Avenues of Quantum Field Theory In Curved Spacetime 2025

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Tours

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Displacement memory for flyby

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Zel'dovich and Polnarev, in their seminal paper on the displacement memory effect [1], suggested that particles hit by a burst of gravitational waves generated by flyby would be merely displaced. Their prediction is confirmed by fine-tuning the wave profile, which is the derivative of a Gaussian proposed by Gibbons and Hawking [2], or of its approximation by a P\"oschl-Teller potential. The latter admits that analytic solutions are consistent with numerical investigations. The study is extended to higher-order derivative profiles as proposed, e.g., for gravitational collapse, etc.
(in collaboration with P.-M. Zhang and Q.-L. Zhao)

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Ground state for a real scalar field in the cosmic string spacetime with arbitrary boundary conditions

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We consider a real, massive scalar field in the cosmic string spacetime. First, we determine all admissible boundary conditions that can be applied at the conical singularity, and we find that no "bound state" solutions exist under these conditions. Next, we construct the two-point function for the ground state that satisfies these boundary conditions, deriving an explicit closed-form expression. Additionally, we analyze the singularities of the resulting two-point functions, demonstrating that they meet the Hadamard form requirement in every globally hyperbolic subregion of the cosmic string spacetime.

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Kinetic theory for electrons in Landau level basis and thermal transport of IQHE: Keldysh QFT in a curved spacetime

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The purpose of this project is to formulate a kinetic theory describing thermal transport of electrons in a uniform magnetic field of arbitrary magnitude and a temperature gradient. Following Luttinger's point of view, the effect of a temperature gradient is equivalent to a gravitational field and, thus, described by a curvature of spacetime. Using Keldysh formalism, we derive the quantum kinetic equation using the Landau-level basis in a torsional and curved spacetime. In the weak-field limit, the lowest order approximation of the quantum kinetic equation reduces to a Boltzmann equation into which the magnetic field enters as the Lorentz force. As an application of our quantum transport

equation, we calculate magneto-thermoelectric coefficients of a disordered two-dimensional electron gas (2DEG) in the quantum hall regime.

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Tensorial chiral gauge theories, generalized anomalies, dynamical symmetry breaking, and Natural Anomaly Matching

Auteur: Kenichi Konishi[1]

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I will discuss the strong-interaction dynamics of tensorial chiral gauge theories in four dimensions, extending previous work on other chiral gauge theories such as the Bars-Yankielowicz or Georgi-Glashow models, based on the consideration of the generalized symmetries and mixed anomalies. The stricter 't Hooft anomaly matching conditions for these new anomalies strongly suggests the systems to go through dynamical colour-gauge symmetry (and flavor symmetry) breaking, caused by certain bifermion condensate, against the hypothesis of confinement, with or without (gauge-invariant multifermion) condensates. The Natural Anomaly Matching mechanism ensures that the conventional as well as new generalized anomalies, with respect to the symmetries which are not spontaneously broken, are fully UV-IR matched by the massless fermions in the low-energy effective theory.

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Hawking Radiation and Scattering Amplitudes

Auteurs: Donal O'Connell[1]; Matteo Sergola[2]; Rafael Aoude[1]

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I will present a novel approach to compute Hawking radiation based on on-shell scattering amplitudes.

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How curved backgrounds affect communication between quantum systems

Auteur: Alessio Lapponi[1]

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Wireless communication between quantum systems can be modeled using a pair of Unruh-deWitt detectors interacting with a field in the background. Leveraging quantum properties, this approach could enhance the ability to send classical messages over distances and pave the way for transmitting quantum information. Motivated by these possibilities, we develop a quantum communication protocol using harmonic oscillator detectors coupled to a field and generalize it for any background spacetime. The communication capacities of the resulting channel are sensitive to the gravitational field of the background, suggesting that a curved spacetime could improve communication performance. Furthermore, this setup offers a novel means to probe the quantum characteristics of gravitational fields by analyzing the channel's behavior.

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Rectangular vielbein in Einstein-Cartan gravity

Auteur: Sergey Bondarenko[1]

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We consider a model of Einstein-Cartan gravity with rectangular vielbein field introduced. A particular case with five internal indexes for the four-dimensional Riemann manifold is explored. As a result we obtain an additional vierbein field absent in the regular formulation of the Einstein-Cartan gravity with equal number of the Riemann and internal indexes. The new vierbein field allows to account the complete internal spin symmetry space of the Dirac fermions in an unified manner by an introduction of the term with γ^5 matrix in the original Dirac's equation through the new vierbein. We discuss a condition requested for the formulation of the theory of the new vierbein as a theory of new field field in the ordinary four dimension space-time.

