Probing high-redshift galaxies with intensity mapping of the Ly-α line

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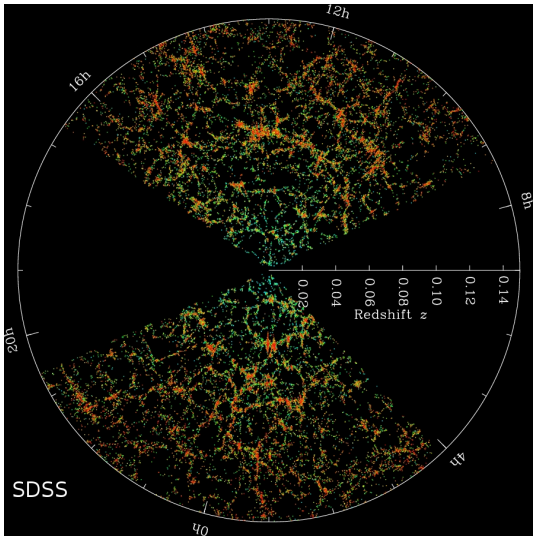
Mapping the large scale structure



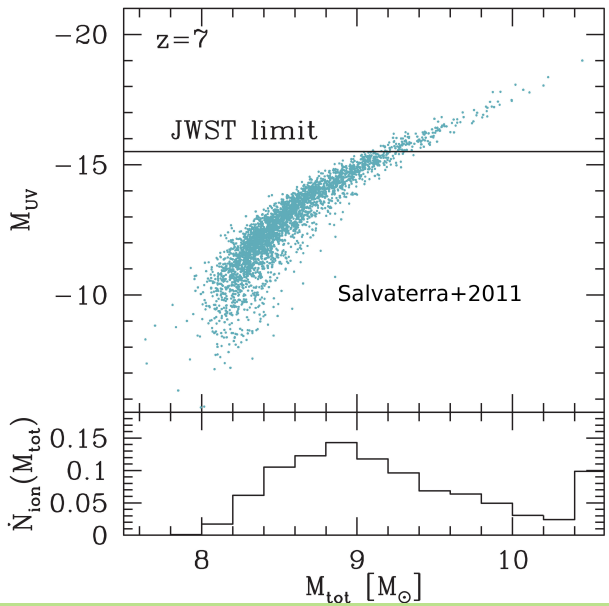
Classical approach:

- Galaxies as test particles.
- Distance from redshift measurements.

Problems with galaxy surveys:

- Not sensitive to faint sources.
- High-z spectroscopy very challenging.

$\Longrightarrow$ forego individual galaxy detection and focus only on large scale structure.



The idea behind intensity mapping

Detect emission from a single line
$\Longrightarrow$ relation between frequency (redshift) and distance.

- Spectroscopic mapping of a large sky area
- 3D map of intensity emitted.
- Divide sky in large voxels $(5 - 10\mathrm{Mpc}^3)$.

Advantages:

- No detection threshold.
- Low resolution.
- Multiple suitable lines.

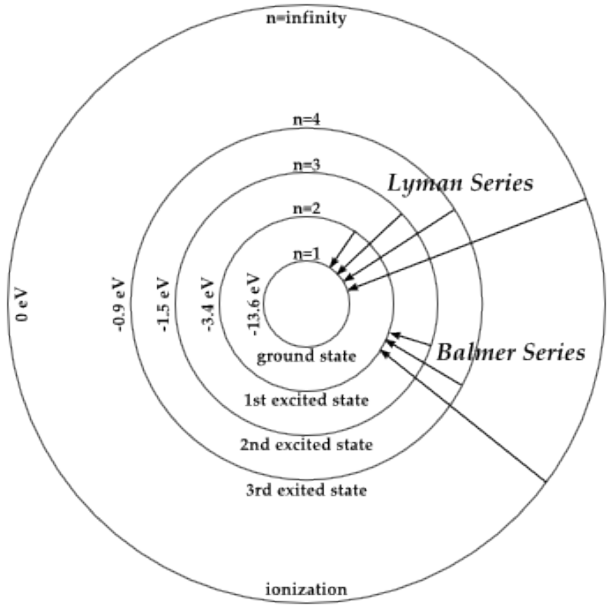
Drawbacks:

- Strong foregrounds:
  - absolute intensity unobservable
  - $\Longrightarrow$ fluctuations
- Low redshift interloping lines.

