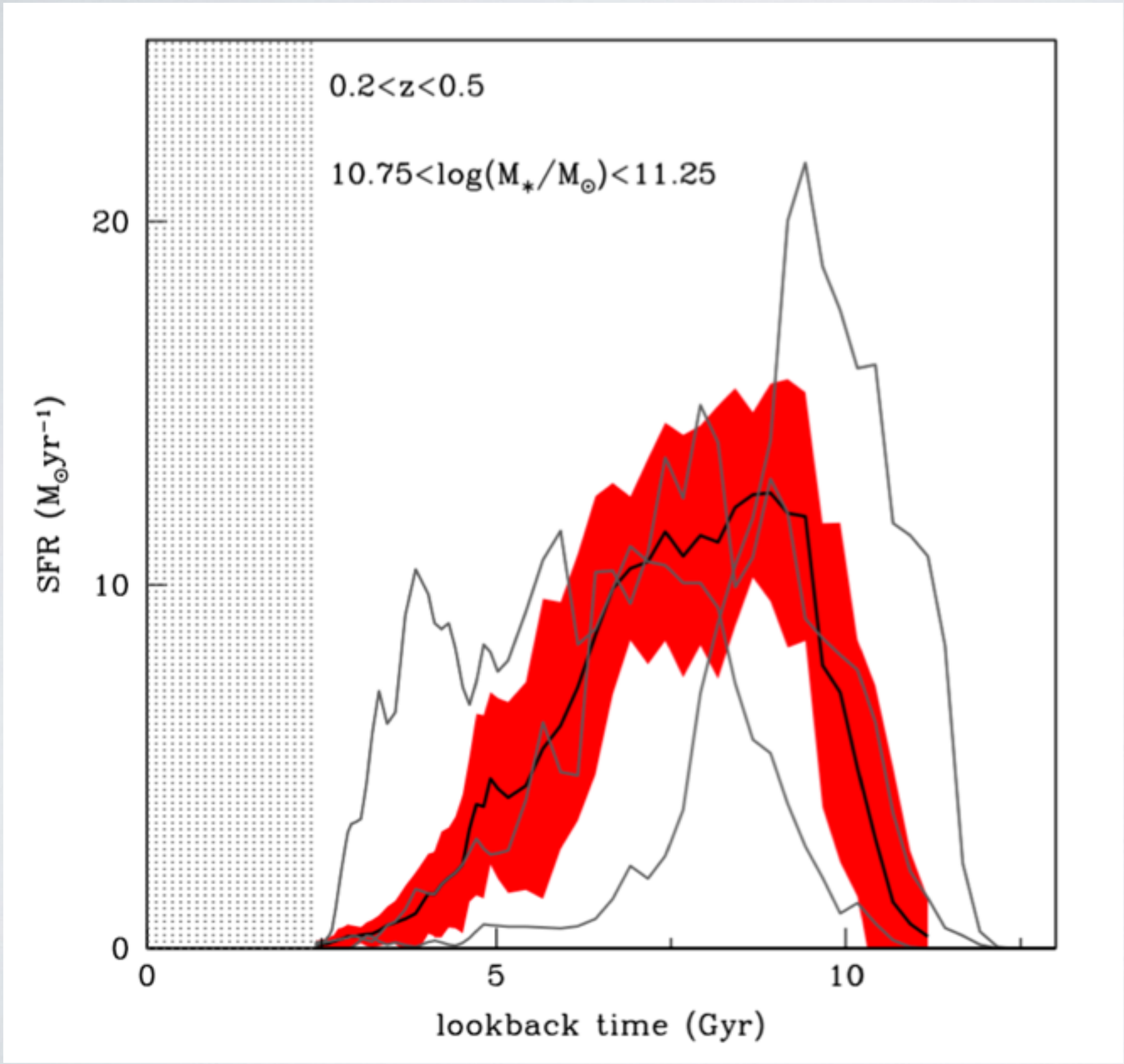

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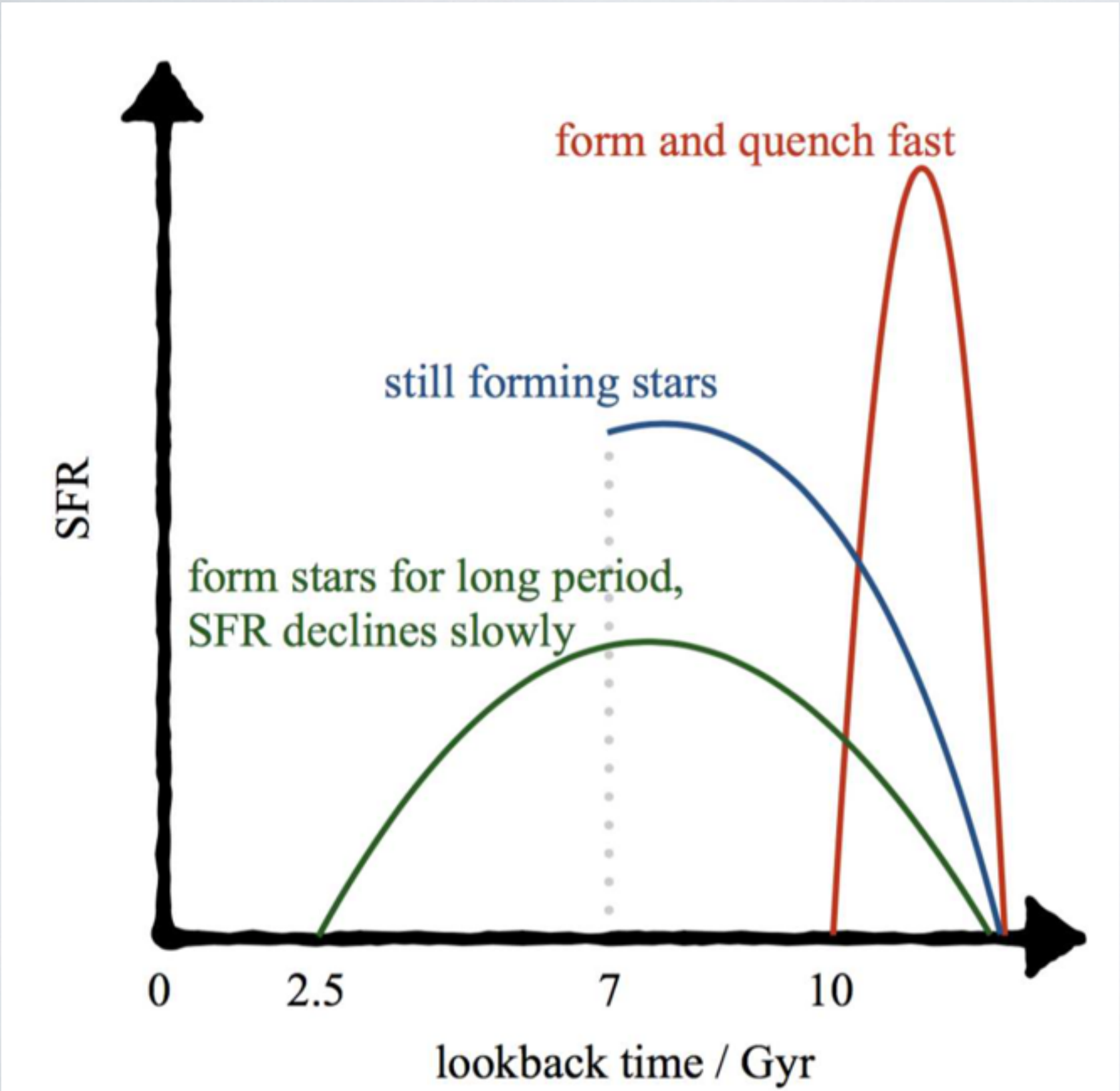

