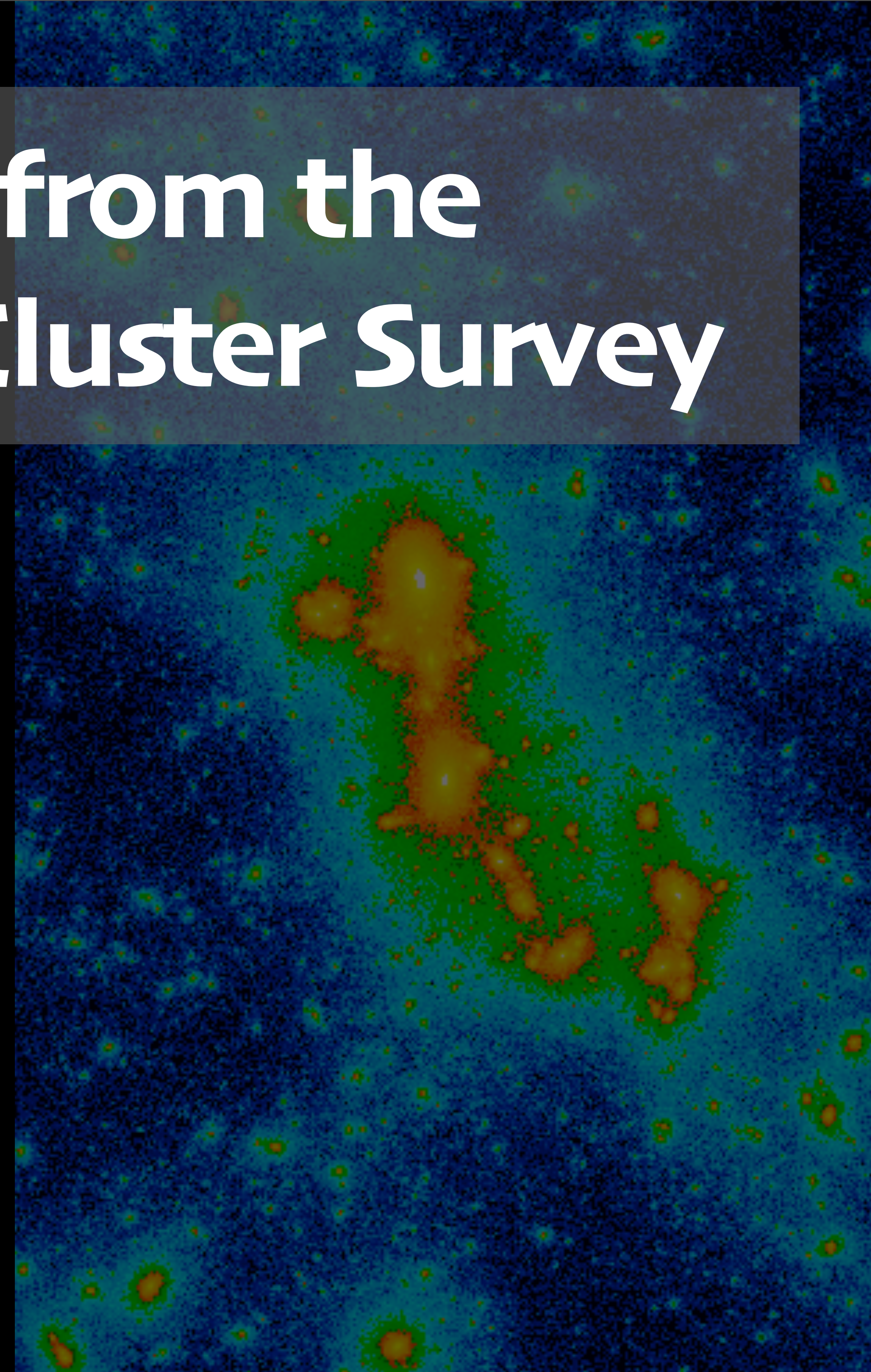
Clusters at z > 1.5 from the SpARCS Infrared Cluster Survey



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Department of Astronomy
Universidad de Concepción

The SpARCS collaboration

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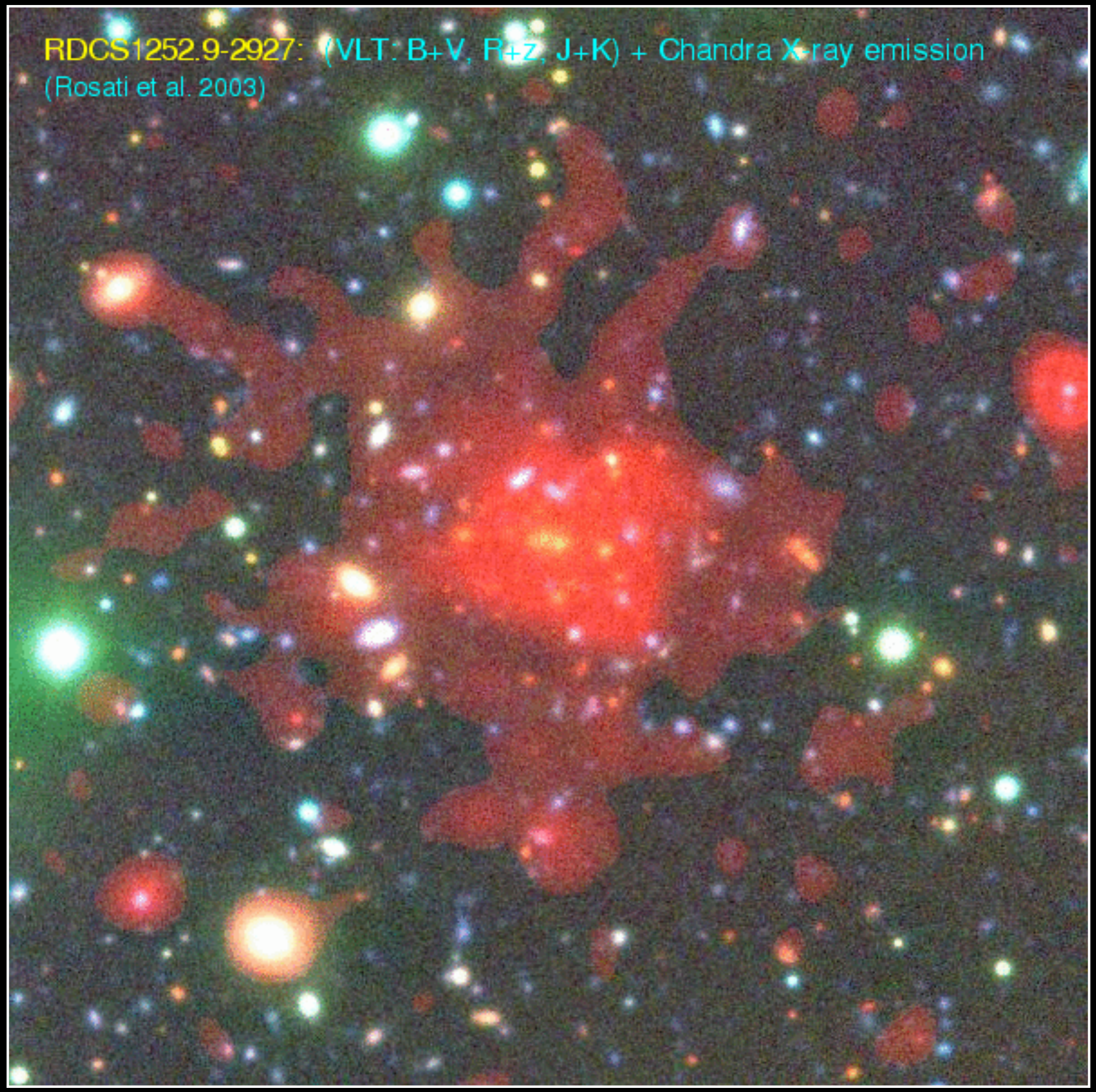
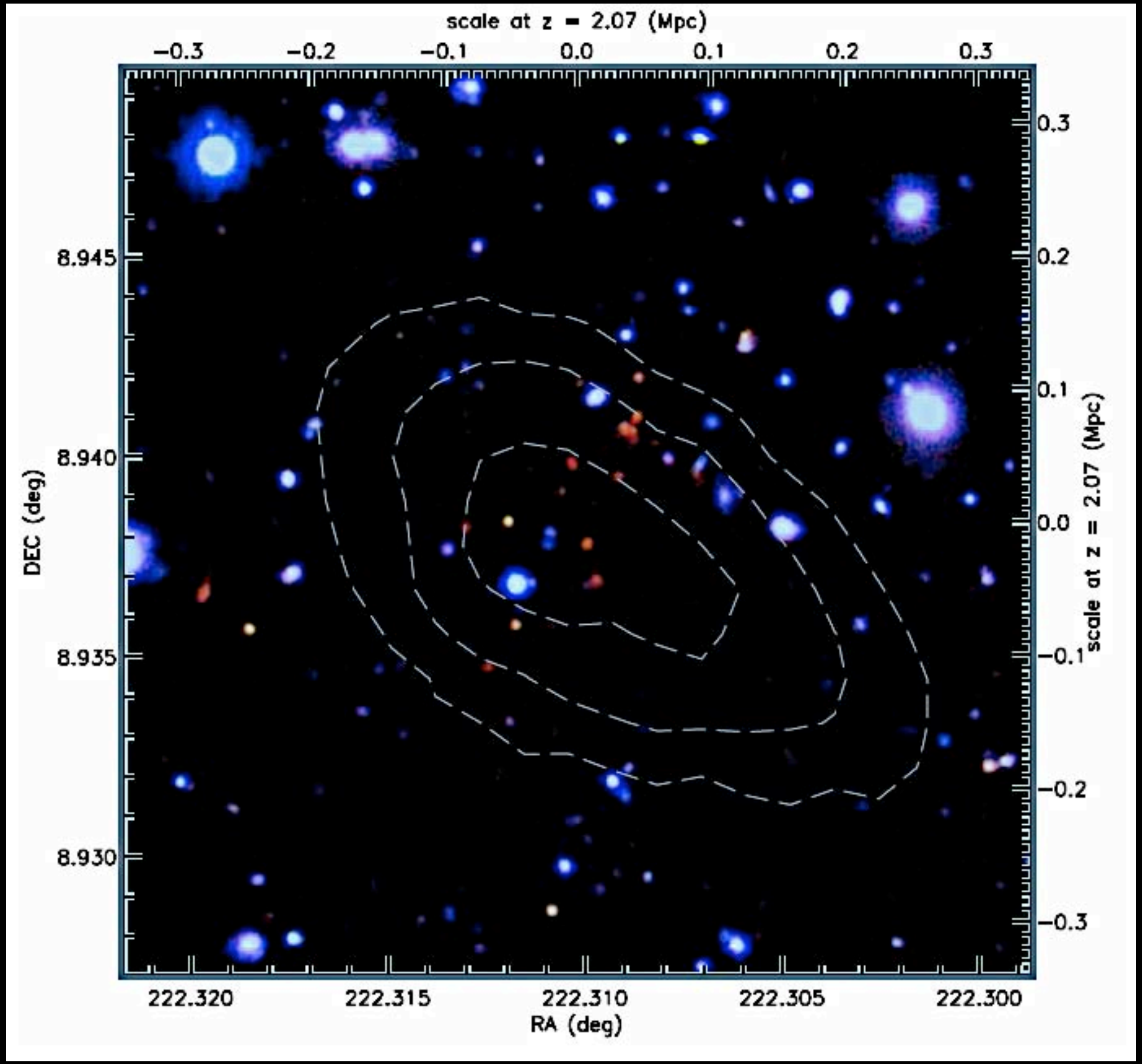
Howard Yee (Toronto)
Chris Lidman (AAO)
Julie Nantais (Concepción)
Alireza Farahmandi (UCR)
Michael Balogh (Waterloo)
Erica Ellingson (Colorado)
Mike Gladders (Chicago)
Hendrik Hilldebrandt (UBC)
Mark Lacy (NRAO)
Allison Noble (McGill)
Remco van der Burg (Leiden)
Adam Muzzin (Leiden)
Alessandro Rettura (Caltech)
Ricardo Demarco (Concepción)
Andrew DeGroot (UCR)
Joseph Cox (UCR)
Douglas Burke (SAO)
David Gilbank (Waterloo)
Amalia Hicks (MSU)
Henk Hoekstra (Leiden)
Jean-Christophe Mauduit (Caltech)
Jason Surace (Caltech)
Tracy Webb (McGill)

Searching for Galaxy Clusters

X-ray



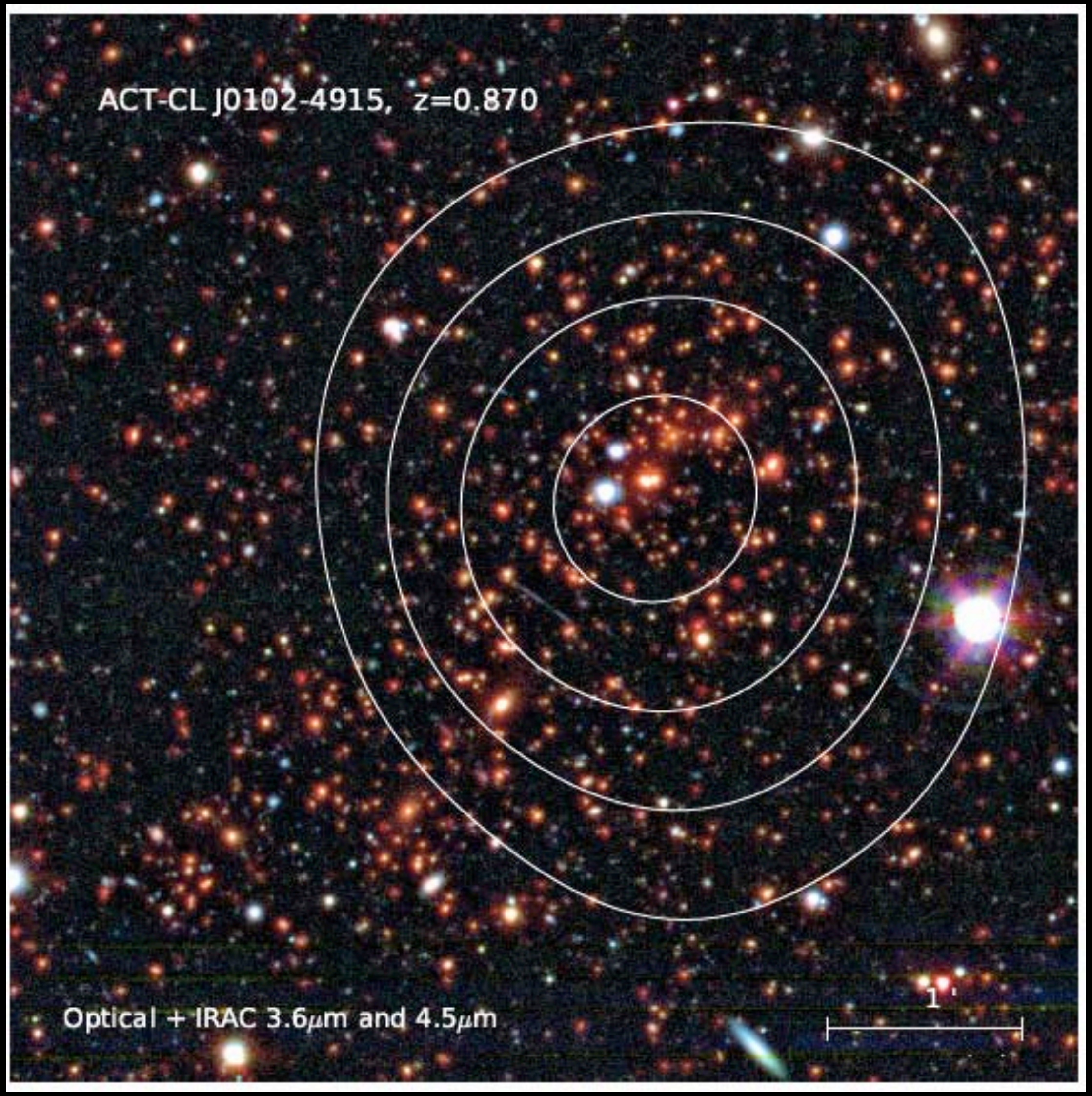
Rosati et al. (2004)

