

HOW CONSTANTS ARE FUNDAMENTAL CONSTANTS?

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One of the cardinal assumptions of Physics is that laws of Physics are the same everywhere in the universe and the values of fundamental constants like the speed of light are unaffected by the changes in time and / or space. Till recently little doubt has been raised in the validity of these premises using which deductions of all kinds are being made. Scientists used to calculate the processes and phenomena billions of light years away sitting here on earth or predict things that may happen far out in future. However, P A M Dirac had long ago indicated that it is possible that the values of fundamental contents may vary with time. So far there were no experimental evidences to support Dirac's conjecture.

With the spectacular progress in the observational techniques, especially with space-based instruments, experimental measurements hitherto considered as impracticable, could be taken up successfully. For example, the results gathered by the Hubble space telescope opened up many new vistas in our understanding of the universe. Observations at the very edge of the visible universe have yielded new facts causing cosmological theories to be revised and rewritten.

A team of astrophysicists from Australia, Cambridge, Pennsylvania and California lead by Dr. J. K. Webb of School of Physics at University of New South Wales in Sydney, has now come up with an amazing observation that the fine structure constant α ($\alpha = 2\pi e^2/hc \approx 1/137$) could vary with time. These investigators obtained the results on the time variability of the fine structure constant using the absorption systems in the spectra of distant quasars, which shine with brightness of billions of Suns. The gas cloud surrounding the bright source produces absorption lines in the spectra. Any variation in α would cause detectable shift in the rest wavelengths of the red shifted resonance transitions seen in quasar absorption systems. For relativistic fine structure splitting in alkali type doublets, the separation between lines is proportional to α^2 so that small variations in the relativistic separation are proportional to α . Though alkali doublet method is simple to apply, more precision is available by adopting what is known as "many multiplet method" instead of simple alkali doublet method.

Using the HIRES echelle spectrograph on the 30 foot wide Keck I telescope atop Mount Mauna Kea in Hawaii, the team led by Dr. Webb analyzed the multiplet structure in the spectral features of Fe II, Mg II, Ni II, Cr II, Zn II and Si IV in the light from distant quasars. By choosing the quasars over a range of red shifts (greater the red shift, greater is the distance to the source from earth as per Hubble's law), spanning to 23 to 87 % of the life of the universe, these investigators were able to probe α values over most of the history of universe.

The results strongly suggest that α may have been smaller in the past with fractional deviation $\Delta\alpha / \alpha = -(1.09 \pm 0.6) \times 10^{-5}$

The consequence of this observation on science would be so far reaching and hence many scientists are waiting for further confirmation of these results from other independent evidence. On the other hand, these findings would fit with some theorists' new view of the universe, particularly the prediction that previously unknown dimensions might exist in the fabric of space. Dr. Webb says, "It is possible that there is a time evolution of the laws of Physics". He also adds, "If it is correct, it is the result of a life time". The present findings could not only force revisions in Cosmology and / Physics, but also give credence to an unproven theory of Physics called string theory which predicts that as much as 5 to 7 extra dimensions exist (other than 3+1 dimension that we are aware of). String theory postulates that space contains tiny unseen dimensions and any change in size of these dimensions like the expansion of the universe in the space we are familiar with, could change quantities like fine structure constant. Other methods like geological processes, for example, naturally occurring nuclear fission, have been used to determine any variation in the value of α over centuries; but the present quasar observation is much superior to all these because of its reach much farther back in time. Many great physicists like Professor Sheldon Glashow (Nobel prize winner for Physics in 1979) of Boston University thinks that these findings are "potentially revolutionary".

Time variability of fundamental constants has direct bearing on the so-called "anthropic principle" introduced by Brandon Carter in 1974. According to this principle, when there is a conscious observer who makes measurements, he finds the values of the fundamental constants as well as other parameters of the universe (like its age) exactly as required for the existence of intelligent life. However, "the prerequisites for getting out of bed in the morning are many and varied" as the astrophysicist Virginia Trimble emphasized in a conference held at the end of August 2001 in Cambridge on anthropic principle, in which many eminent physicists like Stephen Hawking participated. The observed nonuniqueness of α suggests that instead of a universe with one set of 'fine tuned' values of fundamental constants, giving conditions appropriate for origin of life, there may be a "multiverse" with different sets of values for such parameters. Life could arise only if the constants were close to their observed values. We should feel lucky that we happen to live in one of the universes that is conducive to life!

Reference: "Further evidence for the cosmological evolution of fine structure constant"

J. K. Webb, M. T. Murphy, V. V. Flambaum, V. A. Dzuba, J. D. Barrow, C. W. Churchill, J. X. Prochaska and A. M. Wolfe, *Physical Review Letters* **87**. 91301 (2001)