Niayesh Afshordi, Perimeter Institute

Dynamical Emergence of Universal Horizons during the formation of Black Holes

Motivations for existence of a fundamental preferred frame in the theory of gravity range from pure phenomenology to attempts to solve the non-renormalizability of quantum gravity, problem of time (and scale), or the cosmological constant problem(s). In many explicit constructions, such as Einstein-Aether or Gravitational Aether theories, Cuscuton, Shape Dynamics, or (non-projectable) Ho\v{r}ava-Lifshitz gravity, the low energy theory contains a fluid (defining a preferred frame) with superluminal or incompressible excitations. In this paper, we study the formation of black holes in the presence of such a fluid. In particular, we focus on the incompressible limit of the fluid (or Constant Mean Curvature, CMC, foliation) in the space-time of a spherically collapsing shell within an asymptotically cosmological space-time. In this case, ignoring the fluid back reaction, we can analytically show that an observer inside $3/4$ of Schwarzschild radius cannot send a signal outside, after a stage in collapse, even using signals that propagate infinitely fast in the preferred frame. This confirms the dynamical emergence of {\it universal horizons} that have already been found in static solutions. We argue that this universal horizon should be considered as the future boundary of the classical space-time.

Emanuele Alesci , University of Warsaw

Quantum Reduced Loop Gravity

We present a new framework to study symmetric sectors of loop quantum gravity. The reduction is performed at a quantum level using projected spin networks coherent states and spinfoam techniques that allow us to project the Hilbert space of the full canonical theory. As a first application we present an inhomogeneous extension of the Bianchi I model and discuss the semi-classical limit of the theory.

Giovanni Amelino-Camelia, La Sapienza University of Rome

Status of quantum-gravity phenomenology

I review the status of quantum-gravity phenomenology focusing on recent developments

Mohamed Anber, University of Toronto

On the running of the gravitational constant

We show that there is no useful and universal definition of a running gravitational constant G(E) in the perturbative regime below the Planck scale. By consideration of the loop corrections to several physical processes we show that the quantum corrections vary greatly in both magnitude and sign and do not exhibit the required properties of a running coupling constant.

Fabio Anza, Universit di Pisa

Twisted geometries and Secondary constraints

It has been suggested by Dittrich and Ryan that the secondary constraints of Plebanski's action for general relativity are realized at the discrete level by the shape matching conditions reducing twisted geometries to Regge geometries. We investigate this idea in the toy model of the 4-simplex where there is a well-defined Hamiltonian constraint imposing flatness of the bulk and comment on the role of the secondary constraints as providing an embedding of the SU(2) phase space in the covariant phase space.

Mehdi Assanioussi, University of Warsaw

A Quantum Curvature Operator for LQG

We introduce a new operator in Loop Quantum Gravity - the 3D curvature operator - related to the 3-dimensional Ricci scalar. The construction is based on the concepts of Regge. We define this operator starting from the classical expression of Regge curvature then we derive some of its properties and discuss some explicit checks of the semi-classical limit.

Valerio Astuti, La Sapienza University of Rome

The effects of Hamiltonian constraint on a discrete spacetime

We consider examples of some discrete spacetime whose properties have been so far analyzed only at a level which corresponds to the kinematical Hilbert space in a covariant formulation of quantum mechanics. We find that imposing the Hamiltonian constraint one has significant changes of the spacetime picture. We offer a perspective on how our toy models may provide guidance in the study of Loop Quantum Gravity and other quantum-gravity proposals with spacetime discretization.

Angel Ballesteros, Universidad de Burgos

Drinfel'd doubles for (2+1)-gravity

All possible Drinfel'd double structures for the anti-de Sitter Lie algebra so(22) and de Sitter Lie algebra so(31) in (2+1)-dimensions are explicitly constructed and analysed in terms of a kinematical basis adapted to (2+1)-gravity. Each of these structures provides in a canonical way a pairing among the (anti-)de Sitter generators as well as a specific classical r-matrix and the cosmological constant is included in them as a deformation parameter. It is shown that four of these structures give rise to a Drinfel'd double structure for the Poincar algebra iso(21) in the limit where the cosmological constant tends to zero. We explain how these Drinfel'd double structures are adapted to (2+1)-gravity and we show that the associated quantum groups are natural candidates for the quantum group symmetries of quantised (2+1)-gravity models and their associated non-commutative spacetimes.

Andrzej Banburski, Perimeter Institute

Snyder Momentum Space in Relative Locality

We review the recently proposed principle of relativtiy of locality. We then go on to study the first example of a momentum space with a metric connection and curvature - the de Sitter space. We show that the spacetime that emerges is the classical remnant of the first ever proposed quantized spacetime - Snyder spacetime. We finish with analyzing processes described by closed loops in phase space and come to the conclusion that in a theory with curved momentum space no more than two clocks can be synchronized simultaneously.

Aristide Baratin, Albert Einstein Institute

Group field theory as a non-commutative field theory

We will briefly review and discuss the applications of the star-product formulation of group field theories and their corresponding spin foam amplitudes.

Julian Barbour, University of Oxford

Shape Dynamics and the Arrow of Time

Shape dynamics is a theory of gravitation that reproduces all known confirmations of Einstein's general relativity but trades foliation invariance for three-dimensional conformal invariance. Two key aspects of shape dynamics are: 1) it introduces a unique definition of simultaneity in a spatially closed universe corresponding in general relativity to foliation by spatial hypersurfaces of constant mean extrinsic curvature; 2) everything in the theory is expressed in terms of dimensionless quantities. I shall draw attention to the implications of these facts for the question of the origin of the arrow of time and the nature of quantum gravity.

Joseph Ben Geloun, Perimeter Institute

Classes of Renormalizable Rank d >= 2 Tensorial Group Field Theory

We will introduce several classes of renormalizable tensorial group field theories (without gauge invariance assumed on the tensor fields). The tensor fields considered live in the momentum space of some compact group manifold. Typically, we will focus on models over $SU(2)^D$ and $U(1)^D$. Written in momentum space variables, the kinetic term of a model may be chosen in a suitable way in order to meet renormalizability requirements for the model. Our discussion will also include matrix models. The UV behavior of these models will be addressed as well.

Paolo Bertozzini, Thammasat University

A Higher C*-categorical Formalism for Relational Quantum Theory

In 1994 Carlo Rovelli developed a relational interpretation of quantum mechanics and he suggested the existence of a deep connection (that would be fundamental for any present or future theory of quantum

gravity) between the observer dependent character of states in quantum theory and the covariant description of space-time localization via "contiguity" in general relativity: both of them originating from correlations of subsystems due to interactions.

We propose a higher C*-categorical formalism (originally developed in the study of categorical non-commutative geometry) that seems perfectly suitable for a mathematical approach to relational quantum physics. If time is available, we will also discuss a few conceptual issues on the interpretation of quantum mechanics that are raised by such categorical re-formulation and we will tentatively suggest its relevance, in the context of modular algebraic quantum gravity (arXiv:1007.4094), for the attempts of a spectral reconstruction of non-commutative space-time, that seems in line with Carlo Rovelli's original intuition.

Stefano Bianco, La Sapienza University of Rome

Causality and momentum conservation from relative locality

Theories with a curved momentum space, as those that became recently of interest in the quantum-gravity literature, can in general violate many apparently robust aspects of our current description of the laws of physics, including relativistic invariance, locality, causality and momentum conservation. Previous studies showed that one can find theories with curvature of momentum space in which at least a weaker notion of locality applies, the so-called "relative locality", and a relativistic formulation is allowed (but with the scale of curvature acquiring the role of relativistic invariant, as possible for DSR-relativistic theories). We here provide evidence that on such theories with relative locality there is no violation of causality and momentum conservation.

Norbert Bodendorfer, Pennsylvania State University

Black hole entropy in LQG and the Wald formula

In this talk some recent developments in computing black hole entropy within loop quantum gravity will be reviewed and put into context. These include: 1. Using physical states based on a constant mean curvature gauge fixing in general relativity conformally coupled to a scalar field and a resulting apparent discrepancy in the entropy formula. 2. An extension of the isolated horizon framework to higher dimensions including a boundary condition and boundary symplectic structure. 3. A direct derivation of the Wald entropy formula for theories formulated on the phase space of higher-dimensional general relativity with standard matter. 4. An analytic continuation of the Barbero-Immirzi parameter to +-i that allows a comparison with a semi-classical effective action for pure GR in 3+1 dimensions and also yields the correct prefactor 1/4 for the entropy.

Martin Bojowald, Pennsylvania State University

Loop quantum cosmology: A eulogy

A review of all too formal aspects of loop quantum cosmology.

Julien Bolmont, LPNHE & UPMC

New constraints on Lorentz Invariance Violation from the analysis of four bright Gamma-Ray Bursts observed by the Fermi Large Area Telescope

Because they are bright, distant and because they show very short timescale variability, Gamma-Ray Bursts (GRBs) have been used for more than a decade to test propagation of photons and to constrain relevant Quantum Gravity (QG) models in which the velocity of photons in vacuum can depend on their energy. With its unprecedented sensitivity and energy coverage, the Fermi satellite has provided the most constraining results on the QG energy scale so far. In this talk, the latest results obtained from the analysis of four bright GRBs observed by Fermi's Large Area Telescope will be reviewed. These robust results, cross-checked using three different analysis techniques set the limit on Quantum Gravity energy scale at $E_{QG,1} > 7.6$ times the Planck energy for the linear dispersion and $E_{QG,2} > 1.3 \times 10^{11}$ GeV for the quadratic dispersion (95% CL). After describing the data and the analysis techniques in use, results will be discussed and confronted to latest constraints obtained with Active Galactic Nuclei.

Valentin Bonzom, Perimeter Institute

Introduction and review of tensor models and group field theories

The talk is an introduction to the GFT and tensor model session. The purpose is to provide the people interested in attending the session with the basics of the approach and some intuition to understand the main results. The different directions of expansion of the field will be reviewed.

