

Italian Women in Quantum Technologies 2025



PROGRAMMA E BOOK OF ABSTRACT



Finanziato
dall'Unione europea
NextGenerationEU



Ministero
dell'Università
e della Ricerca



Italiadomani
PIANO NAZIONALE
DI RIPRESA E RESILIENZA



NQSTI
National Quantum Science
and Technology Institute

PROGRAMMA 11/12/25	
9:00 – 10:00	Registrazione
10:00 – 10:15	Opening
10:15 – 10:40	P. Verrucchi <i>Unsupervised Learning to Recognize Quantum Phases of Matter</i>
10:40 – 10:55	M. Nazzaro <i>Q-Train: Quantum Tech Transfer to Industry</i>
10:55 – 11:10	M. Vizzuso <i>Non-adiabatic self-healing of Trotter errors</i>
11:10 – 11:25	S. Mukhereeie <i>Detection of Noise Correlations in Small Quantum Networks by Machine Learning</i>
11:25 – 11:40	L. Woswijk <i>Towards a new quantum computing platform based on Yb atoms in optical tweezer arrays</i>
11:40- 12:10	COFFEE
12:10 - 12:35	M. D'Angelo <i>Correlation imaging, from 3D to hyperspectral</i>
12:35 - 13:00	E. Missale <i>Centri di colore in diamante: strumenti e tecniche per una fabbricazione flessibile</i>
13:00 14:30	PRANZO
14:30 – 14:55	N. Fabbri <i>Diamond defects for quantum science and technologies</i>
14:55 – 15:20	I. Gianani Spectral characterisation of biphoton states
15:20 – 15:45	N. Bruno <i>A photon-atom interface at telecom wavelength</i>
15:45 – 16:00	Mineo/Chiechio - online
16:00 – 16:30	COFFEE
16:30 – 16:55	V. Brosco <i>Superconducting quantum devices based on twisted heterostructures</i>
16:55 – 17:20	F. Lombardi - online Tuning the Ground State of Quantum materials via Substrate Engineering
17:20 – 17:40	G. Del Pace <i>Shapiro steps in a strongly-interacting atomic Josephson junction under AC drive</i>
17:40 – 17:55	M. Frometa Fernandez <i>Angular momentum of rotating fermionic superfluids by Sagnac phonon interferometry</i>
17:55 – 18:10	V. Stanzione <i>Tailoring transport in quantum spin chains</i>
18:10 – 19:30	SESSIONE POSTER
20:00 - 21:30	CENA
21:30 – 22:30	Momento informale di networking/mentoring

PROGRAMMA 12/12/25

9:00 - 9:25	S. Maniscalco
9:25 - 9:50	M. Chiofalo <i>Quantum Toolbox for Neurobiology Sensory Systems</i>
9:50 - 10:05	G. Di Bello <i>Environment-induced quantum phase transitions and quantum Fisher information in two-level systems</i>
10:05 - 10:20	A. Chiatto <i>Computational Intelligence for Variational Quantum Algorithms</i>
10:20 - 10:35	P Savarese <i>Programmable non-Hermitian quantum walks via liquid-crystal metasurfaces</i>
10:35 -10:50	A. Zaheer <i>2D MXene-Based Hybrid Platforms for Next-Generation Quantum and Bio-Sensing Interfaces</i>
10:50 – 11:15	R. Citro <i>Quantum Transport and Quantum Materials: Approaches and Strategies</i>
11:15- 11:45	COFFEE
12:00 – 13:00	Tavola Rotonda: L. Farina-Busto, N. Bruno, S. Maniscalco, S. Pirrone
13:00 – 14:00	PRANZO
14:00 – 14:20	A. Sorgi <i>Towards the Detection of Quantum Correlations in THz Quantum Cascade Lasers</i>
14:20 – 14:35	E. Fanella <i>Single molecules as quantum optomechanical devices: leverage vibrational modes in fluorophores</i>
14:35 – 15:00	A. Cacciapuoti - online <i>Design Philosophy for the Quantum Internet</i>
15:00 – 15:20	L. Parlato <i>Superconducting nano/microstrip single photon detectors: from device fabrication to quantum applications</i>
15:20 – 15:45	M. Bondani <i>Photon-number-resolving detectors for quantum state engineering</i>
15:45 – 16:15	COFFEE

Quantum Sensing
Quantum Communication
Quantum Computing/Info
Quantum Materials

Maria Bondani (CNR - Istituto di Fotonica e Nanotecnologie)

Titolo: *Photon-number-resolving detectors for quantum state engineering*

Abstract: Photon-number-resolving detectors (PNRDs) are essential tools for both quantum state characterization and quantum state engineering. We show that room-temperature PNRDs—such as hybrid photodetectors (HPDs) and silicon photomultipliers (SiPMs)—provide reliable access to the photon-number content of pulsed optical states. This capability enables the reconstruction of photon-number statistics for classical and nonclassical fields, the measurement of classical and quantum correlations, and the heralded generation of non-Gaussian and sub-Poissonian conditional states. In addition, these detectors can be effectively employed in phase-estimation protocols, homodyne-like measurement schemes, and a broad range of quantum information processing tasks.

