Dust in Lyman Alpha Emitters

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The Dark Ages VIrtual Department

http://www.arcetri.astro.it/twiki/bin/view/DAVID/WebHome

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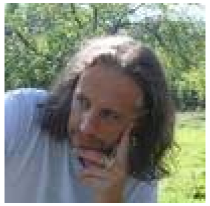

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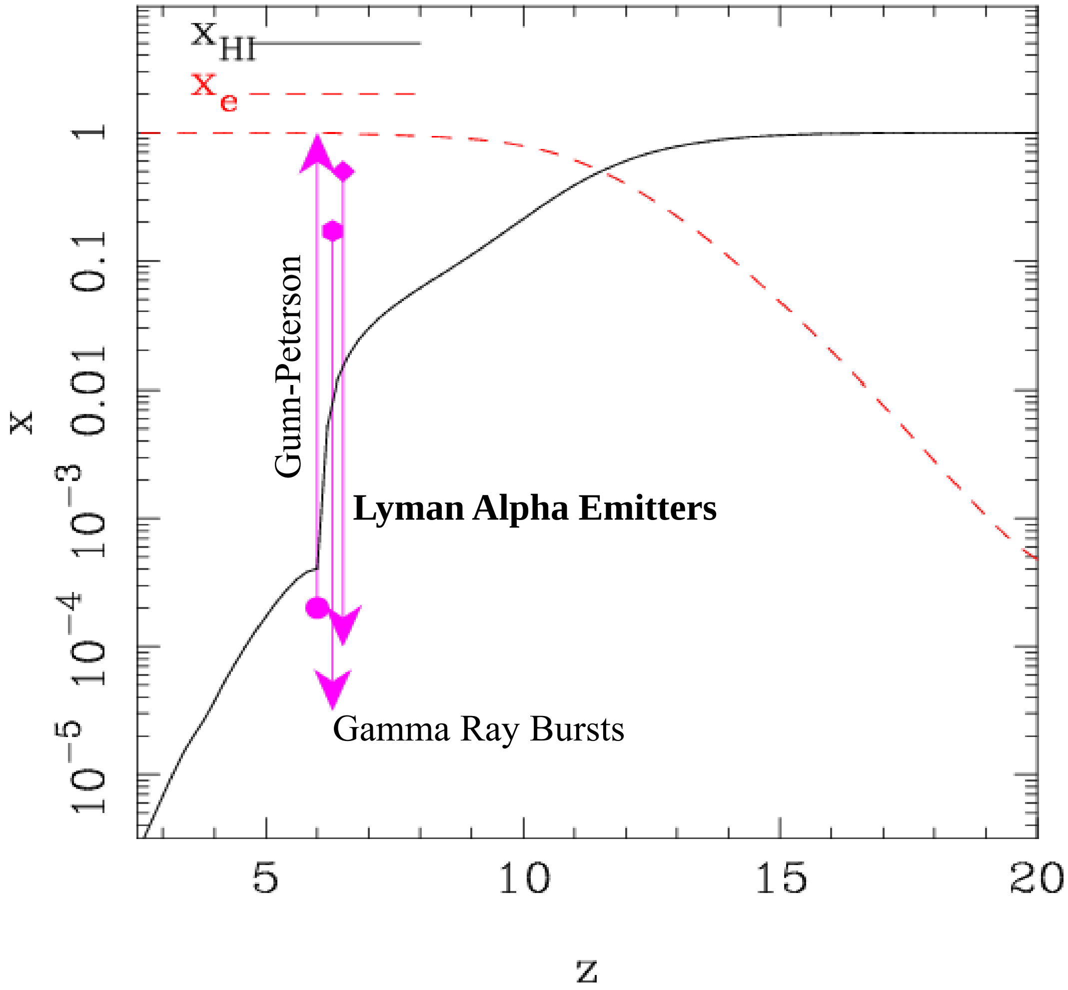
Choudhury & AF 2005, 2006

