Collective variables and composite fields

Victor Novozhilov and Yuri Novozhilov
V.A.Fock Department of Theoretical Physics,
St.Petersburg State University, 198904, St.Petersburg, Russia

Abstract

We consider use of collective variables for description of composite fields as collective phenomena due to the strong coupling regime. We discuss two approaches, where identification of collective variables of complex quantum system does not depend on knowledge of other degrees of freedom: (a) collective variables as parameters of group transformations changing the path integral of the system, and (b) collective variables as background fields for quantum system. In the case (a) we briefly present an approach. In the case (b) we consider fermions in an external scalar field, which serves as a collective variable in a nonlinear model for composite scalar field with a finite compositeness scale.

Introduction

In absence of particle-creation interaction, to describe a composite field means to solve the Schroedinger equation for constituent particles. When interaction changes particle number, one should work in the Fock space, and if coupling is strong, even a single particle should be described in the Fock space by the column vector with many rows; a single particle becomes ”dressed”. A composite particle state in the Fock space will include rows corresponding to different ways of combining indefinite many more elementary systems into states with the same internal quantum numbers. In Quantum Field Theory, this situation can be also expressed in language of the Bethe-Salpeter
and the Schwinger-Dyson equations as necessity to take into consideration more and more graphs. In other words, in the strong coupling regime a composite field becomes a collective phenomenon. Its properties may be quite different from what can be guessed from perturbation theory.

As a collective phenomenon, composite particles in a strong coupling regime - with respect to the underlying fundamental particles - are similar to macroscopic systems with respect to underlying microscopic systems. Bogolyubov description of superconductivity in terms of collective variables belonging to the microscopic level is a well-known example of such an approach. In complex systems, identification of collective degrees of freedom is a starting point for their description.

In QFT, to find an appropriate picture of composite particles in a strong coupling regime is one of the main problems of the theory. In Quantum Chromodynamics a solution of this problem is needed in order to compare low energy QCD with an experiment. Understanding of composite quantum fields is necessary in order to look for properties of theories at different mass scales.

In this paper we consider two approaches for choosing collective variables in QFT, namely, (a) collective variables as parameters of non-invariance groups, and (b) collective variables as external fields’ background for quantum fields.

Quantum composite fields as parameters of non-invariance groups

In the modern QFT collective variables can be introduced in the generating functional. Consider a field \( \Phi(x) \) with the Lagrangian \( L(x) \) and vacuum functional

\[
Z = \int D\Phi e^{i \int L dx} \tag{1}
\]

Let \( \Pi(x) \) be a local field with quantum numbers of a composite system made out of \( \Phi \). The functional measure \( D\Phi \) is over all independent degrees of freedom of \( \Phi \); thus it includes also degrees of freedom of \( \Pi(x) \) together with remaining degrees \( X \) which are considered inessential. If we change variables

\[
\{ \Phi \} \to \{ \Pi, X \} \tag{2}
\]
and transform $Z$

$$Z = \int D\Pi DX J(\partial\Phi/\partial\Pi, \partial\Phi/\partial X) e^{i \int L(\Pi,X) dx} \equiv Z_{\text{inv}} \int D\Pi e^{i \int L_{\text{eff}}(\Pi) dx}$$

(3)

then after integrating out inessential variables $X$ we arrive at the effective Lagrangian $L_{\text{eff}}(\Pi)$ for a collective variable $\Pi$ describing a composite field. The functional $Z_{\text{inv}}$ does not depend on $\Pi$; $J$ is a Jacobian of transformation $\{\Phi\} \rightarrow \{\Pi,X\}$.

In practice, to find directly variables $X$ and the Jacobian is a difficult task. However, there are some classes of collective variables $\Pi$, when knowledge of $X$ is not necessary in order to find an effective Lagrangian $L_{\text{eff}}(\Pi)$, namely, when $\Pi$ are parameters of non-invariance groups and different classes correspond to different groups. "Non-invariance" is understood in relation to the vacuum functional: $\delta Z/\delta \Pi \neq 0$. In this case one can hope to integrate $\delta Z/\delta \Pi$ up to a factor in vacuum functional $Z$ depending only on $\Pi$.

