From downtown to ghost-town:

Shedding light on the red sequence build-up era in galaxy cluster cores with CANDELS.

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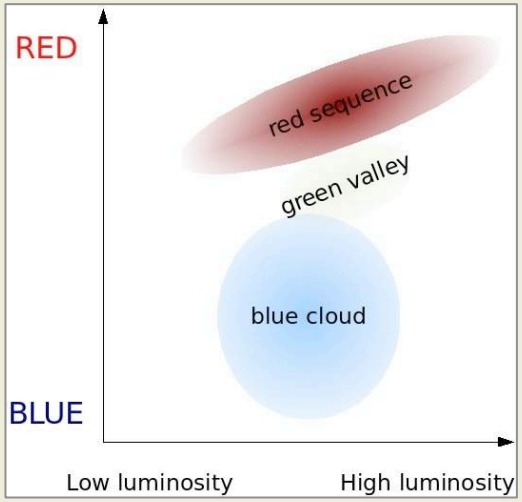
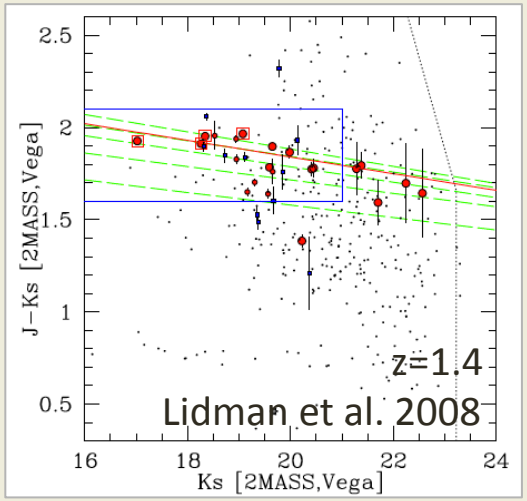
On behalf of the CANDELS Clustering Group

Galaxy clusters

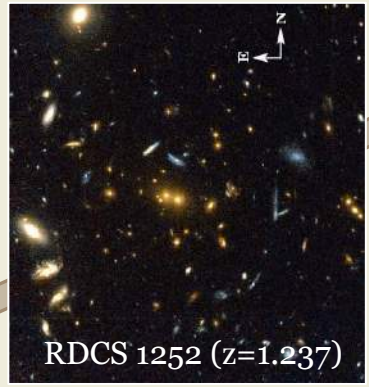
- Densest, most massive, bound systems in the Universe
- Masses of $10^{14\text{-}15}$ solar masses / Tens to thousands of galaxies / Scale of several Mpc
- Star-forming galaxies in the outskirts /Cores dominated by massive, early-type galaxies

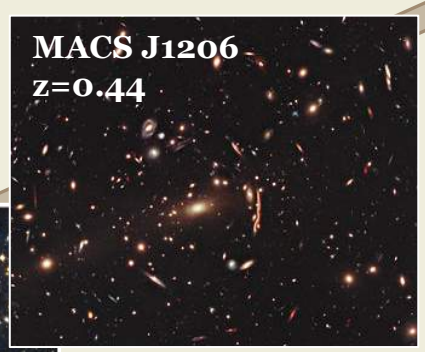




"Red sequence" up to z~1.5

< z~2





z=0

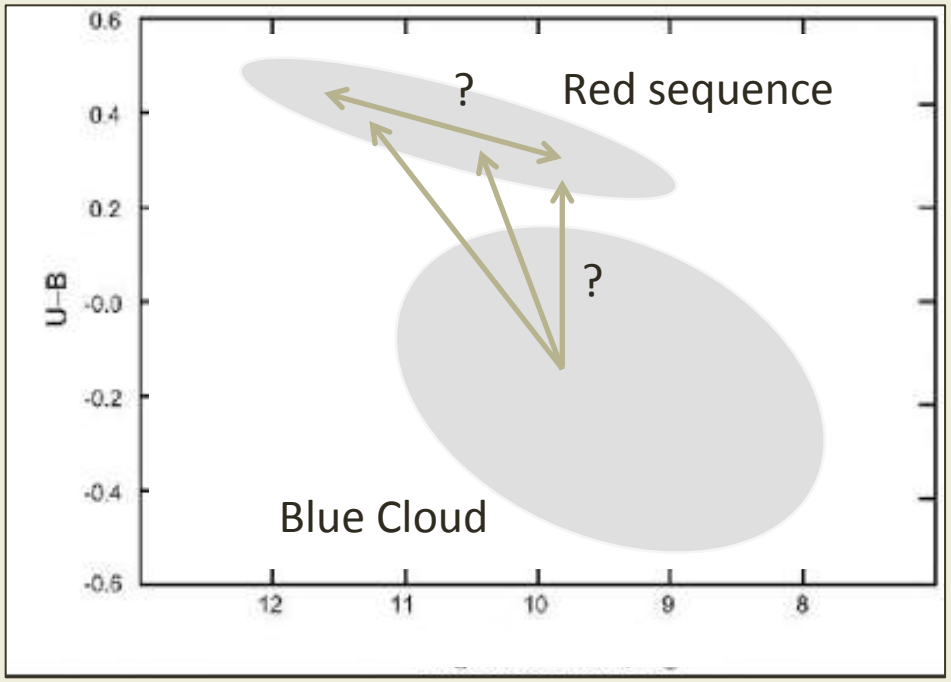
The build-up of the red sequence

Open questions:

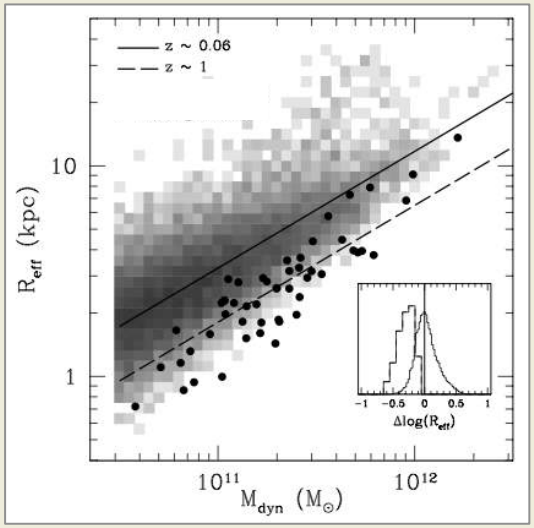
- Quenching

  How did the star-forming galaxies became red and dead?
  When?

- Red Sequence build-up scenario
  - "Hierarchical"? i.e., Built from mergers?
  - "Downsizing"? i.e., Massive galaxies quenched earlier?
  - A mix?

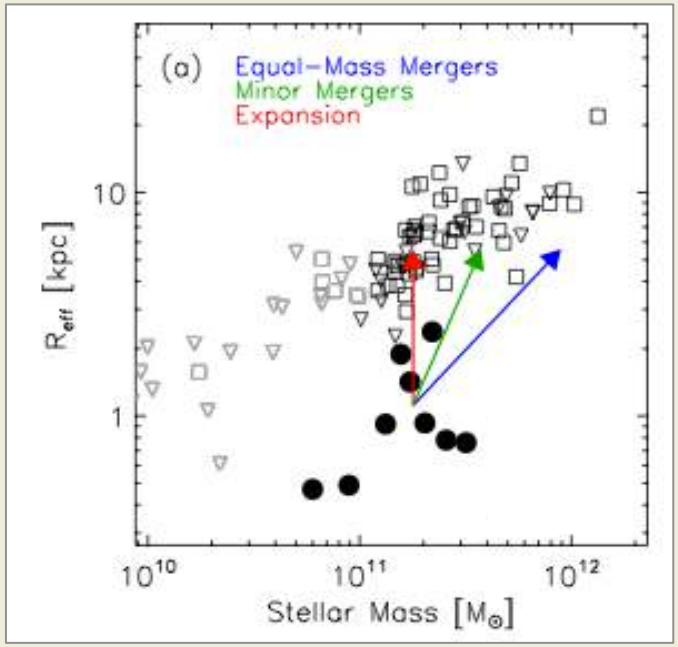


Early-type size growth in time

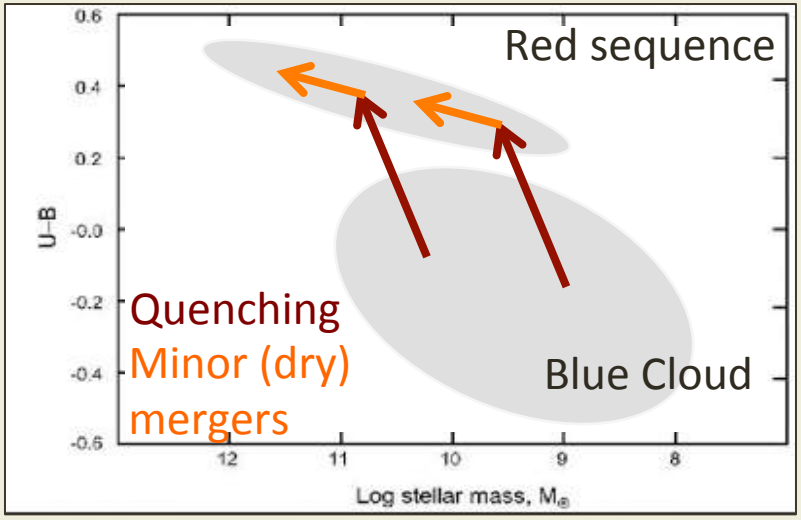


Van der Wel 2008

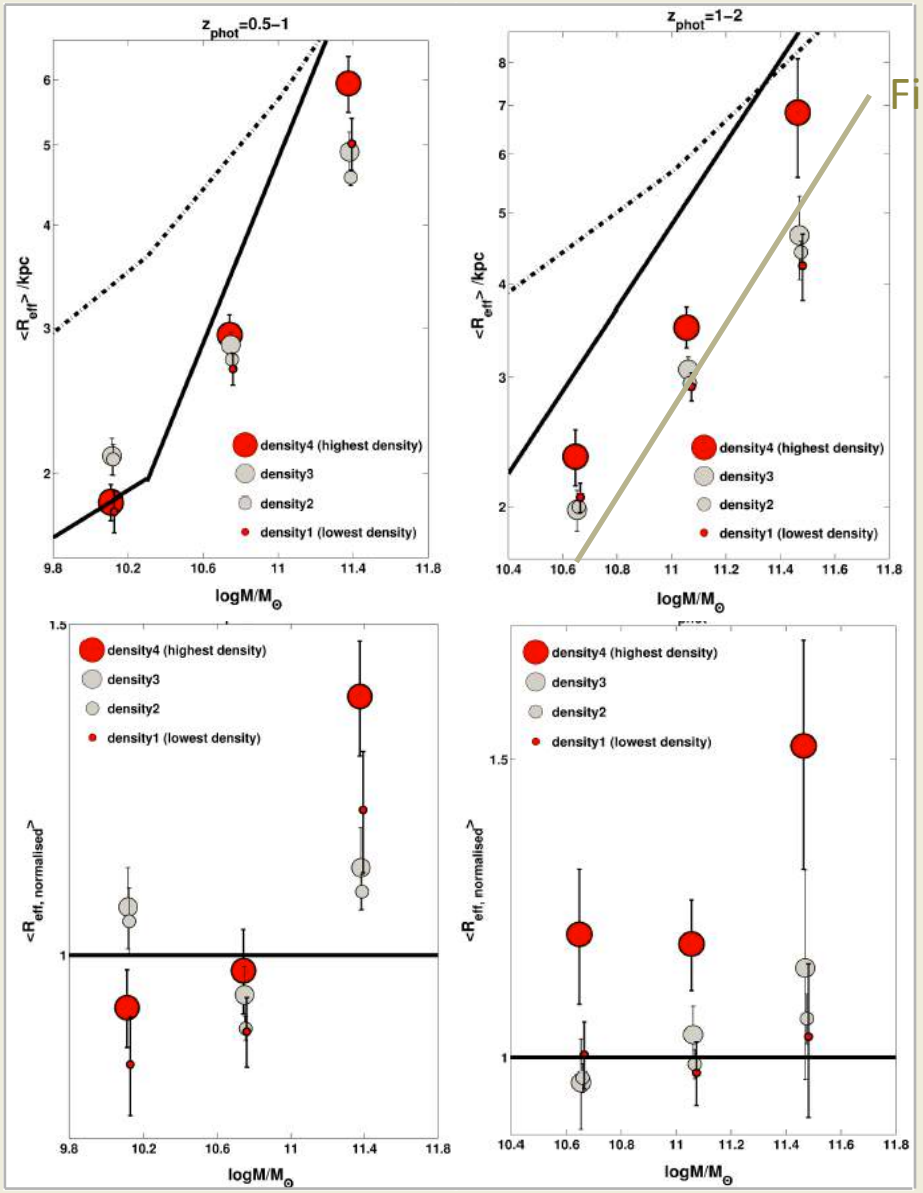
ETG in field (local vs. z~1) - Factor of 2 in size



