Galaxy Cluster Science with Future Wide-Field Infrared Surveys

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Galaxy clusters & predictions for the ESA Euclid mission (Laureijs et al. 2011)

- Beside the primary science of Euclid, the wide survey will cover 15,000 deg^2 down to VIS_{AB}=24.5 mag and YJH_{YAB}=24 mag, and the deep fields will cover 40 deg^2 down to VIS_{AB}=26.5 and YJH_{YAB}=26.0

- Euclid will find ~100,000 clusters with $M>10^{14}M_{sun}$, between z=0.2 and z=2, with ~20,000 with z>1, ~6000 with z>1.5 (updated to Planck cosmology)

    - Constraints on cosmology - understanding of the selection function and cluster mass determination (lensing!)

    - Galaxy evolution in dense environments and ETG progenitors

E-ELT MOSAIC (Evans et al. 2014)

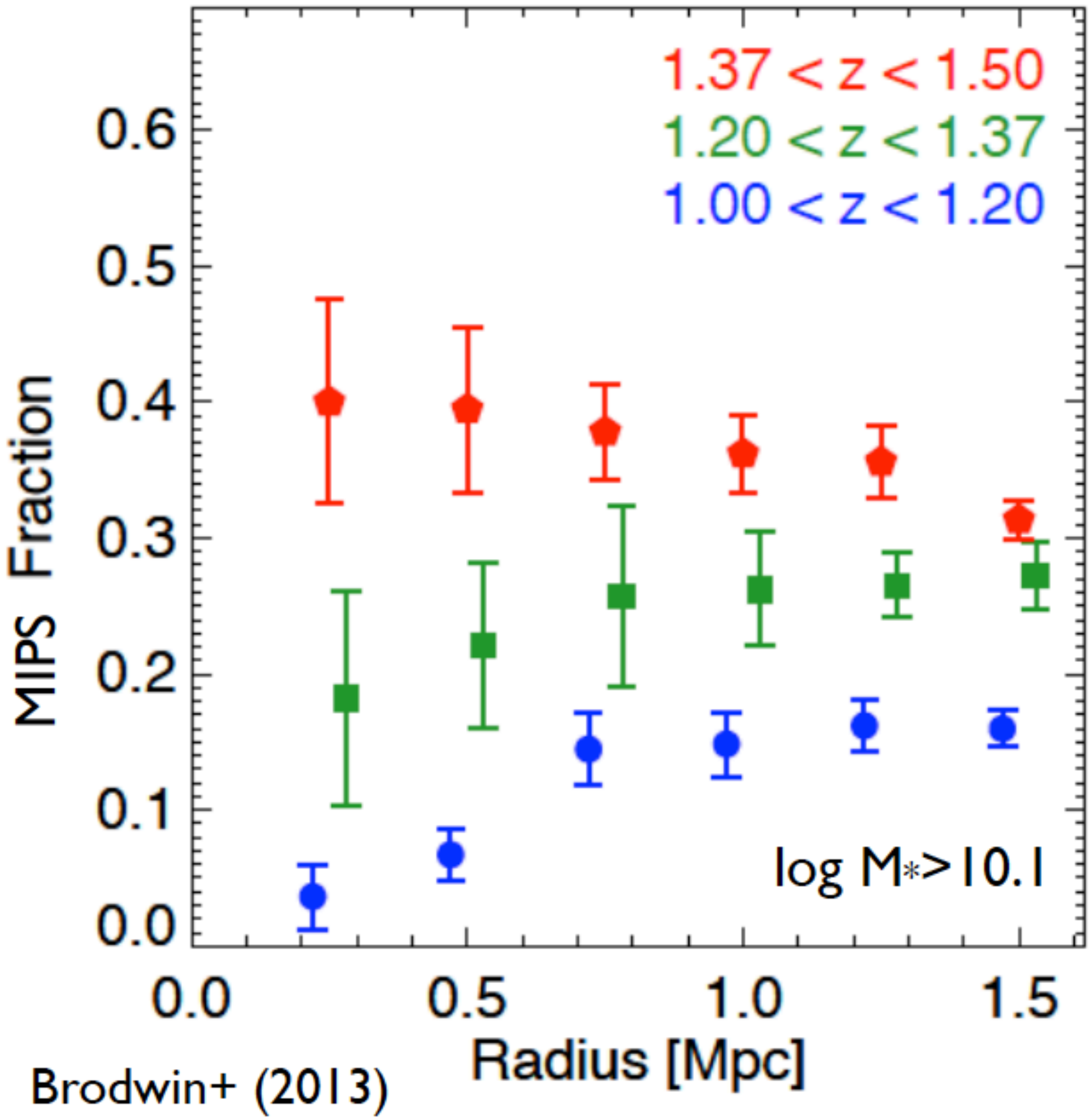
- The E-ELT and other ELTs will be ideal for Euclid higher redshift galaxies follow-up. As an example, the E-ELT/MOSAIC IFU (Evans et al. 2014) will target ETG progenitors up to z~5 and study their dynamics and chemical composition

Table 3: Summary of top-level requirements from each Science Case; 'desirable' requirements are shown in italics.

Case	Multiplex	FoV/target	Spatial pixel size	λ-coverage (μm)	*R*
SC1 *First light*	20-40	2" × 2"	40-100 mas	1.0-1.8 *1.0-2.45*	5,000
	≳150	–	(GLAO – 0.6"Ø)	1.0-1.8 *1.0-2.45*	>3,000
SC2 *IGM & Gal. clusters*	10-15	2" × 2"	(GLAO – IFU)	0.4-1.0 *0.37-1.0*	>3,000
	50-100	–	(GLAO)	0.6-1.8 *0.6-2.45*	>3,000
SC3 *Gal evol.*	≳10	2" × 2"	50-80 mas	1.0-1.8 *1.0-2.45*	5,000
	≳100	–	(GLAO – 0.6"Ø)	1.0-1.7 *0.8-2.45*	≥5,000 *~10,000*
SC4 *AGN*	~10 per field	2" x 2"	≤100 mas	1.0-1.8	>3,000
SC5 *Extragal stellar pops.*	Dense	1" × 1" *1.5" × 1.5"*	≤75 mas *20-40 mas*	1.0-1.8 *0.8-1.8*	5,000
	10s arcmin^{-2}	–	(GLAO)	0.4-1.0	≥5,000 *≥10,000*
SC6 *Gal archaeol.*	10s arcmin^{-2}	–	(GLAO)	0.41-0.46 & 0.64-0.68 *0.38-0.52 & 0.60-0.68*	≥15,000 *≥20,000*
SC7 *GC science*	Dense	≥2" x 2"	≤100 mas	1.5-2.45	≥5,000 *≥10,000*
SC8 *Planet form.*	10s per field	–	(GLAO)	0.5-0.6	≥20,000

Note: Minimum target size for SC1 is reduced to 1"x1" if on/off sky subtraction is used.

