The OIST Workshop

# "Quantum and Gravity in Okinawa" 2019

July 23–July 27, 2019
OIST Conference Center/OIST Seaside House
Organizers: Shinobu HIKAMI (OIST), Reiko TORIUMI (OIST)
This workshop is supported by OIST

## Schedule

### Tuesday, July 23 (OIST Campus, C700)

Chair: (Morning) Reiko Torumi, (Afternoon) Slava Lysov

8:45-9:00 Opening

9:00–10:00 **Renate Loll (Radboud University Nijmegen)**
*Title: "Lattice gravity, diffeomorphisms and curvature"*

12:00–12:30 **Cisco Gooding (University of Nottingham)**
*Title: "Backreaction in Analogue Gravity Systems"*

10:30-11:00 Coffee Break

11:00–12:00 **Special Lecture: Vincent Rivasseau (University Paris-Sud, Orsay)**
*Title: "Science without borders, a key to mankind survival?"*
*Special Lecture is held at B250, Floor B, Center Bldg.

12:00-14:00 Lunch

14:00–15:00 **Bianca Dittrich (Perimeter Institute for Theoretical Physics)**
*Title: "Holography for general boundaries"*

15:00–15:30 **Seth Kurankyi Asante (Perimeter Institute for Theoretical Physics)**
*Title: "Holographic description of boundary fields for finite boundaries"*

15:30–16:30 **Fay Dowker (Imperial College London)**
*Title: "Recent progress in causal sets"*

16:30-17:00 Coffee Break

17:00–17:30 **Lu Heng Sunny Yu (University of California, Irvine)**
*Title: "Gravitational Fluctuations as an Alternative to Inflation"*

17:30–18:00 **Marcus Reitz (Radboud University)**
*Title: "Geometric flux formula for the gravitational Wilson loop"*

18:00–19:00 **Jan Ambjorn (Niels Bohr Institute, University of Copenhagen)**
*Title: "Can one define quantum gravity on a lattice"*

19:00 - Dinner (Restaurant, B floor, Center Bldg.)

## Wednesday, July 24 (OIST Seaside House)

Chair: (Morning) Bianca Ditrich, (Afternoon) Shinobu Hikami

9:00–10:00 **Masanori Hanada (University of Southhampton)**
*Title: "What the ants are telling us about black hole and QGP"*

10:00–10:30 **William Cunningham (Perimeter Institute for Theoretical Physics)**
*Title:* "Timelike Hypersurfaces in Causal Set Quantum Gravity"

*10:30-11:00 Coffee Break*

11:00–11:30 **Enrico Rinaldi (RIKEN)**
*Title: "Towards a non-perturbative study of quantum gravity effects"*

11:30–12:30 **Jun Nishimura (KEK)**
*Title: "Complex Langevin simulation of the Lorentzian type IIB matrix model and the emergence of smooth (3+1)D expanding space-time"*

12:30-14:30 Lunch

14:30–15:30 **Ricardo Schiappa (Instituto Superior Technico)**
*Title:*

15:30–16:00 **Kento Osuga (University of Alberta)**
*Title: "Super Airy Structures and Super Virasoro Algebras"*

*16:00–16:30 Poster Preview*

*16:30-18:00 Poster Session and coffee*

18:00–18:30 **Guilherme Sadovski (OIST)**
*Title: "A renormalizable topological quantum field theory for gravity"*

18:00–19:00 **Vyacheslav Lysov (OIST)**
*Title: "Journey to the microscopic derivation of the Bekenstein-Hawking formula"*

19:00- Dinner (Chura Hall, Seaside House)

## Thursday, July 25 (OIST Campus, B250)

Chair: (Morning) Renate Loll, (Afternoon) Ricardo Schiappa

9:00–10:00 **Vincent Rivasseau (University Paris-Sud, Orsay)**
*Title: "From random tensors to holography"*

10:00–11:00 **Valentin Bonzom (University Paris 13)**
*Title: "Studying universality classes of triangulations in dimensions greater than 2"*

11:00-11:30 Coffee Break

11:30–12:00 **Guillaume Valette (Universite Libre de Bruxelles)**
*Title: "A new large N expansion for tensor and matrix-tensor models"*

12:00–12:30 **Paolo Gregori (Instituto Superior Tecnico - Lisbon)**
*Title: "D-Brane Probes in Melonic Matrix Quantum Mechanics"*

12:30-14:30 Lunch

14:30–15:30 **Frank Ferrari (Universite Libre de Bruxelles)**
*Title:* "CFT1, SYK Models and Holographic Boundary Condition Changing Operators"

15:30–16:30 **Joao Caetano (Stony Brook University)**
*Title: "Fishnet theory and correlation functions"*

16:30–17:00 Coffee Break

17:00–17:30 **Romain Pascalie (University of Bordeaux, University of Münster)**
*Title: "Solvable Tensor Field Theory"*

17:30–18:00 **Carlos Perez Sanchez (University of Warsaw)**
*Title: "Schwinger-Dyson equations in Tensor Field Theory as higher-dimensional Tutte's equations"*

18:00–19:00 **Thomas Krajewski (Centre de Physique Theorique, Marseille)**
*Title: "The SYK model and random tensors"*

19:00- Dinner (Restaurant, B floor, Center Bldg.)

