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Peer Review

Review of: "Coexistence of Ergodic and Non-Ergodic Behaviour and Level Spacing Statistics in a One-Dimensional Model of a Flat Band Superconductor"

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In this article, the authors use a one-dimensional on-site/bond singlet (OBS) model inspired by the projected dice lattice Hamiltonian to investigate the quasiparticle dynamics and coexistence of ergodic and non-ergodic behavior in flat band superconductors. With integrable dynamics defined by local integrals of motion (LIOMs), the model shows that mobile Cooper pairs can coexist with localized quasiparticles. By adjusting model parameters, the work reveals transitions between integrable and chaotic regimes using level spacing statistics. These findings shed light on many-body quantum dynamics, weak ergodicity breaking in lattice models, and the non-trivial interaction between localization and superfluidity in flat band systems. By examining the OBS model's energy spectrum and non-equilibrium dynamics, the authors find quasi-degenerate states and demonstrate how certain coupling constants determine ergodic and non-ergodic behavior. Non-ergodic dynamics and memory retention of initial particle configurations result from localized particles acting as barriers to Cooper pair propagation for specific parameter values. These restrictions dissolve when parameters vary, enabling uniform particle dispersion and revealing chaotic ergodic behavior. These transitions are supported by the level spacing statistics, which display Poissonian distributions for integrable instances and predictions from random matrix theory for chaotic cases.

Although the authors present interesting numerical and analytical results, the structure of the manuscript is not very reader-friendly and should be restructured by putting some details in the supplementary/Appendix. Below are my questions and comments:

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1. Finite-size scaling should be studied to confirm if the level spacing statistics are still valid in thermodynamic systems.
2. No proper explanation is given for the choice of the parameters λ_2 and λ_3 and their physical meaning.
3. Authors should also look into the entanglement entropy to understand ETH values.

Declarations

Potential competing interests: No potential competing interests to declare.