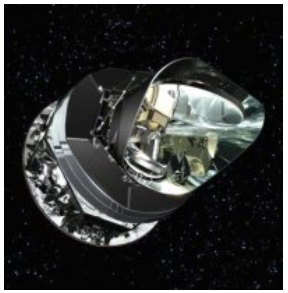
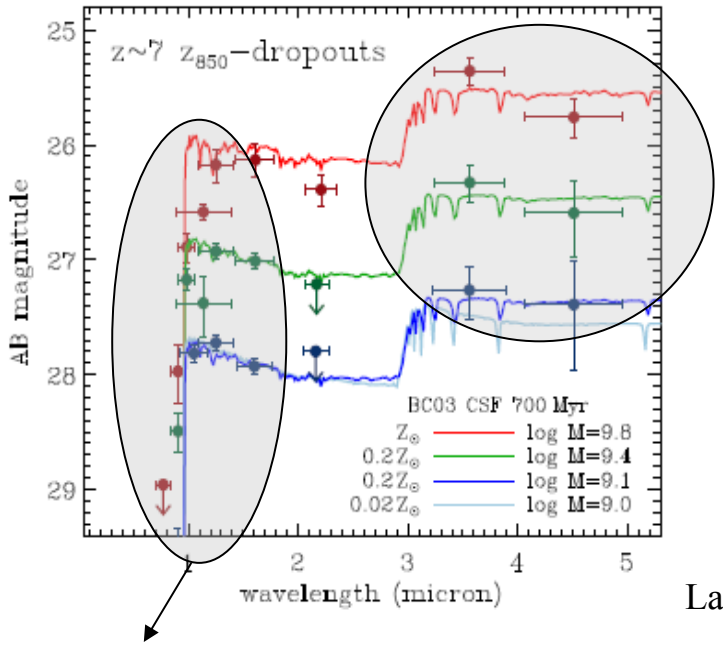


