Symposium Entanglement (SYEN)

jointly organized by
Section Dynamics and Statistical Physics (DY),
Section Low Temperature Physics (TT), and
Section Semiconductor Physics (HL)

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Overview of Invited Talks and Sessions

(lecture rooms H1)

Invited Talks

SYEN 1.1	Thu	14:00–14:30	H1	**Probabilities (and more) from entanglement** — •Wojciech Zurek
SYEN 1.2	Thu	14:30–15:00	H1	**Entanglement and the Foundations of Statistical Mechanics** — •Sandu Popescu
SYEN 1.3	Thu	15:00–15:30	H1	**Universality and classical simulation of quantum computation** — Maarten van den Nest, Wolfgang Dür, Akimasa Miyake, Guifre Vidal, •Hans Briegel
SYEN 1.4	Thu	15:30–16:00	H1	**Towards the convex roof of multipartite entanglement measures** — •Andreas Osterloh, Jens Siewert, Robert Lohmayer, Armin Uhlmann
SYEN 1.5	Thu	16:00–16:30	H1	**Decoherence induced by interacting quantum spin baths** — •Rosario Fazio
SYEN 1.6	Thu	16:30–17:00	H1	**Sweep a qubit to learn about its environment** — •Peter Hänggi, Martijn Wubs, Keiji Saito, Roland Doll, Sigmund Kohler, Yosuke Kayanuma

Sessions

SYEN 1.1–1.6	Thu	14:00–17:00	H1	**Symposium Entanglement**

SYEN 1: Symposium Entanglement

Time: Thursday 14:00–17:00 Location: H1

Invited Talk SYEN 1.1 Thu 14:00 H1

Probabilities (and more) from entanglement — •Wojciech Zurek — Theory, Los Alamos

I will discuss consequences of envariance (entanglement - assisted invariance; symmetry exhibited by entangled quantum states). I shall focus on implications of envariance for the understanding of the origins and nature of ignorance, and, hence, for the origin of probabilities in physics. While the derivation of the Born's rule for probabilities ($p_k = |\psi_k|^2$) is the principal result of this research, I shall explore the possibility that several other symptoms of the quantum - classical transition that are a consequence of decoherence can be justified directly by envariance – i.e., without invoking Born's rule.

References: W. H. Zurek, Phys. Rev. Lett. 90, 120404 (2003); Rev. Mod. Phys. 75, 715 (2003); Phys. Rev. A71, 052105 (2005).

Invited Talk SYEN 1.2 Thu 14:30 H1

Entanglement and the Foundations of Statistical Mechanics — •Sandu Popescu — H H Wills Physics Lab, Bristol University, Bristol, UK

Statistical mechanics is one of the most successful areas of physics. Yet, almost 150 years since its inception, its foundations and basic postulates are still the subject of debate. Here we suggest that the main postulate of statistical mechanics, the equal a priori probability postulate, should be abandoned as misleading and unnecessary. We argue that it should be replaced by a general canonical principle, whose physical content is fundamentally different from the postulate it replaces: it refers to individual states, rather than to ensemble or time averages. Furthermore, whereas the original postulate is an unprovable assumption, the principle we propose is mathematically proven. The key element in this proof is the quantum entanglement between the system and its environment. Our approach separates the issue of finding the canonical state from finding out how close a system is to it, allowing us to go even beyond the usual boltzmannian situation.

Invited Talk SYEN 1.3 Thu 15:00 H1

Universality and classical simulation of quantum computation — Maarten van den Nest[1], Wolfgang Dür[1,2], Akimasa Miyake[1,2], Guifre Vidal[3], and •Hans Briegel[1,2] — [1]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria — [3]School of Physical Sciences, University of Queensland, Australia

We will review recent work on the theoretical foundations of quantum computation and the role of entanglement in this context [1,2]. In the measurement-based (one-way) model of quantum computation [3], the resource character of entanglement is particularly highlighted. We have recently found necessary criteria that relate the entanglement of the resource state to its universality and/or to the classical simulatability of the measurement-based computation. These investigations shed some new light on the basic questions "What are the essential features that give quantum computers their additional power over classical devices?" and "Which types of quantum algorithms can be simulated efficiently by a classical Turing machine".

