Probing the star-formation history using redshift evolution of luminosity functions

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semi-analytic modeling the SFR

Modified Press-Schechter (PS) formalism is used to calculate the number density of halos (Sasaki 1994)

$$N(M, z, z_c)\, \mathrm{d}M\, \mathrm{d}z_c = N_M(z_c) \left(\frac{\delta_c}{D(z_c)\sigma(M)} \right)^2 \frac{\dot{D}(z_c)}{D(z_c)} \frac{D(z_c)}{D(z)} \frac{\mathrm{d}z_c}{H(z_c)(1+z_c)}\, \mathrm{d}M$$

Star formation rate (SFR) at z of a halo of mass M and has collapsed at an earlier z_c (Chiu & Ostriker, 2000; Choudhury & RS 2002)

$$\dot{M}_{\mathrm{SF}}(M, z, z_c) = f_* \left(\frac{\Omega_b}{\Omega_m} M \right) \frac{t(z) - t(z_c)}{\kappa^2 t_{\mathrm{dyn}}^2(z_c)} \exp\left[- \frac{t(z) - t(z_c)}{\kappa t_{\mathrm{dyn}}(z_c)} \right]$$

Samui, RS, Kandu, 2007, MNRAS, 377, 285

Semi-analytic modeling the SFR

$$
\begin{aligned}
t_{\rm dyn}(z) &= \sqrt{\frac{3\pi}{32G\rho_{\rm vir}(z)}} \\
\rho_{\rm vir}(z) &= \Delta_c(z)\rho_c(z) \\
\Delta_c(z) &= 18\pi^2 + 82d(z) - 39d^2(z) \\
d(z) &= \frac{\Omega_m(1+z)^3}{\Omega_m(1+z)^3 + \Omega_\Lambda} - 1 \\
\rho_c(z) &= \frac{3H^2(z)}{8\pi G}.
\end{aligned}
$$

Barkana & Loeb, 2001

Semi-analytic modeling the SFR

The global star formation rate is given by

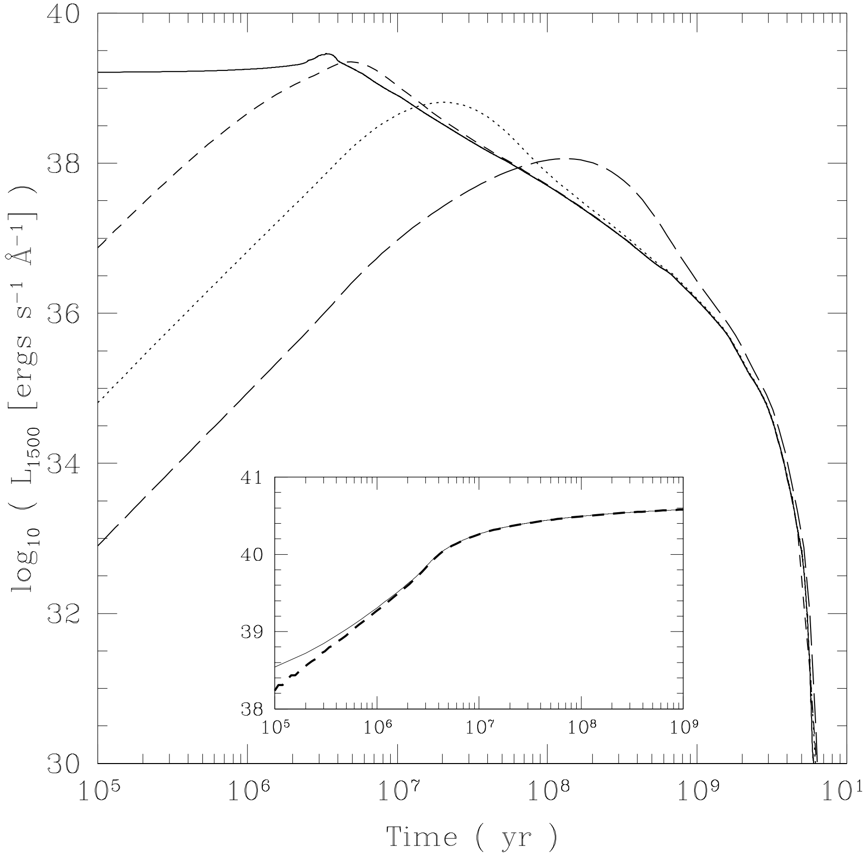
$$\dot{\rho}_{\rm SF}(z) = \int_z^\infty {\rm d}z_c \int_{M_{\rm low}}^{M_{\rm up}} {\rm d}M' \dot{M}_{\rm SF}(M', z, z_c) \times N(M', z, z_c)$$

$M_{\rm low}$ is decided by cooling efficiency of the gas. If a halo is forming from neutral region, gas can cool by atomic cooling ($T \sim 10^4\ K$) or Molecular cooling (${\rm H}_2$, HD) ($T \sim 300\ K$) [Abel & Rees, 2000].

Halos in an ionized region can only cool only if $v_c \geq 35$ km s^{-1} [Thoul & Weinberg 1996; Dijkstra et al. 2004]

The upper mass cut-off $M_{\rm up}$ may come from AGN feedback (Bower et al. 2006) and we use $f_{sup} = 1/[1 + (M/10^{12} M_\odot)^3]$

Semi-analytic modeling the SFR



$$L_{1500}(M,T) = \int_{T}^{0} \dot{M}_{\rm SF}(M,T-\tau)\, l_{1500}(\tau)\, \mathrm{d}\tau$$

$$M_{AB} = -2.5 \log_{10}(L_{\nu 0}) + 51.60$$

Luminosity functions & integrated source counts

The luminosity function $\Phi(M_{AB}, z)$ at any redshift z is then given by

$$\Phi(M_{AB}, z)\mathrm{d}M_{AB} = \int_z^\infty \mathrm{d}z_c \, N(M, z, z_c) \quad \frac{\mathrm{d}M}{\mathrm{d}L_{1500}} \, \frac{\mathrm{d}L_{1500}}{\mathrm{d}M_{AB}} \, \mathrm{d}M_{AB}$$

