A look at the interface between gravity and quantum theory
July 23-25, 2025

Abstracts booklet

Davide Giordano Ario Altamura (University of Trieste, Italy)
Title: Enhancement of the effects due to the Schrödinger-Newton equation
The Schrödinger-Newton (SN) equation introduces a nonlinear self-gravitational term to the standard Schrödinger equation, offering a paradigmatic model for semiclassical gravity. However, the small deviations it predicts from standard quantum mechanics pose significant experimental challenges. We propose a novel method to amplify such deviations through periodic modulation of the trapping frequency in a levitated mechanical oscillator. We identify specific regimes where the SN-induced effects on the dynamics of second moments are significantly enhanced—by up to six orders of magnitude compared to unmodulated setups. We show that this protocol remains feasible within current magnetic levitation technologies and enables distinguishability between standard and SN dynamics using measurable quantities such as the position variance. Our results pave the way for a viable experimental test of the SN equation, offering a new route to probe the interface between quantum mechanics and gravity.

Oliviero Angeli (University of Trieste, Italy)
Title: Probing the Quantum Nature of Gravity through DiffusionTBA
The quest to determine whether gravity is quantum has challenged physicists since the mid-20th century, due to the impracticability of accessing the Planck scale, where potential quantum gravity effects are expected to become relevant. While recent entanglement-based tests have provided a more promising theoretical path forward, the difficulty of preparing and controlling large mass quantum states has hindered practical progress. We present an alternative strategy that shifts the focus from complex quantum state manipulation to the simpler observation of a probe's motion. By proving that a classical and local gravitational field must inherently display randomness to interact consistently with quantum matter, we show that this randomness induces measurable diffusion in a probe's motion, even when the probe is in a classical state. This diffusion serves as a distinctive signature of classical gravity coupling to quantum matter. Our approach leverages existing experimental techniques, requiring only the accurate tracking of a probe's classical center-of-mass motion, and does not need any quantum state preparation, thereby positioning this method as a promising and practical avenue for advancing the investigation into the quantum nature of gravity.

Moisés Bermejo (Bilkent University, Turkey)
Title: Causal observables and forcing
Forcing is a technique extensively used in set theory to extend models of mathematics by adding certain "generic" objects. The fundamental theorem of forcing establishes an internal language to describe the extension, where the satisfiability of statements follows the rules of intuitionistic logic. The role of intuitionistic logic in physical theories can be traced to synthetic differential geometry (Kock) and in foundational approaches involving variable sets (Takeuti), sheaf logic (Caicedo and Benavides), and more generally topos theory (Isham, Butterfield, and Döring), where several

connections with quantum theory have been investigated, such as the emergence of classicality. Moreover, concepts such as \"causal horizon\" can be defined within the forcing language relative to an internal causal structure, in the spirit of Markopoulos. The aim of this talk is to show how these approaches naturally fit within the framework of forcing and to suggest new avenues for discussion at the intersection of quantum theory and gravity.

Marion Cromb (University of Nottingham, UK)
Title: Creation of a black hole bomb instability in an electromagnetic system
The amplification and generation of electromagnetic radiation by a rotating metallic or lossy cylinder, first theorized by Zel'dovich in the 1970s, is tightly connected to the concepts of energy extraction from rotating black holes and runaway mechanisms such as black hole bombs. Recent advances include acoustic analogues of the Zel'dovich effect and the observation of a negative resistance in a low-frequency electromagnetic model. Here, we demonstrate experimentally that a mechanically rotating metallic cylinder not only definitively acts as an amplifier of a rotating electromagnetic field mode but also, when paired with a low-loss resonator, becomes unstable and acts as a generator of such a mode, seeded only by noise. The system exhibits an exponential runaway amplification of rotating electromagnetic modes thus demonstrating the electromagnetic analogue of Press and Teukolsky's 'black hole bomb'. The exponential amplification from noise supports theoretical investigations into black hole instabilities and is promising for the development of future experiments to observe quantum friction in the form of the Zel'dovich effect seeded by the quantum vacuum. arXiv:2503.24034

Andrea Di Biagio (IQOQI Vienna, Austria)
Title: A tale of two localities
The discussion of theory-independent theorems about gravity mediated entanglement raises the question of the difference between relativistic locality and circuit locality. The first arises naturally in field theory and is based on spacetime regions, while the second is based on the notion of subsystems and is a basic principle of quantum-information theory. We will see how the two are seen to be interconnected and we will argue that, given our field-theoretic understanding of the world, subsystem locality is an effective, derived notion. We will also discuss the relevance for the no-go theorems for gravity-mediated entanglement.

Lajos Diosi (Wigner Research Center for Physics, Hungary)
Title: TBA
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Adrian Kent (University of Cambridge, UK)
Title: Constraints on gravitational interferometry revisited
I review arguments by Mari et al., Belenchia et al. and Danielson et al. analysing thought experiments in which a distant Bob measures the gravitational field of Alice's gravitional interferometer and potentially decoheres her system. I give an extended version of the experiment which clarifies that Bob is able to observe the effect of Alice's gravitational dipole, rather than the quadrupole. I discuss other extensions of the experiment which give improved bounds on Bob's decoherence rate and thus improved lower bounds on the time required for successful interferometry by Alice. I explore further the analysis of such experiments within relativistic quantum field theory.

