Gaseous Cosmological Structures and Metagalactic UV Background (Fluctuations)

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UVBG spatial correlations

- Source shot noise produces spatial correlations

$$\xi_J(r) = \; < J(0)J(r) > / < J >^2 -1$$
$$= \frac{1}{4\pi\lambda_{\rm mfp}^3 n_{\rm eff}} \frac{\lambda_{\rm mfp}}{r} I_J\left(\frac{r}{\lambda_{\rm mfp}}\right)$$

(Zuo 1992)

- Effective number density of sources

$$\frac{1}{n_{\rm eff}} = \frac{< L_{\rm gal}^2 > + < L_{\rm QSO}^2 >}{(< L_{\rm gal} > + < L_{\rm QSO} >)^2}$$

N.B. $< L_{\rm QSO}^2 > \sim L_{\rm QSO,max}^{3-\beta}$ ($\beta < 3$ at high z)

UVBG power spectrum

- Linear perturbation theory (matter and shot noise)

$$P_J(k) = T_J^2(k) P_{\delta_m^L}(k) + \tilde{n}_{\rm eff}^{-1}(k)$$

where $P_{\delta_m^L}(k)$ is the linear matter power spectrum and T_J depends on radiative transfer and bias of sources

(Pontzen 2014; Gontcho A Gontcho+ 2014; AM & McQuinn 2019)

- Effect on power spectra of tracing objects (eg HI)

$$P_o(k,\mu) = \left[b_o + b_J T_J(k) + f\mu^2\right]^2 P_{\delta_m^L}(k) + b_J^2 \tilde{n}_{\rm eff}^{-1}(k)$$

($\mu = \hat{\mathbf{n}} \cdot \hat{\mathbf{k}}$; $f \approx \Omega_m^{0.6}(z)$) Typically, $b_J < 0$.

Role of UVBG fluctuations

- Lyα forest flux autocorrelation

(and Baryonic Acoustic Oscillations)

- 21cm intensity mapping

  (eg CHIME; HIRAX; MEERKAT)

- Lyα forest high optical depths at

  high redshifts

UV background model

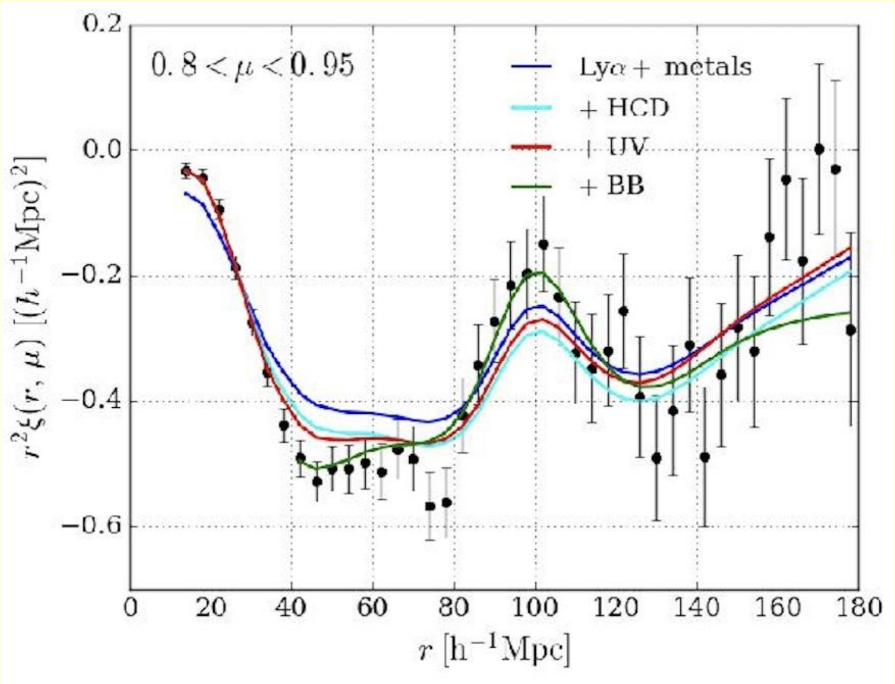
- Assume galaxy luminosity function of Bouwens et al. (2015)
- Photoionizing photon escape fraction from Haardt & Madau (2012):

