NEB-21

Monday 1 September 2025 - Thursday 4 September 2025

Corfu

Book of Abstracts

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Spinning Black Holes in Binaries Observed with Gravitational Waves

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The spins of black holes in binaries observed with gravitational waves are an essential probe of physics on multiple scales, from the astrophysical formation environments of compact binaries to fundamental physics. At the same time, the imprint of spin on the observed signals is weak, making constraints more challenging compared to the other key property of black holes, namely their mass. I will discuss how spins affect the mergers of black holes, the current status of spin measurements and its astrophysical implications, and challenges in ensuring robust and unbiased measurements.

Parallel Session B / 2

Shadow/QNMs correspondence for black holes in KK gravity

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In this work we present a new solution of a black hole surrounded by massive vector fields in the context of Kaluza-Klein theory. This vector field corresponds to a spin-1 graviton that modifies the law of gravity and allows the effects attributed to dark matter in the universe. In order to analyze the influence of the parameters associated to this solution, we perturb the geometry with a massive scalar field and find the interrelated quasinormal modes (QNMs). Then, we calculate the radius of the shadow of the black hole and confirm the correspondence Shadow/QNMs. Finally, we also constrain the parameters of the model using observational data from SgrA*.

Morning / 8

Exploring Composition of Neutron Star Matter with Astrophysical Observations

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In this work, we perform a Bayesian analysis putting together the available knowledge from the nuclear physics experiments and astrophysical observations to explore the equation of state of supranuclear matter. In particular, we employ a relativistic metamodeling technique to nuclear matter to

cover the uncertainties in the parameter space of the saturation properties of nuclear matter, both in the isoscalar and isovector sectors. Then, we investigate if it is possible to reconcile the inferred values of those quantities from observational data with the values obtained from nuclear experiments and compute a joint posterior of these quantities incorporating all the available knowledge. We further probe the fractions of different particle species that the interior of a neutron star may contain, particularly the proton fraction in the core and the consequences of the allowed compositions within our metamodel. We also incorporate the possible emergence of hyperons in the system and the number of ways that the nucleonic metamodel can accommodate hyperons in the neutron star matter. Finally, we calculate the strangeness content in the star and discuss its observational implications.

Morning / 9

Vector induced gravitational waves sourced by primordial magnetic fields

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In the presence of an active source like primordial magnetic fields (PMFs), the vector perturbations of the metric do not necessarily decay away, but may become significant depending upon the background equation-of-state (EoS) parameter, w for instance during reheating. In this work, we develop a generic formalism for the study of tensor perturbations induced at second order by first-order vector metric perturbations, dubbing these induced tensor modes *vector-induced gravitational waves* (VIGWs). Notably, considering an inflation-inspired power-law type magnetic field power spectrum of the form $P_B(k) \propto k^{n_\mathrm{B}}$ (where n_B is the magnetic spectral index), we show that the VIGW signal is enhanced for stiff post-inflationary EoS, with the maximum enhancement happening for $w = 1$. We explicitly demonstrate this contribution is dominant over the first-order magnetically-sourced GWs. The VIGW spectrum exhibits a maximum at around the scale crossing the cosmological horizon at the end of reheating, k_reh, with its present day peak amplitude scaling as $\Omega_\mathrm{GW}(k_\mathrm{reh}, \eta_0) \propto \Delta N_\mathrm{reh} \times (H_\mathrm{inf}/M_\mathrm{Pl})^8$, where H_inf is the Hubble parameter at the end of inflation and ΔN_reh the duration of the post-inflationary era in e-folds. For $w = 1$ (kination) and $n_\mathrm{B} > -3/2$, one further obtains a nearly n_B-independent frequency scaling of the GW spectrum of the form $\Omega_\mathrm{GW}(f, \eta_0) \propto \left(\frac{f}{f_\mathrm{reh}}\right)^{-2.8}$ for $f > f_\mathrm{reh} \equiv k_\mathrm{reh}/(2\pi)$. Finally, we need to highlight that the VIGW signal can be well within the detection bands of several next-generation interferometric GW missions at small scales. Indicatively, for $H_\mathrm{inf} \sim O(10^7)$ GeV and $O(10^{14})$ GeV, and $\Delta N_\mathrm{reh} \sim 15$ and 10, the VIGW signal is found to be detectable by LISA and ET respectively.

Morning / 10

Symphony of Spacetime: Tuning into EMRI resonances with LISA

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Extreme-mass-ratio inspirals (EMRIs) are binary systems composed of a primary supermassive black hole and a secondary compact object of stellar mass. Owing to their significant mass disparity, EMRIs emit gravitational waves in the millihertz frequency band, making them accessible only to future space-based detectors such as LISA. These systems evolve adiabatically, with the secondary

effectively tracing the spacetime geometry of the primary. This unique characteristic allows EMRIs to serve as precise probes for testing General Relativity and investigating the complex astrophysical environments surrounding supermassive black holes.

Their gradual evolution also implies that EMRIs may pass through orbital resonances —special configurations where orbital frequencies become commensurate —leading to distinct imprints on gravitational-wave signals. In this talk, I will summarize the concept of orbital resonances and explore three key aspects: (i) their influence on gravitational-wave emission in EMRIs with Kerr black hole primaries, (ii) the amplified effects of resonances when the primary deviates from the Kerr geometry, exhibiting chaotic behavior, and (iii) the role of resonances in initially spherical EMRIs orbiting both integrable (deformed Kerr) and non-integrable (non-Kerr) rotating primaries. These gravitational-wave features present strong prospects for observational detection and must be modeled with high precision to be reliably identified in future LISA data.

Parallel Session A / 11

A multi-parameter expansion for Extreme Mass Ratio Inspirals in astrophysical environments

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Asymmetric binaries have attracted increasing attention as golden sources for probing the astrophysical environment in which they evolve. Black holes do not exist in isolation; they inhabit diverse environments where particles and fields, possible of unknown nature, interact with each others and with compact objects. For example, massive BHs are surrounded by accreting matter, dark matter halos, which may consist of exotic fields or beyond-standard-model candidates. Moving beyond vacuum general relativity presents significant challenges due to the lack of relativistic solutions describing BHs embedded in matter and the complexities introduced by metric-matter couplings. As a result, modeling environmental effects on extreme mass ratio inspirals often relies on post-Newtonian approaches, though fully relativistic descriptions remain key to confidently extract small deviation from vacuum predictions. I along with Prof. Andrea Maselli, develope a multi-parameter framework to describe environmental effects on BHs, where the surrounding matter is modeled as a fluid stress-energy tensor. We adopt a general anisotropic prescription, incorporating both radial and tangential pressure components. We compute axial and polar perturbations at first order in the mass ratio, induced by the secondary on the geometry of a non-rotating BH embedded in an environment. We discuss practical, ready-to-use expressions for computing gravitational and fluid perturbations, as well as the resulting GW emission, as functions of environmental parameters and the secondary's orbital motion.

Parallel Session A / 12

Tidal Heating: signature of black holes

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With the observation of the multiple binary inspirals, we begin to question whether the components of the binary are black holes or some exotic compact objects (ECOs). The "black holeness" or the deviation from it can be tested in several ways. The distinguishing feature of a black hole from ECOs in the presence of the horizon. This surface acts as a one-way membrane that absorbs energy. Due to this different behavior from ECOs, in the last stages of an inspiral black hole exchange energy. These backreact on the orbit, transferring energy and angular momentum from their spin into the orbit. This effect is called tidal heating. I will discuss how tidal heating can be used to test "black hole ness"; and distinguish black holes from other compact objects. I will also discuss how the black hole tidal heating affects waveform modeling, especially in post-ISCO regime.

