The 11th Conference of the Polish Society on Relativity

Registrants Book

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Mr. Tadeusz Adach #81

Personal Data

Affiliation: University of Wrocław
PoToR member: No

Contribution

Title: Discrete symmetries in kappa-Minkowski field theories

Abstract: I will present some new results on deformed C, PT and CPT symmetries for field theories in kappa-Minkowski noncommutative spacetime based on recent work that we have done on scalar and spinor fields, as well as the relationship between the discrete sector and kappa-Poincare.

Ms. Cynthia Belen Arias Pruna #63

Personal Data

Affiliation: Charles University

PoToR member: No

Contribution

Title: Constructing Teukolsky-Compatible Symmetry Operators for Maxwell Fields

Abstract: We study a class of symmetry operators acting on vector perturbations in the Kerr spacetime and employ them to generate new solutions of the Maxwell equations. The operators are second-order in derivatives and are directly constructed from the principal Killing-Yano tensor. One of them reproduces a known result from the Debye potential theory, while the other yields a novel symmetry. When applied to a single mode solution, this new operator naturally reproduces the Teukolsky separation constant, indicating its role in the analysis of spin-1 fields in rotating black hole backgrounds.

Dr. Mehdi Assanioussi #42

Personal Data

Affiliation: NCBJ (Warsaw)
PoToR member: Yes

Contribution

Title: Graph coherent states in loop quantum gravity

Abstract: The construction of graph coherent states in the loop quantum gravity framework is based on the notion of graph change, as for instance the one induced by the loop quantum dynamics for Yang-Mills and gravity. Using a Fock-like canonical structure, these states take the form of an infinite superposition of basis network states with different graphs. In this talk, I will revisit the construction of the graph coherent states in loop quantum gravity coupled to matter, present new results regarding the properties of these states and discuss certain extensions of the construction and other avenues to explore.

Prof. Fernando Barbero #33

Personal Data

Affiliation: Instituto de Estructura de la Materia
PoToR member: No

Contribution

Title: Some reflections on Hamiltonians and GR

Abstract: 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.

Mr. Michał Bobula #92

Personal Data

Affiliation: University of Wrocław

PoToR member: No

Contribution

Title: Cosmic inflation prevents black hole singularity formation

Abstract: I will discuss a modified model for the Oppenheimer–Snyder collapse scenario where the exterior of the collapsing dust ball is a Hayward black hole spacetime and the interior is a dust Friedmann–Robertson–Walker cosmology. This interior cosmology is entirely determined by the junction conditions with the exterior black hole. It turns out to be non-singular, displaying a power-law contraction which precedes a de Sitter phase or, reversely, a power-law expansion followed by a de Sitter era. I will demonstrate that cosmic inflation in the collapse setting is a mechanism that decelerates collapsing matter, thereby preventing singularity formation. I will also analyse the global causal structure and the viability of the model.

Mr. Luca Cafaro #70

Personal Data

Affiliation: University of Warsaw

PoToR member: No

Contribution

Title: Quantum Oppenheimer-Snyder model

Abstract: The Oppenheimer-Snyder (OS) model provides the simplest framework for describing spherically symmetric gravitational collapse. Due to its simplicity, it has been extensively employed as a toy model for probing the semiclassical limits of various approaches to quantum gravity. Within Loop Quantum Gravity (LQG), significant efforts have been devoted to the semiclassical analysis of this model, demonstrating that the classical singularity is replaced by a quantum bounce. However, progress at the fully quantum level remains limited. In this talk, I will present a fully quantum treatment of the OS model within the framework of LQG, drawing heavily on techniques developed in Loop Quantum Cosmology. I will show that the singularity resolution emerges as a robust prediction of the quantum theory and that the semiclassical models previously studied provide an accurate approximation of the overall dynamics.

Prof. Carla Cederbaum #34

Personal Data

Affiliation: University of Tübingen
PoToR member: No

Contribution

Title: On photon spheres and photon surfaces in static spacetimes

Abstract: It is well-known that the Schwarzschild spacetime of positive mass m contains a photon sphere at $r=3m$. We will show that it also possesses a rich family of spherically symmetric photon surfaces, i.e., timelike hypersurfaces P such that any null geodesic initially tangent to P remains tangent to P, and analyze their behavior near the black hole horizon and near infinity. We will also show that these are essentially the only photon surfaces in the Schwarzschild. These results extend accordingly to higher dimensions, to negative mass Schwarzschild, Reissner—Nordström, (anti-)de Sitter and many other spacetimes. Conversely, we will show that the Schwarzschild spacetimes are the only static, vacuum, asymptotically flat spacetimes possessing so-called "equipotential" photon surfaces, again in all dimensions. Physically speaking, this asserts that static, vacuum, equipotential photon surfaces have no hair. This can be proved by various methods which I will briefly sketch. This result also extends to electro-vacuum and other matter models. The talk builds on joint works with Borghini, Cogo, Fehrenbach, Galloway, Jahns, Leandro, Paulo dos Santos, Senthil Velu, Vi\v{c}\'anek Mart\'inez, and Wolff.

Prof. Piotr Chruściel #35

Personal Data

Affiliation: CFT PAN (Warsaw)
PoToR member: Yes

Contribution

Title: Gluing variations

Abstract: I will review various ways of constructing spacetimes of interest using spacelike and gluing constructions methods.