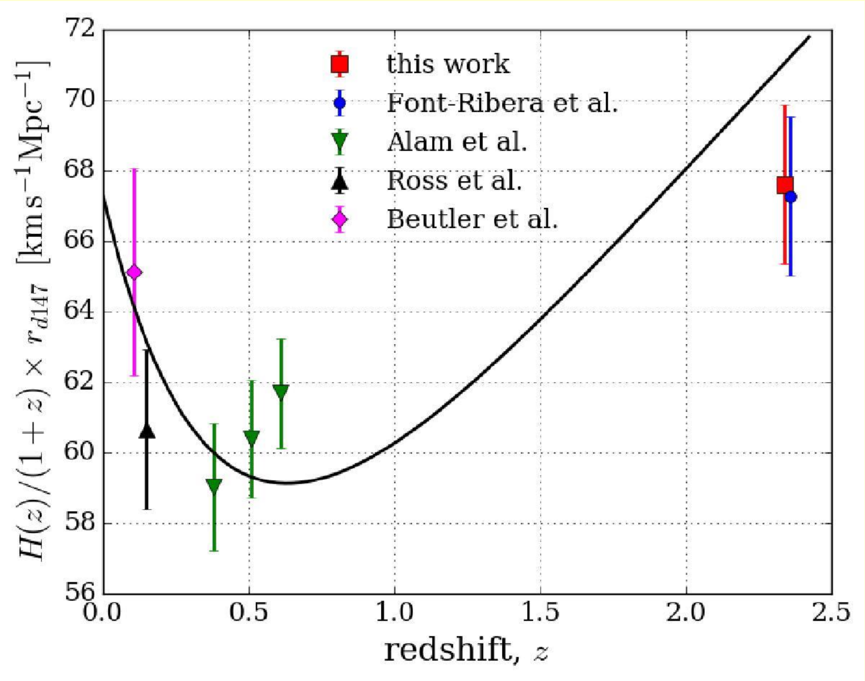
$$f_{\rm esc} = 1.8 \times 10^{-4}(1+z)^{3.4}$$

- QSO luminosity function(s) from Hopkins et al. (2007)
- Mean free path of photons at the Lyman edge from Worseck et al. (2014)

I. Lyα forest flux autocorrelation: include transverse-to-los data

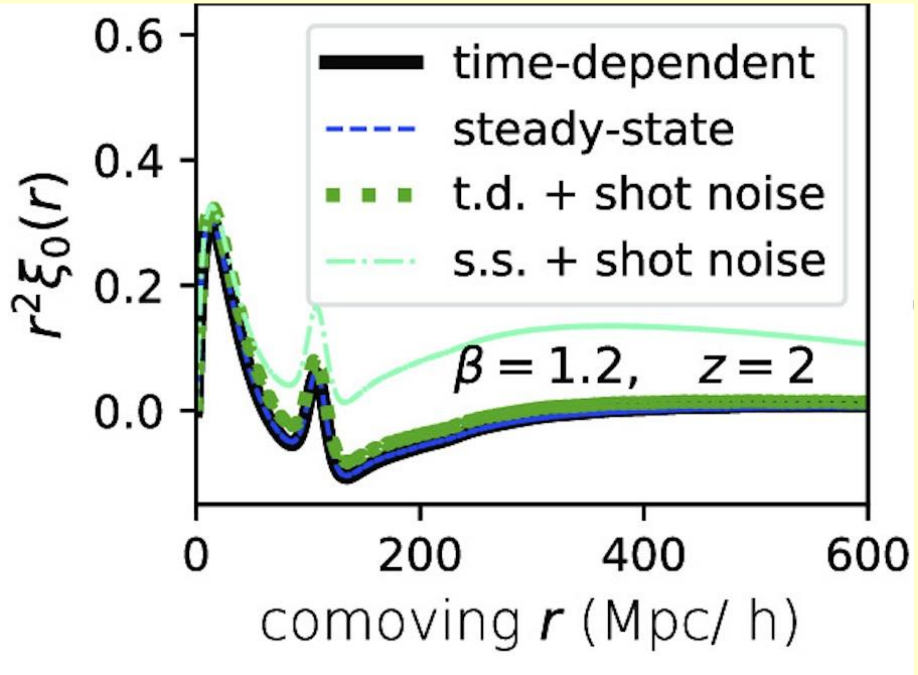
Baryon Oscillation Spectroscopic Survey/ SDSS-III

