BOOK OF ABSTRACTS

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ABSTRACTS

Ahmad Al-Badawi

Solutions of Dirac equation in the regular Bardeen black hole surrounded by quintessence

The exact solutions of the Dirac equation that describe a massive, non-charged particle with spin 1/2 in the curved spacetime geometry of regular Bardeen black hole surrounded by quintessence (BBHQ) are investigated. We first, derive the Dirac equation in the BBHQ background using a null tetrad in the Newman-Penrose formalism. Afterwards, we separate the Dirac equation into ordinary differential equations for the radial and angular parts. The angular part equations are solved exactly in terms of standard spherical harmonics. The radial part equations are transformed into a Schrodinger like differential wave equations with effective potentials. In addition we investigate the behaviour of the effective potentials by varying the quintessence parameters, magnetic monopole charge parameter and the frequency of the particle.

Ignatios Antoniadis

Inflation from supersymmetry breaking

I will discuss the problem of scale hierarchies in particle physics and cosmology and propose ways to address it. In particular I will present a framework of obtaining inflation from supersymmetry breaking by identifying the inflaton with the superpartner of the goldstino and will describe its phenomenological consequences.

Irina Aref'eva

Holography for heavy-ion collision

Holographic models of heavy-ion collision based on anisotropic 5-dimensional metric will be discussed. Calculations of holographic entanglement entropies of elongated and differently oriented relative to the beam-line three-dimensional regions will be presented. Significant fluctuations near the critical temperature for given chemical potential of these holographic entanglement entropies will be shown. We show that the fluctuations themselves are strongly dependent on anisotropy and orientation.

Sudipto Bhattacharjee

Role of particle creation mechanism on the collapse of a massive star

In this presentation the collapse dynamics of a spherically symmetric massive star in the framework of non-equilibrium thermodynamic prescription through particle creation mechanism has been studied. For simplicity, the thermodynamic system is chosen to be adiabatic so that the effective bulk viscous pressure is linearly related to the particle creation rate. Consequently, the evolution of the collapsing star also depends on the choice of particle creation rate. By suitable choice of creation rate as a function of the Hubble parameter, we found that the end state of the collapse may be either a black hole (BH) or a naked singularity (NS).

Asmus Bisbo

A polynomial basis for the paraboson Fock spaces

The generalization of the usual bosonic fields to parabosonic fields was done by Green in 1952. Parabosons have since then been studied in many different contexts, including areas such as quantum field theory and Wigner quantum systems. Although interest in parabosons remains to this day, fundamental questions about the structure of the paraboson Fock spaces still remain unanswered. In particular it turns out that no "explicit" bases for the paraboson Fock spaces are known(apart from combinatorial Gelfand-Zetlin bases); I intend to change this by presenting the construction of a natural polynomial bases for the paraboson Fock spaces.

It is know that the paraboson Fock spaces are characterized by a parameter $p > 0$ and can be identified as irreducible representations, $V(p)$ of the orthosymplectic Lie superalgebra $\mathfrak{osp}(1|2n)$.

Building on the work done by Lievens, Stoilova, and Van der Jeugt on the structure of $V(p)$, I will observe that the dimensions of the weight spaces of $V(p)$ coincide with the number of semistandard Young tableaux of corresponding weight and height $\leq p$ and show how this observation leads to the construction of a basis for $V(p)$ consisting of Clifford algebra valued polynomials. Finally, I will make some remarks on the calculation of matrix elements in the newly constructed basis.

This is joint work with Hendrik de Bie and Joris Van der Jeugt.

David Edward Bruschi

On the weight of entanglement

One of the most important open questions is how do quantum systems gravitate. Quantum mechanics, our theory of the very small, well describes physical phenomena that occur at low temperatures and small distances, where particles exhibit their quantum features. On the other hand gravity, our theory of the very large, is successful at tackling questions of astrophysical or cosmological nature. The two theories are known to be incompatible, leaving many scientists unsatisfied by the apparent impossibility of unifying them. Quantum gravity aims precisely at this, that is, solving the riddle of the unification of our main theories of Nature. Regardless of the the enormous progress in the scientific community, and the rise and fall of many approaches, it is still not understood if and how the twain shall meet. To date, no conclusive answer to this question has yet been given.

We discuss the study of the effects of entanglement on the gravitational field. Our work employs semi-classical gravity in a regime where it arguably can give sensible predictions. The main aims is to establish a direct and uncontroversial relation between quantum correlations of a state and gravitational corrections to a "classical gravitational field" that are induced by such correlations. Preliminary results are encouraging, providing a framework to potentially study more complex scenarios.

Furthermore, motivated by considerations on the nature of energy in quantum systems, we propose a radical change to the theory of gravitation, arguing that not all energy is a source for gravity. We analyse the proposed modification and discuss the implications. We conclude by emphasising the necessary next steps to transform this idea and intuition, not conclusively established, into the core of a new approach to understanding how quantum matter gravitates.

Francisco Bulnes

Baryongenesis until dark matter: H-particles proliferation

A digression on the dark matter and dark energy considering the baryongenesis and their evolution until the actual Universe is realised. The factors of inflation and matter-energy production are analysed, likewise the hadrons as fundamental part in the dark matter production are considered. Some results on torsion in baryongenesis are used to complete the evidences as baryons acoustic oscillations, the effects due to the cosmic expansion, redshift, space-time distortions,

and other inhomogeneous effects observed. Then is established a theorem in mathematical cosmology that affirms that the dark energy is given beyond of the fundamental interacting of the baryongenesis and arises with the proliferation of the H-particles in extended photon sources.

Maja Burić

Singularity resolution in fuzzy de Sitter cosmology

We analyze the spectrum of time observable in fuzzy de Sitter cosmological model. We find that cosmic time is not a self-adjoint operator but appropriate restrictions of the space of physical states give self-adjoint extensions which have discrete spectrum. Calculated on physical states, the radius of the universe is bounded below, which resolves the big bang singularity. Another immediate consequence of the model is breaking of the original symmetry at the Planck scale.

Nuno Cirilo Antonio

Einstein-Kähler metrics and four-point Schlesinger system

Following M. V. Babich and D. A. Korotkin (1998) we review the relationship between a class of Einstein-Kähler metrics and the four-point Schlesinger system. Namely, we study the relation between these metrics and the tau-function of the four-point Schlesinger system.

Diego Cirilo-Lombardo

Dynamical symmetries, coherent states and nonlinear realizations: the $SO(2,4)$ case

Nonlinear realizations of the $SO(4,2)$ group are discussed from the point of view of symmetries. Dynamical symmetry breaking is introduced. One linear and one quadratic model in curvature are constructed. Coherent states of the Klauder-Perelomov type are defined for both cases taking into account the coset geometry. A new spontaneous compactification mechanism is defined in the subspace invariant under the stability subgroup. The physical implications of the symmetry rupture in the context of nonlinear realizations and direct gauging are analyzed and briefly discussed.

Radu Constantinescu

Special methods for solving nonlinear differential equations through polynomial expansion

A special technique in finding traveling wave solutions for nonlinear differential equations is presented. The technique implies a change of variable which decrease the degree of differentiation, followed by a polynomial expansion. The method is illustrated on a generalized class of reaction-convection-diffusion equations.

Ion Cotaescu

Leptogenesis in a spatially flat Milne-type universe

The quantum electrodynamics on a spatially flat $(1 + 3)$-dimensional Friedmann-Lemaitre-Robertson-Walker space-time with a Milne-type scale factor is considered focusing on the amplitudes of the allowed effects in the first order of perturbations. The definition of the transition rates is reconsidered obtaining an appropriate angular behavior of the probability of the pair creation from a photon which has a similar rate as the leptons creation from vacuum.