Valentina Brosco (Istituto dei Sistemi Complessi, CNR)

Titolo: *Superconducting quantum devices based on twisted heterostructures*

Abstract: Van der Waals assembly provides a route to fabricate novel Josephson junctions with atomically sharp interfaces between two exfoliated and relatively twisted $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ (Bi2212) flakes. At twist angles near 45° , these junctions enter a regime in which interlayer two-Cooper-pair tunneling dominates the current–phase relation. I present two recent works where we proposed utilizing this unique junction behavior to realize a capacitively shunted qubit, which we term the "flowermon". Owing to the d-wave symmetry of the superconducting order parameter, the flowermon exhibits inherent protection against charge-noise-induced relaxation as well as quasiparticle-induced dissipation. This protected architecture belongs to a class of high-coherence hybrid superconducting quantum devices exploiting unconventional superconducting heterostructures.

Natalia Bruno (CNR-INO/LENS)

Titolo: *A photon-atom interface at telecom wavelength*

Abstract: Enabling communication between quantum devices, such as clocks, computers, and simulators has the potential to significantly enhance the capabilities of their applications, such as quantum sensing and computing. The key to achieving this lies in establishing efficient communication channels among these quantum devices even over a long distance, which involves the exchange of qubits encoded in light at telecom wavelengths through optical fibers. In this context, I will present an overview of the new experiment that we are building in Florence, which focuses on interfacing single photons at telecom wavelengths with individual neutral ytterbium atoms trapped in optical tweezers. By leveraging the unique properties of the ytterbium clock state and its telecom transitions, our objective is to interface a long-lived "matter" qubit and resonant light, including atom-resonant heralded single photons or photons forming entangled pairs. I will discuss the first

developments, the motivation for exploring this research line and its impact as a crucial foundation for distributing entanglement between light and matter.

Angela Sara Cacciapuoti (Università di Napoli)

Titolo: Design Philosophy for the Quantum Internet

Abstract: This talk outlines key architectural principles for the emerging Quantum Internet, with a focus on scalability and robustness. We argue for moving beyond traditional network control approaches toward quantum-native abstractions and control mechanisms, and discuss their implications for the network design.

Silvia Cassina (Università degli studi Roma Tre)

Titolo: *Coarse graining in continuous time quantum walk*

Abstract: Complex networks provide a powerful framework to model the behaviour of complex systems, and quantum walks represent an ideal paradigm to study how information propagates within such structures. Understanding information spreading in large networks is crucial for applications in quantum communications, quantum computation, and energy transport in natural systems. To bridge theoretical models and realistic implementations, it is essential to introduce a coarse-graining procedure that accounts for the finite size and resolution of experimentally accessible sites, thus enabling a faithful comparison between theoretical descriptions and discrete photonic realizations.

EQWALITY tackles this challenge by developing a highly tailorable photonic platform based on correlated photon pairs to implement fully programmable 2D spectral quantum walks. This platform will support advanced multiparameter estimation enhanced by machine-learning algorithms and will enable the exploration of nontrivial quantum-walk dynamics through Hamiltonian learning.

Angela Chiatto (Università di Napoli)

Titolo: *Computational Intelligence for Variational Quantum Algorithms*

Abstract: Recent advancements in quantum hardware have brought quantum computing closer to practical realization, marking the onset of the Noisy Intermediate-Scale Quantum (NISQ) era. In fact, the current quantum processors face significant limitations, including a restricted number of physical qubits and the presence of noise, which degrades the reliability of deep quantum circuits. In this context, Variational Quantum Algorithms (VQAs) have emerged as a promising

strategy for harnessing NISQ devices. By utilizing a quantum computer trained by a classical optimizer, VQAs reduce quantum resource requirements—such as qubit count and circuit depth—compared to algorithms designed for fault-tolerant quantum computers. Despite their potential, VQAs face critical challenges, such as vanishing gradients (barren plateaus), noise-induced errors, and high computational cost for gradient-based optimization, which hinder their scalability. During the talk, I will explore how Computational Intelligence techniques can address these issues, enhancing both the trainability and efficiency of VQAs. Specifically, I will discuss how Evolutionary Algorithms offer a powerful strategy to overcome trainability limitations in both quantum classification [1] and optimization [2]. Additionally, I will show how fuzzy clustering techniques can effectively reduce the complexity of VQAs in quantum optimization [3].

[1] G. Acampora, A. Chiatto, and A. Vitiello, *Pattern Recognition Letters*, Elsevier, volume 170, pages 32-38, 2023.

[2] G. Acampora, A. Chiatto, and A. Vitiello, *Applied Soft Computing*, Elsevier, volume 142, page 110296, 2023.

[3] G. Acampora, A. Chiatto, and A. Vitiello, 2023 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), pages 1–7, 2023.