At z>1.5 more star forming galaxies in the cluster cores



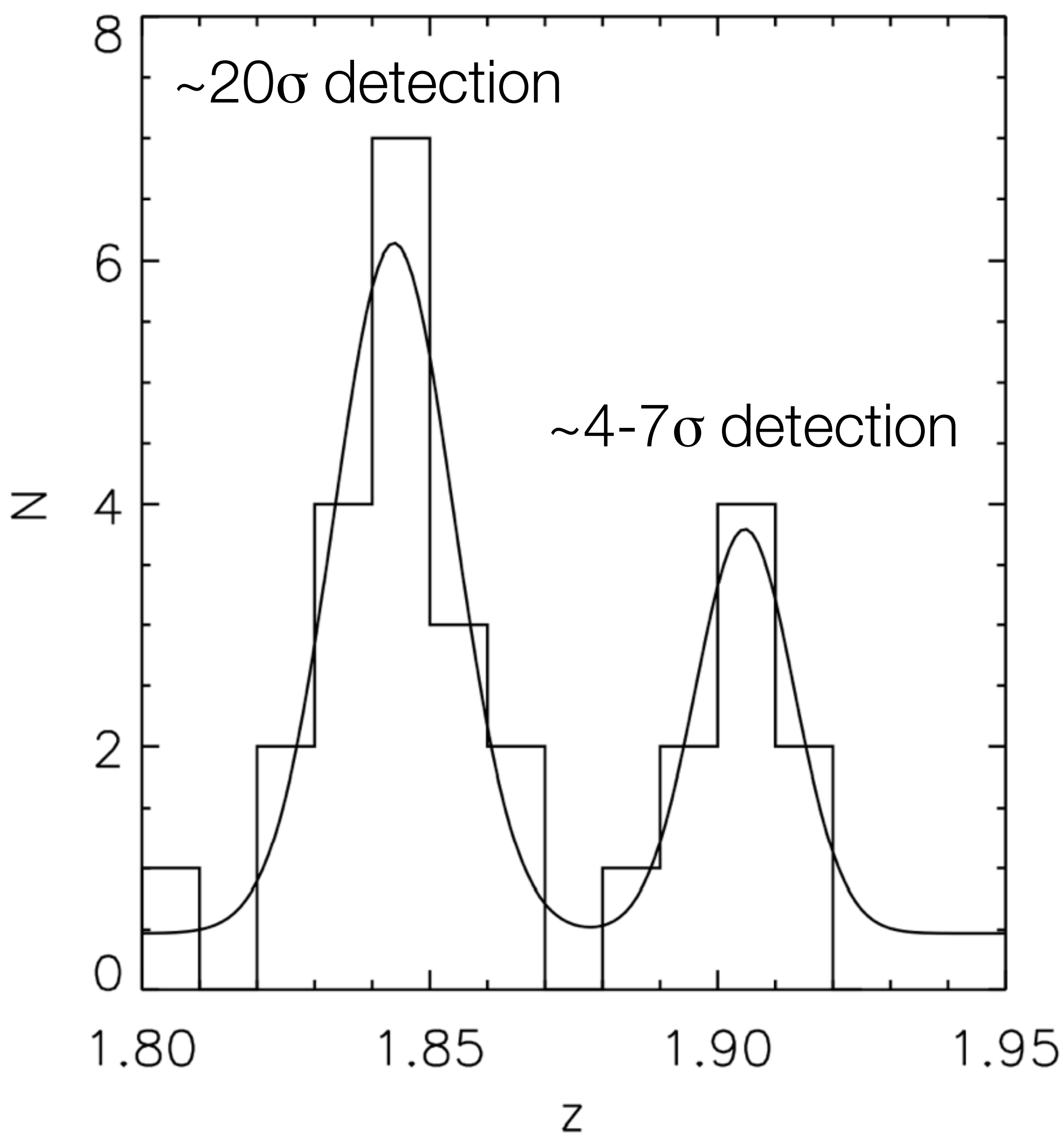
Brodwin et al. 2013; Muzzin et al. 2012, and references therein

