Noncommutative geometry, quantum symmetries and quantum gravity II

XXXVII Max Born Symposium & COST Action "QSpace" WG3 Meeting

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List of talks with abstracts

Giovanni Amelino-Camelia (Rome) — **Hopf-algebra symmetries and cosmological neutrinos**

Abstract: I start by giving a brief overview of the use of Hopf algebras in quantum-gravity research, with emphasis on the use of Hopf algebras in the formulation of scenarios for anomalous particle propagation in a quantum spacetime. I compare this class of models with data recently announced by the IceCube neutrino telescope, showing that the present experimental situation is still inconclusive but preliminarily favors a new-physics scenario which can be based on Hopf algebras.

Gleb Arutyunov (Hamburg) — **Integrable eta-deformations: Scale invariance, T-duality and modified IIB supergravity**

Abstract: We consider the background underlying the eta-deformed AdS_5 x S^5 sigma model. We show that this background satisfies a certain modification of IIB supergravity equations of motion. Although the corresponding sigma model is not Weyl invariant, i.e. it does not define a critical string in the usual sense, it still defines a UV finite theory on flat 2d world-sheet. This property follows from the formal relation via T-duality between the eta-deformed model and the one defined by an exact type IIB supergravity solution that has 6 isometries albeit broken by a linear dilaton.

Michele Arzano (Rome) — **Planck scale kinematics with dimensional reduction to two**

Abstract: I introduce a new model of deformed relativistic kinematics at the Planck scale based on a non-abelian energy-momentum group manifold. I discuss the action of Lorentz group and the composition law for momenta for such momentum space. A relevant feature of the model is that it exhibits a running spectral dimension with the characteristic short distance reduction to the value of 2 found in most quantum gravity scenarios.

Paolo Aschieri (Alessandria&Turin) — **Cartan’s structure equations and Levi-Civita connection in Noncommutative Geometry from Drinfeld Twist**

Abstract: Deformation quantization of manifolds via Drinfeld twists allows to canonically deform the algebra of functions and the differential geometry. This leads to a general notion of NC connections on bimodules and on products of bimodules (no equivariance condition with respect to the group underlying the twist deformation being required). In particular given a connection on the bimodule of vector fields we canonically obtain a connection on the bimodule of one forms and on their tensor products. On one hand this is used to derive NC Cartan's structure equations that unify different approches to torsion and curvature tensors. On the other hand we prove the fundamental theorem of NC Riemannian geometry: any metric tensor defines a unique torsion free and metric compatible connection. The construction does not require the choice of a basis of one forms or vector fields and generalize to arbitrary twists previous results on abelian twists.

Angel Ballesteros (Burgos) — **(A)dS Poisson homogeneous spaces and Drinfel'd doubles**

Abstract: The correspondence between Poisson homogeneous spaces of a given Poisson-Lie group G and Lagrangian subalgebras of the Drinfel'd double of G is revisited. Connections with the construction of the corresponding quantum homogeneous spaces are studied, and the particular case in which G is a Drinfel'd double by itself is explored in detail. In particular, Poisson homogeneous spaces for the AdS group in (1+1) dimensions are constructed. In the (2+1) case, the two Poisson homogeneous spaces connected with the AdS Poisson--Lie structures coming from two Drinfel'd double structures of the AdS Lie algebra are presented.

John Barrett (Nottingham) — **The commutative limit of finite spectral triples**

Abstract: This talk is part of a programme to realise quantum gravity as a functional integral over geometries that are represented by finite spectral triples. This general idea will be described, followed by some more specific details about how a finite spectral triple, in which the Dirac operator is a finite-dimensional matrix, can be used to approximate a compact Riemannian manifold. The main examples are Dirac operators for fuzzy spaces.

Tomasz Brzeziński (Swansea&Białystok) — **Noncommutative gauge theory of generalized (quantum) Weyl algebras**

Abstract: Generalized (quantum) Weyl algebras (over a polynomial ring in one variable) can be understood as models for non-commutative surfaces. We describe quantum principal bundles over such algebras, and demonstrate how this algebraic approach to non-commutative gauge theory leads to introduction of differential and spin geometry (Dirac operators) of these algebras.

Marija Dimitrijević Ćirić (Belgrade) — **NC SO(2,3)_\star gravity: noncommutativity as a source of curvature and torsion**

Abstract: In this talk we discuss a NC gravity theory as a NC SO(2,3)_\star gauge theory. The expanded NC gravity action is calculated using the Seiberg-Witten map and the expansion is done up to the second order of the deformation parameter. From the action, we calculate the equations of motion and discuss their consequences. Finally, a correction to the flat space-time solution (Minkowski space-time) is presented. This solution is an example of how the noncommutativity generates curvature.

