Observations and Inferences from Lyman-α Emitters

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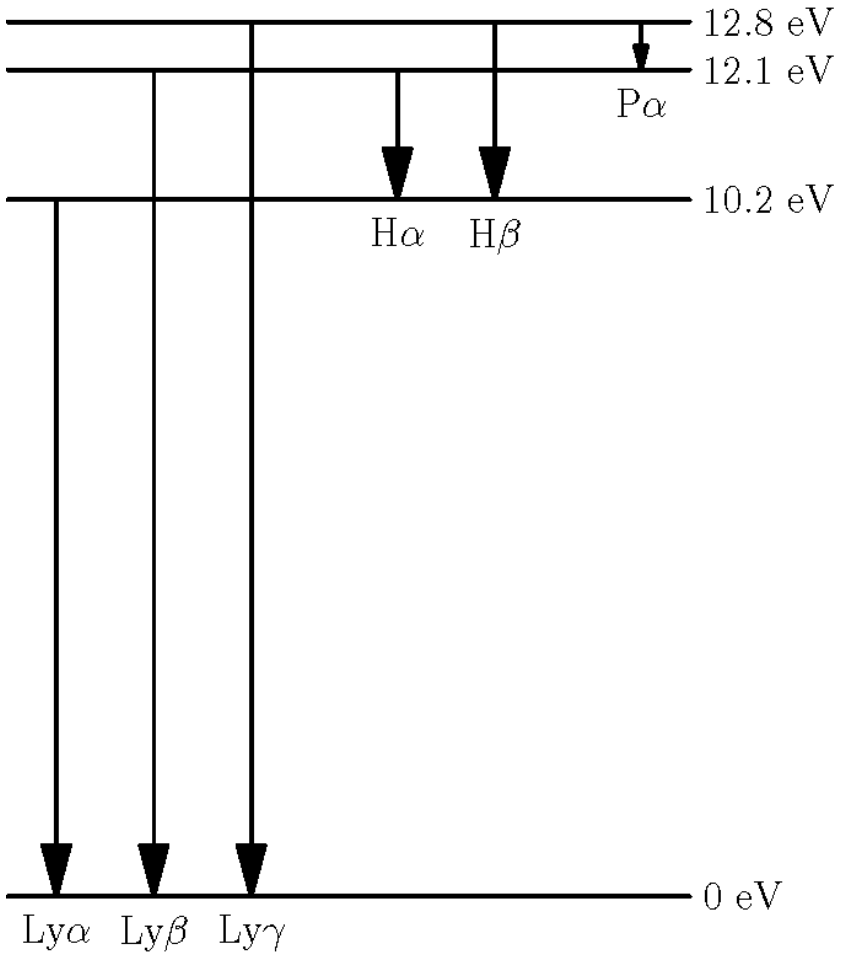
6 March 2013

Outline

The Lyα Line

- $n = 2 \rightarrow 1$ transition of H
- $\lambda = 1216$ Å
- Strongly scattered by neutral H
- Red-skewed in distant sources

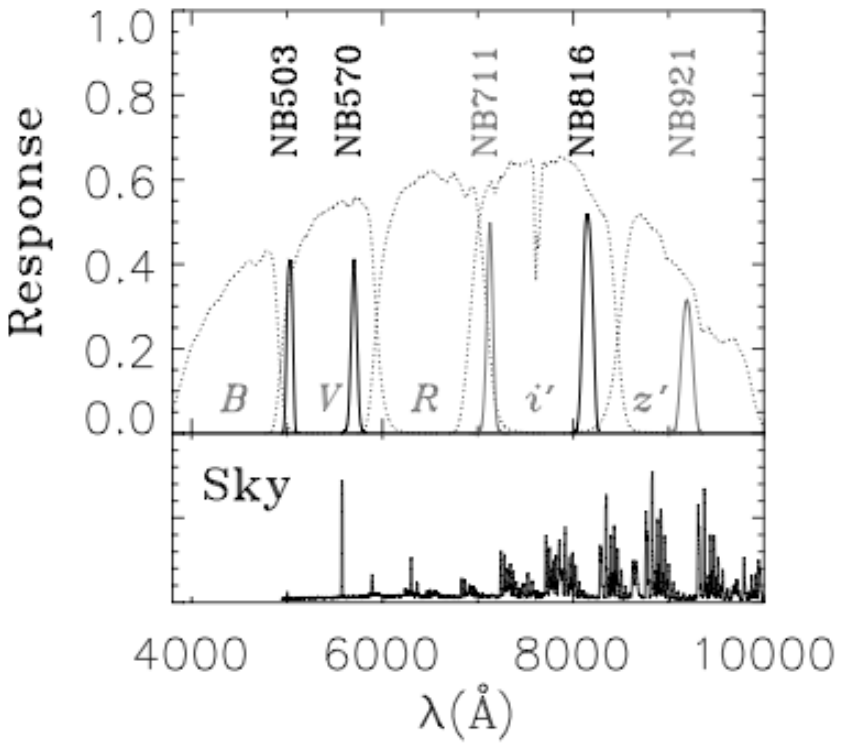


Relation to Early Galaxies

- Lyman Alpha Emitters (LAEs) observed
- Need hot stars $\Rightarrow$ star forming
- Blocked by dust $\Rightarrow$ low-metallicity
- Seen for $z \simeq 2$–7
- Primordial?

