Quantum Roundabout

29th June – 2nd July 2014
The University of Nottingham

PROGRAMME

SUNDAY 29th JUNE

15:00-19:00 Registration @ Hugh Stewart Hall

MONDAY 30th JUNE

07:30-08:30 **Breakfast**

09:00-09:30 **Opening remarks**

09:30-10:40 **Anna Sanpera**
Quantum information in strongly correlated systems

10:40-11:05 **Andrea Cadarso**
Phase Stabilization of a Frequency Comb using Multipulse Quantum Interferometry

11:05-11:30 **Giacomo De Palma**
A generalization of the Entropy Power Inequality to bosonic quantum systems

11:30-12:00 **Coffee break**

12:00-12:25 **Antonella De Pasquale**
Discriminating Strength: a bona fide measure of non-classical correlations

12:25-12:50 **Yelena Guryanova**
Almost Quantum

MONDAY 30th JUNE (continued)

12:50-13:15 **Lorenzo Catani**
Accessible information in a two-qubit system through the quantum steering ellipsoid formalism

13:15-14:15 **Lunch break**

14:15-15:25 **Anna Sanpera**
Quantum information in strongly correlated systems (continued)

15:25-15:50 **Ksenia Samburskaya**
Parallel Quantum Memory for Optical Images Based on Λ-Scheme of Atomic Levels

15:50-16:15 **Ambrož Kregar**
Realization of qubit gates with a coherent evolution of two electron states in a quantum dot in presence of Rashba coupling

16:15-16:45 **Coffee break**

16:45-17:10 **Anna Szczepanek**
Maximum dynamical entropy and Hadamard matrices

17:10-17:35 **Alessandro Farace**
Steady-state entanglement activation in optomechanical cavities

17:35-18:00 **Federico Carollo**
Environment Induced Entanglement in Mesoscopic Systems

19:00-21:00 **Poster session**

TUESDAY 1st JULY

07:30-08:30	**Breakfast**
09:00-10:10	**Roger Colbeck** *Are there random processes in nature?*
10:10-10:35	**Ralph Silva** *Optimal Weak Measurements and Multiple Violations of Bell Inequalities*
10:35-11:00	**Joseph Bowles** *Certifying classical and quantum dimension with independent devices*
11:00-11:30	**Coffee break**
11:30-11:55	**Sandra Rankovik** *The alternate ticks time game*
11:55-12:20	**Thomas Kauten** *Testing the Foundations of Quantum Mechanics with Multipath Interferometers and Single Photons*
12:20-12:45	**Johannes Kleiner** *QT and GR united? An introduction to causal fermion systems*
12:45-13:45	**Lunch break**

TUESDAY 1st JULY (continued)

13:45-14:55 **Roger Colbeck**
Are there random processes in nature? (continued)

14:55-15:20 **Sina Salek**
Negative Conditional Entropy of Post-Selected States

15:20-15:45 **Christian Arenz**
Distinguishing decoherence from alternative quantum theories

15:45-16:10 **Fabio Deelan Cunden**
Statistics of Quantum Transport in Chaotic Cavities: a Random Matrix approach

17:30-22:00 **"Round-a-boat"**
Boat trip in River Trent
(Dinner will be served onboard)

Quantum Roundabout

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WEDNESDAY 2nd JULY

07:30-08:30 **Breakfast**

09:00-10:10 **Vlatko Vedral**
Three roads to quantum thermodynamics

10:10-10:35 **Philipp Kammerlander**
Work extraction in resource theories and possible implementations

10:35-11:00 **Artur Malabarba**
Quantum Systems Equilibrate Rapidly for Most Observables

11:00-11:30 **Coffee break**

11:30-11:55 **Nana Liu**
Quantum Thermodynamics of Cosmology, Accelerating Observers and Black Holes

11:55-12:20 **Felix Binder**
An operational first law of thermodynamics for open quantum systems

12:20-12:45 **Carole Addis**
What we talk about when we talk about non-Markovianity

12:45-13:45 **Lunch break**

WEDNESDAY 2nd JULY (continued)

13:45-14:55	**Vlatko Vedral** *Three roads to quantum thermodynamics (continued)*
14:55-15:20	**Amikam Levy** *On the local and global approach to quantum transport and violation of the second-law of thermodynamics*
15:20-15:50	**Coffee break**
15:50-16:15	**Raam Uzdin** *Universal features in the maximal work per efficiency of hot quantum Otto engines*
16:15-16:40	**Francesco Mazza** *Thermoelectric efficiency of three-terminal quantum thermal machines*
16:40-17:00	**Closing remarks**

