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RG Improvement of the Scalar Effective Potential in Finite Temperature Quantum Field Theory

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Stochastic gravitational wave (GW) backgrounds from first-order phase transitions are a compelling target for next-generation GW observatories, offering a novel probe of dark sectors with strong phase transitions. However, reliable theoretical predictions for the GW signal strength remain challenging, particularly beyond the high-temperature regime where standard techniques like dimensional reduction become unreliable. In this talk, we present the Optimized Partial Dressing (OPD) framework, a thermal mass resummation method that uses gap equation solutions inserted into the tadpole of the potential to systematically improve perturbative calculations of the finite-temperature effective potential without relying on high-temperature expansion.

We will review how OPD controls perturbation theory at finite temperature and then introduce a self-consistent renormalization group (RG) improvement of the scalar potential within the OPD formalism. This RG improvement substantially reduces the scale dependence of physical quantities and improves the robustness of predictions for gravitational wave signals from cosmological phase transitions.

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