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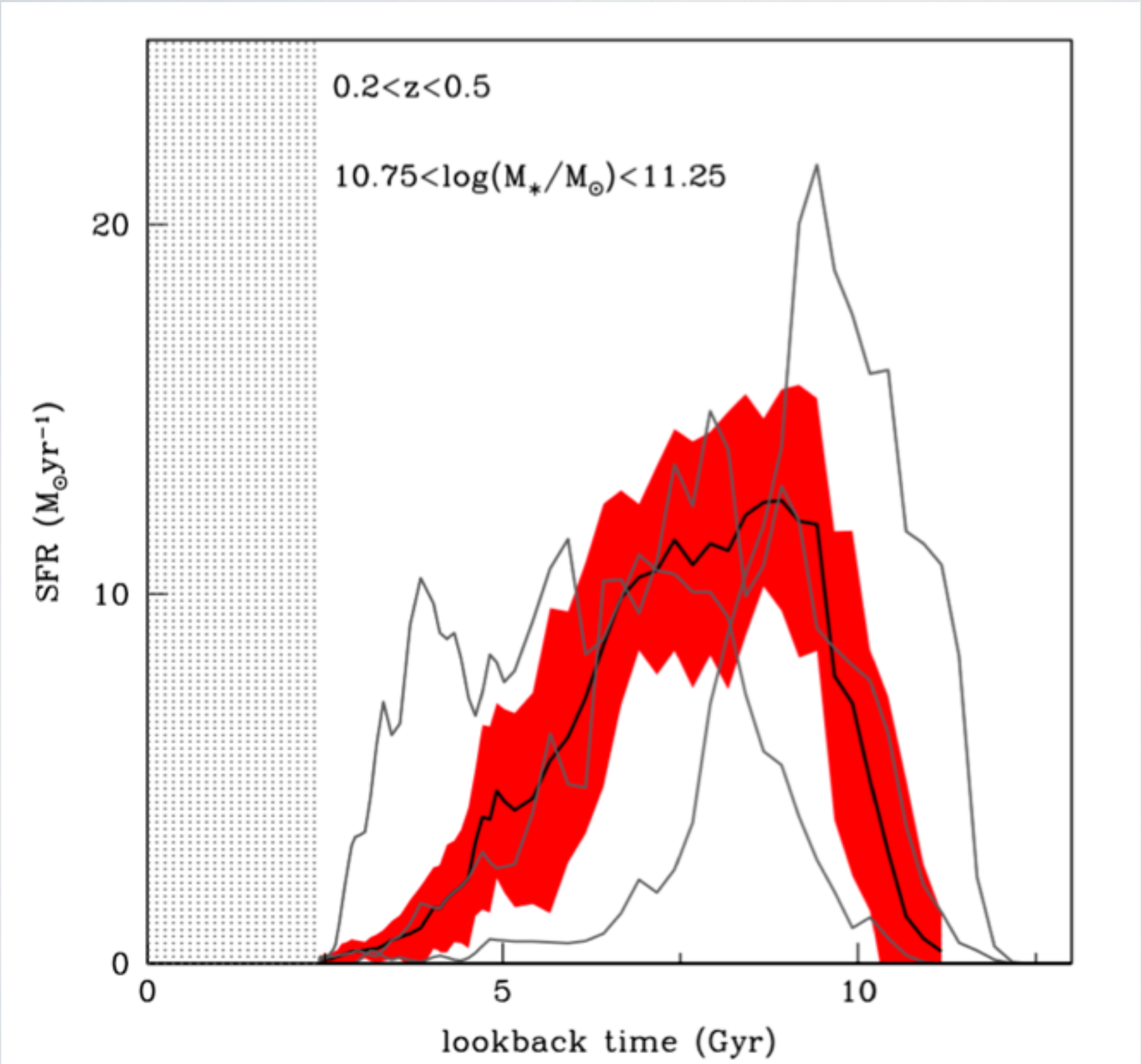

