Loops'24 International Conference on Quantum Gravity

Report of Contributions

https://indico.global/e/1305

Contribution ID: **4** Type: **not specified**

Canonical Quantum Gravity Dynamics

Monday, May 6, 2024 9:00 AM (40 minutes)

The purpose of this talk is to give an overview of the development and the various branches of the Hamiltonian approach to quantum gravity, with focus on its dynamics, over the past decades.

Presenter: THIEMANN, Thomas (FAU Erlangen)

Contribution ID: **5** Type: **not specified**

The Hilbert Space of de Sitter Quantum Gravity

Monday, May 6, 2024 9:40 AM (40 minutes)

Presenter: RAJU, Suvrat (ICTS - Bengaluru)

Contribution ID: **6** Type: **not specified**

Complex Critical Point Methods

Monday, May 6, 2024 10:50 AM (40 minutes)

Presenter: QU, Dongxue (PI - Waterloo)

Contribution ID: **7** Type: **not specified**

sl2cfoam-next: New developments and applications

Monday, May 6, 2024 11:30 AM (40 minutes)

Presenter: DONA, Pietro (CPT - Marseille)

Contribution ID: **8** Type: **not specified**

Shell Crossings and Shocks during Gravitational Collapse in Effective LQG

Tuesday, May 7, 2024 9:00 AM (40 minutes)

Presenter: HUSSAIN, Viqar (UNB - New Brunswick)

Contribution ID: **9** Type: **not specified**

Dust Collapse in Effective LQG: Fate of Shocks and Covariance

Tuesday, May 7, 2024 9:40 AM (40 minutes)

Presenter: LIU, Hongguang (FAU - Erlangen)

Contribution ID: **10** Type: **not specified**

Quantum Oppenheimer-Snyder & Swiss Cheese Model

Tuesday, May 7, 2024 10:50 AM (40 minutes)

Presenter: ZHANG, Cong (FAU - Erlangen)

Contribution ID: **11** Type: **not specified**

Horizons and Null Infinity

Tuesday, May 7, 2024 11:30 AM (40 minutes)

While there are many fascinating results on quantum black holes and their evaporation in LQG, the focus tends to be on singularity resolution and the structure of the quantum-extended space-time. Issues of entanglement and recovery of information, that originally sparked interest in black hole evaporation in the wider physics community, have not received the attention they deserve. The goal of this talk is to point directions for future work by the LQG community –especially by researchers who have focused on null surfaces–to address these issues. The talk is based on recent work with Simone Speziale (arXiv:2401.15618 and arXiv:2402.17977).

Presenter: ASHTEKAR, Abhay (PennState)

Contribution ID: **12** Type: **not specified**

Physics of Loop Quantum Cosmology: New Answers to Old Questions

Wednesday, May 8, 2024 9:00 AM (40 minutes)

In the last two decades several groups have extensively explored detailed physics of standard LQC. Given the lack of a direct bridge to LQG, the role of quantization ambiguities in physical implications, and how one can generalize beyond standard LQC remain open. After a brief overview, we revisit some old questions in LQC on the quantum bounce, inflationary paradigm and its alternatives, the role of matter, and potential observable signatures, and indicate the way answers may change given some recent developments.

Presenter: SINGH, Parampreet (LSU)

Contribution ID: **13** Type: **not specified**

Loop Quantum Gravity and Cosmology

Wednesday, May 8, 2024 9:40 AM (40 minutes)

My talk will review how cosmological observations can be used to test quantum gravity, and also to provide some guidance for future progress. I will discuss how to make contact with cosmological data from loop quantum cosmology, observational constraints on the realization of various cosmological scenarios (such as inflation, ekpyrosis and the matter bounce) within loop quantum cosmology, as well as the connection between loop quantum cosmology and full loop quantum gravity. Finally, I will describe some open problems in cosmology, and present potential mechanisms whereby loop quantum gravity may be able to resolve them.

Presenter: WILSON-EWING, Edward (University of New Brunswick)

Contribution ID: **14** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Corner Symmetry and Quantum Geometry

Wednesday, May 8, 2024 10:50 AM (40 minutes)

Presenter: GEILLER, Marc

Contribution ID: **15** Type: **not specified**

Gravitational Path Integral and Entropy

Thursday, May 9, 2024 9:00 AM (40 minutes)

Presenter: COLAFRANCESCHI, Eugenia

Contribution ID: **16** Type: **not specified**

Effective Spin Foams

Thursday, May 9, 2024 9:40 AM (40 minutes)

Presenter: ASANTE, Seth (UNI - Jena)

Contribution ID: **17** Type: **not specified**

A finite and computable spinfoam model with cosmological constant

Thursday, May 9, 2024 10:50 AM (40 minutes)

In this talk, I will overview the 4-dimensional Lorentzian spinfoam model with a non-vanishing cosmological constant and discuss its inviting properties, namely (1) that it gives finite spinfoam amplitude for any spinfoam graph, (2) that it is consistent with general relativity with a non-zero cosmological constant at its classical regime and (3) that there exists a feasible, concrete and computable program to calculate physical quantities and quantum corrections with this spinfoam model using stationary phase analysis.

Presenter: PAN, Qiaoyin (FAU - Florida)

Contribution ID: **18** Type: **not specified**

Group Field Theory and Spin Foam Renormalization

Thursday, May 9, 2024 11:30 AM (40 minutes)

Presenter: PITHIS, Andreas (LMU - München)

Contribution ID: **19** Type: **not specified**

Isolated Horizons

Friday, May 10, 2024 9:00 AM (40 minutes)

Presenter: KAMINSKI, Wojciech (University of Warsaw)

Contribution ID: **20** Type: **not specified**

Towards covariant LQG 2.0

Friday, May 10, 2024 9:40 AM (40 minutes)

Presenter: GIRELLI, Florian (University of Waterloo)

Contribution ID: **21** Type: **not specified**

CANCELLED - Phenomenology of Modified Loop Quantum Cosmological Models

Friday, May 10, 2024 10:50 AM (40 minutes)

In recent years, new progress has been made in the direction of the alternative loop cosmological models as compared with standard loop quantum cosmology (LQC). These modified loop quantum cosmological (mLQC) models arise from different quantization prescriptions of the classical Hamiltonian constraint in loop quantum gravity (LQG) for a spatially-flat Friedmann-Lema\ˆitre-Robertson-Walker (FLRW) universe. In this talk, I will focus on the phenomenology of two of the mLQC models, namely mLQC-I and mLQC-II. The former is also called Dapor-Liegener model in the literature. In particular, I will first summarize the main properties of the background evolution of the mLQC-I/II universes and then concentrate on the results of the primordial power spectra in these two models. Finally, I will address the potential issues which are still to be resolved in these models.

Presenter: LI, Baofei

Contribution ID: **22** Type: **not specified**

Quantum Geometry of the Light Cone

Friday, May 10, 2024 11:30 AM (40 minutes)

Presenter: WIELAND, Wolfgang (FAU - Erlangen)

Contribution ID: **24** Type: **not specified**

Black holes panel

Thursday, May 9, 2024 2:00 PM (55 minutes)

Contribution ID: **27** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Scalar cosmological perturbations from quantum-gravitational entanglement

Thursday, May 9, 2024 3:25 PM (15 minutes)

A major challenge at the interface between quantum gravity and cosmology is to understand how cosmological structures can emerge from physics at the Planck scale. In this talk, I will provide a concrete example of such an emergence process by extracting the physics of scalar and isotropic cosmological perturbations from full quantum gravity, as described by a causally complete Barrett-Crane group field theory model (described in detail in Alexander Jercher's talk). From the perspective of the underlying quantum gravity theory, cosmological perturbations will be associated with (relational) nearest-neighbor two-body entanglement, providing crucial insights into the potentially purely quantum-gravitational nature of cosmological perturbations. I will also show that at low energies the emergent relational dynamics of these perturbations are perfectly consistent with those of general relativity, while at trans-Planckian scales quantum effects become important. Finally, I will comment on the implications of these quantum effects for the physics of the early universe and outline future research directions.

Author: MARCHETTI, Luca (University of New Brunswick)

Presenter: MARCHETTI, Luca (University of New Brunswick)

Session Classification: Cosmology, Black Holes, and other applications/phenomenology

Contribution ID: **28** Type: **Covariant QG: Fundamental theory**

Loop Quantum Gravity, Permutation Symmetry and Entanglement

Monday, May 6, 2024 3:15 PM (15 minutes)

Are the atoms of space distinguishable? In this talk I discuss recent developments on the construction of a diffeomorphism invariant notion of entanglement entropy of a region in loop quantum gravity and spinfoams.

Author: BIANCHI, Eugenio (PennState)

Presenter: BIANCHI, Eugenio (PennState)

Session Classification: Covariant LQG

Contribution ID: **31** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Shell-crossing singularities/ shock waves in effective Lemaître-Tolman-Bondi collapse

Tuesday, May 7, 2024 4:30 PM (15 minutes)

Effective models of gravitational collapse in loop quantum gravity for the Lemaître-Tolman-Bondi spacetime predict that collapsing matter reaches a maximum finite density, bounces, and then expands outwards. I explain how in the marginally bound case, shell-crossing singularities commonly occur for inhomogeneous initial profiles of the dust energy density; this is the case in particular for all profiles that are continuous and of compact support, including configurations arbitrarily close to the Oppenheimer-Snyder model. When a shell-crossing singularity occurs, it is necessary to seek weak solutions to the dynamics; I argue that weak solutions typically develop shock waves. I will conclude by showing numerical simulations where shock waves arise in weak solutions of Lemaître-Tolman-Bondi effective equations written in generalized Painlevé-Gullstrand coordinates, both for marginally bound and unbound configurations.

Author: FAZZINI, Francesco (University of New Brunswick)

Presenter: FAZZINI, Francesco (University of New Brunswick)

Session Classification: Black Holes

Contribution ID: **32** Type: **Canonical QG: Fundamental theory**

Asymptotic safety and canonical quantum gravity

Monday, May 6, 2024 2:45 PM (15 minutes)

The asymptotic safety (ASQG) and canonical (CQG) approach to quantum gravity have been developed to a large extent independent of each other. In this work we take first steps to bringing them into closer contact by working with the Lorentzian version of the functional renormalisation group of ASQG which we relate to the reduced phase space formulation of CQG.

Authors: FERRERO, Renata (FAU - Erlangen); Prof. THIEMANN, Thomas

Presenter: FERRERO, Renata (FAU - Erlangen)

Session Classification: Canonical LQG

Contribution ID: **33** Type: **Canonical QG: Fundamental theory**

Fermions in LQG

Monday, May 6, 2024 3:00 PM (15 minutes)

We explore the modifications to the fundamental geometric variables due to the inclusion of fermions and the resulting gravitational dynamics. Finally we speculate on how to proceed with the quantization of the system.

Author: FRAGOMENO, Federica (University of Alberta)

Presenter: FRAGOMENO, Federica (University of Alberta)

Session Classification: Canonical LQG

Contribution ID: **35** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Temporary horizons: the life and times of a quantum black hole

Tuesday, May 7, 2024 5:30 PM (15 minutes)

I will discuss a class of time-dependent, asymptotically flat and spherically symmetric metrics which model gravitational collapse in quantum gravity developed by myself and the other listed authors. Motivating the work was the intuition that quantum gravity should not exhibit curvature singularities and indeed, the metrics lead to singularity resolution with horizon formation and evaporation following a matter bounce. A noteworthy result of this metric is that we can recover the Hawking evaporation time Mˆ3 for the lifetime of the black hole.

Author: HERGOTT, Samantha (York University / Perimeter Institute for Theoretical Physics)

Presenter: HERGOTT, Samantha (York University / Perimeter Institute for Theoretical Physics)

Session Classification: Black Holes

Contribution ID: **36** Type: **Covariant QG: Fundamental theory**

Quantization of Constantly Curved Tetrahedron

Monday, May 6, 2024 5:00 PM (15 minutes)

In this talk, we develop a quantum theory of homogeneously curved tetrahedron geometry, by applying the combinatorial quantization to the phase space of tetrahedron shapes defined in arXiv:1506.03053. Our method is based on the relation between this phase space and the moduli space of SU(2) flat connections on a 4-punctured sphere. The quantization results in the physical Hilbert space as the solution of the quantum closure constraint, which quantizes the classical closure condition M4M3M2M1=1, Mv∈ SU(2), for the homogeneously curved tetrahedron. The quantum group Uq(su(2)) emerges as the gauge symmetry of a quantum tetrahedron. The physical Hilbert space of the quantum tetrahedron coincides with the Hilbert space of 4-valent intertwiners of Uq(su(2)). In addition, we define the area operators quantizing the face areas of the tetrahedron and compute the spectrum. The resulting spectrum is consistent with the usual Loop-Quantum-Gravity area spectrum in the large spin regime but is different for small spins. This work closely relates to 3+1 dimensional Loop Quantum Gravity in presence of cosmological constant and provides a justification for the emergence of quantum group in the theory.