Dr. habil. Adam Chudecki #58

Personal Data

Affiliation: Lodz University of Technology
PoToR member: Yes

Contribution

Title: On Walker and para-Hermite Einstein spaces

Abstract: A special class of (complex) para-Hermite Einstein spaces is analyzed. For this class of spaces the self-dual Weyl tensor is type-[D] in the Petrov-Penrose classification. The anti-self-dual Weyl tensor is algebraically degenerate, equivalently, there exists an anti-self-dual congruence of null strings. It is assumed that this congruence is parallely propagated. Thus, the spaces are not only para-Hermite but also Walker. A classification of the spaces according to three criteria is given. Finally, explicit metrics of all admitted Petrov-Penrose types are found.

Dr. Malgorzata Curylo #83

Personal Data

Affiliation: Monash University
PoToR member: No

Contribution

Title: Phase-coherent gravitational-wave sky maps with pulsar timing arrays

Abstract: Pulsar timing arrays, which probe nanohertz-frequency gravitational waves, have recently produced the very first evidence for the presence of a stochastic background. This background most likely originates from a superposition of inspiraling supermassive black hole binaries. However, more speculative sources such as cosmic strings and phase transitions cannot be ruled out. Mapping the gravitational-wave sky is one of the most promising methods to identify and characterise the source of the signal. In particular, any sign of anisotropy or hot spots would suggest the signal is a superposition of black hole binary signals. Initial studies, which map gravitational-wave power, suggest the signal is consistent with an isotropic background. In the talk, I describe a phase-coherent approach to gravitational-wave cartography in which one measures the plus and cross polarisation states of gravitational waves across the sky. I apply this framework to data from the MeerKAT Pulsar Timing Array and argue that the phase coherent approach creates lossless maps, which help us to discriminate between different types of signals.

Dr. Marco de Cesare

#101

Personal Data

Affiliation: Scuola Superiore Meridionale
PoToR member: No

Contribution

Title: Gravitational wave oscillations in bimetric cosmology

Abstract: Gravitational wave oscillations represent a distinctive signature of some gravitational theories beyond general relativity, notably bimetric gravity. In this theory, gravitational waves are generated as a superposition of massless and massive graviton states, which undergo mixing as they propagate through spacetime. This phenomenon, which displays some analogies to neutrino oscillations, is characteristic of theories with extra tensor modes and does not have an analogue in general relativity. In this talk, I will present analytical techniques to study the propagation of tensor modes in an expanding universe and extract accurate predictions for the redshift-dependent corrections to the amplitude and phase of the gravitational wave signal.

Dr. Orest Dorosh #5

Personal Data

Affiliation: NCBJ (Warsaw)
PoToR member: No

Contribution

Title: Searching for quasi-normal modes from Binary Black Hole mergers

Abstract: We present a new method to search for gravitational waves from quasi-normal modes in the ringdowns of the remnants of the mergers of the binary black hole systems. The method is based on maximum likelihood estimation. We derive a time-domain matched-filtering statistic that can be used to search for any number of modes in the data. The parameters of the modes can be estimated and the modes present in the data can be reconstructed. We perform Monte Carlo simulations of the method by injecting the quasi-normal mode waveforms to noise. We analyze performance of the method for searches of quasi-normal modes in the advanced detectors data like LIGO and Virgo, in the third generation of detectors like Einstein Telescope and Cosmic Explorer and in the space detector LISA data.

Prof. Maciej Dunajski #1

Personal Data

Affiliation: University of Cambridge

PoToR member: Yes

Contribution

Title: Gravitational Instantons - beyond self-duality.

Abstract: 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, and since then a lot of effort has been put to make the term ‘look–like’ into a precise mathematical statement. 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. I will review the subject and present some new results which disprove the "Euclidean Black Hole Uniqueness Conjecture".

Dr. Filip Ficek #72

Personal Data

Affiliation: University of Vienna

PoToR member: Yes

Contribution

Title: Instability of nonlinear scalar field on asymptotically AdS black hole backgrounds

Abstract: We study how the dynamics of a conformal cubic scalar field on the Reissner-Nordström-anti-de Sitter background depends on the black hole size, charge, and the choice of the boundary condition. In particular, we observe a new instability mechanism that emerges for large black holes at the specific critical value of the charge. Similarities between Reissner-Nordström and Kerr black holes let us suspect that a similar effect may also occur for rotating black holes. This is a joint work with Maciej Maliborski.

Mr. Ernest Głowacki #73

Personal Data

Affiliation: University of Białystok

PoToR member: No

Contribution

Title: Narrow-band searches for gravitational waves from known pulsars

Abstract: Gravitational-wave astronomy is a new field of astronomy initiated in 2015 by detecting gravitational waves emitted by two colliding black holes. One yet-undetected type of gravitational wave is continuous-type gravitational waves emitted by rotating single neutron stars in our Galaxy. Several data-analysis pipelines for searching for continuous gravitational waves in data collected by LIGO/Virgo/KAGRA detectors already exist, and the Polish Virgo-Polgraw group is creating a new pipeline based on the use of the F-statistic derived by Jaranowski, Królak and Schutz. This presentation will provide an overview of the Virgo-Polgraw group's pipeline aimed at the narrow-band search for gravitational waves from known pulsars.

