Resolving gas-phase metallicity gradients of $0.1 < z < 0.8$ galaxies

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CRAL

Sterrewacht Leiden

muse
multi unit spectroscopic explorer

Thanks

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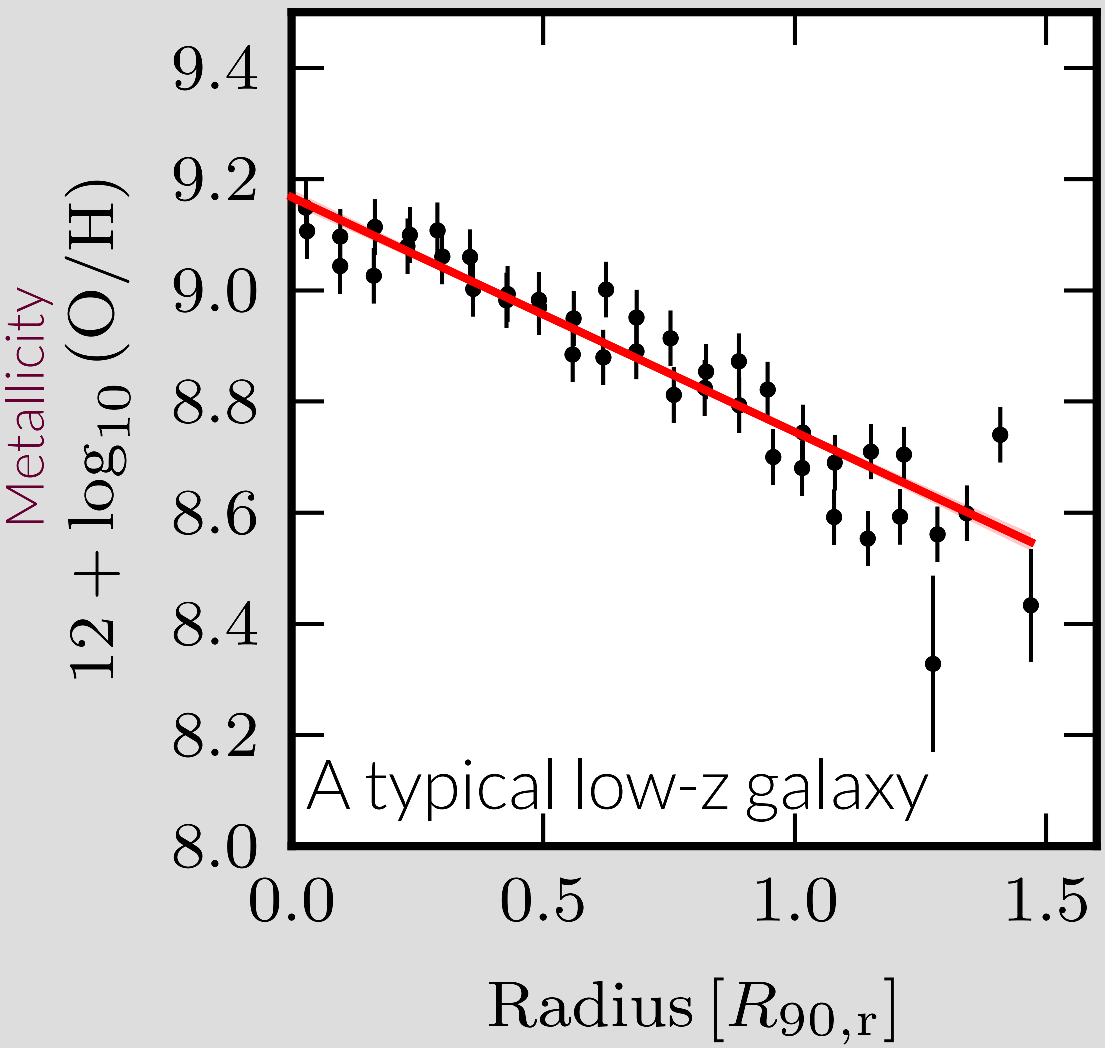
& The MUSE-GTO team

(Gas-phase) Metallicity gradients

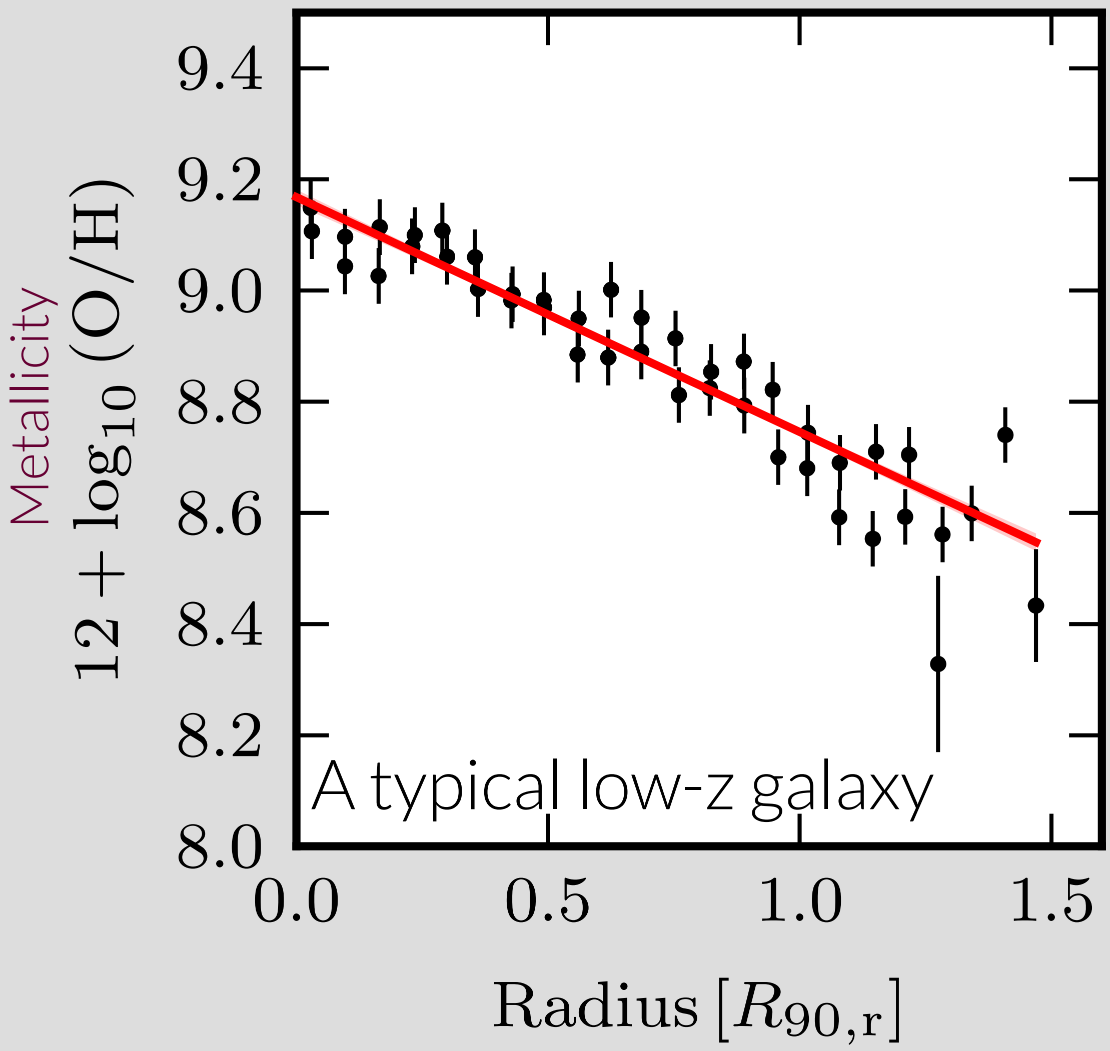


Metals built up from successive stellar generations

Galaxy centres older and metal-rich
a.k.a. "Inside-out growth"

