SYQI 1: Entanglement in quantum information, condensed matter and gravity

Time: Wednesday 15:00–17:30 Location: H 0105

Invited Talk SYQI 1.1 Wed 15:00 H 0105

The Quantum Internet: Concepts, Challenges and Progress — •Ronald Hanson — QuTech and Kavli Institute of Nanoscience Delft, Delft University of Technology, The Netherlands

Entanglement - the property that particles can share a single quantum state - is arguably the most counterintuitive yet potentially most powerful element in quantum theory. The non-local features of quantum theory are highlighted by the conflict between entanglement and local causality discovered by John Bell. Decades of Bell inequality tests, culminating in a series of loophole-free tests in 2015, have confirmed the non-locality of nature.

Future quantum networks, spanning a Quantum Internet [1], may harness these unique features of entanglement in a range of exciting applications, such as blind quantum computation, secure communication andenhanced metrology. To fulfill these promises, a strong worldwide effort is ongoing to gain precise control over the full quantum dynamics of multi-particle nodes and to wire them up using quantum-photonic channels.

Here I will introduce the field of quantum networks. I will then discuss our most recent work, including first results on entanglement distribution over deployed fiber on metropolitan scale. I will finally touch upon prospects for scaling these technologies.

[1] Quantum internet: A vision for the road ahead, S Wehner, D Elkouss, R Hanson, Science 362 (6412), eaam9288 (2018).

Invited Talk SYQI 1.2 Wed 15:30 H 0105

Strange metals - A platform to study entanglement in condensed matter? — •Silke Paschen — Institute of Solid State Physics, TU Wien, Vienna, Austria

It is generally considered to be notoriously difficult to define, detect, or even quantify entanglement in condensed matter systems. I will discuss the potential of the "strange metal" state to make progress. Strange metal behavior, best known as a linear-in-temperature electrical resistivity at low temperatures instead of the normal Fermi liquid square-in-temperature one, occurs across many classes of quantum materials [1,2]. Its full understanding is a major challenge. Heavy fermion compounds are particularly versatile model materials for studying this physics: they are comparatively simple, clean, and highly tunable, and several characteristics beyond linear-in-temperature resistivity have already been identified. I will give an overview and highlight recent results, including dynamical scaling of the terahertz conductivity [3], strongly suppressed shot noise [4], and a quantum Fisher information analysis of inelastic neutron scattering data [5].

[1] S. Paschen, Q. Si, Nat. Rev. Phys. 3, 9 (2021).
[2] J. G. Checkelsky, B. A. Bernevig, P. Coleman, Q. Si, S. Paschen arXiv:2312.10659, to appear in Nat. Rev. Mater. (2024).
[3] L. Prochaska et al., Science 367, 285 (2020).
[4] L. Chen et al., Science 382, 907 (2023).
[5] F. Mazza et al., unpublished (2024).

Invited Talk SYQI 1.3 Wed 16:00 H 0105

Quantum black holes may not have interiors — •Vijay Balasubramanian — University of Pennsylvania, Philadelphia, PA 19004, USA

Recent advances at the interface of quantum gravity, quantum computation, and quantum information theory suggest that sufficiently complex external observers can use quantum entanglement to probe the putative interior of black holes. The causal separation of the classical black hole into an interior and exterior separated by a horizon may then be an artifact of the classical limit.

Invited Talk SYQI 1.4 Wed 16:30 H 0105

Gauge Symmetry-Resolved Entanglement in Lattice Gauge Theories: A Tensor Network Approach — Noa Feldman[1], Johannes Knaute[2], Erez Zohar[2], and •Moshe Goldstein[1] — [1]Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel Aviv 6997801, Israel — [2]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Lattice gauge theories (LGT) play a central role in modern physics, providing insights into high energy physics, condensed matter physics, and quantum computation. Due to the nontrivial structure of the Hilbert space of LGT systems, entanglement in such systems is tricky to define. However, when one limits themselves to superselection-resolved entanglement, that is, entanglement corresponding to specific gauge symmetry sectors (commonly denoted as superselection sectors), this problem disappears, and the entanglement becomes well-defined. The study of superselection-resolved entanglement is interesting in LGT for an additional reason: When the gauge symmetry is strictly obeyed, superselection resolved entanglement becomes the only distillable contribution to the entanglement. In our work, we study the behavior of superselection-resolved entanglement in LGT systems. We employ a tensor network construction for gauge-invariant systems as defined by Zohar and Burrello [New J. Phys. 18, 043008 (2016)] and find that, in a vast range of cases, the leading term in superselection-resolved entanglement depends on the number of corners in the partition - corner-law entanglement. To our knowledge, this is the first case of such a corner-law being observed in any lattice system.

Invited Talk SYQI 1.5 Wed 17:00 H 0105

Parameter estimation of gravitational waves with a quantum metropolis algorithm — •Miguel Angel Martin - Delgado — University complutense of Madrid

After the first detection of a gravitational wave in 2015, the number of successes achieved by this innovative way of looking through the Universe has not stopped growing. However, the current techniques for analyzing this type of events present a serious bottleneck due to the high computational power they require. In this article we explore how recent techniques based on quantum algorithms could surpass this obstacle. For this purpose, we propose a quantization of the classical algorithms used in the literature for the inference of gravitational wave parameters based on the well-known quantum walks technique applied to a Metropolis*Hastings algorithm. Finally, we develop a quantum environment on classical hardware, implementing a metric to compare quantum versus classical algorithms in a fair way. We further test all these developments in the real inference of several sets of parameters of all the events of the first detection period GWTC-1 and we find a polynomial advantage in the quantum algorithms, thus setting a first starting point for future algorithms.