- Large variety of shapes for the SFHs of quiescent galaxies
- The SED colors allow us to distinguish between a spiky and a more extended SFH
- Median is bell-shaped. Stars form for long period of time

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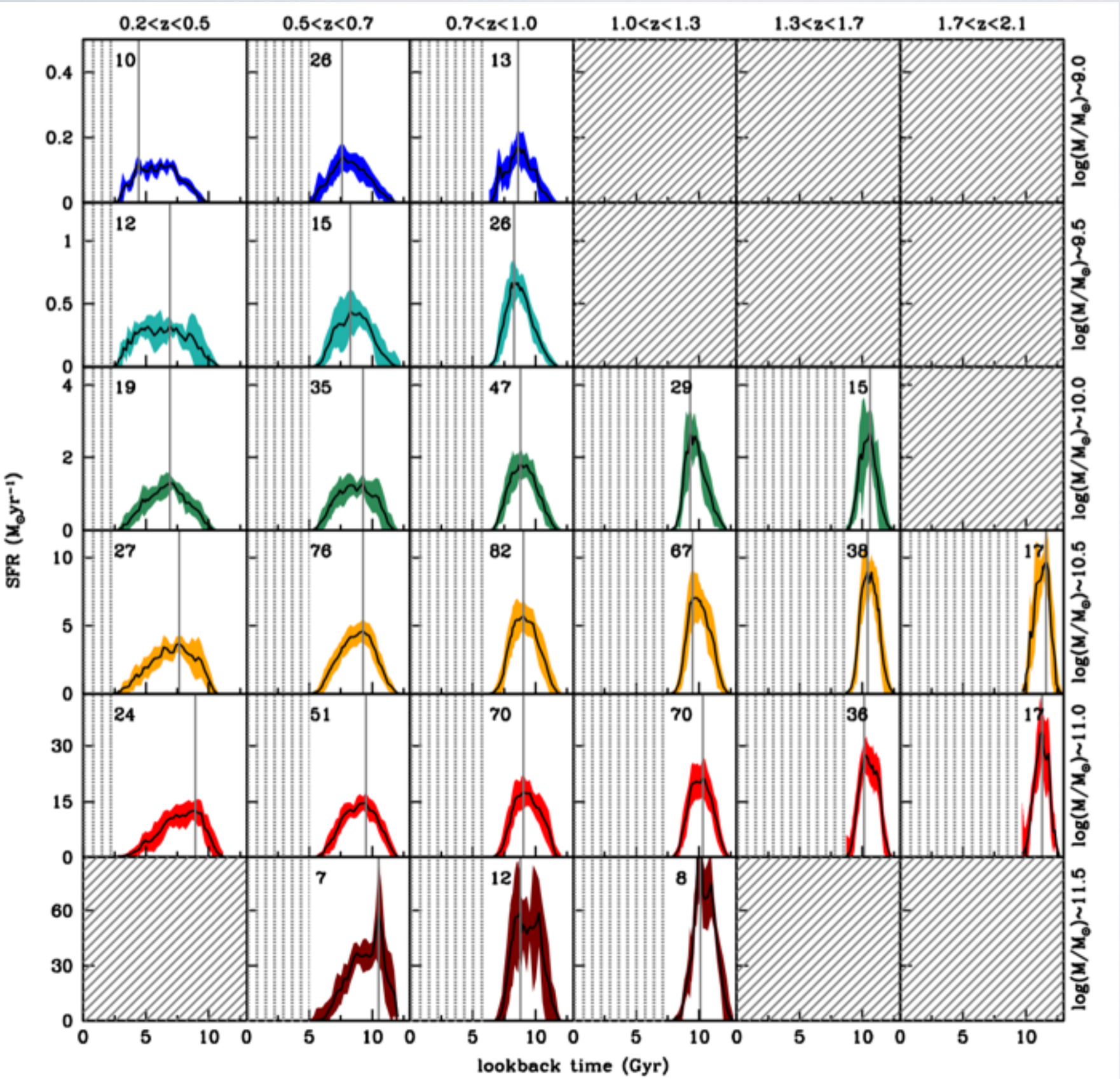

