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QCD effective potential with strong electromagnetic fields at zero and finite temperatures

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Motivated by the observation that non-central heavy-ion collisions in RHIC and LHC are accompanied by extremely strong magnetic fields, much attention has been paid to the QCD dynamics in strong electromagnetic fields. In particular, the change of vacuum properties such as quark condensates has been investigated in terms of both effective models and lattice simulations. While both of these approaches predict, at zero temperature, an enhancement of quark condensates in the presence of magnetic fields (called "magnetic catalysis"), their results do not coincide with each other at finite temperatures. Namely, at finite temperatures, lattice QCD simulations at physical point predict "inverse" magnetic catalysis which is never reproduced by effective models. In order to bridge the gap between effective models and lattice QCD, an analytic study of QCD in the presence of strong magnetic fields should be necessary.

As a first step towards understanding the effects of magnetic fields on QCD vacuum properties, we analytically investigate the QCD effective potential within one loops of gluon and quark including all order interactions with chromo-electromagnetic fields and $U(1)_{em}$ electromagnetic fields at zero and finite temperatures. First, we will show the results of QCD effective potential with strong magnetic fields at zero temperature [1]. The resulting effective potential is renormalization-group invariant. We found that the chromo-magnetic field prefers to be parallel to the external magnetic field, and thus the QCD vacuum with strong magnetic fields is spatially anisotropic. This result is consistent with recent lattice data [2,3]. Furthermore, the chromo-magnetic condensate increases with an increasing magnetic field, which supports the "gluonic magnetic catalysis" as observed in current lattice data [2].

Next, we will discuss the effective potential with strong electromagnetic fields at finite temperatures [4]. In particular, we focus on the influence of electromagnetic fields on the center symmetry in QCD. The pure Yang-Mills theory has the center symmetry (being spontaneously broken at high temperature), but dynamical quarks explicitly break it. We will show how the electric and magnetic fields affect the explicit symmetry breaking, by using the effective potential for the Polyakov loop. We will also discuss a relation between the property of the Polyakov loop in the presence of magnetic fields and the inverse magnetic catalysis, whose importance is pointed out from the recent lattice study [5].

References:

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