Prof. Andrzej Góźdź #26

Personal Data

Affiliation: Maria Curie-Skłodowska University
PoToR member: Yes

Contribution

Title: Temporal momentum

Abstract: Treating time on quantum level as a quantum observable, similar to position, a problem of dual observable arise. The main features of the temporal momentum have to be described in Minkowski space. The role of the temporal momentum in dynamics, description of clocks and others will be presented.

Prof. Zbigniew Haba #43

Personal Data

Affiliation: University of Wrocław
PoToR member: Yes

Contribution

Title: Chern-Simons states in SO(1,n) Yang-Mills gauge theory of quantum gravity

Abstract: We discuss a quantization of the Yang-Mills theory with an internal symmetry group SO(1,n) treated as a unified theory of all interactions. In one-loop calculations we show that Einstein gravity can be considered as an approximation to gauge theory. We discuss the role of the Chern-Simons wave functions in the quantization.

Mr. Tomáš Hale #68

Personal Data

Affiliation: Charles University
PoToR member: No

Contribution

Title: Thermodynamic Features of Charged and Accelerating Black Holes

Abstract: Closer inspection of charged accelerating black holes spacetimes reveals some new unexpected features. More precisely, a reparametrization of the C-metric describing a charged and slowly accelerating black hole in asymptotically AdS spacetime with cosmic strings enables a tuning of the functional dependence of thermodynamic quantities. For example, the boost Killing vector normalization can be eliminated, the overall conical deficit from the cosmic strings can be chosen to vanish, or the solution can have pure AdS asymptotics. In the latter case, the thermodynamic electric potential picks up a modification which also appears when coupled to nonlinear electrodynamics. This can be uncovered e.g. by calculating the Euclidean on-shell action. In this talk I want to discuss some of these results.

Dr. Betti Hartmann #36

Personal Data

Affiliation: University College London

PoToR member: No

Contribution

Title: Black holes and boson stars with wavy scalar hair

Abstract: Static, spherically symmetric black holes can carry scalar hair when coupling standard Einstein gravity minimally to a self-interacting complex scalar field and a U(1) gauge field. For this scalar hair to exist, the frequency of the scalar field needs to be fine-tuned. In this talk, I will discuss these solutions and point out that for sufficiently large gravitational coupling, the space-time splits into two distinct parts: (a) an inflating interior and (b) an exterior which is described by the extremal Reissner-Nordström solution. Moreover, for a specific range of parameters, the scalar hair develops spatial oscillations, i.e. black holes can carry so-called wavy scalar hair. I will also comment on the globally regular counterparts of these solutions: charged boson stars which can reach so-called frozen states for specific choices of the coupling constants.

Dr. Falk Hassler #49

Personal Data

Affiliation: University of Wrocław
PoToR member: No

Contribution

Title: Strings, Membranes, and a Hidden Symmetry Algebra in Quantum Gravity

Abstract: Geometry underpins gravity, while the quantum world is governed by algebras of observables. In string theory, (super)gravity and its quantum corrections emerge from specific vibration modes of relativistic strings, described by vertex operator algebras in two-dimensional conformal field theories. However, the precise map between these two is highly non-trivial and is only known explicitly to the first orders in a perturbative expansion. I will reveal a new, infinite-dimensional symmetry algebra that at least reproduces the leading two orders of quantum corrections. Remarkably, it has the potential to evade a no-go theorem that rules out competing approaches to uncover hidden symmetries in supergravity beyond second-order corrections. Beyond fundamental insights, these results have broad applications, including the construction of new supergravity solutions, the analysis of their spectrum, the computation of renormalization group flows in two-dimensional σ-models, and the study of integrable strings. A generalization of Cartan geometry is found on the mathematical side.

Dr. Filip Hejda #88

Personal Data

Affiliation: CENTRA, IST (Lisbon) & CEICO, FZU (Prague)
PoToR member: No

Contribution

Title: Energy extraction from black holes via collisional Penrose process with charged particles

Abstract: Following the realisation by Bañados, Silk and West that particles coming from rest at infinity can collide close to a black hole with arbitrarily large centre-of-mass collision energy (under idealised conditions), interest was renewed in finding the best-case scenario for the collisional Penrose process. Although the energy that can be extracted in the vacuum case turned out to be constrained by strict unconditional upper bounds even for the most favourable scenarios, such bounds disappear whenever both the black hole and the escaping particles are electrically charged. We showed that this is the case for arbitrarily small values of black hole charge [PhysRevD.105.024014, APhysPolBSupp.15.1-A5], using the simplifying assumptions of the black hole being extremal and the collision happening infinitely close the horizon. In the present talk, we consider a further generalisation in which these assumptions are relaxed. For subextremal black holes, the rest mass of particles that can be produced becomes tightly constrained, yet significant energy extraction remains possible in principle. Nevertheless, the most important question that we address is whether such possibilities are compatible with inclusion of charged particles with realistic properties.

Dr. Anna Horváth #54

Personal Data

Affiliation: Wigner RCP & Eötvös Loránd University

PoToR member: No

Contribution

Title: Extra dimensions in strong gravitational field

Abstract: Studying the effects of an extra compactified spatial dimension on the phase space of massive particles. We investigate the dispersion relation within the Kaluza-Klein model, in a spherically symmetric, static spacetime. Modifications to the scalar curvature of phase space due to gravity and the scalar field appearing in the Kaluza-Klein model are considered. This helps us to understand both strong gravitational effects, and the possible multidimensional structure of space-time at microscopical scales.

