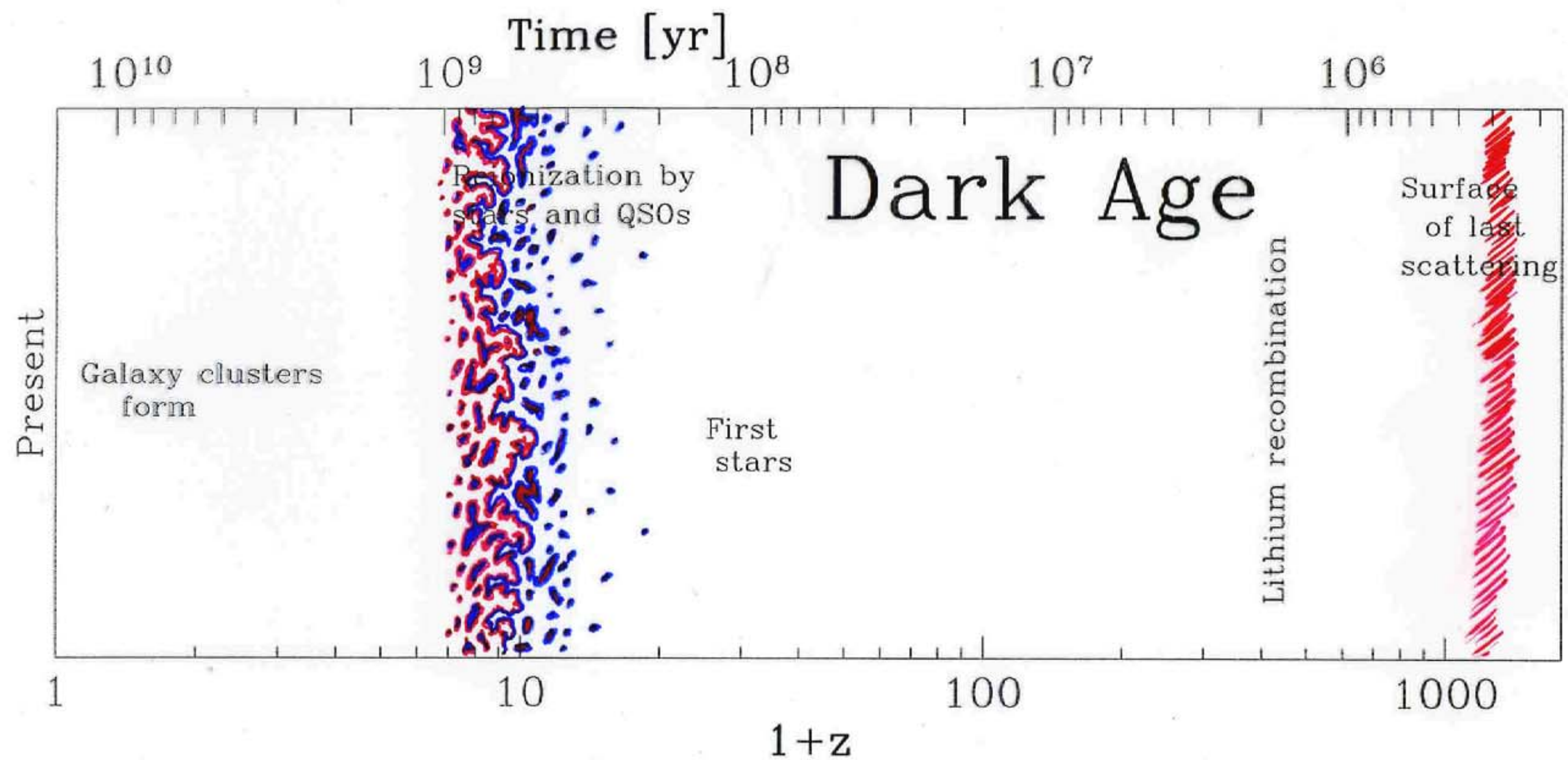
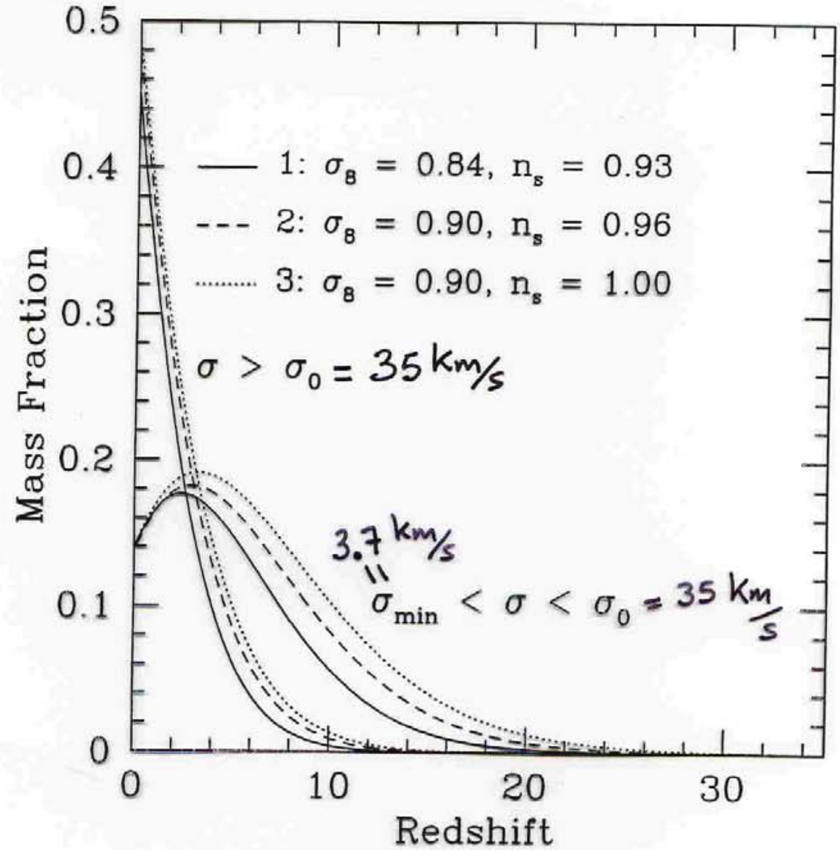


