Protocluster search conducted by narrow/medium-band imaging

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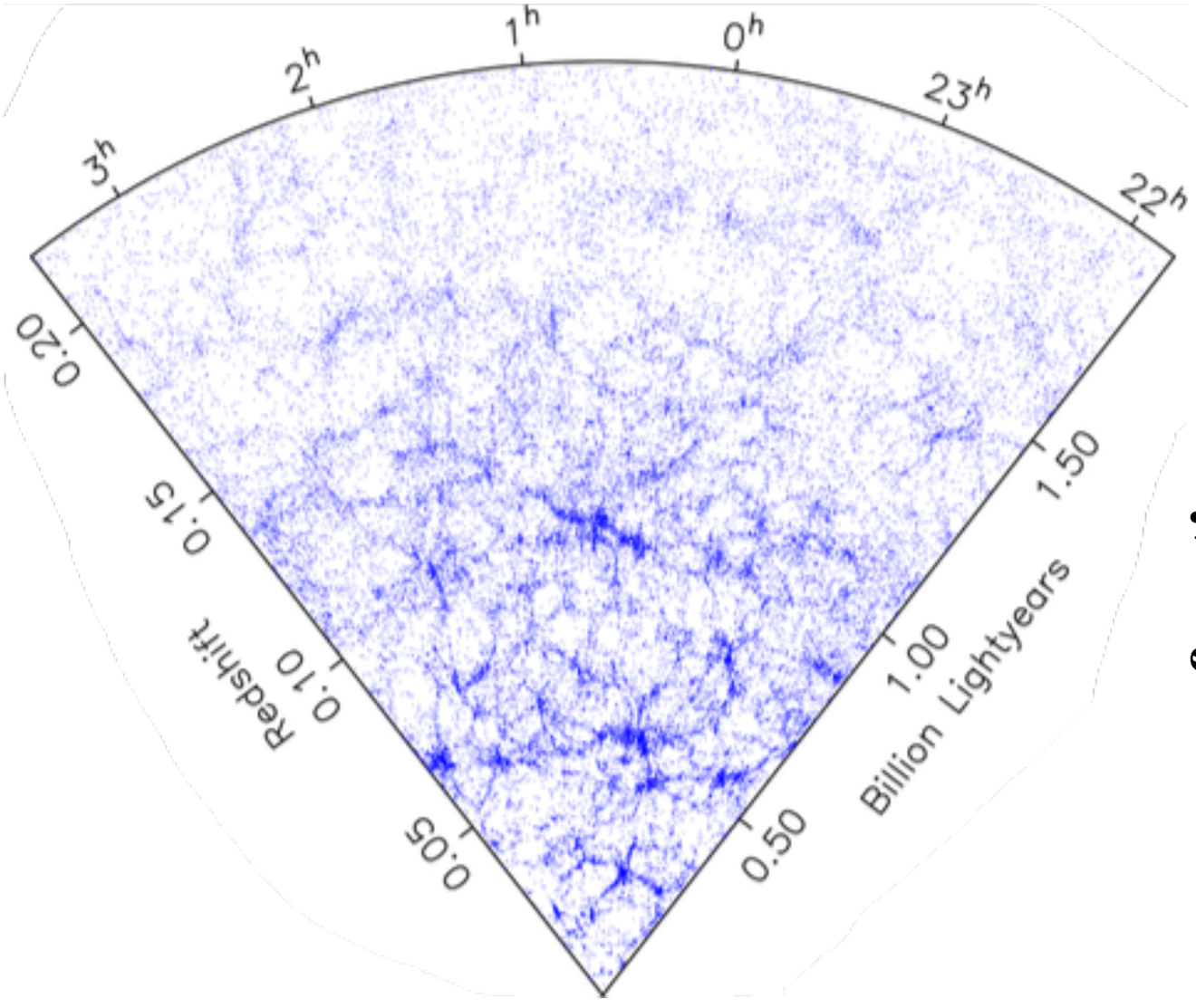
Outline

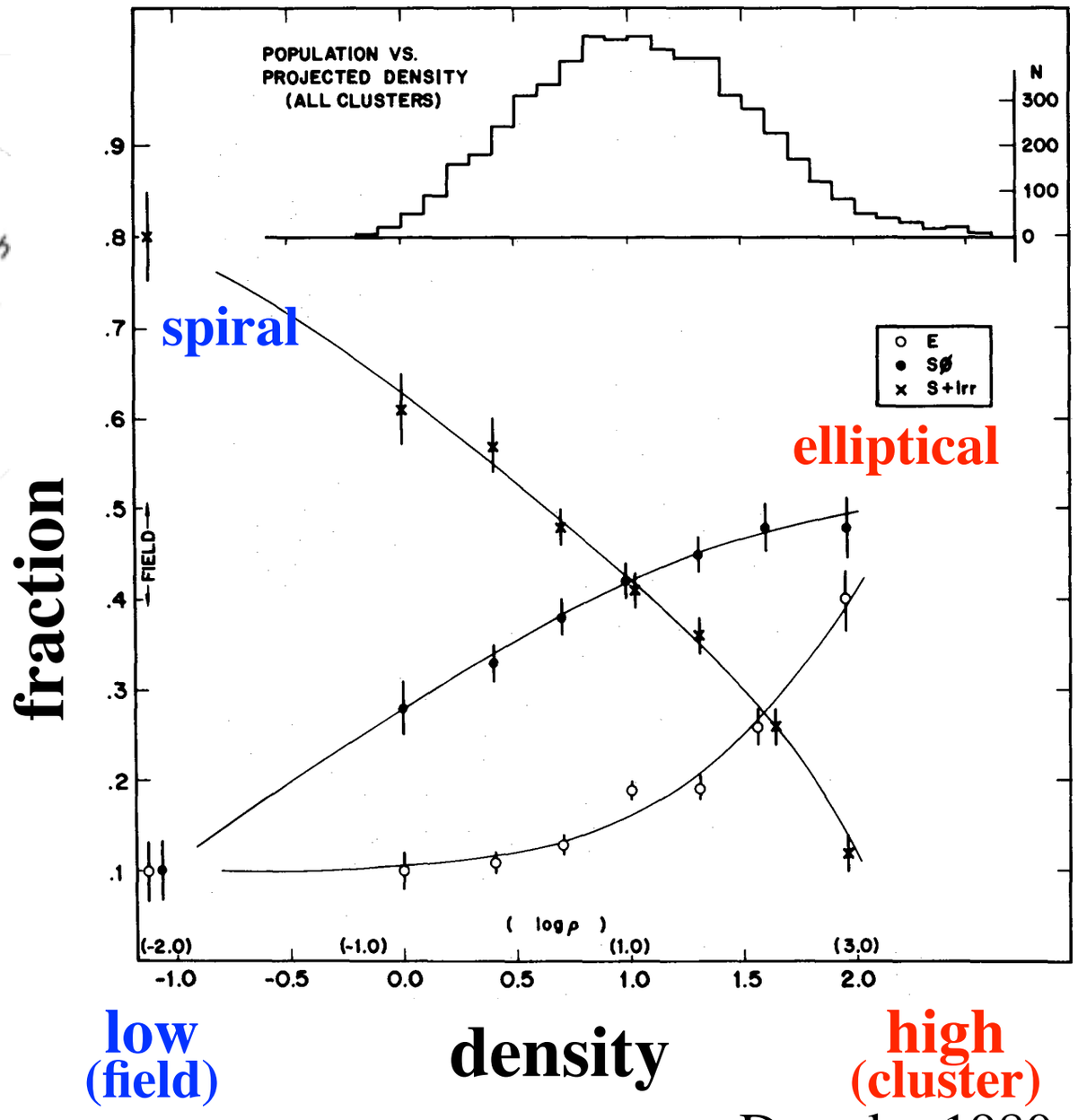
- Introduction
  - previous studies
- Protocluster search by:
  - **broad-band** (BB) imaging
  - **narrow-band** (NB) imaging
- Galaxy population in protoclusters
  revealed by **medium-band** (MB) imaging
- Summary

Importance of galaxy clusters

Galaxy clusters have an important role
in **structure formation** and **galaxy evolution.**

2dF Galaxy Redshift Survey

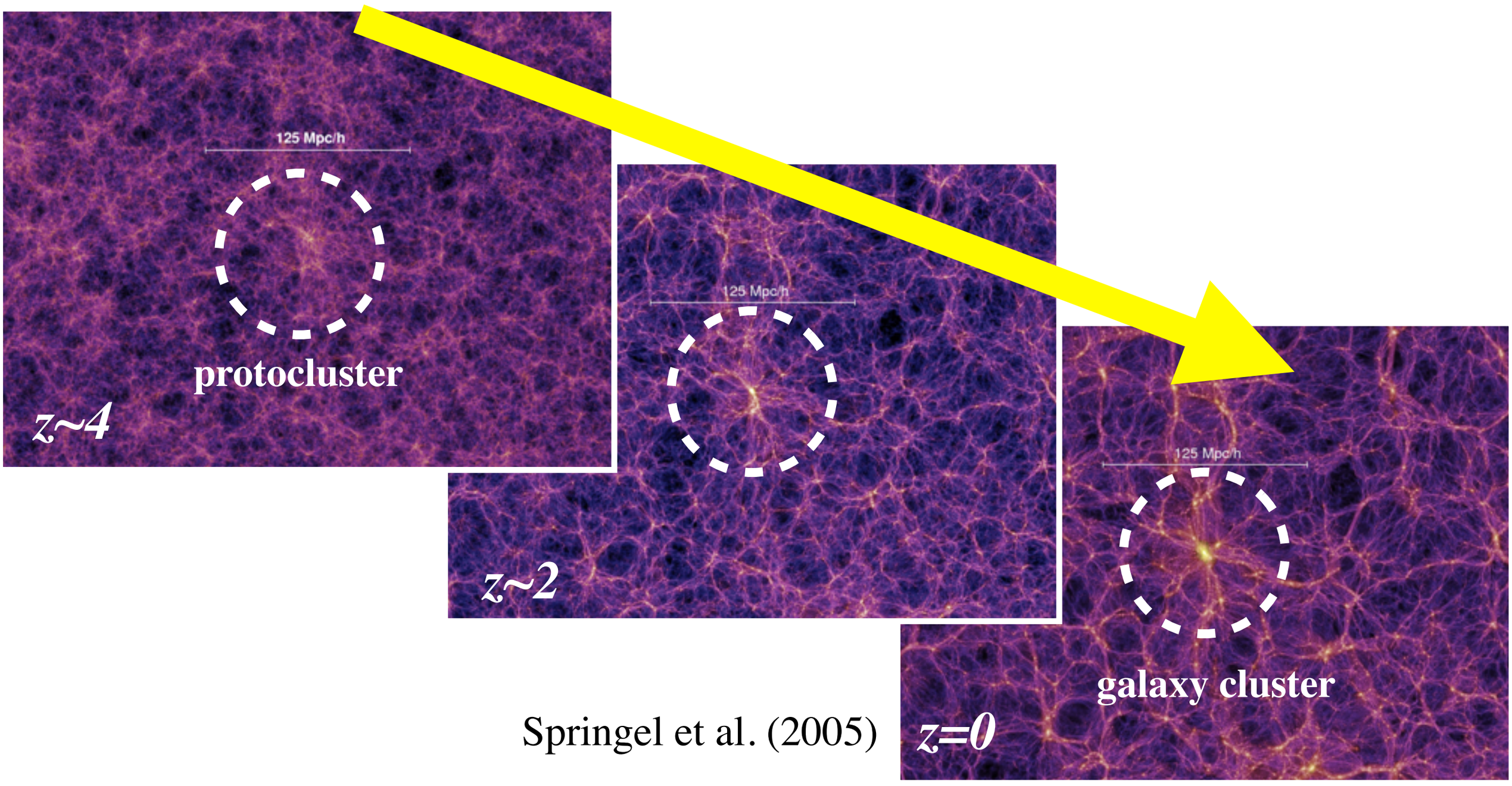




Dressler 1980

How are galaxy clusters formed?

