

Measuring the BAO peak using $\text{Ly}\alpha$ 3d auto and cross correlation functions (DR14)

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May 7, 2019

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- ▶ Ly α absorption **auto-correlation** function :
de Sainte Agathe et al., 2019
<https://arxiv.org/abs/1904.03400>

- ▶ Ly α absorption - QSO **cross-correlation** function :
Blomqvist et al., 2019
<https://arxiv.org/abs/1904.03430>

picca software

The screenshot shows the GitHub profile for 'igmhub', which is described as 'IGM analysis tools'. The profile has 14 repositories, 0 people, and 0 projects. A banner encourages users to 'Grow your team on GitHub' with a 'Sign up' button. Below the banner is a search bar for repositories, with filters for 'Type: All' and 'Language: All'. The main content area features the repository 'picca', described as a 'set of tools for continuum fitting, correlation function calculation, cosmological fits...'. It includes tags for 'cosmology', 'astrophysics', 'lyman-alpha', and 'bao', and is written in Python. To the right, there are sections for 'Top languages' (Python, C++, Jupyter Notebook, Shell, CSS) and 'Most used topics' (astrophysics, bao, cosmology, lyman-alpha). The 'L'YMAN ALPHA' logo is visible in the bottom right corner of the page content.

igmhub
IGM analysis tools
<http://igmhub.github.io>

Repositories 14 People 0 Projects 0

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picca
set of tools for continuum fitting, correlation function calculation, cosmological fits...

cosmology astrophysics lyman-alpha bao

Python ★ 5 🗄 2 📄 GPL-3.0 Updated 3 days ago

LyaCoLoRe
Code development to use CoLoRe simulations for generating simulated Lyman alpha forest spectra

Top languages

- Python
- C++
- Jupyter Notebook
- Shell
- CSS

Most used topics

- astrophysics
- bao
- cosmology
- lyman-alpha

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<https://github.com/igmhub/picca>

Adding the Ly β region

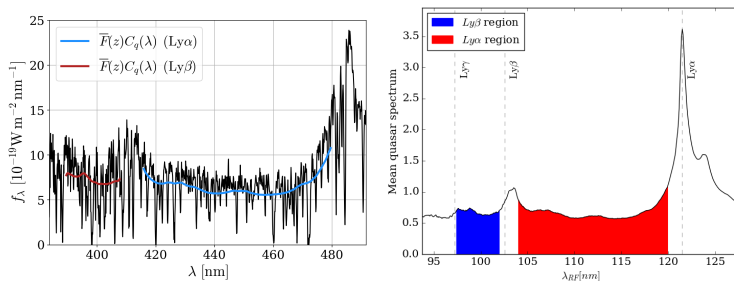


Figure: Ly α and Ly β regions in the quasar spectrum.

- ▶ Auto : Ly α (Ly α) \times Ly α (Ly α) and Ly α (Ly α) \times Ly α (Ly β)
- ▶ Cross : QSO \times Ly α (Ly α +Ly β)

→ We extend by 9% the number of absorptions

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

α_{\parallel} controls the position of the BAO peak along the LOS

α_{\perp} controls the position of the peak transversally to the LOS

Table 6. Best fit values of $(\alpha_{\parallel}, \alpha_{\perp})$ for the $\text{Ly}\alpha(\text{Ly}\alpha) \times \text{Ly}\alpha(\text{Ly}\alpha + \text{Ly}\beta)$ 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	α_{\parallel}	α_{\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 $(b_{\text{Ly}\alpha}, \beta_{\text{Ly}\alpha}, b_{\text{HCD}})$	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

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

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

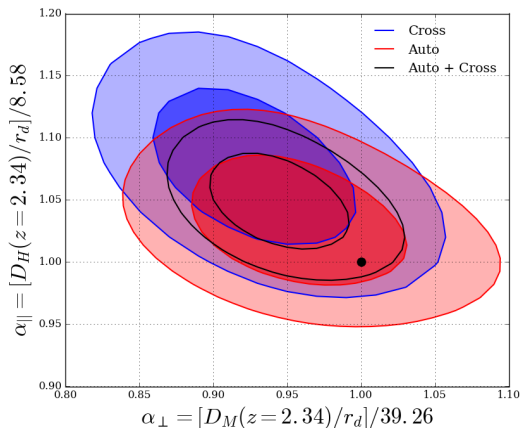
Table A.1. Results of non-standard fits. The first group presents results of successively adding complications from physical effects to the basic Ly α -only model. These complications are: metals, absorption by high-column density systems, the transverse proximity effect, and the relativistic dipole, 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 $\xi^{\text{HCD}} = 0$). The last group presents fits for non-standard data samples: no absorption in the Ly β 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	α_{\parallel}	α_{\perp}	β_{α}	$b_{\eta\alpha}$	χ^2_{min}/DOF , probability
Ly α	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	$3236.62/(3180 - 13)$, $p = 0.19$
+ rell	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 Ly β	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	$3217.64/(3180 - 14)$, $p = 0.26$