Narrowband Photometry

- Use narrowband filter
- Tune to Lyα at chosen z
- Contamination?
  - [O II]
  - [O III]
  - Hα



Ouchi 2008

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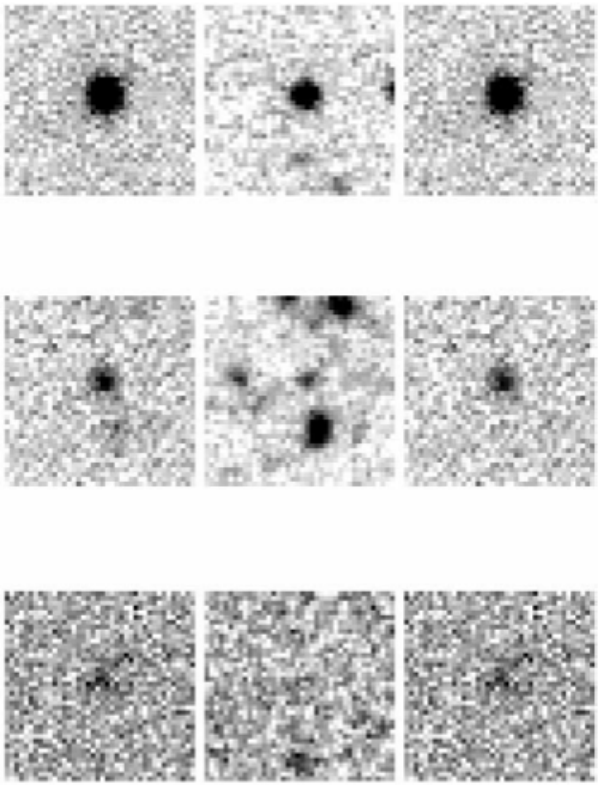
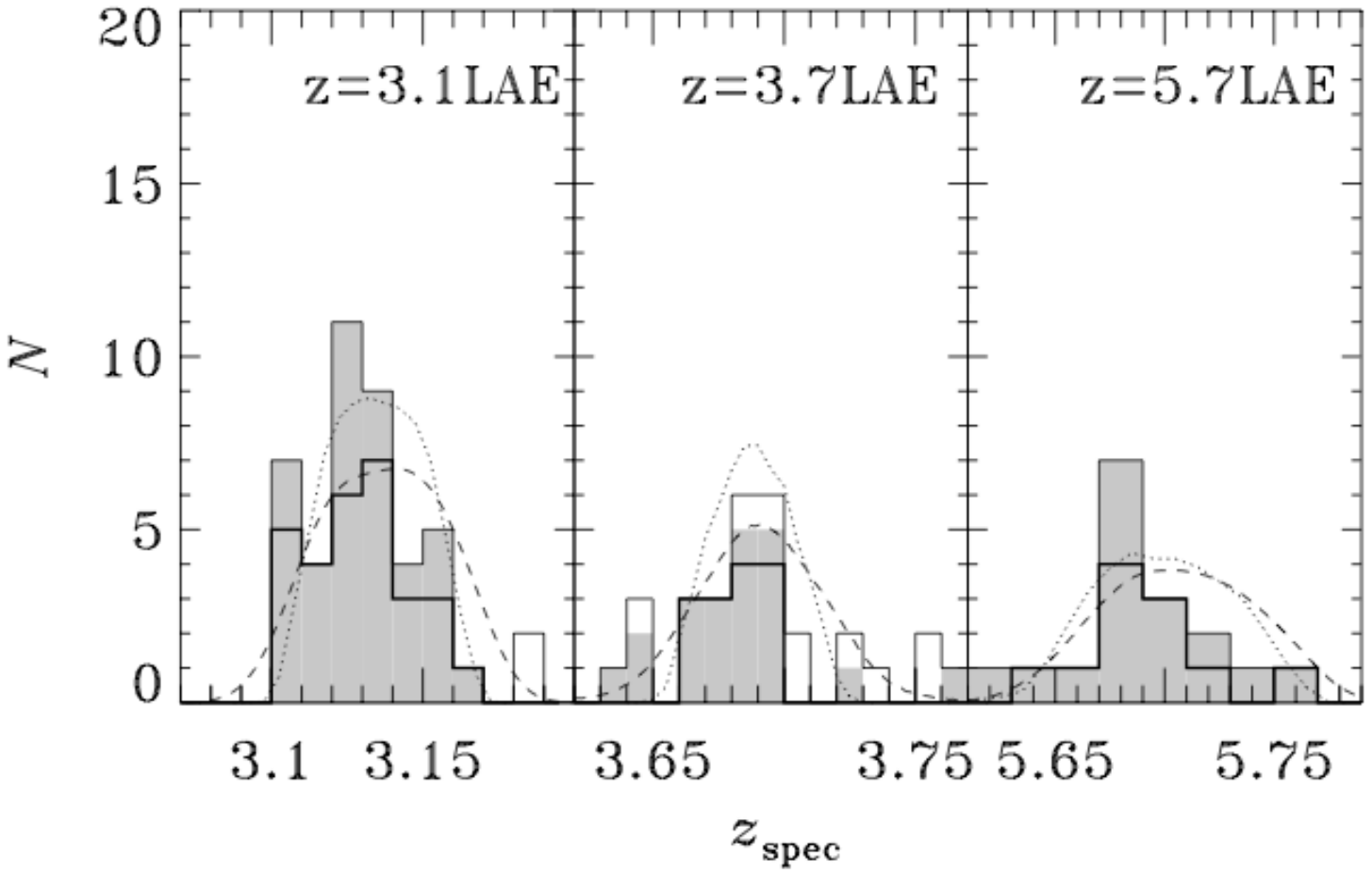


