Lyman-α Forest Cosmology

Lecture 3: Beyond BAO and future

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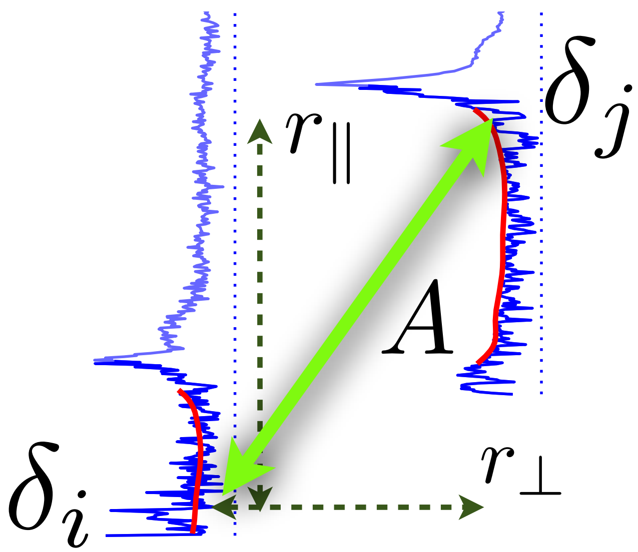
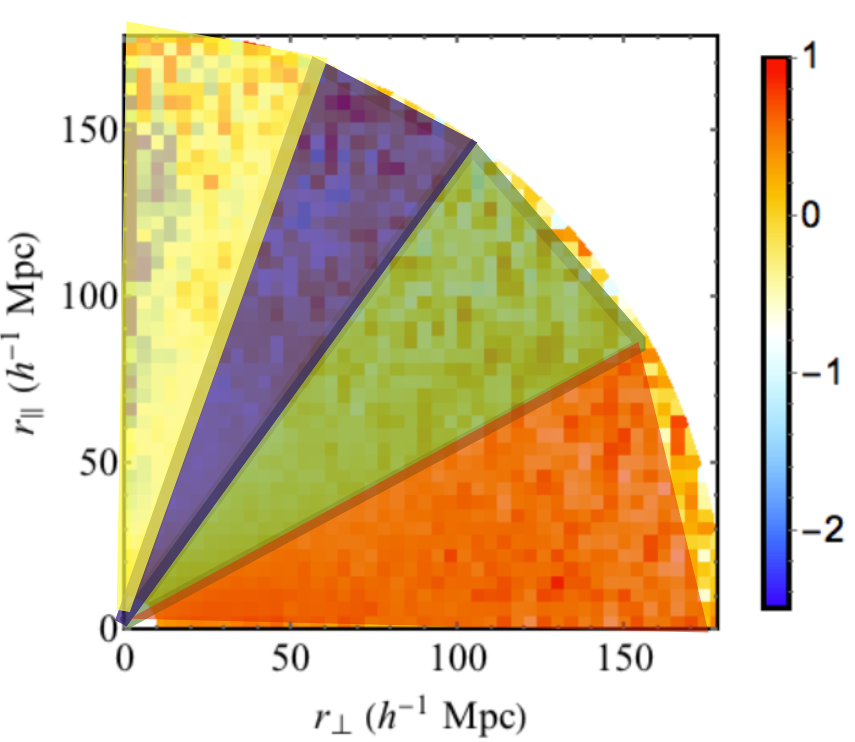
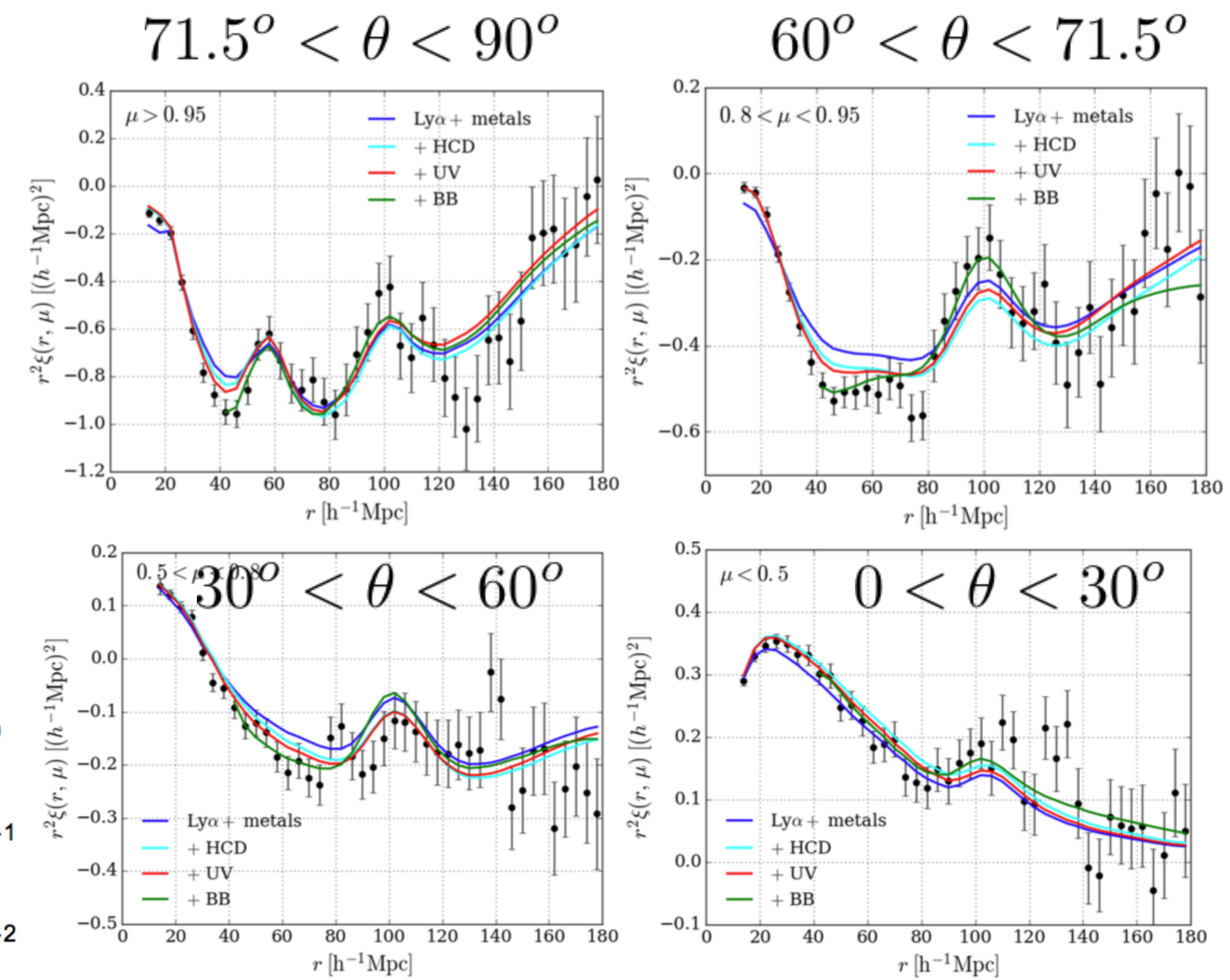
Contents

- End of lecture 2: systematics on BAO
- Cross-correlations: quasars, DLAs
- Neutrino masses
- Future of Lyman-alpha

Correlation function







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List of tests on systematic errors

Astrophysical systematics

- contamination by **metals**: Si, C
- contamination by **DLAs**, or BALs
- contamination by galactic absorption
- effect of UV background fluctuations
- effect of continuum fitting

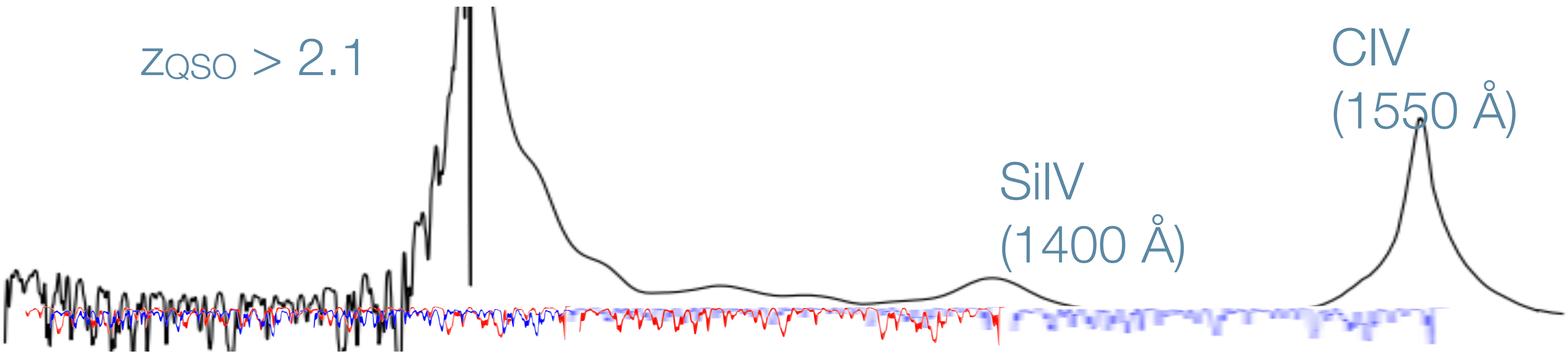
Instrumental systematics

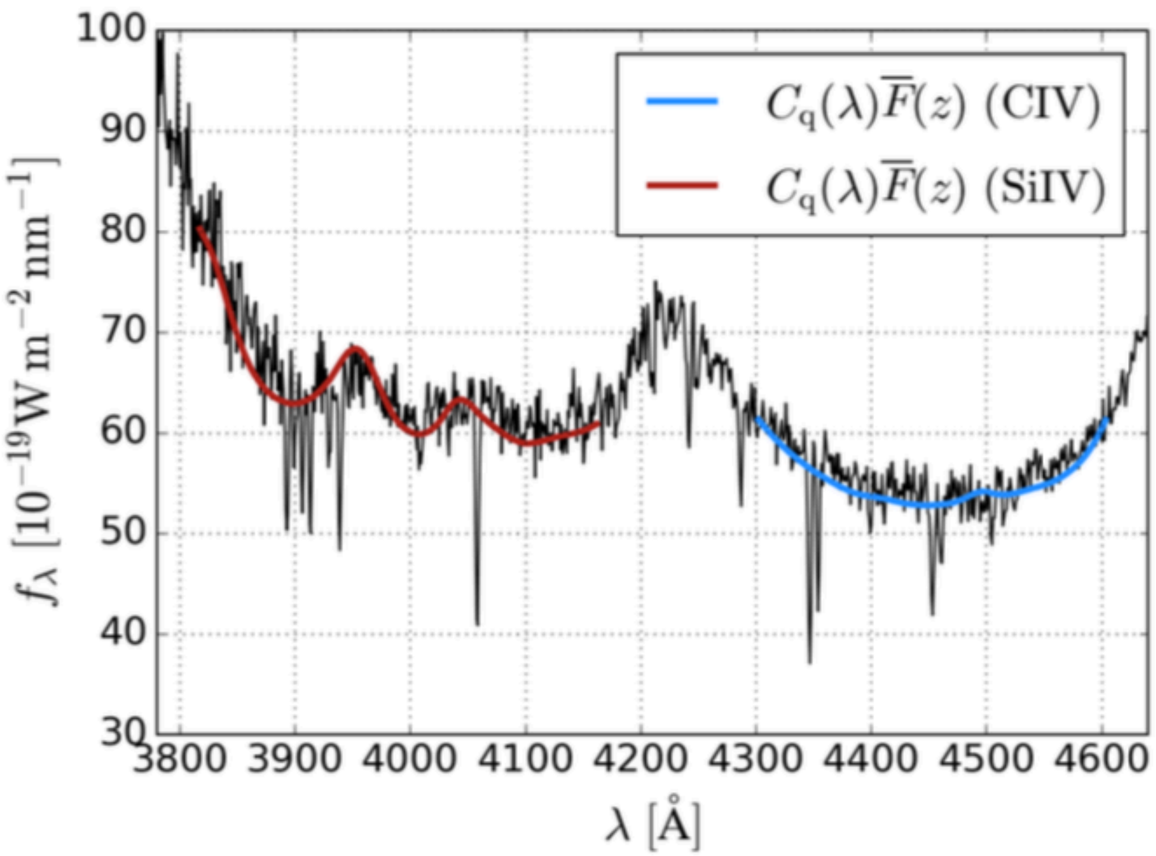
- impact of flux calibration
- impact of sky residuals
- impact of fiber cross-talk
- impact of extraction

