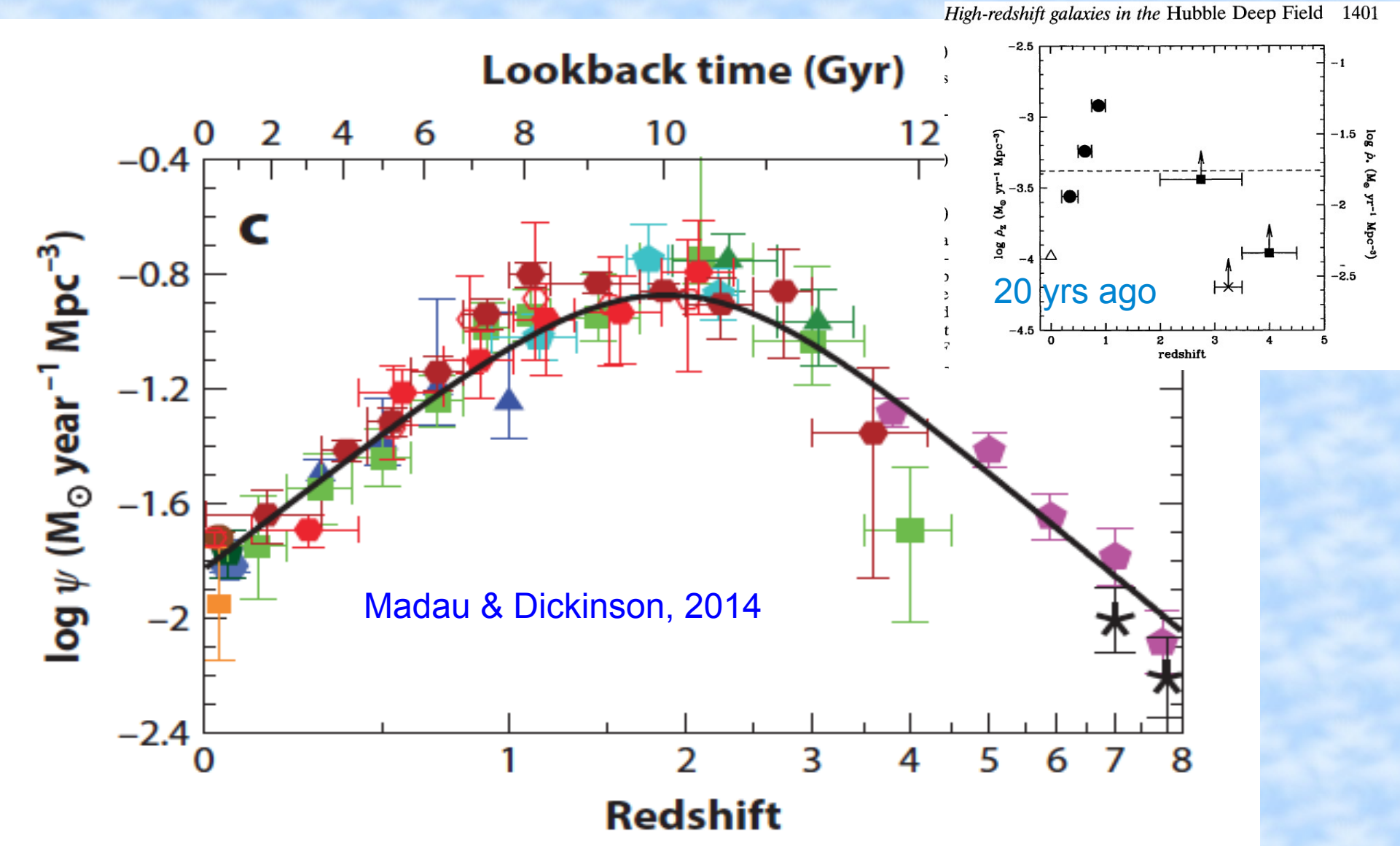
The Dominance of Quenching at All Cosmic Times

(Sometime simplest things come last to mind)



Alvio.Renzini@Subaru, Hilo, February 12, 2016

Playing with just two items (and for now, forget all the rest)

