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Book of Abstracts

Alessandra Silvestri

Instituut-Lorentz, Universiteit Leiden

Gravity in the era of Stage IV Surveys

Stage IV Large Scale Structure Surveys are ushering in a new era of precision cosmology! In this talk, I will explore the effort to test gravity on cosmological scales, highlighting the theoretical advancements aimed at constructing an optimal framework. I will also touch on the synergy with gravitational wave surveys. Additionally, I will provide a detailed review of recent findings based on currently available data and conclude with an outlook on the challenges and future prospects in this field

Daniela Doneva

University of Tübingen

Black hole mergers in theories beyond general relativity

Gravitational waves are among the most powerful tools for testing fundamental physics and can provide further insight into the nature of gravity in the regime of strong fields. The advance of gravitational wave detectors calls for a further development of numerical relativity beyond GR with the final goal to produce accurate gravitational waveforms as well as predict qualitative new effects. In this talk, I will discuss the current status of binary black hole simulations in modified theories of gravity, focusing on some of the astrophysically most interesting predictions and their observability.

Carlos Sopuerta

Institute of Space Sciences

Symmetries in the Perturbative Dynamics of Black Holes

Black Hole Perturbation Theory (BHPT) has been shown to be very successful to describe physical processes in the vicinity of the BH horizon. In particular, the scattering of electromagnetic and gravitational waves (and other physical fields) and the so-called quasinormal mode (QNM) oscillations. The case of QNMs is particularly relevant as they are excited in the last stage of the coalescence of a binary BH (BBH), the ringdown. One remarkable feature of BHPT, both for non-rotating and rotating BH backgrounds, is that all the physically observable quantities can be obtained only in terms of (gauge-invariant) master functions that decouple the perturbative Einstein equations. In this talk, after briefly presenting the basic ingredients of BHPT, I will show that, for the case of non-rotating (Schwarzschild) black holes, this is due to the fact that the space of master functions has the property of Darboux covariance. In addition, deformations of the time-independent Schroedinger-type master equations along the flow of the completely integrable Korteweg-de Vries (KdV) equation introduce an infinite set of conserved quantities, the KdV integrals. I will also show how these conserved quantities completely determine the classical scattering probabilities in terms of a classical moment problem. Finally, I will discuss the additional integrability structures that appear and the important role that they can play in getting a deeper understanding of the general dynamics of BHs and what are the prospects of using these methods in the BBH problem.

Luciano Rezzolla

Trinity College Dublin

Using black holes and neutron stars to explore fundamental physics

I will discuss the recent progress made in modelling these compact objects and how it can be used to address questions in fundamental physics. First, I will illustrate how the gravitational signal from binary mergers can provide tight constraints on the equation of state, sound speed, and the occurrence of phase transitions. Second, I will discuss a novel correlation between the energy and angular-momentum losses in the late-time portion of the post-merger signal, i.e., the ”long ringdown”, and the properties of the EOS at the highest pressures and densities in neutron-star cores. Finally, I will discuss how a microphysical description of collisionless plasmas can help model relativistic jets and understand the extraction of energy from rotating black holes via the Penrose and the Blandford-Znajek processes.

Renate Loll

Radboud University Nijmegen

Causal Dynamical Triangulations: Lattice quantum gravity reloaded

Lattice methods are a powerful tool to investigate quantum field theories beyond perturbation theory, as demonstrated by the impressive successes of lattice QCD. Due to the dynamical character of spacetime in gravity, putting the quantum-gravitational path integral on the lattice faces formidable obstacles, which for a long time were thought to be insurmountable. Key to overcoming them is the use of dynamical lattices, while also making sure that the Lorentzian character of spacetime is built in from the outset. Both features are realized by the use of causal dynamical triangulations (CDT), a methodology that also allows us to obtain evidence for the presence of a nontrivial UV fixed point.

Lattice quantum gravity 2.0 based on CDT is well-tested and operational, using state-of-the-art Monte Carlo simulations. It has opened a computational window near the Planck scale, where numerical experiments can be performed, giving for the first time quantitative information on the spectra of geometric observables characterizing quantum gravity nonperturbatively, with unexpected results. Remarkably, the path integral produces a quantum spacetime with some large-scale properties matching those of a de Sitter universe, as well as genuine quantum gravity signatures. It gives rise to a concrete roadmap for how we may connect fundamental quantum gravity to early-universe cosmology.

Ángel Murcia

`Universitat de Barcelona`

Dynamical formation of regular black holes

Recently, it has been shown that the addition of an infinite tower of higher-curvature terms to the Einstein-Hilbert action in dimensions greater or equal than five regularises the Schwarzschild black hole singularity. In this talk, I will present a dynamical process of thin-shell collapse which leads to the formation of these regular black holes. Starting at some finite radius, the shell collapses up to a minimum radius inside the regular black hole inner horizon. This is followed by a bounce which makes it emerge in a new universe until reaching a turning point, from which the process of collapse is restarted. Finally, I will also describe how regular black holes arise within the Oppenheimer-Snyder construction in an entirely analogous fashion. Mainly based on Phys. Rev. Lett. 134, 181401 and Phys. Rev. D 111, 104009.

Cristian Erices

`Universidad Central de Chile`

A New Approach for Constructing Stealth Solutions and Their Thermodynamic Imprints

We study a class of solutions within the context of modified gravity theories, characterized by a non-trivial field that does not generate any back-reaction on the metric. These stealth configurations are effectively defined by the stealth conditions, which correspond to a vanishing stress-energy tensor. In this work, we introduce a novel approach to constructing this class of solutions. In contrast to the standard procedure, the starting point requires satisfying the stealth conditions for a given ansatz independently of the gravitational dynamics. This approach simultaneously determines the non-trivial field and the geometries capable of supporting it as a stealth configuration. Consequently, a gravity model can accommodate a stealth field only if its vacuum solution falls within the geometries permissible under stealth conditions. By applying this reverse procedure in the non-minimal R^2 coupling, we recover all previously known stealth configurations and present new solutions. Although it seems intuitive to assume that this "gravitationally undetectable" scalar field leaves no physical traces, it remarkably reveals thermodynamic imprints, as its presence screens the black hole mass and modifies the entropy according to the first law.

