Quantum Effects in Gravitational Fields

Monday 28 August 2023 - Friday 01 September 2023

Leipzig University

Book of Abstracts

Contents

Morning session 2 / 7

On the global Hadamard parametrix in QFT and the signed squared geodesic distance defined in domains larger than convex normal neighbourhoods

Author: Valter Moretti[1]

[1] *University of Trento*

We consider the global Hadamard condition and the notion of Hadamard parametrix whose use is pervasive in algebraic QFT in curved spacetime (see references in the main text). We point out the existence of a technical problem in the literature concerning well-definedness of the global Hadamard parametrix in normal neighbourhoods of Cauchy surfaces. We discuss in particular the definition of the (signed) geodesic distance and related structures in an open neighbourhood of the diagonal of larger than UxU, for a normal convex neighbourhood U, where (M, g) is a Riemannian or Lorentzian (smooth Hausdorff paracompact) manifold. We eventually propose a quite natural solution which slightly changes the original definition by Kay and Wald and relies upon some non-trivial consequences of the paracompactness property. The proposed re-formulation is in agreement with Radzikowski's microlocal version of the Hadamard condition.
(From Letters in Mathematical Physics volume 111, Article number: 130 (2021))

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Infrared Finite Scattering Theory in QFT and Quantum Gravity

Authors: Gautam Satishchandran[1]; Robert Wald[2]; Daine Danielson[2]

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[2] *University of Chicago*

A long-standing problem in QFT and quantum gravity is the construction of an "IR-finite" S-matrix. In the gravitational case, the existence of these "infrared divergences" is intimately tied to the "memory effect" (i.e. the permanent displacement of test masses due to the passage of a gravitational wave). In this talk, I shall explain the origin of these connections and illustrate that the construction of an IR-finite S-matrix requires the inclusion of states with memory (which do not lie in the standard Fock space). In massive QED an elegant solution to this problem was provided by Faddeev and Kulish who constructed an incoming/outgoing Hilbert space of charged particles "dressed" with memory. We illustrate the "preferred status" of such states and their relationship to the superselection structure of QED. However, we show that this construction fails in the case of massless QED, Yang-Mills theories, linearized quantum gravity with massless/massive sources, and in full quantum gravity. In the case of quantum gravity, we prove that the only "Faddeev-Kulish" state is the vacuum state. We also show that "non-Faddeev-Kulish" representations are also unsatisfactory. Thus, in general, it appears there is no preferred Hilbert space for scattering in QFT and quantum gravity. We argue that, at a fundamental level, one must formulate scattering theory without an a priori choice of Hilbert space. We outline the framework of such a manifestly IR-finite scattering theory.

Afternoon session 2 / 13

Stress-energy tensor on global anti-de Sitter space-time with Robin boundary conditions

Author: siva namasivayam[1]

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We study the renormalised stress-energy tensor (RSET) for a massless, conformally coupled scalar field on four dimensional anti-de Sitter space-time (adS4). As ads4 is not a globally hyperbolic space-time, we impose boundary conditions on the space-time boundary to have a well posed quantum field theory. We use Dirichlet, Neumann and Robin (mixed) boundary conditions applied to the scalar field and compute both the vacuum (v.e.v.) and thermal (t.e.v.) expectation values of the RSET. When either Dirichlet or Neumann boundary conditions are applied, the v.e.v of the RSET is a multiple of the space-time metric. Applying Robin boundary conditions break the underlying symmetry seen with the vacuum state, and results in a RSET that varies with the space-time position. However, for all Robin boundary conditions, both the v.e.v and t.e.v. converge, at the space-time boundary, to the common v.e.v.s seen when either Dirichlet or Neumann boundary conditions are applied.

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Adiabatic Ground states in Non-smooth Spacetimes.

Authors: Elmar Schrohe[None]; Yafet Erasmo Sanchez Sanchez[None]

The analysis of quantum states in non-smooth spacetimes has two main motivations. First, there are several models of physical phenomena that require spacetime metrics with finite regularity. These include models of gravitational collapse, astrophysical objects and general relativistic fluids. Second, the well-posedness of Einstein's equations, viewed as a system of hyperbolic PDE requires spaces with finite regularity.

