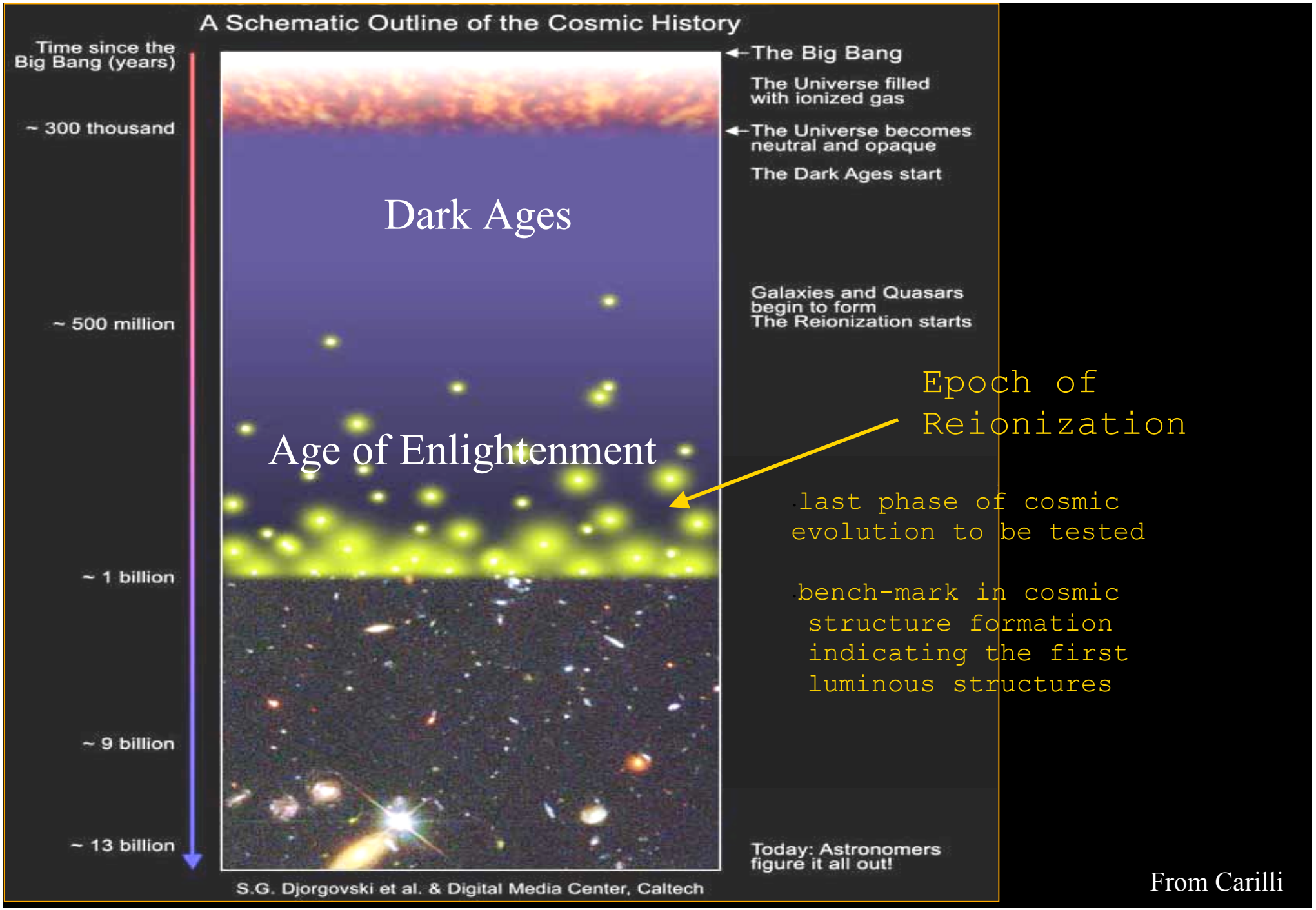
High Redshift Galaxies with EAGLE

J.-G. Cuby, M. Swinbank, N. Welikala,
J. Richard, B. Clement, V. Lebrun, M.
Puech, S. Morris, C. Evans, et al.

DRSP Workshop, Garching, 28 May 2009

Science & Technology Facilities Council
UK Astronomy Technology Centre



Epoch of Reionization

- last phase of cosmic evolution to be tested
- bench-mark in cosmic structure formation indicating the first luminous structures

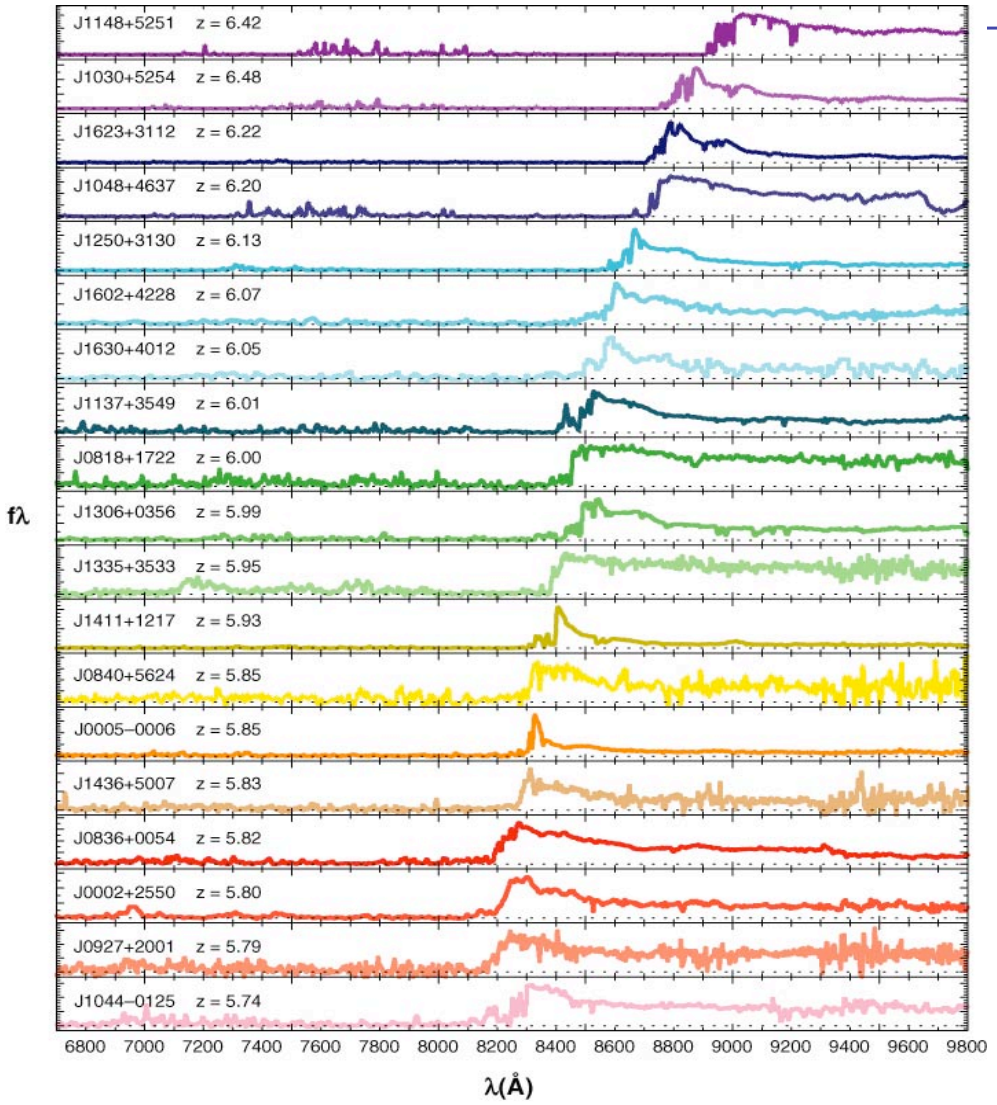
From Carilli

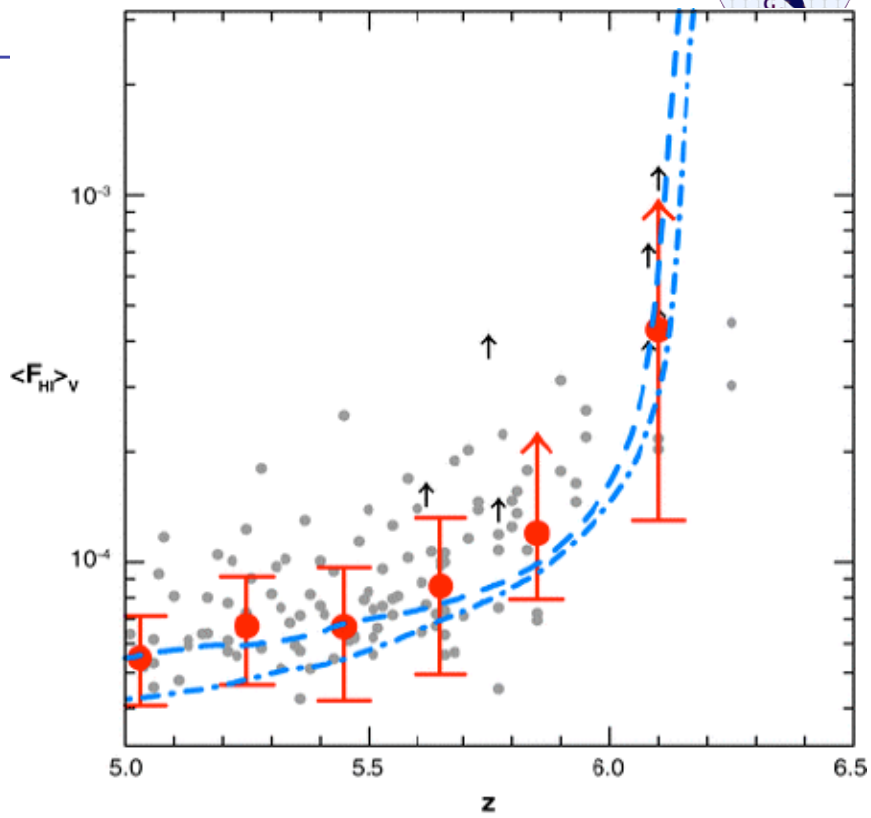
Re-ionization

- When did it start ?
- When did it end ?
- What sources caused it, …

- Gunn-Peterson trough in QSOs
- GRBs
- UVLF & Lyα LF of Ly α Emitters (LAEs)
- CMB
- HI 21-cm

