

論文 / 著書情報  
Article / Book Information

題目(和文)	
Title(English)	Novel non-perturbative analyses of QCD spectral functions
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出典(和文)	学位:博士(理学), 学位授与機関:東京工業大学, 報告番号:甲第10393号, 授与年月日:2017年3月26日, 学位の種別:課程博士, 審査員:岡 眞,伊藤 克司,今村 洋介,肥山 詠美子,陣内 修
Citation(English)	Degree:Doctor (Science), Conferring organization: Tokyo Institute of Technology, Report number:甲第10393号, Conferred date:2017/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)  
Doctoral Program

## 論文要旨

THESIS SUMMARY

専攻 : Department of	基礎物理学	専攻 :	申請学位 (専攻分野) : 博士 (理学)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

Quantum Chromo-Dynamics (QCD) is widely accepted as the fundamental theory of elementary particles of quarks and gluons. Hadrons are composite particles consisting of quarks and gluons, so that their properties themselves are one of the main topics which should be clarified from QCD. Perturbative approaches in QCD are not applicable in the low energy region since the effective coupling constant becomes larger in the region. Furthermore, in addition to such a practical problem, some effects, which in principle cannot be taken into account by the perturbation theory, are believed to play important roles in the lower energy region. Thus, one states that a "non-perturbative" approach is necessary to resolve such practical and/or fundamental problems. Due to the above theoretical difficulty, related physics with hadron properties, confinement and spontaneous breaking of chiral symmetry, may not be satisfactorily understood from QCD even today. In association of recent development of computers, the lattice QCD simulation as a numerical approach has become a powerful non-perturbative method and clarifies hadron properties and the related physics. On the other hand, analytic approaches are also important to understand QCD more deeply. The QCD sum rule is one of the analytic non-perturbative approaches and is utilized to study hadrons from around the same time as the lattice QCD entered the stage. The QCD sum rule is a method to calculate a hadronic spectral function (SPF), which we would like to know from QCD in order to study hadron properties. This method consists of roughly two stages: construction of integral rules for SPF from QCD and determination of SPF from them. The construction of integral rules is based on two important key words, analyticity and factorization. The analyticity of a correlation function leads to a dispersion relation, which gives the relation between the integral of SPF with a kernel and the correlation function in the virtual momentum region. Factorization enables us to obtain the correlation function in the special form: a sum of condensates multiplied by their Wilson coefficients. This is called Operator Product Expansion (OPE). It is the condensate that reflects non-perturbative effects. Thus, we construct integral rules of SPF taking into account non-perturbative effects. For the determination of SPF, traditionally one assumes its functional form to be simplified being "one pole + continuum". Although this scheme is successful to extract the information on the lowest (ground) state in the analyzed channel, one must ignore other (or excited) states. Recently, there appears an evolution to tackle this difficulty, that is, the application of the maximum entropy method (MEM) to QCD sum rules. In this method, one can uniquely determine SPF from the integral rule without any strong assumption on its functional form as is done in the traditional method. It is, however, known by some studies that only one peak is reproduced from the usual Borel sum rules with MEM. From this point of view, we realize that there remain fundamental problems in the stage of construction of the integral rules.

In this thesis, two attempts are proposed to bring fundamental improvement of the QCD sum rule or go beyond the QCD sum rule. The first attempt is the generalization of the Borel sum rule to the complex variable sum rule. By carefully considering the analyticity in the stage of construction of integral rules, we show that the parameter of the integral rule, which is conventionally considered to be real values, can have also complex values. This simple discovery leads to the complex Borel sum rule (CBSR), where the Borel mass is generalized to have not only real values but also complex ones. It is shown that the analysis system using CBSR and MEM has the ability to reproduce the second peak. This approach is applied to charmonia (bound states of charm and anti charm quarks) at finite temperature. By temperature effects hadrons are expected to become free from the confinement to disappear (melt). Thus, the melting temperature is one of the important quantities to study the confinement. In this study, both the melting temperatures of the ground and excited states are estimated. The second attempt is to take an infinite summation of partial series in the OPE. It is the OPE in the whole system of QCD sum rules that reflects the non-perturbative future of QCD to hadronic SPF. Usually one truncates the expansion at a certain dimension of operators because the values of higher dimensional condensates are not well known and the calculation of their Wilson coefficients becomes more and more difficult. However, it is theoretically interesting to study what kind of roles such a truncated infinite series plays. It is shown that by using the Schwinger-Dyson equations one can systematically take an infinite summation of a partial series of the OPE. Actually, the infinite summation of the power series of the chiral condensate is analytically obtained by this approach, which results in the explicit pole shifts of correlation functions. The result is meaningful since the chiral condensate is an order parameter of the spontaneous chiral symmetry breaking. Furthermore, it is discussed how the QCD sum rule analysis is modified when such an infinite summation of non-perturbative effects is introduced.

備考 : 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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