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Book of Abstracts

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Security of Quantum Key Distribution

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The security of classical cryptosystems is based on the assumption about the impossibility of solving certain mathematical problems, like the factorization of large numbers. Unfortunately the advent of quantum computers represents a serious problematic owing their exponentially higher computational power; this problem is known as "quantum threat". However quantum mechanics can be as well exploited to build new cryptographic protocol like in the case of Quantum Key Distribution (QKD). QKD can be considered the quantum answer to the quantum threat, being its security based on the properties of quantum systems and thus no more depending on the technological advancement. A particular QKD protocol known as BB84 will be described and the tools needed to study its security will be introduced.

Session 4 / 3

Multipartite Entanglement and Quantum Frustration

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Frustration is a phenomenon commonly encountered in various domains, from social and psychological contexts to the realm of physics. In particular, the concept of frustration has a significant role in quantum systems, where it describes situations in which the individual components of a system cannot achieve a globally optimal state due to conflicting interactions. This presentation will delve into the distinction between multipartite and bipartite entanglement, we will introduce computational algorithms for simulating a large number of quantum states, particularly focusing on systems of multiple qubits. The talk will explain how frustration emerges in these quantum systems and how it can be studied computationally through statistical approaches. Specifically, we will analyze the distribution of bipartite and multipartite entanglement in frustrated systems, revealing how frustration affects different states, including random states and states with uniform real-phase distributions. Through this analysis, we will highlight the distinct ways in which frustration manifests in different types of quantum states.

Session 1 / 4

Axions from Neutron stars mergers: production and detection signatures

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In this work, the flux of axions produced during the merger of two neutron stars has been studied. To compute the flux, the most recent neutron star merger models have been employed. Subsequently, the flux of observable gamma rays resulting from the conversion of these axions in the Galactic magnetic field have been estimated.

Session 1 / 5

Asymptotics of open quantum systems: a (quite) gentle introduction

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In this talk we will discuss some basic notions about
the dynamics of open quantum systems, with a particular focus on
the asymptotic evolution of the system.
After recalling the dynamics of closed quantum systems, we will review
how the states and the evolution are described in the open-system scenario.
Moreover, the definition of the asymptotic subspace will be introduced and
justified.
In the last part of the seminar, I will discuss several recent results about
the large-time dynamics of open quantum systems.

Session 1 / 6

Two-states Ornstein-Uhlenbeck particle in a trapping potential

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In recent years, much attention has been paid to the observation of non-Gaussian probability density functions for diffusing systems in a variety of experiments and theoretical models, as such property could entail new physical insight. In this work, we solved analytically the Langevin equation of motion in the overdamped regime of a particle moving both in absence and in presence of a harmonic potential, assuming the diffusion coefficient to be a Telegraph Process, i.e. the diffusion coefficient changes stochastically between two states. We computed analytically the first four momenta of the distribution of the particle position observing a non-Gaussian behaviour for short times. We found that the duration of the non-Gaussian behaviour decreases with the strength of the confinement and increases with the increasing of the microscopic time scale of the subordinating process. The

relations we determined can become a very useful tool in experiments to determine the value of the unknown microscopic time scale starting from the value of kurtosis.

Session 2 / 7

Robustness of quantum symmetries against perturbations

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A privileged role in the description of a quantum system is played by symmetries, which are operators that remain constant in time (in the Heisenberg picture). It is well known that these are represented by operators that commute with the Hamiltonian of the system.
Quantum symmetries can be further classified based on their stability with respect to perturbations of the Hamiltonian. There are robust symmetries, which, despite the perturbation, stay close to their initial values throughout the evolution. On the other hand, fragile symmetries accumulate significant deviations from their initial values over time due to the perturbation. Our goal is to provide a precise characterization of both robust and fragile symmetries.

Session 2 / 8

The Hawking-Unruh Effect

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The Unruh effect is a quantum field prediction according to which a uniformly accelerated observer in the vacuum detects thermal particles with a temperature directly proportional to its acceleration. In other words, an accelerating thermometer in empty space will record a non-zero temperature.
This phenomenon is closely related to the Hawking effect, which describes the theoretical thermal radiation emitted by a black hole. The connection is provided by the equivalence principle, which shows how the two effects are the manifestation of the same physical phenomenon.

