Dana Anderson
Cold Quanta
"Triple-Well Atomtronic Transistor Below 100 nK: Theory and Experiments"

Abstract.
A triple-well atomtronic transistor consist of a narrow gate well sandwiched by a source well and a drain well with a pair of potential barriers defining the gate region. There are two characteristic energy scales to consider in a dynamical analysis of the transistor: one is the characteristic energy level spacing of the bound states of the gate, the other is the characteristic energy width of the barriers for which reflection from and transmission through the gate are non-classical. The first is set by the separation of the barriers and the second is set by the width of the barriers. One expects quantum effects to play a strong role in transistor dynamics when the thermal energy of the atoms in the source well is on the order of or below these characteristic energies. In our experimental system this corresponds to atomic temperatures in the range of 100 nK and less. In past work we studied the transistor behavior at comparatively higher temperatures utilizing gate barrier heights that were much greater than the atomic thermal energy and chemical potential. At low atomic temperatures there would not be sufficient flux to enable observation of the transistor current. To study the dynamics of the transistor in the very low temperature regime, we utilize a painted potential to impose a large potential bias at the source. In these conditions one might expect that the gate well would act much like a Fabry-Perot cavity, allowing only a narrow band of atomic energies to be transmitted into the drain. This is not what we observe. First, as also observed at higher temperatures, atoms Bose condense in the gate despite the fact that the gate is initially empty, and that the entering atom energy is very high compared to the gate ground state energy. Second, our theoretical treatment assumes that the condensate can be excited, corresponding to simple dipole oscillation. In such a case, the oscillating dipole causes coupling between the two highest bound states. This coupling, in turn, leads to substantially broadening of the atomic energies that can enter the gate and subsequently exit into the drain. In other words, the current that flows from the source to the drain is much higher than one might otherwise expect. We observe the time-dependence of the source temperature: starting with empty gate and drain wells the source temperature shows a rapid rise during the formation of the gate condensate, followed by a rapid fall as the gate approaches a steady-state population and the energetic source atoms escape into the drain and allow the source to evaporatively cool. We compare the atom current in the transistor with the same structure having a single barrier (i.e., no source-gate barrier and therefore no gate.) The atom current is notably different in the two cases: We argue that the transistor flux exhibits quantum-mechanical coherence.

Natan Andrei
Rutgers University, USA

" Quantum Work of an Optical Lattice"

Abstract.
The typical quench experiment consists of a cold atomic gas suddenly released from an optical lattice. The local properties of the quench dyamics have been extensively studied however the global properties of this non-equilibrium quantum systems have received far less attention. Here we study several aspects of global non-equilibrium behavior by calculating the amount of work done by the quench as measured through the work distribution function. Using Bethe Ansatz techniques we determine the Loschmidt echo and work distribution function of a gas of bosons initially held in a deep periodic lattice and subsequently 1. completely released 2. the barriers

a lowered. We find the average work and its universal edge exponents and determine the long time decay of the Loshcmidt echo and highlight striking differences caused by the the interactions as well as changes in the geometry of the system. We extend our calculation to the attractive regime of the interacting bosons. Finally we examine the prominent role played by bound states in the work distribution and show that, with low probability, they allow for work to be extracted from the quench.

Aidan Arnold
Department of Physics, University of Strathclyde (UK).

"Enhanced optical geometries for atomic manipulation"

Abstract.
Spatial light modulators (SLMs), acousto-optic modulators and Fresnel zone plates (FZPs) enable the realisation of exquisite smooth optical dipole potentials for ultracold atomic samples. I will review and contrast work in this area, and discuss new results with high-purity Laguerre Gauss modes and a hybrid technique to combine the advantages of SLMs and FZPs for simple atomic circuits.

Mark Baker
Australia

"BEC superfluid dynamics in versatile optical potential"

Abstract.
In the past years, we have developed two experimental apparatus to study ^{87}Rb BEC confined in a variety of geometries derived from versatile optical potentials. In this talk I will discuss recent experimental progress with these two systems, developing and studying atomtronic circuits and applications.

The first of these systems utilises time-averaged "painted" optical potentials, generating large, smooth ring geometries for BEC [1]. To date, most studies of superfluid behaviour in condensates has focused on single component systems. A natural extension is to study BEC of multi-component spin states. The internal degrees of freedom allows us to explore the superfluid behaviour of BEC spin mixtures, of various miscibility, in this geometry. We present here preliminary results with this system, where we explore the link between classical and quantized rotation using two immiscible condensate components [2].

The second experimental apparatus uses structured light fields projected from a digital micromirror device, which gives near sub-micron control over the BEC potential landscape [3]. Our recent efforts have focused on realising a high-tunable "dumbbell" superfluid oscillator circuit. For low currents, the quantitative model we have developed accurately describes the superfluid system in terms of an acoustic model based on Helmholtz resonators [4]. At high currents, this regime breaks down, and we observe turbulent shedding of vortices and density waves. The circuit resistance under such conditions is consistent with a phase slip model, which we test over a wide parameter range.

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[3] G. Gauthier, et al, Optica 3, 1136–1143 (2016)

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Denis Basko
LMMC, Grenoble

“Coherent quantum phase slips in spatially inhomogeneous Josephson junction chains”

Abstract.
We study coherent quantum phase slips in a Josephson junction chain whose parameters may vary from junction to junction. We consider a modulation which is periodic in space [1] as well as a random spatial variation [2]. In the random case we include two types of quenched disorder: random spatial modulation of the junction areas and random induced background charges. Usually, the quantum phase-slip amplitude is sensitive to the normal-mode structure of superconducting phase oscillations in the chain (Mooij-Schön modes, which are all localized by the area disorder). However, we show that the modes' contribution to the disorder-induced phase-slip action fluctuations is small, and the fluctuations of the action on different junctions are mainly determined by the local junction parameters. We study the statistics of the total quantum phase-slip amplitude on the chain and show that it can be non-Gaussian if the chain is not sufficiently long.

