Protoclusters at z~3-6 Probed by Wide-field Imaging

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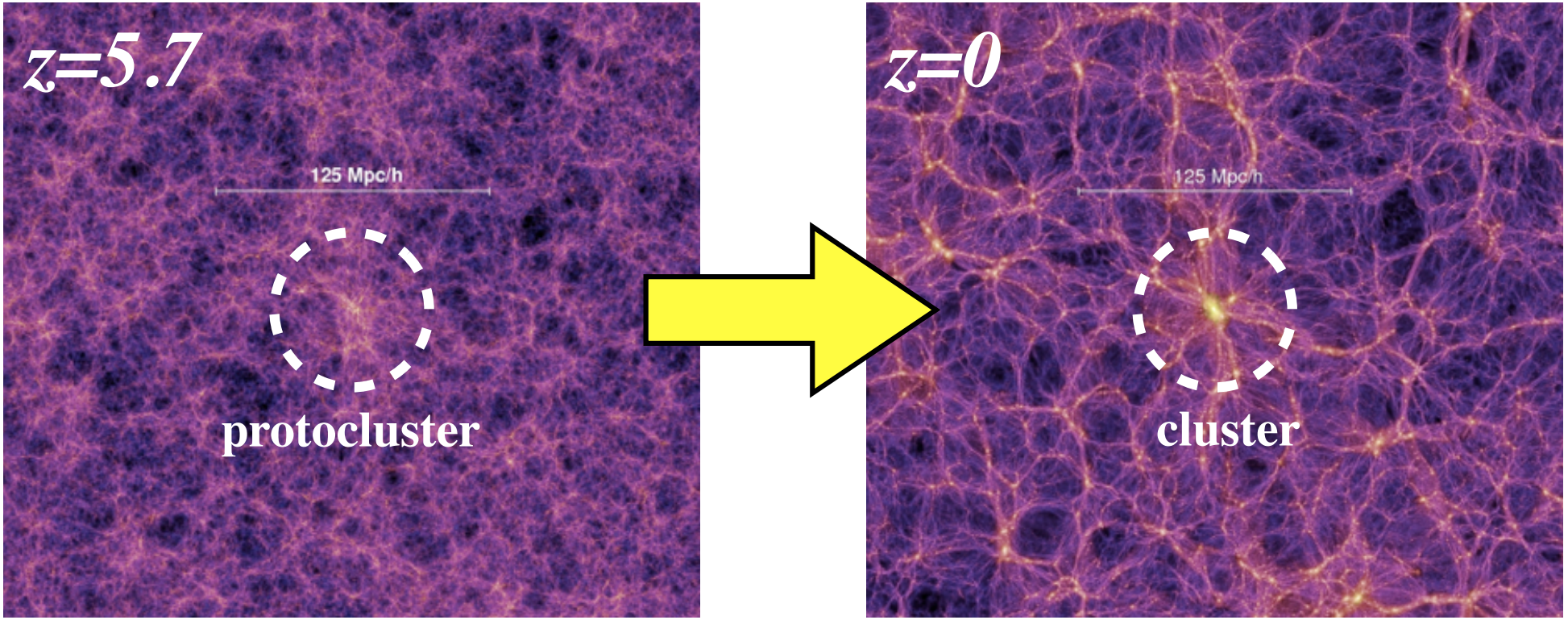
- Summary

Importance of protoclusters

When and how are galaxy clusters formed?

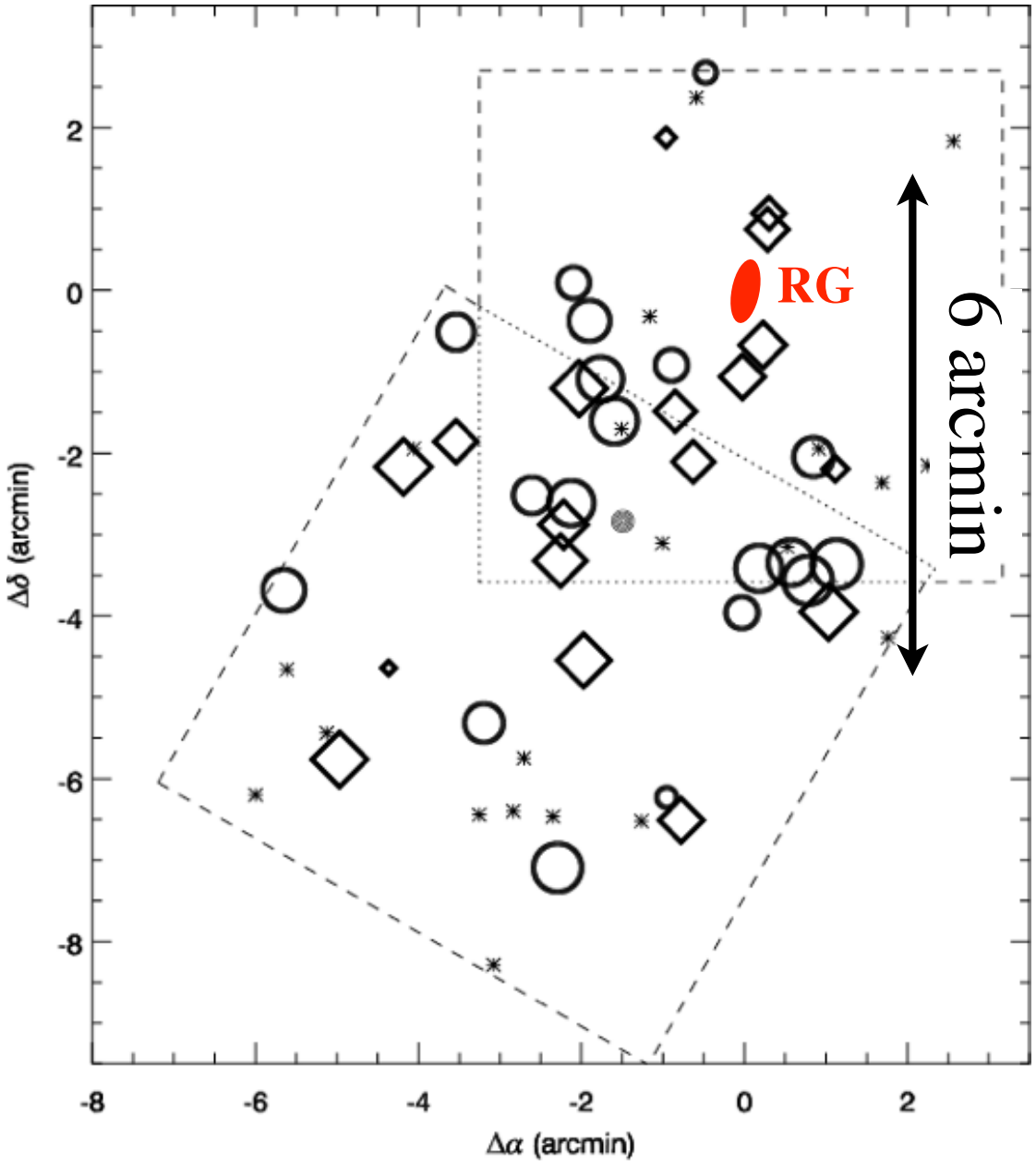
Protoclusters in the early universe would reveal the primordial condition of clusters at their birth.



