Lyman-α Cosmology with BOSS

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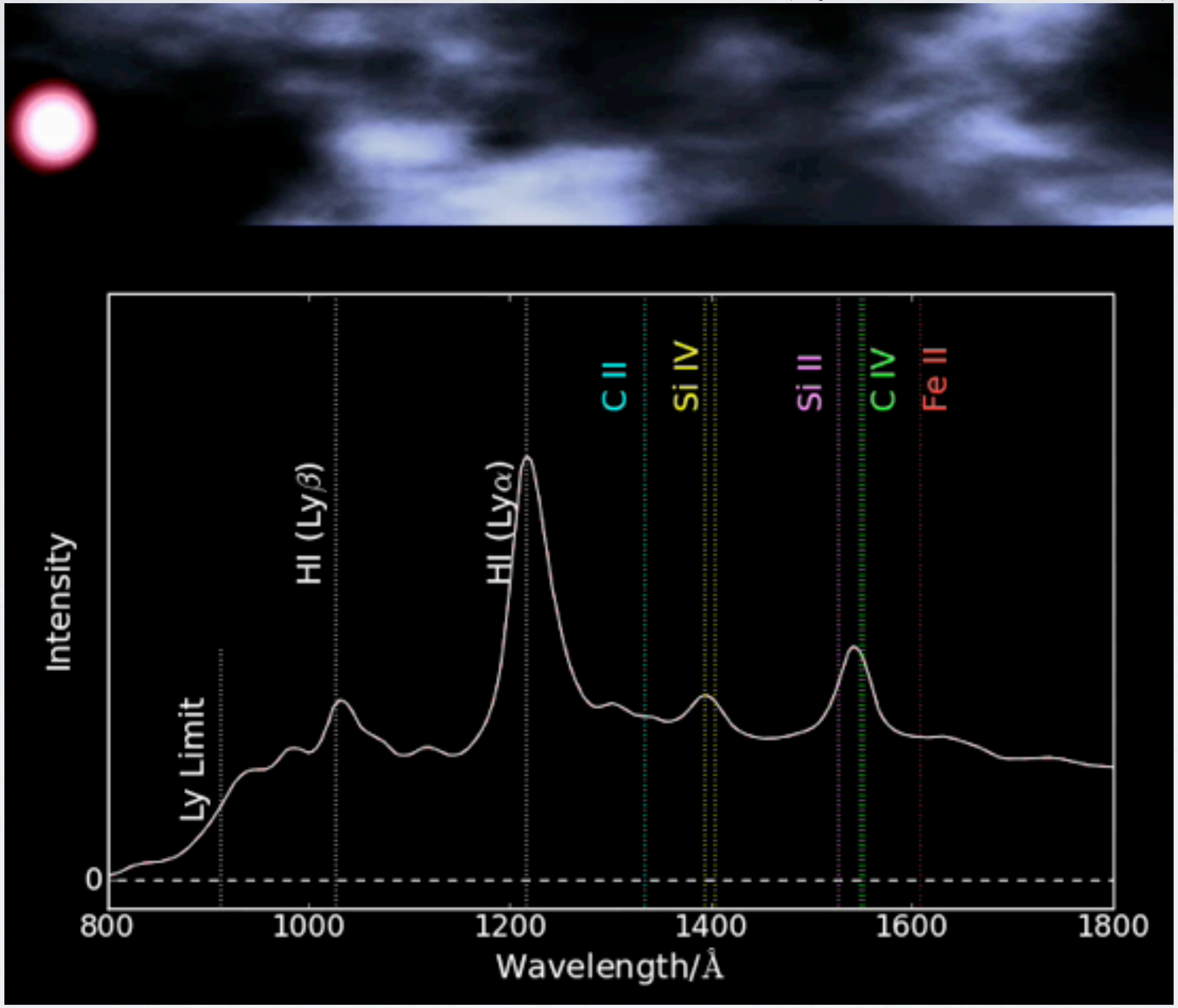
Rencontres du Vietnam
Cosmology 2015

Lyman-α Forest of a Quasar

(by Andrew Pontzen)



$$F(\lambda_{\text{obs}}) = \frac{\text{Observed flux}}{\text{Unabsorbed flux}}(\lambda_{\text{obs}})$$

Lyman-α Forest of a Quasar

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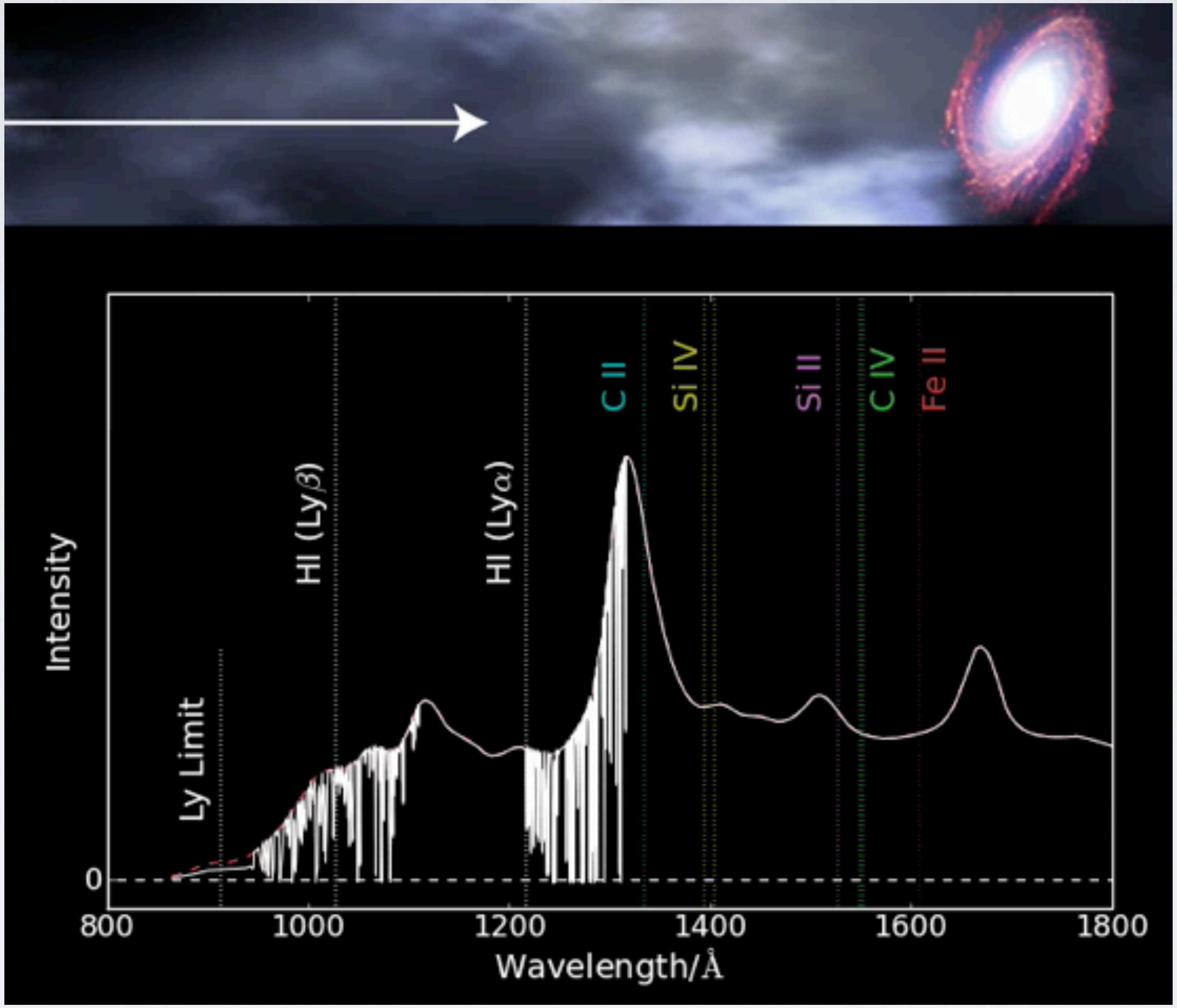
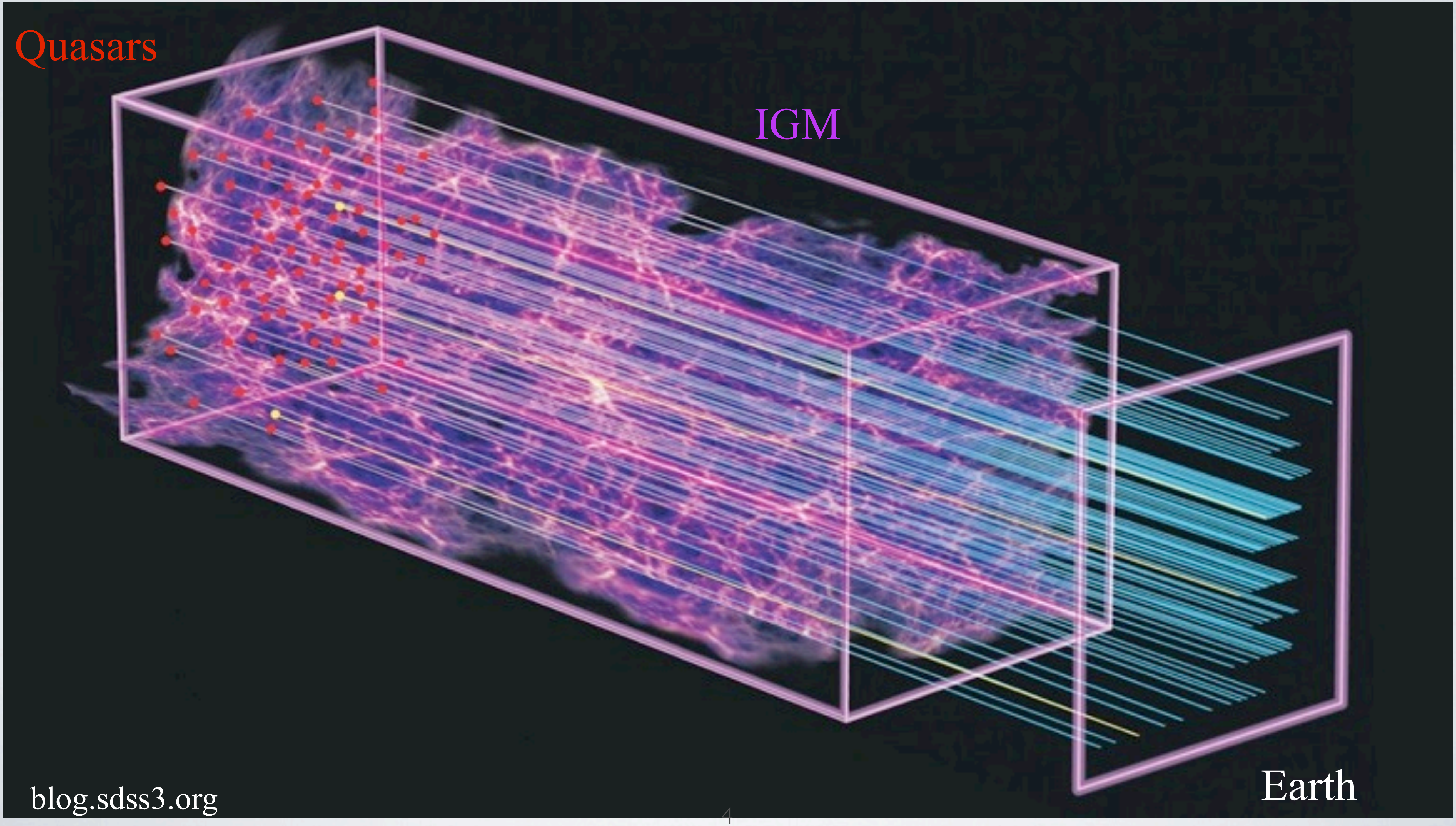


$$F(\lambda_{\rm obs}) = \frac{\text{Observed flux}}{\text{Unabsorbed flux}}(\lambda_{\rm obs})$$

