Star-forming galaxy properties at z~4 and impact of nebular emission : applying lesson from z~2

Back at the edge of the Universe, Sintra,
2015

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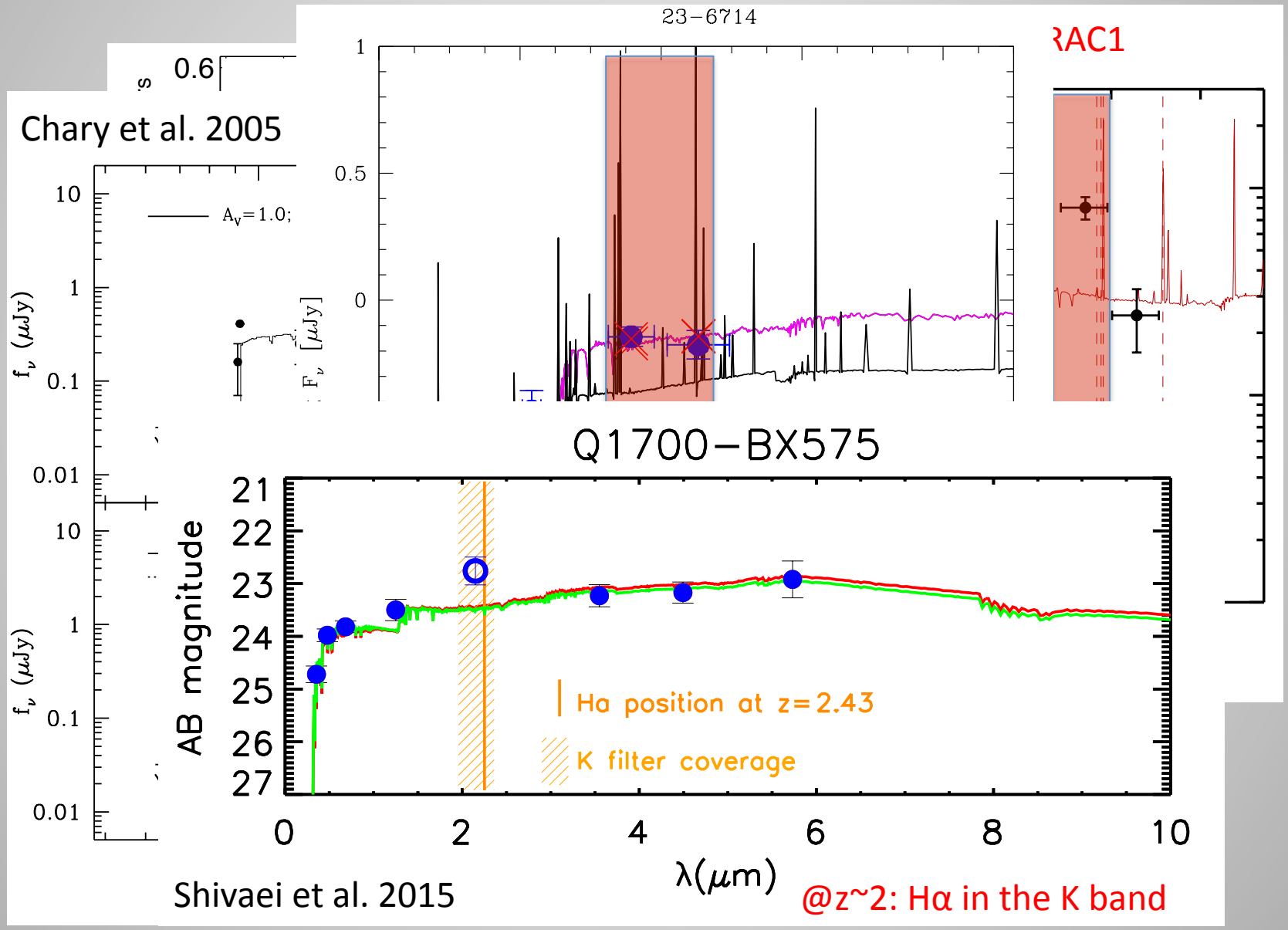
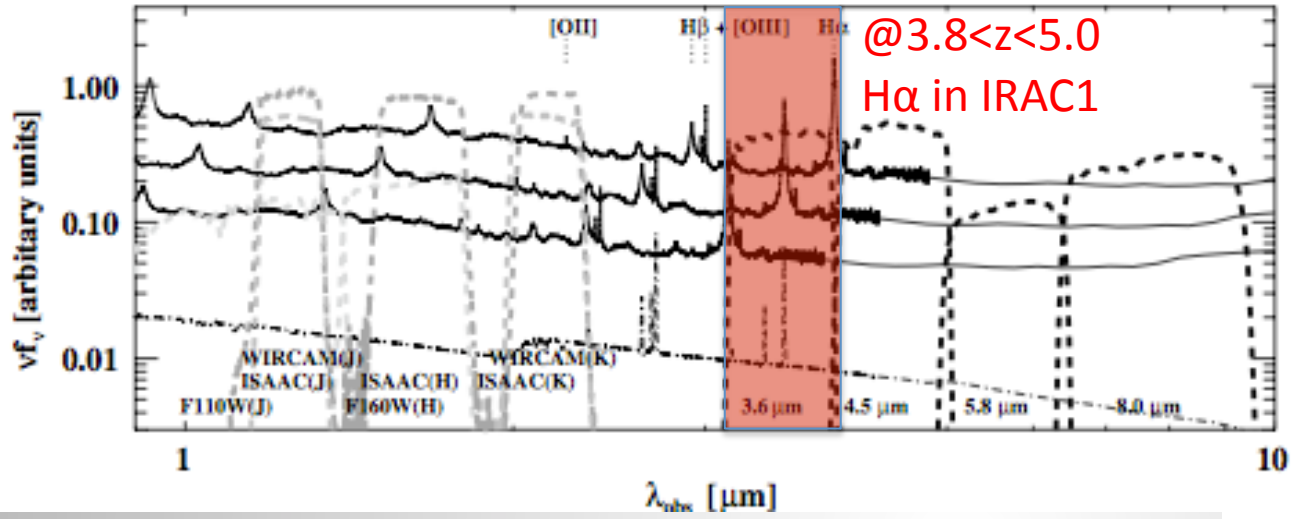
Why care about nebular emission when dealing with broad-band photometry?