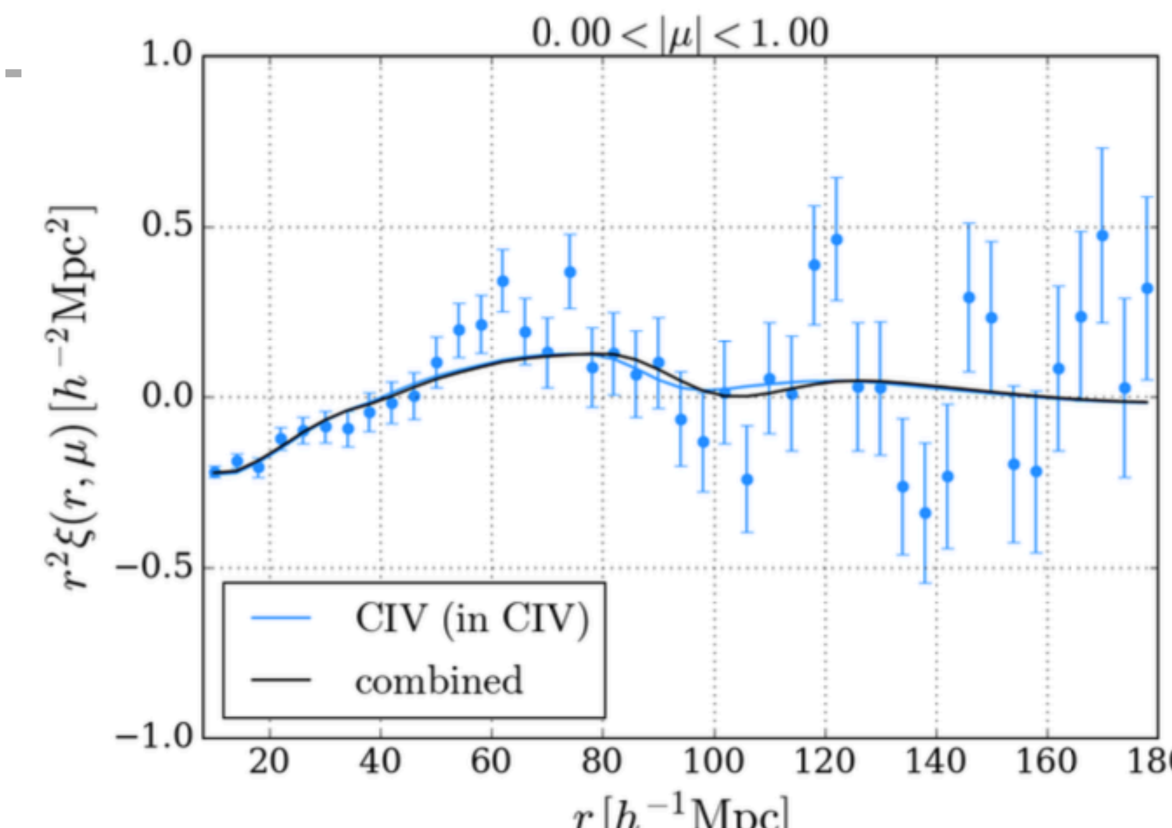
All tests were performed on data and mock catalogs

Metals

Forest of Metals : CIV, SIV, MgII, etc



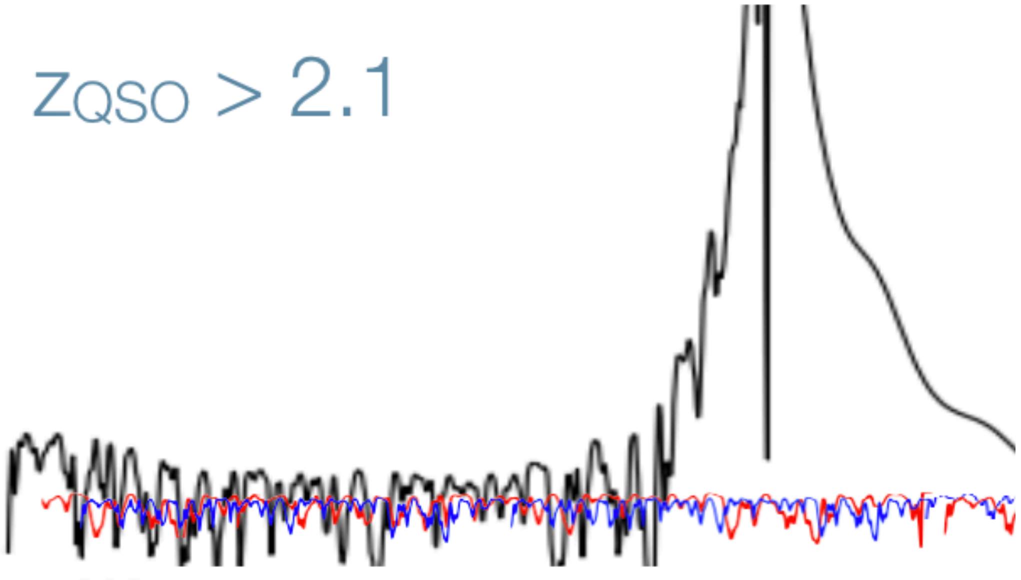




$$b_{\mathrm{CIV}}(z_{\mathrm{eff}} = 2.00) = -0.0144 \pm 0.0010$$

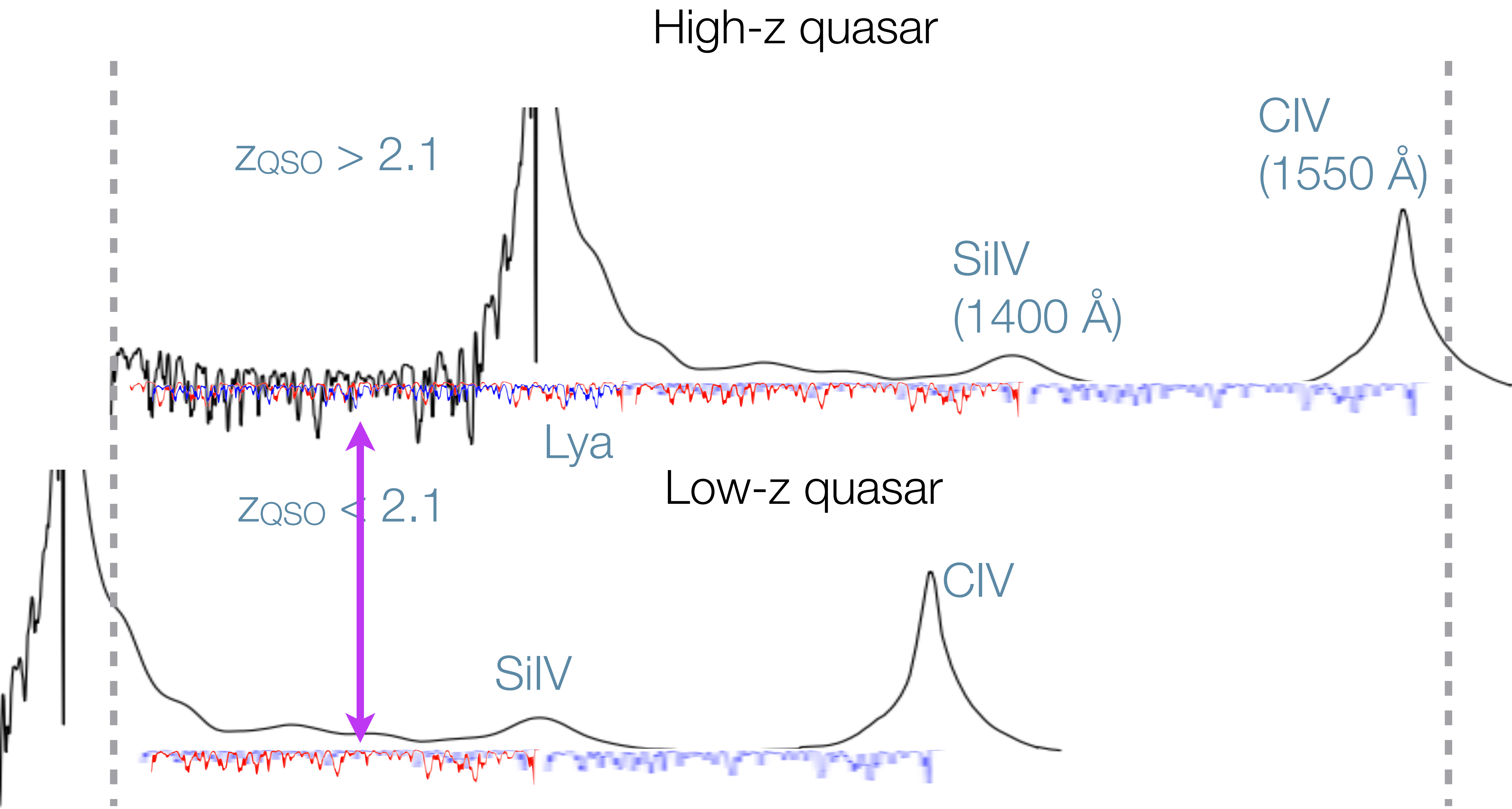
$$b_F = -0.131 \pm 0.017$$

Blomqvist et al. 2018

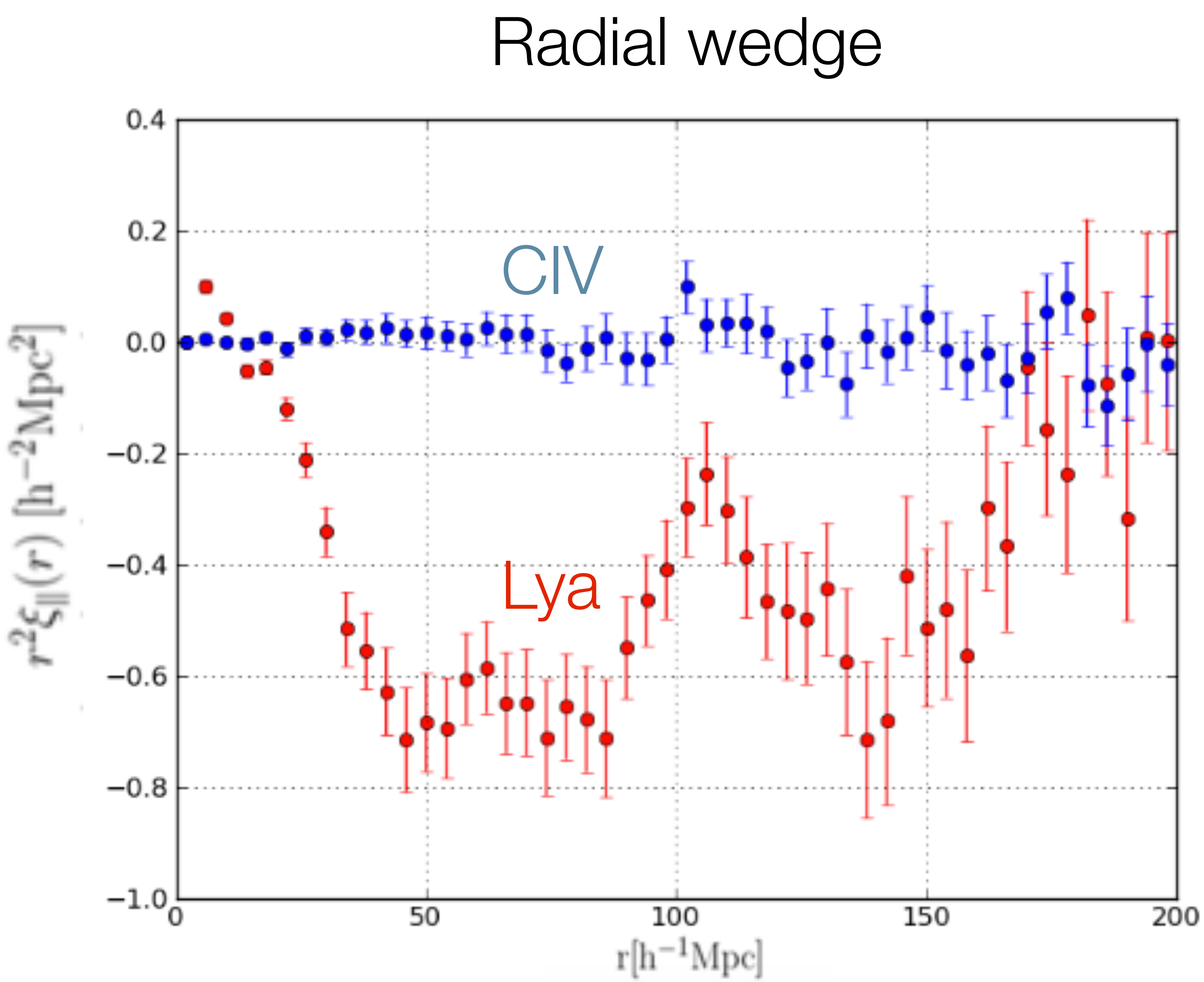


How about **metals overlapping** with the Lyman-alpha forest?

Metals in the Lyman-alpha forest



Metals in the Lyman-alpha forest



Impact of CIV in the Lyman-alpha forest clustering is negligible
(at this statistical level)

That’s not all with metals…

Metals in the Lyman-alpha forest

Separation at
z = 2.34

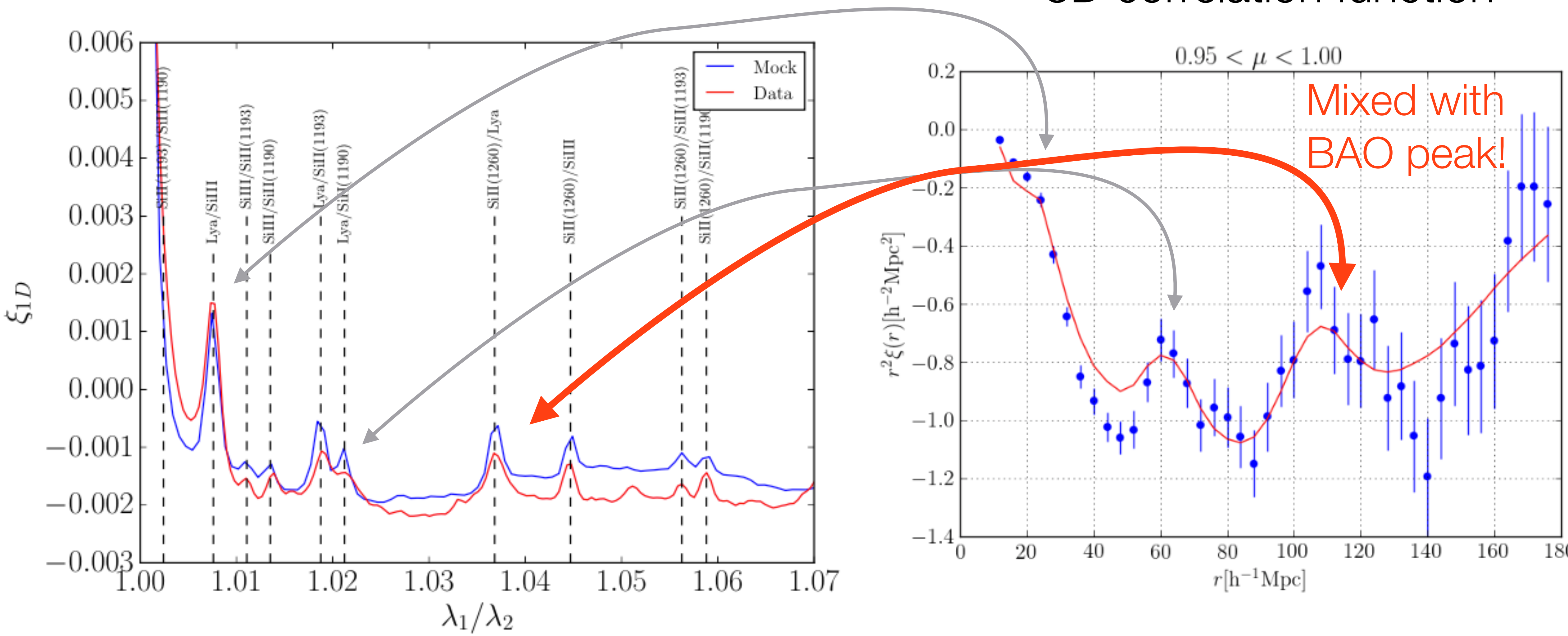
Transitions	λ_1/λ_2	$r_{\parallel}^{\mathrm{ap}}[h^{-1}\mathrm{Mpc}]$
Si II(1193)/Si II(1190)	1.002	7
Lyα(1216)/Si III(1207)	1.008	21
Si III(1207)/Si II(1193)	1.011	31
Si III(1207)/Si II(1190)	1.014	38
Lyα(1216)/Si II(1193)	1.019	52
Lyα(1216)/Si II(1190)	1.021	59
Si II(1260)/Lyα(1216)	1.037	105
Si II(1260)/Si III(1207)	1.045	126
Si II(1260)/Si II(1193)	1.056	157
Si II(1260)/Si II(1190)	1.059	164