James Gaunt (Nottingham) — **Dirac Operator on the Fuzzy Torus**

Abstract: Fuzzy spaces are of specific interest in quantum gravity models due to there attractive quality of a finite length scale cut off. For the purpose of quantum gravity we are interested in geometry and hence the Dirac operator on these spaces. Despite this, there is only one example of a Dirac operator on a fuzzy space to date, namely the Grosse-Presnajder operator on the fuzzy sphere. Here we will present a new Dirac operator on the well known fuzzy torus, as well as showing some semi-classical limits of the operator and its spectrum.

Giulia Gubitosi (London) — **Phenomenology of particles with q-de Sitter symmetries**

Abstract: I discuss the kinematics of free relativistic particles whose symmetries are compatible with the ones described by the q-de Sitter Hopf algebra. The quantum deformation parameter of the algebra is a function of the Planck length and the de Sitter radius, and it is taken such that when the Planck length vanishes, the algebra reduces to the de Sitter algebra, while when the de Sitter radius is sent to infinity one recovers the kappa-Poincare Hopf algebra. In the first limit one obtains the picture of a particle with trivial momentum space geometry moving on de Sitter spacetime, in the second one the picture is that of a particle with de Sitter momentum space geometry moving on Minkowski spacetime. When both the Planck length and the inverse of the de Sitter radius are non-zero, effects due to spacetime curvature and non-trivial momentum space geometry are both present and affect each other, or that the particles' motion is described in a full phase space picture. In particular, redshift effects that are usually associated to spacetime curvature become energy-dependent and the energy dependence of particles' travel times that is usually associated to momentum space non-trivial properties is modified in a curvature-dependent way.

Machiko Hatsuda (Juntendo/KEK) **Type II superspace with manifest T-duality and superstring action**

Abstract: T-duality is an essential feature of the gravity theory obtained as the low energy effective theory of the string theory. A superspace formulation of type II superstring background with manifest T-duality symmetry is presented. This manifestly T-dual formulation is constructed in a space spanned by two sets of nondegenerate super-Poincare algebra. We introduce Ramond-Ramond charges as a central extension of the algebra. We also present a gauge invariant superstring action with manifest T-duality preserving the two-dimensional diffeomorphism invariance and the kappa-symmetry.

Larisa Jonke (Zagreb) **Sigma models from Courant algebroids and background fluxes of string theory**

Abstract: We present a membrane sigma model constructed from the Courant algebroid data that could provide a consistent world-sheet approach to realizing new geometries appearing in string theory. We show that at the level of the world-sheet sigma model action one is naturally lead to an apparent doubling of degrees of freedom by careful analysis of equation of motion. Furthermore, the bulk/boundary consistency condition provide a well-defined procedure for obtaining the 2D reduced theory with background fluxes.

Tajron Jurić (Zagreb) **Noncommutative field theories on R^3**

Abstract: We analyze several models of QFT on a certain deformations of R^3. The first one is a noncommutative gauge theory models on R^3_\theta. This model can accommodate gauge invariant harmonic terms, thanks to the existence of a relationship between the center of R^3_\theta and the components of the gauge invariant 1-form canonical connection. This latter object shows up naturally within the present noncommutative differential calculus. Restricting ourselves to positive actions with covariant coordinates as field variables, a suitable gauge-fixing leads to a family of matrix models with quartic interactions and kinetic operators with compact resolvent. Their perturbative behavior is then studied. We first compute the 2-point and 4-point functions at the one-loop order within a subfamily of these matrix models for which the interactions have a symmetric form. We find that the corresponding contributions are finite. We then extend this result to arbitrary order. We find that the ampllitudes of the ribbon diagrams for the models of this subfamily are finite to all orders in perturbation. This result extends finally to any of the models of the whole family of matrix models obtained from the above gauge-fixing. The origin of this result is discussed. The existence of a particular model related to integrable hierarchies is indicated, for which the partition function is expressible as a product of ratios of determinants. We will also discuss a complex scalar field theory on a deformed R^3 space. Using different star products we show that the model is finite at one loop order and therefor free of UV/IR mixing.

Jerzy Kowalski - Glikman (Wrocław) **Kappa-Poincare as a symmetry of flat spacetime in quantum gravity**

Abstract: There is one to one correspondence between the algebra of constraints of gravity and the algebra of symmetries of the associated spacetime. In my talk I will show that by analyzing the algebra of quantum constraints of 3D gravity we obtain kappa-Poincare algebra, as an algebra of symmetries of quantum spacetime.

