

# GROWING UP IN THE CITY: GALAXY POPULATIONS IN A $z \sim 3$ PROTOCLUSTER

ERNST KUIPER, LEIDEN OBSERVATORY

IN COLLABORATION WITH:

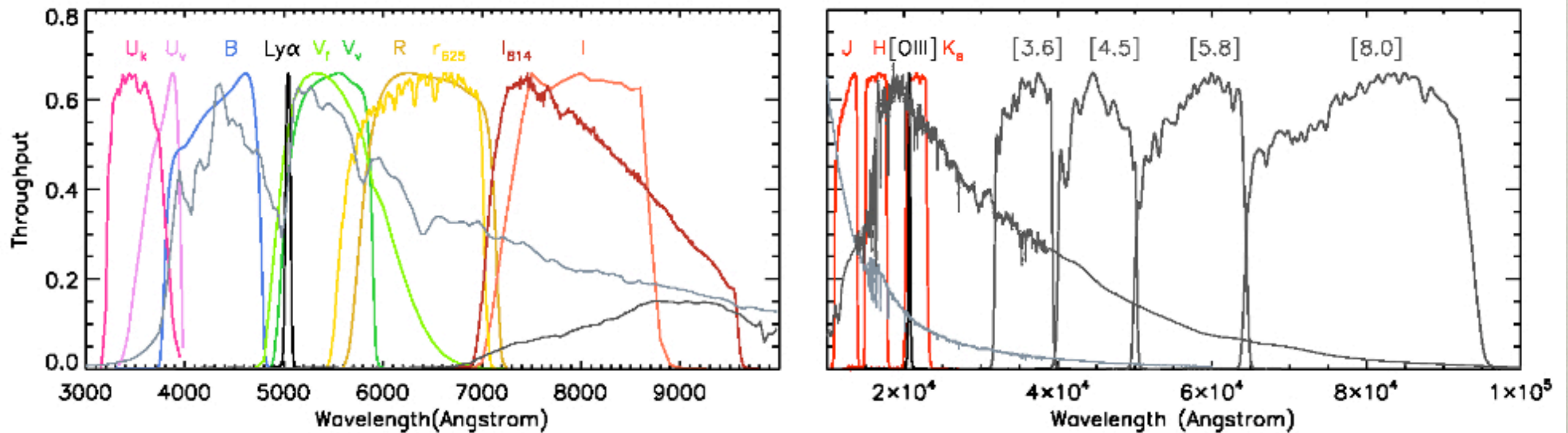
NINA HATCH, GEORGE MILEY, HUUB ROTTGERING, BRAM VENEMANS, RODERIK OVERZIER, CARLOS DE  
BREUCK, STEVE CROFT, MASARU KAJISAWA, TADAYUKI KODAMA, JARON KURK, LAURA PENTERICCI,  
ADAM STANFORD, ICHI TANAKA AND ANDREW ZIRM

GALAXY CLUSTERS IN THE EARLY UNIVERSE  
PUCÓN, CHILE  
9-12 NOVEMBER 2009



# THIS STUDY

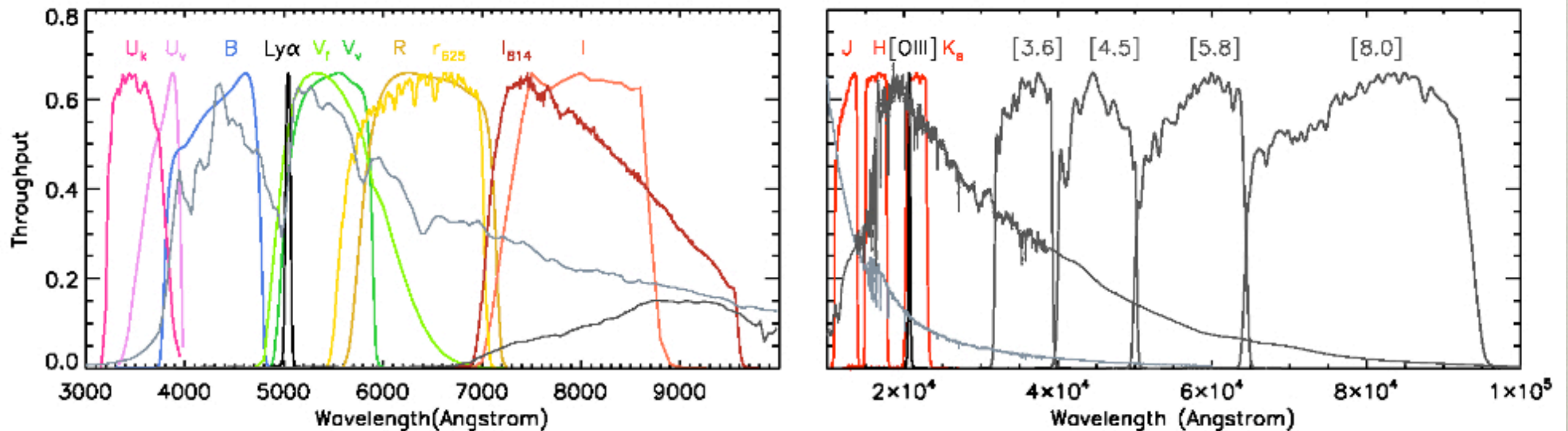
We use a large set of broadband images to study the galaxy populations in  $z=3.13$  protocluster around MRC 0316-257





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We use a large set of broadband images to study the galaxy populations in  $z=3.13$  protocluster around MRC 0316-257

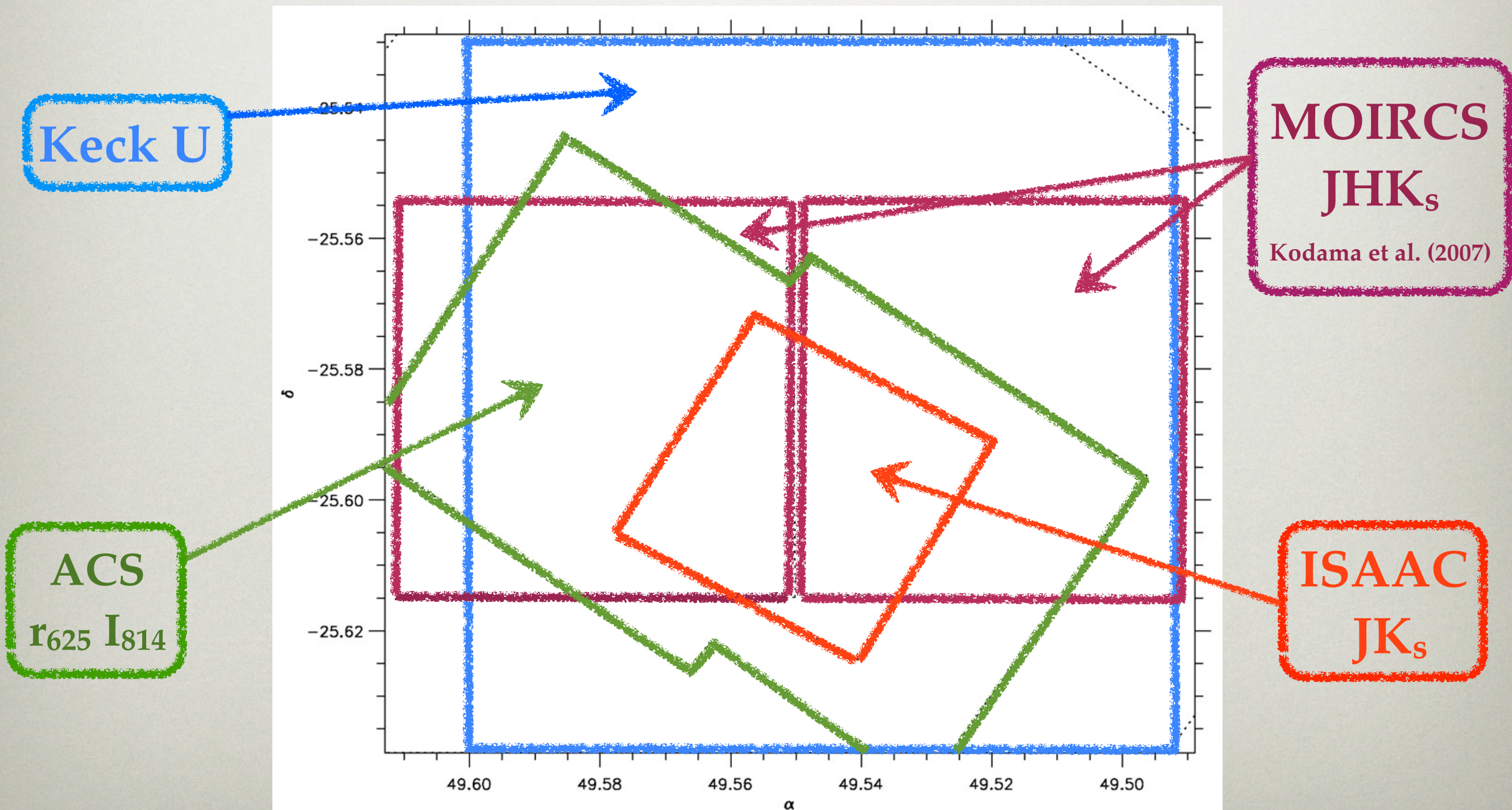


- Use both existing and newly identified galaxy samples
- Assess number densities. Overdensities?
- Are cluster galaxies different from the field at  $z \sim 3$ ?
- Correlations between position and galaxy properties?



# SAMPLE SELECTION

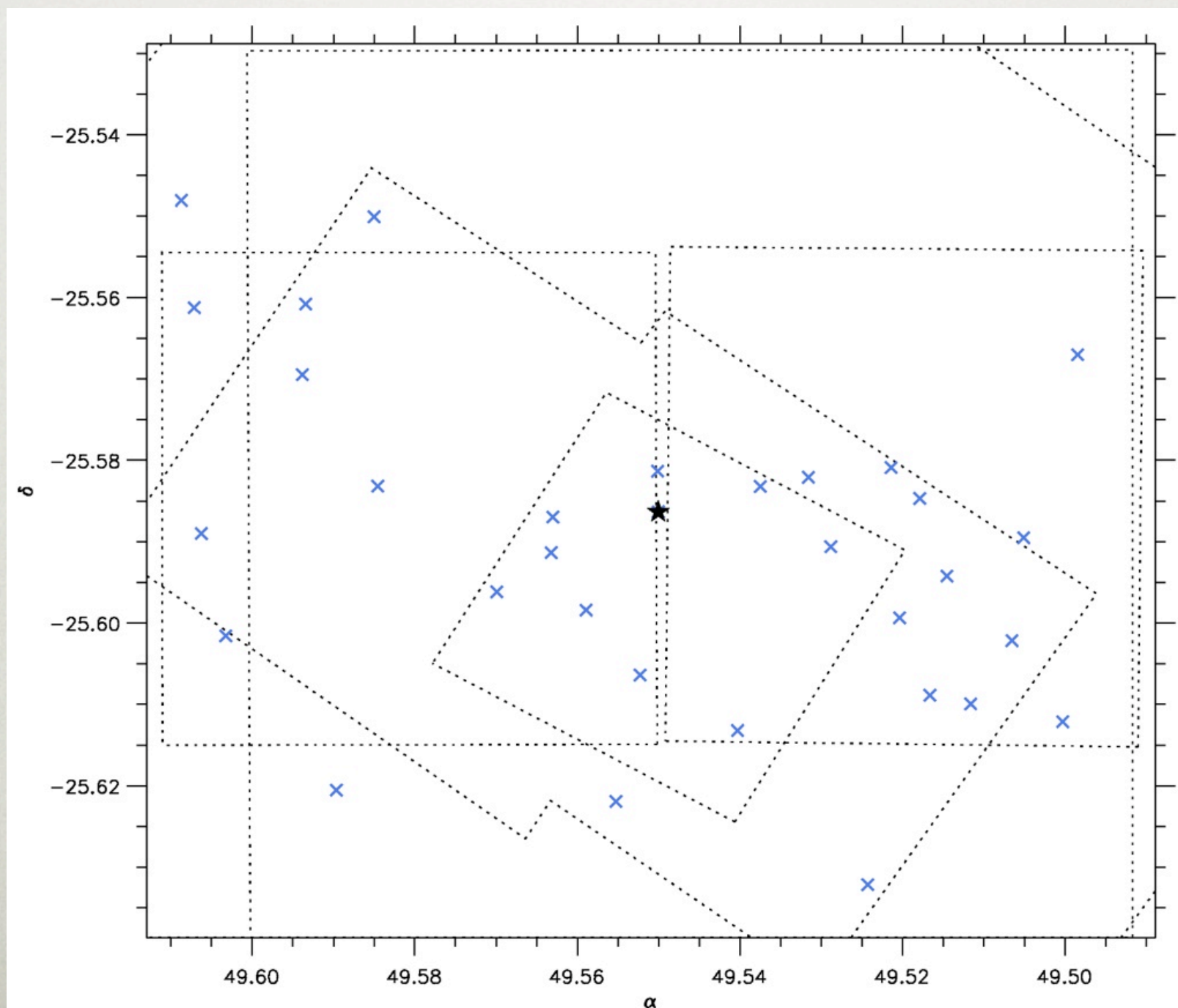
VIMOS UBVR and FORS I cover whole field,  
IRAC data cover all but the corners





