High-z sources with JWST and ELTs

J.-G. Cuby, N. Welikala, B. Clément, V. Lebrun
Laboratoire d'Astrophysique de Marseille (LAM)

M. Swinbank, J. Richard
University Durham

Outline

- JWST and the ELT projects
- Compared performance
- LAEs with JWST & ELTs

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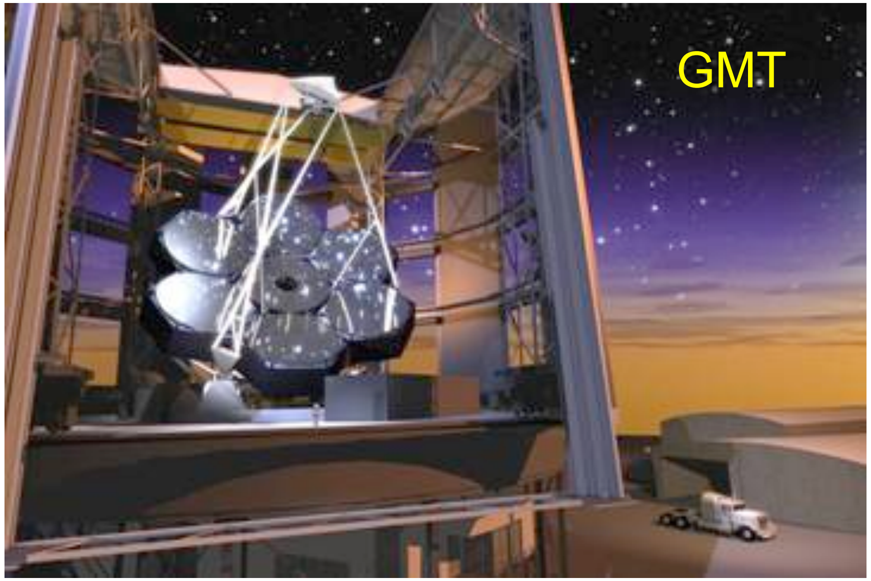
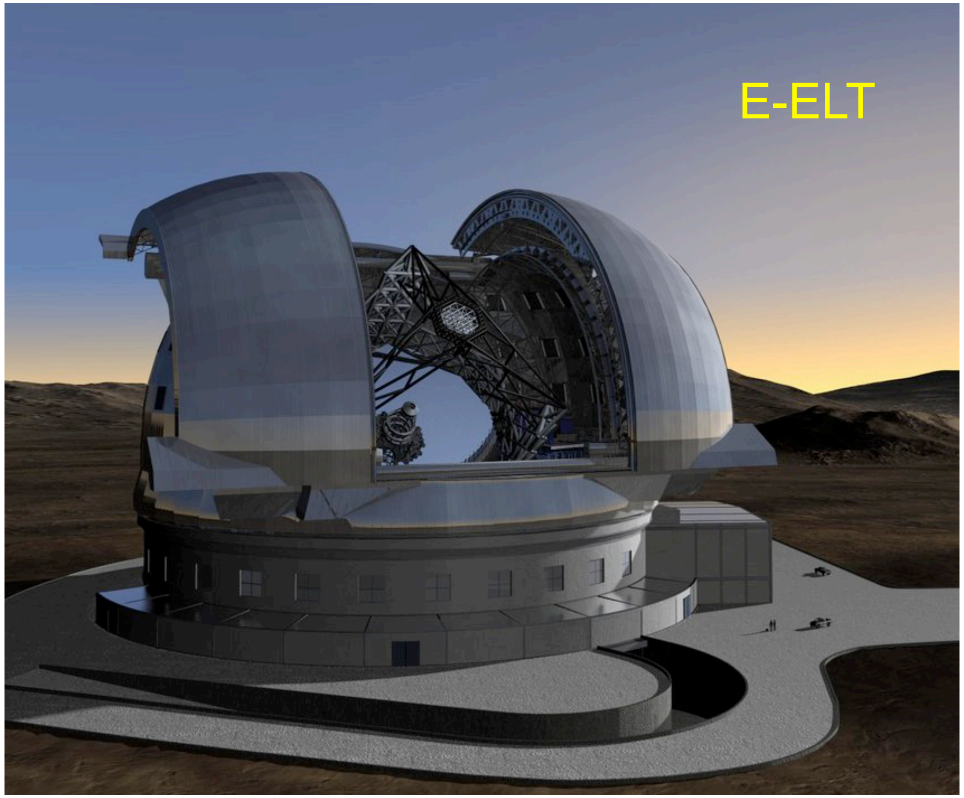
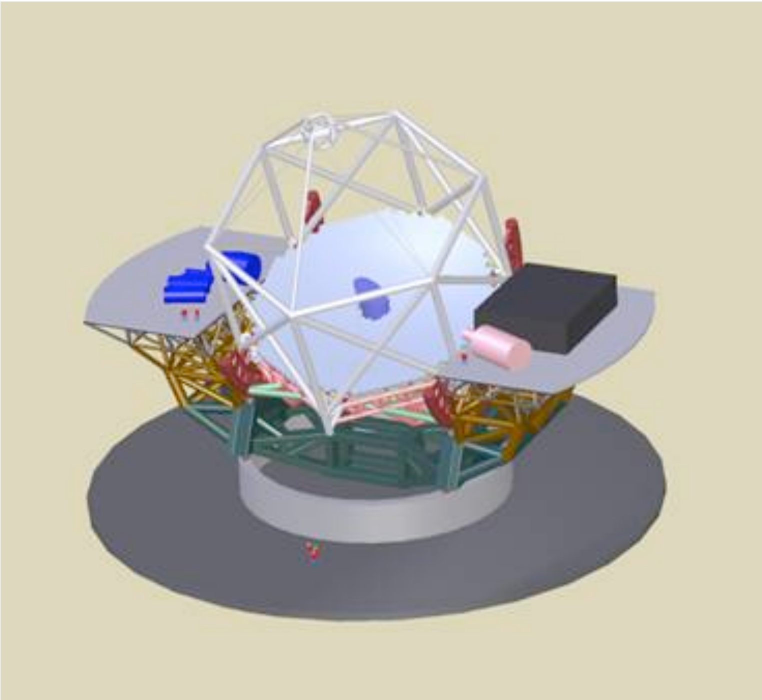
ELTs



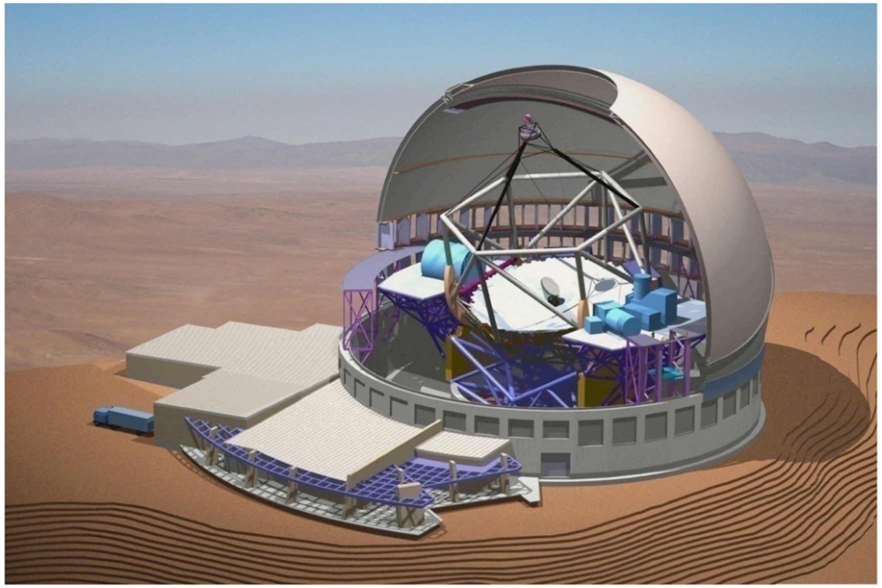
- Common features:
  - Looking for a site (TMT & E-ELT)
  - ... and funding (all)



