EUROPEAN ACADEMY of Sciences and Arts

EASA
ARTS MEET SCIENCES
COLLOQUIUM
WINTER SEMESTER 2026
October 30, 2026 / 6.00 p.m

Abstract

QUANTUM NONLOCALITY: A POWERFUL RESOURCE FOR QUANTUM COMPUTERS

MARIA LUISA DALLA CHIARA AND ROBERTO GIUNTINI

For a long time quantum mechanics has been regarded as “mysterious and potentially paradoxical”. But over the last few decades, this critical attitude has completely changed. One has realized that “quantum enigmas” can be transformed into powerful resources even from a technological point of view. And the theory that has essentially contributed to this “change of mind” is quantum computation theory. As is well known, the main character of quantum computation is the concept of qubit, which represents an uncertain piece of information that might correspond to a certain classical bit with a given probability-value. Today we know that qubits can be materialized in different ways by means of different physical platforms. In these technologi-cal frameworks one can study in a new light the quantum enigmas that had worried Einstein and Schr¨odinger: the ideas of superposition, entanglement and nonlocality. This allows us to distinguish different degrees of quantum-ness which can naturally be used as increasingly powerful resources for real quantum computers. We describe some experiments that we have realized in order to benchmark a special form of nonlocality termed hybrid nonlo-cality. To this aim we have used some quantum computers hosted at the Leibniz-Rechenzentrum (in Munich) and on the new AQT cloud platform (in Innsbruck).

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Dipartimento di Lettere e Filosofia, Universita` di Firenze, Via della Per-gola 60, I-50121 Firenze, Italy, marisa.dallachiara@gmail.com

Dipartimento di Pedagogia, Psicologia, Filosofia, Universita` di Cagliari, Cagliari, Italy, giuntini@unica.it

SHORT CV

Maria Luisa Dalla Chiara graduated in philosophy at the University of Padua. Soon after her "laurea" she has studied logic and philosophy of science at the University of Milan. In the years 1970 -2010 she has been professor of Logic and Philosophy of Science at the University of Florence. She is a past president of the "International Quantum Structures Associa-tion" and of the "Italian Society of Logic and Philosophy of Science". Now she is an emerita professor of the University of Florence.
Dalla Chiara's research-activity started in the years Sixties: a "renaissance-period" for logical investigations in Italy, due to the pioneering work of Et-tore Casari, who had studied logic in Mu¨nster with some great German scholars. The years Seventies have witnessed an increasing interest for non-classical logics, stimulating discussions about the questions: to what extent can the choice of a "right logic" be determined by experience? Is logic an empirical science? Since its birth quantum mechanics had inspired new logical ideas. The apparently "strange" behavior of quantum objects has been reconstructed in the framework of a special example of non-classical logic that has been termed quantum logic. To quantum-logical investigations Dalla Chiara has devoted a number of contributions. An example is the book Reasoning in Quantum Theory. Sharp and Unsharp Quantum Logics, Kluwer, 2004 [with R. Giuntini and R. Greechie]. More recently, new forms of quantum logic (called quantum computational logics) have been inspired by quantum computation (investigated in the book Quantum Computation and Logic. How Quantum Computers Have Inspired Logical Investigations, Springer, 2018 [with R. Giuntini, R. Leporini and G. Sergioli]. These logics have suggested some interesting applications to fields (even far from micro-physics) where ambiguity, vagueness, holism and contextuality play a relevant semantic role. An example is represented by a quantum-theoretic analysis of musical languages, that Dalla Chiara and Giuntini (in collaboration with the musicologist Eleonora Negri and with the composer Riccardo Luciani) have proposed in a series of contributions (for instance, in the book From Quantum Information to Musical Semantics, College Publications, 2012).

SHORT CV

Roberto Giuntini is Full Professor of Logic and Philosophy of Science at the University of Cagliari. His research spans quantum logic and the foundations of quantum mechanics, fuzzy and many-valued logics and quantum computation.

More recently it has extended to quantum-inspired machine learning and the benchmarking of quantum computers.

In 1987 he was an Alexander von Humboldt Fellow at the Institute for Theoretical Physics in Cologne, working with Peter Mittelstaedt. From 2018 to 2021 he was seconded to the Centro Linceo Interdisciplinare "Beniamino Segre" of the Accademia dei Lincei. In 2023–2024 he was Philosopher in Residence at the Institute for Advanced Study of the Technical University of Munich, of which he is now an Alumnus.
He received the Birkho–von Neumann Prize of the International Quantum Structures Association (IQSA) in 1998 and the Jur Hronec Medal of the Slovak Academy of Sciences in 2020.
He has served as President of IQSA (2010–2012) and of the Italian Society for Logic and Philosophy of Science (SILFS, 2017–2020).
He is a Corresponding Member of the Académie Internationale de Philosophie des Sciences.