Oral Talks

1. *Dario Benedetti* (Université Paris-Sud XI)

   Title: Effective dynamics for the spatial volume of 3-dimensional CDT

   Abstract: A spacetime condensation phenomenon underlies the emergence of a macroscopic universe in causal dynamical triangulations (CDT), where the time extension of the condensate, or droplet, is strictly smaller than the total time of the quantum universe. I will present an effective model for the dynamics of the spatial volume, which can be obtained as a minisuperspace reduction of Horava-Lifshitz gravity, and I will show that a study of the minima of the action (supported also by Monte-Carlo simulations) leads to a phase diagram with a droplet phase similar to that of CDT.

2. *Timothy Budd* (Radboud University, Nijmegen)

   Title: Geometry of two-dimensional quantum gravity coupled to $O(n)$ loop models

   Abstract: Many aspects of the fractal geometry of "pure" two-dimensional quantum gravity are well-understood, thanks to a variety of methods in the enumeration of planar maps and continuum processes in Liouville Quantum Gravity. The presence of coupled matter systems limits the applicability of these methods, and several open questions remain. In this talk I will discuss the generalization of one of these methods, the peeling exploration, to random planar maps coupled to an $O(n)$ loop model. Relying on exact scale-invariance in the scaling limit some explicit distance statistics can be obtained.

3. *Benoit Collins* (Kyoto University)

   Title: PPT and PPT2

   Abstract: In quantum information theory, PPT (positive partial transpose) is a notion that allows to decide very efficiently that a state is entangled. However, it is known that it is not sufficient to characterize entanglement except in very special cases, and in fact, entanglement is very difficult to characterize fully in general. PPT has a very nice graphical interpretation, which turns the problem of studying the typicality of PPT for some tensor models into pleasant combinatorics of random matrices and random tensors. One other relation of PPT to entanglement is much more mysterious, namely, it is an open question whether a special combination of two PPT states results into an entangled state (whence the notation PPT2). Again, this question is very pleasantly rephrased in diagrammatic terms. We will review background on this open question, and recent progress involving matrix and tensor models.

4. *Paola Cristofori* (Università di Modena e Reggio Emilia)

   Title: Topological aspects of colored tensor models

   Abstract: $(d+1)$-colored graphs, that is $(d+1)$-regular graphs endowed with a proper edge-coloration, are the objects of a long-studied representation theory for PL d-manifolds. Quite recently, a link between colored graphs and random tensors has been established through Colored Tensor Models (CTM): the Feynman graphs of a d-dimensional CTM are precisely $(d+1)$-colored graphs. In this context a particular significance is assumed by the Gurau degree ("G-degree"), which is the sum of the genera of the closed surfaces where a colored graph admits a particular type of embedding. This gives rise also to the definition of an invariant, again called G-degree, for PL manifolds, or, more generally, pseudomanifolds. In this talk we discuss topological and combinatorial properties of the G-degree in any dimension and we present classification results for all 3-pseudomanifolds and for 4-dimensional singular manifolds according to the value of the G-degree of their representing graphs. Since the G-degree drives the $1/N$ expansion in the setting of tensor models, these results yield a better understanding of the topology of the spaces involved in certain terms of the $1/N$ expansion.

5. *Bertrand Duplantier* (Université Paris-Saclay)

   Title: Random planar map $O(n)$ nesting and CLE in Liouville Quantum Gravity

   Abstract: A deep conjecture states that Liouville Quantum Gravity (LQG) is the universal continuum limit of random planar maps, as weighted by critical statistical models. Schramm-Loewner Evolution (SLE) and the associated Conformal Loop Ensemble (CLE) are predicted to be the universal scaling limits of random interfaces and loops in these models.

   We first study the the loop nesting statistics of the $O(n)$ model on a random planar triangulation, and establish rigorously its explicit large deviations distribution by combinatorial methods. The multifractal distribution of CLE extreme nesting in the Euclidean plane was rigorously derived in [Miller, Watson and Wilson '14]. We convolute it with Liouville quantum gravity and show that the Euclidean and LQG nesting statistics are conjugate of each other via a novel continuous KPZ transform. Furthermore, the LQG convoluted distribution recovers that obtained in the random planar map $O(n)$ model. This yields a check of the above conjecture at the refined level of large deviations.