Negative metallicity gradient

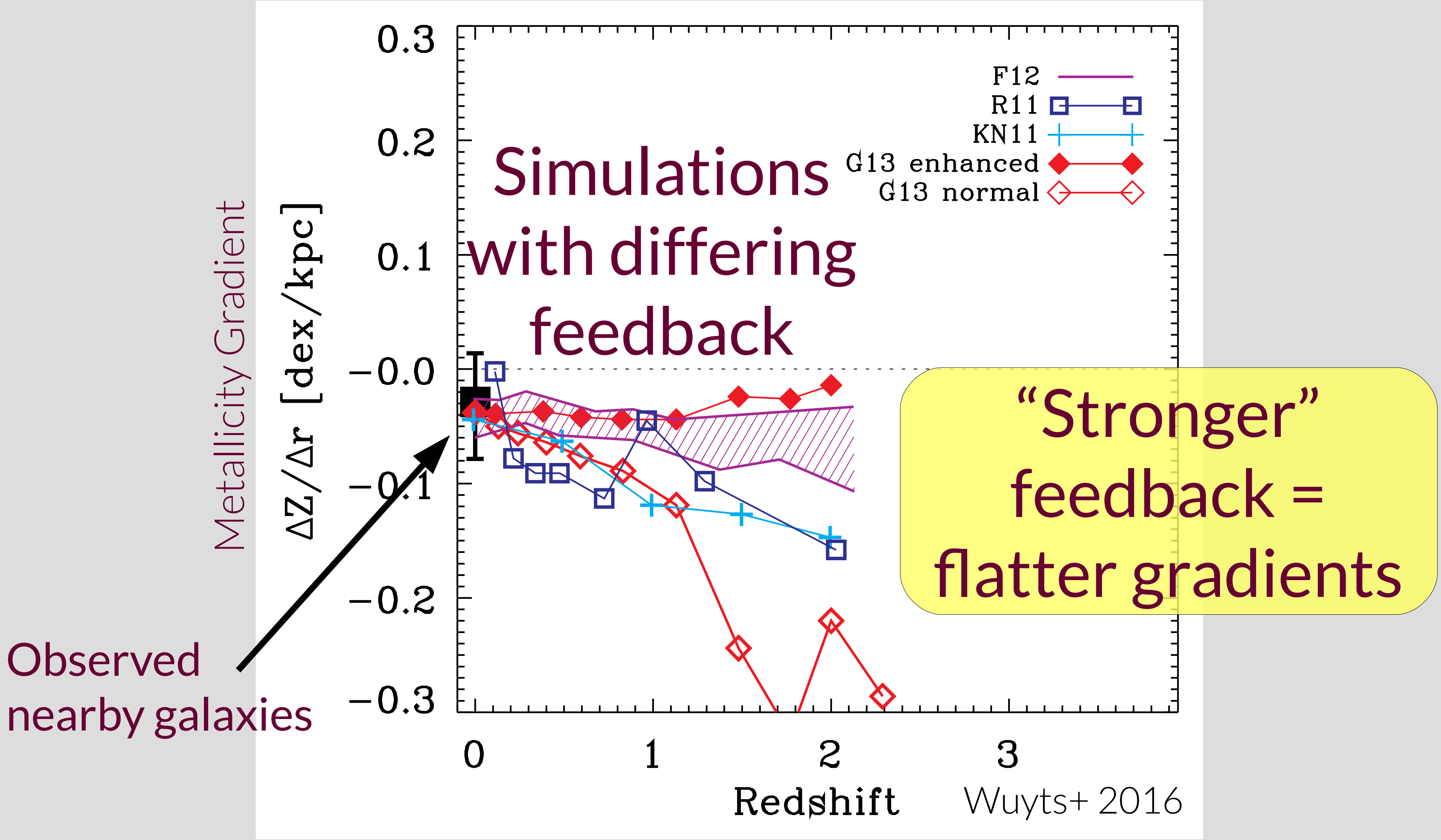
Metallicity traces gas flows



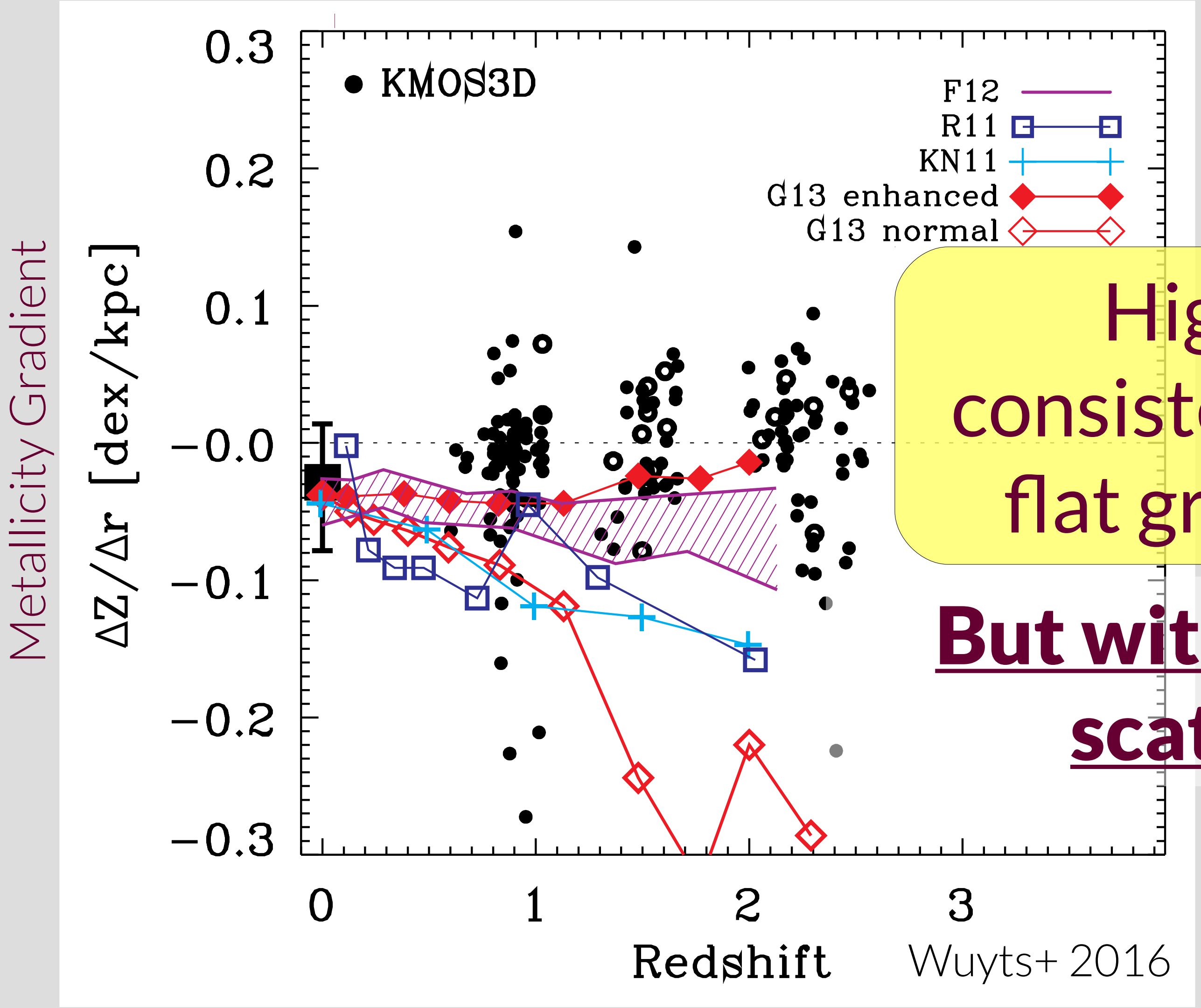
Gradients are modified by:

- Accretion of fresh gas
  - Dilution
- Galactic winds
  - Transport / removal of metal rich gas
- Galaxy-galaxy interactions
  - Radial mixing

Metallicity gradient evolution



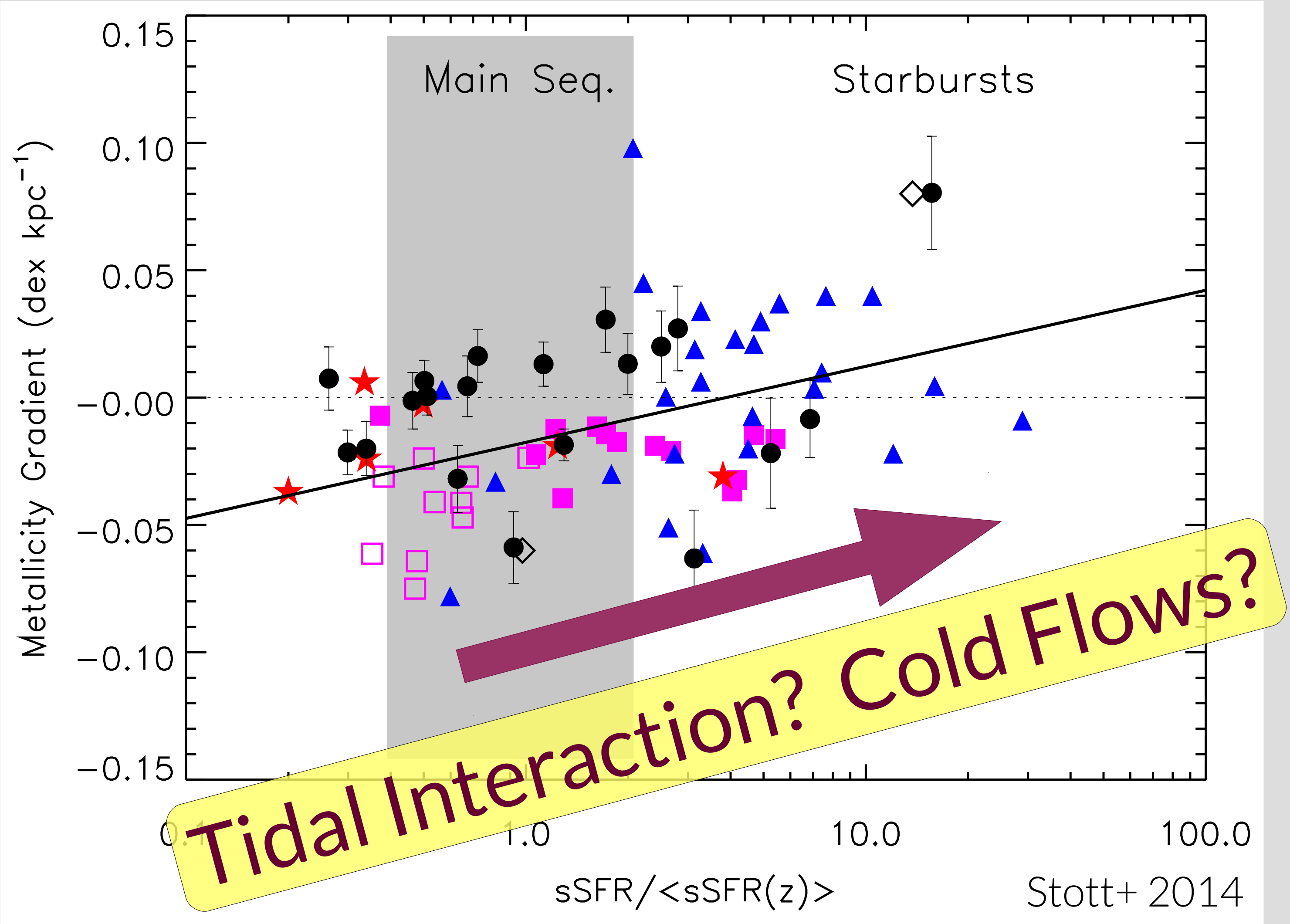
Metallicity gradient evolution



High-z consistent with flat gradient

But with much scatter

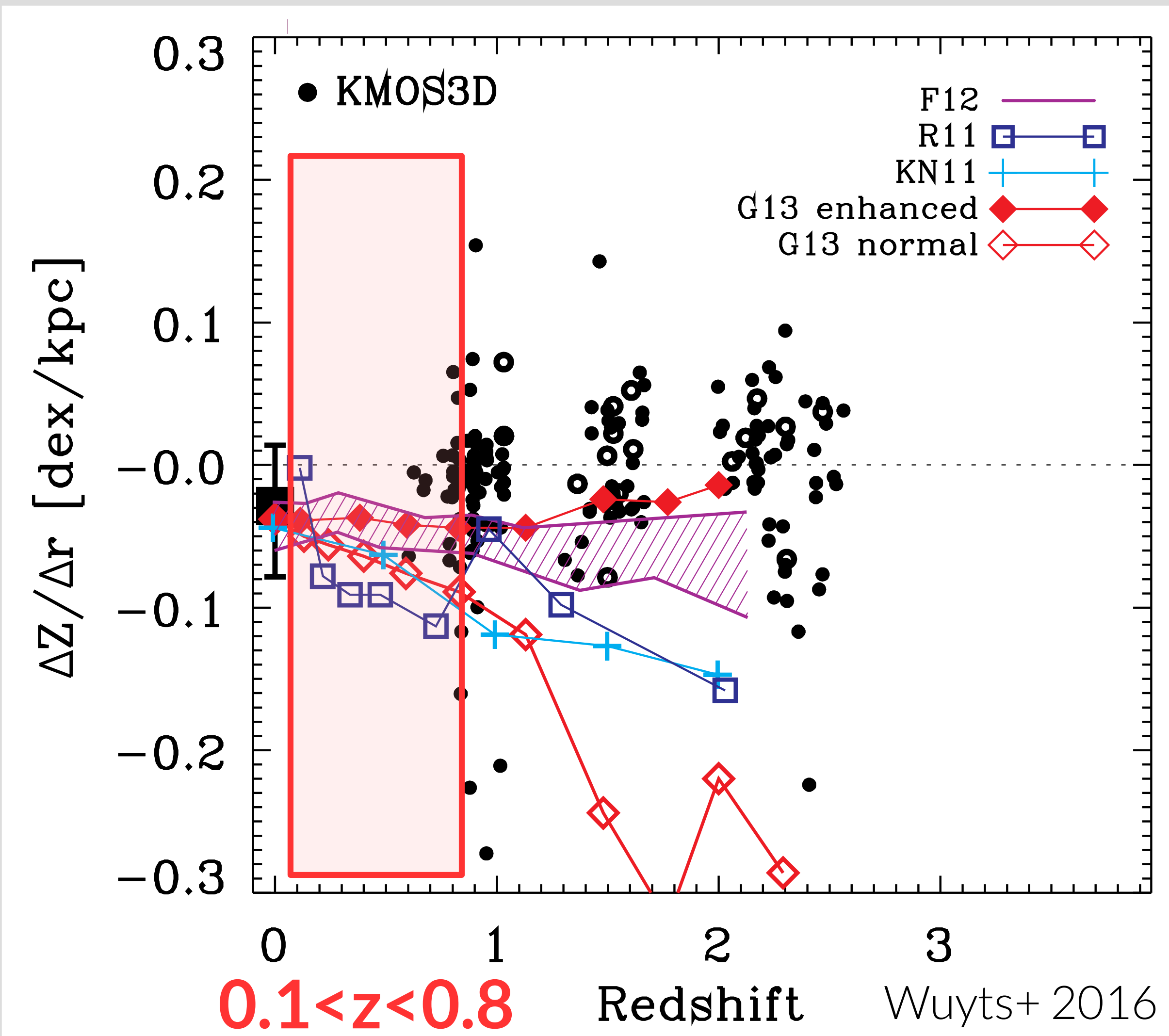
What causes positive gradients?



sSFR relative to Main Sequence

Metallicity gradient evolution?

