

QGSKY Annual Meeting 2025 - Catania

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UniCt - DFA

Book of Abstracts

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The Roman Galactic Exoplanet Survey: expanding our vision on extrasolar planets

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The incoming Roman Galactic Exoplanet Survey promises to detect more than 1500 bound planets by the microlensing technique. These planets are particularly precious as they cover a corner of the parameter space barely touched by other methods (1-10 au orbits down to Mars mass planets). In addition, hundreds of free-floating planet detections will shed light on these mysterious wanderers. The Italian contribution consists in the development of the most efficient tools for fast and robust interpretation of microlensing events, including advanced computational algorithms that are now a standard in the community. In preparation of the Roman survey, we have already performed a precursor survey with the Euclid space telescope. Thousands of past microlensing events can be reviewed with these new data upgrading the scientific information of twenty years of surveys.

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New avenues to detect light bosons and gravitational waves

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Light bosons such as the QCD axion are leading dark matter candidates, with photon couplings enabling both laboratory and astrophysical searches. I will highlight new cavity-based experiments, in particular FLASH, which makes use of high- Q resonators and quantum sensors to open previously inaccessible parameter space and even probe high-frequency gravitational waves. Complementing these efforts, I will present Green Bank Telescope searches for transient radio signals from axion substructures, targeting $m_a \sim 33\text{--}42 \mu\text{eV}$ with high spectral resolution. Together, these approaches illustrate how precision cavities and astrophysical observations provide powerful and complementary paths to light up the dark Universe.

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Pre-geometric Gravity and Emergent Cosmology

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The gravitational interaction, in the form of the Einstein–Cartan theory, can emerge from a pre-geometric gauge theory via a mechanism of spontaneous symmetry breaking. In this context, pre-geometry refers to the lack of a metric structure for spacetime, which can be recovered only in the spontaneously broken phase, below a critical energy near the Planck scale. The fundamental field of this formulation à la Yang–Mills is the gauge potential of the (anti-)de Sitter group, which yields both the tetrads and the spin connection of the Lorentz group after the spontaneous symmetry

breaking. The Higgs-like field that allows such dynamics is a supermassive boson with implications for Cosmology. In the ultra-high-energy limit of the unbroken phase where the gauge symmetry is restored, the metric theory of gravity is then superseded by the pre-geometric one and all notions of spacetime singularity cease to be meaningful. At a cosmological level, a pre-geometric de Sitter universe is an exact and regular solution of the theory, and can represent the pre-geometric state of the early Universe from which the inflationary epoch emerges. This framework can thus provide a simple resolution for the problem of the Big Bang singularity.

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Equivalence principle violation in metric-affine gravity

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We explore violations of the equivalence principle within the framework of metric-affine gravity and establish their connection to finite-temperature effects. Thermal corrections to particle dynamics—originally derived in quantum field theory—can be reformulated in a Riemannian setting, leading to a temperature-dependent shift in the gravitational-to-inertial mass ratio. We show that the ensuing deviation from geodesic motion admits an equivalent description in metric-affine gravity, where the non-metricity tensor provides a purely geometric mechanism for modifying Newton's law. Additionally, we introduce a generalized Fermi–Walker derivative adapted to non-Riemannian geometries, which provides a direct geometric signature of the equivalence principle breakdown in full generality. Potential implications for experimental tests such as lunar laser ranging and the Planetary Ephemeris Program (PEP) are also discussed.

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Beyond the Standard Candle: Cosmology with Quasars

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I introduce quasars as new cosmological probes, leveraging the UV–X-ray luminosity relation and the Lusso & Risaliti catalog to build an extended Hubble diagram up to $z \sim 7$. I present joint analyses with several crucial probes as SNe Ia, BAO, DES, and CMB to test Λ CDM and dark energy models. The results show that simple model extensions fail to resolve current tensions, while interacting dark sector scenarios show improved consistency. This highlights the key role of quasars in bridging the gap between late and early-Universe observations.