Ly-α IM and our estimate

The Ly-α line:

- Recombinations
- Absorption of Ly-n photons



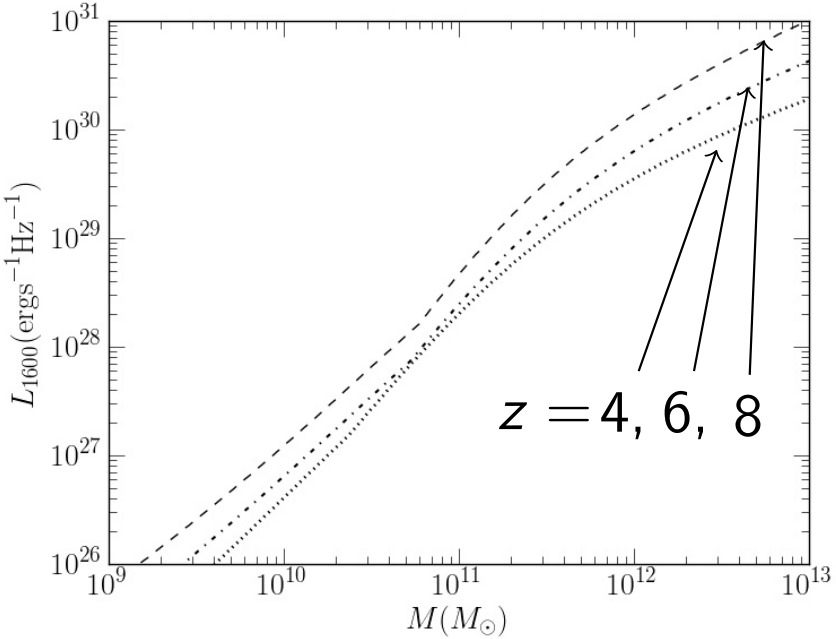
Aim:

- predict the Lyα power spectrum at $z > 4$.
- understand the physics that could be probed.

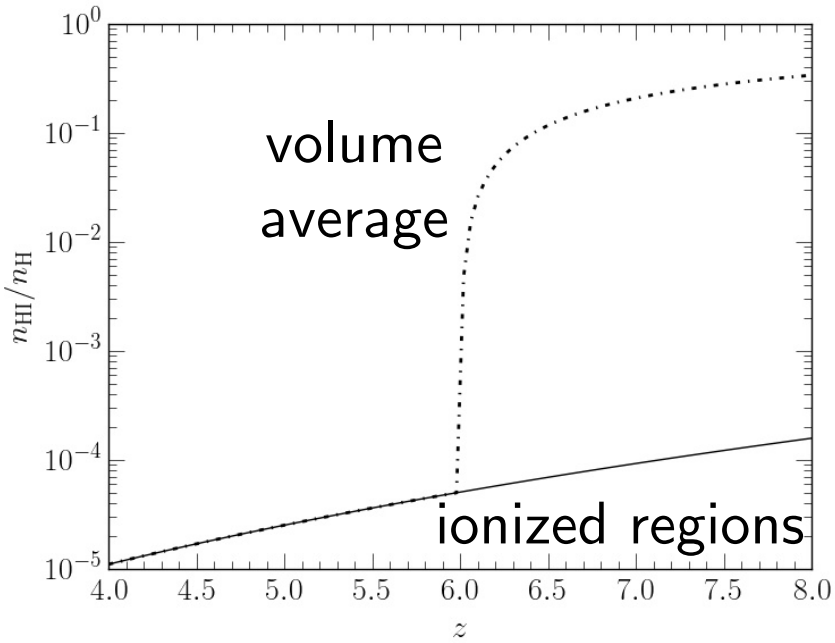
Method:

- analytical model for galaxies and IGM.

- Galaxy model:
  - Abundance Matching
  - `Starburst99`
  - Poorly constrained parameters: escape fraction, dust, stellar age, etc...



- Effect on IGM and ISM:
  - $E > 13.6$eV photons
    $\rightarrow$ ionizations, recombinations.
  - $10.2 - 13.6$eV photons
    - Redshift in Ly-n line.
    - IGM absorption $\rightarrow$ Ly-α.