Rob G. Leigh (Illinois) **Quantum Space-time and Metastrings**

Abstract: I will discuss the geometric structures that arise in modular quantization. Such quantization results in a quantum notion of space, which is coordinatized by the modular variables originally introduced by Aharonov. These geometric structures are precisely those found in our recent work on metastrings. Putting the two together results in a new notion of quantum gravity.

Jerzy Lewandowski (Warszawa) **Canonical Loop Quantum Gravity - Status Report**

Abstract: This lecture will provide a bird's eye view of the present status of the subject. Special emphasis will be laid upon the quantum algebra of the constraints and their solutions. A recently discovered relation with the Minkowski theorem on polyhedra will be explained.

Niccolò Loret (Zagreb) — **The interplay between Finsler geometry and curved momentum-space formalism**

Abstract: The study of Planck scale effects through noncommutative geometry has lead to two different approaches to the quantum-gravity problem. One is the formal investigation of the algebraic structure, while the other is the phenomenological exploration on the possibility to observe macroscopic manifestations of Planckian effects. The first approach may lead to lose a simple intuition of the physical observables, while the second to make predictions not compatible with the theory structure.

In this talk I'd like to show how the interplay between Finsler geometry and Curved momentum-space formalism can connect those two aspects of this approach to quantum gravity. We will go through Finsler Killing equations and deformed relativistic symmetries; we will discuss about the relativistically invariant line-element and particles' worldlines; we will consider the possibility to obtain a mathematically solid way to generalize DSR theories to curved spacetimes; and show the simple relations between coalgebraic structure and coordinate transformations in curved momentum-space.

Yongge Ma (Beijing) — **Noncommutative Geometry from Quantum Cosmology**

Abstract: Coherent state functional integrals for the minisuperspace models of quantum cosmology are studied. By the well-established canonical theories, the transition amplitudes in the path-integral representations of Wheeler-DeWitt quantum cosmology and loop quantum cosmology can be formulated through group averaging. The effective action and Hamiltonian with higher-order quantum corrections are thus obtained in both models. It turns out that for a non-symmetric Hamiltonian constraint operator, the Moyal (star)-product emerges naturally in the effective Hamiltonian. This reveals the intrinsic relation among coherent state functional integral, effective theory and noncommutative geometry.

Flavio Mercati (Waterloo) — **Covariant kappa-deformed field theory in the language of differential forms**

Abstract: My talk will be based on IJMPD 25, 1650053 (2016). I will introduce in a Lorentz-covariant way some basic tools of noncommutative differential geometry in kappa-Minkowski: bicovariant differential calculus, Lie and inner derivatives, the integral, the Hodge-star and the metric. These tools are useful to construct field theories which are covariant under the symmetries of kappa-Minkowski, which are described by the kappa-Poincare quantum group. I will show the utility of differential-geometric concept in the analysis of symmetries and conserved quantities of field theories, by considering the example of a complex scalar field, for which I am able to identify a vector-valued differential form which generalizes the energy-momentum tensor. Its closedness is proved, expressing in a covariant form the conservation of energy-momentum, which is a new result. The tools I introduced are useful for constructing more interesting field theories in a covariant way, e.g. gauge theories.

Jakub Mielczarek (Kraków) — **The Nonlinear Field Space Theory**

Abstract: In recent years the idea that not only the configuration space of particles, i.e. spacetime, but also the corresponding momentum space can have a nontrivial geometry has attracted significant attention, especially in the context of quantum gravity. The aim of the talk is to discuss extension of this concept to the domain of field theories, the so-called Nonlinear Field Space Theory (NFST).

After presenting the motivation and general aspects of the approach we will focus on analysis of the prototype (quantum) NFST of a scalar field. The case of compact field space is especially interesting, which is a natural way to implement the "Principle of finiteness" of physical theories, which once motivated the Born-Infeld theory. Predictions and possible areas of application of NFST, including early universe cosmology and condensed matter physics, will be discussed.

Tomasz Miller (Warszawa) — **Causality for probability measures**

Abstract: In a joint work with M.Eckstein we propose and study the extension of the causal

precedence relation onto the space of Borel probability measures on a given spacetime M. I will illustrate the concept with several characterisations, which are all equivalent if the causal properties of M are sufficiently robust. I will briefly present thus developed formalism, which draws from the optimal transport theory, and discuss its possible applications in the study of causality in quantum theory.