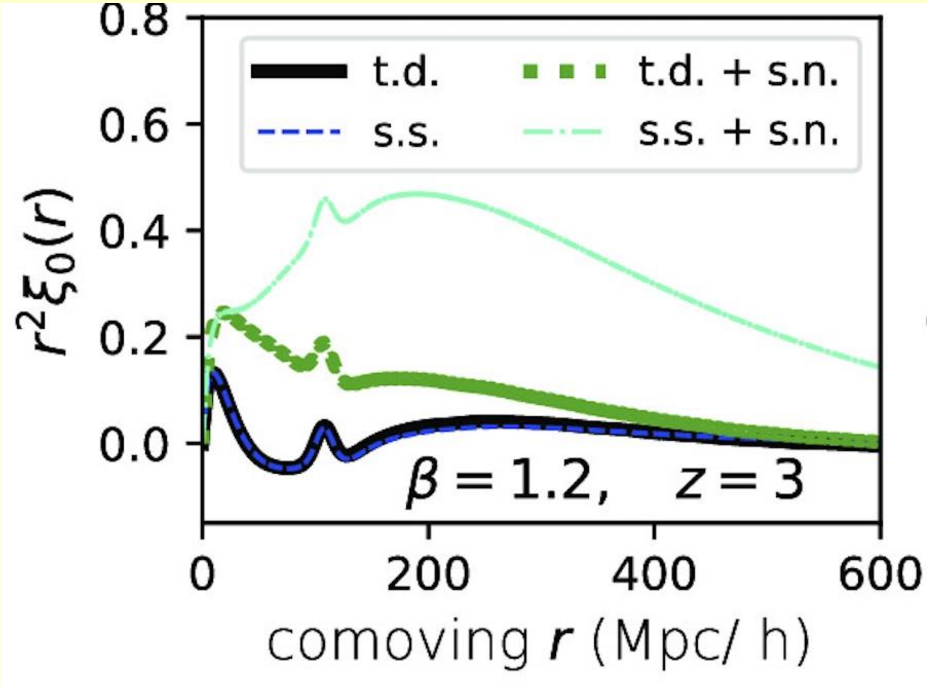




Bautista et al. (2017)

