Symposium Entanglement (SYEN)

jointly organised by
the Theoretical and Mathematical Physics (MP),
the Gravitation and Relativity (GR), and
the Working Group on Philosophy of Physics (AGPhil)

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Entanglement has gone a long way from a puzzle about some peculiar quantum mechanical states, triggering illustrous disputes about the interpretation of QM, to a dominant effect in finite-temperature solid-state physics, a resource in quantum computation, a driving agent in black hole thermodynamics, and a tool in quantum measurement. The symposium aims to present some of these amazing facets with interest to many communities.

Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Invited Talks

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Sessions

SYEN 1.1–1.1	Mon	16:30–17:10	Audimax	**Entanglement in Experiments**
SYEN 2.1–2.1	Mon	17:10–17:50	Audimax	**Entanglement and Interpretation**
SYEN 3.1–3.1	Mon	17:50–18:30	Audimax	**Entanglement and Complexity**

SYEN 1: Entanglement in Experiments

Time: Monday 16:30–17:10 Location: Audimax

Invited Talk SYEN 1.1 Mon 16:30 Audimax
Squeezed and entangled light - now exploited by all gravitational-wave observatories — •Roman Schnabel — Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Since 2010, the gravitational-wave (GW) detector GEO600 has been using light with a squeezed quantum uncertainty in basically all of its searches for GWs. The successful nonclassical sensitivity improvement that was achieved with the squeeze laser built in my group [1] triggered the implementation of squeeze lasers also in Advanced LIGO and Advanced Virgo. Since April 1st, 2019, these observatories have provided an increased GW event rate of up to 50% that is due to the exploitation of squeezed states of light [2,3,4]. Injecting a squeezed laser field into an interferometer generates strong entanglement between the light fields in the two arms [5]. The entanglement is actually the quantum resource that reduces the measurement noise behind the differential arm length signal below the semi-classical limit. In this talk, I explain how squeezed and high-quality entanglement (Einstein-Podolsky-Rosen-entanglement) has been produced in my laboratories over the past 15 years, with the goal to improve GW observatories and to enable otherwise impossible applications.

[1] LIGO Scientific Collaboration, Nature Physics 7, 962 (2011);
[2] M. Tse et al., Phys. Rev. Lett. 123, 231107 (2019);
[3] F. Acernese et al., Phys. Rev. Lett. 123, 231108 (2019);
[4] R. Schnabel, Annalen der Physik 532, 1900508 (2020);
[5] T. Eberle et al., Phys. Rev. A 83, 052329 (2011).

SYEN 2: Entanglement and Interpretation

Time: Monday 17:10–17:50 Location: Audimax

Invited Talk SYEN 2.1 Mon 17:10 Audimax
Entanglement and Explanation — •Chris Timpson — Faculty of Philosophy, University of Oxford

The last thirty years have seen significant increases in our understanding (and exploitation) of the phenomenon of quantum entanglement. Much of this (quantitative and qualitative) understanding has been driven by developments in quantum information theory. However many traditional conceptual puzzles about how we should understand entanglement remain, particularly when we seek to explain the violation of Bell Inequalities in correlations between spacelike separated measurement events. Perhaps surprisingly, there remain good reasons why even so straightforward a question as whether such an explanation must involve nonlocality continues to be disputed. I will sketch this landscape of debate out, with a particular focus on the questions 1) of what kind of explanation one might seek, and 2) on whether John Bell's formal statement of his informal Local Causality principle in fact fully captures the informal idea when considering families of theories which may involve fundamental non-separability like entanglement.

SYEN 3: Entanglement and Complexity

Time: Monday 17:50–18:30 Location: Audimax

Invited Talk SYEN 3.1 Mon 17:50 Audimax
Entanglement and complexity in quantum many-body dynamics — •Tomaz Prosen — University of Ljubljana, Faculty of Mathematics and Physics, Jadranska 19, SI-1000 Ljubljana, Slovenia

The question of characterising the complexity of dynamics of quantum systems with many interacting particles is, at the same time, very attractive and extremely illusive. Although a generalisation of the notion of Kolmogorov complexity to (non-commutative) quantum dynamical systems has existed for a long time, it does not provide a very useful measure of complexity. For example, it assigns positive complexity even to quasi-free or non-interacting evolutions in the so-called thermodynamic limit.

Within a recent intense burst of studies on dynamical chaos in many-body systems, which were largely motivated by the proposals of Kitaev, Maldacena, Stanford and others on holographic models of black holes, new, more intuitive and more useful, measures of dynamical complexity have been proposed. Amongst the most promising one is the concept of the so-called operator spreading with a complexity indicator given by operator entanglement. Most recently, even non-trivial, exactly solvable models of many-body dynamical chaos appeared, where measures of state and operator entanglement can be computed and the transitions from regularity to chaos analytically shown. These models are particularly topical, as they provide physical examples that may be used to demonstrate quantum supremacy of the currently emerging quantum computers.