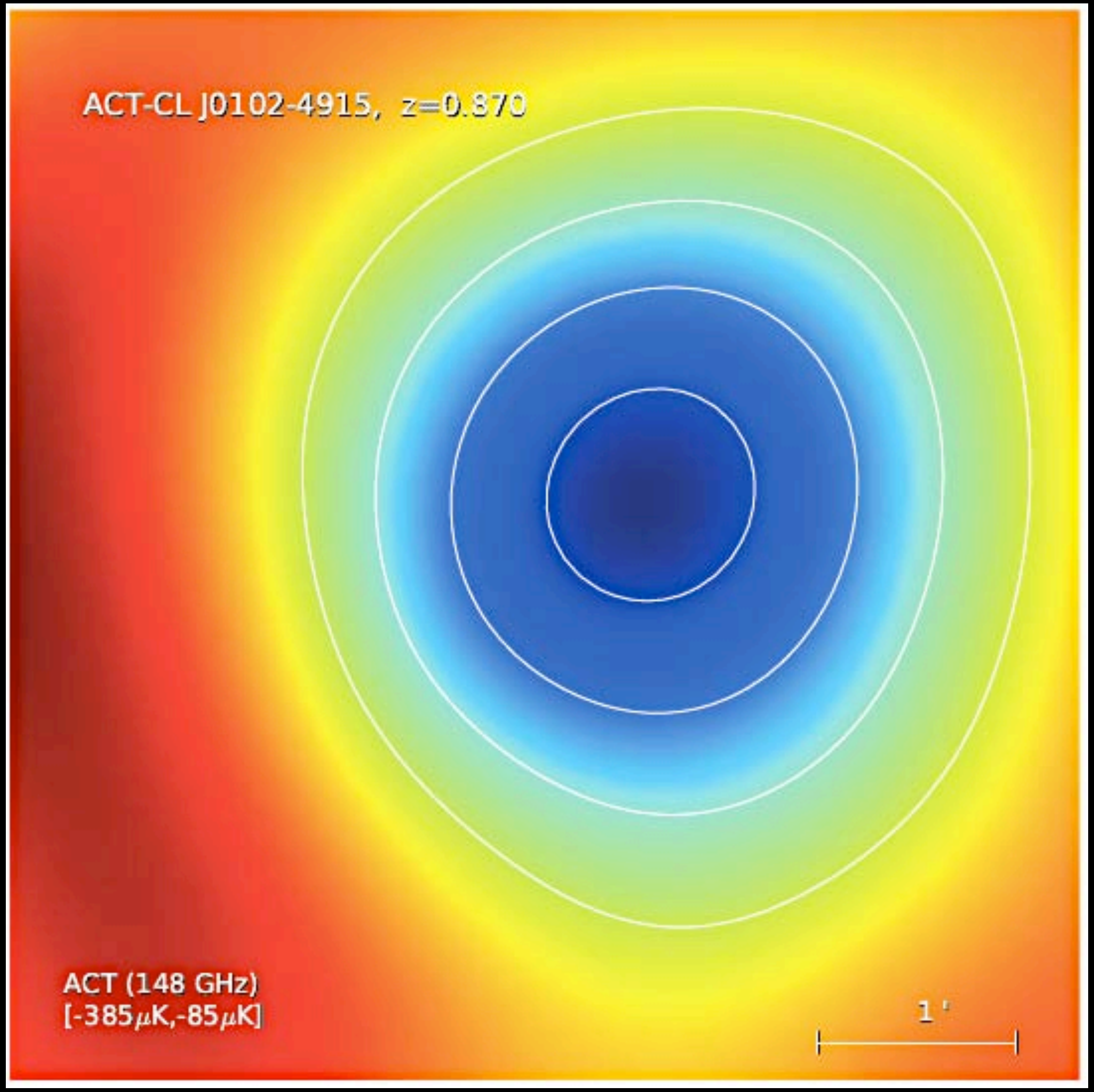


Gobat et al. (2011)

Searching for Galaxy Clusters

Sunyaev-Zel'dovich

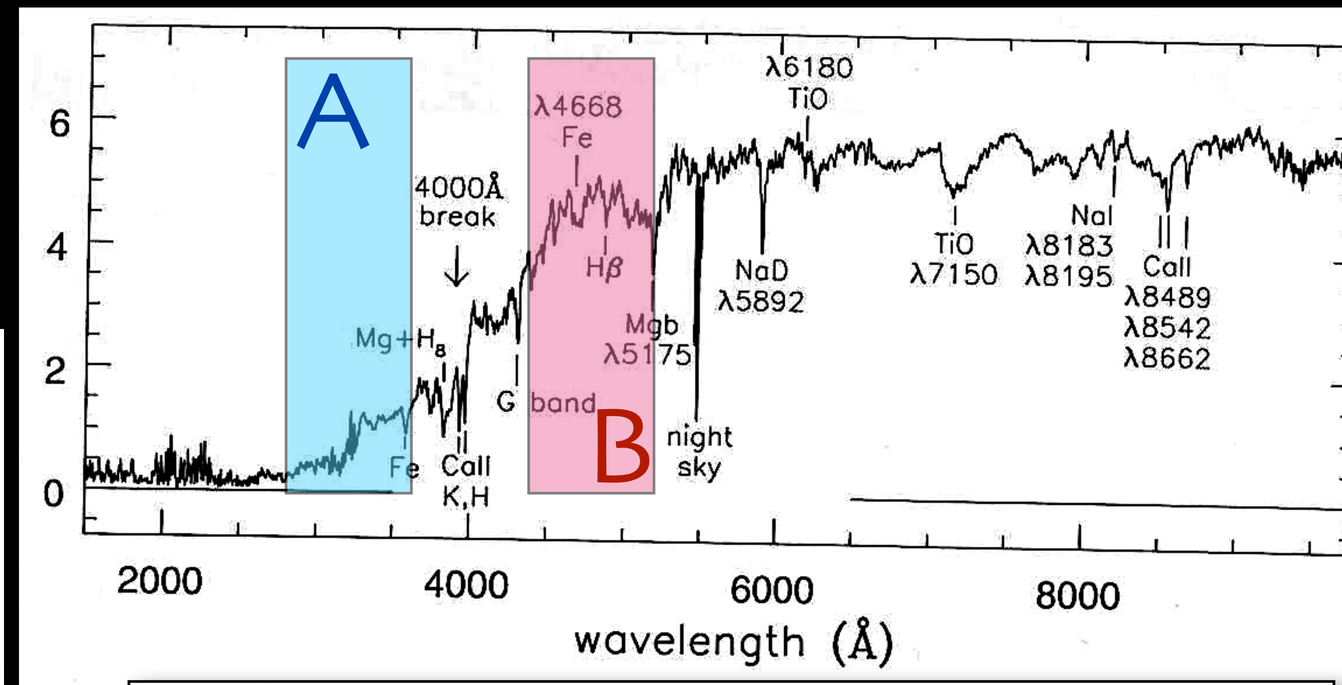


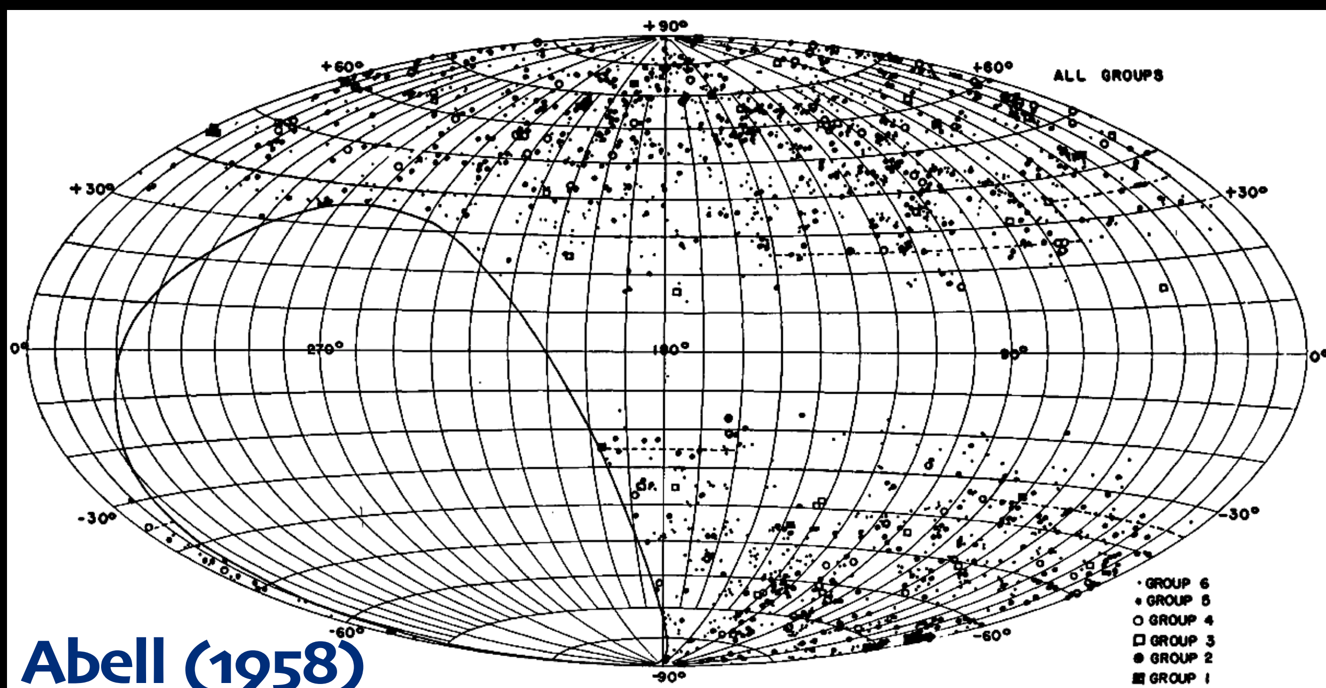


Menanteau et al. (2011)

