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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Aleksey Lunkin

PhD Program: Physics

Title of Thesis: Sachdev-Ye-Kitaev model in the presence of the quadratic perturbation

Supervisor: Assistant Professor Konstantin Tikhonov

Name of the Reviewer: Yuriy Makhlin

I confirm the absence of any conflict of interest	**Date: 15-06-2022**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

The thesis analyzes effects of quadratic terms in the SYK (Sachdev-Ye-Kitaev) model. The focus is on the behavior of the strongly interacting fermionic system and the Fermi-liquid vs. non-Fermi-liquid behavior. Recent research on strongly correlated materials demonstrates the need for development of new approaches in the theoretical description of non-Fermi-liquid states, which is complicated by the necessity to deal with non-Gaussian path integrals. The SYK model is of great current interest as a rare example of an exactly solvable strongly interacting model, and the presented research is of great quality and at the forefront of the current research activities. After an introduction into the topic in Chapter I, the author briefly describes in Chapter II the known results in the path-integral description, the low-energy sector of the model and reduction to a 1D quantum mechanical problem. It is concluded with a calculation of the average Green function. Further chapters investigate how this is modified by quadratic perturbations. In Chapter III it is demonstrated that for sufficiently weak perturbation the long-time SYK behavior persists, which indicates stability of the interacting model. A transition at growing perturbation is found. In Chapter IV, with the use of a geometric interpretation of the model, a new parameter range is studied. It is found that at intermediate amplitudes of quadratic perturbation the conformal-solution behavior persists to longer, perturbation-dependent time scales, where it crosses over to the Fermi-liquid-like behavior. The final Chapter V provides conclusions.

Theoretical work in the thesis is of very high quality. Analytical results are supported by numerics. The approach, used in the thesis, allowed to obtain novel results of great interest and relevance to the current research worldwide. These results have been published in renowned scientific journals. The results on this relevant and challenging topic are of high importance.

My only concern is that the thesis describes the results obtained very briefly, without dwelling on the technical details, some of which however are taken care of in the appendices. The problem under study has many parameters, including time, perturbation amplitude, temperature, and in my view, it would have been useful to have a single brief table or plot, summarizing the studied behavior of the Green function in various regimes and demonstrating the previously known and novel results. Nevertheless, I should say that I have enjoyed reading the manuscript, partially, exactly due to its brevity and focus on the most important points. I have particularly enjoyed the elegant presentation of the geometric analogy, very useful for grasping the developments in the work. Apart from this, I have only minor remarks or suggestions concerning the presentation and misprints (attached).

In my view, the work presented in the thesis is of high quality, and I do recommend that the candidate should proceed to the formal defense of the thesis.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*
☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*

Below a few remarks/questions/editorial suggestions are provided, which the candidate may optionally consider taking into account in the final version of the thesis. This refers mostly to misprints and possible clarifications.

After (2.17), it may be useful to indicate the value of alpha_S explicitly.

Before (2.22): the symmetry group is three-dimensional. Clarify, why only one parameter fixes the gauge.

The curve in the Poincare disk: would it make any sense to consider solutions with other winding numbers?

p.10 Majorana should be capitalized, degeneration→degeneracy

(2.5) tau→tau_1

If q is used, it may be useful to introduce the relevant Hamiltonian alongside (2.1)

Before (2.12): “These equation”

p.16, extra by in the top line; “no exact” → not

filed→field

(2.19): clarify, why sign is missing compared to Bagrets et al.

“We are interesting”

(2.21): clarify, why powers of G are needed.

(2.23): is exp(nDF(tau0)) missing?

continuum→continuous (before 2.25); wawe→wave

(2.26): is the notation for the states consistent with 2.25?

evolutionary→evolution

Before 2.28: “Taking all integrals” - one integral appears to remain

2.29: q*Delta=1, should one replace it here?

qualitative→qualitatively, regime→regimes

Notations tc, T* etc. used earlier than explained. Summary of notations somewhere?

Before 4.1: “This representation is valid if...”. Why are these conditions relevant? Can we consider the curve phi(l) for any function phi(l)?

“extrinsic curvature” - a curve does not have any intrinsic curvature in the standard sense. What is implied?

After 4.2: what is d\mu? 4.3: two different beta’s

After 4.17: “For simplicity, we assume that T>>..”. Is it for simplicity, or we can proceed only in this regime?

“the sufficiently changes”; “Do these results” → “Are these results”