1. **Xi Chen (CSIC)**

   Title: Superoscillating Quantum Control Induced By Sequential Selections

   Abstract: Superoscillation is a counterintuitive phenomenon for its mathematical feature of "faster-than-Fourier", which has allowed novel optical imaging beyond the diffraction limit. Here, we provide a superoscillating quantum control protocol realized by sequential selections in the framework of weak measurement, which drives the apparatus (target) by repeatedly applying optimal pre- and post-selections to the system (controller). Our protocol accelerates the adiabatic transport of trapped ions and adiabatic quantum search algorithm at a finite energy cost. We demonstrate the accuracy and robustness of the protocol in the presence of decoherence and fluctuating noise and elucidate the trade-off between fidelity and rounds of selections. Our findings provide avenues for quantum state control and wave-packet manipulation using superoscillation in quantum platforms such as trapped ions.

2. **Conor McKeever (Quantinuum)**

   Title: Quantum circuits for time evolution via tensor networks

   Abstract: In the first part of this talk I will discuss our recent work [1] in which we use tensor network methods to find quantum circuits for Hamiltonian simulation. In the second part I will discuss our related work [2] in which we employ similar techniques for adiabatic time evolution. In particular, I will discuss how we utilise variational matrix product operators to approximate adiabatic gauge potentials and how these can then be used to classically optimize a parameterized quantum circuit which simultaneously captures quasi-adiabatic evolution together with an associated counterdiabatic driving.

   [1] C. Mc Keever and M. Lubasch. "Classically optimized Hamiltonian simulation." Physical review research 5.2 (2023): 023146.

   [2] C. Mc Keever and M. Lubasch. "Towards adiabatic quantum computing using compressed quantum circuits." PRX Quantum 5.2 (2024): 020362.

3. **Narendra Hegade (Kipu Quantum)**
4. **Koushik Paul (UPV-EHU)**

   Title: Lyapunov Controlled Counterdiabatic Quantum Optimization

Abstract: We introduce a quantum algorithm integrating counterdiabatic (CD) protocols with quantum Lyapunov control (QLC) to tackle combinatorial optimization problems. This approach offers versatility, allowing implementation as either a digital-analog or purely digital algorithm based on selected control strategies. By examining spin-glass Hamiltonians, we illustrate how the algorithm can explore alternative paths to enhance solution outcomes compared to conventional CD techniques. This method reduces the dependence on extensive higher-order CD terms and classical optimization techniques, rendering it more suitable for existing quantum computing platforms. The combination of digital compression via CD protocols and the adaptable nature of QLC methods positions this approach as a promising candidate for near-term quantum computing.

5. **Mikel Garcia de Andoin (Tecnalia & UPV-EHU)**

   Title: Extensions of Digital-analog computation

Abstract: Regarding its applicability, it has already been shown useful for implementing ubiquitous quantum algorithms and solving various problems. Among them, the quantum Fourier Transform, the algorithm for solving a linear system of equations (HHL) or a simulation of fermionic systems. In this talk, we will focus on two new recent works that advance the state-of-the-art of DAQC. First, we propose a new protocol to simulate arbitrary two-body Hamiltonians. We showed that the simulation of an arbitrary two-body target Hamiltonian of n qubits requires O(n^2) analog blocks with guaranteed positive times, providing a polynomial advantage compared to the previous schemes . Second, we focus on the stability of DAQC in a noisy environment. Previously, it was shown that DAQC provided better resilience against both incoherent (dephasing and decoherence) and coherent errors (deviations on single qubit gate angles). Now, we study the effect of misscalibration of the system, in particular, errors in the measurement of the couplings in the system. We show that DAQC is stable when measuring local observables for quantum simulation tasks. This allows us to show that the errors don’t grow with the system size. Both results contribute to showing the feasibility of scaling DAQC implementations to a higher number of qubits

6. **Qi Zhang (Kipu Quantum)**

   Title: Analog Counterdiabatic Quantum Computing (ACQC)

Abstract: Analog Counterdiabatic Quantum Computing (ACQC), a new paradigm by Kipu Quantum GmbH, aims to extend neutral atom hardware to combinatorial optimization. Counterdiabaticity (CD) was previously introduced to accelerate adiabatic processes, enabling shorter evolution times and higher solution quality. However, no instances of CD protocol being implemented on neutral atom quantum computers exist due to well-known hardware limitations: encoding problems in the native Hamiltonian

and restricted parameter ranges, which limit the number of treatable computational problems.

