

The effect of environment in the early Universe: a comparison of protocluster and field galaxies at $z \sim 2$

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WHEN DOES ENVIRONMENT BEGIN TO AFFECT GALAXIES?

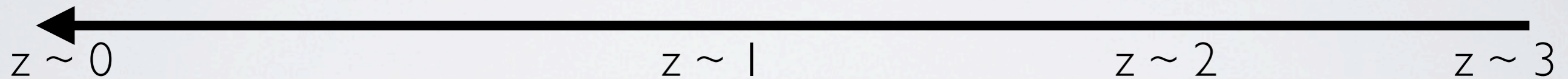
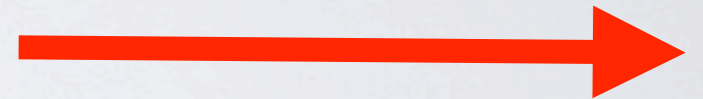


Bassett,
Muzzin,
Patel,
Kurk,
Rettura



Blakeslee+ (2003)

?



Need:

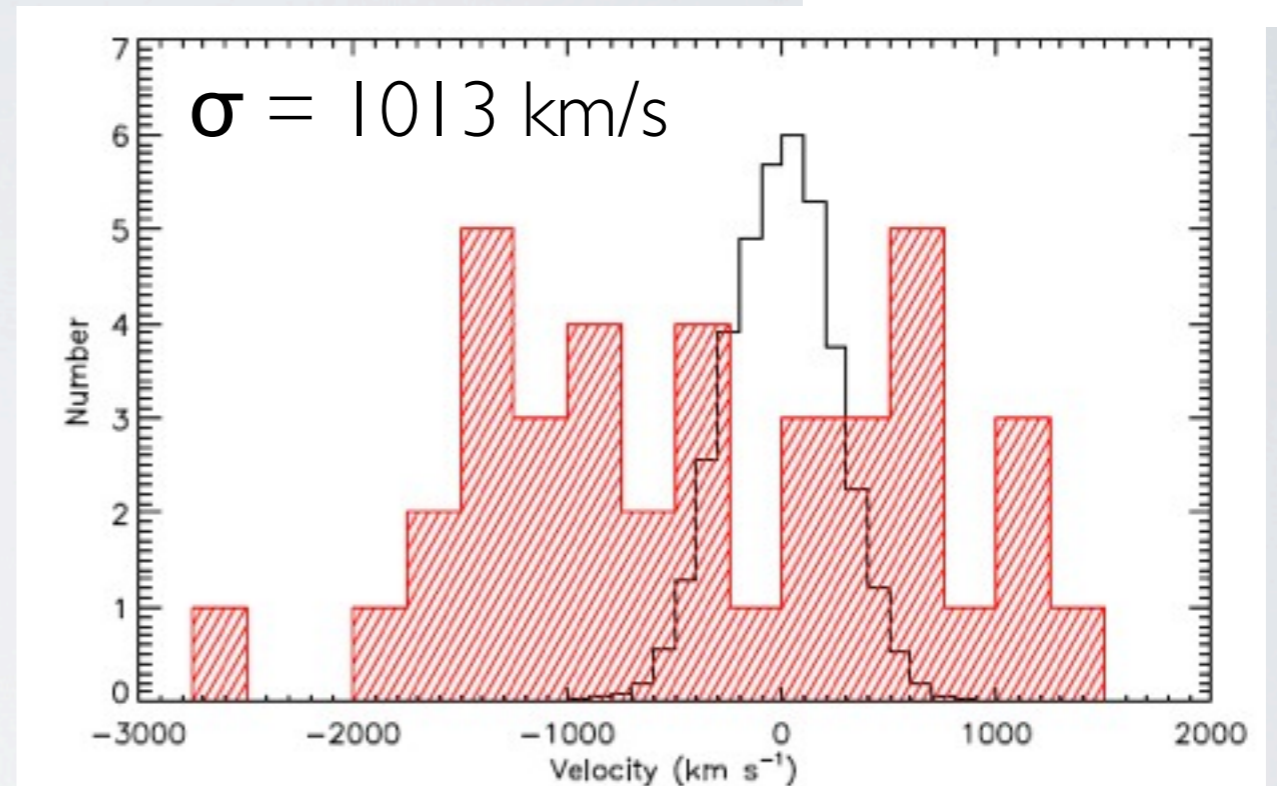
- a clean sample of protocluster galaxies
- a similarly selected field sample

Perform a NB survey targeting $H\alpha$ emitters.

NOT CLUSTERS

Spiderweb Protocluster at $z=2.2$

LAEs & HAEs



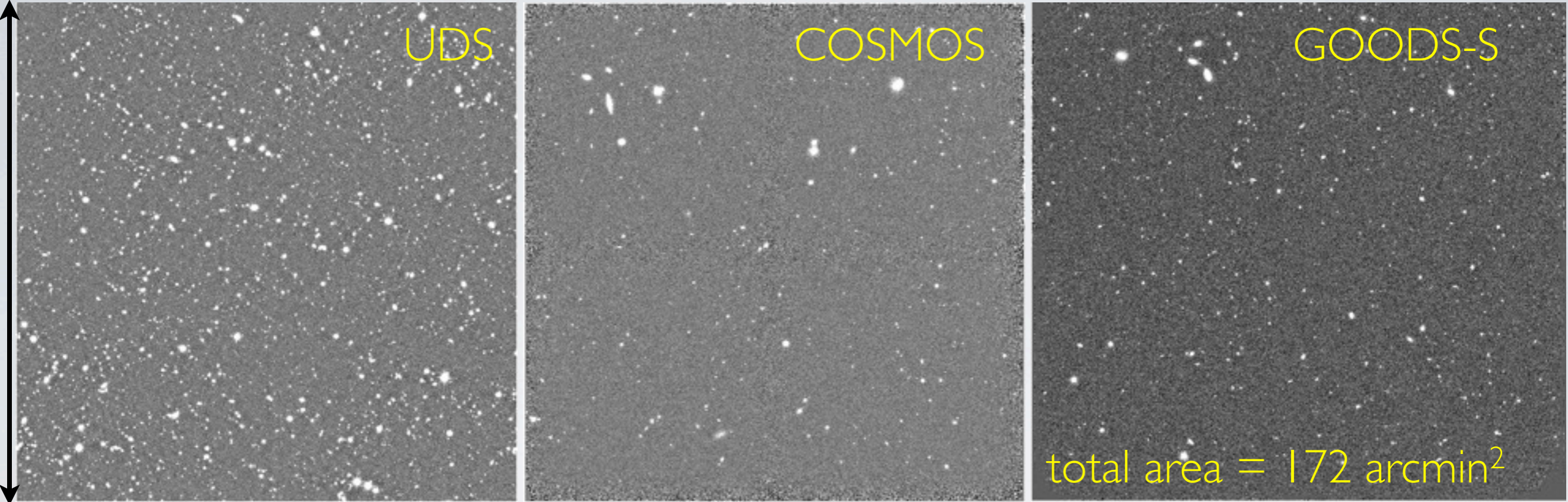
Mass = $2 \times 10^{15} M_{\odot}$ IF virialised \longrightarrow 4 x more massive than allowed by Λ CDM
Mortonson et al. (2011)

Predicted X-ray = 6×10^{44} erg/s
Observed X-ray $\sim 1.5 \times 10^{44}$ erg/s (Carilli et al. 2002)

Kuiper, NAH, et al. (2011)

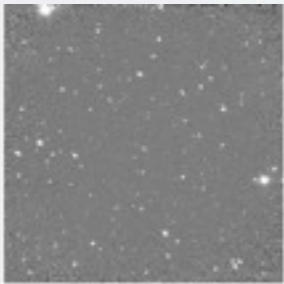
SAMPLES

7.5' x 7.5'

