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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 paper, the authors introduce a one-dimensional on-site/bond singlet (OBS) model, an analogue of the projected dice lattice Hamiltonian, to analyze quasi-particle localization in flat-band superconductors within a simplified one-dimensional framework. They numerically investigate the ergodic and non-ergodic behavior of the OBS model and support their findings with analytical insights. To demonstrate indications of localized integrals of motion (LIOMs), the authors calculate the level-spacing distribution of the OBS model Hamiltonian and also analyze the time evolution for specific initial state configurations containing an on-site bond pair and unpaired particles. The main finding of this work is the numerical evidence for LIOMs in the OBS model, even in the presence of on-site/bond singlet conversion terms in the Hamiltonian.

The authors present interesting numerical and analytical results, effectively illustrating the ergodic and non-ergodic behavior of the OBS model. However, the current manuscript is overly lengthy and somewhat difficult to follow. Before it is considered for publication, the authors could shorten the introduction and move some of the analytical results to the appendix. Below are my comments and suggestions for enhancing the manuscript:

(i) The authors are encouraged to illustrate the mapping of the on-site/bond singlet (OBS) model from its analogue, the projected dice lattice Hamiltonian, through a schematic figure. Such a figure would be particularly beneficial for non-expert readers, reducing reliance on reference [25] and enhancing the manuscript’s accessibility.

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(ii) In both the introduction and conclusions, the authors should explain their findings without relying on mathematical symbols (e.g., $\lambda 3$). Instead, they could describe the physical significance of the parameters to make the text more accessible to a broader audience.

(iii) The symbols used in Fig. 1 to represent the initial states (e.g., those with an on-site pair and two unpaired particles) are somewhat confusing. A clearer representation or additional explanation would greatly enhance comprehension.

(iv) While the authors provide rigorous numerical results for the level-spacing statistics of the OBS model, they do not compare these results across different system sizes. Including such comparisons would strengthen the robustness of their findings.

(v) The authors could also explore the time-dependent entanglement dynamics using different initial states and varying parameters of the OBS model Hamiltonian to better understand the localization and delocalization of quasi-particles.

Declarations

Potential competing interests: No potential competing interests to declare.