Environmental Effects and Star Formation Quenching in SpARCS 0.1<z<1.1 Galaxy Clusters

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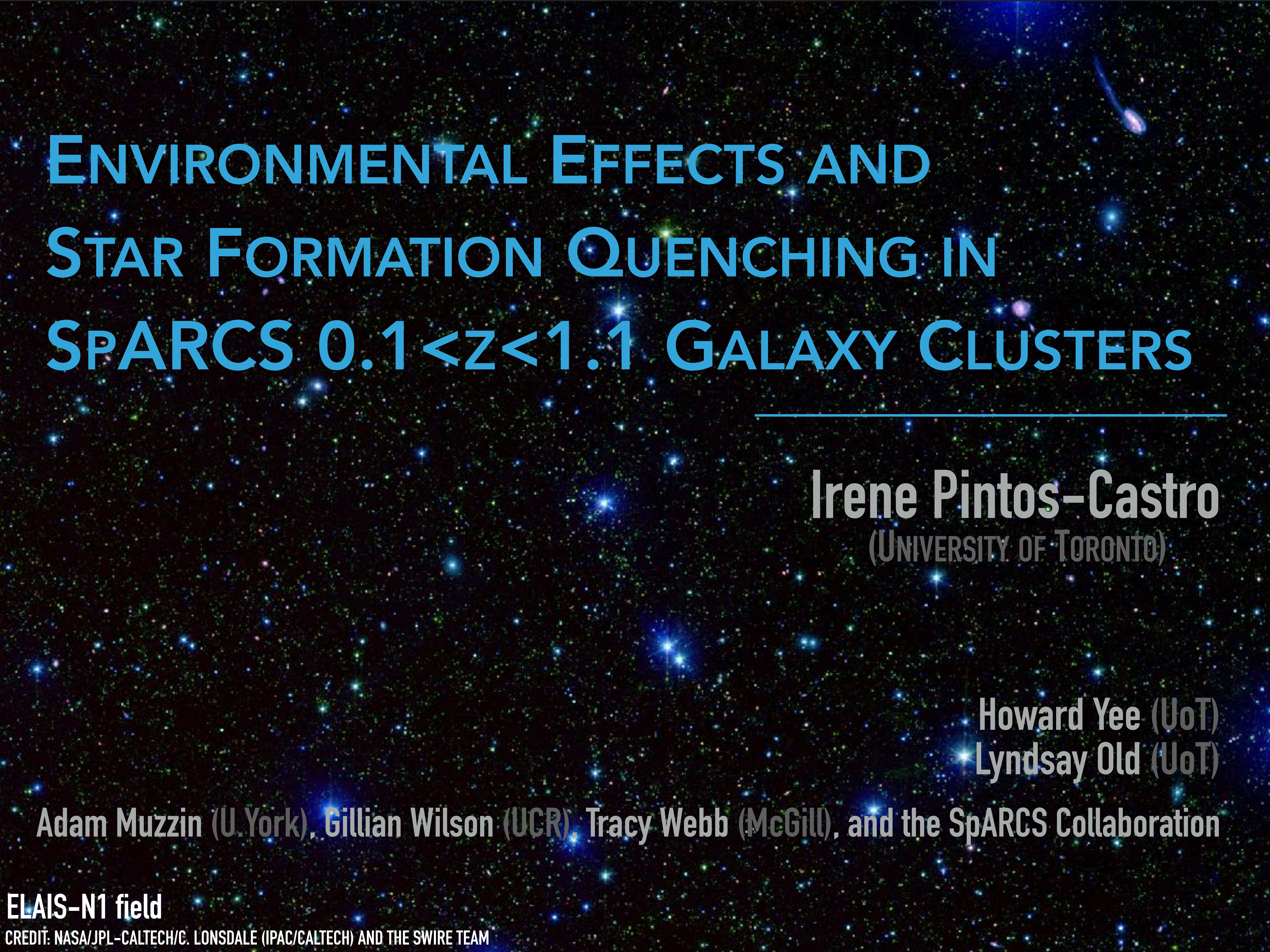


ELAIS-N1 field
CREDIT: NASA/JPL-CALTECH/C. LONSDALE (IPAC/CALTECH) AND THE SWIRE TEAM

OUTLINE

- SpARCS survey
- Our project: study star formation and environment with SpARCS clusters up to redshift ~1
  - Two first fields: a wealth of (public) data
  - Defining the clusters and their galaxies (i.e. generation of catalogues)
  - Star formation properties and their relation with $M_\star$, R, z
- Conclusions and near future

SpARCS

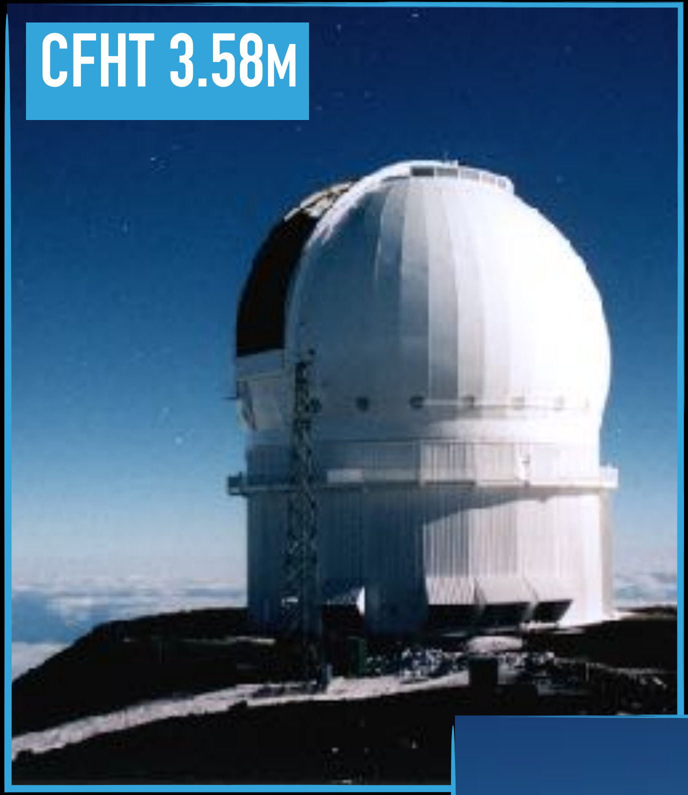
Spitzer Adaptation of the Red-sequence Cluster Survey

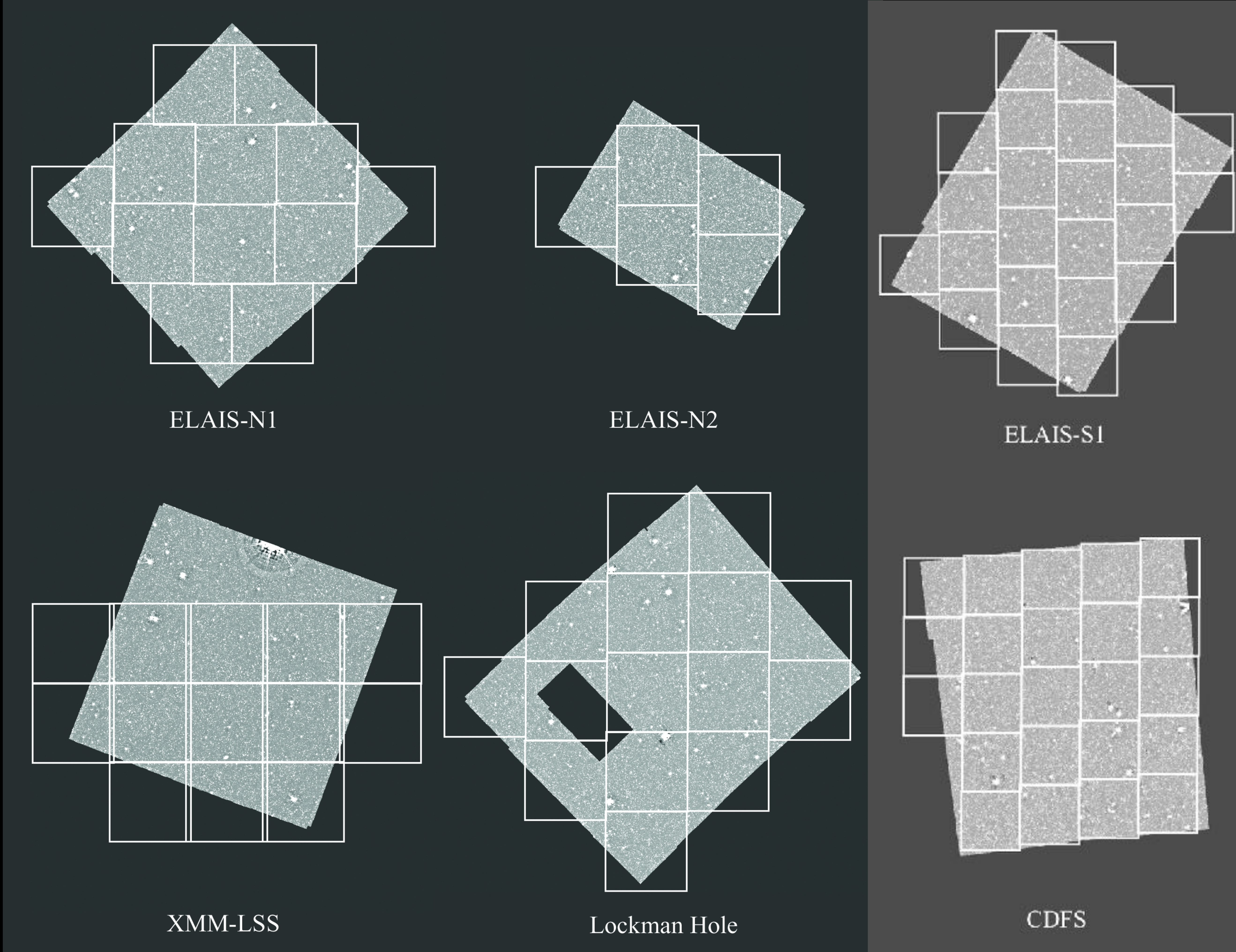
- Deep-wide z′-band survey combined with Spitzer SWIRE 50 deg^2 survey
- Clusters are selected based on z′- IRAC 3.6μm colour using the red sequence technique (Muzzin+09, Wilson+09)
- ~200 new cluster candidates at $z > 1$ with estimated $M_\star > 10^{14}\ M_\odot$