Morning / 13

Penrose inequality for integral energy conditions

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The classical Penrose inequality (PI), a relation between the ADM mass and the area of any cross section of the black hole event horizon, was introduced as a test of the weak cosmic censorship: if it fails, the trapped surface is not necessarily behind the event horizon and a naked singularity could form. Since that original derivation, a variety of proofs have developed, mainly focused on the initial data formulation on maximal spacelike slices of spacetime. Most of these proofs are applicable only for classical fields, as the energy conditions required are violated in the context of quantum field theory. In this talk I will present two generalizations of the PI for spherically symmetric spacetimes: 1) a proof of PI with a classical energy inequality using initial data and 2) a proof of a generalized PI for evaporating black holes with a connection to the weak cosmic censorship using a condition inspired by quantum energy inequalities. The latter case could also be applicable to quantum fields. Finally, I will provide physically motivated examples for both. Based on: arXiv:2504.19794

Parallel Session B / 15

A Directive for obtaining Algebraically General Solutions of Einstein's Equations

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Algebraically general solutions in General Relativity are notably rare and less mathematically tractable compared to their algebraically special counterparts. Nevertheless, this kind of solutions is quite interesting in mathematical and physical point of view.
In a previous study conducted in vacuum with cosmological constant under the framework of Newman-Penrose formalism, we explored an analytical solution extraction technique assuming the existence of canonical Killing tensor forms combined with a general null tetrad transformation. This led us only to algebraically special solutions encompassing Petrov types D, III, and N. In this regard, a Petrov type D solution emerges, describing a general family of cosmological models which are topological products of two-dimensional spaces with constant curvature.

In the present work, we extend this approach by introducing a specific class of Lorentz transformations. Under the same initial assumptions, this leads to a new algebraically general solution featuring a curvature singularity. This result also raises new questions regarding the role and preferability of specific transformations in the solution extraction process.

These findings suggest a new directive in solution extraction: the assumption of canonical Killing tensor forms, combined with special Lorentz transformations in the context of symmetric null tetrads, provides new and broader classes of algebraically general solutions of Einstein's equations.

Parallel Session A / 16

Circular equatorial orbits of extended bodies with spin-induced quadrupole around a Kerr black hole

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The worldline of an extended body in curved spacetime can be described by the Mathisson-Papapetrou-Dixon equations when its centroid, i.e., its center of mass, is fixed by a spin supplementary condition (SSC). Different SSC choices result in distinct worldlines. To examine the properties of these choices, we investigate the frequency of circular equatorial orbits of extended bodies within the pole-dipole-(spin-induced) quadrupole approximation moving around a Kerr black hole for the Tulzcyjew-Dixon (TD) and the Mathisson-Pirani (MP) SSCs. First, we examine similarities and discrepancies in the prograde and retrograde orbital frequencies by expanding these frequencies in power series of the spin without taking into account the fact that both the position of the centroid and the spin measure change under the transition from one SSC to another. Then, by taking into account the centroid transition laws, we examine the orbital frequencies convergence between the non-helical MP frame and the TD frame. In particular, we demonstrate that, in analogy to the pole-dipole approximation, the transition from one circular orbit to another within the pole-dipole-(spin-induced)quadrupole approximation under a change in the SSC, results in convergence between the SSCs only up to certain terms in the spin expansion and does not extend to the entire power series. Finally, we discuss the innermost stable circular orbits (ISCOs) in the pole-dipole-(spin-induced)quadrupole approximation under TD and MP SSCs.

Parallel Session A / 17

Detectability of stochastic gravitational wave background from weakly hyperbolic encounters

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This talk concerns the computation of the stochastic gravitational wave (GW) background generated by black hole-black hole (BH-BH) hyperbolic encounters with eccentricities close to one and their comparison with the respective sensitivity curves of planned GW detectors. In this study we took into account hyperbolic encounters that take place in clusters up to redshift 5 and with BH masses spanning from 5 $M_{\odot}$ to 55 $M_{\odot}$. We studied several cluster models with different mass and virial velocity, and finally obtain an accumulative result, displaying the background as an average. Our results suggest that the background from these encounters is likely to be detected by the third-generation detectors Cosmic explorer and Einstein telescope, while the tail section at lower frequencies intersects with DECIGO, making it a potential target source for both ground and space-based future GW detectors.

Morning / 18

Searching for gravitational waves in real LIGO noise using neural networks

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Conventional searches for gravitational wave signals in detector data are computationally demanding and struggle when certain transient noise sources are present. Recently, machine-learning algorithms have been proposed to address current and future challenges. We present a neural-network based algorithm to search for binary black hole waveforms. We also apply our algorithm to real O3b data and recover the relevant events of the GWTC-3 catalog.

Parallel Session B / 20

A new model of spontaneous scalarization induced by curvature and matter

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We present a model of black hole scalarization where a scalar field couples simultaneously to the Gauss–Bonnet invariant and a U(1) gauge field (can be identified as a dark photon or an electromagnetic field). This combined interaction broadens the conditions for spontaneous scalarization and unify the previous models in one. framework. We track how the electric charge and the two coupling constants control the onset of the scalar field and uncover new solution branches with non-trivial scalar profiles. Scalarization occurs across a wide range of parameters and even with negative Gauss–Bonnet coupling at sub-extremal charge . Scalar clouds and fully scalarized black holes form above several mass thresholds; varying the matter coupling or the charge makes the highest threshold mass almost three times the lowest. Multiple branches of scalarized solutions converge to the same final state, indicating non-unique growth of scalar hair. The model also produces overcharged black holes while the Gauss–Bonnet coupling remains positive. Several examples show horizon areas larger than those of the Reissner–Nordström solutions with the same mass and charge. The matter term shifts the scalarization onset and tends to stabilize the solutions, as seen from the evolution of the scalar charge and horizon quantities. These results provide an alternative route to scalarization, may avoid the instabilities of curvature-only or matter-only models, and open new possibilities for testing strong-gravity effects in upcoming observations.

Morning / 21

Extensions of General Relativity and cosmological dark matter

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Assuming that gravity on cosmological scales is described by General Relativity (GR), observations indicate that 80% of matter is in the form dark matter. The underlying cosmological model, ΛCDM, provides a superb fit to the data on scales of around 1 Mpc or larger. However, the dark matter particle responsible is so far undetected. Moreover, galactic dynamics display an element of regularity, suggesting a fundamental description that is not easily provided by a dark matter particle. In this talk, I will present recent extensions of GR with additional degrees of freedom which are screened on smaller scales so that the success of GR is restored. These provide excellent fits to galactic data, propagate tensor mode gravitational waves at the speed of light and lead to an effective ΛCDM description on large scales reproducing observations of the cosmic microwave background and large-scale structure. I will briefly present the status of these models and discuss future directions.

Morning / 22

Some Constraints on Some Alternative Theories of Gravity

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I will present some theoretical and observational cosmological constraints on classes of alternative gravitational theories.

Parallel Session A / 23

Exploiting the effective-one-body approach for large-mass-ratio black hole binaries

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The gravitational waves (GWs) that we have detected so far are emitted by compact binaries where the mass ratio between the two objects is of order 1:1 to 1:10. Third-generation GW detectors will instead allow us to receive different signals, like the ones coming from black hole binaries with a larger mass ratio, from 1:100 up to 1:10^6. The orbits of such systems are expected to be eccentric and inclined, thus requiring a careful and accurate modelling. In this talk, I will present ongoing work to exploit the effective-one-body approach for the description of such binaries.