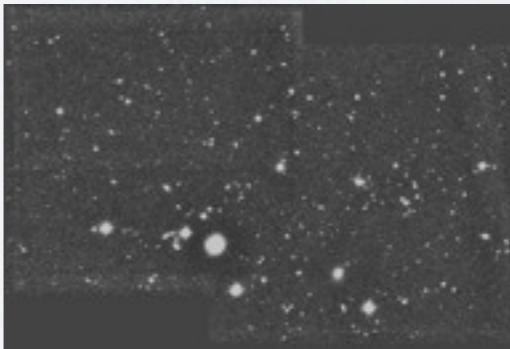


4C+10.48 (z=2.35)

2.5' x 2.5'

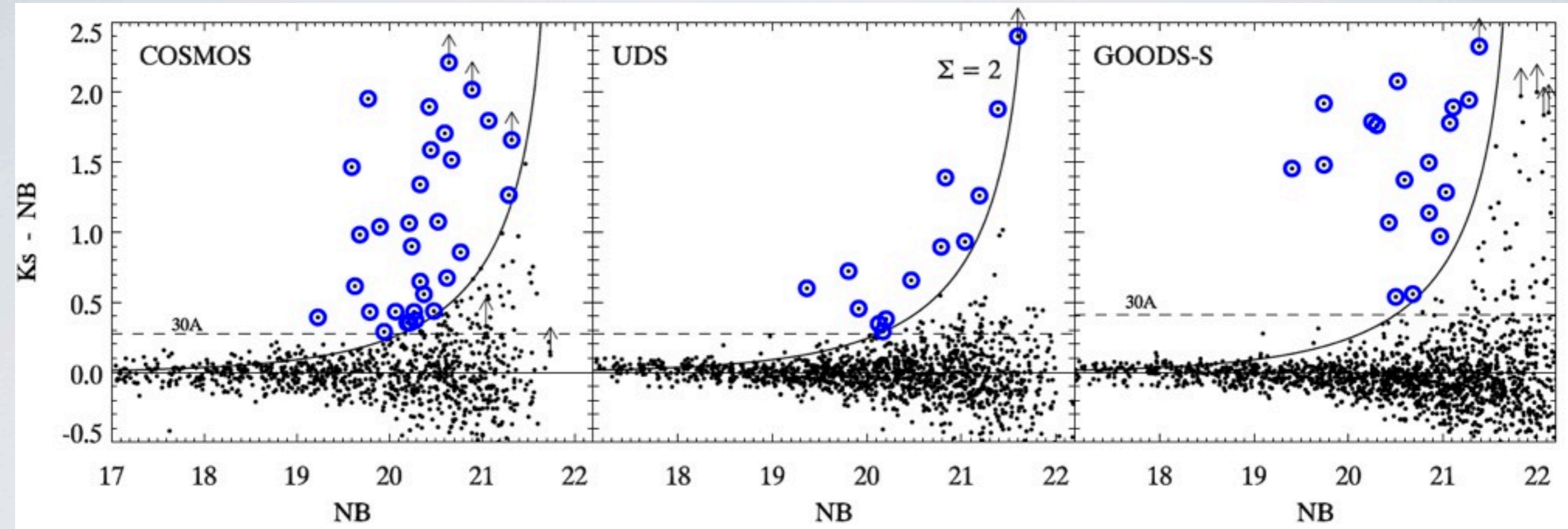


Spiderweb protocluster
(z=2.16; Kurk 2004)



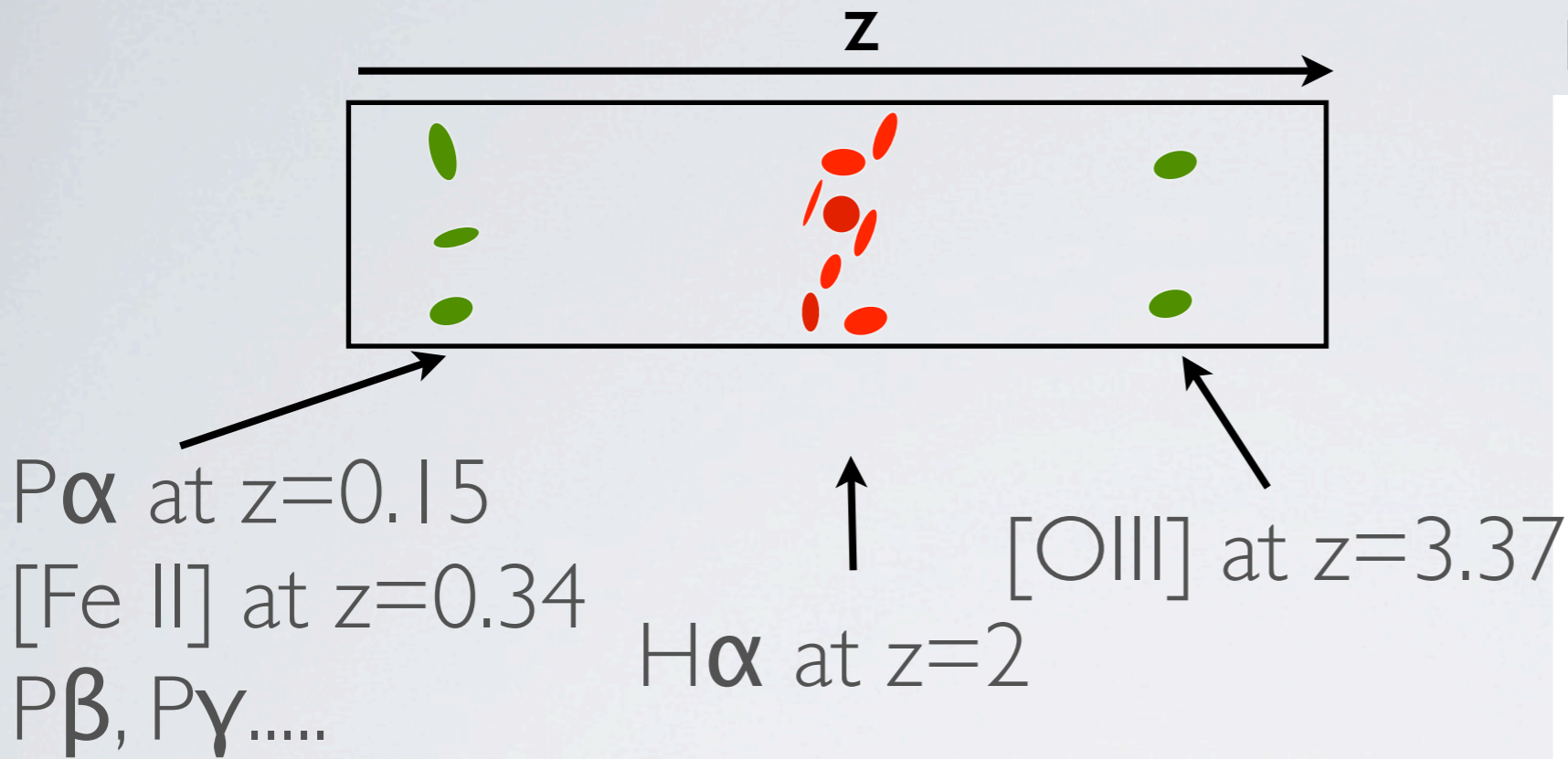
2x 2.5' x 2.5'

