Is the fine structure constant constant?

- constant in time?
- constant in space?

these are primarily cosmological questions

red shift measures cosmic expansion/cosmic time

$$1 + z = \lambda_{obs}/\lambda_{emit} = a_{now}/a_{then}$$

where "a" is expansion factor

furthest back we can see is CMB

z_{CMB} = 1091 at t_{CMB} = 380,000 y

age of universe (t=0): 13.799±0.021 Gy

Spatial Variation

Quasar absorption lines

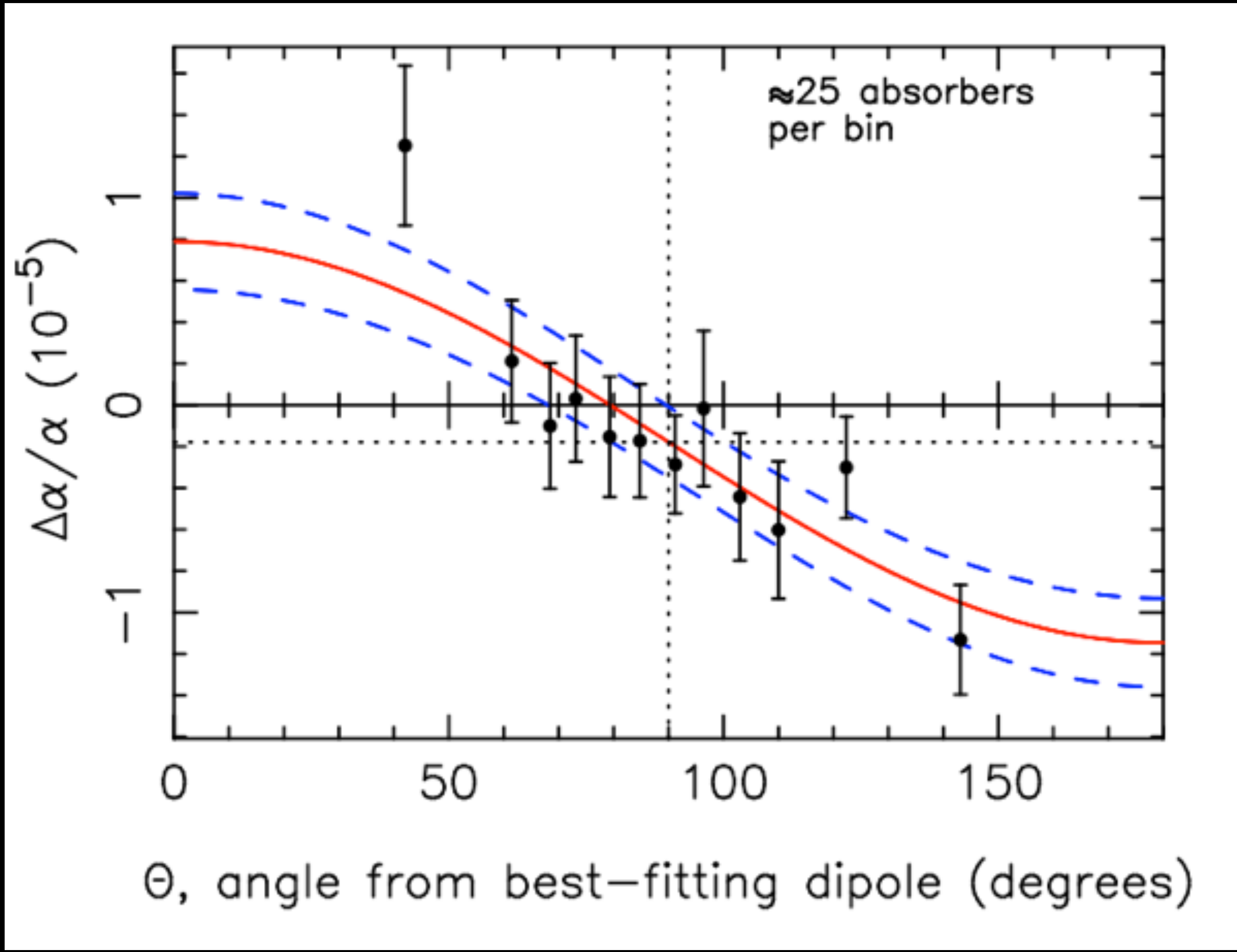
arXiv:1008.3907 23 Aug 2010

Evidence for spatial variation of the fine structure constant

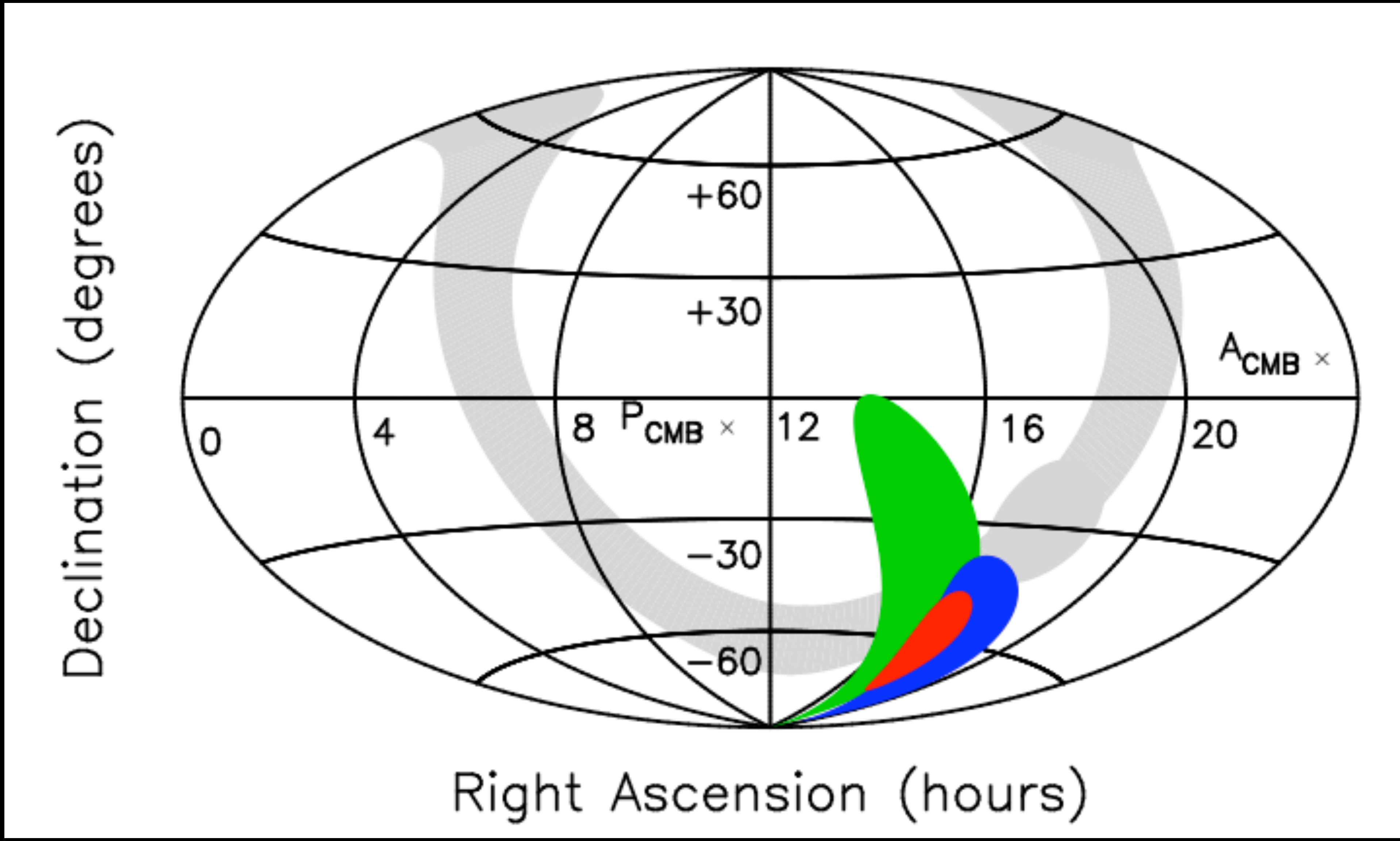
Authors: J. K. Webb, J. A. King, M. T. Murphy, V. V. Flambaum, R. F. Carswell, M. B. Bainbridge

We previously reported observations of quasar spectra from the Keck telescope suggesting a smaller value of the fine structure constant, alpha, at high redshift. A new sample of 153 measurements from the ESO Very Large Telescope (VLT), probing a different direction in the universe, also depends on redshift, but in the opposite sense, that is, alpha appears on average to be larger in the past. The combined dataset is well represented by a spatial dipole, significant at the 4.1 sigma level, in the direction right ascension 17.3 +/- 0.6 hours, declination -61 +/- 9 degrees. A detailed analysis for systematics, using observations duplicated at both telescopes, reveals none which are likely to emulate this result.