Ground states are a well-known class of Hadamard states in smooth spacetimes.
In this talk, I will present our proof that the ground state of the Klein–Gordon field in a non-smooth ultra static spacetime is an adiabatic state characterised by a Sobolev Wavefront set condition that depends on the regularity of the metric.

Afternoon session 1 / 19

The vacuum strikes back: Black stars

Authors: Julio Arrechea[1]; Carlos Barceló[None]; Raúl Carballo-Rubio[None]; Luis J. Garay[None]

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I will show that the repulsive effects associated to the zero-point energies of quantum fields are capable of supporting ultracompact stars that overcome the compactness limits present in general relativity for any sphere in hydrostatic equilibrium. These objects are self-consistent solutions in semiclassical gravity that incorporate the backreaction of the renormalized stress-energy tensor (RSET) of quantum fields in vacuum. We arrive at stars of striking qualitative agreement through two independent modelings of the RSET, evidencing the generality and robustness of this result. The main physical properties of these novel black hole mimickers are reviewed.

Afternoon session 2 / 20

Quantum effect unique to gravity based on the weak equivalence principle

Authors: Youka Kaku[1]; Shin'ya Maeda[1]; Yasusada Nambu[1]; Yuki Osawa[1]

[1] *Nagoya university*

The construction of a quantum gravity theory remains a challenge. One of the difficulties stems from the lack of sufficient experimental evidence. As a first step toward the quantum gravity experiment, Bose et al. proposed a low-energy experiment to test if Newtonian gravity can generate quantum entanglement or not. However, they assumed that only gravity is mediating in the system, and their proposals fail when other quantum interactions come into play.
To overcome this issue, we explore an alternative experimental setup that can distinguish gravity-induced entanglement and entanglement resulting from other interactions. Specifically, we investigate an interference experiment of a quantum clock particle that feels a weak gravitational field as well as Coulomb potential. As a result, we find that the interference does not recohere only when gravity induces entanglement, while other cases exhibit periodic decoherence and recoherence. Furthermore, we discuss the deep connection between our experimental setup and the weak equivalence principle.
This talk is based on the collaborated work with Y. Nambu, S. Maeda and Y. Osawa, published in Phys.Rev.D 106 (2022) 12, 126005.

Afternoon session 1 / 22

Entanglement harvesting from conformal vacuums between two Unruh-DeWitt detectors moving along null paths

Author: Subhajit Barman[1]

Co-authors: Dipankar Barman [2]; Bibhas Ranjan Majhi [2]

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It is well-known that the (1+1) dimensional Schwarzschild and spatially flat FLRW spacetimes are conformally flat. This work examines entanglement harvesting from the conformal field vacuums in these spacetimes between two Unruh-DeWitt detectors, moving along outgoing null trajectories. In (1+1) dimensional Schwarzschild spacetime, we considered the Boulware and Unruh vacua for our investigations. In this analysis, one observes that while entanglement harvesting is possible in (1+1) dimensional Schwarzschild and (1+3) dimensional de Sitter spacetimes, it is not possible in the (1+1) dimensional de Sitter background for the same set of parameters when the detectors move along the same outgoing null trajectory. The qualitative results from the Boulware and the Unruh vacuums are alike. Furthermore, we observed that the concurrence depends on the distance d between the two null paths of the detectors periodically, and depending on the parameter values, there could be entanglement harvesting shadow points or regions.

Afternoon session 1 / 25

Why 5? Semi-classical analysis of a Kerr-AdS black hole in five dimensions

Authors: Alessandro Monteverdi[1]; Elizabeth Winstanley[1]

[1] *University of Sheffield*

Some of the quantum properties of rotating black holes in (3+1)-dimensional spacetimes remain unresolved. However, studying higher-dimensional cases may provide insight into their behaviour. In this talk, we investigate the behaviour of a massive scalar field in a Kerr-AdS (4+1)-dimensional spacetime. Specifically, we focus on the existence of a Hartle-Hawking state, which is a vacuum state with important properties, such as being a thermal and Hadamard state, which means that it is well-behaved and has a finite energy density.
While the Hartle-Hawking state has been studied in various types of black holes, our focus is on rotating black holes where we have observed a correlation between the presence of the light surface and the existence of the Hartle-Hawking state. It should be noted that the Hartle-Hawking state does not exist in Kerr black holes, but it does exist in Kerr-AdS black holes. In four dimensions, the analysis of this state is very challenging, but in five dimensions, the enhanced symmetry of the system simplifies the analysis. Finally, by using the Hartle-Hawking state, we also present a method for evaluating observables, starting with the vacuum polarization.

