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Phase Unwrapping and One-Dimensional Sign Problems

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Lattice QCD estimates of correlation functions with non-zero U(1) baryon number suffer from a well known signal-to-noise problem at large time separations. Previous work has shown that this can be attributed to a widening phase distribution over a circular domain, where standard estimators perform exponentially poorly as the distribution approaches uniform. We present a new approach to this problem: we apply phase unwrapping from the MRI and radar domains to translate the phase circular distribution to an "unwrapped phase" distribution over the reals. Applied to the simple harmonic oscillator as a toy model, unwrapping demonstrates no exponential signal-to-noise growth in time at leading order in a convergent cumulant expansion. We explore choices of unwrapping schemes and demonstrate precise ground-state energy estimates with a good scheme choice. Truncation error in the cumulant expansion is found to be highly sensitive to the choice of unwrapping scheme, indicating that more a robust family of schemes or choice of expansion is needed to apply this technique to non-trivial models. Arguments based on topological defects suggest that multidimensional unwrapping schemes should be more robust to regions of undersampling, motivating future work with spatially-resolved correlators in higher dimensions.

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