# SAMPLE (1)

LAEs: 32 objects, all at the protocluster redshift  
factor 2-4 denser than the field,  
cluster mass of  $4-6 \times 10^{14} M_{\text{sun}}$  (Venemans et al. 2005)

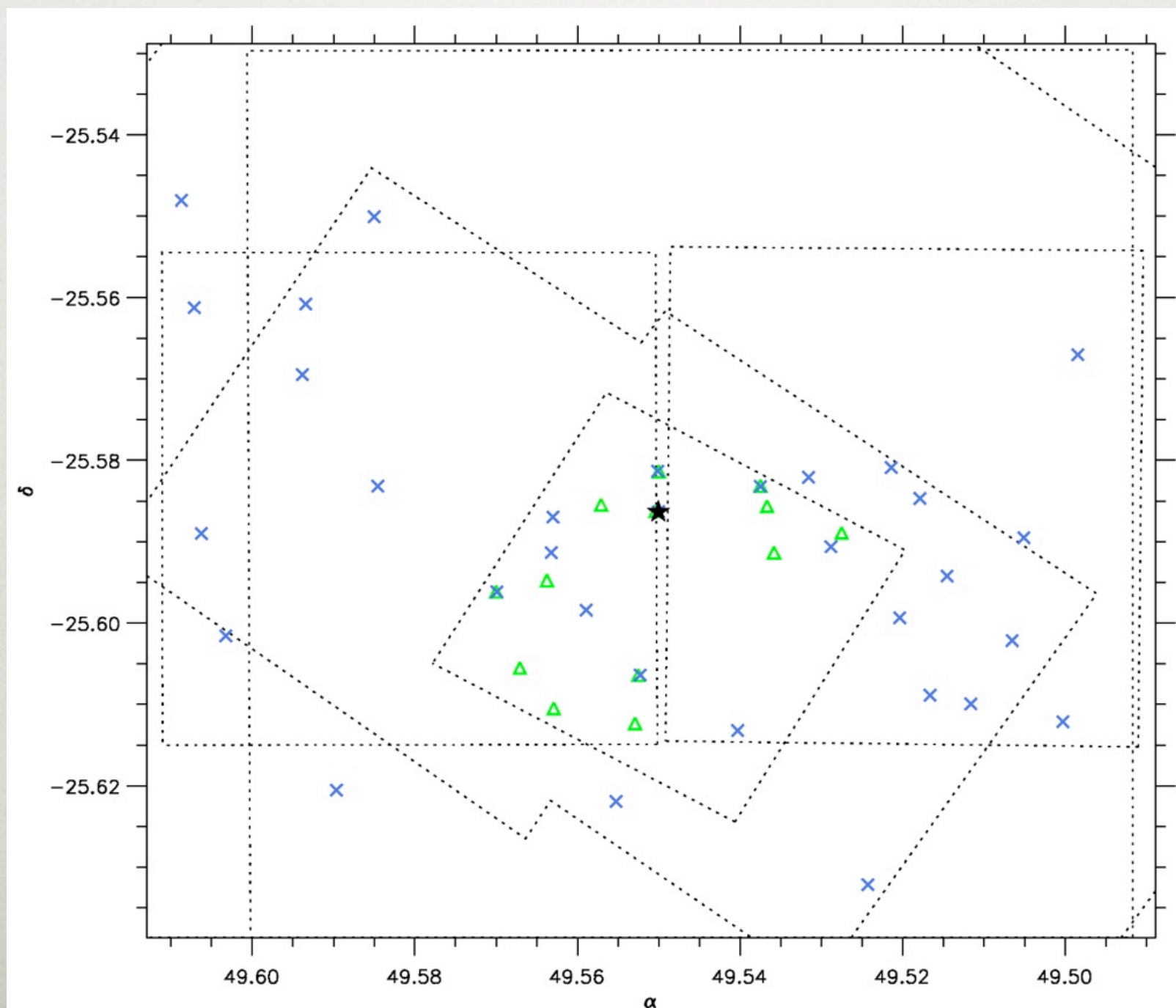




# SAMPLE (2)

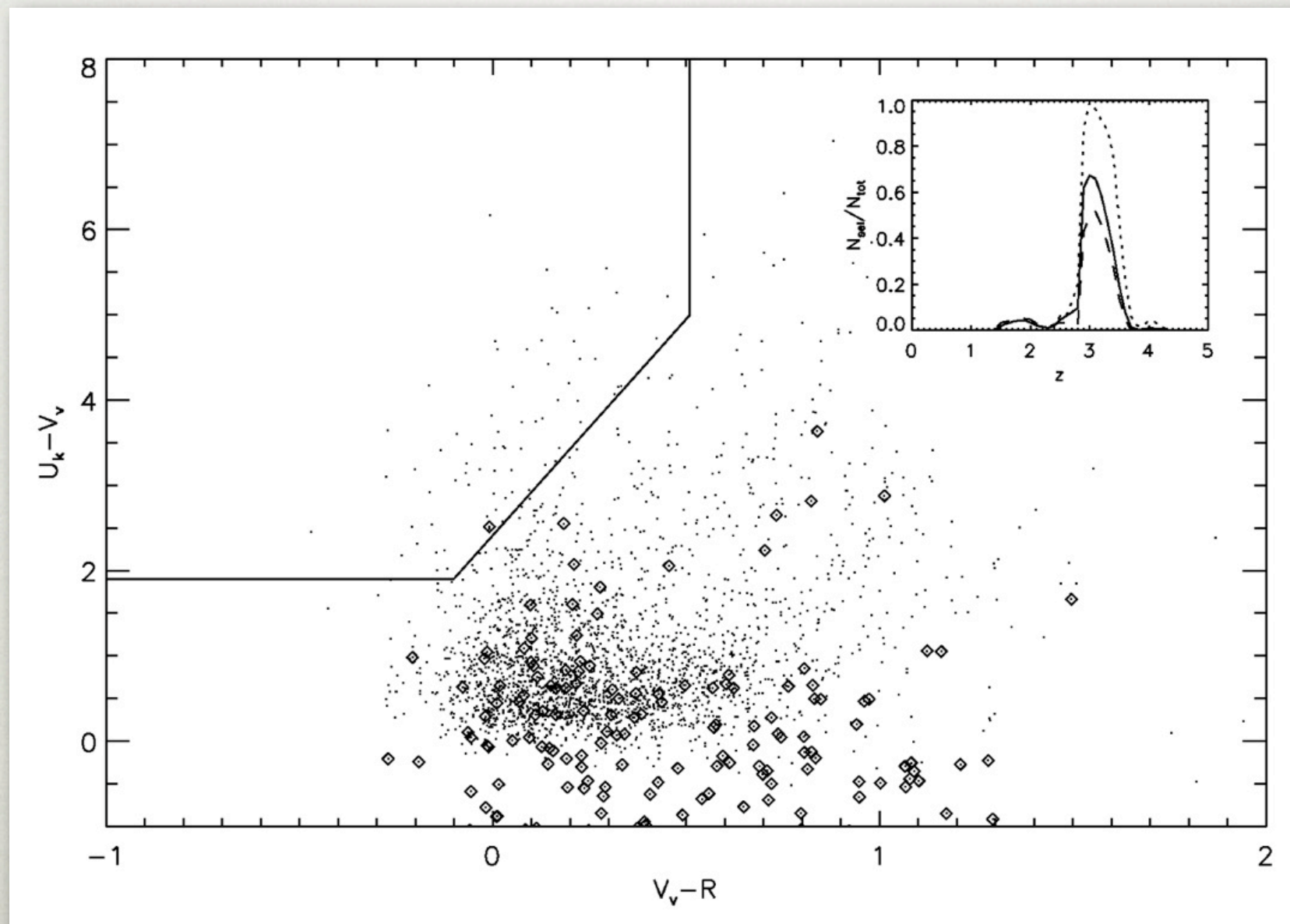
[OIII] emitters: 13 objects

5 LAEs, 5 without redshift and 3 @  $z=3.10$ ,  
possible superstructure? (Maschietto et al. 2008)





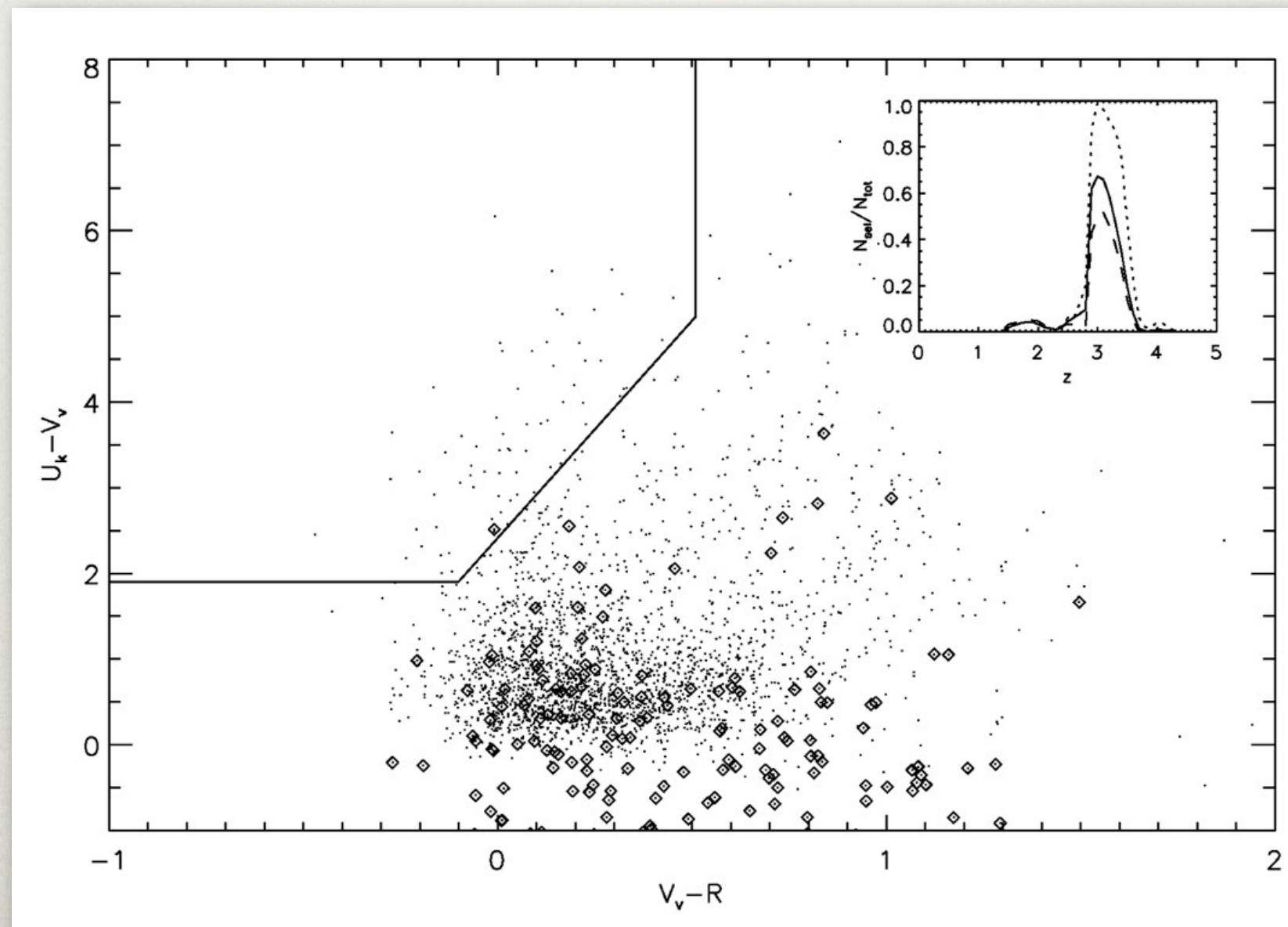
# SAMPLE (3)