Onken & Miralda-Escudé 2003

Models of reionization

Fraction of mass in halos of velocity dispersion σ:



- The predicted epoch of reionization depends on the efficiency parameter ϵ_{halo} :

How many ionizing photons are emitted per baryon in collapsed halos per Hubble time?

Emissivity: $\epsilon = F_{halo} \cdot \epsilon_{halo}$

Observational determination of ϵ at $z=4$

Intensity of ionizing background:

- Lyα forest mean transmitted flux
- $\Omega_b h^2 = 0.022$
- CDM models

$\Rightarrow$ $\Gamma \simeq 5 \cdot 10^{-13}\, s^{-1}$

or $n_{photon} \simeq 0.4\, n_{atom}$ at $z=4$

Mean free path of ionizing photons:

Abundance of Lyman limit systems $\Rightarrow$ $\lambda \simeq 0.06\, cH^{-1}(z=4)$

Inferred emissivity: $\frac{\epsilon}{H n_{atom}} = \frac{n_{photon}}{n_{atom}} \cdot \frac{c}{H\lambda} \simeq 7 \frac{\text{photons}}{\text{atom} \cdot \text{Hubble time}}$

(At $z=4$)

$\epsilon_{halo} = \frac{\epsilon}{F_{halo}} \simeq 50 \frac{\text{photons}}{\text{atom} \cdot \text{Hubble time}}$

($F_{halo} \simeq 0.15$)

$\sigma > 35\, km/s$

Maximum theoretically possible emission, with stars: all baryons turn to massive stars with zero metallicity: then $\epsilon_{halo} \cdot t_* \simeq 10^5 \cdot \frac{\text{photons}}{\text{atom}}$

Consider two halos with same σ at different z:

Why should there be any difference in emissivity?
The only obvious difference is that gas density should be higher at high redshift.
But gas cooling is already efficient at high redshift.
Metallicity should be similar, at fixed σ.

Emissivity model: two halo populations.

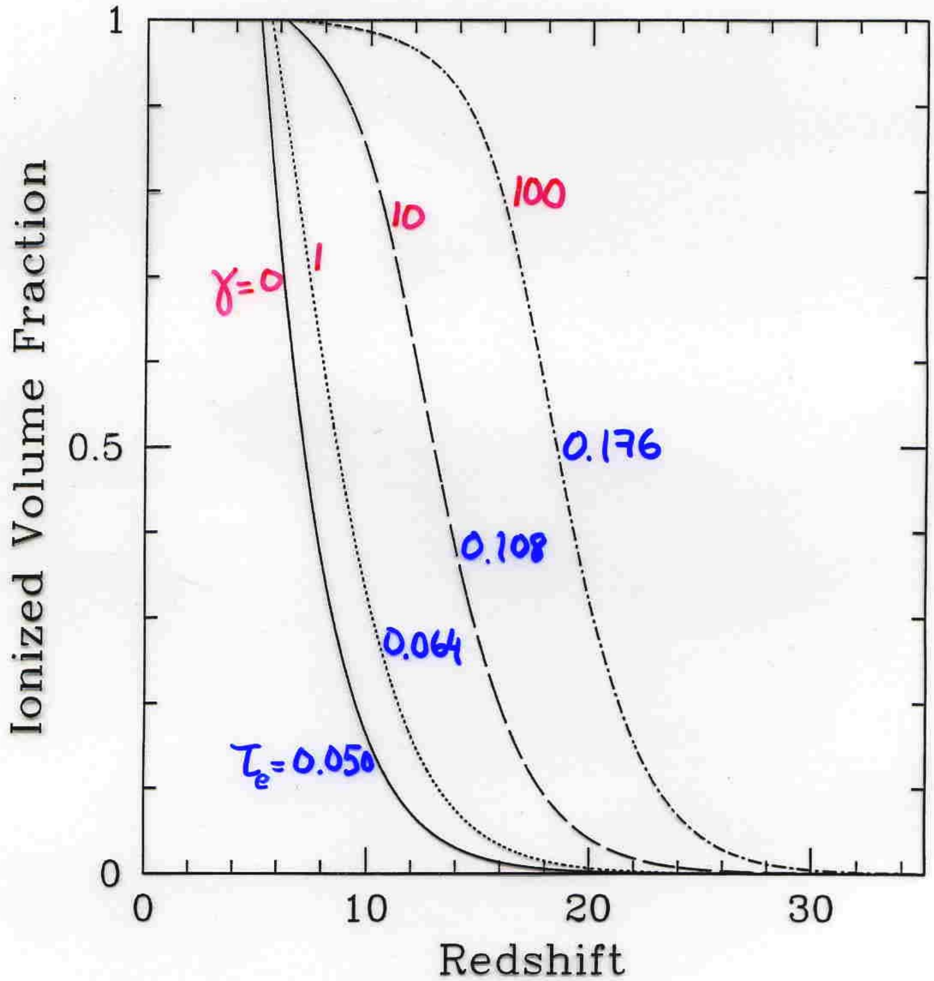
$\sigma > 35\ \mathrm{km/s}$: $\quad \epsilon_h = \epsilon_4 = \text{constant} = 7 \dfrac{\text{ionizing phot}}{\text{atom} \cdot \text{Hubble time}}$