Over
BAO p

Metals in the Lyman-alpha forest

1D correlation function

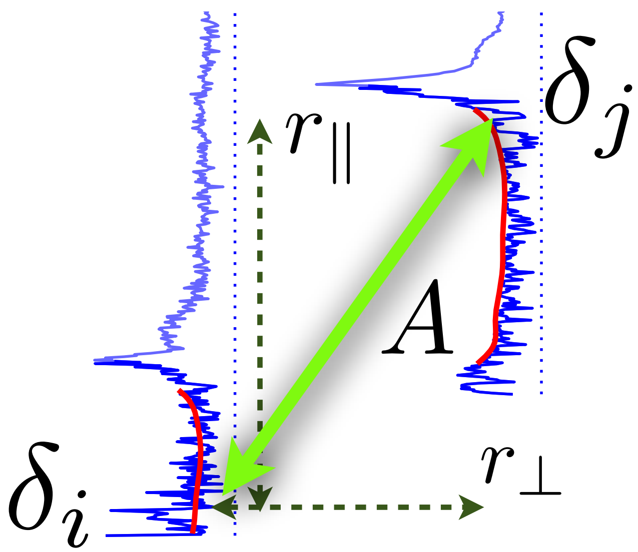
Radial wedge of
3D correlation function

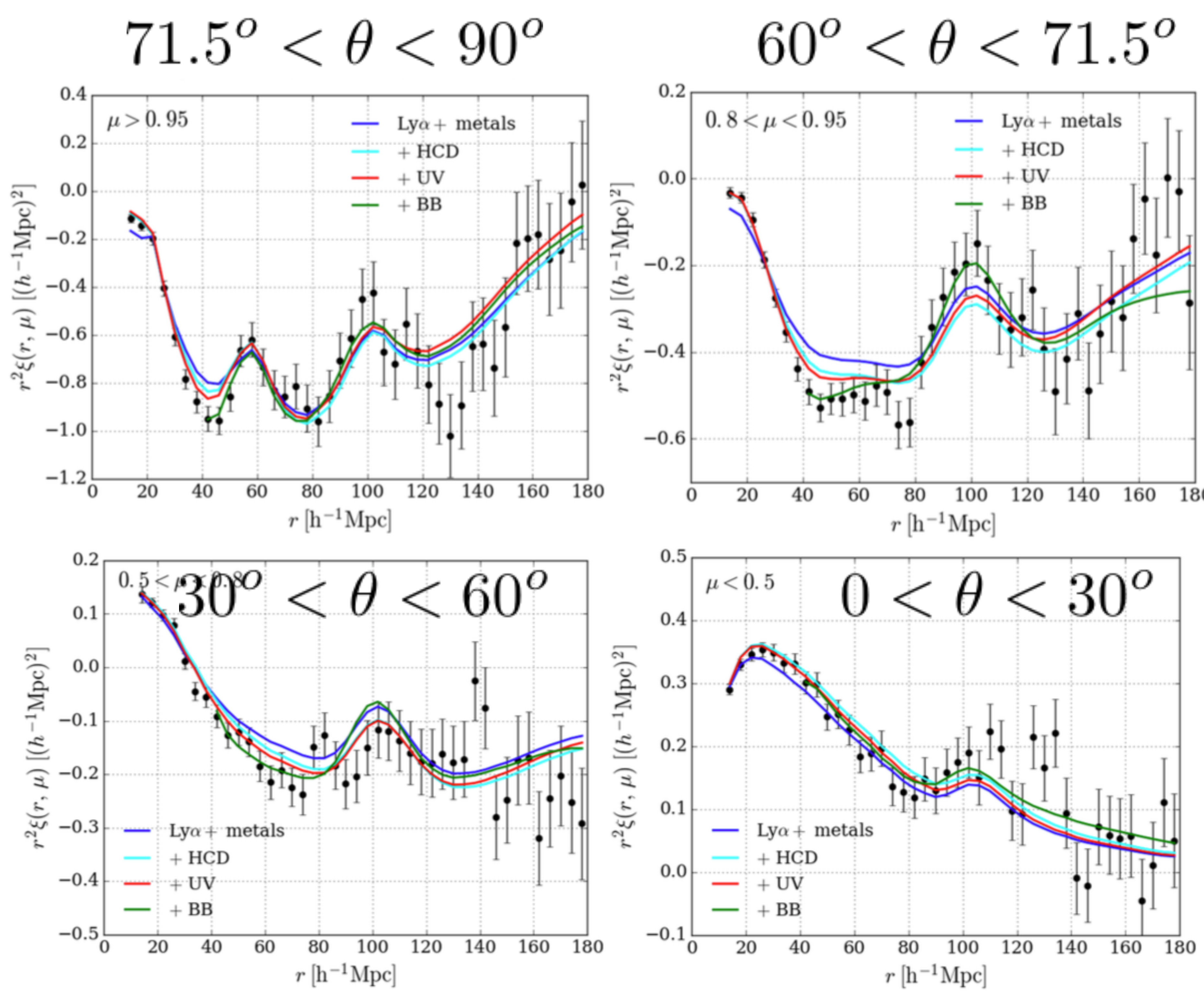


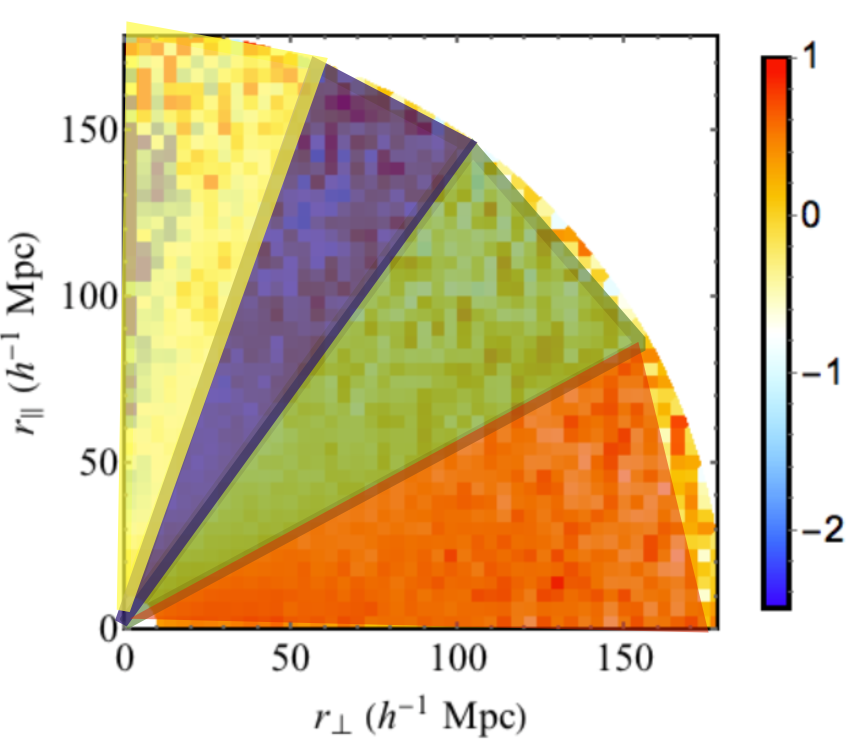
We marginalize over metal correlations (2 parameters per transition)

Impact on BAO: more robust + increase of errors by 25%

Lyman-alpha Auto-Correlation function







Bautista et al. 2017

Damped Lyman-Alpha systems (DLAs)

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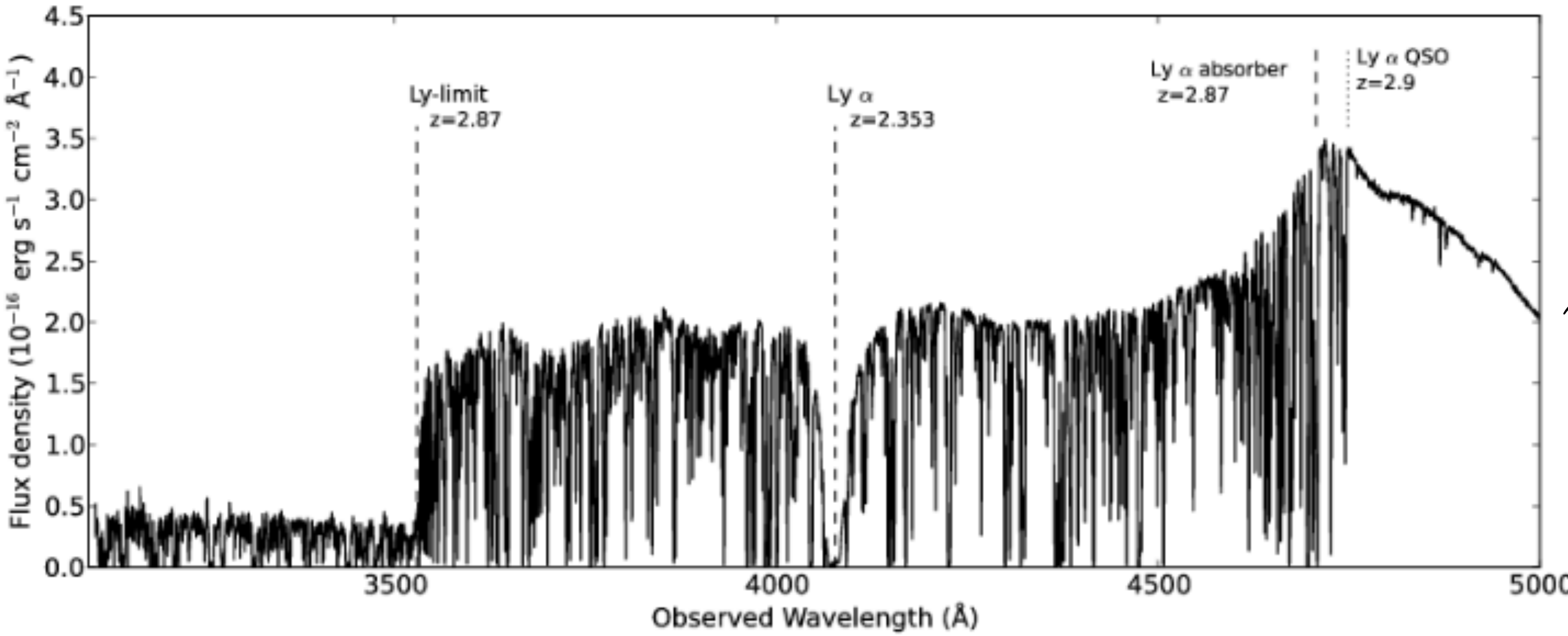
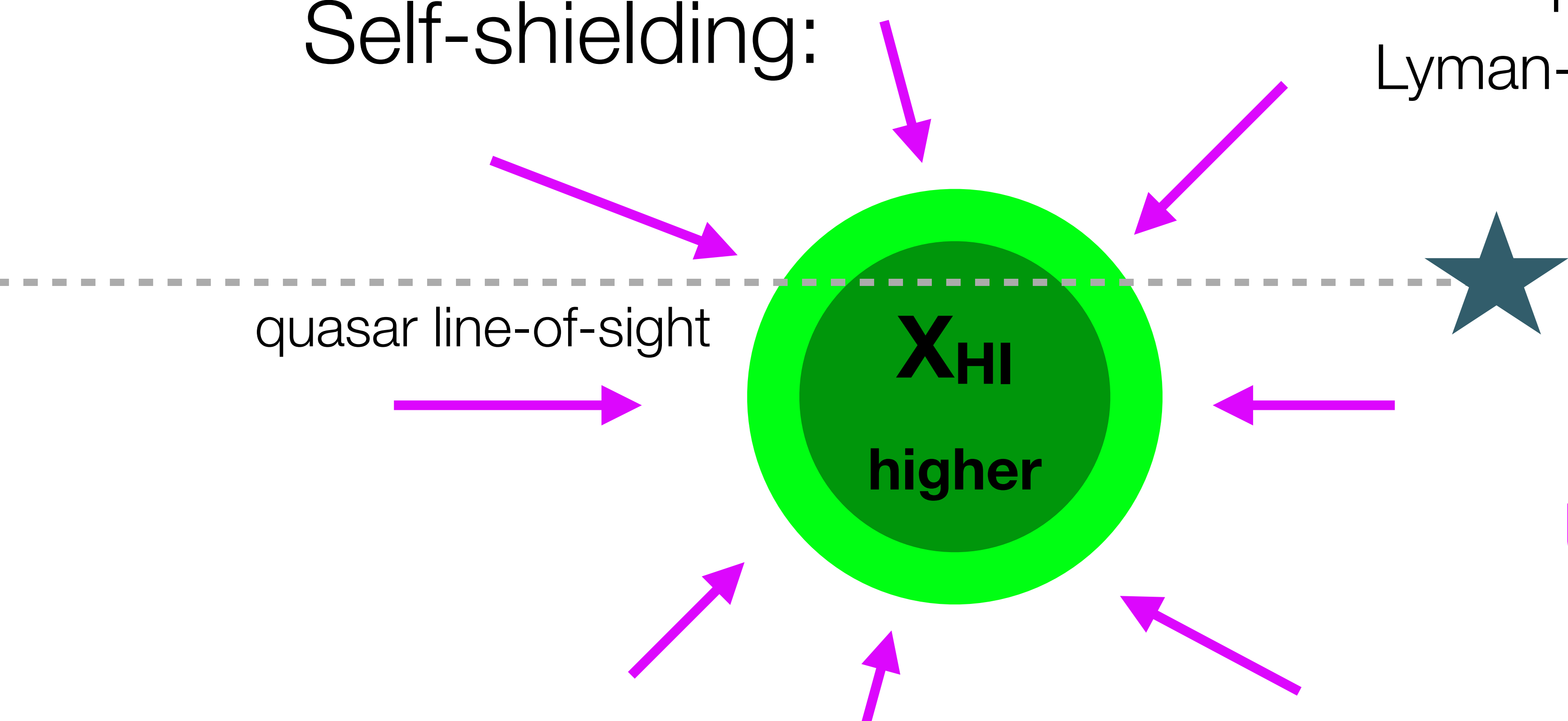