Anna Pachoł **Observables and quantum spacetimes**
(London)

Abstract: Noncommutative geometry, as the generalised notion of geometry, can be helpful in providing the phenomenological models quantifying the effects of quantum gravity. The noncommutative nature allows for obtaining quantum gravitational corrections to the classical solutions. One of the mostly studied possible phenomenological effects of quantum gravity is the modifications in wave dispersion.
In my talk I will introduce the mathematical framework for quantum spacetimes within the Hopf algebras formalism. Twisted differential calculus and twisted generators of the Hopf algebra symmetry allow on a fresh look on modifications in dispersion relations and bring new insights into the discussion on the choice of physical observables. The proposed formalism also allows for study of the curved backgrounds. I will mention the Friedman-Robertson-Walker case as an example.

Giovanni Palmisano **Generalizations of 2+1 Gravity Momentum Space to 3+1 Dimensions**
(Rome)

Abstract: In 2+1 Gravity it is possible to reach an insightful description of the kinematics of a particle by integrating out the gravitational degrees of freedom. The resulting effective theory can be conveniently characterized in terms of a curved momentum space, with an Anti de Sitter metric and a deformed composition law for the momenta of interacting particles.
We propose a characterization of the composition law in terms of some properties that identify it as a function of the 2+1 dimensional Anti de Sitter metric and define what we call the Hopf composition law associated to the given metric. Then we show that the generalization to 3+1 dimensions cannot be developed without breaking the relativistic covariance of the theory, and we discuss some possible alternatives with a non Hopf structure.

Roberto Percacci **Quantum gravity, unification and NCG**
(Trieste)

Abstract: There are hints that gravity is a gauge theory in the Higgs phase and that this is related to the unification of all forces. From this point of view, the most fundamental issue for a quantum theory of gravity would be to understand how a nondegenerate metric arises dynamically. In this endeavour, continuum QFT methods have been so far of limited use. I present some results about the discrete NCG models of Barrett and Glaser that may lead to some progress in this direction.

Danijel Pikutić **Vector-like deformations of Minkowski space and Lorentz symmetry**
(Zagreb)

Abstract: The most general vector-like deformations of Minkowski space are presented. These include kappa-Minkowski space, Snyder space, generalized Snyder spaces and kappa-Snyder spaces. For the generalized Lorentz transformations, the backreaction factors are calculated in the first order. We consider possible phenomenological applications.

Artur Sergyeyev **An extension of R-matrix approach to construction of integrable systems to (3+1) dimensions**
(Opava)

Abstract: In the present talk based on arXiv:1605.07592 we introduce a multi-dimensional version of the R-matrix approach to the construction of integrable hierarchies. Applying this method to the case of the Lie algebra of functions with respect to the contact bracket, we construct integrable hierarchies of (3+1)-dimensional dispersionless systems of the type recently introduced in arXiv:1401.2122.

Andrzej Sitarz **Towards new real structure for spectral triples**
(Kraków)

Abstract: Spectral triples are the most accepted proposal to define geometry over noncommutative algebras. Real structure for them is used to define the Dirac operator as a type of first order differential operator. Yet for many examples of physically motivated deformations this definition provides no answer. In a recent paper together with T.Brzezinski, N.Ciccoli and L.Dabrowski we proposed a new, twisted reality condition. I shall briefly review the idea and illustrate with examples from the world of deformations of Riemannian geometries, including the renowned kappa deformation.

Zoran Škoda (Zadar) **Hopf algebroid twists for deformed spaces**

Abstract: I shall review Drinfeld twists of Hopf algebroids as introduced by Ping Xu with emphasis on the deformation of the Heisenberg-Weyl algebra. Then I am going to show how special twists bring out the Hopf algebroid structures for Heisenberg doubles of universal enveloping algebras of Lie algebras and of kappa-deformed spaces. I shall emphasize the role of canonical elements. If time permits I shall also give a sketch of work in progress on the Hopf algebroid structures on Heisenberg doubles of universal enveloping of Lie algebroids and speculate on the role of such a generalization for the deformation theory.

Harold Steinacker (Vienna) **Emergent 4D gravity on covariant quantum spaces in the IKKT model**

Abstract: We study perturbations of the 4-dimensional fuzzy sphere as a background in the IKKT or IIB matrix model. The linearized 4-dimensional Einstein equations are shown to arise from the classical matrix model action, without adding an Einstein-Hilbert term. The excitation modes with lowest spin are identified as gauge fields, metric and connection fields. In addition to the usual gravitational waves, there are also physical "torsion" wave excitations. The quantum structure of the geometry encodes a twisted bundle of self-dual 2-forms, which leads to a covariant 4-dimensional noncommutative geometry. The formalism of string states is used to compute one-loop corrections to the effective action. This leads to a mass term for the gravitons which is significant for S4S4, but argued to be small in the Minkowski case.