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Decoherence of Primordial Perturbations and Maldacena's Consistency Condition

Auteurs: Fumiya Sano[1]; Junsei Tokuda[2]

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Supported by observational evidence indicating that cosmological scalar perturbations were nearly Gaussian at the beginning of the universe, it is anticipated that the origin of these perturbations is quantum fluctuations. Consequently, cosmic inflation provides a valuable setting for testing the quantum nature with/of gravity. Quantumness is characterized by features such as quantum coherence, quantum entanglement, and quantum incompatibility of measurements, all of which are sensitive to the specific setup of the observation. The quantum correlations between observable system and environment during inflation is induced by gravitational non-linearities. In this work, we provide a convenient way to calculate the decoherence using Maldacena's consistency condition. Furthermore, we discuss several consequences arising from taking into account all the interactions in the same perturbative order, such as regularization of divergences, the local observer's effect, etc.

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The poor people's Quantum gravity: hydrodynamics with fluctuations

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Ideal hydrodynamics, as a generally covariant theory, can
be considered as a simplified version of general relativity. We will
show that this general covariance is intimately related to statistical
mechanics underlying local thermalization. We will then describe the
problem of including statistical fluctuations in relativistic
non-ideal hydrodynamics, a still open issue connected to the still mysterious onset of thermalization in small systems. We will show that most approaches to this so far break general covariance, and outline a way to resolve this issue, based on expanding in statistical cumulants
rather than gradients, imposing fluctuation-dissipation relations and including general covariance at the outset.
We close by discussing the analogies of this problem with the one of
quantization of gravity.

Based on 2307.07021 , 2109.06389 and ongoing work

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Band Flattening and Overlap Fermion

Auteur: Taro Kimura[1]

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We show that, for each symmetry class based on the tenfold way classification of topological insulators/superconductors, the effective Dirac operator obtained by integrating out the additional bulk direction takes a value in the corresponding classifying space, from which we obtain the flat band Hamiltonian. We then obtain the overlap Dirac operator for each symmetry class and establish the Ginsparg-Wilson relation associated with C and T symmetries, and also the mod-two index theorem.

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Qubit Picture of the Vacuum Energy

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We develop a non-conventional description of the vacuum energy in quantum field theory in terms of quantum entropy. Precisely, we show that the vacuum energy of any non-interacting quantum field at zero temperature is proportional to the quantum entropy of the qubit degrees of freedom associated with virtual fluctuations. We prove this for fermions first and then extend the derivation to quanta of any spin.

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Nontrivial self-consistent backreaction of quantum fields in 2D dilaton gravity

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We consider (1+1)-dimensional dilatonic black hole with two horizons, canonical temperatures of which do not coincide. We show that the presence of quantum fields in such a background leads to a substantial backreaction on the metric: 2D dilatonic analog of the semiclassical Einstein equations are solved self-consistently, and we demonstrate that taking into account of backreaction leads to a geometry with two horizons with coinciding temperatures.

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Quantum Uncertainty and Superposition under the Influence of Gravity

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Investigating quantum mechanical principles within the context of gravity reveals significant insights into how spacetime curvature fundamentally influences quantum phenomena, particularly regarding the uncertainty principle and quantum coherence. This study presents a covariant Generalized Uncertainty Principle (GUP) that incorporates curvature-induced modifications to canonical commutation relations, resulting in non-commutative position operators. Adopting a geometric formalism, we establish a connection between the uncertainty principle and momentum space geometry, which is modeled as a four-dimensional extension of Lobachevsky space, where the Riemann curvature is dictated by modified dispersion relations. Additionally, we analyze gravitational decoherence as driven by the Riemann curvature tensor, demonstrating its consistent role in diminishing quantum coherence within gravitational fields. In contrast to kinematic effects, curvature-induced decoherence persistently disrupts quantum superpositions, thereby providing a direct relationship between the structure of spacetime and the behavior of quantum systems.

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Qubit Casimir effect

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A new interpretation of the Casimir effect is presented, in which the Casimir energy is expressed as the quantum "Von Neumann" entropy associated to a 2-qubit, mixed, non-separable, pseudo-density

matrix of the quantum fluctuations. This new interpretation draws parallels to the concept of quantum inseparability of quantum information theory and suggest that the Casimir energy is a measure of the entanglement of quantum fluctuations.

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Removing spurious degrees of freedom from EFT of gravity

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Effects of ultraviolet completions of gravity can be captured in low-energy regimes by local higher curvature corrections. Such description, however, is limited to yield strictly perturbative corrections, due to unphysical Ostrogradsky instabilities induced by higher derivatives in the correction terms. I will present a procedure for expunging spurious degrees of freedom from effective theories of gravity, and casting them as lower-derivative theories that capture all the information about the corrections, but propagates only the massless spin-2 graviton degree of freedom. Resulting reduced theories fall under the category of Minimally modified gravity theories, that preserve spatial diffeomorphisms, but modify temporal diffeomorphisms in a way that preserves the constraint structure. Such theories are free from Ostrogradsky instabilities, and can be used to study the ultraviolet effects self-consistently.