+9 published papers on clusters and galaxy evolution

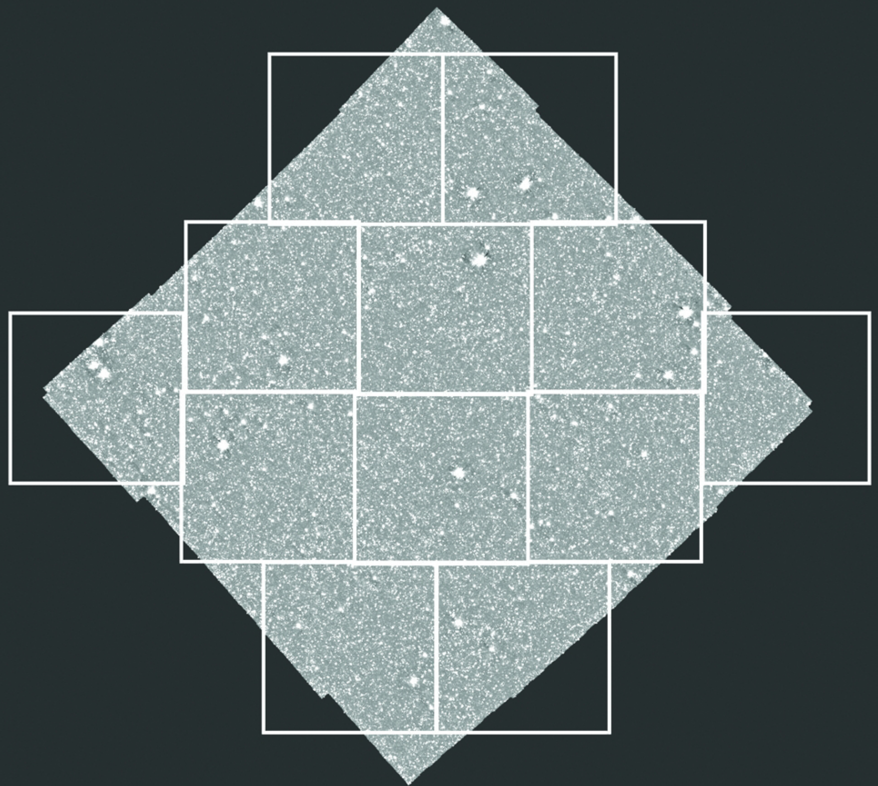
but also

~ 850 cluster candidates at $0.1 < z < 1.1$

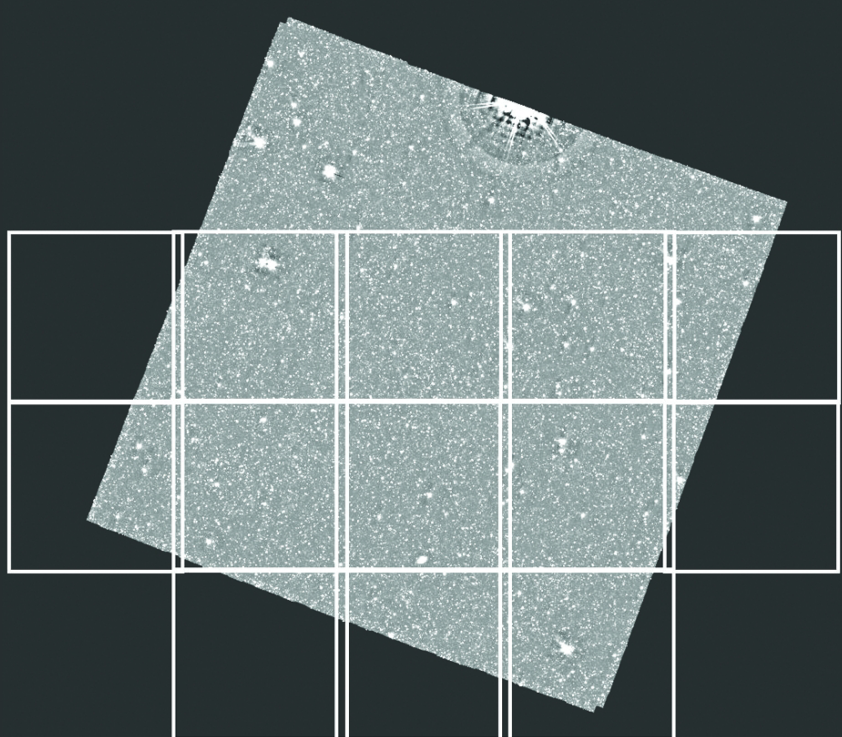



ELAIS-N1
ELAIS-N2
ELAIS-S1
XMM-LSS
Lockman Hole
CDFS

Two First Fields



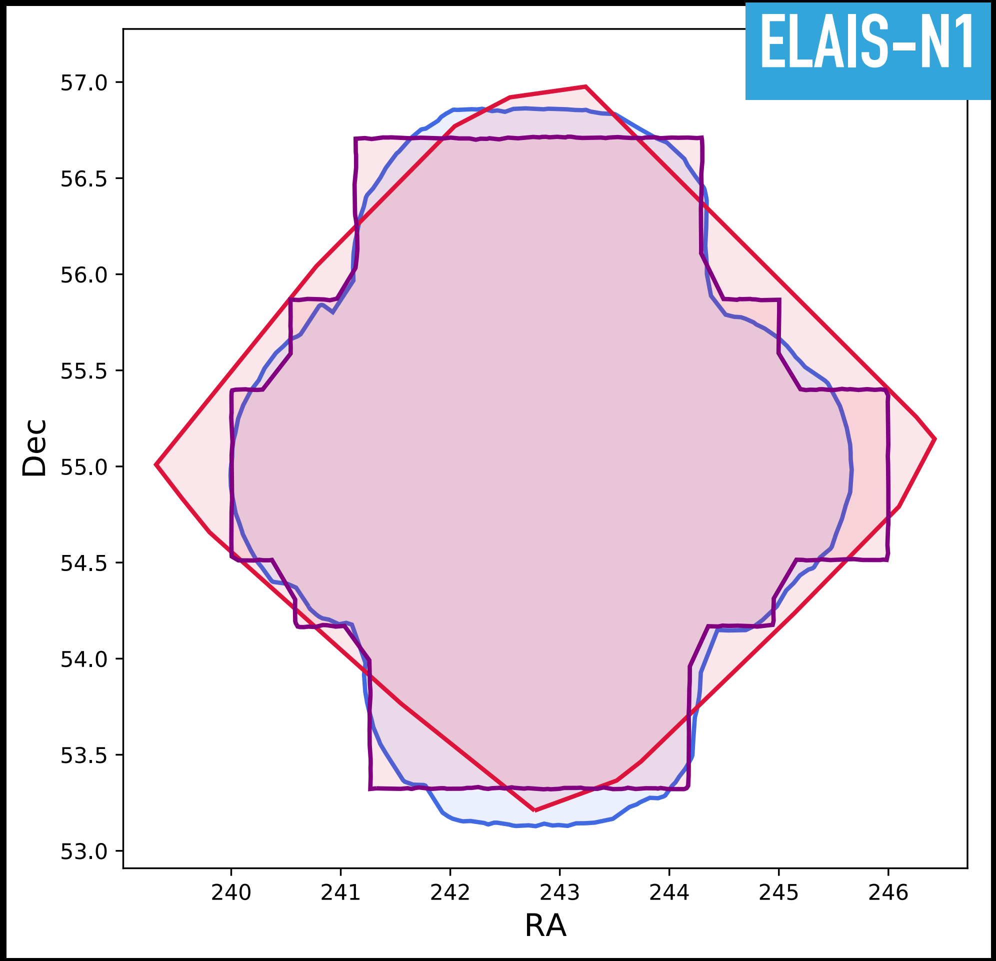
ELAIS-N1

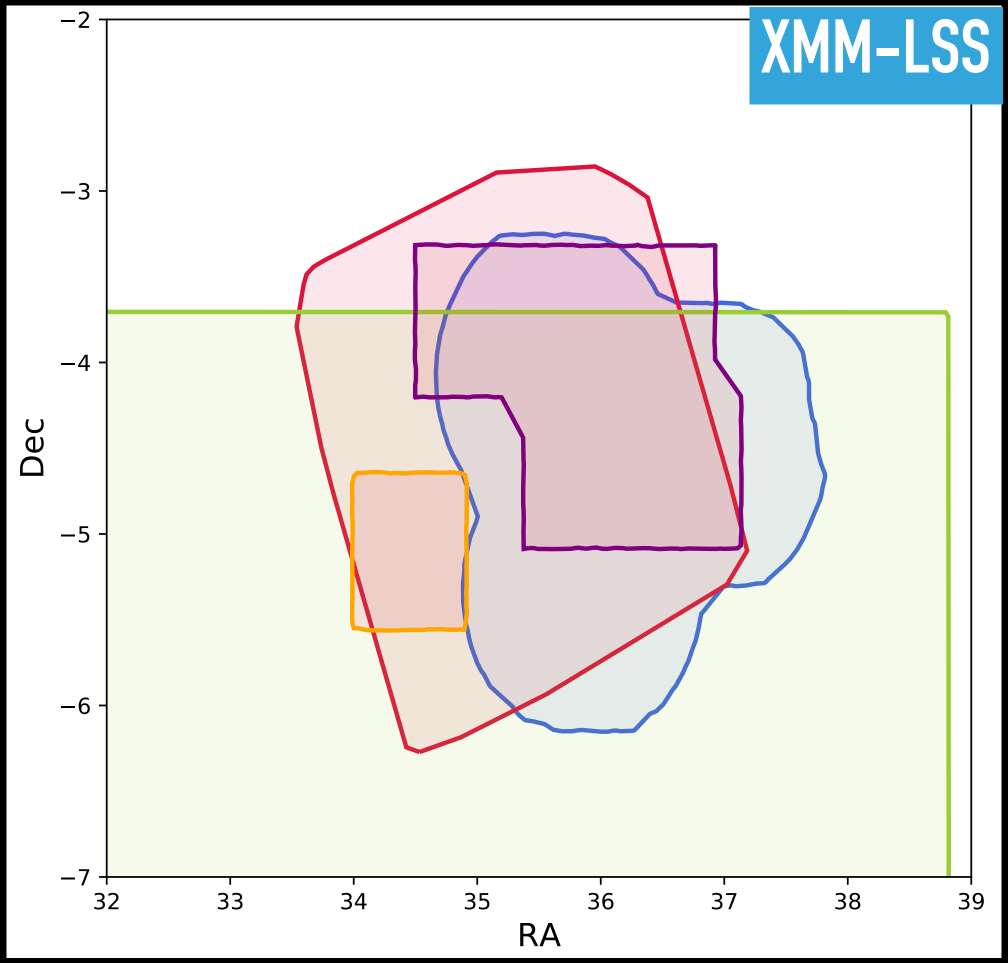


XMM-LSS

	XMM-LSS	ELAIS-N1
RA (J2000)	02:21:20	16:11:00
Dec (J2000)	-04:30:00	+55:00:00
SWIRE 3.6μm area	9.4	9.8
SpARCS z′ area	11.7	10.3
Usable area	7.3	7.9
No. of clusters ($0.1<z<1.1$, $N_{RED}>6$)	143	173

Two First Fields





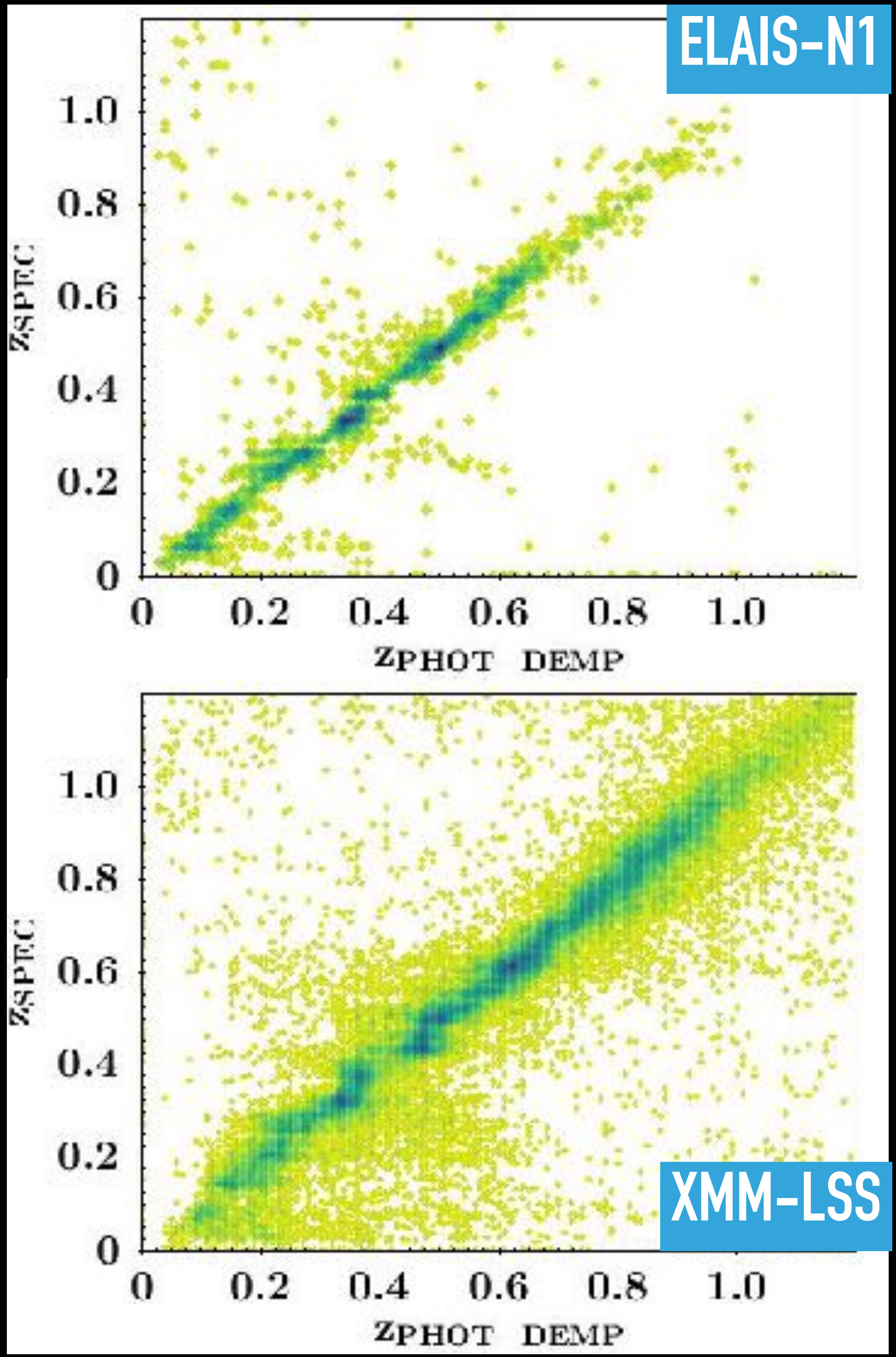
- Hyper Suprime-Cam SSP Deep fields (grizY), DR1 include *photometric redshifts*
- CFHTLS (ugriz) @XMM-LSS
- UKIDSS DXS and UDS @XMM-LSS
- SWIRE (IRAC and MIPS)
- HerMES (PACS and SPIRE)

HSC Subaru Strategic Program*

- Multi-band imaging survey with HSC (1.5 deg diameter FoV with 0.168″ of pixel scale) on the 8.2m Subaru Telescope.

	Fields	Area (deg2)	Filters and depth
Wide	Spring & Autumn equatorial stripes, Hectomap	1400	grizY (r~26)
Deep	**XMM-LSS**, E-COSMOS, **ELAIS-N1**, DEEP2-F3	27	grizY+4NB (r~27)
Ultradeep	SXDS, COSMOS	3.5	grizY+4NB (r~28)