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Selecting modified gravity through Noether symmetries: the case of Gauss-Bonnet cosmology

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Throughout the years, various theoretical and experimental findings have challenged the validity of General Relativity at both ultraviolet and infrared scales. In an effort to address some of these shortcomings, extended gravity models considering modifications of the gravitational action have been proposed. One possible extension involves including the so-called Gauss-Bonnet term in the Lagrangian. In doing so, additional geometric contributions can effectively play the role of a cosmological constant, without the need to invoke dark energy models. Among the different possible formulations, the starting action can be selected using the Noether symmetry approach, a physically motivated criterion based on Noether's theorem, aimed at identifying viable models that exhibit symmetries. We demonstrate that applying this approach to a scalar-tensor Gauss Bonnet model allows for a reduction of the dynamical system and the associated minisuperspace, thus enabling the derivation of exact solutions to the equations of motion. In particular, we consider a cosmological context, where the method proves useful in addressing both the early- and late-time accelerated phases of the Universe.

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Recent Advances in the Pre-Big Bang Scenario

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I will discuss recent progress in string cosmology. Including all-order α' corrections leads to a richer and consistent picture of the pre-Big Bang universe. In this framework, the early universe can evolve smoothly through a non-singular bounce, connecting two dual phases without encountering a singularity. When a suitable potential is added for the dilaton, this setup can also stabilize the string coupling and lead to realistic late-time cosmologies, such as matter-dominated or inflationary expansion. These theoretical improvements open up new phenomenological possibilities. During the high-curvature string phase, small changes in the sound speed of perturbations can greatly enhance the production of primordial black holes. Similarly, recent observations from NANOGrav hint at a gravitational wave background that could be naturally explained by non-minimal versions of the pre-Big Bang scenario. These results suggest non-perturbative string correction, could leave observable imprints in today's universe.

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Sum rules for Chiral, Conformal and Gravitational Anomaly and the Hadronic Gravitational Form Factors

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We present a unified framework for chiral, gravitational, and conformal anomaly sum rules using momentum-space conformal field theory and dispersive techniques. We show that the longitudinal sectors of the one-loop anomaly correlators (AVV, TTA, and TJJ) obey universal area-law sum rules, governing the spectral flow between anomaly poles and the continuum. This elucidates how massless anomaly poles emerge in the conformal limit and how they are replaced by dispersive strength at finite momentum. We perform the perturbative QCD analysis of the non-Abelian TJJ vertex at one loop, extracting the conformal trace-anomaly form factor and its spectral density. Within the factorization formalism, this provides a perturbative input for dispersive studies of hadronic matrix elements, relevant to the high-momentum-transfer behavior of the pion and proton gravitational form factors and their possible contribution to the Ji sum rule.

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Symmetry-Based Selection of Gravitational Theories with Topological Terms

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I will explore extended theories of gravity that include topological terms, focusing on how symmetry principles can be used to identify physically viable models. Symmetries provide a natural criterion for selecting and constraining the allowed gravitational actions and they also play a central role in shaping the underlying geometric and topological structure of spacetime. By employing these criteria, one can simplify the cosmological field equations and formulate the problem within the ADM formalism, paving the way toward a quantum cosmology framework. Interestingly, the same symmetry arguments that guide the selection of the theories can also be shown to generate or constrain the topological invariants themselves. This symmetry-topology interplay offers a unified perspective for studying both the classical and quantum aspects of modified gravitational dynamics.

Talks / 14

Evanescent 2D black holes: singularity resolution via a negative central charge

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For this presentation, we analyze a 1-loop corrected extension of the classical CGHS model of two-dimensional dilaton gravity. The 1-loop effective action consists of three key components, the first being the standard non-local Polyakov action, accounting for quantum fluctuations of matter fields, while the second is a Polyakov-type term constructed using an auxiliary flat metric, which captures fluctuations of ghost fields associated with the underlying reparametrization invariance. The third term is a local counterterm that preserves the flatness of the auxiliary metric, guarantees the exact solvability of the model, and ensures that 2D Minkowski space remains an exact solution of the backreacted equations. The analysis is performed in a regime where the total central charge of the theory is negative. In doing so, the classical spacetime singularity is resolved, suggesting the possible preservation of unitarity.