Afternoon session 1 / **29**

Boundary conditions and infrared divergences

Authors: Claudio Dappiaggi[1]; Luca Sinibaldi[1]; Lissa Campos[1]

[1] *University of Pavia*

We review the procedure to construct ground and KMS states, for real scalar fields whose dynamics is dictated by the Klein-Gordon equation, on standard static Lorentzian manifolds with a time-like boundary. We observe that this construction, depending on which boundary condition we fix on the boundary, does not always lead to a bi-distribution $w_2 \in \mathcal{D}'(M \times M)$ for the two-point correlation function of the given state. The reason why it fails to be a bi-distribution is the presence of infrared divergences. We discuss an explicit example, namely a real scalar field on Bertotti-Robinson spacetime, proving that infrared divergences occur when Neumann boundary conditions are imposed at the time-like boundary, while for those of Robin-type the underlying two-point correlation function is a well defined bi-distribution of Hadamard form.

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Towards the optimal experiment of gravity-induced quantum entanglement

Author: Tomohiro Fujita[1]

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Recently, various experiments have been proposed to verify quantum entanglement induced by Newtonian gravitational interactions. However, no feasible setup has yet been found that is certainly achievable with existing techniques. To search for an optimal setup, we compute the logarithmic negativity of two oscillators with arbitrary quadratic potential and coupled by gravity. We find that unstable inverted oscillators generate gravity-induced entanglement most quickly and are most resistant to decoherence from environmental fluctuations. As such an example, we propose an experiment of optical levitation of mirrors using the anti-spring effect.

Afternoon session 1 / 36

Linear Stability of Semiclassical Theories of Gravity

Author: Paolo Meda[1]

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A characteristic feature of semiclassical theories of gravity involving the backreaction of a quantum matter field is the presence of higher order derivatives in the dynamical equations. Hence, the appearance of pathological "runaway solutions" is often argued, i.e., solutions of the linearized equations around a background spacetime that grow exponentially in time. In this talk, this issue is studied in a semiclassical toy model, consists of a quantum scalar field coupled with a classical scalar field in Minkowski spacetime. This toy model mimics also the evolution induced by Semiclassical Einstein Equations for linear perturbations on flat and cosmological spacetimes. It is shown that, if the quantum field which drives the backreaction is massive, then there are choices of the renormalization parameters for which the linear perturbations with compact spatial support decay polynomially in time for large times, thus indicating stability of the underlying semiclassical solution.

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Relative entropy and dynamical black holes

Author: Edoardo D'Angelo[1]

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Since the discovery of the Bekenstein-Hawking formula, there had been many attempts to derive the entropy of black holes from the entanglement between the degrees of freedom inside and outside the event horizon. This entanglement entropy reproduces the area-law, but it suffers from divergences in the continuum limit. In this talk, I show how to derive the Bekenstein-Hawking entropy from the relative entropy, which is well-defined also for continuum theories such as QFT, in the case of dynamical, spherically symmetric black holes. I first review the algebraic quantization of a free scalar field on curved space-times, and show how to compute its relative entropy from the initial data at infinity. Using the back-reaction of a free, scalar quantum field on the metric, I show that a variation in the relative entropy between coherent states of the field produces a variation of one-quarter of the black hole horizon area.

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Characteristic renormalization and applications to black hole formation

Author: Daan Janssen[1]

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We present a regularization prescription for Hadamard two-point functions defined on the boundary of a lightcone, which can be used to analyze renormalized quantities for linear scalar fields in a curved background. This can be applied to formulate the semi-classical Einstein equations as a characteristic initial value problem. Furthermore, we shall discuss how these tools can be used to estimate backreaction effects of quantum fields near gravitationally collapsing bodies and study formation of horizons and singularities in semi-classical gravity.

Afternoon session 2 / 41

Graviton couplings on Hilbert space

Authors: Christian Gass[1]; José M. Gracia-Bondía[None]; Karl-Henning Rehren[2]

[1] *University of Warsaw*

[2] *Universität Göttingen*

A fresh attempt towards a quantum field theory of gravitons interacting with matter is based on the Fock space quantization of Wigner's helicity 2 representation, rather than canonical quantization of a massless rank-2 tensor field. In this way, all issues with indefinite state spaces, overshooting degrees of freedom, gauge fixing, etc. are avoided. It turns out that quantum consistency of this approach is exactly as restrictive on the structure of the interactions, as the postulate of general covariance in the canonical approaches, to the extent that general covariance may be regarded as a quantum prediction, rather than an assumed principle.