- *PDR1 on 28th February 2017*



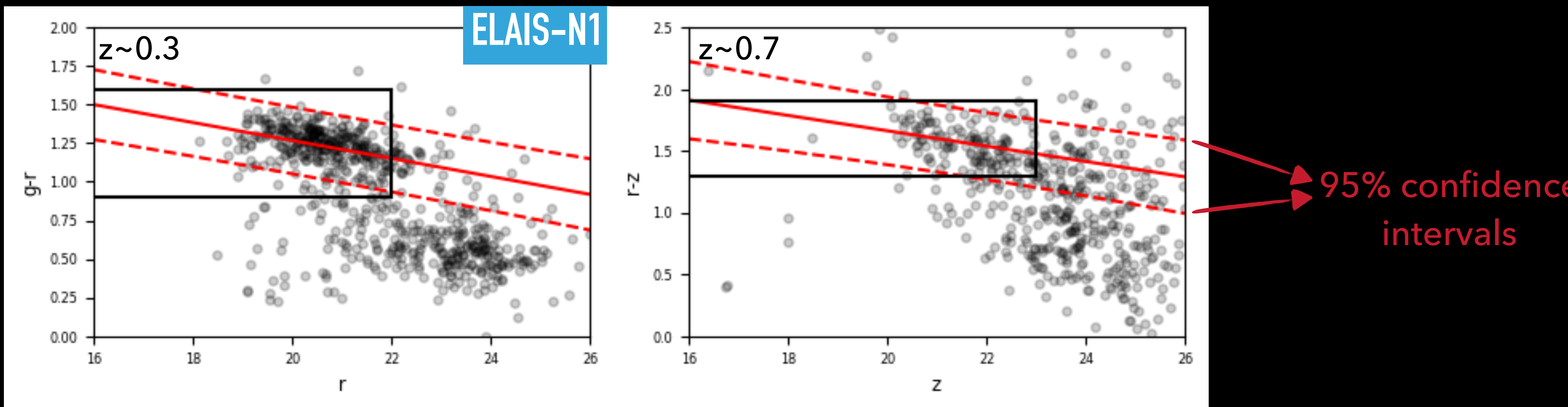
✳ http://hsc.mtk.nao.ac.jp/ssp/

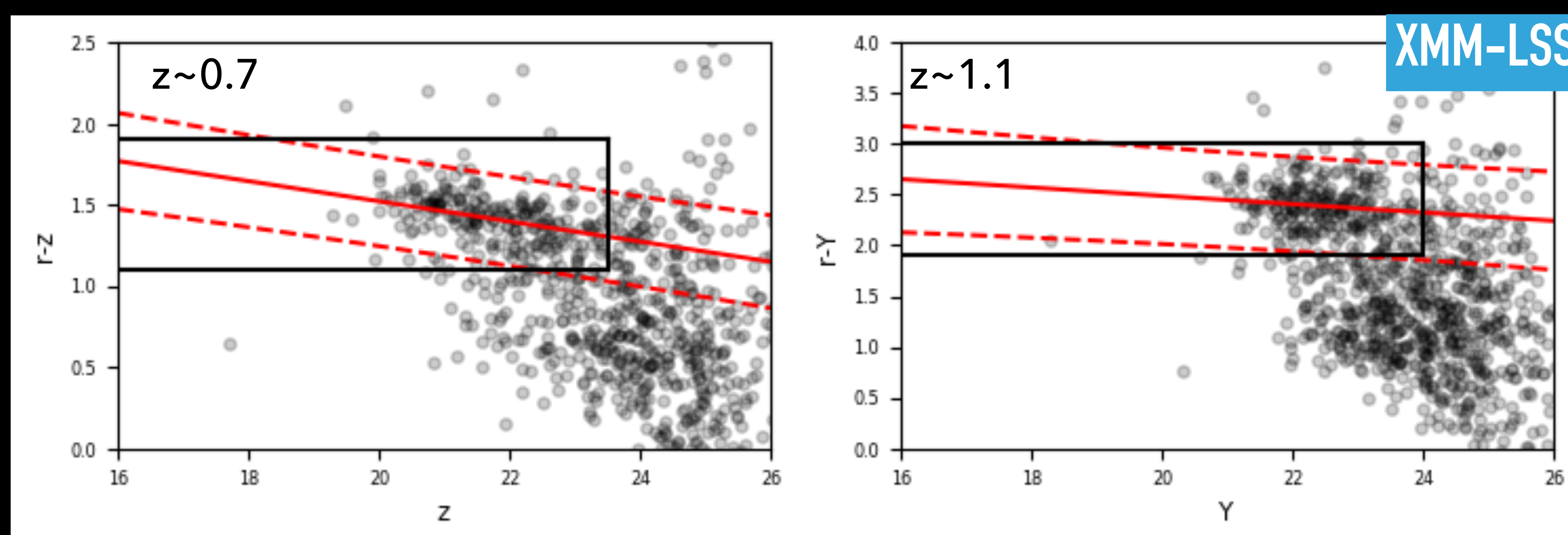
OBJECTIVE

Study how star formation is quenched and/or enhanced as galaxies in-fall into clusters over a wide redshift range, with a sample sufficiently large enough to control intrinsic properties of galaxies.

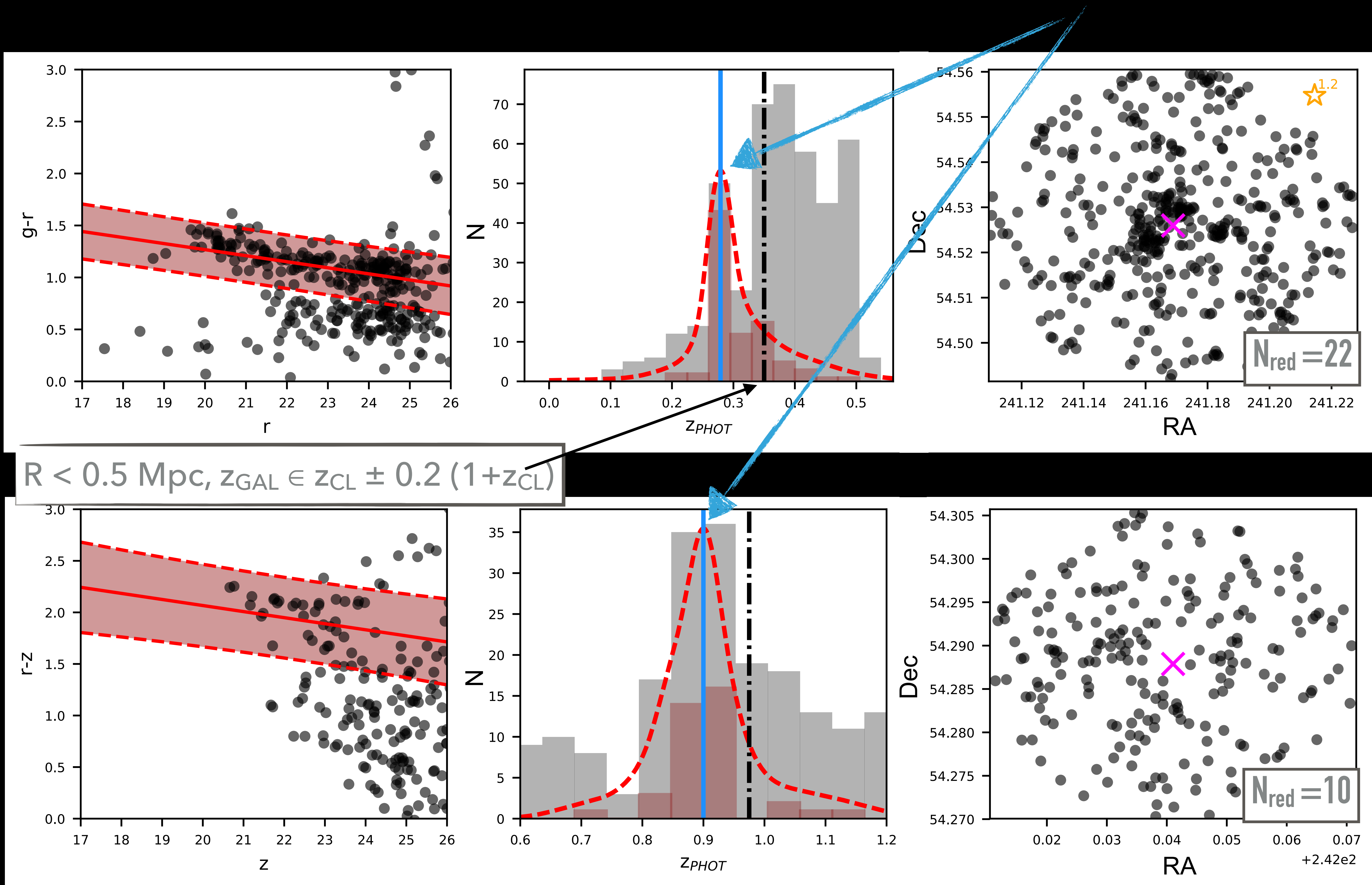
DETERMINING CLUSTERS RED SEQUENCE

By stacking central regions of clusters in bins of 0.1 in z_{CL}, we included galaxies that are at R < 1.5Mpc and which $z_{GAL} \in z_{CL} \pm 0.05(1+z_{CL})$



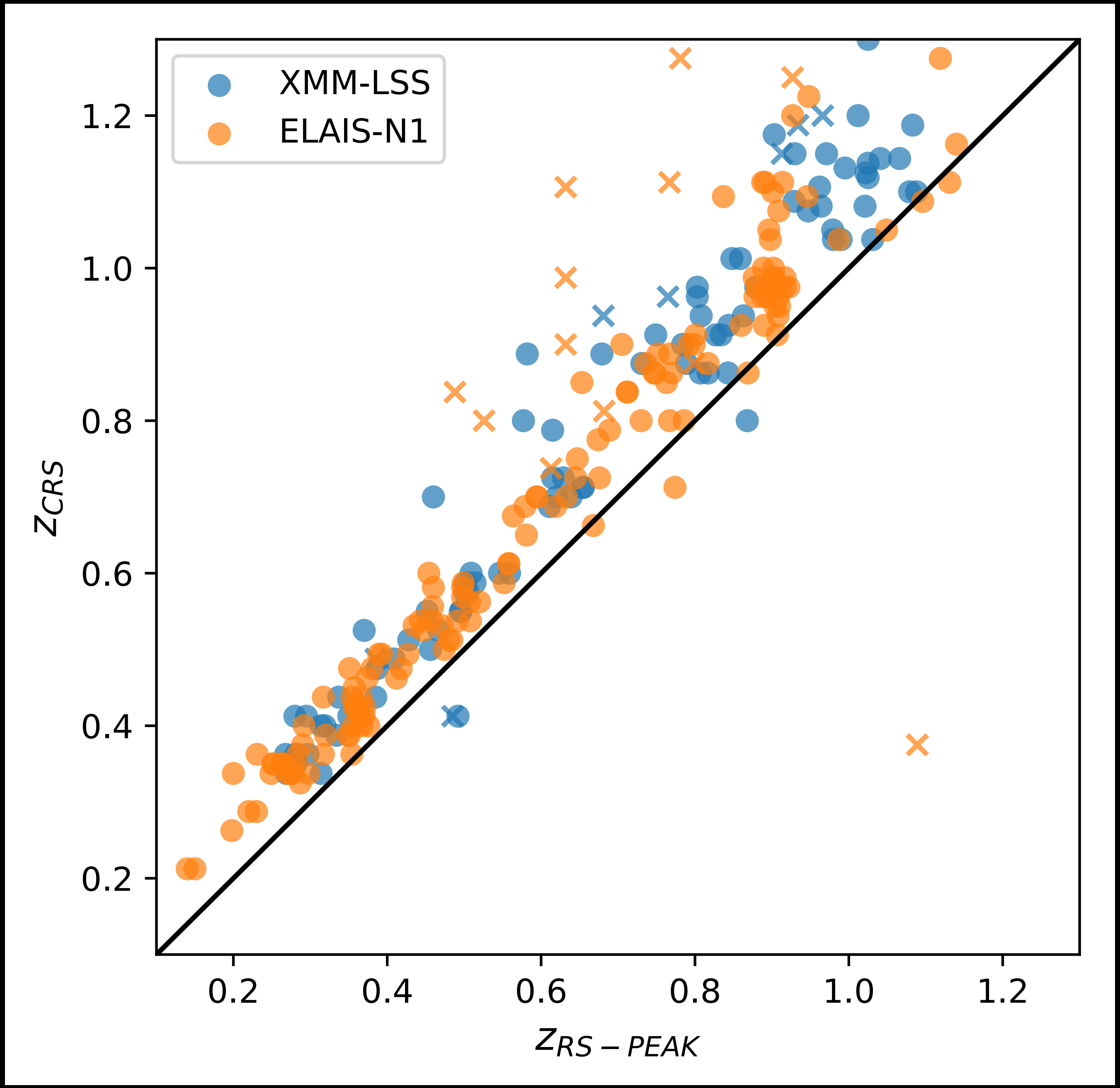


Determining Clusters Redshift: $z_{RS\text{-}PEAK}$



DETERMINING CLUSTERS REDSHIFT:

$z_{RS\text{-}PEAK}$ VS z_{CRS}

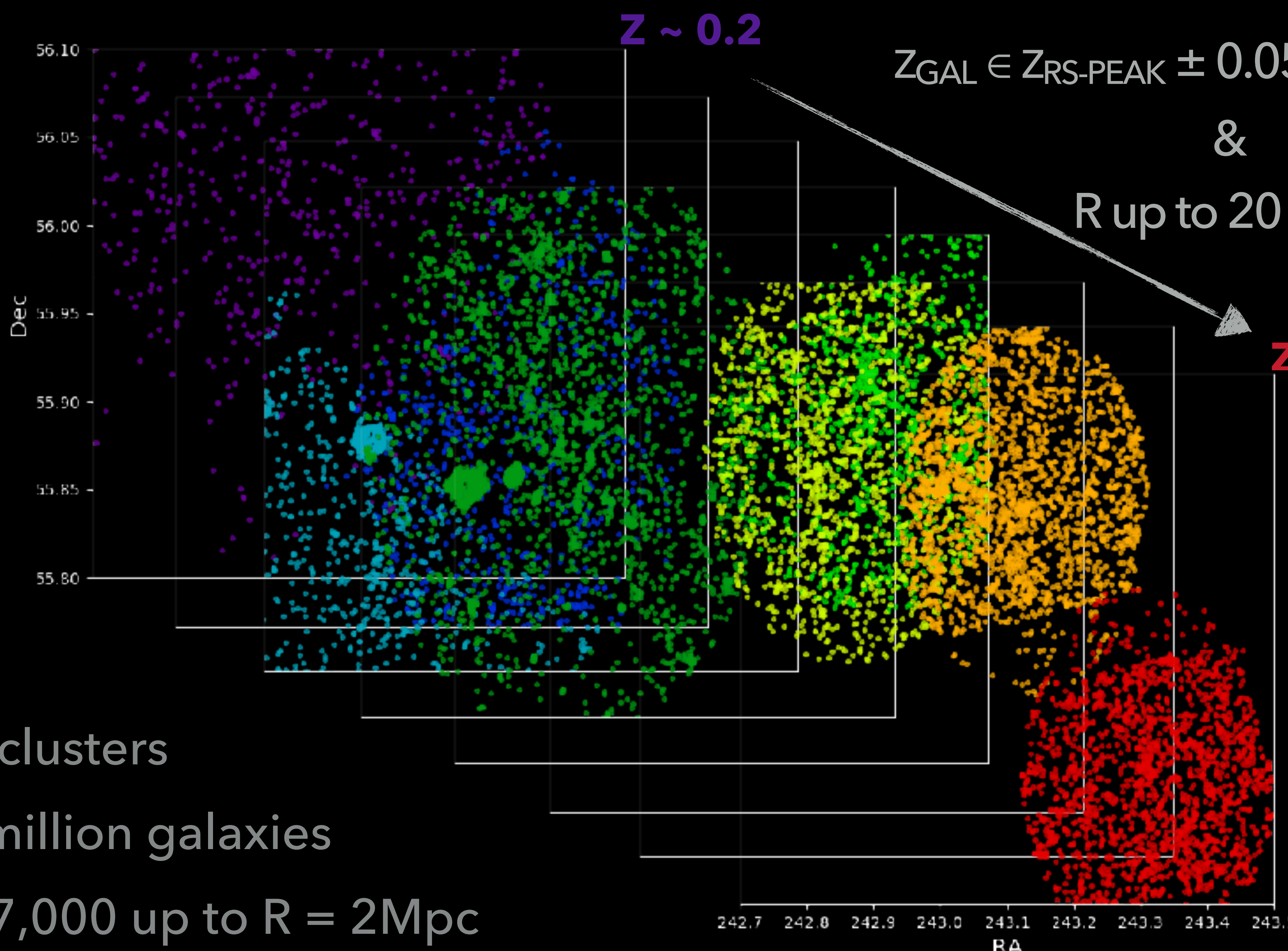


***$z_{RS\text{-}PEAK}$*:** determined by the peak of the z_{PHOT} distribution of RS galaxies

***z_{CRS}*:** original SpARCS redshift based on RS modelling

Systematic shift of ~0.1, already known

Building the Catalogue



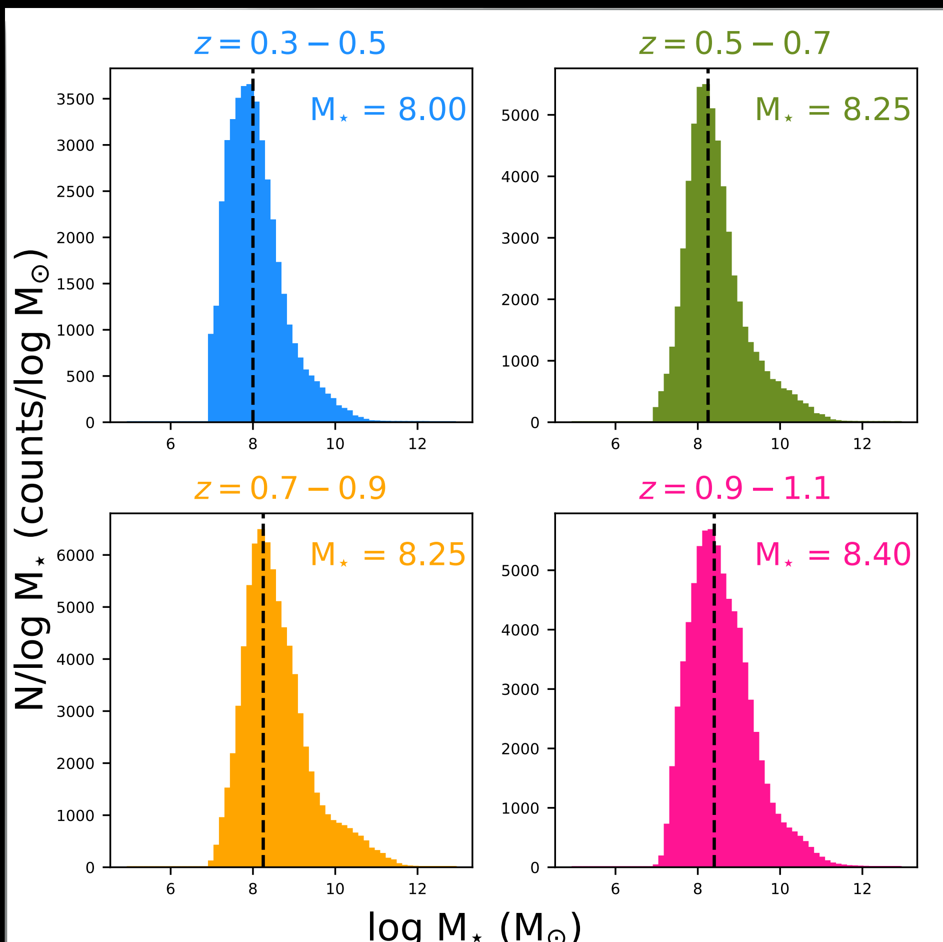
$z_{GAL} \in z_{RS\text{-}PEAK} \pm 0.05\ (1 + z_{RS\text{-}PEAK})$

&

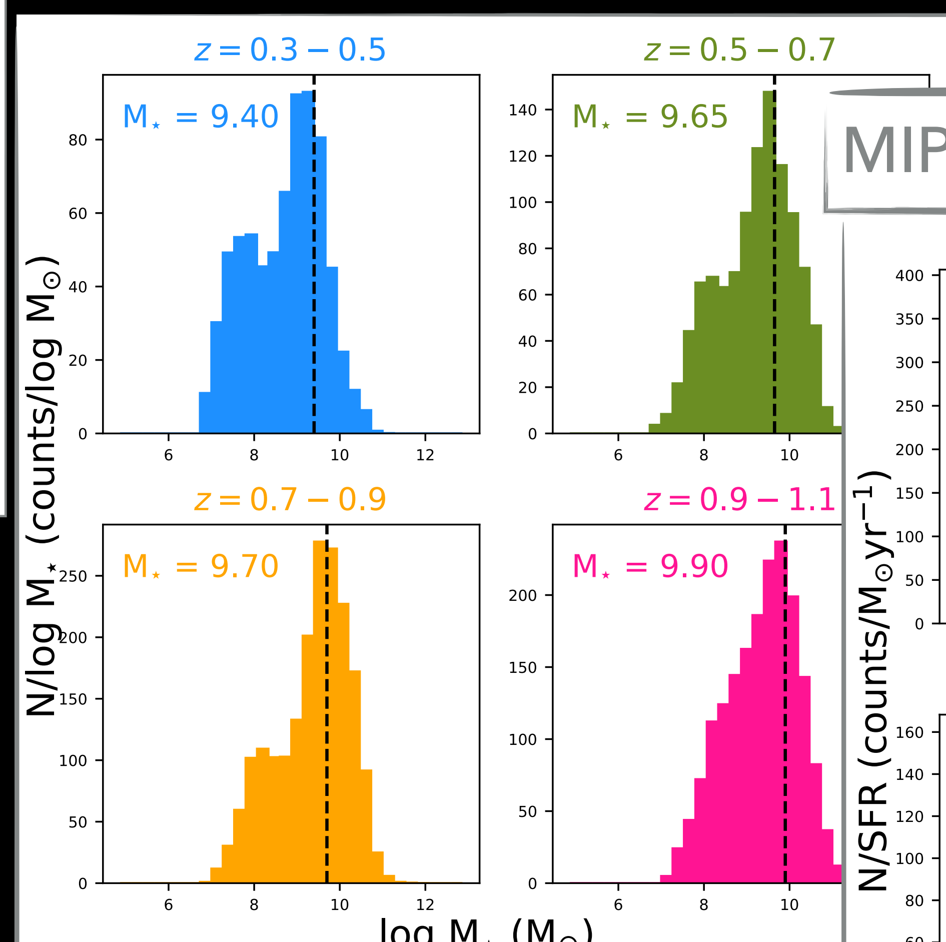
R up to 20 Mpc

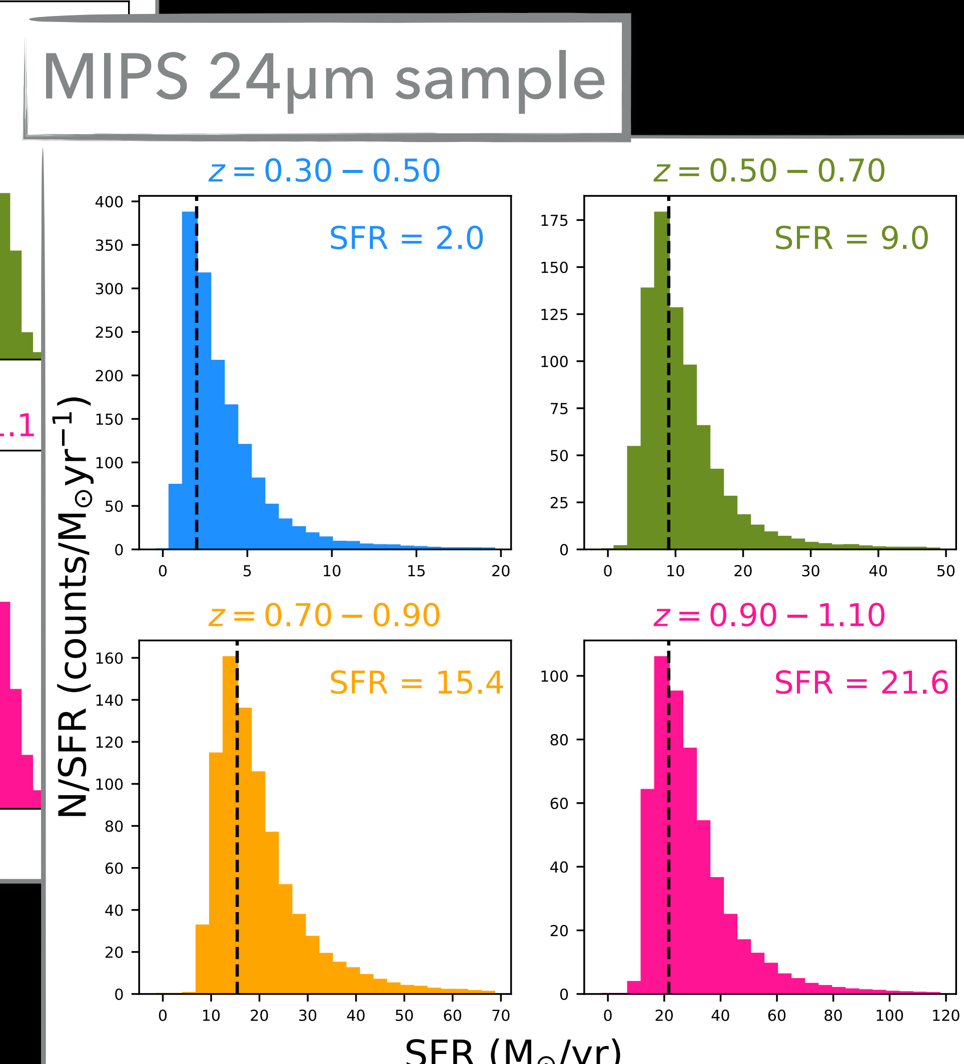
- 228 clusters
- 2.6 million galaxies
- ~207,000 up to R = 2Mpc
- 84,655 MIPS 24μm sources

M★, SFR, and Rest-Frame Colours



- We use *Le Phare* (BC03) to compute stellar masses
- M★ compl. from 8M⊙ @0.5 to 8.4M⊙ @1.1

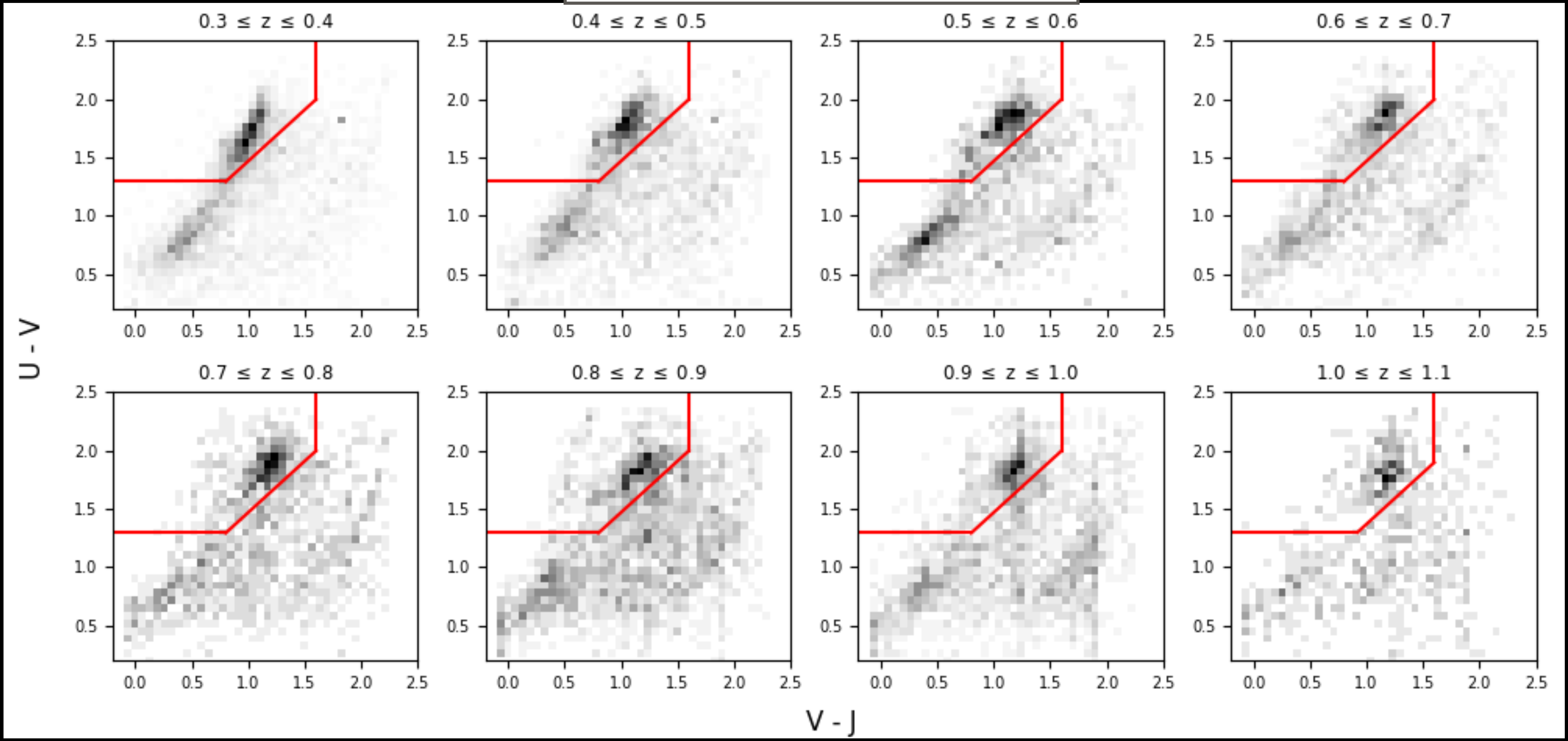




- SFR derived from 24μm following *Wuyts+11*
- SFR compl. from 2M⊙/yr @0.5 to 21.6M⊙/yr @1.1