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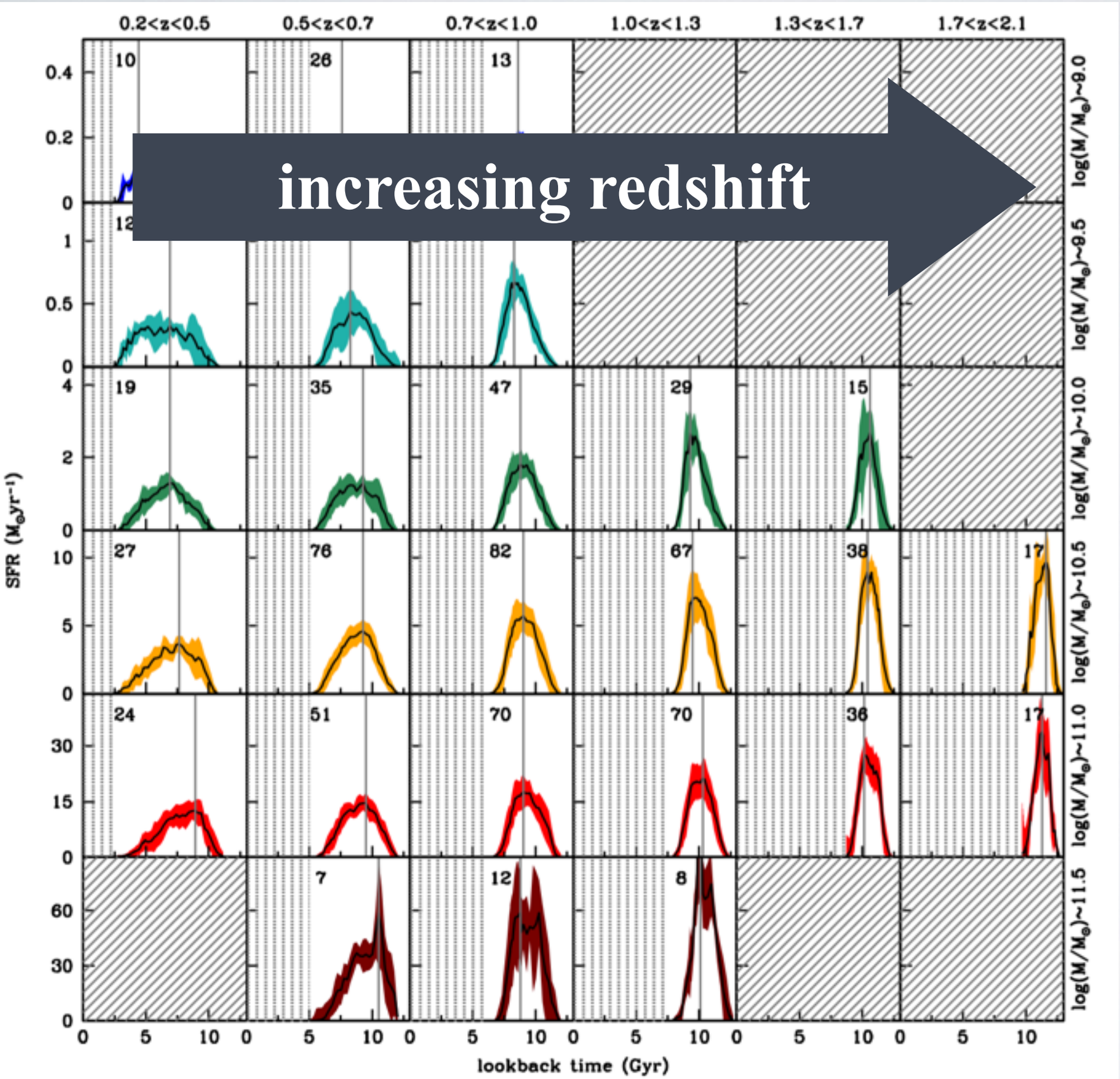

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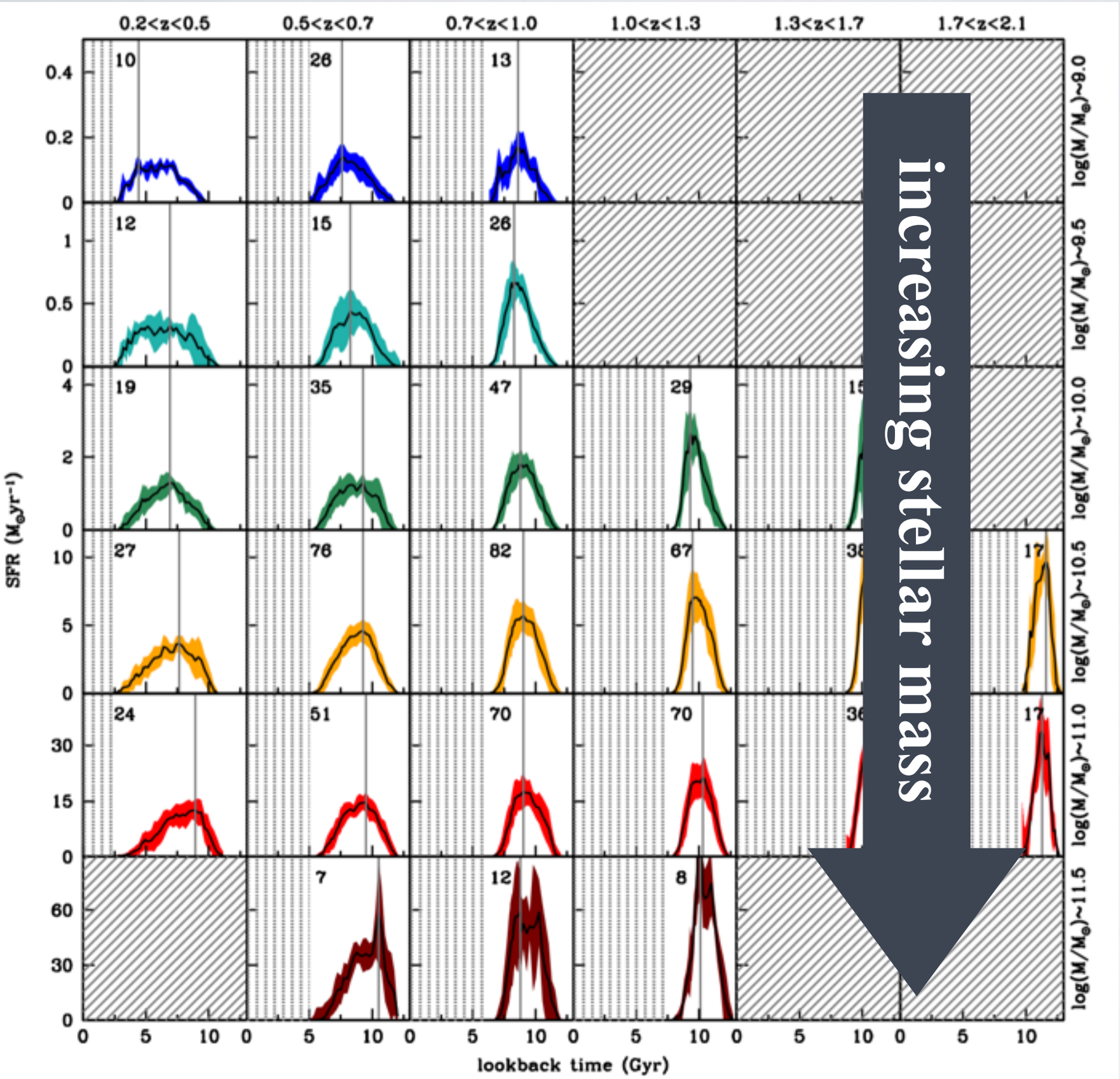