Author: HSIAO, Chen Hung (FAU - Florida)

Presenter: HSIAO, Chen Hung (FAU - Florida)

Session Classification: Covariant LQG

Contribution ID: **37** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Motivating semiclassical gravity: a classical-quantum approximation for bipartite quantum systems

Thursday, May 9, 2024 3:55 PM (15 minutes)

We derive a "classical-quantum"approximation scheme for a broad class of bipartite quantum systems from fully quantum dynamics. In this approximation, one subsystem evolves via classical equations of motion with quantum corrections, and the other subsystem evolves quantum mechanically with equations of motion informed by the evolving classical degrees of freedom. Using perturbation theory, we derive an estimate for the growth rate of entanglement of the subsystems and deduce a "scrambling time"—the time required for the subsystems to become significantly entangled from an initial product state. We argue that a necessary condition for the validity of the classical-quantum approximation is consistency of initial data with the generalized Bohr correspondence principle. We illustrate the general formalism by numerically studying the fully quantum, fully classical, and classical-quantum dynamics of a system of two oscillators with nonlinear coupling. This system exhibits parametric resonance, and we show that quantum effects quench parametric resonance at late times. Lastly, we present a curious late-time scaling relation between the average value of the von Neumann entanglement of the interacting oscillator system and its total energy: S ˜ 2/3ln(E). The corresponding publication is the following: https://journals.aps.org/prd/abstract/10.1103/PhysRevD.108.086033.

Author: JAVED, Irfan (University of New Brunswick)

Presenter: JAVED, Irfan (University of New Brunswick)

Session Classification: Quantum Foundations and QG

Contribution ID: **39** Type: **Quantum Gravity: Computations**

Graph-changing vertex evolution and volume expectation-value computation

Friday, May 10, 2024 3:00 PM (15 minutes)

Computations in canonical loop quantum gravity are severely hindered by the graph-changing nature of the scalar Hamiltonian constraint. In fact, not even the action of this constraint on 4-valent spin-network vertices has been fully derived in the literature to date. For this reason, drastic approximations, such as graph-non-changing constraints, are usually implemented. In order to overcome this challenge, we derive the complete action of the scalar Euclidean Hamiltonian constraint on 3- and 4-valent vertices, based on which we introduce a new computational method that allows for application of this graph-changing constraint on vertices of arbitrary spins. The method includes no approximations and allows for iterative applications of the constraint on a chosen spin-network vertex, enabling perturbative calculations. Our code also includes a key geometrical observable in loop quantum gravity, the quantum volume. Making use of this new tool, we search for new eigenstates of the constraint. Furthermore, through the numerical calculation of volume expectation values of spin networks, as well as the changes in the expectation values of such observable caused by evolution, we finally provide concrete evidence of the effect of implementing graph-non-changing approximations on the quantum volume, having as reference the action of the complete, graph-changing Euclidean Hamiltonian constraint. Our work represents a new computational milestone in the development of loop quantum gravity, whose numerical power is expected to open new doors for the investigation of the dynamics of spin networks and their geometrical observables in canonical loop quantum gravity.

Author: LUCENA DE MACEDO GUEDES, Thiago (Forschungszentrum Jülich)

Presenter: LUCENA DE MACEDO GUEDES, Thiago (Forschungszentrum Jülich)

Session Classification: Foundation of Quantum Gravity

Contribution ID: **40** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Emergent dark energy from loop quantum cosmology

Tuesday, May 7, 2024 2:00 PM (15 minutes)

By using the regularization freedom of the Hamiltonian constraint for loop quantum gravity, the observational cosmological constant can emerge at large volume limit from the model of loop quantum cosmology, and the effective Newtonian constant satisfies the experimental restrictions in the meantime. Therefore, the so-called dark energy could be an emergent effect of LQG.

Author: MA, Yongge (Beijing Normal University)

Presenter: MA, Yongge (Beijing Normal University)

Session Classification: Cosmology

Contribution ID: **41** Type: **Boundaries, Symmetries, and Classical aspects**

General covariance and dynamics with a Gauss law

Friday, May 10, 2024 3:00 PM (15 minutes)

A 4-dimensional generally covariant gauge theory with local degrees of freedom is presented. It leads to the Gauss constraint but lacks both the Hamiltonian and spatial diffeomorphism constraints. The canonical theory therefore resembles Yang-Mills theory without the Hamiltonian. We describe its observables, quantization, and some generalizations.

Author: MEHMOOD, Hassan (University of New Brunswick)

Presenter: MEHMOOD, Hassan (University of New Brunswick)

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **42** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Quantization of a black hole interior model in Loop Quantum Cosmology

Monday, May 6, 2024 5:15 PM (15 minutes)

Considerable attention has been paid to the study of the quantum geometry of nonrotating black holes within the framework of Loop Quantum Cosmology. This interest has been reinvigorated since the introduction of a novel effective model by Ashtekar, Olmedo, and Singh. Despite recent advances in its foundation, there are certain questions about its quantization that still remain open. Here we complete this quantization taking as starting point an extended phase space formalism suggested by several authors, including the proposers of the model. Adopting a prescription that has proven successful in Loop Quantum Cosmology, we construct an operator representation of the Hamiltonian constraint. By searching for solutions to this constraint operator in a sufficiently large set of dual states, we show that it can be solved for a continuous range of the black hole mass. This fact seems in favour of a conventional classical limit (at least for large masses) and contrasts with recent works that advocate a discrete spectrum. We present an algorithm that determines the solutions in closed form. To build the corresponding physical Hilbert space and conclude the quantization, we carry out an asymptotic analysis of those solutions, which allows us to introduce a suitable inner product on them.

Author: MÍNGUEZ-SÁNCHEZ, Andrés (CSIC)

Presenter: MÍNGUEZ-SÁNCHEZ, Andrés (CSIC)

Session Classification: Black Holes

Contribution ID: **45** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Semiclassical geometrodynamics of homogeneous cosmology

Tuesday, May 7, 2024 4:30 PM (15 minutes)

We present the classical-quantum (CQ) hybrid dynamics of homogeneous cosmology from a Hamiltonian perspective where the classical gravitational phase space variables and matter state evolve self-consistently with full backreaction. We compare numerically the classical and CQ dynamics for isotropic and anisotropic models, including quantum scalar-field induced corrections to the Kasner exponents. Results indicate that full backreaction effects leave traces at late times in cosmological evolution; in particular, the scalar energy density at late times provides a potential contribution to dark energy. We also show that the CQ equations admit exact static solutions for the isotropic, and the anisotropic Bianchi IX universes with the scalar field in a stationary state. We study the classical-quantum (CQ) hybrid dynamics of homogeneous cosmology from a Hamiltonian perspective where the classical gravitational phase space variables and matter state evolve self-consistently with full backreaction. We compare numerically the classical and CQ dynamics for isotropic and anisotropic models, including quantum scalar-field induced corrections to the Kasner exponents. Our results indicate that full backreaction effects leave traces at late times in cosmological evolution; in particular, the scalar energy density at late times provides a potential contribution to dark energy. We also show that the CQ equations admit exact static solutions for the isotropic, and the anisotropic Bianchi IX universes with the scalar field in a stationary state.

Author: MUZAMMIL, Muhammad (University of New Brunswick)

Presenter: MUZAMMIL, Muhammad (University of New Brunswick)

Session Classification: Cosmology

Contribution ID: **46** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Higher order black hole perturbations

Monday, May 6, 2024 4:30 PM (15 minutes)

Black hole perturbations are mostly considered up to second order. In this talk we investigate the problem of incorporating perturbations of higher than second order and the new technical challenges that arise.

Author: NEUSER, Jonas (FAU - Erlangen)

Presenter: NEUSER, Jonas (FAU - Erlangen)

Session Classification: Black Holes

Contribution ID: **47** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Revisiting quantum black holes from effective loop quantum gravity #21

Monday, May 6, 2024 5:00 PM (15 minutes)

Abstract: This work examines a family of loop quantizations for the classical Kruskal spacetimes using the effective description motivated from loop quantum gravity for four generic parameters, c_o, m, δ_b, and δ_c, where the latter two denote the polymerization parameters capturing the underlying quantum geometry. The focus lies on the family where polymerization parameters remain constant on dynamical trajectories, and of which the Ashtekar-Olmedo-Singh (AOS) and Corichi-Singh (CS) models emerge as special cases. General features of singularity resolution in all these models due to quantum gravity effects are studied, and the solutions are analytically extended across the white hole (WH) and black hole (BH) horizons to the exterior. It is found that the leading term in the asymptotic expansion of the Kretschmann scalar is r^{-4}. However, for AOS and CS models, black holes with masses greater than solar mass exhibit the dominant term behaving as r^{-6} for the size of the observable universe, allowing for the analysis to phenomenologically constrain the choice of parameters for other models. Additionally, the parameter c_o can be uniquely fixed by requiring the Hawking temperature at the BH horizon to the leading order to be consistent with its classical value for a macroscopic BH. Assuming that the BH and WH masses are of the same order, a family of choices of δ_b and δ_c is identified, which share all the desired properties of the AOS model.

Authors: CHANDRA ONGOLE, Geeth (Baylor); SINGH, Parampreet (LSU); WANG, Anzhong (Baylor University)

Presenter: CHANDRA ONGOLE, Geeth (Baylor)

Session Classification: Black Holes

Contribution ID: **48** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Uniform Asymptotic Approximation Method with Pöschl–Teller Potential

Tuesday, May 7, 2024 2:45 PM (15 minutes)

We study analytical approximate solutions for second-order homogeneous differential equations with the existence of only two turning points (but without poles) by using the uniform asymptotic approximation (UAA) method. To be more concrete, we consider the Pöschl-Teller (PT) potential, for which analytical solutions are known. Depending on the values of the parameters involved in the PT potential, we find that the upper bounds of the errors of the approximate solutions in general are <= 0.15~10% for the first-order approximation of the UAA method. The approximations can be easily extended to high orders, for which the errors are expected to be much smaller. Such obtained analytical solutions can be used to study cosmological perturbations in the framework of quantum cosmology as well as quasi-normal modes of black holes.

Authors: PAN, Rui (Baylor); SAEED, Jamal (Baylor); CLEAVER, Gerald (Baylor University, Waco, Texas, USA); WANG, Anzhong (Baylor University)

Presenter: PAN, Rui (Baylor)

Session Classification: Cosmology

Contribution ID: **49** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Diffusive effects of Planckian discreteness: the thermal bath of quantum-gravity defects

Tuesday, May 7, 2024 6:00 PM (15 minutes)

The concept of spacetime discreteness is a common feature in quantum gravity theories. Recently, it has been speculated that the presence of discrete fundamental degrees of freedom should ultimately manifest, at least in the low-energy regime, in the form of diffusive effects, just as the presence of molecules generates diffusion in fluids. As for an effective description, such dissipation effects can be accounted for in the framework of Unimodular Gravity (UG). Given a specific model of diffusion, UG predicts precise deviations from standard cosmology that can be tested even with current or foreseeable observations, making these models relevant for the quantum gravity phenomenology programme. It can be shown that well-defined diffusion in UG is formally obtained by introducing the 'quantum-gravity defects': hidden degrees of freedom that play the role of an effective thermal bath in which matter fields can dissipate energy. In this formalism, modeling diffusion corresponds to selecting an appropriate action for the defects. Interestingly, this seems to allow for the definition of a novel notion of temperature of spacetime.

Author: PELLECCHIA, Pietro (UNINA)

Presenter: PELLECCHIA, Pietro (UNINA)

Session Classification: Cosmology

Contribution ID: **51** Type: **Canonical QG: Fundamental theory**

Spherically-Symmetric Gravity on a Graph

Monday, May 6, 2024 5:45 PM (15 minutes)

Following the techniques of canonical loop quantum gravity, a full Thiemann regularization is performed on the scalar constraint of classical general relativity. The regularized Hamiltonian is then considered for a general spherically-symmetric spacetime, without recourse to additional gauge-fixing conditions commonly imposed to aid in computing the radial holonomies. By investigating the form of the modified scalar constraint in various contexts, including cosmological and black hole spacetimes, we develop an effective framework for the dynamics of spherically-symmetric spacetimes endowed with an underlying discrete structure.