Asier Alonso-Bardaji

University of the Basque Country (UPV/EHU)

A Quantum Tale: The Lifecycle of 'Loopy´ Black Holes

We present a covariant effective model of loop quantum gravity describing the collapse of a spherical star. This model generalizes the classical Lemaître-Tolman-Bondi spacetimes and provides a gauge-independent framework to study the formation and evaporation of nonsingular black holes. We will show that the theory predicts the existence of Planck-scale remnants.

Marcello Ortaggio

Institute of Mathematics of the Czech Acadmy of Sciences

All nonexpanding gravitational waves in D-dimensional (anti-)de Sitter space

We present a complete, theory-independent classification of D-dimensional Kundt spacetimes of Weyl and traceless-Ricci type N. This leads to three invariantly defined subfamilies: pp-waves, Siklos waves, and (generalized) Kundt waves, all of which turn out to belong to the Kerr-Schild class. In Einstein´s gravity, these solutions describe nonexpanding gravitational waves in an (anti)-de Sitter background accompanied by electromagnetic radiation. Applications to extended theories such as Gauss-Bonnet, Lovelock, and quadratic gravity are also briefly illustrated, as well as the relation with universal and almost-universal spacetimes.

Adrian del Rio

Universidad Carlos III de Madrid

Electric-magnetic duality anomaly in accelerated waveguides: a tabletop approach to gravitational effects.

Maxwell´s equations in vacuum exhibit a duality invariance under electric-magnetic rotations. This is a Noether symmetry of the source-free Maxwell theory in any curved spacetime, and implies that the circular polarization state (the Stokes V parameter) of classical electromagnetic waves is conserved during propagation, even in the presence of strong gravitational fields.

Remarkably, quantum vacuum fluctuations of the electromagnetic field, when enhanced by gravitational effects, can break this symmetry. Specifically, we found that the vacuum expectation value of the Noether charge operator is no longer conserved over time, and its time evolution is governed by the spacetime geometry (Phys. Rev. Lett. 2017, arXiv:1607.08879). This constitutes a quantum anomaly for spin-1 fields—a direct analogue of the chiral anomaly for spin-1/2 fermions in gauge fields, and previously unknown for photons. Interestingly, this anomaly arises if and only if the gravitational field carries a flux of circularly polarized gravitational waves (Phys. Rev. Lett. 2020, arXiv:2002.01593). However, the expectations for observing this quantum effect in astrophysical settings are low. This motivates the search for manifestations of the electric-magnetic duality anomaly in analogue-gravity systems.

In this talk, I will show that the vacuum expectation value of this charge also fails to be time-independent inside a long, cylindrical empty waveguide undergoing both linear and rotational acceleration from rest. Specifically, I will show how photon pairs are spontaneously excited from the quantum vacuum by the accelerated background, while the helical motion induces an imbalance in the number of right- and left-handed modes produced. This photon helicity non-conservation reflects a genuinely relativistic quantum effect that breaks the classical duality symmetry (arXiv:2505.20409).

Salvador Mengual Sendra

Universitat de Valencia

xIdeal, a Mathematica package for IDEAL characterizations and determinations

A longstanding problem in General Relativity is determining whether two explicit solutions to Einstein´s equations represent the same spacetime, differing only by a coordinate transformation. One approach to this question that has recently attracted attention is the so-called IDEAL characterization method. An IDEAL (Intrinsic, Deductive, Explicit and ALgorithmic) characterization consists of a set of tensorial equations covariantly constructed out of spacetime metric concomitants that are satisfied if, and only if, the given spacetime locally belongs to the desired class. This philosophy can also be employed to algorithmically determine expressions for intrinsic quantities and properties of the spacetime under consideration using only metric concomitants. We will refer to such algorithms as IDEAL determinations.

Among many other advantages, the algorithmic structure of the IDEAL approach makes it especially well-suited for implementation in a formal computational framework. An example of such a formal calculation program is xAct, a collection of Mathematica packages designed for tensor computer algebra. In this talk, I will explain how some of these algorithms have been implemented on xIdeal, an xAct package that can be found in its current version at. In particular, I will show the IDEAL characterization of the Schwarzschild spacetime, the IDEAL determination of the Petrov-Bel type of a given metric and the IDEAL determination of the multiple Debever null directions, among others.

Albert Duran Cabacés

`Universidad de Valladolid`

Quasi-normal modes and echoes of generalized black hole bounces and their correspondence with shadows

We study the quasi-normal modes (QNMs) of a family of generalized black bounces interpolating between regular black holes and traversable wormhole solutions according to a single extra parameter a. Firstly, working with a generic spherically symmetric spacetime with arbitrary radial function and an anisotropic fluid matter source, the general equations for the gravitational waves are obtained. Then, we focus on such particular space-time metric and use the time-domain method to find the evolution of the QNMs with respect to the parameter a, finding larger frequencies and damped modes as a grows. Furthermore we find that, for a gap in the values of a for which no horizon is present but several photon spheres are, echoes are produced. Such echoes, which come from trapped modes in the potential well that are eventually leaked off for higher frequencies, appear as repetitions of the original wave but with modulated amplitude and decreased frequencies, and study their evolution with a. In addition, at the light of the correspondence recently discussed in the literature between QNMs and black hole imaging, we discuss the relation of the features of such echoes with those features (photon rings and shadows) of optical images from thin accretion disks. Despite working with simplified models and settings, our analysis provides useful insights on the usefulness of the correspondence for both gravitational waves and shadows.