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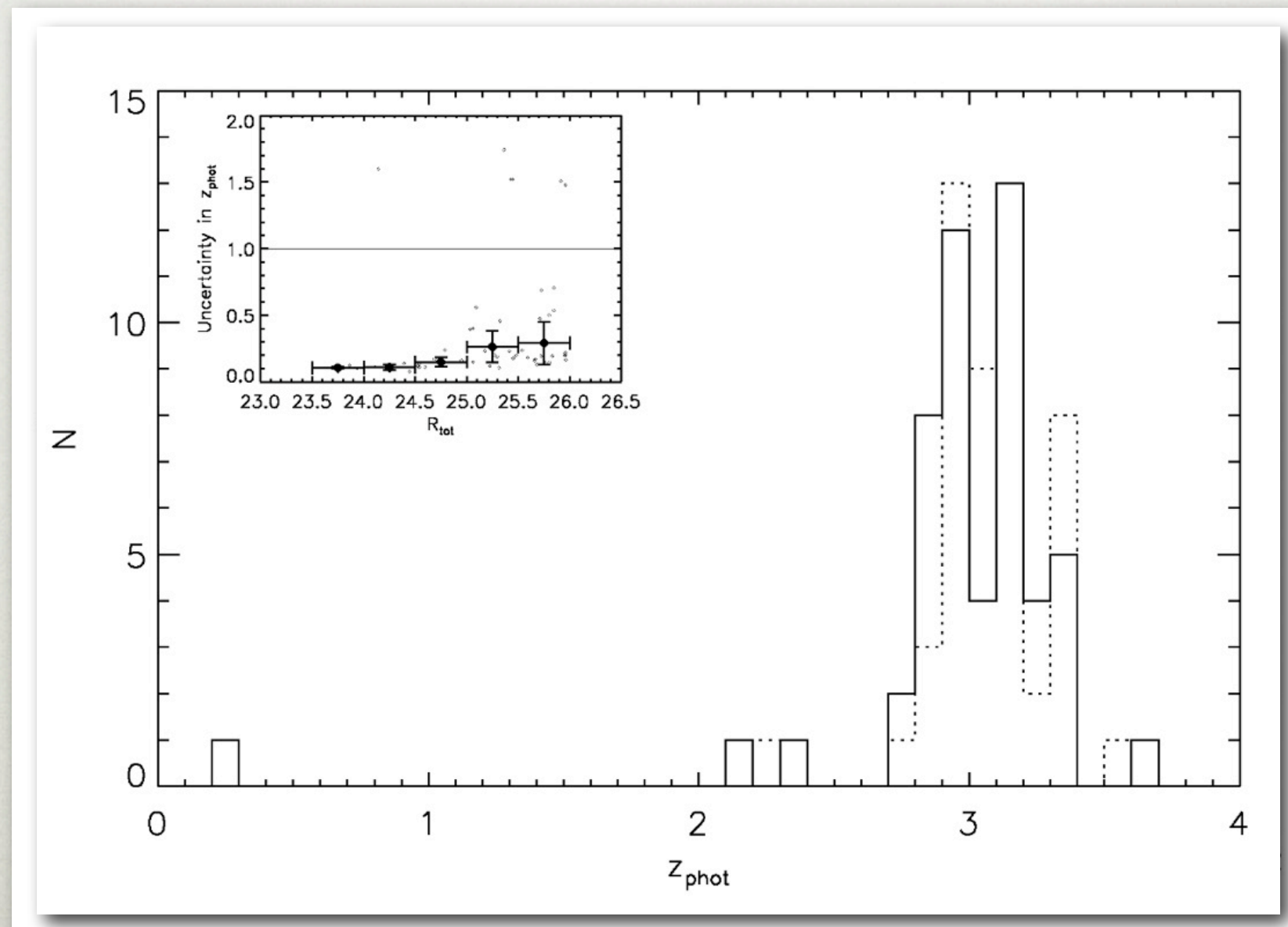
LBGs: Colour selection criterion based on BC03 models and photometric redshift determination (EAZY, Brammer et al. 2008)





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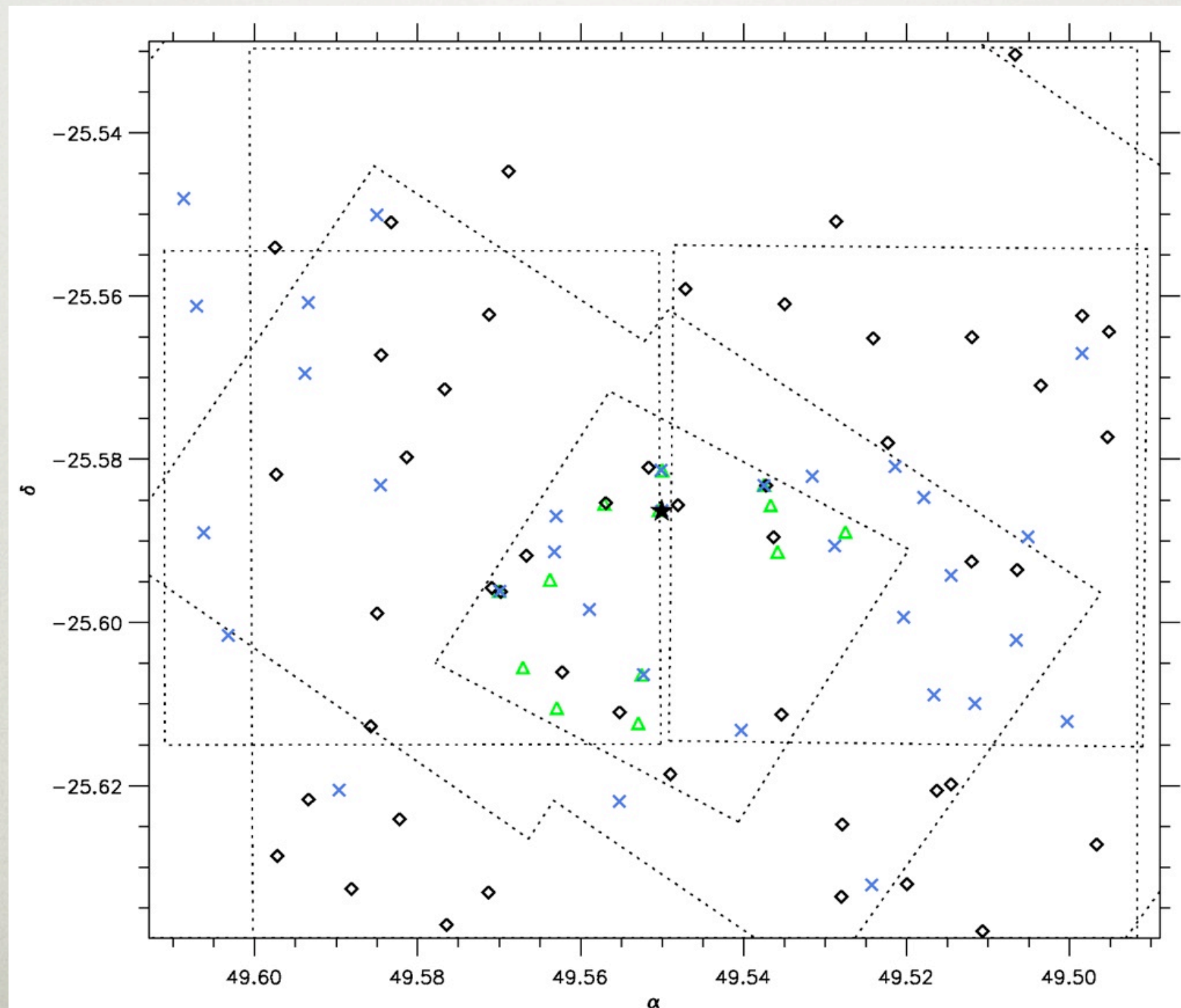
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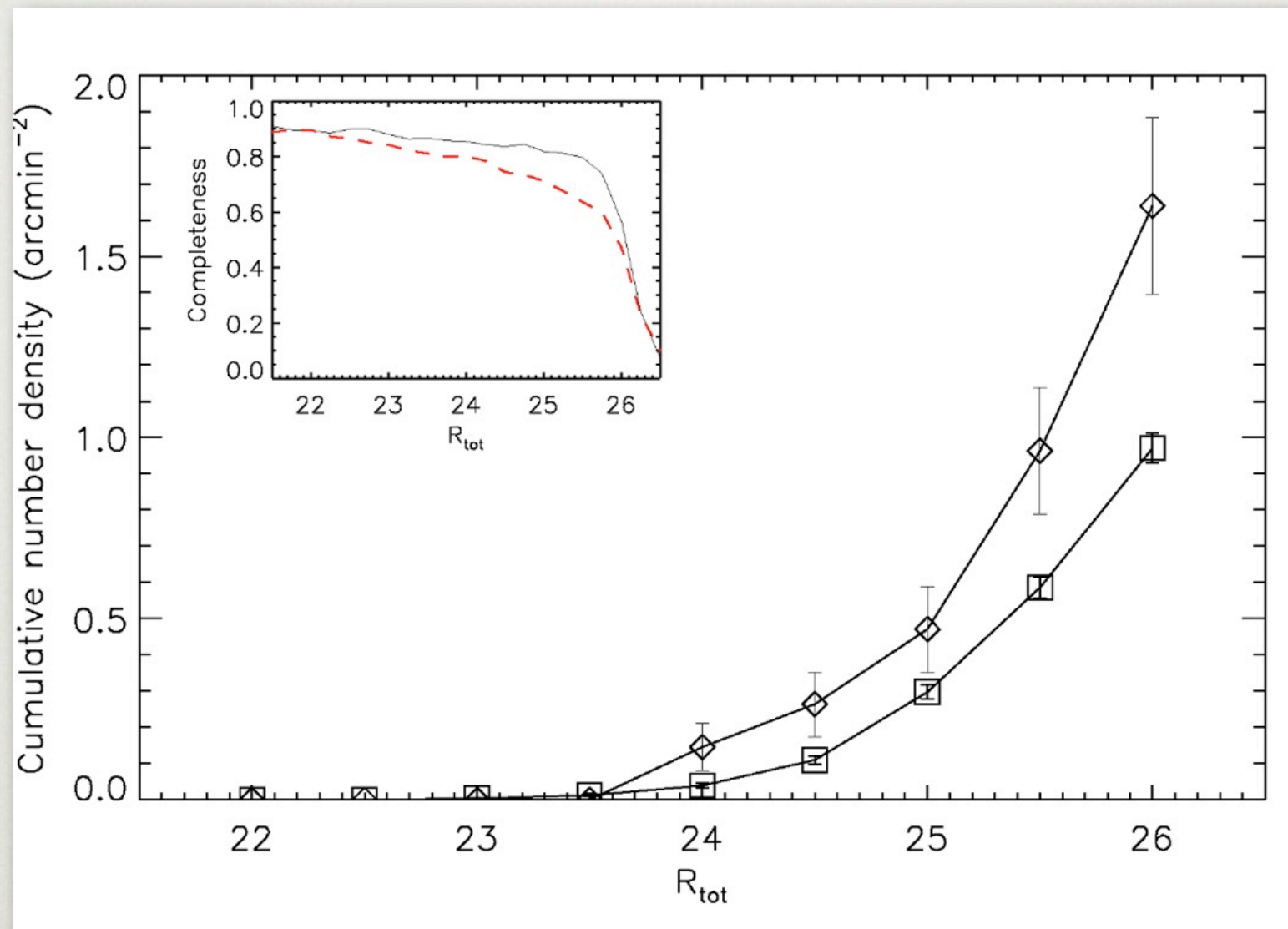
# SAMPLE (3)