SELECTING H α EMITTERS

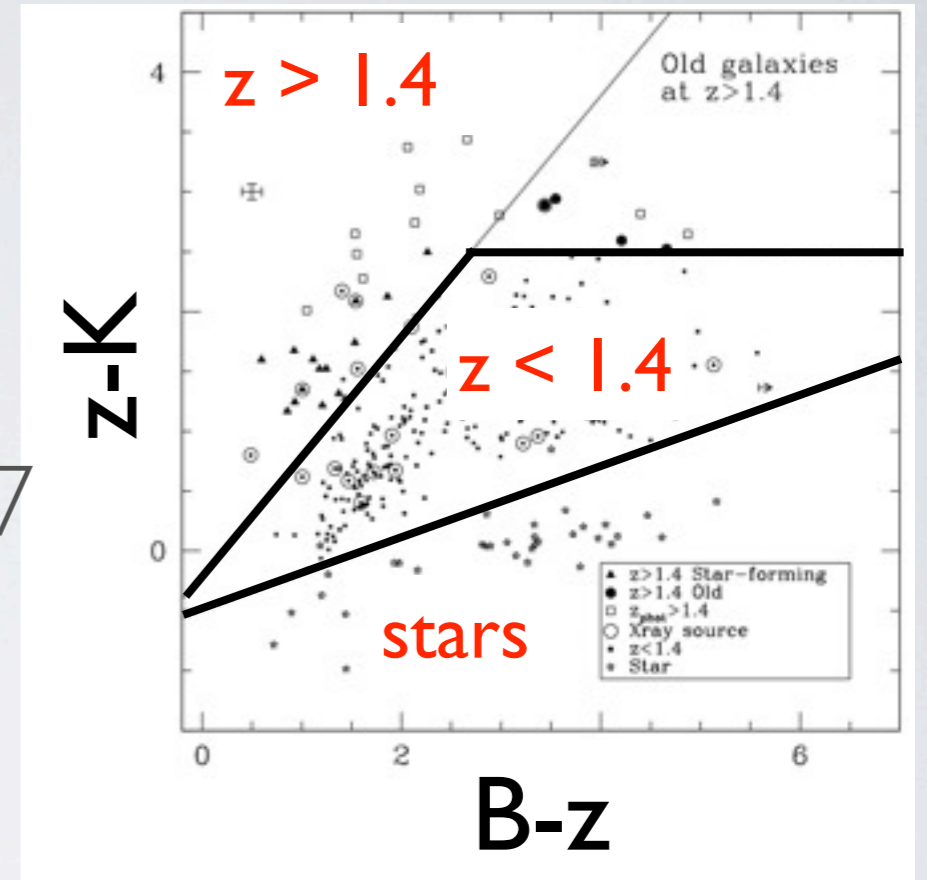


H α emitters selected in **exactly** the same way in **ALL** fields

Emission line contaminants



BzK criteria (Daddi et al. 2004)

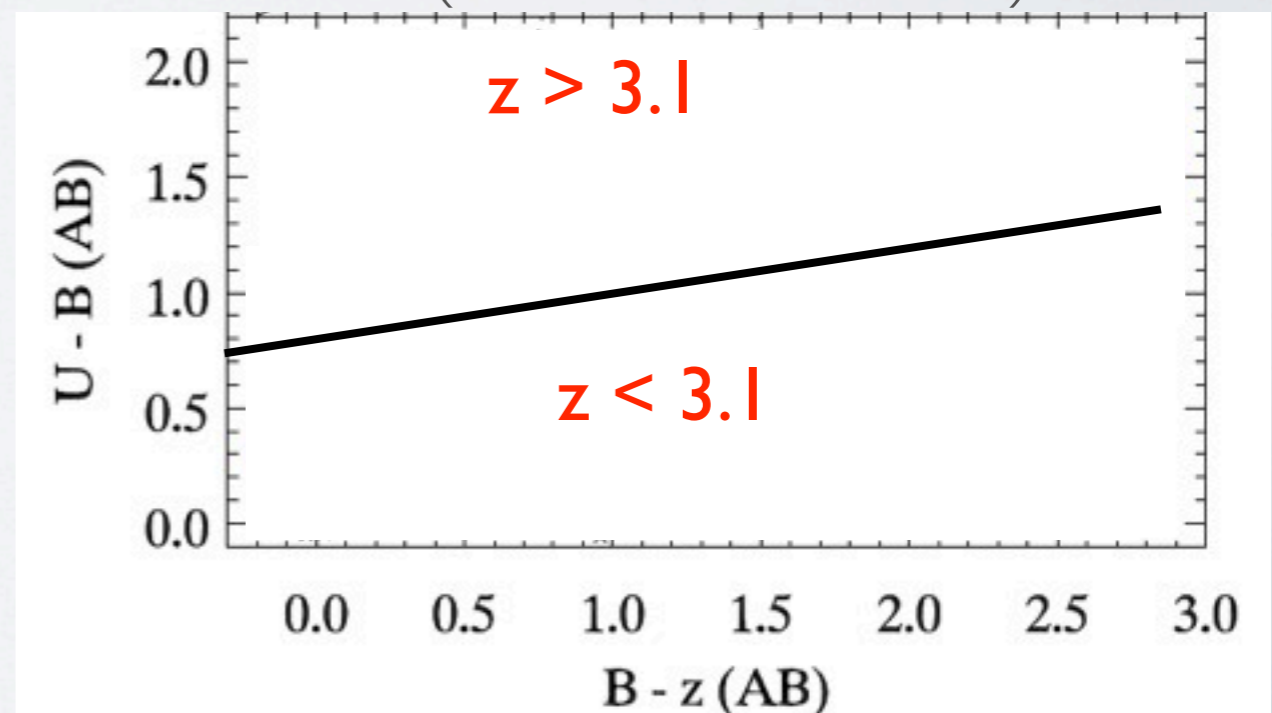


- 55% of **control field** candidates are contaminants

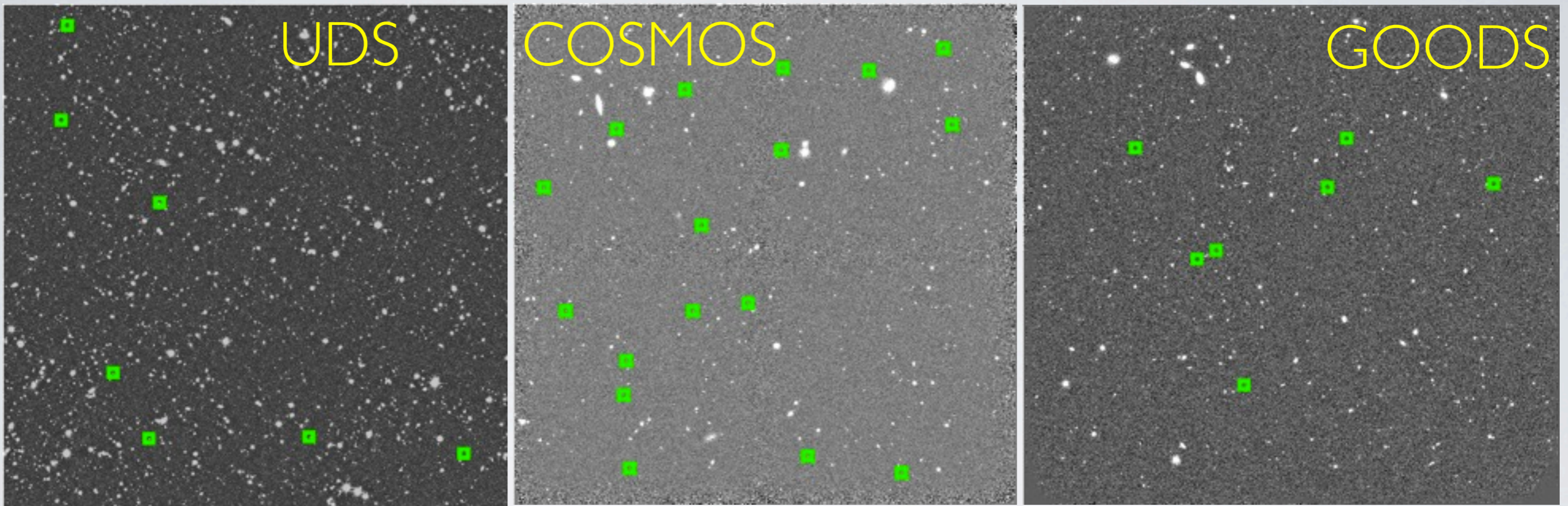
- Surface density of contaminants
 $= 0.13 \text{ arcmin}^{-2}$