The comoving number density of objects at redshift z having apparent magnitude less than m_0, i.e.

$$\mathcal{N}(z, m < m_0) = \int_{-\infty}^{M_0(z, m_0)} \Phi_{M_{AB}}(M_{AB}, z) \, \mathrm{d}M_{AB}$$

Semi-analytical Modeling:reionization

Time evolution of average ionized hydrogen fraction f_{HII} is

$$\frac{\mathrm{d}f_{HII}}{\mathrm{d}z} = \frac{\dot{N}_\gamma}{n_H(z)} \frac{\mathrm{d}t}{\mathrm{d}z} - \alpha_B n_H(z) f_{HII} C \frac{\mathrm{d}t}{\mathrm{d}z}$$

Assumptions:

- all the baryons are in the form of hydrogen
- all the Lyman continuum photons that escape a star forming galaxy are used for ionization
- Clumping factor C is defined as $C \equiv \langle n_H^2 \rangle / \bar{n}_H^2 = 1 + 9 \left(\frac{7}{1+z} \right)^2$
- Case B recombination (α_B) at T = 3$\times 10^4$ K is assumed.

Semi-analytic models: Ionization History

- The photon production rate is obtained from the SFR density using,

$$\dot{N}_\gamma = \frac{\dot{\rho}_{\rm SF}(z)(1+z)^3}{m_p} n_\gamma f_{esc} \tag{1}$$

- $\dot{\rho}_{\rm SF}$ is average comoving star formation rate density of universe

- Reionization occur when $f_{HII} = 1$

Parameters of the model

Cosmological:

Ω= 1, $\Omega_\Lambda = 0.74$, $\Omega_b = 0.044$, h = 0.71, σ_8 = 0.75, n_s = 0.95

Astrophysical:

f_* - fractional mass of baryons that goes through SF.
mass fraction of stars

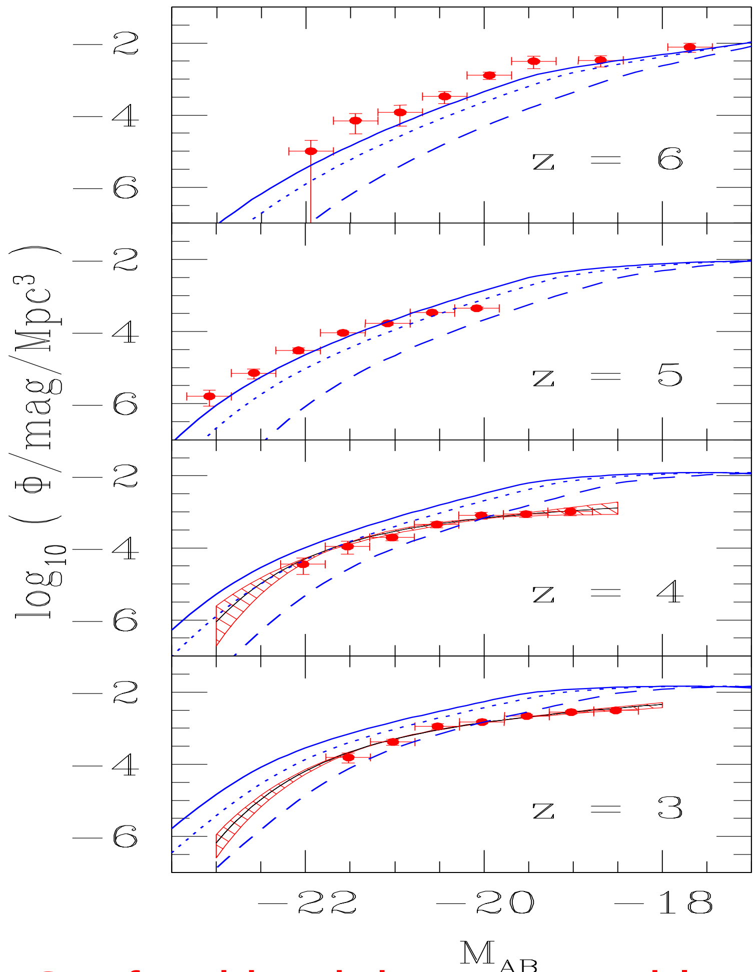
κ - Related to the duration of SF activity.
Balmer break

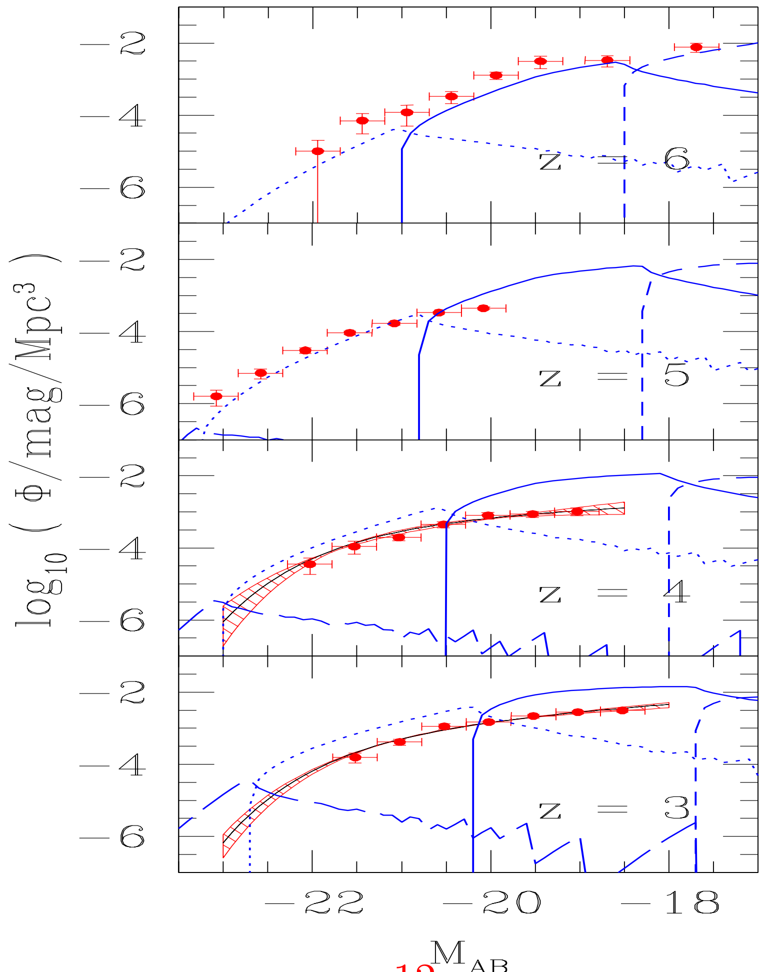
η - Reddening correction factor - 4.5
from the IR colors