Marilù Chiofalo (Università di Pisa)

Titolo: *Quantum Toolbox for Neurobiology Sensory Systems*

Abstract: The quantum-like paradigm has emerged over the last decade to describe non-linear, dynamical, complex phenomena using quantum mechanics as a tool. In essence, it takes advantage of the linearity of quantum information processing, allowing for complex correlations through entanglement. In a quantum- and neuroscience truly interdisciplinary research, we found that an open quantum spin network, mapping a neural system, can successfully simulate the human sense of number as a global dynamical property, in contrast with the poor performance of conventional Artificial Neural Networks. Here, we discuss how the simulation can be extended to other important complex perceptual phenomena like the perception of space, time, and numbers, known to be interdependent with each other, suggesting that a shared neuronal mechanism is operating in the brain. Here we present a research program that aims at creating a quantum toolbox to simulate this integrated space-time-number sensory ability of our brain, with open-quantum systems methods. We will explore the implications of more general quantum-matter paradigms, and their possible coding into a quantum technology.

Roberta Citro (Università di Salerno)

Titolo: *Quantum Transport and Quantum Materials: Approaches and Strategies*

Abstract: This talk gives an overview of recent studies on quantum transport phenomena and their relevance in emerging quantum materials. Beginning with the

foundations of mesoscopic and quantum transport, we explore how quantum coherence and phase interference shape electron dynamics at the nanoscale. We introduce the Landauer-Büttiker formalism and the scattering matrix approach, offering powerful tools to model electronic conduction in low-dimensional systems. These concepts are applied to the study of topological insulators, superconductors and quantum pumps, where topology-driven transport leads to robust, dissipationless edge states and quantized charge flow. The series of examples concludes with an overview of spin-orbitronics, highlighting how spin-orbit coupling in quantum materials enables novel device functionalities with potential applications in quantum technologies.

Milena D'Angelo (Università di Bari)

Titolo: *Correlation imaging, from 3D to hyperspectral*

Abstract: We shall present recent advances in correlation imaging modalities enabling scanning-free high-resolution hyperspectral imaging, 3D imaging and 3D microscopy, with at least one order of magnitude advantage over typical tradeoffs such as resolution versus depth of field and spatial versus spectral resolution.

Both entangled light beams and chaotic light are employed, depending on the specific application scenario.

Speed-up enabled by both SPAD arrays and AI denoising approaches are presented, demonstrating the effective capability of the presented approaches to compete with state of the art approaches, while overcoming their intrinsic limitations.

Giulia Del Pace (Università di Firenze)

Titolo: *Shapiro steps in a strongly-interacting atomic Josephson junction under AC drive*

Abstract: The Josephson effect is one of the most striking manifestations of a macroscopic system phase coherence. Besides representing a powerful probe of phase coherence, Josephson junctions (JJ) are also fundamental building blocks for atomtronics circuits, thanks to their well defined current-chemical potential and current-phase characteristics.

In this talk, I will present our recent research on the response of an atomic JJ with Fermi superfluids of lithium-6 under an AC driving. To inject in the junction an alternate current, we modulate the position of the tunneling barrier at a given frequency and probe the chemical potential imbalance developed across the junction after a few modulation periods. The AC drive introduces in the current-chemical potential characteristic a number of Shapiro steps at a chemical potential value that is an integer multiple of the driving frequency, similarly to superconducting JJ with an external radiofrequency drive. We connect the presence of the steps to the synchronization of the relative phase at the junction with the external drive, which leads to n phase slips events in the n -th Shapiro steps, which we could directly access by counting the number of emitted vortices. Our work not only demonstrates the

existence of Shapiro steps in fermionic JJ, but also highlights the microscopic mechanism behind such a phenomenon.

Grazia Di Bello (Università di Napoli)

Titolo: *Environment-induced quantum phase transitions and quantum Fisher information in two-level systems*

Abstract: We investigate the dynamical and thermodynamic properties of the open Rabi model, a two-level system coupled to an oscillator beyond the rotating-wave approximation, and its two-qubit extension, focusing on equilibrium quantum phase transitions (QPTs) and dynamical quantum phase transitions (DQPTs) induced by environmental interactions. To address these problems, we employ the Density-Matrix Renormalization Group (DMRG) algorithm for equilibrium states and the Time-Dependent Variational Principle (TDVP) for non-equilibrium dynamics, both based on a tensor-network variational ansatz, representing open quantum systems as Matrix Product States (MPSs). These approaches are complemented by worldline Monte Carlo simulations at equilibrium and methods inspired by Feynman and Mori for dynamical analysis.

On the thermodynamic side, we show that increasing the coupling to the oscillator mediating environmental interactions triggers a Berezinskii-Kosterlitz-Thouless (BKT) transition in both single- and two-qubit models within the deep-strong coupling regime. Dynamically, we observe a coherent-to-incoherent crossover and the BKT transition: weak coupling leads to Rabi oscillations, whereas stronger coupling induces exponential relaxation, with relaxation functions flattening at the BKT point [1]. As an application, we compute local ergotropy in a work-extraction protocol, finding that both its static and dynamical behavior witness the BKT transition [2]. Furthermore, quenches of the qubit-oscillator coupling reveal two distinct classes of DQPTs, depending on qubit interactions and entanglement, each with unique critical exponents. These are signaled by non-analyticities in the Loschmidt echo, occurring in the same parameter regime as the thermodynamic BKT transition [3].