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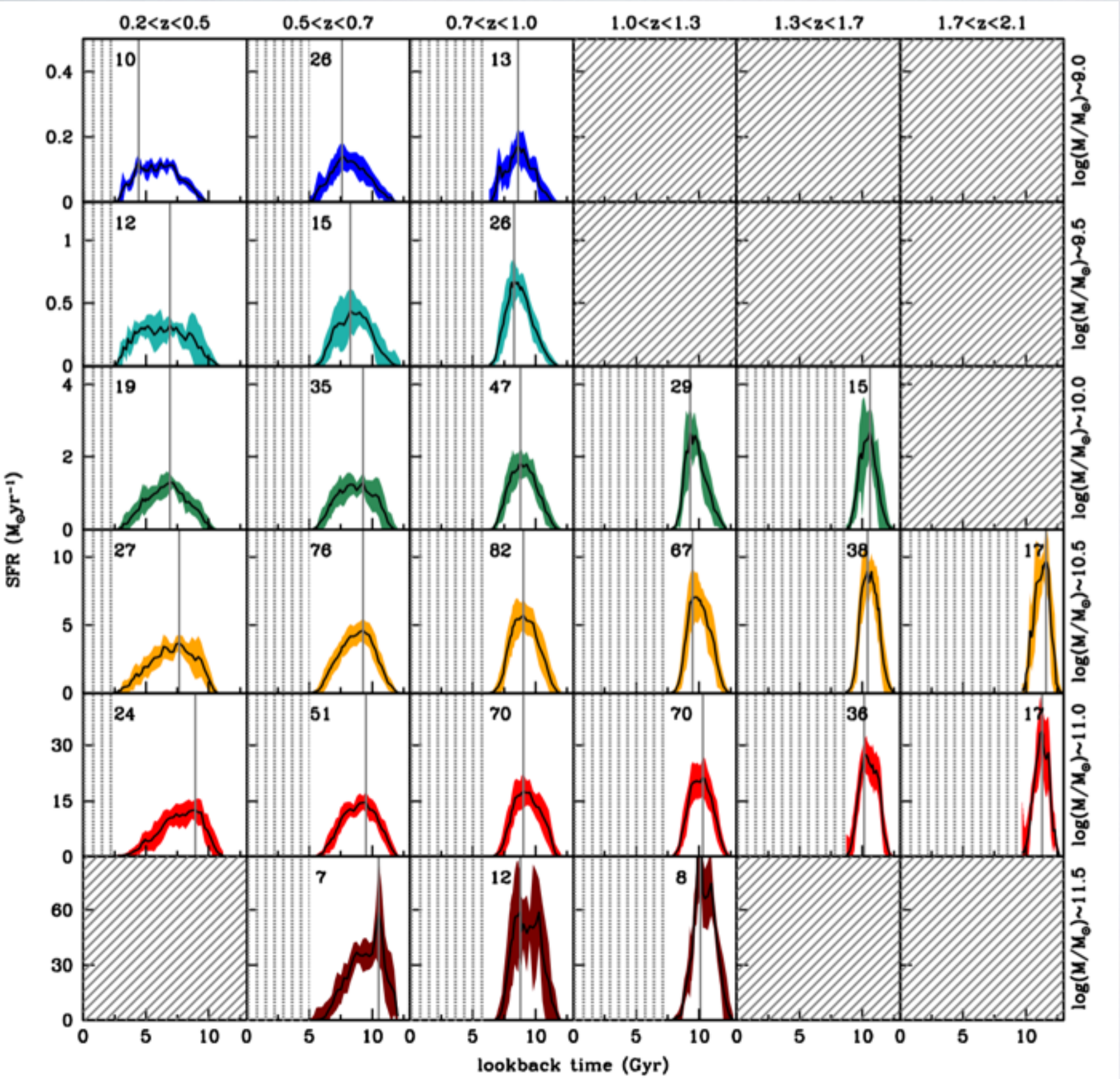

- SFHs rise and then decline
- At different stellar masses and redshifts we measure the peaks and widths of the median SFHs
- Peak happens earlier for more massive galaxies (downsizing)

Conclusions

- We have amazing quality and quantity of data and we will have more
- We need to use adequate models to interpret such data
- We can use the models to plan for future observations (JWST, TMT, etc.)
- We need to combine theory and observations, speaking the same language

- We can measure the SFHs of galaxies
  - Stellar mass is not the only driver of galaxy evolution
  - Star formation in quiescent galaxies extends for long periods of time
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Julianne Dalcanton: "In Romeo and Juliet, it is not just 'boy and girl meet, parents don't approve, boy and girl die'. There is much more than that."

Large Early Galaxy Astrophysics Census (started Dec 2014)