Protoclusters are important objects
to reveal the formation history of galaxy clusters.



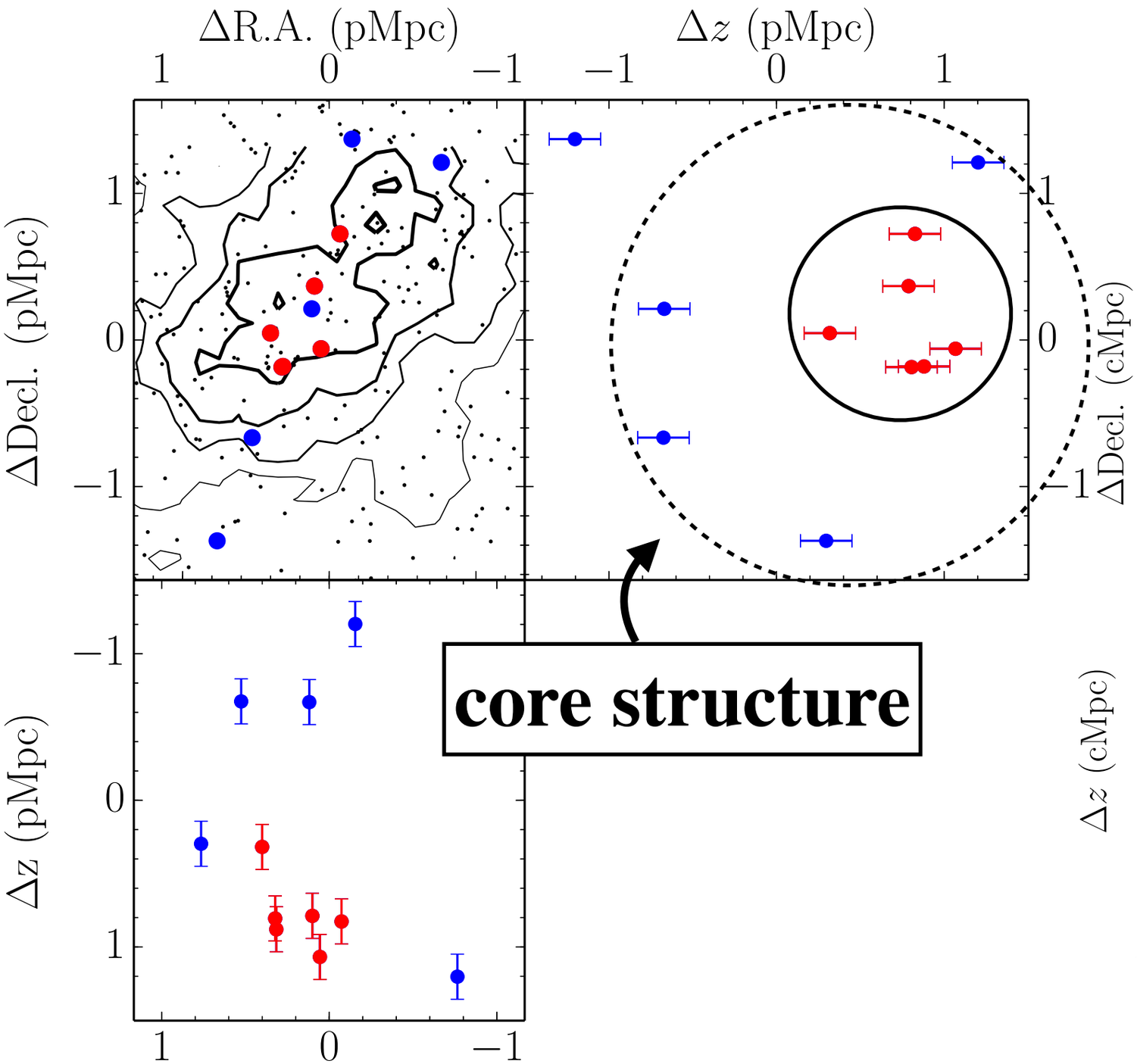
Springel et al. (2005)

Our previous studies

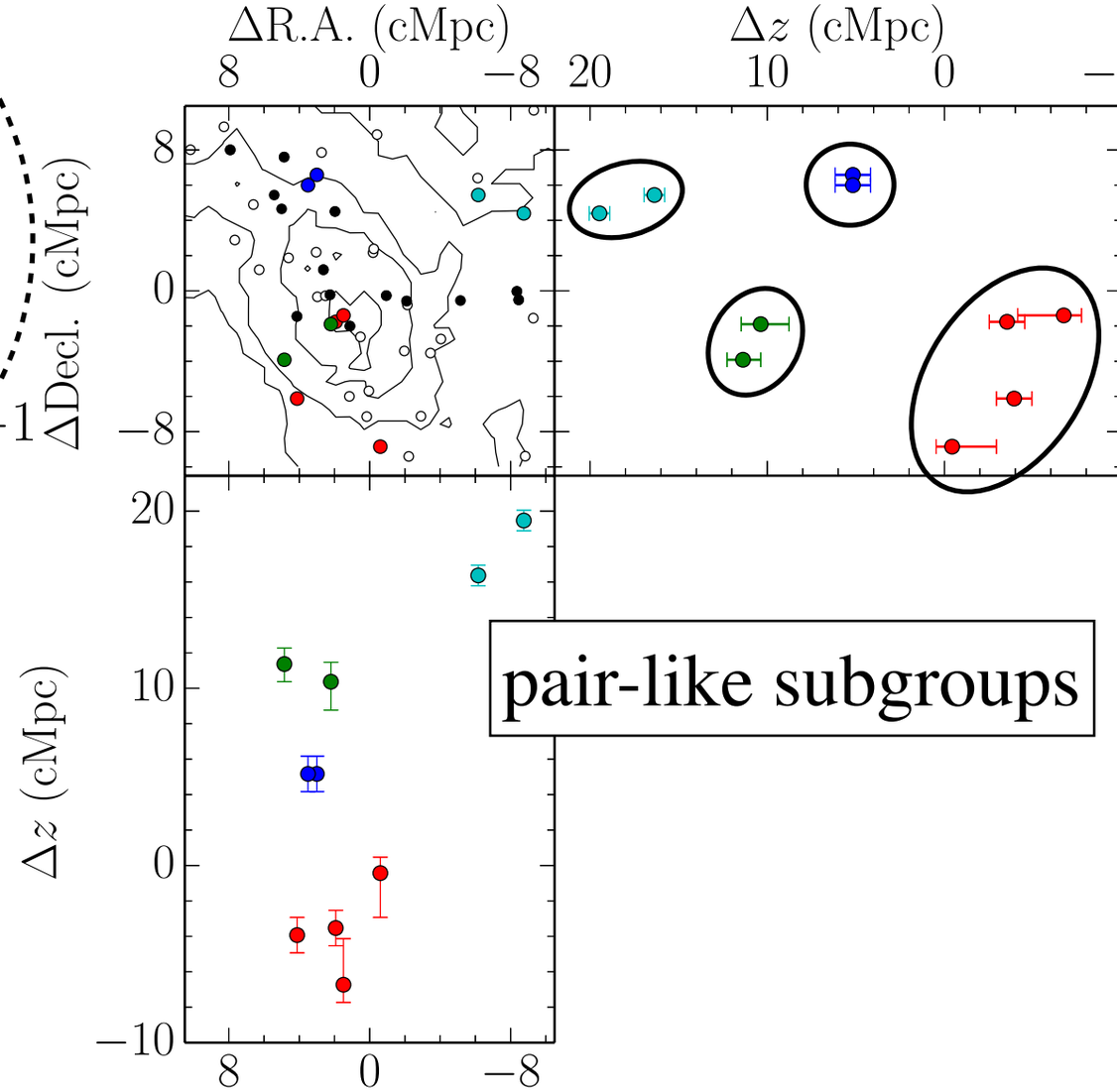
- Protocluster search at z~3-6 -

Protocluster structure

at z=3.67



at z=6.01



Protocluster structure

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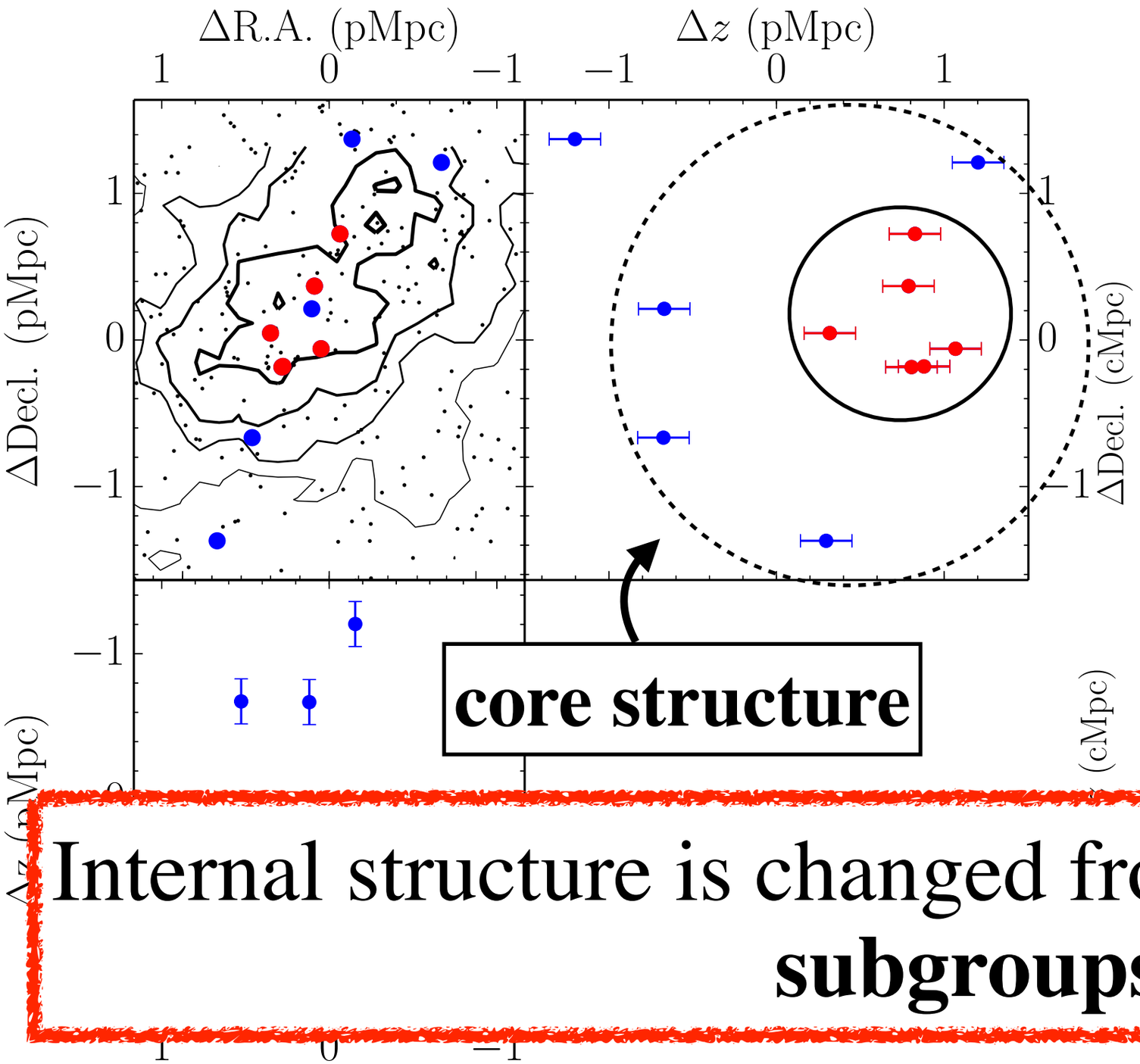
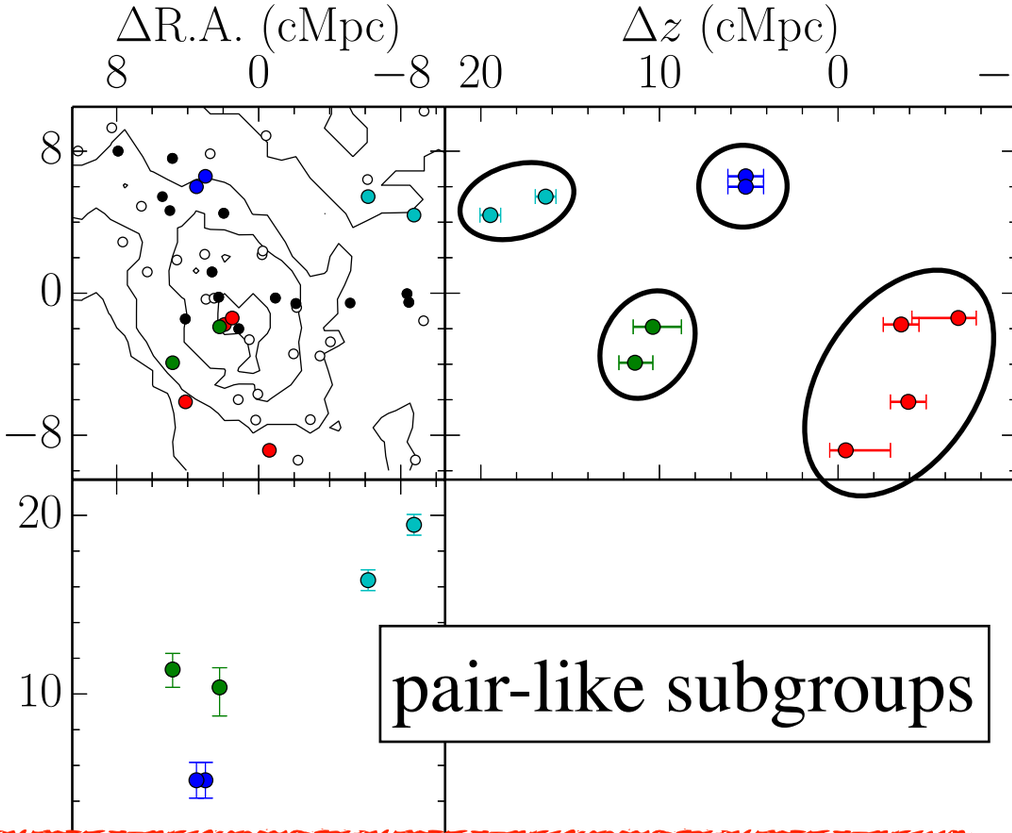