Author: ROBERTS, Jorden (University of Alberta)

Presenter: ROBERTS, Jorden (University of Alberta)

Session Classification: Black Holes

Contribution ID: **52** Type: **Cosmology, Black Holes, and other applications/phenomenology**

The white holes predicted by LQG could be dark matter

Tuesday, May 7, 2024 3:45 PM (15 minutes)

Covariant LQG predicts that the end of the black hole evaporation leaves a long-living remnant described by a white hole geometry, and stabilized by the LQG area gap. This result provides an intriguing candidate for dark matter, which does not require any new physics besides General Relativity and quantum theory,

Author: ROVELLI, Carlo

Presenter: ROVELLI, Carlo

Session Classification: Black Holes

Contribution ID: **53** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Universal properties of the universe in modified loop quantum cosmologies

Tuesday, May 7, 2024 3:00 PM (15 minutes)

The evolution of the universe in modified loop quantum cosmologies exhibits universal properties for sharply peaked states, similar to that in the standard loop quantum cosmology (LQC). In this talk, I shall present our recent investigations on such universal properties for the modified loop quantum cosmological model I (mLQC-I), by paying particular attention to the evolution before the quantum bounce - the so-called contracting phase. In particular, we find that the evolution is soon dominated by a Planck-size effective cosmological constant, whereby the universe enters a pre-de Sitter epoch, which is universal and independent of the choice of the potential of the scalar field. Thus, the whole contracting phase can be universally divided into two periods, the pre-de Sitter and the pre-bouncing. Although the duration of the pre-bouncing period depends on the potential of the scalar field, the background solution during this epoch is universal.

Author: SAEED, Jamal (Baylor)

Co-authors: PAN, Rui (Baylor University); Mr BROWN, Christian (Baylor University); CLEAVER, Gerald (Baylor University, Waco, Texas, USA); WANG, Anzhong (Baylor University)

Presenters: SAEED, Jamal (Baylor); Mr BROWN, Christian (Baylor University)

Session Classification: Cosmology

Contribution ID: **54** Type: **Boundaries, Symmetries, and Classical aspects**

Deformed Spheres in General Relativity

Friday, May 10, 2024 3:15 PM (15 minutes)

The Kerr spacetime hypothesis can be tested by using two approaches namely the top-bottom approach and bottom-up approach. The first one involves introducing the deviations in the Kerr metric through a theoretical model. The second approach involves introducing the deviations in terms of parameters. The metric proposed by Johannsen and Psaltis is one such parametrically deformed Kerr spacetime. It reduces to the Kerr metric when one sets the deviation parameters to zero. We construct some generalizations of this spacetime including the charged and accelerated versions and discuss their horizon structure and dynamics.

Author: SAIFULLAH, Khalid

Presenter: SAIFULLAH, Khalid

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **55** Type: **Boundaries, Symmetries, and Classical aspects**

Symmetry charges on reduced phase space and BMS algebra

Monday, May 6, 2024 3:15 PM (15 minutes)

The investigation of boundary charges in asymptotically flat spacetime draw a lot of attention recent years, which has provided us valuable insight and significantly enhanced our general understanding of gravity. However, most of previous studies along this line are based on the traditional general relativity, which is a pure constraint theory in the bulk. The boundary charges based on the reduced phase are less known to the community. In this talk, I will discuss our recent progress in the symmetry charges (including the bulk parts and the boundary parts) in the reduced phase space based on the Brown-Kuchaˇr Formalism. In this work, we introduce specific asymptotically flat boundary conditions to make the variation of the physical Hamiltonian well-defined. Using these boundary conditions, we construct the boundary-preserving symmetries, including supertranslations. The algebra of these symmetry generators is given by the Poisson brackets, which contains a central extension. A suitable quotient of this algebra closely relates to the BMS algebra at spatial infinity by Henneaux and Troessaert. Our results can give us some insights of gravity quantization. Furthermore, our work may enable us to construct a new type of bulk/boundary duality.

Author: TAN, Hongwei (FAU - Florida)

Presenter: TAN, Hongwei (FAU - Florida)

Session Classification: Canonical LQG

Contribution ID: **57** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Uniqueness of the Fock quantization of a massless scalar field in Kantowski-Sachs spacetime and its Hamiltonian.

Tuesday, May 7, 2024 2:45 PM (15 minutes)

Author: Álvaro Torres-Caballeros Instituto de Estructura de la Materia, IEM-CSIC Serrano 121, 28006 Madrid, Spain alvaro.torres@iem.cfmac.csic.es Co-authors: Jerónimo Cortez Departamento de Física, Facultad de Ciencias, Universidad Nacional Autónoma de México. Ciudad de México 04510, Mexico jacq@ciencias.unam.mx Beatriz Elizaga Navascués Department of Physics and Astronomy, Louisiana State University Baton Rouge, LA 70803-4001, USA bnavascues@lsu.edu Guillermo A. Mena Marugán Instituto de Estructura de la Materia, IEM-CSIC Serrano 121, 28006 Madrid, Spain mena@iem.cfmac.csic.es José Velhinho Faculdade de Ciências and FibEnTech-UBI, Universidade da Beira Interior R. Marquês D'Ávila e Bolama, 6201-001 Covilhã, Portugal jvelhi@ubi.pt
ABSTRACT: We discuss a criterion to guarantee the uniqueness of the Fock quantization of a massless free scalar field in a Kantowski-Sachs background. In general spacetimes, the infinite ambiguity of choosing a set of annihilation and creation operators leads to non-equivalent Fock representations, a fact that is due to the unavailability of a privileged vacuum state in the theory. In the case of a Kantowski-Sachs spacetime, we show that the problem can be overcome by imposing invariance under the spatial symmetries of the background and quantum dynamics that admit a unitary implementation. We also show that this criterion fixes the freedom for background-dependent scalings involved in the choice of creation and annihilation variables. The remaining freedom for background-dependent changes can be employed to attain a Hamiltonian for the scalar field that is asymptotically diagonal in the ultraviolet sector. These results may find applications in the quantization of matter fields and perturbations on anisotropic cosmologies and, moreover, on the interior of nonrotating black hole spacetimes.

Author: TORRES-CABALLEROS, Alvaro (CSIC)

Presenter: TORRES-CABALLEROS, Alvaro (CSIC)

Session Classification: Black Holes

Contribution ID: **58** Type: **Covariant QG: Fundamental theory**

Coupling of matter to gravity using higher gauge theory

Friday, May 10, 2024 2:45 PM (15 minutes)

We will report on the latest advances within the program of generalized spinfoam models using the framework of higher gauge theory. This framework, based on the idea of describing gauge symmetry using 2-groups, 3-groups and other higher-order categorical structures, has the advantage of treating both matter and gravity on an equal footing, which allows us to discuss matter-related topics such as the Higgs mechanism in the context of generalized spinfoam models.

Author: VOJINOVIC, Marko

Presenter: VOJINOVIC, Marko

Session Classification: Foundation of Quantum Gravity

Contribution ID: **60** Type: **Quantum Foundations and QG**

Quantum Properties and Gravitational Field of a Proper Time Oscillator

Friday, May 10, 2024 3:15 PM (15 minutes)

By assuming matter can oscillate in proper time, we demonstrate that a matter field with proper time oscillations can mimic the properties of a bosonic field. The particles observed are proper time oscillators. The assumption also gives rise to properties that can reduce differences between quantum theory and general relativity, e.g., self-adjoint internal time operator and proper time uncertainty relation. If we neglect all quantum effects, a proper time oscillator can be treated as a 'stationary'classical object, equivalent to a point mass at rest in general relativity. Under this assumption, we demonstrate that the proper time oscillator can curve the surrounding spacetime and generate a gravitational field; its solution is the Schwarzschild metric. To test the theory, we propose to study the uncertainty of the neutrinos/photons arrival time and the decaying rate of a muon. In motion, the proper time oscillation translates to oscillations in both time and space. These oscillations lead to uncertainties in particles' decaying time and arrival time. The possible detection of these uncertainties can test the theory proposed. References [1] Yau, H. Y.: Proper time operator and its uncertainty relation. J. Phys, Commun. 105001 (2021) [2] Yau, H. Y.: Schwarzschild field of a proper time oscillator. Symmetry 12(2), 312 (2020) [3] Yau, H. Y.: Self-adjoint time operator in a quantum field. J. Quant. Info. 1941016 (2020) [4] Yau, H. Y.: Thin shell with fictitious oscillations" , in Spacetime Physics1907 –2017, Chapter 6 (Minkowski Institute Press, Montreal, 2019) [5] Yau, H. Y.: Time and space symmetry in a quantum field. J. Phys.: Conf. Ser. 1194, 012116 (2019) [6] Yau, H.Y.: Temporal vibrations in a quantized field. In: Khrennikov, A., Toni, B. (eds.) Quantum Foundations, Probability and Information, pp. 269. Springer-Verlag, Heidelberg (2018)

Author: YAU, Hou (SFSU)

Presenter: YAU, Hou (SFSU)

Session Classification: Foundation of Quantum Gravity

Contribution ID: **61** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Spinfoams, γ-duality and Parity Violation in the Primordial Universe

Monday, May 6, 2024 4:45 PM (15 minutes)

The Barbero-Immirzi parameter appears in the EPRL spinfoam model via a duality rotation. In an effective field theory description, this duality rotation results in a relation between the coupling constants of parity-even and parity-odd higher-curvature terms. We study cosmic inflation in this effective theory and show that the observation of a primordial tensor polarization, together with the tensor tilt and the tensor-to-scalar ratio, provides a measurement of the Barbero-Immirzi parameter and, therefore, of the scale of the discreteness in loop quantum gravity.

Authors: BIANCHI, Eugenio (PennState); RINCON RAMIREZ, Monica (Pennsylvania State University)

Presenter: RINCON RAMIREZ, Monica (Pennsylvania State University)

Session Classification: Covariant LQG

Contribution ID: **62** Type: **Quantum Foundations and QG**

Quantum Reference Frames and the Localisation of Events in Superpositions of Spacetimes

Thursday, May 9, 2024 3:40 PM (15 minutes)

When describing a physical system, it is very common to do so with respect to a reference frame - a ruler used to determine the position of a particle, for example, or a clock, which tracks the time that elapses while it is moving. Usually, reference frames are treated as purely classical objects with well-defined properties. But what happens if we take into account the quantum properties of the reference frame itself? This question has motivated a recent wave of research on quantum reference frames (QRFs), which investigates how the description of our world changes when described relative to different quantum systems.

When dealing with QRFs, quantum features previously thought to be absolute, such as superposition and entanglement, become dependent on the frame. Here, we provide a novel explanation for this frame-dependence by tracing it back to the question of how configurations or locations are identified across different branches in superposition. We show that, in the presence of symmetries, whether a system is in "the same"or "different"configurations across the branches depends on the choice of QRF. Thus, sameness and difference - and, as a result, superposition and entanglement - lose their absolute meaning.

These ideas carry over to the context of semi-classical spacetimes in superposition, such as the one - arguably - sourced by a gravitating object in superposition. This regime serves as a useful platform to examine the conceptual implications of QRF changes on the interface between quantum theory and gravity. In particular, one can see that, in this context, there is no preferred way of identifying points across the branches of the superposition - and thus no absolute meaning to the statement that the gravitational source is in a superposition in the first place. We make this idea concrete by using coincidences of four scalar fields to construct a comparison map between all spacetimes in superposition, which allows us to determine whether a system or an event is located at the "same"or "different"points across the branches. Different choices of scalar fields can be understood as different instantiations of QRFs and give rise to different ways of comparing spacetime points across the superposition. As an explicit application of this formalism, we explore how the localisation of events is relative to the choice of QRF and discuss the implications thereof for a generalisation of Einstein's famous hole argument, indefinite causal order and the locality of interaction.

Authors: KABEL, Viktoria (IQOQI Vienna); DE LA HAMETTE, Anne-Catherine; APADULA, Luca (IQOQI Vienna); CEPOLLARO, Carlo (University of Vienna); GOMES, Henrique (Oxford University); BUTTERFIELD, Jeremy (Cambridge University); BRUKNER, Časlav (University of Vienna)

Presenter: KABEL, Viktoria (IQOQI Vienna)

Session Classification: Quantum Foundations and QG

Contribution ID: **63** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Effective LTB: from dust collapses to regular black holes

Monday, May 6, 2024 3:30 PM (15 minutes)

In this talk I will present a framework which allows to construct effective LTB models starting from a polymerized spherical symmetric model. Then I will focus on dust collapses and show how these results can be related via coordinate transformations to other models in the literature. At last I want to analyze polymerized vacua and explore the formulation of a Birkhoff like theorem as well as the link to well known regular black hole metrics.