The Stellar Initial Mass Function at the Epoch of Reionization

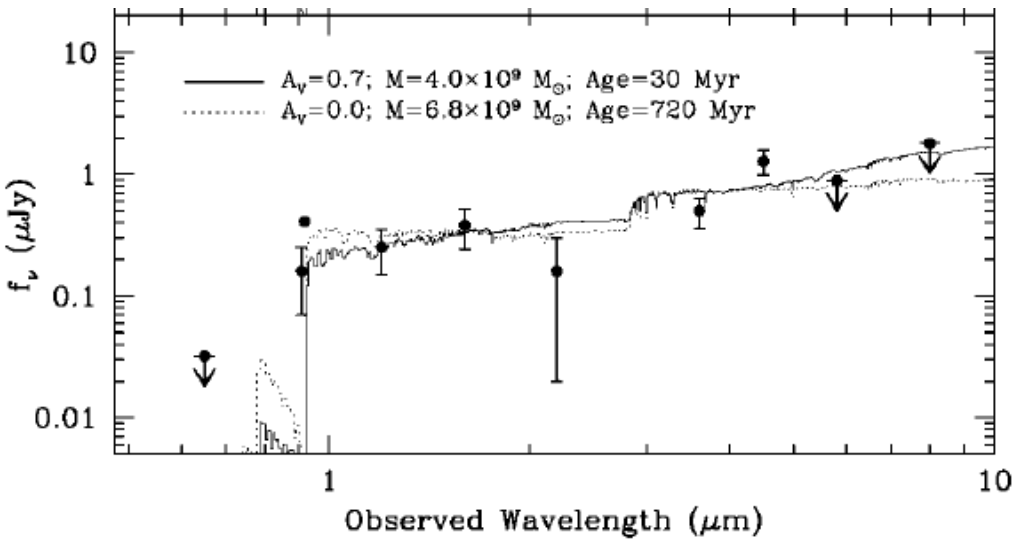
Ranga-Ram Chary

Spitzer/Planck/IPAC

California Institute of Technology



Labbe et al. 2010

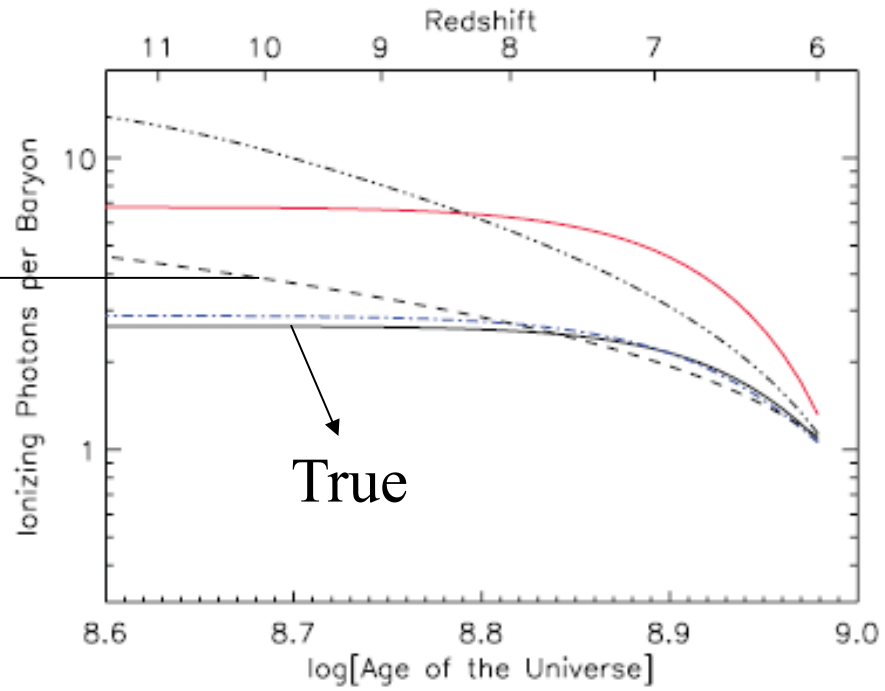


RC, stern, eisenhardt 2005

- We are measuring UV luminosities of z>6 galaxies
  - Need to convert UV luminosities into LyC photons
    - Depends on IMF, escape fraction, stellar rotation

- We are measuring rest-frame V band light from galaxies
  - This can be utilized to derive the stellar mass and age
  - Faint galaxies are blue and young; Bright galaxies show older stellar pops
  - Stellar mass is the past history of ionizing photon production modulo the IMF

- To assess if star-forming galaxies can account for reionization, need to know how many photons are required
  - Madau, Haardt & Rees prescription ?
    - It assumes instantaneous reionization
    - Assumes a fully ionized medium (including He)

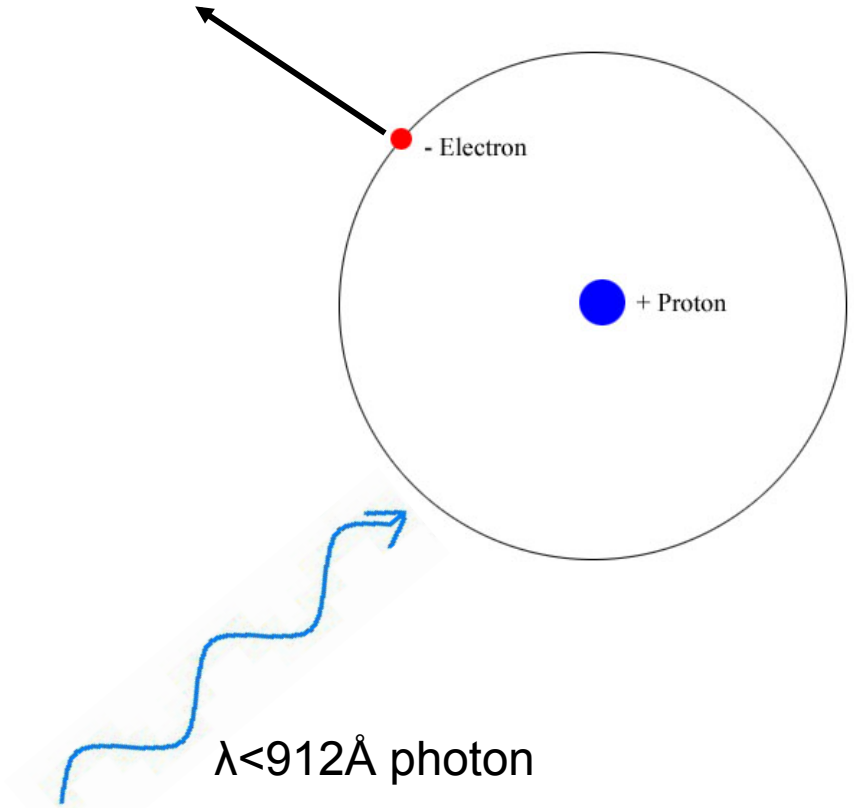


MHR

True

RC 2008, ApJ

Need 1 photon/baryon to start reionization



$$R = n_e n_{\mathrm{H\,II}} \alpha_{\mathrm{B}} C \ \mathrm{s}^{-1}\ \mathrm{Mpc},^{-3}$$

