STA Workshop 2026

15-16 July
University College Cork, Cork, Ireland

Programme

Location: University College Cork, Main Campus, O'Rahilly Building, Room 255

Wednesday, 15 July

9:00 Registration

9:15 Welcome

9:20 – 9:30 **David Rea** (University College Cork):
STA in UCC: Reminiscences of a Senior Collaborator

9:30 – 10:10 **Daniel Alonso Ramírez** (Universidad de La Laguna):
Operational Relation Between One-Time and Two-Time Work Protocols and Measurement-Resolution-Induced Transitions in Quantum Work Statistics

10:10 – 10:50 **Steve Campbell** (University College Dublin):
Quantum control to probe non-equilibrium dynamics

10:50 – 11:30 Coffee break and Photo

11:30 – 12:10 **Anthony Kiely** (University College Cork):
Universally Robust Quantum Control

12:10 – 12:40 **Ankit Shrestha** (University of Luxembourg):
Shortcuts to Adiabaticity for non-Hermitian systems in Krylov Space

12:40 – 14:30 Lunch break

14:30 – 15:00 **Mara Vizzuso** (Università degli Studi di Napoli Federico II):
Nonadiabatic Self-Healing of Trotter Errors in Digitized Counterdiabatic Dynamics

15:00 – 15:30 **Artur Machado Lacerda** (Trinity College Dublin):
Shortcuts to adiabaticity for holonomic gates in cat qubits

15:30 – 16:00 **James Urquhart** (University Sussex):
Benchmarking Microfabricated QCCD Junctions for Fast Transport

16:00 – 16:30 Coffee break

16:30 – 16:50	**Conor Sexton** (University College Cork): *Optimised quantum feedback control protocols: Advantages and limitations*
16:50 – 17:10	**Zhiyu Wang** (University College Cork): *Quantum phase control of Liouvillian-skin-induced quantum Mpemba effect*
19:00	**Social evening in the Franciscan Well Brewpub with pizzas**

Thursday, 16 July

9:30 – 10:10	**Xiaoji Zhou** (Peking University): *Atomic quantum simulator with tunable temperature*
10:10 – 10:50	**Jing Li** (University College Cork): *Quantum control of pistons: From Rabi-coupled Bose-Einstein condensates to Two-Ion device*
10:50- 11:20	**Coffee break**
11:20 – 11:50	**Chris Whitty** (University of the Basque Country): *Smooth time-dependent control of dipolar Bose-Einstein condensates*
11:50 – 12:20	**Ronan McElvogue** (University College Dublin): *Fast and robust quantum state transfer in a 2D multi-domain SSH model*
12:20 – 12:50	**Ruijin Sun** (Northeast Normal University, University College Cork): *Enhanced shortcuts to adiabaticity in an interacting giant atom atomic waveguide system*
12:50 – 14:30	**Lunch break**
14:30 – 15:10	**Andreas Ruschhaupt** (University College Cork): *Enhanced Shortcuts to Adiabaticity*
15:10 – 15:50	**David Guéry-Odelin** (Université de Toulouse): *Applying Control Theory to Quantum Systems* (online talk)
15:50 – 16:00	Good-bye
16:00 - 16:30	**Good-bye Coffee**

Title & Abstract:

Daniel Alonso Ramírez (Universidad de La Laguna):

Operational Relation Between One-Time and Two-Time Work Protocols and Measurement-Resolution-Induced Transitions in Quantum Work Statistics

Abstract: We establish a direct operational link between one-time measurement (OTM) and two-time measurement (TTM) protocols for quantum work statistics, showing that OTM work distributions, including coherence signatures, can be reconstructed from standard TTM data through classical post-processing alone. This demonstrates that coherence information is already encoded in TTM measurements and can be extracted without modifying the experimental setup. For a driven two-level system with finite-resolution energy measurements, we uncover a resolution-induced statistical transition: intermediate measurement resolutions generate non-analytic work distributions with square-root singularities, while projective and weak measurements remain smooth. The critical behavior is governed by experimentally accessible dynamical parameters, which also determine the relative entropy of coherence, enabling coherence quantification using only energy measurements.