## Friday, July 26 (OIST Campus, B250)

Chair: (Morning) Fay Dowker, (Afternoon) Valentin Bonzom

9:00–10:00 **John Barrett (University of Nottingham)**
*Title: "Non-commutativity and the Dirac operator"*

10:00–11:00 **Roberto Percacci (SISSA, Trieste)**
*Title: "Asymptotic safety 40 years later"*

11:00-11:30 Coffee Break

11:30–12:00 **Arkadiusz Bochniak (Jagiellonian University)**
*Title: "Noncommutative geometry for bimetric gravity models"*

10:00–10:30 **Lisa Glaser (University of Vienna)**
*Title: "It's not fuzzy, it's truncated"*

12:30-14:30  Lunch

14:30–15:30  **Kasia Rejzner (University of York)**
*Title: "Non-locality and observables in quantum gravity"*

15:30–16:30  **Sylvie Paycha (University of Potsdam)**
*Title: "Are locality and renormalisation reconcilable?"*

16:30–17:00  **Pierre Clavier (University of Potsdam)**
*Title: "A PROPs approach to Feynman graphs"*

17:00–17:30 Coffee Break

17:30–18:00  **Yannick Kluth (University of Sussex)**
*Title: "Asymptotically Safe Gravity with Riemann and Ricci Tensors*

18:00–18:30  **Riccardo Martini (Friedrich Schiller University Jena)**
*Title: "Universal properties in quantum gravity"*

18:30–19:00  **Kevin Falls (SISSA, Trieste)**
*Title: "Background independent exact renormalisation"*

19:00-   Dinner (Restaurant, B floor, Center Bldg.)

## Saturday,  July 27 (OIST Seaside House)

Chair:  Frank Ferrari

9:00–10:00  **Philipp Höhn (Austrian Academy of Science & University of Vienna)**
*Title: "Quantum general covariance and the trinity of relational quantum dynamics"*

10:00-11:30  Poster Session and Coffee

11:30–12:30  **Dionysios Anninos (King's College London)**
*Title: "Sphere partition functions and de Sitter space"*

12:30–13:30  **William Donnelly (Perimeter Institute for Theoretical Physics)**
*Title:*

13:30-  Lunch

19:00-   Dinner (Chura Hall, Seaside House)

# Titles and Abstracts

Oral Presentations

### Renate Loll (Radboud University Nijmegen)

Title: "Lattice gravity, diffeomorphisms and curvature"

After giving a short introduction into lattice quantum gravity in terms of Causal Dynamical Triangulations, I will focus on the role of diffeomorphisms in this framework and report on what we have learned so far from introducing and implementing a notion of Ricci curvature in a Planckian regime.

### Lisa Glaser (University of Vienna)

Title: “It's not fuzzy, it's truncated”

In general non-commutative geometries can consist of finite or infinite dimensional algebras. But when exploring infinite dimensional algebras as solutions in physical contexts, we will never be able to ascertain an infinite number of degrees of freedom. This raises the question, how much information is contained in the truncation of an infinite dimensional algebra? And how well do certain well known properties of non-commutative geometries hold under these circumstances?
Together with Abel Stern and Walter von Suijlekom we have numerically explored the Heisenberg relation introduced by Chamseddine, Connes and Mukhanov and created visualisations of the resulting geometries.

### Vincent Rivasseau (University Paris Sud, Orsay)

**Special Lecture**
Title: “Science without borders, a key to mankind survival?”

Modern science is an international endeavour critical for mankind to survive at the ten billion level on our small planet. To address efficiently challenges and threats such as the current rising tide of nationalism and the accelerating climate change, we urgently need to better cooperate. In particular the many barriers which currently prevent science and modern technology to thrive in developing countries must be broken down. This can be done in a win-win perspective. I shall share with the audience some of my experience as researcher on quantum gravity and regular teacher in Africa, co-founder of the AIMS-Sénégal institute. Indeed even our most fundamental research on space, time and the universe can greatly benefit from the fresh and open-minded contributions of scientists coming from all corners of the world, and in turn will also lead to unexpected applications.

### Seth Kurankyi Asante (Perimeter Institute for Theoretical Physics)

Title: “Holographic description of boundary fields for finite boundaries”

We shall discuss the interplay between holographic duality and boundary degrees of freedom known as boundary gravitons in (2+1) and (3+1) dimensions for spacetimes with finite boundaries. We shall describe a boundary theory for these boundary gravitons which can be encoded in geodesics lengths normal to the boundary spacetime. We shall also use renormalization techniques to compute the Hamilton Jacobi functionals and one loop partition functions for gravity. These renormalization techniques connect computations performed in both discrete and continuum spacetimes.

**Fay Dowker (Imperial College London)**

Title: "Recent progress in causal sets"

After a brief introduction to the causal set approach to quantum gravity , I will give some examples of recent progress to illustrate some of the work that is going on in the area. I will describe work that shows we can "count" the area of the horizon of a black hole and of other causal horizons, work on defining a "growth model" for causal set dynamics that doesn't rely on any labelling of causal set elements and progress on comparing predictions from the "Everpresent Lambda" phenomenological model of cosmology derived from causal sets with observations.

**Lu Heng Sunny Yu (University of California, Irvine)**

Title: "Gravitational Fluctuations as an Alternative to Inflation"

The ability to reproduce the cosmological power spectrum to high accuracy has often been regarded as a great triumph and evidence of inflation. In this work, we explore an alternative explanation for the power spectrum that is motivated by gravitational fluctuations alone. It can be shown that by only assuming Einstein's gravity and quantum field theory, without relying on the usual assumptions associated with inflationary models, which usually relies on one or more scalar fields, both the galaxy and CMB cosmological power spectra can be fully reproduced, and thus offering a compelling alternative to inflation. In addition, several testable predictions can be derived in this gravitationally-motivated picture that deviate from the conventional inflation one, which will hopefully become verifiable in the near future with increasingly precise cosmological measurements.

**Marcus Reitz (Radboud University)**

Title: "Geometric flux formula for the gravitational Wilson loop"

Finding suitable diff eomorphism-invariant observables to probe gravity at the Planck scale is an essential part of addressing meaningful questions in quantum gravity. The non-infi nitesimal Wilson loop of the four-dimensional Levi-Civita connection is a potentially interesting ingredient in the construction of such an observable. This has motivated our classical investigation of how and under what circumstances such Wilson loops can provide a (coarse-grained) measure of spacetime curvature. Invoking arguments similar to those used in the non-Abelian Stokes' theorem, we present an expression for a geometric flux, which in the presence of a totally geodesic surface relates non-infi nitesimal gravitational Wilson loops to surface integrals of the scalar curvature.

