Quantum spacetime and the Renormalization Group

674. WE-Heraeus-Seminar

June 18 - 22, 2018
at the Physikzentrum Bad Honnef/Germany

WILHELM UND ELSE
HERAEUS-STIFTUNG

Introduction

The Wilhelm und Else Heraeus-Stiftung is a private foundation which supports research and education in science, especially in physics. A major activity is the organization of seminars. By German physicists the foundation is recognized as the most important private funding institution in their fields. Some activities of the foundation are carried out in cooperation with the German Physical Society (Deutsche Physikalische Gesellschaft).

Aims and scope of the 674. WE-Heraeus-Seminar:

Quantum Gravity is a very active area of theoretical research into the largely unknown realm of physics beyond the Standard Model. Recent years have seen a growing awareness throughout the quantum gravity community that Renormalization Group techniques may constitute a crucial element in unraveling the microscopic quantum structure of spacetime. Nowadays, the development of these ideas have reached a stage where, firstly, a cross-fertilization between different quantum gravity programs will be fruitful and, secondly, some programs may even be able to connect the microscopic quantum- gravity regime to physics at energy scales accessible by observations. The last years have also seen the development of novel ideas how imprints of (asymptotically safe) quantum gravity could become detectable in particle physics, cosmology and astrophysics which provide a fruitful basis for further exploration.

The main goals of the workshop are

- contributing to sharpening the major conceptual and technical open questions of the field and identifying routes to answer these.
- triggering new collaborations, in particular between researchers from neighboring communities, enabling a fruitful exchange of ideas and transfer of knowledge.
- providing in particular young researchers with a comprehensive overview of the most pressing questions in the field, motivating them to tackle these from new angles.
- producing novel ideas how to bridge the gap between a fundamental theory of quantum gravity and observations and triggering new developments towards observational tests of quantum gravity.

Scientific Organizers:

Dr. Astrid Eichhorn	Universität Heidelberg, Germany E-mail: eichhorn@thphys.uni-heidelberg.de
Dr. Dario Benedetti	Université Paris-Sud, France E-mail: dario.benedetti@th.u-psud.fr
Dr. Frank Saueressig	Radboud University, The Netherlands E-mail: f.saueressig@science.ru.nl

Program

Program

Sunday, June 17, 2018

17:00 – 21:00	Registration	
18:00	*BUFFET SUPPER and get-together*	

Monday, June 18, 2018

08:00	*BREAKFAST*	
08:50 – 09:00	Scientific organizers	**Welcome & Opening**
09:00 – 09:35	Christof Wetterich	**Graviton fluctuations erase the cosmological constant**
09:35 – 10:10	Martin Reuter	**Entanglement entropy, asymptotic safety and the background fractal**
10:10 – 10:45	Benjamin Bahr	**Exploring the RG flow of truncated spin foam models**
10:45 – 11:15	*COFFEE & TEA*	
11:15 – 11:50	Tim Koslowski	**Optimizing the FRGE in matrix and tensor models**
11:50 – 12:25	Jack Laiho	**Euclidean dynamical triangulations**
12:25 – 12:35	**Conference photo** (in the front of the lecture hall)	
12:35	*LUNCH (followed by coffee and/or tea)*	

Program

Monday, June 18, 2018

14:30 – 15:30	Andrei Barvinsky	**Renormalization of gauge theories in the background-field approach**
15:30 – 16:05	Stefan Lippoldt	**Renormalized functional renormalization group**
16:05 – 16:35	*COFFEE & TEA*	
16:35 – 17:10	**Poster flash talks**	
17:10 – 18:00	**Poster session**	
18:30	*DINNER*	

Program

Tuesday, June 19, 2018

08:00	*BREAKFAST*	
09:00 – 10:00	N. Emil J. Bjerrum-Bohr	**General relativity from particle scattering**
10:00 – 10:35	Jan M. Pawlowski	**On asymptotic safety in matter-gravity systems**
10:35 – 11:05	*COFFEE & TEA*	
11:05 – 11:40	Dario Ambjorn	**Field renormalization in QG**
11:40 – 12:15	Bianca Dittrich	**Bootstrapping quantum granity**
12:15 – 12:50	**Discussion**	
12:50	*LUNCH (followed by coffee and/or tea)*	
14:30 – 15:30	Kellogg Stelle	**Black holes in higher derivative gravity**
15:30 – 16:05	Alessia Platania	**Towards self-consistent black hole solutions in asymptotically safe gravity**
16:05 – 16:35	*COFFEE & TEA*	
16:35 – 18:00	**New collaborations**	
18:00 – 19:00	**Poster session**	
19:00	*DINNER*	

Program

Wednesday, June 20, 2018

08:00	*BREAKFAST*	
09:00 – 10:00	Stefan Weinzierl	**Amplitudes in Yang-Mills theory and gravity**
10:00 – 10:35	Sylvain Carrozza	**Large N fermionic tensor models in d = 2**
10:35 – 11:05	*COFFEE & TEA*	
11:05– 11:40	Tim Morris	**Perturbatively renormalizable quantum gravity**
11:40 – 12:15	Senarath de Alwis	**Exact RG floiw equations and quantum gravity**
12:15 – 12:50	Carlo Pagani	**Scaling properties of geometric operators in the asymptotic safety scenario for quantum gravity**
12:50	*LUNCH (followed by coffee and/or tea)*	
14:30 – 18:00	**Excursion**	
18:00	*DINNER*	

Program

Thursday, June 21, 2018

08:00	*BREAKFAST*	
09:00 – 10:00	Gudrun Hiller	**Directions for model building from asymptotic safety**
10:00 – 10:35	Francesco Sannino	**Charting fundamental interactions**
10:35 – 11:05	*COFFEE & TEA*	
11:05– 11:40	Holger Gies	**Curvature bound from gravitational catalysis**
11:40 – 12:15	Judah Unmuth-Yockey	**Geometric fermions and lattice gravity**
12:15 – 12:50	Daniel Litim	**Asymptotic safety of gauge theories**
12:50	*LUNCH (followed by coffee and/or tea)*	

Program

Thursday, June 21, 2018

14:30 – 15:00	Benjamin Knorr	**Towards reconstructing the quantum effective action of gravity**
15:00 – 15:30	Aaron Held	**The status of asymptotic safety for quantum gravity and the standard model**
15:30 – 16:05	Alfio Maurizio Bonanno	**The final state of BH evaporation in AS**
16:05 – 16:35	*COFFEE & TEA*	
16:35 – 17:10	Joseph Ben Geloun	**A renormalizable SYK-type tensor field theory**
17: 10 – 17:25	Stefan Jorda	**About the Wilhelm and Else Heraeus-Foundation**
17:25 – 19:00	**Discussion & new collaborations**	
19:00	*HERAEUS DINNER* *(social event with cold & warm buffet and complimentary drinks)*	

Program

Friday, June 22, 2018

08:00	*BREAKFAST*	
09:00 – 09:35	Daniele Oriti	**The continuum limit of discrete quantum gravity via group field theory renormalization**
09:35 – 10:10	Renate Loll	**Quantum gravity and the quest for observables**
10:10 – 10:45	Roberto Percacci	**Gravity with less or more variables**
10:45 – 11:15	*COFFEE & TEA*	
11:15– 12:15	**Two poster prize talks**	
12:15 – 12:45	**Roadmap: Fundamental aspects**	
12:45 – 13:15	**Roadmap: Phenomenological implications**	
13:15 – 13:30	Scientific organizers	**Closing**
13:30	*LUNCH (followed by coffee and/or tea)*	

End of the seminar and departure

NO DINNER for participants leaving on Saturday morning

Posters

Posters

Yuri Bonder	**Quantum gravity phenomenology: A systematic approach**
Marios Bounakis	**Gravitational corrections to Higgs potentials**
Lennart Brocki Josua Unger	**Quantum ergosphere and brick wall entropy**
B. Alicia Castro Bermúdez	**CDT matrix model and FRGE**
Joshua H. Cooperman	**Tracing renormalization group trajectories with the spectral dimension in causal dynamical triangulations**
Gustavo P. de Brito	**Relating renormalizability and unitarity with the absence of Newtonian singularities in higher-derivative models of quantum gravity**
Tobias Denz	**Real-time graviton spectral functions**
Kevin Falls	**Flow equations and the path integral measure**
Marco Finocchiaro	**Radiative corrections in GFT models for QG**
Gabriele S.J. Gionti	**Hamiltonian analysis of asymptotic safe gravity**
Lisa Glaser	**Matter in causal sets**
Mattew P. Kellett	**Renormalization group properties of the conformal mode of a torus**