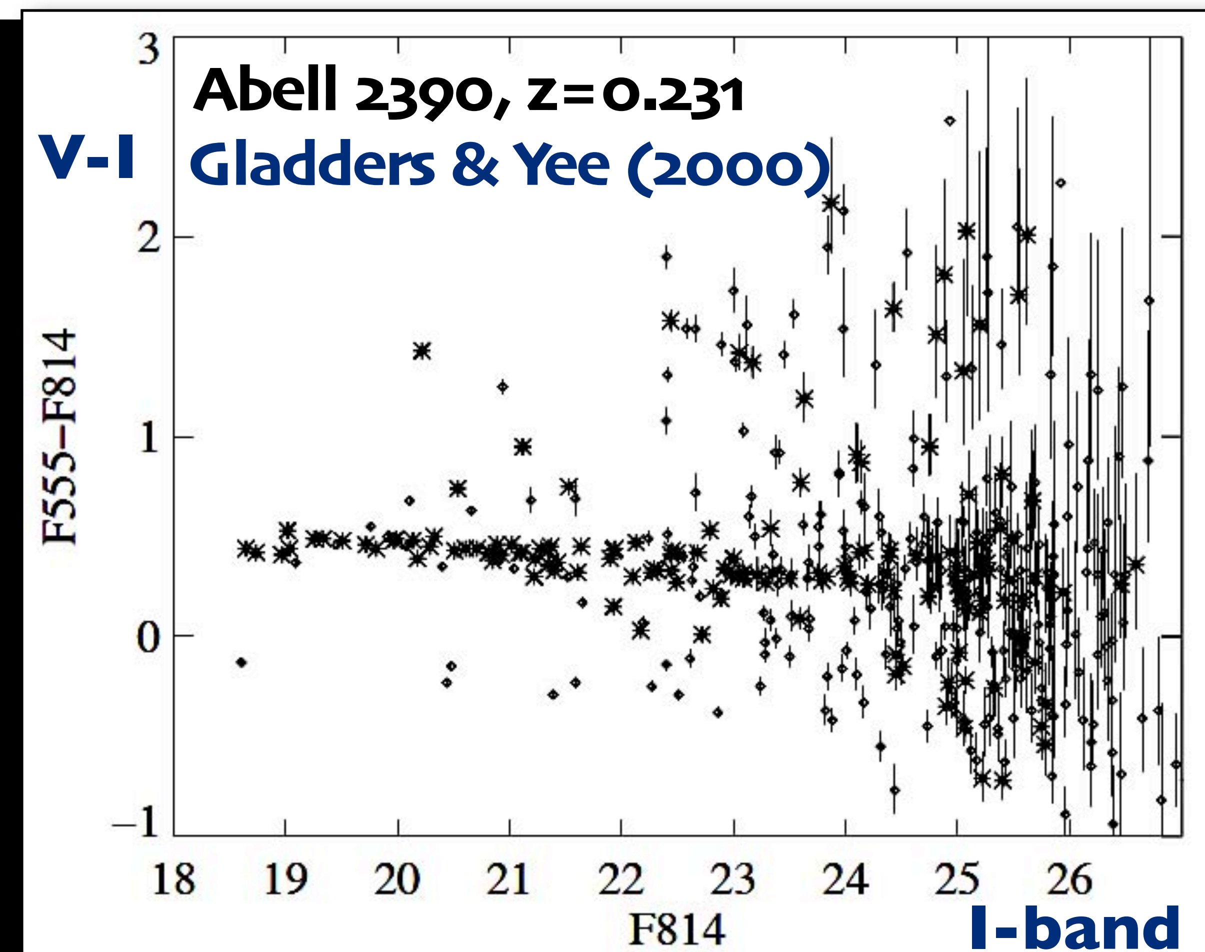
Searching for Galaxy Clusters

Optical





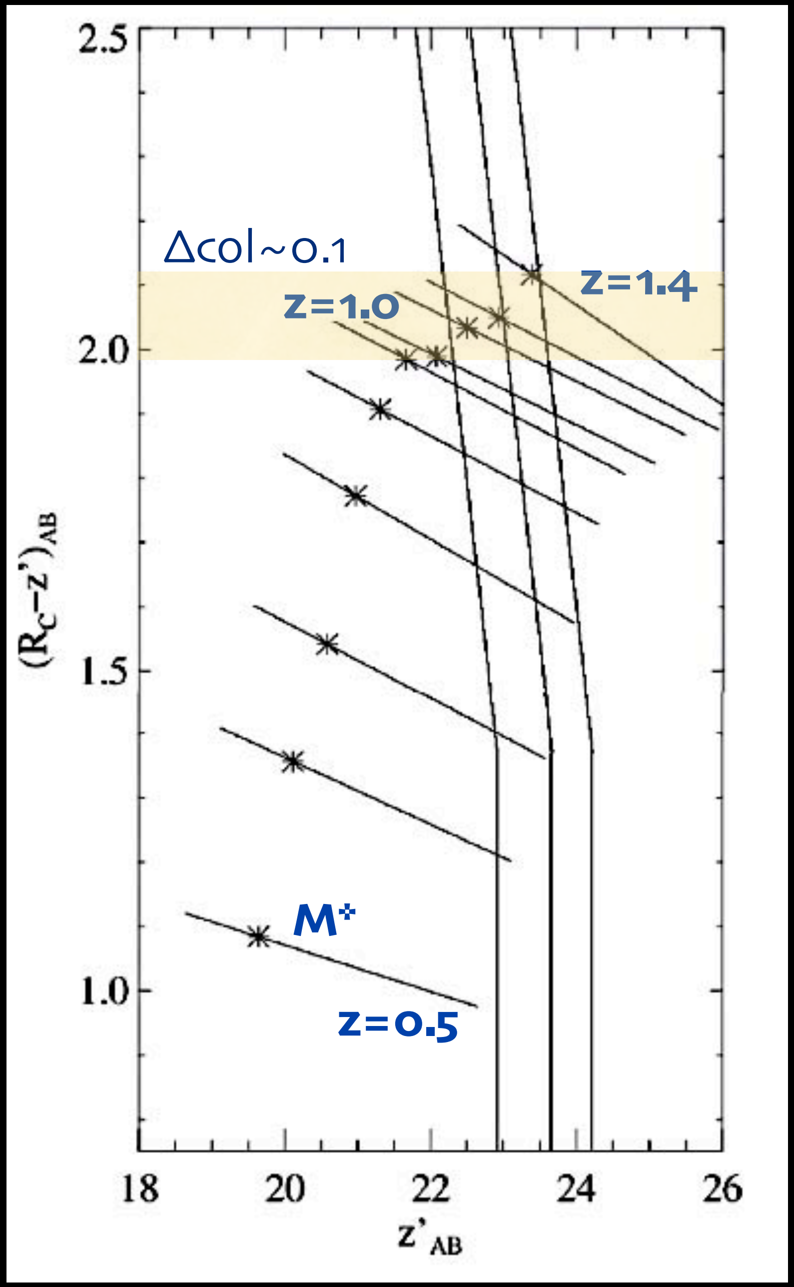
Abell catalog: Z<0.2 (Abell et al. 1089)



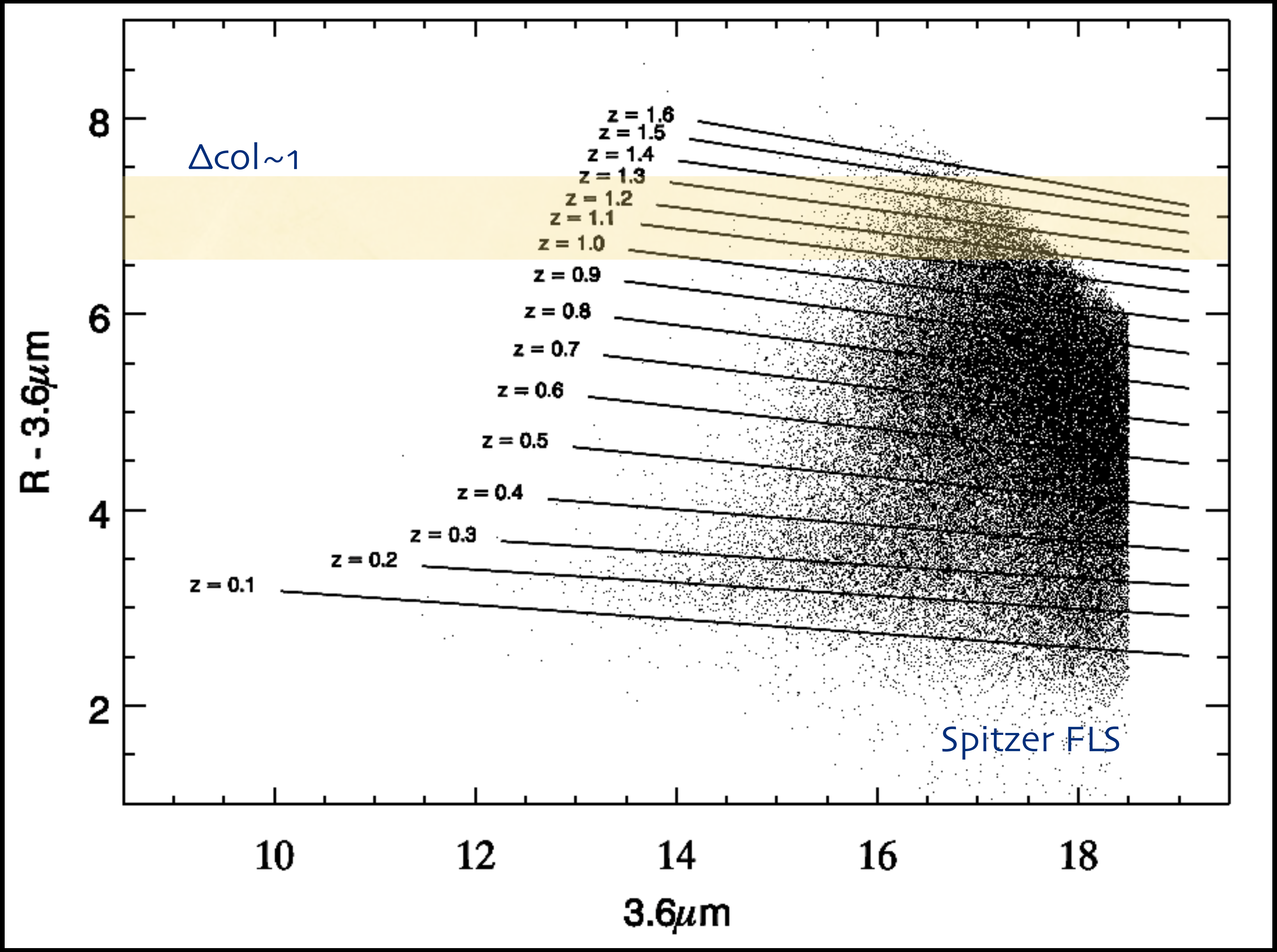
Red Sequence technique: Z≲1

Searching for Galaxy Clusters

Optical, Optical-NIR



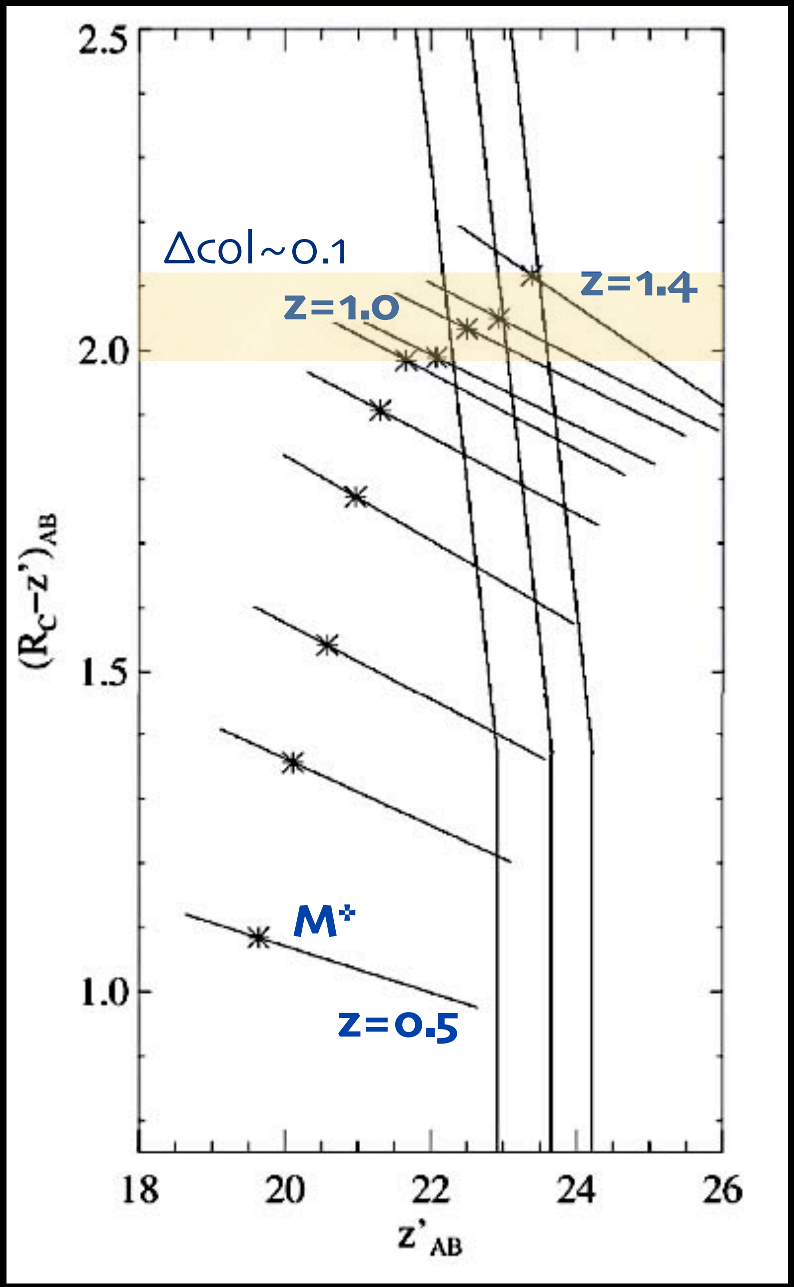
Gladders & Yee (2005)



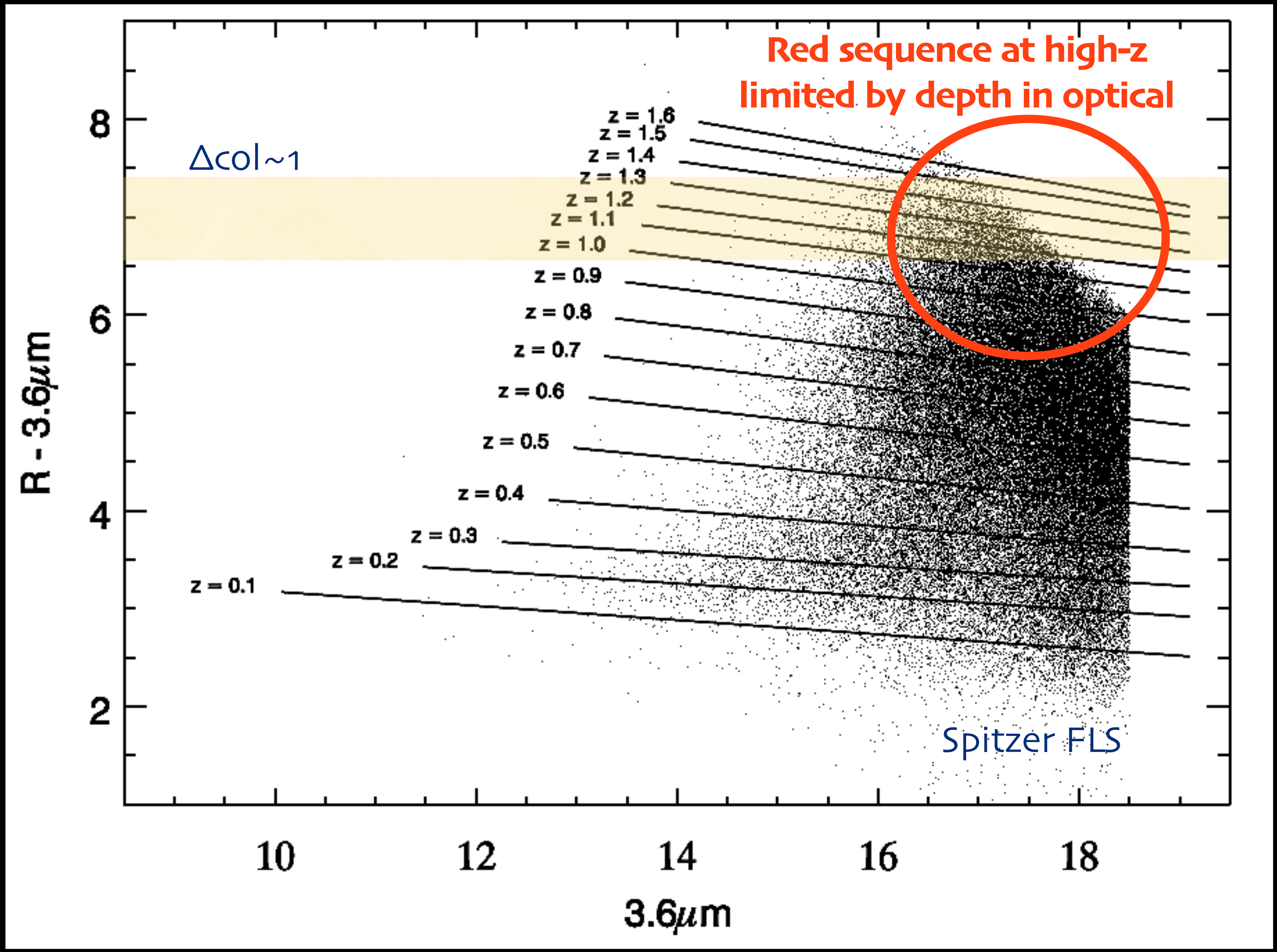
Muzzin et al. (2008)

Searching for Galaxy Clusters

Optical, Optical-NIR



Gladders & Yee (2005)



Muzzin et al. (2008)