Suddhsattwa Brahma, Pennsylvania State University

(Canonical) Effective Equations for QFT

In this new formulation of Quantum Field Theories using moment expansions we not only recover the results obtained using standard methods but also extend them for instance by allowing for more general states (useful for cosmology). For certain versions of (canonical) quantum gravity these methods also provide a way of systematically deriving higher curvature corrections.

Thomas Cailleteau, Pennsylvania State University

Two main corrections from effective Loop Quantum Cosmology: algebra colsure

During this talk I will review the consequences of the two main corrections coming from the LQG-inspired Loop quantum cosmology (LQC) theory. At the effective level when one tries to include the main effects due to the Inverse Volume (IV) and Holonomy corrections one has to make sure that these corrections should not bring anomalies in the algebra of deformation and therefore add counter-terms to remove these anomalies. This step leads to new phenomenon as shown in different articles (change of signature asymptotic silence specific spectrum). Several works have been devoted to the closure of the algebra taking into account the corrections independently. I will show that it is possible to combine both corrections such that first new results were obtained for both IV and Holonomy algebras and

second a new full algebra for the IV+Holonomy case can be derived. I will finally present some physical consequences and conclude by showing what we could expect from the whole theory.

Miguel Campiglia, Raman Research Institute

Studies of condensate representations in LQG

We investigate the condensate-geometry representation introduced by Koslowski and further developed by Sahlmann hereafter referred to as KS. We build upon a recent result by Varadarajan which points at the necessity to include a new class of operators -exponentials of three-dimensional smearings of the connection against background triads- for a proper implementation of the constraints in the KS setting. This leads to a reinterpretation of KS as a quantization based on the augmented algebra of holonomies plus background exponentials. Based on this picture we provide a comprehensive implementation of the group averaging for the diffeomorphism and Gauss law constraints thus putting the condensate representation on the same footing as the standard LQG one. The treatment extends previous results to allow for degenerate background triads. We finally comment on the possibility of applying the framework to address asymptotically flat boundary conditions in LQG. Based on work done in collaboration with M. Varadarajan.

Sylvain Carrozza, Albert Einstein Institute

Renormalization of an SU(2) Tensorial Group Field Theory in Three Dimensions

I will outline the proof of renormalizability of a 3d TGFT based on the group SU(2) in which the 'closure constraint' of spin foam models is implemented. This will provide interesting lessons both technical and conceptual as regards the extension of this work to 4d quantum gravity models.

Atousa Chaharsough Shirazi, Florida Atlantic University

Pure momentum path integral for spin foams

Spin-foams have been proposed as a way to define the dynamics of loop quantum gravity via path integral. In specifying any path integral it is important that the integrand have the correct phase and modulus at each point in the space of histories. The modulus of the integrand is usually referred to as the measure factor. The correct measure factor descends from the Liouville measure on the reduced phase space and its calculation is a task of canonical analysis. The covariant formulation of gravity from which Spin-foams are derived is the Plebanski-Holst formulation of gravity. The basic variables in this formulation of gravity are a Lorentz connection and a Lorentz-algebra valued two-form called the Plebanski two-form. In prior work the measure factor for the Plebanski-Holst path integral with both connection and two-form variables present was calculated. However in the actual spin-foam sum one only sums over spins and intertwiners which label eigenstates of only the Plebanski two-form. The spin-foam sum is therefore a discretized version of a pure momentum Plebanski-Holst path integral in which the connection degrees of freedom have been integrated out. In this work we perform this integration providing a measure which can be discretized and directly incorporated into spin-foams. In order to be confident about numerical factors we perform the calculation in two independent ways.

Lin-Qing Chen, Perimeter Institute

Is Relative Locality causal?

Relative Locality is a proposal for describing the Planck scale modifications to relativistic dynamics resulting from non-trivial momentum space geometry. A simple construction of interaction processes shows that causal loops can be solutions of the theory, with a strange property of x-dependence. We then prove that in Kappa Poincare momentum space, the orientability of classical loop process, global momentum conservation and x-independence are equivalent, and the preservation of causality is contingent on the former three.

Goffredo Chirco, Aix-Marseille University

Coupling General-Covariant Systems

We consider the open problem of statistical mechanics in a full general covariant context by focussing on the study of a definition of statistical equilibrium for completely parametrized systems. In particular, we show how to provide a consistent pre-symplectic description of dynamical coupling between parametrized systems. Understanding coupling is the prerequisite to characterize the thermalization hypothesis in a general covariant context. There is an interesting relation between the emergence of equilibrium and the definition of a pure gauge sector in the constrained dynamics, due to redundancy in the partial observables description, for the coupled system.

Christopher Coleman-Smith, Duke University

A ``Helium Atom'' of Space: Dynamical Instability of the Isochoric Pentahedron

We present an analysis of the dynamics of the equifacial pentahedron on the Kapovich-Millson phase space under a volume preserving Hamiltonian. The classical dynamics of polyhedra under such a Hamiltonian may arise from the classical limit of the node volume operators in loop quantum gravity. The pentahedron is the simplest nontrivial polyhedron for which the dynamics may be chaotic. We consider the distribution of polyhedral configurations throughout the space and find indications that the borders between certain configurations act as separatrices. We examine the local stability of trajectories within this phase space and find that locally unstable regions dominate although extended stable regions are present. Canonical and micro-canonical estimates of the Kolmogorov-Sinai entropy suggest that the pentahedron is a strongly chaotic system. The presence of chaos is further suggested by calculations of intermediate time Lyapunov exponents which saturate to non-zero values.

Adriano Contillo, Radboud University Nijmegen

The paradigm of Asymptotic Safety as a guiding principle to the early universe dynamics

The Functional Renormalisation Group technique has received great attention in recent times proving itself as a powerful tool to describe the high energy behaviour of gravitational interactions. In particular much evidence has been gathered about the emergence of the so-called Asymptotic Safety scenario an

ultraviolet fixed point in the scale-dependent action of gravity that seems able to tame the divergences appearing in the perturbative quantisation. In this talk I will discuss the consequences of this picture to the gravitational dynamics describing the most peculiar features of the main renormalisation group improvement schemes. I will then focus on the early universe dynamics showing that Asymptotic Safety is able to trigger a phase of accelerated expansion that naturally flows towards classical relativistic dynamics. The features of this inflationary phase can then be related to those of the renormalisation group flow providing a first testing ground for the predictions of Asymptotic Safety.

Joshua Cooperman, University of California, Davis

On the renormalization group flow of the cosmological constant in causal dynamical triangulations

I demonstrate a technique for extracting the renormalization group flow of the dimensionless product of the Newton constant and the cosmological constant within the causal dynamical triangulations approach to the quantization of gravitation. This method applies to the phase of quantum spacetime geometry possessing semiclassical Euclidean de Sitter-like properties that emerges from the causal dynamical triangulations of Einstein gravity with positive cosmological constant for 4-sphere spacetime topology. I present only a portion of this renormalization group flow as significantly more numerical simulations will be required to probe its full extent.

Antonin Coutant, Albert Einstein Institute

Transplanckian question: lessons from acoustic black holes

In 74 Hawking derived his famous prediction that black holes should emit a steady radiation of finite temperature. However his derivation assumes that the radiating field propagates freely on a classical gravitational background. The validity of this hypothesis was then questioned by pointing out the huge redshift that occurs near a horizon. In 81 Unruh proposed to mimic the behavior of fields around black hole geometries by looking at perturbations waves on a moving fluid. In particular a fluid whose velocity crosses the speed of sound behaves much like a horizon where the Hawking effect can be studied. One of the theoretical interest of this analogy is that it can be seen as a laboratory to test the potential influence of ultraviolet physics on Hawking radiation as we know the microscopic structure of fluid dynamics. In this talk we first present the general ideas of analog models. To study the Hawking effect because of the infinite redshift on the horizon one must take into account the necessary violations of Lorentz invariance at short wavelength. Using a WKB approximation we establish under which conditions the Hawking process is recovered. We also argue that near a black hole ultraviolet deviations of Lorentz invariance can be probed at energies much smaller than the Planck scale. We then discuss peculiar effects arising in acoustic black holes namely ``the black hole laser instability'' and ``undulation generation''.

Andrea Dapor, University of Warsaw

QFT on quantum spacetime

We develop a systematic classical framework to accommodate canonical quantization of both geometric and matter perturbations on a quantum homogeneous isotropic flat spacetime. It is shown that the existing approach of standard cosmological perturbations is good only (i) up to first order in the inhomogeneities and (ii) if the background is treated classically. A new set of classical phase space variables is proposed which in a natural gauge define a complete and canonical algebra of relational Dirac observables. We compute the physical Hamiltonian that generates the dynamics of such observables (with respect to the homogeneous mode of a Klein-Gordon clock field) and offer a proposal for quantization: what we obtain is a theory of quantum perturbations on a quantum (cosmological) spacetime.

Stephane Dartois, ENS de Lyon

The 1/N expansion of multi-orientable random tensor models

Multi-orientable group field theory (GFT) has been introduced in A. Tanasa J. Phys. A 45 (2012) 165401 arXiv:1109.0694 as a quantum field theoretical simplification of GFT which retains a larger class of tensor graphs than the colored one. In this paper we define the associated multi-orientable identically independent distributed multi-orientable tensor model and we derive its 1/N expansion. In order to obtain this result a partial classification of general tensor graphs is performed and the combinatorial notion of jacket is extended to the multi-orientable graphs. We prove that the leading sector is given as in the case of colored models by the so-called melon graphs.

Ghanashyam Date, The Institute of Mathematical Sciences

Implementation of continuous symmetries in the context of polymer/loop quantization

The question of `Lorentz violation' in LQG has been raised many times. To sharpen any possible violation it is useful to appreciate features of symmetry implementation in the chosen quantization scheme. First steps in this direction have been taken in arXiv:1211.0823 (published in CQG). Further developments in this regard will be presented.

