Center Symmetry in the Presence of Dynamical Quarks

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The center symmetry is a prosperous implement to characterize each phase in the pure non-abelian gauge theories at finite temperature. The lattice simulations in the pure gauge theories have quantitatively confirmed the critical characteristics predicted by the effective theories belonging to the same universality class.
In contract to the pure gauge theories any attempt to distinguish the confined phase from the deconfined one is not yet successful for systems including dynamical (fundamental) quarks so far. Once the thermal excitations of light quarks are allowed, the center symmetry is broken explicitly. Then the Polyakov loop is no longer an adequate indicator of confinement because it remains finite even in the confined phase as well as in the deconfined phase due to the absence of the center symmetry.
The Polyakov loop is still employed approximately as a characteristic parameter to detect the deconfinement transition and then it is found that the temperatures corresponding to the deconfinement transition and the chiral phase transition happen to coincide. This should be, however, interpreted as the shift of the constituent quark mass and does not mean that the deconfinement transition and the chiral phase transition occur simultaneously. To clarify the deeper relation between them an appropriate indicator of the deconfinement transition is indispensable.
In our study we investigate the canonical ensemble with respect to the quark number, which is one of candidates to detect the deconfinement transition. In the first instance we adopt the Ising model as the simplest effective model and demonstrate how the canonical description would emanate from the grand canonical ensemble. We show that the apparent difference expected in the canonical description is attributed to the finite size effects and that no difference would survive in the thermodynamic limit. This result is far from trivial since it is not the number density but the number that should be fixed in our formulation. From the statistical point of view, there is no reason why these two ensembles become equivalent in the thermodynamic limit. Then we extend the arguments to the more realistic case of QCD on the lattice. Under the condition that the quark triality conservation must be preserved, we propose a prescription to evaluate the expectation value of the Polyakov loop. As a result the broken center symmetry is regained so that the Polyakov loop can serve as an order parameter.
In order to illustrate physical implications we apply our prescription to an effective model which can deal with both the deconfinement and the chiral symmetry restoration on an equal footing. We call it as the Gocksch-Ogilvie model. Within the framework of that model study the obtained results indicate passive correlation between the deconfinement transition and the chiral phase transition.

References

[1] Kenji Fukushima, e-print: hep-ph/0204302.