GP trough with QSOs





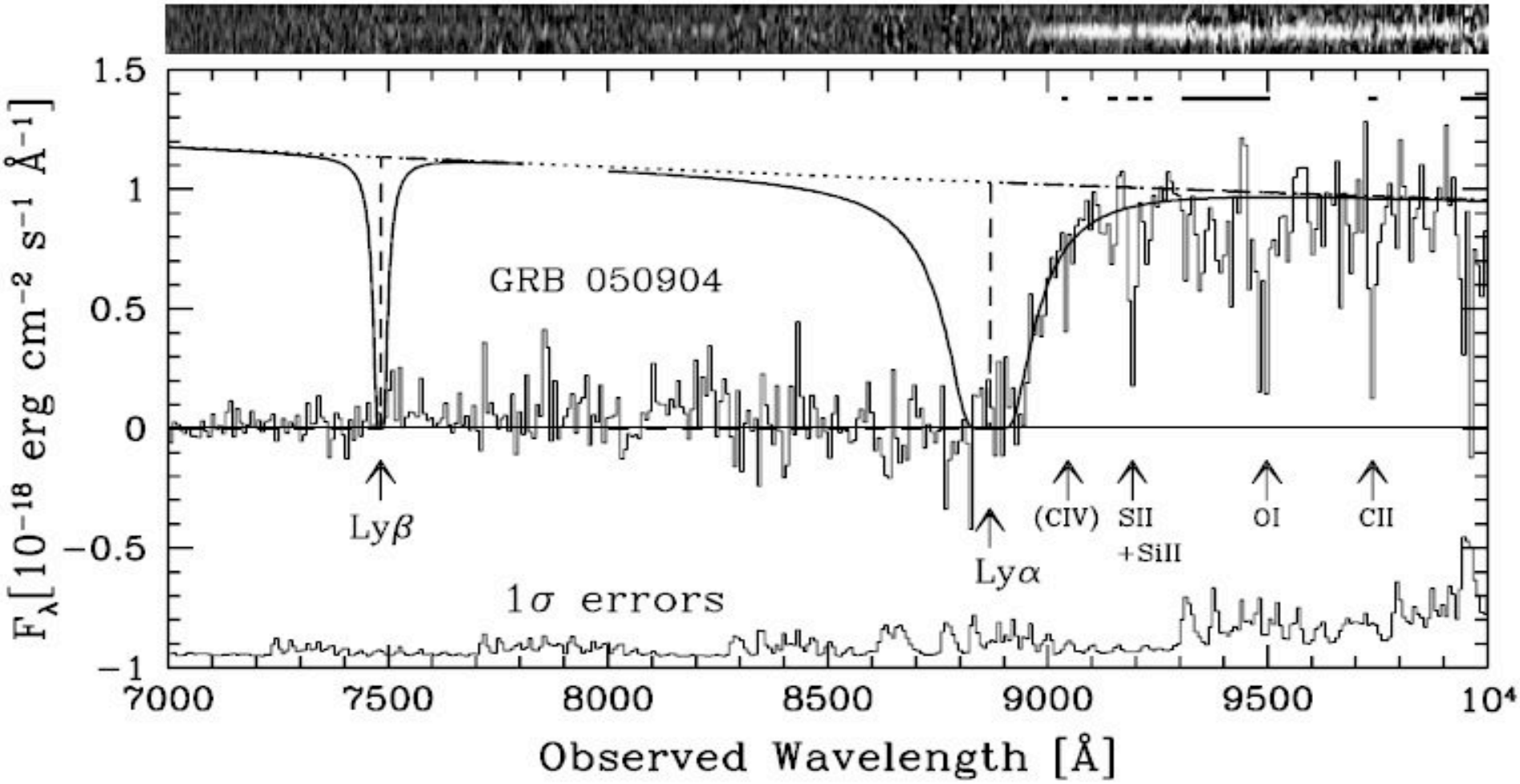
- Only traceable until neutral fraction (HI / H) $< 10^{-3}$

Fan X, et al. 2006.
Annu. Rev. Astron. Astrophys. 44:415–62

Re-ionization with GRBs

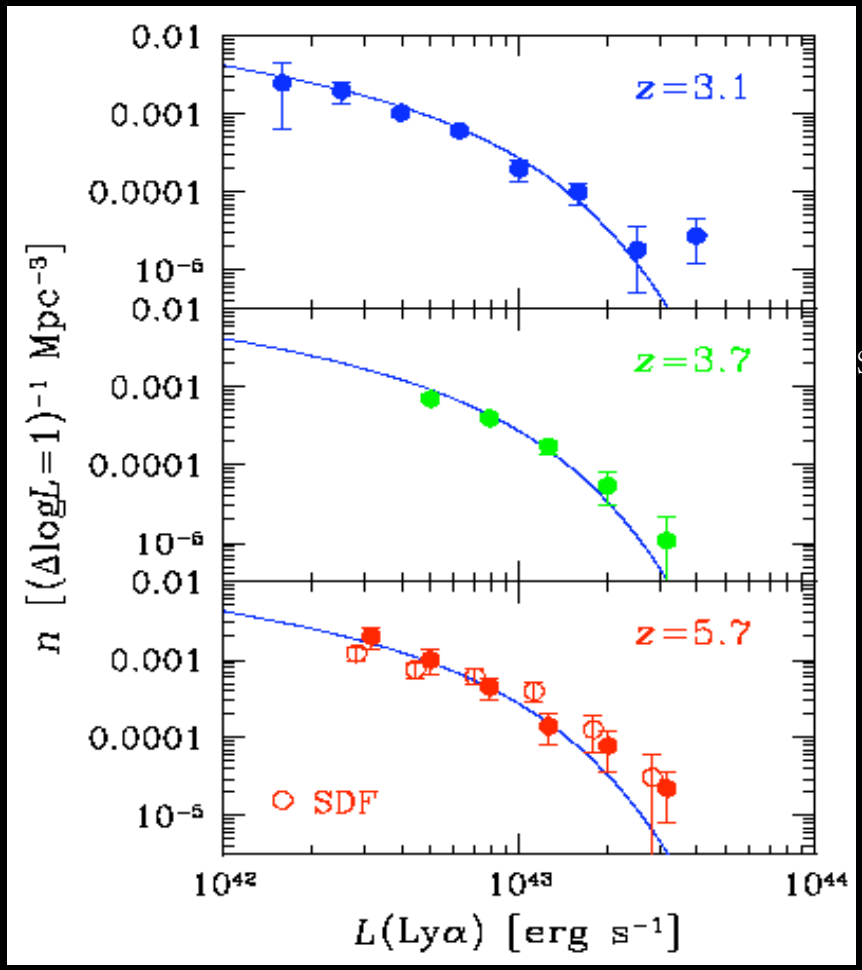
DLA model with z=6.295, log N_{HI} = 21.62

From Totani



luminosity functions

Lyman α luminosity function of LAEs



Data from SXDF

Ouchi, Murozono et al. 2006
In prep

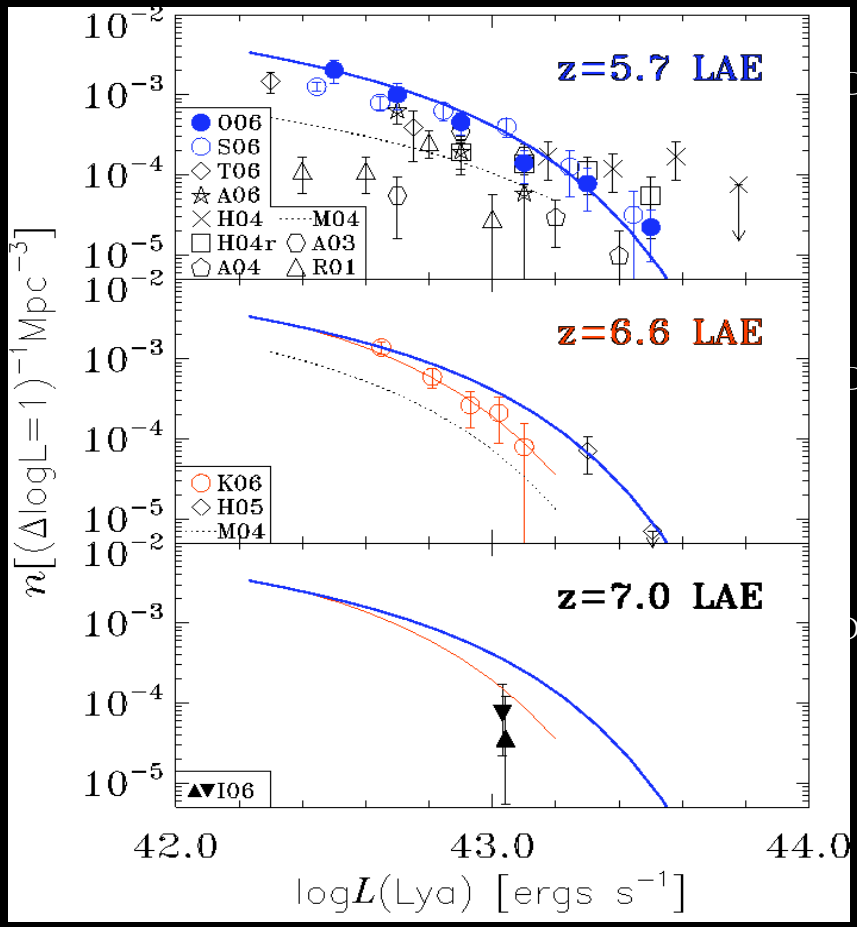
Data from SDF

Shimasaku et al. 2006, PASJ, 58, 313
(z=5.7)

Number density of LAEs unchanged over 3<z<6

Fraction of 'young' galaxies increases with redshift?