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Causal symplectic geodesic structures in terms of bilinear functionals for Haag- Araki theory

Auteur: Evgeniy Gudkov[None]

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In this paper, a proof of the theorem on the global hyperbolicity of space-time M on the sphere S^4 is proposed based on the topology of open light cones; the work uses the so-called concrete approach to the construction of the Haag-Araki axiomatics.
The properties of causal geodesic structures on the paracompact complement of space-time are investigated.1. A description of quasi-equivalent sectors has been created within the framework of super selection rules\\
2. It is proven that each layer on a star-shaped surface is a projective limit for a tubular region in axiomatic field theory on a factor space\\
3. It is proved that the temporal ordering operator of the causal geodesic structure in the symplectic case

1. The advantages from the point of view of physical motivation for choosing the criterion of extended isotonia are indicated \\
2. A superstructure on the Bowen-Waters ultrametrics has been introduced in relation to axylmatic quantum field theory.\\
3. A new proof of the generalized Cook's criterion for ω_o states of the system has been found, based on the SEM (condition for positive energy on the symplectic layer).

4. It is shown that the Markovian time ordering operator $T^{*}_{\check{\omega}\lambda}$ has a closed spectrum The author has proven the following theorem Let there be a pseudo-Riemannian metric E with signature $(+,-,+-)$ in class C^p on which there is an isomorphism defining an almost complex structure (E,σ) with gauge function σ, which defines a family of symplectic forms of the form $d\lambda^n$. This theorem can be reformulated like this:\par\textit{A symplectic structure based on the 1-form $d\sigma$ in the class C^p has a contractible fiber . For this purpose, an auxiliary lemma was proved. \\ \textit{Lemma 1. $\exists$ at least 1 vector $v_b^a \perp TM$ non-orthogonal to the timelike surface } In order to find an object suitable for proving Lemma 1, it is necessary to prove the following theorem \begin{theorem} The paracompact complement of spacetime $\check{M}$ is a non-extensible globally hyperbolically complete spacetime

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Field redefinition and its impact in relativistic hydrodynamics

Auteur: Rajeev Singh[1]

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In this talk, I will explore the impact of field redefinition on the spectrum of linearized perturbations in relativistic hydrodynamics. I show that the spectrum of hydrodynamics modes is never affected by the local field redefinition, however, the spectrum of the non-hydrodynamic modes is affected. Through an appropriate all-order redefinition, non-hydrodynamic modes can be eliminated, leading to a new frame where the spectrum contains only hydrodynamic modes. We also show that the resulting stress-energy tensor may have an infinite series in momentum space, with a convergence radius linked to the eliminated non-hydrodynamic mode. In certain special cases, higher-order terms in the stress-energy tensor under field redefinition may cancel, indicating that non-hydrodynamic modes are mere artefacts of the fluid variable choice and hold no physical significance, even if they appear to violate physical constraints. Using a special toy example, I will give a criterion to distinguish between physical and unphysical non-hydrodynamic modes.

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Quantum effects in cosmological free-streaming

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We calculate the energy density and pressure of a scalar field after its decoupling from a thermal bath in the spatially flat Friedman–Lemaître–Robertson–Walker space-time, within the framework of quantum statistical mechanics. By using the density operator determined by the condition of local thermodynamic equilibrium, we calculate the mean value of the stress-energy tensor of a real scalar field by subtracting the vacuum expectation value at the time of the decoupling. If the expansion rate is comparable or larger than mass or the decoupling temperature, both energy density and pressure get strong quantum corrections which substantially modify their classical dependence on the scale factor a(t) and drive pressure to large negative values.

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Tunneling method for Hawking radiation in analogue gravity

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Analogue Hawking radiation from acoustic horizons is now a well-established phenomenon, both theoretically and experimentally. Its persistence, despite the modified dispersion relations characterizing phonons in analogue spacetimes, represents an evidence of the robustness of this effect against the ultraviolet non-relativistic modification of the particles' behavior. Previous theoretical explanations of this effect are based on Bogoliubov transformations, relating asymptotic states, for which an analytical treatment represents a hard challenge and usually stops at the leading order around the relativistic limit.
In this talk (based on ArXiv:2406.14603) I will address the analogue Hawking effect making use of the tunneling method. Within a unified treatment, I will show how the simplicity of this method allows to describe both the case of superluminal and subluminal dispersion relations, going beyond the leading order approximation. I will clarify also the mechanism behind the puzzling appearance of excitations for horizonless spacetimes, namely for a subcritical flow, which are expected in the case of subluminal dispersions.

