Galaxy groups up to $z = 2.5$ in deep infrared surveys

Detection and quenched fractions

Florian Sarron
in collaboration with Chris Conselice

MANCHESTER 1824
The University of Manchester

University of Nottingham
UK | CHINA | MALAYSIA

Upcoming paper : Sarron & Conselice (2021) recommended for publication in MNRAS

GCF2021
June 14th 2021

Outline

1. **REFINE survey : Data and data products**

2. **Group detection :** $\mathrm{DETECTIF}z$ **algorithm**

3. **Quenched fraction in groups and field at** $0.12 < z < 2.32$

DATA

Data

Three of the deepest near infrared surveys

- K band selected photometric sample from Mundy+17
- 10 to 30 photometric bands from UV to IR

$\rightarrow$ **UKIDSS-UDS** $0.63\ \mathrm{deg}^2$

$K < 24.3$

$\sigma_z \sim 0.045 \times (1+z)$

$\rightarrow$ **COSMOS/UltraVISTA** $1.45\ \mathrm{deg}^2$

$K_s < 23.4$

$\sigma_z \sim 0.01 \times (1+z)$

$\rightarrow$ **VIDEO/CFHTLS-D1** $1\ \mathrm{deg}^2$

$K_s < 22.5$

$\sigma_z \sim 0.035 \times (1+z)$

REFINE project

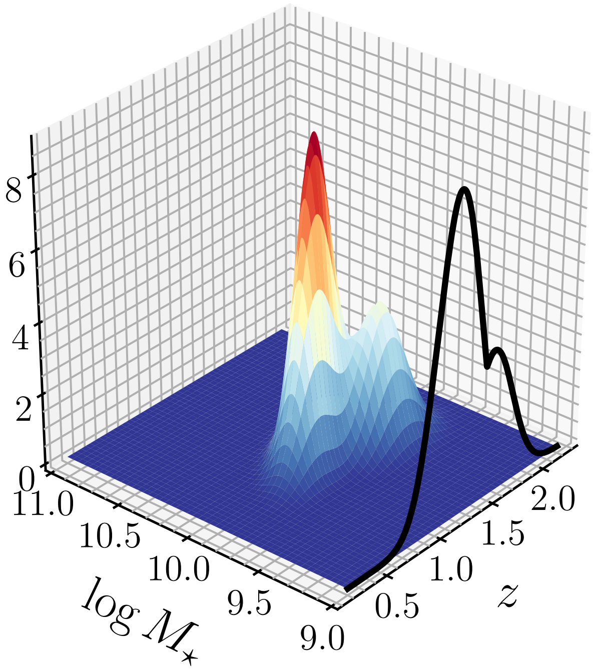
- Homogeneously reduced data
- $\sim 3\ \mathrm{deg}^2$ at $0.1 < z < 3.5$.

Data products : probabilistic approach

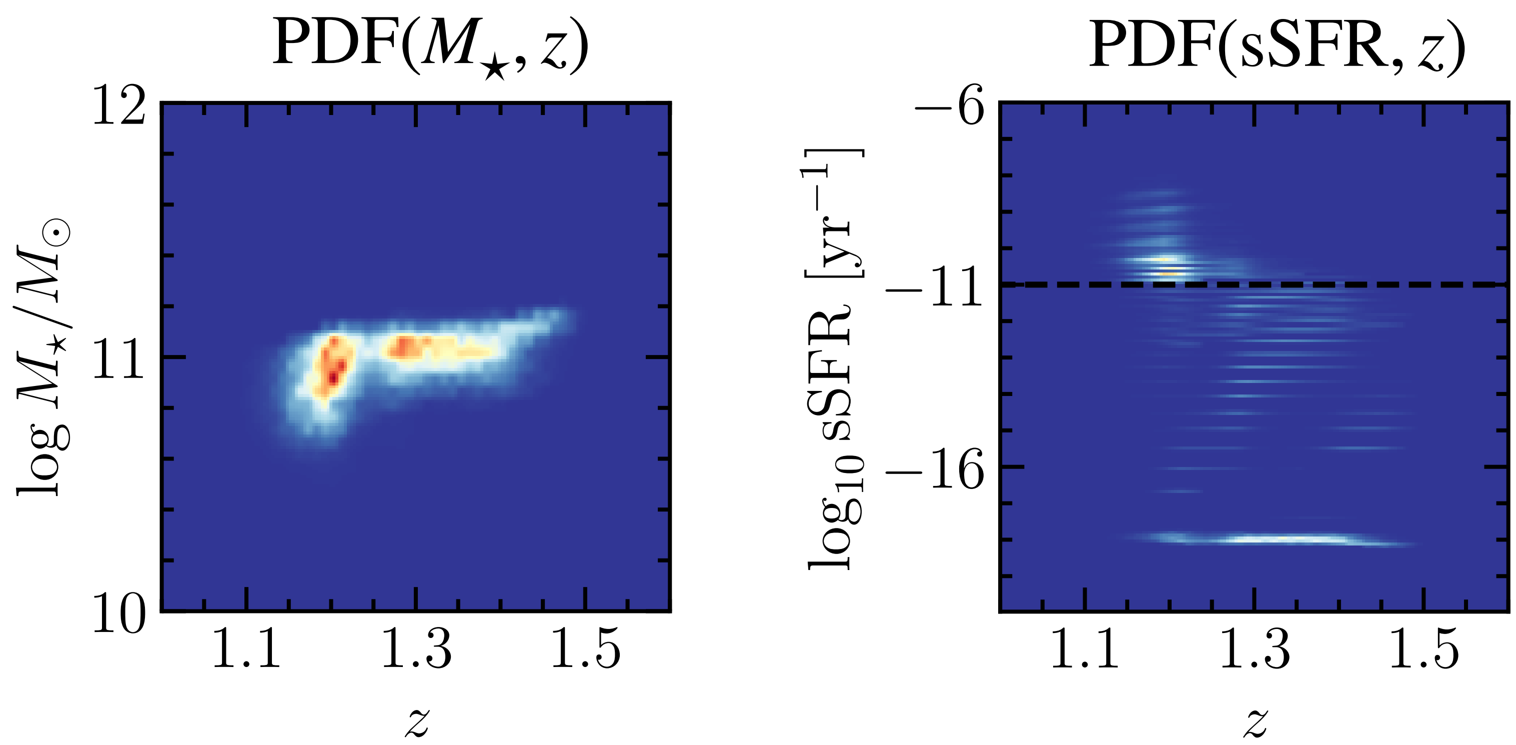
- Mundy+17 : **Photometric redshifts** with EAZY (Brammer+08)
- This work : **Physical parameters** with SMPY (Duncan+19)

→ 2D joint distributions PDF(X, z)