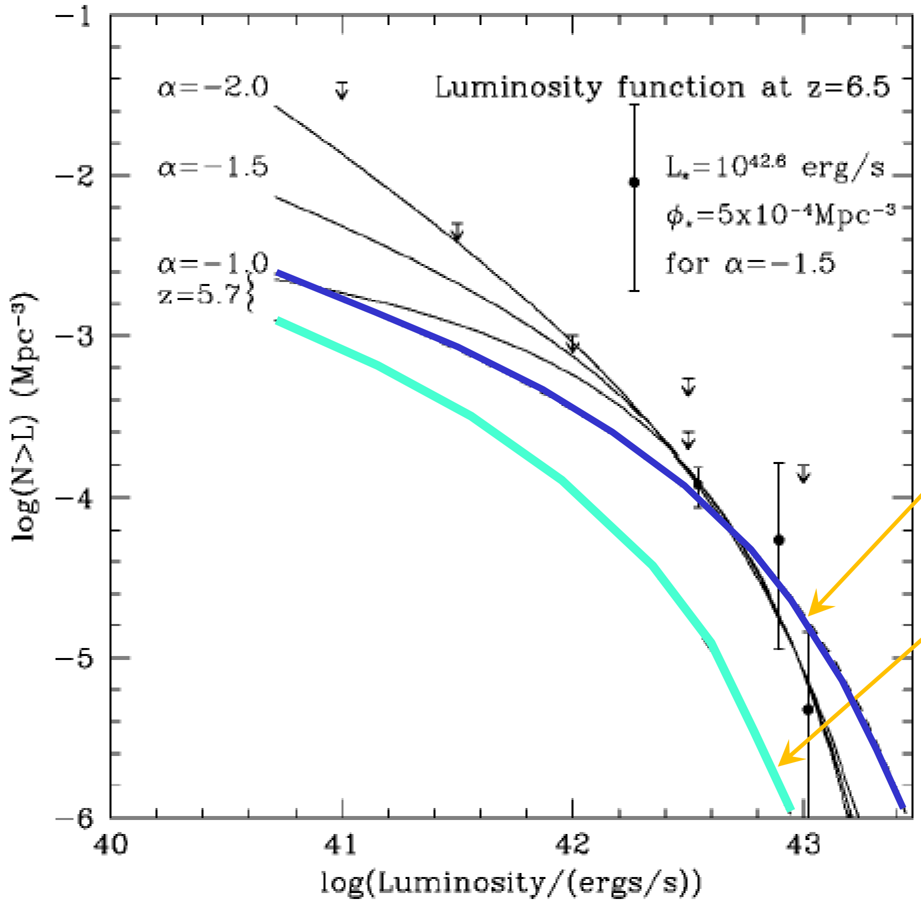


Malhotra & Rhoads 2004

USING THE LUMINOSITY FUNCTION

$x_{HI} < 0.3$

$z \approx 6.5$



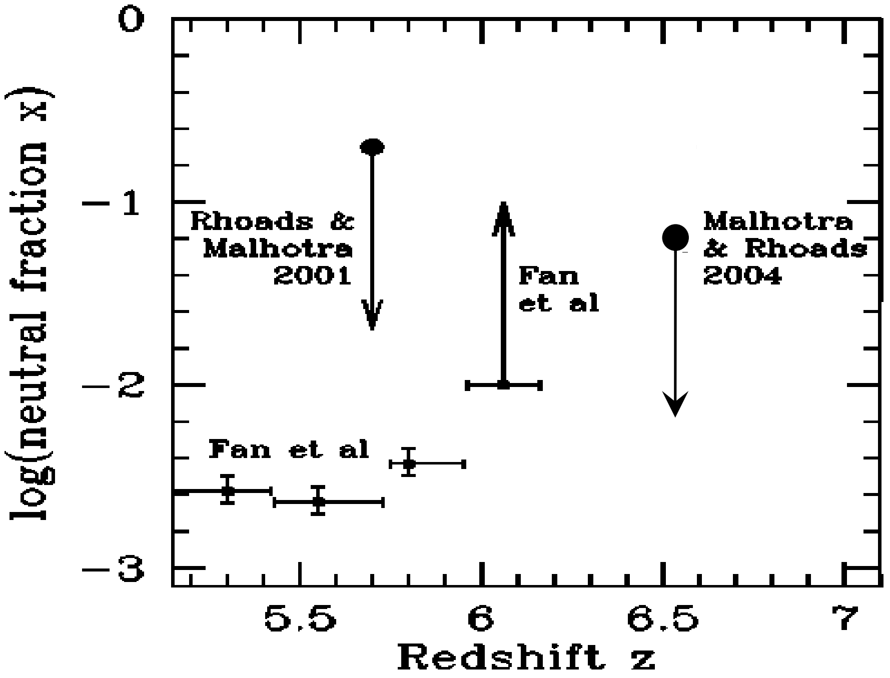
Best-fitting z=5.7 Lyα LF

3× attenuated z=5.7 Lyα LF (*minimum* for neutral gas)

