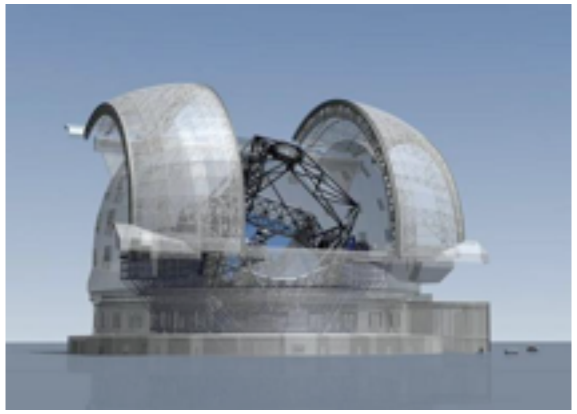


‘First light’: Detection and characterization of high redshift galaxies with E-ELT and EAGLE

Niraj Welikala

(Laboratoire d’Astrophysique de Marseille)

Jean-Gabriel Cuby (LAM), Mark Swinbank (Durham), Johan Richard (Durham), Simon Morris (Durham), Mathieu Puech (GEPI), Matthew Lehnert (GEPI), Chris Evans (Edinburgh), Jean-Paul Kneib (LAM) and the EAGLE team

JWST and the ELTs: An Ideal Combination, April 14, ESO

The EAGLE Science Case

- Wide-field multi IFU NIR spectrograph, with AO system
- EAGLE addressed some of the most prominent science cases of the E-ELT:
- **1. Spatially resolved properties of distant galaxies**
- **2. First light - The Highest Redshift Galaxies**
- **3. Physics of galaxy evolution from stellar archeology**
- Very strong synergy with JWST and ALMA.

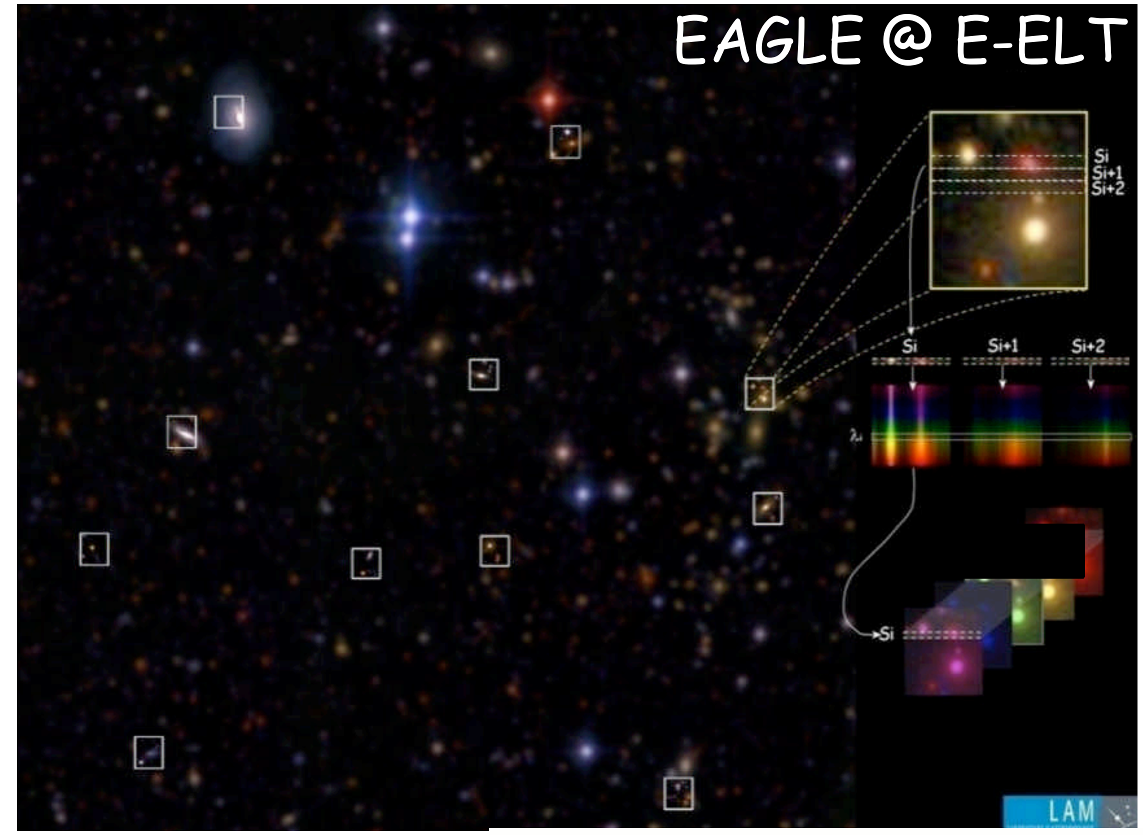
JWST versus ELTs in Spectroscopy:

Spectroscopy: Continuum & line sensitivities in 10^5 secs at SNR=5, R~3000-4000

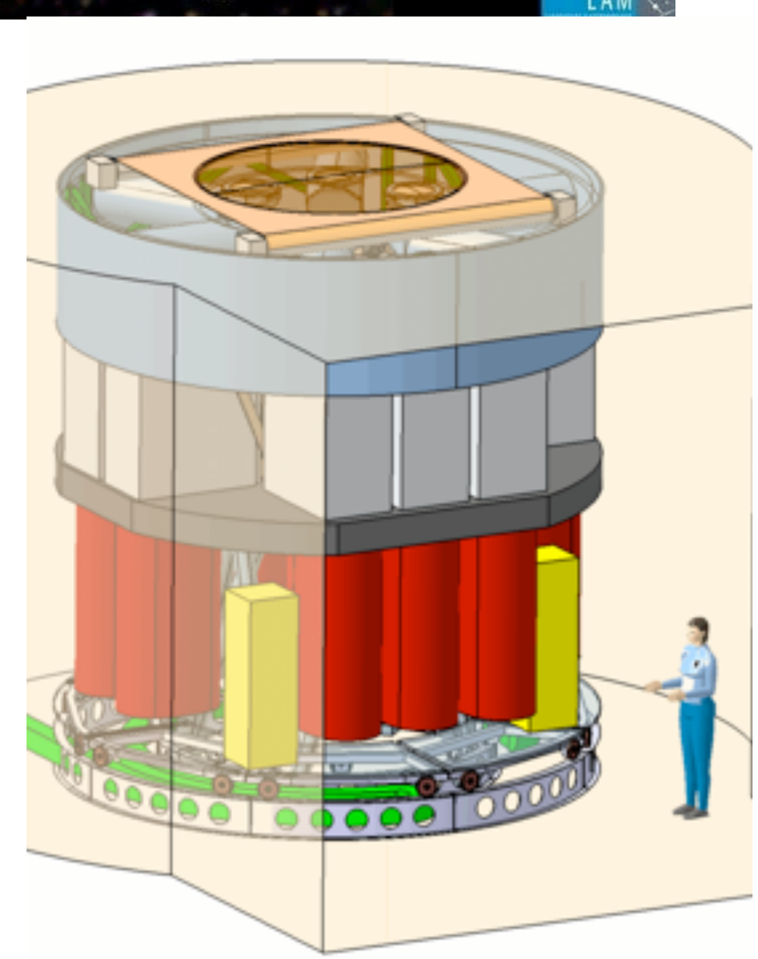
	Continuum (AB mag)	Line (ergs/s/cm^2)	Aperture
JWST(NIRSpec)	24.5	4.0×10^{-19}	0.2” x 0.4”
ELT (MCAO/ MOAO)	27.0	5.0×10^{-20}	0.15” x 0.15”

EAGLE Science Requirements

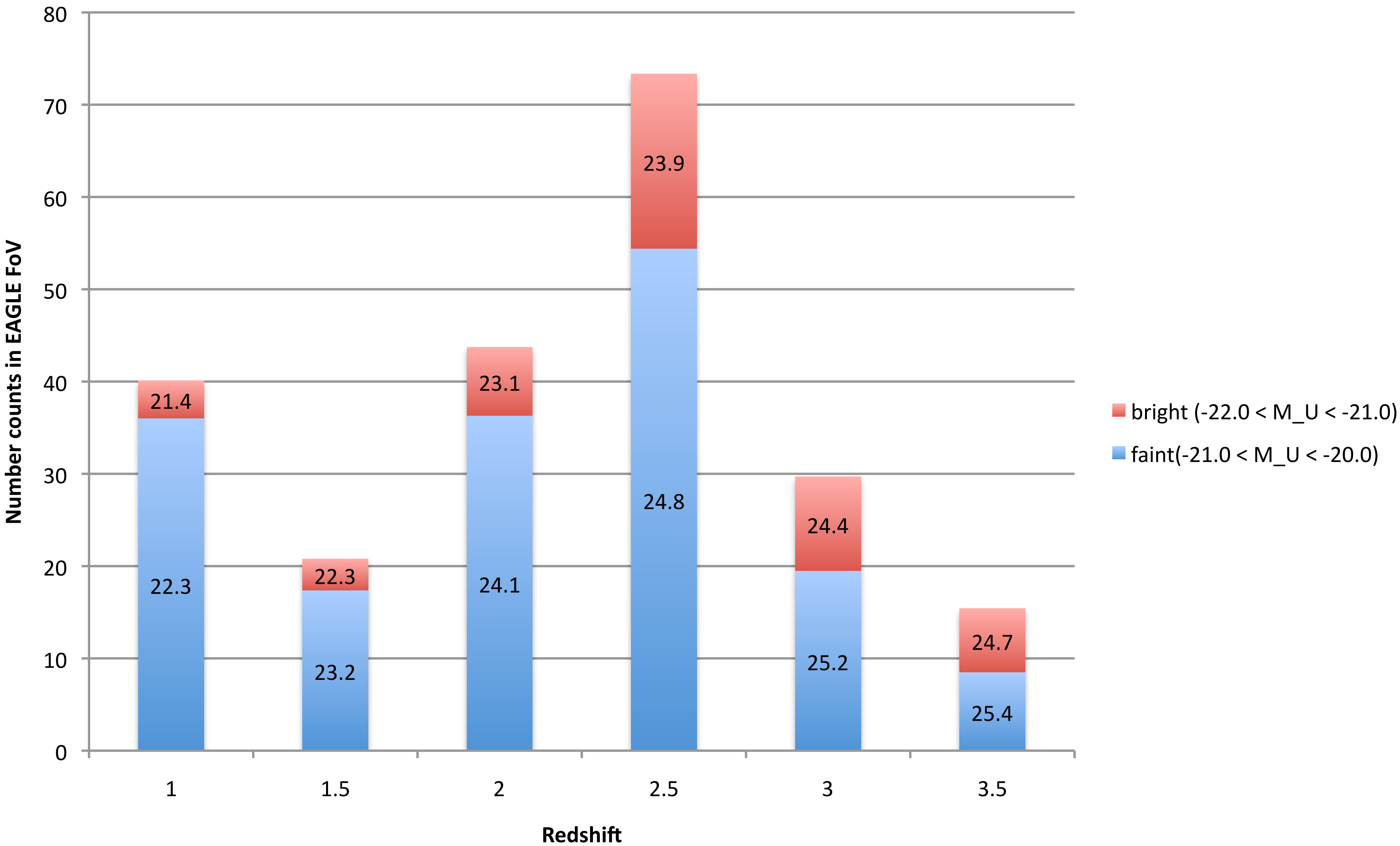
Parameter	Requirement
Patrol field	>5' diameter
Science (IFU) sub-field	1.65"X1.65"
Multiplex	20
Spatial resolution	>30% EE in 75mas
Spectral resolving power	4,000 & 10,000
Wavelength coverage	0.8 - 2.45 μm
Instrument modes	1. Distributed & clustered targets 2. maps contingous regions



Deployable near-IR multi-IFU in ~40 sq. arcminute FoV, assisted by adaptive optics (MOAO, 6 LGS, 5 NGS). Each science field AO-corrected and partitioned into 44 identical slices at input focal plane