Bezanson et al. 2009



Early-type size growth vs. density



Field galaxies at z~1

Lani et al. 2013
UKIDSS UDS
Structural parameters
calibrated on CANDELS data

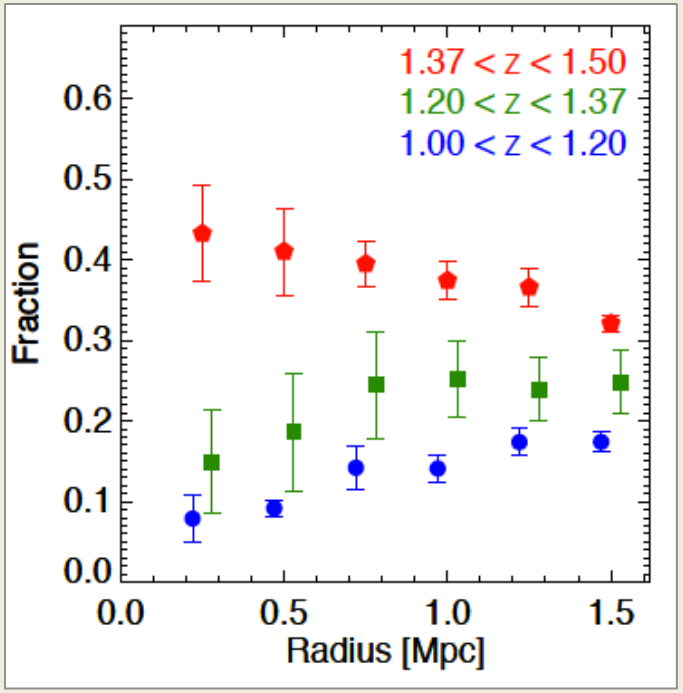
Accelerate size growth for ETG in dense regions

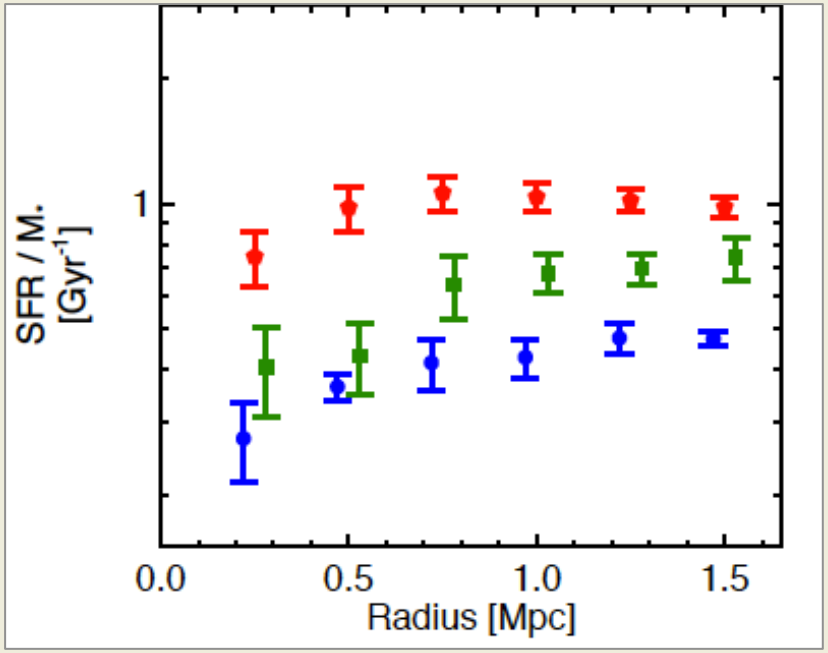
Star-forming cluster cores at z > 1.4

Brodwin et al. 2013:

16 ISCS clusters imaged in MIPS 24μm

$1.0 < z < 1.5$ - $\log(M^*/M_\odot) > 10.1$





Transition at z~1.4 :
End of the SF era
Beginning of the quenching epoch

High-redshift galaxy (proto-)clusters To the near-infrared and beyond …

- X-ray extended ICM emission
- Red-sequence algorithm
- The Sunyaev-Zel'dovich effect

Classical methods of « low-z » cluster search obsolete at high-z

- Need to shift to redder wavelength
- Need high-resolution imaging

    - >> Targeted follow-up of known clusters with HST/WFC3

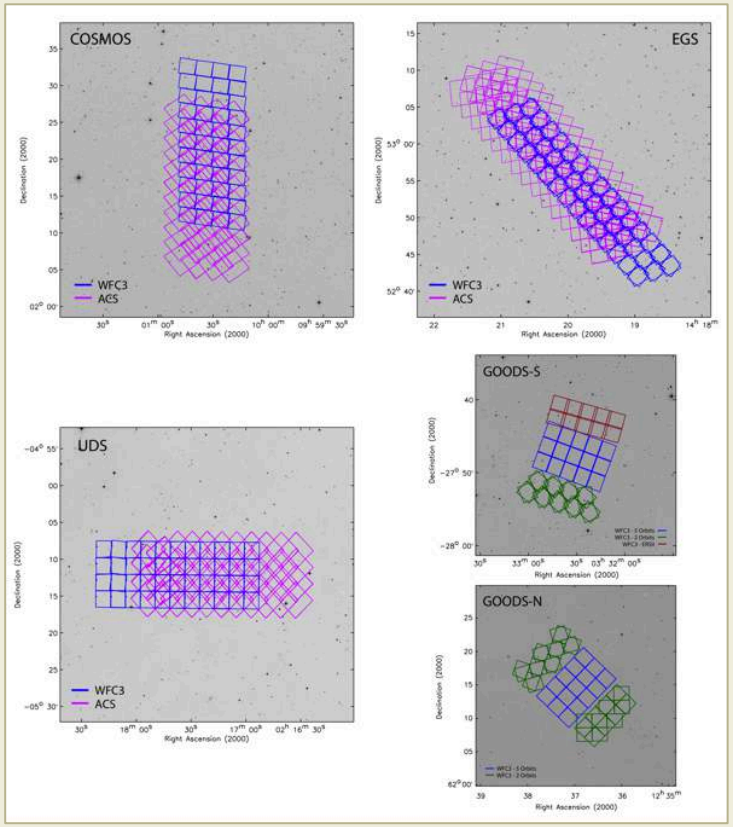
    - Or >> Random wide-field survey with WFC3 … and luck!!

Outline

- CANDELS
- Cluster/group search in CANDELS-UDS
- The core of high-redshift clusters (z>1.5)
- Large-scale structure in the UKIDSS UDS (z=0.65)

CANDELS in brief

- Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey
- P.I.s: H. Ferguson (STScI); S. Faber (UCSC) - Grogin et al. 2011, Koekemoer et al. 2011
- Imaging with WFC3 (F125W,F160W) & ACS (F606W,F814W)
- 902 orbits - 3 years(2010-2013) - 5 well-studied sky regions
- Synergy with 3D-HST (*HST* Grism spectroscopy "counterpart")



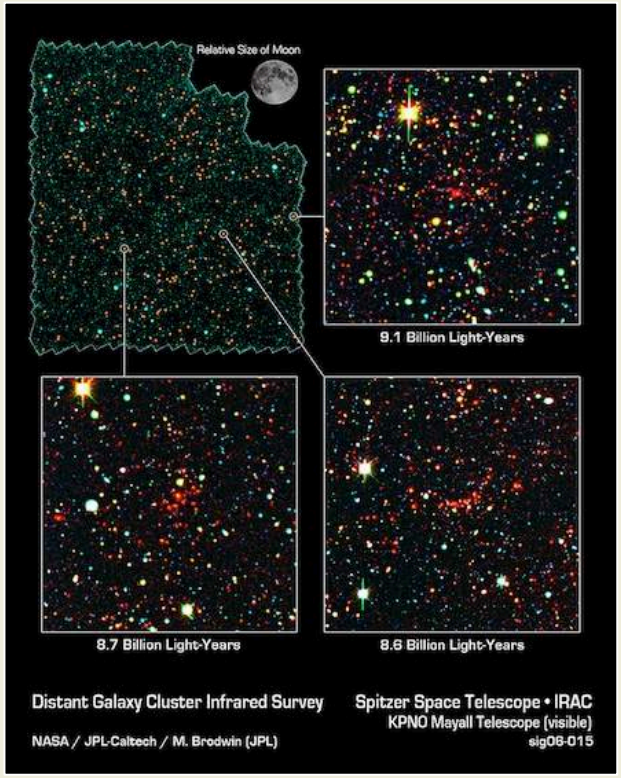
- Multiwavelength photometry catalogues
  - UDS (Galametz2013; 19 bands)
  - Goods-South catalogue (Guo2013; 17 bands)
  - EGS finalized (Stefanon et al. in prep.)
  - COSMOS and Goods-North - internal testing
- Photometric redshifts:
  - Dahlen et al. 2013, Ferguson et al. in prep.
- Stellar masses:
  - Santini et al. submitted, Mobasher et al. in prep.
- GALFIT profiles and Sersic
  - Van der Wel et al. 2012
- Visual morphology
  - Kartaltepe et al. 2013 (UDS, GOODS-S)

Cluster science with CANDELS?

CANDELS = 0.22 sq. degrees

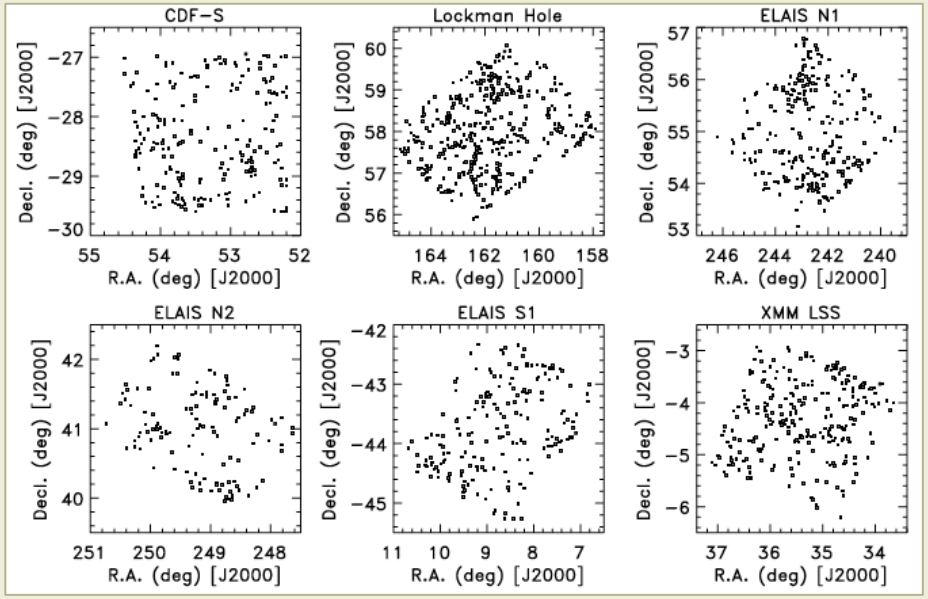
IRAC Shallow/Deep Cluster Survey
Eisenhardt et al. 2008
335 clusters; 106 at z>1 in 7.25 sq. deg

In 0.22 sq. deg.: 10 clusters; 3.2 at z>1

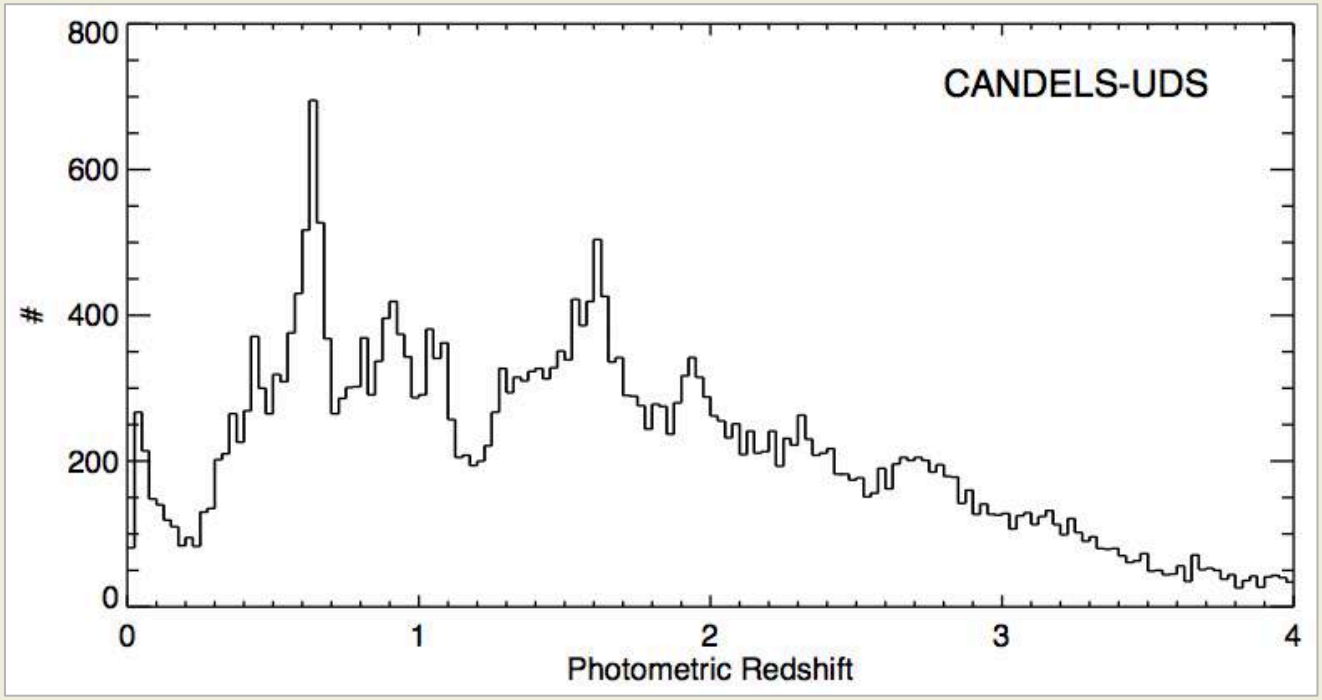


IRAC high-z cluster search in SWIRE
Papovich et al. 2008
Mean z>1 cluster density: 28 deg^{-2}
(upper limit due to selection purity)