- Concept



- Realistic case



In this work

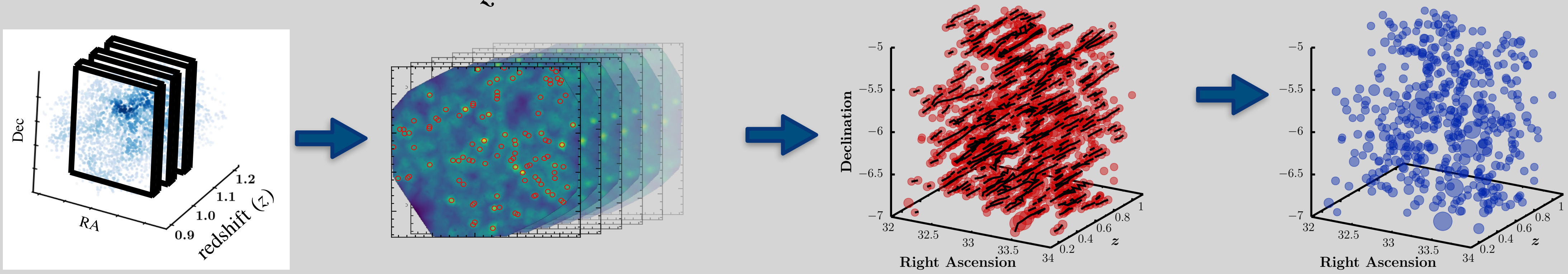
- Use the information contained is these PDFs
  - → account for correlated uncertainties
  - → deal with degeneracies

→ Probabilistic framework

GROUP DETECTION

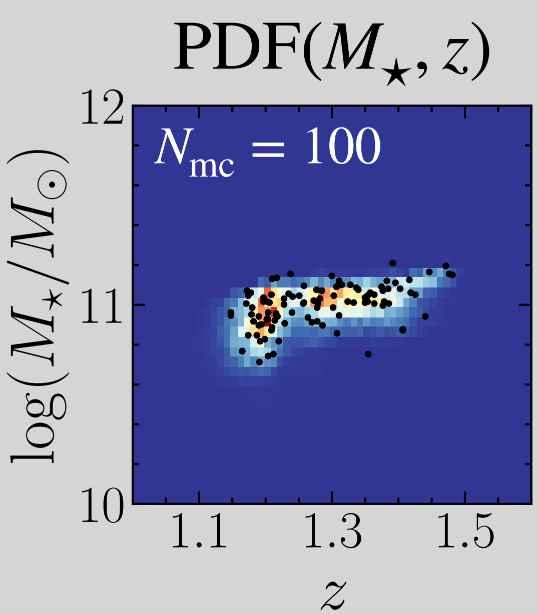
Basic idea is classical

→ Photometric redshifts : $\sigma_z \gg$ group size in z



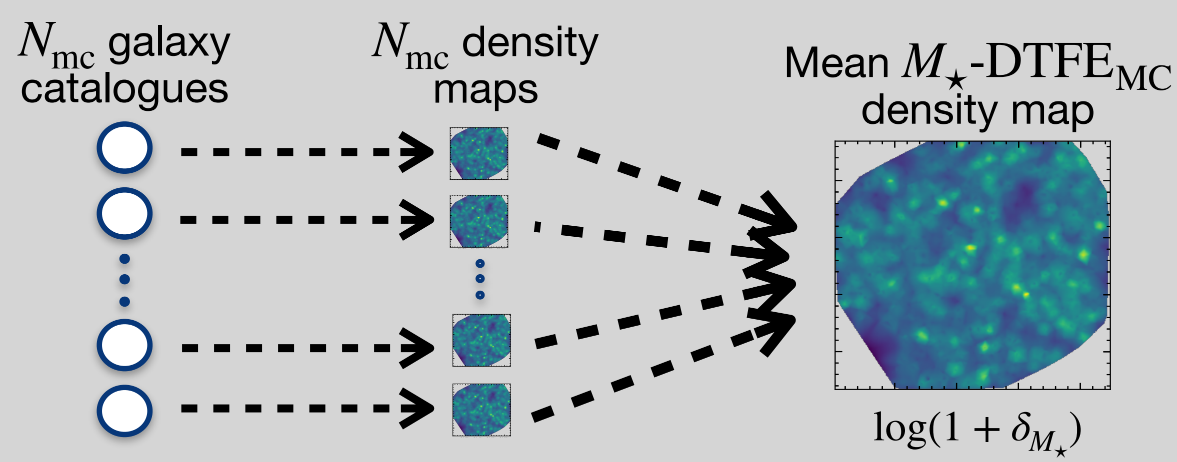
What makes its specificity

- Monte Carlo sampling



- Density estimation

  Similar to VMC algorithm (Cucciatti+18, Hung+20)



Outputs

- Group catalogue with $\mathrm{PDF}_{group}(z)$ and R_{200}
- Group members catalogue with probability memberships P_{mem}

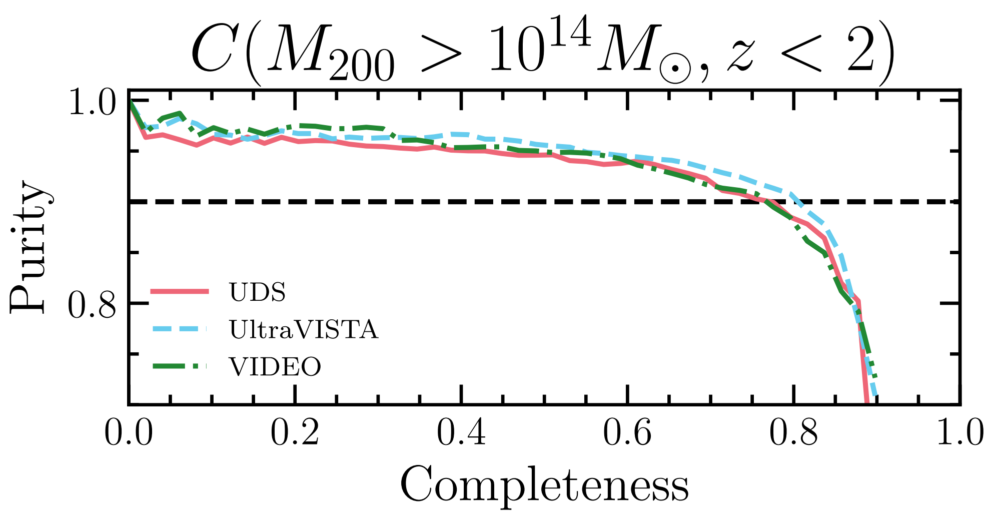
Mock data

Henriques+15 lightcones
+ empirical photometric noise

with $\mathrm{PDF}(M_\star, z)$ for each galaxy

$\rightarrow$ DETECTIFz applied to mocks

Purity and completeness of the catalogues



Mock data

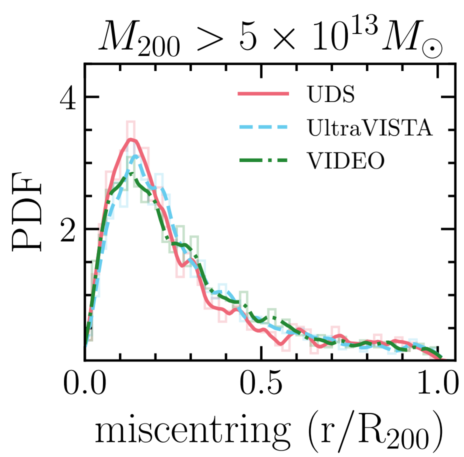
Henriques+15 lightcones
+ empirical photometric noise