Springel et al. (2005)

The number of known protoclusters is still small, especially at high redshift (N~10-20 at z>3)**.**

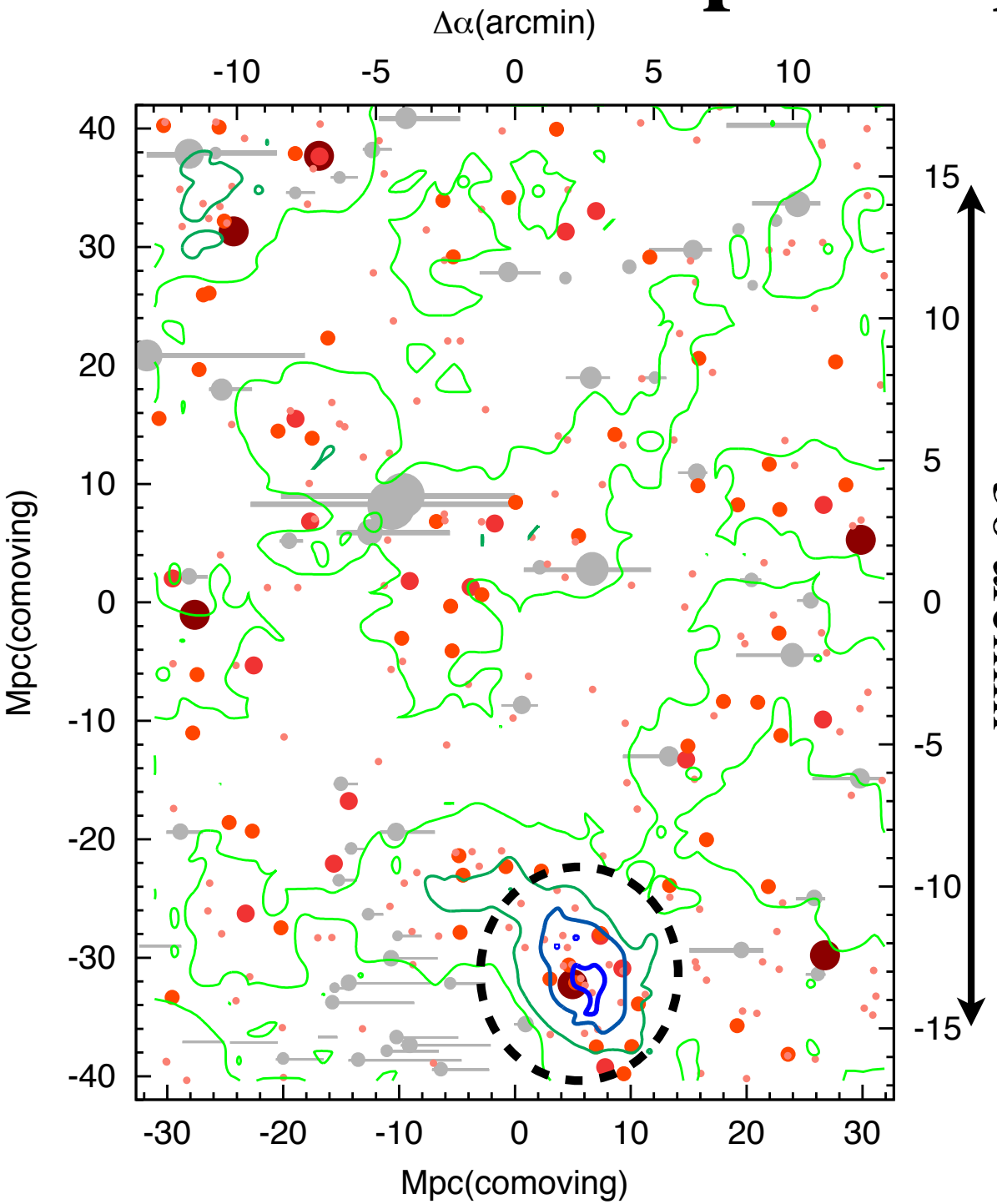
Some examples of protoclusters



Venemans et al. (2007)

protocluster at z=4.11
in **radio galaxy** (RG) field
(TN J1338-1942)

Some examples of protoclusters



Toshikawa et al. (2012)

protocluster at z=6.01
in **blank** field
(Subaru Deep Field: SDF)

Wide-field imaging

We search for protoclusters at z~3-6 in blank field using wide-field imaging.

