Hellenic Society on Relativity, Gravitation and Cosmology

NEB - 17
RECENT DEVELOPMENTS IN GRAVITY

Book of Abstracts

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PLENARY SPEAKERS

ASHTEKAR Abhay

(Penn State University)

Quantum Gravity in the Sky: Interplay between fundamental theory and observations

Observational missions have provided us with a reliable model of the evolution of the universe starting from the last scattering surface all the way to future infinnity. Furthermore given a specific model of inflation, using quantum field theory on curved space-times this history can be pushed back in time to the epoch when space-time curvature was some 62-orders of magnitude larger than that at the horizon of a solar mass black hole! However, to extend the history further back to the Planck regime requires input from quantum gravity. I will discuss a proposal that provides first steps in this direction. Specically, principles that link quantum geometry and Heisenberg uncertainties in the Planck epoch with late time physics lead to specific initial conditions and observational predictions. There is a surprising link between the ultraviolet to the infrared that open up the possibility of seeing Planck scale effects in the CMB.

BARBERO Fernando

(Universidad Complutense de Madrid)

Parametrized field theories: the role of boundaries and gauge symmetries

Parametrized field theories are important test beds to understand the role of diffeomorphisms in field theories and how they can be dealt with when approaching their quantization. Here I will concentrate on the Hamiltonian formulation of parametrized field theories defined on bounded spatial regions and also on the interplay between internal gauge symmetries and parametrization. The correct treatment of these singular systems requires a thorough application of appropriate geometric methods designed to deal with the complications posed by the additional ingredients present in them.

BRANDENBERGER Robert

(McGill University, Montreal)

String Theory and Early Universe Cosmology

I will review challenges to construct a viable early universe theory based on the fundamental principles of superstring theory.

CAPOZZIELLO Salvatore
(University of Napoli "Federico II")

Constraining models of extended gravity using Gravity Probe B and LARES experiments

We consider models of extended gravity and in particular, generic models containing scalar-tensor and higher-order curvature terms, as well as a model derived from noncommutative spectral geometry. Studying, in the weak-field approximation (the Newtonian and post-Newtonian limit of the theory), the geodesic and Lense-Thirring processions, we impose constraints on the free parameters of such models by using the recent experimental results of the Gravity Probe B (GPB) and Laser Relativity Satellite (LARES) satellites. The imposed constraint by GPB and LARES is independent of the torsion-balance experiment, though it is much weaker.

DAFERMOS Mihalis
(Cambridge/Princeton)

The interior of dynamic vacuum black holes and the strong cosmic censorship conjecture

I will discuss recent work on black hole interiors for dynamical vacuum spacetimes (without any symmetry assumptions) and what this means for the question of the nature of generic singularities in general relativity and the celebrated strong cosmic censorship of Penrose. This is joint work with Jonathan Luk (Stanford).

KOKKOTAS Kostas
(University of Tübingen)

Gravitational Waves from Neutron Stars

Neutron stars are the densest objects in the present Universe. These unique and irreproducible laboratories allow us to study physics in some of its most extreme regimes. The multifaceted nature of neutron stars involves a delicate interplay among astrophysics, gravitational physics, and nuclear physics.
The recent direct detection of gravitational waves turned gravitational physics into an observational science. Gravitational Waves by tight binary neutron star systems, supernovae explosions, non-axisymmetric or unstable spinning neutron stars will provide us with a unique opportunity to make major breakthroughs in gravitational physics, in particle and high-energy astrophysics.
The focus of the talk will be on neutron star as sources of gravitational waves and their impact on astrophysics and nuclear physics.

LAGUNA Pablo
(Georgia Tech)

Relativistic Tidal Disruption Events

I will review the current status of modeling relativistic tidal disruption events and the prospects for detecting multi-messenger signatures. These tidal disruption events involve ultra-close encounters of stars with massive black holes. In some scenarios, the tidal disruption yields a flare followed by the prompt formation of a puffed disk accreting at a highly super-Eddington rate.

LEHNER Luis
(Perimeter Institute)

Promises, challenges & (some) answers in the era of gravitational wave astronomy.

With the era of gravitational wave astronomy resoundingly started, it is important to step back and assess the theoretical challenges lying ahead to take full advantage of the ability to detect and analyze gravitational wave data. This talk will discuss a few of such challenges and how a combination of observations will be instrumental to ensure the most physics can be extracted.

LOLL Renate
(Radbound University, Nijmegen)

Causal Dynamical Triangulations - a progress report

I will summarize and discuss progress in nonperturbative quantum gravity, based on Causal Dynamical Triangulations (CDT), with emphasis on the physical case of four spacetime dimensions, and covering the most important recent developments. These include a refined understanding of CDT's phase structure and second-order phase transition(s), further evidence of semi-classical behaviour and the applicability of renormalization group methods in the 'background-free' Planckian regime of the theory.

PSALTIS Dimitrios
(University of Arizona)

The Event Horizon Telescope

The Event Horizon Telescope will offer near horizon-scale resolution for imaging the shadows cast by several supermassive black holes on the emission from the surrounding accretion flows. This will allow us to probe the spacetimes of black holes, identify the role and topology of magnetic fields near the horizons of black holes, the dominant processes of emission in accretion flows, and the location of jet launching, when present. I will present the current status of this project and discuss new techniques that will exploit the unprecedented capabilities of the Event Horizon Telescope in probing supermassive black holes.

SHOEMAKER Deidre
(Georgia Tech)

Numerical Relativity and the first Detection of Gravitational Waves

For decades, both the gravitational wave and numerical relativity communities has worked to prepare for the era of gravitational wave astronomy. With the first observation of two black holes merging (GW150914), quickly followed by a second (GW151226), the new era of gravitational wave astronomy has begun. I will present the role that numerical relativity played in the unveiling of the gravitational wave sky and anticipate how it might improve our understanding of astrophysics.

UNRUH William
(University of British Columbia)

Dumb hole - experimental analogs to black holes

Black hole evaporation radiation will be very difficult to see. However it was shown 35 years ago that analogs (sonic and other) can also have horizons and can emit thermal radiation. This talk will amongst other things describe recent experiments which demonstrate the reality of such radiation.

WALD Robert
(University of Chicago)

Canonical Energy and Black Hole Stability

We review the canonical energy approach for determining the stability of black holes (in arbitrary spacetime dimensions) to axisymmetric perturbations. Positivity of canonical energy implies mode stability, whereas failure of positivity implies the existence of perturbations that cannot approach a perturbation towards another stationary black hole at late times. It is shown that positivity of canonical energy is equivalent to thermodynamic stability. It is shown that the "kinetic energy" contribution to canonical energy is always positive, thereby allowing one to obtain a variational principle formula for growth rate of unstable perturbations. The relationship between canonical energy and the energy of the Regge-Wheeler quantity used in the Schwarzschild stability proof of Dafermos, Holzegel, and Rodnianski is discussed.

PARALLEL SESSIONS

Mathematical Relativity

AHMED Jamil

(Quaid-i-Azam University)

Quantum tunneling from black strings

In this talk I would like to give analytical expression of temperature of radiations from black strings. I will explain semi-classical approach and WKB approximation to do this.

ANABALON Andres

(UAI, Chile)

Holographic Equation of State in Fluid/Gravity Duality

We establish a precise relation between mixed boundary conditions for scalar fields in asymptotically anti de Sitter spacetimes and the equation of state of the dual fluid. We provide a detailed derivation of the relation in the case of five bulk-dimensions for scalar fields saturating the Breitenlohner-Freedman bound. As a concrete example, we discuss the five dimensional scalar-tensor theories describing dark energy in four dimensions.

BENAKLI Karim

(LPTHE)

On Swift Gravitons

We use the method of characteristics to study superluminal graviton (thereof called swift graviton) propagation in theories of higher curvature gravity of the form (Riemann)2, (Riemann)3, ∇2(Riemann)2 and (Riemann)4. We consider a pp-wave background. When probed by gravitons with an appropriate polarisation, several of the gravitational theories under consideration exhibit characteristic hypersurfaces outside the flat spacetime light-cone.

CUADROS-MELGAR Bertha
(University of Sao Paulo)

Dynamical transition from AdS to a Lifshitz black hole

We study the holographic dual of a quenching mechanism on a strongly coupled CFT that is driven to a non-relativistic fixed point with Lifshitz scaling for a dynamical exponent z close to unity. On the gravity side this amounts to finding a dynamical bulk solution which interpolates between AdS and Lishitz spacetimes as time evolves. We show that an asymptotically Lifshitz black hole is always formed in the final state. This indicates that it is impossible to reach the vacuum state of the Lifshitz theory from the CFT vacuum as a result of the proposed quenching mechanism. The nonequilibrium dynamics following the breaking of the relativistic scaling symmetry is also probed using both local and non-local observables.