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Probing the Big Bang with Quantum Fields

Auteur: Marc Schneider[1]

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The singularity theorems of Penrose and Hawking are based on geodesic incompleteness and predict the occurrence of classical singularities under rather general circumstances. In general relativity, these singularities represent absolute boundaries where space-time ends.
Physically, however, this criterion refers to the fate of point like classical test particles. We raise the question: What if one uses quantum fields instead? Intuitively, quantum probes are much more fundamental and bear a richer structure. We will begin with the proof that one can unambiguously evolve quantum fields across them in a rigorous sense. Thus when probed with quantum fields, the big bang is not an absolute boundary where physics breaks down. Additionally we will discuss the behavior of composite operators such as the expectation values of renormalized products of fields and the renormalized stress-energy tensor and show that they too remain well-defined as distributions.
The overall conclusion is twofold: first quantum mechanical considerations provide more refined tools to probe classically singular structures, and second, the big bang singularity of classical general relativity is tamer when seen from a quantum perspective.

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Perturbatively Confined Phase of QCD under Imaginary Rotation

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In this talk, we will report our recent achievements based on refs. [1,2]. Below are highlights from our results.

Perturbative Confinement under Imaginary Rotation
We perturbatively calculated the Polyakov loop potential at high T by introducing *imaginary* angular velocity. Under the rapid imaginary rotation, the potential favors zero Polyakov loop, i.e. confinement. In ref. [1], we found a phase transition to confinement around $\omega/T = i\pi/2$. Furthermore, we argued that this perturbatively confined phase can be smoothly connected to the hadronic phase.

Chiral Symmetry Breaking
In ref. [2], we introduced fermions and investigated the chiral phase transition. Our results show the spontaneous breaking of chiral symmetry in our previously found confined phase with imaginary angular velocity for any high T.

Inhomogeneity
In ref. [2], we also showed that the Polyakov loop potential exhibits an inhomogeneous distribution of the Polyakov loop. There should appear a spatial interface separating the confined phase and the deconfined phase in imaginary rotating systems. Although the analytical continuation to real rotation has some subtle points, the inhomogeneity can presumably persist in real rotating systems.

[1] S. Chen, K. Fukushima, and Y. Shimada, Phys.Rev.Lett. 129 (2022)
[2] S. Chen, K. Fukushima, and Y. Shimada, Physics Letters B, 859 (2024)

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Quantum-corrected anti-de Sitter space-time

Auteur: Elizabeth Winstanley[1]

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We study the back-reaction of a quantum scalar field on anti-de Sitter (AdS) space-time. The renormalized expectation value of the stress-energy tensor operator (RSET) for a quantum scalar field on global AdS space-time acts as a source term on the right-hand-side of the Einstein equations for the quantum-corrected metric. We find the RSETs for rotating and nonrotating thermal states on global AdS and compare them with results from relativistic kinetic theory. We then solve the quantum-corrected Einstein equations. We interpret these quantum-corrected metrics as asymptotically-AdS solitons.

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Dynamical de Sitter conjecture and its applications to quintessence

Auteurs: Kunihito Uzawa[1]; Muneto Nitta[2]

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The de Sitter conjecture yields a severe bound on scalar potentials for a consistent quantum gravity. We extend the de Sitter conjecture by taking into account the kinetic term of the scalar field. We then apply such an extended de Sitter conjecture to a quintessence model of inflation for which dynamics of the scalar field is essential, and obtain an allowed region for parameters of the scalar potential wider than previously considered. The new bounds in the swampland conjecture could have implications in several situations to construct compactification models.

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Resummations (or how pairs are created in quantum field theory)

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Recently there has been a considerable debate about possible novel mechanisms for pair creation in the context of quantum field theories in external backgrounds. These results are based on appropriate resummation techniques that allow a nonperturbative analysis of the corresponding theory.

In this talk, we will review new developments in resummations for scalar, gauge and gravitational backgrounds, together with their physical applications. In particular we will focus on pair creation, summarizing the state of the art and explicitly showing the analogue of the Schwinger effect in gravity, as well as the role played by static fields.

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QCD at finite theta, magnetic field, and rotation

Auteur: Kenji Fukushima[1]

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The talk is based on two recent works: 2409.18652 about magnetovortical matter in collaboration with Koichi Hattori and Kazuya Mameda and a forthcoming paper about Chiral EFT for the system where finite θ and magnetic field B coexist, which was done in collaboration with Prabal Adhikari. In the former, we found a nontrivial interplay between the spin, the orbital angular momentum, and the magnetic field. In particular, if B is strong, the orbital angular momentum overcomes the spin, contrary to our physics intuition. In the latter, we specifically studied the phase transition at $\theta = \pi$ and again, the strong B would change the nature of the phase transition.