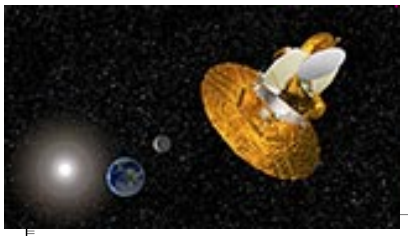
Sensitive to:

1. Clumpiness of the gas
2. Temperature of the gas
3. Co-moving electron density

Chary 2008, ApJ, 680, 32

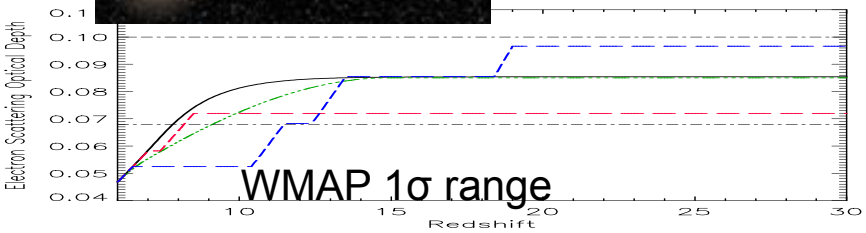
Need ~3 photons/baryon to maintain ionized hydrogen due to recombinations for best estimate

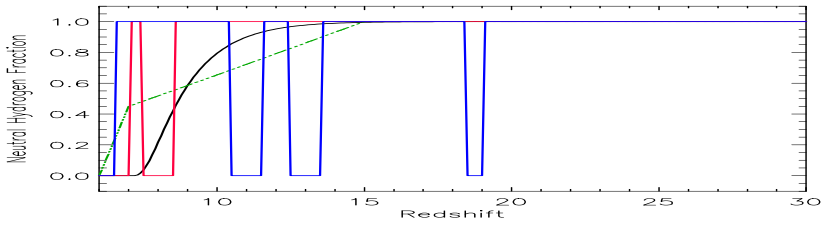
WMAP constrains large HI fractions…..weakly