Our Research

Search for protoclusters at z~3-6

- Protocluster candidates
- Follow-up spectroscopy
- Discussion:
  protocluster structure and galaxy properties

Photometric data

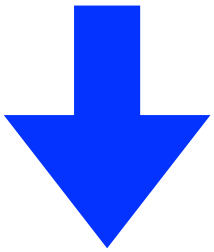
CFHT Legacy Survey Deep fields (CFHTLS D1 - D4)

- **wide field**

  four separated fields, each field ~1 degree^2 (totally ~4 degree^2)

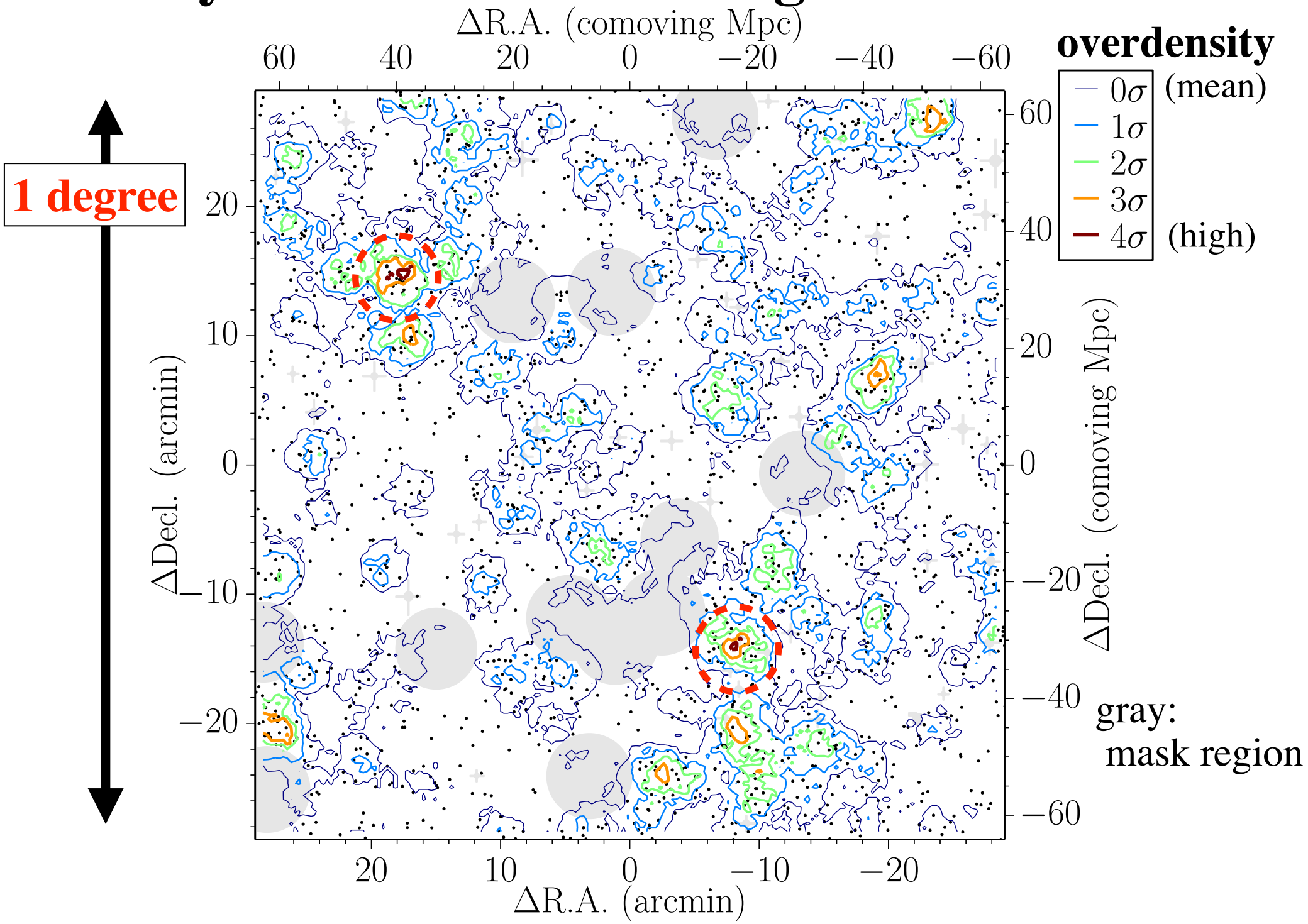
- **deep multi-band photometry**

  3σ limiting magnitude: ~27.2 (*i*-band), ~26.2 (*z*-band)

