Quenching in GOGREEN Galaxy Groups at 1<z<1.5

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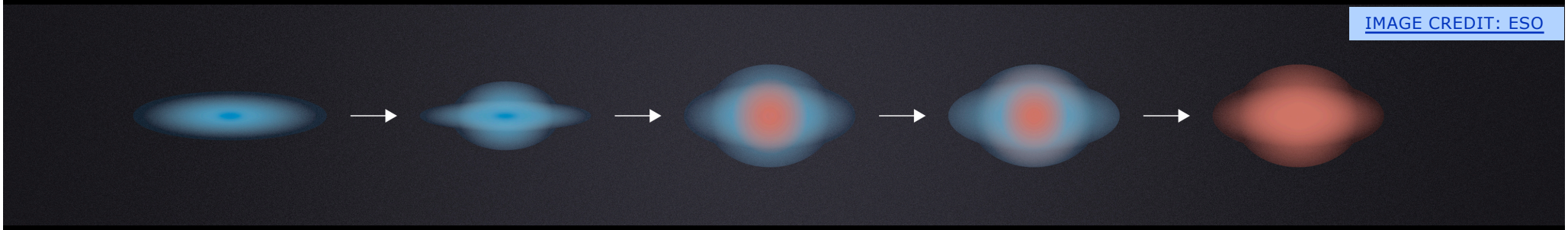
Image credit: Adam Block, UA

“Quenching”?

Dictionary definition: to *extinguish*, *stifle*, or *suppress*



Blue Sequence **Red Sequence**

Star Formation and Quenching in Galaxies

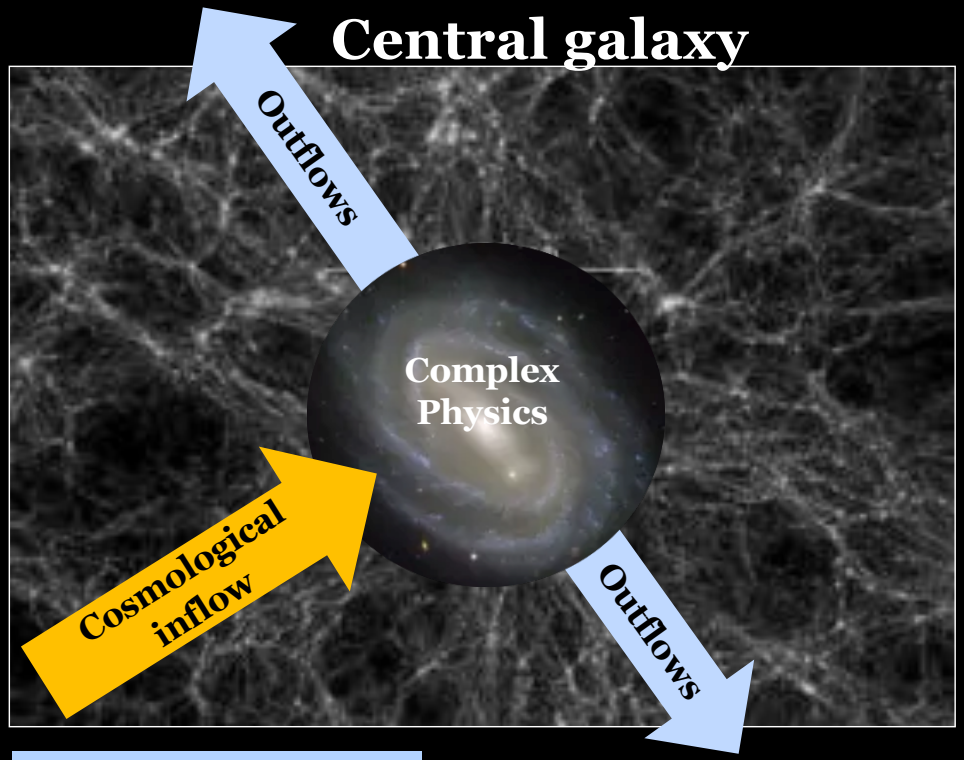
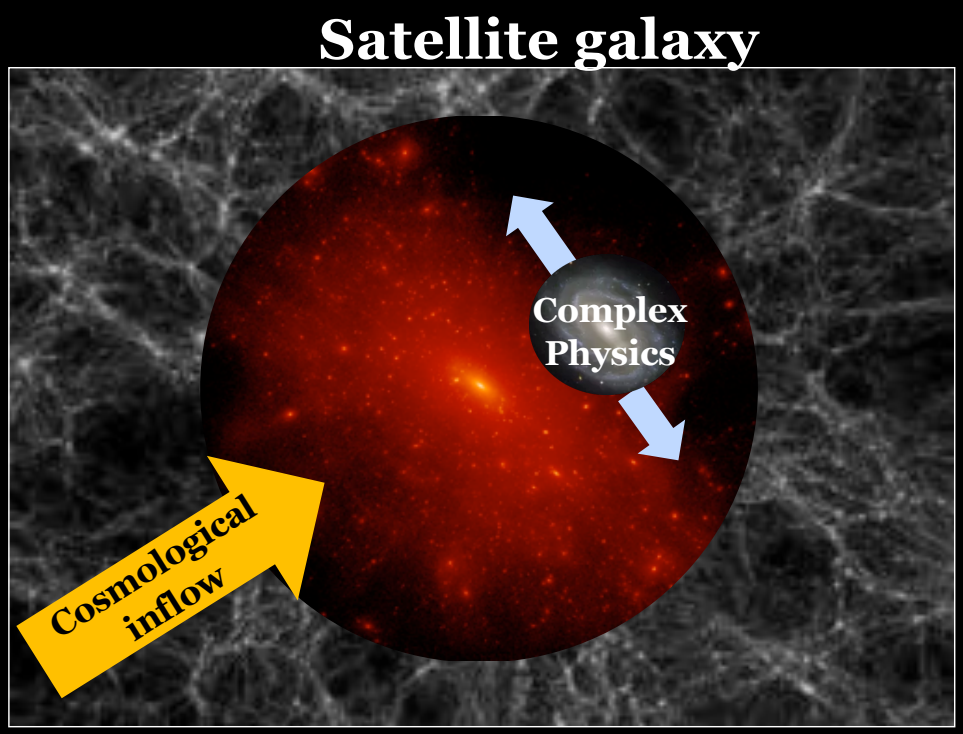


