SPECTRA OF DISTANT QUASARS AND VERIFICATION OF POSSIBLE VARIATION OF FUNDAMENTAL CONSTANTS OVER COSMOLOGICAL TIME-SCALES

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Abstract. Constraints on possible variation rate of the fine-structure constant, $|\dot{\alpha}/\alpha| < 4 \times 10^{-14}$ yr^{-1}, and the electron-proton mass ratio $\mu = m_e/m_p$, $|\dot{\mu}/\mu| < 3 \times 10^{-13}$ yr^{-1}, over cosmological time scales are obtained from analyses of quasar spectroscopic data.

The problem of possible time variation of the fundamental physical constants was discussed by many authors (see below-cited papers for the references). An analysis of high-redshift quasar spectra makes it possible to check if the constants changed during $\sim 10^{10}$ yrs. Compared to previous works, we have performed more accurate analyses based on a more complete set of spectroscopic data, which enabled us to derive the most reliable upper limits on the possible time variation of the fine-structure constant $\alpha = e^2/\hbar c$ and the electron-proton mass ratio $\mu = m_e/m_p$.

The rate of the possible variation of α is estimated from a statistical analysis of the relative fine splitting $\delta\lambda/\lambda$ of 1414 pairs of doublet absorption wavelengths of alkalilike ions in quasar spectra at redshifts $z = 0.2 - 3.7$, compiled from data published in 1980–1992. If α were z-dependent, then the ratio $\frac{(\delta\lambda/\lambda)_z}{(\delta\lambda/\lambda)_0} = (\alpha_z/\alpha_0)^2$ would vary with z. However our analysis (Potekhin and Varshalovich 1993) revealed no statistically significant variation. The estimate of the variation rate reads

$$\alpha^{-1}\mathrm{d}\alpha/\mathrm{d}z = (-0.6 \pm 2.8) \times 10^{-4}. \quad (1)$$

At 95% significance level, an upper bound on this rate $|\alpha^{-1}\mathrm{d}\alpha/\mathrm{d}z| < 5.6 \times 10^{-4}$ is imposed. In the standard cosmological model with parameters $H_0 = 75$ km s^{-1} Mpc^{-1}, $q_0 = \frac{1}{2}$ ($\Omega = 1$) and $\Lambda_0 = 0$ this corresponds to the restriction $|\dot{\alpha}/\alpha| < 4 \times 10^{-14}$ yr^{-1}.

The rate of the possible variation of μ is estimated from a comparison of wavelengths λ for different electron-vibro-rotational lines of molecular hydrogen H_2 at $z = 2.811$ in the spectrum of quasar PKS 0528 – 250. If μ were z-dependent, then the ratio $\frac{(\lambda_i/\lambda_k)_z}{(\lambda_i/\lambda_k)_0} \approx 1 + K_{ik}(\Delta\mu/\mu)$ would deviate from unity. However our analysis (Varshalovich and Levshakov 1993) revealed no statistically significant deviation. The estimate of the variation is

$$(\Delta\mu/\mu)_{z=2.811} = (1 \pm 2) \times 10^{-3}. \quad (2)$$

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The 95%-significance upper bound on the variation rate is $|\mu^{-1}\mathrm{d}\mu/\mathrm{d}z| < 1.8\times10^{-3}$. In the standard cosmological model with the above-mentioned parameters this corresponds to the restriction $|\dot{\mu}/\mu| < 3 \times 10^{-13}$ yr^{-1}.

References

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