Gronwall 2007

Spectroscopic Followup

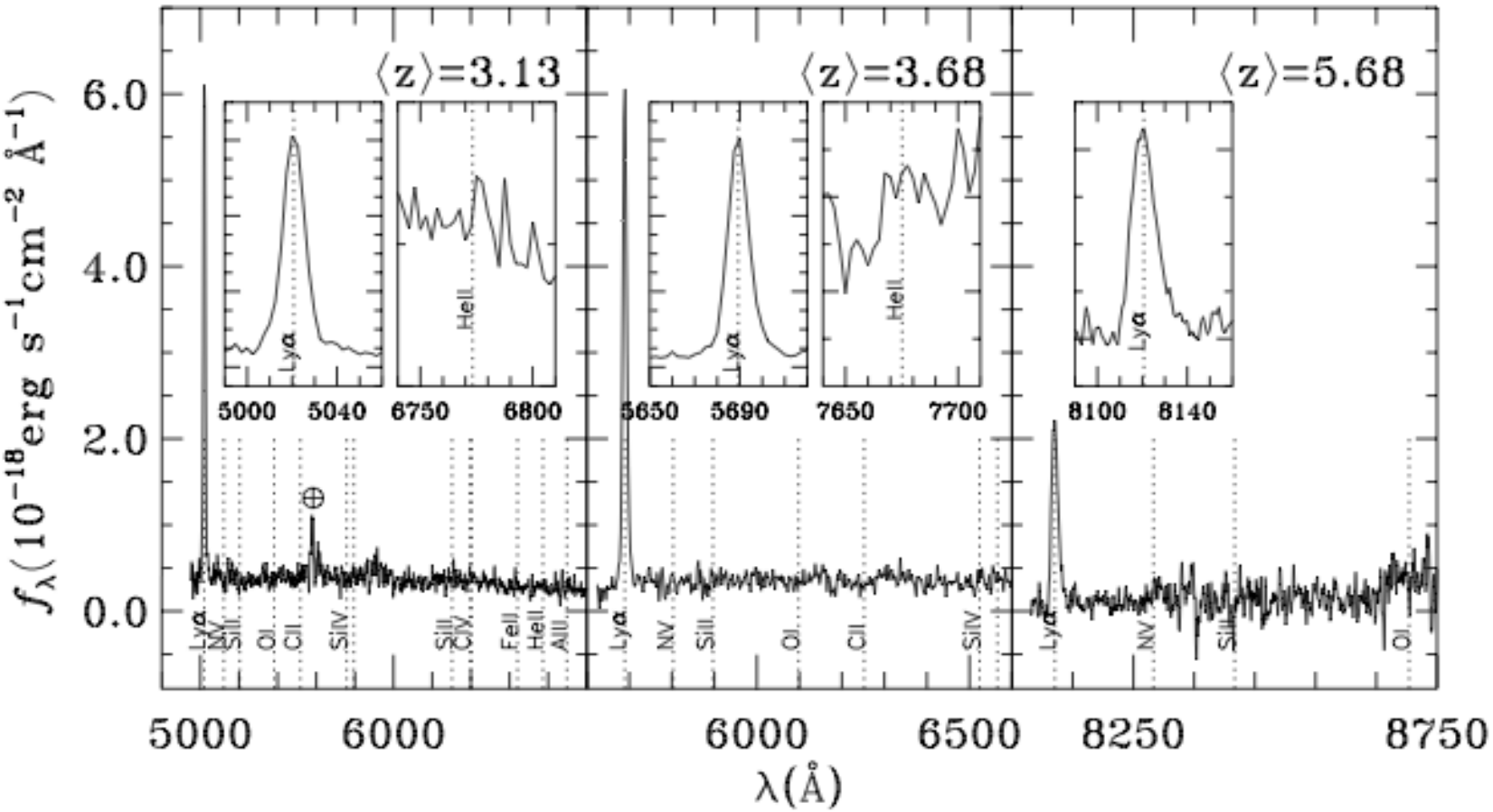


Ouchi 2008

Spectroscopic Followup

- AGN?: high-ionization lines
- $\lesssim$ 10% AGN
- No He II: not primordial

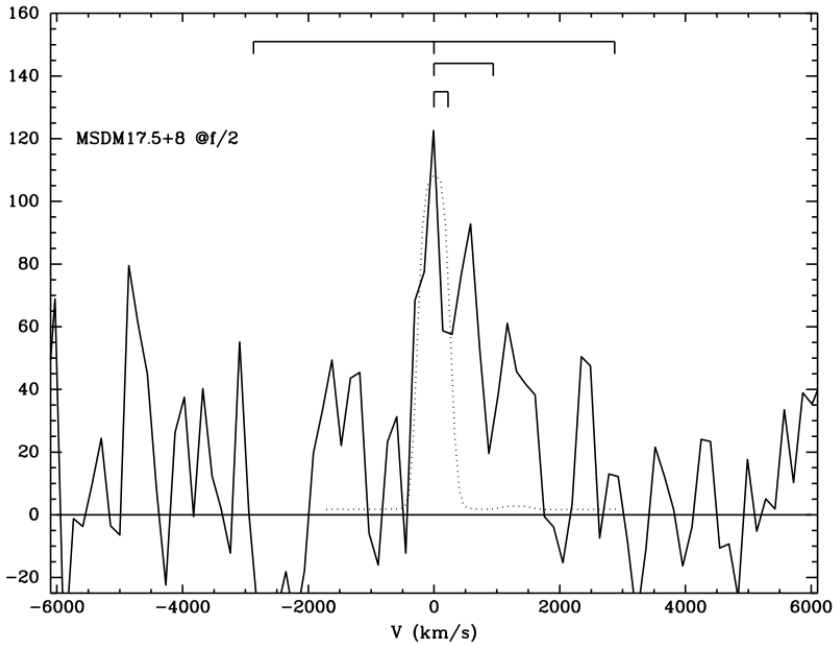
Spectroscopic Followup



