HIGH-ENERGY SCATTERING IN QCD AND IN QUANTUM GRAVITY AND TWO-DIMENSIONAL FIELD MODELS

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It is known [1], that gluons and gravitons are reggeized at least in the leading logarithmic approximation (LLA) of the perturbation theory. It means that the inelastic amplitudes in the multi-Regge kimematics for particles produced in high energy collisions ($\sqrt{s} \to \infty$) have the multi-Regge form

$$A^{LLA}_{2\to 2+n} = \sum_{i=1}^{n+1} s^{\alpha(q_i^2)}\, A^{tree}_{2\to 2+n}, \quad s_i >> q_i^2, \quad s = \frac{\sum_{i=1}^{n+1} s_i}{\sum_{i=1}^{n} (\vec{k}_i)^2}, \tag{1}$$

where $s_i = (k_{i-1} + k_i)^2$ are energy invariants for final particles with momenta k_i and q_i are momentum transfers ($q_i = k_i + q_{i-1}$).

In eq.(1) $\alpha(q_i^2)$ are Regge trajectories of the gluon (g) or the graviton (G). In LLA one obtains: $\alpha_g(t) = 1 + 0(g^2)$, $\alpha_G = 2 + 0(\kappa^2)$, where g and κ are coupling constants for QCD and gravity respectively.

$A^{tree}_{2\to 2+n}$ are the production amplitudes in the tree approximation. They have a multiperipheral form and are constructed from the vertices $\gamma_{\lambda\lambda'}$ and Γ_{λ_i} describing respectively the scattering of the initial particles $A \leftrightarrow A'$, $B \leftrightarrow B'$ with the conserved helicities $\lambda_i' = \lambda_i'$ and the production of the particles with helicities λ_i [1].

The total cross section for colourless particle collisions, obtained with the use of the LLA amplitudes (1), grows with energy as its power and violates the Froissart bound $\sigma_{tot} < c \ln^2 s$ [1]. The reason for this violation is the fact that in LLA the scattering amplitudes do not satisfy requirements of the s-channel unitarity. In the given paper the effective scalar field theories are formulated which give in the tree and leading logarithmic approximations the above production amplitudes $A^{tree}_{2\to 2+n}$ and $A^{LLA}_{2\to 2+n}$ but satisfy the unitarity requirements.

The real particles in s-channel intermediate states are described in these theories by complex fields φ and the virtual particles in q_i^2-channels are described by real fields $A^{\pm}$. We obtain the following local effective actions for QCD and gravity:

$$
\begin{aligned}
S^{QCD} &= \int d^2\rho\, d^2 z \{-2\,(\nabla_+ \partial \varphi_a)\,(\nabla_- \partial^* \varphi_a^*) - 2\,(\partial A_a^+)(\partial^* A_a^-) + \\
&+ \frac{1}{2} g A^{+a}\,[(\partial^* \varphi^*)\, T^a\, i \overleftrightarrow{\nabla}_+ (\partial \varphi)] + \frac{1}{2} g A^{-a}\,[(\partial \varphi^*)\, T^a\, i \overleftrightarrow{\nabla}_- (\partial^* \varphi)] + \\
&+ g \varphi^{*a}\,[(\partial^* A^+)\, T^a\, (\partial A^-)] + g \varphi^a\,[(\partial^* A^-)\, T^a\, (\partial A^+)]\}, \\
S^{Gr} &= \int d^2\rho\, d^2 z \{-2(\nabla_+ (\partial^*)^2 \varphi)\,(\nabla_- \partial^2 \varphi) - 2(\partial^* A^+)\,(\partial A^-) + \\
&+ \kappa A^+\,[(\partial^2 \varphi^*) \overleftrightarrow{\nabla}_+ \overleftrightarrow{\nabla}_+ (\partial^2 \varphi)] + \kappa A^-\,[(\partial^2 \varphi^*) \overleftrightarrow{\nabla}_- \overleftrightarrow{\nabla}_- (\partial^*)^2 \varphi] + \\
&+ \kappa \varphi^*\,[(\partial^{*2} A^+)\,(\partial^2 A^-) - (|\partial|^2 A^+)\,(|\partial|^2 A^-)] + \kappa \varphi [(\partial^*)^2 A^-)\,(\partial^2 A^+) - (|\partial|^2 A^-)\,(|\partial|^2 A^+)]\}
\end{aligned}
\qquad (2)
$$

where $\partial = \partial/\partial\rho$, $\nabla_\pm = \partial/\partial z_\pm$ and $\rho = x^1 + ix^2$, $z_\pm = x^3 \pm x^0 (p_A^{1,2} = p_B^{1,2} = 0)$; T^a are the colour group generators in the adjoint representation.

The S-matrix, corresponding to actions (2), can be expressed in terms of an integral over some auxiliary coupling constants from the product of the Green functions for the two-dimendional field theories (see [2]).

References

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