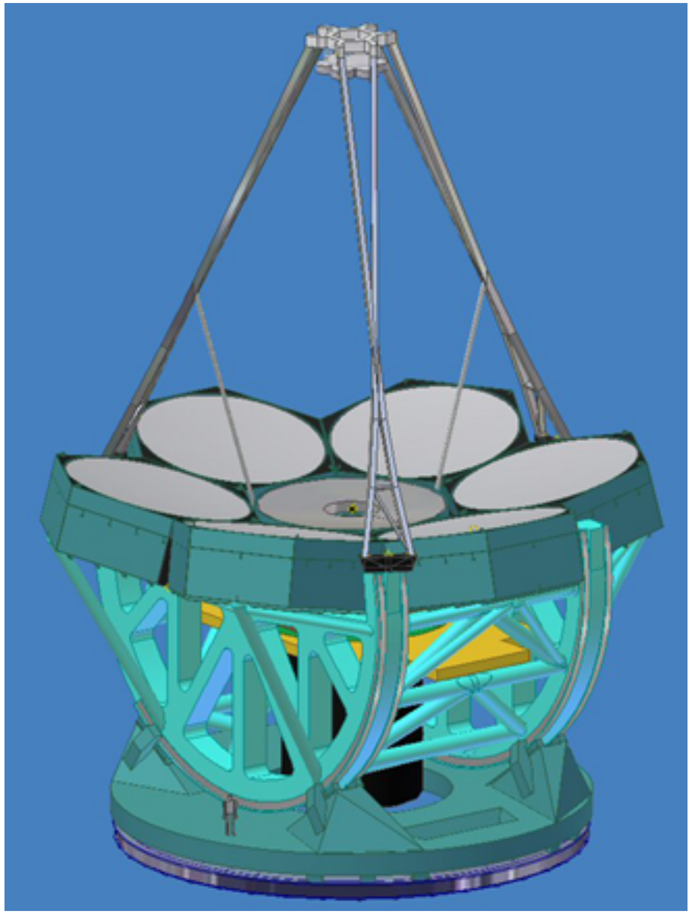
TMT

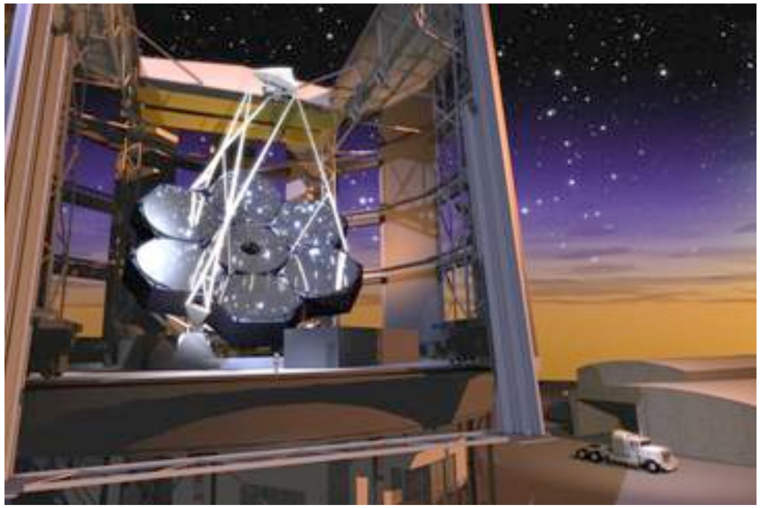


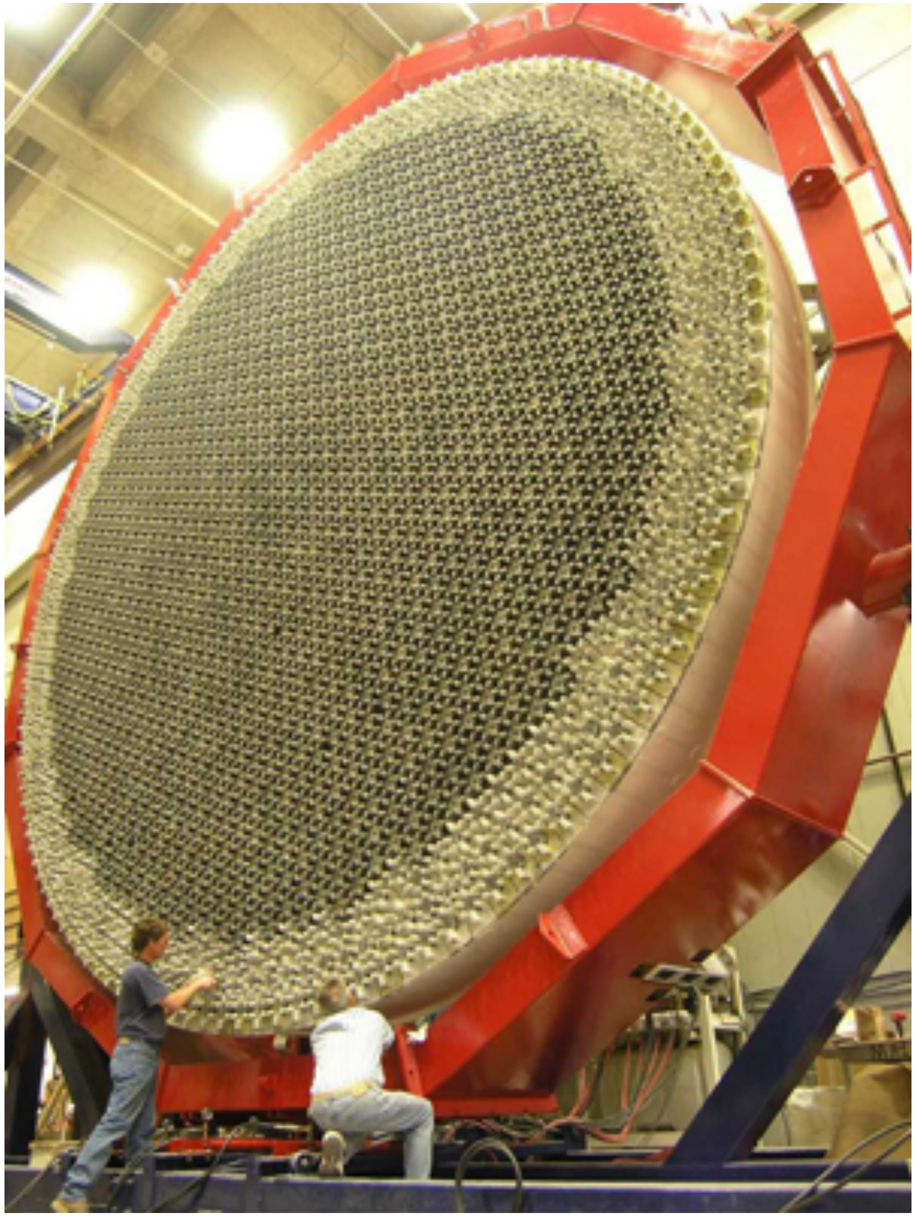
- Caltech + U. of California + Canada +
  - Moore foundation, Japan
- 30 metres diameter
- 2017
- 2 potential sites (Hawaii, Chile)
  - Selection soon
- 3 first gen. instruments: WFOS, IRMS, IRIS



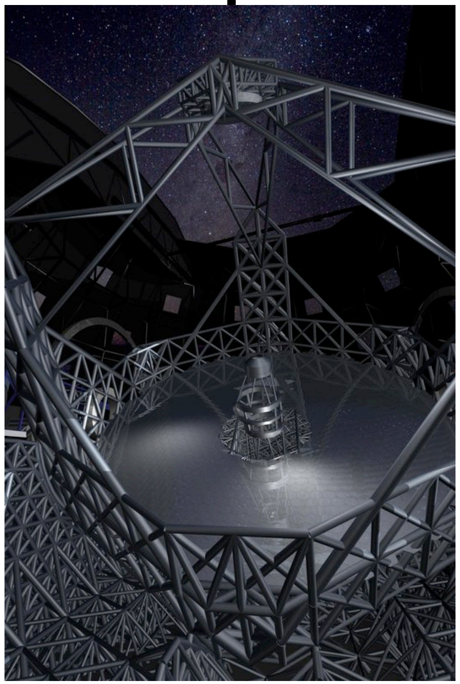
GMT



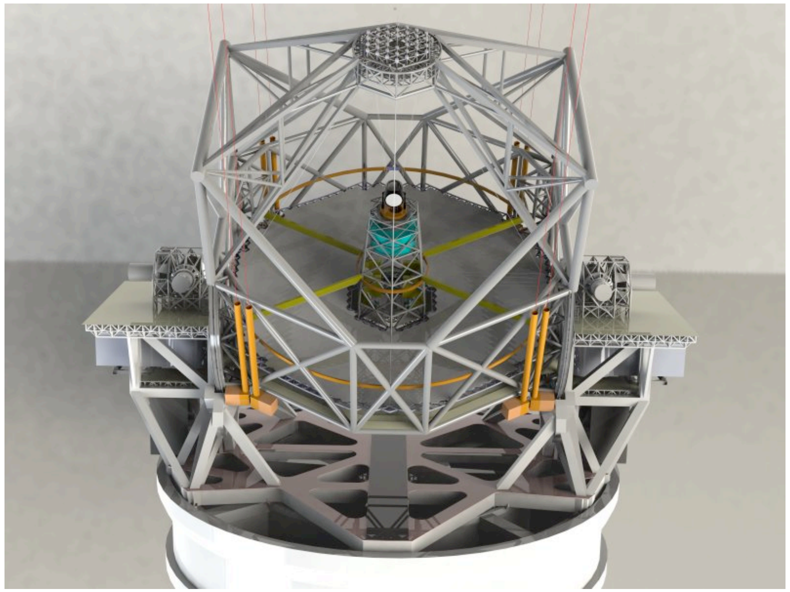


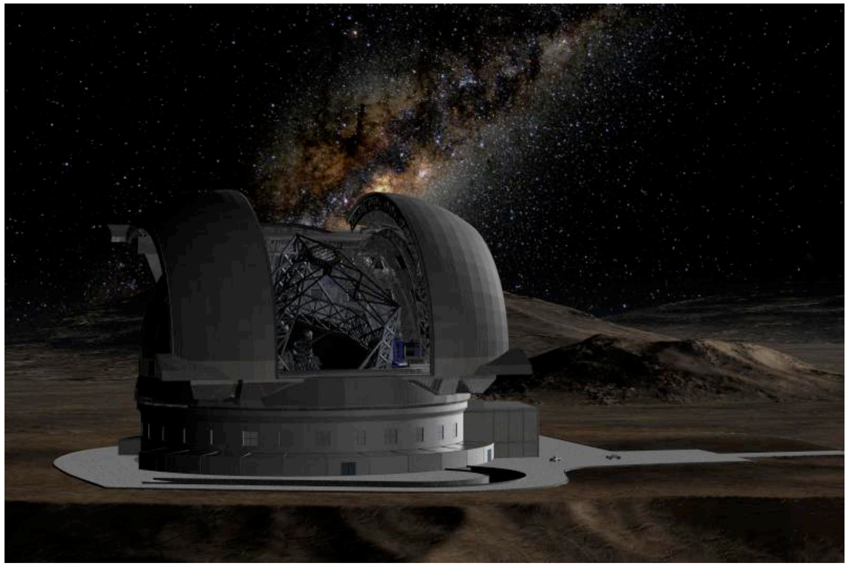


The European Extremely Large Telescope

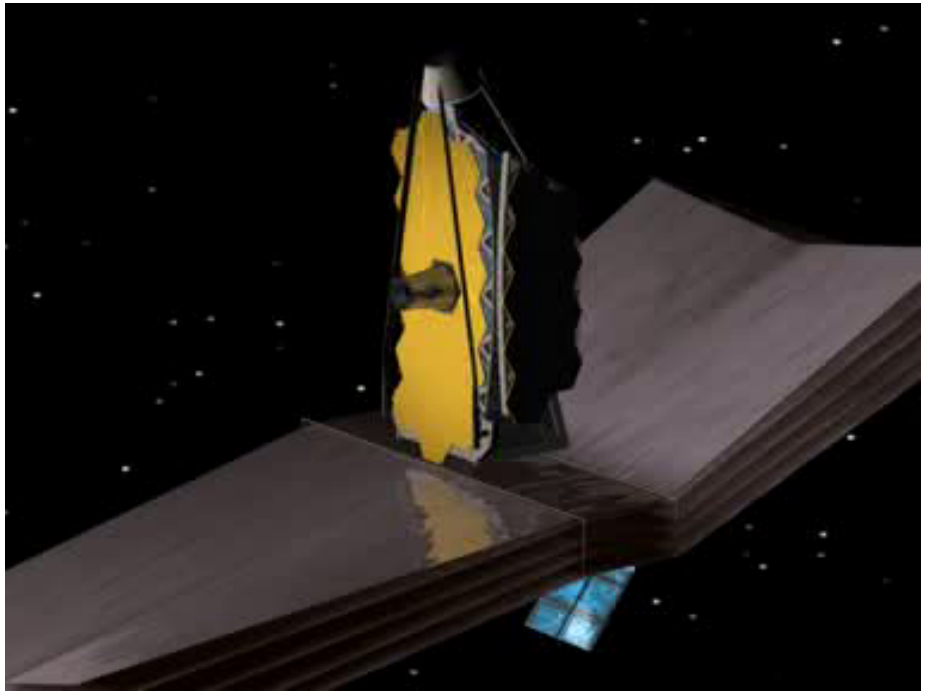


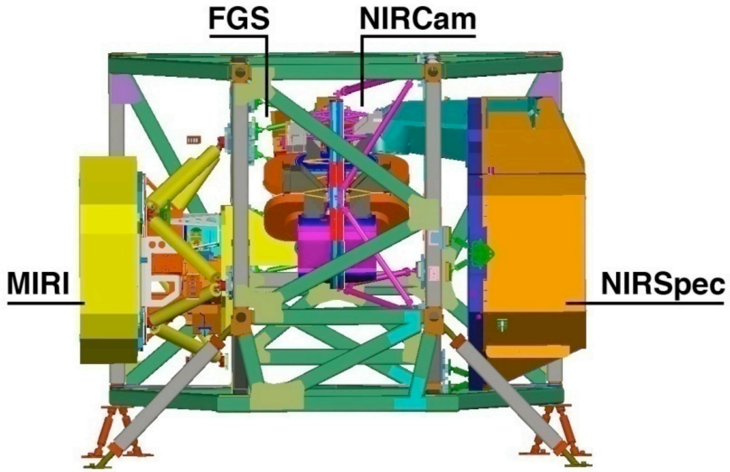
- ESO
- 42 m diameter
- 5-mirror design
- 2018
- Potential sites Chile, La Palma
- Decision for construction: end of 2010
- 8 instruments under study, a few of potential interest for first light and re-ionization





JWST





- 6.5m
- NASA, ESA, CSA
- Launch 2014

- MIRI
  - Imager & Spectrograph 5-27 μm
- NIRCam
  - Imager, 0.6 to 5 μm
- NIRSpec
  - MOS spectrograph 0.6 to 5 μm
- FGS
  - Tunable Filter 1.6 to 5 μm

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- LAEs with JWST & ELTs

JWST & ELTs

- All 'single' general purpose facilities
- There will be at most 3 ELTs for some time
  - While we have 10+ 8-10 m telescopes
- ELTs have AΩ product ~ similar to 8-10 m telescopes
  - Instruments typically have ~1 (diffraction limited) to 5-10 (seeing limited) arcmin fov
- JWST
  - Full day operation (unlike HST)
  - Typically [3-5] arcmin fov instruments

- Compared to 8-10 m telescopes and HST which will have invested 100s of nights on first light and re-ionization projects by 2015-2018, ELTs and JWST will go faint, but over significantly smaller fields, and with tighter competition for observing time.
- → Faint end LF !

