Quantum Gravity and Random Geometry

Rapport sur les contributions

https://indico.math.cnrs.fr/e/7542

ID de Contribution: **5** Type: **Non spécifié**

Welcome and opening remarks

lundi 16 janvier 2023 09:05 (10 minutes)

ID de Contribution: **6** Type: **Non spécifié**

The universe as a quantum fluid: quantum gravity, hydrodynamics and cosmology

lundi 16 janvier 2023 09:30 (50 minutes)

The hydrodynamics of quantum fluids can be mapped to relativistic cosmological dynamics, and both share the same conformal symmetries, which can be unravelled via geometric methods in superspace. This suggests a more general correspondence between hydrodynamics and cosmology, and a picture of the universe as a quantum gravity condensate. This picture is in fact realized also in some quantum gravity formalisms, like group field theory and lattice gravity, in which an emergent cosmological dynamics can be extracted from the quantum dynamics of fundamental quantum simplices in a condensate phase.
A key ingredient is the relational understanding of space and time, which makes superspace the natural arena for gravitational dynamics, as opposed to the "spacetime" manifold. These results suggest an exciting dialogue between quantum gravity, the theory of quantum fluids and cosmology, as well as a new direction for analogue gravity simulations in the lab.

Orateur: ORITI, Daniele (Arnold Sommerfeld Center for Theoretical Physics, LMU, Munich)

ID de Contribution: **7** Type: **Non spécifié**

Extended corner symmetry algebra and the Wald-Zoupas prescription

lundi 16 janvier 2023 10:50 (50 minutes)

Boundaries and corners of gravitational subsystems allow the construction of non-trivial Noether charges generating infinite-dimensional symmetries, which have been advocated as a new promising tool to understand quantum gravity. In this talk I will focus on classical properties of these symmetries, with the goals of explaining how they appear, how they provide a description of non-local observables, and how physical prescriptions are required in order to remove ambiguities in their construction.

Orateur: SPEZIALE, Simone (CNRS, CPT Marseille)

ID de Contribution: **8** Type: **Non spécifié**

3d Quantum Gravity and Quantum Groups

lundi 16 janvier 2023 11:40 (50 minutes)

I will give a quick overview of the q-deformed Loop Quantum Gravity (LQG) model which describes 3-dimensional quantum gravity with a cosmological constant. The model is characterized in terms of quantum group structures and the quantum Hamiltonian constraints define the Wheeler-DeWitt equations in this framework and generate the Turaev-Viro model (with real q, q being the deformation parameter). I will show, using the spinorial approach, how to construct a complete set of observables and how the notion of parallel transport can be encoded in terms of a quantum R-matrix.

Orateur: DUPUIS, Maïté

ID de Contribution: **9** Type: **Non spécifié**

Random matrices and magnetic amplitude for discretized strings

lundi 16 janvier 2023 14:30 (50 minutes)

Magnetic amplitudes for strings in a background 3-form H involve a 2-form potential B integrated on surfaces of arbitrary topology. We propose a random matrix model whose topological expansion lead to a discretized version of these amplitudes, in the case of a propagation on an finite space X quotiented by a finite group G. Besides the fluxes induced by B, they also involve topological defects on the surface, weighted by additional fields that are constructed using the group cohomology of G.

Orateur: KRAJEWSKI, Thomas (Centre de Physique Théorique, Aix-Marseille Université)

ID de Contribution: **10** Type: **Non spécifié**

Towards the phase structure of first order Lorentzian Palatini gravity via Group field theory

lundi 16 janvier 2023 15:50 (30 minutes)

The Barrett-Crane (BC) spin foam and GFT model is a state-sum model which provides a tentative quantization of first order Lorentzian Palatini gravity written as a constrained BF-theory. Its completion in terms of spacelike, timelike and lightlike components has only recently been accomplished. It is conjectured that this model gives rise to continuum spacetime with General Relativity as an effective description for the dynamics at criticality via phase transition.
In this talk, we discuss how phase transitions in this model can be studied using Landau-Ginzburg mean-field theory. In a first step, we demonstrate this by restricting the building blocks of the complete model such that the Feynman diagrams are dual to spacelike triangulations. This setting lays the groundwork to study the critical behavior when arbitrary Lorentzian building blocks are incorporated and also paves the way for the analysis of the phase structure of the complete model via functional renormalization group techniques in future research. This work is based on arXiv:2112.00091, arXiv:2206.15442, arXiv:2209.04297 and arXiv:2211.12768.