Parallel Session B / 26

Maxwell Fields, Hidden Symmetries, and the Teukolsky Equation

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

Parallel Session A / 27

Interacting Models of Dark Energy and Dark Matter in Einstein scalar Gauss Bonnet Gravity

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We study the dynamics of the interacting models between the Gauss-Bonnet (GB) coupled scalar field and the dark matter fluid in a homogeneous and isotropic background. A key feature of GB coupling models is the varying speed of gravitational waves (GWs). We utilize recent constraints on the GW speed and conduct our analysis in two primary scenarios: model-dependent and model-independent. In the model-dependent scenario, where determining the GW speed requires a specific GB coupling functional form, we choose an exponential GB coupling. We adopt a dynamical system analysis to obtain the necessary constraints on the model parameters that describe different phases of the universe and produce a stable late-time accelerating solution following the GW constraint, and find that to satisfy all these constraints, fine-tuning of the free parameters involved in the models is often needed. In the model-independent scenario, the GW speed is fixed to one, and we construct the autonomous system to identify the late-time stable accelerating critical points. Furthermore, we adopt a Bayesian inference method using late-time observational data sets, including 31 data points from cosmic chronometer data (Hubble data) and 1701 data points from Pantheon+ and find that all the observational constraints can be satisfied without fine-tuning. In addition, we also utilize simulated binned Roman and LSST data to study the evolution of the universe in the model-independent scenario. We find that the model shows significant deviation at higher redshifts from ΛCDM and fits the current data much better than ΛCDM within the error bars.

Parallel Session B / 28

General stationary axisymmetric spacetimes: circularity and beyond

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I will discuss properties of general stationary and axisymmetric spacetimes, with a particular focus on circularity - an accidental symmetry enjoyed by the Kerr metric, and therefore widely assumed when searching for rotating black hole solutions in alternative theories of gravity as well as when constructing models of Kerr mimickers. It can be shown the local existence of a Kerr-like gauge, specified by six free functions. Within this gauge the differential circularity conditions can be solved to translate them into algebraic relations among the metric components. This result opens the way to investigating the consequences of circularity breaking in a controlled manner. In particular, I will show two simple analytical examples of non-circular deformations of the Kerr spacetime and discuss their properties.

Parallel Session B / 29

Rotating spacetimes with a free scalar field in four and five dimensions

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We construct explicit rotating solutions in Einstein's theory of relativity with a minimally coupled free scalar field rederiving and finding solutions in four or five spacetime dimensions. These spacetimes describe, in particular, the back-reaction of a free scalar field evolving in a Kerr spacetime. Adapting the general integrability result obtained many years ago from Eriş-Gürses to simpler spherical coordinates, we present a method for rederiving the four-dimensional Bogush-Gal'tsov solution. Furthermore, we find the five-dimensional spacetime featuring a free scalar with two distinct angular momenta. In the static limit, these five-dimensional geometries provide higher-dimensional extensions of the Zipoy-Voorhees spacetime. Last but not least, we obtain the four-dimensional version of a Kerr-Newman-NUT spacetime endowed with a free scalar, where the scalar field's radial profile is extended to incorporate dependence on the polar angular coordinate. Our results offer a comprehensive analysis of several recently proposed four-dimensional static solutions with scalar multipolar hair, representing a unified study of spacetimes with a free scalar field in both four and five dimensions under the general integrability result of Eriş-Gürses.

Parallel Session A / 30

Geodesic Chaos in Stationary Spacetimes: Numerical Study of Test-Particle Motion in a Black Hole Metric Perturbed by a Rotating Thin Disc

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Motivated by the complex phenomena occurring in the vicinity of accreting black holes, this study revisits how additional matter distorts otherwise integrable geodesic motion. Whereas most earlier work considered static, axis-symmetric configurations, real accretion discs rotate and drag the surrounding space-time. To quantify the dynamical impact of this rotation-induced frame-dragging, test-particle trajectories in a Schwarzschild black hole perturbed by a rotating thin disc are examined. High-order RK integration is employed to construct Poincaré sections while systematically varying the disc's specific angular momentum. Chaoticity is characterised through several Lyapunov indicators—finite-time exponents, FLI, and MEGNO—and through a global estimator, the Kolmogorov–Sinai entropy, computed for each resulting phase-space portrait. Finally, the potential bias introduced by the disc's idealised sharp edges is assessed, underscoring the importance of smooth-edge models in future analyses.

Parallel Session A / 32

Geometric formulation and cosmological dynamics of kinetic k-essence

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We introduce a novel type of (integrable) vectorial nonmetricity, extending the previous literature by the inclusion of a cubic, completely symmetric term, reminiscent of statistical manifolds. The vectorial degree of freedom and three coefficients completely determine the geometric properties of the proposed connection. We find conditions on these coefficients, which guarantee the preservation of lengths, angles and volumes under (auto)parallel transport. Formulating the simplest linear action in this geometry, implemented through Lagrange multipliers, we show that the theory is equivalent to purely kinetic k-essence with quadratic terms. We generalise previous dynamical systems works by allowing for an arbitrary sign dependence in the coefficients, and derive detailed stability conditions for the theory. Using these stability conditions, we conduct and MCMC analysis with well-motivated priors, and find that, contrary to previous claims in the literature, purely kinetic k-essence is a viable candidate to describe late-time data, and is in fact statistically indistinguishable from ΛCDM. However, the scalar field behaves like evolving dark energy, unlike in the standard ΛCDM paradigm.

Afternoon / 34

Motion of test particles in spacetimes with torsion and nonmetricity

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We derive the equations of motion of a test particle with intrinsic hypermomentum in spacetimes with both torsion S and nonmetricity Q (along with curvature R). Accordingly, S and Q can be measured by tracing out the trajectory followed by a hypermomentum-charged test particle in such a non-Riemannian background. The test particle is approximated by means of a Dirac δ-function. Thus we find a tangible way to observe and measure the effects of torsion and nonmetricity. We apply our insight and evaluate how far-reaching the so-called 'geometrical trinity of gravity'really is.

Parallel Session B / 35

General features of energy extraction from black holes through charged particle production

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There has been a surge of interest into collisional Penrose process after Bañados, Silk and West described an idealised edge case, in which particles coming from rest at infinity can collide with

arbitrarily high centre-of-mass collision energy close to the horizon of a black hole. However, it turned out that in the vacuum case, there is an unconditional upper bound on the efficiency of extraction of energy from the black hole through such processes even under the most idealised conditions. On the other hand, in the less studied charged case, no such bound has been found. Indeed, in our previous work [PhysRevD.100.064041, PhysRevD.105.024014], we have shown that the bound is absent whenever both the black hole and the escaping particle are charged, even if the black-hole charge is arbitrarily small. Nevertheless, this conclusion was derived under the approximation of the black hole being extremal and the collision happening at an infinitesimal coordinate distance from the horizon. Such approximations are not the most fitting for elementary particles, which have enormous charge-to-mass ratios. In the present talk, we examine a simple model process with such realistic particles and show that it has generic features, which are similar for both extremal and subextremal black holes, but which are not captured by the near-horizon approximation in the extremal case.

Morning / 37

AresGW: Unveiling New Gravitational Wave Events with Machine Learning

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The detection of gravitational waves has revolutionized our understanding of the universe, offering unprecedented insights into its dynamics. A major goal of gravitational wave data analysis is to speed up the detection and parameter estimation process using machine learning techniques, in light of an anticipated surge in detected events that would render traditional methods impractical. Here, we present new gravitational-wave candidate events, the first to be identified in data from a network of interferometric detectors through machine learning. We discuss several new enhancements of our ResNet-based deep learning code, AresGW, that increased its sensitivity, including a new hierarchical classification of triggers, based on different noise and frequency filters. The enhancements resulted in a significant reduction in the false alarm rate, allowing AresGW to surpass traditional pipelines in the number of detected events in its effective training range (single source masses between 7 and 50 solar masses and source chirp masses between 10 and 40 solar masses), when the new detections are included. We calculate the astrophysical significance of events detected with AresGW using a logarithmic ranking statistic and injections into O3 data. In addition, the AresGW code exhibited very good performance when tested across various two-detector setups and on observational data from the O1 and O2 observing periods. Our findings underscore the remarkable potential of AresGW as a fast and sensitive detection algorithm for gravitational-wave astronomy, paving the way for a larger number of future discoveries.