JWST & ELTs

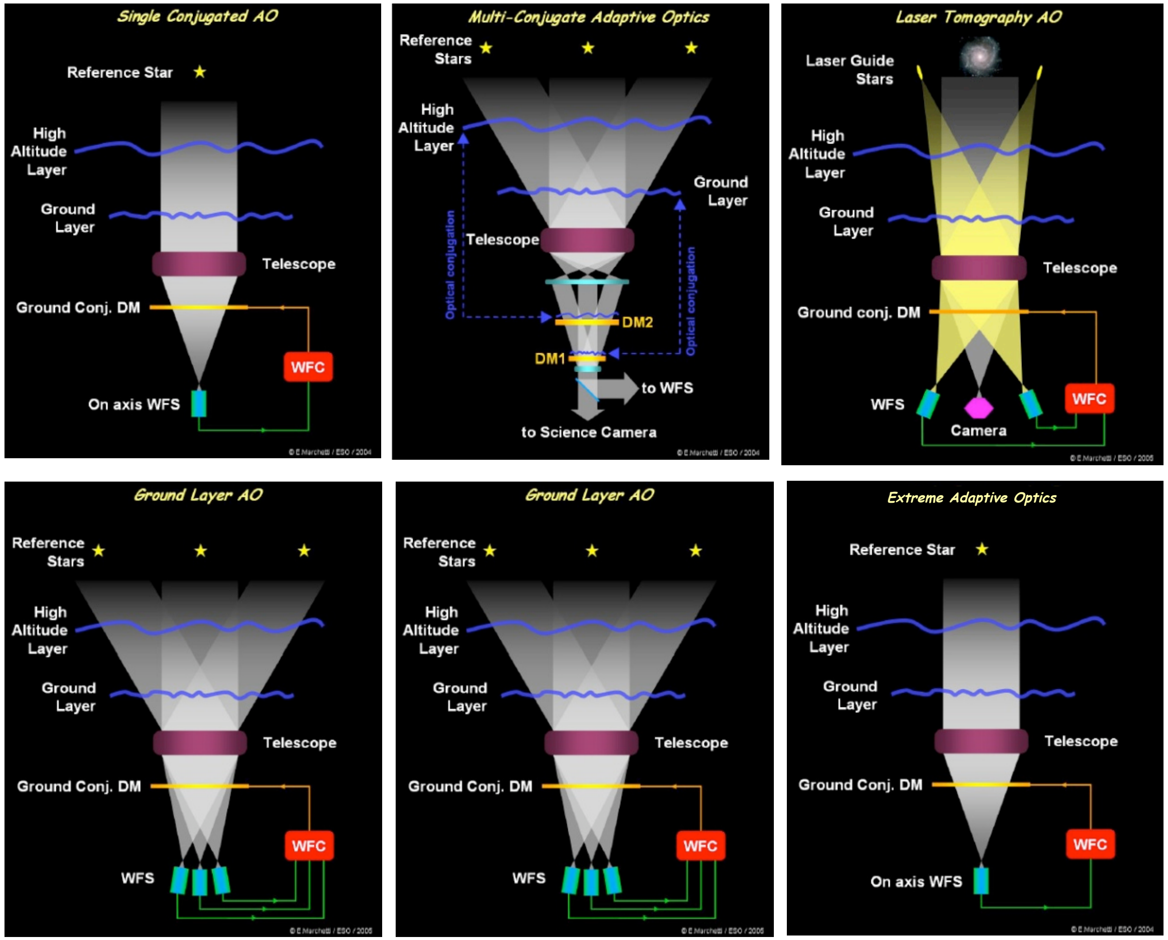
- Near IR (< 2.5 μm):
  - JWST limited by zodiacal light
  - ELTs limited by OH emission in imaging and in spectroscopy by the continuum (a few times the zodiacal light) between the OH lines

- Mid-IR (> 2.5 μm):
  - ELTs dominated by thermal background, JWST unbeatable

- Spatial resolution:
  - ELTs better than JWST (~ x 5) if diffraction limited (Adaptive Optics (AO))
  - JWST better (~ x 5-10) if seeing limited

→ Adaptive Optics a requirement (and a challenge) for ELTs

ELTs & The Adaptive Optics Zoo



SCAO, MCAO, LTAO,
GLAO, MOAO, XAO

2 Families:

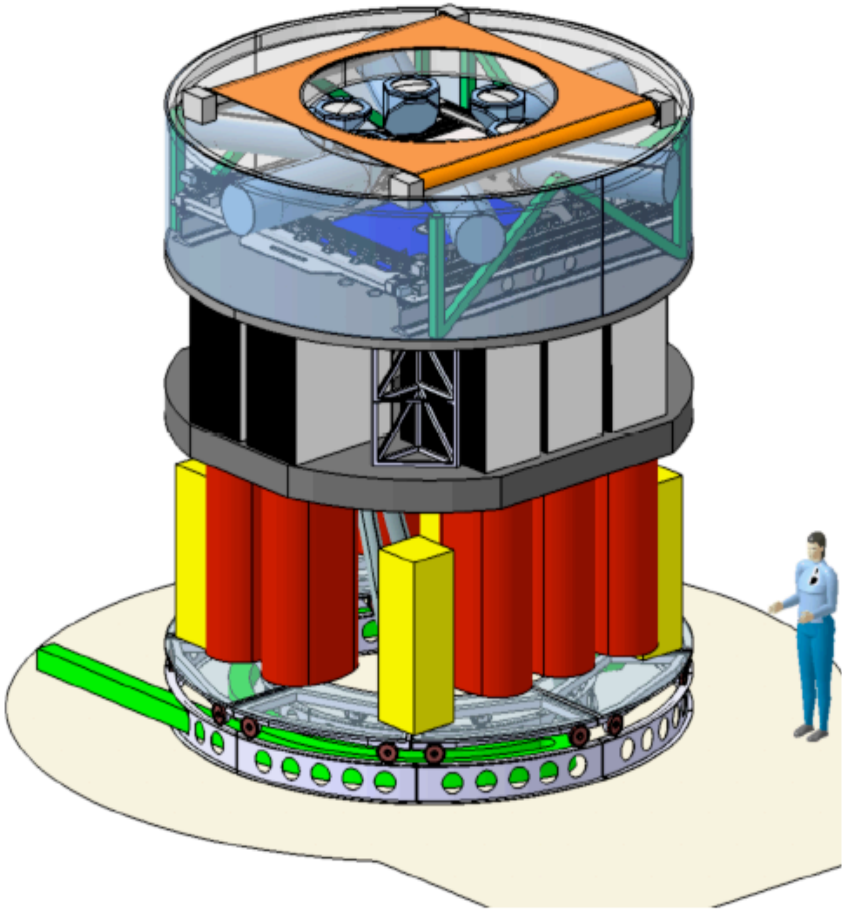
High correction over ~1-2' arcmin fov (MCAO),
o
r
locally over 5-10' fov (MOAO)

- MCAO / MOAO
- IQ From 5-10 mas to 100 mas

Low correction over a 5-10' fov

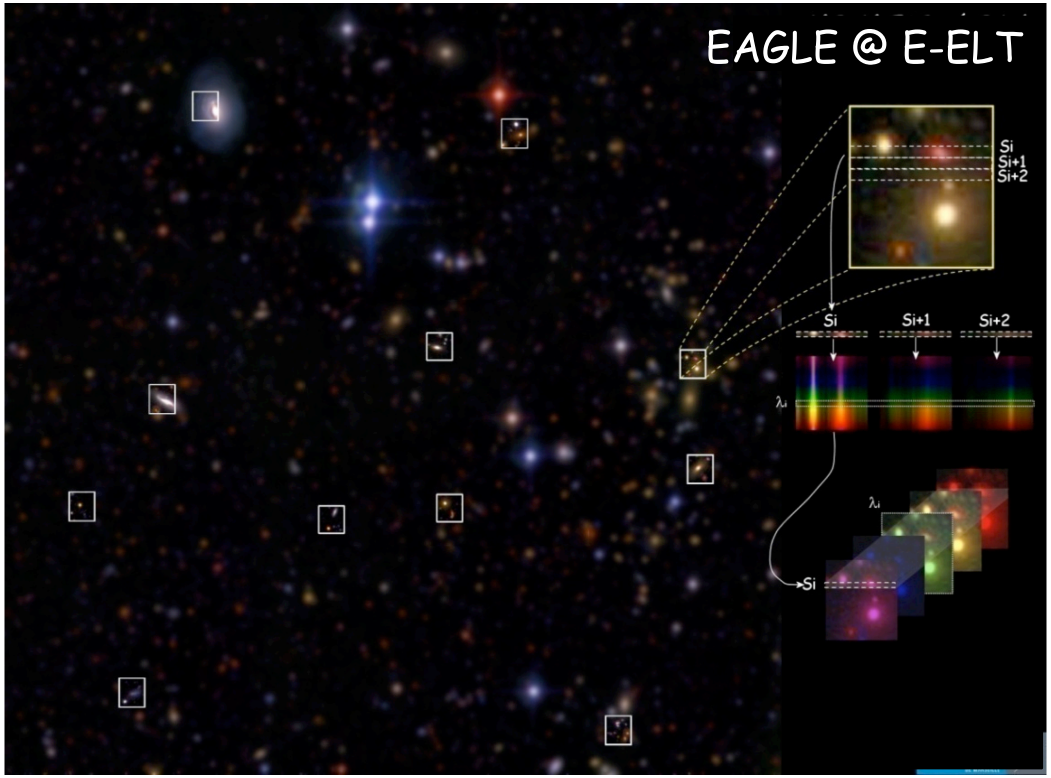
- noAO / GLAO
- IQ ~ 300-600 mas

Ex: EAGLE @ E-ELT



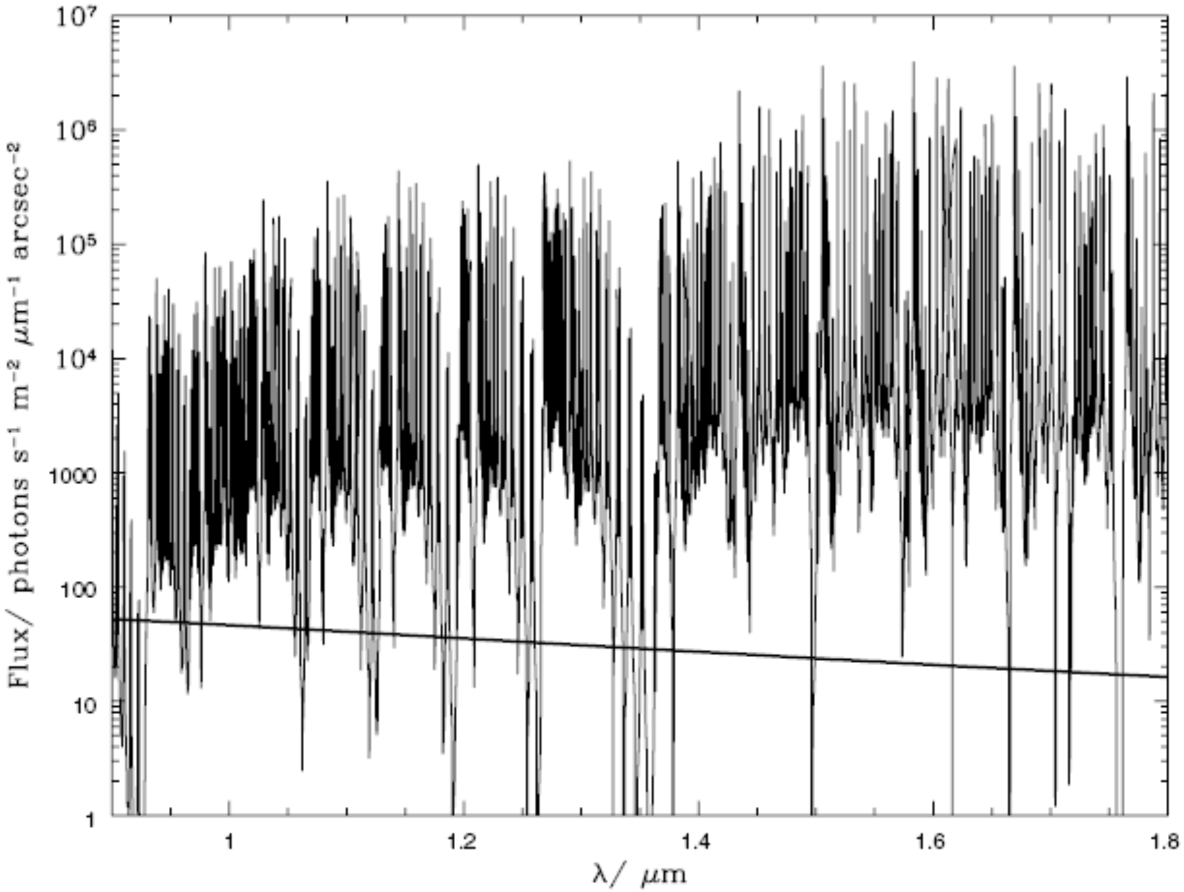
Deployable near IR multi-IFU in ~ 7′ diameter fov, assisted by Adaptive Optics (MOAO)

