The Planck Scale II
XXXV Max Born Symposium
Wroclaw, Poland, 7 - 12 September 2015

Book of Abstracts

Thanu Padmanabhan
Title: *Distribution function of the atoms of spacetime and the nature of gravity*
Abstract: A natural guiding principle for gravitational dynamics is that the field equations of gravity should remain invariant when a constant is added to the Lagrangian. This principle uniquely selects the Lanczos-Lovelock models of gravity in D dimensions and Einstein's theory in D = 4. More importantly, it leads to a thermodynamic interpretation for several geometrical variables as well as for the equation describing the spacetime evolution. Extending these ideas one level deeper, I show how the relevant thermodynamic variational principle can be obtained from a distribution function for the number density of the "atoms of spacetime". This is based on the curious fact that the renormalized spacetime endows each event with zero volume but finite area!

Roberto Percacci
Title: *Progress towards asymptotic safety of gravity*
Abstract: I will review recent progress in finding functional fixed points for gravity.

Leslaw Rachwał
Title: *Finite and Nonlocal Quantum Gravity*
Abstract: In this talk I will introduce and extensively study a class of non-polynomial higher derivative theories of gravity that realize a ultraviolet (UV) completion of Einstein general relativity. These theories are unitary (ghost free) and at most only one-loop divergences survive. The outcome is a class of theories super-renormalizable in even dimension and finite in odd dimension. Moreover, we explicitly prove in D = 4 that there exists an extension of the theory that is completely finite and all the beta functions vanish at all loop orders. Therefore we have the possibility for finite quantum gravity in any dimension. Moreover I will comment on the recent developments about exact solutions and scattering amplitudes in this theory.

Angel Ballesteros
Title: *(A)dS Drinfel'd doubles and Quantum Gravity with cosmological constant*
Abstract: Quantum groups provide a solid mathematical background for the introduction of non-commutative spacetimes, deformed dispersion relations and curved momentum spaces, three concepts that can be meaningful in Quantum Gravity phenomenology. In this contribution we present some recent results on two specific quantum deformations of (Anti) de Sitter groups and algebras in (2+1) dimensions that have been shown to be compatible with the Chern-Simons approach to gravity coupled with point particles. Such compatibility is guaranteed by the underlying Drinfelʹd double structure of the (A)dS Lie algebra in (2+1) dimensions, and it reflects the emergence of quantum doubles in the quantization of (2+1) gravity. The first results concerning the (3+1) dimensional generalization of this approach will be also presented, and the role of the cosmological constant in all these quantum structures will be emphasized.

Steffen Gielen
Title: *Space as a quantum gravity condensate: quantum cosmology from fundamental quantum gravity*
Abstract: Models that describe quantum gravity effects in early universe cosmology are often obtained in a minisuperspace approximation, and their precise relation to a theory of quantum gravity is not clear. Here we present a new approach in which minisuperspace quantum cosmology is viewed as an effective mean-field (hydrodynamic) approximation to quantum gravity, describing the universe as a 'condensate' of many elementary 'atoms' of geometry. We work with a quantum field theory for such atoms known as group field theory (GFT), itself a second quantised formalism for loop quantum gravity. The analogy between these quantum gravity condensates and real condensates is used to extract cosmological phenomenology directly from models for quantum gravity. We discuss several possibilities, such as large-scale effects of fundamental discreteness, and describe how observationally interesting information about inhomogeneities can be extracted in this approach.

Jakub Bilski
Title: *Scalar field in the cosmological sector of loop quantum gravity*
Abstract: Working within the framework of Quantum Reduced Loop Gravity (QRLG), I will show the quantization of the Hamiltonian constraint for the Einsteinian theory of gravity minimally coupled to a scalar field. This procedure relies on the method proposed by T. Thiemann (QSD V) and developed in the collaboration with E. Alesci and F. Cianfrani. The scalar field is described in terms of point-holonomies, located at the nodes of the graph. I will show how to regularize the action of the scalar field Hamiltonian in the diffeomorphism invariant Hilbert space of QRLG, and present the resulting action of the Hamiltonian constraints operator, which contains only analytic coefficients. I will then explain how in the large j limit, the Hamiltonian eigenvalues approach the classical Hamiltonian at the leading order. The next-to-the-leading order corrections are purely quantum, and can be discussed in conjunction with their possible phenomenological implications.