Authors: Dr LIU, Hongguang (Friedrich-Alexander Universität Erlangen-Nürnberg); Prof. GIESEL, Kristina (Friedrich-Alexander Universität Erlangen-Nürnberg); Prof. SINGH, Parampreet (Louisiana State University); WEIGL, Stefan (Friedrich-Alexander Universität Erlangen-Nürnberg)

Presenter: WEIGL, Stefan (Friedrich-Alexander Universität Erlangen-Nürnberg)

Session Classification: Canonical LQG

Contribution ID: **64** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Precision cosmology as a probe of quantum gravity

Tuesday, May 7, 2024 5:15 PM (15 minutes)

Next generation CMB experiments may provide stronger constraints for primordial observables that are sensitive to the semi-classical regime of quantum gravity. Here we present some tools to compare the predictions for the primordial power spectrum, tilt, running and running-of-the-running given by generic models of slow-roll inflation. These tools have been used in an effective field theory approach to quantum gravity, and can also be extended to previous results in LQC and other approaches.

Author: GAMONAL SAN MARTIN, Mauricio

Co-author: BIANCHI, Eugenio (PennState)

Presenter: GAMONAL SAN MARTIN, Mauricio

Session Classification: Cosmology

Contribution ID: **65** Type: **Canonical QG: Fundamental theory**

Anomalous diffusion and factor ordering in (1+1)-dimensional Lorentzian quantum gravity

Friday, May 10, 2024 3:30 PM (15 minutes)

Using properties of diffusion according to a quantum heat kernel constructed as an expectation over classical heat kernels on S^1, we probe the non-manifold-like nature of quantized space in a model of (1+1)-dimensional quantum gravity. By computing the mean squared displacement of a diffusing particle, we find that diffusion is anomalous, behaving similarly to that on a porous substrate, network, or fractal over short distances. The walk dimension of the path for a particle diffusing in quantized space is calculated to have an infimum of 4, rising to arbitrarily large values depending on a parameter labeling the choice of factor ordering in the quantum Hamiltonian for our model and figuring in the asymptotic behavior of the wavefunction used to construct the quantum heat kernel. Additionally, we derive an expansion for return probability of a diffusing particle, whose modifications from the classical power-series form depend on the factor-ordering parameter.

Author: MAITRA, Rachel (Wentworth Institute of Technology)

Presenter: MAITRA, Rachel (Wentworth Institute of Technology)

Session Classification: Foundation of Quantum Gravity

Contribution ID: **66** Type: **Covariant QG: Fundamental theory**

Spinfoam: Bulk from Boundary

Monday, May 6, 2024 2:30 PM (15 minutes)

Based on the exact holographic duality formula related the Ponzano-Regge amplitudes for 3d quantum gravity and the 2d inhomogeneous Ising model, I will clarify the relation between bulk path integrals and boundary theory in the context of spinfoams. Through simple toy-models, I will explain how bulk observables become the coupling constants of the boundary theory, and vice-versa how the bulk theory can be reconstructed as an infinite refinement of an edge mode network.

Author: LIVINE, Etera (CNRS)

Presenter: LIVINE, Etera (CNRS)

Session Classification: Covariant LQG

Contribution ID: **67** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Angular power spectrum from different regularizations in LQC

Tuesday, May 7, 2024 3:15 PM (15 minutes)

In Loop Quantum Cosmology (LQC), as in any other quantum theory, various regularizations of the Hamiltonian constraint and quantum ambiguities yield distinct physical implications. Specifically, the treatments of the Euclidean and Lorentzian parts of the Hamiltonian constraint for spatially flat, homogeneous, and isotropic spacetime before quantization results in alternative quantizations of the LQC model—namely, standard LQC, modified LQC-I (mLQC-I), and modified LQC-II (mLQC-II). These models exhibit different background dynamics and pre-inflationary phases, wherein the effects of each regularization might be captured, leading to modifications in the primordial power spectrum and the corresponding angular power. To this end, we compare the primordial power spectrum in the infrared regime for all three different models, tuning the inflaton's mass and the initial value of the scalar field in such a way that all models predict almost the same number of e-foldings, and the same scale-invariant regime, with the relative difference in power being less than one percent in the scale invariant regime. Our findings reveal that the shape and amplitude of the primordial power spectrum in infra-red regime depend on the chosen regularizations, quantum ambiguities, the order of adiabatic initial states, and how far they are imposed in the contracting branch. Upon computing the corresponding angular power spectrum for each model, we observed a larger amplitude in large angle, i.e., low l multipoles, for all models, with mLQC-I demonstrating the highest consistency with observations, employing a hybrid approach.

Authors: MOTAHARFAR, meysam (Louisiana State University); SINGH, Parampreet (Louisiana State University); LI, Bao-Fei (Zhejiang's University); SINGH, Parampreet (LSU)

Presenter: MOTAHARFAR, meysam (Louisiana State University)

Session Classification: Cosmology

Contribution ID: **70** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Timelike building blocks in quantum cosmology

Thursday, May 9, 2024 3:40 PM (15 minutes)

In this talk, I discuss recent advances in Lorentzian quantum cosmology using group field theory (GFT) condensate cosmology and effective spin foams.

First, in the GFT approach, I introduce the complete Barrett-Crane (cBC) TGFT model coupled to four scalar fields, establishing a connection between the causal character of quantum geometry and relational scalar clock and rods. This allows to derive relational cosmological perturbation equations from quantum entanglement between spacelike and timelike tetrahedra (discussed in detail in Luca Marchetti's talk).

Second, in the effective spin foam approach, I introduce Lorentzian frustum geometries for spatially flat, isotropic and homogeneous cosmology, addressing causality violations, scalar field coupling, and discrete dynamics. Following new results in (2+1)-dimensional Lorentzian spin foams (see José Diogo Simão's talk), we propose an effective spin foam model for (2+1)-dimensional quantum cosmology with a path integral measure derived from spin foams.

Overall, this talk epmhasizes the importance of timelike building blocks in quantum cosmology, advocating for models that incorporate a causally complete set of discrete Lorentzian geometries.

Author: JERCHER, Alexander (Friedrich-Schiller-University Jena)

Co-authors: PITHIS, Andreas (LMU - München); Dr MARCHETTI, Luca (University of New Brunswick); STEINHAUS, Sebastian (Friedrich-Schiller-Universitaet Jena)

Presenter: JERCHER, Alexander (Friedrich-Schiller-University Jena)

Session Classification: Cosmology, Black Holes, and other applications/phenomenology

Contribution ID: **71** Type: **Quantum Gravity: Computations**

Stabilizer entropy of quantum tetrahedra

Monday, May 6, 2024 3:30 PM (15 minutes)

How complex is the structure of quantum geometry? In loop quantum gravity, atoms of space are SU(2) 4-valent intertwiners, which describe quantum tetrahedra. The complexity of this construction has a concrete consequence in recent efforts to simulate quantum geometry models and toward experimental demonstrations of quantum gravity effects. There is, then, a computational and an experimental complexity inherent to this class of models. We study this complexity under the lens of Stabilizer Entropy (SE). We show how to calculate the SE of the gauge-invariant basis states and its average in the SU(2)–gauge invariant subspace. States of definite volume are singled out by the (near) maximal SE and provide precise bounds to the verification protocols for experimental demonstrations on available quantum computers.

Authors: CHIRCO, Goffredo (Università di Napoli Federico II); Mr CEPOLLARO, Simone (Scuola Superiore Meridionale -Naples); Prof. HAMMA, Alioscia (Università di Napoli Federico II); Mr ESPOSITO, Gianluca (Scuola Superiore Meridionale - Naples); Mr CUFFARO, Gianluca (University of Massachusetts Boston)

Presenter: CHIRCO, Goffredo (Università di Napoli Federico II)

Session Classification: Covariant LQG

Contribution ID: **72** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Thermodynamics from entanglement in quantum field theory and black holes

Tuesday, May 7, 2024 6:00 PM (15 minutes)

In asymptotically flat quantum gravity, the dimension of the Hilbert space is given by the exponential of the Bekenstein-Hawking entropy. Can we understand this thermodynamic entropy as a consequence of entanglement in a typical state at a definite ADM energy? We approach this question by exploring the behavior of the typical entanglement entropy in large quantum systems under constraints. This technique allows us to obtain an entanglement entropy that does not diverge in quantum field theory. Furthermore, this entanglement entropy also reproduces the smaller subsystem's thermodynamic entropy. To explore this correspondence between entanglement and thermodynamics, we examine a quantum electromagnetic field in a box. In this system, we show that the typical entanglement entropy coincides with the known black-body thermodynamic entropy at the leading order. Moreover, we obtain a non-thermodynamic correction that reproduces a contribution reported before in the context of condensed matter.

Author: MUINO GARCIA, Erick (Penn State University)

Co-author: BIANCHI, Eugenio (PennState)

Presenter: MUINO GARCIA, Erick (Penn State University)

Session Classification: Black Holes

Contribution ID: **73** Type: **Quantum Gravity: Computations**

Generative Flow Networks in Spin Foam Cosmology

Monday, May 6, 2024 4:30 PM (15 minutes)

Spin foams arose as the covariant (path integral) formulation of quantum gravity depicting transition amplitudes between different quantum geometry states. Though a lot of progress has been made in defining the underlying mathematics, actually calculating the corresponding amplitudes is still a challenging topic, especially for more complicated, thus more physically-relevant cases. Following recent advances, where stochastic algorithms (Markov Chain Monte Carlo-MCMC) were used, we employ "Generative Flow Networks", a newly developed machine learning algorithm to compute the expectation value of the dihedral angle for a 4-simplex and compare the results with previous works.

Authors: KOGIOS, Athanasios (Perimeter Institute/University of Waterloo); Mr WOGAN, Jared; Dr BUNAO, Joseph; Dr FRISONI, Pietropaolo

Presenter: KOGIOS, Athanasios (Perimeter Institute/University of Waterloo)

Session Classification: Covariant LQG

Contribution ID: **75** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Post-Newtonian gravitational waves with cosmological constant derived from Einstein-Hilbert action

Tuesday, May 7, 2024 5:45 PM (15 minutes)

We explain the analysis of the compact binary system dynamics in the Post-Newtonian approach adding the cosmological constant Λ at the first Post-Newtonian (PN) order from the Einstein-Hilbert action. Considering small values of Λ we find that it plays the role of a PN factor, and we us this feature to compute the Lagrangian of a binary compact system at the center of mass frame at 1PN order, as well as the phase function $\phi(t)$ and the polarizations h_+ and $h_\times$. We observe changes due to Λ only at very low constant frequencies and in certain particular values, we find that the amplitudes of the polarizations are canceled at Newtonian order (0PN).

This talk is based in Phys. Rev. D 109, 064051 (2024).

Author: ESCOBEDO, Ricardo (Universidad de Guadalajara)

Co-authors: Dr MORENO, Claudia (Universidad de Guadalajara); Dr HERNÁNDEZ-JIMÉNEZ, Rafael (Universidad de Guadalajara)

Presenter: ESCOBEDO, Ricardo (Universidad de Guadalajara)

Session Classification: Cosmology

Contribution ID: **76** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Axial perturbations in Kantowski-Sachs spacetimes

Tuesday, May 7, 2024 2:30 PM (15 minutes)

We present a description of axial perturbations in Kantowski-Sachs spacetimes, corresponding to nonrotating, uncharged black hole interiors. Perturbations are expressed in terms of perturbative gauge invariants, linear perturbative constraints, and their momenta. Moreover, the entire system formed by these perturbations and the background degrees of freedom is described by a canonical set of variables. We employ a hybrid approach to quantize this system, combining a quantum representation of the background sector using Loop Quantum Cosmology with a conventional field quantization of the perturbations.

Author: MENA MARUGAN, GUILLERMO ANTONIO (Instituto de Estructura de la Materia, CSIC)

Co-author: MÍNGUEZ SÁNCHEZ, Andrés (Instituto de Estructura de la Materia, CSIC)

Presenter: MENA MARUGAN, GUILLERMO ANTONIO (Instituto de Estructura de la Materia, CSIC)

Session Classification: Black Holes

Contribution ID: **77** Type: **Covariant QG: Fundamental theory**

A new 2+1 coherent spin-foam vertex for quantum gravity

Monday, May 6, 2024 5:15 PM (15 minutes)

This talk reports on a recent proposal for a Lorentzian spin-foam coherent amplitude in 2+1 dimensions, defined for an arbitrary combination of space- and time-like edges. The construction makes use of a new set of boundary coherent states, derived from the correspondence between Majorana spinors and space-like 2+1 vectors. The amplitude is shown to recover the Lorentzian Regge action in the semiclassical limit.

