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STOCHASTIC MECHANISM OF SYMMETRY BREAKING

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СТОХАСТИЧЕСКИЙ МЕХАНИЗМ НАРУШЕНИЯ СИММЕТРИИ

Предлагается новый механизм нарушения симметрии, обусловленный наличием в вакууме хаотических полей. В результате возникают массивные поля Янга-Миллса, которые можно интерпретировать как "макроскопическое" проявление "микроскопической" безмассовой теории Янга-Миллса.

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STOCHASTIC MECHANISM OF SYMMETRY BREAKING

A new symmetry breaking mechanism conditioned by presence of random fields in vacuum is proposed. Massive Yang-Mills fields finally arise, that may be interpreted as "macroscopic" manifestation of the "microscopic" Yang-Mills massless theory.

Yerevan Physics Institute
Yerevan 1983

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The basis of gauge field theory consists of symmetry principles, the main one of which is the principle of local gauge invariance. Breaking of symmetry and obtaining of the scale parameter not loosing renormalization is the main point of gauge theories. At present, we know two mechanisms of symmetry breaking: Higgs mechanism and dynamical breaking. This work is devoted to a mechanism of symmetry breaking via extracting vacuum random fields and averaging over set of initial data.

The ground state of the field theory - the vacuum - must satisfy some requirements: homogeneity and isotropy; to be the lowest energy state; to be stable with respect to quantum fluctuations. Since energy density is a positive value, vacuum is to have a zero energy density. As we know [1 ,], in Yang-Mills theory trivial vacuum ($F^{a}_{\mu\nu} = 0$) is unstable with respect to quantum fluctuations. Because of breaking of the stability condition, one has to consider a possibility of change of the first two conditions. If zero energy density is replaced by constant one, then in vacuum will arise vector fields which will break vacuum isotropy. However, if these fields are random, then, in the mean, the isotropy will be restored.

We will show that excitations over such vacuum will acquire mass due to the interaction with random vacuum fields. The question on stability of such vacuum will be discussed below.

To be concrete, consider classical equations of Yang-Mills fields corresponding to the SU(2) group:

$$\partial_\mu F^a_{\mu\nu} + \epsilon^{abc} A^b_\mu F^c_{\mu\nu} = 0 \tag{1}$$

where

$$F^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + \epsilon^{abc} A^b_\mu A^c_\nu$$

It was shown in Refs.[3–5] that the system (1) has a class of solutions whose behaviour is stochastic. The solutions of this class we denote $\hat{a}_\mu$, where $\hat{a}_\mu = a^a_\mu T_a$, T_a are the SU(2) group generators. Remind briefly the results of Refs.[3–5]. There were considered homogeneous fields $a_i = a_i(t)$ in gauge $\hat{a}_0 = 0$. Via numerical experiments with a computer there was shown that solutions $\hat{a}_i(t)$ behave stochastically at arbitrary initial data. It is convenient to make with $\hat{a}_i(t)$ gauge transformations that depend on time only:

$$\hat{a}_i' = S^{-1}(t)\,\hat{a}_i(t)\,S(t)$$
$$\hat{a}_0' = S^{-1}(t)\,\dot{S}(t)$$

Let us choose $S(t)$ so that a component $\hat{a}_0$ varies randomly, too. Such gauging can be naturally called stochastic. Suppose that vacuum of Yang-Mills fields is filled with homogeneous random fields. We shall construct real vacuum fields from stochastic solutions of the system (1) via averaging over the set of initial data. Let us introduce a notion of such averaging. Consider the solution $\hat{a}_\mu(t)$ which depends on the initial data ($\hat{a}_\mu(0)$; $\dot{\hat{a}}_\mu(0)$), as well as a small vicinity of this point in phase space. From each point of this vicinity there starts some trajectory whose behaviour is stochastic. As the averaging over the assembly of initial data we shall call the one in the bunch of solutions whose initial data fill that vicinity. Denote this averaging by a sign $< \; >$. Note that the syste (1) stochastic solutions are exponentially unstable relative to change of the initial data. This results in that at change of the initial data in a small vicinity, the bunch of solutions fills the whole stochasticity region. Hence it follows that thus averaged fields satisfy the following relations:

$$< a^a_\mu (t) > = 0 \tag{2}$$

$$< a^a_\mu (t)\, a^b_\nu (t') > = m^2 \delta^{ab} \delta_{\mu\nu} \exp\left[- m^2 (t-t')^2\right]$$

where m^2 is a dimension parameter.

It is natural to take as vacuum fields the ones averaged over the assembly of the field which satisfy the relations (2). The general solution of the system (1) we present in the form of a sum of two terms:

$$\hat{A}_\mu = \hat{a}_\mu + \hat{B}_\mu \tag{3}$$

where $\hat{a}_\mu$ is a solution of the system (1) from a stochastic sector, $\hat{B}_\mu$ are excitations on the stochastic background. Let us require that the division (3) be gauge-invariant. We find out from this requirement the law of fields transformation $\hat{B}_\mu$ with respect to local gauge transformations:

$$\hat{B}'_\mu = S^{-1} \hat{B}_\mu S$$

It is convenient to impose the gauge conditions on the random component $\hat{a}_\mu$. For $\hat{a}_\mu$ we will choose a stochastic gauging, so that the component $\hat{a}_0$ will satisfy also the conditions (2) after averaging over the initial data assembly.

. Then the tension tensor for fields has the form:

$$F^a_{\mu\nu}(A) = f^a_{\mu\nu}(a) + G^a_{\mu\nu}(B) + \epsilon^{abc}\left(a^b_\mu B^e_\nu + B^b_\mu a^c_\nu\right) \qquad (4)$$

where $$f^a_{\mu\nu}(a) = \partial_\mu a^a_\nu - \partial_\nu a^a_\mu + \epsilon^{abc} a^b_\mu a^c_\nu$$

$$G^a_{\mu\nu}(B) = \partial_\mu B^a_\nu - \partial_\nu B^a_\mu + \epsilon^{abc} B^b_\mu B^c_\nu$$

The last term in (4) corresponds to the interaction of the stochastic background and excitation.

Substituting relations (3) and (4) into the set (1) and averaging over assembly of initial data for the random fields $\hat{a}_\mu$, we find out an equation for $\hat{B}_\mu$:

$$\partial_\mu G^a_{\mu\nu}(B) + \epsilon^{abc} B^b_\mu G^e_{\mu\nu}(B) = m^2 B^a_\nu$$

In terms of $\hat{A}_\mu$ fields the theory is gauge-invariant and massless. Such fields can be naturally called microscopical. The fields $\hat{B}_\mu$ over stochastic vacuum have acquired mass and broken local gauge symmetry. We will call such fields macroscopical. The occurrence of mass of fields $\hat{B}_\mu$ is caused by their interaction with vacuum random fields. The Yang-Mills theory in terms of $\hat{A}_\mu$ is renormalizable. After extraction of vacuum background we have got a non-renormalizable massive theory. However, as it follows from stated above, the Yang-Mills massive theory can be interpreted as a macroscopical manifestation of a renormalizable microscopic theory.

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