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Phase diagram of QCD-based theories in a small volume

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The phase diagram of QCD at non-zero chemical potential is difficult to calculate from first principles because the coupling strength is large, preventing ordinary perturbation theory, and the action is complex, leading to the "sign problem" and preventing conventional lattice simulations. To understand better how to deal with complex actions and to obtain a qualitative picture of the phase diagram of QCD with chemical potential it can be useful to study the theory in a very small spatial volume, which allows for perturbation theory to be employed at all temperatures. We consider QCD and QCD-based theories on S^1 x S^3 for small S^3 from one-loop perturbation theory. Thermodynamic observables calculated as a function of the chemical potential, such as the free energy and quark number, as well as the Polyakov lines, provide a sketch of the phase diagram for QCD and supersymmetric QCD in the limit of large Nc and Nf, where the theory is described by a matrix model. Finally we consider the effect of additional interactions which lead to spontaneous chiral symmetry breaking for sufficiently small chemical potentials.

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