Mihailo Čubrović

Toward eternal traversable hairy wormholes

We aim to build stable and reasonably natural traversable wormhole solutions. We show that conventional semiclassical matter in the bulk cannot support a Poincare-symmetric wormhole. Then we construct stable semiclassical hairy wormhole solutions where the hair violates the Poincare invariance. Finally, we argue that stringy effects make wormhole pair production generic (in fact, not ending up with wormholes requires fine tuning). We also discuss the Kolmogorov-Sinai entropy of the wormhole hair, compare it to the Bekenstein-Hawking entropy and discuss the thermodynamic stablity of the wormhole solutions.

Branislav Cvetković

Entropy in Poincare gauge theory: Hamiltonian approach

The canonical generator of local symmetries in Poincare gauge theory is constructed as an integral over a spatial section of spacetime. Its regularity (differentiability) on the phase space is ensured by adding a suitable surface term, an integral over the boundary infinity, which represents the asymptotic canonical charge. For black hole solutions, there are two boundaries, one at infinity and one at horizon. It is shown that the canonical charge at horizon defines entropy, and the condition of regularity yields the first law of black hole thermodynamics.

Ljubica Davidović

T-duality between effective string theories

We consider the open bosonic string moving in the constant background. We investigate whether the solving of the constraints obtained by applying the Dirac procedure to the boundary conditions of the open string, which leads to effective closed string theory and the T-dualization procedure are commutative. We consider the string with mixed boundary conditions. We start by applying the Dirac procedure to these conditions, which results in two parameter dependent constraints. These constraints are solved and for the solution the effective theory is obtained. On the other hand applying the T-dualization procedure to the initial theory one obtains the T-dual theory. As usual, the form of the theory is such that as if the T-dual boundary conditions are already chosen, so that the T-dual coordinates satisfy

exactly the opposite set of the boundary conditions then the corresponding coordinates of the initial string. We apply the Dirac procedure to the T-dual boundary conditions, obtain the parameter dependent constraints and solve them to obtain the T-dual effective theory. We show that the effective theories of the initial and T-dual theory remain T-dual, and find the effective T-duality coordinate transformation laws.

Ivan Dimitrijević

Cosmological solutions of a nonlocal square root gravity

Despite of numerous significant phenomenological confirmations and many nice theoretical properties, General Relativity (GR) is not final theory of gravity. Problems mainly come from quantum gravity, cosmology and astrophysics. For example, if GR is applicable to the universe as a whole and the universe is homogeneous and isotropic, then it follows that the universe contains about 68% of dark energy, 27% of dark matter and only about 5% of visible matter. However, validity of GR at the very large cosmic scale is not verified, as well as dark matter and dark energy are not yet observed in laboratory experiments. Also, GR contains cosmological singularity. These and some other problems give rise to investigate extensions of GR.

In this talk, we present modification of GR extending $R - 2\Lambda$ by nonlocal term $\sqrt{R-2\Lambda}\mathcal{F}(\Box)\sqrt{R-2\Lambda}$, where $\mathcal{F}(\Box)$ is an analytic function of the d'Alembert operator $\Box$. The choice of $\mathcal{F}(\Box)$ in the analytic form is motivated by existence of analytic expressions with $\Box$ in string field theory and p-adic string theory.

We have found some exact cosmological solutions of the corresponding equations of motion without matter and with $\Lambda \neq 0$. One of these solutions is $a(t) = At^{\frac{2}{3}}e^{\frac{\Lambda}{14}t^2}$, which contains properties similar to an interplay of the dark matter and the dark energy. For this solution we computed some cosmological parameters which are in good agreement with their values in the standard ΛCDM model. This nonlocal gravity model has not the Minkowski space solution. Also, some constraints on function $\mathcal{F}(\Box)$ are obtained.

This is joint work with Branko Dragovich, Alexey Koshelev, Zoran Rakic and Jelena Stankovic, and based on the recent paper `arXiv:1906.07560`.

Marija Dimitrijević Ćirić

Nonassociative differential geometry and gravity

In the context of string theory, it is expected that closed string sector provides a framework for a quantum theory of gravity. Namely, the massless bosonic modes of the closed string sector contain gravitational degrees of freedom such as the metric, the B-field, and the dilaton. In particular, in locally non-geometric backgrounds one expects to find a low-energy limit of closed string theory which is described by an effective nonassociative theory of gravity on spacetime.

Attempts to formulate a consistent effective gravity theory in the space-time, starting from the nonassociative phase space of closed strings were done in [1,2,3]. There the construction is done using the twist approach. The twist approach provides a well defined way to introduce the noncommutative/nonassocaitive differential geometry and the notions of connections and curvature. The essential step [2, 3] is the projection from the phase space to the spacetime via the zero momentum leaf. This talk is based on [2,3]. In the talk we will explain how the metric aspects of nonassociative differential geometry tailored to the parabolic phase space model of constant locally non-geometric closed string vacua are developed. We will use the nonassociative differential geometry to construct preliminary steps towards a nonassociative theory of gravity on spacetime. Explicit expressions for the torsion, curvature, Ricci tensor and Levi-Civita connection in nonassociative Riemannian geometry on phase space are obtained in this way. Using the projection to the zero momentum leaf, we construct the R-flux corrections to the Ricci tensor on spacetime, and comment on the potential implications of these structures.

[1] R. Blumenhagen and M. Fuchs, *JHEP* **07** (2016) 019.
[2] P. Aschieri and R. Szabo, *J. Phys. Conf. Ser.* **634** (2015) 012004.

[3]. P. Aschieri, M. Dimitrijević Ćirić and R. Szabo, *JHEP* **02** (2018) 036.

Goran Đorđević

Tachyon inflation and holography

We present result of a model of tachyon inflation in the framework of holographic cosmology. A holographic braneworld scenario with a D3-brane located at the holographic boundary of an asymptotic ADS_5 bulk is used. The existence of tachyons in the perturbative spectrum of string theory indicates that the perturbative vacuum is unstable and a true vacuum exists towards which a tachyon field θ tends. Basically, this process is described by an effective (DBI) Lagrangian

$$\mathcal{L} = -V(\theta)\sqrt{1 - g^{\mu\nu}\theta_{,\mu}\theta_{,\nu}}\,. \tag{1}$$

Holographic cosmology [1], based on the effective four-dimensional Einstein equations on the holographic boundary in the framework of anti de Sitter/conformal field theory (AdS/CFT) correspondence [2], has a property that the universe starts from a point at which the energy density and cosmological scale are both finite. As a continuation of the previous papers [3,4], where we studied tachyon inflation on a Randall-Sundrum type of braneworld (RSII), we consider a D3-brane located at the holographic boundary in asymptotic ADS_5 bulk.

The analytical calculations are improved up to higher orders in the slow-roll parameters. The evaluation equations are solved numerically and our results for the observational parameters are confronted with Planck 2018 data.

[1] N. Bilić, *Phys. Rev. D* **93**, 066010 (2016), `arXiv:1511.07323`.
[2] P. Binetruy, E. Kiritsis, J. Mabillard, M. Pieroni and C. Rosset, *JCAP* **1504**, 033 (2015), `arXiv:1407.0820`.
[3] N. Bilić, D. Dimitrijevic, G. Djordjevic and M. Milosevic, *Int. J. Mod. Phys. A* **32**, 1750039 (2017), `arXiv:1607.04524`.
[4] N. Bilić, S. Domazet and G. S. Djordjevic, *Phys. Rev. D* **96**, 083518 (2017), `arXiv:1707.06023`.