Orateur: PITHIS, Andreas (Universität München (LMU, ASC, MCQST))

ID de Contribution: **11** Type: **Non spécifié**

Trisections in colored tensor models

jeudi 19 janvier 2023 15:50 (30 minutes)

We give a procedure to construct trisections for closed 4-manifolds generated by colored tensor models without restrictions on the number of simplices in the triangulation, therefore generalizing previous works in the context of crystallizations and PL-manifolds. We give a description of how trisection diagrams can arise from colored tensor model graphs for closed 4-manifolds.

Orateur: TORIUMI, Reiko (OIST)

ID de Contribution: **12** Type: **Non spécifié**

tba

Orateur: HORAVA, Petr (University of California, Berkeley)

ID de Contribution: **13** Type: **Non spécifié**

Provable properties of asymptotic safety in f(R) approximation

mardi 17 janvier 2023 10:50 (50 minutes)

We study an $f(R)$ approximation to asymptotic safety, using a family of cutoffs, kept general to test for universality. Matching solutions on the four-dimensional sphere and hyperboloid, we prove properties of any such global fixed point solution and its eigenoperators. For this family of cutoffs, the scaling dimension at large n of the n^{th} eigenoperator, is $\lambda_n \propto b\, n \ln n$. The coefficient b is non-universal, a consequence of the single-metric approximation. For right-sign conformal mode cutoff, the fixed points form at most a discrete set. The eigenoperator spectrum is quantised. They are square integrable under the Sturm-Liouville weight. For wrong sign cutoff, as required if starting from the Einstein-Hilbert action, the fixed points form a continuum, and so do the eigenoperators unless we impose square-integrability. If we do this, we get a discrete tower of operators, infinitely many of which are relevant. These are $f(R)$ analogues of novel operators in the conformal sector which were used recently to furnish an alternative quantisation of gravity.

Orateur: MORRIS, Tim (University of Southampton)

ID de Contribution: **14** Type: **Non spécifié**

Entropy versus the Action in Causal Set Theory

mardi 17 janvier 2023 11:40 (50 minutes)

The quantum partition function of causal set quantum gravity is a phase weighted
sum over all locally finite posets or causal sets. As the size n of the causal sets grows, however, the overwhelmingly dominant entropic contribution comes from a class of causal sets that look nothing
like continuum spacetime. A long standing question has been whether this entropy can be overcome
in the large n, classical limit by the discrete Einstein-Hilbert Action, to give spacetime-like causal sets a fighting chance. I will discuss recent progress on this as well as some of the open strands of questions that still remain.

Orateur: SURYA, Sumati (Raman Research Institute)

ID de Contribution: **15** Type: **Non spécifié**

A universal mechanism for the emergence of gravitons from effective spin foams and lattice gravity

mardi 17 janvier 2023 14:30 (50 minutes)

Spin foams are discretized path integrals for quantum gravity based on a rigorous definition of quantum geometry. This does however lead to very complicated amplitudes, making e.g. the extraction of a continuum limit difficult. Thus, a long-standing open question was whether spin foams do describe gravity in their semi-classical and continuum limit.
The situation has changed with the recent introduction of effective spin foams, which on the one hand are much more amenable to numerical simulations, but also offer a much more transparent encoding of the dynamics.
This has allowed first results on the perturbative continuum limit, which reveal that effective spin foams do lead to gravitons. I will explain an underlying mechanism applicable to a large class of models and choices of underlying lattices.
Furthermore, one can derive a lowest order correction to the Einstein Hilbert action, given by a Weyl squared terms. These results can be confirmed by an independent construction, that works entirely in the continuum, and is based on a modification of the Plebanski formulation of Gravity.