Lyα emission

- $E > 13.6$eV photons:

$$I_{\mathrm{ISM}}^{\mathrm{Ly}\alpha} \propto \langle f_{\mathrm{esc}}^{\alpha} \rangle \left(1 - \langle f_{\mathrm{esc}}^{912} \rangle\right) \dot{n}_{912}$$

Lyα dust absorption

Escape fraction

$$I_{\mathrm{Ly}\alpha}^{\mathrm{IGM\ rec}} \propto \alpha_B(T)\ C(z)\ n_{\mathrm{HII}}^2$$

IGM T

Clumping factor

- $10.2 - 13.6$eV photons:

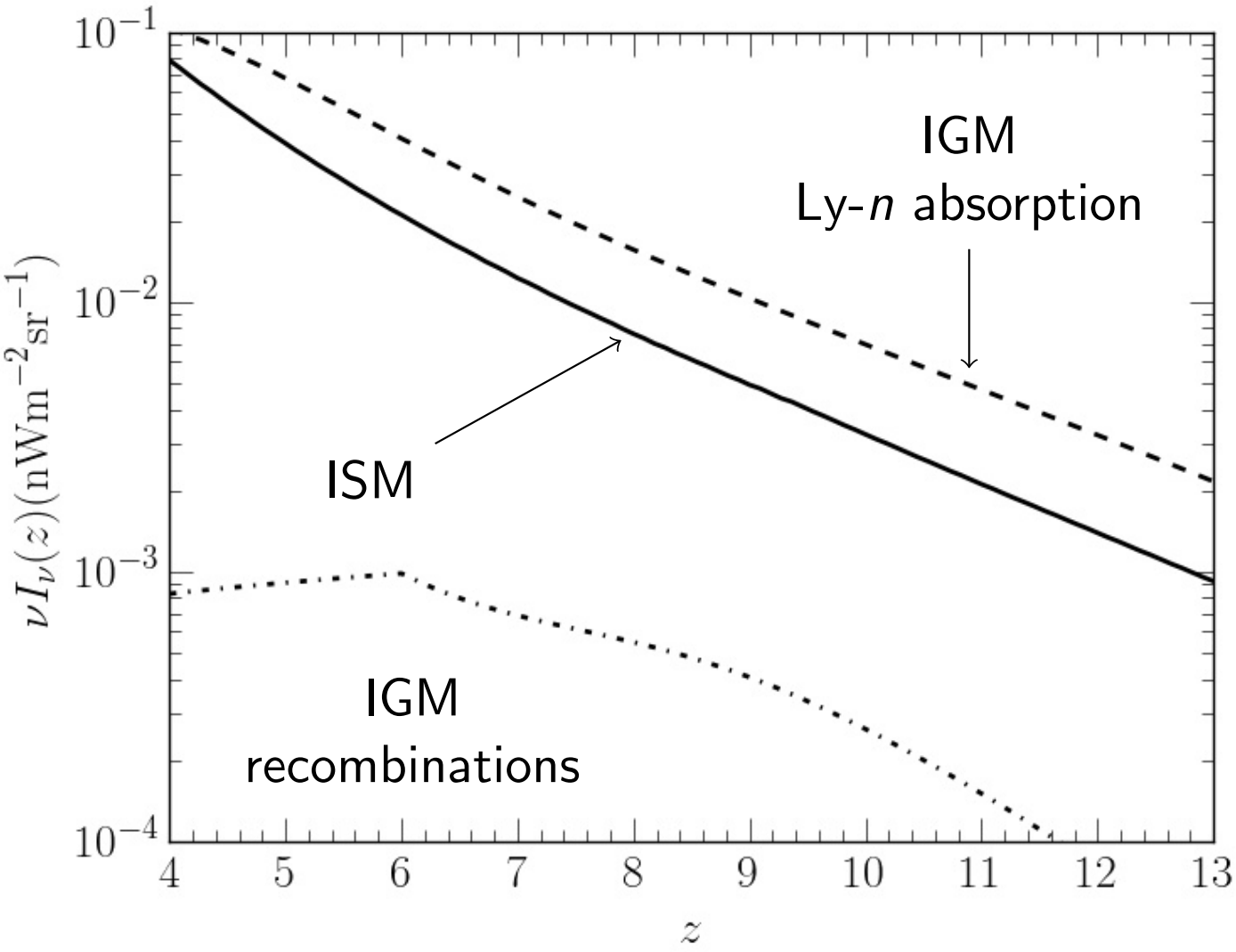
$$I_{\mathrm{Ly}\alpha}^{\mathrm{IGM\ Ly}}(z) \propto \sum_n P_{\mathrm{abs}}(n, z)\ f(n) \int_z dz'\ \dot{n}_{\nu'}(z')\ \langle f_{\mathrm{esc}}^{\nu'} \rangle$$

