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ABSTRACT

It is shown that in the superdense matter must be the interaction with the H-bosons of the form $C_m (\sqrt{2}\, G_F)^{1/2} H\, \Theta_{\mu\mu}^{(m)}$, where the $\Theta_{\mu\nu}^{(m)}$ is the macroscopical energy-momentum tensor of the matter and C_m is the constant. Some consequences of this interaction are discussed.

As well known the ground state of the Higgs scalar field can be characterized by nonzero values of the such macroscopical parameters as the temperature [1-3], the density of the leptonic charge [4], the Yand-Mills field strength [5,6] (see also ref. [7]). For sufficiently large values of this quantities the spontaneous broken gauge symmetry is restored. For example, in the theory of electroweak interactions by Weinberg-Salam (the standard model) the critical temperature is $T_c \sim 300$ GeV [1-3,7]. In the examples mention above the vacuum state of the field φ is the medium which contain the background (with respect to φ) matter of large density. For the determination of the ground state of the field φ, the possible interaction of the Higgs bosons with this matter must be taken in to account. Below we will consider the interaction of the physical H-bosons with the superdense matter in the limits of the standard model. Since the effective range of the Higgs forces is m_H^{-1}, the neglect the discrete structure of the matter is correct when the mean distance apart the particles of the matter $\ell \lesssim m_H^{-1}$; if massless fields are also present than the wavelengths $\lambda \gtrsim m_H^{-1}$ are considered. If this conditions are fulfilled we will describe the matter with the help of such macroscopic characteristics as the energy density, pressure and so on.

In the linear approximation in H the Lagrangians of the interaction of the H-bosons with the fermions and vector mesons are [8,9]

$$L_{Hf} = -(\sqrt{2}G_F)^{1/2} m_f \bar{f} f H, \quad L_{HV} = -(\sqrt{2}G_F)^{1/2} m_V^2 V_\mu V_\mu H \tag{1}$$

where G_F is the Fermi coupling constant of the weak interaction, f is the fermion field, V_μ is the vector boson field, m_f and m_V are corresponding masses. For the macroscopical description of the background matter we must compute the expectation values $\langle m | m_f \bar{f} f | m \rangle$, $\langle m | m_V^2 V_\mu V_\mu | m \rangle$ where the state vector $|m\rangle$ describe the state with the high density of fermions and vector bosons. The direct computation of this averages is very difficult problem demanding the detail information on the behaviour of the fermions and vector bosons in the superdense state. However the phenomenological calculation of this averages is possible. For this purpose one notice that the traces of energy - momentum tensors of fermions and vector bosons are

$$\theta^{(f)}_{\mu\mu} = m_f \bar{f} f \quad , \quad \theta^{(V)}_{\mu\mu} = m_v^2 V_\mu V_\mu \qquad (2)$$

The formulas (2) are correct not only for the free particles but for the interacting particles too (in neglect of it's interaction with the Higgs field and conformal anomalies) because the conformal invariance of the initial Lagrangians in the standard model and QCD is broken by the mass terms only. The expectation value $\langle m | m_f \bar{f} f | m \rangle + \langle m | m_v^2 V_\mu V_\mu | m \rangle$ is obviously the trace of the macroscopical energy-momentum tensor $\theta^{(m)}_{\mu\mu}$. Thus the Lagrangian of the interaction of the H-bosons with the dense matter is

$$L_{Hm} = -(\sqrt{2}\, G_F)^{1/2} H \theta^{(m)}_{\mu\mu} \qquad (3)$$

i.e. the trace $\theta^{(m)}_{\mu\mu}$ is the classical current interacting with the Higgs bosons.