Searching for Galaxy Clusters

optical-NIR, MIR

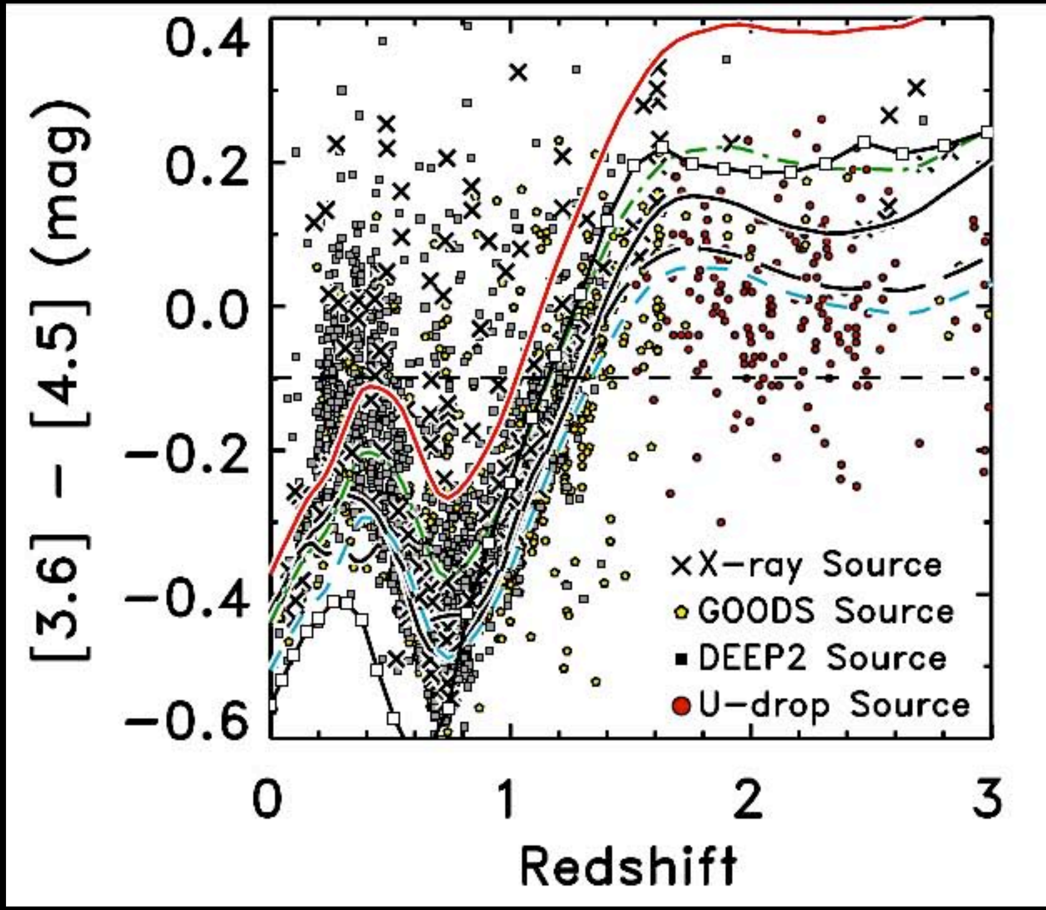
SpARCS

Instead of the R-band, z′-band is used to go deeper in the optical.

By z~1.1 the z′-band is no longer redward of the rest-frame 4000Å-break. Using the z′-band and the [3.6]-band allow us to identify red galaxies and discover z≳1 galaxy cluster candidates.

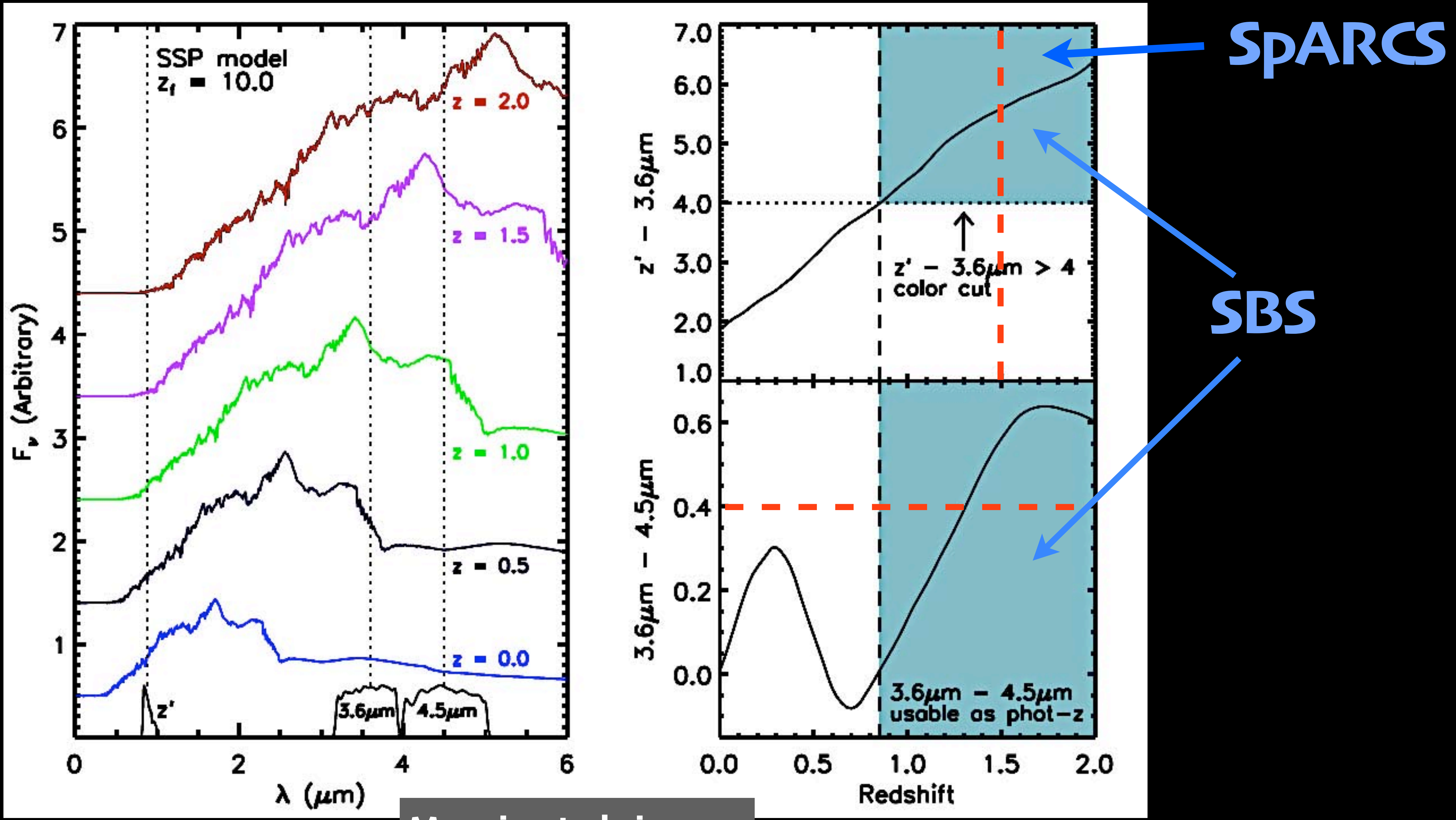
Total area~45 deg^2, z′-band (CTIO, CFHT) and [3.6]-band (Spitzer). ~200 cluster candidates at z≳1, 15 spec. confirmed at z>0.85 (2 at z>1.6).

See: Wilson et al. (2009), Muzzin et al. (2009, 2012), Demarco et al. (2010a)



Papovich (2008), Papovich et al. (2010)