Nebular emission at z~4

Shim et al. 2011



➢(3.6-4.5)μm: straightforward basically model independent derivation of *observed* Hα flux

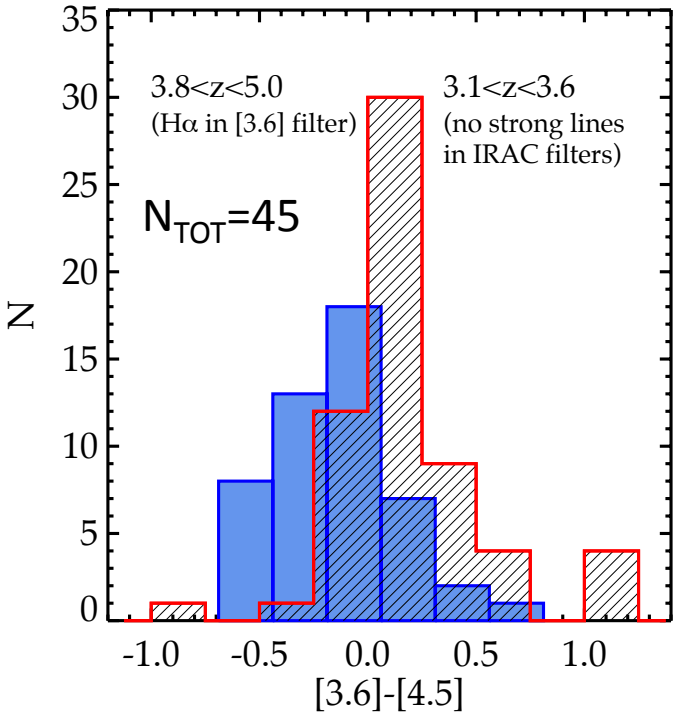
➢Possibility to derive instantaneous SFR, sSFR, SFR density, the SFH (stochastic/episodic vs smooth?)

BUT a lot of unknows at z~4:

- Attenuation curve
- Lyman continuum escape fraction
- ISM physical conditions
- IMF

