Report on the thesis

Foundational insights on physics and information processing arising from the paradigm of generalised probabilistic theories.

by

John Selby

Dr **John Harry Selby** obtained the title Doctor of Philosophy at the Imperial College, London in 2018. In 2024 he submitted his habilitation thesis consisting of a cycle of 13 related scientific articles written in 2018-2024. All of them were published in world-class scientific journals including three papers in *Physical Review Letters* and four in *Quantum*. There are no single-author papers in this cycle, but the number of co-authors is not huge and by each article Dr Selby described precisely his contribution to a given paper. The Thesis is accompanied by declarations of the coauthors, so it is possible to judge that his overall contribution to this cycle of papers was decisive.

The dissertation concerns mathematical foundations of quantum theory. The author makes several sound contributions to the generalized probabilistic theories, which include, as a special case, the standard quantum theory. As quantum information processing provides several advantages with respect to the classical theory, a natural question arrives, whether generalized probabilistic theories may offer some further gains, with respect to the standard quantum theory. Although a full conclusive answer to this question is still unknown, Dr. Selby analysed techniques used for optimization purposes in quantum theory and proposed their analogues into a wide class of generalised probabilistic theories.

Furthermore, Dr Selby proposed an original formal approach to generalized contextuality and introduced ontological models of generalized probabilistic theories. The candidate constructed novel tests for generalized contextuality and demonstrated that the

generalized contextuality should be considered as a key resource indispensable to achieve the quantum advantage. He obtained also important results concerning quantum steering and resource theory of quantum coherence with respect to a given basis. Other results include new schemes to observe non-classicality in physical systems.

Last but not least, some papers forming the habilitation concern the problems of apparent incompatibility of the theory of gravitation and quantum theory. Dr Selby proposed a model to analyse the effects of quantum entanglement in the system of two masses interacting by the gravitational field. The key conclusion is that possible observation of the effects of quantum entanglement can only be considered as evidence that the interaction field is not a classical one.

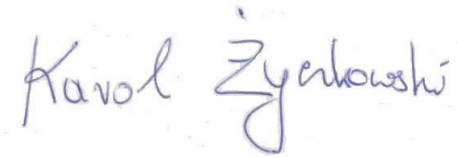
The papers forming the dissertation, rigorously written with a mathematical culture, demonstrate that their authors have a broad knowledge of quantum mechanics, the theory of quantum information and mathematical physics. It is worth to emphasize proficiency concerning the recent literature – studying the papers forming the dissertation one can acquire a good overview on this rapidly developing subfield. .

Apart of twelve papers forming the dissertation, the publication record of Dr Selby contains several valuable publications. The scientific achievements of the candidate include also seven other papers written after Ph.D. which do not belong to the habilitation. According to the data base Web of Knowledge all 45 of his papers were quoted jointly more than 1100 times, while the most known article concerns reconstructing quantum theory form diagrammatic postulates. This single paper, published jointly with Scandalo and Coecke in 2021 in *Quantum* was quoted more than 80 times. Taking into account that the papers in mathematical physics are typically less cited than these in other branches of physics, this publication and quotation record is significant.

After defending his Ph.D. thesis Dr. Selby gained considerable international experience paying extended research visits in Argentina, Japan and Canada. He co-organized

a workshop on foundations of quantum theory at Perimeter Institute, Waterloo, Ontario and a conference on quantum logic organized in Gdańsk in 2021. Furthermore, he participated in several international conferences and presented his results in Brasil, Argentina, Canada, United States, Austria, France, Portugal and United Kingdom and reviewed numerous papers for several prestigious scientific journals. He has a broad experience in realization of research projects. John Selby participated in a Horizon European project and as the principal investigator led an Opus project founded by National Science Center NCN. Furthermore, he serves as a leader of an international QuantEraII project on optimising resources for quantum computation realized in 2024-2027. Dr Selby delivered courses on foundations of quantum theory at the Perimeter Institute and at the University of Gdańsk, so he has experience in teaching and tutoring Ph.D. students.

I will conclude this report by emphasizing my appreciation the scientific merit of all the results presented by the candidate. In my opinion the cycle of articles forming the habilitation can be considered as a significant achievement and a substantial contribution to the foundations of quantum theory. Hence, I do believe, the dissertation and the overall publication record of Dr. John Selby meets all the conditions required for the habilitation degree according to article 221 par, 8 of the Act of 20 July 2018, Law on Higher Education and Science. It is then a pleasure to recommend proceeding with further steps of the procedure to confer **Dr John Selby** the title *Doktor habilitowany w zakresie nauk fizycznych*.



Cracow, March 3, 2025

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