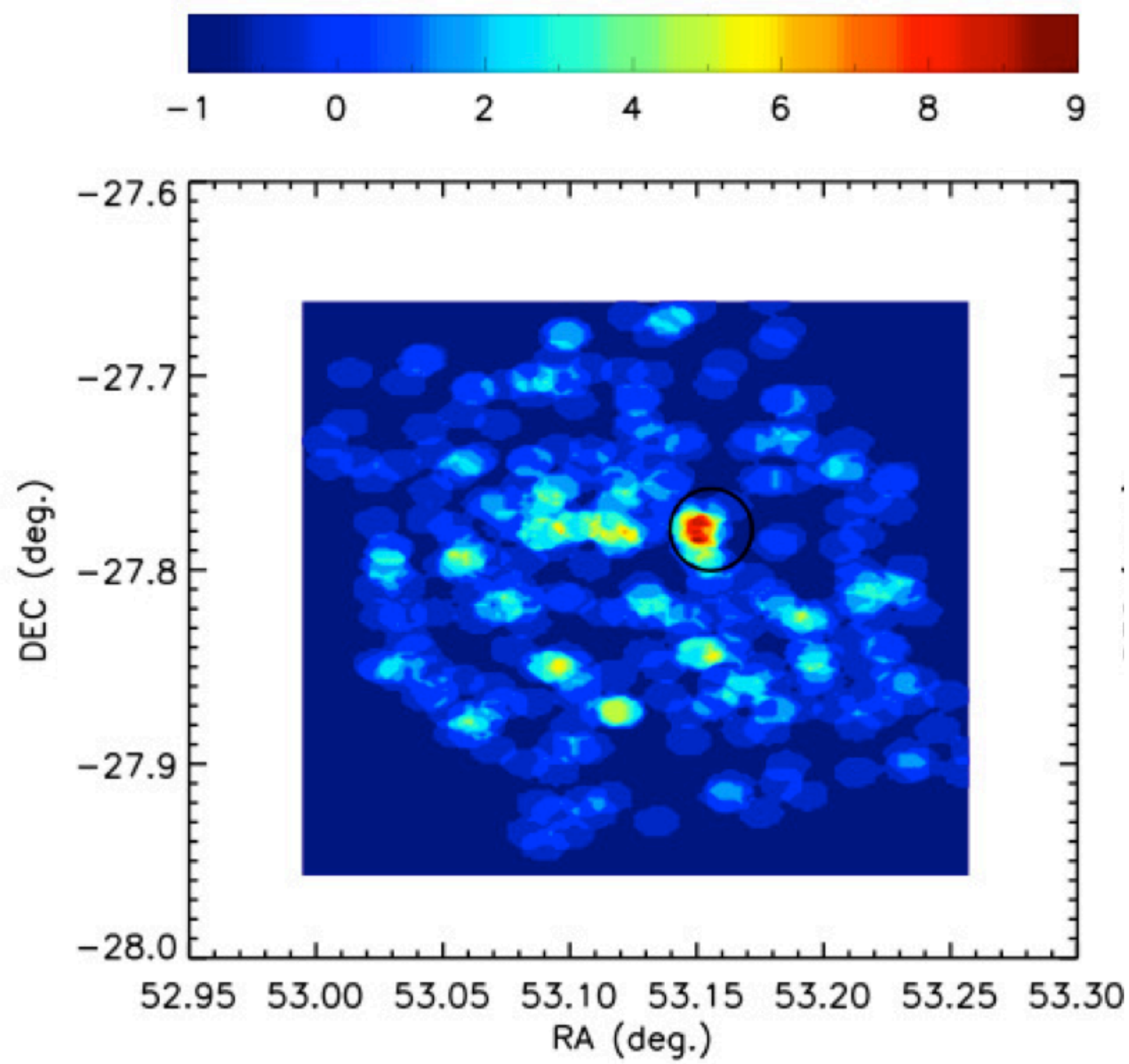
Clusters and proto-clusters at z~1.6-2

Name	Identification	z	Overdensity	σ_{disp} (km/s)	Mass ($10^{14} \times M_\odot$)	X–ray Lum./Detection (10^{43} erg s^{-1})	Reference
CL J033211.67-274633.8	Group	1.61	$\sim 5\sigma$	...	$M_{200}^{(a)} = 0.32 \pm 0.08$	1.8 ± 0.6	Tanaka et al.
IRC-0218A/XMM-LSS J02182-05102	Proto–cluster	1.62	$> 20\sigma$	860 ± 490	$M_{200}^{(b)} \sim 0.1 - 0.4$	$> 4\sigma$ Detection	Papovich et al. 2010; 2012
SpARCS J022427-032354	Cluster	1.63	...	...	...	Detection	Muzzin et al. (2013)
IDCS J1426+3508	Cluster	1.75	...	...	$M_{200}^{(a)} \sim 5.6 \pm 1.6$	55 ± 12	Stanford et al. 2012; Brodwin et al. 2012
JKCS 041	Cluster	1.80	...	...	$M_{200}^{(c)} \sim 2$	76 ± 5	Newman et al. 2013; Andreon et al. 2013
HUDFJ0332.4-2746.6	Proto–cluster	1.84	$\sim 20\sigma$	730 ± 260	$M_{200}^{(b)} = 2.2 \pm 1.8$	$< 1 - 6$	Mei et al. 2014
IDCS J1433.2+3306	Cluster	1.89	...	...	$M_{200} \sim 1$	...	Zeimann et al. 2012
HUDFJ0332.5-2747.3	Group	1.90	$\sim 4 - 7\sigma$	...	...	...	Mei et al. 2014
CL J1449+085	Cluster	1.99	$> 20\sigma$	...	$M_{200}^{(a)} = 0.53 \pm 0.09$	6.4 ± 1.8	Gobat et al. 2013

Mei et al. 2014

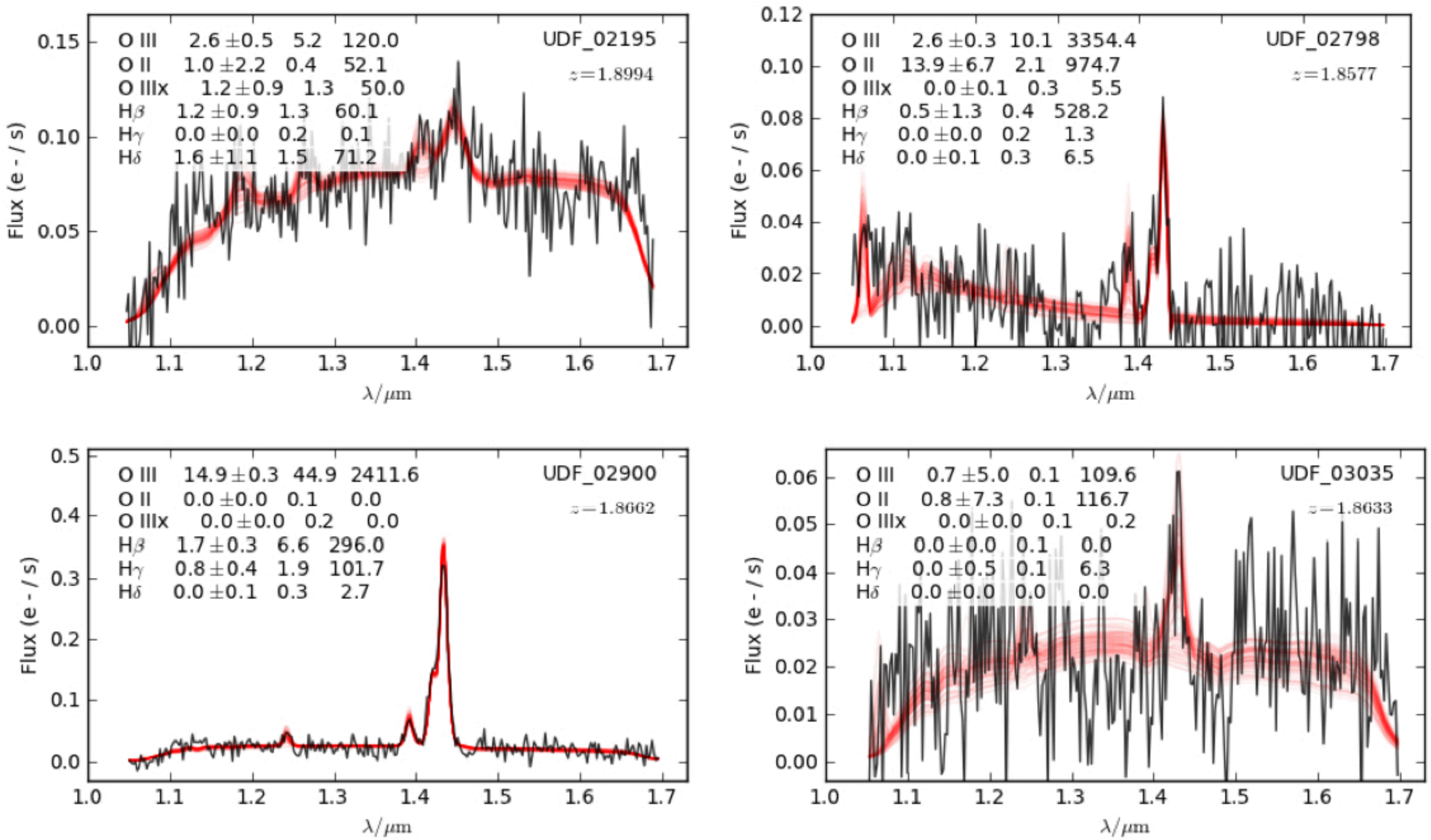
HUDFJ0332.4-2746.6 and HUDFJ0332.5-2747.3 CANDELS and 3D-HST overdensities at z=1.84 and 1.9