Derive nebular properties at « low » z: go to z~2

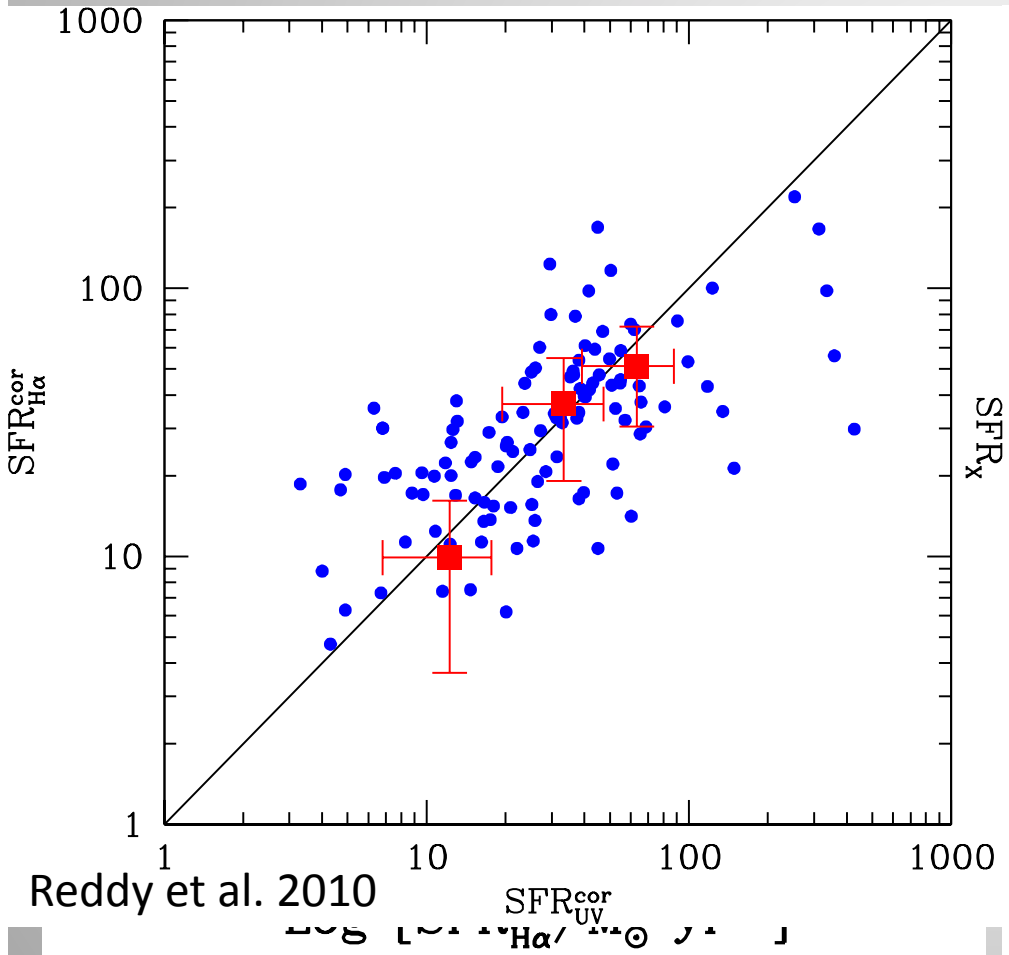
Stark et al. 2013



Nebular emission at z~2

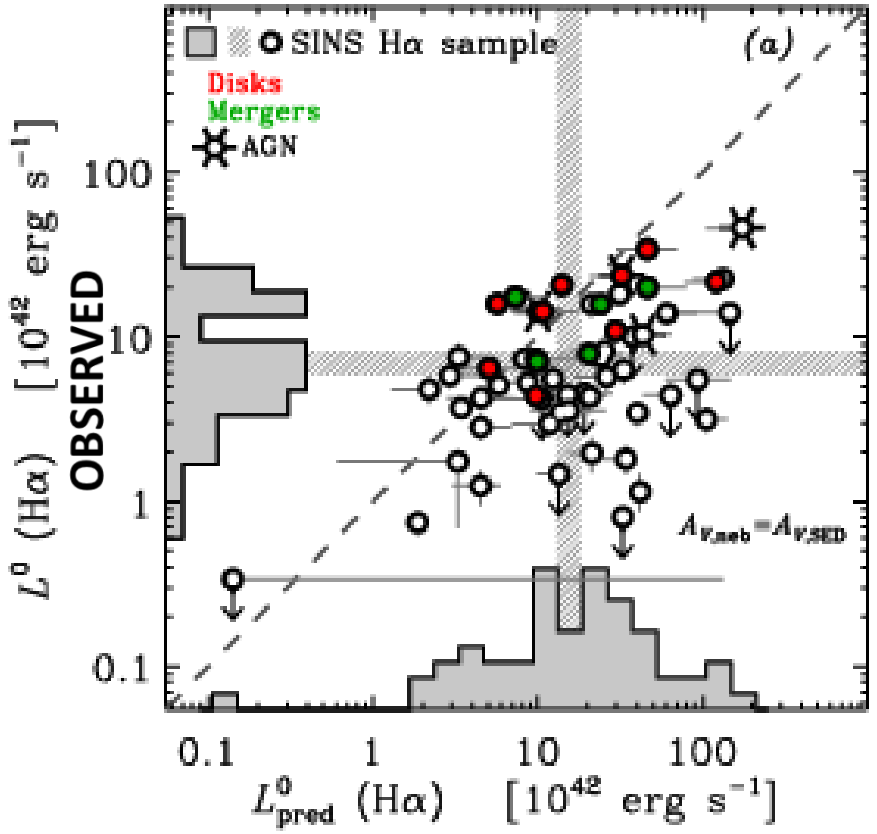
In local star-forming galaxies (Calzetti et al. 2000):

$$\underbrace{E(B-V)_{stellar}}_{\text{Calzetti attenuation curve}} = (0.44 \pm 0.03) \times \underbrace{E(B-V)_{nebular}}_{\text{Line of sight attenuation curve}}$$