Based on arXiv:2401.10324 and arXiv:2402.05993.

Author: SIMAO, Jose Diogo (FSU Jena)

Presenter: SIMAO, Jose Diogo (FSU Jena)

Session Classification: Covariant LQG

Contribution ID: **78** Type: **Boundaries, Symmetries, and Classical aspects**

Relating Canonical and Covariant Hamiltonian frameworks

Monday, May 6, 2024 2:30 PM (15 minutes)

Despite common assumptions that canonical and covariant hamiltonian methods yield equivalent physical theories, we revisit the issue and show that, after properly identifying what one might mean by equivalence, there are instances in which these two methods are indeed inequivalent when boundaries are present.

Author: CORICHI, Alejandro (UNAM, Mexico)

Presenter: CORICHI, Alejandro (UNAM, Mexico)

Session Classification: Canonical LQG

Contribution ID: **79** Type: **Covariant QG: Fundamental theory**

New algorithms for computing spin foam amplitudes

Monday, May 6, 2024 3:00 PM (15 minutes)

Computing spin foam amplitudes explicitly is still a challenging task, in particular for 2-complexes consisting of multiple vertices. In this talk I will present three algorithms that will help construct and compute amplitudes more efficiently.
The first algorithm allows us to easily construct 2-complexes and the associated amplitude. We define the number of spin foam vertices and choose along which edges they are glued. For each edge we can specify the wiring of the faces. Then, the algorithm determines how many faces there are and whether they are in the bulk or at the boundary. Once the boundary data are specified, it computes the amplitude.
The second and third algorithm aim at making the calculation of spin foam amplitudes more efficient. In one we write the calculation as a contraction of a tensor network with smaller, lower-valent tensors, while the other uses a Monte Carlo algorithm for coherent intertwiners. I will demonstrate how they work for the coherent vertex amplitude and how they can be generalized to larger triangulations.
So far, these algorithms are for SU(2) BF theory as a proof of principle. Since they are written in Julia, it should be straightforward to interface them e.g. with the package sl2cfoam-next to compute Lorentzian EPRL amplitudes.
The projects are partially in collaboration with Seth Asante, Kevin Siebert and José Diogo Simão.

Author: STEINHAUS, Sebastian (FSU Jena)

Co-authors: SIMAO, Jose Diogo (FSU Jena); Mr SIEBERT, Kevin (FSU Jena); ASANTE, Seth

Presenter: STEINHAUS, Sebastian (FSU Jena)

Session Classification: Covariant LQG

Contribution ID: **80** Type: **Covariant QG: Fundamental theory**

Matter coupled to 3d Quantum Gravity: One-loop Unitarity

Monday, May 6, 2024 6:00 PM (15 minutes)

We expect quantum field theories for matter to acquire intricate corrections due to their coupling to quantum fluctuations of the gravitational field. This can be precisely worked out in 3D quantum gravity: after integrating out quantum gravity, matter fields are effectively described as non-commutative quantum field theories, with quantum-deformed Lorentz symmetries. An open question remains: Are such theories unitary or not? On the one hand, since these are effective field theories obtained after integrating out high energy degrees of freedom, we may expect the loss of unitarity. On the other hand, as rigorously defined field theories built with Lorentz symmetries and standing on their own, we naturally expect the conservation of unitarity. In an effort to settle this issue, we explicitly check unitarity for a scalar field at one-loop level in both Euclidean and Lorentzian space-time signatures

Author: MARIS, Valentine (LPENSL)

Co-author: Dr LIVINE, Etera (CNRS)

Presenter: MARIS, Valentine (LPENSL)

Session Classification: Covariant LQG

Contribution ID: **81** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Black hole as a semi-classical configuration with maximum entropy

Thursday, May 9, 2024 3:10 PM (15 minutes)

One property that characterizes a black hole is that it maximizes entropy in a finite region with a fixed surface area. It may be a more fundamental one than the existence of a horizon in the context of quantum gravity, where there is no notion of continuum geometry. Using this characterization, we consider the interior of a black hole in the 4D semi-classical Einstein equation. For simplicity, we consider spherical static finite configurations for various sufficiently excited quantum states, apply thermodynamic typicality to a small subsystem, and estimate entropy including self-gravity, to derive its upper bound. By the saturation condition and consistency with local thermodynamics, the entropy-maximized configuration is uniquely determined as a radially uniform dense configuration with near-Planckian curvatures and a surface just outside the Schwarzschild radius. The interior metric is a non-perturbative self-consistent solution in the Planck constant. The maximum entropy, given by the volume integral of the entropy density, becomes the Bekenstein-Hawking formula due to the strong self-gravity, yielding the Bousso bound. Thus, this compact dense configuration may be a candidate for black hole in quantum theory. We finally discuss some similarities to quantum gravitational condensation in group field theory.

Author: YOKOKURA, Yuki (RIKEN, Interdisciplinary Theoretical and Mathematical Sciences Program)

Presenter: YOKOKURA, Yuki (RIKEN, Interdisciplinary Theoretical and Mathematical Sciences Program)

Session Classification: Cosmology, Black Holes, and other applications/phenomenology

Contribution ID: **82** Type: **Boundaries, Symmetries, and Classical aspects**

Poincare symmetries for 4D gravity and spin networks

Thursday, May 9, 2024 3:55 PM (15 minutes)

"3D gravity in tetrad variables shows a rich symmetry structure that includes both rotations and Kalb-Ramond translations which has been instrumental in understanding its properties. Therefore, extensions of this type of symmetries to the four-dimensional case, like the $\mathfrak{isu}(2)$-algebra described in [1910.05642] for Loop Quantum Gravity, may be crucial in understanding states of quantum geometry.
Here, we present a set of $\mathfrak{iso}(1,3)$ symmetries of 4D gravity that form the direct analogue of the 3D ones, which were described in [1704.04248], and describe their canonical generators for the first time. We also highlight their implications and uses for spin networks and the kinematics of quantum geometry."

Author: LANGENSCHEIDT, Simon (LMU München, MCQST)

Co-author: Prof. ORITI, Daniele (Complutense Madrid)

Presenter: LANGENSCHEIDT, Simon (LMU München, MCQST)

Session Classification: Cosmology, Black Holes, and other applications/phenomenology

Contribution ID: **83** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Investigating Singularity Resolution in Loop Quantized Bianchi-IX Spacetimes: Ekpyrotic Potentials

Tuesday, May 7, 2024 3:30 PM (15 minutes)

Understanding the fundamental factors which shape the quantum structure of spacetime in loop quantized Bianchi-IX spacetimes offers valuable insights into the generic resolution of singularities and discerning the significance of anisotropies in the Planck regime. Conversely, it has been argued that ekpyrosis could mitigate the effects of anisotropies. Further, recent investigations into the physics of loop quantized Bianchi-I models have unveiled certain novel relationships between energy density and the anisotropic shear at the bounce. An important question arises regarding the modification of these findings in the Bianchi-IX framework, where the role of spatial curvature holds pivotal significance. To address this, we conduct extensive numerical simulations of the effective Hamiltonian dynamics governing Bianchi-IX spacetimes in Loop Quantum Cosmology (LQC), where quantum geometric effects universally bound the anisotropic shear and energy density at the bounce. We explore two distinct ekpyrotic potentials and their physical implications for singularity resolution. Furthermore, we explore the interplay between the energy density and the anisotropic shear at the bounce across various potentials to assess the robustness of results in the context of Bianchi-I spacetimes. Our results provide interesting insights on the genericness of results found in Bianchi-I LQC and the role of ekpyrosis.

Author: BROWN, Rachel (Louisiana State University)

Co-author: SINGH, Parampreet (LSU)

Presenter: BROWN, Rachel (Louisiana State University)

Session Classification: Cosmology

Contribution ID: **85** Type: **not specified**

Entanglement aspects of Hawking radiation in evaporating black hole

Wednesday, May 8, 2024 11:30 AM (40 minutes)

Presenter: ELIZAGA DE NAVASCUES, Beatriz

Contribution ID: **88** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Diffeomorphism covariance and the quantum Schwarzschild interior

Tuesday, May 7, 2024 5:15 PM (15 minutes)

A notion of residual diffeomorphism covariance in quantum Kantowski-Sachs (KS), describing the interior of a Schwarzschild black hole will be introduced, and the solution for the family of Hamiltonian constraint operators satisfying the condition will be briefly presented.
The result will then be compared to Hamiltonian constraints proposed for Loop Quantum KS in the literature, especially to the recently presented AOS model. In addition, we discuss how the choice of lapse affects the desired quantization.
The presentation is based on the publication "Diffeomorphism Covariance and the Quantum Schwarzschild Interior" (Universe 2024, 10, 89. https://doi.org/10.3390/universe10020089)

Authors: BORNHOEFT, Ian (Florida Atlantic University); Prof. ENGLE, Jonathan (Florida Atlantic University); GUOLO DIAS, Rafael (Florida Atlantic University)

Presenter: GUOLO DIAS, Rafael (Florida Atlantic University)

Session Classification: Black Holes

Contribution ID: **89** Type: **Covariant QG: Fundamental theory**

A Chern-Simons approach to self-dual gravity in (2+1)-dimensions and quantisation of Poisson structure

Friday, May 10, 2024 3:30 PM (15 minutes)

We present a Chern-Simons theory for the (2+1)-dimensional analog self-dual gravity theory that is based on the gauge group $SL(2,\mathbb{C})_{\mathbb{R}} \ltimes \mathbb{R}^6$. This is formulated by mapping the $3d$ complex self-dual dynamical variable and connection to $6d$ real variables which combines into a $12d$ Cartan connection.

Quantization is given by the application of the combinatorial quantisation program of Chern-Simons theory. The Poisson structure for the moduli space of flat connections on $(SL(2,\mathbb{C})_{\mathbb{R}} \ltimes \mathbb{R}^6)^{n+2g}$ which emerges in the combinatorial description of the phase space on $\mathbb{R} \times \Sigma_{g,n}$, where $\Sigma_{g,n}$ is a genus g surface with n punctures is given in terms of the classical r-matrix for the quantum double $D(SL(2,$
$CC)_{RR)}$ viewed as the double of a double $D(SU(2) \bowtie AN(2))$. This quantum double provides a feature for quantum symmetries of the quantum theory for the model.

Author: OSEI, Prince (African Institute for Mathematical Sciences (AIMS) Ghana)

Presenter: OSEI, Prince (African Institute for Mathematical Sciences (AIMS) Ghana)

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **90** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Inflationary and pre-inflationary scalar perturbations on closed universes in loop quantum cosmology

Tuesday, May 7, 2024 2:30 PM (15 minutes)

We analyze the evolution of scalar cosmological perturbations in a closed universe on a background described by a loop quantum cosmology model with an inflationary regime consistent with the constraints on inflation set by the observations of the CMB by the Planck mission. Initial conditions for the perturbations are set before the bounce, and the perturbations are numerically evolved until the end of the inflationary regime, allowing the determination of the primordial power spectrum for the scalar perturbations. The power spectrum includes corrections due to quantum effects in the background evolution and to the presence of spatial curvature. Such corrections can become relevant for the largest observable modes of the CMB even for spatial curvatures much smaller than the observational bound obtained without considering the pre-inflationary evolution of the perturbations.

Author: YOKOMIZO, Nelson (Federal University of Minas Gerais)

Presenter: YOKOMIZO, Nelson (Federal University of Minas Gerais)

Session Classification: Cosmology

Contribution ID: **91** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Spherical collapse and black hole evaporation

Tuesday, May 7, 2024 2:15 PM (15 minutes)

We consider 4d spherical collapse of a massless scalar field with a novel Areal Radius dependent coupling and obtain the following results:
(i) classical collapse is described by the Vaidya solution (ii) quantum back reaction can be explicitly computed (iii) the semiclassical solution
describes black hole formation, subsequent evaporation along a timelike 'dynamical horizon' and a back reaction corrected balance
law at future null infinity. The analysis, supportive of the Ashtekar-Bojowald paradigm, suggests the emergence of all information including
that in the collapsing matter along a quantum extended future null infinity.

