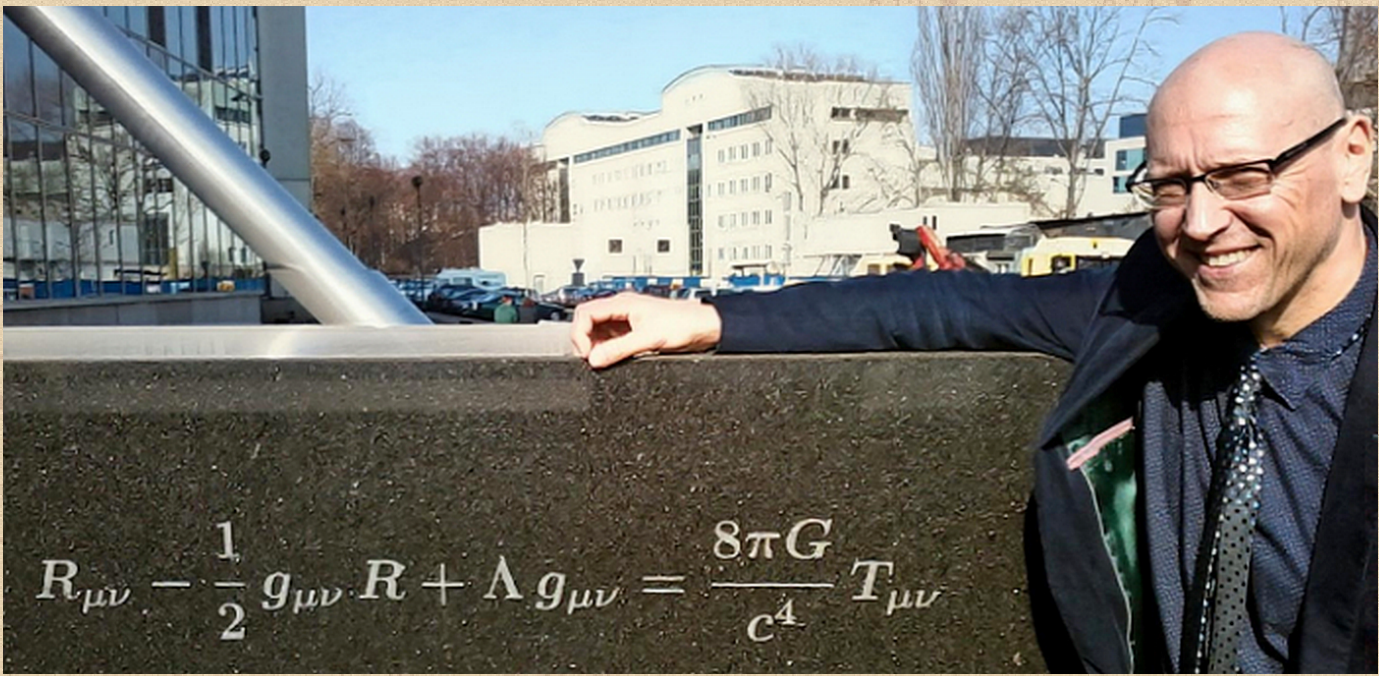
Geometry of classical and quantum space-times