IMAGE CREDIT: Michael Balogh



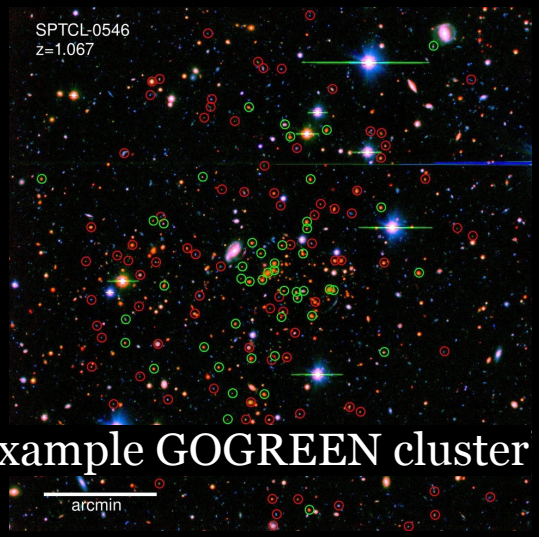
<u>Goal of the study of "quenching" in 1<z<1.5 groups/clusters:</u>
to constrain/understand how quenching processes in galaxies depend on halo mass as well as redshift

The GOGREEN Survey

GOGREEN = Gemini Observations of Galaxies in Rich Early ENvironments

GOGREEN Science goals:

- Environmental-Quenching of Low Mass Galaxies
- Hierarchical Assembly of Baryons
- Cluster Dynamics and Masses



Example GOGREEN cluster

Unique features of GOGREEN:

1. Very deep, unbiased spectroscopy for all galaxy types, probing stellar masses below 10^{10} M_{Sun} at $1 < z < 1.5$ (accompanied by deep 10-band photometry and HST F160W imaging)

2. Wide range of halo masses, ranging from groups (10^{13} M_{Sun}) to massive clusters (10^{15} M_{Sun})

The GOGREEN team

Michael Balogh	Waterloo (PI)
Adam Muzzin	York
Gregory Rudnick	Kansas
Gillian Wilson	UC Riverside
Bob Abraham	Toronto
M. Victoria Alonso	Cordoba
Andrea Biviano	Trieste
Richard Bower	Durham
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Pierluigi Cerulo	Concepcion
Charlie Conroy	CfA Harvard
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Erica Ellingson	Boulder
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Dennis Zaritsky	Arizona

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“Galaxy Groups” in the GOGREEN Survey