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The quantum scalar field on Kerr-de Sitter

Authors: Christiane Klein[1]; Soltani Mojgan[None]

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In order to study physical effects of quantum fields on curved spacetimes, one needs appropriate Hadamard states to describe the fields. In this talk, we present a rigorous construction, including the proof of the Hadamard property, of the Unruh state for the free scalar field on slowly rotating Kerr-de Sitter spacetimes. We sketch how this state can be used to compute the stress-energy tensor of the quantum field and present some results of this computation.

Afternoon session 2 / 45

Relative entropy in de Sitter wedges and diamonds

Authors: Markus B. Fröb[1]; Albert Much[None]; Kyriakos Papadopoulos[None]

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The role of entropy, in particular entanglement entropy, in quantum field theory has become increasingly prominent, and entropy has appeared in relation with several primary research topics in QFT: area theorems, c theorems, the AdS/CFT correspondence, quantum null energy inequalities etc. While von Neumann entropy, the basic concept in information theory, is divergent in QFT and can thus only be defined in cutoff theories (e.g. on a lattice), relative entropies are finite and can be directly defined in the continuum QFT. In the framework of Tomita-Takesaki modular theory, the relative entropy between the vacuum and a coherent excitation can be computed using the modular operator associated to the vacuum and the spacetime region that one is interested in. Unfortunately, its explicit form is only known in a few special cases.

Using the known modular operator for de Sitter wedges and a recent result for the modular operator for conformal fields in de Sitter diamonds, we compute the relative entropy between the de Sitter vacuum state and a coherent excitation thereof in these regions. We show explicitly that the result is positive and monotone, and thus satisfies the expected properties for a relative entropy.

Afternoon session 1 / 46

Quantum energy inequalities in integrable models

Author: Jan Mandrysch[1]

Co-authors: Daniela Cadamuro [1]; Henning Bostelmann [2]

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[2] *University of York*

Many results in general relativity rely crucially on classical energy conditions inflicted on the stress-energy tensor. Quantum matter, however, violates these conditions since the energy density can fluctuate and in particular become arbitrarily negative at a point. Nonetheless quantum matter should have some reminiscent notion of stability, which can be captured by so-called quantum (weak) energy inequalities (QEIs), lower bounds of the smeared quantum stress-energy tensor. QEIs could be proven in many free quantum field theories (QFT) on both flat and curved spacetimes. However, it is less clear what happens in models with self-interaction.

We will present numerical and analytical results on QEIs in a large class of 1+1d models referred to as integrable QFTs. As particular examples we treat the O(n)-nonlinear-sigma and sinh-Gordon model at 1- and 2-particle level.

Parts of the talk are based on https://arxiv.org/abs/2302.00063.

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Cosmological solutions to the semiclassical Einstein equation with Minkowski-like vacua

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We will discuss some newly found solutions to the full massless semiclassical Einstein equation (SCE) in a cosmological setting (with Λ=0).
After a short introduction to the relevant notions we present the SCE in a particular shape which allows for the construction of certain vacuum states. These states may be viewed as as the least possible generalization of the Minkowski vacuum to general (cosmological) space-times. In this setting, solving the SCE breaks down into solving a certain ODE which can be approached numerically and, at least generically, we obtain solutions that well fit physical expectations. Moreover, these solutions indicate dark energy as a quantum effect back-reacting on cosmological metrics and, since in our model m=Λ=0, this may not be traced back to the occurrence of a non-vanishing renormalized cosmological constant. Also we will shortly discuss how our model can be used to solve the cosmic horizon problem and we present parameter regimes in which it matches certain aspects of CMB physics.