Number counts of star-forming galaxies in 1<z<4 and the EAGLE multiplex



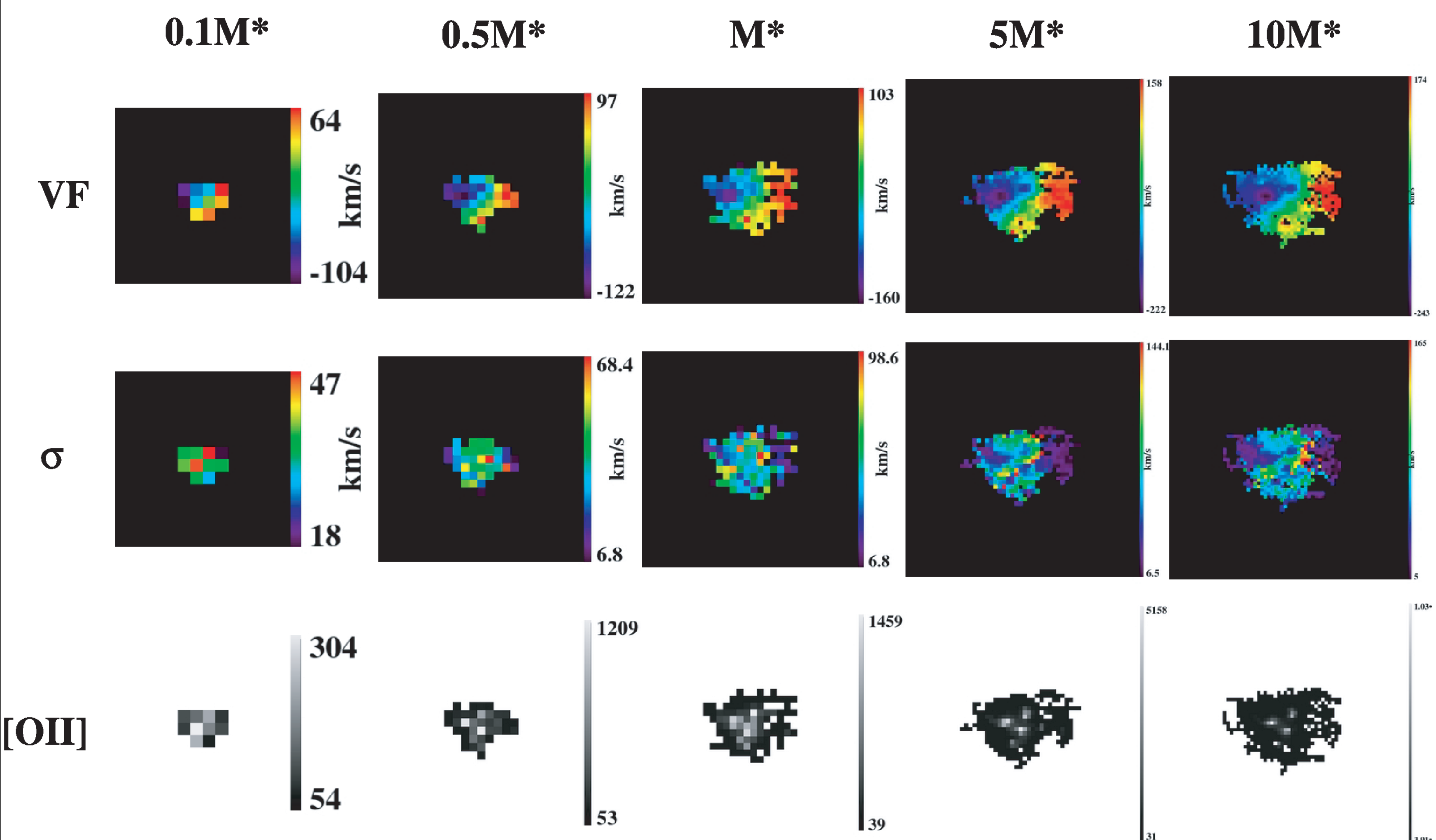
COSMOS galaxies (photometric) - selecting blue galaxies with M_{AB}(NUV) - M_{AB}(r') < 3.5, and I_{AB} < 26. Complete down to M_U<~ -19.0 and z~4

Spectroscopic success rate for emission lines - Hα, [OII[, [OIII] - folded in.

AB mags (J/H/K) marked

Spatially resolved properties of distant galaxies

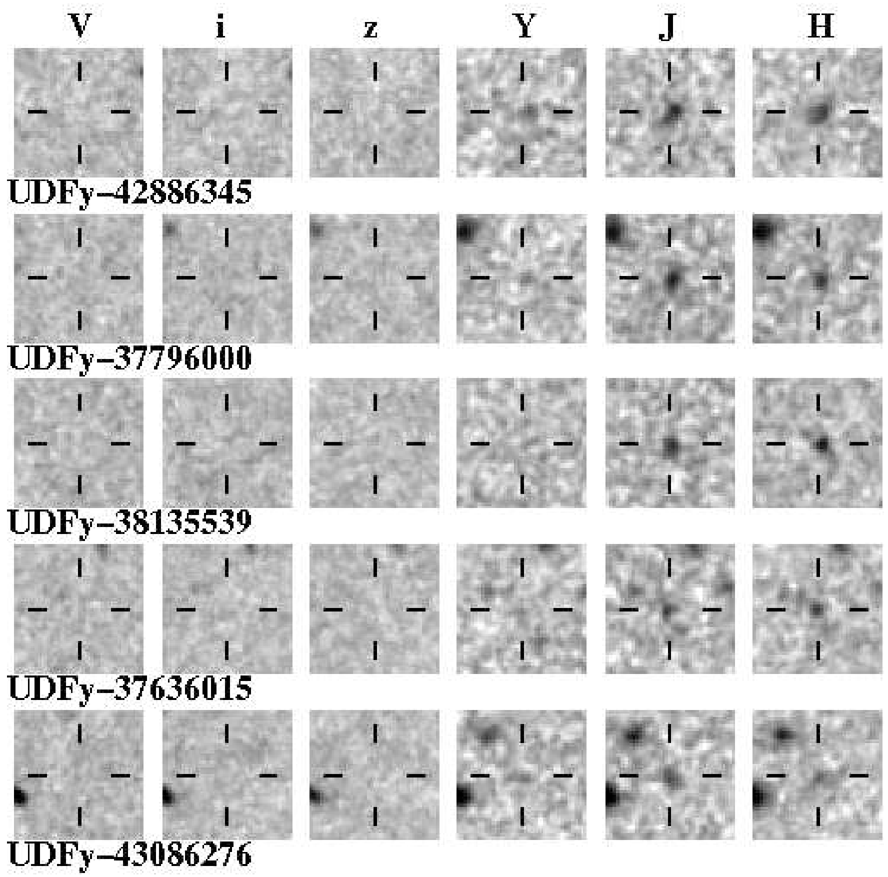
Simulations for z ~ 4 clumpy galaxy for MOAO case

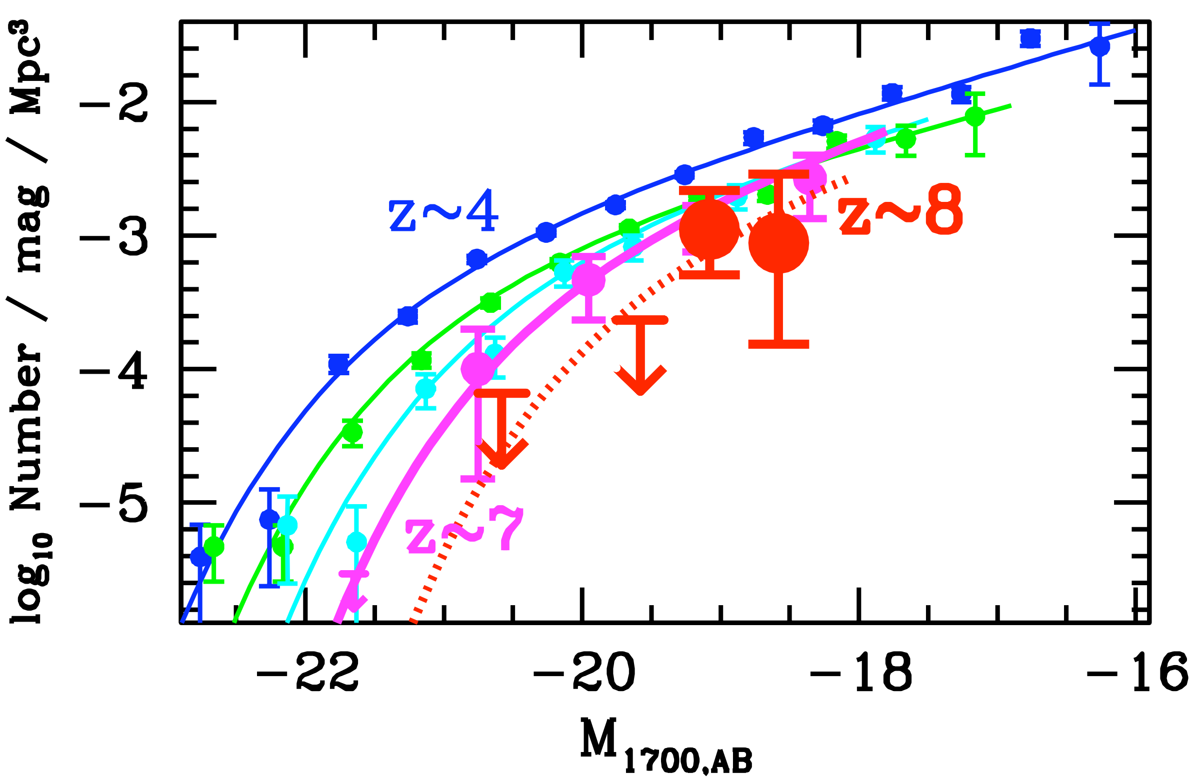


Design Reference Science Plan (DRSP) Proposal:
50-100 nights
200 galaxies in total
3 redshift bins (2,4,5.6)
3 mass bins (0.5 to 5 M*)
Mapping velocity fields & metallicities