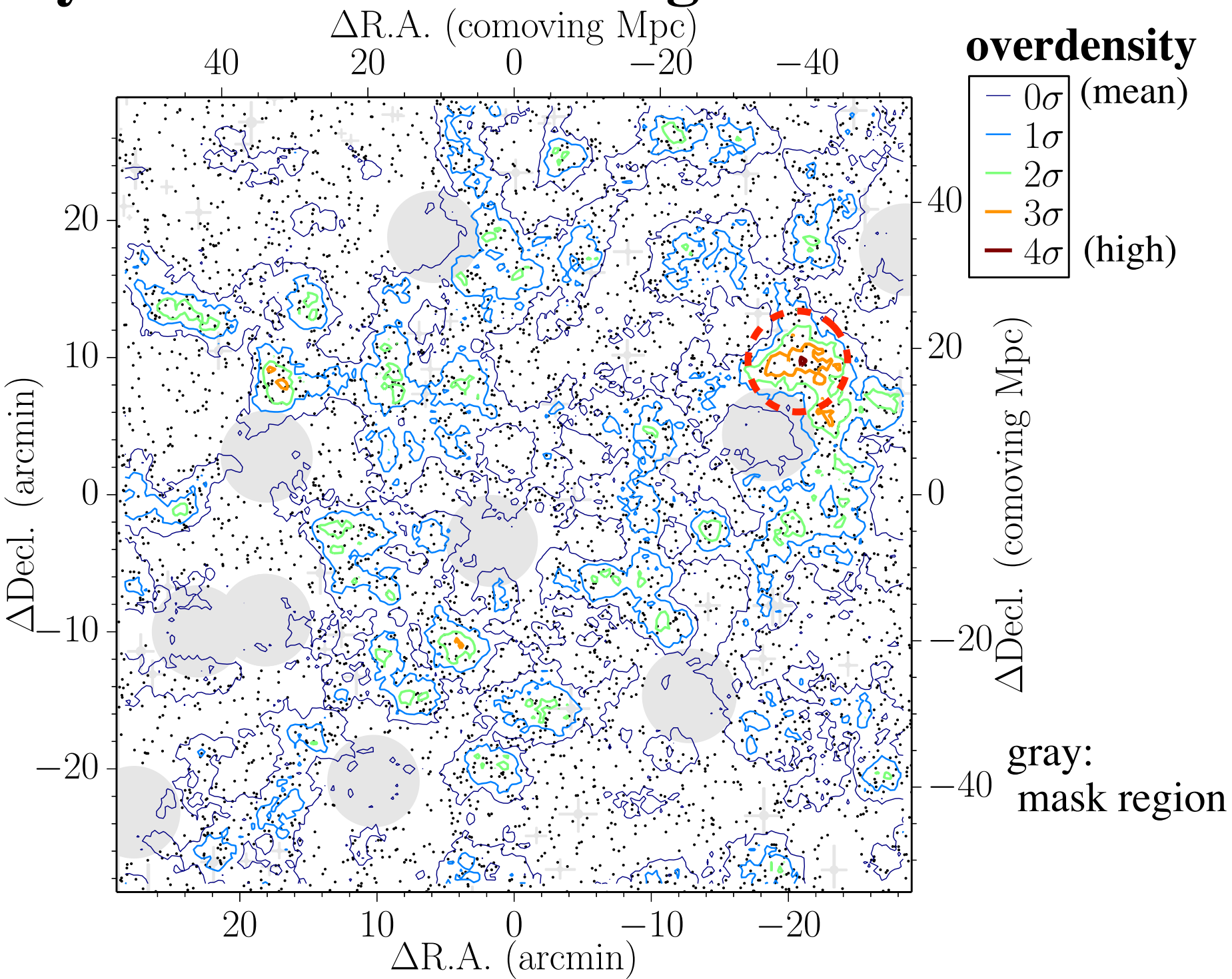


select z~3-6 LBGs (u-, g-, r-, and i-dropout)