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Victor Bastidas
NTT, Japan

"Quantum simulation with superconducting qubits: localization and thermalization in periodically-driven systems"

Abstract.
The interplay between disorder and interactions in nonequilibrium systems leads to counter-intuitive behaviors such as the suppression of thermalization and diffusive transport [1]. Localized systems are able to preserve quantum superpositions for long time, which has potential applications to construct efficient quantum memories for quantum information processing. There is an enormous interest on the theoretical and experimental investigation of localization in isolated manybody systems. However, little is known about localization properties of interacting particles under the effect of periodic driving [2]. In this talk, I will discuss localization properties of interacting photons in arrays of superconducting qubits under the effect of disorder and periodic driving[3]. Among the zoo of Noisy Intermediate-Scale Quantum (NISQ) devices, superconducting qubits is one of the setups that offer the most promising near-term applications ranging from material science to quantum simulation of exotic phases [4]. I will describe how to combine tools from complex networks and Floquet theory in order to unveil the dynamics of many-body systems in nonequilibrium conditions. At the end of my talk, I will discuss in detail possible experimental realizations of the discussed ideas in existing superconducting qubits chips [4].

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Ashton Bradley
Centre for Quantum Science, University of Otago, New Zealand

"Giant vortex clusters in a quantum fluid"

Abstract.
Atomic Bose-Einstein condensates (BECs) provide a uniquely controllable setting in which to study quantum fluid dynamics. In a stirred superfluid, quantized vortices typically proliferate, injecting linear and angular momentum into the fluid. In 1949, while studying the point-vortex model, Onsager predicted that confinement of quantum vortices can produce a surprising result: the possibility of vortices reaching negative temperatures. Negative temperature states contain significant energy, forming a collective storm of vortices circulating in the same direction: a giant vortex cluster. Vortex cluster states are the quantum analogue of the Great Red Spot, visible on the surface of Jupiter as a manifestation of classical fluid turbulence. I will describe our work on the theory of giant vortex clusters, and joint work with the BEC group at the University of Queensland to observe them for the first time in a quantum gas controlled by a digital micromirror device. Despite expectations that such high energy states should be unstable, we observe giant quantum vortex clusters with very long lifetimes. Our work confirms Onsager's prediction after some 70 years, and opens the door to a new regime for quantum vortex matter at negative absolute temperatures, with implications for quantum turbulence, helium films, nonlinear optical materials, and fermi superfluids.

Jean-Philippe Brantut
EPFL, CH

“Interacting Fermi gas in a high-finesse cavity and applications to atomic transport”

Abstract
Light matter coupling is the main tool for extracting information on quantum gases. Dynamical measurements call naturally for continuous diagnostic methods, which can in principle achieved in a weakly destructive fashion using high finesse cavities. We are setting up an experimental setup featuring strongly interacting Fermions produced within a high finesse cavity. I will present the experimental progresses and develop the perspectives opened by such a system for the continuous, quantum limited measurement of atomic currents in mesoscopic structures.

Donatella Cassettari
St. Andrews, UK

"Holographically-generated optical traps for ultracold atoms"

Abstract

The development of new laser-beam shaping methods is important in a variety of fields within optics, atomic physics and biophotonics. Spatial light modulators offer a highly versatile method of time-dependent beam shaping, based on imprinting a phase profile onto an incident laser beam which then determines the intensity in the far field, where the atoms are trapped. The calculation of the required phase is a well-known inverse problem, which can be tackled with different approaches. Our method based on conjugate gradient minimisation [1] not only allows the calculation of smooth and accurate intensity profiles suitable for trapping cold atoms, but can also be used to generate multi-wavelength traps [2] and for simultaneous control over both the intensity and the phase of the light [3], with exceptionally high reconstruction fidelity. Here we describe our experimental progress of trapping ultracold atoms in arbitrary SLM-generated traps. In this experiment, we demonstrate two reservoirs connected by a channel, a guide interrupted by a junction, and a cross shape with a junction at the centre. The width of the junctions in these light patterns is determined by the diffraction limit of our optics. The cross pattern has a possible future application to the simulation of the topological Kondo effect with ultracold atoms [4].

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Frederic Chevy
Ecole normale supérieure, LKB, Paris

"The 2N+1 body problem: an impurity immersed in a superfluid of spin 1/2 fermions"

Abstract.
In my talk I will discuss some properties of an impurity immersed in a fermionic superfluid, a problem that generalizes the Fermi-polaron model that was studied extensively in the context of spin-imbalanced superfluid. I will present experimental and theoretical results on the lifetime and the energy of the impurity and I will highlight the role of three-body physics in the phase diagram of the system.

Charles Clark
Joint Quantum Institute, USA

"Vortex lattices of light and neutrons"

Abstract
Spin-orbit coupling of light has come to the fore in nano – optics and plasmonics and is a key ingredient of topological photonics and chiral quantum optics. We demonstrate some basic tools for incorporating analogous effects into neutron optics: the generation and detection of neutron beams with coupled spin and orbital angular momentum. [1–6] We use 3He neutron spin-filters in conjunction with specifically oriented triangular coils to prepare neutron beams with lattices of spin-orbit correlations, as demonstrated by their spin- dependent intensity profiles. These correlations can be tailored to specific applications, such as neutron studies of topological materials.