ABSTRACTS (Talks)

Anna Sanpera

Quantum information in strongly correlated systems

Quantum Information is having a profound impact in several areas of physics ranging from quantum optics, quantum many-body systems, or high energy physics just to mention some. In this lectures we will focus in strongly correlated systems and in the plethora of exciting phenomena that such systems present. We will then approach these systems from a quantum information perspective analyzing the behaviour displayed by the quantum correlations present in the system. We will see that this approach allows us to recover well stablished condensed matter concepts such as criticality, universality and quantum phase transitions and to link symmetries and conformal field theory to quantum information quantities. In the second lecture we will discuss bipartite versus multipartite entanglement in strongly correlated systems and briefly overview many most open questions in the subject.

Andrea Cadarso

Phase Stabilization of a Frequency Comb using Multipulse Quantum Interferometry

From the interaction between a frequency comb and an atomic qubit, we derive quantum protocols for the determination of the carrier-envelope offset phase, using the qubit coherence as a reference, and without the need of frequency doubling or an octave spanning comb. Compared with a trivial interference protocol, the multipulse protocol results in a polynomial enhancement of the sensitivity O(N−2) with the number N of laser pulses involved.

Giacomo De Palma

A generalization of the Entropy Power Inequality to bosonic quantum systems

A fundamental result at the basis of classical information theory is the so called Entropy Power Inequality. This states that mixing two arbitrary independent random variables (e.g. two electromagnetic signals) with fixed entropies, the entropy of the output variable is maximized if the inputs are Gaussian with proportional covariance matrices. Electromagnetic signals are, however, ultimately quantum mechanical fields and cannot be described as classical random variables. We have proved one possible generalization of the Entropy Power Inequality to quantum mechanical systems. The impact of this inequality in quantum information theory is potentially large and we have considered some relevant implications.

Antonella De Pasquale

Discriminating Strength: a bona fide measure of non-classical correlations

We introduce a measure of non-classical correlations which quantifies the ability of a given bipartite probing state to discriminate between the application or not of a unitary map to one of its two subsystems. This new measure can be seen as the discrete version of the recently introduced Intereferometric Power measure and a formal connection is provided also with the Local Quantum Uncertainty measure. Analytical expressions are derived which allow us to formally prove that, within the set of separable configurations, the maximum value of our non-classicality measure is achieved over the set of quantum-classical states (i.e. states which admit a statistical unravelling where each element of the associated ensemble is distinguishable via local measures on the reference subsystem). This project has been partially supported by the project Thermodynamics of Mesoscopic Quantum Systems (TherMiQ).

Yelena Guryanova

Almost Quantum

Quantum theory is not only successfully tested in laboratories every day, but also constitutes a robust theoretical framework: small variations of it usually lead to implausible consequences, such as faster-than-light communication or a significant increase in computational power. It has been even argued that quantum theory may be special and represent ``an island in theory space''. Here we show that, at the level of correlations, quantum theory is not as special as previously thought. We define a set of correlations, dubbed ``almost quantum'', and prove that it (i) strictly contains the set of quantum correlations but (ii) satisfies all-but-one of the proposed principles to capture quantum correlations. We present numerical evidence that the remaining principle is satisfied too. Finally, we discuss how almost quantum correlations naturally emerge in the consistent histories approach to quantum physics introduced in quantum gravity. Our result thus open an avenue to possible generalisations of quantum theory.

Lorenzo Catani

Accessible information in a two-qubit system through the quantum steering ellipsoid formalism

The aim of my research is to study the accessible information in a two-qubit system through the quantum steering ellipsoids formalism. The latter is a geometrical tool to represent correlations and, according to it, the qubit state of Alice is represented by an ellipsoid inside her Bloch sphere originated by all the measurements Bob can perform on his qubit. We start by considering the case in which Bob performs a measurement composed by two elements, so he steers Alice to two state vectors in her Bloch sphere. We intuitively expect the maximum of the mutual information will occur for the couple of furthest points on Alice's ellipsoid surface, because this is the configuration nearer to the classical (and so distinguishable) case. This reflects the idea that the mutual information directly depends on the distance between points, however we found it is not always true and a particular unexpected behavior arises.