Dr. Surajit Kalita #56

Personal Data

Affiliation: University of Warsaw

PoToR member: No

Contribution

Title: Illuminating the Hubble Tension with Fast Radio Bursts

Abstract: Fast Radio Bursts (FRBs) are millisecond radio transients with high dispersion measures, making them powerful tracers of ionized matter across cosmological distances. In this talk, I present a Bayesian analysis of a sample of localized extragalactic FRBs from multiple telescopes to constrain the Hubble constant. Our results show that FRBs can effectively measure the Hubble constant in the late Universe, yielding tighter constraints than previous FRB studies. Notably, the derived values with 1-sigma uncertainties under Lambda-CDM cosmology no longer overlap with early-Universe estimates, reinforcing the Hubble tension and highlighting the potential of FRBs as precision cosmological tools.

Dr. Igor Kanatchikov #90

Personal Data

Affiliation: KCIK (Gdańsk)
PoToR member: Yes

Contribution

Title: Dark matter and dark energy from first principles of precanonical quantum gravity

Abstract: Precanonical quantum gravity posits a quantum spacetime geometry characterised by a fluctuating spin connection foam (SCF). This framework naturally yields a characteristic acceleration scale, $a_*=8\pi G \hbar \varkappa$, which is related to the cosmological constant, $\Lambda \sim (8\pi G \hbar \varkappa)^2$. Here, $\varkappa\sim (\Delta m)^3$ represents a parameter inherent to the theory, demonstrated to correlate with the mass gap of the Yang-Mills sector of the Standard Model. The hadronic scale of $\varkappa$ renders a_* and Λ consistent with the observed magnitudes of the Milgromian acceleration and the cosmological constant, respectively. Furthermore, an analysis of a nonrelativistic test particle, moving within the gravitational field of a mass M and immersed in the static approximation of the SCF, results in a modified Newtonian potential. The asymptotic behaviour of this potential, at both small and large distances, aligns with the potential derived from approaches to flat galactic rotation curves based on conformal gravity. It also reproduces the modified Newtonian dynamics (MOND) proposed by Milgrom as an alternative to dark matter. Both results are derived from the first principles of precanonical quantum gravity. We discuss their consequences across scales, from the outer Solar System to the Universe's large-scale structure, and their implications for research in 'dark sectors' and modifications of classical General Relativity.

Mr. Ghafran Khan #53

Personal Data

Affiliation: Jagiellonian University

PoToR member: No

Contribution

Title: Thin finite accretion disk confined to the equatorial plane of the Kerr space time

Abstract: We construct a general relativistic kinetic model of a thin, finite accretion disk confined to the equatorial plane of the Kerr spacetime. Our model is generalized by considering a disk with a finite radial extent. We investigate both monoenergetic and Maxwell–Jüttner-type particle distributions at the outer edge of the disk. In each case, we account for both scattered and absorbed particles. Additionally, we determine the mass accretion rate, the energy accretion rate, and the angular momentum accretion rate.

Prof. Jerzy Kijowski #79

Personal Data

Affiliation: CFT PAN (Warsaw)
PoToR member: Yes

Contribution

Title: Gravity on a Large Scale—Does It Necessarily Look like It Does on a Small Scale?

Abstract: The notion of a local inertial reference frame is thoroughly analyzed. Dynamics of a field of such frames is 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 this sector, equivalent to Einstein's vacuum equations, is obtained unambiguously and admits no ad hoc corrections. The cosmological constant is an essential element of this construction and cannot be removed. It has been shown that the second sector of this theory corresponds to electrodynamics, while the last sector could possibly describe dark matter.

Mr. Jerzy Knopik #78

Personal Data

Affiliation: Jagiellonian University

PoToR member: No

Contribution

Title: Late-time dynamics of standing waves in the massive nonlinear Klein-Gordon equation with cubic-quintic terms: a hyperboloidal approach

Abstract: We consider a simplified model of boson stars and investigate a family of time-periodic solutions known as Q-balls in the 3+1 dimensional complex nonlinear Klein-Gordon equation with cubic and quintic nonlinearities on a Minkowski background. The spectral stability of these solutions is analyzed using the Vakhitov-Kolokolov criterion. We further study the long-time evolution of unstable stationary solutions under small perturbations, employing a hyperboloidal foliation of Minkowski spacetime to track their relaxation dynamics. This is joint work with Piotr Bizoń.

Dr. Dionysios Kokkinos #18

Personal Data

Affiliation: Hellenic Mediterranean University
PoToR member: No

Contribution

Title: A Directive for Deriving (Algebraic) General Solutions of Einstein's Equations Based on Canonical Killing Tensor Forms

Abstract: This work builds upon our previous study, where by assuming the existence of canonical Killing tensor forms and applying a general null tetrad transformation we derive exact solutions of Einstein's Field equations in vacuum with Λ (Petrov types D, III, and N). Among these, we identified a unique Petrov type D solution that admits the second canonical form, featuring a shear-free, diverging, and non-geodesic null congruence. Additionally, we obtained a Petrov type I solution, also characterized by a shear-free, diverging, and non-geodesic null congruence, by applying two null rotations while assuming the same canonical form of the Killing tensor. Building on this, and inspired by the role of symmetric null tetrads in deriving the general Petrov type D solution (Debever-Plebanski-Demiański solution) and in the GHP formalism, we propose a new approach to derive (algebraic) general solutions with hidden symmetries.

