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Conjecture about the QCD Phase Diagram

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Content

The QCD phase diagram is one of the most prominent, outstanding puzzles within the Standard Model. Various experiments, which aim at its exploration beyond small baryon density, are in preparation. From the theoretical side, this is an issue of non-perturbative QCD, and therefore for lattice simulations. However, the inclusion of a finite baryon density entails a technical problem (known as the “sign problem"), which has not been solved yet. Here we present a study of an effective theory, the O(4) non-linear sigma model. It undergoes spontaneous symmetry breaking with the identical group structure as 2-flavor QCD in the chiral limit, which strongly suggests that they belong to the same universality class. Since we are interested in high temperature, we further assume dimensional reduction to the 3d O(4) model, which implies topological sectors. As shown by Skyrme, Wilczek and others, its topological charge takes the role of the baryon number. Hence the baryon chemical potential mu_B appears as an imaginary vacuum angle, which can be included in the lattice simulation without any sign problem. We present numerical results for the critical line in the chiral limit, and for the crossover in the presence of light quark masses (represented by an external magnetic field). Their shapes are compatible with other predictions, but up to the value of about mu_B = 300 MeV that we could explore so far, we do not find a Critical Endpoint.

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