Cosmology and the Higgs Mass

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It is demonstrated that a very small or zero Higgs mass is excluded by experiment.

Recently Linde[1] pointed out that the magnitude of the cosmological constant in the case of spontaneous symmetry breakdown as supposed in the Weinberg model differs 49 orders of magnitude from the experimentally observed constant. Independently, but later, the present author observed[2] the same fact, and concluded that this undermines the credibility of the Higgs mechanism. A third paper, by Dreitlein,[3] makes again the same observation, but draws the conclusion that the Higgs mass must be very nearly zero. This indeed reduces the cosmological contribution from the spontaneous symmetry breakdown to the required small level provided the mass is less than 2.35×10^{-27} MeV. The range of the associated force is thus of the order of 10^{16} cm, i.e. macroscopic. According to Dreitlein, if the proton is coupled with equal but opposite strength, no major contradictions result.

However, this is not true. The coupling of the electron to this particle φ is of the form

$$-(gm/2M)\varphi(\bar{\psi}\psi), \tag{1}$$

where

$$g^2 = 8M^2G, \quad G = 1.02\times 10^{-5} m_p^{-2}/\sqrt{2}.$$

Here m, m_p, and M are the electron, proton, and intermediate-vector-meson masses. For an electron in a bound state i in an atom the coupling is thus proportional to

$$\int d^3x\, \bar{\psi}_i(x)\psi_i(x), \tag{2}$$

where ψ_i is the wave function of that state. These wave functions are normalized such that

$$\int d^3x\, \bar{\psi}_i\gamma^4\psi_i = 1. \tag{3}$$

It is obvious that the expression (2) will be different from (3) to the extent that the small components are nonzero; in fact this depends on the particular state i.[4] Thus the coupling of the field φ to an atom depends on the states occupied by the electrons. Obviously, if for some material the total force (from electrons and protons) is zero, it will be nonzero for other materials. The force in question would be many orders of magnitude larger than the gravitational force, and is experimentally excluded. To be somewhat more specific, the coupling of electrons to the gravitational field is given by

$$\kappa h_{\mu\nu}\bar{\psi}\gamma^{\mu}\partial_{\nu}\psi, \tag{4}$$

with $\kappa = 5.8\times 10^{-22}\ \mathrm{MeV}^{-1}$, and further similar terms. Considering only the terms with $\mu=\nu=4$, and assuming the electron to be nonrelativistic so that ∂_4 may be replaced by im, one sees that the relative magnitude of the coupling constants is given by

$$(gm/2M)(m\kappa)^{-1} \approx 6.5\times 10^{16}.$$

Suppose now equilibrium for an electron in the ground state of hydrogen. For the excited states kinetic energies are of the order of, say, 1 eV. I find $v^2/c^2 \sim 10^{-6}$. Furthermore, gravity senses the sum of proton and electron masses, which gives a factor 2000 in favor of gravity. It follows that the Higgs coupling remains 7 orders of magnitude stronger than the gravitational coupling.

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[2] M. Veltman, to be published.
[3] J. Dreitlein, Phys. Rev. Lett. 33, 1243 (1974).
[4] H. A. Kramers, *Quantum Mechanics* (North-Holland, Amsterdam, 1957), p. 306.