Special issue: quantum structures and quantum information theory

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1 Editors presentation

The *Quantum Cagliari Conference* was held during October 8 to October 10, in 2018, at the University of Cagliari, in Italy. It gathered experts working in quantum structures and quantum information theory from different countries around the world. There was a convivial atmosphere where researchers, postdoctoral fellows and doctoral and graduate students warmly debated about fundamental questions of different quantum structures in connection with quantum information theory. This special issue reflects the content of several talks presented at the Conference and also includes contributions from other authors as well. We present the selected list of contributions below.

In the paper “From a quantum theory to a classical one,” by Coppo et al. (2020), the quantum to classical transition is discussed under the light of a formalism based on the group-theoretic construction of coherent states. After reviewing the fundamental aspects of the approach in standard quantum mechanics, the authors discuss the role played by a global symmetry of the system in allowing to obtain a well-defined classical theory in the large N limit. They discuss the quantum-to-classical crossover of angular momentum and analyze the example of N free one-dimensional spinless particles. As a concluding discussion, the authors focus on the requirement that any classical description should ultimately be derived from an underlying quantum theory, pointing out that the latter should not be confused with the one obtained via a quantization procedure of the classical one.

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In the paper “Evolution of quantum observables: from non-commutativity to commutativity,” by Fortin et al. (2019), the quantum-to-classical limit is studied from an algebraic standpoint. The authors describe the classical limit as a transition from a non-commutative algebra of observables to a commutative one. In order to do this, they rely on a formalism based on Gamow vectors, which represent resonances and exhibit exponential decays in their time evolution. This is done first for operators that act on a space spanned by the Gamow states and endowed with a Krein pseudometric. Next, they discuss an algebraic formalism taken from scattering theory. The authors show that in these examples, there exist non-commuting algebras that become commutative in the infinite time limit.

In the article “Faithful orthogonal representations of graphs from partition logics,” by Svozil (2019), quantum-like probabilities are studied from the point of view of partition logics, in connection with different notions relevant for understanding the quantum formalism. The author shows that the logico-empirical structure of observables does not determine the type of probabilities alone. Next, he shows that complementarity does not imply contextuality.

In the paper titled “Quantum and quantum-like machine learning: a note on differences and similarities,” Sergioli (2019) deals with a very actual topic in the context of machine learning. In particular, the author shows a way to exploit the potentiality of the quantum formalism in order to gain some benefit in the standard classification in terms of the accuracy of the problem. It is an application of quantum theory that does not require to involve the quantum computer because it runs on standard computer; this is why it is named “quantum-like” machine learning. Differences and similarities of this approach compared with the standard quantum machine learning are highlighted in this paper.

In the paper “Explaining versus describing human decisions: Hilbert space structures in decision theory,” by Sozzo (2019), the quantum cognition research program is analyzed. The effectiveness of quantum structures to model decision-making problems is discussed. The author proposes a realistic–operational foundation for decision processes,

using as a starting point a well-known decision-making puzzle, the Ellsberg paradox. It is then argued that the proposed approach could serve as a foundational motivation for a general use of quantum-like structures in human cognition.

In the article “A new method to predict the interference effect in quantum-like Bayesian networks,” by Dai and Deng (2020), the authors discuss decision-making problems under the light of a quantum-like probabilistic approach. These quantum models have been developed to model decision-making situations which are difficult to describe using classical probability theory. In the quantum-like Bayesian networks, certain parameters represent the phenomenon of interference between different decisions. In this paper, the authors propose a method to measure these interference effects. The method is confronted with empirical data from several Prisoners dilemma games, characterizing its efficiency.

In the paper “How images combine meaning: quantum entanglement in visual perception,” by Arguëlles and Sozzo (2020), a quantum-like probabilistic framework is used to study violations of the CHSH inequality in a cognitive scenario. A Hilbert space representation for a dataset collected using “Google Images” as search engine was used to obtain a significant violation of the CHSH inequality. The authors discuss these results with regard to the existence of non-classical structures in visual perception. They suggest that the presence of some sort of “quantum entanglement” can be used as an explanation for the meaning of connection between the component concepts, in cases where the connection is expressed through images.

The paper “Fuzzy representation of finite-valued quantum gates,” by Loporini et al. (2020), is devoted to provide innovative results in the framework of the quantum computational logic. The initial idea is based on the fact that the meaning of a formula is associated with a density operator and the logical connectives are identified with quantum gates. In particular, the author analyzes the probabilistic behaviors of different gates in the context of many valued logic. Interestingly enough, the author focus on the properties arising from a holistic approach based on the application on n -ary gates to non-factorizable density operators.

The main topic of the article “An equational theory of sigma-complete orthomodular lattices,” by Freytes (2019), is regarding the quantum probability theory. In particular, the author provides an equational theory for the category of sigma-complete orthomodular lattices. In this structure, the author shows the congruences theory and directly irreducible algebras, establishing an equational completeness theorem. Finally, a Hilbert-style calculus related to sigma-complete orthomodular lattices is introduced, and a completeness theorem is provided.

In the paper “On residuation in paraorthomodular lattices,” by Chajda and Fazio (2020), the authors address the problem whether paraorthomodular lattices, i.e. generalizations of lattices of quantum effects ordered under the Olson spectral ordering, can be considered as logics in their own right. To this aim, the authors focus on conditions ensuring a paraorthomodular lattice to be equipped with a suitable “implication” operation. Hence, the paper shows that the above algebras represent a meaningful source of applications in algebraic logic studies and the foundation of quantum mechanics.

In the contribution “Violation of CHSH inequality and marginal laws in mixed sequential measurements with order effects,” by Sassoli de Bianchi (2019), a Bell-test experimental setting is considered, in which the parties perform incompatible measurements in a sequential way, with mixed orders of execution. The author first remarks that the order effects will produce, in general, a violation of the marginal laws. Next, an upper limit for the observed correlations is derived. The author discusses the data of numerous Bell-test experiments and suggests that his proposal could be a possible mechanism for explaining them.

We hope that the list of selected papers will be of interest for the community working in the connections between quantum structures and quantum information theory.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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