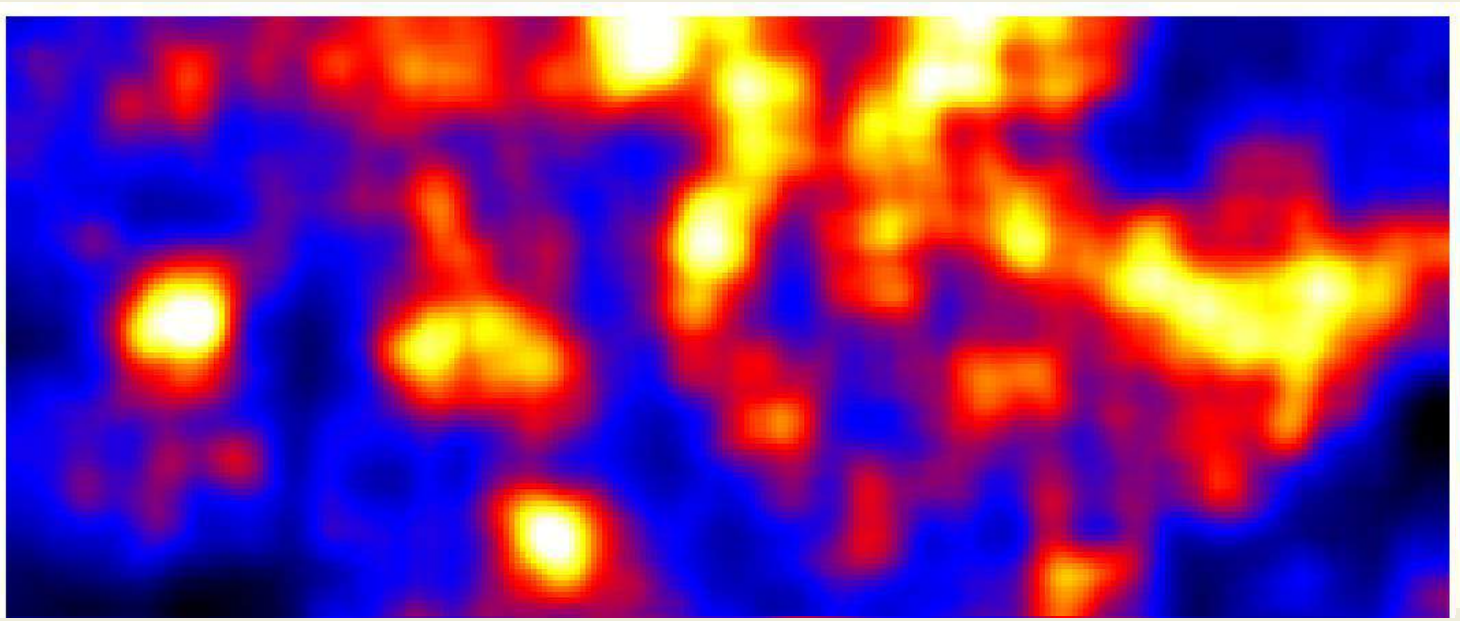
In 0.22 sq. deg.: 6 z>1 clusters

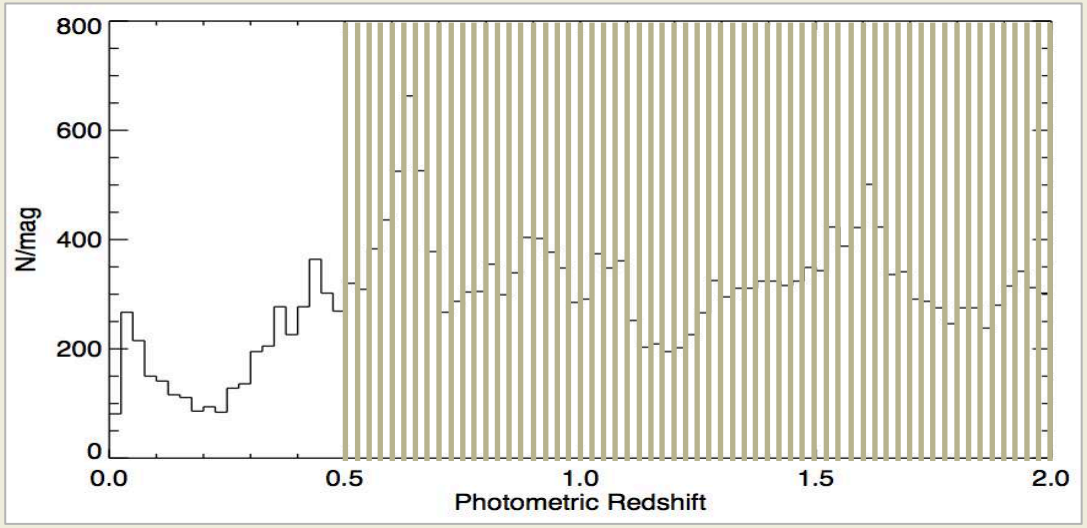


Clusters/Groups in CANDELS-UDS

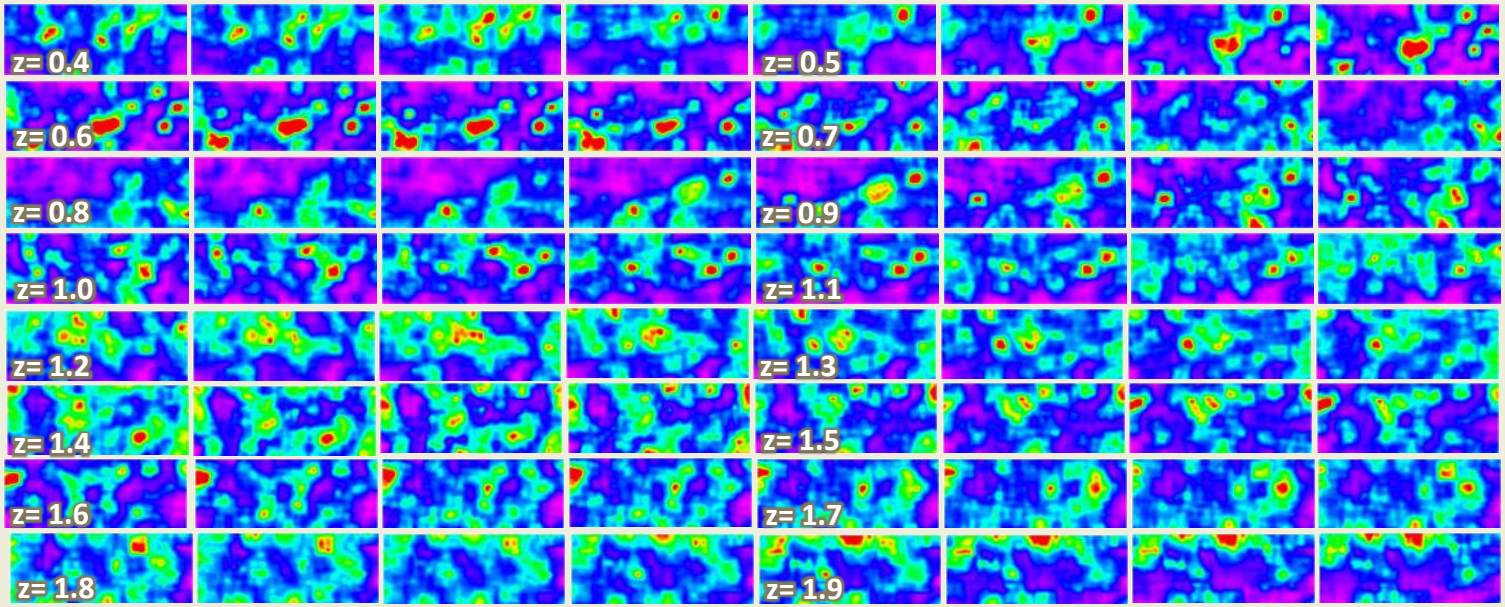


Clusters/Groups in CANDELS-UDS





Clusters/Groups in CANDELS-UDS

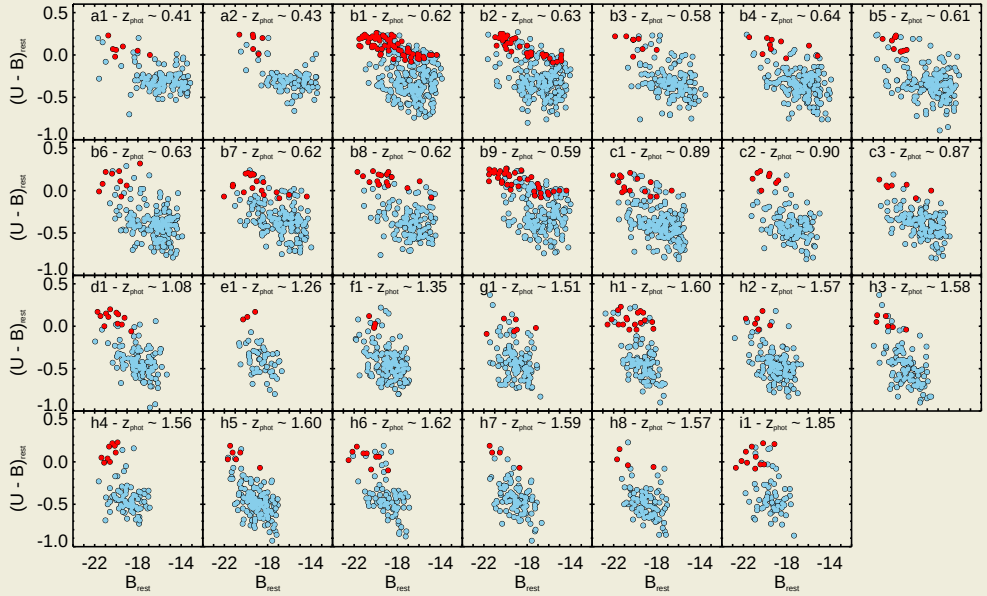


Cluster candidates at z>0.5:

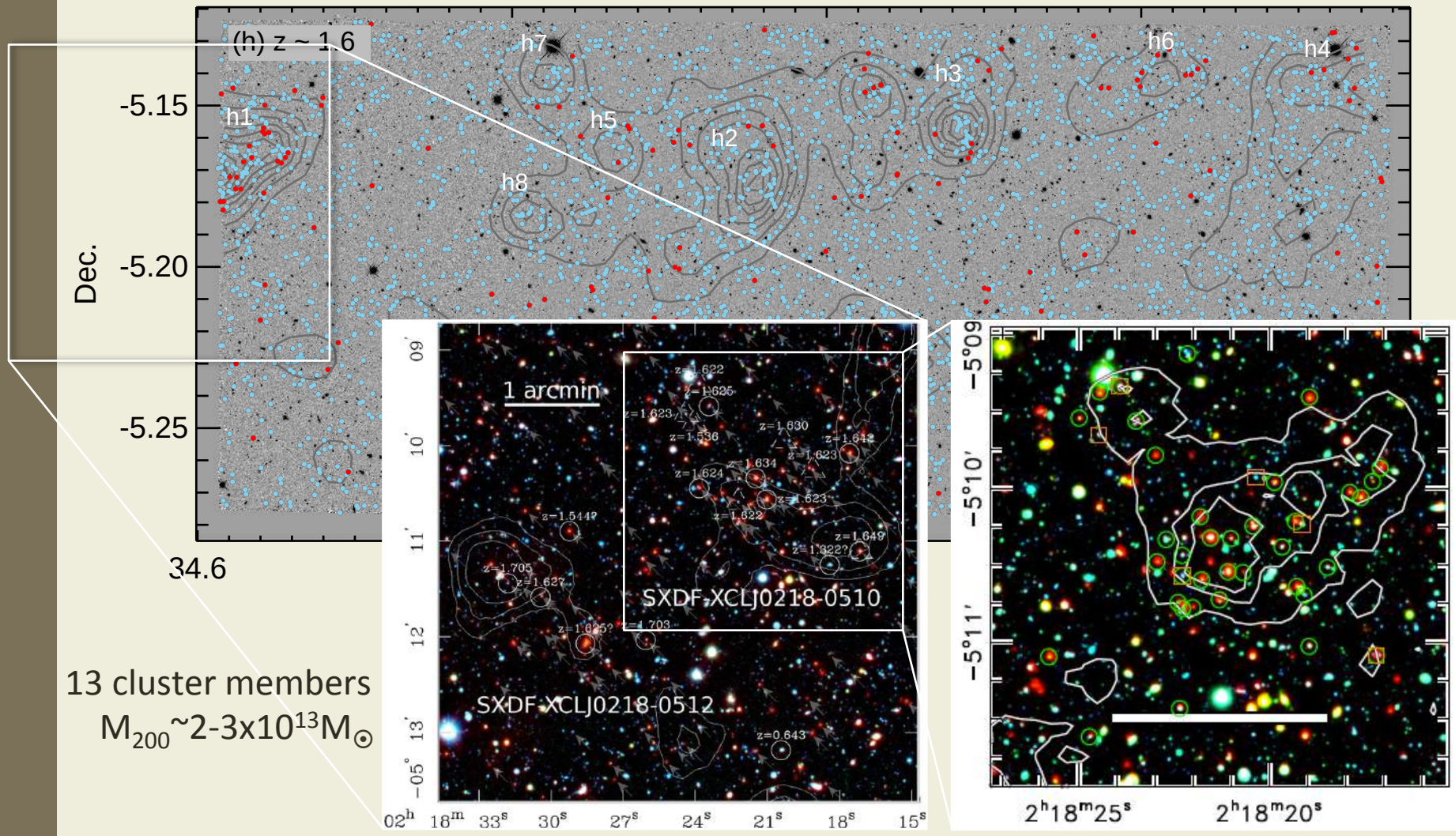
- 14 at 0.5 < z < 1
- 3 at 1 < z < 1.5;
- 10 at z > 1.5 (8 at z~1.6)