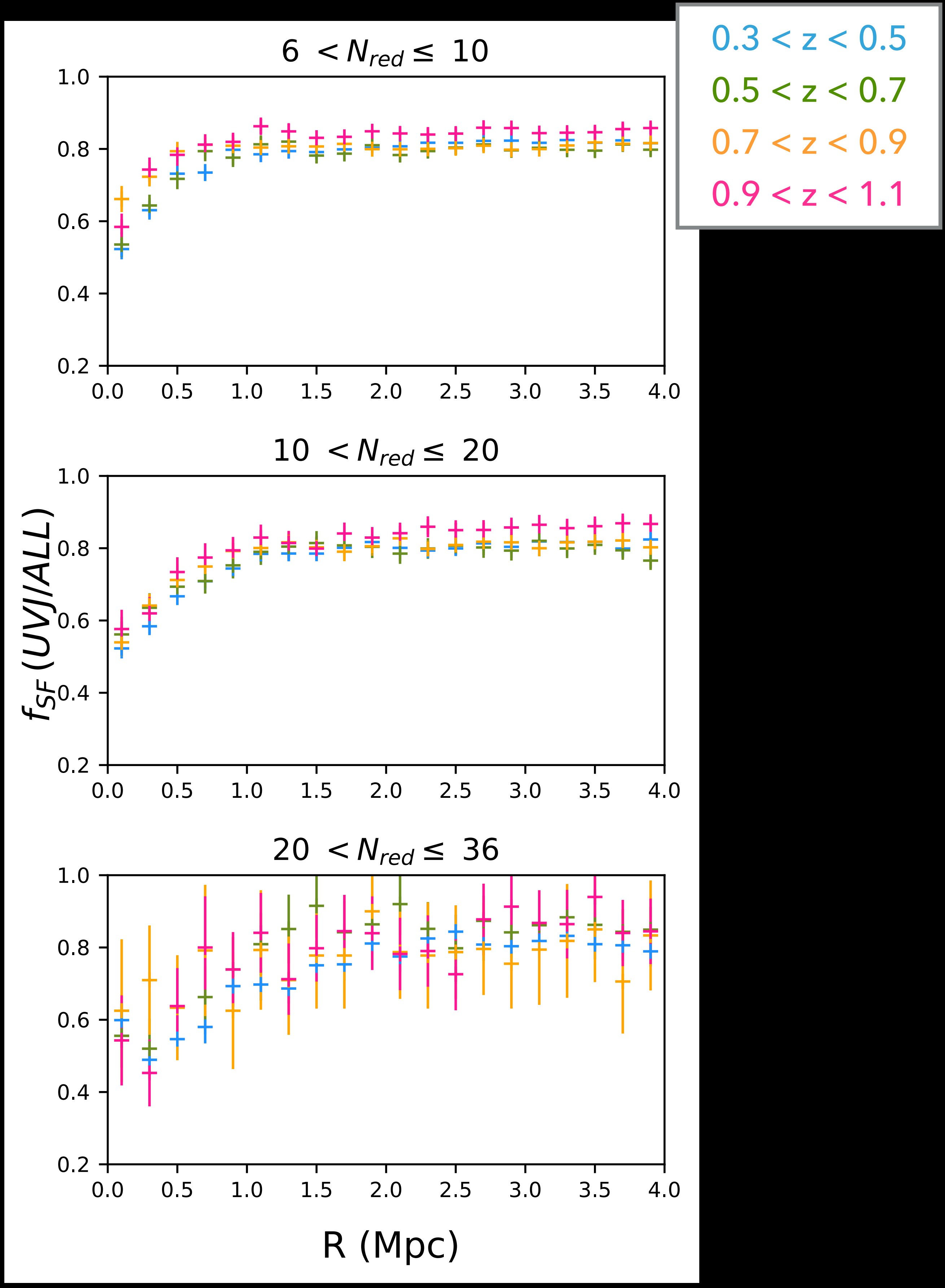
$M_\star$, SFR, and Rest-Frame Colours

Cluster Core: 0 < R < 0.5 Mpc



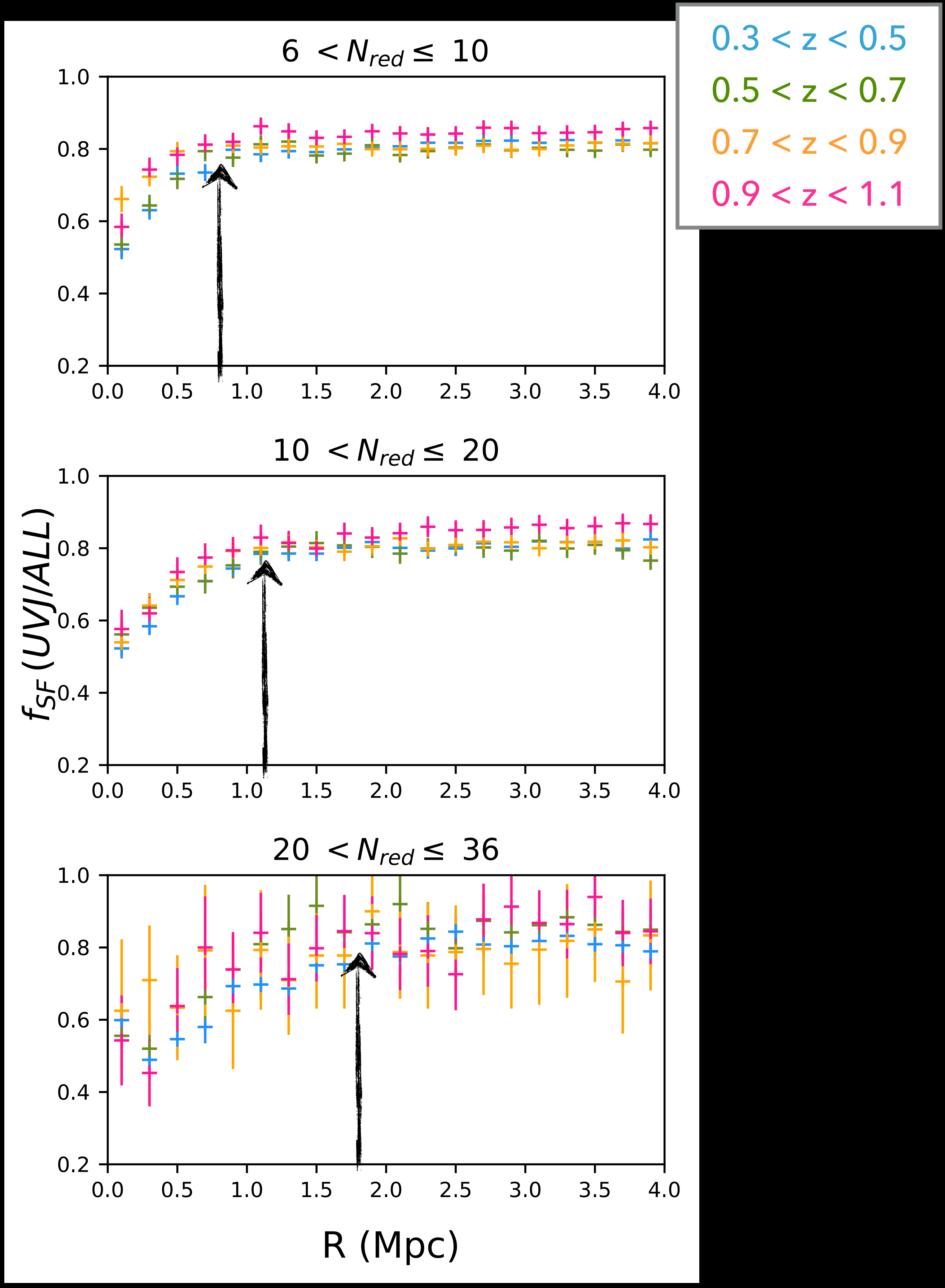
We use EAZY to estimate U-V and V-J rest-frame colours , and follow the two-colour separations defined in Williams+09