Fluctuations in HI opacity





z= 2

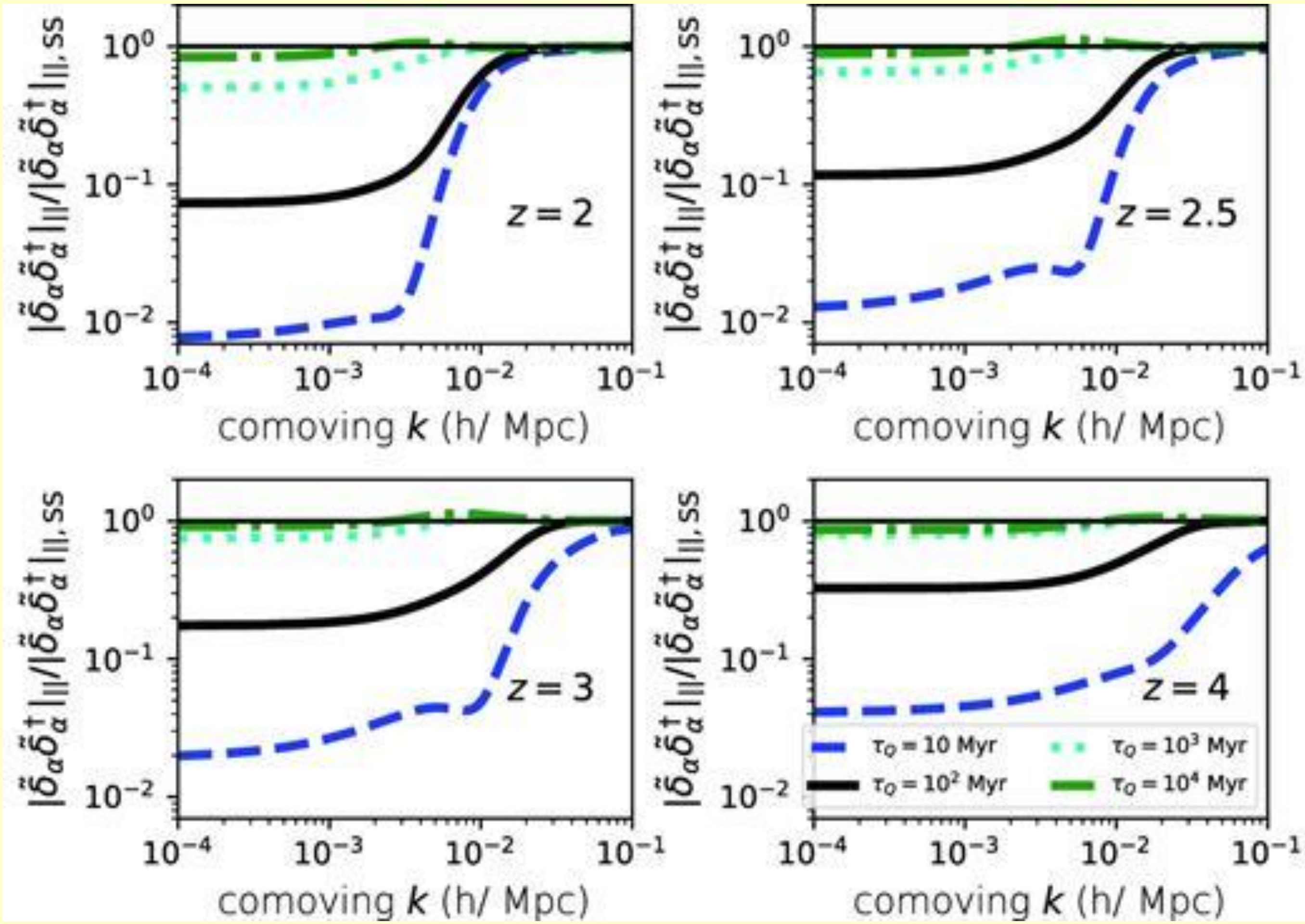
τ_{QSO} = 100 Myr

z= 3

l = 0 Legendre component of redshift space HI correlation function

(AM & McQuinn 2019)

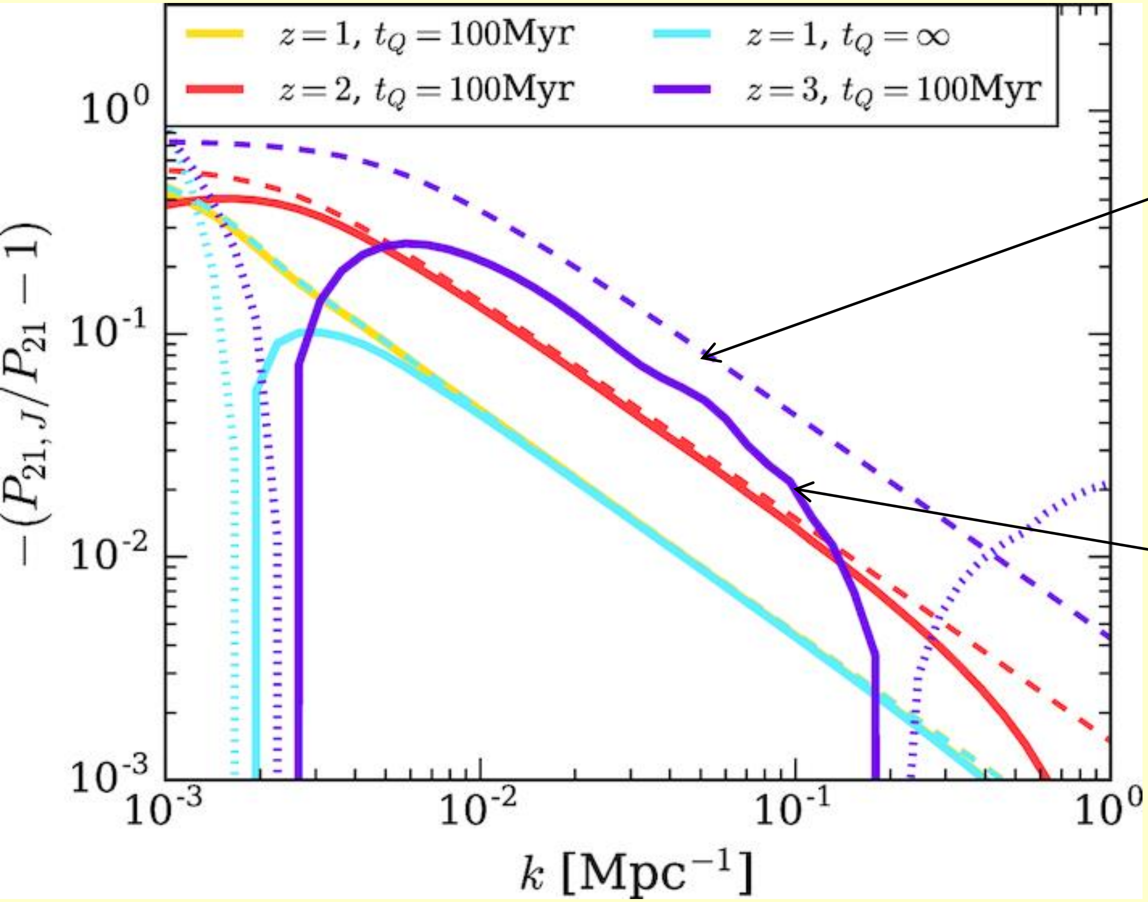
Fluctuations in HI opacity



Time-dependent shot noise contribution diminishes with QSO lifetime on large scales $\longrightarrow$ constrains QSO lifetimes.