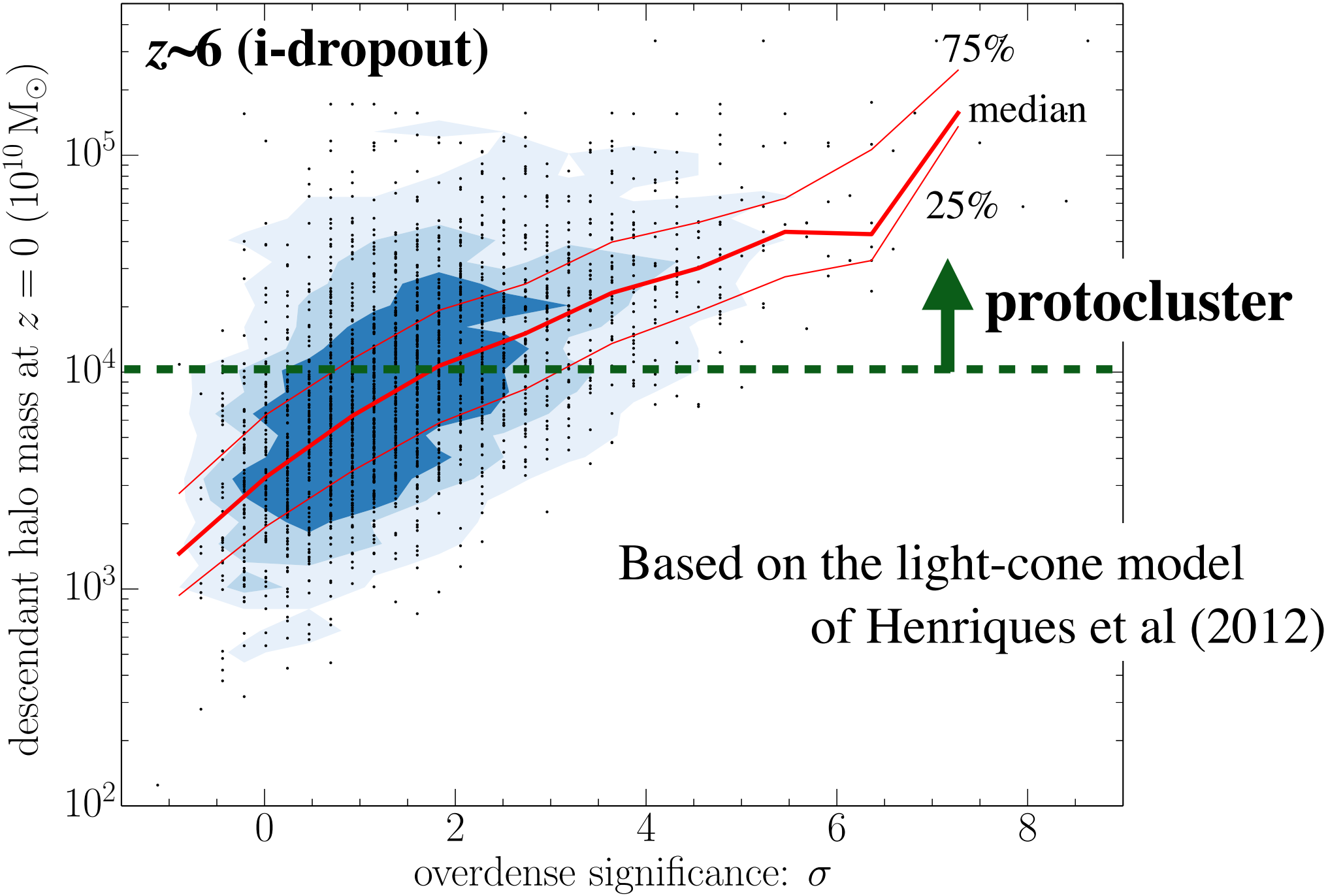
Sky distribution of z~5 galaxies in D4



Sky distribution of z~3 galaxies in D1



What overdense regions are protoclusters?



Protocluster candidates

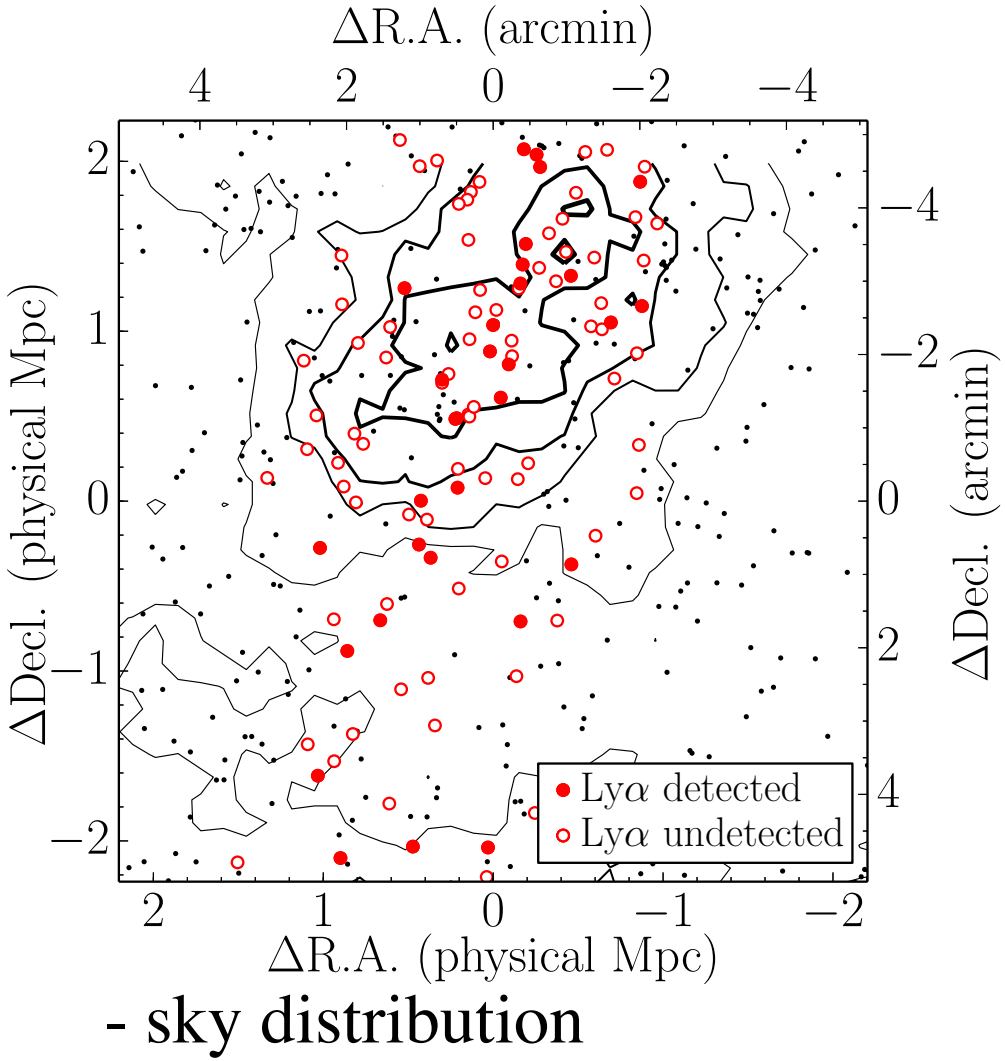
Criterion of protocluster candidate: >4σ overdenisty

(~85% of candidates are expected to be real protoclusters.)

