The Hermann Weyl Prize

The Hermann Weyl Prize was created in 2000 by the Standing Committee of the International Group Theory Colloquium.

The purpose of the Weyl Prize is to provide recognition for young scientists (younger than 35) who have performed original work of significant scientific quality in the area of understanding physics through symmetries.

The Hermann Weyl prize consists of a certificate citing the accomplishments of the recipient, prize money of $500 and an allowance towards attendance of the bi-annual International Group Theory Colloquium at which the award is presented.

The previous winners of the award were: Edward Frenkel (2002), Nikita A. Nekrasov (2004), Boyko Bakalov (2006) and Mohammad M. Sheikh-Jabbari (2008).

The Selection Committee of the Weyl Prize 2010 consisted of S. T. Ali (Concordia University), E. Corrigan (Durham University), P. Kulish (St. Petersburg Mathematical Institute of the Russian Academy of Sciences), R. Mosseri (CNRS Paris) and M. A. del Olmo (University of Valladolid, chairman). This Committee has made the following announcement:

*The Weyl Prize for the year 2010 was awarded to Dr Giulio Chiribella, in recognition of his pioneering work on the application of group theoretical methods in Quantum Information Theory. In particular, for providing a general solution to the problem of optimal estimation of symmetry transformations based on the notion of quantum entanglement between representation and multiplicity spaces, for the derivation of optimal protocols for the alignment of quantum reference frames, for the characterization of extreme quantum measurements in finite dimensions, for the proof of equivalence between asymptotic cloning and state estimation and for the proof of the optimality of measure-and-reprepare for quantum learning of unitary transformations.*
Laudatio of Giulio Chiribella

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Dear Colleagues,

It is an honour for me to deliver the Laudatio on the occasion of the award of the 2010 Hermann Weyl Prize to Giulio Chiribella in recognition of his pioneering work on the application of group theoretical methods in Quantum Information Theory.

Let me start by giving you some biographical notes about the awardee. Giulio Chiribella was born in 1980 in Mantova (Italy). In the period 1998–2002 he studied Physics at the Almo Collegio Borromeo in Pavia, and in June 2003 he received a Laurea degree “cum laude” in Physics with a thesis entitled “Quantum State Estimation for Covariant Sets” under the supervision of G. M. D’Ariano. During the years 2003–2006 he was a student at the Scuola Avanzata di Formazione Integrata in Pavia. During this period he studied for a Ph.D. at the University of Pavia under the supervision of G. M. D’Ariano with a grant of the Italian Ministry of Education. In January 2007 he was awarded this Ph.D. degree in Physics. His thesis was entitled “Optimal estimation of quantum signals in the presence of symmetry”. In the period 2007–2009 he was a postdoctoral fellow at the Quantum Information Theory Group of the University of Pavia.

At present he has a postdoctoral fellowship of the Quantum Foundations and Quantum Information groups at the Perimeter Institute for Theoretical Physics and he is also an affiliate member of the Institute for Quantum Computing, both in Waterloo (Canada).

The research work of G. Chiribella has focused on quantum information theory. More precisely, he has been involved in the resolution of problems of quantum estimation, measurement theory and quantum information processing, using the underlying group-theoretical and algebraic structures of the systems under consideration.

The main contributions made by Chiribella and his collaborators to quantum information theory are: the discovery of the role of equivalent group representations in quantum estimation, the derivation of the optimal protocols for the alignment of quantum reference frames, the characterization of extreme quantum measurements
in finite dimensions, the proof of equivalence between asymptotic cloning and state estimation and the formulation of the theory of quantum combs and testers.

