論文の内容の要旨

論文題目　Effective theory for the quark-hadron phase transition
(クォーク・ハドロン相転移の有効理論)

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In this thesis, we propose an approach for describing the quark-hadron phase transition by using an effective model which is written in terms of quarks. Our starting point is the Nambu-Jona-Lasinio model with the Polyakov loop (PNJL model), that describes both the chiral phase transition and the de-confinement phase transition. Unlike many previous works based on the mean-field approximation, we take the mesonic and the baryonic fluctuations into account, because they play an important role in order to describe properly the hadronic phase at low temperatures and low densities.

Firstly, we include only the mesonic fluctuations into the two-flavour PNJL model at zero chemical potential. In this model, only the quarks and antiquarks are treated as dynamical variables, and the mesons are constructed from quarks and antiquarks as collective modes. They are introduced in the partition function as auxiliary fields. By considering their thermal fluctuations, their contribution to the equation of state can be calculated in the path integral method. We find that the pressure and the entropy are dominated by the mesonic fluctuations at low temperatures. On the other hand, the quarks and the gluons dominate at high temperatures after the mesons have melted into quarks and antiquarks. We also discuss at which temperature the mesons (the pions and the sigma mesons in the two-flavour case) change into quarks and antiquarks in order to obtain some informations of the transition region.

Next, we extend the two-flavour calculations to the three-flavour case. Due to the increased number of flavours, 18 species of mesons (9 scalar mesons and 9 pseudo-scalar mesons) appear. Since the heavy mesons are expected to give a very small contribution to the pressure at low temperatures, we take into account only the eight lightest species of mesons (three degenerated pions, four degenerated kaons and the sigma meson ) and we neglect all the heavier mesons.

Finally, we extend the two-flavour PNJL model to the case of a finite chemical potential by including both the mesons and the baryons. By introducing an additional interaction term in the original Lagrangian, a diquark condensate can be described as well as the quark condensate. We assume that a diquark and a quark form a baryon, just like that a quark and an antiquark form a meson, so that we now insert auxiliary fields for mesons, diquarks, anti-diquarks, baryons, and anti-baryons with an additional coupling between quarks and diquarks. We calculate analytically the pressure of the diquark fluctuations and of the baryonic fluctuations, and we discuss how they contribute to the pressure at low temperatures.