- The observed evolution of the SFR density, SFRD(t)=

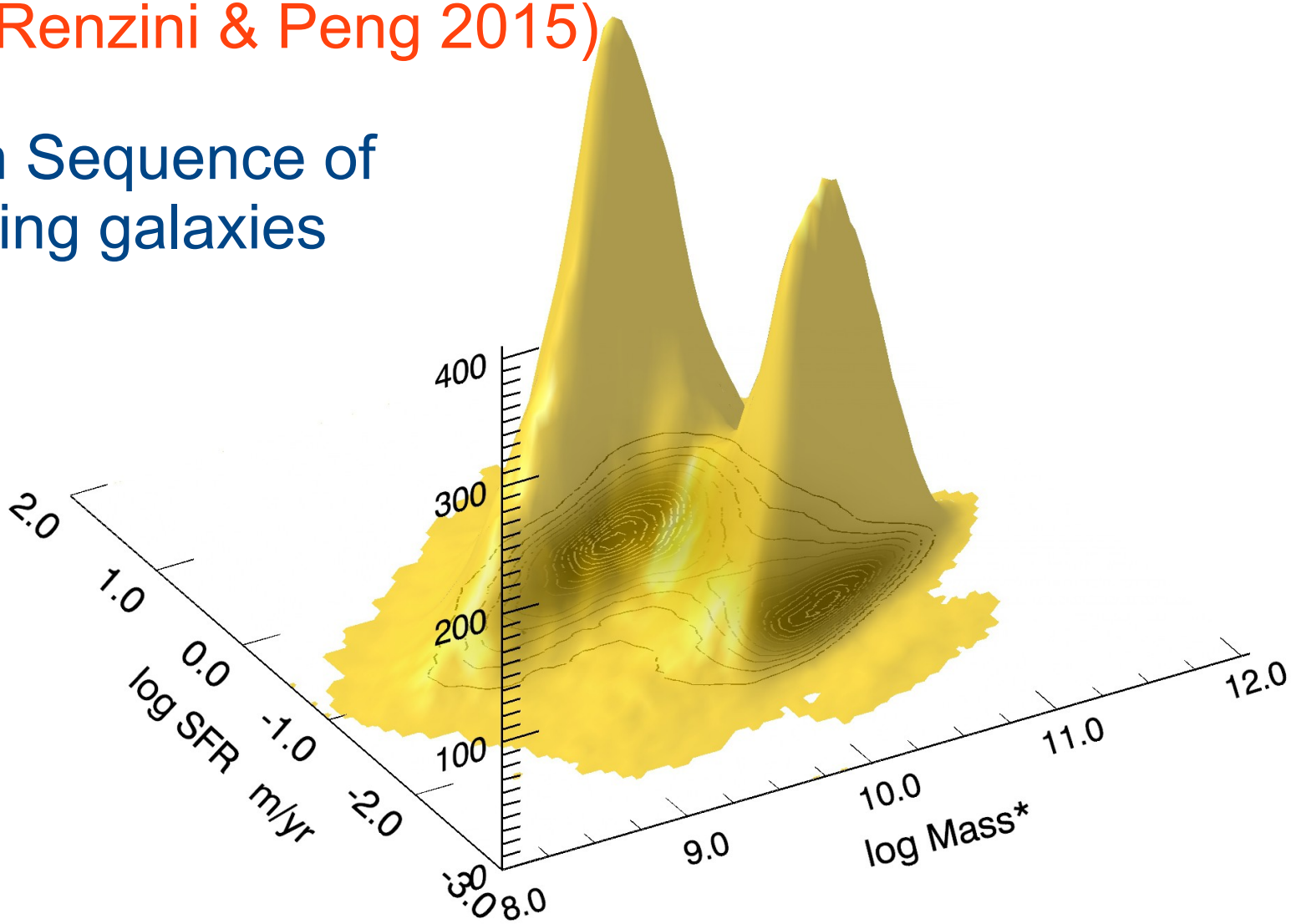
$$\psi(z) = 0.015\,\frac{(1+z)^{2.7}}{1+[(1+z)/2.9]^{5.6}}\ \mathrm{M_\odot\,year^{-1}\,Mpc^{-3}}.$$

- The observed evolution of the Main Sequence of SF galaxies, SFR(t, M_*) from Peng+10 (P10):

sSFR(t) = ~2.5 η (t/3.5 Gyr)$^{-2.2}$ yr^{-1} Mpc^{-3} for t>3.5
= flattening, for t<3.5 Gyr (i.e. z > ~2).