DEMIR Durmus
(Izmir Institute of Technology)

Curvature-Restored Gauge Invariance and Ultraviolet Naturalness

In this talk it will be shown that, $(a\Lambda^2 + b|H|^2)R$ in a spacetime of curvature R is a natural ultraviolet (UV) completion of $(a\Lambda^4 + \Lambda^2|H^2)$ in the flat-spacetime Standard Model (SM) with Higgs field H, UV scale Λ and loop factors a, b. This curvature completion rests on the fact that a Λ-mass gauge theory in flat spacetime turns, on the cut-view $R = 4\Lambda^2$, into a massless gauge theory in curved spacetime. It provides a symmetry reason for curved spacetime, wherein gravity and matter are both low-energy effective phenomena. Gravity arises correctly if new physics exists with at least 63 more bosons than fermions, with no need to interact with the SM and with dark matter as a natural harbinger. It can source various cosmological, astrophysical and collider phenomena depending on its spectrum and couplings to the SM.

EMELYANOV Viacheslav
(Karlsruhe Institute of Technology)

QED in the background of evaporating black holes

Far away from black holes, one might expect that quantum field quantization performed in Minkowski space is a good approximation. Indeed, all experimental tests in the particle colliders reveal no deviations so far. Nevertheless, black holes should leave imprints of their presence in quantum processes. In this talk, we shall discuss several imprints of small evaporating black holes in QED in the weak gravity regime.

FRODDEN Ernesto
(Centro de Estudios Cientificos, Chile)

Nöther charges for asymptotic (a)dS spacetimes with tetradic-connection variables

Gauge symmetries are seen as playing a role in the explanation of black hole entropy. This is so through the so called surface degrees of freedom which would become relevant at the quantum level ('soft hair'). We review the deduction of the surface degrees of freedom for gravity written in the tetrad-connection variables in the language of forms. Cosmological constant is considered and consequently the influence of an Euler term in the action is taking into account. As a preliminary check we show that, when gauge symmetries are promoted to exact symmetries, the first law of black hole mechanics is recovered for the (anti-) de Sitter Schwarzschild solution family.

GOHAR Hussain
(University of Szczecin, Poland)

Varying Constants theories from Thermodynamics perspective

We formulate the basic framework of thermodynamical entropic force cosmology which allows variation of the gravitational constant G and the speed of light c. Some cosmological solutions are given and tested against combined observational data (supernovae, BAO, and CMB). We observationally test that the fit of the data is allowed for the speed of light c growing and the gravitational constant G diminishing during the evolution of the universe. We also obtain a bound on the variation of c to be $\Delta c / c \propto 10^{-5} > 0$, which is at least one order of magnitude weaker than the quasar spectra observational bound.

GUMRUKCUOGLU A. Emir
(Imperial College London)

Suppressing Lorentz violations in observables and the mixed derivative extension of Horava Gravity

A major obstacle for any Lorentz violating gravity theory is the restoration of Lorentz invariance at low energies in the matter sector, where observational constraints are very stringent. There are several approaches to circumvent this problem, although realizing these in concrete theoretical setups is challenging. My main focus will be the mechanism proposed by Pospelov and Shang (2010), which restricts the Lorentz violations to the gravity sector at tree level and which then percolate the matter sector only though graviton loops. In this set-up, one can keep the Lorentz-violating terms in the matter sector under control, although in the context of Horava gravity, the vector graviton loops lead to a technical naturalness problem. After a short review of Horava gravity with an emphasis on theoretical consistency requirements and observational constraints on the Lorentz breaking, I will discuss the mixed-derivative extension of the theory, designed to resolve the naturalness problems in the Pospelov-Shang mechanism.

JOSSET Thibaut
(Aix-Marseille Université)

Statistical mechanics of reparametrization-invariant systems

The serious modifications of the notions of time and energy in the (general) relativistic context apparently prevent us from applying the standard tools of statistical mechanics. Nevertheless, some progress has recently been done in the simple case of reparametrization-invariant systems described by a single Hamiltonian constraint. If the system splits into two subsystems, one can define the equilibrium state of one part with respect to the other one. Moreover, a generalization of the zeroth law naturally arises. Finally, ongoing work seem to indicate that interaction should play a crucial role in presence of additional gauge degrees of freedom. This new approach to relativistic statistical mechanics is only a first step in a better understanding of thermodynamical properties of spacetime.
G. Chirco, T. Josset, and C. Rovelli, "Statistical mechanics of reparametrization-invariant systems. It takes three to tango.", Classical and Quantum Gravity, vol. 33, no. 4, p. 045005, 2016. arXiv:1503.08725

KRSSAK Martin
(IFT, Sao Paulo State University)

Local Lorentz Invariance in Teleparallel Gravity Models

Teleparallel gravity is a well-known alternative approach to general relativity and construct modified gravity theories. But, it was known to suffer from the problem of violating the local Lorentz invariance, which was particularly sever in the modified case. In this talk, I will show how to avoid this problem and define teleparallel gravity in a locally Lorentz invariant way. I will show that this invariance has slightly different interpretation than we are used to in general relativity and I will try to understand its consequences.

MARKAKIS Charalampos
(University of Illinois Urbana-Champaign)

Acoustical metric and canonical fluid dynamics in numerical relativity

Gravitational waves from neutron-star and black-hole binaries carry valuable information on their physical properties and probe physics inaccessible to the laboratory. Neutron stars can be well-modelled as simple barotropic fluids during the part of binary inspiral most relevant to gravitational wave astronomy, but the crucial geometric and mathematical consequences of this simplification have remained computationally unexploited. In particular, Carter and Lichnerowicz have described barotropic fluid motion via classical variational principles as conformally geodesic. Moreover, Kelvin's circulation theorem implies that initially irrotational flows remain irrotational. Finally, the acoustical metic formulations of Christodoulou and Unruh can be utilized to evolve the Hamiltonian of a fluid element. Applied to numerical relativity, these concepts lead to novel Hamiltonian or Hamilton-Jacobi schemes for evolving fluid flows in numerical general relativity.

MARKEVICIUTE Julija
(University of Cambridge)

Stirring black holes: a new mechanism for violating cosmic censorship in AdS4

In this talk I will present our current work on AdS_4 solitons and black holes with a rotating boundary. The rotation profile is dipolar and depends on the polar angle and a parameter, ϵ These solutions exhibit an intriguing behavior when the strength of rotation is increased. As $\epsilon \to 2$ the horizon area of the large branch of black holes increases without bound and enters a scaling regime. We argue that this simple setup provides a natural scenario for the violation of weak cosmic censorship.

MELAS Evangelos
(University of Athens)

Asymptotic symmetries in 3-dim general relativity: the b(2,1) case. I. General results.

The ordinary Bondi-Metzner-Sachs (BMS) group B is the common asymptotic symmetry group of all asymptotically flat Lorentzian space-times. As such, B is the best candidate for the universal symmetry group of General Relativity (G.R.). However, in studying quantum gravity, space-times with signatures other than the usual Lorentzian one, and complex space-times, are frequently considered. For this purpose McCarthy constructed generalisations of *B* appropriate to these other signatures and complex space-times. Here, we follow this programme for 3-dim G.R. and construct for this case, for all signatures and complex space-times, all possible asymptotic symmetry groups in all asymptotic directions with all possible notions of asymptotic flatness. There are such groups. The relationships between these various groups are described. Strongly continuous unitary irreducible representations (IRs) of B(2,1), the analogue of B in three space-time dimensions, are analysed in the Hilbert topology. It is proved that that all induced IRs of B(2,1) arise from IRs of compact `little groups'. It follows that some IRS of B(2,1) are controlled by the IRs of the finite symmetry groups of regular polygons in ordinary Euclidean 2-space. It is proved that all IRS of B(2,1) are obtained by Mackey's semi-direct product theory notwithstanding the fact that B(2,1) is not locally compact in the employed Hilbert topology. The paper closes with the explicit construction of the IRs of B(2,1).

MOSCHIDIS Georgios
(Princeton University)

Superradiant instabilities for short-range non-negative potentials on Kerr spacetimes

The scalar wave equation on subextremal Kerr spacetimes does not admit exponentially growing or time-periodic mode solutions, as was established by Whiting and Shlapentokh-Rothman, respectively. This is a highly non-trivial result in the case when the angular momentum of the black hole is non-zero, in view of the phenomenon of superradiance. The analogue of this result fails for long-range perturbations of the wave equation, such as the

Klein-Gordon equation.
In this talk, we will address the question of whether the absence of time-periodic modes persists under short-range perturbations of the wave equation on Kerr spacetimes. We will construct time-periodic (and exponentially growing) mode solutions to the wave equation on Kerr spacetimes with a potential term, for a suitable non-negative time-independent potential with compact support in space. As an application of this result, we will construct examples of spacetimes which are deformations of the subextremal Kerr exterior in the far away region (with the same ergoregion structure), on which the free wave equation admits time-periodic (and exponentially growing) mode solutions.