Posters

Isha Kotecha	**Statistical equilibrium in group field theory**
Johannes Lumma	**Universality classes for the continuum limit in rank-3-tensor models**
Riccardo Martini	**A curvature bound from gravitational catalysis**
Gustavo Medina Vazquez	**Conformal window of asymptotic safety at NNLO**
Carlos M. Nieto Guerrero	**Split Weyl transformations in quantum gravity**
Robin Ooijer	**Asymptotically safe phenomenology beyond RG improvements**
Antonio D. Pereira	**Functional renormalization group and tensorial group field theories: recent developments**
Andreas Pithis	**Phase transitions in GFT: The Landau perspective**
Marco Piva	**The ultraviolet behavior of quantum gravity**
Carlos I. Pérez Sánchez	**The pyramid of analytic Schwinger-Dyson equations for complex and SYK-like tensor models**
Giovanni Rabuffo	**Renormalization in symmetry reduced spin foams**
Manuel Reichert	**Asymptotic safety of gravity-matter systems**
Chris Ripken	**Catching ghosts: Reflection positivity in higher derivative scalar theories**

Posters

Marc Schiffer	**Ultraviolet dynamics of fermions and gravity**
Samuele Silveravalle	**The phase diagram of asymptotically safe black holes**
Sebastian Steinhaus	**Emergence of spacetime in a restricted spin-foam model**
Christian F. Steinwachs	**Quantum properties of f(R) gravity**
Tom Steudtner	**Fixed points in simple gauge-Yukawa theories**
Dennis Stock	**Quantum-improved Schwarzschild-(A)dS and Kerr-(A)dS spacetimes**
Anderson A. Tomaz	**Asymptotic safety and field parametrization dependence in f(R) truncation**
Arthur Vereijken	**Relating different regularization schemes in asymptotic safety**
Fleur Versteegen	**Spatial distances in conformally flat causal sets**
Masatoshi Yamada	**Quantum gravity effects on Majorana fermion**

Abstracts of Talks

(in chronological order)

Graviton fluctuations erase the cosmological constant

Christof Wetterich

Universität Heidelberg, Institut für Theoretische Physik, Germany

Graviton fluctuations induce strong non-perturbative infrared renormalization effects for the cosmological constant. In flat space the functional renormalization flow drives a positive cosmological constant to zero. We propose a simple computation of the graviton contribution to the flow of the effective potential for scalar fields. Within variable gravity, with effective Planck mass proportional to a scalar field, we find that the potential increases asymptotically at most quadratically with the scalar field. With effective Planck mass proportional to the scalar field, the solutions of the derived cosmological equations lead to an asymptotically vanishing cosmological “constant” in the infinite future, providing for dynamical dark energy in the present cosmological epoch. Beyond a solution of the cosmological constant problem, our simplified computation also entails a sizeable positive graviton-induced anomalous dimension for the quartic Higgs coupling in the ultraviolet regime, as required for the successful prediction of the Higgs boson mass within the asymptotic safety scenario for quantum gravity.

Entanglement Entropy, Asymptotic Safety and the Background Fractal

C. Pagani and M. Reuter

Institute of Physics, University of Mainz, D-55099 Mainz, Germany

E-mail: reuter@thep.physik.uni-mainz.de

The entanglement entropy of matter fields living on the effectively fractal spacetimes originating from asymptotically safe quantum gravity is discussed. It is shown that, at least within a test field approximation, Asymptotic Safety cures the notorious quadratic divergences occurring in standard calculations of the entanglement entropy. A number of further general results obtained by applying the test field approximation to self-consistent fractal spacetime backgrounds will be discussed as well.

References

[1] C. Pagani and M. Reuter, arXiv: 1804.02162
[2] C. Pagani and M. Reuter, in preparation

Exploring the RG flow of truncated Spin Foam Models

B. Bahr

II. Institute for Theoretical Physics
University Hamburg
Luruper Chaussee 149
22761 Hamburg
E-mail: benjamin.bahr@desy.de

Advances in the treatment of the discrete path integral for quantum gravity in the Loop Gravity context allow to explore the renormalization group flow of these models. By switching on and off specific degrees of freedom, and a consequent projection of the RG flow, one can investigate the phase diagram, and gain insight into the properties of LQG and Spin Foam models. In my talk, I will demonstrate how one can numerically find indications for a non-Gaussian fixed point of the theory in the UV. I will also discuss the diverging volume fluctuations, which are an indication for a restoration of broken diffeomorphism-invariance at that point.

References

[1] B. Bahr, S. Steinhaus, Phys.Rev.Lett. **117** 141302 (2017)
[2] B. Bahr, G. Rabuffo, S. Steinhaus, arXiv:1804.00023

Optimizing the FRGE in Matrix and Tensor Models

T. Koslowski[1]

[1]*Instituto de Ciencias Nucleares, UNAM, Mexico City, Mexico*
E-mail: koslowski@nucleares.unam.mx

The Functional Renormalization Group Equation (FRGE) can be applied to matrix models that describe lattice quantum gravity in two dimensions and tensor models which are candidates for lattice quantum gravity in higher dimensions. In this talk I discuss the FRGE setup for these models and show that the FRGE is a very effective tool to find possible continuum limits as fixed points of the RG flow. I will then discuss how the FRGE can be used to obtain precision results for the critical behavior. One way to enhance precision is through optimization of the RG scheme which I will discuss in the context of matrix models.

References

[1] A. Eichhorn, T. Koslowski, **Phys.Rev. D88 (2013) 084016**

[2] A. Eichhorn, T. Koslowski, **Phys.Rev. D90 (2014) no.10, 104039**

Euclidean Dynamical Triangulations

<u>J. Laiho</u> and S. Bassler

Syracuse University
E-mail: jwlaiho@syr.edu

We review the evidence for asymptotic safety coming from Euclidean dynamical triangulations (EDT), and we discuss the similarities and differences between our results and those coming from the functional renormalization group and from causal dynamical triangulations. The prospects for adding matter are also discussed.

Renormalization of gauge theories in the background-field approach

A.O.Barvinsky

Theory Department, Lebedev Physics Institute, Russia
E-mail: barvin@td.lpi.ru

Using the background-field method we demonstrate the Becchi-Rouet-Stora-Tyutin (BRST) structure of counterterms in a broad class of gauge theories. Put simply, we show that gauge invariance is preserved by renormalization in local gauge field theories whenever they admit a sensible background-field formulation and anomaly-free path integral measure. This class encompasses Yang--Mills theories (with possibly Abelian subgroups) and relativistic gravity, including both renormalizable and non-renormalizable (effective) theories. Our results also hold for non-relativistic models such as Yang--Mills theories with anisotropic scaling or Horava gravity. They strengthen and generalize the existing results in the literature concerning the renormalization of gauge systems. Locality of the BRST construction is emphasized throughout the derivation. We illustrate our general approach with several explicit examples.

Renormalized Functional Renormalization Group

S. Lippoldt[1]

[1]Institut für Theoretische Physik, Universität Heidelberg,
Philosophenweg 16, 69120 Heidelberg, Germany
E-mail: s.lippoldt@thphys.uni-heidelberg.de

We present a new version of the effective average action together with its flow equation. The construction entails in particular the consistency of fluctuation field and background field equations of motion, even for finite renormalization group scales. Here we focus on the quantum gravity application, while the generalization of this idea to gauge theories is obvious. Our approach has immediate impact on the background field approximation, which is the most prominent approximation scheme within the asymptotic safety scenario. We outline the calculation of quantum gravity observables from first principles using the new effective average action.

General relativity from Particle Scattering

N. Emil J. Bjerrum-Bohr

Niels Bohr International Academy and Discovery Center The Niels Bohr Institute, Blegamsvej 17, DK-2100

We will review how general relativity consistently can be quantized as an effective field theory. We will discuss recent progress in efficient computation of scattering amplitudes and review how gravity amplitudes can be factorized into products of gauge theory amplitudes and straightforwardly computed using on-shell helicity methods. We will also discuss how to use scattering amplitudes to derive results in general relativity, exemplified by the phenomenon of light bending near massive objects.

References

1) N. E. J. Bjerrum-Bohr, B. R. Holstein, J. F. Donoghue, L. Planté and P. Vanhove, ``**Illuminating Light Bending,"** PoS CORFU (2017) 077 doi:10.22323/1.292.0077 [arXiv:1704.01624 [gr-qc]].

2) N. E. J. Bjerrum-Bohr, J. F. Donoghue, B. R. Holstein, L. Plante and P. Vanhove, ``**Light-like Scattering in Quantum Gravity,"** JHEP **1611** (2016) 117 doi:10.1007/JHEP11(2016)117 [arXiv:1609.07477 [hep-th]].

On asymptotic safety in matter-gravity systems

Astrid Eichhorn[1], Kevin Falls[1], Daniel Litim[2], Jan M. Pawlowski[1], Manuel Reichert[1], Marc Schiffer[1]

[1]Institut für Theoretische Physik, Heidelberg University, Heidelberg, Germany
[1]Dep. Of Physics and Astronomy, University of Sussex, Brighton, BN1 9QH, U.K.

In this talk recent progress on the asymptotic safety scenario in matter-quantum gravity systems is discussed. Results concern the stability of general matter-gravity systems in the absence of marginal operators [4], the solution of the quantum equations of motion of systems with fully curvature-dependent couplings [3], as well as the effective universality of avatars of the Newton coupling in the vicinity of the asymptotically safe UV fixed point of matter-gravity systems [1,2].