Feb. 2012 https://arxiv.org/pdf/1202.4758v1.pdf



Θ from best-fit dipole, Δα/α= AcosΘ + m, A = (0.97 ± 0.21) × 10–5 and m = (–0.18 ± 0.08) × 10–5. Dashed lines illustrate ±1σ errors on the dipole fit. The best-fit dipole is at right ascension 17.3 ± 0.6 hours, declination –61 ± 9 degrees and is statistically preferred over a monopole model at the 4.1σ level. Δα/α for the combined Keck and VLT data vs angle



All-sky plot showing the independent Keck (green) and VLT (blue) best-fit dipoles, and the combined sample (red), in equatorial co-ordinates. Approximate 1σ confidence contours are from the covariance matrix. A bootstrap anal- ysis gives the chance-probability of getting the observed (or better) alignment between the independent Keck and VLT dipoles is only 4%. The cosmic microwave background dipole and antipole are illustrated for comparison.

The grey shaded area represents the Galactic plane with the Galactic centre indicated as a bulge.

7.2 Implications

The dipole-like variation in α presented here, if confirmed, would be a detection of new physics at the most fundamental level. It would directly demonstrate the existence of a preferred frame in the universe; it may be that this anisotropy could be detected in other cosmological measurements. Additionally, it would demonstrate that the Einstein Equivalence Principle is only an approximation.

Updated constraints on spatial variations of the fine-structure constant

March, 2016

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Abstract

Recent work by Webb *et al*. has provided indications of spatial variations of the fine-structure constant, α, at a level of a few parts per million. Using a dataset of 293 archival measurements, they further show that a dipole provides a statistically good fit to the data, a result subsequently confirmed by other authors. Here we show that a more recent dataset of dedicated measurements further constrains these variations: although there are only 10 such measurements, their uncertainties are considerably smaller. We find that a dipolar variation is still a good fit to the combined dataset, but the amplitude of such a dipole must be somewhat smaller: 8.1 ± 1.7 ppm for the full dataset, versus 9.4 ± 2.2 ppm for the Webb *et al*. data alone, both at the 68.3% confidence level. Constraints on the direction on the sky of such a dipole are also significantly improved. On the other hand the data can't yet discriminate between a pure spatial dipole and one with an additional redshift dependence.

https://arxiv.org/pdf/1603.04498v1.pdf

Object	z	$\Delta\alpha/\alpha$ (ppm)	Spectrograph	Ref.
3 sources	1.08	4.3 ± 3.4	HIRES	[13]
HS1549+1919	1.14	-7.5 ± 5.5	UVES/HIRES/HDS	[10]
HE0515−4414	1.15	-0.1 ± 1.8	UVES	[14]
HE0515−4414	1.15	0.5 ± 2.4	HARPS/UVES	[15]
HS1549+1919	1.34	-0.7 ± 6.6	UVES/HIRES/HDS	[10]
HE0001−2340	1.58	-1.5 ± 2.6	UVES	[16]
HE1104−1805A	1.66	-4.7 ± 5.3	HIRES	[13]
HE2217−2818	1.69	1.3 ± 2.6	UVES	[9]
HS1946+7658	1.74	-7.9 ± 6.2	HIRES	[13]
HS1549+1919	1.80	-6.4 ± 7.2	UVES/HIRES/HDS	[10]
Q1101−264	1.84	5.7 ± 2.7	UVES	[14]

Table 1: Recent dedicated measurements of α. Listed are, respectively, the object along each line of sight, the redshift of the measurement, the measurement itself (in parts per million), the spectrograph(s), and the original reference. The recent UVES Large Program measurements are [9, 10]. The quoted errors include both statistical and systematic uncertainties (to the extent that these were estimated in the original works), added in quadrature. The first measurement is the weighted average from 8 absorbers in the redshift range $0.73 < z < 1.53$ along the lines of sight of HE1104-1805A, HS1700+6416 and HS1946+7658, reported in [13] without the values for individual systems, and therefore won't be included in our analysis.

Dataset & c.l.	Amplitude (ppm)	Right Ascension (h)	Declination (°)
Webb *et al.* (68.3%)	9.4 ± 2.2	17.2 ± 1.0	-61 ± 10
Webb *et al.* (99.7%)	9.4 ± 6.4	$17.2^{+4.4}_{-5.3}$	< -28
All data (68.3%)	8.1 ± 1.7	17.2 ± 0.7	-58 ± 7
All data (99.7%)	8.1 ± 5.0	17.2 ± 2.9	< -37

Table 2: One- and three-sigma constraints on the Amplitude and coordinates of maximal variation (Right Ascension and declination) for a pure spatial dipole variation of α. The 'all data' case corresponds to using the data of Webb *et al.* [3] together with the 10 individual measurements presented in Table 1. These results are also graphically displayed in Figure 2.