Ouchi 2008

Blank-Field Spectroscopy

- Multiple slits on instrument
- Smaller samples
- Good for faint objects
- Faintness problem for followup/confirmation



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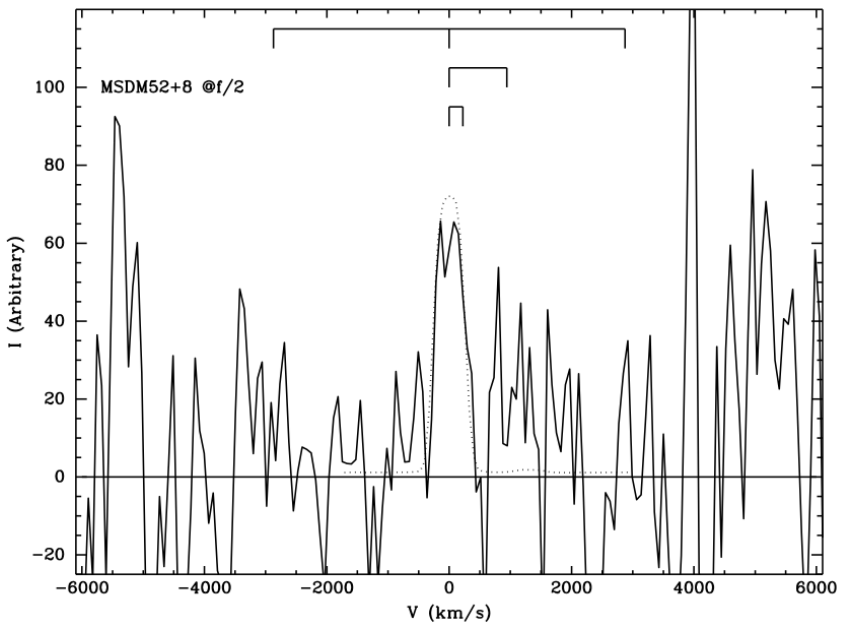


