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Special issue on foundations of quantum information

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Although it has been mainly during the last 15 years that the number of scientific investigations relating to quantum information has become great enough that Quantum Information Science (QIS) could be identified as a distinct field of research encompassing quantum computing and cryptography, its roots can be seen as extending back to the early decades of quantum theory itself. That is, QIS can be viewed as resulting from the on-going study of fundamental questions in quantum mechanics, now often referred to as simply Quantum Foundations. It relates mechanics and information in the microscopic realm, offering new insights by connecting the concepts and constraints of communications theory to information theory in a way that provides new methods for probing the elements of fundamental mechanics. It is to such probing of the implications of quantum correlations, measurements, and information theory that this Special Issue of *Quantum Information Processing* is devoted, focusing on foundational ones.

Despite a tremendous increase in activity surrounding the technological aspects of quantum information and entanglement, which is to say surrounding applications of the *qubit* and the *e-bit* in communication and information processing, foundational issues relating to quantum correlation, measurement, and information theory remain in need of further clarification and development (cf., e.g. [1]). This is evident here, for example, in the contribution of Mauro D'Ariano and Alessandro Tosini, who consider tests of postulates of the "fair operational framework" in which quantum mechanics is understood as a set of rules allowing experimenters to predict the results of future measurement events that can be used to yield information on the basis of suitable tests,

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assuming local control and low experimental complexity, by applying them to more general toy mechanical theories.

Similarly, the contributions of Paul Busch and Heinz-Jürgen Schmidt, Marek Czachor, Hoshang Heydari, and John Myers and Tai Wu, show the importance of further explorations of the mathematics of quantum information science and quantum theory through approaches to the qubit and/or e-bit that are traditionally associated with the description of the behavior of space-time, in which both mechanics and the communication of quantum information occur and in which locality can be defined. These explorations illustrate in a range of ways the benefits of a geometrical treatment of quantum states, especially those in which quantum entanglement is exhibited.

The significance of foundational questions in quantum information theory can be seen not only in regard to questions such as those involved in extending quantum entanglement theory, for example, so as to describe multiple-system mixed states and the role of entanglement in the speedup promised by quantum computing algorithms, but also in formal questions in the theory of information processing, as can be seen in the contribution of Karl Svozil here, and in the deeper significance of non-local correlations. Also regarding the latter, several researchers who wear the hat of philosophers of science and who are active investigators of quantum information—Harvey Brown, Michael Seevinck, and Christopher Timpson—have here provided deeply illuminating contributions that demonstrate the connection of quantum correlations with basic questions regarding compound quantum systems and their ontology.

The significance of the relationship between quantum mechanics and information is increasingly being recognized (cf., e.g. [2]). The contributions to this special issue provide further novel insights into this relationship. It can be expected ultimately to bear significantly on the interpretation of the theory of quantum mechanics itself. The contributions to this volume further demonstrate that with developments of the last two decades, Quantum Foundations is a more exciting and valuable area of investigation than ever.

References

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