- **Number of protocluster candidates** (CFHTLS: 4 × 1deg^2)

	z~3.1	z~3.8	z~4.8	z~5.9	
total	5	5	6	5	**21**
model prediction	2.9	3.0	5.2	6.4	
follow-up spec.	2	2	2	2	**8**

Protocluster confirmation

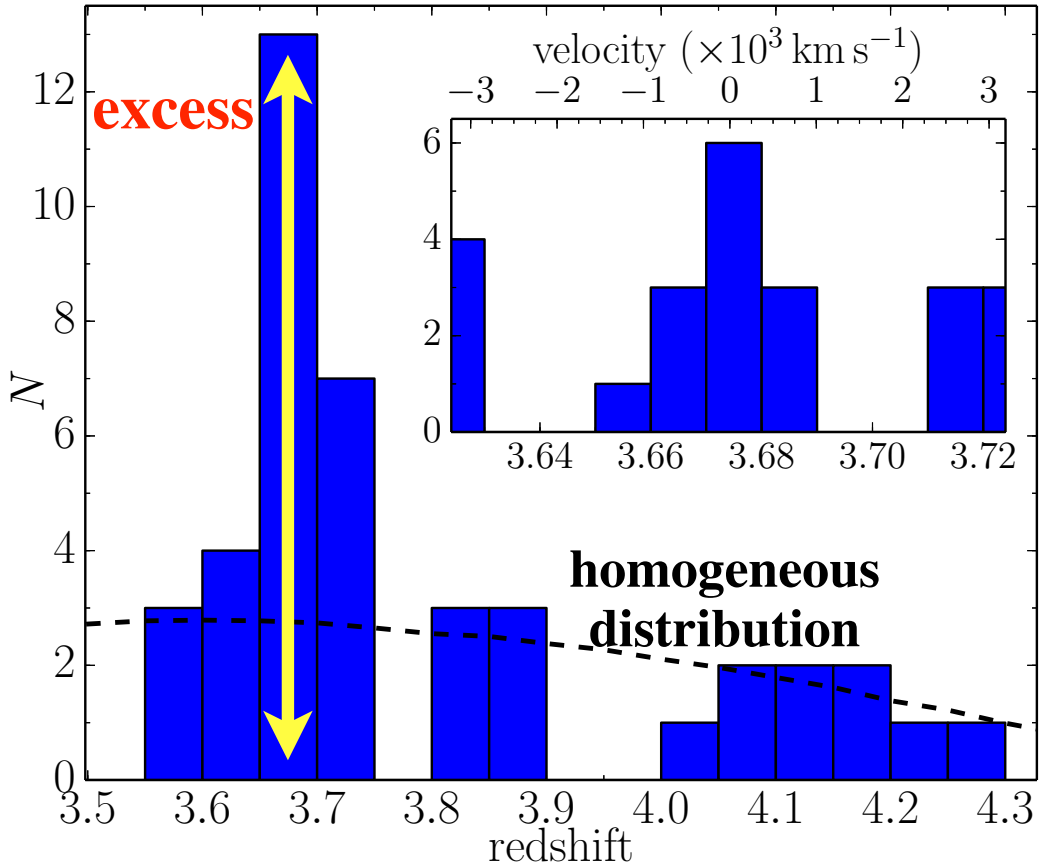


- sky distribution

Clustering at z=3.67 (Δz=0.016)