Ksenia Samburskaya

Parallel Quantum Memory for Optical Images Based on Λ-Scheme of Atomic Levels

The study focuses on realization of quantum memory protocol for efficient storage and retrieving of nonclassical states of light, such as squeezed light. Considered quantum memory protocol for spatially multimode light is based on the interaction of light with atomic ensemble in a Λ-configuration of energy levels. The phase locked Sub-Poissonian laser and Degenerate Optical Parametric Oscillator (DOPO) are chosen as sources of squeezed light. Evolution of the atomic medium and field is described by a system of partial differential equations which are solved analytically for the case when the interaction time considerably exceeds a lifetime of excited state. This time ratio makes it possible to apply adiabatic approximation. Relation between writing and reading times and an optical density of the medium was optimized, in order to ensure a high retrieval efficiency of the quantum image. We analyzed squeezing properties for light in pulse mode and estimate a degree in which light preserves squeezing during the full process of writing and read-out of a light pulse of particular configuration.

Ambrož Kregar

Realization of qubit gates with a coherent evolution of two electron states in a quantum dot in presence of Rashba coupling

We study a possibility of using a system of two electrons in a square quantum dot in presence of magnetic field and Rashba spin-orbit coupling as a building block of quantum computer. We show that singlet and triplet state of electrons in a dot can be used as states of a qubit. Single qubit gate can be realized via coherent time evolution of a system with externally controlled Rashba coupling and gate voltage in static global magnetic field. Two-qubit fully entangling gate are achieved with coherent evolution of states in two neighbouring dots, interacting via weak Coulomb coupling.

Anna Szczepanek

Maximum dynamical entropy and Hadamard matrices

We consider successive measurements performed on a d-dimensional quantum system, whose evolution between two subsequent measurements is given by a unitary operator. As a result, we obtain a random sequence of the measurement outcomes. We quantify the randomness arising from the unitary evolution by means of dynamical entropy (with respect to a measurement) and investigate unitary operators for which some PVM measurement leads to the maximum possible value of dynamical entropy, i.e. ln(d). We indicate a straightforward connection between these operators and complex Hadamard matrices of size d. For d = 2 we give a complete characterization of the set of operators for which PVMs give the maximum possible dynamical entropy and compute the volume of this set in the ensemble U(2). For an arbitrary unitary operator we calculate the maximum possible entropy attainable for PVMs and the mean value of this quantity over U(2).

Alessandro Farace

Steady-state entanglement activation in optomechanical cavities

Quantum discord, and related indicators, are raising a relentless interest as a novel paradigm of nonclassical correlations beyond entanglement. Here, we discover a discord-activated mechanism yielding steady-state entanglement production in a realistic continuous-variable setup. This comprises two coupled optomechanical cavities, where the optical modes communicate through a fiber. We first use a simplified model to highlight the creation of steady-state discord between the optical modes. We show next that such discord improves the level of stationary optomechanical entanglement attainable in the system, making it more robust against temperature and thermal noise.

Federico Carollo

Environment Induced Entanglement in Mesoscopic Systems

We consider two non-interacting infinitely long spin chains immersed in a same microscopic heat bath. While their mean field behaviour is completely classical, we show that, at the level of their fluctuation observables, the two chains behave mesoscopically as a fourmode bosonic open quantum system that can become entangled by the sole action of the microscopic noise.

Roger Colbeck

Are there random processes in nature?

Quantum mechanics is one of the most successful physical theories. One of the central ways in which it differs from classical theory is that it does not in general give deterministic predictions. In my lectures, I will discuss the evidence we have for random processes in nature, and how we might verify their presence in a theory-independent way (i.e., without relying on quantum mechanics). In doing so, we will cover the EPR paradox and Bell's theorem before pushing towards some recent results that give arguably the strongest evidence for randomness to date.

Ralph Silva

Optimal Weak Measurements and Multiple Violations of Bell Inequalities

In quantum mechanics, a weak measurement corresponds to only partially disturbing a system, at the cost of not obtaining the complete information corresponding to a strong measurement. Such (weak) measurements are usually studied along with postselection (leading to the fruitful concept of weak values). In this work, we demonstrate that weak measurements without post-selection are useful by obtaining an arbitrary long sequence of consecutive and independent violations of the CHSH-Bell inequality with a single entangled state. We also derive the pointer state for weak measurements that optimizes the trade-off between the disturbance of the state and the information gained from the measurement.