Parallel Session B / 38

Black Hole Ringdown in Astrophysical Environment

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When a black hole (BH) rings due to some external perturbation, it emits gravitational waves described by quasi-normal modes (QNMs) –a series of exponentially damped harmonic oscillations. If the Kerr(-Newman) metric fully describes the BH, QNMs carry a unique signature of the BH parameters encoded in the modes' complex frequencies. Consequently, any deviation in the QNMs spectrum from the Kerr-Newman prediction would provide compelling evidence challenging general relativity and offer valuable insight into the true nature of BHs. However, astrophysical BHs are rarely isolated. Even a mild astrophysical environment, such as an accretion disc, modifies the spacetime geometry, thereby affecting the QNMs spectrum. In this talk, I present our efforts to investigate these effects and discuss spectral features that could help disentangle them from potential deviations associated with theories beyond general relativity.

Parallel Session B / 43

Geometric Unification of Elementary Particles

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Imposing the metric as the fundamental structure of the 4-dimensional spacetime, Einstein derived the gravitational interaction. If instead of the metric we assume as fundamental structure the Frobenius integrable system of geodetic and shear-free Newman-Penrose null tetrad, all the elementary particles and gauge interactions are derived. This fundamental geometric structure is called lorentzian CR (LCR) structure, which is a special totally real CR-structure. It extends ordinary conformal (Weyl) transformation into a tetrad-Weyl transformation. The electron LCR-structure is directly related with Kerr-Newman manifold, providing a raison d'etre of its gyromagnetic ratio g=2, already computed by Carter. The neutrino LCR-structure is related to a twisted Robinson-Trautman metric. The tetrad-Weyl symmetry determines uniquely (up to duality) a dual type SU(N) gauge field equation without sources, which admits solutions of ordinary gluon equation with sources. This pseudo-conformal field theory (PCFT) is "quantized" using the Bogoliubov perturbative causal approach of the S-matrix combined with Scharf order by order elimination of the unphysical modes of the spin-one and spin two fields. The final result is the standard model of elementary particles with the Einstein equations. C. N. Ragiadakos, "Pseudo-conformal Field Theory", Journal of Physics: Conference Series 2912 (2024) 012015; ibid. arXiv:hep-th/1704.00321.

Parallel Session B / 44

Fixing the dynamical evolution of self-interacting vector fields

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I will discuss the Cauchy problem of self-interacting massive vector fields, and explain why they often face instabilities and apparent pathologies. After showing that these issues are due to the breakdown of the well-posedness of the corresponding initial-value problem, I will characterize the well-posedness breakdowns and explicity show that they can be avoided by fixing the equations in a suitable way. As an application, I will numerically show that no Tricomi-type breakdown takes place in the quadratic case, and investigate initial configurations which lead to gravitational collapse and the formation of black holes.

Parallel Session B / 45

U(1) gauged boson stars and hairy Reissner-Nordström black holes

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We construct black holes in U(1) gauged scalar theories, minimally coupled to Einstein gravity in asymptotically flat space. Particular examples include non-linear O(3) sigma model, Einstein-Maxwell-Friedberg-Lee-Sirlin type model and in the Einstein-Maxwell-Skyrme theory. We analyze the properties of the hairy black holes and determine their domain of existence. Our discussion focuses mostly on the case of a long-ranged massless real scalar field. Our results indicate that, depending on the coupling constants, the resonant hairy dyonic black holes may bifurcate from Reissner-Nordström black holes at maximal chemical potential, while the limiting solutions at minimal chemical potential may be related to the Penney solution.

Parallel Session B / 47

Self-gravitating pulsed spinning mesonic tubes

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New exact pulsed and spinning self-gravitating solutions for the four dimensional SU(2) Einstein-non-linear-sigma model and the Einstein-Skyrme model both minimally coupled to the Maxwell field will be presented. These solutions describe mesonic tubes with finite energy and angular momentum and which are asymptotically gyratons. We show that the found solutions are free of curvature invariants or matter distribution singularities. First, using the SU(2) non-linear sigma model coupled to General Relativity and the Maxwell field, asymptotically flat spinning pulsed tubes will be constructed. Then, the model will be promoted to the Skyrme theory, showing that the inclusion of the Skyrme term necessarily requires the space-time structure to be asymptotically de Sitter.

Parallel Session A / 48

Dynamics of Brane-world models

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We present our work on a class of brane-world models that consist of a flat 3-brane embedded in a five-dimensional bulk space filled with a fluid that satisfies a non-linear equation of state of the form $p = \gamma\rho^{\lambda}$, where p is the 'pressure'and ρ is the 'density'depending on the fifth space coordinate, and γ, λ are parameters. We show that for $\gamma < 0$ and $\lambda > 1$, it is possible to obtain a regular and physically plausible solution that satisfies the null energy condition and successfully localizes gravity on the brane. Such regular behavior was not feasible in the framework of previous studies where we modelled the bulk content by a fluid satisfying a simple linear equation of state. The importance of the regular solution derived from a non-linear fluid lies in the fact that it can serve to revive the so-called self-tuning mechanism as an approach to the cosmological constant problem. We also present current work that explores the possibility of finding a field-theory realization of the non-linear equation of state.

[1] Regular braneworlds with nonlinear bulk-fluids, I. Antoniadis, S. Cotsakis, I. Klaoudatou, The European Physical Journal C 81, 771, 2021.

[2] Brane-world singularities and asymptotics of five-dimensional bulk fluids, I. Antoniadis, S. Cotsakis, I. Klaoudatou, Philosophical Transactions of the Royal Society A 380 (2230), 20210180, 2022.
[3] Brane-world asymptotics in a nonlinear fluid bulk, I. Antoniadis, S. Cotsakis, I. Klaoudatou, The Sixteenth Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, Astrophysics and Relativistic Field Theories: Proceedings of the MG16 Meeting on General Relativity Online; 5–10 July 2021, pp. 2645-2656, 2023.

Morning / 52

Importance of Noise Filtering for Improving the False Alarm Rate in Gravitational Wave Events

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We used AresGW, a deep residual neural network for gravitational wave detection, to process O3 data from the two LIGO detectors, generating a list of triggers with high significance. To improve the false alarm rate, we also used Gravity Spy, a convolutional neural network designed to identify glitches. We processed ARESGW triggers by removing those that were common between the two networks. Filtering out these common triggers, together with other filtering techniques employed in AresGW, was important to reduce the false alarm rate of several new candidate events, the first to be identified by a machine-learning pipeline.

Parallel Session B / 54

Using shadow observations to distinguish black holes from ultra-compact objects

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The recent detections from the EHT Collaboration of the shadows generated by the supermassive objects at the heart of M87 and Milky Way galaxies has prompted a new era in theoretical strong-field astrophysics. In this talk I will discuss the theoretical and basis of this new observational window and its latent power for distinguishing between canonical black holes, regular black holes, and ultra-compact objects such as boson stars, wormholes, and more exotic candidates.