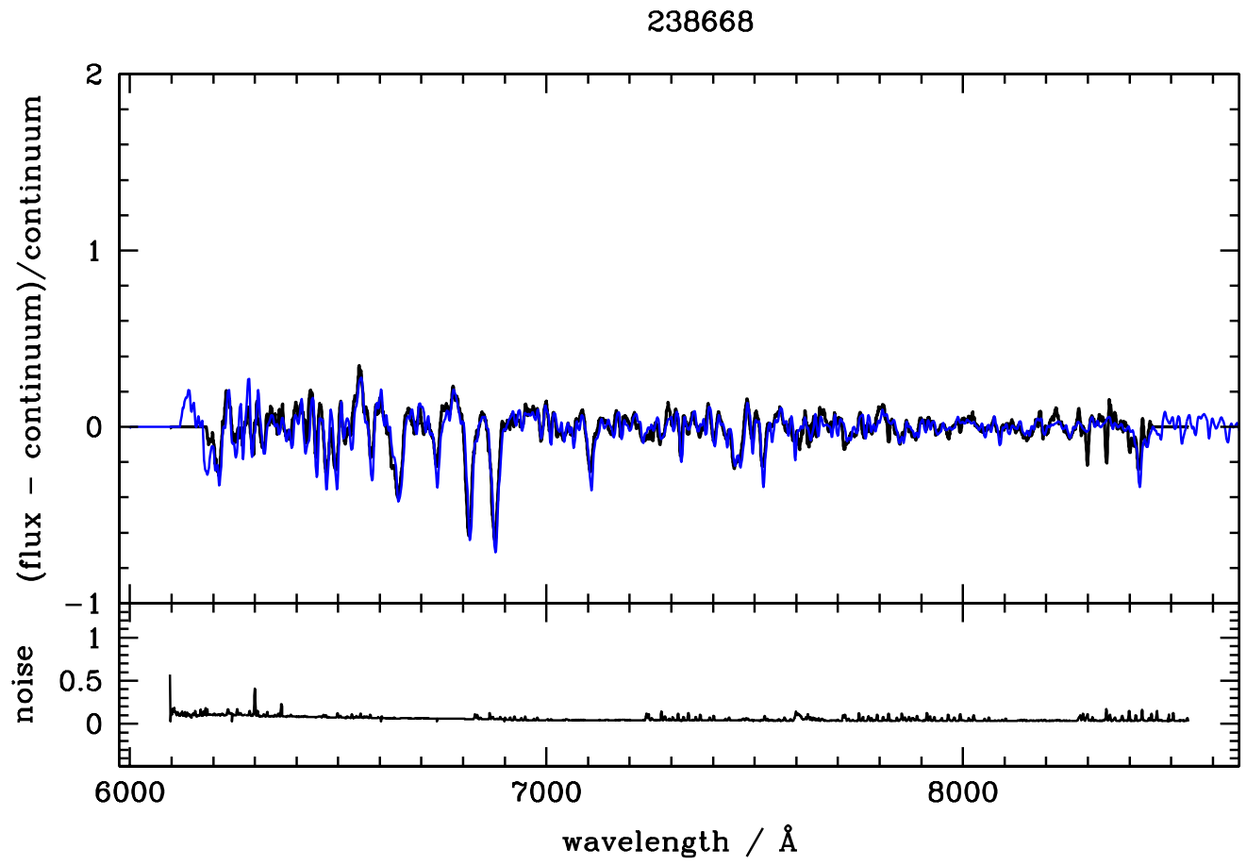
PI: Arjen van der Wel (MPIA)

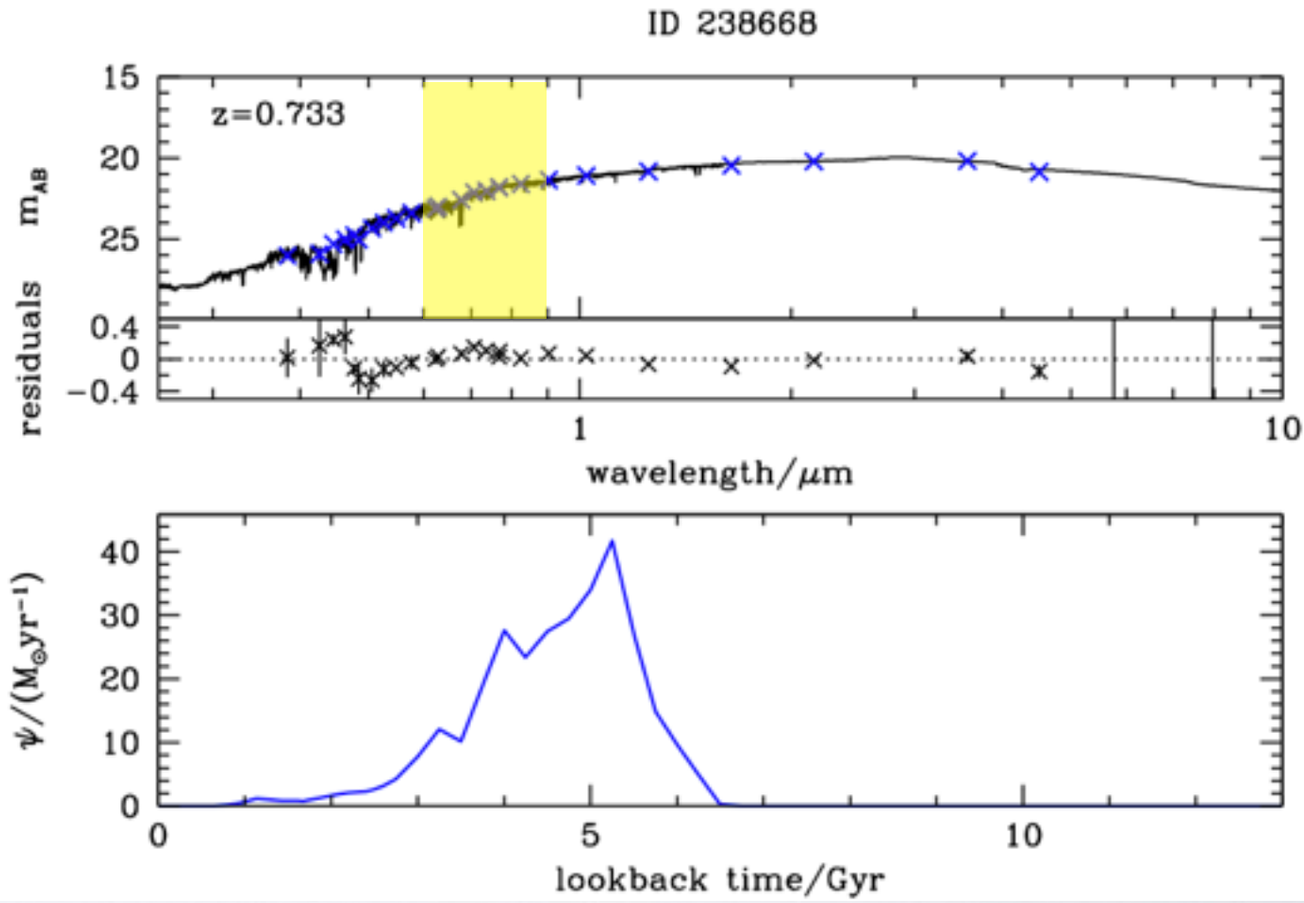
- **survey manager: Kai Noeske**
- **ESO Large Program: VLT 128 night survey**
- **Redshifts 0.6 – 1**
- **~3000 galaxies, stellar masses > 2 x 10^{10} Msun**