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R. Citro
Università di Salerno, Italy

"Phase diagram of boson ladders in the presence of artificial gauge fields"

Abstract
We consider a two leg bosonic ladder in a U(1) gauge field with both interleg hopping and interleg repulsion. As a function of the flux, a Meissner to a Vortex phase transition takes place which is replaced by a charge density wave phase at finite interleg interaction. A disorder point is also found after which the correlation functions develop a damped sinusoid behavior signaling a melting of the vortex phase. We discuss the differences on the phase diagram for attractive and repulsive interleg interaction. In particular, we show how repulsion favors the Meissner phase at low flux and a phase with a second incommensuration in the correlation functions for intermediate flux, leading to a richer phase diagram. The effect of the temperature on the chiral current is also discussed.

R. Dumke
CQT, Singapore

"Atomtronics and Beyond".

Abstract
The field of Atomtronics has progressed significantly over the last few years, fuelled by the experimental developments and supported by the advances in theory. This presentation will discuss the generation of novel trapping structures for atomtronic circuits based on optically tailored vortex distributions on a type II superconducting thin film chip. Furthermore novel developments to hybridize superconducting circuits with ultra-cold atomic systems in an mK environment will be reviewed. In this type of experimental setup trapping lifetimes of ultra cold atoms up to 10 minutes can be achieved. This long lifetime gives us access to employ the ultracold atoms as an extremely sensitive probe for detecting static and fluctuating electric and magnetic fields.

Richard Deblock
Université Paris Sud, France

Revealing topological transport in bismuth with mesoscopic interferences

Abstract
The protection against backscattering provided by topology is a striking property. In two-dimensional insulators, a consequence of this topological protection is the ballistic nature of the one-dimensional helical edge states. One demonstration of ballisticity is the quantized Hall conductance. Here we provide another demonstration of ballistic transport, in the way the edge states carry a supercurrent. The system we have investigated is a micrometer-long monocrystalline bismuth nanowire with topological surfaces, that we connect to two superconducting electrodes. We have measured the relation between the Josephson current flowing through the nanowire and the superconducting phase difference at its ends, the current–phase relation. The sharp sawtooth-shaped phase-modulated current–phase relation we find demonstrates that transport occurs selectively along two ballistic edges of the nanowire. It was also predicted that low temperature ac susceptibility measurements could reveal the topological protection of these edge states by probing their low energy Andreev spectrum at finite frequency. We have performed such a microwave probing of a phase-biased Josephson junction built around a bismuth nanowire. We find absorption peaks at the Andreev level crossings, whose temperature and frequency dependencies point to protected topological crossings with an accuracy limited by the electronic temperature of our experiment.

Mark Edwards
Georgia South. Univ/ Joint Quantum Institute, USA

"Producing smooth flow in "racetrack" atom circuits by stirring at zero and non-zero temperature"

Abstract.
We have studied the production of smooth flow in atom circuits where initially a Bose Einstein condensate (BEC) is formed at finite temperature. The BEC is assumed to be strongly confined to a horizontal plane and, within this plane, subjected to a two-dimensional "racetrack" potential. The racetrack potential consists of two straight parallel channels connected on both ends by semicircular channels of the same width and energy height as the straightaways. The zero-temperature behavior of the system is simulated using the Gross-Pitaevskii equation and at non-zero temperature by the Zaremba-Nikuni-Griffin model. The system is stirred with a rectangular barrier that moves along the channel. We conducted simulations of stirring racetrack BECs for a range of different racetrack geometries, barrier speeds and maximum energy heights both at zero and non-zero temperatures. We also investigated the mechanism for producing flow in order to be able to predict the amount of flow and its onset using a 1D model. We will present the results of the simulations and also discuss the effect of temperature on the amount of flow produced.

Ron Folman
Ben-Gurion University of the Negev, Israel.

“Interferometry on the atom chip”

Abstract.
Matter-wave interferometry provides an excellent tool for probing the environment and studying its coupling to isolated atoms. We present several interferometry experiments done with a BEC on an atom chip [1] and in which different effects of the environment have been investigated. First, we discuss fluctuations in the nearby environment probed by an interference of atoms trapped in a magnetic lattice very close (5µm) to a room temperature surface [2,3]. Here an order-of-magnitude improvement has been obtained over previous atom-surface distances for which spatial interference has been observed. Next, we present a new interferometry of self-interfering clocks and show, in a proof-of-principle experiment, how it could probe the interplay of QM and GR [4]. We also describe a rule for "clock complementarity", which we deduce theoretically and verify experimentally [5]. Finally, we discuss Stern-Gerlach interferometry [6] and describe it in the context of time irreversibility [7]. We analyze this Stern-Gerlach configuration, which is perhaps the first to follow the originally envisioned experiment with static magnetic gradients, in the context of previous theoretical work relating the difficulties in realizing Stern-Gerlach interferometry to time irreversibility. If time will allow, we will also describe results from a novel T^3 interferometer, and present a new design for a Sagnac interferometer.

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[7] Y. Margalit et al., "Realization of a complete Stern-Gerlach interferometer", https://arxiv.org/abs/1801.02708.