Afternoon session 1 / 49

Creases, corners and caustics: non-smooth structures on black hole horizons

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The event horizon of a dynamical black hole is generically a non-smooth hypersurface. I shall describe the types of non-smooth structure that can arise on a horizon that is smooth at late time. This includes creases, corners and caustic points.
I shall discuss perestroikas" of these structures, in which they undergo a qualitative change at an instant of time. A crease perestroika gives an exact local description of the event horizon near theinstant of merger" of a generic black hole merger. Other crease perestroikas describe horizon nucleation or collapse of a hole in a toroidal horizon. I shall discuss the possibility that creases contribute to black hole entropy, and the implications of non-smoothness for higher derivative terms in black hole entropy. This talk is based on joint work with Maxime Gadioux.

Morning session 1 / 50

The euclidean vacuum state for linearized gravity on de Sitter spacetime

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We will explain the construction of the euclidean vacuum state for linearized gravity on de Sitter spacetime by a rigorous version of Wick rotation. We will discuss issues related to gauge invariance, positivity and invariance under de Sitter isometries.

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Semiclassical Einstein equations from holography and boundary dynamics

We consider how to formulate semiclassical problems in the context of the AdS/CFT correspondence, based on the proposal of Compere and Marolf [arXiv:0805.1902]. Our prescription involves the effective action with self-action term for boundary dynamical fields, which can be viewed as imposing mixed boundary conditions for the gravity dual. We derive the semiclassical Einstein equations sourced by boundary CFT stress-energy tensor. Analyzing perturbations of the holographic semiclassical Einstein equations, we find a universal parameter which controls the contribution from boundary CFTs and specifies dynamics on the AdS boundary. As a simple example, we examine the semiclassical Einstein equations in 3-dimensions with 4-dimensional AdS gravity dual, and show that the boundary BTZ black hole with vanishing expectation value of the stress-energy tensor becomes unstable due to the backreaction from quantum stress-energy tensor when the parameter exceeds a certain critical value.

Afternoon session 1 / 54

Gravity beyond General Relativity: Quantum Fluctuations and Nonlinear Dynamics

Author: Aaron Held[1]

[1] *Jena University*

I review the status of the asymptotic safety program which posits a nonperturbative ultraviolet completion of gravitational quantum field theory. In particular, I put emphasis (i) on systematic extensions of approximation schemes, (ii) on the role of field redefinitions, and (iii) on observable consequences.

The latter naturally connects the asymptotic safety program to an effective field theory approach for a joint theory of gravity and matter. Herein, I focus on the classical gravitational sector where I summarize recent progress on formulating a well-posed initial data evolution of the nonlinear dynamics.

The interplay between both parts of my talk provides a potential link between current astrophysical observations of black holes and our fundamental assumptions about quantized gravity.

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Entanglement structure of geometric states in holography

Motivated by a long-standing aim to understand the emergence of spacetime and its relation to entanglement in the context of gauge/gravity duality, we study the relations between subsystem entanglement entropies. These quantities are delimited by the so-called holographic entropy cone, characterized conveniently by holographic entropy inequalities or alternately by certain extreme states. This construct reveals a surprisingly rich structure, whose intricacy grows rapidly with the number of subsystems. We review recent progress in understanding the holographic entropy cone, both from the perspective of the defining inequalities as well as from that of the extreme rays, both of which seem to hint at a deeper organizational principle.

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Mode-Sum Renormalization in Black Hole Spacetimes

It is well known that the expectation value of the stress-energy tensor for a quantum field must be renormalized. While there exists a well-understood formal resolution to the renormalization problem, the practical implementation is technically difficult in black hole spacetimes. The first successful computation of the renormalized stress-energy tensor in a black hole spacetime dates back to seminal work in the 1980s by Candelas and Howard. However, there had been little improvement on their prescription in the intervening decades, despite some drawbacks to their method. In recent years, alternative approaches to computing renormalized stress-energy tensors in black hole spacetimes have emerged. I will discuss one such scheme that has proved very efficient in static black hole spacetimes in arbitrary dimensions. As an application of this method, I will also present results for the renormalized stress-energy tensor for scalar fields in the Hartle-Hawking, Unruh and Boulware states in the Reissner-Nordstrom spacetime.