Steve Campbell (University College Dublin):

Quantum control to probe non-equilibrium dynamics

Abstract: The rapid development of techniques to coherently manipulate quantum systems has come to the forefront of research as the race to develop useful quantum devices pushes on. The exquisite levels of control over quantum systems has allowed for remarkable advances in diverse areas including the simulation of quantum systems, the realisation of prototype nanoscale devices to test the limits of quantum mechanics, and it continues to push the state-of-the-art in NISQ devices. However, beyond the clear practical relevance, quantum control also provides a uniquely insightful window into understanding the underlying physics of a given system. Following this ethos, it can be demonstrated that assessing control and controllability provides a remarkably versatile tool to probe and characterise quantum systems, e.g. by providing a means to understand fundamental bounds on their evolution as dictated by the quantum speed limit, to explore the dynamical response of a system extending beyond the adiabatic theorem, and to probe the controllability of a complex system.

Anthony Kiely (University College Cork):

Universally Robust Quantum Control

Abstract: We study the robustness of the evolution of a quantum system against small uncontrolled variations in parameters in the Hamiltonian. We show that the fidelity susceptibility, which quantifies the perturbative error to leading order, can be expressed in superoperator form and use this to derive control pulses which are robust to any class of systematic unknown errors. The proposed optimal control protocol is equivalent to searching for a sequence of unitaries that mimics the first-order moments of the Haar distribution, i.e. it constitutes a 1-design. We highlight the power of our results for error resistant single- and two-qubit gates.

Reference: Phys. Rev. Lett. 132, 193801 (2024)

Ankit Shrestha (University of Luxembourg):

Shortcuts to Adiabaticity for non-Hermitian systems in Krylov Space

Abstract: Adiabatic Gauge Potential (AGP) in its native form remains hard to compute in general many-body systems as it requires exact diagonalization at each parameter value. In this talk, I will present a general, diagonalization-free framework to engineer STA in non-Hermitian systems by representing the AGP in Krylov Space. I will recast the AGP for weak non-Hermitian systems as an infinite series and use the Krylov basis generated using biLanczos and Arnoldi algorithms for effective truncation. I will demonstrate the efficiency of the truncation in various models including Hatano-Nelson model, PT symmetric Heisenberg chain, and non-Hermitian Transverse Field Ising Model.

Mara Vizzuso (Università degli Studi di Napoli Federico II):

Nonadiabatic Self-Healing of Trotter Errors in Digitized Counterdiabatic Dynamics

Abstract: Trotter errors in digitized quantum dynamics arise from approximating time-ordered evolution under noncommuting Hamiltonian terms with a product formula. In the adiabatic regime, such errors are known to exhibit long-time self-healing [Phys. Rev. Lett. 131, 060602 (2023)], where discretization effects are effectively suppressed. Here we show that self-healing persists at finite evolution times once nonadiabatic errors induced by finite-speed ramps are compensated. Using counterdiabatic driving to cancel diabatic transitions and isolate discretization effects, we study both noninteracting and interacting spin models and characterize the finite-time scaling with the Trotter steps and the total evolution time. In the instantaneous eigenbasis of the driven (gapped) Hamiltonian, the leading digital error maps to an effective harmonic perturbation whose dominant Fourier component yields an analytic upper bound on the

finite-time Trotter error and reveals the phase-cancellation mechanism underlying self-healing. Our results establish finite-time self-healing as a generic feature of digitized counterdiabatic protocols, clarify its mechanism beyond the long-time adiabatic limit, and provide practical guidance for high-fidelity state preparation on gate-based quantum processors.

Artur Machado Lacerda (Trinity College Dublin):

Shortcuts to adiabaticity for holonomic gates in cat qubits

The formulation of shortcuts to adiabaticity in open quantum systems remains less developed than in the unitary setting. A central difficulty is that the open-system analogue of the adiabatic gauge potential, which becomes a superoperator, need not generate valid completely positive trace-preserving dynamics. I will discuss an important exception: when the instantaneous steady-state manifold forms a decoherence-free subspace, the counterdiabatic generator reduces to unitary evolution, given by the adjoint action of the Kato Hamiltonian.

Cat qubit architectures are a promising route toward fault-tolerant quantum computation, and in their standard formulation the degenerate steady-state manifold is spanned by coherent states that form a decoherence-free subspace. This makes cat qubits a natural setting for formalism. I will describe how the Kato-Hamiltonian framework can be used to accelerate holonomic gates, whose implementation conventionally relies on adiabatic protocols.