20 IFUs, 1.65″ x 1.65″ each



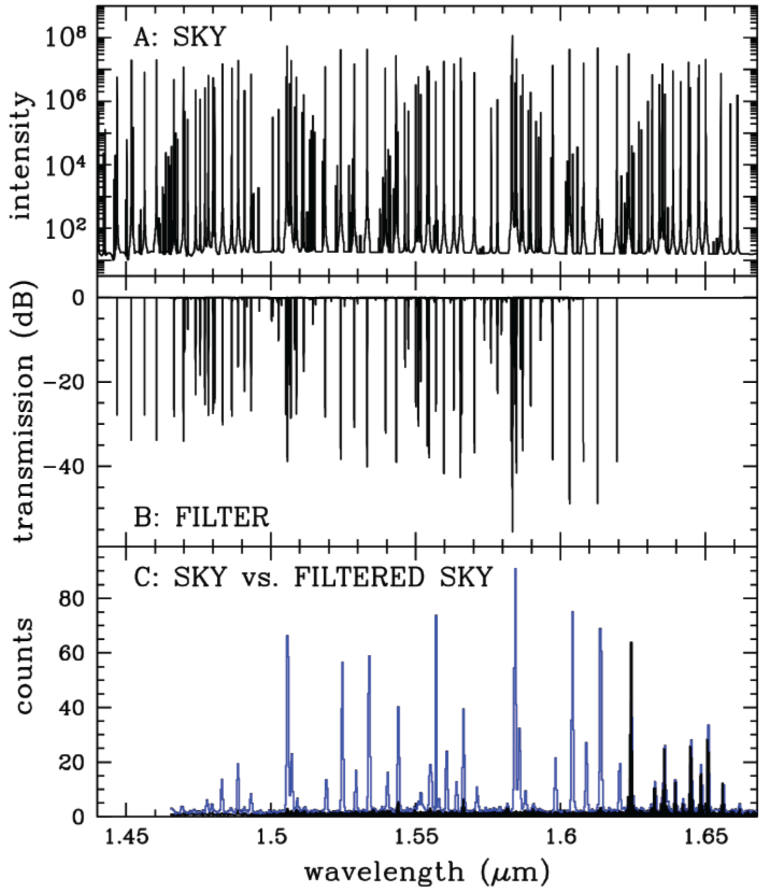
The sky background from the ground

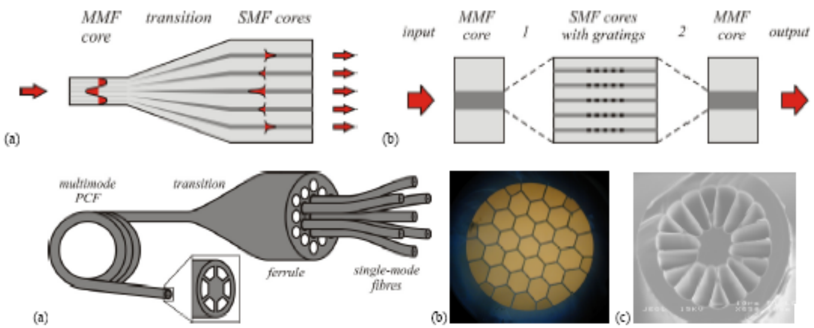
- Claim (Ellis & Bland-Hawthorn, 2008) that true continuum between OH lines is ~ zodiacal light (=space)
  - Limited by instrument scattered light
  - From H=14 to H = 21 !!!



Ellis & Bland-Hawtorn, 2008

The promises of OH Suppression





- All OH suppression systems by nature mono-mode / slow beams

- Implementation remains challenging.

- Roadmap: spectroscopy first (reduces scattered light ; allows lower R), imaging long term (e.g. 1arcmin^2 at Diffraction Limit = 10^7 single modes at H !)

- We assume for now the *conservative* traditional value for the sky background between the OH lines to estimate the performance of the ELTs

JWST & ELTs: Imaging

Limiting AB magnitudes in 10^4s at SNR = 10

	AB	Band	Aperture (Ø)
JWST	28.7	1.2-1.8 μm	0.1″
ELT (noAO / GLAO)	26.5	J/H	0.5″
ELT (MCAO / MOAO)	27.8	J/H	0.1″

- JWST will go one to two magnitudes deeper in imaging than the ELTs for objects of the order of 0.1″ in size, representative of high-z sources
- ELTs will compete on point sources close to the diffraction limit if good AO correction

JWST & ELTs: Spectroscopy

Continuum and line sensitivities in 10^5s at SNR = 5

R ~ 3000-4000

	Continuum AB	Line ergs.s^{-1}.cm^{-2}	Aperture (Ø)
JWST	24.5	4.0×10^{19}	0.20″ x 0.40″
ELT (noAO / GLAO)	25.8	1.5×10^{19}	0.45″ x 0.45″
ELT (MCAO / MOAO)	27.0	5.0×10^{20}	0.15″ x 0.15″

- ELTs will go significantly deeper than JWST in spectroscopy, even under low AO correction (and consequently larger apertures)
- JWST read noise limited in spectroscopy at R > 100
- ELTs read noise limited in spectroscopy at the diffraction limit, but not over ~ 0.1″ or larger apertures (unless continuum between sky fainter than assumed and / or partially suppressed)

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LAEs & JWST: imaging

	Ultra Deep		Shallow Wide		
Filter	AB S/N=5	Exposure Time (hrs)	AB S/N=3	Number of fields	Exposure Time (hrs)
F070W	30.3	23.4	28.5	7	8.8
F090W	30.6	35.8	28.5	7	7.7
F115W	30.9	54.2	28.5	7	6.8
F150W	31.3	97.6	28.6	7	5.8
F200W	31.3	83.2	28.7	27	5.0
F270W	31.3	83.2	28.7	27	15.2
F336W	31.3	83.2	28.7	27	124
F444W	30.9	99.8	28.2	27	77.7
Total		294.2			223.4

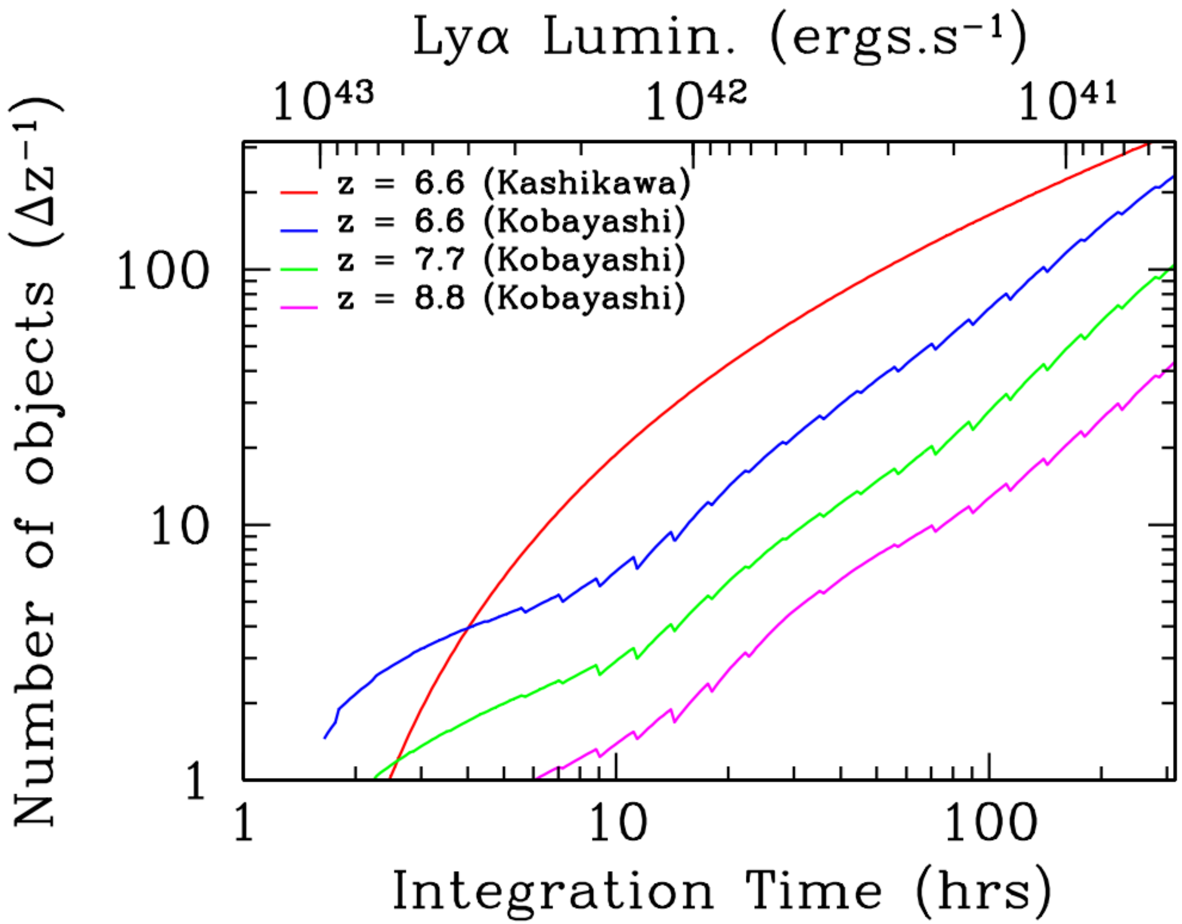
Stiavelli et al.
A strategy to study First Light with JWST, from the Bouwens et al. LBG LF at z ~ 7

- Survey design (NIRCam) to find 140 high-z sources in the z = [9-20] range per filter ($\Delta z \sim 2$) at SNR = 5

→ ballpark estimate of the number of high-z objects:

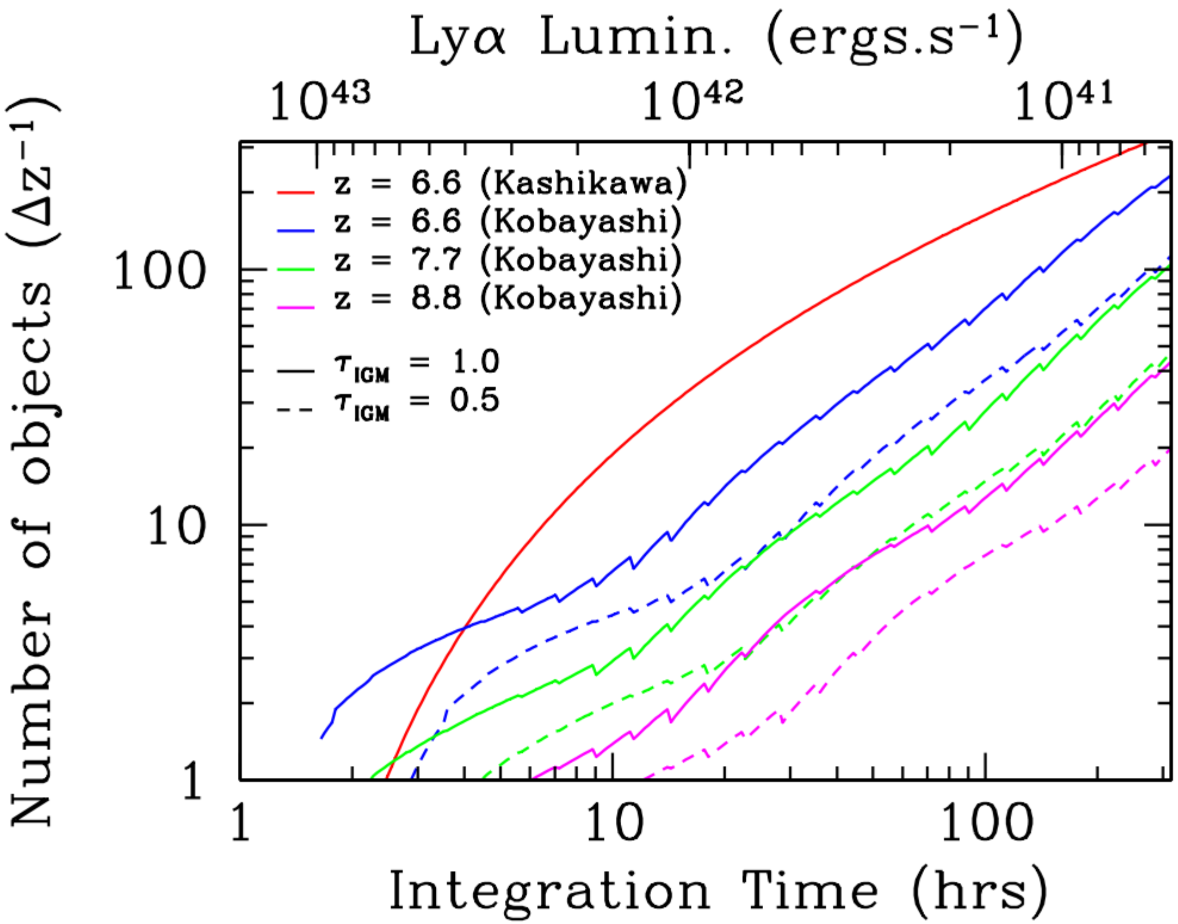
70 high-z sources per $\Delta z \sim 1$ at ~ 1.5 μm (J/H) in ~ 30 hrs at SNR = 5

LAEs & JWST: spectroscopy



Number of LAEs vs. Time in spectroscopy
(NIRSpec, one field)

LAEs & JWST: spectroscopy



Number of LAEs vs. Time in spectroscopy
(NIRSpec, one field)

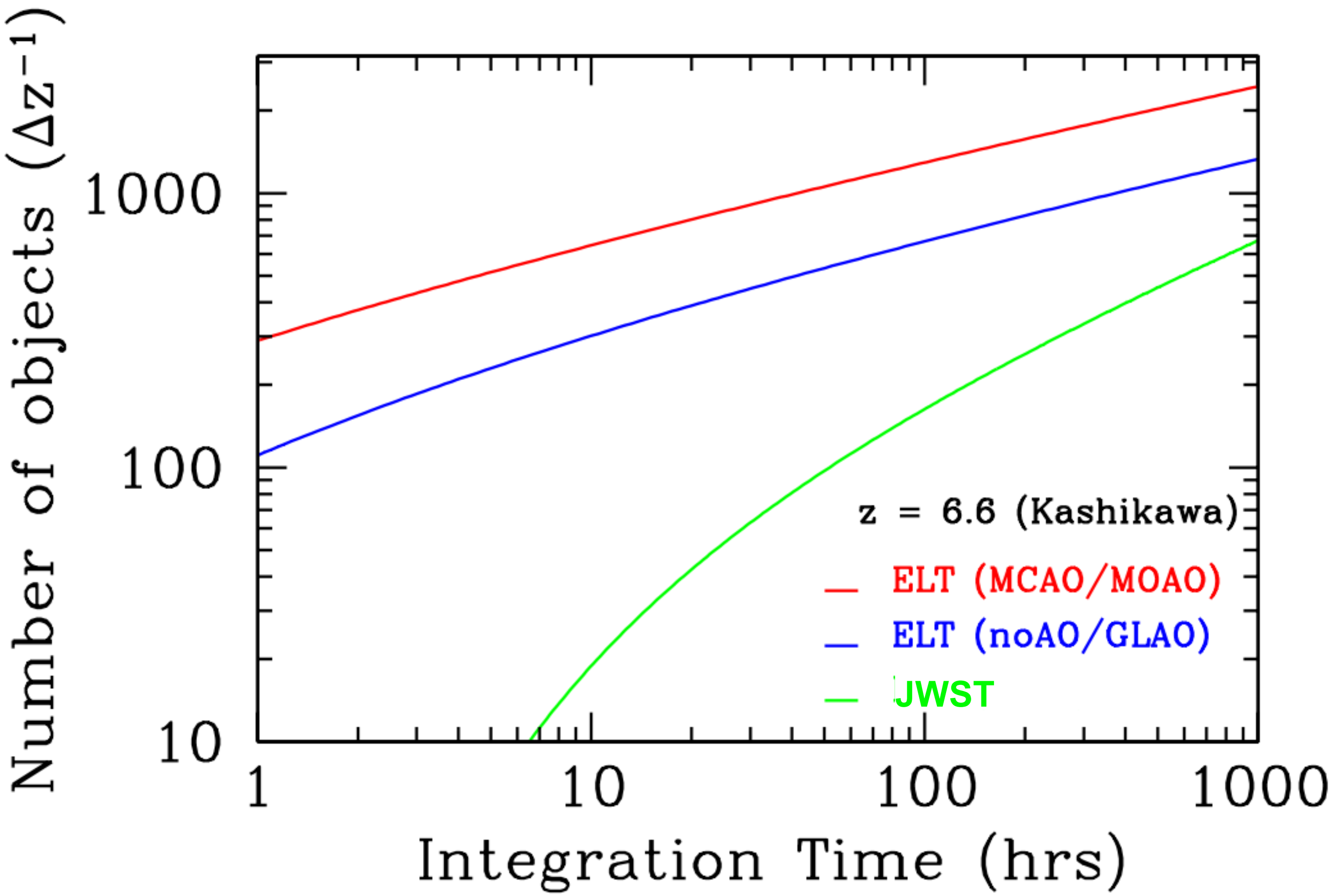
LAEs & JWST: strategy

- NIRCAM Broad Band Imaging (~600 hrs)
- FGS TF Narrow Band Imaging (~200 hrs)
- NIRSpec follow-up Spectroscopy (~200 hrs)
  - (from Stiavelli et al.)

- 1000 hrs, similar to HST COSMOS, GOODS and UDF

- Deliver several 100s of sources in imaging and several 10s LAEs in spectroscopy

LAEs : comparison of JWST & ELTs

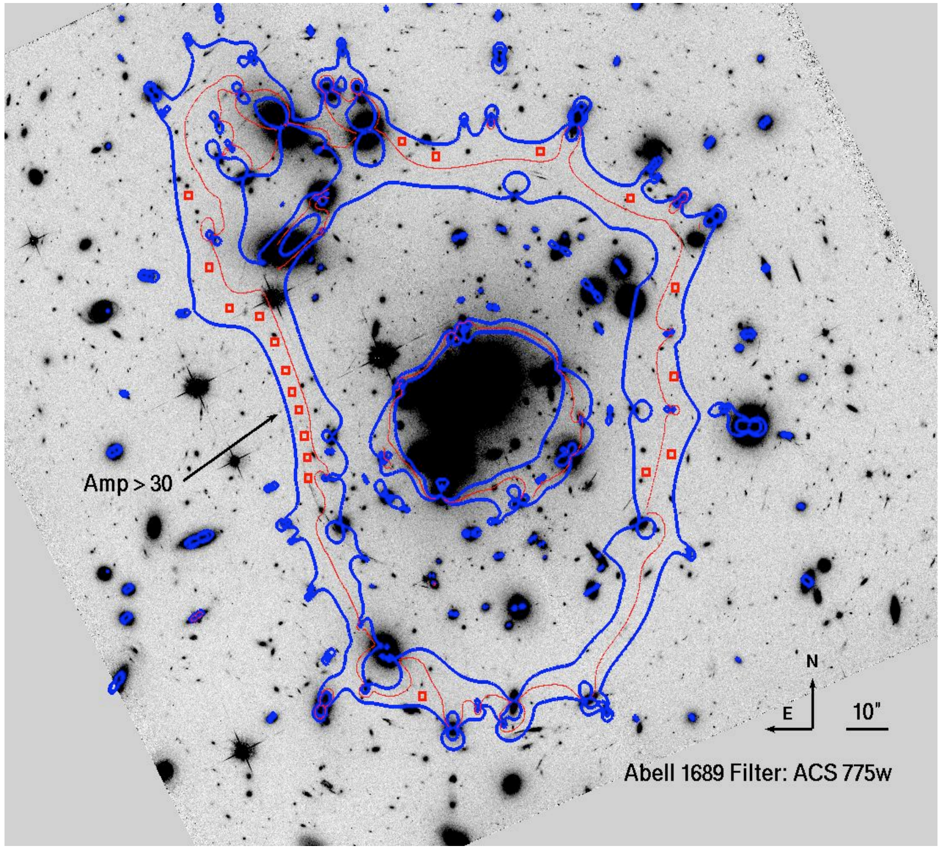


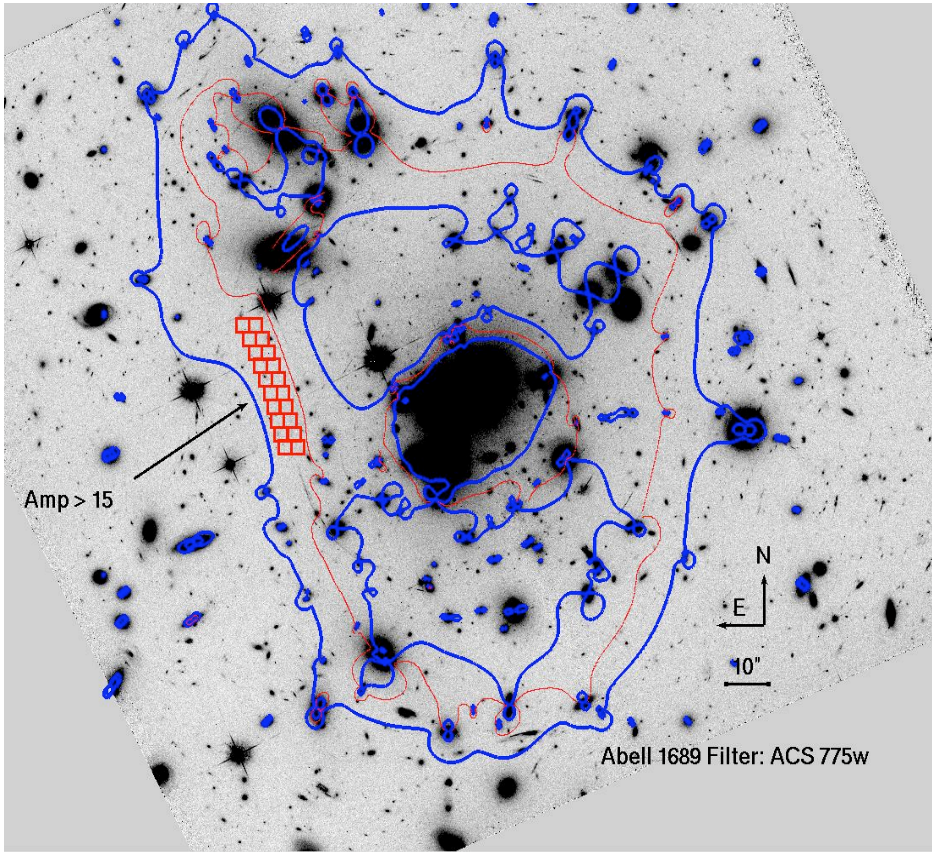
Line detection - ELTs much faster than JWST in spectroscopy