References

[1] Astrid Eichhorn, Jan M. Pawlowski, Manuel Reichert, Marc Schiffer, **work under completion**

[2] Astrid Eichhorn, Peter Labus, Jan M. Pawlowski, Manuel Reichert, **arXiv:1804.00012**

[3] Nicolai Christiansen, Kevin Falls, Jan M. Pawlowski, Manuel Reichert, **Phys.Rev. D97 (2018) no.4, 046007**

[4] Nicolai Christiansen, Daniel F. Litim, Jan M. Pawlowski, Manuel Reichert, **Phys.Rev. D97 (2018) no.10, 106012**

Field renormalization in QG

Jan Ambjorn

The Niels Bohr Institute, Copenhagen
email: ambjorn@nbi.dk

While field renormalization as we know it from continuum quantum field theory is also present and unproblematic in lattice quantum field theory, it seems to be much more subtle in lattice quantum gravity and lattice string theory. I will discuss the implications of this for a world where geometry is quantized.

Bootstrapping quantum granity

Bianca Dittrich

Perimeter Institute for Theoretical Physics, Waterloo, Canada

Black Holes in Higher Derivative Gravity

K.S. Stelle

Theoretical Physics Group
Imperial College London
E-mail: k.stelle@imperial.ac.uk

Quantum corrections to the gravitational action in four spacetime dimensions generically include terms quadratic in the curvature tensor. Moreover, these terms are distinguished with respect to other higher corrections in that their inclusion renders the d=4 theory renormalisable. The talk will review the occurrence of new types of black hole solutions in the enhanced theory as well as wormholes and horizonless solutions. Thermodynamic implications for the relative stability of classic Schwarzschild as compared to new black-hole solutions will also be discussed.

References

[1] H. Lu, A. Perkins, C.N. Pope and K.S. Stelle, Phys.Rev.Lett. 114 (2015), 171601
[2] H. Lu, A. Perkins, C.N. Pope and K.S. Stelle, Phys.Rev. D92 (2015), 124019
[3] H. Lu, A. Perkins, C.N. Pope and K.S. Stelle, Phys.Rev. D96 (2017), 046006

Towards self-consistent black hole solutions in Asymptotically Safe Gravity

A. Platania[1]

[1]*Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany*
E-mail: platania@thphys.uni-heidelberg.de

The existence of spacetime singularities marks the breakdown of the classical description of gravity within the framework of General Relativity. The occurrence of such singularities is encountered in regimes where quantum fluctuations of spacetime can no longer be neglected and it is expected that a quantum theory for the gravitational interaction will shed some light on this problem.
In this talk I will discuss the modifications of classical black hole solutions induced by Asymptotically Safe Gravity. The leading quantum gravitational effects can be taken into account by means of an iterative procedure. The first step of this iteration, i.e. the "RG-improvement" of classical solutions, shows that the anti-screening behavior of the Newton's coupling makes the singularity much milder. Recent developments on improving this description will be discussed. In particular it will be shown that, under certain assumptions, the sequence of RG-improvements rapidly converges to a (self-consistent) black hole solution which can be determined exactly.

Amplitudes in Yang-Mills theory and gravity

Stefan Weinzierl

Institut für Physik, Johannes Gutenberg-Universität Mainz
weinzierl@uni-mainz.de

Albeit Yang-Mills theory and gravity appear to be unrelated theories, there are interesting relations between the (tree-level) scattering amplitudes of the two theories.
In this talk I will discuss the connection between scattering amplitudes in perturbative Yang-Mills theory and perturbative quantum gravity.

Large N fermionic tensor models in d = 2

D. Benedetti[1], S. Carrozza[2], R. Gurau[3], A. Sfondrini[4]

[1]Laboratoire de Physique Théorique, Orsay, France
[2]Perimeter Institute for Theoretical Physics, Waterloo, Canada
[3]Ecole Polytechnique, Palaiseau, France
[4]ETH, Zurich, Switzerland
E-mail: sylvain.carrozza@perimeterinstitute.ca

Tensor models are generalizations of matrix models which describe the dynamics of fields with $r > 2$ indices. As discovered some years ago (see [1] and references therein), they enjoy a large N expansion which is (perhaps surprisingly) much simpler than the large N expansion of matrix models. It is dominated by the so-called *melonic* family of Feynman diagrams, which can sometimes be resumed explicitly. This has recently led to the introduction of fermionic quantum many-body models [2,3] governed by: 1) a solvable large N limit [4,5]; and 2) an emergent conformal symmetry in the strongly coupled regime, in exact analogy with the celebrated Sachdev-Ye-Kitaev (SYK) model (see [6] and references therein). I will review aspects of these developments and of their relevance to quantum gravity, in the context of holography. I will then focus on a generalization to quantum field theory in $d = 2$ [7] (see also [8]), emphasizing the differences and similarities with [3]. Interestingly, the structure of the renormalization group of this model leads to the identification of a weakly coupled infrared fixed point in $d = 2 - \varepsilon$ for small ε, which is conjectured to govern the strongly coupled SYK-like phase of [3] in the limit of ε going to 1.

References

[1] R. Gurau, *Random Tensors*, Oxford University Press (2016)

[2] E. Witten, *An SYK-like model without disorder*, arXiv:1610.09758 [hep-th]

[3] I. Klebanov, G. Tarnopolsky, *Uncolored Random Tensors, Melon Diagrams, and the SYK Models*, Phys. Rev. D 95, 046004 (2017)

[4] R. Gurau, *The 1/N expansion of colored tensor models,* Annales Henri Poincare 12 (2011) 829-847

[5] S. Carrozza, A. Tanasa, *O(N) random tensor models*, Lett.Math.Phys. 106 (2016) no.11, 1531-1559

[6] J. Maldacena, D. Stanford, *Remarks on the Sachdev-Ye-Kitaev model*, Phys.Rev. D94 (2016) no.10, 106002

[7] D. Benedetti, S. Carrozza, R. Gurau, A. Sfondrini, *Gross-Neveu Tensor Models,* JHEP 1801 (2018) 003

[8] S. Prakash, R. Sinha, *A Complex Fermionic Tensor Model in d Dimensions,* JHEP 1802 (2018) 086

Perturbatively renormalizable quantum gravity

Tim R. Morris

University of Southampton, Southampton, U.K.
E-mail: t.r.morris@soton.ac.uk

The Wilsonian renormalization group (RG) requires Euclidean signature. The conformal factor of the metric then has a wrong-sign kinetic term, which has a profound effect on its RG properties. In particular around the Gaussian fixed point, it supports a Hilbert space of renormalizable interactions involving arbitrarily high powers of the gravitational fluctuations. These interactions are characterised by being exponentially suppressed for large field amplitude, perturbative in Newton's constant but non-perturbative in Planck's constant. By taking a limit to the boundary of the Hilbert space, diffeomorphism invariance is recovered whilst retaining renormalizability. Thus the so-called conformal factor instability points the way to constructing a perturbatively renormalizable theory of quantum gravity.

Exact RG Flow Equations and Quantum Gravity

S. P. de Alwis

Physics Department, University of Colorado,
Boulder, CO 80309 USA

Abstract

We propose an RG flow equation for the Wilsonian action that is close in spirit to the Polchinski equation, to study Weinberg's asymptotic safety program for defining quantum gravity. Using this we find that the cosmological constant recieves contributions (apart from the cosmological and Einstein-Hibert terms) only from higher derivative terms (i.e. terms such as $R\Box^n R$) in the effective Wilsonian action. In pure gravity our argument also implies that just considering $f(R)$ theories will miss this effect. We expect similar results for the Einstein-Hilbert term as well.

Scaling properties of geometric operators in the Asymptotic Safety scenario for Quantum Gravity

M. Becker[1], C. Pagani[1], and M. Reuter[1]

[1]Institut für Physik (WA THEP), Johannes-Gutenberg-Universität, Staudingerweg 7, 55099 Mainz / Germany
E-mail: capagani@uni-mainz.de

We consider the scaling properties of geometric operators such as parametrized curves, surfaces, and volumes in the context of the Asymptotic Safety scenario for Quantum Gravity. We also discuss the scaling properties of geodesics and their possible role in the Asymptotic Safety scenario.

References

[1] C. Pagani and M. Reuter, Phys. Rev. D **95**, 066002 (2017).
[2] M. Becker, C. Pagani and M. Reuter, in preparation.

Directions for model building from asymptotic safety

A.Bond, G. Hiller, D.Litim and K.Kowalska

Building on recent advances in the understanding of gauge-Yukawa theories we explore possibilities to UV-complete the Standard Model in an asymptotically safe manner. Minimal extensions are based on a large flavor sector of additional fermions coupled to a scalar singlet matrix field. We find that asymptotic safety requires fermions in higher representations of $SU(3)C \times SU(2)L$. Possible signatures at colliders are worked out and include *R*-hadron searches, diboson signatures and the evolution of the strong and weak coupling constants. We discuss variants including U(1)-groups, that appear in the Standard Model, and are common to its extensions.

based on the paper

JHEP 1708 (2017) 004

by A.Bond, GH, D.Litim and K.Kowalska

Charting Fundamental Interactions

Francesco Sannino

University of Southern Denmark
Odense, Denmark

I'll review the state of the art.