PAPAKOSTAS Taxiarchis
(TEI of Crete)
Interior solutions in GRG

The search for exact interior solutions in the case of stationary and axially symmetric spaces of GR is an alternative to the black hole model. I present a survey of the actual situation in this domain and some new results.

RACZ Istvan
(AEI and Wigner Research Center)
Constraints as evolutionary systems

Seven decades ago the constrains of Einstein's theory of gravity were converted to semilinear elliptic system by the seminal work of Lichnerowicz and York. All the currently applied techniques developed to solve the constraints are based on this approach which, as it involves conformal rescaling of the basic variables, also referred as the conformal method. In this talk a new alternative approach is proposed which endows the constraints with a radically new evolutionary character. In particular, it is shown that the constraints may be put either to a parabolic-hyperbolic system or to a strongly hyperbolic system subsided by an algebraic relation. As local (some cases global) existence and uniqueness of solutions to these evolutionary systems is guaranteed the proposed new approach is expected to yield new techniques to solve the constraints.

ROUPAS Zacharias
(Institute of Physics, Eötvös Loránd University)
Gravitational Liquid Crystals

Dynamical properties of self-gravitating systems dominated by a central potential evolve in different timescales. Such systems include galactic nuclei hosting a central supermassive black hole, globular clusters with a central intermediate mass black hole, planetary systems around stars or moons around planets. In particular, the orbital plane orientations are driven very rapidly into an internal thermodynamic equilibrium before global thermal equilibrium is attained. We find that the thermodynamics of such self-gravitating systems exhibits striking resemblance to liquid crystals with analogous ordered-nematic and disordered-spherical phases, that appear for axially symmetric configurations. The nematic ordered phase represents a double disk containing two counter-rotating subgroups of bodies. The system undergoes a first order phase transition between the ordered and disordered phases below a critical total angular momentum value. At exactly the critical point the phase transition becomes second order while for higher values of total angular momentum there is smooth crossover. We also report negative temperature solutions in striking analogy with spin systems inside a magnetic field. In addition to the axially symmetric states, we find metastable triaxial equilibria, that we estimate to have significant lifetime. At sufficiently high temperature an instability sets in, causing the triaxial states to decay to the axially symmetric ones.

TOUSSAINT Vladimir

(University of Nottingham)

Connection Between Unruh-DeWitt Fermionic and Scalar Detectors in d >= 2 Minkowski spacetimes

We examine an Unruh-DeWitt particle detector which couples linearly to the scalar density of a massless Dirac field on the cylindrical quotient of the d >= 2-dimensional Minkowski spacetime and on its cylindrical quotient in d = 2 dimension, allowing the detector's motion to remain arbitrary, working to leading order in perturbation theory, and setting the field in a vacuum state with respect to Minkowski time translations. In Minkowski the detector's response in d-dimension is identical to that of a detector coupled linearly to a massless scalar field in 2d-dimension higher, differing only by a coefficient constant which depends on the dimension of the spacetime, exhibiting no infrared ambiguity, and leading to the usual Unruh effect results in the special case of uniform acceleration. On the cylindrical spacetime, we show that the detector's response distinguishes the periodic and antiperiodic spin structures, and the zero mode that is present for periodic spinors contributes to the response by a state-dependent but well defined and controllable amount. Explicit analytic and numerical results are obtained for inertial and uniformly accelerated trajectories.

TRZESNIEWSKI Tomasz

(University of Wroclaw)

A model of the Nonlinear Field Space Theory.

Phase spaces with nontrivial geometry appear in different approaches to quantum gravity and may also be useful in other areas of theoretical physics. However, so far only the phase spaces of particles or strings have been investigated in this context. We consider an extension of the usual field theory formalism to the framework of fields with the curved phase space for field values. To explore such an idea we construct a prototype scalar field with the spherical field phase space and study its quantized version with the help of perturbative methods. As the result we find a variety of effects that are known from the quantum gravity research, including algebra deformations, a generalization of the uncertainty relations, the vacuum energy shift and modifications of the charge and propagation speed of field excitations. The applicability of the theory can be tested in, e.g., the description of primordial cosmological perturbations.

Alternative Theories of Gravity

BENKEL Robert
(University of Nottingham)

Spherical collapse in Einstein-dilaton-Gauss-Bonnet gravity

I will discuss spherical gravitational collapse in a scalar-tensor theory of gravity that includes a linear coupling of the scalar field to the Gauss-Bonnet invariant. Black holes in this theory are known to have scalar hair and this makes the study of collapse particularly interesting. I will consider various limits of the theory and present results of numerical simulations. I will then discuss the physical implications of these results.

DE LAURENTIS Mariafelicia
(Goethe University Frankfurt)

Cosmological inflation in F (R, G) gravity

Cosmological inflation is discussed in the framework of F (R G). gravity where F is a generic function of the curvature scalar R and the Gauss–Bonnet topological invariant G. The main feature that emerges in this analysis is the fact that this kind of theory can exhaust all the curvature budget related to curvature invariants without considering derivatives of R, $R_{\mu\nu}$, $R_{\lambda\sigma\mu\nu}$, etc., in the action. Cosmological dynamics results driven by two effective masses (lengths) are related to the R scalaron and the G scalaron working respectively at early and very early epochs of cosmic evolution. In this sense, a double inflationary scenario naturally emerges.

DIALEKTOPOULOS Konstantinos
(University of Napoli "Federico II")

Turnaround Radius in f(R) gravity

The acceleration of the universe opposes the gravitational attraction created by normal matter. At large scales, the universe is dominated by a repulsion that causes the acceleration, while at small scales gravity is the dominant force. Thus, there should be a point where these two forces cancel each other. This point, known as the turnaround radius, gives a bound on the maximum sizes of the structures of our universe. I will present the form of the turnaround radius in f(R) gravity and I'll put some constraints on the structure of the theory by comparing with some observational data.

KOFINAS Georgios
(University of the Aegean)

A modified Brans-Dicke gravity with energy exchange

A modified Brans-Dicke gravity is presented with energy exchange between the scalar field and ordinary matter uniquely defined. The new parameter which generalizes Brans-Dicke appears as integration constant in the derivation of the theory. The action of the vacuum theory as well as of a special matter theory is found in the Jordan or the Einstein frame. In a radiation FRW universe, the general solution is found which happens to completely remove the initial singularity, while at the same time a transient acceleration period can occur within deceleration. At late times acceleration is found numerically in agreement with the correct behavior of the density parameters and the dark energy equation of state. A study of linear perturbations around the FRW background is performed and spherically symmetric solutions are analyzed.

LAGOS Marcela
(Universidad de Concepción)

Perturbative instabilities of black strings and black p-branes in higher curvature gravity

This talk shows that the homogeneous black string and black p-branes of Gauss-Bonnet theory in ten dimensions are unstable. The perturbation that we consider is spherically symmetric and it is characterized by a total momentum k along the extended directions. There is a critical wavelength above which the instability is triggered, as it is the case for black strings and black p-branes in General Relativity. The master equation is solved by power series. We observe that the critical wavelength increases with the number of extended directions p, while the maximum exponential growth decreases as p increases.

NASHED Gamal
(BUE)

Graceful exit inflation in in $f(T)$-gravity

We investigate a possible graceful exit inflation model in the Friedmann-Robertson-Walker (FRW) universe within in $f(T)$-gravity framework. We study the cosmic thermal evolution, the model predicts a super-cold universe during the pre-inflation episode, while it performs a reheating period by the end of inflation with maximum temperature much below the Grand Unified Theory (GUT) temperature. Then the model avoids reproducing monopoles at the end of inflation, however, it matches the radiation temperature of the hot big bang at later stages.

OVALLE Jorge

(Simon Bolivar University)

Extra-dimensional gravity: a possible sign of conformal symmetry

By using the Minimal Geometric Deformation (MGD) approach, originally developed in the context of the Randall-Sundrum Braneworld, we probe the incompatibility between this approach and f(R) theories. In consequence a generalization of the MGD is developed and used in the extra-dimensional context, generating thus new black hole solutions. We show that the MGD could be a direct consequence of a conformal symmetry associated with the new gravitational sector non described by General Relativity.