Morning / 55

Universal description of a neutron star's surface and its key global properties: A machine learning approach for nonrotating and rapidly rotating stellar models

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Neutron stars provide an ideal theoretical framework for exploring fundamental physics when nuclear matter surpasses densities encountered within atomic nuclei. Despite their paramount importance, uncertainties in the equation of state (EoS) have shrouded their internal structure. For rotating neutron stars, the shape of their surface is contingent upon the EoS and the rotational dynamics. This work proposes new universal relations regarding the star's surface, employing machine-learning techniques for regression. More specifically, we developed highly accurate universal relations for a neutron star's eccentricity, the star's ratio of the polar to the equatorial radius, and the effective gravitational acceleration at both the pole and the equator. Furthermore, we propose an accurate theoretical formula for $(d\log R(\mu)/d\theta)_{\mathrm{max}}$. This research addresses key astronomical aspects by utilizing these global parameters as features for the training phase of a neural network. Along the way, we introduce new effective parametrizations for each star's global surface characteristics. Our regression methodology enables accurate estimations of the star's surface $R(\mu)$, its corresponding logarithmic derivative $d\log R(\mu)/d\theta$, and its effective acceleration due to gravity $g(\mu)$ with accuracy better than 1%. The analysis is performed for an extended sample of rotating configurations constructed using a large ensemble of 70 tabulated hadronic, hyperonic, and hybrid EoS models that obey the current multimessenger constraints and cover a wide range of stiffnesses. Above all, the suggested relations could provide an accurate framework for the star's surface estimation using data acquired from the NICER X-ray telescope or future missions, and constrain the EoS of nuclear matter when measurements of the relevant observables become available. DOI: https://doi.org/10.1103/PhysRevD.111.083056

Parallel Session B / 56

Universal black hole solutions for all F(R) gravitational theories

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Extended gravitational models have gained large attention in the last couple of decades. In this talk, I'll examine the solution space of vacuum, static, and spherically symmetric spacetimes within F(R) theories, introducing novel methods that reduce the vacuum equations to a single second-order equation. I'll derive analytic expressions for the metric functions in terms of the arbitrary functional F(R), providing detailed insight into how the gravitational action impacts the structure of spacetime. I'll analyze conditions under which solutions are asymptotically flat, regular at the core, and contain an event horizon, obtaining explicit expressions for entropy, temperature, and specific heat in terms of F(R). By using a single metric degree of freedom, I'll identify the most general solution and examine its (un)physical properties, showing that resolving singularities is not possible within this restricted framework in vacuum. For the general case involving two metric functions, I'll use several approximation schemes to explore corrections to Schwarzschild-(anti)de Sitter spacetimes, finding that F(R) extensions to General Relativity induce instabilities that are not negligible. Finally, through an analysis of axial perturbations, I'll derive a general expression for the potential of quasinormal modes of a black hole as a function of the arbitrary Lagrangian. If time suffices, I'll show a glimpse of current work on a no-hair theorem for F(R) theories.
The talk will based on the publication https://doi.org/10.1103/PhysRevD.111.044020

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On the Challenges of Evaluating ML Pipelines for Gravitational Wave Searches

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The detection of gravitational waves (GWs) from compact binary mergers has transformed astrophysics and pushed the development of more efficient search methods. While matched-filtering remains the standard, the growing data volumes from LIGO, Virgo, and KAGRA have spurred interest in machine learning (ML) for its scalability. This work evaluates the sensitivity of AresGW model 1, an ML-based pipeline, using several month-long datasets with real detector noise. We measure performance by the number of recovered waveform injections and the sensitive distance at various false alarm rate thresholds. Tests on data with and without real GW signals reveal notable fluctuations in sensitivity due to dataset variability. These results highlight key challenges in ML-based detection, particularly with finite-duration data, and underscore the need for stronger statistical validation. Our findings aim to guide future benchmarking of both ML and traditional GW search methods.

Parallel Session B / 59

Black holes with primary scalar hair

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We present an algorithm to obtain exact black holes endowed with primary scalar hair within the shift-symmetric and Z_2-symmetric subclass of beyond Horndeski theories. These solutions depend, in addition to the conventional mass parameter, on a second free parameter encoding primary scalar hair. In the limit of vanishing scalar hair, the solutions smoothly reduce to the Schwarzschild, while, as the scalar hair increases, the metric solutions gradually depart from GR solutions. Notably, for a particular relation between mass and scalar hair, the central singularity completely disappears, resulting in the formation of regular black holes or solitons. Among these solutions, the well-known regular Bardeen solution emerges as a special case.

Morning / 60

Gravitational waves from a curvature-induced phase transition of a Higgs-portal dark matter sector

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Our latest study (2407.18845) investigates the possibility of generating gravitational waves (GWs) from a curvature-induced phase transition of a non-minimally coupled scalar dark matter field with

a Higgs-portal. This analysis is conducted during the transition from inflation to kination for various inflationary scales, considering both positive and negative values of the non-minimal coupling, while also examining the potential for triggering Electroweak symmetry breaking. Notably, kination enhances the GW amplitudes, significantly restricting the viable parameter space. While the GW spectra are high-frequency for high-scale inflation, certain regions of the parameter space allow for a potential detection with future experiments.

Parallel Session A / 61

Gravitational memory as a theory guiding principle

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The future space-borne gravitational wave observatory LISA may provide the first single event measurement of permanent marks in the fabric of spacetime that remember the passage of a gravitational wave. This effect, known as gravitational memory, is one of the most intriguing predictions of general relativity that has not been observed yet. After offering a particularly illuminating theoretical foundation of GW memory, this talk will offer insights into very recent work, showing that even before its first measurement, the phenomenon of gravitational memory already has noteworthy impact on the theoretical landscape of vector-tensor theories, with implications that reach all the way to the theory of classical electromagnetism.

Based on:
- JZ, Guangzi Xu, Benedetta Rosatello, Lavinia Heisenberg, "Constraining Superluminal Einstein-Æther Gravity through Gravitational Memory", accepted for publication in Phys.Rev.D (2025), https://arxiv.org/abs/2505.09544
- JZ, "Enhanced electromagnetic memory", under review in PRL (2025) , https://arxiv.org/abs/2507.09555
- Guangzi Xu, Benedetta Rosatello, Lavinia Heisenberg, JZ, "Gravitational Memory in Generalized Proca Gravity", under prep.

Further references:
- JZ, Lavinia Heisenberg, Nicolás Yunes, "Gravitational wave memory beyond general relativity", Phys.Rev.D 108 (2023) 2, 024010, https://arxiv.org/abs/2303.02021
- JZ, Guangzi Xu, Lavinia Heisenberg, "Unifying ordinary and null memory", JCAP 05 (2024) 119, https://arxiv.org/abs/2401.05936
- Henri Inchauspé, Silvia Gasparotto, JZ, et al. , "Measuring gravitational wave memory with LISA", (2024), https://arxiv.org/abs/2406.09228

Parallel Session A / 62

Non-linear Dynamics During Kination

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We investigate the effects of large scalar inhomogeneities during the kination epoch, a period in which the universe's dynamics are dominated by the kinetic energy of a scalar field, by fully evolving Einstein's equations using numerical relativity. By tracking the non-linear growth of scalar perturbations with both sub-horizon and super-horizon initial wavelengths, we are able to compare their evolution to perturbative results. Our key findings show that in the deep sub-horizon limit, the perturbative behaviour remains valid, whereas in the super-horizon regime, non-linear dynamics

exhibit a much richer phenomenology. Finally, we discuss the possibility of primordial black hole formation from the collapse of such perturbations and assess whether this process could serve as a viable mechanism to reheat the universe in the post-inflationary era.

Parallel Session B / 63

Black Mirrors: CPT-Symmetric Alternatives to Black Holes

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Einstein's equations imply that a gravitationally collapsed object forms an event horizon. But what lies on the other side of this horizon? In this talk, I am going to discuss the results of our new paper (https://arxiv.org/abs/2412.09558), presenting an alternative, topologically distinct solution: the Black Mirror. In the black hole solution, the horizon connects the exterior metric to an interior metric which contains a curvature singularity. In the black mirror, the horizon instead connects the exterior metric to its own CPT mirror image, yielding a solution with smooth, bounded curvature. We give the general stationary (charged, rotating) black mirror solution explicitly, and also describe the general black mirror formed by gravitational collapse. The black mirror is the relevant stationary point when the quantum path integral is equipped with suitably CPT-symmetric boundary conditions, that we propose. It appears to avoid many vexing puzzles which plague the conventional black hole.