Branko Dragovich

On p-adic mathematical physics

p-Adic mathematical physics is a branch of modern mathematical physics based on application of p-adic numbers, p-adic analysis and other parts of p-adic mathematics to modeling some physical systems and related phenomena. Beginning of p-adic mathematical physics was in 1987, when successful construction of scattering amplitudes for scalar p-adic strings was done. In this case string world-sheet is presented by p-adic numbers. Since that time many models have been constructed – from strings via bioinformation systems to the universe as a whole. There have been p-adic consideration in string theory, QFT, quantum mechanics, gravity and cosmology, dynamical systems, stochastic processes, wavelets, genetic code, ... Complex systems with hierarchical structure are very suitable for p-adic treatments. Adelic generalizations of some p-adic models are also considered.

p-Adic numbers are quite different with respect to real numbers, and it follows from the fact that p-adic numbers are endowed with an ultrametric distance while distance between real numbers is the ordinary one. Real and p-adic numbers contain rational numbers, and they can be treated simultaneously within adeles. Ultrametricity of p-adic numbers provides their application for description of systems and phenomena with hierarchy. p-Adic numbers are discovered by mathematician Kurt Hensel in 1897 and play significant role in many parts of mathematics.

In this talk I will present a very brief review of motivations, mathematical background, some methods and characteristic examples (e.g see reviews [1,2]). As an illustration of p-adic modeling of bioinformation I will mention the genetic code [3].

[1] B. Dragovich, A. Yu. Khrennikov, S. V. Kozyrev and I. V. Volovich, *p-Adic Numbers, Ultrametric Analysis and Applications* **1**, 1 (2009), `arXiv:0904.4205`.
[2] B. Dragovich, A. Yu. Khrennikov, S. V. Kozyrev, I. V. Volovich and E. I. Zelenov, *p-Adic Numbers, Ultrametric Analysis and Applications* **9**, 87 (2017), `arXiv:1705.04758`.
[3] B. Dragovich, A. Yu. Khrennikov and N. Ž. Mišić, *Applied Mathematics and Computation* **309**, 350 (2017), `arXiv:1704.04194`.

Stefano Gregorio Giaccari

Causality in nonlocal gravity

The definition of quantum gravity is hindered by the difficulty of reconciling the requirements of renormalizability and unitarity. For example, the Einstein-Hilbert action is non-renormalizable, but, if we include infinitely many counterterms, it is pertubatively unitary. Higher-derivative theories of gravity, while possibly renormalizable, are generically expected to be non-unitary. Recently it has also been pointed out that higher-derivative terms are associated with a violation of causality at scales larger than the Planck length. This can be avoided by adding an infinite tower of massive higher spin particles, which are in fact expected in a weakly coupled string theory. On the other hand this argument seems to rule out causality for quantum gravity theories containing only conventional particles with spin not greater than 2.

In this talk we argue the requirement of causality can still be satisfied for a class of weakly nonlocal gravitational theories which have been proposed as compatible with perturbative unitarity and renormalizability. This result will be justified computing Shapiro's time delay in terms of tree-level scattering amplitudes for nonlocal gravity models with and without matter. We will then argue how generic nonlocal gravity theories consistent with causality can be obtained by a field redefinition from standard local theories. In particular we will discuss a Einstein-Maxwell-Scalar nonlocal field theory and the N=1 nonlocal supergravity.

Dragoljub Gočanin

Noncommutative $OSp(4|2)$ supergravity

In our quest for the theory of "Quantum Gravity", we must be prepared to go beyond the usual assumptions on which we are accustomed, in particular, at very short length scales (very high energies) we might have to abandon the notion of a continuous spacetime and mathematical construct of differentiable manifold that is associated with it. One distinguished approach to the problem is Noncommutative (NC) Field Theory - a classical field theory on NC-deformed spacetime. It is based on the method of *quantization by deformation* via NC $\star$-product first developed in the context of phase-space quantum mechanics. One speaks of a deformation of an object/structure whenever there is a family of similar objects/structures for which we can parametrize their " distortion" from the original, undeformed one. In physics, this so-called *deformation parameter* appears as some fundamental constant of nature that measures the deviation from the classical (undeformed) theory. To deform the classical structure of spacetime, we introduce an abstract algebra of NC coordinates. These NC coordinates, denoted by $\hat{x}^\mu$, satisfy some non-trivial commutation relations. The simplest case of noncommutativity is the so-called *canonical noncommutativity*, $[\hat{x}^\mu, \hat{x}^\nu] = i\theta^{\mu\nu}$ where $\theta^{\mu\nu}$ are components of a *constant* antisymmetric matrix. The quantity $\theta^{\mu\nu}$ is a, presumably small, deformation parameter that has dimensions of $(length)^2$. It is a fundamental constant, like the Planck length or the speed of light. Equivalently, one can introduce NC Moyal-Weyl $\star$-product instead of the ordinary commutative point-wise field multiplication and deform the commutative algebra of functions on classical spacetime manifold. The resulting structure is capable of capturing the quantum character of spacetime.

In this setting, NC gravity can be obtained by canonical NC deformation of the AdS gauge theory of gravity in which spin-connection and vierbein are unified, being the components of a general $SO(2,3)$ connection. We present a classical (undeformed) action invariant under $SO(2,3)$ gauge transformations, that reduces to the standard Einstein-Hilbert action with cosmological constant after gauge fixing, for which we use a constrained auxiliary field. NC correction is obtained perturbatively, by expanding the NC action invariant under $SO(2,3)_\star$ deformed gauge transformations, in powers of deformation parameter $\theta^{\alpha\beta}$, and they are quadratic in $\theta^{\alpha\beta}$. For this, we employ the enveloping algebra approach and the Seiberg-Witten map. A deformation of Minkowski metric is derived, and we explain the breaking of diffeomorphism invariance in NC theory. After that, we introduce matter fields into the framework, in particular, Dirac spinor field and $U(1)$ gauge field. NC corrections are now *linear* in $\theta^{\alpha\beta}$. Phenomenological consequences are most significantly reflected through the NC-deformed Dirac equation in flat spacetime. We discuss how spacetime noncommutativity modifies Landau levels of an electron in a background magnetic field.

It is well known that one can define a consistent theory of extended $N = 2$ anti-de Sitter (AdS) Supergravity (SUGRA) in $D = 4$, by gauging orthosymplectic graded Lie group $OSp(4|2)$. The two real (Majorana) spin-3/2 fields (comprising the fermionic sector of the $OSp(4|2)$ super-connection) can be combined into the single complex spin-3/2 field (charged gravitino). Beside local $SO(1,3) \times U(1)$ gauge symmetry, the resulting classical action is also invariant under complex local SUSY whose gauge field is the complex spin-3/2 field. This theory unifies gravitation and electromagnetism, the photon now belonging to the gauge super-multiplet of complex local SUSY. We present a classical action invariant under $OSp(4|2)$ gauge transformations that reduces to the $N = 2$ AdS_4 SUGRA action after suitable gauge fixing. The geometric character of the $OSp(4|2)$ invariant action makes it ideally suited for NC deformation. NC correction of pure $N = 1$ Poinacaré SUGRA are very difficult to find, being quadratic in the deformation parameter. Introducing charged matter (Dirac spinor) removes this difficulty. Since the two Majorana spinors of $OSp(4|2)$ can be combined into a charged spinor, NC deformation of the $OSp(4|2)$ invariant action also exhibits linear NC corrections.

Alexey Golovnev

Spin connections, local Lorentz transformations and cosmological perturbations in modified teleparallel theories of gravity

There used to be a lot of confusion in the literature regarding the properties of modified teleparallel gravity models such as $f(T)$. The reason is that the local Lorentz rotations of a tetrad are realised as symmetries in TEGR only up to a surface term in the action. Of course, upon modification, they generically fail to be symmetries in any good sense, and new degree(s) of freedom do appear. These peculiarities must be properly taken into account even in most basic calculations of linear perturbation theory around the simplest cosmological backgrounds. In recent years there was considerable progress, and these topics got to be much better understood than before, though

many important questions are yet unanswered. I will review both what we already know well, as well as give some speculations and personal opinions about the further development and perspectives of the field.