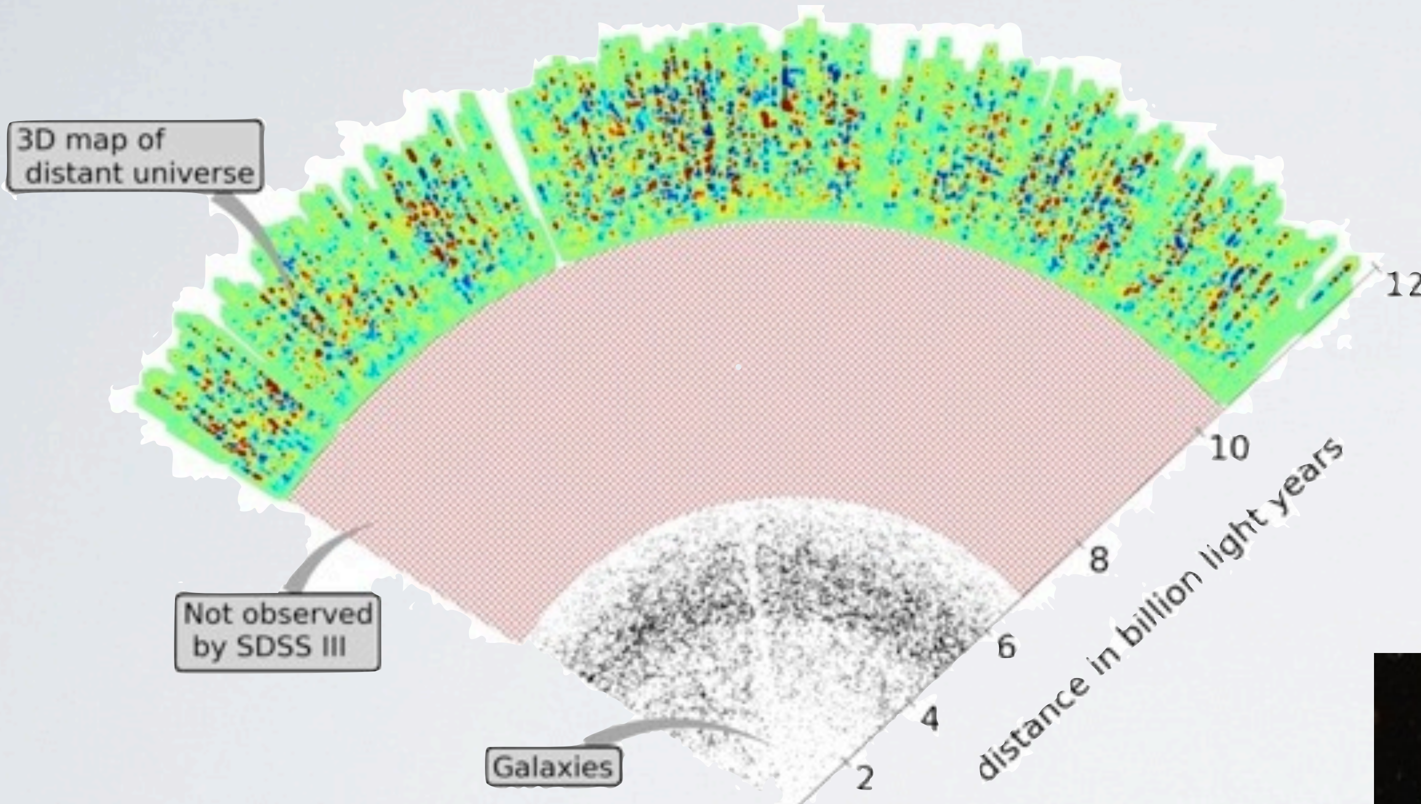
Survey of Lyman-α Forests

Tracers of matter distribution in the Universe



BOSS

Baryon Oscillation Spectroscopic Survey



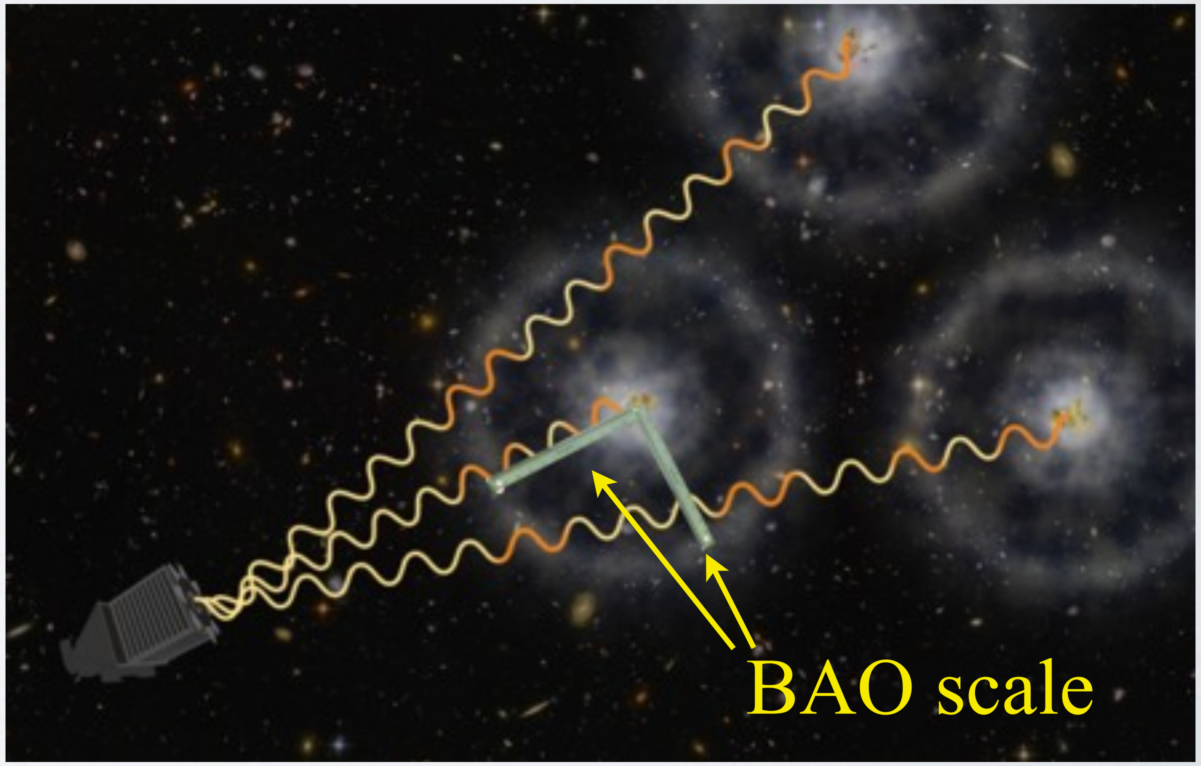
DR12

190 000 quasars at $2 < z < 3.5$

15% more than DR11

Measuring BAO when the Universe was one fifth of its age

BAO ↔ Expansion rate ↔ Dark Energy

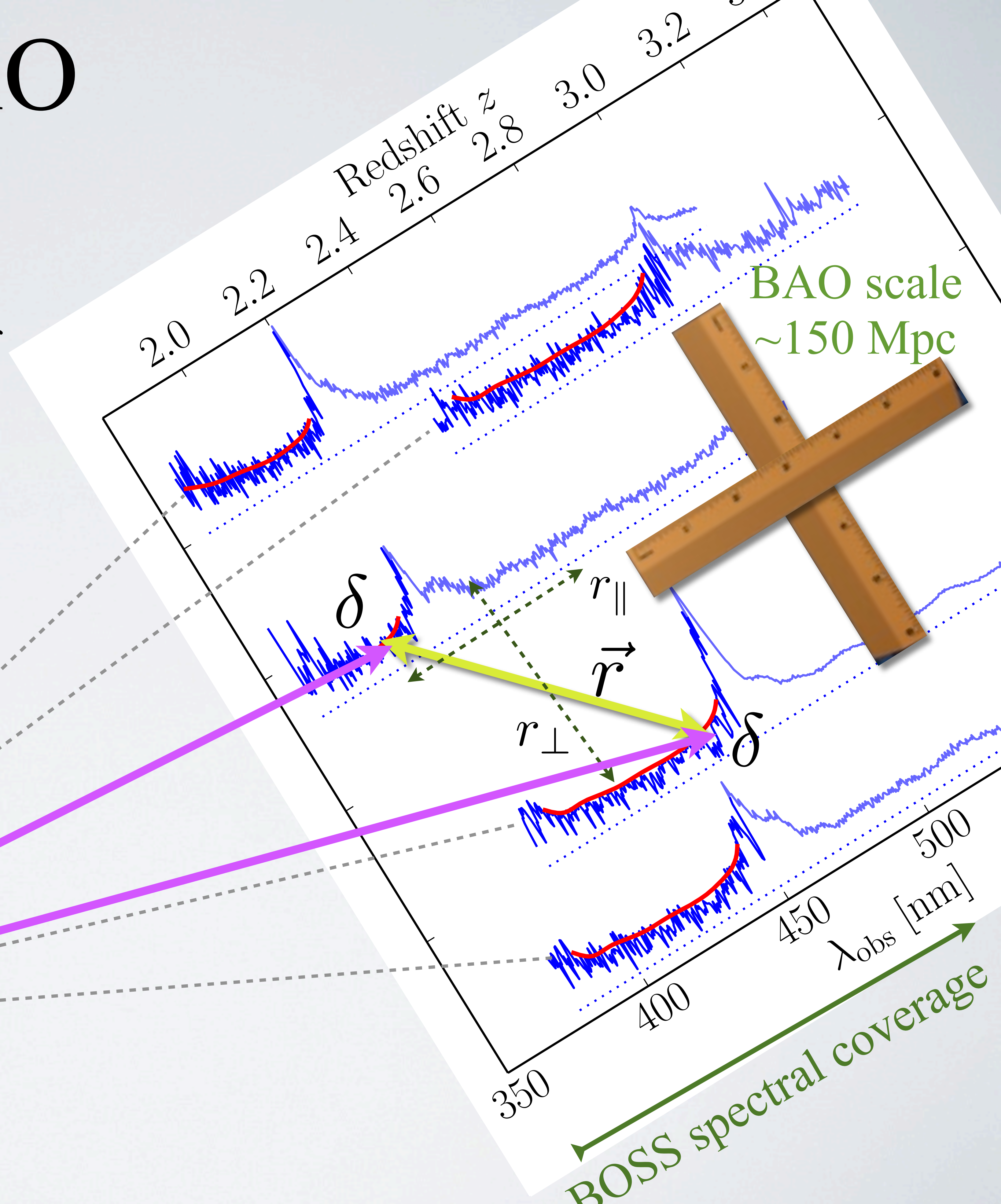


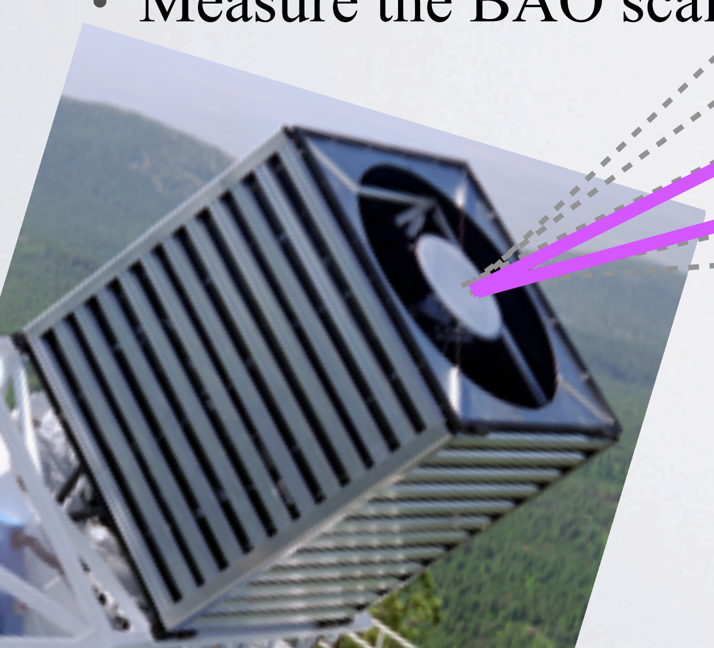
Measuring BAO with forests

- Quasar redshifts: visual inspection of all targets (Paris++2014)
- Continuum level → amount of absorption
- Compute correlation function

