Has α changed over time?

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Has α changed over time?

Dirac (1937) **'Very large and very small dimensionless universal constants cannot be pure mathematical numbers and should rather be considered as variable parameters characterizing the state of the Universe.'**

Fine structure constant

$$\alpha = \frac{e^2}{\hbar c} \sim 1/137$$

In some unification theories (Kaluza-Klein, superstring) constants of nature are functions of a low mass scalar field which slowly changes over cosmological timescales

(e. g. Uzan 2003)

Astrophysical methods (e. g. Garcia-Berro et. al. 2007) allow to measure α (z) by analyzing

- Cosmic Microwave Background
- Big Bang Nucleosynthesis
- Fine structure splitting of atomic lines in QSO
  - -Alkali Doublet Method
  - -Many Multiplet Method

$\Delta\alpha / \alpha < 10^{-2}$-$10^{-3}$

$\Delta\alpha / \alpha < 10^{-5}$-$10^{-6}$

but controversial

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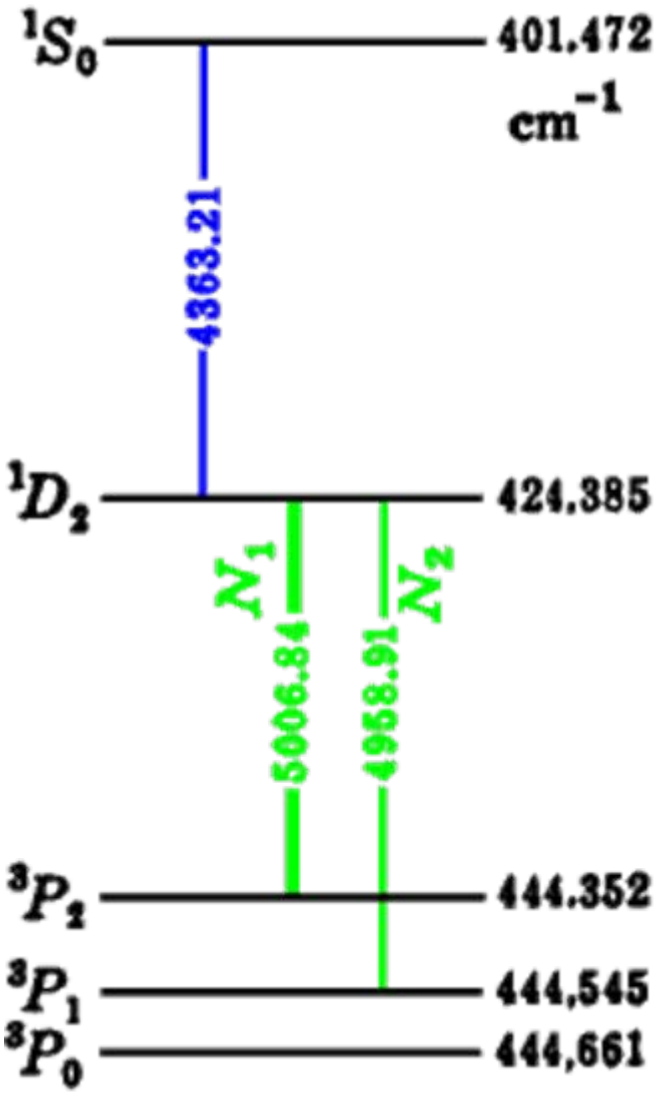
We follow a method (Bahcall & Salpeter 1965) based on the relative separation of [OIII] doublet produced in the NLR of QSOs

[OIII] doublet

λ_2=5008 Å

λ_1=4960 Å

$$\alpha(z) \sim (\lambda_2-\lambda_1)(z)$$



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$$\frac{\Delta\alpha}{\alpha}(z) = \frac{1}{2}\left\{\frac{[(\lambda_2-\lambda_1)/(\lambda_2+\lambda_1)]_z}{[(\lambda_2-\lambda_1)/(\lambda_2+\lambda_1)]_0} - 1\right\}$$

Uzan (2003)