Finally, we employ DMRG and TDVP to analyze the Quantum Fisher Information Matrix (QFIM) as a metrological probe in a paradigmatic two-level open quantum system: the spin-boson model. Its static component exhibits peaks near the BKT transition, allowing the critical coupling to be extrapolated, and these sensitivity enhancements correlate with the monotonic growth of von Neumann entropy, linking parameter estimation precision to entanglement. Dynamically, QFIM displays oscillations in the coherent regime, and their suppression across the coherent-to-incoherent crossover, providing a quantitative signature of non-Markovian effects [4].

These results clarify how criticality and non-Markovian effects manifest in open quantum systems and suggest possible strategies for exploiting these features in quantum sensing protocols.

References

[1] G. De Filippis, A. de Candia, G. Di Bello, C. A. Perroni, L. M. Cangemi, A. Nocera, M. Sasseti, R. Fazio, and V. Cataudella, “Signatures of dissipation driven quantum phase transition in Rabi model”, *Phys. Rev. Lett.* 130, 210404 (2023).

[2] G. Di Bello, D. Farina, D. Jansen, C. A. Perroni, V. Cataudella, and G. De Filippis, “Local ergotropy and its fluctuations across a dissipative quantum phase transition”, *Quantum Sci. Technol.* 10, 015049 (2025).

[3] G. Di Bello, A. Ponticelli, F. Pavan, V. Cataudella, G. De Filippis, A. de Candia, and C. A. Perroni, “Environment induced dynamical quantum phase transitions in two-qubit Rabi model”, *Commun. Phys.* 7, 364 (2024).

[4] D. Parlato, G. Di Bello, F. Pavan, G. De Filippis, and C. A. Perroni, “Quantum Fisher information as a witness of non-Markovianity and criticality in the spin-boson model”, arXiv:2508.16413 (2025), accepted for publication in *Phys. Rev. B*.

Nicole Fabbri (CNR-INO, LENS)

Titolo: *Diamond defects for quantum science and technologies*

Abstract: In the rapidly advancing field of quantum science and technology, quantum defects in diamond have gained attention for their long-lived spin coherence and control capability, combined with integrability into chip-scale architectures and room temperature operation. I will present a few examples showing how spin control, together with the ability to engineer the defect’s interaction with its environment, can be exploited for improving precision in sensing applications and, more foundationally, to investigate the effect of coherence and fluctuations on the spin dynamics and thermodynamics.

Elena Fanella (CNR-INO, LENS)

Titolo: *Single molecules as quantum optomechanical devices: leverage vibrational modes in fluorophores*

Abstract: Following the path toward on-demand control of quantum states, we develop a method to give rise and to populate a hybrid quantum state in a fluorescent single molecule. In particular, we aim the creation of hybrid entangled states of electrons, photons, and vibrations, since this enables the frequency conversion over very different energy scales within a single-molecule device, pushing further the limits of speed and size, up to the single-molecule scale.

We focus on DBT molecules embedded in anthracene nanocrystals (DBT in AC) since they are well-established quantum emitters due to their narrow optical transitions and photostability. [1] By operating in the high-saturation regime, we establish quantum coherence between electronic and vibrational levels, forming non-classical vibronic entangled states. The interactions between these levels are engineered and manipulated through the use of two laser beams at different frequencies. When coherent coupling is achieved, population is coherently transferred from the

electronic state to the vibrational mode. This results in observable changes in fluorescence: specifically, a suppression of the zero-phonon line (ZPL) and an increase in decay rates [2,3]—both of which serve as indirect evidence of strong coupling and entry into a high-cooperativity regime. [4]

Our experimental observations confirm these effects under various two-color laser configurations, demonstrating the feasibility of synthetically engineering the energy diagram of a single molecule by tuning experimental parameters and pave the way for scalable molecular quantum technologies.

References

[1] Toninelli, Nat. Mater. 20 (2021): 1615–1628

[2] De Bernardis, Quantum Sci. Technol. 10 (2025) 045051

[3] Zirkelbach, J. Chem. Phys. 156 (2022): 104301

[4] Kimble, Phys. Scr. 127 (1998)

Marcia Frometa Fernandex (CNR-INO, LENS)

Titolo: *Angular momentum of rotating fermionic superfluids by Sagnac phonon interferometry*