Marius Krumm (University of Innsbruck, Austria)
Title: A relativistic variational quantum circuit
The field of relativistic quantum information seeks to understand the quantum information properties of relativistic quantum systems. A popular approach for this purpose is the Unruh-DeWitt model for qubits interacting with quantum fields on curved spacetime. In my talk, I will present a relativistic variational quantum circuit (VQC) in which the interaction between qubits is mediated by the relativistic quantum field. An important consequence is that the tunable time evolution of the qubits depends on spacetime properties and quantum field propagators. Therefore, our VQC presents first steps in a quantum machine learning approach that seeks to extract quantum properties of spacetime and fields when no hand-crafted protocol is available. Our approach works in a regime in which the time evolution of the qubits is unitary and the quantum field does not act as a decohering environment, which we believe to be interesting in its own right.

Julen Simon Pedernales (Ulm University, Germany)
Title: TBA
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Nicolò Piccione (University of Trieste, Italy)
Title: Newtonian Gravity from a Poissonian Spontaneous Collapse Model
A possible path to merge quantum mechanics and gravitation is to keep spacetime classical and have it interact with quantum matter through a measurement and feedback process. Tilloy and Diósi (TD) took a first step in this direction by sourcing Newtonian gravity on spontaneous continuous measurements. However, this allows for negative mass readings and a potentially unstable vacuum in the relativistic version. Here, we investigate a model based on spontaneous Poissonian measurements which does not have these problems because the gravitational field associated with empty space is exactly vanishing, contrary to the TD case predicting it to be zero on average. As in the TD case, the model is experimentally testable, the Newtonian classical field is recovered upon averaging, and additional decoherence appears due to the gravitational back-reaction. We study general features of this model and treat in detail the decoherence of a single particle and a rigid spherical body. Phenomenologically, the most striking difference from TD models is that the additional decoherence due to gravity is short-ranged and that the spatial decoherence can be lower than what is set by the so-called principle of least decoherence.

Martin Plávala (Leibniz Universität Hannover, Germany)
Title: Probing the nonclassical dynamics of a quantum particle in a gravitational field
In quantum mechanics, the time evolution of particles is given by the Schrödinger equation. It is valid in a nonrelativistic regime where the interactions with the particle can be modelled by a potential and quantised fields are not required. This has been verified in countless experiments when the interaction is of electromagnetic origin, but also corrections due to the quantised field are readily observed. When the interaction is due to gravity, then one cannot expect to see effects of the quantised field in current-technology Earth-bound experiments. However, this does not yet guarantee that in the accessible regime, the time evolution is accurately given by the Schrödinger equation. Here we propose to measure the effects of an asymmetric mass configuration on a quantum particle in an interferometer. For this setup we show that with parameters within experimental reach, one can be sensitive to

possible deviations from the Schrödinger equation, beyond the already verified lowest-order regime. Performing this experiment will hence directly test the nonclassical behaviour of a quantum particle in the gravitational field.

Antoine Tilloy (Mines Paris - PSL, France)
Title: TBA
TBA

Germain Tobar (Stockholm University, Sweden)
Title: Compelling Tests of Quantum Gravity with Gravitational Wave Detectors
Gravitational wave detectors are emerging as powerful platforms to probe the quantum nature of gravity. In this talk, I will present two possible approaches that could provide direct evidence for gravitational field quantisation. First, I will show how single gravitons may be detected via stimulated absorption in quantum-limited acoustic resonators, offering a gravito-phononic analogue of the photoelectric effect, providing the first experimental signature of gravitons. Second, I will discuss how pre-existing entanglement in gravitational waves could be witnessed through violations of inseparability criteria, unachievable by any classical field theory. Together, these tests would combine to provide both initial evidence and unambiguous confirmation of gravity's quantum nature.

Marko Toroš (University of Ljubljana, Slovenija)
Title: Relativistic Dips in Entangling Power of Gravity
The salient feature of both classical and quantum gravity is its universal and attractive character. However, less is known about the behaviour and build-up of quantum correlations when quantum systems interact via graviton exchange. In this work, we show that quantum correlations can remain strongly suppressed for certain choices of parameters even when considering two adjacent quantum systems in delocalized states. Using the framework of linearized quantum gravity with post-Newtonian contributions, we find that there are special values of delocalization where gravitationally induced entanglement drops to negligible values, albeit non-vanishing. We find a pronounced cancellation point far from the Planck scale, where the system tends towards classicalization. In addition, we show that quantum correlations begin to reemerge for large and tiny delocalizations due to Heisenberg's uncertainty principle and the universal coupling of gravity to the energy-momentum tensor, forming a valley of gravitational entanglement.
Ref: Relativistic Dips in Entangling Power of Gravity M Toroš, M Schut, P Andriolo, S Bose, A Mazumdar Phys. Rev. D 111, 036026 (2025); Relativistic Effects on Entangled Single-Electron Traps M Toroš, P Andriolo, M Schut, S Bose, A Mazumdar Phys. Rev. D 110, 056031 (2024)

David Trillo (CUNEF Universidad, Spain)
Title: Entanglement generation from gravity: the Diósi-Penrose model
The most popular proposals of table-top experiments to demonstrate the quantum character of gravity involve the measurement of gravitationally induced entanglement. Contrary to popular belief, we show that models of classical gravity interacting with quantum matter are also able to produce entanglement in matter. We study in great detail the most prominent of these: the Diósi-Penrose (DP) model. We show that its entanglement generation capabilities are qualitatively different than those of semi-classical gravity, and that these experiments have the capability to rule out so-far unexplored regions of the parameter space of the DP model.