Sara F. Uria

University of the Basque Country

Matter Does Matter: On Its Role in the Bianchi IX Dynamics Towards the Singularity

In the literature, it is generally considered that matter effects are negligible in the Bianchi IX dynamics near the singularity, as the energy density of matter typically decays faster than the anisotropies. However, in this study, we challenge the well-known saying that "matter does not matter" and show that the influence of matter vanishes only exactly at the singularity, that is, in the strict limit of zero spatial volume. In particular, we compute the leading-order matter corrections near the Bianchi IX singularity and analyze how they modify the widely studied vacuum dynamics. For the matter content, we consider one whose dominant contribution in this region can be described as a barotropic perfect fluid with a linear equation of state. As in the vacuum case, this dynamics is characterized by a sequence of kinetic-dominated periods connected by quick transitions, and for the first time in the literature, we analytically compute the transition laws, approximately, by performing a perturbative analysis around the vacuum solution. We find that although matter corrections become weaker closer to the singularity, they remain strong enough to alter the standard vacuum picture. In this way, we also highlight certain features with intriguing physical implications, which have not yet been thoroughly explored. Furthermore, we discuss the special case of stiff matter, where matter effects cannot be neglected, as the energy density scales at the same rate as the anisotropies, and an exact (non-perturbative) analysis can be performed.

Araceli Soler Oficial

University of the Basque Country (UPV/EHU)

Dipolar perturbations of nonbidiagonal black holes in bigravity

In bimetric gravity, nonbidiagonal solutions describing a static, spherically symmetric, and asymptotically flat black hole are given by a pair of Schwarzschild geometries, one in each metric sector. The two geometries are linked by a nontrivial diffeomorphism, which can be fully determined analytically if the two geometries possess the same isometries. This exact solution depends on four free parameters: the mass parameters of the two black holes, the ratio between the areal radii of the two metrics, and the proportionality constant

between their (appropriately normalized) time-translation invariance Killing vector fields. We study the dynamics of axial dipolar perturbations on such a background and obtain general analytical solutions for their evolution. We show that, in general, the characteristic curves followed by dipolar gravitational waves are spacelike with respect to both metrics, and thus the propagation is superluminal. In fact, the velocity of a pulse, as measured by a static observer, turns out to increase with the distance to the black hole. The only exception to this general behavior corresponds to the special case where the two proportionality constants linking the areal radii and the Killing vectors coincide, for which waves travel at the speed of light. Therefore, we conclude that this is the only physically reasonable background, and thus our results restrict the class of viable black-hole solutions in bimetric gravity.

Adam Zychowicz

`Astronomical Observatory of the Jagiellonian University`

High-frequency limit and backreaction of cylindrical standing gravitational waves

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

Marco Sebastianutti

`University of Sussex`

A coherent electrically-charged quantum black hole as a guide to singularity resolutions

We improve upon the results presented in [R. Casadio, et al., Phys. Rev. D 105 (2022) 124026] deriving a quantum-corrected Reissner–Nordström geometry containing an integrable singularity at its center while being devoid of spurious oscillations around the classical configuration. The fact that the central singularity can be removed for a specific choice of the parameters of the model has motivated further investigations in the broader direction of a static and spherically-symmetric geometry. We describe the most general conditions under which regularity at the origin can be achieved and elaborate on some physically-relevant applications.

Matús Papajcík

Charles University

All electrovacuum spacetimes in 3D Einstein gravity with a cosmological constant

Theories of gravity in lower dimensions play an important role in studies of quantum gravity, AdS/CFT correspondence, and even in understanding certain aspects of 4D general relativity. As a result, exact solutions to these theories have become increasingly popular.

We present an important family of exact spacetimes that solve the coupled system of Einstein-Maxwell equations in 3D with a cosmological constant. These solutions can also be interpreted as spacetimes with a minimally coupled, massless scalar field. The entire family splits into two geometrically distinct classes, namely the nonexpanding Kundt class and the expanding Robinson-Trautman class.

We show that the Kundt geometries admit only an aligned electromagnetic field, which is an analogue of the Mariot-Robinson theorem in 4D. In contrast, the Robinson-Trautman geometry allows both aligned and nonaligned electromagnetic fields. We fully investigate the aligned case, which contains type I black holes with a non-null electromagnetic field, and we find the nonrotating, charged BTZ black hole as its special sub-case. We also demonstrate the existence of nonaligned solutions by constructing a simple explicit example.

Alejandro Sebastian Rueda Manosalvas

Universidad Complutense de Madrid

Traversable wormholes with multiple unstable critical curves

The number and position of unstable critical curves, as well as the nature of the accretion disk around compact objects, play a fundamental role in their optical appearance. Identifying differences in the optical spectrum of various observed compact objects can help classify them as black holes or black hole mimickers, such as traversable wormholes. Although multiple unstable critical curves have been reported to appear is asymmetric traversable wormholes, in this work we construct symmetric traversable wormholes with multiple unstable critical curves. We propose a general rational redshift function that allows us to trace the number of critical points of the effective potential and determine their nature as maxima or minima. The ray tracing method is used to study the trajectories of massless particles, particularly their behavior near the unstable critical points.

Finally, a thin accretion disk model is implemented to analyze the optical appearance of the solution.

Matteo Fontana

Università degli Studi dell''Insubria

General relativistic models of disc galaxies

Galaxy dynamics have traditionally been described using Newtonian mechanics, where low velocities and weak gravitational fields imply that general relativity (GR) plays a minor role. Yet, the persistence of nearly flat rotation curves in disc galaxies led to the postulation of dark matter (DM), a non-baryonic component still undetected directly. While DM is central to the ΛCDM model, its elusive nature has prompted alternative proposals, including Modified Newtonian Dynamics and Modified Gravity. Nevertheless, GR offers a compelling alternative due to the non-linear nature of the Einstein Equations (EE) and the additional degrees of freedom it introduces. Among the most significant effects is frame dragging, which becomes particularly relevant in extended, rotating systems. In this talk I will present the (η, H) models corresponding to exact solutions to the EE for a stationary, axisymmetric spacetime describing a rotating disc of dust. These models effectively represent disc galaxies in regions where both the assumed symmetries and the dust approximation hold, i.e., far from the rotation axis and near the galactic plane. I will then emphasize the crucial impact of the choice of reference frame on predicted rotation curves, focusing on the rigidly rotating dust limit known as the Balasin-Grumiller model. When analyzed by Zero Angular Momentum Observers (ZAMOs), this model reproduces flat rotation curves of the Milky Way without invoking dark matter. Finally, I will show how GR´s nonlinearity can produce observable deviations from Newtonian gravity on large scales, under non-relativistic conditions, by introducing Asymptotically Conically Minkowskian (ACM) spacetimes-locally flat but conical geometries at large distances. These topological features could be probed by (1) measuring holonomy via parallel transport around the symmetry axis, (2) detecting angular-deficit signatures in gravitational lensing, and (3) analyzing scalar-field propagation to uncover vacuum-state ambiguities.

