Search for a drifting proton–electron mass ratio from H_2

Wim Ubachs[1]

[1] *Department of Physics and Astronomy, LaserLaB, Vrije Universiteit, Amsterdam, Netherlands*

An overview is presented of the H_2 quasar absorption method to search for a possible variation of the proton–electron mass ratio $\mu = m_p/m_e$ on a cosmological time scale [1]. The method is based on a comparison between wavelengths of absorption lines in the H_2 Lyman and Werner bands as observed at high redshift with wavelengths of the same lines measured at zero redshift in the laboratory. For such comparison sensitivity coefficients to a relative variation of μ are calculated for all individual lines and included in the fitting routine deriving a value for $\Delta\mu/\mu$. Details of the analysis of astronomical spectra, obtained with large 8–10 m class optical telescopes, equipped with high-resolution echelle grating based spectrographs, are explained. The methods and results of the laboratory molecular spectroscopy of H_2, in particular the laser-based metrology studies for the determination of rest wavelengths of the Lyman and Werner band absorption lines, are reviewed. Theoretical physics scenarios delivering a rationale for a varying μ will be discussed briefly, as well as alternative spectroscopic approaches to probe variation of μ, other than the H_2 method. Also a recent approach to detect a dependence of the proton-to-electron mass ratio on environmental conditions, such as the presence of strong gravitational fields, will be highlighted. Currently some 56 H_2 absorption systems are known. Their usefulness to detect μ-variation is discussed, in terms of column densities and brightness of background quasar sources, along with future observational strategies. The astronomical observations of ten quasar systems analyzed so far set a constraint on a varying proton-electron mass ratio of $|\Delta\mu/\mu| < 5 \times 10^{-6}$ (3-σ), which is a null result, holding for redshifts in the range $z = 2.0 - 4.2$. This corresponds to look-back times of 10–12.4 billion years into cosmic history. Attempts to interpret the results from these 10 H_2 absorbers in terms of a spatial variation of μ are currently hampered by the small sample size and their coincidental distribution in a relatively narrow band across the sky.

References

[1] Ubachs W., Bagdonaite J., Salumbides E.J., Murphy M.T., Kaper L., Rev. Mod. Phys., 2016, 88, 021003.