with PDF($M_\star, z$) for each galaxy

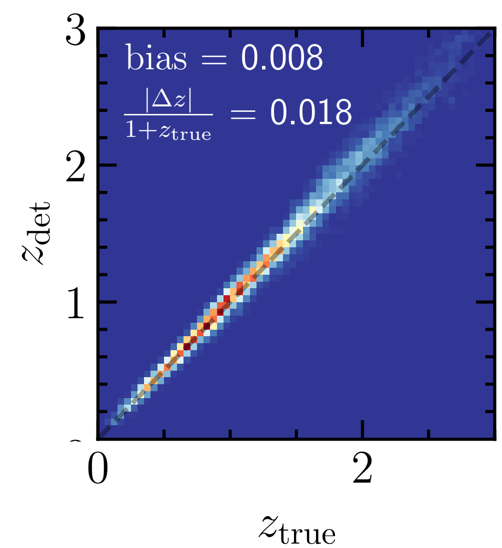
→ DETECTIFz applied to mocks

Properties of groups

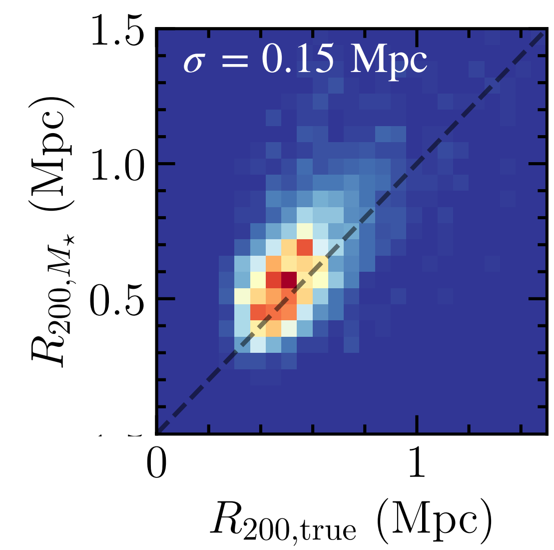
well centered



low bias, low scatter redshift

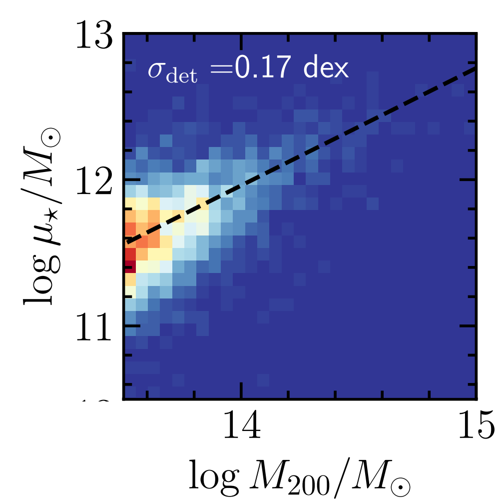


R_{200} estimate : $+10\ \%$ bias
($< 1\ \%$ for clusters)