In this contribution, we introduce a CD protocol directly implementable on current commercial neutral atom hardware. We demonstrate for the example of a combinatorial optimization problem that ACQC enhances the performance by a factor of two on average without applying additional optimization on the hardware or post-processing algorithms. This allows us to tackle larger computational problems at lower computational costs.

7. **Alberto Bottarelli (U. of Trento)**

   Title: Symmetry-enhanced Counterdiabatic quantum computing

   Abstract: We present a symmetry-enhanced digitized counterdiabatic quantum algorithm utilizing qudits, addressing challenges in qubit-based variational quantum algorithms. Our approach achieves three types of compression compared to conventional variational circuits: reduced circuit depth through counterdiabatic protocols, more efficient problem representation by using qudits, and fewer parameters by leveraging system symmetries. We demonstrate this method on the graph-based optimization problem Max-3-Cut. Our numerical results indicate improved convergence with lower circuit depth and reduced measurement overhead, advancing the design of shallow variational quantum circuits for near-term qudit devices.

8. **Pablo Rodriguez-Grasa (UPV-EHU)**

   Title: "Neural quantum kernels"

   Abstract: In recent years, various quantum machine learning models have been proposed. While parameterized quantum circuits face trainability issues, quantum kernel-based models require optimal feature map selection tailored to the problem. In this talk, we present neural quantum kernels: embedding quantum kernels constructed from a quantum neural network. We will discuss how combining these two approaches can yield a more robust model and showcase a practical application in the field of satellite image classification.

9. **Kasturi R. Swain (U. of Luxembourg)**

   Title: Quantum chaos in random Ising networks

   Abstract: In this talk, I will present our recent work (arXiv:2405.14376), titled 'quantum chaos in random Ising networks'. We examine the emergence of quantum chaotic signatures in the transverse field Ising model by varying the connectivity and strength of the transverse field. Specifically, I will cover our analysis of local spectral measures, including level spacing and level velocity statistics, which provide insight into short-range spectral correlations. Additionally, I will introduce the spectral form factor as a global measure, used to investigate energy level correlations across a broad spectral range.

10. **Antonio Ferrer Sanchez (U. of Valencia)**

Title: Physics-informed neural networks for an optimal counterdiabatic quantum computation.

Abstract: A novel methodology that leverages physics-informed neural networks to optimize quantum circuits in systems with qubits by addressing the counterdiabatic (CD) protocol is introduced. The primary purpose is to employ physics-inspired deep learning techniques for accurately modeling the time evolution of various physical observables within quantum systems. To achieve this, we integrate essential physical information into an underlying neural network to effectively tackle the problem. Specifically, the imposition of the solution to meet the principle of least action, along with the hermiticity condition on all physical observables, among others, ensuring the acquisition of appropriate CD terms based on underlying physics. This approach provides a reliable alternative to previous methodologies relying on classical numerical approximations, eliminating their inherent constraints. The proposed method offers a versatile framework for optimizing physical observables relevant to the problem, such as the scheduling function, gauge potential, temporal evolution of energy levels, among others. This methodology has been successfully applied to 2-qubit representing molecule using the STO-3G basis, demonstrating the derivation of a desirable decomposition for non-adiabatic terms through a linear combination of Pauli operators. This attribute confers significant advantages for practical implementation within quantum computing algorithms.

11. **Sebastian Romero (Kipu Quantum)**
12. **Adolfo del Campo (U. of Luxembourg)**

Title: Kink statistics in physics and computing

Abstract: Kink statistics in physics and computing

The study of fluctuations is widely recognized as a fertile ground for novel discoveries in nonequilibrium statistical mechanics. We focus on studying fluctuations in the number of

topological defects and, specifically, the kink statistics in driven quantum Ising models. Such emphasis is essential in the study of universality in quantum phase transitions beyond the Kibble-Zurek mechanism. It also sheds new light on quantum quenches and approximate counterdiabatic driving. We thus propose it as a novel benchmark of counterdiabatic quantum algorithms.