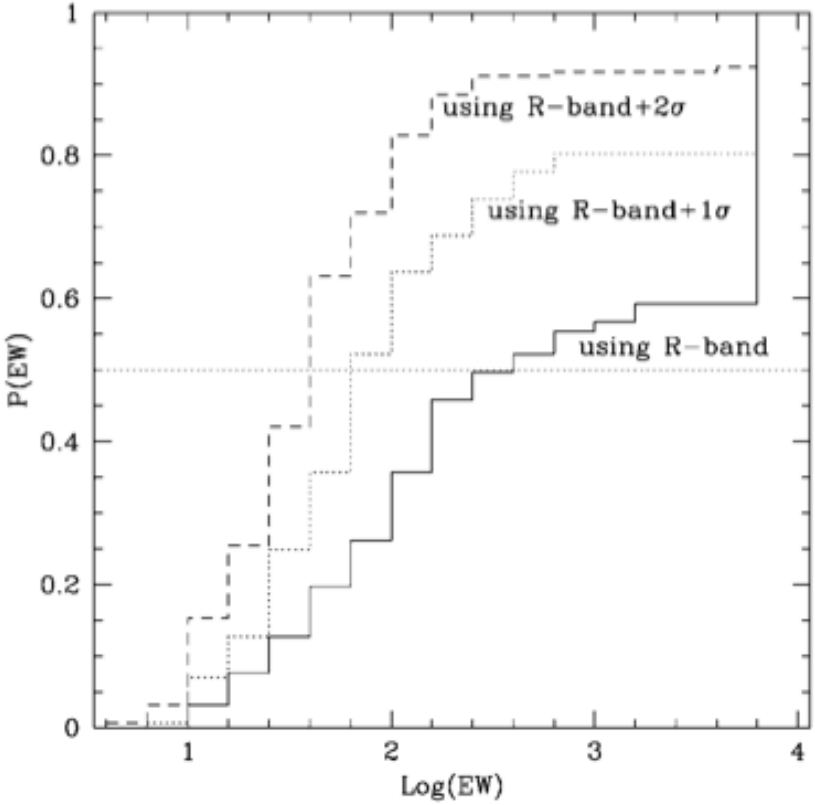
Martin 2008

The Data So Far

- 1–2 thousand observed
- Specific redshift windows, $2 \lesssim z \lesssim 7$
- Small studies: statistics
- Changing fraction of population
  - $z = 5$: outnumber LBGs 4 : 1
  - Disappearing by $z = 2$

LALA

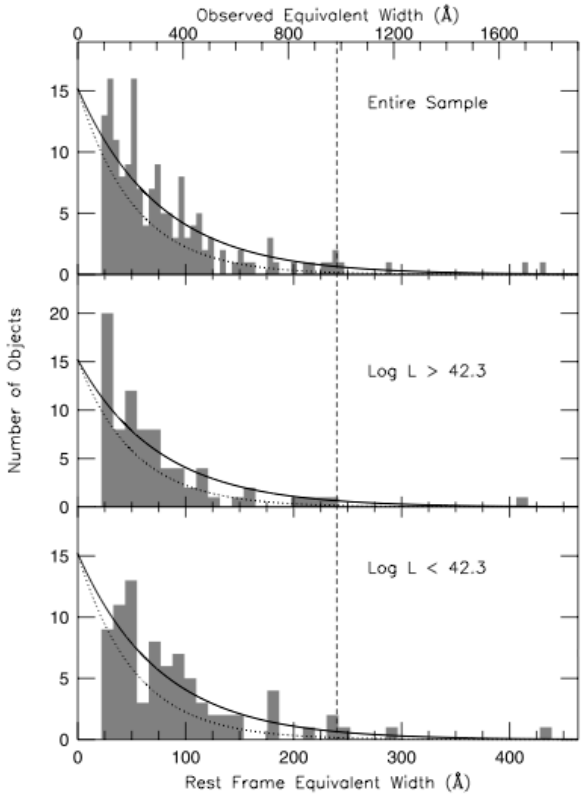
- Large Area Lyman Alpha survey
- 0.72 deg^2
- $4.37 < z < 4.57$
- Too many large EWs $\Rightarrow$
  - Zero metallicity?
  - Top-heavy IMF?
  - Episodic star formation?



