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Exploring Quantum Many-Body Spin Dynamics with Truncated Wigner Methods

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Recent experiments in atomic, molecular, and optical physics offer controlled and clean environments to experimentally study non-equilibrium dynamics of large many-body quantum spin-models with variable range interactions. Thus, efficient computation of such dynamics is of great importance. While in one dimension, time-dependent density matrix renormalization group methods (t-DMRG) have proven effective under certain conditions, computing dynamics in higher dimensional systems remains an outstanding challenge. Recently we formulated the discrete truncated Wigner approximation (DTWA), a semi-classical method based on the truncated Wigner approximation (TWA) that has been proven to be surprisingly accurate in predicting quench dynamics in high-dimensional lattices with up to tens of thousands of quantum spins. Here, we introduce the DTWA and show how it can compute time-evolution of quantum states in experiments that engineer spin-models with polar molecules in optical lattices or with ions in two-dimensional Penning traps. We show, how the DTWA can provide results for the time-evolution of classical and quantum correlations in quench experiments in regimes where other numerical methods are generally unreliable. We report on progress of how to incorporate higher order corrections to the method, and how to adapt it to systems with both spin and bosonic degrees of freedom.