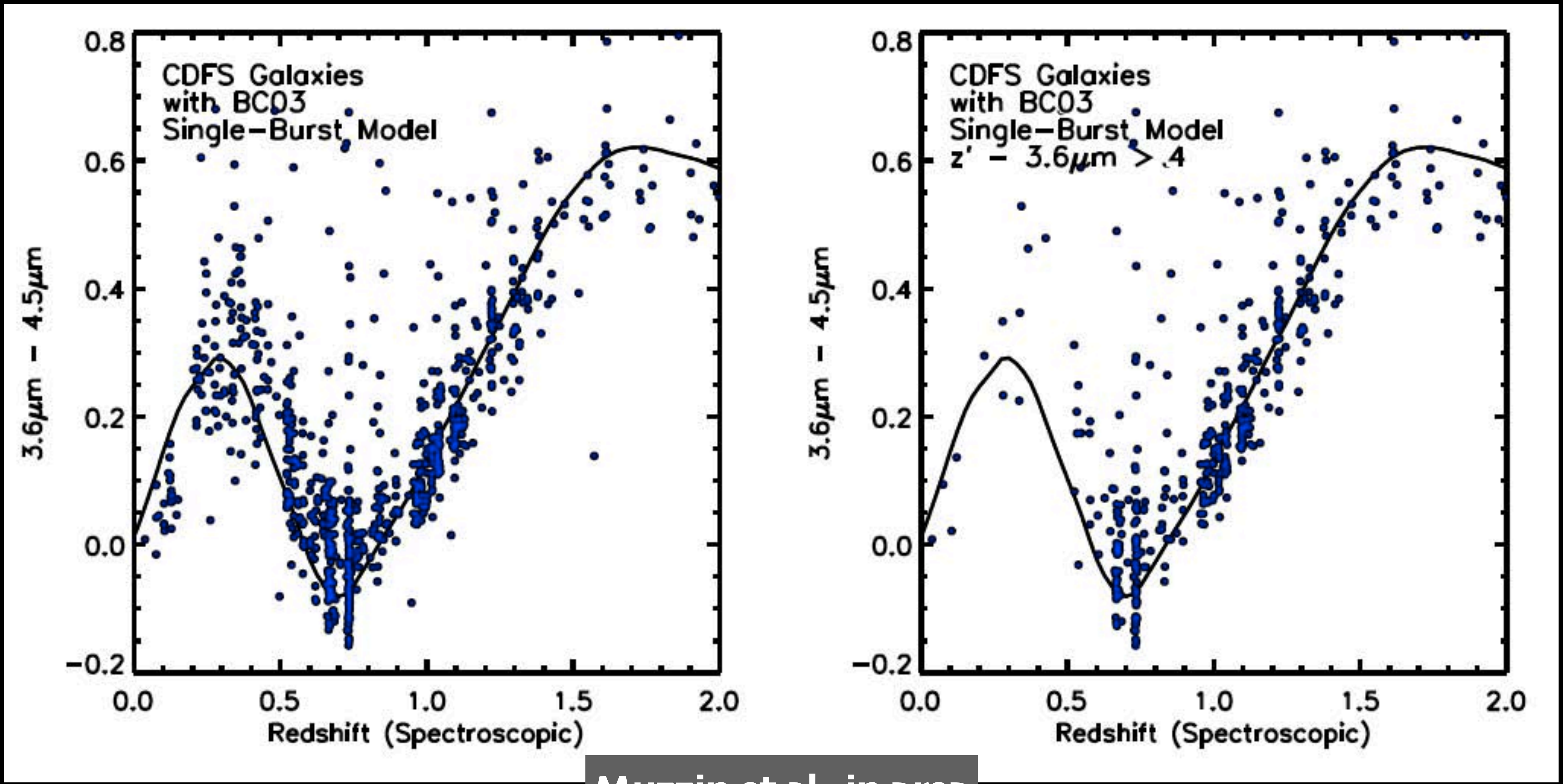
The Stellar-Bump Sequence method



Muzzin et al., in prep

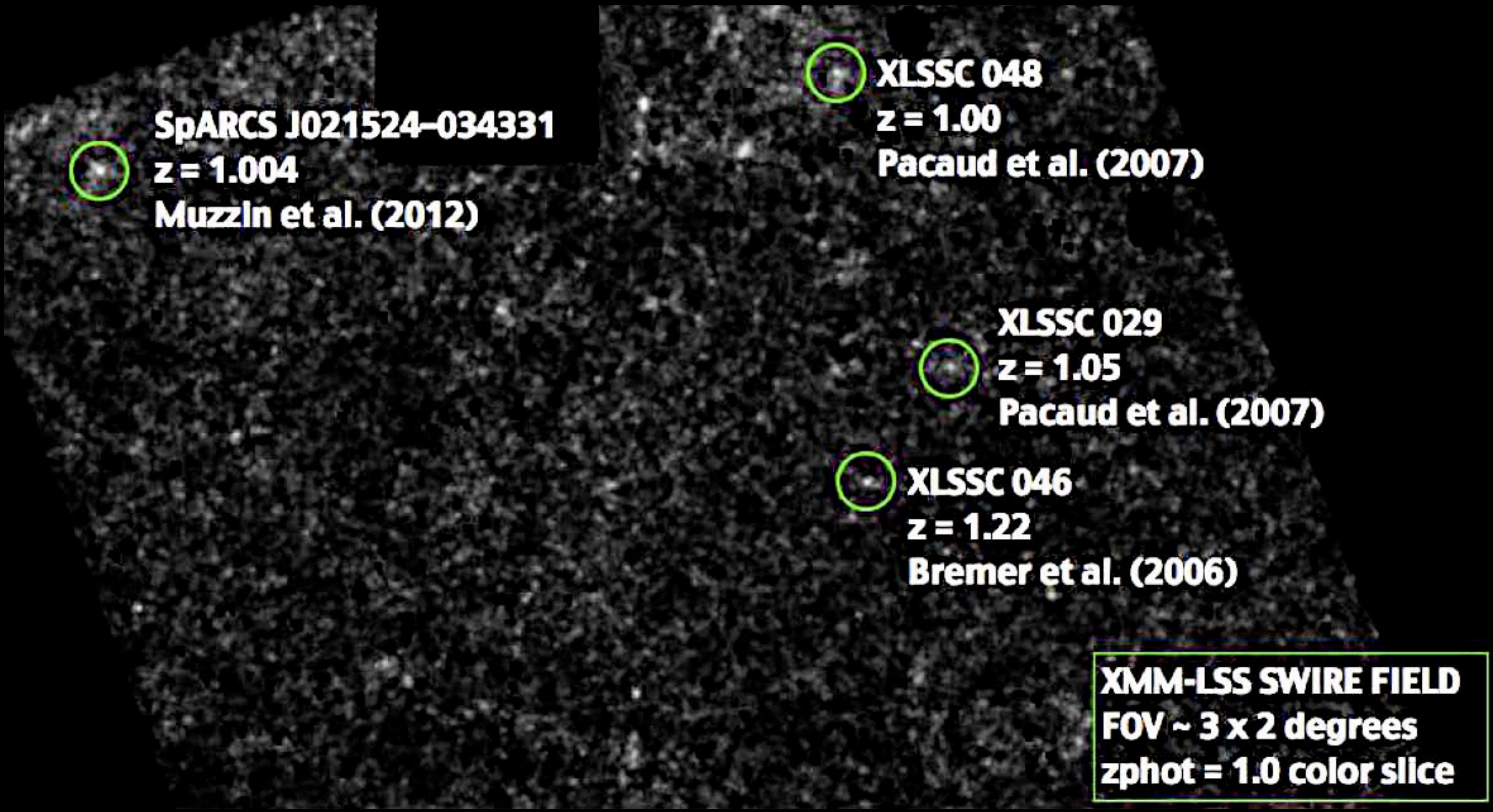
See also: Muzzin's talk

The Stellar-Bump Sequence method

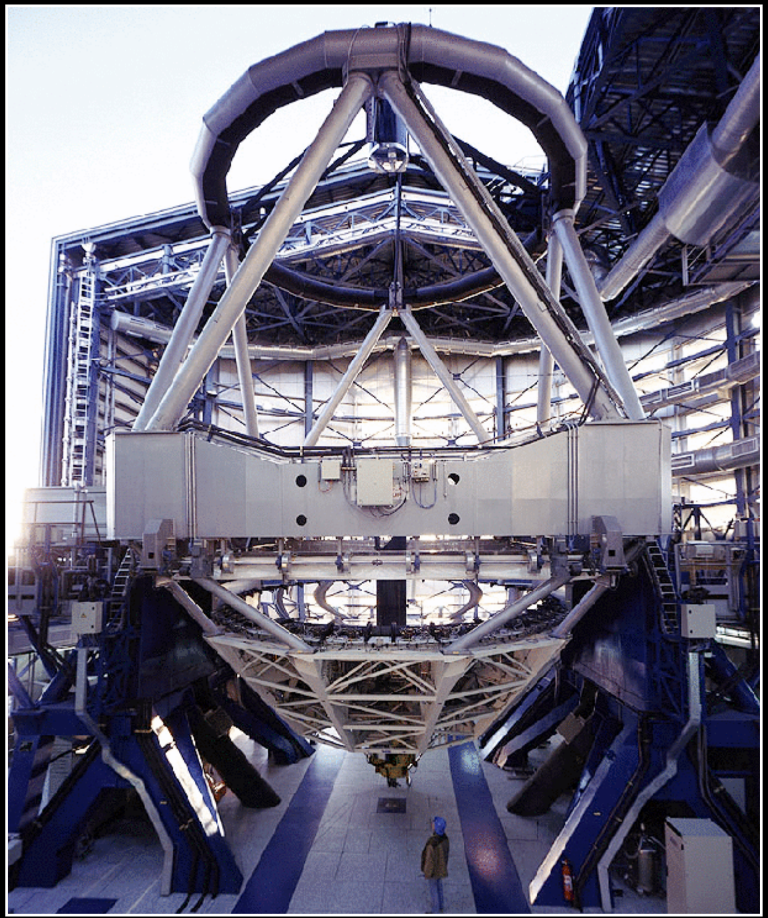


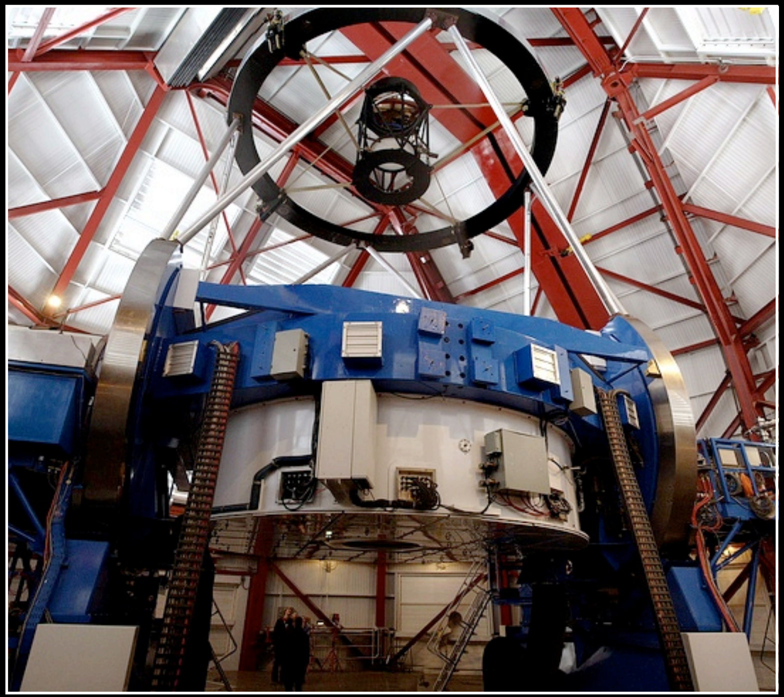
Muzzin et al., in prep

The Stellar-Bump Sequence method



Muzzin et al., in prep





High Redshift Stellar-Bump Cluster Candidates:

SpARCS J0331-2843: **CDFS-44**, $z_{phot} \sim 1.7$
SpARCS J0224.5-0323.5: **XMM-113**, $z_{phot} \sim 1.7$

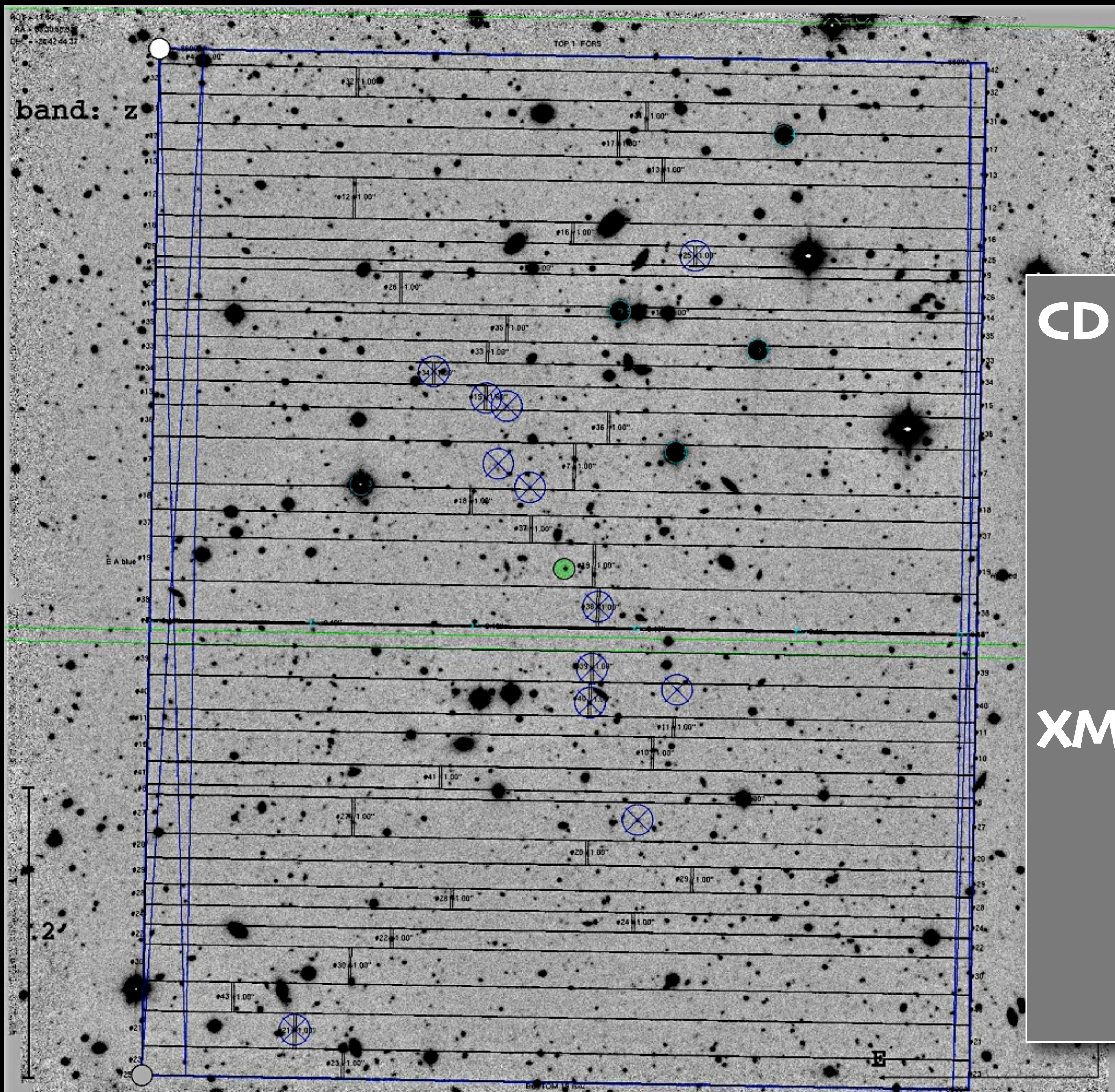
Multi-wavelength dataset:

	FORS2 spec.	HAWK-I	IMACS/ FORS2	Spitzer	CTIO/ CFHT
CDFS-44	6000-10500Å	Y J K_s	g′r′i′z′	3.6μm, 4.5μm	z′
XMM-113	6000-10500Å	Y J K_s	g′r′i′z′	3.6μm, 4.5μm	z′

FORS2 color-color selection for spectroscopy:

Class 1: SBS with z′<22.5
Class 2: SBS with z′>22.5 and MIPS detection
Class 3: SBS with z′>22.5 and no MIPS detection
Classes 4 to 6: in classes 1 to 3 and R>700 kpc
Class 7: anything else with detection in z′ and IRAC
Class 8: anything else with detection in z′ (FORS2)

Spectroscopic FORS2 observations



ESO P85: **21 hours** awarded

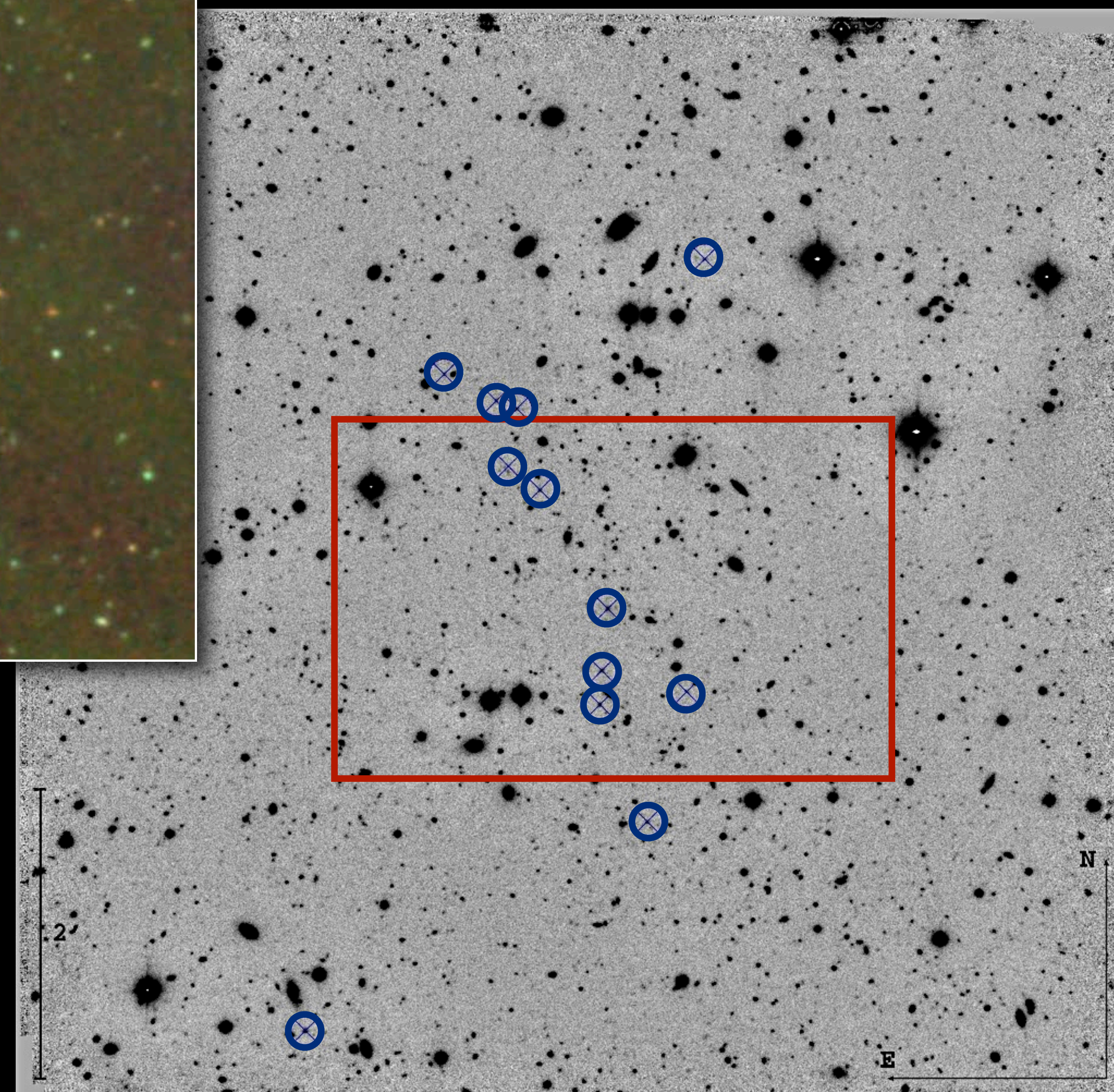
MXU mode with 300I grism
(~ 6000 - 10500 Å, R~600)

CDFS-44: 2 masks (**3.75 h/mask**),
37 and 39 slits
- targeted: 39
- emission line: 25
- redshifts: 26

XMM-113: 2 masks (**3.75 h/mask**),
32 slits each
- targeted: 32
- emission line: 28
- redshifts: 29