$$\tau = \int_0^{z_e} dz \sigma_T n_e(z) c \frac{dt}{dz}$$

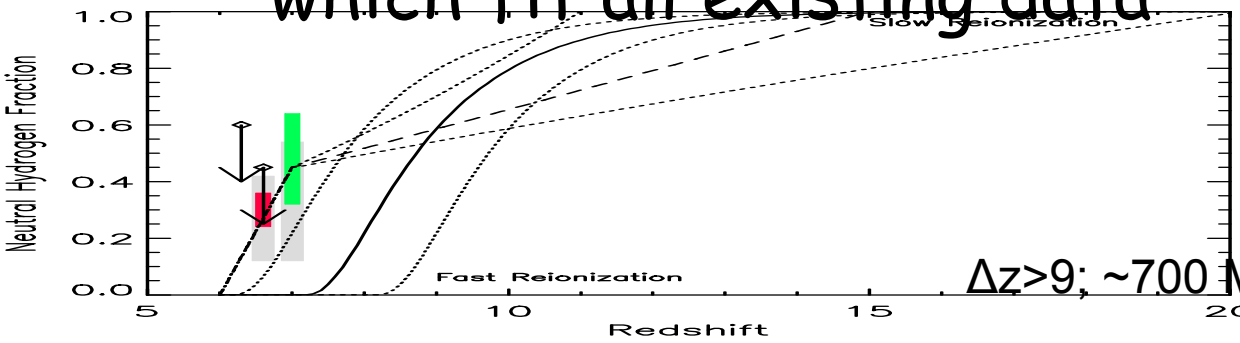
=0.084±0.016





0.04 of the WMAP signal comes from 0<z<6

We can consider two reionization histories which fit all existing data

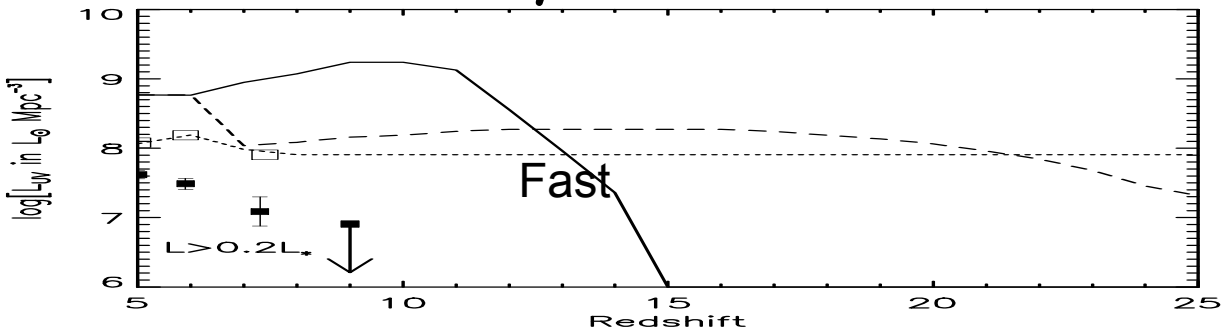


Δz>9; ~700 Myr

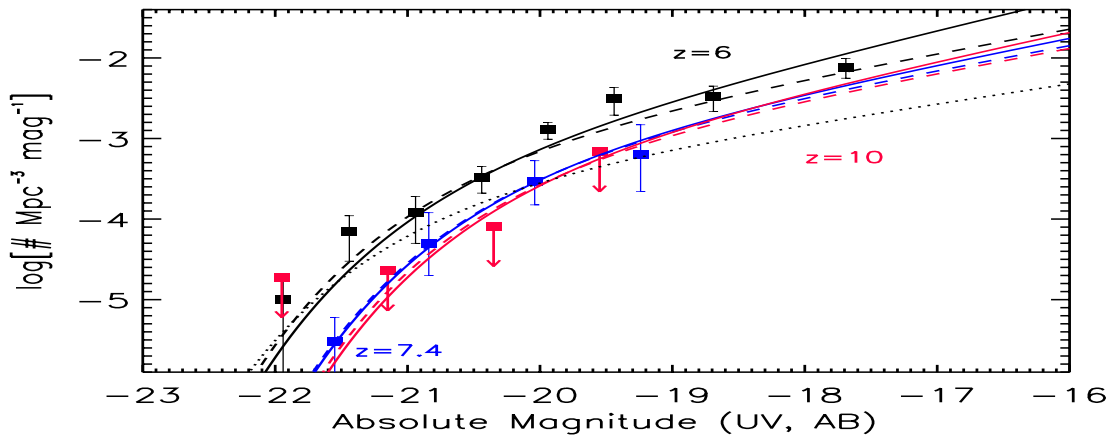
Δz~3; ≤400 Myr

RC & Cooray 2010

Minimum Required Evolution of UV Luminosity Density for Reionization



Slow



Bright