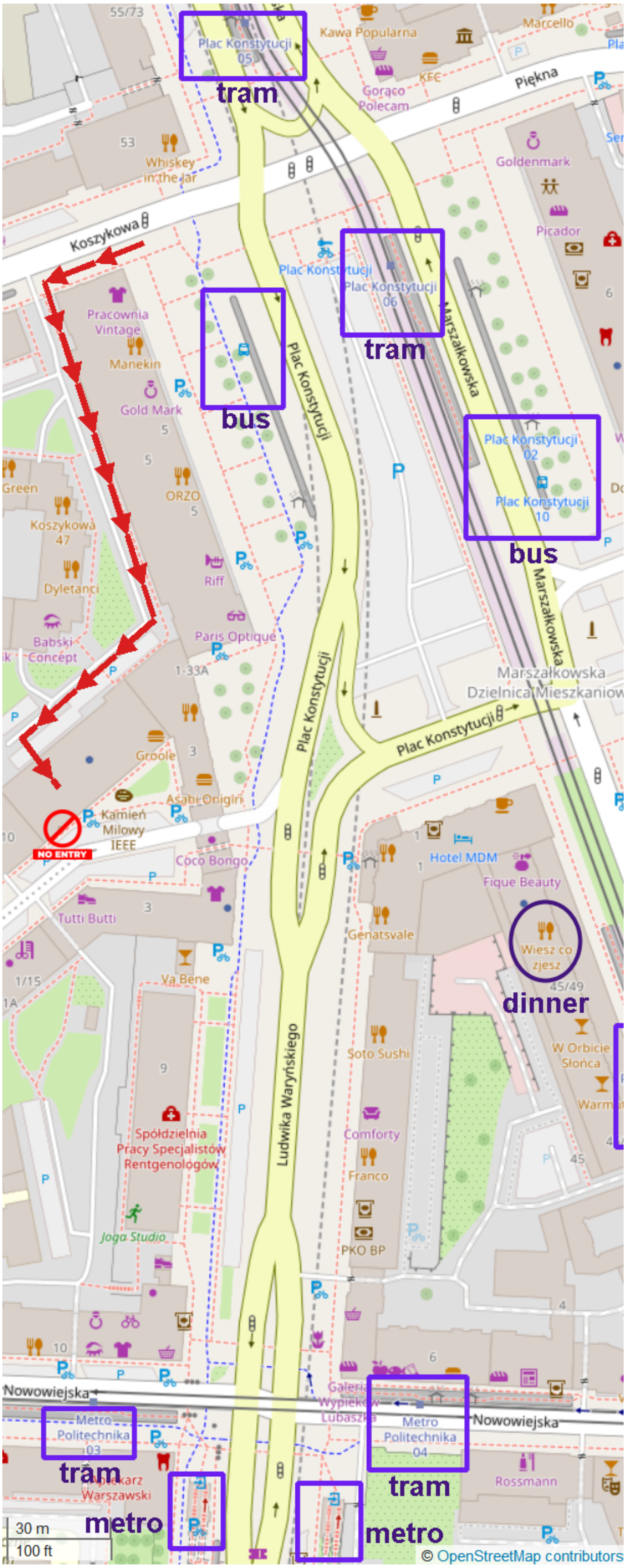
Jerzy Lewandowski Memorial Conference



15–19 September 2025
Warszawa, Poland

`jurekmemorial.fuw.edu.pl`

Abstracts and schedule



Venue:
Banach Center,
Institute of Mathematics,
Polish Academy of Sciences,
ul. Śniadeckich 8
(entry from: ul. Koszykowa 53)
room 321

Due to construction works inside Banach Center, the main entry, from Śniadeckich street, is currently closed, and the only entry is from the Koszykowa street, as indicated by the red arrows on the map.

Upon entering Banach Center, turn left immediately and enter the reception area through the small corridor. There you will need to sign up in the Banach Center's entrance book. The conference room (#321) is on the third floor, which is accessible via the staircase. If you require assistance, then please inform the receptionist (or contact us) about it. The way towards the conference room will be marked by signs.

Directions:
The nearby tram and bus stops are called "Plac Konstytucji". There is also a nearby "Politechnika" metro station, located 5 minutes by walk towards south from Plac Konstytucji. For the up-to-date public transport planner for Warszawa, see:
jakdojade.pl/warszawa

Dinner:
17.09.2025 (Wednesday),
starting at 19:00,
in "Wiesz co zjesz" restaurant,
at Plac Konstytucji 1.

Photo on the cover:
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Last update of this booklet:
26.09.2025, 17:00 CET

Invited speakers:

Robert Alicki, Abhay Ashtekar, Fernando Barbero, Ingemar Bengtsson, Luca Cafaro, Piotr T. Chruściel*, Marek Demiański, Maciej Dunajski*, Jonathan Engle, Christian Fleischhack, Kristina Giesel*, Jerzy Kijowski, Maciej Kolanowski, Jerzy Kowalski-Glikman, Jorma Louko, James Lucietti, Yǒnggé Mǎ*, Ilkka Mäkinen, Lionel Mason, Guillermo A. Mena Marugán, José M. Cidade Mourão, Maciej Ossowski, Tomasz Pawłowski, Roger Penrose*, István Rácz, Carlo Rovelli, Hanno Sahlmann, George A. J. Sparling, Simone Speziale, Arman Taghavi-Chabert, Yaser Tavakoli*, Thomas Thiemann, Madhavan Varadarajan*, Cōng Zhāng

Contributing speakers:

Alex Colling, Mikołaj Korzyński, Ryshard-Pavel Kostecki, David Kubizňák, Wolfgang Wieland

Poster presenters:

Hristu Culetu, Grzegorz Czelusta, Igor Kanatchikov, Patryk Mieszkalski, Hugo A. Morales-Técotl, Antonio Panassiti

Organising institutions:

Banach Center, Institute of Mathematics, Polish Academy of Sciences
Center for Theoretical Physics, Polish Academy of Sciences
Faculty of Mathematics, Physics and Informatics, University of Gdańsk
Faculty of Physics, University of Warsaw

Organising committee:

Mehdi Assanioussi, Denis Dobkowski-Ryłko, Wojciech Kamiński, Mikołaj Korzyński, Ryshard-Pavel Kostecki, Andrzej Okołów, Marek Szczepańczyk, Adam Szereszewski

Schedule:

	Monday	Tuesday	Wednesday	Thursday	Friday
8:30–8:45	Registration				
8:45–9:00	Opening				
9:00–9:40	A. Ashtekar	J. Cidade Mourão	P. Chruściel*	C. Rovelli	Y. Mǎ*
9:40–10:20	G. Mena Marugán	S. Speziale	M. Demiański	H. Sahlmann	T. Pawłowski
coffee break			Poster session		
10:50–11:30	J. Lucietti	L. Mason	T. Thiemann	R. Penrose*	R. Alicki
11:30–12:10	M. Ossowski	A. Taghavi-Chabert	F. Barbero	G. Sparling	J. Louko
lunch break					
14:00-14:40	W. Wieland	J. Engle	M. Varadarajan*	J. Kowalski-Glikman	I. Mäkinen
14:40–15:20	Y. Tavakoli*	K. Giesel*	C. Fleischhack	M. Kolanowski	L. Cafaro
coffee break					
15:50–16:30	J. Kijowski	I. Bengtsson	Memorial session	C. Zhāng	D. Kubizňák
16:30–17:10	M. Korzyński	I. Rácz	Memorial session	R.-P. Kostecki	A. Colling
17:10–17:50		M. Dunajski*			
19:00–22:00			Dinner		