Author: VARADARAJAN, Madhavan

Presenter: VARADARAJAN, Madhavan

Session Classification: Black Holes

Contribution ID: **92** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Status of Birkhoff's theorem in polymerized semiclassical regime of Loop Quantum Gravity

Tuesday, May 7, 2024 4:45 PM (15 minutes)

The collapse of a spherically symmetric ball of dust has been intensively studied in Loop Quantum Gravity (LQG). From a quantum theory, it is possible to recover a semiclassical regime through a polymerization procedure. In this setting, general solutions to the Polymerized Einstein Field Equations (PEFE) will be discussed both for the interior and the exterior of the dust cloud. Exterior solutions are particularly interesting since they may lead to a semiclassical version of the Birkhoff's theorem. It is seen that if time independence of the vacuum is imposed, there exists a class of solutions depending on two parameters. Nevertheless, the possibility of more intricate time dependent solutions is not ruled out completely.
A second approach to study semiclassical spacetimes is by considering an Oppenheimer-Snyder model. Namely, one glues the portion of spacetime containing dust with the vacuum part by matching the extrinsic curvatures. In this way, one gets a metric tensor for the vacuum which can be compared to the one obtained previously.
Although these two methods are completely independent from each other, the results we obtained are in perfect agreement.

Authors: LEWANDOWSKI, Jerzy; CAFARO, Luca (University of Warsaw)

Presenter: CAFARO, Luca (University of Warsaw)

Session Classification: Black Holes

Contribution ID: **93** Type: **Covariant QG: Fundamental theory**

Tunneling of quantum geometries in spinfoams

Monday, May 6, 2024 2:45 PM (15 minutes)

Quantum gravitational tunneling effects are expected to give rise to a number of interesting observable phenomena, including, in particular, the evolution of black holes at the end of their existence. Covariant Loop Quantum Gravity provides a framework to study these phenomena, yet a precise identification of tunneling processes is still not known. Motivated by tunneling processes, I will present the simplest case of Ponzano-Regge amplitudes in 3D: we find a surprising and detailed analogy of a class of transition amplitudes with tunneling processes in non-relativistic quantum mechanics.

Author: HAGGARD, Hal (Bard College)

Co-authors: ROVELLI, Carlo; VIDOTTO, Francesca; DONA, Pietro

Presenter: HAGGARD, Hal (Bard College)

Session Classification: Covariant LQG

Contribution ID: **94** Type: **Quantum Gravity: Computations**

Towards canonical LQG with neural networks: From the basics to 3d gravity in Smolin's weak coupling limit

Monday, May 6, 2024 2:15 PM (15 minutes)

The problem of obtaining and interpreting solutions to the quantum Hamilton constraint of LQG is a long-standing and difficult one. We approach this problem with novel numerical methods which leverage the power of neural networks, therefore taking the first step in applying deep learning methods in LQG.

We present the basic idea of parameterizing quantum states with a neural network, and of obtaining solutions to the constraints in this way. Then we consider U(1) BF theory and Smolin's weak coupling limit of 3d gravity as a toy model to demonstrate the applicability of neural network quantum states (NNQS). The quantum theory is truncated by introducing a fixed graph and a cutoff on representations, to make it accessible for numerics. We show that NNQS can approximate solutions to the constraints, and that they can be used to go beyond the regime in which exact diagonalization methods are applicable. We also discuss limitations and the dependence on the truncation.

In an application that points beyond the toy model, we compare approximate solutions of Thiemann's regularization of the Hamilton constraint with a more naive one and show quantitatively that they have much more in common than one might expect.

Authors: SAHLMANN, Hanno (Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)); Mr SHERIF, Waleed (Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU))

Presenter: SAHLMANN, Hanno (Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU))

Session Classification: Canonical LQG

Contribution ID: **95** Type: **Quantum Foundations and QG**

The problems of time, normalizability and classical limit in canonical quantum gravity: A pilot-wave approach

Thursday, May 9, 2024 4:10 PM (15 minutes)

Abstract: Quantum gravitational theories generically suffer from issues such as the problems of normalizability, time and classical limit. Despite decades of technically sophisticated efforts, based on the orthodox quantum formulation, there remains a lack of consensus on these issues. In this talk, I will develop the viewpoint that these issues are not technical but conceptual, rooted in interpretational questions. In particular, I will show how the conceptual structure of pilot-wave theory (deBroglie-Bohm) provides a natural resolution of these issues in non-perturbative quantum gravity using recent work.

I will first illustrate some key ideas using non-normalizable solutions of the quantum harmonic oscillator in pilot-wave theory. I will then reformulate the discussion in a holomorphic representation, which will make clear the connection to non-perturbative quantum gravity in terms of Ashtekar variables. I will then apply the pilot-wave formulation to the interacting fermionic-gravitational system in (Phys. Rev. D 106.10 (2022): 106012). I will show how a real global time is obtained without semiclassical approximations by parameterizing the variation of the fermionic field. I will then discuss the classical limit in this approach using guidance equation for the Ashtekar connection. Lastly, I will show the existence of unitary states in minisuperspace.

Based on:
1. Sen, I. Physical interpretation of non-normalizable harmonic oscillator states and relaxation to pilot-wave equilibrium. Nat. Sci. Rep. 14, 669 (2024).
2. Sen, I., Alexander, S., & Dressel, J. A Realist Interpretation of Unitarity in Quantum Gravity. arXiv:2310.15157 (2023).

Author: SEN, Indrajit

Co-authors: Dr DRESSEL, Justin (Chapman University); Prof. ALEXANDER, Stephon (Brown University)

Presenter: SEN, Indrajit

Session Classification: Quantum Foundations and QG

Contribution ID: **96** Type: **Cosmology, Black Holes, and other applications/phenomenology**

The central role of Gauss constraint across LQC and LQG

Tuesday, May 7, 2024 5:30 PM (15 minutes)

We address the problem of the SU(2) internal symmetry in Loop Quantum Cosmology (LQC) and its relationship with canonical Loop Quantum Gravity (LQG). We introduce new tools to treat non-diagonal Bianchi models in LQC, and we discuss the Gauss constraint and the role of gauge freedom. This allows us to prove that, in the minisuperspace cosmological framework, there exist suitable variables in which the Gauss constraint can be recast into three Abelian constraints.

We identify the Gauss constraint as the primary element that connects the SU(2) group with the full quantum theory (LQG). Building on these new results, we seek an approach to the cosmological sector that preserves the Gauss constraint, requiring to move beyond the minisuperspace framework. We propose a strategy to face this challenge, based on the geometric structure underlying Yang-Mills theories.

Author: BRUNO, Matteo

Presenter: BRUNO, Matteo

Session Classification: Cosmology

Contribution ID: **97** Type: **Covariant QG: Fundamental theory**

De Sitter horizon entropy from a simplicial Lorentzian path integral

Monday, May 6, 2024 5:45 PM (15 minutes)

Can one compute thermodynamic quantities, such as entropy, with a Lorentzian path integral? Using a regularization of the path integral via Regge calculus, we will see that the answer is affirmative.
Irregularities in the light cone structure, e.g. configurations with contractible closed timelike curves, play an essential role for this conclusion. Such light cone irregularities contribute imaginary terms to the gravitational action, which can lead to an enhancing effect and explain how one can obtain a positive entropy from a real-time path integral.
We will discuss how Regge calculus deals with these singularities and allows for an explicit treatment of the path integral for the partition function computing the dimension of the Hilbert space of a 3-ball, from which one can extract the de Sitter entropy.

Author: PADUA ARGÜELLES, José de Jesús (Perimeter Institute)

Co-authors: Prof. DITTRICH, Bianca (Perimeter Institute); Prof. JACOBSON, Theodore (University of Maryland)

Presenter: PADUA ARGÜELLES, José de Jesús (Perimeter Institute)

Session Classification: Covariant LQG

Contribution ID: **98** Type: **Boundaries, Symmetries, and Classical aspects**

Supertranslations at spatial infinity and boundary conditions for Ashtekar-Barbero variables

We want to explore suitable boundary conditions for the asymptotically flat scenario of general relativity presented in terms of Ashtekar-Barbero variables. While the standard parity conditions have been already extensively studied, it turns out that they fail to produce non-trivial supertranslations at spatial infinity. We propose new parity conditions for the Ashtekar-Barbero variables that do yield non-trivial supertranslation charges at spatial infinity.

Author: BAKHODA, Sepideh (Beijing Normal University)

Presenter: BAKHODA, Sepideh (Beijing Normal University)

Session Classification: Canonical LQG

Contribution ID: **99** Type: **Boundaries, Symmetries, and Classical aspects**

Geometry, Dynamics, and Phase Space of Carrollian Stretched Horizons

Friday, May 10, 2024 2:15 PM (15 minutes)

The membrane paradigm illustrates a profound link between gravity on a stretched horizon and hydrodynamics. While this connection has been explored semi-classically, it holds potential for illuminating fundamental aspects of quantum spacetime, such as degrees of freedom, symmetries, and dynamics. In this work, we revisit the membrane viewpoint and introduce the concept of stretched Carroll (sCarroll) structures, which are a generalization of Carroll structures of null surfaces, to timelike stretched horizons. We then establish a correspondence between gravity degrees of freedom and dynamics on the stretched horizon and Carrollian hydrodynamics. Furthermore, we demonstrate that the canonical phase space of gravity on the stretched horizon is completely captured by the sCarroll structure. Finally, we discuss the diffeomorphism symmetries of the horizon and, through the Noether theorem, derive Einstein's equation on the surface and the associated Noether charges, particularly including the transverse translation and the spin-2 symmetry.

Author: JAI-AKSON, Puttarak (RIKEN iTHEMS)

Presenter: JAI-AKSON, Puttarak (RIKEN iTHEMS)

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **100** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Full spacetime of a minimal uncertainty quantum black hole

Tuesday, May 7, 2024 5:45 PM (15 minutes)

We construct the full spacetime of a minimal uncertainty inspired black hole, borrowing the improved prescription from loop quantum gravity. In the minimal uncertainty approach, minimalization of the uncertainty relations leads to the deformation of the algebra leading to an effective theory. We show that the asymptotic and classical limits of our model match the Schwrazschild solution, and the singularity is resolved. We also report on an interesting relation between the minimal uncertainty parameters and the Barbero-Immirzi parameter. Finally we show the modified behaviour of infalling geodesics and the photon sphere compared to the classical Schwarzschild spacetime.

Author: VIENNEAU, Evan (University of Alberta)

Co-authors: GINGRICH, Doug (University of Alberta (CA)); FRAGOMENO, Federica (University of Alberta); Prof. RASTGOO, Saeed (University of Alberta); HERGOTT, Samantha (York University / Perimeter Institute for Theoretical Physics)

Presenter: VIENNEAU, Evan (University of Alberta)

Session Classification: Black Holes

Contribution ID: **101** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Understanding gravitationally induced decoherence parameters in neutrino oscillations using a microscopic quantum mechanical model

Thursday, May 9, 2024 3:10 PM (15 minutes)

Open quantum systems provide a framework in which models for gravitationally induced decoherence can be formulated. In this talk a microscopic quantum mechanical model for gravitationally induced decoherence introduced by Blencowe and Xu is investigated in the context of neutrino oscillations. The focus lies on the
comparison with existing phenomenological models and the physical interpretation of the decoherence parameters in such models. It will be shown that for neutrino oscillations in vacuum gravitationally induced decoherence can be matched with a subclass of phenomenological models. When matter effects are included, the decoherence parameters show a dependence on matter effects and thus vary in the different layers of the Earth. Such a dependence can be explained with the form of the coupling between neutrinos and the gravitational wave environment inspired by linearised gravity. As a consequence, in the case of neutrino oscillations in matter, the microscopic model does not agree with many existing phenomenological models that assume constant decoherence parameters in matter, and their existing bounds cannot be used to further constrain the model considered here. The probabilities for neutrino oscillations with constant and varying decoherence parameters are compared and it is shown that the deviations can be up to 10%. On a theoretical level, these different models can be characterised by a different choice of Lindblad operators, with the model with decoherence parameters that do not include matter effects being less suitable from the point of view of linearised gravity.