- < 1 interloper in 4C+10.48 field
- < 2 interlopers in Spiderweb

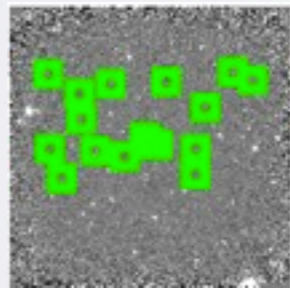
LBG criteria (Steidel et al. 2003)



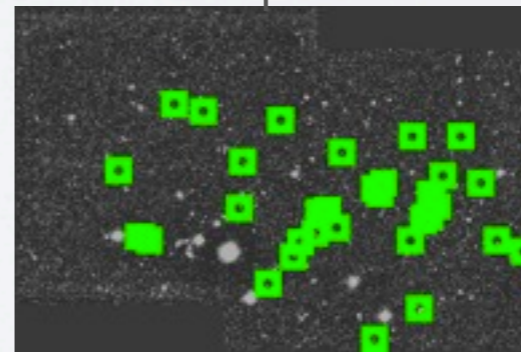
DISTRIBUTION OF HAEES



4C+10.48 ($z=2.35$)

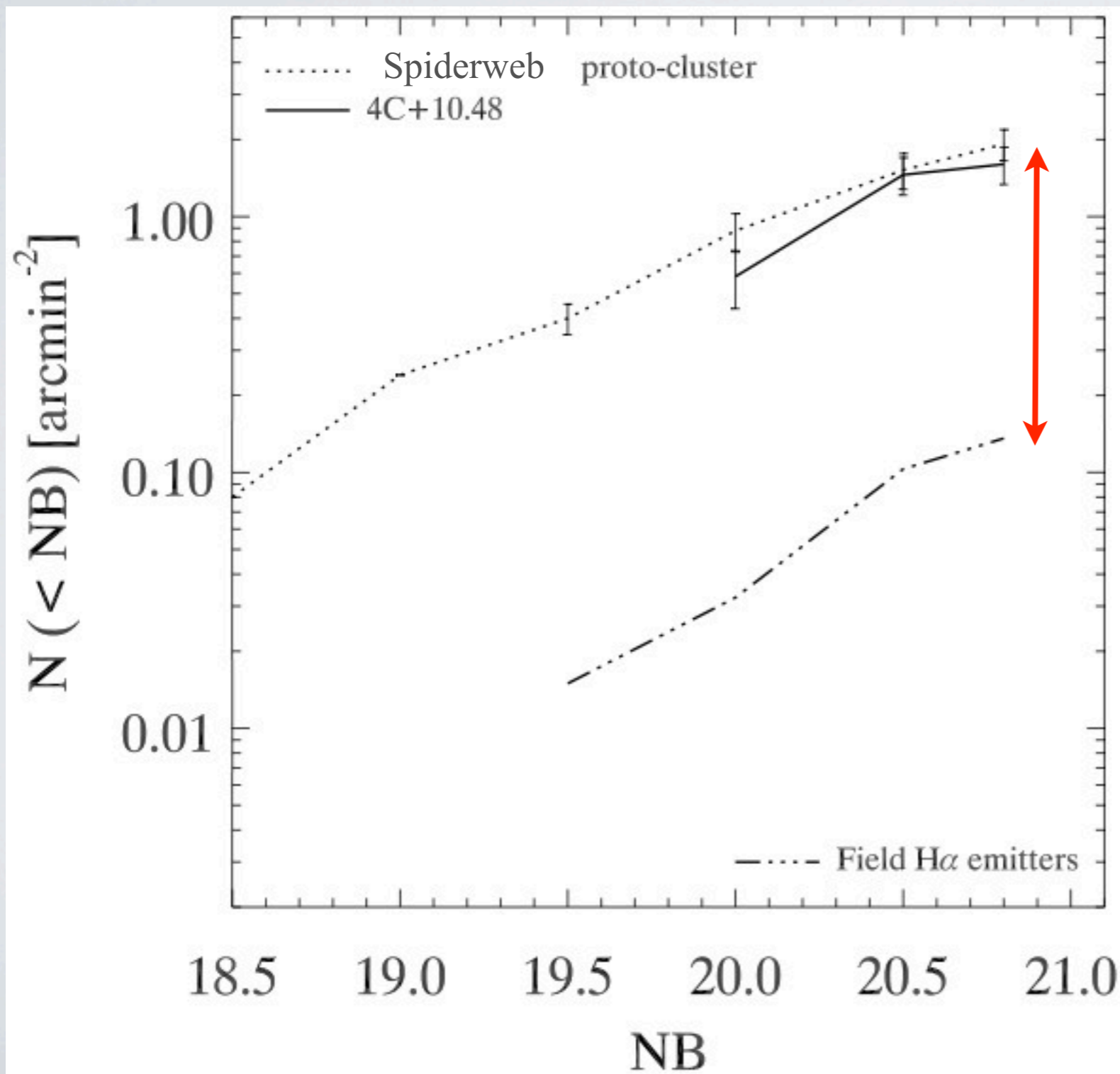


Spiderweb protocluster ($z=2.16$)



- <1 interloper in 4C+10.48 field & <2 interlopers in Spiderweb
- less than 10% of candidates in protocluster fields are contaminants.