Jozsef Fortagh
University of Tübingen

"Atoms in a coplanar superconducting microwave cavity"

Abstract.
In this talk, I will reportabout experiments with ultracold rubidium atoms trapped on a surpeconducting atom chip. I present recent results on Rydberg excitation of atoms near a superconducting co-planar microwave cavity and the coupling of Rydberg state pairs to the microwave field of the cavity. I am going to discuss the possibility of long range atomic interactions and quantum gate operations mediated by a microwave cavity in a thermal state.

Simon Gardiner
Durham University, UK

"Characterising Optical Lattice Depths with Simple Atomic Dynamics"

Abstract.
Precise knowledge of optical lattice depths is important for a number of areas of atomic physics and atomtronics, most notably in quantum simulation, atom interferometry and for the accurate determination of transition matrix elements. We present analytic models for the time evolution of the atomic populations of the lowest momentum-states, in both pulsed [1] and continuous [2] optical lattice induced atomic diffraction scenarios, sufficient for a "weak" lattice, as well as numerical simulations incorporating higher momentum states for both relatively strong and weak lattices, considering also the role of different temperatures.

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Barry Garraway
University of Sussex, UK

“Dressing ultra-cold atoms for circuits, shells and lattices”

Abstract
Dressing atoms with radio-frequency and microwave radiation can produce a variety of different types of atom trap [1,2]. This is because of the flexibility inherent in the vector coupling of a magnetic dipole moment to electromagnetic fields: these fields can be varied in time, frequency, orientation and space. In this talk we will introduce the concept of the dressed atom, and present applications to circuits (loops and ring traps), shell traps, and lattices with controllable lattice sites. Recent work has quantified atomic losses [3] and also shown how dressing with multiple fields can be used for fine-tuning [4].

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David Guery-Odelin
University Paul Sabatier (Toulouse)

"Strong time-modulation of an optical lattice: from cooling in reciprocal space to chaos assisted tunneling"

Abstract.
In this talk, we propose to address three topics that we have recently investigated with our BEC experiment using time-dependent optical lattices:
1) We have studied the kinetics of the quantum transition to staggered states for phase-modulated lattice. Our data once combined with numerics enables us to identify quantum fluctuations as the triggering mechanism for spontaneous four-wave mixing.
2) Using standard lattice depth, and an amplitude modulation of the lattice whose frequency is sweep appropriately, we transpose the idea of evaporative cooling in momentum space. This new method enables one to cool directly a sample of atoms in a lattice.

3) Using deep and strongly modulated optical lattice, we have generated a classically mixed phase space. We report here new results where the diffraction pattern of our BEC initially placed at different positions in phase space enables us to reconstruct the classical phase space. We also observe the quantum tunneling between the two stable islands and its strong variations depending on the system parameters. The detailed analysis of the tunneling curve also reveals the intermediate states that mediates the transport between islands.
The two last topics provide new tools for quantum simulation in general and atomtronics in particular.

Tobias Haug
Centre for quantum technologies, Singapore

"Topological pumping in atomtronic circuits"

Abstract
Topological Thouless pumping and Aharonov-Bohm effect are both fundamental effects enabled by the topological properties of the system. Here, we study both effects together: topological pumping of interacting particles through Aharonov-Bohm rings. This system can prepare highly entangled many-particle states, transport them with topological protection and interfere them, revealing a fractional flux quantum. The type of the generated state is revealed by non-trivial Aharonov-Bohm interference patterns that could be used for quantum sensing. The reflections induced by the interference result from transitions between topological bands. Other types of states can be robustly transported with a band gap scaling as the square-root of the particle number. Our system paves a new way for a combined system of state preparation and topological protected transport.

Jordi Mompart
Universitat Autònoma de Barcelona, Spain

"*Ultracold atoms with orbital angular momentum: a single ring for quantum sensing and a lattice of rings for quantum simulation****"***

Abstract
On the one hand, overcoming the current limits of sensing technologies is one of the main challenges of modern physics, opening the door to high-precision measurements of fundamental constants, as well as to applications in many different areas of science. On the other hand, since the observation of the Quantum Hall effect in two-dimensional electron gases and the discovery of its relationship to topology, the study of systems with non-trivial topological properties has become a central topic in condensed matter physics. In this talk, we will show that ultra-cold atoms with orbital angular momentum (OAM) constitute a promising platform for exploring both scenarios. With respect to quantum sensing, we propose a novel device to measure with high precision non-linear interactions, scalar magnetic fields and rotations [1]. It consists of an imbalanced superposition of the OAM modes of a Bose-Einstein condensate (BEC) in a ring trap with opposite winding numbers, for which a line of minimum atomic density appears. A weak two-body interaction between the atoms of the BEC leads to a rotation of the line of minimum atomic density whose angular frequency is directly related to the strength of such interactions. We derive an analytical expression that relates the angular rotation frequency of the minimum density line with the strength of non-linear atomic-atomic interactions and the difference between the populations of the counter-propagating modes. In addition, we propose a complete experimental protocol based on direct fluorescence imaging

of the BEC that allows to measure all the quantities involved in the analytical model and to use the system for detection purposes. With respect to quantum simulation and topology, we study the single-particle properties of a system formed by ultracold atoms loaded into the manifold of l=1 OAM states of an optical lattice with a diamond chain geometry [2,3]. Through a series of successive basis rotations, we demonstrate that the OAM degree of freedom induces phases in some tunneling amplitudes of the tight-binding model that are equivalent to a net π flux through the plaquettes and result in a topologically non-trivial band structure and protected edge states. In addition, we show that quantum interferences between the different tunneling processes involved in the dynamics may lead to Aharanov-Bohm caging in the system. All these analytical results are confirmed by exact diagonalization numerical calculations.