$$\tau(z) = \Sigma(z) N_{\mathrm{HI}}(z)$$

Column density [cm^{-2}]

Most of forest: $N_{HI} \sim 10^{\mathbf{13\text{-}16}}$ cm^{-2}
Lyman-limit systems: $N_{HI} \sim 10^{1\mathbf{6\text{-}20}}$ cm^{-2}
DLAs: $N_{HI} \sim 10^{\mathbf{20\text{-}23}}$ cm^{-2}

Self-shielding:



Damped Lyman-alpha Systems (DLAs)

Look at simulations:

$$\frac{P_{\text{Contaminated}}(k) - P_{\text{forest}}(k)}{P_{\text{forest}}(k)}$$

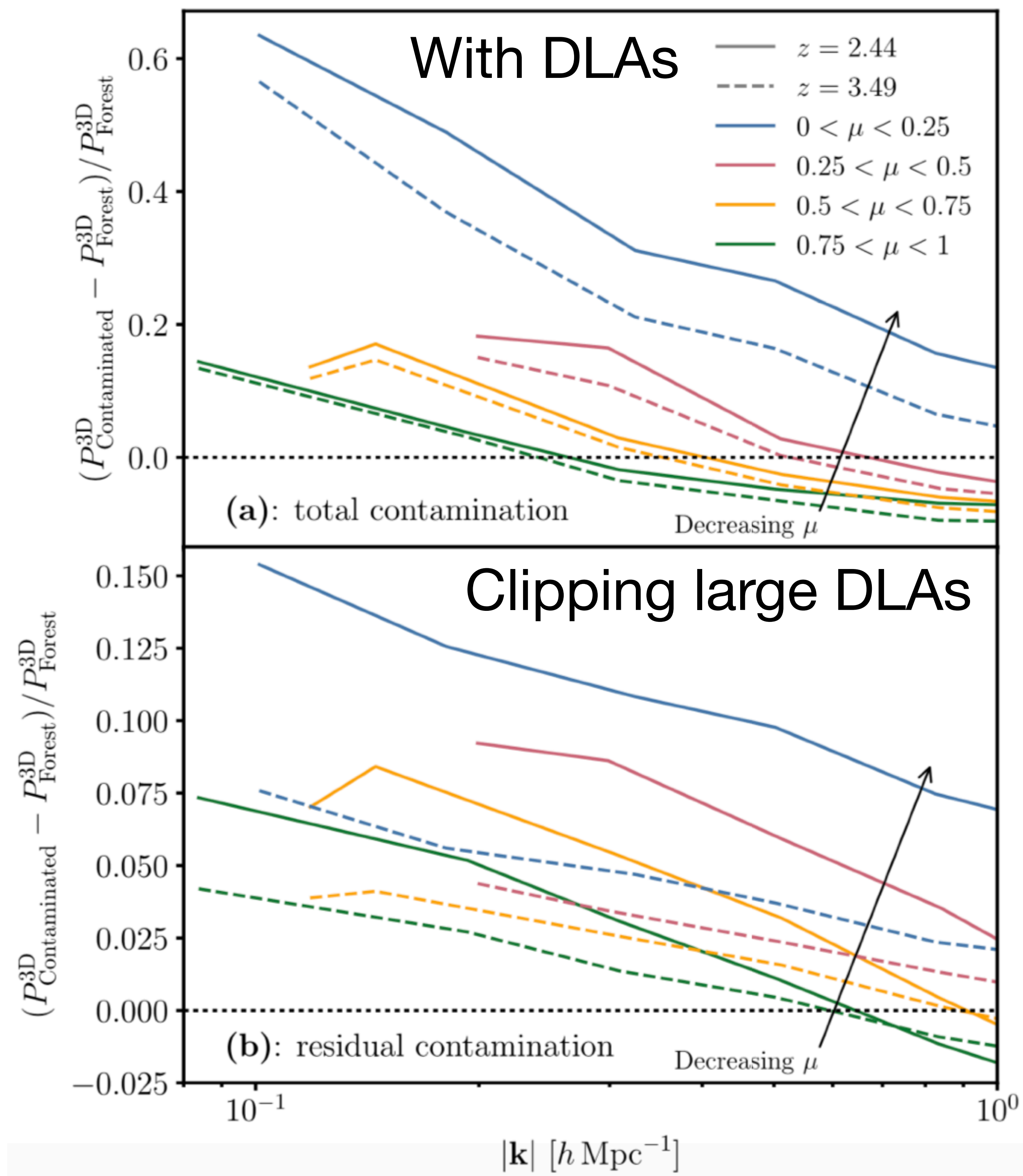
Up to 15% increase after clipping large DLAs

We model it as:

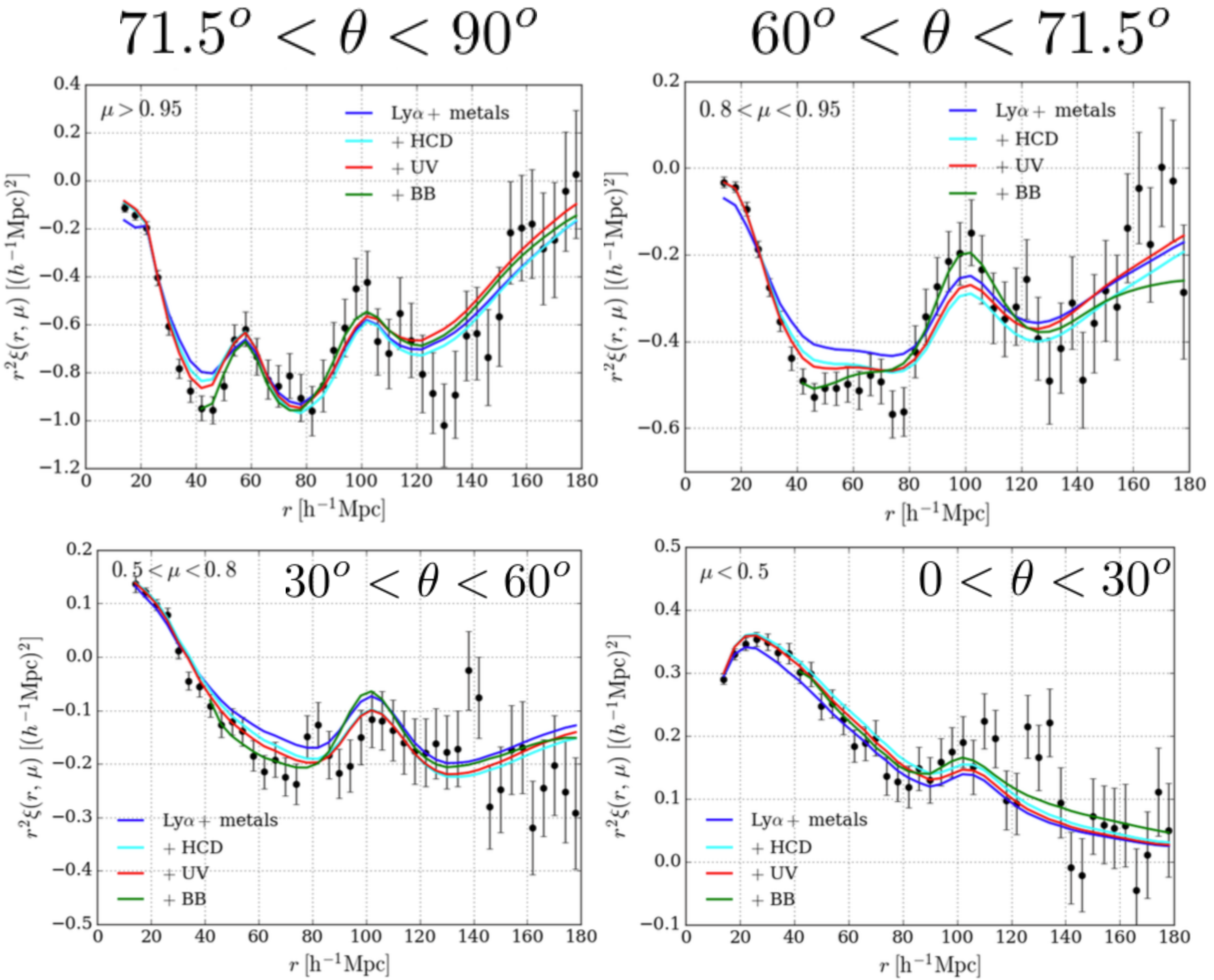
$$b'_{\mathrm{Ly}\alpha} = b_{\mathrm{Ly}\alpha} + b_{\mathrm{HCD}} F_{\mathrm{HCD}}(k_{\|})$$

$$b'_{\mathrm{Ly}\alpha}\beta'_{\mathrm{Ly}\alpha} = b_{\mathrm{Ly}\alpha}\beta_{\mathrm{Ly}\alpha} + b_{\mathrm{HCD}}\beta_{\mathrm{HCD}} F_{\mathrm{HCD}}(k_{\|})$$

where $F_{\mathrm{HCD}} = \exp(-L_{\mathrm{HCD}} k_{\|})$.