LAEs & ELTs

- Targets from:
  - JWST (several 100s of hrs)
  - Fallback with 8-10m
    teles
    copes, VISTA, etc. (partly broad band, partly NB) (extensive…)

Other Strategy to find the sources: blind searches on critical lines of clusters





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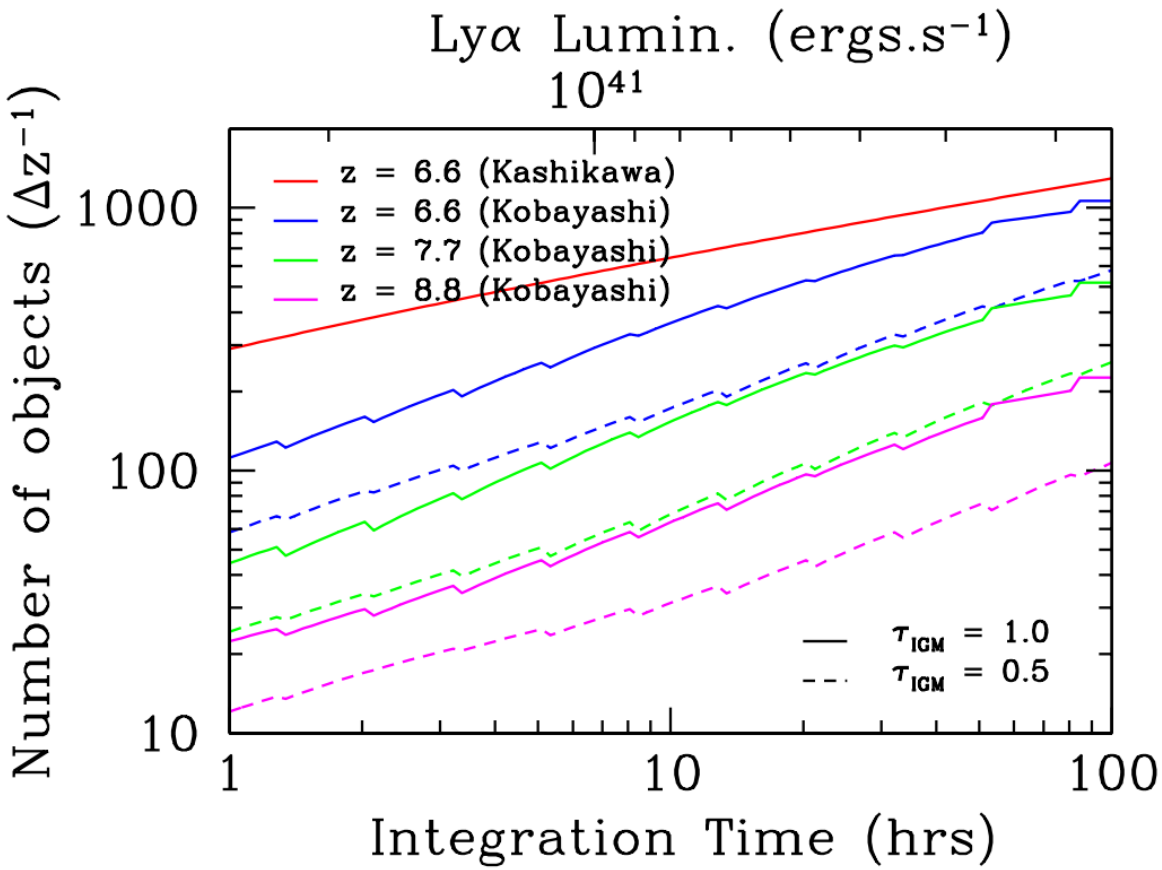
- Follow-up in spectroscopy
  - Line detections very efficient

LAEs & ELTs: spectroscopy



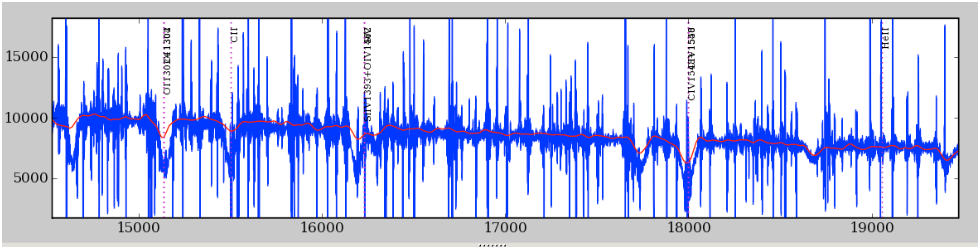
Number of LAEs vs. Time in spectroscopy, assuming sources are known, over a ~ 5′ diameter fov

LAEs & ELTs

- Targets from
  - JWST (several 100s of hrs)
  - Fallback with 8-10m
    teles
    copes, VISTA, etc. (partly broad band, partly NB) (extensive…)
- Follow-up in spectroscopy
  - Line detections very efficient
  - UV continuum, down to AB ~ 27, impossible with JWST

LAEs & ELTs

Success



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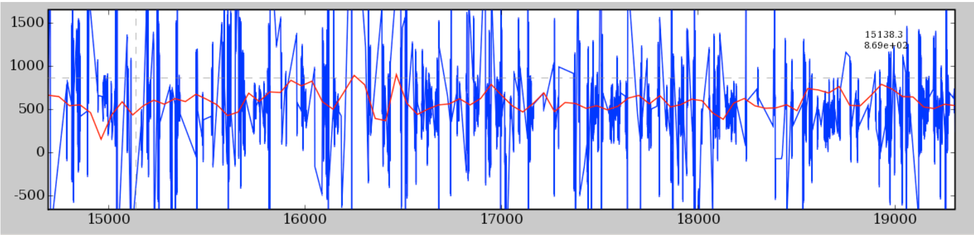
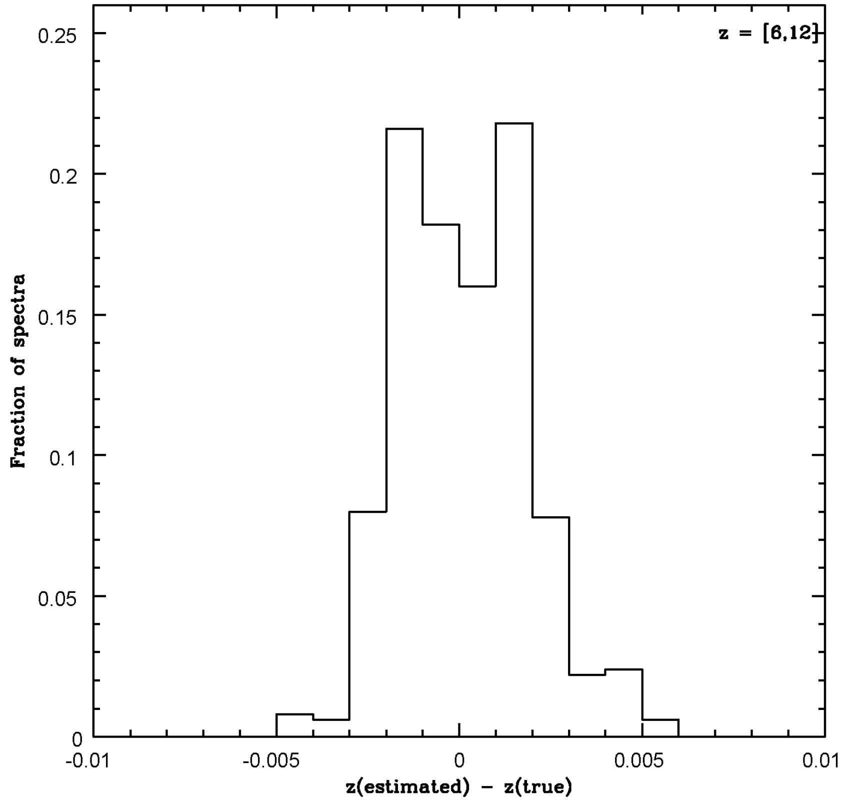
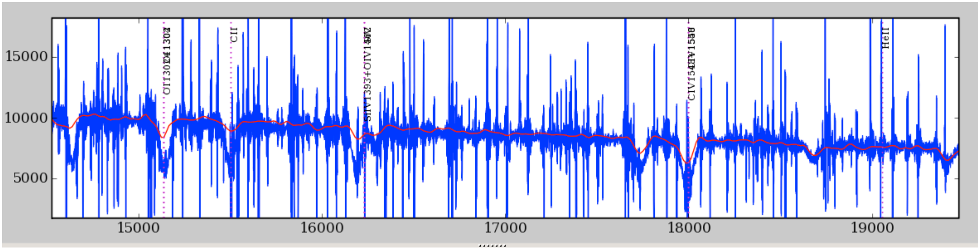




- Automatic redshift detection with UV continuum

LAEs & ELTs

Success



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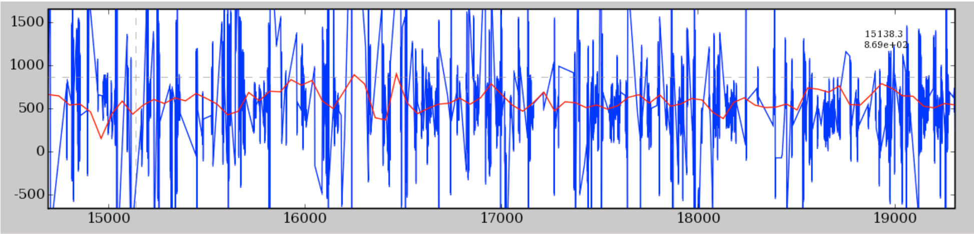
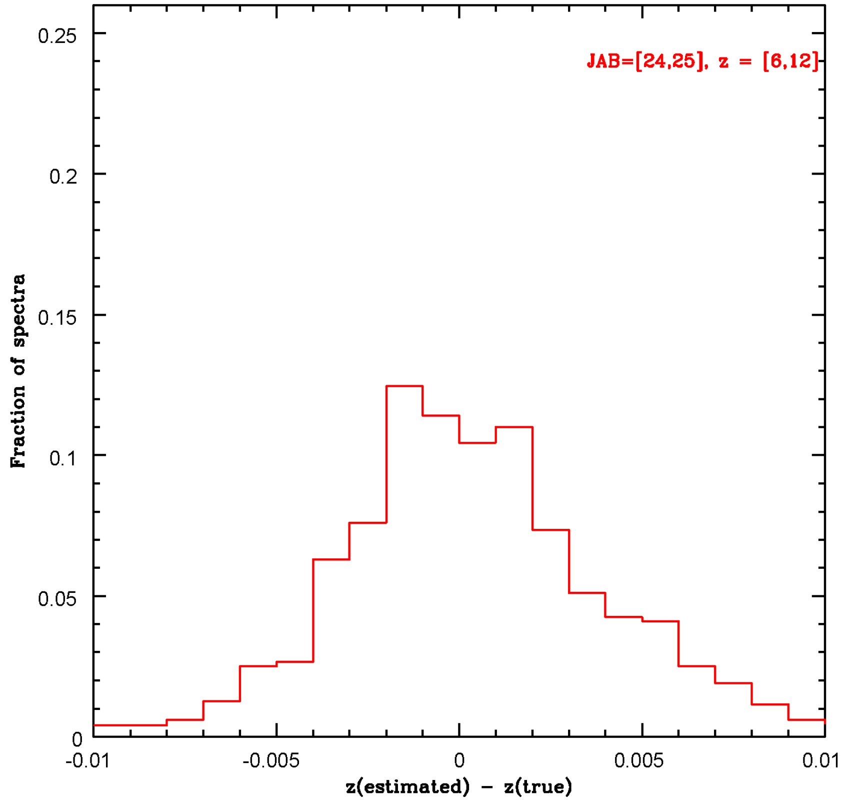