Joseph Bowles

Certifying classical and quantum dimension with independent devices

Current research in quantum information has seen an increase in 'device independent quantum information'. Here, the aim is to construct protocols which allow the user to make statements about the properties of physical systems purely from the raw experimental data, without placing assumptions on the workings of the devices used to prepare and measure the systems. Such approaches are thus experimentally attractive, since any experimental set up will include devices that are not fully characterised and subject to unknown errors. We apply this method in order to asses the dimension of quantum and classical systems in a prepare-and-measure scenario. We introduce one natural additional assumption that separate devices should act in an uncorrelated manner and show that under this assumption quantum systems can vastly outperform classical systems of the same dimension. Finally, we highlight that our techniques may be useful in constructing robust protocols for semi-device independent randomness expansion. (DOI: 10.1103/PhysRevLett.112.140407).

Sandra Rankovik

The alternate ticks time game

Time, considered as a classical parameter, has always played a special role both in classical and in non-relativistic quantum mechanical descriptions of physical systems. But is this parametric view of time unavoidable? Here we outline an attempt to introduce a new, more general, operational notion of time. Towards this goal, we first define the main properties that time and the clock measuring it should have in the quantum setting. Then we describe a quantum game where the aim of the players is to produce alternate ticks (e.g. light signals) for as long as possible. They can agree on the strategy, and a particular set-up for configuring their systems before the game, but are not allowed to communicate, nor to share any sources (e.g classical information or entangled quantum states), once the game has started. The goal of the game is to investigate possibilities for defining time operationally, and the fundamental limitations to the construction of good quantum clocks.

Thomas Kauten

Testing the Foundations of Quantum Mechanics with Multipath Interferometers and Single Photons

Quantum mechanics is a fundamental theory to describe the physics of microscopic objects, but there are still questions whether this theory is complete or not. One fundamental axiom of quantum mechanics is Born's rule, which claims that the description of nature is probabilistic.
I will present results of five-path interferometer experiments with the goal of putting a bound on the potential magnitude of higher order interference. This experiment was first proposed by Sorkin in 1994 [1], and was experimentally implemented in 2010 by Sinha et al. [2]. Our experiment expands this to five paths, which not only allows us to measure third and fourth order interference terms but also allows testing for the possibility of quantum mechanical wavefunctions based on quaternions or octonions rather than complex numbers [3].

[1] Sorkin, Mod.Phys.Lett. A9, 3119-3128 (1994)
[2] Sinha et al., Science 329, 418-421 (2010)
[3] Peres, Phys.Rev.Lett. 42, 683-686 (1979)

Johannes Kleiner

QT and GR united? An introduction to causal fermión systems

Causal fermion systems are a proposal for a fundamental physical theory with sensible limits both in the QT and GR regime. In this talk, I will give an introduction to the topic and explain the relation between causal fermion systems and quantum theory. Particular focus will be put upon the question of how the wave function (now an effective description) evolves in time.

Sina Salek

Negative Conditional Entropy of Post-Selected States

We define a quantum entropy conditioned on post-selection which has the von Neumann entropy of pure states as a special case. This conditional entropy can take negative values which is consistent with part of a quantum system containing less information than the whole which can be in a pure state. The definition is based on generalised density operators for postselected ensembles. The corresponding density operators are consistent with the quantum generalisation of classical conditional probabilities following Dirac s formalism of quasiprobability distributions.

Christian Arenz

Distinguishing decoherence from alternative quantum theories

A longstanding challenge in the foundations of quantum mechanics is the verification of alternative collapse theories despite their mathematical similarity to decoherence. To this end, we suggest a novel method based on dynamical decoupling. Experimental observation of nonzero saturation of the decoupling error in the limit of fast decoupling operations would provide evidence for alternative quantum theories.

Fabio Deelan Cunden

Statistics of Quantum Transport in Chaotic Cavities: a Random Matrix approach

Random Matrix Theory could provide the mathematical framework to develop a statistical theory of quantum transport in mesoscopic (chaotic) cavities. Essentially, the theory is based on a maximum entropy model constructed to describe transport properties of mesoscopic systems.
The subjects of this talk are the joint statistics (including large deviation tails) of electrical conductance and shot noise originated from this maximum entropy hypothesis. We map this problem to the computation of the partition function of a Coulomb gas system. This (classical) system exhibits a rich phase diagram characterized by high-order phase transitions.