Metallicity Gradient



MUSE

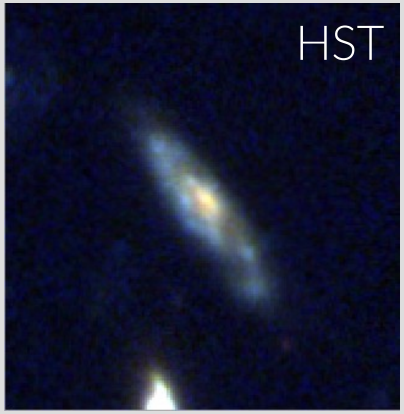
Our MUSE sample:

84 star-forming galaxies

Various fields:

- Deep (11 arcmin²)
  - >10h depth
  - Good seeing (FWHM < 0.7”)
- Shallow (24 arcmin²)
  - 1h depth
  - Poor seeing (0.7” < FWHM < 1.1”)

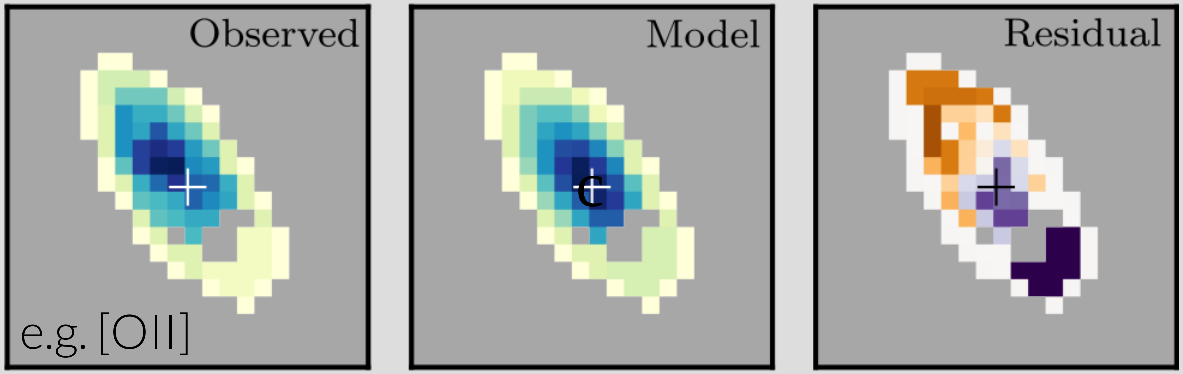
Necessary to model PSF effects



Metallicity is measured from optical emission lines

But MUSE data is marginally resolved

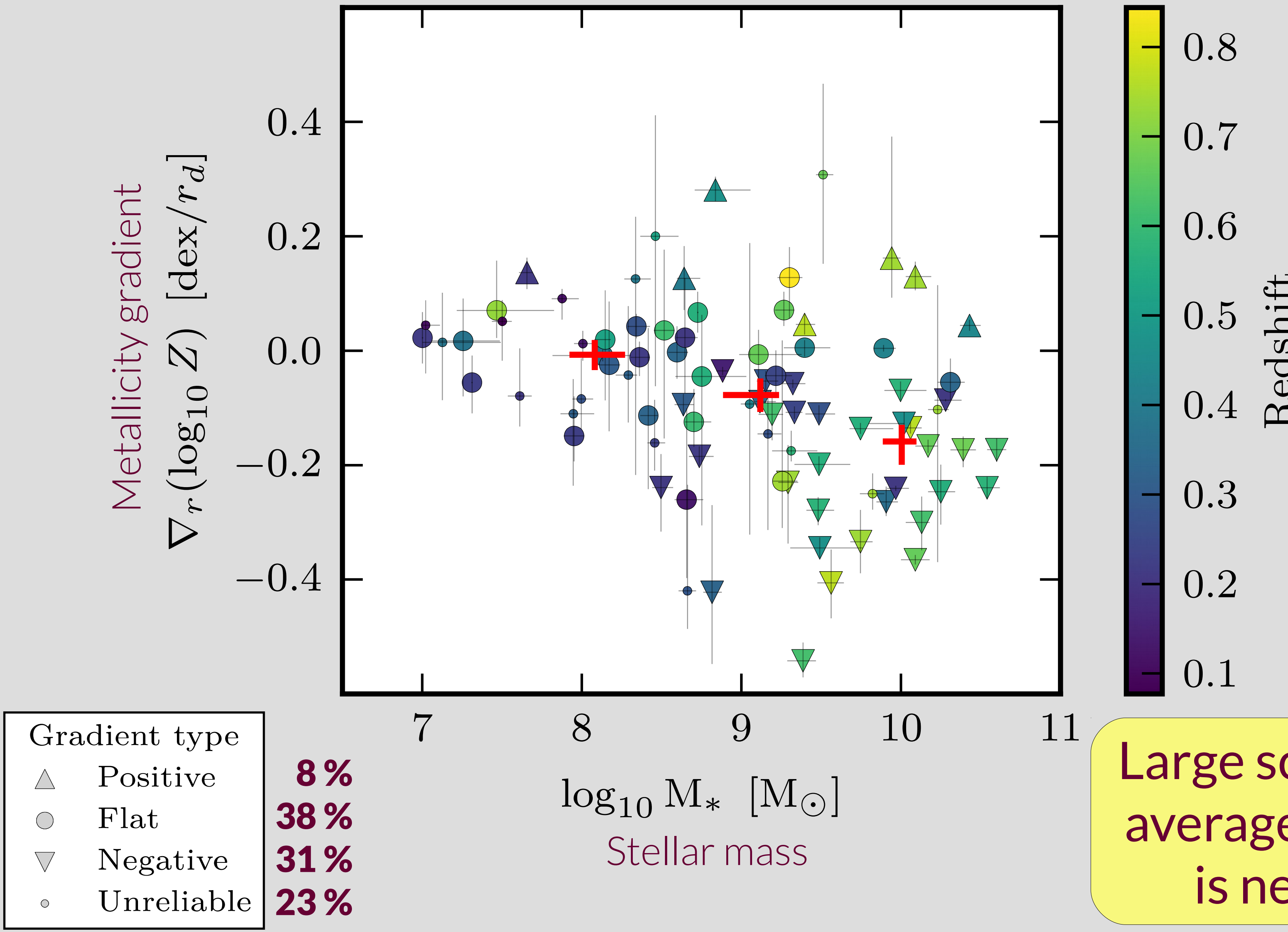
- PSF heavily distorts / blurs the observed metallicity gradient
- We must forward model the observations



Model described: Carton+ 2017

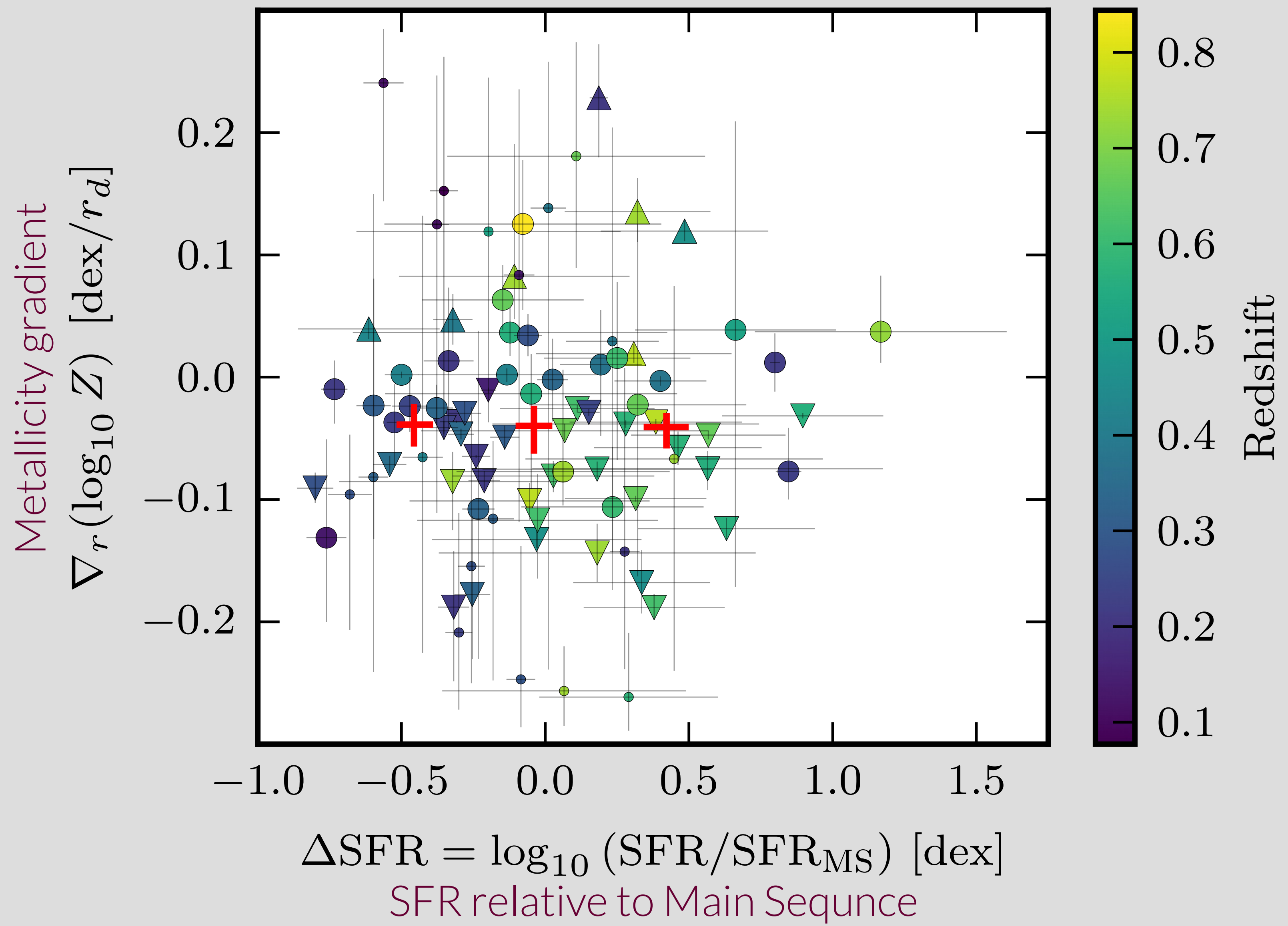
Results shown: Carton+ (subm.)