Jacobo Diaz Polo, Louisiana State University

On the continuous limit of graphs

Spin networks (oriented graphs with colored edges) provide the standard basis for LQG states thus encoding geometry in discrete structures. Semi-classical states should however reproduce the classical smooth geometry in the appropriate limits. The question of how to recover a continuous smooth geometry from these discrete structures is therefore highly relevant in this context. Here we analyze this question from a general mathematical perspective using properties of Voronoi graphs to search for compatible continuous geometries.

Bianca Dittrich, Perimeter Institute

Discrete or not discrete: cylindrical consistent dynamics, renormalization, criticality and all that

LQG techniques allow the construction of a continuum theory via a (cylindrically consistent) family of Hilbert spaces describing the kinematical degrees of freedoms supported on a given graph. I will describe how this notion can be extended to the dynamics of the theory. I will also clarify in which sense a 'continuum limit' can be performed in a continuum theory like LQG and how this might be performed via a coarse graining or renormalization process.

Andreas Doering, University of Oxford

The Topos Approach to Quantum Theory and Quantum Gravity

A short review of the so-called topos approach to quantum theory and quantum gravity is given emphasizing on the physical aspects. The topos approach was initiated by Isham and Isham/Butterfield and substantially developed in the last seven years by the speaker Isham Landsman Flori et al. On the one hand the approach addresses certain deep conceptual and structural issues that any theory of quantum gravity will have to face - notably the role of observers and the role of continuum ideas in the mathematical formulation of the theory. On the other hand a whole number of new technical tools have been developed that give structural insights that would not be available from a more conventional Hilbert space-based perspective. In particular a new kind of non-commutative phase space for quantum systems has been found and a new kind of logic for arguing about physical systems has been developed. The formalism is 'Hamiltonian' in the sense that it is based on a phase space picture but it goes well beyond the usual formulations relying in some form on an (underlying) manifold. While most of the work on the topos approach so far has been done on algebraic quantum theory extensions to quantum field theories and gravitational theories now seem in reach.

Maite Dupuis, University of Erlangen-Nuernberg

deformed Phase Space for Hyperbolic Surfaces.

In the quantum gravity regime, the introduction of a nonzero cosmological constant is usually done using a quantum group. From the phase space construction of loop quantum gravity, it is not clear how such a quantum group appears. Using a Poisson-Lie group, I will generalize the standard holonomy-flux algebra to introduce the cosmological constant and describe (2d) hyperbolic discrete geometries. I will show how the closure constraint imposed on a vertex can be related to the hyperbolic cosine law for the dual triangle. At the quantum level, this formulation will give rise to $U\_q(su(2))$ spin networks or equivalently in the dual picture to hyperbolic quantum triangles glued together. If time permits, I will also discuss the flatness constraint that appears in this deformed context.

Christopher Duston, Florida State University

Models for Topology Change Coming from Coherent Intertwiners and Topspin Networks

In this talk we will combine the U(N) coherent intertwiner techniques with the topspin network approach to loop quantum gravity. The explicit representation of SU(2) in terms of a pair of harmonic oscillators will allow us to find a representation of the deck transformation on the Hilbert space of coherent intertwiners and can also be used to construct models for topology change. We will also discuss using this approach to study the geometry of spin and topspin networks.

Astrid Eichhorn, Perimeter Institute

Probing the quantum nature of spacetime with a diffusing particle

Many approaches to quantum gravity have resorted to diffusion processes to characterize the spectral properties of the resulting quantum spacetimes. I will critically discuss these quantum-improved diffusion equations and point out that a crucial property, namely positivity of their solutions, is not preserved automatically. I will then show how to construct a novel set of diffusion equations with positive semi-definite probability densities, applicable to Asymptotically Safe gravity, Horava-Lifshitz gravity and Loop Quantum Gravity. These recover all previous results on the spectral dimension and shed further light on the structure of the quantum spacetimes by assessing the underlying stochastic processes. Pointing out that manifestly different diffusion processes lead to the same spectral dimension, I propose the probability distribution of the diffusion process as a refined probe of quantum spacetime.

Jonathan Engle, Florida Atlantic University

Quantum isotropy and dynamical quantum symmetry reduction

We give a diffeomorphism and gauge covariant condition equivalent to homogeneity and isotropy which in principle can be quantized yielding a definition of a diffeomorphism-invariant homogeneous isotropic sector of LQG without fixing a graph. We specialise this condition to Bianchi I cosmologies yielding a condition for isotropy. We show how by quantizing and imposing this condition in the Bianchi I LQC model one recovers isotropic LQC with standard `improved dynamics.'

Kevin Falls, University of Sussex

Fixed Points in f(R) quantum gravity

The asymptotic safety conjecture is examined in four-dimensional euclidean quantum gravity for actions which are functions of the Ricci scalar. Within a high order polynomial approximation an ultraviolet fixed point is found with three relevant directions. Increasing the order of the approximation operators are found to be increasingly irrelevant. Furthermore the universal scaling exponents take near-Gaussian values despite the presence of residual interactions. Asymptotic safety of metric gravity would seem in reach if this pattern carries over to the full theory.

Laurent Freidel, Perimeter Institute

Non equilibrium thermodynamics of space time bubbles

In this talk I review the deep analogy between the gravity equations and non-equilibrium thermodynamics of bubbles and interfaces.

Ivette Fuentes, University of Nottingham

Quantum information processing in spacetime

Cutting-edge experiments in quantum communications are reaching regimes where relativistic effects can no longer be neglected. For example there are advanced plans to use satellites to implement teleportation and quantum cryptographic protocols. Relativistic effects can be expected at these regimes: the Global Positioning System (GPS) which is a system of satellites that is used for time dissemination and navigation requires relativistic corrections to determine time and positions accurately. Therefore it is timely to understand what are the effects of gravity and motion on entanglement and other quantum properties exploited in quantum information. In this talk I will show that entanglement can be created or degraded by gravity and non-uniform motion. While relativistic effects can degrade the efficiency of teleportation between moving observers the effects can also be exploited in quantum information. I will show that the relativistic motion of a quantum system can be used to perform quantum gates. Our results which will inform future space-based experiments can be demonstrated in table-top experiments using superconducting circuits.

Rodolfo Gambini, Universidad de la Republica

A local Hamiltonian for spherically symmetric gravity coupled to a scalar field

The problem of finding a gauge fixing that leads to a local Hamiltonian for spherically symmetric gravity coupled to scalar field had proved elusive. Here we present a gauge fixing that achieves that goal: the resulting total Hamiltonian is the integral of a local density.

Angel Garcia, UAMI

Towards the fermion propagator in polymer quantum field theory.

Polymer quantum mechanics mimics the loop quantization of gravity in mechanical systems like a free particle or a harmonic oscillator. Moreover when considered for each of the modes of a scalar field it has served to study departures from the standard quantization of such a field for systems ranging from cosmology to black holes and wave propagation. In this work we focus in the important case of a fermion field. Our starting point is its analysis in flat spacetime leading to a tower of Fermi oscillators which are subsequently subject to polymer quantization. Thereby some hints on its propagator are obtained revealing its behaviour at high energies.

Marc Geiller, Institute for Gravitation and the Cosmos

The Barbero-Immirzi parameter, black hole entropy, and the reality conditions

We present some recent intriguing observations concerning the role of the original complex Ashtekar variables in loop quantum gravity and spin foam models. This is illustrated with the computation of 4d black hole entropy with an imaginary Barbero-Immirzi parameter, the deviration of the entropy of a BTZ black hole, and finally a formulation of three-dimensional gravity with a Holst-like action.

Steffen Gielen, Perimeter Institute

Homogeneous cosmologies in discrete quantum gravity

We report on recent progress on the description of macroscopic, spatially homogeneous geometries within group field theory (GFT) that can also be interpreted in terms of spin networks or simplicial geometries. We are able to extract the effective cosmological dynamics of such states directly from the quantum GFT equations of motion, obtaining a nonlinear and nonlocal version of quantum cosmology in general. In a WKB regime and in the isotropic case, with mild assumptions on the GFT model, we recover the classical Friedmann equation.

Lisa Glaser, Niels Bohr Institue

A CDT Hamiltonian from Horava–Lifshitz gravity

Causal Dynamical Triangulations (CDT) is an approach to quantum gravity which attempts to regularize the path integral of gravity by discretizing the manifold.   So far it has not been possible to directly connect the quantum theory of CDT to any classical theory.   Both Horava Lifshitz gravity and CDT require a preferred foliation of space time, so it has been proposed that CDT might be a quantum theory for Horava Lifshitz gravity.   In this talk I will present recent work on connecting CDT to the classical theory of Horava Lifshitz gravity. I will show how to obtain the effective 2d CDT Hamiltonian through canonical quantization of 2d Horava-Lifshitz gravity.

Julien Grain, Institute for Space Astrophysics

Phenomenological aspects of loop quantum cosmology in the CMB

Since the last decade loop quantum cosmology has drastically progressed. The most recent developments in the theory of cosmological perturbations evolving on a quantum universe now allow us to compute the amount of cosmological perturbations produced in the primordial universe. Those perturbations leave their footprints on the CMB anisotropies making possible to investigate loop quantum cosmology from an observational perspective. From that observational perspective I will present how the recently proposed theory(ies) of cosmological perturbations in loop quantum cosmology distorts the expected angular power spectra of CMB anisotropies. I will propose an intuitive understanding on how loop quantum cosmological evolution affect the CMB anisotropies and confront those predicted angular power spectra to their latest measurements.