Reddy et al. 2010

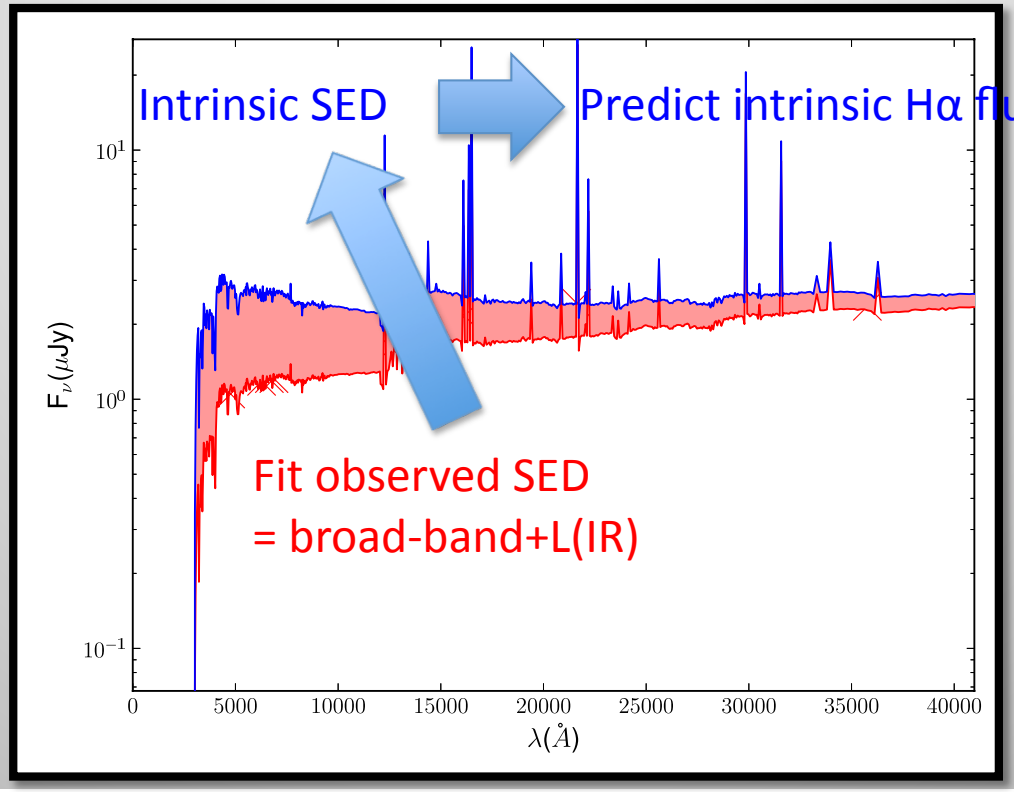
Förster Schreiber et al. 2009



SED PREDICTED

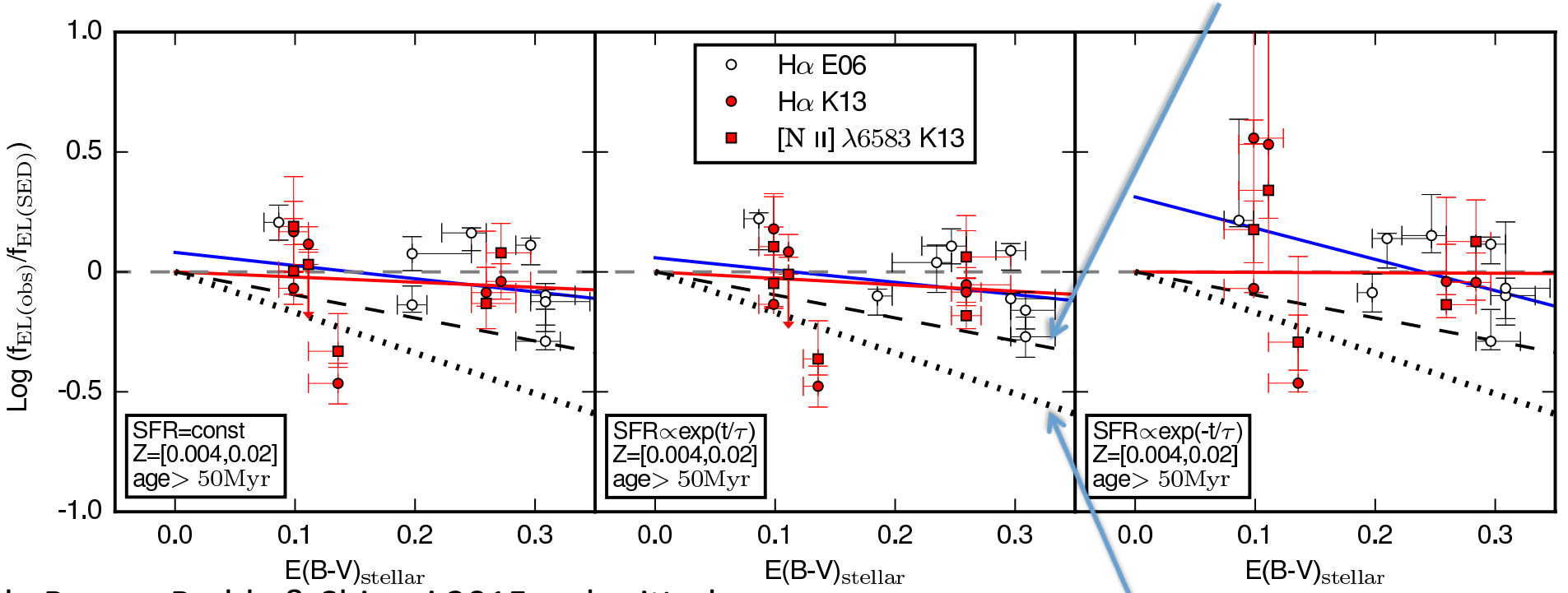
Nebular emission at z~2

➢Sample of 37 spectroscopically confirmed UV-selected galaxies at z~2 (Steidel et al. 2003, 2004, Adelberger et al. 2004)
+ MIPS 24μm ➔ L(IR) (Chary & Elbaz 2001)
+ NIRSPEC and MOSFIRE Hα flux measurements (Erb et al. 2006, Kulas et al. 2013)
➢SED fitting
+ Energy balance
+ Calzetti attenuation curve
+ nebular emission modeling (Schaerer & de Barros 2009, 2010)



Nebular emission at z~2

$$A_{H\alpha,Cardelli} = 5.72 \times E(B-V)_{stellar}$$



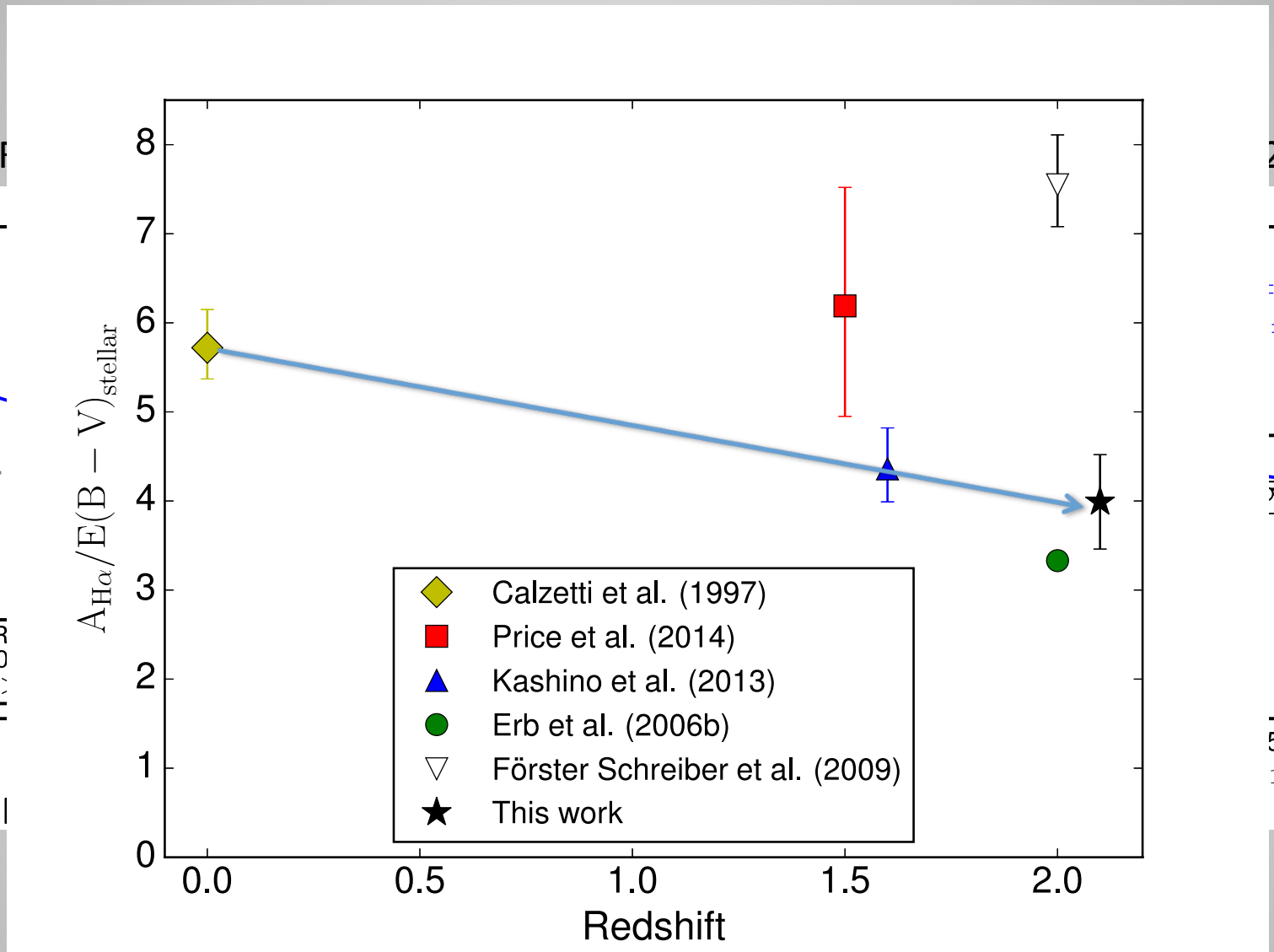
de Barros, Reddy & Shivaei 2015, submitted

$$A_{H\alpha,Calzetti} = 7.55 \times E(B-V)_{stellar}$$

$$E(B-V)_{nebular} = (1.20 \pm 0.16) \times E(B-V)_{stellar}$$

See also Pannella et al. 2015: UV + Herschel FIR + radio VLA = ratio ~1.3 @z~2.3

Nebular emission at z~2



Galaxy surface dominated by HII regions at high-z?

