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Spontaneous symmetry breaking induced by complex fermion determinant — yet another success of the complex Langevin method

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In many interesting systems, the fermion determinant becomes complex and its phase plays a crucial role in the determination of the vacuum. For instance, in finite density QCD at low temperature and high density, exotic fermion condensates are conjectured to form due to such effects. When one applies the complex Langevin method to such a complex action system naively, one cannot obtain the correct results because of the singular-drift problem associated with the appearance of small eigenvalues of the Dirac operator. Here we propose to add a fermion bilinear term to the action to avoid this problem and extrapolate its coefficient to zero. We test this idea in an $SO(4)$ -invariant matrix model with a Gaussian action and a complex fermion determinant, whose phase is expected to induce the spontaneous breaking of the $SO(4)$ symmetry. Our results agree well with the previous results obtained by the Gaussian expansion method.

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