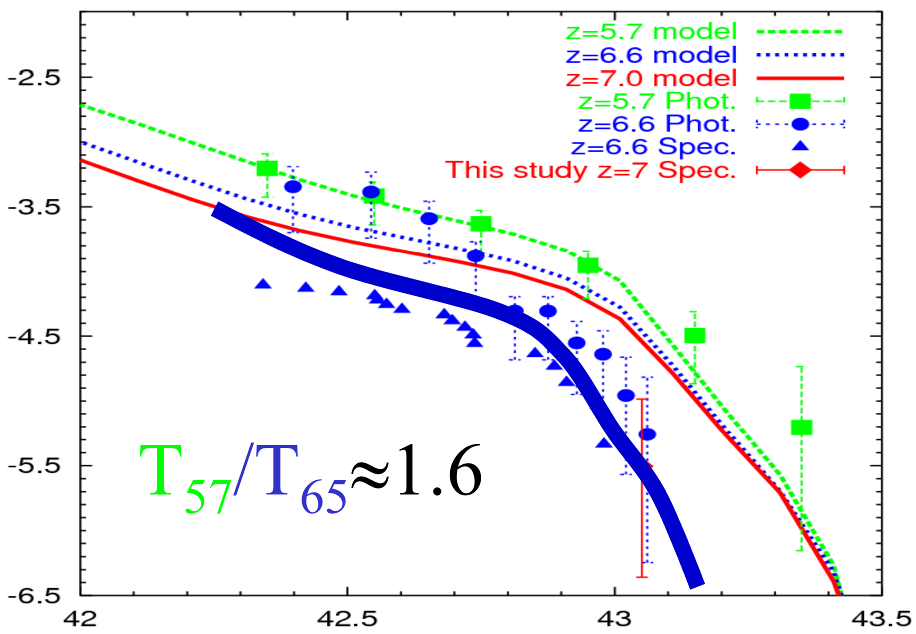
Kobayashi+2007

IS THE LF SHAPED BY REIONIZATION…

$x_{HI} < 0.3$



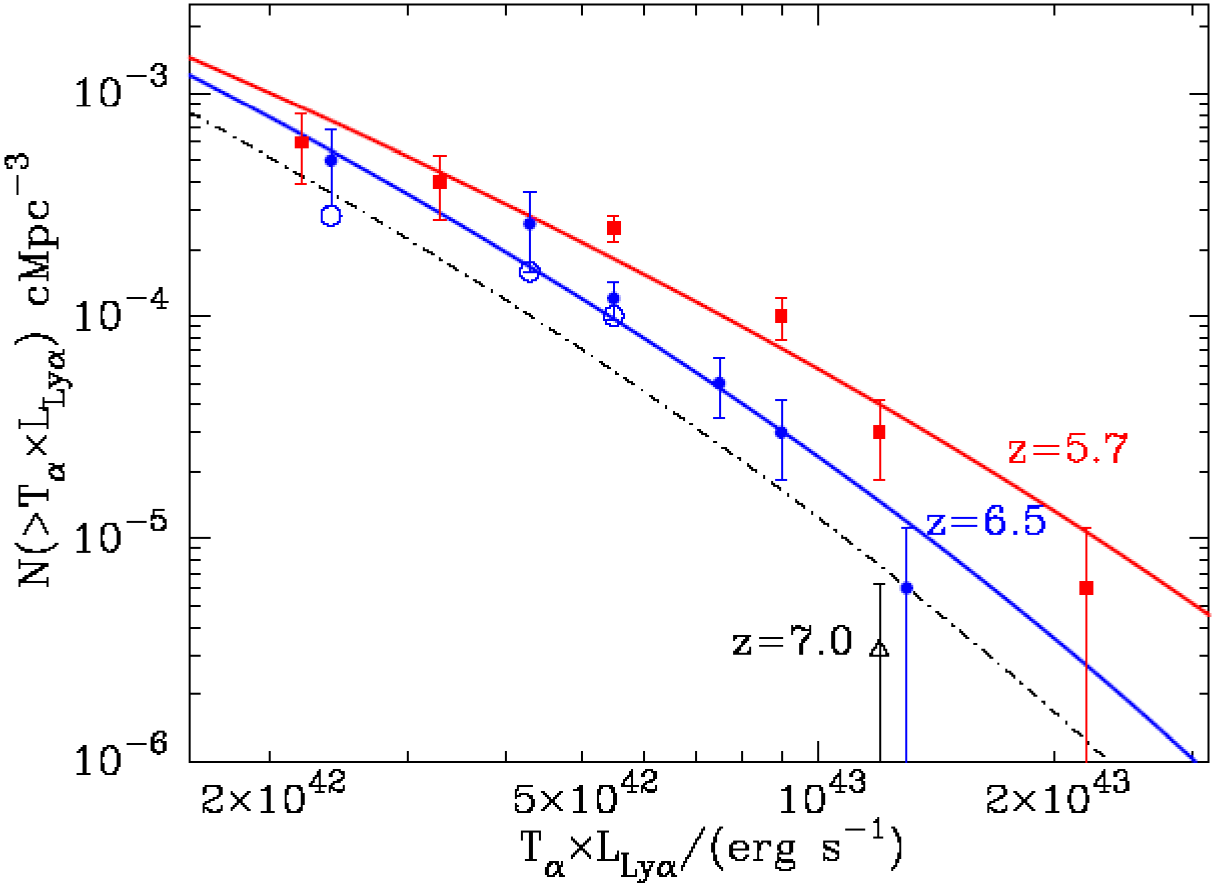
$0.24 < x_{HI} < 0.36$



Dijkstra+2007

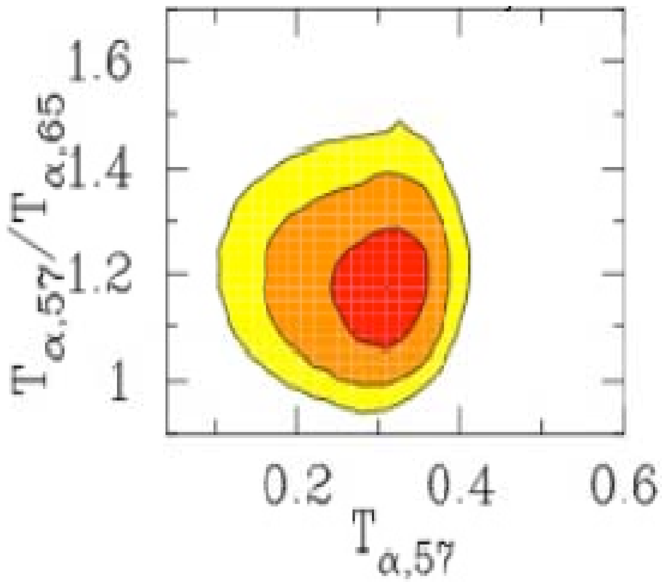
…. OR NOT ?

Pure halo mass function evolution



Dijkstra+2007

PROBABLY NOT !



$$\frac{T_{57}}{T_{65}} = 1.2 \pm 0.1$$

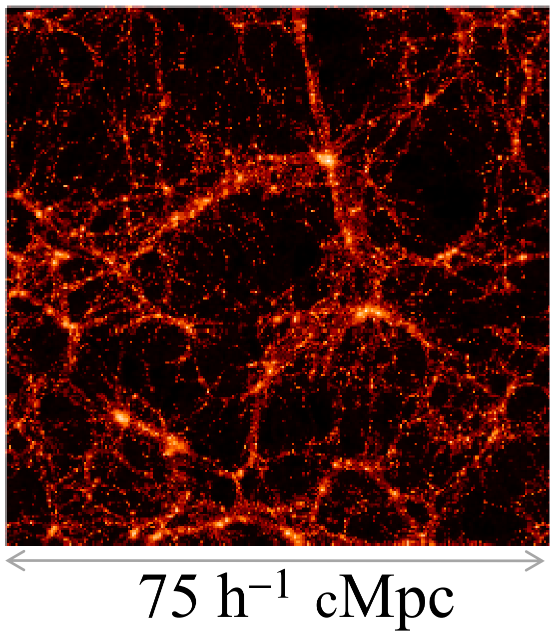
The ~20% decrease of transmissivity from z=5.7 to z=6.5 is consistent with the IGM density evolution (~30%)

Early-sh reionization ?

Dayal+2008, Dayal & AF 2009a

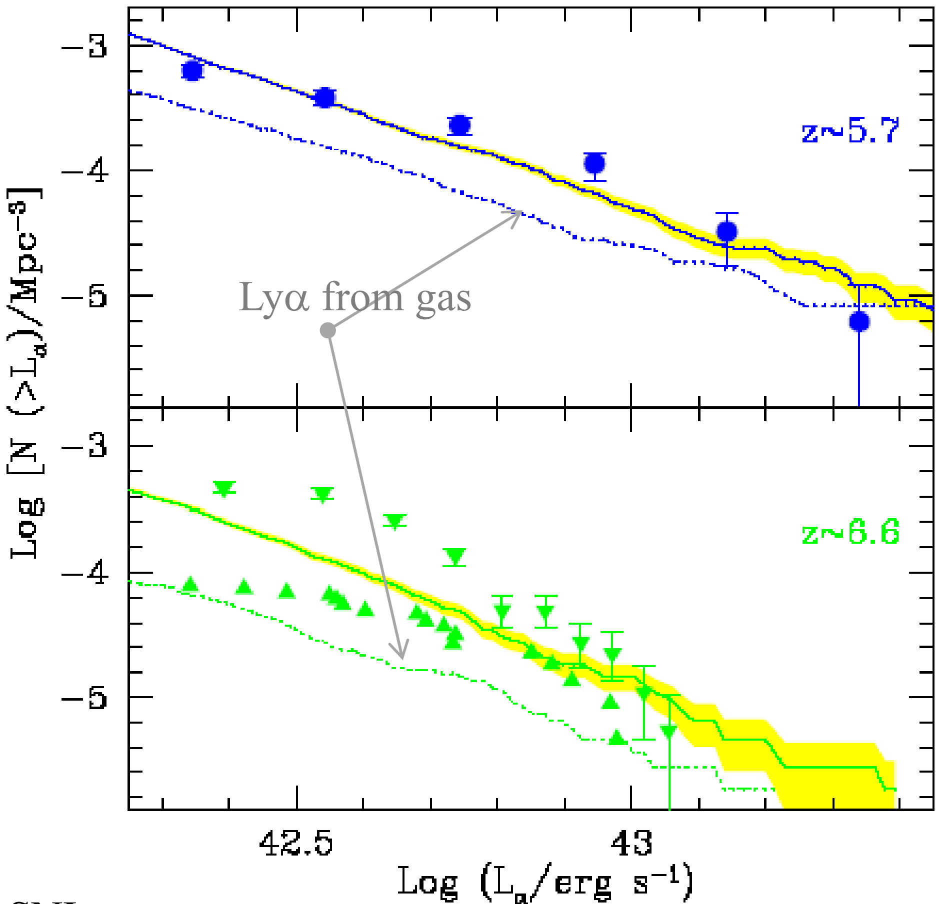
SIMULATING LAEs

arXiv:0907.0337 (today!)