**Jan Ambjorn (Niels Bohr Institute, University of Copenhagen)**

Title: "Can one define quantum gravity on a lattice"

I quantum field theory most observables are defined using Green functions. These Green functions depend on distances between spacetime points in a given spacetime, in the simplest case just flat Minkowskian spacetime. In quantum gravity distances become operators and the nature of the Green functions change in such a way that it might not be possible to use a lattice as a regulator. I will illustrate the situation by a simple string theory calculation which shows the difficulty of defining string theory on a lattice.

**Masanori Hanada (University of Southhampton)**

Title: “What the ants are telling us about black hole and QGP”

I will talk about my recent work with a few different sets of collaborators, including the one in progress which is still speculative.

If the gauge/gravity duality is correct, Schwarzschild black hole in ten dimensions, which has the negative specific heat (E~T^{-7}) as Hawking has discovered, has to be described by QFT. But how can the negative specific heat be described by a healthy quantum theory? In the first part of the talk, I explain the partial deconfinement --- SU(M) degrees of freedom in SU(N) (M<N) deconfine while the rest of the degrees of freedom confine --- naturally explains the negative specific heat, including the power -7.

At first sight, the partial deconfinement appears to be ad hoc. However it is actually a generic feature of various gauge theories. In order to demonstrate it, I will introduce a startling similarity between the ant trail and black hole. Namely, by identifying the ants, pheromone and ant trail with D-branes, open strings and black hole, the dynamics of the ants is essentially the same as the thermodynamics of D-branes and strings in superstring theory. The collective behavior of the ants can be understood intuitively, and lead us to the understanding of the generic mechanism behind the black hole formation in string theory and deconfinement transition in gauge theory.

The lessons we learn from the ants suggest that the partial deconfinement is generic, even without gravity dual. Once we know it, we can actually confirm the partial deconfinement in various theories. An interesting point here is that the partial deconfinement is a well-defined notion even for the theories without center symmetry, such as QCD. The partial deconfinement phase spontaneously breaks the gauge symmetry (precise meaning is explained in the talk) and hence the two transitions --- breaking of gauge symmetry, which corresponds to the transition from the confined phase to the partially deconfined phase, and the restoration of gauge symmetry, which corresponds to the transition from the partially deconfined phase to the completely deconfined phase --- characterize the deconfinement. Similar "partial breaking" can also take place when the chiral symmetry breaks, and interesting physics, which may be actually happening in colliders, shows up.

**William Cunningham (Perimeter Institute for Theoretical Physics)**

Title: “Timelike Hypersurfaces in Causal Set Quantum Gravity”

While it has long been known the causal set action diverges upon the inclusion of timelike boundaries, there has been little study of where divergence this originates, how to correct for it, or how to independently measure the boundary geometry. In this talk, we address these problems as well as new phenomena uncovered during their study. Ultimately, we aim to understand how to accurately measure the volume and extrinsic curvature of generic timelike hypersurfaces in finite-sized systems.

**Enrico Rinaldi (RIKEN)**

Title: “Towards a non-perturbative study of quantum gravity effects”

Lattice field theories are a useful tool to define gauge theories in their non-perturbative regime. At the same time, the gauge/gravity duality conjectures that certain gauge theories in the non-perturbative regime are dual to weakly-coupled gravity. This suggests the possibility of relating weakly-coupled gravity to gauge theories defined on the lattice. As a first step, this conjecture needs to be tested by comparing suitable observables on both sides of the duality.

This first step has been successfully carried out as I will show and the duality can be used as a non-perturbative definition of gravity via gauge theories defined on a lattice, and can make new and unexpected predictions.
I will show examples in D0-branes quantum mechanics and explore quantitatively and non-perturbatively both the gauge/gravity duality and phase transitions. In addition to testing the duality, we will add some predictions to stringy corrections in the gravity side, assuming the validity of the duality.

**Jun Nishimura (High Energy Accelerator Research Organization (KEK))**

Title: "Complex Langevin simulation of the Lorentzian type IIB matrix model and the emergence of smooth (3+1)D expanding space-time"

The Lorentzian type IIB matrix model is a promising candidate for a nonperturbative formulation of superstring theory.
In particular, the emergence of (3+1)D expanding space-time was suggested by Monte Carlo simulation in 2011. Recently we have found that the structure of the space represented by the matrices generated by the simulation is singular in that only two eigenvalues increase with time. This property has been attributed to the incorrect treatment of the sign problem, which occurs due to the phase factor $e^{iS}$ in the integrand of the partition function. Here we apply the complex Langevin method to solve this problem, and find that the space-time structure tend to become smooth while keeping the (3+1)D expanding behavior intact.
Ref.) JHEP 1906 (2019) 077 [=arXiv:1904.05919 [hep-th]]

**Kento Osuga (University of Alberta)**

Title: "Super Airy Structures and Super Virasoro Algebras"

Matrix models have been studied as a constructive approach to 2d quantum gravity, and topological recursion, as developed by Eynard and Orantin, is a mathematical formalism that recursively computes correlation functions of such models. A bonus is that topological recursion is not only useful for matrix model; it is a powerful computational tool for enumerative invariants. Recently, Kontsevich and Soibelman introduced Airy structures that generalize topological recursion from an algebraic point of view. Since Lie algebras play a crucial role in Airy structures, an interesting question arises; can we further generalize Airy structures by upgrading Lie algebras to Lie superalgebras? In this talk I will first give a brief review of Airy structures and their applications to mathematical physics, and then I will introduce super Airy structures. To conclude, I will construct a set of examples by using N=1 vertex operator superalgebras which we expect to work as a bridge among integrable system, enumerative geometry, and physics. This is a joint work in progress with V. Bouchard, P. Ciosmak, L. Hadasz, B. Ruba, and P. Sulkowski.