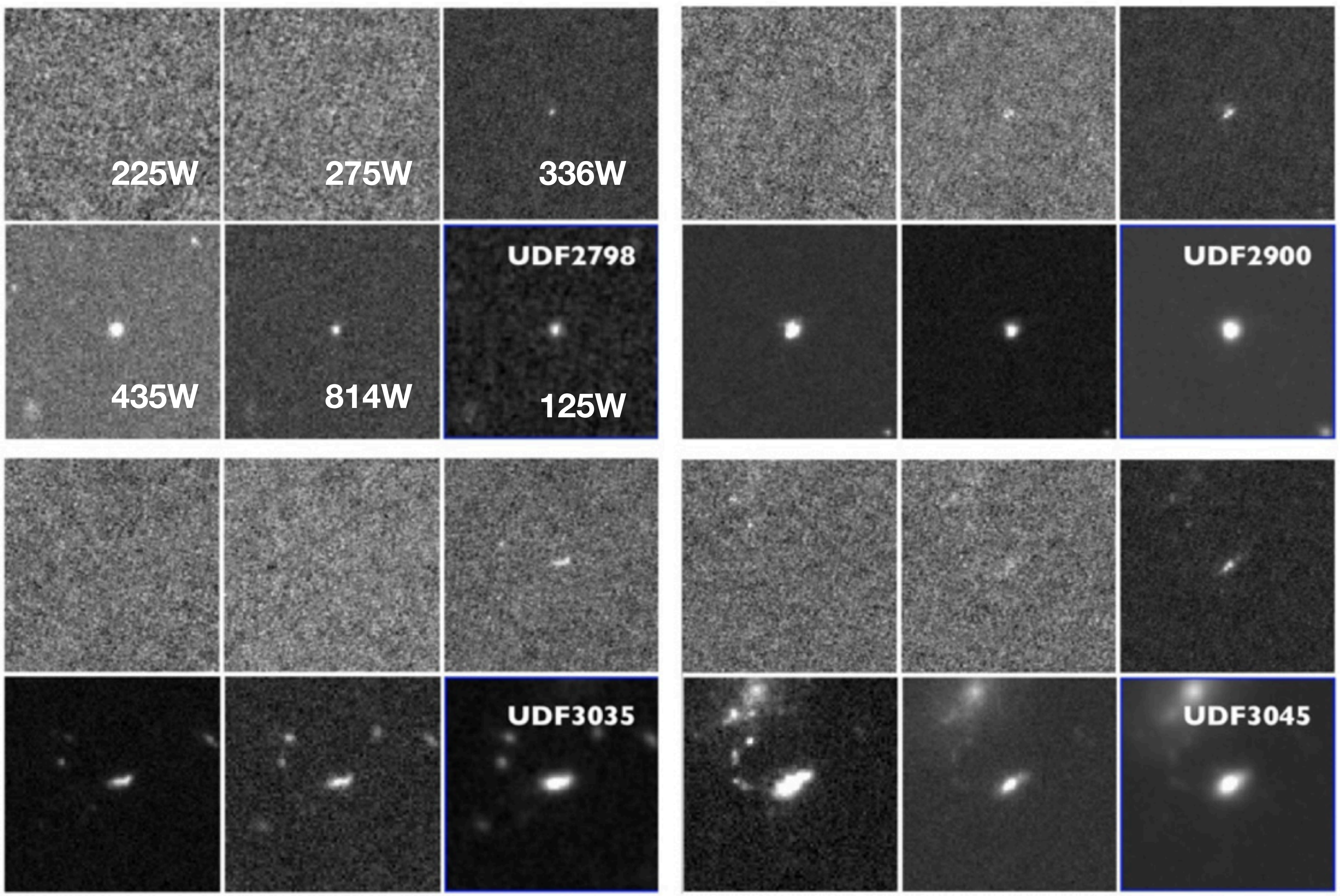
Mei et al. 2014

WFC3 Grism Spectroscopy from CANDELS and 3D-HST+GMASS



3D-HST spectra from Brammer et al. 2012

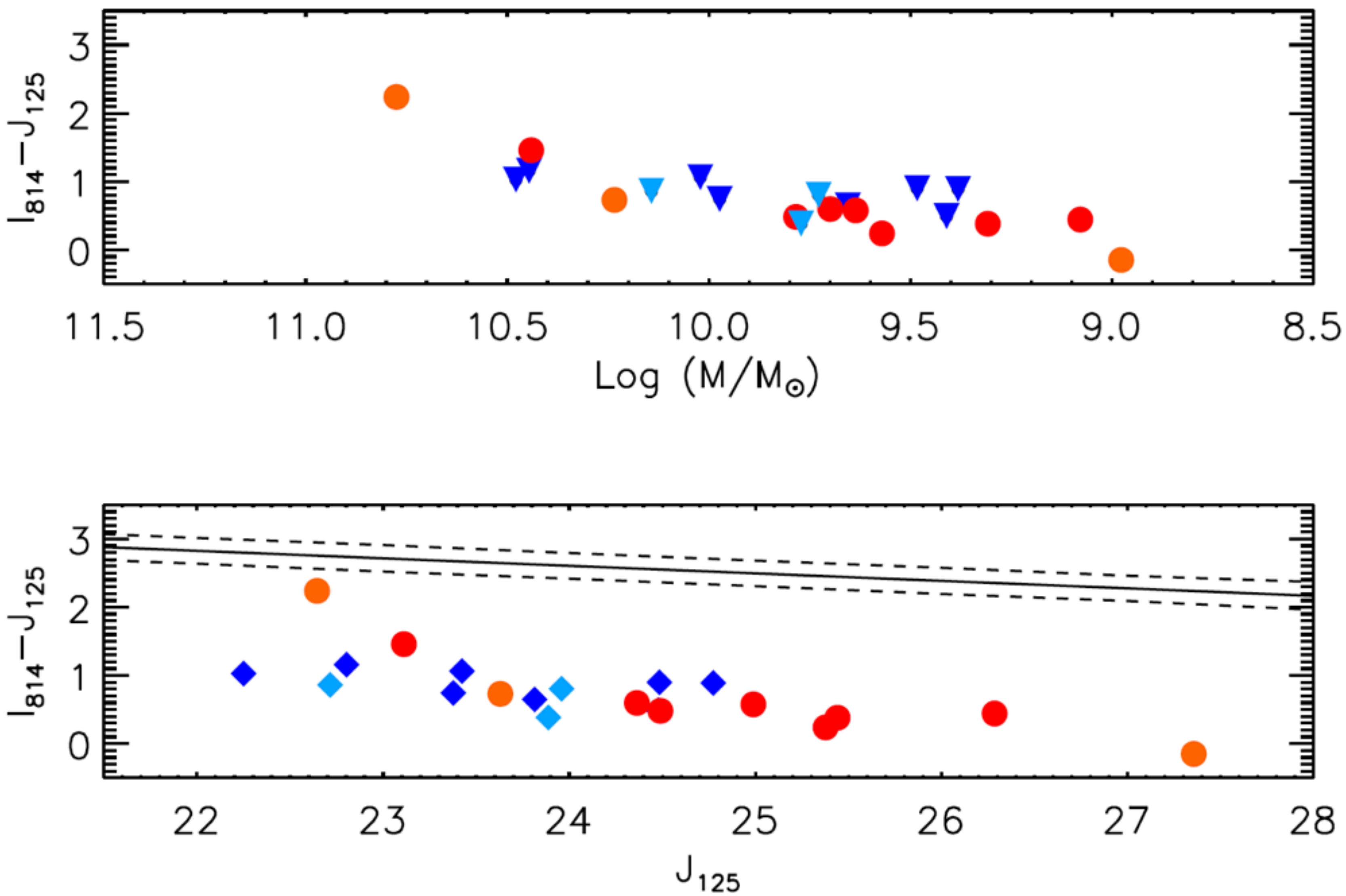
Lyman break confirmation



Mei et al. 2014

CANDELS imaging combined with HUDF UV (Teplitz et al. 2013)