Parallel Session A / 64

The Common Solution Space of General Relativity

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We review the solution space for the field equations of Einstein's General Relativity for various static, spherically symmetric spacetimes. We consider the vacuum case, represented by the Schwarzschild black hole; the de Sitter-Schwarzschild geometry, which includes a cosmological constant; the Reissner-Nordström geometry, which accounts for the presence of charge. Additionally we consider the homogenenous and anisotropic locally rotational Bianchi II spacetime in the vacuum. For the aforementioned gravitational models can be expressed in the equivalent form of the null geodesic equations for conformally flat geometries. Consequently, the solution space for the field equations is common, and it is the solution space for the free particle in a flat space. This approach open new directions on the construction of analytic solutions in gravitational physics and cosmology.

e-Print: 2406.01998 [gr-qc]

Parallel Session B / 65

Robinson-Trautman spacetimes in the Einstein-Gauss-Bonnet theory

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We derive the explicit form of the Einstein-Gauss-Bonnet field equations for D-dimensional geometries that admit non-twisting, shear-free, and expanding null geodesic congruences, forming thus the famous Robinson-Trautman class of spacetimes, and discuss their structure and particular solutions. In D=4 GR, this class contains Weyl type II spacetimes or algebraically more special solutions such as spherical black holes or exact type N gravitational waves; however, in D>4, there are only Weyl type D solutions. Examining the RT class within the EGB could indicate whether this discrepancy arises from gravitational theory or the behaviour of the higher-dimensional RT geometries themselves.

Parallel Session A / 66

Toward Testing Strong Gravity: Higher Post-Newtonian Corrections in Tidal Response

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The tidal response of compact objects reflects the underlying gravitational theory and leaves imprints on the gravitational waveforms emitted during the inspiral phase of binary coalescences. High-precision modeling that includes higher-order post-Newtonian effects is essential to test gravity in a strong regime through constraints on such tidal responses. In this talk, I present a formulation of the corrections from dynamical tidal response based on the Mano–Suzuki–Takasugi (MST) solutions for metric perturbations in the exterior of the object, combined with the framework of worldline effective field theory. A key feature of this formulation is that it does not rely on the detailed internal structure of the object or the specific degrees of freedom in modified gravity theories. Furthermore, time permitting, I will also discuss the outlook for waveform modeling and nonlinear tidal responses.

Parallel Session A / 67

Quantum Gravity Meets DESI: Dynamical Dark Energy in Light of Swampland Trans-Planckian Censorship Conjecture

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The question "How do we use quantum gravity to understand modern cosmology?" is on the same footing as "How do we use quantum gravity to understand the Standard Model?" The Swampland conjectures distill our lessons about quantum gravity from string theory, the holographic principle, and black-hole physics, imposing powerful constraints on and continually deepen our understanding of low-energy physics over the past twenty years. In this talk, I will explain how the latest DESI observations of dynamical dark energy align with the predictions of the Trans-Planckian Censorship Conjecture (TCC), and show how one can use Swampland TCC criteria to constrain dynamical dark energy parametrizations (CPL, BA, JBP, EXP, LOG) and theoretical realizations in modified gravity (f(T), f(Q) gravities), which prohibits eternal cosmological acceleration and aligns naturally with the quintom-B behavior from the latest DESI DR2 data. Our findings imply that viable dynamical dark energy scenarios would asymptotically transit to deceleration, shedding light on new physics consistent with both cosmological observations and fundamental Quantum Gravity principles. This talk is based on arXiv:2504.07791.

Morning / 68

Extreme Tidal Disruption Events as probes of Nuclear Star Cluster

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Nuclear star clusters (NSCs), found in most galaxies, appear as compact stellar systems located around supermassive black holes (SMBHs) in their centers. They often contain a mix of old and young stars and frequently exhibit signs of recurrent star formation. SMBHs define the loss cone of small angular momentum orbits that plunge to the immediate vicinity of the event horizon, where tidal forces exceed the star's self-gravity. Tidal disruption event (TDE) occurs when a star approaches the black hole on an orbit whose pericenter is close to the critical radius (R_t). A fraction of the star' s material becomes ejected, while the rest remains bound on a new trajectory. The orbital dynamics of stellar debris is qualitatively different due to relativistic precession and frame dragging. We explore the mechanisms that bring stars close enough to R_t and below it. This can happen by chance (depending on the NSC's distribution function), but the orbital decay can also be enhanced by the hydrodynamical influence of the interstellar environment (e.g., a gaseous or dusty accretion disc or torus) or gravitational radiation losses (Extreme Mass Ratio Inspiral). The rate of TDEs, the emerging radiation signal, and the corresponding duty cycle of its (quasi-)periodicity should reflect the mechanisms of orbital decay that operate in a given galactic nucleus.

Parallel Session B / 69

Re-examining the Foundations of Supergravity: The Spin-1/2 Sector

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This talk explores the overlooked spin-1/2 sector of basic supergravity, challenging the long-standing view—present since the origins of supergravity in the late 1970s—that it is non-physical. We show that this belief arose from assuming the validity of the Dirac conjecture of the theory of constrained Hamiltonian systems. We demonstrate that the conjecture does not hold in this particular case, and that additional off-shell analyses allow us to conclude that the spin-1/2 sector actually propagates. This result explains why unconventional supersymmetry (USUSY) models by Alvarez, Valenzuela, and Zanelli make phenomenological sense. Finally, we discuss the implications for supergravity phenomenology and outline open questions and future research directions in this area.

Morning / 72

Causality with Gravity

Author: Claudia De Rham[1]

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I will discuss the interplay between the behaviour of particle physics and gravity as we observe them in our "every day"-experiments and observations, and the embedding of these effective description within a meaningful quantum theory of gravity, emphasizing the subtle relation to causality.

Parallel Session B / 73

In search of a higher-dimensional Kerr-Newman solution

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Almost four decades have passed since the generalization of vacuum Kerr solutions to higher dimensions in the form of Myers–Perry black holes, yet an exact solution generalizing their charged extension (Kerr-Newman) to higher dimensions remains unknown in Einstein-Maxwell theory. In this talk, I will discuss this issue from the viewpoint of the (generalized) Kerr–Schild class. Time permitting, I will also briefly comment on the problem of charging multi-NUT solutions in higher dimensions.

Morning / 75

Self-force in hyperbolic scattering

Author: Leor Barack[1]

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I will review recent work to apply self-force methods to the black-hole scattering problem in the extreme-mass-ratio domain, enabling useful comparisons with similar calculations in post-Minkowskian theory. In particular, I will demonstrate how benchmarking of scattering observables using self-force data can inform efficient resummations of post-Minkowskian formulas that remain accurate even in the strong-field regime.

Parallel Session B / 77

Differential curvature invariants as detectors of horizon and ergosurface radii for accelerating, rotating and charged black holes in (anti-)de Sitter background.

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In this work we compute novel analytical expressions for differential curvature invariants for accelerating Kerr-Newman black holes in (anti-)de Sitter spacetime. We explore and prove that some of the calculated frame agnostic scalar polynomial invariants (SPIs), can be used on the detection of horizon and ergosurfaces of this important class of black holes. Using the Bianchi identities we calculate in closed-form in the Newman-Penrose tetrad formalism, the Page-Shoom curvature invariant as well as some relevant Cartan invariants. The differential invariants which are norms associated with the gradients of the first two Weyl invariants, are explored in detail. Although both locally single out the horizons, their global behaviour is also intriguing. Both reflect the background angular momentum and electric charge as the volume of space allowing a timelike gradient decreases with increasing spin and charge.

Afternoon / 78

Generalised Galileon Duality

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There exists a duality in the form of a non-local field redefinition that maps two different Galileon theories into each other while preserving scattering amplitudes. This duality arises naturally in the context of massive gravity and bigravity theories where the Galileon emerges in the decoupling limit as the helicity zero mode of the massive graviton, with the duality being the decoupling limit remnant of diffeomorphism invariance. Remarkably, the duality extends to any scalar field theory and nontrivially maps the class of theories that have second order equations of motion into each other. I will discuss how to couple such scalar theories to gravity (massless and massive) in a way that preserves the duality properties.

