Previous research description

Abstract

I have been working on two different approaches in non-perturbative Yang-Mills theory. If the temperature is high enough the quasi-classical consideration becomes applicable and one can accurately approximate Yang-Mills partition function by classical configurations. To push forward this idea I analytically calculated the quantum weight of some classical configurations of the Yang-Mills field. The second approach is AdS/CFT. With my collaborators we proposed an efficient quasi-classical method to compute quantum corrections to the classical energy spectrum. It allows to test in many ways the conjectured asymptotic Bethe equations for $N = 4$ YM and and put forward our own proposal for $N = 6$ Chern-Simons theory. One of the most important open questions in the AdS/CFT integrability subject is how compute spectrum of short strings and finite length operators. As a considerable step towards this goal we proposed a general method to find spectrum of 2D integrable QFTs in arbitrary finite volume which was successfully applied to S^3-sigma model.

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The first approach is devoted to confinement/deconfinement phase transition. If the temperature is high enough the quasi-classical consideration becomes applicable and one can accurately approximate Yang-Mills partition function by classical configurations. To push forward this idea I analytically calculated the quantum weight of some classical configurations of the Yang-Mills field for $SU(2)$ gauge group in the work [P15][1] in collaboration with D. Diakonov, V. Petrov and S. Slizovsky. These configurations called the instantons with non-trivial holonomy generalize the usual instantons in case of non-zero temperature. They lead to zero Polyakov loop and that is one of the confinement criterion at non-zero temperature. In the collaboration with S. Slizovsky, we generalized the results of the previous work to other representations and gauge groups [P13,P12,P21]. Then, in collaboration with D. Diakonov, we studied the measure on the moduli space of these classical configurations [P14]. As a result we gave the estimation of the confinement/deconfinement phase transition temperature which agrees with the previous numerical lattice simulations.

The second approach which recently has become fast-developing is based on the following idea. If the dual theory of the QCD was known, for which the perturbation theory would be given by a series in inverse powers of gauge coupling g, one could resolve many problems unreachable in the usual formulation. The dual theory for $\mathcal{N} = 4$ super-symmetric generalization of 4D Yang-Mills theory is conjectured to be 10D string theory in the $AdS_5 \times S^5$ background. There are also several conjectures about gauge theories with smaller number of super-symmetries.

I have been working on this subject for three years now and have already published fourteen articles and one is in preparation. The first paper titled "Double scaling and finite size corrections in SL(2) spin

[1] in the list of publications

chain" concerns Yang-Mills part of the duality, namely the computation of the finite size corrections to the anomalies dimensions of very long operators using the underlying integrable structure. In this paper we developed the general method of finding the finite size corrections for a system described by Bethe equation. The results of this article were extended to the conjectured $AdS_5 \times S^5$ string Bethe ansatz equation in [P3] where 2-loop energy shift was computed for a classical string. The results of [P3] were subsequently remarkably confirmed by an independent method in [1, 2].

In the next work "Strings as multi-particle states of quantum sigma-models" in collaboration with V. Kazakov, K. Sakai and P. Vieira [P10] it is shown how the classical integrable structure (algebraic curve) comes from the Zamolodchikovs' bootstrap approach to the integrable field theories. In the bootstrap formulation Bethe ansatz has one extra equation with respect to the corresponding subsector of the string Bethe ansatz, which restricts momenta of the physical particles constituting the state. In the subsequent paper with V. Kazakov [P9] we show that in the limit of large number of the physical particles the extra degree of freedom can be integrated out which leads precisely to the conjectured string Bethe ansatz for S^3 sub-sector. I should emphasize that the bootstrap approach fixes uniquely the algebraical equations describing the theory. Moreover, before integrating out the set of extra variables, equations look much simpler and have clear physical and mathematical meaning. Thus it was an important test of the equations conjectured from the superstring theory.

In the series of three papers in collaboration with P. Vieira [P6,P7,P8] we show how the energy level spacings and the 1-loop corrections to energy levels can be computed directly from the classical algebraic curve of the finite gap method. We have also reproduced the old results obtained by the direct quantization of the Metsaev-Tseytlin action for some simple classical string motions. Our results are more general and are not restricted to particular classical solutions. Basing on them we prove in the full generality that the conjectured Bethe ansatz perfectly reproduces the 1-loop corrections computed from the field theory side. Thus, we performed a very general and highly nontrivial test of the conjectures involved into the AdS/CFT correspondence. The method we developed in the series of papers was shown to be particularly efficient when applied to Giant Magnon string solution [P5,P1],[3, 4] where one can explore physics beyond the asymptotic Bethe ansatz. We show that the quantum corrections to the dispersion relation of the Giant Magnon are in perfect agreement with the conjectured generalization of Lüscher formula, which describes finite size corrections to the asymptotic Bethe ansatz.

The possibility to describe the spectrum of AdS/CFT exactly and thus to extend the asymptotic Bethe ansatz to the arbitrary length operators or short strings is my other research direction. In collaboration with V.Kazakov and P.Vieira we did an important step towards complete solution of AdS/CFT theory. In the last work [P18] we developed a method of solution 2D relativistic integrable models in finite volume. Our method is shown to be very general and I hope to apply it for AdS/CFT for arbitrary, and not only asymptotically long operators, like Konishi operator.

Recently, another example of AdS/CFT correspondence was explored. The so-called ABMJ theory has $\mathcal{N} = 6$ Chern-Simons theory at one side of the correspondence and string theory in $AdS_4/\mathbb{CP}^3$ background at another. In our works with P.Vieira [P20,P2] we conjectured asymptotic Bethe ansatz equations for that theory. Our equations were confirmed by a few convincing tests, and all seeming discrepancies of these tests with our equations appeared to be due to ambiguities in the string theory computations as was shown in my work with PhD student V.Mikhaylov [P19].

In general, my research is developing into the direction of a better understanding of the strong (nuclear) interactions - one of the four fundamental interactions of nature and could provide us with better understanding some physical phenomenons which will be beneficial in the future. In addition, many of my results on quantum integrability contain new mathematical methods and they could be used in other domains of physics, such as the condensed matter problems of strongly correlated electrons.

I have already published twenty one papers, fifteen of which are in the refereed journals and I gave six talks on the international conferences mentioned in my Curriculum Vitae. I have worked as an invited researcher in such institutions as Nordita (Denmark), Porto University (Portugal) and Max Planck Institute for Gravitational Physics (Germany). I have done my PhD studies in the Ecole Normale Superieur de Paris under the supervision of Prof. Kazakov, one of the leading experts in the subject of integrability in AdS/CFT correspondence november 2007. I also was a postDoc in CEA Saclay for one year and currently I am a postDoc in DESY. In both places there are very experienced and famous researchers ready to share with me their knowledge.

References

[1] Z. Bajnok, J. Balog, B. Basso, G. P. Korchemsky and L. Palla, arXiv:0809.4952 [hep-th].

[2] D. Volin, arXiv:0812.4407 [hep-th].

[3] Y. Hatsuda and R. Suzuki, *Finite-Size Effects for Multi-Magnon States*, *JHEP* **09** (2008) 025 [0807.0643].

[4] D. Bombardelli and D. Fioravanti, *Finite-Size Corrections of the* $\mathbb{CP}^3$ *Giant Magnons: the Lúscher terms*, 0810.0704.