Consider a group $G$ of transformations $U = \exp i\Pi$ of field $\Phi$, $\Phi \rightarrow U\Phi \equiv \Phi^U$ with the invariant measure $D(UU') = DU$ and the vacuum functional

$$Z[U] = \int D\Phi \exp \left( i \int dx L(\Phi^U) \right)$$

(4)

Integrating over $U$ we get $G$-invariants

$$Z_0 = \int DU Z[U], Z_{\text{inv}}^{-1} = \int DU Z^{-1}[U]$$

(5)

which can be used in order to substract from $Z$ a $G$-invariant part leaving a functional $Z_U$ for $U$

$$ZZ_0^{-1} \simeq ZZ_{\text{inv}}^{-1} = Z_U \equiv \int DU \exp \left( i \int dx L_{\text{eff}}(U) \right)$$

(6)

and identifying an effective action for $U = \exp i\Pi$ as

$$W_{\text{eff}}(U) = \int dx L_{\text{eff}}(U) = -i \ln \frac{Z}{Z[U]}$$

(7)

We use $\simeq$ to show that $Z_0$ and $Z_{\text{inv}}$ differ by $G$-invariant terms. Thus, $L_{\text{eff}}$ is defined up to $U$-independent terms.
We see that inessential variables $X$ were effectively integrated out in integration over all initial degrees of freedom. A replacement $\Phi \rightarrow \Phi^U$ in both the measure and lagrangian in $Z$ is just a change of notations and cannot change $Z$. Thus, the Jacobian $J$ in (3) is expressed in terms of $W_{\text{eff}} (U)$.

This is a group-theoretical way to derive low energy effective lagrangians for chiral field $U = \exp i \Pi$, where pseudoscalar field $\Pi$ describes pions and kaons, an extended chiral field $\mathcal{U}$ of the extended chiral group $E \chi$ describing pseudoscalar mesons and diquarks, and dilaton field $\sigma(x)$ related to the conformal transformation $g_{\mu \nu} \rightarrow (\exp 2 \sigma) g_{\mu \nu}$. In this way we get quantum composite fields $U, \mathcal{U}$ and $\sigma$ with their vacuum functionals, i.e. with integration over these fields.

Quantum fields in classical background and induced classical action for composite field

Induced classical gravity.

Quantum matter fields on curved space represent the most general example of such class. Vacuum fluctuations of matter fields transform a given metric into a classical dynamical gravitational field with the Einstein action in the longwave region which got the name of 'Induced Gravity'. This fact was discovered by Zeldovich and Sakharov and developments were reviewed by Adler. Due to ambiguity in definition of Newton constant Induced Gravity was forgotten for a decade and reconsidered with modern calculational tools in the framework of bosonization approach. "Einsteinization" of external metric under influence of collective vacuum mode of matter fields represents a phenomenon of 'partial compositeness', when quantum fields do not create a new field, but only provide an existing field with kinetic term and interactions.

Let $L (\Psi, g_{\mu \nu})$ be a lagrangian of matter fields $\Psi$ on curved background $g_{\mu \nu}$ and $Z_{\Psi} [g_{\mu \nu}]$ denote the vacuum functional

$$Z_{\Psi} [g_{\mu \nu}] = \int D\Psi \exp \left( \int dx L (\Psi, g_{\mu \nu}) \right)$$

Integration over matter $\Psi$ in $Z_{\Psi}$ takes into account vacuum fluctuations of fields $\Psi$. As a result, an external metric $g_{\mu \nu}$ entering the lagrangian $L$ in integrand comes out as an argument of an effective action $W (g_{\mu \nu})$.
\[
\exp (iW (g_{\mu\nu})) = Z_{\Psi} [g_{\mu\nu}]
\] 

(9)

It is the action \(W (g_{\mu\nu})\) that describes induced Einsteinian gravity if evaluation of \(Z_{\Psi}\) is implemented carefully.

Induced action for mesons with finite compositeness scale

As an example, consider quantum quark field \(\psi\) in background of scalar field \(S(x)\) which serves as a collective variable in a model of scalar mesons \([12]\). Model of flavor vector mesons in a similar approach was constructed earlier \([13]\).

The purpose of the model is to develop a theory of isotriplet and isosinglet scalar mesons \(a_0\) and \(f_0\) from the viewpoint of the low energy QCD as a part of renormalized theory. Induced action for scalar mesons is obtained by integration over quark fields in the quark functional integral. But we add an assumption that these mesons exist within finite compositeness region with the upper scale \(\Lambda_s\), thereby describing the slope of the coupling constant beyond the chiral breaking scale. We use an approach proposed for the model of composite electroweak bosons \([14]\) and definition of a composite particle in renormalisation theory through radiative corrections \([15]\). We use also similarity between low energy scalars and Higgs fields when gauge fields are also present.