… but the number density decreases beyond z=5.7



Ouchi et al. 2006, in press

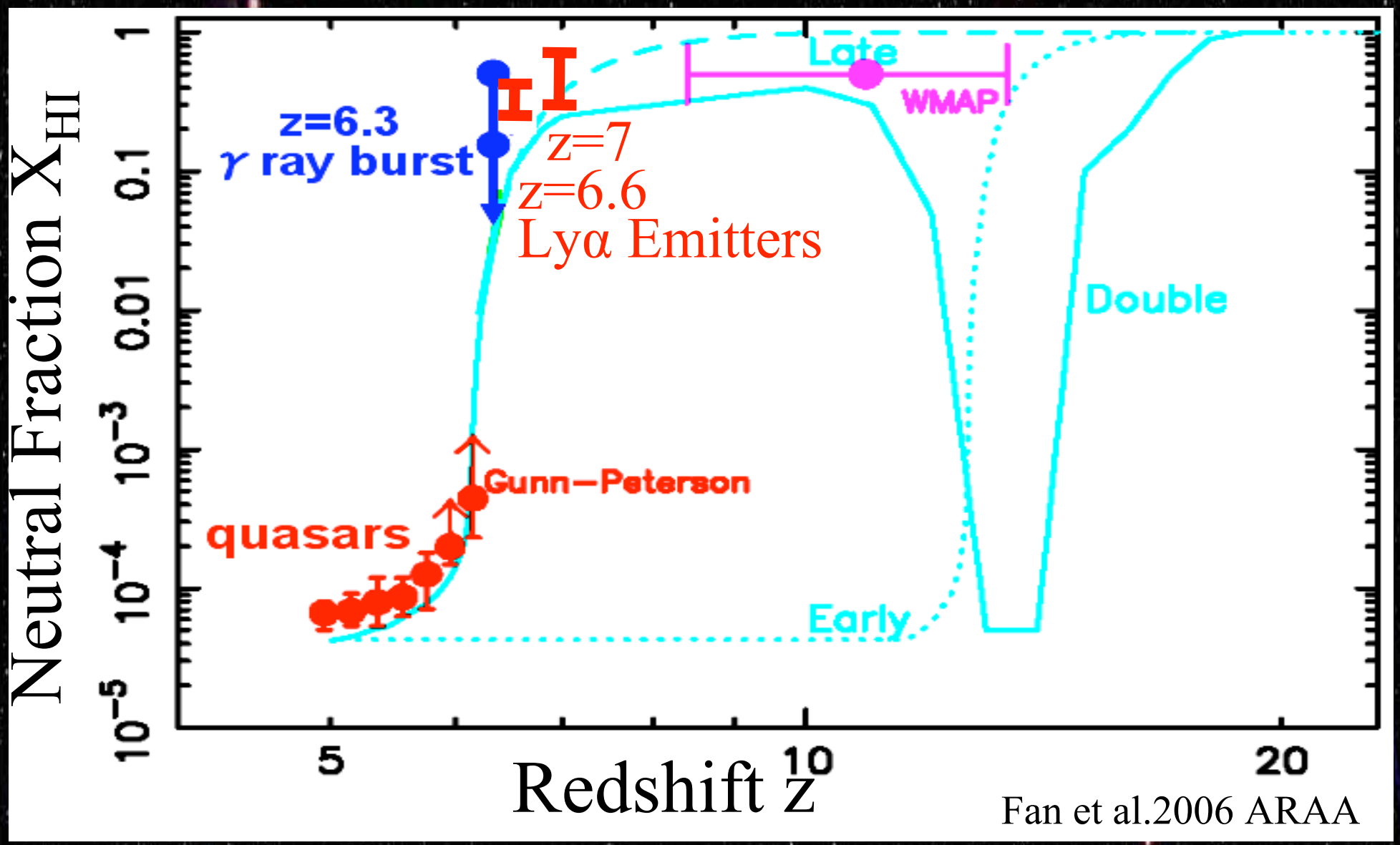
Data for z=5.7 :
Shimasaku et al. 2006, PASJ, 58, 313 (SDF)
Ouchi et al. in prep (SXDF)

Data for z=6.5 :
Kashikawa et al. 2006, ApJ, 648, 7 (SDF)

Data for z=7.0 :
Iye et al. 2006, Nature, 443, 186 (SDF)

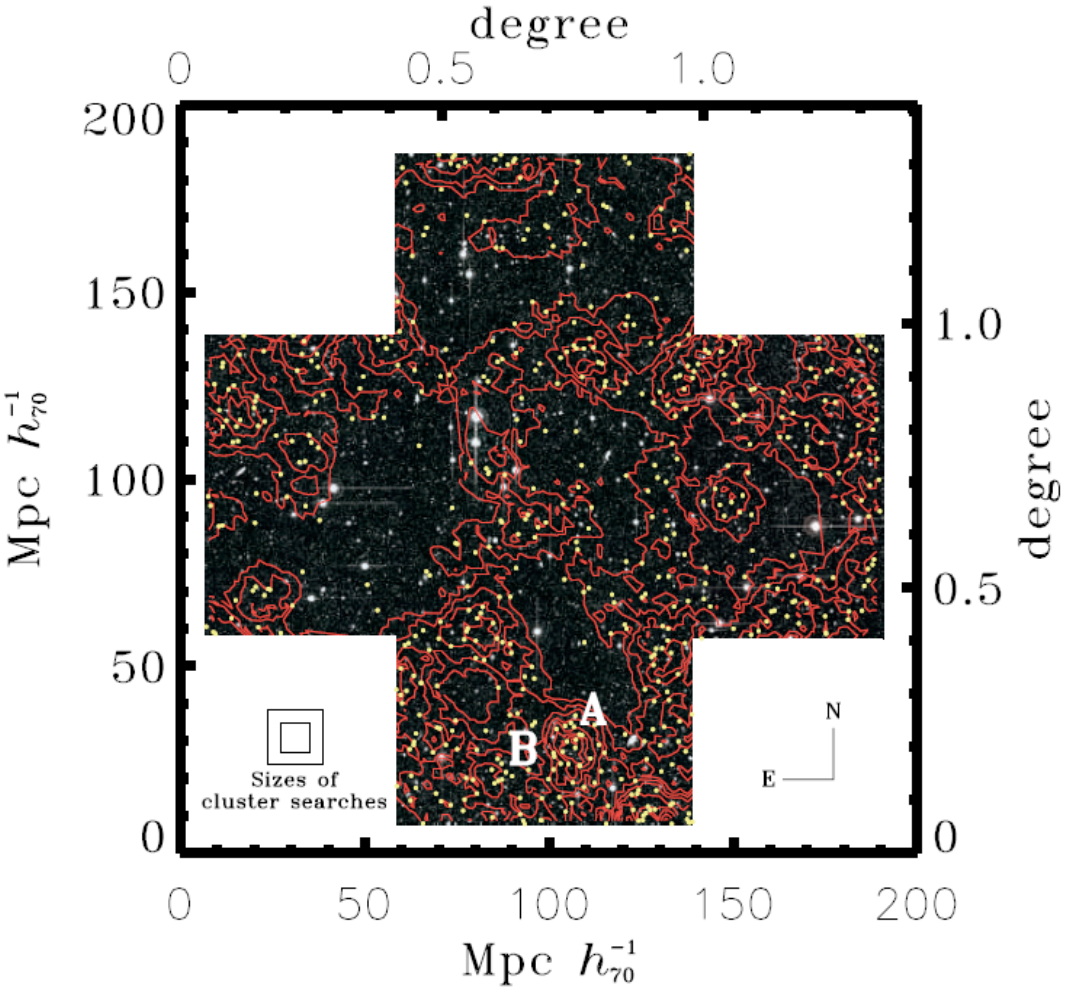
intrinsic evolution of LAEs?
Increase in the neutral fraction of the IGM is more likely,
as the change in the far-UV LF is much milder.