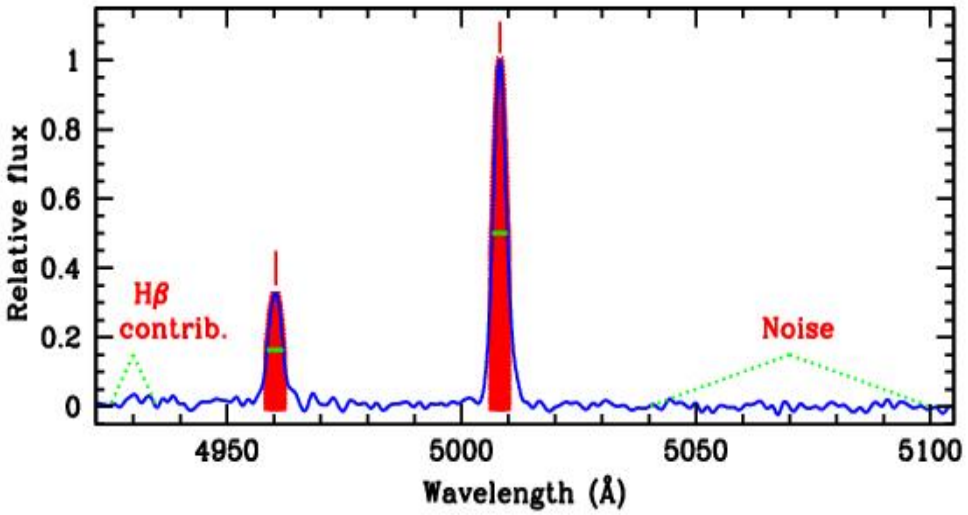
SAMPLE

- SDSS DR6 spectroscopic survey contains 77,082 QSOs,
- resolution 2000 km/s
- range 3400-9200 Å
- [OIII] up to z~0.85 (28,860 objects)

Checking the calibration:

OI line 5578.885 Å, σ= 0.287 Å
(theory gives 5578.887 Å)

On the basis of intensity of OIII, H_β, and continuum we select ~1600 spectra.