Surajit Chattopadhyay
Title: *Scalar field dark energy models in chameleon Brans-Dicke cosmology*
Abstract: We report on a study of the new holographic dark energy (NHDE) model in the framework of chameleon Brans-Dicke cosmology. We have studied the correspondence between the quintessence, the DBI-essence, and the tachyon scalar-field models with the NHDE model in the framework of chameleon Brans-Dicke cosmology. Deriving an expression of the Hubble parameter H and, accordingly, D in the context of chameleon Brans-Dicke chameleon cosmology, we have reconstructed the potentials and dynamics for these scalar-field models. Furthermore, we have examined the stability for the obtained solutions of the crossing of the phantom divide under a quantum correction of massless conformally invariant fields, and we have seen that the quantum correction could be small when the phantom crossing occurs and the obtained solutions of the phantom crossing could be stable under the quantum correction. It has also been noted that the potential increases as the matter; chameleon coupling gets stronger with the evolution of the universe.

Artur Sergyeyev
Title: *Infinitely many nonlocal conservation laws for vacuum anti-self-dual Einstein equations with nonzero cosmological constant*
Abstract: It is well known that vacuum anti-self-dual Einstein equations with nonzero cosmological constant can be locally written as a single equation for a scalar function (the Przanowski equation). We present an infinite hierarchy of nonlocal conservation laws for the equation in question and touch upon possible applications of this hierarchy.

Khrystyna Gnatenko

Title: *Rotational symmetry in a space with canonical noncommutativity of coordinates*

Abstract: An important problem in a space with canonical noncommutativity of coordinates is the problem of rotational symmetry breaking. In order to preserve the rotational symmetry we consider a tensor of noncommutativity which is defined with the help of additional coordinates governed by a rotationally symmetric system. For simplicity we suppose that these coordinates are governed by harmonic oscillator. As a consequence we propose noncommutative algebra which is rotationally invariant, moreover this algebra is equivalent to the canonical noncommutative algebra [1].

We find the corrections to the energy levels of hydrogen atom in rotationally invariant noncommutative space [1,2]. On the basis of the obtained results the upper bound of the parameter of noncommutativity is estimated.

We also study the motion of a particle in a uniform field in noncommutative space with preserved rotational symmetry. It is shown that there is an effect of noncommutativity on the mass of a particle. As an example we examine the motion of a particle in a uniform gravitational field.

It is shown that the equivalence principle is violated in rotationally invariant noncommutative space. We propose the condition to recover this principle. It is important to note that this condition is in the agreement with the condition which gives the possibility to solve the problem of violation of the equivalence principle in a two-dimensional space with canonical noncommutativity of coordinates [3].

[1] Kh.P. Gnatenko, V.M. Tkachuk, Phys. Lett. A 378, (2014) 3509.
[2] Kh.P. Gnatenko, Yu.S. Krynytskyi, V.M. Tkachuk, Mod. Phys. Lett. A 30, (2015) 1550033.
[3] Kh.P. Gnatenko, Phys. Lett. A 377, (2013) 3061.

Larus Thorlacius

Title: *Black Hole Complementarity: The Inside View*

Abstract: Hawking's black hole information paradox arises when the formation and subsequent evaporation of a black hole is examined in the context of quantum theory. In a gravity theory with a gauge theory dual, the paradox must be resolved in favor of unitary evolution. The challenge is then to implement unitarity on the gravity side and a key issue, which is at the center of the recent debate on firewalls, is whether this requires giving up the equivalence principle. For a black hole formed in a generic pure quantum state, we argue that a typical infalling observer will see no drama on their way to the stretched horizon and a proposal is made for an approximate interior effective field theory description where this conclusion holds until the observer approaches the black hole singularity.