* – *online talk*

Talks

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Robert Alicki
(University of Gdańsk)

Cosmology without inflaton

The previously proposed modification of the standard inflationary Lambda CDM model in which the inflaton field(s) and "dark energy" are replaced by a single object – the vacuum in expanding Friedmann–Lemaitre–Robertson–Walker Universe is studied. The expanding joint vacuum of all ingredients of matter, including Standard Model particles and a dark matter sector, is treated as a thermal equilibrium state at temporal Gibbons-Hawking temperature, proportional to the Hubble parameter, and chemical potentials equal to particle masses. This theory provides not only the new mechanism of inflation and its graceful exit, but also explains acceleration of expansion for the late Universe, and can be combined with the anomalous quantum gravity effects leading to a viable baryogenesis mechanism and estimation of dark matter particle masses and lifetimes. Finally, the analogy between the proposed modification of Friedmann equations and the superfluorescence model in quantum optics is discussed, suggesting an alternative approach to quantum gravity.

R. Alicki., G. Barenboim, and A. Jenkins, "Quantum thermodynamics of de Sitter Space", Phys. Rev. D **108**, 123530 (2023).
R. Alicki, G. Barenboim, and A. Jenkins, "The irreversible relaxation of inflation", Phys. Lett. B **866**, 139519 (2025).

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Abhay Ashtekar
(Pennsylvania State University)

*Black hole thermodynamics, arbitrarily far from equilibrium**

Dynamical Horizon Segments (DHSs) represent black hole boundaries away from equilibrium. They are uniquely foliated by marginally trapped surfaces (MTSs). It turns out that the evolution from one MTS to another naturally projects down to the space E of equilibrium states of black holes, providing us with a unique trajectory in E. By pull-back, one can assign to each MTS, the thermodynamic parameters available on E. Then, one of the implications of Einstein's equations on the DHS is a generalization of the first law of thermodynamics of black holes, arbitrarily far from equilibrium. If one restricts oneself to infinitesimally separated MTSs, one recovers the familiar first law. This discussion also removes the mystery behind a recent finding that when first order perturbations are included, entropy is naturally associated with the area of a MTS 'behind' the event horizon of the stationary black hole.

* Dedicated to Jurek Lewandowski who made seminal contributions to our understanding of quasi-local horizons.

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Fernando Barbero
(IEM-CSIC, Madrid)

Some reflections on hamiltonians and GR

In this talk I will discuss a number of issues regarding the Hamiltonian description of diff-invariant field theories related to general relativity. In particular I will insist on the necessity of carefully implementing the known procedures designed to analyze constrained systems: the Dirac approach and the Gotay–Nester–Hinds geometric method. I will do this by focusing on two particular models: a variation of the Husain–Kuchar model recently introduced by Husain and Mehmood, and the self-dual action for Euclidean General Relativity. In this second example I will show how the Ashtekar formulation can be found without using any gauge fixing.

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Ingemar Bengtsson
(Stockholm University)

A discrete structure in Hilbert space: constructions

On Jurek's 60th birthday I tried to convince him that he ought to be interested in the SIC-POVM existence problem. It comes from quantum information theory, but has since encountered an unsolved problem in number theory ("Hilbert's 12th"). The solution is still not in sight, but there have been some dramatic developments.

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Luca Cafaro
(University of Warsaw)

On the gravitational collapse in loop quantum gravity

Since Oppenheimer and Snyder's seminal paper in 1939, relativistic gravitational collapse has drawn considerable attention as a mechanism for the formation of black holes. Despite its success, general relativity alone cannot account for the full evolution of the collapse, as it predicts the emergence of a singularity. In my talk, I will discuss the work I have started with Prof. Lewandowski on a semiclassical model of gravitational collapse inspired by Loop Quantum Gravity (LQG). In particular, I will discuss a wide class of fluid collapses, namely the Lemaitre–Tolman–Bondi model, and show how LQG can replace the singularity with a bounce, in close analogy with results from Loop Quantum Cosmology. I will also address the presence of shell-crossing singularities, which are not resolved by the inclusion of current quantum corrections, highlighting limitations of this model and suggesting that more work is needed in that direction.

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José M. Cidade Mourão
(IST, Lisboa)

Momentum space quantization for cotangent bundles of symmetric spaces and coherent state transforms

For non-abelian Lie groups the momentum space quantization has to be changed. We use geometric quantization to define appropriate momentum polarizations and coherent state transforms to relate the corresponding momentum space quantizations with the Schroedinger quantization.

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Piotr T. Chruściel
(Beijing Institute of Mathematical Sciences and Applications; CFT PAN)

Hyperbolic mass in 2 + 1 dimensions

I will review what is known about 2-dimensional vacuum initial data sets with a negative cosmological constant, with particular emphasis on the definition of mass and its properties.