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Poster session

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"Facets of Unitarity Violation in Dynamical Spacetimes" by Ka Hei Choi (Ludwig Maximilian University of Munich);
"Gravity and the Superposition Principle" by Hristu Culetu (Ovidius University);
"The master Dyson-Schwinger equation and the Wilsonian renormalization group flows in a generally covariant setting" by Andras Laszlo (Wigner Research Centre for Physics, Budapest);
"Uniformly accelerated particles and gravitational waves: The Unruh effect and zero-Rindler-energy modes" by Felipe Portales-Oliva (Federal University of ABC);
"Towards a Probabilistic Foundation of Relativistic Quantum Theory: The One-Body Born Rule in Curved Spacetime" by Maik Reddiger (Anhalt University of Applied Sciences);
"Modelling quantum particles falling into a black hole: the deep interior limit" by Sami Viollet (CPT Marseille);
"Scattering Analogy of Cosmological Particle Production in a BEC-Quantum simulator" by Christian F. Schmidt (Friedrich-Schiller-Universität Jena);
"Hawking radiation around and inside rotating and accreting black holes" by Tyler McMaken (ILA and the University of Colorado Boulder);
"The Utility of Lorentzian Network Histories" by Cecilia Giavoni (Munich)
TBD by Maria Alberti (Leipzig)

Afternoon session 1 / 59

From QFT to quantum gravity using the algebraic approach

In this talk I will discuss how the algebraic approach to (perturbative) quantum field theory can benefit the search for the theory quantum gravity through several different approaches. I will discuss the problem of constructing gauge invariant observables, the asymptotic safety program and consequences of potential discreteness of spacetime at small scales.

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Quantum Effects on Black Hole Cauchy Horizons

Black hole spacetimes harbor intricate internal structures, featuring geometry that extends through an inner horizon to another external universe. This regularity of the inner horizon, which plays the causal role of a Cauchy horizon, challenges predictability within black holes. The strong cosmic censorship conjecture offers a solution, asserting that the Cauchy horizon becomes sufficiently irregular under perturbations, hence negating its existence. While this scenario is known to hold classically in some cases, its validity amidst quantum perturbations remains an open question.
Answering this question requires understanding how quantum energy fluxes influence the internal geometry of black holes, particularly at the inner horizon. A divergence in these fluxes could dramatically alter the internal structure, potentially restoring predictability by rendering the inner horizon impassable. Recent works have conquered the challenge of computing semiclassical energy fluxes (T_{uu} and T_{vv} stress-energy tensor components in Eddington coordinates)
within black hole interiors, shedding light on the nature of the Cauchy horizon under quantum backreaction.
My talk outlines these recent advancements, presenting results in both asymptotically at (Zilberman,Casals,Ori&Ottewill) and asymptotically deSitter (Hollands,Zahn&Wald) cases, briefly mentioning possible implications for the inner horizon traversability.

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Parallel sessions

Afternoon session 2 / 64

The semiclassical Einstein equation in cosmological spacetimes: Existence and uniqueness of the solutions

During this talk we shall discuss some properties of the semiclassical Einstein equation.
This equation is used to model the backreaction of quantum matter on classical backgrounds.
In this talk we shall in particular analyze the case of backgrounds which describe cosmological spacetimes.
The quantum field we shall consider is massive and satisfies a linear equation with a generic coupling to the scalar curvature.
We observe that a nonlocal term with higher order derivatives is present in the expectation value of the matter stress tensor which sources gravity.
This term prevents a direct analysis of that equation, we show how to deal with it in order to put the semiclassical equation in a form which can then be treated with Banach fixed point methods.

Morning session 1 / 65

Quantum field simulator for dynamics in curved spacetime

Quantum fields in curved spacetimes have many tantalizing theoretical properties, for example particles are being produced by the time-dependence of the geometry. I will describe how quantum fields in geometries with spacetime curvature and different cosmologies can be quantum-simulated with Bose-Einstein condensates in specifically designed trapping potentials and with time-dependent interaction strengths. Analytical results for relativistic scalar fields in cosmologies with 2+1 spacetime dimensions will be compared with recent experimental results obtained in Heidelberg laboratories.

Morning session 1 / 66

Anomalies and the stability of stars

What are the essential aspects of quantum theory needed in order to understand compact relativistic objects? Relying solely on universal properties of QFTs at high energies, we show that as a star contracts towards its Buchdahl radius the effects of the trace anomaly become macroscopic at densities much below the Planck scale. As a consequence the unstable modes of scalar fields disappear, implying the system recovers linear stability under scalar perturbations.