We have revisited recent indications of spatial variations of the fine-structure constant, α, by considering the impact of the current set of dedicated measurements listed in Table 1 on this analysis. While this dataset is currently still small, it has already been shown that it plays a significant role in obtaining constraints on dark energy and Weak Equivalence Principle violations [19]. Here we have confirmed that they also have a noticeable impact on constraints on spatial variations, thereby updating the original analysis of Webb *et al*.

also, see analysis of x-ray cluster. further (weak) evidence

arXiv:1612.06739v1 [astro-ph.CO]

Red-shift Variation

arXiv:1002.4777v1

Feb 25, 2010

The analysis is done by measuring the position of the fine structure lines of the [OIII] doublet (λλ4959 and λλ5008) in QSO nebular emission.

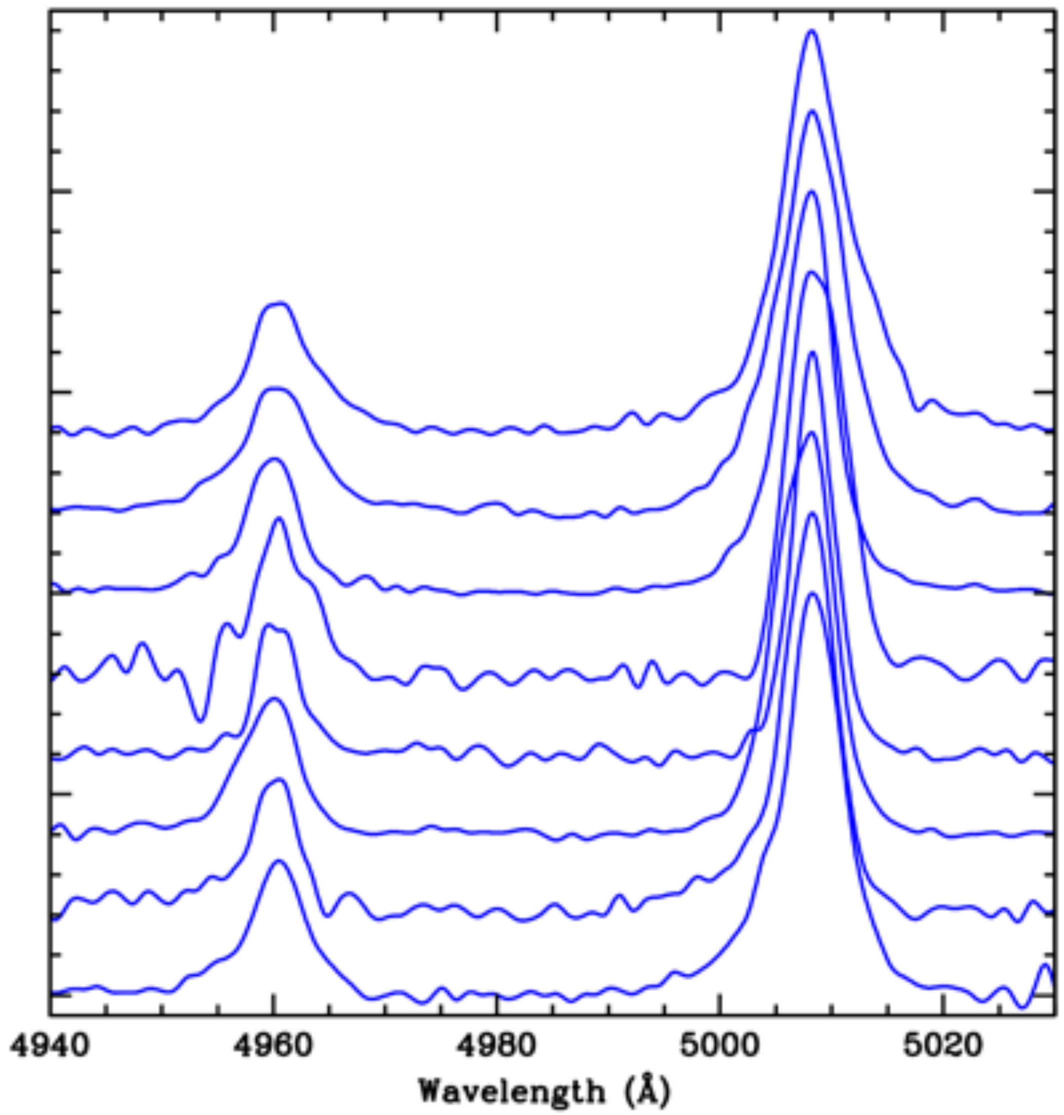
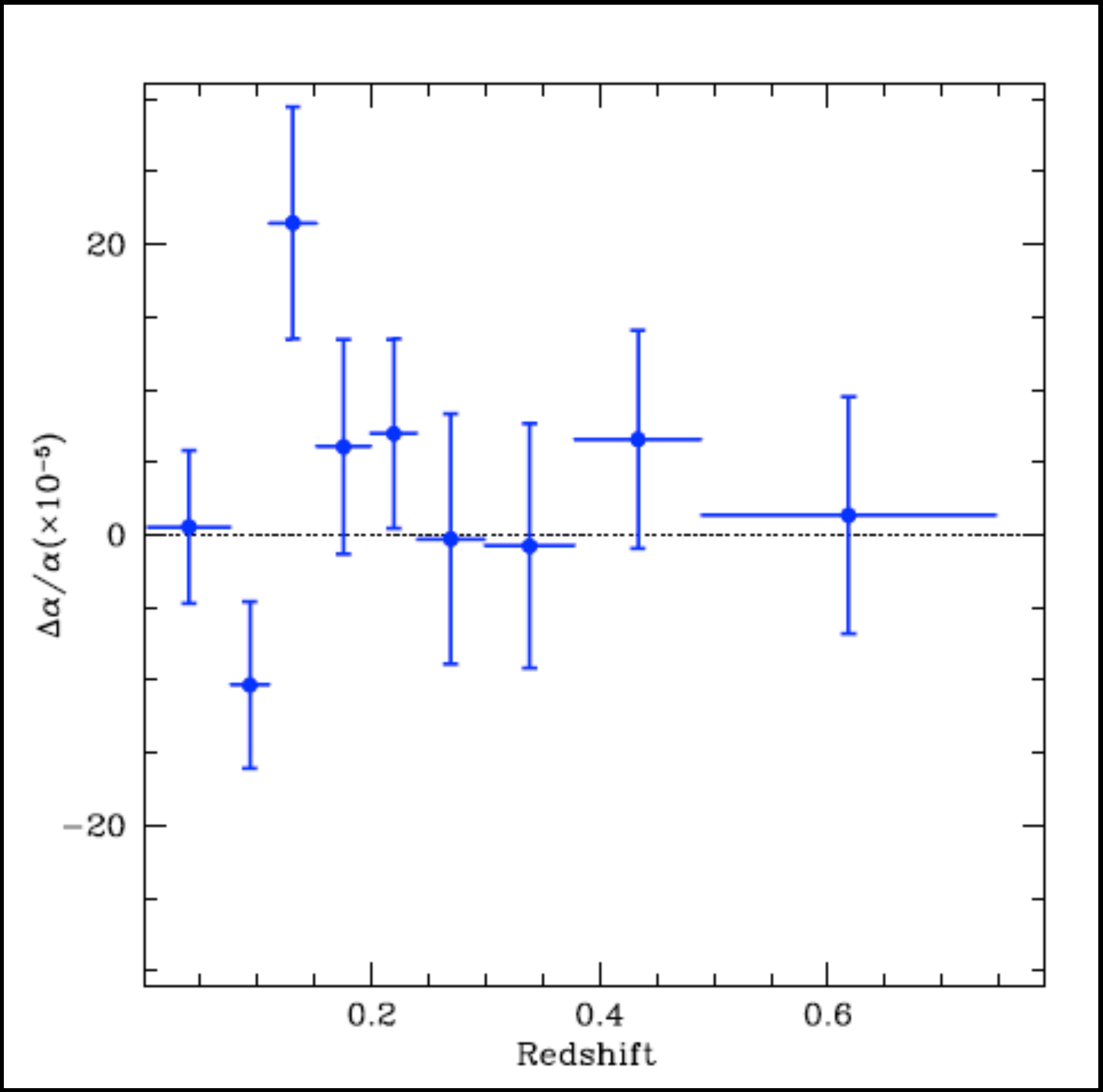


Fig. 3.— The spectral region around the [OIII] doublet for some of the objects included in the clean sample (see the main text). The spectra have been normalized with respect to the peak of the main [OIII] line.