James Urquhart (University Sussex):

Benchmarking Microfabricated QCCD Junctions for Fast Transport

Abstract: One approach for developing a quantum computer is a controllable array of electrodes (QCCD) on a microchip, capable of transporting trapped ions between different zones. To make the array 2-dimensional, junctions between linear zones need to be integrated, additionally allowing all-to-all connectivity. It is important for transport operations to be diabatic (fast and with low motional excitation) to increase the clock speed and improve coherent quantum operations. Since the performance of diabatic transport depends on both the electrode design [1] and the sequence of electric potentials [2] realised by a voltage waveform, we have numerically simulating ion trajectories for a large span of candidate designs in order to explore a large parameter space and a Pareto front [3]. By combining multidimensional optimal control [4] with a model of motion induced by large electric fields, this predicts corner transport at 40 ms-1 on the current leading candidate design.

References:

[1] C. Zhang et al., New J. Phys. 24, 073030 (2022)

[2] W. Burton et al., Phys. Rev. Lett, 130, 173202 (2023)

[3] M. Siegele-Brown, PhD Thesis, University of Sussex (2024)

[4] M. Orozco-Ruiz, et al., Phys. Rev. A, 108, 022601 (2023)

Conor Sexton (University College Cork):

Optimised quantum feedback control protocols: Advantages and limitations

Abstract: Standard projective quantum measurements are instantaneous and irreversible, resulting in the complete collapse of the quantum state into an eigenstate of the measured observable. However, continuous measurement allows for the quantum system to be monitored in time while only weakly perturbing it. This alternate measurement paradigm results in a stochastic measurement record and quantum trajectories which are otherwise inaccessible by projective measurement. Within closed loop control, the measurement record is leveraged to produce time-dependent feedback protocols which guide the system to a target state despite unwanted noise and errors.

It has been previously shown that feedback with a delayed measurement record or signal can be described by the quantum Fokker-Planck master equation [Phys. Rev. Lett. 129, 050401 (2022)]. We first extend this approach to include the effects of measurement inefficiency, allowing for the modelling of more realistic experimental conditions. A numerically efficient approach to compute the steady state of a system and detector in the presence of feedback is provided in [Phys. Rev. A 113, 032442 (2026)]. Using this charge-resolved master equation, we apply numerical optimisation techniques to the feedback control function f(D) with respect to a general function of the steady state, where D represents the filtered measurement signal.

In this talk, we present the theoretical foundations of continuous measurement and their application within quantum feedback systems, the methodology involved in optimising a steady state feedback protocol including our use of the adjoint method in calculating the gradient, and our current results which compare different feedback control strategies and their corresponding target state fidelity in the steady state regime.

Zhiyu Wang (University College Cork):

Quantum phase control of Liouvillian-skin-induced quantum Mpemba effect

Abstract: The Mpemba effect has attracted growing interest in both classical and quantum nonequilibrium systems. In this work, we study coherence-phase control of quantum Mpemba relaxation in a one-dimensional open quantum chain with coherent hopping, asymmetric dissipative hopping processes, and nearest-neighbor interactions. Under open boundary conditions, the asymmetric dissipation gives rise to Liouvillian skin modes, so that relaxation is strongly affected by the biorthogonal overlap between the initial state and the slow Liouvillian modes. We introduce a coherent initial state with a tunable relative phase and show that this phase changes the projection onto the slow-mode sector. For suitable phases, destructive interference suppresses the slow-mode weight, thereby modifying the relaxation trajectory and shifting the Mpemba crossing time. We further examine how interactions reshape the Liouvillian spectrum and slow-mode structure, leading to interaction-dependent changes in the optimized relaxation dynamics. Our results identify the coherence phase as an effective control parameter for tuning quantum Mpemba relaxation in interacting Liouvillian skin systems through initial-state preparation. Future work will explore shortcut-to-adiabaticity protocols for preparing optimized coherent states and further investigate how many-body interactions modify coherence-controlled relaxation mechanisms.

Xiaoji Zhou (Peking University):

Atomic quantum simulator with tunable temperature

Abstract: The temperature of atoms is an important parameter in quantum simulations. In this talk, first I will report the all-optical production of a Bose–Einstein condensate in an orbital microgravity environment aboard Tiangong space station [1], and the achievement of an equivalent temperature 10 pK opens the door to the quantum simulation in extreme low temperature. Furthermore, we produce an interacting atomic quantum simulator with continuous tunability of anisotropy and temperature, and probe the universal phase diagram of dimensional crossover [2]. The universal scaling of many-body effects in quantum tunneling process with the independent control of barrier, temperature and interaction is also given [3]. Next, we realize an anyonic thermodynamic ensemble obeying generalized exclusion statistics and detect its anyonic thermodynamics in a one-dimensional strongly interacting quantum gas. By tuning interaction strength and temperature over a wide range, we measure the equation of state and identify clear departures from Bose-Einstein and Fermi-Dirac statistics [4]. Finally, we report a Ramsey-Bordé interferometer of coherent matter waves modified by a moving optical lattice in a gravitational field, and explore a resulting multipath interference with tunable coherence or the different temperature [5].