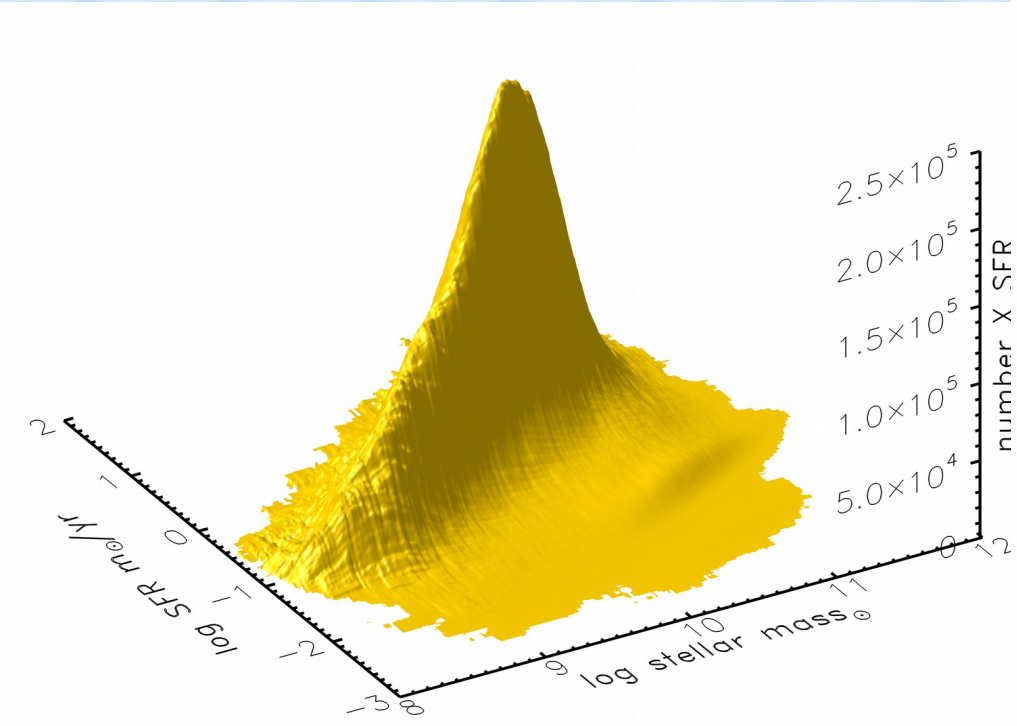
The 3D SFR-M*-Number Relation for Galaxies in the Local Universe (Renzini & Peng 2015)