Reionization History



Fan et al.2006 ARAA

Galaxy formation and large scale structures



Distribution of ~ 500 $z = 5.7 \pm 0.05$ LAEs in the SXDF

Two overdense clusters A & B

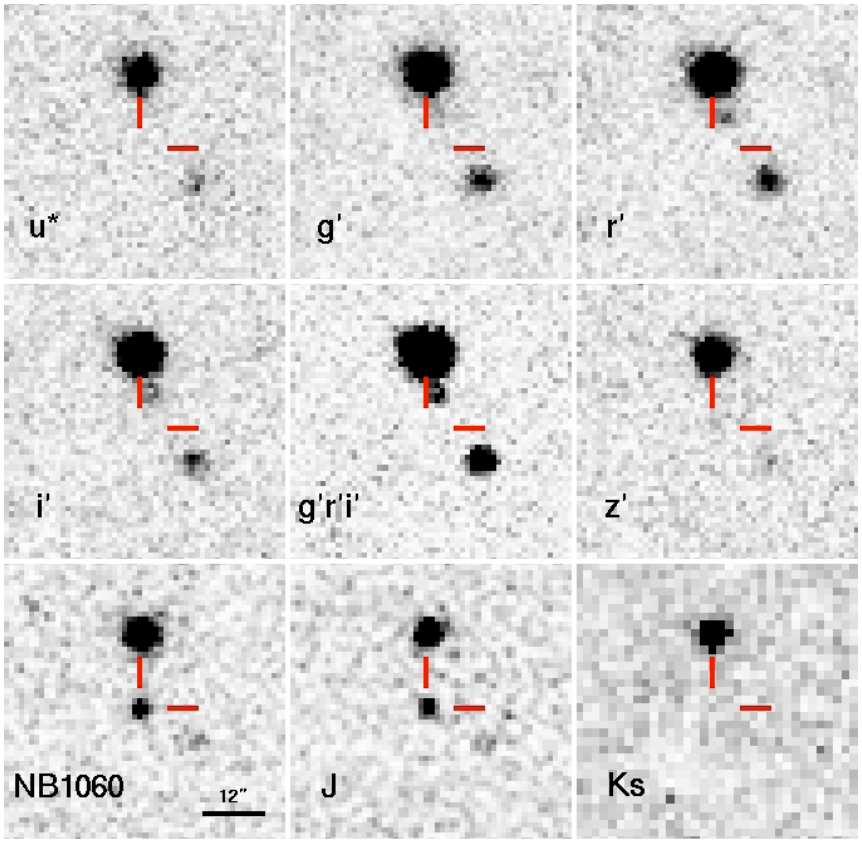
Bias ~ 3

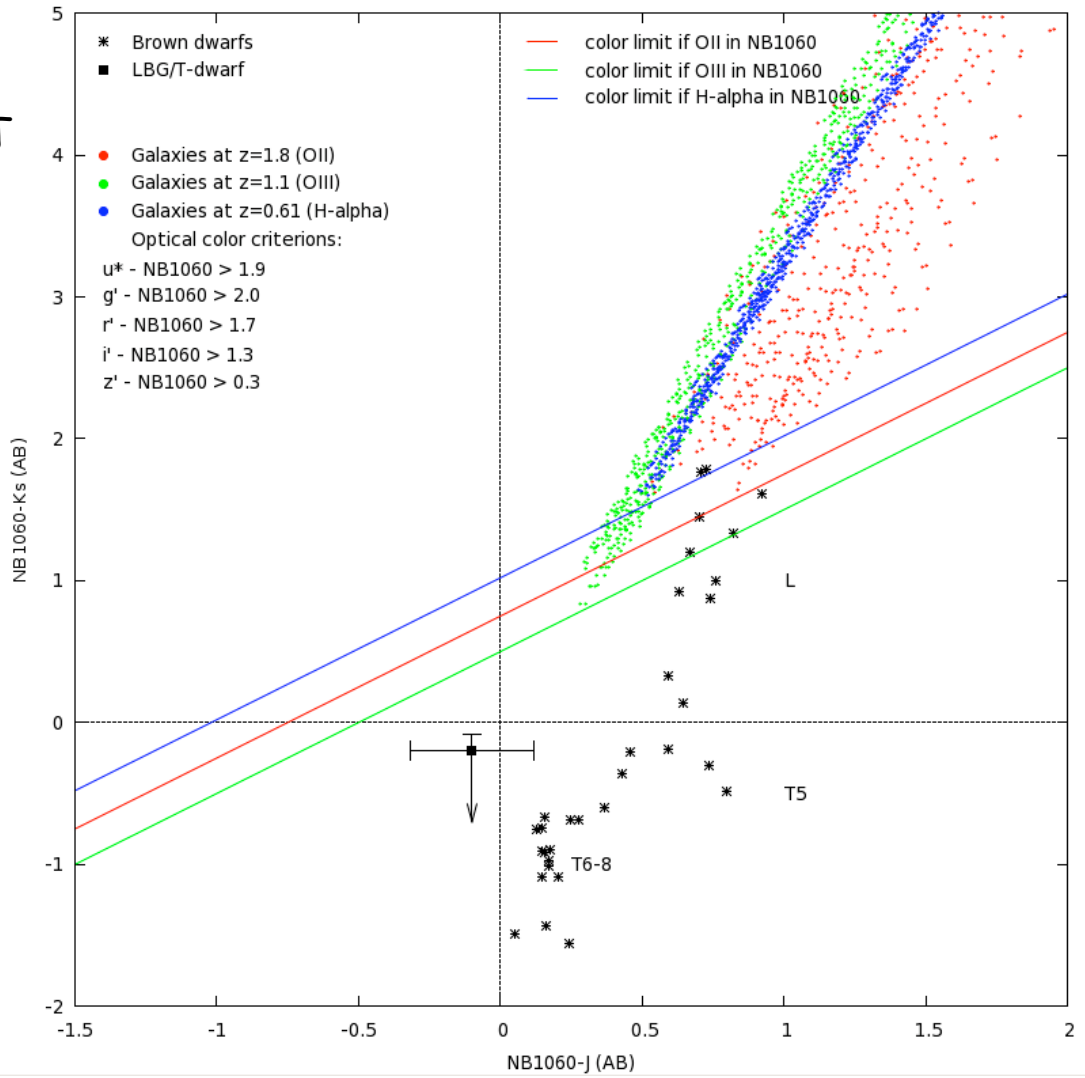
Bias ~ 30 on clusters A&B

(Ouchi et al., ApJ, 2005)

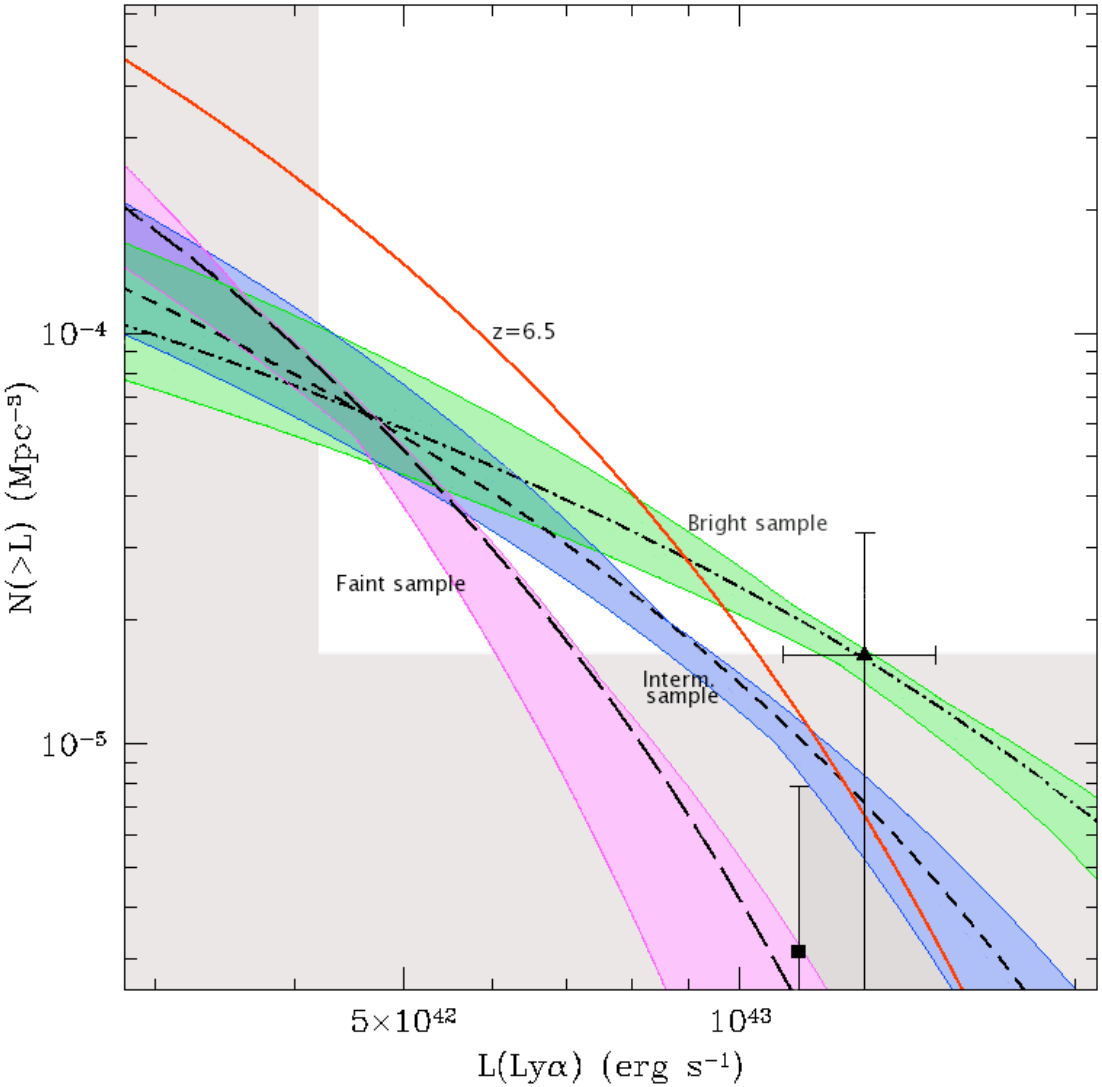
Going beyond z = 7: current status

- Only one object (GRB @ z=8.2) ...
- LBGs (Bouwens et al., Stark et al.)
- LAE searches
  - WIRCAM @ CFHT and HAWK-I @ VLT





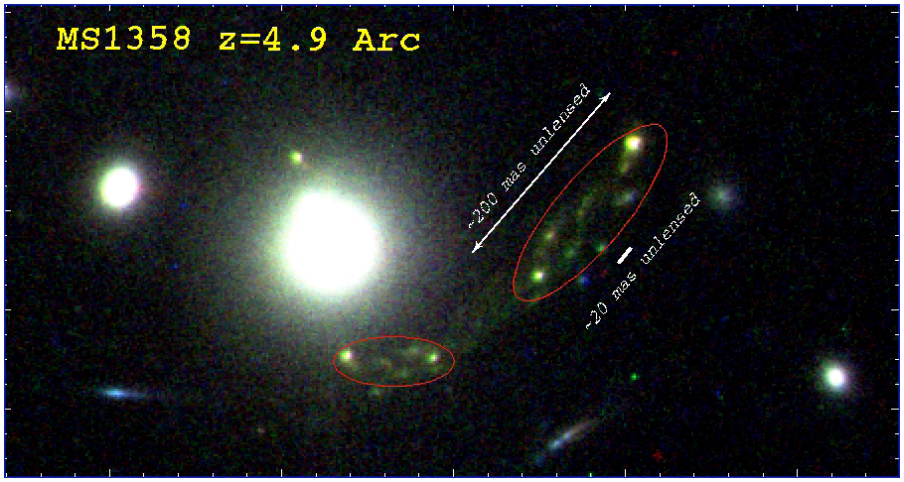
Going beyond z = 7 : LF of z = 7.7 Lyα LAE