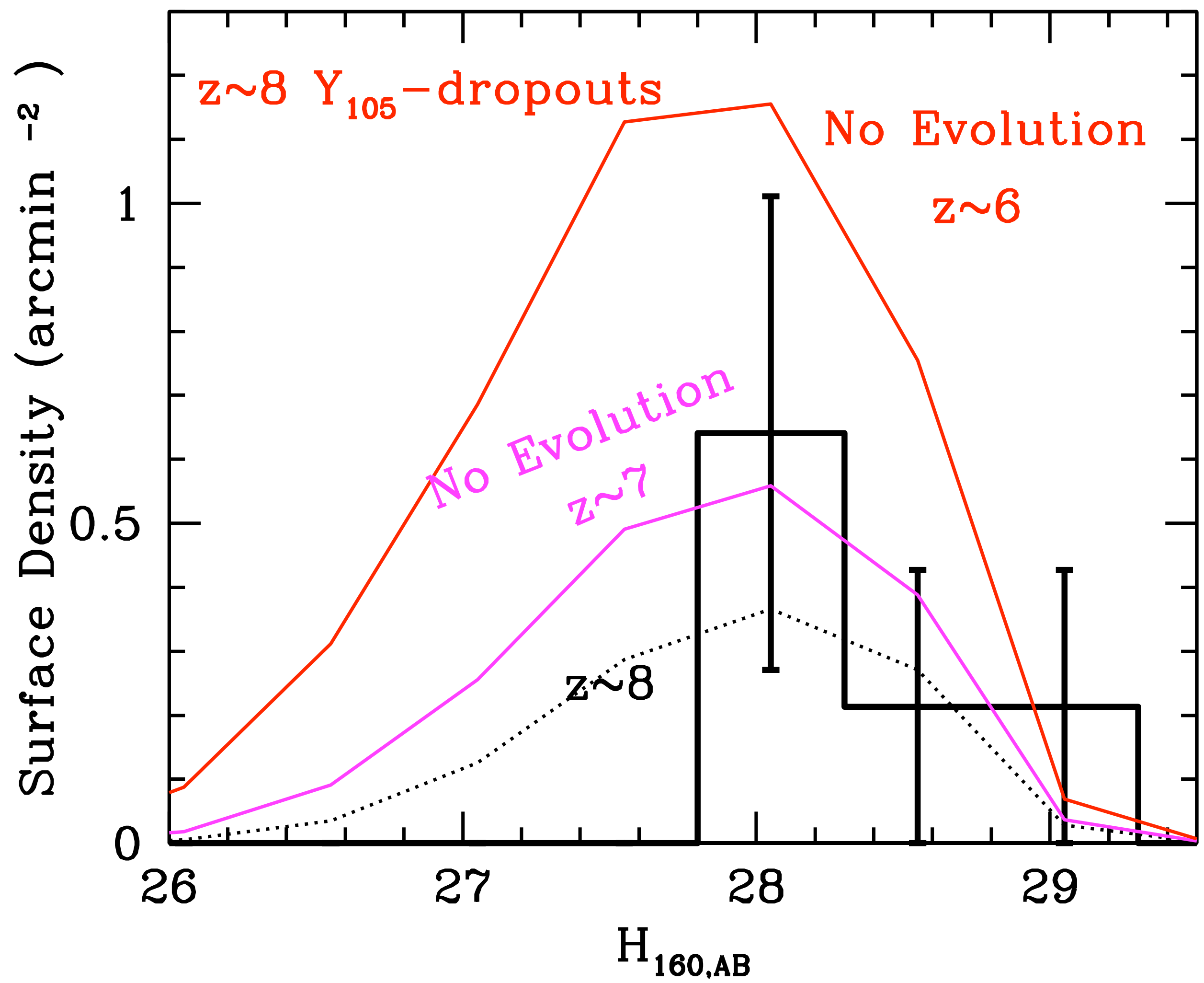
Puech et al. , MNRAS, 2010

First light: the highest redshift galaxies



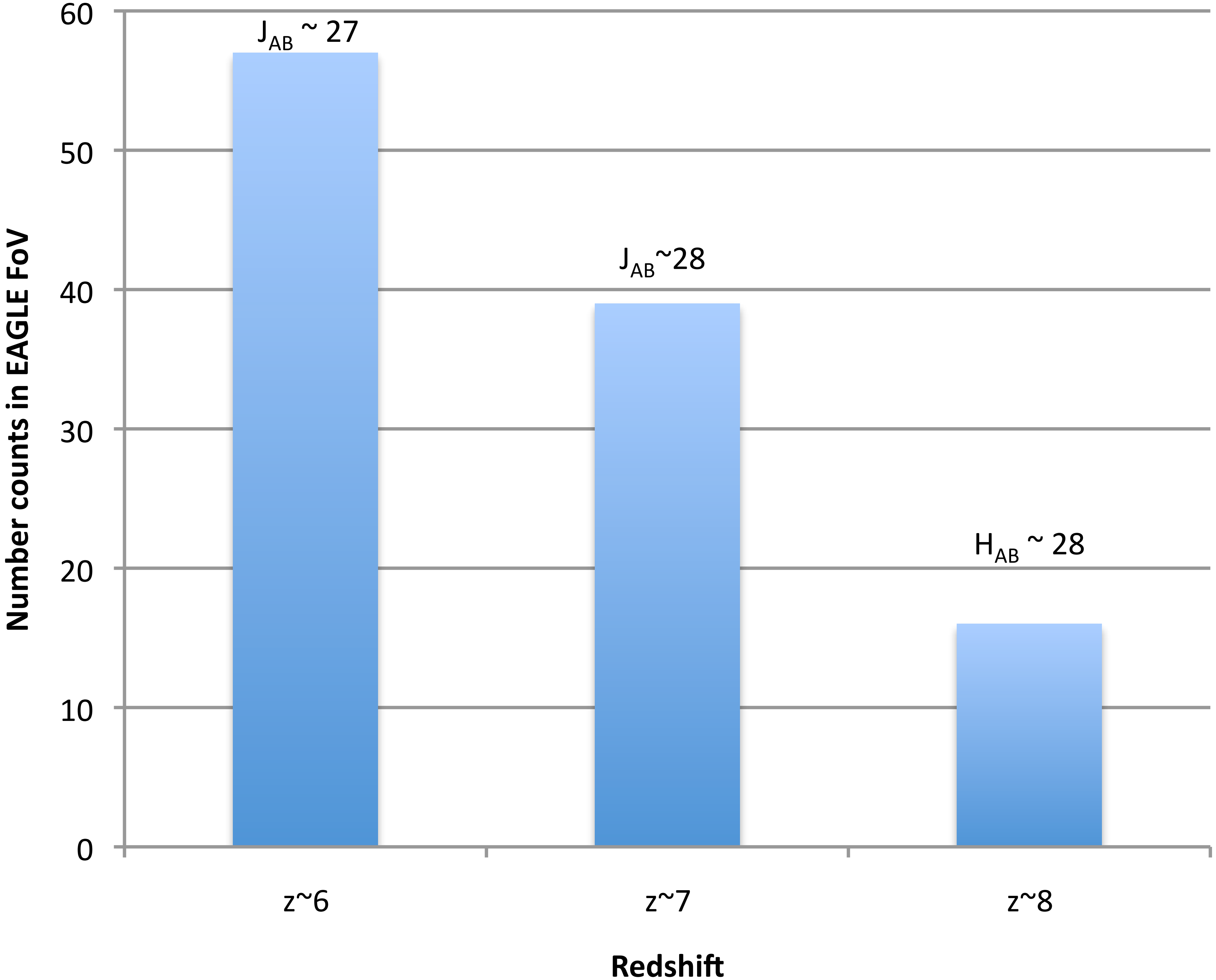


Many recent results from HST/WFC3
~ 1object/sq. arcminute down to
AB=27.5 at z>7
150 mas half light radius



Bouwens et al. 2010, ApJ 709, 133

Estimated target counts (with Lyα emission) at high redshifts (6<z<8)



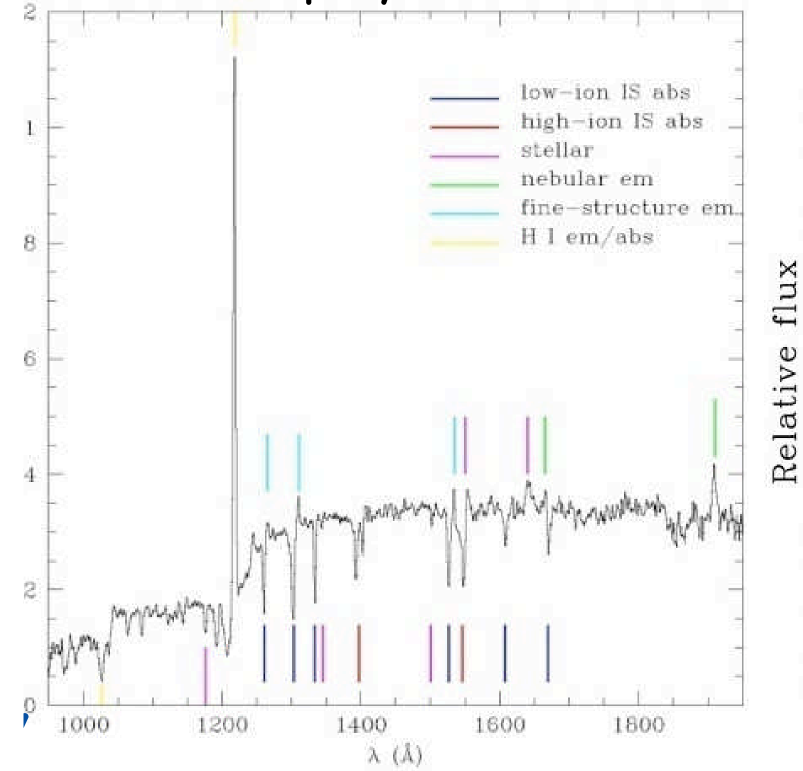
Estimates from surface densities of:
(i) i_{775}-dropouts from Bouwens et al. (2008) at z~6 (HUDF/HST deep fields)
(ii) z_{850}-dropouts from Oesch et al. (2009) at z~7 (WFPC3/HST)
(iii) Y_{105}-dropouts from Bouwens et al. (2010) at z~8 (WFPC3/HST)

Spectrosopic success rate for Lyα emission then folded in.

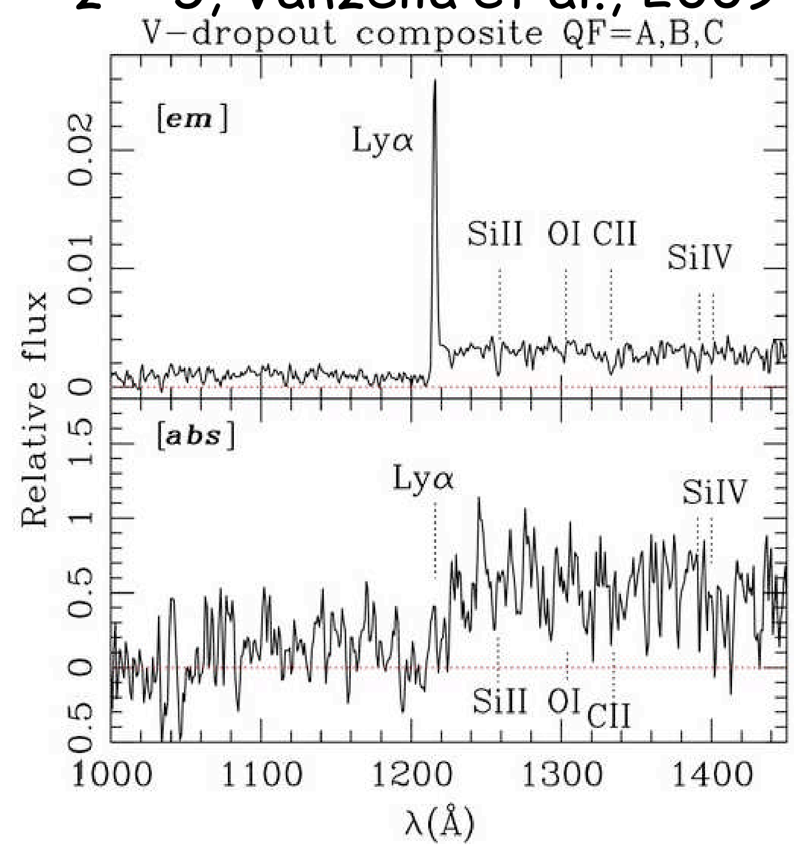
First light: the highest redshift galaxies

- Do at z ~ 8 the z~3 LBG science
- HST/VLT/JWST will provide 100s of targets by 2018-2020
- EAGLE is well suited to this science case and will still be highly topical in the JWST era - needs field, H&K filters, AO correction for sensitivity
- UV continuum spectroscopy of galaxies at z >7 - Dynamical and chemical composition of first galaxies + Reionization of the Universe

