WEINBERG'S MODEL OF WEAK INTERACTIONS AND STRUCTURES OF HADRONS AND LEPTONS

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There have been many recent investigations of the model proposed a few years ago by Weinberg [1] for weak and electromagnetic interactions. It is pointed out in the present paper that inclusion of hadrons in this model leads to definite consequences concerning the structures of hadrons and leptons.

We consider the Lagrangian describing weak and electromagnetic (WEM) interactions of hadrons as well as leptons (no symmetry breaking):

$$L = L_h(h, B_\mu) + L_\ell(\ell, B_\mu) + L'. \tag{1}$$

Here L_h and L_ℓ describe the WEM interactions of the hadrons and leptons, respectively, B_μ is a quartet (or triad, depending on the model [1, 2]) of vector field and contains the bosons $w_\mu^\pm$ and the electromagnetic field A_μ. L' describes individual interactions of the hadrons and leptons. According to the discussed model, L_h and L_ℓ are invariant with respect to a certain symmetry group G_w (either the group $SU_2 \times U_1$ or O_3, see [1, 2]). The fields h, ℓ, and B_μ realize certain representations of this group. What is important, however, is that the transformations from this group are subgroups of symmetry groups of both hadrons and leptons (if the lepton asymmetry group G_ℓ is $SU_3 \times SU_3$, then G_w is its subgroup according to the construction of [3]; this is true also with respect to the hadron group G_h). Since G_h and G_ℓ have a common subgroup G_w, it follows that the hadrons (quarks) and leptons realize certain representations G_w, and consequently the quarks (leptons) realize a certain representation G_ℓ (G_h), or are part of such a representation. It is natural to assume that G_ℓ and G_h are subgroups of a certain inclusive group G. Let G be semi-simple and compact. Then there are the following three possibilities: 1) $G = G_h$, $G_\ell \subset G$, 2) $G = G_\ell$, $G_h \subset G$, 3) $G_\ell \subset G$, $G_h \subset G$.

Let us consider the first possibility. In this case it must be admitted that the leptons are made up of quarks. We choose some simple subgroup G_s of the group G (if G is not simple, for example, we have $G_s = SU_3$ for $G = SU_3 \times SU_3$). Then both the quarks and the leptons realize certain representations of this group, the quarks and antiquarks being set in correspondence with elementary representations. However, inasmuch as the simple groups possess not more than three elementary representations [4] (and the SU_n groups have only two), then it must be admitted that the leptons are transformed in accordance with the non-elementary representation of the Group G_s, and can consequently be regarded as made up of quarks. This possibility must apparently be discarded, for otherwise the leptons would have to take part in the strong interactions.

A similar consideration of the case 2) (assuming that the known leptons realize an elementary representation of group G_ℓ) leads to the conclusions that the hadrons are made up of leptons. It is easy to verify that this is also inadmissible.

We are thus left only with the third possibility. In this case we have the following alternatives: either (a) the leptons and hadrons are made up of certain (identical) very simple objects, or (b) the leptons and quarks are components of a single multiplet that realizes an elementary representation of the group G. Case (a) deserves a special treatment and will not be discussed here. Consider the possibility (b). If the leptons and quarks are combined in a single multiplet $\psi = (\ell, q, \ldots)$ (the dots imply the possible existence of other members of this multiplet), then the question arises of the extent to which the particles that enter initially perfectly on a par can differ ultimately so strongly in their properties. Within the framework of Weinberg's general approach, two different schemes can be advanced by way of an answer to this question.

1. We postulate the existence of short-range mass-dependent forces. This is done by introducing (in a gauge-invariant manner) massive fields with spin 2, realizing a nontrivial representation of the group G. Then the quarks, which acquire a large mass as a result of symmetry breaking, turn out to be strongly-interacting particles, whereas the leptons interact weakly. Such a theory will be renormalizable in the usual sense.

2. Another possibility that preserves the renormalizability of the theory is that there exist gluon vector and/or scalar (neutral) fields that interact strongly ($g \sim 1$) both with quarks and with leptons. On the other hand, if we assume that these fields have (or acquire) a large mass M (on the order of the quark mass) then, in spite of their strong interaction with the leptons, the latter will not form bound states, by virtue of the inequality $m_\ell \ll M$ (i.e., the effective radius $1/M$ is much less than the Compton wavelength $1/m_\ell$). At such energies, these forces reduce to a four-fermion interaction between the leptons and the neutral currents with a coupling constant $\sim g^2/M^2$. Experimental estimates of the corresponding constants [5] are $G_{h\ell} \lesssim 0.3G_F$ and $G_{\ell\ell} \lesssim 0.6G_F$. This yields for the gluon mass an estimate $M \gg 580$ mp, which is simultaneously also an estimate for the quark mass. An isolated proton remains stable, although the baryon charge, depending on the details of the model, will be conserved either rigorously or in modulo 2. The corresponding transition probability can be made small enough not to contradict the experiment.

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DYNAMIC SELF-POLARIZATION OF NUCLEI IN SOLIDS

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We consider here a system of nuclear spins interacting with electrons, which are artificially maintained in a disordered spin state. We shall show that under these conditions, at sufficiently low temperature, the disordered state of the nuclear spins is unstable (even in the absence of an external magnetic field). On the other hand, the state with practically complete ionization of the nuclei turns out to be stable. In this state, the polarized nuclei