

Supervisor's review of the doctoral thesis of Michal Kloc

Title: Quantum phase transitions in systems with a finite number of degrees of freedom
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The doctoral thesis of Michal Kloc deals with various aspects of quantum phase transitions (QPTs) in models describing quantum systems with finite numbers of degrees of freedom. In particular, the author focuses mostly on various versions of the Dicke model, formulated in 1954, that captures key features of the collective interaction of an ensemble of atoms with quantized electromagnetic field in a cavity. This model at present meets a wave of renewed interest due to the recent experimental realization of its superradiant QPT. The author investigates various properties of the Dicke system and probes how they are influenced by another type of quantum critical phenomena – so called excited-state quantum phase transitions (ESQPTs), which represent some anomalies of spectra and structure of the Hamiltonian eigenstates at high excitation energies.

The work is based on 3 papers published in (a) *Annals of Physics*, (b) *Journal of Physics A*, and (c) *Physical Review A*. In all cases, Michal was the main author. Besides this, he was a coauthor of 1 paper in *Physica Scripta* and 1 contribution in *AIP Conference Proceedings*.

The main focus of the first paper is the identification of quantum phases of the Dicke model and the description of atom-field and atom-atom entanglement present in excited states (with regard to the ESQPTs). The second paper maps the relation of a specific ESQPT in the integrable (so called Tavis-Cummings) version of the model to the classical and quantum monodromy. The third paper is devoted to the study of quantum quench dynamics in the Dicke model and its links to the ESQPTs. The results are interesting and significant, which is indicated by the fact that all papers smoothly passed through detailed reviewing procedures in the respective high-quality journals and were already several times quoted.

I consider the work of Michal Kloc fairly sufficient for awarding him the title PhD. He consistently mapped numerous quantum features of the Dicke model and considerably contributed to the knowledge in this field. There is beyond any doubt that Michal proved his ability for an independent scientific work in theoretical many-body physics.

On a more personal note, it is true that the Thesis might have been completed somewhat sooner without Michal's simultaneous involvement in several other projects (studying educational physics at our Faculty, teaching physics at a secondary school, involvement in some programming activities at the Czech Technical University, popularization lectures etc.). Nevertheless, I am convinced that all those activities were worth and useful for Michal's personal and professional growth. I can be only positive about Michal's and mine scientific collaboration.

I recommend the doctoral committee to accept the Thesis of Michal Kloc as the PhD. work.

In Prague, August 16, 2018

Prof. Pavel Cejnar, DSc.