competitive mass proxy

$$\mu_\star = \sum P_{\rm mem} \times M_\star$$



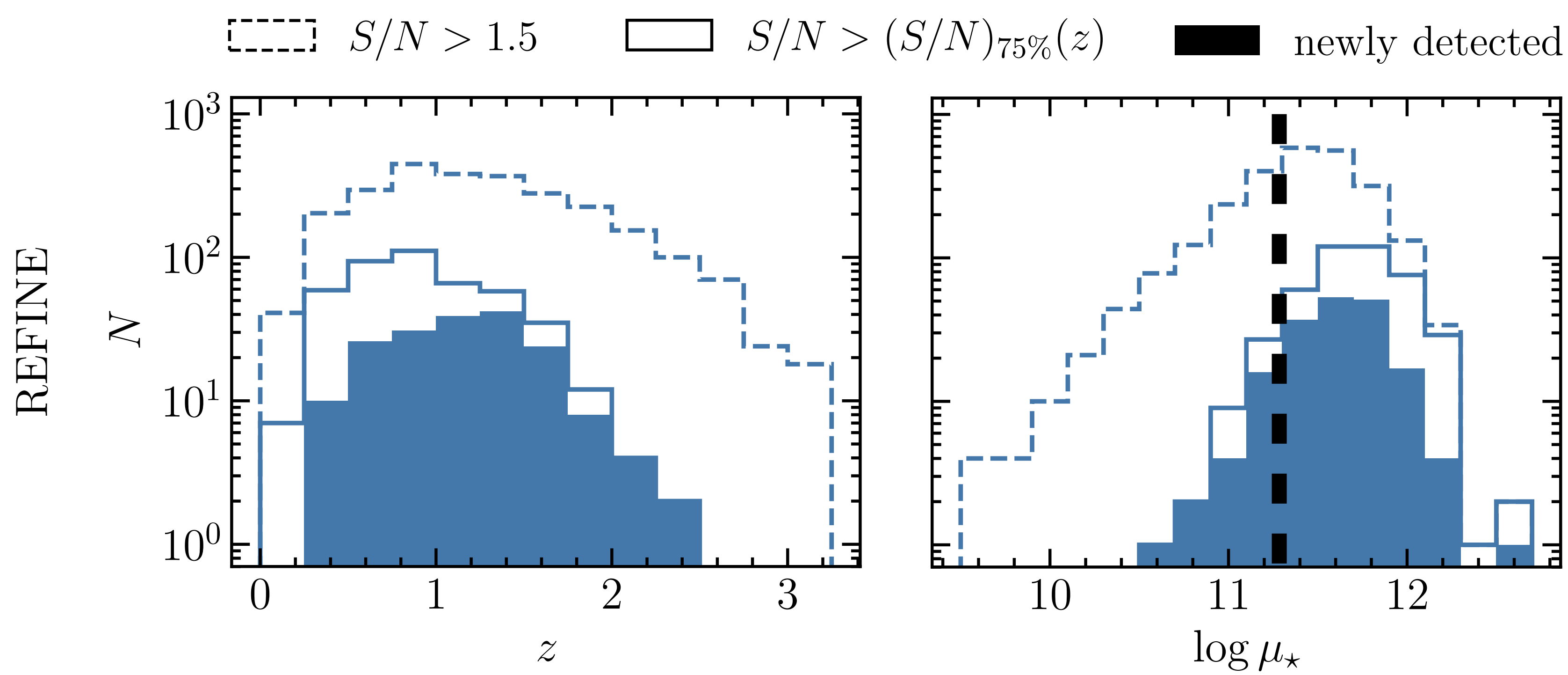
Overview : DETECTIFz catalogues

DETECTIFz catalogues on REFINE data

→ $90\,\%$ pure sample : 448 candidates groups at $0.12 \leq z \leq 2.32$

→ 186 newly detected

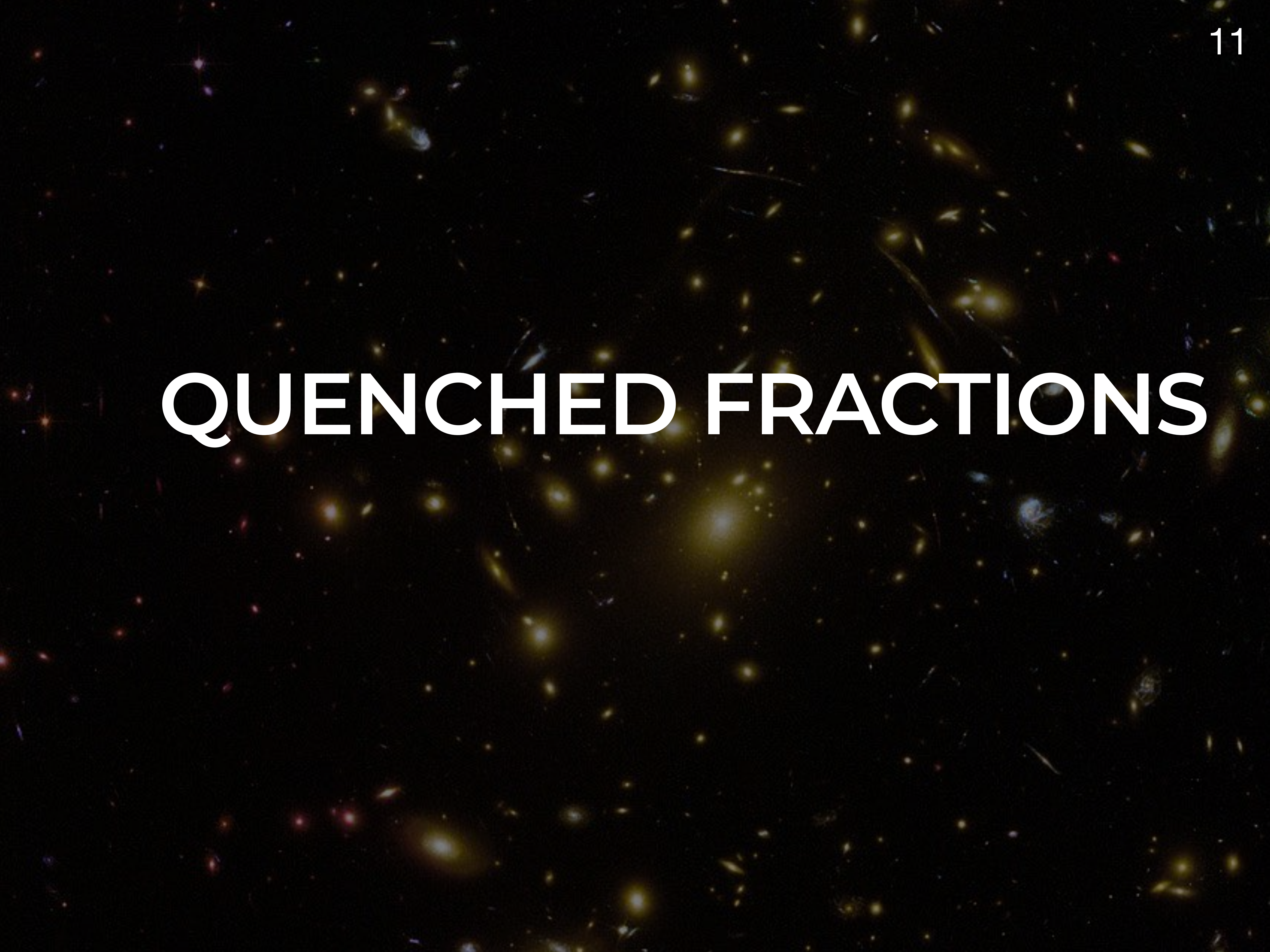
→ 53 groups at $z > 1.5$



Sample for quenched fractions (total stellar mass selected) :

→ $\log \mu_\star > 11.25$

→ 407 candidates groups at $0.12 \leq z \leq 2.32$



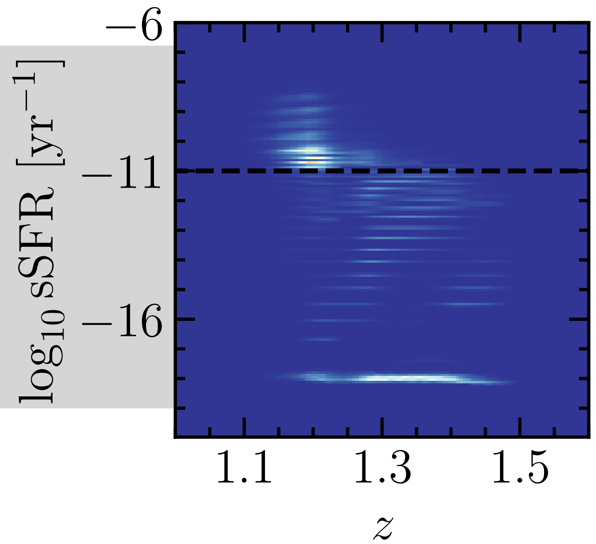
QUENCHED FRACTIONS

Using PDF(X, z) to study galaxy populations in groups

Quenched vs star-forming

from PDF(sSFR, z) $\rightarrow$ $P^q(z)$

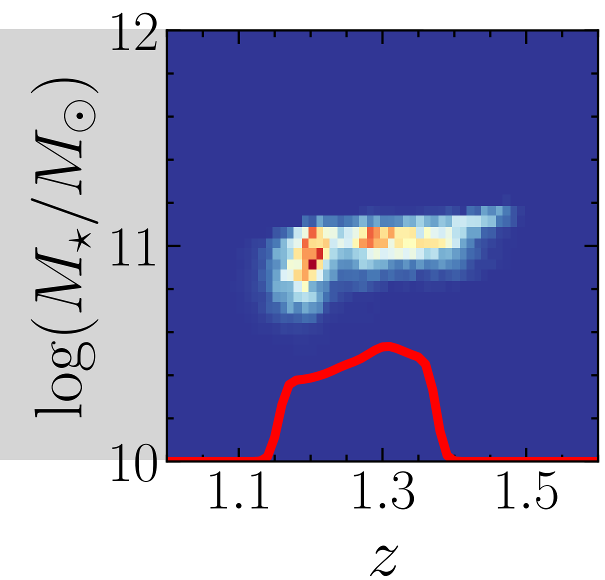
quenched $\equiv$ sSFR $< 10^{-11}$ yr^{-1}



Number counts

from PDF($M_\star, z$) $\rightarrow$ $N(M_\star, z)$ (Lopez-Sanjuan+17)

+ $\mathrm{PDF}_{\mathrm{group}}(z) \rightarrow N_{\mathrm{group}}(M_\star)$ - **group galaxy numbers counts**



Take away :

- New formalism to study group galaxies from PDF(X, z)
- Using PDF(X, z) : better treatment of correlated uncertainties and degeneracies