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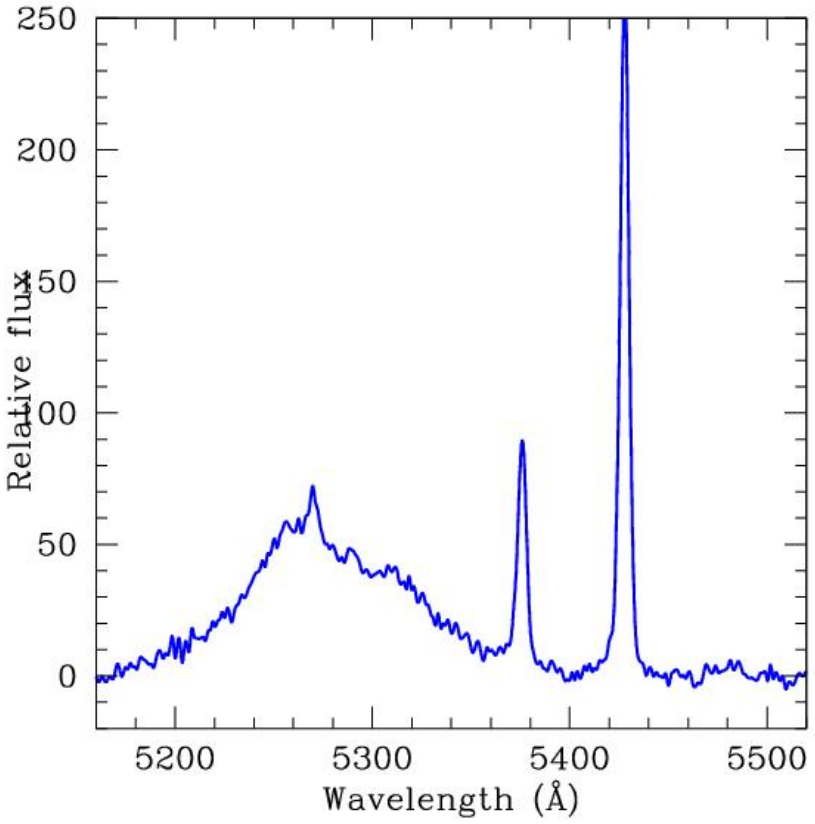
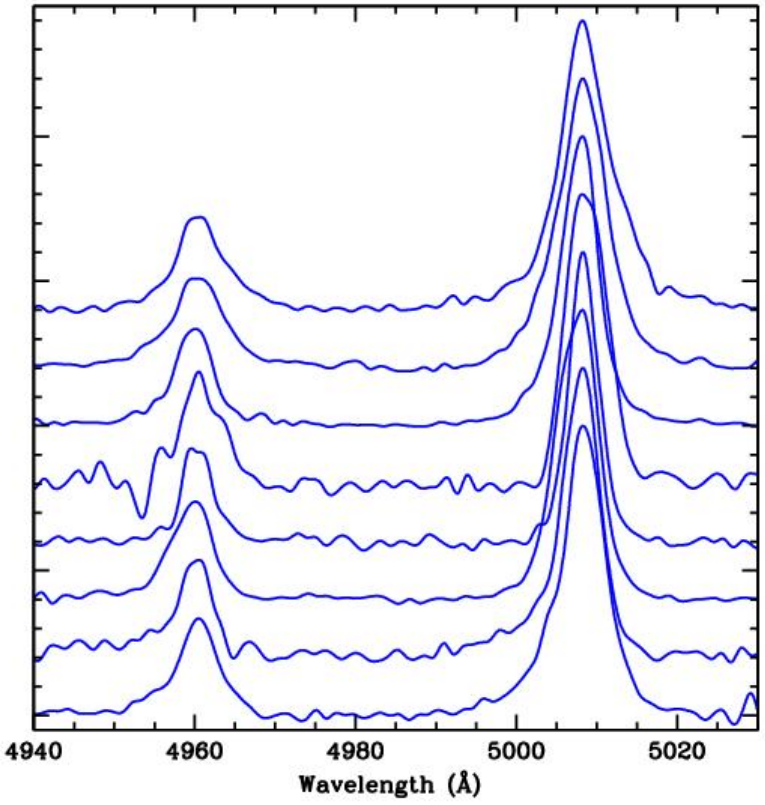
Some examples

Rejected (95 %)