(AM & McQuinn 2019)

II. 21cm intensity mapping



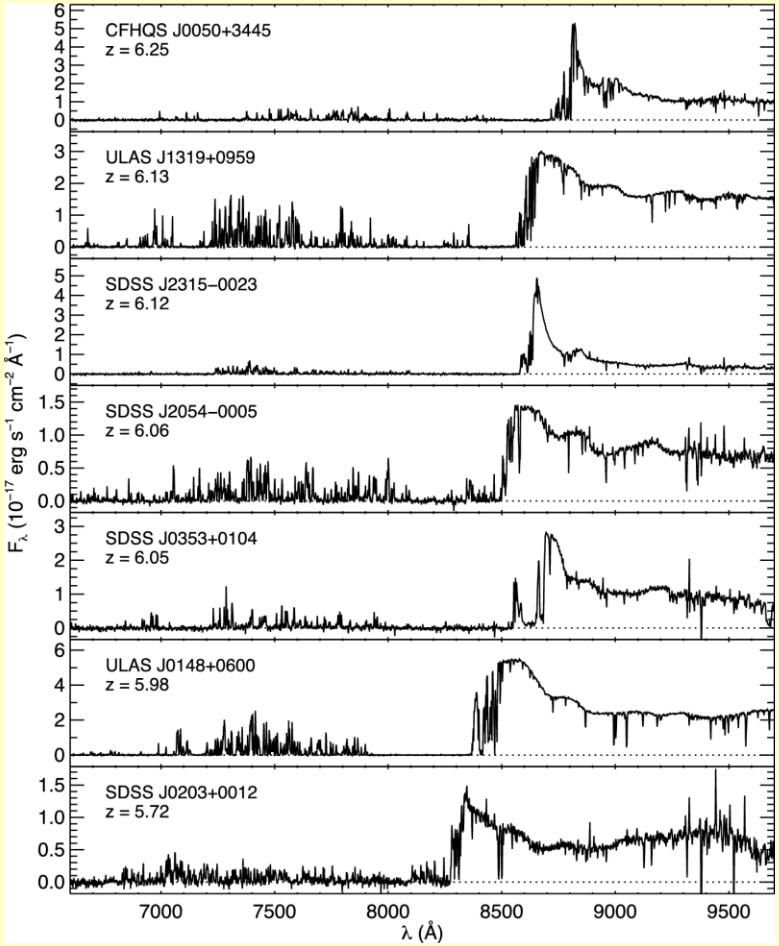
An enhancement in the UV background reduces the HI around galaxies, suppressing 21cm emission power.

Allowing for the source shot noise contribution to the UVBG fluctuations reduces the suppression at intermediate k.

(Upton Sanderbeck, Iršič, McQuinn, AM 2019)

III. Lya forest high optical depths

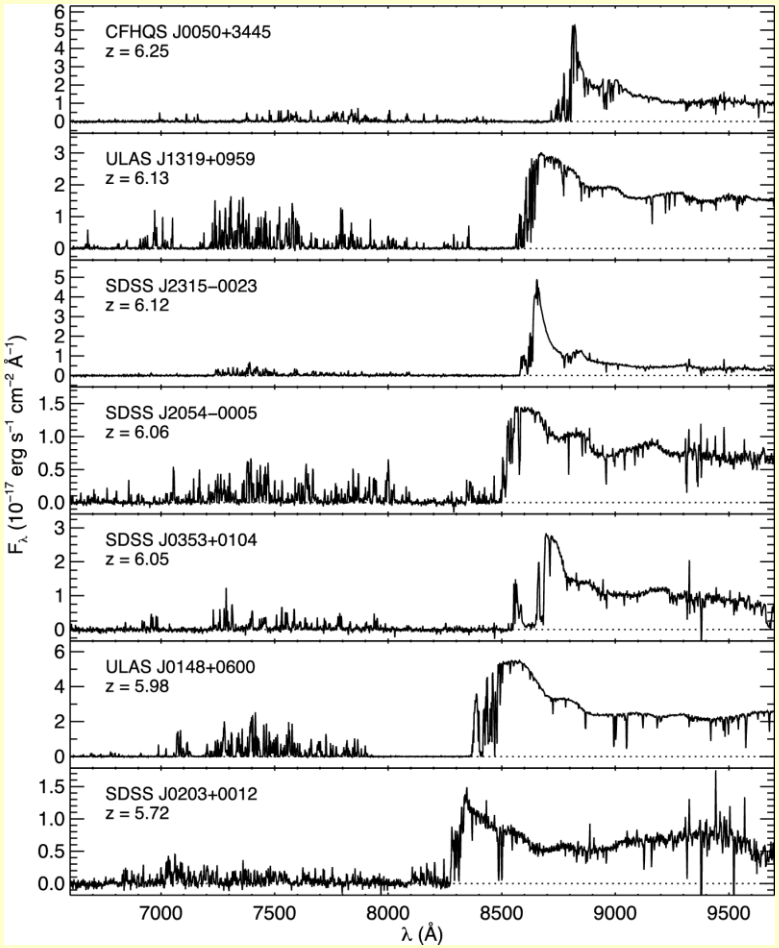
Why are there large line of sight variations at high z?



