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E.SH.EGORIAN, S.G.MATINYAN

COLOR CONFINEMENT AS A RESULT OF STOCHASTICITY

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The functional integral of the gauge theory, where fields are coupled to random currents, generates a gluon propagator corresponding to confinement.

Yerevan Physics Institute
Yerevan 1983

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Эд.Ш.ЕГОРЯН, С.Г.МАТИНЯН

КОНФАЙНМЕНТ ЦВЕТА КАК СЛЕДСТВИЕ СТОХАСТИЧНОСТИ

Функциональный интеграл калибровочной теории, в которой поля связаны со случайными токами, генерирует пропагатор глюонов, приводящий к конфайнменту.

Ереванский физический институт
Ереван 1983

YEREVAN PHYSICS INSTITUTE

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Yerevan 1983

The discovery of the stochasticity of free classical non-abelian gauge fields [1,2] and of the phase transition of the "disorder-order" type ("confinement phase" - "Higgs phase") in these systems [3] makes very attractive the idea that the observed phenomena are preserved to some degree in the real (i.e. quantum) vacuum of QCD and that namely the presence of random colored vacuum fields in it is responsible for the color confinement.

From this viewpoint, of special interest is the phenomenon of lowering of dimensionality of quantum spin systems coupled to a random magnetic field near the critical point [4] and utilizing it for the confinement problem [5,6].

It has been shown [5] that the necessary and sufficient condition for the area law for the Wilson loop average $W(c)$ is the presence of random fields in vacuum.

In ref. [6] the reduction, due to stochastic vacuum fields, of $W(C)$ of the four-dimensional Yang-Mills theory to $W(c)$ of the appropriate two-dimensional one and, hence, the area law is illustrated.

Unfortunately, refs. [5,6] are made less convincing largely due to the fact that authors have restricted themselves to the consideration of planar loops. Note also ref.[7] where the concept of the localization of one-dimensional disorder systems is used to qualitatively obtain the confinement.

In the present paper we have shown that if one takes into account, in the functional integral of theory, the gauge fields generated by randomly distributed currents, then the appropriate two-particle Green functions will correspond to the confinement. The physical picture of the gluon propagator is of course not exhausted with these fields, for we cannot estimate, on the background of random fields, the relative contribution in the functional integral of the fields of another, nonstochastic nature, which should be particularly important for small or average, compared to the confinement radius Λ^{-1} or, in our problem, to the radius of correlation of random currents μ^{-1} distances.

Taking into account this remark, consider tha gauge theory with external random color currents which are Gaussian-distributed (the so-called "white noise"):

$$\langle J_\mu^a(x) J_\nu^b(y) \rangle = \mu^2 \delta_{\mu\nu} \delta^{ab} \delta^{(4)}_{(x-y)} \tag{1}$$

In agreement with the abovestated, the dynamics of gluons at the distances $\sim \Lambda^{-1} \sim \mu^{-1}$ is determined by the stochastic differential equation

$$\frac{\delta S}{\delta A_\mu^a} = J_\mu^a \tag{2}$$

where S is the action of gauge theory in the four-dimensional space - time (below we use the Euclidean formulation), and the quantum averaging is determined by the relation

$$\langle A^{a_1}_{\mu_1}(x_1)\dots A^{a_n}_{\mu_n}(x_n) = \langle {}^J\!A^{a_1}_{\mu_1}(x_1)\dots {}^J\!A^{a_n}_{\mu_n}(x_n)\rangle_J \quad (3)$$

where the fields ${}^J\!A^a_\mu$ are determined from eq. (2), and the averaging $\langle\cdots\rangle_J$ in the right hand side of (3) is performed according to the Gaussian distribution of currents $J^a_\mu(x)$

$$\exp\left\{-\frac{1}{2\mu^2}\int J^a_\mu(x)\,J^a_\mu(x)\,d^4x\right\}$$ corresponding

to (1).

The generating functional of our theory corresponding to (3) is given by the expression

$$Z(h^a_\mu) = \int \mathcal{D}J\,\exp\Big\{-\int\Big[\frac{1}{2\mu^2}J^a_\mu(x)\,J^a_\mu(x) - h^a_\mu(x)\,{}^J\!A^a_\mu(x)\Big]d^4x\Big\} \qquad (4)$$

whose differentiation in the quantum source $h^a_\mu(x)$ defines the (3).