NUMBER DENSITY



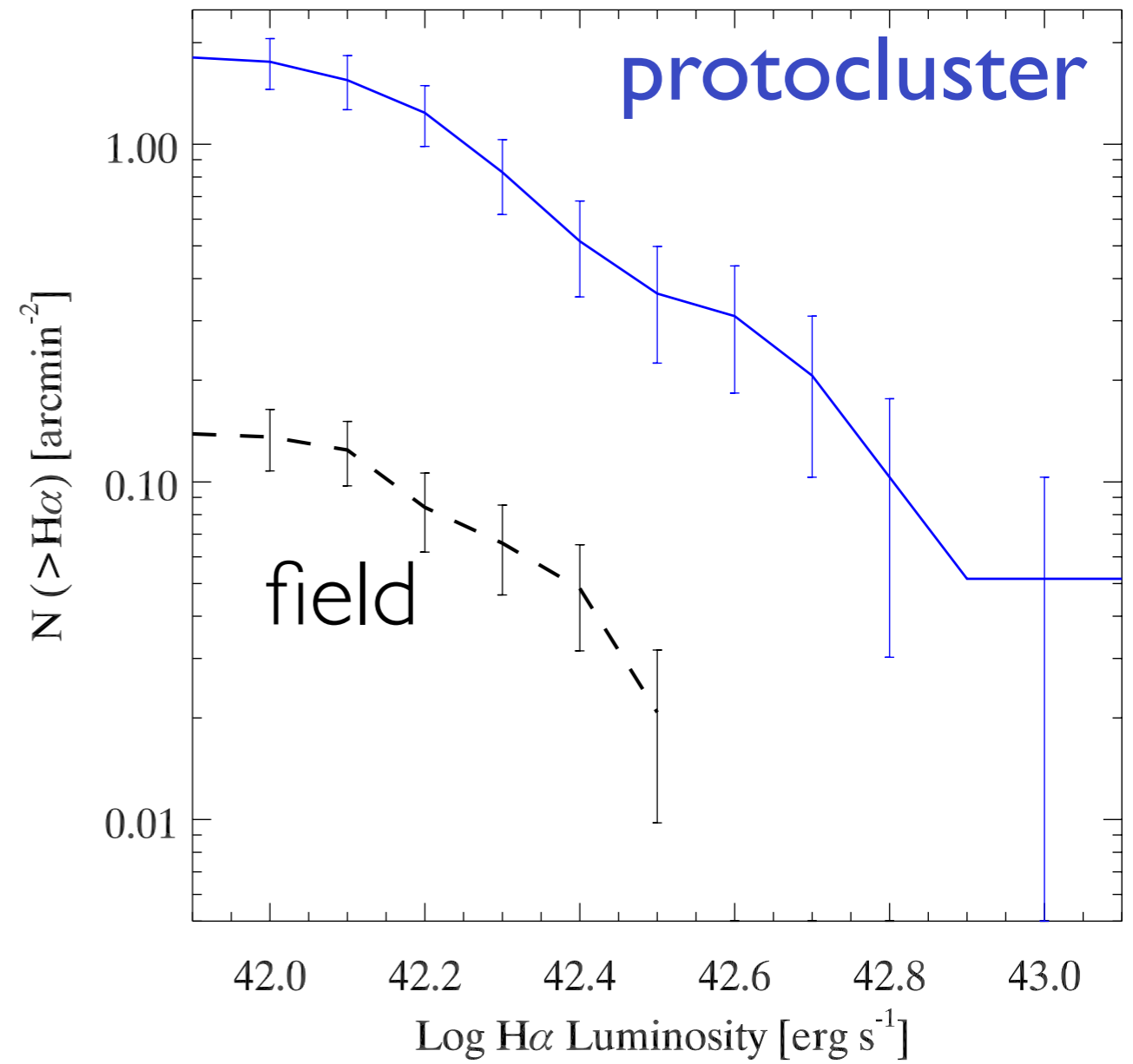
Spiderweb and 4C+10.48 have very similar densities