The Main Sequence of star-forming galaxies

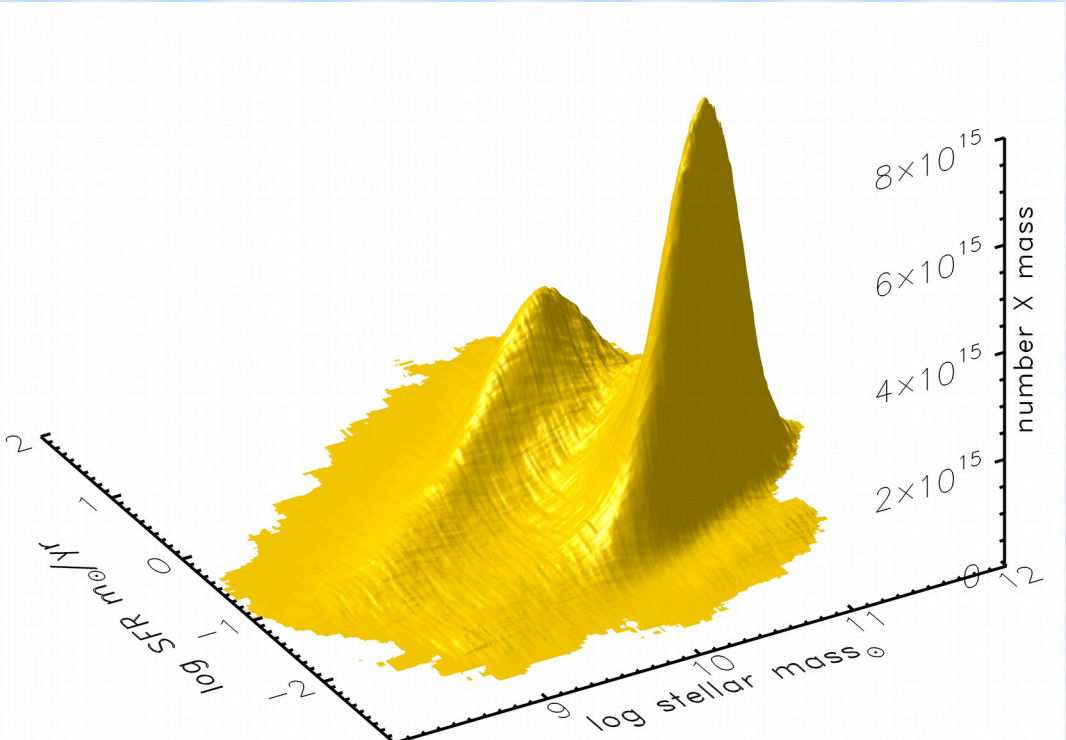


Where is the SFR and where is the mass

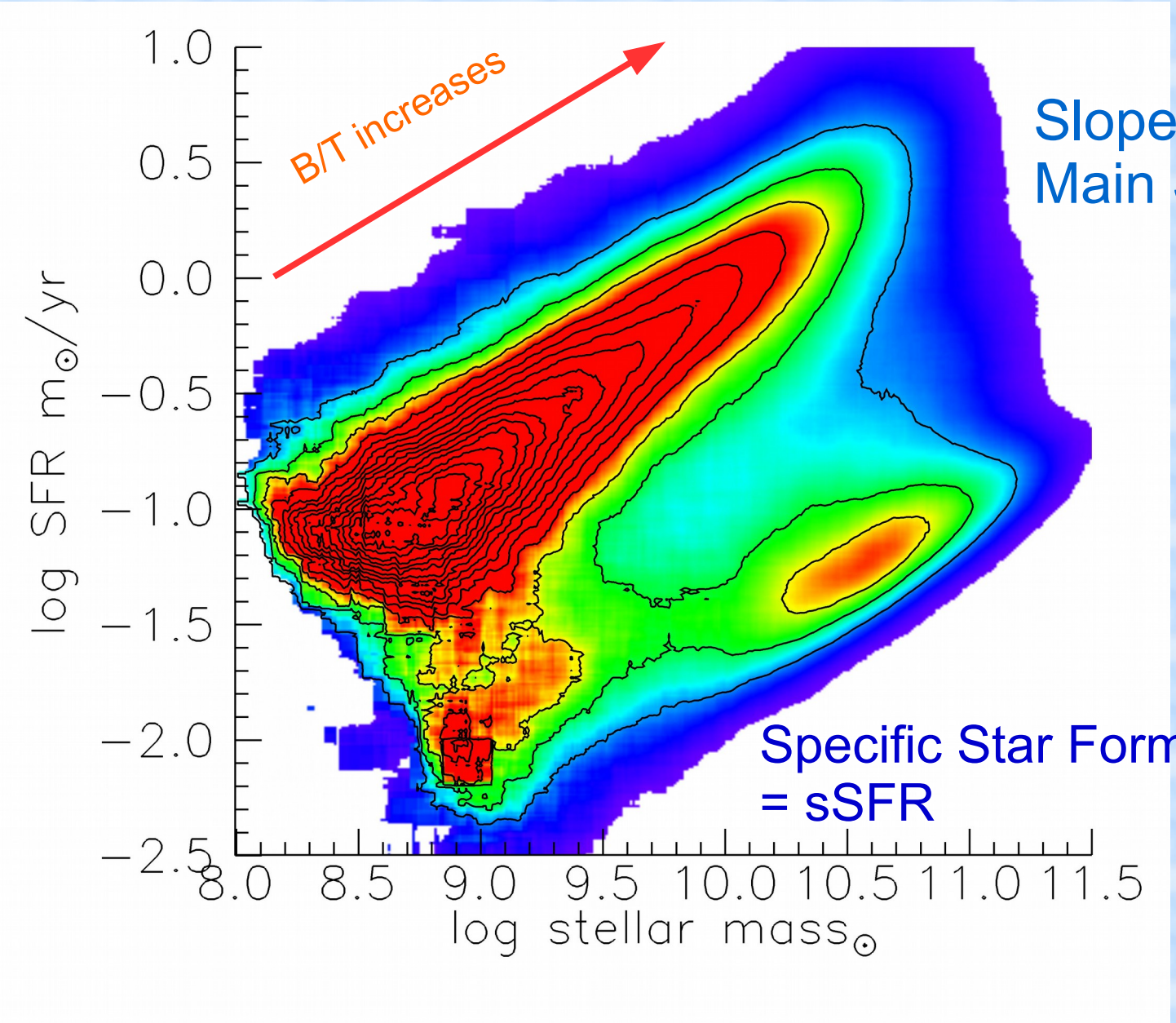
Number x SFR



Number x M*



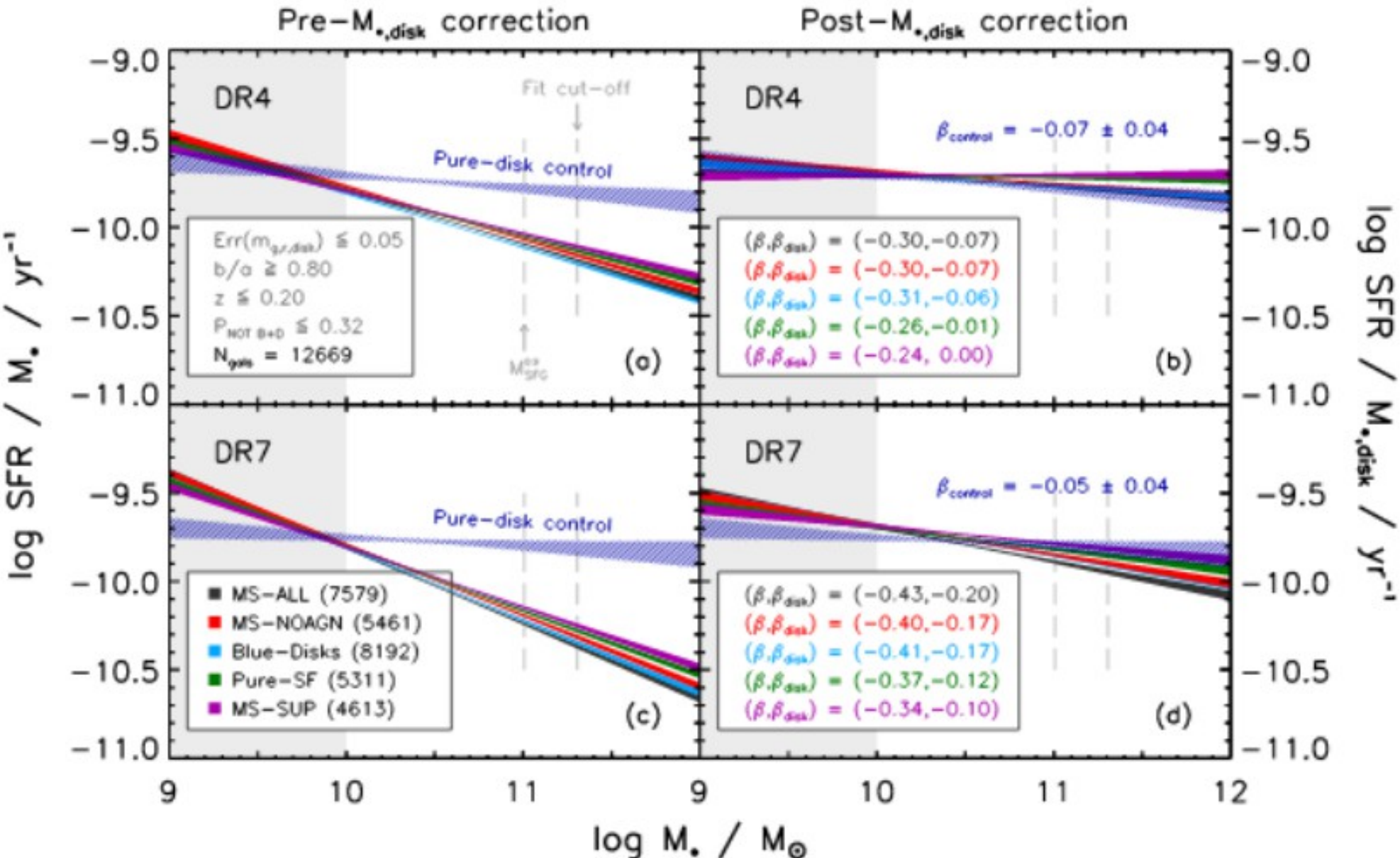
And its projection on the SFR-M* Plane



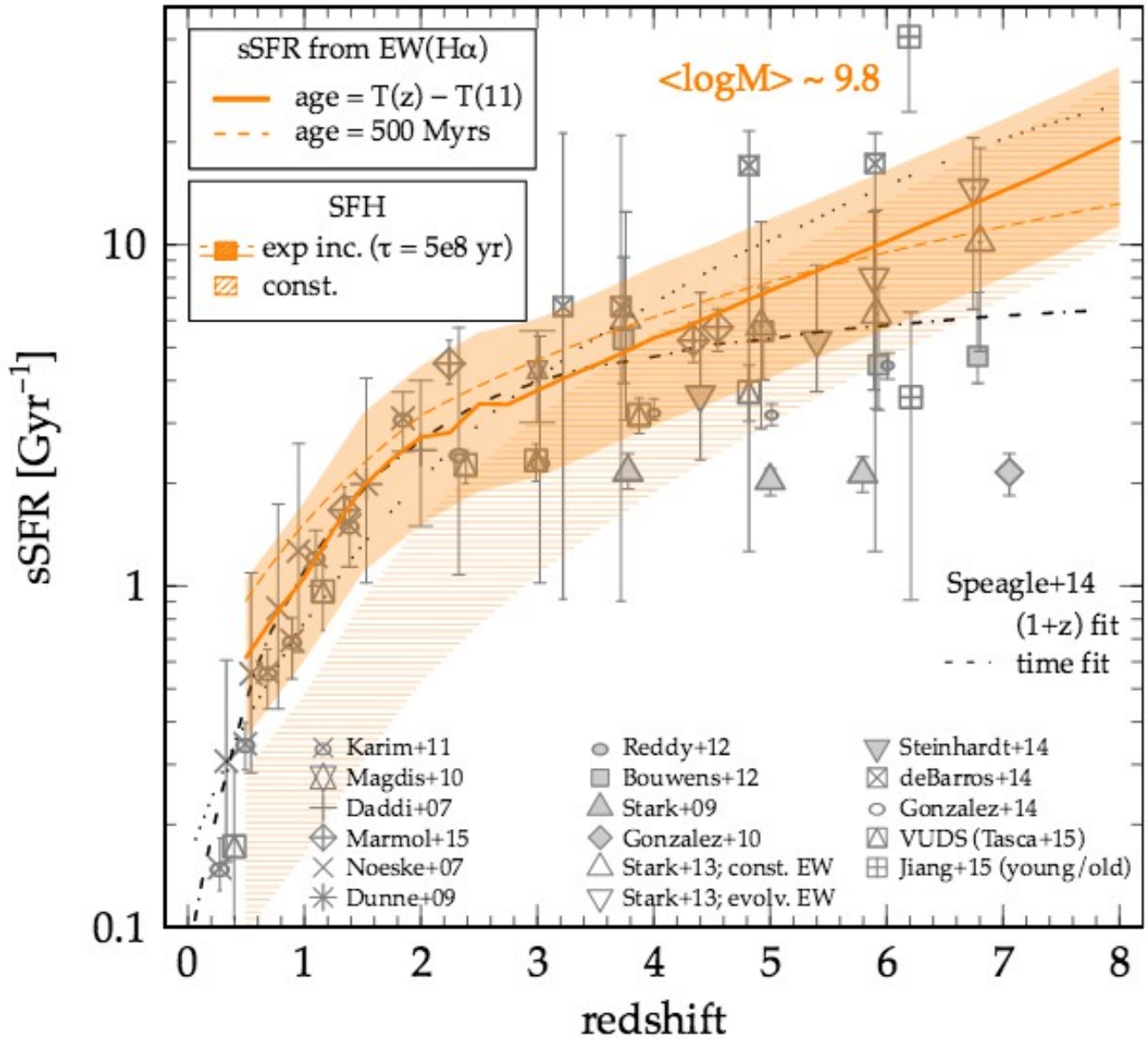
Slope of the
Main Sequence ~ 0.8

Specific Star Formation rate = SFR/M*
= sSFR