UVJ Star Forming Galaxies



Notice we are using running bins of 0.5Mpc wide every 0.2Mpc

UVJ Star Forming Galaxies



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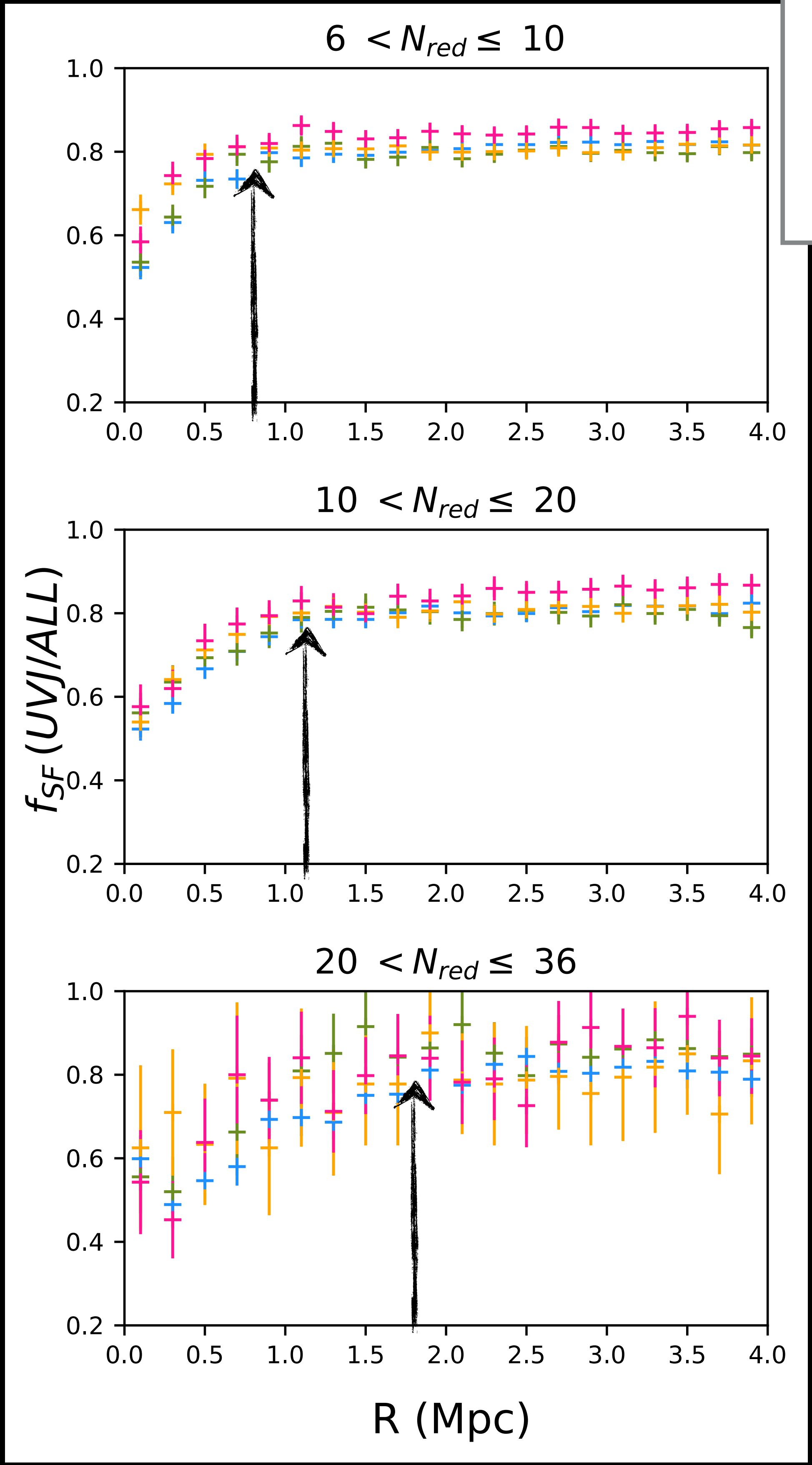
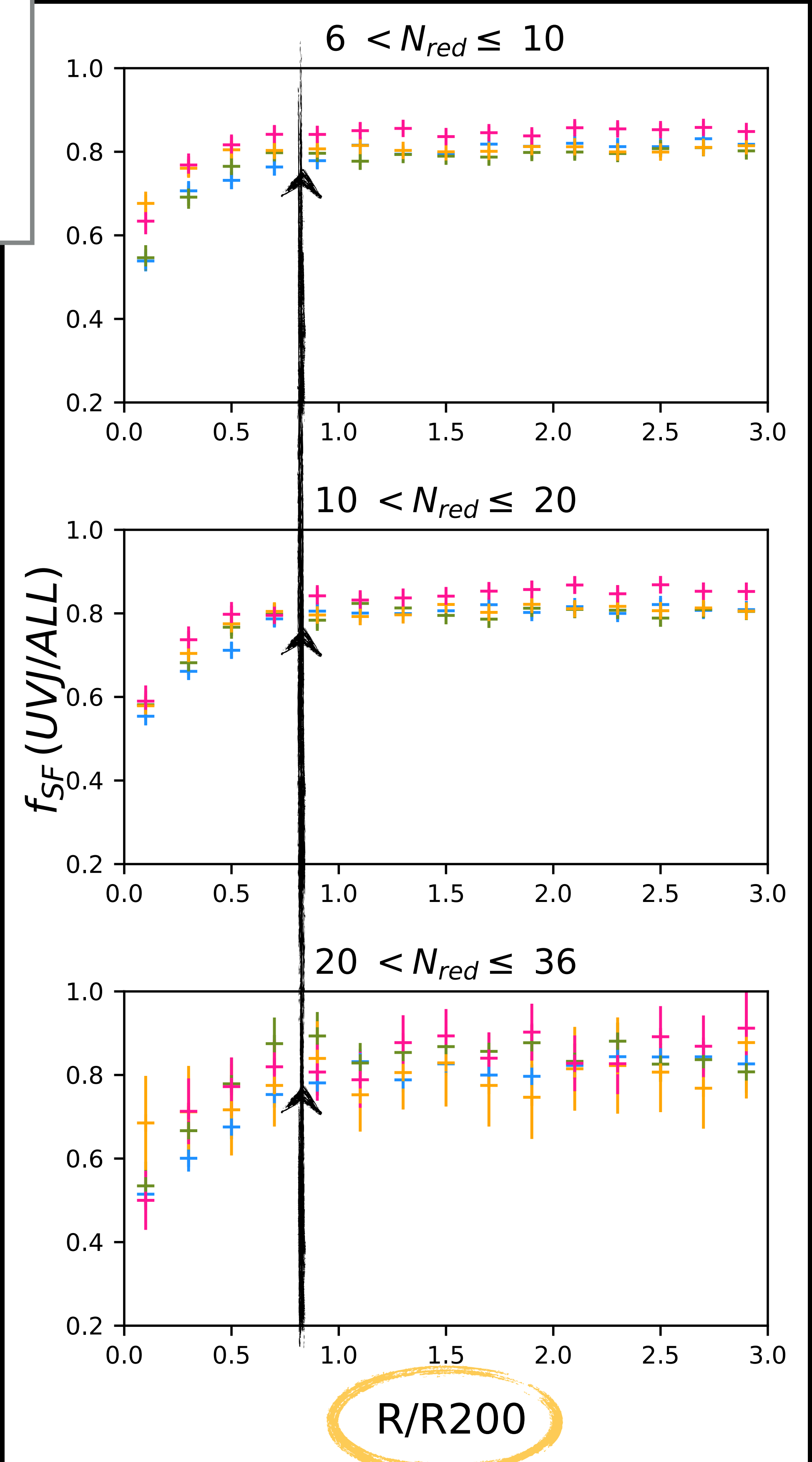
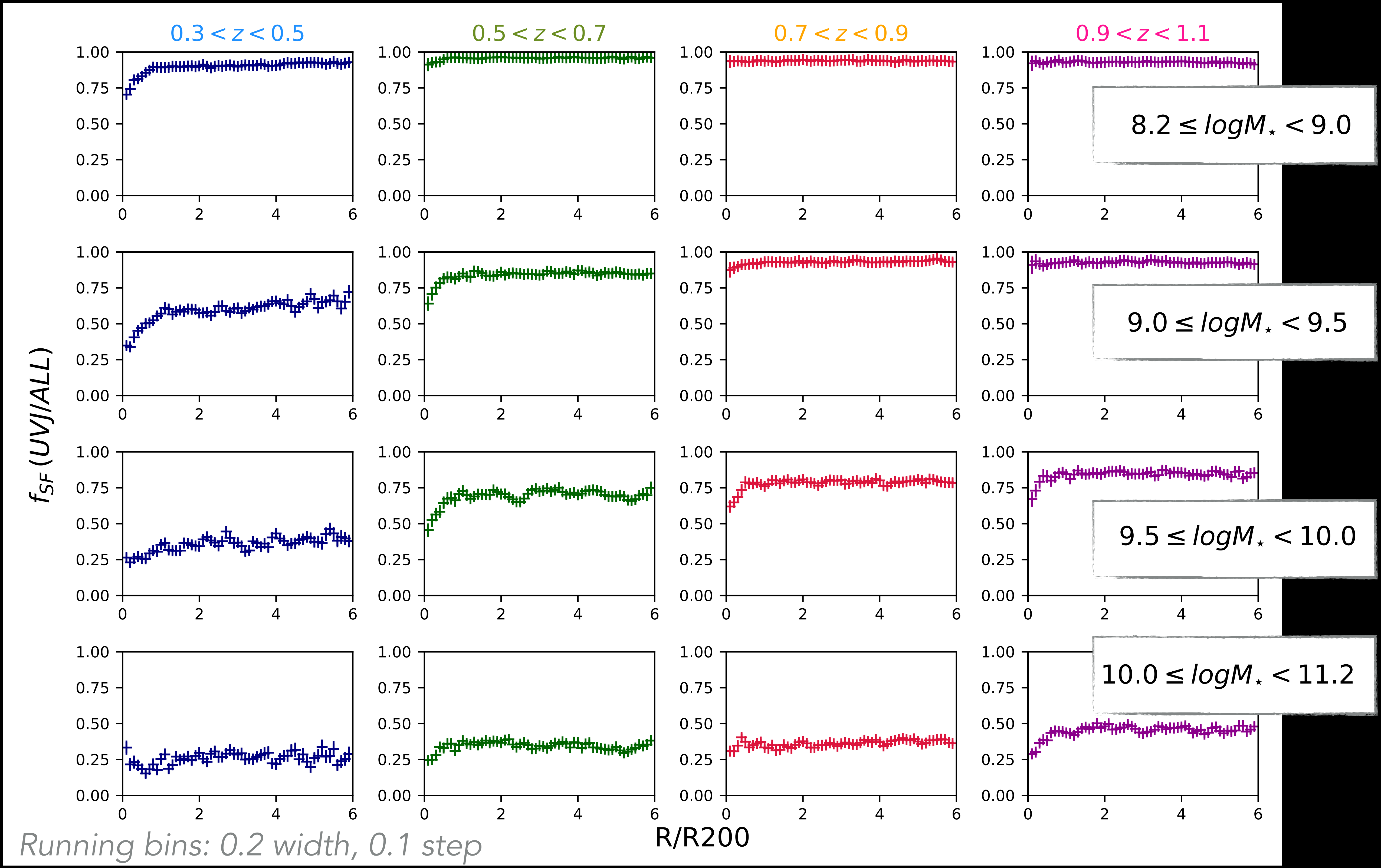
UVJ Star Forming Galaxies



0.3 < z < 0.5
0.5 < z < 0.7
0.7 < z < 0.9
0.9 < z < 1.1

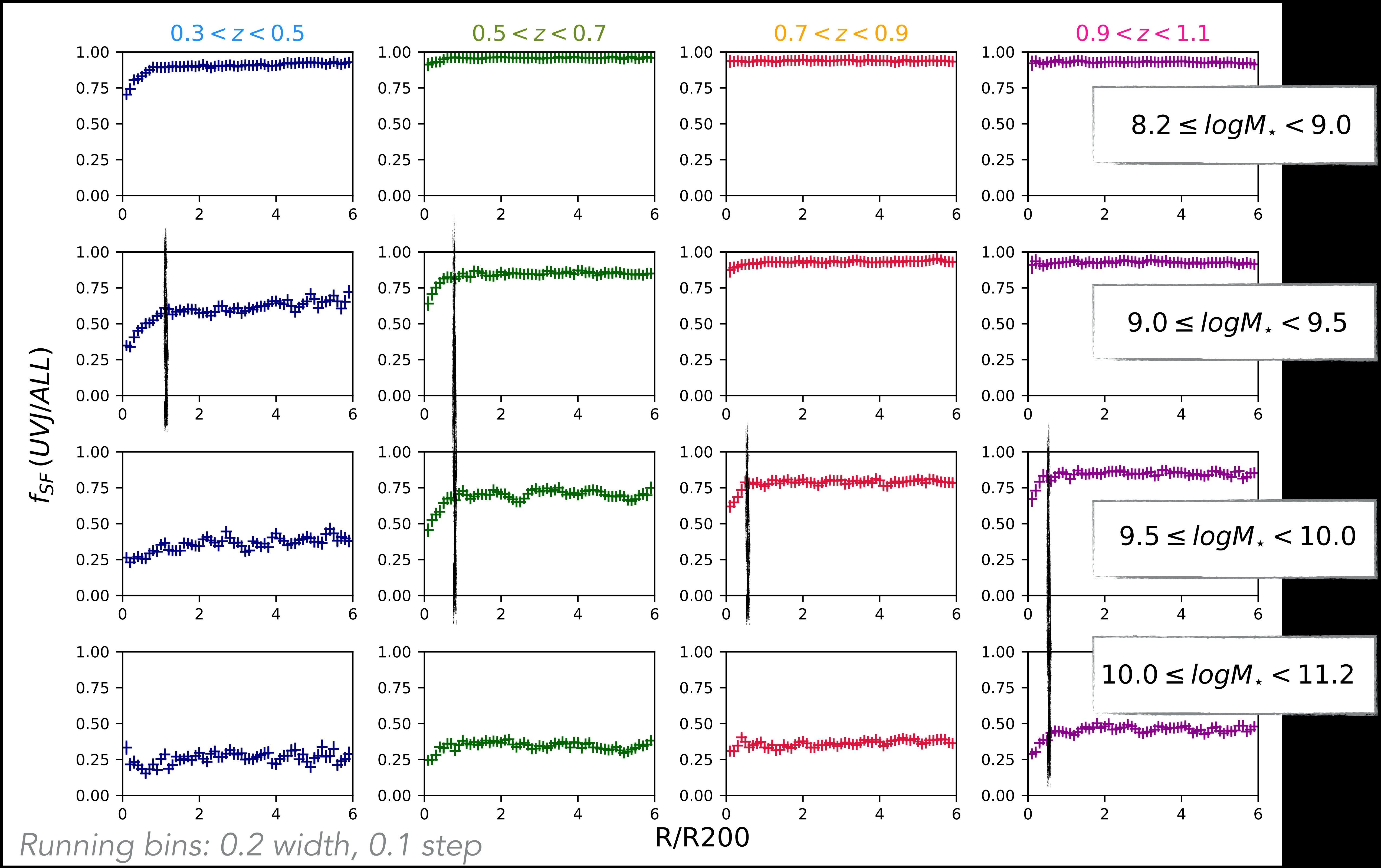


UVJ Star Forming Galaxies



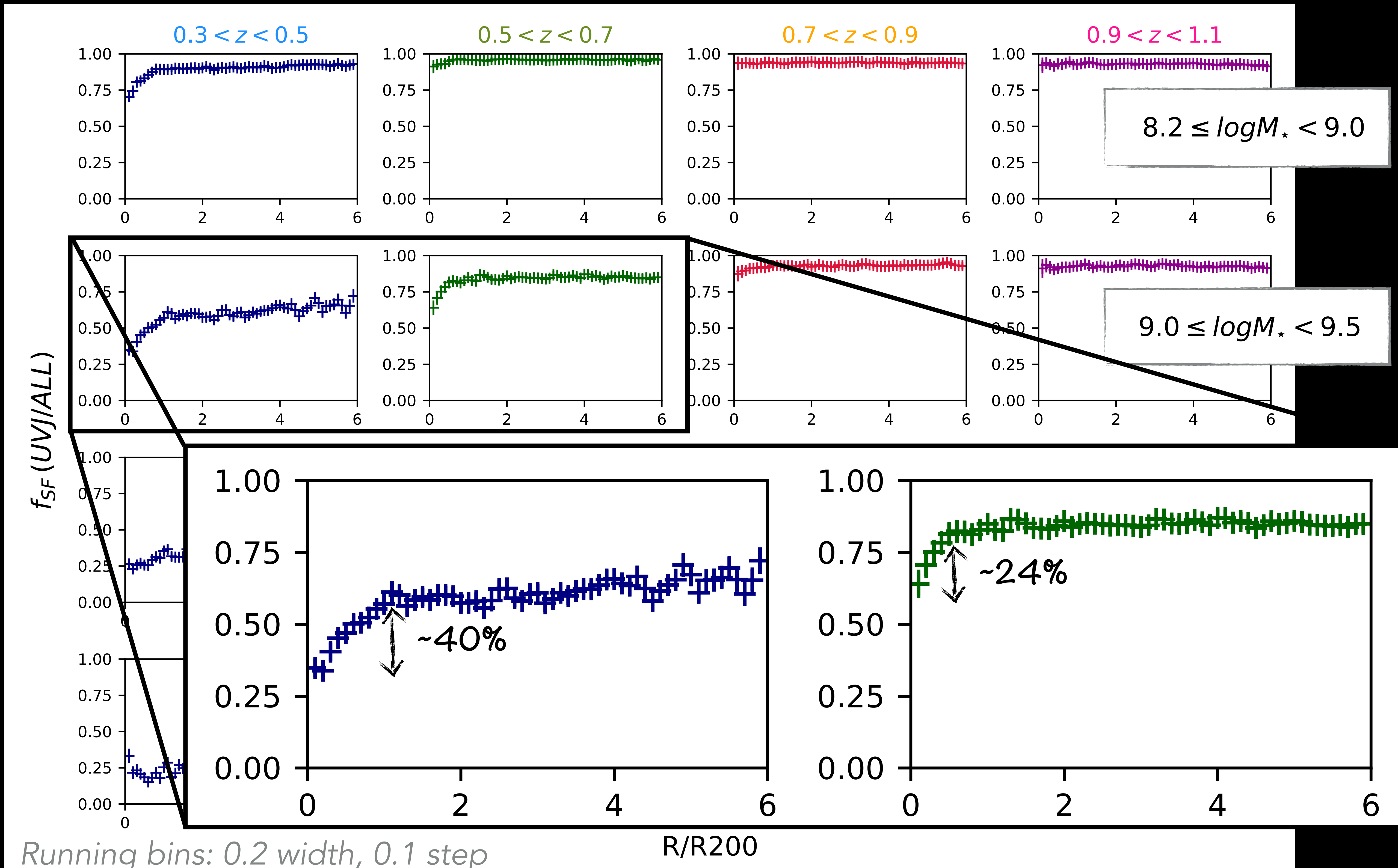
At a fixed z, the fraction decreases towards the high mass bin