Jonathan Granot, Open University of Israel

Searches for Quantum Gravity Signals using Gamma-Ray Bursts

I will discuss recent searches for quantum gravity signatures using high-energy photons from gamma-ray bursts (GRBs), focusing on the search for Lorentz Invariance Violation in the form of a dependence of the photon propagation speed on its energy. Fermi gamma-ray space telescope observations of ~8 keV to ~30 GeV photons from the short (< 1 s) GRB 090510 at a cosmological distance (z = 0.903), enabled for the first time to put a direct time of flight on a possible linear variation of the speed of light with phton energy that is beyond the Planck scale. Parameterizing $|v/c-1| = E/E_{QG}$ our most conservative limits are up to 1-2 orders of magnitude stricter. I will finish by briefly outlining the prospects for future GRB observations by the Cherenkov Telescope Array (CTA) - the next generation ground based very high energy (from ~20-30 GeV to ~300 TeV) observatory.

Sean Gryb, Radboud University Nijmegen

Global Symmetry Trading and Observers in Shape Dynamics

We provide a framework for trading the global symmetries of de Sitter spacetime, relating different inertial observers, for the group of conformal symmetries (including special conformal transformations) on the plane, relating different scale-invariant observers in flat space. This map provides a duality between a spacetime ontology for inertial observers and a scale-invariant ontology, constituting a proposal for a concrete ontology for observers in homogeneous and isotropic Shape Dynamics in the presence of a positive cosmological constant.

Giulia Gubitosi, La Sapienza University of Rome

Relative Locality in k-Poincar

I show that the k-Poincar Hopf algebra can be interpreted in the framework of curved momentum space leading to relative locality. I discuss the consequences for particle propagation and energy-momentum conservation law in interaction vertices. I also describe the action of boost transformation on multi-particle systems showing that the covariance requirement implies the introduction of a dependence of the rapidity parameter on the particle momenta.

Hal Haggard, Centre de Physique Theorique

General boundary field theory, thermality, and entanglement

Twisted geometry is a piecewise-flat geometry less rigid than Regge geometry. In Loop Gravity it provides the classical limit for each step of the truncation utilized in the definition of the quantum theory. We define the torsionless spin-connection of a twisted geometry. The difficulty given by the discontinuity of the triad is addressed by interpolating between triads. The curvature of the resulting spin connection reduces to the Regge curvature in the case of a Regge geometry.

Maximilian Hanusch, University of Paderborn

Classical and Distributional Symmetric Connections in LQG

In LQG symmetries usually are represented by Lie groups of automorphisms of the underlying bundle. The corresponding invariant connections then serve as a starting point for the construction of a reduced quantum configuration space as used in LQC. Alternatively one might aim at a symmetry reduction directly on quantum level. This indeed can be done successfully by means of new lifting results for group actions that lead to the notion of an invariant (or symmetric) distributional connection. In this talk we want to compare this two reduction concepts. Moreover we provide a tool that often helps to calculate the invariant classical connections w.r.t. a certain symmetry.

Bruno Hartmann, Perimeter Institute

From empirical practice to observables and the action principle

Physical theories ought to be built up from colloquial notions such as long bodies energetic sources etc. in terms of which one can define pre-theoretic ordering relations such as longer than more energetic than. One of the questions addressed in previous work is how to make the transition from these pre-theoretic notions to quantification such as making the transition from the ordering relation of longer than (if one body covers the other) to the notion of how much longer. In similar way we introduce dynamical notions more impulse (if in a collision one object overruns the other) and more energetic (if the effect of one source exceeds the effect of the other). In a physical model - built by coupling congruent standard actions - those basic pre-theoretic notions become measurable. We derive all (classical and relativistic) equations between basic physical quantities of Energy Momentum and Inertial Mass and ultimately the principle of least action.

Jeffrey Hazboun, Utah State University

Time and general relativity as a consequence of gauging the Euclidean conformal group

We show that the Lorentz structure of spacetime and the Einstein equation may be derived as part of the solution within a conformal gauge theory of Euclidean space. Quotients of the conformal group of n-dim (pseudo-)Euclidean spaces by their Weyl subgroups are called biconformal spaces. These 2n-dim spaces naturally include both metric and symplectic form. We start from two known results. First these spaces allow a scale-invariant action linear in the curvatures making this theory distinct from the quadratic-curvature Weyl gravity theory. The linear action leads to general relativity on the configuration submanifold. Second flat solutions in the Euclidean case that are metric phase spaces are necessarily Lorentzian time arises as part of the solution in a Euclidean theory.We generalize combining these results. We show that Lorentz symmetry and the Einstein equation follow from the Euclidean gauge theory with linear action when the biconformal space admits orthogonal metric configuration and momentum submanifolds assuming only separability of the torsion field equation. The separable field equations lead generically to a signature (n-11) metric with orthogonality of the conjugate submanifolds leading directly to the compatible Lorentzian connection on both. We find exact solutions in which the

Weyl vector is hypersurface orthogonal to spatial slices of the configuration and momentum submanifolds. Relationships to shape dynamics and to models breaking Lorentz invariance will be discussed.

Tobias Henz, University of Heidelberg

Dilaton Quantum Gravity

The properties of dilatation symmetric quantum gravity are studied using functional renormalization group methods and a new class of simple fixed point solutions is proposed that are approached as the dimensionless combination chi/k tends to zero. They feature a vanishing potential for the scalar field chi and the coupling to gravity is realized by the only term allowed by dilatation symmetry, namely $chi^2 R$. Smooth continuations into the regime of finite chi/k as well as the renormalisation flow close to the fixed point are presented and cosmological implications are discussed.

Hector Hernandez, Universidad Autonoma de Chihuahua

Anisotropy by lattice refinement

We show how previous isotropic and homogeneous models in loop quantum cosmology can lead to the study of anisotropies by lattice refinement which in turn can be studied by effective settings in the theory.

Jeff Hnybida, Perimeter Institute

Quantum Twisted Geometry

We construct a new discrete basis of 4-valent SU(2) intertwiners. This basis possesses both the advantage of being discrete while at the same time representing accurately the classical degrees of freedom; hence it is coherent. The closed spin network amplitude obtained from these intertwiners depends on twenty spins can be evaluated by a generalization of the Racah formula for an arbitrary graph. The asympototics of this symbol are found to give a generalization of the Regge action to twisted geometry.

Philipp Hoehn, Perimeter Institute

Dynamics and (broken) symmetries of discrete gravity models

This review talk will summarize recent developments in the study of discrete gravity models, such as Regge Calculus, which (classically) are subject to a variational action principle. I shall discuss the issue of (broken) symmetries in the discrete and how the propagating data and dynamics can be extracted by means of a constraint analysis. Along the way, I shall mention how a time varying discretization and, hence, a time varying number of degrees of freedom, can be consistently described in canonical language in both the classical and quantum theory.

Matthew Hogan, Florida Atlantic University

Consistency of operator orderings in Bianchi I and isotropic loop quantum cosmology

We discuss how different operators in Bianchi I and isotropic LQC can be ordered in such a way as to ensure consistency between the two models. The operators we consider include the Hamiltonian constraint as well as observables such as volume directional Hubble rates expansion and shear which are central to investigations of singularity resolution

Giorgio Immirzi, INFN

spinor formulation of spin-foam theory

An attempt to use spinors to 'solve' the constraints and treat on the same footing space-like and time-like tetrahedra.

Matt Johnson, Perimeter Institute

Searching for other universes

Centuries of astronomy and cosmology have led to an ever-larger picture of our 'universe' — everything that we can observe. For just as long, there have been speculations that there are other regions beyond what is currently observable, each with diverse histories and properties, and all inhabiting a 'Multiverse'. A nexus of ideas from cosmology, quantum gravity, and string theory lead to the prediction that we inhabit one of the most interesting sorts of Multiverses one could imagine: one that arises as a natural consequence of compelling explanations for other physics, and one that at least in principle can be tested with observations. In this talk, I will outline these ideas, and discuss the first observational tests of the Multiverse using data from the Wilkinson Microwave Anisotropy Probe.

Mikhail Kagan, Pennsylvania State University

Quantum matter in quantum space-time

We discuss quantum matter in quantum space-time using general properties of energy-conservation laws and their tight relation to space-time symmetries. From the canonical point of view closure of the constraint algebra is necessary for the possibility of stating conservation of energy. It can then be shown that quantum-corrected constraints must lead to modifications of space-time structures and the resulting correction terms cannot simply be absorbed in appropriate conservation laws of standard type. Such modifications of the conservation law of matter would be of great interest for cosmological perturbation theory whose equations in terms of gauge- invariant quantities can be derived from the behavior of the stress-energy tensor without reference to the more complicated Einstein equation.

Wojciech Kaminski, Perimeter Institute

Curvature constraints in the spin foam models

I will present surprising constraints for internal holonomies in the asymptotic (semi-classical) limit in the EPRL model.

Marcin Kisielowski, University of Warsaw

On first-order contributions to the Dipole Cosmology transition amplitude

We discuss some first-order contributions to the (Euclidean) Dipole Cosmology transition amplitude. These amplitudes correspond to spin foams having the boundary graph of Dipole Cosmology one internal vertex and no edges connecting this vertex with itself. We expect that the amplitudes are dominated by the Bianchi-Rovelli-Vidotto transition amplitude in a limit of large volume of the universe and the transition amplitude including contributions from all these spin foams gives the correct Friedmann dynamics in the classical limit.

Tim Koslowski, University of New Brunswick

Shape dynamics and quantum gravity

A difficult and still open problem in the LQG program is the construction of the physical Hilbert space for pure quantum gravity. This is due to the complicated nature of the Hamilton constraints. The Shape Dynamics description of General Relativity replaces the Hamilton constraints with spatial Weyl constraints so the problem of finding the physical Hilbert space reduces to the problem of quantizing the Weyl constraints. Unfortunately it turns out that a loop quantization of Weyl constraints is far from trivial despite their intuitive physical interpretation. I give a proposal and discuss the implications of this proposal.

Thomas Krajewski, Centre de Physique Theorique

An exact renormalization group equation for group field theories

We will derive an exact renormalization group equation for group field theories and tensor models based on the Schwinger-Dyson equations. This equation encodes the integration over some unobserved degrees of freedom in the effective action. Finally we will illustrate its use on some truncations of the theory involving restricted class of graphs.