Jarosław Kopiński #15

Personal Data

Affiliation: University of California, Davis
PoToR member: No

Contribution

Title: Conformal geometry of spacetimes with prescribed asymptotic behavior

Abstract: Our universe can be modeled as a solution to the Einstein field equations starting with an initial Big Bang singularity and evolving toward late-time asymptotics characterized by exponential expansion driven by a positive cosmological constant. I will demonstrate how the methods of conformal geometry can be applied to describe the asymptotic behavior of this model through the conformal compactification of spacetime. This approach establishes a connection between the stress-energy tensor and the geometric quantities associated with the hypersurfaces representing the regularized initial and final states of the model.

Dr. habil. Mikołaj Korzyński #10

Personal Data

Affiliation: CFT PAN (Warsaw)
PoToR member: Yes

Contribution

Title: Redshift and position drift in cosmology

Abstract: I will discuss the redshift and position drifts for nearby and cosmological sources in cosmology. In particular, I will explain what kind of information about the geometry of spacetime we can extract from the multipole decomposition of the drifts and the bulk motions. The talk is based on a recent project with Asta Heinesen.

Dr. Ryshard-Pavel Kostecki #59

Personal Data

Affiliation: RCQI (Bratislava)
PoToR member: Yes

Contribution

Title: Topos-theoretic approach to vacuum algebraic quantum field theory over curved space-times

Abstract: Topos-theoretic approach to the foundations of quantum theory, developed by Chris Isham and his collaborators, has emerged from the consideration of some foundational problems in quantum gravity and quantum cosmology. However, it has not included any notion of space-time and has so far only dealt with the foundations of quantum mechanics. We bring it back to the quantum/gravity interface, by extending the spectral presheaf formalism to vacuum algebraic quantum field theory over curved space-times. More specifically, we will apply this formalism to the causal logics (developed by Cegła, Jadczyk, Jancewicz, 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 sub-algebras of a 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 presheafs. The co-Heying structure of a spectral presheaf leads to a natural appearance of the boundary operator (for causally closed regions, as well as for von Neumann algebra subfactors), satisfying Leibniz rule. Furthermore, the presence of closed time-like (or vertex) curves corresponds to the nontriviality of bi-Heyting modal operators. Finally, by introducing a natural category-theoretic generalisation of Haag’s "tentative postulate", we construct a representation of the vacuum a.q.f.t. as a suitable functor between the above 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.).

Mr. Maciej Kowalczyk #99

Personal Data

Affiliation: University of Wrocław

PoToR member: No

Contribution

Title: The Primodial Power Spectrum in Loop Quantum Cosmology for different regularizations

Abstract: In Loop Quantum Cosmology, the quantization of the Hamiltonian constraint involves a regularization procedure subject to certain ambiguities. Moreover, different regularizations lead to distinct mathematical formulations and, consequently, to different physical predictions. In this talk, we will explore the impact of this regularization on the primordial power spectrum of cosmological perturbations. Similarities with the situation found in delayed-inflationary scenarios are discussed.

Prof. Jerzy Kowalski-Glikman #23

Personal Data

Affiliation: NCBJ (Warsaw) & University of Wrocław
PoToR member: Yes

Contribution

Title: Quantum corner algebra, entanglement, and the area law

Abstract: In my talk, based on an upcoming paper with L. Ciambelli and L. Varrin, I will begin by recalling the construction of the corner algebra associated with a region in classical gravity, and its quantum counterpart in the case of two-dimensional gravity, where the region becomes a semi-infinite segment. I will then show how to compute the entanglement entropy between the segment and its complement. Finally, using the relation between two-dimensional gravity and spherically symmetric four-dimensional spacetimes, I will demonstrate that, in an appropriate limit, the resulting entanglement entropy reproduces the Bekenstein–Hawking area law.

Dr. Martin Krssak

#102

Personal Data

Affiliation: Comenius University in Bratislava

PoToR member: No

Contribution

Title: Regularisation of the gravitational action and self-excited instantons

Abstract: Finite Euclidean action solutions play a key role in understanding black hole thermodynamics and the path integral approach to quantum gravity. In the standard formulation of general relativity, obtaining such solutions typically requires adding the Gibbons-Hawking-York boundary term and finding an appropriate reference spacetime to eliminate IR divergences. In this talk, I will present an alternative approach based on the teleparallel formulation of general relativity, where no boundary terms are needed but requires matching the teleparallel spin connection with the tetrad. This leads to certain ambiguities in the procedure, linked to the topological properties of spacetime, and is closely related to our recent proposal of self-excited gravitational instantons.

Dr. habil. Patryk Mach #16

Personal Data

Affiliation: Jagiellonian University
PoToR member: Yes

Contribution

Title: Kinetic description of matter in the Kerr spacetime

Abstract: I will discuss recent progress concerning the general-relativistic kinetic theory in the Kerr spacetime. In this case, the main difficulty is related to controlling the phase-space geometry (for instance, finding an appropriate parameterization of the separatrix between scattered and plunging orbits). I will discuss applications to accretion problems, in particular the accretion of dark matter modeled as a collisionless gas, focusing on stationary solutions. Due to phase-space mixing, they are generally inaccessible to initial-value problem simulations. I will discuss models confined to the equatorial plane, but also comment on recent results involving off-equatorial motion.