Curvature bound from gravitational catalysis

Holger Gies and **Riccardo Martini**

Theoretisch-Physikalisches Institut, FSU Jena, Germany
E-mail: holger.gies@uni-jena.de

We determine bounds on the curvature of local patches of spacetime from the requirement of intact long-range chiral symmetry. The bounds arise from a scale-dependent analysis of gravitational catalysis and its influence on the effective potential for the chiral order parameter, as induced by fermionic fluctuations on a curved spacetime with local hyperbolic properties. The bound is expressed in terms of the local curvature scalar measured in units of a gauge-invariant coarse-graining scale. We argue that any effective field theory of quantum gravity obeying this curvature bound is safe from chiral symmetry breaking through gravitational catalysis and thus compatible with the simultaneous existence of chiral fermions in the low-energy spectrum. With increasing number of dimensions, the curvature bound in terms of the hyperbolic scale parameter becomes stronger. Applying the curvature bound to the asymptotic safety scenario for quantum gravity in four spacetime dimensions translates into bounds on the matter content of particle physics models.

References

[1] H. Gies and R. Martini, Phys. Rev. D 97, 085017 (2018), arXiv:1802.02865 [hep-th]

Geometric fermions and lattice gravity

S. Bassler, S. Catterall, R. Jha, J. Laiho, and J. Unmuth-Yockey

Syracuse University, Syracuse NY, U.S.A.
E-mail: jfunmuth@syr.edu

Using the lattice analogues of the exterior calculus and facts from homology theory, we are able to construct boundary and co-boundary operators which act on simplices. From these we construct the Kähler-Dirac operator whose square gives the lattice Laplacian for all simplices. We present methodology concerning their construction, and results on the spectrum and quenched correlation functions from these operators when applied to lattice gravity configurations.

Asymptotic safety of gauge theories

Daniel F. Litim

University of Sussex, Department of Physics and Astronomy, Brighton / UK

Towards reconstructing the quantum effective action of gravity

Benjamin Knorr and Frank Saueressig

Institute for Mathematics, Astrophysics and Particle Physics (IMAPP), Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

Starting from a parameterisation of the quantum effective action for gravity we calculate correlation functions for observable quantities. The resulting templates allow to reverse-engineer the couplings describing the effective dynamics from the correlation functions. Applying this new formalism to the autocorrelation function of spatial volume fluctuations measured within the Causal Dynamical Triangulations program suggests that the corresponding quantum effective action consists of the Einstein-Hilbert action supplemented by a non-local interaction term. We expect that our matching-template formalism can be adapted to a wide range of quantum gravity programs allowing to bridge the gap between the fundamental formulation and observable low-energy physics.

The poster presents the results of [1].

References

[1] B. Knorr and F. Saueressig, arXiv:1804.03846

The status of asymptotic safety for quantum gravity and the Standard Model

Aaron Held

Universität Hamburg, Institut für Theoretische Physik, Heidelberg/Germany

In the absence of intermediate scales, Renormalization Group flows provide an unobstructed link between Planck- and electroweak-scale physics. This could allow to test implications of asymptotically safe quantum gravity at accessible energy scales. The requirement of phenomenological viability puts significant constraints on the microscopic gravitational parameter space. Moreover, the paradigm of asymptotic safety could surpass the predictive power of the Standard Model and retrodict the values of gauge, Yukawa and scalar-quartic couplings from first principles in a microscopic model including quantum gravity. I will present the underlying mechanisms and discuss recent evidence in favor of the phenomenological viability and increased predictivity of this framework.

The final state of BH evaporation in AS

A. Bonanno[1] and S. Silveravalle[2]

[1]INAF – INFN Catania, Italy
[2] University Milano Bicocca, Milano, Italy
E-mail: alfio.bonanno@inaf.it

The phase diagram of the recently discovered Non-Schwarzschild BH is discussed according the Asymptotically Safe Scenario. We show that in the limit of vanishing Hawking-Zeldovich temperature the spacetime approach a "triple point" in the space of possible solutions. We argue by means of thermodynamic considerations that this configuration characterizes the final state of the BH evaporation.

A Renormalizable SYK-type Tensor Field Theory

J. Ben Geloun[1] **and V. Rivasseau**[2]

[1]*Laboratoire d'Informatique de Paris Nord, Villetaneuse, Univ. Paris Nord, France*
[2] *Laboratoire de Physique Theorique d'Orsay, Univ. Paris Sud, France,*
E-mail: bengeloun@lipn.univ-paris13.fr, Vincent.Rivasseau@th.u-psud.fr

A simple field theoretic version of the Carrozza-Tanasa-Klebanov-Tarnolposki (CTKT) tensor model will be discussed. It gives a familiar interpretation of abstract modes of the SYK or CTKT model in terms of momenta. The propagator of the model is that of the usual Fermionic condensed matter models, i.e. with a spherical Fermi surface, while the interaction is kept nonlocal in the form of the CTKT model. Using a multi-scale analysis, we extract the power counting theorem for high modes (UV) which led us to the proof that the model is just renormalizable to all orders of perturbation theory in the UV regime.

The continuum limit of discrete quantum gravity via group field theory renormalization

Daniele Oriti

Albert Einstein Institute, Potsdam, Germany
E-mail: daniele.oriti@aei.mpg.de

This talk will present an introduction to group field theory renormalization, clarifying the motivations and potential impact of work in this direction. While avoiding discussing in detail specific examples of group field theory models analysed in this context, it will focus on the general set-up of renormalization analysis of these models and on key technical steps that need to be tackled. It will also give an overview of the main results obtained in this area of research in the last 10 years.

Quantum Gravity and the Quest for Observables

Renate Loll[1]

[1]IMAPP, Radboud University, Nijmegen, The Netherlands

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 spacetimes. I will argue that a key reason for why this approach has advanced considerably is its elegant resolution of the vexed issue of dealing with diffeomorphism symmetry in the full, background-free quantum theory. This has enabled the concrete computation in CDT of geometric observables in a highly nonperturbative, Planckian regime, which are a prerequisite to making any meaningful contact with phenomenology.

The theoretical challenge in this and other approaches to quantum gravity is to enlarge the arsenal of suitable observables, which on the one hand allow us to characterize "quantum geometry" quantitatively, and on the other hand can be extrapolated or scaled to semi-classical and cosmological regimes. I will use the example of the recently introduced notion of quantum Ricci curvature to illustrate these points.

References

[1] N. Klitgaard, R. Loll: Introducing quantum Ricci curvature, Phys. Rev. D97 (2018) 046008 [arXiv:1712.08847]

[2] N. Klitgaard, R. Loll: Implementing quantum Ricci curvature, Phys. Rev. D97 (2018) 106017 [arXiv:1802.10524]

Gravity with less or more variables

R. Percacci[1]

[1] SISSA, Via Bonomea 265, 34134 Trieste, Italy

I will review various formulations of gravity, their pros and cons. Some are just different off shell extensions of Einstein's theory. It is expected that they remain equivalent also at the quantum level.
Other formulations that involve an independent connection are physically inequivalent. They naturally lead to ways of unifying gravity with all the other interactions. I will review what little is known of such unified theories.

References

[1] S. Gielen, R. de León Ardón, R. Percacci, "Gravity with more or less gauging" arxiv:1805.11626 [gr-qc]

[2] .R. de León Ardón, N. Ohta, R. Percacci, "Path integral of unimodular gravity", Phys.Rev. D97 (2018) no.2, 026007 arXiv:1710.02457 [gr-qc]

Abstracts of Posters

(in alphabetical order)

Quantum Gravity Phenomenology: A systematic approach

Y. Bonder[1]

[1]Instituto de Ciencias Nucleares, Universidad Nacional Autonoma de Mexico, Ciudad de Mexico, Mexico

Quantum Gravity Phenomenology (QGP) is a program in which the main goal is to find empirical clues of quantum gravity. I will present a systematic "algorithm" for QGP where the key step is to use a general parametrization describing all the possible effects associated with violating a principle of conventional physics. This step allows one to perform self-consistency tests and to compare bounds obtained with different experiments. As an example, I will discuss the phenomenological program to test local Lorentz invariance.

References

1. Y. Bonder, arXiv:1704.02404

Gravitational corrections to Higgs potentials

Marios Bounakis and **Ian G. Moss**

School of Mathematics, Statistics and Physics, Newcastle University

Understanding the Higgs potential at large field values corresponding to scales in the range above 10^{10} GeV is important for questions of vacuum stability, particularly in the early universe where survival of the Higgs vacuum can be an issue. In this work we show that the Higgs potential can be derived in a way which is independent of the conformal frame for the spacetime metric. Questions about vacuum stability can therefore be answered unambiguously. We show that frame independence leads to new relations between the beta functions of the theory and we give improved limits on the allowed values of the Higgs curvature coupling for stability.