IMF, n_ν - shape and cutoff masses.
Salpeter –topheavy

f_{esc} - 0 at local universe and $\sim$0.3 at z$\sim$3.

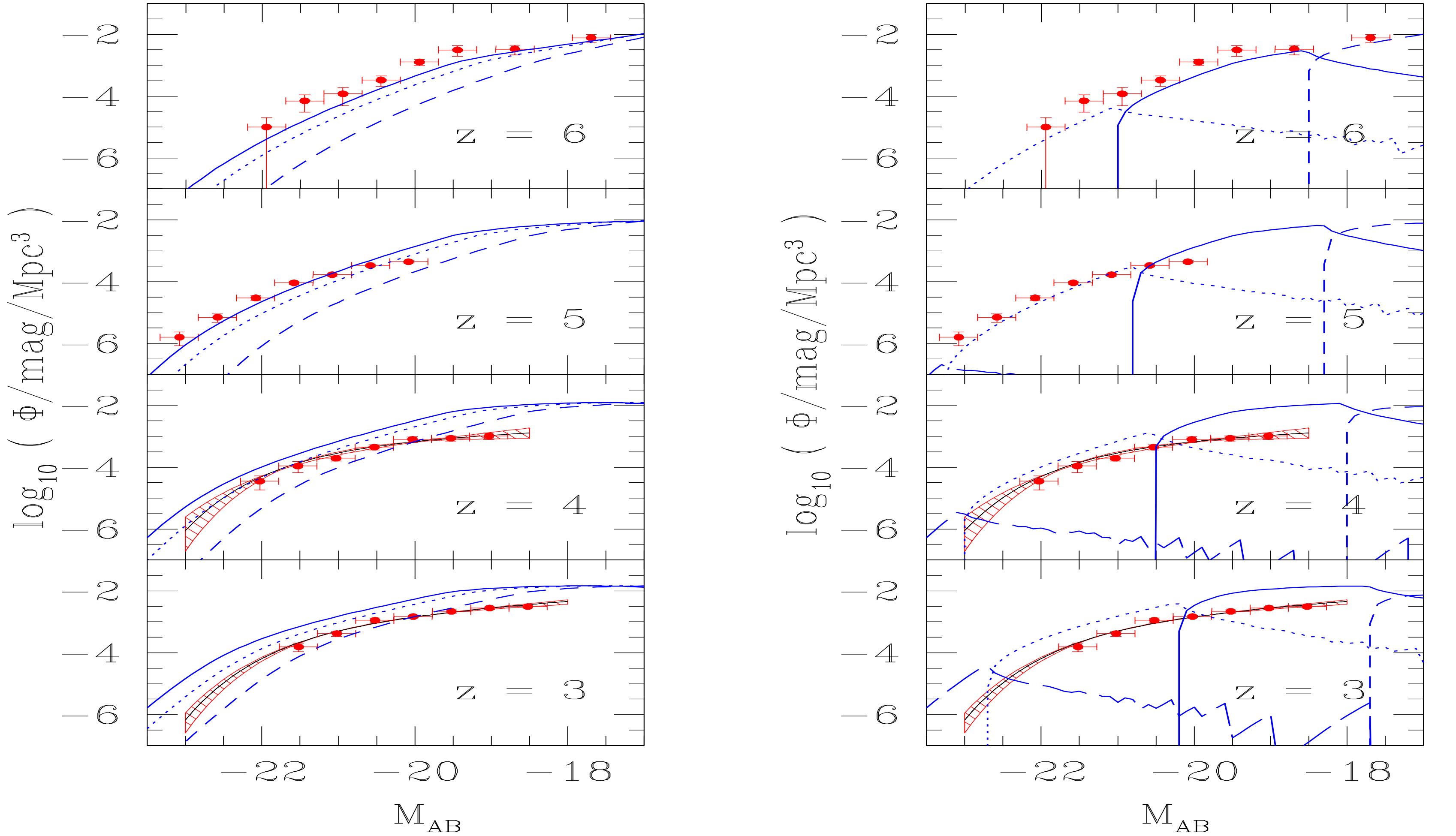
Luminosity function at z$\leq$6:



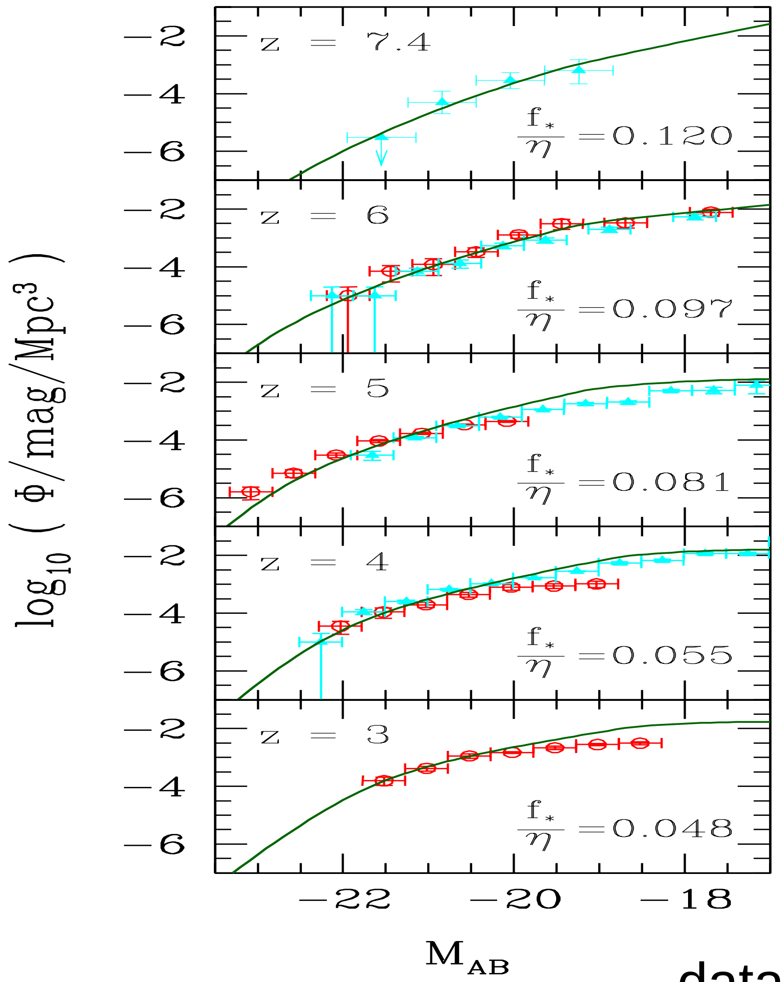


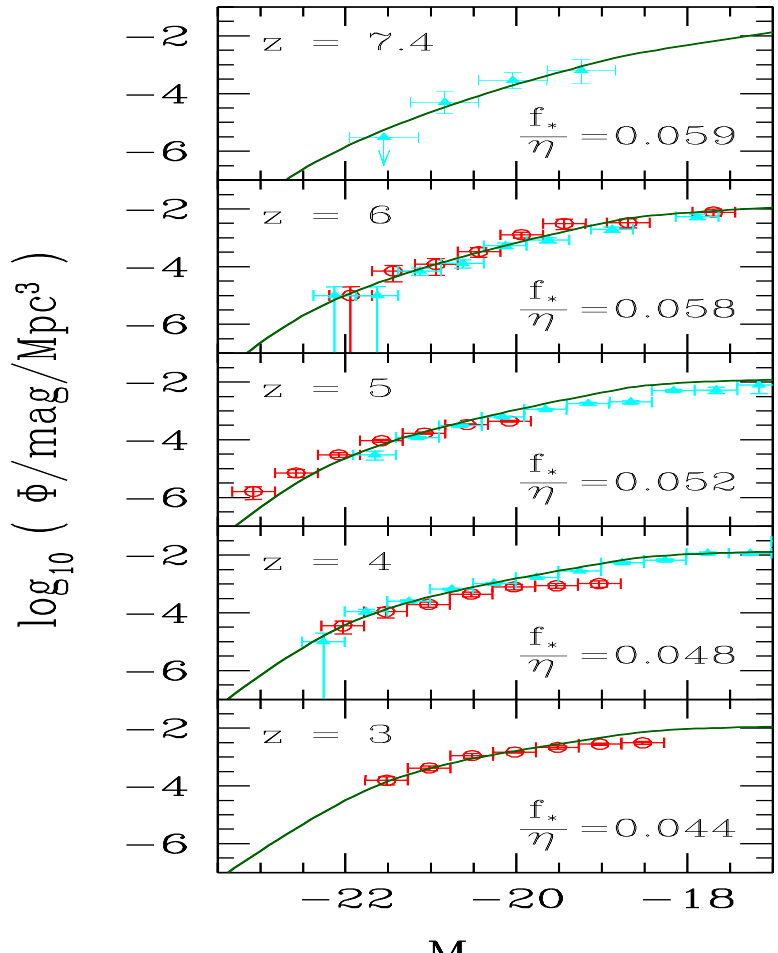
AGN feed back is not a problem as long as $M_{cut} \geq 10^{12}$ $M_{\odot}$

Luminosity function at z≤6:



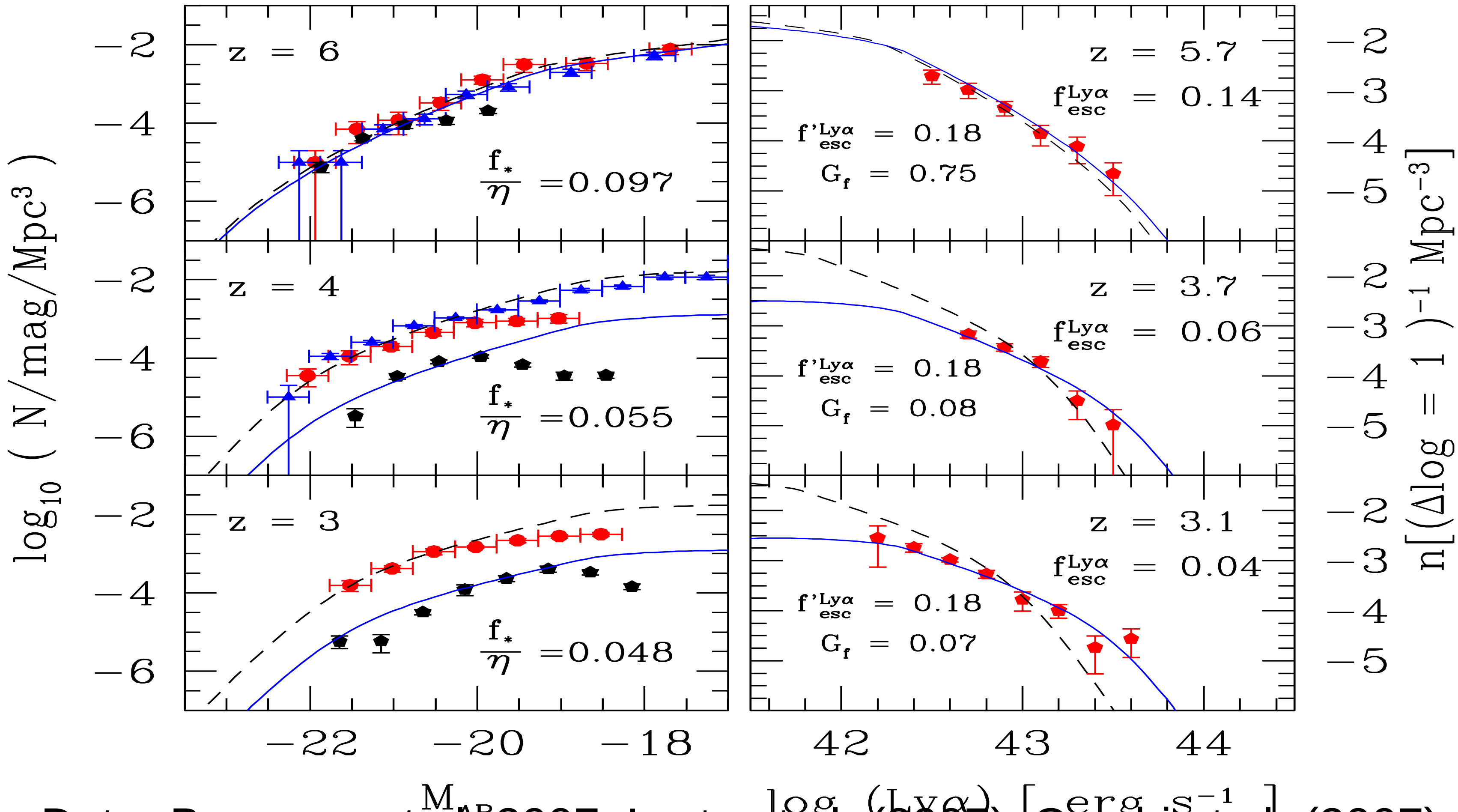
Luminosity function at $z \leq 6$): Mass function





data points are from Bouwens et al. 2007

Luminosity function at z≤6): Lyman$-\alpha$ emitters



Data: Bouwens et al. 2007; Iwata et al. (2007), Ourchi et al. (2007)