Malhotra 2002

ECDF-S

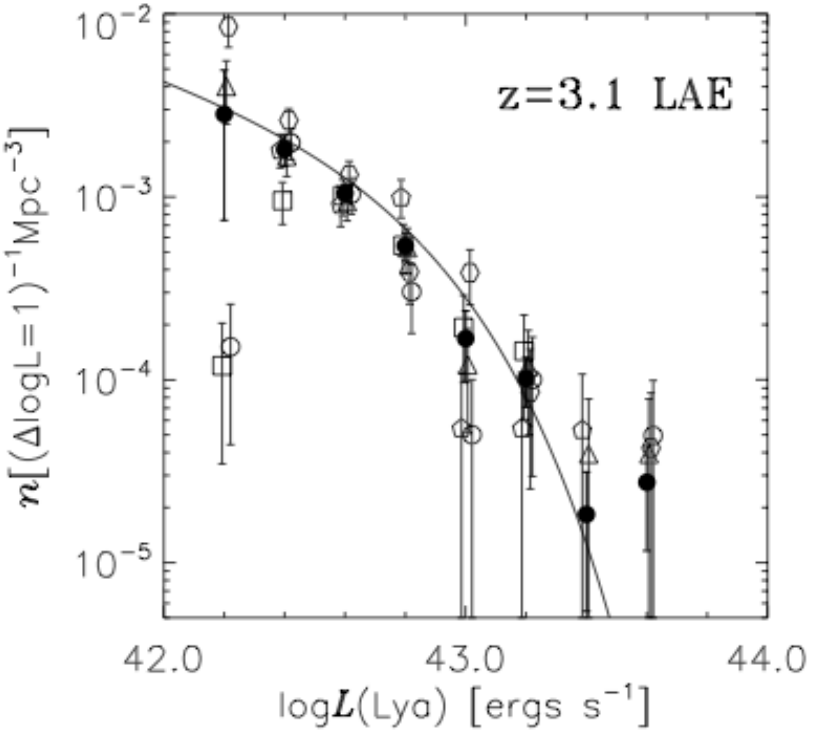
- Extended Chandra Deep Field
- 0.28 deg^2
- $z = 3.1$
- EWs not too large
- Signs of dust



Gronwall 2007

SXDS

- Subaru, XMM-Newton, etc.
- $z = 3.1$, 3.7, 5.7
- "Lyα LFs of LAEs do not evolve by more than a factor of 2–3 in either luminosity or number density"
- May co-evolve with IGM



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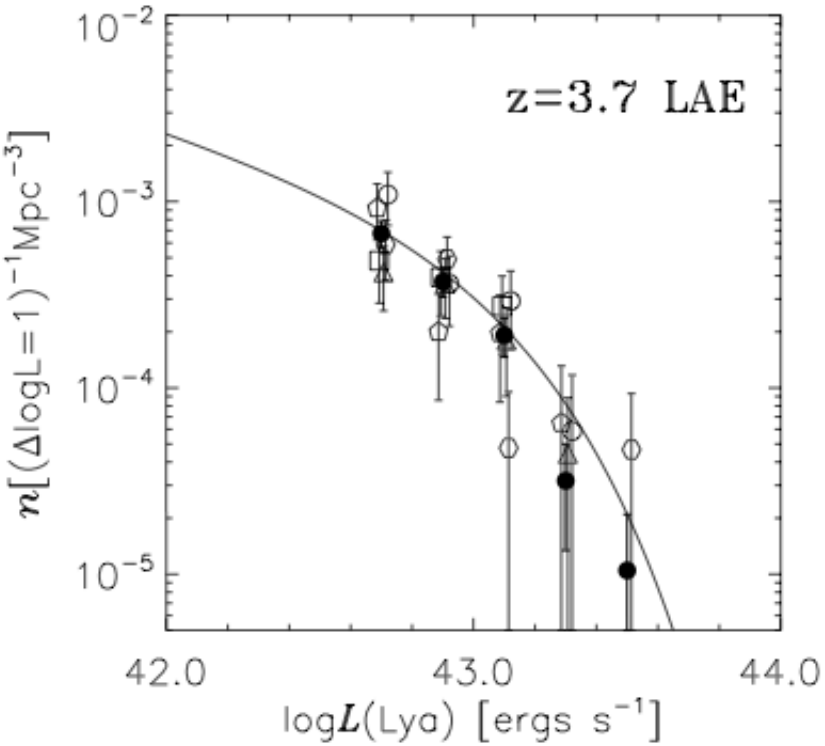