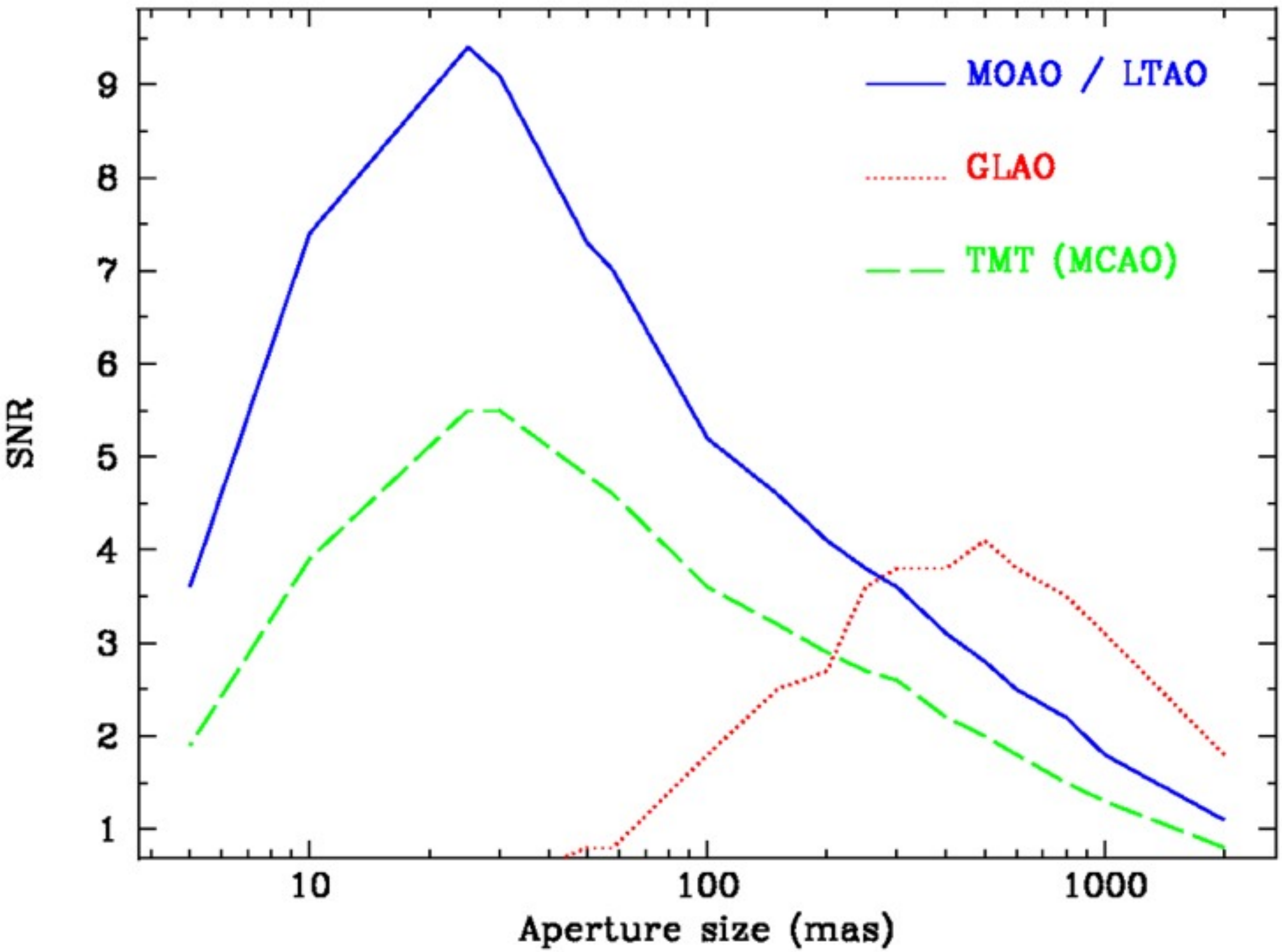
z ~ 3, Shapley et al., 2003



z ~ 5, Vanzella et al., 2009

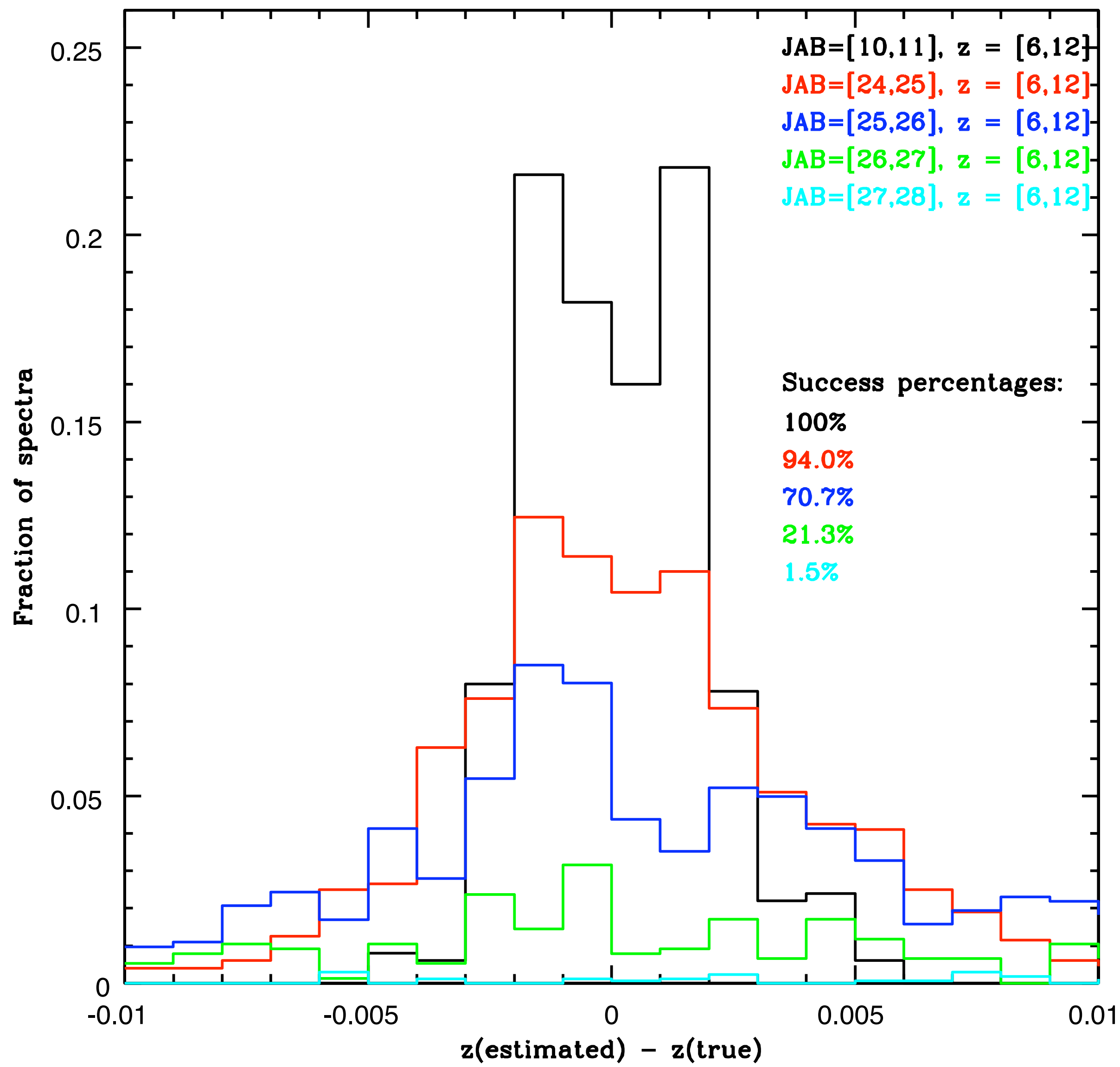


Detecting high-z objects: performance



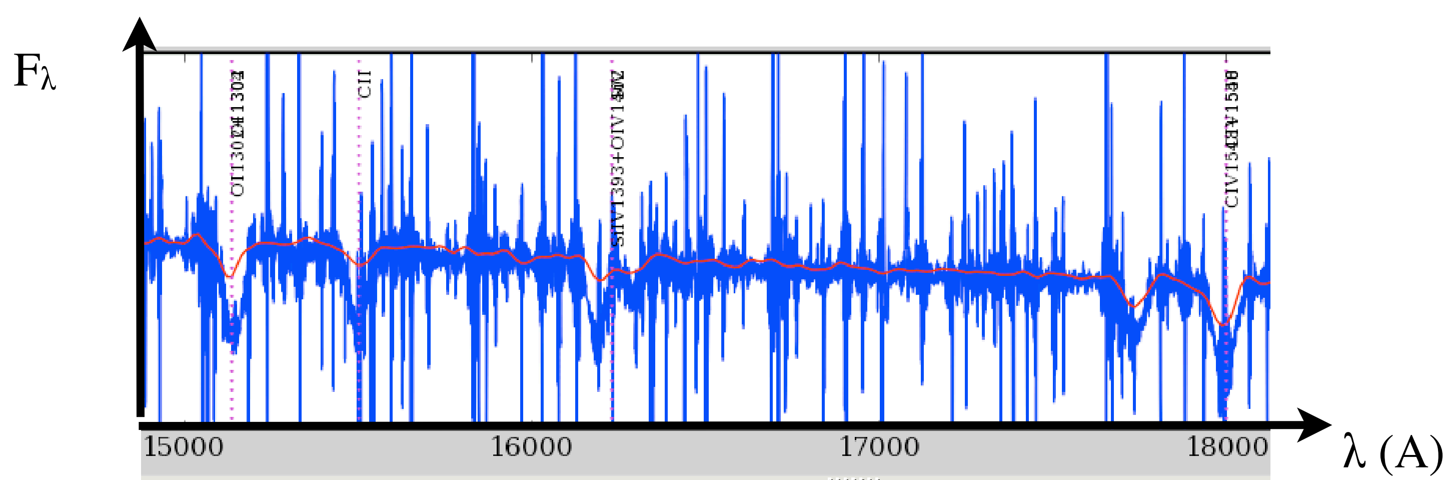
SNR as a function of aperture size, computed for 27 mag (AB) object with 30 hours integration time, split into 30 min intervals

Recovering redshifts and UV spectra of distant galaxies



Automatic redshift finding:
Simulated spectra cross-correlated with high-z galaxy spectrum. Success rate criteria conservative:

Δz=0.01

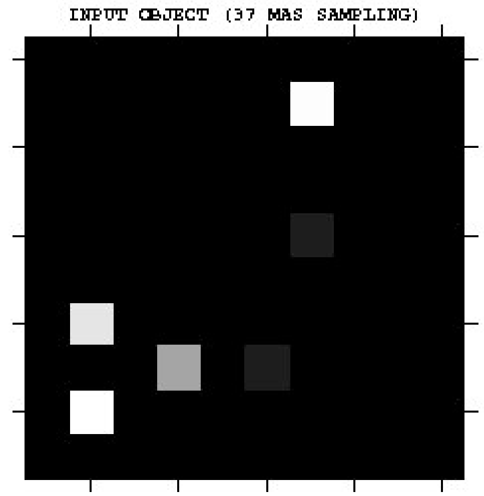


Example simulated spectra (R=4000, integration time = 30 hrs and J_{AB} = 24)

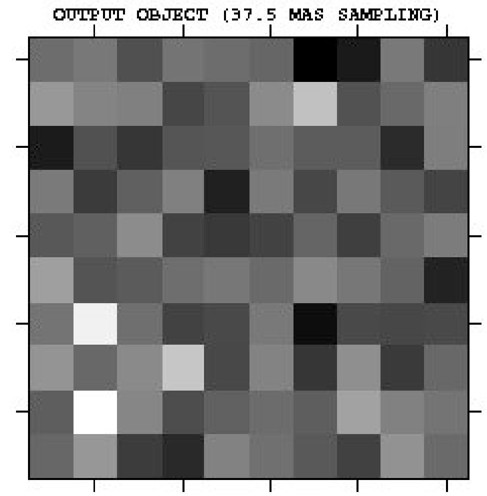
Simulations of a z~7 clumpy galaxy

Total magnitude of object J_{AB} = 27, brightest spot has J_{AB}=28.4. Total integation time = 10^5 secs R=4000

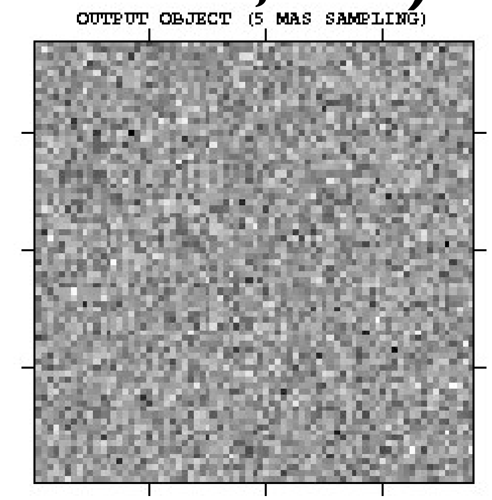
Input object (37.5mas)