Main conclusions:
We reproduce nebular emission at z~2 + no need for extra attenuation

Back at z~4

- CANDELS data: GOODS-S & GOODS-N (+70000 objects) = best available photometry!
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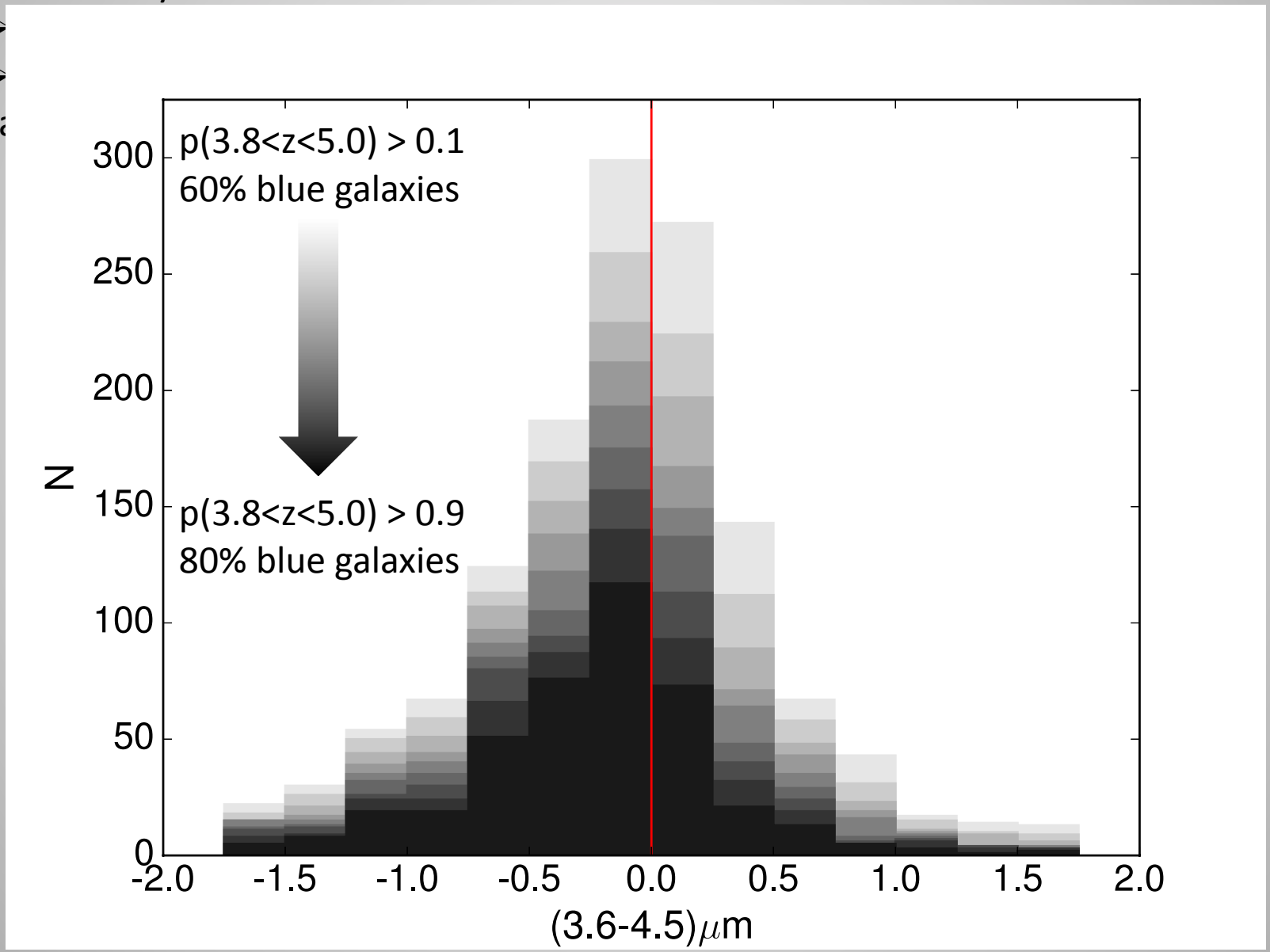
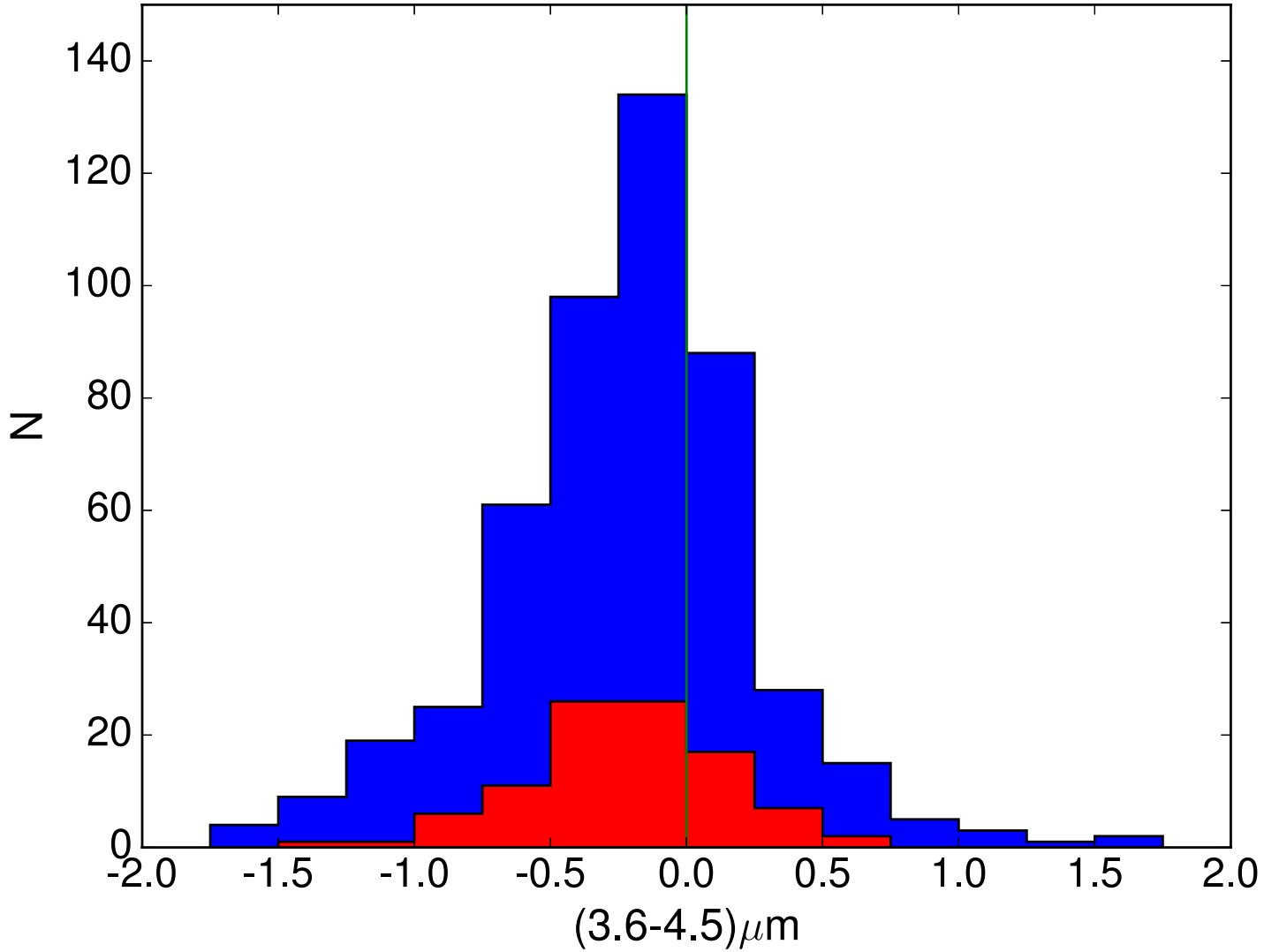


