Measuring the BAO peak using Lyα 3d auto and cross correlation functions (DR14)

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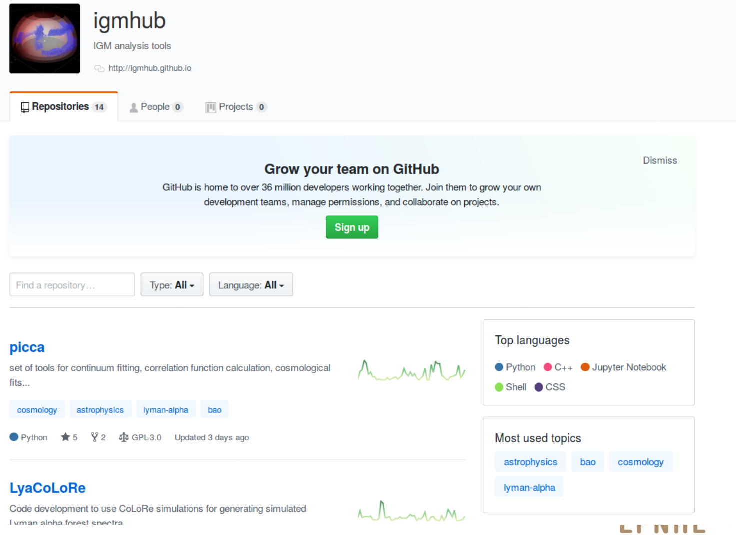
May 7, 2019

- Lyα absorption **auto-correlation** function :
de Sainte Agathe et al., 2019
https://arxiv.org/abs/1904.03400

- Lyα absorption - QSO **cross-correlation** function :
Blomqvist et al., 2019
https://arxiv.org/abs/1904.03430

picca software



https://github.com/igmhub/picca

Adding the Lyβ region

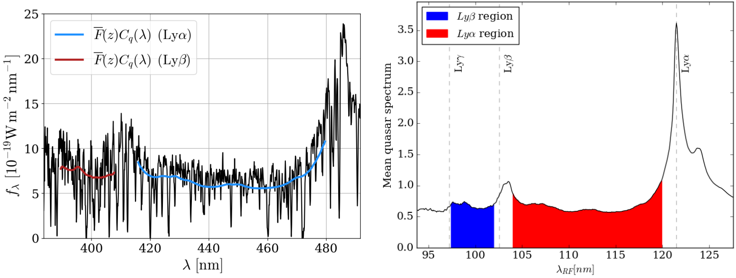


Figure: Lyα and Lyβ regions in the quasar spectrum.

- Auto : Lyα(Lyα)$\times$Lyα(Lyα) and Lyα(Lyα)$\times$Lyα(Lyβ)
- Cross : QSO$\times$Lyα(Lyα+Lyβ)

$\longrightarrow$ We extend by 9% the number of absorptions

Auto : the position of the BAO peak is not model dependant

$\alpha_{\|}$ controls the position of the BAO peak along the LOS
$\alpha_{\perp}$ controls the position of the peak transversally to the LOS

Table 6. Best fit values of $(\alpha_{\|}, \alpha_{\perp})$ for the Lyα(Lyα) × Lyα(Lyα+Lyβ) correlation function fit with various models. The first group includes physical models starting with the basic Kaiser redshift-space model and then including, progressively, metals, HCD, and UV corrections. Fits in the second group include polynomial broadband terms, as described in the text.

Models	$\alpha_{\|}$	$\alpha_{\perp}$	χ^2/DOF	Probability
Kaiser	1.021 ± 0.028	0.977 ± 0.040	3624.74/(3180-4)	3.46×10^{-8}
+Metals	1.025 ± 0.032	0.979 ± 0.044	3607.96/(3180-9)	7.14×10^{-8}
+HCD (baseline)	1.033 ± 0.031	0.953 ± 0.042	3258.92/(3180-12)	0.127
+UV	1.033 ± 0.031	0.953 ± 0.042	3258.84/(3180-13)	0.125
BB				
Physical priors on $(b_{\mathrm{Ly}\alpha}, \beta_{\mathrm{Ly}\alpha}, b_{\mathrm{HCD}})$	1.037 ± 0.028	0.972 ± 0.040	3006.25/(3030-36)	0.434
No additional priors	1.032 ± 0.027	0.980 ± 0.039	3001.00/(3030-36)	0.460

$\longrightarrow$ We have tried many different models and the $(\alpha_{\|}, \alpha_{\perp})$ are stable