**Guilherme Sadovski (OIST)**

Title: "A renormalizable topological quantum field theory for gravity"

In 1989 E. Witten, using traditional QFT techniques, develop an exact path integral representation to many classes of topological invariants. These QFTs, so-called Topological QFTs (TQFTs), share the property that all of their observables are metric-independent. In other words, the observables are global invariants classifying the topological and smooth structure of spacetime. In this sense, one could say, that TQFTs are examples of background independent and exactly soluble perturbative QFTs.

One of the most proeminent example perhaps is the four dimensional Topological Yang-Mills theory (TYM). This theory can be obtained by the BRST quantization of the Pontryagin invariant ∫ Tr(FF), instead of the tradition Yang-Mills action ∫ Tr(F⋆F). The observables are known to be the Donaldson's polynomials, which classify the smooth structure of the underlying manifold. In particular, TYM theory is so symmetric that it has remarkably simple quantum properties. For instance, in the Landau gauge, it is actually finite (all quantum corrections vanish).

These remarkable properties led Witten to hypothesize if such a theory could describe an unbroken phase of General Relativity. In this talk, we will propose a renormalizable TYM theory that can generate gravity via an explicity breaking of its topological BRST symmetry - thus fulfilling Witten's vision. In particular, we will consider the family of Lovelock-Cartan theories of gravity due to their generality and closer relation to the gauge structure.

### Vyacheslav Lysov (OIST)

Title: "Journey to the microscopic derivation of the Bekenstein-Hawking formula"

I will briefly review the major steps in the progress of understanding the microscopic derivation of the Bekenstein-Hawking formula: string states counting, AdS/CFT, Kerr/CFT and the most recent soft hair approach.
Then I will discuss the details the soft hair approach including recent progress and problems to solve.

### Vincent Rivasseau (University Paris-Sud, Orsay)

Title: "From random tensors to holography"

Random tensors were introduced to perform a quantum sum over space-time pondered by the Einstein-Hilbert action. Recently the melonic approximation which governs their behavior at large size was found to have surprising holographic properties, providing in particular quantum models of black-holes that can be investigated on a computer. We propose some preliminary ideas to tentatively connect the two approaches.

### Valentin Bonzom (University Paris 13)

Title: "Studying universality classes of triangulations in dimensions greater than 2"

It is well known that families of planar maps, e.g. triangulations, quadrangulations and generic maps, share universal properties in the large scale limit, such as the entropy exponent from their asymptotic enumeration, or their continuum limit known as the Brownian sphere. Few theorems exist in higher dimensions, due to the intricate nature of higher-dimensional combinatorics and topology. In this introductory talk, we will show that colored triangulations provide a good arena because they are amenable to precise combinatorial analysis and theorems can be proven. I will focus on a combinatorial generalization of Euler's relation for planar triangulations, which is to bound the number of (d-2)-simplices linearly in the number of d-simplices, and identifying the triangulations which maximize the bound for different colored building blocks. In 3d, I prove that those triangulations, built from any set of colored building blocks homeomorphic to the 3-ball, are in bijection with trees (or branched polymers). In even dimensions, we have proved that other universality classes can be recovered. Other interesting approaches are in preparation and would be interesting to mention if time permits.

**Guillaume Valette (Universite Libre de Bruxelles)**

Title: "A new large N expansion for tensor and matrix-tensor models"

In this talk, we describe a new large N expansion for tensor and matrix-tensor models, based on arXiv:1709.07366. Random tensor models generalize random matrix models in higher dimensions, in the sense that they provide a theory of random discretized geometries in dimensions larger or equal to three in the same way as matrix models does in two dimensions. They also support a large N expansion, which is organized according to the Gurau degree and whose leading sector corresponds to melonic graphs. In many instances, it is interesting to enlarge the leading sector, that is, to work with a larger class of graphs at leading order. We explain how this can be done by enhancing the large N scaling of the coupling constants entering the action. The new large N expansion obtained this way is organized according to a new quantity called the index, which has an interesting combinatorial interpretation in terms of the matrix models embedded in the tensor model. In the second part, we introduce matrix-tensor models, which are obtained by rewriting the tensor in terms of matrices. In these models, there is a new natural parameter D that allows one to define a large D expansion in addition to the large N one. We discuss the interesting features of these expansions and their connection with high-energy physics, more specifically with SYK-like physics.

**Paolo Gregori (Instituto Superior Tecnico - Lisbon)**

Title: "D-Brane Probes in Melonic Matrix Quantum Mechanics"

Recently, a new approximation scheme for matrix quantum mechanics was proposed. It is a large D limit for models in which D U(N) matrices interact through an O(D) invariant action. For a specific choice of the interaction terms, this limit has been shown to reproduce the physics of the SYK model without the need of random couplings. In this talk, I will show how a generalization of the concept of D-brane probe can be introduced for such an SYK-like matrix model, and how the corresponding probe brane action can be computed exactly. This leads to a test of a non-trivial relation with the free energy of the model. I will also provide new insight on the properties of the new large D limit of matrix quantum mechanics, by addressing several new model building issues.

**Frank Ferrari (Universite Libre de Bruxelles)**

Title: "CFT1, SYK Models and Holographic Boundary Condition Changing Operators"

The SYK model provides a remarkable bridge between condensed matter theory, black hole physics and holography. In my presentation, I will explain how a surprising feature of conformal field theories in one dimension - the logical possibility of associating *two* distinct conformal dimensions to a primary operator - can be realised both in interesting generalizations of the usual complex SYK models and in AdS2 holography.

