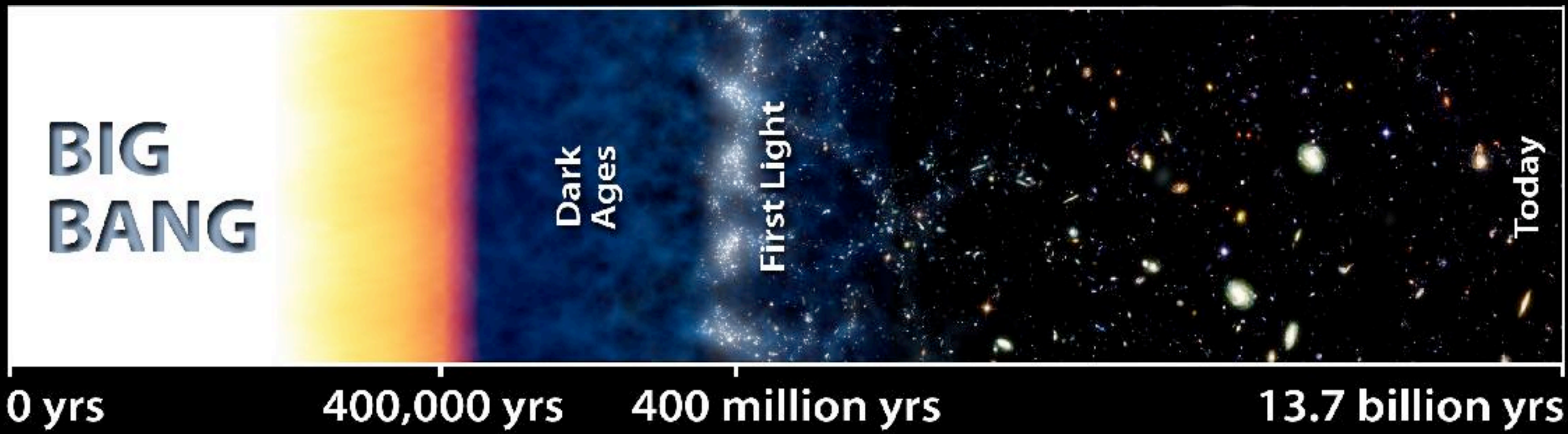
Exploring massive galaxy evolution with deep multi-wavelength surveys



Ross McLure, Henry Pearce, Michele Cirasuolo, Jim Dunlop (Edinburgh)
Omar Almaini (Nottingham), Chris Simpson (Liverpool)

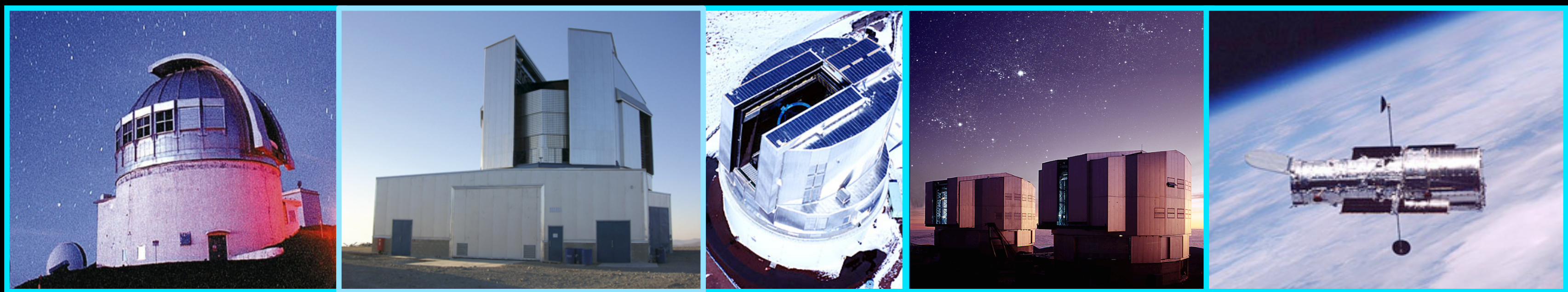
Outline

1. Massive galaxy evolution at $0<z<4$ with UKIDSS UDS

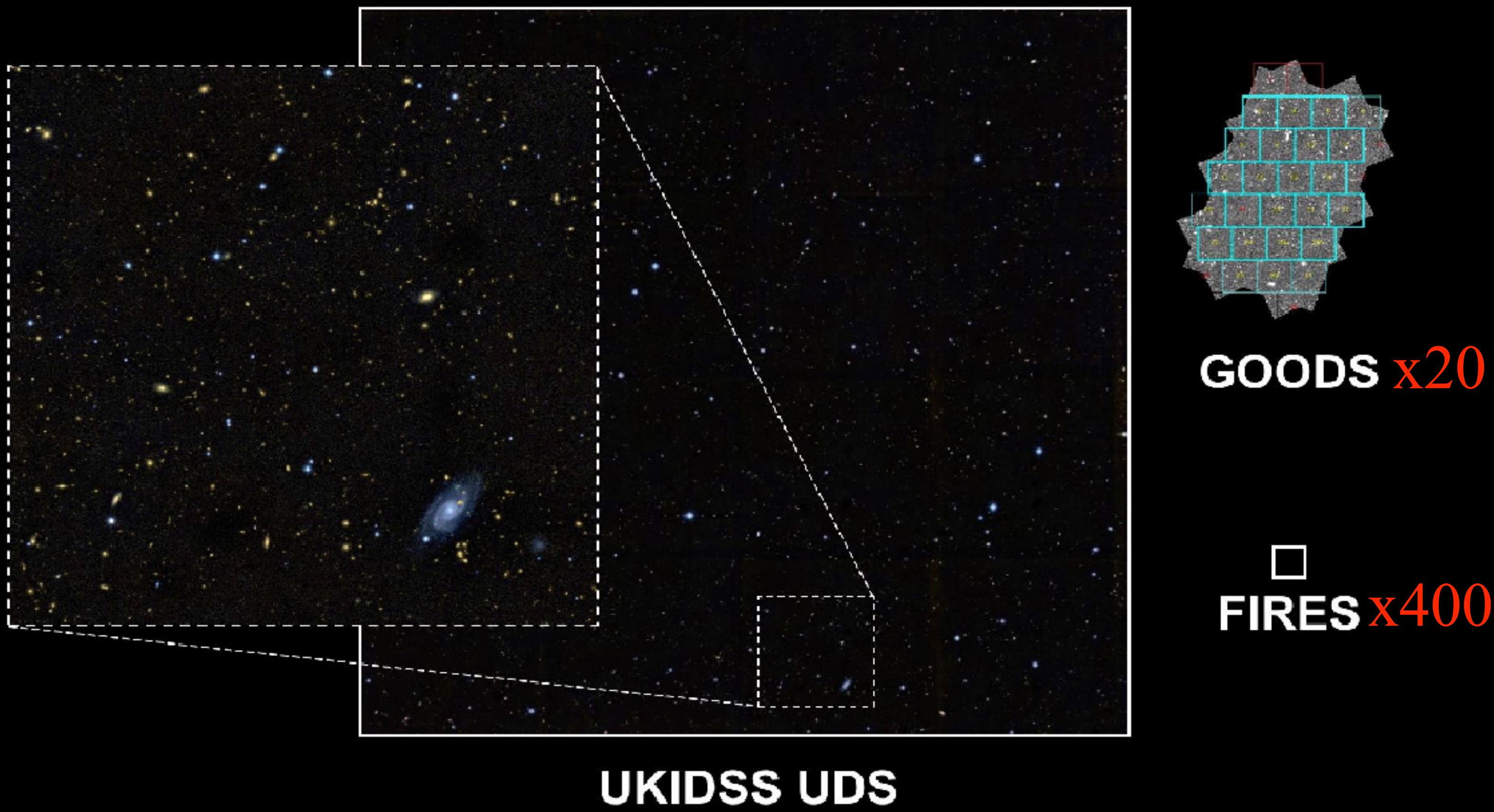
2. Preliminary results from UDSz spectroscopic programme

3. Massive galaxy evolution at $4<z<7$ with SXDS/UDS

4. Wide-field galaxy studies at $z>7$ with UDS/VISTA



The UKIDSS Ultra-Deep Survey



Unique depth+area in NIR plus strong + multi-wavelength coverage

5σ depths >24 (AB) from 1-5 microns

Key science driver: massive galaxy assembly at z>1

The evolution of colour bimodality

Cirasuolo et al. 2007

Well studied in the local Universe

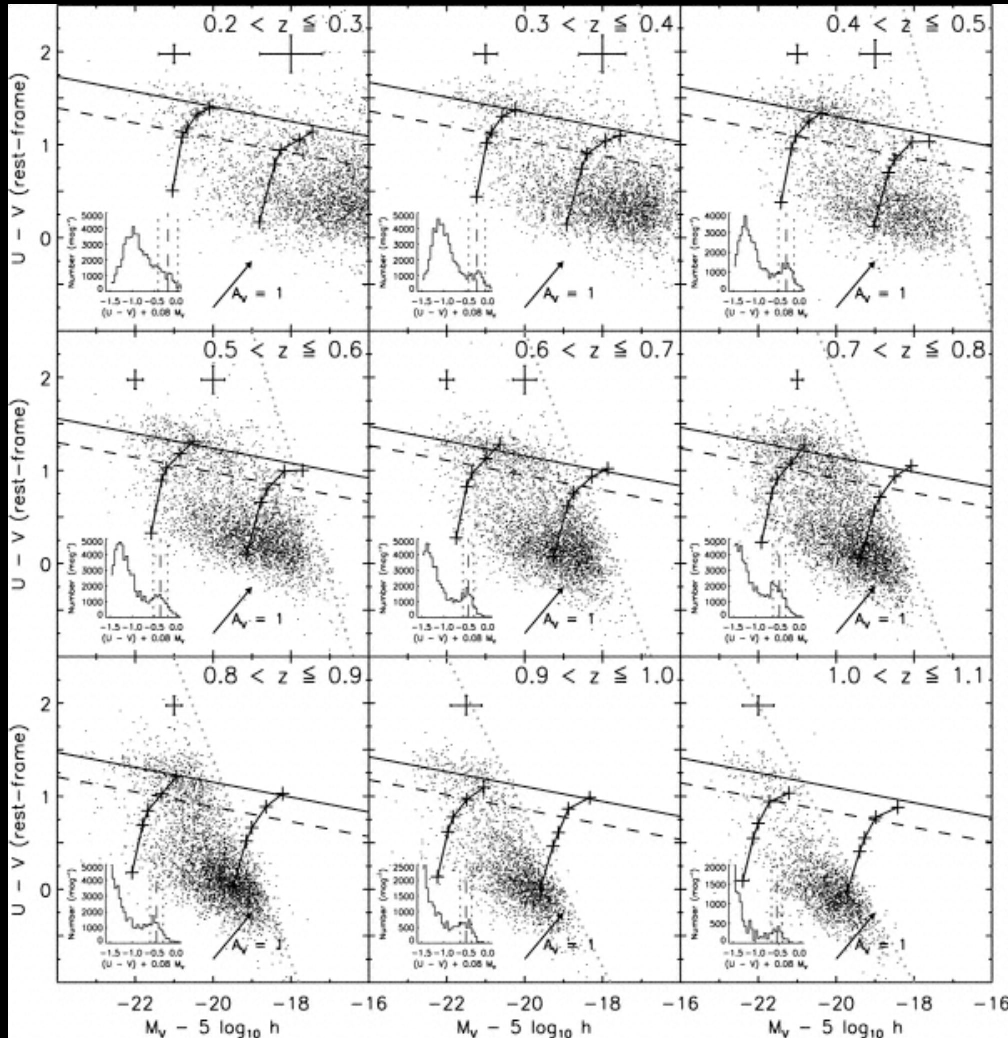
Visvanathan & Sandage 1977; Bower et al. 1992;

Starteva et al. 2001; Baldry et al. 2004

Extended up to z =1

Bell et al. 2004; Willmer et al. 2005;