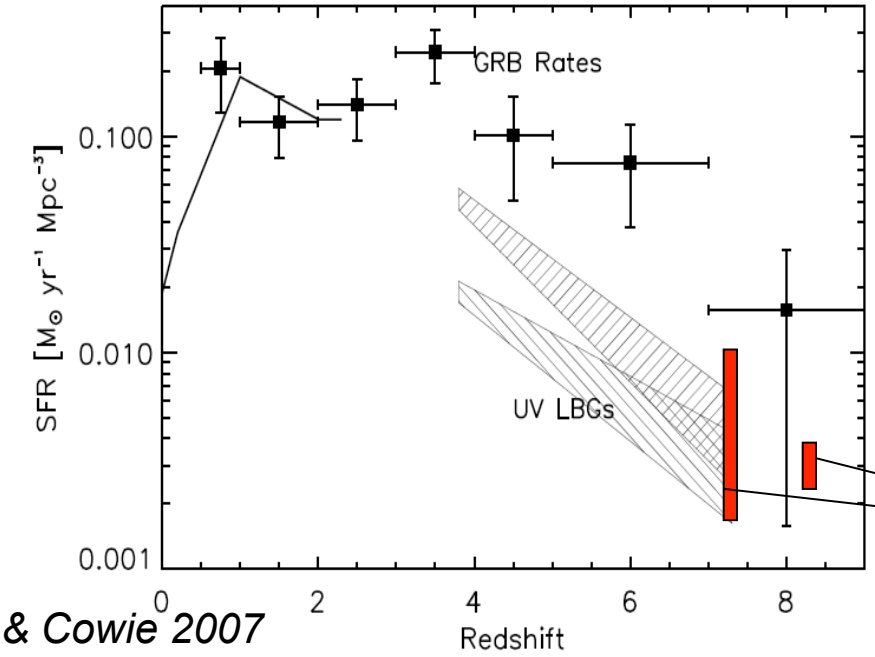
Faint

Solid lines: Required for Reionization
Dashed lines: Measured

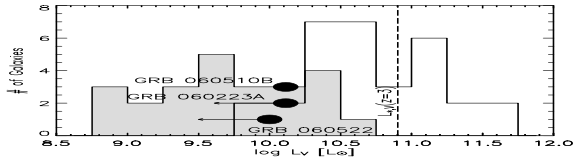
Data/fits from
Bouwens et al. ‘08
Bouwens et al. ‘10

Some uncertainty in the faint end slope of the UVLF
But clear evolution in L* between 6 and 7

Are we getting a complete picture ?
Evidence #1: Hint of a higher SFR at z~6 from GRBs



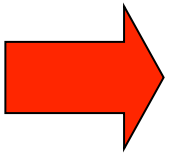
WFC3 UDF
(Bouwens)