**Joao Caetano (Simons Center for Geometry and Physics & C.N. Yang Institute at Stony Brook University)**

Title: "Fishnet theory and correlation functions"

In this talk, I will review general aspects of the conformal fishnet theory, which is an integrable conformal field theory in four dimensions in the planar limit without supersymmetry. I will discuss how integrability techniques based on the hexagon formalism can be used to determine correlation functions of local operators in this theory.

**Romain Pascalie (University of Bordeaux, University of Münster)**

Title: “Solvable Tensor Field Theory”

We will present the derivation of the Schwinger-Dyson equations in Tensor Field Theory, which are obtained using Ward-Takahashi identities, focusing on the 2-point function.
Then after taking the large N limit, we find the 2-point function of a particular model in term of Lambert's W-function.

**Carlos Perez Sanchez (University of Warsaw)**

Title: “Schwinger-Dyson equations in Tensor Field Theory as higher-dimensional Tutte's equations”

The equivalence between Tutte's equations for the enumeration of discrete surfaces and the Schwinger-Dyson equations of a suitable matrix model is well-known (see e.g. B. Eynard `Counting Surfaces' 2016). I will explain how the Schwinger-Dyson equations of Tensor Field Theory can be interpreted as higher-dimensional Tutte's equations, and discuss further geometric perspectives. The focus is on dimension 3.

**Thomas Krajewski (Centre de Physique Theorique, Marseille)**

Title: "The SYK model and random tensors"

The SYK model involves N Majorana fermions in 1+0 dimensions with quenched Gaussian disorder that proves to be exactly solvable in the large N limit at strong coupling. It has been initially proposed by Sachdev and Ye as a model of condensed matter and later gained some interest as a toy model of AdS/CFT correspondence, thanks to the work of Kitaev. On the other side, random tensors are generalisations of random matrices to objets that carry more than two indices. It turns out that the SYK model and random tensors involve a special class of Feynman graphs known as "melons". We will briefly review both constructions.
Then, we will show how non Gaussian disorder can be reduced to a Gaussian one, treating the coupling as a random tensor, thanks to Gurau's Gaussian universality result. This last part is based on https://arxiv.org/abs/1812.03008.

**John Barrett (University of Nottingham)**

Title: “Non-commutativity and the Dirac operator”

In the first part of the talk I will describe how the fields and action of the standard model of particle physics respect the structure of a non-commutative geometry. The framework is Connes' version of non-commutative geometry, based around the mathematical structure of the Dirac operator. In the second part of the talk I will discuss - more speculatively - how I hope to use a similar mathematical structure to describe space-time with a finite Planck scale. Along the way I will try to discuss what it takes to invent a new physical theory and how this differs from calculating the consequences of an existing one.

**Roberto Percacci (SISSA, Trieste)**

Title: "Asymptotic safety 40 years later"

I will give a quick overview of the current status of the asymptotic safety program, in particular the work in the continuum based on the use of a functional renormalization group equation, and present some recent results.

**Arkadiusz Bochniak (Institute of Physics, Jagiellonian University)**

Title: “Noncommutative geometry for bimetric gravity models”

Bimetric gravity models are possible extensions of the standard cosmological model. Originally the action for this class of models contained free coefficients which characterize cosmological scenarios, and even slight change of them may be crucial. We propose an approach, based on the noncommutative geometry methods, that will possibly allow to determine these parameters using properly chosen spectral triples and methods of Wodzicki residuum computation for generalized Dirac operators. Therefore, it seems like it is possible to derive the form of this action from purely geometrical considerations. This work is still in progress and the results which will be presented are dependent on actual progress in the research.

**Cisco Gooding (University of Nottingham)**

Title: “Backreaction in Analogue Gravity Systems”

Analogue gravity systems allow complex gravitational phenomena to be explored in a laboratory setting. The current focus of analogue gravity research is on the behaviour of classical and quantum fields on fixed background spacetimes. However, in many cases of interest, including the scattering of high-amplitude waves from small compact objects or the extreme case of late-stage Hawking evaporation, the spacetime geometry is altered significantly by interactions with a field. How such fields backreact onto the spacetime geometry is only partially understood, and requires further investigation. I will discuss a recent analogue black hole experiment that exhibits backreaction, and also admits a relatively simple theoretical description. I will then comment on future backreaction experiments, and the possibility of using analogue systems to provide experimental guidance for quantum gravity.

**Kasia Rejzner (University of York)**

Title: “Non-locality and observables in quantum gravity”

In this talk I will discuss the problem of choosing appropriate gauge-invariant observables in quantum gravity. I will focus on the example of relational observables that can be obtained from their classical counterparts using the framework of perturbative algebraic quantum field theory (pAQFT). Applying these ideas in cosmological models reproduces in first order the standard quantities used in cosmological perturbation theory.

**Sylvie Paycha, University of Potsdam, on leave from the University Clermont-Auvergne**

Title: "Are locality and renormalisation reconcilable?"

According to the principle of locality in physics, events taking place at different locations should behave independently, a feature expected to be reflected in the measurements. The latter are confronted with theoretic predictions which use renormalisation techniques in order to deal with divergences from which one wants to derive finite quantities.
The purpose of this talk is to confront locality and renormalisation.

Sophisticated (co)algebraic methods developed by physicists enable to keep track of locality while renormalising. They mostly use a univariate regularisation scheme such as dimensional regularisation. We shall present an alternative multivariate approach to renormalisation which encodes locality as an underlying algebraic principle. We shall apply it to various situations involving renormalisation, such as divergent multizeta functions and their generalisations, namely discrete sums on cones and discrete sums associated with trees.

This is based on joint work with Pierre Clavier, Li Guo and Bin Zhang.

