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High-precision limit on variation in the fine-structure constant from a single quasar absorption system

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In the last 15 years, studies of velocity shifts between metal transitions observed in high-resolution quasar spectra with the largest optical telescopes identified possible evidence for variation in the fine-structure constant, α. Recent 'supercalibration'techniques have shown that these spectra likely have significant systematic distortions in their wavelength scales that undermine the $\Delta\alpha/\alpha$ measurements.

We have selected the brightest southern quasar HE 0515−4414 at $z_{\rm abs} > 1$ to obtain the highest S/N spectrum available, achieve the smallest statistical error on $\Delta\alpha/\alpha$ to date and, most importantly, to allow systematic effects to be tracked and corrected with high fidelity. For this purpose we have combined HE 0515−4414 spectra observed with UVES/VLT over 10 years, producing an extremely high signal-to-noise ratio spectrum (peaking at S/N $\approx 250\,{\rm pix}^{-1}$). This provides the most precise measurement of $\Delta\alpha/\alpha$ from a single absorption system to date, $\Delta\alpha/\alpha = -1.42 \pm 0.55_{\rm stat} \pm 0.65_{\rm sys}$ parts per million (ppm). This has a similar precision to previous measurements from large samples of ∼150 absorption systems. This measurement is corrected for the largest systematic effect present in all (except one) previous measurements, the long-range wavelength distortions, which would add 10 ppm to the systematic error budget. We also discuss how our methods for correcting the spectra, in this case, can be applied to future spectra, in particular from the upcoming ESPRESSO spectrograph. Our spectrum also offers a preview of the data quality available from the next generation of telescopes, but also the problems that must be overcome to access the full photon-limited precision.

Summary

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