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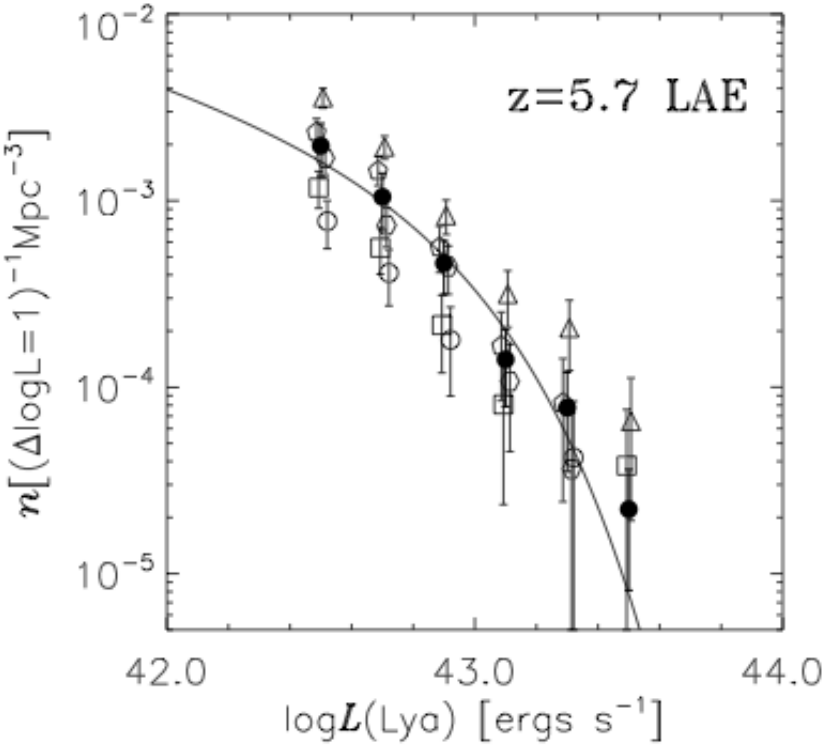
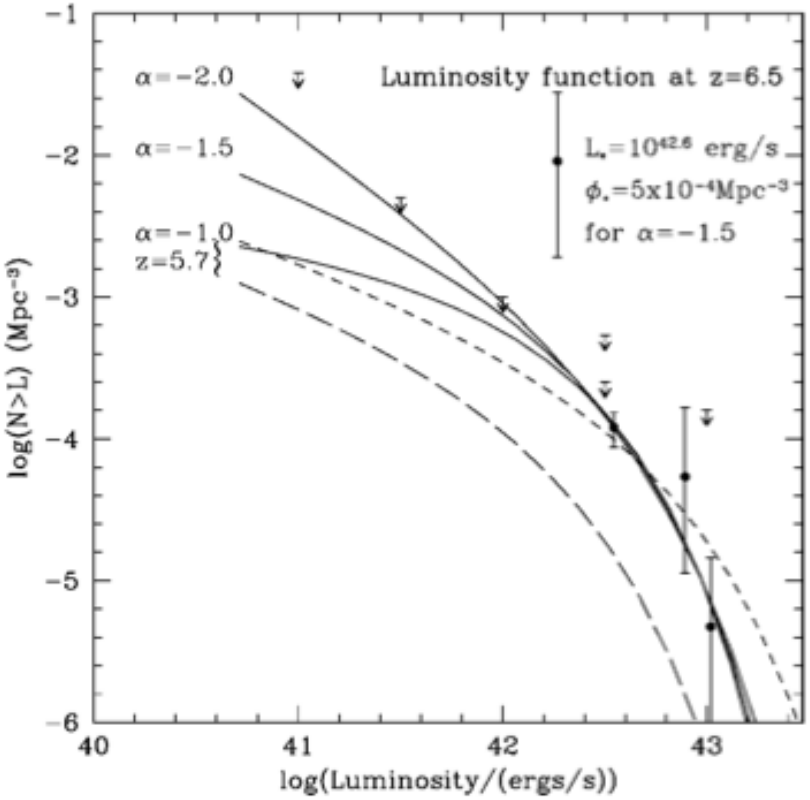


Ouchi 2008

Probing Reionization

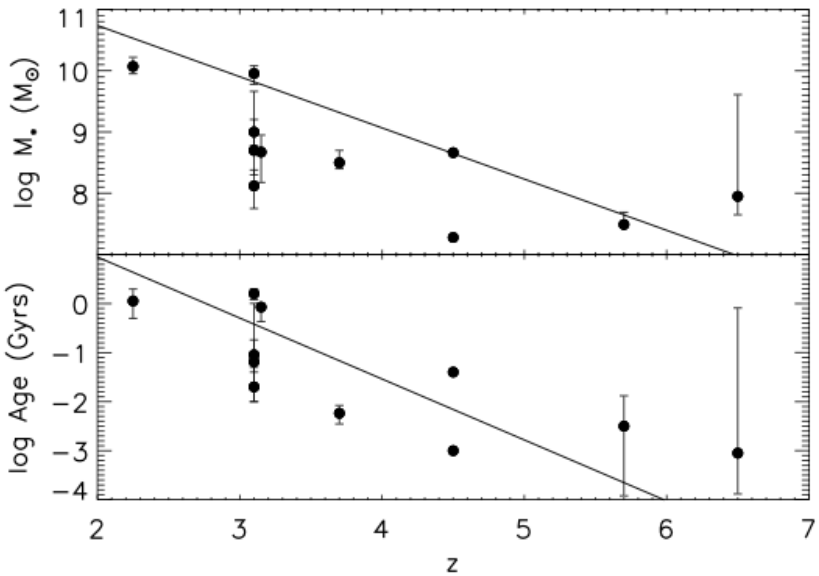
- Neutral IGM $\Rightarrow$ attenuation of Lyα
- Gunn-Peterson trough in QSOs for $z > 6$
- No significant attenuation for LAEs