Manuel Kramer, University of Cologne

Potential observational effects from Wheeler-DeWitt quantum cosmology

In any approach to quantum gravity it is crucial to look for observational effects in order to discriminate between different candidate theories. Here we discuss how quantum-gravitational contributions to the anisotropy spectrum of the cosmic microwave background radiation arise in the framework of canonical quantum gravity by performing a semi-classical approximation to the Wheeler-DeWitt equation. This

leads to a modification of the power spectrum at large scales. While the effect is currently too weak to be observable we find an upper bound on the energy scale of inflation. We also compare these results with predictions from loop quantum cosmology

Eugene Kur, University of California, Berkeley

Discrete Exterior Calculus and Regge Calculus

Discrete exterior calculus is an approach to discretizing field theories. Applying it to GR we obtain a theory reminiscent of Regge calculus but seemingly more general. I will discuss the basics of implementing discrete exterior calculus and what it tells us about discrete gravity.

Suzanne Lannery, University of Erlangen-Nuernberg

An Alternative State Space for Quantum Gravity

I will present an extension of the state space of LQG, developed in the search of an embedding of LQC in LQG. I will also discuss some tools related to this extension, that could have applications to other open questions in quantum gravity.

Antony Lee, University of Nottingham

Shaking Entanglement - Teleportation in Relativistic Motion

We present an analysis of the entanglement generation between modes of quantum fields in non-uniformly moving cavities. In our fully relativistic model the cavities can undergo generic travel scenarios where the cavity trajectories are composed of segments of inertial motion and uniform acceleration. We show how the field of Gaussian state quantum information can be used to analyse entanglement generated within a moving cavity. Our results suggest strong links between quantum information quantum fields in curved spacetimes and gravitational analogues by way of the equivalence principle. As a particular example we discuss how the quantum teleportation protocol between two cavities containing Gaussian states of light are influenced by the motion [N.F. et al. Phys. Rev. Lett. 110 113602 (2013)]. An experimental proposal to test this model in state of the art quantum optics laboratories is also presented.

Jerzy Lewandowski, University of Warsaw

Exact solutions of canonical LQG

In the case of LQG coupled to the massless scalar field (the Rovelli-Smolin model) the form of the quantum scalar constraint drastically simplifies in comparison to other cases. The properties of the physical Hamitonian will be discussed.

Linda Linsefors, LPSC-Grenoble/CNRS

Duration of inflation as a prediction of effective LQC

Loop quantum cosmology together with a massive scalar field has been shown to predict a high probability of sufficiently long enough inflation to fit observations. However these predictions were derived from setting initial conditions at the bounce. In this study we take seriously the direction of causality from past to future and therefore set initial conditions before the bounce. The phase of the scalar field is assumed to be a random variable with a flat probability distribution. A key point of this distribution is that it is not linked to a specific point in time. Our result is independent of how long before the bounce we set the initial conditions given reasonable assumptions. In this framework we can show that the number of e-folds of slow-roll inflation is peaked around N=145. This is one of the first clear theoretical prediction for the duration of inflation and it is also in agreement with observations. In addition the fraction of potential energy at the bounce usually taken as a free unknown parameter driving many observable effects can also be shown to be sharply peaked. Finally we use those results to derive an original upper limit on the Barbero-Immirzi parameter : gamma < 11 which is two orders of magnitude better than the previous limit coming from cosmology.

Kinjalk Lochan, Tata Institute of Fundamental Research

correction to B-H area law in loop black holes

We discuss the entropy of quantum black holes in the Loop quantum gravity formalism when the number of punctures on the horizon is treated as a quantum hair that is we compute the black-hole entropy in the grand canonical (area) ensemble. The entropy is a function of both the average area and the average number of punctures and bears little resemblance to the Bekenstein-Hawking entropy.In the thermodynamic limit both the temperature and the chemical potential can be shown to be functions only of the average area per puncture. At a fixed temperature the average number of punctures becomes proportional to the average area and we recover the Bekenstein-Hawking area-entropy law to leading order provided that the Barbero-Immirzi parameteris appropriately fixed. We also see that the Barbero Immirizi parameter is related to the chemical potential and we obtain a positive logarithmic correction to entropy area relation.

Niccol Loret, La Sapienza University of Rome

Introducing Lateshift

In the last few years many approaches to the problematic behaviour of spacetime symmetries at Planck length have investigated the possibility to express them into a non-trivial momentum-space geometry. More recently many papers [arXiv:1101.0931 arXiv:1106.5710 arXiv:1107.1724] introduced the idea that those momentum-space symmetries deformations could be formalised as a momentum-space curvature whose effects on spacetime can be interpreted as Relative Locality features. In this talk we will deepen the interplay between spacetime curvature and momentum-space curvature using the rainbow-metrics formalism. The key aspect we would like to point out is that as the spacetime dependance of de

Sitter dispersion relation can be described as an inference of spacetime curvature on momentum-space at the same time the relative locality features we find in k-Minkowski-formalized quantum-spacetime [arXiv:1102.4637] can be interpreted as an inference of momentum-space deformation on spacetime. We will introduce the concept of Lateshift as a dual-redshift feature and on the other hand we will show how the well-known redshift effect due to spacetime expansion can be expressed as a Relative Locality on momentum-space.

Matteo Giuseppe Lostaglio, Imperial College London

Scale anomaly as the origin of time

We explore the problem of time in quantum gravity in a point-particle analogue model of scale-invariant gravity. If quantized after reduction to true degrees of freedom it leads to a time-independent Schroedinger equation. As with the Wheeler--DeWitt equation time disappears and a frozen formalism that gives a static wavefunction on the space of possible shapes of the system is obtained. However if one follows the Dirac procedure and quantizes by imposing constraints the potential that ensures scale invariance gives rise to a conformal anomaly. So scale invariance is quantum mechanically broken. A behaviour closely analogous to renormalization-group (RG) flow results. The wavefunction acquires a dependence on the scale parameter of the RG flow. We interpret this as time evolution and obtain a novel solution of the problem of time in quantum gravity. We apply the general procedure to the three-body problem showing how to fix a natural initial value condition introducing the notion of complexity. We recover a time-dependent Schrodinger equation with a repulsive cosmological force in the `late-time' physics and we analyse the role of the scale invariant Planck constant. We suggest that several mechanisms presented in this model could be exploited in more general contexts.

Yongge Ma, Beijing Normal University

Loop quantum scalar-tensor theory and its cosmological application

In this talk we will review the non-perturvative loop quantization of scalar-tensor theories which include f(R) modified gravity and Brans-Dicke gravity as special cases. Then we construct loop quantum Brans-Dicke cosmology by mimicking the construction of above full theories. The quantum bounce and inflation in this cosmological model will also be discussed.

Seth Major, Hamilton College

On Loop Quantization of Plane Gravitational Waves

Classically spacetimes of plane gravitational waves with parallel rays may be obtained by a reduction of the polarized Gowdy model with the addition of a new constraint. This new constraint is diffeomorphism invariant in the symmetry reduced model. When expressed in terms of the new variables of loop quantum gravity the system of constraints forms a first-class but non-Lie algebra. The eventual goal of the project is to investigate whether (and if so how) the apparent discreteness of spatial geometry in loop quantum gravity affects the propagation of gravitational waves. This talk focuses on the

quantization of this model. Progress towards solving the constraints and identifying a space of Minkowski-type solutions will be discussed.

Antonino Marciano, Fudan University & INFN

Gravitational origin of the weak interaction's chirality

We present a new unification of the electro-weak and gravitational interactions based on the joining the weak SU(2) gauge fields with the left handed part of the spacetime connection into a single gauge field valued in the complexification of the local Lorentz group. Hence the weak interactions emerge as the right handed chiral half of the space-time connection which explains the chirality of the weak interaction. This is possible because as shown by Plebanski, Ashtekar and others the other chiral half of the space-time connection is enough to code the dynamics of the gravitational degrees of freedom. This unification is achieved within an extension of the Plebanski action previously proposed by one of us. The theory has two phases. A parity symmetric phase yields as shown by Speziale a bi-metric theory with eight degrees of freedom: the massless graviton a massive spin two field and a scalar ghost. Because of the latter this phase is unstable. Parity is broken in a stable phase where the eight degrees of freedom arrange themselves as the massless graviton coupled to an SU(2) triplet of chirally coupled Yang-Mills fields. It is also shown that under this breaking a Dirac fermion expresses itself as a chiral neutrino paired with a scalar field with the quantum numbersof the Higgs.

Mercedes Martin Benito, Perimeter Institute

Coarse Graining Methods for Spin Net and Spin Foam Models

The large scale physics arising from spin foam models remains to be an open question. The complexity of these models makes the analysis of their possible continuum phases a very difficult task. In the last years progress in this direction has been made by considering simplified, yet featured-rich, analog models to spin foams, the so-called spin net models. In this talk we review the use of tensor network renormalization group techniques to analyze the coarse graining of spin nets. These models retain the main dynamical ingredient of spin foams, namely the simplicity constraints. We will analyze the fate under coarse graining of the spin nets simplicity constraints and the resulting phase diagram, which interestingly displays unexpected fixed points. We will comment on how to extend these analyses to spin foam models.

Eduardo Martin-Martinez, Perimeter Institute & Institute for Quantum Computing

Listening to the early universe in the quantum noise

We identify a signature of quantum gravitational effects that survives from the early universe to the current era: fluctuations of quantum fields as seen by comoving observers are significantly influenced by the history of the early universe. In particular we will show how the existence (or not) of a quantum bounce leaves a trace in the background quantum noise that is not damped and would be non-negligible even nowadays. We will discuss how this signature might be observed and therefore used to build falsifiability tests of quantum gravity theories.