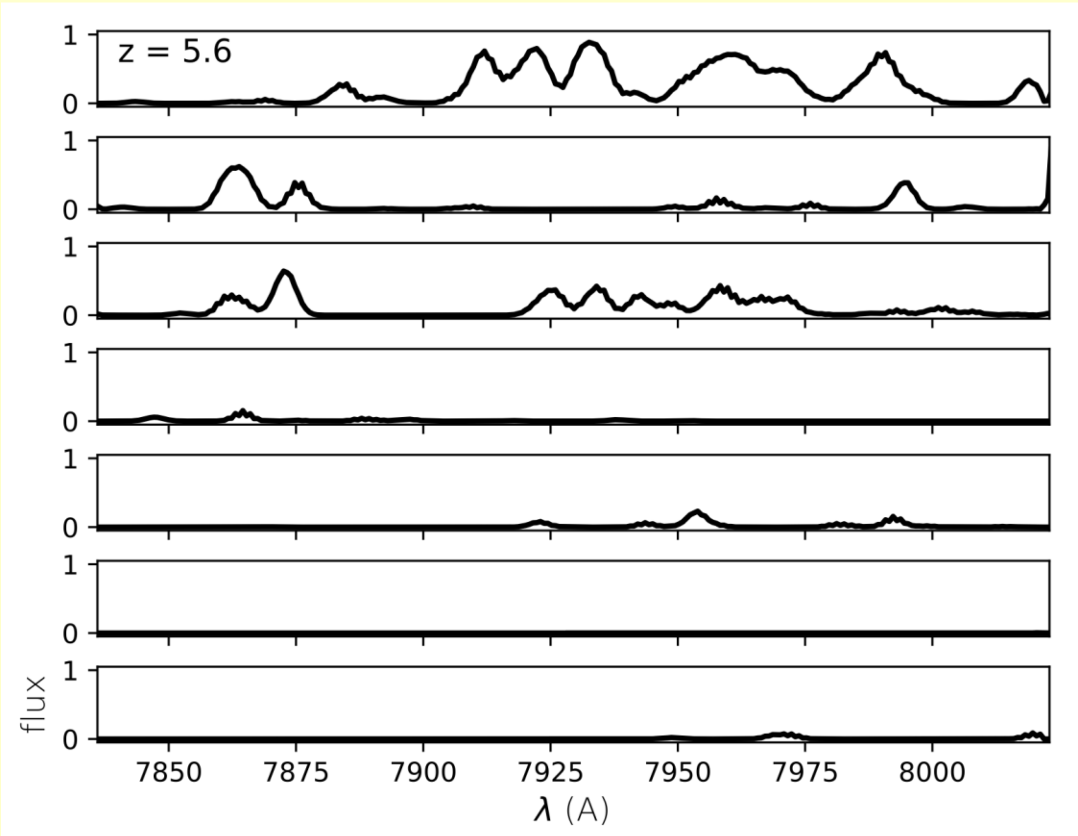
Becker et al. (2015)

III. Lya forest high optical depths

Why are there large line of sight variations at high z?



Becker et al. (2015)