Vlatko Vedral

Three roads to quantum thermodynamics

The laws of thermodynamics need to be generalized to the finite, quantum, non-equilibrium domain. It is by no means clear how to achieve this. In particular, how exactly are we to phrase the concepts of heat, work and entropy in the most general context?

I plan to review three of the most relevant approaches. The first is based on what is called the “resource theory”, the second is known as the “single shot thermodynamics” and the last is based on the non-equilibrium fluctuation-dissipation (Jarzynski) relations. I will first review each of the approaches and then, based on this, I will argue that: a) the usual entropies (due to Shannon and von Neumann, classically and quantumly respectively) are not sufficient to discuss state transformations (we need a more general concept of “majorisation”); b) the relationship between information and work requires us to use more generalized (Renyi) entropies; c) work is, in the quantum setting, not represented by an operator; d) any conclusions are highly sensitive to how we define the “rules of the game”; e) we need to include finite time transformations.

These are just some of the issues we need to face, but there may be others en route to formulating the most general theory of thermodynamics. This is, of course, not only of pure academic interest, but is becoming of practical importance though our advances in the nano- and quantum technologies. I will also draw parallels between how we understand entanglement through local operation and how we formulate thermodynamical entropy.

Philipp Kammerlander

Work extraction in resource theories and possible implementations

An interesting question of active research in quantum thermodynamics is how much work can be extracted from a non-equilibrium quantum state. Among the frameworks which allow us to treat this question is the resource theory of thermal operations (Brandao et al., PRL 11 250404, 2013). In arXiv:1302.2811 Skrzypczyk et al. made use of this framework and proposed a protocol that extracts optimal average work from any finite dimensional quantum system. Interestingly enough, this protocol relies essentially on one unitary operation that is applied repeatedly to different subsystems. In this talk, I start by reviewing the protocol by Skrzypczyk et al. and show how the main unitary operation can be implemented in ion traps using current trapped ion technology. Finally I will put this result into a broader context in the field of quantum thermodynamics.

Artur Malabarba

Quantum Systems Equilibrate Rapidly for Most Observables

Considering any Hamiltonian, any initial state, and measurements with a small number of outcomes compared to the dimension, we show that most measurements are already equilibrated. To investigate non-trivial equilibration we therefore consider a restricted set of measurements. When the initial state is spread over many energy levels and we consider the set of observables for which this state is an eigenstate, most observables are initially out of equilibrium yet equilibrate fast. Moreover, all two-outcome measurements, where one of the projectors is of low rank, equilibrate fast.

Nana Liu

Quantum Thermodynamics of Cosmology, Accelerating Observers and Black Holes

Our aim is to investigate the quantum thermodynamical properties of quantum fields in curved spacetime. Our approach is to consider quantum fields in curved spacetime as a quantum system undergoing out-of-equilibrium transformations. Recent ideas about how to quantify work (Jarzynski) and entropy production (Tasaki-Crooks) have been introduced for thermodynamical systems driven out of equilibrium and we will apply these new ideas in this novel setting of relativistic quantum systems. We will investigate three examples in quantum field theory in curved spacetime which are characterized by the same mathematical description: cosmological expansion, the Unruh effect and the radiating eternal black hole. In each of these scenarios, we compute the work and entropy production and provide the second law of quantum thermodynamics for these cases.

Felix Binder

An operational first law of thermodynamics for open quantum systems

The accurate description of work and heat is one of the main objectives when extending thermodynamics to the regime of individual quantum systems. Exploiting the concept of state passivity the relation between the work potential of an out-of-equilibrium state and the work 'deposited' when creating the same state in a general unitary process is demonstrated. This allows for a clear identification of three separate contributions to the energy change under general quantum evolution: operational work and heat as well as a genuine non-equilibrium part.
Subsequently, consistency with the Hatano-Sasa statement of the second law of thermodynamics is demonstrated and followed by highlighting the role of majorisation for the operational heat generated under evolution with a completely-positive and trace-preserving map.