at z=6.01



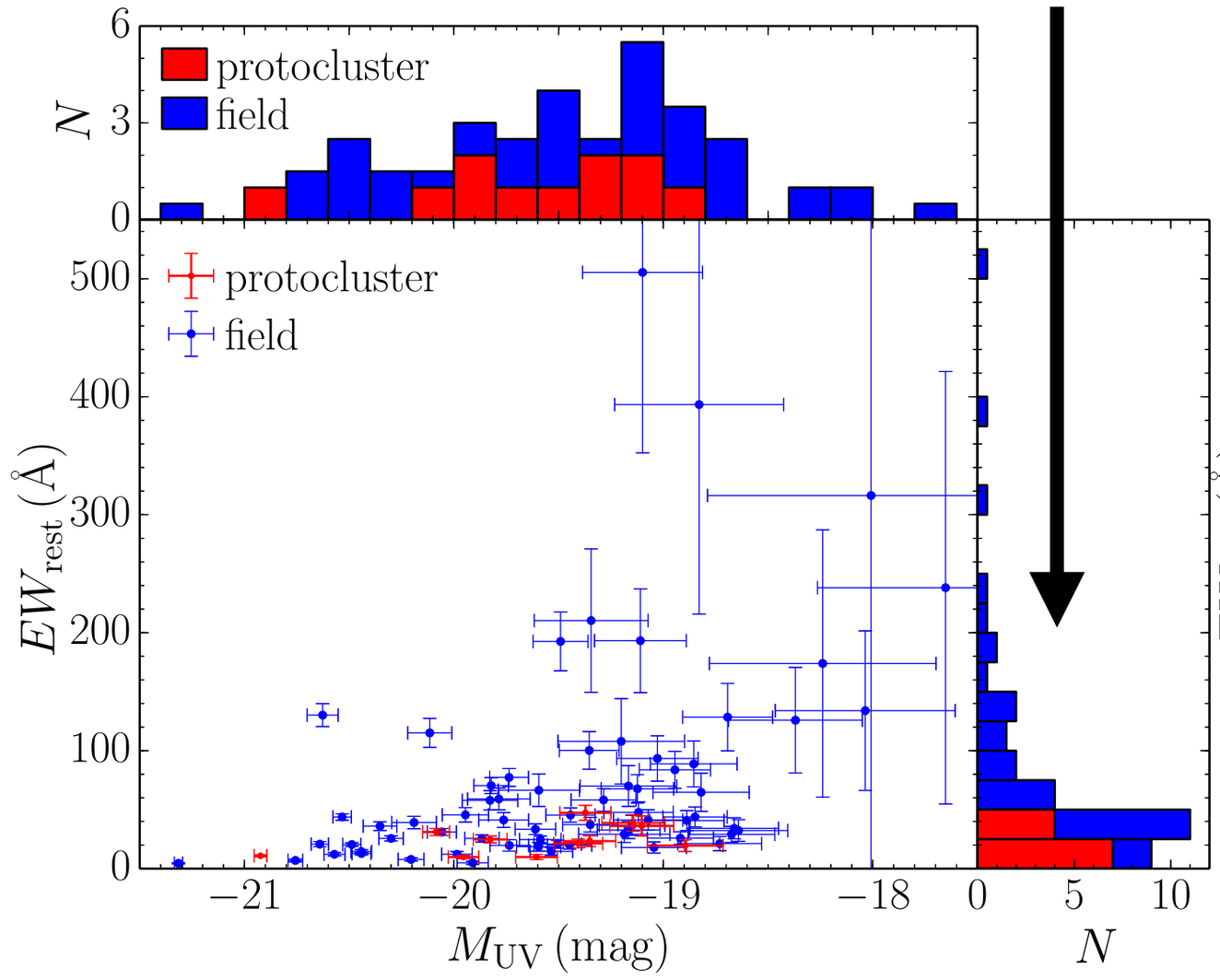
Internal structure is changed from z~6 to z~3:
subgroups to core structure.

Galaxy properties

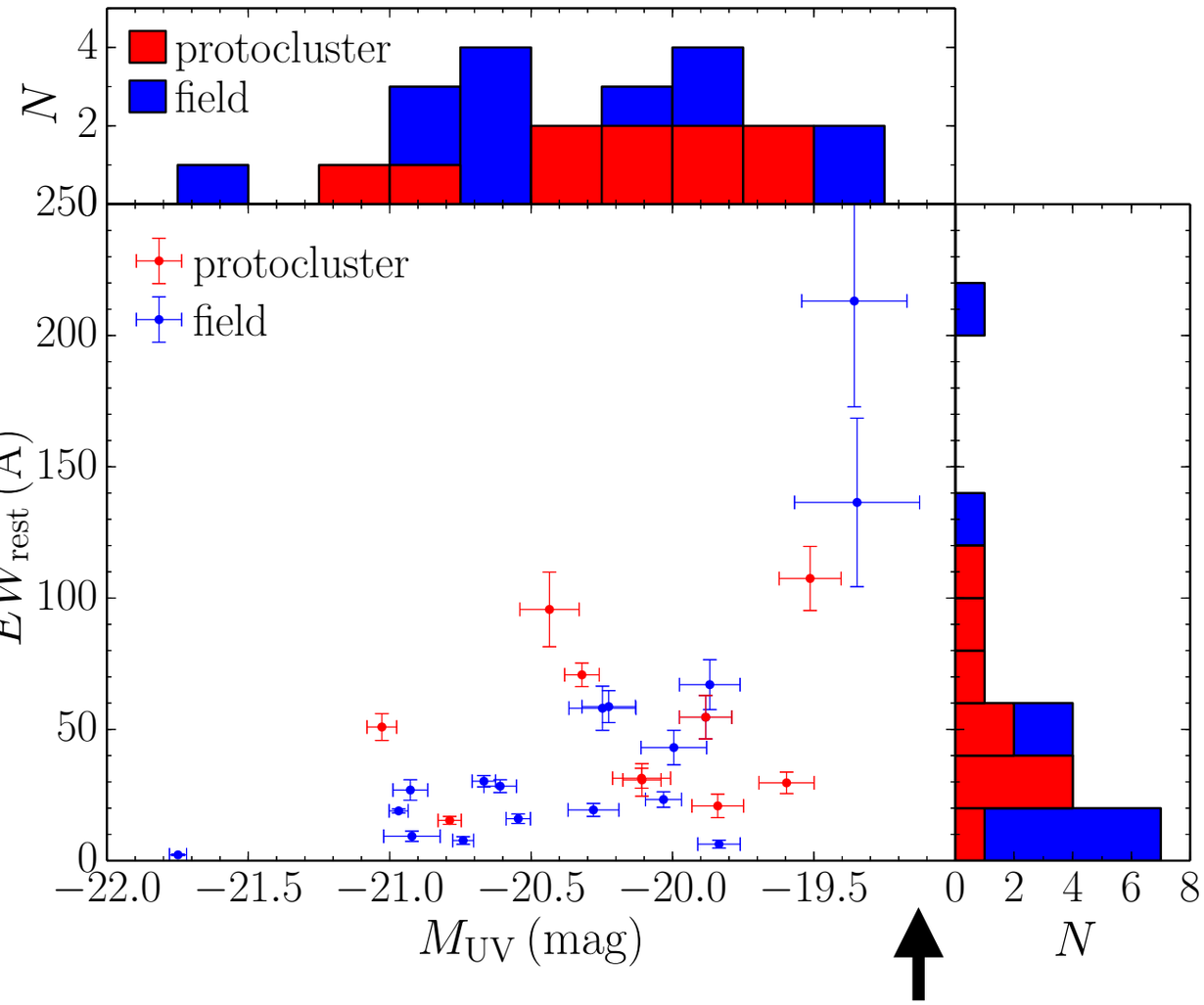
smaller Lya EW in protocluster

dust? or HI gas?