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A covariant approach to the Dirac field in LRS space-times**Author:** Giuseppe De Maria¹¹ *Istituto Nazionale di Fisica Nucleare***Corresponding Author:** giuseppe.demaria@edu.unige.it

In this talk, I will report on a new covariant reformulation of the Dirac field in General Relativity, based on its polar decomposition allowing a fluid-like spinorial description without the explicit use of tetrads or Clifford matrices. Working in the “spinorial” signature $(+, -, -, -)$, a fully covariant $(1+1+2)$ framework is presented, in which the velocity and spin fields are the generators of time-like and space-like congruences. This formulation provides a geometrically transparent way to analyze a self-gravitating Dirac field and its compatibility with Locally Rotationally Symmetric (LRS) spacetimes of types I, II, and III.

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X17 and anomalies in particle physics**Author:** Raoul Serao¹¹ *Istituto Nazionale di Fisica Nucleare***Corresponding Author:** rserao@unisa.it

In this talk, I will present the experimental results that have motivated the introduction of a possible fifth fundamental force, mediated by a massive vector boson. I will also discuss how the inclusion of such a massive vector mediator could help address certain discrepancies between the theoretical predictions of the Standard Model and recent experimental observations.

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Probing Large Extra Dimensions induced Primordial Black Holes through Stochastic Gravitational Wave Background**Authors:** Giuseppe Filiberto Vitale¹; Gaetano Lambiase¹; Luca Visinelli²; Tanmay Kumar Poddar¹¹ *Istituto Nazionale di Fisica Nucleare*² *Università degli Studi di Salerno***Corresponding Authors:** giuseppeg.vitale@gmail.com, tanmaypoddar06@gmail.com, lambiase@sa.infn.it, lvisinelli@unisa.it

We investigate the stochastic gravitational wave background (SGWB) generated by primordial black hole (PBH) encounters in the framework of large extra dimensions (ADD model).

In this scenario, gravity propagates in $D=4+n$ dimensions, modifying the short-distance gravitational potential.

We derive the spectral energy distribution dE/df for PBH–PBH interactions, where a localized burst of gravitational-wave radiation is generated near the pericenter and compute the total emission by statistically averaging over realistic velocity distributions and impact parameter probabilities within virialized dark-matter halos.

The emission spectrum is separated into two regimes according to the pericenter distance: a higher-dimensional (ADD) channel for $r < R(n)$, and a four-dimensional one for $r > R(n)$, both weighted by the same 4D geometric cross section.

The resulting averaged spectrum is then integrated over redshift to obtain the contribution to the stochastic background $\Omega_{\text{GW}}(f)$.

This analysis suggests that stochastic gravitational-wave observations can probe both the existence of large extra dimensions and primordial black hole populations.

We show that the inclusion of extra-dimensional effects enhances the high-frequency component of the SGWB, potentially leaving observable imprints accessible to the next generation of GW detectors.

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Radiation-reaction correction to scattering binary dynamics at the Next-to-Leading Post-Newtonian Order

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In this work, we compute the next-to-leading-order radiation-reaction modification to the harmonic coordinate quasi-Keplerian parametrization of the binary dynamics, the two bodies undergoing a scattering process. The solution for the radiation-reaction corrections to the orbital parameters is examined both in the time domain and in the frequency domain. The knowledge of the radiation-reaction corrected orbit is a key ingredient for the calculation of the fractional 3.5PN corrections to the radiative losses as well as to the radiative multipole moments needed to build up the waveform at the same accuracy.