**Pierre Clavier (Mathematic Institute, University of Potsdam)**

Title: “A PROPs approach to Feynman graphs”

PROPs (PROduct and Permutations) are very general structures, allowing operations with multiple input and output. Oriented graphs can be given a PROP structure, which enjoys an universal property. I will explain how we use this universal property to prove meromorphicity results for regularised Feynman graphs. This allows then to renormalise these graphs.

**Yannick Kluth (University of Sussex)**

Title: “Asymptotically Safe Gravity with Riemann and Ricci Tensors

In this talk we take a look into the asymptotic safety conjecture of pure quantum gravity. After a brief review of the state-of-the-art, we test the conjecture for two different gravitational actions. The first one being a function of the Ricci tensor while the second one includes functions of the square of the Riemann tensor and the Ricci scalar. Using functional renormalisation and a bootstrap search strategy we determine fixed points and scaling exponents to high polynomial order. Results between the two models are compared and implications are discussed.

**Riccardo Martini (Friedrich Schiller University Jena)**

Title: “Universal properties in quantum gravity”

I will present a study of the universality classes of quantum gravity in the context of the Asymptotic Safety scenario. In particular I will study the analytical extension of two dimensional gravity far from its upper critical dimension. Since the physically interesting case is the analytical continuation to d=4, I will focus the analysis on the correction to the critical exponents due to higher order derivative operators.

**Kevin Falls (SISSA, Trieste)**

Title: “Background independent exact renormalisation”

I will present a new background independent exact renormalisation group equation which can be applied to gauge theories and quantum gravity. The equation is based on a gauge invariant regularisation of the path integral which is achieved without fixing the gauge. I will discuss the advantages of this formalism over the effective average action approach to asymptotic safety.

**Philipp Höhn (Austrian Academy of Science & University of Vienna)**

Title: "Quantum general covariance and the trinity of relational quantum dynamics"

I will summarize a 'perspective-neutral' approach to quantum reference systems, which admits a quantum notion of general covariance. The approach permits one to switch between the descriptions of physics relative to different choices of quantum reference systems, providing a quantum analog of coordinate changes on a manifold. I will then focus on applying this approach to relational dynamics. Apart from offering a systematic method for switching from the evolution relative to one quantum clock to that relative to another, it also allows one to link three approaches to the problem of time that were previously pursued independently. In particular, the relational dynamics in terms of (a) relational observables in Dirac quantization, (b) deparametrizations in reduced quantization, and (c) the conditional state formulation of Page and Wootters, can, under certain restrictions, be mapped into one another. As such, they can be interpreted as three different faces -- the trinity -- of the same relational quantum dynamics.

**Dionysios Anninos (King's College London)**

Title: “Sphere partition functions and de Sitter space”

After a brief overview of some aspects of de Sitter spacetimes, we consider the partition function of quantum fields on the Euclidean sphere, and its relation to quantum fields on de Sitter space. We express the sphere partition function in terms of group characters of the de Sitter group, providing a general expression for arbitrary spin and mass. Time permitting, we apply our results to a theory with an infinite tower of massless higher spin fields, which is the linearised spectrum of Vasiliev theory.

# Titles and Abstracts

Poster Presentations

## Sebastián Bahamonde (University of Tartu)

1) Title: "Is really General Relativity the correct starting point for quantum gravity? "

In this poster I will introduce the Trinity of gravity. The first theory is General Relativity (GR) whose connection is torsionless and contains curvature, and the metric satisfies the compatibility condition. The second one is the Teleparallel equivalent of GR (TEGR) which is also constructed from a metric which satisfies the metric compatibility condition but the connection is curvatureless and contains torsion. The last theory is Coincident GR (CGR) which has zero curvature and torsion but the metric does not satisfy the metric compatibility condition. These three theories give the same classical Einstein field equations, but both their physical interpretation and quantum descriptions are different. I will argue that all the efforts to construct a viable quantum gravity theory has been done by considering GR as the starting point, but in principle, one can start with either TEGR or CGG and then study their possible quantum theories. Some interesting possible advantages for studying these two alternatives gravitational theories in the context of quantum gravity will be also pointed out.

2) Title: "Reviving Horndeski gravity using Teleparallel gravity"

General Relativity (GR) is based on a manifold with curvature and zero torsion and on the contrary, Teleparallel gravity (TG) is a theory which assumes a non-zero torsion with zero curvature. It turns out that it is possible to write down a theory in Teleparallel gravity that is equivalent to GR in terms of the field equations. Even though these theories are equivalent in field equations, their modifications are different. Horndeski gravity which is based from GR was highly constraint from the recent gravitational waves observations due to $|c_g/c - 1| < 10^{-15}$. We constructed an analogue version of Horndenki gravity which is based in Teleparallel gravity and showed that in this context, it is possible to construct a theory satisfying $c_T = c_g/c = 1$ without eliminating the coupling functions $G_5(\phi , X)$ and $G_4(\phi , X)$ that were highly constraint in standard Horndeski theory. Hence, in the Teleparallel approach, one is able to restore these terms creating an interesting way to revive
Horndeski gravity.

## Jinzhao Wang (ETH, Zurich)

1) Title: "On the geometry of small causal diamonds"

The geometry of small causal diamonds in the absence of matter is considered, based on three distinct constructions that are common in the literature, namely the geodesic ball, Alexandrov interval and lightcone cut. The causal diamond geometry is studied perturbatively using Riemann normal coordinate expansion up to the leading order in both vacuum and non-vacuum. We provide a collection of results including the area of the codimension-two edge, the maximal hypersurface volume and their isoperimetric ratio for each construction. In particular, by solving the evolution equations of the optical quantities on the lightcone, we find that intriguingly only the lightcone cut construction yields an area deficit proportional to the Bel-Robinson superenergy density W in four dimensional spacetime, but such a direct connection fails to hold in any other dimension. We also compute the volume of the Alexandrov interval causal diamond in vacuum, which we believe is important but missing from the literature. Our work systematically studies various causal diamonds under the same setting, and extends the earlier works on the causal diamond geometry by Gibbons and Solodukhin, Jacobson, Senovilla and Speranza and many others. Some potential applications of our results in mathematical general relativity and quantum gravity are discussed.