[1] Wei Xiong et al. Quantum Gases Below 10 Picokelvin in Space, Science (under reviewing) (2026)

[2] J. Y. Tian, Z. C. Yu, J. Liu, C. K. Lai, L. Pizzino, C. Y. Wu, H. M. Shui, T. Giamarchi, H. P. Yao, Xiaoji Zhou, Probing universal phase diagram ofdimensional crossover with an atomic quantum simulator, Nature Communications 17, 5210 (2026).

[3] H. M. Shui, C. K. Lai, C.Y. Wu, L. Pizzino, C. Zhang, G. H. Shen, T. Giamarchi, H. P. Yao, and Xiaoji Zhou1, Universal scaling of many-body effects in quantum tunneling, arXiv:2606.31659(2026)

[4] F.W. Wei, C. Zhang, Z. M. Ye, D. B Wang, B. T. Wang, Xiaoji Zhou, and H.P. Yao, Observation of anyonic thermodynamics and generalized Pauli principle, arXiv:2606.19009 (2026)

[5] P. Peng, D. K. Mao, Y. Liang, G. L. Yin, H. M. Shui, B. Song and Xiaoji Zhou, Realizing a spatially correlated lattice interferometer, Phys. Rev. A 112, 053313 (2025

Jing Li (University College Cork):

Quantum control of pistons: From Rabi-coupled Bose-Einstein condensates to Two-Ion device

---

Abstract: This talk will focus on two theoretical proposals for microscopic quantum heat-engine physics. First, I will discuss a hybrid quantum–classical model in which a Rabi-coupled Bose–Einstein condensate interacts with a classical piston. In this setting, the condensate pressure drives the piston motion, while the piston in turn modifies the condensate dynamics. The model shows that the piston can be controlled by an optimized design of the time-dependent Rabi field. Second, I will present a theoretical proposal for a two-ion device in which a light ion acts as a quantum working medium and a heavy ion serves as an effective classical piston through Coulomb coupling. The model exhibits self-consistent backaction, a narrow quantum regime connecting two broader classical ones, and high-fidelity piston control by inverse engineering of the trap frequency. Together, these two examples illustrate how different theoretical platforms can be used to explore both the working-medium and piston aspects of microscopic thermal machines.

Chris Whitty (University of the Basque Country):

Smooth time-dependent control of dipolar Bose-Einstein condensates

---

Abstract: We consider protocols for control of dipolar Bose-Einstein condensates where the critical role is played by the long-range anisotropic interatomic magnetic dipole-dipole interaction. The phase diagram of such a condensate has been explored theoretically and experimentally with certain values of the interatomic scattering length corresponding to superfluid and supersolid phases, where supersolidity appears as a modulation in the ground state density. Preparation of this modulated ground state is challenging, since excitations appear as a result of a finite-time evolution required to produce qualitative changes in the wavefunction density. To solve this problem we consider the time-dependent control of a dipolar Bose-Einstein condensate using shortcuts to adiabaticity techniques, concentrating on design of the time-dependent scattering length, a parameter of the system easily tunable by contemporary experiments. The first technique is the variational approach based on the Euler-Lagrange equations for a separable ansatz describing the evolution of the superfluid state. Secondly, we study the transition from superfluid to supersolid using a direct optimization protocol. We discuss the fidelity of the developed protocols in terms of the evolution time.

Ronan McElvogue (University College Dublin):

Fast and robust quantum state transfer in a 2D multi-domain SSH model

---

Abstract: Efficient transfer of quantum information between distant parts of a device is a central challenge in the development of scalable quantum technologies. We show that quantum state transfer across a two-dimensional array can be achieved quickly and reliably using concepts from topological physics. Our system is based on a simple 2D extension of the Su–Schrieffer–Heeger (SSH) model, engineered to contain multiple domain walls that host well-localized and topologically-protected states. These states form a super-lattice of quantum `repeaters', whose couplings can be tuned in time to quickly transfer quantum information betweendistant locations with near perfect fidelity. Crucially, this transfer remains robust even in the presence of disorder and timing errors, and occurs significantly faster than standard adiabatic approaches. Interestingly, models with full higher-order topology, such as the Benalcazar-Bernevig-Hughes (BBH) lattice, do not perform as well. We also compare to perfect-state-transfer protocols. Both highlight the need for compromise between the competing tendencies for protection and mobility when optimizing state transfer. For the 2D SSH model, we identify the optimal domain-wall configuration that simultaneously maximizes fidelity and minimizes transfer time.