Quenched fraction in REFINE

Quenched fractions

Stellar mass limits : $10.25 < \log M_\star/\mathrm{M}_\odot < 11$

$\rightarrow f^q_{\rm groups}$ in $0.5 \times R_{200}$

$\rightarrow f^q_{\rm field}$ outside $2 \times R_{200}$ of detected groups

Quenched fraction in REFINE

Quenched fractions

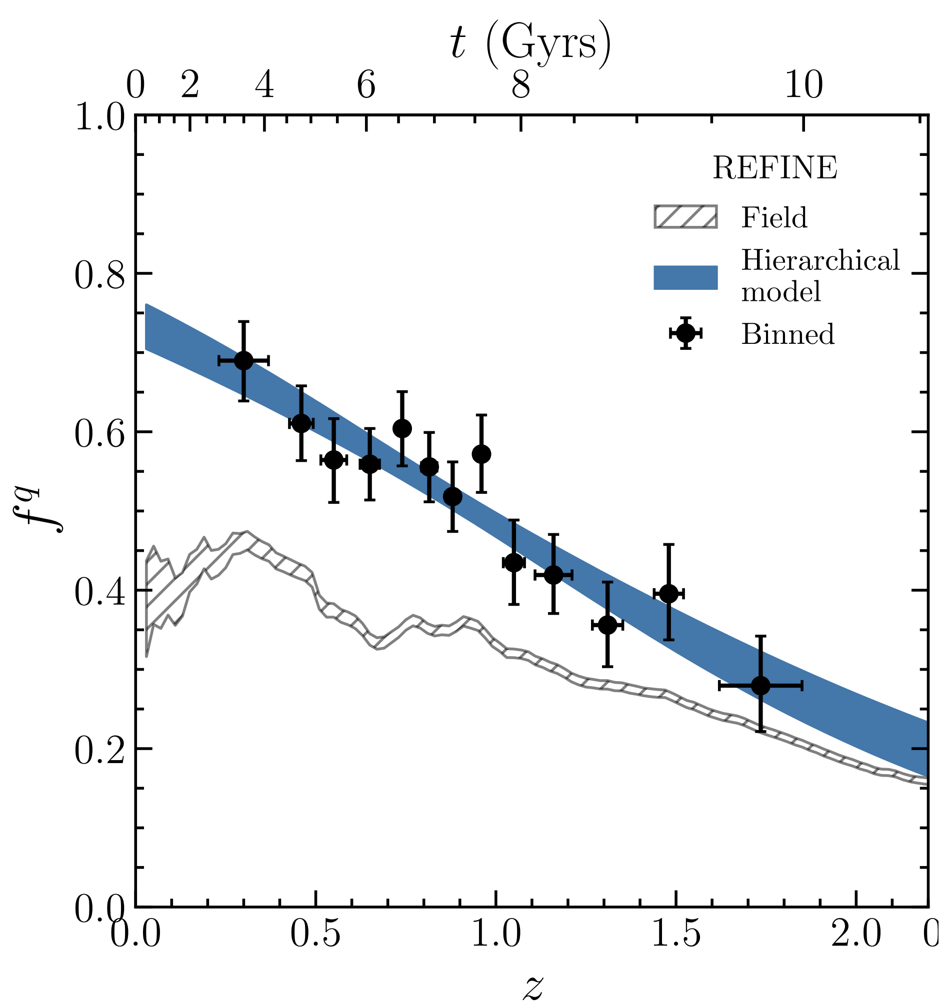
Stellar mass limits : $10.25 < \log M_\star/\mathrm{M}_\odot < 11$

$\rightarrow f^q_{\mathrm{groups}}$ in $0.5 \times R_{200}$

$\rightarrow f^q_{\mathrm{field}}$ outside $2 \times R_{200}$ of detected groups

Hierarchical Bayesian model

linear redshift evolution $f^q_{\mathrm{group}}(z) = \mathtt{ilogit}\,[f_1 + \alpha_z \times (z-1)]$ Adapted from Raichoor+12



$\rightarrow$ linear model provides a good fit

$\rightarrow f^q_{\mathrm{group}} > f^q_{\mathrm{field}}$ with confidence $> 1\sigma$ up to $z = 2.23$

Comparison to other works

Quenched fractions

Stellar mass limits : $10.25 < \log M_\star/\mathrm{M}_\odot < 11$

→ $f^q_{\rm groups}$ in $0.5 \times R_{200}$

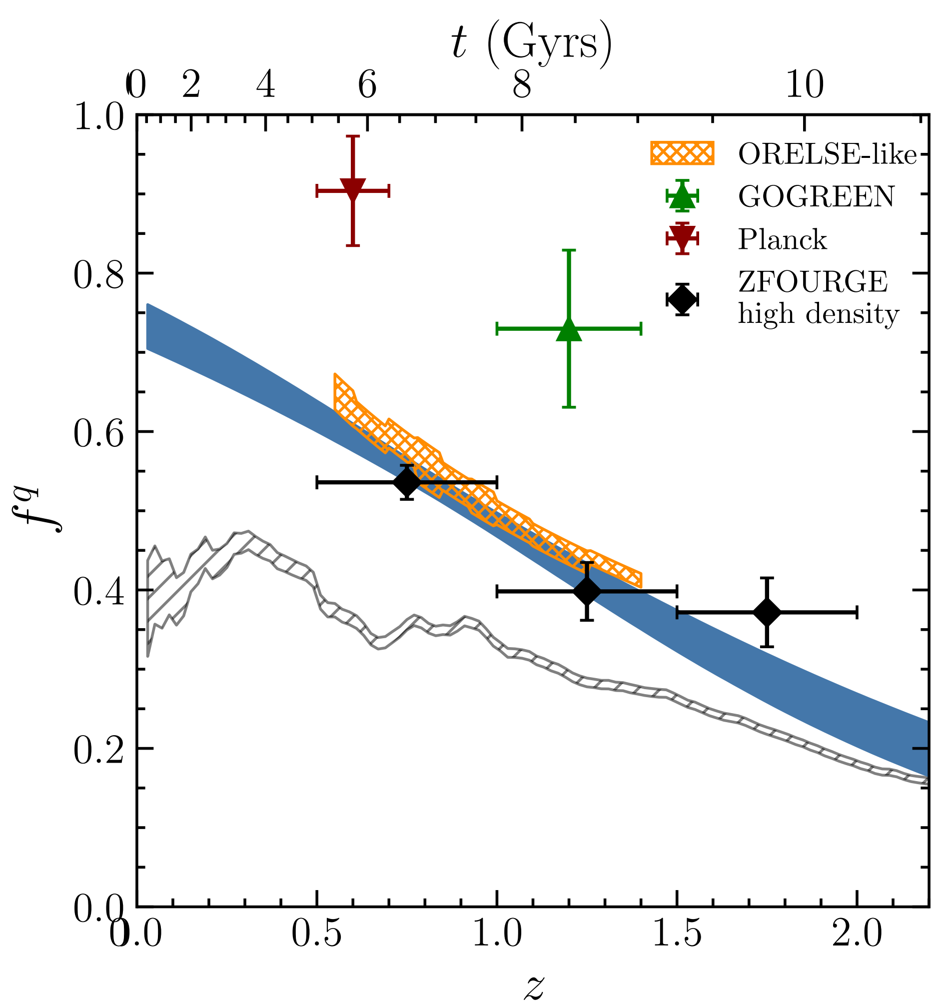
→ $f^q_{\rm field}$ outside $2 \times R_{200}$ of detected groups

zFOURGE: Papovich+18

ORELSE: Lemaux+19

Planck clusters : van der Burg+18

GOGREEN : van der Burg+20



→ competitive constraints on $f^q_{\rm group}$ at $z > 1$

→ Good agreement with ZFOURGE, ORELSE

→ Lower f^q than Planck clusters, GOGREEN

Lower mass groups have lower f^q than massive clusters at $0.5 < z < 1.4$???