Carole Addis

What we talk about when we talk about non-Markovianity

In this work, we present a detailed critical study of several recently proposed non-Markovianity measures. We analyse their properties for single qubit and two-qubit systems in both pure-dephasing and dissipative scenarios. More specifically we investigate and compare their computability, their physical meaning, their Markovian to non-Markovian crossover, and their additivity properties with respect to the number of qubits. The bottom-up approach that we pursue is aimed at identifying similarities and differences in the behavior of non-Markovianity indicators in several paradigmatic open system models. This in turn allows us to infer the leading traits of the variegated phenomenon known as non-Markovian dynamics and, possibly, to grasp its physical essence.

Amikam Levy

On the local and global approach to quantum transport and violation of the second-law of thermodynamics

Clausius' statement of the second law of thermodynamics reads: Heat will flow spontaneously from a hot to cold reservoir. This statement should hold for transport of energy through a quantum network composed of small subsystems each coupled to a heat reservoir. When the coupling between nodes is small, it seems reasonable to construct a local master equation for each node in contact with the local reservoir. The energy transport through the network is evaluated by calculating the energy flux after the individual nodes are coupled. We show by analysing the most simple network composed of two quantum nodes coupled to a hot and cold reservoir, that the local description can result in heat flowing from cold to hot reservoirs, even in the limit of vanishing coupling between the nodes. A global derivation of the master equation which prediagonalizes the total network Hamiltonian, and within this framework derives the master equation, is always consistent with the second-law of thermodynamics.

Raam Uzdin

Universal features in the maximal work per efficiency of hot quantum Otto engines

We study "internal" work optimization over the energy levels of a generic hot quantum Otto engine and find universal features in the efficiency at maximal output. For simple optimization constraints, the classical results of "external" power optimization are reproduced. Yet, we give examples that cannot be obtained from classical linear response theory.

Francesco Mazza

Thermoelectric efficiency of three-terminal quantum thermal machines

The efficiency of a thermal engine working in linear response regime in a multi-terminal configuration is discussed. For the generic three-terminal case, we provide a general definition of local and non-local transport coefficients: electrical and thermal conductances, and thermoelectric powers. Within the Onsager formalism, we derive analytical expressions for the efficiency at maximum power, which can be written in terms of generalized figures of merit. Also, using two examples, we investigate numerically how a third terminal could improve the performance of a quantum system, and under which conditions non-local thermoelectric effects can be observed.

ABSTRACTS (Posters)

Daniel Benedicto-Orenes

Magnetic Dipole-Dipole interactions in a spinor BEC

Anisotropy and long range behaviour are features of magnetic dipole-dipole interactions. These can play a role in the quantum dynamic of physical systems, such as condensed matter systems, and the possibility of understanding and using these interactions in physical systems make them an important subject of study. Using laser cooling techniques it is possible to create an optically trapped 87Rb spinor BEC in an optical lattice where these interactions are present. However, the coupling between the atomic spin and the external magnetic field under typical experimental conditions overwhelm the effects of dipole-dipole interactions. Shielding the BEC from external magnetic fields down to a level of ~10 pT will enhance the effects of these interactions. According to theoretical predictions many quantum phases and spin textures will appear in this regime, each of which can be tuned via experimental parameters, allowing us to give new insights into the phenomenology of quantum magnetism.

Stephen Duffus

A Corrected Markovian Master Equation For a SQUID Coupled to a Thermal Bath

The first correction to the Markovian Master Equation of a SQUID Coupled to a thermal bath is presented. Future developments and purpose of work is also outlined, with the aim of being able to derive master equations for a SQUIDs Coupled to engineered environments, such as a two photon absorber.

Umer Farooq

Information Dissipation in Random Quantum Networks

We study the information dynamics in a network of spin-1/2 particles when edges representing XY interactions are randomly added to a disconnected graph accordingly to a probability distribution characterized by a "weighting" parameter. In this way we model dissipation of information initially localized in single or two qubits all over the network. We then show the dependence of this phenomenon from weighting parameter and size of the network.

Jack Ford

Applied quantum electrodynamics: molecular fluorescence and intermolecular excitation transfer

The QED group at U.E.A. specialises in basic research concerning interactions between light and molecules, with particular interest in resonant excitation transfer and multiphoton absorption/emissions. In quantum field theory (with retardation effects built-in) each discrete chromophore locally interacts with the quantised radiation field, not with other chromophores directly. The Hamiltonian operator for all such systems thus consists of exactly three terms – one each for molecules, the radiation state, and interactions. Each interaction Hamiltonian is expressible as the contraction of light's field vectors with a molecular response tensor, and fits into a perturbative expansion describing multiple distinct interactions. The Fermi rule then allows a sum-over-states calculation for the rate of a multi-interaction process. The sum-over-states for any N-interaction process crucially includes a sum over N! interaction event time-orderings. Such calculations reveal detailed effects of molecular position, orientation, and symmetry. Our results are particularly useful in the design of energy transfer systems.