UVJ Star Forming Galaxies



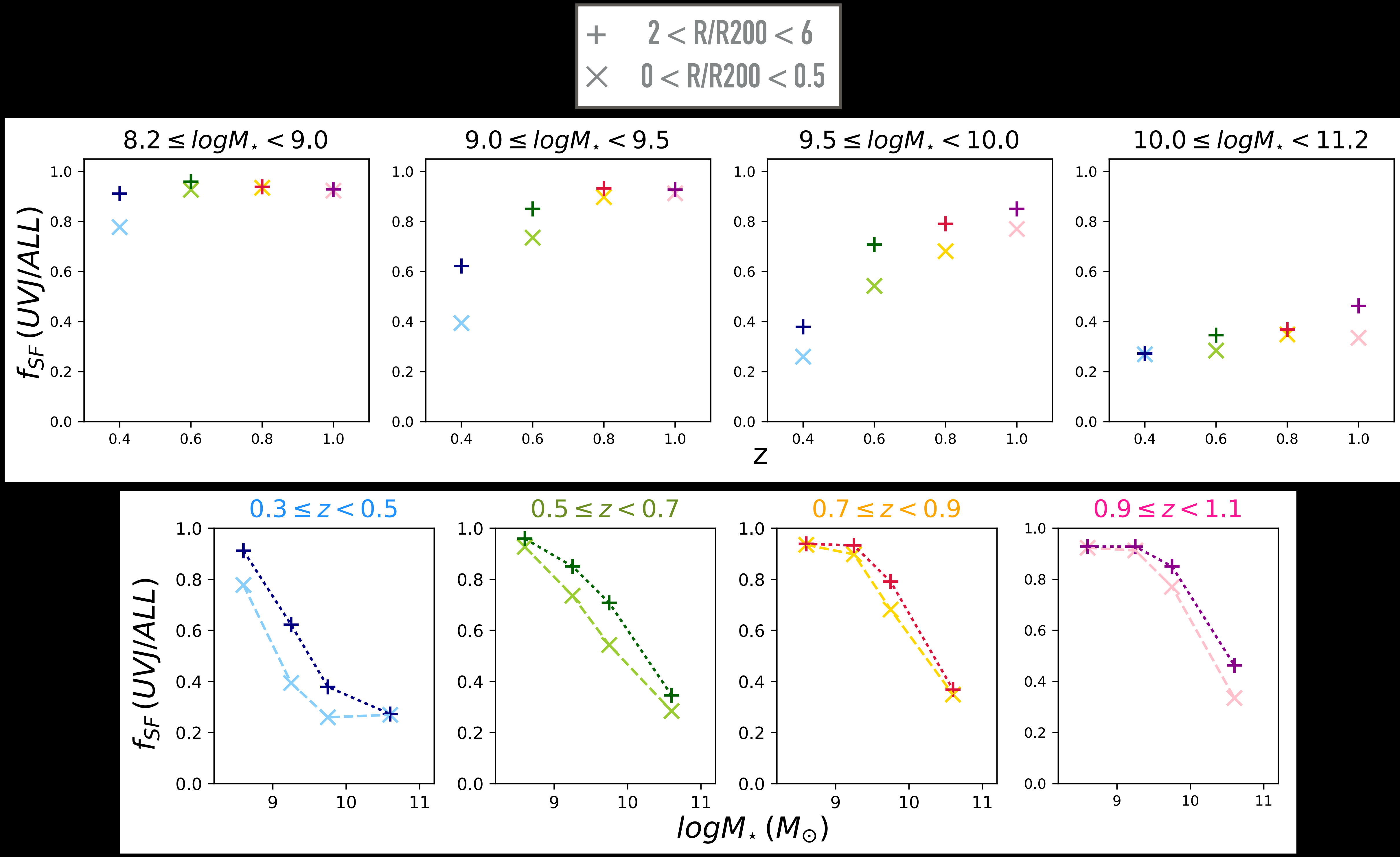
Decrement of $f_{SF\text{-}UVJ}$ begins *further* from the cluster core for lower z

UVJ Star Forming Galaxies



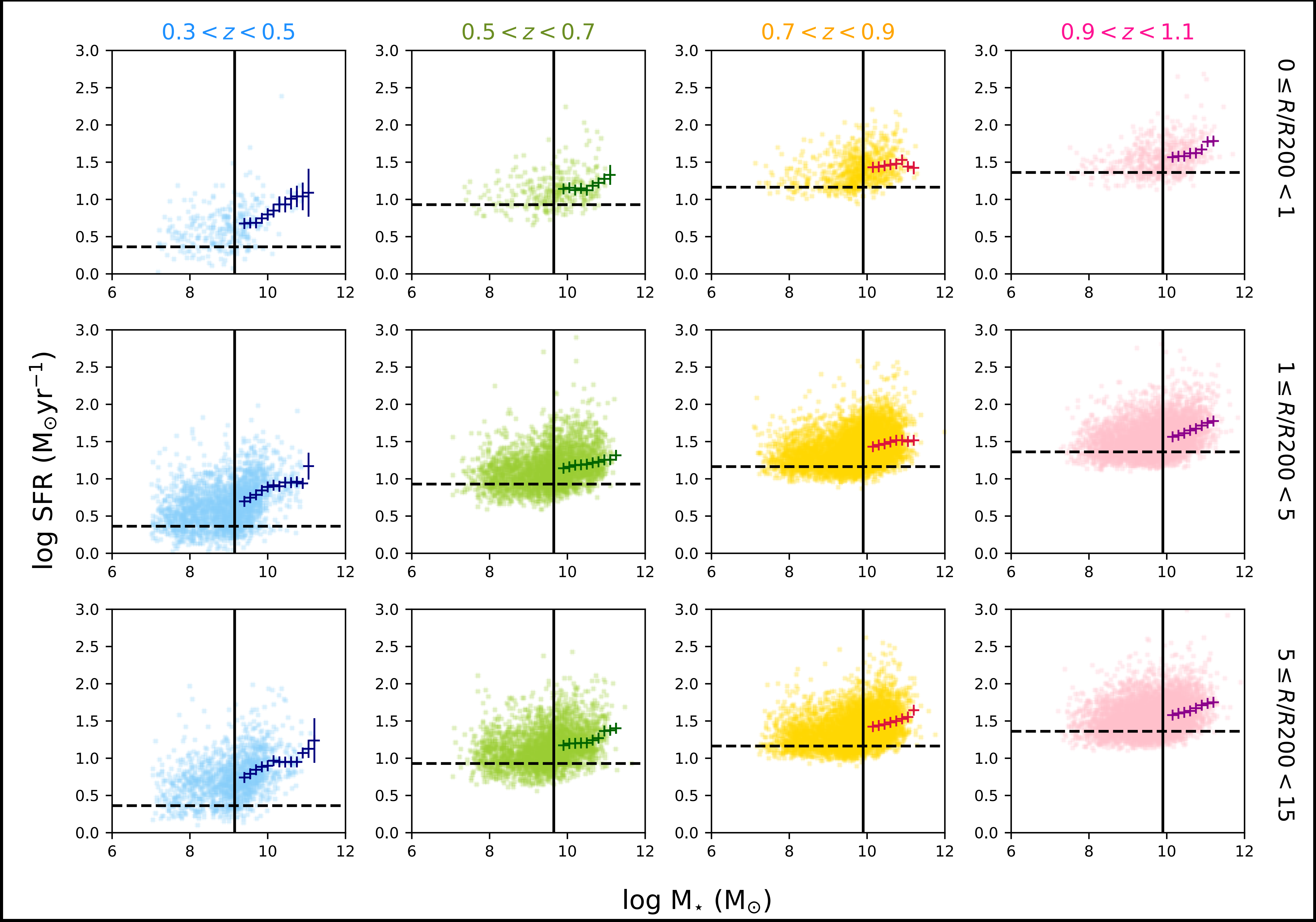
Decrement of f_{SF-UVJ} begins *further* from the cluster core and is *larger* for lower z

UVJ Star Forming Galaxies: B-O effect

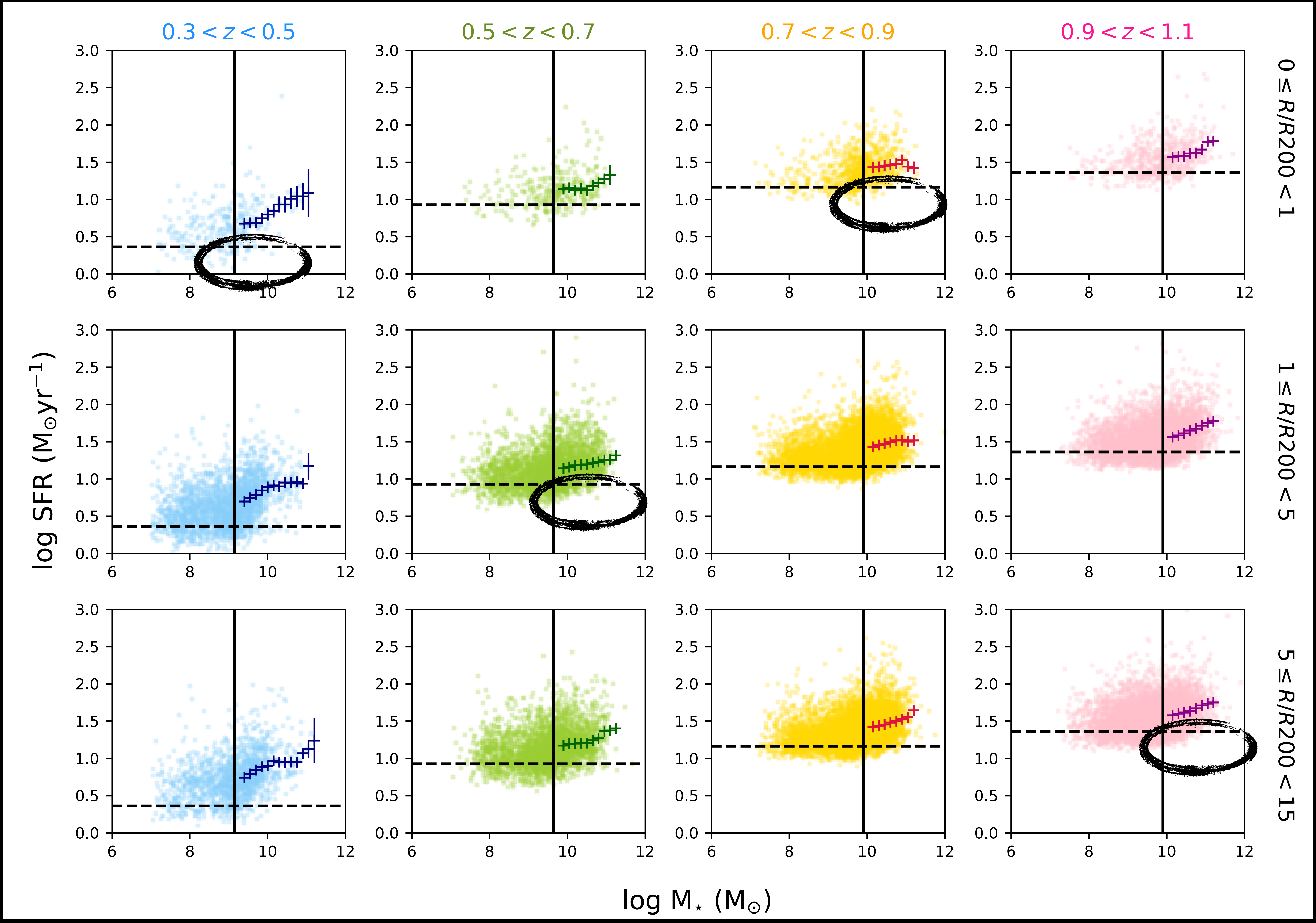


- *Faster* evolution for the 9-10 log $M_{\odot}$ stellar mass bin
- Quenching process *intensified* by the cluster core