Igor Kanatchikov

Title: *Quantum gravity as a quantization of differential forms*

Abstract: I outline the ideas and the necessary technical ingredients of precanonical quantization applied to scalar fields (for introductory purposes) and the Einstein-Palatini action of vielbein gravity. Using the example of scalar field theory I argue that the standard QFT based on canonical quantization is a limiting case kappa going to infinity of the formulation obtained from precanonical quantization. kappa is an UV-scale which is introduced on the level of precanonical quantization, when the dynamical variables represented by differential forms are quantized in terms of Dirac matrices. Precanonical formulation of vielbein gravity leads to the formulation of quantum gravitation dynamics in terms of the the Clifford algebra valued wave function on the spin-connection bundle, which satisfies the precanonical analogue of the Schrodinger equation on this bundle. Quantum geometry is described in terms of the transition amplitudes on this bundle, which leads to the picture of "spin-connection foam". The metric tensor and the related distances are becoming operator-valued quantities. We discuss some implications of this description on the Planck scale and, when applied to a simple cosmological model, the cosmological scale.

Marco Letizia

Title: *Phenomenology of effective geometries from quantum gravity*

Abstract: In a recent paper (arXiv:1412.6000) a general mechanism for emergence of cosmological space-time geometry from a quantum gravity setting was devised and departure from standard dispersion relations for elementary particle were predicted. We elaborate here on this approach extending the results obtained in that paper and showing that generically such a framework will not lead to higher order modified dispersion relations in the matter sector. Furthermore, we shall discuss possible phenomenological constraints to this scenario.

Vasyl Vasyuta

Title: *Hydrogen atom in space with spin noncommutativity*

Abstract: One of the problems of noncommutative theories is a violation of a rotational symmetry. There are different approaches to incorporating noncommutativity with a rotational invariance. One of them is so-called spin noncommutativity (noncommutativity due to spin), where noncommutative coordinates are built using spin operators [1,2,3].

We consider the hydrogen atom spectrum in space with the algebra with spin noncommutativity [1], where coordinate commutators are proportional to spin operators. It is remarkable that this algebra is invariant under spatial rotations.

Corrections to the energy levels of hydrogen atom due to noncommutativity were calculated using perturbation theory. Within the ordinary perturbation theory we find the corrections to the energy levels with a nonzero orbital quantum number. These corrections are proportional to the square of the parameter of noncommutativity. For s-levels ordinary perturbation theory diverges. Using an idea proposed in [4] we develop a modified perturbation theory. It gives us a possibility to obtain corrections to the energy of s-levels, which are logarithmic.

Moreover, we compare our theoretical results with measurements of the transition energy between 2s-1s levels of the hydrogen atom [5] and find the upper bound for a parameter of the noncommutativity, which is consistent with estimations made by other authors, e.g. [6].

[1] H. Falomir, J. Gamboa, J. López-Sarrión, F. Mèndez, P.A.G. Pisani, Phys. Lett. B 680, 384 (2009).

[2] M. Gomes, J.V. Kupriyanov, A.J. da Silva, Phys. Rev. D 81, 085024 (2010).

[3] V.M. Vasyuta, J. Phys. Stud. 17, 3001 (2013).

[4] M.M. Stetsko, V.M. Tkachuk, Phys. Rev. A 74, 012101 (2006).

[5] A. Matveev et al., Phys. Rev. Lett. 110, 230801 (2013).

[6] Kh.P. Gnatenko, V.M. Tkachuk, Phys. Lett. A 378, 3509 (2014).