$\sigma < 35\ \mathrm{km/s}$
$\sigma > 3.7\ \mathrm{km/s}$
$$\epsilon_h = \epsilon_4 \cdot \left(1 + \gamma \cdot \ln \frac{35\ \mathrm{km/s}}{\sigma}\right)(1-y)$$

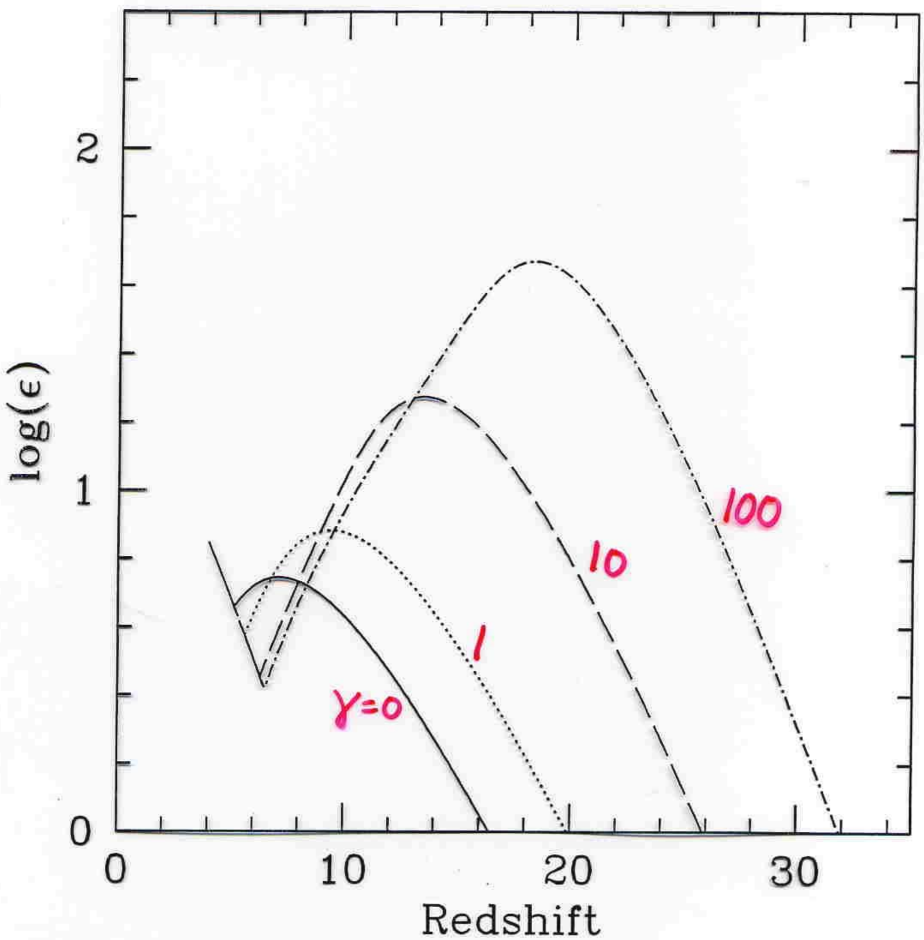
y: fraction of volume ionized.

Result for history of reionization

Assume clumping factor = 1



Emissivity history



CONCLUSIONS

If the emissivity per unit mass has been constant in all halos at $z > 4$, reionization should end at $z \simeq 6$ in CDM models, and $\tau_e \simeq 0.05$.

To reach $\tau_e = 0.17$, the central WMAP value, we need a factor $\gamma \simeq 100$ increase in emissivity from high-σ halos at $z = 4$ to low-σ halos at $z \simeq 15$.