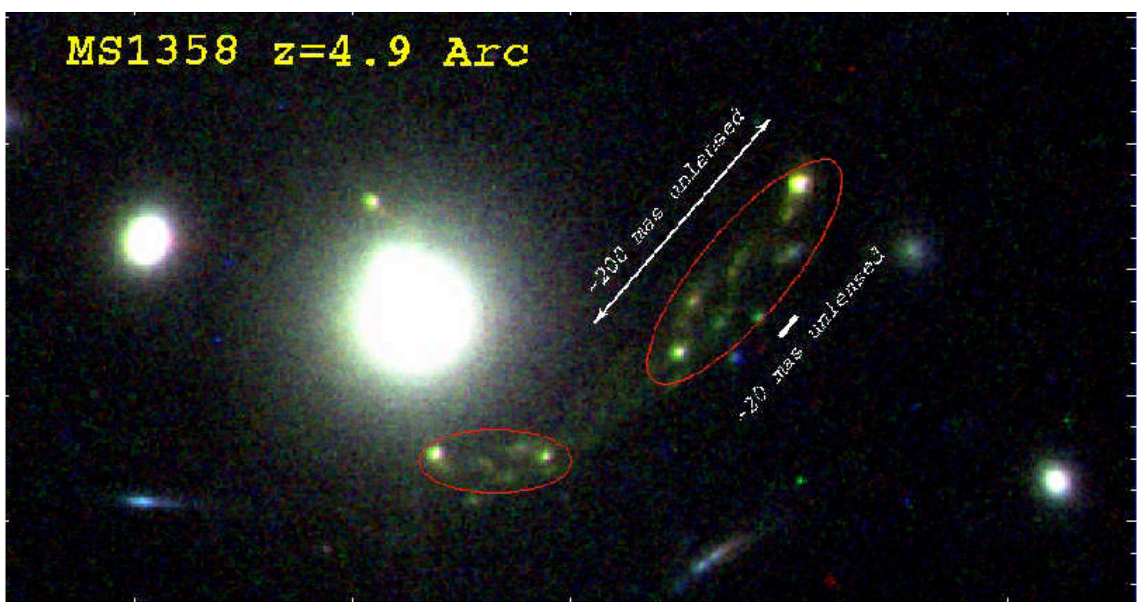


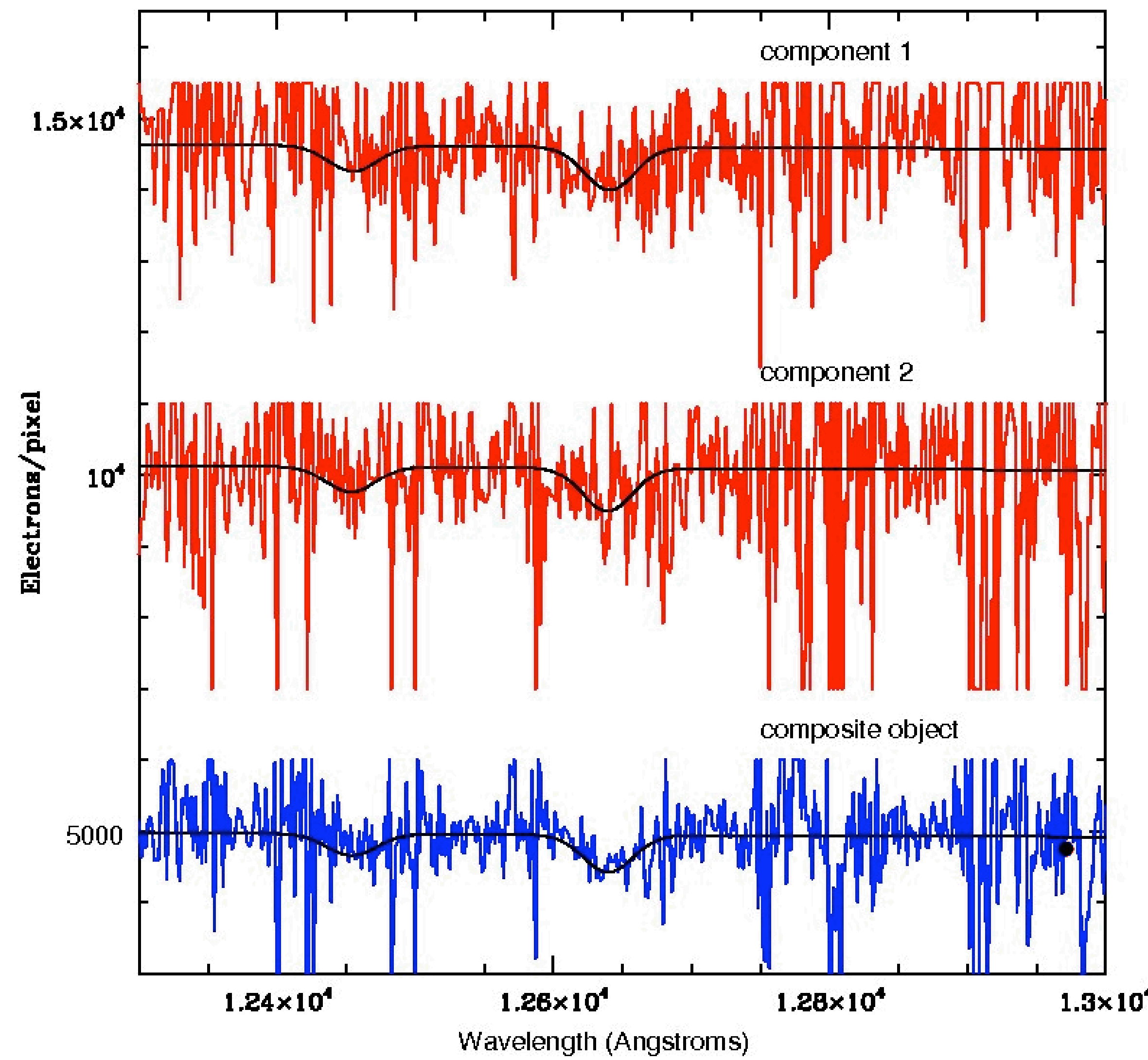
Output (37.5 mas)



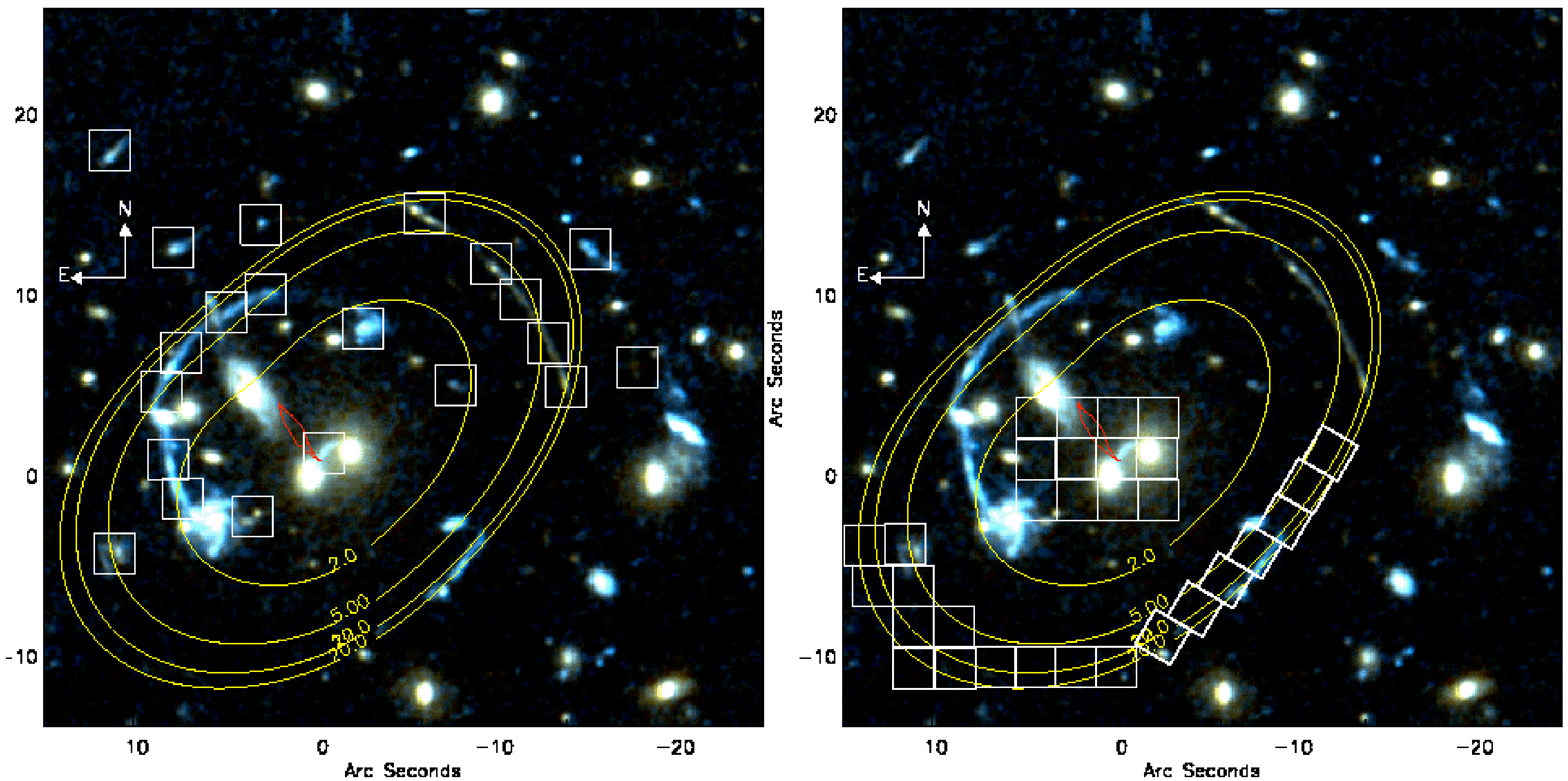
Output (diffraction limit, 5mas)



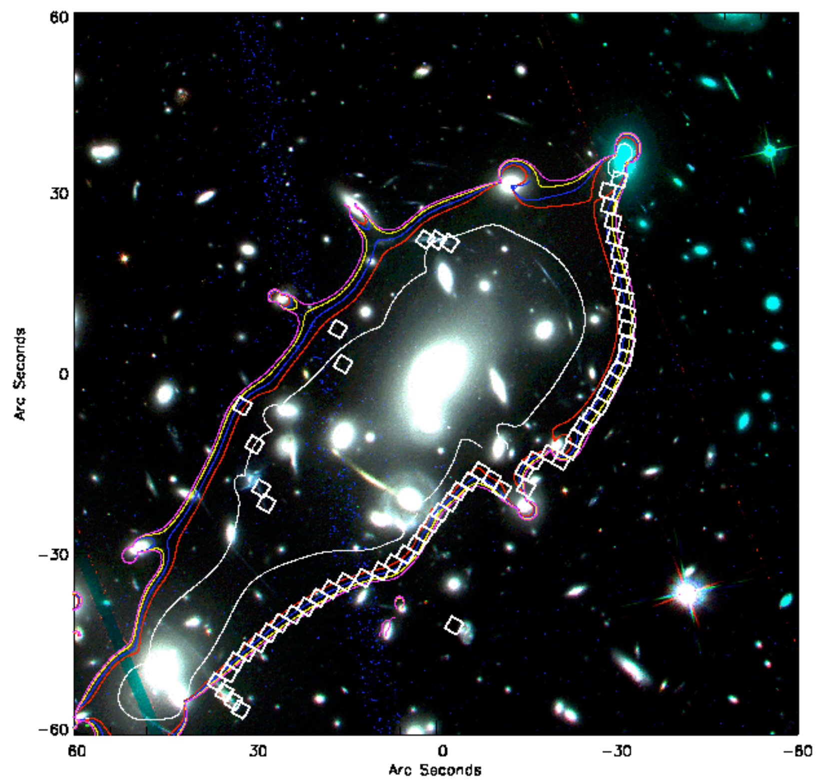




Example galaxy clusters with EAGLE IFU



Mapping out caustic lines + doing blind searches for distant galaxies -> configure IFUs along complex geometries