Diego Tessainer Bonet

Universidad Complutense de Madrid

Multi-field TDiff interactions in the dark sector

We study theories breaking diffeomorphism (Diff) invariance down to the subgroup of transverse diffeomorphisms (TDiff) through the matter sector, consisting of multiple scalar fields in a cosmological background, coupled to gravity through power-law functions of the metric determinant. The Diff symmetry breaking results in the individual energy-momentum tensors not being conserved, although the total conservation-law is satisfied. Consequently, an energy exchange takes place between the fields, acting as an effective interaction between them. With this in mind, we consider the covariantized approach to describe the theory in a Diff invariant way but with an additional field, and discuss the phenomenological consequences of these models when it comes to the study of the dark sector.

Javier Olmedo

`University of Granada`

Gravitational Waves and Duality Anomalies in Curved Spacetimes

Einstein´s vacuum equations admit a striking analogy with source-free Maxwell theory, including an electric-magnetic duality symmetry. In this talk, I will present a formulation of linearized gravity in which the gravitational wave degrees of freedom are explicitly described in terms of gravitoelectric and gravitomagnetic fields. This allows for a clear demonstration of the duality symmetry and the construction of an associated conserved current. The corresponding conserved charge is interpreted as the difference in intensity between right- and left-handed circular polarizations of the gravitational field, i.e., its self- and anti-self-dual components. Remarkably, this conservation law remains valid even in the presence of arbitrary classical gravitational backgrounds. I will then explore whether this duality symmetry survives quantization. We find that in flat spacetime, the symmetry is preserved, but it is generally broken in curved spacetimes-leading to a net polarization of gravitons. This result provides a spin-2 analog of the well-known chiral anomaly for fermions and vector fields, with potential implications for the early universe and gravitational wave detection.

Ana Alonso Serrano

`Humboldt University of Berlin & AEI-MPG`

Effective quantum corrections to Bianchi models and its connection to BKL scenarios

In this talk I present an analysis of Bianchi I and Bianchi II universes as solutions to an effective quantum-gravity dynamics. We have found modified Bianchi solutions with different matter fields and studied their dynamics to connect it with the classical BKL conjecture

Pantelis Pnigouras

University of Alicante

Explaining magnetar quasi-periodic oscillations via nonlinear coupling

The quasi-periodic oscillations (QPOs) observed in the tails of magnetar giant gamma-ray flares have long been interpreted as normal oscillation modes of these stars. However, most studies modelling QPOs have neglected some key features in the analyses of the signals, namely that QPOs appear to be detectable only intermittently and exhibit drifts in their frequencies. These are typical characteristics of nonlinear mode coupling, where, at leading order, the modes couple and evolve collectively as triplets. We show that a model which incorporates such nonlinear effects is able to explain the observed QPO phenomenology and provides a way to infer details of the magnetar"s internal magnetic field geometry.

Rüter Hannes

CENTRA, Instituto Superior Técnico, Universidade de Lisboa

A kinetic theory model for relativistic stars

I present a model to evolve spherical stars within full kinetic theory by solving the relativistic Vlasov-Boltzmann equation coupled to the Einstein field equations. The Vlasov-Boltzmann equation allows to fully consistently model matter out of thermal equilibrium, overcoming the restrictions of ideal and near-ideal fluid models typically used for neutron stars. I will discuss the spectral discretisation method that helps to cope with the six-dimensional phase space of the Vlasov-Boltzmann equation. Furthermore I will present some physical results that are enabled by the model.

Ananya Adhikari

CENTRA, Instituto Superior Técnico

Neutron star evolution by combining discontinuous Galerkin and finite volume methods

Increasingly improving gravitational wave (GW) detectors with progressively lower signal-to-noise ratios will provide GW signal data with higher accuracy at increasing detection frequency. This, in turn, poses a challenge to the numerical relativity community in generating numerical relativity simulations with greater accuracy at greater speed. Here, we present a new hybrid scheme that combines a discontinuous Galerkin (DG) method with finite volume (FV) and finite difference (FD) methods. The computational mesh is divided into smaller elements that touch but do not overlap. Like a pure DG method, our new hybrid scheme requires information exchange only at the surface of neighboring elements. This avoids the need for ghostzones, usually many points deep in traditional FV implementations, and also reduces the number of neighboring elements from which information is needed in non-cuboid meshes. Through this reduction in communication, we aim to retain the high scalability of DG when using large supercomputers. The goal is to use DG in elements with smooth matter fields and to fall back onto the more robust FV/FD method in elements that contain non-smooth shocks or star surfaces. We devise trouble criteria for this to decide whether an element should be evolved with DG or FV/FD. We use the Nmesh program to implement and test the new scheme. We successfully evolve various single neutron star cases in full 3D, including the challenging cases of a neutron star initially in an unstable equilibrium, migrating to a stable configuration and a boosted neutron star.

Mario Misas Arcos

Universidad de Sevilla

A FEM approach to Black Hole perturbation theory: the Kerr-Newman problem

It is known that gravito-electromagnetic perturbations of a Kerr-Newman black hole do not seem to be separable in the Teukolsky´s formalism, in contrast to the rest of black-hole families. In an effort to circumvent this issue, we propose the use of FEniCSx, an open-source computing platform designed for solving partial differential equations via the finite element method. Although this framework has demonstrated significant success in disciplines such as electrohydrodynamics, its application to numerical relativity remains largely unexplored. In our work, as a part of the PhD Thesis research with ID SOL2024-31517 being carried out at Universidad de Sevilla, we delve into the potential benefits of this approach. We present a portion of the problems successfully assessed so far and discuss their relevance to advancing our understanding of the Kerr-Newman stability problem.

