

Relevant PhD Committee
University of Warsaw
Poland

Postal address:
Institut für Theoretische Physik,
TU Dresden, Helmholtzstraße 10,
01069 Dresden, Germany

Visitor address:
Zellescher Weg 17, Room 119,
01069 Dresden, Germany

Report on PhD thesis of Maciej Łebek, titled "Kinetic theory and hydrodynamics of nearly-integrable gases"

Overall Summary and Recommendation: The thesis submitted by Maciej Łebek incorporates an impressive body of work in the field of non-equilibrium quantum many-body physics. The work included in the thesis stems from six papers coauthored by the candidate, of which he is the lead author in three. In addition, the candidate has also published four papers in a different subfield with other collaborators, which are not described in the thesis because they do not directly fit in the theme.

By any reasonable measure, the achievements are remarkable. I recommend granting of the PhD degree with distinction.

The more detailed report follows.

Topic of Thesis: The topic discussed in the thesis is at the intersection of the fields of integrability, hydrodynamics, thermalization, kinetic theory and ultracold atoms.

Integrable many-body systems have long fascinated theorists due to their potential tractability and beautiful mathematical structure. The relevance of integrability however goes far beyond aesthetics: integrable models can be relevant to experimentally realized physical systems which are not exactly integrable, since proximity to integrability can govern behavior up to experimentally accessible time and length scales. As this 'perturbative' reason for the importance of integrable models has become more widely appreciated, it has become vital to understand nearly-integrable systems. Mr. Łebek's PhD work is a series of important, in fact foundational, steps in this direction.

For more than a century, hydrodynamics has been a standard framework for thinking about non-equilibrium phenomena. The underlying idea is that the dynamics of a few locally conserved macroscopic variables should form the relevant description of macroscopic matter, and we should not have to keep track of all microscopic degrees of freedom. For integrable models, however, this idea is tricky to implement because these models by definition have a large number of conserved quantities. About a decade ago, a solution to this problem was proposed in the form of generalized hydrodynamics (GHD).

Given these two lines of developments, it is natural to ask, how does GHD, which describes integrable models, relate to 'usual' hydrodynamics (Euler equations or Navier-Stokes equations)? The work described in this thesis provides a rather thorough answer to this question. This work has generalized frameworks developed for the kinetic theory of weakly interacting models of particles (BBGKY hierarchy, the Chapman-Enskog expansion, etc), and applied them successfully to nearly-integrable gases.

Structure of the dissertation: The bulk of the thesis consists of the six publications of the author, in Chapter 2. In addition there is an introductory chapter 1 and a concluding chapter 3.

The Introduction is well-structured and appropriately detailed, guiding the reader through the hierarchy of theoretical descriptions relevant to the thesis. The material on the Lieb-Liniger model, Bethe Ansatz, Thermodynamic Bethe Ansatz, and Generalized Gibbs Ensembles is presented clearly and provides the necessary foundation. The discussion of Generalized Hydrodynamics and its extensions, including the GHD-Boltzmann equation, is particularly useful as it sets the stage for the original results. While much of this material is available in the literature, the coherent presentation here serves as an excellent introduction to the main work, and demonstrates the author's command of the field and understanding of the context. In addition, there are a number of schematic diagrams used to illustrate the broad ideas, which I found to be very helpful.

In Chapter 2, the six papers are included. Each is prefaced by a relatively brief (about a page each) 'big-picture' overview of the work presented in the publication. Since the publications themselves are highly technical in nature, these mini-introductions are essential. A brief statement is also given regarding the candidate's contribution to each of the publications.

The structure was new to me --- I am aware that reprinting publications verbatim is not uncommon for PhD dissertations, but the ones I dealt with until now took the path of rewriting the material of the papers for the thesis. Given the highly technical nature of Mr. Łebek's work, the current format is perhaps more suitable. Due to the excellent introductory chapter and the overviews before each of the six publications, the structure worked quite well.

Final comments and assessment: The thesis presents a coherent and systematic program of study carried out over the course of six projects. Those manuscripts which have been published/accepted have found homes in high-profile and competitive journals, very justifiably in my opinion. Several of the results are physically non-obvious and thus expands our understanding of such dynamics, and also open up new questions. In addition, the technical breakthroughs --- obtaining the Navier-Stokes equations from GHD-Boltzmann equations,

generalizing Chapman-Enskog theory to nearly integrable systems, etc, are important and will doubtless be used by the community in future work.

Among the theses that I have evaluated directly myself, in different countries and universities, this is perhaps the most impressive . While I have not interacted with the candidate personally, from the thesis and publication record alone, it seems certain that he is ready to conduct independent scientific research at the highest level.

So, I find it easy to recommend acceptance of the thesis for the doctoral degree. I also believe this collection of work deserves a distinction, as the level is well above that of an average PhD dissertation.

Yours Sincerely,



Masudul Haque

Institut für Theoretische Physik,
Dresden University of Technology, Dresden, Germany