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Alex Colling
(University of Cambridge)

Symmetries of extremal horizons

We will discuss the intrinsic geometry of extremal Killing horizons in a spacetime. This may be viewed as a special case of the study of isolated horizons developed by Lewandowski. Building on work by Dunajski and Lucietti, we prove an intrinsic version of Hawking's rigidity theorem: for any rotating extremal horizon with compact cross sections in a spacetime obeying the null energy condition, the induced metric on the cross section must admit a Killing vector field. Assuming the dominant energy condition, it follows that the associated near-horizon geometry admits an enhanced isometry group. We also discuss the implications for the classification problem of extremal horizons in four- and five-dimensional Einstein–Maxwell theory.

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Marek Demiański
(University of Warsaw)

Discovering black holes

I will present a brief history of how black holes were discovered, concentrating mostly on different observations.

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Maciej Dunajski
(University of Cambridge)

Einstein–Maxwell gravitational instantons

Gravitational instantons are solutions to the four-dimensional Einstein equations in Riemannian signature which give complete metrics and asymptotically 'look-like' flat space. Their study has been initiated by Stephen Hawking in his quest for Euclidean quantum gravity. While Euclidean quantum gravity does not anymore aspire to a status of a fundamental theory, the study of gravitational instantons has influenced both theoretical physics and pure mathematics.

Until recently, it was believed that Euclidean Schwarzschild and Kerr solutions are the only asymptotically flat Ricci flat gravitational instantons. This "Euclidean Black Hole Uniqueness Conjecture" was disproven by Chen and Teo, who found an explicit two-parameter family of counterexamples. It has remained an open problem to find the Einstein–Maxwell analogs of the Chen–Teo metrics. I will present a solution to this problem obtained jointly with Bernardo Araneda.

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Jonathan Engle
(Florida Atlantic University)

Spinfoams and Ponzano–Regge

Spin foams provide a path integral definition of the dynamics for loop quantum gravity that generalize the Ponzano–Regge model of 3D quantum gravity to four dimensions. In this talk I will summarize the EPRL spin-foam model with emphasis on motivation, and summarize the generalizations of the model introduced by Kamiński, Kisielowski, and Lewandowski and others. I will also summarize open issues and how light might be shed on them by looking once again at the original Ponzano–Regge model and puzzles present there.

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Christian Fleischhack
(Paderborn University)

Jurek's uniqueness

The LOST theorem, named after Jerzy Lewandowski, Andrzej Okolow, Hanno Sahlmann and Thomas Thiemann, is one of the cornerstones of loop quantum gravity. Similar to the Stone–von Neumann theorem in quantum mechanics, it shows that the kinematical structure of loop quantum gravity is unique. Even more, it has become the role model for respective theorems in loop quantum cosmology. In our talk, we will review these results.

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Kristina Giesel
(FAU Erlangen-Nürnberg)

Gravity quantised

Quantising systems that involve gravity is often more challenging than systems where gravity is absent or treated classically. First, the tasks that must be accomplished in order to formulate such quantum models in the context of quantum gravity, as well as the associated challenges, are discussed. These include, for example, the choice of dynamical reference frames, the choice of a representation, and the formulation of the dynamics. Next, some existing models for which certain choices have been made are presented, and their implications are discussed.

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Jerzy Kijowski
(Center for Theoretical Physics of the Polish Academy of Sciences)

What is gravity? (Can we extrapolate the validity of a successful physical theory by 20 orders of magnitude?)

The notion of a local inertial reference frame is thoroughly analyzed. Dynamics of a field of such frames arises, in a natural way, as a local version of the Newton's First Law. It can also be derived from the variational principle. It is shown that the resulting theory splits naturally into three sectors, one of which is purely gravitational. Field dynamics in the gravitational sector is equivalent to conventional Einstein's vacuum equations. It is obtained unambiguously and admits no ad hoc corrections. The cosmological constant is an essential element of this construction and cannot be removed. We show that the second sector of this theory describes electrodynamics in a way which has been suggested by Hermann Weyl, while the last sector could possibly describe dark matter.

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Maciej Kolanowski
(University of California, Santa Barbara)

Quantum (near) extremal black holes

Prof. Lewandowski's contributions to gravitational physics were both profound and wide-ranging, spanning topics from quantum gravity to the study of extremal horizon equations. In this talk, we will argue that these two areas are in fact deeply connected, in at least two important ways. First, the geometry of near-extremal horizons is highly sensitive to ultraviolet physics, which generically produces large tidal forces that are visibly absent in the Einstein–Maxwell theory. Second, the presence of a long AdS_2 throat implies that certain geometric modes become strongly coupled at low temperatures, already within the two-derivative theory. As a consequence, the saddle-point approximation breaks down, and cold black holes must be understood as genuinely quantum objects.

These phenomena make near-extremal black holes a perfect laboratory for studying quantum gravity. Without question, Prof. Lewandowski's pioneering results on the classification of extremal horizons will continue to provide an essential foundation for future work in this area.

