CDT and Friends, Talk Titles and Abstracts

– DAY 1 – Tuesday, Dec 11

M. Visser: Triangle inequalities in Lorentzian signature
Z. Burda: Quantum widening of CDT universe
J. Laiho: Exploring Euclidean Dynamical Triangulations
S. Jordan: A second-order phase transition in Causal Dynamical Triangulations
A. Görlich: Euclidean Dynamical Triangulations with a measure term

– DAY 2 – Wednesday, Dec 12

B. Durhuus: Some simple statistical mechanical systems on random infinite graphs
M. Atkin: A combinatorial approach to 2D CDT with matter
T. Jonsson: The spectral dimension of two-dimensional causal triangulations
J. Wheater: Scale dependent spectral dimension on random graphs
G. Calcagni: Field theory on multifractal spacetimes
S. Zohren: Branching and growth process for uniform infinite causal triangulations

– DAY 3 – Thursday, Dec 13

P. Hořava: Lifshitz gravity and Lifshitz holography
S. Weinfurtner: Spectral dimension as a probe of the ultraviolet continuum regime of CDT
J. Cooperman: Where has causal dynamically triangulated Hořava-Lifshitz gravity led us?
G. 't Hooft: Discretization and determinism in string theory
J. Gizbert-Studnicki: The transfer matrix in four-dimensional CDT
A. Kreienbühl: Renormalization group flow in Causal Dynamical Triangulations

– DAY 4 – Friday, Dec 14

F. Saueressig: Quantum Einstein Gravity – a status report
B. Dittrich: Coarse graining spin nets and spin foams: first results
T. Budd: Causal Dynamical Triangulations and trees
V. Bonzom: Random tensor models in the large N limit
D. Benedetti: The mixed blessing of a foliation

p.t.o.

Abstracts (in order of play)

Triangle inequalities in Lorentzian signature

(M. Visser, Victoria U., Wellington)

The Lorentzian signature triangle inequalities are qualitatively different from those in Euclidean signature, a fact which has significant implications for how dynamical triangulations (more precisely, dynamical simplexifications) are to be implemented. The effects are both dimension dependent and model dependent. I will discuss some simple low dimensional implementations, based on work carried out with Kyle Tate. – References: JHEP 1111 (2011) 072 arXiv:1108.4965; JHEP 1201 (2012) 028 arXiv:1110.5694 [gr-qc].

Quantum widening of CDT universe

(Z. Burda, Jagiellonian U., Krakow)

The physical phase of Causal Dynamical Triangulations (CDT) is known to be described by an effective, one-dimensional action in which three-volumes of the underlying foliation of the full CDT play a role of the sole degrees of freedom. Here we map this effective description onto a statistical-physics model of particles distributed on 1d lattice, with site occupation numbers corresponding to the three-volumes. We identify the emergence of the quantum de-Sitter universe observed in CDT with the condensation transition known from similar statistical models. Our model correctly reproduces the shape of the quantum universe and allows us to analytically determine quantum corrections to the size of the universe. We also investigate the phase structure of the model and show that it reproduces all three phases observed in computer simulations of CDT. In addition, we predict that two other phases may exist, depending on the exact form of the discretised effective action and boundary conditions. We calculate various quantities such as the distribution of three-volumes in our model and discuss how they can be compared with CDT.

Exploring Euclidean Dynamical Triangulations

(J. Laiho, U. Glasgow)

We investigate the phase diagram of (Euclidean) Dynamical Triangulations with a nontrivial local measure term. The possibility of defining gravity nonperturbatively via the asymptotic safety is studied in this model. Interesting similarities between this approach and causal dynamical triangulations are discussed.

A second-order phase transition in Causal Dynamical Triangulations

(S. Jordan, Radboud U., Nijmegen)

Covariant approaches to Quantum Gravity, such as Causal Dynamical Triangulations (CDT), generically need to implement a discretization of the system to make the path integrals well defined. This either leads to a discrete theory or to a lattice regularization of a continuum theory. We are interested in the question whether CDT in 3+1 dimensions possesses a continuum limit and thus fits into the latter category. One typically expects such a continuum limit to be found at a critical point in the phase diagram. Past searches for critical points in dynamically triangulated models have been mostly fruitless. In this talk I present results based on Monte Carlo measurements, which strongly support the existence of a second-order phase transition line in CDT in 3+1 dimensions.

Euclidean Dynamical Triangulations with a measure term

(A. Görlich, Niels Bohr I., Copenhagen)

We present recent results obtained for Euclidean Dynamical Triangulations with local measure term. We study the phase diagram of this model using non-degenerated triangulations and focus on properties of a possible new phase.