Integration over fermions in the quark path integral in its simplest form is equivalent to one-loop approximation which produces polynomials of scalar fields and, consequently, may lead to scalar condensate. Advantage of the path integral approach is that it can easily take into account the quark and gluon condensates. The problem which arises in the low energy QCD is whether the compositeness scale \(\Lambda_s\) for scalars coincides with the scale of the chiral symmetry breaking or it should be introduced as a separate low energy parameter. We assume that \(\Lambda_s\) coincides with the upper scale of the QCD low energy region defined in terms of the quark and gluon condensates \([16]\).

Our aim is to obtain an effective Lagrangian for a dynamical composite field \(\hat{S}(x)\) through radiation corrections to the Dirac Lagrangian with an external field \(S(x)\). A composite field \(\hat{S}(x)\) is defined by vanishing of its renormalisation constant \(z_{\hat{S}} \left( \frac{\Lambda}{\mu} \right) \to 0\) when \(\mu\) reaches the compositeness scale \(\Lambda\) \([15]\). We consider composites in the approximation of fermion loops resulting from integration over fermions in the path integrals. If \(S(x)\) were elementary, its renormali-
sation constant would be $z_S = 1 + \Delta$, where $\Delta$ contains logarithms. For a composite $\hat{S}(x)$ suitable normalisation leads to $z_S = \Delta$.

The Lagrangian for fermions interacting with scalar background $S$ and vector fields $V_\nu = (g_V/2i) V^k_\nu \tau_k$, $A_\nu = (g_A/2i) A^k_\nu \tau_k$ and corresponding path integral are given by

$$L = \overline{\psi} (\not{D} + S) \psi$$

$$Z[S] = \int D\overline{\psi} D\psi \exp\{i \int dxL\} \equiv Z_\psi[D + S]. \quad (10)$$

We consider only fermion loops as a main reason for existence of a dynamical scalar $\hat{S}(x)$ and in the fermion path integral integrate out fermions between the gauge invariant compositeness scale $\Lambda$ and a running scale $\mu = \Lambda \exp(-\sigma)$, $\sigma \geq 0$. An effective action $W_{\text{eff}}(\hat{S})$ for the composite field $\hat{S}$ is then

$$\exp\left(iW_{\text{eff}}(\hat{S})\right) = \frac{Z_\psi[D + S; \Lambda]}{Z_\psi[D + S; \mu]} \quad (11)$$

where $Z[...] : \Lambda$ means that the path integral is extended up to the scale $\Lambda$. Self-consistency of such definition requires that kinetic energy of $\hat{S}$ in the compositeness region should be positive and disappear at the compositeness scale, while the potential part of $W_{\text{eff}}$ should give positive mass.

We consider first the case of one quark generation $u, d$ with common mass $m$ when dynamics of composite pseudoscalar and vector fields is well described by the Chiral theory and the relevant energy scales -the low energy QCD region $R_{QCD}$ - are defined by the quark and gluon condensates $[18]$. This region can be described also by the quark spectral asymmetry and invariant cutoff $[16]$. The chiral and scale anomalies dominate strong interaction physics in $R_{QCD}$ $[6]$. We assume that $R_{QCD}$ is also the compositeness region $R_S$ for a scalar field $S(x)$.

The quark path integral in the Euclidean space is represented in the form

$$\ln Z_\psi[\hat{D}] = Tr \ln \left(\frac{D}{\Lambda}\right) \cdot \Theta \left(\Lambda^2 - (D - M)^2\right) \quad (12)$$

with parameters $\Lambda$ and $M$ defined in terms of the quark $C_q$ and gluon $C_g$ condensates and $\Lambda$ identified with the compositeness scale $\Lambda_S$; here $\kappa$ is the normalization scale.
Let us for a moment omit vector field $V_\mu$ from the Dirac operator $\not D$. Integrating out fermions between $\Lambda$ and $\mu = \Lambda \exp(-\sigma), \sigma \geq 0$, we get the following effective lagrangian for $\hat{S}(x)$ in the Minkowski space

$$L_{\text{eff}}(\hat{S}) = \frac{N_c}{8\pi^2} \sigma \text{tr}_f \left(D_\mu \hat{S}\right)^2 + 3\sigma F_\pi^2 \text{tr}_f \hat{S}^2 \xi_2 - \frac{N_c}{8\pi^2} \sigma \text{tr}_f \hat{S}^4$$

$$-3\sigma C_q \xi_3 \text{tr}_f \hat{S} - \sigma \frac{N_c}{2\pi^2} M \xi_1 \text{tr}_f \hat{S}^3$$