Back at z~4

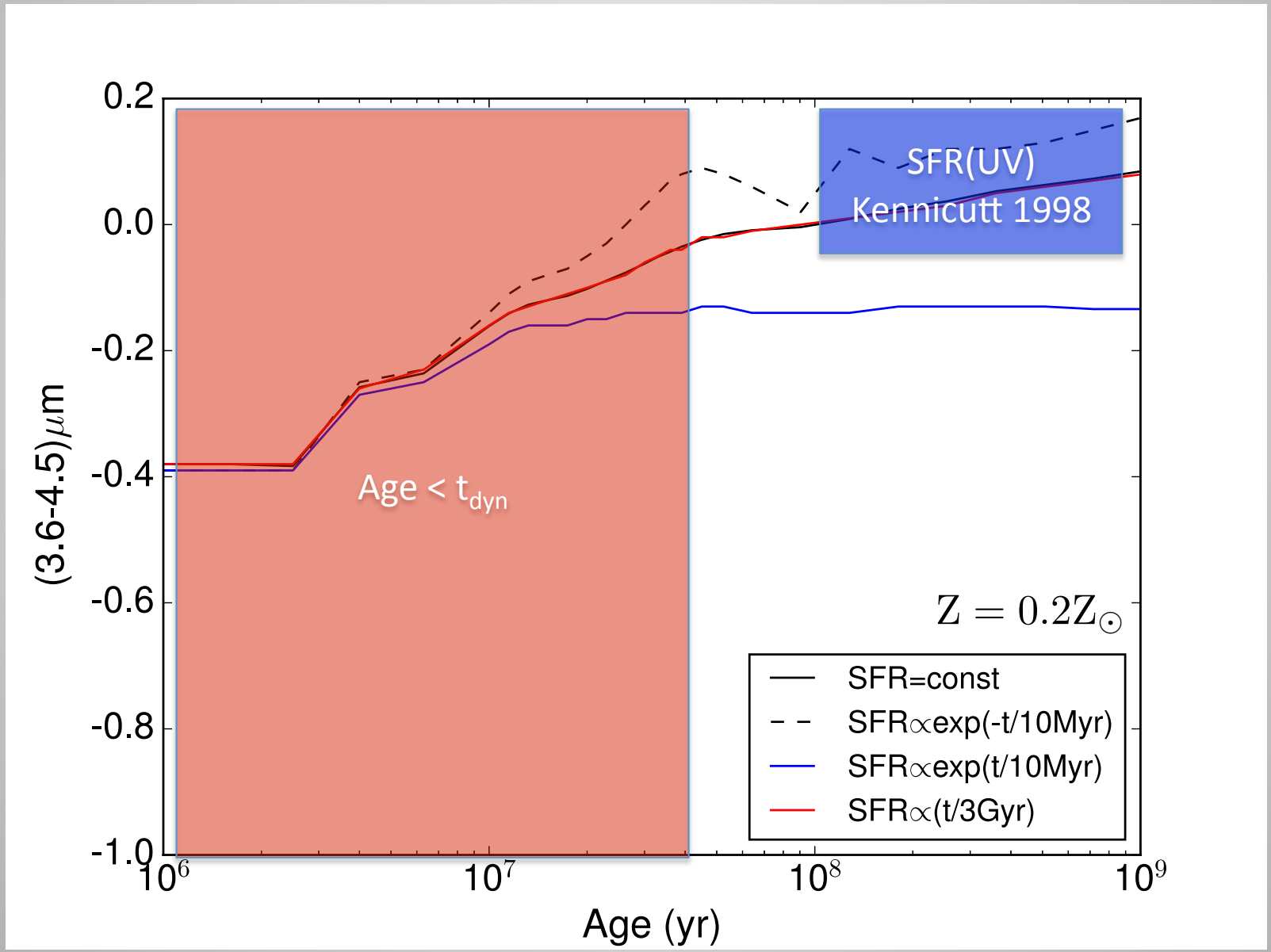
de Barros, Mobasher, et al. 2015, in prep.