PACILIO Costantino

(SISSA)

Smarr formula for Lovelock black holes: A Lagrangian approach

The mass formula for black holes can be formally expressed in terms of a Noether charge surface integral plus a suitable volume integral, for any gravitational theory. The integrals can be constructed as an application of Wald's formalism. The formalism is applied to compute the mass and the Smarr formula for static Lovelock black holes. A new prescription for Wald's entropy in the case of Lovelock black holes is proposed, which takes into account topological contributions to the entropy functional.

PALIATHANASIS Andronikos

(Universidad Austral de Chile, Valdivia)

Integrability in modified theories of gravity

The integrability of the gravitational field equations in minisuperspace approach is studied for the fourth-order theory of gravity f(R) and the second-order theory f(T). The two approach which are applied are that of the existence of group invariant transformations and that of movable singularities.

PAPANTONOPOULOS Eleftherios

(National Technical University of Athens)

Gravitational Collapse in Horndeski Theory

The gravitational collapse of a homogeneous time-dependent scalar field is discussed which, besides its coupling to curvature, it is also kinematically coupled to the Einstein tensor. This coupling is a part of the Horndeski theory and its effect on the collapsing process is investigated. It was found that the time required for the scalar field to collapse depends on the value of the derivative coupling and the singularity is protected by a horizon. Matching the internal solution with an external Schwarzschild-AdS metric we show that a black hole is formed, while the weak energy condition is satisfied during the collapsing process.

PRAVDA Vojtech
(Czech Academy of Sciences)

Exact solutions to quadratic gravity

The expected corrections to General relativity in the high energy regime start with quadratic terms leading to quadratic gravity. However, up to recently, very few non-trivial exact solutions to quadratic gravity have been known. We will discuss recent progress in this field and we will present new classes of exact solutions to this theory.

PRAVDOVA Alena
(Czech Academy of Sciences)

Universal spacetimes

Universal spacetimes possess a remarkable property that they simultaneously solve vacuum field equations of any theory of gravity with the Lagrangian constructed from the metric, the Riemann tensor and its covariant derivatives of arbitrary order. We will review our recent results on type N, III and II universal spacetimes. For type N and III, the results are dimension-independent and we arrive at a large class of universal metrics, which includes, as a special case, the well known pp-waves. For type II, the situation is much more complicated. We prove the non-existence of type II universal spacetimes in five dimensions and we provide explicit examples of type II universal spacetimes in all composite number dimensions. The existence of type II universal spacetimes for prime number dimensions n>5 remains open.

RODRÍGUEZ GARCÍA Yeinzon
(Universidad Antonio Nariño & Universidad Industrial de Santander)

From Scalar Galileons to Generalized and Covariantized (non-Abelian) Vector Galileons

With the purpose of building cosmological inflationary models whose field equations are second order or less, getting rid of possibles instabilities and the Ostrogradsky ghost, we elaborate on the construction of the scalar Galileons and find the generalized and covariantized action both for a vector field that is not subject to any gauge invariance and for a multiplet of vector fields that enjoys a global non-Abelian gauge invariance. This paves the way for a systematic study of anisotropies both in the cosmic expansion and in the statistical distribution of fluctuations during inflation.

SALGADO Marcelo
(UNAM)

Black holes in f(R) gravity: scalar-hair or absence thereof

We discuss the conditions under which BH's with trivial (i.e. constant) Ricci scalar exist in f(R) gravity and show that such BH's are identical to the corresponding BH's existing in GR except for a redefinition of the cosmological and the gravitational constants. We then focus on static and spherically symmetric spacetimes and provide the equations and regularity conditions required for the existence of spherically symmetric BH's. Using several specific f(R) models we provide analytical and numerical evidence for the absence of geometric scalar hair in asymptotically flat (AF) spacetimes. The analytical evidence consists in the implementation of the no-hair theorem(s) that exist in the so called Einstein-Higgs system via a conformal transformation (i.e. using the Einstein frame representation). When the theorems do not apply or the use of the Einstein frame is ill-defined in some of the f(R) models, we solve the equations numerically in the original (Jordan) frame, and show that BH's solutions with non-trivial Ricci scalar in AF spacetimes seem to be absent, and the only ones that exist have exotic asymptotics.

SARAVANI Mehdi
(University of Nottingham)

Stuckelberg approach to quadratic curvature gravity

Curvature squared terms, when added to the Einstein-Hilbert action and treated non-perturbatively, generically result in the propagation of an extra massive scalar state and an extra massive spin-2 ghost state. Using the Stuckelberg trick, I study the high-energy limit in which the mass of the spin-2 state is taken to zero, with strong-coupling scales held fixed. The Stuckelberg approach makes transparent the interplay between the ghost graviton and the healthy graviton which allows the theory to evade the usual Λ_3 strong coupling scale of massive gravity and become renormalizable, at the expense of stability.

SARIDAKIS Emmanuel
(Baylor U., Texas, USA & NTUA, Greece)

Torsional modified gravity and cosmology

Almost all the efforts in modifying gravity have been performed in the usual curvature-based framework. On the other hand, it is well known that one can equivalently describe gravity using torsion. We investigate the case where one modifies gravity based on its torsional-teleparallel formulation, and we study the corresponding cosmological applications. Moreover, we analyze the perturbations of the theory examining the growth history, we construct a cosmological bounce, and we use solar system and cosmological observations in order to impose constraints on the torsional modifications. Additionally, we analyze the charged black hole solutions of these theories. Finally, we study the case where torsion is nonminimally coupled to a scalar field or its derivatives, as well as other extensions of the theory, using higher-order torsion invariants, or various torsion-matter couplings.

TOLLEY Andrew
(Case Western Reserve University)

Galileon Dualities

I will review recent developments in Galileon theories with a particular emphasis on the recently discovered Galileon Dualities.

VIKMAN Alexander
(Czech Academy of Sciences)

Expelling Cosmological Ghosts

We discuss time-dependent classical and quantum canonical transformation. In particular, we demonstrated that for the quantum canonical transformations the Hamiltonian is transformed as a connection in non-abelian gauge theories. We explicitly construct such quantum and classical transformations which change the sign the Hamiltonian. Hence one can canonically transform a ghost into a field with the correct standard sign in front of the quadratic action, and vice versa. We show how this procedure works for cosmological perturbations. Therefore the usual naive criteria for the presence or absence of ghost-like vacuum instabilities on time-dependent backgrounds are not well physically motivated and the actual information about instabilities is hidden in the interactions.

Relativistic Astrophysics & Gravity Waves

APOSTOLATOS Theocharis
(University of Athens)

Kerr black hole analogues from Newtonian mechanics.

The Kerr black hole solution of vacuum Einstein equations is a very particular one. We show that there is a Newtonian gravitational analogue that shares a lot of the special characteristics of Kerr. They both form an integrable system of equations related to geodesic motion, while the fundamental frequencies of these orbits are very similar. This similarity could be used as a tool to study the odd behavior of adiabatic evolution of orbits whenever they cross a resonance, by evolving the Newtonian analogue due to an artificial self-force that resembles the relativistic self-force in Kerr.

CALDERÓN BUSTILLO Juan
(Georgia Tech)

Higher order modes of Compact Binaries' Gravitational Radiation. Impact on detectability and parameter estimation.

In February 2016, LIGO announced the first discovery of a binary black hole via the direct detection of its gravitational wave emission, GW150914. Gravitational wave signal models used in current searches for such sources only consider the dominant quadrupolar mode of the full emitted signal, omitting the so called higher order modes. In this talk I discuss the impact of this omission in current and future searches in terms of both event losses and bias in the inferred parameters of the source. In particular it will be shown that higher modes are needed for both purposes for the case of unequal mass binary black holes whose total mass is above ~70 solar masses, known as intermediate mass binary black holes.

CISTERNA ROA Adolfo
(Universidad Austral de Chile)

Slowly rotating neutron stars in the nonminimal derivative coupling sector of Horndeski gravity.

This work is devoted to the construction of slowly rotating neutron stars in the framework of the nonminimal derivative coupling sector of Horndeski theory. We match the large radius expansion of spherically symmetric solutions with cosmological solutions and we find that the most viable model has only one free parameter. Then, by using several tabulated and realistic equations of state, we establish numerically the upper bound for this parameter in order to construct neutron stars in the slow rotation approximation with the maximal mass observed today. We finally study the surface redshift and the inertia of these objects and compare them with known data.

COATES Andrew

(University of Nottingham)

Gravitational Higgs Mechanism in Neutron Star Interiors

I will explain how nonminimally coupled scalar fields can lead to modification of the microphysics in the interiors of relativistic stars. As a concrete example, I will consider the generation of a non-zero photon mass in such high-density environments. This is achieved by means of a light gravitational scalar, and the scalarization phase transition in scalar-tensor theories of gravitation. I will present two distinct models, and phenomenological implications will be briefly discussed.