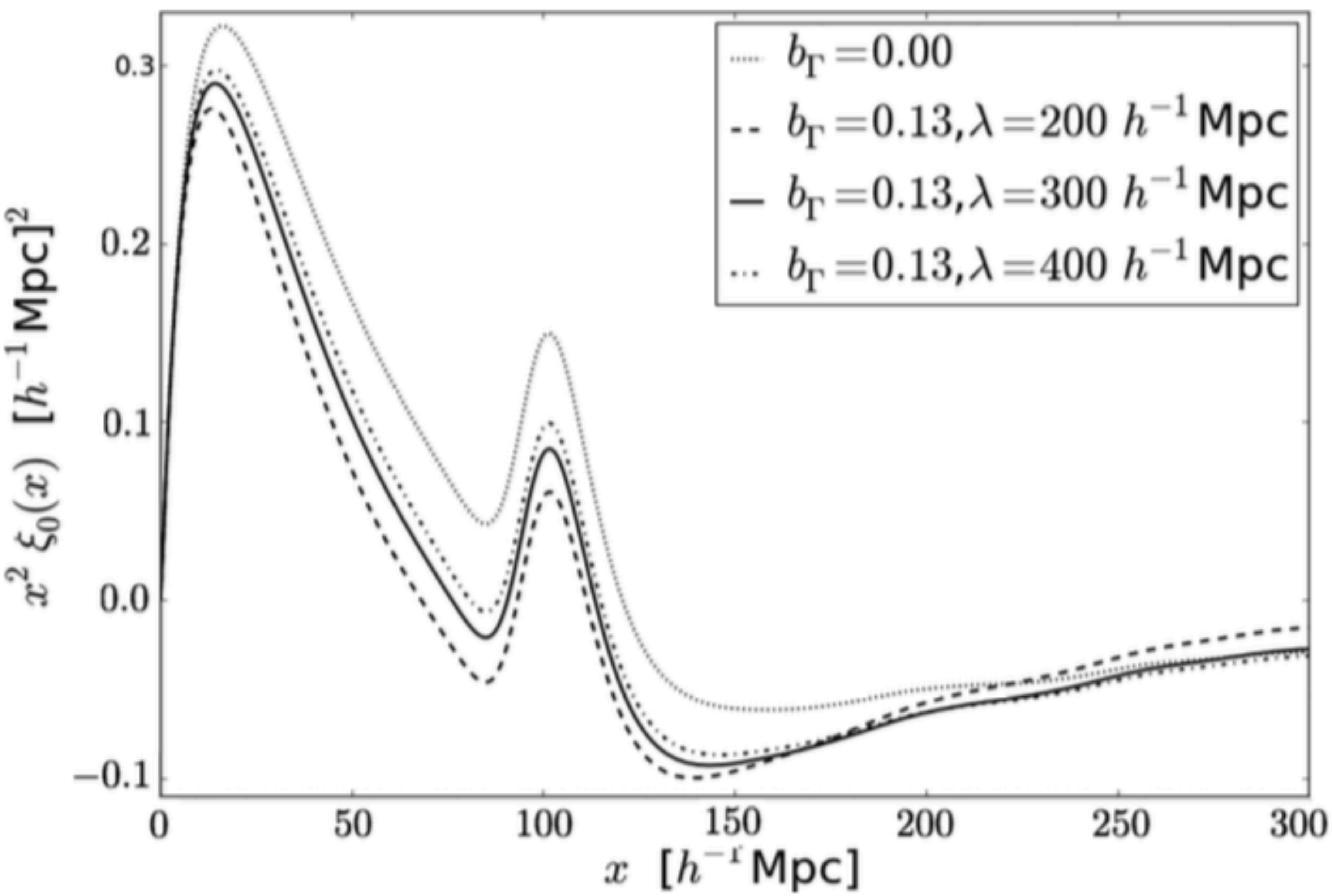
Rogers et al. 2018a



Bautista et al. 2017

UV background fluctuations

Gontcho A Gontcho et al. 2014

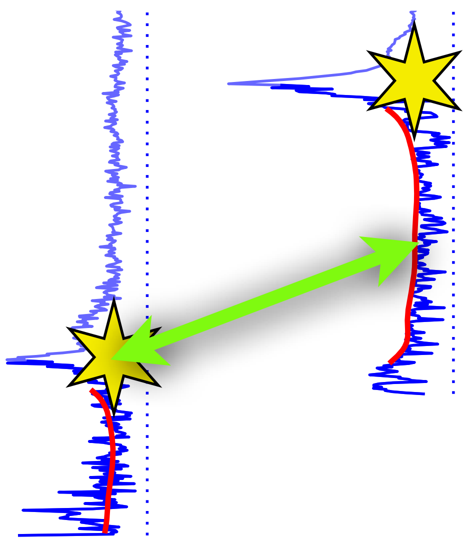


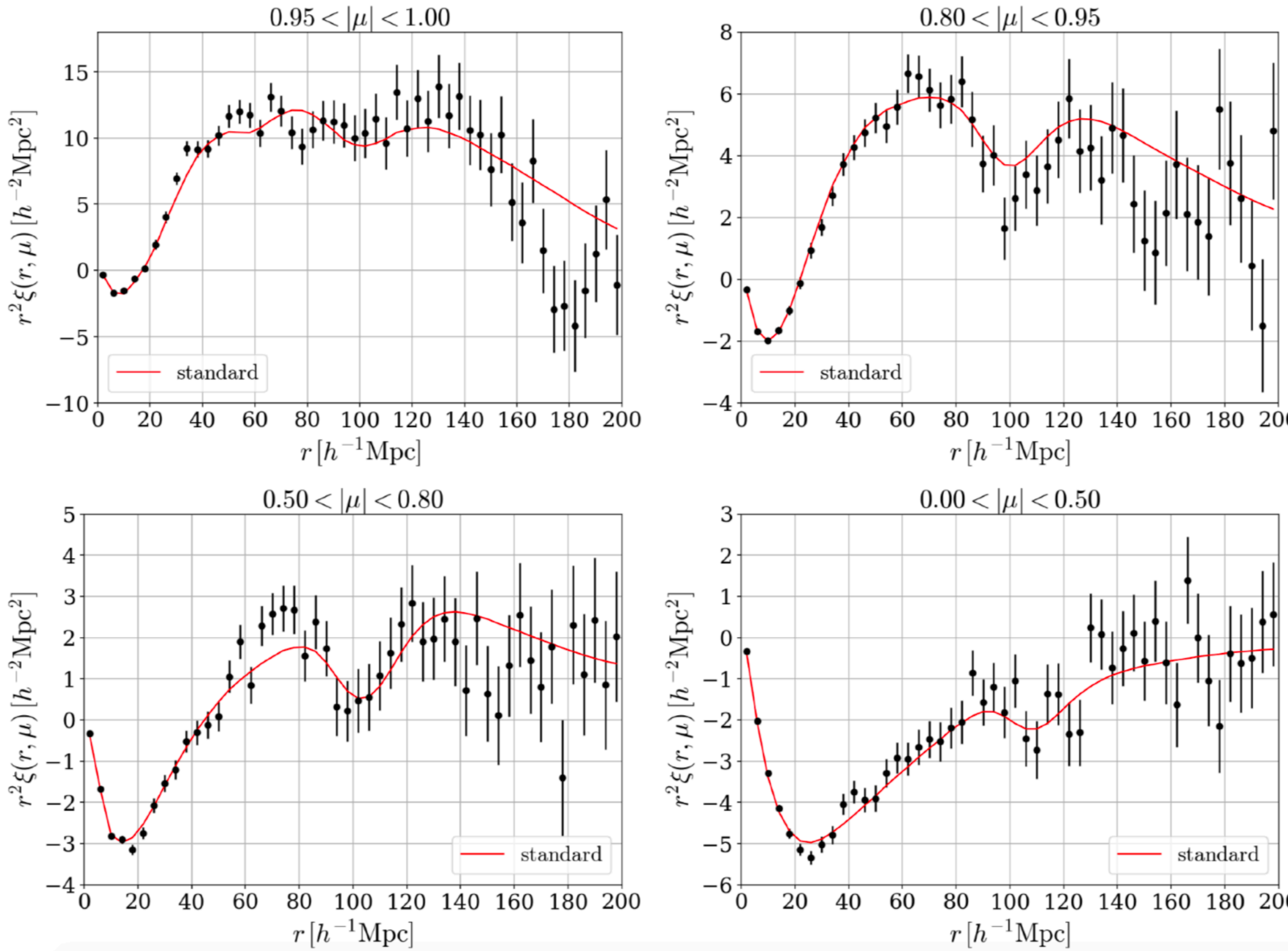
Implemented in fit: does not improve chi2

Cross-correlations

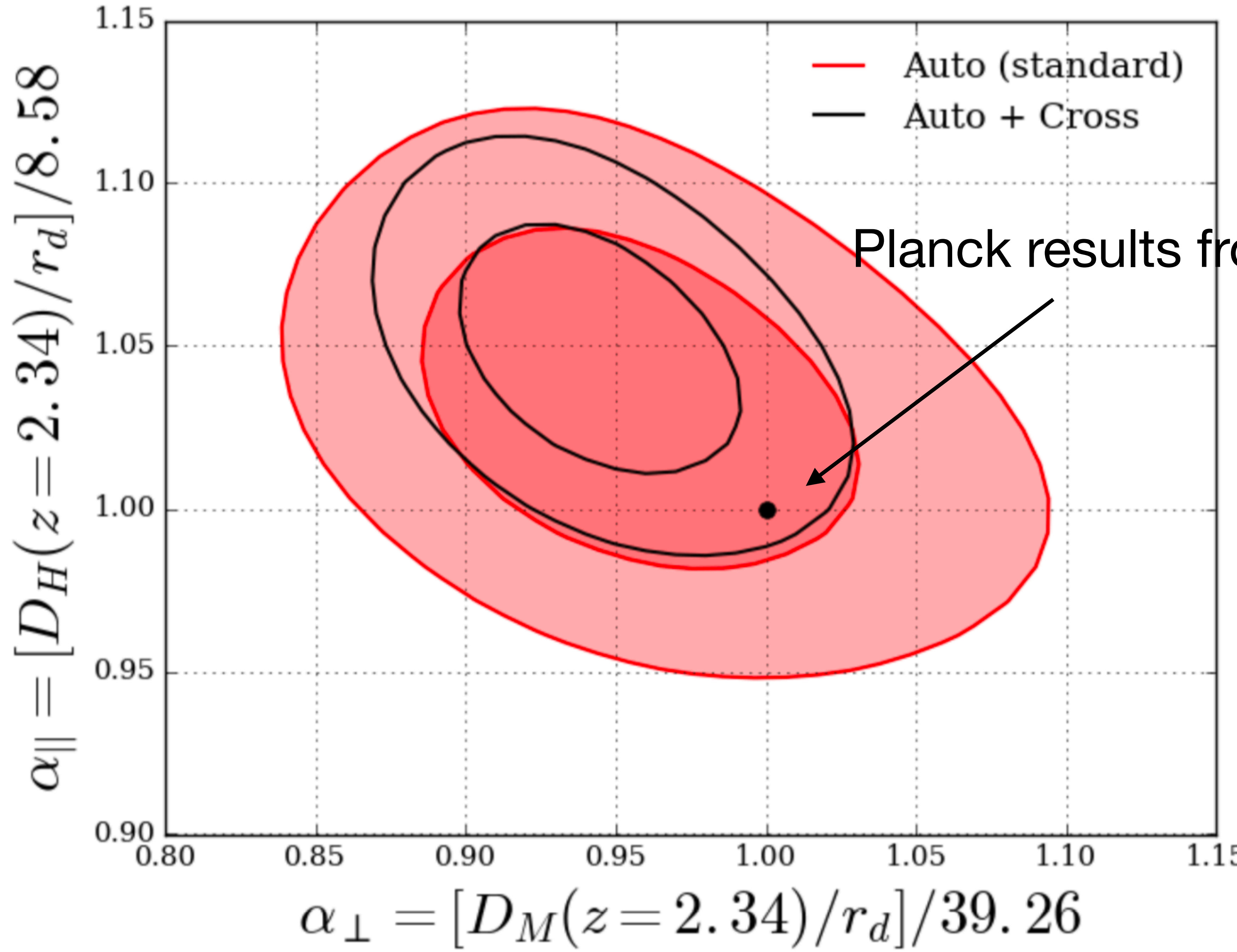
Quasar-Forest Cross-Correlation

Provides complementary BAO information with the same sample!
(Font-Ribera et al. 2013, Du-Mas-des-Bourboux et al. 2017, Blomqvist et al. 2019)