Conclusions

What you can re-use

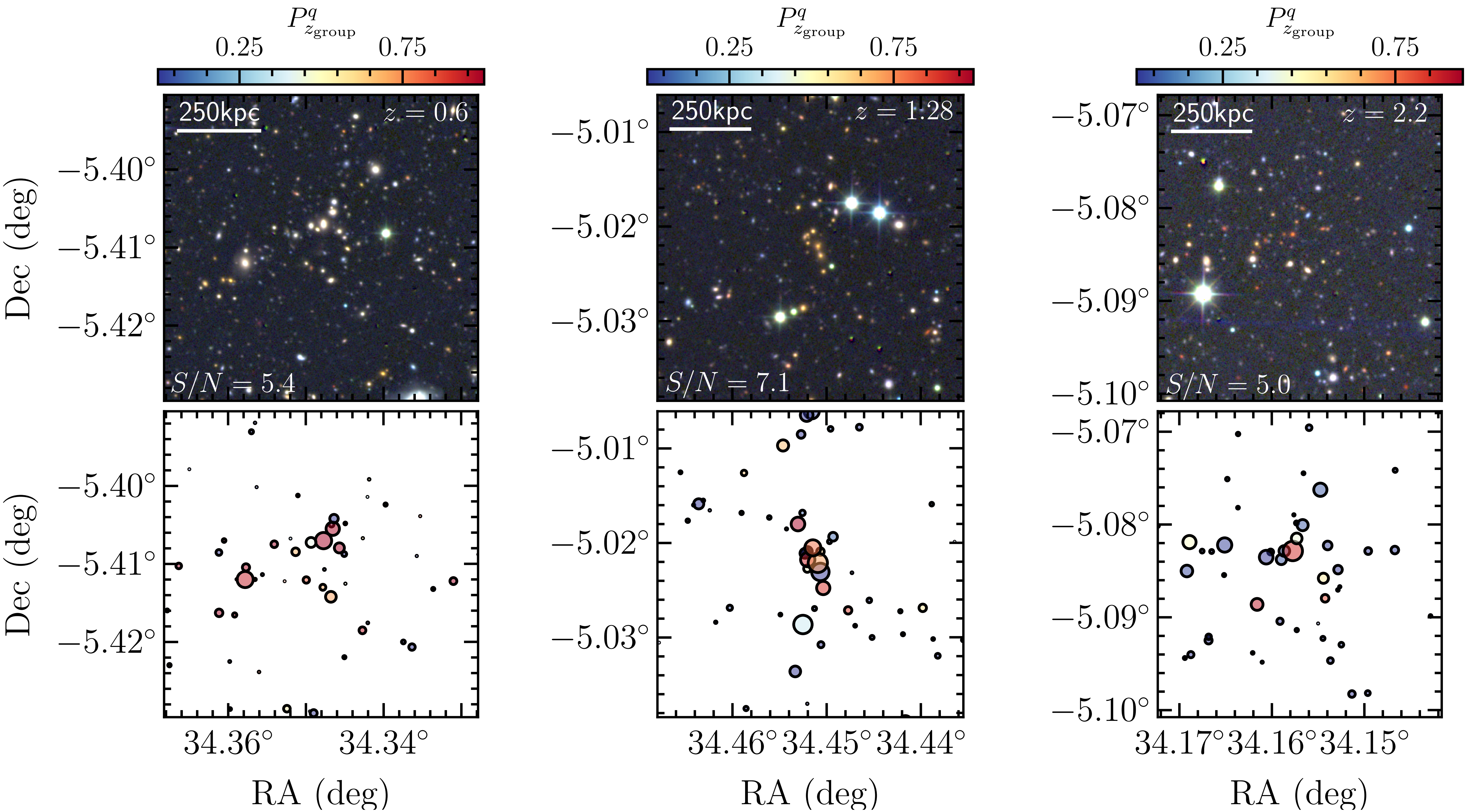
- DETECTIFz algorithm
- Group sample at $z < 2.5$
- Probabilistic framework to study galaxy properties in groups

Main result

- Quenched fraction is higher in groups than in the field at $z < 2$

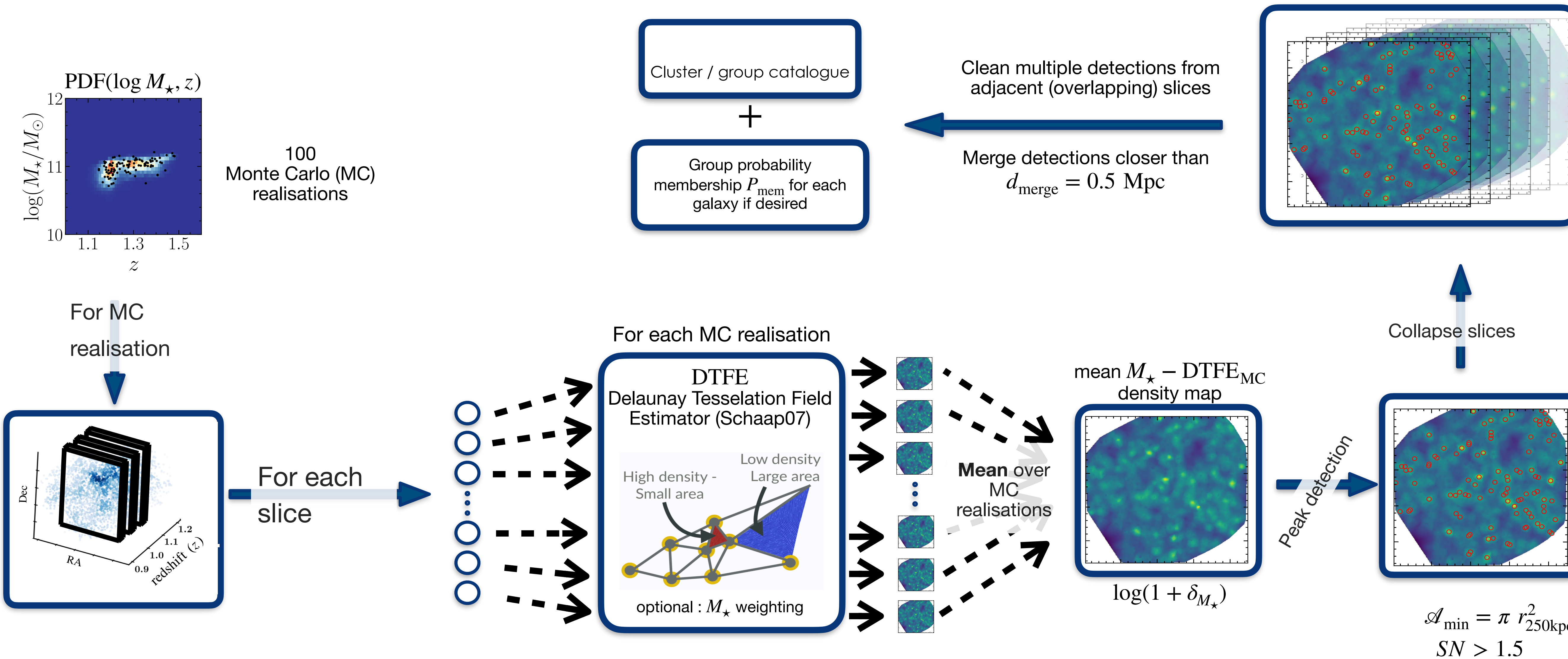
Perspective

- Galaxy stellar-mass function + Radial distributions
- How do our high z groups trace proto-clusters ?