Into the space region where the $\theta^{(m)}_{\mu\mu}(x) \neq 0$ the field H has the additional nonzero vacuum expectation value $\langle H \rangle \neq 0$ which result in change of the masses m_f and m_v. If $|(\sqrt{2}\, G_F)^{1/2} \langle H \rangle| \ll 1$ they are $m_{f,v} \rightarrow m_{f,v}(1 + (\sqrt{2}\, G_F)^{1/2} \langle H \rangle)$ [8,9]. The sign of $\langle H \rangle$ is determined by the sign of $\theta^{(m)}_{\mu\mu}(x)$, that is why particle masses can both decrease and increase. The energy dominance conditions for the classical matter [10] lead to inequality $\theta^{(m)}_{\mu\mu} \geqslant 0$ $(\theta^{(m)}_{00} > 0)$ that is $\langle H \rangle \leqslant 0$ and the masses $m_{f,v}$ are decrease. In the other words the spontaneously broken symmetry tend to restoration one into the matter satisfing the condition $\theta^{(m)}_{\mu\mu} > 0$. In principle it is possible the opposite case realizing, for example, by superhard equation of state by Zeldovich [11] when $\theta_{\mu\mu} = \varepsilon - 3p = -2p < 0$. In the last case the scale of the gauge symmetry broaking increase, and correspondingly the masses $m_{f,v}$ increase too. The conditiom $\theta^{(m)}_{\mu\mu} \geqslant 0$ as well as the other energetic conditions can be broken by the quantum corrections. In any case this corrections must be taken into account when the background matter which gives the main contribution in the $\theta^{(m)}_{\mu\nu}$ has the equation of state $\rho = 3p$, $\theta^{(\rho)}_{\mu\mu} = 0$. In this connection we point out the possible role of the conformal anomalies leading to the nonzero value of the trace $\theta_{\mu\mu} \neq 0$ even for massless fields. Since the direct coupling of the H-bosons with the massless particles is absent, in this case the special investigation of the possible forme of the interaction of the field H with the anomalous $\theta_{\mu\mu}$ is necessary. For example, the well known gluon anomaly in QCD lead to the trace [8,9]

$$\theta^{(gl)}_{\mu\mu} = -\frac{9\alpha_s}{8\pi} G^a_{\mu\nu} G^a_{\mu\nu} \qquad (4)$$

On the other hand the effective Lagrangian of the interaction of the H-bosons with gluons due to the intermediate heavy ($m_q > m_H$) quarks is [8,9]

$$L^{eff} = -\sum_{m_q > m_H} (\sqrt{2}\, G_F)^{1/2} \frac{\alpha_s}{12\pi} G^a_{\mu\nu} G^a_{\mu\nu} H \qquad (5)$$

Comparing (4) and (5) one can write the effective Lagrangian of the interaction of the H-bosons with the matter which containing the gluonic condensate as the sum of L_{Hm} and

$$L_{H,gl} = (\sqrt{2}\, G_F)^{1/2} \frac{2 n_h}{27} H \theta^{(gl)}_{\mu\mu} \qquad (6)$$

where n_h is the number of the heavy quarks.

Corrections to masses become comparable with ones when $\theta^{(m)}_{\mu\mu} \sim m_H^2 / G_F$. For $m_H \approx 10$ GeV one has $\theta^{(m)}_{\mu\mu} \approx 10^{24}$ g/cm^3. In this case the consideration of nonlinear terms both self-interaction of the H-bosons and it's interaction with the matter is necessary. If the exact initial Lagrangians of the interaction of the H-bosons with fermions L_{Hf} and vector mesons L_{HV} be used [9], it is easily seen that L_{Hf} is conserved the form (1) and L_{HV} becomes $L_{HV} = -(\sqrt{2}\, G_F)^{1/2} \theta^{(v)}_{\mu\mu}(H + H^2/2)$. In the fact we considered above the cold (T = 0) matter. In the case of T $\neq$ 0 we must take the trace of energy-momentum tensor $\theta^{(m)}_{\mu\mu}$ of the hot matter and take also into account the thermal fluctuations of the Higgs field. This can be done in full accordance with the ref. [1-3,7].

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