[1] M. Van den Nest, A. Miyake, W. Dür, and H.-J. Briegel, Phys. Rev. Lett. 97, 150504 (2006). [2] M. Van den Nest, W. Dür, G. Vidal, and H.-J. Briegel, quant-ph/0608060. [3] R. Raussendorf and H.-J. Briegel, Phys. Rev. Lett. 86, 5188 (2001).

Invited Talk SYEN 1.4 Thu 15:30 H1

Towards the convex roof of multipartite entanglement measures — •Andreas Osterloh[1], Jens Siewert[2], Robert Lohmayer[2], and Armin Uhlmann[3] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, D-30167 Hannover, Germany — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [3]Institut für Theoretische Physik, Universität Leipzig, D-04109 Leipzig, Germany

Selective measures for genuine multipartite entanglement of pure states have been presented recently. Their extension to mixed states via the convex roof is approached starting from the three-tangle. We provide a thorough analysis of mixed three-qubit states composed of a GHZ state and a W state orthogonal to the former. We present optimal decompositions and convex roofs for the three-tangle. These results highlight intriguing differences compared to the properties of two-qubit mixed states, and may serve as a quantitative reference for future studies of entanglement in multipartite mixed states. From our studies we derive an analytical method to decide whether or not an arbitrary rank-2 state of three qubits has vanishing three-tangle. This result can be generalized for N-tangles of rank-2 N-qubit states ($N \geq 3$).

References:

A. Osterloh and J. Siewert, e-print quant-ph/0506073 Int. J. Quant. Inf. **4**, 531 (2006).

R. Lohmayer, A. Osterloh, J. Siewert, A. Uhlmann, e-print quant-ph/0606071, Phys. Rev. Lett. **97**, 260502 (2006).

Invited Talk SYEN 1.5 Thu 16:00 H1

Decoherence induced by interacting quantum spin baths — •Rosario Fazio — International School for Advanced Studies (SISSA), 34014 Trieste, ITALY

We study decoherence induced on a two-level system coupled to a one-dimensional quantum spin chain. We consider the cases where the dynamics of the chain is determined by the Ising, XY, or Heisenberg exchange Hamiltonian. This model of quantum baths can be of fundamental importance for the understanding of decoherence in open quantum systems, since it can be experimentally engineered by using atoms in optical lattices. As an example, here we show how to implement a pure dephasing model for a qubit system coupled to an interacting spin bath. We provide results that go beyond the case of a central spin coupled uniformly to all the spins of the bath, in particular showing what happens when the bath enters different phases, or becomes critical; we also study the dependence of the coherence loss on the number of bath spins to which the system is coupled and we describe a coupling-independent regime in which decoherence exhibits universal features, irrespective of the system-environment coupling strength. Finally, we establish a relation between decoherence and entanglement inside the bath. For the Ising and the XY models we are able to give an exact expression for the decay of coherences, while for the Heisenberg bath we resort to the numerical time-dependent Density Matrix Renormalization Group.

Invited Talk SYEN 1.6 Thu 16:30 H1

Sweep a qubit to learn about its environment — •Peter Hänggi[1], Martijn Wubs[1], Keiji Saito[2], Roland Doll[1], Sigmund Kohler[1], and Yosuke Kayanuma[3] — [1]Institut für Physik, Universität Augsburg — [2]University of Tokyo, Japan — [3]Osaka Prefecture University, Japan

We derived the exact zero-temperature transition probability for the dissipative Landau-Zener problem. The standard (non-dissipative) Landau-Zener problem is an exactly solvable textbook example in time-dependent quantum mechanics which has found many applications in physics and chemistry. Our exact result [1] constitutes an important generalization: it describes how the coupling of the qubit to its environment changes the transition probability. Moreover, we find that the final quantum state exhibits a peculiar entanglement between the qubit and the bath. A large class of realistic types of coupling is considered. Surprisingly, the final transition probability is not affected at all by environments that only cause pure dephasing. In general, we find that Landau-Zener sweeps provide a robust tool for characterizing the environment of a tunable qubit. Promising applications include superconducting qubits, especially in circuit QED [2,3].

[1] M. Wubs *et al.*, Phys. Rev. Lett. **97**, 200404 (2006).
[2] K. Saito *et al.*, Europhys. Lett. **76**, 22 (2006).
[3] R. Doll *et al.*, Europhys. Lett. **76**, 547 (2006).