Accepted 5 %



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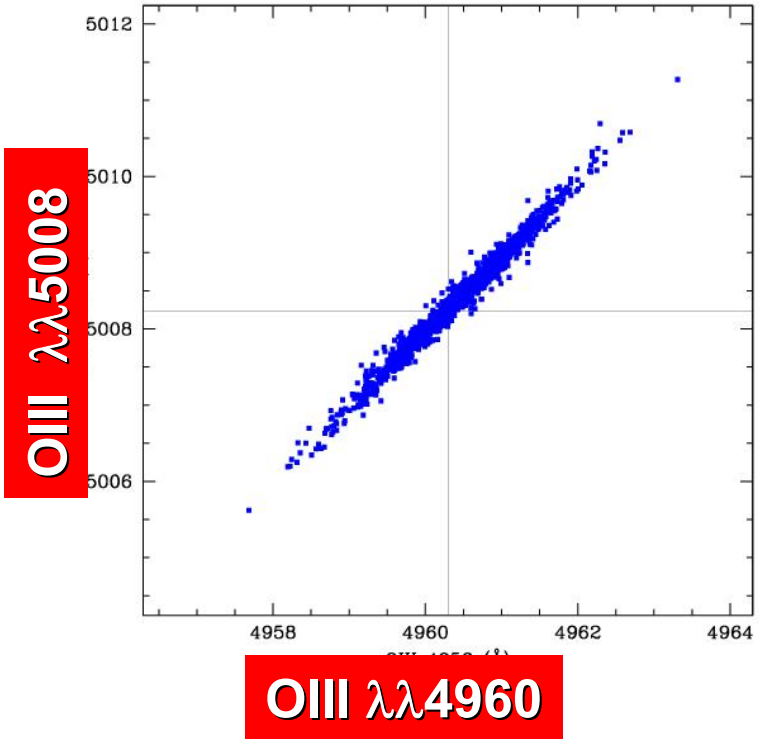
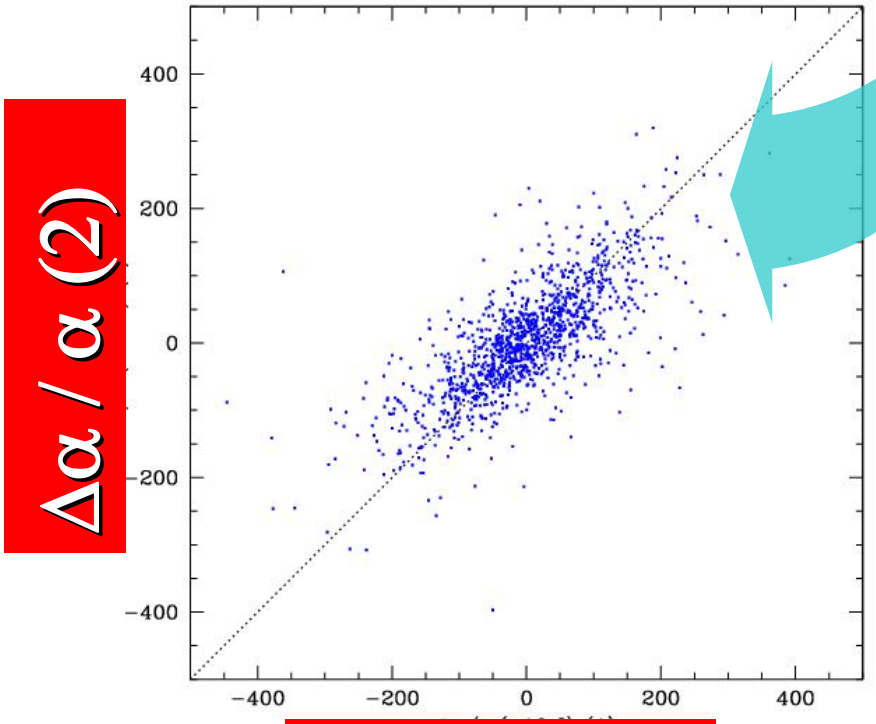
Rest frame position of [OIII] lines

Two methods to estimate the centroids give similar results





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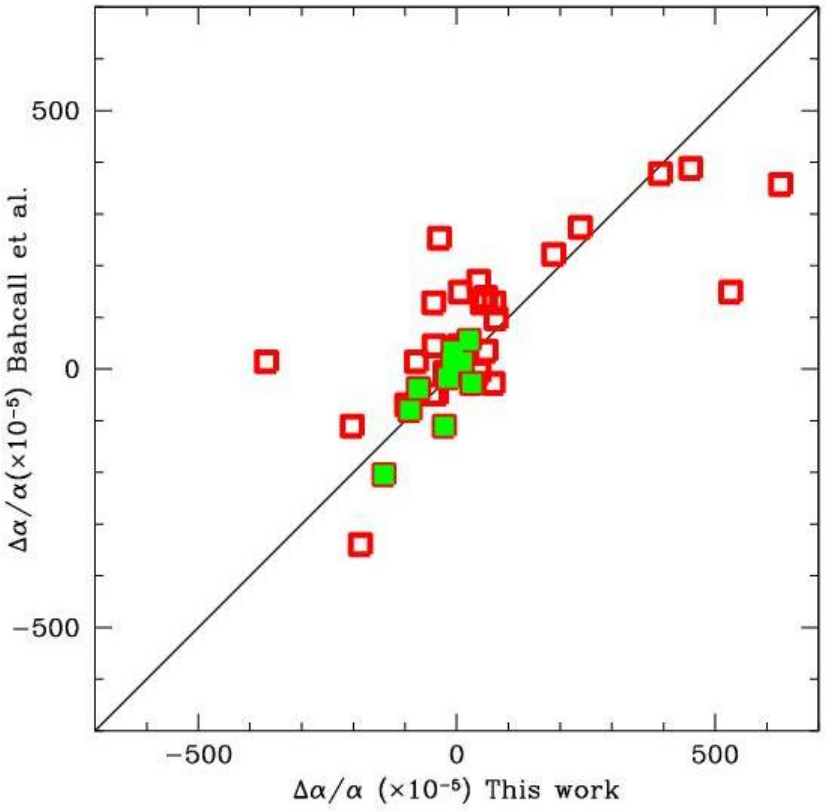
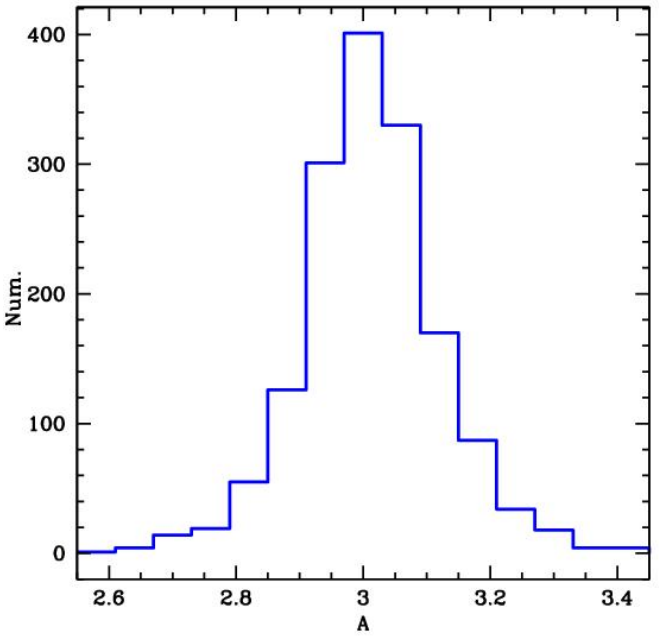
Comparison with Bahcall et al. (2004)