LBGs: 48 objects with  $R < 26$  mag and  $2.7 < z_{\text{phot}} < 3.5$





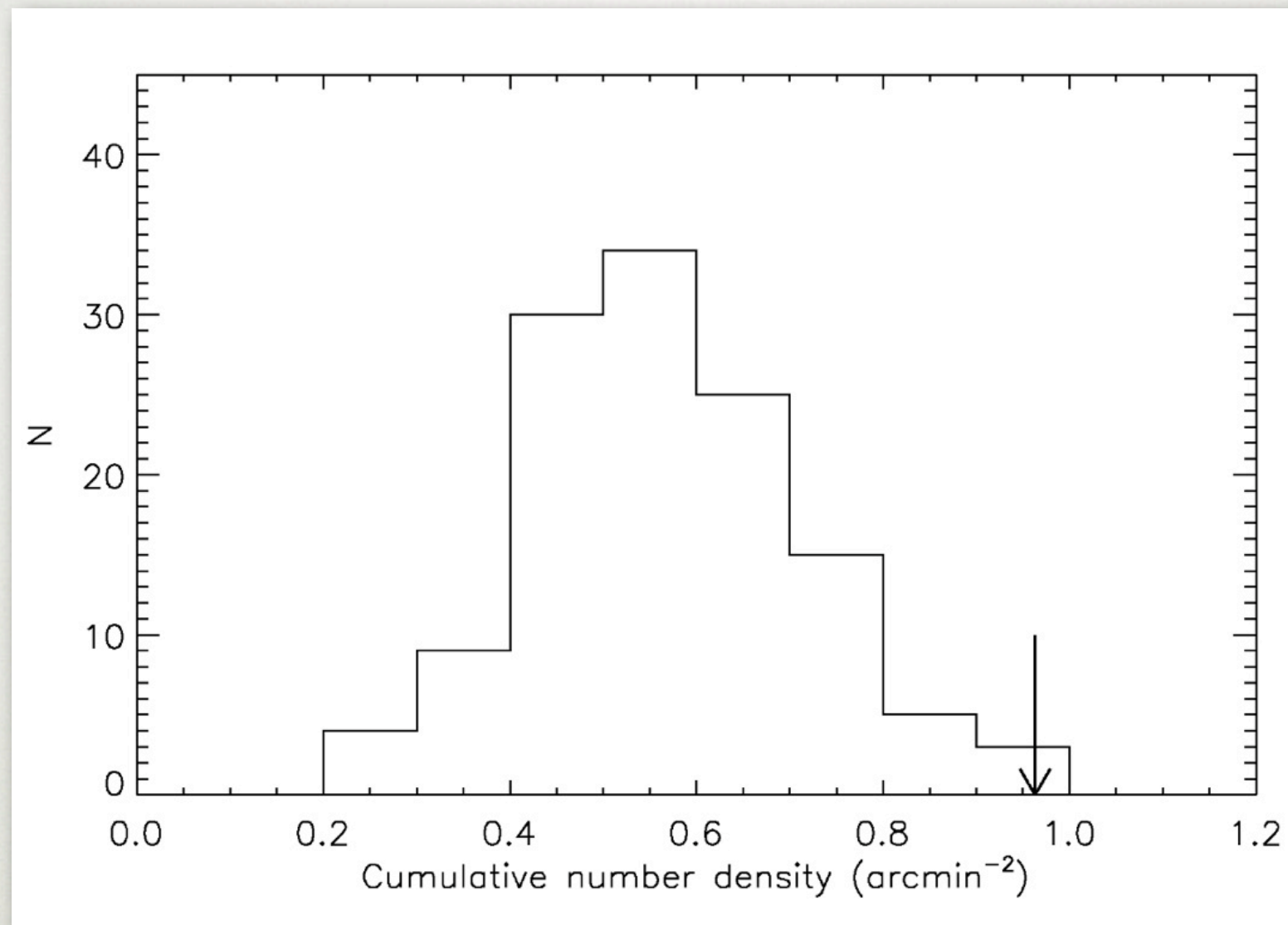
# OVERDENSITIES: LBGs



Comparison with the MUSYC ECDF-S shows that the 0316 field is denser in LBGs by a factor  $1.6 \pm 0.3$



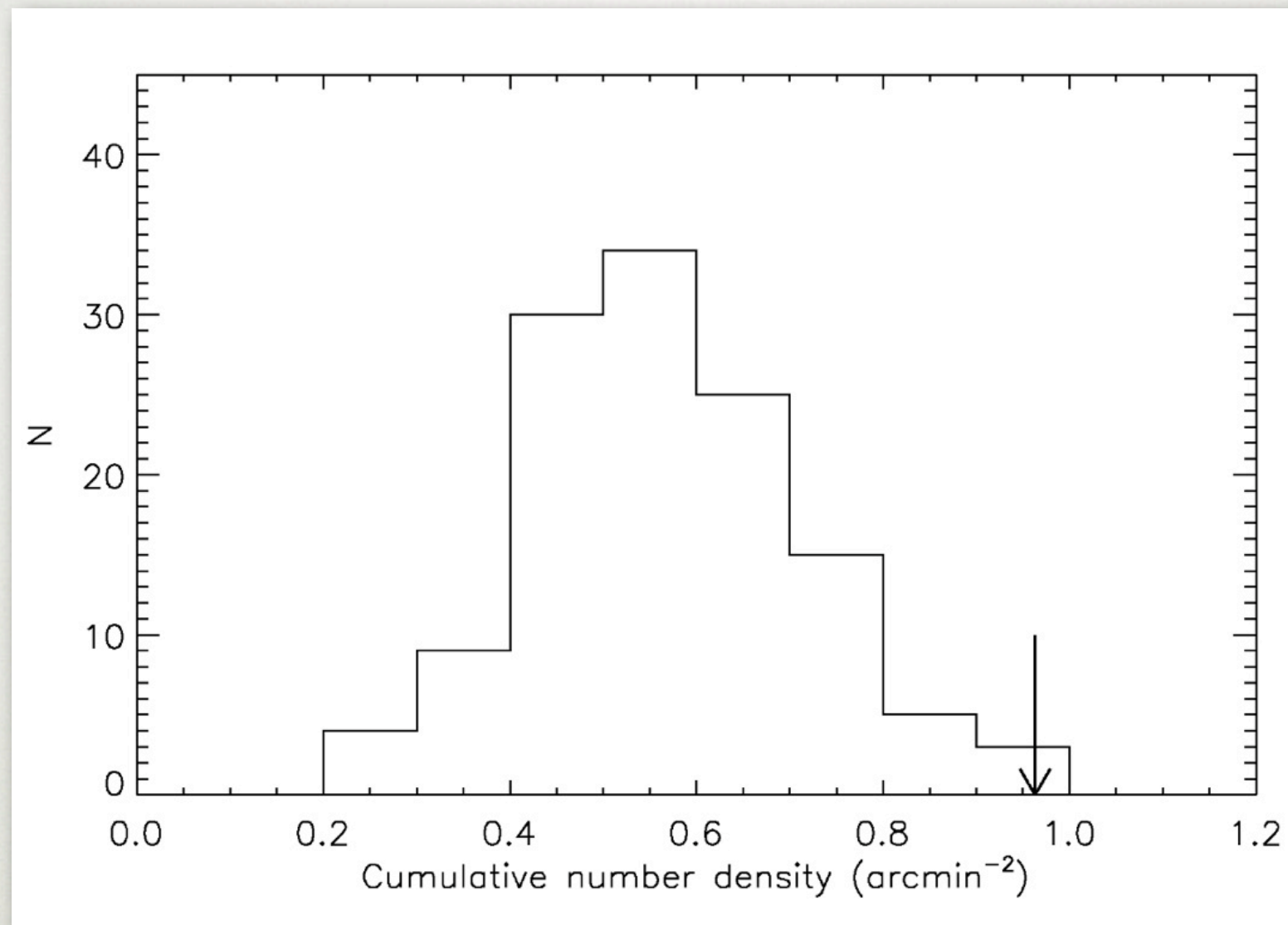
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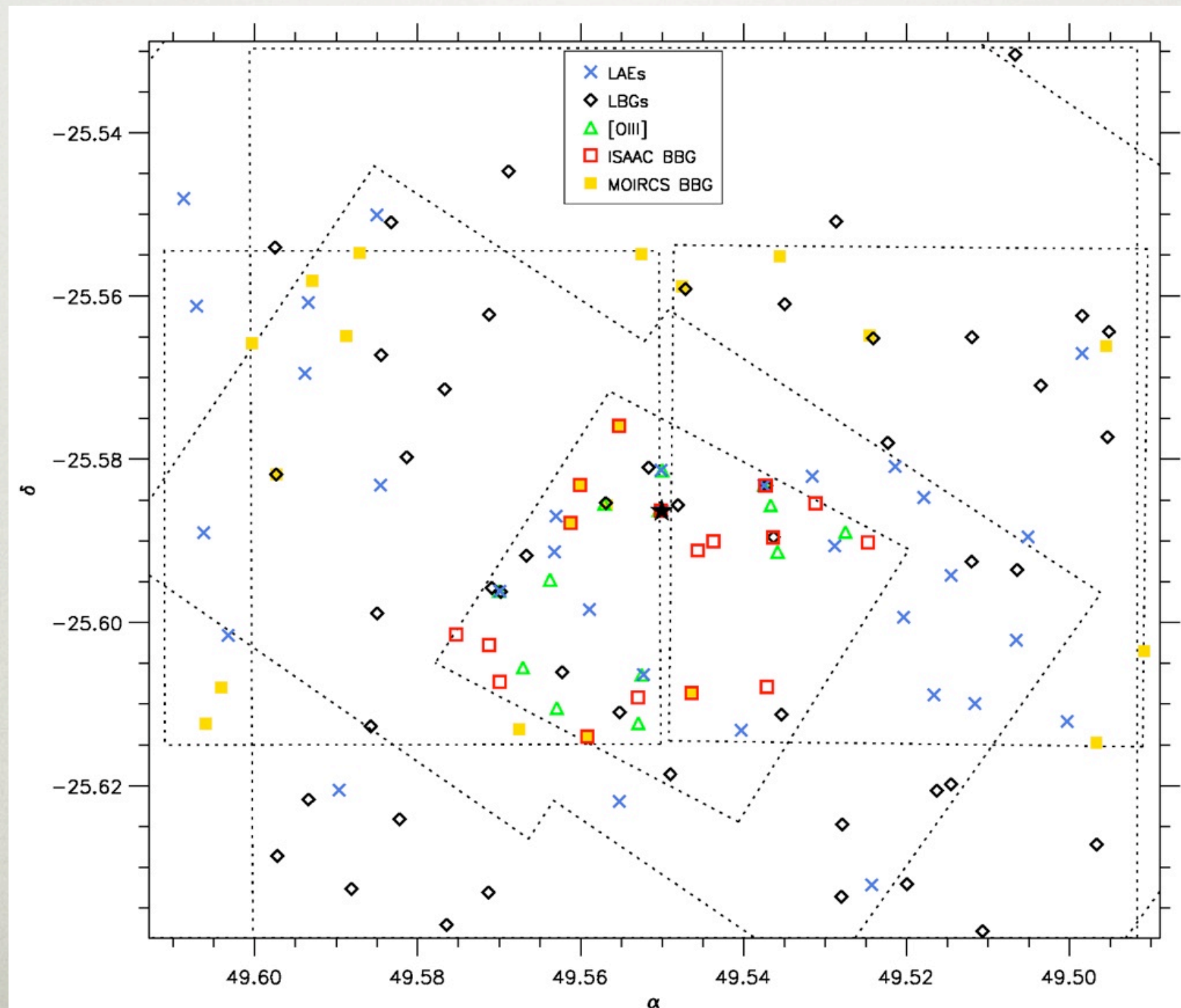
This indicates a volume density  $8 \pm 4$  times higher than the field

More evidence for a superstructure?