(13)

where $D_\mu = \partial_\mu + [V_\mu, \circ]$ is a covariant derivative, $\xi_n$ describe running of masses and scalar condensate

$$\xi_n = \frac{1 - e^{-n\sigma}}{n\sigma}$$

(14)

$F_\pi$ is the pion decay constant, $N_c$ is number of colors, $\Lambda$ and $M$ are expressed in terms of the condensates

$$C_q = -\frac{N_c}{2\pi^2} \left(\Lambda^2 M - \frac{M^3}{3}\right); C_g = \frac{3N_c}{2\pi^2} \left(6\Lambda^2 M^2 - \Lambda^4 - M^4\right)$$

(15)

The gluon condensate $C_g$ does not appear explicitly in $L_{\text{eff}}(\hat{S})$; $\text{tr}_f$ refers to flavor matrices. Kinetic energy in $L_{\text{eff}}$ is positive for $\sigma > 0$ and disappears at the compositeness scale $\Lambda$. Main terms of induced potential $\hat{U}(\hat{S})$ are presented in the first line; they include $\hat{S}^2$ and $\hat{S}^4$ terms. The term with $\hat{S}^2$ enters $L_{\text{eff}}$ with a wrong sign, so that $\hat{U}(\hat{S})$ may have a minimum.

We see that integrating over quarks with the background field $S$ in the quark lagrangian give rise to an effective lagrangian $L_{\text{eff}}(\hat{S})$ for a dynamical field $\hat{S}$ with coefficients defined by quarks.

**Nonlinear representation of composite field**

We consider nonlinear representation of composite field $\hat{S}(x)$ and denote it in this case by $\Phi = \Phi_0 \exp \phi$, where $\Phi_0$ is a large field and $\phi = \phi_0 + \phi_k \tau_k$ are small fluctuations, $\tau_k$ are Pauli matrices for isospin.

To study characteristic features of the model we consider first the case when the spectral asymmetry $M = 0$ and consequently, the
quark condensate is absent, $C_q = 0$. The effective lagrangian $L^0 = L_{\text{eff}} (M = 0)$ has the standard form

$$L^0 (\Phi) = Z_\Phi \frac{1}{2} (\partial \nu \phi_a)^2 + \mu^2 tr \Phi^2 - \frac{\lambda}{2} tr \Phi^4$$

with $a = 0, k$, renormalization constant $Z_\Phi = N_c \sigma \Phi_0^2 / 2 \pi^2$, and potential parameters

$$\mu^2 = 3 F^2 \sigma \xi_2, \lambda = \frac{N_c \sigma}{4 \pi^2}$$

The minimum $\Phi_0$ of the potential $U(\Phi)$ and masses of fields $\phi_a$ are given by relations

$$\Phi_0^2 = \frac{\mu^2}{\lambda}, m_\phi^2 = 4 \Phi_0^2$$

which held independently of $\sigma$. Dynamical quark mass is $m_\psi = \Phi_0$, or $m_\phi = 2 m_\psi$. This relation is characteristic for many models [19].

Masses $m_\phi^2$ run with $\sigma$ due to factor $\xi_2 (\sigma)$ and decrease for increasing positive $\sigma$.

Let us now restore $M$. The effective lagrangian $L^M$ gets two additional terms

$$L^M = L^0 - 3 C_q \sigma \xi_3 tr \Phi - \frac{N_c M}{2 \pi^2} \sigma \xi_1 tr \Phi^3$$

and $\Phi_0$ is to be found from the equation

$$\Phi_0^3 + \frac{3 N_c M}{4 \pi^2 \lambda} \sigma \xi_1 \Phi_0^2 - \frac{\mu^2}{\lambda} \Phi_0 + \frac{3 C_q}{2 \lambda} \sigma \xi_3 = 0$$

At the compositeness scale $\sigma = 0$ the solution is simple

$$(\Phi_0 + M)^2 = 3 \Lambda^2$$

and in this case $m_\phi^2 = 4 (\Phi_0 + M)^2$ while for the quark dynamical mass we have the same relation $m_\psi = \Phi_0$ as for $M = 0$. Additional contribution to $m_\phi$ arises from condensates.