Valery N. Tolstoy (Moscow) **On the classification of quantum deformations for the complex D=4 homogeneous Lie symmetry and its real forms: Euclidean, quaternionic, Kleinian and Lorentzian**

Abstract: Using the isomorphism o(4;C)~o(3;C)+o(3;C)~sl(2;C)+sl(2;C) we present new simple algebraic method for a complete classification of quantum deformations -- the classical r-matrices -- for the complex Lie algebra o(4;C) and its real forms: Euclidean, quaternionic, Kleinian and Lorentzian. Key elements of this approach are the triad: the Cartan--Weyl basis, sl(2;C)-grading of the o(4;C) classical Yang Baxter equation and compact explicit formulas of automorphisms for the Lie algebra sl(2;C).

Luca Tomassini (Rome) **The DFR approach to noncommutative spacetime: from flat to curved**

Abstract: We will start with a presentation of the basic ideas of the DFR approach to spacetime non-commutativity, with particular emphasis on physical motivations. In this light, we will on one side briefly discuss (and advocate for the need of clarification of) the relations with other approaches to Quantum Gravity, and on the other we will address some criticisms. Then, after an introduction to the DFR model of (quantum field theory on) Minkowski spacetime, we will present recent attempts to extend the analysis to cosmological spacetimes and to clarify the role of Einstein's equations in this context.

Josip Trampetić (Zagreb) **Equivalence and/or Quantum Duality of Field Theories related by theta-exact Seiberg-Witten map**

Abstract: We show that in the perturbative regime defined by the coupling constant, the theta-exact Seiberg-Witten map applied to noncommutative U(N) Yang-Mills --with or without Supersymmetry-- gives an ordinary gauge theory which is, at the quantum level, dual to the former. We do so by using the on-shell DeWitt effective action and dimensional regularization. We explicitly compute the one-loop two-point function contribution to the on-shell DeWitt effective action of the ordinary U(1) theory furnished by the theta-exact Seiberg-Witten map. We find that the non-local UV divergences found in the propagator in the Feynman gauge all but disappear, so that they are not physically relevant. We also show that the quadratic noncommutative IR divergences are gauge-fixing independent and go away in the Supersymmetric version of the U(1)

theory.

Kentaroh Yoshida (Kyoto) **Recent progress towards the gravity/CYBE correspondence**

Abstract: There is a systematic way to consider integrable deformations of the AdS_5 x S^5 superstring. It is based on classical r-matrices satisfying classical Yang-Baxter equation (CYBE). Then a classical r-matrix corresponds to a gravitational solution that describes a deformed AdS_5 x S^5 geometry. In this talk, we perform the supercoset construction explicitly for some examples including the Lunin-Maldacena backgrounds for beta deformations of the N=4 super Yang-Mills theory, the Maldacena-Russo backgrounds for non-commutative gauge theories, and Schroedinger spacetimes dual for non-relativistic conformal field theories. The supercoset construction works well for abelian classical r-matrices, but it seems likely that for non-abelian classical r-matrices the resulting backgrounds should be solutions of a generalized type IIB supergravity proposed by Arutyunov et al.

Ramin Zahedi (Hokkaido) **A Direct Derivation of the Gravitational Field Equations by First Quantization of the Special Relativistic Energy-Momentum (Algebraic) Relation**

Abstract: This article is a summary of an expanded version of my previous publication [1]. In particular, n Ref. [1] using a new axiomatic matrix approach – which has been formulated on the basis of ring theory and the generalized Clifford algebra – by first quantization (as a postulate) of the linearized (and simultaneously parameterized, as necessary algebraic conditions) unique algebraic (Lorentz symmetric) forms of the special relativistic energy-momentum relation, a unique massive form of gravitational (single-particle) wave equations – with certain complex torsion which is generated by the invariant mass of the field carrier particle – is derived directly. It is shown that the massless case of these equations is equivalent to the Einstein field equations (including a cosmological constant). Moreover, it has been shown that the derived gravitational field could be also formulated in the framework of the geometric algebra formalism (via a matrix representation) – where as a basic discrete symmetry we also assume chiral symmetry for the source-free cases of field equations derived.

References:

[1]- Ramin Zahedi, "On Discrete Physics: a Perfect Deterministic Structure for Reality – And "A (Direct) Logical Derivation of the Laws Governing the Fundamental Forces of Nature"", AFSIL, Hokkaido University Publs., JAPAN, 16 (2): 1-97, 2015.