« Secure z» sample: 519 galaxies (98 z_{spec})

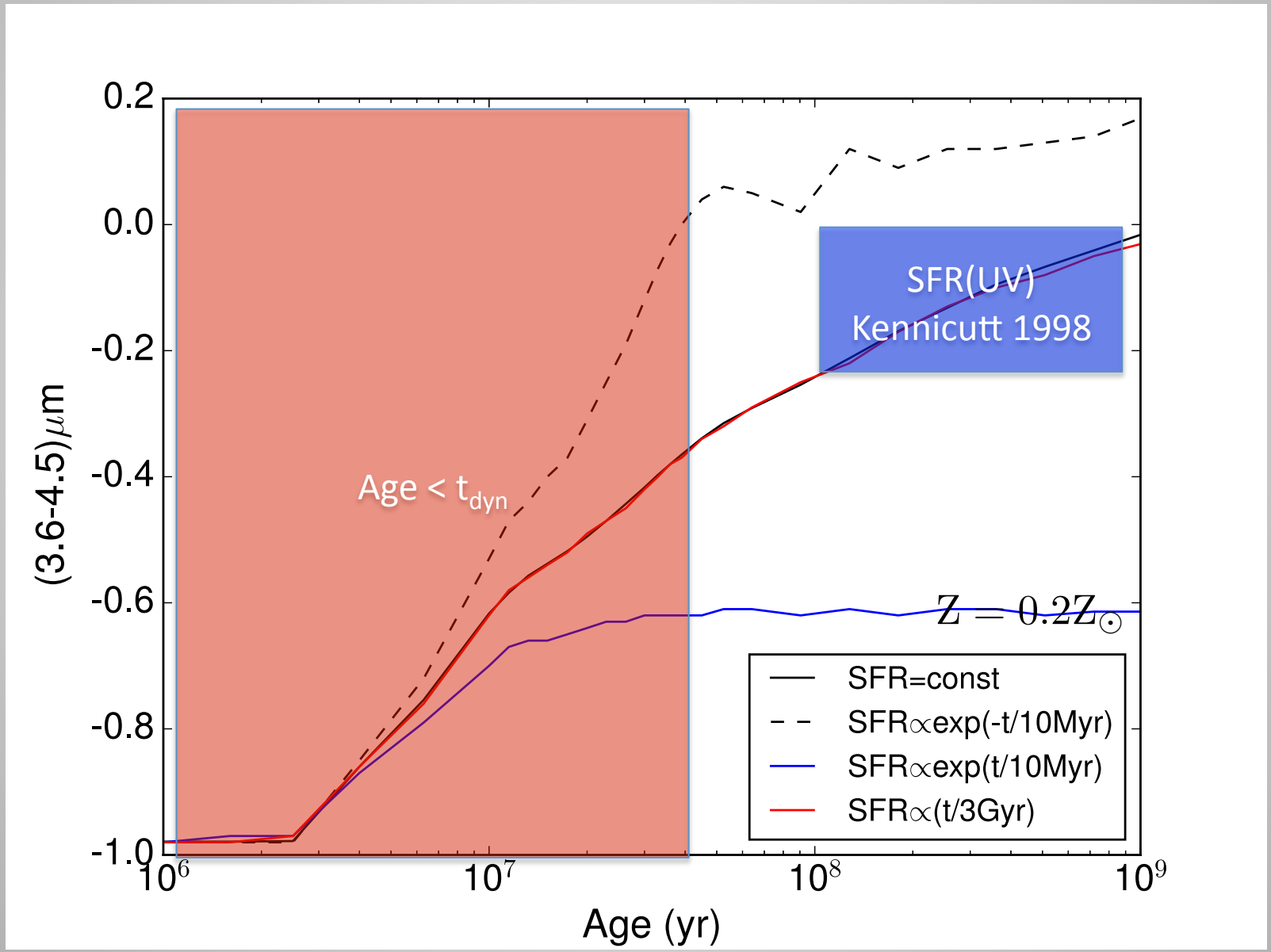
Back at z~4

Theoretical expectation from BC03 templates (no nebular emission)



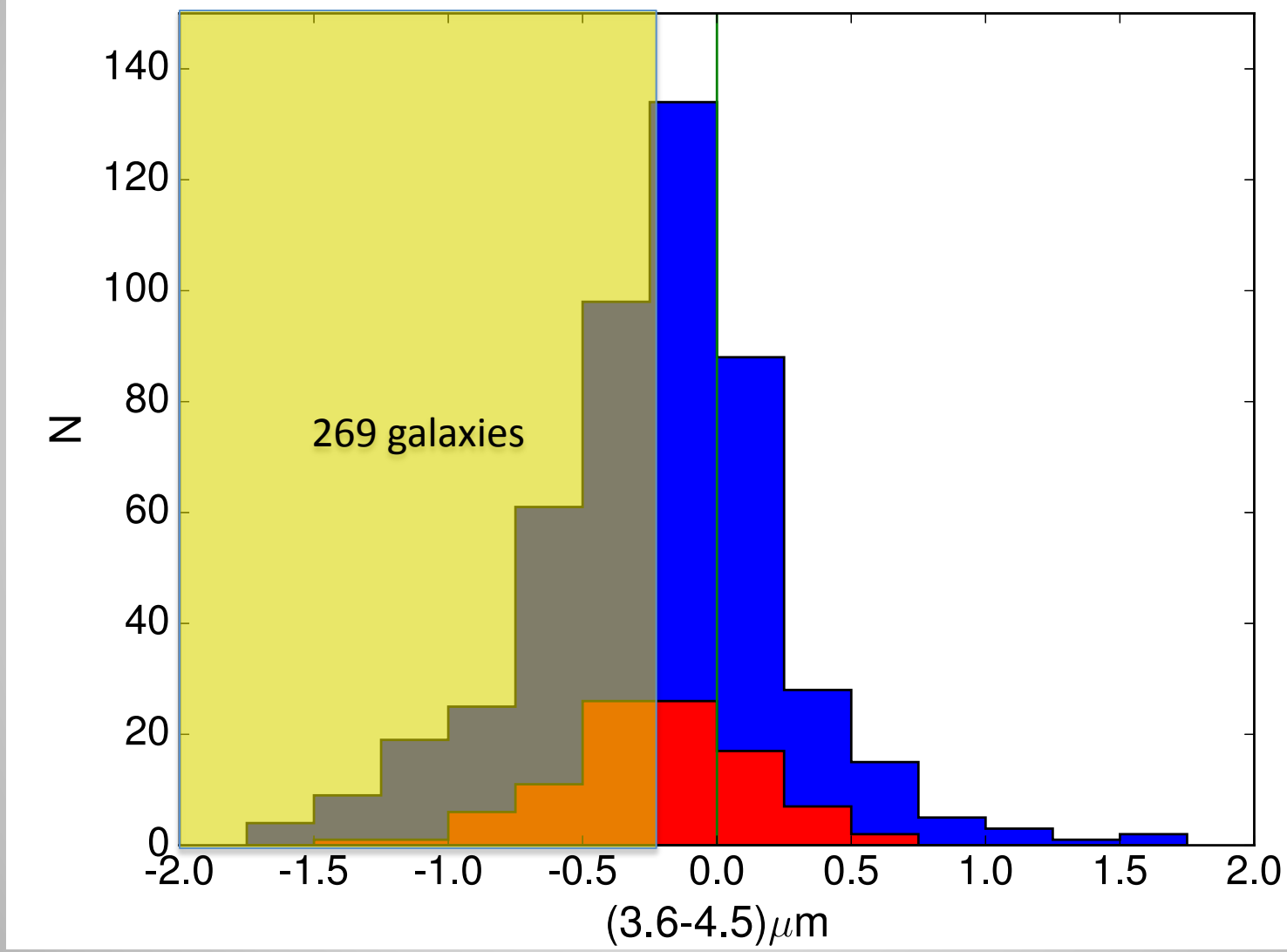
Back at z~4

Theoretical expectation from BC03 templates (+ nebular emission)