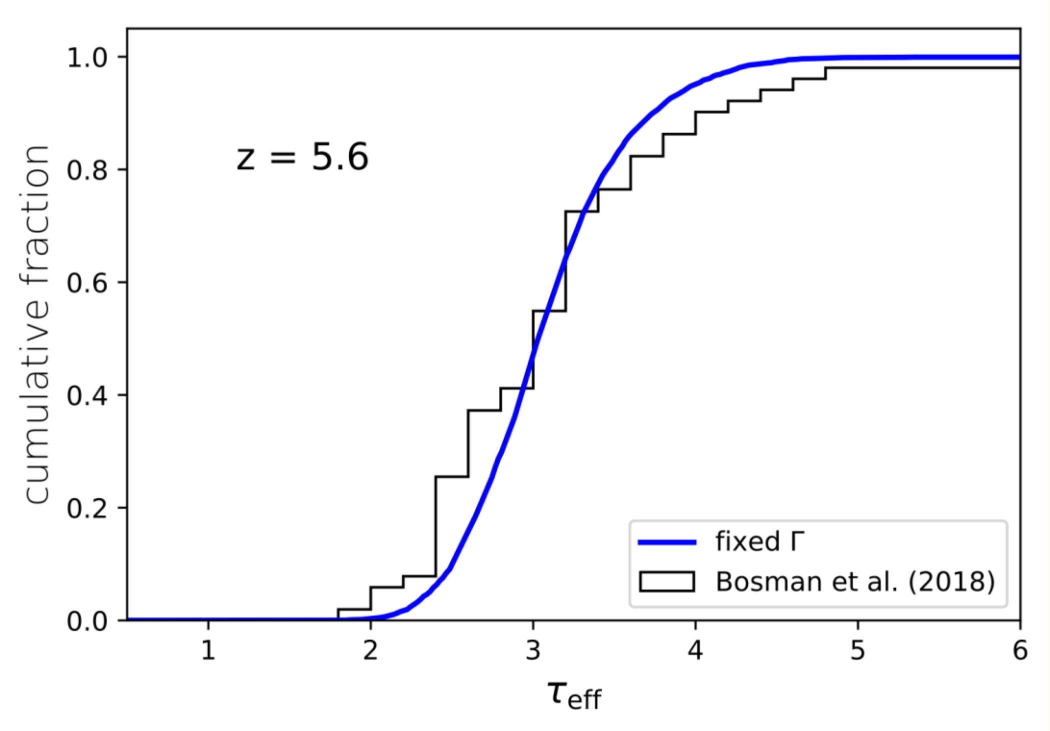


⟵ 50 h^{-1} cMpc ⟶

Include shot noise ξ_J

Lyα forest optical depth distribution

$$\langle e^{-\tau_\alpha} \rangle_{\Delta x} = e^{-\tau_{\rm eff}}; \quad \Delta x = 50h^{-1}{\rm cMpc}$$

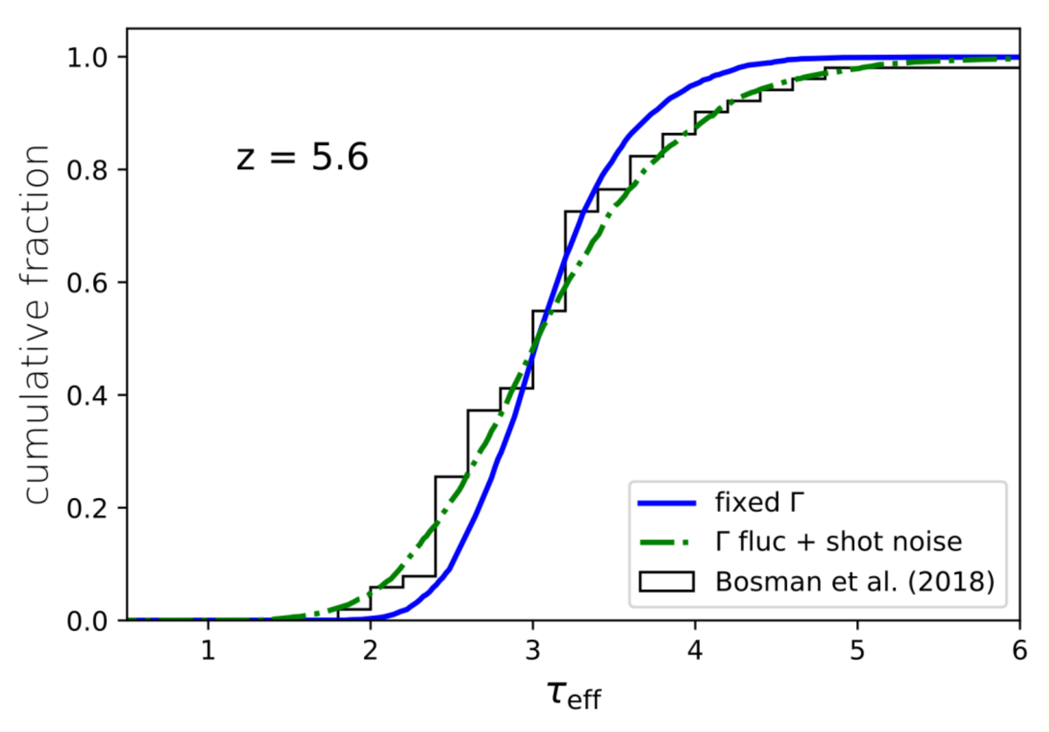


Assume uniform UV background

(AM 2019)