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Martin Lebrat
ETH Zürich

“Beyond particle transport at an atomic quantum point contact: thermoelectric effects and spin control”

Abstract.
In this talk, we report on a few remarkable transport properties of lithium-6 atoms through a quantum point contact (QPC) precisely defined by a set of optical potentials. The versatility of cold-atom techniques allows us to directly measure heat or spin currents and to tune interatomic interactions. In a first experiment performed with a unitary Fermi gas close to the superfluid transition, we probe the thermoelectric effects induced by a temperature difference accross the QPC. We show that the system evolves towards a non-equilibrium steady state, associated with a reduced heat diffusion and a strong violation of the Wiedemann-Franz law. In a second experiment performed with weakly interacting atoms, we locally lift the spin degeneracy of atoms inside the QPC using an optical tweezer tuned very close to atomic resonance. We observe quantized, spin-polarized transport that is robust to dissipation and sensitive to interaction effects on the scale of the Fermi length. These results open the way to the quantum simulation of efficient thermoelectric and spintronic devices with cold atoms.

Wenhui Li
Centre for quantum technologies, Singapore.

"Electromagnetically induced transparency in an interacting Rydberg gas"

Abstract:
In this talk, I will first briefly review current research activities in Rydberg physics. I will then present our experimental efforts in studying interacting Rydberg gases, especially with electromagnetically induced transparency, and some of our future plans. With this, I hope to

invite ideas and discussion on how to implement the concept of Atomtronics in the system of Rydberg atoms.

Oliver Morsch
INO-CNR, Italy

“Experimental studies of percolation phenomena in driven-dissipative Rydberg gases”

Abstract:
In my talk I will review our recent experiments on strongly driven dissipative Rydberg gases. Combining the facilitation mechanism (i.e., off-resonant conditional excitation of a Rydberg atom in the presence of another Rydberg atom at a well-defined distance) with spontaneous decay, we realized a model for directed percolation. By varying the driving parameters we explored the phase transition between the absorbing (no Rydberg excitations) and the active state of the system. Finally, I will give an outlook on future experiments in which we plan to control dissipation and to study other percolation and transport models.

Piero Naldesi
LPMMC CNRS, France

“Angular momentum fractonalization for atttracting bosons in ring-shaped potentials”

Abstract.
Quantum mechanics is characterized by quantum coherence and entanglement. After having discovered how these fundamental concepts govern the physical reality, scientists have been devoting intense efforts to harness them to shape the future science and technology. This is a highly nontrivial task because most often quantum coherence and entanglement are difficult to access. Here, we present a quantum many-body system in which quantum coherence and entanglement explicitly demonstrate the quantum advantage of quantum technology over the classical one. Our physical system is made of strongly correlated attracting neutral bosons flowing in a ring-shaped potential of mesoscopic size. Quantum analogs of bright solitons are formed in the system by the attractive interactions, and, as a genuine quantum-many-body feature, we demonstrate that an angular momentum fractionalization occurs. As a consequence, the matter-wave current in our system is able to react to very small changes of rotation or other artificial gauge fields. We discuss how our results put the basis to devise rotation sensors and gyroscopes with enhanced sensitivity.

Maxim Olchanyi
University of Massachusetts Boston, USA

“Some Empirical Implementations of the Multi-Dimensional Reflection Groups”

Abstract.
In this presentation, I will review some of our recent successes in finding a three-dimensional empirical room for the abstract multidimensional kaleidoscopes. The latter ensure solvability of the former. The areas of implementation include (a) quantum one-dimensional hard-core particles with nontrivial mass-spectra, on a line, in a box, or in a harmonic potential; (b) a quantum one-dimensional bosonic dimer interacting with a barrier; (c) a field of a static electric charge in a conducting cavity surrounded by four spherical segments. Concrete experimental suggestions include (a) an “entanglement amplifier”, (a’) integrability induced peaks in a

relaxation time vs. mass ratio curve for a binary mass mixture, (b) a novel observable selection rule for some one-dimensional chemical processes and the usage thereof for miniaturization of chip-based atom interferometers, and (c) nineteen three-parametric families of solvable electrostatic problems in piece-wise-spherical cavities with conducting grounded walls.

Axel Perez-Obiol
Kochi University of Technology, Japan

“Repulsive Bose-Einstein condensate on a 1D ring stirred with a rotating Dirac delta"

Abstract.
We consider a repulsive Bose-Einstein condensate in a 1D ring with a Dirac delta rotating at constant speed. The spectrum of stationary solutions is analyzed in terms of the nonlinear coupling, delta velocity, and delta strength, which may take positive and negative values. It is organized into a set of energy levels conforming a multiple swallow tail structure in phase space, consisting in bright solitons, gray and dark solitonic trains, and vortices. We compute the critical velocities and perform a Bogoliubov analysis for the ground state and first few excited levels, establishing possible adiabatic transitions between the states. An adiabatic cycle is proposed in which a gray soliton is obtained from the ground state by setting and unsetting a moving attracting delta.

Helene Perrin
CNRS / Paris 13 University / LPL

"Dynamical ring formed by a superfluid rotating at a supersonic speed"

Abstract.
In this talk I will present recent results concerning the dynamics of a quantum degenerate Bose gas confined in a `bubble-shape' adiabatic potential and rotating at supersonic velocity. The atoms are confined to an ellipsoid surface obtained by dressing atoms in a with a radiofrequency field.
We study the atom dynamics as we introduce a rotation around the vertical, symmetry axis. In the absence of rotation, atoms gather at the bottom of the ellipsoid, and we observe the formation of a very anisotropic oblate Bose-Einstein condensate. At moderate rotation frequencies, a vortex lattice develops in the quantum gas. At higer rotation frequencies, the centrigugal force pushes the atoms away from the symmetry axis and the atoms `climb' on the ellipsoid as a hole forms in the centre of the cloud. We end up with a thin annulus of Bose condensed atoms rotating at a speed ten times larger than the speed of sound in the condensate. We observe the resonant response of this out of equilibrium superfluid to a quadrupolar excitation.