CDFS-44

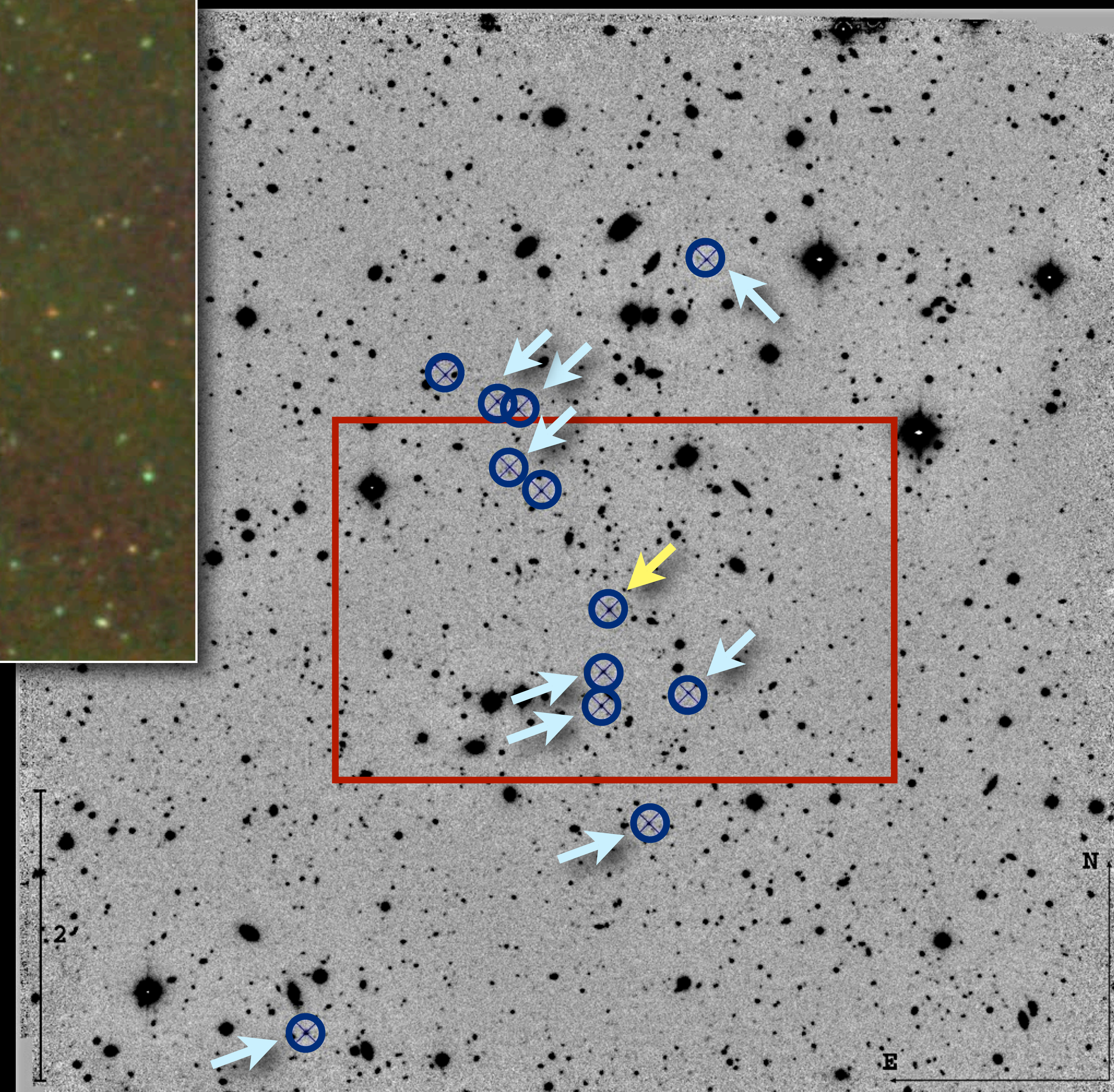
~3.5′x2.5′ (1.8 Mpc x 1.3 Mpc), z′YKs



2′→1 Mpc

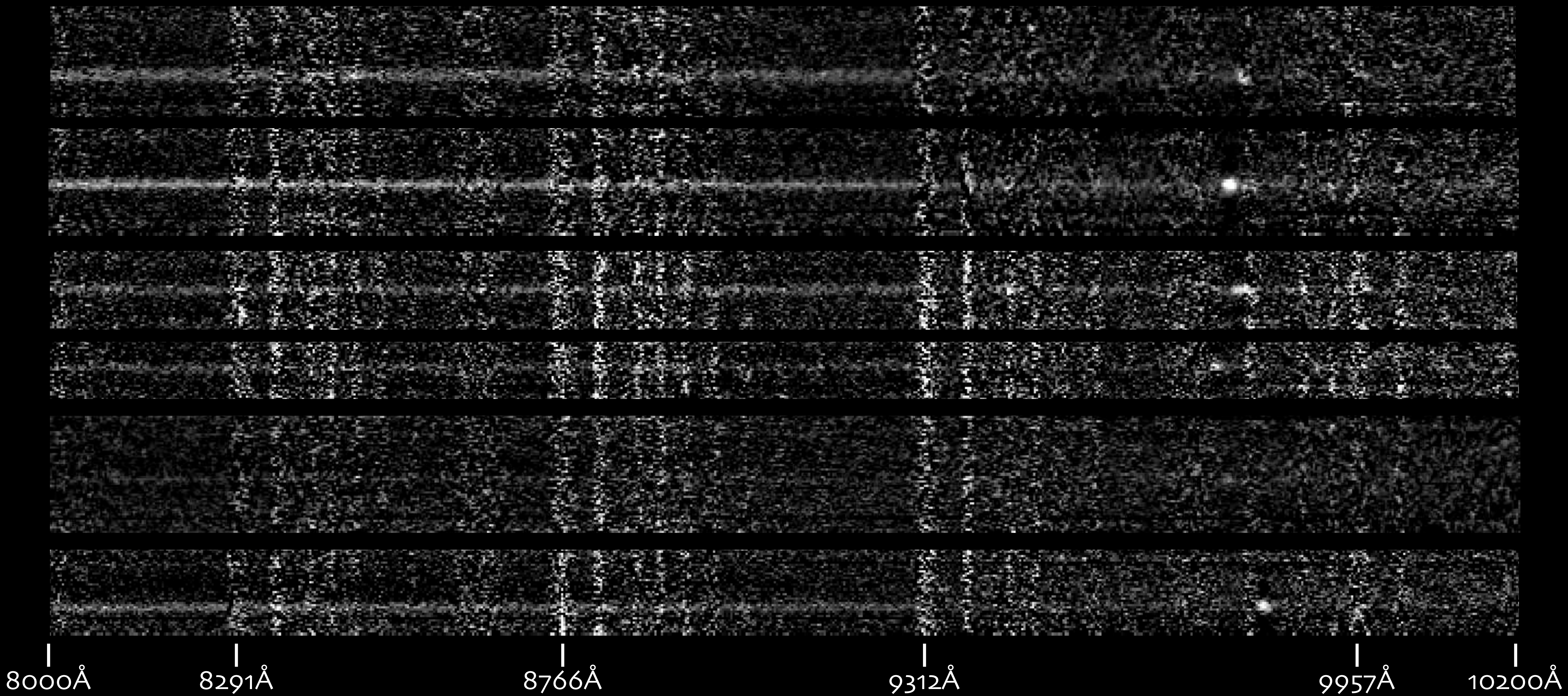
CDFS-44

~3.5′x2.5′ (1.8 Mpc x 1.3 Mpc), z′YKs



2′→1 Mpc

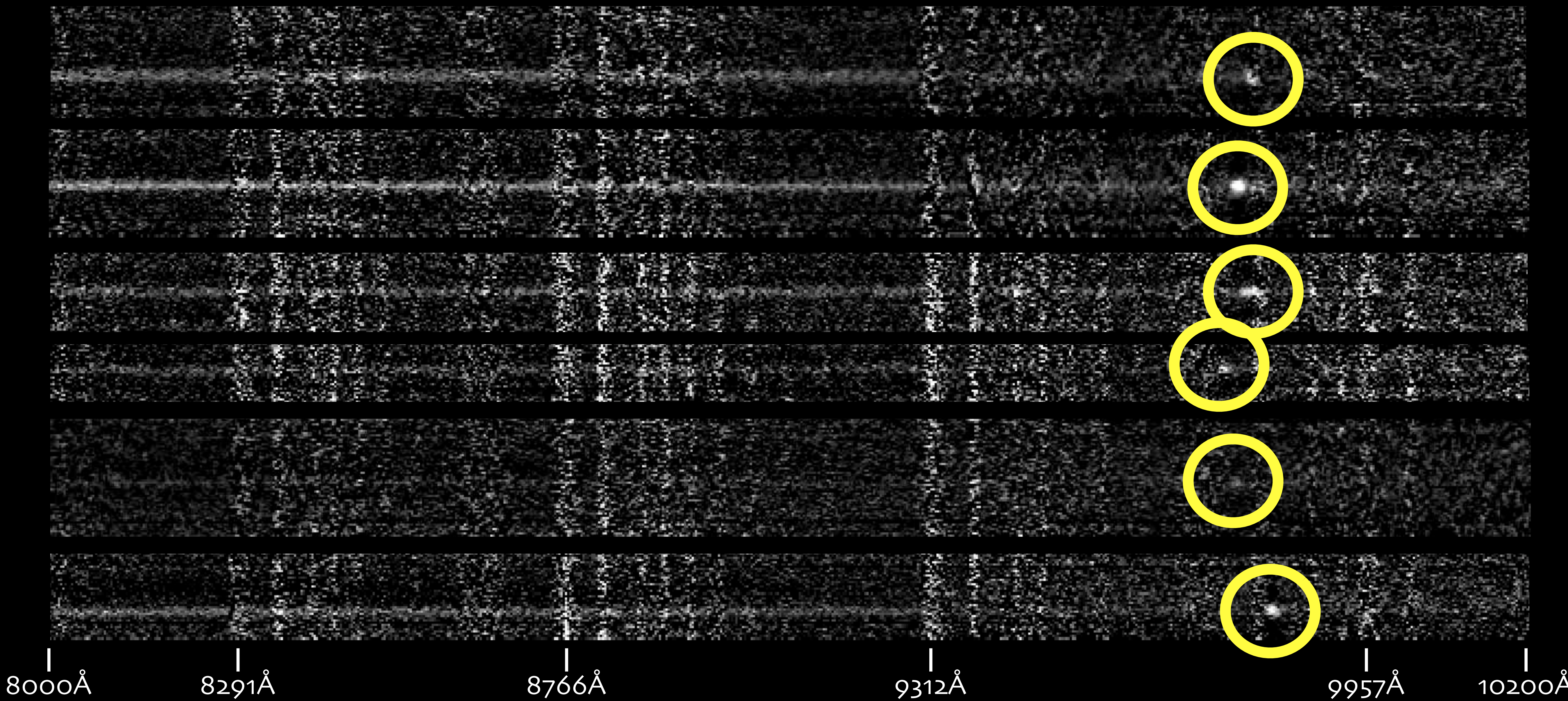
CDFS-44 (sample spectra)



Members: 12 Emission line: 10

Wilson et al., in prep

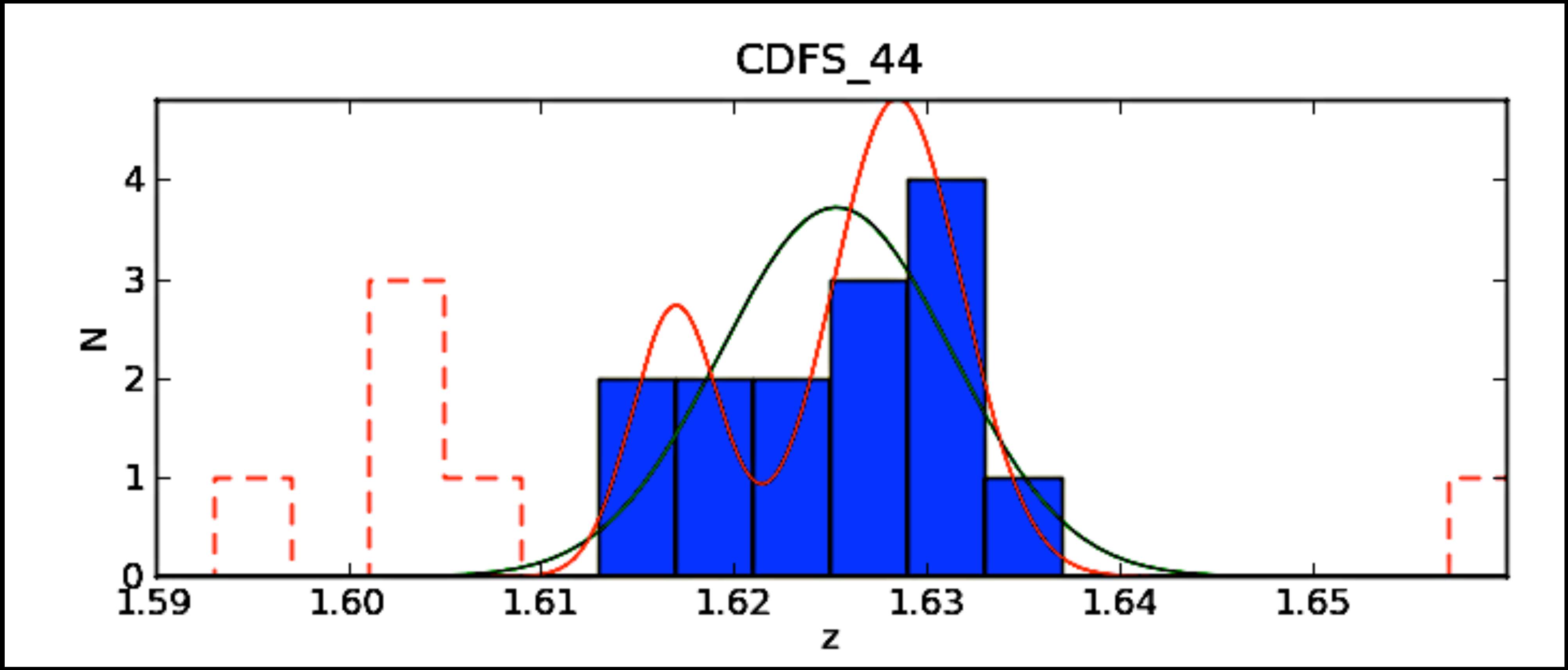
CDFS-44 (sample spectra)