MUSE gradients (0.1 < z < 0.8)



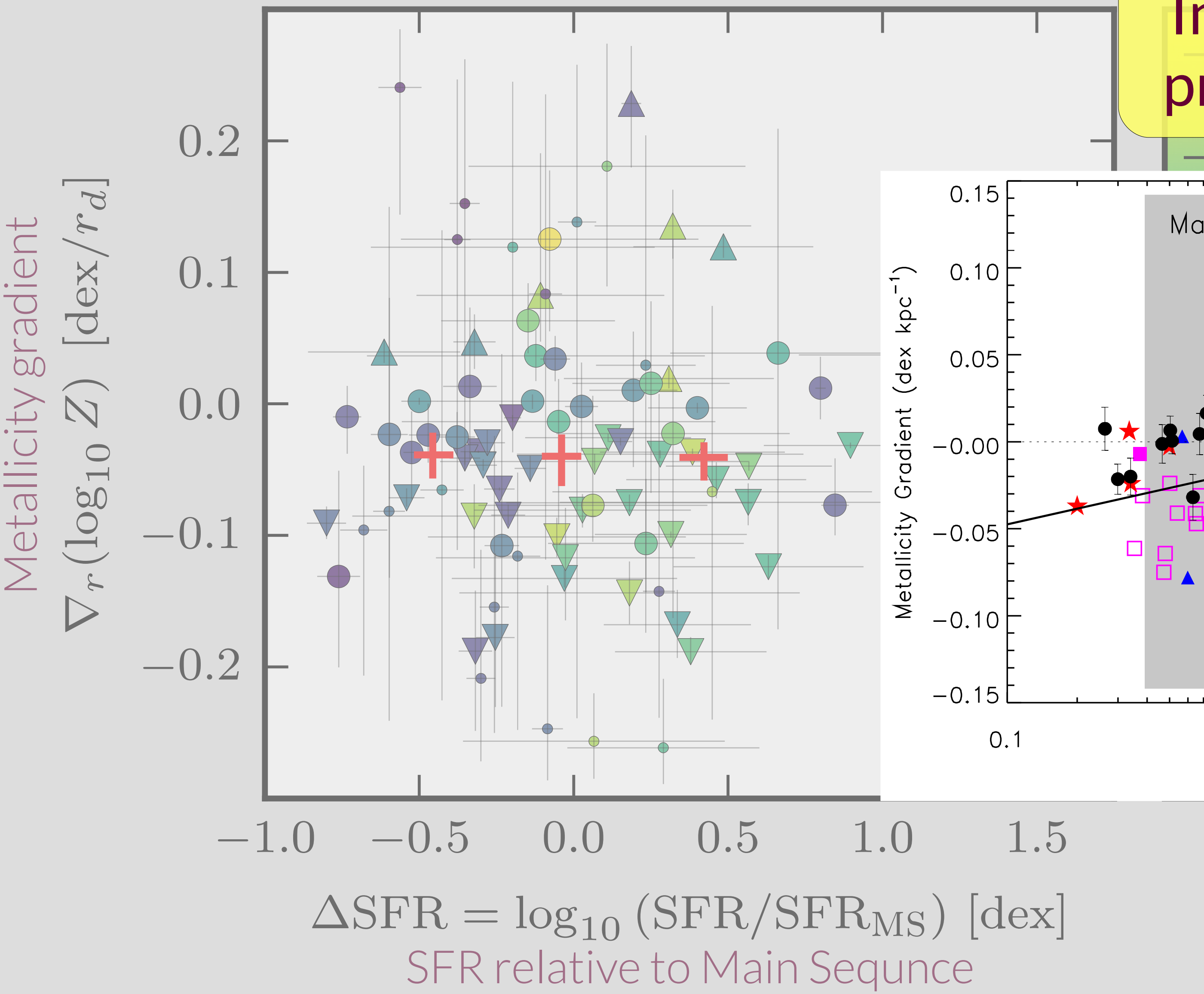
Large scatter, but average gradient is negative

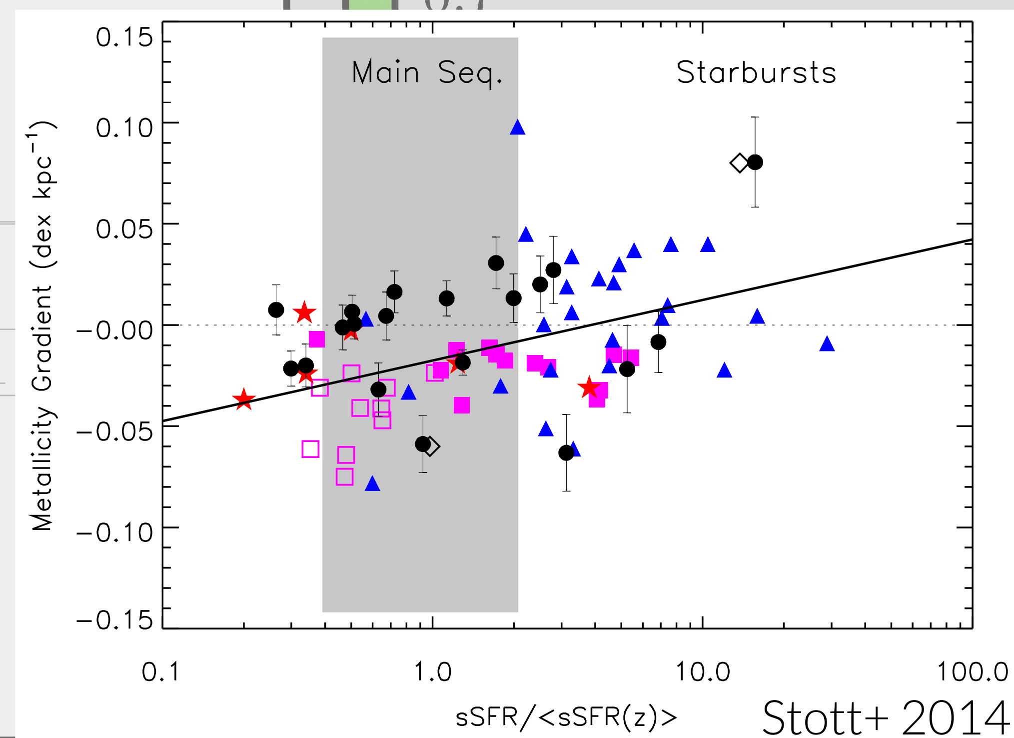
No trend with SF intensity



No trend with SF intensity

In contrast with previous studies



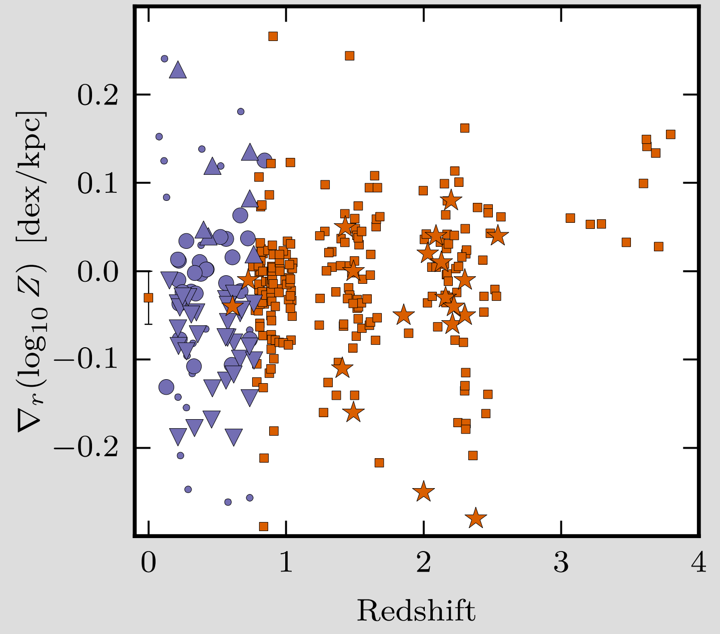


Stott+ 2014

Interpretation

We do not find as many inverted metallicity gradients as other (z>0.6) studies

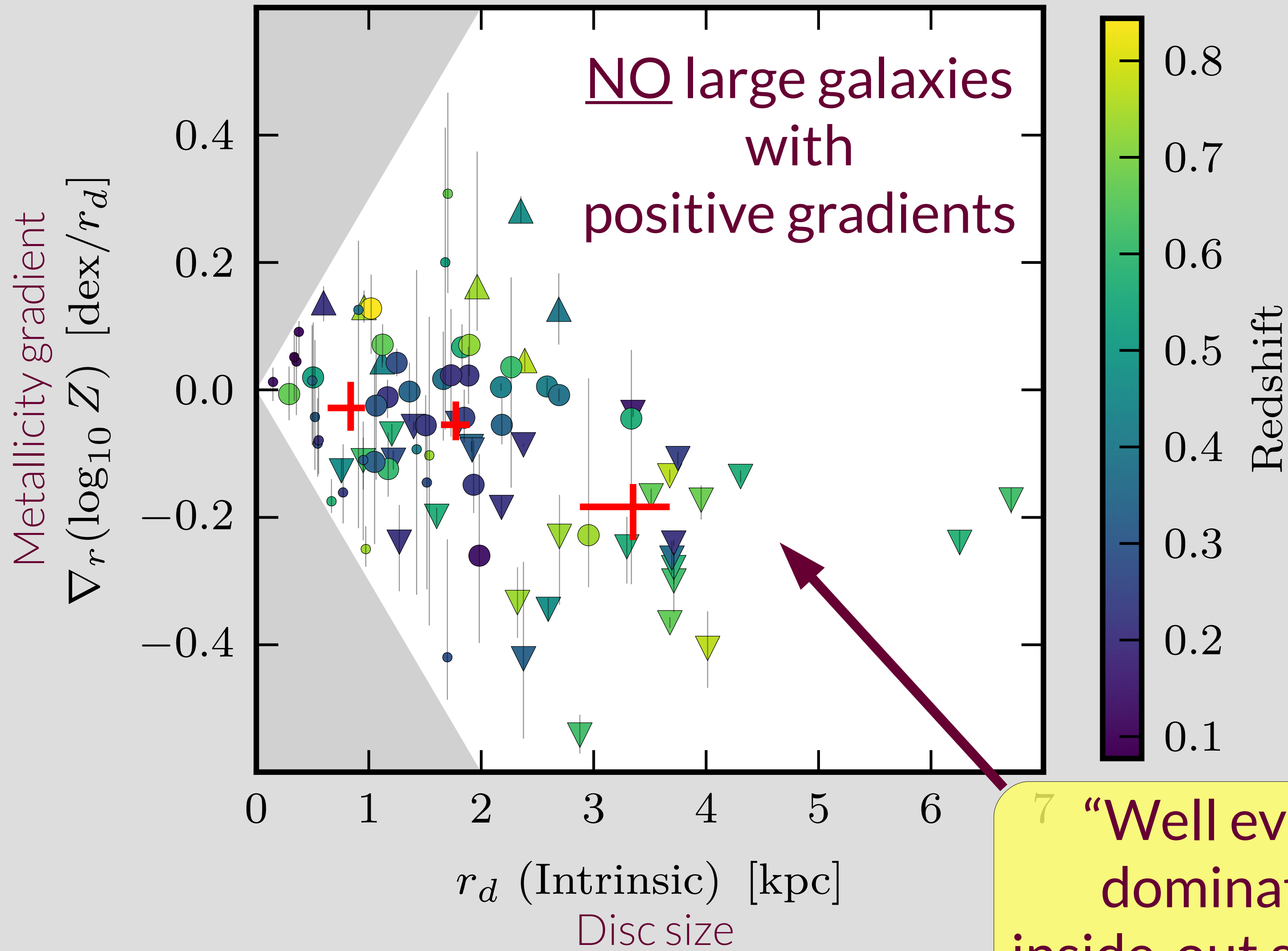
- Redshift evolution ?
  - Cold flows not as common ?
  - Secular evolution ? *(Next slide)*



Metallicity gradient does not correlate with intensity of star formation

- Perhaps global (integrated) SFRs are a poor indicator of gas accretion / interaction ?

A speculative trend with size



“Well evolved” dominated by inside-out growth ???

Summary

($0.1 < z < 0.8$) have negative metallicity gradients on average, but with considerable scatter.

- However, there are no large galaxies ($r_d > 3$kpc) with inverted (positive) gradients

Limitations

Current sample (84 galaxies) is small and <u>incomplete</u> :(

- But more MUSE data will help :)

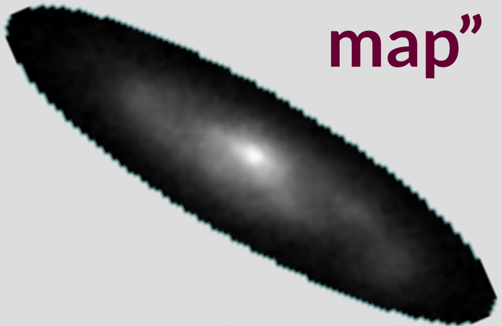
Our current emission line modelling is <u>too simplistic</u>

- Non-parametric models can be computationally expensive!