Mihaela-Andreea Baloi

Title: *Fermion production in magnetic fields on de Sitter Universe*

Abstract: The problem of fermion production in magnetic fields on de Sitter expanding universe is studied. The amplitudes and probabilities for generation of massive fermions are obtained using the exact solution of the Dirac equation in momentum-helicity basis. We found that the most probable transitions are those in which the fermion pair is generated perpendicular to the direction of magnetic field. The behavior of the probabilities is studied graphically for large/small values of the expansion factor. The phenomenon of fermion production is significant only at large expansion. Contrary to this for a vanishing expansion factor we recover the Minkowski limit where these processes are forbidden by the energy-momentum conservation laws.

Ciprian Sporea

Title: *The scattering of Dirac fermions on Schwarzschild black holes - a partial wave analysis approach*

Abstract: The aim of this talk is the study of Dirac fermions scattered on Schwarzschild black holes with the help of partial wave analysis. This analysis is applied to asymptotic analytic solutions of the Dirac equation in Schwarzschild chart. The solutions where obtained in the Cartesian gauge. After we obtain an analytical expression for the phase shift we calculate the absorption and

differential cross section, the polarization degree as functions of scattering angle, mass and energy of the fermion and black hole's mass. At the end a graphical study is presented in order to better understand the physical consequences of our results.

Johannes Thuerigen

Title: *Dimensional flow in superpositions of spin networks*

Abstract: The spectral dimension as an observable of geometry has recently attracted attention in quantum gravity both as a test for the semiclassical and continuum regime as well as due to the occurrence of a dimensional flow in some approaches. I show that such a flow is generic for a particular class of superpositions of discrete quantum geometries. In particular, any value of dimension smaller than the topological dimension can be obtained in a dimensional flow for some such quantum state. These results apply, in particular, to special superpositions of spin-network states in loop quantum gravity.

Stijn van Tongeren

Title: *Noncommutative field theory as a hologram*

Abstract: I will explain how the conventional example of AdS/CFT can be deformed to get various noncommutative spacetimes on the field theory side, including ones like kappa-Minkowski space. Starting from a two dimensional integrable field theory, after a stringy detour I will end up with noncommutative versions of (supersymmetric) Yang-Mills theory. These deformations are all of Drinfeld twist type. I will keep technical details to a minimum.

Jakub Mielczarek

Title: *Phenomenology of Causal Dynamical Triangulations*

Abstract: The purpose of the talk is to discuss possible empirical consequences of the Causal Dynamical Triangulations (CDT) approach to quantum gravity. The analysis will be based on two characteristic features of CDT: the dimensional reduction and the non-trivial phase structure. In the first case, quantum modified dispersion relation for a test field will be reconstructed based on numerical analysis of a discrete diffusion process defined on simplicial geometry of CDT. The obtained dispersion relation allows to study impact of the quantum gravity effects on propagation of astrophysical photons and primordial cosmological perturbations. Both possibilities will be discussed in the talk.

As we will show, Fermi satellite observations allow to rule out a possibility of "low-energy" (below around 10 EeV) dimensional reduction. In case of the primordial cosmological perturbations, it will be demonstrated that for a scenario when length scale of dimensional reduction exceeds the Hubble radius the nearly scale-invariant scalar perturbations might arise from the vacuum state. However, the predicted magnitude of deviation from the scale-invariance is in contradiction with the up to date Planck and BICEP2 results. Other scenarios, which are not in conflict with observations, are still possible. A yet different possibility is given by a higher-order gravitational phase transition, which has been observed in CDT. The phase transition interpolates between a non-geometric crumpled phase of gravity, and an extended phase with classical properties. We will discuss whether the phase transition might generate primordial perturbations which are consistent with cosmological observations.

Peter Stichel

Title: *On the nonrelativistic limit of a self-gravitating pressureless and irrotational fluid with energy flow*

Abstract: We start with a relativistic self-gravitating (geodesic) fluid whose energy-momentum tensor is dust-like with a nontrivial energy flow. The corresponding covariant propagation and constraint equations are considered in a covariant nonrelativistic limit (Newton-Cartan framework) whose analytic shear-free (cosmological) solutions determine the 1st –order relativistic correction to the spatial curvature. This leads to a possible new interpretation of the accelerated expansion of the

Universe.