$$A \propto \frac{A(5008)\Delta E(5008)}{A(4959)\Delta E(4959)}$$





A=3.012 ± 0.003 ± 0.010

Larger sample (~x 25)

Better sensitivity (~5-6)

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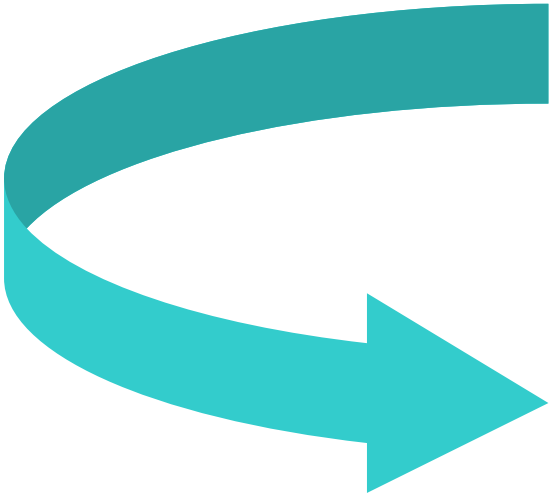
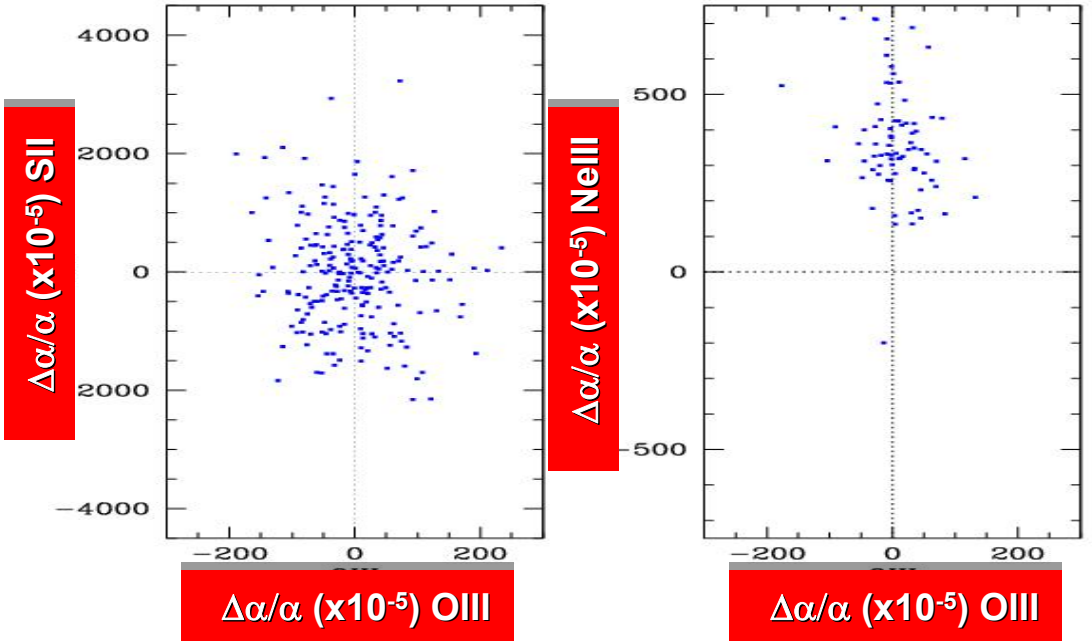
- Other doublets ([NeIII], [NeV], [SII], [OI]) offer the possibility to check the results and extend the analysis to higher redshifts.
- However, those lines are usually fainter and are subject to several uncertainties (contaminants, unaccurate theoretical values, etc)