Abstract: Fermionic many-body systems provide an unrivaled arena to investigate how interactions drive the emergence of collective quantum behavior, such as macroscopic coherence and superfluidity. Central to these phenomena is the formation of Cooper pairs, correlated states of two fermions that behave as composite bosons and condense below a critical temperature. However, unlike elementary bosons, these pairs retain their internal structure set by underlying fermionic correlations, essential for understanding superfluid properties throughout the BEC-BCS crossover. Here, we harness a sonic analog of the optical Sagnac effect to disclose the composite nature of fermionic condensates across the BEC-BCS crossover. We realize an in-situ loop interferometer by coherently exciting two counter-propagating long-wavelength phonons of an annular fermionic superfluid with tuneable interparticle interactions. The frequency degeneracy between clock- and anticlock-wise sound modes is lifted upon controllably injecting a quantized supercurrent in the superfluid ring, resulting in a measurable Doppler shift that enables us to probe the elementary quantum of circulation and the angular momentum carried by each particle in the fermionic fluid. Our observations directly reveal that the superflow circulation is quantized in terms of $h/2m$, where m is the mass of the constituents. Further, by operating our interferometer at tuneable temperature, we measure the thermal depletion of the superfluid in the unitary

Fermi gas, demonstrating phonon interferometry as a powerful technique for probing fundamental properties of strongly-correlated quantum systems.

Ilaria Gianani (Università Roma Tre)

Titolo: Spectral characterisation of biphoton states

Abstract: Encoding information in the time–frequency domain demonstrates its potential for quantum information processing. It offers a novel scheme for communications with large alphabets, computing with large quantum systems, and new approaches to metrology. It is then crucial to secure full control on the generation of time–frequency quantum states and their properties. Characterizing the spectral phase in particular poses a great challenge, one that has similarly been taken up by classical ultrafast metrology to control ultrashort pulses. In this seminar we will explore novel approaches to the spectral phase characterization of biphoton states spanning from techniques borrowed from classical ultrafast metrology to more directly quantum approaches.

Floriana Lombardi (Department of Microtechnology and Nanoscience, Chalmers University of Technology,)

Titolo: Tuning the Ground State of Quantum materials via Substrate Engineering

Abstract: In cuprate high-temperature superconductors, the doping level is fixed during synthesis, making it difficult to tune the charge carrier density—unlike in many two-dimensional materials. Recently, strain engineering has emerged as a powerful tool to control key properties of cuprates, particularly charge and spin orders, and their interplay with superconductivity. Thin-film cuprates offer further tunability through substrate surface morphology. In this presentation, I will show how nanofaceted substrates—formed during high-temperature reconstruction—induce electronic nematicity and a unidirectional charge density wave (CDW) in nanometer-thick $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ films. This results in a novel ground state, distinct from that of thicker films and single crystals. Remarkably, these structural modifications also lead to a strong enhancement of superconducting properties: the superconducting onset temperature increases by over 20 K, and the upper critical magnetic field) is enhanced by more than 50 T compared to single crystals with the same doping level. These enhancements can be attributed to an effective interfacial potential at the film-substrate boundary, which captures the impact of the nematic and CDW order. These findings establish a new paradigm in which substrate engineering offers a powerful strategy for high performance superconducting materials.

Sabrina Maniscalco (Algorithmiq/University of Helsinki)

Titolo: TBA

Abstract: TBA

Elena Missale (Fondazione Bruno Kessler)

Titolo: *Centri di colore in diamante: strumenti e tecniche per una fabbricazione flessibile*

Abstract: I centri di colore nei semiconduttori rappresentano una delle piattaforme più promettenti nell'ambito delle tecnologie quantistiche di nuova generazione. Grazie alla loro capacità di emettere singoli fotoni, questi difetti puntuali consentono progressi significativi nel sensing quantistico, nella computazione e nelle comunicazioni su larga scala. Per integrarli efficacemente in dispositivi quantistici, è cruciale generare centri di colore in modo controllato in termini di densità e di posizionamento laterale all'interno della matrice cristallina. Presso FBK disponiamo di laboratori in cui tecniche avanzate di nanofabbricazione si combinano con strumentazione ottica ad alte prestazioni.

Grazie alla tecnologia di Focused Ion Beam (FIB), siamo in grado di produrre difetti quantistici in semiconduttori a larga band gap con precisione laterale inferiore ai 100 nm, controllando sia la profondità tramite l'energia del fascio sia il numero di ioni impiantati, così da ottenere singoli emettitori. A questo si aggiunge la possibilità di effettuare avanzate analisi ottiche attraverso l'utilizzo di un microscopio confocale per misure Raman/PL con sensibilità di singolo fotone, equipaggiato con un interferometro HBT per le misure di antibunching, che consente una caratterizzazione minuziosa dei centri di colore come sorgenti quantistiche a stato solido. In questo lavoro saranno presentati i risultati ottenuti nella formazione di emettitori quantistici nel diamante basati su centri GeV^- e SiV^- , creati mediante l'impianto delle rispettive specie ioniche con il FIB, e la loro integrazione in strutture fotoniche come i nanopillars. L'impiego del FIB consente inoltre di realizzare regioni conduttive tramite la grafitizzazione del diamante, utili per creare strati conduttivi integrati o sepolti, necessari per pilotare elettricamente i centri colore o per ottenere elettrodi con un buon contatto ohmico. Infine, saranno illustrati la realizzazione di centri NV poco profondi (shallow) mediante impianto broad-beam, particolarmente indicati per costruire sensori essendo prossimi alla superficie, e i progressi nello sviluppo di tecniche per la fabbricazione controllata di lamelle di diamante destinate alla nano-termetria quantistica.

