Titles and Abstracts for Trieste MAWI Conference 2025 in Chronological Order

Tuesday, 18. February:

Speaker: Natalia Bruno
Title: Experimental quantum optics and quantum information
Abstract: The course will give an introduction to experimental quantum optics and quantum information, main experiments, basic tools and open challenges. We will see how to practically prepare and measure quantum states of light, discrete variables and single photon detectors, continuous variables, and learn basic notions and measurement techniques for the study of light-matter interactions with applications in quantum communication and sensing.

Speaker: Marco Fattori
Title: Differential Mach-Zehender interferometry with trapped Bose Einstein condensates
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Abstract: We report on the first realization of a gradiometric sensor based on Mach-Zehender trapped atom interferometers. By using innovative Beat Note Superlattices [1] we create an array of double-well traps loaded with Bose Einstein condensates of atomic potassium. Once the collisional scattering length is cancelled with a broad magnetic Feshbach resonance, we can operate the beam splitters of the interferometers with simple control of the tunneling probability of the atoms through the central barrier. This allows us to determine the phase of each interferometer without releasing the atoms from the trap and measuring the final atomic population in the two modes. The simultaneous operation of the interferometers allows us to perform a differential analysis and cancel the common phase noise of the sensors. A coherence times of several hundred milliseconds is reported [2].
Our system opens the possibility to exploit quantum entangled states in trapped atom interferometry, even in presence of strong noise and paves the way to high precision measurements of forces with high spatial resolution. In the long term, we envision the possibility of exploiting our system for the measurement of higher-order interaction terms, such as magnetic dipolar interaction and three-body elastic collisions and the production of maximally entangled atomic quantum states.
[1] L. Masi et al. “Spatial Bloch oscillations of a quantum gas in a “beat-note” optical superlattice”, PRL **127** 020601 (2021).
[2] T. Petrucciani et al. in preparation.

Speaker: Federico Cerisola
Title: Nanoscale electro-mechanical systems for quantum information
Abstract: State of the art nanoscale electro-mechanical devices are promising platforms for future quantum information applications thanks to their ability to reach very high quality factors. In this talk, I will discuss our ongoing work on two such platforms and their potential applications. First, I will present recent experimental work with quantum dots on suspended carbon nanotubes. I will present evidence of quantised electron transport through quantum dots, and the interplay between spin qubits and mechanical motion. In particular, I will discuss how we exploited these effects to implement an autonomous Landauer erasure process. Moreover, I will discuss the first ever experimental observation of coupling between spin qubits and mechanical motion of the CNT, which is mediated by the strong spin-orbit coupling present in the system. The observation of this spin-mechanics coupling further opens the doors to a new range of experimental applications such as sensing and the manipulation of quantum states of the oscillator. Second, I will discuss our current ongoing efforts towards designing a mechanical qubit using suspended graphene membranes in an electrical circuit. Via careful design of these electro-mechanical

systems, heating and environmental dissipation can be suppressed, to finally exploit the quadratic coupling between the mechanical displacement and the electric field. This non-Gaussian interaction is an essential ingredient for quantum information processing. Short term applications include two-phonon cooling, the creation of non-classical mechanical states, quantum non-demolition measurements. The long-term goal is the creation of a mechanical qubit that can be coherently manipulated.

Speaker: Pasquale Calabrese
Title: The quantum Mpempa effec
Abstract: The Mpemba effect is a striking and counterintuitive phenomenon in which, under certain conditions, hotter water cools more quickly than colder water. Although originally observed in classical systems, recent theoretical and experimental studies have uncovered an analogous effect in extended quantum systems.
A specific manifestation of this quantum effect occurs when the system starts in a state that explicitly breaks a given symmetry, yet the time evolution leads to the eventual restoration of that symmetry, sometimes at an unexpectedly fast rate.
To systematically investigate this phenomenon, we introduce the entanglement asymmetry, a quantity which quantifies the degree of symmetry breaking in a quantum state. This measure is inspired by concepts from entanglement theory in many-body systems and provides a powerful tool to track the restoration of symmetry over time. By leveraging entanglement asymmetry, we gain new insights into non-equilibrium quantum dynamics and the fundamental mechanisms governing symmetry restoration.
This talk will explore the theoretical foundations of the quantum Mpemba effect, recent experimental observations, and the implications of entanglement asymmetry for understanding non-equilibrium processes in quantum many-body physics.