Large Early Galaxy Astrophysics Census (started Dec 2014)

preliminary

quiescent galaxy



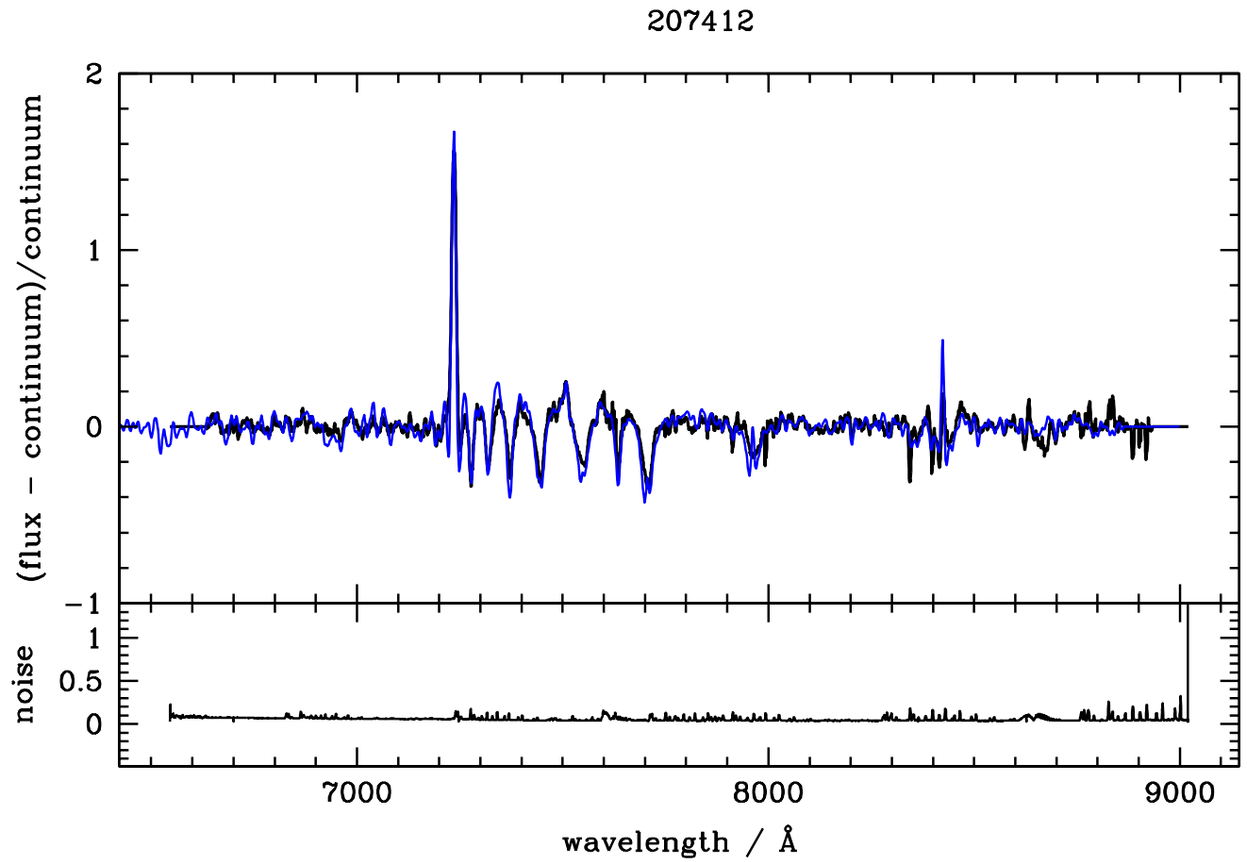


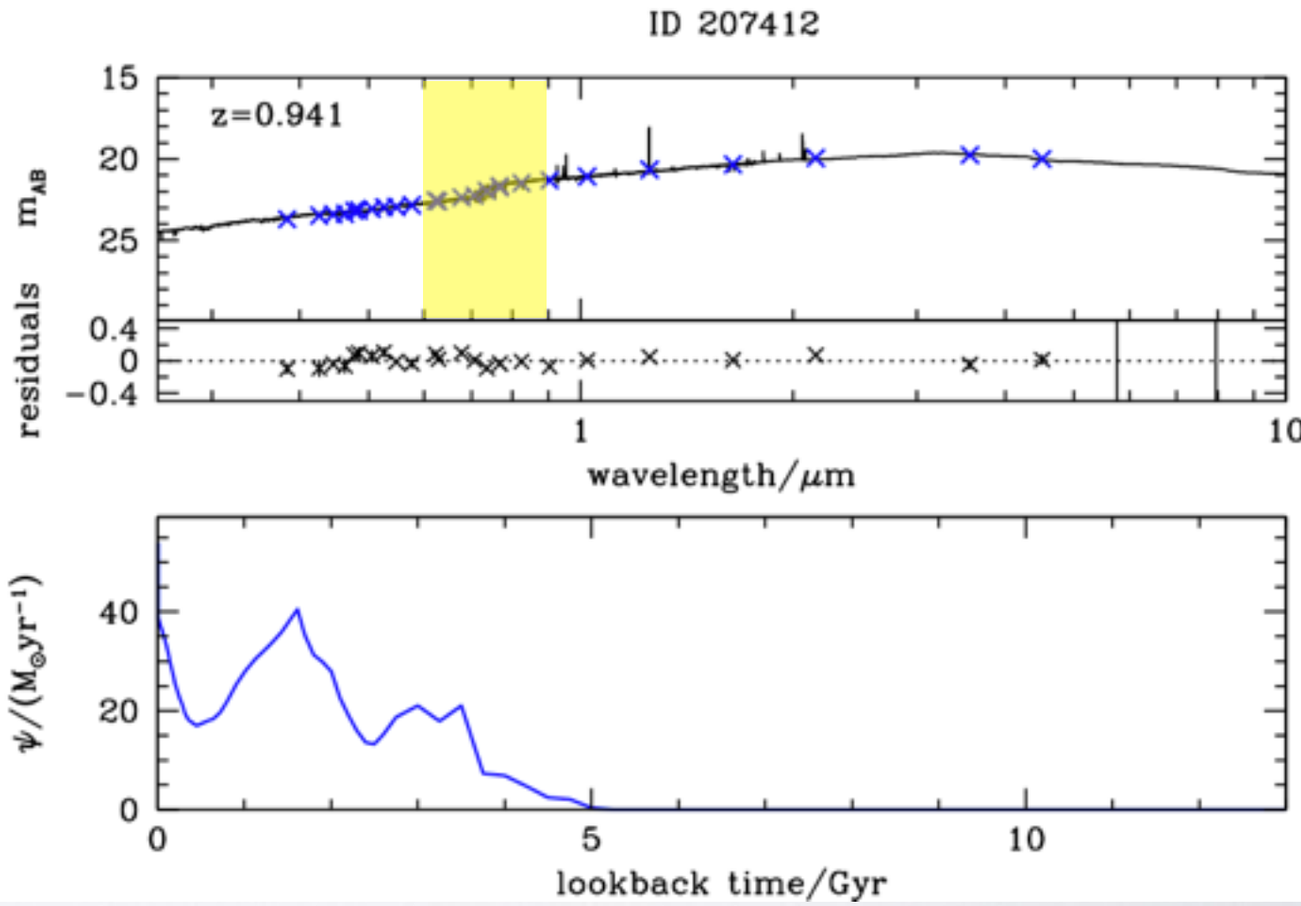
UltraVISTA photometry
(Muzzin et al. 2013)

Large Early Galaxy Astrophysics Census (started Dec 2014)

preliminary

star-forming galaxy