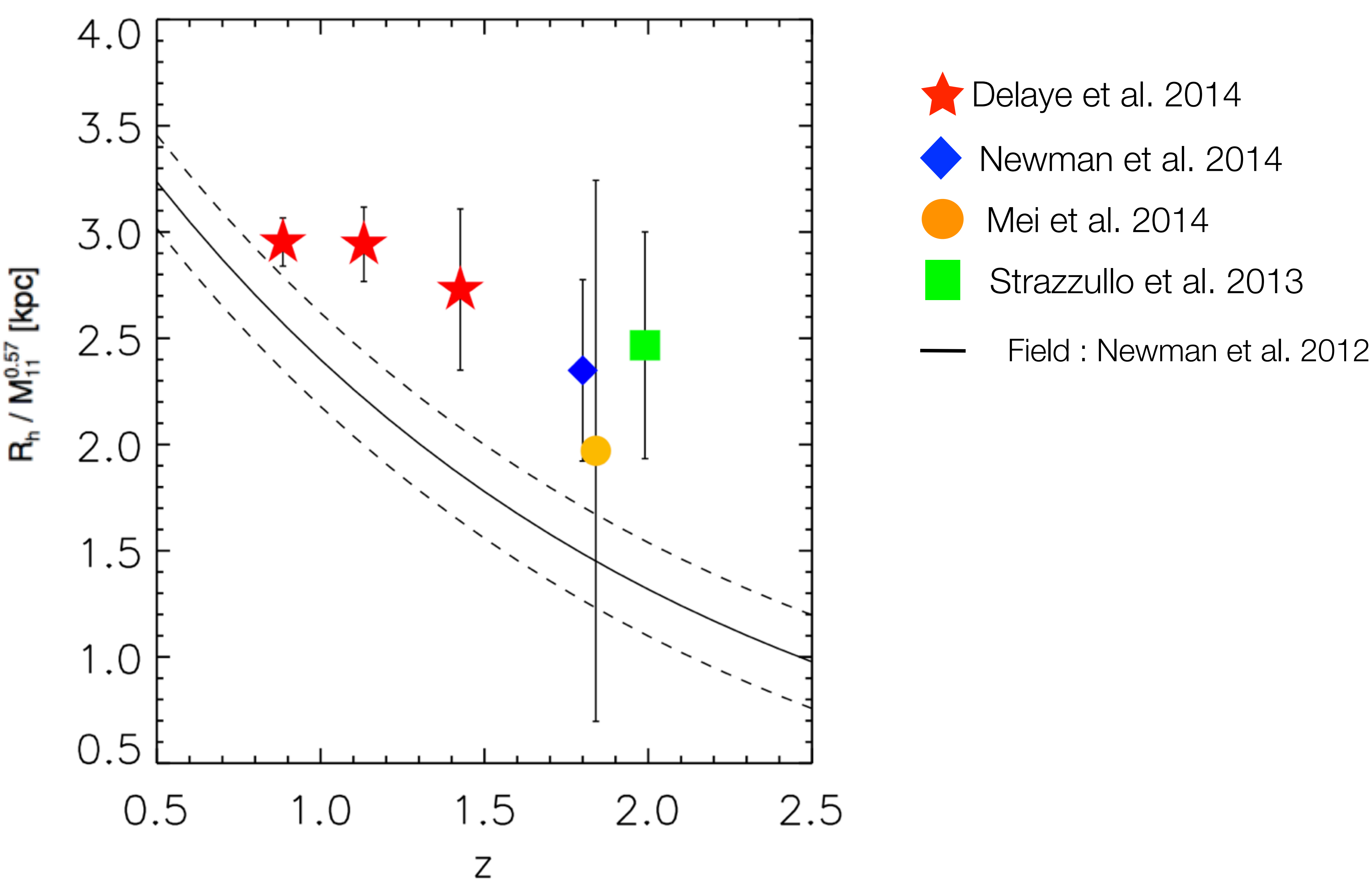
Blue ETGs, mostly star-forming



The continuous line if the passively evolved CMR from z~1.3 clusters from Mei et al. 2009