GONDEK-ROSINSKA Dorota

(University of Zielona Góra)

On the properties of differentially rotating neutron stars in GR

Newly born, hot neutron stars or a remnant of a binary coalescence rotate differentially. Differential rotation can temporarily stabilize a massive star against prompt collapse to a black hole. This may have important consequences for gravitational waves observations and explanations of gamma ray bursts. A highly accurate, multidomain spectral code is used in order to construct sequences of general relativistic, differentially rotating neutron stars in axisymmetry and stationarity. For different equation of state, we investigate the solution space corresponding to broad ranges of degree of differential rotation and stellar densities. We find that the solution space contains various types of configurations, which were not considered in previous work, mainly due to numerical limitations. Obtained results give a new view on properties of differentially rotating neutron stars and are the starting point to study in a systematic way their stability.

KARNESIS Nikolaos

(AEI-Hannover)

LISA Pathfinder: The first step towards a Gravitational-Wave observatory in space

LISA Pathfinder (LPF) is a European Space Agency mission that was launched in December 2015. The aim of LPF is to pave the way for future missions by testing in-flight the very concept of Gravitational Wave detection: it is monitoring two test masses in a near-perfect gravitational free-fall conditions, and control and measure their motion with unprecedented accuracy. Even before the end of its nominal operations, the results from the LPF mission exceeded all expectations by unveiling a sensitivity matching the one required for a space-based Gravitational-Wave observatory, such as the proposed Laser Interferometer Space Antenna (LISA). In this talk, I will present the idea behind LPF, and I will go through the dedicated experiments that were performed on-board the satellite. Finally, I will conclude by discussing the impact of the latest LPF results in future Gravitational-Wave astronomy.

KLUZNIAK Wlodek
(Copernicus Astronomical Center)

Oscillations of accretion tori and high frequency QPOs in black holes

Some accreting black holes are known to exhibit stable quasi-periodicities (QPOs) at two frequencies in a 3:2 ratio (e.g. 300 Hz and 450 Hz in a 6 solar mass black hole). I am going to review work modeling these high-frequency QPOs as eigenmodes of accretion tori in the appropriate metric.

LUKES-GERAKOPOULOS Georgios
(ITP, Charles University in Prague)

Gravitational waves from a spinning compact object in EMRI

The Mathisson-Papapetrou (MP) equations are describing the motion of a spinning particle in a curved spacetime. Thus, these equation can approximate the motion of a stellar compact object moving in the spacetime background of a supermassive Kerr black hole. For defining the wordline along which the MP equations evolve the body, we need a spin supplementary condition (SSC). There are various SSCs and each of them define a different worldline for a compact object. We will discuss the impact of the SSCs on the dynamics and on the gravitational wave production of circular equatorial orbits.

MASELLI Andreas
(University of Tübingen)

Geodesic models of Quasi Periodic Oscillations as probe of strong gravity effects

In this talk I analyze the chances to detect strong gravity effects through quasi-periodic oscillations (QPOs) of rotating black holes. I derive the epicyclic frequencies of a slowly rotating black hole in quadratic gravity theories, finding that they differ from those computed in General Relativity. Then I compare various geodesic models used to interpret QPOs from low mass X-ray binaries, showing that the differences between the frequencies predicted by the theories of gravity considered, can be large enough to be observed.

PAPPAS George
(Instituto Superior Técnico)

The spacetime around compact objects and astrophysical observables

There is a great volume of work on the topic of describing the spacetime exterior to compact objects, such as neutron stars, using an analytic solution. There are two approaches to the problem. The first is to use an approximate spacetime, following for example the Hartle-Thorne method, while the second is to use an exact analytic vacuum spacetime that is constructed by using one of the various generating technics that have been developed in the

last decades. Past work has shown that the approximate spacetimes can be quite accurate for slowly rotating models, while exact vacuum spacetimes can be very accurate for models with any rotation up to the maximally rotating limit. The problem with the latter solutions has been that they can be very complicated in form and difficult to implement in practise. Here we present an approximate analytic solution produced using the Ernst formalism and one of the well known generating technics. The solution is parameterised by the multipole moments of the compact object up to the mass hexadecapole and can be tailored to describe neutron stars by using the so called "3-hair" universal relations for the moments. The accuracy of the resulting 3-parameter spacetime and some astrophysical applications are discussed.
Finally an extension of this solution to the case of scalar-tensor theories of gravity is also presented.

ROSA Joao

(University of Aveiro, Portugal)

Superradiance in the sky

I will discuss the generic properties of gravitational plane wave scattering in the Kerr spacetime. I will then show how these results can be applied to realistic astrophysical systems involving a rotating black hole and a companion that emits gravitational radiation, and examine the conditions under which an overall amplification of the companion's luminosity due to superradiant scattering may occur. I will then discuss examples of realistic systems where observational signatures of black hole superradiance may potentially be found and which may allow for novel tests of general relativity with compact objects.

ROSATI Giacomo

(University of Wrocław)

IceCube and GRB neutrinos propagating in quantum-gravity/quantum-spacetime

I report on our recent results (arXiv:1605.00496) on how IceCube data might be anifestations of quantum-gravity-modified laws of propagation for neutrinos. In all scenarios of interest for this kind of analysis one should find a correlation between the energy of an observed neutrino and the difference between the time of observation of that neutrino and the trigger time of a GRB. The strategy of data analysis we propose has the advantage of being applicable to several alternative possibilities for the laws of propagation of neutrinos in a quantum spacetime. We select accordingly some GRB-neutrino candidates among IceCube events, and our data analysis finds a rather strong such correlation, with a ``false alarm probability" of less than 1%.

SOTANI Hajime
(National Astronomical Observatory of Japan)

Gravitational wave asteroseismology in protoneutron stars

We examine the spectra of gravitational waves radiating from protoneutron stars after bounce of core-collapse supernova, where we adopt the relativistic Cowling approximation. To calculate the frequencies of photoneutron stars, we construct the stellar models with the assumption that the protoneutron stars would be quasi-static at each moment. Solving the eigenvalue problem numerically, we obtain the frequencies. Then, we find that the frequencies of f-mode are almost independent from the distributions of electron fraction and entropy per baryon, but depend on the mass and radius of protoneutron stars. In addition, the frequencies are almost proportional to the average density of protoneutron stars, whose proportional constant is completely different from that for cold neutron stars. Thus, combining the observations for the so-called g-mode oscillations around protoneutron stars, one could determine the radius and mass of protoneutron stars via the observation of f-mode oscillations. We will also show the results how the frequencies depend on the progenitor mass and equation of state.

VAYENAS Constantinos
(University of Patras)

Gravitational interactions of relativistic neutrinos

As suggested originally by the neutrino geons analysis of Wheeler, gravitational interactions between relativistic neutrinos can be quite significant and can lead to the formation of gravitationally confined rotational states. This is because, according to the equivalence principle, their gravitational mass equals their inertial mass and the latter is known to equal $\gamma^3 m_o$, where γ is the Lorentz factor $(1-v^2/c^2)^{-1/2}$. This result, originally derived by Einstein in for linear motion, has been recently shown to hold also for arbitrary particle motion. Hence, the gravitational attraction of ultrarelativistic neutrinos with energies above 100 MeV can be easily shown using Newtons's gravitational law to be very strong, e.g. much stronger than the Coulombic attraction of two opposite unit charges at the same distance. Thus by using Newton's gravitational law in conjunction with de Broglie's wavelength equation one may construct a Bohr type model, without any adjustable parameters, for three rotating neutrinos, using gravity as the attractive force, and show that the resulting rotational structures have masses (~1 GeV) and several other properties similar to those of hadrons. The same results within a factor of two are obtained via the use of the Schwarzschild geodesics of GR. We will discuss such gravitationally confined two- or three-neutrino structures as well as structures formed by rotating relativistic neutrino-positron and neutrino-electron pairs.

Cosmology

ACQUAVIVA Giovanni

(Charles University in Prague)

Dark matter perturbations with causal bulk viscosity

We analyse the evolution of perturbations of cold dark matter endowed with bulk viscosity. Focusing on structure formation well within the Hubble radius, the perturbative analysis is carried out in the Newtonian approximation while the bulk viscosity is described by Israel-Stewart's causal theory of dissipation. Differently from previous analysis based on non-causal theories, we obtain a density contrast evolution governed by a third order equation. This framework can be employed to address some of the current inconsistencies in the observed clustering of galaxies.