Juan Polo-Gomez
Okinawa Institute of Science and Technology, Japan

"Oscillations and decay of superfluid currents in a one-dimensional Bose gas on a ring"

Abstract.
We study the time evolution of a supercurrent imprinted on a one-dimensional ring of interacting bosons in the presence of a defect created by a localized barrier. Depending on interaction strength and temperature, we identify various dynamical regimes where the current oscillates, is self-trapped or decays with time. We show that the dynamics is captured by a dual Josephson model, and involves phase slips of thermal or quantum nature.

Nick P. Proukakis
Joint Quantum Centre (JQC) Durham-Newcastle and Newcastle University

"Quenched Dynamics in Connected Ring Traps"

Abstract.
Quenching an ultracold bosonic gas in a ring across the BEC phase transition, is known to lead to the spontaneous emergence of persistent currents, which has been seen experimentally and found to be in good agreement with the Kibble-Zurek mechanism. In this talk I examine how this process generalizes to a system of two coupled rings exhibiting a weak, or strong, density coupling at a common interface, delineating key dependencies and addressing optimal regimes for its experimental observation. Based on our findings, we also comment on the potential transfer of winding numbers across two rings, which could be envisaged as a prototypical atomtronic switch.

Andrea Richaud
Politecnico di Torino, Italy

"Formation of supermixed solitons in ultracold boson mixtures loaded in ring lattices"

Abstract.
We investigate the mechanism of formation of supermixed soliton-like states in bosonic binary mixtures loaded in ring lattices. We evidence the presence of a common pathway which, irrespective of the number of lattice sites and upon variation of the interspecies attraction, leads the system from a mixed and delocalized phase to a supermixed and localized one, passing through an intermediate phase where the supermixed soliton progressively emerges. The degrees of mixing, localization and quantum correlation of the two condensed species, quantified by means of suitable indicators commonly used in Statistical Thermodynamics and Quantum Information Theory, allow one to reconstruct a bi-dimensional mixing-supermixing phase diagram featuring two characteristic critical lines. Our analysis is developed both within a semiclassical approach capable of capturing the essential features of the two-step mixing-demixing transition and with a fully-quantum approach

Matteo Rizzi
J Universität zu Köln / Forschungszentrum Jülich

"Flat band systems"

Abstract.
Geometric and gauge constraints can lead to perfectly flat single-particle dispersion relation in a lattice, in particular through so-called Aharonov-Bohm caging. Once interactions are turned on, a wealth of interesting phenomena can arise. Here we examine two of them in one-dimensional (1D) systems, namely (a) fractional topological phases and (b) exotic transport properties:

(a) We show that a hierarchy of symmetry-protected topological (SPT) phases at filling $1/(r+2)$ can emerge for fermions in presence of interactions within the first r neighbouring sites, once the single-particle band structure describes a (crystalline) topological insulator. In sharp contrast to the non-interacting limit, however, these topological density waves do not follow the boundary-edge correspondence, as their edge modes are gapped.
Ref.: S. Barbarino, D. Rossini, M. Rizzi, R. Fazio, G.E. Santoro, and M. Dalmonte, New J Phys. 21, 043048 (2019)

(b) We explore the bosonic phase diagram of a chain of rhombi subject to a magnetic flux and local repulsion: Besides the more conventional Mott-insulator and superfluid (Luttinger liquid) phases, a pair-superfluid (pair-Luttinger liquid) phase emerges there. We find however that such exotic phase is very sensitive to changes away from perfect frustration (half-flux), and provide some suggestions to make it more resilient. We also study the bipartite entanglement properties of the chain: While having the same central charge, the two gapless phases display a fundamental difference in the properties of the low-lying entanglement spectrum levels.
Ref.: C. Cartwright, G. De Chiara, and M. Rizzi, Phys. Rev. B 98, 184508 (2018)

Halina Rubinsztein-Dunlop
The University of Queensland, Australia

"Quantum Atom Optics with Sculpted Light"

Abstract.
Spatial light modulators (SLM) or Digital Micromirror Devices (DMD) give us a great flexibility in sculpting light. What is means is that we have perfect tools that can be used for production of configurable and flexible confining potentials and utilise them to confine atoms as well as lager scale objects and conduct novel experiments outlining light –matter interation in these systems. In general we divide the techniques that are used to sculpt light to those based on time average methods and those utilising SLMs in either Fourier plane or direct imaging plane. A Gaussian beam can be modulated using two-axis acousto-optic modulator (AOM) to create highly configurable time-averaged traps. SLMs in Fourier plane control the phase and /or amplitude of an input Gaussian beam, with the pattern representing the spatial Fourier transform of the desired amplitude pattern. The optical system then focuses this sculpted light pattern to the plane containing the system of interests, performing a Fourier transform and recovering the desired pattern. The optical system then focuses this sculpted light pattern to the plane containing the system of interests, performing a Fourier transform and recovering the desired pattern. DMD can configure the amplitude of an input beam either in the Fourier plane or in a direct imaging configuration. Sculptured light produced using these methods promises high flexibility and an opportunity for trapping and driving systems ranging from studies of quantum thermodynamics using ultra cold atoms to trapping and manipulating nano and micron-size objects or even making measurements *in-vivo* inside a biological cell.