Cross : the position of the BAO peak is not model dependant

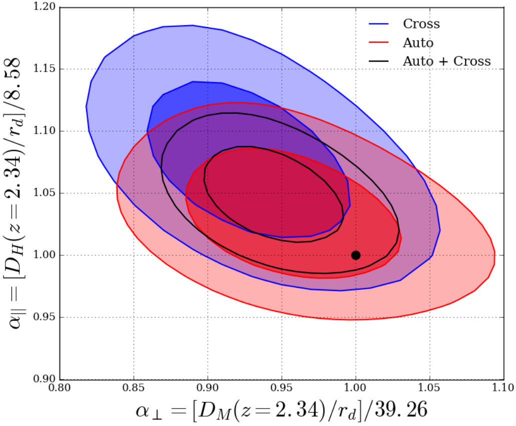
Table A.1. Results of non-standard fits. The first group presents results of successively adding complications from physical effects to the basic Lyα-only model. These complications are: metals, absorption by high-column density systems, the transverse proximity effect, and the relativistic dipole, corresponding to the standard fit from column 1 of Table 5. The second group presents fits which include fluctuations of the UV background radiation, the odd multipoles $\ell = (1, 3)$ or the broadband function (for this group we set $\xi^{qHCD} = 0$). The last group presents fits for non-standard data samples: no absorption in the Lyβ region or no correction of DLAs in the spectra. The fit is over the range $10 < r < 180\ h^{-1}$ Mpc. Errors correspond to $\Delta\chi^2 = 1$.

Analysis	$\alpha_{\parallel}$	$\alpha_{\perp}$	β_{α}	$b_{\eta\alpha}$	χ^2_{min}/DOF, probability
Lyα	1.073 ± 0.041	0.925 ± 0.045	2.75 ± 0.21	-0.285 ± 0.012	$3268.55/(3180-6), p = 0.12$
+ metals	1.074 ± 0.041	0.921 ± 0.045	2.76 ± 0.22	-0.281 ± 0.012	$3239.52/(3180-10), p = 0.19$
+ HCD	1.074 ± 0.041	0.921 ± 0.045	2.76 ± 0.22	-0.281 ± 0.017	$3239.52/(3180-12), p = 0.18$
+ TP	1.075 ± 0.040	0.923 ± 0.043	2.31 ± 0.30	-0.269 ± 0.014	$3236.62/(3180-13), p = 0.19$
+ rel1	1.076 ± 0.040	0.923 ± 0.043	2.28 ± 0.31	-0.267 ± 0.014	$3231.61/(3180-14), p = 0.20$
UV	1.077 ± 0.040	0.923 ± 0.043	2.34 ± 0.32	-0.274 ± 0.020	$3231.30/(3180-13), p = 0.21$
odd-ℓ	1.074 ± 0.040	0.927 ± 0.045	2.33 ± 0.32	-0.267 ± 0.014	$3223.25/(3180-16), p = 0.23$
BB (0,2,0,6)	1.083 ± 0.039	0.921 ± 0.043	2.53 ± 0.46	-0.280 ± 0.022	$3223.75/(3180-24), p = 0.20$
no Lyβ	1.084 ± 0.040	0.921 ± 0.042	2.33 ± 0.32	-0.272 ± 0.014	$3231.05/(3180-14), p = 0.21$
keep DLAs	1.071 ± 0.042	0.929 ± 0.049	2.08 ± 0.27	-0.279 ± 0.016	$3217.64/(3180-14), p = 0.26$

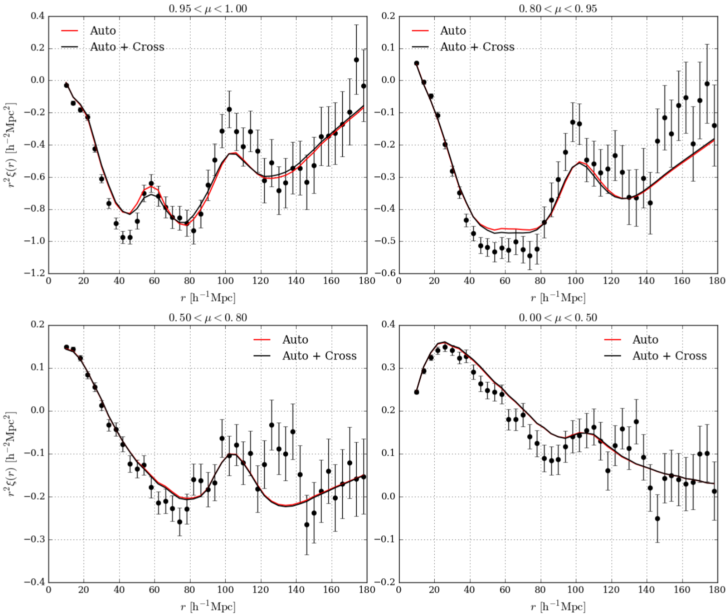
$\longrightarrow$ We have tried many different models and the $(\alpha_{\parallel}, \alpha_{\perp})$ are stable