GADGET-2
$2 \times (512)^3$ particles
$m_{dm} \approx 1.7 \times 10^8 \ h^{-1} \ M_\odot$
Z-dependent cooling
Feedback, metal enrichment by SNII & SNIa
Dust formation/destruction modelling

Early reionization model



Hirashita & AF 2002; Dayal & AF 2009

INCLUDING DUST

from simulations

production — destruction — astration

$$\frac{dM_{dust}}{dt} = y_d \gamma \dot{M}_* - \frac{M_{dust}}{\tau_{dest}} - \frac{M_{dust}}{M_{gas}} \dot{M}_*$$

continuum optical depth

$$\tau_c = \frac{3\Sigma_d}{4as}$$

continuum escape fraction

$$f_c = \frac{1 - e^{-\tau_c}}{\tau_c}$$

Lyα escape fraction

$$f_\alpha = q(A_\lambda, C)\, f_c$$

Lyα equivalent width

$$EW = EW^{int} \left(\frac{f_\alpha}{f_c} \right) T_\alpha$$

Dayal & AF 2009

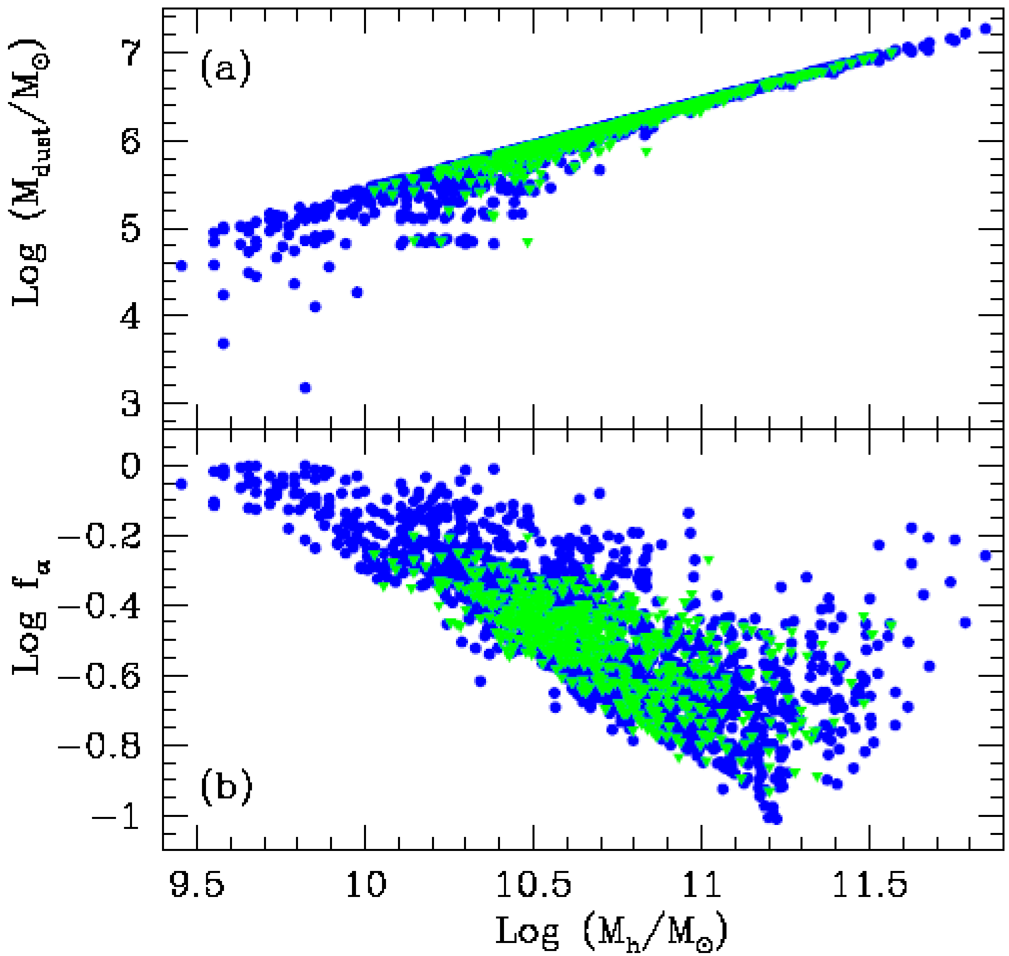
DUST EFFECTS

Dust mass

● $z = 5.7$

▲ $z = 6.6$

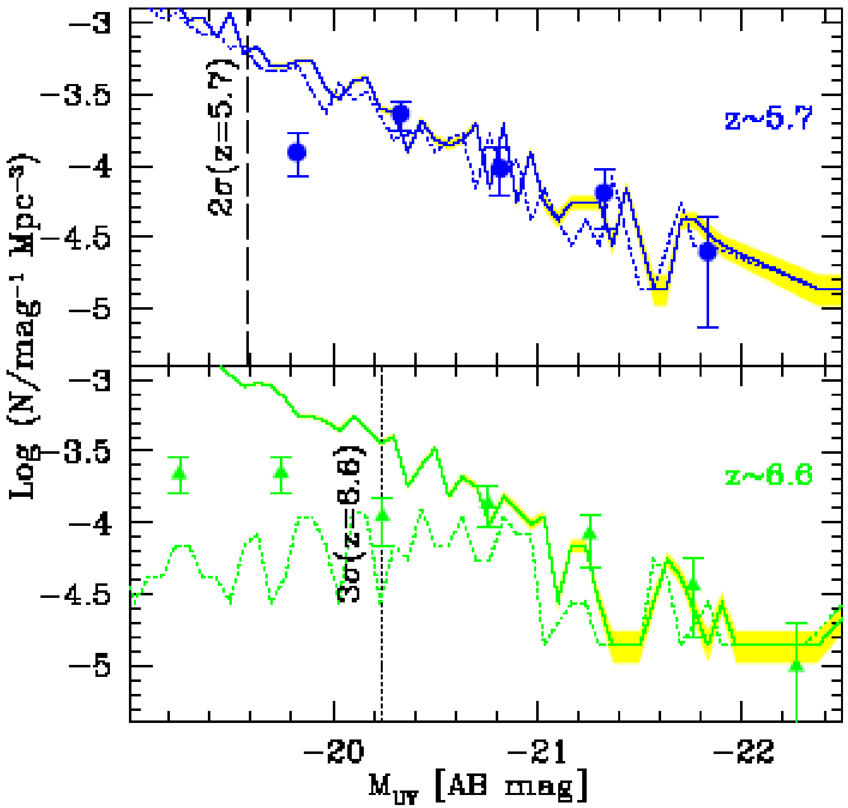
Lya escape fraction
(no clumping)