In the case $\sigma \neq 0$ the mass of scalars $\phi_a$ as a function of $\sigma$ is defined in terms of $\Phi_0 (\sigma)$ and $\xi$

$$m_\phi^2 = 6 \left[ \Phi_0^2 + 2 M \Phi_0 \xi_1 + \left( M^2 - \Lambda^2 \right) \xi_2 \right]$$
$m_\phi$ decreases with increasing positive $\sigma$ from its maximal value $m_\phi = 2 (\Phi_0 + M)$ at $\sigma = 0$.

Interaction of scalars $\phi_a$ with pseudoscalar mesons has the same structure as in the dilaton model for scalars \[6, 17\] but with different coefficient: $M_1 \left(\frac{3\sigma}{2\pi^2}\right)^{1/2}$ instead of $F_\pi$. It reduces width $\Gamma_\phi$ compared with the dilaton model.

Let us reintroduce vector fields $V_\nu$ and $A_\nu$ and study their interaction with scalar condensate $\Phi_0$. The field $V_\nu$ appears only in kinetic part of $L_{\text{eff}}(\Phi)$, and $\Phi_0$ does not break symmetry. Thus, the only impact of integration over quarks on $V_\nu$ is the contribution $\Delta V = \frac{1}{12\pi^2} / g_2$ to coupling $1 / g_2$ in the original lagrangian $L_V = \frac{1}{2g_2} tr V_{\mu \nu}^2$ for elementary field $V_\nu$.

The axial vector $A_\nu$ enters $L_{\text{eff}}(\Phi, A_\nu)$ quadratically

$$L_{\text{eff}}(\Phi, A_\nu) = \frac{2}{3} \mu^2 tr A_{\nu}^2 - \frac{\lambda}{2} tr \{A_\nu, \Phi\}^2 - \frac{N_c M}{\pi^2} \sigma_1 tr \left( A_{\nu}^2 \Phi \right)$$

(23)

It follows that field $A_\nu$ will get contribution $\delta m^2_A = \Delta_A m^2_\phi$ to 'bare' mass $m^2_{0A}$, if $A_\nu$ is elementary, giving the total mass $m^2_A$

$$m^2_A = m^2_{0A} + \Delta_A m^2_\phi$$

(24)

where $\Delta_A = \Delta_V = \lambda / 3$ is one-loop contribution to the renormalization constant $Z_A = 1 + \Delta_A$, or to $1 / g^2_A$ in initial lagrangian $L_A = (1 / 2g^2_A) tr (D_\mu A_\nu - D_\nu A_\mu)^2 + [A_\mu, A_\nu]^2$ . The mass $\delta m^2_A$ induced by scalar condensate depends also on the quark and gluon condensates through the asymmetry parameter $M_\nu$, and disappears at the compositeness scale $\sigma = 0$. If $A_\nu$ is a composite field with the same compositeness scale $\Lambda_A = \Lambda_\phi$, then it acquires the mass $m^2_A = m^2_\phi$.

Let us review results of the model. We have found relations of the scalar condensate to the quark and gluon condensates and thereby can explain why mass of $q\bar{q}$ scalar mesons may be considerably higher than two quark masses $2m_q$. Certainly, a contribution from gluons is present here, though composition of scalar meson cannot be identified as $qq\bar{q}$ or $qqg\bar{q}$ etc. If to use this language, one should rather speak about mixture of combinations $q \langle \bar{q} q \rangle_0 \bar{q}$ and $q \langle G^2_{\mu \nu} \rangle_0 \bar{q}$ containing the quark and gluon condensates.

We have found a contribution $\delta m^2_A$ from scalar condensate to the mass of axial vector meson in the model (a), when internal symmetry
is not broken, so that, for vector mesons, analogous contribution does not exist, $\delta m^2_\gamma = 0$. Thus, both results $m_{q\bar{q}} - 2m_q$ and $\delta m^2_\Lambda$ have the same origin in interplay of the quark and gluon condensates. Another result is that nonleptonic decay widths of scalar mesons will be lower in this approach than in the case of dilaton-quarkonia [17].