Lyα forest optical depth distribution

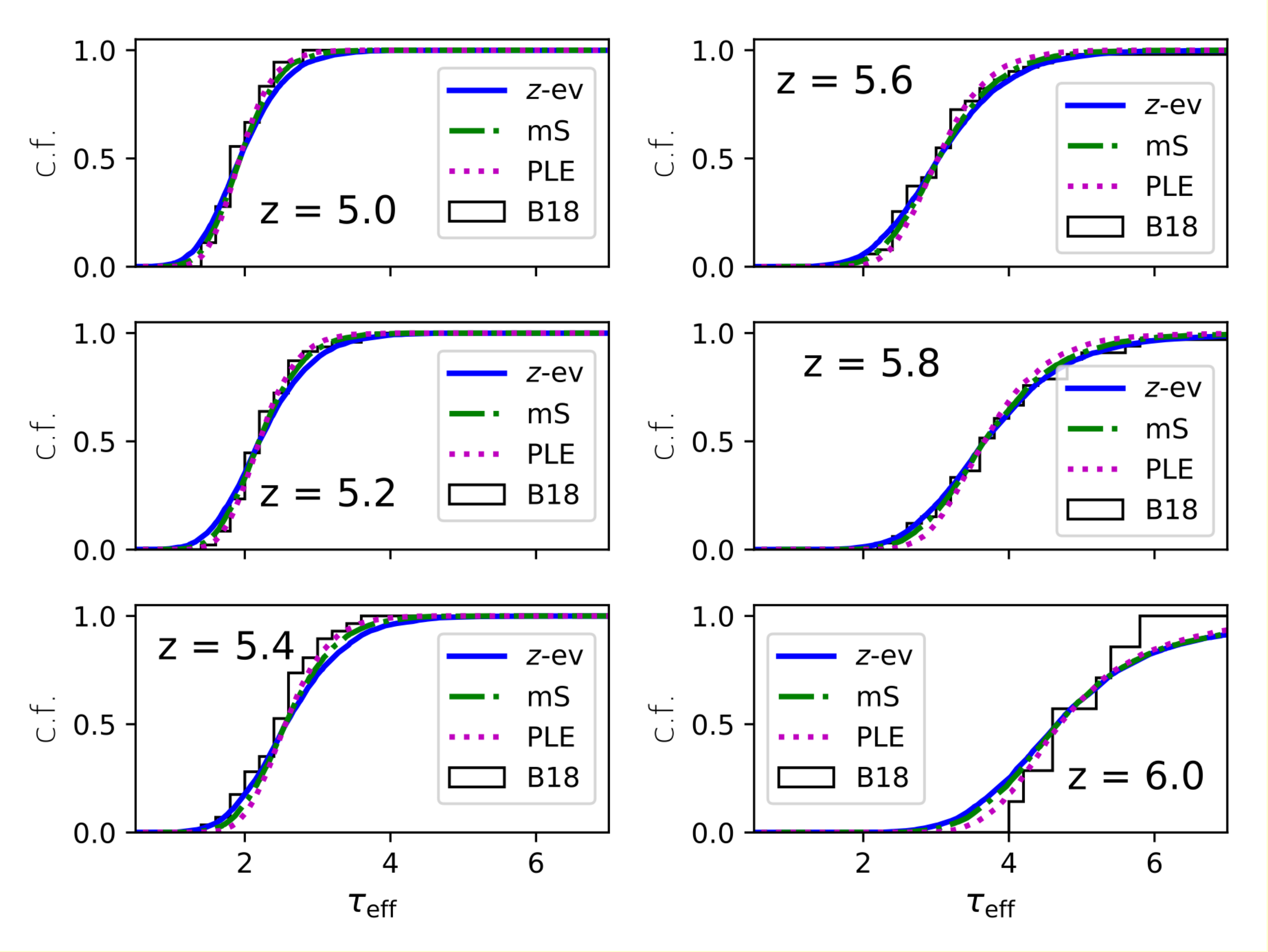
$$\langle e^{-\tau_\alpha}\rangle_{\Delta x} = e^{-\tau_{\rm eff}}; \quad \Delta x = 50h^{-1}{\rm cMpc}$$



Include fluctuations in UV background

(AM 2019)

Lyα forest optical depth distribution



(AM 2019)

Conclusions

- Power spectra of large-scale gaseous cosmological structures are sensitive to large-scale fluctuations in the UV background: these must be accounted for to use the power spectra as effective cosmological probes
- Modifications to the HI distribution by UV background fluctuations may be used to constrain QSO properties: their maximum lifetimes and luminosities
- Modifications to the power spectra depend on the bias factor connecting the objects (HI in absorption or emission, or even galaxies), and the UV background