Speaker: Aurélien Perrin
Title: Engineering atomic interactions with Feshbach resonances
Abstract: Collisional properties of ultracold atoms are fully encoded in the scattering length, a parameter that is nearly proportional to the phase shift that appears in the scattering states of the relative motion between two atoms. When the energy of such scattering state becomes nearly degenerate with a bound molecular state, the scattering phase shift can experience abrupt changes giving rise to a so-called Feshbach resonance. Taking advantage of the Zeeman effect to continuously tune the energy of scattering states, many Feshbach resonances have been observed and characterized experimentally for a large variety of atomic species. Novel techniques relying on optical, microwave or radiofrequency fields have also been explored in more recent years.
Feshbach resonances have now become a central tool in the development of experimental platforms dedicated to quantum simulations, allowing for a fine control of the interaction properties of the system, from the attractive to the repulse regime. In this seminar, I will review the theoretical basis of Feshbach resonances and illustrate when relevant with recent observations realized with sodium atoms on our experimental setup.

Speaker: Tomas Fernholz
Title: Towards an atomic Sagnac interferometer - state-dependent transport of dressed atoms
Abstract: Over recent years, atomic Sagnac interferometers have reached sensitivities that rival their optical counterparts.
In particular their high level of accuracy - or bias stability - makes them promising tools for inertial navigation.
For the realisation of compact devices, it is desirable to explore interferometers that use guided or trapped atoms rather than free-falling ensembles.
Here, I will present our approach based on radio-frequency-dressed potentials and discuss recent results on the state-dependent transport of atoms

around a loop above a chip surface. I will also present first results on a method to reduce an inherent potential mismatch leading to an improvement of coherence time.

Speaker: Diego Blas (Online)
Title: Quantum technologies for gravitational wave searches
Abstract: In this talk I will explain how gravitational waves can be detected with detectors at the frontier of quantum sensing, including large scale atom interferometers, electromagnetic cavities and magnetometers. My target is to trigger discussion and interest on how to foster the dialogue to exploit the current revolution in the quantum frontier for new milestones in fundamental physics.

Wednesday, 19. February:

Speaker: Hsu Chung Chuan (Michael)
Title: The Atom Interferometer Observatory and Network (AION): searching for fundamental physics with ultracold strontium atoms
Abstract: The Atom Interferometry Observatory and Network (AION) [1], a consortium of UK institutes, is developing a network of long-baseline atom interferometer to search for fundamental physics effects, such as decihertz gravitational waves, scalar- and vector-ultralight dark matter, fifth-force searches, and macroscopic tests of quantum mechanics. AION will complement current detectors, bridging frequency gaps for gravitational waves and setting bounds on dark matter models.
At the University of Cambridge, we are developing advanced cooling and transport technologies for long-baseline atom interferometry in AION. Our work aims to realise the efficient production and rapid delivery of ultracold atomic ensembles via enhanced optical transport techniques, aiming to achieve high repetition rates and meet stringent sensitivity requirements. This will support integration into long-baseline interferometers (10m–1km) for enhanced sensitivities. I will present our progress in these key technologies for AION.
[1] Badurina, L., et al. Journal of Cosmology and Astroparticle Physics, 2020(05)

Speaker: Greta Firenze
Title: Gravity survey using a differential quantum gravimeter
Abstract: The DQG is a double atom interferometer capable of measuring simultaneously gravity and vertical gravity gradient. The access to both quantities distinguishes it from previous devices only measuring one of them. This makes it a potentially powerful tool to perform gravity surveys. In order to evaluate this potential, together with the Lisbon Archeological Center (CAL), the Portuguese Quantum institute (PQI) and in collaboration with the FIQUgS project, we performed a gravity and gravity gradient survey in the streets of downtown Lisbon, with the goal of detecting a XVIIIth century sewer.
From the survey we were able to produce a map for each of the measured quantities. It was shown that the SNR of the gradient signal was significantly better than for gravity in this case. Further analysis using inversion techniques produced a cartography of the local mass density variations, revealing the presence of cavities compatible with the sewer network.