Combining fit using both auto and cross correlation functions

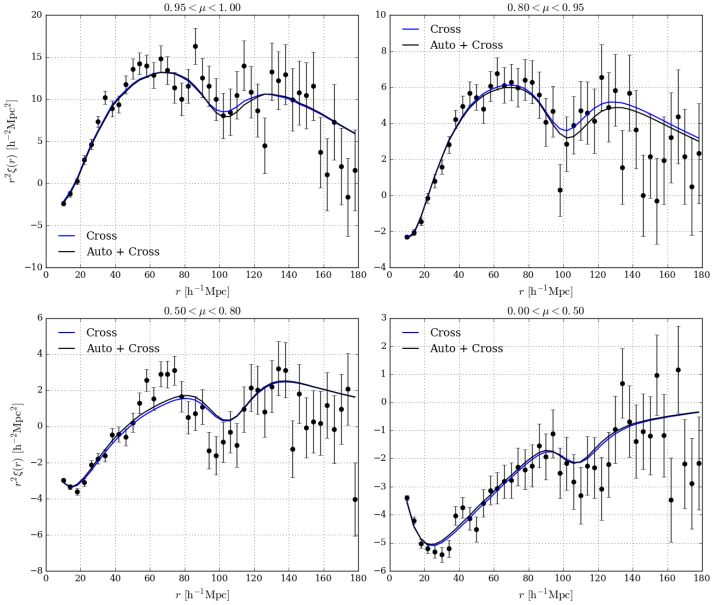
Parameter	Lyα-quasar	Lyα-Lyα	combined
$\alpha_{\parallel}$	1.076 ± 0.042	1.033 ± 0.034	1.049 ± 0.026
$\alpha_{\perp}$	0.923 ± 0.046	0.953 ± 0.048	0.942 ± 0.031



The Lyα auto-correlation function



The QSO×Lyα cross-correlation function



Constraining Ω_M, Ω_Λ parameters

$$\alpha_\parallel = \frac{D_H/r_d}{[D_H/r_d]_{fid}} \qquad \alpha_\perp = \frac{D_M/r_d}{[D_M/r_d]_{fid}} \tag{1}$$

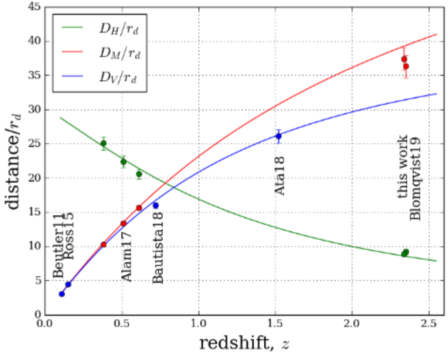


Fig. 10. BAO measurement of D_H/r_d and D_M/r_d using BOSS galaxies (Alam et al. 2017), Lyα absorption in BOSS-eBOSS quasars (this work) and correlation between BOSS-eBOSS quasars and Lyα absorption (Blomqvist et al. 2019). Other measurements give D_V/r_d, with $D_V = D_M^{2/3}(zD_H)^{1/3}$, using galaxies (Beutler et al. (2011), Ross et al. (2015), Bautista et al. (2018)) and BOSS-eBOSS quasars (Ata et al. 2018). Solid lines show the Pl2015 values (Planck Collaboration et al. 2016).

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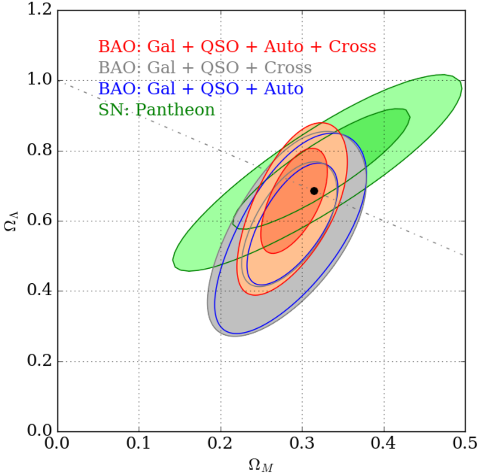
Constraining Ω_M, Ω_Λ parameters

$\longrightarrow$ combined with galaxies and quasars BAO measurements gives :

$$\Omega_M = 0.293 \pm 0.027 \qquad \Omega_\Lambda = 0.675 \pm 0.099 \tag{2}$$



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Conclusion

- The ensemble of BAO measurements is in **good agreement with the CMB-inspired flat ΛCDM model**. By themselves, the BAO data provide a good confirmation of this model.

- The BAO measurements presented here will be **improved by DESI** by increasing the number of quasars and improving the spectral resolution.

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