Prof. Shahn Majid #38

Personal Data

Affiliation: Queen Mary University of London
PoToR member: No

Contribution

Title: Baby quantum gravity models and the cosmological constant

Abstract: I describe recent work with Blitz on a solution to the problem of the cosmological constant that builds on an idea of Carlip involving the energy of spacetime fluctuations in quantum gravity. We compute the latter using a baby quantum gravity model on a Lorentzian square and show that it is consistent with such an explanation. If time, I will also cover recent work with Liu revisiting Kaluza-Klein ideas but with fuzzy sphere fibre geometry at each point of spacetime. We show that this potentially provides a mechanism whereby gravity + Yang-Mills as we see it at low energies emerges due to quantum gravity on the fibre (which is justified as the fibre anyway needs to be about 11 Planck lengths to match the electroweak force). Both models will use a recent formalism of quantum or noncommutative Riemannian geometry.

Ilkka Mäkinen #61

Personal Data

Affiliation: NCBJ (Warsaw)
PoToR member: No

Contribution

Title: Dynamics of one-vertex states in quantum-reduced loop gravity

Abstract: We study the dynamics of simple quantum states of geometry, whose spin network graph consists of a single six-valent vertex, in the setting of quantum-reduced loop gravity. The Hamiltonian operator governing the dynamics of these states is derived from a corresponding operator defined within the framework of full loop quantum gravity. The dynamics generated by the Hamiltonian is explicitly computable at the level of numerical simulations. As a concrete example, we present results on the time evolution of semiclassical states representing homogeneous and isotropic spatial geometries. We further observe a certain formal similarity between the Euclidean part of the Hamiltonian of the one-vertex model and the Hamiltonian operator used in models of Bianchi I spacetimes in loop quantum cosmology. By extending this formal analogy to the Lorentzian part of the Hamiltonian, which is represented in our model by the three-dimensional scalar curvature, we propose a possible modified approach to the definition of the Hamiltonian constraint operator in loop quantum cosmology.

Ms. Jana Menšíková #44

Personal Data

Affiliation: Charles University

PoToR member: No

Contribution

Title: New interpretation of the original charged BTZ black hole spacetime

Abstract: In their seminal 1992 paper, Bañados, Teitelboim and Zanelli (BTZ) proposed a simple charged generalization of what is now known as the spinning BTZ black hole. However, it soon became clear that this spacetime does not satisfy Maxwell equations and was thus discarded. In this talk, we will see that this incorrect original BTZ metric can actually be redeemed - it can be interpreted as a solution of recently discovered Deshpande-Lunin theory which enables us to construct charged and spinning black holes in all odd dimensions by slightly modifying the action with special topological term.

Dr. Jurgen Mifsud

#107

Personal Data

Affiliation: University of Malta
PoToR member: No

Contribution

Title: Learning the Cosmos: Machine Learning Meets the Universe

Abstract: The rapid expansion of cosmological data, from surveys like Euclid, LSST, and DESI, presents unprecedented opportunities and challenges in extracting fundamental insights about the Universe. Traditional analysis pipelines, though robust, often face computational bottlenecks and model limitations in the era of high-dimensional data. This talk explores how machine learning (ML) is revolutionizing cosmological analyses. We will highlight recent advances in likelihood-free inference via artificial neural networks and reconstruction of cosmological observables without adapting any cosmological model. This talk aims to provide both a conceptual overview and practical insights into the current and future landscape of machine learning in cosmology.

Dr. Anna Pachoł #39

Personal Data

Affiliation: University of South-Eastern Norway
PoToR member: Yes

Contribution

Title: Noncommutative quantum phase spaces and their physical effects

Abstract: Possible deviations or extensions of quantum theory and incorporation of gravitational effects at the quantum scale can be explored by introducing modifications to quantum mechanical phase spaces. Quantum space-times and noncommutative geometry provide a natural framework where such modifications arise, leading to modifications of the canonical Heisenberg relations. These are often investigated to identify potential new effects that can be tested experimentally or used to constrain model parameters. In my talk, I will introduce various noncommutative generalizations of quantum phase spaces and discuss their possible effects and influence on physical systems.

Dr. Aliasghar Parvizi #98

Personal Data

Affiliation: University of Wrocław
PoToR member: No

Contribution

Title: Quantum Master Equation of Matter Fields in a Quantum Universe

Abstract: We explore the dynamics of quantum fields propagating in a quantum cosmological spacetime, focusing on the derivation and application of a quantum master equation. Our investigation examines how Planck-scale fluctuations in spacetime geometry introduce non-linearities in the field evolution equations. Using the quantum master equation, we analyze the phase-space dynamics of the matter field subsystem and the power spectrum of fields in cosmological settings. This framework provides insights on the quantum-to-classical transition, particularly elucidating how classical trajectories emerge from underlying quantum dynamics in interacting gravity-matter systems. We will present new results based on this approach, extending previous findings outlined in arXiv:2407.05500 and arXiv:2110.03069, while discussing their implications for early universe cosmology and the emergence of classical spacetime

Mr. Rene Payne #46

Personal Data

Affiliation: University of Wrocław

PoToR member: No

Contribution

Title: Covariant Phase Space and Noether Charges in Theory of Gravity

Abstract: We study conserved charges in gauge and gravitational theories using the Covariant Phase Space (CPS) formalism. Starting with electromagnetism, we show that the CPS charge reproduces Gauss's law. Applying the method to General Relativity, we recover the Komar charge from the Einstein–Hilbert action. When Analyzing Schwarszschild-Anti de Sitter spacetime, we find that the Komar charge diverges. To fix the divergence, the Pontryagin and Euler topological terms are introduced and we determine the corresponding coefficient to regularize the Komar mass. We determined the coefficient to be $\beta = -\frac{1}{16\pi} \frac{3}{16}$. We address non-conservation of charges associated with diffeomorphisms orthogonal to the boundaries and introduce the Extended Phase Space formalism.

