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Inequivalence between the Euclidean and Lorentzian Versions of the Type IIB Matrix Model from Lefschetz Thimble Calculations

The type IIB matrix model is conjectured to describe superstring theory nonperturbatively in terms of ten $N \times N$ bosonic traceless Hermitian matrices A_μ ($\mu = 0,\cdots,9$), whose eigenvalues correspond to (9+1)-dimensional space-time. Quite often, this model has been investigated in its Euclidean version, which is well defined although the SO(9,1) Lorentz symmetry of the original model is replaced by the SO(10) rotational symmetry. Recently, a well-defined model respecting the Lorentz symmetry has been proposed by "gauge-fixing"the Lorentz symmetry nonperturbatively using the Faddeev-Popov procedure. Here we investigate the two models by Monte Carlo simulations overcoming the severe sign problem by the Lefschetz thimble method, in the case of matrix size $N=2$ omitting fermionic contributions. We add a quadratic term $\gamma\,\mathrm{tr}(A_\mu A^\mu)$ in the action and calculate the expectation values of rotationally symmetric (or Lorentz symmetric) observables as a function of the coefficient γ. Our results exhibit striking differences between the two models around $\gamma=0$ and in the $\gamma>0$ region associated with the appearance of different saddle points, clearly demonstrating their inequivalence against naive expectations from quantum field theory.

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