Franzetti et al. 2006



Bell et al. 2004 Combo-17 R < 24

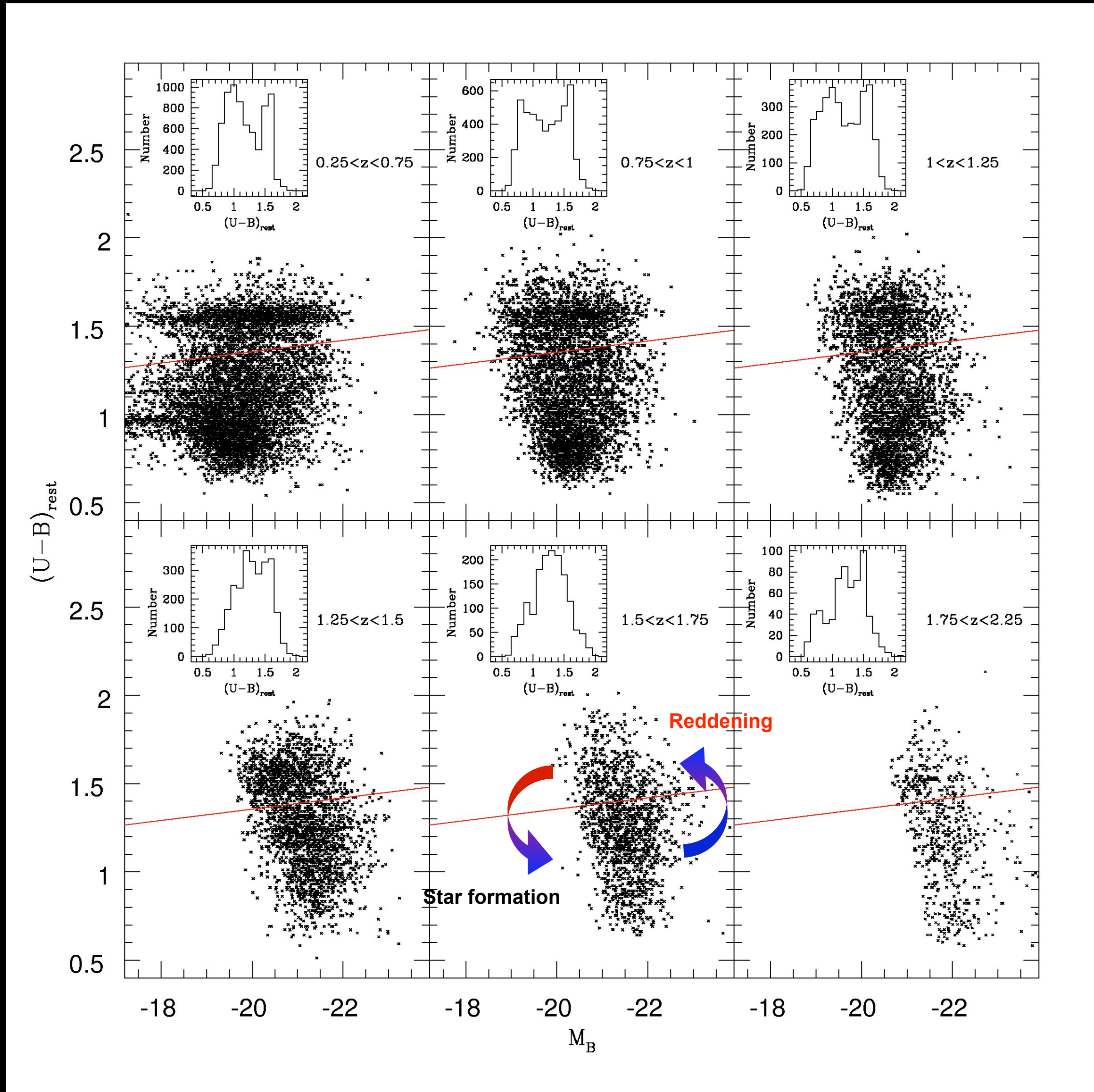
The evolution of colour bimodality

Cirasuolo et al. 2007

Primary selection in K-band ⇒
No bias against red objects

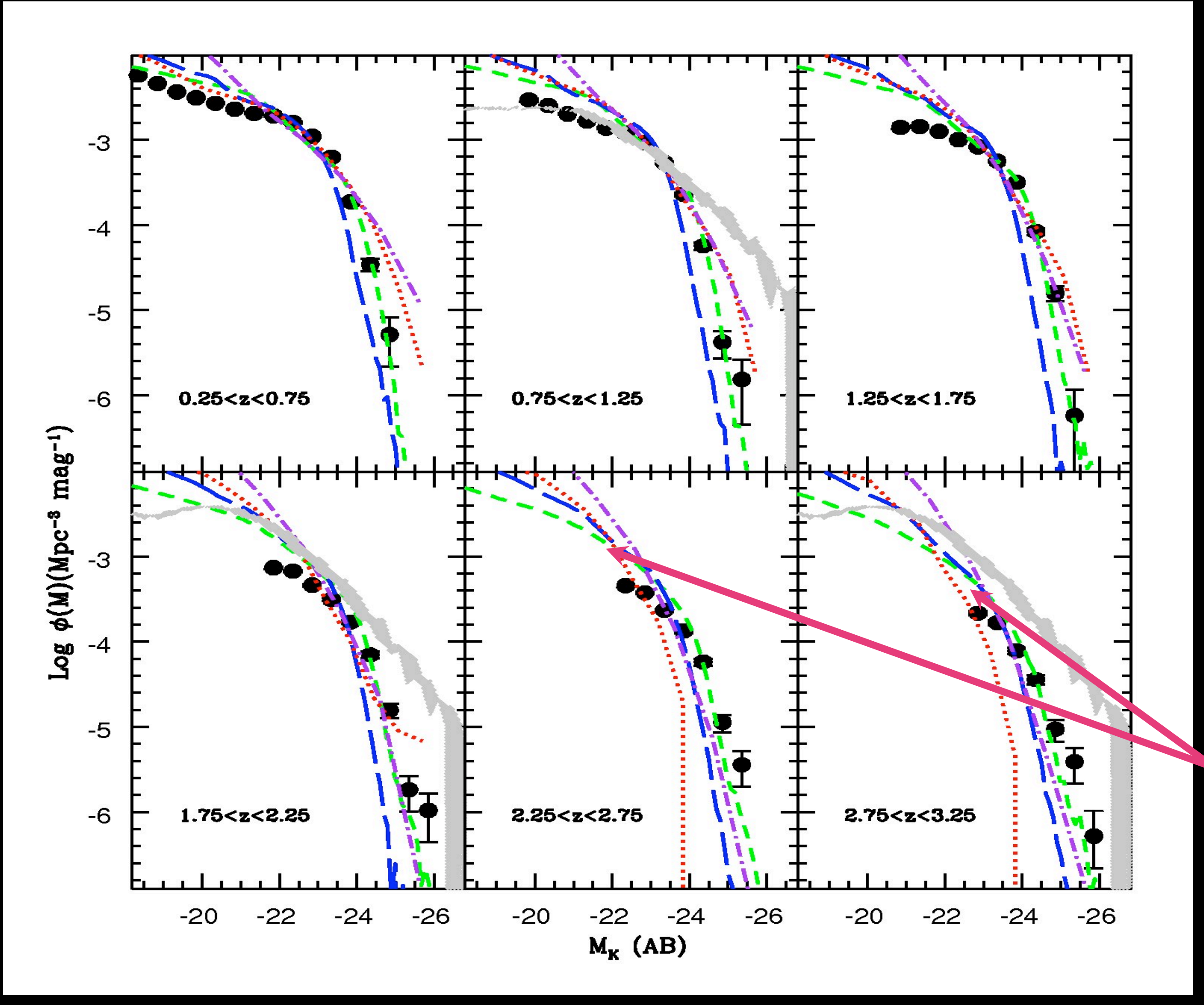
Red objects present at any redshift

Strength of bimodality
decreases with redshift



Evolution of the near-IR galaxy LF

Cirasuolo et al. 2009, in press



Bower 2006

De Lucia 2007

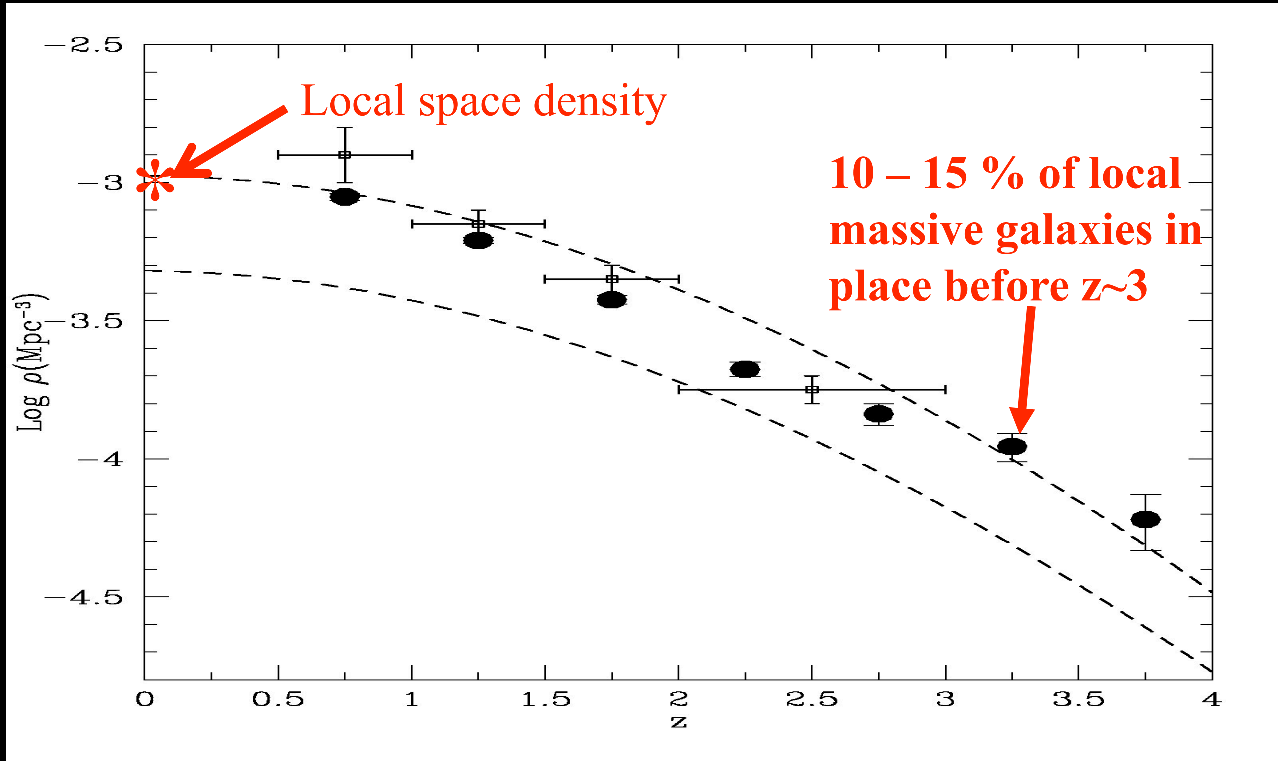
Monaco 2007

Menci 2006

Nagamine 2006

next data-release will push one magnitude deeper

Massive galaxy assembly at 0<z<4



Conclusion: colour bimodality, luminosity function and stellar mass densities all imply that epoch of massive galaxy assembly is 1<z<3

So far, everything based on photo-z's; $\delta z/(1+z)=0.03$

However, detailed clustering studies and accurate determination of galaxy ages, masses and metallicities requires spectroscopy

The assembling of 80% of massive galaxies occurs in the

ESO Large Programme: UDSz (PI: Almaini)

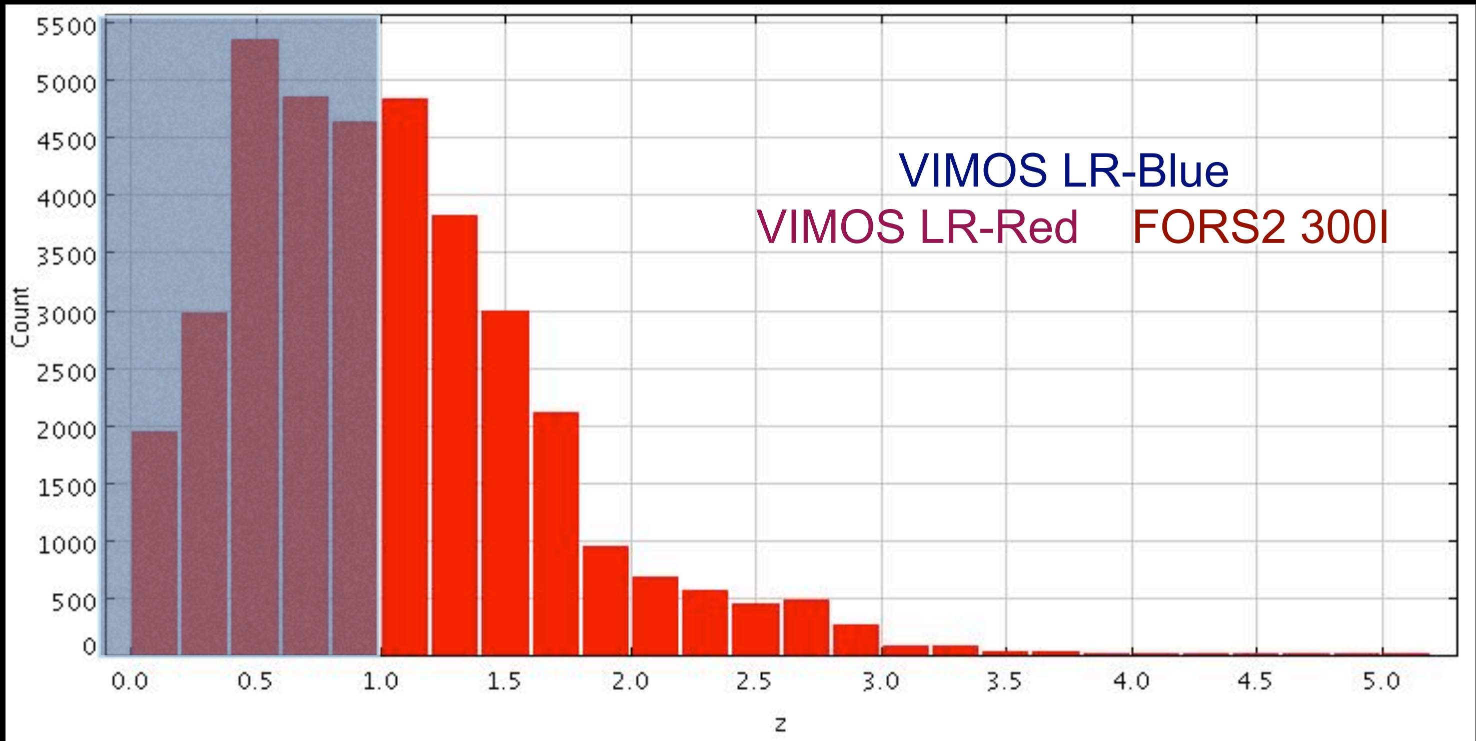
93 hours VIMOS (Nottingham), 142 hours FORS2(Edinburgh)