Mei et al. 2014

Size growth - only ETGs

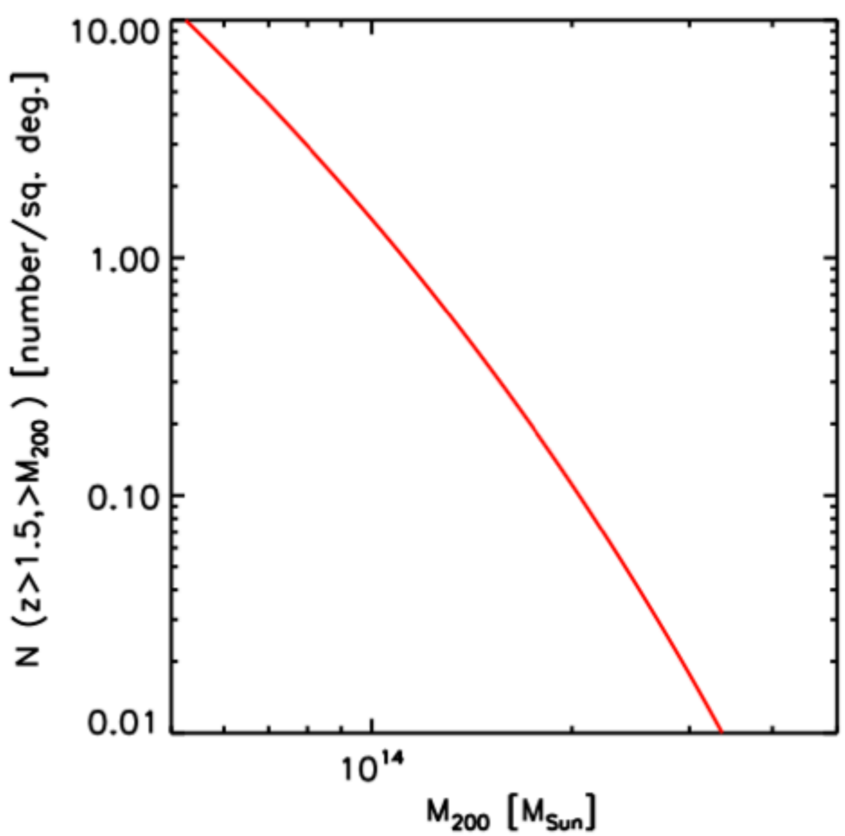


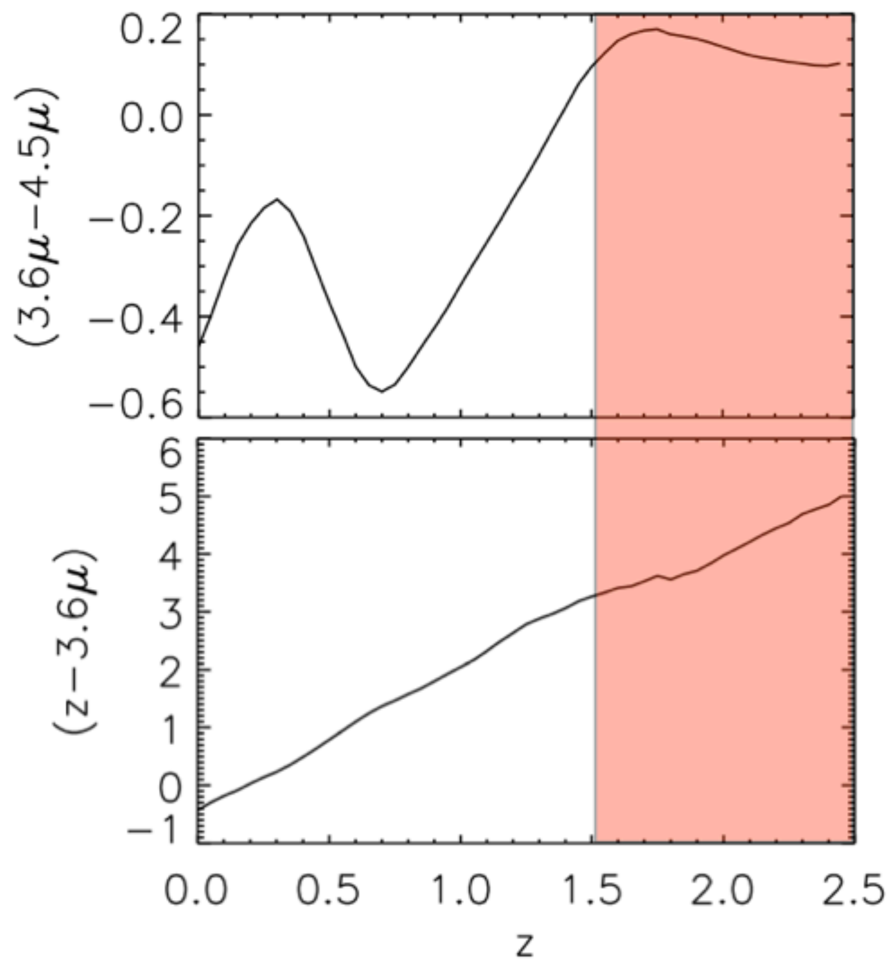
Delaye et al. 2014; Mei et al. 2014

South Pole Telescope Spitzer Deep Field (SSDF)

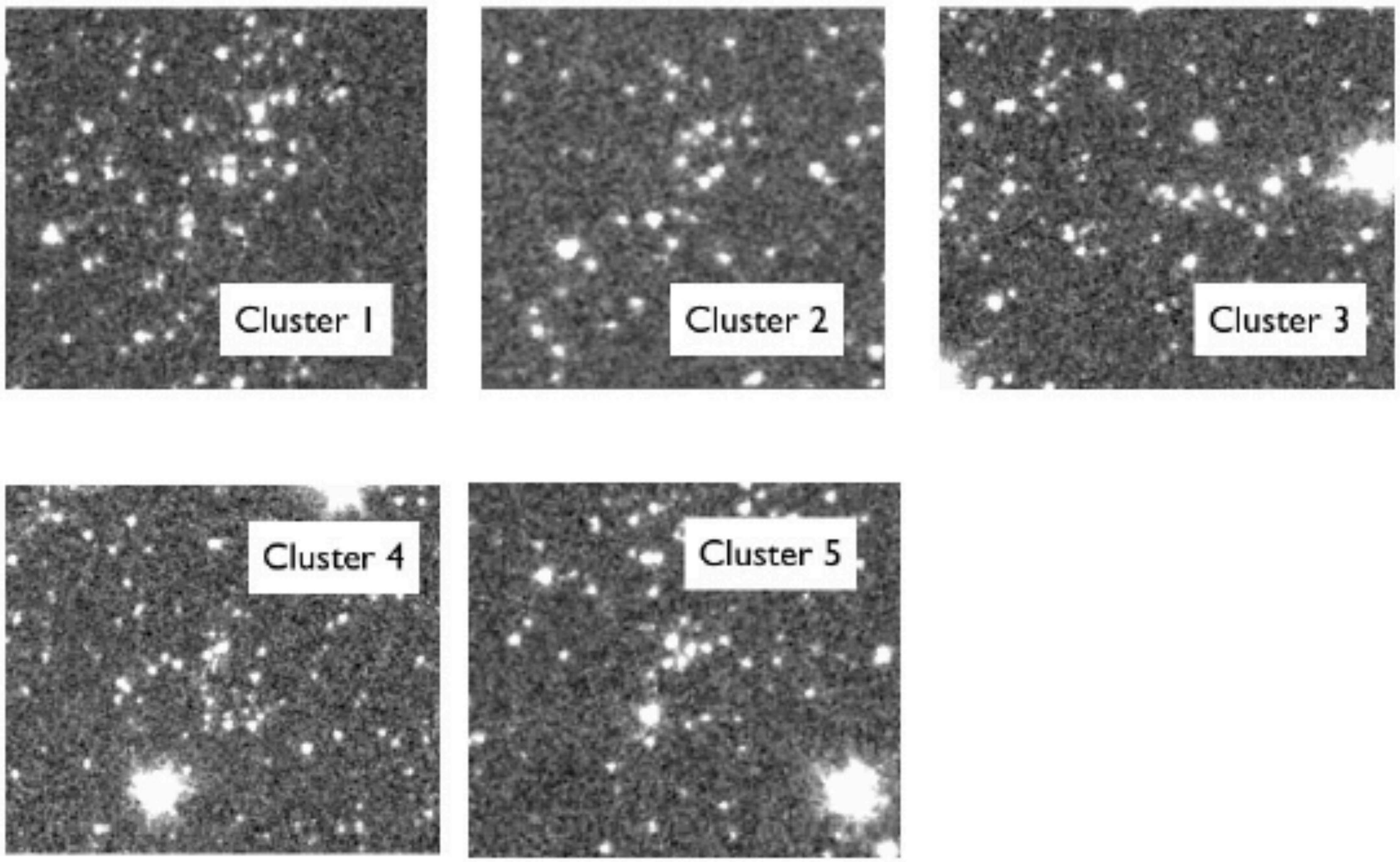
PI: A. Stanford - see Rettura's talk - with Licitra, Lidman, Stanford, Ashby, Bartlett, Brodwin, Gettings, Gonzales, Martinez-Manso, Pierre, Sadibekova, Stern

- 100 deg. sq. covered with Spitzer IRAC 3.6μ and 4.5μ in the SPTpol field
- Survey completed in 2012 (Ashby et al. 2013; Rettura et al. 2014) - ~100 clusters at z>1.5
- Optical coverage of 25 sq.deg. with CTIO/DECam from the XXL consortium (PI: Lidman)





South Pole Telescope Spitzer Deep Field (SSDF)
combined with CTIO/DECam



VLT/KMOS follow-up - pilot program with Capaccioli and Covone at the University of Naples - Rossella Licitra, SM, et al. in preparation

Euclid Cluster Detection Challenge (2013-2014)