Ruijin Sun (Northeast Normal University, University College Cork):
Enhanced shortcuts to adiabaticity in an interacting giant atom atomic waveguide system

Abstract: We investigate a time-dependent multi-atom quantum system, which is a composite system consisting of a giant atom coupled to a one-dimensional atomic waveguide. Due to the time dependence and non-local coupling effects in this system, achieving fast and high-fidelity finite-time quantum control becomes a challenging problem. By applying the Lewis–Riesenfeld invariant-based inverse engineering method, we design a shortcut-to-adiabaticity (STA) protocol to realize fast finite-time control and to improve the final-state fidelity. Furthermore, we employ the enhanced shortcut to adiabaticity (eSTA) method to suppress the influence for non-ideal terms and to improve the final fidelity. This study numerically investigates enhanced shortcut to adiabaticity control in an interacting multi-atom system. By comparing different boundary conditions and different atomic interactions, we show that the fidelity performance is affected by the structure of the atomic chain, while the enhanced shortcut to adiabaticity method can significantly improve the final fidelity in the presence of coupling-induced deviations.

Andreas Ruschhaupt (University College Cork):

Enhanced Shortcuts to Adiabaticity

Abstract: The fast and robust control of quantum states is of the utmost importance for all quantum technologies and Shortcuts to Adiabaticity (STA) are techniques for designing such fast and robust quantum control protocols.

However, there are still quantum systems where these STA methods cannot be applied. Therefore, I will present a new technique for such scenarios, called “Enhanced Shortcuts to Adiabaticity” (eSTA). This method works for previously intractable Hamiltonians by providing an easy to calculate analytical correction to existing STA protocols. I will show some applications of eSTA as the manipulation of an internal atomic state, the transport of ions and spin squeezing in internal bosonic Josephson junctions.

David Guéry-Odelin (Université de Toulouse):

Applying Control Theory to Quantum Systems (online talk)

Abstract: Quantum systems offer remarkable opportunities for precision measurements, quantum simulation, and quantum information processing, provided that their dynamics can be controlled with high accuracy. In this talk, I present recent developments in the application of control theory to quantum systems, focusing on experiments with Bose–Einstein condensates in optical lattices.

These systems provide a versatile platform where the Hamiltonian can be engineered with high precision through the control of lattice depth, position, and phase. By combining theoretical tools from optimal control theory—such as the Pontryagin maximum principle—with experimental implementations, it becomes possible to design control protocols that steer the quantum state toward a desired target in a finite time.

I will illustrate how optimal control techniques enable the preparation of tailored quantum states in momentum space, including arbitrary superpositions of momentum components with high fidelity. These methods also allow us to shape the evolution operator itself, opening new perspectives for the realization of quantum gates and engineered Floquet Hamiltonians.

Finally, I will discuss recent results where quantum control is used to enhance parameter estimation protocols. By optimizing both the system dynamics and the measurement strategy, it becomes possible to approach the fundamental precision limits set by quantum Fisher information.

These results highlight how control theory provides a powerful framework to manipulate complex quantum systems and design new quantum technologies.

Bibliography:

1. Ombredane, E. Flament, C. Babin, D. Sugny, D. Guéry-Odelin, B. Peaudecerf arXiv:2512.17836
2. F. Arrouas, J. Hébraud, N. Ombredane, E. Flament, D. Ronco, N. Dupont, G. Lemarié, B. Georgeot, Ch. Miniatura, J. Billy, B. Peaudecerf, D. Guéry-Odelin, arXiv:2503.01777, to appear in Nature Communications
3. E. Flament, N. Ombredane, F. Arrouas, D. Ronco, B. Peaudecerf, D. Sugny, D. Guéry-Odelin, Phys. Rev. Research 7, 033069 (2025).
4. N. Dupont, L. Gabardos, F. Arrouas, N. Ombredane, J. Billy, B. Peaudecerf, D. Guéry-Odelin, Phys. Rev. Lett. 131, 133401 (2023).
5. Phase-space distributions of Bose-Einstein condensates in an optical lattice: Optimal shaping and reconstruction N. Dupont, F. Arrouas, L. Gabardos, N. Ombredane, J. Billy, B. Peaudecerf, D. Sugny, D. Guéry-Odelin, New J. Phys. 25, 013012 (2023).