Mag. Range	Success rate with z in range [6 – 12]
[24 – 25]	94%



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LAEs & ELTs

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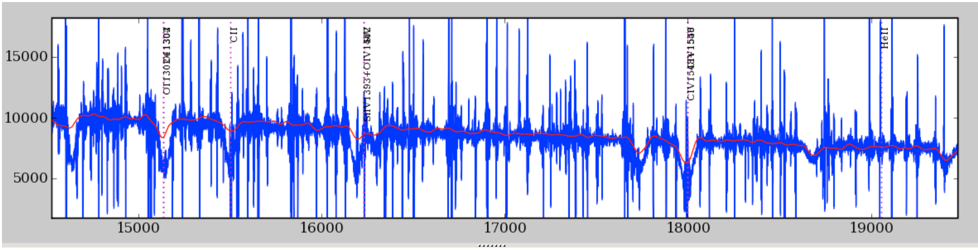

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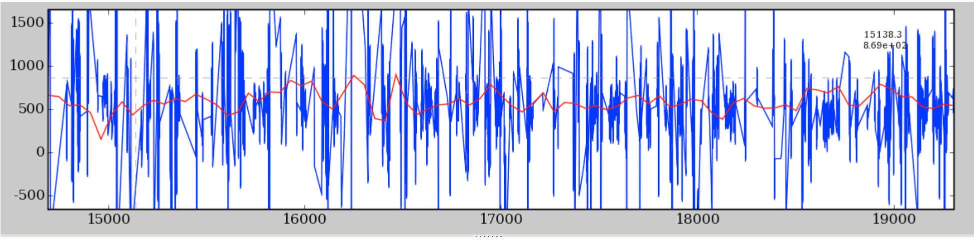
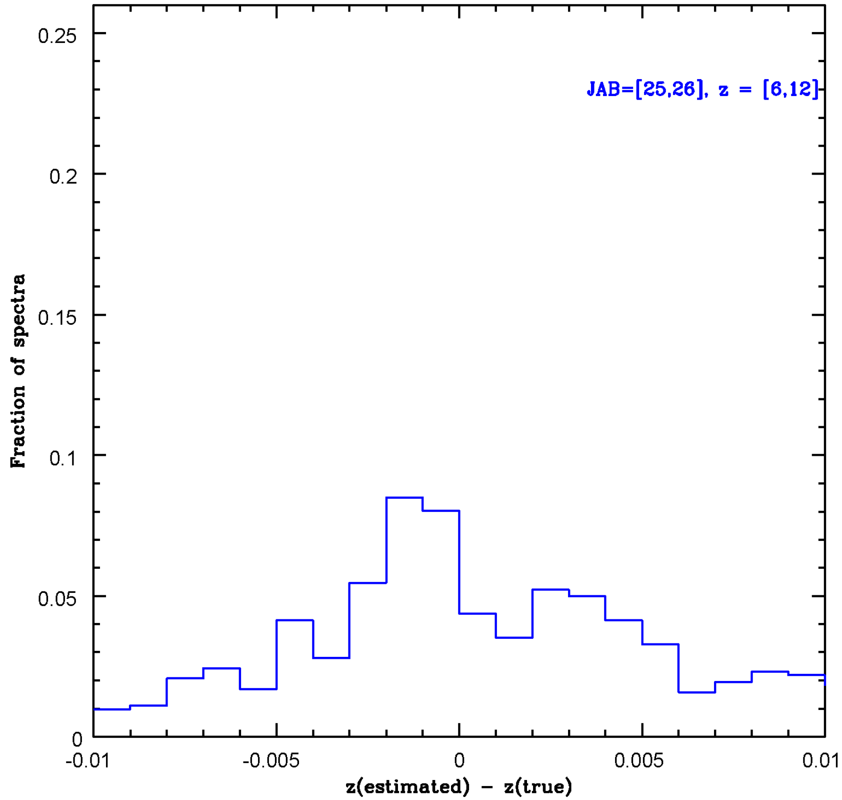


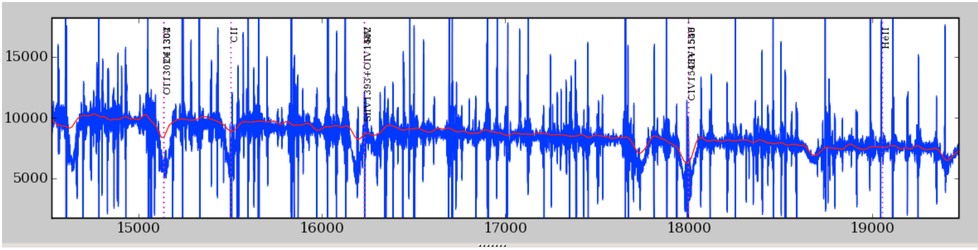
Mag. Range	Success rate with z in range [6 – 12]
[24 – 25]	94%
[25 – 26]	71%



- Automatic redshift detection with UV continuum

LAEs & ELTs

Success



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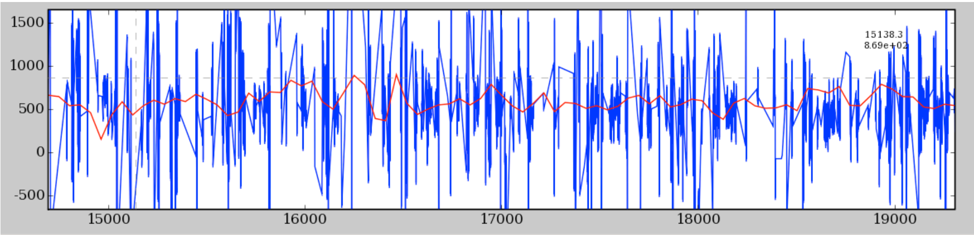
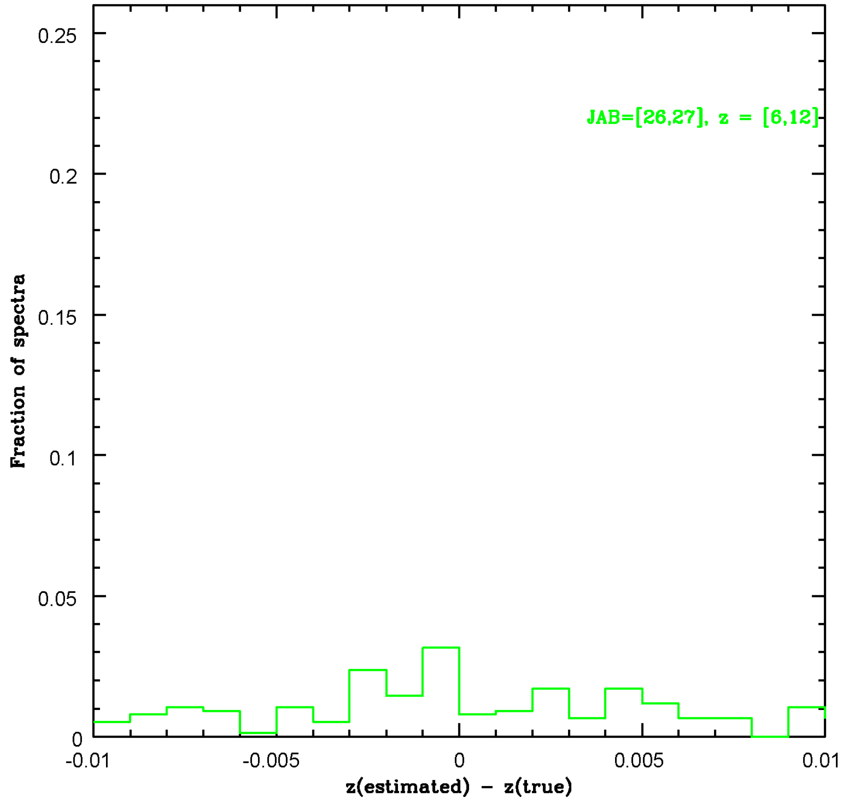


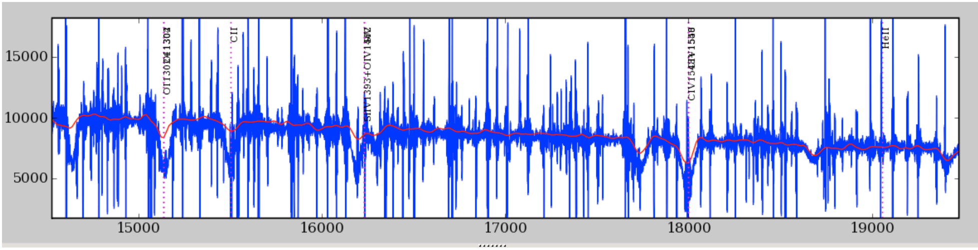
Mag. Range	Success rate with z in range [6 – 12]
[24 – 25]	94%
[25 – 26]	71%
[26 – 27]	21%



- Automatic redshift detection with UV continuum

LAEs & ELTs

Success



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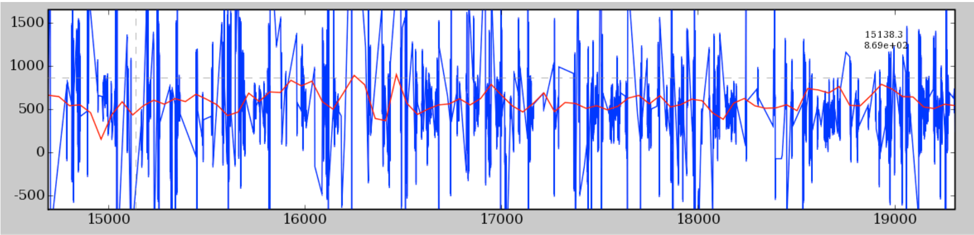
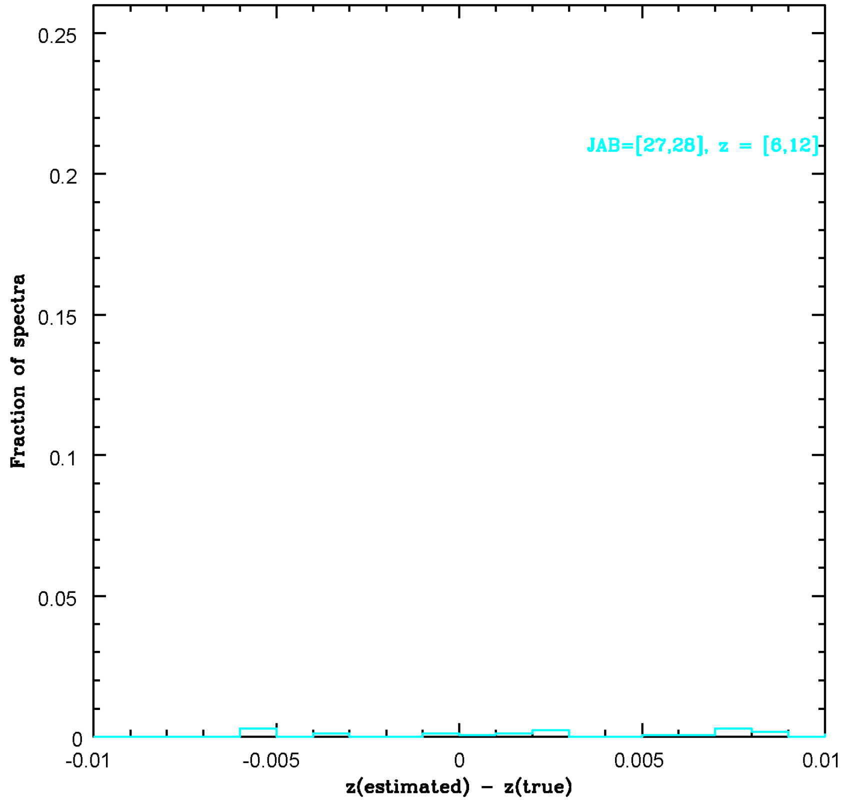


Mag. Range	Success rate with z in range [6 - 12]
[24 - 25]	94%
[25 - 26]	71%
[26 - 27]	21%
[27 - 28]	1%