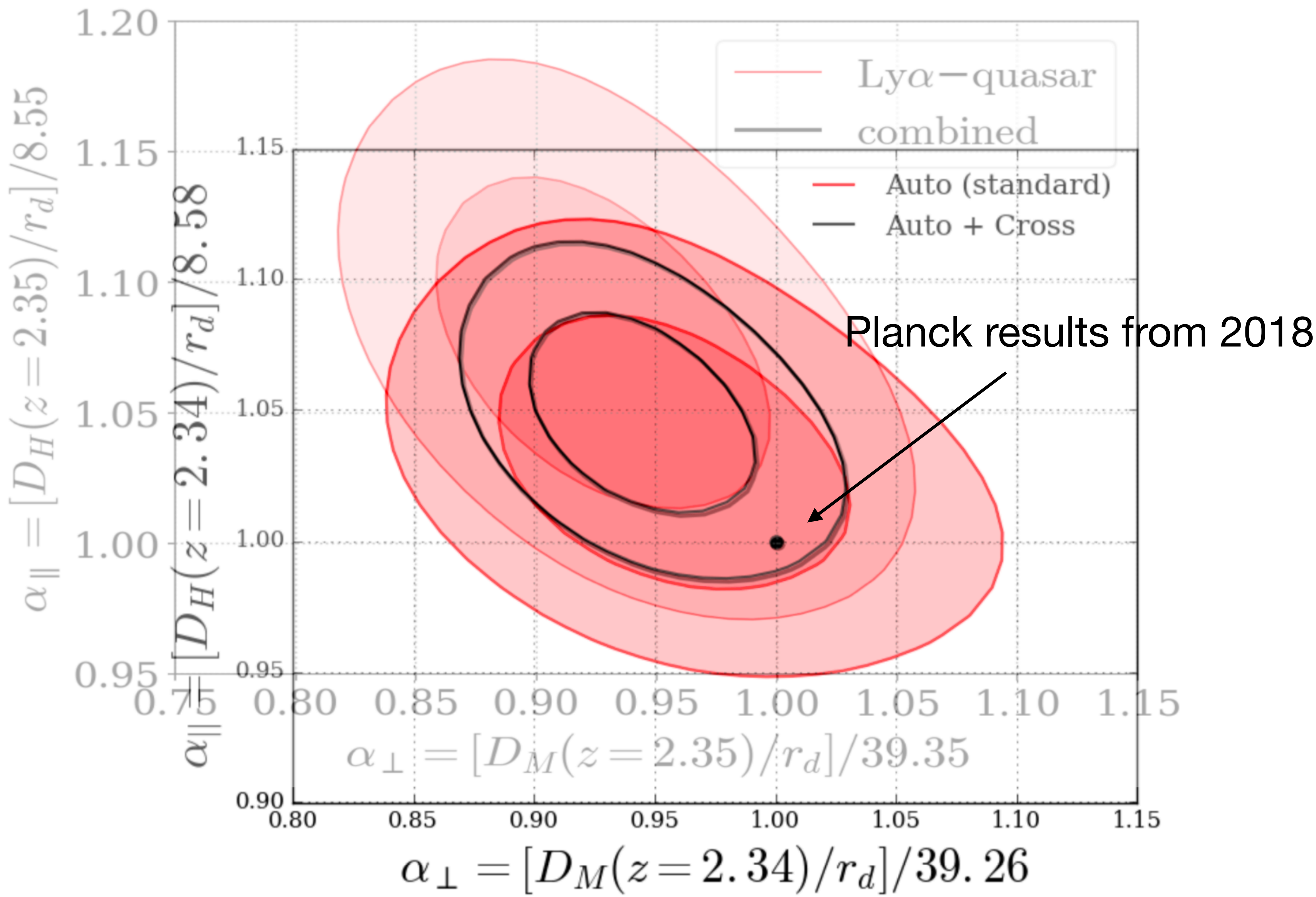


Auto-correlation BAO constraints from DR14

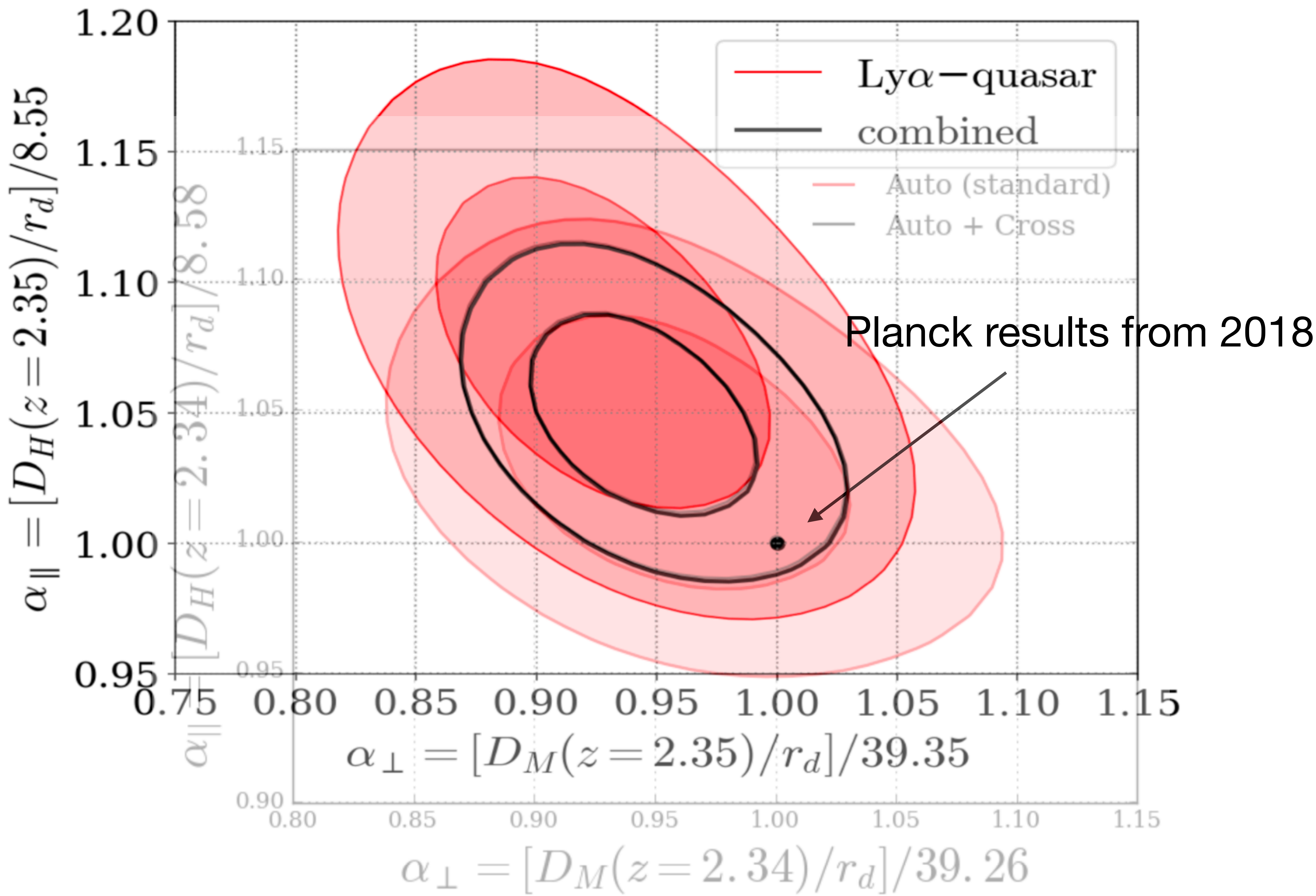


Planck results from 2018

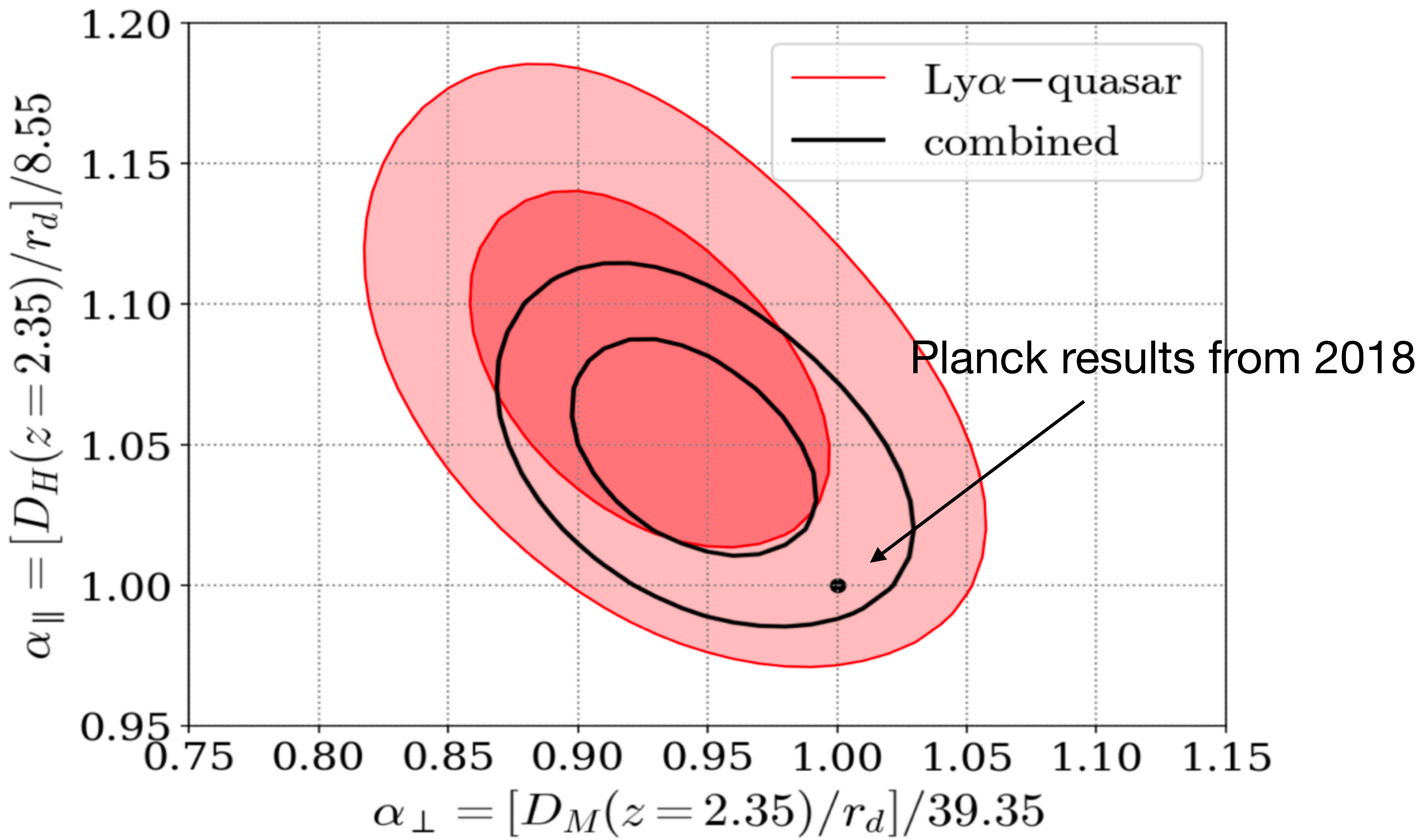
Auto-correlation BAO constraints from DR14



Quasar-Lya cross-correlation BAO constraints from DR14

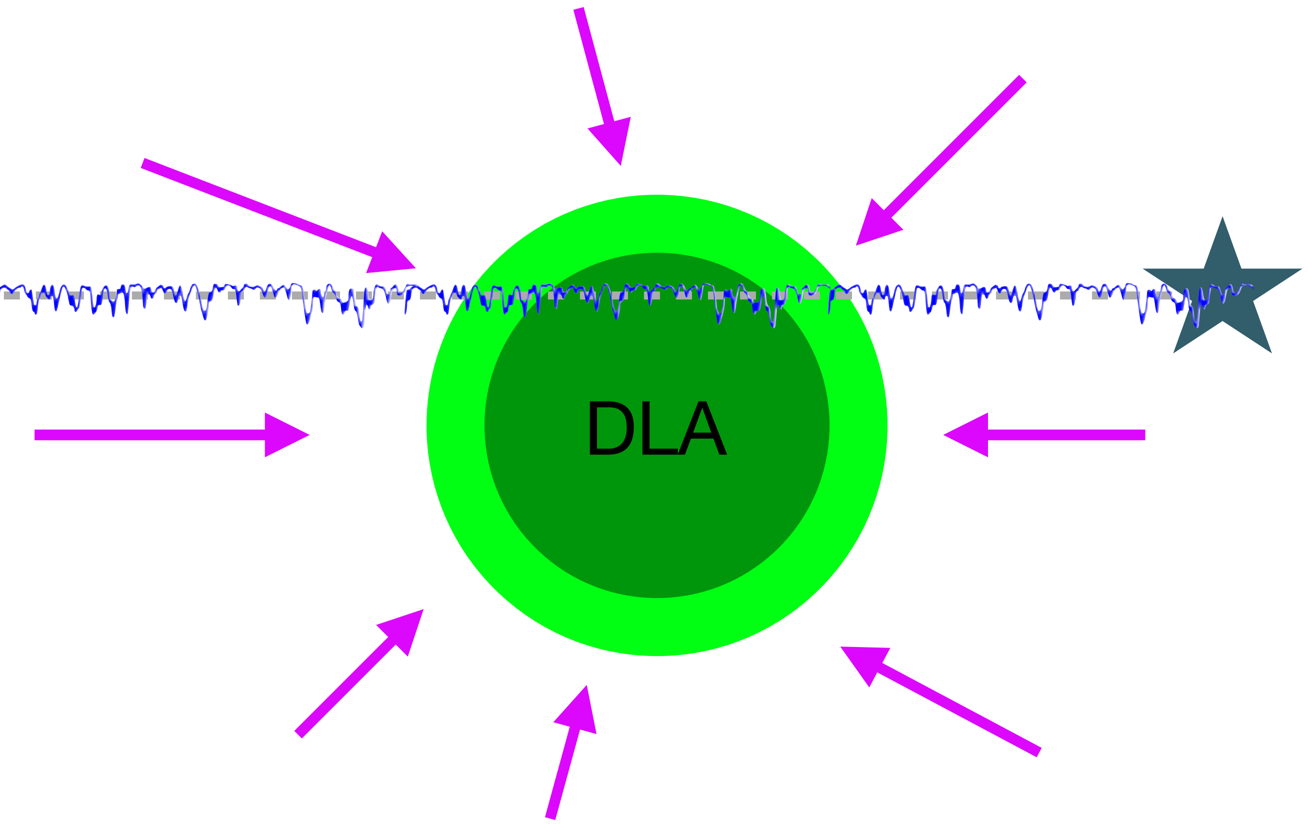


Quasar-Lya cross-correlation BAO constraints from DR14



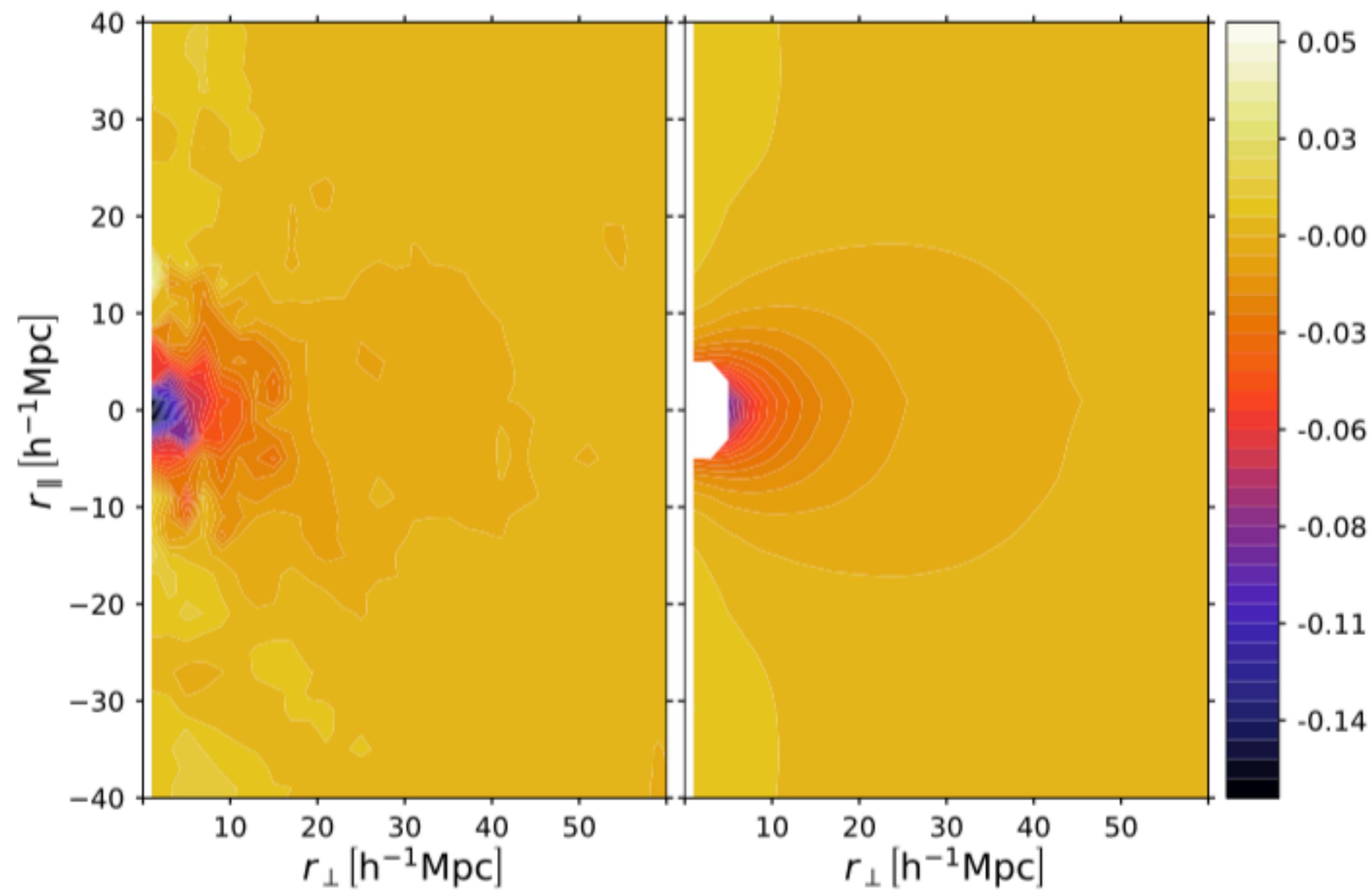
Tension with Planck reduced from 2.3 sigma to 1.7 sigma