Shreyasi Mukherjee (Università di Catania)

Titolo: *Detection of Noise Correlations in Small Quantum Networks by Machine Learning*

Abstract: We investigate a machine learning based classification of noise acting on a three-level system with the aim of detecting spatial or multilevel correlations, and the interplay with Markovianity. We control a three-level system by inducing coherent population transfer exploiting different pulse amplitude combinations as inputs to train a feedforward neural network. We show that supervised learning can classify different types of classical dephasing noise affecting the system. Three non-Markovian ((1) quasi-static correlated, (2) quasi-static anti-correlated and (3) quasi-static uncorrelated) and (4) Markovian noises are classified with more than 99% accuracy. On the contrary, Markovian (4a) correlated and (4b) anti-correlated noise cannot be discriminated with our method. We then extend the protocol to a network of two ultrastrongly coupled qubits driven by symmetric STIRAP-based control. Remarkably, in this case, our approach achieves over 95% accuracy in classifying these noise classes, including classification between Markovian correlated and anti-correlated noise. The method requires minimal experimental resources, relying solely on three inputs to a shallow neural network, without the need for time-series data or real-time monitoring. Our results highlight how the combination of coherent control and machine learning analysis can improve the characterization of quantum-hardware.

Michela Nazzaro (Università di Napoli)

Titolo: *Q-Train: Quantum Tech Transfer to Industry*

Abstract: The rapid expansion of quantum technologies demands new models of industrial capacity building capable of connecting low-TRL quantum research with real-world innovation cycles. Q-TRAIN responds to this need through an evidence-based, multi-layered training and tech-transfer architecture designed for managers, engineers and innovation officers. Its mission is to demystify quantum technologies, enhance industrial readiness and align companies with national and European funding instruments - addressing both the gap between fundamental research (TRL 1–4) and industrial adoption, and the difficulty organizations face in evaluating and strategically positioning quantum technologies.

Its first implementation, "Calcolo Quantistico: un approccio full-stack" – a two-day training initiative at the University of Naples Federico II – combines hands-on sessions on key software frameworks (Qiskit, tensor networks) with an overview of emerging hardware platforms (superconducting, photonic, NMR). Beyond technical upskilling, Q-TRAIN builds an interface layer between high-complexity quantum research and corporate decision-making, equipping participants with tools to identify quantum-enabled innovation opportunities, understand hybrid HPC–QC architectures and navigate funding ecosystems.

Aligned with the emerging European paradigm of distributed quantum-skills infrastructures Q-TRAIN adopts an iterative, data-informed structure aimed at

scalability. It offers a reproducible blueprint for bridging research and industry, contributing to a concrete national pathway toward quantum readiness.

Elena Nieto Hernández (Fondazione Bruno Kessler)

Titolo: *Verso la fabbricazione di emettitori a singolo fotone integrati in SiC*

Abstract: Il carburo di silicio (SiC) si sta affermando come una piattaforma solida e scalabile per dispositivi quantistici, grazie alla possibilità di operare sia a temperatura ambiente sia in criogenia, alla maturità nella integrazione con componenti elettroniche e alla presenza di emettitori a singolo fotone nel vicino infrarosso (NIR).

I centri di colore più studiati nel SiC legati soltanto a difetti intrinseci, come le vacanze di silicio (VSi) e le vacanze divacanza (VV), mostrano proprietà di spin rilevanti per il quantum sensing ed emissioni coerenti adatte alle comunicazioni quantistiche. Tuttavia, la realizzazione ripetibile e integrata di questi emettitori in dispositivi fotonici ed elettronici rimane una sfida aperta.

In questo lavoro, sviluppiamo un approccio per la fabbricazione localizzata di singoli centri VV e VSi mediante impiantazione ionica tramite Focused Ion Beam (FIB), combinata con protocolli di annealing ottimizzati. La variazione delle dosi di impianto, delle specie ioniche, delle condizioni di annealing e del tipo di substrato è utilizzata per individuare una ricetta deterministica per la formazione controllata di sorgenti a singolo fotone che possano essere integrate nelle strutture fotoniche.

Loredana Parlato (Università di Napoli)

Titolo: *Superconducting nano/microstrip single photon detectors: from device fabrication to quantum applications*