at z=3.67



at z=6.01



no difference

Galaxy properties

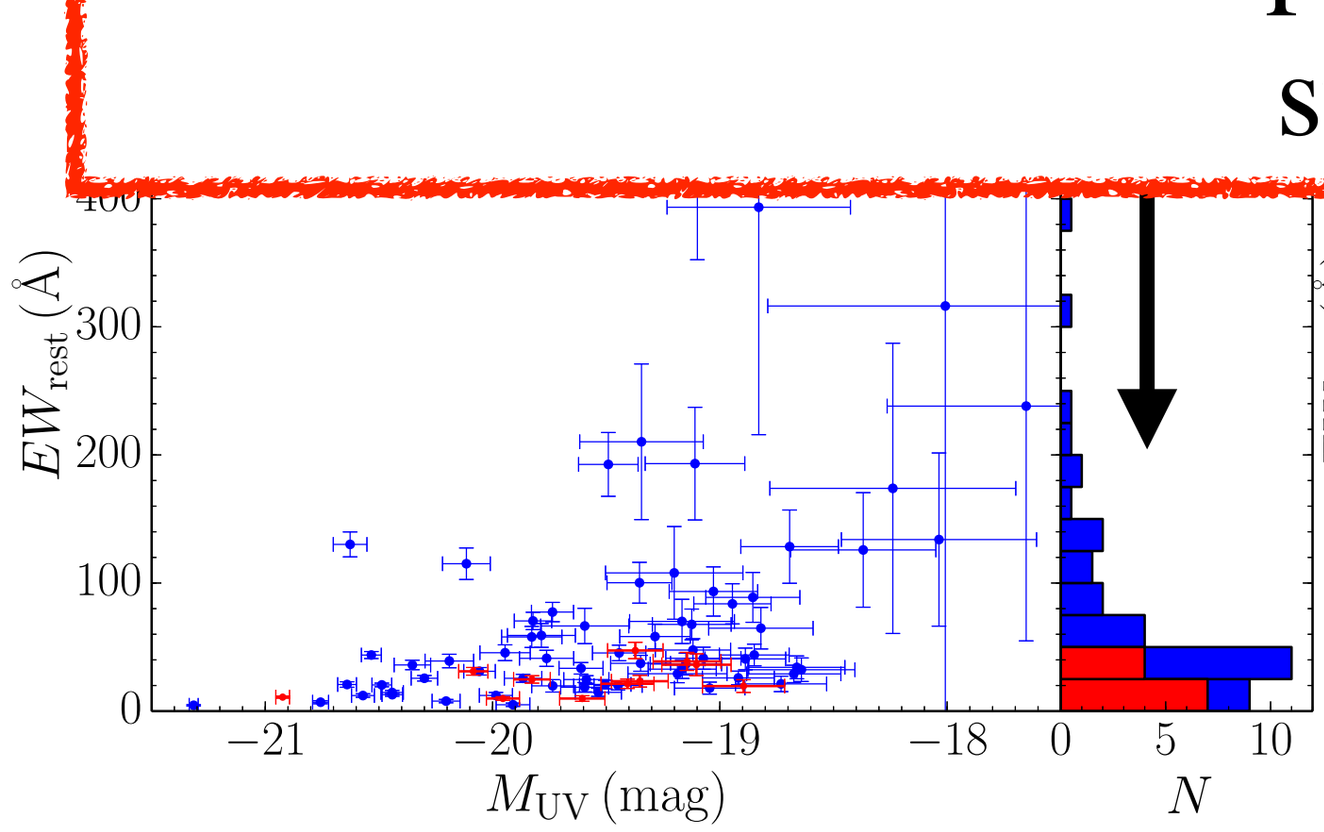
smaller Lya EW in protocluster

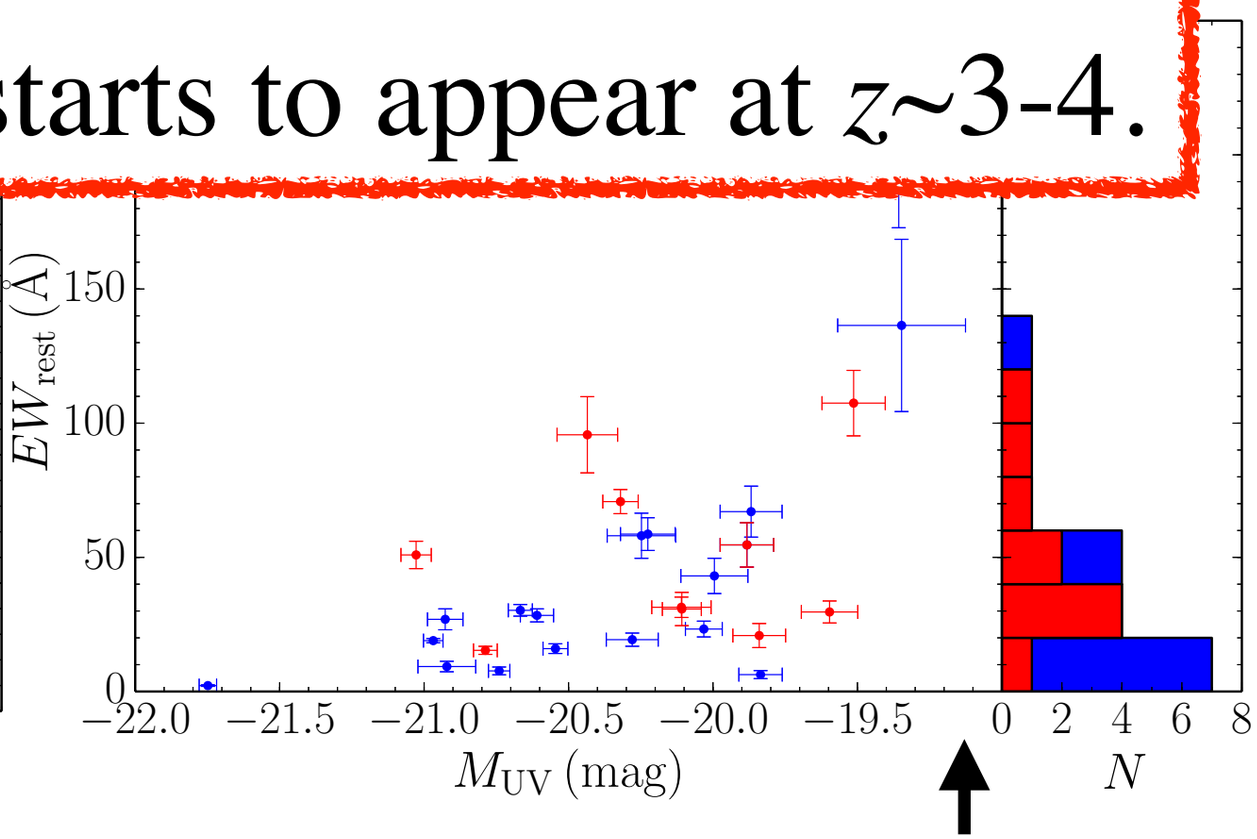
dust? or HI gas?

at z=3.67

at z=6.01

The difference between protocluster and field starts to appear at z~3-4.



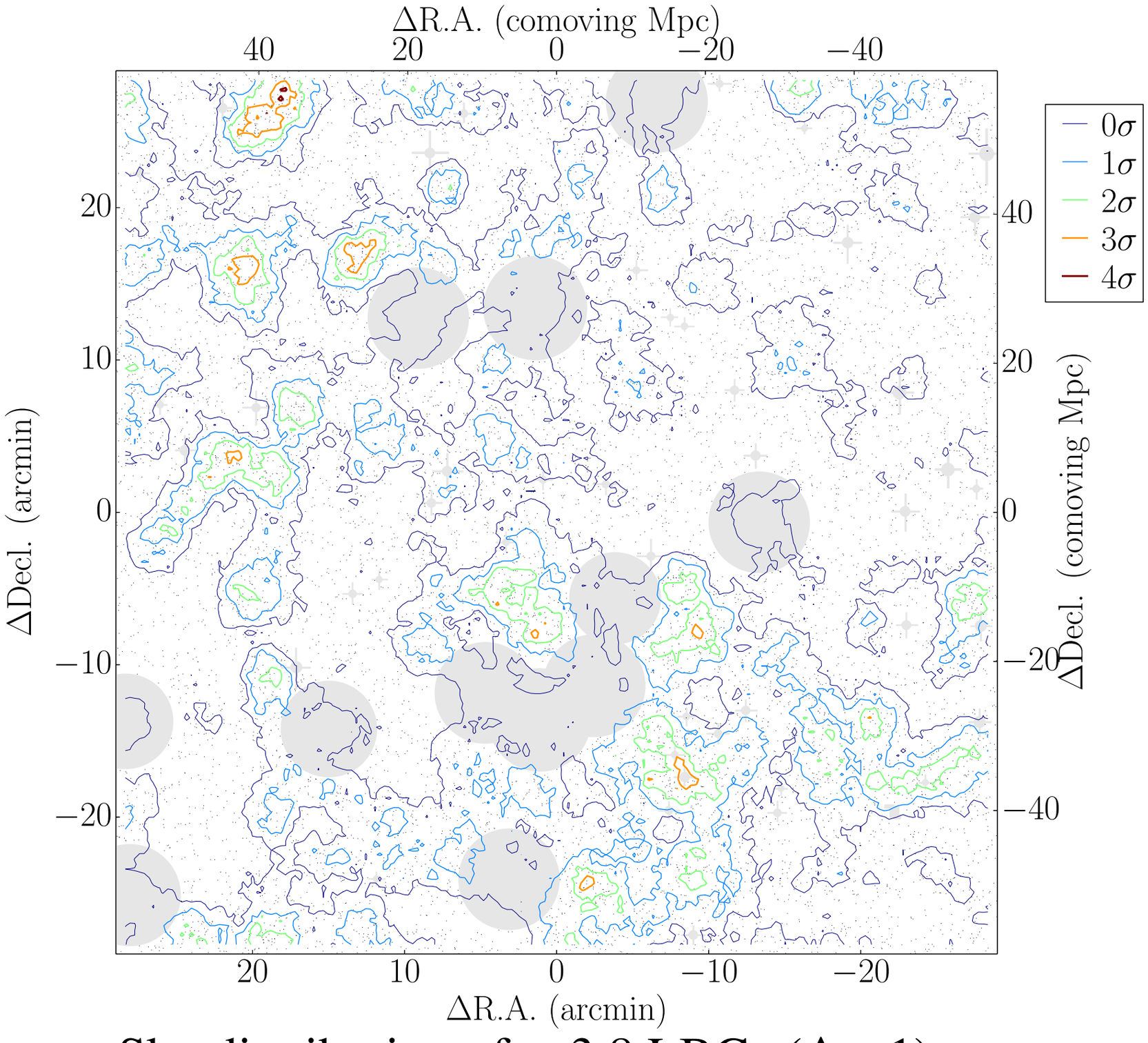


no difference

Protocluster search

How to find protoclusters

- by using BB imaging (Toshikawa et al. 2015)



Sky distribution of z~3.8 LBGs (Δz~1)

How to find protoclusters

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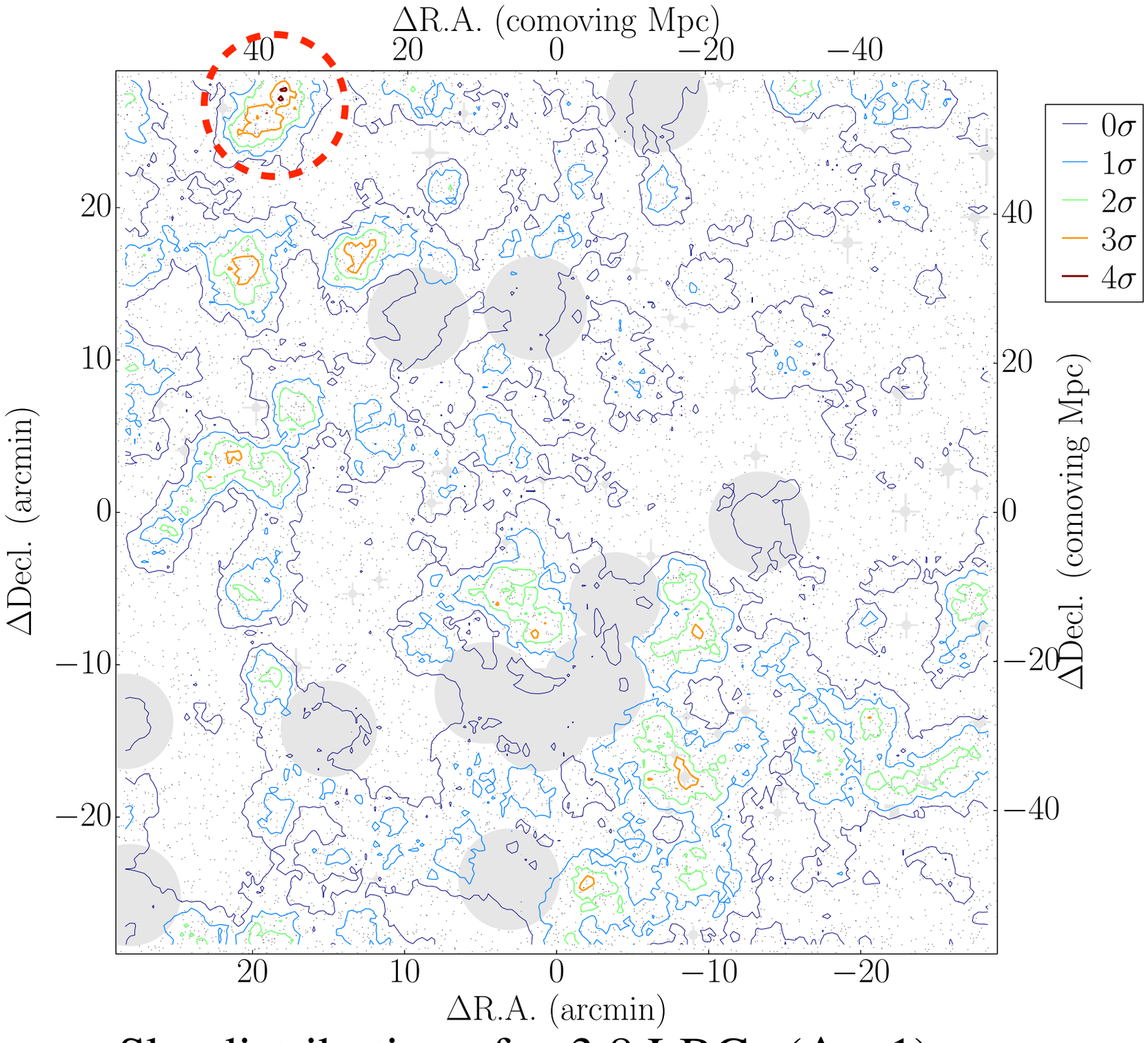