Attached you may find a simple example, namely the simulation of a plane gravitational wave incising on a Schwarzschild black hole.

Darío Jaramillo-Garrido

Universidad Complutense de Madrid (UCM)

Canonizing k-essence?

General classes of field theories with non-canonical kinetic terms are shown to be dynamically equivalent to canonical theories with broken diffeomorphisms invariance. The equivalence does not require invoking new couplings to extra fields in the action, which remains invariant under the subgroup of transverse diffeomorphisms. Explicit examples of canonizable theories include k- essence, non-linear electromagnetism, or f(R) theories.

Robert Monjo

Saint Louis University **U(1,3) colored gravity: a new path to quantum gravity?**

Colored gravity is an extension of the gauge formalism in teleparallel gravity (Weitzenböck connection), based on the complexification of the Minkowskian metric, which leads to a natural U(1, 3) symmetry for Dirac bispinor fields, also transforming the spacetime algebra (or Clifford Cl(1,3) algebra) generators [1]. Specifically, a double-copy U(1, 3) gauge transformation of the metric could be a key in quantization procedures of gravity. Moreover, the non-compact U(1, 3) group can embed the U(1) $\times$ SU(2) $\times$ SU(3) group, key in standard particle physics. The new theoretical framework could solve some existing open issues such as the proton stability and the prediction of Weinberg mixing angle for post-broken symmetry generators [2].

[1] Monjo R., Rodríguez-Abella Á., Campoamor-Stursberg R. (2024). From colored gravity to electromagnetism. General Relativity and Gravitation 56, 117. DOI: 10.1007/s10714-024-03307-8

[2] Monjo R. (2025). Weak mixing angle under U(1,3) colored gravity. Journal of High Energy Physics 2025, 207. DOI: 10.1007/JHEP06(2025)207

Stella Kiorpelidi

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

Thermodynamic Stability and Phase Transitions of Scalarized Charged Black Holes

We perform a detailed thermodynamic analysis of curvature-induced scalarized charged black holes in Einstein-scalar-Gauss-Bonnet theory. Local and global stability of the resulting scalarized configurations are analyzed. For a fixed electric charge Q within a specific range, small and large black holes coexist. On the contrary, when Q is out of this range, only a single branch of scalarized solutions exists. We find that small scalarized black holes are locally stable, whereas the large ones are locally unstable. The thermodynamics of the scalarized black holes is analyzed in the canonical ensemble, uncovering a rich thermodynamic phase structure. In the strongly coupled regime, we identify novel reentrant phase transitions as the temperature monotonically increases, namely, from charged hot flat space to large scalarized black holes and back to charged hot flat space. In contrast, in the weakly coupled regime, the system exhibits a sequence of three phase transitions: first, a first-order phase transition from charged hot flat space to large scalarized black holes; then, a zeroth-order phase transition to small scalarized black holes; and finally, a zeroth-order phase transition returning to charged hot flat space. Remarkably, in this regime, small scalarized black holes emerge as the only locally and globally thermodynamically stable configuration. These results enrich our understanding of black hole thermodynamics in scalar-tensor theories, highlighting the intricate interplay between scalarization and thermodynamic phase transitions.

Izarne Martínez-Donato

`Universitat de Valencia`

Phase Transitions in Binary Neutron Stars Mergers

Binary neutron star (BNS) mergers are key sources in multimessenger astronomy and can provide new insights into the physics of high-density matter. A key question remains whether there is a threshold density at which a first-order phase transition (FOPT) occurs. We perform full general relativistic simulations of BNS mergers that undergo a FOPT. The stars are modelled using a nuclear equation of state (EoS) that incorporates FOPT, as well as by its piecewise polytropic (PP) representation and its thermodynamically adaptive slope piecewise polytropic (T-ASPP) representation. Consistent with previous findings, our simulations show that the T-ASPP representation reproduces more accurately the behavior of nuclear EoSs in the FOPT region compared to the piecewise models. From the analysis of stellar properties for isolated stars, we find that some thermodynamic variables derived from the T-ASPP model have errors of less than 5% with respect to the original tabulated ones. However, we do not observe any significant signatures of the PT in the gravitational wave (GW) frequencies, or at least none that can be identified using the T-ASPP model. We compute the GW spectra and find that the main frequencies of the signals are nearly identical in both models, with a shift of 50 Hz. These results suggest that the post-merger evolution is influenced more by the outer layers of the remnant than by the densest core.

Antonio Panassiti

`Università degli Studi di Catania - Radboud University Nijmegen`

On the Phase Space for the Cauchy Horizon (In)Stability of Regular Black Holes

Regular black hole solutions typically come with an outer event horizon and an inner Cauchy horizon. For the Reissner-Nordstrom geometry, the analysis based on the Ori model shows that the Cauchy horizon in unstable against perturbations, because of the mass-inflation effect. However, when such analysis is applied to regular black holes, a richer picture emerges. For different regular geometries, like the Bardeen solution and the Hayward black hole, we show how to depict the whole phase space related to the dynamical system corresponding to the Ori model itself, illustrating all the possible fates for the perturbed spacetime at the Cauchy horizon, in relation to clusters of initial conditions. Beyond the standard mass-inflation scenario, other phases are found. In particular, we analyze the stability of a new solution obtained from a model of asymptotically safe gravitational collapse (Phys.Rev.Lett. 132 (2024) 3, 031401). Remarkably, for this geometry, there is a phase where the Misner-Sharp mass at the Cauchy horizon remains of the same order of magnitude of the mass of the unperturbed black hole, since its growth is just logarithmic.

Ramón Serrano Montesinos

Universitat de València

Relativistic Positioning Systems in Minkowski space-time with static emitters

In the 2000 edition of this meeting, held in Valladolid, the development of the theory of relativistic positioning systems (RPS) was proposed. In this communication, examples of RPS in Minkowski space-time are presented and the physical and geometrical elements involved are interpreted. For four static emitters, the transformation from emission to inertial coordinates is studied to obtain the location of users of the system from the trajectories of the emitters and their proper times (emission coordinates). The solution to the positioning problem applied in current satellite navigation systems (in a non-relativistic and approximate context) is recovered.