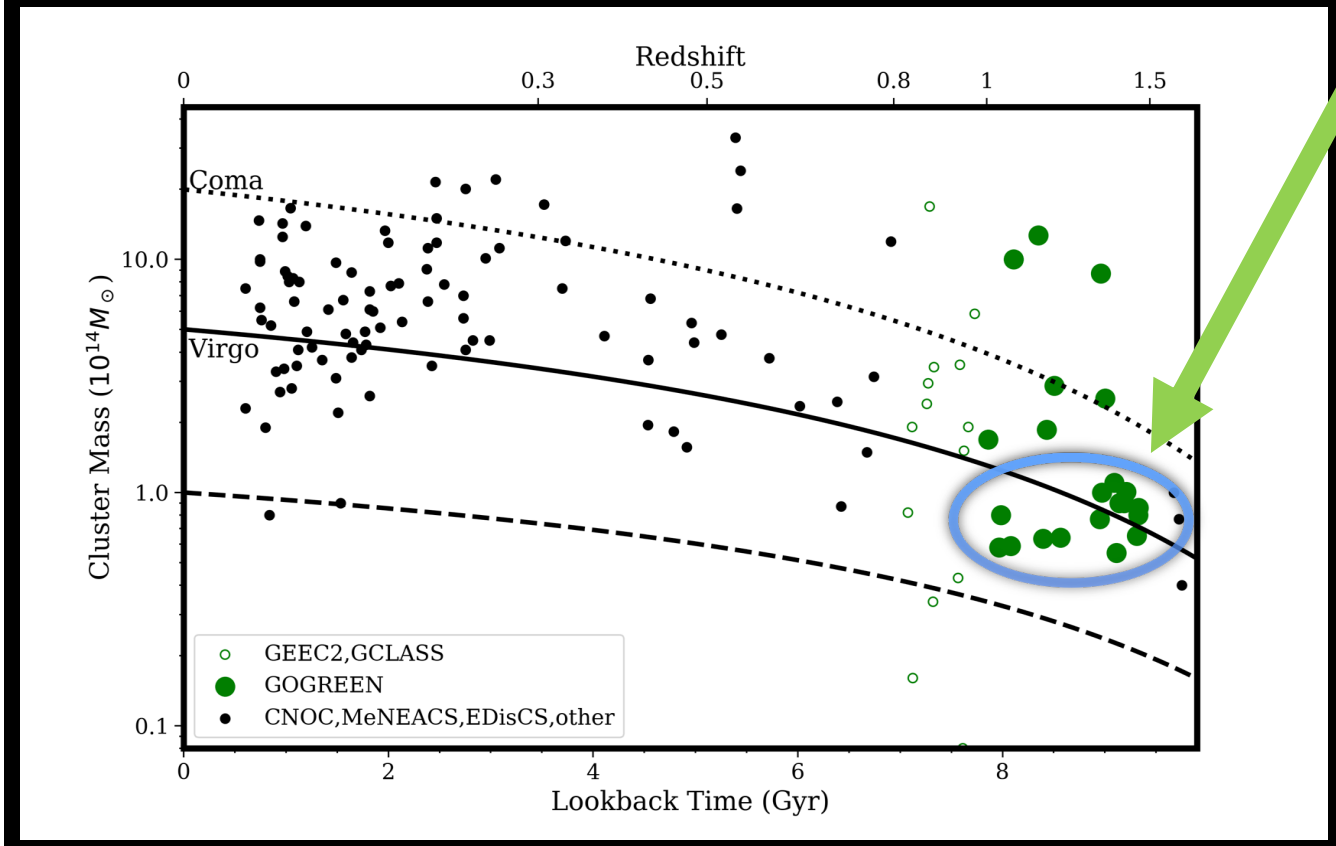


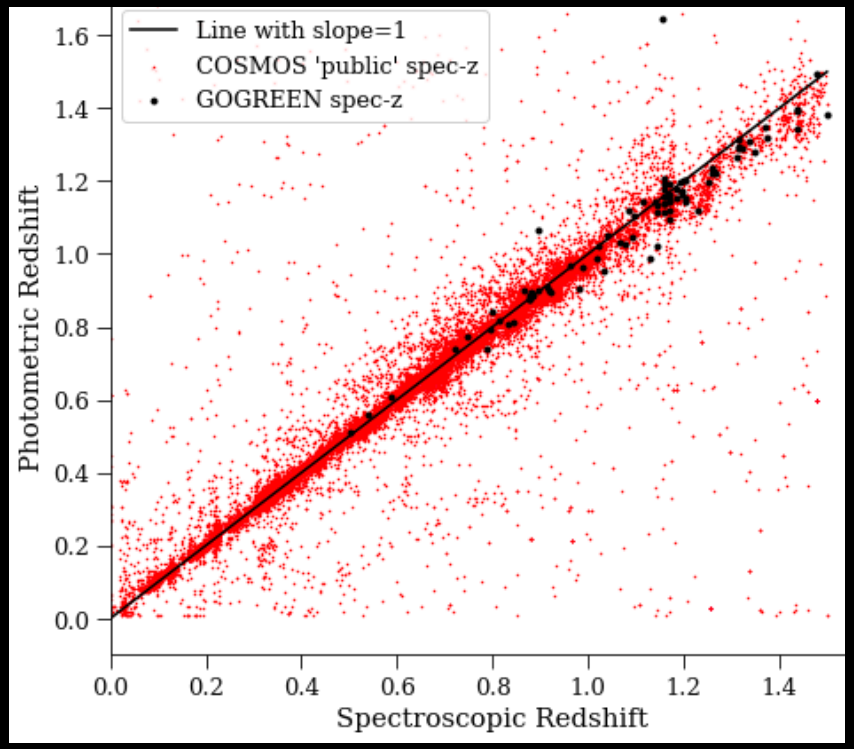
IMAGE CREDIT: GOGREEN Collaboration

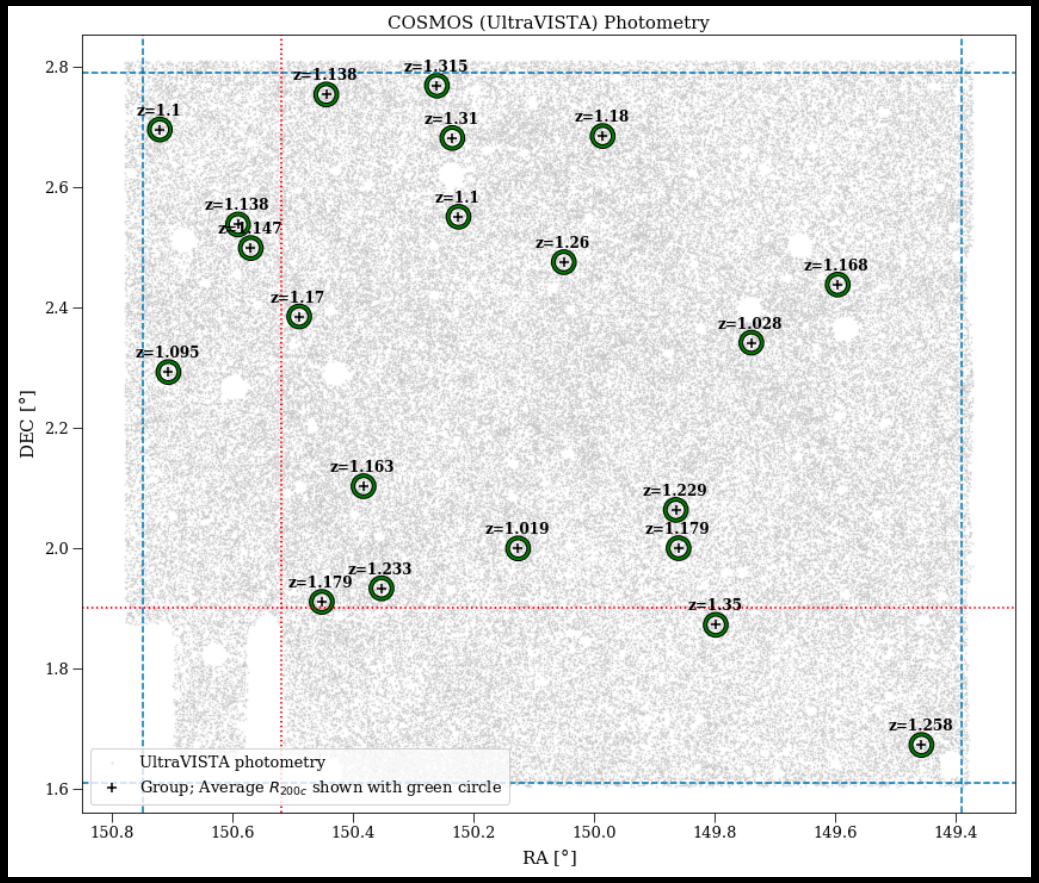
“Groups” in GOGREEN are gravitationally bound collections of galaxies with halo masses $M_h < 10^{14} M_\odot$

- **21 groups at 1<z<1.5** in COSMOS group catalog, with halo masses estimated based on x-ray flux [Gozaliasl+2018]

The COSMOS Galaxy Groups

COSMOS survey region has excellent photometric redshifts:



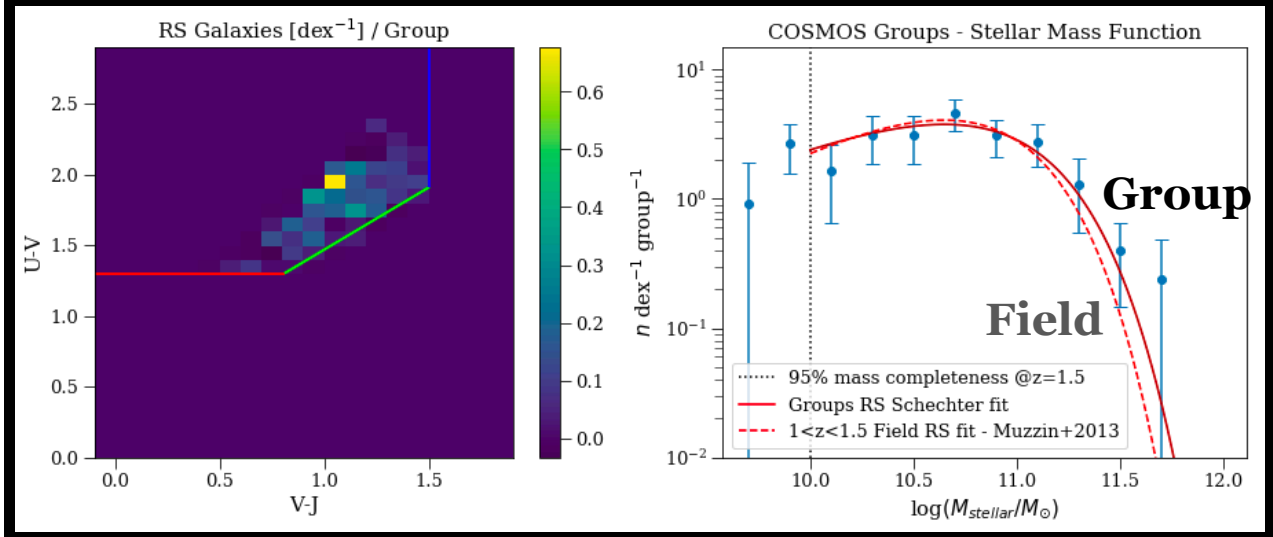


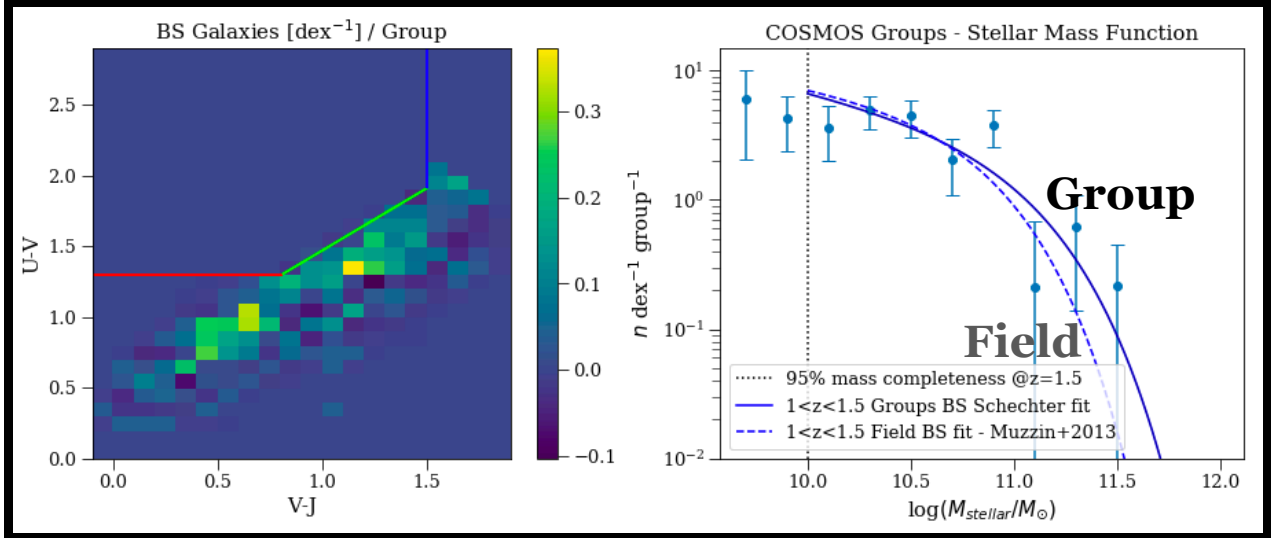
Background subtraction:

$$N_G = N_C - N_{\text{field}} \left(\frac{A_C}{A_{\text{field}}} \right)$$

Stellar Mass Functions:

What is the distribution of red/blue galaxies at a given stellar mass?





Group Red Sequence (field):

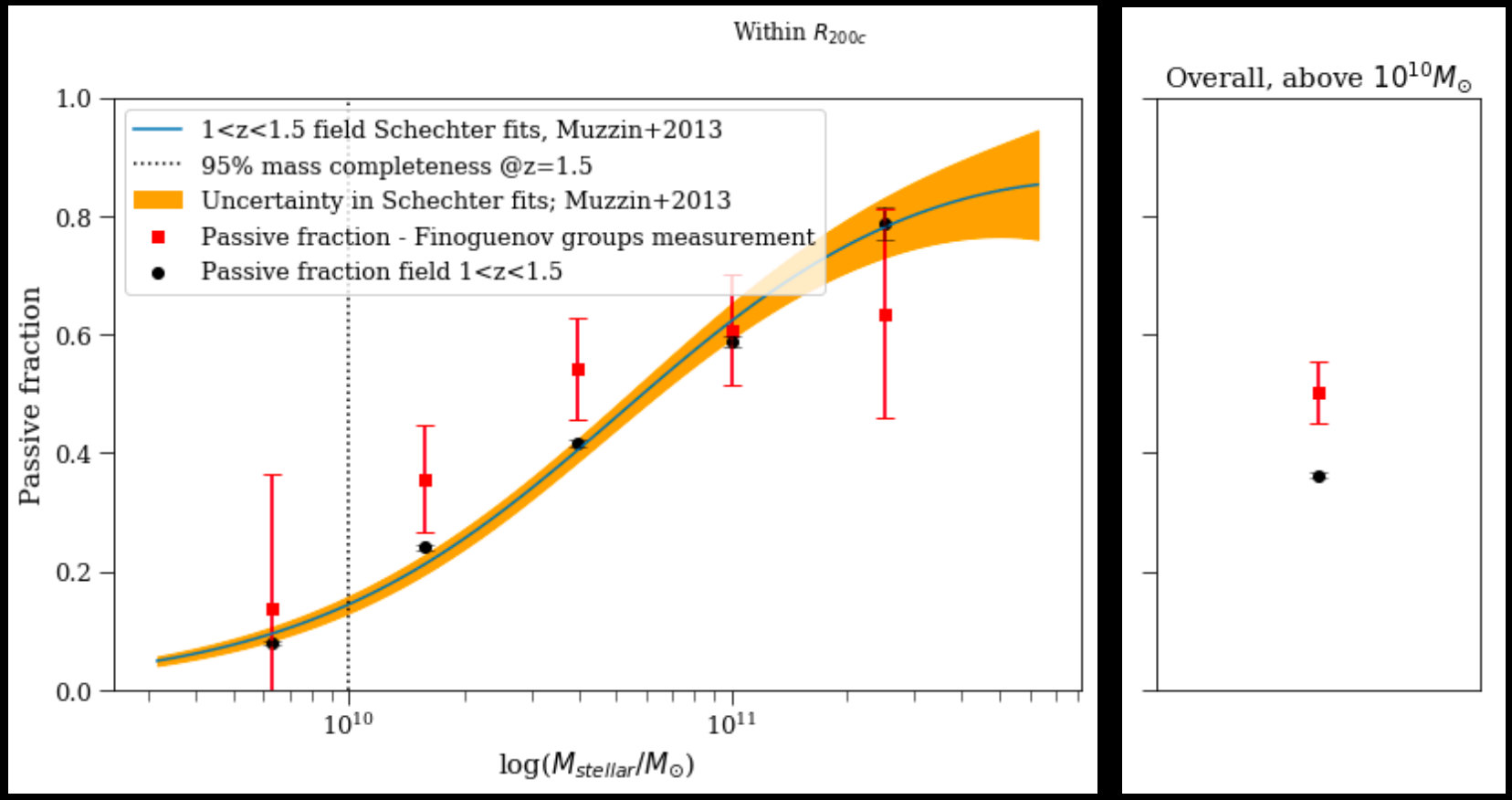
- $\alpha \approx -1.3$ ($\alpha \approx -0.17$)
- $M^* \approx 10^{10.9}$ ($M^* \approx 10^{10.73}$)

$$\phi(M) = \phi^* \left(\frac{M}{M^*}\right)^{\alpha+1} exp\left(-\frac{M}{M^*}\right)$$