$$\xi(\vec{r}) = \langle \delta_i \delta_j \rangle$$

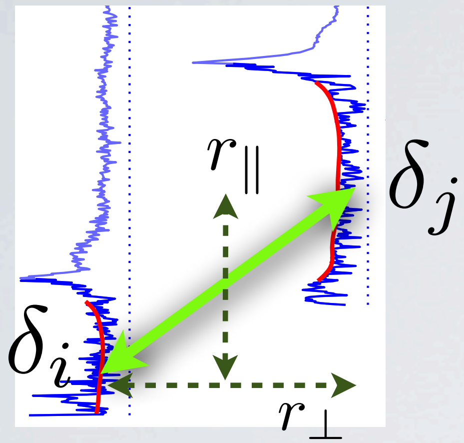
- Measure the BAO scale

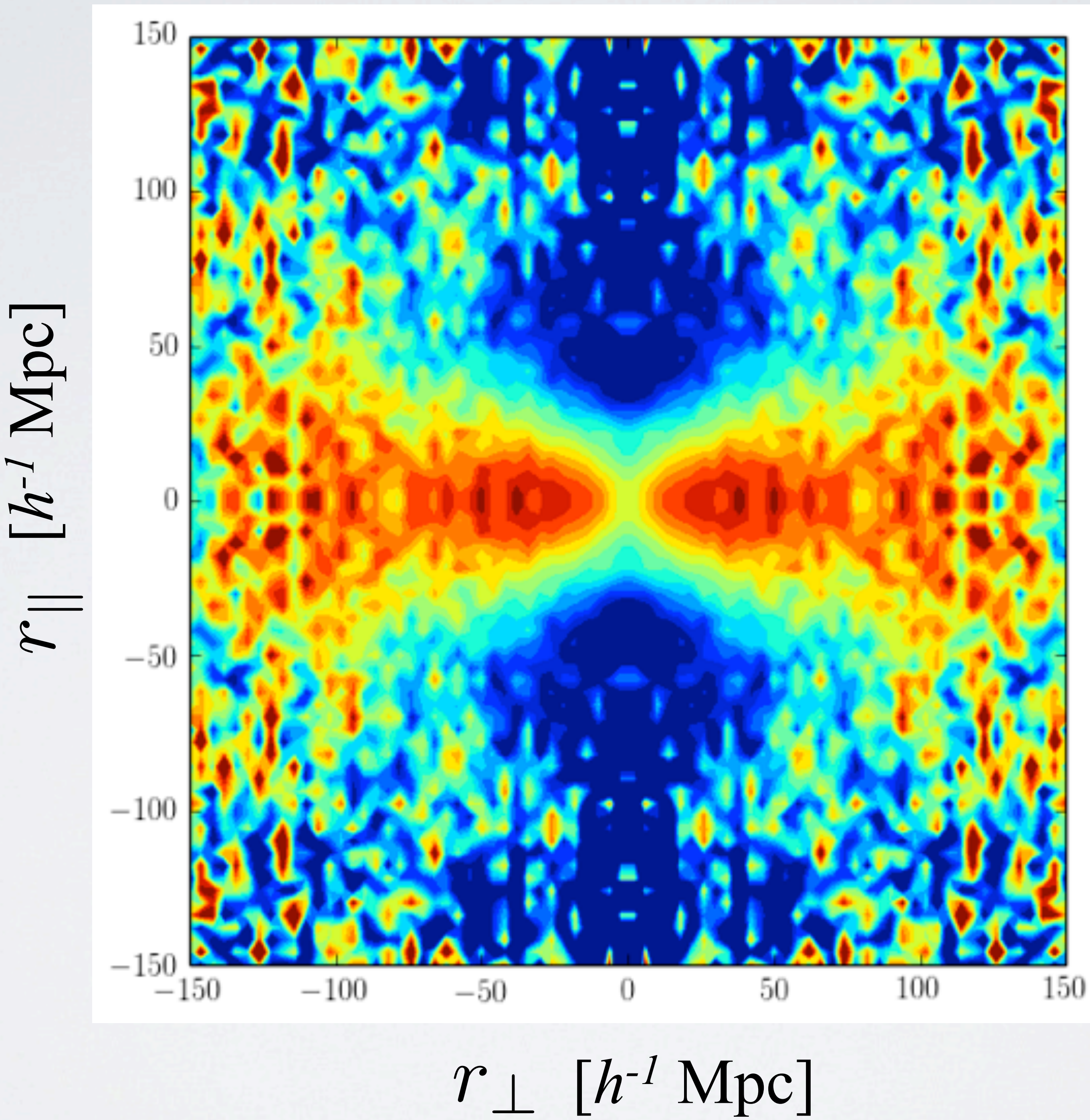




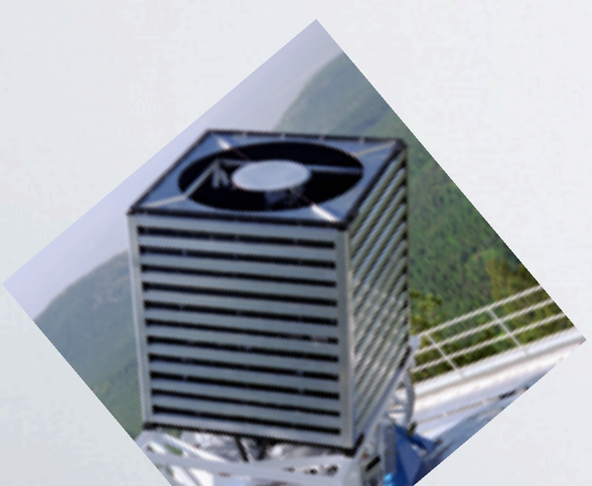
Lyman-α auto-correlation function

DR11 $r^2\xi(r_\perp, r_\parallel)$

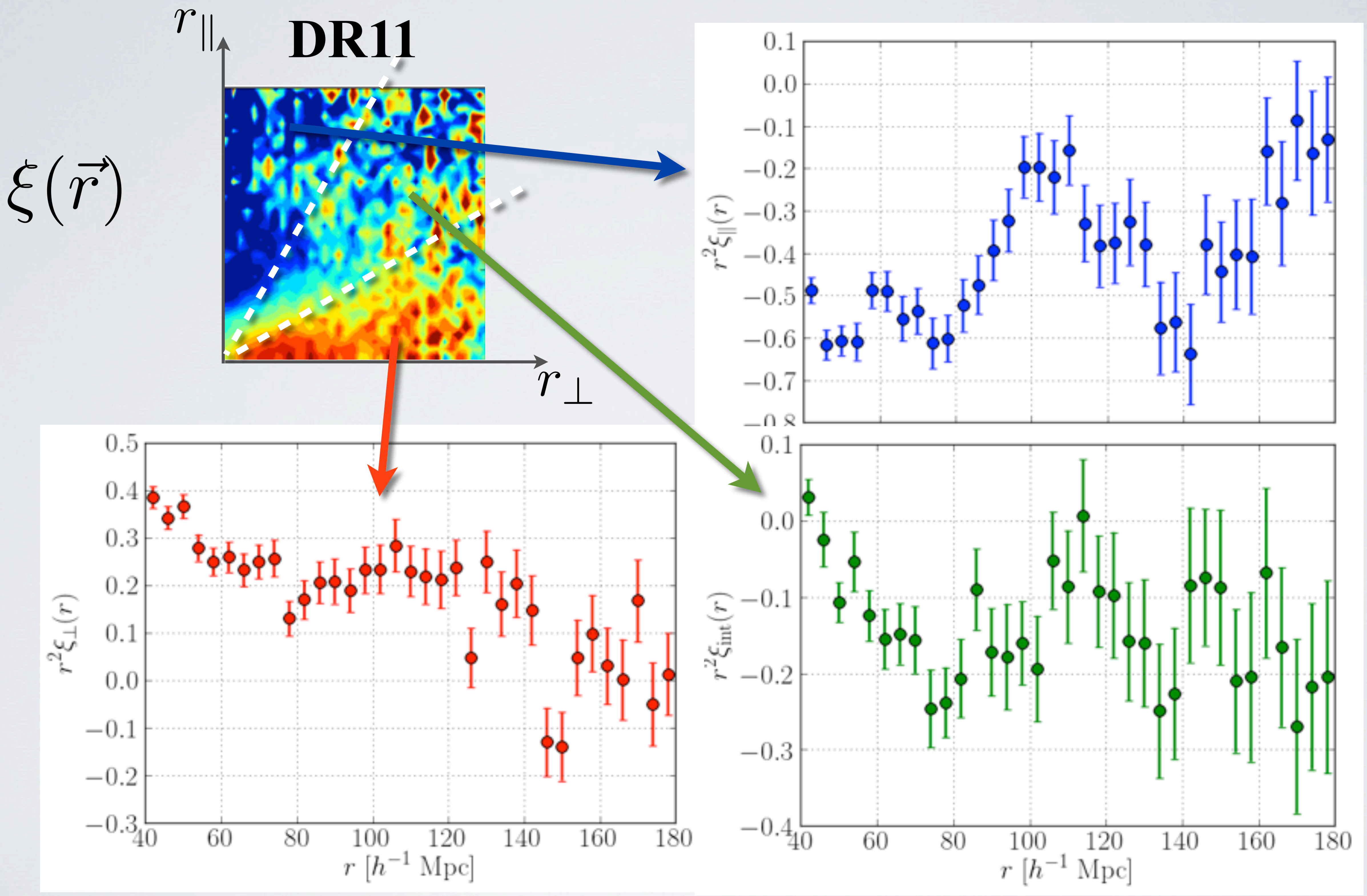




(Delubac, JB, ++ 2015)



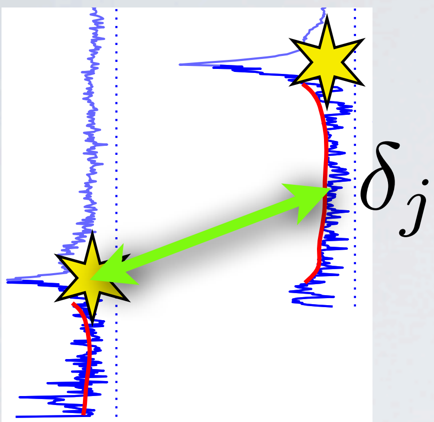
Lyman-α auto-correlation function

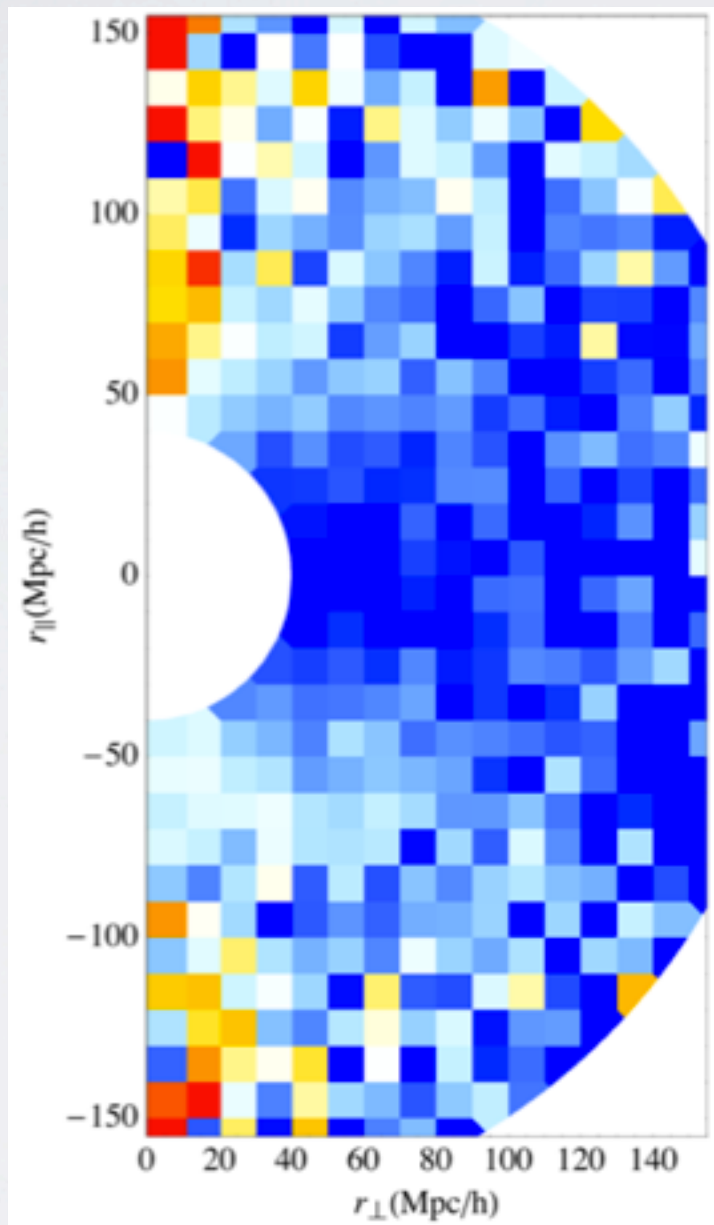


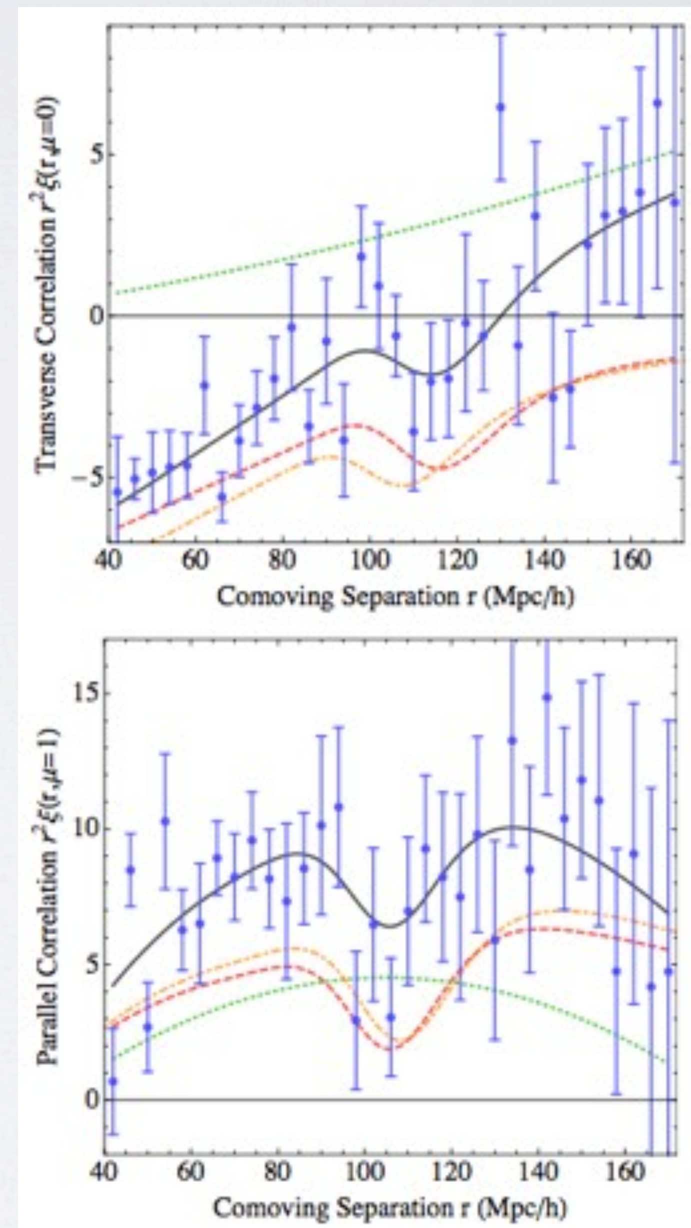
(Delubac, JB, ++ 2015)

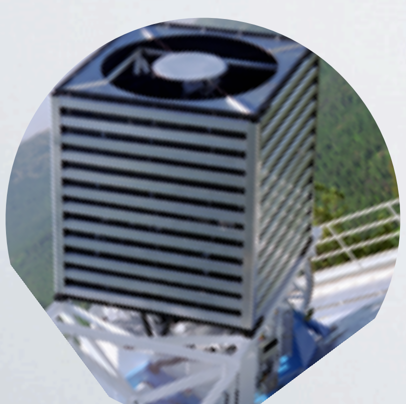
Quasar Lyman-α cross-correlation function

DR11









(Font-Ribera++2014)

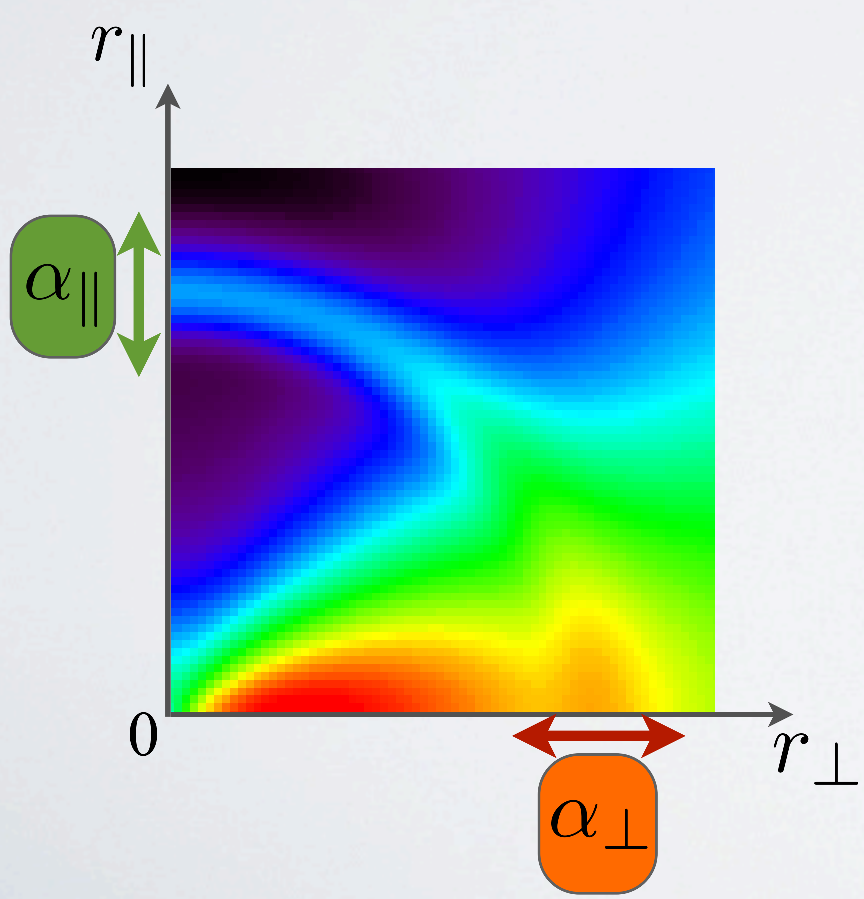
Fitting BAO model

BAOfit package with continuum distortion model
(Kirkby++ 2013, Blomqvist++ 2015)