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Mikołaj Korzyński
(Center for Theoretical Physics of the Polish Academy of Sciences)

Redshift and position drift in cosmology

The position and redshift drifts are small, secular variations of the redshift and apparent position of a light source at cosmological distances. I will discuss the redshift and position drifts for sources at small cosmological distances. In particular, I will explain what kind of information about the geometry of spacetime and about the bulk motions of matter we can extract from the multipole decomposition of the drifts.

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Ryshard-Pavel Kostecki
(Research Center for Quantum Information, Slovak Academy of Sciences)

Topos-theoretic extension of vacuum algebraic quantum field theory over curved space-times

Topos-theoretic approach to the foundations of quantum mechanics, developed by Isham and his collaborators, has emerged from consideration of foundational problems in quantum gravity and quantum cosmology. We bring it back to the quantum/gravity interface, by extending its key structure, the spectral presheaf formalism, to vacuum sector of algebraic quantum field theory (=: v.a.q.f.t.) over curved space-times. More specifically:

(1) We apply this formalism to the causal logics (developed by Cegła, Jadczyk, Florek, Casini, and others), i.e. the orthocomplemented (not necessarily orthomodular) lattices of causally closed regions of (not necessarily globally hyperbolic) time-oriented lorentzian space-time, as well as to the orthocomplemented lattices of factor von Neumann subalgebras of a factor von Neumann algebra. It turns out that the (various variants of) relativistic nonsignalling, as well as the commutant of subfactors, are represented by paraconsistent negation operators in the corresponding spectral presheaves. The properties of these operators lead to a natural appearance of the boundary operator (for causally closed regions, as well as for von Neumann algebra subfactors), satisfying Leibniz rule.

(2) Haag proposed that v.a.q.f.t.s over Minkowski space-time could be given by homomorphisms from causal logic of time-like signalling in Minkowski to lattices of factor von Neumann algebras. We introduce a natural category-theoretic weakening of this postulate, admitting arbitrary causal logics, and we construct a topos-theoretic extension of v.a.q.f.t. as a corresponding functor between the respective spectral presheaves. This allows to study the context-dependent quantitative properties of the vacuum sector of an underlying theory (as reflected in the structure of von Neumann subfactors), while allowing for the wide structural variability of causal structures (e.g., time-like vs time-and-null-like signalling, presence of closed time-like curves, discretisation of the space-time, etc.).

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Jerzy Kowalski-Glikman
(University of Wrocław)

From corner proposal to emergence of the area law

In this talk, I will present the construction of the corner algebra associated with a region, emphasizing its analogy with the Poincaré algebra in Quantum Field Theory. I will then turn to the toy model of two-dimensional quantum gravity, illustrating how segments can be cut and glued. Building on this framework, I will show how to compute the entanglement entropy between a segment and its complement. Finally, by exploiting the relation between two-dimensional gravity and spherically symmetric four-dimensional spacetimes, I will demonstrate that, in an appropriate semiclassical limit, the resulting entanglement entropy reproduces the Bekenstein–Hawking area law.

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David Kubizňák
(Charles University)

On a lower-dimensional Killing vector origin of irreducible Killing tensors

Considering a spacetime foliated by co-dimension-2 hypersurfaces, we find the conditions under which lower-dimensional symmetries of a base space can be lifted up to irreducible Killing tensors of the full spacetime. In this construction, the key ingredient for irreducibility is the non-commutativity of the underlying Killing vectors. It gives rise to a tower of growing rank Killing tensors determined by the structure constants of the corresponding Lie algebra. A canonical example of a metric with such emergent non-trivial hidden symmetries in all dimensions is provided by rotating (off-shell) generalized Lense–Thirring spacetimes, where the irreducible Killing tensors arise from the underlying spherical symmetry of the base space. A physical on-shell realization of this construction in four dimensions is embodied by a rotating black hole in the Einstein–Maxwell–Dilaton–Axion theory. Further examples of equal spinning Myers–Perry spacetimes and spacetimes built on planar and Taub–NUT base metrics are also discussed.

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Jorma Louko
(University of Nottingham)

Waiting around for Unruh

In the ongoing work towards observing the circular motion Unruh effect in (2+1)-dimensional analogue spacetime systems, one challenge is that the effective temperature experienced by a local detector is much smaller than the linear acceleration prediction when the detector's energy gap is small and the interaction time is long. We show that an effective temperature of the order of the linear acceleration prediction can be regained via a controlled long-time-small-gap double limit, where the detector's coupling to the field is allowed to change sign. Such sign changes may be naturally realisable in experiments where a laser beam plays the role of the detector. As a mathematical tool, we provide a new implementation of the long interaction time limit, with a precise asymptotic control of both the coupling strength and its Fourier transform. (Based on arXiv:2508.19987 with Leo J. A. Parry, Diego Vidal-Cruzprieto and Christopher J. Fewster.).