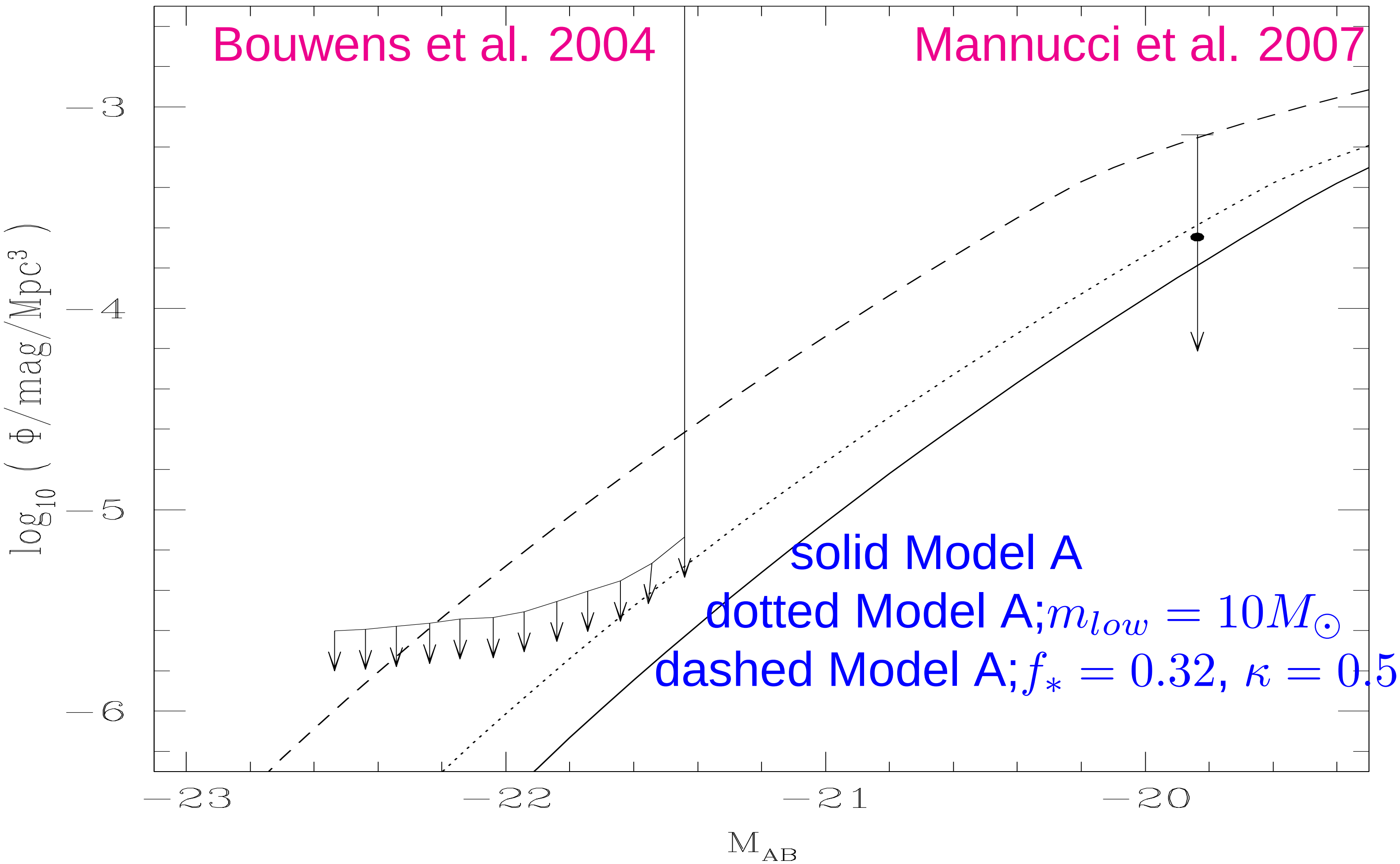
Constraining star-formation at z$\geq$6

- As the redshift probed coincides with the expected range in the redshift of reionization one will be able to see the effects of radiative feedback.

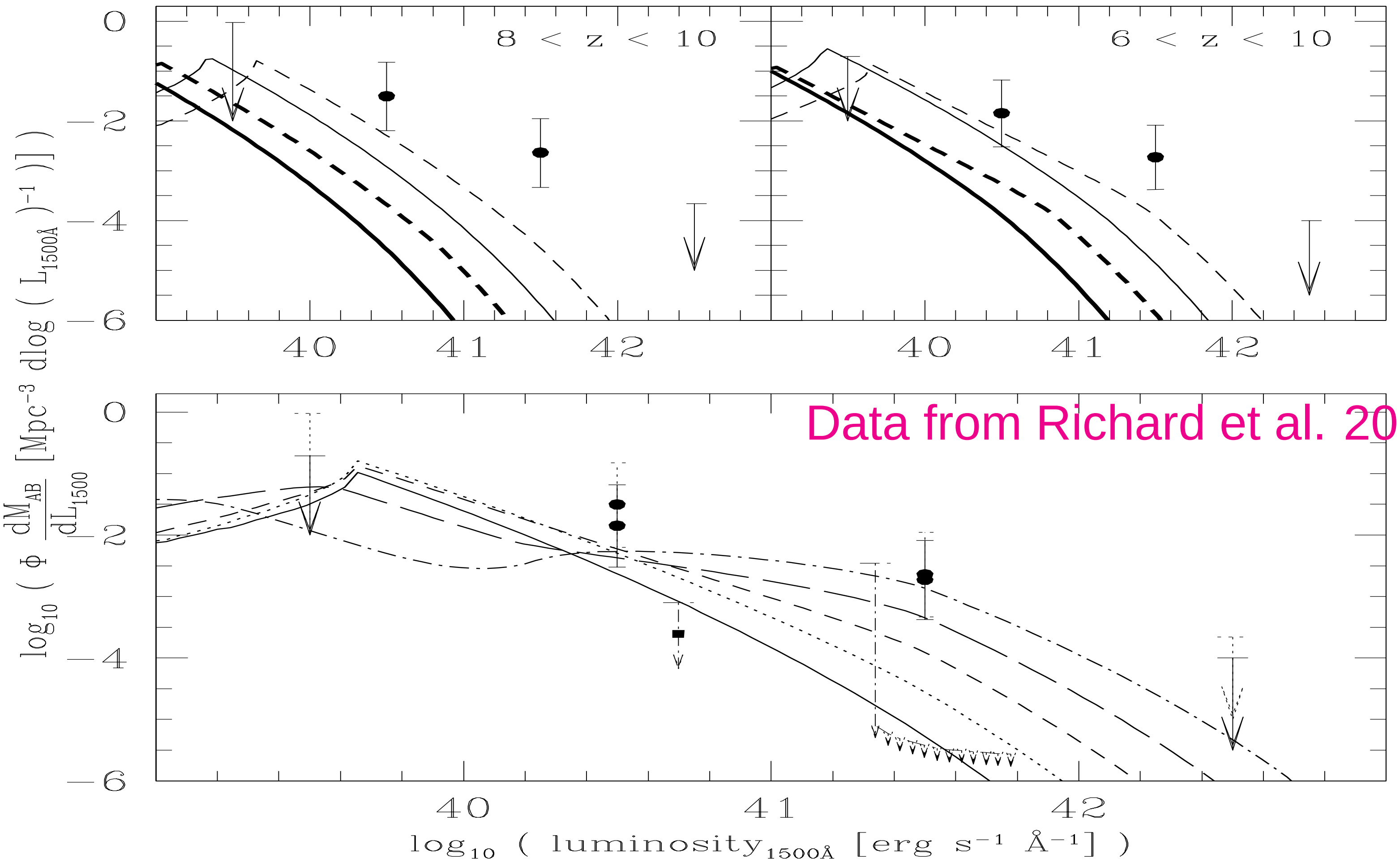
- The spectroscopic redshift measurements are not available and one has to depend on the photometric redshift measurements.

- Two sets of measurements are available: (i) based on HST Ultra Deep field (Bouwens et al. 2005; Mannucci et al. 2007) and (ii) IR selected galaxies around strong gravitationally lensing clusters (Richard et al. 2006).