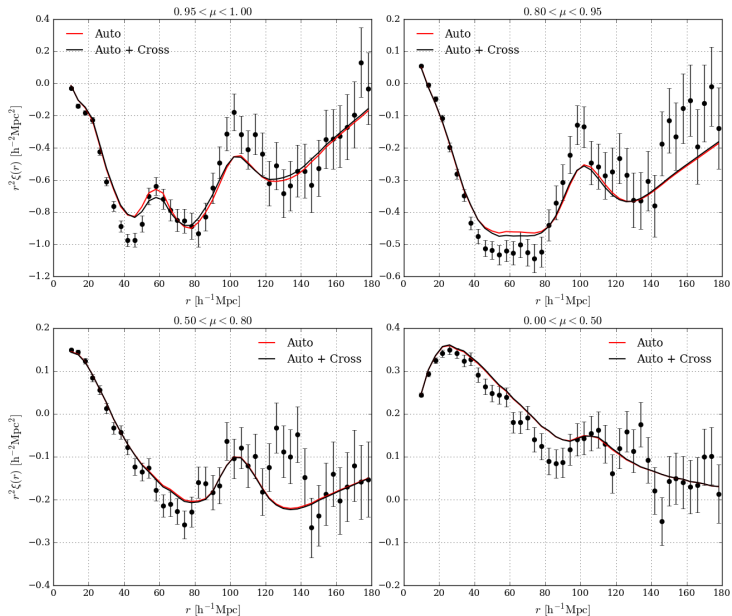
→ We have tried many different models and the $(\alpha_{\parallel}, \alpha_{\perp})$ are stable

Combining fit using both auto and cross correlation functions

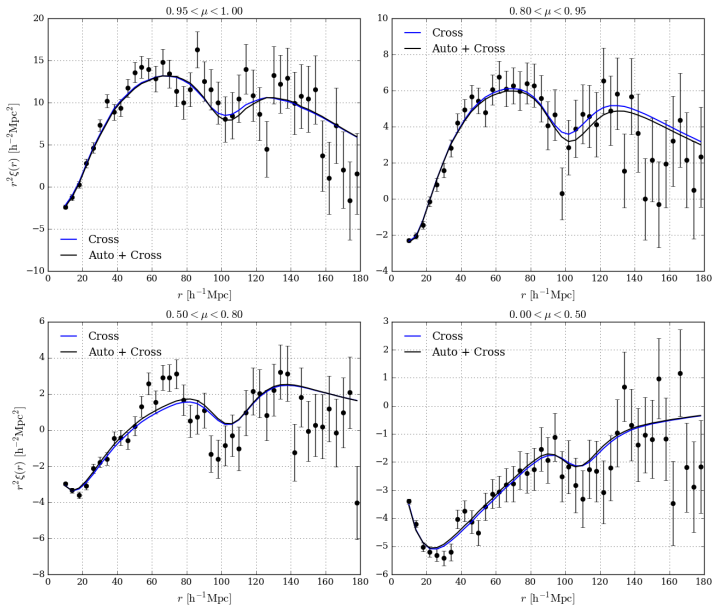
Parameter	Ly α -quasar	Ly α -Ly α	combined
α_{\parallel}	1.076 ± 0.042	1.033 ± 0.034	1.049 ± 0.026
α_{\perp}	0.923 ± 0.046	0.953 ± 0.048	0.942 ± 0.031



The Ly α auto-correlation function



The QSO \times Ly α cross-correlation function



Constraining Ω_M, Ω_Λ parameters

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

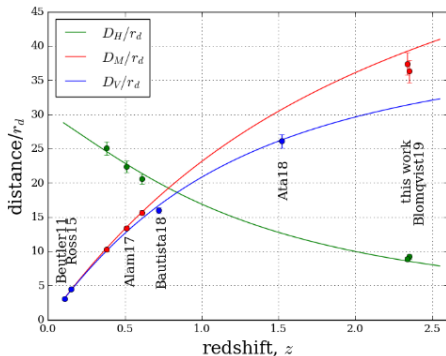


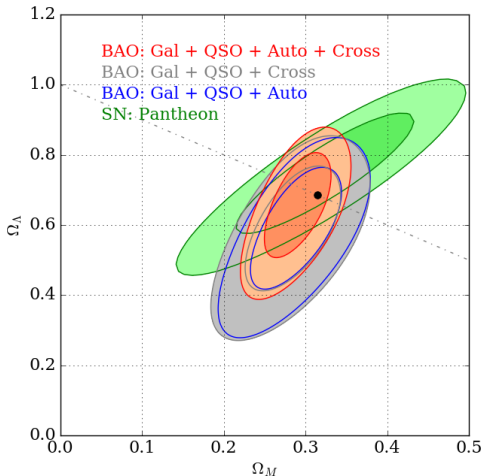
Fig. 10. BAO measurement of D_H/r_d and D_M/r_d using BOSS galaxies (Alam et al. 2017), Ly α absorption in BOSS-eBOSS quasars (this work) and correlation between BOSS-eBOSS quasars and Ly α absorption (Blomqvist et al. 2019). Other measurements give D_V/r_d , with $D_V = D_M^{2/3}(zD_H)^{1/3}$, using 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 Planck 2015 values (Planck Collaboration et al. 2016).



Constraining Ω_M, Ω_Λ parameters

→ combined with galaxies and quasars BAO measurements gives :

$$\Omega_M = 0.293 \pm 0.027 \quad \Omega_\Lambda = 0.675 \pm 0.099 \quad (2)$$



Conclusion

- ▶ The ensemble of BAO measurements is in **good agreement with the CMB-inspired flat Λ CDM 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.