Raphael Saint-Jalm
Laboratoire Kastler Brossel, Paris

“Scale-invariant dynamics and breathers of an interacting 2D Bose gas”

Abstract.
The dynamics of an interacting many-body system is usually difficult to predict fully, but some of its features can be captured if the system has underlying symmetries such as scale invariance. Here we study the dynamics of a 2D ultracold cloud of ultracold Rubidium atoms in a harmonic potential. Such a system has scale-invariant properties and exhibits an exact SO(2,1) symmetry. We produce an initial cloud strongly out of equilibrium with a uniform density and a tunable shape, and we observe that its dynamics obeys scaling laws according to this symmetry. Moreover, in the Thomas-Fermi limit where the system can be described by hydrodynamic equations, we demonstrate a additional scaling law that applies to the dynamics. We also report on the observation of particular shapes whose evolution is periodic, which we attribute to breathers of the 2D Gross-Pitaevskii equation.

Francesco Scazza
CNR-INO/LENS

"A tunable Josephson junction between BEC-BCS crossover superfluids"

Abstract.
Pristine quantum phenomena, such as the Josephson effects, emerge upon weakly connecting two superfluids or superconductors with one another. At the same time, dissipation plays an important role in many superfluid systems, and it is essential for the operation of superconducting quantum devices. Understanding the interplay between dissipationless and resistive flow in superfluids is a crucial task within the emerging field of atomtronics.
In this talk, I will report on quantum transport experiments performed with atomic BEC-BCS crossover superfluids at LENS. We create the atomic analogue of a Josephson junction by bisecting an elongated superfluid into two weakly connected reservoirs, exploiting a thin and programmable optical barrier.
In a first set of experiments, we have studied the dynamics of the Josephson junction triggered by a variable population imbalance between the two reservoirs. While for small initial biases we observe purely coherent evolutions of both the population imbalance and relative phase, for larger biases a resistive flow is identified [1]. We find phase slippage induced by vortex nucleation to be the dominant microscopic source of such dissipative transport, for interaction strengths throughout the BEC-BCS crossover. In the regime of low phase-slippage rates, when only few excitations are nucleated, Josephson plasma oscillations are restored after a transient resistive current. In the opposite regime of strong dissipation, the junction operation is irreversibly affected by vortex proliferation, that causes the complete loss of coherence between the reservoirs.
In a second set of experiments, we have explored the AC and DC Josephson effects in fermionic crossover superfluids, exploiting the versatility of a new optical setup based on digital micromirror devices (DMD) [2]. By selectively illuminating one superfluid reservoir with a homogeneous non-resonant light pattern, we mimic a constant applied voltage across the junction. In this way, we observe a coherent AC current whose frequency matches the applied energy bias, as expected for the AC Josephson effect. The applied relative energy shift is interferometrically calibrated by measuring the relative phase imprinted by the homogenous light pattern after a variable illumination time.
Finally, we produce a controlled superfluid DC current across the junction by moving the barrier at a constant velocity over small distances. By tracking the relative population imbalance and phase as a function of the current, we extract the critical current of the junction its current-phase relation. We vary the barrier parameters, as well as the gas temperature and interaction

strength across the BEC-BCS crossover, providing a first comprehensive study of the critical Josephson current in atomic Fermi superfluids.

[1] A. Burchianti, F. Scazza, A. Amico, G. Valtolina, J. A. Seman, C. Fort, M. Zaccanti, M. Inguscio, G. Roati. Phys. Rev. Lett. 120, 025302 (2018).
[2] W. Kwon et al., in preparation.

Sandro Stringari
University of Trento

"Non dissipative spin drag and fast dynamic response"

Abstract.
When the phase of one of the two components of a spinor quantum mixture is imprinted by a fast perturbation the motion of the second component is affected by spin drag. The resulting mechanism is driven by the equation of continuity and is the consequence of interaction effects. Explicit examples will be discussed, including the Andreev-Bashkin effect in two interacting Bose superfluids, the case of a normal Fermi liquid and the case of a Rabi coupled Bose-Einstein condensed mixture.

Tian Tian
Institute for Interdisciplinary Information Sciences (Tsinghua University)

“Observation of Dynamical Quantum Phase Transitions in a Spinor Condensate”

Abstract.
A dynamical quantum phase transition can be characterized by a non-analytic change of the quench dynamics when a parameter in the governing Hamiltonian is varied. Such a transition typically only shows up in long-time dynamics for extensive systems with short-range couplings. We analyze a model Hamiltonian of spin-1 particles with effectively infinite-range couplings, and demonstrate that for this system the non-analytic transition occurs for local observables in short-time durations even when the system has a large size. We experimentally realize this model Hamiltonian and observe the dynamical quantum phase transitions in an antiferromagnetic spinor Bose-Einstein condensate of around 10^5 sodium atoms. Our observations agree well with the theoretical prediction. We also analyze the scaling exponent near these dynamical phase transitions and discuss its relation with the excited state spectrum of the system.