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James Lucietti
(University of Edinburgh)

Intrinsic rigidity of extremal horizons and black hole uniqueness

I will survey the classification of extremal horizons in vacuum spacetimes (including a cosmological constant) and present a recent rigidity theorem which shows that the intrinsic geometry of compact cross-sections of such horizons must admit a Killing vector field. In particular, this implies that the extremal Kerr horizon is the most general such horizon in four-dimensional General Relativity, completing their classification. I will also discuss the application of such intrinsic horizon rigidity to the corresponding black hole classification, in particular, a recent uniqueness theorem which shows that the extremal Schwarzschild–de Sitter spacetime (or its near-horizon geometry) is the only analytic Einstein spacetime with positive cosmological constant that contains a static extremal horizon with a compact cross-section.

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Yǒnggé Mǎ (马永革)
(Beijing Normal University)

Loop quantum gravity effects on forming a black hole: in collaboration with Jurek Lewandowski

After a short introduction to the collaboration between Professor Lewandowski and BNU Gravity Group, the collaborated work on the quantum Oppenheimer–Snyder model will be presented. This is the first example to realize the black hole to white hole transition by the collapsing of a dust ball with the effect of loop quantum gravity. The image of this transition may provide observational effect of quantum gravity.

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Ilkka Mäkinen
(National Centre for Nuclear Research)

Scalar curvature operator: applications to models of LQG dynamics

The three-dimensional scalar curvature is relevant to loop quantum gravity both as a central geometrical observable characterizing the geometry of the spatial manifold, and as a possible ingredient for the formulation of the dynamics in the canonical theory (as the Lorentzian term of the Hamiltonian constraint operator). In my talk I will review the construction of an operator introduced by Jurek and myself to represent the Ricci scalar on the Hilbert space of loop quantum gravity restricted to a fixed cubical graph. I also discuss some potential applications of this operator to loop quantum cosmology, and to the computation of time evolution of simple semiclassical states in quantum-reduced loop gravity.

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Lionel Mason
(University of Oxford)

Celestial holography from twistor space

The celestial holography programme seeks to find a holographic dual to four-dimensional gravity defined at the null infinity at the boundary of an asymptotically flat space-time. The correlation functions of the dual theory at infinity are meant to compute the scattering amplitudes of the bulk gravity. This talk will review some of the progress and explain how the ideas are tied up with twistor formulations of physical theories with the celestial symmetries being simply the natural geometric symmetries of twistor space. The twistor formulations of physical theories arising from twists of conventional string theories in twistor space. This is joint work with Adam Kmec, Romain Ruzziconi and Atul Sharma. Arxiv:2506.01888.

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Guillermo A. Mena Marugán
(IEM-CSIC, Madrid)

A hamiltonian formalism for perturbed (interiors of) nonrotating black holes

There is an increasing interest in classical and quantum Kantowski-Sachs cosmologies owing to their relation with the interior of nonrotating black holes. We recently developed a Hamiltonian formalism for (axial) perturbations of these cosmologies, with which it is straightforward to find all physical perturbative gauge invariants. Adopting this formalism, I will present a geometric interpretation of Darboux transformations between (axial) gauge invariants, characterizing them as generalized canonical transformations that preserve the Hamiltonian structure of the perturbations in the black hole interior.

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Maciej Ossowski
(University of Warsaw)

Topologically non-trivial black holes and their spacetimes

I will talk about the horizons with non-trivial bundle topology and their embedding into the Plebański–Demiański family of spacetimes. Although the spherical case is of the most interest, the classification of Petrov type D horizons with the space of null generators being a Riemann surface of any genus has been obtained. Unexpectedly, this construction hints that the conical singularity must be observer-dependent in spacetimes with NUT.

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Tomasz Pawłowski
(University of Wrocław)

Propagation of light over (loop) quantum universe

One of principal aspects in which the effects of quantum gravity are hoped to manifest itself through possible modification to a dispersion relation of electromagnetic (e-m) waves. In context of loop quantization a technically viable approach to determine it become possible after a seminal work by Ashtekar, Kamiński and Lewandowski on emerging quantum field theory over loop cosmological spacetime: by combining (i) the symmetry reduced approaches to spacetime quantization (like loop quantum cosmology), and (ii) the (extension of the)

Born–Oppenheimer approximation of interacting fields, one can build a reliable though still quasi-phenomenological model for a description of propagation of the e-m radiation over a cosmological spacetime. I will review past works of Professor Jerzy Lewandowski employing this approach as well as further (including recent) results of the follow-up works and extensions of the original studies. In particular, the reexamination of the approach leads to the following conclusions: (i) the e-m wave propagation agrees with the one predicted by general relativity in the low energy limit, and (ii) loop quantum effects actually suppress the modifications to the dispersion relation in comparison with those predicted, where the geometry is quantized via geometrodynamics.

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Roger Penrose
(Mathematical Institute, Oxford University)

Gravitational radiation and dark matter with positive Λ

In view of Lewandowski's interest in quantum gravity with positive cosmological constant, it is appropriate to consider how the theory of CCC (conformal cyclic cosmology) addresses this issue. In CCC it is appropriate to consider the degrees of freedom in dark matter to be intimately related to those of the gravitational field itself. In this talk, the formalism of 2-component spinors is employed in order to to gain insights into this issue.

