QI 3: Quantum Information and Foundations I

Time: Monday 14:00–16:00 Location: H4

Invited Talk QI 3.1 Mon 14:00 H4

Quantum Non-Locality in Networks — •Nicolas Gisin — University of Geneva, Switzerland — Schaffhausen Institute of Technology, SIT-Geneva, Switzerland

Quantum non-locality, i.e. the violation of some Bell inequality, has proven to be an extremely useful concept in analyzing entanglement, quantum randomness and cryptography, among others. In particular, it led to the fascinating field of device-independent quantum information processing.

Historically, the idea was that the particles emitted by various quantum sources carry additional variables, known as local hidden variables. The more modern view, strongly influenced by computer science, refers to these additional variables as shared randomness. This, however, leads to ambiguity when there is more than one source, as in quantum networks. Should the randomness produced by each source be considered as fully correlated, as in most common analyses, or should one analyze the situation assuming that each source produces independent randomness, closer to the historical spirit?

The latter is known, for the case of n independent sources, as n-locality. For example, in entanglement swapping there are two sources, hence *quantumness* should be analyzed using 2-locality (or, equivalently, bi-locality). The situation when the network has loops is especially interesting. Recent results for triangular networks will be presented.

Invited Talk QI 3.2 Mon 14:30 H4

Quantum Foundations Meets Causal Inference — •Robert W. Spekkens — Perimeter Institute, Waterloo, Canada

Can the effectiveness of a medical treatment be determined without the expense of a randomized controlled trial? Can the impact of a new policy be disentangled from other factors that happen to vary at the same time? Questions such as these are the purview of the field of causal inference, a general-purpose science of cause and effect, applicable in domains ranging from epidemiology to economics. Researchers in this field seek in particular to find techniques for extracting causal conclusions from statistical data. Meanwhile, one of the most significant results in the foundations of quantum theory—Bell's theorem—can also be understood as an attempt to disentangle correlation and causation. Recently, it has been recognized that Bell's 1964 result is an early foray into the field of causal inference and that the insights derived from more than 50 years of research on his theorem can supplement and improve upon state-of-the-art causal inference techniques. In the other direction, the conceptual framework developed by causal inference researchers provides a fruitful new perspective on what could possibly count as a satisfactory causal explanation of the quantum correlations observed in Bell experiments. Efforts to elaborate upon these connections have led to an exciting flow of techniques and insights across the disciplinary divide. This talk will explore what is happening at the intersection of these two fields.

QI 3.3 Mon 15:00 H4

Symmetries in quantum networks — •Kiara Hansenne[1], Zhen-Peng Xu[1], Tristan Kraft[1,2], and Otfried Guehne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria

Quantum networks are promising tools for the implementation of long-range quantum communication. The characterization of quantum correlations in networks and their usefulness for information processing is therefore central for the progress of the field, but so far only results for small basic network structures or pure quantum states are known. In this contribution, we show that symmetries provide a versatile tool for the analysis of correlations in quantum networks. We provide an analytical approach to characterize correlations in large network structures with arbitrary topologies. As examples, we show that entangled quantum states with a bosonic symmetry can not be generated in networks; moreover, cluster and graph states are not accessible either. Our results allow us to design certification methods for the functionality of specific links and have direct implications for the design of future network structures.

QI 3.4 Mon 15:15 H4

Self-testing maximally-dimensional genuinely entangled subspaceswithin the stabilizer formalism — •Owidiusz Makuta and Remigiusz Augusiak — Center for Theoretical Physics, Polish Academy of Sciences, Warsaw, Poland

The main goal of our work is to identify the largest genuinely entangled stabilizer subspaceand to show that such a subspace can be self-tested. To this end, we first introduce a frameworkallowing to efficiently check whether a given stabilizer subspace is genuinely entangled. Building on it, wethen determine the maximal dimension of genuinely entangled subspaces that can be constructed within thestabilizer subspaces and provide an exemplary construction of such maximally-dimensional subspaces for anynumber of qubits. Third, we construct Bell inequalities that are maximally violated by any entangled state fromthose subspaces and thus also any mixed states supported on them, and we show these inequalities to be usefulfor self-testing. Interestingly, our Bell inequalities allow for identification of higher-dimensional face structuresin the boundaries of the sets of quantum correlations in the simplest multipartite Bell scenarios in which everyobserver performs two dichotomic measurements.

QI 3.5 Mon 15:30 H4

Measurement classicality in the prepare and measure scenario — •Carlos de Gois[1], George Moreno[2], Ranieri Nery[2], Samuraí Brito[2], Rafael Chaves[2], and Rafael Rabelo[1] — [1]"Gleb Wataghin" Physics Institute, University of Campinas — [2]International Institute of Physics, Federal University of Rio Grande do Norte

Quantum communication is expected to become a widespread technology. In that regard, dense coding, random access coding, and quantum key distribution are some of the most outstanding communication protocols where quantum systems provide advantage over their classical counterparts. These will arguably be building blocks for the so-called quantum internet, and recent experiments prove they are feasible in practice. Prepare and measure scenarios — the central theme in this presentation — are a useful abstraction within which a common basis for many such protocols can be found. In these scenarios, an objective of primal importance is determining which preparations and measurements can or cannot lead to nonclassical behaviors, and what are the quantum features that enable nonclassicality to happen. Focusing on the measurements, we provide a general method that can certify, through a sufficient condition, if a given set of measurements are classical (i.e., they never lead to nonclassicality), no matter what quantum preparations they may act upon. As an application, we demonstrate the existence of a large set of incompatible measurements that are nevertheless classical, thus showing incompatibility is insufficient for nonclassicality in the prepare and measure scenario.

Ref.: PRX Quantum 2, 030311 (2021)

QI 3.6 Mon 15:45 H4

Bound entanglement from randomized measurements — Satoya Imai[1], •Nikolai Wyderka[2], Andreas Ketterer[3,4], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany — [2]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, D-40225 Düsseldorf, Germany — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany — [4]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

In scenarios with limited control over multipartite quantum states, randomized measurements provide a powerful tool to characterize quantum correlations. To that end, we analyze the moments of the resulting probability distribution in a systematic way and show (near-)optimal criteria to detect entanglement in different scenarios of bipartite and tripartite systems. In particular, we analyze the geometry of the space of higher-dimensional bipartite quantum systems in order to derive explicit criteria that are able to detect bound entanglement, a very weak form of entanglement, in this setting.