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The stress-energy tensor of an Unruh-DeWitt detector

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In this talk, we present a theoretical model to describe a finite-size particle detector, focusing on the derivation of its energy-momentum tensor from a covariant Lagrangian formulation. The model encompasses both the quantum field associated with the detector (ϕ_{D}) and the elements responsible for its localization: a complex scalar field (ψ_{C}) and a perfect fluid. The local interaction between the detector and the complex field is designed to ensure the quadratic integrability of the detector modes, while the fluid plays a crucial role in defining the spatial profile of ψ_{C}, guaranteeing precise localization in space. Furthermore, we explore the physical properties of the resulting energy-momentum tensor, including all system components. We demonstrate that, under general conditions, the derived energy-momentum tensor is physically consistent and satisfies the energy conditions. This approach opens new perspectives for modeling detectors in quantum and relativistic scenarios, offering a robust framework for future applications in field theory.

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Renormalization of the primordial inflationary power spectra

Auteurs: Silvia Pla Garcia[1]; Ben Stefanek[2]

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This project explores the effects of renormalization on the amplitude of the inflationary spectra at scales measurable in the cosmic microwave background.

Via a gauge-invariant analysis, it is explained why the standard prediction for the spectra on super-horizon scales is a late-time attractor while they are UV finite at all times. This result is independent of the equation of state after inflation, showing that the standard prediction is fully robust.

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Advances in quantum dynamics of photons in curved spacetime

Auteur: David Edward Bruschi[1]

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General relativity and quantum mechanics are the two frameworks through which we understand Nature. To date, they have been successful at providing accurate predictions of natural phenomena in their respective domains of validity. Many attempts to find a unified theory of Nature that can

describe all of observable phenomena have been tried with varying degrees of success. Regardless, the quest for unification remains open, and therefore continues.

One avenue for investigating the overlap of general relativity and quantum mechanics that is less ambitious but can still provide potentially observable and measurable predictions is that of (low energy) quantum field theory in curved spacetime viewed through the lens of quantum information. In recent years, a great deal of attention has been given to this approach, which has provided novel and intriguing insights into phenomena that can be tested in the laboratory.

We present updates on the investigation into the quantum nature of the gravitational redshift, seeking to understand which are the quantum dynamics that lead to the effective classical observable effect. We present the current state-of-the-art and discuss novel discoveries. We also discuss the place that this avenue of research has in the broader context of relativistic and quantum physics.

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Arnol'd cat lattice field theories as probes and frameworks for quantum effects in curved spacetime

Auteur: Stamatios Nicolis[1]

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Arnol'd cat maps describe accelerating observers that probe the near horizon geometry of extremal black holes, when the microstates can be resolved. As single particle probes, they display the requisite properties of fast scrambling, that is the hallmark of consistent information processing in black hole spacetimes and they satisfy the non-trivial requirements of eigenstate thermalization.
Recently a construction of coupled Arnol'd cat maps has been proposed. This leads to the definition of lattice field theories that do not possess an integrable limit, but can be completely solved. We review the construction, that is relevant for multiparticle probes of the near horizon geometry, as well as for providing a framework for describing the geometry itself.

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Gravitational S-matrix, infrared divergences and BMS representations

Auteur: Yannick Herfray[1]

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In the last years, it has been demonstrated that asymptotic symmetries of gravity (the so called BMS group) constrain the gravitational S-matrix. In particular, infrared divergences of the gravitational S-matrix are now understood to arise from to the impossibility of the usual fock space of massless particles to ensure the conservation of the BMS charges.

I will review these results taking the original perspective of representation theory: It is indeed natural to conjecture that asymptotic states suited for an infrared finite S-matrix should be unitary representations of the BMS group and thus BMS particles, rather than the usual Poincaré particles of Wigner.

In a recent work with X. Bekaert and L. Donnay we constructed explicitly such BMS particles and this talk aim to serve as an introduction for Xavier's.

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BMS particles

Auteur: Xavier Bekaert[1]

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Wavefunctions for unitary irreducible representations (UIRs) of the Bondi-Metzner-Sachs (BMS) group are constructed. They are shown to describe quantum superpositions of (Poincaré) particles propagating on inequivalent gravity vacua. This follows from reconsidering McCarthy's classification of BMS group UIRs through a unique, Lorentz-invariant but non-linear, decomposition of supermomenta into hard and soft pieces.

