Quantum Monte Carlo Level Spectroscopy

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We develop an effective method to estimate the energy gap of the quantum spin systems from the imaginary time correlation functions obtained by the worldline quantum Monte Carlo method. The numerical error of the conventional moment method is successfully eliminated in a systematic way. Combining with the loop algorithm or the worm algorithm, and novel parallelization technique, we can evaluate the excitation gaps of various quantum magnets, such as the Haldane chains, as well as spin-wave velocity, anomalous dimensions and central charge at the criticality in (1+1)-dimensions with quite high accuracy.

Furthermore, by choosing a specific combination of different energy gaps carefully, one can eliminate the severe logarithmic corrections to the finite-size scaling associated with the Kosterlitz-Thouless type phase transition. We demonstrate that our quantum Monte Carlo level spectroscopy technique enables us to determie the location and the critical exponents of the quantum phase transition between the spin liquid and dimer phases in the one-dimensional spin-Peierls model precisely for the first time.