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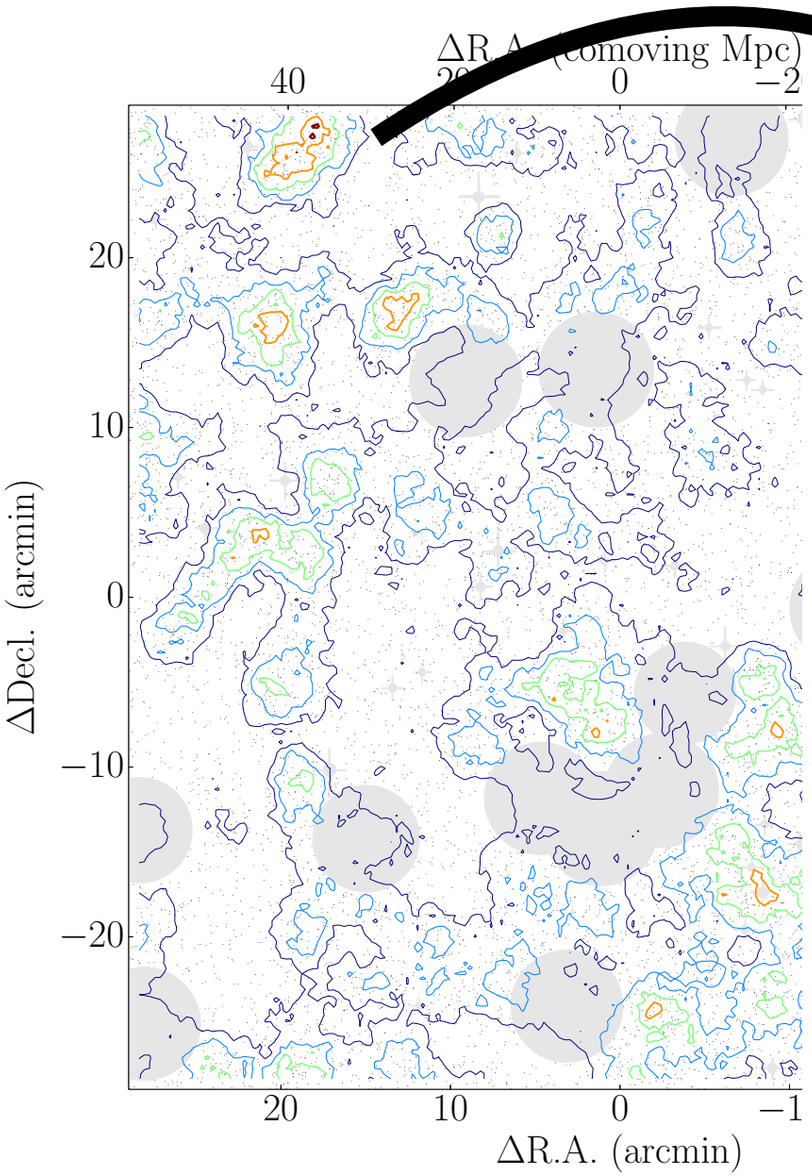
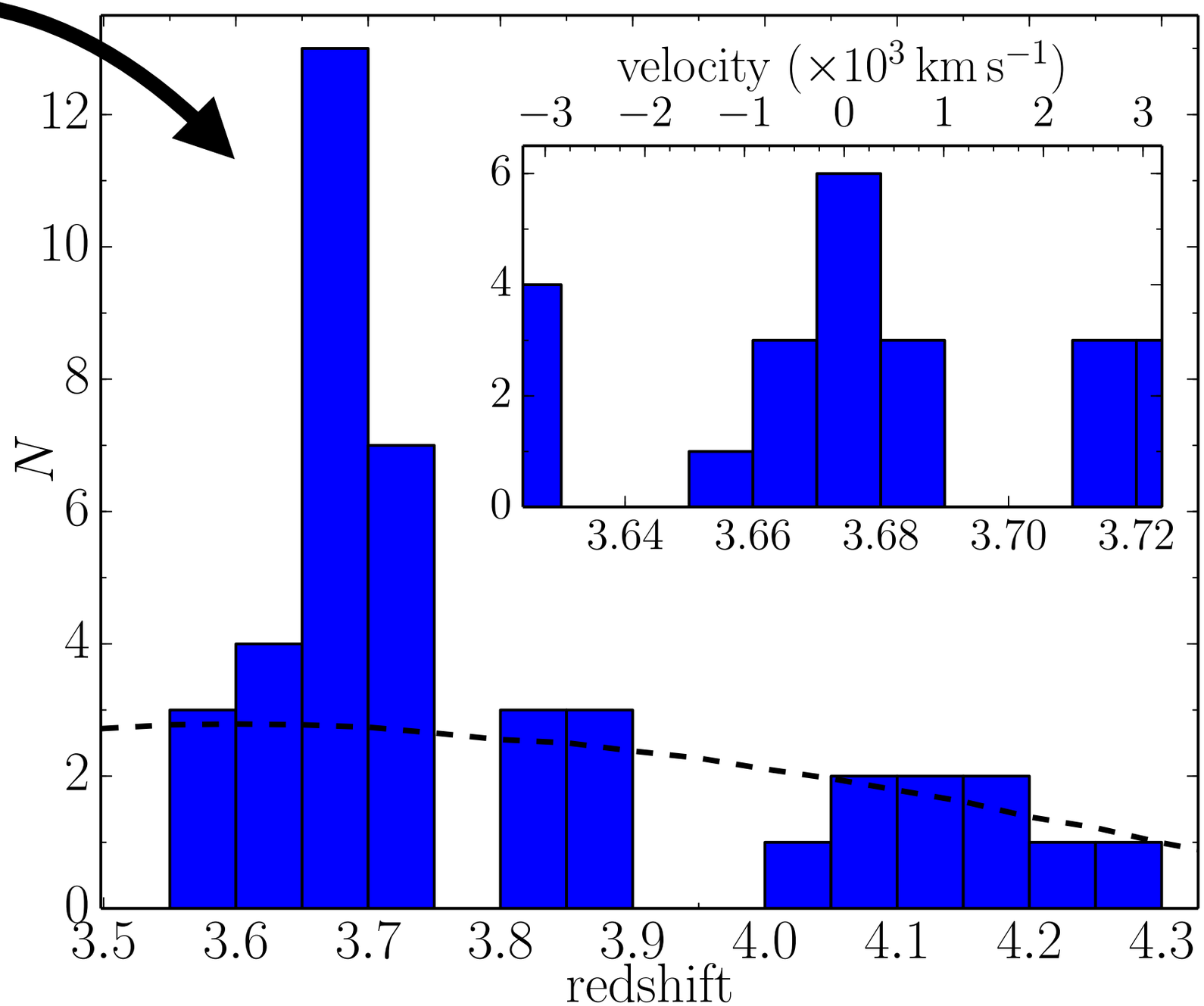
Follow-up spectroscopy

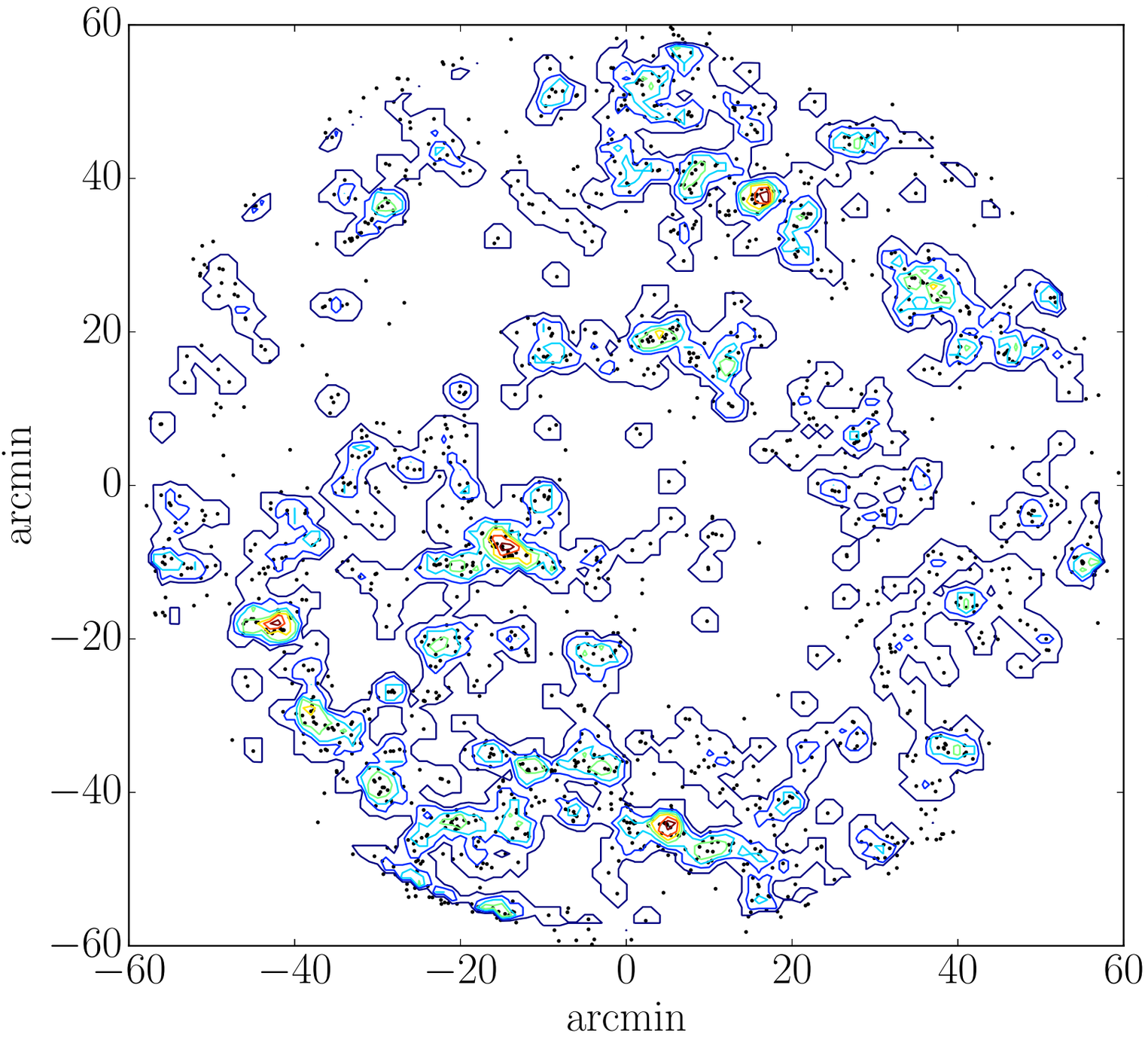




How to find protoclusters

- by using NB imaging

Sky distribution of
mock z~2.2 HAEs (Δz=0.03)