Authors: R. Serrano Montesinos and J.A. Morales Lladosa Speaker: R. Serrano Montesinos

Roberto Dale Valdivia

Universidad Miguel Hernández

CHSH-like Inequalities in Cosmology: Testing with CMB Data

The cosmic microwave background (CMB) offers a natural laboratory for testing the limits of local realism on cosmological scales. By adapting the Clauser–Horne–Shimony–Holt (CHSH) inequality to a cosmological context, we investigate whether temperature fluctuations across causally disconnected regions of the sky can be described by hidden-variable models consistent with local realism. We construct a theoretical framework in which a cosmic CHSH-like inequality emerges under the assumption that CMB anisotropies—originating from primordial density fluctuations—can be modelled as deterministic functions of pre-existing hidden variables. This formulation enables a direct comparison with observational data. After validating the approach with COBE measurements, we extend our analysis to high-resolution temperature maps from WMAP and Planck, employing rigorous statistical procedures and resolution-adjusted map processing. This study provides new insights into the use of CMB observations as probes of fundamental physics, raising questions about the role of entanglement, causality, and realism in cosmology.

Francisco Javier Marañón González

Universitat de Valencia - IFIC

Singularity resolution in backreacted geometries from 2D matter with negative central charge

2D dilatonic gravity theories provide insightful models to study the dynamics of semiclassical black holes. They are often coupled to conformal 2D scalar fields, since the resulting QFT implements some quantum effects (such as the trace anomaly) while often being simple enough to be solved analytically. Purely from a 2D QFT perspective, the central charge is positive for unitary theories. However, 2D theories with negative central charge are expected to mimic some effects of unitary QFTs in 4D of renewed interest (e.g. dimensionless scalar fields). Recent studies [1], [2] concluded that a negative central charge removes the singularity in the 2D backreacted geometry. In this work, we discuss that the singularity resolution mechanism is a consequence of the negative central charge and not the specific dynamics of the model. We review a few examples of this mechanism and discuss some of the future prospects.

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Luis Acedo

University of Extremadura

The Parker Solar Probe mission. A test of General Relativity

The Parker Solar Probe is a spacecraft designed to study the Sun´s corona from inside. It is providing unprecedented detailed information on the density and composition of the Sun´s atmosphere as well as the electromagnetic fields, plasma and solar wind. On the other hand, this probe is to achieve record speeds in the International Celestial Reference Frame (ICRF) never obtained before in any previous mission. It is expected that in the last perihelion of 2025 it would move at 0.064 9.86 solar radii to the center of the Sun. These orbital conditions make the Parker´s Solar Probe also an interesting experiment concerning the validity of General Relativity (GR). In this communication we discuss and orbital model designed to carry on this test.

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2) Sebastián, A., Acedo, L. & Moraño, J. A. Adv. Space Res. 70, 842-853 (2022).

Guillem Fernández Rodríguez

University of Valencia

Glitch classification impact of spectrogram parameters and better visualization in the Virgo detector

This work explores feature selection for glitch classification in gravitational wave detectors, where transient noise events are grouped by their time-frequency morphology. Gravity Spy is a citizen-science project that provides a standard dataset built from four Q-transform views of glitches. Follow-up studies introduced attention-based multi-view models, transfer learning, and examined the effect of the Q-transform quality factor. These results point to spectrogram parameters as a key factor in model generalization and bias. We run a random search over Q-transform and time window settings, as well as explore various signal whitening methods and spectrogram visualization strategies to train several computer vision models, and evaluate their behavior using Virgo data.

Emel Altas

Abdullah Gul University **Vanishing of Conserved Charges in Cotton Gravity**

Cotton gravity was recently introduced as a higher derivative extension of General Relativity. The field equations of the theory involve the rank-3 Cotton tensor. Here we show that all solutions of the theory, including the black holes, have vanishing conCotton gravity was recently introduced as a higher derivative extension of General Relativity. The field equations of the theory involve the rank-3 Cotton tensor. Here we show that all solutions of the theory, including the black holes, have vanishing conserved charges, i.e. mass and angular momentum. This result implies that either the theory is unphysical since all the black holes carry the charges of the vacuum and can be created at no energy cost, or the theory has confinement of mass/energy and all other conserved quantities.

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Ivan Kolar

`Charles University`

Symmetry reduction of gravitational Lagrangians: Classification and application

Symmetry reduction of gravitational Lagrangians is consistent-i.e., yields field equations equivalent to the symmetric sector of the full theory-only if the symmetry group action satisfies the principle of symmetric criticality (PSC). In this talk, I present a complete classification of all infinitesimal group actions of 4-dimensional spacetimes that admit PSC, using the framework of Fels and Torre and the Hicks classification based on isometry Lie algebras and their isotropy subalgebras. For each action, we identify the corresponding invariant metrics and l-chains (for reduction of integrable densities), analyze residual diffeomorphism freedom and Noether identities, and present results in adapted coordinates, enabling identification of mutual relationships among the group actions and familiar metrics. The outcome is a unified and practical ”guide” to all consistent symmetry reductions in gravitational theories, supported by a fully automated implementation in the xAct package for Mathematica. The talk is based on Phys. Rev. D 111, 064062.

Margarida Lima

`Instituto Superior Técnico / CAMGSD` **Quadratic f(R) Cosmological Dynamics: Analysis in Jordan and Einstein Frames**

The f(R) theory of gravity extends General Relativity and admits two mathematically equivalent but physically distinct representations: the Jordan frame and the Einstein frame. In the Jordan frame, the modifications appear explicitly in the gravitational sector, while in the Einstein frame, which is obtained via a conformal transformation, the theory takes the form of General Relativity coupled to a scalar field. It is essential to understand the relationship between these frames to assess the viability of f(R) models and their agreement with observations. In this work, we analyse the dynamics of the quadratic f(R) theory, considering a flat Friedmann-Robertson-Walker metric with a perfect fluid that obeys an equation of state. We construct a global and regular dynamical system formulation in both frames, enabling us to identify solutions that are globally mapped between the Jordan and Einstein frames, providing a comprehensive picture of the state space.