Quasar emission lines



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

consistent with zero

updated analysis October 2015

A new analysis of fine-structure constant measurements and modeling errors from quasar absorption lines

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Quasar absorption lines

ABSTRACT

We present an analysis of 23 absorption systems along the lines of sight towards 18 quasars in the redshift range of $0.4 \leqslant z_{abs} \leqslant 2.3$ observed on the Very Large Telescope (VLT) using the Ultraviolet and Visual Echelle Spectrograph (UVES). Considering both statistical and systematic error contributions we find a robust estimate of the weighted mean deviation of the fine-structure constant from its current, laboratory value of $\Delta\alpha/\alpha = (0.22 \pm 0.23) \times 10^{-5}$, consistent with the dipole variation reported in Webb et al. (2011) and King et al. (2012).

https://arxiv.org/pdf/1510.02536v2.pdf

To summarise, the steps are as follows:

(i) We select all possible subsets of n from k observations.

(ii) For each combination we compute the weighted mean value of $\Delta\alpha/\alpha$, varying σ_{rand} in the quadrature error term such that the observed χ^2_ν is equal to the expected value, given by Eq.17 in King et al. (2012). σ_{rand} is then determined in a more robust manner, without undue influence from anomalously deviant points, if any.

(iii) Finally the σ_{rand} deemed to be applicable to the whole sample is selected as the smallest value out of all possible combinations. Selecting the smallest value of σ_{rand} ensures that it's value is not overestimated by high scatter points and that any possible outliers are not 'masked' by an artificially inflated σ_{rand}. In this way we into take into account, in a robust way, any possible systematic contribution to the overall error on $\Delta\alpha/\alpha$.

(iv) After applying σ_{rand} to the entire dataset we search for any points with $|r_i| = |(\Delta\alpha/\alpha - \text{model prediction})/\sigma_{tot}| \geqslant 3$ as outliers. However, none were found in this analysis.