Van Breukelen et al. 2007:

- 2 groups at z=0.65
- 1 group at z=0.9



High-z: Clusters/Groups at z ~ 1.6



13 cluster members

M_{200}~2-3x$10^{13}M_{\odot}$

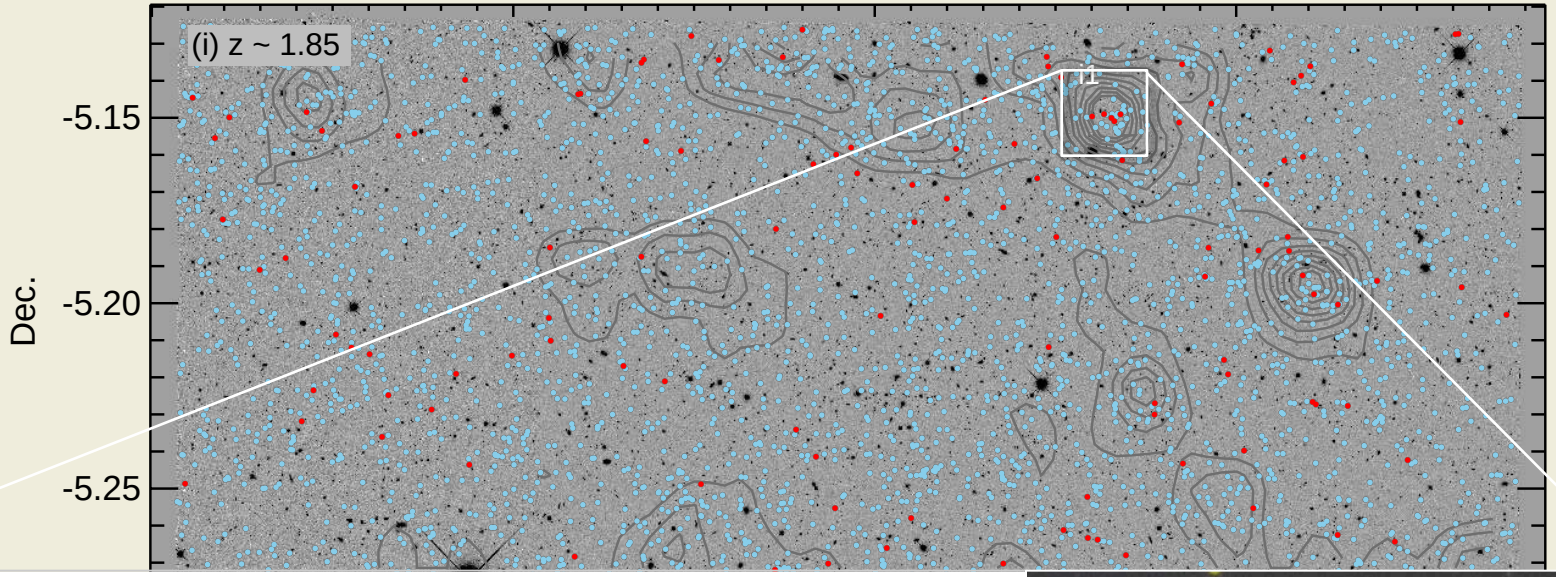
Tanaka et al. 2010

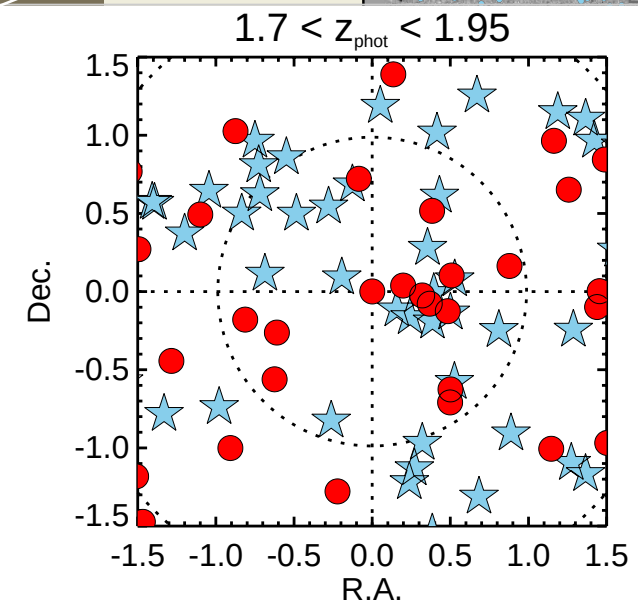
Z_{phot} selected

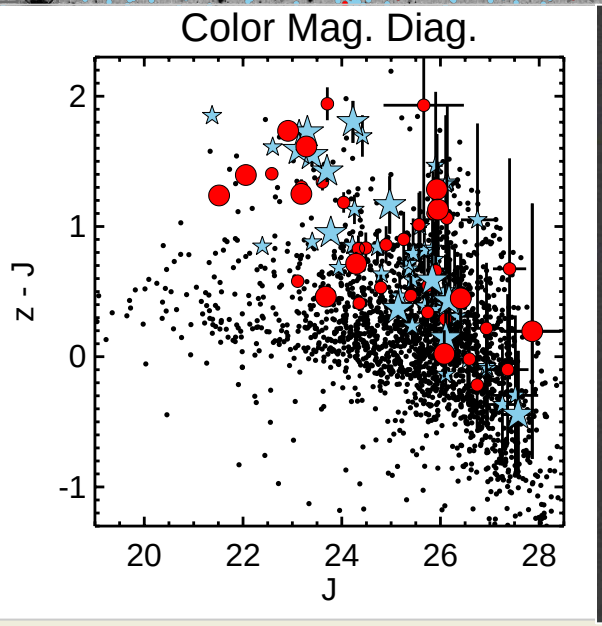
Papovich et al. 2010

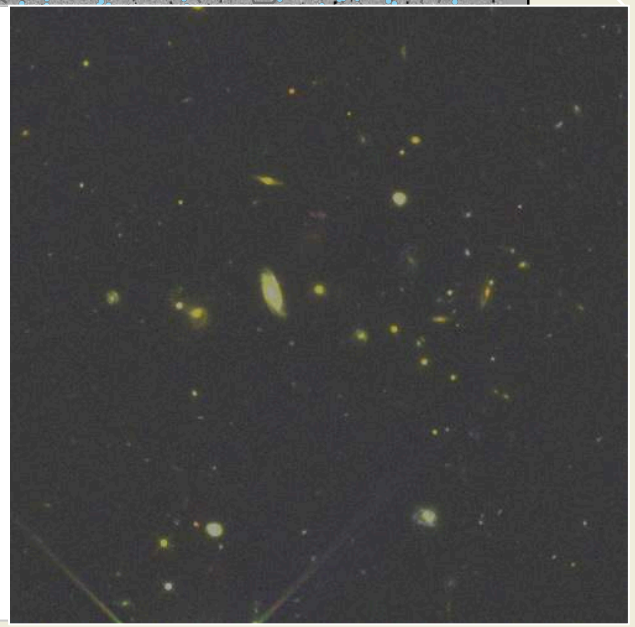
IRAC-selected

A cluster candidate (?) at z = 1.83





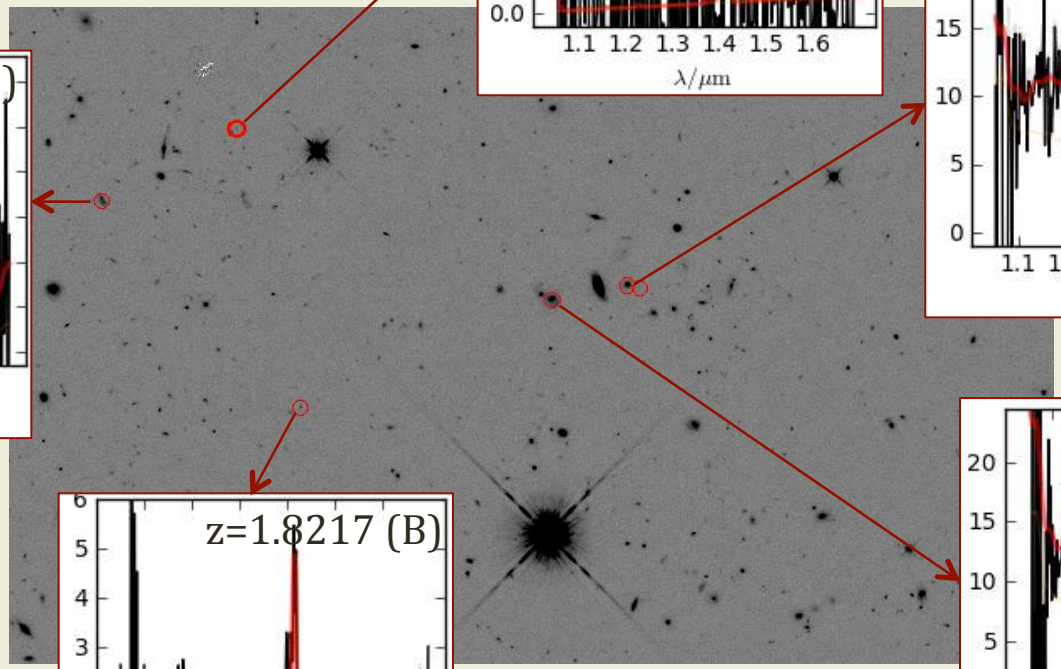


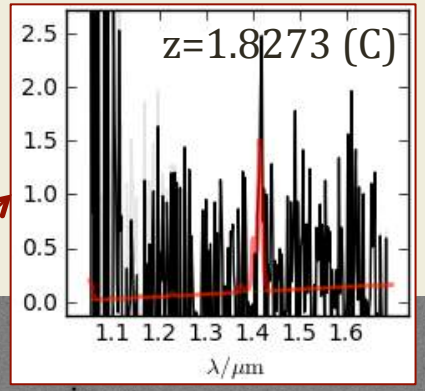


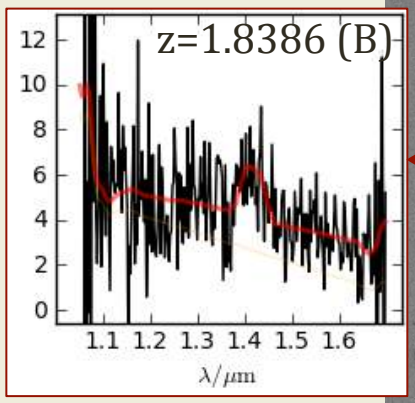
A cluster candidate (?) at z = 1.83

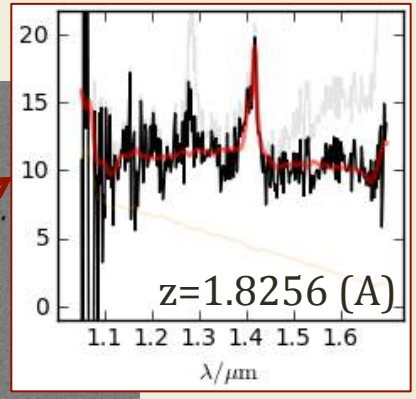
Spectroscopic follow-up(s):

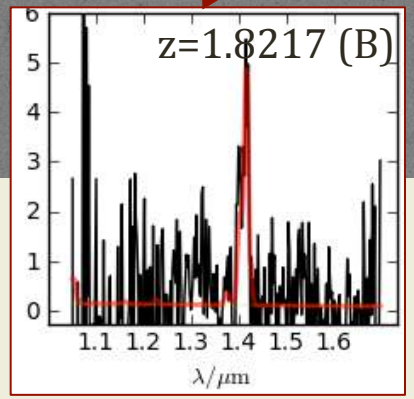
- LBT/LUCI
- VLT/KMOS (SV) – 1/5hr
- 3D-HST grism (Brammer et al. 2012):