Extra Bits

Forward Model

"Star formation map"



e.g. HST image as best guess

\+

Metallicity profile

Z(r)

\+

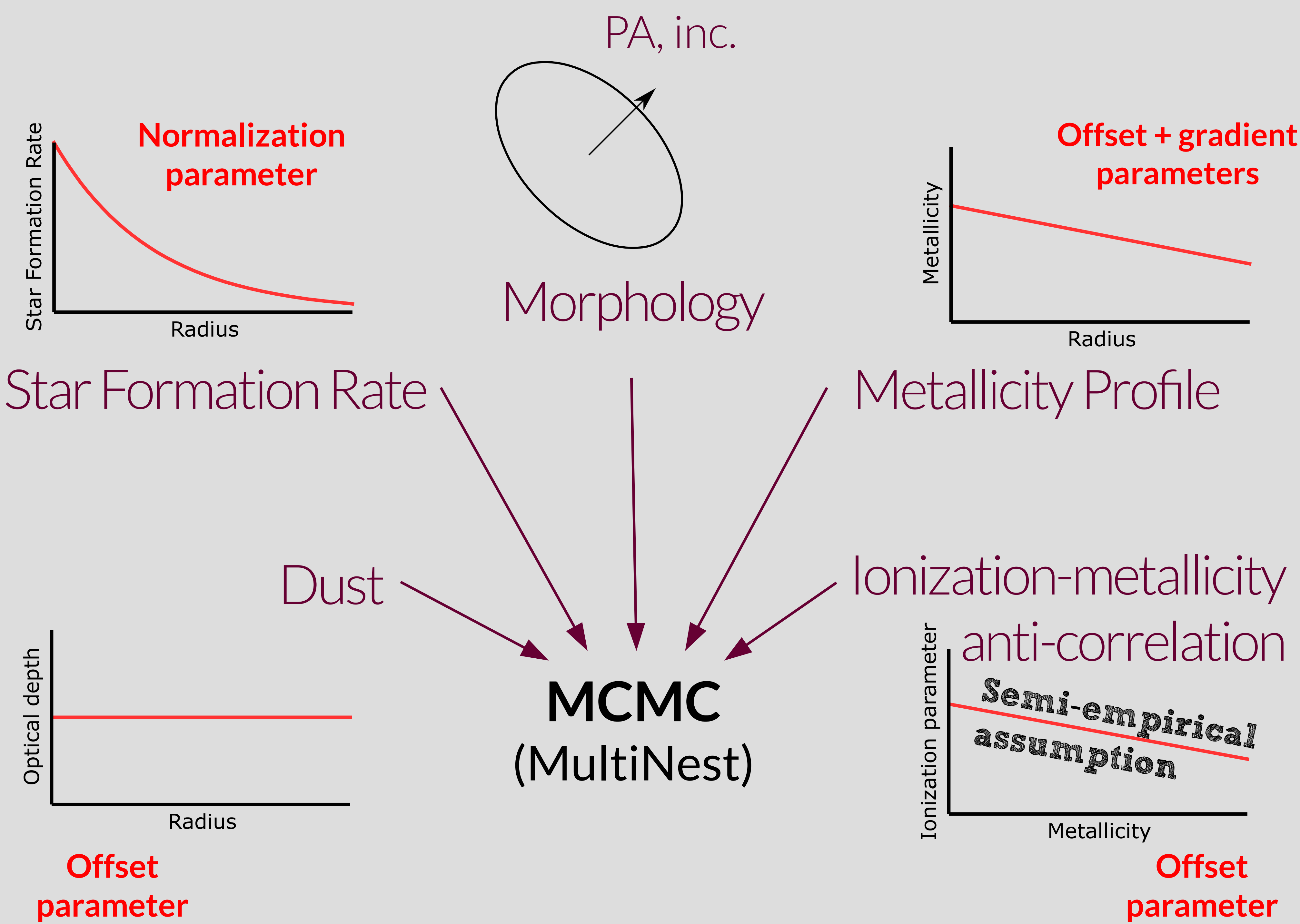
Photoionization Models

PSF

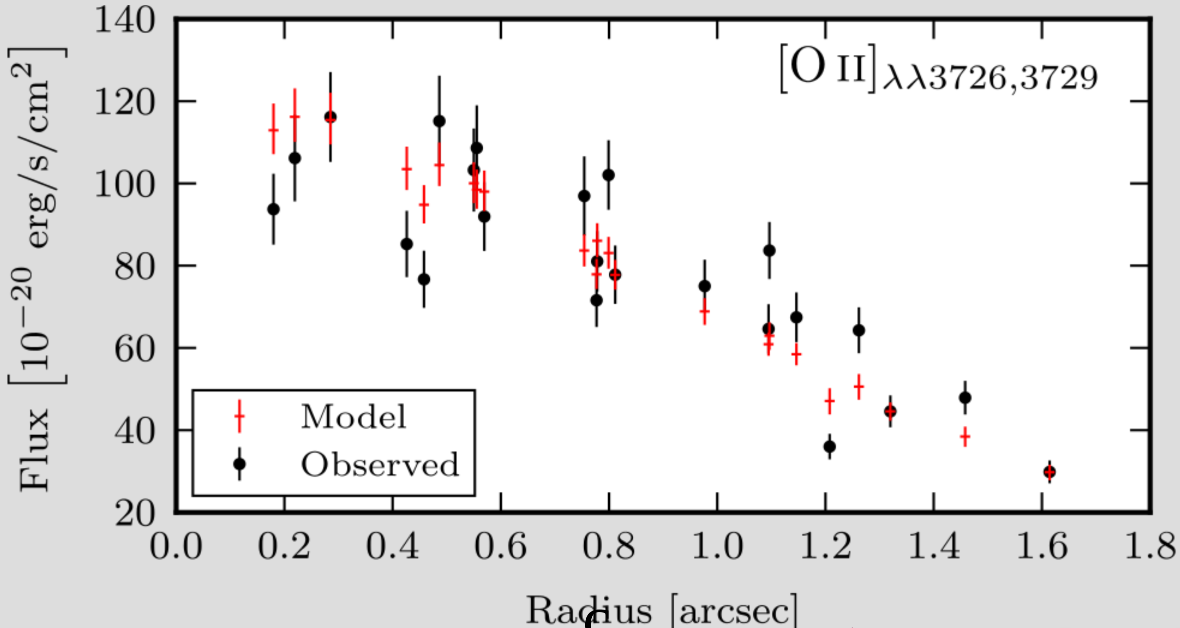
Data (Fluxes)

MCMC

Recover best fit:
Metallicity gradient & Central metallicity (+errors)

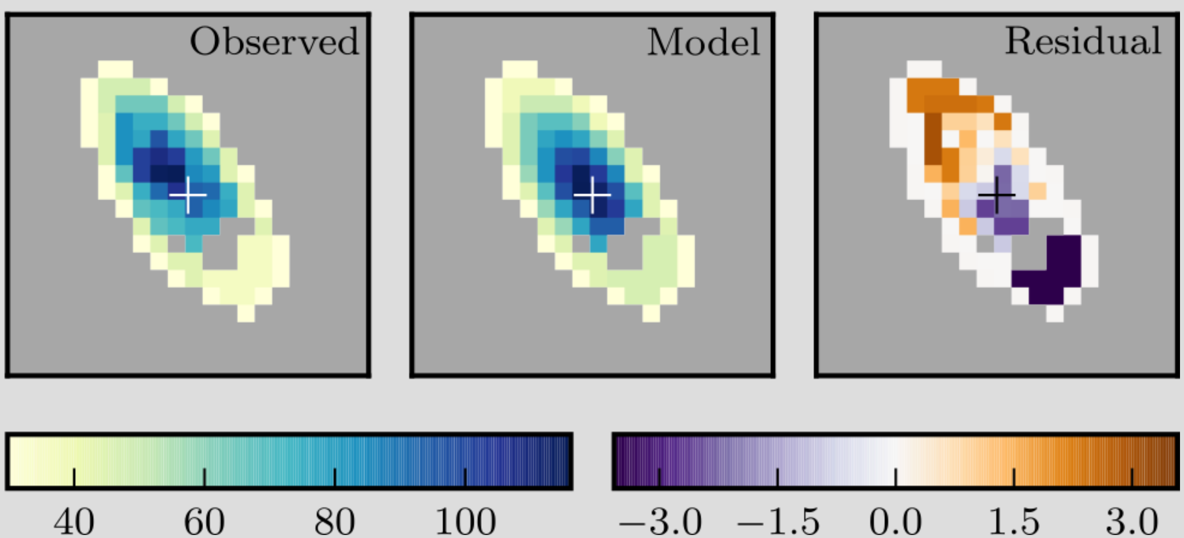

PA, inc.
Morphology
Normalization parameter
Star Formation Rate
Radius
Star Formation Rate
Offset + gradient parameters
Metallicity
Radius
Metallicity Profile
Dust
Optical depth
Radius
Offset parameter
Ionization-metallicity anti-correlation
Ionization parameter
Metallicity
Semi-empirical assumption
Offset parameter
MCMC
(MultiNest)

Example Fit

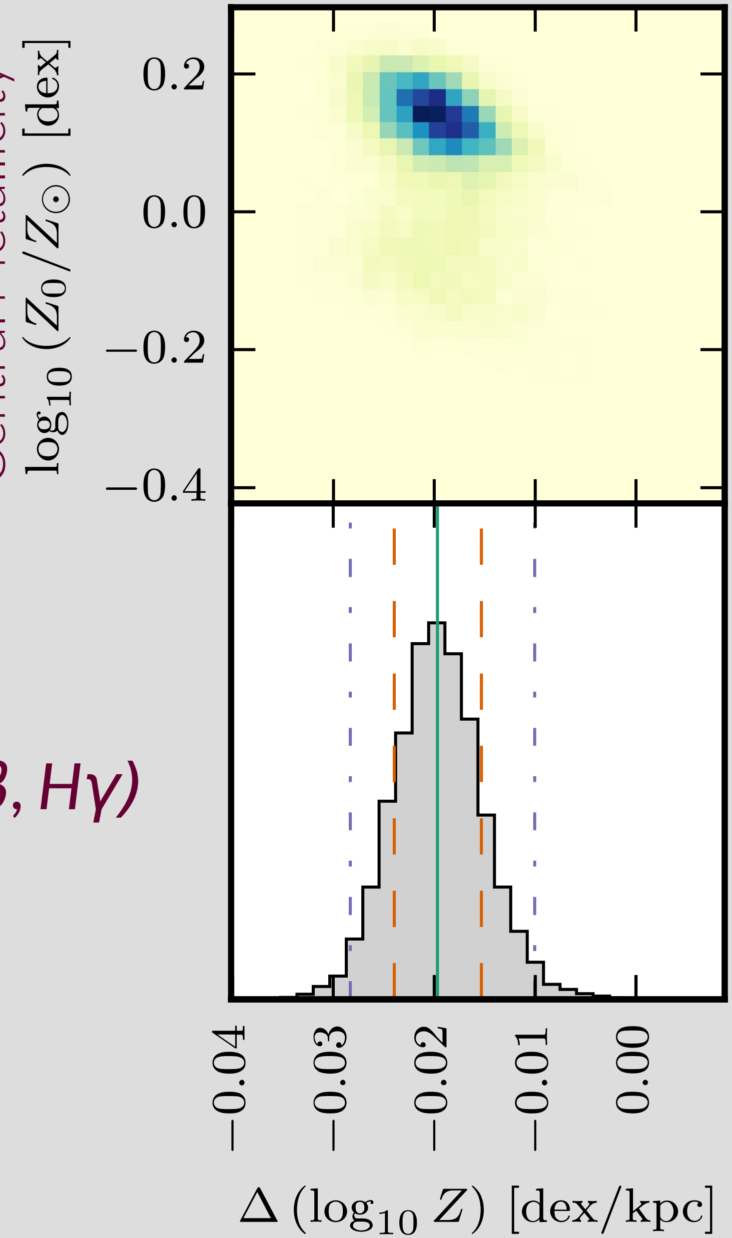


c

(also fit: [OIII], Hβ, Hγ)