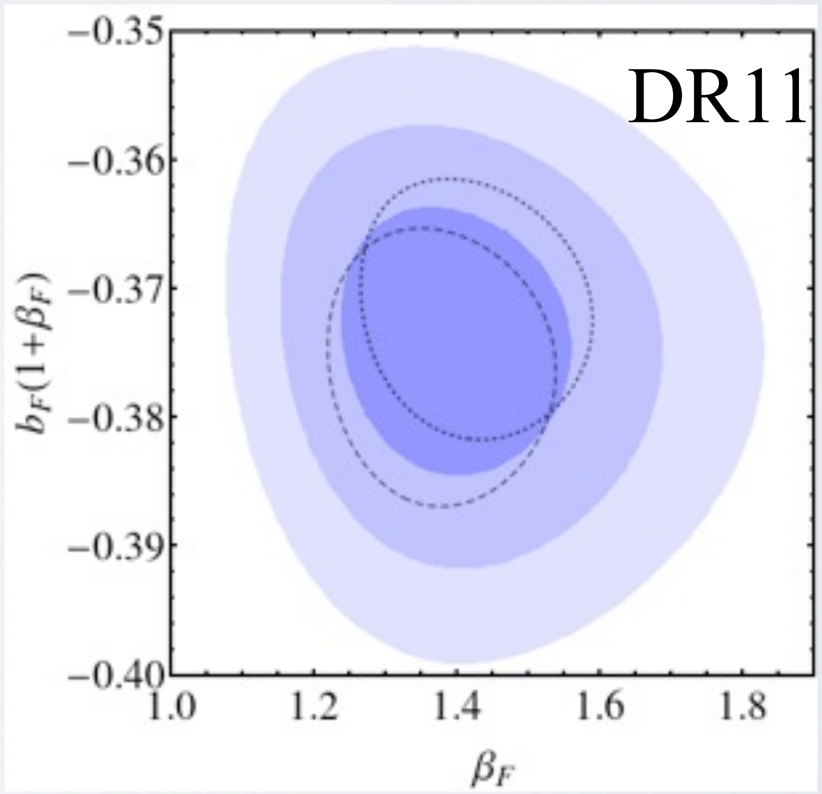
$$\xi_{\text{model}}(\vec{r}, \alpha_{||}, \alpha_{\perp}) = \xi_{\text{cosmo}}(\vec{r}, \alpha_{||}, \alpha_{\perp}) + \xi_{\text{broadband}}(\vec{r})$$

$$\alpha_{||} = \frac{D_H(\bar{z})/r_d}{[D_H(\bar{z})/r_d]_{\text{fid}}} \quad \text{and} \quad \alpha_{\perp} = \frac{D_A(\bar{z})/r_d}{[D_A(\bar{z})/r_d]_{\text{fid}}}$$

Radial BAO | Transverse BAO



Bias

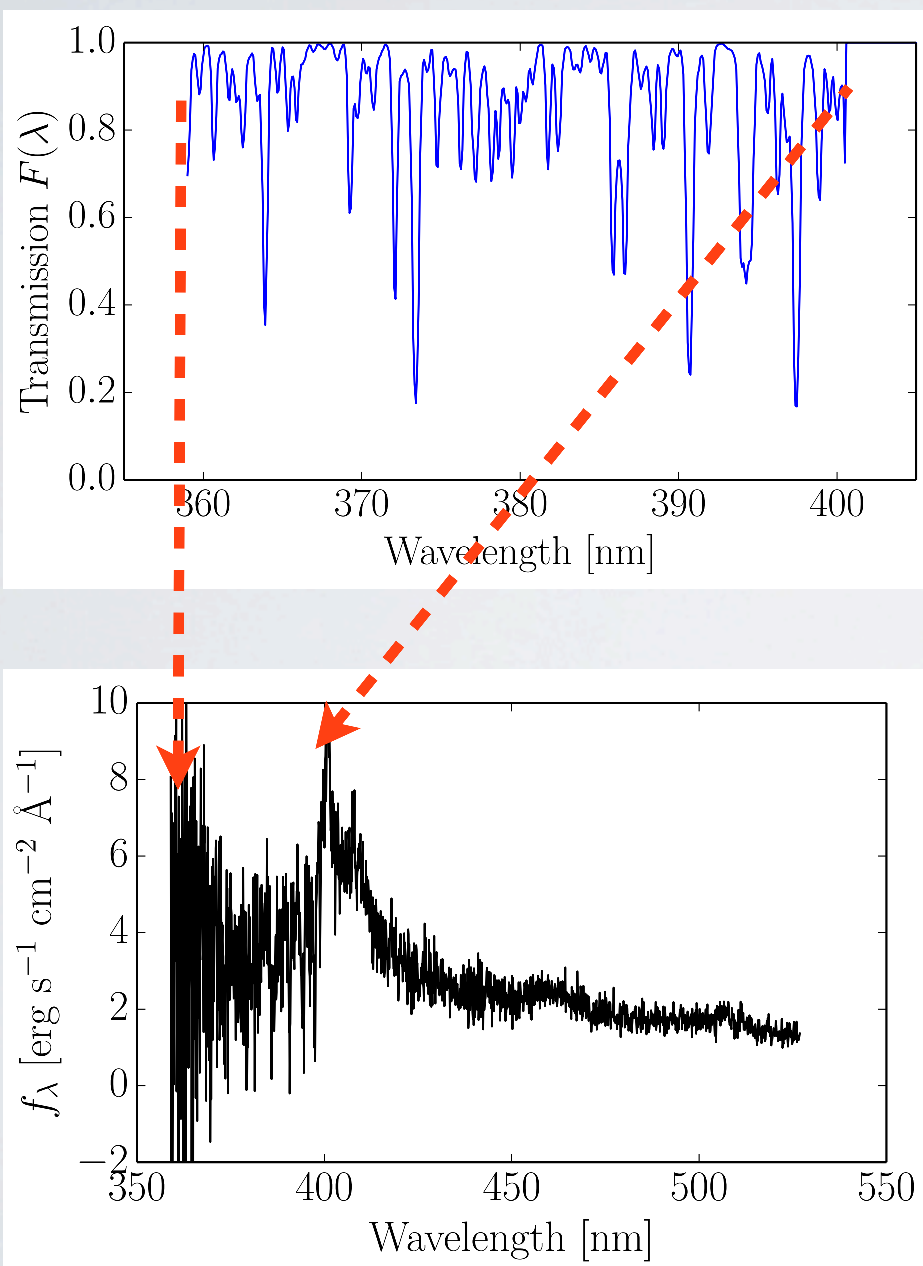


Redshift-space distortions

Tests on Mock Catalogs

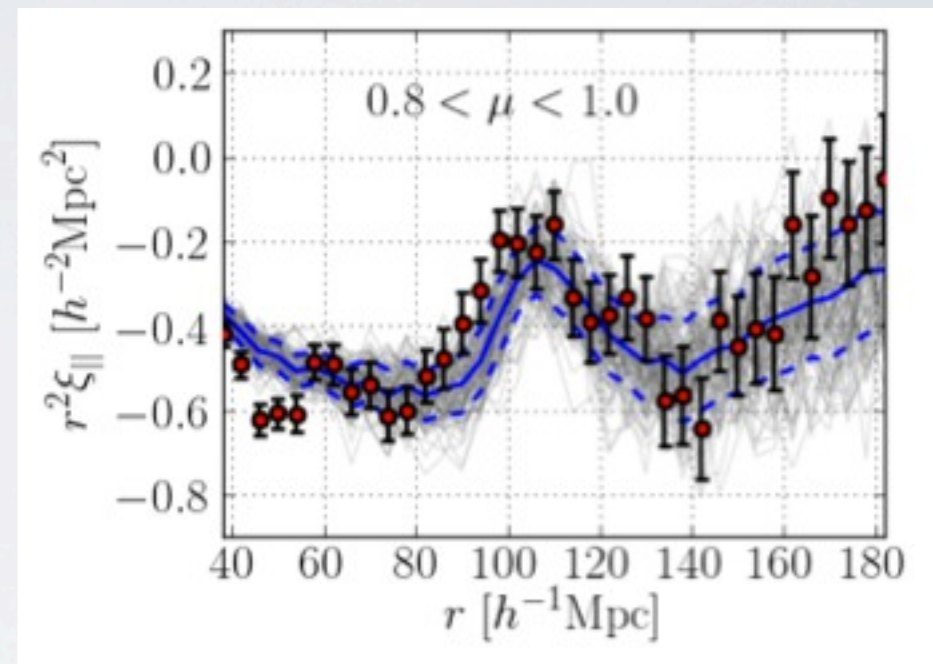
(JB++2015)