# SAMPLE (4)

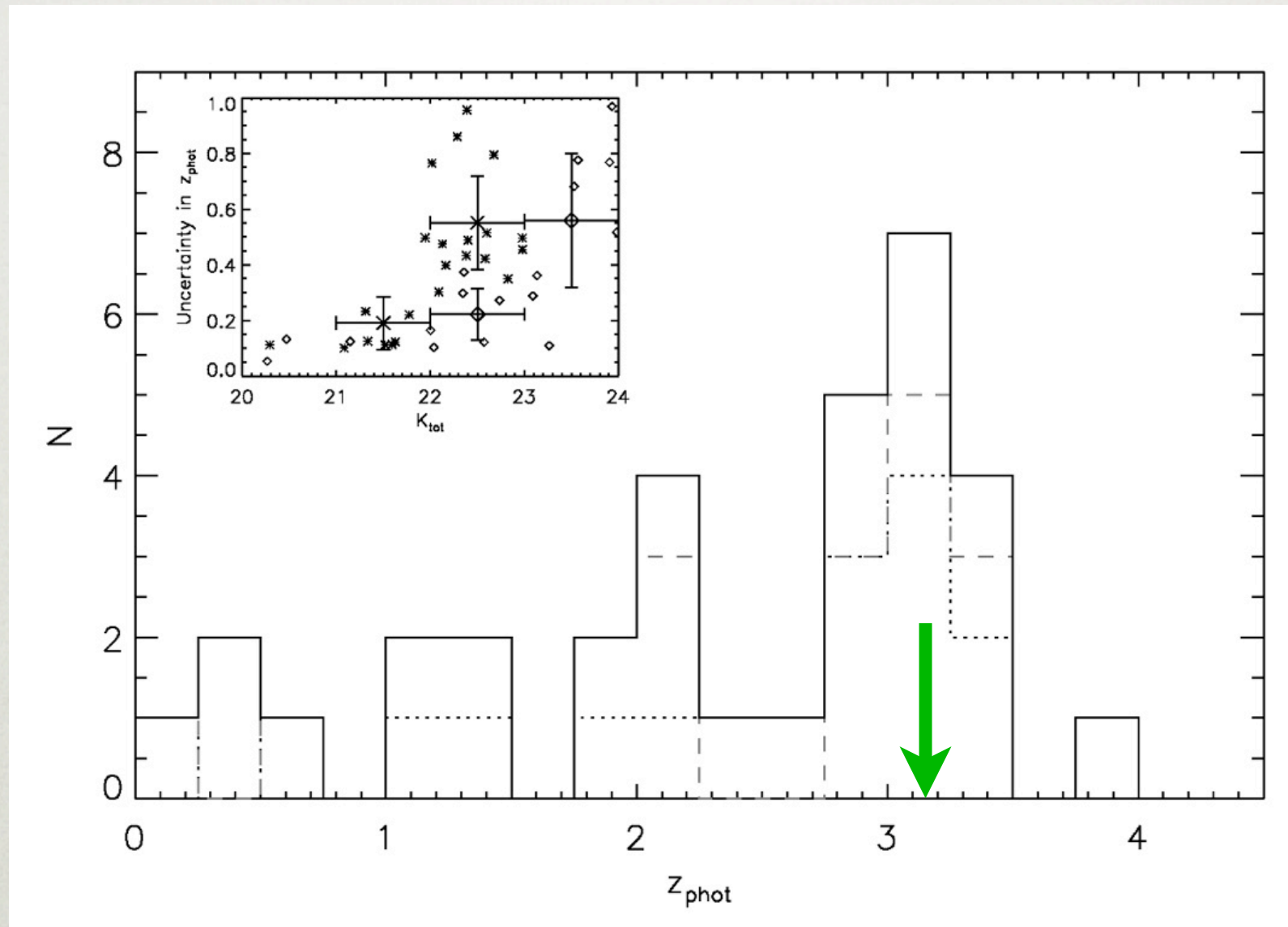
DRGs/BBGs (Franx et al. 2003): 17 from ISAAC with  $K_s < 24$  mag and 23 from MOIRCS with  $K_s < 23$  mag





# SAMPLE (4)

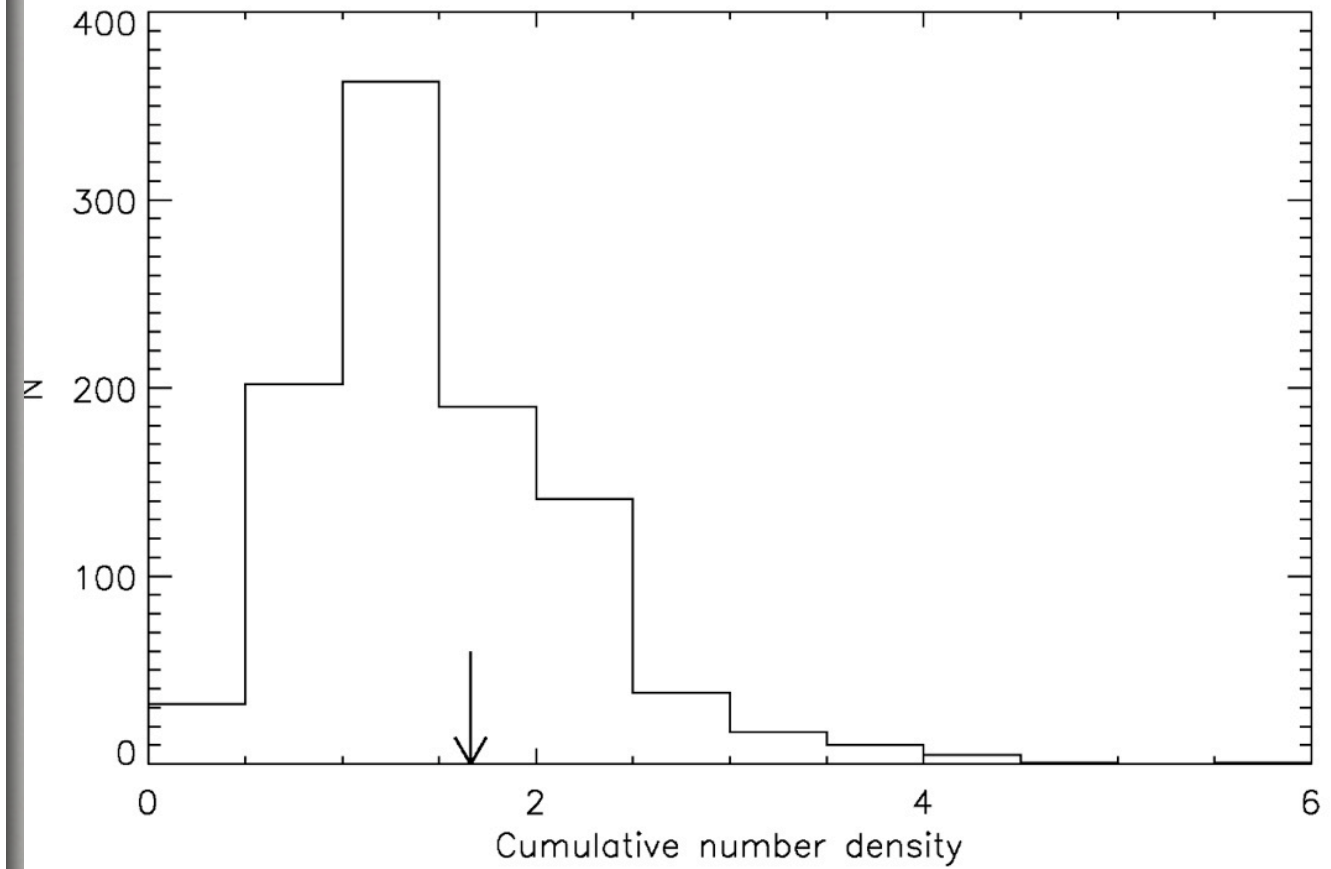
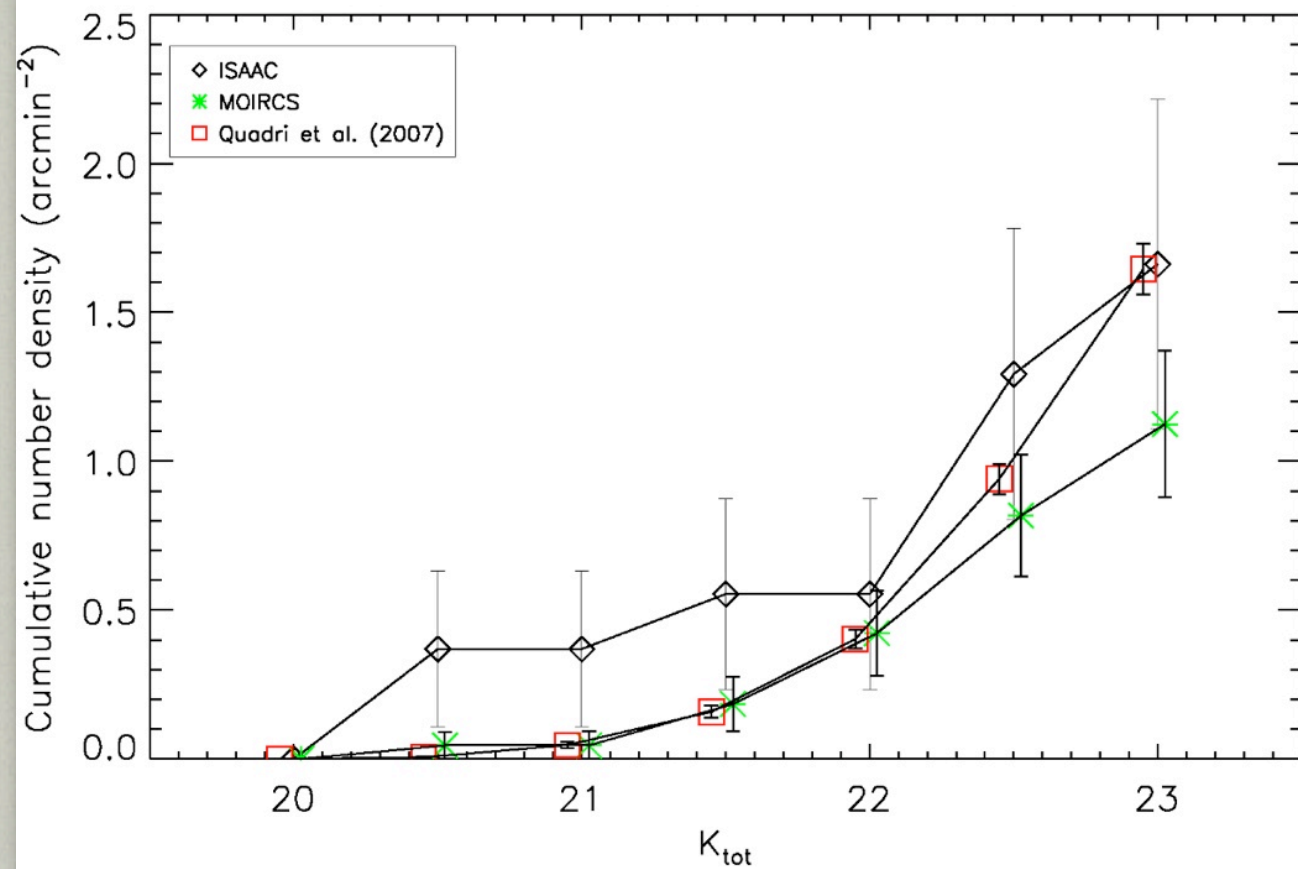
$z_{\text{phot}}$  distribution shows peak at  $z=3.13 \rightarrow$  overdensity?