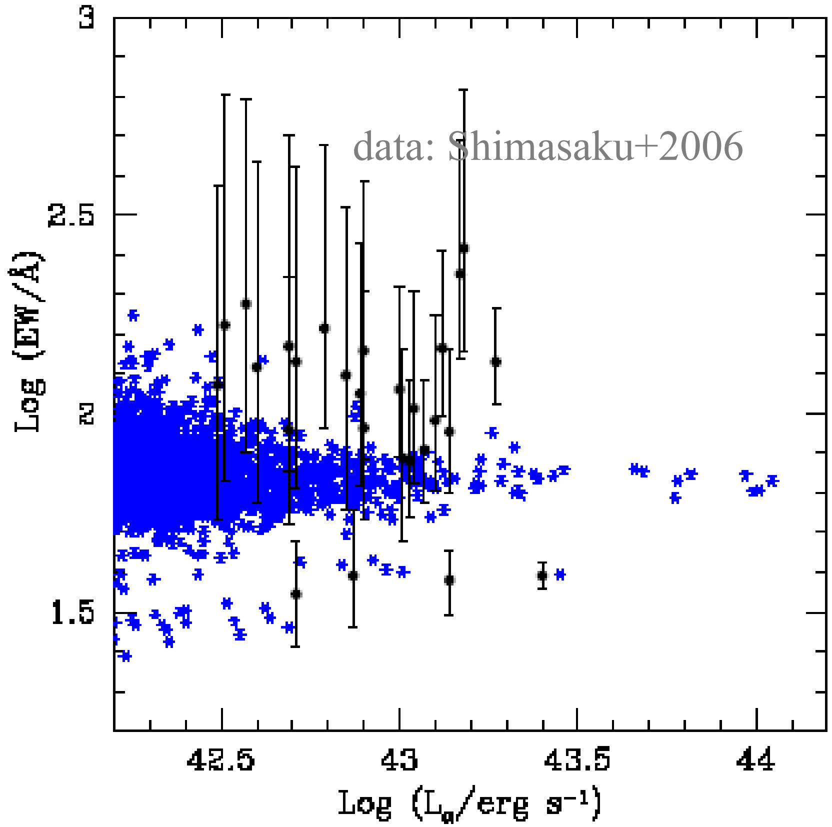
Dayal & AF 2009

MATCHING ALL OBSERVABLES

UV Luminosity Function



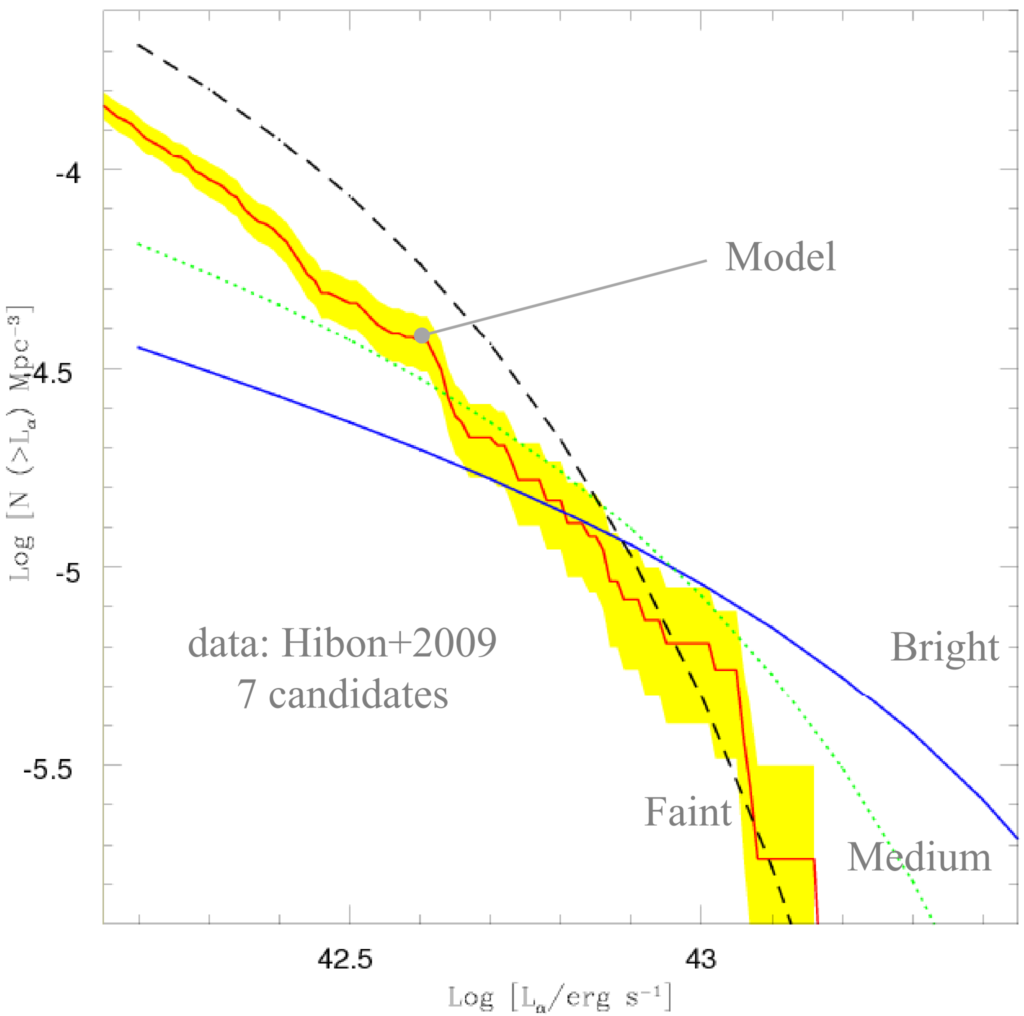
Lyα Equivalent Width



Dayal & AF 2009

HIGHER REDSHIFT: PREDICTIONS

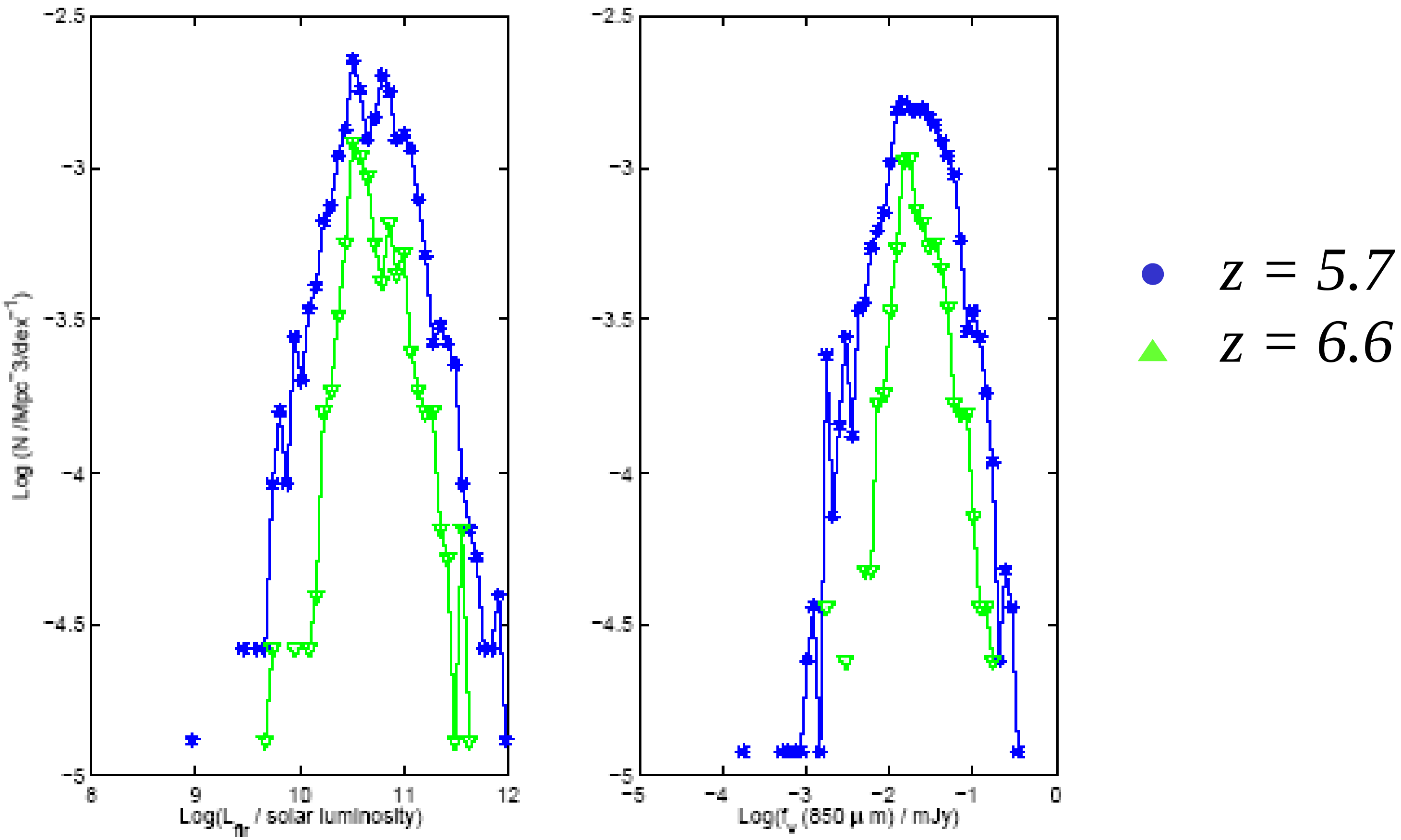
z = 7.6



Finkelstein+09; Dayal+ in prep

MATCHING ALL OBSERVABLES

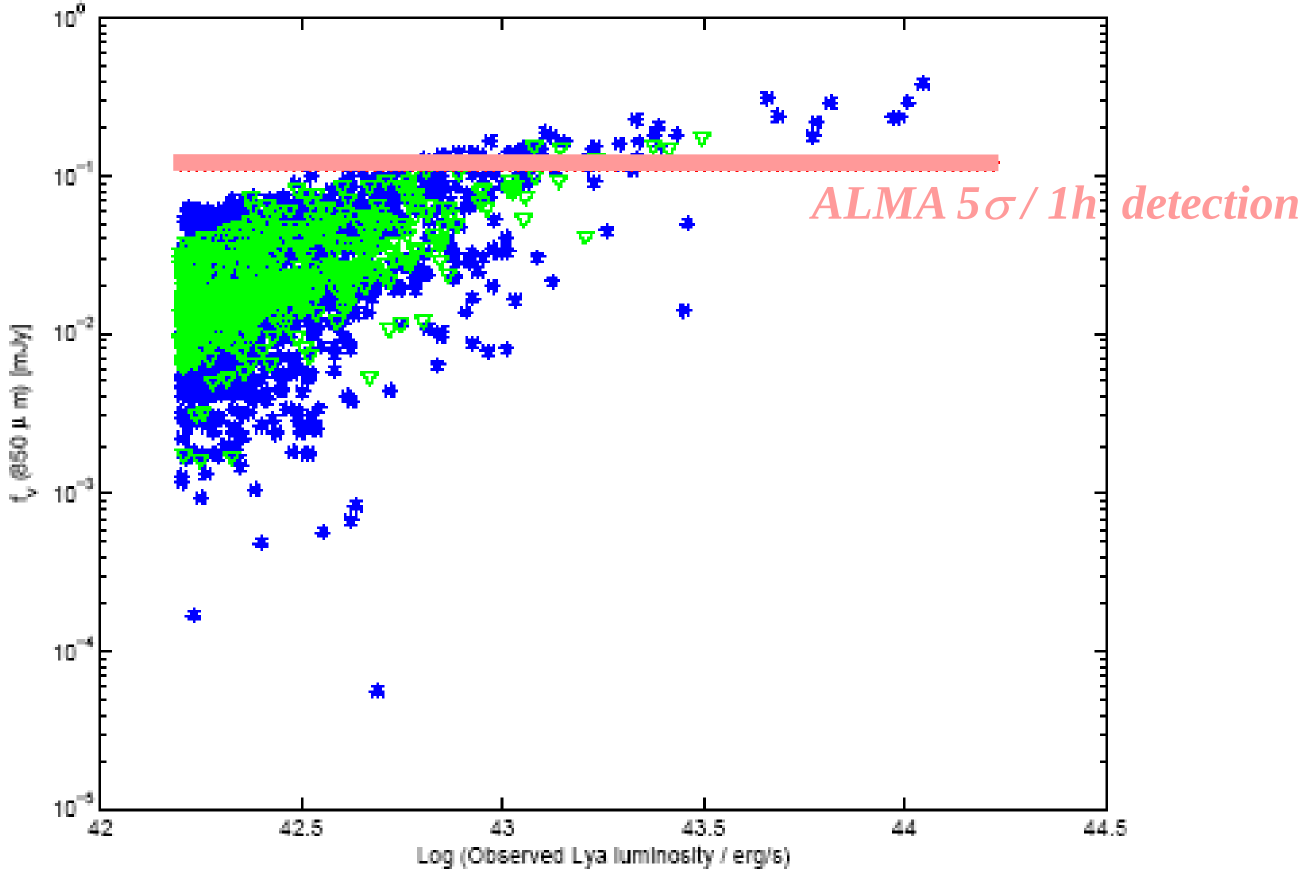
FIR Luminosity Function



Finkelstein+09; Dayal+ in prep

MATCHING ALL OBSERVABLES

Lyα - FIR Luminosity relation



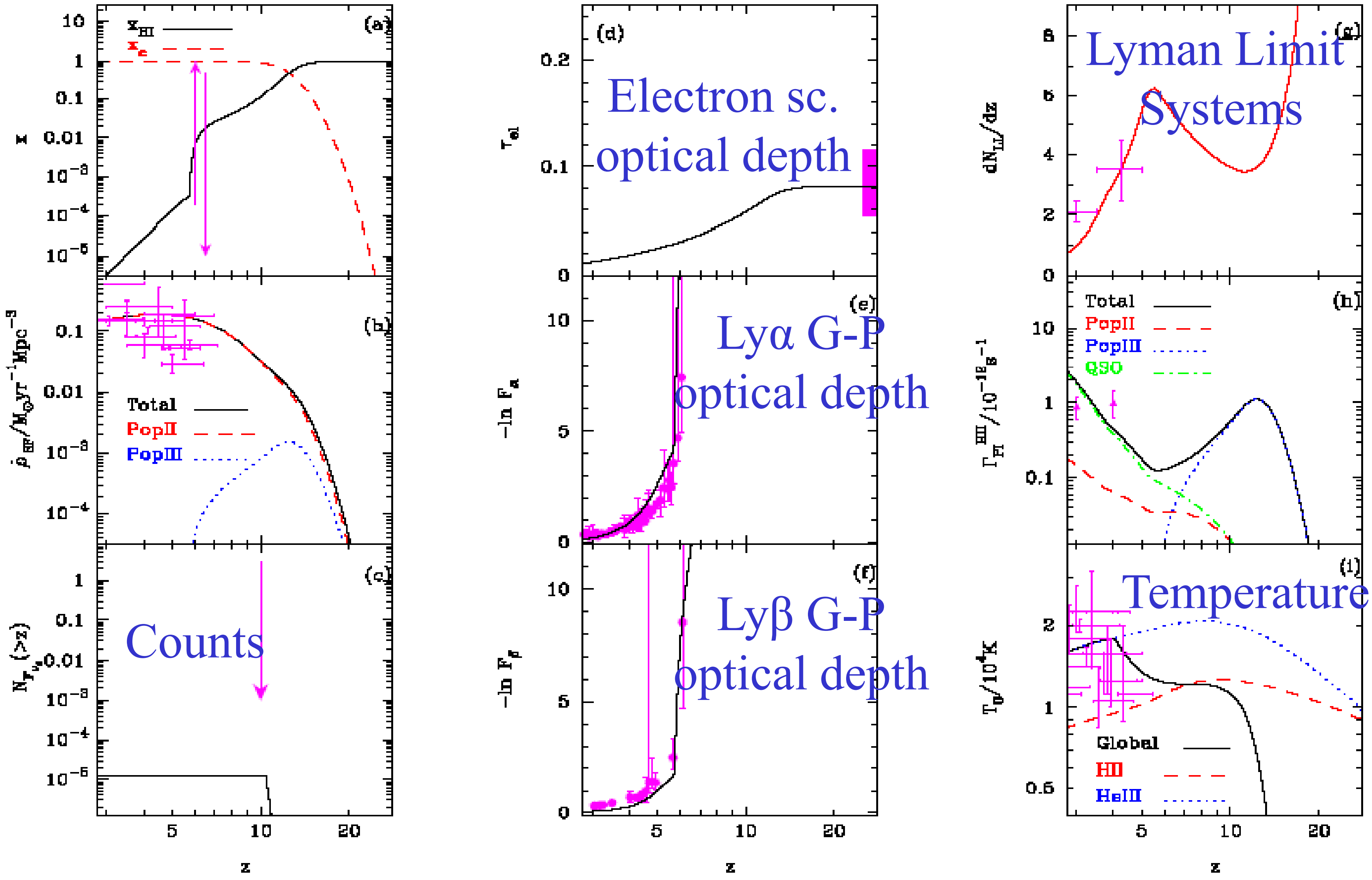
● $z = 5.7$

▲ $z = 6.6$