Ilija Ivanišević

Courant and Roytenberg bracket and their relation via T-duality

We consider the σ-model for closed bosonic string propagating in the coordinate dependent metric and Kalb-Ramond field. We are interested in calculating the Poisson bracket algebras between the generalized currents, objects defined as arbitrary linear combinations of canonical momenta and coordinate derivatives, as they contain all for bosonic string theory relevant commutativity relations.

First, we consider a generalized current $J_{(u,a)} = u^\mu(x)\pi_\mu + a_\mu(x)x'^\mu$. The Poisson bracket algebra of these currents is obtained and we see that it gives rise to the Courant bracket. The Courant bracket is a fundamental structure of the generalized complex geometry. It generalizes the Lie bracket, so that it includes both vectors and 1-forms on an equal footing.

Secondly, we define another set of generalized currents in a new basis. That basis consists of coordinate derivatives, as well as the auxiliary currents, obtained by adding the 1-form of the Kalb-Ramond field contracted with the coordinate derivative to the canonical momenta. The Poisson bracket algebra of these generalized currents is obtained and it gives rise to the Courant bracket, twisted by the Kalb-Ramond field.

Finally, we calculate the algebra of the T-dual generalized currents. T-duality interchanges the momenta with winding numbers, so the T-dual generalized currents are obtained by this transformation acting on the generalized currents. The Poisson bracket algebra of T-dual generalized currents gives rise to the Roytenberg bracket, equivalent to the bracket obtained by twisting the Courant bracket by the non-commutativity parameter, which is T-dual to the Kalb-Ramond field. The Roytenberg bracket is the generalization of the Courant bracket, so that it includes a bi-vector. We show that the twisted Courant bracket and the Roytenberg bracket are mutually related via T-duality.

Nikolaos Kalogeropoulos

q-entropy: from geometry to statistical mechanics and cosmology

In an attempt to understand the dynamical foundations of q-entropy, we present its role in the theory of, not necessarily smooth, metric measure spaces and point out its potential relevance for statistical mechanics, and more indirectly, for cosmology.

Nikola Konjik

Angular noncommutative scalar field phenomenology in flat and curved space

In this presentation a noncommutative deformation of scalar field theory is introduced by an angular twist. The angular twist is an Abelian twist, defined by two commuting vector fields: the generator of the time translations and the generator of rotations around the z-axis. The noncommutative $\phi^4_\star$ quantum field theory is analyzed at the one-loop level and contributions to the propagator of both planar and non-planar diagrams are calculated. Using these results, UV/IR mixing is discussed. Noncommutative deformation induces a deformations of the momentum conservation law. This deformation can be expressed in terms of $\star$-sums of momenta. The $\star$-sum is a direct consequence of the deformed (twisted) coproduct of momenta. In the second part of this presentation a noncommutative scalar field in curved space is discussed. In particular, the dynamics of a noncommutative charged scalar field in the Reissner-Nordström black hole background is analyzed. Solving the scalar field equation of motion with appropriate boundary conditions, the quasinormal mode spectrum is obtained. Noncommutativity induces a splitting of spectral

lines with respect to the magnetic quantum number m. Different methods are used to calculate the quasinormal mode spectrum: WKB method, continued fraction method and an analytic method. The results obtained by these methods are compared and a good qualitative agreement is shown.

Abhijit Mandal

Thermodynamic study of Reissner-Nordström quintessence black hole

Direct local impacts of cosmic acceleration upon a black hole are matters of interest. Babichev et. al. had published before that the Friedmann equations which are prevailing the part of fluid filled up in the universe to lead (or to be very specific, 'dominate') the other constituents of universe and are forcing the universe to undergo present-day accelerating phase (or to lead to violate the strong energy condition and latter the week energy condition), will themselves tell that the rate of change of mass of the central black hole due to such exotic fluid's accretion will essentially shrink the mass of the black hole. But this is a global impact indeed. The local changes in the space time geometry next to the black hole can be analyzed from a modified metric governing the surrounding space time of a black hole. A charged de Sitter black hole solution encircled by quintessence field is chosen for this purpose. Different thermodynamic quantities are analyzed for different values of quintessence equation of state parameter, ω_q. Specific jumps in the nature of the thermodynamic space near to the quintessence or phantom barrier are noted and physically interpreted as far as possible. Nature of phase transitions and the situations at which these transitions are taking place are also explored. It is determined that before quintessence starts to work ($\omega_q = -0.33 > -\frac{1}{3}$) it was preferable to have a small unstable black hole followed by a large stable one. But in quintessence ($-\frac{1}{3} > \omega_q > -1$), black holes are destined to be unstable large ones pre-quelled by stable/unstable small/intermediate mass black holes.

Keywords: thermodynamics, black hole, quintessence field, geometrothermodynamics, Ricci scalar, thermodynamics phase transition.

Nenad Manojlović

Separation of variables for the elliptic Gaudin model with boundary

Using the generic solution of the corresponding reflection equation we construct the generalized elliptic $sl(2)$ Gaudin algebra based on the relevant non-unitary classical r-matrix. Following the separation of variables approach we study both classical and quantum elliptic Gaudin model with boundary.

Aleksandar Miković

Piecewise flat metrics and quantum gravity

We introduce a piecewise metric for a Regge triangulation of a spacetime and describe its properties in the Euclidean and in the Minkowski case. Then we show how to define the path integral for the wavefunction and the propagator in the case of the triangulations which correspond to the minisuperspace models.

Milan Milošević

Slow-roll parameters in extended RSII model

The inflation theory proposes a period of extremely rapid (exponential) expansion of the universe during the very early stage of the

universe. Although inflationary cosmology has successfully complemented the Standard Model, the process of inflation, primarily the way it begins, is still largely unknown.

A popular class of the inflationary cosmological models introduce a scalar field with nonstandard tachyonic Lagrangian of the Dirac-Born-Infeld (DBI) type. Our research is motivated by the second Randall-Sundrum (RSII) cosmological model. In this work, we study a tachyon cosmological model based on the dynamics of a 3-brane in the RSII model extended to include matter in the bulk. The presence of matter modifies the RSII cosmology and tachyon potential. We study different types tachyonic potential (inverse power law, exponential and inverse cosh) in the context of the braneworld cosmology.

The slow-roll approximation is used only to estimate the initial conditions. The solutions for the dynamics of inflation is calculated numerically. The results are used to calculate the Hubble parameter, as well as the observational parameters for random values of the free parameters in a given range and the corresponding initial conditions.

The results obtained for observational cosmological inflation parameters: the scalar spectral index (n_s) and the tensor-to-scalar ratio (r) for a braneworld inflationary scenarios will be presented. The calculated numerical values of observational parameters are compared with the latest results of observations obtained by the Planck Collaboration (2018).

Đorđe Minić

From string theory and quantum gravity to dark matter and dark energy

I will introduce the concept of Born geometry that underlies general quantum non-locality, consistent with causality. I will then discuss a realization of Born geometry in string theory, viewed as a theory of quantum gravity, and show how Born geometry is represented in the zero mode sector. Finally, I will present a new picture of dark matter and dark energy in this formulation of quantum gravity.

Bojan Nikolić

From $3D$ torus with H-flux to torus with R-flux and back

We consider 3D closed bosonic string propagating in the constant metric and Kalb-Ramond field with one non-zero component, $B_{xy} = Hz$, where field strength H is infinitesimal. In the first part of the article, applying Buscher T-dualization procedure and generalized one, we T-dualize along line $x \to y \to z$, which means that we T-dualize first along x coordinate, then along y and, finally, along z coordinate. After first two T-dualizations we obtain Q flux theory which is just locally well defined, while after all three T-dualizations we obtain nonlocal R flux theory. Origin of non-locality is variable ΔV defined as line integral, which appears as an argument of the background fields. Rewriting T-dual transformation laws in the canonical form and using standard Poisson algebra, we obtained that Q flux theory is commutative one and the R flux theory is noncommutative and nonassociative one.