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Mimicking quantum field theory in curved spacetimes with classical open water channel flows

Auteur: Germain Rousseaux[1]

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In this talk, we will make a review of the recent achievements of Analogue Gravity in interfacial hydrodynamics with the purpose of probing field theory with tabletop experiments in the laboratory. We will present our daily measurements of Hawking radiation with water waves on the top of a decelerating inhomogeneous current emulating the scattering of light waves by an analogue horizon. We will show our measurements of the greybody factor of a hydraulic black hole by sending waves inside it as well as the demonstration of interstellar travel in both directions of a wormhole in between a black hole and a white fountain horizons. Finally, we will present a classification of the flow regimes amenable to Analogue Gravity experiments both without dispersion and with dispersion akin to a quantum gravity like behavior where the Planck scale role is played by the capillary length controlled by surface tension in the aquatic analogue.

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TBA

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TBA

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Emergent thermal space-time in rotating systems

Auteur: Matteo Buzzegoli[1]

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In this talk, I first summarize how systems at local thermal equilibrium are described by the partition function of the underlying QFT in a fictitious curved space-time constructed with the hydrodynamic fields [1]. I list how this duality has been used to study systems at thermal equilibrium in the presence of acceleration and rotation. In particular, I show how this helps to describe systems with macroscopic spin properties and to resolve the ambiguities related to the definition of a spin tensor [2]. Finally, I discuss how the spin-rotation coupling of a particle differs in a actual rotational space-time and in a rotating medium [3].

[1] M. Hongo, Annals Phys. 383 (2017);
M. Crossley, P. Glorioso and H. Liu, JHEP 09 (2017) 095;
M. Selch, R. A. Abramchuk and M. A. Zubkov, PRD 109 (2024) no.1, 016003
[2] M. Buzzegoli, A. Palermo, [2407.14345]
[3] M. Buzzegoli, D. Kharzeev, PRD 103 (2021) 116005 [2102.01676]

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Universality of curvature corrections in statistical QFT in curved space-time and analytic distillation

Auteurs: Francesco Becattini[1]; Francesco Palli[1]

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In this work, we present a new result concerning the stress-energy tensor of a quantum field theory at global thermodynamic equilibrium in curved space-time. By using known exact results in literature for the massless scalar free field in Minkowski, deSitter, antideSitter and Einstein static Universe, we demonstrate that the stress-energy tensor at equilibrium in curved space-time has the same expression, with the same coefficients, independently of the space-time if one requires the analyticity in the curvature tensors and the derivatives of the Killing vector defining equilibrium, i.e. local acceleration and vorticity. Specific corrections depending on the global properties of the space-time are always non-analytic for zero curvature and thermal vorticity. We conjecture that this feature is a general one which applies to any space-time and to any local observable for a given quantum field. We illustrate in some detail the method of analytic distillation which makes it possible to effectively extract the analytic part of functions expressed by complicated series.

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Quantum Inequalities and Cosmic Censorship

Auteur: Antonia Micol Frassino[1]

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In this talk, I will explore the impact of quantum corrections on black holes regarding spacetime inequalities and the weak cosmic censorship conjecture. I will present refined versions of the quantum Penrose and reverse isoperimetric inequalities, valid in three-dimensional asymptotically anti-de Sitter spacetimes, and discuss their implications for cosmic censorship and black hole entropy. Additionally, I will analyze test particle dynamics in quantum rotating BTZ black holes, showing that quantum effects strengthen cosmic censorship.

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Symmetry Breaking in Accelerated Frames: Can It actually Be Restored?

Auteur: Marco Pasini[1]

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In recent years, a considerable amount of literature has suggested that spontaneously broken quantum field theories can undergo a phase transition to an unbroken phase due to the effect of Unruh radiation, experienced by uniformly accelerated observers, at sufficiently high accelerations. However, earlier works (including one by Unruh himself) and standard renormalization techniques in curved spacetimes rule out this possibility. In this talk, we will explore the fundamental reasons behind this discrepancy. The main assumptions and differing considerations, whether explicitly or implicitly supported by the two distinct factions, will be discussed. Finally, conclusions will be drawn, aiming to compare the results obtained for uniformly accelerated systems with those of the more general gravitational case.

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Weyl Geometry in Weyl Semimetals

Auteur: Giandomenico Palumbo[None]

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A novel oscillatory behaviour of the DC conductivity in Weyl semimetals with vacancies has recently been identified [1], occurring in the absence of external magnetic fields. Here, we argue that this effect has a geometric interpretation in terms of a magnetic-like field induced by an emergent Weyl connection. This geometric gauge field is related to the non-metricity of the underlying effective geometry, which is physically induced by vacancies in the lattice system. As a consequence of our geometric model, we postulate that the chiral magnetic effect in Weyl semimetals can be affected by the presence of dynamical vacancies.

[1] J. P. Santos Pires, S. M. Joao, A. Ferreira, B. Amorim, and J. M. Viana Parente Lopes, Anomalous transport signatures in weyl semimetals with point defects, Phys. Rev. Lett. 129, 196601 (2022).