Andrew Goldsborough

Self-assembling tensor networks and holography in disordered spin chains

We show that the numerical strong disorder renormalization group algorithm (SDRG) of Hikihara et al. for the disordered Heisenberg model naturally describes a tree tensor network (TTN) with an irregular structure defined by the strength of the couplings. Using developments from TTNs and the multi-scale entanglement renormalization ansatz (MERA) we can efficiently calculate expectation values and entanglement entropy directly from the tensor network wavefunction. We also analyse the effect of the disordered geometry of the TTN on the two-point correlation functions and entanglement entropy. We show that disorder averaged correlation scales with the average path length through the tensor network, as suggested by Evenbly and Vidal in the context of regular tensor network geometries and that entanglement entropy increases with both disorder and length, resulting in an area-law violation consistent with the results of Refael and Moore.

Kaila Hall

System characterisation under experimental constraints

Characterising properties of quantum many-body systems is a challenging task not only due to the exponential number of parameters but also experimental constraints. We examine two situations in the context of trapped atoms in optical lattices. Firstly, we determine the fidelity of a physical system to a cluster state where cross-talk contaminates local measurements. Secondly we consider the witnessing of entanglement with incomplete measurements and particle loss.

Sahar Hejazi

Ion trapping and Cavity QED

The complementary benefits of trapped ions and photons as carriers of quantum information make it appealing to combine them in a joint system. Ions provide low decoherence rates, long storage times and high readout efficiency, while photons travel over long distances. To interface the quantum states of ions and photons efficiently we use calcium ions coupled to an optical high-finesse cavity via a Raman transition.

For strong ion-cavity coupling, deterministic transfer of quantum states between ions and photons is possible. Each basis state of the ion is linked with one polarization mode of the cavity. Through a partially transparent cavity mirror, a freely propagating photon is generated which can be used to distribute quantum information, for example to entangle distant ions in a network of multiple quantum nodes. For moderate coupling, quantum entanglement may be generated probabilistically. Ions coupled to two orthogonally polarized cavity modes are projected to an entangled state upon detection of photons emitted from the cavity with different polarization. The realization of these schemes requires the development of novel techniques to combine ion traps with miniature optical cavities, as the strength of the ion-photon coupling increases with shrinking cavity mode volume. We are presently testing two different setups, optimized for the different interaction regimes discussed above.

Senaida Hernandez

Local temperature in interacting spin systems

In standard thermodynamics, temperature is an intensive quantity: the state of a subsystem of a big system in a thermal state at temperature T also corresponds to a thermal state at the same temperature. The intensive behaviour of temperature however does not necessarily hold for strongly correlated systems. We study whether it is possible to associate an effective thermal state and temperature to subsystems of a big system in a thermal state in quantum systems of interacting spin-1/2 particles. We study the effect of correlations and criticality in the definition of this effective thermal state and discuss the possible implications for the classical simulation of thermal quantum systems.

Katarzyna Krzyzanowska

Testing the computational power of discord

Entanglement and purity are often considered a fundamental feature of quantum systems to enable quantum computation. There has been a huge progress in the experimental demonstration of architectures that could implement quantum algorithms based on these resources. However, the scalability of these systems still remains an unsolved issue. Deterministic quantum computations with one clean qubit (DQC1) is a protocol based on mixed states , which requires only one coherent qubit. Although DQC1 does not provide universal computation, it can offer speed up for specific large scale compuatational tasks, because its power scales up with a number of qubits in mixed states. We present an experimental setup that will test the DQC1 protocol using cold Rubidium atoms and electromagnetically inducted transparency (EIT) to perform controlled-Raman rotations.