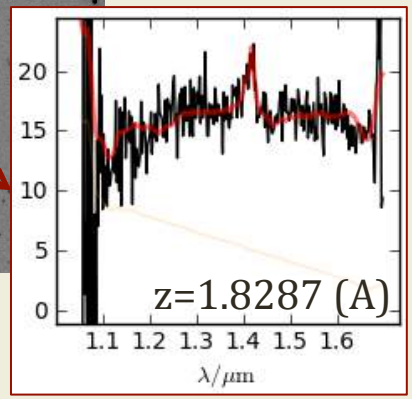




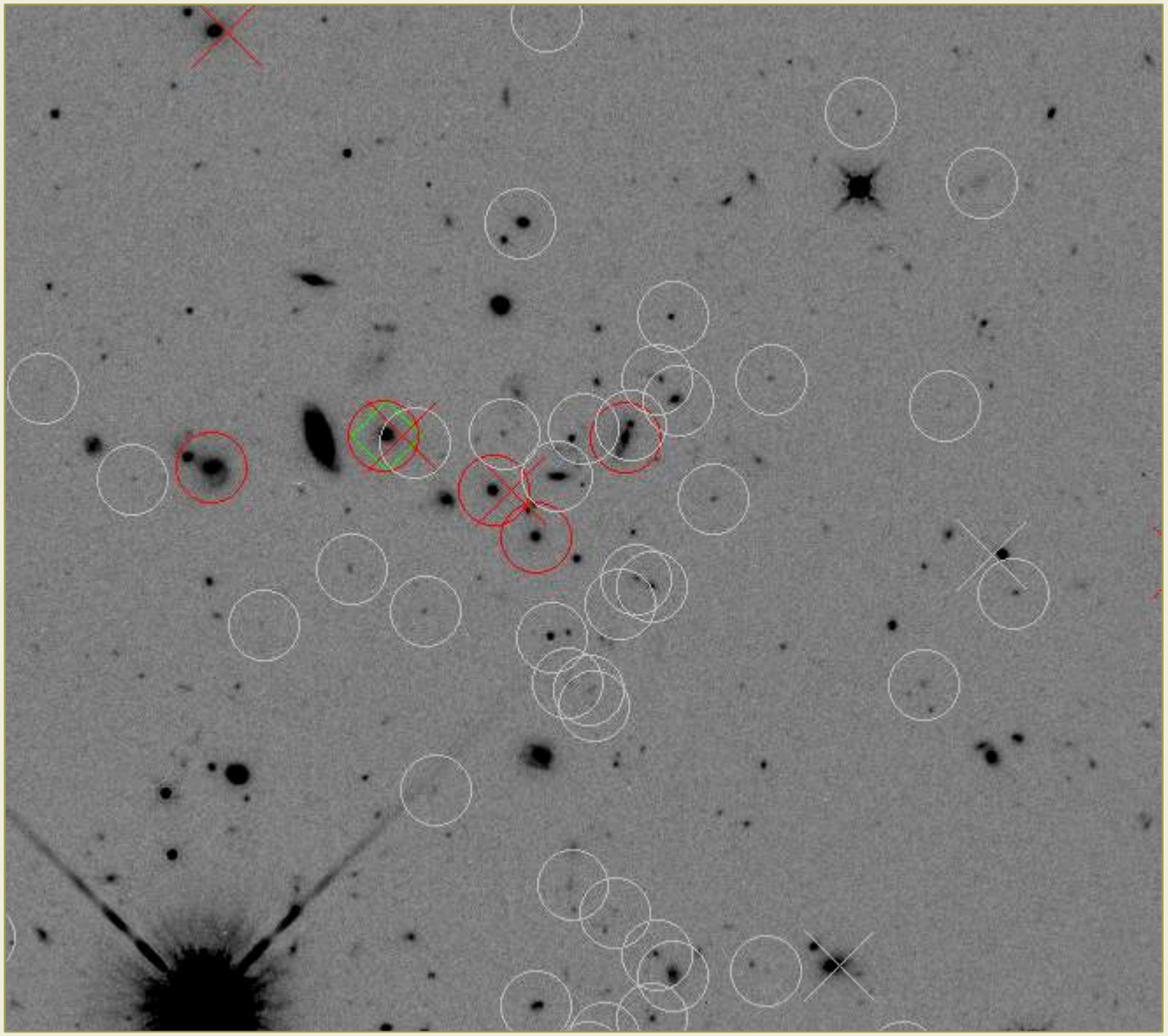




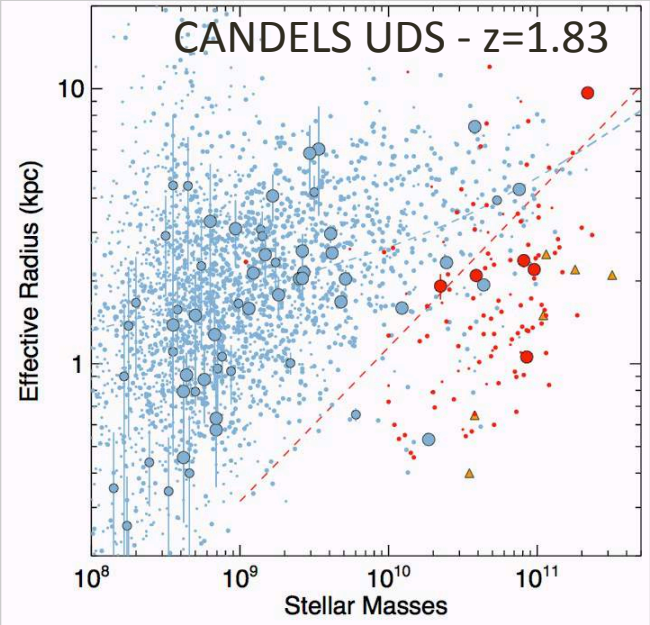


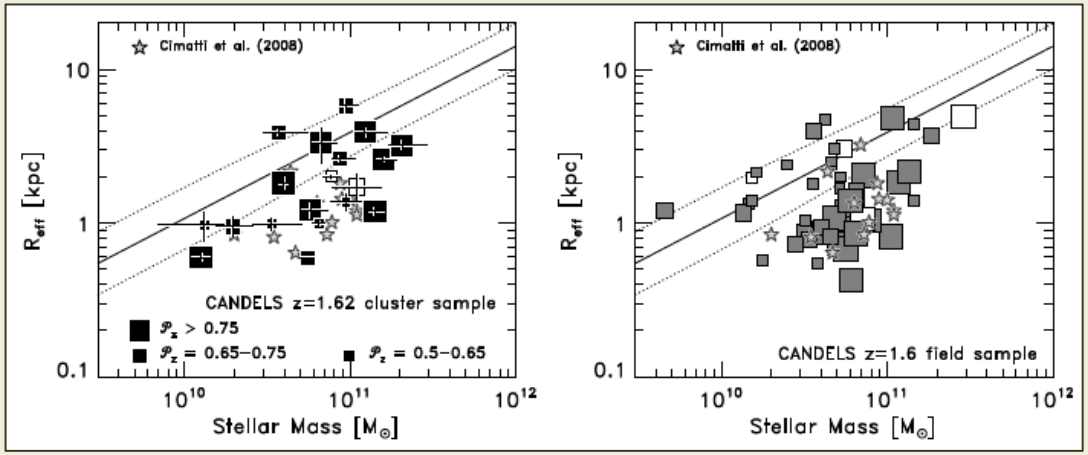


Synergy with KMOS^{3D} and VIRIAL



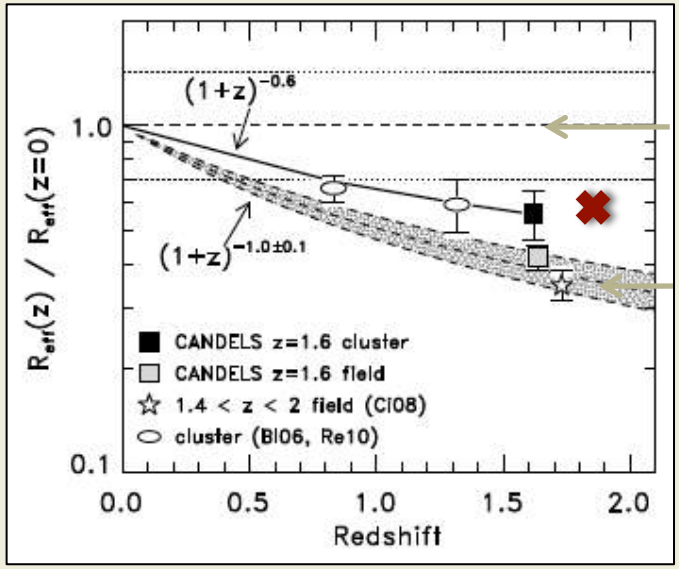
Quiescent galaxy size: cluster vs. field





CANDELS UDS – z=1.62; Papovich et al. 2012

Accelerated size growth in cluster cores.

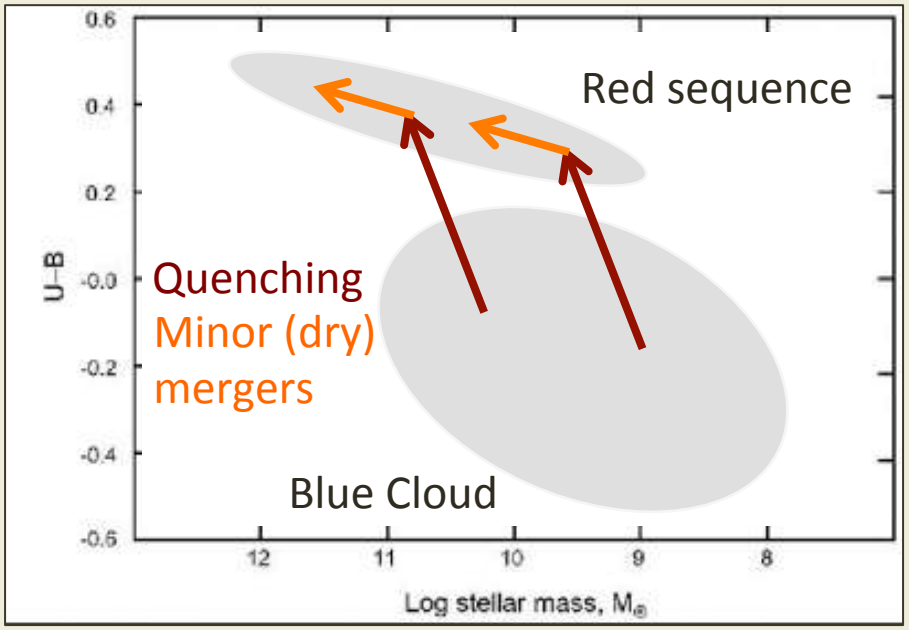


Shen et al. 2003 (local relation)

Van der Wel et al. 2008 (field)

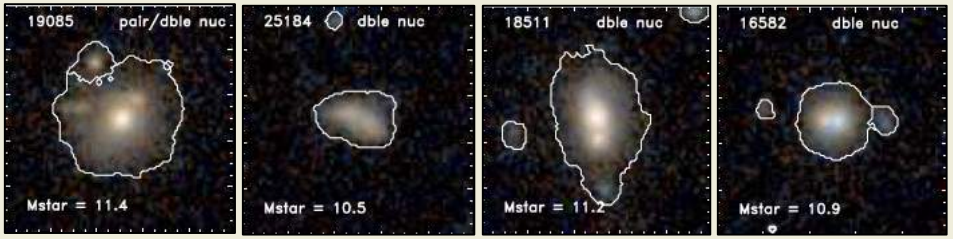
Quiescent galaxy size: cluster vs. field

Minor mergers: increase in size, little increase in mass, little/no SF

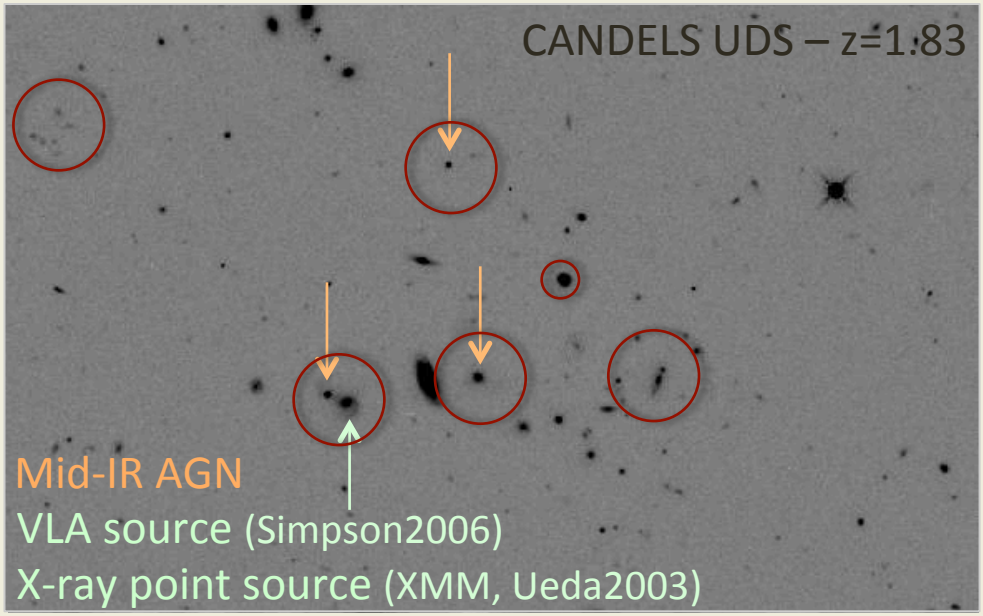


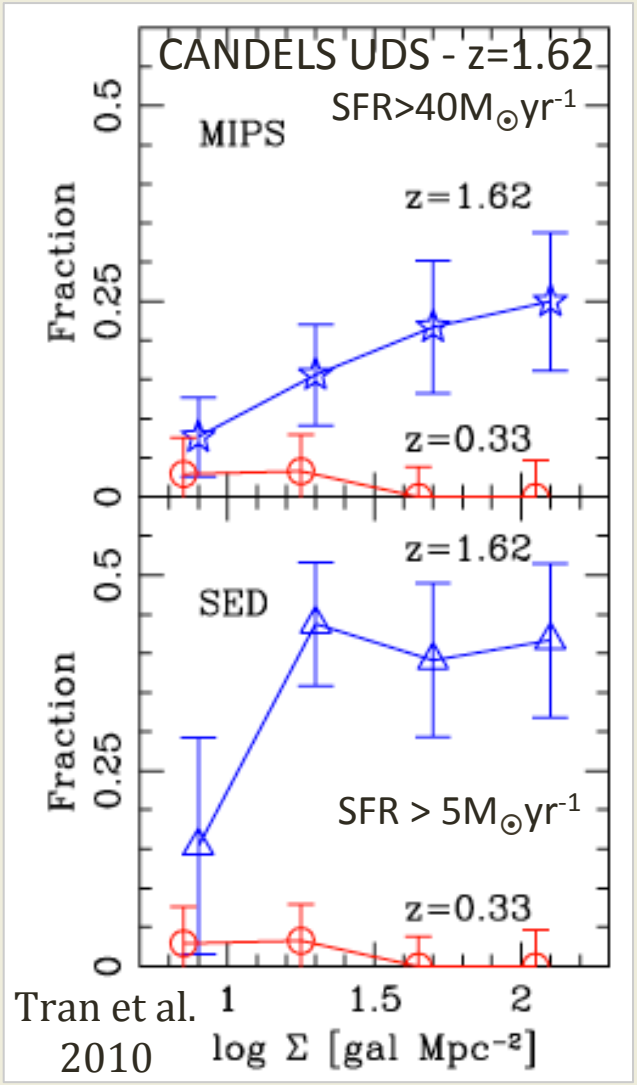
CANDELS UDS – z=1.62
Lotz et al. 2013

~60% of 3 x 10^{10} $M_{\odot}$
are close pairs or double nuclei
(vs. 11% for the field)