Group Blue Sequence (field):

- $\alpha \approx -1.8$ ($\alpha \approx -1.21$)
- $M^* \approx 10^{10.76}$ ($M^* \approx 10^{10.76}$)

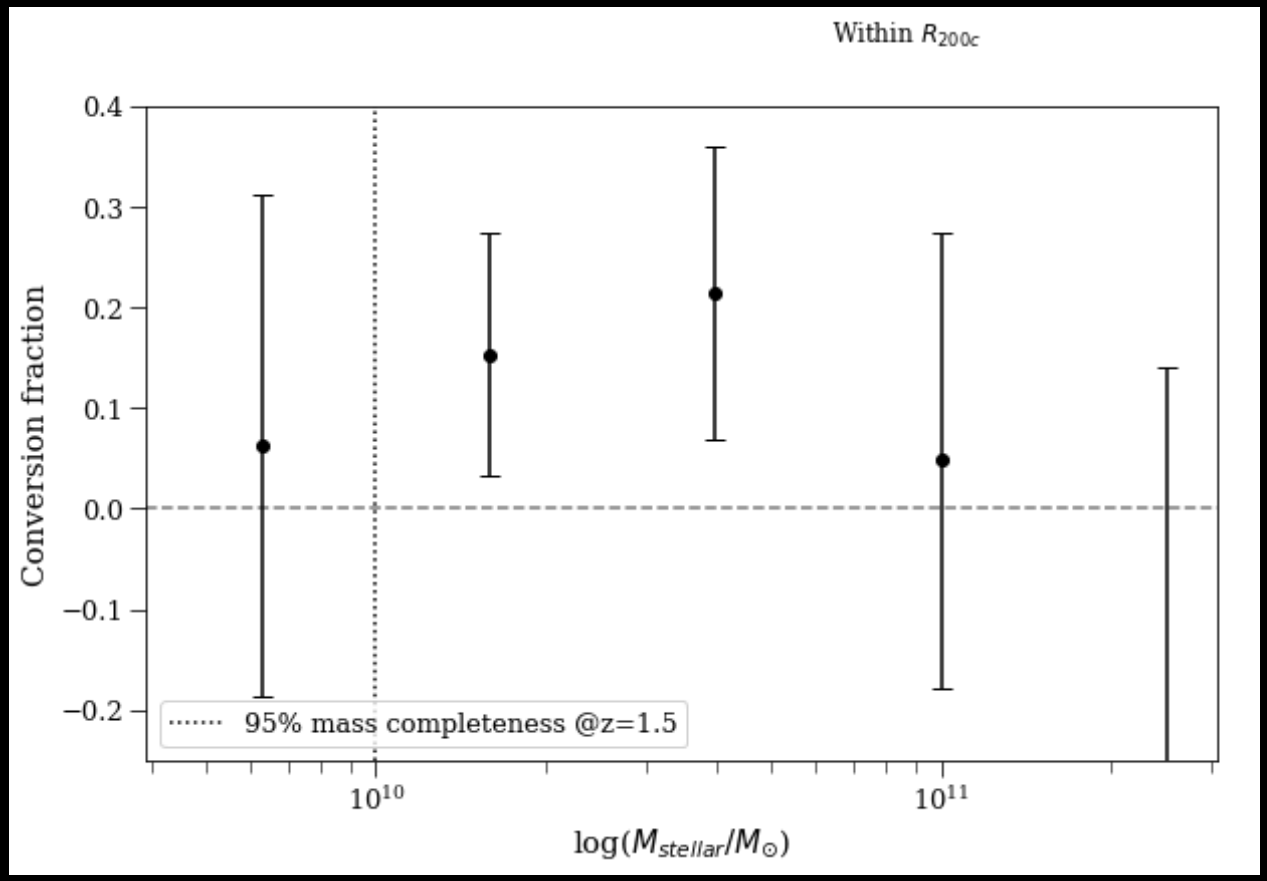
Quenched Fraction

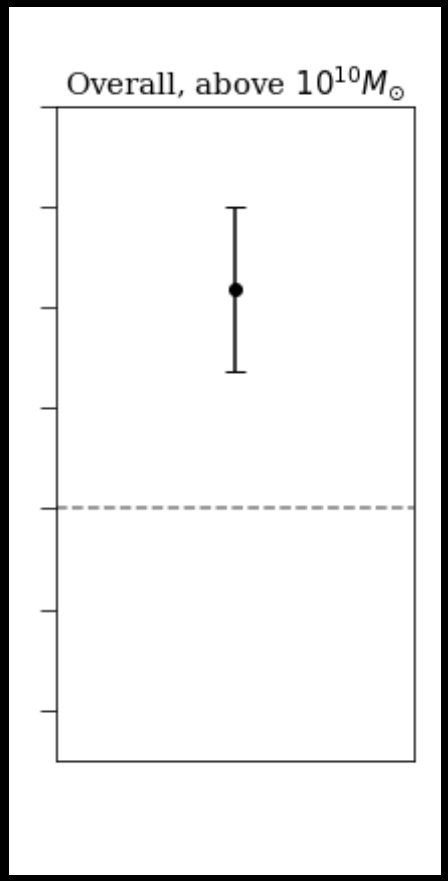


Group quenched fraction (field):