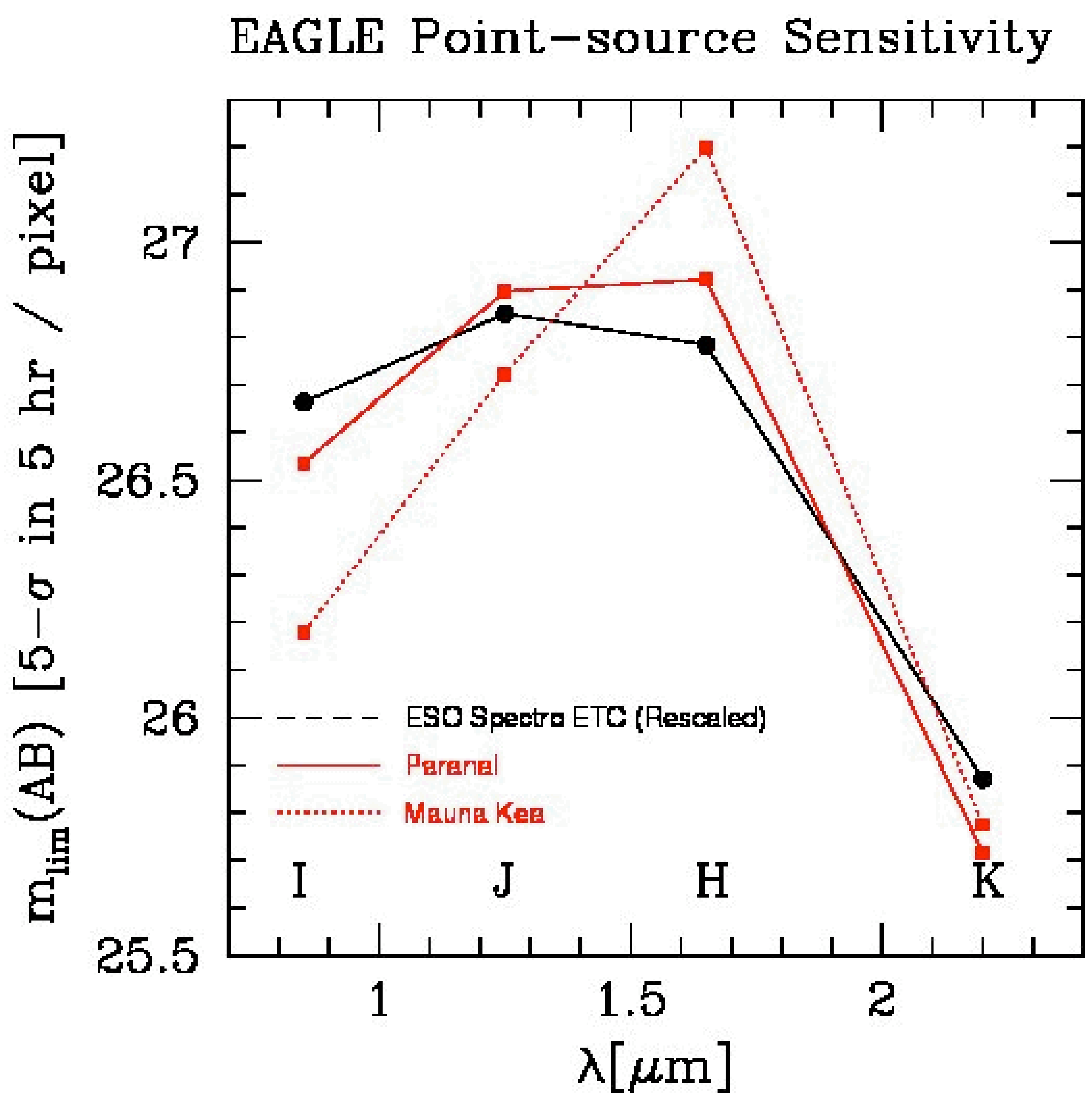


Top: Lensing cluster RCS0224-002 at z=0.76, showing high-z critical curves for z=2,5,10, 20 **Bottom:** Abell 2218 galaxy cluster with IFU footprints on a number of spectroscopically confirmed high-z galaxies (z=1-7) + to map out high-z critical curves

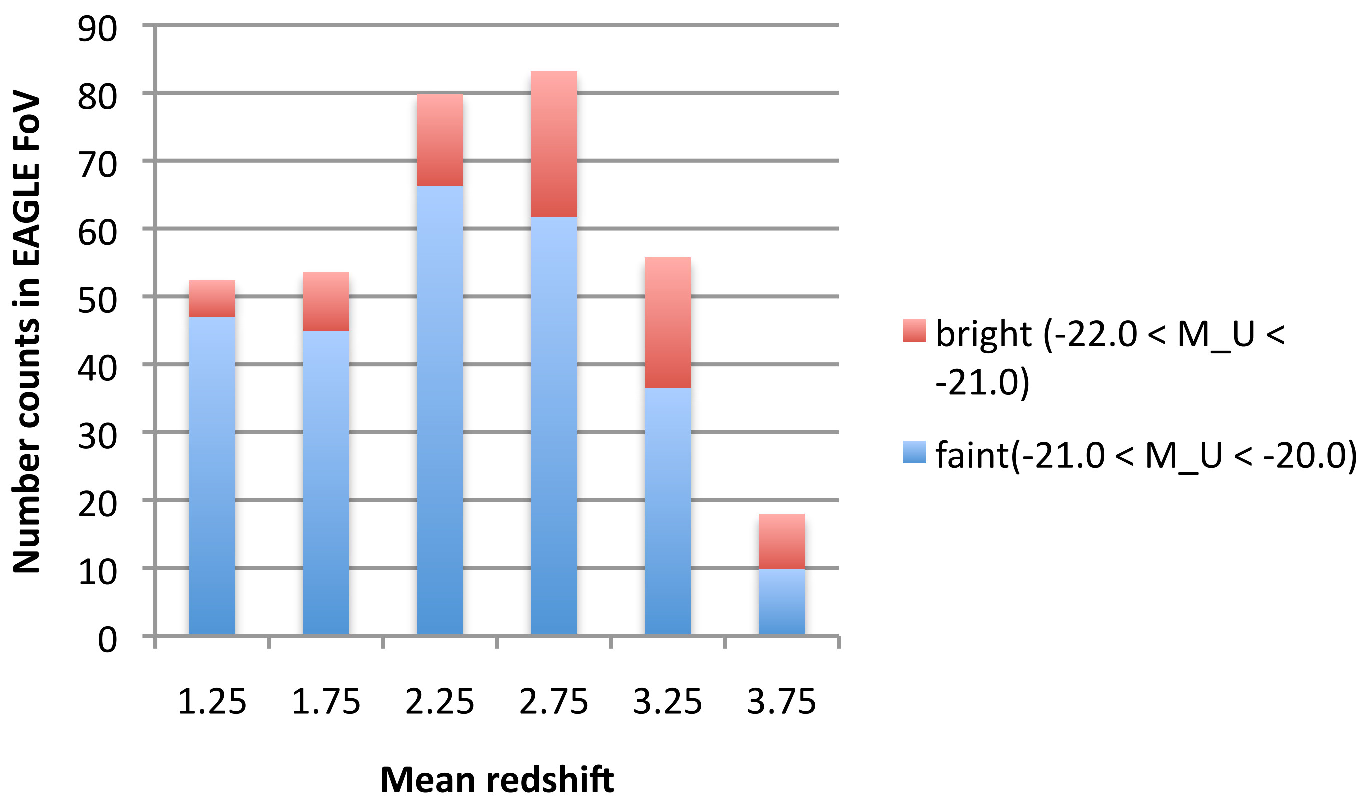
Conclusions

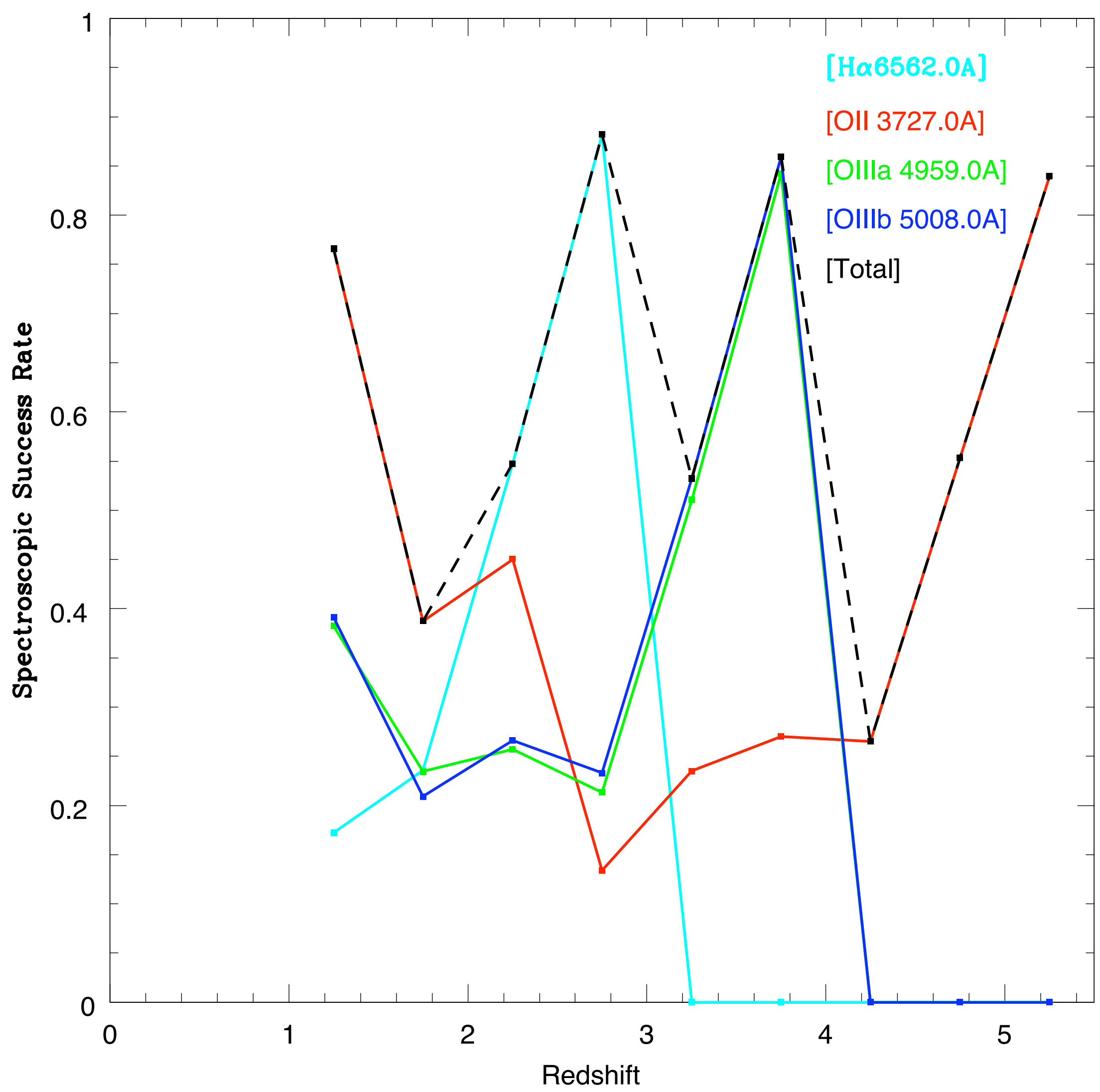
- EAGLE will advance our knowledge of the most outstanding problems in astrophysics: from first galaxies to their physics and evolution.
- Opens a new region of parameter space with its high spatial resolution, high multiplex and moderate spectral resolution
- JWST has advantage in discovering distant galaxies, getting their redshfits and constraining stellar populations through UV/blue continuum shape
- EAGLE will resolve their individual components, determine if they are common halo objects/mergers, properties of hot ISM through UV absorption lines, estimate outflow rates (from covering fraction and column density of gas)
- **Poster of S. Morris: EAGLE: A MOAO-fed multiple deployable IFU system working in the NIR on the E-ELT**
- **http://eagle.oamp.fr**

ADDITIONAL/REFERENCE SLIDES


EAGLE Point-source Sensitivity
m_{lim}(AB) [5−σ in 5 hr / pixel]
27
26.5
26
25.5
1
1.5
2
λ[μm]
ESO Spectro ETC (Rescaled)
Paranal
Mauna Kea
I
J
H
K