J.S. Dunlop (Edinburgh, UK), S.J. Maddox, A. Arag´on-Salamanca, C. Conselice , S. Foucaud, L. Dunne, M. Gray (Nottingham, UK), A. Cimatti (Bolgogna, I), I. Smail (Durham, UK), M. Lehnert (Paris, F), M. Bremer (Bristol, UK), C. Simpson (Liverpool JM, UK), D. Clements (Imperial, UK), M. Franx (Leiden, NL), S. Croom (Sydney, AUS), M. Watson (Leicester, UK), M. Akiyama (NAOJ, Japan)

ESO Large Programme: UDSz (PI: Almaini)

93 hours VIMOS (Nottingham), 142 hours FORS2(Edinburgh)

- K-selected sample to K_{AB}<23 over 0.6 sq degrees
- Pre-selected with z_{phot}>1 (plus control sample)
- Sampling 1/6 galaxies (~4000)



Example FORS2 spectra

All courtesy of Henry Pearce (Edinburgh)

- Full programme features 20 FORS2 masks:

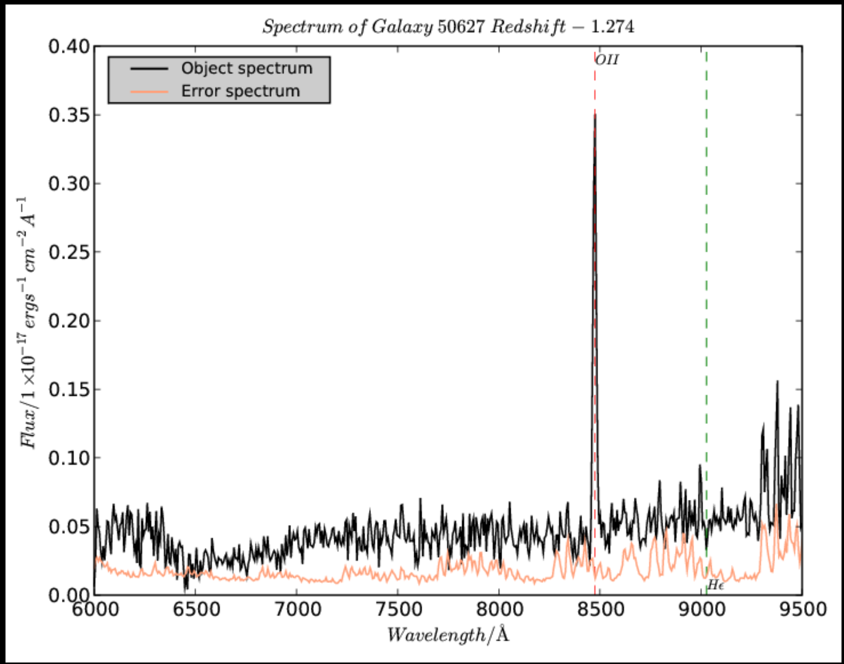
- 35-40 objects with K<23(AB), i<24.5(AB) per mask

- Photo-z pre-selection in range 0.8<z<2.0

- 3-5 “extra” targets per mask, made of interesting objects such as: z>5 LBGs, SMG, AGN etc

- Currently analysing first 10 masks with new, optimised pipeline

- Achieving >80% spectroscopic completeness, wide variety of spectral types

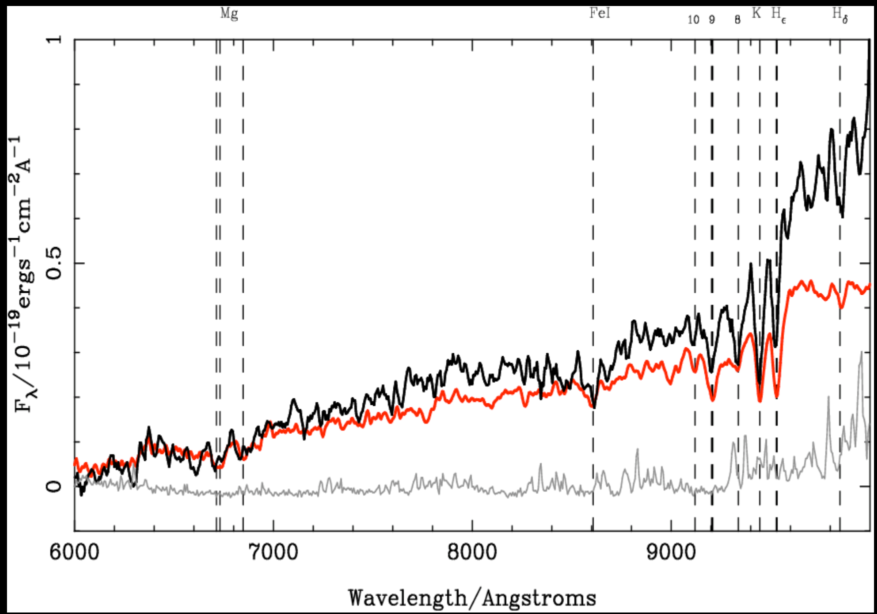


Example strong OII emitter at z=1.3

Example FORS2 spectra

All courtesy of Henry Pearce (Edinburgh)

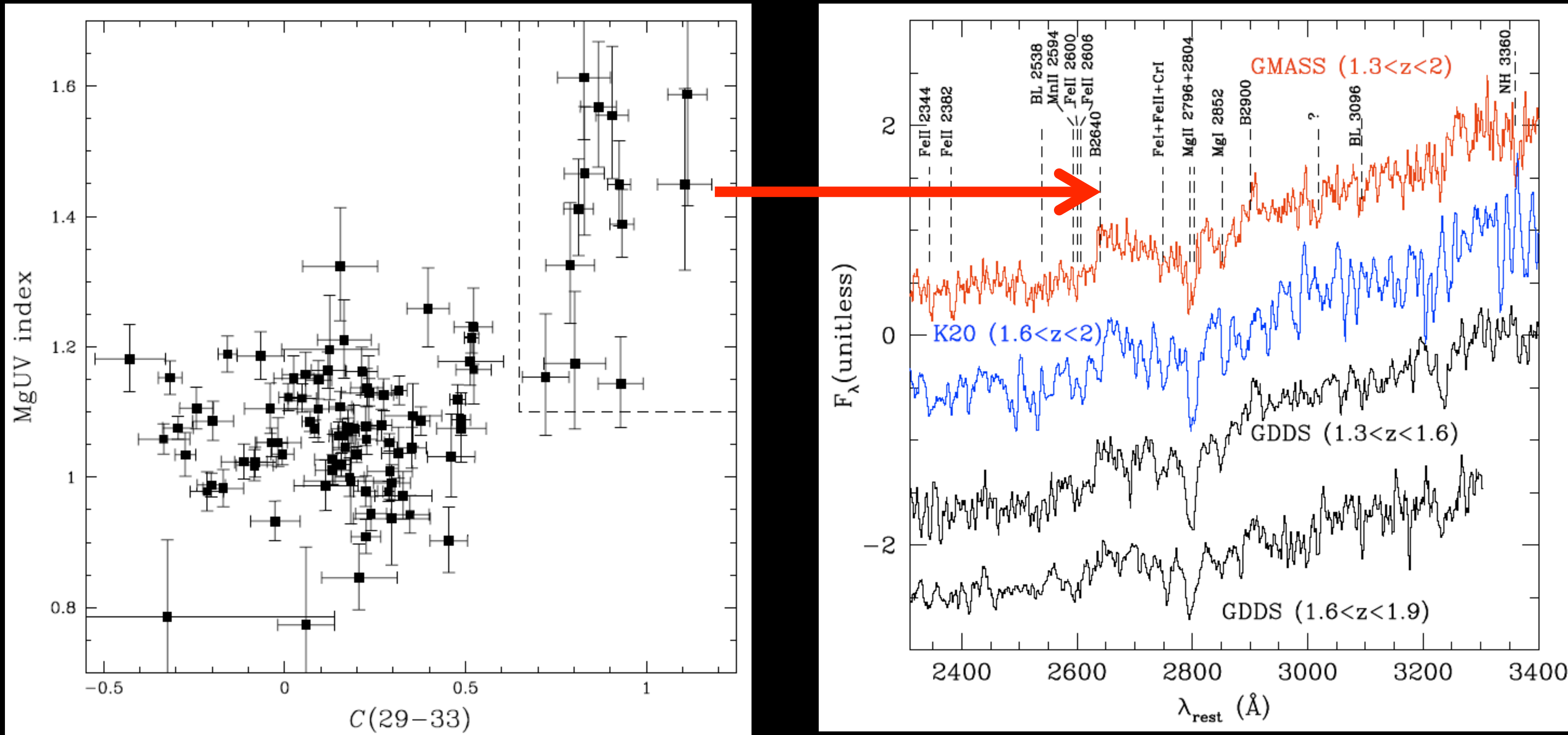
- Full programme features 20 FORS2 masks:
- 35-40 objects with K<23(AB), i<24.5(AB) per mask
- Photo-z pre-selection in range 0.8<z<2.0
- 3-5 “extra” targets per mask, made of interesting objects such as: z>5 LBGs, SMG, AGN etc
- Currently analysing first 10 masks with new, optimised pipeline
- Achieving >80% spectroscopic completeness, wide variety of spectral types



Example passive galaxy at z=1.4

UDS FORS2 programme: initial results

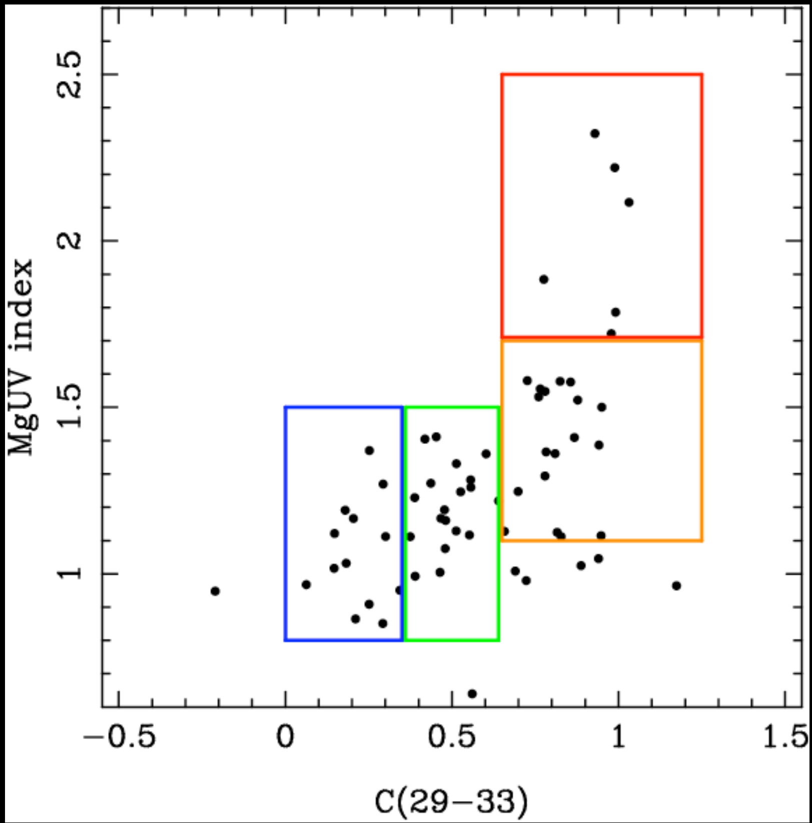
Old galaxies at high redshift



GMASS survey (Cimatti et al 2008): FORS2 spectra of $m_{4.5}$<23 (AB), i<26 (AB)