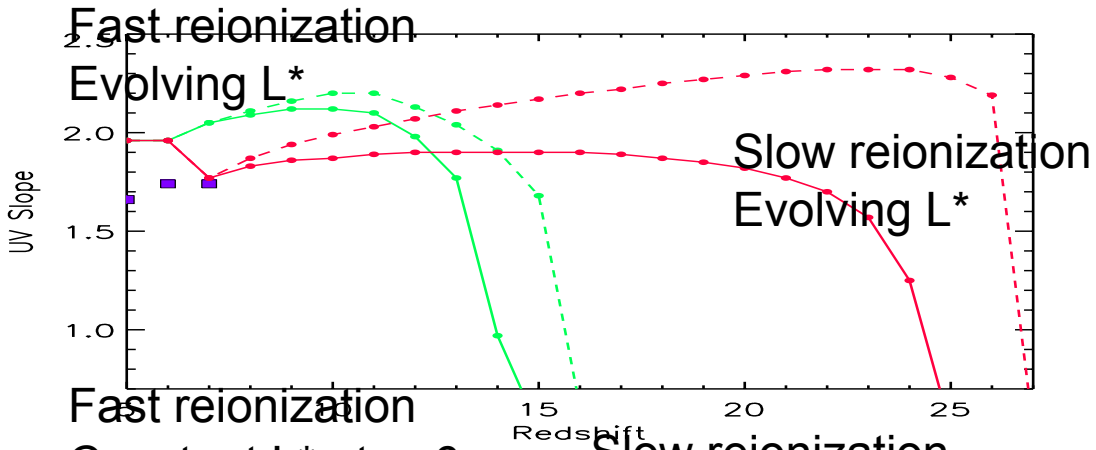


Chary, Berger & Cowie 2007

The Faint End of the Galaxy LF cannot be steeper than the Halo Mass Function

Dark Matter Halo Mass Function

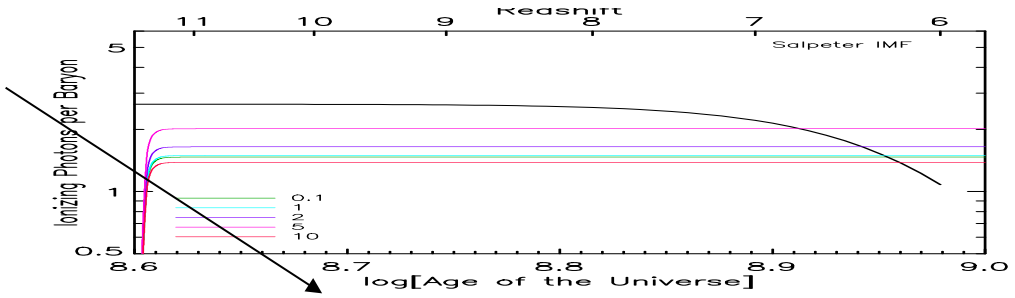




Chary & Cooray '10

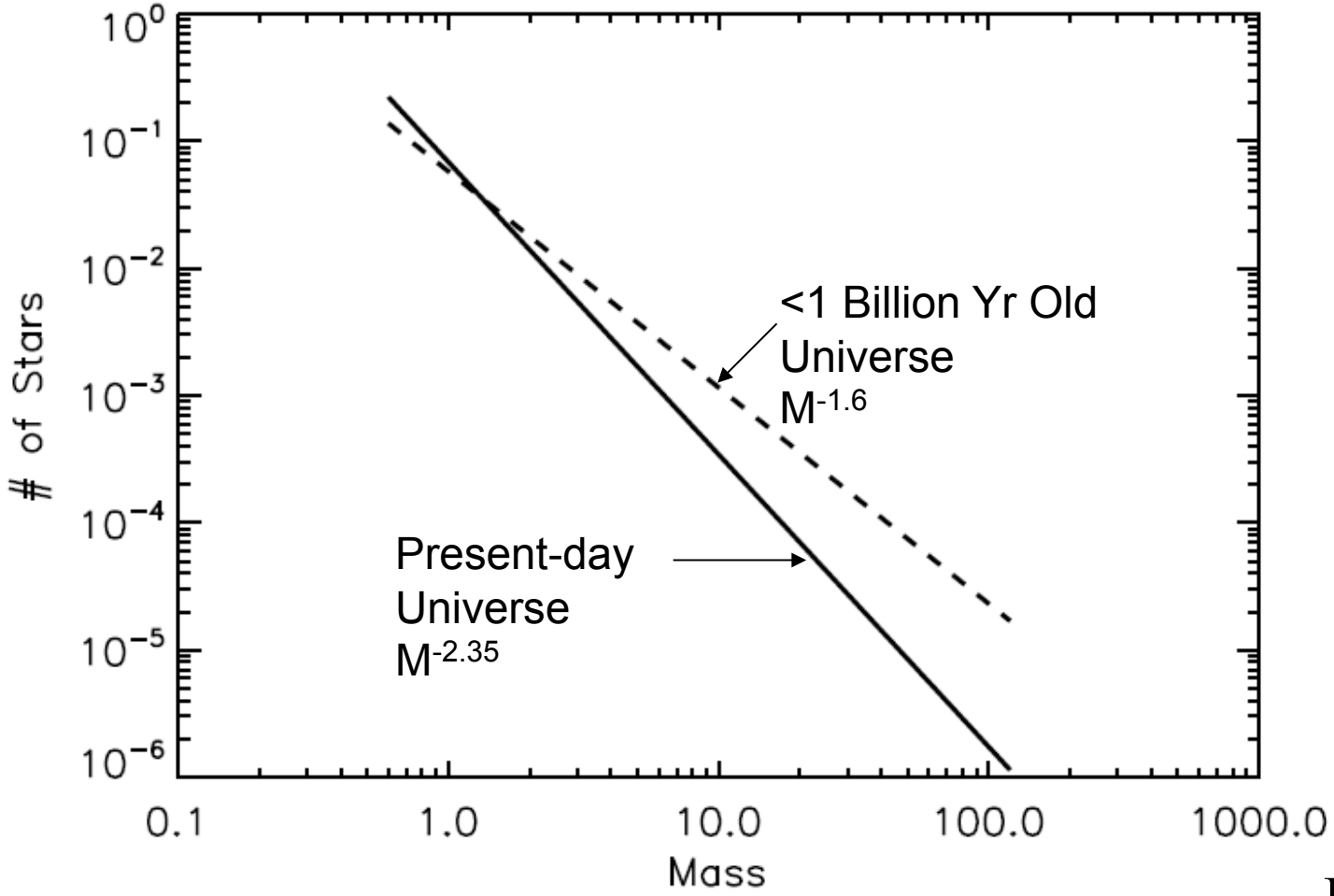
Salpeter IMF results in x2 too much stellar mass at z=6

Minimum number of ionizing photons required



Need to increase the efficiency of ionizing photon production for same stellar mass