Marco Finocchiaro

Title: *The imposition of simplicity constraints in spin foam models: prescriptions and implications*

Abstract: Spin foam models are constructed by imposing, directly at the quantum level, the required geometricity constraints turning topological quantum simplicial BF theory into quantum simplicial gravity. Therefore they depend on the specific prescription adopted for implementing the constraints, on additional choices in the construction, e.g. the prescription for gluing simplicial cells and on the choice of the quantization map, that is the choice of the operator ordering ambiguities. In my talk I will discuss these aspects and their implications by comparing the resulting spin foam amplitudes (more in detail the corresponding fusion coeffcients) for different models proposed in the literature (and new ones obtained as variations of the known constructions). The analysis will be performed by rewriting the spin foam amplitudes in terms of different sets of variables (spins, group elements, flux variables). Moreover I will introduce a general definition of embedding map applicable to all these models and discuss its properties. Other relevant issues as the choice of the boundary Hilbert space and the requirement of proper behaviour of the amplitudes under composition will be also considered.

Antonia Zipfel

Title: *A stability criterion for coherent states*

Abstract: Coherent states play an important role in the semiclassical analysis of a given quantum theory. In order to also study the semiclassical features of the dynamics it is necessary to construct a system of states that does not loose its semiclassical properties during the evolution. I will introduce and discuss a stability criterion for complexifier coherent states, which are used in LQG. It turns out that already for quantum mechanical system the introduced criterion is quite restrictive. However, there is a way to circumvent these restrictions by introducing action-angle coordinates. These mechanisms are potentially also applicable in symmetry reduced models such as LQC.

Norbert Bodendorfer

Title: *Symmetry reductions in loop quantum gravity based on classical gauge fixings*

Abstract: We discuss a new strategy to perform a symmetry reduction in loop quantum gravity based on classically gauge fixing the spatial diffeomorphism constraint. Symmetry reductions can then be performed by demanding the vanishing of certain classical phase space functions, which translates into implementing (some part of) spatial diffeomorphism invariance on the reduced phase space, thus solving the spatial diffeomorphism constraint "twice". We illustrate how this process works for reductions to spherical symmetry and Bianchi I cosmological models.

Jerzy Lukierski

Title: *Quantum-deformed covariant phase spaces as Hopf algebroids*

Abstract: Quantum-deformed quantum phase spaces can not be described as Hopf algebras. One can show, however, that distinguished class of covariant quantum-deformed phase spaces, described as semidirect product of a pair of Hopf algebras (generalized coordinates + generalized momenta) has the structure of Hopf algebroid. Hopf algebroids will be described and we shall show explicitely their algebraic properties on the example of D = 4 covariant kappa-deformed phase space, calculated in Majid-Ruegg bicrossproduct basis.

Andrea Addazi

Title: *Neutron Majorana mass from Exotic Instantons*

Abstract: We show how a Majorana mass for the neutron could result from non-perturbative quantum gravity effects peculiar to string theory. In particular "exotic instantons" in un-oriented string compactifications with D-branes extending the (supersymmetric) standard model could generate an effective six quarks' operator (udd)^{2}/M^{5}. A Majorana mass for the neutron can

be tested in the next generation of experiments in neutron-antineutron oscillations. Other B-violating signatures for LHC or future colliders, neutrino physics, UHECR are discussed.