$$f_Q = \frac{N_{red}}{N_{red} + N_{blue}} = \mathbf{0.50 \pm 0.05}\ (0.36)$$

Environmental Conversion Fraction

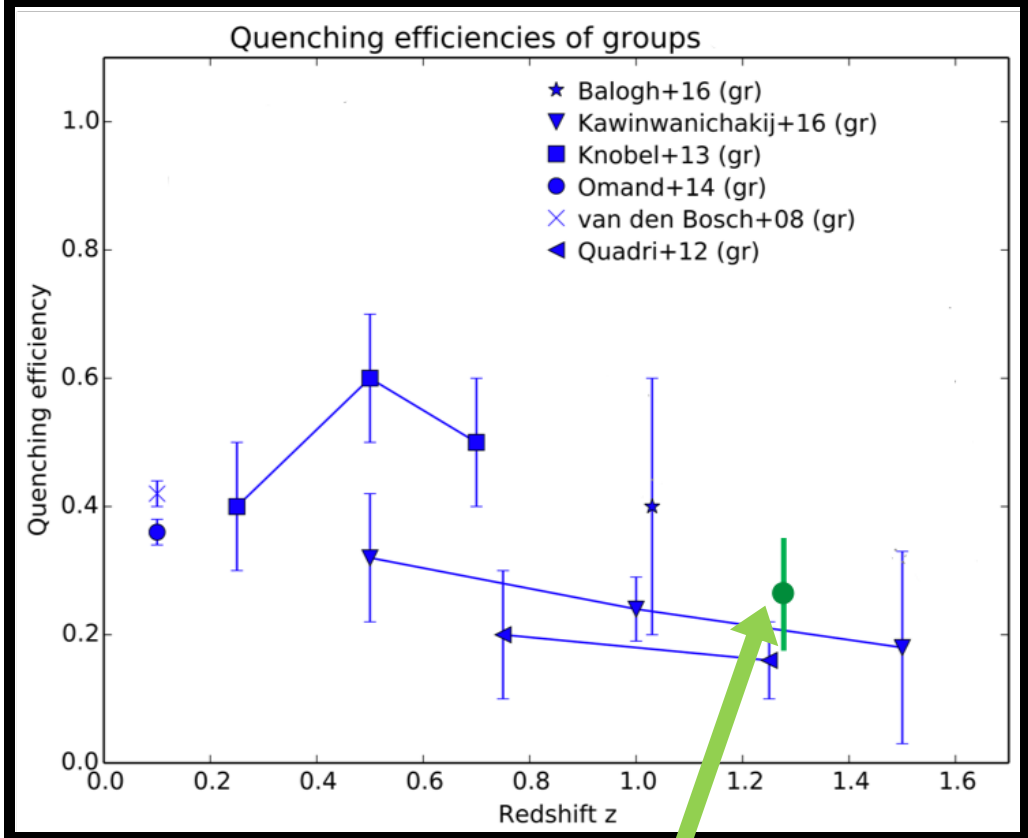




Environmental Conversion Fraction:

$$f_{convert} = \frac{f_{Q,groups} - f_{Q,field}}{f_{blue,field}} = \mathbf{0.24 \pm 0.09}$$

* *Preliminary* * GOGREEN Measurements in Context



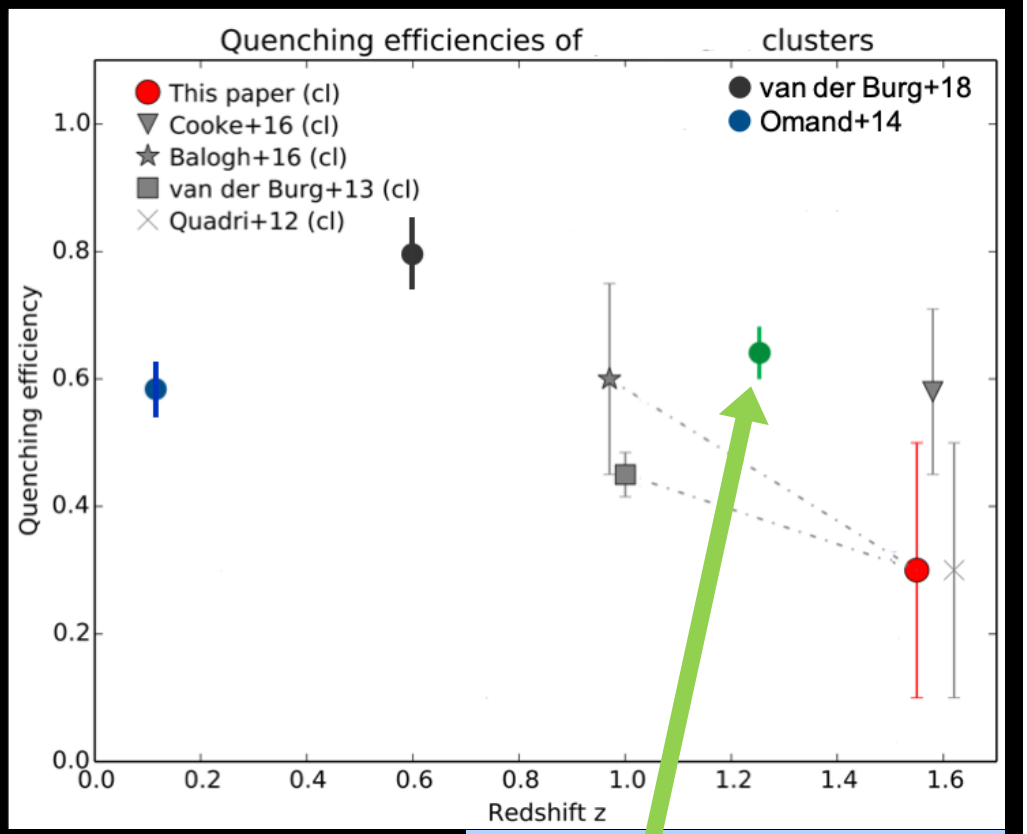


IMAGE CREDIT: Nantais+2016

GOGREEN Groups:

- **Mean $M_{halo} \approx 6.2\times10^{13}\ M_{\odot}$**
- $f_{convert} = 0.24 \pm 0.09$
  (for galaxies above $10^{10} M_{\odot}$ in stellar mass)

GOGREEN Clusters:

- **Mean $M_{halo} \approx 3.3\times10^{14}\ M_{\odot}$**
- $f_{convert} = 0.64 \pm 0.06$
  (for galaxies above $10^{10.3} M_{\odot}$ in stellar mass)