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István Rácz
(Wigner Research Center for Physics)

Construction of hyperboloidal initial data without logarithmic singularities

It is well known that general solutions obtained using the elliptic method contain poly-logarithmic singularities in the hyperboloidal initial value setting. In this lecture, we will demonstrate that, when the Bondi energy and momentum are well-defined, the generic solutions of the parabolic-hyperbolic form of these constraints are free of logarithmic singularities. This result verifies the smoothness assumptions Penrose made when proposing the concept of asymptotically simple spacetimes.

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Carlo Rovelli
(CPT, Aix-Marseille University)

Should we expect a 20μg particle?

The LQG area gap implies that minimal non-vanishing energy BH's are around 20μg. If the transition to Minkowski is suppressed by the large interior volume, these objects may be long living. An energy and area eigenstate have maximally spread extrinsic curvature. Hence these objects are superpositions of black and white holes.

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Hanno Sahlmann
(FAU, Erlangen-Nuremberg)

Why loop quantum gravity with selfdual variables is hard

Ashtekar's selfdual variables have very interesting structural properties that make them a natural starting point for a canonical quantum theory of gravity. It is therefore striking that, despite the work undertaken in this direction, more progress has been achieved for quantizing real connection variables.

We sketch a no-go theorem that perhaps explains some of the difficulties. It shows that a quantization in the spirit of canonical loop quantum gravity, with holonomies and fluxes playing an important role, and adjointness relations expressing the reality conditions, subject also to some further, more technical assumptions, does not exist.

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George A. J. Sparling
(University of Pittsburgh)

Signposts to the future: the legacy of Jerzy Lewandowski

From the perspective of twistor theory, first I will discuss Jerzy's celebrated work with Cauchy–Riemann structures, then the theory of isolated horizons in spacetime; this will lead naturally to the applications to these theories of concepts arising in the context of Penrose limits. The emphasis throughout will be on future developments building on the sound foundations provide by Jerzy and his co-authors. This talk will present joint work with Jonathan Holland.

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Simone Speziale
(CPT, Aix-Marseille University)

Symmetries of non-expanding horizons and general null hypersurfaces

I will review Jurek's work on symmetries and Noether charges for non-expanding horizons, and relate it to similar studies on general null hypersurfaces.

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Arman Taghavi-Chabert
(Łódź University of Technology)

Cauchy–Riemann geometry in general relativity: a brief survey

Complex methods have long been used in the study of exact solutions to Einstein's field equations. On a conceptual level, Cauchy–Riemann structures underlie the geometry of light rays. In this talk, I will give a brief survey of the historical development of this topic, to which Jerzy Lewandowski significantly contributed in his early career.

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Yaser Tavakoli
(University of Guilan)

Fermions in loop quantum cosmology

We study fermionic perturbations on a closed FLRW spacetime in LQC, using a Hamiltonian approach. Expanding in spinor harmonics and truncating at quadratic order, we obtain a decoupled, mode-by-mode description as time-dependent Fermi oscillators. In the test-field limit, massive modes propagate on dressed metrics with Planck-scale corrections, while massless modes experience conformally corrected backgrounds. Going beyond this regime via a Born–Oppenheimer approximation, fermionic backreaction induces a rainbow metric, with each mode contributing a state-dependent shift to the background. Vacuum occupation delays the quantum bounce; excited states advance it. At large volumes, massive fermions generate a residual energy density – acting as an emergent cosmological constant – capable of driving late-time acceleration, while massless modes decouple.

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Thomas Thiemann
(FAU Erlangen-Nürnberg)

Canonical quantum gravity

We discuss several key ingredients of the canonical quantisation approach to quantum gravity.

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Madhavan Varadarajan
(Raman Research Institute)

Hilbert space non-separability as a virtue

Two issues of interest to qft in cs and quantum gravity are, respectively, (1) an articulation of a notion of unitarity between states which live in different Hilbert spaces and (2) a Lorentz covariant view of discrete spacetime structures. We argue, through 2 examples in the context of flat spacetime quantum field theory, that Hilbert space non-separability may offer a fresh perspective on these issues.

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Wolfgang Wieland
(FAU, Erlangen-Nuremberg)

Local subsystems on the light front: luminosity and local amplitudes

This presentation gives an outline of a research programme to investigate the effects of the loop gravity discreteness of space on the quantization of gravitational null initial data. The starting point is a non-perturbative characterization of the gravitational phase space on a null boundary for tetradic gravity with the parity violating γ-term (Holst term) in the action. Then, the description is taken to the quantum level. Starting from the standard Thiemann quantisation of half-densities in loop quantum gravity, a model of a quantum null geometry is found. The spatial sections of the three-dimensional null initial surface are thereby tessellated into a fixed number of plaquettes. Each of these plaquettes is akin to the punctures that characterize the quantum geometry of an isolated horizon. But now we are in a more general setting in which we allow the null congruence that forms the null boundary to have shear. Each of these punctures carries a CFT. Depending on the value of the central charge, two regimes can be distinguished. There is an infra-Planckian regime in which the central charge is positive and an ultra-Planckian regime in which it is negative. A negative central charge is problematic because it is a strong indication for a non-unitary CFT, which has no positive-definite inner product on its physical state space. For an asymptotic boundary, the two regimes are separated by the Planck power. Below the Planck power, the spectrum of the radiated power is discrete and the central charge is positive. Above the Planck power, the central charge is negative. The talk is based on arXiv:2402.12578, arXiv:2401.17491, arXiv:2104.05803.