Morning session 2 / 67

Spontaneous Hawking radiation in a Bose-Einstein condensate and analogue cosmological particle creation in a fluid of light

We confirm that Hawking radiation from an analogue black hole in a Bose-Einstein condensate is spontaneous, thermal, and stationary. Furthermore, we follow the time evolution of the Hawking radiation, and compare and contrast it with the predictions for real black holes. We observe the ramp up of the Hawking radiation, similar to a real black hole. The end of the spontaneous Hawking radiation is marked by the formation of an inner horizon. The Maryland group predicted that particles emanating from the inner horizon can cause stimulated Hawking radiation. We find that these stimulated Hawking pairs are directly observable. We also present our observation of analogue cosmological particle creation in a 3-dimensional quantum fluid of light. The process is seen to be spontaneous, and in close quantitative agreement with the quantum-field theoretical prediction. We find that the long-wavelength particles provide a window to early times. This latter work introduces a new quantum fluid, as cold as an atomic Bose-Einstein condensate.

Morning session 1 / 68

Black Holes Decohere Quantum Superpositions

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We show that if a massive body is put in a quantum superposition of spatially separated states, the mere presence of a black hole in the vicinity of the body will eventually destroy the coherence of the superposition. This occurs because, in effect, the gravitational field of the body radiates soft gravitons into the black hole, allowing the black hole to harvest "which path" information about the superposition. A similar effect occurs for quantum superpositions of electrically charged bodies. The effect is very closely related to the memory effect and infrared divergences at null infinity.

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Parallel sessions

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Welcome speech

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Gravity and the Superposition Principle

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We use C.Kiefer's idea that QG means any theory in which the superposition principle (SP) is applied to the gravitational field. For masses above the Planck mass, we conjecture that the Schrodinger equation should contain the universal constant G and c, instead of the Planck constant h. The wave packet expansion depends on G, c and the acceleration $Gm/^2_0$, where $_0$ is the initial width of the wave packet. The source of gravity appears to be in superposition w.r.t. a freely falling observer

Morning session 1 / 72

Superradiance and quantum states on black hole space-times

We consider the definition of the Boulware and Hartle-Hawking states for quantum fields on black hole space-times. The properties of these states on a Schwarzschild black hole have been understood for many years, but neither of these states has a direct analogue on a Kerr black hole. We show how superradiant modes play an important role in the definition of quantum states on Kerr. Superradiance is also possible on static black hole space-times, in particular for a charged scalar field on a Reissner-Nordstrom black hole. We explore whether analogues of the Boulware and Hartle-Hawking states exist in this situation.

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Discreteness Unravels the Black Hole Information Puzzle: Insights from a Quantum Gravity Toy Model

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Social dinner / 74

Social dinner

The conference's social dinner will take place at 19:30h on Wednesday August 30 at Barthel's Hof in the city centre: Hainstraße 1, 04109 Leipzig, see https://www.barthels-hof.de/en/?lan=en

There is a choice of 3 menus (a soup plus a main dish with the choices of: beef, fish, vegetarian/vegan), all at a cost of 25Euro (excluding drinks).

Morning session 2 / 75

Facets of Unitarity Violation in Dynamical Spacetimes

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We investigate the roots of unitarity violations of quantum field theory in dynamical spacetimes and its connection to back-reactions and measurement processes. Within the framework of effective field theories, local observables require compact configuration spaces given by the domain of validity of the effective description and in accordance with detector specifications. Using the functional Schrödinger representation of quantum field theory, we investigate how compact configuration spaces cause unitarity violations in quantum evolution groups. The loss of unitarity can be traced back to two (distinct) phenomena: An increasing impact of back-reactions and the information loss associated with the detector failing to distinguish quantum fluctuations from classical backgrounds.

Afternoon session 2 / 76

Quasinormal modes of Schwarzschild de Sitter black holes from Liouville CFT

We consider black hole linear perturbation theory in a four-dimensional Schwarzschild de Sitter background. The relevant differential equation is a Heun equation, which is a second order ODE with four regular singularities. After showing how the exact connection formulae for the Heun equation can be obtained from the semiclassical limit of Virasoro conformal blocks, we use these formulae to obtain the quantization condition which gives the quasinormal mode frequencies as series expansions in the radius of the black hole horizon. We conclude discussing how the method can be applied to different backgrounds, such as Kerr-de Sitter or asymptotically anti-de Sitter black holes, emphasising the problems in which the method is more effective.

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Registration