Technische Universität Darmstadt | Hochschulstrasse 4A | 64289 Darmstadt

TECHNISCHE UNIVERSITÄT DARMSTADT

Institut für Angewandte Physik
Theoretische Quantenphysik

Prof. Dr. Gernot Alber

Hochschulstrasse 4A
64289 Darmstadt

Tel. +49 6151 16 – 20400
Sekr.. +49 6151 16 – 20321
Fax +49 6151 16 – 20402
gernot.alber@physik.tu-darmstadt.de

Datum
21.02.2021

# Report on the Dissertation Thesis
## "Asymptotic Properties of Quantum Markov Processes"

## by Ing. Jiří MARYŠKA

Quantum Markov processes constitute a general mathematical framework for describing the dynamics of open quantum systems. Thus, understanding their dynamical properties is of significant physical interest. They do not only play an important role in clarifying still open issues concerning the establishment of thermal equilibrium but they are also of topical interest in current developments in quantum information science. It is a main goal of this thesis of Ing. Jiří MARYŠKA to investigate theoretically characteristic asymptotic properties of finite dimensional trace-non-increasing homogeneous quantum Markov processes. Thereby this thesis work builds on previous work of both supervisors and extends these previous results significantly by exploring systematically the rich structure of asymptotic attractor spaces of these quantum Markov processes, by relating the structure of the generators of these processes to these attractor spaces, and by establishing several versions of a new Jaynes' principle. All these results explore open topical issues concerning the theory of open quantum systems and shed new light onto current developments in quantum thermodynamics and quantum information science.

After an introduction motivating the main goal of this thesis work, a summary of important already known theoretical basis concepts concerning open quantum systems, the Jaynes principle and quantum Markov processes are presented in chapters 2 and 3 of this thesis. The new methodological theoretical developments of this thesis work are presented in the subsequent chapters 4 and 5. In chapter 6 these developments are applied to the theoretical description of an interesting open quantum system modelling photosynthesis, namely an energy excitation transfer network. Chapter 7 finally concludes this thesis work with a summary and an interesting outlook onto further possible theoretical developments. The new theoretical developments presented in chapters 4 and 5 build on previous work of the supervisors in which first basic aspects of the attractor formalism have been developed, which is used and further generalized systematically in this thesis work. Central new results of these generalizations, presented in chapter 4, are the establishment of general relations between the attractor spaces in the Schrödinger picture and in its dual Heisenberg picture and generalizations of previous results, which are applicable to faithful quantum Markov processes only, to general quantum Markov processes. Central new results presented in chapter 5 are the introduction of generalized Gibbs states and their relations to constants of motion and the establishment of remarkable relations between statistical physics and general quantum Markov processes by formulating generalized Jaynes' principles for general quantum Markov processes. The example presented in chapter 6 models photosynthesis processes with the help of an interacting qubit network. Applying the theoretical methods developed in chapters 4 and 5 to this example demonstrates in a convincing way the power of these theoretical methods and the intricate insights which may be obtained by their application. With these original and interesting methodological developments the goals of this thesis work as formulated in the introduction have been achieved in an impressive way.

The new methodological developments presented in chapters 4 and 5 constitute significant new theoretical developments: Firstly, they provide powerful analytical tools to explore systematically the asymptotic dynamics of general quantum Markov processes. Thereby, they also yield novel insights into the relation between the Schrödinger and the Heisenberg picture in situations in which dynamics are described by normal but in general not unitary linear superoperators. Secondly, it establishes a remarkable link between statistical physics and general quantum Markov processes by the establishment of a generalized Jaynes' principle for general quantum Markov processes.

The original and extensive theoretical investigations of Ing. Jiří MARYŠKA are presented in this thesis in a clear and scientifically sound way. In view of the scientific originality of the presented new theoretical results of this thesis and of their excellently clear presentation I strongly recommend this thesis work for presentation and for defense.

Darmstadt, 21.02.2021

.........................................
(Prof. Dr. G. Alber)