SF/AGN activity in high-z clusters





Tran et al. 2010

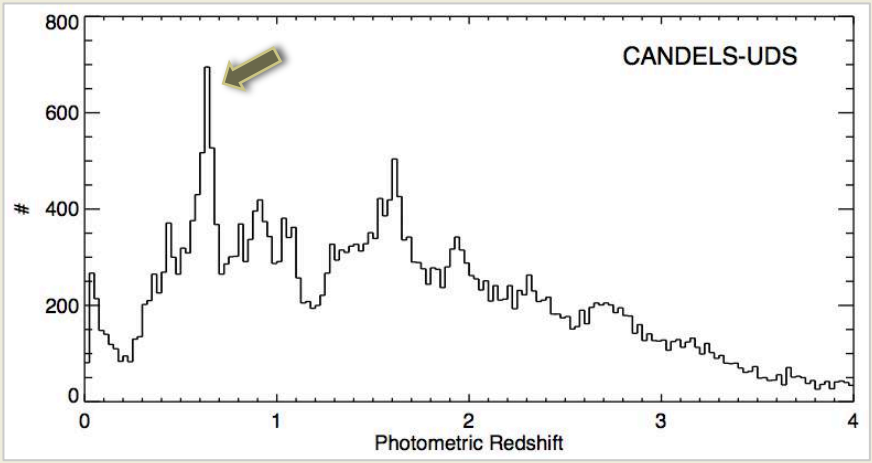
Enhanced star-formation + AGN fraction
in cluster cores:

= Increase of SF/AGN activity with density

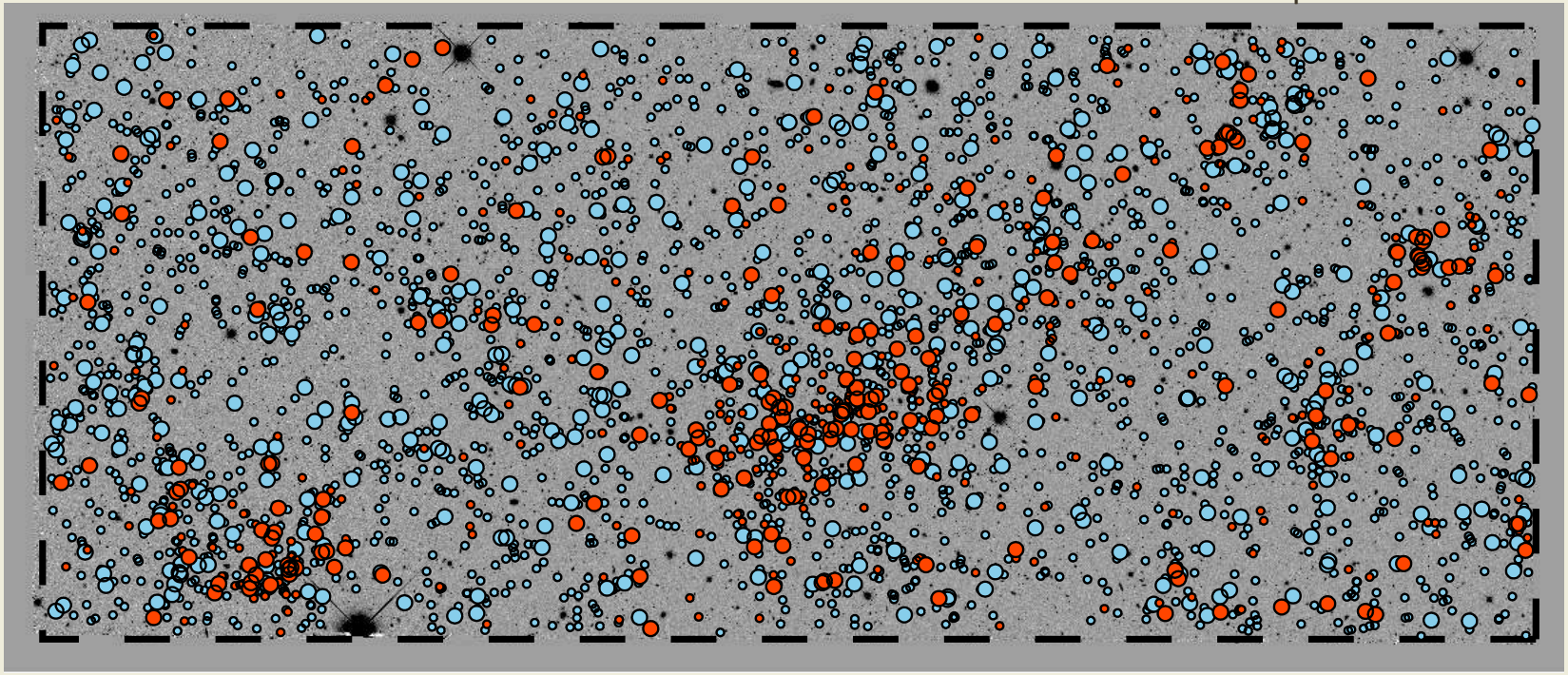
≠ trend at lower-z

17 members with $L_{IR} > 10^{11} L_\odot$
but 2 X-ray AGN (Lotz et al. 2012)