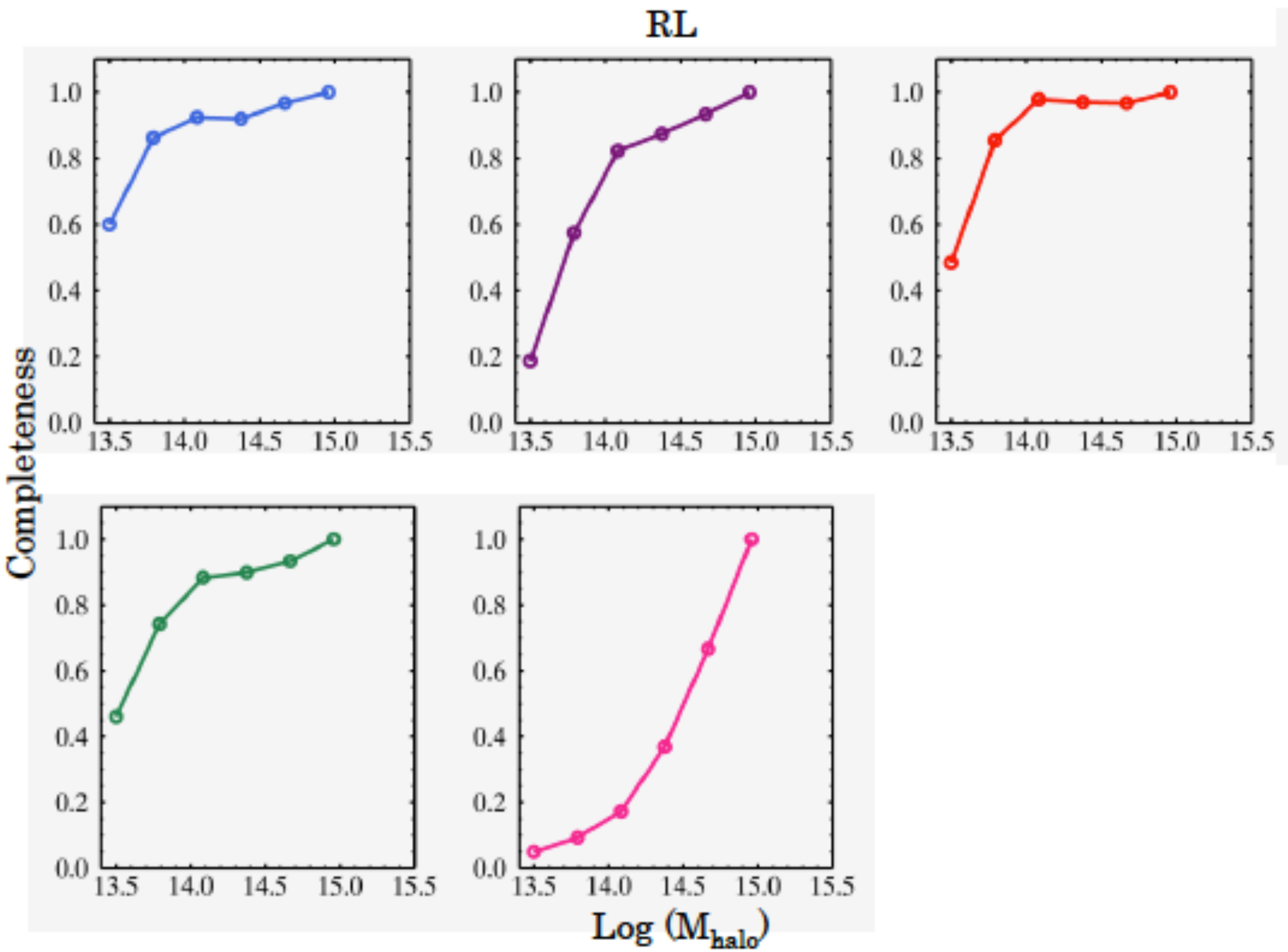
Authors: A. Iovino[3], S. Farrens[1], S. Maurogordato[2], A. Biviano[1]

Contributors:

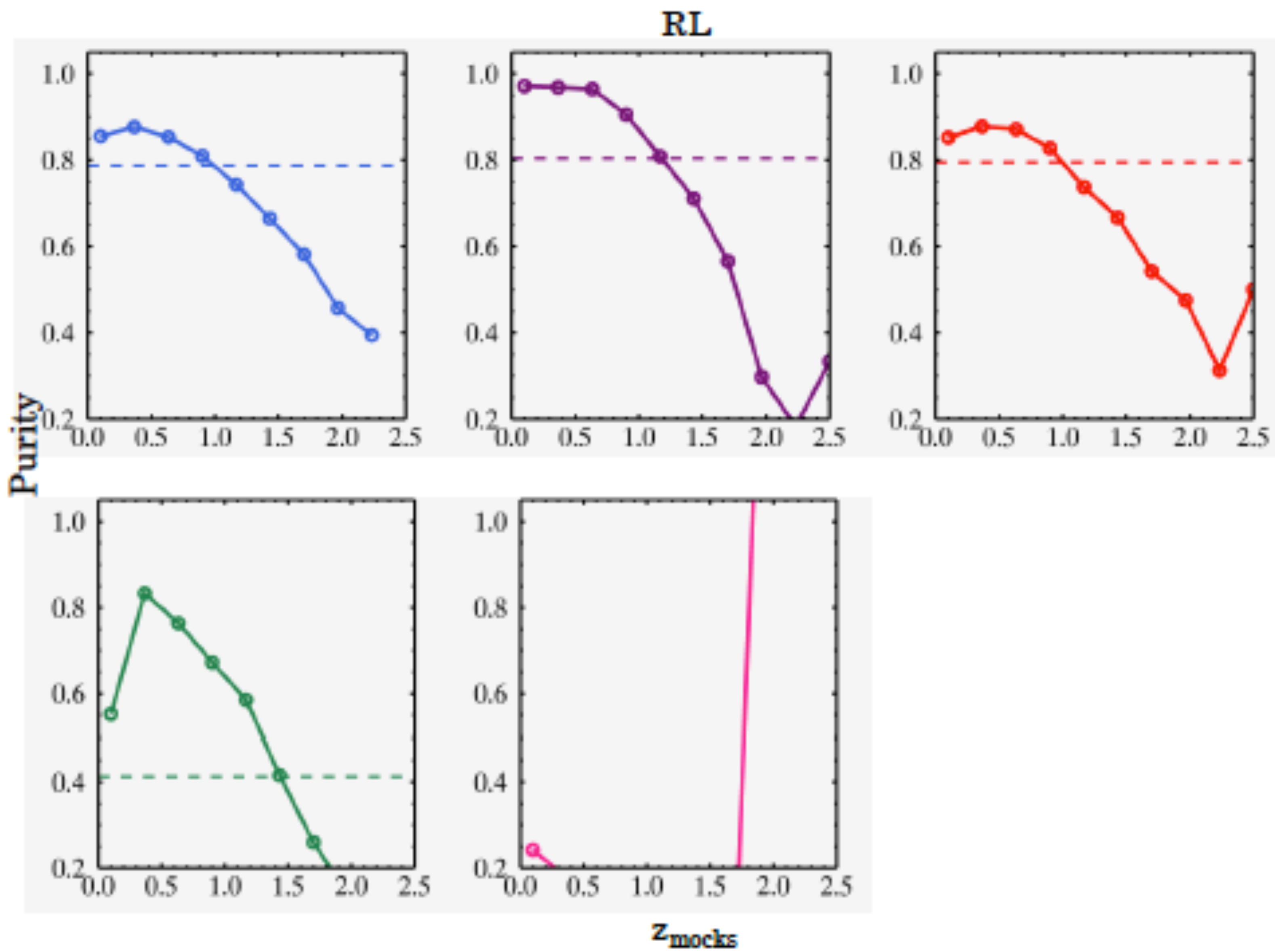
C. Adami[4], code development and testing
F. Bellagamba[5], code development and testing
C. Benoist[2], code development and testing
A. Cappi[6], mock catalog adaptation to challenge
O. Cucciati[5,6], code development and testing
F. Durret[7], code development and testing
S. Farrens[1], code development and testing, analysis of results
A. Gonzalez[8], code development and testing
A. Iovino[3], code development and testing, analysis of results
R. Licitra[9], code development and testing
S. Mei[9], code development and testing
M. Roncarelli[5], code development and testing
S. Bardelli[6], mock catalog analysis
J. G. Bartlett[10], discussions
C. Baugh[11], mock catalog preparation
S. Borgani[12,1], discussions
A. Merson[11], mock catalog preparation
L. Moscardini[5], discussions
M. Vannier[2], analysis of results and set up of the platform to run the challenge