Miguel Orbaneja Pérez

`Universidad Complutense de Madrid`

Inflation in theories with broken diffeomorphisms

In this work we analyse the impact of breaking diffeomorphism invariance in the inflaton sector. In particular, we consider inflaton models which are invariant under the subgroup of transverse diffeomorphims and address the possibility of implementing a slow-roll phase. We study in detail the quadratic potential model, combining asymptotic and numerical analysis. We obtain new expressions for relevant quantities such as the slow-roll parameters and the number of *e*-folds. The post-inflationary behaviour is also studied, obtaining novel dynamics compared to the diffeomorphism-invariant case.

Pablo Agustín Blasco Gil

`Universitat de Valencia`

Adiabatic Regularization for Quantum Fields inside Black Holes

The computation of observables in the interior region of a black hole within a semiclassical gravity theory allows us to gain some understanding of how quantum effects behave near the curvature singularity. In turn, these quantum effects play an important role in the semiclassical theory, modifying the original geometry through the stress-energy tensor of the quantum fields, in a process known as backreaction. In particular, they might have a significant effect on the nature of the singularity that appears in the classical theory. One relevant observable is the vacuum polarization of a quantum scalar field ^{2}(x) , since it serves as a starting point to compute the stress-energy tensor of the scalar field- which acts as a quantum source of gravity in the semiclassical theory. In [1], a formal expression for the two-point function (x),(x´) in the interior of a Schwarzschild black hole was provided; in [2], a numerical procedure was devised to renormalize ^{2}(x). In our work, we use adiabatic regularization to compute the renormalized vacuum polarization inside a Schwarzschild black hole. This regularization method, originally conceived for cosmological scenarios, consists in a high-frequency, high-angular-momentum expansion of the fields. It provides a straightforward practical implementation grounded in physical arguments. In this talk, we will present ongoing results [3], and discuss their validity by comparison with existing results, supporting the use of our method to address the renormalized stress-energy tensor problem.

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Carmelo López Mediavilla

University of the Basque Country

COMPARATIVE STUDY OF THE STRONG BACKREACTION REGIME IN AXION INFLATION: THE EFFECT OF THE POTENTIAL

The requirement of a highly flat inflationary potential V () to satisfy the slow-roll conditions has led to axion inflation models, in which an axion-like particle plays the role of the inflaton. In our research, we focus on scenarios where the inflaton is coupled to a U (1) gauge field via the lowest-dimensional operator allowed, $\phi\tilde{F}F$. Recently, it has been shown that in models described by a simple quadratic monomial potential and with sufficiently strong coupling, the system´s behavior deviates significantly from analytical predictions due to the substantial influence of inflaton inhomogeneities during the final stages of inflation. In this talk we will review the results recently published in [arXiv:2505.19950] where we analyze simulations of inflationary models involving a set of well-studied inflaton potentials and a range of couplings where strong backreaction (SBR) effects arise.

Matheus Elias Pereira

Universidade Federal Fluminense

Quantum System Analogue for a Particle in a Black Hole Background

The thin-layer method proposed by da Costa [1] allows us to study the behavior of a wavefunction on a surface or curve embedded in an Euclidean space, with or without the presence of an electromagnetic field, and there are a number of papers on the exact solution of Schrödinger´s and Pauli´s equation on surfaces such as cylinders, spheres, tori, among others [2,3]. The surface of choice will determine the number, types and ranks of singularities of the differential equations, which in turn may be of easy solution once we examine the properties of the said singularities. In particular, we propose [4] a system consisting of a particle on the surface of a spheroid. Upon solving Schrödinger´s and Pauli´s equation on a prolate spheroid with and without an external non-central potential, we repeatedly encounter differential equations of Heun type, ranging from three to five singularities, the last case pertaining to a generalized Heun or Lamé [5] type of equation. Because of this, we exactly solve and present the solutions to these problems using Heun´s special functions. Additionally, we introduce Schäfke -function [6] to be used as Pauli´s equation solution on the prolate spheroid. We connect our problems with the dynamics of a particle on the background of black holes such as Kerr-Newman and Kerr-Sen [7,8] black holes, and show that our equations and its solutions are identical to those of particles in curved spaces close to black holes. Because of the obvious difficulties in directly studying black holes, they are an ideal real-world target system for our quantum system as an analogue model. We note that it is possible to construct such a prolate spheroid in a laboratory, as shown by Rich and colleagues [9] and Hansen [10].

João Dinis Ribeiro Machado de Carvalho Álvares

`Instituto Superior Técnico, CENTRA, IST`

Charged Scalar Field at Future Null Infinity

Quasinormal modes and power-law late-time decay tails of a charged scalar field in a charged black hole background have been studied, but never in the fully non-linear regime, as far as we know. We study the dependence of these properties on the charges of scalar field and black hole. For the quasinormal modes, a fit of the spherical fundamental mode is shown for the purely uncharged case and compared to the charged one. We also see for the first time the transition from gravitational decay to pure electromagnetic decay, and show disagreement with the oscillation frequency between real and imaginary parts of the scalar field prescribed in the literature. Full non-linear evolutions of hyperboloidal slices in spherical symmetry were used to obtain our results, allowing for the extraction of signals at future null infinity.

Mykola Stetsko

`Ivan Franko National University of Lviv, Ukraine`

Black hole solution in Lovelock gravity with nonlinear electromagnetic field

In the framework of Lovelock gravity we obtain black hole solutions with nonlinear Plebanski-type electromagnetic field contribution. We derive and analyze solutions different types of topologies, namely apart of the spherically symmetric case we also consider the so-called topological solutions. We also do not restrict oneself with particular Lovelock terms, which allows as to derive solutions up to the maximal possible terms for a given fixed dimension of space-time in higher dimensional case. We also study thermodynamic properties of the obtained solutions and compare them with their counterparts in Einsteinian General Relativity. Within the extended thermodynamics (whenever the cosmological constant is supposed to be a thermodynamic variable) we derive and study equation of state and show that critical point of higher caused by the nonlinear electromagnetic field contribution are possible for the considered system.