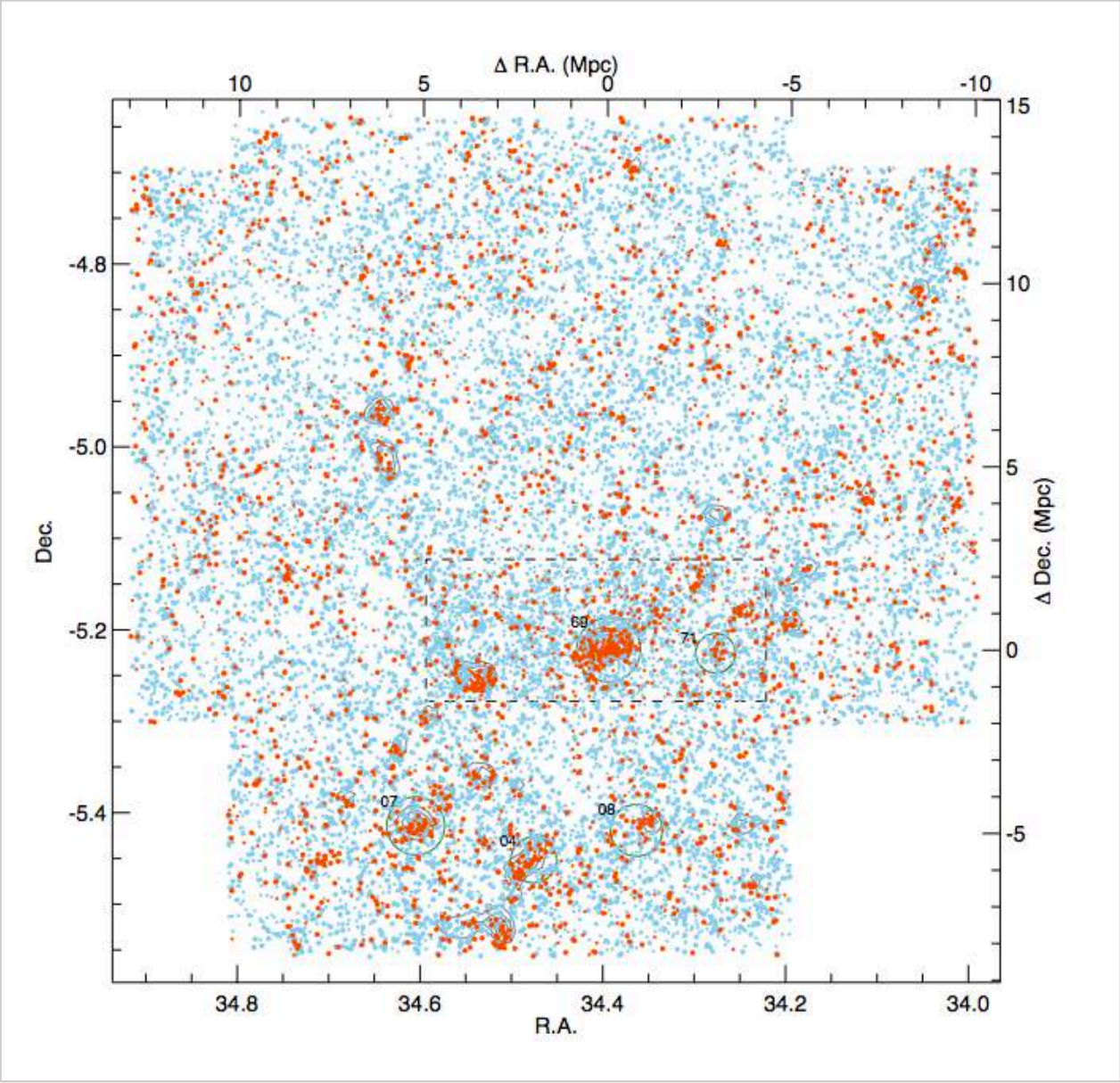
A z=0.65 superstructure in UKIDSS-UDS



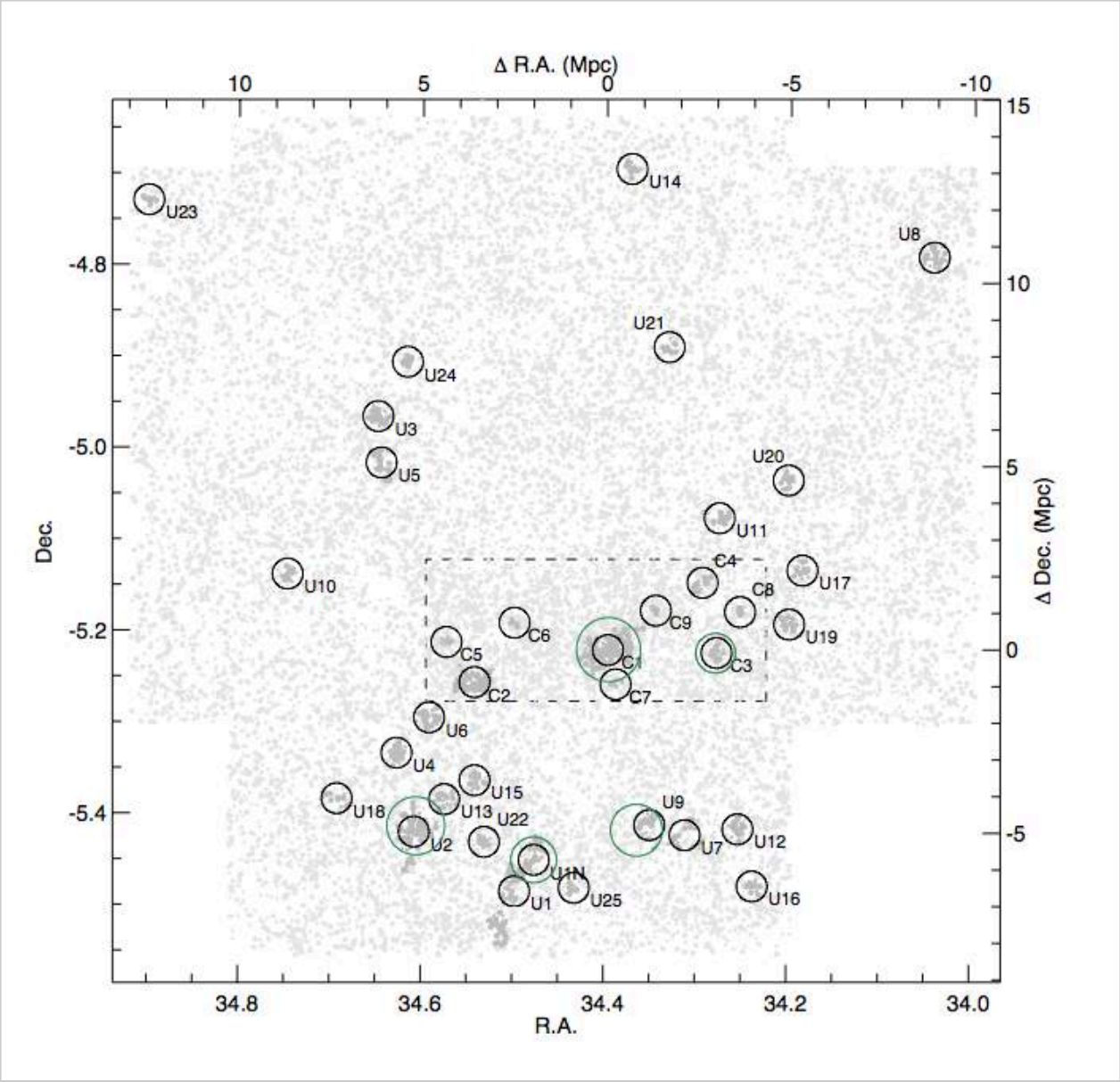
$z_{phot} \sim 0.645$



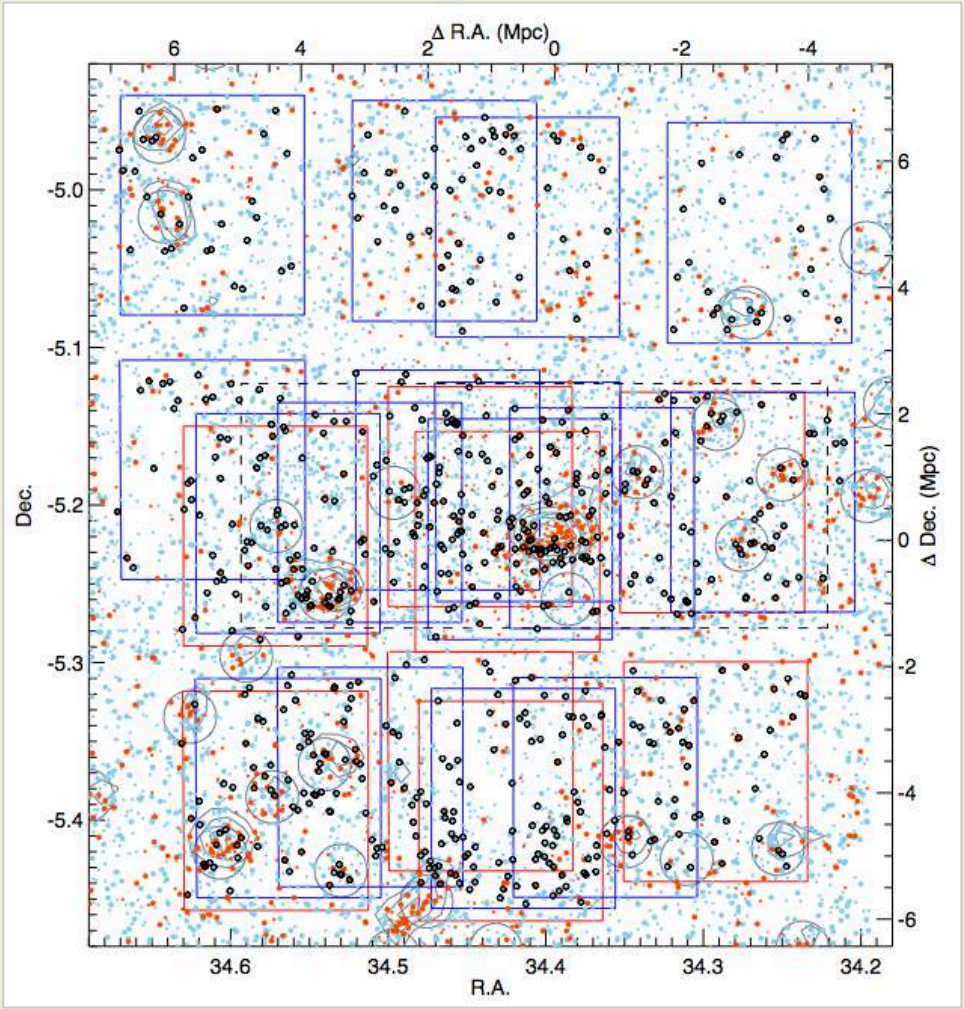
A large-scale structure at z~0.65



(2+1)D-search for substructures

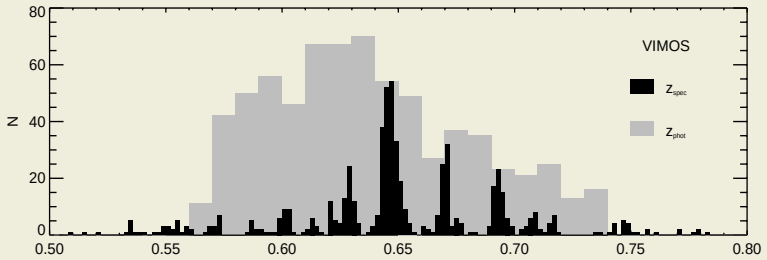


Spectroscopic follow-up - VIMOS



- November 2013
- P.I. A. Galametz
- 6 VIMOS masks
  - 2 'Deep' (passive) + 4 'Shallow' (SF)
  - 750 targets / 710 z_{phot}~0.65

- Success rate: 85 to 93% (z_{phot}~0.65)
- 625 sources with spec-z (46 ser.)



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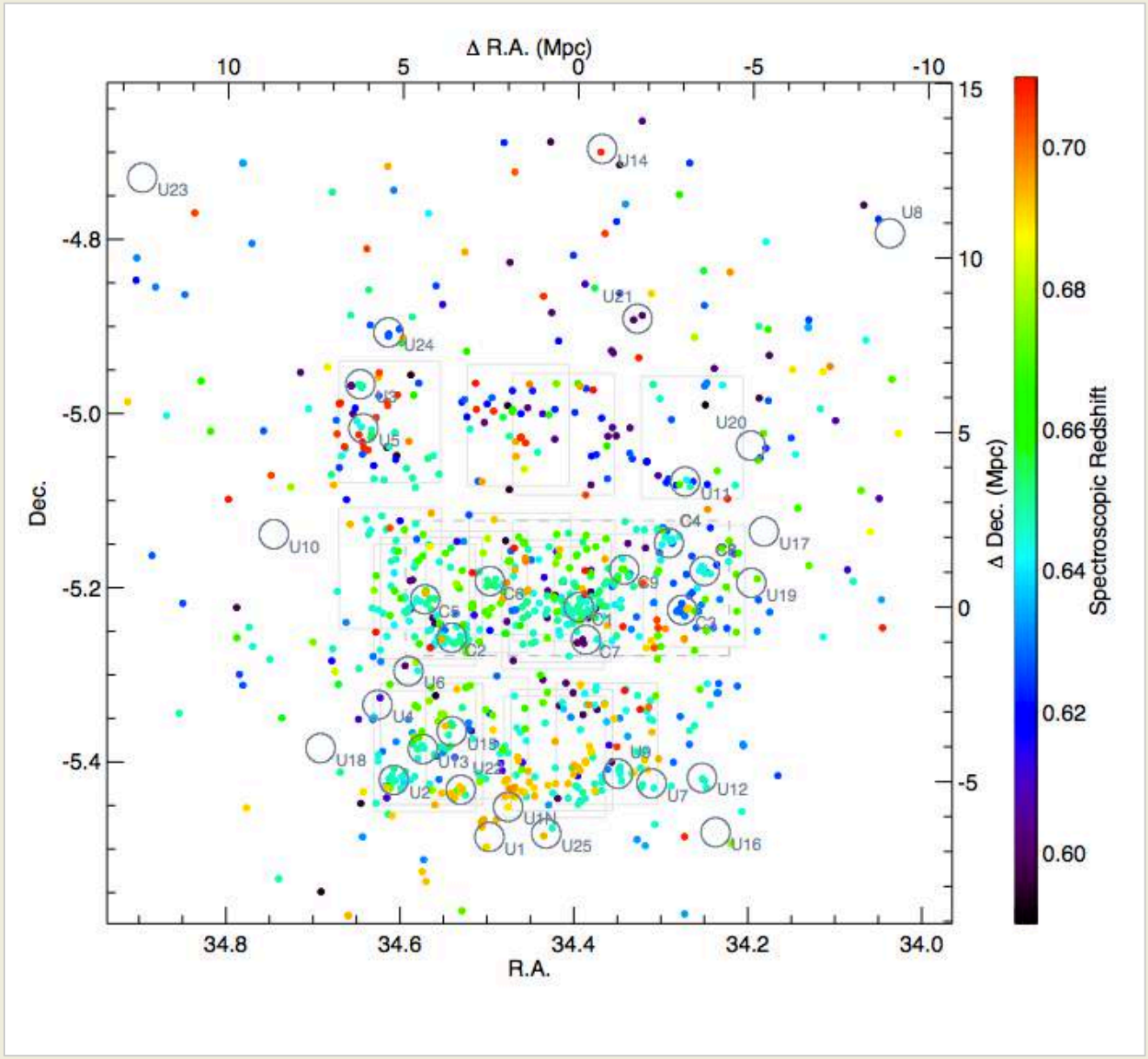

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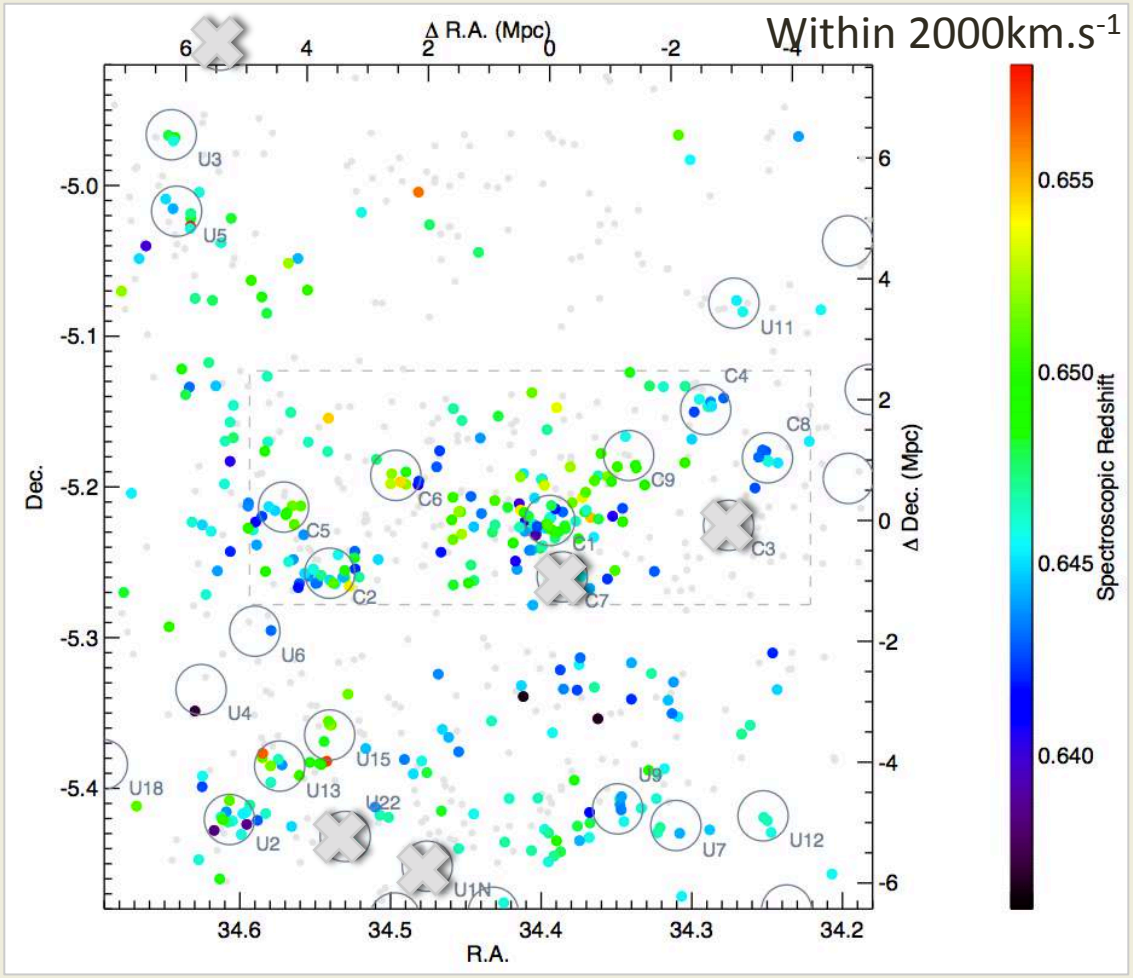
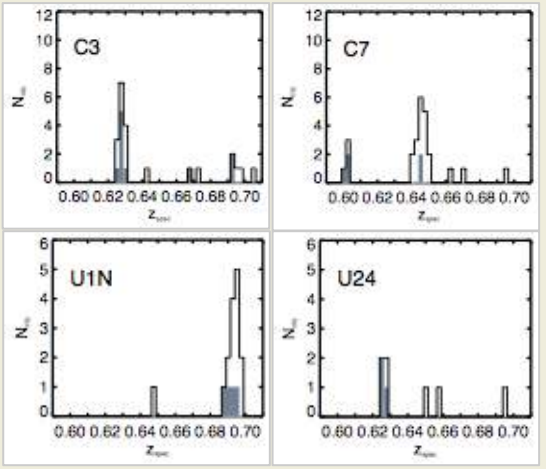
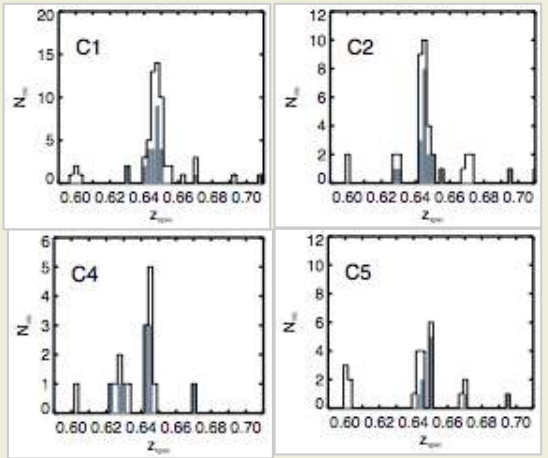
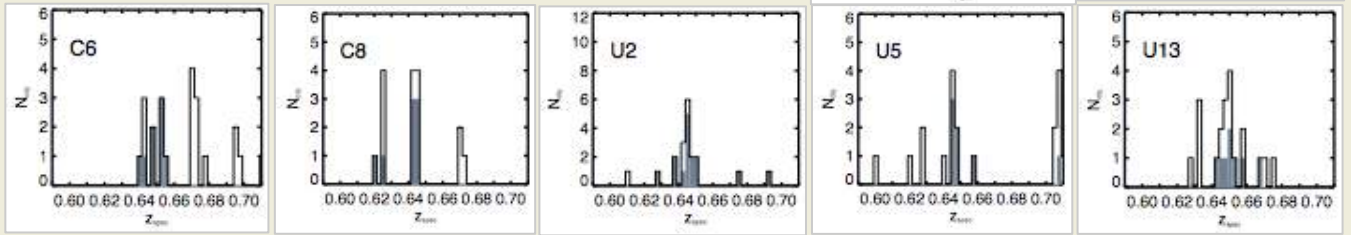