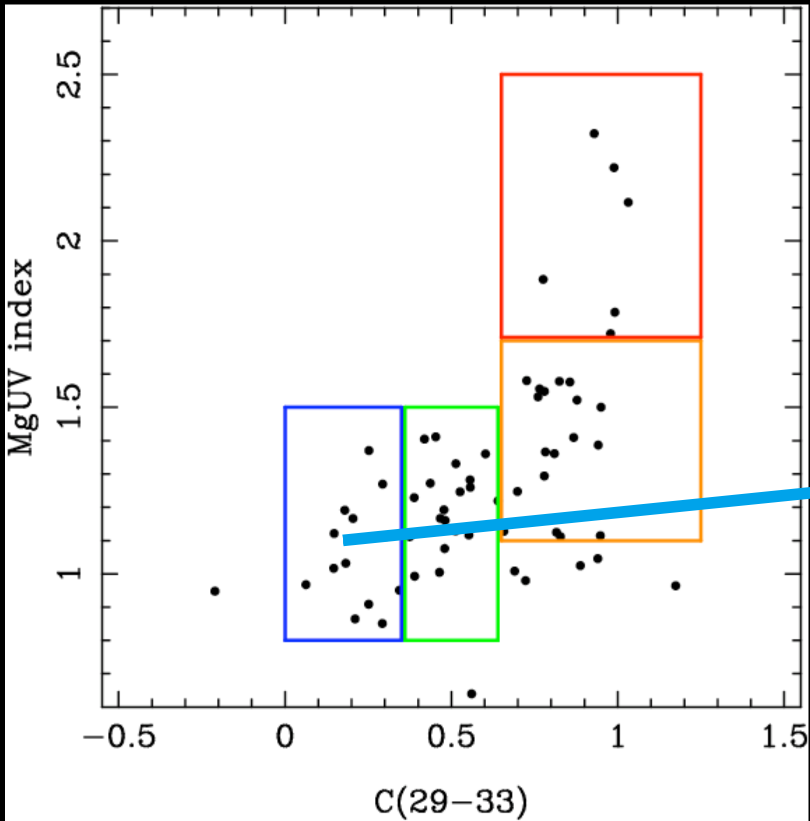
UDS FORS2 programme: initial results

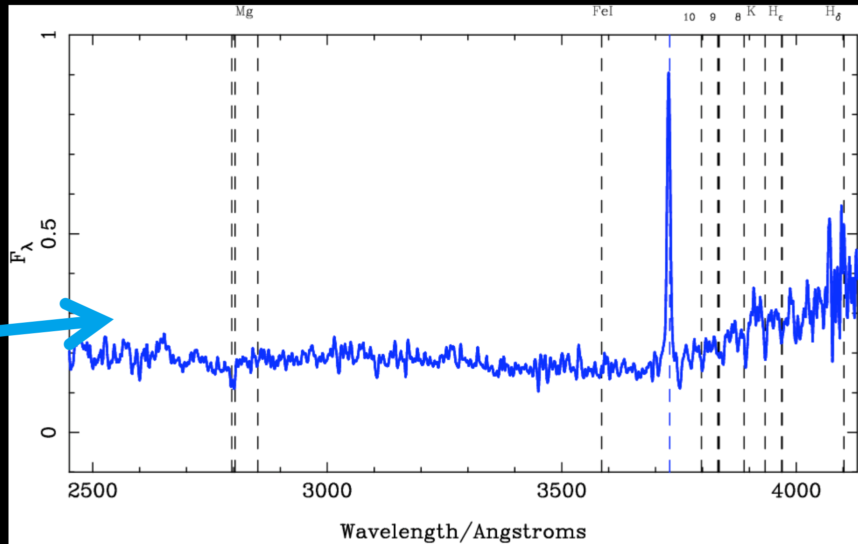
Old galaxies at high redshift



UDS FORS2 programme: initial results

Old galaxies at high redshift

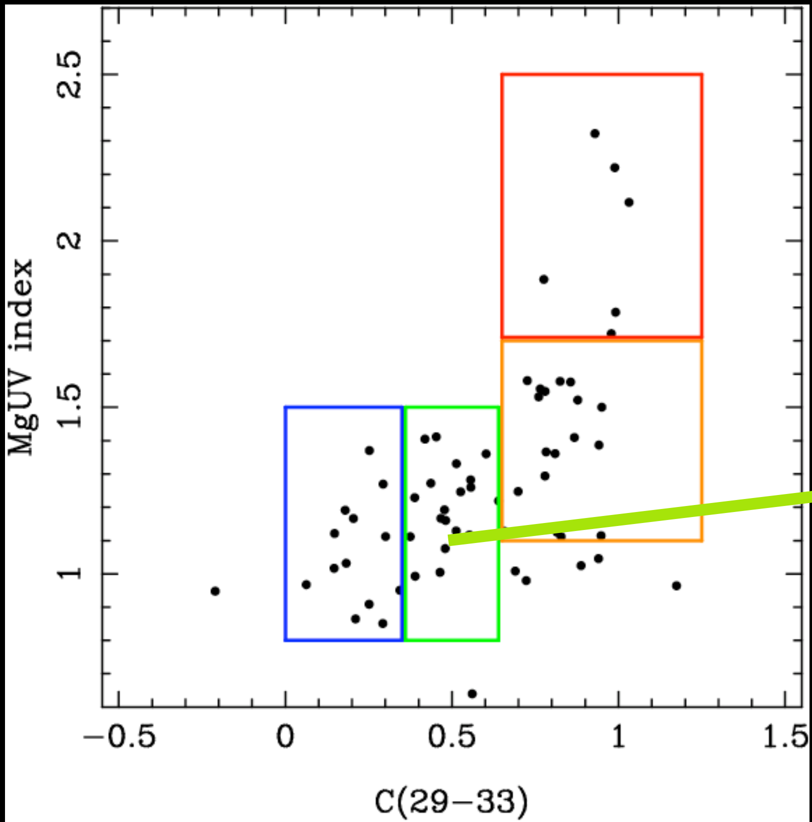


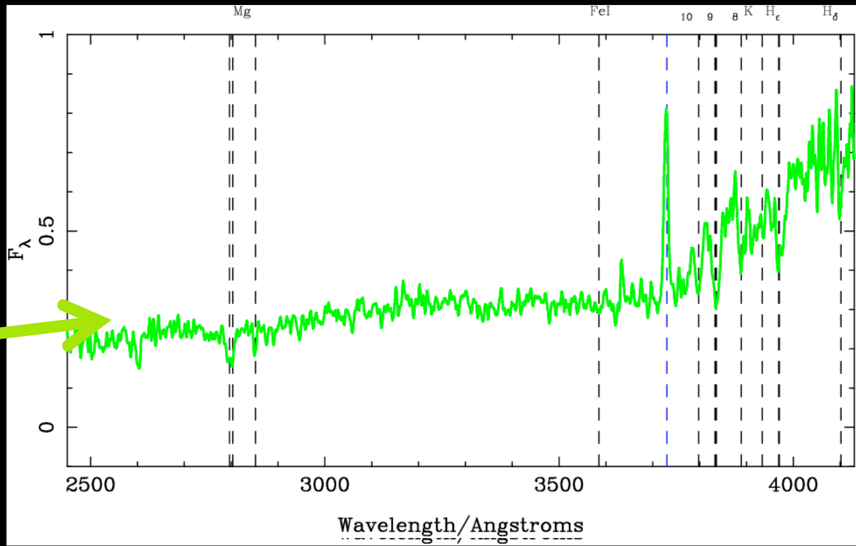


young, blue composite

UDS FORS2 programme: initial results

Old galaxies at high redshift

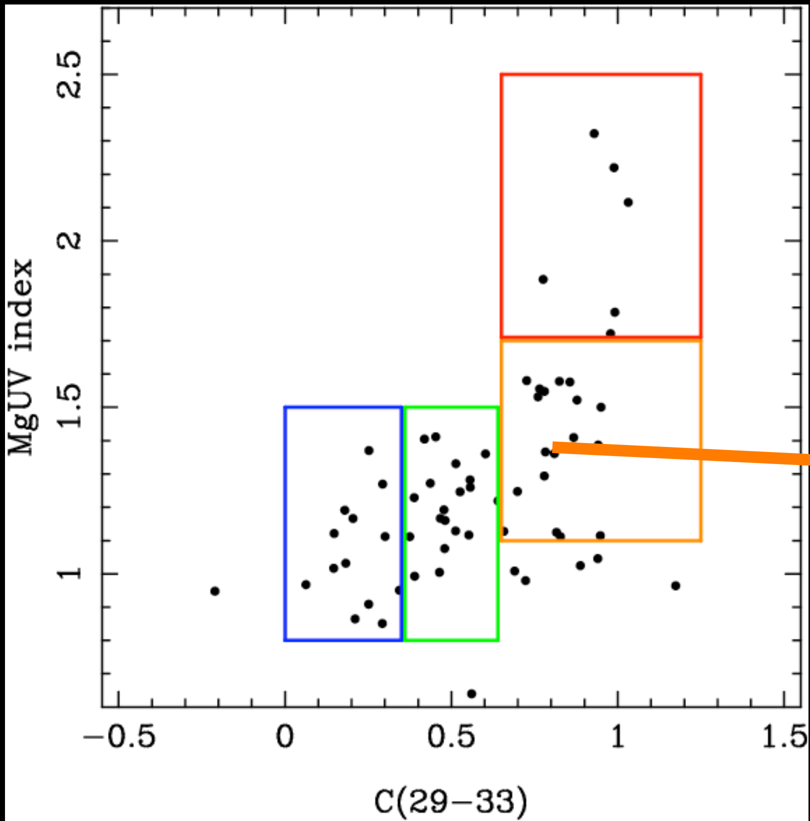


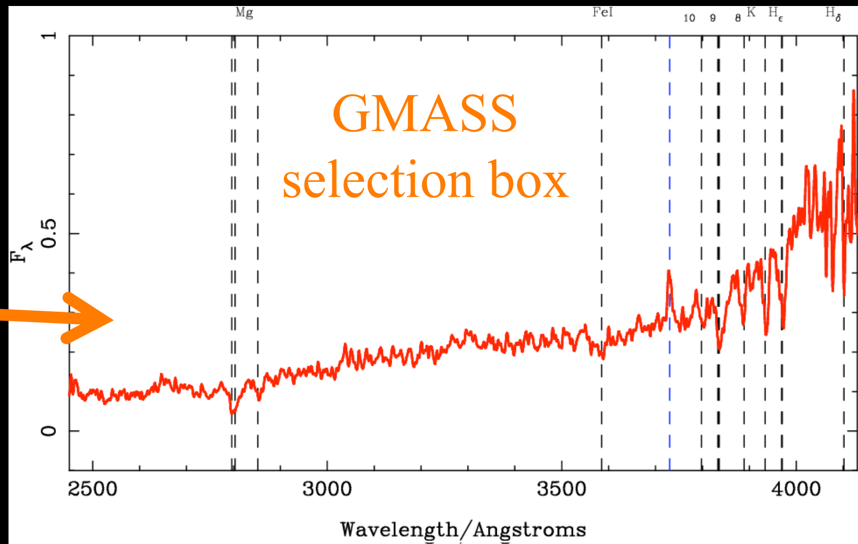


intermediate composite

UDS FORS2 programme: initial results

Old galaxies at high redshift