Andrea Trombettoni
CNR and SISSA, Trieste, Italy

“Integrable Floquet Hamiltonian for a Periodically Tilted 1D Gas”

Abstract.
After a brief introduction on 1D ultracold gases, I discuss how to implement an integrable Floquet Hamiltonian for a periodically tilted 1D Bose gas. In general, an integrable model subjected to a periodic driving gives rise to a non-integrable Floquet Hamiltonian. Here we

show that the Floquet Hamiltonian of the integrable Lieb--Liniger model in presence of a linear potential with a periodic time--dependent strength is instead integrable and its quasi-energies can be determined using the Bethe ansatz approach. We discuss various aspects of the dynamics of the system at stroboscopic times and we also propose a possible experimental realization of the periodically driven tilting in terms of a shaken rotated ring potential.

Reinhold Walser
TU Darmstadt

"Optimal pulse propagation in an inhomogeneously gas-filled hollow-core fiber"

Abstract.
We study optical pulse propagation through ahollow-core fiber filled with a radially inhomogeneous cloud of cold atoms. A co-propagating control field establishes electromagnetically induced transparency. In analogy to a graded index fiber, the pulse experiences micro-lensing and the transmission spectrum becomes distorted. Based on a two-layer model of the complex index of refraction, we can analytically understand the cause of the aberration, which is corroborated by numerical simulations for a radial Gaussian-shaped function. With these insights, we show that the spectral distortionscan be rectified by choosing an optimal detuning from one-photon resonance.

Wolf von Klitzing
IESL-FORTH (Greece)

"Hypersonic transport of Bose-Einstein condensates in a neutral-atom accelerator ring."

Abstract.
Some of the most sensitive and precise measurements to date are based on matterwave interferometry using freely falling atoms, where atomic waves are split into different paths. Their extreme sensitivity originates from the dependence of the recombination process on minute energy differences in the paths travelled. Examples include ultra-high-precision measurements of inertia[1], gravity[2] and rotation sensing[3]. In order to achieve these very high sensitivities, the interaction time has to be very long, which forces devices to be ten or even one hundred meters high or experiments to be performed in micro gravity on the space station[4–7]. Coherent matterwave guides[8] and atomtronics[9,10] would result in highly compact devices having much extended interaction times and thus much increased sensitivity both for fundamental and practical measurements. In this letter, we demonstrate extremely smooth, coherence-preserving matterwave

guides by moving Bose-Einstein condensates (BEC) over macroscopic distances without affecting their internal coherence: We use a novel magnetic accelerator ring for neutral atoms to accelerate BECs to very high speeds (16x their velocity of sound) and transport them in a matterwave guide for 15 cm whilst preserving their internal coherence. The high angular momentum of more than 40000 $\hbar$ per atom and high velocities give access to the higher Landau levels of quantum Hall states of atoms and open new perspectives in the study of superfluidity. The barriers in the matterwave waveguides can be controlled down to 200 pK giving rise to new regimes of tunnelling and transport through mesoscopic channels[11–13]. Coherent matterwave guides will result in much longer interaction times (here > 4 s) and much increased sensitivity in highly compact devices, thus opening the spectre of compact, portable guided-atom interferometers for fundamental experiments and applications like gravity mapping or navigation.

David Wilkovski
NTU/CQT/Majulab, Singapore

“Non-Abelian geometric transformations in a cold Fermionic strontium gas”

Abstract.
In this talk, I will present some recent work on a laser-cooled gas of Fermionic strontium atoms coupled to laser fields through a 4-level resonant tripod scheme [1]. By cycling the relative phases of the tripod beams, we realize non-Abelian SU(2) geometrical transformations acting on the dark-states of the system and demonstrate their non-Abelian character. We also reveal how the gauge field imprinted on the atoms impact their internal state dynamics. It leads to a new thermometry method based on the interferometric displacement of atoms in the tripod beams. This work open the door toward matter-wave optics using non-Abelian gauge structure.

[1] F. Leroux, K. Pandey, R. Rebhi, F. Chevy, C. Miniatura, B. Gremaud, and D. Wilkowski, Nature Communications 9, 3580 (2018)

Alexander Yakimenko
Taras Shevchenko National University of Kyiv

“Quantum nonlinear effects in coupled persistent currents of ultracold atomic gases"

Abstract.
Considerable progress in experimental studies of atomic gases in a toroidal geometry has opened up novel prospects for the investigation of fundamental properties of superfluid states and creation of new configurations for atomtronic circuits. In particular, atomic Bose-Einstein condensates loaded in a dual-ring trap suggest a possibility to consider the tunneling dynamics between coupled condensates and quantum dynamics of merging superfluid toroidal condensates with *different* angular momenta.

Accordingly, we address the tunneling in a pair of coaxial ring-shaped condensates separated by a horizontal potential barrier. A weak-coupling truncated (finite-mode) Galerkin model and direct numerical simulations of the underlying three-dimensional Gross-Pitaevskii equation are used for the analysis of tunneling superflows driven by an initial imbalance in atomic populations of the rings. The superflows through the Bose-Josephson junction are strongly affected by persistent currents which are present in the rings. Josephson oscillations of the population imbalance and angular momenta in the coupled rings are obtained for co-rotating states and non-rotating ones. On the other hand, the azimuthal structure of the tunneling flow implies formation of Josephson vortices (fluxons) with *zero net current* through the junction for hybrid states, built of *counter-rotating persistent currents* in the coupled rings.
We address merger of two parallel superfluid rings with different angular momenta in a three-dimensional (3D) trap. We observe substantially 3D evolution of quantum vortices, which determines the development of the Kelvin-Helmholz instability at the interface between the rings, in the framework of a single-component weakly dissipative mean-field model. The final state of the condensate crucially depends on an initial population imbalance in the double-ring set. Remarkably, a more populated ring, carrying a persistent current, can drag an initially non-rotating one into the same vortex state.