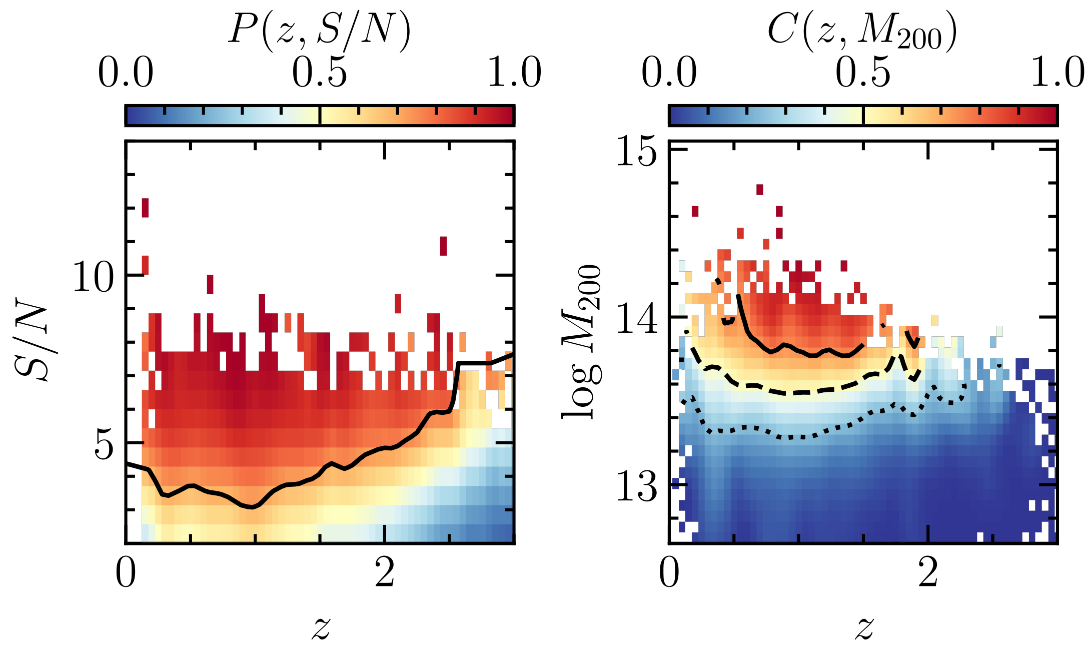
$P^q_{z_{\rm group}}$
0.25
0.75
250kpc
$z = 0.6$
$z = 1.28$
$z = 2.2$
$S/N = 5.4$
$S/N = 7.1$
$S/N = 5.0$
Dec (deg)
RA (deg)
−5.40°
−5.41°
−5.42°
−5.01°
−5.02°
−5.03°
−5.07°
−5.08°
−5.09°
−5.10°
34.36°
34.34°
34.46°
34.45°
34.44°
34.17°
34.16°
34.15°

