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Variable Constants - A Theoretical Overview

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Abstract. In many theories of unified interactions, there are additional degrees of freedom which may allow for the variation of the fundamental constants of nature. I will review the motivation for such variations, and describe the theoretical relations between variations of gauge and Yukawa couplings.

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Variations of fundamental constants are certainly possible within the context of unified theories of particle interactions. Indeed, in the context of string theories, the presence of a dilaton and other moduli fields almost guarantee that at some level gauge and Yukawa coupling constants are dynamical. Whether or not, these fields are fixed at or near the Planck scale (rendering our constants constant over effectively all of the history of the Universe) is unknown. If not, then there is the interesting possibility that the value of these constants varied over cosmological timescales (Olive (2009)).

There are a number of important astrophysical and terrestrial constraints on the fine-structure constant that must be respected. The most primordial of the limits comes from big bang nucleosynthesis (BBN) which tests for variations back to a cosmological redshift as high as $\sim 10^{10}$. The relatively good agreement between theory and observation for ^{4}He in BBN allows one to set a limit of $|\Delta\alpha/\alpha| < 0.04$ using $|\Delta Y/Y| < 4\%$ ($\Delta Y/Y$ scales with $\Delta\alpha/\alpha$). Since this limit is applied over the age of the Universe, we obtain a limit on the rate of change $|\dot{\alpha}/\alpha| < 3 \times 10^{-12}$ yr^{-1} over the last 13.7 Gyr. In the context of unified or string-inspired theories, this limit is significantly stronger and improves by about two orders of magnitude.

Very strong constraints on the variation of α can be obtained from the Oklo natural reactor which operated in Gabon approximately two billion years ago. The site has a rich uranium deposit which is naturally enriched in ^{237}U at the level of about 3.7%. The observed isotopic abundance distribution at Oklo can be related to the cross section for neutron capture on ^{149}Sm. The key isotopic ratio is that of ^{149}Sm/^{147}Sm which is 2% at the Oklo site relative to the common terrestrial value of about 90%, indicating strongly that ^{149}Sm was depleted by a thermal neutron source. Assuming that the energy difference is due to the α-dependence of the Coulomb energy alone, a limit

$$-0.56 < \Delta\alpha/\alpha \times 10^7 < 0.66 \qquad (0.1)$$

can be obtained. However, if all fundamental couplings are allowed to vary interdependently, a much more stringent limit $|\Delta\alpha/\alpha| < (1-5) \times 10^{-10}$ may be obtained.

There are also reported and disputed measurements of variations. These will be what make the session and these proceedings particularly interesting.

References

Olive, K. A., proceedings of JD 9 IAU Symposium, Rio 2009, to appear in Mem. S.A. It.. nd Vangioni, E., 2009 *in preparation*.