	Jordan frame	Einstein frame	Covariant
$16\pi^2\beta_\xi$	$(6\xi - 1)\lambda$	$-\lambda$	2λ
$16\pi^2\beta_{\mu^2}$	$6\mu^2\lambda$	$6(\mu^2 + \xi R)\lambda$	$6(\mu^2 + \xi R)\lambda - 3\lambda R$
$16\pi^2(\beta_{\mu^2} + R\beta_\xi)$	$6(\mu^2 + \xi R)\lambda - \lambda R$	$6(\mu^2 + \xi R)\lambda - \lambda R$	$6(\mu^2 + \xi R)\lambda - \lambda R$

Table 1: $\beta-$functions for the curvature coupling and the mass of a gravity coupled scalar field at leading order for small R.

The calculation results in the emergence of the effective mass $m_{eff}^2 = \mu^2 + 12\xi H^2$, with ξ being the curvature-Higgs coupling and H the expansion rate, given from the Ricci scalar on a four-dimensional sphere as $R = 12H^2$. This effective mass is invariant of the conformal frame, resulting in it being meaningful concerning questions of vacuum stability, when the non-covariant methodology is adopted. The running of the effective mass squared, as shown in Fig.1, is dependent on its initial value. For small enough values, the effective mass becomes negative leading to further implications on Higgs stability and result in the emergence of a second maximum in the potential.

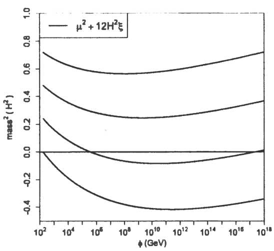


Figure 1: The running of the effective mass squared μ_{eff}^2, with an initial value of $\mu^2(170\text{GeV}) = 0$.

References

Bounakis, M. & Moss, I.G. J. High Energ. Phys. (2018) 2018: 71.

Quantum Ergosphere and Brick Wall Entropy

L. Brocki[1] and J. Unger[1]
[1] *Institute for Theoretical Physics University of Wrocław, Pl. Maksa Borna 9, Pl–50-204 Wrocław, Poland*

In a first attempt to obtain a microscopic derivation of black hole entropy 't Hooft had to introduce by hand a cutoff close to the horizon, the so-called brick wall. Here we argue that taking into account the backreaction from the Hawking radiation on the spacetime removes the need for such an ad hoc assumption. By identifying the quantum ergosphere, a consequence of the backreaction, with the brick wall we can determine the value of the cutoff parameter in terms of the total luminosity. The standard entropy of a black hole is recovered approximately.

CDT Matrix Model and FRGE

Alicia Castro[1]

[1] *Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, CDMX, México*

In this work the Matrix Model describing 2D Causal Dynamical Triangulations proposed in [1] is studied using the Functional Renormalization Group Equation, in order to analyze the existence of a non-gaussian fixed point and then comparing this results with the non-causal ones (obtained in [2]). This is interesting because Matrix Models provide a path to follow to work with dynamics of higher dimensional spacetimes (Tensor and Group Field Theory) and it is not clear yet how to incorporate causality in those models.

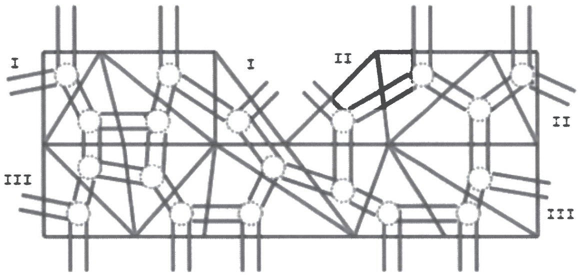


Fig. 1 CDT and the dual fatgraph described by a matrix model

References

[1] D. Benedetti and J. Henson. Imposing causality on a matrix model. Phys. Lett. B678:222–226 (2009)

[2] A. Eichhorn and T. Koslowski. Continuum limit in matrix models for quantum gravity from the Functional Renormalization Group. Phys. Rev. D88:084016 (2013)

Tracing renormalization group trajectories with the spectral dimension in causal dynamical triangulations

J. H. Cooperman

15 Pond Drive West, Rhinebeck, New York 12572, United States of America

Within the program of causal dynamical triangulations, one aims to construct a quantum theory of gravity as the continuum limit of a lattice-regularized model of quantum spacetime geometry. The search for such a continuum limit requires a renormalization group analysis. The efforts of several authors demonstrate that the implementation of a complete renormalization group scheme for causal dynamical triangulations requires the determination of further physical observables with which to delineate renormalization group trajectories [1, 2, 3, 4]. I propose a method for using the spectral dimension to trace renormalization group trajectories. This method draws on my recent analysis of the spectral dimension's scaling properties [5] and my forthcoming study of the spectral dimension's physical scales [6] to realize my original suggestion [2].

References

[1] J. Ambjørn, A. Görlich, J. Jurkiewicz, A. Kreienbuehl, and R. Loll. "Renormalization group flow in CDT." *Classical and Quantum Gravity* 31 (2014) 165003.

[2] J. H. Cooperman. "On a renormalization group scheme for causal dynamical triangulations." *General Relativity and Gravitation* 48 (2016) 1.

[3] J. Ambjørn, D. N. Coumbe, J. Gizbert-Studnicki, and J. Jurkiewicz. "Searching for a continuum limit of causal dynamical triangulation quantum gravity." *Physical Review D* 93 (2016) 104032.

[4] J. H. Cooperman. "Comments on 'Searching for a continuum limit in CDT quantum gravity'." arXiv: 1604.01798.

[5] J. H. Cooperman. "Scaling analyses of the spectral dimension in 3-dimensional causal dynamical triangulations." *Classical and Quantum Gravity* 35 (2018) 105004.

[6] J. H. Cooperman and M. Dorghabekov. "Setting the physical scale of dimensional reduction in causal dynamical triangulations." In preparation.

Relating Renormalizability and Unitarity with the absence of Newtonian Singularities in Higher-Derivative models of Quantum Gravity

A. Accioly, J. de Almeida, G.P. de Brito and W. Herdy

Centro Brasileiro de Pesquisas Físicas

In this work we investigate an interesting connection between the absence of newtonian singularities in the classical non-relativistic potential and renormalizability properties in Higher-Derivative models of Quantum Gravity. In the framework of a large class of D-dimensional Higher-Derivative models of Quantum Gravity [1], we compute the non-relativistic potential energy associated with two point-like masses. Investigating its behavior for small distances, we conclude that there emerges an algebraic condition which is sufficient for the cancellation of the newtonian singularity. It may be verified that the same condition is necessary to ensure power-counting renormalizability and, as a consequence, we conclude that renormalizable Higher-Derivative models do not exhibit the so-called newtonian singularity. Finally, we discuss the role of ghosts in the mechanism for the cancellation of newtonian singularities.

References

[1] A. Accioly, J. de Almeida, G.P. de Brito and W. Herdy, arXiv:1707.02083.

Real-time graviton spectral functions

A. Bonnano[1], T. Denz[2], J.M. Pawlowski[2,3], and M. Reichert[2]

[1] *INAF, Osservatorio Astrofisico di Catana, via S. Sofia, 78, 95123 Catania, Italy*
[2] *Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany*
[3] *ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenhaftung mbH, Planckstraße 1, 64291 Darmstadt, Germany*

We investigate asymtotically safe quantum gravity using a systematic vertex expansion. We obtain physical graviton spectral functions from Euclidean correlation functions via analytical continuation. We investigate the resulting resulting real-time graviton spectra.

Flow equations and the path integral measure

Kevin Falls

Institute for theoretical physics, Heidelberg University, Philosophenweg 12, 62910 Heidelberg, Germany.

Motivated by the application of the exact renormalisation group flow equations to quantum gravity we revisit the generalisation of the well known flow equations to curved spacetime. Generically this demands that the functional measure is non-trivial depending on the spacetime metric and the cutoff scale to ensure the regularisation of vacuum terms involving spacetime curvature terms. We also show how the relations between the Wilsonian effective action and the effective average action generalise such that the former can be reconstructed from the latter along with the explicit form of the measure.

References

1. Kevin Falls (in preparation)

Radiative corrections in GFT models for QG.

M. Finocchiaro[1]

[1]*Max Planck Institute for Gravitational Physics*
(Albert Einstein Institute), Science Park Am Mühlenberg 1
D-14476 Potsdam-Golm, Germany

Group field theories (GFTs) are combinatorially non-linear and non-local quantum field theories defined on several copies of a given Lie Group *G*. By construction the perturbative expansion of the partition function of such theories Z_{GFT} generates the sum on all possible cellular complexes as a weighted sum on stranded Feynman graphs. In recent years the study of the perturbative and non-perturbative renormalizability of specific classes of GFT models has witnessed several major developments. The analysis of the radiative corrections to the *N*-point functions of both topological and geometrical GFT models plays a key role in this framework, since it allows to derive and test explicit bounds on the amplitudes' UV scaling behaviour thus providing further constraints on the models' theory space.