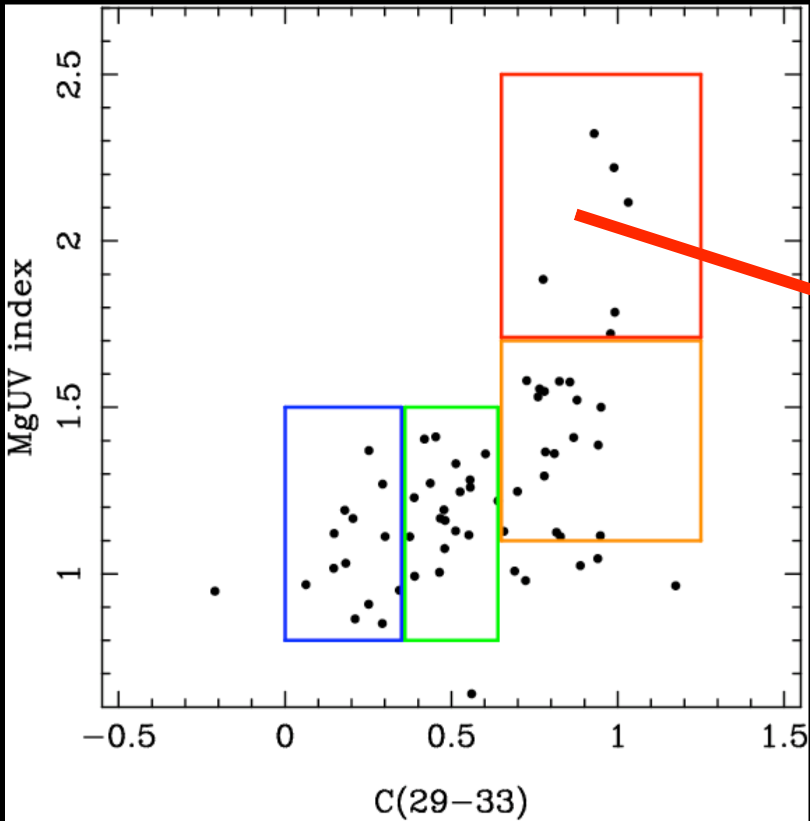


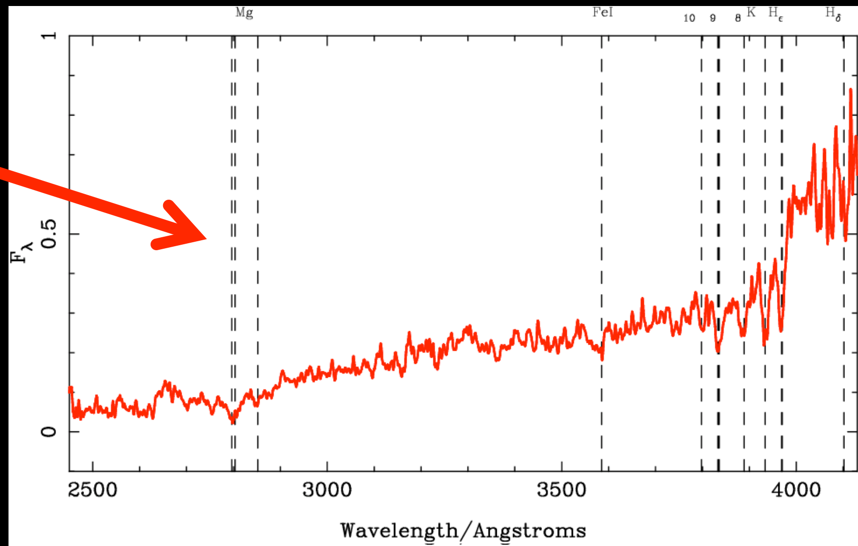


old composite

UDS FORS2 programme: initial results

Old galaxies at high redshift

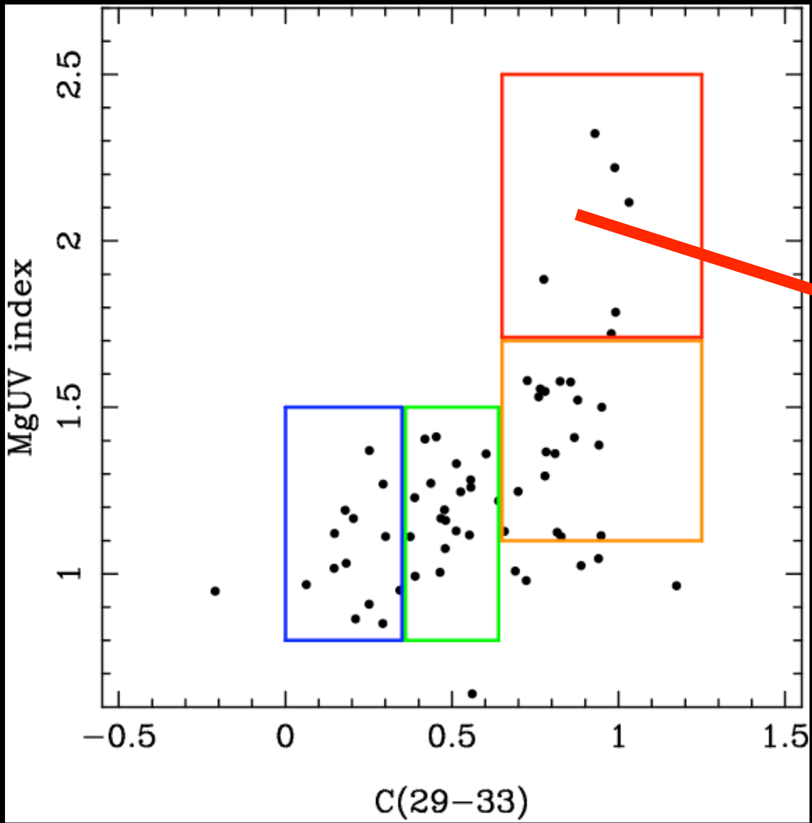


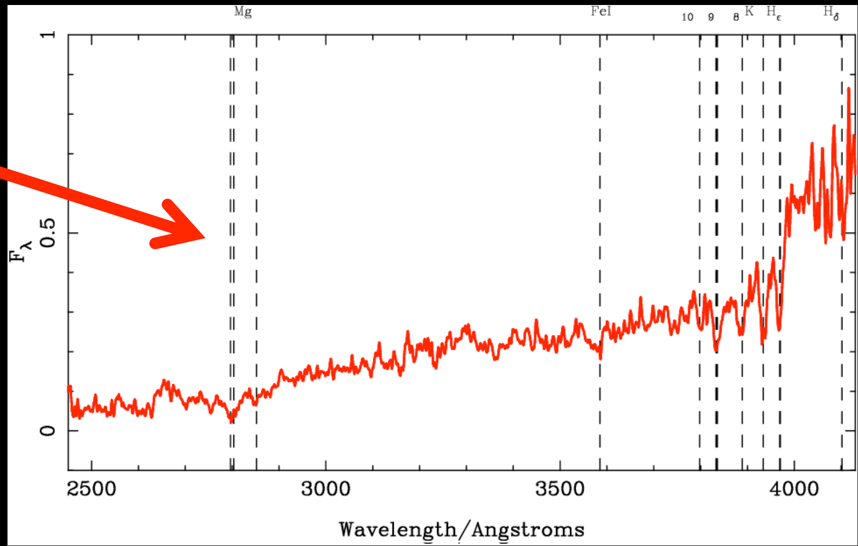


very old composite

UDS FORS2 programme: initial results

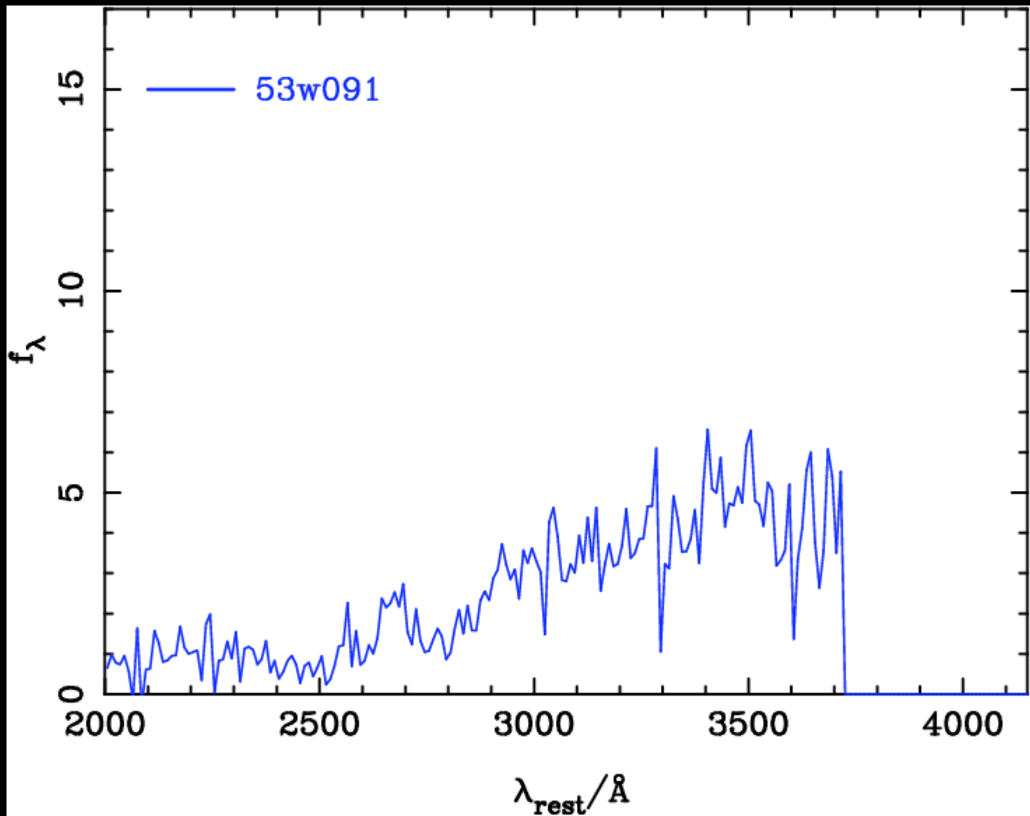
Old galaxies at high redshift





UDS FORS2 programme: initial results

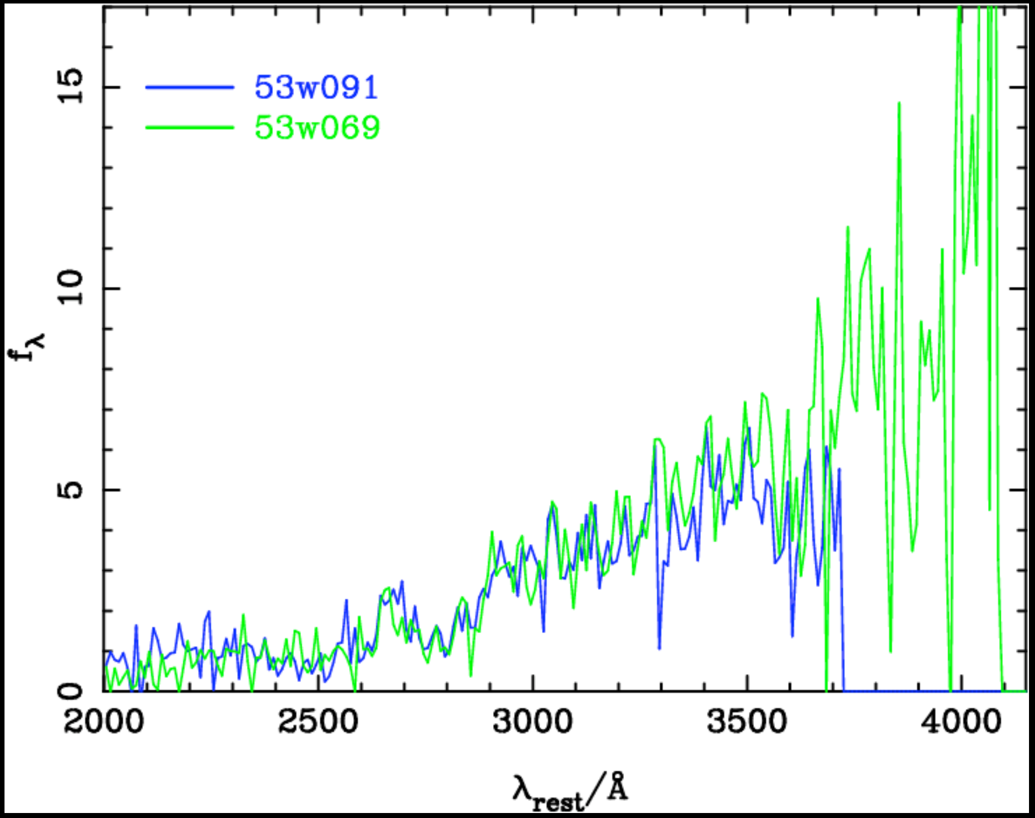
Old galaxies at high redshift



Comparison with archetypal red/dead radio galaxies at z~1.5 (Dunlop et al. 1996)