Some simple statistical mechanical systems on random infinite graphs

(B. Durhuus, U. Copenhagen)

The primary topic of the talk will be the Ising model in an external magnetic field on a generic random infinite tree. In particular, a demonstration of the absence of spontaneous magnetization will be given in this framework. Furthermore, we comment on a few other models of random graphs coupled to matter, including certain dimer models on trees and on 2D causal triangulations.

A combinatorial approach to 2D CDT with matter

(M. Atkin, U. Bielefeld)

A pressing problem in CDT is the development of better analytic tools. Even in two dimensions, analytical techniques for coupling CDT to matter are not as developed as one would like. I will discuss recent work in which the hard dimer model coupled to 2D CDT was solved using a bijection between CDT and labeled trees. We also discuss the relation to recent matrix model results and directions of future work.

The spectral dimension of two-dimensional causal triangulations

(T. Jonsson, U. Iceland, Reykjavik)

We review the proof of the recurrency of 2d CT and show how one can bound the spectral dimension by 2 from above with suitable estimates of the resistance of triangulations. We will furthermore discuss a potentially interesting observable for pure gravity: the spectral measure.

Scale dependent spectral dimension on random graphs

(J. Wheater, U. Oxford)

The phenomenon of scale dependent spectral dimension in systems described by an ensemble of random graphs will be discussed. The general principles will be explained together with some explicit examples, concluding with the ensemble of multigraphs obtained by radial reduction of the CDT which show similar properties to numerical simulations of the full CDT.

Field theory on multifractal spacetimes

(G. Calcagni, I. de Estructura de la Materia - CSIC, Madrid)

We review a recent proposal where spacetime is characterized by a multifractal geometry where dimension changes with the scale. This "anomalous" type of spacetime texture improves the UV behaviour of perturbative quantum field theories, including gravity. After introducing the basic ingredients, we discuss properties of quantum mechanics and field theories living thereon. The formalism has also connections with noncommutative geometry and other theories of quantum gravity based upon the renormalization group flow.

Branching and growth process for uniform infinite causal triangulations

(S. Zohren, Pontificia Universidade Catolica, Rio de Janeiro)

In the first part of the talk, we discuss the uniform measure on infinite causal triangulations (UICT) through a relation to size-biased critical Galton-Watson trees. It is shown how this relation can be used to obtain the continuum quantum Hamiltonian of CDT from analysing the convergence of the rescaled boundary length and area process to a diffusion process. In the second part, we introduce a growth process, which samples sections of UICT. This growth process is directly related to the loop equations of the matrix model for CDT and provides a mathematically precise formulation of the so-called peeling procedure. We conclude by discussing the relation between the two formulations.

Lifshitz gravity and Lifshitz holography

(P. Hořava, UC Berkeley)

Holographic duality with asymptotically Lifshitz boundary conditions has been often studied with various relativistic bulk models involving Einstein gravity with various additional ad hoc matter. In our recent work with Tom Griffin and Charles Melby-Thompson, we show that Lifshitz spacetimes are vacuum solutions of minimal nonprojectable HL gravity, and argue that this setting provides the minimal holographic dual capable of reproducing known structure of anisotropic Weyl anomalies. I will also comment on some intriguing features of black hole solutions in Lifshitz holography.

Spectral dimension as a probe of the ultraviolet continuum regime of Causal Dynamical Triangulations

(S. Weinfurtner, SISSA, Trieste)

We explore the ultraviolet continuum regime of causal dynamical triangulations, as probed by the flow of the spectral dimension. We set up a framework in which one can find continuum theories that can in principle fully reproduce the behaviour of the latter in this regime. In particular, we show that, in 2+1 dimensions, Hořava-Lifshitz gravity can mimic the flow of the spectral dimension in causal dynamical triangulations to high accuracy and over a wide range of scales. This seems to provide evidence for an important connection between the two theories.

Where has causal dynamically triangulated Hořava-Lifshitz gravity led us?

(J. Cooperman, UC Davis)

I apply the causal dynamical triangulations approach to Hořava-Lifshitz gravity, a recently proposed power-counting renormalizable yet unitary classical theory of gravity. Employing Markov chain Monte Carlo methods, I study the vacuum persistence amplitude of (2+1)-dimensional projectable Hořava-Lifshitz gravity for spherical spacetime topology. This amplitude exhibits three distinct phases of quantum spacetime geometry. I explore the physical properties of these phases and their relation to the analogous phases in the causal dynamical triangulations of Einstein gravity. These investigations of Hořava-Lifshitz gravity have motivated the adaptation of two standard techniques – the computation of transition amplitudes and the extraction of renormalization group flows – to the setting of causal dynamical triangulations. After introducing the methodologies behind these new tools, I present preliminary results of their implementation. These techniques also hold promise for elucidating the nature of gauge invariance in causal dynamical triangulations and for clarifying the relation of other quantum gravity programs to causal dynamical triangulations.

