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Report on the PhD thesis by Martin Plávala
Non-classical effects on generalized quantum channels

Within the last fifteen-to-twenty years science of quantum information has become one of the ``hottest'' topics in physics. Many aspects of manipulation of information encoded in quantum systems have been studied. New forms of communication, such as quantum teleportation or superdense coding, based on the existence of quantum entanglement have been proposed and experimentally tested. The importance of investigations of the physics of quantum information cannot be overestimated. Firstly, these studies help us to understand deeper fundamental properties and features of quantum world. Secondly, novel entanglement-enabled technologies open new perspectives for potential real-life applications such as precision measurements, communication protocols, quantum simulations, etc. The significance of the (socio-economic) importance of quantum information sciences can be demonstrated also by the Quantum Flagship initiative of the European Commission. This illustrates the timeliness and importance of the topic of the topic of the proposed thesis.

The PhD thesis by Martin Plávala is focused on a very interesting topic – general probabilistic theories and their applications within the context of quantum information sciences. The thesis is composed of two parts. The first one is an introductory review of general probabilistic theories, while the second part contains a collection of 5 research articles by Martin Plávala. The review itself is very well written and it represents a very good and pedagogically very well presented introduction to general probabilistic theories starting with basic definitions, (such as definitions of the state space, the effect algebra, the convex effect algebra, etc.). And as one can expect after this "kinematic" part transformations over states (channels, measurements, etc.) are presented. Overall, this is a standard presentation of familiar topics, however, the author has made this review very accessible even to non-specialists and can it be used as an introductory text for students.

The second part of the thesis contains 5 original scientific papers by the candidate. I present the list of these five publications below, since I find it rather impressive that by the time when I write this report all the five papers have been published, but also that the candidate has four more papers to report.

1) M. Plávala, “All measurements in a probabilistic theory are compatible if and only if the state space is a simplex,” Phys. Rev. A, 94, 042108 (2016).
2) A. Jenčová and M. Plávala, “Conditions on the existence of maximally incompatible two- outcome measurements in general probabilistic theory,” Phys. Rev. A, 96, 022113 (2017).
3) M. Plávala, “Conditions for the compatibility of channels in general probabilistic theory and their connection to steering and Bell nonlocality,” Phys. Rev. A, 96, 052127 (2017).
4) T. Heinosaari, L. Leppäjärvi and M. Plávala, “No-free-information principle in general prob- abilistic theories.” Quantum 3, 157 (2019).
5) A. Jenčová and M. Plávala, “On the properties of spectral effect algebras.” Quantum 3, 148 (2019).

Moreover, out of these five papers the candidate has two papers in Phys. Rev. A as a sole author. This is really an outstanding situation and it is far from common that a PhD thesis is of such a high standard.

Even though I do not intend to comment on each of the five papers which in my opinion are of high quality, but I will only briefly comment on the first paper from the list in which the candidate has studied the compatibility of measurements on finite-dimensional compact convex

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state space in the framework of general probabilistic theory. He has formulated necessary and sufficient conditions for two-outcome measurements to be compatible and he has used these conditions to show that there exist incompatible measurements whenever the state space is not a simplex. Results presented in this work are important since incompatibility of measurements is one of the key aspects of quantum theories. I did not check proofs presented in the work by myself, however the importance of the work can be demonstrated by the fact that it has already attracted 20 citations (see google scholar) which for mathematically oriented papers is rather significant in such a short time.

I do not have specific scientific comments on the work, though I would like to reflect on a rather "frivolously" written text of the introduction of the review. Namely, the first sentence of the introduction "Let's build a new theory." makes me as a physicist a bit uncomfortable since any decision to develop a new physical theory must be justified by the experimental (observational) necessity. In addition, the author uses rather flexibly notions such as "information", probability, measurement, randomness etc. For instance, what is the meaning of the statement "randomness exists". Certainly, I do understand that these and other concepts are in some detail specified later in the review, though I would call for more careful usage of language.

In conclusion, Martin Plávala has prepared an outstanding thesis. One of the attractive features of the thesis is that it opens some new perspectives on further investigation of general probabilistic theories and their applications within the context of quantum information sciences. The introductory/review part of the thesis is written very well. The thesis also contains many original scientific results which have been published in five papers in high-impact journals. The thesis clearly manifests that Martin Plávala is proficient in and capable of promoting original research in the field of Theoretical and Mathematical Physics. I recommend that Martin Plávala is awarded PhD. I give the grade **"A"** for the thesis.

Bratislava, 10th July 2019

Vladimír Bužek