Orateur: DITTRICH, Bianca (Perimeter Institute)

ID de Contribution: **17** Type: **Non spécifié**

Blobbed topological recursion of the $\lambda\phi^4$ matrix model

mercredi 18 janvier 2023 09:30 (50 minutes)

We consider an $N\times N$ Hermitian matrix model with measure $d\mu_{E,\lambda}(\Phi) = \frac{1}{Z}\exp(-\frac{\lambda N}{4}\mathrm{tr}(\Phi^4))d\mu_{E,0}(\Phi)$ where $d\mu_{E,0}$ is the Gau\ss{}ian measure with covariance $\langle\Phi_{kl}\Phi_{mn}\rangle = \frac{\delta_{kn}\delta_{lm}}{N(E_k+E_l)}$ for given $E_1, ..., E_N > 0$. We explain how this setting gives rise to two ramified coverings x, y of the Riemann sphere strongly tied by $y(z) = -x(-z)$ and a family $\omega_{g,n}$ of meromorphic differentials. We provide strong evidence that the $\omega_{g,n}$ obey blobbed topological recursion due to Borot and Shadrin. A key step is to extract from the matrix model a system of six meromorphic functions which satisfy interwoven Dyson-Schwinger equations. Two of these functions are symmetric in the preimages of x and can be determined from their consistency relations. Their expansion at ∞ gives global linear and quadratic loop equations for the $\omega_{g,n}$. These global equations provide the $\omega_{g,n}$ not only in the vicinity of the ramification points of x but also in the vicinity of all other poles located at opposite diagonals $z_i + z_j = 0$ and at $z_i = 0$.

Orateur: WULKENHAAR, Raimar (University of Münster)

ID de Contribution: **18** Type: **Non spécifié**

Perturbing isoradial triangulations

jeudi 19 janvier 2023 14:30 (50 minutes)

Isoradial triangulations are example of critical planar graphs, on which discrete analyticity, integrability, discrete and continuous conformal invariance can be defined and studied for many models. I present some results on the deformations of such triangulations, which break integrability, and their effect on the critical Laplacian and some of its extensions, and for their conformal properties. The relevance and the consequence of these results for some models of two dimensional quantum gravity will be discussed.
(joint work with J. Scott)

Orateur: DAVID, Francois

ID de Contribution: **19** Type: **Non spécifié**

Emergence of macroscopic spacetimes in a certain large-N limit of canonical tensor model

vendredi 20 janvier 2023 09:30 (50 minutes)

It is challenging to realize emergence of macroscopic spacetimes in tensor models. We study a wave function of a tensor model in the canonical formalism in a certain large-N limit, in which the wave function can reliably be computed classically (namely, by saddle points). We show that spacetimes develop through successive first-order phase transitions, in which numbers of "points" increase one by one. When a positive cosmological constant is turned on, Lie-group symmetric macroscopic spacetimes with locality have large amplitudes.

Orateur: SASAKURA, Naoki (Yukawa Institute for Theoretical Physics, Kyoto University)

ID de Contribution: **20** Type: **Non spécifié**

Topological recursion for weighted Hurwitz numbers

mercredi 18 janvier 2023 10:50 (50 minutes)

Combinatorial maps are a well-known discrete approach to 2-dimensional quantum gravity. Planar maps satisfy multiple universal properties at large scale, which guarantee the universality of the continuum limit. But more universal structures can be observed in the all-genera structures of maps, e.g. they satisfy the KP integrable hierarchy and the topological recursion. Double weighted Hurwitz numbers are a generalization of maps, for which it was natural to ask whether the same universal properties hold true. In particular, the KP hierarchy being known to be satisfied, is it possible to prove the topological recursion? I will explain in details what the weighted Hurwitz numbers are and derive their generating series in the Schur basis. I will finally explain how we proved the topological recursion for them recently. While another group proved the same result simultaneously, it is remarkable that our methods are completely different. I will explain the originality of our approach. It is based on a work with G. Chapuy, S. Charbonnier and E. Garcia-Failde.

Orateur: BONZOM, Valentin (LIPN - Institut Galilée - Université Paris 13)

ID de Contribution: **21** Type: **Non spécifié**

Does GCDT solve the Hubble constant tension ?

jeudi 19 janvier 2023 10:50 (50 minutes)

CDT might define a quantum theory of gravity, but how one can locate the asymptotic safety UV fixed point is still unclear. However, so-called generalized CDT models, which allow for baby universe creation, make it possible to conjecture how quantum corrections can influence late time cosmology. The quantum corrections lead to a modified Friedmann equation which does not involve a cosmological constant but nevertheless results in a late time exponential expansion of the universe and in addition solves the Hubble constant tension.

