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Title: “Complex Langevin simulation of the Lorentzian type IIB matrix model and the emergence of smooth (3+1)D expanding space-time”

The Lorentzian type IIB matrix model is a promising candidate for a nonperturbative formulation of superstring theory.

In particular, the emergence of (3+1)D expanding space-time was suggested by Monte Carlo simulation in 2011. Recently we have found that the structure of the space represented by the matrices generated by the simulation is singular in that only two eigenvalues increase with time. This property has been attributed to the incorrect treatment of the sign problem, which occurs due to the phase factor  $e^{iS}$  in the integrand of the partition function. Here we apply the complex Langevin method to solve this problem, and find that the space-time structure tends to become smooth while keeping the (3+1)D expanding behavior intact.

Ref.) JHEP 1906 (2019) 077 [[arXiv:1904.05919](https://arxiv.org/abs/1904.05919) [hep-th]]