Samanta Piano

Theory of Genuine Tripartite Nonlocality of Gaussian States

We investigate the genuine multipartite nonlocality of three-mode Gaussian states of continuous variable systems. For pure states, we present a simplified procedure to obtain the maximum violation of the Svetlichny inequality based on displaced parity measurements, and we analyze its interplay with genuine tripartite entanglement measured via Rényi-2 entropy. The maximum Svetlichny violation admits tight upper and lower bounds at fixed tripartite entanglement. For mixed states, no violation is possible when the purity falls below 0.86. We also explore a set of recently derived weaker inequalities for three-way nonlocality, finding violations for all tested pure states. Our results provide a strong signature for the non-classical and nonlocal nature of Gaussian states despite their positive Wigner function, and lead to precise recipes for its experimental verification.

Matthew Power

Stability properties of quantum correlations in the Cluster-Ising model

We study the thermodynamic properties of the phase transition from a cluster state to an Ising state for a closed chain characterised by the Cluster-Ising model [1]. We examine the global discord and classical correlations in the ground and excited states. We obtain analytical results in the extreme limit of zero Ising interaction or zero cluster term. Mutual information and global discord are examined numerically in the ground state and we show that global discord can pick up the transition to an Ising state. Stability of these correlations to thermal fluctuations is examined and we find evidence that topological protection plays an important role in the persistence of correlations. Finally, we perform a comparison with other well known measures of quantumness, namely the bipartite entanglement and geometric entanglement.

[1] W. Son et al., Europhys. Lett. vol. 95, 50001 (2011)

Dominik Safranek

Quantum parameter estimation with imperfect reference frames

Quantum metrology studies limit of precision of estimating parameter of interest. However, in this framework a shared reference frame is usually assumed. We study the effects of not having a shared reference frame on the precision of estimation, where the ultimate bound is given by quantity called Quantum Fisher Information(QFI). To do that, we derive how QFI changes under a projective noise. I present easy-to-interpret formula for pure initial state together with equivalence conditions for two extreme cases, case where the noise does not affect the precision of measuring the parameter and the case where the parameter of interest can no longer be estimated.

Whei Yep Suen

Quantum Epsilon Machine of 1D Ising Model

Mathematical models have allowed us to simulate stochastic processes by generating future predictions from past information. However, even with the optimal classical model, there is a wastage of information. In other words, we are storing much more information than what is relevant. Here, in the study of the one-dimensional Ising model, we show that, by storing information in quantum states, we are able to construct a quantum model that is much more efficient and intuitive in capturing the structure of the system.

Ryan Sweke

Simulation of Single-Qubit Open Quantum Systems

One of the primary motivations for the development of quantum computation is the possibility of efficiently simulating quantum systems. The natural first step towards this vision is the simulation of closed quantum systems, undergoing Hamiltonian generated evolution, and over the past two decades consistent progress has been made in this field. However, equally as interesting is the simulation of open quantum systems and in this talk I will present an explicit algorithm for the efficient simulation of Markovian dynamics of single-qubit open quantum systems, within the traditional circuit model of quantum computation. In order to present this result I plan to briefly survey some previous results and techniques, from both Hamiltonian simulation and the simulation of open quantum systems. It will also be neccessary to review elements of the theory of open quantum systems, in particular the representations and geometric properties of quantum channels.

Mathew Williams

Challenging issues in the information content of quantised light and vortices

Optical vortices, beams endowed with Orbital Angular Momentum (OAM), offer an avenue to increase and hopefully maximise data transfer rates when compared with current technologies lacking an OAM character. The greater content of information in quanta of light is accommodated by an increase in the degrees of freedom; Laguerre-Gaussian is one distribution readily applied, offering two further parameters in addition to the standard two, wave vector and polarisation, of the beam. However, several challenges are faced when attempting to exploit the maximum information that can be conveyed in a quantum of light and will be detailed in this poster. Current techniques for generating OAM light relies on wavefront modification of a pre-existing beam by a suitably chosen optical element, which imposes a helical progression in phase around the singular axis; although, more recent theory has now conceived a mechanism for the direct emission of such structured light.

Benjamin Yadin

New criteria for macroscopic quantum states

Macroscopic quantum states are being sought in experiments, partly as a test of the limits of the validity of quantum mechanics and as a way to probe the emergence of classical physics. There have recently been a number of theoretical attempts to characterise such states by defining an effective size to describe the extent to which the quantum behaviour of a system extends to the macroscopic scale. We ask whether some of the existing proposed measures for systems of qubits should and can be extended to classify a larger set of states (including cluster states) as macroscopic. Answering this question may help improve the understanding of which operations can increase or decrease the quantum macroscopicity of a system.