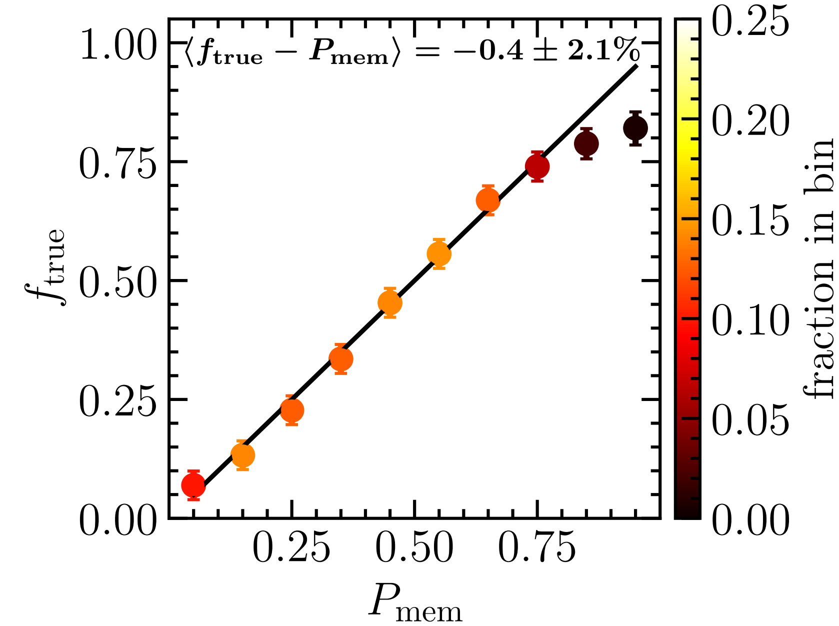
DETECTIFz workflow



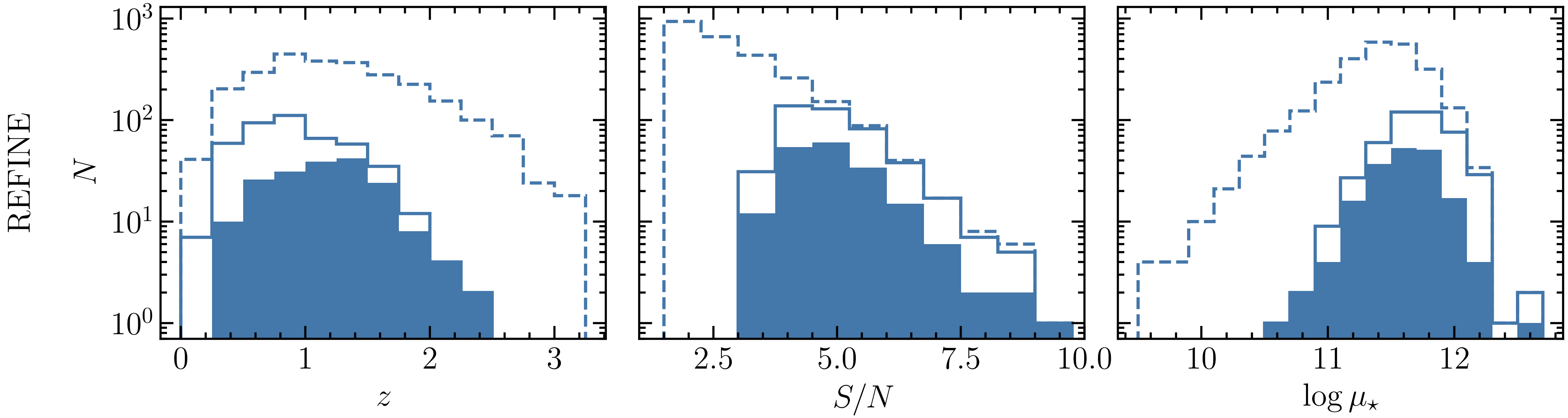
More on DETECTIFz selection function

in UDS





REFINE group catalogue

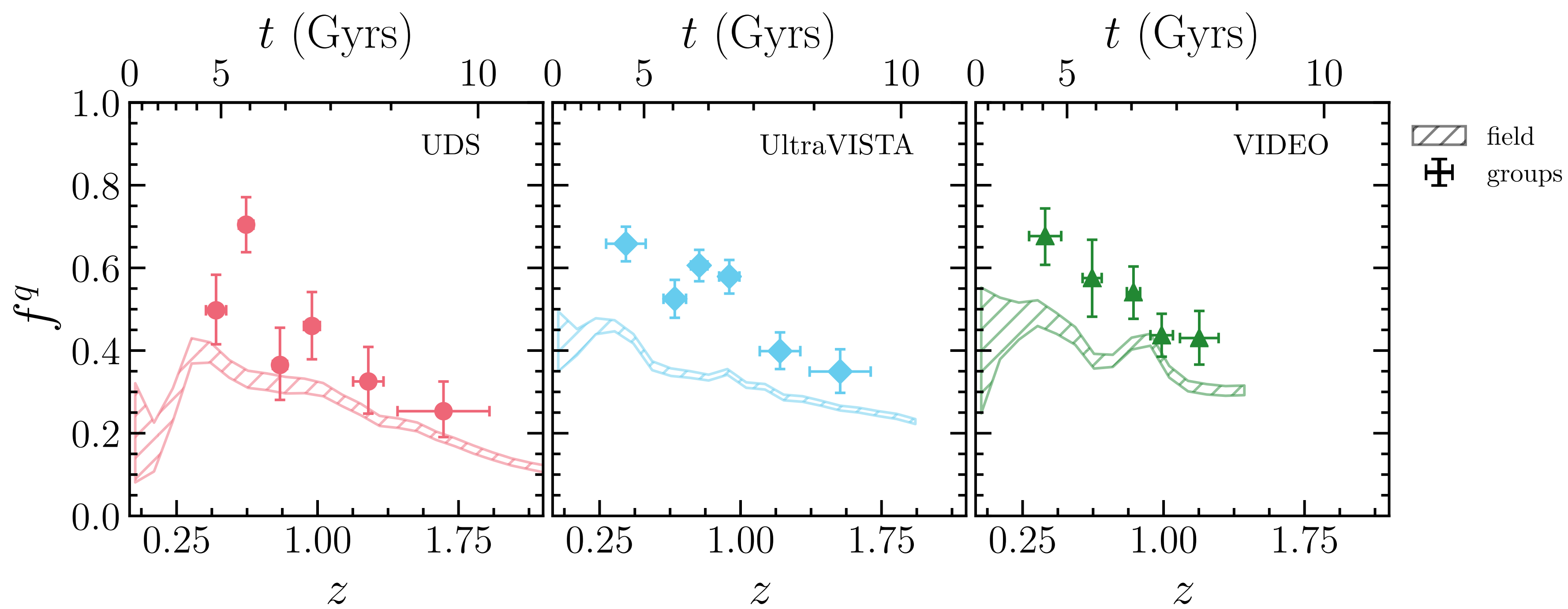


Quenched fractions f^q: groups and field

Bayesian model from D'Agostini+04, Andreon+06

$f^q_{\rm groups}$ in $0.5 \times R_{200}$

$f^q_{\rm field}$ outside $2 \times R_{200}$ of detected groups



Similar behaviour : we can study the joint REFINE sample !

Quenched fraction excess in REFINE

Quenched fractions

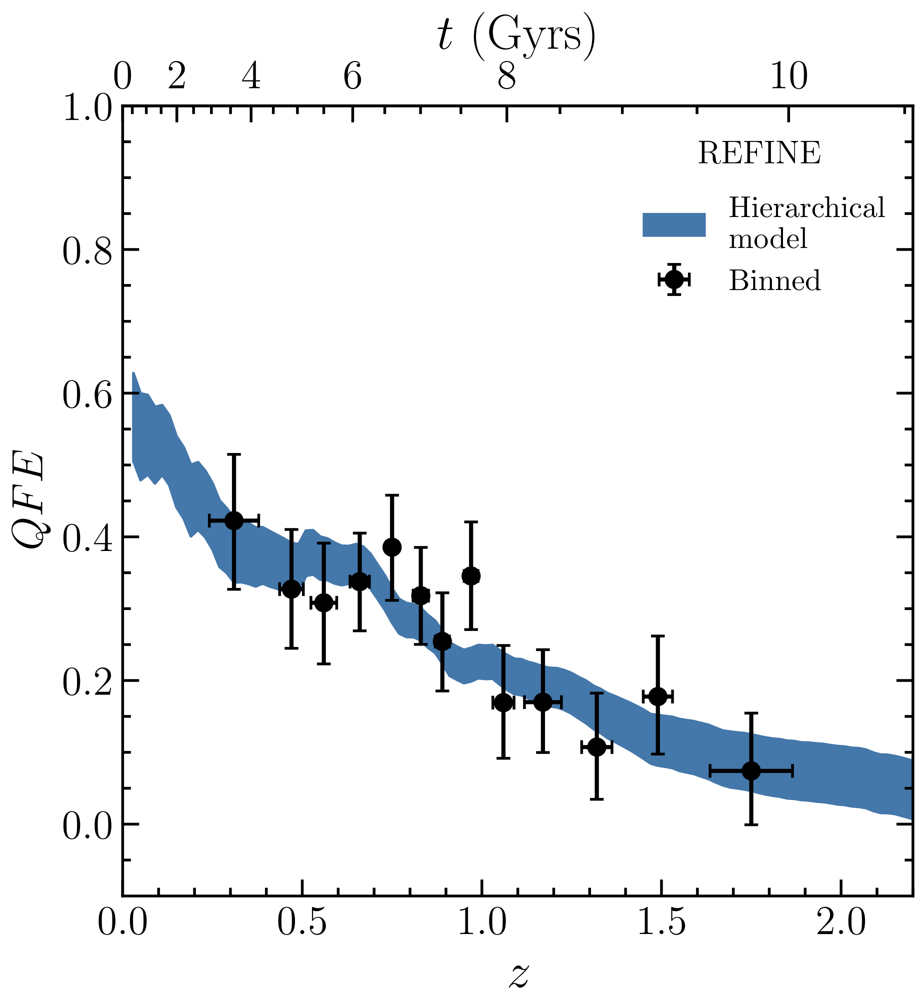
Stellar mass limits : $10.25 < \log M_\star/\mathrm{M}_\odot < 11$

$\rightarrow f^q_{\rm groups}$ in $0.5 \times R_{200}$

$\rightarrow f^q_{\rm field}$ outside $2 \times R_{200}$ of detected groups

$$QFE = \frac{f^q_{\rm group} - f^q_{\rm field}}{1 - f^q_{\rm field}} \rightarrow$$

Fraction of galaxies quenched in the groups that would have been star-forming in the field environment



$\rightarrow QFE > 0$ up to $z = 2.03$ (95 % confidence)

$\rightarrow QFE$ increases with decreasing redshift

Interpretation is not straightforward

- Group $\langle \mu_\star \rangle$ and $\langle \delta_{M_\star} \rangle$ are constant with z
  - $\rightarrow$ High z groups are not progenitors of low z ones
  - $\rightarrow$ Cannot disentangle for pre-processing

Heriarchical Bayesian model

Adapted from Raichoor+12

$$\mathrm{obs}N_{\mathrm{field}} \sim \mathrm{Poisson}(\mathrm{true}N_{\mathrm{field}})$$

$$\mathrm{obs}N_{\mathrm{tot}} \sim \mathrm{Poisson}(\mathrm{true}N_{\mathrm{field}} \times \frac{\Omega_{\mathrm{group}}}{\Omega_{\mathrm{field}}} + \mathrm{true}N_{\mathrm{group}})$$

$$\mathrm{obs}N^{q}_{\mathrm{field}} \sim \mathrm{Binomial}(f^{q}_{\mathrm{field}}, \mathrm{obs}N_{\mathrm{field}})$$

$$\mathrm{obs}N^{q}_{\mathrm{tot}} \sim \mathrm{Binomial}(f^{q}_{\mathrm{tot}}, \mathrm{obs}N_{\mathrm{tot}})$$

$$f^{q}_{\mathrm{tot}} = \frac{f^{q}_{\mathrm{field}} \times \mathrm{true}N_{\mathrm{field}} \times \frac{\Omega_{\mathrm{group}}}{\Omega_{\mathrm{field}}} + f^{q}_{\mathrm{group}} \times \mathrm{true}N_{\mathrm{group}}}{\mathrm{true}N_{\mathrm{field}} \times \frac{\Omega_{\mathrm{group}}}{\Omega_{\mathrm{field}}} + \mathrm{true}N_{\mathrm{group}}},$$

$$f^{q}_{\mathrm{group}} = \mathtt{ilogit}\left[f_1 + \alpha_z(z^{\mathrm{true}}_{\mathrm{group}} - 1)\right],$$

$$z^{\mathrm{obs}}_{\mathrm{group}} = \mathcal{N}(\mu = z^{\mathrm{true}}_{\mathrm{group}}, \sigma = \sigma^{68}_{\mathrm{PDF}_{\mathrm{group}}(z)})$$