Parallel Session A / 79

Time evolution in higher-derivative theories of gravity

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I will clarify that higher-derivative theories and associated opposite-sign kinetic terms are no obstruction for long-lived classical motion. For point-particle models, integrability allows for proof of global stability. For scalar field theories, mathematical theorems establish well-posed time evolution for sufficiently small, compactly-supported initial data and numerical scattering solutions suggest that said small-data global stability extends also to large data. These toy-models moreover demonstrate that (i) higher frequency modes are more stable not less stable, and (ii) heavy ghosts can be integrated out. Finally, I connect these insights to recent progress in numerical relativity, enabling well-posed time evolution in higher-derivative effective field theories of gravity.

Morning / 80

Modeling the strong-field dynamics of binary neutron stars

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Binary neutron star mergers (BNSM) are associated with powerful gravitational and electromagnetic astronomical transients. Multimessenger observations of BNSMs promise to deliver unprecedented insights on fundamental physics questions, including constraints on dense matter models and the production of heavy elements. Detailed theoretical predictions of the merger dynamics are crucial for extracting information from such observations. This talk reviews recent progress in the modeling of BNSMs using simulations in 3+1 numerical general relativity. I will first discuss the first predictions for the complete (inspiral-merger-postmerger) gravitational-wave spectrum and their application in gravitational-wave astronomy. Afterwards, I will focus on recent results on the merger remnants and mass ejecta, the mechanisms behind kilonova light and their application to the analyses of astrophysical data.

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Bayesian Inference of Gravitational-Wave Signals from Merging Massive Black Hole Binaries

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Merging massive black hole binaries (MBHBs) are important gravitational wave (GW) sources for the future space-based observatory LISA. The GW signal from the merger will be detected throughout the entire Universe. Characterization of the GW signal allows us to infer masses and spins of MBHs, the position of the source in the sky and the distance. This information will allow us to understand the mechanism of MBHs formation and their evolution through cosmic history.
The binary could be surrounded by a gaseous disk accreting on each companion, which causes a variability in the X-ray emission correlated with the GW signal. Observation of this feature is a "smoking gun" of a binary system present in the active galactic nuclei. An accurate measure of the MBHB sky position will facilitate simultaneous multimessenger (GW and e/m) observation of merging MBHBs, provided that we already have an estimate of the coalescence time from the inspiral part of the signal.
In this project, we consider the detection of MBHB mergers in the LISA band. During Bayesian parameter estimation, the sky localization of the source in the sky could be improved if we detect higher modes of the GW signal, which we expect to be significant (breaking degeneracies in the parameter space). In addition, we show the prospect of implementing a heterodyned mode-by-mode likelihood scheme, in order to significantly reduce the computational time in Bayesian inference, specifically when including multiple radiation harmonics in the analysis.

Morning / 83

Gravitational waves in quadratic gravity

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We will discuss the framework of quadratic gravity where both General Relativity (GR) and "hairy" black holes coexist. We explore the phenomenology of the solutions and go over the regime of stability. We will then examine quadratic gravity as a candidate for beyong-GR effects in current and upcoming gravitational wave (GW) observations.

Morning / 84

Gravitational Waves: A Decade of Exploring the Universe

Author: Alicia Sintes[1]

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Over the past ten years, the LIGO and Virgo observatories—and now KAGRA—have transformed gravitational-wave detection from an audacious dream into a powerful and routine window onto the cosmos. This talk will retrace that remarkable journey, beginning with the historic first detection of GW150914 on September 14, 2015—a breakthrough that inaugurated gravitational-wave astronomy and forever changed our view of the universe. I will highlight the extraordinary technical innovations that made this possible: kilometer-scale interferometers capable of sensing distortions smaller than a proton, quantum "squeezing"to tame fundamental noise, and exquisitely engineered mirror suspensions that overcome Earth's restless seismic activity. The talk will then showcase the most exciting scientific results from the LIGO-Virgo-KAGRA network—from the spectacular GW170817 binary neutron star merger that launched multi-messenger astronomy, to recent detections of intermediate-mass black holes that challenge our understanding of stellar evolution. Looking forward, I will present the roadmap for upcoming observing runs and upgrades, designed to push sensitivity to new frontiers and dramatically expand the number and diversity of detections. Finally, we will peer into the coming decades of gravitational-wave astronomy, exploring how next-generation observatories such as the Einstein Telescope and Cosmic Explorer—and ambitious space missions like LISA—will probe cosmological distances, illuminate the nature of black holes and neutron stars, and even offer glimpses into the earliest moments of the universe.

Morning / 85

Cosmological Reconstructions with Neural Networks: From Data to Theory

Author: Konstantinos Dialektopoulos[None]

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In this talk, I will present a machine learning approach to reconstructing cosmological dynamics using artificial neural networks (ANNs), applied to late-time expansion, structure growth, and scalar-tensor gravity models. This non-parametric method learns directly from observational data—such as cosmic chronometers, BAO, and supernovae—while incorporating realistic uncertainties and correlations. I will highlight results from ΛCDM null tests and demonstrate how ANN-based reconstructions constrain viable scalar-tensor theories, offering a scalable and model-independent route to cosmological inference in the precision era.

Parallel Session A / 86

Addressing cosmological tensions within f(Q) cosmology

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We explore the potential of f(Q) gravity as an alternative framework to address the H_0 and S_8 tensions in cosmology. Focusing on three representative f(Q) models, we perform a comprehensive Bayesian analysis using a combination of cosmological observations, including cosmic chronometers, Type Ia supernovae, gamma-ray bursts, baryon acoustic oscillations, and redshift-space distortions.
Our results demonstrate that most of these models can yield higher values of H_0 than those predicted by the concordance cosmological model ΛCDM, offering a partial alleviation of the tension. In addition, one model satisfies the condition Geff < G and predicts S_8 values consistent with weak lensing observations, making it a promising candidate for addressing the S_8 tension. However, these improvements are accompanied by mild internal inconsistencies between different subsets of data, which limit the overall statistical preference relative to ΛCDM. Despite this, f(Q) gravity remains a promising and flexible framework for latetime cosmology, and our results motivate further exploration of extended or hybrid models that may reconcile all observational constraints.

Parallel Session B / 88

Gravitational Waves generation using the Lehmann-Symanzik-Zimmermann formalism

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Gravitational Waves (GW) emission is usually studied within the framework of the Regge-Wheeler-Zerilli equations, which are not exact and often times require numerical integration or extrapolation (a process which involves tuning additional parameters). Our aim is to prescribe a theoretical framework which alleviates some of these technical challenges by employing a Lehmann-Symanzik-Zimmerman (LSZ) like method, similar to how scattering is handled in Quantum Field Theory (QFT). This requires that the black hole is treated like an ensemble of gravitons bound by an effective potential, i.e. the black hole is a bound state of gravitons. Furthermore, the plunging star is treated like a localized scalar field which interacts with the black hole via an exchange of gravitons at any given moment. This incoherent beam of incoming gravitons then scatter off the black hole in this LSZ (scattering) picture. Our main objective is to find an analytical expression for the scattered beam of gravitons and explore additional effects stemming from the QFT framework employed.We prove that, in the limit of an infinite number of scattered gravitons, we recover the gravitational wave emitted by the binary system (plunging star & black hole) via an emission of graviton coherent states.
Our secondary objective is to provide a mathematical foundation for 'graviton condensates' in the framework of the Renormalization Group and to show that the Schwarzschild geometry emmerges from higher order corrections of the quantized action for the graviton field.
Regarding future work, we seek to generalize this LSZ approach to other processes (black hole mergers, inspirals etc) and recover the energy spectrum of the emitted GWs.

