Witnessing environment induced topological phase transitions via quantum Monte Carlo and cluster perturbation theory studies

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Abstract: We investigate environmental effects on the Su-Schrieffer-Heeger model coupled with local baths, showing how specific couplings induce topological transitions. The phase diagram is unveiled by using Monte Carlo approaches and cluster perturbation Theory.

We study the nonperturbative effects of environmental coupling on the Su-Schrieffer-Heeger (SSH) chain, where local harmonic oscillator baths interact with either intracell or intercell transfer integrals. Contrary to common assumptions, this type of coupling, when properly engineered, can induce transitions to topological phases. To move beyond the weak coupling regime described by Lindbladian formalism, we use a world-line quantum Monte Carlo (QMC) technique [1] to map the full phase diagram of the model (see Fig. 1 (a) and (b)).

In this framework, we identify the probability distribution of polarization as a key marker of topological phase transitions under open boundary conditions. Notably, this distribution exhibits a bimodal behaviour in the topological phase, both with and without environmental interactions, highlighting the emergence of edge states (see Fig. 1 (c)).

Additionally, we provide a qualitative and analytical description using cluster perturbation theory (CPT) [3], which is well-suited for lattice models with dominant local interactions under periodic boundary conditions. This formalism enables accurate calculations of dressed Green's functions, allowing us to determine spectral functions and the topological invariant [2]. The discontinuous behaviour of the topological invariant reveals the critical coupling strength at which the topological phase transition occurs, in agreement with Monte Carlo results. This critical point is further marked by the closing of the energy gap between the two bands, observed as the merging of the two main peaks in the spectral functions.

Finally, we demonstrate that environmental interactions introduce non-Hermitian effects in the fermionic subsystem [4], providing an effective non-Hermitian Hamiltonian description.

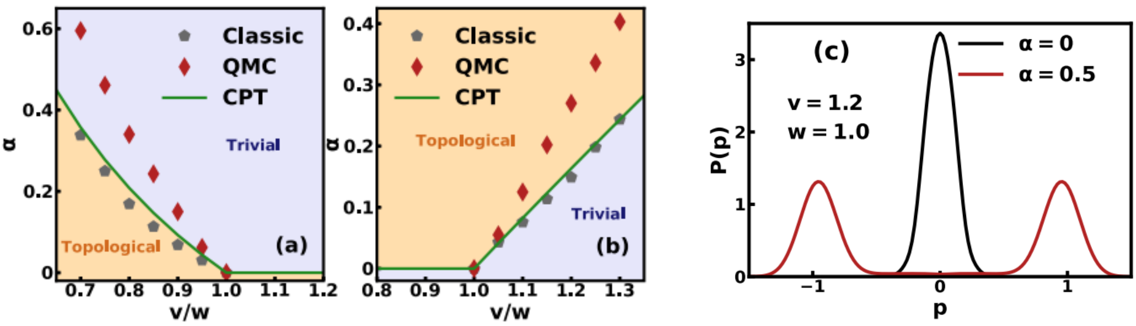

Fig. 1 . Phase diagram, in the case of intra[inter]cell hopping coupled with local baths in (a) [(b)], for quantum (red diamonds) and classical bosons (grey points) through MC technique. Green line denotes the critical values of the couplings obtained through CPT for quantum baths. (c) Polarization probabilty distribution in the case of intercell hopping coupled with local baths.

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