But not counting the mass of quenched bulges: slope ~1 (Abramson+2014)



Beyond redshift ~2 sSFR are more uncertain



Faisst+2016

Playing with just two items (and for now, forget all the rest)

- The observed evolution of the SFR density, SFRD(t)=

$$\psi(z) = 0.015\,\frac{(1+z)^{2.7}}{1+[(1+z)/2.9]^{5.6}}\ \mathrm{M_\odot\,year^{-1}\,Mpc^{-3}}.$$

- The observed evolution of the Main Sequence of SF galaxies, SFR(t, M_*) from Peng+10 (P10):

sSFR(t) = ~2.5 η (t/3.5 Gyr)$^{-2.2}$ yr^{-1} Mpc^{-3} for t>3.5
= flattening, for t<3.5 Gyr (i.e. z~2).

A few trivial relations

- $d\varrho_* /dt = (1-R)\ SFRD(t)$ Assume R=0.3
- $SFRD(t) = sSFR(t)\ \varrho^{SF}_*(t)$
- $\varrho^{SF}_*(t) = SFRD(t)/sSFR(t)$
- $\varrho^{Q}_*(t) = \varrho_*(t) - \varrho^{SF}_*(t)$
- Use η as a fudge factor to absorb possible relative systematcs in M* & SFRs used in M&D and P10.