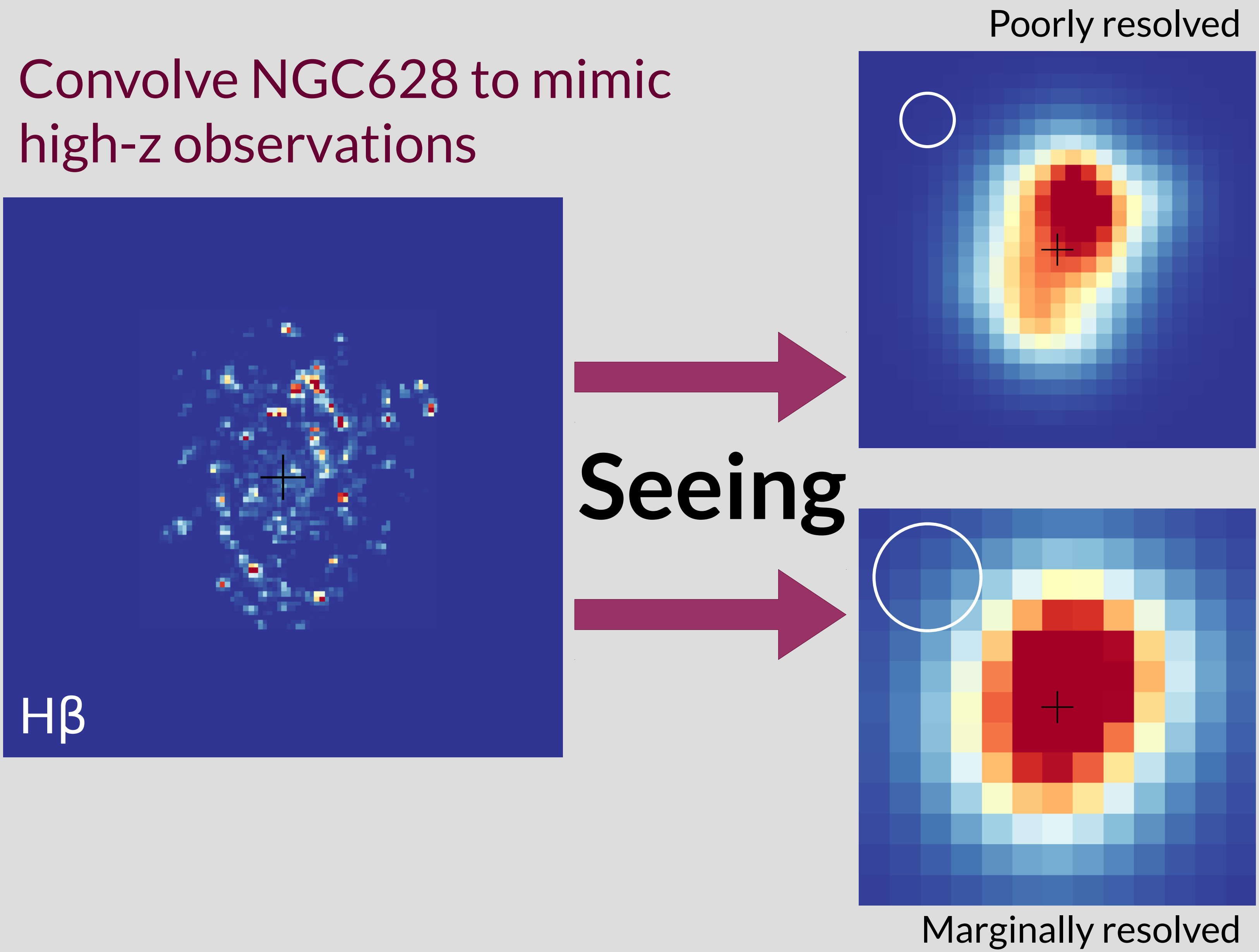
Central Metallicity



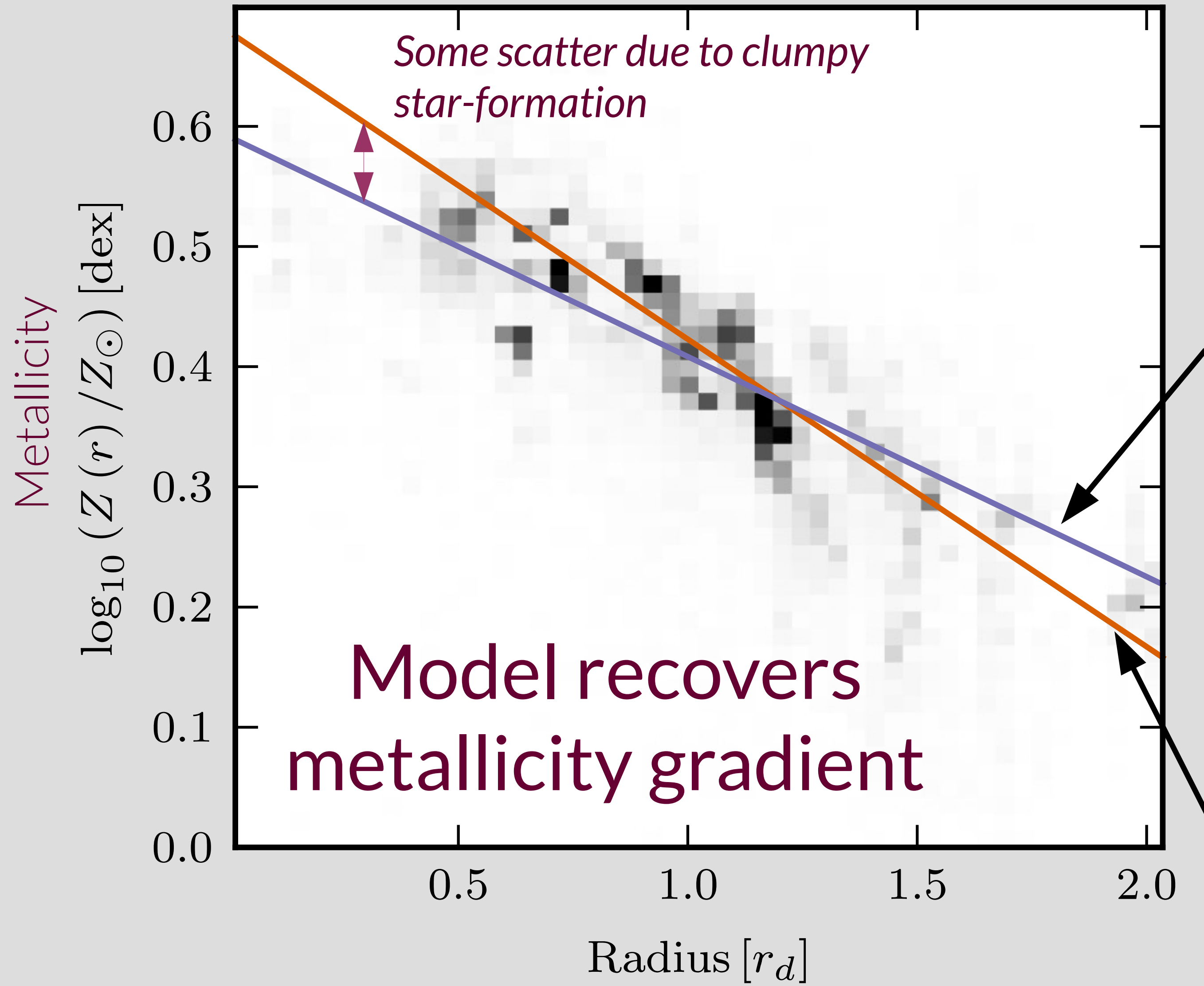
Metallicity Gradient

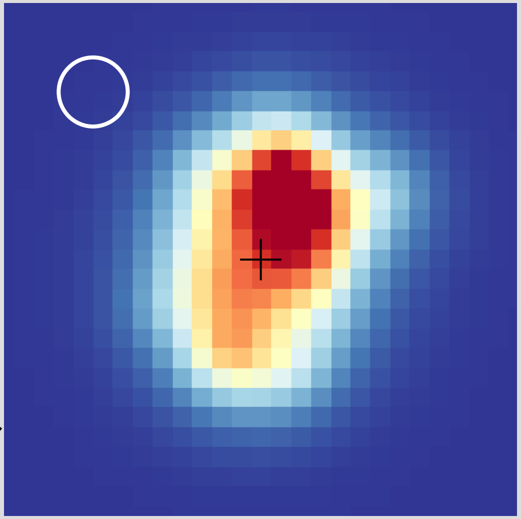
Testing the model

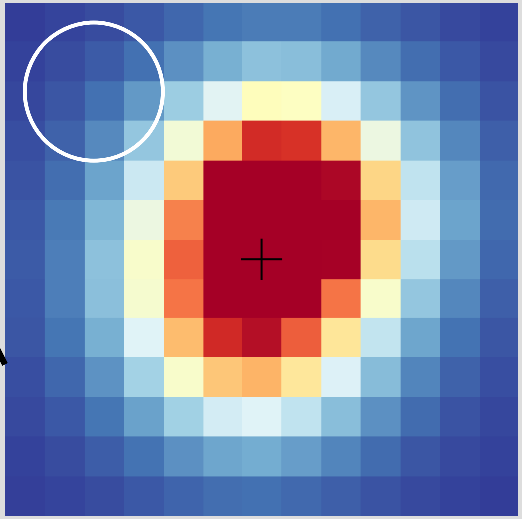
ConvSolve NGC628 to mimic high-z observations



