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Effective models of QCD with an infrared confinement

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Quantum chromodynamics (QCD) is the fundamental theory of the strong interaction. Its equation of state at finite temperatures has been computed from first principles using lattice QCD simulations with Monte Carlo methods. At finite baryon densities, however, the known fermion sign problem prevents the application of these methods. In order to obtain results in this regime, which is relevant for astrophysical applications involving neutron stars and gravitational wave phenomenology, it is necessary to develop alternative theoretical approaches. Therefore, we focus on a description based on effective models of QCD. One of the theory's fundamental properties is asymptotic freedom, where the coupling strength decreases with increasing energy scale. Consequently, at sufficiently high energies QCD matter is expected to undergo a phase transition from a state of confined hadrons to the quark-gluon plasma, observed in heavy-ion collisions. As such, the deconfinement phase transition is a critical aspect of QCD, yet it is often absent in traditional treatments utilizing effective models such as the Nambu–Jona-Lasinio (NJL) model and linear sigma model with quarks (LSMq). These models, for instance, predict timelike quark mass poles and hadronic decays into quarks, unphysical features that contradict the confining nature of QCD. Therefore, in this work we set to explore the consequences of the introduction of an infrared regulator in proper-time regularization, eliminating unphysical quark production thresholds. In this way, we can investigate the deconfinement phase transition through the dynamics of this regulator. Our findings indicate that chiral symmetry restoration occurs as a smooth crossover, consistent with results from lattice QCD, and that the deconfinement phase transition is sharper and happens at higher temperatures.

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