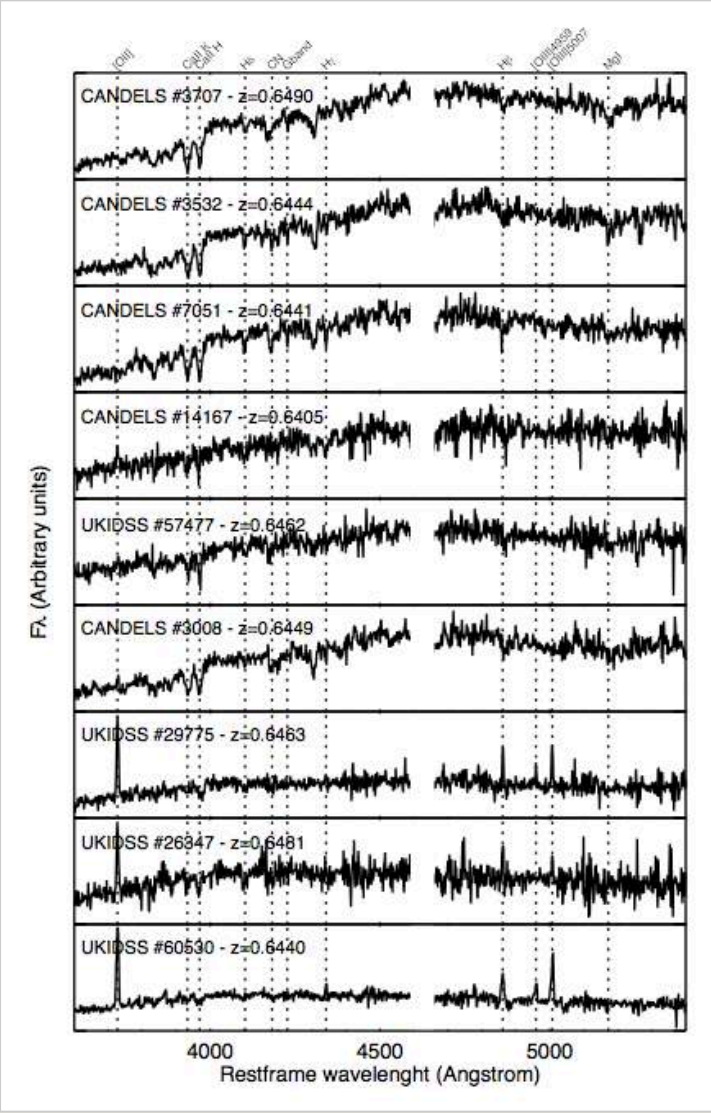


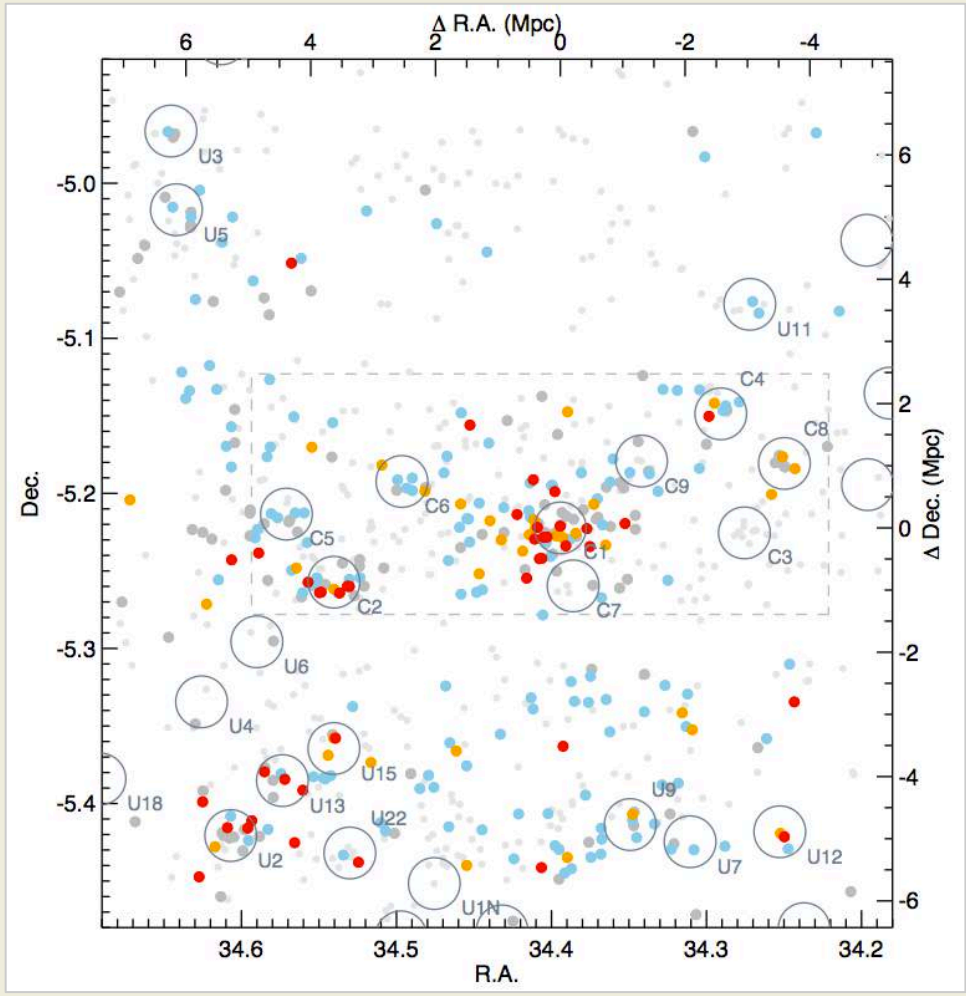


Cluster properties

Name	Nb z_{spec}	Redshift	Velocity km/s	R_{200} Mpc	M_{200} $10^{14}M_{\odot}$	M_{200_X} $10^{14}M_{\odot}$
C1	49	0.6470+/-0.0006	742.2+/-95.6	1.29	3.19	1.47
C2	26	0.6452+/-0.0006	523.5+/-118.4	0.91	1.12	1.9σ det. σ<320km/s
C5	15	0.6459+/-0.0012	791.5+/-372.4	1.37	3.87	-
C4	9	0.6450+/-0.0007	-	-	-	-
C6	9	0.6478+/-0.0019	-	-	-	-
C8	8	0.6448+/-0.0009	-	-	-	-
C9	10	0.6501+/-0.0004	221.8+/-295.4	0.38	0.08	-
U2	15	0.6455+/-0.0008	535.8+/-499.2	0.93	1.20	1.07
U13	13	0.6487+/-0.0010	647.5+/-255.1	1.12	2.11	-
U15	10	0.6495+/-0.0009	462.9+/-299.4	0.80	0.77	-
U3	3	0.6484+/-0.0010	-	-	-	-
U5	8	0.6458+/- 0.0013	-	-	-	-
U9	15	0.6459+/-0.0007	438.0+/-101.9	0.76	0.65	0.81
U28	11	0.6469+/-0.0005	298.9+/-98.1	0.52	0.21	-
C7	4	0.6027+/-0.0010	-	-	-	-
C3	14	0.6279+/-0.0006	363.2+/-91.8	0.64	0.38	0.31
U33	5	0.6240+/-0.0028	-	-	-	-
U24	4	0.6262+/-0.0013	-	-	-	-
U22	6	0.6924+/- 0.0004	-	-	-	-

Spectral signatures vs. environment

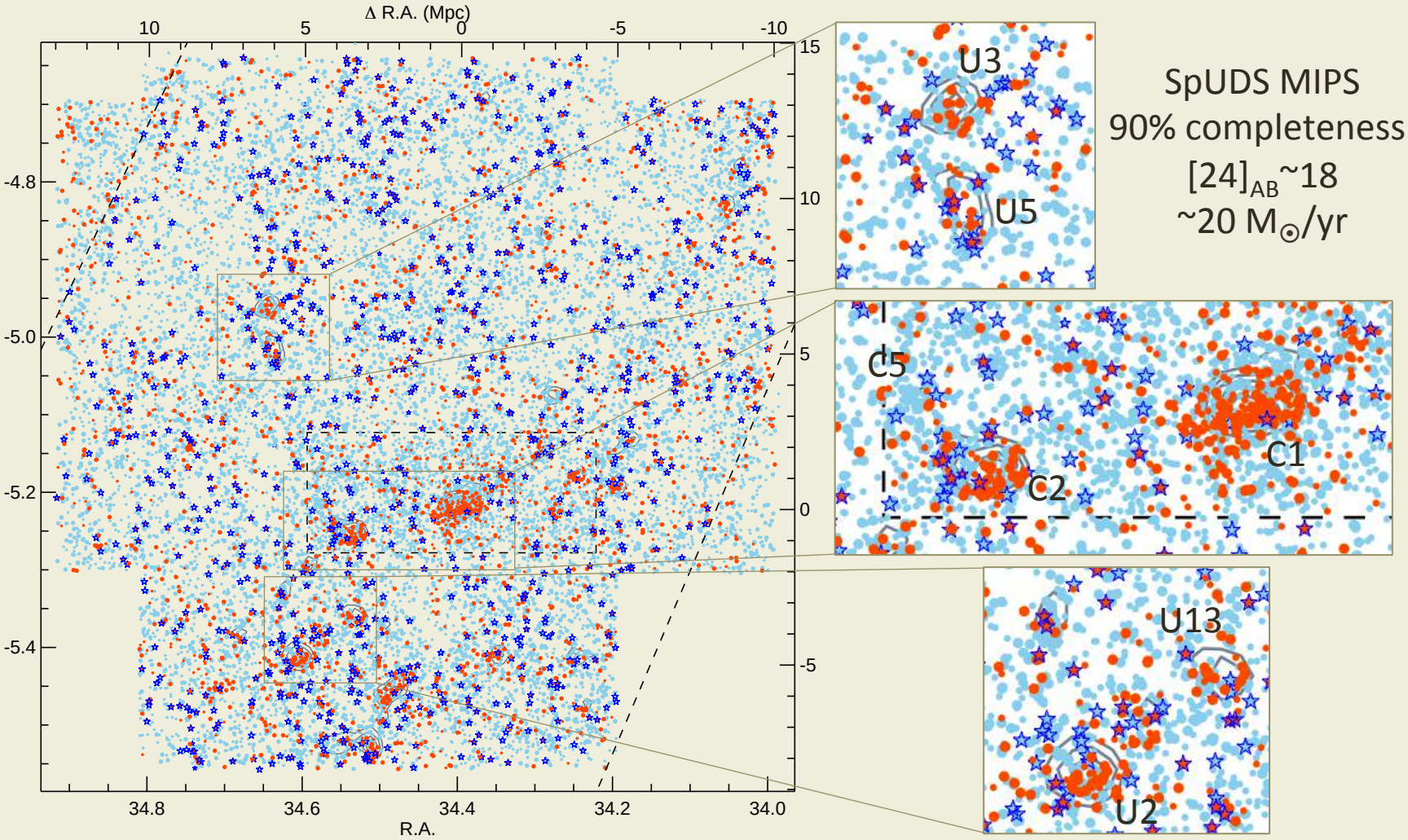




Emission/Stellar absorption feature measurements in progress …

Star-formation in UDS0217-05

- Star-formation rates derived from SED fitting
- Star-formation as seen in the mid-infrared:
  MIPS 24μm-detected cluster/structure members



SpUDS MIPS
90% completeness:
$[24]_{AB}$~18
~20 $M_{\odot}$/yr

Conclusions & Perspectives

- CANDELS/UKIDSS-UDS hosts a number of groups/clusters at z>0.5
  - To be taken into account when deriving statistical properties of the 'field'

- CANDELS hosts one cluster at z=1.62 and one candidate at z=1.83
  - They both host a number of quiescent galaxies in their core whose sizes support the accelerated size growth for quiescent galaxies in dense environments
  - Their cores are both the locus of both on-going SF and AGN activity suggesting that their core population is still building up.
  - SFR mapping of the core ongoing.
  - Spectroscopy, spectroscopy, spectroscopy …

- CANDELS/UKIDSS-UDS hosts a large-scale structure at z=0.65
  - A perfect playground for study of dependence of galaxy properties with environment
  - Perspectives:
    - SF mapping?
    - Lensing in the CANDELS FoV
    - AGN fraction and distribution? - deeper Chandra data for UDS coming !!!