Mikel Artola Pérez

University of the Basque Country (UPV/EHU)

Is CPL dark energy a mirage?

Recent observations coming from the Dark Energy Spectroscopic Instrument (DESI) challenge the consensus cosmological model, CDM, pointing toward a dynamical dark energy component. The Chevalier-Polarski-Linder (CPL) parameterization — perhaps the simplest two-parameter function of dark energy"s equation of state — indicates strong early phantom behavior and a recent crossing of the phantom divide. This prompts inquiries into the early phantom nature of dark energy and the significance of phantom crossing. To investigate, we propose two families of two-parameter dark energy parameterizations that mimic CPL at recent times while reducing early phantomness through the use of sigmoid functions, allowing for smoother evolution. Using latest DESI data in combination with CMB and Type Ia supernovae data, we find that CPL is a robust parameterization, with less phantom models only marginally favored or disfavored. We conclude that current surveys lack the precision to differentiate between CPL-like parameterizations in a statistically significant manner at the redshifts probed by late-time observables.

Ángel Rincón

Silesian University in Opava

Perturbations Around Regular Black Holes with Dark Matter Effects

We study quasinormal modes (QNMs) and absorption cross sections of a 4-dimensional Bardeen black hole surrounded by perfect fluid dark matter. Building on earlier work focused on massless scalar fields, we examine massive scalar and massless Dirac field perturbations. QNMs are computed using the third-order WKB method, known for its accuracy when the effective potential has a single peak and the overtone number is small. For validation, we also apply the Pöschl-Teller approximation. Frequencies are evaluated by varying the scalar field mass , dark matter parameter , and magnetic charge q, with results shown in tables and figures. Using the WKB method, we further compute reflection/transmission coefficients and partial absorption cross sections, illustrating their dependence on and through plots.

César García-Pérez

Università di Genova & Universidad de Valencia **New heat kernel resummation formulas**

Over the last few decades, heat kernels have become one of the more popular tools used in the study of effective actions for semiclassical systems, i.e. quantum systems interacting with a classical (curved) background. However, there are several technical and conceptual hiccups when it comes to fully understanding the properties of these heat kernels. Resummation formulas have been proposed in several contexts in order to simplify computations and derive nonperturbative information from these systems. In this presentation, I will discuss some recent works whose aim is to streamline these resummation schemes for a variety of systems in flat spacetime, as well as to present a discussion on possible generalizations to more complex setups, namely curved spacetime backgrounds.

Igor Kanatchikov

National Quantum Information Centre in Gdansk (KCIK), Poland

Λ, a_0, and MOND from quantum spin connection fluctuations

We discuss the estimation of the cosmological constant Λ, and the MOND acceleration scale a_0, and their interrelation, within the spin connection foam picture of quantum gravity, which involves two fundamental scales: the Planck scale of $G\hbar$ and the hadronic scale of the parameter κ, which is shown to be related to the mass gap in the pure Yang-Mills sector of the Standard Model. Considering a non-relativistic test particle moving in the static approximation of the spin connection foam leads to a quantum modification of Newtonian dynamics (qMOND), where the gravitational potential of a point mass becomes asymptotically linear with slope $\bar{a}$. A transformation to the non-inertial reference frame associated with the mean-field acceleration arising from these quantum fluctuations of spin connection yields Milgromian MOND. This framework provides a theoretically predicted interpolating function and establishes the precise relation between $\bar{a}$ and a_0. We also discuss implications for galaxy rotation curves, the dynamics of galaxy clusters, gravitational lensing, interpretive issues in quantum cosmology, and the potential for laboratory detection of spin connection fluctuations using already existing atto-Newton gravity sensors. Based on: [1] IV Kanatchikov and VA Kholodnyi, EPL 150 (2025) 59002, 2 J Phys Conf Ser 3017 (2025) 012031, [3] arXiv:2311.05525, [4] IV Kanatchikov, J Phys Conf Ser 2533 (2023) 012037, [5] arXiv: 1512.09137.

Riahi Natascha

University of Vienna

On late-time quantum gravity correction terms in cosmology

Providing a natural time, unimodular quantum cosmology admits the description of quantum dynamics by a Schrödinger like equation for the wavefunction of the universe. The interplay of growing uncertainties and deviations from classical orbits yields late-time correction terms for the Hubble parameter and the matter density. With a scalar field as a phenomenological model for the matter in the universe we analyse the conditions for significant divergence between quantum and classical dynamics for various characteristic cosmological spacetimes. Quantum cosmology based on unimodular gravity gives rise to an evolution of expectation values of operators associated with the cosmic parameters that deviate from the dynamics of their classical counterparts. These quantum correction terms are induced by quantum fluctuations that are proven to accumulate with time if specific conditions on the trajectories of the corresponding classical dynamical system apply. This kind of non-classical behaviour seems to be generic since the non-classicality conditions are fulfilled by several characteristic trajectories of a class of scalar field models describing universes evolving from a stiff matter era, followed by a radiation and dust phase and ending in a de-Sitter expansion as well as universes undergoing a perfect fluid evolution. We explore the range of corrections for cosmological parameters with explicit solutions for characteristic extremal cases of a stiff matter and a de-Sitter universe.

Elena Simón Félix

Universidad de Murcia

The Non-Relativistic Limit of Type II Supergravity Theories

We discuss the non-relativistic limit of type IIB and massive type IIA supergravity in the democratic formulation, where all Ramond-Ramond (R-R) potentials are considered. We first study it at the level of the action and prove the existence of a well-defined magnetic limit. The democratic formulation plays a pivotal role in ensuring the cancellation of ”divergent” terms in the action. We also compute the non-relativistic limit at the level of the equations of motion. The resulting system is a non-trivial set of equations, organized in a reducible but indecomposable representation under Galilean boosts. We further investigate the role of the R-R fields in the Poisson equation and in the geometry.

Dragana Pilipovic

CERN

To be confirmed

Mario Navarro

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To be confirmed