In the second part of the article, we reverse the T-dualization line and T-dualize along $z \to y \to x$. All three theories are nonlocal, because variable ΔV appears as an argument of background fields. After the first T-dualization we obtain commutative and associative theory, while after we T-dualize once more, along y, we get noncommutative and associative theory. At the end, dualizing along x, we come to the theory which is both noncommutative and nonassociative. The form of the final T-dual action does not depend on the order of T-dualization while noncommutativity and nonassociativity relations could be obtained from those in the $x \to y \to z$ case by replacing $H \to -H$.

Emil Nissimov

Non-Riemannian volume elements dynamically generate inflation

We propose a simple modified gravity model *without* any initial matter fields in terms of several alternative non-Riemannian space-time volume elements within the metric (second order) formalism. We show how the non-Riemannian volume elements, when passing to the physical Einstein frame, create a canonical scalar field and produce dynamically a non-trivial inflationary-type potential for the latter with a large flat region and a stable low-lying minimum. We study the evolution of the cosmological solutions from the point of view of theory of dynamical systems. The theory predicts the spectral index $n_s \approx 0.96$ and the tensor-to-scalar ratio $r \approx 0.002$ for 60 e-folds, which is in accordance with the observational data. In the future Euclid and SPHEREx missions or the BICEP3 experiment are expected to provide experimental evidence to test those predictions.

Sergei Odintsov

The universe acceleration in modified gravity: an overview

General introduction to cosmology of modified gravity is given. It is shown that different forms of modified gravity are possible: many of them being consistent with Solar system tests and cosmological bounds. Special attention is paid to $F(R)$ gravity. It is shown that such theory may naturally describe the early-time inflation with late-time acceleration (dark energy epoch). Realistic versions of $F(R)$ gravity are proposed. The inflationary indices are shown to be consistent with Planck experiment. New ghost-free versions of modified gravity are introduced and their cosmological evolution is studied. It

is shown that it may naturally give the unification of inflation with dark energy while scalar field which appears there plays the role of dark matter.

Anna Pachol

Digital quantum geometries

Noncommutative geometry, as the generalised notion of geometry, allows us to model the quantum gravity effects in an effective description without full knowledge of quantum gravity itself. On a curved space one must use the methods of Riemannian geometry - but in their quantum version, including quantum differentials, quantum metrics and quantum connections.

The brief introduction to the general framework involving noncommutative differential graded algebra and construction of quantum Riemannian geometry elements will be provided. This framework has been applied to classification of all possible noncommutative Riemannian geometries in small dimensions, working over the field $\mathbb{F}_2$ of 2 elements and with coordinate algebras up to dimension $n \leq 3$. We have found a rich moduli of examples for $n = 3$ and top form degree 2, including 9 that are Ricci flat but not flat. The choice of the finite field in this framework proposes a new kind of 'discretisation scheme', which we called the 'digital geometry'.

Shibesh Kumar Jas Pacif

An accelerating cosmological model from a parametrization of Hubble parameter

In view of late-time cosmic acceleration, a dark energy cosmological model is revisited wherein Einstein's cosmological constant is considered as a candidate of dark energy. Exact solution of Einstein field equations (EFEs) is derived in a homogeneous isotropic background in classical general relativity. The solution procedure is adopted, in a model independent way (or the cosmological parametrization). A simple parametrization of the Hubble parameter H as a function of cosmic time t is considered which produces an exponential type of evolution of the scale factor a and also shows a negative value of deceleration parameter at the present time with a signature flip from early deceleration to late acceleration. Cosmological dynamics of the model obtained have been discussed illustratively for different phases of the evolution of the Universe. The evolution of different cosmological parameters are shown graphically for $a(t)$ and closed cases of Friedmann-Lemaitre-Robertson-Walker (FLRW) space-time for the presented model (open case is incompatible to the present scenario). We have also constrained our model parameters with the updated (36 points) observational Hubble dataset.

Tijana Radenković

Hamiltonian analysis of the $3BF$ theory for a generic Lie 3-group

The constrained BF models are based on deformations of the BF theory, by adding constraints to the topological BF action that promote some of the gauge degrees of freedom into physical ones, for example giving rise to general relativity as in the case of the well known Plebanski model. The higher category theory can be employed to generalize the BF action to the so-called n-BF action, by passing from the notion of a gauge group to the notion of a gauge n-group. Specifically, the notion of a 3-group in the framework of higher category theory is introduced as a 3-category with only one object where all the morphisms, 2-morphisms and 3-morphisms are invertible. It has been proved that a strict 3-group is equivalent to a 2-crossed module. Then, a $3BF$ action can be defined for a 2-crossed module $(L \xrightarrow{\delta} H \xrightarrow{\partial} G\,, \triangleright\,, \{\_\,,\_\})$ as:

$$S_{3BF} = \int_{\mathcal{M}_4} \langle B \wedge \mathcal{F} \rangle_{\mathfrak{g}} + \langle C \wedge \mathcal{G} \rangle_{\mathfrak{h}} + \langle D \wedge \mathcal{H} \rangle_{\mathfrak{l}}\,,$$

where $B \in \mathcal{A}^2(\mathcal{M}_4, \mathfrak{g})$, $C \in \mathcal{A}^1(\mathcal{M}_4, \mathfrak{h})$ and $D \in \mathcal{A}^0(\mathcal{M}_4, \mathfrak{l})$ are Lagrange multipliers, and $\mathcal{F} = \mathrm{d}\alpha + \alpha \wedge \alpha - \partial\beta$, $\mathcal{G} = \mathrm{d}\beta + \alpha \wedge^{\triangleright} \beta - \delta\gamma$, $\mathcal{H} = \mathrm{d}\gamma + \alpha \wedge^{\triangleright} \gamma + \{\beta \wedge \beta\}$ are the elements of 3-curvature $(\mathcal{F}, \mathcal{G}, \mathcal{H})$ for a 3-connection (α, β, γ) defined on the manifold $\mathcal{M}_4$ given by the algebra-valued differential forms $\alpha \in \mathcal{A}^1(\mathcal{M}_4\,, \mathfrak{g})$, $\beta \in \mathcal{A}^2(\mathcal{M}_4\,, \mathfrak{h})$ and $\gamma \in \mathcal{A}^3(\mathcal{M}_4\,, \mathfrak{l})$. The Killing forms $\langle \_, \_ \rangle_{\mathfrak{g}}$, $\langle \_, \_ \rangle_{\mathfrak{h}}$ and $\langle \_, \_ \rangle_{\mathfrak{l}}$ are G-invariant bilinear symmetric nondegenerate Killing forms on $\mathfrak{g}$, $\mathfrak{h}$ and $\mathfrak{l}$, respectively.

The complete Hamiltonian analysis of the $3BF$ action for a general Lie 3-group is performed by using the Dirac procedure. This analysis is the first step towards a canonical quantization of a $3BF$ theory, an important stepping-stone for the quantization of the complete Standard Model of elementary particles coupled to Einstein-Cartan gravity formulated as a $3BF$ action with suitable simplicity constraints.

It is shown that the resulting dynamic constraints eliminate all local degrees of freedom, i.e. the $3BF$ theory is a topological field theory.

Marcelo Enrique Rubio

On well-posedness of non-linear theories in mathematical physics

One of the most challenging purposes of theoretical physics is to develop theories that attempt to explain and understand, as accurately as possible, the evolution of physical systems given a certain initial configuration. This aspect is crucial and inevitable in order to guarantee the predictability power of the theory. The theory of partial differential equations provides results and powerful tools to study this problem, which is known as the Cauchy problem or initial value problem. Although functional analysis helps to formalize several aspects associated with the functional spaces in which the existence, uniqueness and continuity of the evolution with respect to the initial data is guaranteed, there is a series of purely algebraic tools that univocally characterize well-posed systems.