   Joint work with Gaëtan Borot (MPI-Bonn) and Jérémie Bouttier (ENS-Lyon).

6. *Masafumi Fukuma* (Kyoto University)

   Title: Random volumes from matrices

   Abstract: I will discuss a new class of models generating 3D random volumes, where the Boltzmann weight of each configuration is given by the product of values assigned to the triangles and the hinges. These "triangle-hinge models" are characterized by semisimple associative algebras, and the set of possible diagrams can be reduced by an appropriate large N limit such that they represent only and all of the tetrahedral decompositions of 3D manifolds. When defining the associative algebras are matrix rings, the models have a novel strong-weak duality which replaces the roles of triangles and hinges. I will explain a prescription to put local matters on simplices of any dimensions (tetrahedra, triangles, edges and vertices). Simple examples include the Ising model coupled to three-dimensional quantum gravity, and the 3D colored tensor models can be obtained by putting specific matters on both tetrahedra and triangles. I will discuss the critical behavior of the models.

7. *Shotaro Shiba Funai* (OIST, Okinawa)

   Title: Renormalization, thermodynamics, and feature extraction of machine learning

   Abstract: Recently the machine learning has been applied to data analysis in various research fields. The methods of the machine learning are roughly classified by supervised learning and unsupervised learning. In the latter we train the machine so that it can reconstruct given dataset, then the machine seems to extract features of the dataset. Since extraction of feature resembles the coarse-graining, many researchers naively consider it is closely related to the renormalization.

   In this talk, however, I'd like to show that the feature extraction of the machine learning has a clear difference from the renormalization. For the training, we use the images of the spin configurations in Ising model, since we know well about its renormalization group (RG) flow. We generate the flow of images by iterative reconstructions of the machine, and compare it with the RG flow. As a result, we find the machine flow is more affected by thermodynamic property than the renormalization.

8. *Razvan Gurau* (Ecole Polytechnique, Palaiseau)

   Title: A beginners guide to tensor models and tensor field theories

   Abstract: Over the past several years tensor models and tensor field theories have been intensely studied. In this talk I will give an overview of various species of subspecies of models and their applications to quantum gravity and conformal field theory.

9. *Takashi Hara* (Kyushu University)

   Title: Stochastic geometry of self-avoiding Walks, percolation, and lattice animals on hyper cubic lattices

   Abstract: Self-avoiding random walks, percolation, and lattice animals are simple but interesting random geometric objects on discrete lattices. In this talk, I discuss probabilistic aspects of these models, on hyper cubic lattices Z^d. In particular, I focus on their so-called "mean field" type scaling behavior, which are exhibited in sufficiently high dimensions. I also describe briefly on a method (lace expansion) which is particularly useful in analyzing these models in high dimensions.

10. *Þórður Jónsson* (University of Iceland)

    Title: The structure of spatial slices of 3-dimensional causal triangulations

    Abstract: We prove that there is a bijection between the spatial slices of 3-dimensional causal triangulations and a class of 2-dimensional cell complexes satisfying certain properties.

11. *Jun Kigami* (Kyoto University)

    Title: Weighted partition of a compact metrizable space, its hyperbolicity and Ahlfors regular conformal dimension

    Abstract: Successive divisions of compact metric spaces appear in many different areas of mathematics such as the construction of self-similar sets, Markov partitions associated with hyperbolic dynamical systems, dyadic cubes associated with a doubling metric space. The common feature in these is to divide a space into a finite number of subsets, then divide each subset into finite pieces and repeat this process again and again. In this paper we generalize such successive divisions and call them partitions. Given a partition, we consider the notion of a weight function assigning a "size" to each piece of the partition. Intuitively we believe that a partition and a weight function should provide a "geometry" and an "analysis" on the space of our interest. We are going to pursue this idea in three parts. In the first part, the metrizability of a weight function, i.e. the existence of a metric "adapted to" a given weight function, is shown to be equivalent to the Gromov hyperbolicity of the graph associated with the weight function. In the second part, the notions like bi-Lipschitz equivalence, Ahlfors regularity, the volume doubling property and quasisymmetry will be shown to be equivalent to certain properties of weight functions. In particular, we find that quasisymmetry and the volume doubling property are the same notion in the world of weight functions. In the third part, a characterization of the Ahlfors regular conformal dimension of a compact metric space is given as the critical index p of p-energies associated with the partition and the weight function corresponding to the metric.