Log-normal absorption fields



BOSS like spectrua

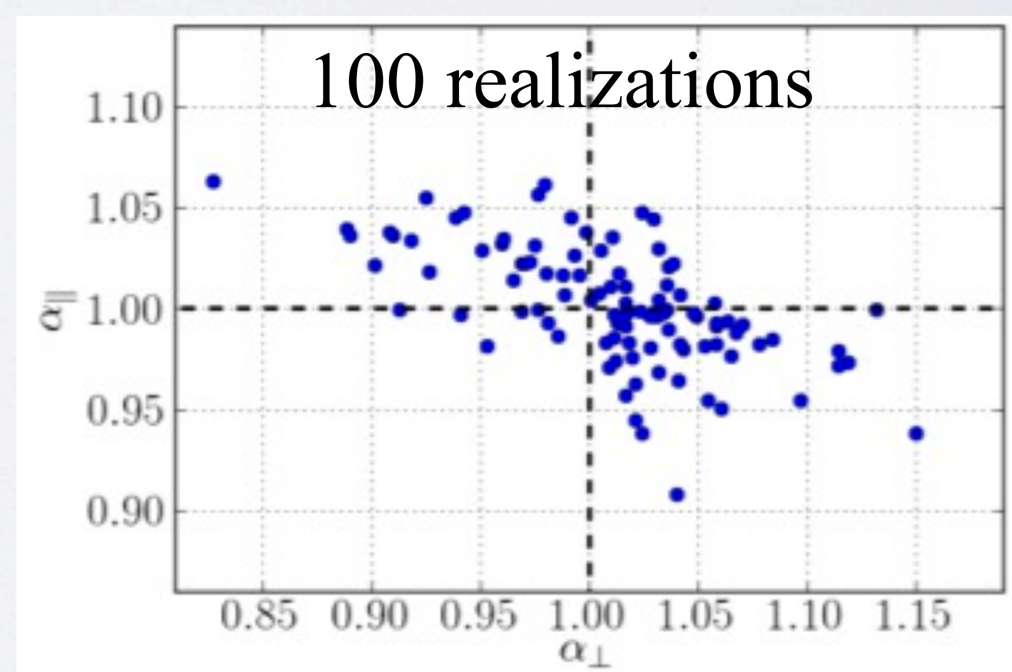
Correlation functions

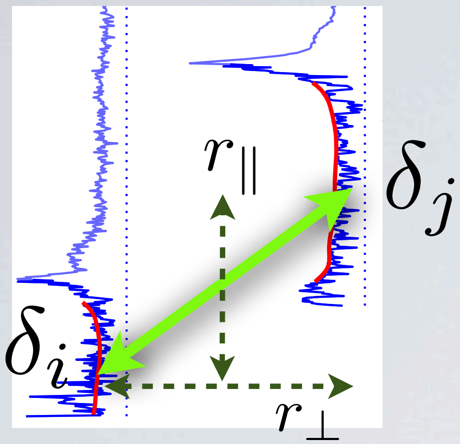


DR11

Mocks

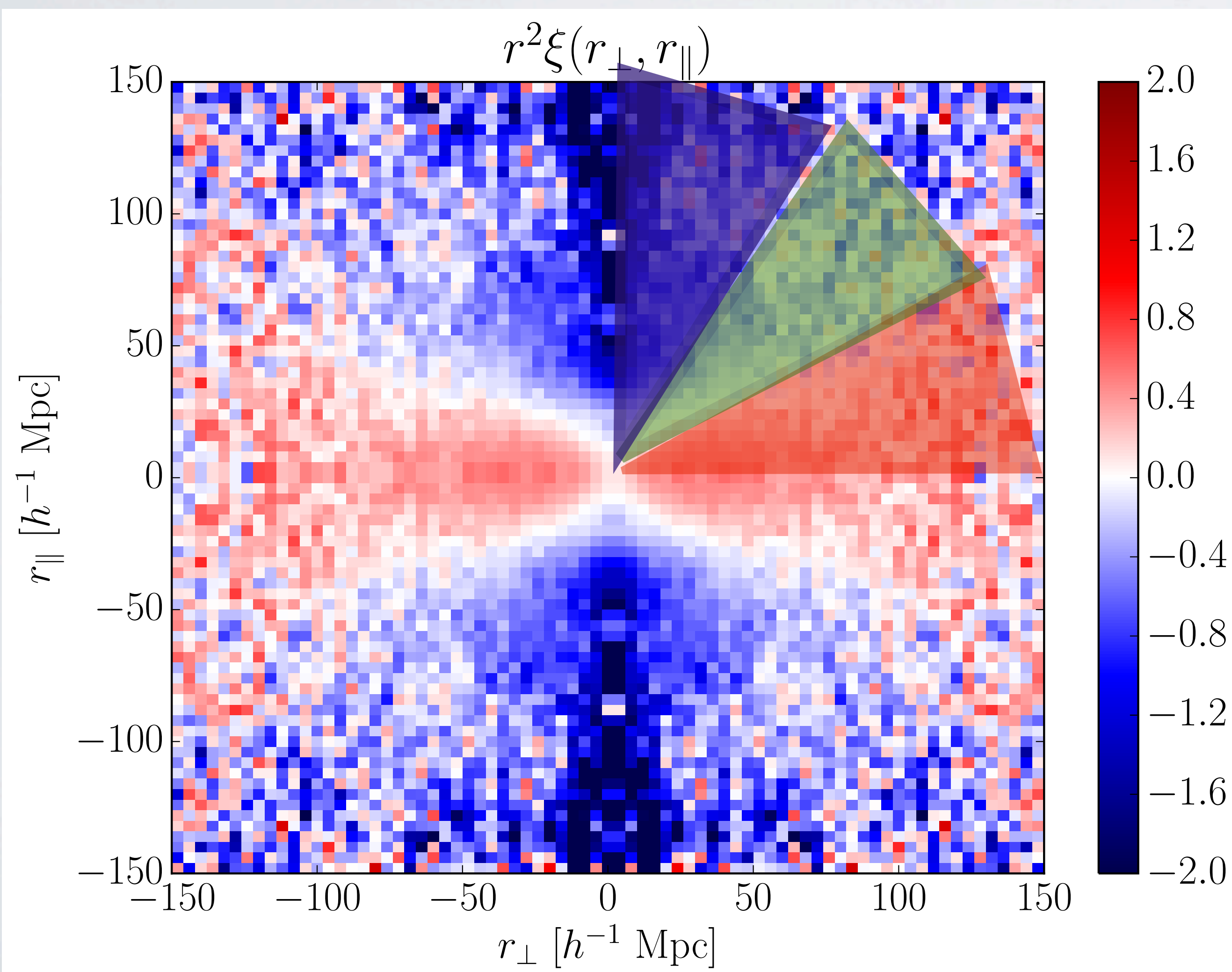
BAO best-fits

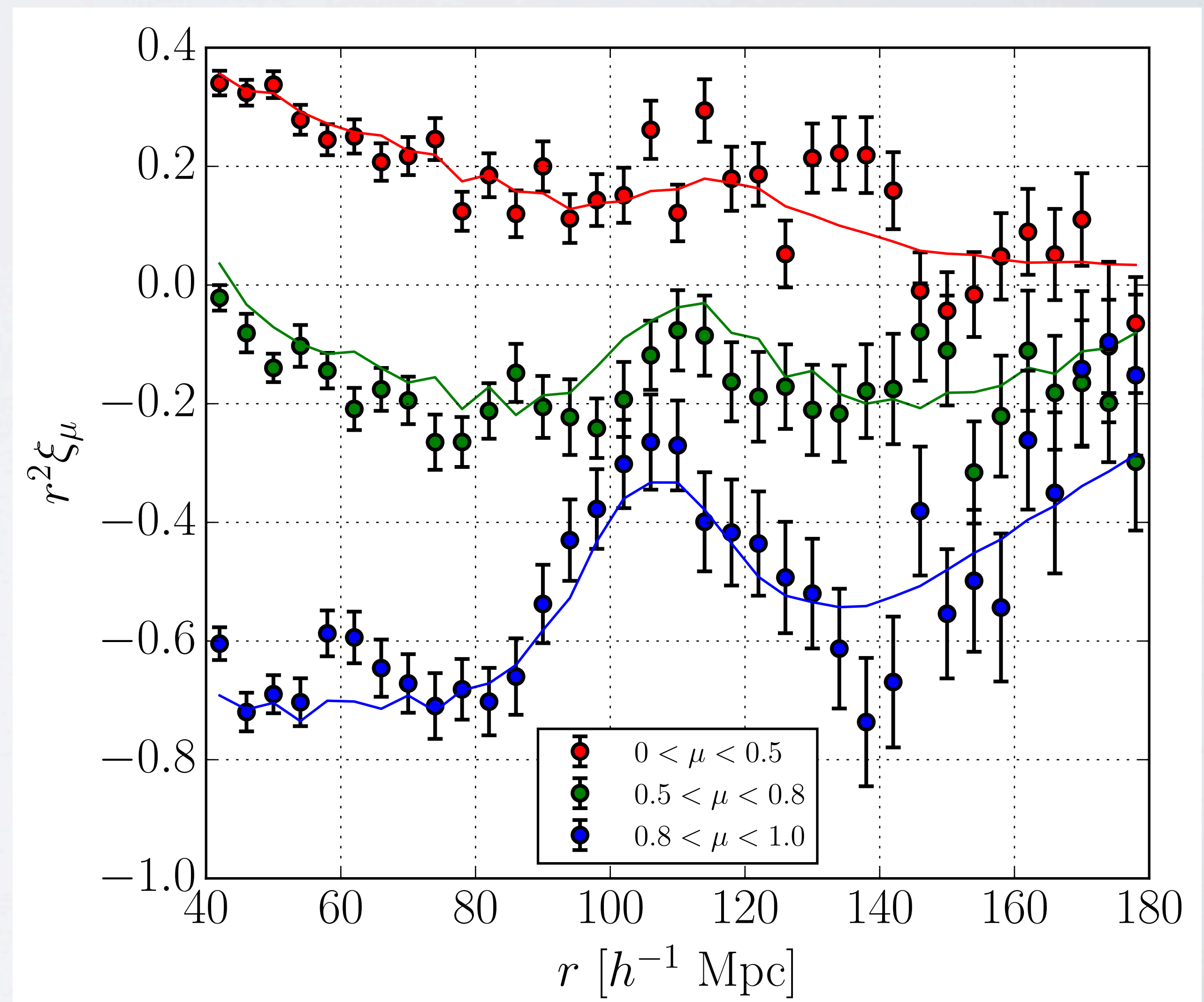




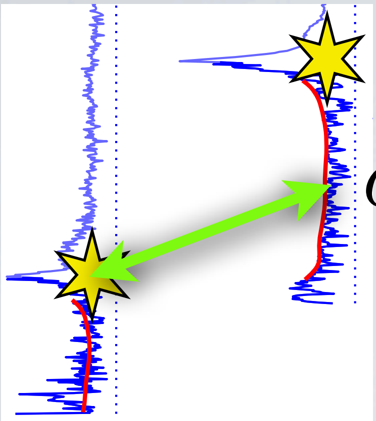
Lyman-α auto-correlation function

Preliminary DR12



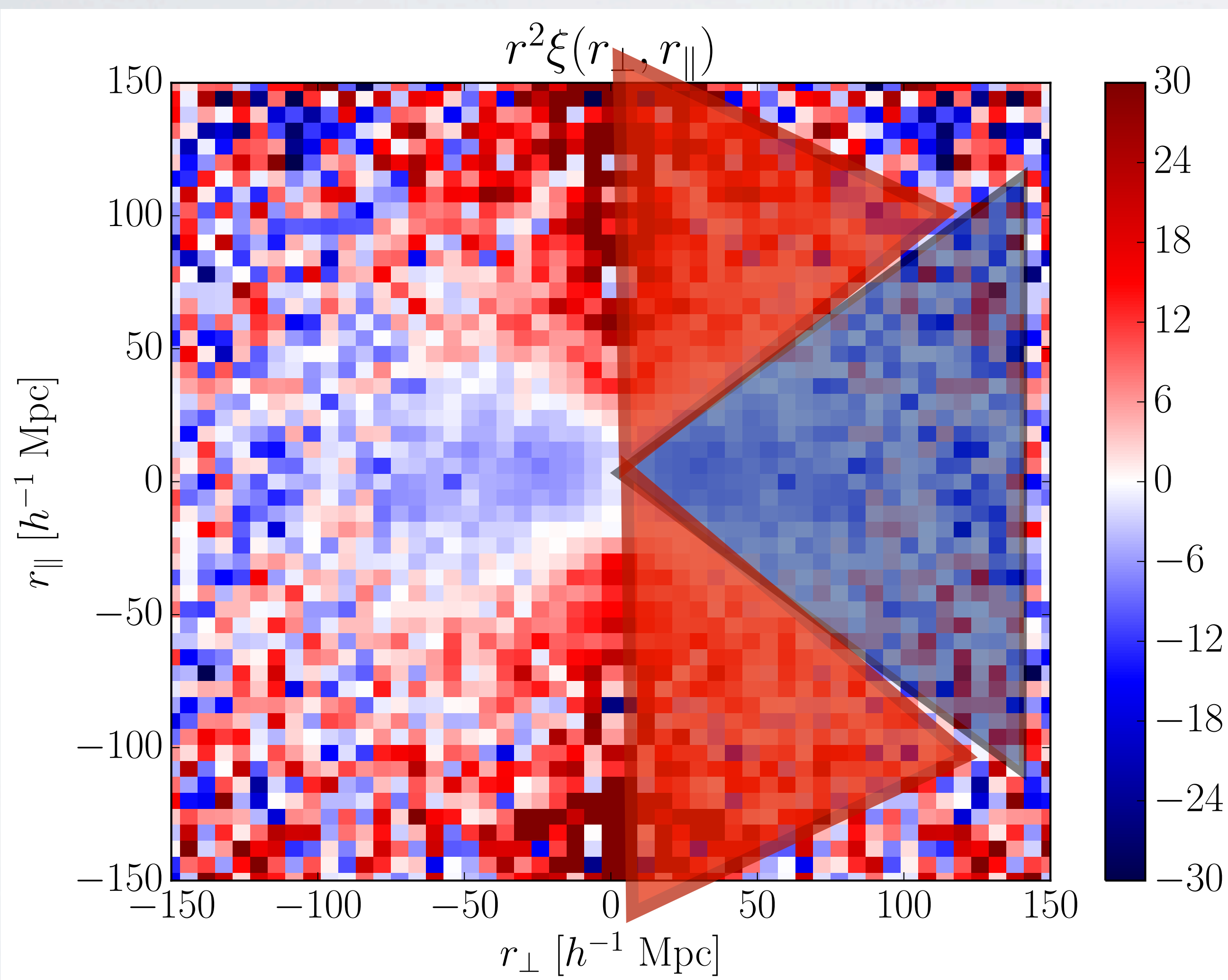


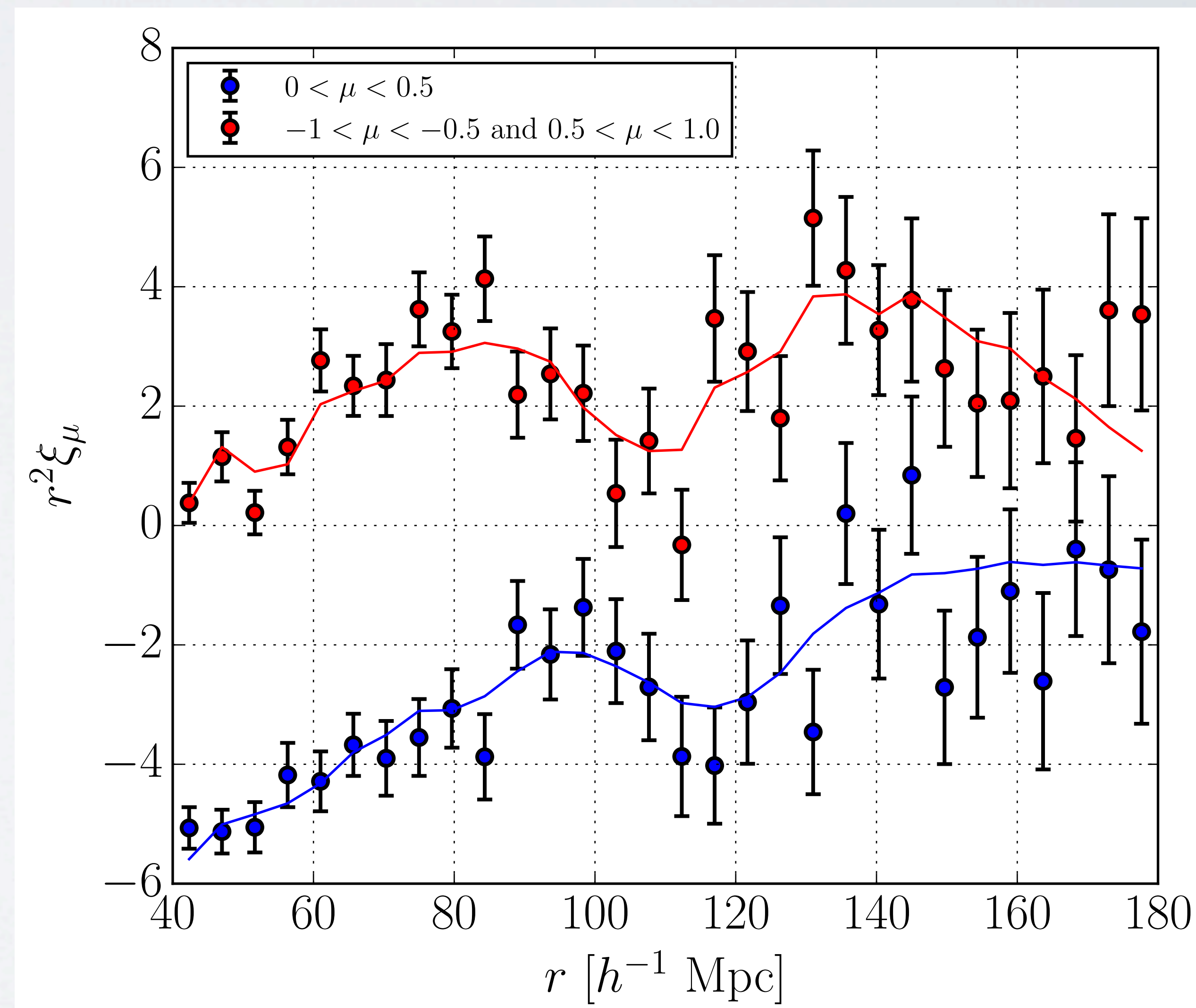
JB++ in prep



Quasar Lyman-α cross-correlation function

Preliminary DR12



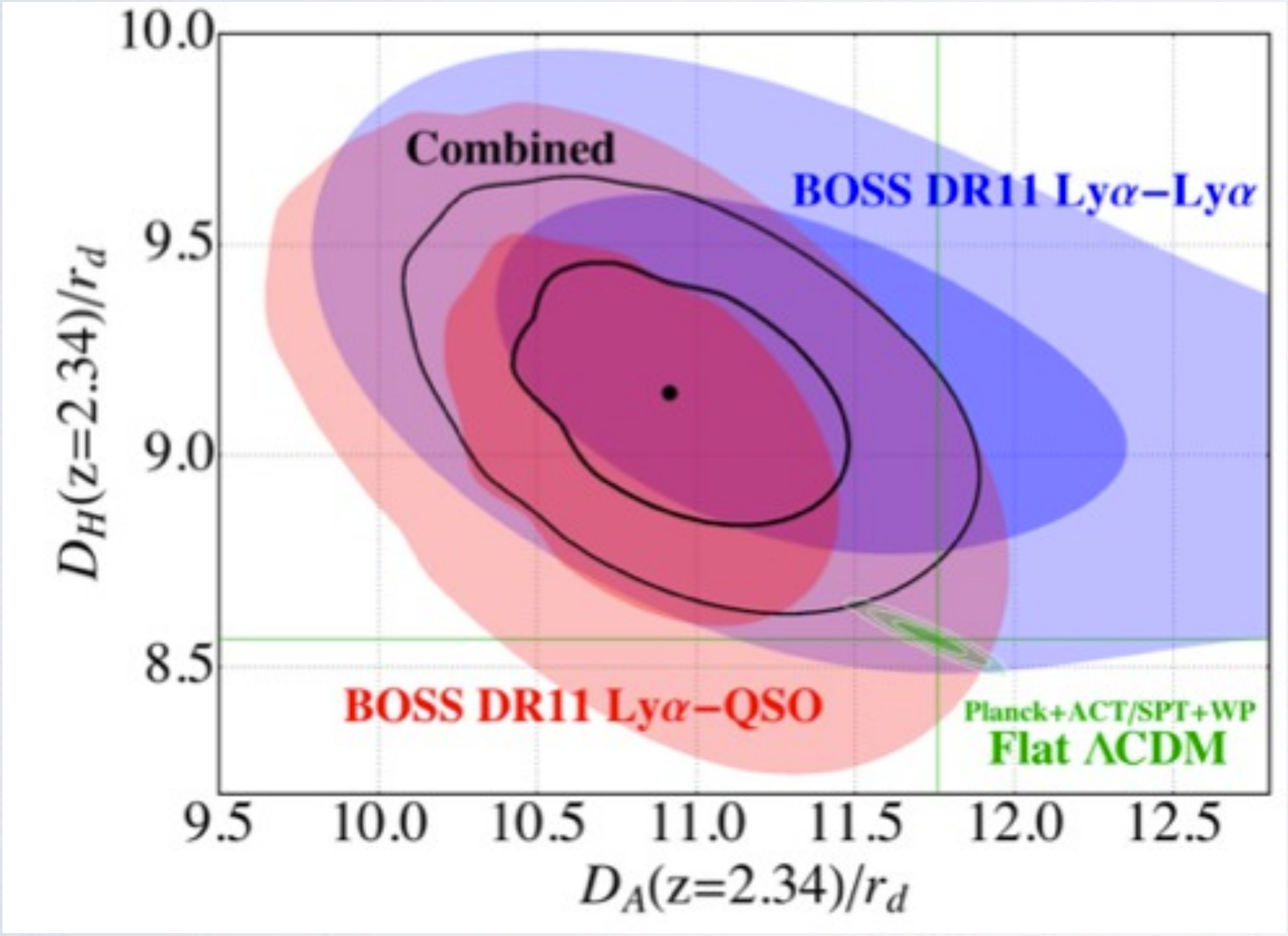


JB++ in prep

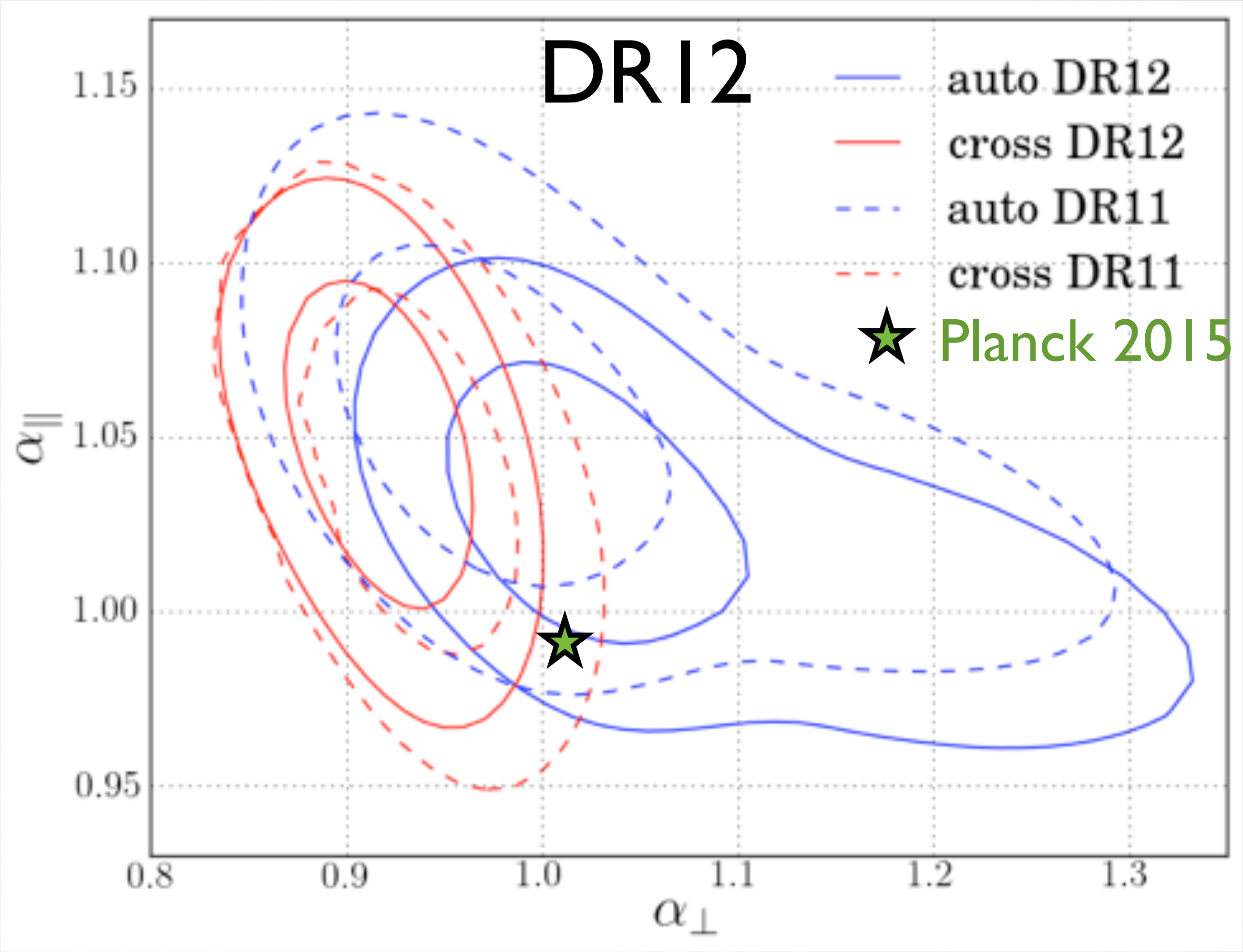
BAO Results

DR11 and DR12 Preliminary