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Cōng Zhāng (张聪)
(Beijing Normal University)

General covariance in effective quantum black hole models

In this talk, I will present a series of results concerning general covariance in effective quantum black hole (BH) models. Within the framework of spherically symmetric models, general covariance is precisely formulated as a set of equations, leading to necessary and sufficient conditions for a generally covariant theory. Using these conditions, we derive equations for the effective Hamiltonian constraint and solve them to obtain the most general form of the Hamiltonian constraint describing generally covariant BH models. Remarkably, the results show that any one-parameter family of static, spherically symmetric spacetime

metrics can be embedded as the unique vacuum solution set of a generally covariant theory of pure gravity. This provides a complete resolution to the inverse problem of Birkhoff's theorem and establishes a systematic method for reconstructing covariant dynamics from a given geometry. Finally, we apply this framework to loop quantum gravity-inspired spacetimes and derive the corresponding covariant effective Hamiltonian constraint.

Posters

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Hristu Culetu
(Ovidius University)

Geodesics in a static spacetime applied in microphysics

A time dependent conformally flat spacetime is studied in this paper. The source of curvature is given by an anisotropic stress tensor that satisfies all energy conditions. An observer placed at fixed spatial coordinates feels a nonzero energy flux density along x-direction. The null geodesics are investigated. Apart from the standard ones (in flat spacetimes) a null geodesic is obtained from the vanishing of the conformal factor. A lot of numerical examples are given, emphasizing the strong curvatures near the asymptotes of the hyperbola. The spacetime becomes Minkowskian far from the light cone.

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Grzegorz Czelusta
(Jagiellonian University)

Spin networks on quantum computers

Spin network states are a powerful tool for constructing SU(2) gauge theories on a graph. In loop quantum gravity (LQG) they have yielded many promising predictions, although progress has been limited by the computational challenge of dealing with high-dimensional Hilbert spaces. To explore more general configurations, quantum computing methods can be applied by representing spin network states as quantum circuits. We present different methods for constructing quantum circuits for 4-valent Ising spin networks and their use in computing quantum information aspects of space-time geometry.

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Igor Kanatchikov
(National Centre for Quantum Information, University of Gdańsk)

On the quantum gravitational origin of MOND

Precanonical quantisation of pure GR yields the spin connection foam (SCF) model of quantum spacetime, described by one- and two-point amplitudes on the spin connection bundle over spacetime. Within this framework, the metric structure emerges as a derived quantity. Analysing a nonrelativistic test particle immersed in the SCF of Minkowski spacetime, within the gravitational field of a point mass M, reveals a quantum modification of the Newtonian potential at large distances. A transformation to a non-inertial reference frame, defined by the mean-field acceleration arising from vacuum fluctuations of the spin connection within SCF, reproduces Milgromian MOND with a theoretically derived interpolating function. The theory also establishes the relation between the Milgromian acceleration a_0 and the cosmological constant Λ. Their small numerical values are linked to a hadronic scale of the parameter $\varkappa$, which is introduced in precanonical quantisation and connected to the mass gap in the pure Yang–Mills sector of the Standard Model.

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Patryk Mieszkalski
(Wrocław University)

Dual differential geometry

I'll show dual version of First Order Differential Calculus, and its usage in obtaining covariant differential calculus on module algebras on an example of kappa-Poincare.

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Hugo A. Morales-Técotl
(Universidad Autónoma Metropolitana Iztapalapa)

General covariance in effective models motivated by loop quantum gravity

A criterion for testing general covariance in effective quantum gravity theories is presented based on invariance under diffeomorphisms of the Einstein-Hilbert action and adapted to the case of effective canonical models. This scheme is adapted to spherically symmetric spacetimes in vacuum with inverse triad and holonomy modifications that arise in loop quantization. It is found that, in addition to the initial modifications of the Hamiltonian, quantum corrections of the classical metric itself are needed as well in order to obtain generally covariant models. Finally a comparison with alternative approaches is provided.

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Antonio Panassiti
(Università degli Studi di Catania; Radboud University Nijmegen)

On the Cauchy horizon (in)stability of regular black holes

Regular black hole solutions typically come with an outer event horizon and an inner Cauchy horizon. For the Reissner–Nordstrom geometry, the analysis based on the Ori model shows that the Cauchy horizon in unstable against perturbations, because of the mass-inflation effect. However, when such analysis is applied to regular black holes, a richer picture emerges. For different regular geometries, like the Bardeen solution and the Hayward black hole, we show how to depict the whole phase space related to the dynamical system corresponding to the Ori model itself, illustrating all the possible fates for the perturbed spacetime at the

Cauchy horizon, in relation to clusters of initial conditions. Beyond the standard mass-inflation scenario, other phases are found. In particular, we analyze the stability of a new solution obtained from a model of asymptotically safe gravitational collapse [Phys. Rev. Lett. 132 (2024) 3, 031401]. Remarkably, for this geometry, there is a phase where the Misner–Sharp mass at the Cauchy horizon remains of the same order of magnitude of the mass of the unperturbed black hole, since its growth is just logarithmic.