12. *Renate Loll* (Radboud University, Nijmegen)

Title: Quantum Ricci Curvature and the search for observables in nonperturbative quantum gravity

Abstract: Causal Dynamical Triangulations (CDT) is a candidate theory for quantum gravity, formulated nonperturbatively as the scaling limit of a lattice theory in terms of triangulated, piecewise flat spacetimes. Compared to other formulations on smooth manifolds, CDT is both background-free and does not face the hard problem of how to treat four-dimensional diffeomorphism symmetry in the quantum theory.

The physical properties of any quantum gravity theory must be explored using suitable geometric observables, describing the properties of quantum spacetime. To establish whether a particular quantum observable matches classical expectations on large scales, it needs to be scalable. In the nonperturbative context, very few observables of this type are known. An additional challenge of using non-smooth geometry is how to represent curvature, which in the continuum is captured by the Riemann tensor. I will present new results obtained in (C)DT on "quantum Ricci curvature", a scalable quantum observable that overcomes these difficulties.

13. *Cyril Marzouk* (Université Paris Diderot)

Title: Geometric and spectral aspects of planar maps with high degrees

Abstract: We consider random infinite planar maps in which the degree of a typical face has infinite variance, and more precisely its tail distribution decays like $k^{-\alpha}$ for some $\alpha \in (1, 2)$. Such maps can be obtained as the gasket of a loop $O(n)$ model on a quadrangulation, with n related to α. We will discuss several recent results on these lattices and their dual graph, focusing on two properties: first their volume growth which exhibits an interesting phase transition in the dual case at $\alpha = 3/2$, and then the behaviour of a random walk on these latices.

The talk is based on works by Timothy Budd and Nicolas Curien, and joint works with these authors.

14. *Laurent Ménard* (Université Paris Nanterre)

Title: Random triangulations coupled with an ising model.

Abstract: Angel and Schramm proved in 2003, that uniform planar triangulations converge for the local topology. The limiting law, known as UIPT (for Uniform Infinite Planar Triangulation) has been much studied since and is now a well understood object. In this talk, we will study random triangulations with an Ising configuration sampled according to their energy and not the uniform measure. We will discuss how to extend the local convergence of Angel and Schramm to this model. The limiting object turns out to be much harder to study than the UIPT and is believed to belong to another universality class at criticality.

This is a joint work with Marie Albenque and Gilles Schaeffer.

15. *Kazuhiko Minami* (Nagoya University)

Title: New fermionization formula using only commutation relations

Abstract: A new fermionization formula is introduced [1] in which series of solvable Hamiltonians and the transformation that diagonalize them are obtained simultaneously from a series of operators satisfying specific commutation relations. The Jordan-Wigner transformation is a special case of this method.

The two-dimensional Ising model with periodic interactions, the one-dimensional XY model with period 2, the transverse Ising chain and other composite quantum spin chains are diagonalized by this formula [1]. An infinite number of spin chains are solved and it is derived that the ground-state phase transitions belong to the universality classes with central charge $c = m/2$, where m is an integer [2].

The fermionization formula is generalized to two-dimensional systems, and the two-dimensional Jordan-Wigner transformation appear as a special case. The honeycomb lattice Kitaev model $\mathcal{H}_K$ with two kind of Wen-Toric-code four-body interactions $\mathcal{H}_{WT}$ is investigated exactly and the ground state phase diagram is obtained. Six kind of three-body interactions are also considered. A Hamiltonian equivalent to the honeycomb lattice Kitaev model is also introduced. The model $\mathcal{H}_K + \mathcal{H}_{WT}$ is symmetric in four-dimensional interaction space, and the anyon excitations appear in each phase [3].