Author: GIESEL, Kristina

Co-authors: DOMI, Alba; EBERL, Thomas; FAHN, Max Joseph; HENNIG, Lukas; KATZ, Ulrich; KEMPER, Roman; KOBLER, Michael

Presenter: GIESEL, Kristina

Session Classification: Quantum Foundations and QG

Contribution ID: **102** Type: **Cosmology, Black Holes, and other applications/phenomenology**

The Bounce in the Bianchi models as a quantum scattering

Tuesday, May 7, 2024 5:00 PM (15 minutes)

We provide a new picture for the emergence of a bouncing cosmology at a pure quantum level, according to the idea that a semiclassical behavior of the Universe towards the singularity is not available in many relevant Minisuperspace models. In particular, we clarify how any Bianchi I localized wave packet unavoidably spreads when the singularity is approached, and therefore the semiclassical description of the model in the Planckian region loses its predictability, especially when the generic cosmological solution is taken into account. Then, we highlight the isomorphism between the Wheeler-DeWitt equation for the Bianchi models in the Misner variables and the Klein-Gordon equation for a relativistic scalar field. In particular, we identify the positive and negative frequency solutions with the collapsing and expanding Universe respectively. Then, we calculate the transition amplitude between a collapsing Universe and an expanding one for the Bianchi I model, according to the standard techniques of relativistic quantum mechanics, thanks to the introduction of an ekpyrotic-like matter component which mimics a time-dependent potential term and breaks the frequency separation. In particular, the transition probability of this "Quantum Big Bounce" shows the same symmetrical reconnection of the semiclassical bouncing cosmology. The same technique is improved by using the Dirac equation, in order to solve some issues related to the Klein-Gordon equation. This new approach is well adapted also to the study of the Kasner transition in the BKL map of the Bianchi IX model, in which the time-dependent potential is naturally present by construction and depends on the gravitational degrees of freedom.

Author: GIOVANNETTI, Eleonora (CPT Marseille)

Presenter: GIOVANNETTI, Eleonora (CPT Marseille)

Session Classification: Cosmology

Contribution ID: **103** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Hydrodynamics on minisuperspace: connecting quantum gravity and cosmology

Tuesday, May 7, 2024 2:15 PM (15 minutes)

We show how cosmological dynamics can be mapped to hydrodynamics (on minisuperspace) via field symmetries. We then connect the same hydrodynamics (on minisuperspace) to several quantum gravity directions, starting from group field theory, and argue that it may represent a general effective framework for the cosmological sector of quantum gravity.

Author: ORITI, Daniele (Universidad Complutense Madrid)

Presenter: ORITI, Daniele (Universidad Complutense Madrid)

Session Classification: Cosmology

Contribution ID: **104** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Effective loop quantum gravity black holes: A covariant, improved-dynamics scheme

Monday, May 6, 2024 5:30 PM (15 minutes)

We use emergent modified gravity as a covariant, effective framework for obtaining black hole solutions in loop quantum gravity with an arbitrary, scale-dependent holonomy parameter λ in vacuum spherical symmetry. The construction is robust and can be applied in general for any type of triangulation. We obtained vacuum solutions not only for asymptotically flat spacetime but also for dS and AdS backgrounds, where we solved the dynamics in different gauges related by coordinate transformation. In particular, we show that the $\bar{\mu}$-scheme resolves several asymptotic pathologies of the alternative μ_0 scheme where λ is a constant parameter, at the expense of not recovering a flat spacetime in the zero mass limit.

Authors: DUQUE, Erick Ivan (The Pennsylvania State University); BELFAQIH, Idrus (The University of Edinburgh); Mr BOJOWALD, Martin (The Pennsylvania State University); BRAHMA, Suddhasattwa (The University of Edinburgh)

Presenter: BELFAQIH, Idrus (The University of Edinburgh)

Session Classification: Black Holes

Contribution ID: **105** Type: **Boundaries, Symmetries, and Classical aspects**

Purification of Hawking radiation: messages from a moving mirror analogue

Thursday, May 9, 2024 4:10 PM (15 minutes)

Time-dependent reflective boundary conditions (i.e. a moving mirror) in a scalar field theory in 1+1 dimensions have the power to model key aspects of Hawking radiation. In particular, this valuable pedagogical tool allows one to understand how early thermal quanta could be purified by late field modes. In this talk, we discuss a mirror trajectory that mimics an evaporating black hole; with a time-dependent mass dictated by the amount of energy radiated. We find that this model materializes concretely an exciting scenario previously suggested by Hotta, Schutzhold, and Unruh. Here, Hawking radiation is purified by late-time vacuum fluctuations, which, while carrying no energy or momentum, are still capable of purifying the state. Although not all messages extracted from this analogy may apply to black holes, the calculations reveal interesting lessons about the relation between purification and energy fluxes in evaporating scenarios. A study of similar issues on more realistic black hole scenarios will be discussed at this conference by Beatriz Elizaga Navascués.

Authors: ELIZAGA DE NAVASCUES, Beatriz (Louisiana State University); AGULLO, Ivan (Louisiana State University); CALIZAYA CABRERA, Paula (Louisiana State University)

Presenter: CALIZAYA CABRERA, Paula (Louisiana State University)

Session Classification: Cosmology, Black Holes, and other applications/phenomenology

Contribution ID: **106** Type: **Boundaries, Symmetries, and Classical aspects**

Dynamical symmetries for cosmologies and black holes

Tuesday, May 7, 2024 3:30 PM (15 minutes)

Homogenous cosmological models and black holes belong to classes of space-time metrics defined in terms of a finite number of degrees of freedom. For these, the dynamics reduces to a one-dimensional mechanical model. It is then easy to investigate their classical symmetries and the corresponding Noether charges.
These dynamical symmetries have a geometric interpretation, not in terms of spacetime geometry, but in terms of motion on the field space. Moreover, they interplay with the fiducial scales, introduced to regulate the homogeneous model, suggesting a relationship with the boundary structure of the full theory.
Finally, I will describe a framework where the connection between these symmetries and the boundary structures can be tested explicitly, thanks to the inclusion of inhomogeneities.

Author: SARTINI, Francesco (OIST)

Presenter: SARTINI, Francesco (OIST)

Session Classification: Black Holes

Contribution ID: **107** Type: **Quantum Gravity: Computations**

Landscape of 4D spinfoam quantum geomoetry: Results from next-to-leading order spinfoam large-j asymptotics of 1-5 Pachner move

Monday, May 6, 2024 3:45 PM (15 minutes)

To study the large-j asymptotics of Lorentzian spinfoam EPRL models on complex four dimensional geometries with internal points, it is crucial to first understand the underlying impact of geometrical structures on the spinfoam amplitudes, due to the existence of continuous critical points and their non-trivial contribution in the covariant path integral formalism. In this paper we propose several criteria to probe the non-trivialities of four dimensional 1-5 Pachner move geometry impacting spinfoam amplitude, including the standard deviation of 4-volumes of constituting 4-simplices, the smallest 4-simplex volume, and also whether the directions of tetrahedron 4-normals are close to the null direction. By computing numerically and analyzing in detail the spinfoam amplitudes up to next-to-leading order of large amounts of 1-5 move samples sharing the same boundary 4-simplex, the connection between non-trivial quantum geometry and spinfoam amplitudes is revealed as large standard deviation of 4-simplex volumes can result in both leading order and next-to-leading order amplitudes being large, while the close to null tetrahedron 4-normals impact on the increase of next-to-leading order amplitude much greater than it impact the leading order amplitude, making it mostly a quantum effect. After comparing all of the samples we computed, we are able to further confirm that the factors we investigate in our work are the major impacting factors on spinfoam amplitude of samples with the same boundary, since the randomness of each sample can be fully explained by taking into account of these factors. The results we obtain in this work can be naturally generalized to the large-j analysis of other graphs as well.

Authors: HAN, Muxin (Florida Atlantic University); LI, Haida (South China University of Technology); LIU, Hongguang (FAU - Erlangen); QU, Dongxue (PI - Waterloo)

Presenter: LI, Haida (South China University of Technology)

Session Classification: Covariant LQG

Contribution ID: **108** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Nonsingular spherical black holes with holonomy corrections

Monday, May 6, 2024 4:45 PM (15 minutes)

We explore spherically symmetric black-hole models with corrections motivated by loop quantum gravity. We derive a general family of Hamiltonians satisfying specific covariance conditions so that the dynamics generated by such families define a spacetime geometry independently of gauge or coordinate choices. By construction, there are no propagating degrees of freedom, but we show that the usual minimal coupling is still covariant within the modified geometric models. We apply these results to effective Lemaître-Tolman-Bondi spacetimes and show how holonomy corrections can resolve black-hole singularities.

Author: ALONSO-BARDAJI, Asier

Presenter: ALONSO-BARDAJI, Asier

Session Classification: Black Holes

Contribution ID: **109** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Bouncing cosmology from LQC with ekpyrotic and matter fields

Tuesday, May 7, 2024 4:45 PM (15 minutes)

I will present an ongoing work about the evolution of a two-field bouncing scenario in Loop Quantum Cosmology. The model features a quasi-dust field with a slightly negative equation of state, dominating in the far past of the contraction phase, which is known as a possible candidate to explain the red tilt observed in the CMB power spectrum. To avoid instabilities, an ekpyrotic field dominates around the bounce for a sufficiently long time. I will present the dynamics of this system and the results obtained so far.

Author: FRION, Emmanuel (University of Western Ontario, Physics and Astronomy)

Co-authors: Prof. VIDOTTO, Francesca (The University of Western Ontario); Mr PASCUAL GOMEZ-CUETARA, Mateo

Presenter: FRION, Emmanuel (University of Western Ontario, Physics and Astronomy)

Session Classification: Cosmology

Contribution ID: **110** Type: **Boundaries, Symmetries, and Classical aspects**

A New Criterion for Angular Momentum at Null Infinity

Friday, May 10, 2024 2:30 PM (15 minutes)

The enhancement of the symmetry group for asymptotically flat spacetimes from the Poincare group to the infinite-dimensional BMS group gives a rich structure to the theory. The existence of supertranslations in the BMS group plays a key role in a variety of asymptotic phenomenon. In particular, there is a well-known "supertranslation ambiguity" in defining the angular momentum of an isolated gravitational system. Although this should be viewed as a generic feature of the theory, it does present the issue that, apriori, there may not seem to be a "preferred" definition of angular momentum. We propose a new criterion to assess the viability of definitions of angular momentum at null infinity: cross-section continuity. Although the Dray-Streubel (DS) definition automatically satisfies this condition due to the existence of a flux, the one-parameter family of angular momenta proposed by Compere and Nichols (CN) - which encompasses multiple other definitions - does not. We also verify the Chen-Wang-Yao (CWY) definition is cross-section continuous.

Author: PARAIZO, Daniel (Penn State)

Presenter: PARAIZO, Daniel (Penn State)

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **111** Type: **Canonical QG: Fundamental theory**

Revisiting loop quantum gravity with selfdual variables

Friday, May 10, 2024 2:30 PM (15 minutes)

We consider the quantization of gravity as an SL(2,C) gauge theory in terms of Ashtekar's selfdual variables and reality conditions for the spatial metric (RCI) and its evolution (RCII).
We start from a holomorphic phase space formulation and consider holomorphic cylindrical wave functions over SL(2,C) connections. We use an overall phase ambiguity of the complex selfdual action to obtain Poisson brackets that mirror those of the real theory. We then show that there is a representation of the corresponding canonical commutation relations the space of holomorphic cylindrical functions.
We describe a class of cylindrically consistent measures that implements RCI. We also consider a regularization of RCII and show that there are no solutions in the class of measures that we are considering.
We end with a comparison to the literature and some general observations on the consistency of reality conditions, commutation relations and use of holonomies as basic variables.

Authors: SAHLMANN, Hanno (Friedrich-Alexander-Universität Erlangen-Nürnberg); Mr SEEGER, Robert (Friedrich-Alexander-Universität Erlangen-Nürnberg)

Presenter: SAHLMANN, Hanno (Friedrich-Alexander-Universität Erlangen-Nürnberg)

Session Classification: Foundation of Quantum Gravity

Contribution ID: **112** Type: **Covariant QG: Fundamental theory**

What configurations should we sum over in the Lorentzian gravitational path integral?

Monday, May 6, 2024 2:00 PM (15 minutes)

I will discuss the Lorentzian quantum gravity path integral in simplicial approaches like Regge calculus and spin foams. I will draw connections between three different aspects of the Lorentzian path integral: firstly the appearance of light cone irregular configurations, which result in a surprising ambiguity for the Lorentzian path integral, secondly the fate of spike configurations in the Lorentzian path integral and thirdly the question whether the Lorentzian path integral can fully avoid the conformal factor problem of the Euclidean approaches. These issues shed new light on the question of what kind of configurations we should sum over in the path integral I will also draw interesting conclusions on the recently debated question of whether the no-boundary wave function can be constructed via a Lorentzian path integral.