Differs from the Grazian et al. (2008)  $z_{\text{phot}}$  distribution at the  $3\sigma$  level.



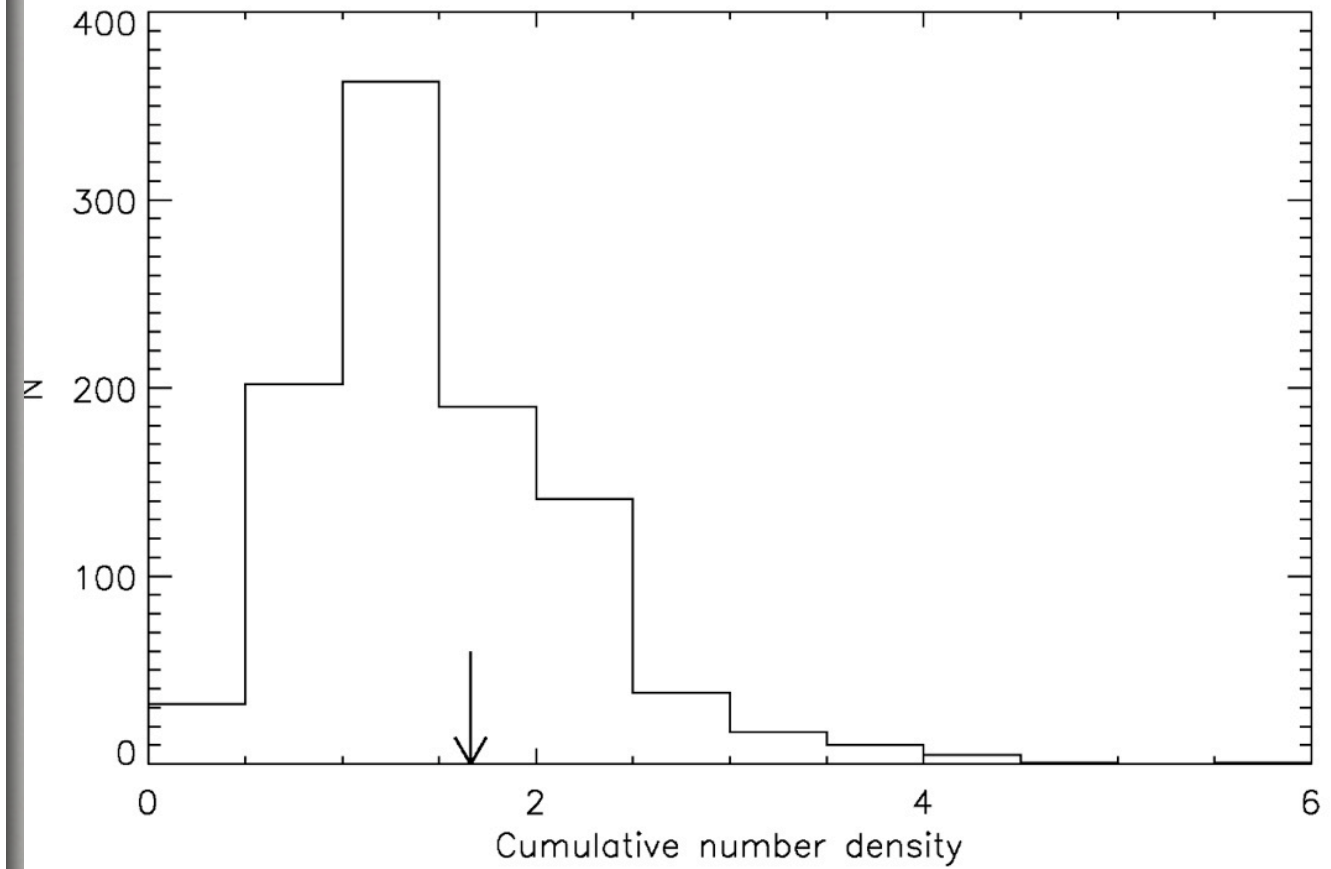
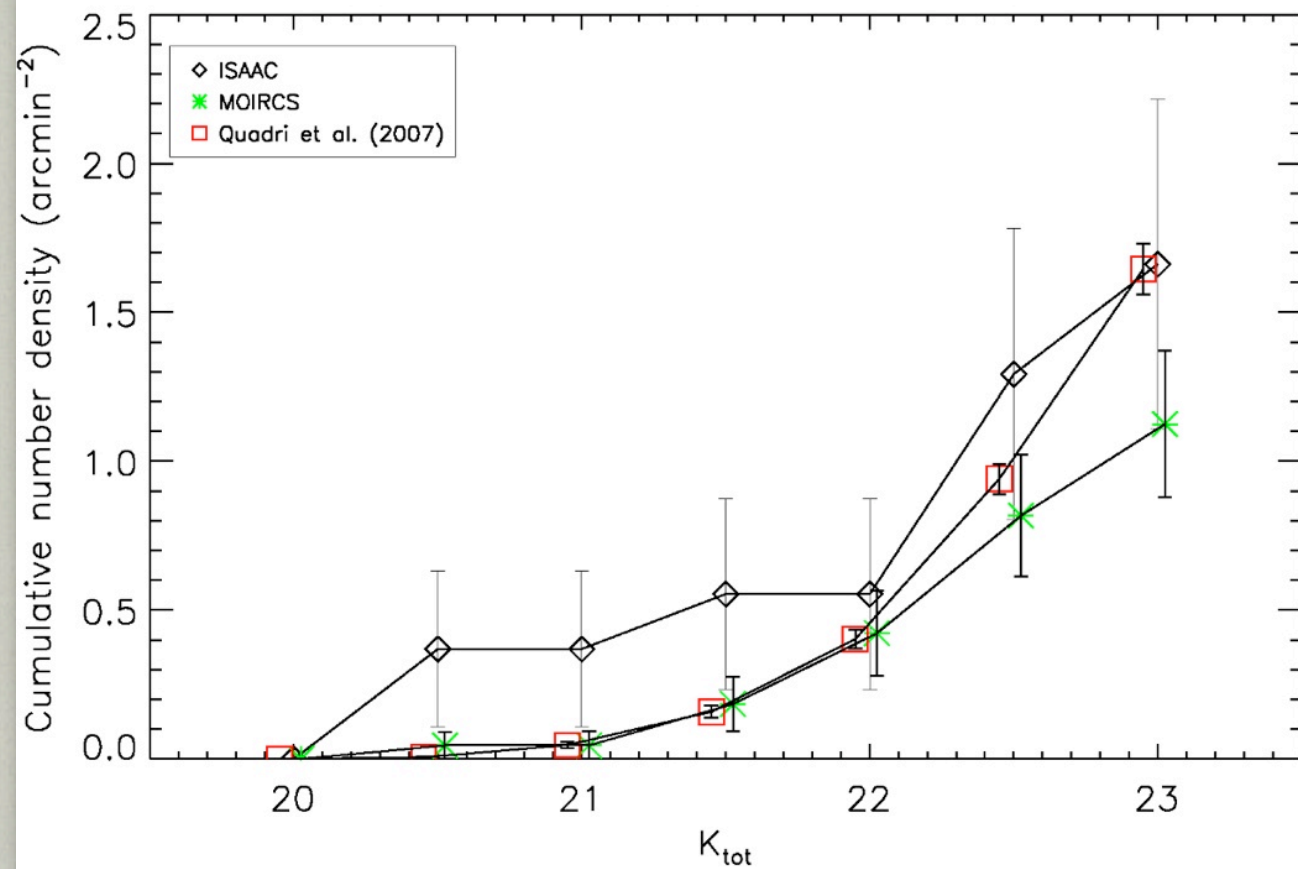
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Comparison with 4 MUSYC fields (Quadri et al. 2008) show no signs of an overdensity in the BBG number counts.



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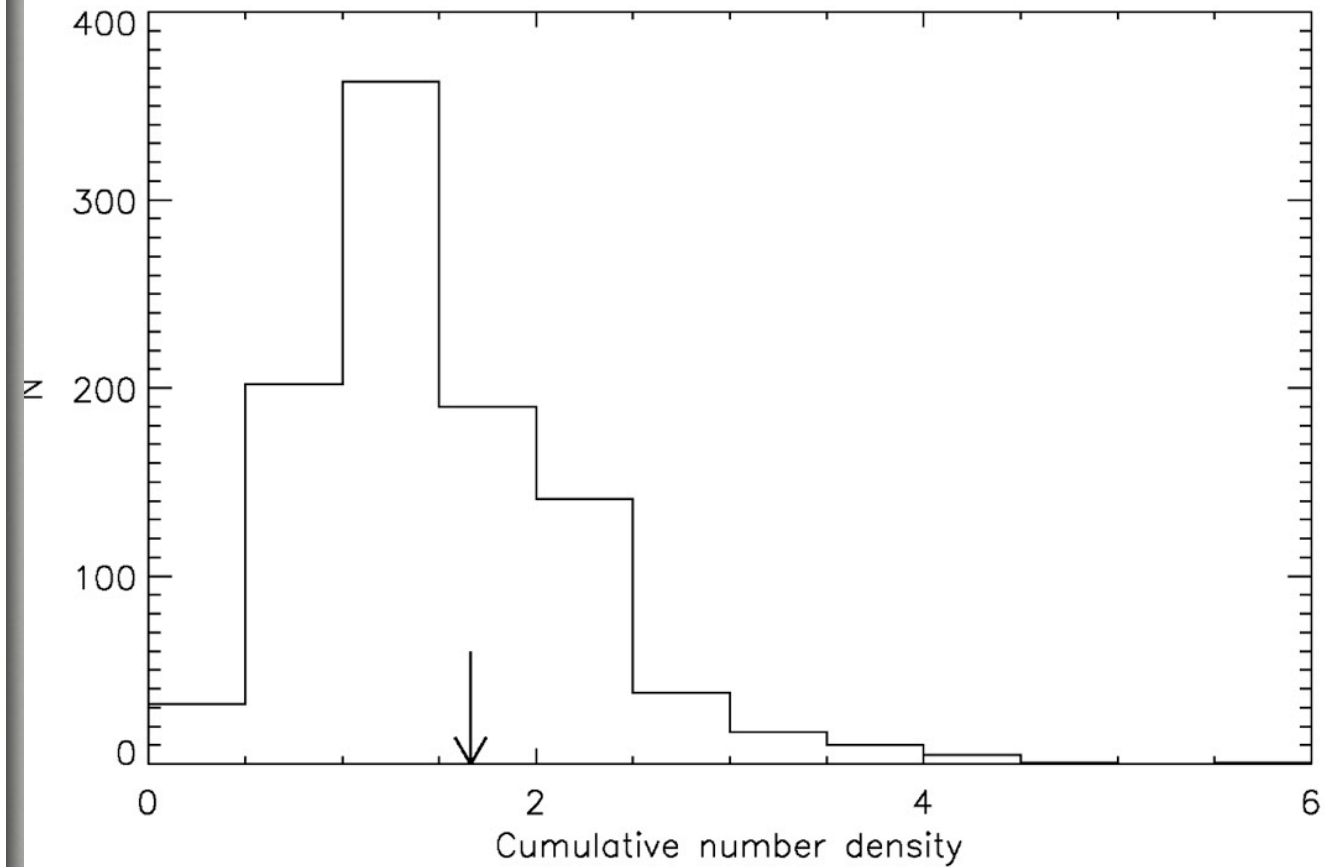
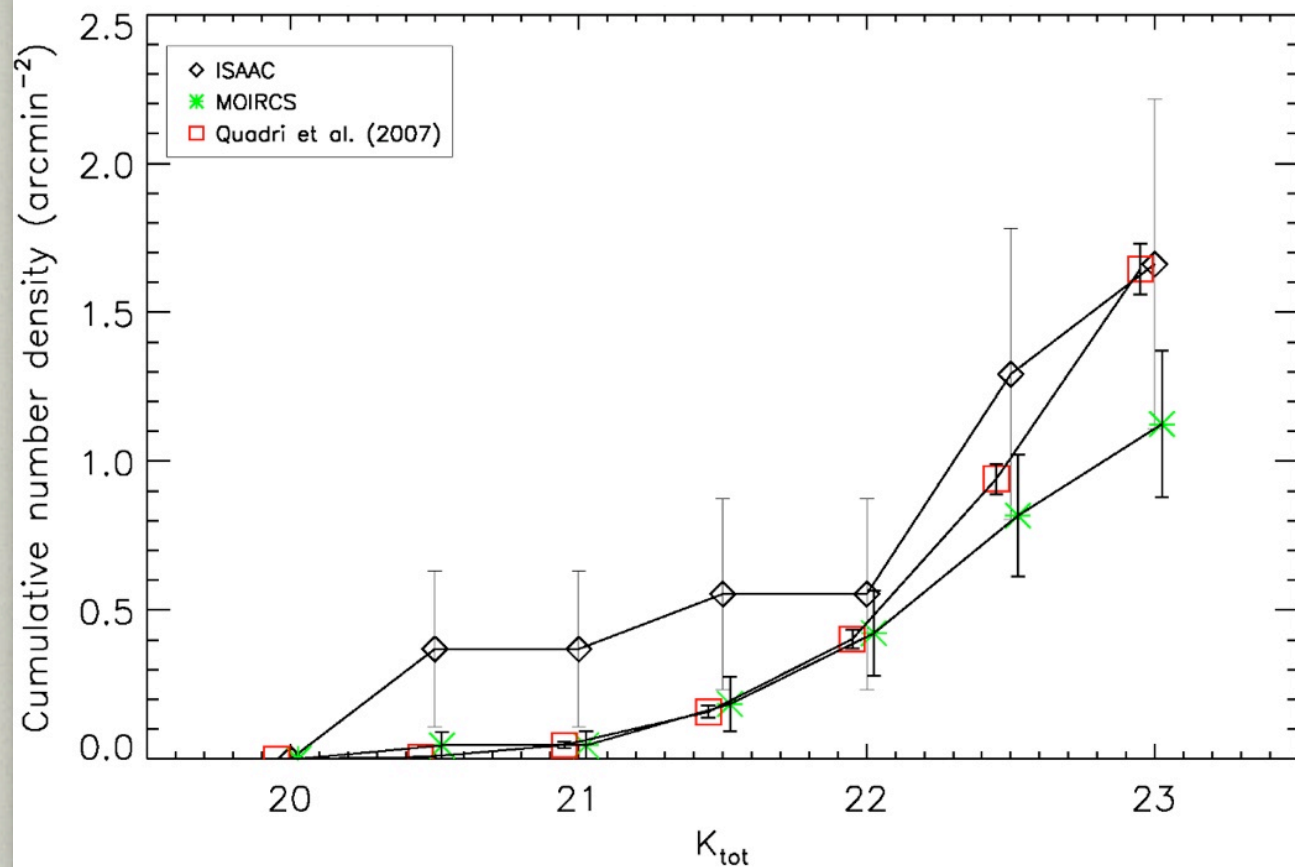