Mock HAEs are selected
from the light-cone model
of Henriques et al (2015).

selection criteria:
2.240<z<2.272
SFR>20 M_{sun}/yr

How to find protoclusters

- by using NB imaging

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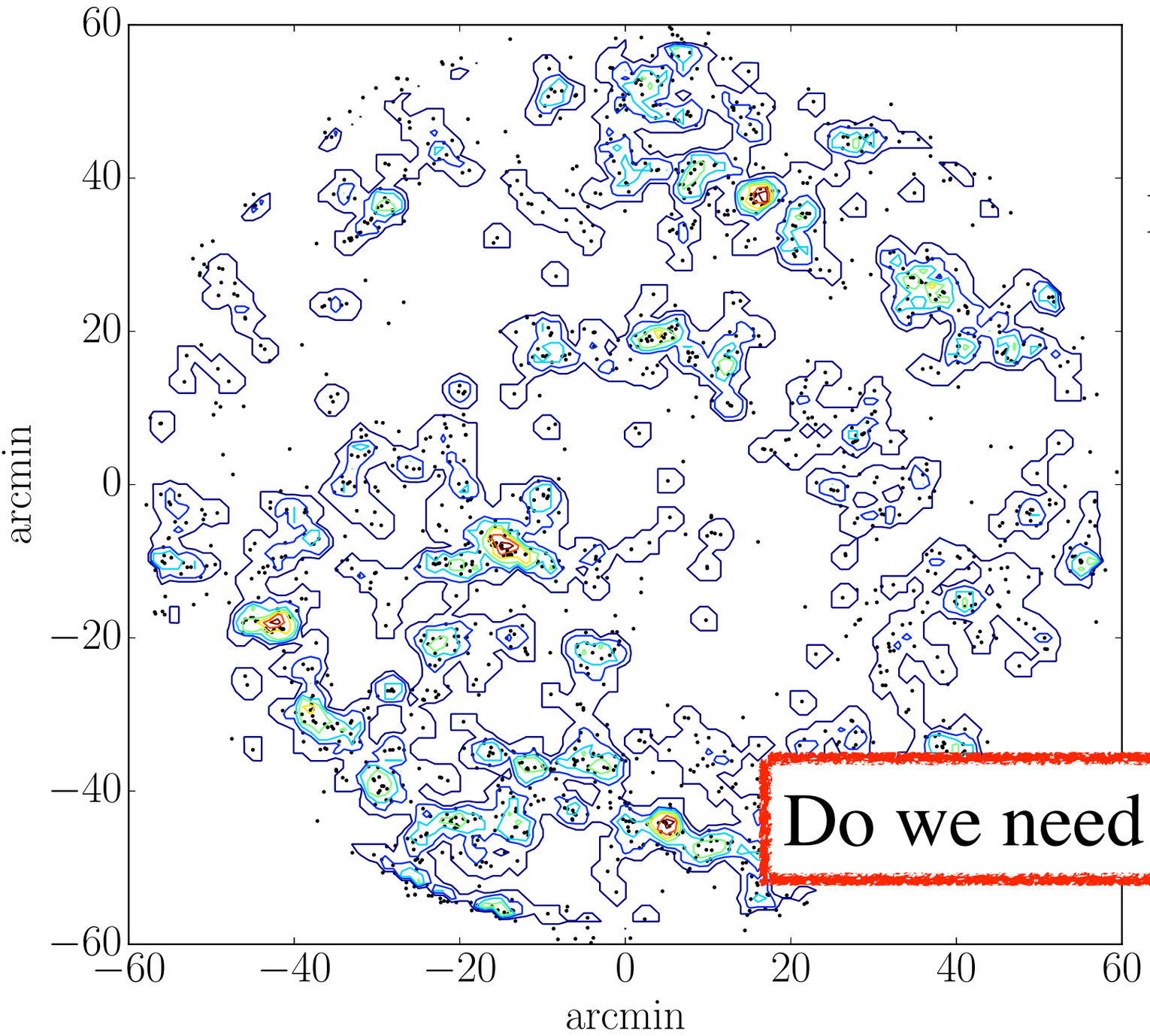

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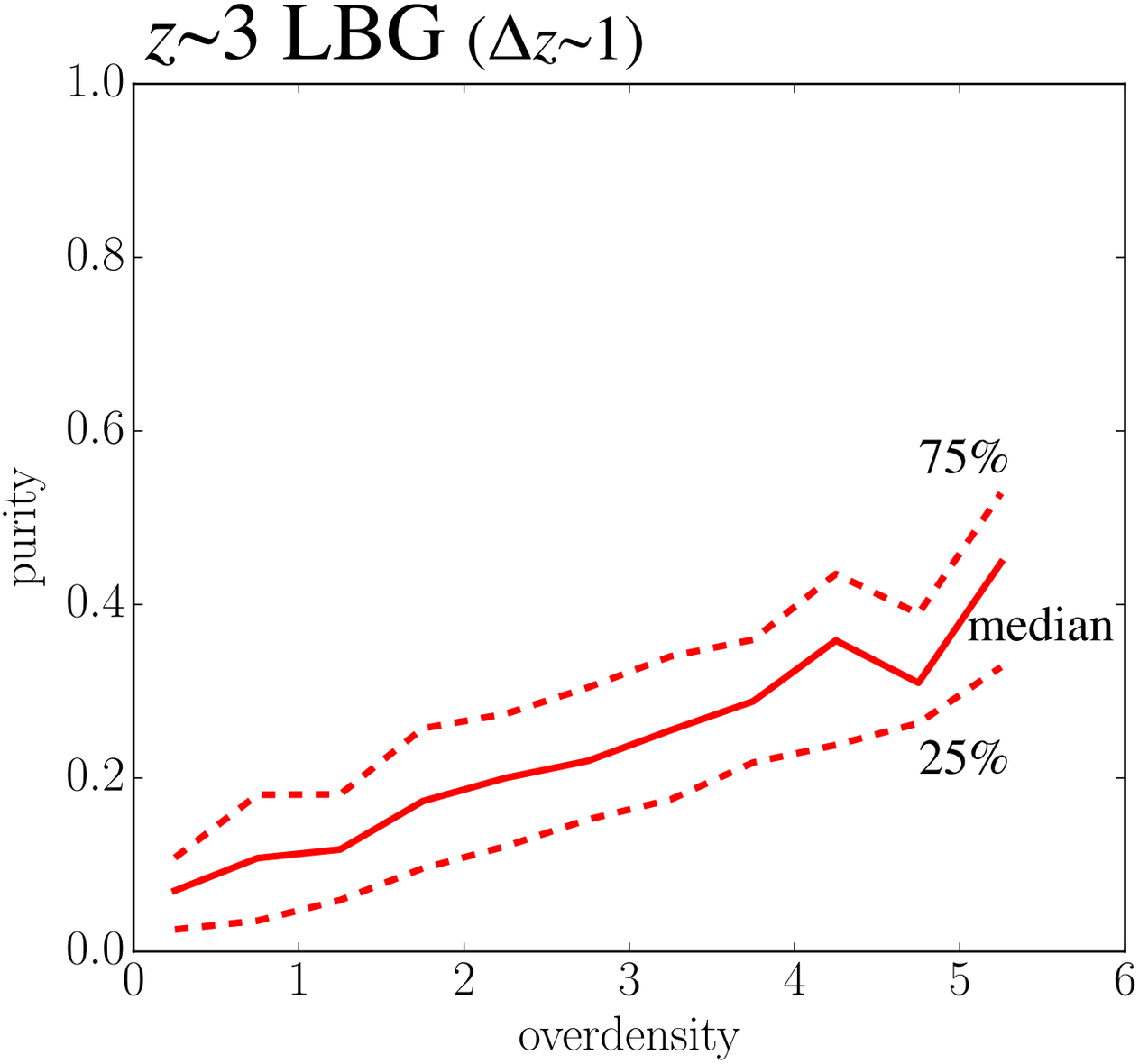
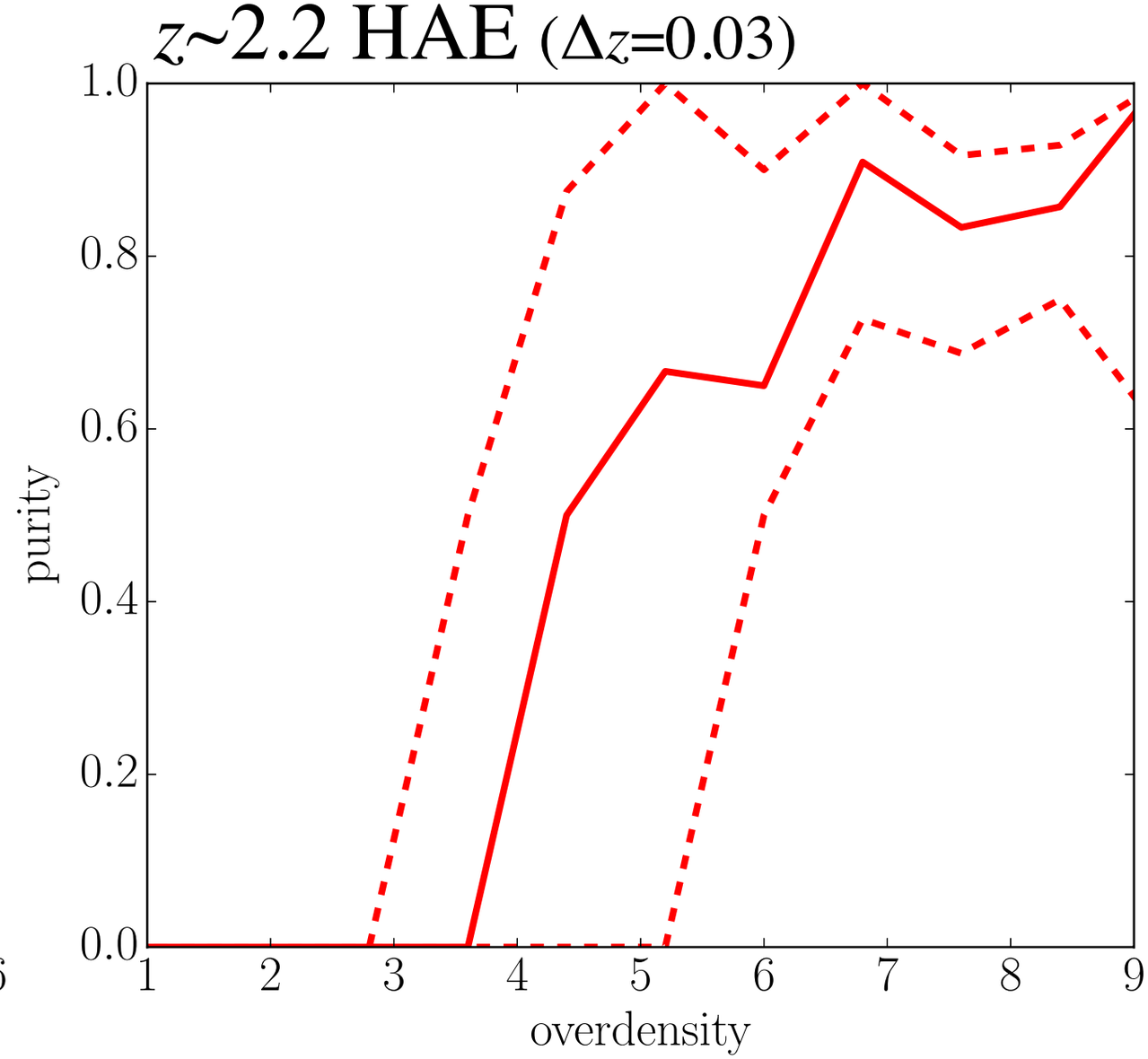
Do we need follow-up spectroscopy?