Members: 12 Emission line: 10

Wilson et al., in prep

CDFS-44

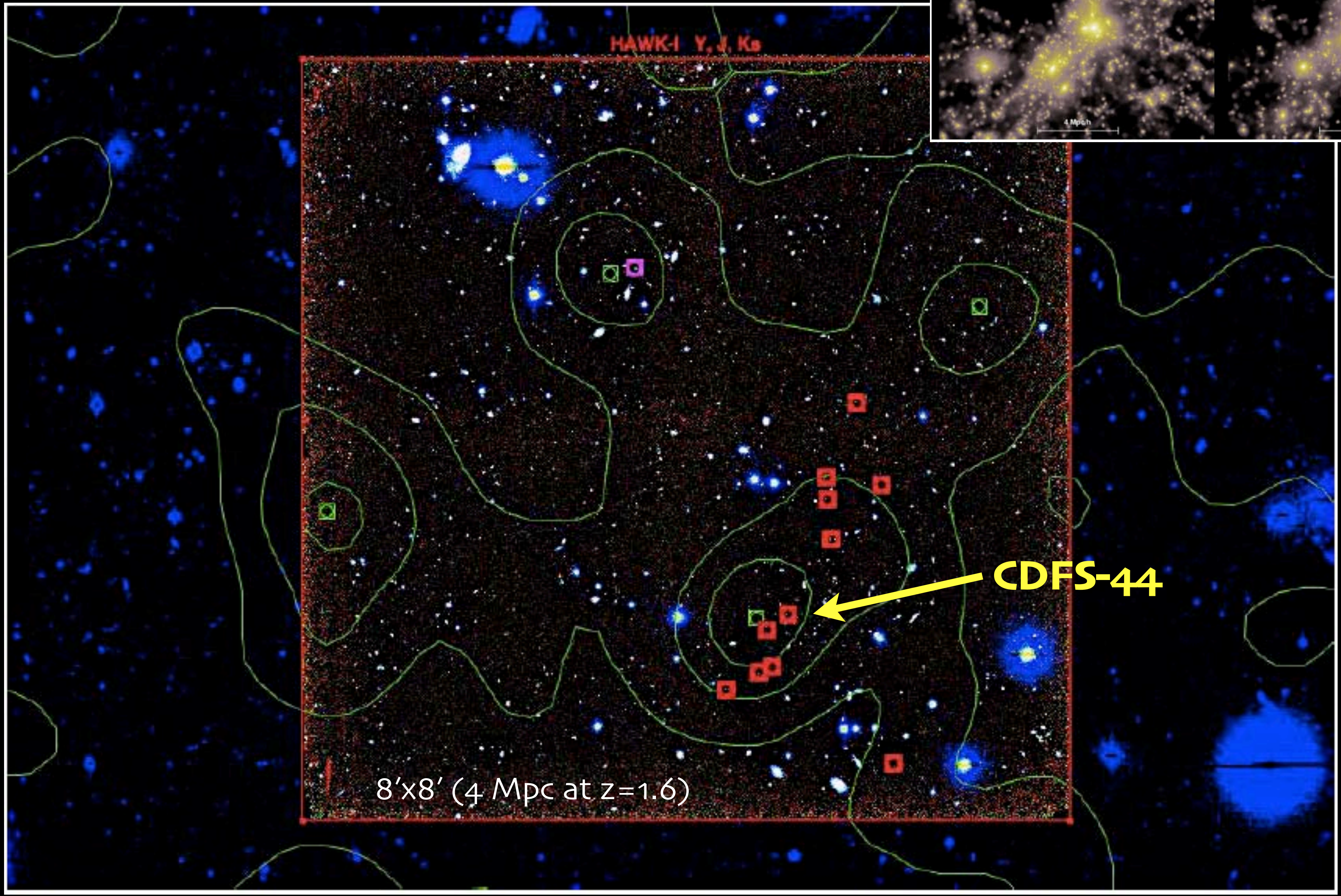


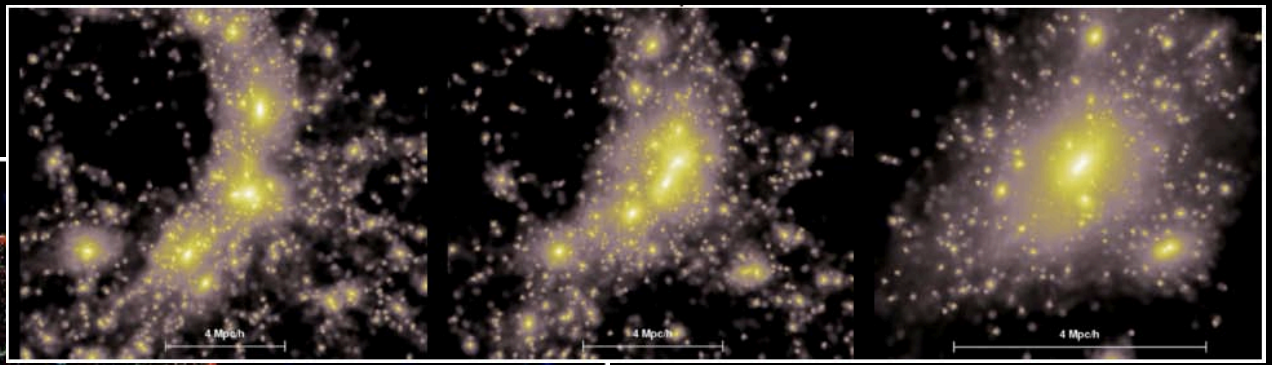
Wilson et al., in prep

Members within 2 Mpc from BCG. Velocity distribution consistent with one single gaussian (KS test). There is no evidence for substructure (DS test).
<z>=1.626 , σv≲700 km/s

$$z_{cl}=1.6259^{+0.0020}_{-0.0017} \qquad \sigma_v=695^{+84}_{-192}\ \text{km/s}$$

Large Scale Structure around CDFS-44



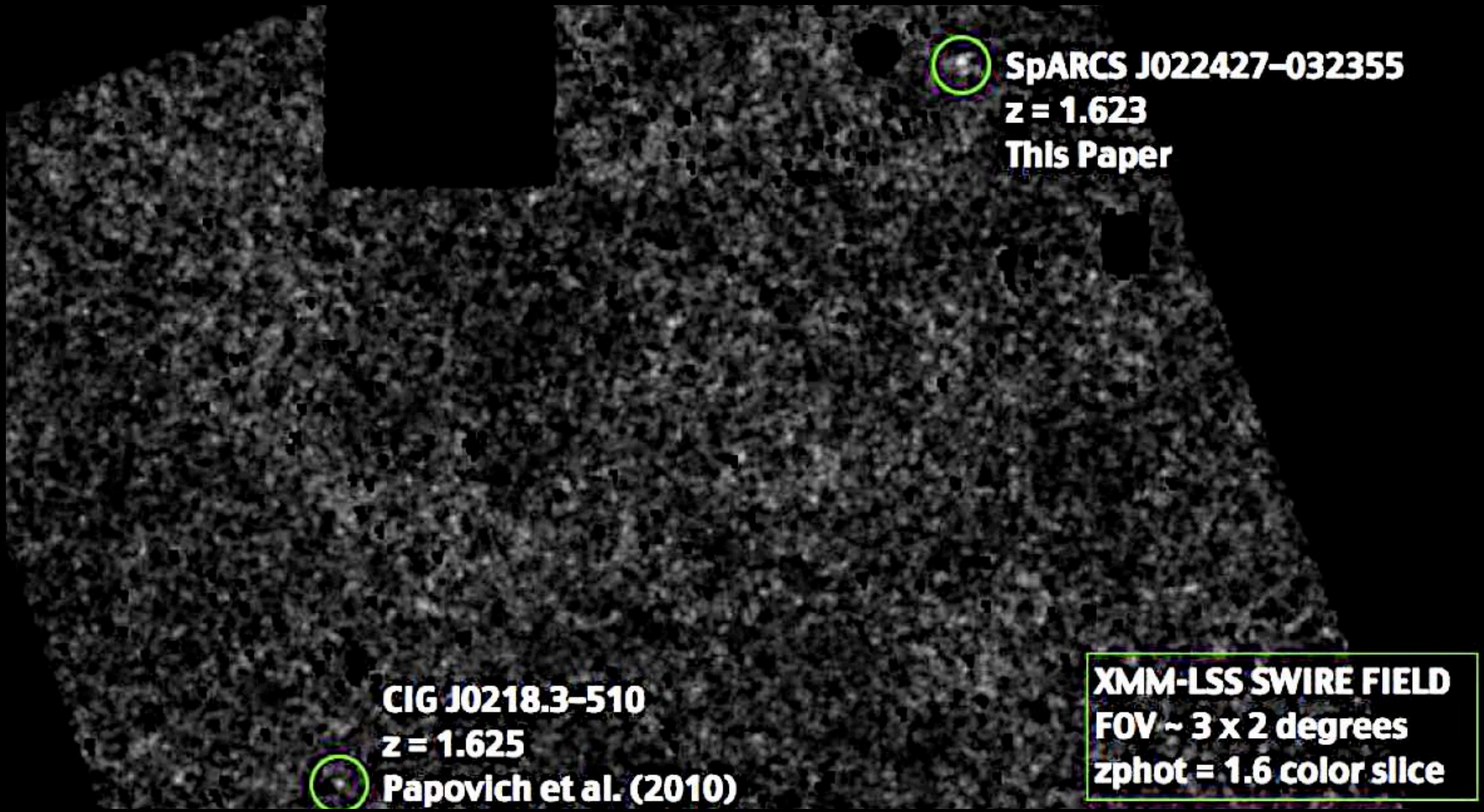


Springel et al. 2006

FORS2/MXU and IMACS multiband imaging pending

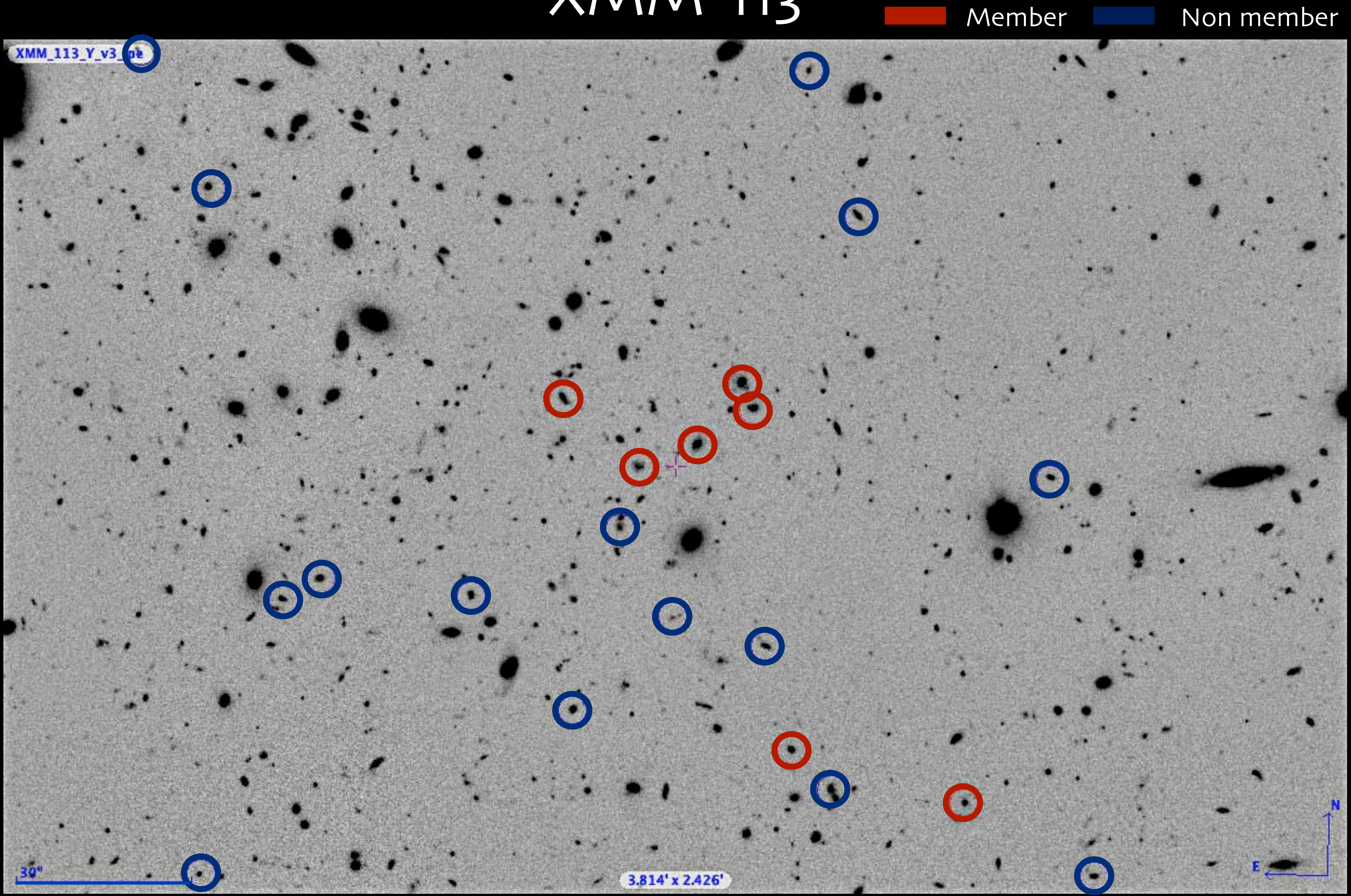
Excess of galaxies with [3.6]-[4.5]≈0.6 (z~1.6)