Daniel Martn de Blas, Instituto de Estructura de la Materia

Approximative methods in inhomogeneous loop quantum cosmology

We consider the hybrid quantization of the linearly polarized Gowdy T^3 model with matter to study methods of approximation to the complicated action that the Hamiltonian constraint has in loop quantum cosmology owing to the inclusion of the improved dynamics prescription and the presence of inhomogeneous fields and anisotropies. In this way we obtain physically interesting approximate quantum solutions.

Guillermo Antonio Mena Marugan, Instituto de Estructura de la Materia

Hybrid quantization of cosmological models with inflation

A complete quantization of an approximately homogeneous and isotropic universe with small scalar perturbations is carried out by means of an hybrid approach in Loop Quantum Cosmology. The matter content is provided by a minimally coupled massive scalar field. The homogenous sector of the geometry degrees of freedom is polymerically quantized while the inhomogeneities are quantized employing Fock techniques. The Fock quantization adopted is a privileged one picked out in a unique way by criteria of dynamical unitarity and symmetry invariance in the context of quantum field theory in curved spacetimes. We propose a prescription for the representation of the Hamiltonian constraint as an operator on the kinematical Hilbert space and show how to characterize its solutions by their data on the minimum volume section in each super-selection sector of the theory.

Flavio Mercati, Perimeter Institute

Gravity as a dissipative system on shape space

Aleksandar Mikovic, Lusofona University

Spin cube models of quantum gravity

We generalize the spin foam models of quantum gravity by using the Poincare 2-group instead of the Lorentz group in order to define the state sum. This allows for the introduction of labels for the edges in addition to triangle and tetrahedron labels. The state sum amplitude is then associated to a colored 3-complex. We show that the weights can be chosen such that the corresponding effective action has the Regge action in the classical limit.

Jonah Miller, University of Colorado

Transition Amplitudes in Causal Dynamical Triangulations

We study the causal dynamical triangulations of (2+1)-dimensional pure Einstein gravity with positive cosmological constant in the presence of past and future spacelike boundaries of fixed intrinsic geometries. For spatial topology of a 2-sphere we determine the form of the Einstein-Hilbert action supplemented by the Gibbons-Hawking-York boundary terms within the Regge calculus adapted to

causal dynamical triangulations. Employing this action we numerically simulate a variety of transition amplitudes from the past boundary to the future boundary all falling into one of three classes: minimal boundary minimal boundary minimal boundary non-minimal boundary and non-minimal boundary non-minimal boundary. We compare these results to the Hartle-Hawking wavefunction.

Djordje Minic, Virginia Tech

Relative Locality Born Reciprocity and String Theory

We examine the notion of T-duality in string theory from a phase space point of view and then emphasize the concept of Born's reciprocity a natural generalization of T-duality which posits the more general duality between spacetimeand momentum space. We propose that Born's reciprocity (and relative locality)demand a dynamical momentum space and thus a dynamical phase space opening up an exciting possibility for new dualities in string theory and new connections to the real world.[This work is done together with Laurent Freidel (Perimeter Institute) and Rob Leigh (Urbana).]

Edison Montoya, Instituto de Fisica y Matematicas

Qualitative Effective Dynamics in Bianchi IX Loop Quantum Cosmology

We consider the issue of singularity resolution within loop quantum cosmology for the homogeneous and anisotropic Bianchi IX model. We present results of numerical evolutions of the effective equations. To address the issue of singularity resolution we examine the time evolution of geometrical and curvature invariants that yield information about the semi-classical spacetime geometry. Finally we discuss generic behavior found for a variety of initial conditions.

Tim Morris, University of Southampton

Asymptotic safety in the f(R) approximation

I will review progress in understanding the structure of fixed points in quantum gravity in the infinite dimensional approximation in which the effective lagrangian is taken to be a general function of f(R).

Markus Mueller, Perimeter Institute

From information-theoretic axioms to quantum theory and beyond

Why are the laws of physics formulated in terms of complex Hilbert spaces? Are there natural and consistent modifications of quantum theory that could be tested experimentally? In the talk, I report on recent work with Lluis Masanes and other co-authors, where we look at different aspects of this question. In particular, we prove the following result [1], based on earlier work [2,3]: suppose that physics takes place in d spatial dimensions, and some events happen probabilistically (not assuming quantum theory in any way). Then suppose that there is a particularly nice information-theoretic interplay between geometry and probability, in a sense made precise. We prove that this uniquely determines spatial dimension d=3 and the complex Hilbert space formalism of quantum theory, and it allows observers to infer local spatial geometry from probability measurements. [1] MM and Ll.

Masanes, "Three-dimensionality of space and the quantum bit: an information-theoretic approach", New J. Phys. 15, 053040 (2013).

[2] L. Hardy, "Quantum Theory From Five Reasonable Axioms", arXiv:quant-ph/0101012

[3] Ll. Masanes and MM, "A derivation of quantum theory from physical requirements", New J Phys. 13, 063001 (2011).

Yasha Neiman, Pennsylvania State University

The imaginary part of the action in classical gravity and in spinfoams

The action of Lorentzian classical gravity has an imaginary part which appears related to black hole entropy. I show how this imaginary part arises from the action's boundary term in both second-order and first-order formulations with or without a Holst term. I then show that the same imaginary part is present in the large-spin effective action of the 4-simplex spinfoam if and only if the Immirzi parameter is sent to +/- i. The result suggests that a real Immirzi parameter should be thought of as a calculational aid to be discarded at the end. It also raises some thoughts concerning the physical meaning of the large-spin limit in LQG.

Robert Oeckl, Centro de Ciencias Matematicas

Recent results in the general boundary formulation and their implications for quantum gravity

I present a number of recent advances in the development of the general boundary formulation. In each case I emphasize lessons that can be drawn for quantum gravity. Topics include: (a) Exact and universal results in free field theory (b) Fermions and Krein spaces (c) Emergent time from Fermions (d) taking the modulus squared of a theory (rather than of individual amplitudes) (e) locality in quantum field theory.

Javier Olmedo, Universidad de la Repblica de Uruguay

The SL(2R) totally constrained model within the Uniform Discretizations quantization approach.

We provide a complete quantization of a totally constrained system whose constraint algebra corresponds to a non-compact $sl(2mathbbR)$ Lie algebra. In particular we consider the Uniform Discretizations approach for the quantization. The resulting physical Hilbert space is a subspace of the kinematical one whose basic bricks are the eigenstates of the Hamiltonian associated to the infrared counterpart of its discrete spectrum. We conclude that our physical Hilbert space together with a (quantum-mechanically) modified $so(21)times so(21)$ observable algebra reproduce a semi-classical limit compatible with the continuum theory. Besides we compare this result with the previous ones provided by different quantization schemes.

Jonathan Oppenheim, University College London

Generalisations of Quantum Theory in Light of the Black Information Problem

I'll discuss two possible responses to the block hole information problem: in one, the evolution laws are modified [arXiv:0902.2361] and in the other, we modify the state space of quantum theory

[arXiv:1206.5030]. The former, allows us to have fundamental destruction of information, while still preserving conservation laws. The latter allows information to become delocalised, living neither inside nor outside the black hole -- something impossible in ordinary quantum mechanics due to the no hiding theorem. More generally, black holes provide a means of testing alternative theories and guide us in their construction, and I'll discuss some ideas in this direction.

Daniele Oriti, Albert Einstein Institute

Group field theory as the 2nd quantization of loop quantum gravity

We present a 2nd quantized reformulation of canonical loop quantum gravity in both kinematics and dynamics, and we show how it leads directly to a group field theory formalism. This clarifies the precise relation between the two formalisms, in particular between the canonical projector operator and the GFT action and amplitudes. In particular, thus, it establishes the general lines of the correspondence between canonical and spin foam dynamics, via GFT.

Dine Ousmane Samary, International Chair in Mathematical Physics and Applications

Beta Function of U(1)^d just renormalizable tensor models

This work report the first order beta-function of recently proved just renormalizable random tensor models endowed with a U(1)^d gauge invariance. The model that we consider are polynomial Abelian phi^4_6 and phi^6_5 models. We show that both models are asymptotically free in the UV.

Giovanni Palmisano, La Sapienza University of Rome

Implication of the Interplay between Metric and Affine Connection on Momentum Space

In the framework of relative locality we consider some implication of the interplay between metric and affine connection on momentum space. Our case study has de Sitter metric on momentum space and different possible affine connections. We are particularly interested in the conditions required for DSR-relativistic compatibility of the momentum-space geometry. We also find that DSR-relativistic compatibility is a geometric property of momentum space.

Daniele Pranzetti, Albert Einstein Institute

Black hole entropy from KMS-states of quantum isolated horizons

By reintroducing Lorentz invariance in canonical loop quantum gravity, we define a geometrical notion of temperature for quantum isolated horizons. Upon imposition of the reality conditions in the form of the linear simplicity constraints for an imaginary Barbero-Immirzi parameter, the exact formula for the temperature can be derived. This is done by demanding that the horizon state satisfying the boundary conditions be a KMS-state. In this way, our analysis reveals the connection between the passage to the Ashtekar self-dual variables and the thermality of the horizon. The horizon equilibrium state can then be used to compute both the von Neumann and the Boltzmann entropies. We show that the two provide

the same finite answer which allows us to recover the Bekenstein-Hawking formula in the semi-classical limit. If time remains, the connection with Connes-Rovelli thermal time proposal is illustrated.

Jorge Pullin, Louisiana State University

Quantization of vacuum spherically symmetric gravity

We find a rescaling that makes the constraint algebra of spherically symmetric vacuum gravity a true Lie algebra. We are able to complete the Dirac quantization finding in closed form the space of physical states. New observables without quantum counterparts arise. The metric can be viewed as an evolving constant of the motion acting as an operator on the physical space of states and the singularity is eliminated.