In this talk we will review some motivational and relevant results when approaching and studying the initial value problem in physics, and after commenting on open problems and difficulties that appear, we will illustrate their use for the study of non-linear relativistic extensions of classical theories such as electromagnetism and hydrodynamics.

Igor Salom

Generalized $sl(2)$ Gaudin algebra and corresponding Knizhnik-Zamolodchikov equation

The Gaudin model has been revisited many times, yet some important issues remained open. In this talk, I will present our recent results on this topic. In particular, I will discuss the relationship between the off-shell Bethe vectors and the solutions of the corresponding Knizhnik-Zamolodchikov equations for the non-periodic $sl(2)$ Gaudin model. Next, I will derive the norm of the eigenvectors of the Gaudin Hamiltonians. Additionally, I will also provide a closed-form expression for the scalar products of the off-shell Bethe vectors. Finally, I will demonstrate an explicit closed-form of the off-shell Bethe vectors, together with a sketch of a proof of implementation of the algebraic Bethe ansatz in full generality.

Gauranga Charan Samanta

Wormhole modeling in general relativity

In this paper, the traversable wormhole solutions are investigated for Einstein's field equations with cosmological constant. Using redshift function $\Phi(r)$ and shape function $b(r)$ as $\Phi(r) = -1/r^2$ and $b(r) = \frac{r_0 \log(r+1)}{\log(r_0+1)}$ in the static and spherically symmetric metric of wormholes, the spherical regions are determined where the energy conditions are satisfied for positive value of cosmological constant.

Branislav Sazdović

The field strength of non-geometric theories

In order to enable open string invariance at string end-points under: local gauge transformations of the Kalb-Ramond field and its T-dual general coordinate transformations, we added new terms in the action with Neumann and Dirichlet vector gauge fields.

Performing generalized T-dualization of the vector gauge fields linear in coordinates, we will obtain non-local and hence locally non-geometric theory. The same theory can be described as a theory with constant field strength and then we can perform standard Buscher T-dualization. These two approaches lead to the relation between T-dual gauge fields of non-geometric theory and T-dual field strength of geometric theory.

The connection between them is non-standard for two reasons. First, because we must use derivatives of vector fields with respect not only to the T-dual variable y_μ but also to its double $\tilde{y}_\mu$, which is source of non-locality. Second, because the T-dual field strength contains both antisymmetric and symmetric parts. Consequently, with the help of T-duality we are able to introduce the field strength in terms of gauge fields for non-geometric theories.

All above results can be interpreted as coordinate permutations in double space. So, in the open string case complete set of T-duality transformations form the same subgroup of the $2D$ permutation group as in the closed string case.

Dejan Simić

Memory effect of massive gravitational waves

The memory effect for gravitational waves was first discovered by Zel'dovich and Polnarev, originally, conclusion of their paper is that test masses initially at rest will suffer permanent displacement after the passage of a gravitational wave. Afterwards, Bondi and Pirani as well as Grishchuk and Polnarev arrived at a different conclusion in their analysis. Namely, they concluded that passage of a gravitational wave will be encoded, not in permanent displacement but, in non-zero relative velocity of test masses. Recently, Zhang et al analyzed this problem too and, among other things, concluded that velocity, and not displacement, memory effect happens for the case of plane gravitational waves and that is connected with soft gravitons.

Unrelated, at first sight, investigation of asymptotic symmetries at null infinity gave some unexpected results which connected asymptotic symmetries, soft theorems and displacement memory effect. This line of reasoning is applied on black holes by Hawking et al, and offered new insights into black hole physics. More precise, they derived that black holes have infinite number of additional soft charges which highly constrain their dynamics. Importance of this insight is still under investigation, just to mention that Afshar et al, using this idea, constructed microstates of three dimensional black holes.

Because all the analysis, of previously mentioned works, is done in the framework of general relativity it is not clear are soft gravitons the essential component for the validness of the obtained results. In this talk we review the analysis of the geodesic motion in asymptotically flat plane wave space-time first in three dimensions for theory that has no mass-less degrees of freedom and second in four dimensional space-time but for the case of massive gravitational waves. We discover the presence of velocity memory effect in both cases. Without a doubt, we can conclude that no soft particles are needed for the memory effect. Immediate, implications of this on a relation of asymptotic symmetries and soft theorems is not clear and requires further investigation.

Paul Sorba

Some aspects of non-equilibrium quantum field theory

Quantum junctions with the geometry of a star graph are considered. The system is in a non-equilibrium steady state, characterized by the temperatures and chemical potentials of the heat reservoirs connected to the edges of the graph. The study of the non-equilibrium expectation values of the particle and heat currents reveals that the junction operates as an energy converter, transmuting heat to chemical potential energy and vice versa (i.e. quantum heat engine). An analysis of the universal microscopic features of quantum transport, which breaks time reversal spontaneously, is then performed. Based on the probability distribution, it is generated by the correlation functions of the entropy production operator. One can show that all moments of the entropy production distribution are non-negative, thus providing a microscopic version of the second law of thermodynamics.

Ciprian Sporea

Fermionic quasibound states for Reissner-Nordström black holes

In this work we discuss the existence of Dirac (quasi)bound states in the gravitational field of a Reissner-Nordström black hole. We have found that such type of states do exist and we obtain them by analysing the discrete quantum modes that are square integrable solutions of the Dirac field in this type of geometry. By imposing a suitable quantization condition of these modes, we were able to derive an analytical expression for the ground state. The energy of higher states are then obtained numerically. In the limit of small black hole mass M the energy of the RN quasibouns states are compared with the Dirac-Coulomb energy levels, and we have found that the two are in good agreement.

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Alexei Starobinsky

Pre-inflation, inflation and post-inflationary heating in $f(R)$ and scalar-tensor modified gravity

Several new results on inflation and pre- and post-inflationary evolution of the Universe in the $f(R)$ and related scalar-tensor gravity models are presented. The $R + R^2$ (Starobinsky) model where R is the Ricci scalar, augmented by small one-loop quantum gravitational corrections, represents the pioneer inflationary model [1] which still remains viable. It contains only one adjustable parameter taken from observations, has a graceful exit from inflation and a natural mechanism for creation and heating of matter after its end, and produces a very good fit to existing observational data on the power spectrum of primordial scalar (adiabatic density) perturbations. More generally, all viable slow-roll inflationary models in $f(R)$ gravity should be close to this model over some range of R. It also represents a dynamical attractor for slow-rolling scalar fields strongly coupled to gravity, as well as for the mixed R^2-Higgs inflationary model [2]. As follows from observational data on the primordial scalar (matter density) perturbation spectrum, running of the dimensionless coefficient in front of the R^2 term with curvature due to loop quantum-gravitational corrections is small and does not exceed a few percents [3]. The same refers to the $R\Box R$ correction considered perturbatively, without increasing the number of degrees of freedom [4]. Also studied is the problem of inflation formation from preceding generic classical curvature singularity, and which conditions are needed for this in $f(R)$ [5] and scalar-tensor [6] gravity. Some exact anisotropic solutions describing it are presented. Since this process is generic, too, for inflation to begin inside a patch including the observable part of the Universe, causal connection inside the whole patch is not necessary. However, it becomes obligatory for a graceful exit from inflation in order to have practically the same number of e-folds during inflation inside this patch. Finally, heating of matter through quantum-gravitational particle production after the end of inflation in the $R+R^2$ and related inflationary models is considered.