UDS FORS2 programme: initial results

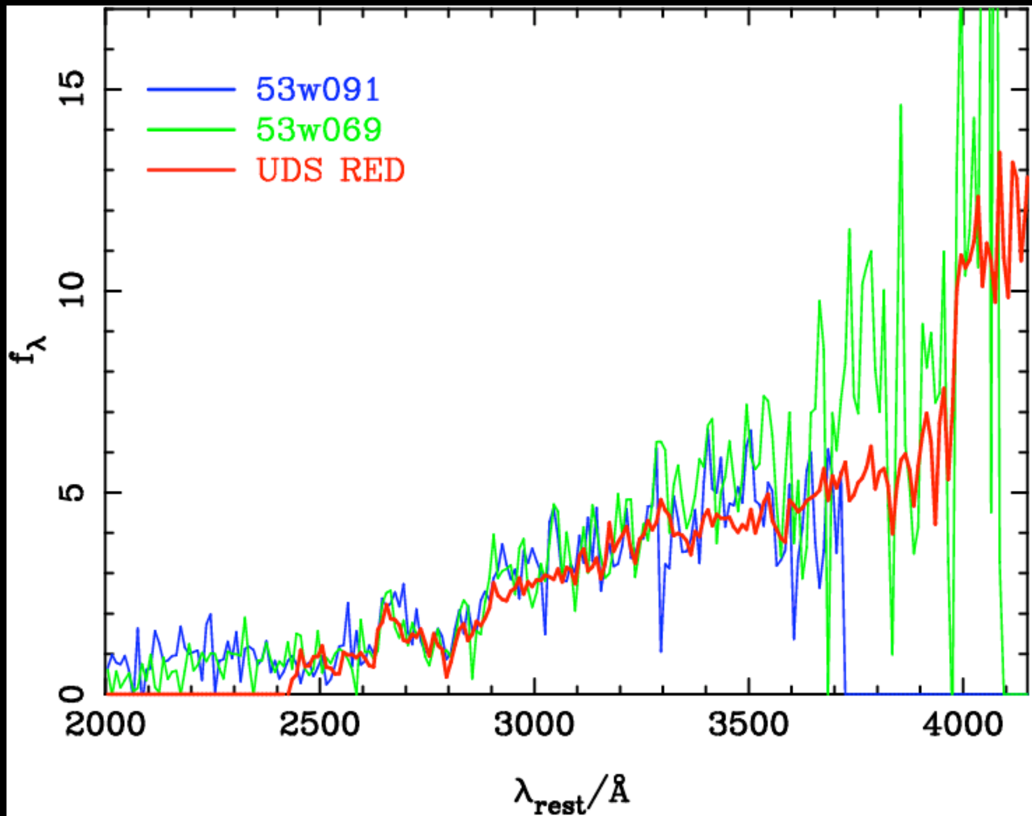
Old galaxies at high redshift



Comparison with archetypal red/dead radio galaxies at z~1.5 (Dunlop et al. 1996)

UDS FORS2 programme: initial results

Old galaxies at high redshift

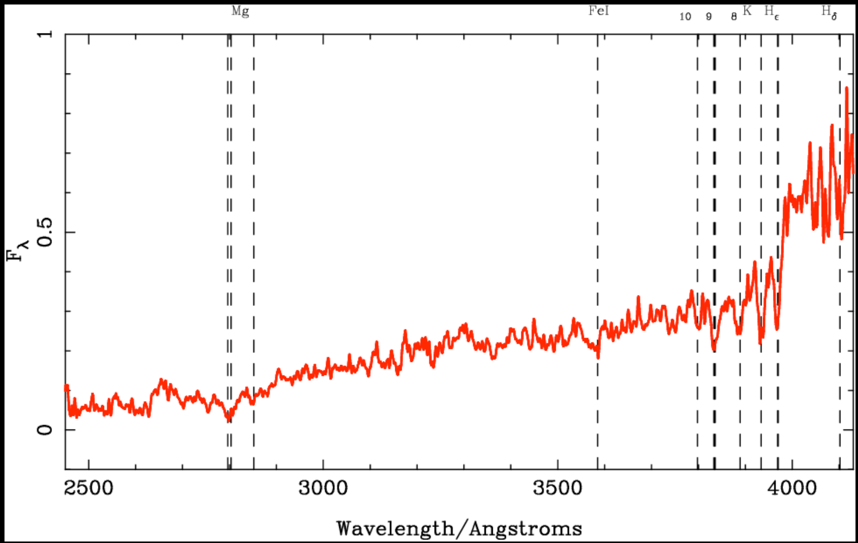


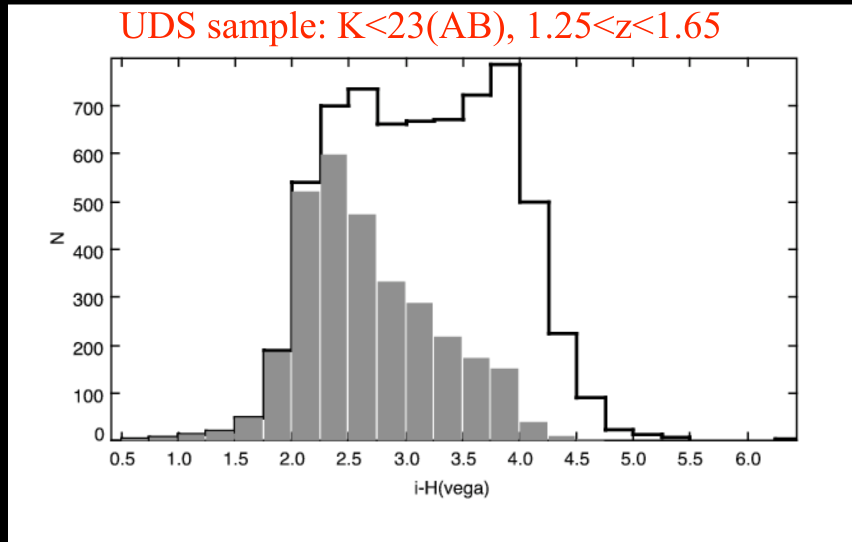
Comparison with archetypal red/dead radio galaxies at z~1.5 (Dunlop et al. 1996)

Radio galaxies are tracing red envelope, but are not necessarily extreme objects

Studying red galaxies at z>1 with FMOS

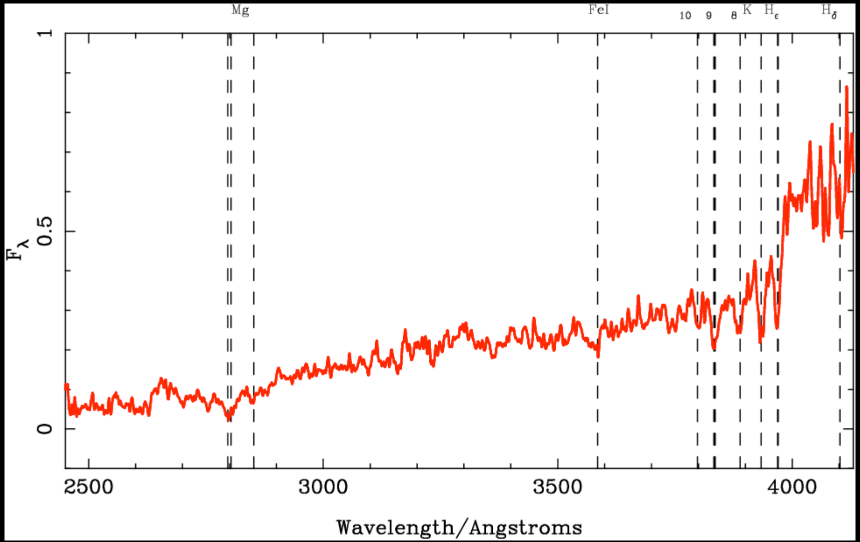
Currently unable to study the reddest galaxies at 1<z<2

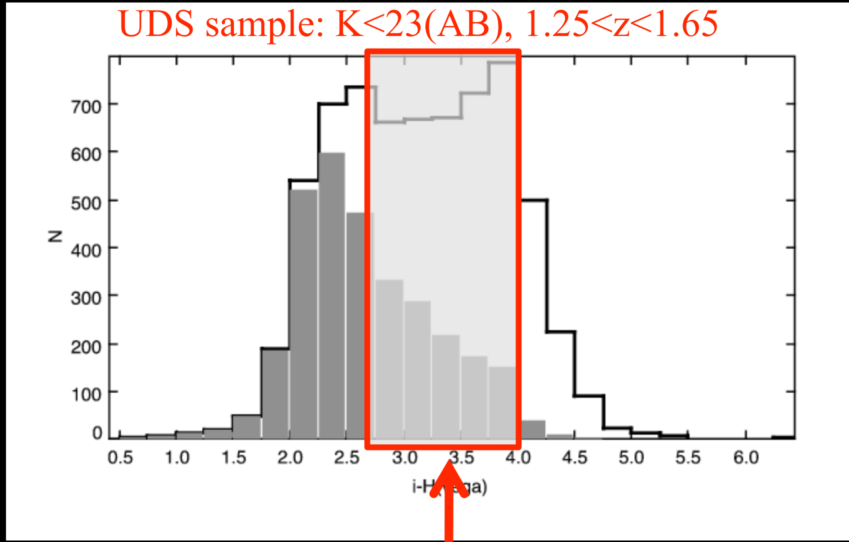




Studying red galaxies at z>1 with FMOS

Currently unable to study the reddest galaxies at 1<z<2

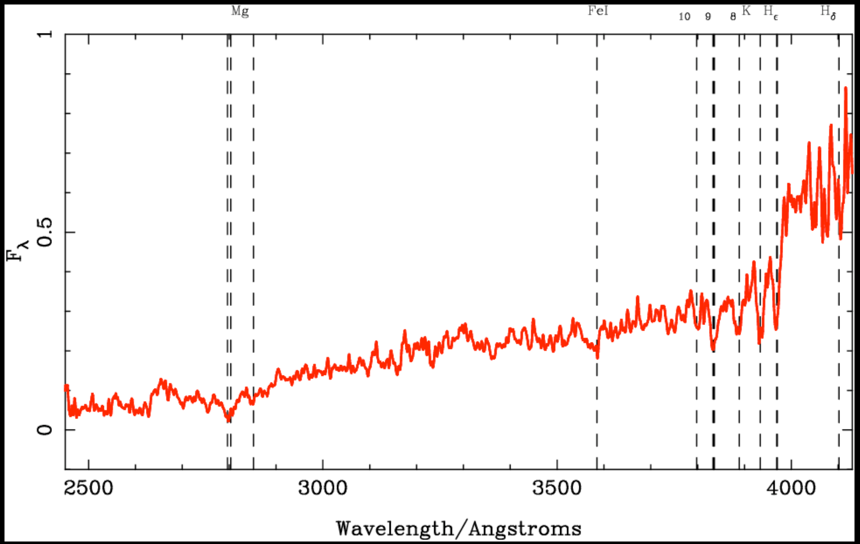


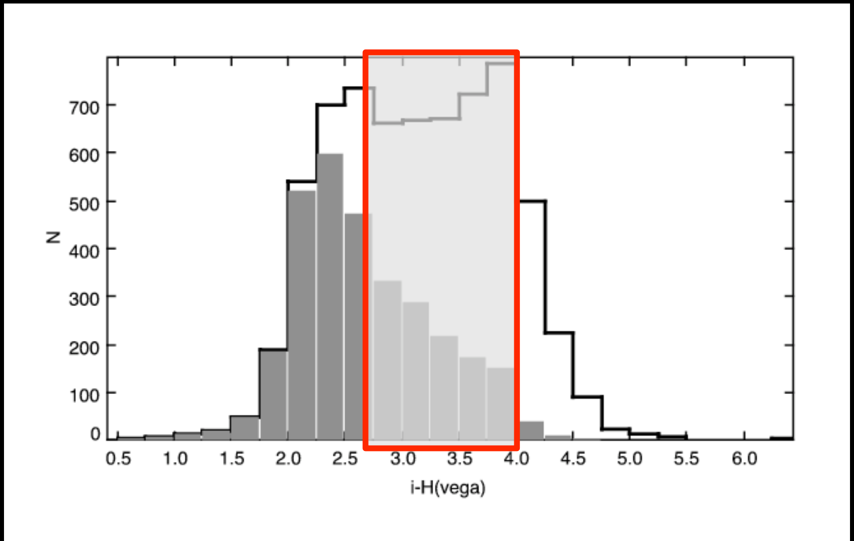


FMOS can reach this population

Studying red galaxies at z>1 with FMOS

Currently unable to study the reddest galaxies at 1<z<2





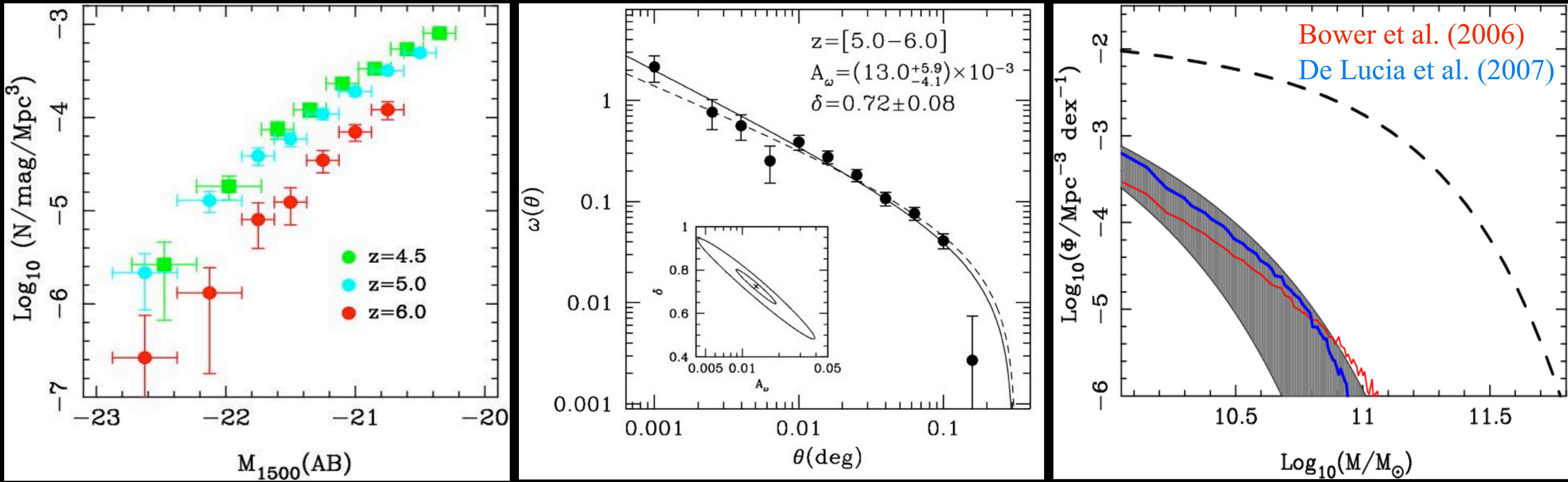
UKIDSS Ultra-deep Survey ideal field for FMOS:

FMOS can reach ~10σ continuum detection at H~21.5(AB); 4-5 hours
~9500 objects at H<21.5 in central 0.6 sq degree UDS area

e.g. consider redshift range 1.25<z<3.00 – where 4000A/Balmer break is available
~1500 objects at H<21.5 in central 0.6 sq degree UDS area, or ~500 per FMOS pointing

Massive galaxies at 4.5<z<6.5

McLure et al. (2009)

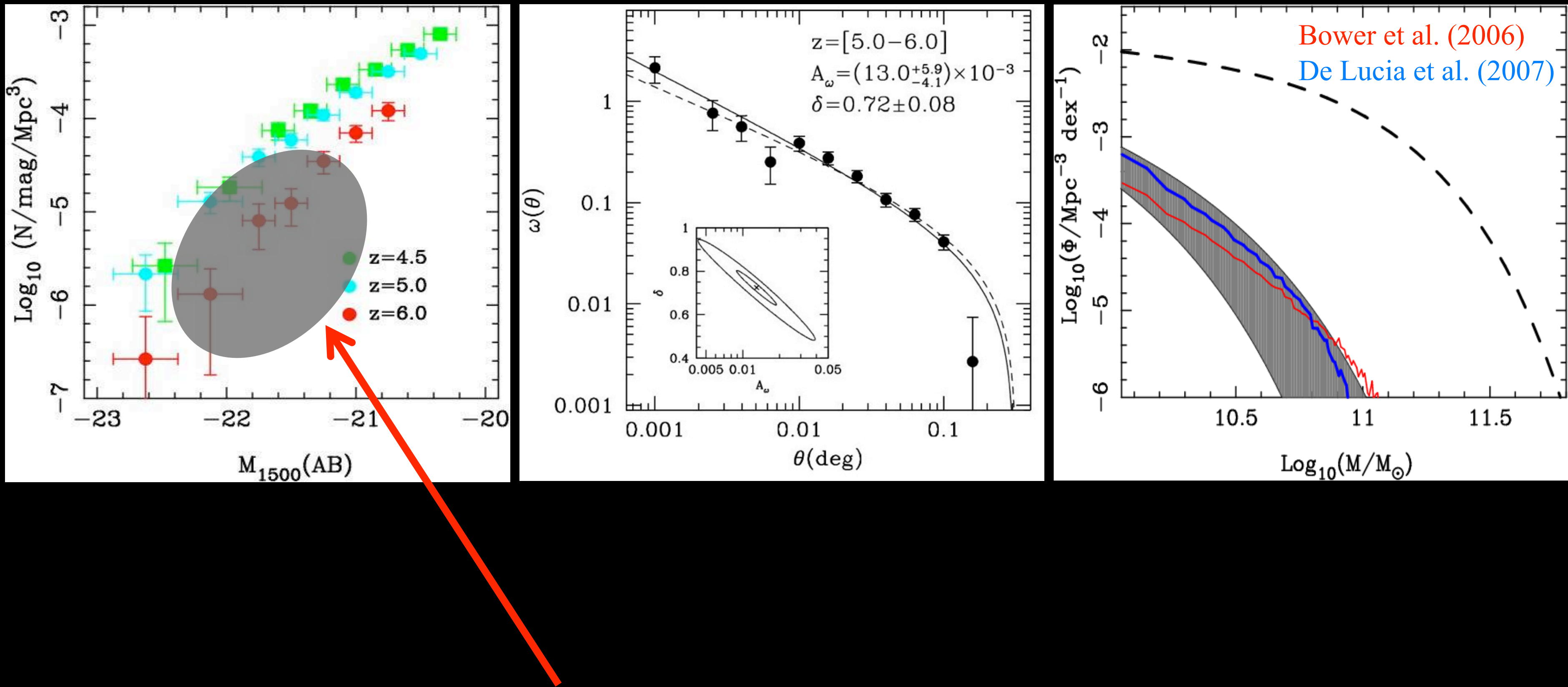


1. Clear evolution in UV LF from z=5 to z=6 : $M^\star$ dims by ~0.7 magnitudes
2. Clustering analysis suggests: r_o=8 Mpc , halo masses ~ $5\times10^{11} M_\odot$
3. Estimate of z~5.5 stellar mass function: consistent with latest semi-analytic models

Key point: ground-based, wide-field provides info on bright end of high-redshift luminosity function

Massive galaxies at 4.5<z<6.5

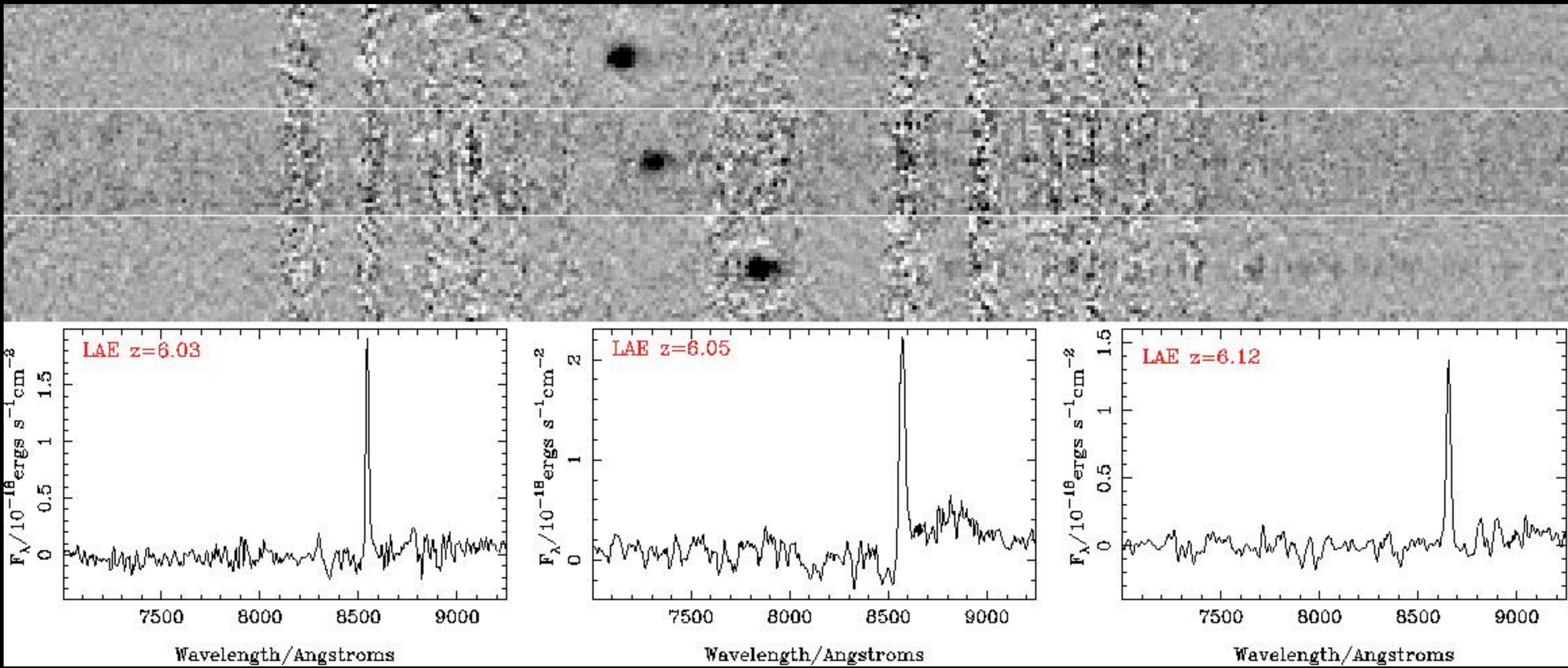
McLure et al. (2009)