Speaker: Angelo Bassi
Title: Precision tests of models of spontaneous wave function collapse
Abstract: Quantum mechanics is founded on the superposition principle, which underlies both its remarkable success and technological potential, as well as the conceptual challenges in its interpretation. The question of why superpositions do not extend from the microscopic to the macroscopic scale remains a topic of debate. Spontaneous wave function collapse models have been proposed to account for the gradual breakdown of quantum superpositions in sufficiently large systems. These models achieve this by modifying Schrödinger dynamics, making them empirically testable. Since the predicted deviations are extremely small, their detection requires high-precision measurements. In this talk, I will review collapse models and discuss the latest experimental tests.

Speaker: Christoph Amtmann
Title: A quantum interference magnetometer for scientific space applications
Abstract: The Coupled Dark State Magnetometer is an all-optical scalar magnetometer based on the quantum interference effect of coherent population trapping in rubidium. The instrument was designed and developed for scientific space missions in Graz by the Institute of Experimental Physics at Graz University of Technology and the Space Research Institute of the Austrian Academy of Sciences.
The magnetometer was launched into space for the first time in 2018. Currently, it is operating on three space missions: the China Seismo-Electromagnetic Satellite (CSES-1), the Jupiter Icy Moons Explorer (JUICE), and the Macau Science Satellite-1 (MSS-1).
The talk will give an overview of the magnetometer's measurement principle, its space-oriented design, and its application in space onboard the CSES-1 and JUICE spacecraft.

Speaker: Francesco Scazza
Title: Ytterbium atoms in optical tweezers for fermionic quantum simulations
Abstract: I will report on a novel experimental apparatus developed in Trieste, allowing to cool and trap ytterbium atoms in optical tweezer arrays. Odd (fermionic) ytterbium isotopes present instrumental features for effective state preparation and detection, while offering a unique interaction toolbox for novel fermionic simulations. I will first present our experimental schemes for laser cooling, loading and imaging individual tweezer-trapped fermionic ytterbium atoms with ~Hz repetition rates. In particular I will focus on a recently implemented fast single-atom resolved imaging scheme, which does not rely on strong and/or magic wavelength confinement and works also in free space. I will then illustrate near-future research directions, enabled by coherent control of the clock state with single-atom resolution in ultracold mesoscopic ensembles.

Speaker: Alberto Biella
Title: Correlated quantum Zeno effect in a monitored qubit dimer via stochastic Gutzwiller ansatz
Abstract: In this talk I will discuss the stochastic dynamics of two qubits subject to one- and two-site correlated continuous weak measurements [1]. When measurements dominates over the local unitary evolution the system's dynamics is constrained and part of the physical Hilbert space becomes inaccessible: a typical signature of the Quantum Zeno (QZ) effect. The competition between these two measurement processes give rise to two distinct QZ regimes, we dubbed standard and correlated, characterised by a different topology of the allowed region of the physical Hilbert space being a simply and non-simply connected domain, respectively. The transition between these two phases and an ergodic region where the entirety of the Hilbert space is accessible is discontinuous and is reflected on the structure of classical two-site correlation function. We develop a theory based a stochastic Gutzwiller ansatz for the wavefunction which is able to capture the structure of the phase diagram. Finally we show how the two QZ regimes are intimately connected to the topology of the flow of the underlying non-Hermitian Hamiltonian governing the no-click evolution. [1] S. Zeni, G. Chakraborty, A. Romito, A. Biella, *in preparation*.

Speaker: Fabio Franchini
Title: The Frustration of Being Odd
Abstract: We consider the effects of combining periodic boundary conditions inducing geometrical frustration with quantum interaction, a setting we call "topological frustration" (TF). Already in 1D spin chains we observe the emergence of phenomenologies precursor of systems with massive amount of frustration, rendering it an ideal platform for bottom-up studies that clarifies the effect of frustration. In this seminar I will introduce these concepts and show how to exploit TF to improve the performance of a quantum battery.

Thursday, 20. February:

Speaker: Krueger
Title:
Abstract:

Speaker: Lucas Mairhofer
Title: Quantum Communication Technologies
Abstract: Quantum Computers put new demands for the exchange for information. On the one hand Shor's algorithm will soon allow breaking the cryptographic standards which nowadays secure virtually all our communication in the the internet. On the other hand, connecting quantum computers in networks requires the exchanging quantum states between those computers over long distances.
Quantum Communication allows exchanging Qubits between several parties. This can be used to share cryptographic key, which cannot be broken even by quantum computers. On the other hand, this will allow building networks of Quantum Computers.
The talk gives an overview over physical principles behind quantum communication technologies as well as an overview of groundbreaking experiments as well as the current state of the art.