Session 3 / 9

Primordial Graviton Production and Detection Prospects in the Pre-Big Bang Scenario

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I will discuss the interpretation of the NANOGrav signal as a relic stochastic background of primordial gravitons, potentially produced within the framework of string cosmology's pre-big bang scenario. We demonstrate that this interpretation encounters limitations within a minimal version of the scenario; however, it becomes feasible when considering generalized, non-minimal extensions, even while preserving the S-duality symmetry intrinsic to string theory. In both scenarios, a significant gravitational wave signal could be produced, with the potential to be detected across multiple frequency ranges by upcoming interferometers, including Advanced LIGO, ET, LISA, and DECIGO.

This presentation will be based on:

1. I. Ben-Dayan, G. Calcagni, M. Gasperini, A. Mazumdar, E. Pavone, U. Thattarampilly and A. Verma, *Gravitational-wave background in bouncing models from semi-classical, quantum and string gravity*, JCAP **09**, 026 (2024).
2. P. Conzinu, G. Fanizza, M. Gasperini, E. Pavone, L. Tedesco, and G. Veneziano, *Constraints on the parameters of the Pre-Big Bang scenario from NANOGrav data* (in preparation).

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Simulation of quantum algorithms and quantum many-body systems

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The inadequacy of conventional computers in simulating the behavior of many-body quantum systems, due to their limited computational resources, has led to the development of quantum computers, based upon the intrinsic properties of quantum systems themselves. While an ordinary computer operates on classical bits, a quantum computer is built upon qubits, which are two-level quantum systems that can be in states other than "0" and "1", thanks to superposition. However, building a working quantum computer is really challenging due to quantum noise, which is introduced in the simulation by external manipulations of the qubits.
The promise of quantum computers, together with quantum algorithms, is the achievement of a computational speedup with respect to the best known classical algorithm in solving the same task, regardless of the fact that it is related to quantum mechanics.
In parallel with the development of quantum computers, new methods have also been developed in recent years to enable and improve quantum-inspired simulations on classical computers, among which Tensor Networks (TN) methods that allow to simulate with good approximation large many-body quantum systems on classical computers. The key idea of these methods is to efficiently model a composite quantum state by means of a Tensor Network (TN). TNs enable to efficiently represent quantum states by encoding their relevant information into a series of small tensors, representing the individual components of a multi-partite quantum system. Thus, by arranging and connecting the tensors in a specific way, tensor networks allow to capture information about the entanglement structure of the encoded state.
Due to their ability to efficiently, though approximately, simulate large quantum states on ordinary computers, TN methods have gained ground recently in many fields, including applied mathematics, machine learning, chemistry, condensed matter physics and quantum information theory.
In this talk, I will present an overview of TN quantum-inspired simulation methods, focusing especially on matrix product states (MPS), and discuss some applications of these techniques in implementing quantum algorithms (e.g., quantum Fourier transform) and emulating the dynamics of many-body systems (e.g., waveguide QED).

Session 3 / 11

Heavy meson decays as precision tools for new physics: A search for beyond Standard Model signals

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During the years several tensions were found between experimental results and Standard Model (SM) predictions, in particular in the flavour sector. Individually, these anomalies are not large enough to disproof SM but all together they are telling us that a theory beyond it is required. In particular, measurements of semileptonic B decays are pointing out a violation of the lepton flavour universality (LFU) of the SM, an accidental symmetry broken only by the Yukawa interactions. Furthermore, two different determinations of the Cabibbo–Kobayashi–Maskawa (CKM) matrix elements
$lvertV_{ub}$
$lvert$ and
$lvertV_{cb}$
$lvert$ from exclusive and inclusive B decays are in tension between them. These issues related to B decays indicate that these processes are an interesting subject to investigate for the presence of new physics (NP) that can explain one or all of the anomalies.

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High frequency gravitational waves shining in photons in Galactic magnetic fields

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High-frequency gravitational waves (f
$gtrsim$ MHz) are a smoking gun for the existence of exotic physics. Indeed, GW backgrounds generated in the early Universe could be characterized by high-frequency signals, allowing one to probe inflation, first-order phase transitions, topological defects and primordial black holes. The lack of current and future gravitational waves experiments sensitive at those frequencies leads to the need of employing different indirect techniques. Notably, one of the most promising one is constituted by graviton-photon conversions in magnetic fields. In this talk, I will focus on conversions of a stochastic gravitational wave background into photons inside the Milky-Way B-fields, taking into account the state-of-the-art models for both regular and turbulent components. I will discuss how graviton-to-photon conversions may lead to unexpected imprints in the Cosmic Photon Background (CPB) spectrum in the range of frequencies $f \sim 10^9 - 10^{26}$ Hz. Hence, the absence of any significant evidence for a diffuse photon flux induced by gravitational-wave conversions induce stringent constraints on the gravitational-wave strain h_c.