[1] Kazuhiko Minami, J. Phys. Soc. Jpn. 85, 024003 (2016). "Solvable Hamiltonians and fermionization transformations obtained from operators satisfying specific commutation relations".
[2] Kazuhiko Minami, Nuclear Physics B, 925 (2017) 144-160. "Infinite number of solvable spin chains, with cluster state, and with central charge $c = m/2$".
[3] Kazuhiko Minami, submitted, "Honeycomb lattice Kitaev model with Wen-Toric-code interactions, and anyon excitations".

16. *Taro Nagao* (Nagoya University)

Title: Scale-free networks and random matrices

Abstract: The spectral analysis of the adjacency matrices of complex scale-free networks is discussed. We focus on the static Goh-Kahng-Kim (GKK) type models of scale-free networks. In the GKK model, the adjacency matrix elements are independently but not identically distributed. We consider the relationship to ordinary random matrices with independently and identically distributed elements.

17. *Ion Nechita* (Université Paul Sabatier, Toulouse)

    Title: Enumerating meanders: three perspectives

    Abstract: The problem of enumerating meanders is a long-standing open problem in combinatorics. Many different techniques have been used to provide bounds on the asymptotic growth rate of the number of meanders over $2n$ bridges. Here, we present some of the old methods and some new ones, coming from three (related) points of view. First, as noted by Fukuda and Sniady, meanders appear in relation to the partial transposition operation in quantum information theory. A second model for meandric numbers comes from random matrix theory: we shall review some old models due to di Francesco and present some new ones. Finally, I shall present a joint work with M. Fukuda on a third point of view, that of non-commutative probability. Using the operations of free and boolean moment-cumulant transforms, we enumerate large sub-classes of meanders, generalizing previous work of Goulden, Nica, and Puder.

18. *Shinsuke Nishigaki* (Shimane University)

    Title: Janossy densities of chiral random matrix models and QCD Dirac spectra

    Abstract: Chiral random matrix models that share the global symmetries of QCD have been utilized to extract low-energy constants from the Dirac spectra of lattice gauge theories in the chirally broken phase. In this talk we shall present a Fredholm-determinantal formula which expresses the individual eigenvalue distributions of chRMMs as the Janossy densities and is suited for accurate numerical evaluation by the quadrature method. As an application, we employ our formula to judge whether a lattice gauge model of walking technicolor candidate is near-conformal or chirally broken.

19. *Pierre Nolin* (City University of Hong Kong)

    Title: Near-critical percolation with heavy-tailed impurities and forest fires

    Abstract: We study forest fire processes on a two-dimensional lattice: all vertices are initially vacant, and then become occupied at rate 1. If an occupied vertex is hit by lightning, which occurs at a (typically very small) rate, its entire occupied cluster burns immediately, i.e. all its vertices become vacant.

    In particular, we want to analyze the near-critical behavior of such processes, that is, when large connected components of occupied sites start to appear. For that, we develop a substantial generalization of near-critical percolation to a lattice containing "impurities" (left by the successive fires). These impurities are not only microscopic, but also allowed to be "mesoscopic", which makes the proofs quite delicate.

    This talk is based on a joint work with Rob van den Berg (CWI and VU, Amsterdam).

20. *Ippei Obayashi* (WPI-AIMR, Tohoku University & RIKEN)

Title: The theory and applications of persistent homology

Abstract: In this presentation, I will talk about persistent homology, a new tool to analyze data from the viewpoint of topology. Homology is a classical mathematical theory in the field of topology and homology has 100 years history. Persistent homology is invented to apply the idea of homology to the data analysis, and is developed from the theory to the applications. Persistent homology characterizes the shape of data quantitatively and effectively from the viewpoint of topology. Persistent homology is used to analyze the data of materials science, life science, and sensor networks. In this presentation, I will introduce the fundamental ideas of persistent homology, some applications to materials science, and data analysis software based on persistent homology.