To be clear:

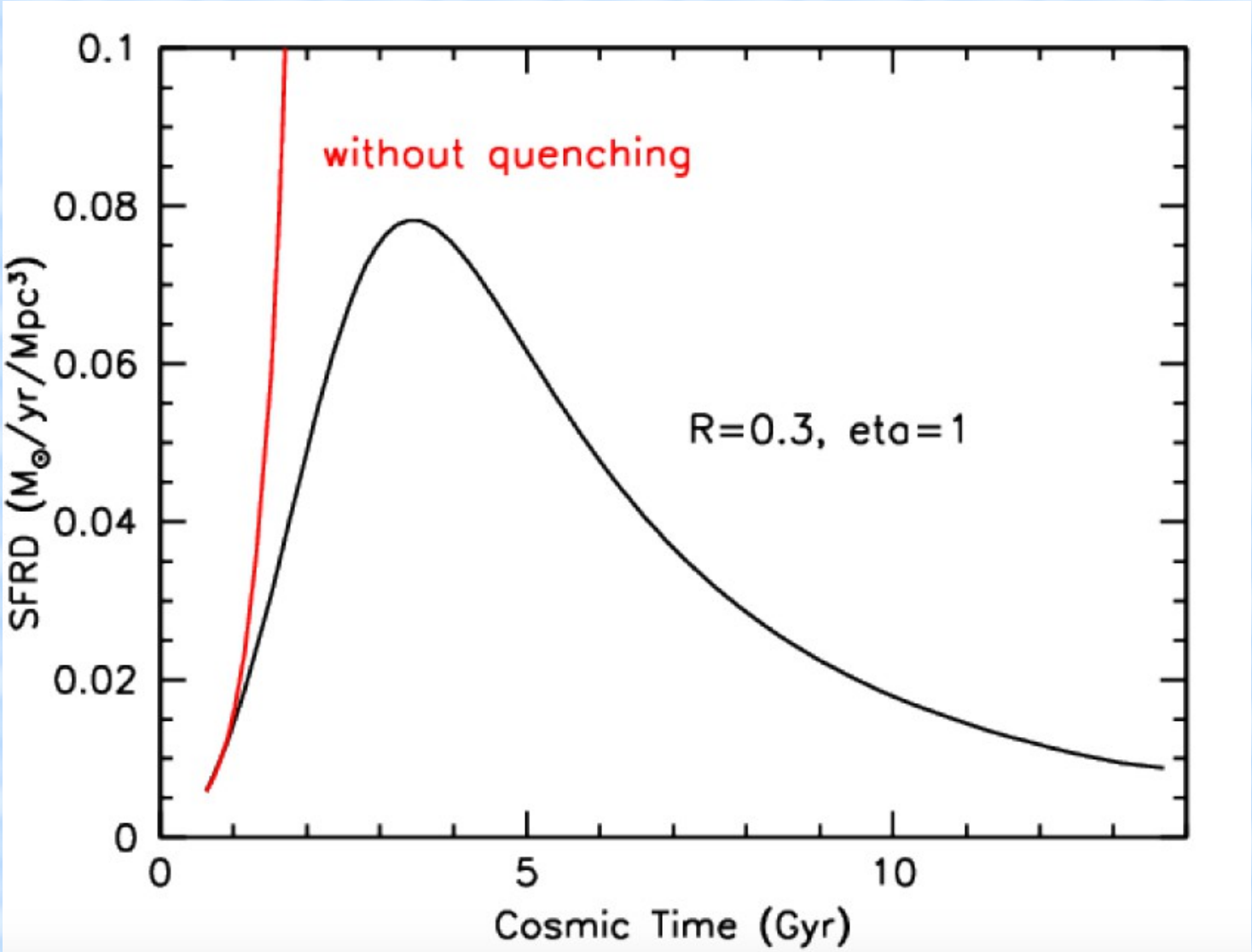
- $\varrho_*(t)$ is the total stellar density ($M_\odot$ Mpc^{-3})
- $\varrho^{SF}{}_*(t)$ is the cosmic stellar density of stars in star-forming environments, i.e., in the star-forming portions of galaxies on/near the MS
- $\varrho^{Q}{}_*(t)$ is the cosmic stellar density of stars in NON-star-forming environments, i.e., in quenched galaxies and in quenched halos & bulges
- Use of a linear SFR-M* relation is justified if the stellar mass refers only to the star-forming regions of galaxies (Abramson+14; Selmi+12), so