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Neutron interferometry as a probe for the Dark Sector of the Universe

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Neutrons can play a crucial role in exploring possible extensions of the Standard Model involving hidden sectors. Among the proposed scenarios, the mirror matter model predicts the existence of mirror neutrons as viable dark matter candidates. In this work, we investigate how neutron-mirror neutron mixing could manifest through two complementary interferometric signatures. The first is a geometric phase acquired by ordinary neutrons, detectable through a dedicated interferometric scheme. The second relies on an alternative setup based on bandpass multilayers, designed to measure intensity variations of the neutron beam.

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Scalar- and Vector-Dark Matter Admixed Neutron Stars

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The effect of dark scalar- and vector-mediated interactions on the stellar structure of dark matter admixed neutron stars are investigated employing the two-fluid formalism of the TOV equations. Three different nuclear equations of state (BSk22, MPA1 and APR4) are used to describe the baryonic sector, while the dark component consists of fermionic particles treated within a relativistic mean field framework. Both linear and quadratic scalar interactions with the dark fermion are considered, including a quartic self-interaction in the latter case. The parameters of the dark matter models are inferred via a Bayesian analysis that incorporates data from NICER observations and binary neutron star merger detections. The resulting neutron star configurations develop dark matter cores, leading to more compact objects with smaller masses and radii. Scalar interactions are generally found to have a weaker impact on the stellar structure than vector-mediated ones, though quantitative differences arise.

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Metric-Affine Theories of Gravity

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Extensions of equivalent representations of gravity are discussed in the metric-affine framework. First, we focus on: (i) General Relativity, based upon the metric tensor whose dynamics is given by the Ricci curvature scalar R ; (ii) the Teleparallel Equivalent of General Relativity, based on tetrads and spin connection whose dynamics is given by the torsion scalar T ; (iii) the Symmetric Teleparallel Equivalent of General Relativity, formulated with respect to both the metric tensor and the affine connection and characterized by the non-metric scalar Q with the role of gravitational field. They represent the so-called Geometric Trinity of Gravity, because, even if based on different frameworks and different dynamical variables, such as curvature, torsion, and non-metricity, they express the same gravitational dynamics. Starting from this framework, we construct their extensions with the aim to study possible equivalence. We discuss the straightforward extension of General Relativity, the $f(R)$ gravity. With this paradigm in mind, the dynamical equivalence is achieved if boundary terms are considered, that is $f(T-B)$ and $f(Q-B)$ theories. Finally, we study the projective transformations in Metric-Affine Theories, considering the general non-metric quadratic gravity, i.e. curvature and nonmetricity. We discuss the conditions under which a projective transformation conserves the Lagrangian. Then we proceed to compute the pertinent geometric variables of a subclass of the most general projective transformations.

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FIELD QUANTIZATION AND NEUTRINO MIXING IN EINSTEIN-CARTAN SPACETIME

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Within the framework of quantum field theory, we investigate neutrino oscillations in the presence of a torsion background. Adopting the Einstein–Cartan theory, we analyze two distinct scenarios: a constant torsion field and a torsion field linearly dependent on time. In both cases, we derive modified neutrino oscillation formulas that explicitly depend on the spin orientation of the particles. The torsion-induced energy splitting alters both the oscillation amplitudes and frequencies. The effect reaches its maximum when the torsion magnitude is comparable to the neutrino masses and for very low neutrino momenta, while it vanishes for large torsion values. Furthermore, for torsion strengths significantly exceeding neutrino masses and momenta, neutrino oscillations are strongly suppressed. We also examine the implications of torsion on the CP asymmetry of oscillations. Finally, we discuss the potential relevance of these effects for future experimental investigations, such as the PTOLEMY project, aimed at detecting the cosmological neutrino background, where neutrinos possess extremely low momenta.