Auto-correlation	DR11	DR12	Cross-correlation	DR11	DR12
χ^2	= 1499.1/(1515-13)	1479.2 / (1515-13)	χ^2	= 1957.93 / (1926-20)	426.4/420
$\alpha_{\parallel}$	= 1.054(32)	1.030(26)	$\alpha_{\parallel}$	= 1.050(30)	1.042(34)
$\alpha_{\perp}$	= 0.973(56)	1.018(45)	$\alpha_{\perp}$	= 0.916(29)	0.930(36)



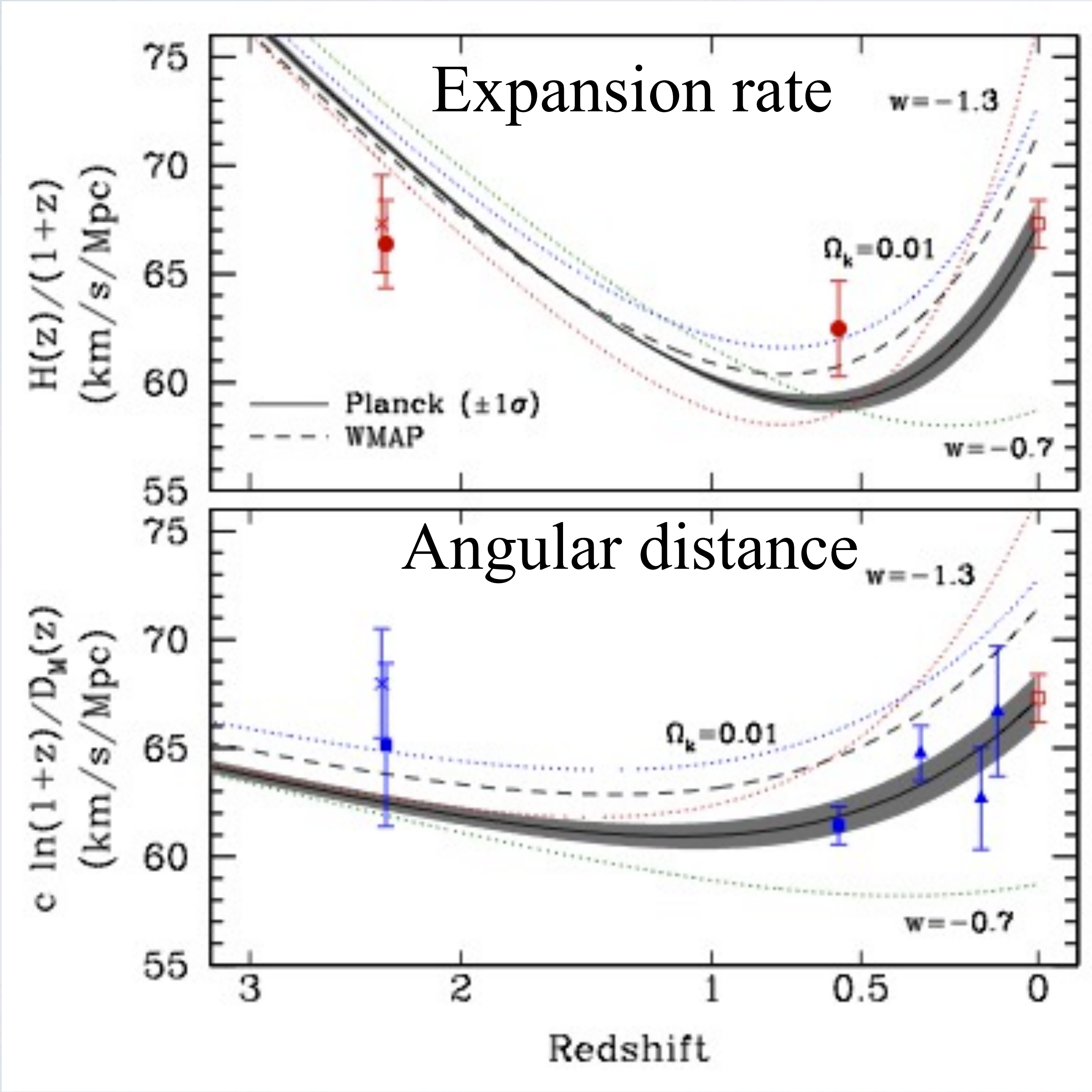
Delubac, JB++2015

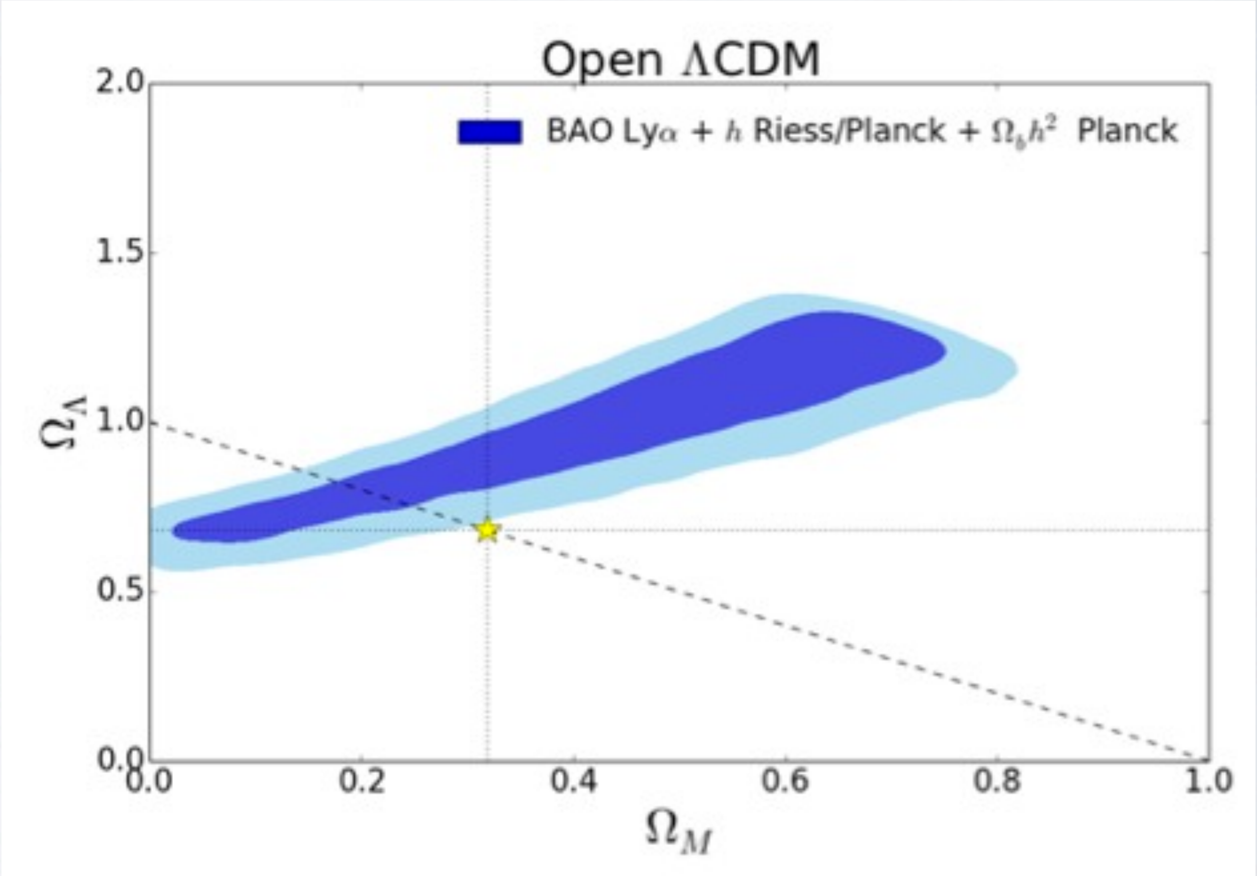


JB++ in prep

Cosmology

DR11





(Aubourg++2014)

What is new in DR12

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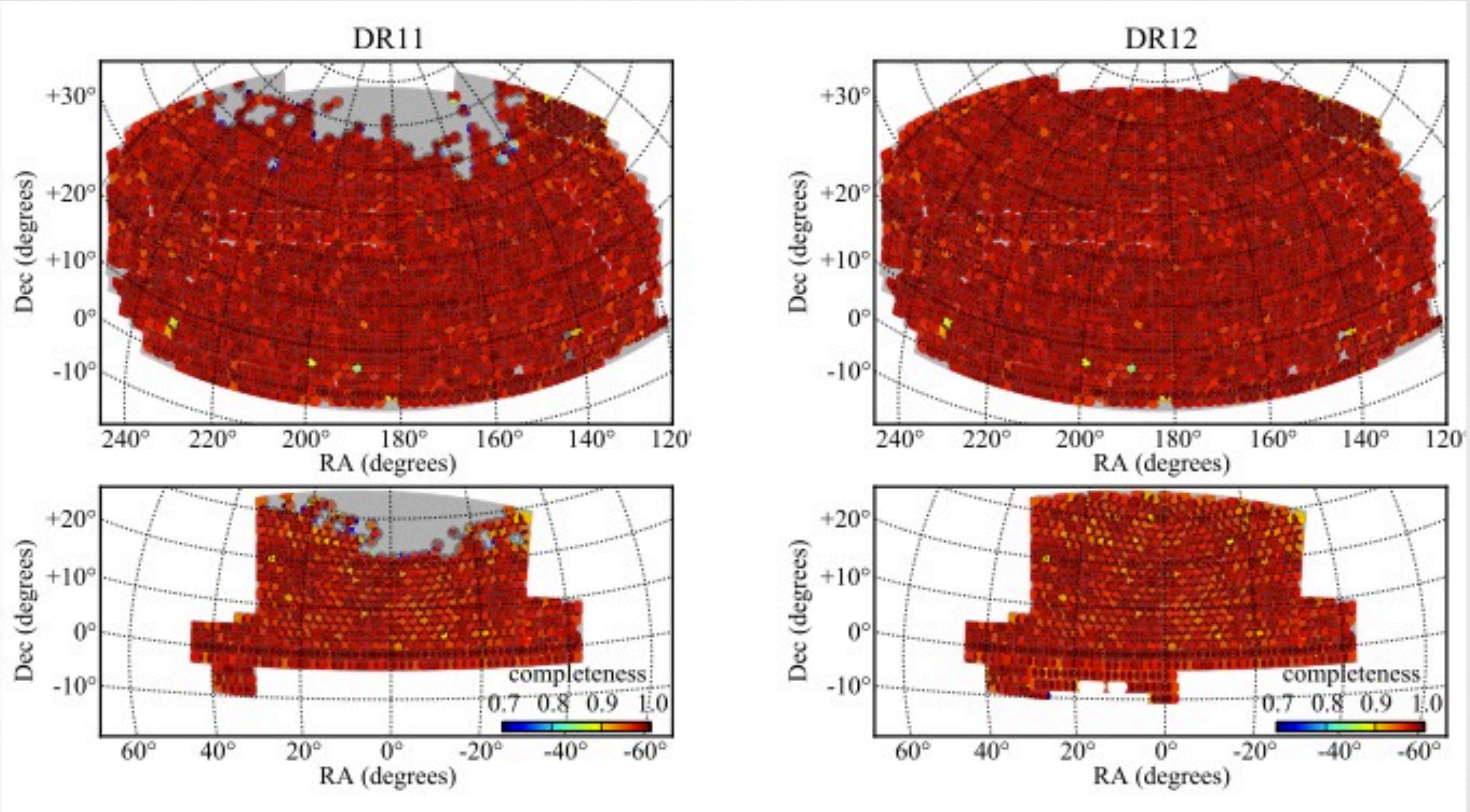
190 000 quasars at $2 < z < 3.5$

15% more than DR11



What is new in DR12

Work in progress!