Dr. Aleksandra Pędrak #27

Personal Data

Affiliation: NCBJ (Warsaw)
PoToR member: Yes

Contribution

Title: Integral quantization based on the Heisenberg-Weyl group: Minkowski spacetime

Abstract: The proposed quantization method exemplifies an integral quantization method and is based on coherent states generated by the Heisenberg-Weyl group, where the main element of this construction are positive operator valued measures, which are suitably defined for the purpose. The method presented here is dedicated to the description of the motion of a spinless particle in Minkowski spacetime. However, it is believed that this formalism should also allow for a generalisation to curved spacetime. During the presentation, the application of the formalism to the standard example of the one-dimensional nonrelativistic harmonic oscillator and the Hamiltonian associated with the motion of a relativistic particle in the Minkowski spacetime will be demonstrated.

Prof. Włodzimierz Piechocki #2

Personal Data

Affiliation: NCBJ (Warsaw)
PoToR member: Yes

Contribution

Title: Ascribing quantum system to gravitational system using integral quantization

Abstract: We present quantization method that can be used for ascribing quantum system to gravitational system. The latter can be taken to be a cosmological model or a compact astrophysical object. The method, called Integral Quantization, can be applied whenever one can ascribe a group structure to the space of elementary variables of underlying gravitational system. That group is expected to have an irreducible unitary representation in a Hilbert space. To illustrate our method, we outline quantization of the Oppenheimer-Snyder model of black hole. Another application may concern quantization of geodesic motion of test particle in fixed spacetime.

Mr. Marcin Postolak #13

Personal Data

Affiliation: University of Wrocław

PoToR member: No

Contribution

Title: Dynamical systems applied to non-minimally coupled (chameleon-like) scalar field dark matter/quintessence

Abstract: We revisit non-minimally coupled scalar field cosmologies in the Einstein frame and present a comprehensive analysis that spans background dynamics, linear perturbations, thermodynamics, quantum gravity constraints and baryogenesis. Using a dynamical systems approach, we classify all analytical critical points for a representative set of scalar field potentials: axions/ALPs, cyclic ekpyrotic, exponential/ekpyrotic with Λ, quintessence, and scalar field dark matter. We show that a chameleon-like coupling $f(\phi)=e^{\beta\phi}$ modifies both the expansion history and the growth of structure in a way that remains compatible with current fifth force searches. Analytical transfer matrices for primordial tensor modes are derived, revealing a scale–dependent break in the gravitational wave spectrum whose position and amplitude are fixed by the coupling parameter β. A causal Israel–Stewart treatment demonstrates that the same coupling supplies an effective bulk pressure that drives a smooth bounce while respecting quantum energy inequalities. Penrose's Weyl-curvature hypothesis is recovered dynamically: during an ekpyrotic phase with $\omega\gg1$ the Weyl invariant decays as $a^{-6(1+\omega)}$, resetting gravitational entropy without violating the generalized second law. A time–varying ϕ simultaneously generates an effective chemical potential $\mu_B\simeq\beta\dot{\phi}/M_*^{2}$, allowing for spontaneous high-scale baryogenesis whose back reaction on ϕ is negligible for $M_{*}\gtrsim 10^{15}\sqrt{\beta}$ GeV. Swampland distance and de Sitter criteria are automatically satisfied because the ekpyrotic phase confines the field excursion to $\Delta\phi\lesssim\mathcal{O}(1)M_{\mathrm{Pl}}$. These results establish new links between dark sector interactions, entropy production, and late-time acceleration.

Dr. Natascha Riahi #87

Personal Data

Affiliation: University of Vienna

PoToR member: No

Contribution

Title: Dynamical effects of quantum gravity from unimodular theory with a focus on phenomenological models of the Universe

Abstract: The calculation of quantum gravity correction terms to dynamical observables requires a distinguished time variable which is not automatically at hand in canonically quantized general relativity. The quantization of unimodular theory which is practically equivalent to general relativity on the classical level represents an approach towards a dynamical quantum gravity theory. We focus in particular on cosmological models for a flat, Friedmann-Roberstson-Walker universe with a scalar field with an exponential potential that are appropriate to represent phenomenologically the evolution of our universe. We derive the quantum gravity correction terms for the Hubble parameter and the matter density and find in particular a quantum gravity correction to the Hubble parameter for representative special cases.