AVGOUSTIDIS Tasos

(University of Nottingham)

Cosmic (super)strings as cosmological probes into the Early Universe

String networks are generic predictions of a wide class of well-motivated models of the early universe. They can evolve over cosmological timescales giving rise to a host of potentially observable effects, and, since their properties are sensitive to the underlying HEP theory, they provide an ideal cosmological probe into HEP. In particular, cosmic superstrings, produced in models of brane inflation in string theory, have properties set by the fundamental string coupling and compactification data, thus providing a potential observational window into string theory. I will review recent progress in modelling the cosmological evolution of string networks, focusing on distinctive effects that arise in the case of cosmic superstrings. I will also discuss key observational signals from string networks and the prospects of improving current constraints with upcoming CMB polarisation data, using a powerful analytical technique we have recently developed in Nottingham.

BABICHEV Eugeny

(LPT Orsay, IAP Paris)

Gravitational origin of dark matter

I will discuss a possibility Dark matter is a part of gravity itself. The only known ghost-free extension of General Relativity involving a massless and a massive spin-2 field, automatically contains a Dark Matter candidate. The massive spin-2 particle can be heavy, stable on cosmological scales, and it interacts with matter only through a gravitational type of coupling. These features persist in the same region of parameter space where bimetric theory satisfies the current gravity tests.

ELGHOZI Thomas
(King's College London)
The D-universe: Inflation and Graviton

The D-material universe, that is a model of a brane world propagating in a higher-dimensional bulk populated by collections of D-particle stringy defects, provides a model for the growth of large-scale structure in the universe via the vector field in its spectrum. The latter corresponds to D-particle recoil velocity excitations as a result of the interactions of the defects with stringy matter and radiation on the brane world. In this talk, I will present a cosmic evolution for the D-material universe by analysing the conditions under which the late eras of the universe associated with large-scale structure are connected to early epochs, where inflation takes place. It can be shown that inflation is induced by dense populations of D-particles in the early universe, with the role of the inflaton field played by the condensate of the D-particle recoil-velocity fields under their interaction with relativistic stringy matter, for sufficiently large brane tensions and low string mass scales compared to the Hubble scale. In addition, I will present how this condensate affects the graviton wave equation. The deviation from the standard gravitational wave equation can be used to constrain the mass scale of the model, that is the string mass, using the latest experiments in this field.

GANGULY Chandrima
(University of Cambridge)
Anisotropic pressures in Cyclic universes

Cyclic universe scenarios, like the ekpyrotic model have often been considered as a contender to conventional inflationary scenarios. In this talk, I shall present the results of an investigation on whether scenarios which incorporate a non-singular bounce, do indeed lead to isotropisation on approach to a singularity (or bounce) in the presence of dominant ultra-stiff pressure anisotropies. This study then specialises to consider the closed Bianchi type IX universe and shows that when the anisotropic pressures are stiffer on average than any isotropic ultra-stiff fluid then, they dominate on approach to the singularity. An isotropic ultra-stiff ghost fluid with negative energy density is also included in order to create a cosmological bounce at finite volume in the absence of the anisotropic fluid. When the dominant anisotropic fluid is present it leads to an anisotropic cosmological singularity rather than an isotropic bounce. The inclusion of anisotropic stresses generated by collisionless particles in an anisotropically expanding universe is therefore essential for a full analysis of the consequences of a cosmological bounce or singularity in cyclic universes.

KARAGIORGOS Alexandros
(University of Athens)
General Analytical Solutions of Scalar Field Cosmology with Arbitrary Potential

We present the solution space for the case of a minimally coupled scalar field with arbitrary potential in a FLRW metric. This is made possible due to the existence of a nonlocal integral of motion corresponding to the conformal Killing field of the two-dimensional minisuperspace metric. The case for both spatially flat and non flat are studied first in the presence of only the scalar field and subsequently with the addition of non interacting perfect fluids. It is verified that this addition does not change the general form of the solution, but only the particular expressions of the scalar field and the potential. The results are applied in the case of parametric dark energy models where we derive the scalar field equivalence solution for some proposed models in the literature.

MAJUMDAR Archan S
(S. N. Bose National Centre for Basic Sciences)
Does structure formation impact the future cosmological evolution?

We consider the future evolution of the presently accelerating universe that is observed to contain inhomogeneities at various levels up to at least large scales of $\le 100h^{-1}Mpc$. Backreaction due to such inhomogeneities on the global metric (assumed to be FLRW at very large scales) continues to grow with time as a result of structure formation. We compute the effect of backreation from inhomogeneities on the future evolution of the universe using the Buchert formalism for obtaining the global metric based on averaging over time-like hypersurfaces. First, assuming a two scale void-wall model along with the current observational parameters for accelerated expansion as inputs, we find that the effect of inhomogeneities leads to the slowing down of acceleration with time. For a range of model parameters, the acceleration can vanish at a finite future time, leading to the universe entering another decelerating era. The presently accelerating expansion also entails a cosmological event horizon, the consideration of which leads to further interesting consequences on the global evolution in the presence of inhomogeneities. We finally consider a more realistic multi-scale model in which it is again possible to obtain future deceleration and avoidance of the big-rip problem. Certain observational constraints on the parameters of such models are discussed.

PANTAZIS George
(University of Ioannina)
A Comparison of Thawing and Freezing Dark Energy Parametrizations

Dark energy equation of state w(z) parametrizations with two parameters and given monotonicity are generically either convex or concave functions. This makes them suitable for fitting either freezing or thawing quintessence models but not both simultaneously. Fitting a dataset based on a freezing model with an unsuitable (concave when increasing) w(z) parametrization (like CPL) can lead to significant misleading features like crossing of the

phantom divide line, incorrect $w(z=0)$, incorrect slope{etc.} that are not present in the underlying cosmological model. To demonstrate this fact we generate scattered cosmological data both at the level of $w(z)$ and the luminosity distance $D_L(z)$ based on either thawing or freezing quintessence models and fit them using parametrizations of convex and of concave type. We then compare statistically significant features of the best fit $w(z)$ with actual features of the underlying model. We thus verify that the use of unsuitable parametrizations can lead to misleading conclusions. In order to avoid these problems it is important to either use both convex and concave parametrizations and select the one with the best χ^2 or use principal component analysis thus splitting the redshift range into independent bins. In the latter case however, significant information about the slope of $w(z)$ at high redshifts is lost. Finally, we propose a new family of parametrizations (nCPL) $w(z) = w_0 + w_a\{z/(1+z)\}^n$ which generalizes the CPL and interpolates between thawing and freezing parametrizations as the parameter n increases to values larger than 1.

PLIONIS Manolis

(Aristotle University of Thessaloniki)

A New Hubble Expansion tracer and Cosmological Constraints

After a brief review of the current cosmological set up, I will present details on a new tracer of the Hubble expansion, that of HII galaxies, which can trace higher redshifts than SNIa (up to z~3.5) and our efforts to study possible systematics related to the new tracer. I will also present a preliminary pilot study of a small sample of high-z HII galaxies that we have observed with VLT.

Tsagas Christos

(Aristotle University of Thessaloniki)

On the kinematics of "tilted" Friedmann Universes

We consider observers in typical galaxies that move relative to the Hubble expansion of a Friedmann universe filled with a pressureless perfect fluid. Using a ``tilted'' cosmological model, we look into the mean kinematics of such peculiar motions and compare to the kinematics of the smooth Hubble flow. The aim is to examine whether and to what extent relative-motion effects can interfere with the way the aforementioned observers interpret the expansion history of the universe they live in.

Quantum Gravity & Quantum Cosmology

ALESCI Emanuele
(SISSA)

Quantum Reduced Loop Gravity and the relation with LQC

We present Quantum Reduced Loop Gravity a gauge fixed version of LQG. We show how QRLG provides a promising framework for a consistent characterization of the early Universe. *Its effective semiclassical dynamics and the inclusion of a scalar field will be discussed.* In particular I will show how this theory allows to derive Loop Quantum Cosmology from the full theory.

