
DIPARTIMENTO DI FISICA

Via Amendola, 173
I-70126 Bari, Italy
Tel. +39 080 544 3222
Fax +39 080 544 3462
Email: paolo.facchi@uniba.it
paolo.facchi@ba.infn.it

25 November 2024

Dean's Office,
Faculty of Physics, Astronomy
and Applied Computer Science
Jagiellonian University, Kraków, Poland

Object: Report on the Ph.D. thesis entitled "Optimal generalized quantum measurements and other fantastical beasts" submitted by Jakub Czartowski

TO WHOM IT MAY CONCERN

The thesis submitted by the candidate contains six main chapters and twenty-eight sections.

The introductory chapter constitutes a very enjoyable summary of quantum information theory. The style is pedagogical and 'hands-on', with a wise and well-balanced use of observations and illuminating examples. The sections are not unduly burdened by heavy mathematical formalism, making the reading accessible to a broader audience.

The same style is also found in the chapters dedicated to the original results, all preceded by an enjoyable introduction aimed at presenting the state of the art and the problems that are intended to be addressed.

The original material is reported in chapters 2, 3, 4, 5, 6. All chapters have already given rise to publications, except the last one. The quality of this scientific enterprise is top-class and all the results are interesting, timely and new.

The original material covers a variety of topics, and can be summarized as follows:

- A complete classification of all equivalence classes of iso-entangled bases for joint projective measurements on two qubits, which has important applications in understanding the role of nonlocality in quantum networks.
- The analysis of the quantum metrological problem of simultaneous estimation of non-commuting rotations of a spin at the ultimate Heisenberg-scaling sensitivity.
- The investigation of thermal operations in a resource-theoretic approach to quantum thermodynamics. The state of the art has been significantly improved along

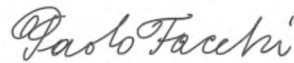
two main directions. It is shown, partly analytically and partly numerically, that any thermal operation, with an arbitrarily non-Markovian dynamics, can be recovered with arbitrary precision by a sequence of Markovian thermal operations in the presence of an ancillary memory initialized to thermal equilibrium. Moreover, for arbitrary thermal operations, the role of a catalytic ancillary system is studied and interesting bounds on the dimension and structure of the states needed for catalysis of thermal operations are given, and are applied to the generation of entanglement by thermal operations.

- The introduction of the new idea of designs of quantum channels, their analysis, and the demonstration that they can be built as designs induced by unitary designs. A nice construction using the Clifford group and Choi states is applied to the estimation of the effective environment dimension of the IBM Kyoto 127-qubit quantum computer. This chapter is a handy gem and may be very useful as a seminal reference for future research.

The thesis demonstrates an outstanding mastery of mathematical and physical ideas around quantum information theory, a wealth of original results born from the candidate's innate sense for interesting and fruitful problems, and his remarkable technical prowess in solving them.

This is an excellent doctoral thesis by all European standards and, in my experience, belongs to the top 3% of all Ph.D. dissertations I have evaluated. Therefore, in light of the formidable amount of new and original research material contained in this thesis, and considering the effort made by the candidate to present it in a scientifically rigorous, neat and self-contained way, I have no hesitation whatsoever in recommending that the Ph.D. degree be awarded with the highest distinction.

Yours faithfully,



Prof. Paolo Facchi

Professor of Theoretical Physics
and Mathematical Methods

Dipartimento di Fisica
Università di Bari, Italy

Istituto Nazionale di Fisica Nucleare
Sezione di Bari, Italy