The analysis of the radiative corrections rests on two pillars: the generation of the relevant (connected) GFT Feynman graphs contributing to the perturbative expansion of the partition function and its cumulants (*N*-point functions) and the evaluation of the corresponding integrals. In my poster I will present the main results regarding the analysis of the leading order radiative corrections to the *N*-point functions ($N<=6$)

for a new class of geometrical GFT models for euclidean quantum gravity. I will also introduce and describe the Mathematica package I wrote for constructing GFT Feynman graphs. Given in input a consistent set of vertices (for an arbitrary rank Tensor or GFT model) the program, based on a recursive approach, is able to generate all Vacuum graphs as well as all Feynman diagrams for a given *N*-point function up to a chosen truncation order.

Hamiltonian Analysis of Asymptotic Safe Gravity

Gabriele Gionti S.J.
Vatican Observatory

The aim of this research is to study, from a Hamiltonian point of view, the dynamic of a General Relativity Action in which the Gravitational Constant and the Cosmological Constant are now function of the Space-Time coordinates after a cut-off identification has been performed following the general procedure of Asymptotically Safe Gravity. The Dirac's constraint analysis of this system is performed and connections with the correspondent Branse-Dicke Theory are made.
A minisuperspace model of this system based on FLRW metric is studied and it is shown that it contains bouncing and emergent universe.

Matter in Causal Sets

L. Glaser[1]

[1]IMAPP, Radboud University, Nijmegen, Netherlands
[2] another Institute, another town, another country

Causal set theory is a discrete approach to quantum gravity. Recent work using a subclass of all Causal sets, the so called 2d orders, has made big strides in using Monte Carlo methods to explore the path integral over these theories numerically. In the work presented here I show results on how the causal set behaves when coupled to matter, in the case of a simple Ising model.

In [1] I probed the phase diagram in terms of the Wick rotation parameter β and the Ising coupling j and found that the matter and the causal sets together give rise to an interesting phase structure with five different phases and that at least one new phase transition arises, in which the Ising spins push the causal set into the crystalline phase.

References

[1] Glaser, L. The Ising model coupled to 2d orders. *Class. Quantum Grav.* (2018).

doi:10.1088/1361-6382/aab139

Renormalization Group Properties of the Conformal Mode of a Torus

Matthew P. Kellett[1] and **Tim R. Morris**[1]

[1] *STAG Research Centre & Department of Physics and Astronomy, University of Southampton, Highfield, Southampton, SO17 1BJ, U. K.*

M.P.Kellett@soton.ac.uk, T.R.Morris@soton.ac.uk

The Wilsonian renormalization group properties of the conformal factor of the metric are profoundly altered by the fact that it has a wrong-sign kinetic term. If couplings are chosen so that the quantum field theory exists on $\mathbb{R}^4$, it fails to exist on manifolds below a certain size, if a certain universal shape function turns negative. We demonstrate that this is triggered by inhomogeneity in the cases of $\mathbb{T}^4$ and $\mathbb{T}^3 \times \mathbb{R}$, including twisted versions. Varying the moduli, we uncover a rich phenomenology.

Statistical Equilibrium in Group Field Theory

I. Kotecha[1] and **D. Oriti**[2]

[1,2] Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam-Golm, Germany
[1] Humboldt University of Berlin, Germany
[2] University of Hamburg, Germany

Formulating statistical equilibrium in background independent settings, where the standard notions of time and energy are absent, is an open issue [1]. This is especially so in a closely related, but still different, context of non-perturbative approaches to quantum gravity not based on spatiotemporal structures (which are then emergent). In this work [2] we first clarify the different characterizations of statistical Gibbs equilibrium, while focusing on those distinctions crucial for background independent systems, namely Jaynes' entropy maximization principle and the Kubo-Martin-Schwinger condition. By utilizing these conceptual insights we tackle the issue of defining Gibbs states in the group field theory (GFT) [3] formalism. In a GFT Fock representation, the candidate quantum gravitational microstates are modeled as many-body quantum states [4]. This facilitates formulation of a quantum statistical mechanics of spin networks composed of quanta or 'atoms' of space. Based on this we construct examples of Gibbs states in GFT and note the distinct notions of equilibrium that they encode: a geometric volume Gibbs state, which supports Bose-Einstein condensation to a low-spin phase; structural momentum Gibbs states with respect to internal translations on the base manifold; and relational equilibrium states in a system deparametrized with respect to a coupled matter scalar field clock.

References

[1] C. Rovelli, Phys. Rev. D **87**, 084055 (2013)
[2] I. Kotecha, D. Oriti, submitted to New J. Phy. Preprint: arXiv:1801.09964 (2018)
[3] D. Oriti, World Scientific, 100 Years of GR - Vol. 4 (2017), T. Krajewski, PoS QGQGS 005 (2011)
[4] D. Oriti, Class. Quant. Grav. **33**, 085005 (2016)

Universality classes for the continuum limit in rank-3-tensor models

A. Eichhorn[1], T. Koslowski[2], A. Pereira[1] and J. Lumma[1]

[1]Institute for Theoretical Physics, University of Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany

[2]Instituto de Ciencias Nucleares, Universidad Nacional Autnóma de México, Cto. Exterior S/N, C.U., Del. Coyoacán, CDMX, México

Using the FRG, we search for continuum limits in a model of real tensors whose indices transform under different copies of the O(N) group. Tensor models generalize matrix models, which arose in the 90s as a tool to solve the path integral of quantum gravity in two dimensions, to higher dimensions.

References

[1] A. Eichhorn, T. Koslowski, J. Lumma, A. Pereira, *Work in progress*

A curvature bound from gravitational catalysis

H. Gies[1,2] and R. Martini[1]

Theoretisch-Physikalisches Institut, Friedrich Schiller University, Jena, Germany
[2] Helmholtz-Institut, Jena, Germany

Gravitational catalysis expresses an interplay between the curvature of the spacetime and fluctuation-induced mass generation of quantum matter. Ii is possible to show how a scale-dependent analysis of this phenomenon on local AdS backgrounds leads to the identification of bounds on the curvature of local patches of spacetime, based on the requirement of long-range chiral symmetry. The bound will be expressed in terms of the ratio between the local scalar curvature and the gauge-invariant coarse-graining scale, pointing out a dependence of the result on the relevant modes of the observed Physics.

Conformal window of asymptotic safety at NNLO

Andrew D. Bond[1], Daniel F. Litim[1], Gustavo Medina Vazquez[1], and Tom Steudtner[1]

[1]*Department of Physics and Astronomy, U Sussex, Brighton, BN1 9QH, U.K.*

Asymptotic safety establishes that an interacting fixed point in the ultraviolet can lead to a UV complete theory by describing all interactions up to the highest energy scales. In this work we investigate the interacting fixed points of gauge theories with matter in four dimensions up to the complete next-to-next-to-leading order in perturbation theory. We derive expressions for the fixed point, scaling exponents and anomalous dimensions associated to it, in a series expansion with a small parameter. We describe the ordering principle that consistently determines the fixed point, order by order in the series expansion, which is different from conventional perturbation theory. We then derive boundaries for the conformal window of asymptotic safety in various approximations, including up to three-loop and two-loop order in the gauge and the scalar beta functions respectively. By comparing constraints from the series expansion and the renormalization group running of the couplings in different approximations we can uncover a consistent picture, where boundaries arise from the onset of strong coupling, fixed point mergers and vacuum stability. The tightest constraint in the most advanced approximation arises from vacuum stability conditions. In all cases we find that the entire conformal window consistently lies within the regime where perturbation theory is applicable.

Split Weyl Transformations in Quantum Gravity

C. M. Nieto[1,2,3] ,R. Percacci[1,2] and V. Skrinjar[1,2]

[1]*International School for Advanced Studies, via Bonomea 265, I-34136 Trieste, Italy*
[2] *INFN, Sezione di Trieste, Italy*
[3] *International Center for Theoretical Physics, Strada Costiera 11, 34151 Trieste, Italy*

We discuss various realizations of the Weyl group in the background field expansion of quantum gravity in the presence of a cutoff, as required in applications of the functional renormalization group. In order to study the background–dependence, special attention is given to split gauge transformations, which act on the background field and fluctuation keeping the total metric unchanged. We find a way of writing the cutoff terms such that the broken Ward identity resulting from the change in the effective action allows us to write a split weyl-invariant flow equation. The results generalize previous works on global and local scale transformations

References

[1] J. A. Dietz and T. R. Morris, JHEP **1504**, 118 (2015)
[2] R. Percacci and G. P. Vacca Eur. Phys. J. C. **77**, 1 (2017)
[3] P. Labus, T. R. Morris and Z. H. Slade Phys. Rev. D **94 no. 2**, 1 (2017)
[4] N. Ohta, PTEP **2017 no. 3**, 033E02 (2017)

Asymptotically Safe Phenomenology Beyond RG Improvements

G.Gubitosi[1,2] , R.Ooijer[2], C.Ripken[2] and F.Saueressig[2]

[1]*Dipartimento di Fisica, Università di Roma "La Sapienza", Roma, Italy*
[2] *Institute for Mathematics, Astrophysics and Particle Physics, Radboud University, Nijmegen, The Netherlands*

We investigate the compatibility of cosmological constraints on inflation and the cosmological constant with the asymptotic safety scenario of quantum gravity. The effective action is taken to be of f(R) form, truncated to second order, corresponding to the action for Starobinsky inflation. The flow generated by the FRGE is analysed and it is found that it facilitates regimes in which the cosmological constraints are met. We show that there exist trajectories satisfying all constraints, providing evidence for the compatibility of cosmology with asymptotically safe quantum gravity. In particular, Starobinsky inflation may occur naturally from the gravitational effective dynamics generated in the trans-Planckian regime.