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A volume overdensity of  $7 \pm 4$  would result in a factor 1.2 higher BBG surface density  $\longrightarrow$  not detectable.



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A volume overdensity of  $7 \pm 4$  would result in a factor 1.2 higher BBG surface density  $\longrightarrow$  not detectable.

A  $3\sigma$  surface overdensity would translate to a volume overdensity of approximately 45  $\longrightarrow$  not likely.....



# GALAXY PROPERTIES

We determine galaxy properties using FAST code (Kriek et al. 2009) with BC03 and CB07 population synthesis models.

- Solar metallicity
- Salpeter IMF
- Redshifts are fixed to  $z_{\text{spec}}$  for LAEs and [OIII] emitters and the EAZY redshifts for LBGs and BBGs

SFH: $\tau$	7.0	10.0	0.1
Log(age/yr)	7.0	9.3	0.1
$A_v$	0.0	3.0	0.1



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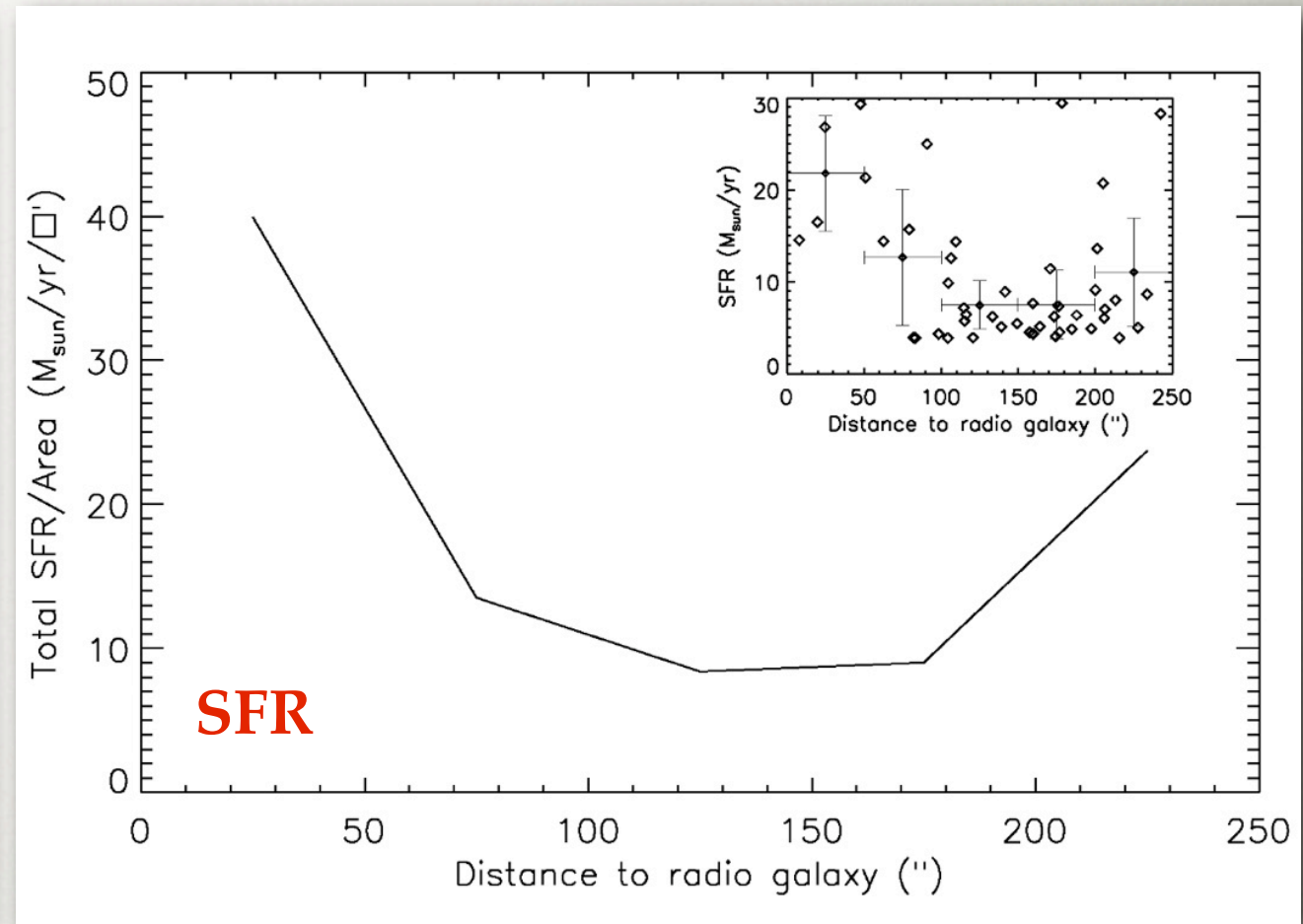
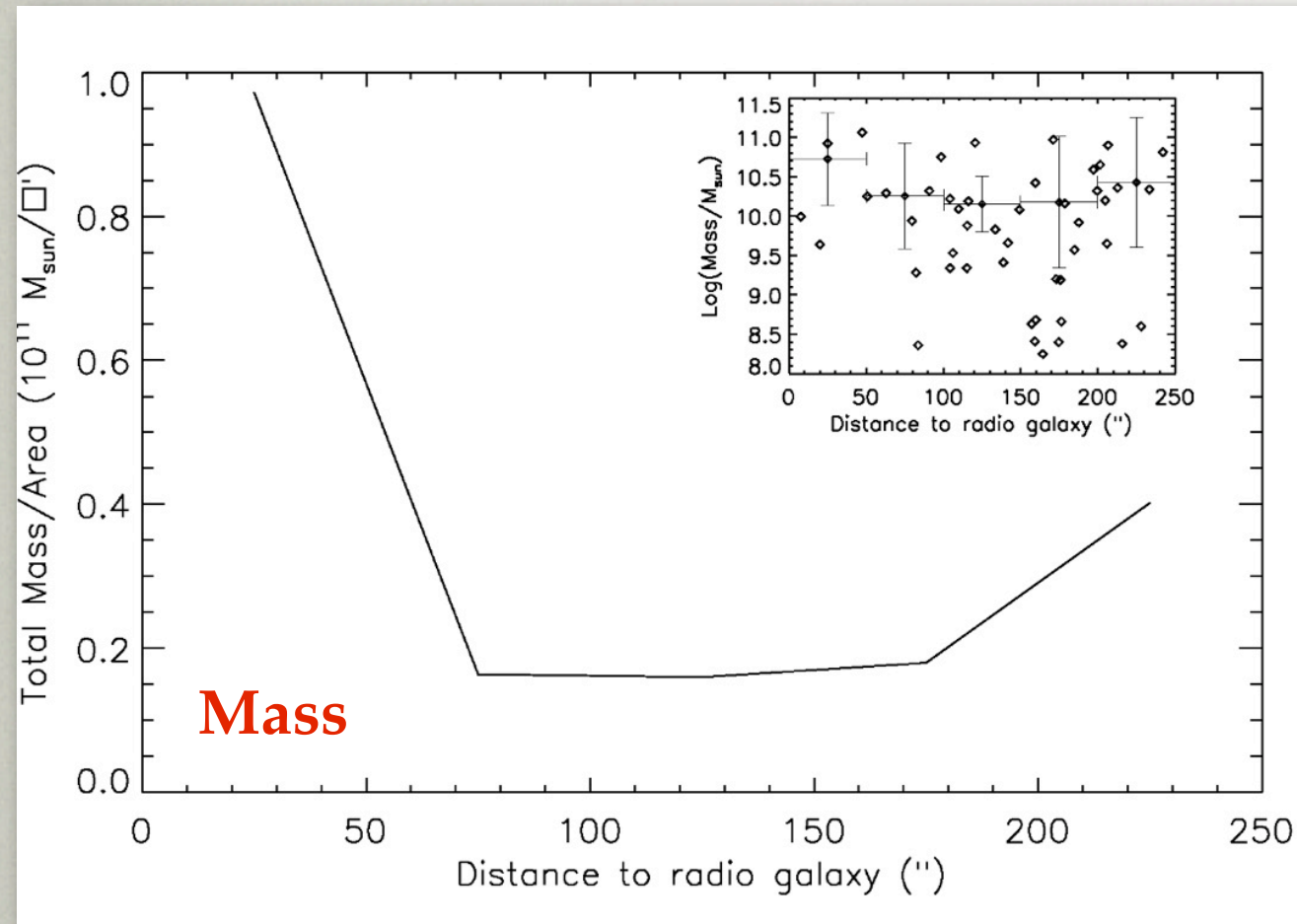
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**Long story short:**