Target and spectroscopic sampling rates in COSMOS galaxies (1<z<4)

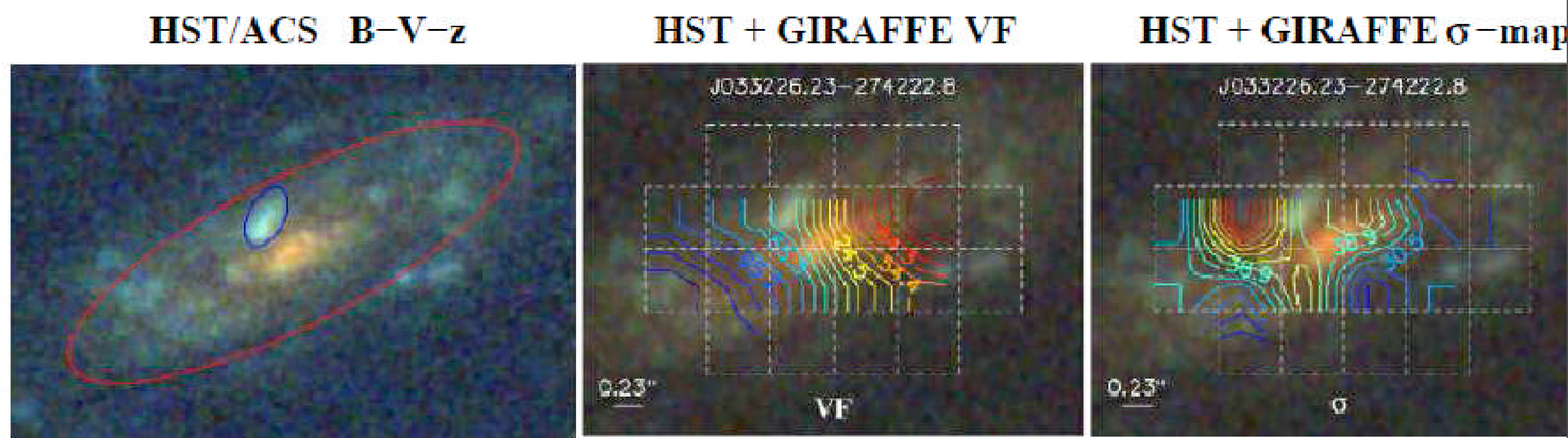


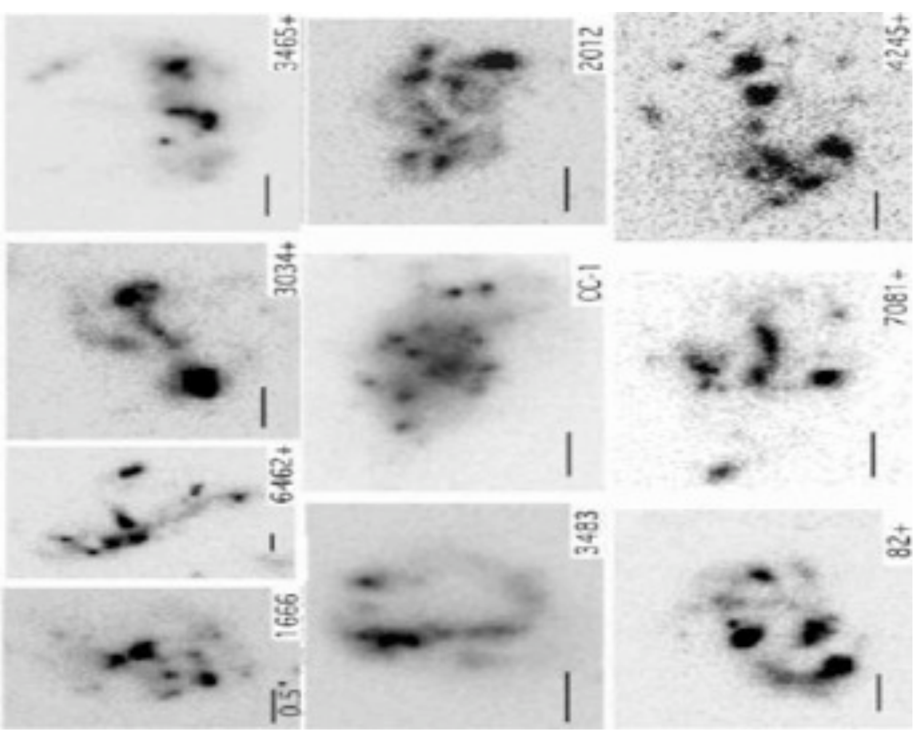


Spatially resolved properties of distant galaxies

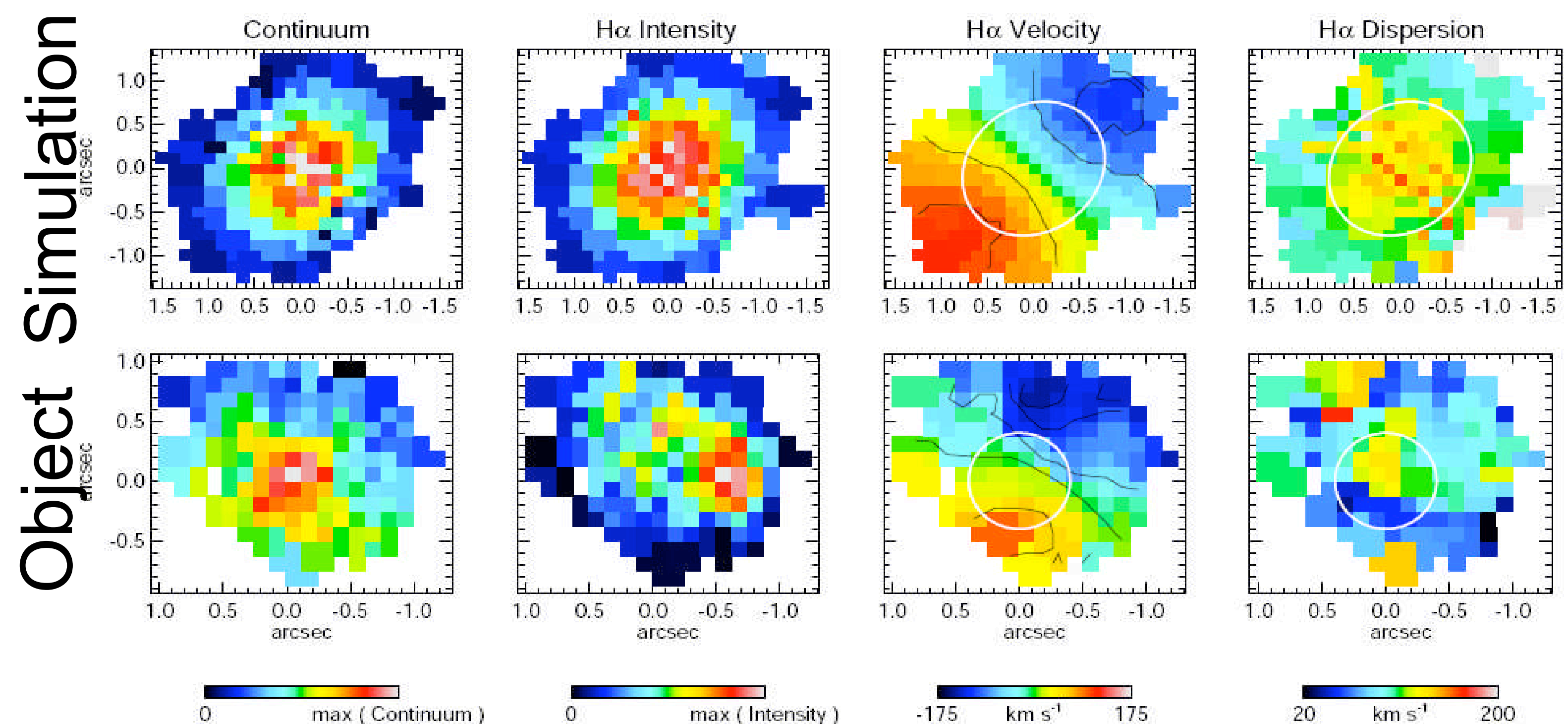
What is the main channel for mass assembly in galaxies in 2<z<6?
Cold gas accretion along filaments?
Major/minor mergers?