Cross-correlation with Damped Lyman-alpha Systems (DLAs)



About 20% of forests contain DLAs

Cross-correlation with forests



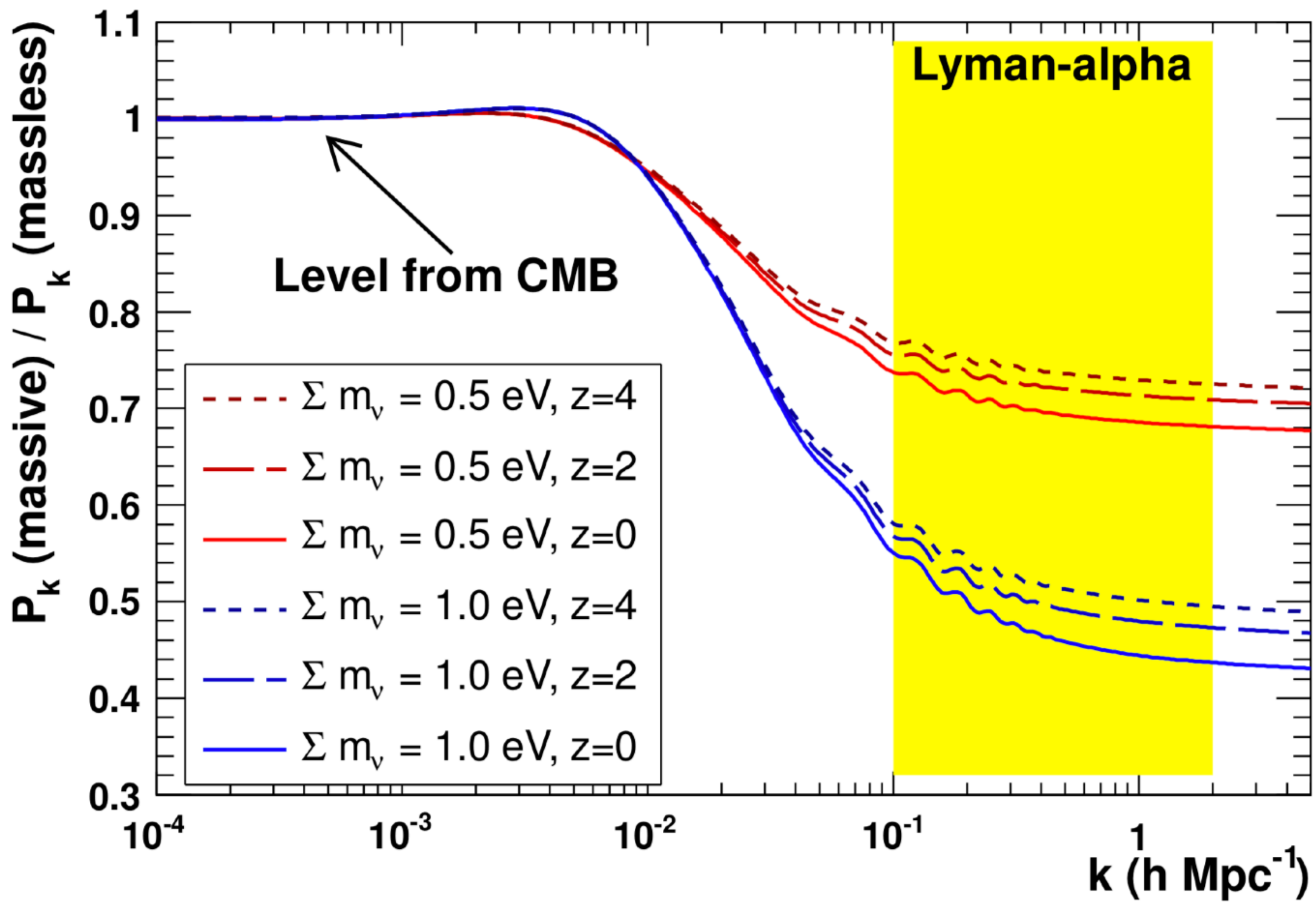
Font-Ribera et al. 2012, Pérez-Ràfols et al. 2018

$b_{\rm DLA} = 2.00 \pm 0.19$ Host halo mass ~ $4 \cdot 10^{11}\, h^{-1} {\rm M}_\odot$

Neutrino masses with forests

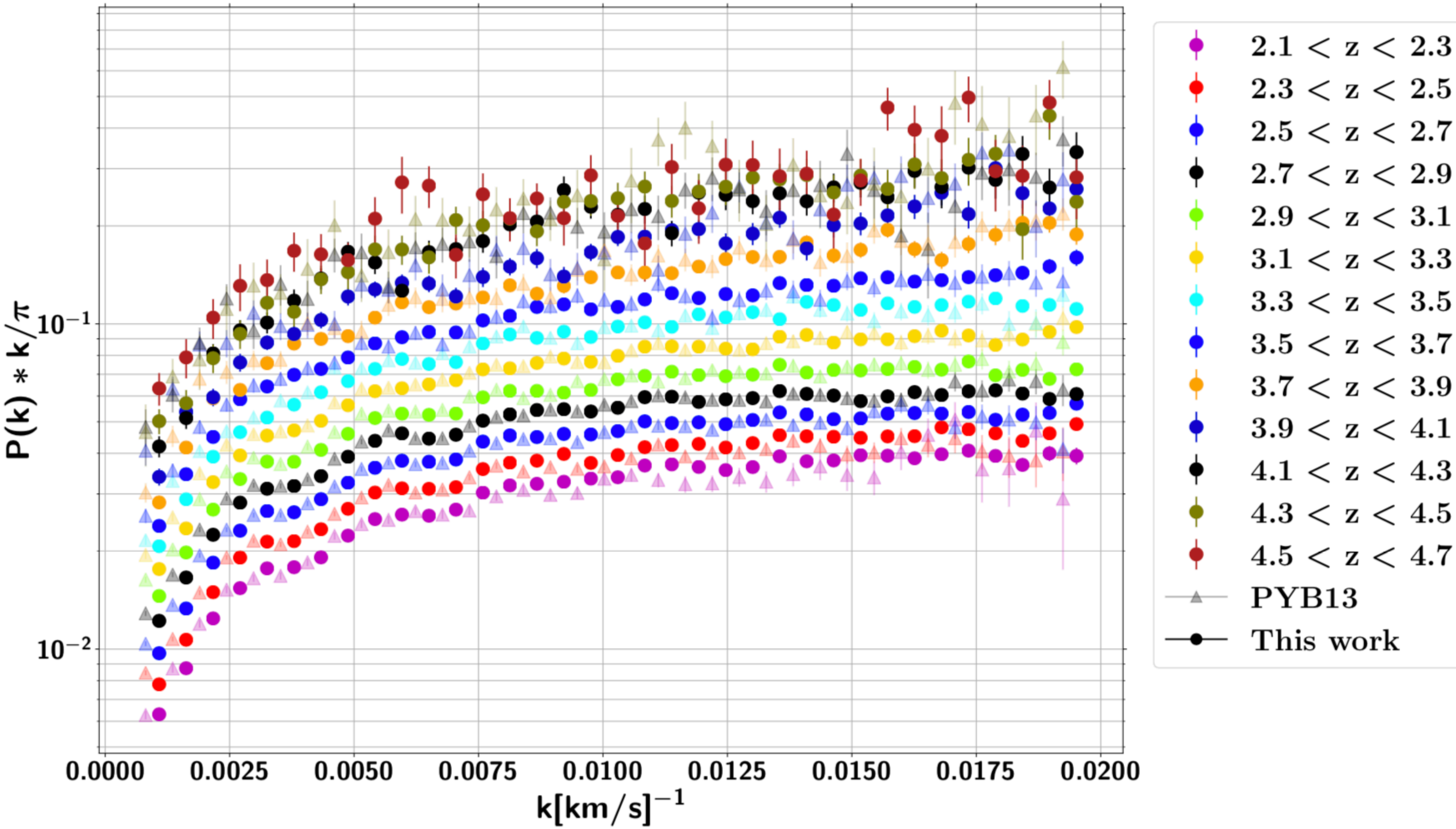
Neutrino masses with forests

Impact on linear matter power-spectrum
Palanque-Delabrouille et al. 2014



One-dimensional power spectrum

BOSS+eBOSS data: 43k forests
Chabanier et al. 2018



units: $\Delta v = c\dfrac{\Delta\lambda}{\lambda}$ [km/s] $k \equiv \dfrac{2\pi}{\Delta v}$ [s/km]

Pixel size: 69 km/s ~ 0.3 Mpc/h at z ~ 3
k^{max} ~ 0.09 [s/km]

Hydro-simulations to model the signal

Suite of 48 hydro-sims (Gadget-3) for several values of
both cosmological and IGM parameters, and resolutions for "splicing"
Borde et al. 2014, Rossi et al. 2014

Parameter	Value	
$\sigma_8(z=0)$	0.83	± 0.05
n_s	0.96	± 0.05
H_0 [km s^{-1} Mpc^{-1}]	67.5	± 5.0
Ω_m	0.31	± 0.05
Ω_b	0.044	
Ω_Λ	0.69	
$T_0(z=3)$[K]	15 000	± 7000
$\gamma(z=3)$	1.3	± 0.3
Starting redshift	30	