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Alexei Starobinsky

The mixed Higgs-R^2 inflationary model

The Higgs model with a strong non-minimal coupling of the Higgs scalar field to the Ricci scalar R and the $R + R^2$ (Starobinsky) model augmented by small one-loop quantum gravitational corrections represent the simplest and the most economic inflationary models which remain viable. They contain only one adjustable parameter taken from observations, have a graceful exit from inflation and natural mechanisms for creation and heating of matter after its end, and produce a very good fit to existing observational data on the power spectrum of primordial scalar (adiabatic density) perturbations, for which their predictions coincide if expressed in terms of the number of e-folds N from the end of inflation. That is why it is interesting to study the mixed Higgs-R^2 inflationary model which is an example of double inflation driven by two effective scalar fields. It also removes some UV problems of inflation in the pure Higgs model. It appears that for the set of the most interesting inflationary trajectories, the $R + R^2$ model represents a dynamical attractor for the Higgs field strongly coupled to gravity. As a result, double inflation in the mixed model effectively reduces to the single one in the Starobinsky model with a renormalized scalaron mass [1]. Particle production by varying background gravitational and Higgs fields after the end of inflation in the mixed Higgs-R^2 model is investigated. For the most typical class of inflationary trajectories, it appears to be less efficient that in the pure Higgs model. Thus, reheating cannot be completed in a few Hubble times in the violent particle production regime, and it requires longer time for the scalaron decay, similar to the case of the pure $R + R^2$ model [2].

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Mykola Stetsko

Black holes in the theory with nonminimal derivative coupling and some aspects of their thermodynamics

Scalar-tensor theories of gravity have been attracted considerable attention for recent years. This interest is mainly motivated by well-known Dark Matter/Dark Energy problem which even for the simplest approaches brings additional scalar degrees of freedom coupled to gravity. Among vast area of scalar-tensor theories so-called Horndeski gravity possesses several attractive features, which is supposed to be the most general scalar-tensor theory where the equations of motion are of the second order. In our work we consider a particular case of general Horndeski gravity where scalar field is nonminimally coupled to gravity with additional material field which has standard minimal coupling with gravity. The action integral for such a system can be written in the form:

$$S = \frac{1}{16\pi} \int d^{n+1}x\sqrt{-g} \left(R - 2\Lambda - \frac{1}{2} \left(\alpha g^{\mu\nu} - \eta G^{\mu\nu} \right) \partial_\mu \varphi \partial_\nu \varphi + \mathcal{L}_m \right), \tag{1}$$

where R is the scalar curvature, $g_{\mu\nu}$ and g denote metric tensor and its determinant respectively, $G^{\mu\nu}$ is the Einstein tensor, φ is the scalar field, α and η are coupling constants and $\mathcal{L}_m$ denotes a Lagrangian of a material field. It is worth noting that in our work we consider electromagnetic field with power-law and Born-Infeld Lagrangians.

We find solutions of equations of motion that follows from the action (1) that represent static black holes, namely the general structure of the metrics can be cast in the form:

$$ds^2 = -U(r)dt^2 + W(r)dr^2 + r^2 d\Omega^{2(\varepsilon)}_{(n-1)},$$

where $U(r)$, $W(r)$ are metric functions and $d\Omega^{2(\varepsilon)}_{(n-1)}$ is a length element of a constant curvature surface. The obtained black holes' solutions are investigated and it is shown that they share common features with black holes in the framework of standard general relativity.

We also study thermodynamics of the obtained black holes and derive their temperature, entropy and the write the first law. In particular to obtain the relation for entropy and the first law Wald's approach is used. Due to the presence of the cosmological constant Λ Weyl anomaly appears for odd space-time dimensions, which brings additional contribution into thermodynamic relations. To calculate Weyl anomaly we use standard procedure which is based on Fefferman-Graham expansion.

Ovidiu Cristinel Stoica

Some applications of Clifford algebras to the Standard Model — chiral asymmetry in the weak interaction

The Dirac spinor's left an right components seem to be related to the spin, which appears from the representation of the Poincaré group. At the same time, only the left chiral components of leptons and quarks take part in weak interactions. This makes chirality to be simultaneously a property related to spacetime, and to the internal degrees of freedom.

How can this be explained? The generators of the weak symmetry group extends the Dirac algebra $\mathbb{C}\ell_4$ to the Clifford algebra $\mathbb{C}\ell_6$. On the one hand, in terms of Clifford algebra representations, chirality corresponds to the spinor being even or odd. On the other hand, the doublet and singlet representations of the weak symmetry group corresponds to the exterior algebra $\bigwedge^\bullet \mathbb{C}^2$. These two observations lead to a geometric explanation of chirality in weak interaction, which is contained automatically in the Clifford algebra $\mathbb{C}\ell_6$.

At the same time, the same Clifford algebra $\mathbb{C}\ell_6$ admits an SU(3) symmetry that decomposes it into ideals which are representations of the color symmetry group, and has the right colors, electric charges, weak isospins, hypercharges, and chiralities as the leptons and quarks in the Standard Model. This decomposition corresponds, again, to an exterior algebra, $\bigwedge^\bullet \mathbb{C}^3$, which, when tensored with the one used to connect chirality and the weak interaction, from the entire Clifford algebra $\mathbb{C}\ell_6$. The electroweak symmetry is present in an already broken form, with a bare Weinberg angle θ_W given by $\sin^2\theta_W = 0.25$.

The talk is based mainly on the model proposed in reference [1], detailing some implicit aspects which were not explained extensively enough there.

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Fumihiko Sugino

Highly entangled quantum spin chains

Quantum entanglement is one of the most surprising features of quantum mechanics. Ground states of quantum many-body systems with local interactions typically obey an "area law" meaning the entanglement entropy proportional to the boundary length. For a ground state $|\mathrm{GS}\rangle$, the density matrix of the total system is $\rho = |\mathrm{GS}\rangle\langle\mathrm{GS}|$. When the system is divided into two subsystems A and B, the reduced density matrix for A is defined by tracing out the states on the subsystem B: $\rho_A = \mathrm{Tr}_B\,\rho$. Then, the entanglement entropy is given by the von-Neumann entropy for ρ_A: $S_A = -\mathrm{Tr}_A\,(\rho_A \ln \rho_A)$. It is exceptional when the system is gapless, and the area law had been believed to be violated by at most a logarithm for over two decades.

Recent discovery of Motzkin and Fredkin spin chain models is striking, since these models provide significant violation of the entanglement beyond the belief, growing as a square root of the volume in spite of local interactions. Although importance of intensive study of the models is undoubted to reveal novel features of quantum entanglement, it is still far from their complete understanding. In this talk, I will explain how such violation of the area law arises mainly in the Motzkin model [1].

The Rényi entropy defined by $S_{A\,\alpha} = -\frac{1}{1-\alpha} \ln \mathrm{Tr}_A \, \rho_A^\alpha$ is a generalization of the entanglement entropy. When the parameter α (the Rényi parameter) approaches to 1, it reduces to the entanglement entropy. The Rényi entropy is an important quantity, since the whole spectrum of an entangled subsystem can be reconstructed once $S_{A,\,\alpha}$ is known as a function of α. We first analytically compute the Rényi entropy for the Motzkin and Fredkin spin chains, and find non-analytic behavior with respect to α, which is a novel phase transition never seen in any other spin chain model studied so far. The Rényi entropy grows proportionally to the volume in one phase, whereas it scales as a logarithm of the volume in another phase. The transition point itself forms the third phase of the square-root scaling [2].

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Michał Szczachor

The conformal gravity of MacDowell-Mansouri type

Recently the anti-de Sitter gravity is well investigated as it plays a crucial role in AdS-CFT correspondence principle. That was the initial motivation for investigating such model, especially that it is well-defined in $4D$. MacDowell-Mansouri mechanism was chosen as a model which allows for build a gauge theory of gravity i.e. base on forms occurs on $4D$ manifold and valued in algebra of assumed symmetry. The reformulation of this mechanism in BF theory assures that model contains set of all possible topological invariants.