XMM-113



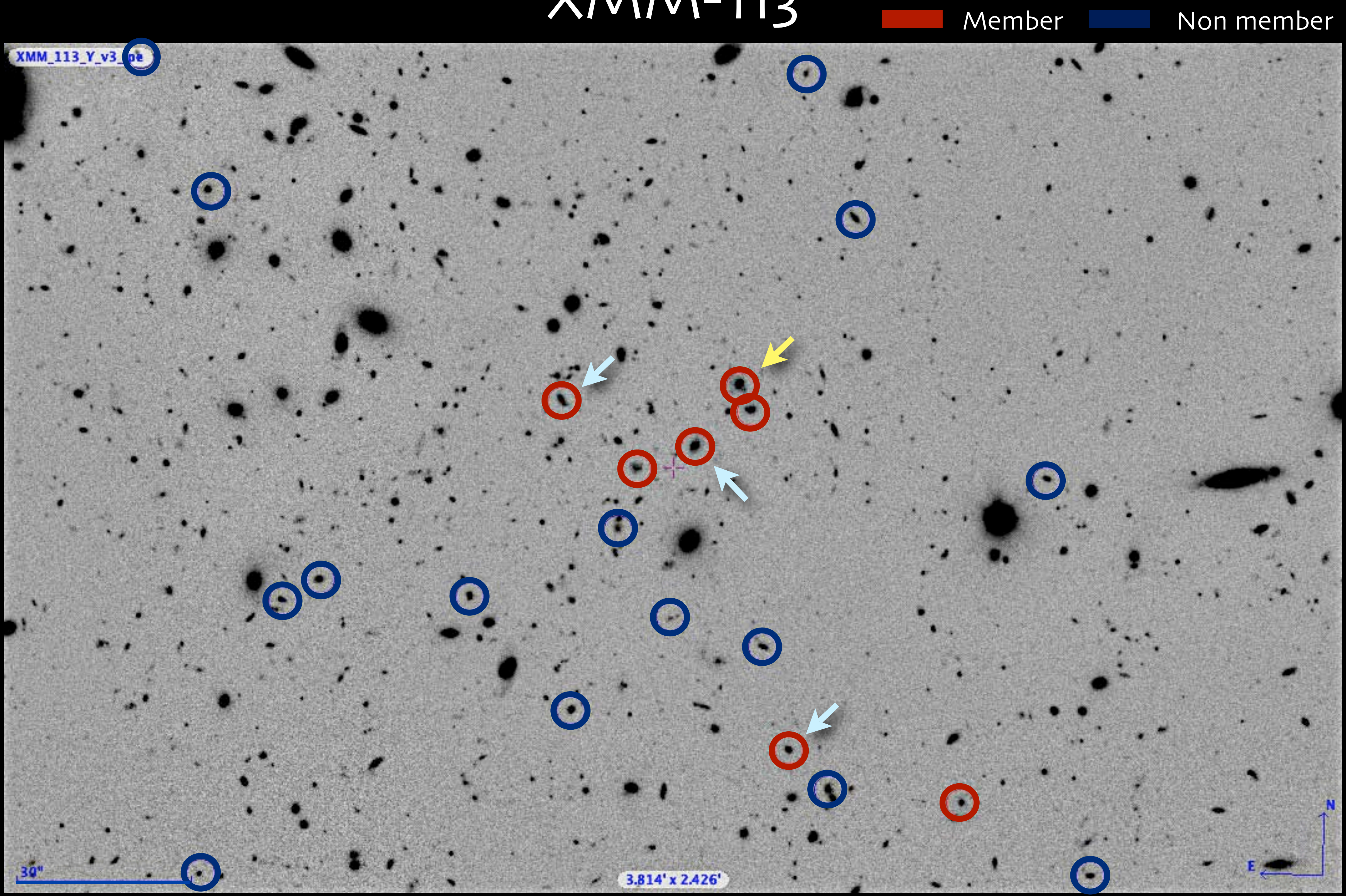
Muzzin et al., in prep

XMM-113



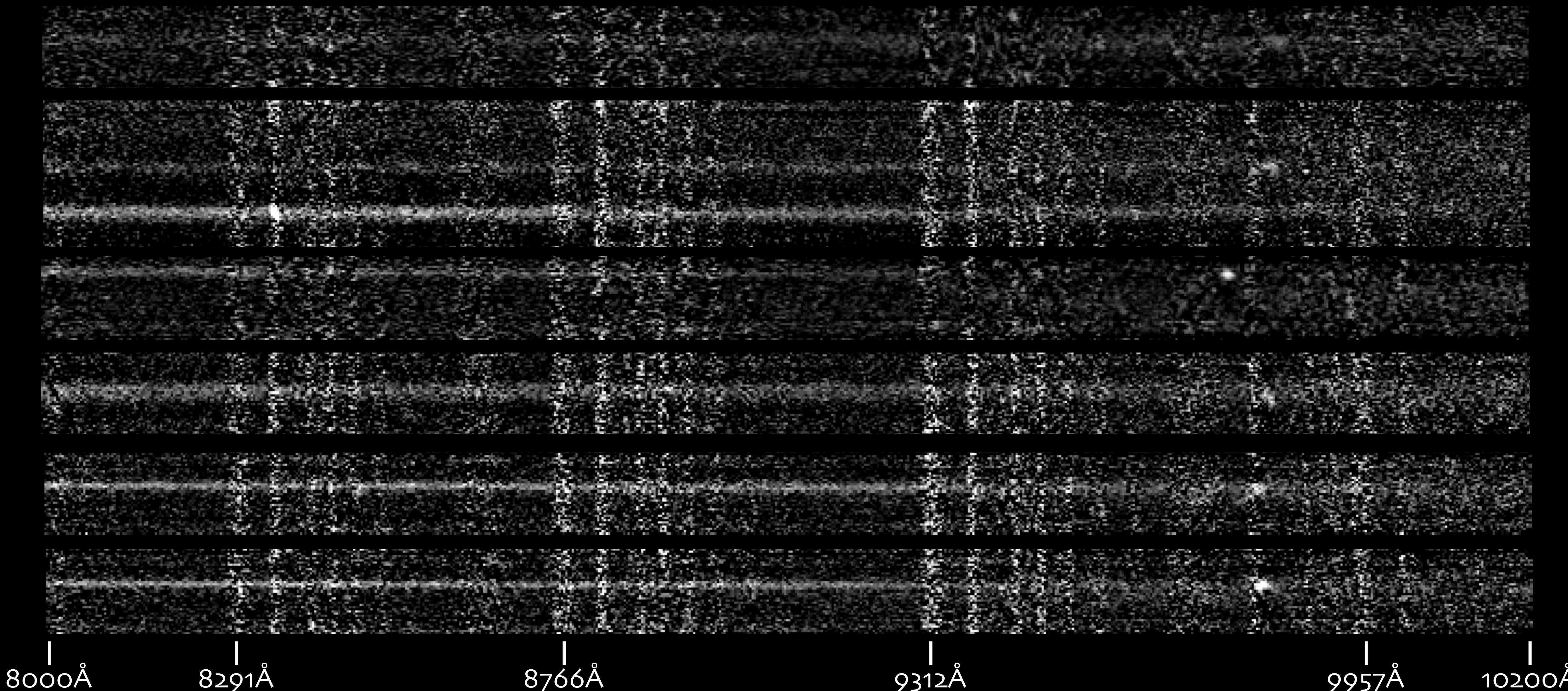
30″→0.25 Mpc

XMM-113



30″→0.25 Mpc

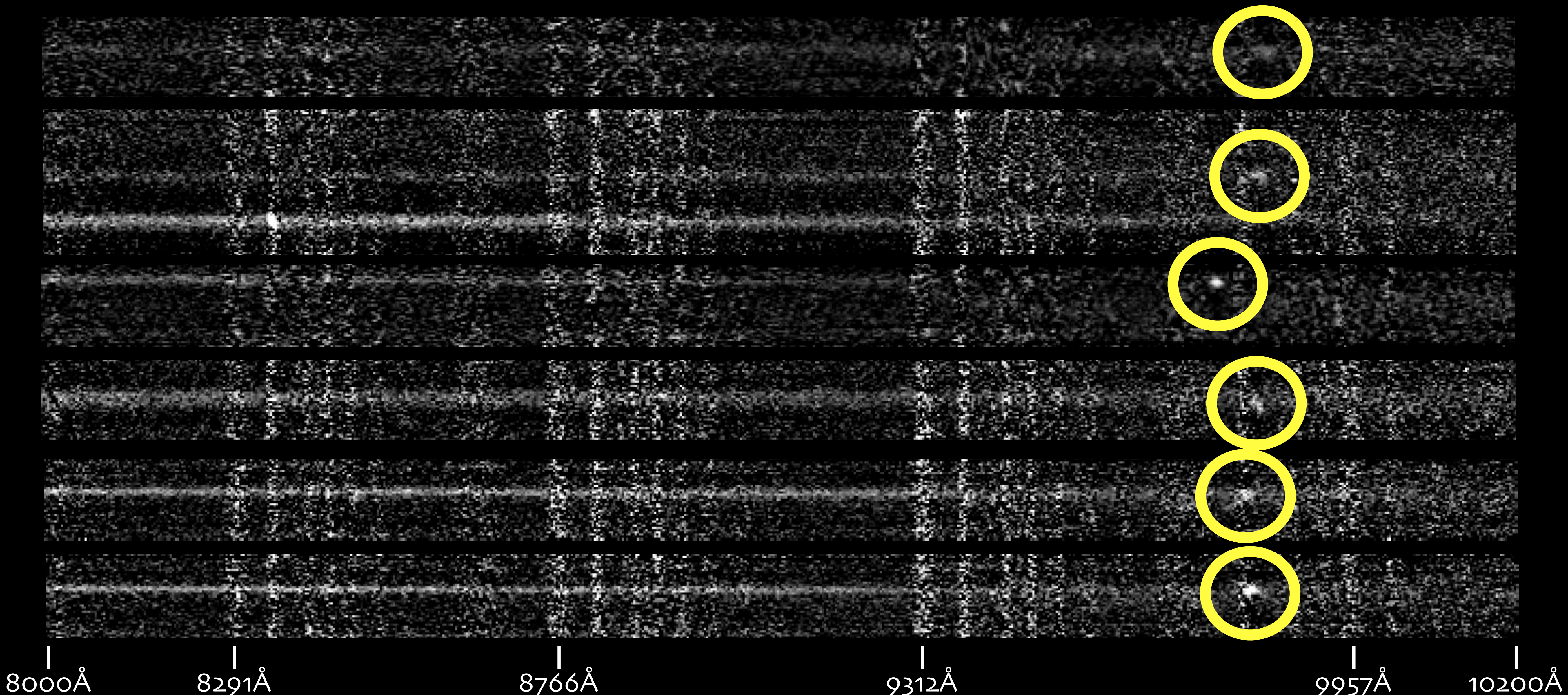
XMM-113 (sample spectra)



Members: 12 Emission line: 8

Wilson et al., in prep

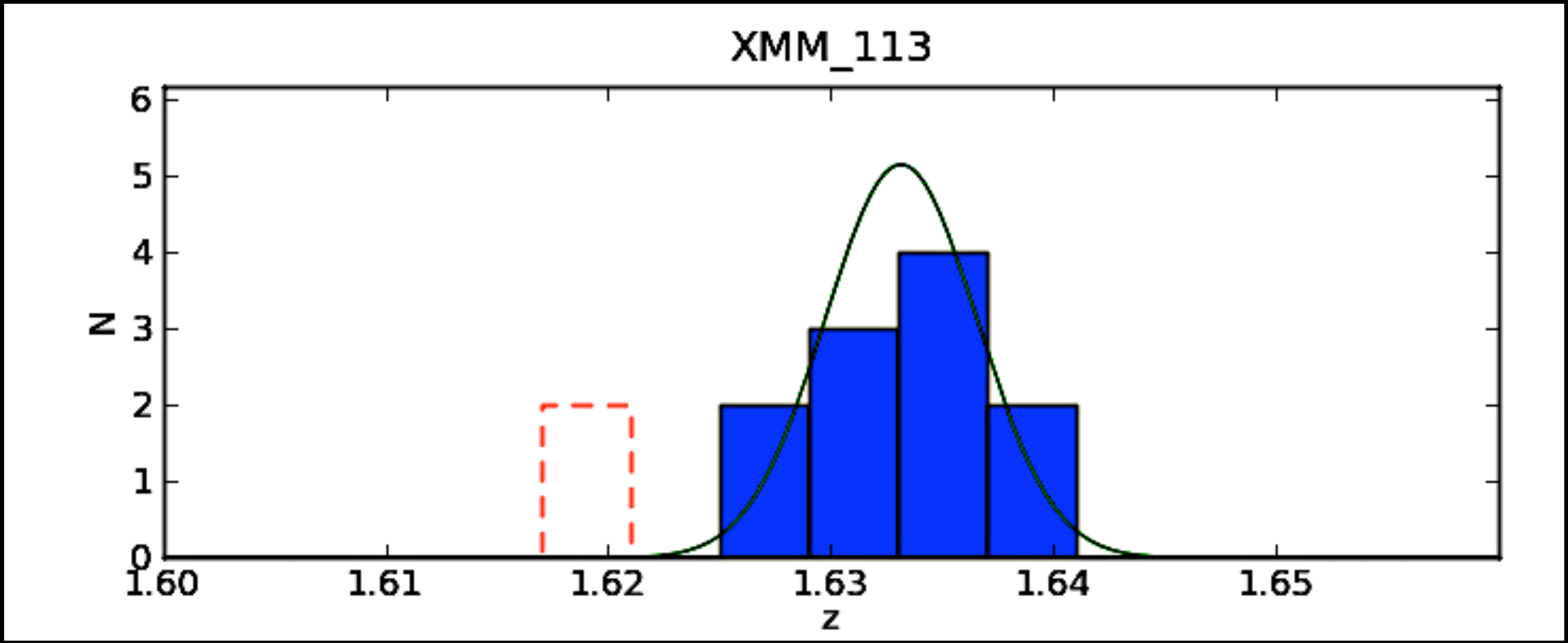
XMM-113 (sample spectra)



Members: 12   Emission line: 8

Wilson et al., in prep

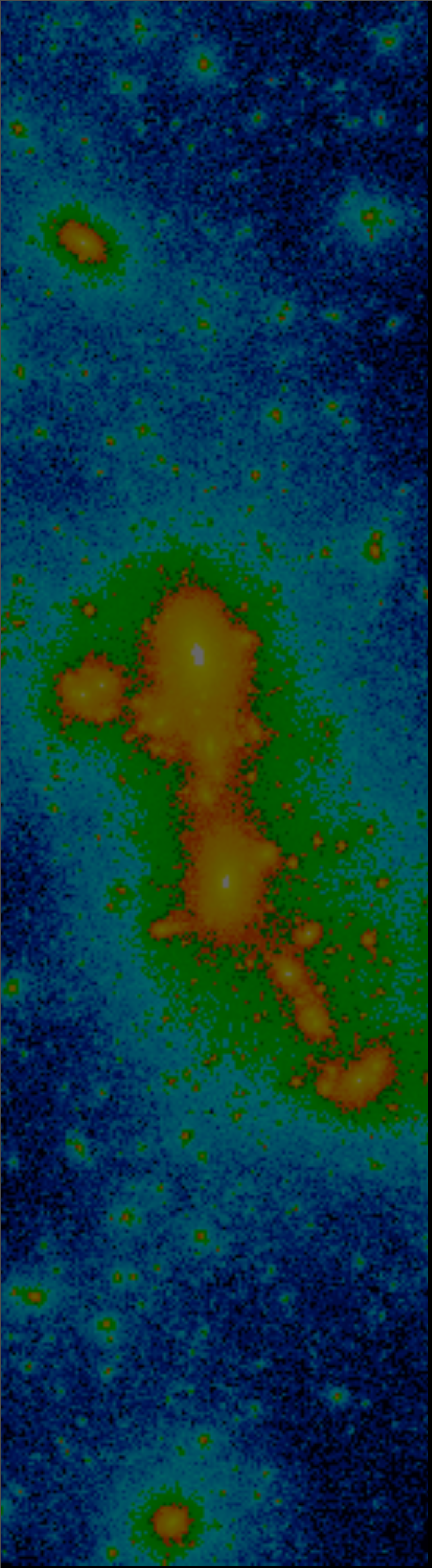
XMM-113



Wilson et al., in prep

Members within 1.5 Mpc from BCG. Velocity distribution consistent with one single gaussian (KS test). There is no significant evidence for substructure (DS test). **<z>=1.633 , σv≲400 km/s** .

$$z_{cl}=1.6332^{+0.0010}_{-0.0010} \qquad \sigma_V=393^{+19}_{-101}\ \mathrm{km/s}$$



Conclusions

- The Stellar-Bump Sequence (SBS) method is an efficient and effective algorithm to find z>1.5 clusters.

- The SBS algorithm is unbiased against lower-mass and more common clusters, allowing us to find structures that will become Coma-like clusters by z=0.

- Two clusters spectroscopically confirmed at z~1.63 (CDFS-44 [12] and XMM-113 [12]).

- These clusters have velocity dispersions $\sigma_v < 700$ km/s and their cores are populated by galaxies with on-going star formation. These systems may be representative of "more common" clusters that will become Coma-like by z=0.

Next: to survey the surrounding (<10') region around clusters in search for groups and filaments (pre-infall cluster pop.)