**Conclusions. Relation to other models**

We have demonstrated two ways of choosing collective variables in QFT in order to find effective actions for composite fields without knowledge of inessential variables. Both approaches are quite universal if a complex quantum system is described by functional integral. The group-theoretical approach leads to an action for composite quantum field, while the Induced action approach gives us a classical action for composite field. In the first case collective variables (parameters of group transformation) are not present in the initial lagrangian. In the second case external fields in the initial lagrangian have all quantum numbers of required composite fields, and functional integration provides them with kinetic term and interactions.

Induced action formalism is closely related to that for a quantum scalar field, if we assume that the scalar background field in the quark Lagrangian arises due a mechanism which produces this quantum field with a scale independent potential $U(S)$ (weight function) of dim 4. If such a potential is absent, the induced action for classical scalar field corresponds to the quantum case when the quark scalar current has zero expectation value in vacuum. The Nambu-Jona-Lasinio model [19] contains a dim 2 potential $U(S)$. Finite compositeness scale approach to these models is considered separately [20].

**References**

[1] H.A.Bethe and E.E.Salpeter, Phys.Rev.82 (1951) 309; ibid 84 (1951) 1232.

[2] F.J. Dyson, Phys.Rev. 75 (1949) 1736; J.Schwinger, Proc.Nat.Acad.Sci. 37 (1951) 452.

[3] N.N.Bogolyubov. JETP, 34 (1958), 58,73; N.N. Bogolubov, V.V.Tolmachev, D.V.Shirkov, New method in the theory of superconductivity, 1958, Moscow,
[4] Yu.V.Novozhilov, A.G.Pronko, D.V.Vassilevich, Phys.Lett. B343 (1995) 358; B351 (1995) 601,
[5] A.Andrianov and Yu.V.Novozhilov; Phys.Lett. 153B (1985) 422, A.Andrianov; Phys.Lett. 157B (1985) 425,
[6] A.A.Andrianov, V.A.Andrianov, V.Yu.Novozhilov, Yu.V.Novozhilov; Phys.Lett. 186B (1987) 401,
[7] Ya.B.Zeldovich, Pis'ma Zh.Eksp.Teor.Fiz. 6 (1967) 883, A.D.Sakharov, Dokl.Acad.Sci.USSR 177 (1967) 70; Teor.Mat.Fiz. 23 (1975) 178,
[8] S.L.Adler, Rev.Mod.Phys. 54 (1982) 729,
[9] F.David, Phys.Lett. B138 (1984) 383,
[10] Yu.V.Novozhilov, D.V.Vassilevich, Lett.Math.Phys., 21 (1991) 253,
[11] D.V.Vassilevich, Yu.V.Novozhilov, Vestnik LGU, Physics, 2 (1991) 76,
[12] V.Yu.Novozhilov and Yu.V.Novozhilov, in Proc. VIII UNESCO Int.School of Physics "Quantum Theory in honour of V.Fock", 1998, 220, ed.Yu.Novozhilov, St.Petersburg, 1998.
[13] V.Novozhilov; Phys.Lett. 228B (1989) 240,
[14] Yu.V.Novozhilov; Phys.Lett. B225 (1989) 165.
[15] K.Hayashi et al; Fortsch.d.Phys. 15 (1967) 625.
[16] A.A.Andrianov, V.A.Andrianov, V.Yu.Novozhilov, Yu.V.Novozhilov, Lett.Math.Phys. 11 (1986) 217,
[17] A.Boduylkov and V.Yu.Novozhilov; Nuovo Cim. 103A (1990) 1381; V.Novozhilov, V.Soloviev; Vestnik Sankt-Petersburg University 18 (1993) 26.
[18] M.A.Shifman, A.I.Vainstein, V.I.Zakharov; Nucl.Phys. B147 (1979) 385,
[19] Y.Nambu, G.Jona-Lasinio; Phys.Rev.122 (1961) 345; V.Elias, M.D.Scadron; Phys.Rev.Lett.53 (1984) 1129; M.K.Volkov; Ann.Phys.(N.Y.) 157 (1984) 282; A.Dhar, R.Shankar, S.Wadia; Phys.Rev. D3 (1985) 3256.
[20] V.Yu.Novozhilov and Yu.V.Novozhilov, "Model with a finite com-
positeness scale for composite scalar field", Rep. StPbU-104/99.