13x more H α emitters

COMPARING PROTOCLUSTER AND FIELD GALAXIES

- ~25 field galaxies
- ~35 protocluster galaxies

H α LUMINOSITY FUNCTION



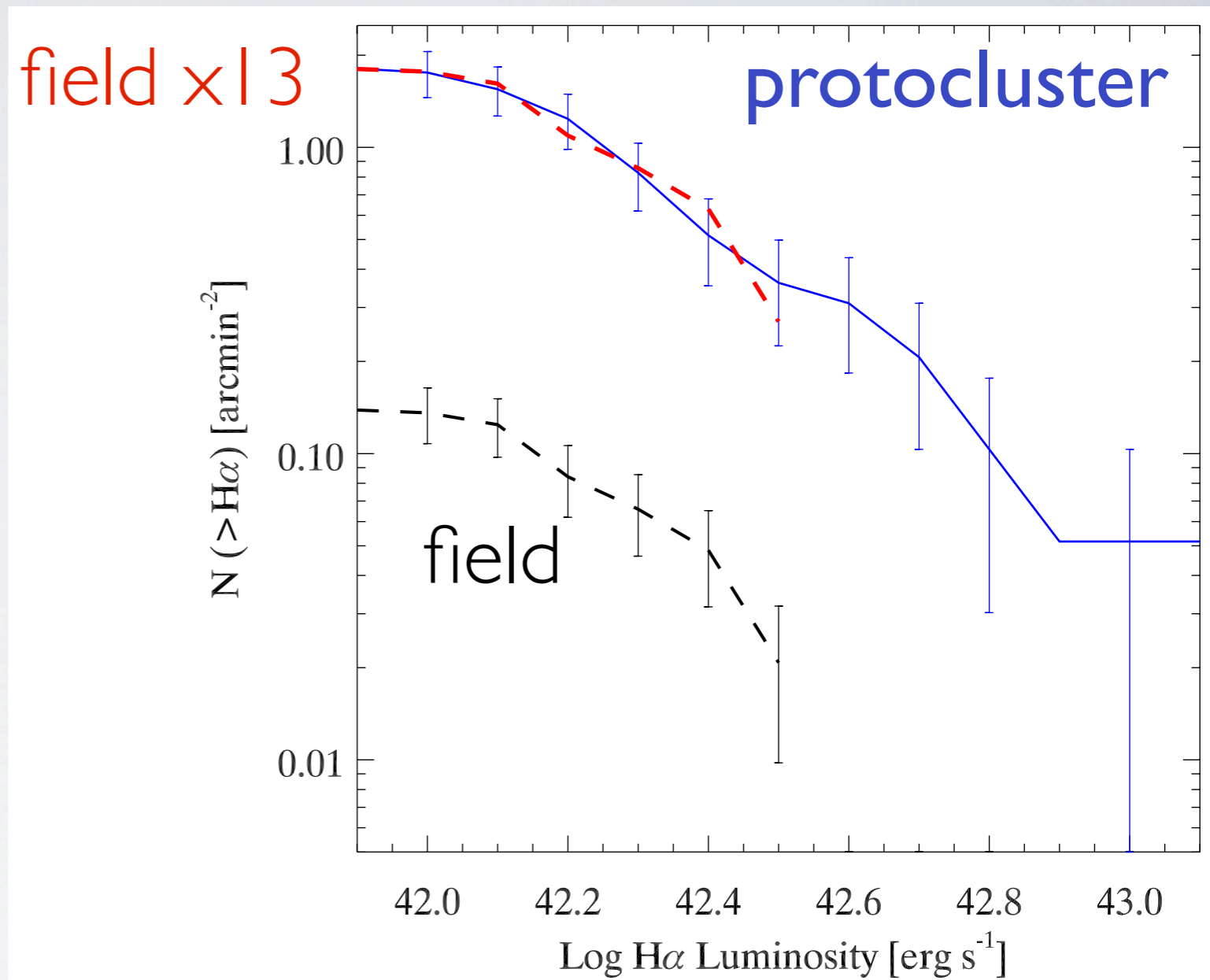
H α LUMINOSITY FUNCTION

- SFR of star forming galaxies is not affected by environment

KS test 97%

see also Tanaka et al. 2011;
Tadaki et al. 2011

and talks by Koyama &
Hayashi



H α LUMINOSITY FUNCTION

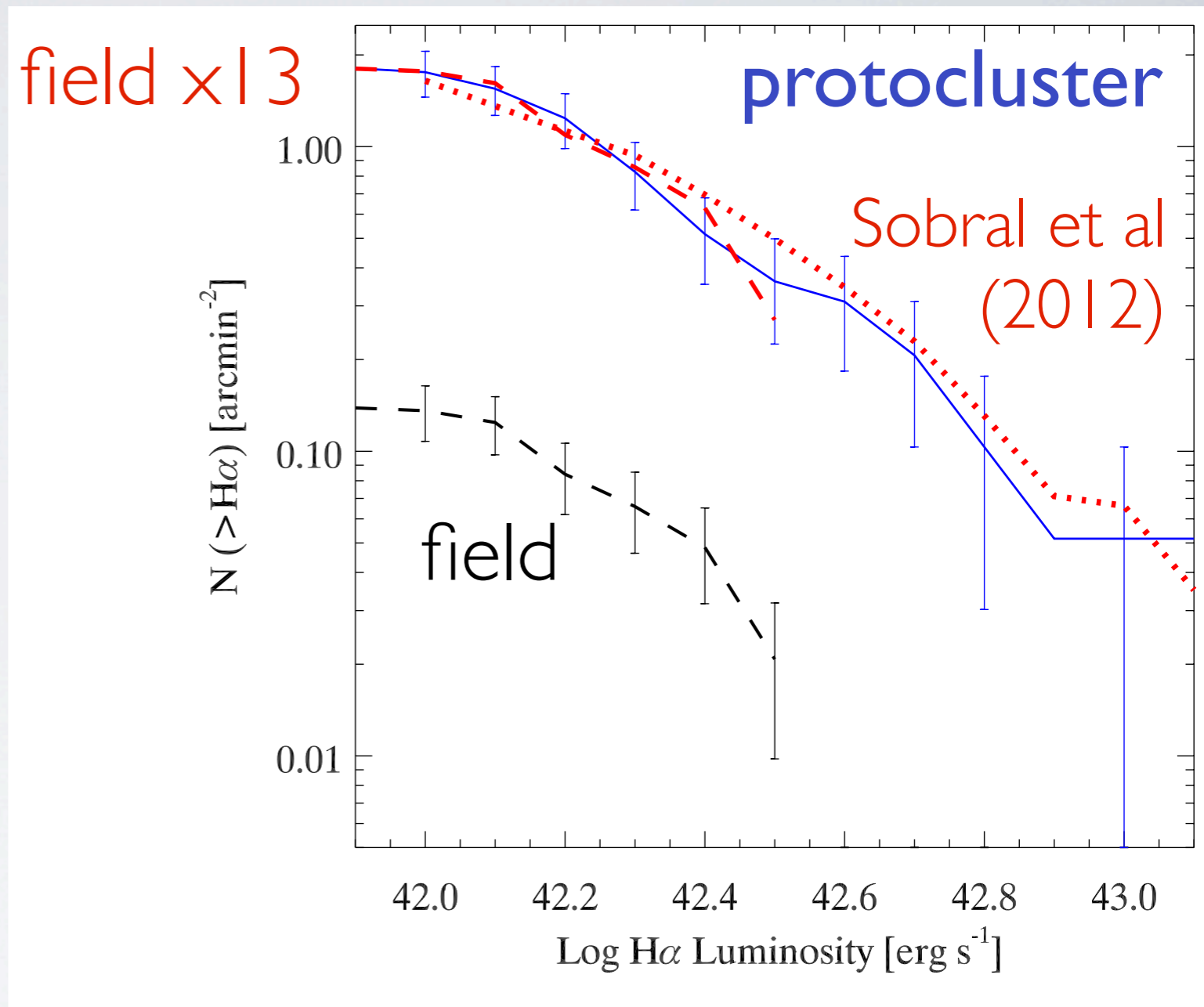
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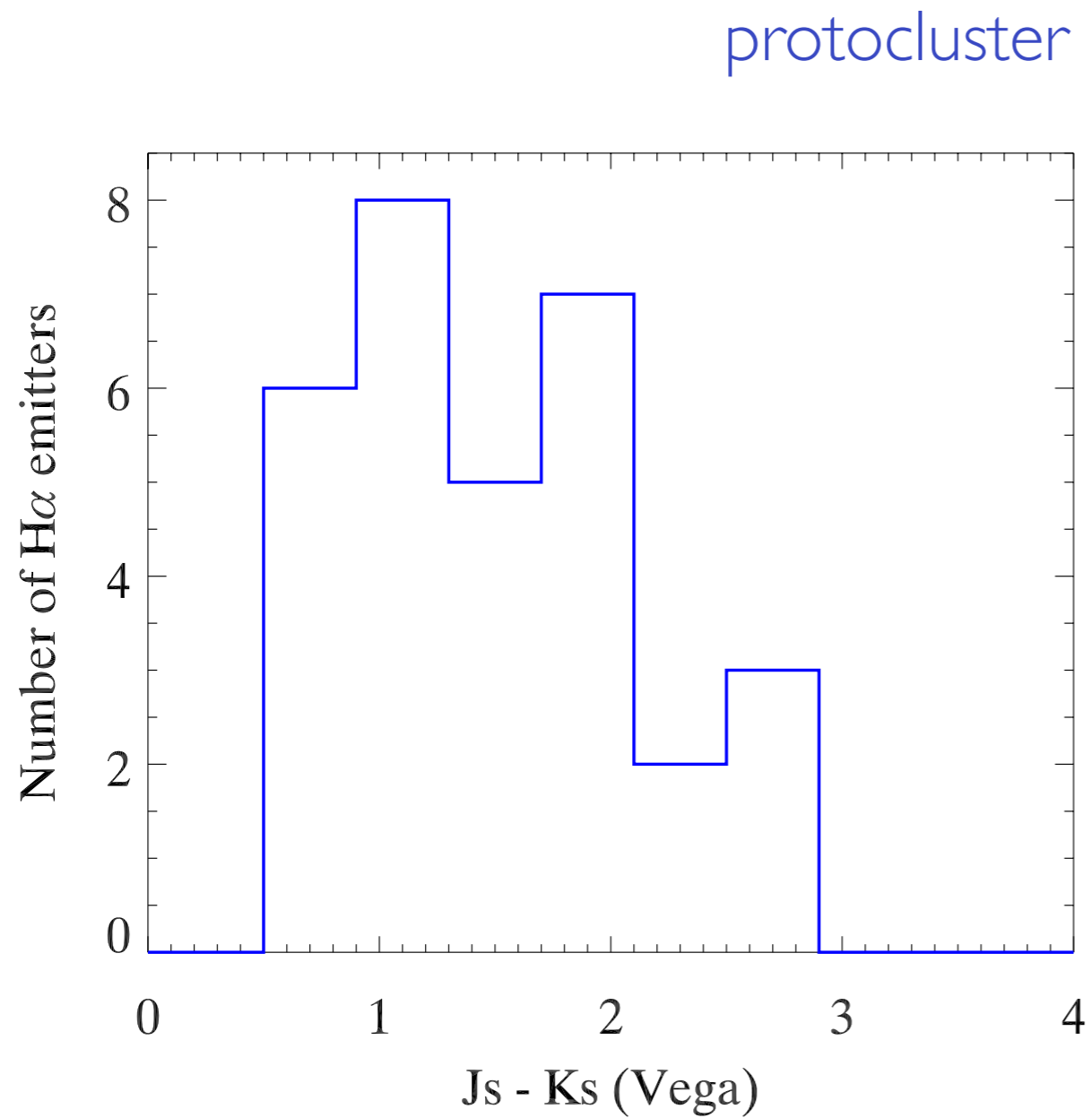
see also Tanaka et al. 2011;
Tadaki et al. 2011

and talks by Koyama &
Hayashi

- SFR of protoclusters = ρ SFR(field) \times 13x Volume
SFR of protoclusters \sim 3000 M $_{\odot}$ /yr (1.5 Mpc)