LBGs at bright-end of LF can be targeted with FORS2

Massive galaxies at 4.5<z<6.5

McLure et al. (2009), in prep

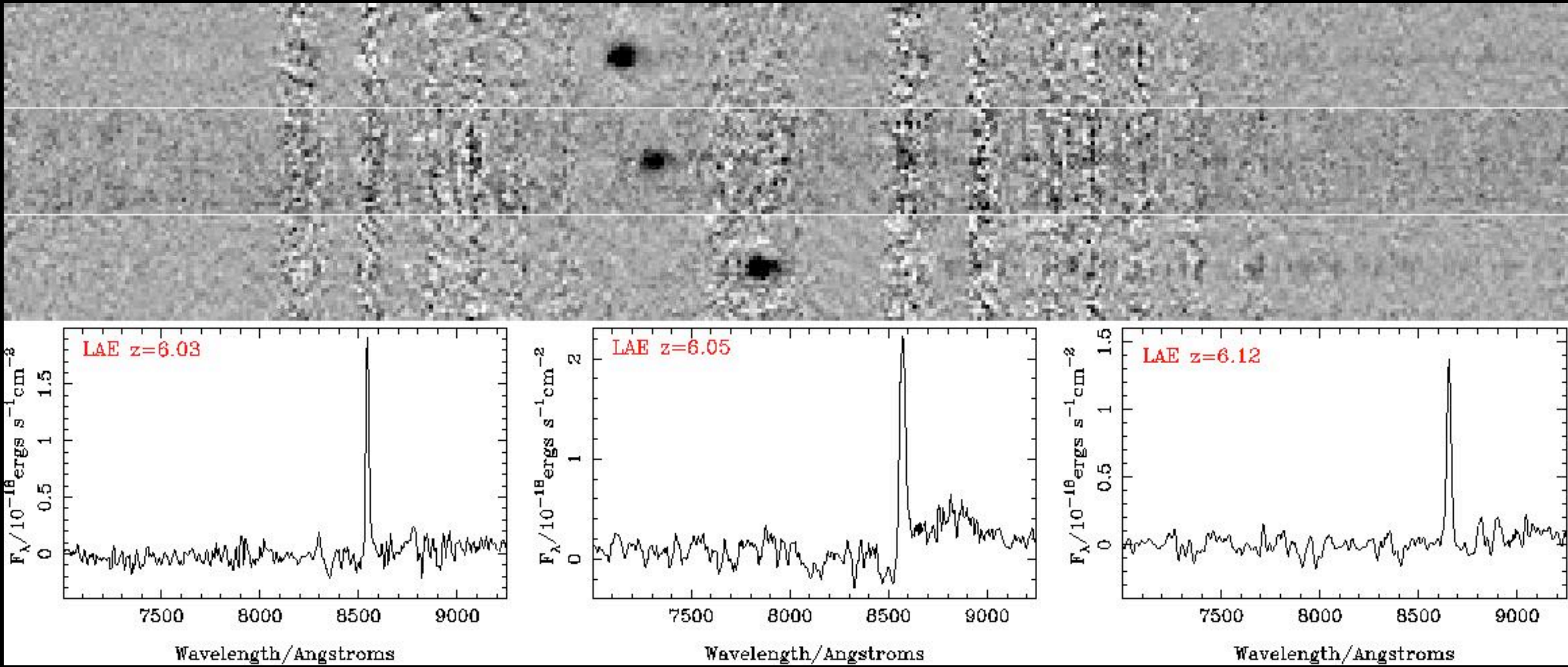


>50% of luminous LBGs observed at z>6 are strong LAEs

Lyα line fluxes are typical 3×10^{-17} cgs, i.e. SFR~10 $M_\odot$ yr^{-1}

Massive galaxies at 4.5<z<6.5

McLure et al. (2009), in prep

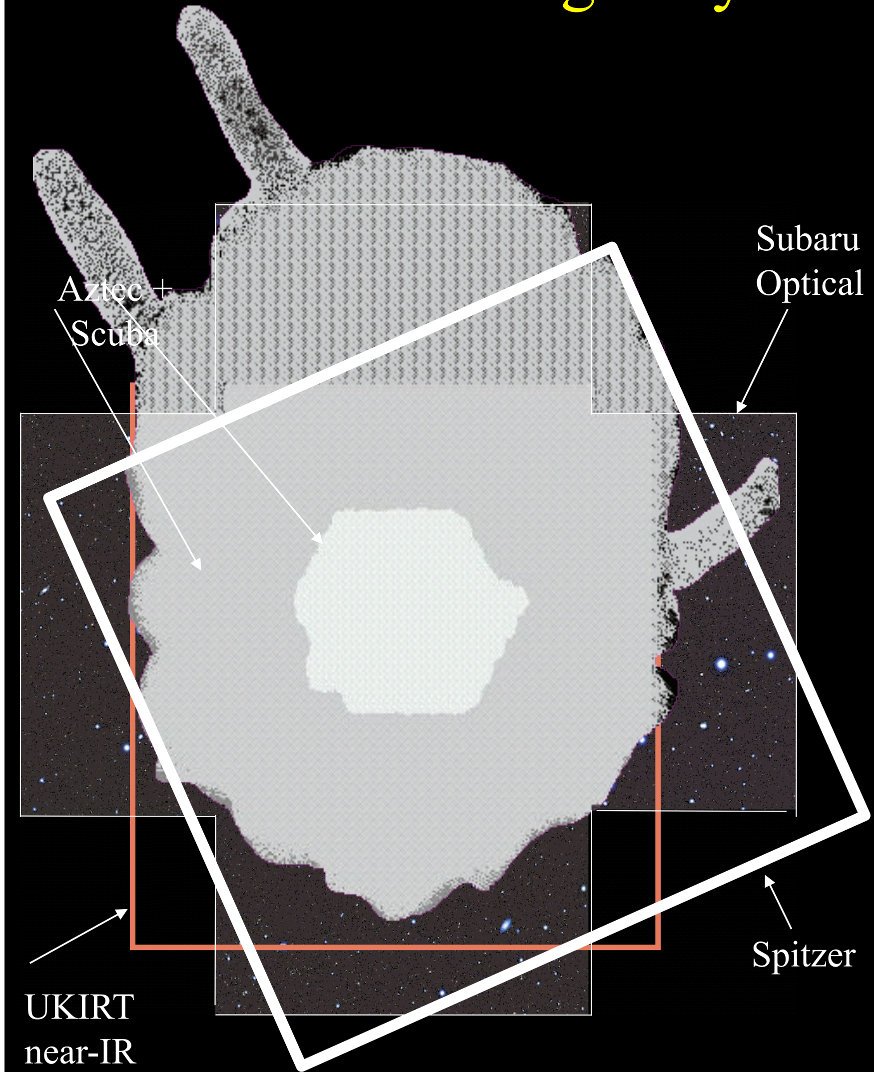


>50% of luminous LBGs observed at z>6 are strong LAEs

Lyα line fluxes are typical 3×10^{-17} cgs, i.e. SFR~10 $M_{\odot}\ yr^{-1}$

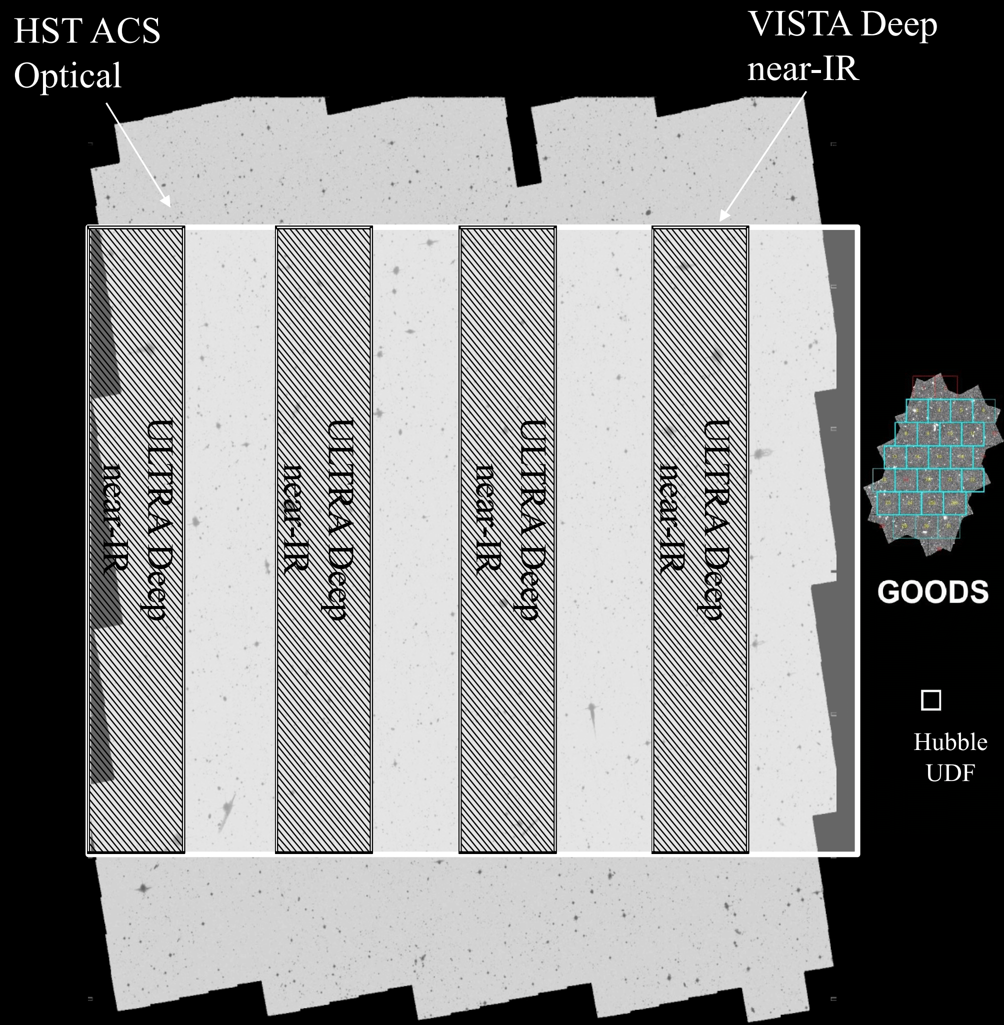
FMOS simulations suggest: do-able in 5-10 hours with FMOS at z>6.5

Widefield galaxy studies at z>7 with UDS/VISTA



UKIDSS UDS

RA = 02 18 00, Dec = -05 00 00

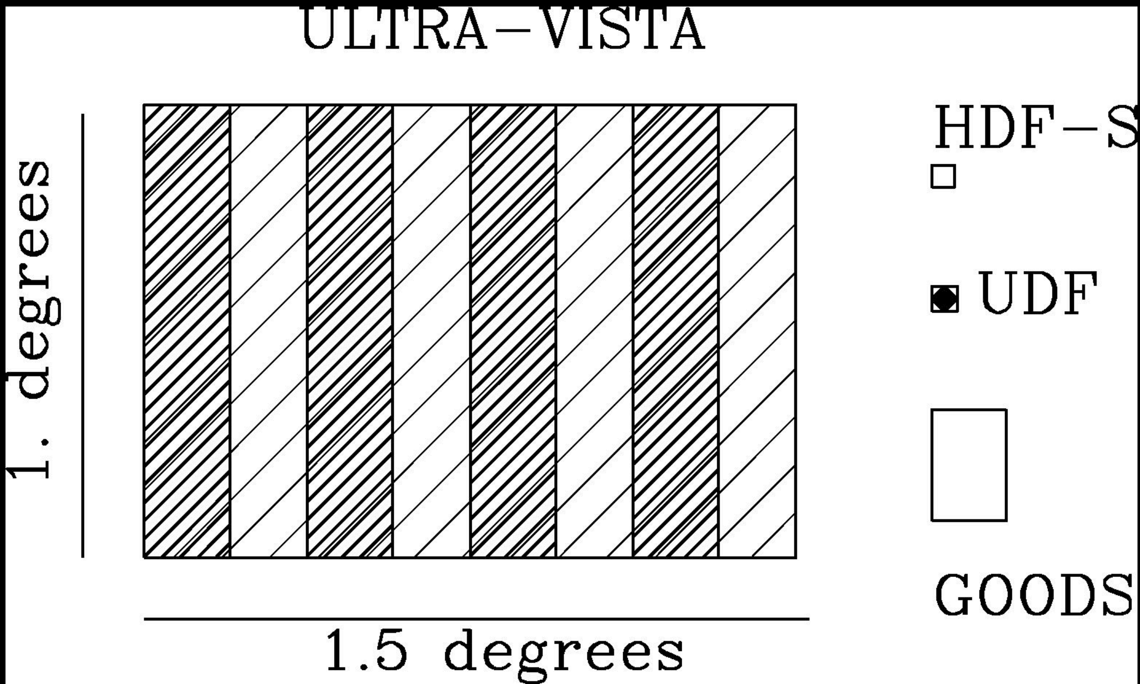


COSMOS Ultra-VISTA

RA = 10 00 28, Dec = +02 12 21

Ultra-Vista – new public survey with Vista telescope

- PIs Dunlop, Franx, Le Fevre, Fynbo
- 0.9 sq deg, in COSMOS / CFHTLS D2, Y=26.7, J=26.6, H=26.1, K=25.6
- Narrow-band survey at z = 8.8
- shallower survey covering full 1.5 sq. deg
- 1800 hr over 5 years – expect commence Jan 2010



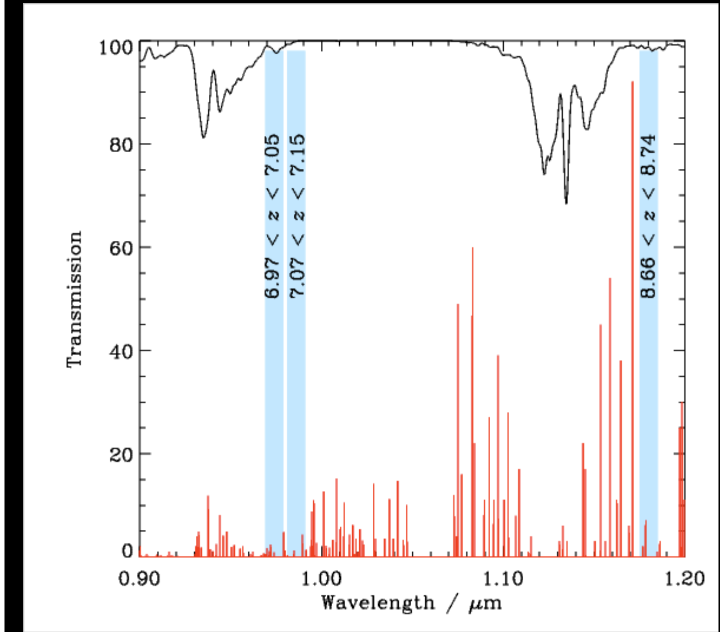
Predicted Numbers of LBGs:

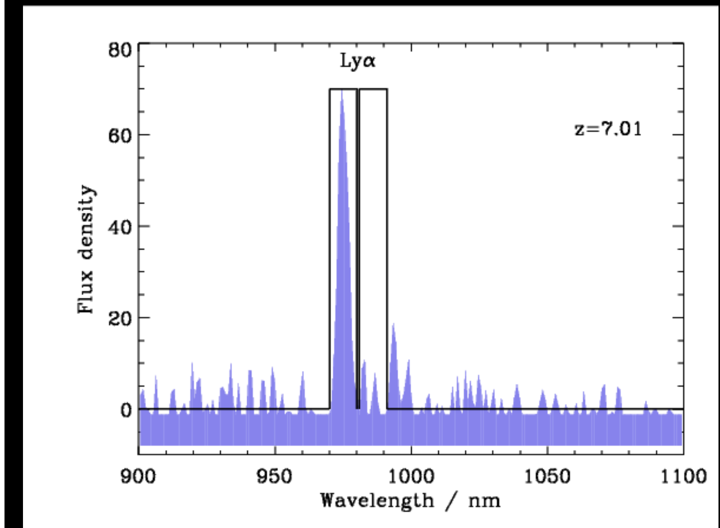
~ 400 Y-drops at z~7.5
~ 200 J-drops at z~8.5

Clear that 100s of “plausible” candidates will require NIR spectroscopy

VISTA narrow-band search for z~7 galaxies

(either LASER or LAGER survey; Herts, Oxford, Edinburgh, Liverpool)





- Find the first large sample of galaxies within the epoch of reionisation (expect 50-200 in GT)
- Determine their luminosity function and clustering properties
- Ideal candidates for integral-field spectroscopy with SWIFT and E-ELT in the future.
- Also measure the properties of [OII] and Hα emitting galaxies at lower redshifts.
- Current plan is to target UDS+COSMOS
- HR FMOS observations could confirm asymmetry of Lyα line, and exclude interlopers

Summary

- Rapid progress being made on the evolution of massive, "red" galaxies at $z>1$
- However, red optical spectroscopy struggles to reach the true red population
- FMOS set to make big impact in $1<z<3$ red galaxy studies
- Several wide-field, ground-based studies of LAEs at $7<z<9$ are imminent
- FMOS ideal for confirming Lyα assymetry and excluding interlopers