2) Title: “On the Hawking-Hayward mass in arbitrary dimensions”

The quasilocal mass is a crucial but yet fully understood notion in gravity. In General Relativity, many proposals for a good definition of quasilocal mass have been given over the past half-century. However, most of the proposals do not have sound generalisations beyond four spacetime dimensions. We study here the natural generalisation of the Hawking-Hayward mass to arbitrary dimen- sions, which uniquely inherits some nice properties of the original definition in four dimensions. In the small sphere limit, however, the Hawking-Hayward mass fails to be proportional to the Bel- Robinson superenergy in dimensions other than four. Given the uniqueness of both generalisations of the Hawking-Hayward mass and the Bel-Robinson superenergy to higher dimensions, our result points at the inconsistency of the local behaviors of quasilocal mass in higher dimensions. Potential solutions await the proper generalisations of other quasilocal mass definitions, and ultimately the understanding of its quantum origin.

**Salvatore Baldino, Roberto Vega Alvarez, and Maximilian Schwick (IST, University of Lisbon)**

Title: "Towards Nonperturbative Solutions of 2D gravity and supergravity"

In the settings of 2D quantum gravity and quantum supergravity, the Painlevé I and Painlevé II equations play prominent roles in obtaining the corresponding partition functions. Solutions to these Painlevé equations are subject to non-trivial, non-linear Stokes phenomena, where some of the Stokes data can be related to ZZ-brane amplitudes. It is expected that the complete Stokes data can be further related to FZZT-brane amplitudes (and in fact to the full semi-classical content of these theories). However, currently, there is no analytical procedure that produces the complete Stokes data for those equations.

We have developed a numerical method to compute Stokes data in a general setting. This method is based on the transseries representation in [1]. By imposing smoothness of the Borel resummed transseries at the Stokes lines, systems of equations involving polynomial combinations of Stokes data can be written, whose coefficients can be computed through numerical Borel resummations of asymptotic series within the transseries.

We obtained a systematic way to extract values for the Stokes data, alongside numerical results of this analysis, within the setting of the Painlevé I and Painlevé II equations, confirming the partial results obtained through other methods in [2] and [3], and presenting a plethora of new data. We present an interpretation of this data as building blocks that allow us to write a globally defined partition function for the models. We have conjectured relations between the Stokes data to reduce the amount of independent data, and tested them using the numerical results. These results, that will be presented in the poster, will appear in [4].

[1] Inês Aniceto, Gökçe Başar, Ricardo Schiappa. "A Primer on Resurgent Transseries and Their Asymptotics." Physics Reports (2019). arXiv preprint arXiv:1802.10441
[2] Inês Aniceto, Ricardo Schiappa, Marcel Vonk. "The Resurgence of Instantons in String Theory." Commun. Num. Theor. Phys. 6 (2012) 339-496. arXiv preprint arXiv:1106.5922
[3] Ricardo Schiappa, Ricardo Vaz. "The Resurgence of Instantons: Multi-Cut Stokes Phases and the Painlevé II Equation." Commun. Math. Phys. 330 (2014) 655-721. arXiv preprint arXiv:1302.5138
[4] Salvatore Baldino, Ricardo Schiappa, Maximilian Schwick, Roberto Vega, (2019) to appear.

**Alessio Baldazzi (SISSA, Trieste)**

Title: “Wicked metrics vs path integral in Lorentzian spacetimes”

There are various ways of defining the Wick rotation in a gravitational context.
In order to preserve the manifold structure, it would be preferable to view it as an analytic continuation of the metric, instead of the coordinates. We focus on one very general definition and show that it is not always compatible with the additional requirements of preserving the field equations and the symmetries at global level.
Then we consider another approach based not on the deformation of the time or the metric, but of the integration contour of the fields. In particular we discuss the calculation of one-loop effective actions in Lorentzian spacetimes, based on a very simple application of the method of steepest descent to the integral over the field. We show that for static spacetimes this procedure agrees with the analytic continuation of Euclidean calculations. When applied to quantum gravity on static backgrounds, our procedure is equivalent to analytically continuing time and the integral over the conformal factor.

**Shoichiro Miyashita (Waseda University)**

Title: “DOS of GR”

In quantum gravity, gravity would thermalize, in the sense that some observables defined on the spacetime boundary reach equilibrium. The information of such gravitational thermal states could be obtained statistical mechanically. The partition functions of gravity are formally defined by certain kinds of Euclidean path integral of General Relativity(GR). However, since there are known to be the divergent problem in Euclidean path integral of GR, its integration contour must be genuinely complex which generally picks up complex saddle-point geometry. In this work, we seek the suitable integration contour for the microcanonical partition function or Density of States(DOS) of a quantum spacetime with R × S^2 boundary by using minisuperspace approximation. Although we found that there always exists only one saddle point for any given boundary data, it does not always dominate the possible integration contours. One of the obtained DOS shows exponential of Bekenstein-Hawking entropy for a certain energy range where it is dominated by the saddle point. However, for sufficiently high energy, where the saddle point no longer dominates, the DOS approaches a positive constant. This presentation is based on arXiv:1906.11838.