Functional renormalization group and tensorial group field theories: recent developments

Antonio D. Pereira

Institut für Theoretische Physik, Universität Heidelberg, Heidelberg, Germany

E-mail: a.pereira@thphys.uni-heidelberg.de

The continuum limit of discrete approaches to quantum gravity as group field theories is a major open challenge that can be explored by the functional renormalization group. At the same time, such theories are unconventional quantum field theories due to the non-trivial combinatorial structure of their interactions and subtleties in the application of functional methods come in. In this contribution I will discuss the complete (momentum independent) quartic order truncation of the effective average action of a real Abelian rank-3 tensorial group field theory. At this order, the truncation is complete due to the inclusion of non-melonic as well as double-trace interactions. Usually, one would expect that the inclusion of more operators that belong to the underlying theory space corresponds to an "improvement" of the truncation of the effective average action. We show that such an enlargement of the truncation brings non-trivial effects coming from the double-trace operator. Some perspectives on how to circumvent these issues are discussed.

Phase transitions in GFT: The Landau perspective

A. G. A. Pithis[1] and J. Thürigen[2]

[1]Department of Physics, King's College London, University of London,
Strand WC2R 2LS, London, United Kingdom, EU

[2] Department of Physics, Department of Mathematics
Humboldt-Universität zu Berlin
Unter den Linden 6, 10099 Berlin, Germany, EU

We investigate the critical behavior of group field theory (GFT) systems in the Gaussian approximation. By applying the Ginzburg criterion to quantify quantum fluctuations, we find that this approximation is valid for a Lorentzian GFT on SL(2,R), while it breaks down in the case of the GFT model for 3d Euclidean quantum gravity, the so-called Boulatov model. From this we conclude that the Gaussian approximation provides a trustworthy description of a phase transition in the former case. However, it is insufficient for the same purpose in the case of the Boulatov-model and suggests that a nonperturbative treatment using FRG methodology is needed to settle this question. On the other hand, the results in the case of a Lorentzian GFT on SL(2,R) may indicate the necessity of GFT models to be defined on non-compact domains for phase transitions to occur. In this way, our work contributes to the ongoing research to understand the notion of phases, phase transitions and their connection to the recovery of a continuum geometry in the GFT setting.

References

[1] A. G. A. Pithis and J. Thürigen, Phase transitions in GFT: The Landau perspective, in preparation;

[2] S. Carrozza, Flowing in Group Field Theory Space: a Review, SIGMA 12 (2016), 070, 30 pages;

[3] D. Benedetti, Critical behavior in spherical and hyperbolic spaces, J. Stat. Mech. (2015) P01002;

[4] P. Kopietz, L. Bartosch and F. Schutz, Introduction to the functional renormalization group, Lect. Notes Phys. 798 (2010) 1–380;

The Ultraviolet Behavior Of Quantum Gravity

D.Anselmi and <u>M. Piva</u>

Dipartimento di Fisica "Enrico Fermi", Università di Pisa,
Largo B. Pontecorvo 3, 56127 Pisa, Italy

A new theory of quantum gravity is proposed by means of a novel quantization prescription, which turns the would-be ghosts into "fakeons", i.e. fake degrees of freedom. The new prescription is based on the features of the Lee-Wick models, recently reformulated as nonanalytically Wick rotated Euclidean theories [1], and it is able to make renormalizability compatible with unitarity [2,3].
Computation at one-loop are presented to show how the graviton/fakeon prescription works [4]. In particular we illustrate the renormalization of the theory, obtained with the help of the Batalin-Vilkovisky formalism, as well as the absorptive part of the graviton self energy, which involves novel techniques. The fakeons disentangle the real part of the self energy from the imaginary part. The former obeys a renormalizable power counting, while the latter obeys the nonrenormalizable power counting of the low energy expansion and is consistent with unitarity in the limit of vanishing cosmological constant.
Finally, the case of nonvanishing cosmological constant is addressed by introducing auxiliary fields [5]. The results are presented and compared with other theories, pointing out their physical difference.

References

[1] D.Anselmi and M. Piva, "A new formulation of Lee-Wick quantum field theory", J. High Energy Phys. 06 (2017) 066 and arXiv:0805.2156 [hep-th].
[2] D.Anselmi and M. Piva, "Perturbative unitarity of Lee-Wick quantum field theory", Phys. Rev. D 96 (2017) 045009 and arXiv:1703.05563 [hep-th].
[3] D.Anselmi, "Fakeons and Lee-Wick models", J. High Energy Phys. 02 (2018) 141 and arXiv:1801.00915 [hep-th].
[4] D. Anselmi and M.Piva, "The ultraviolet behavior of quantum gravity", arXiv:1803.07777 [hep-th].
[5] D.Anselmi and M.Piva, to appear.

The pyramid of analytic Schwinger-Dyson equations for complex and SYK-like tensor models

Carlos I. Pérez Sánchez

Mathematisches Institut der Westfälischen Wilhelms-Universität Münster, Germany

Tensor models are usually treated in a conservative variation of quantum field theories (QFT) –known as Tensor Field Theories (TFT)– in the sense that one modifies the QFT-structure only if this is really required. Here we address one of the differences between TFT and QFT in the non-perturbative approach. Namely, that the "tower" of analytic Schwinger-Dyson equations for complex tensor models has rather the form of a pyramid [1,2], as a consequence of the intricate classification of the correlation functions in TFT. In this poster we derive this pyramid, give its interpretation in terms of bordisms and discuss ongoing work (in collaboration with T. Krajewski, R. Pascalie, A. Tanasa and R. Wulkenhaar [3]) that extends these techniques to Sachdev-Ye-Kitaev-like tensor models.

References

[1] Carlos I. Pérez-Sánchez. The full Ward-Takahashi identity for colored tensor models. Commun. Math. Phys., **358**(2):589–632, 2018

[2] Carlos I. Pérez-Sánchez, Raimar Wulkenhaar. Correlation functions of coloured tensor models and their Schwinger-Dyson equations, (to appear in) Annales de l'Institut Henri Poincaré D (arXiv:1706.07358)

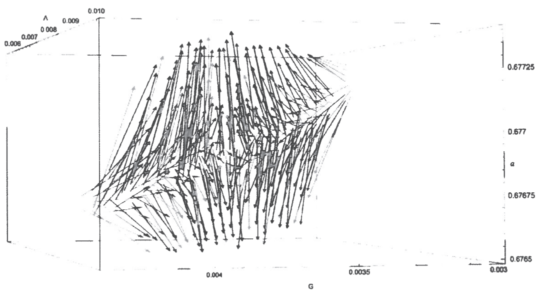
[3] Thomas Krajewski, Romain Pascalie, Carlos I. Pérez Sánchez, Adrian Tanasa, Raimar Wulkenhaar, Schwinger-Dyson Equations of Tensorial SYK-like Models (work in progress) 2018

Renormalization in symmetry reduced Spin Foams

B.Bahr[1], G.Rabuffo[1] and S.Steinhaus[2]

[1]II Institute for Theoretical Physics, Hamburg, Germany
[2] Perimeter Institute, Waterloo, Canada

Spin Foam (SF) models provide a non-perturbative and background independent path integral formulation of Quantum Gravity. The models are built on a fiducial discretization of spacetime, which serves as a tool to control the d.o.f. of geometry. In fact, a given discretization can be thought as a scale at which we look at spacetime, while its coarse graining (refinement) resembles a shift towards IR (UV) regimes. In the light of this interpretation, a SF state sum is understood as an effective theory for the available d.o.f. provided by the lattice. Then, the Wilsonian renormalization group stands out as an ideal tool to organize and describe the flow of the theory along a scale of complexity of the lattice.
While many promising results have been achieved in SF, the dynamics of these models is still hard to solve and most calculations are performed on extremely coarse discretizations. In order to get access to finer lattices we *reduce* the path integral state sum to certain symmetric configurations [1]. This allows us to evaluate numerically some geometric observables on coarser and finer discretizations. Their comparison defines the *renormalization group flow* of the model in the parameter space.



Notably, we find a *fixed point* with one repulsive and two attractive directions in the three-dimensional parameter space of the asymptotic 4d Euclidean EPRL Spin Foam Model [2]. In such point, the expectation value of the observables do not depend on the lattice complexity. Thus, the existence of a fixed point allows to study another open problem of SF, i.e. the *continuum* (infinite refinement) *limit*.