Dr. habil. Dorota Rosińska #40

Personal Data

Affiliation: University of Warsaw

PoToR member: Yes

Contribution

Title: Gravitational Waves Astrophysics - 10 years of breakthrough discoveries

Abstract: The first direct detection of gravitational waves on September 14th, 2015 originating from the merger of two stellar-mass black holes, opened an entirely new way of observing the Universe. The signal GW150914, not only marked the birth of gravitational wave astronomy but also provided the first evidence for the existence of binary black holes and validated general relativity in the strong-field regime, previously inaccessible to observation. For this groundbreaking discovery, the 2017 Nobel Prize in physics was awarded to key contributors from the LIGO–Virgo collaboration. Since then, over 300 gravitational-wave signals, predominantly from binary black hole coalescences, have been observed leading to major breakthrough discoveries. Currently, the fourth LIGO-Virgo-Kagra network observing run is ongoing and gravitational wave alerts are sent to the international community to support multimessenger follow-up observations. In this talk, I will review the key results from the first decade of gravitational-wave observations, with emphasis on their implications for astrophysics, fundamental physics and cosmology and present prospects for future detectors.

Dr. Farshid Soltani #71

Personal Data

Affiliation: University of Warsaw

PoToR member: No

Contribution

Title: Gravitational collapse in effective loop quantum gravity

Abstract: A black hole horizon is formed once a star collapses within its own Schwarzschild radius. After that, the collapsing matter reaches Planckian densities in a short proper time. What happens next is outside the reach of general relativity, as it involves the quantum behavior of the gravitational field in the strong field regime. Starting from the Oppenheimer-Snyder model, and considering quantum corrections coming from loop quantum gravity, I will show how the quantum-corrected Oppenheimer-Snyder model predicts a `bounce' of the collapsing star and a non-singular black hole interior where the trapped region smoothly transitions into the anti-trapped region of a white hole. The same qualitative bouncing physics is also present in the gravitational collapse of an inhomogeneous perfect fluid with pressure. However, in this scenario, the dynamics generally develops shell-crossing singularities, as in the classical theory. This shows that, contrary to widespread belief, the mere inclusion of pressure and quantum gravitational effects is not able to resolve shell-crossing singularities. Finally, going back to the context of the quantum-corrected Oppenheimer-Snyder model, I will briefly comment on the quantum physics of the horizon of the black hole. If the evaporation process of the black hole is taken into account, its horizon will eventually reach Planckian size, where quantum gravitational effects can no longer be neglected. A natural assumption is then that, at this point, the horizon of the black hole undergoes a quantum transition from trapping to anti-trapping consistently with the transition of geometry taking place in the interior of the hole. In this scenario, known as the black-to-white hole transition, the black hole evolves into a white hole `remnant' living in the future of the parent black hole, in its same asymptotic region and location.

Mr. Aravindhan Srinivasan #30

Personal Data

Affiliation: Charles University & MU, CAS (Prague)

PoToR member: No

Contribution

Title: Generalized Kerr-Schild spacetimes in higher-dimensions: optical and algebraic properties

Abstract: In this talk, after reviewing the famous Goldberg–Sachs theorem in four dimensions, I will discuss a version of its generalization to higher dimensions in the context of generalized Kerr–Schild spacetimes. Time permitting, I will also briefly discuss its application to obtaining/identifying exact solutions in the Kerr–Schild class in Einstein–Maxwell theory.

Dr. habil. Robert Stańczy #24

Personal Data

Affiliation: University of Wrocław
PoToR member: No

Contribution

Title: Tolman-Oppenheimer-Volkoff equation

Abstract: We consider general dynamical system motivated by TOV equation in Milne variables. We prove the existence of Lyapunov function and heteroclinic connection between zero and singular density. Critical mass theorem follows from the estimate of this heteroclinic orbit.

Prof. Nikolaos Stergioulas #41

Personal Data

Affiliation: Aristotle University of Thessaloniki

PoToR member: No

Contribution

Title: Leveraging Machine Learning for Gravitational Wave Discoveries: From Binary Black Hole Mergers to Probing High-Density Nuclear Matter

Abstract: Machine Learning is finding diverse applications in the field of astrophysics and gravitational wave astronomy. This talk surveys our recent advancements in applying such methodologies. We demonstrate the utility of Deep Residual Networks (ResNets) in discovering new gravitational wave events from binary black hole mergers. Furthermore, we discuss the importance of using robust metrics for evaluating the sensitivity of detection pipelines and present the calculation of the astrophysical probability in the framework of a machine-learning detection code. Finally, we discuss the application of normalizing flows within Preconditioned Monte Carlo methods to significantly accelerate Bayesian parameter estimation for binary neutron star post-merger signals.

Prof. Sebastian Szybka #48

Personal Data

Affiliation: Jagiellonian University
PoToR member: Yes

Contribution

Title: Halilsoy and Chandrasekhar standing gravitational waves in the linear approximation

Abstract: Halilsoy and Chandrasekhar cylindrical standing gravitational waves correspond to two different classes of solutions to the vacuum Einstein equations. Both families satisfy the definition of standing gravitational waves proposed by Stephani, but only the latter class fulfills the stricter definition introduced by Chandrasekhar. The aim of this research is to compare both classes of solutions within the linear regime. We discover that the linearized Halilsoy and Chandrasekhar standing waves are gravitational analogues of two different types of electromagnetic polarization standing waves.

Mr. Adam Zychowicz #74

Personal Data

Affiliation: Jagiellonian University

PoToR member: No

Contribution

Title: Backreaction of cylindrical standing gravitational waves

Abstract: We calculate the high-frequency limit of the Halilsoy and Chandrasekhar standing gravitational wave solutions. Using Green-Wald framework we find the effective stress energy tensor and show that the backreaction effect is the same for these classes of solutions. We analyze the causal structure of the effective spacetime.