$$SFRD(t) = sSFR(t)\ \varrho^{SF}{}_*(t)$$

The red line is obtained by integrating

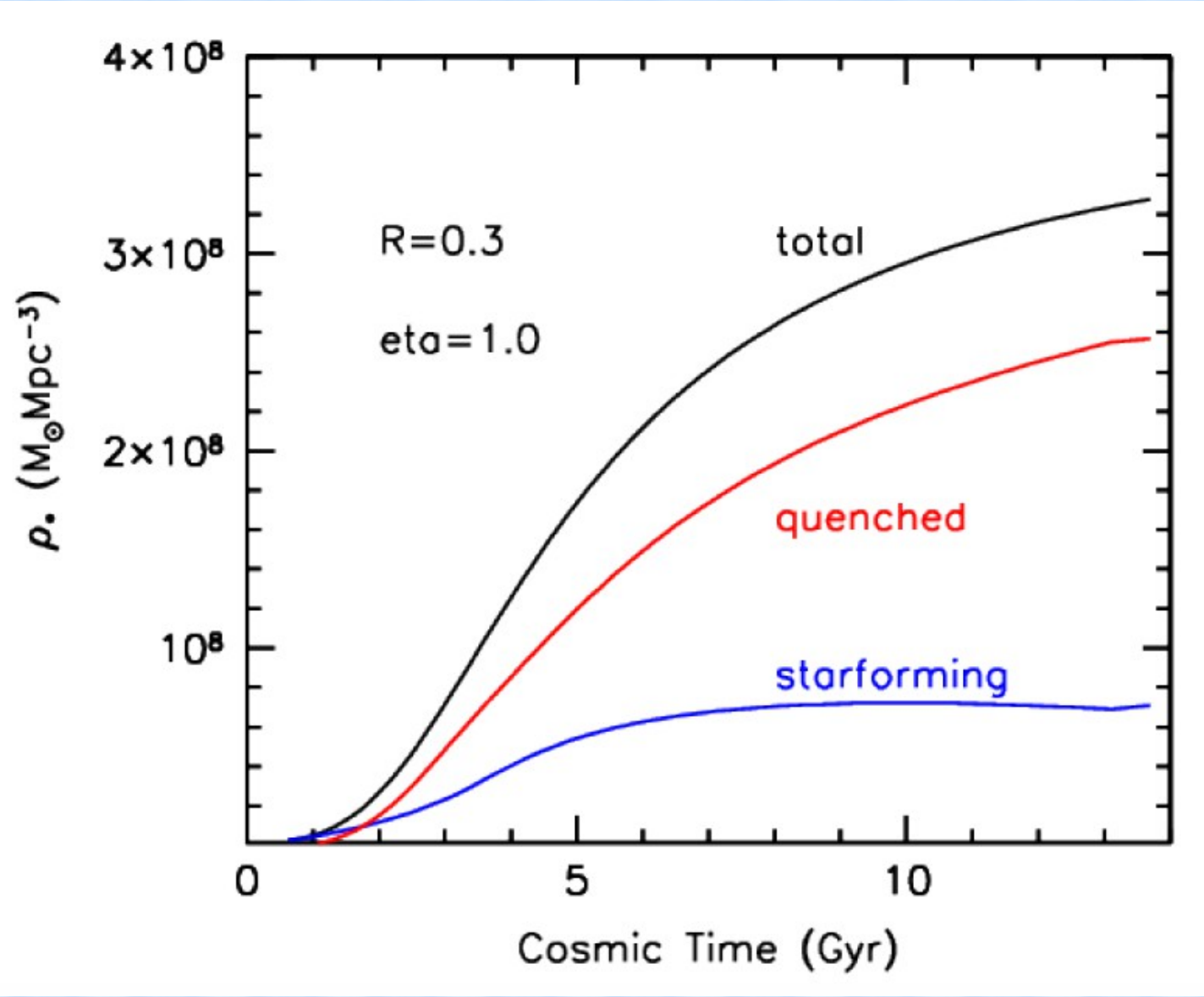
$$d\varrho_* /dt = (1-R)sSFR(t)\ \varrho_*(t)$$

Quenching must set in very early!!!



$\varrho^{SF}_*(t) = SFRD(t)/sSFR(t)$

$\varrho^{Q}_*(t) = \varrho_*(t) - \varrho^{SF}_*(t)$



78% quenched

22% star-form.

At z=0

If All This is (kind of) Right, then ...

- Quenching dominates at (almost) all times
- $\varrho^{Q}_{*}(t) > \varrho^{SF}_{*}(t)$ from almost the beginning
- We may have missed lots of quenched "mass" at z>~3
- sSFR unlikely to keep increasing beyond z ~ 2
- ϱ^{SF}_{*} as been almost constant over the last ~10 Gyr
- The fraction of star-forming mass density (~22%) at z=0 nicely agrees with the ~23% estimated from SDSS by Abramson (private communication)


Thank You!