Matti Raasakka, University Paris-Nord XIII

Connes-Kreimer combinatorial renormalization for the Ben Geloun-Rivasseau tensor field theory

Tensor field theories (TFTs) are `combinatorially non-local' quantum field theories whose stranded Feynman diagrams are dual to cell complexes. Their partition functions thus define (quantum) statistical models of discrete geometry. This makes TFTs highly interesting from the quantum gravity point-of-view for the purpose of formulating a well-defined quantum theory of spacetime geometry. Recently a number of perturbatively renormalizable TFT models has been discovered among them the Ben Geloun-Rivasseau model. Renormalizability of a QFT model is particularly important for making the model physically meaningful. In addition renormalization in the TFT context corresponds to coarse-graining of the discrete geometries and is therefore intimately related to understanding the scaling behavior and the continuum limit of these models. Connes and Kreimer have shown how the structure of perturbative renormalization of ordinary local QFT models can be encoded into a combinatorial Hopf algebra of Feynman diagrams now called the Connes-Kreimer algebra.In this talk I will explain how the Connes-Kreimer algebra arises in the case of the stranded Feynman diagrams of the Ben Geloun-Rivasseau TFT model. As a simple exercise in taking advantage of this structure I will write down the BPHZ prescription for obtaining the renormalized amplitudes of the Ben Geloun-Rivasseau TFT model in all orders in perturbation theory and point out further applications.

Michael Reisenberger, Instituto de Física Facultad de Ciencias

The holographic entropy bound and semi-classical gravitational back reaction.

I report on work in progress to understand Bousso's form of the holographic entropy bound as a consequence of gravitational backreaction on a quantum scalar field coupled to a classical spacetime geometry via the expectation value of the stress-energy tensor.

Trevor Rempel, Perimeter Institute

Scalar field theory in curved momentum space

We present a derivation of an action for scalar quantum field theory with cubic interaction term in the context of relative locality. Beginning with the generating functional for standard ph^3--theory and the corresponding Feynman rules we modify them to account for the non-trivial geometry of momentum space. These modified rules are then used to reconstruct the generating functional and extract the action for the theory. A method for performing a covariant Fourier transform is then developed and applied to the action. We find that the transformed fields depended implicitly on a fixed point in momentum space with fields based at different points being related by a non-local transformation. The interaction term in the action is also non-local but the kinetic term can be made local by choosing the base point to be the origin of momentum space.

Aldo Riello, Aix-Marseille University

Self energy of the Lorentzian EPRL-FK model of quantum gravity

I discuss the most divergent contributions to the Lorentzian EPRL-FK self-energy (melon graph) and their geometrical interpretation. In particular I treat in detail the (geometrically) non-degenerate sector of the sum over the spins showing that it is much less divergent than in BF theory. Furthermore I give some hints about the degenerate sector and the difficulties arising in its analysis. Finally I present the perspectives for the EPRL model arising from this calculation.

Andreas Rodigast, Heidelberg University

Renormalisation Group of Quantum Gravity in Flat Background

James Ryan, Albert Einstein Institute

Melons are branched polymers

Melonic graphs constitute the family of graphs arising at leading order in the 1/N expansion of tensor models. They were shown to lead to a continuum phase reminiscent of branched polymers. We show here that they are in fact precisely branched polymers that is they possess Hausdorff dimension 2 and spectral dimension 4/3.

David Schroeren, Balliol College

Decoherent Histories of Spin Networks

The decoherent histories formalism developed by Griffiths Gell-Mann and Hartle is a general framework in which to formulate a timeless `generalised' quantum theory and extract predictions from it. Recent advances in spin foam models allow for loop gravity to be cast in this framework. I propose a decoherence functional for loop gravity and interpret existing results as showing that coarse grained

histories follow quasi-classical trajectories in the appropriate limit. (This talk is based on a recent paper in Found. Phys.; DOI: 10.1007/s10701-013-9698-4)

Bernd Schroers, Heriot-Watt University

Semiduality in 3d gravity

In models of 3d quantum gravity semi-duality is a map which exchanges position and momentum degrees of freedom. In particular this map allows for a systematic study of the relationship between non-commutativity of position coordinates and curvature in momentum space. It turns out that it can also be used to generate new candidate quantum group symmetries for 3d gravity and to investigate relations between them. The purpose of this talk is to explain these points and to illustrate them with examples.

Sanjeev Seahra, University of New Brunswick

Polymer primordial perturbations

We consider the generation of primordial perturbations where the inflation is quantized using polymer techniques. We find that this leads to high frequency oscillations superimposed on the standard nearly scale invariant spectrum. The feasibility of detecting such oscillations using cosmological observations is discussed.

Giuseppe Sellaroli, University of Waterloo

Tensor operators for the Lorentz group in Loop Quantum Gravity

Tensor operators for SU(2) can been used in 3D Euclidean loop quantum gravity as the building blocks for observables. In the (2+1) Lorentzian case, SU(2) must be replaced by the non-compact group SL(2,R), the double cover of the Lorentz group. I present the generalization of the usual results for tensor operators in this non-compact case; in particular I give an analogue of the well-known Wigner-Eckart theorem. These results are then used to investigate if a Jordan-Schwinger representation always exists for SL(2,R), in order to carry on the techniques used in the Euclidean case.

Vasudev Shyam, The Center For Fundamental Research and Creative Education

On the Geometric Quantization and Shape Dynamics

The classical theory of shape dynamics possesses many interesting features such as a true Hamiltonian generating evolution with respect to the York time as well as two first class constraints both linear in the momenta. The aforementioned features also tell us that the problem of finding the physical inner product is completely disentangled from that of the quantum dynamics. We study this particular problem in the context of BRST extended geometric quantization wherein the space of extended geometric states corresponds to the ghost number 2 (m/2 in general for m bosonic constraints) states which are the states for which Dirac quantization and non minimal Hamiltonian BRST quantization coincide. The physical states are identified with the ghost number 0 singlets which are formed from the

previously mentioned states, further, an attempt is made at partially resolving the inner-product problem for quantum shape dynamics.

Lorenzo Sindoni, Albert Einstein Institute

GFT condensates: hydrodynamics and cosmological dynamics

Group field theory condensed states are a first attempt at the development of effective methods to extract continuum dynamics directly from the microscopic model for quantum gravity. They are indeed an interesting case in which an effective dynamics for geometry is derived in a pre-geometric setting. After describing the steps necessary to obtain such an effective dynamics even in a simplified context I will describe the similarities and differences with the hydrodynamics of quantum fluids the possible generalizations and some future developments like the inclusion of inhomogeneities.

Matteo Smerlak, Albert Einstein Institute

Falling into a black hole: the light from above

What happens when a freely-falling observer crosses a black hole horizon? In this talk I will show that already at the semi-classical level the answer to this question strongly depends on the energy E of the observer. I will show in particular that when E is much smaller than 1 (detectors dropped from just above the horizon) detectors will record ingoing radiation with temperature proportional to 1/E. Far from seeing nothing special such observers would therefore perceive Hawking radiation as a kind of cosmic radiation. I will comment on the role of spacetime curvature in this (somewhat surprising) near-horizon effect.

Lee Smolin, Perimeter Institute

The Emergence of Spacetime from a Theory of Energetic Causal Sets

I discuss a new approach to relativistic quantum theory based on energetic causal sets in which spacetime and some aspects of quantum physics are emergent. This provides a kind of pregeometric setting for relative locality in which energy-momenta and causal structure are prior to spacetime.   This is based on work in progress with Marina Cortes.

Robert Spekkens Perimeter Institute

On causal explanations of quantum correlations

This talk will focus on the implications of Bell's theorem for causal structure in quantum theory. We use the framework of causal models developed by researchers in the machine learning community. In particular, we make use of causal discovery algorithms. These take as their input facts about correlations among a set of observed variables, and return as their output causal structures that can account for the correlations. We show that any causal explanation of Bell-inequality-violating correlations must contradict a core principle of these algorithms, namely, that an observed statistical independence between variables should not be explained by fine-tuning of the causal parameters. The

fine-tuning criticism applies to all of the standard attempts at causal explanations of Bell correlations, such as superluminal causal influences, superdeterminism, and retrocausal influences that do not introduce causal cycles. Finally, we discuss the possibility of salvaging a causal explanation of quantum correlations using a quantum generalization of causal models. In such models, the causal structure is still described by a directed acyclic graph, but conditional probabilities are replaced by conditional quantum states (or equivalently, quantum channels). We argue that to make sense of such models, one must understand much of the formalism of quantum theory as an innovation to the theory of Bayesian inference.

Joint work with Christopher Wood. Based on arXiv:1208.4119

Simone Speziale, Centre de Physique Theorique

Simple twistors and loop quantum gravity

I will review the recent results on the twistorial description of loop quantum gravity how it improves the geometric understanding of the theory and the open questions for the dynamics.

Sebastian Steinhaus, Perimeter Institute

Continuum limit of spin net / spin foam models via embedding maps

The continuum limit of spin foams i.e. the many simplices regime is still unknown and its compatibility with the macroscopic space time its dynamics (GR) and its symmetries (diffeomorphisms) is one of the most pressing issues. Ultimately renormalization techniques e.g. tensor network renormalization should be applied to spin foams in order to examine how the models change under refinement and whether there exist different phases of the model which allow for geometrical interpretations. The fate of the simplicity constraints plays a crucial role in this since their implementation places the model in between the topological low temperature (BF) phase and the degenerate high temperature phase. Is it possible that this intermediate phase stands the test of coarse graining or is the model destined to flow away from it? To discuss this question we will introduce dynamical embedding maps which relate Hilbert spaces associated to coarse and fine boundaries to one another: They are used to truncate the boundary data with minimal error and to keep track of the variable redefinitions in each renormalization step. In this talk we will show how to use them to renormalize spin net models in two and higher dimensions.

Alexander Stottmeister, University of Erlangen-Nuernberg

Born-Oppenheimer decomposition for non-commuting slow variables

I will discuss a possible extension of the (generalised) Born-Oppenheimer ansatz to encompass Hamiltonians involving non-commuting slow variables. The proposed method makes use of coherent state techniques thereby allowing to consider the adiabatic and semiclassical limit in a unified framework. Furthermore, I will discuss possible approximation schemes in common with the traditional Born-Oppenheimer framework, and how to derive effective equations.