CHRISTODOULAKIS Theodosios
(University of Athens)

Conditional symmetries in axisymmetric quantum cosmologies with scalar fields and the fate of the classical singularities

In this paper, the classical and quantum solutions of some axisymmetric cosmologies coupled to a massless scalar field are studied in the context of minisuperspace approximation. In these models, the singular nature of the Lagrangians entails a search for possible conditional symmetries. These have been proven to be the simultaneous conformal symmetries of the supermetric and the superpotential. The quantization is performed by adopting the Dirac proposal for constrained systems, i.e. promoting the first-class constraints to operators annihilating the wave function. To further enrich the approach, we follow [1] and impose the operators related to the classical conditional symmetries on the wave function. These additional equations select particular solutions of the Wheeler-DeWitt equation. In order to gain some physical insight from the quantization of these cosmological systems, we perform a semiclassical analysis following the Bohmian approach to quantum theory. The generic result is that, in all but one model, one can find appropriate ranges of the parameters, so that the emerging semiclassical geometries are non-singular. An attempt for physical interpretation involves the study of the effective energy-momentum tensor which corresponds to an imperfect fluid. (JCAP 1605 (2016) no.05, 066)

GIELEN Steffen
(Imperial College London)

Connecting loop quantum cosmology and quantum gravity condensates

Recent years have seen great progress towards deriving quantum cosmology models from the effective dynamics of condensate states in the group field theory (GFT) approach to quantum gravity; in short, 'cosmology is the hydrodynamics of quantum gravity'. In this setting, the classical Friedmann dynamics for homogeneous, isotropic universes, as well as loop quantum cosmology (LQC) corrections to general relativity have been shown to emerge from fundamental quantum gravity. I report on recent results in this setting that show how a 'low spin regime' of a macroscopic universe made up of many fundamental quanta of Planck size, with total volume proportional to the number of quanta, emerges generically from the dynamics of GFT in a rather wide class of models. The type of quantum state usually assumed in the derivation of LQC (in its 'improved dynamics' form) is hence derived from a more fundamental quantum gravity setting.

KARAMI MAJOOMERD Asieh

(School of Astronomy, IPM)

Effective Bianchi IX model in loop quantum cosmology

We briefly review the reduced loop quantization of the diagonal Bianchi type IX model. We explore different quantization prescriptions that extend the work of Wilson-Ewing. We show that how the Hamiltonian constraint operators are obtained and how some operator ordering can formally resolve the singularity. Then, we present the effective equations associated with the different quantization prescriptions which provide some corrections to the classical equations of motion. The correction terms include the holonomy correction effects and those ones which come from the inverse triad operators in the Hamiltonian constraint and play an important role to avoid the classical chaotic behavior of the mode. We use geometrically defined scalar observables to explore the physical implications of each of these quantizations at semi-classical level. Also, we study the relation with the closed FLRW model that, classically, is contained within the Bianchi IX model.

PITHIS Andreas

(King's College London)

Effects of nonlinear effective interactions in GFT condensate cosmology

The Group Field Theory (GFT) proposal to quantum gravity is closely related to and draws from Loop Quantum Gravity, simplicial quantum gravity, matrix models as well as condensed matter theory. Its Group Field Cosmology (GFC) spin-off aims at providing a framework for quantum cosmology. Its main conceptual idea and conjecture is that continuum spacetime is a thermodynamical phase of an underlying GFT system, that is obtained through a phase transition (“geometrogenesis”) in the quantum gravity analogue of the thermodynamic limit used in condensed matter systems. In this context, we discuss the main aspects of the GFC condensate picture exemplified through a particular free model and report progress on the analysis of several effectively interacting GFC models.

PRANZETTI Daniele
(SISSA)

Conformal symmetry and holography from quantum geometry

We show how degrees of freedom coming from the diffeomorphims that are broken by the singularities of the basic states of loop quantum gravity on the boundary of a space-like surface are described by two-dimensional conformal field theories living on punctures. The commutators of these broken diffeomorphims charges of quantum geometry at each puncture satisfy a Virasoro algebra. When the boundary corresponds to an isolated horizon, we show that these new degrees of freedom satisfy an holographic bound which coincides with Bekenstein-Hawking entropy independently on the value of the Immirzi parameter.

SCARDIGLI Fabio
(American University of the Middle East)

Quantum corrections to the Newtonian potential and generalized uncertainty principle

In this talk we propose a technique to compute the deformation parameter of the generalized uncertainty principle (GUP) by using the leading quantum corrections to the Newtonian potential. The calculation gives, to this order, an unambiguous numerical result. The physical meaning of this value is discussed, and compared with analogous previous results, and with known bounds on the GUP deformation parameter.

ZAMPELI Adamantia
(University of Athens)

Canonical quantization of pure gauge gravitational systems and probability analysis

We study minisuperspace models with n degrees of freedom under no assumption for the lapse function N. Instead, the gauge freedom, i.e. the reparametrization invariance under arbitrary changes of the independent variable, is transferred to the choice of one of the scalar degrees of freedom, say q. The rest of the scalars are expressed as functions of q, thus resulting to the decoupling of the reparametrization invariant part of the system from the rest of the equations of motion. The quantization of this two dimensional constrained system of (N,q) leads to a quantum probability with extrema on the classical solution of the initial n-dimensional system.

POSTERS

J. Abedi, H. Arfaei, A. Bedroya, M. Noori Kohani, A. Mehin Rasulian, K. Salehi Vaziri

(Sharif University of Technology)

Quantum Field Theory Corrections to Black Holes

We consider the Back Reaction of QFT fluctuations reflected in trace anomaly on Schwarzschild and Reisner Nordstrom Black holes and the process of collapse. The Schwarzschild BH develops an internal horizon which turns out to be the limit of inner Horizon of RN black hole when its charge vanishes. This puts a lower limit of mass of the black holes which corresponds to the extremal limit of the Schwarzschild case with zero temperature and no Hawking radiation. We also find the modification of Mass Charge relation for RN case to avoid naked singularity as a modification to the standard relation Q=M for the extremal case. Furthermore we study thermodynamics of the BH solutions and the modifications due to trace anomaly. We have also shown that the final stage of life of a black hole after Hawking radiation will be the extremal Schwarzschild BH.

Finally we study the effect of QFT trace anomaly on the collapse of a spherically symmetric shell and show that the singularity does not form. The collapse stops at a finite radius, the bounce radius as also expected from quantum gravity considerations.

Tolga Birkandan, Ceren Guzelgun, Elif Sirin, Mustafa Can Uslu

(Istanbul Technical University)

Open Source Computer Algebra Systems for General Relativity

Computer algebra systems are essential tools for theoretical physic for some decades. They are mainly important in general relativity where lengthy tensorial and differential geometry calculations are inevitable. Many of these programs have special internal or external packages for tensor manipulation and differential geometry calculations. Eventhough commercial programs dominate the area, codes written on commercial programs cannot be easily distributed as those programs may not be available for scientists with less funds for purchasing software. Besides, many of the manipulations needed in calculations do not need a sophisticated computation engine. Open source computer algebra systems such as Sage (or SageMath) and Maxima provide a complete tool for general relativity and quantum field theory applications with their specialized packages. Some freely available programming languages such as Python also offers special tools for such manipulations. We will first utilize Maxima (with ctensor package), Sage (with SageManifolds package) and Python language (with Sympy and GraviPy modules) for some essential calculations in general relativity. We will provide the benchmark results for these systems. The ever-developing open source Sage program has gathered many utilities such as Maxima, GAP, R, and the power of Python language with native Python modules like NumPy, Sympy and matplotlib. Sage can be installed on personal computers and moreover it has a powerful cloud computing server on which the user can work on projects anywhere and share them with other users easily. The recent package SageManifolds for tensor and differential geometry calculations is also installed on the cloud server. These properties make the Sage+SageManifolds system the best open source choice for general relativity and quantum field theory. In the main part of our study, we will focus on Sage and SageManifolds package in detail to calculate and visualize the geodesic motion, and solutions of Klein-Gordon and Dirac equations for black hole metrics.

CG Vayenas, AS Fokas, Grigoriou Dimitrios
(University of Patras)

Gravitationally confined relativistic neutrinos

Combining special relativity, the equivalence principle and Newton's universal gravitational law with gravitational rather than rest masses, one computes that gravitational interactions between relativistic neutrinos with kinetic energies above 10 MeV are very strong and can lead to formation of gravitationally confined composite structures. One may model the formation of such composite structures by considering three neutrinos moving symmetrically on a circular orbit under the influence of their gravitational attraction, and by assuming quantization of their angular momentum, as in the Bohr model of the H atom. The model contains no adjustable parameters and its solution leads to composite state radii close to 1 fm and neutrino velocities so close to c, that the corresponding Lorentz factor, gamma, values are of the order of 5*109. It is thus found that when the neutrino rest masses are of the order of 0.05 eV/c^2, then the mass, 3(gamma)mo, of such three rotating neutrinos structures is very similar to that of hadrons (~ 1 GeV/c^2). The thermodynamics of the phase condensation of neutrinos to form such structures are compared with QCD calculations for the quark-gluoncondensation temperature. Using the same approach we find that the mass of relativistic rotating Ve – e+/- pairs is 81 GeV/c^2, close to that of W+/-bosons.