Abstract: In the last decades the advancing of quantum information science concerning quantum computation, quantum communication and sensing has largely pushed the development of single-photon detectors (SPDs). Conventional semiconducting SPDs, such as photomultipliers and avalanche photodiodes, are successfully used for visible light detection but their performance drastically worsens in detecting near-infrared photons. Conversely, superconducting materials with an energy gap of a few meV, could allow to detect single photons with high efficiency in a wide range of wavelengths, from ultraviolet to mid-infrared range [1]. From 2001 [2] significant developments in SNSPDs technology produced detectors characterized by >95% detection efficiency DE (the probability of detecting a single photon), picosecond time resolution, milli-Hertz dark count rates DCR (false detecting events) and nanosecond recovery time [1, 3]. High-performance commercial products based on NbN or NbTiN SNSPDs in customized cryostats are now available both for quantum and interdisciplinary technologies for operation up to 1550 nm wavelengths where they outperform semiconducting materials. However, many challenges are still open to optimize the performance of these devices for specific applications such as the large area coverage. Superconducting microstrip single photon detectors (SMSPDs) are increasingly attracting the interest of the

scientific community as a new platform for large area detectors with unprecedented advantaged in terms of fabrication. Moreover, there is an increasing demand of devices capable of detecting low-energy photons, as in free space communications, due to a reduced solar background, or space-ground integrated quantum network. We present our research activity regarding the impact of SNSPDs and SMSPDs in various applications including Quantum Key Distribution [4,5].

Martina Peluso (Università di Napoli)

Titolo: *Enhancing Quantum Key Distribution with Superconducting Nanowire Single-Photon Detectors*

Abstract: Quantum Key Distribution (QKD) enables the exchange of cryptographic keys with unconditional security, directly rooted in the fundamental principles of quantum mechanics. With their exceptional system detection efficiencies (SDE) and extremely low dark-count rates (DCR) at 1.55 μm , Superconducting Nanowire Single-Photon Detectors (SNSPDs) significantly enhance the performance of QKD systems, enabling record transmission distances as well as high key generation rates.

This work aims to evaluate the integration of low-DCR SNSPDs into a commercial QKD platform. Our system has demonstrated secure key exchange over metropolitan distances at rates up to 50 kbps. Future field tests on the Naples Quantum Metropolitan Area Networks (QMAN) will evaluate its performance in a real urban environment.

Paola Savarese (Università di Napoli)

Titolo: *Programmable non-Hermitian quantum walks via liquid-crystal metasurfaces*

Abstract: In recent years, non-Hermitian photonics has collected significant attention as a rising field in optics due to the emergence of numerous physical concepts and novel effects. Unlike systems described by a Hermitian Hamiltonian, where the Hermitian conjugate ensures system closure to the environment and energy conservation, a non-Hermitian system enables the description of open systems, facilitating an understanding of how a system can interact with its environment.

Here, we propose an innovative approach for simulating non-Hermitian dynamics by realizing a non-unitary photonic quantum walk based on a light beam propagating in free space and manipulated via step operators acting jointly on its polarization and transverse momentum. Within this framework, we use the latter degrees of freedom to encode the coin and walker systems, respectively, typically characterizing coined quantum walks. To induce spin-rotation, we utilize a uniform liquid-crystal (LC) plate and an LC dichroic polarization grating to obtain a spin-dependent non-unitary translation operation on the walker. Through the combination of liquid crystals and absorbing dyes, we can manipulate both polarization and light amplitude, effectively recreating a dispersive system. This development yields a compact and versatile

platform that significantly expands the scope of photonic simulations in studying quantum dynamics. It also introduces a new dimension for manipulating topological states, enabling the observation of phenomena such as those related to non-Hermitian topological phases.

Alessia Sorgi (CNR-INO)

Titolo: *Towards the Detection of Quantum Correlations in THz Quantum Cascade Lasers*

Abstract: Quantum technologies are rapidly expanding toward unconventional spectral regions, where the peculiar features of terahertz (THz) radiation open new opportunities for quantum sensing, metrology and communication. In this context, THz quantum cascade lasers (QCLs) have recently been identified as promising solid-state platforms for the generation of non-classical states of light. QCLs are, to date, the most efficient miniaturized lasers at THz frequencies. Their broad gain and controlled group velocity dispersion has recently enabled compact frequency comb (FC) generation, based on four-wave mixing (FWM) processes that take place within the gain medium. These processes are also responsible for generating quantum correlations among the FC modes. Therefore, QCL-FCs are ideal candidates for the generation of multimode squeezed states of light, due to the presence of quantum-correlated side-band modes. Demonstrating and detecting such correlations would unlock quantum-enhanced sensitivity and enable a new generation of THz applications, including improved spectroscopic techniques, sub-shot-noise imaging, and advanced sensing schemes based on nonclassical states of light.

Nevertheless, accessing quantum correlations at THz frequencies remains highly challenging because of limited detector performance and the lack of suitable optical components. I will introduce the main practical limitations and present our first steps toward a dedicated experimental platform. I will discuss the design and characterization of a THz grating, a key component for spectral selection and mode manipulation, and therefore crucial for building a simple experimental setup to enable squeezing measurements, i.e. twin-beam quantum-correlation detection in THz QCL-Fcs.

Vittoria Stanzione (Università di Pisa)

Titolo: *Tailoring transport in quantum spin chains*

Abstract: The interplay of disorder space-time heterogeneous collisional noise shapes the transport dynamics of anisotropic spin chains. Localization-delocalization transitions are found across regimes with single and multiple excitations. Space homogeneous collisions favor the shaping of regions where the localization degree sets in the form of subsequent plateaus at a rate and duration universally scaling with the collision rate. It is possible to establish relevant connections to noise-engineering

of quantum devices in noisy intermediate-scale quantum simulators platforms, and to realistic biological systems where noise and disorder coexist.