Discretization and determinism in string theory

(G. ‘t Hooft, Utrecht U.)

It is indicated how Quantum Mechanics can be emergent in String Theory. The quantized string theory seems to be mathematically equivalent to an entirely deterministic classical automaton. We show how this works in the bulk domain of the string's world sheet. We find moreover that the target space of the classical system is not the continuum but a space-time lattice. The lattice link's size is expressed in terms of the string's tension constant, alpha-prime. More difficult are the string's end points or periodic boundary conditions and the string interactions, but we indicate how these may be included in the picture that emerges.

The transfer matrix in four-dimensional CDT

(J. Gizbert-Studnicki, Jagiellonian U., Krakow)

The Causal Dynamical Triangulations model (CDT) in four dimensions was successful in spontaneously generating quantum fluctuations of the scale factor of the universe around the semi-classical de Sitter solution. There is evidence that fluctuations are governed by the discretization of the mini-superspace action. The form and the parameters of the action could be accessed indirectly by the measurement of the covariance matrix of volume fluctuations. We propose a new way to measure the effective action directly. This is done by introducing a simple phenomenological transfer matrix whose elements are labeled by the scale factor. The transfer matrix can be measured in Monte Carlo simulations. By a direct measurement we show that the mini-superspace action is valid not only in the large volume range but also in the small volume limit where discretization effects are strong. We compare the parameters of the effective action measured directly with those measured indirectly in our previous work.

Renormalization group flow in Causal Dynamical Triangulations

(A. Kreienbühl, Radboud U. Nijmegen)

In this talk I present preliminary results for the renormalization group flow in Causal Dynamical Triangulations. I explain which kinds of measurements are made and how they can be extracted from Monte Carlo data.

Quantum Einstein Gravity – a status report

(F. Saueressig, Mainz U.)

We give a pedagogical introduction to the Asymptotic Safety program in Quantum Gravity, based on the continuum formulation of the effective average action, before surveying the recent developments and current status of the field. On the fundamental level we will summarize our present understanding of the gravitational RG-flow with a focus on the evidence supporting the existence of the non-trivial renormalization group fixed point at the heart of Asymptotic safety. As a particular interesting example of RG-improvements, the multifractal structure of the emerging space-times is discussed in detail, since it constitutes a first link where Monte Carlo data can be compared with continuum results.

Coarse graining spin nets and spin foams: first results

(B. Dittrich, Perimeter I., Waterloo)

Spin foam models arise from a path integral quantization of gravity and spin net models are lower dimensional analogue models capturing the essential dynamical ingredients of spin foams. We aim at extracting the large-scale dynamics of these models via coarse graining. For the coarse graining of spin net models we can employ tensor network methods, which have been recently developed in

condensed matter and quantum information theory. – We will explain the physical motivation for these methods and present first numerical results that reveal the large-scale behaviour of a certain spin net model.

Causal Dynamical Triangulations and Trees

(T. Budd, Niels Bohr I., Copenhagen)

It has been known for some time in the mathematical literature that quadrangulated surfaces can be encoded in terms of labeled trees. Building on this correspondence I will present a simple model of random trees that includes in a natural way both (Euclidean) DT and CDT in two dimensions. A double scaling limit leads to continuum CDT with spatial topology change, providing an explicit realization of so-called generalized CDT. To emphasize the close friendship between CDT and trees I will show how an interesting identity for generalized CDT, which some time ago was painstakingly derived in the CDT setting, turns into a triviality when reinterpreted in terms of trees (or rather: planar maps).

Random tensor models in the large N limit

(V. Bonzom, Perimeter I., Waterloo)

Tensor models were proposed in 1991 by Ambjorn, Durhuus and Jonsson as generalized matrix models for Euclidean Dynamical Triangulations. Analytical progress only started two years ago and I will review the current status of the field: large N limit, continuum limit and critical behaviors. I want to show the richness of tensor models by also presenting a new Lie algebra generalizing the Virasoro algebra and a new large N limit, which certainly does not lead to branched polymers.

The mixed blessing of a foliation

(D. Benedetti, Albert Einstein I., Golm)

I will review some results (and some so far inconclusive efforts) from analytical studies of (C)DT, highlighting technical advantages and disadvantages brought in by the presence of a foliation. In particular, I will discuss matrix model techniques and their generalization (tensor models).