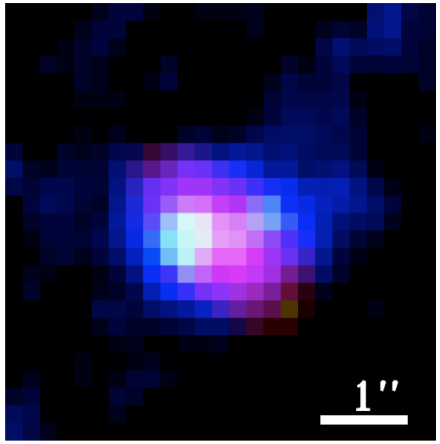
- From a photometric sample of 7 objects from WIRCAM data
- Possible evolution from z = 6.5, but depends on reality of candidates (spectroscopic confirmation requested)

  (Hibon et al. accepted for publication in A&A)

Going beyond z = 7: Requirements



- Near IR
- Spatial resolution: ~ 50-100 mas
- Individual FOV ~ 1"
- Multiplex: a few tens...
  - decreasing with z
- R ~ 4,000 (observation between OH lines)



z = 6.5 LAE, Ouchi et al., 2009

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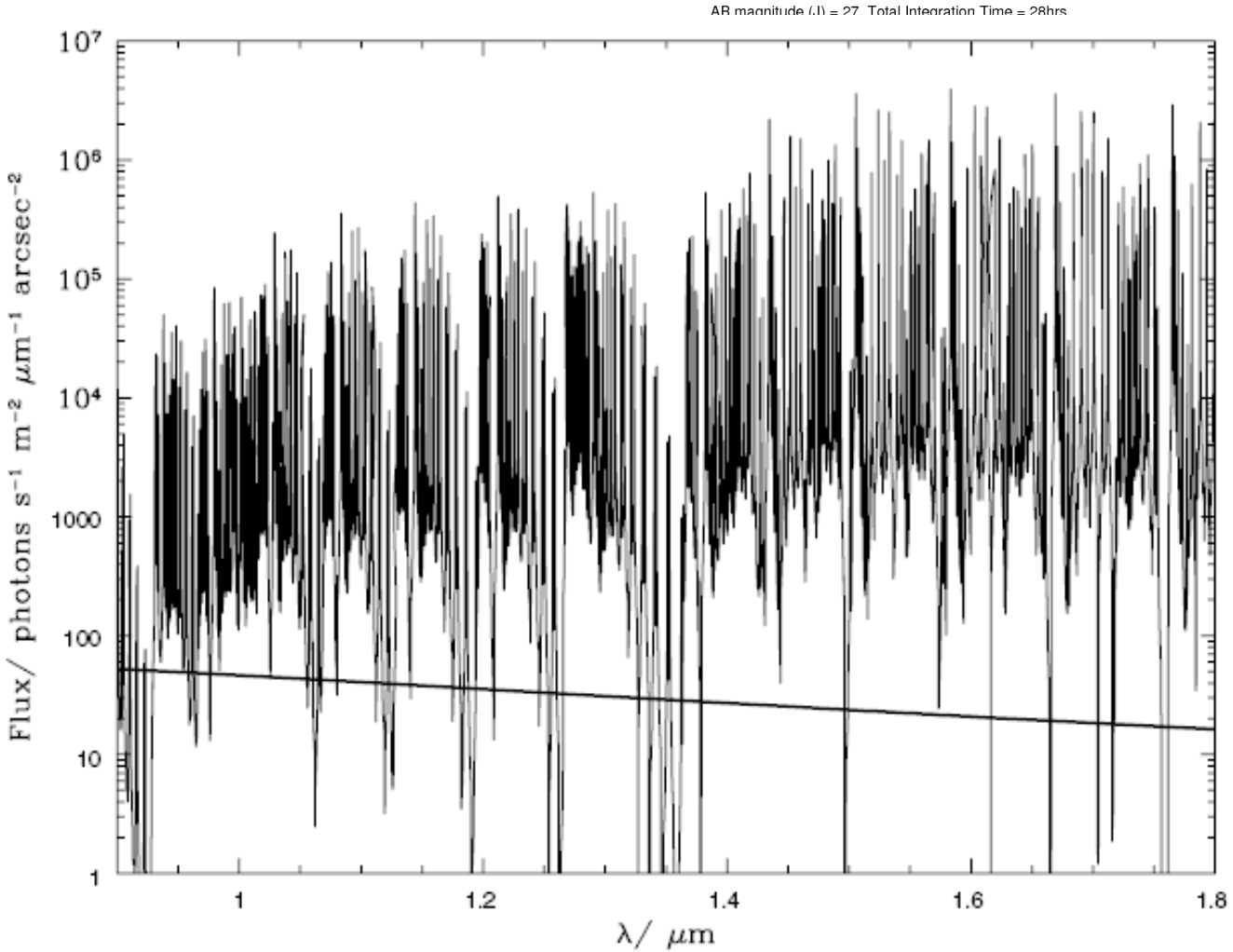
EAGLE: Sensi

- J_{AB} ~ 27, SNR = 5 unresolved
  - Automatic z dete
- Line sensitivities ~5 x 10^{-20} ergs.s^{-1}
- Extremely conser assumptions on sk
- At least one mag better than JWST, possibly significantly more



Ellis & Bland-Hawtorn, 2008

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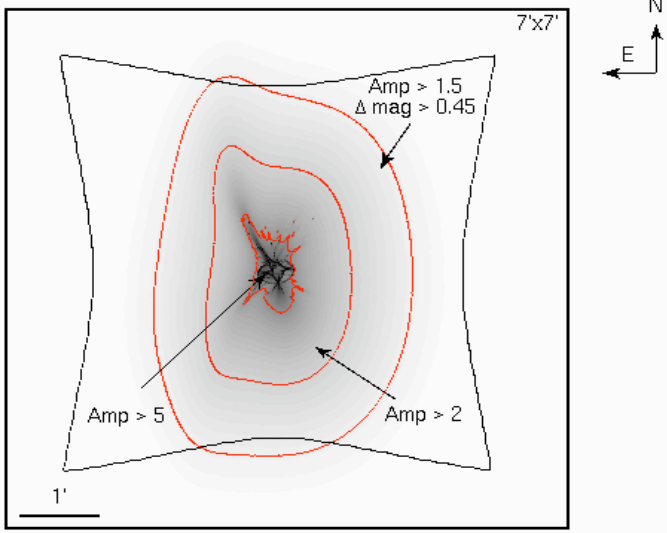
Wavelength (microns)

Finding the targets

- E-ELT itself (Micado)
- JWST will be the most obvious provider of targets. It's been built for this science case. Imaging down to AB ~ 30+
- VISTA (Ultravista starting next year)
  - z = 8.8 NB search
- HST / WFC3
- VLT: HAWK-I

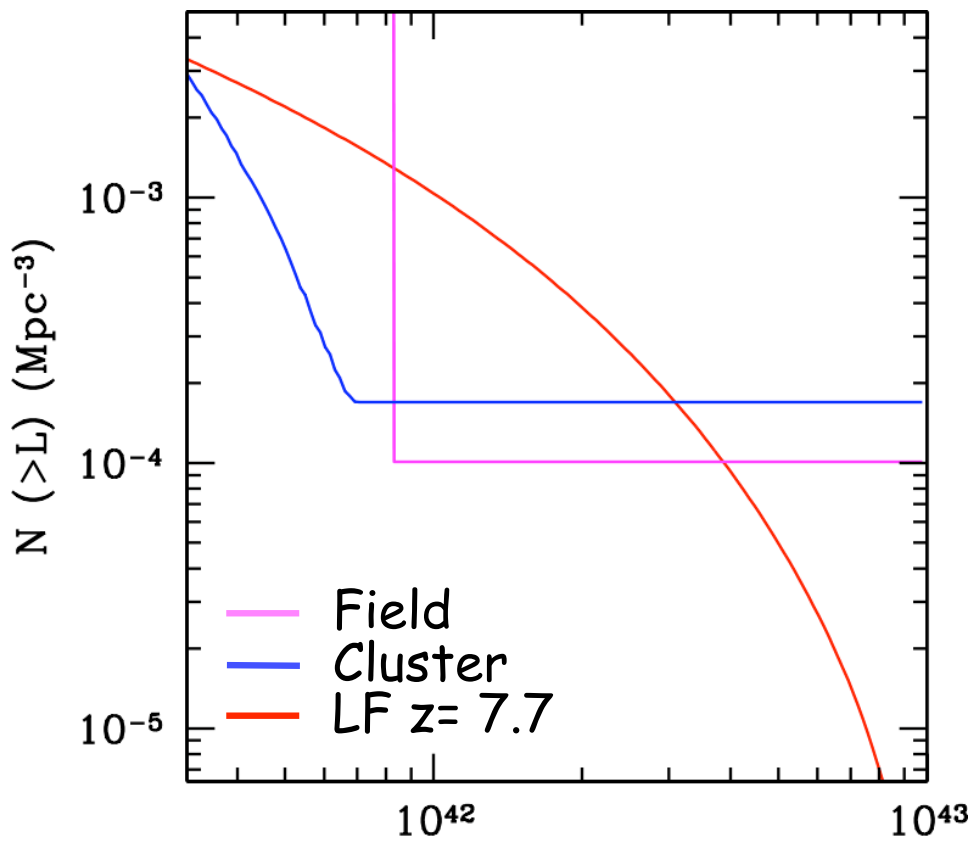
Best strategy for finding sources depends on Luminosity Functions – Unknown as yet