Rosa Vaira (Università di Bari)

Titolo: *Towards Correlation Plenoptic Imaging with entangled photons*

Abstract: Correlations in light beams enable surpassing many classical limits in the field of imaging. Here, we implement a quantum imaging setup using SPDC-generated entangled photons and investigate the information provided by the second-order correlation function $G^{(2)}$ while operating in the many-photon regime. The aim is to explore the potential to perform multi-photon ghost imaging and Correlation Plenoptic Imaging (CPI) with enhanced SNR. In particular, CPI enables 3D imaging, depth resolution, and volumetric reconstruction.

Paola Verrucchi (CNR - Istituto dei Sistemi Complessi)

Titolo: *Unsupervised Learning to Recognize Quantum Phases of Matter*

Abstract: Drawing the quantum phase diagram of a many-body system in the parameter space of its Hamiltonian can be seen as a learning problem, which implies labelling the corresponding ground states according to some classification criterium that defines the phases. In this work we adopt unsupervised learning, where the algorithm has no access to any priorly labeled states, as a tool for determining quantum phase diagrams of many-body systems. The algorithm directly works with quantum states: given the ground-state configurations for different values of the Hamiltonian parameters, the process uncovers the most significant way of grouping them based on a similarity criterion that refers to the fidelity between quantum states, that can be easily estimated, even experimentally. We benchmark our method with two specific spin-1/2 chains, with states determined via tensor network techniques. We find that unsupervised learning algorithms based on spectral clustering, combined with "silhouette" and "elbow" methods for determining the optimal number of phases, can accurately reproduce the phase diagrams. Our results show how unsupervised learning can autonomously recognize and possibly unveil novel phases of quantum matter.

Mara Vizzuso (Università di Napoli)

Titolo: *Non-adiabatic self-healing of Trotter errors*

Abstract: Trotter errors reflect the inexact representation of time evolution operators generated by non-commuting Hamiltonian terms in digitized quantum dynamics. In the adiabatic regime, these errors are known to exhibit a self-healing behavior, where competing dynamical and discretization effects are naturally suppressed within the adiabatic approximation. Here, we demonstrate that this

self-healing behavior persists at finite evolution times, provided that transition-induced errors are properly compensated. Using both non-interacting and interacting spin models, we characterize the scaling of this finite-time self-healing with respect to the Trotter step and the total evolution time. Counterdiabatic driving is employed to correct the nonadiabatic errors, and to disentangle their contribution from leading-order Trotter terms. The results show that the dominant harmonic component of the error governs the observed cancellation, clarifying the dynamical mechanism underlying the self healing behavior. This work establishes finite-time self-healing as an intrinsic property of digitized quantum dynamics and explains its origin beyond the adiabatic regime.

Louise Wolswijk (CNR-INO)

Titolo: *Towards a new quantum computing platform based on Yb atoms in optical tweezer arrays*

Abstract: Alkaline-earth-like atoms are emerging as promising candidates for next-generation, fault-tolerant quantum computing platforms. We are developing a new experiment based on fermionic ^{171}Yb atoms in programmable arrays of optical tweezers. Optical tweezer arrays offer a platform in which the atomic geometry can be arbitrarily reconfigured by programming the phase mask imprinted on the tweezer laser beam using a spatial light modulator (SLM). Rapid rearrangement of atoms within the array can also be performed using a pair of acousto-optic deflectors (AODs). The two nuclear-spin states of ^{171}Yb will be used as robust, long-lived qubits, while the metastable clock state enables quantum-error-correction protocols that exploit ground and metastable states as ancilla and data qubits. Multiqubit gates will be implemented through state-selective coupling to Rydberg states. I will present recent updates on the construction and progress of our new experimental apparatus.

Ayesha Zaheer (Università di Napoli)

Titolo: *2D MXene-Based Hybrid Platforms for Next-Generation Quantum and Bio-Sensing Interfaces*

Abstract: Two-dimensional Ti_3C_2 MXene is emerging as a promising material platform for next-generation quantum-inspired sensing technologies, owing to its tunable electronic states, metallic conductivity, and strong light-matter interactions. In this work, we present MXene-metal nanoparticle hybrid structures synthesized through controlled $\text{HF} + \text{HCl}$ etching, LiCl -assisted delamination, and a self-reduction route that uniformly decorates MXene flakes with Au nanoparticles. Structural and optical analyses (XRD, SEM, TEM, EDXS, UV-Vis) confirm successful exfoliation, expanded interlayer spacing, and robust MXene-AuNP hybrid formation. These engineered interfaces exhibit enhanced charge-transfer dynamics and optical responsiveness, enabling highly sensitive detection performance. By advancing MXene architectures toward miniaturized and quantum-dot-like regimes, this platform provides a compelling pathway for quantum-relevant sensing interfaces and future device engineering.