**Haruka Mori (Kitasato University)**

Title: “Space-time foliations, doubled aspects of Vaisman algebroid and gauge symmetry in double field theory”

Double Field Theory (DFT) is a gravity theory that respects T-duality in string theory. The geometry behind DFT exhibits non-trivial mathematical structures. The metric algebroid proposed by Vaisman (the Vaisman algebroid) governs the gauge symmetry algebra generated by the C-bracket in DFT. Based on a geometric realization of doubled space-time as a para-Hermitian manifold, we examine exterior algebras and a para-Dolbeault cohomology on DFT and discuss the structure of the Drinfel'd double for the DFT gauge symmetry. We find that Lagrangian subbundles (L,\tilde{L}) defined over space-time foliations in a para-Hermitian manifold play Dirac-like structures in the Vaisman algebroid. We also find that an algebraic origin of the strong constraint in DFT is traced back to the compatibility condition needed for (L,\tilde{L}) be a Lie bialgebroid.
We further comment on groupoid structures appearing in the doubled space-time.

**Arkaprava Mukherjee (Indian Institute of Science Education and Research, Kolkata)**

Title: “Quantum out-of-equilibrium cosmology and Bound on Quantum Chaos for GUE”

The one to one correspondence between the conduction phenomena in electrical wires with impurity and the scattering events responsible for particle production during stochastic inflation and reheating implemented under a closed quantum mechanical system in early universe cosmology leads to derivation of quantum corrected version of the Fokker–Planck equation without dissipation and its fourth order corrected analytical solution for the probability distribution profile responsible for studying the dynamical features of the particle creation events . Quantum corrected Fokker–Planck equation describe the particle creation phenomena for Dirac delta scatterer.

The measure of the stochastic non-linearity (randomness or chaos) arising in the stochastic inflation and reheating epoch of the universe(Lyapunov Exponent) has been studied . Quantum chaos in a closed system have a more strong measure, Spectral Form Factor which has been calculated from principles of RMT with GUE. SFF from the computation of two point Out of Time Order Correlation function (OTOC) has been shown to have a bound on $-1/N\ (1 - 1/\pi) \leq \mathrm{SFF} \leq 0$ and $0 \leq \mathrm{SFF} \leq 1/\pi N$, valid for thermal systems with large and small number of degrees of freedom respectively. Also early and late behavior of SFF(quantum chaos) to check the validity and applicability of our derived bound has been discussed.

Reference:-
1."Quantum out-of-equilibrium cosmology"-Eur. Phys. J. C (2019) 79:320, S. Choudhury, A. Mukherjee, P. Chauhan, S. Bhattacherjee
2."Quantum randomness in the sky"-arXiv:1812.04107 [physics.gen-ph], S. Choudhury, A. Mukherjee
3. "A bound on quantum chaos from Random Matrix Theory with Gaussian Unitary Ensemble"-https://doi.org/10.1007/JHEP05(2019)149, S. Choudhury, A. Mukherjee

**Kenta Shiozawa (Kitasato University)**

Title: “Worldsheet Instanton Corrections to Five-branes and Waves in Double Field Theory”

We make a comprehensive study on the string winding corrections to supergravity solutions in double field theory (DFT). We find five-brane and wave solutions of diverse codimensions in which the winding coordinates are naturally included. We discuss a physical interpretation of the winding coordinate dependence. The analysis based on the geometric structures behind the solutions leads to an interpretation of the winding dependence as string worldsheet instanton corrections. We also give a brief discussion on the origins of these winding corrections in gauged linear sigma model (GLSM). We propose a GLSM that provides a string sigma model whose target spaces are a defect NS5-brane, a Kaluza-Klein vortex and an exotic $5^2_2$-brane. This presentation is based on JHEP07(2018)001 and JHEP12(2018)095.

**Carlos Mauricio Nieto Guerrero (SISSA, Trieste)**

Title: “Ultraviolet completion and predictivity from a minimal parameterization of Beyond-Standard-Model physics”

I will discuss the effect of quantum gravity contributions on the running of gauge and Yukawa couplings in the Standard Model. Using a simple but general parametrization for these corrections, I explore different Ultraviolet behaviors of the system of couplings. One of my main goals is to understand the pattern observed in the masses of the quark sector, as well as the CKM mixing angles.

**Kazumasa Okabayashi (Osaka City University)**

Title: “Maximal Efficiency of Collisional Penrose Process with Spinning Particle II Collision with a particle in ISCO”

We analyze the collisional Penrose process between a particle in its ISCO around an extreme Kerr black hole and a particle impinging from infinity in both spinless and spinning case. We evaluate the maximal efficiency, $\eta_{max}$ = (extracted energy)/(input energy), for the elastic collision, the inverse Compton scattering, which are considered as natural process. When spin is taken into account, we obtain $\eta_{max} \approx 8.442$ in the elastic collision, which is the largest value compared with the other case. On the other hand, when we consider the spinless collision, $\eta_{max} \approx 4.041$ is obtained in the inverse Compton scattering, which is the largest value. When spin is taken into account, we find from tables that the efficiency becomes much larger. In this sense, spin plays an important role in the collisional processes, and should not be ignored.

**Vasilis Kiosses (Aristotle University of Thessaloniki)**

Title: “Gravity as black body radiation and black hole themodynamis”

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# Gravitation as blackbody radiation and black hole thermodynamics


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June 24, 2019


**Abstract**

In this presentation, we provide a heuristic way to consider gravity as blackbody radiation. Our formulation involves two basic elements. A quantum spacetime, described by the quantum excitations of a new kind of fields, named as accelerated fields, which live in momentum space. And a massive object defined as a collection of spacetime quanta in thermodynamic equilibrium. This object behaves as a blackbody, emitting quantum lengths and time intervals, at temperature inversely proportional to its mass. Having established a correspondence between quantum and Rindler spacetime (PLB 781, 611, 2018), equivalence principle allows us to identify gravity with the massive object's blackbody radiation, since the last affects the corresponding geometry of spacetime. At Planck scale, our argument directly leads to the Hawking temperature of a black hole (up to a constant) demonstrating that a black hole can actually reach thermal equilibrium if spacetime comes in discrete units.



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