Marcoen Cabbolet

Title: *Berkelian idealism regarding properties in orthodox quantum mechanics, and implications for quantum gravity*

Abstract: In 1710, the famous dictum 'esse est percipi' was put forward by the philosopher George Berkeley: it refers to the idea that an object only exists if it is observed. Although this Berkelian idealism is nowadays considered highly unlikely, the purpose of this talk is to show that orthodox quantum mechanics (OQM) entails a form of Berkelian idealism, and to argue that therefore a quantum theory of gravity is not possible. The first point is that it follows straight from the postulates of OQM (to wit, the Standard Property Postulate and the Projection Postulate) that a quantum only 'has' a property X with quantitative value x upon observation of that property: this is the Berkelian idealism regarding properties (BIRP) entailed by OQM. Now given that in general relativity (GR) space-time is curved due to the energies of objects as expressed by the Einstein field equations, the second point is that it is impossible to recontextualize this principle of curvature in the framework of OQM: the crux is, namely, that on the one hand the curvature of space-time has a definite value at any spatiotemporal point independent of observation, because space-time is not an 'object' that is subject to this BIRP; but on the other hand, due to this BIRP quanta do not 'have' the property energy, which is supposed to be the cause of that curvature, unless the energy is measured. The conclusion is therefore that it is not possible to develop a conceptually coherent extension of OQM that covers gravitation.

David Brizuela

Title: *Quantum-gravitational effects on scalar and tensor perturbations during inflation*

Abstract: The power spectrum of gauge-invariant scalar and tensor perturbations during inflation is computed in the context of canonical quantum gravity. A semiclassical Born-Oppenheimer type of approximation is applied to the Wheeler-DeWitt equation. In this way, a corrected Schroedinger equation is obtained, which contains information about quantum-gravitational effects. The calculations are performed both for a de Sitter universe as well as for a generic slow-roll model.

Ilkka Makinen

Title: *A new Hamiltonian operator for loop quantum gravity*

Abstract: I will present the ideas which have recently led to a construction of a new Hamiltonian operator in loop quantum gravity, and discuss the advantages of the new operator over earlier proposals. The construction applies both to the Hamiltonian constraint operator in the case of vacuum gravity, and to the physical Hamiltonian operator in the case of gravity coupled to a free scalar field, when the scalar field is used as a relational time variable for the evolution of the gravitational field.

Antonino Marciano

Title: *Area-law in loop Quantum Gravity*

Abstract: We recovered the area law for the entanglement entropy in the context of Loop Quantum Gravity, and proposed a viable physical states for the theory to be used while deriving the semi-classical limit of the theory.

Giovanni Palmisano

Title: *DSR Relativistic Compatibility Conditions For Theories With Curved Momentum Space*

Abstract: The relative locality framework introduces a geometrical perspective on theories with deformed relativistic kinematics. In this contest I will discuss an interpretation of the deformed composition law recently proposed in arxiv:1307.7988 [gr-qc] and the geometrical insights that it provides, focusing in particular on the compatibility conditions that allow for a DSR relativistic description of the kinematics.

Masaaki Morita
Title: *Information-theoretic approach to inhomogeneous cosmology*
Abstract: In standard cosmology, the global dynamics of the universe is assumed to be described by a homogeneous and isotropic FLRW universe model, but a realistic universe model should include local inhomogeneities, and the physical properties of such a realistic model averaged over a sufficiently large scale do not necessarily coincide with those of the FLRW universe. In this talk, we give an overview of works studying how local inhomogeneities affect the global expansion. We also point out that, in the framework of averaging inhomogeneities, a natural measure of inhomogeneity is derived, which is known as the relative information entropy in information theory. The temporal behavior of the measure and the relation to the Weyl curvature invariant are explored using the linear perturbation theory of a spatially flat FLRW universe.

Stefano Bianco
Title: *Phenomenology from the DSR-deformed relativistic symmetries of 3D quantum gravity via the relative-locality framework*
Abstract: During the last decade, there have been relevant advances in the study of quantum gravity coupled to point particles in 2+1 dimensions. In the emerging picture the momentum space of the particles is curved, the spacetime coordinates are noncommuting and the symmetries are DSR-deformed relativistic symmetries. In this article we study some phenomenological consequences of these features via the so-called relative-locality framework. We find that a "dual-gravity" lensing effect appears as a consequence of the relativity of spacetime locality associated to the deformed symmetries of the theory.