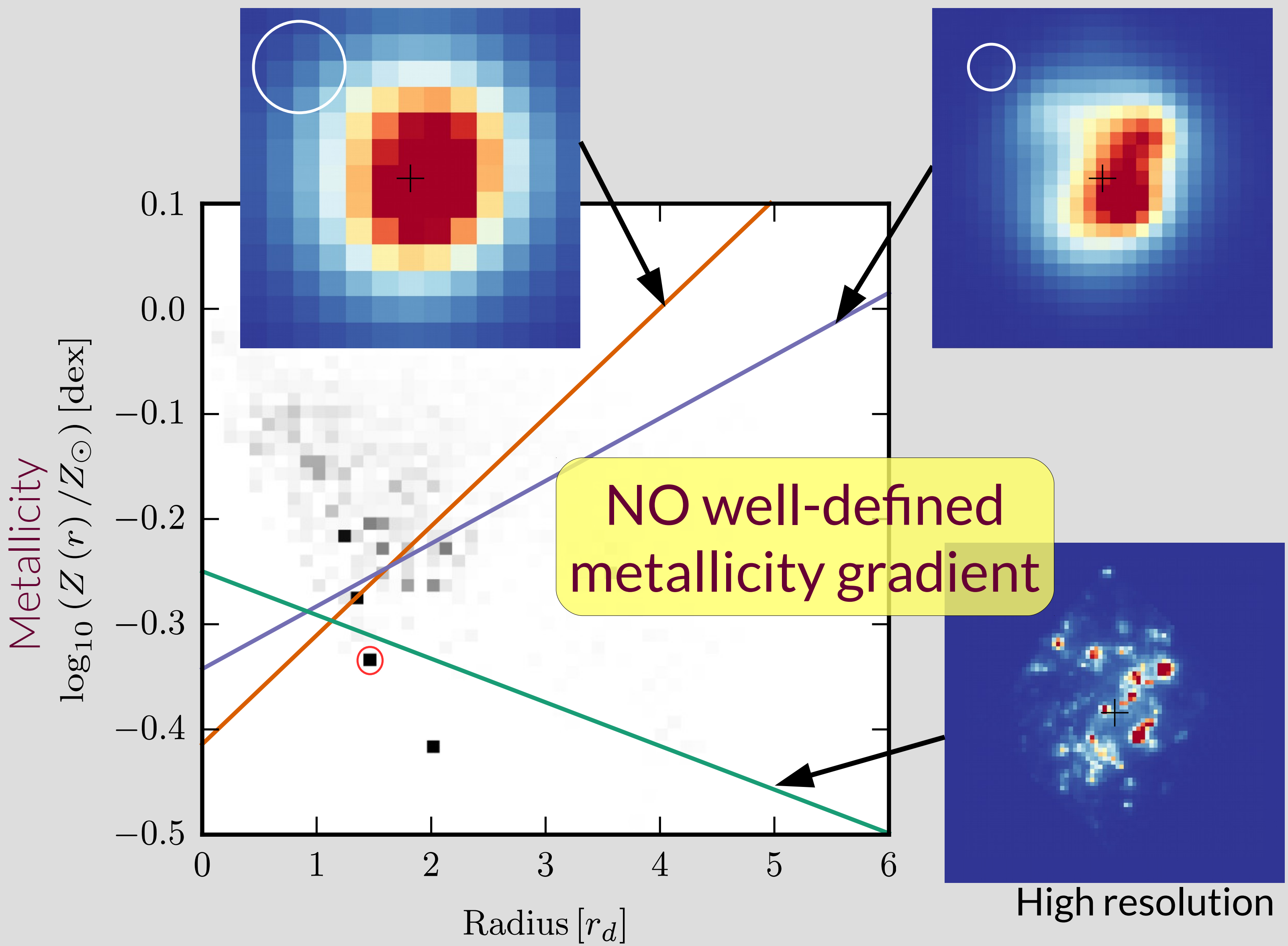
Model works for well behaved galaxies

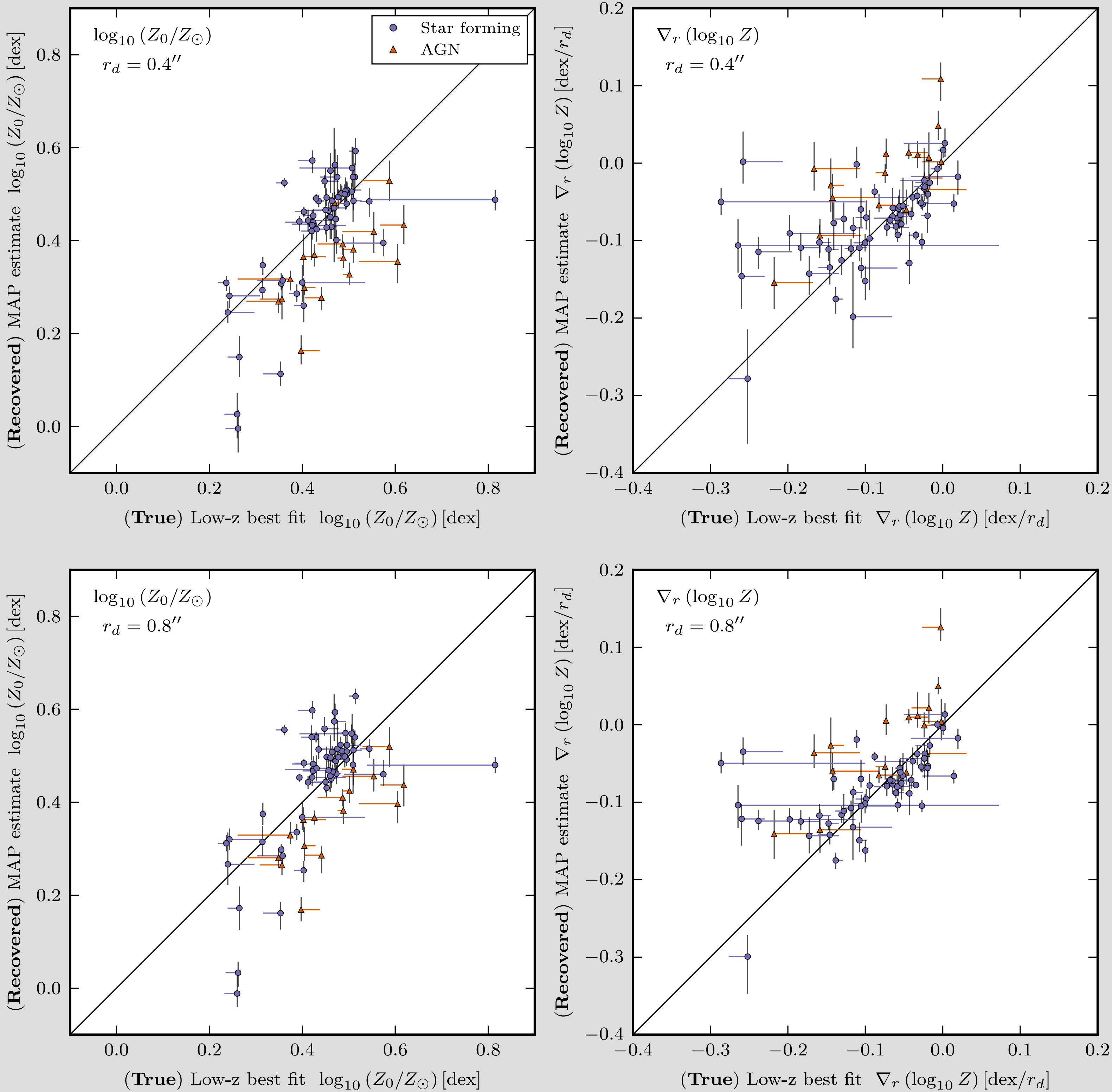




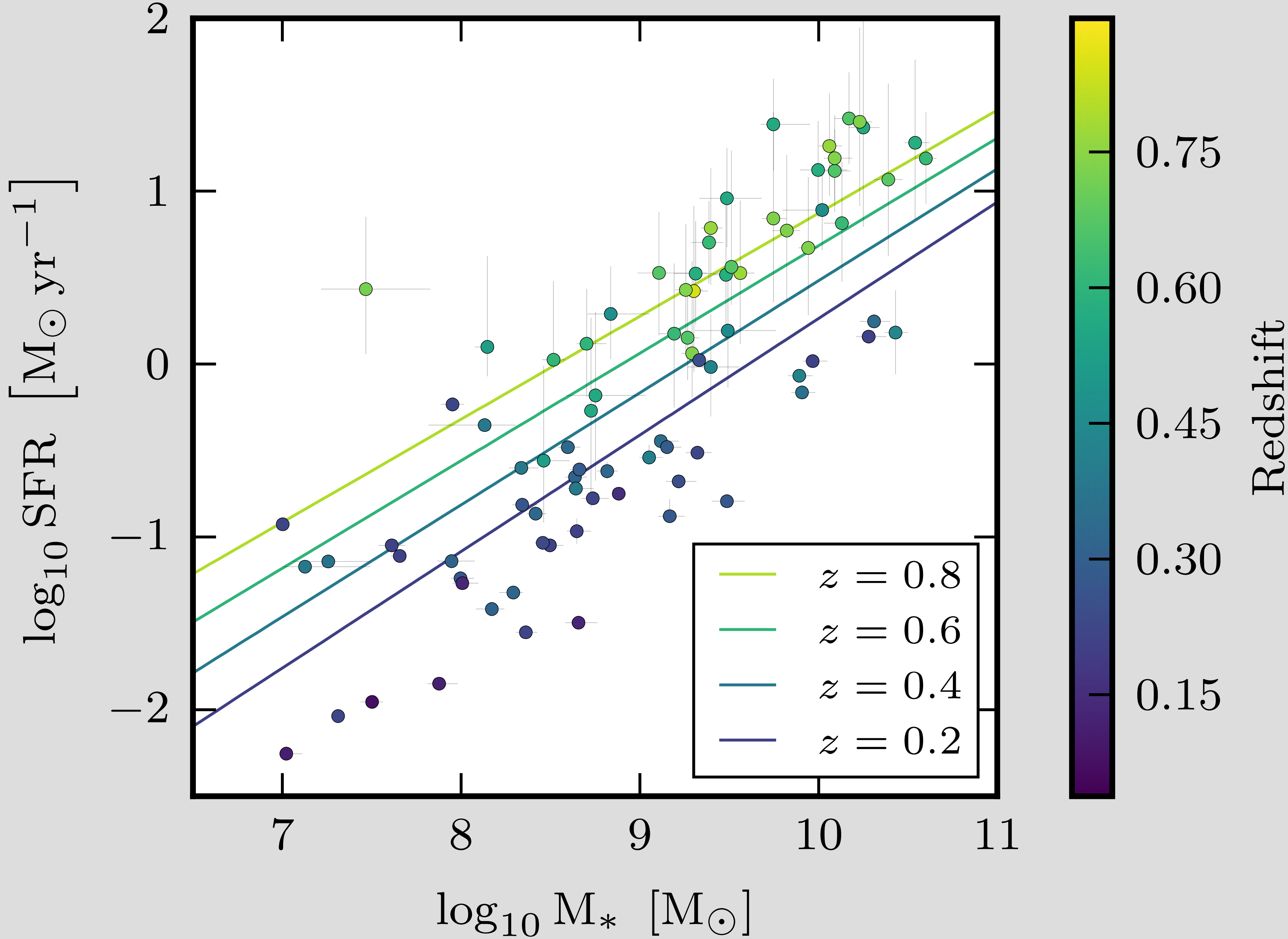


But not for <u>poorly behaved</u> galaxies *e.g. NGC4980*

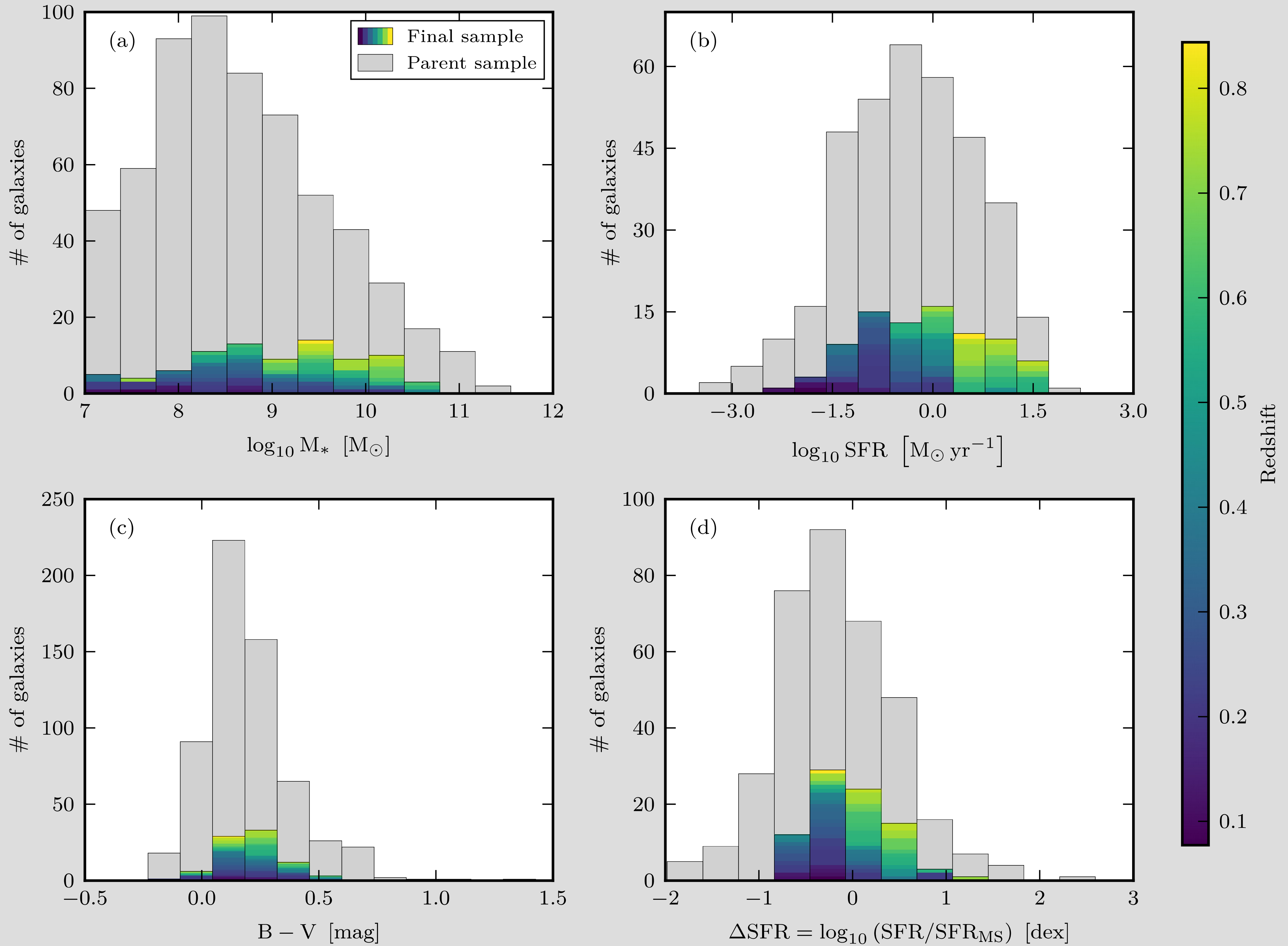


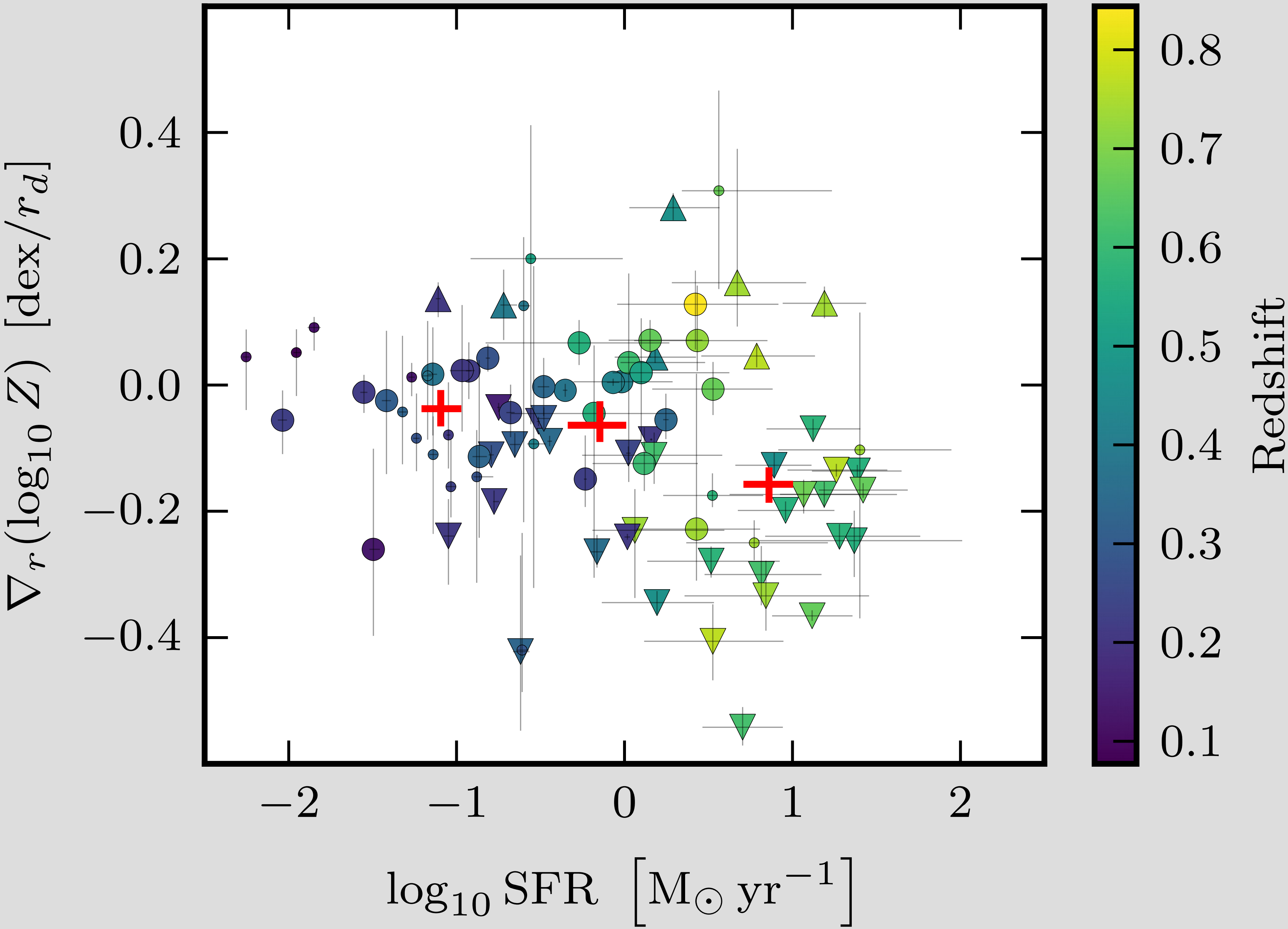


$\log_{10}(Z_0/Z_\odot)$
$r_d = 0.4''$
Star forming
AGN
(**Recovered**) MAP estimate $\log_{10}(Z_0/Z_\odot)$ [dex]
(**True**) Low-z best fit $\log_{10}(Z_0/Z_\odot)$ [dex]
$\nabla_r(\log_{10} Z)$
$r_d = 0.4''$
(**Recovered**) MAP estimate $\nabla_r(\log_{10} Z)$ [dex/r_d]
(**True**) Low-z best fit $\nabla_r(\log_{10} Z)$ [dex/r_d]
$\log_{10}(Z_0/Z_\odot)$
$r_d = 0.8''$
(**Recovered**) MAP estimate $\log_{10}(Z_0/Z_\odot)$ [dex]
(**True**) Low-z best fit $\log_{10}(Z_0/Z_\odot)$ [dex]
$\nabla_r(\log_{10} Z)$
$r_d = 0.8''$
(**Recovered**) MAP estimate $\nabla_r(\log_{10} Z)$ [dex/r_d]