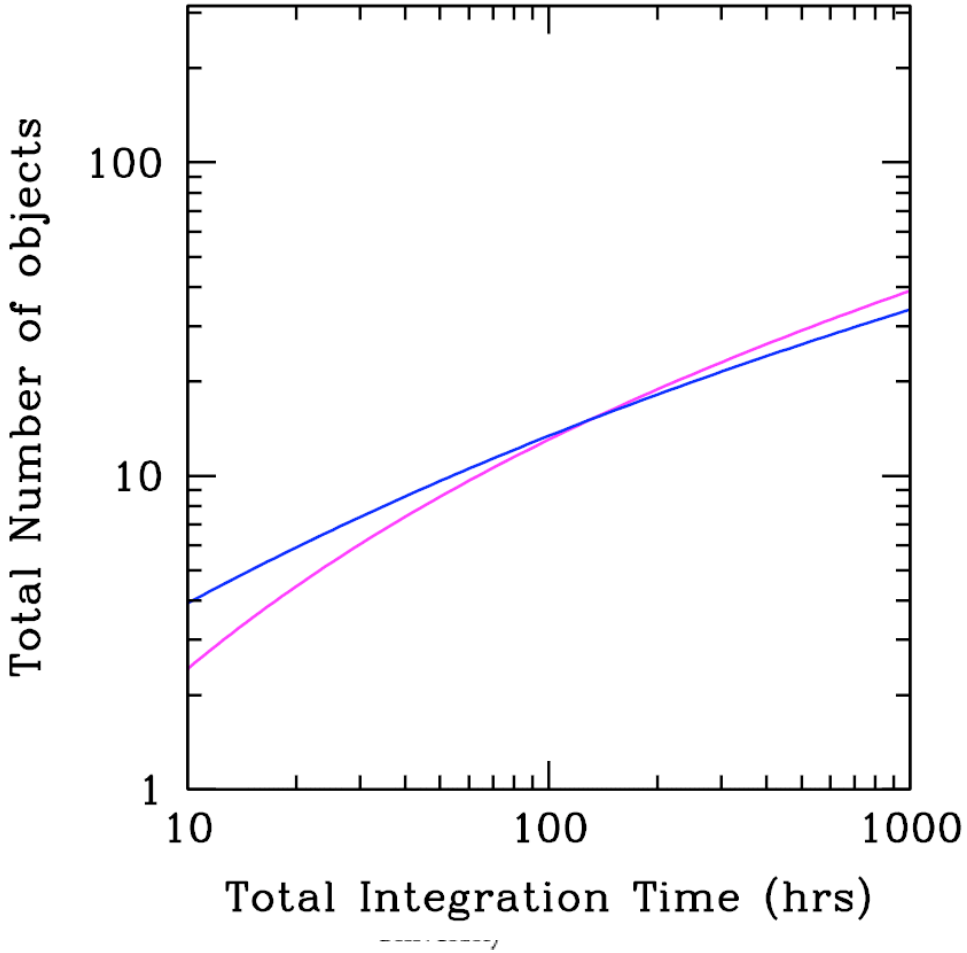
- One pointing ?
- Several pointings ?
- Field ?
- Cluster ?



Finding the targets: strategy

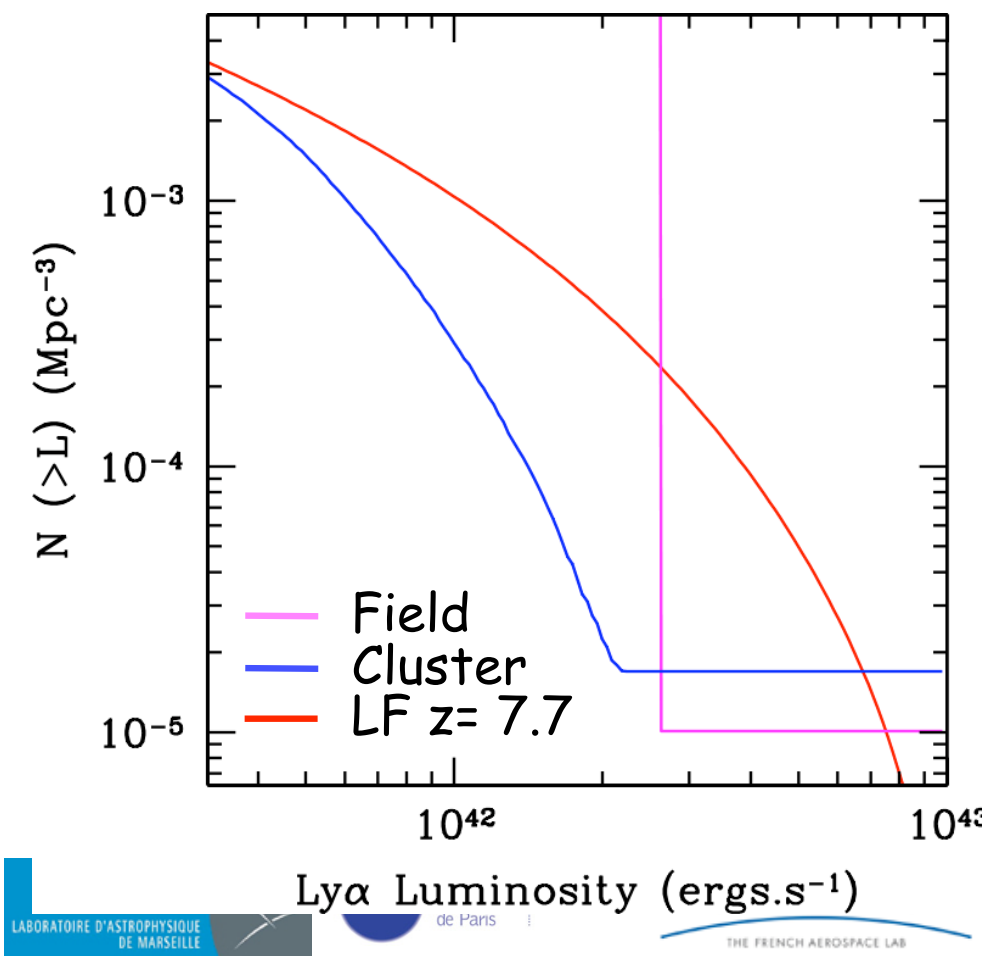
100 hrs, one field

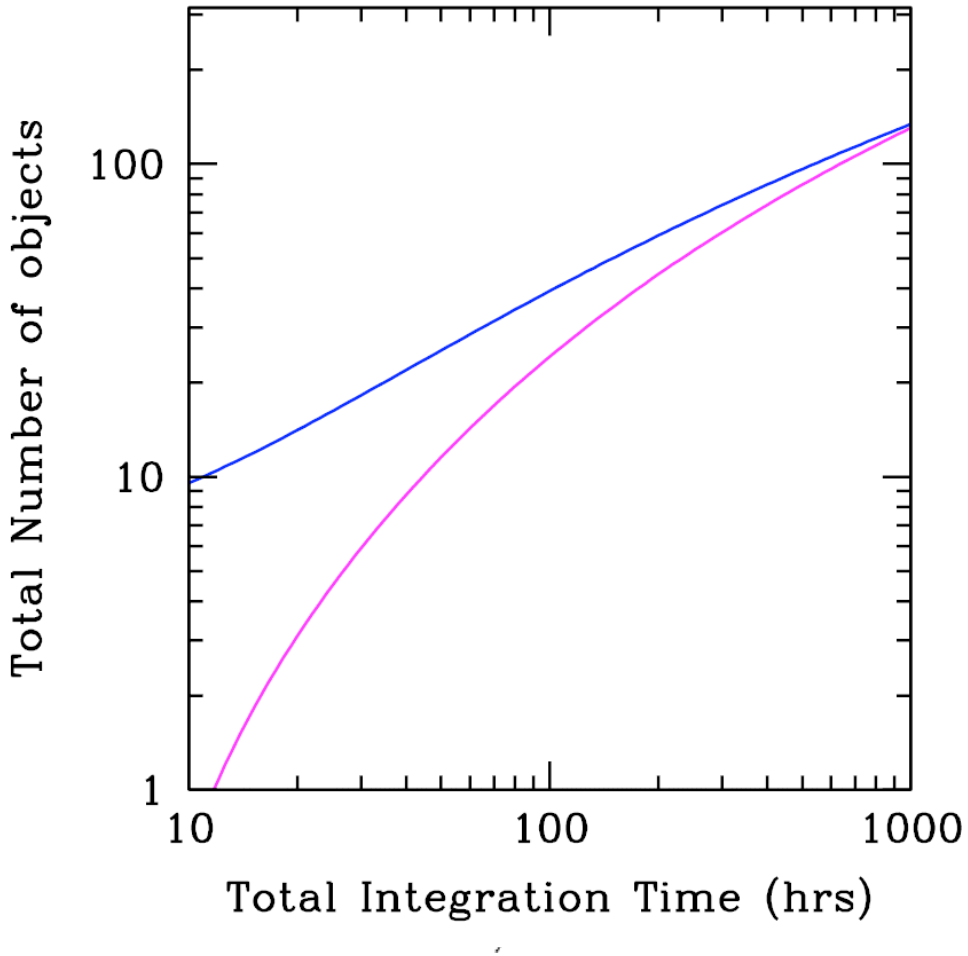




Finding the targets: strategy

10 x 10 hrs, ten fields





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Finding the targets: conclusions

- It will be possible to have candidates relatively easily (VLT, VISTA, HST, JWST, E-ELT).
- JWST will find the targets (imaging) and will do the initial (bright) spectroscopy …
- … and ELTs will do the rest: faint stuff, highest redshifts (9, 10, more ?)
- The choice between multiple fields vs single field and field vs. clusters will be made based on LFs that will be available at that time
  - Clusters better for short integration times (in terms of number of objects), unless LF truncated at the bright end
  - Clusters remain the only way to probe the faint end