SUMMARY OF MAIN POINTS

- Stars dominate the reionization photon budget
- Reionization started by metal-free stars @ z=20; 90% complete @ z=8
- Early reionization ($z > 7$) not in contrast with any experimental data
- LAE LFs (and clustering) properties suggest IGM highly ionized up to z=6.6
- LF shape and EW strongly affected by dust with E(B-V) = 0.09-0.13
- LAE FIR emission easily detectd with ALMA : f_ν(850 μm) = 0.3 mJy

Choudhury & AF 2005, 2006



Ciardi+2003, Choudhury & AF 2005, 2006, Trac & Cen 2007

MODEL FEATURES

✓ Self-consistent treatment of the evolution of ionized regions and thermal history

✓ Follow evolution of neutral, HII and HeIII regions

✓ Three sources of ionizing radiation:

- PopIII stars: early redshifts, Salpeter IMF, zero metallicity
- PopII stars: Salpeter IMF, PopIII-PopII transition included
- Quasars: significant @ $z < 6$, using σ-M_{BH} relation

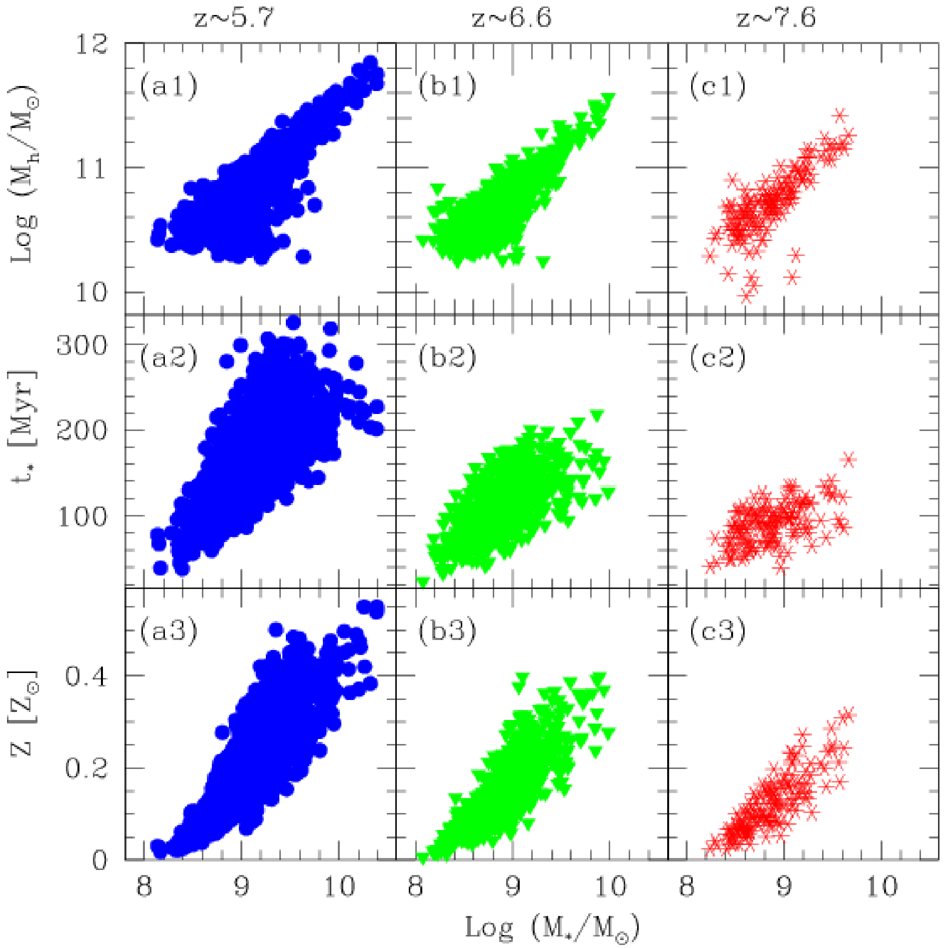
✓ Radiative feedback suppressing SF in low-mass halos, set by:

- Molecular cooling in neutral regions
- Photoionization temperature in ionized regions

Dayal+2008

WHAT ARE THEY?