Passing in (4) from J to the variables ${}^J\!A$ and using the standard method of rewriting the determinant via anticommuting vestor fields ψ^a_μ, $\bar\psi^a_\mu$ we shall obtain the exact formula (for the sake of simplicity we shall later omit the Lorentz and internal indices):

$$Z(h) = \int \mathcal{D}\bar\psi(x)\,\mathcal{D}\psi(x)\,\mathcal{D}A\,\exp\Big\{-\int\Big[\frac{1}{2\mu^2}\Big(\frac{\delta S}{\delta A}\Big)^2\cdot \delta^{(4)}(x-y) - \bar\psi(x)\frac{\delta^2 S}{\delta A(x)\,\delta A(y)}\psi(y) - h\,A(x)\,\delta^4(x-y)\Big]d^4x\,d^4y\Big\}. \qquad (5)$$

One may see from (5) that already in the tree approximation the two-particle function of the type (3)$\langle A^a_\mu(x) A^b_\nu(y)\rangle$ possesses the confinement property (see the first term in the exponent (5)). We shall show it explicitly using another method associated with the introduction of the superfield $\Phi^a_\mu(x, \theta)$ (note the recently observed close relation between the stochastic differential equations of the type (2) and supersymmetry [8]):

$$\Phi^a_\mu(x, \theta) = A^a_\mu(x) + \theta \bar{\Psi}^a_\mu(x) + \Psi^a_\mu(x)\bar{\theta} + C^a_\mu \bar{\theta}\theta \qquad (6)$$

where θ and $\bar{\theta}$ are the anticommuting variables $(\theta^2 = \bar{\theta}^2 = \{\theta, \bar{\theta}\} = 0)$.

For (5) we shall have

$$Z(h) = \int \mathcal{D}\Phi \exp\Big\{-\int\Big[\mathcal{L}(\Phi) - \frac{\mu^2}{2}\Phi\frac{\partial^2}{\partial\bar{\theta}\partial\theta}\Phi - H\Phi\Big]d^4x\,d\bar{\theta}\,d\theta\Big\} \qquad (7)$$

$(H = h(x)\bar{\theta}\theta)$ whence it follows that the Fourier transform of the propagator $\langle \Phi^a_\mu \Phi^b_\nu \rangle$ of the gauge superfield has the structure of $(p^2 \lesssim \mu^2)$:

$$(p^2 + \mu^2\bar{\alpha}\alpha)^{-1}\delta^{ab}\delta_{\mu\nu}$$

where $\alpha, \bar{\alpha}$ are the anticommuting variables corresponding to $\theta, \bar{\theta}$, which after the integration over $\alpha, \bar{\alpha}$ results in the confinement:

$$\int e^{ip(x-y)}\langle A^a_\mu(x) A^b_\nu(y)\rangle \sim \delta_{\mu\nu}\delta^{ab}\mu^2/p^4.$$

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References

I. Матинян С.Г., Саввиди Г.К., Тер-Арутюнян-Саввиди Н.Г. Классическая механика Янга-Миллса. Нелинейные колебания цвета. ЖЭТФ, I98I, т.80, с.830.

2. Чириков В.В., Шепелянский Д.Л. Стохастические колебания классических уравнений Янга-Миллса. Письма в ЖЭТФ, I98I, т.34, с.I7I.

3. Матинян С.Г., Саввиди Г.К., Тер-Арутюнян-Саввиди Н.Г. Стохастичность классической механики Янга-Миллса и ее устранение механизмом Хиггса. Письма в ЖЭТФ, I98I,т.34, с.6I3.

4. Imry Y., Ma S.-K. Random Field Instability of the Ordered State of Continuous Symmetry.- Phys.Rev.Lett., 1975, vol. 35, p.1399.

Grinstein G. Ferromagnetic Phase Transitions in Random Fields: The Breakdown of Scaling Laws.- Phys.Rev.Lett., 1976, vol. 37, p.944.

Aharony A., Imry Y., Ma S.-K. Lowering of Dimensionality in Phase Transitions with Random Fields.- Phys.Rev.Lett., 1976, vol. 37, p.1364.

5. Olesen P. Confinement and Random Fluxes.- Nucl.Phys., 1982, vol. B200, p.381.

6. Kupiainen A., Niemi A. Quark Confinement in Disordered Vacuum Helsinki Preprint, 1982, HU-TFT-82-41.

7. Апенко С.М., Киржниц Д.А., Лозовик Ю.Е. Динамический хаос, локализация Андерсона и конфайнмент. Письма в ЖЭТФ,I982, т.36, с.I72.

8. Parisi G., Sourlas N. Random Magnetic Fields, Supersymmetry and Negative Dimensions.- Phys.Rev.Lett., 1979, vol. 43, p.744.
Parisi G., Sourlas N. Supersymmetric Field Theories and Stochastic Differential Equations.- LPTENS 82/6, 1982.

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