Study results

Quantum Field Theories in Nonextensive Tsallis Statistics

Quarks and gluons are believed to be elementary particles that constitute hadrons like protons and neutrons. Under usual circumstances (at low temperature), quarks and gluons are confined in hadrons and they cannot be free particles. However, at high energy state, quarks and gluons can be free and create kind of particle soup called quark-gluon plasma (QGP). QGP is a very important object in particle physics since it will tell us the property about quarks and gluons. It is expected that a QGP will be produced in ultrarelativistic heavy-ion collision experiments at the BNL Relativistic Heavy Ion Collider (RHIC). The CERN Large Hadron Collider (LHC) will soon be ready for experiments.

In order to investigate QGP, we have constructed quantum field theory for nonextensive systems. QGP may have long-range interactions, and if so, the system becomes nonextensive and we cannot apply quantum field theory for extensive systems that are based on extensive Boltzmann-Gibbs statistics. Quantum field theory for nonextensive systems had been needed and we created it. To construct the theory, we used nonextensive Tsallis statistics that was proposed by Tsallis nineteen years ago. Tsallis statistics is the theory for nonextensive systems and has been successfully applied to a number of nonextensive systems.

We have computed two-point propagators, initial correlations and Hard Thermal Loop (HTL) amplitudes of quark mass and gluon mass. We found out that initial correlations appear which do not exist in extensive quantum field theory. This result is important because initial correlations contribute to the linear response theory. And we also found the effect of nonextensiveness to the propagators and HTL amplitudes those are fundamental quantities in calculating various physical amplitudes.

Improvement of Thermal Operator Representation

Thermal field theory is beautifully constructed theory. However when we try to evaluate various physical quantities, we face awkward calculations that are usually very difficult to carry out. Easier calculation methods had been needed in order to evaluate many physical amplitudes. Recently, Brandt *et al.* have proposed the "thermal operator method" which is very convenient and easy to handle. However, there was an unsatisfactory property in their formalism. With chemical potential, their operators were not completely factorized.

Having an interest in this point, we presented the improved formalism in which thermal operators are completely factorized even in the presence of a chemical potential. Our formalism is much simpler and easier to calculate physical amplitudes. Using our thermal operator, it is expected that one can calculate various physical quantities easily. From theoretical view point, this speculation is very intriguing and has a big potential for investigation of theoretical aspects of thermal field theory.