Sensitivity of tunneling–rotational transitions in ethylene glycol to the variation of electron-to-proton mass ratio

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The parameters of the Standard model considered unchanging over time and space are usually called fundamental constants. But since their exact values cannot be calculated within the Standard model, it is natural to question their invariability. Molecular spectra can be used to study variation of electron-to-proton mass ratio μ.

Ethylene glycol $OH-CH_2-CH_2-OH$ in its ground conformation $g'Ga$ has tunneling transition with the frequency about 7 GHz. This leads to a rather complicated tunneling-rotational spectrum. Because tunneling and rotational energies have different dependence on μ, some transitions can be highly sensitive to the possible μ variation.

Let ω be a present-day experimentally observed transition frequency and ω' a frequency shifted due to possible time (and space) change of μ. This shift $\Delta\omega = \omega - \omega'$ is linked to the change $\Delta\mu$ through dimensionless sensitivity coefficient Q_μ:

$$\frac{\Delta\omega}{\omega} = Q_\mu \frac{\Delta\mu}{\mu} \tag{1}$$

We used relatively simple 14 parameter effective Hamiltonian and known experimental spectrum from [1] to calculate Q_μ's of the tunneling-rotational transitions below 60 GHz, since low-frequency lines are more likely to be highly sensitive to the μ shift. We found out that Q_μ's lie in the range from -17 to +18. The big difference $Q_\mu^{(max)} - Q_\mu^{(min)} \approx 34$ increases sensitivity of the future experiments or observations to μ variation and allows effective control over systematic effects.

Ethylene glycol has been detected in the interstellar medium [2] and in the comet C/1995 O1 (Hale-Bopp) [3]. Observation of the spectrum from extragalactic sources can give us new information about the time-drift of μ. Spectral lines from cold molecular clouds in the Milky Way can be very narrow allowing for high precision spectroscopy. This may be used to study possible dependence of μ on the local matter density, which is predicted by models with chameleon scalar fields.

Results of our work were published in [4].

References

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