May 2009

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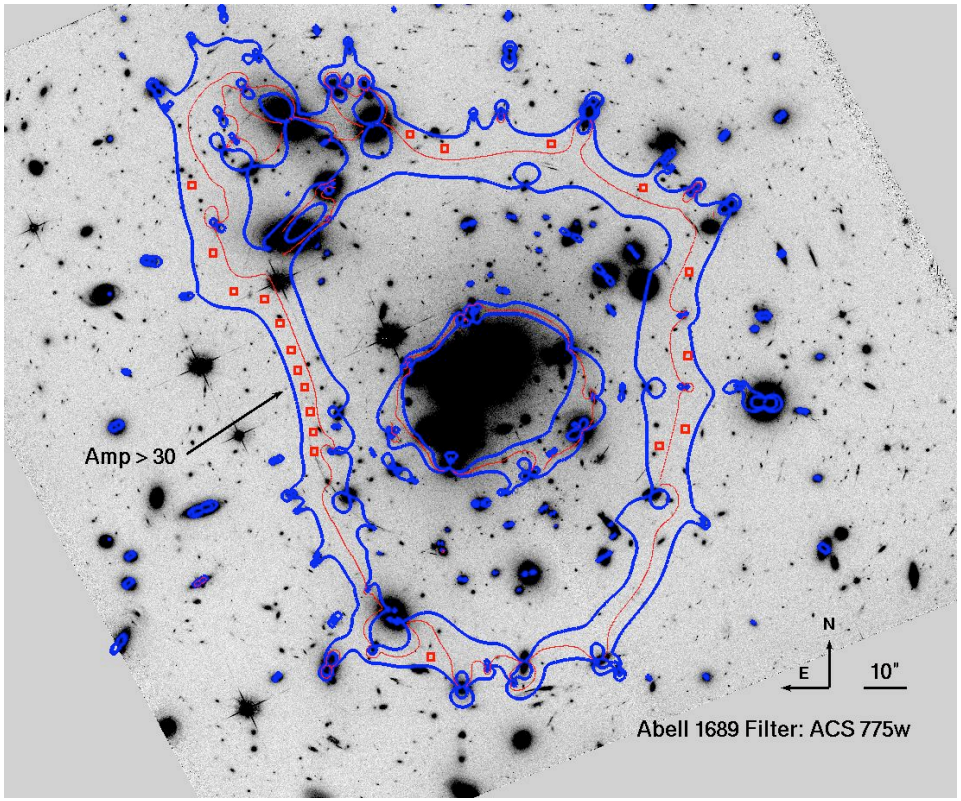
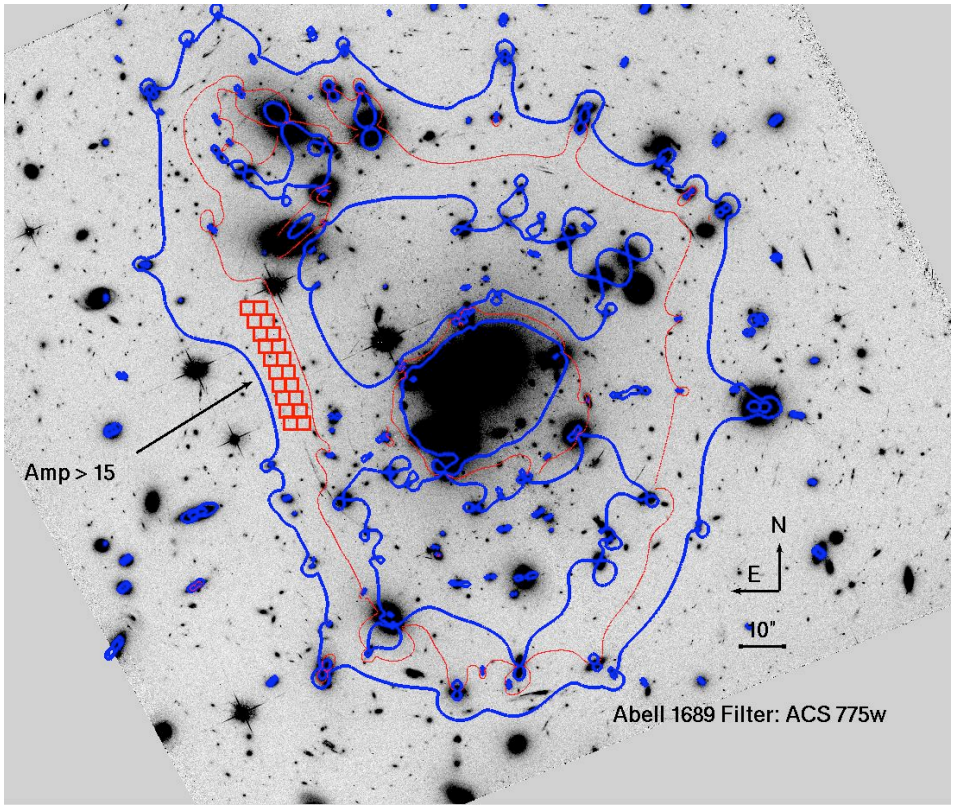
Finding the targets: conclusions

- Numbers highly dependent on LFs
- It will be possible to get samples of 100's or 1000's of targets
- This will be done with JWST
  - Would require several 100's of hrs on VLT (broad band imaging included) – Still feasible
- E-ELT spectroscopic follow-up will require 100's of hrs
  - Continuum (absorption lines, chemical composition, …)
  - Emission lines (Lya, HeII – popIII, …)

Other option: blind searches (line emitters)





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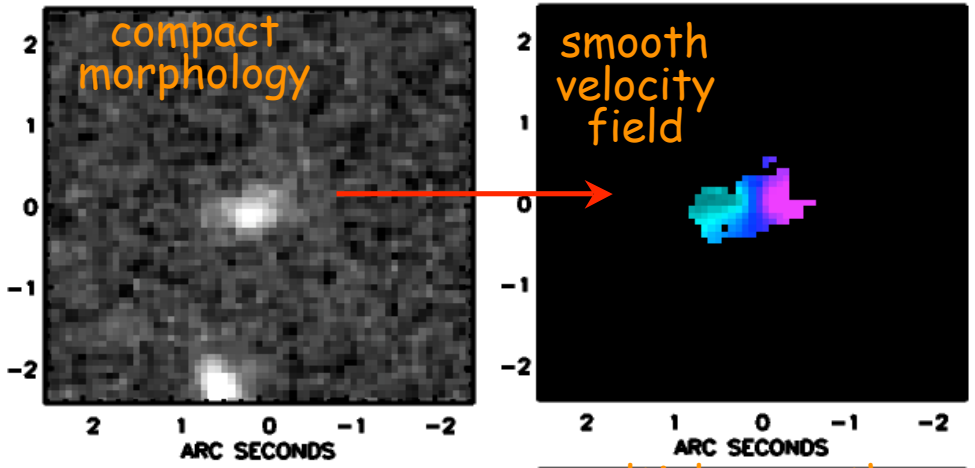
Simulations with EAGLE simulator (M. Swinbank, J. Richard et al.)

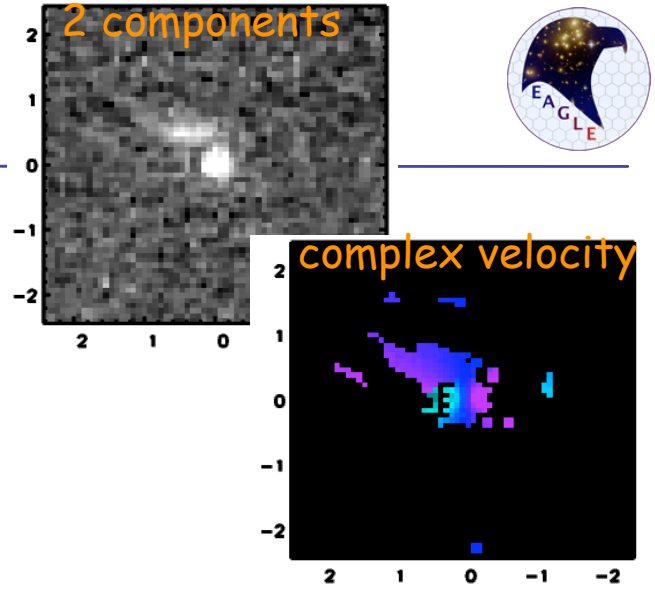
- **Inputs: NICMOS HDF images of high-z galaxies (z=2--4) but redshifted to z=8-9**
  - segmented to find multi-components
  - each component assigned (different) spectral configuration
  - each component assigned different velocity field

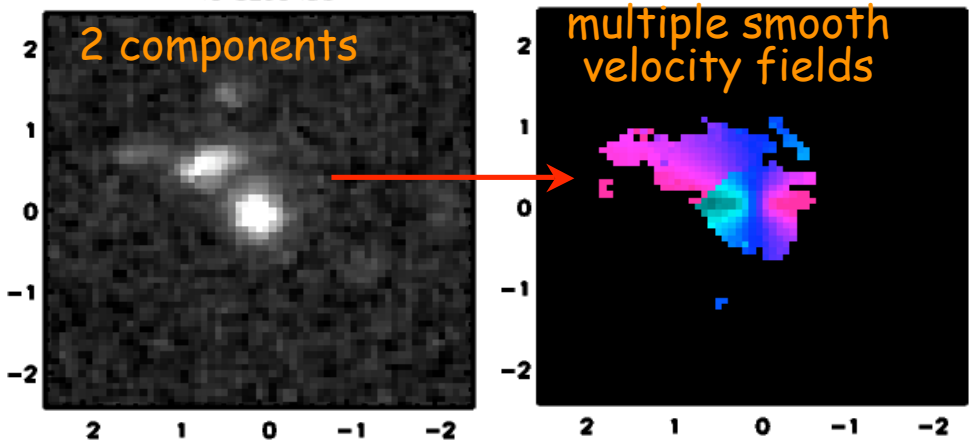
- **Simulation. Parameters:**
  - 12x1200seconds (4hrs)
  - PSF: EAG6GS-J
  - seeing: 0.65"
  - EE=36.2% in 75mas2
  - (manua kea+40m telescope at 280, 240, 150K and e=0.2,0.2,0.7)

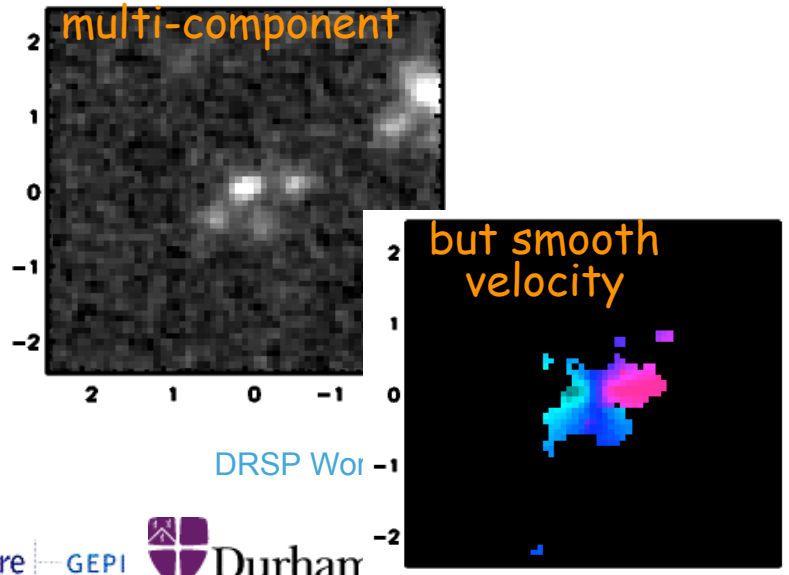
- **Outputs: simulated datacube:**
  - Generated continuum images
  - Recovered velocity field
  - Recovered spectral information