* *Preliminary* * Group Stellar Fraction

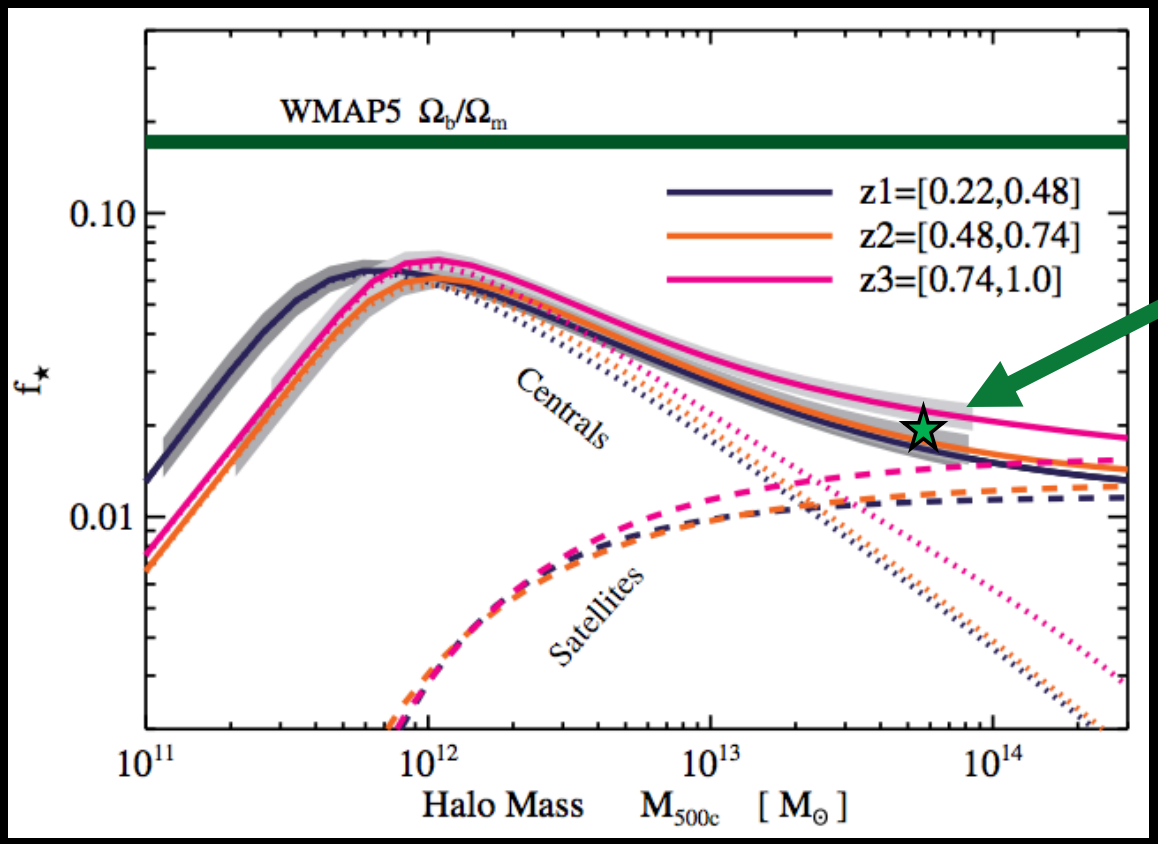


IMAGE CREDIT: Leauthaud+2012

$$f_{stellar} = \frac{M_{stellar}(< R_{500c})}{M_{500c}} = \frac{10^{11.94\pm0.07}}{10^{13.63\pm0.02}} \approx 0.020$$

ie: may be lower than expected for z~1.25

→Star formation may be less efficient in galaxy group-sized dark matter halos than expected at z~1.25

Conclusions

Relative to the field we see:

- SMF ~ same for group and field
- Overall excess quenching of group galaxies:
  - 50% instead of 36% for the field
  - Conversion fraction: 24%

Regarding halo mass dependence:

- Environmental conversion fraction depends strongly on halo mass
- Stellar mass fraction: stars make up ~2% of the halo mass, for halos $M_h \sim 10^{13.8} M_\odot$ at z~1.25

GOGREEN

Gemini Observations of Galaxies in Rich Early ENvironments

For more GOGREEN at CASCA 2019:

- Poster: *"Identifying unusual quiescent galaxies using deep rest-frame UV imaging"*, Karen McNab
- Poster: "*Quiescent galaxy populations at 1<z<1.5*", Kristi Webb
- Michael Balogh, PI of GOGREEN
- Adam Muzzin