→ **real protocluster**

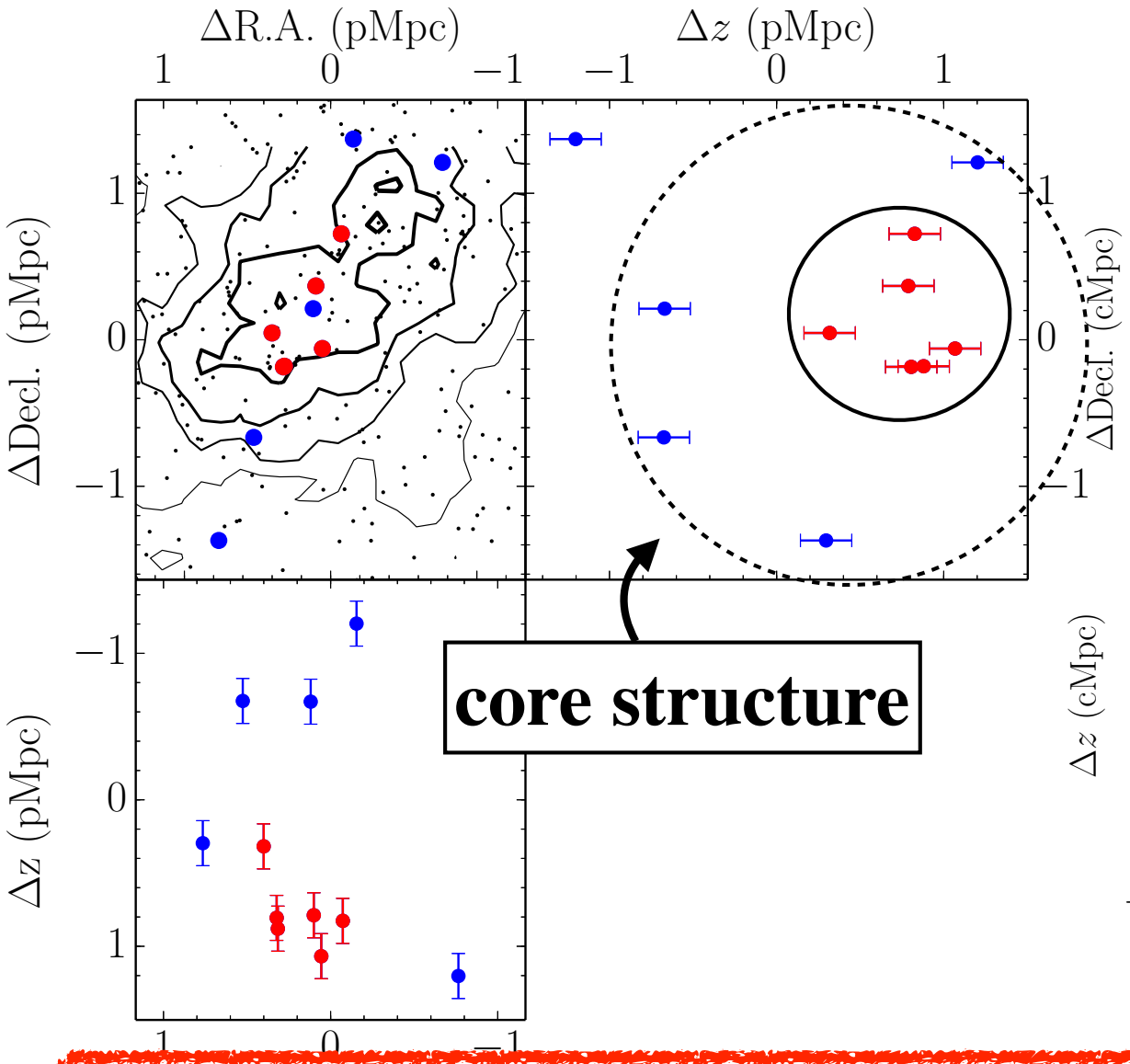
- redshift distribution



We have found **three** protoclusters
at z=3.13, 3.24, and 3.67.