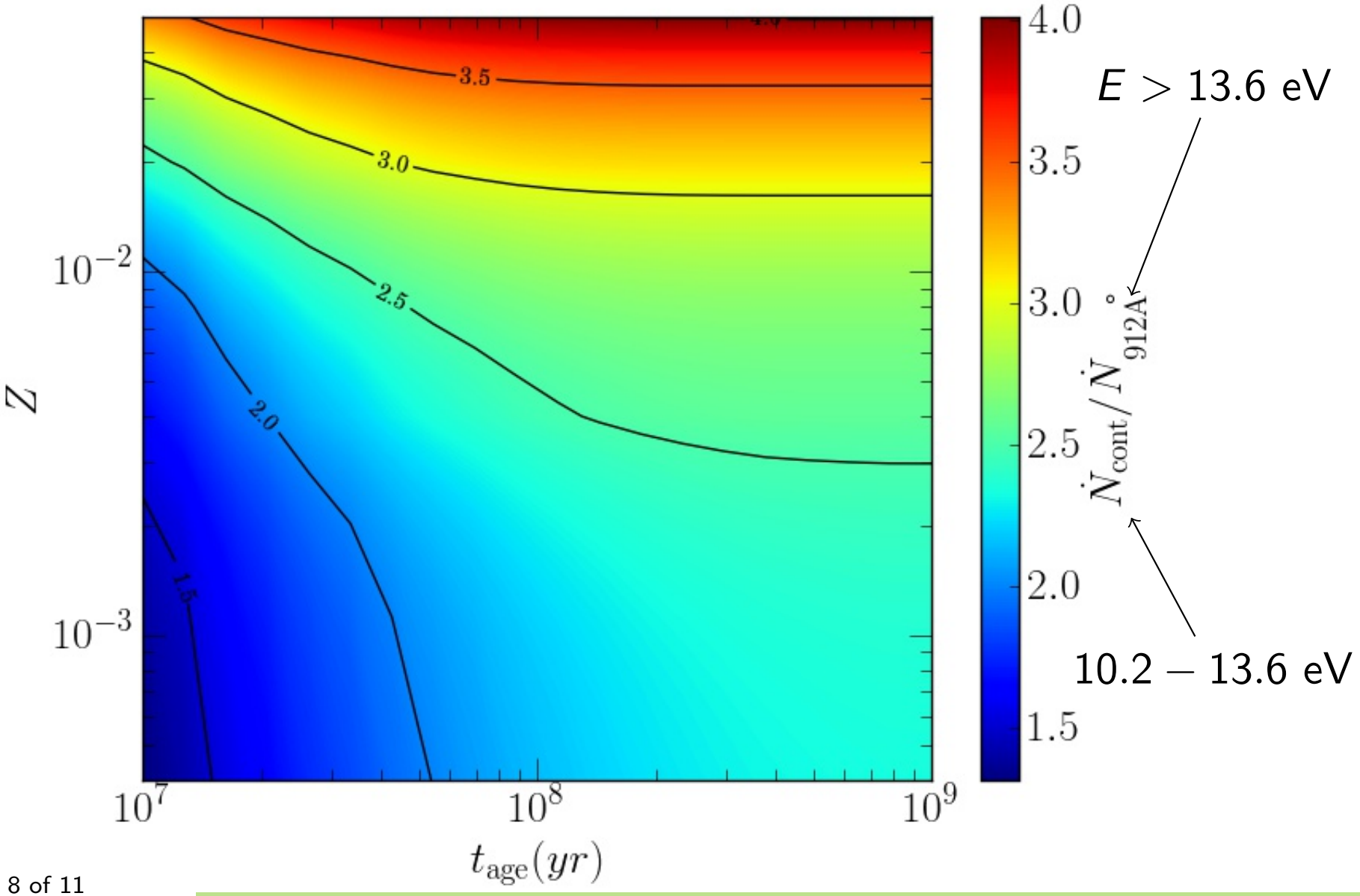
Ly-n absorption probability

UV photons emission

UV dust absorption

Ly-α mean intensity

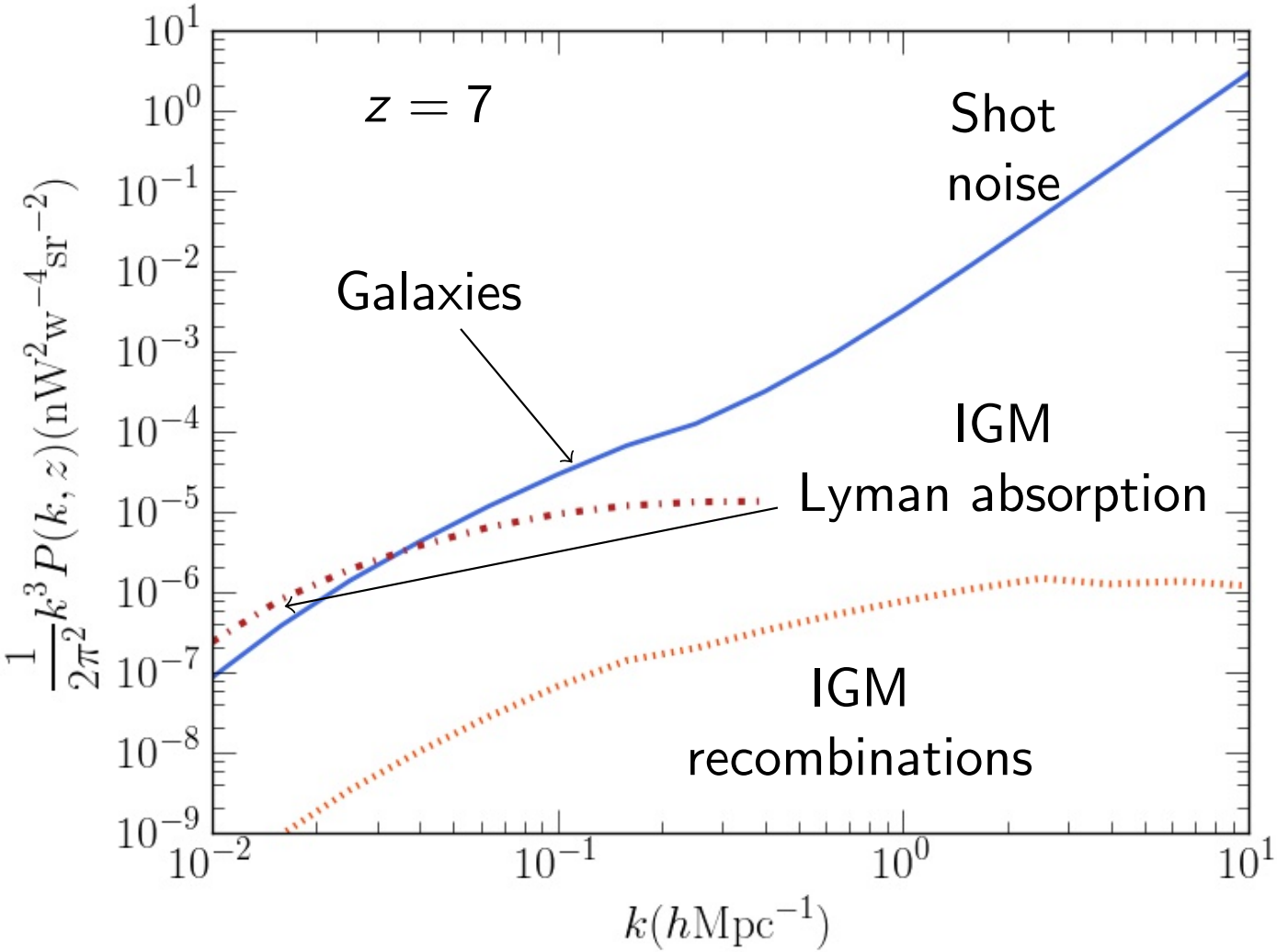



3.5
3.0
2.5
2.0
1.5
10^{-2}
10^{-3}
Z
10^7
10^8
10^9
$t_{\rm age}(yr)$
4.0
3.5
3.0
2.5
2.0
1.5
$\dot{N}_{\rm cont}/\dot{N}_{912\mathring{A}}$
$E > 13.6$ eV
$10.2 - 13.6$ eV

Sources of fluctuations

- Galaxy distribution (star formation):
  - Biased linear fluctuations
$$\delta \to \delta\dot{\rho}_\alpha = \langle b(z)\rangle_\alpha \dot{\rho}_\alpha(z)\delta$$
  - Shot noise (dominates small scales $l < 5 - 10$Mpc).
- IGM density:
  - In IGM recombinations
$$\delta n_{\rm H}^2 = 2 n_{\rm H}\delta$$
  - In the absorption probability of Ly-n photons $P_{\rm abs}$
$$\delta P_{\rm abs} \sim \delta e^{-\tau_{\rm eff}} \propto e^{-\tau_{\rm eff}}\delta$$
- Filling factor (biased).

Ly-α power spectrum



Summary

Analytical model for $z > 4$ Ly-α power spectrum:

- Both IGM and ISM emission is important.
- Fluctuations trace the star formation rate.
- Different shape of the power spectrum for ISM and IGM.