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Search for a variation of fundamental constants on a cosmological time scale

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Since the days of Dirac scientists have speculated about the possibility that the laws of nature, and the fundamental constants appearing in those laws, are not rock-solid and eternal but may be subject to change in time or space. Such a scenario of evolving constants might provide an answer to the deepest puzzle of contemporary science, namely why the conditions in our local Universe allow for extreme complexity: the fine-tuning problem. In the past decade it has been established that spectral lines of atoms and molecules, which can currently be measured at ever-higher accuracies, form an ideal test ground for probing drifting constants. This has brought this subject from the realm of metaphysics to that of experimental science. In particular the spectra of molecules are sensitive for probing a variation of the proton-electron mass ratio μ, either on a cosmological time scale, or on a laboratory time scale. A comparison can be made between spectra of molecular hydrogen observed in the laboratory and at a high redshift (z=2-3), using the Very Large Telescope (Paranal, Chile) and the Keck telescope (Hawaii). This puts a constraint on a varying mass ratio $\Delta\mu/\mu$ at the 10^{-5} level. Further a novel direction will be discussed: it was discovered that molecules exhibiting hindered internal rotation have spectral lines in the radio-spectrum that are extremely sensitive to a varying proton-electron mass ratio. Observations with three different radio-telescopes (Effelsberg, IRAM-Granada, ALMA) provide a stringent constraint on a varying μ.

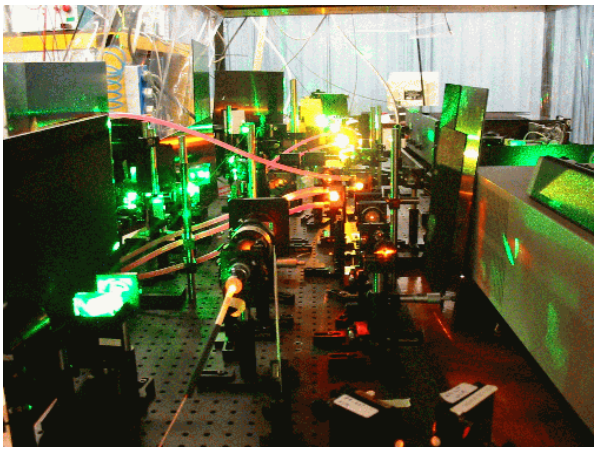

Fig: On the left the laser setup used to measure highly accurate spectra of H_2 molecules in the laboratory; on the right a view on the Very Large Telescope(s) used to detect H_2 at high redshift.