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Confinement and Chiral Phase Transitions: The Role of Polyakov Loop Kinetics Terms

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We studied a crucial but often oversimplified ingredient in predicting gravitational-wave signals from QCD-type phase transitions: the kinetic term of the Polyakov loop. For the first time, we derive this term from first principles in finite-temperature pure SU(3) Yang-Mills theory, incorporating a field-dependent renormalization factor—a calculation we also extend to theories with more colors. Employing this derived kinetic term alongside three commonly-used effective potentials (the Haar-measure, polynomial, and quasi-particle models), we demonstrate that it substantially modifies the predicted GW energy spectrum from confinement transitions by 1-2 orders of magnitude. Based on this, we provide the first complete analysis of the chiral transition within the Polyakov–Nambu–Jona-Lasinio (PNJL) framework, described by the quark condensate. Our results reveal a clear dichotomy: while the Polyakov-loop kinetic term critically shapes GWs from confinement transitions, it has a negligible impact on the dynamics of the chiral transition, which is dominated by fermion condensation effects.

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