Back at z~4

de Barros, Mobasher, et al. 2015, in prep.



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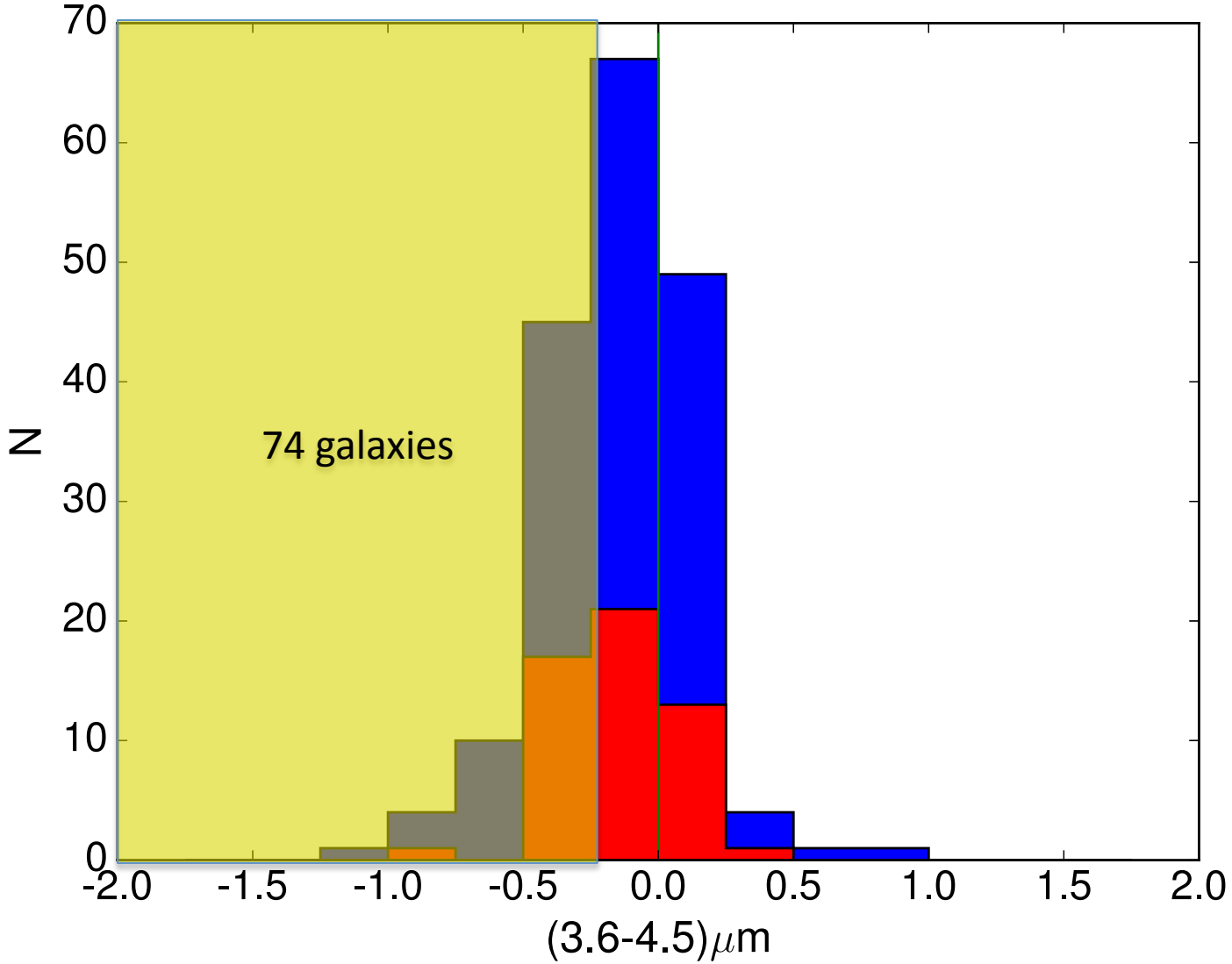

« Secure z» sample + S/N(3.6µm)>5 + S/N(4.5µm)>5: 182 galaxies (53 z_{spec})

Conclusions

At z~2:

- Despite many assumptions (IMF, Lyman continuum escape fraction, empirical ratios, etc…) a simple recipe allows to reproduce observed emission lines
- There is a slight additional color excess toward nebular emission relative to the stellar color excess

$$\mathrm{E(B-V)_{nebular}} = (1.20 \pm 0.16) \times \mathrm{E(B-V)_{stellar}}$$

- Correlation between SFR and $E(B\text{-}V)_{nebular}/E(B\text{-}V)_{stellar}$: can explain discrepant results at z~2?
- The color excess ratio seems to decrease with increasing redshift: likely ~1 at z>3, galaxy surface dominated by HII regions at high-z?

At z~4:

- (3.6-4.5)µm range can not be reproduced without taking account nebular emission
- There is a range of blue (3.6-4.5)µm color (< -0.2) which can not be reproduced with nebular emission and « standard » assumptions (age>100Myr, SFR=const): ~40% of z~4 galaxies
- Explanation: extreme rising SFHs? Stochasticity? IMF? Very young ages?
- Change of SF regime between z~2 and z~4?

Next: SFR(UV) vs. SFR(Hα) for individual galaxies, impact on other physical properties, impact on SFR(SED), revise sSFR, SFRD and stellar mass density

Real?

Galaxies on FIRE (Feedback In Realistic Environments): stellar feedback explains cosmologically inefficient star formation

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