Some examples of inputs:









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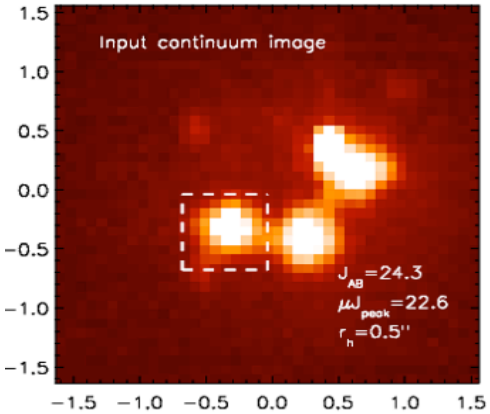
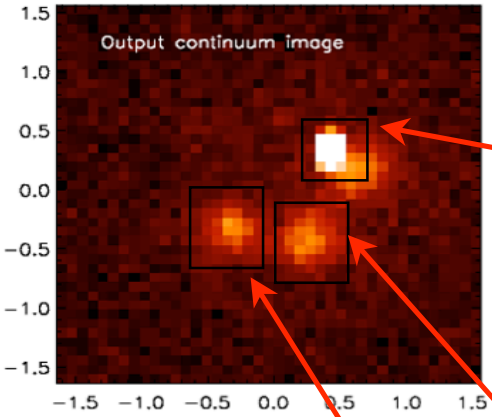
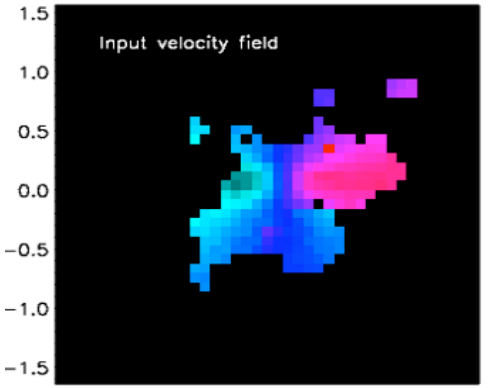
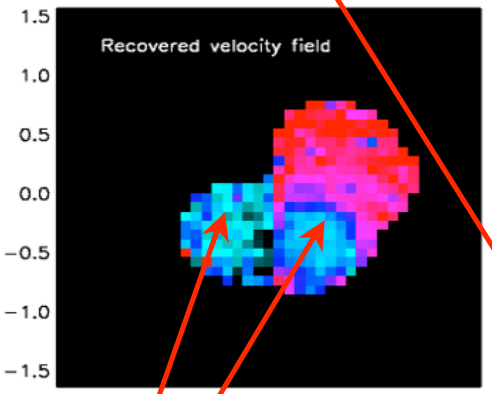
input

recovered output



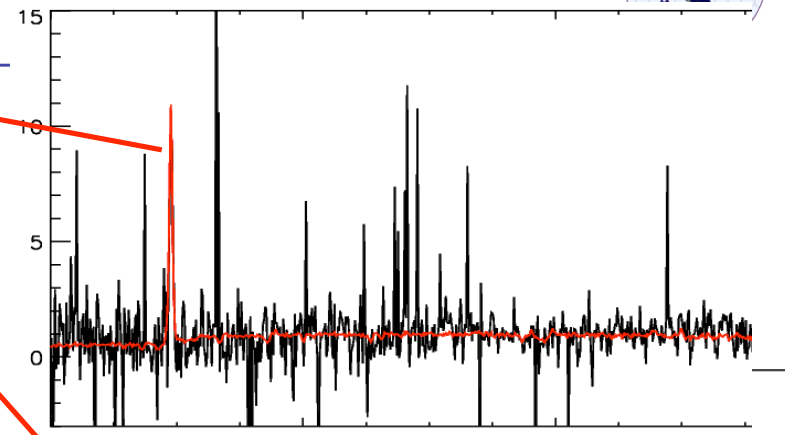




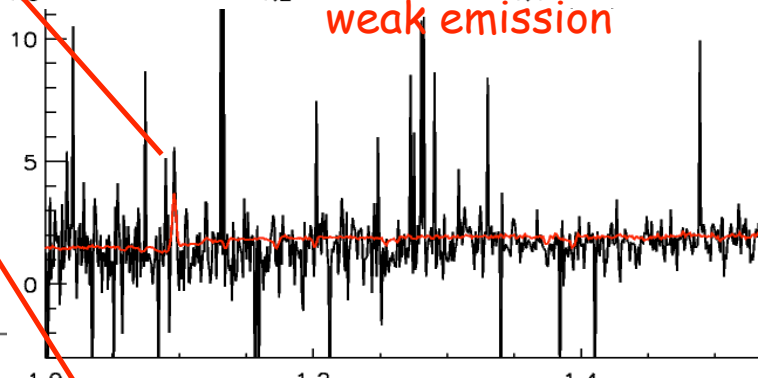


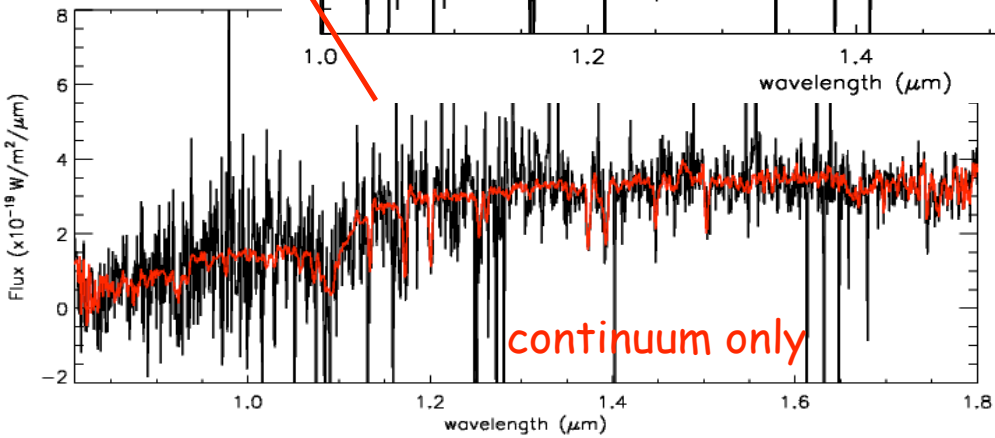
simulated multi-component galaxy

strong emission easily recovered



weak emission





continuum only

bulk velocity gradients recovered

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Synergies

- HST, VLT, VISTA, etc.
  - Many on-going programs
  - Much more to come in next years, KMOS, VISTA, GTC, etc.
  - GRBs
- CMB (Planck, EBEX, ...)
- LOFAR 21-cm HI
- ALMA
- JWST
- E-ELT (Micado)
- DE space mission(s) (?)

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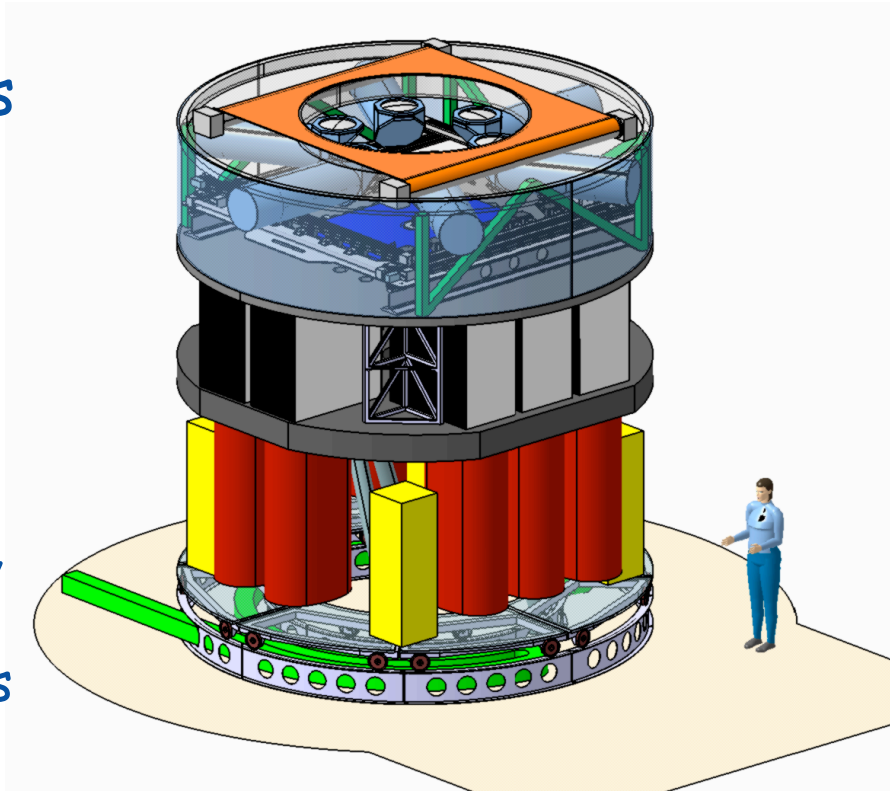
Conclusions

- Contemporary science, much progress expected in coming years
- Very strong synergy with other facilities
- Programs of several 100s of hrs with EAGLE
  - Sample of 100's of objects at z > 7
  - Specs ~ optimal (sampling, sensitivity, etc.)
  - Strategy will be optimised as knowledge on high-z galaxies improves



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