Euclid Cluster Challenge

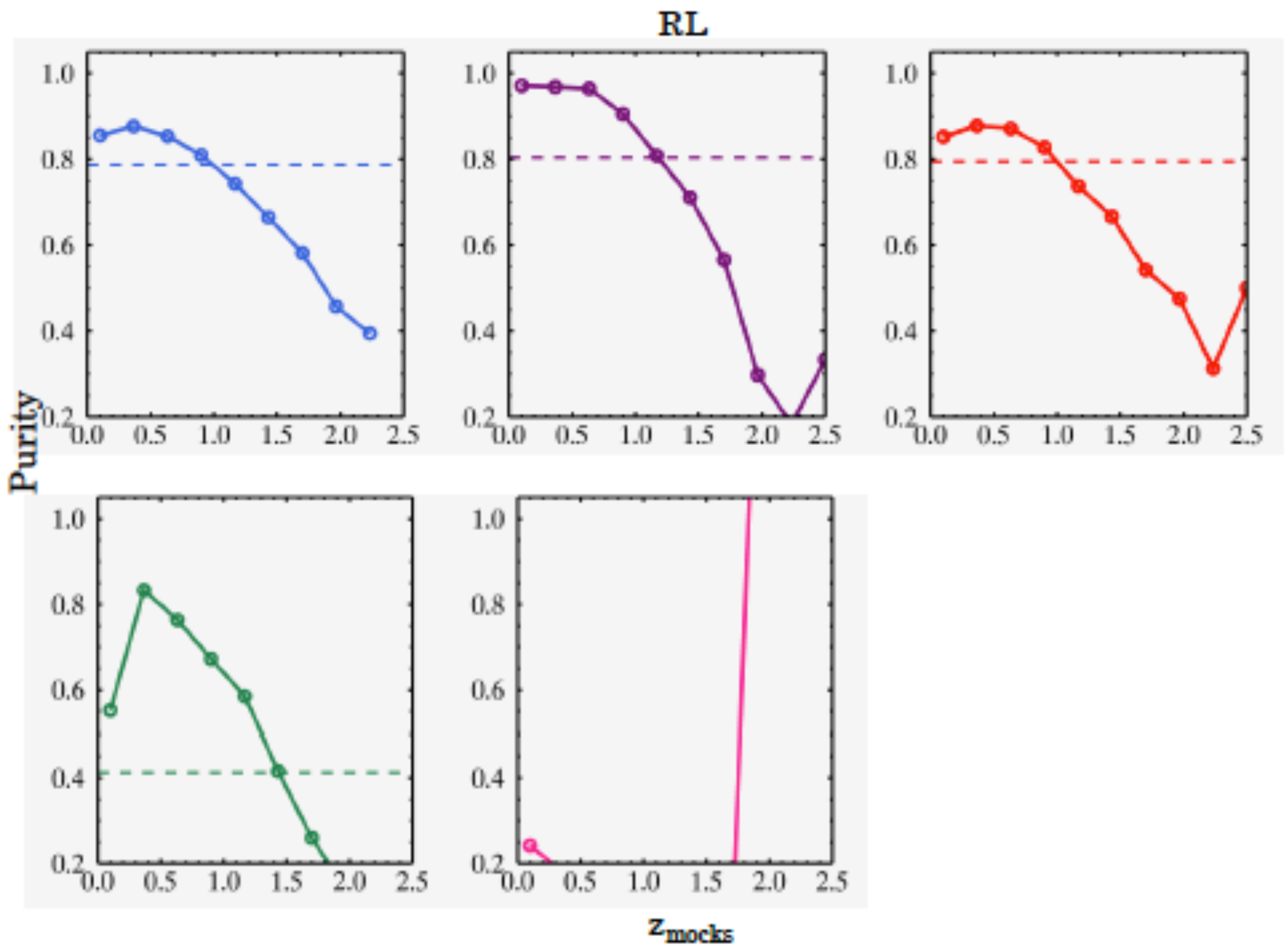
(RL is our cluster detection algorithm - Licitra et al., in preparation)



Euclid Cluster Challenge



Euclid Cluster Challenge



New cluster challenges are on the way, with improved estimation of photometry and photometric errors (Ascaso, SM et al, in preparation) and improved algorithms

Conclusions

- Euclid will find ~100,000 clusters with $M>10^{14}M_{sun}$, between z=0.2 and z=2, with ~20,000 with z>1, ~6000 with z>1.5 (note : updated to Planck cosmology) - Scaled to WFIRST 2400 sq.deg. upper limit ~2400 clusters at z>1.5

- Future ELT spectrograph follow-up (e.g. MOSAIC) will study in detail massive ETG progenitors dynamics and stellar population

- This science is starting now: with HST/WFC3 imaging and grism spectroscopy, Spitzer deep observations and VLT/KMOS and Keck/MOSFIRE follow-up we observe the progenitors of local clusters. But...it is limited in survey area and we have only tens of objects!

- With the current IR and mid-IR surveys we are predicted to detect and analyze ~100 clusters at z>1.5 in the next few-5 years, and ~6000 with the next generation wide field infrared surveys in 5-10 years

Euclid (Laureijs et al. 2011)

SURVEYS		
	Area (deg2)	Description
Wide Survey	15,000 (required) 20,000 (goal)	Step and stare with 4 dither pointings per step.
Deep Survey	40	In at least 2 patches of > 10 deg^2 2 magnitudes deeper than wide survey

PAYLOAD					
Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg^2	0.763×0.722 deg^2			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	3 10^{-16} erg cm-2 s-1 3.5σ unresolved line flux
Detector Technology	36 arrays 4k×4k CCD	16 arrays 2k×2k NIR sensitive HgCdTe detectors			
Pixel Size Spectral resolution	0.1 arcsec	0.3 arcsec			0.3 arcsec R=250