13. **Kazutaka Takahashi (U. of Luxembourg)**

Title: Krylov subspace method for quantum dynamics

Abstract: Krylov subspace method in quantum dynamics identify the minimal subspace in which a process unfolds.
We discuss possible applications of the algorithm to systems with time-dependent Hamiltonians.
The standard construction of the Krylov basis is applied to find the explicit form of the counterdiabatic Hamiltonian.
We also discuss a generalization of the algorithm to describe dynamical evolutions of quantum states in the constructed Krylov space.

14. **Federico Roccati (MPI Erlangen)**

Title: Controlling Markovianity with Chiral Giant Atoms

Abstract: A hallmark of giant-atom physics is their non-Markovian character in the form of self-coherent feedback, leading, e.g., to nonexponential atomic decay. The timescale of their non-Markovianity is essentially given by the time delay proportional to the distance between the coupling points to the 1D field. In parallel to this, with the state-of-the-art experimental setups, it is possible to control complex phases in the atom-light couplings. Such phases simulate an artificial magnetic field, yielding a chiral behavior of the atom-light system. In my talk I will report a surprising connection between these two seemingly unrelated features of giant atoms, showing that by controlling the phase of the giant-atom coupling it is possible to control its Markovianity. In particular, controlling the couplings' phases, a giant atom can, counterintuitively, enter an exact Markovian regime, irrespectively of any intrinsic time delay. I will illustrate this mechanism as an interference process and via a collision model picture.

Ref:

F. Roccati and D. Cilluffo. Phys. Rev. Lett. 133, 063603 (2024)

15. **András Grabarits (U. of Luxembourg)**

Title: Non-Adiabatic Quantum Optimization for Crossing Quantum Phase Transitions

Abstract: We consider the optimal driving of the ground state of a many-body quantum system across a quantum phase transition in finite time. In this context, excitations caused by the breakdown of adiabaticity can be minimized by adjusting the schedule of the control parameter that drives the transition. Drawing inspiration from the

Kibble-Zurek mechanism, we characterize the timescale of onset of adiabaticity for several optimal control procedures. Our analysis reveals that schedules relying on local adiabaticity, such as Roland-Cerf's local adiabatic driving and the quantum adiabatic brachistochrone, fail to provide a significant speedup over the adiabatic evolution in the transverse-field Ising and long-range Kitaev models. As an alternative, we introduce a novel framework, Non-Adiabatic Quantum Optimization (NAQO), that, by exploiting the Landau-Zener formula and taking into account the role of higher-excited states, outperforms schedules obtained via both local adiabaticity and state-of-the-art numerical optimization. NAQO is not restricted to exactly solvable models, and we further confirm its superior performance in a disordered non-integrable model.

16. **Federico Balducci (MPI-PKS)**
17. **Xuan Chen (Shanghai Jiao Tong U)**
18. **José Javier Orquín Marqués (U. of Valencia)**
19. **Carlos Flores Garrigos (U. of Valencia)**

Title: Digital-Analog Quantum convolutional Neural Networks for Image classification.

Abstract: We propose digital-analog quantum kernels for enhancing the detection of complex features in the classification of images. We consider multipartite-entangled analog blocks, stemming from native Ising interactions in neutral-atom quantum processors, and individual operations as digital steps to implement the protocol. To further improving the detection of complex features, we apply multiple quantum kernels by varying the qubit connectivity according to the hardware constraints. An architecture that combines non-trainable quantum kernels and standard convolutional neural networks is used to classify realistic medical images, from breast cancer and pneumonia diseases, with a significantly reduced number of parameters. Despite this fact, the model exhibits better performance than its classical counterparts and achieves comparable metrics according to public benchmarks. These findings highlight the potential of digital-analog quantum convolutions in extracting complex and meaningful features from images, positioning them as a candidate model for addressing challenging classification problems.