Orateur: AMBJORN, Jan

ID de Contribution: **22** Type: **Non spécifié**

Ubiquity of melonic limits in tensor models

vendredi 20 janvier 2023 10:50 (50 minutes)

Analogously to matrix models, which provide a combinatorial approach to two-dimensional quantum gravity, tensor models appear to be well-suited to investigations of random geometry in higher dimensions. Indeed, certain generating functions of discrete (pseudo)manifolds, of arbitrary but fixed dimension, can be expressed in terms of (formal) tensor integrals. This being said, obtaining genuinely new universality classes of random geometry from the currently understood scaling limits of tensor models has proven challenging. Among them, the so-called melonic limit is known to produce a branched-polymer phase at criticality, leading to a random geometry of local dimension 4/3 which is unsuitable for quantum gravity. But not all is lost since the combinatorial simplicity of this type of limit has made it a valuable tool to design solvable strongly coupled quantum (field) theories, and via a 2d version of the AdS/CFT correspondence, to investigate quantum gravity itself (albeit from a different perspective). This state of affair raises the question of how ubiquitous melonic limits actually are in tensor models, which will be the focus of this talk. After summarizing the types of tensor representations and invariant interactions that are already known to support melonic limits, I will discuss further conjectures and open problems.

Orateur: CARROZZA, Sylvain (Radboud University)

ID de Contribution: **23** Type: **Non spécifié**

Topological recursion in 2d quantum gravity

mercredi 18 janvier 2023 11:40 (50 minutes)

I will explain the idea of topological recursion, its implementation for the enumeration of maps (and of large maps), and mention other applications to compute integrals over the moduli space of Riemann surfaces M_{g,n}. I will introduce the idea of geometric recursion which in certain cases allows for a fully geometric proof that topological recursion solves such problems.

Orateur: BOROT, Gaetan (Humboldt-Universität zu Berlin)

ID de Contribution: **24** Type: **Non spécifié**

Graviton, boundaries, BMS symmetry and its cocycles and Beltrami parametrization

jeudi 19 janvier 2023 11:40 (50 minutes)

Done in collaboration with Tom Wetzstein

Orateur: BAULIEU, Laurent (LPTHE)

ID de Contribution: **25** Type: **Non spécifié**

Higher gauge and discrete geometry

vendredi 20 janvier 2023 11:40 (50 minutes)

Crossed modules, or (strict) 2-groups, can be used to decorate faces and edges of a 2-complex. In this sense they provide a generalization of lattice gauge theory. I will discuss how these structures are relevant to 4d topological models, possibly to 4d quantum gravity and also provide new mathematical symmetry structures to explore.

Orateur: GIRELLI, Florian

ID de Contribution: **26** Type: **Non spécifié**

A combinatorial approach to random hyperbolic surfaces

jeudi 19 janvier 2023 09:30 (50 minutes)

Starting with dynamical triangulations of the string world sheet and matrix models, random maps have occupied a central place in the study of 2d (Euclidean) quantum gravity. Advances in combinatorics (e.g. tree bijections) and probability theory (e.g. Gromov-Hausdorff limits of random metric spaces) led to a rigorous construction of 2d quantum gravity in the form of Brownian geometry on surfaces, and its identification with Liouville Quantum Gravity. In this talk I will describe how some of these methods extend naturally to random hyperbolic geometry on surfaces, a natural alternative to random maps. In particular, I will show how a bijection between the moduli space of genus-0 hyperbolic surfaces (with boundaries) and certain labeled trees provides insight into the associated random metric space.
Based on joint works with N. Curien and with T. Meeusen and B. Zonneveld.