- Automatic redshift detection with UV continuum

LAEs & ELTs

- Targets from
  - JWST (several 100s of hrs)
  - Fallback with 8-10m
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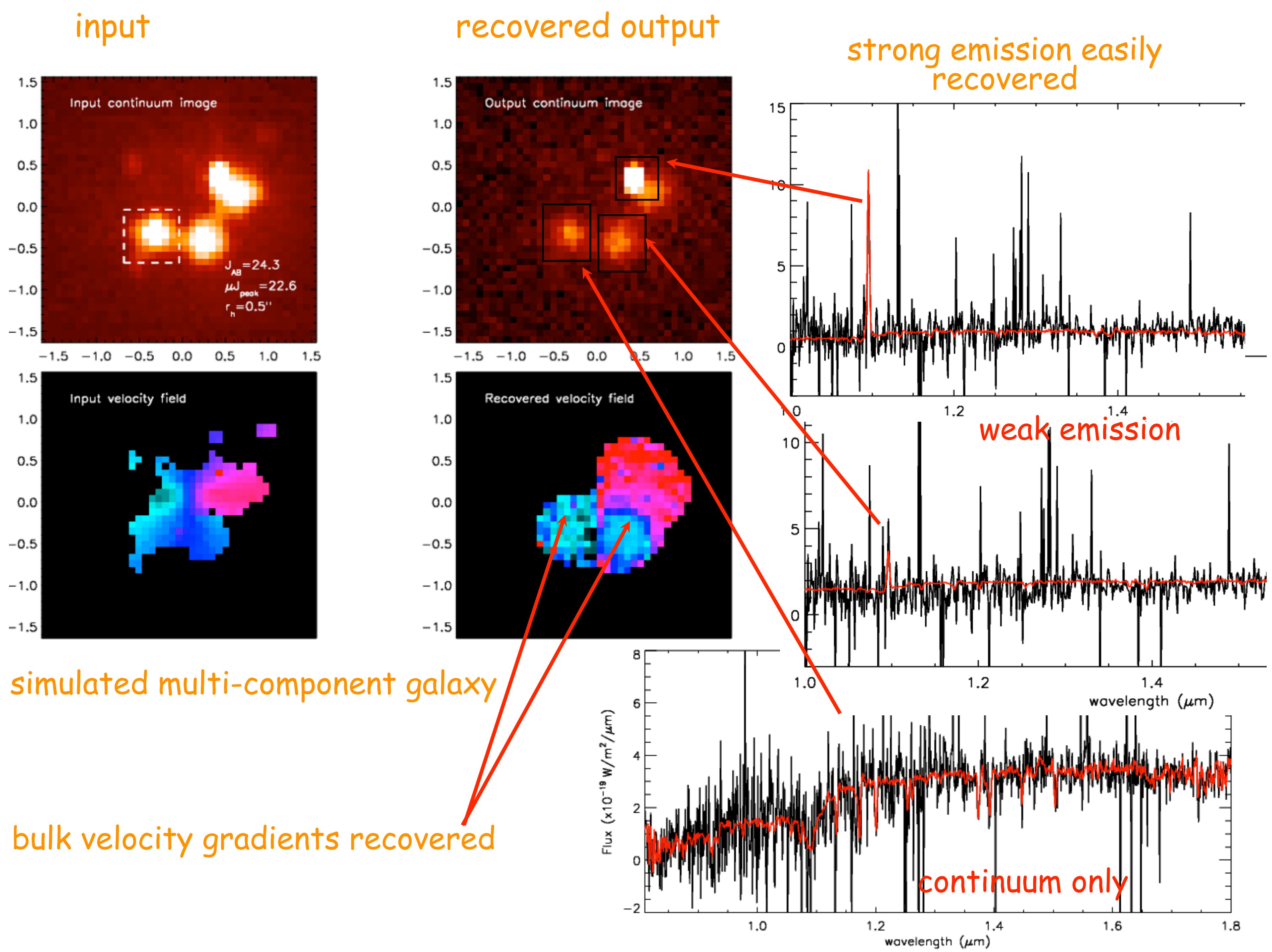
    copes, VISTA, etc. (partly broad band, partly NB) (extensive…)

- Follow-up in spectroscopy
  - Line detections very efficient
  - UV continuum, down to AB ~ 27, impossible with JWST
  - Detailed spatially
    resolved
    spectroscopy for the brightest and / or most extended objects


input
recovered output
strong emission easily recovered
Input continuum image
J_{AB}=24.3
μJ_{peak}=22.6
r_h=0.5''
Output continuum image
Input velocity field
Recovered velocity field
weak emission
wavelength (μm)
Flux (x10⁻¹⁹ W/m²/μm)
continuum only
simulated multi-component galaxy
bulk velocity gradients recovered

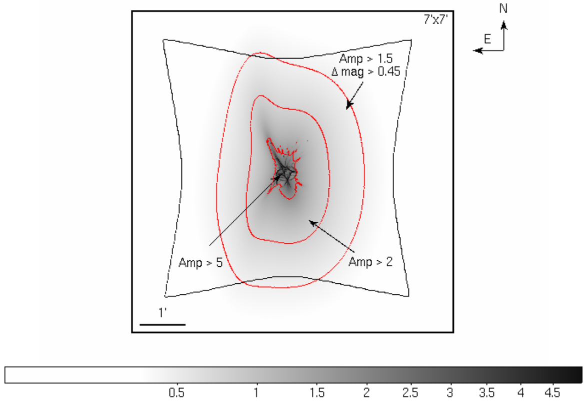
Conclusions

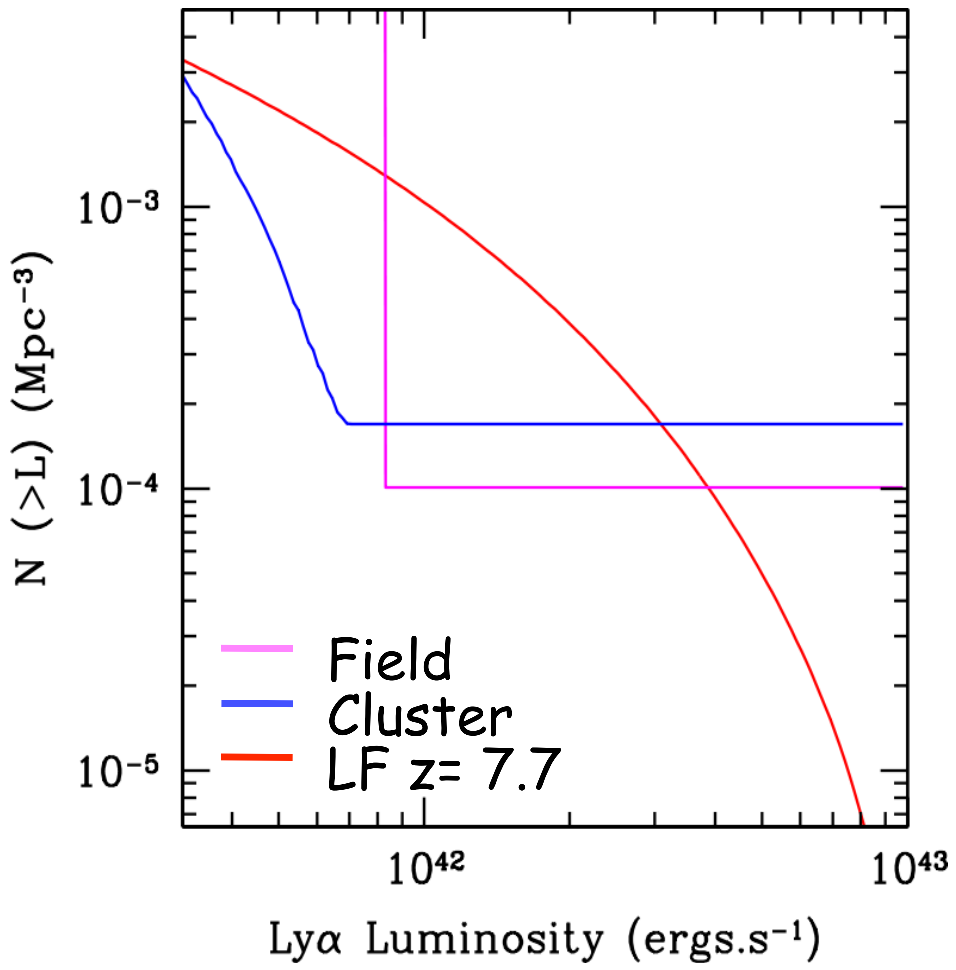
- JWST and ELTs highly complementary

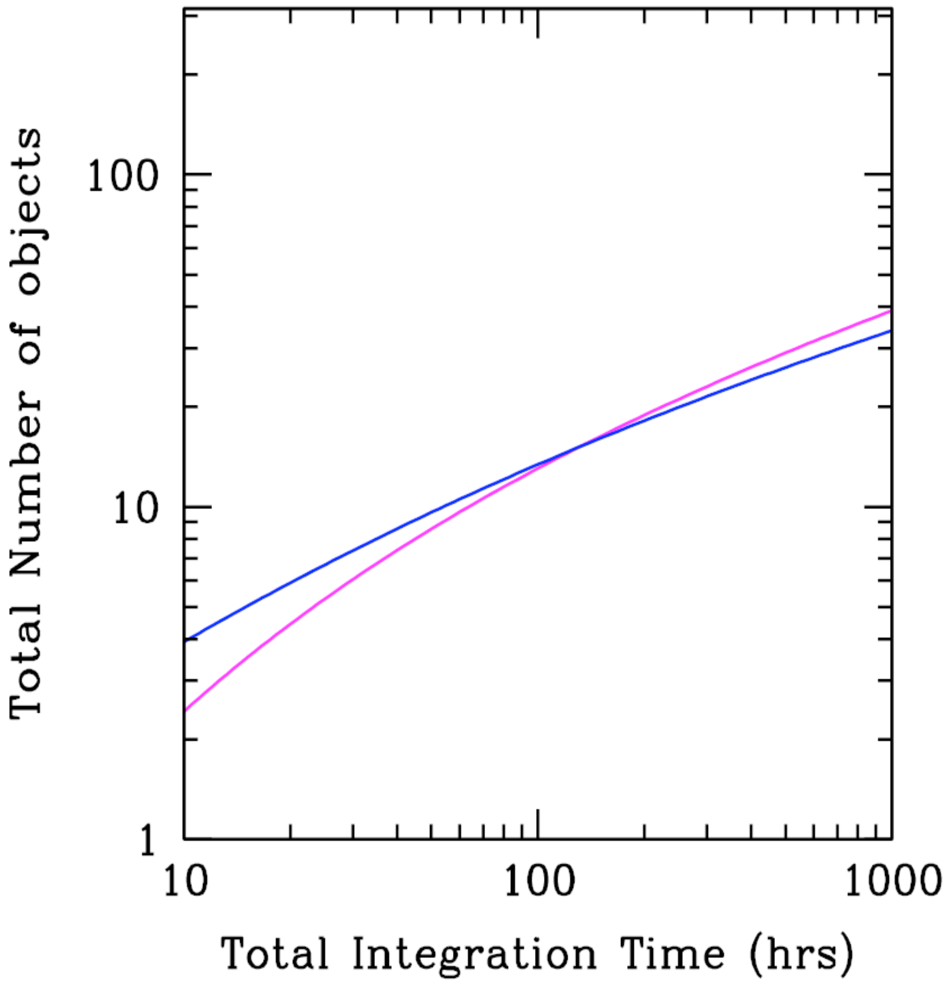
- JWST to provide several hundreds of high-z sources in imaging, possibly thousands over > 5 yrs
  - Extremely detailed SEDs with near IR and mid-IR photometry
- JWST will initiate spectroscopy of LAEs (essentially line detections)

- When the ELTs arrive, they will measure large samples of LAEs
- They will allow UV continuum spectroscopy
- They will allow detailed 3-D spectroscopy of a few objects down to a few mas spatial resolution

Finding the targets: strategy







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