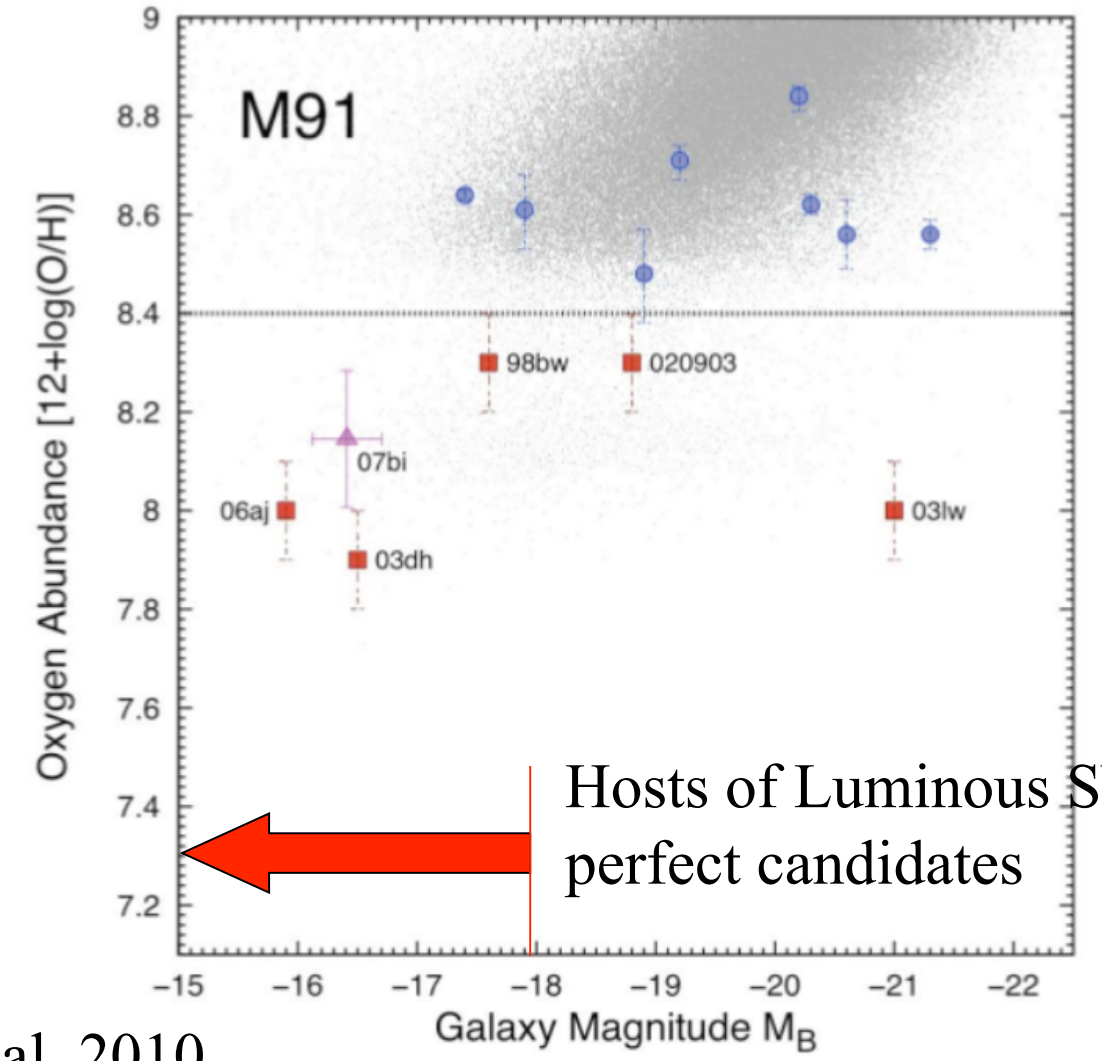
Obesity was ubiquitous in the early Universe



RC, 08

Massive stars end up in stellar remnants (BH, NS)

Impossible to study IMF in galaxies with M>-18 mag at z>6



Hosts of Luminous SNe are perfect candidates

Young et al. 2010

Summary

- Can star-forming galaxies reionize the Universe ?
  - Yes, need a steep faint end slope for the galaxy LF and the faint end slope evolves with redshift
  - But reionization needs to be slow and extended otherwise LF is steeper than DM halo mass function
  - Need a top-heavy IMF otherwise too many stars at z=6
    - Unless C/fesc < 40 (C=10, fesc=0.25 or C=5, fesc=0.125)
- Care must be taken to apply the correct reionization history and redshift evolution of the clumping factor (and not Madau, Haardt & Rees which assumed complete instantaneous reionization)
- How do we study the properties of these fainter than -18 mag galaxies ?
  - Luminous SNe hosts (massive stars, low metals, faint)
  - Ultrafaint local dwarfs