Orateur: BUDD, Timothy (Radboud University, Nijmegen, The Netherlands)

ID de Contribution: **27** Type: **Non spécifié**

Asymptotically Safe Unimodular Quantum Gravity: a Status Report

mardi 17 janvier 2023 09:30 (50 minutes)

Unimodular Gravity is an alternative description of the gravitational dynamics that is equivalent to General Relativity within the classical realm. Since it is based on a different symmetry group, volume-preserving diffeomorphisms, it could be expected that Unimodular Gravity displays very different quantum properties with respect to the quantization of a full diffeomorphism-invariant theory. I will discuss how this comparison fits in the asymptotic safety program for quantum gravity as well as point out the recent progress in this direction. Moreover, I will raise some potential conceptual consequences of such a discussion in a broader quantum-gravity perspective.

Orateur: DUARTE PEREIRA, Antônio (Radboud University & Fluminense Federal University)

ID de Contribution: **28** Type: **Non spécifié**

Flowing from Tensor Field Theory to Tensor Models

lundi 16 janvier 2023 16:20 (30 minutes)

Fields with tensor degrees of freedom provide non-trivial but tractable QFT examples. Their perturbative expansion might (but does not need to) be interpreted as generating random geometries and they can be extended to models of quantum gravity in the spirit of tensorial group field theory. In the later case the tensor degrees of freedom propagate and contribute to the scale of the theory, in contrast to tensor model QFTs. In this talk we discuss how these two kind of theories can be dynamically connected via a renormalization group flow, thereby opening up the possibility that SYK-related tensor theories and random geometry models of quantum gravity are just different regimes of one and the same theory.

Orateur: THÜRIGEN, Johannes (WWU Münster)

ID de Contribution: **29** Type: **Non spécifié**

Generalised spectral dimensions in non-perturbative quantum gravity

jeudi 19 janvier 2023 16:20 (30 minutes)

The seemingly universal phenomenon of scale-dependent effective dimensions in non-perturbative theories of quantum gravity has been shown to be a potential source of quantum gravity phenomenology. This scale-dependent effective dimension in quantum gravity has been found by studying the propagation of scalar fields. It is however possible that the non-manifold like structures, that are expected to appear near the Planck scale, have an effective dimension that depends on the type of field under consideration. To investigate this possibility, we have studied the spectral dimension associated to the Laplace-Beltrami operator generalised to k-form fields on spatial slices of the non-perturbative model of quantum gravity known as Causal Dynamical Triangulations. We have found that the two-form, tensor and dual scalar spectral dimensions exhibit a flow between two scales at which an effective dimension appears. However, the one-form and vector spectral dimensions show only a single effective dimension. Albeit speculative for now, the fact that the one-form and vector spectral dimension do not show a flow of the effective dimension in this model can potentially be related to a dynamically generated absence of a dispersion relation for the electromagnetic field, while tensor and scalar fields are affected by dimensional flow.

Orateur: REITZ, Marcus (Jagiellonian University)

ID de Contribution: **30** Type: **Non spécifié**

Renormalization of composite operators in $2+\varepsilon$ quantum gravity

mardi 17 janvier 2023 15:50 (30 minutes)

We consider higher derivative composite operators in the ε-expansion of 2d quantum gravity and renormalize them at one-loop. We extract the flow of the essential couplings and study their analytic continuation in the background dimensions to compare with Stelle gravity in d=4.

Orateur: MARTINI, Riccardo (INFN - Sezione di Pisa)

ID de Contribution: **31** Type: **Non spécifié**

Background-independent field quantization: N-cutoffs regularization and N-geometries

mardi 17 janvier 2023 16:20 (30 minutes)

We apply a novel background-independent and scale-free quantization scheme on (non-)compact maximally symmetric spacetimes. The "N-cutoffs" is a UV regularization procedure on the spectrum of the fields'fluctuation modes implemented on the quantum number. We apply this regularization to scalar and metric fluctuations: both are found to reduce the curvature of the "N-geometries" leading to vanishing values in the limit of removing the cutoff. We argue then how the curvature singularity related to the "cosmological constant problem" is an artifact resulting from a rigid-background-dependent computation.

Orateur: FERRERO, Renata (Johannes Gutenberg University Mainz)

ID de Contribution: **32** Type: **Non spécifié**

Presentation of the IHP by the deputy director

lundi 16 janvier 2023 09:15 (15 minutes)

Orateur: MOUHANNA, Dominique (IHP)