Author: DITTRICH, Bianca (Perimeter Institute for Theoretical Physics)

Presenter: DITTRICH, Bianca (Perimeter Institute for Theoretical Physics)

Session Classification: Covariant LQG

Contribution ID: **113** Type: **Covariant QG: Fundamental theory**

Area metric actions and the Barbero-Immirzi parameter

Monday, May 6, 2024 5:30 PM (15 minutes)

Area metrics generalize spacetime geometry based on lengths and provide a candidate parametrization of the extended configuration space of loop quantum gravity and spin foams in the semiclassical regime. On this basis, I will consider generally covariant actions to second order in area metric fluctuations and derivatives. The effective actions for the subset of area metric degrees of freedom associated with length metric fluctuations, feature nonlocal corrections quadratic in the Weyl curvature, beyond the Einstein-Hilbert term. For a two-parameter subclass of area metric Lagrangians, the effective graviton propagator remains ghostfree. Strikingly, in the framework of area metric actions from modified non-chiral Plebanski theories, these two parameters can be identified with the parity-breaking Barbero-Immirzi (BI) parameter and the mass of the non-length degrees of freedom of the area metric. The classical dynamics of area metrics is characterized by a mixing of polarizations for the massless spin-2 mode and thereby paves the way for area metric phenomenology and experimental measurements of the BI parameter.

Authors: DITTRICH, Bianca; BORISSOVA, Johanna (Perimeter Institute for Theoretical Physics); KRASNOV, Kirill

Presenter: BORISSOVA, Johanna (Perimeter Institute for Theoretical Physics)

Session Classification: Covariant LQG

Contribution ID: **114** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Geometry of the black-to-white hole transition

Tuesday, May 7, 2024 3:00 PM (15 minutes)

The Oppenheimer-Snyder model is the prototypical example of black hole formation by gravitational collapse. It predicts that a black hole horizon is formed once a star collapses to 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.
By 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. A natural assumption is then that, at the end of the evaporation process, 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. I will construct the effective metric describing this spacetime in a single coordinate patch and discuss the resulting geometry of the black-to-white hole transition.

Author: SOLTANI, Farshid (Western University)

Presenter: SOLTANI, Farshid (Western University)

Session Classification: Black Holes

Contribution ID: **115** Type: **Quantum Foundations and QG**

Entanglement in quantum field theory: lessons from Minkowski and de Sitter space

Thursday, May 9, 2024 3:25 PM (15 minutes)

Entangled states in quantum field theory are not the exception but rather the norm. Even seemingly simple states such as the vacuum in Minkowski or Sitter spacetime are rich in the entanglement they contain. In this presentation, I will discuss recently developed techniques aimed at uncovering and characterizing the distribution of entanglement in field theory. These tools include the definition and computation of the "purifier" of a given mode from the complex structure of a pure state, and how these purifying modes can be leveraged to gain insights into the entanglement content of the state and its spatial distribution. These tools become useful in various scenarios, including black holes (as discussed in Elizaga Navascués and Calizaya-Cabrera's talks), the early universe, and potentially in understanding entanglement in quantum gravity.

Author: AGULLO, Ivan (Louisiana State University)

Presenter: AGULLO, Ivan (Louisiana State University)

Session Classification: Quantum Foundations and QG

Contribution ID: **116** Type: **Boundaries, Symmetries, and Classical aspects**

Quantum Gravity at the Null Asymptote

Friday, May 10, 2024 2:45 PM (15 minutes)

In recent years there has been a renewed interest in the mathematical structure and gravitational physics of the null asymptote, in both classical and quantum regimes. From Carrollian Geometries, BMS symmetry, and the radiative phase space to quantization of null data, asymptotic graviton states, and infrared sectors, there is a vast ocean of mathematics and physics that can be learned from studying the asymptotic structure of asymptotically flat spacetimes. This presentation will review some developments in quantum gravity at the null asymptote. Quantization of gravitational data on null infinity and asymptotic graviton states will be discussed.

Author: KHANDELWAL, Samarth

Presenter: KHANDELWAL, Samarth

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **117** Type: **Cosmology, Black Holes, and other applications/phenomenology**

The role of discreteness in the black hole information puzzle: insights from a quantum gravity toy model

Tuesday, May 7, 2024 3:15 PM (15 minutes)

The black hole information puzzle can be solved if two conditions are met: information about what falls inside a black hole must remain encoded in d.o.f that persist after the black hole has completely evaporated. Moreover, these d.o.f must not contribute significantly to the energy of the system, given that the macroscopic mass of the initial black hole has been radiated to infinity in the form of Hawking radiation. The presence of Planckian geometric d.o.f provides a natural mechanism for achieving these two conditions. In this talk, I will illustrate both key aspects of this mechanism using a solvable toy model of a quantum black hole. I'll start by showing that near the singularity, a massless scalar field in a Kantowski Sachs spacetime is a good approximation to an Hawking particle of zero angular momentum falling into a black hole, and to its backreaction. I'll then show how the quantization of the total system, in a way inspired by loop quantum gravity, naturally brings in Planckian geometric d.o.f. The quantum dynamics thus obtained is totally solvable and allows us to show how matter interacts with these Planckian d.o.f. Finally, I'll explain how correlations between the outgoing Hawking radiation and the ingoing one dissipate in favor of correlations with the Planckian geometric d.o.f. The latter therefore seem necessary to restore the purity of the outgoing Hawking radiation.

Authors: Prof. PEREZ, Alejandro (CPT Marseille); VIOLLET, Sami

Presenter: VIOLLET, Sami

Session Classification: Black Holes

Contribution ID: **118** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Diffue emission from black hole remnants

Tuesday, May 7, 2024 5:00 PM (15 minutes)

At the end of its evaporation, a black hole may leave a remnant where a large amount of information is stored. We argue that the existence of an area gap as predicted by Loop Quantum Gravity removes a main objection to this scenario. Remnants should radiate in the low-frequency spectrum. We model this emission and derive properties of the diffuse radiation emitted by a population of such objects. We show that the frequency and energy density of this radiation, which are measurable in principle, suffice to estimate the mass of the parent holes and the remnant density, if the age of the population is known.

Author: PASCUAL GOMEZ-CUETARA, Mateo

Co-authors: ROVELLI, Carlo; Prof. VIDOTTO, Francesca (The University of Western Ontario); KAZEMIAN, Sina (University of Western Ontario)

Presenter: PASCUAL GOMEZ-CUETARA, Mateo

Session Classification: Black Holes

Contribution ID: **119** Type: **Boundaries, Symmetries, and Classical aspects**

Black hole thermodynamics: Lessons from the boundary

This presentation looks into the realm of black hole thermodynamics, emphasizing its connection with boundary conditions. We will explore how various boundary conditions impact the thermodynamic properties of black holes and examine the geometric interpretations of different thermodynamic potentials. By studying the first laws of thermodynamics, we aim to unravel the interesting connection between thermodynamic ensembles and boundary conditions, shedding light on their implications for the geometric structure of black hole spacetimes.

Author: ODAK, Gloria (Charles University)

Presenter: ODAK, Gloria (Charles University)

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **120** Type: **Canonical QG: Fundamental theory**

Pullin vacuum

Monday, May 6, 2024 2:00 PM (15 minutes)

The quantum state of the flat Ashtekar-Barbero connection is quite well defined in Loop Quantum Gravity theory as an element of the dual space to cylindrical functions. This state is not pathological at all, as Jorge Pullin noticed many years ago, and it can be treated as vacuum. From Pullin's vacuum, other states can be generated using LQG operators. It is easy to construct from them partial solutions of the vector constraints as well as the subspace preserved by the action of the quantum scalar constraint. Pullin's vacuum becomes Minkowski vacuum when we take the original, self-dual Ashtekar variables as the starting point. This opens up a new path to LQG in complex self-dual variables.

Presenter: LEWANDOWSKI, Jerzy

Session Classification: Canonical LQG

Contribution ID: **121** Type: **Boundaries, Symmetries, and Classical aspects**

Charges and fluxes of the gravitational field: conformally invariant approach valid for non zero cosmological constant

Friday, May 10, 2024 2:00 PM (15 minutes)

A covariant and conformally invariant approach to the symplectic structure of gravitational fields is natural to introduce when considering spacetimes with a nonzero cosmological constant. It utilizes the Normal Conformal Cartan Connection as a fundamental element of construction. The resulting symplectic potential is explicitly conformally invariant. One consequence is the regular behavior of the potential on conformal boundaries of spacetime. Another consequence is the advantages arising from the application in the bulk.

Author: LEWANDOWSKI, JERZY (Uniwersytet Warszawski)

Presenter: LEWANDOWSKI, JERZY (Uniwersytet Warszawski)

Session Classification: Boundaries, Symmetries, and Classical aspects

Contribution ID: **122** Type: **not specified**

Concluding Remarks

Friday, May 10, 2024 5:15 PM (30 minutes)

Presenter: ASHTEKAR, Abhay

Contribution ID: **123** Type: **Boundaries, Symmetries, and Classical aspects**

Dynamical frames, relational subsystems and gauge-invariant entanglement entropy

Friday, May 10, 2024 2:15 PM (15 minutes)

One of the most basic notions in physics is the partitioning of a system into subsystems, and the study of correlations among its parts. Operationally, subsystems are distinguished by physically accessible observables which are often implicitly specified relative to some external frame, such as the laboratory, or a background notion of locality. In absence of external relata (as in Page-Wootters dynamics, gauge theories, and gravity), physical observables must be relationally specified relative to some internal dynamical degrees of freedom. Moving from simple finite-dimensional systems to local subregions in gauge theories, where the dynamical frames are provided by boundary edge modes, in this talk, I discuss how different internal frames identify distinct external-frame-independent/gauge-invariant algebras of subsystem's observables. As a result, physical properties of subsystems are contingent on the choice of the internal frame. Special attention is reserved to subsystem entropies; in particular, I explain how such a relational definition of subsystems provides an alternative proposal for defining a gauge-invariant notion of entanglement entropy.

Author: MELE, Fabio Maria (University of Western Ontario)

Presenter: MELE, Fabio Maria (University of Western Ontario)

Session Classification: Foundation of Quantum Gravity

Contribution ID: **124** Type: **Canonical QG: Fundamental theory**

Revisiting the quantum polyhedron

Friday, May 10, 2024 2:00 PM (15 minutes)

In 3d gravity with a cosmological constant, it has been shown that discretizing homogeneously curved geometries requires Poisson Lie group structures. This naturally appears when gluing 2d curved building blocks. At the quantum level, this building blocks are labeled with intertwiners defined in terms of quantum group representations.
To generalize this construction to the 4D case with a cosmological constant, we will show that it will be natural to use 2-group structures and get 2-group intertwiners as basic building blocks of the quantum theory.

Author: DUPUIS, Maite

Presenter: DUPUIS, Maite

Session Classification: Foundation of Quantum Gravity

Contribution ID: **126** Type: **Cosmology, Black Holes, and other applications/phenomenology**

Primordial Black Holes and Loop Quantum Gravity

Tuesday, May 7, 2024 2:00 PM (15 minutes)

Primordial black holes have grown in popularity as a dark matter candidate. Different mass spectrum for them are currently under consideration. In this talk I discuss how Loop Quantum Cosmology can integrate the presence of primordial black holes, either in an inflationary scenario or in a ekpyrotic scenario. I review some recent results and discuss the current work in progress. I focus in particular on the possibility of primordial black holes being in the form of black holes remnants: I review the process of creating the remnants from a black-to-while hole transition and the phenomenology associated to them as dark matter.

Author: VIDOTTO, Francesca (Western University, Canada)

Presenter: VIDOTTO, Francesca (Western University, Canada)

Session Classification: Black Holes

Contribution ID: **127** Type: **Covariant QG: Fundamental theory**

Progresses in Spinfoam Cosmology

Monday, May 6, 2024 2:15 PM (15 minutes)

The conceptual and computational progresses in the covariant framework of LQG have brought a number of results in its application to cosmology. In this talk I highlight some of the most interesting steps forward in spinfoam cosmology. I briefly review the general assumption in defining the cosmological model. I focus then on the development of a novel strategy to compute cosmological primordial correlations and entanglement entropy. I also discuss the current understanding of the cosmological bounce from the covariant perspective.

Author: VIDOTTO, Francesca (The University of Western Ontario)

Presenter: VIDOTTO, Francesca (The University of Western Ontario)

Session Classification: Covariant LQG

Contribution ID: **129** Type: **not specified**

Summary and Outlook Panel

Friday, May 10, 2024 4:20 PM (55 minutes)