- Improved modelling of metal contamination in the forest

- New CCD extraction algorithm

- Throughput correction (Margala++2015)

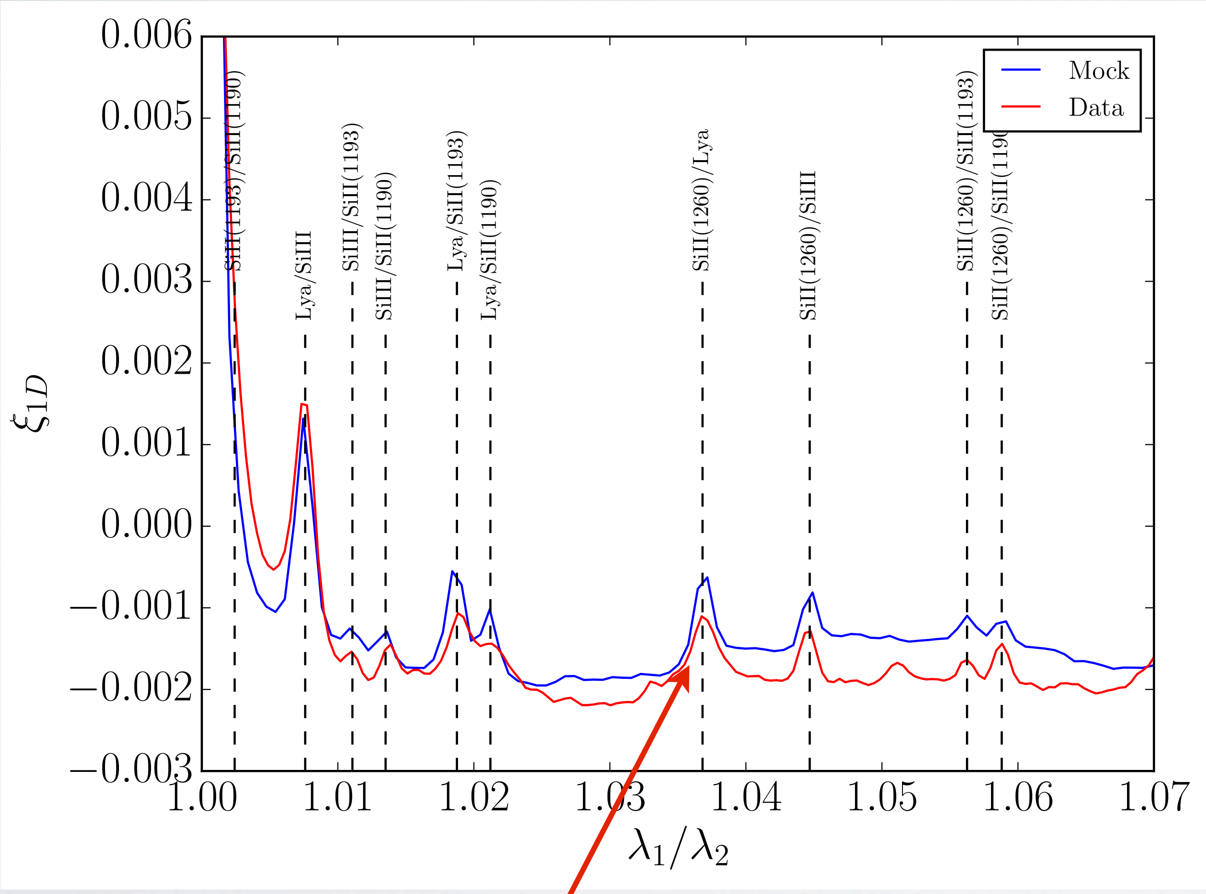
- Null tests

What is new in DR12

Work in progress!

- Improved modelling of metal contamination

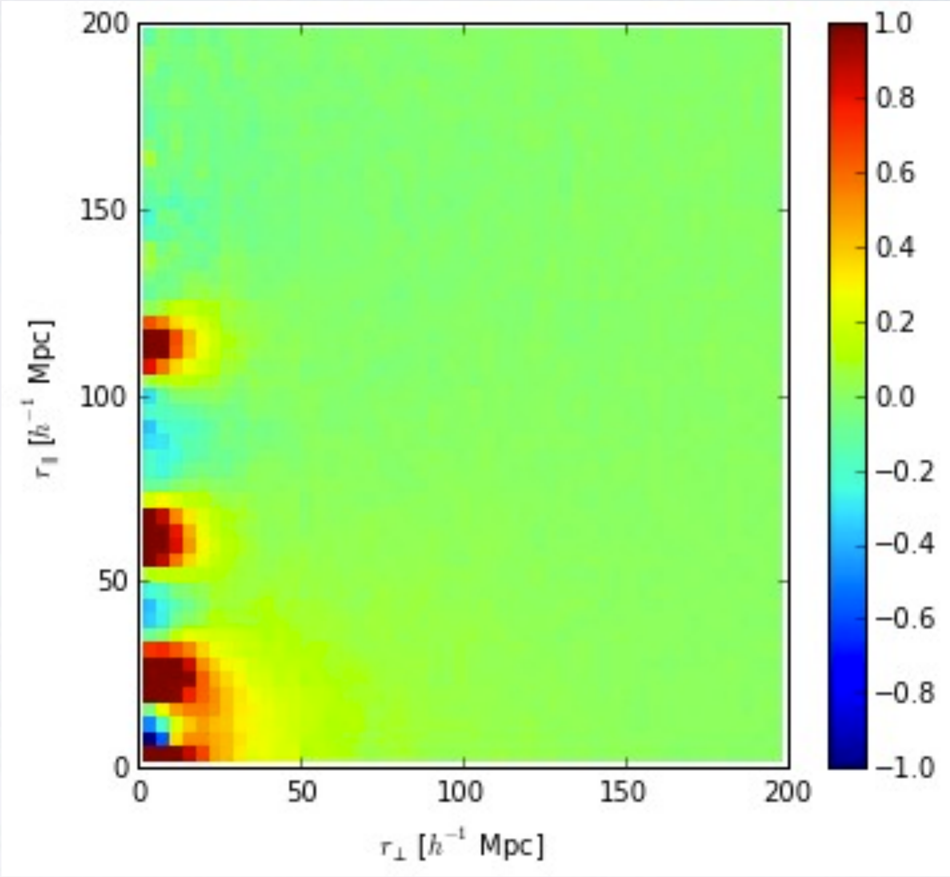
Line of sight correlations



	(nm)
Lyα	121.6
SiIII	120.6
SiII	119.0
SiII	119.3
SiII	126.0

Mocks

$(\xi_{\mathrm{WithMet}} - \xi_{\mathrm{NoMet}})\ [\times 10^{-4}]$



Metal line contaminating the BAO peak

Use of metal templates while fitting for BAO

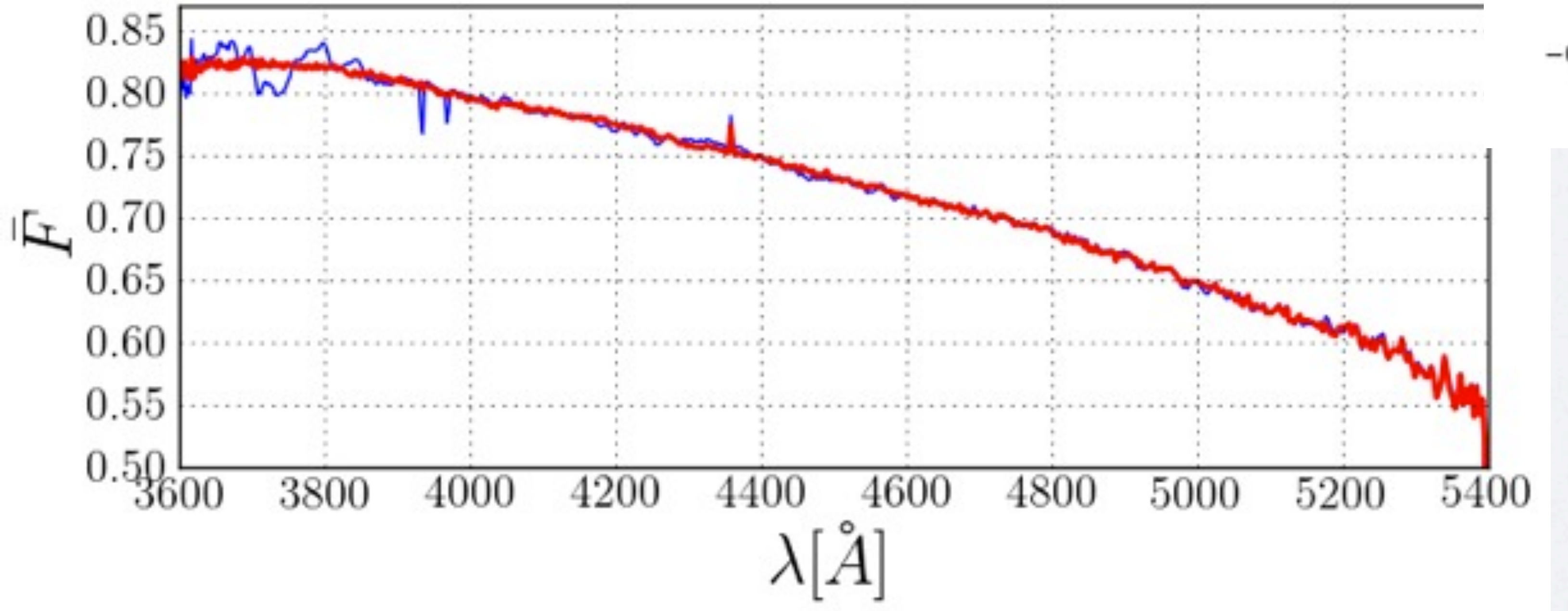
What is new in DR12

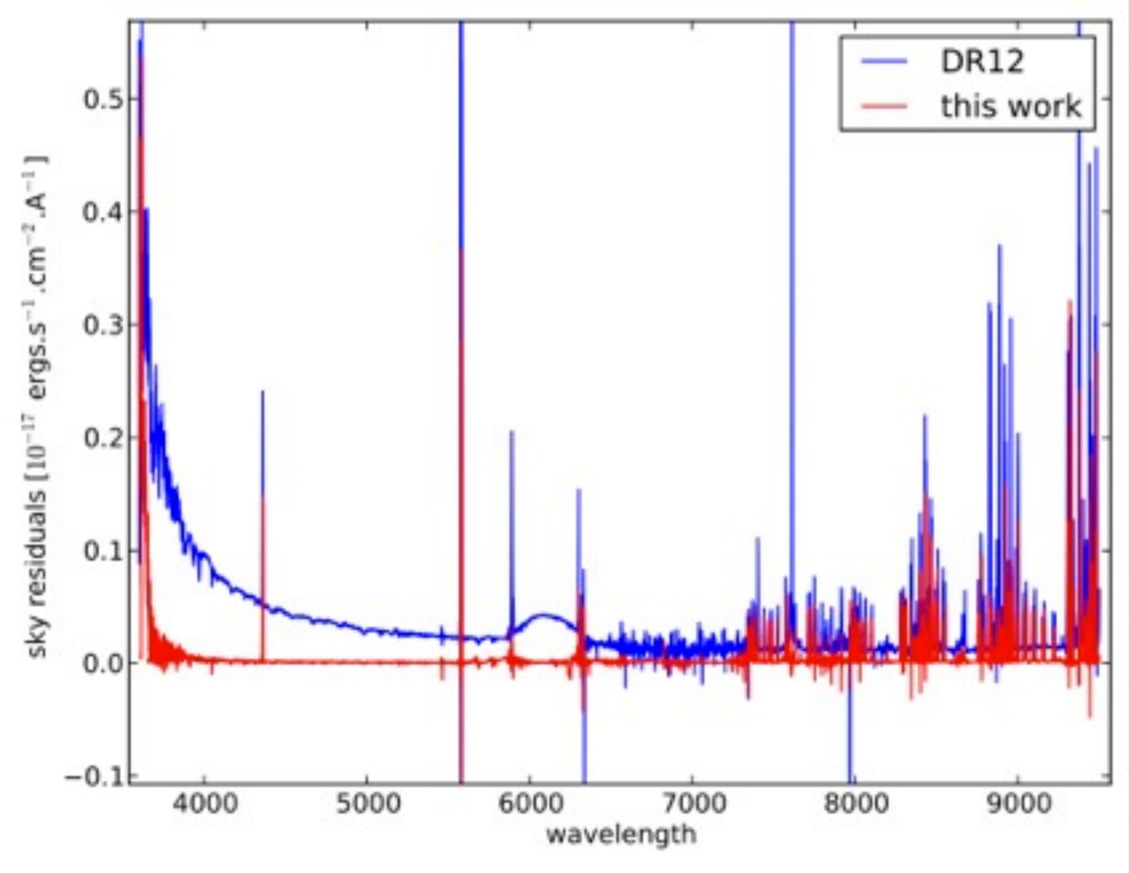
Work in progress!