It was shown in the previous studies that symmetries group in such theories can be enlarged. Moreover, the initial motivation for original work on the conformal gravity made by Weyl was to enlarge symmetry, to be able describe unified theory of gravity and EM. These two arguments i.e. (1) proposed theory can be used for reconstruction gravity theory in the 'bulk' in $4D$, and (2) Poincaré symmetries can be naturally enlarged to conformal, were main trigger for this work.

The BF Lagrangian of MacDowell-Mansouri type has been presented in $4D$. The received action has two point of view. One is an action for bi-gravity (this type of theory has be obtained in previous work). Second allows to recognize dynamical part of effective action as well know Weyl gravity, but with the set of additional topological invariants i.e. a boundary terms which as a matter of fact are action on the $3D$ boundary manifold (they can be written as a Chern-Simons terms).

Nevertheless, presented framework introduce the Holst term (containing Immirzi parameter as a most of the theories belong to LQG or BF-constrained approaches). Boundary terms have been gathered and systematized.

Marek Szydlowski

Starobinsky cosmological model in Palatini formalism

We consider the Starobinsky model $f(\hat{R}) = \hat{R} + \gamma\hat{R}^2$ in the Palatini formalism in both Jordan and Einstein frames. The dynamics of models is also studied using dynamical system methods. We show the evolution of the Friedmann equation can be reduced to the form of a piecewise smooth dynamical system. In result, this system is reduced to a 2D dynamical system of the Newtonian type. From the phase portraits, one can find generic evolutionary scenarios of the evolution of the Universe. At each frame the topological structures of the phase space are different. In the Jordan frame, the sewn singularity appears which represents a finite scale factor type. Such singularity appears in the Starobinsky model in the Palatini formalism when dynamics is determined by the corresponding piecewise-smooth dynamical system. After reformulation of the model in the Einstein frame, we get the FRW cosmological model with a homogeneous scalar field and the vanishing kinetic energy term. In the Einstein frame, in the Friedmann equation, dark energy is in the form of a scalar field with a potential

whose the form is determined in a covariant way by the Ricci scalar of the FRW metric. In this frame, the energy density of matter and dark energy are also parametrized through the Ricci scalar and an interaction appears between matter and dark energy because the dark energy is decaying. In this model, during the cosmic evolution, the accelerating phase for the late times and the early inflation exist. In the Einstein frame undesirable singularities disappear. We calculate the slow roll parameters and the constant roll parameter in terms of the Ricci scalar for the characterization of inflation. We have found a characteristic behavior of the time dependence of density of dark energy on the cosmic time following the logistic-like curve which interpolates two almost constant value phases. From the required numbers of e-folds N we found a limit on the model parameter. These models in both frames are also analysed by statistical methods.

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Francesco Toppan

New issues in superconformal quantum mechanics

Superconformal quantum mechanics and the associated DFF deformed oscillators are recovered from spectrum generating superalgebras. Alternative choices of Hilbert spaces as direct sums of lowest weight representations are discussed. A $3D$ model with spin-orbit interaction and dependent on a real deformation parameter is explicitly solved. It presents unexpected features: a recursive pattern of vacuum energy in function of the deformation parameter; the degeneracy of the energy eigenstates interpolates between two different regimes, an effective $2D$ oscillator at low energy and a $3D$ oscillator at higher energy.

Vitaly Vanchurin

A quantum-classical duality and emergent spacetime

We consider the quantum partition function for a system of quantum spinors and then derive an equivalent (or dual) classical partition function for some scalar degrees of freedom. The coupling between scalars is nontrivial (e.g. a model on 2-sphere configuration space), but the locality structure of the dual system is preserved, in contrast to the imaginary time formalism. We also show that the measure of integration in the classical partition function can be formally expressed through relativistic Green's functions which suggests a possible mechanism for the emergence of a classical spacetime from anti-commutativity of quantum operators.

Olena Vaneeva

Equivalence groupoids, normalization property and group classification problems for evolution equations

It is widely known that there is no general theory for integration of nonlinear partial differential equations (PDEs). Nevertheless, many special cases of complete integration or finding particular solutions are related to appropriate changes of variables. Nondegenerate point transformations that leave a differential equation invariant and form a connected Lie group are called Lie symmetries of this equation. In many cases, the algorithmic Lie reduction method, which uses known Lie symmetries, results in the construction of group-invariant solutions for a given PDE. This places the transformation methods among the most powerful analytic tools currently available in the study of nonlinear PDEs.

Many nonlinear PDEs that are important for applications are parametrized by arbitrary elements (constants or functions) and constitute classes of PDEs. The problem of classification of Lie symmetries for a given class of PDEs is called the *group classification problem*. Another important task is to study transformational properties of such classes, i.e. to describe explicitly nondegenerate point transformations that link members of the class and not necessarily form a group. Such transformations, which are called admissible transformations, appear to be a useful tool not only for finding exact solutions but also for exhaustive solving group classifications problems and study of integrability. The set of admissible transformations considered with the standard operation of composition of transformations is also called the *equivalence groupoid*.

The modern group analysis provides us with two main approaches for solving group classification problems. The first is algebraic one, based on subgroup analysis of the corresponding equivalence group. It results in complete group classification only if the class under study is normalized, i.e. if any point transformation between two fixed equations from this class is induced by a transformation from its equivalence group. Therefore, finding equivalence groupoid and the study of the normalization property for a given class of PDEs is an important problem itself.

We investigate this problem for wide classes of evolution equations in two dimensions. The application of the obtained results for solving group classification problems is discussed.

Mihai Visinescu

Sasaki-Ricci flow on Sasaki-Einstein space $T^{1,1}$

We examine the compact Sasaki manifolds in view of transverse Kähler geometry and transverse Kähler-Ricci flow. In particular we investigate the transverse Kähler structure on the five-dimensional homogeneous Sasaki-Einstein space $T^{1,1}$. For this purpose a set of local holomorphic coordinates is introduced and a Sasakian analogue of the Kähler potential is given. We describe the deformations of the Sasaki-Einstein structure preserving the Reeb vector field, but modifying the contact form with basic functions. Choosing special basic functions which preserve the transverse metric, we generate new families of Sasaki-Einstein metrics. Two convenient particular situations are presented, giving the expressions for the deformed local metrics. We remark that in the case of deformations with such kind of basic functions we have an explicit solution of the equation of the Sasaki-Ricci flow on the underlying manifold. Finally, it is described the constructions of Hamiltonian vector fields and Hamiltonian functions on the $T^{1,1}$ manifold.

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Marko Vojinović

3-groups and higher gauge theory unification of all interactions

We will give a step-by-step overview of the gauge theory construction based on a notion of a 3-group. After we introduce 3-groups

in general, we will focus on the relevant example of a 3-group which describes the Standard Model and Einstein-Cartan gravity at the classical level. The 3-group structure features a novel gauge group, intimately connected to the fermion and scalar sectors of the Standard Model. This structure could potentially provide a new insight into the matter sector of the theory, and open new avenues for research on unification of all interactions and matter. Based on `arXiv:1904.07566`.

Igor Volovich

Weak turbulence in quantum theory

Weak turbulence of the solutions of an evolution equation is characterized in terms of the growth in time of higher Sobolev norms. The weak turbulence of a number of models of quantum mechanics and quantum field theory will be discussed.

Xiaoning Wu

The null-timelike boundary problems of linear wave equations in asymptotically anti-de Sitter space

We study the linear wave equations in an asymptotically anti-de Sitter spacetime. We will consider the mixed boundary problem, where the initial data are given on an outgoing null hypersurface and a timelike hypersurface, and the asymptotic information is given on conformal infinity.

Naqing Xie

Construction of vacuum initial data by the conformally covariant split system

Using the implicit function theorem, we show existence of solutions of the so-called conformally covariant split system on compact 3-dimensional Riemannian manifolds. They give rise to non-CMC vacuum initial data for the Einstein equations. This talk is based a recent joint work with P. Mach and Y. Wang.

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