Physical properties



Halo mass

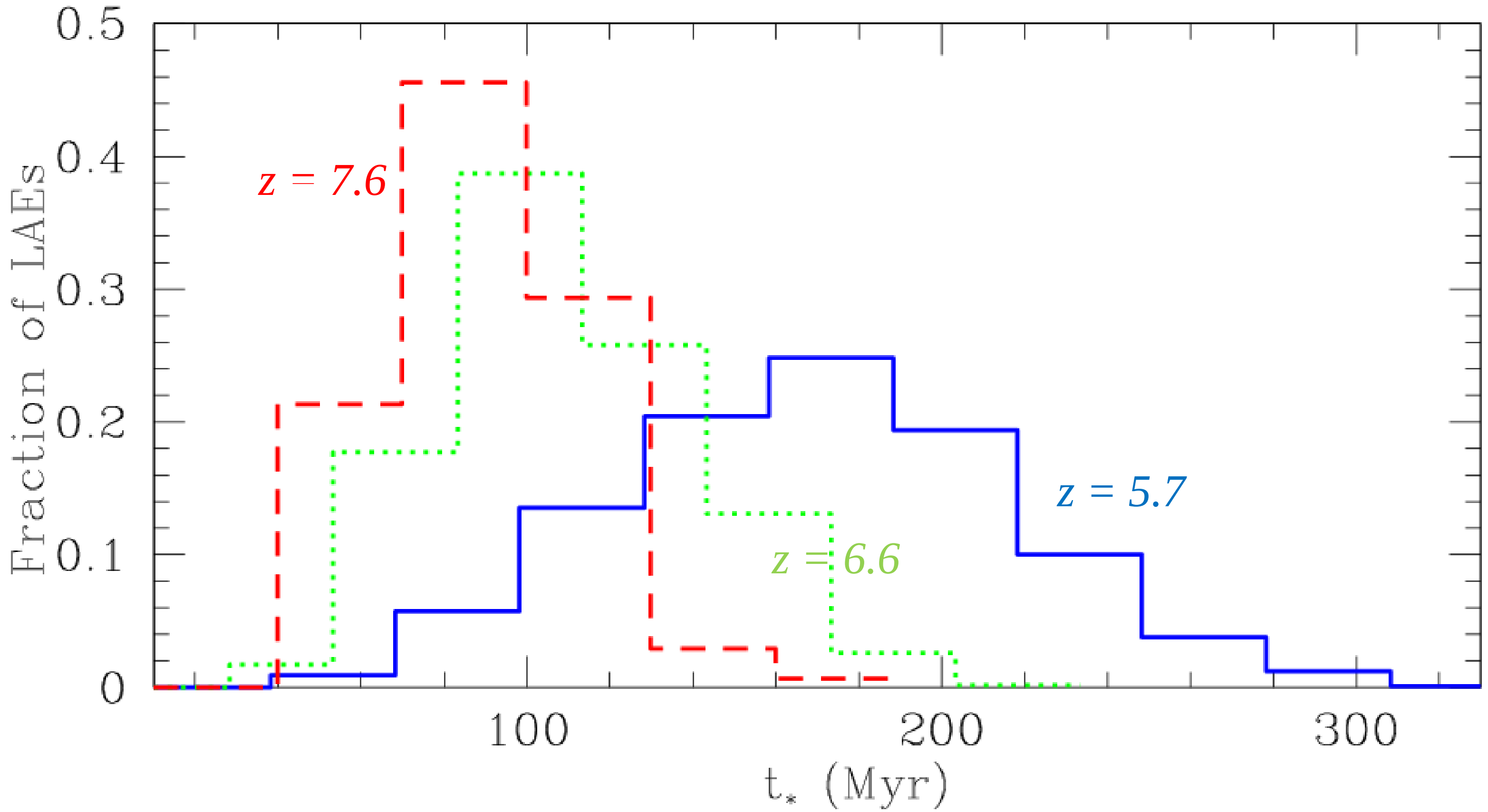
Stellar Age

Stellar Metallicity

Dayal+2008

WHAT ARE THEY?

Mass weighted stellar age distributions



Dayal+ 2009

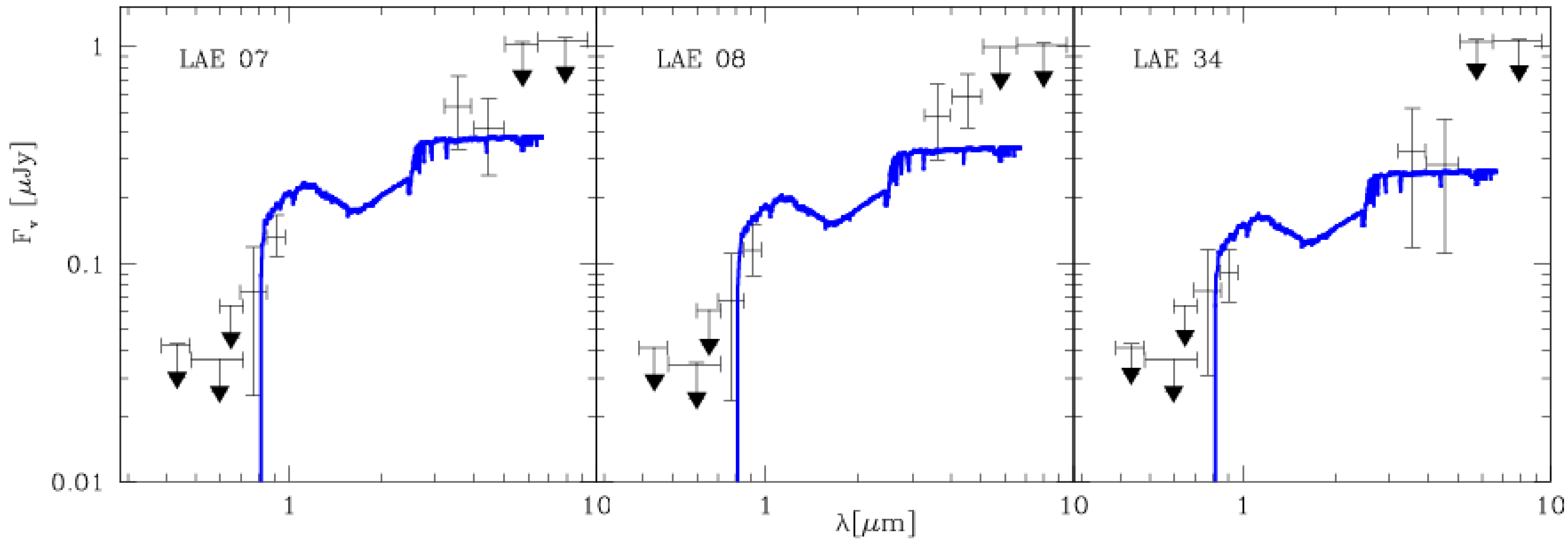
LAEs: STELLAR POPULATIONS

$z \approx 5.7$

Age

#LAE	t_* (Myr)	Z ($Z_\odot$)	$\dot{M}_*$ ($M_\odot yr^{-1}$)	E(B − V)
07	182	0.26	9.9	0.145
08	194	0.21	8.6	0.145
34	166	0.26	7.2	0.145

data: Lai+07



Dayal+ 2008, 2009

LAEs IONIZING POWER

@ $z = 6.6$

$$\log [Q_{LAE} / (s^{-1}\ Mpc^{-3})] = 49.32$$

$$\log [Q_{ion} / (s^{-1}\ Mpc^{-3})] = 51.54 + \log C_{30}$$

LAE contribute ≈ 1% of ionizing budget

Ages ≈ 150 Myr, star formation started at $z > 8$

PASSIVE REIONIZATION TRACERS

Santos 2004, Malhotra & Rhoads 2004, Gnedin & Prada 2004

BASIC IDEA

Furlanetto+2004, Salvaterra+2005