**We find no significant differences between the cluster and field galaxies**



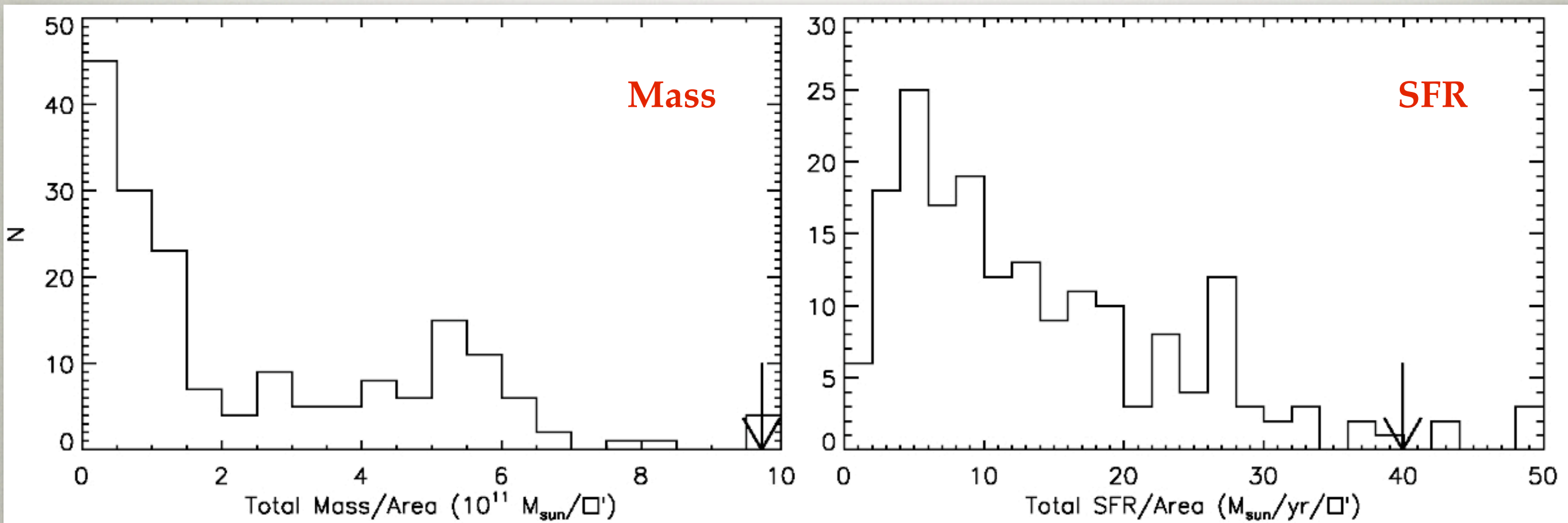
# SPATIAL DEPENDENCE



Most massive and intensely star forming galaxies located close to the radio galaxy



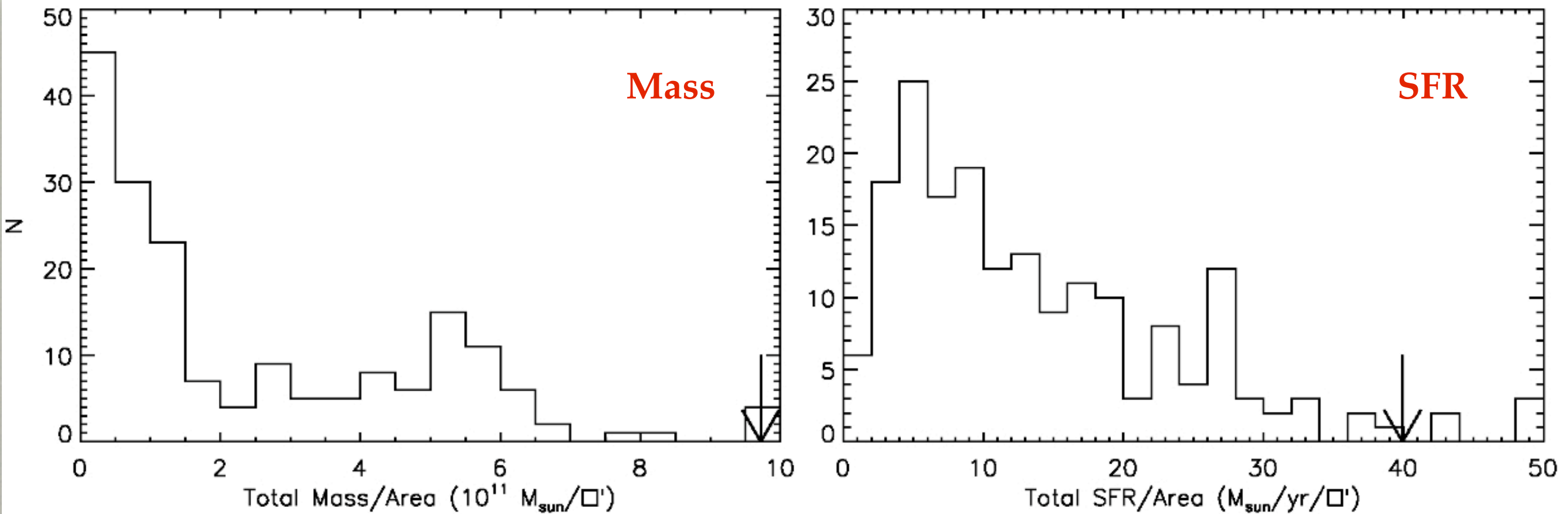
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The protocluster environment influences galaxy evolution at  $z \sim 3$  (in a very different way than at  $z < 1$ )



# WHEN I GROW UP....

Will 0316 evolve in a present day cluster?





# WHEN I GROW UP....

When do red galaxies appear in the protocluster?

Using SED fitting results we can evolve our LBG population



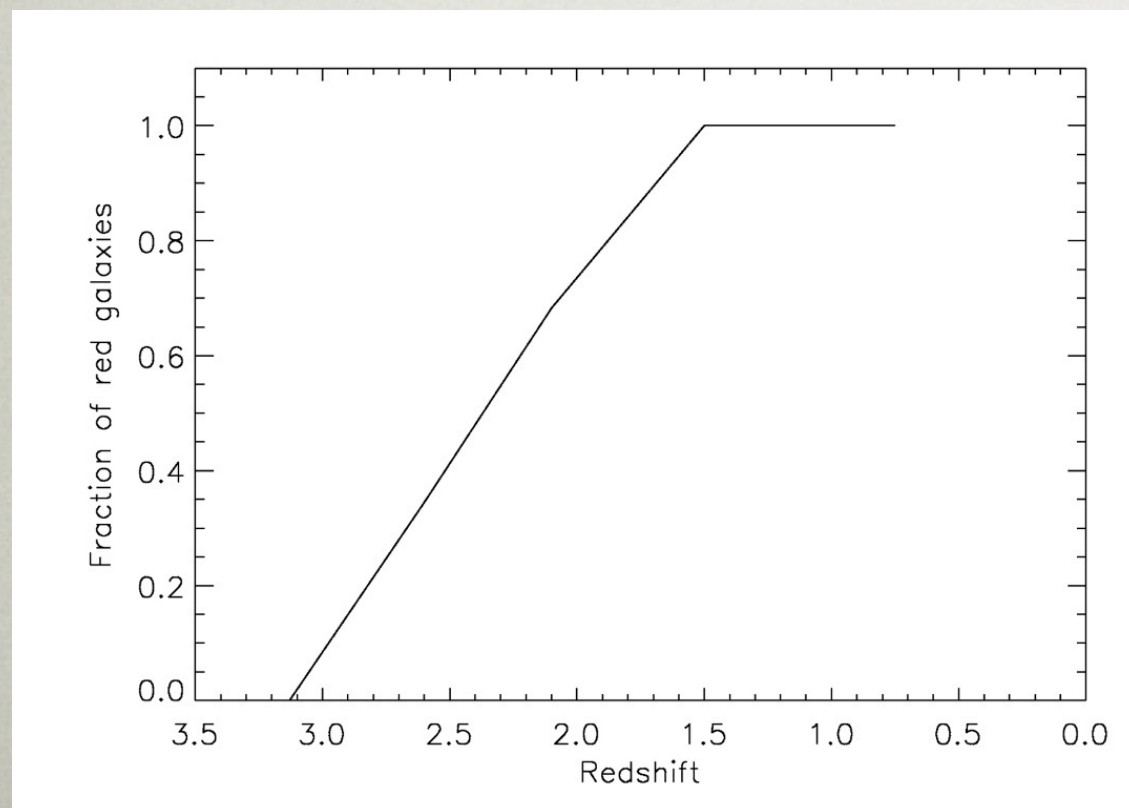


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Using SED fitting results we can evolve our LBG population

The 0316 cluster will host a significant number of quiescent galaxies at  $1.7 < z < 2.3$

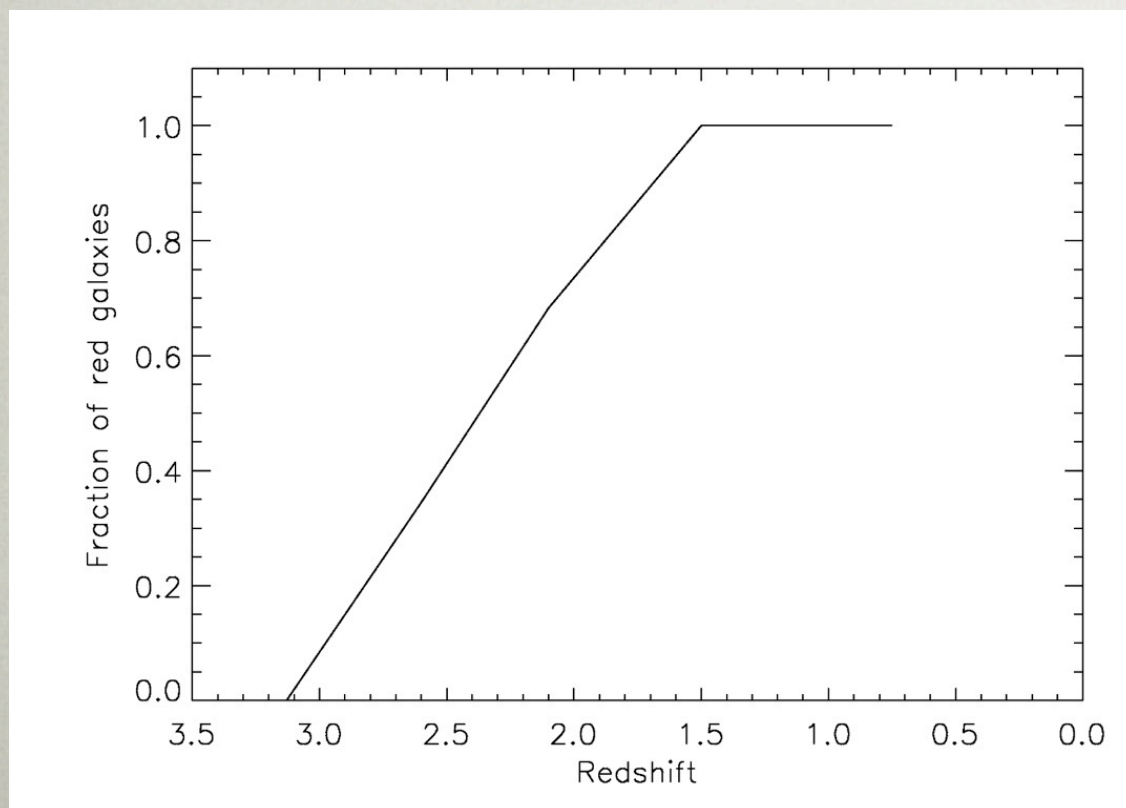




# WHEN I GROW UP....

- ✓ Based on LBG overdensity:  $M_{\text{clus}} \approx 2-12 \times 10^{14} M_{\text{sun}}$
- ✓ The LBGs will evolve into a significant quiescent population at  $z=1.7-2.3$

The 0316 protocluster will evolve into a massive present day galaxy cluster





# THE END IS NIGH (OR SUMMARY)

- We have done a multi-wavelength imaging study of the galaxy populations in the 0316 protocluster at  $z=3.13$
- We find an overdensity of star forming LBGs
- We find no overdensity of BBGs
- BBGs/DRGs are not suited for finding galaxy overdensities around HzRGs at  $z\sim 3$
- The galaxy properties of the protocluster populations as a whole do not differ significantly from field galaxies at  $z\sim 3$
- Within the protocluster the most massive and star forming galaxies are located close to the radio galaxy
- The 0316 protocluster will likely evolve to become a present day massive galaxy cluster