How to find protoclusters

purity: fraction of protocluster galaxies contained in 1.5 Mpc aperture

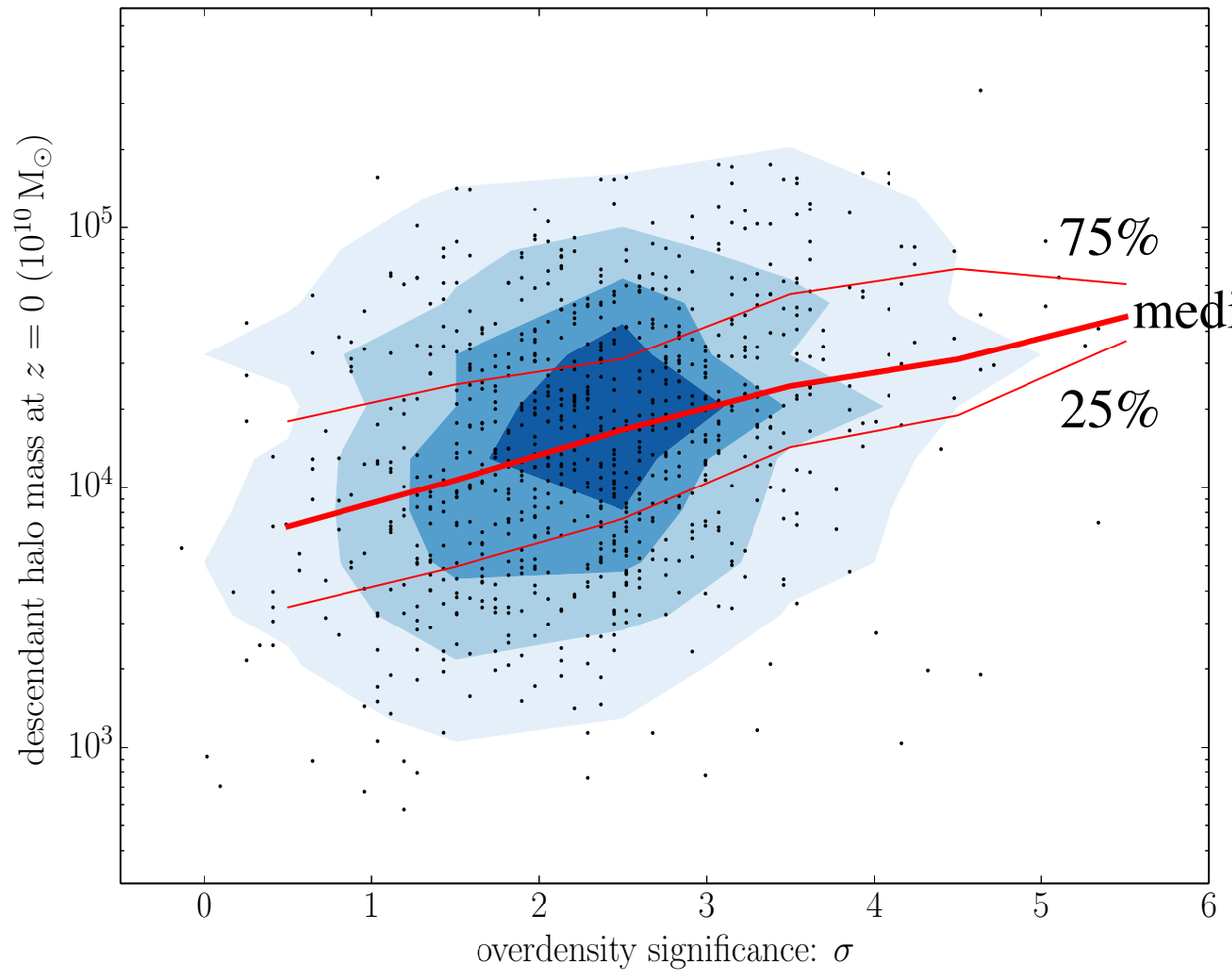




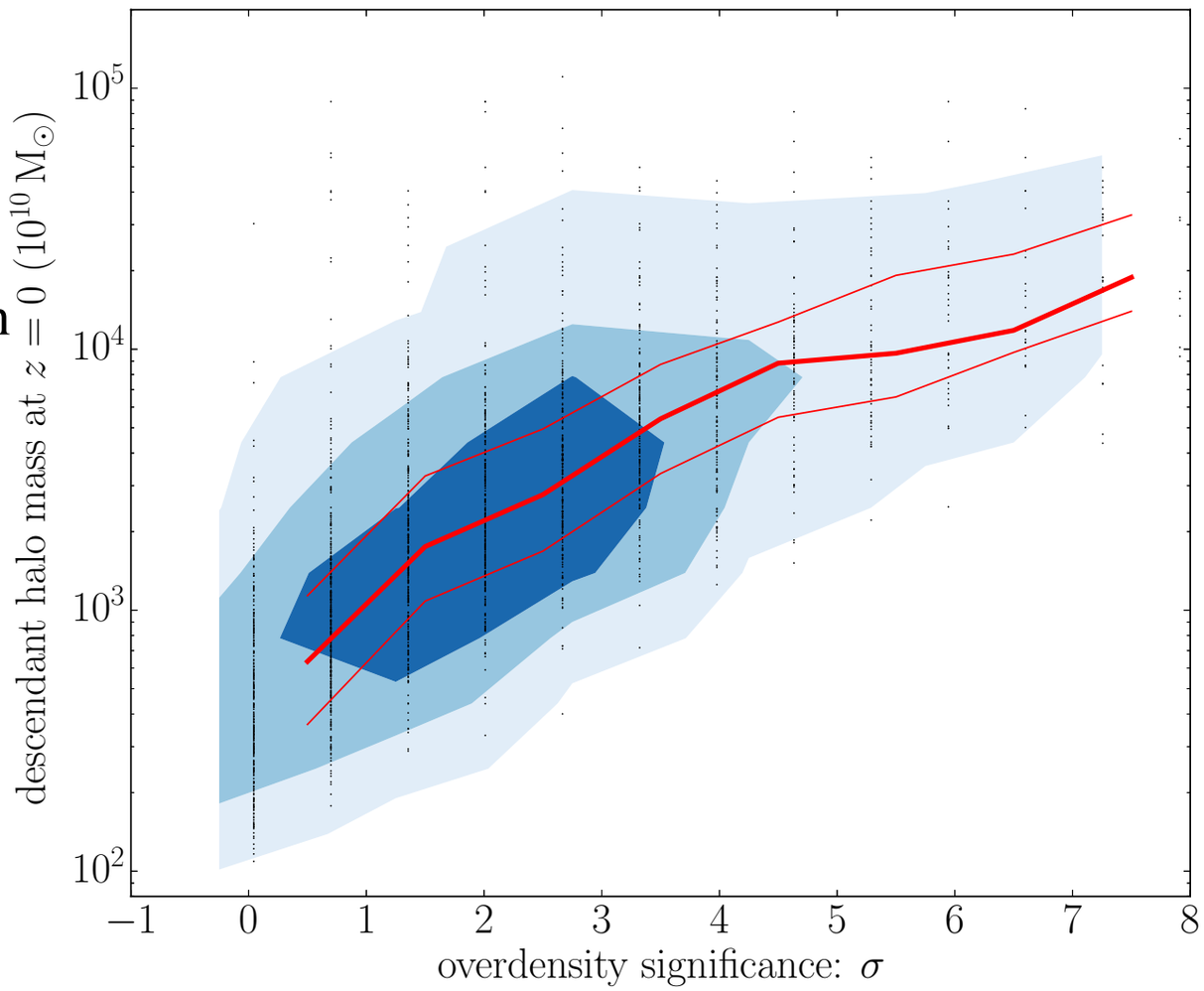
By using narrow-band imaging,
we can identify protoclusters **without spectroscopy**.

Descendant halo mass estimation

z~3 LBG (Δz~1)



z~2.2 HAE (Δz=0.03)



Typical descendant halo mass is

~5×10^{14} M_{sun} (LBG), ~2×10^{14} M_{sun} (HAE).

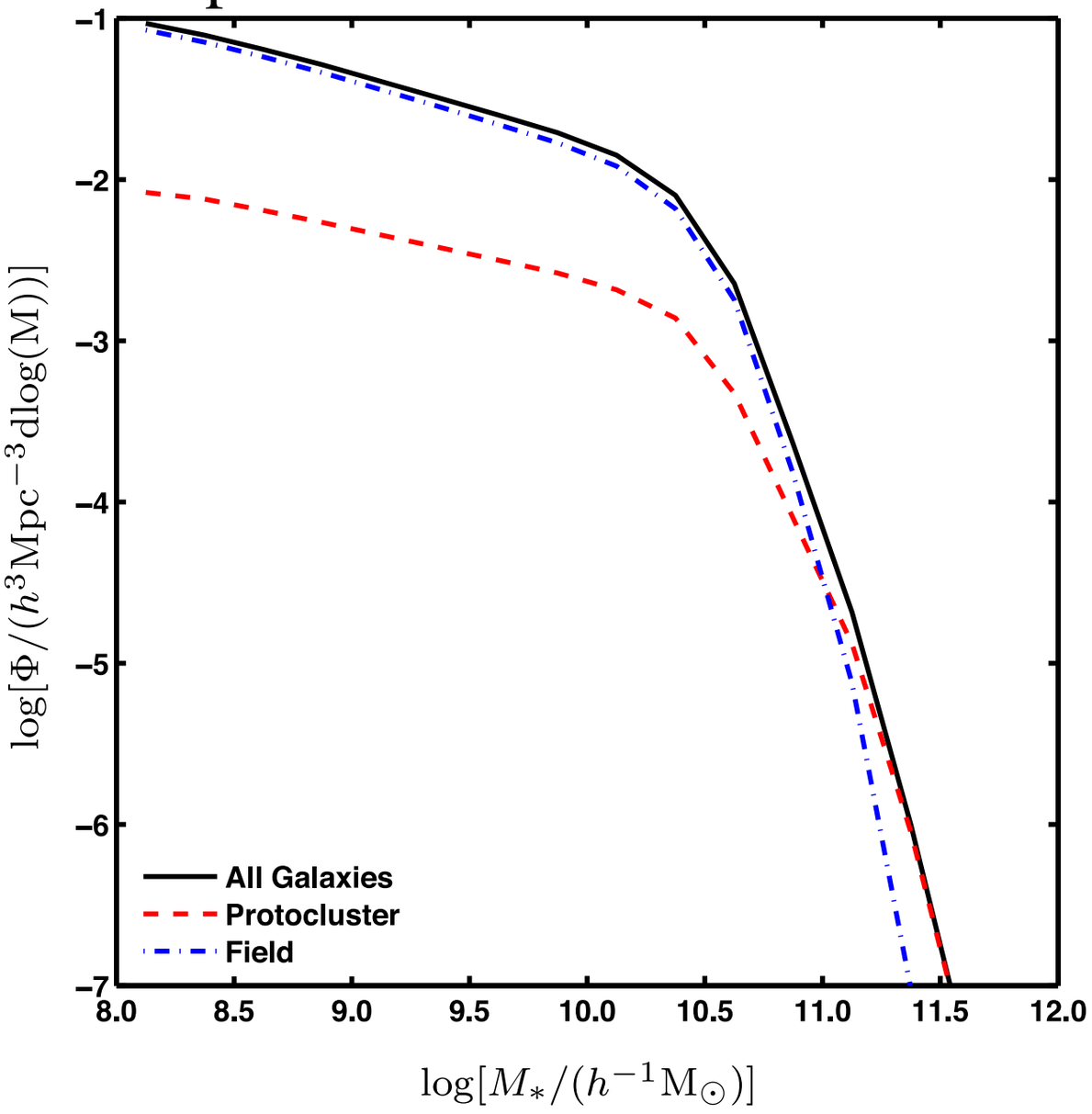
NB imaging can trace smaller protoclusters.