- New CCD extraction algorithm

Unbiased estimator of counts
More accurate propagation of errors (5% increase)

Cleaner mean transmission



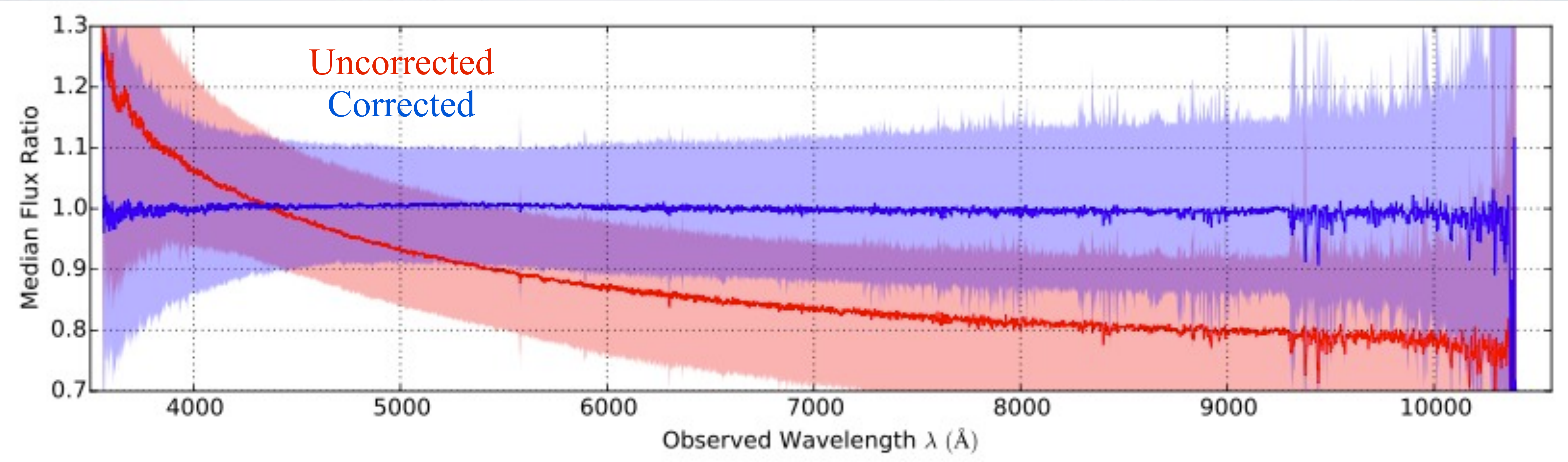


Less sky residuals

What is new in DR12

- Throughput correction (Margala++2015)

Due to different focal plane configurations between stars and quasars



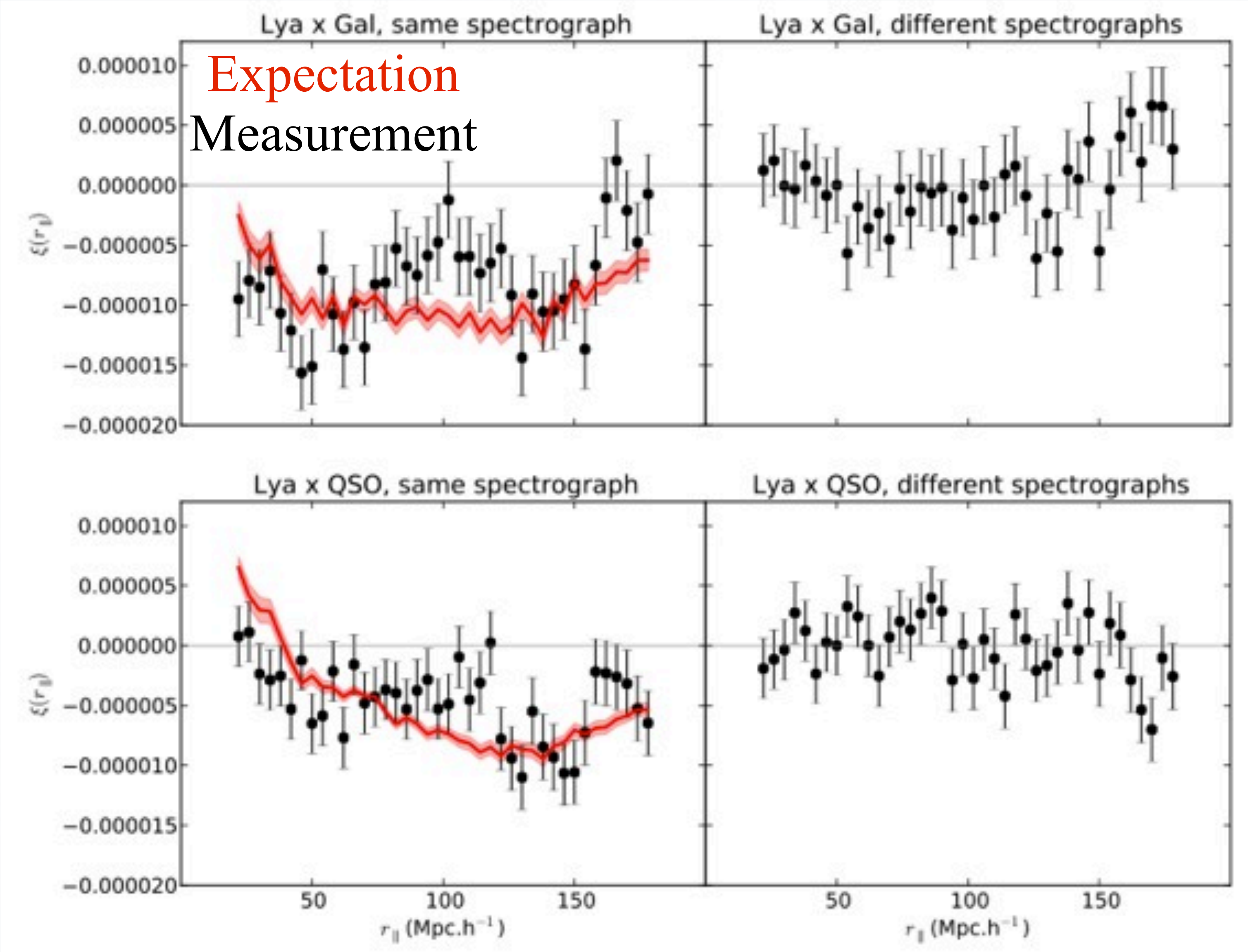
What is new in DR12

Work in progress!

- **Null tests**

  Build fake forests

  Compute correlations



What is new in DR12

Work in progress!

- Systematics

Contributions from sky model, calibration and galactic absorption

	$\Delta\alpha_{\parallel}$	$\Delta\alpha_{\perp}$
Stat.	± 0.026	± 0.045
Sky residuals (in CCD)	$+0.001 \pm 0.002$	$+0.008 \pm 0.005$
Sky residuals (in f.o.v)	-0.003 ± 0.002	$+0.001 \pm 0.005$
Sky model noise	$+0.002 \pm 0.0004$	-0.004 ± 0.001
Calibration noise	< 0.001	$+0.002 \pm 0.0004$
Fiber cross-talk	< 0.001	< 0.001
ISM absorption	< 0.001	< 0.001
Total	$+0.000 \pm 0.003$	$+0.006 \pm 0.007$

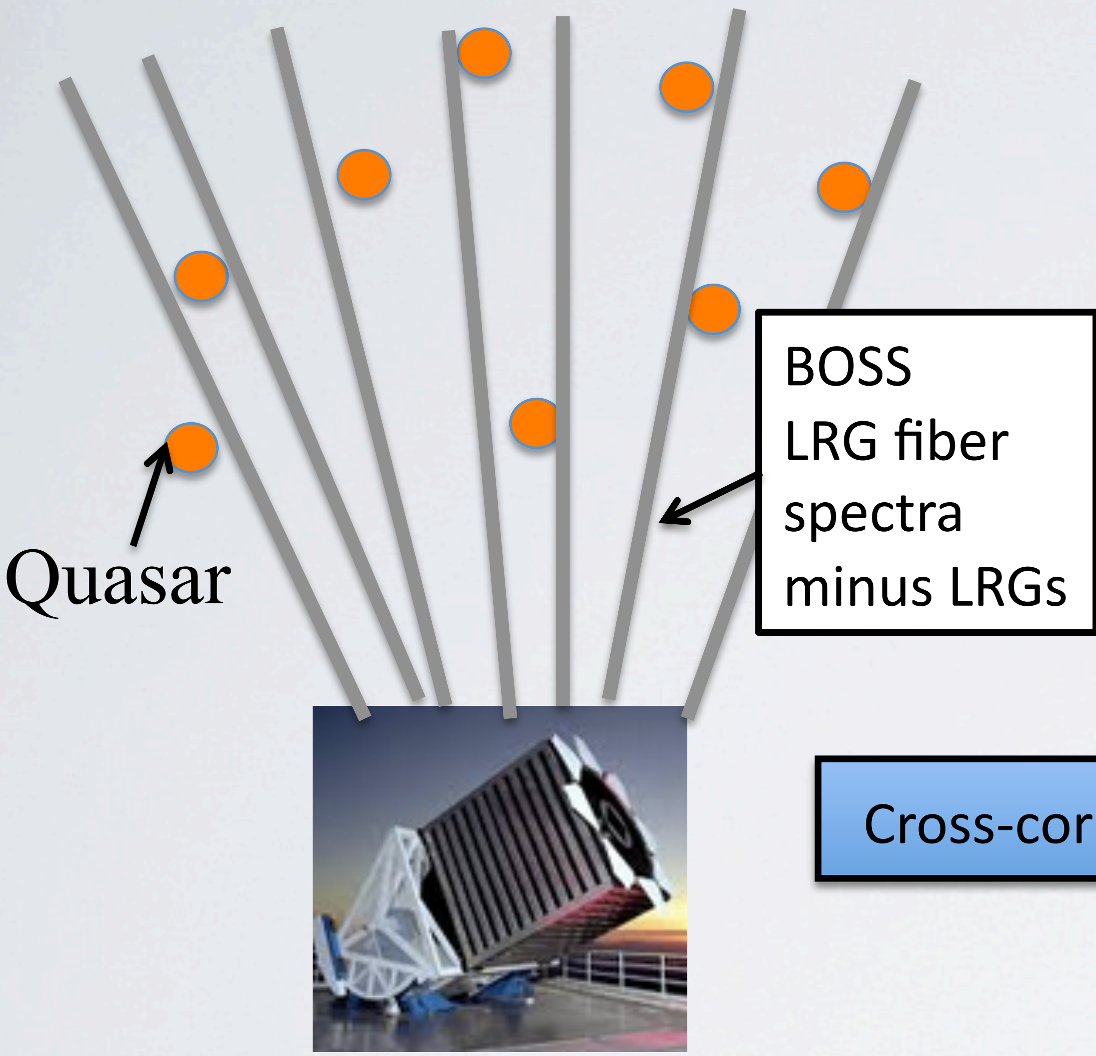
No significant shift in the BAO peak estimates!

CONCLUSIONS

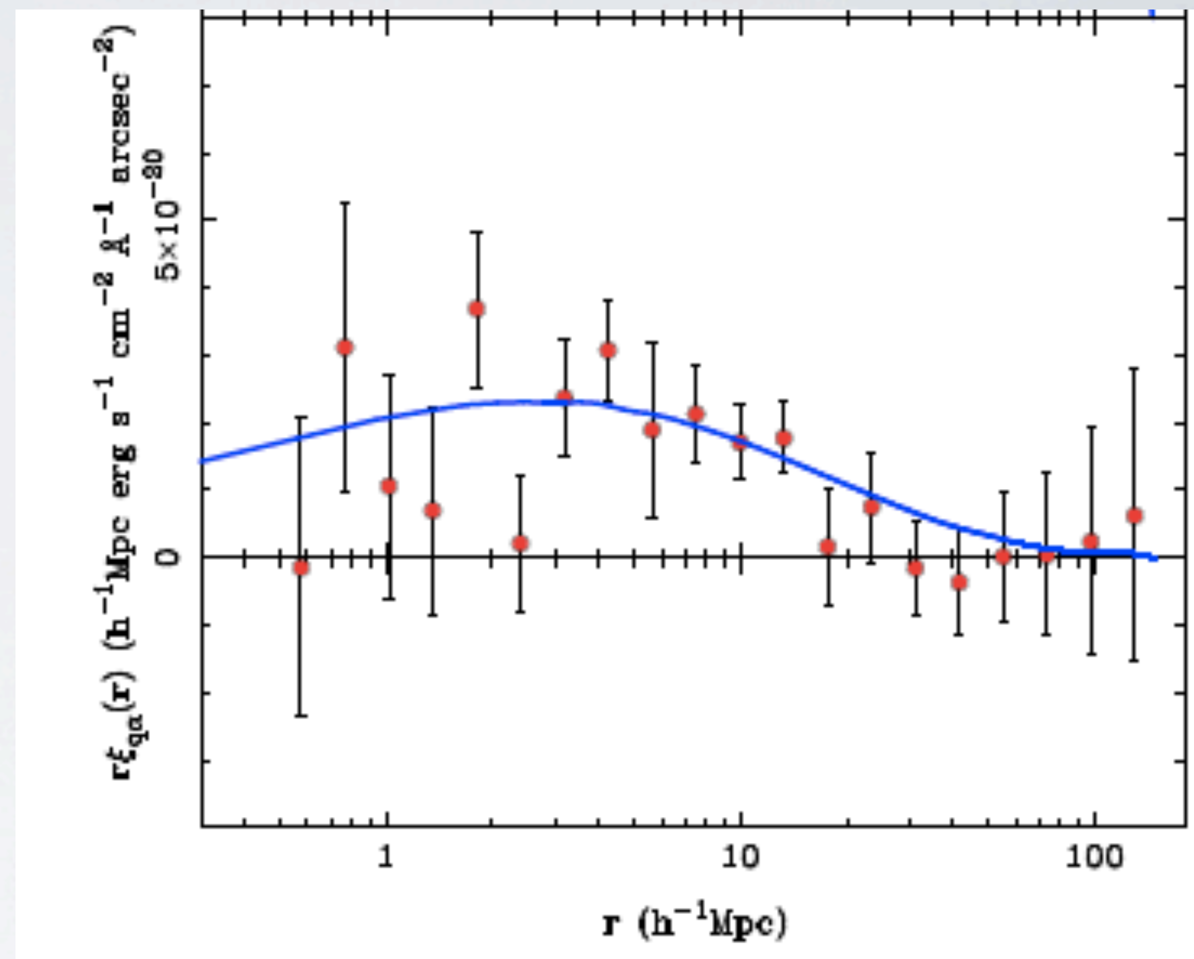
- Lyman-α forest BAO allows us to access expansion at $z \sim 2.3$
- DR12 analysis: 15% more data
- Robust estimate of astrophysical and instrumental systematics
- Stay tuned!

Large-scale structure of Lyman-α **emission** intensity

(First optical intensity mapping result)



Cross-correlation



Quasar-Lya emission cross-correlation:

Shape = Lambda CDM

Amplitude prop. to bias X mean intensity of Lya emission.

Croft, Miralda-Escude, Zheng et al. (2015) arXiv:1504.04088