100 Mpc/h 768^3
25 Mpc/h 768^3
25 Mpc/h 192^3

Adiabatic cooling

Ultraviolet background ionization heating

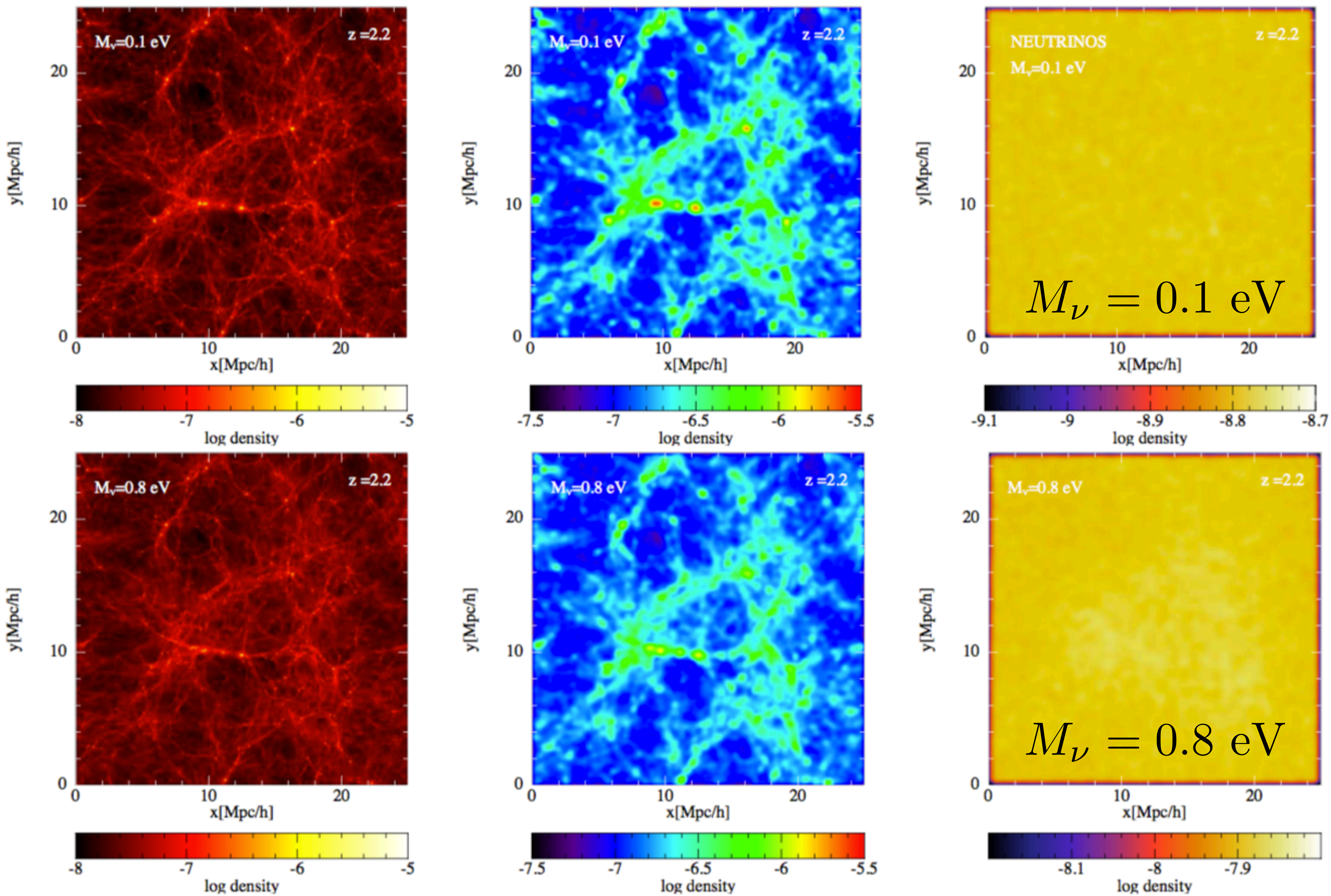
Compton and recombination cooling

Feedback from star formation and AGNs

Particle based neutrino implementation

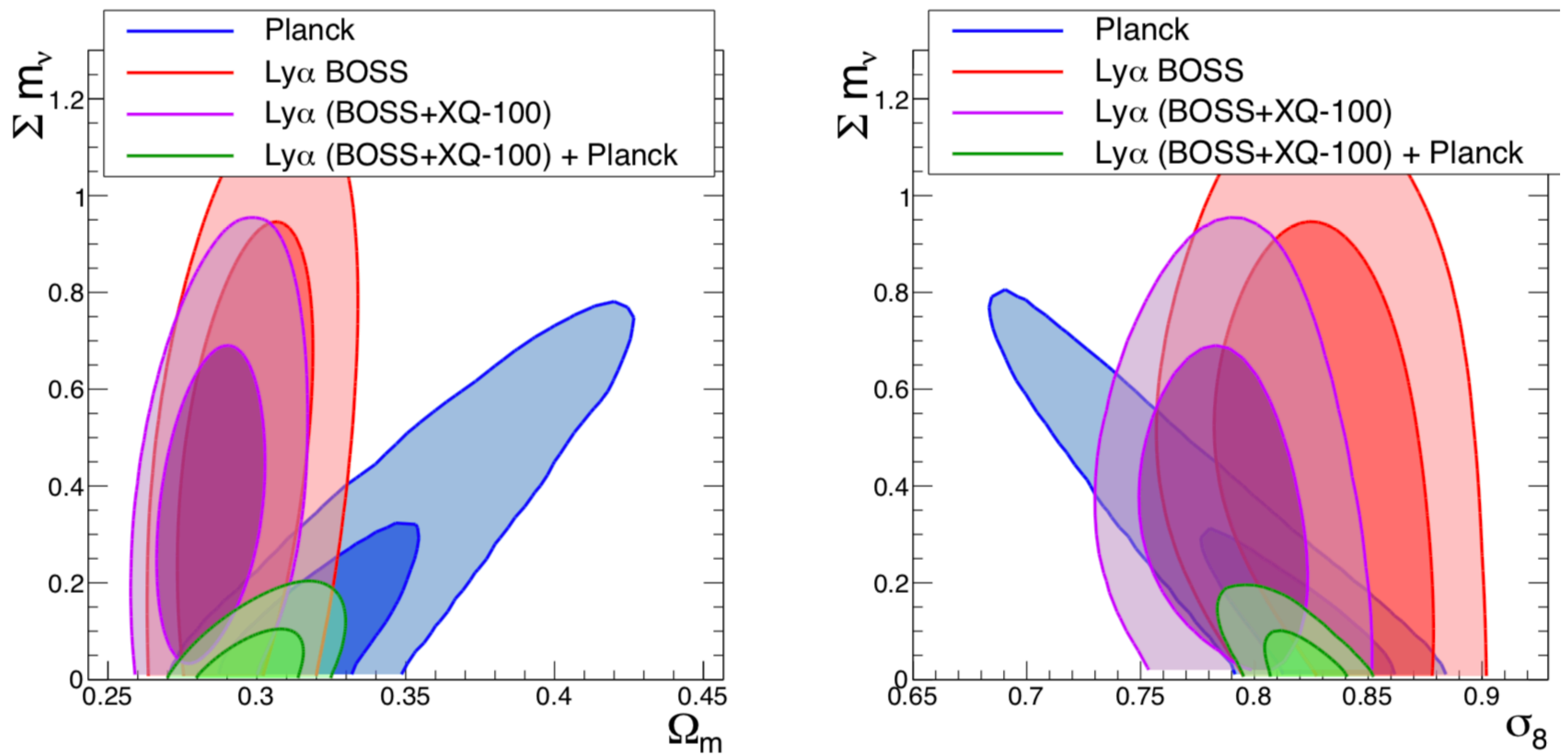
+ neutrino masses: $M_\nu = 0.1, 0.2, 0.3, 0.4,$ and 0.8 eV

Gas Dark Matter Neutrinos



Rossi et al. 2014

Constraints on neutrino mass



Constraints on n_s, σ_8 , warm dark matter and **neutrino masses**

McDonald et al. 2006, Palanque-Delabrouille et al. 2014, **Yèche et al. 2017 (shown)**

$$\sum m_\nu < 0.15\text{eV} \ (95\%)$$

Forests + CMB

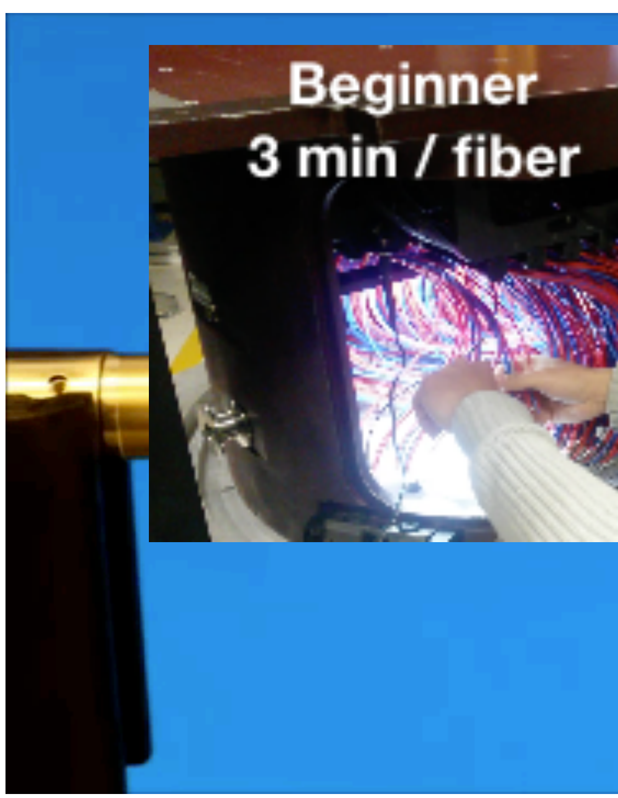
Future of Lyman-alpha forest cosmology

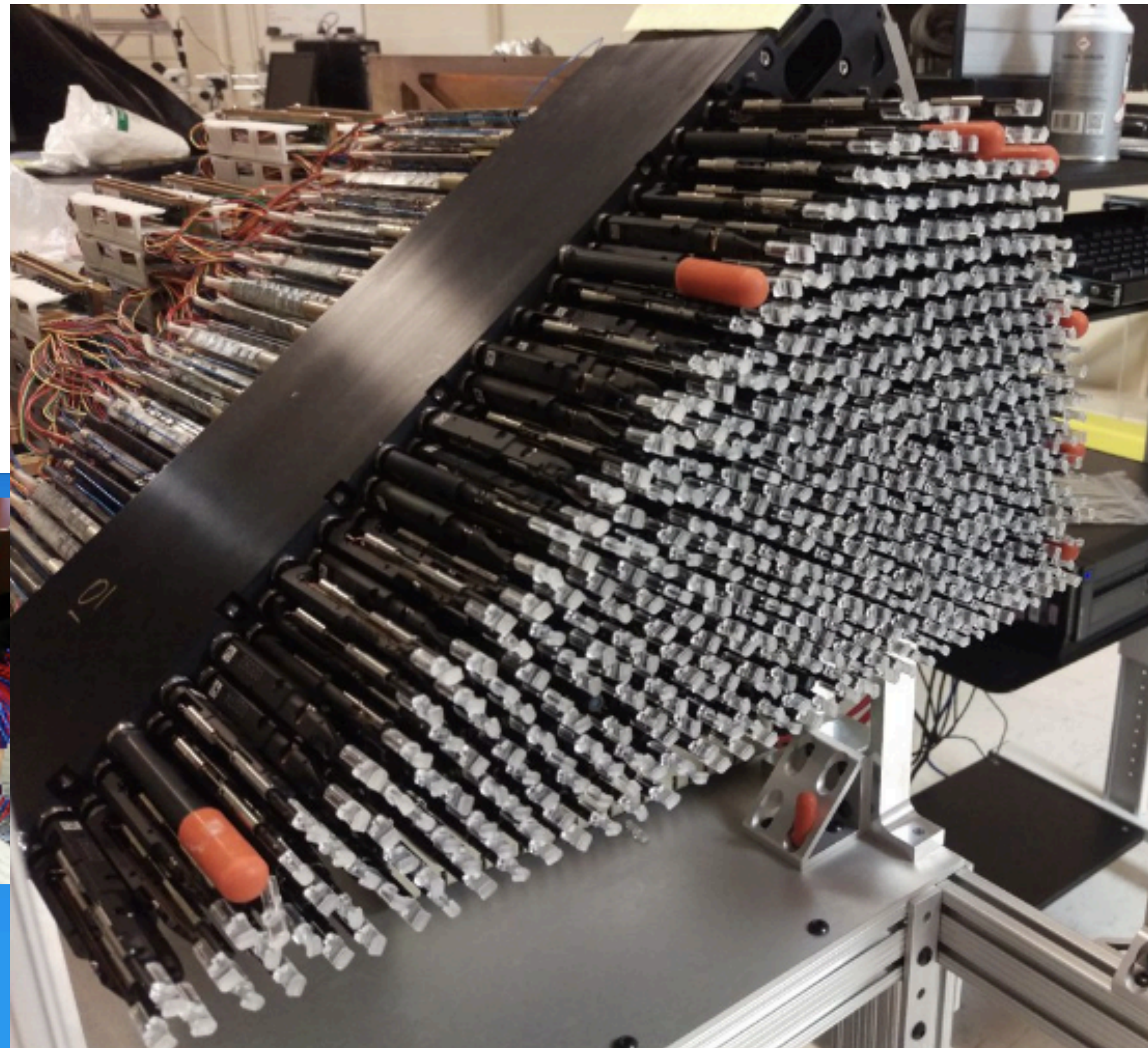
Future surveys

- DESI
- HETDEX
- PFS
- 4MOST
- Euclid
- WFIRST

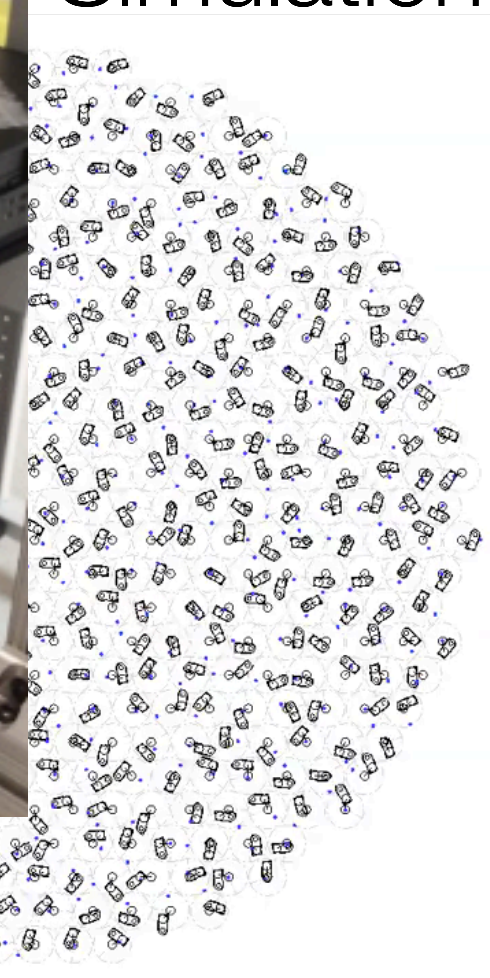
DESI

Dark Energy Spectroscopic Survey
will start operations in 2020





Simulation of “



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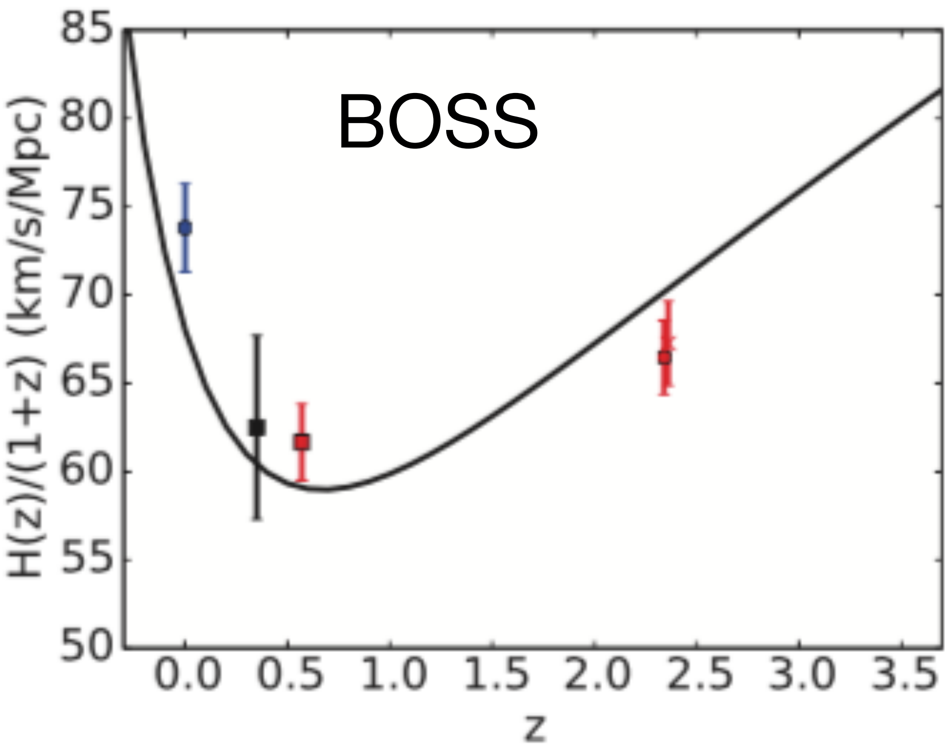

2.5 meters -> 4.0 meters
'500 deg^2 -> 14000 deg^2
000 fibers -> 5000 fibers
| by human -> fibers plugged by robot
similar final spectral S/N

)s