Malhotra 2004

"Low" Redshift

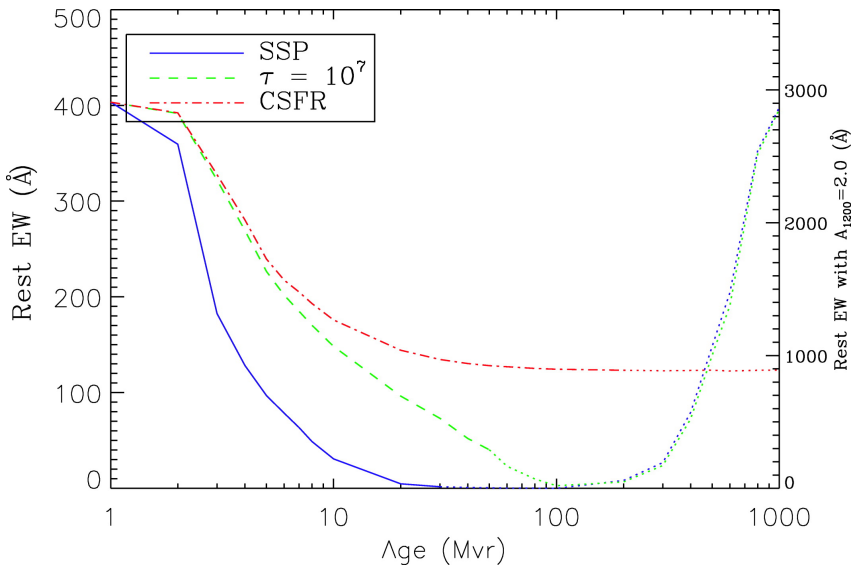
- Study of $z = 2.3$ LAEs
- More massive
- Dusty
- Diverse
- Second burst of star formation



Nilsson 2011

Clumpy Dust

- Suppose dust isolated in cold clumps
- Lyα not likely to penetrate clumps
- Enhance EW without destroying photons
- Explains 1 of 4 $z = 4$ LAEs



Finkelstein 2008

Going Further with HSC

- Large field of view (1.77 deg^2)
- Capable of seeing galaxies and "blobs"
- Multiple narrow-band filters

Going Further with HSC

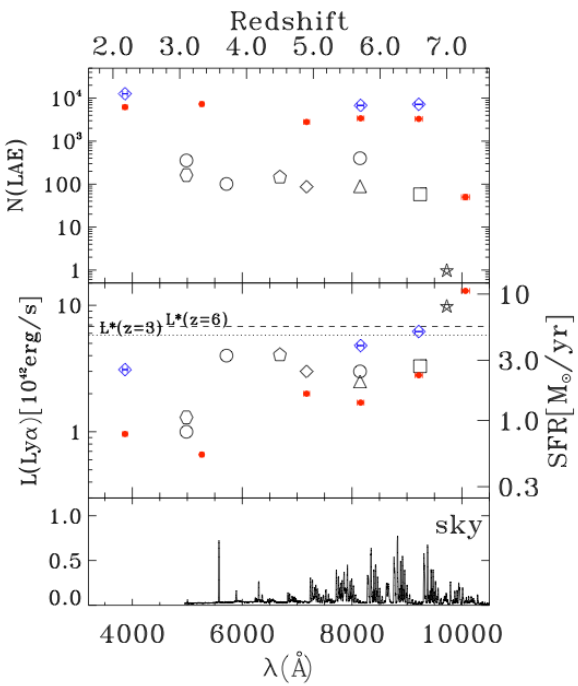


Table 12.1: Lyα Emitter Samples

Narrow band	$NB387$	$NB526$	$NB717$	$NB816$	$NB921$	$NB101$
Redshift	2.2	3.3	4.9	5.7	6.6	7.3
$N^{\dagger}_{\rm Udeep}$	6.2k	7.3k	2.8k	3.4k	3.3k	50
$N^{\dagger}_{\rm deep}$	13k	···	···	6.8k	7.2k	···
$L^{\ddagger}_{\rm Udeep}$	1.0	0.7	2.0	1.7	2.8	13
$L^{\ddagger}_{\rm deep}$	3.1	···	···	4.8	6.2	···

Conclusions

- LAEs common at large redshifts, but hard to observe
- Represent particular epoch of galaxy evolution
  - Not the same as today
  - Not the beginning of the story
- Narrowband photometry
- Better surveys to come

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