Session 2 / 13

Work Fluctuations, Singular Distributions and Big Jumps for a Harmonically Confined Active Particle

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Within the framework of Large Deviation Theory, Large Deviation Functions (LDFs) describe the asymptotics of probability distribution of time-integrated observables and assign fluctuations of any intensity a probability value, thus outperforming the central limit theorem. LDFs hold significant physical importance in the context of statistical mechanics as they provide extensions of the concept of free energy to out-of-equilibrium settings. Moreover, peculiar functional forms and singularities can be interpreted as distinct hallmarks of peculiar dynamical behaviours. In this talk we will present a collection of our recent findings concerning this subject. Our setting is that of single Brownian particles under the effect of a confining harmonic potential and an active force modelling self propulsion. These models are inspired by Active Matter systems, in which each single component is able to transform energy from the environment or internal reservoirs into directed self-propelled motion. Our interest focuses on the fluctuations of Active Work, i.e. the work performed by the active force, due to its physical significance: it captures the energy cost to sustain self propulsion itself and defines thermodynamical efficiency of active engines. Our simple but not trivial setting allows us to tackle the problem analytically for both stationary and generic uncorrelated initial states. Our results show that harmonic confinement can indeed induce singularities in the LDF of Active Work, with linear tails at large positive and negative work values occurring for sufficiently large active force, harmonic confinement and/or initial values. By looking at the system trajectories, we discover that these singularities are associated to peculiar dynamical behaviours: concentrated large values, or big jumps, in the displacement and active force at the initial or ending points of such trajectories. Our results thus uncover a connection between singular LDFs and big jumps, revealing that a condensation-like physical mechanism is in action and also that boundary terms play a relevant role in the problem a hand.

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Probing the structure of chi_c1(3872): heavy quark symmetries at work

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Since 2003, a number of hadronic states have been observed with properties that challenge their classification as predicted by the quark model. Many of these states have a charm-anticharm component in their quark content and are therefore referred to as charmonium-like states.
The first of these states, chi_c1(3872), was observed in 2003 by the Belle collaboration. This observation has been confirmed by several other experiments.
More than twenty years have elapsed since the discovery of chi_c1(3872), and a great amount of theoretical and experimental efforts have been devoted to studying its properties, decays, and production mechanisms. Despite this extensive work, a full understanding of the structure of this state is still missing. Moreover, several other charmonium-like states have been observed that need to be properly identified.
In this talk, I discuss how, exploiting the heavy quark large mass limit, it is possible to analyze radiative decays of chi_{c1}(3872) to S-wave charmonia assuming that it is an ordinary charmonium state. The interest lies in the fact that these modes have been recognized as useful probes for understanding the nature of this state.

Session 1 / 15

Lepton masses and mixing from S3 modular symmetry - an mcmc analysis

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This work presents a detailed analysis of the origin of lepton masses and mixing angles within the framework of S3 modular symmetry.
The main goal is to achieve a consistent theoretical framework for the hierarchy of lepton masses and mixing angles, leveraging the symmetry properties of the modular group.
The model analysis is carried out using the Markov Chain Monte Carlo method to improve the parameter space testing and obtain optimal values compatible with experimental data on leptons.

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Coexistence of Defect Morphologies in Three-Dimensional Active Nematics

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Within a living cell, motor proteins like kinesin are responsible of the transport of intracellular components. The functioning of this active transport is well known, and it has been employed to build synthetic assemblies of microtubules, which are stirred at the level of the single components and evolve out of thermal equilibrium. Such system is a paradigmatic example of an active material, and its realisation has originated lasting efforts, aimed to understand its crucial properties.
The presence of activity drives chaotic flow at the large scale and a sustained proliferation of topological defects, that retain some unique properties compared with passive liquid crystals. We use numerical simulations of a simple model of nematic liquid crystals in the presence of a microscopic active stress to study the morphology and dynamics of these topological defects to deduce fundamental properties of the turbulent state.
In a 3D periodic geometry, a statistically relevant wrapping component is present and quantitatively compatible with a phenomenon of defects percolation. Moreover, while the linear size of finite defects scales linearly with active length, it verifies an inverse quadratic dependence for wrapping defects. The shorter is the active length scale, the more times the defect lines wrap around the periodic boundaries, resulting in extremely long and tangled structures.

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TBA

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Dynamical cluster-based optimization of tensor network algorithms for simulating quantum circuits with finite fidelity

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