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Simulation of Scalar Field Theories with Complex Actions

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Many scalar field theory models with complex actions are invariant under the antilinear ($\mathcal{PT}$) symmetry operation $L^*(-\chi) = L(\chi)$. Models in this class include $i\phi^3$, the Bose gas at finite density and Polyakov loop spin models at finite density. This symmetry may be used to obtain a dual representation where weights in the functional integral are real but not necessarily positive. For a subclass of models satisfying a dual positive weight condition, the sign problem is absent; such models are easily simulated by a simple local algorithm in any number of dimensions. The existence of a positive representation is constrained by Lee-Yang zeros, and tied to the phase structure of a given model. Simulations of models in this subclass show a rich set of behaviors. Propagators may exhibit damped oscillations, indicating a clear violation of spectral positivity. Domain patterns may occur in equilibrium, with both stripe and bubble morphologies occurring. These behaviors appear to be likely in finite density QCD in the vicinity of the critical line.

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