44

Inhomogeneous phases and natural boundaries in LSMq under rotation

Auteurs: Maxim Chernodub[1]; Sergio Morales Tejera[2]; Victor E. Ambruș[3]

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[2] *West university of Timisoara*

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Unbounded rigidly rotating systems necessarily lead to superluminal motion and are, therefore, considered pathological. Remarkably, recent studies on chiral symmetry breaking under rotation provide similar results in the rigorous bounded and formal unbounded approaches. As a particular example, we consider the linear sigma model coupled with dynamical quarks undergoing rigid rotation in unbounded Minkowski spacetime under the Tolman-Ehrenfest approximation. The thermodynamics of this rigidly rotating system induces, kinematically, an infinite local temperature state at the light cylinder, where the velocity of the system equals the speed of light. We show that the infinite-temperature cylinder serves as a natural boundary that shield the system against artifacts of superluminal motion outside of the cylinder. In addition, we demonstrate that the rotation-induced inhomogeneity of the system results into chiral symmetry restoration close to the light-cylinder. As a consequence, the rigidly rotating system cannot host a single chirally broken phase in the whole space. On the contrary, the system in a thermodynamic ground state resides in a mixed phase that comprises dynamically broken and dynamically restored phases located at different distances from the rotation axis.

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Gravitational Particle Production

Auteur: Michael Florian Wondrak[1]

Co-auteurs: Heino Falcke [2]; Walter van Suijlekom [3]

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[2] *Astrophyics, Radboud University Nijmegen*

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This talk discusses a new avenue to particle production in curved spacetimes and black hole evaporation using a heat-kernel approach in the context of effective field theory analogous to deriving the Schwinger effect. Applying this method to an uncharged massless scalar field in a Schwarzschild spacetime, we show that spacetime curvature takes a similar role as the electric field strength in the Schwinger effect. We interpret our results as local pair production in a gravitational field. Comparing the particle number and energy flux to the Hawking case, we find both effects to be of similar order. However, we question the relevance of the presence of a black hole event horizon.

The presentation is partly based on
Wondrak, van Suijlekom, Falcke, Phys. Rev. Lett. 130 (2023) 221502,
Wondrak, van Suijlekom, Falcke, Phys. Rev. Lett. 133 (2024) 229002.

46

Model-independent results on parity violation in the trace anomaly

Auteurs: Jérémie Quevillon[1]; Roman Zwicky[2]; Rémy Larue[3]

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Anomalous parity violation in four dimensions would be significant for phenomenology (baryogenesis, gravitational waves) and mathematical physics. Over the past decade, there has been a controversy in the literature as to whether free Weyl fermions give rise to (anomalous) parity violation in the trace of the energy momentum tensor; expressed by the Pontryagin densities $R\tilde{R}$ and $F\tilde{F}$. We proposed a resolution to this controversy based on the path integral, while addressing any ill-definiteness that arises.
In a subsequent work, we came to the stronger conclusion that for any theory compatible with dimensional regularisation, the Pontryagin-terms are equally absent. It is the finiteness of the diffeomorphism, the Lorentz and the gauge anomalies that prevents anomalous parity violation.

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Quantum strong cosmic censorship and black hole evaporation

Auteur: Benito A Juárez-Aubry[1]

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It is common folklore that semiclassical arguments suggest that in black hole evaporation an initially pure state can become mixed. This is known as the \emph{information loss puzzle} (or {\it paradox}). Here we argue that, if taken at face value, semiclassical gravity suggests the formation of a final singularity instead of information loss. A quantum strong cosmic censorship conjecture, for which we give a rigorous statement, supports this conclusion. Thus, there are no reasons to expect a failure of unitarity in black hole evaporation or for any quantum gravity theory that can 'cure' singularities.

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Rotating Quark Gluon Plasma in cylindrical geometry.

Auteur: Pracheta Singha[1]

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We study the effect of rotation on the confining and chiral properties of QCD using the linear sigma model with quarks coupled to the Polyakov loop in an attempt to resolve discrepancies between the first principle numerical and model-based analytical results. The rotational effects are incorporated through the formulation of this quasiparticle model in an effectively curved space-time metric. Ensuring the causality through spectral boundary condition in the curved co-rotating background, we obtain the phase diagrams in $T-\mu$ and $T-\Omega$ planes. A splitting between the confinement and

chiral phase transitions is discussed as a boundary effect. Finally, we also present a study of the moment of inertia as a function of angular frequency at different radii of the cylindrical system under consideration.