21. *Vincent Rivasseau* (Université Paris-Sud XI)

Title: The tensor track

Abstract: We shall review the tensor track approach to quantum gravity which attempts to extend to three dimensions and more the random matrix approach to quantum gravity in two dimensions.

22. *Naoki Sasakura* (YITP, Kyoto University)

Title: Spacetimes in the canonical tensor model through data analysis techniques

Abstract: Quantization of gravity is a fundamental issue in theoretical physics. There are various proposals trying to resolve the issue, and one of them is the canonical tensor model (CTM). After a brief introduction, we discuss the spacetime notion in CTM. This is not obvious, because the configuration space of CTM is given by a real symmetric three-indexed tensor, but not by spacetimes. We apply three well-known mathematical techniques in data analysis, namely, tensor rank decomposition, persistent homology, and virtual diffusion process, and show that spacetimes with metrics can be extracted from the tensor. As a demonstration, we analyze the classical time-evolutions of homogeneous spheres of various dimensions in CTM, and obtain good agreement with a general relativistic system. We discuss some future directions which can be pursued by the spacetime extraction process.

23. *Vasily Sazonov* (Université Paris-Sud XI)

Title: Towards the rigorous double scaling limit in matrix models

Abstract: Loop Vertex Expansion (LVE) is a constructive tool aimed at studying analyticity properties of QFT, matrix and tensor models. The main ingredient of LVE is a logarithmically growing effective action with bounded derivatives. However, this logarithmic action typically diverges at negative values of the coupling constant, prohibiting the direct use of LVE for approaching the double scaling limit in matrix models. In this work we derive a new version of the effective action, where the dependence on the coupling constant is moved out from the logarithm. This allows us to construct the analytic continuation through the brunch cut of the model and to reach desired negative coupling constants.

24. *Etsuo Segawa* (Yokohama National University)

Title: Sensitivity of quantum walker to some graph geometry

Abstract: A typical property of quantum walks is a coexistence of opposite behaviors; namely linear spreading and localization. In this talk, we treat a special model of quantum walk, so called the Grover walk whose time evolution is uniquely determined by a given connected graph. We will explain a relation between localization and a finite energy combinatorial flow of the graph. A typical example of the flow is a cycle in the graph. Indeed if there is a cycle in the given graph, then there is an initial state to produce the localization of the Grover walk. However we also show that even in an infinite regular tree, which has no cycles, the localization exhibits. This is due to the existence of a finite energy combinatorial flow whose support is infinite. We also discuss on a sensitivity of quantum walker to the boundary of the graph and relation between the recurrence property of underlying random walk.

25. *Daisuke Shiraishi* (Kyoto University)

Title: Natural parametrization for the scaling limit of loop-erased random walk in three dimensions

Abstract: We will consider loop-erased random walk (LERW) and its scaling limit in three dimensions. Gady Kozma (2007) shows that as the lattice spacing becomes finer, LERW in three dimensions converges weakly to a random compact set with respect to the Hausdorff distance. We will show that 3D LERW parametrized by renormalized length converges in the lattice size scaling limit to Kozma's scaling limit parametrized by some suitable measure on it with respect to the uniform norm. This is based on joint works with Xinyi Li (University of Chicago).

26. *Akinori Tanaka* (RIKEN, Wako)

Title: TBA

Abstract:

27. *Yoshiyuki Watabiki* (Tokyo Institute of Technology)

    Title: Emergence of spacetime and Knitting mechanism from 2D CDT

    Abstract: The reason why the 2D CDT approach results in the emergence of spacetime is explained. The key for the emergence of spacetime is the W symmetry. The W symmetry also makes possible to extend the 2D CDT model to higher dimensional models. In these models, the spaces are expanding tangent or hyperbolic tangent, and as a result, the Planck length appears naturally and the knitting mechanism forms the geometry of space. The natural geometry of space formed by knitting mechanism is a torus. The fractal structure of spacetime, this is the quantum effect by quantum gravity, triggers the acceleration of universe.