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The Maldacena-Shenker-Stanford Conjecture in General Relativity and beyond

Authors: Carmen Ferrara¹; Salvatore Capozziello²; Sara Cesare³

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The Maldacena-Shenker-Stanford (MSS) conjecture establishes the existence of an upper bound to the Lyapunov exponent of a thermal quantum system with a large number of degrees of freedom. Holographic calculations of out-of-time order correlation functions (OTOCs), which are conveniently employed as indicators of the magnitude of quantum chaos, motivate such a statement, leading to the identification of black holes as the fastest scramblers in nature. This talk aims to give an insight into the universality of the MSS conjecture. We claim that it can be violated in various metric $f(R)$ gravity models as a consequence of the propagation of metric instabilities in a degenerate Schwarzschild-de Sitter background. Then, following a detailed investigation of the Extended Geometric Trinity of Gravity, a set of three dynamically equivalent theories arising from an ad-hoc extension of the corresponding constituting theories of the Trinity of Gravity (namely General Relativity, the Teleparallel Equivalent to General Relativity, and the Symmetric Teleparallel Equivalent to General Relativity), we conclude that the violation occurs independently of the conferred representation of gravity in such a framework.

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One-loop gravitational action and the cosmological constant problem

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Usual calculations of the (Euclidean) effective action in quantum gravity, performed within the heat-kernel formalism, give rise to quartic and quadratic UV-sensitive contributions (Planck scale) to the vacuum energy. The comparison of this result to the observed value of the vacuum energy unveils

a severe naturalness problem, the strongest facet of the long-standing “cosmological constant problem”. In this talk, I will show that the appearance of these UV-sensitive terms in usual calculations is due to an improper treatment of the path integral measure and of the UV physical cutoff of the theory. When the diffeomorphism invariant measure proposed by Fradkin and Vilkovisky is used, and the UV physical cutoff properly introduced, the radiative correction to the vacuum energy turns out to be only logarithmically sensitive to the UV scale. In this respect, the Fradkin-Vilkovisky measure is sometimes claimed not to be diffeomorphism invariant due to the presence in it of non-covariant g^{00} factors of the time-time component of the inverse metric. I will show that such a claim is incorrect, and that, on the contrary, these g^{00} factors turn out to be crucial to ensure the diffeomorphism invariance of the path integral measure.

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Running of the Newton and cosmological constant in quantum gravity

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Considering the Einstein-Hilbert truncation for the (Euclidean) quantum gravity action, I will mainly focus on the derivation of the Wilsonian renormalization group (RG) equations for the Newton and cosmological constant. I will show that particular attention has to be paid to the path integral measure and to a proper introduction of the physical running scale. It will turn out that, differently from other implementations in previous literature, the RG flow of the effective action is not driven by the fourth power of the running scale. This gives rise to a significantly different RG flow. In particular, I will show that there is no sign of the non-trivial UV-attractive fixed point of the so called asymptotic safety scenario. I will also discuss more general aspects related to its RG structure, with particular reference to its effective (or fully fledged) field theory nature.

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Naturalness of the Higgs boson mass. Impact of gravity

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According to usual calculations in quantum field theory, both in flat and curved spacetime, the mass of a scalar particle is quadratically sensitive to the ultimate scale of the theory, the UV physical cutoff. Elaborating on previous work in quantum gravity, I will show that (when due attention is paid to the path integral measure and to the way the physical cutoff is introduced) the mass of the scalar particle presents only a (mild) logarithmic sensitivity to the cutoff. This result is obtained without resorting to any supersymmetric embedding of the theory. Moreover, no regularization scheme (as dimensional regularization), where power-like divergences are absent by construction, is used.

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(A)dS dilatonic black holes

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The Weak Gravity Conjecture (WGC) was originally formulated for U(1) gauge theories in asymptotically flat spacetime, ensuring the decay of extremal Reissner-Nordström black holes and preventing the existence of stable remnants. This principle implies that gravity must be the weakest force for at least one particle, a condition consistent with observations. Since its proposal, several extensions have been studied, with particular attention to Einstein-Maxwell-dilaton theories and non-flat spacetimes. In this talk, I will discuss the existence conditions and properties of dilatonic black hole solutions with non-trivial dilaton potential in asymptotically (A)dS spacetimes. I will highlight how the strength of the dilaton coupling affects these solutions and examine the resulting implications for formulating an appropriate version of the Weak Gravity Conjecture in this setting.