For a copy of this talk or more GOGREEN information:
gogreensurvey.ca/

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Backup Slides…

The GOGREEN team

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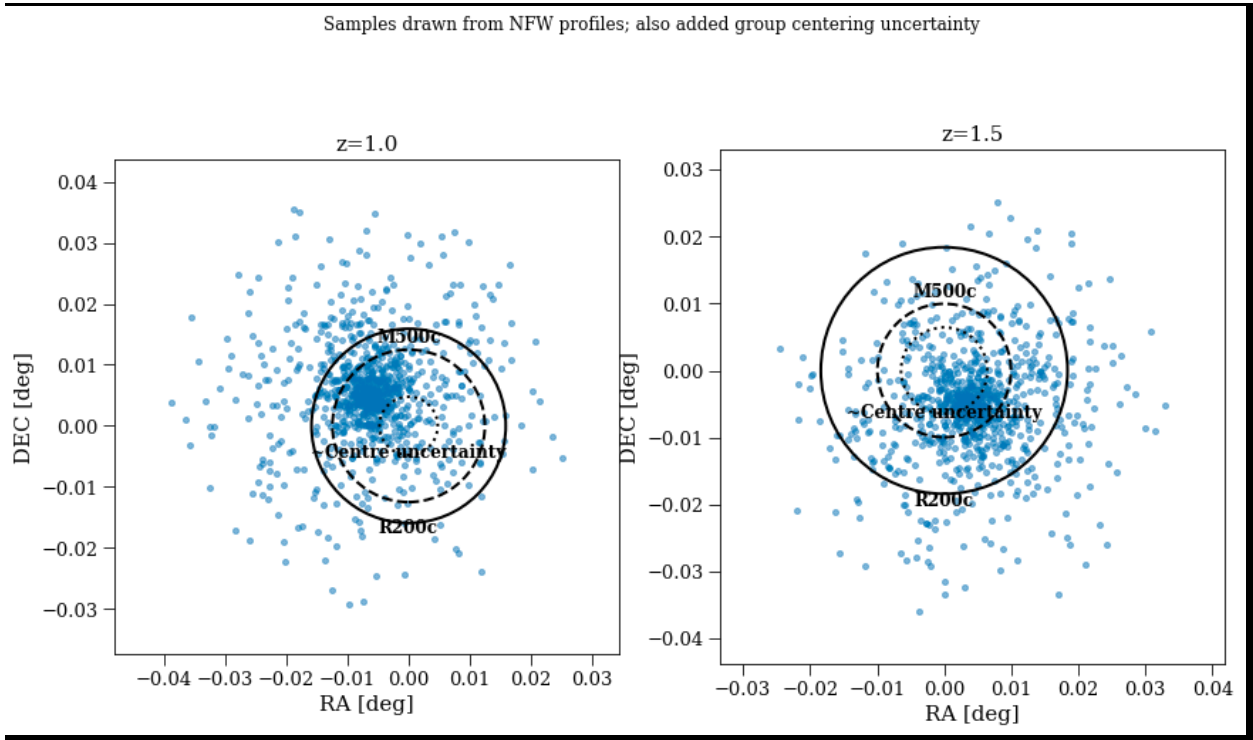
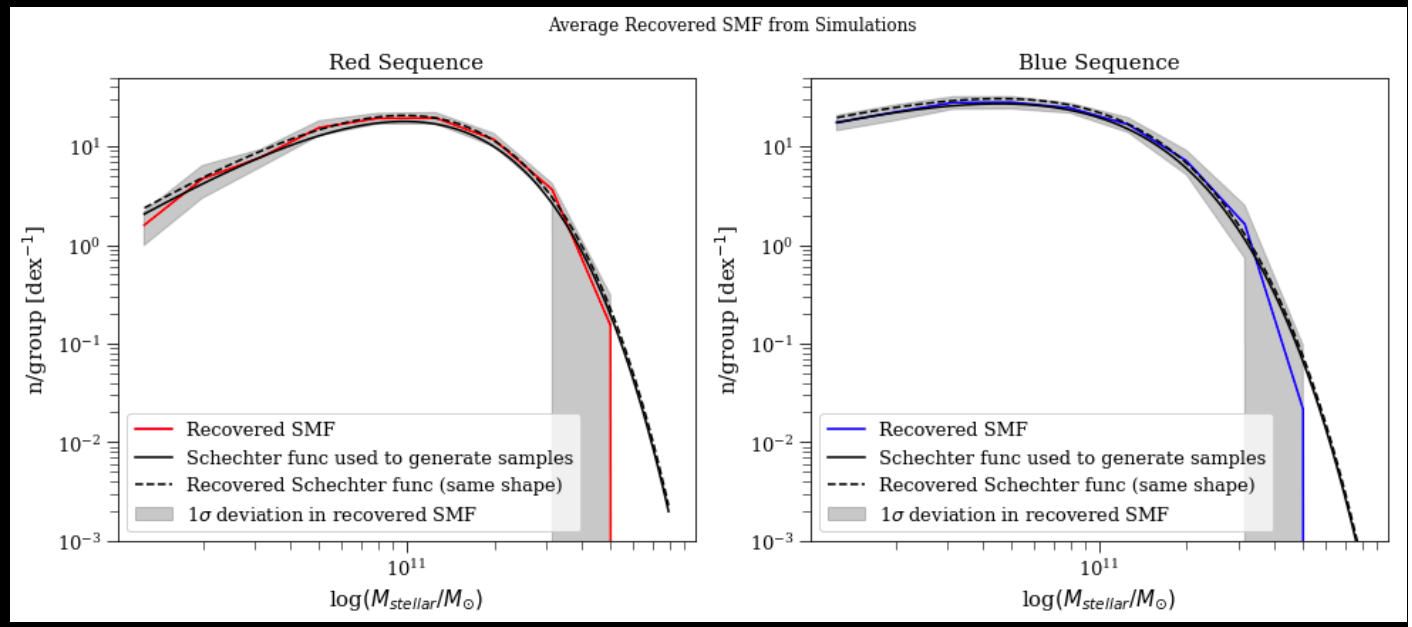


Simulations



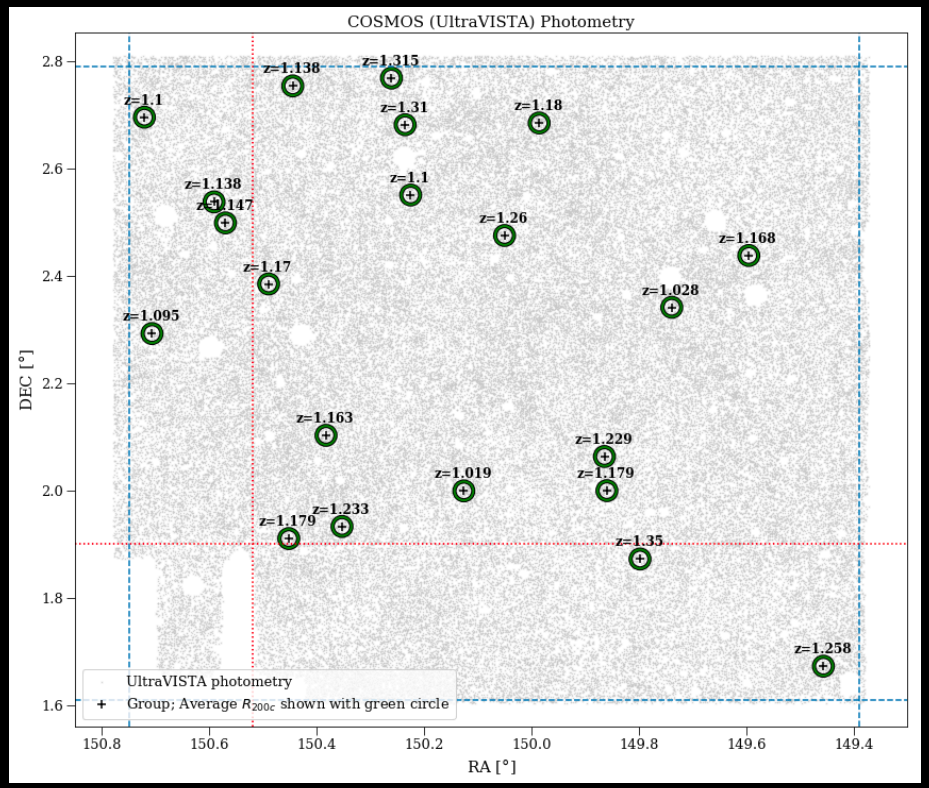
Methodology: Background Subtraction

Rough idea behind background subtraction:

- For each group, use an identified centre. Count all galaxies, N_C, within some radius (eg: R200c ~ 1' @z=1.25) of that centre and with a photo-z within +/- dz=0.2 of the group redshift.
- Count all of the galaxies in the field/survey → N_{field}. Scale that number by the ratio the ratio of the area of the circle to the area of the survey→ (A_C/A_{field}). Subtract that scaled number from the galaxies in the circle.

Finally, average across all groups.

$$N_G = N_C - N_{\text{field}}\left(\frac{A_C}{A_{\text{field}}}\right)$$
$$\approx \sum_g \left[N_{C,z_g} - N_{\text{survey},z_g}\left(\frac{A_C}{A_{survey}}\right)\right]$$



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(data references on next slide)

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