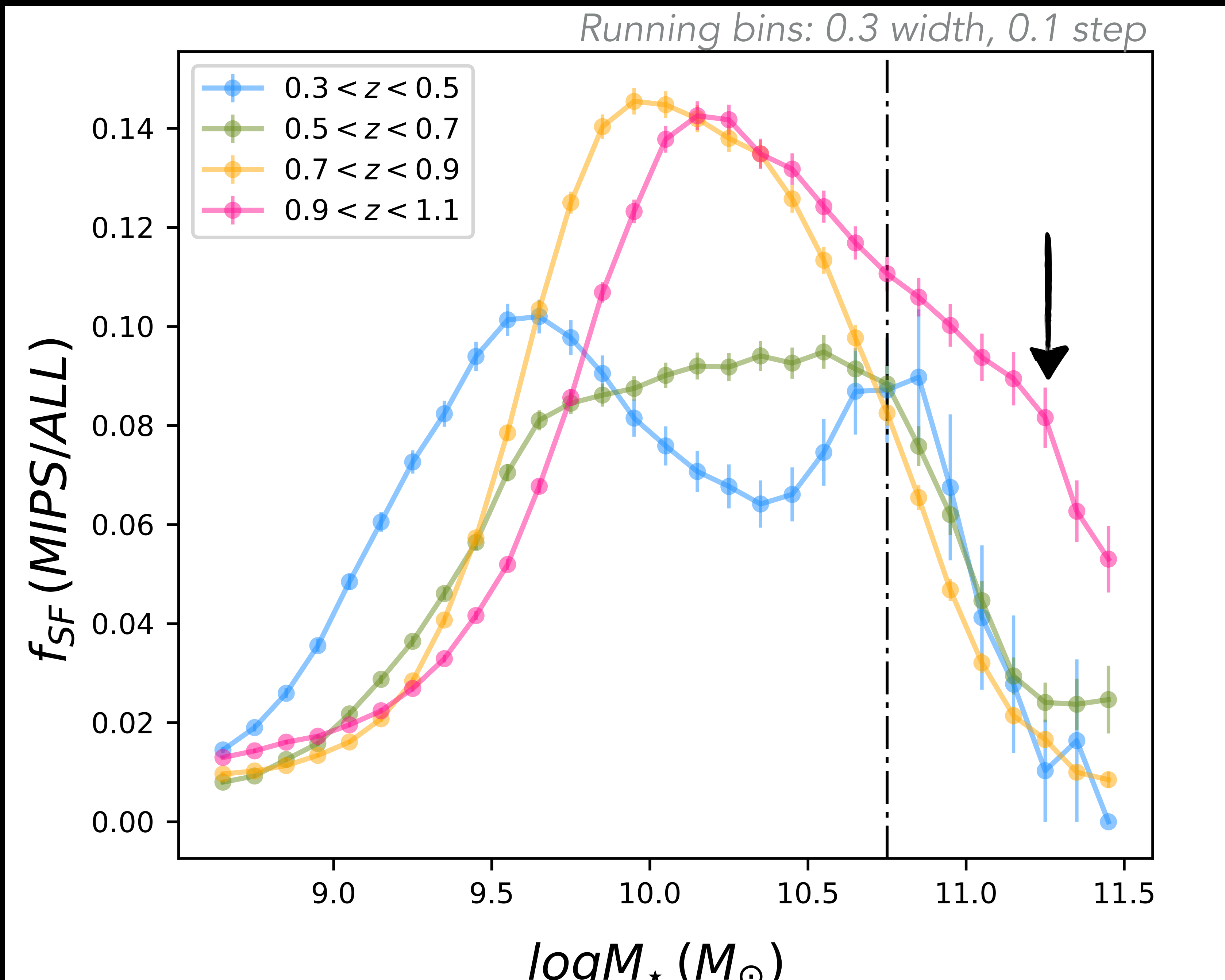
SF FROM MIPS 24μm: SFR vs M★



SF FROM MIPS 24μm: SFR vs M★

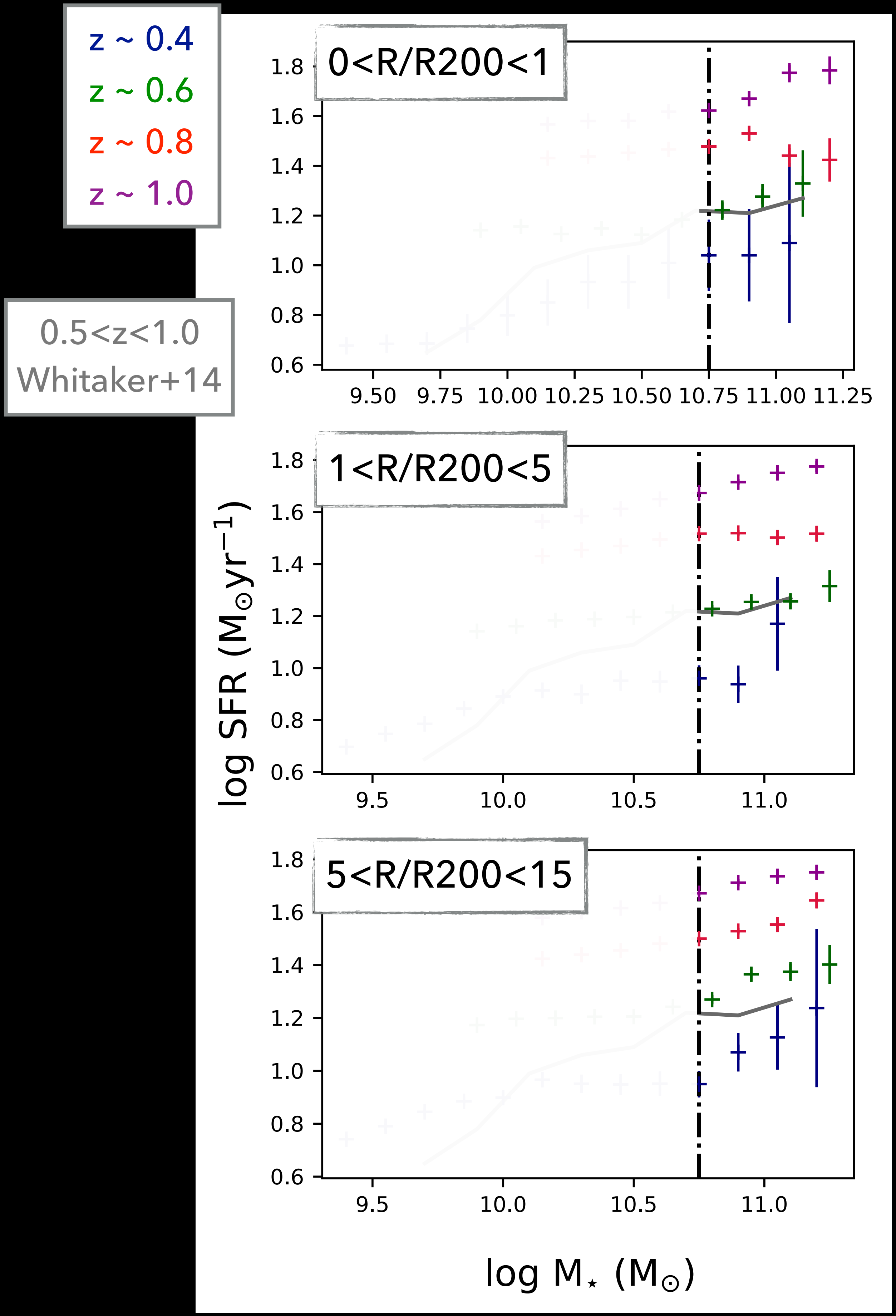


SF FROM MIPS 24µm: completeness?



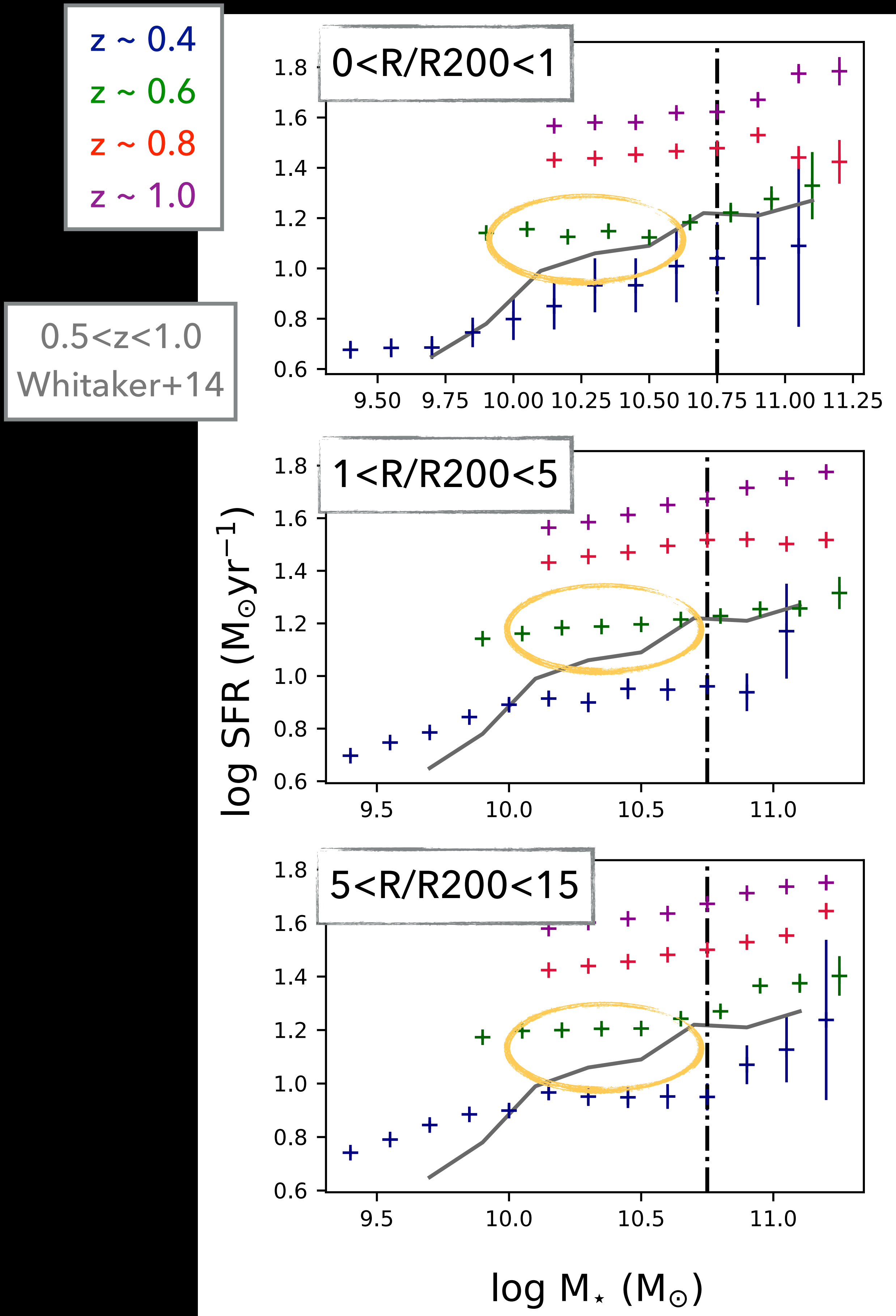
We may consider our sample to be complete down to *log M★~10.7 for clusters up to z~0.9*

SF FROM MIPS 24μm: SFR/sSFR vs $M_\star$



For *z~0.3 to 0.7* down to *logM⋆~10.7* we observe no dependency of the slope with the environment, with an average SFR larger for higher z which could be due to different depths

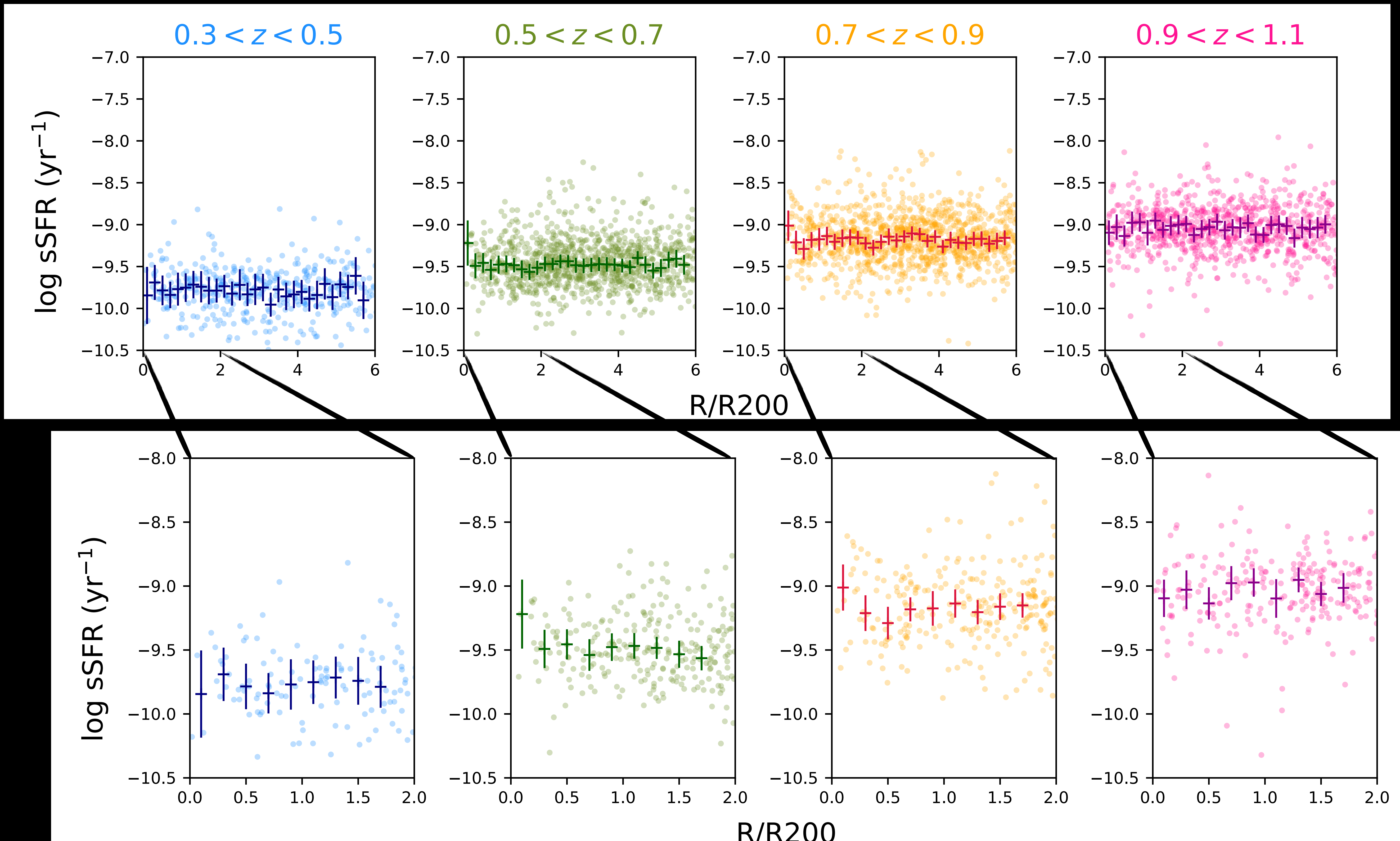
SF FROM MIPS 24μm: SFR/sSFR vs $M_\star$



For *z~0.3 to 0.7* down to *logM$_\star$~10.7* we observe no dependency of the slope with the environment, with an average SFR larger for higher z which could be due to different depths

MIPS 24μm stacking essential to study *low mass* galaxies

SF FROM MIPS 24μm: SFR/sSFR vs M★



No significant trend with the environment found for the sSFR

Summary

- We are using SpARCS $0.1<z<1.1$ clusters in ELAIS-N1 and XMM-LSS fields to study the quenching/enhancement of the star formation activity in a sample sufficiently large enough to control intrinsic properties of galaxies
- We exploit public data from HSC SSP, UKIDSS, and SWIRE
- We built a catalogue with 228 clusters, 2.6 million galaxies, >200,000 cluster members, ~85,000 MIPS 24μm sources
- We found important to normalize R by R200 to study the effect of the environment
- The fraction of UVJ SF galaxies shows a drop towards the cluster centre which begins further from the core and is larger for the lower z. The evolution of this fraction is faster for intermediate mass galaxies (log $M_\star$~ 9-10) and the cluster boosts the quenching once the process is active
- For studying the SFR we are limited to log $M_\star$ = 10.7; down to this value we observed no significant dependency with the environment. We are in the process of stacking MIPS 24μm sources to study low-mass SF galaxies