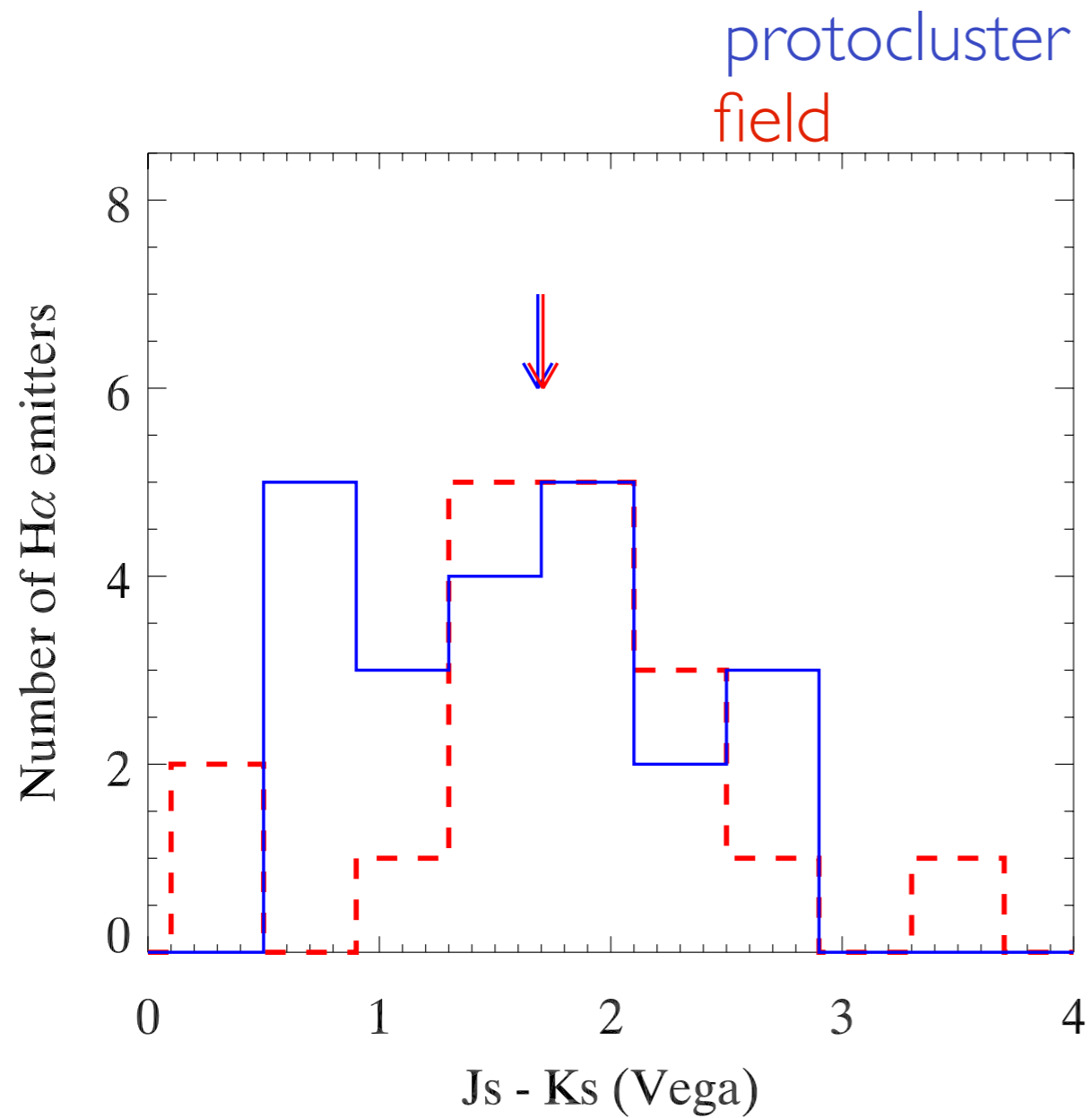


GALAXY COLOUR



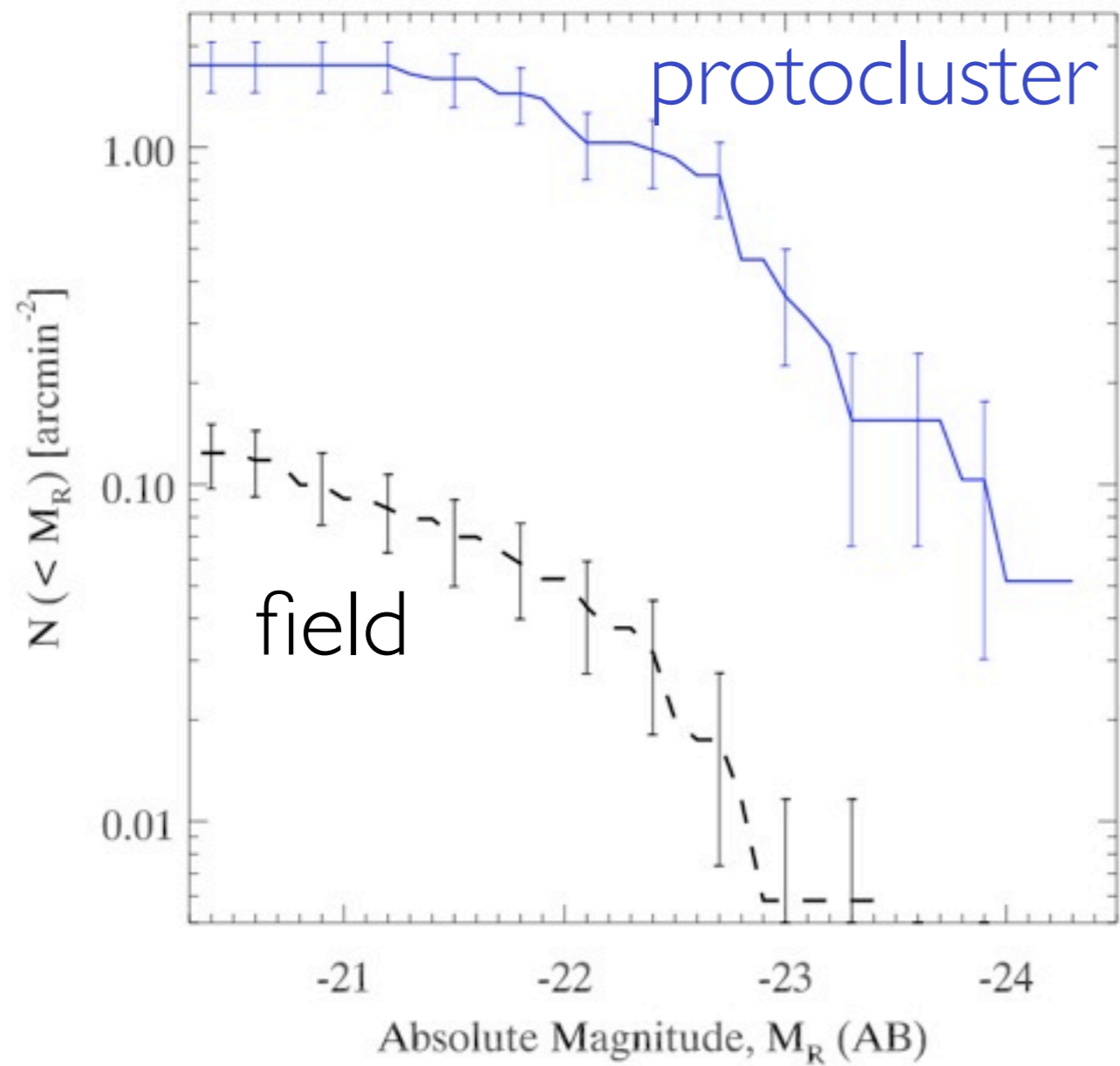
- Most protocluster galaxies are blue

GALAXY COLOUR

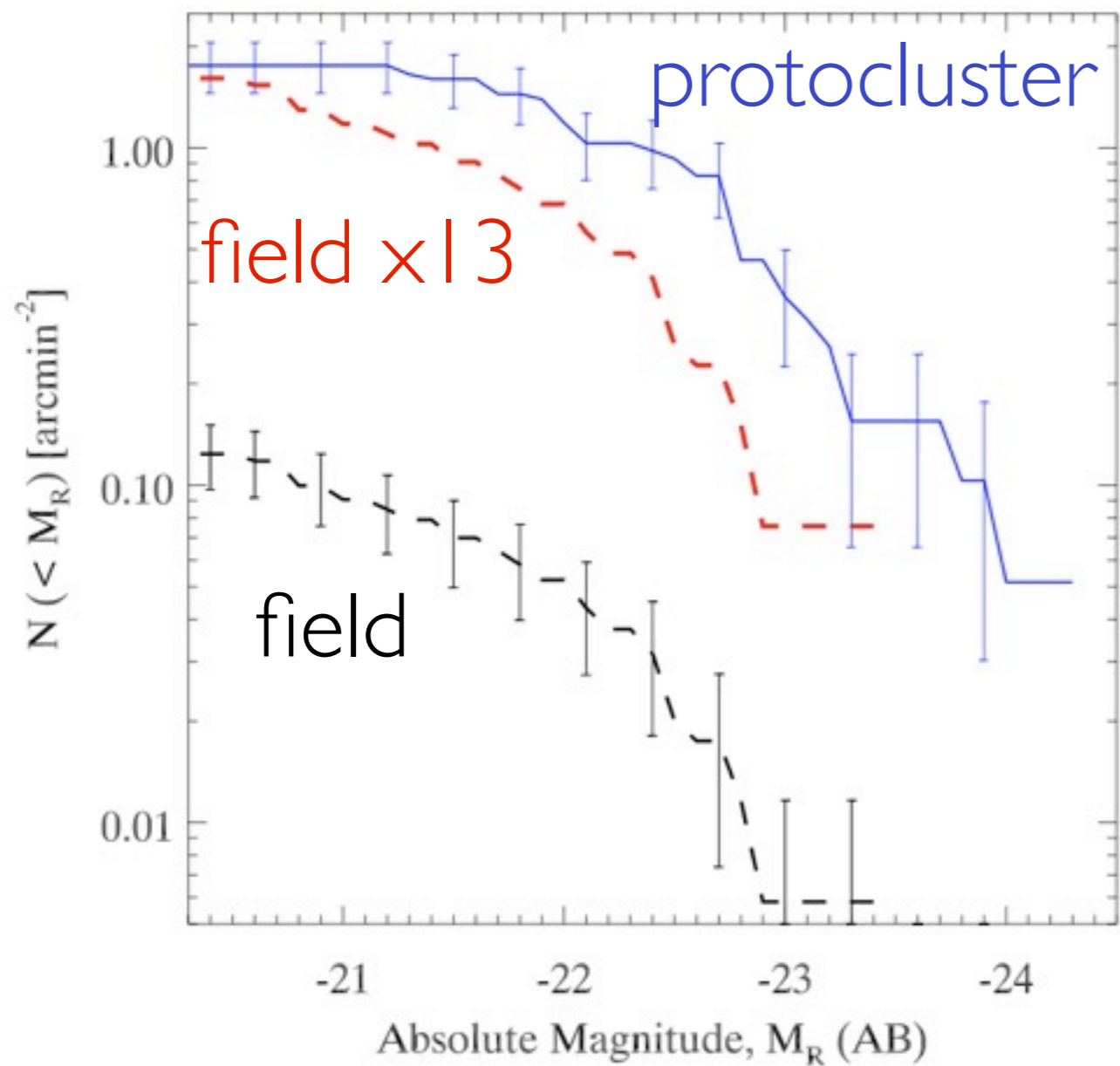


- Most protocluster galaxies are blue
- Galaxy colour is similar

REST-FRAME R LUMINOSITY



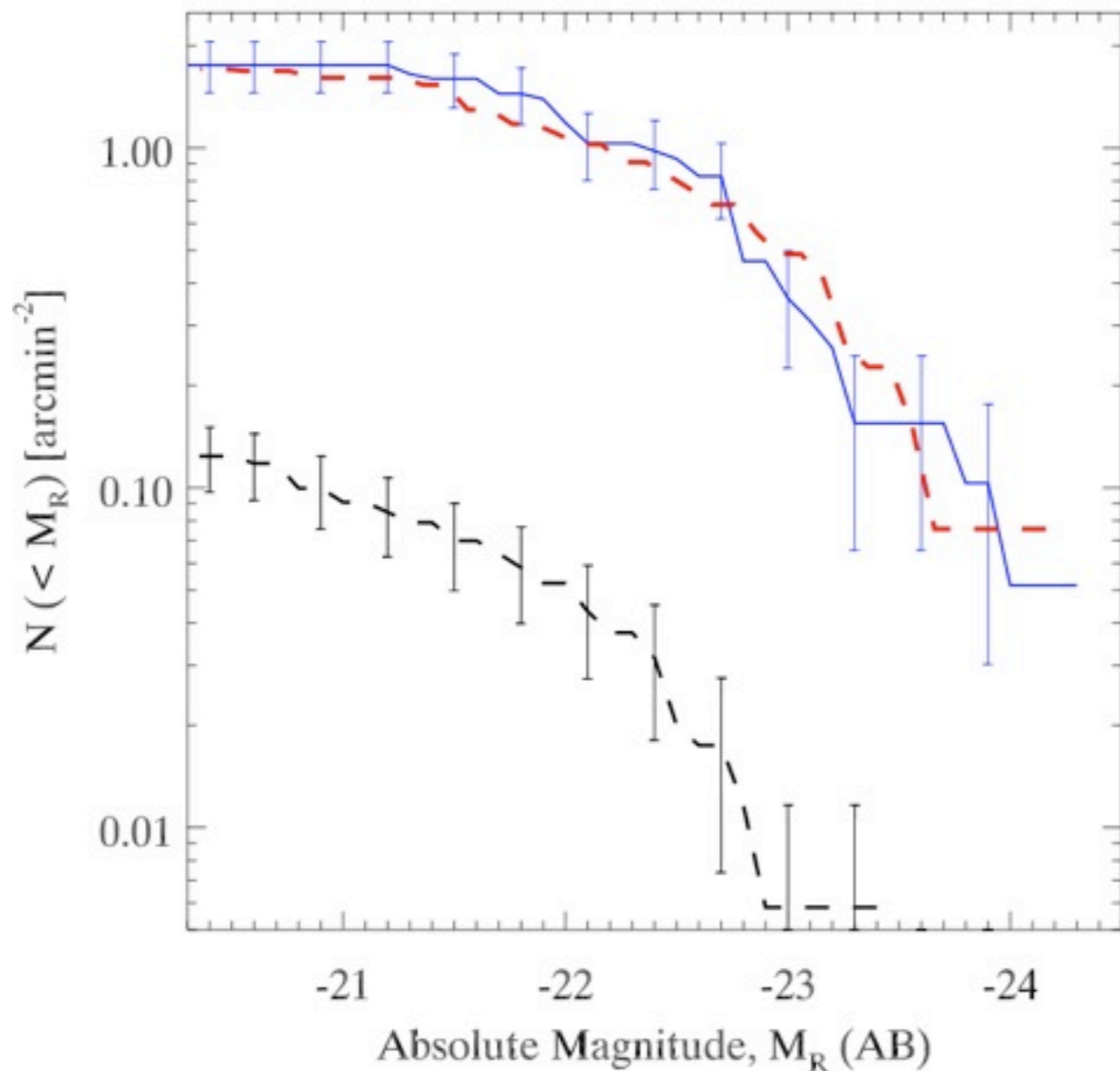
REST-FRAME R LUMINOSITY



KS test gives $P = 0.05$

MASS

field $\times 1.3 - 0.8$ mag



- Star forming PC galaxies are 0.8 mag **brighter** than field galaxies.
- Star forming PC galaxies are **2 x as massive** as field galaxies.
- Cluster galaxies always differed from field galaxies.

Similar results found in other studies: Steidel et al. (2003); Kuiper et al. (2010)

CONCLUSIONS

Environment does matter at $z > 2$

- No effect on SFR (of SF galaxies)
 - Total SFRs of protoclusters $\sim 3000M_{\odot}/\text{yr}$
- Mass function of protocluster and field galaxies differ
 - Protocluster galaxies are twice as massive as their field counterparts