Galaxy population in protoclusters

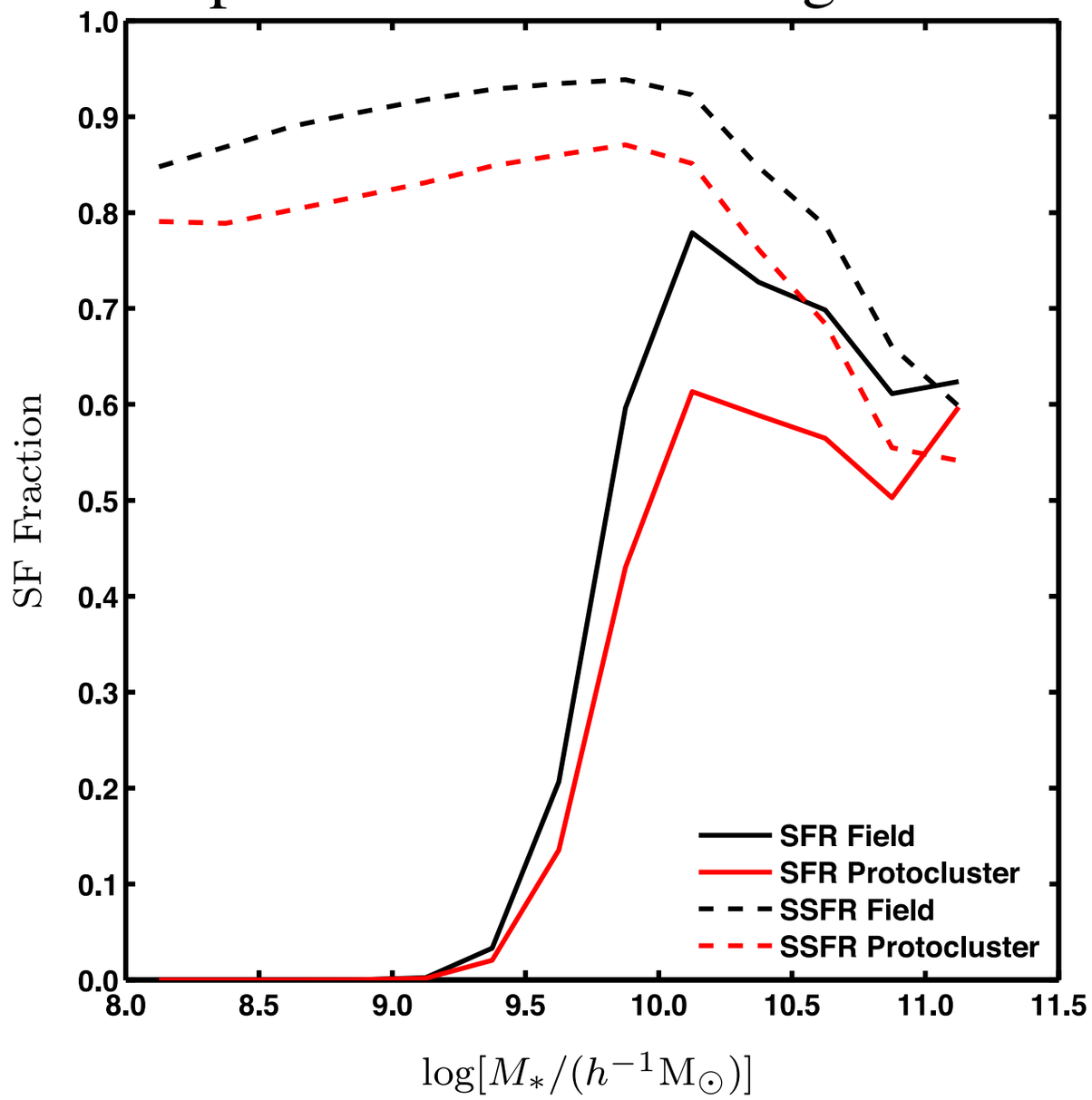
Where are massive/quiescent galaxies?

Protocluster would be a good laboratory
to investigate massive/quiescent galaxies.

expected stellar mass function



expected fraction of SF galaxies



(Muldrew et al. 2015)

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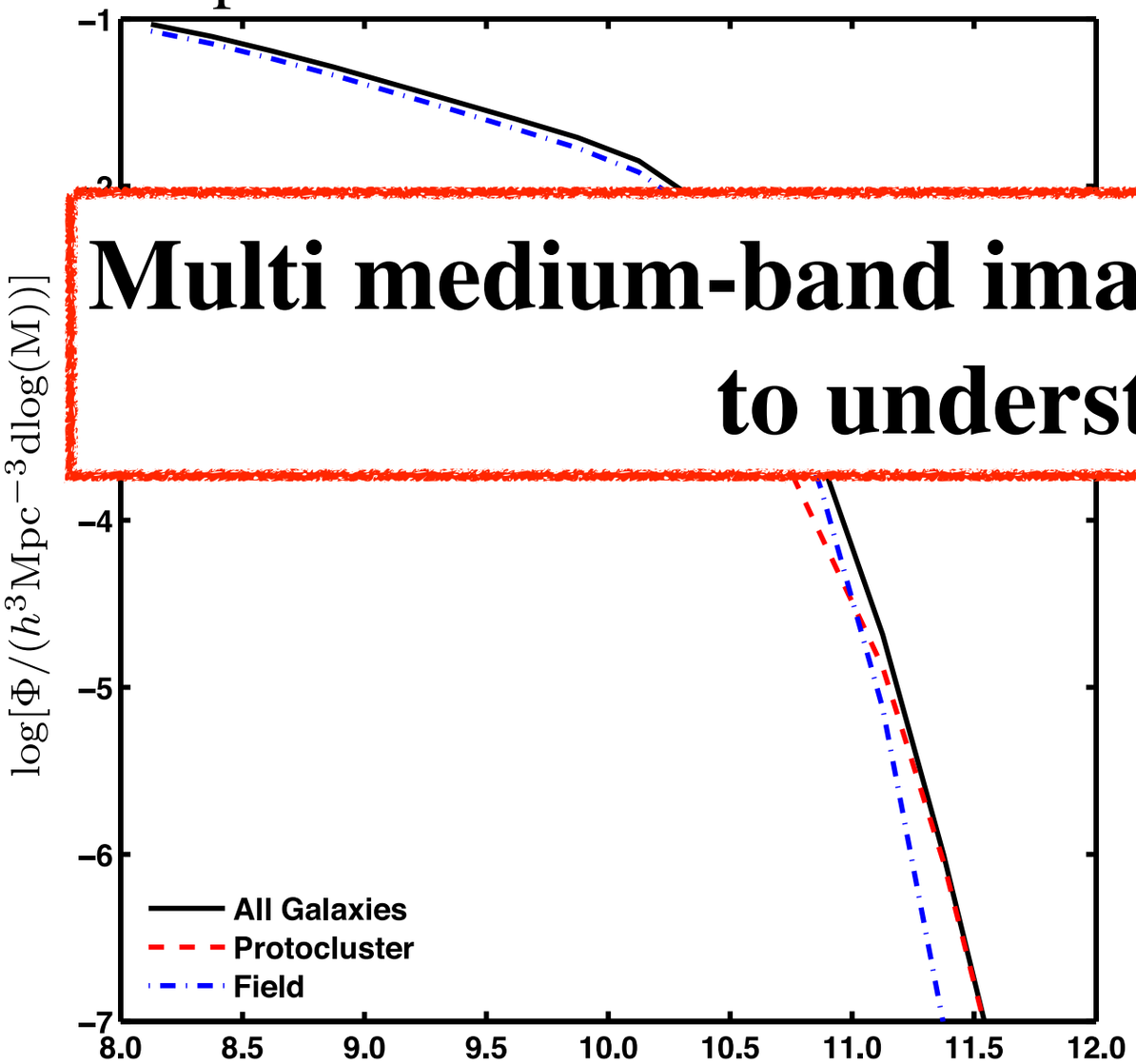

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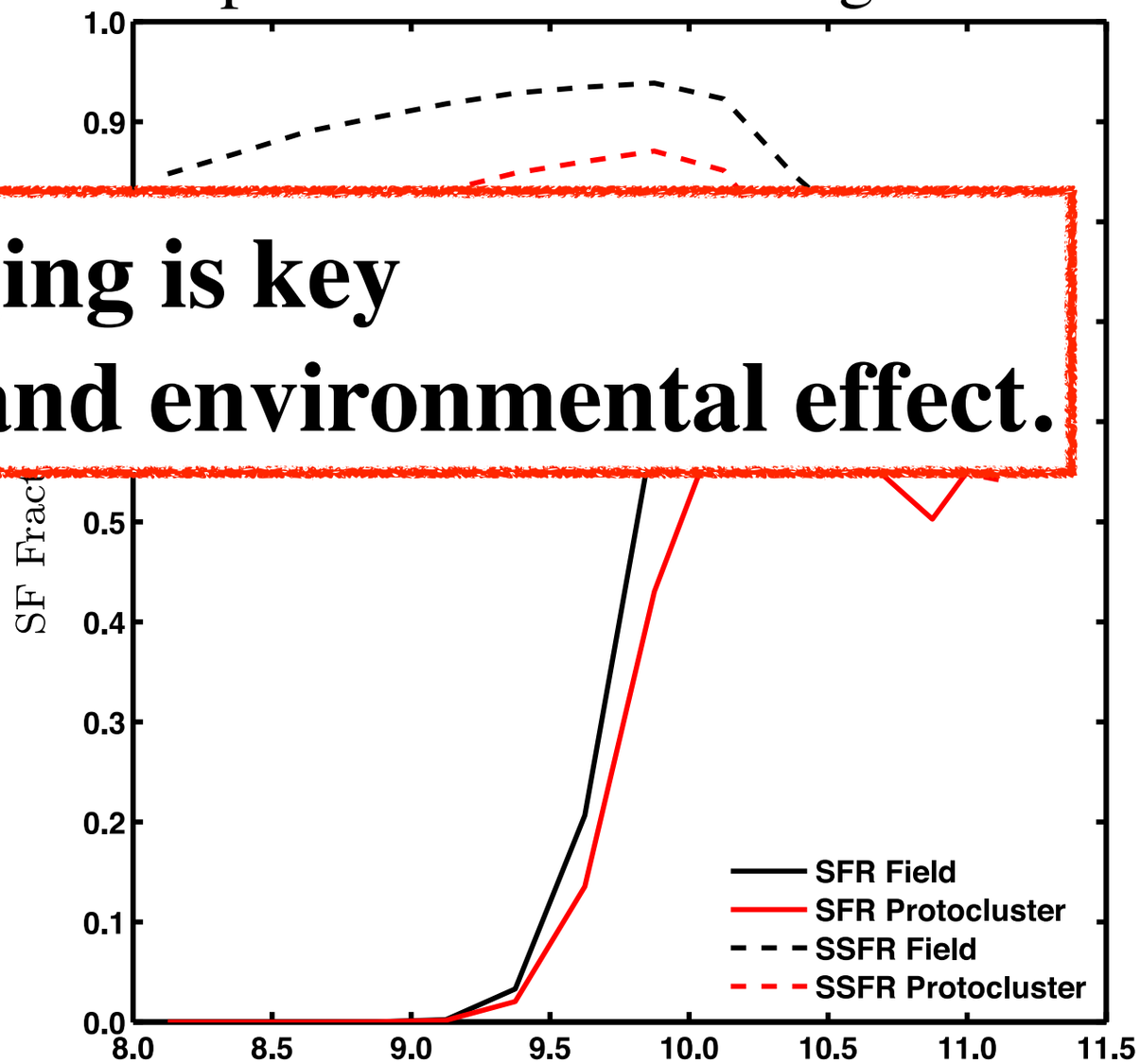

Multi medium-band imaging is key
to understand environmental effect.

(Muldrew et al. 2015)

Summary

- Protocluster are good laboratories to investigate galaxy evolution.
- NB imaging is effective to search protoclusters.
- NB imaging can find different scale of protocluster from BB imaging.
- Protoclusters are good targets to find massive/quiescent galaxies by MB imaging.