(**True**) Low-z best fit $\nabla_r(\log_{10} Z)$ [dex/r_d]

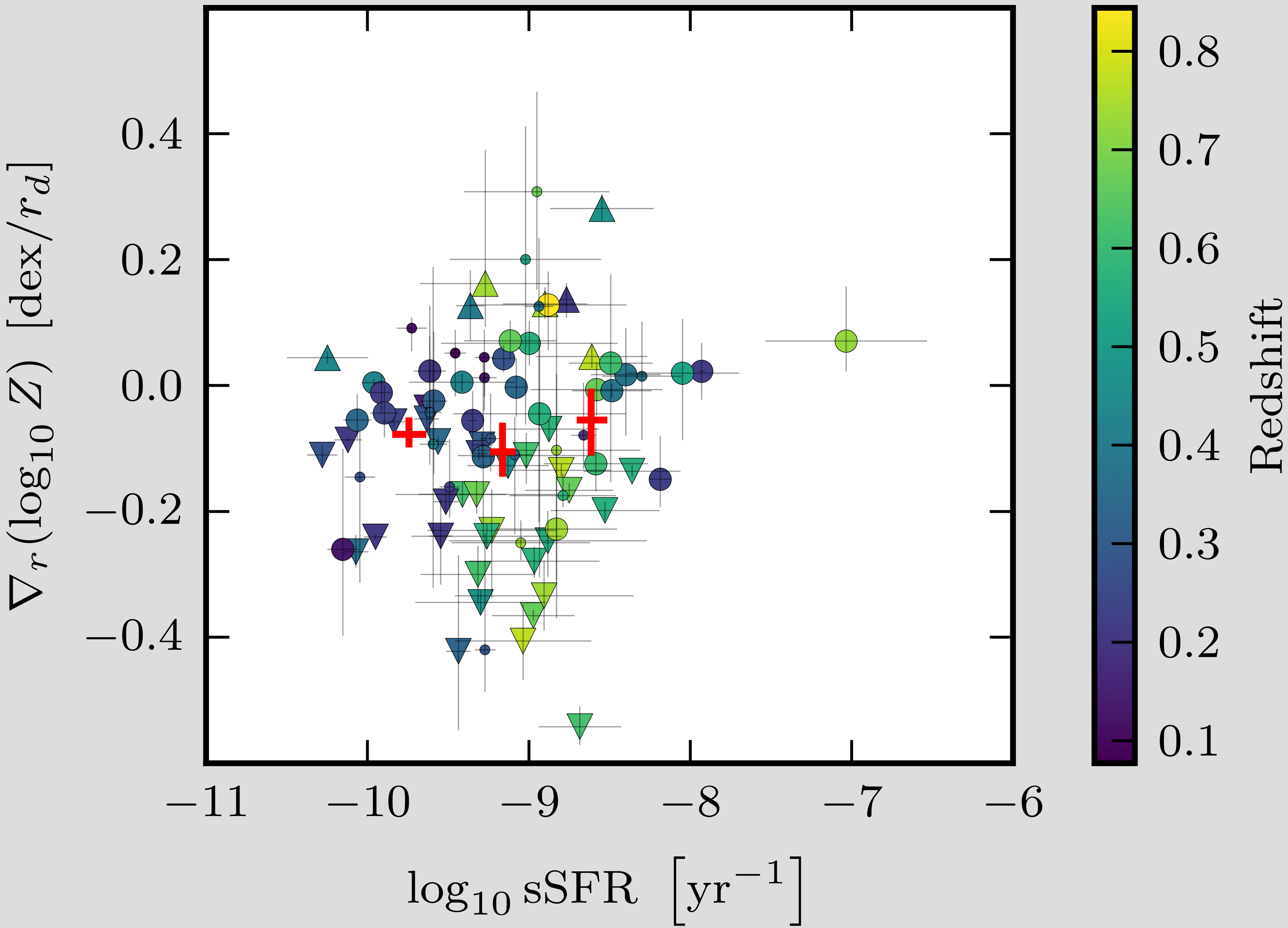


2
1
0
−1
−2
7
8
9
10
11
log10 SFR [M⊙ yr−1]
log10 M∗ [M⊙]
z = 0.8
z = 0.6
z = 0.4
z = 0.2
0.75
0.60
0.45
0.30
0.15
Redshift


(a)
Final sample
Parent sample
# of galaxies
$\log_{10} M_* \ [M_\odot]$
(b)
# of galaxies
$\log_{10} \mathrm{SFR} \ \left[M_\odot \, \mathrm{yr}^{-1}\right]$
(c)
# of galaxies
$B - V$ [mag]
(d)
# of galaxies
$\Delta\mathrm{SFR} = \log_{10}(\mathrm{SFR}/\mathrm{SFR_{MS}})$ [dex]
Redshift



0.4
0.2
0.0
−0.2
−0.4
−2
−1
0
1
2
$\nabla_r(\log_{10} Z)$ [dex/r_d]
$\log_{10}$ SFR [$M_\odot$ yr^{-1}]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Redshift



0.4
0.2
0.0
−0.2
−0.4
$\nabla_r(\log_{10} Z)$ [dex/r_d]
−11
−10
−9
−8
−7
−6
$\log_{10}$ sSFR [yr^{-1}]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Redshift