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A local diagnostic program for unitary evolution in general spacetimes

Auteurs: Ka Hei Choi[1]; Marc Schneider[None]; Stefan Hofmann[None]

[1] *Arnold Sommerfeld Center of Theoretical Physics, Ludwig Maximilian University of Munich*

Auteur correspondant k.choi@physik.uni-muenchen.de

We present a local framework for investigating non-unitary evolution groups pertinent to effective field theories in general semi-classical spacetimes. Our approach is based on a rigorous local stability analysis of the algebra of observables and solely employs geometric concepts in the functional representation of quantum field theory. In this representation, it is possible to construct infinitely many self-adjoint extensions of the canonical momentum field at the kinematic level, and by the usual functional calculus arguments this holds for the Hamiltonian, as well. However, these self-adjoint domains have only the trivial wave functional in common with the solution space of the functional Schrödinger equation. This is related to the existence of boundaries in configuration field space which can be penetrated by the probability flux, causing probability to leak into regions in configuration field space that require a more fundamental description. As a consequence the evolution admits no unitary representation. Instead, in the absence of ghosts, the evolution is represented by contractive semi-groups in the semiclassical approximation. This allows to quantify the unitarity loss and, in turn, to assess the quality of the semi-classical approximation. We perform numerical experiments based on our formal investigations to determine regions in cosmological spacetimes where the semiclassical approximation breaks down for free quantum fields.

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Heat kernel resummations on a constant axial field background

Auteur: César García Pérez[None]

Co-auteurs: Diego Mazzitelli [1]; Sebastian Franchino-Viñas [2]; Silvia Pla [3]; Vincenzo Vitagliano [4]

[1] *Instituto Balseiro*

[2] *Università di Genova*

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In this poster I will be sharing new calculations concerning heat kernel resummation schemes for quantum fields on a flat spacetime background. While in previous works we presented a heat kernel ansatz for both Yukawa and scalar QED interactions, the results presented here look at the case of a spinor field on a constant axial field background, which can also be seen as a torsion-like interaction. This generalisation of already developed techniques to include spinor fields and torsion effects may serve as a launching point for tackling the more complex curved spacetime case.

52

How to create a horizon in the lab and the route to measure entanglement in experiments

Auteur: Maxime Jacquet[1]

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Quantum field theory in curved spacetimes (QFTCS) predicts the amplification of field excitations and the occurrence of classical and quantum correlations, as in the Hawking effect for example. This raises the interest for experiments in which the curvature of spacetime can be controlled and correlations measured. Such analogue simulations are typically done with fluids accelerating from sub- to supersonic speeds: acoustic excitations are dragged by the supersonic flow, effectively trapped inside an acoustic horizon. Quantum fluctuations of the acoustic field are predicted to yield entangled emission across the horizon, as in black holes.

In this talk, I will introduce a new QFTCS simulator in a one-dimensional polaritonic fluid of light. I will explain how we can engineer smooth and steep horizons, which respectively have quasi-thermal, but weak, and strong Hawking radiation. I will then show new measurements of the spectrum on either side of the horizon and evidence the excitation of negative energy waves.

Interestingly, I will show that, beyond phononic excitations as in other systems, our simulator also supports excitations with a tunable massive, relativistic dispersion. This benchmarks and thereby establishes a QFTCS simulator of a new class.
In conclusions I will explain how quantum optics techniques offer the possibility to measure entanglement, giving insight in this outstanding prediction of QFTCS.

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Cosmological coupling of black holes: theoretical issues and observational evidences

Auteur: Massimiliano Rinaldi[1]

[1] *University of Trento*

Auteur correspondant massimiliano.rinaldi@unitn.it

Recently, a renewed interest has emerged towards the possibility that the mass of black holes grow with the expansion of the Universe. This issue was theoretically investigated almost century ago by McVittie but, since then, not much progress was done. However, the recent analysis of a class of elliptical galaxies have open again the possibility that the mass of supermassive black holes can grow with the cosmic expansion, and, in some models, even crucially contribute to the dark energy content. In this talk we review these issues and propose theoretical arguments that reinforce the existence of a cosmological coupling.

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TBA

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——- Poster Session ———

Ground state for a real scalar field in the cosmic string spacetime with arbitrary boundary conditions
Victor Hugo Marques Ramos

How curved backgrounds affect communication between quantum systems
Alessio Lapponi

Nontrivial self-consistent backreaction of quantum fields in 2D dilaton gravity
Prokopii Anempodistov

Quantum Uncertainty and Superposition under the Influence of Gravity
Raghvendra Singh

Quantum effects in curved space
Antonino Flachi

Causal symplectic geodesic structures in terms of bilinear functionals for Haag-Araki theory
Evgeniy Gudkov

Renormalization of the primordial inflationary power spectra
Silvia Pla Garcia

Heat kernel resummations on a constant axial field background
César García Pérez