FLAMES, z ~ 0.6

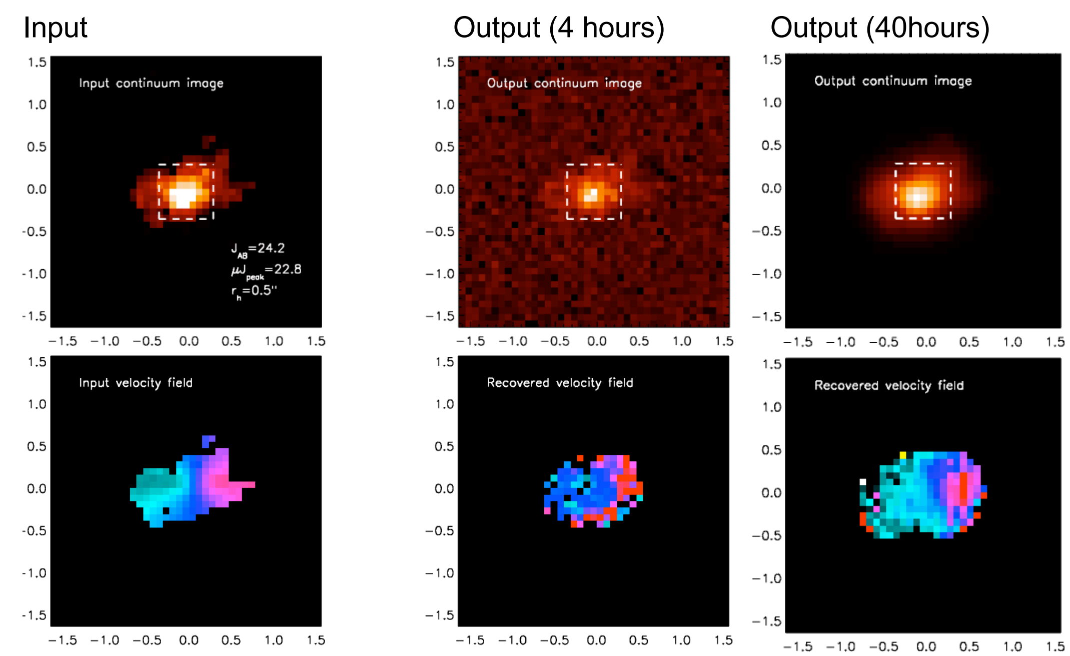




SINFONI, z ~ 2



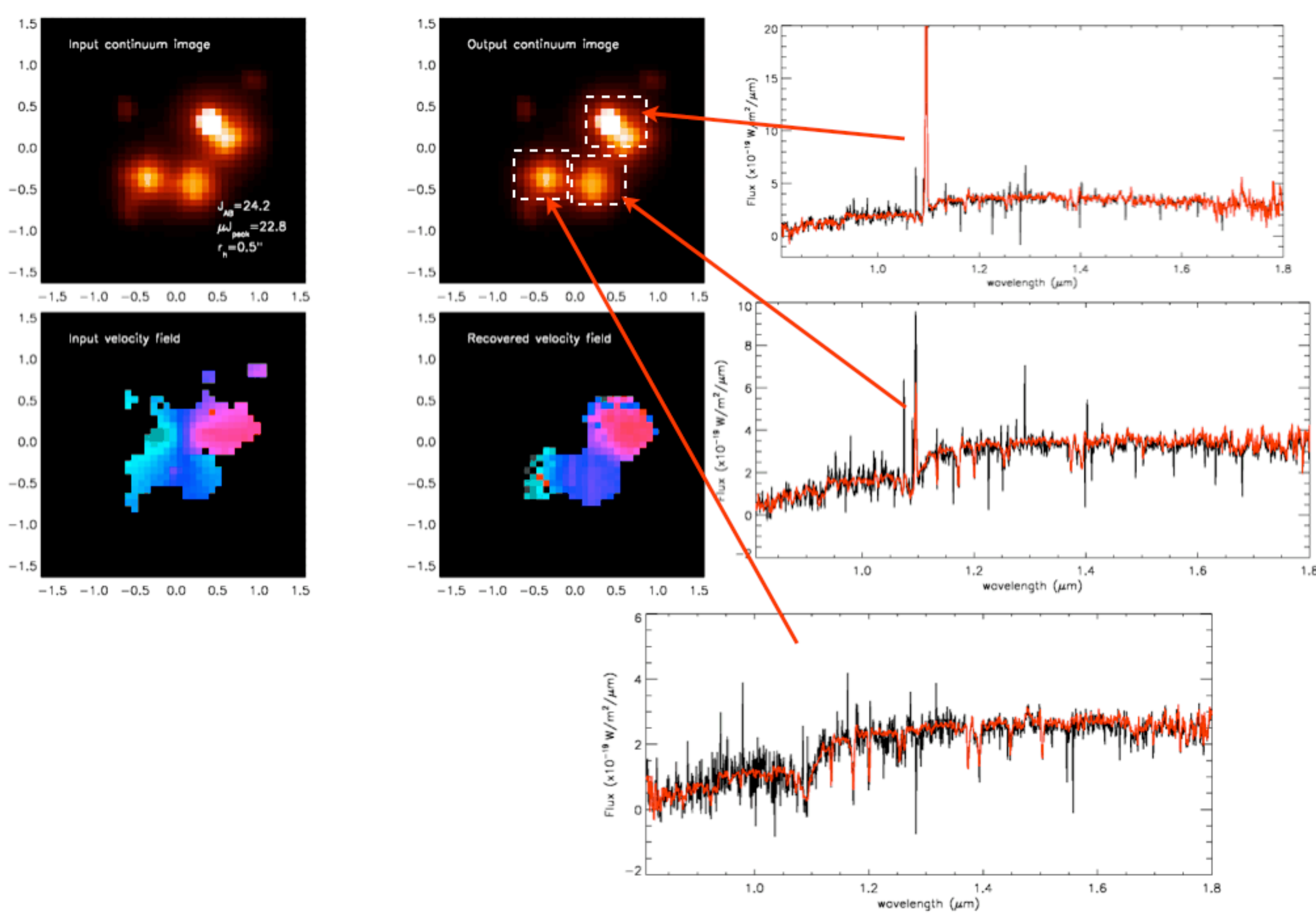
Simulations of multi-component distant galaxies with EAGLE



Examples of brightest galaxies at z~7-8 with JAB~25 as observed within EAGLE IFU

Input: spectroscopically confirmed faint galaxies in HUDF at z=2-4, then redshifted.

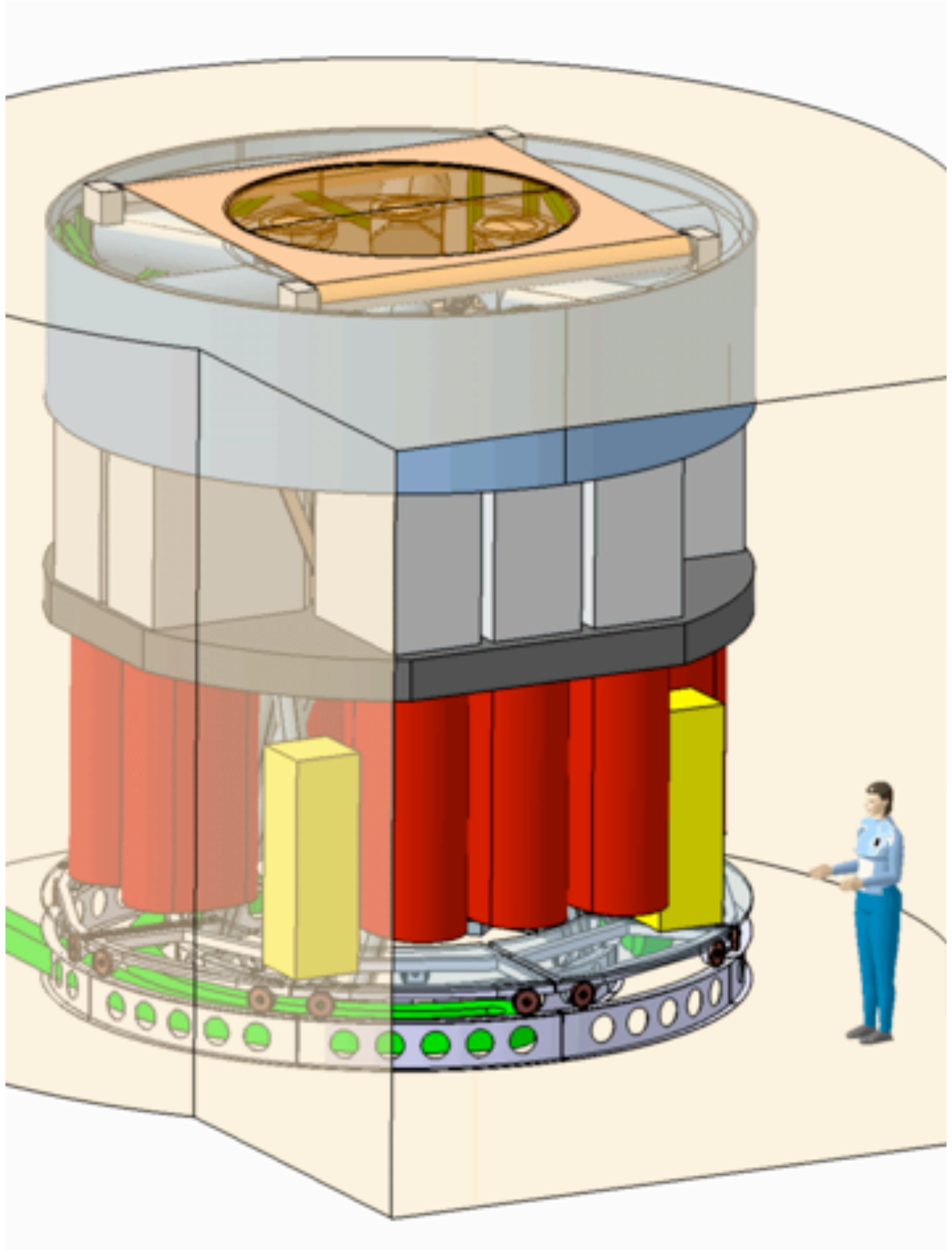
Velocities randomly varied: 100-300 kms-1, with components having velocity offsets of upto 200 kms-1



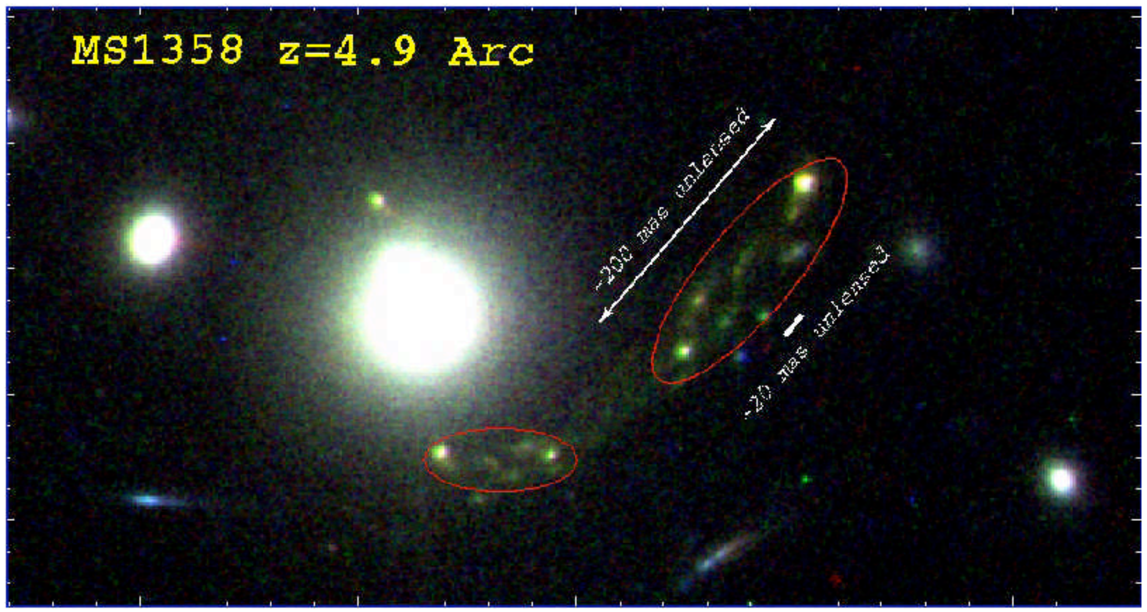
40 hours
object = 0.5" (4 kpc) across

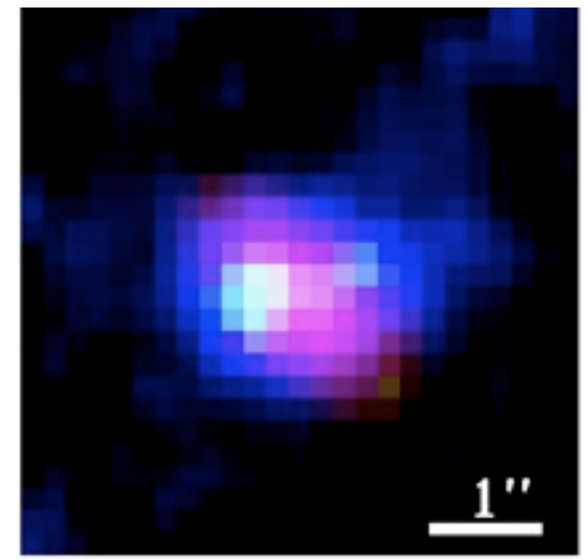
The EAGLE instrument for E-ELT

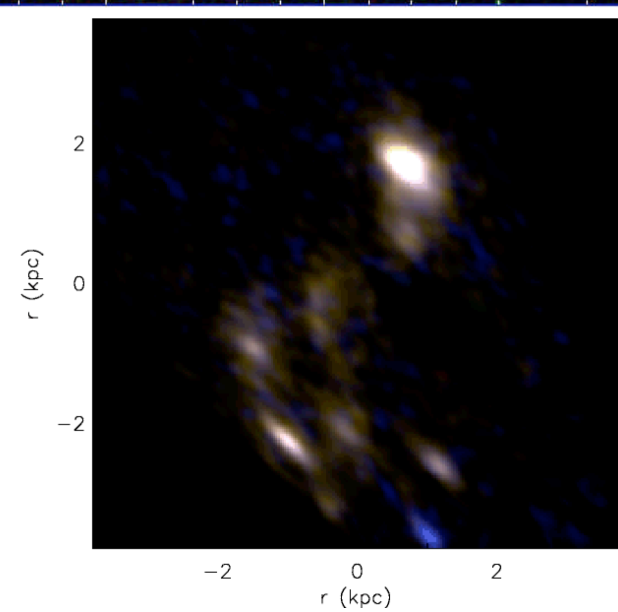
- Wide-field multi IFU NIR (IZ, YJ, H, K) spectrograph, with AO system
- Deployed in Gravity Invariant Focal Station
- Can observe 20 science targets simultaneously
- The 20 science fields are AO-corrected by deformable mirrors and partitioned into 44 identical slices at the input focal plane of spectrograph entrance slit
- Each slice dispersed along spatial direction of slit (2 pixels, 37mas) and presented to one half of a 4KX4K detector -> 44X44 spatial partitioning for each science field
- Multi-object adaptive optics (MOAO) topology, 6 LGS, 5 NGS
- 2 primary instrument modes



Examples of lensed galaxy techniques







LAE @ z = 6.5 (Ouchi 2009)

Don't need to go down to diffraction limit - > object unresolved on 8m but magnified (200 mas)

Spatial resolution= 50-100 mas

R ~ 4000 (between OH lines)

FOV= 1", multiplex ~ a few tens

Image of a lensed galaxy at z ~ 5 (Swinbank et al. 2009) amplified by X 12.5 by foreground galaxy cluster MS1358+62. Bottom: unlensed, galaxy is ~ 200 mas in size with some ~ 20 mas components