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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Kirill Pavlenko

PhD Program: Mathematics and Mechanics

Title of Thesis: Quantum KdV charges, 2d conformal theories and eigenstate thermalization hypothesis

Supervisor: Associate Professor Anatoly Dymarsky

Name of the Reviewer:

I confirm the absence of any conflict of interest	**Date: 19.08.2022**

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

The mechanism of thermalization of isolated quantum many-body systems has been a growing field of study as experimental capabilities of building such systems in the lab has been increasing in recent years. Such systems can exhibit chaotic properties in which case their thermalization is described by the Eigenstate Thermalization Hypothesis (ETH). ETH ansatz is one of the main tools describing quantum thermalization. Several numerical studies of lattice systems (for small lattices) appear to tentatively confirm the predictions of ETH in interacting systems which would be expected to thermalize, however, systems which are integrable tend not to obey ETH. In that case a thermal equilibrium is believed to be described by the Generalized Gibbs Ensemble (GGE). Both theoretical and experimental verifications of these hypothesis are extremely difficult as they require careful study of highly excited states of the given quantum system.

The dissertation of Kirill Pavlenko is devoted to analytical study of ETH for a case of presence of infinitely many conserved charges. As such a system the Korteweg–De Vries (KdV) two dimensional model is considered. There are infinitely many conserved charges in this

model called quantum KdV charges. This model presents an example of two-dimensional conformal field theories (2D CFTs). One of the goal of the dissertation is the study the spectrum of these charges, and their role in thermalization describing by generalized Gibbs ensemble. This is undoubtedly an interesting and relevant task.

Let me describe the contents of the dissertation section by sections

The first section is devoted to the theory of classical KdV charges. The first half is pedagogical and does not contain any new results. The second half of the section is devoted to expression of KdV charges in terms of action variables and co-adjoint orbit invariant, that gives some new insight.

In the second section of the dissertation quasi-classical quantization is applied to the spectrum of KdV charges. In the first three orders of the large central expansion, the form of quantum spectrum of all KdV charges is proposed and then this conjecture is verified numerically.

The third section is devoted to calculation of Generalized partition function of 2D CFTs decorated with higher KdV charges at large central charge. An explicit expression for this generalized partition function is presented.

In the fourth section the author deals with calculations of zero modes in 2D CFTs in which an efficient technique for zero-mode calculation is developed. This leads to an explicit expression for quantum KdV charge in terms of Virasoro operators up to seventh order.

In sections five and six all results obtained above, apply to study ETH and its generalizations to 2D CFTs. Namely, in section five GGE is compared with the "eigenstate ensemble" that consists of a single primary state. At infinite central charge, the ensembles match at the level of expectation values of local operators for any values of qKdV fugacities. When the central charge is large but finite, for any values of the fugacities the aforementioned ensembles are distinguishable. In section six the author makes the main conjecture of the dissertation. He proposes that in the thermodynamic limit large central charge 2d CFTs satisfy generalized eigenstate thermalization hypothesis (GETH) and verifies it by non-trivial calculations involving highly excited states.

As some remarks, that are in fact not crucial, I would like to see why namely KdV is selected as a polygon to study the modification of EHT. Also, I would like to see more details about the code which was used in the numerical calculations and the perspective of it applications, if any, to more general models.

To conclude, let me summarize the main results of the dissertation. They include quantum spectrum of KdV charges at large central charge limit, explicit expression for generalized partition function of 2D CFTs decorated by higher KdV charges and analytically verified proposal of Generalized ETH for 2D CFTs. The results are relevant, new and performed at the high scientific level. The thesis considers timely problem at the overlap area of statistical physics and quantum field theory and provides a new avenue to study thermalization of quantum fields. The credibility of results is also confirmed by the publications in peer-reviewed scientific journals and talks at international scientific conferences.

As the result, I advise to grant PhD degree to Kirill Pavlenko in mathematical physics.

Irina Aref'eva

Professor of Theoretical and Mathematical Physics

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*