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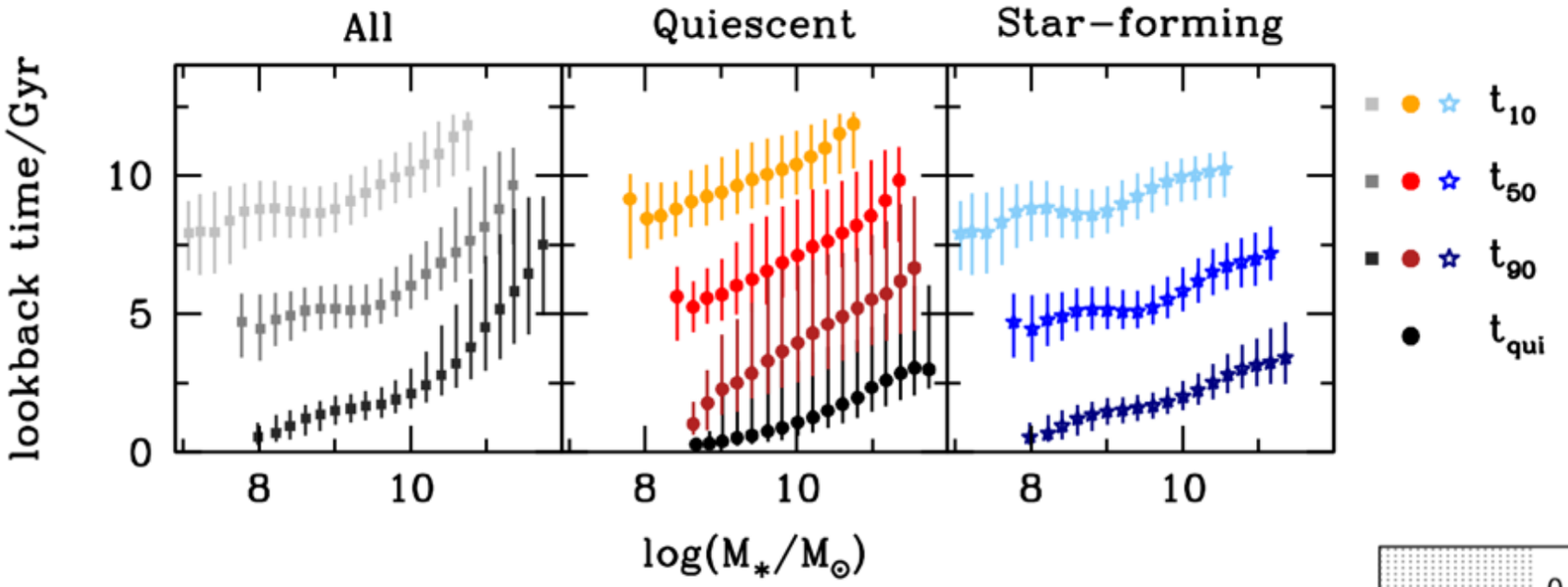

Stellar mass is not the only driver of galaxy evolution.

The SFHs of quiescent galaxies show a variety of shapes. On average, they rise and then decline. The time they reach the peak is a strong function of stellar mass and redshift