Poster presentations

1. *Robert Barish* (University of Tokyo)

    Title: Counting injective walks on triangulations

    Abstract: In this talk we will discuss the computational complexity and practicalities of counting injective walks on planar 3-vertex-connected triangulations. Extending a 1982 NP-completeness proof of Wigderson for deciding the existence of Hamiltonian cycles on this class of graphs, we will show a many-one ("weakly parsimonious") counting reduction from #SAT to the problem of counting simple paths, simple cycles, and Hamiltonian paths. We will also discuss general techniques for finding as well as proving generating functions and (where possible) analytic expressions for counting simple paths, simple cycles, Hamiltonian paths, and Hamiltonian cycles on simple infinite families of "sliced" triangulations having bounded pathwidth.

2. *Stephane Dartois* (University of Melbourne)

    Title: TBA

3. *Jumpei Gohara* (Tokyo University of Science)

   Title: Quantized algebra

   Abstract: We propose a new formulation of quantized algebra by using category theory. There are several ways of quantization of algebra, for example, deformation quantization, matrix regularization and so on. For the unified description of them, we define quantization of an algebra as a functor. A sequence of some categories of algebras is a sequence of corresponding quantized algebras, and the limit of them is a classical algebra. We discuss deformation quantization and matrix regularization closely as examples. There quantized algebras give a new point of view of discretizing space, time.

   Collaborator: Yuji Hirota, Keisui Ino and Akifumi Sako

4. *Naotaka Kajino* (Kobe University)

   Title: The Laplacian on some round Sierpiński carpets and Weyl's asymptotics for its eigenvalues

   Abstract: This poster will present the author's recent results on a "canonical" Laplacian on some *round Sierpiński carpets*, i.e., a subset of $\widehat{\mathbb{C}} := \mathbb{C} \cup \{\infty\}$ homeomorphic to the standard Sierpiński carpet such that its complement in $\widehat{\mathbb{C}}$ consists of disjoint open disks in $\widehat{\mathbb{C}}$. In the classical case of the *Apollonian gasket*, Teplyaev (2004) had constructed a canonical Dirichlet form as one with respect to which the coordinate functions on the gasket are harmonic, and the author later proved its uniqueness and discovered an explicit expression of it in terms of the circle packing structure of the gasket. This last expression of the Dirichlet form in fact makes sense on general circle packing fractals, including round Sierpiński carpets, and defines (a candidate of) a "canonical" Laplacian on such fractals. Moreover, with the knowledge of some explicit combinatorial structure of the fractal it is also possible to prove Weyl's asymptotic formula for the eigenvalues of this Laplacian.

5. *Taigen Kawano* (YITP, Kyoto University)

   Title: Canonical tensor model through data analysis : Dimensions, topologies, and geometries

   Abstract: The canonical tensor model is considered to be a model that can describe both classical and quantum gravity, but there was a question how to extract the spacetime from the dynamical variables of this model. In this study we found out an extraction procedure by using two techniques, tensor-rank decomposition and persistent homology. This progress made it possible to investigate the properties associated with some spaces, such as distances and topological structure.

6. *Nobuyuki Matsumoto* (Kyoto University)

   Title: Emergence of geometry in stochastic systems

   Abstract: We define a geometry to any stochastic system based on Markov chain Monte Carlo (MCMC), by introducing a distance between configurations. This distance enumerates difficulty of transition between given two configurations, and is universal for MCMC algorithms which generate local moves in a configuration space. We show that, when the simulated tempering is implemented to a highly multimodal system, an anti-de Sitter geometry emerges in the configuration space.

7. *Daichi Nakayama* (Yokohama National University)

   Title: On the uniform stationary measure of space-inhomogeneous quantum walks in one dimension

   Abstract: The discrete-time quantum walk (QW) is a quantum version of the random walk (RW) and has been widely investigated for the last two decades. Some remarkable properties of QW are well known. For example, the standard deviation of the walker.

8. *Shohei Satake* (Kobe University)

   Title: On the maximal size of subsets which only a few "distances" appear of vector spaces over finite fields

   Abstract: In this talk, we consider subsets which a few "distances" appear of vector spaces over finite fields. We give a bound of the maximal size of such subsets by using a graph-theoretic tool.