Sumati Surya, Raman Research Institute

Causal Set Dynamics

I will present some work on Monte Carlo simulations of 2D causal set quantum gravity. An interesting phase structure emerges with an emergent flat spacetime dominating the high temperature regime.

Jdrzej Swieewski, University of Warsaw

Geometrical observables for General Relativity coupled to dust

In my talk I will present a proposal for the construction of Dirac observables for General Relativity. The construction relies on the use of geometrically defined coordinates with a clear physical interpretation. I will discuss some problems of the construction and turn to a similar construction of observables for a simplified theory of General Relativity coupled to a dust field.

Karim Thebault, LMU Munich

Symmetry and Evolution in Quantum Gravity

We propose an operator constraint equation for the wavefunction of the Universe that admits genuine evolution. While the corresponding classical theory is equivalent to the canonical decomposition of General Relativity the quantum theory makes predictions that are distinct from Wheeler DeWitt cosmology. Furthermore the local symmetry principle and corresponding observables of the theory have a direct interpretation in terms of a conventional gauge theory where the gauge symmetry group is that of spatial conformal diffeomorphisms (that preserve the spatial volume of the Universe). The global evolution is in terms of an arbitrary parameter that serves only as an unobservable label for successive states of the Universe. Our proposal follows unambiguously from a suggestion of York whereby the independently specifiable initial data in the action principle of General Relativity is given by a conformal geometry and the spatial average of the York time on the spacelike hypersurfaces that bound the variation. Remarkably such a variational principle uniquely selects the form of the constraints of the theory so that we can establish a precise notion of both symmetry and evolution in quantum gravity.

Johannes Thurigen, Albert Einstein Institute

Spectral dimension and Laplacian in quantum gravity

As an indicator of geometry and topology of spacetime and to compare quantum geometry in various approaches to quantum gravity the spectral dimension defined in terms of the Laplacian is an observable recently much discussed. One reason is that it easily extends from continuum to discrete spacetime manifolds. For loop quantum gravity spinfoams group field theory and Regge calculus where spacetime is characterized by geometrical data on discrete structures we present how the relevant Laplacian can be defined in terms of discrete calculus. We then analyze the interplay of discreteness geometry and topology effects in the spectral dimension for quantum space and spacetime in the case of loop quantum gravity and spinfoams.

Casey Tomlin, Pennsylvania State University

towards an anomaly-free quantum dynamics for a weak-coupling limit of Euclidean gravity

The G -->0 limit of Euclidean gravity introduced by Smolin is described by a generally covariant U(1)xU(1)xU(1) gauge theory. The Poisson bracket algebra of its Hamiltonian and diffeomorphism constraints is isomorphic to that of gravity. Motivated by recent results in Parameterized Field Theory and by the search for an anomaly-free quantum dynamics for Loop Quantum Gravity (LQG) the quantum Hamiltonian constraint of density weight 4/3 for this U(1)xU(1)xU(1) theory is constructed so as to produce a non-trivial LQG-type representation of its Poisson brackets

Aaron Trout, Chatham University

Entropy vs. Curvature in Dynamical-Triangulations and the Origin of Dark Energy

Dark energy accounts for most of the matter-energy content of our universe yet we currently have no well-accepted account of its origin. This talk will present a novel well-motivated explanation for dark energy. We claim it arises from a small amount of negative scalar-curvature present even in empty spacetime. The vacuum has this curvature because spacetime is fundamentally discrete and there are more ways for a discrete geometry to have negative curvature than positive. We explicitly compute this effect using the dynamical-triangulations spacetime model and the predicted magnitude for the cosmological constant $10^{(124)}$ in natural units agrees with observation. This result does not rely on any holographic principle or fine-tuned parameters. The only unknown is the sign of and we present strong numerical evidence our model correctly predicts this as well.

Madhavan Venkatesh, Centre for Fundamental Research and Creative Education

Loop Groups and Quantum Gravity

In this talk, I outline the role played by Loop Groups in Quantum Gravity. Why loop groups are being used, is motivated, exploring their link with General Relativity and Quantum Mechanics. A new equivalence relation, the cobordism is introduced on the group of loops, leading to the description of a Chas-Sullivan type product and the construction of new quantities. The Kahler structure of the loop group is discussed, along with possible quantization.

Francesca Vidotto, Radboud University Nijmegen

A covariant perspective on singularity resolution

A simple argument shows that the covariant dynamics of loop quantum gravity may induce a maximal acceleration, and forbid the development of curvature singularities. This reinforces the results obtained by applying canonical methods to cosmology and black holes.

Hans Westman, Instituto de Fisica Fundamental

Exploring Cartan gravity with a dynamical symmetry breaking field

It has been known for some time that General Relativity can be regarded as a Yang-Mills-type gauge theory in a symmetry broken phase. In this picture which is closely related to Cartan geometry the gravity sector is described by an SO(14) or SO(23) gauge field A^ab and Higgs field V^a which acts to break the local gauge symmetry down to that of the Lorentz group SO(13). This symmetry breaking mirrors that of electroweak theory. However a notable difference is that while the Higgs field Phi of electroweak theory is taken as a genuine dynamical satisfying a Klein-Gordon equation the gauge independent component V^2 of the Higgs-type field V^a is typically regarded as non-dynamical. Instead in many treatments V^a either does not appear explicitly in the formalism or is required to satisfy V^2=const by means of a Lagrangian constraint. As an alternative to this we propose to study the class of polynomial actions that treat both the gauge connection A^ab and Higgs field V^a as genuine dynamical fields. The resultant equations of motion consist of a set of first-order partial differential equations. We show that for certain actions these equations may be cast in a second-order form corresponding to various scalar-tensor models of gravity. One simple choice leads to the extensively studied Peebles-Ratra rolling quintessence model. A different choice of action yields a positive cosmological constant and an effective Higgs mass M of the gravitational Higgs field ensuring the constancy of V^2 at low energies and agreement with empirical data if M is sufficiently large. Time permitting we will also consider the MacDowel-Mansouri action which for non-constant V^2 yields a theory with propagating torsion.

Wolfgang Martin Wieland, Aix-Marseille University

Hamiltonian spinfoam gravity

The talk presents a new Hamiltonian formulation of discretised gravity based upon the twistorial framework of loop quantum gravity. Within this setting I derive a continuum action adapted to a simplicial decomposition of space-time. The action is a sum of the spinorial analogue of the topological BF action and the reality conditions that guarantee the existence of a metric. The equations of motion admit a Hamiltonian formulation that allows performing the constraint analysis. I do not find any secondary constraints but only get restrictions on the Lagrange multipliers enforcing the reality conditions. With the action polynomial in the spinors canonical quantisation is straightforward. Transition amplitudes reproduce the EPRL (Engle--Pereira--Rovelli--Livine) spinfoam model.

Edward Wilson-Ewing, Louisiana State University

Confronting Loop Quantum Cosmology with Observations

I will review some recent results that show how linear perturbations can be studied in loop quantum cosmology. Then I will explain how quantum geometry effects can modify the standard predictions of some early universe models and I will discuss whether these quantum-gravity-corrected predictions agree with the latest observations of the Planck Collaboration or not.

Yuki Yokokura, Kyoto University

Fluid-Gravity Duality for a General Screen

We construct space-time fluid dynamics by using a 2+2 decomposition formalism in which the Einstein equation is decomposed into time + radial and two spatial directions. The previous formalism of fluid-gravity duality can be used only for the near horizon region of a black hole and the bulk viscosity is negative. However our formalism can be applied to any timelike surface and the second law of the two-dimension fluid system holds which leads to positive bulk viscosity. Furthermore the Newtonian gravity emerges in the fluid equations.

Jose A Zapata, Centro de Ciencias Matematicas

Study of Noether's theorem for effective theories and its continuum limit

Effective theories of dynamical systems with a discrete time parameter admit a theorem relating symmetries and conserved quantities. We present different types of effective theories and study how well the effective theory describes the system. We observe that the convergence to a continuum limit of the different types of effective theories is qualitatively different. Effective field theories with a discrete spacetime parameter can also be endowed with the necessary structure for a Noether's theorem and the study mentioned above can be extended to this framework. The study is also relevant for effective theories for constrained systems with gauge symmetries.

Mingyi Zhang, Centre de Physique Theorique

Null twisted geometry and loop gravity

Motivated by possibility of extending the spin foam formalism to null boundaries we consider a version the linear simplicity constraints with a null normal. We show that these constraints are all first class and use twistors to construct the reduced phase space. This ends up being a single complex number per link characterising the rotational part of the null little group. We provide a complete set of gauge-invariant observables for which a geometric interpretation can be given in the spirit of twisted geometries. Such null twisted geometries describe anon-degenerate 2d spacelike geometry are more general than 2d Regge calculus and correspond to the conformal structure of Regge calculusplus the scale factors of the dual faces.We also comment on the evolution generated by the boost Hamiltonian and on quantization.

Antonia Zipfel, University of Erlangen-Nuernberg

On the relation between canonical and covariant Quantum Gravity

Heuristically, spin foams can be understood as the Feynman graphs of Quantum Gravity. Yet, summing over all 'histories' would lead to a projector on the physical Hilbert space of the canonical theory rather than to a true propagator due to the constraint nature of GR. Following this idea we construct a spin-foam operator acting on the kinematical Hilbert space and analyze its properties.

Jonathan Ziprick, Perimeter Institute

Spinning geometry = Twisted geometry

We present a new geometrical description of the gauge-invariant loop gravity phase space which we call a spinning geometry. This is a continuous geometry formed by gluing together the polyhedral cells of a twisted geometry. Under the gluing maps, one-dimensional edges in the cell boundaries take the form of helices.