UV luminosity function at z$\sim$ 7



UV luminosity function at 6<z<10

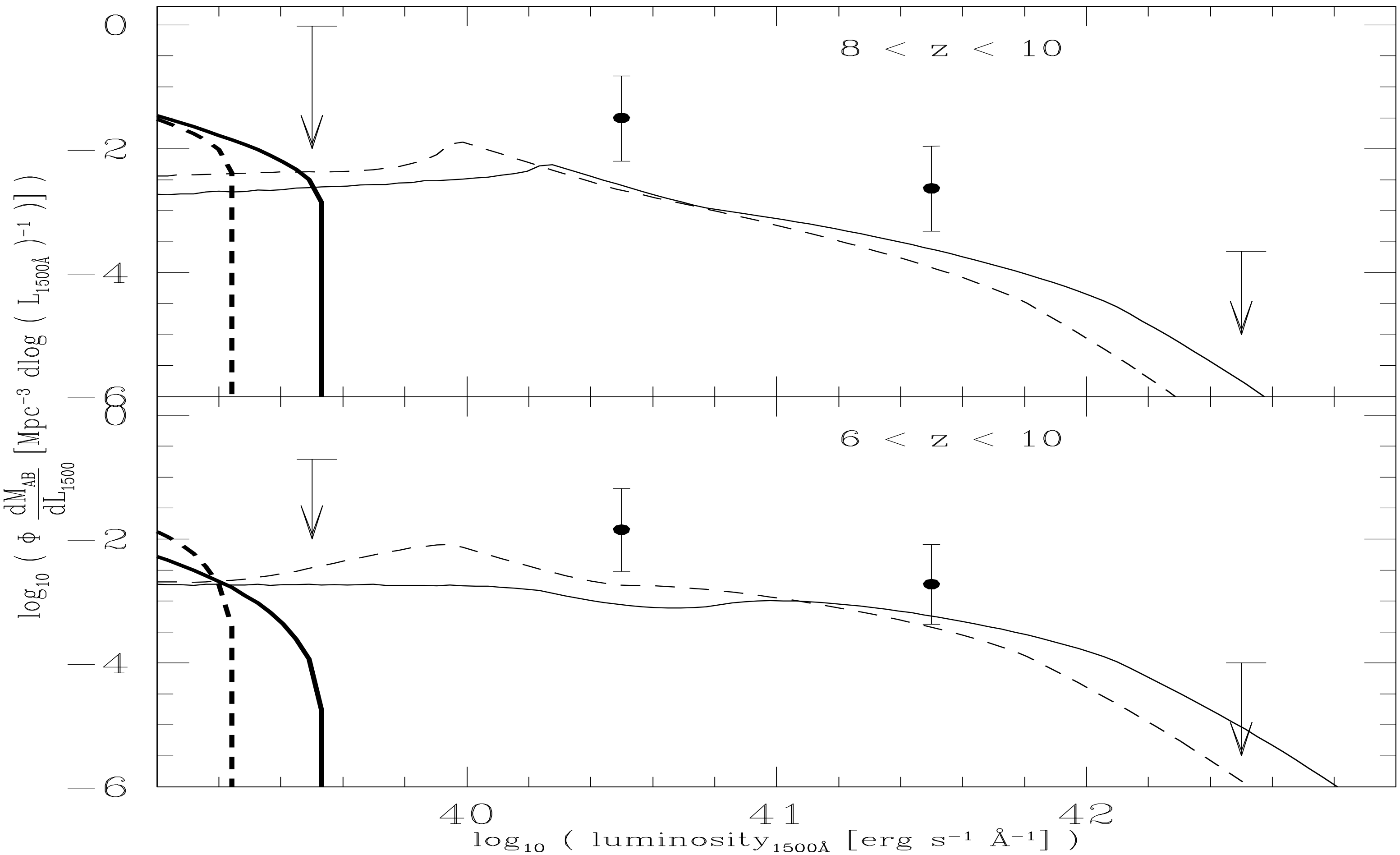


Data from Richard et al. 2006

UV luminosity function at 6$<$z$<$10

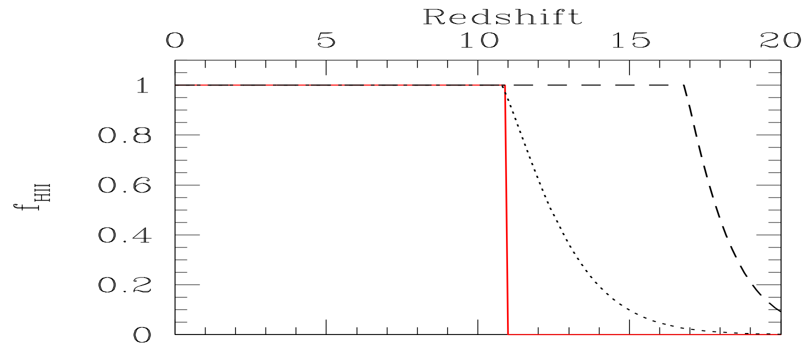
- Upper limits on LFs at z$>$6 from the HUDF are consistent with the predictions of models that fit z$<$6.
- The observed decline in the LF with increasing redshift is naturally produced by the decline in the halo number density from the structure formation models.
- Moreover, average LF obtained by Richard et al. (2006) for 6$\leq z \leq 10$ can only be understood if star formation occurs in burst mode, with high f_*, top-heavy IMF and very little reddening.
- The difference between the two data set is probably larger than cosmic variance.