Comparison with [OIII]





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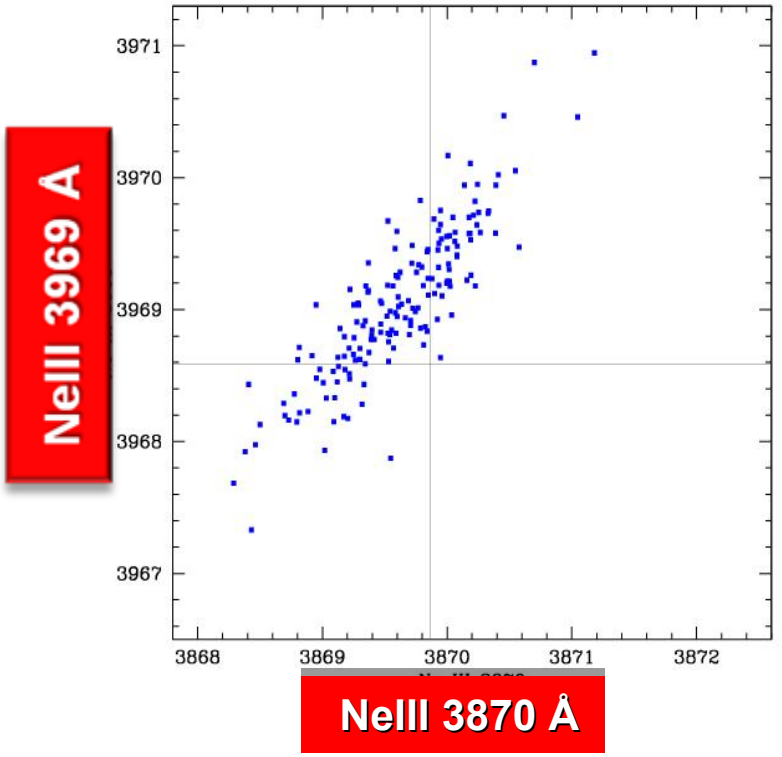
Results for the different atomic species

Doublet	Spectra	$\Delta\alpha/\alpha$ (10^{-5})	1σ Errors
O III	1568	+2.4	2.5
Ne III	168	+358.5	11.2
S II	481	–18.8	41.8

[NeIII] lines shifted likely due to the contamination of H_ε, CaII-H or wrong theoretical values (not completely clear)