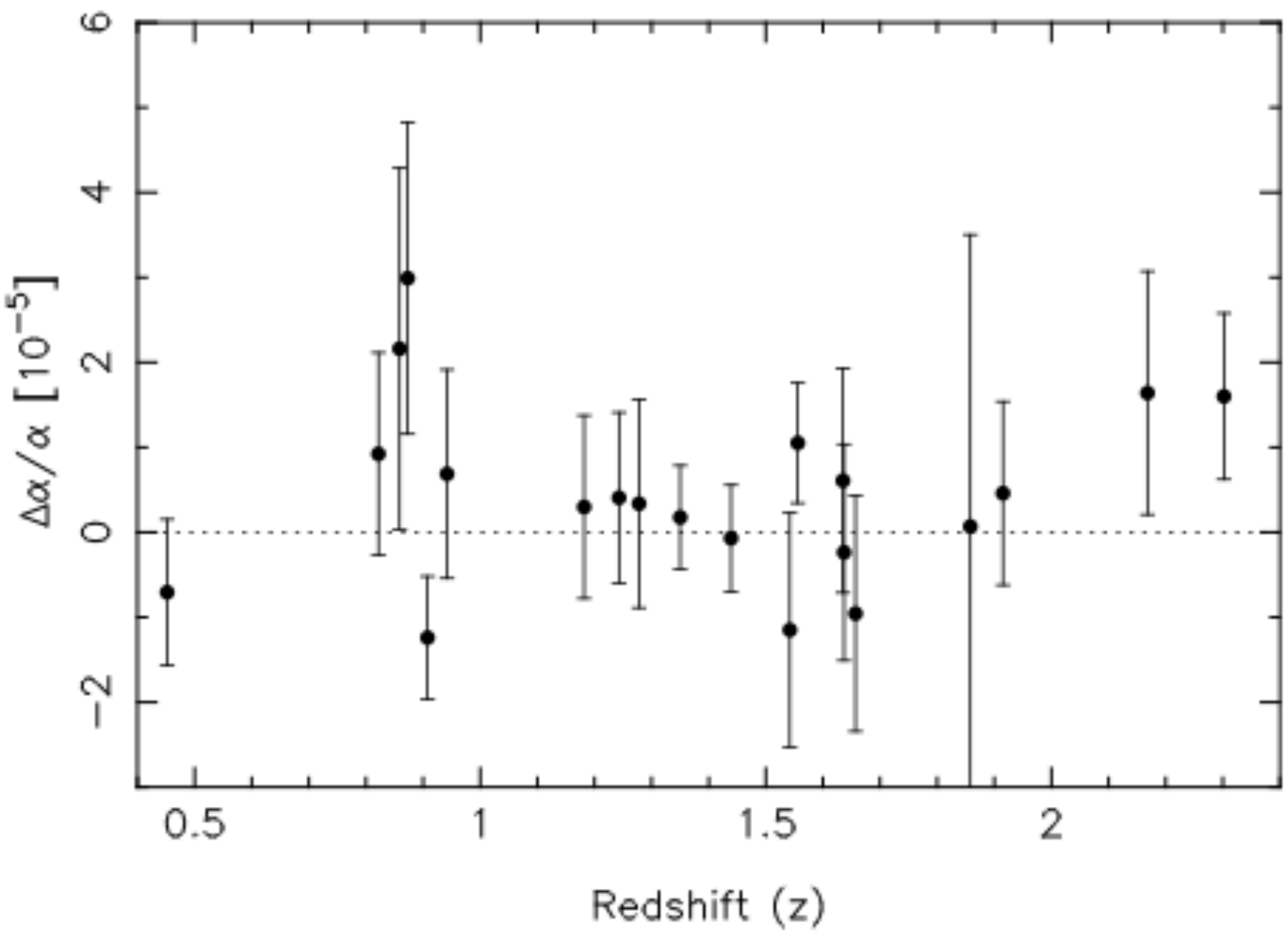

Figure 2. Results from our best fits after increasing error bars on individual measurements of $\Delta\alpha/\alpha$. 1σ errors shown are $\sigma^2_{total} = \sigma^2_{stat} + \sigma^2_{rand}$. The weighted mean for this analysis is $\Delta\alpha/\alpha = (0.223 \pm 0.226) \times 10^{-5}$.

2 ppm, order of magnitude better constraint

arXiv: 1601.02950 January 2016

Fine-structure constant constraints on dark energy: II. Extending the parameter space