Morning / 89

Secondary Gravitational Waves as probes of the early Universe and Gravity

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In the new era of gravitational wave (GW) astronomy, we have access to a new window to investigate cosmology. In this talk, I am going to focus on the so-called scalar induced (stochastic) gravitational waves (SIGW) and how they can act as probes of the early Universe as well as the underlying gravitational theory itself. Specifically, the main results of my PhD thesis will be presented, which include: the GW signal from a population (gas) of primordial black holes (PBH) both in GR and f(R) theories of modified gravity and the GW phenomenology of some notable models of beyond standard model particle physics like (no-scale) supergravity and running vacuum models. Most significantly, some of these GW signals can lie within the detection bands of major future GW observatories like LISA and can be used to explain the PTA data.

Parallel Session A / 90

Explaining Dark Matter through Primordial Black Holes (PBHs) in Horndeski Gravity

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Dark matter remains one of the major open problems in modern cosmology, and PBHs provide a natural and compelling candidate, with the potential to constitute a significant fraction of it. Simultaneously, General Relativity may require modification, particularly in the early universe. In this work, we explore a novel inflationary scenario within Horndeski gravity, focusing on a subclass with a Galileon-type G3(ϕ,X) interaction, which induces an ultra-slow-roll phase near the end of inflation. This phase enhances the scalar power spectrum on small scales, leading to PBH formation, which are able to constitute a substantial part of DM. Our model accommodates standard inflationary potentials, remains consistent with Cosmic Microwave Background constraints, and can potentially generate observable signatures in the form of second-order gravitational waves.

Morning / 91

A f(R)esh look at the dynamics of modified gravity

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Afternoon / 92

From gravitating Skyrmions to QCD at finite density and back

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In the present talk I will describe the first analytic example of a gravitating Skyrmion of unit Baryonic charge in General Relativity minimally coupled to Skyrme model in (3+1) dimensions. I will describe the remarkable properties of this analytic solution and how such gravitating soliton gave rise to the first analytic solutions with non-vanishing Baryonic charge of the Skyrme model on flat space-times (clarifying why it is easier to solve the Einstein-Skyrme field equations rather than the Skyrme equations alone). At the end, I will describe the explicit construction of Euclidean wormholes of Baryonic charge 1 in the Euclidean version of Einstein Skyrme theory and their interpretation as Instantons of the theory

Afternoon / 93

Symmetric methods for long-time integration of partial differential equations

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We explore symmetric and discontinuous integrators for solving partial differential equations (PDEs) over long periods. Explicit solvers are Courant-limited and fail to preserve Noether symmetries, impacting their effectiveness in long-time integration scenarios. We thus explore symmetric (exponential, Padé, or Hermite) integrators, which are unconditionally stable and known to preserve certain Noether symmetries and phase-space volume, making them ideal for long-term computations. For linear hyperbolic or parabolic PDEs, these implicit integrators can be cast in explicit form, making them well-suited for long-time evolution. A matricization technique facilitates integration into a method-of-lines framework, enabling efficient parallelization on CPUs and GPUs.

We demonstrate the unconditional stability, efficiency and accuracy of symmetric methods in black hole perturbations in numerical general relativity and LISA source modelling. We extract Price tails and numerically simulate the Aretakis instability for extremal Kerr black holes. We also introduce methods for modeling discontinuities in linear hyperbolic or parabolic PDEs from distributional sources. In a method-of-lines context, this involves a discontinuous collocation method for spatial differentiation and a novel class of discontinuous time-steppers for temporal integration.

Parallel Session A / 95

Dynamics of Scalar-Field Quintom Cosmological Models

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We present a comprehensive dynamical analysis of scalar-field Quintom cosmological models,focusing on scenarios with exponential potentials and both quintessence and phantom compo nents. These models accommodate transitions across the phantom divide (w = −1), permittingrich cosmological behavior including multiple inflationary epochs and bouncing solutions. Em ploying a compact phase-space formulation, we identify critical points, classify their stability,and explore their physical interpretations–such as attractors linked to inflation and non-singular bouncing trajectories. We also incorporate spatial curvature and demonstrate the robustness of inflationary solutions under its influence. Linear perturbation theory is developed within theNewtonian gauge using gauge-invariant variables, enabling us to analyze the evolution of escalar perturbations in an extended phase space. This framework enhances predictive power for struc ture formation and cosmic history. Our findings provide foundational insights for constructing viable models of early- and late-time cosmic acceleration, grounded in scalar field dynamics [1, 2]. References

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Morning / 96

From Algorithms to Astrophysics: Machine Learning in Gravitational Wave Astronomy

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Machine Learning is finding diverse applications in the field of astrophysics and gravitational wave astronomy. This talk surveys our recent advancements in applying such methodologies. We demonstrate the utility of Deep Residual Networks (ResNets) in discovering new gravitational wave events from binary black hole mergers. Next, we present the calculation of the astrophysical detection probability in the framework of a machine-learning detection code. Furthermore, we discuss the application of deep neural networks in predicting the properties of neutron stars in an alternative theory of gravity and, finally, we present the application of normalizing flows within Preconditioned Monte Carlo methods to significantly accelerate Bayesian parameter estimation for binary neutron star post-merger signals.

Morning / 97

Resonance-induced eccentricity in spherical extreme-mass-ratio inspirals

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It has been shown that spherical orbits around Kerr black holes remain spherical (zero eccentricity) under the influence of gravitational radiation reaction in the adiabatic limit. I will show that spherical orbits in non-Kerr black holes that still preserve most of the good qualities and symmetries of Kerr spacetime can access certain resonances in such a way that an initially spherical inspiral acquires nonzero eccentricity and becomes nonspherical. The strength of resonant excitation of eccentricity depends on the initial position and inclination of the integrable EMRI system. The harmonics of gravitational waves emitted from these inspirals undergo a frequency modulation as the orbit "metamorphoses"from spherical to nonspherical, due to the effect of resonant eccentricity excitation. The gain that low-amplitude harmonics experience in these oligochromatic EMRIs, due to resonances, may be detectable with future spaceborne detectors and serves as an indicator of non-Kerrness of the background spacetime.

Morning / 99

NA

Afternoon / 100

Closing remarks

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Afternoon / 101

Open EFT for gravity and gauge fields

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I will discuss how to construct an EFT that captures non-conservative effects based on recent developments in Schwinger-Keldysh (SK) EFTs. The leading dissipative terms added to the SK action deform the conservation laws in a controlled manner, as demonstrated by two representative examples: Maxwell's theory and general relativity. I will also briefly discuss phenomenological applications in inflation.

Afternoon / 102

On the geometric origin of the energy-momentum tensor improvement terms

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I will show how the Belinfante-Rosenfeld improvement terms, that render the energy-momentum tensor symmetric, emerge by coupling the matter to the affine-connection. In this sense the improvement terms correspond to the hypermomentum (microproperties) of matter. I will show how this is realized in two standard examples, the Maxwell field and the Dirac field. I will also show how the connection-matter couplings can also result in a traceless energy tensor when the theory is invariant under frame rescalings, by revisiting the known example of a conformally invariant scalar field. Generalizations to higher derivative as well as higher spin theories will also be discussed.

Morning / 103

10 years of Gravitational-Wave Tests of GR

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Testing the relativistic strong-field dynamics of general relativity (GR) has been a major motivation in the century-long quest to detect gravitational waves (GWs). Since the first GW detection in 2015, we have been probing the dynamics of gravity and the nature of compact objects, by analysing the observed signals from coalescing black holes and neutron stars. In this talk, I will review the variety of tests that have been developed for this purpose and the constraints that they have placed on alternative scenarios to our standard GR model for compact binaries. I will also discuss the most promising directions and the most pressing challenges ahead as we continue probing fundamental physics with upcoming observations from the current generation of detectors at design sensitivity, as well as with the next generation of interferometers, on the ground and in space.