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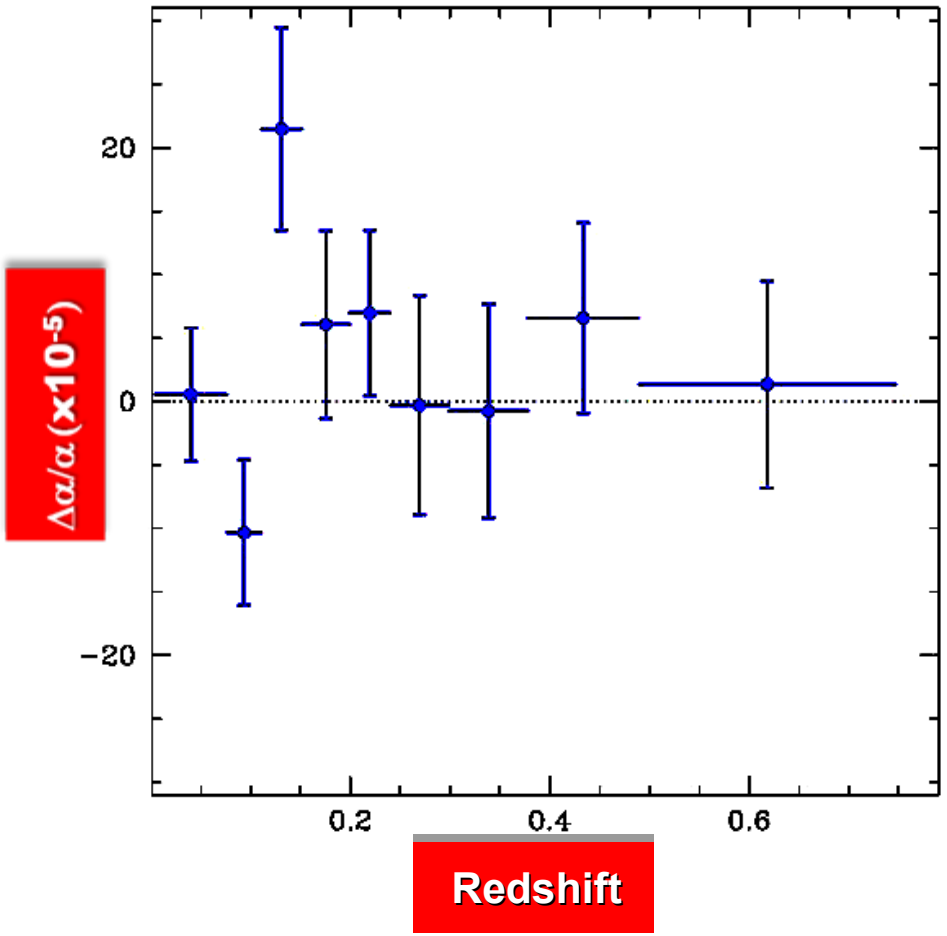

Redshift	$\Delta\alpha/\alpha$ (10^{-5})	1σ Errors
0.003-0.076	+0.6	5.2
0.076-0.110	–10.3	5.7
0.110-0.152	+21.5	8.0
0.152-0.199	+6.1	7.4
0.199-0.240	+7.0	6.5
0.240-0.300	–0.3	8.6
0.300-0.378	–0.8	8.4
0.378-0.490	+6.6	7.5
0.490-0.747	+1.4	8.2

$$\Delta\alpha / \alpha < (+2.4 \pm 2.5) \times 10^{-5}$$

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Conclusions

(details in Gutiérrez & López-Corredoira 2010, ApJ, 713, 46)

1. From the relative position of the nebular emission of [OIII] λλ5007 and λλ4959 Å in the spectra of ~1600 QSOs, we do not find evidence of changes in α up to z=0.8, and put the following constraint $\Delta\alpha / \alpha < (+2.4 \pm 2.5) \times 10^{-5}$ (improves previous analysis by a factor 5-6).
2. The maximum rate of change in $\Delta\alpha / \alpha$ allowed is $(+0.7 \pm 0.7) \times 10^{-14}\ yr^{-1}$ in the last 6.6 Gyr.

Future

-new methods and better control of systematics
-analysis of Planck data
-new spectroscopic surveys (SDSS-III, Euclid, etc)
-surveys in high resolution spectrographs in large telescopes (VLT +ESPRESSO, GTC+ high resolution spectrograph, E-ELT+CODEX,…)
-specially devoted instruments (?)

Thanks!