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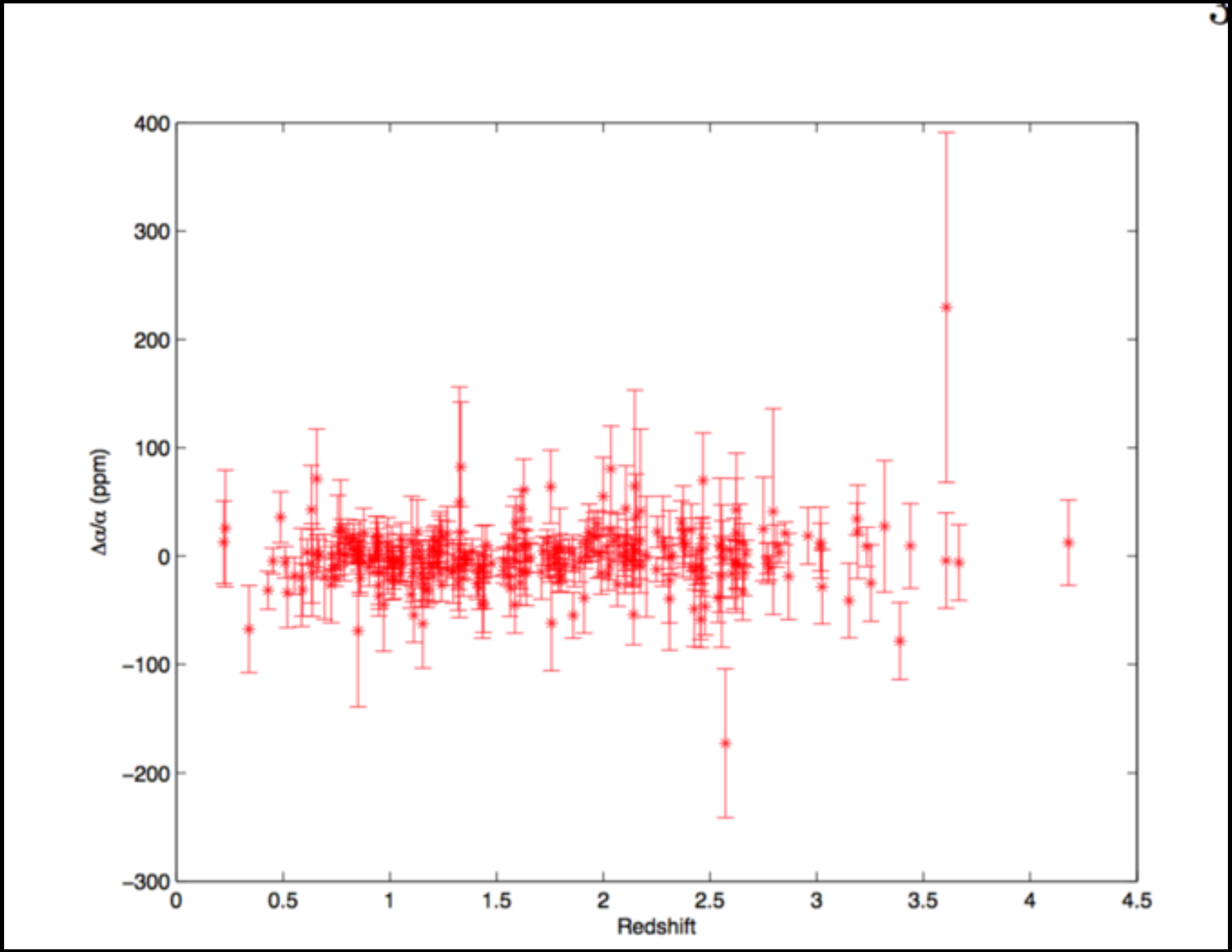
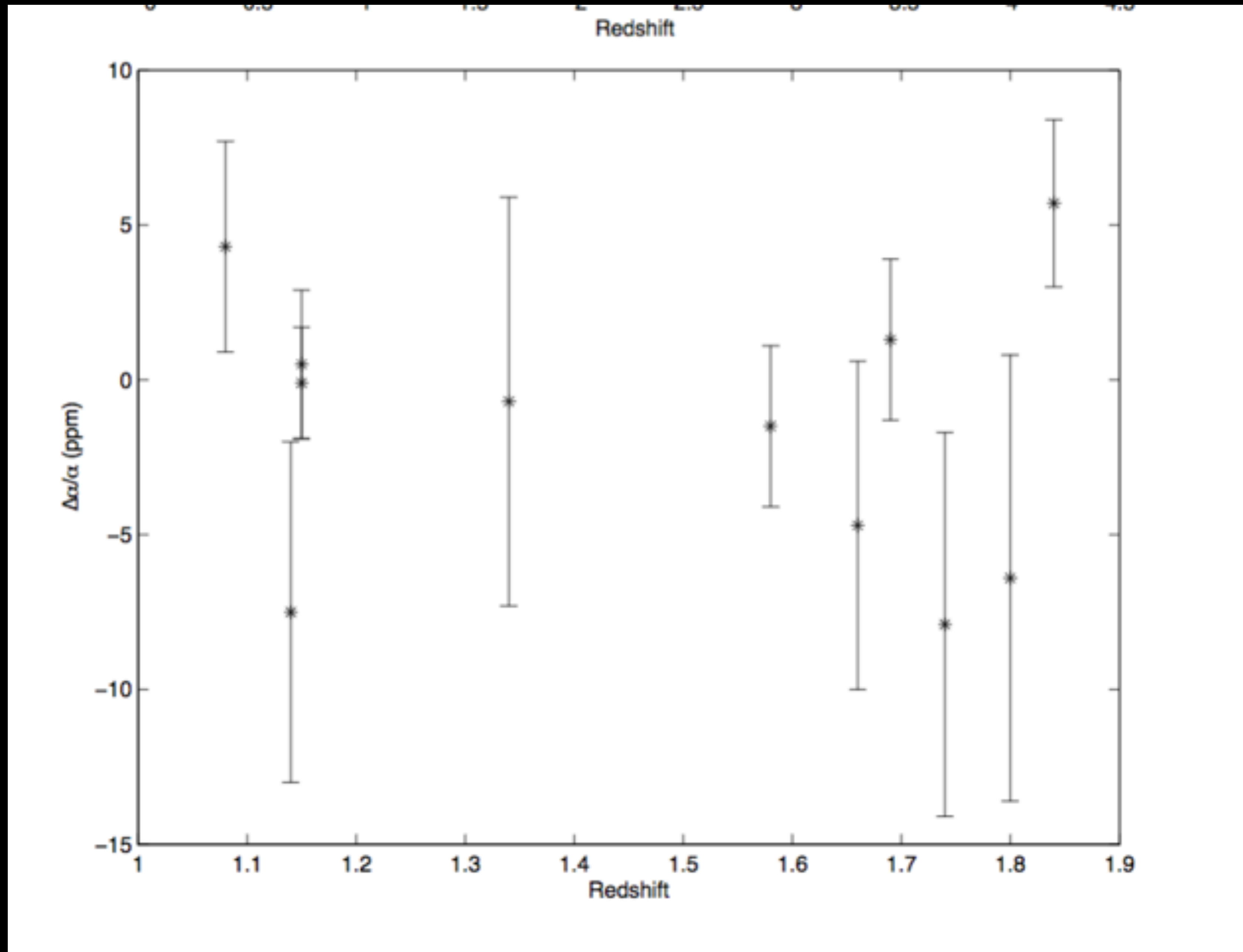
https://arxiv.org/pdf/1601.02950v1.pdf



all previous data



more recent, higher precision data

Data used to constrain models of dark energy, theoretically responsible for accelerated expansion of universe as measured by type 1A supernova red shift