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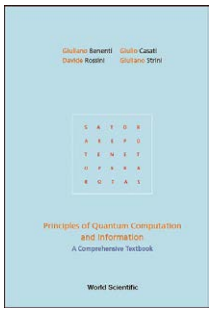

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Principles of Quantum Computation and Information
A Comprehensive Textbook

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This great textbook of more than 700 pages is presented by the authors (now four, thanks to the addition of Davide Rossini of the University of Pisa) as the second edition of the previous set of two volumes on the principles of quantum computation and information, published by WS in 2004 and 2007, on which I had the pleasure to report in these columns of Il Nuovo Saggiatore (Vols. 21, N. 1-2, p. 97 (2005) and 24, N. 5-6, p. 109 (2008), respectively). At the time of the first edition I remarked the novelty of a tutorial approach to a subject of recent interest and rapid expansion in innumerable directions. As such it looked a daring enterprise, aimed at singling out, within the flood of papers and reviews on the subject already appearing in those years, the general concepts and the common threads meant to last, and therefore worth being taught. The second volume, devoted to the various theoretical and experimental aspects of quantum computation and information (QCI), actually appeared three years later as the ideal complement to the first basic volume, so as to provide students, who have been previously introduced to the subject in their graduate studies, with wide and fascinating research perspectives for their PhD, and a window on the future. The two volumes were written in a very clear style, accessible to both undergraduate and graduate students in physics, computer science and engineering. However the authors did not only consider students and young researchers in the field, but also scholars in other research areas and with a limited knowledge of quantum physics, who nevertheless want or need to keep pace with QCI novelties. This was well justified by the pervasive and interdisciplinary character of QCI and even more today with the gradual approach to artificial intelligence.

Clear signs that the original endeavour was farsighted are this second, long awaited edition, and the fact that the original trends in theory and experiment outlined in the 2007 second volume have actually expanded and proliferated over the last twelve years. The authors have succeeded in maintaining the excellent style and tutorial character of the first edition, while extending the domain of QCI to many new entries like entanglement quantifiers, quantum discord, non-Markovian dynamics, quantum simulators, and in particular, quantum information in condensed matter and strongly correlated quantum many-body systems. As explained in the preface, the development in the field has been tumultuous, with possible economical and societal effects. On the applicative side, quantum cryptography has entered a market worth several hundred million dollars, under the increasing need of cybersecurity; another example mentioned by the authors is the progress towards the realization of a global, satellite-based, quantum communication network.

On the theoretical side the authors underline the cross-fertilization between quantum information science and quantum theory of many-body systems, which has contributed new deep insight in both fields. Davide Di Vincenzo and Chris Fuchs start their recent *Physics Today* article (Feb. 2019) on quantum foundations with an illuminating statement: "It's sometimes said that the field of quantum information and computing ougth to be called applied quantum foundations. That's because so many of the ideas that first arose when scientists began thinking deeply about the mysteries of quantum theory –entanglement, Bell inequality violations, parallel worlds, interference of probabilities, and quantum contextuality– are now seen to be resources for attaining feats in information processes unimaginable in a classical world." This statement illustrates how often fundamental issues, far from being pure philosophical speculations, may have astounding implications in other apparently distant research areas and in advanced technology. Viceversa QCI can likely help clarifying some of the above quantum "mysteries". After all a good science is the one which poses good (meaningful) questions before looking for their answers. Whitehead has conceived an onthology appropriate to quantum mechanics: the onthology of processes instead of onthology of objects, and quantum processes are something like the alphabet of QCI. Another interesting example of a possible connection between QCI and fundamental physics is the *toy model* proposed in 2001 by Alexei Yu. Kitaev in connection with quantum computing and soon recognized as one of the earliest and far-reaching suggestions of Majorana fermions in condensed matter. The book has also a section in Chap. 11 on this intriguing aspect.

The book is organized in eleven chapters. It starts with an introduction to classical computation, then the basic concepts of quantum mechanics, of quantum computation and quantum communication. The different aspects of entanglement, non-classical correlations and decoherence are exposed in Chapts. 6 and 7, and are followed by the two important chapters on quantum information theory and quantum information correction. The concluding chapters present the experimental implementations of quantum protocols and quantum information in many-body systems. The book is enriched by an appendix with elements of linear algebra required in quantum theory formalism, a series of exercises in each chapters with solutions in a second appendix, and a vast bibliography.

The propedeutical part of the book has the appropriate style to definitely deserve a wide audience. On top of so many fascinating notions that a wide spectrum of students and researchers can grasp from this excellent book, there is an important lesson about the unpredictable ways fundamental science can impact on technology, and therefore on economy and society. A lesson about the essential role of fundamental research and its long-term benefits, that many policy makers should try to understand.

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