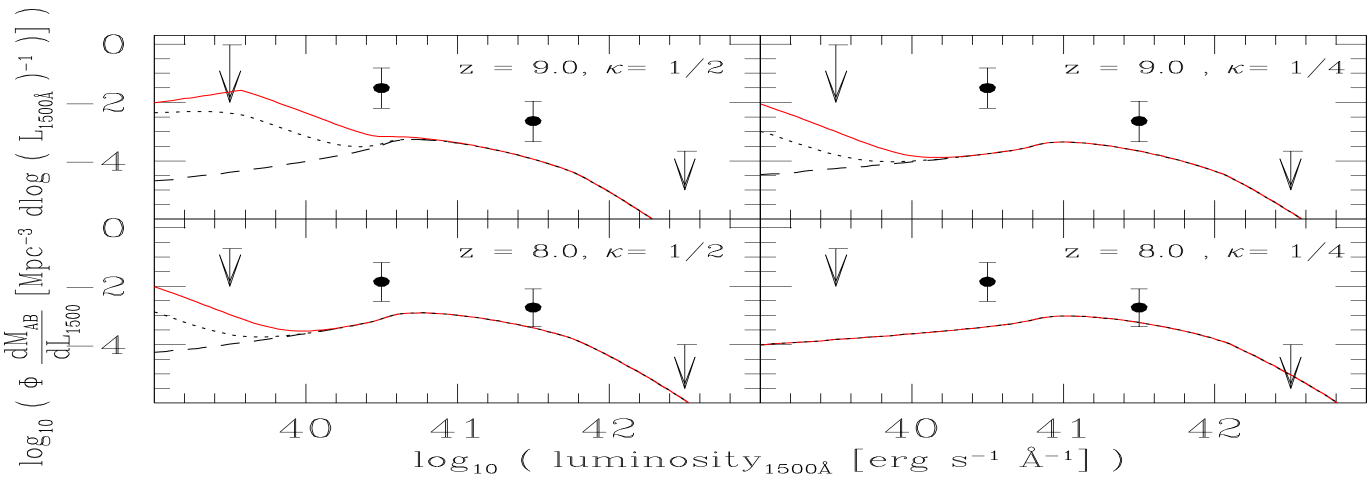
Probing reionization at z>6



Direct detection of H_2 cooled halos is difficult?

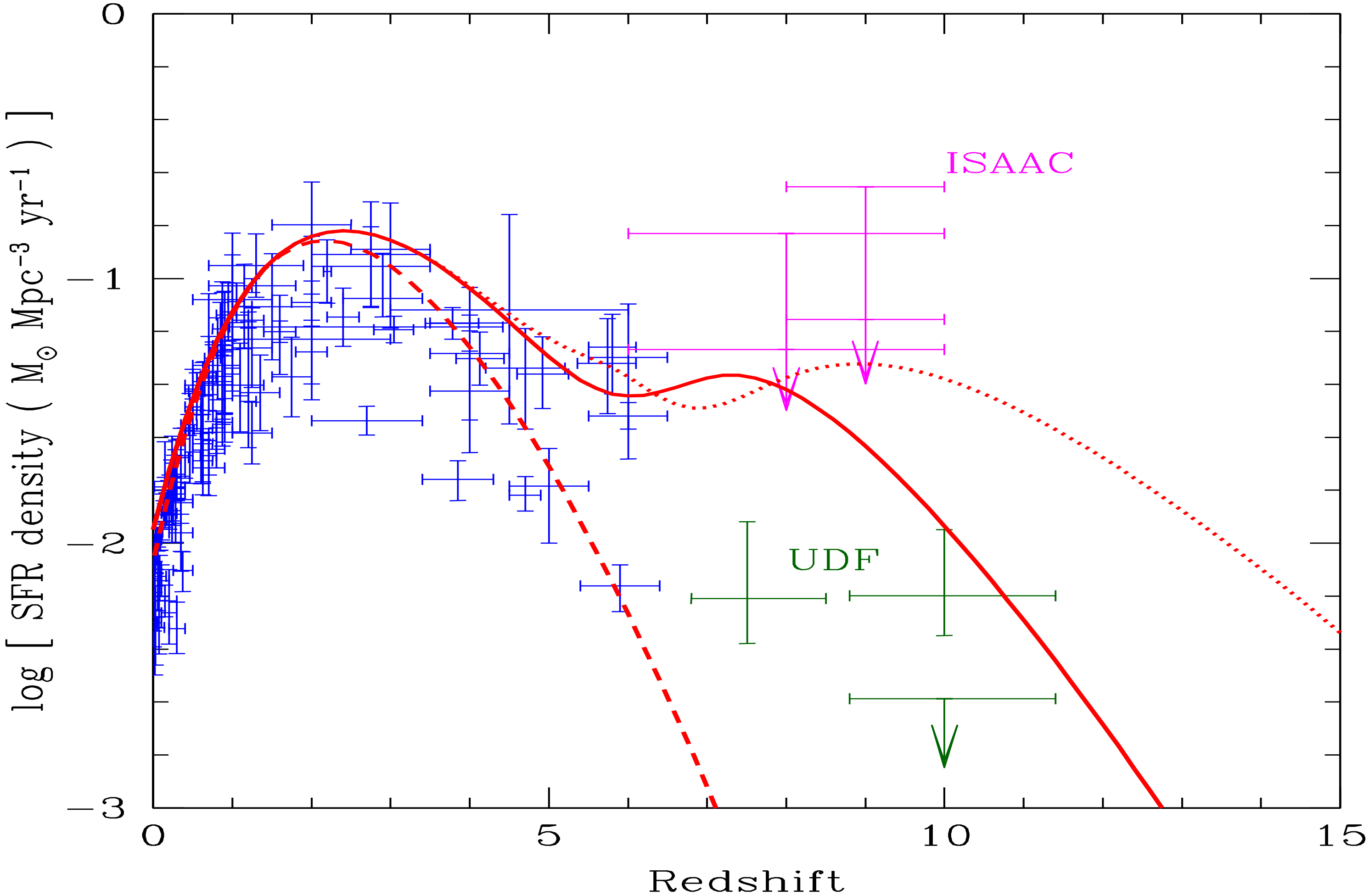
Probing reionization at z>6





Redshift evolution of LF will give some clues

Redshift evolution of star-formation rate density



What next?

- Outflows from the galaxies- metallicity floor in the IGM and high metallicity halos around galaxies- Samui, Subramanian & RS (2008).

- Fitting the Luminosity function taking into account the feedback due to winds

- Redshift distributions SNe and GRB.

- Effect of Cosmic rays from the starformation.