Georgios Lioutas, Nikolaos Stergioulas
(Ludwig-Maximilians-Universitaet Munich)

An approximate relation for estimating the gravitational-wave damping timescales of f-modes in neutron stars

The damping timescale due to gravitational wave emission of f-modes neutron stars is known with high accuracy only for nonrotating or slowly rotating stars. We investigate several approximate relations for estimating this timescale and identify the one that agrees best with exact numerical data for nonrotating stars. The same relation could be applied also for rotating stars and binary neutron star merger remnants, in the absence of exact numerical results in full general relativity. Furthermore, we show that the difference between the exact and approximate results for nonrotating stars follows a universal empirical relation which is quadratic in the mass to radius ratio M/R, with very small error.

Naulak Malsawmtluangi and P.K. Suresh
(University of Hyderabad)

Inflation and the BB-mode correlation spectrum of the Cosmic Microwave Background from massive gravity

Graviton, which is commonly believed to be massless, is endowed with mass and hence, the primordial gravitational waves are considered to be massive and are placed in the squeezed vacuum state. The corresponding BB-mode correlation angular power spectrum of the cosmic microwave background is obtained for various slow roll inflation models. The gravitational waves are also placed in thermal state in addition to the squeezed vacuum state. The angular power spectrum for each model is compared with the limit of BICEP2/Keck and Planck joint analysis data.

Ondrej Kopacek, Vladimir Karas
(Astronomical Institute of the Czech Academy of Sciences)

Regular and chaotic motion in general relativity: The case of an inclined black hole magnetosphere

Dynamics of charged test particles in the vicinity of a rotating black hole embedded in the external large-scale magnetic field is numerically investigated. In particular, we consider a non-axisymmetric model in which the asymptotically uniform magnetic field is inclined with respect to the axis of rotation. We construct the effective potential in a suitably chosen reference frame in order to investigate regions of allowed motion. Moreover, we study the effect of inclination onto the prevailing dynamic regime of particle motion, i.e. we ask whether the inclined field allows regular trajectories or if instead, the deterministic chaos dominates the motion. To characterize the measure of chaoticness we compute maximal Lyapunov exponents and employ the method of Recurrence Quantification Analysis.

Giovanni Amelino-Camelia, Michele Ronco, Malu' Maira Silva
(La Sapienza, Rome)

Spacetime-noncommutativity regime of Loop Quantum Gravity

A recent study by Bojowald and Paily derived some Loop-Quantum-Gravity-based modifications to the hypersurface deformation algebra and observed that certain modifications are still present in the limiting case where this algebra usually produces the Poincarè algebra. However, the preliminary search performed by Bojowald and Paily of the quantum-spacetime picture emerging from the relevant deformations of the Poincare algebra was unsuccessful. We here show that the results obtained by Bojowald and Paily are consistent with κ-Minkowski noncommutativity.

Hassan Firouzjahi, Tahereh Rostami, Asiyeh Karami
(School of Astronomy, IPM)

Primordial inhomogeneities from massive defects during inflation

We consider the imprints of local massive defects, such as a black hole or a massive monopole, during inflation. The massive defect breaks the background homogeneity. We consider the limit that the physical Schwarzschild radius of the defect is much smaller than the inflationary Hubble radius so a perturbative analysis is allowed. The inhomogeneities induced in scalar and gravitational wave power spectrum are calculated. We obtain the amplitudes of dipole, quadrupole and octupole anisotropies in curvature perturbation power spectrum and identify the relative configuration of the defect to CMB sphere in which large observable dipole asymmetry can be generated. We observe a curious reflection symmetry in which the configuration where the defect is inside the CMB comoving sphere has the same inhomogeneous variance as its mirror configuration where the defect is outside the CMB sphere.

Magdalena Szkudlarek, D. Gondek-Rosinska, M. Giersz, T. Bulik, A. Askar
(University of Zielona Góra)

Globular clusters as sources of GW150914-like Black Hole binaries

First ever direct detection of gravitational waves was from binary black hole system (GW150914). Measured masses of both objects exceeded 25 M_{sol} each. This implies the formation of GW150914 binary in a low metalicity environment. Globular clusters are highly probable to generate such kind of binaries. In our work we analyse evolutionary simulations of globular clusters made with MOCCA code and calculate the event rate of compact binary mergers. In particular we consider systems like GW150914.

Magdalena Szkudlarek, D. Gondek-Rosinska, M. Ansorg, L. Villain
(University of Zielona Góra)

On the maximum mass of differentially rotating Neutron Stars.

Strange quark stars are considered as a possible alternative to neutron stars as compact objects. A hot compact star (a proto-neutron star or a strange star) born in a supernova explosion or a remnant of neutron stars binary merger are expected to rotate differentially. Rotating compact stars are considered as important sources of gravitational waves for Advanced Virgo/Ligo detectors. We present results of the first relativistic calculations of differentially rotating strange quark stars for broad ranges of degree of differential rotation and maximum densities and compare with results for neutrons stars. Using a highly accurate, relativistic code we show that rotation may cause a significant increase of maximum allowed mass and can temporarily stabilize stars against prompt collapse into a black hole.

Rashmi Uniyal, Hemwati Nandan, K. D. Purohit
(Government Degree College Narendranagar Tehri Garhwal)

Geodesic motion around kerr-sen black hole spacetime

String theory is one of the leading candidate theories to unify gravity with other fundamental forces in nature. In the present study, we consider time-like geodesic congruences around a Black Hole (BH) spacetime which arises in low energy heterotic string theory, popularly known as Sen BH. Most of the BH solutions in string theory are characterized by one or more charges associated with the Yang-Mills fields or the anti-symmetric tensor gauge field. The Sen BH carries a finite amount of charge, angular momentum and magnetic dipole moment and it could be produced by twisting method and starting from a rotating BH having no charge, i.e. the Kerr BH in GR and sometimes referred as twisted Kerr BH or Kerr-Sen BH. In order to analyse the properties of BHs using geodesics, the separability and integrability of the geodesic equations are essential and based on these standpoints, we have analysed the complete orbit structure for both the timelike and null geodesics in view of the corresponding effective potential. In addition to the orbits in the equatorial plane, we have also obtained the approximate solution for the radius of spherical photon orbits in non-equatorial plane. The results obtained for Sen BH are also compared with those of various charged/rotating/uncharged/(KN), Kerr, Reissner-Nordstrom (RN) and Schwarzschild class solutions in GR.

Mateusz Wiśniewicz
(University of Zielona Góra)

The effects of stellar rotation and general relativity on the stability of an accretion disc around neutron stars

We present numerical calculations of orbital and epicyclic frequencies of nearly circular orbits around rotating neutron stars and strange quark stars. Many promising equations of state were used to describe the structure of neutron stars while the MIT bag model was used to model the equation of state of strange quark stars. All the uniformly rotating stellar configurations were computed in full general relativity. We find that the vertical epicyclic frequency and the related nodal precession rate of inclined orbits are very sensitive to the oblateness of rotating star. These findings may have implications for models of kHz QPOs In particular, we have studied higher multipoles decay with the distance from the star which is the crucial for these effects.

Mateusz Wiśniewicz
(University of Zielona Góra)

Long-term quasi-periodicity of 4U 1636-536 resulting from accretion disc instability

We present the results of a study of the low-mass X-ray binary 4U 1636-536. We have performed temporal analysis of all available RXTE/ASM, RXTE/PCA, Swift/BAT and MAXI data. We have confirmed the previously discovered quasi-periodicity of ~45 d present during ~2004, however we found it continued to 2006. At other epochs, the quasi-periodicity is only transient, and the quasi-period, if present, drifts. We have then applied a time-dependent accretion disc model to the interval with the significant X-ray quasi-periodicity. For our best model, the period and the amplitude of the theoretical light curve agree well with that observed. The modelled quasi-periodicity is due to the hydrogen thermal-ionization instability occurring in outer regions of the accretion disc. The model parameters are the average mass accretion rate (estimated from the light curves), and the accretion disc viscosity parameters, α cold and α hot, for the hot and cold phases, respectively. Our best model gives relatively low values of α cold and α hot .

Naqing Xie
(Fudan University)

Brown-York Mass and Trapped Surface Conjecture

We present some results concerning the trapped surface conjecture for the Brown-York quasi-local mass. This talk is based on the joint work with E. Malec.

Ramin Zahedi
(Hokkaido University)

A Direct Derivation of a Definite Massive Gravitational Field Equations Solely by First Quantization of the Relativistic Energy-Momentum (algebraic) Relation

Using a new axiomatic matrix approach – which has been formulated on the basis of ring theory and the generalized Clifford algebra – by first quantization of the relativistic energy-momentum relation (as a special relativistic algebraic relation), a unique massive form of the gravitational field equations is derived solely. It is shown that the massless case of these equations is equivalent to the Einstein field equations (including a cosmological constant). Moreover, the geometric algebra formulation (via a matrix representation) of the derived gravitational field is presented.