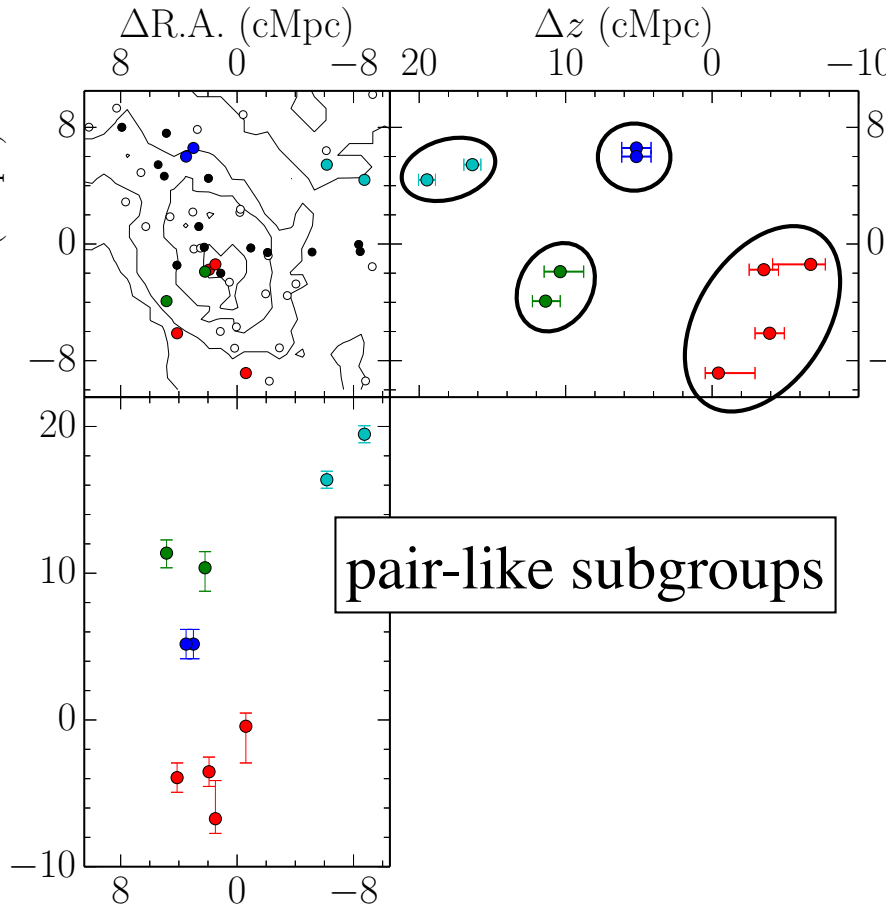
Protocluster structure

at z=3.67



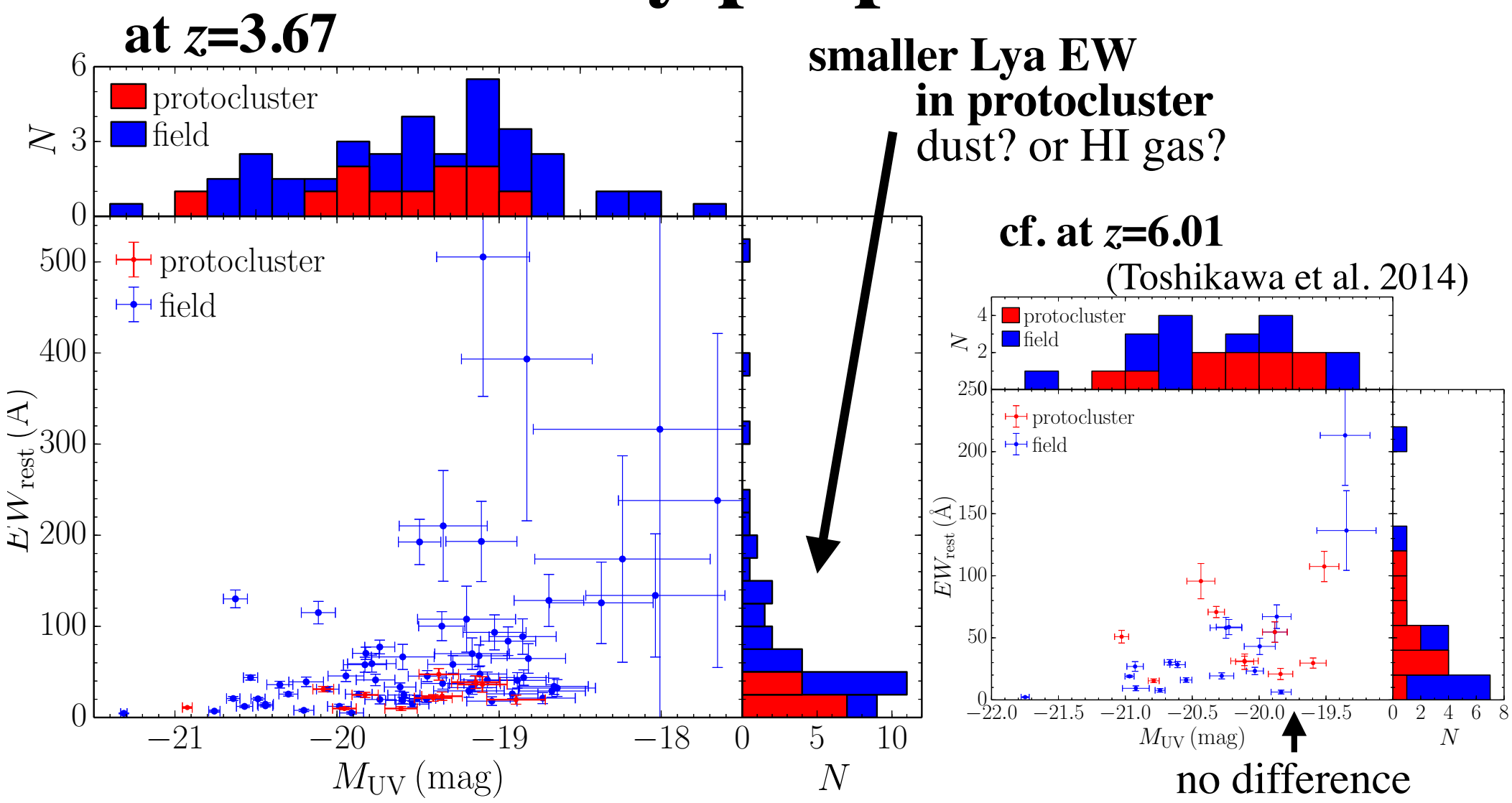
cf. at z=6.01

(Toshikawa et al. 2014)



Internal structure is dramatically changed
from z~6 to z~4: **subgroups to core structure**.

Galaxy properties



The difference between protocluster and field appeared at z~4.

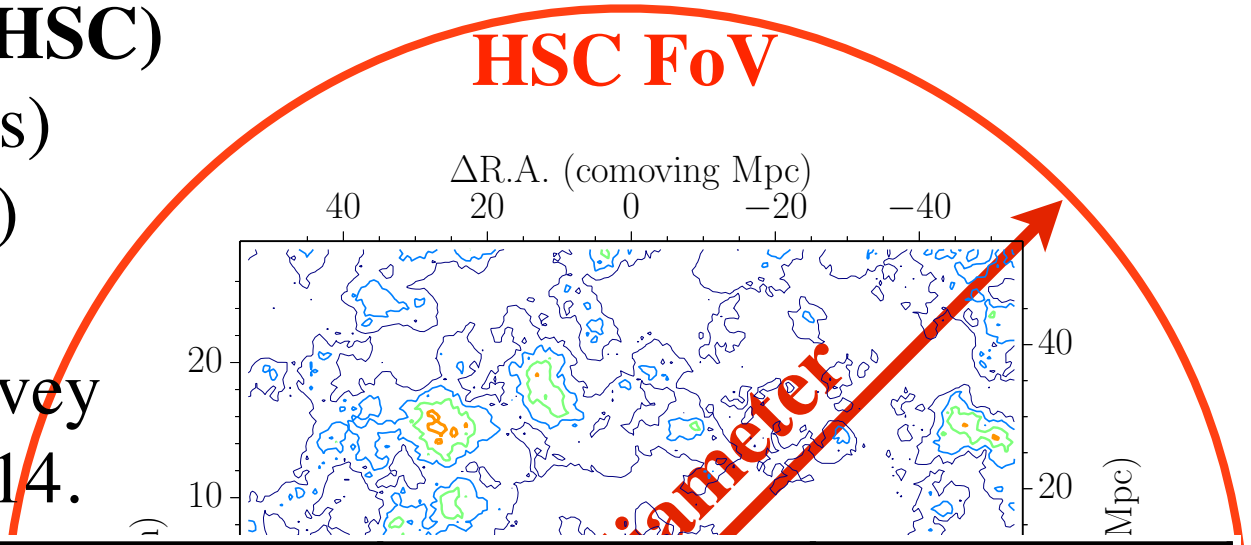
Future work

Subaru/HSC strategic survey

Ongoing survey with HSC

Hyper Suprime Camera (HSC)

- ~1.7 deg^2 FoV (104 CCDs)
- 5 broad-bands (g, r, i, z, y)
- many narrow-bands
- Subaru/HSC strategic survey started from April, 2014.



layer	area (deg^2)	filters	depth (mag)
Wide	1400 (700 deg^2 × 2 fields)	*grizy*	z~25.1
Deep	27 (7 deg^2 × 4 fields)	*grizy* + 3NB	z~26.3
Ultradeep	3.5 (1.8 deg^2 × 2 fields)	*grizy* + 3NB	z~26.8

>10 protoclusters at z~6 and ~1000 at z~4 will be found by the HSC strategic survey.

Summary

- 21 protocluster candidates are identified
  from z~6 to z~3 in the CFHTLS Deep Fields.
- We carried out follow-up spectroscopy for eight of them.
- **New three protoclusters were confirmed.**
- The internal structure of protoclusters would be changed
  from z~6 to z~4: from pair-like substructure to core structure.
- **The difference of galaxies properties**
  between protocluster and field galaxies appeared at z~4.
- More protoclusters will be discovered by HSC survey.

Thanks!