

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Polovnikov Kirill

PhD Program: Physics

Title of Thesis: On connection between sparse graphs and hyperbolic geometry

Supervisor: Professor Mikhail Gelfand, Skoltech

Professor Sergey Nechaev, Interdisciplinary Scientific Center Poncelet

Name of the Reviewer: Professor Gleb Oshanin

I confirm the absence of any conflict of interest

(Alternatively, Reviewer can formulate a possible conflict)

Signature:

Date: 12-08-2020

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

PhD Thesis by K. POLOVNIKOV, entitled "On connection between sparse graphs and hyperbolic geometry" and supervised by Professors M. GELFAND and S. NECHAEV, summarises the results obtained by the applicant together with different collaborators within the last four years. The focal interest of the research presented in this Thesis is in a relationship between the spectral content of sparse matrices and hyperbolic geometries. Sparse matrices appear in various domains of science and play an important role across many disciplines. In turn, hyperbolic geometries, also called Lobachevskian or Bolyai–Lobachevskian geometries, are non-Euclidan spaces emerging in many domains of mathematics, as well as in diverse physical systems as a result of an appropriate conformal mapping. The research of the applicant bridges the gap between these two mathematical frameworks by demonstrating that the spectral density of sparse graphs can be well approximated by the Dedekind eta-function, from which fact many important statements and results follow. It also establishes a link with localisation phenomena and also with the so-called Lifshitz singularities.

The material presented in the Thesis, which resulted in six publications in top-rank international journals, is structured as follows: The Thesis consists of an introductory part, six chapters and a conclusion section. The introduction provides a rather concise and lucid general outlook on spectral densities of dense versus sparse matrices, and also describes some models, such as e.g. the so-called stochastic block model, as well as some conventional approaches. Chapter 2 describes the relation between the statistics of rare events and modular invariance. Chapter 3 presents a derivation of the eikonal equation in presence of "buckling", with applications to growth rates of plants' leaves boundaries. Further on, Section 4 focuses on anomalous fluctuations of standard two-dimensional random walks in the large-deviations regime. Next, in Chapter 5 the author considers a core-periphery organisation of the cryptocurrency in markets as inferred by the modularity operator. Chapter 6 is devoted to the analysis of order and stochasticity in folding of individual *Drosophila* genomes. Lastly, Chapter 7 discusses particular structures emerging in sparse chromatin interaction networks. The conclusion part recapitulates the obtained results and puts them in a more general unifying framework.

The results obtained by the applicant are of a very high scientific quality and are at the front edge of international research in this field. The publications are well appreciated by scientific community and are well cited. In my personal opinion, I find that the derivation of an exact expression for the spectral density of sparse matrices, which exhibits an essential (Lifshitz) singularity in the vicinity of an edge of the band, is an absolutely outstanding achievement which will attract a very strong interest in the years to come.

To conclude, I find that the presented Thesis is a sound and an important piece of work proving that the applicant is a bright young scientist, who is mature enough and has all necessary skills and competences for conducting an independent research. I thus unconditionally support granting him a PhD Degree in Physics and wish him much success in future.

Provisional Recommendation
<i>X I recommend that the candidate should defend the thesis by means of a formal thesis defense</i>
<i>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</i>
<i>The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense</i>