Quantum estimation theory deals with the problem of choosing the best estimation strategy, i.e., the experimental and/or theoretical procedure that optimizes the decoding of a signal state with respect to a given optimality criterion in order to recover the classical information encoded into it. A quantum system, prepared in some known state, undergoes an unknown transformation group, which has to be estimated with the maximum precision allowed by Quantum Mechanics. The estimation of physical parameters associated with transformation groups, such as time-translations, spatial-rotations and displacements in phase space, was treated in Chiribella’s Ph.D. thesis. This work pointed out for the first time the role of multiple equivalent group representations in quantum estimation. In other words, quantum entanglement between representation spaces and multiplicity spaces associated with the irreducible representations of the group under consideration is shown to be the essential feature of optimal estimation. The general solution for a large class of problems of this kind was presented in different works covering the case of all finite and compact groups and, also, several examples of non-compact groups. As application of the theory some problems in quantum optics, where non-compact groups are involved, have been considered: the optimal estimation of squeezing (\( \mathbb{R} \)), the joint estimation of squeezing and displacement (affine group of the line), the study of quantum tomography (\( SU(1,1) \)), and the derivation of quantum benchmarks for the teleportation of squeezed states (\( \mathbb{R} \)).

The determination of the ultimate precision limits for the estimation of group parameters has important applications, in addition to its intrinsic interest, in high-sensitivity measurements, quantum metrology, uncertainty relations, and the study of quantum clocks and gyroscopes (quantum reference frames). The primitive systems that can be used for communication of reference frames are quantum spins, that can be considered as elementary quantum gyroscopes. Chiribella and his co-workers have shown that \( N \) spin-1/2 particles can be used as a quantum gyroscope to encode the directions of 3 cartesian axes with an error (variance) that vanishes as \( 1/N^2 \), a scaling that would be impossible in classical statistics. They have recently shown how the \( 1/N^2 \) scaling can be used in a cryptographic context, yielding new protocols that allow two distant parties to align their cartesian axes secretly and with minimum error. The scaling \( 1/N^2 \) has been proven optimal in the most general class of possible quantum protocols, including protocols with many rounds of forward and backward communication, where the two communicating parties can exchange both quantum particles and classical messages.

Another contribution by Chiribella is the proof of the equivalence between asymptotic cloning and state estimation. In quantum information asymptotic cloning denotes a physical process that produces a large number of approximate copies of an unknown input state. The open problem consisted in proving that any such process can be simulated by the estimation of the unknown input state, followed by the subsequent repreparation of many identical copies of the estimate. Using permutation symmetry, Chiribella showed that the distance between a copy produced by cloning and a copy produced by estimation vanishes as \( 1/M \), where \( M \) is the number of copies. This result proves that the distribution of quantum information to a large number of indistinguishable users is essentially a classical task.

The formulation of the theory of quantum combs and testers has initiated a new line of research on higher-order quantum information. The idea is to generalize the theory
of quantum measurements and transformations to the case where the input object is not a quantum state, but rather a quantum circuit (a physical device). This leads to the definition of \textit{supermaps} (a general transformation that maps an input quantum operation into an output quantum operation). \textit{Quantum combs} are a convenient representation of supermaps in terms of positive operators. A \textit{quantum tester} is a special case of a comb that tests another comb, \textit{i.e.}, it represents a device that tests a network of quantum devices. This provides an extension of the theory of quantum measurements to the case where the measured object is a whole circuit. The theory provided an advance in traditional quantum estimation problems, in particular in the estimation of an unknown transformation from a finite number of identical copies. Quantum combs and testers have been used in combination with group-theoretical and algebraical techniques to derive the optimal cloning of unitary transformations, the optimal tomography of quantum channels, the analysis of quantum protocols for the alignment of reference frames using an arbitrary number of rounds of forward and backward communication, and the characterization of multiround protocols that enjoy symmetry with respect to the action of a given group.

After addressing the merits of the laureate, I will take the liberty of encouraging the Group28 participants to promote the nomination of young scientists, who have performed original work of significant scientific quality in the area of understanding physics through symmetries, to the Herman Weyl Prize. It is necessary to continue in the path opened in 2002 by Edward Frenkel and that Giulio Chiribella now joins in such a brilliant way.

The future of this Colloquium depends on our ability to win over promising and enthusiastic young physicists and mathematicians to work in any of the multiple research topics where symmetry plays a relevant role. And this Weyl Prize is a way to boost their scientific careers.

Thank you very much for your attention!