References

1. B.Bahr, S.Klöser, G.Rabuffo, Phys. Rev., vol. D96, no. 8, p. 086009, (2017)
2. B.Bahr, G.Rabuffo, S.Steinhaus, 1804.00023, (2018)

Asymptotic safety of gravity-matter systems

M. Reichert[1]

[1]*Institute for Theoretical Physics, Heidelberg University, Germany*

We review the status of asymptotically safe gravity-matter systems. The existence of a UV fixed point in such systems is guaranteed if the matter-self coupling is weak and if higher-derivative gravity terms are neglected [1]. We show how this could manifest itself in a functional renormalisation group computation and how effective universality of different avatars of Newton couplings helps to reduce the size of the truncation [2]. Furthermore we present first results of gravity-matter systems with higher-derivative gravity [3].

References

[1] N. Christiansen, D.F. Litim, J.M. Pawlowski and M. Reichert, arXiv:1710.04669

[2] A. Eichhorn, P. Labus, J.M. Pawlowski and M. Reichert, arXiv:1804.00012

[3] J.M. Pawlowski, M. Reichert and M. Yamada, in preparation

Catching ghosts: Reflection positivity in higher derivative scalar theories

F. Arici,[1] D. Becker,[1] C. Ripken,[1] F. Saueressig,[1] and W.D. van Suijlekom[1]

[1] *Institute for Mathematics, Astrophysics and Particle Physics, Radboud University, Nijmegen, the Netherlands*

Reflection positivity constitutes an integral prerequisite in the Osterwalder-Schrader reconstruction theorem, which relates quantum field theories defined on Euclidean space to their Lorentzian signature counterparts. However, theories that satisfy reflection positivity are notoriously scarce, with Klein-Gordon theory being one of the few examples.
With this poster, based on [1], we rigorously prove the violation of reflection positivity in a large class of free scalar fields with a rational propagator. This covers in particular higher-derivative theories where the propagator admits a partial fraction decomposition as well as degenerate cases including e.g. p^4-type propagators.

References

[1] F. Arici, D. Becker, C. Ripken, F. Saueressig and W.D. van Suijlekom. ArXiv:1712.04308 (2017)

Ultraviolet Dynamics of Fermions and Gravity

A. Eichhorn[1], S. Lippoldt[1] and M. Schiffer[1]

[1]*Institute for Theoretical Physics, Heidelberg, Germany*

We study the interplay of gravity and fermions in the ultraviolet. The considered system features an interacting fixed point, where fermions and gravity can be coupled to each other. Symmetry arguments suggest that this fixed point features non-zero interactions of fermions and curvature tensors. We investigate the viability of the asymptotic safety scenario under the inclusion of such a non-minimal interaction. Furthermore, we analyse structural similarities of two avatars of the Newton coupling, a gravitational self-coupling and a fermion-gravity coupling. We discover near effective universality for the Newton coupling at the interacting fixed point for one single fermion. This provides evidence for the physical nature of the discovered fixed point.

The phase diagram of Asymptotically Safe Black Holes

A. Bonanno[1] and S. Silveravalle[2]

[1]Osservatorio Astrofisico di Catania, Catania, Italy
[2] Università di Milano Bicocca, Milano, Italy

According to the asymptotically safe scenario in quantum gravity, the Einstein + Weyl + R^2 theory naturally emerges on the ultraviolet critical manifold around the non-gaussian fixed point at very high energies. The phase diagram of the BH solutions for this theory is thus explicitly constructed by means of a modified shooting method which allows for a rigorous determination of the horizon properties of both Schwarzschild and non-Schwarzschild BHs, in terms of the free parameters of the theory. In particular we show that the AS theory discussed in [2] makes definite predictions on the thermodynamical properties and the structure of the new class of BHs recently determined by Lü *et al.* in [1].

References

[1] H. Lü, A. Perkins, C. N. Pope, K. S. Stelle, Phys. Rev. D **92**, 124019 (2015)
[2] D. Benedetti, P. F. Machado, F. Saueressig, Mod. Phys. Lett. A **24**, 2231-2241 (2009)

Emergence of Spacetime in a restricted Spin-foam model

S. Steinhaus[1] **and J. Thürigen**[2]

[1]*Perimeter Institute f. Theoretical Physics, 31 Caroline St N, Waterloo N2L 2Y5, Canada*

[2] *Department of Physics, Department of Mathematics, Humbuldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany*

The spectral dimension has proven to be a very informative observable to understand the properties of quantum geometries in approaches to quantum gravity. In loop quantum gravity and its spin foam description, it has not been possible so far to calculate the spectral dimension of spacetime. As a first step towards this goal, here we determine the spacetime spectral dimension in the simplified spin foam model restricted to hypercuboids. Using Monte Carlo methods we compute the spectral dimension for state sums over periodic spin foam configurations on infinite lattices. For given periodicity, i.e. number of degrees of freedom, we find a range of scale where an intermediate spectral dimension between 0 and 4 can be found, continuously depending on the parameter of the model. Under an assumption on the statistical behaviour of the Laplacian we can explain these results analytically. This allows us to take the thermodynamic limit of large periodicity and find a phase transition from a regime of effectively 0-dimensional to 4-dimensional spacetime. At the point of phase transition, dynamics of the model are scale invariant which can be seen as restoration of diffeomorphism invariance of flat space. Considering the spectral dimension as an order parameter for renormalization we find a renormalization group flow to this point as well. Being the first instance of an emergence of 4-dimensional spacetime in a spin foam model, the properties responsible for this result seem to be rather generic. We thus expect similar results for more general, less restricted spin foam models. The poster is based on the article [1].

References

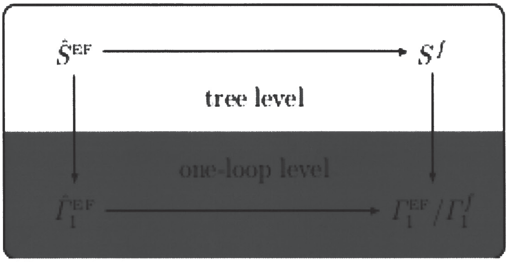
[1] S. Steinhaus and J. Thürigen, pre-print: arXiv:1803.10289

Quantum properties of f(R) gravity

Michael S. Ruf[1] and Christian F. Steinwachs[1]

[1]Institute of Physics, Albert-Ludwigs-Universität Freiburg, Hermann-Herder Str. 3, 79104 Freiburg, Germany

*We calculate the divergent part of the one-loop effective act*ion for f(R) gravity on an arbitrary background manifold. Our result generalizes previous results for quantum corrections in f(R) gravity, which have been limited to spaces of constant curvature. We discuss a new technical aspect connected to operators with degenerate principal symbol. Our result has important applications in cosmology and allows to study the quantum equivalence between f(R) theories and scalar-tensor theories.



We investigate whether the classical equivalence of f(R) gravity and its formulation as scalar-tensor theory still holds at the quantum level. We explicitly compare the corresponding one-loop divergences and find that the equivalence is broken by off-shell quantum corrections, but recovered on-shell. This result is relevant for the use of the renormalization group in cosmology and raises the question about an unambiguous definition of gauge and reparametrization invariant quantum observables in cosmology.

References

[1] Michael S. Ruf and Christian Steinwachs, Phys. Rev. **D 97**, no.4, 044049 (2018)

[2] Michael S. Ruf and Christian Steinwachs, Phys. Rev. **D 97,** no.4, 044050 (2018)

Fixed points in simple gauge-Yukawa theories

A. Bond[1], D. Litim[1] and T. Steudtner[1]

[1]University of Sussex, Falmer, United Kingdom

We investigate a broad range of 4d SU(N) gauge theories with fermionic and scalar matter featuring a single Yukawa coupling. The availability of interacting UV or IR fixed points with stable vacua is investigated in dependence on matter field representations, global symmetries, and the structure of the Yukawa sector. All weakly coupled fixed points and phase diagrams are provided to the leading non-trivial orders in perturbation theory. Extensions towards strong coupling and implications for model building are indicated.

Quantum-improved Schwarzschild-(A)dS and Kerr-(A)dS Spacetimes

Jan M. Pawlowski[1, 2] and Dennis Stock[3, 1]

[1] *Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany*

[2] *ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung mbH, Planckstr. 1, 64291 Darmstadt, Germany*

[3] *University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen, Germany*

We study the effects of quantum gravity on black hole geometries within the set-up of asymptotically safe quantum gravity. Under the assumption that leading order quantum effects are taken into account by promoting Newton's and the cosmological constant to scale-dependent functions, we arrive at a quantum-improved metric for Schwarzschild- (A)dS and Kerr-(A)dS. Because scale identifications based on a radial path or the eigentime of an infalling observer in the quantum improved geometry lead to problems, we base our scale identification on the upgraded classical Kretschmann scalar. The arising spacetimes are discussed by studying the Penrose diagrams, the motion of test particles, the effect on the central curvature singularity and the implication for the endpoint of the black hole evaporation process.

Asymptotic safety and field parametrization dependence in f(R) truncation

Gustavo P. de Brito[1], Nobuyoshi Ohta[2,3], Antonio D. Pereira[4], Anderson A. Tomaz[1] and Yamada Masatoshi[4]

[1] *Brazilian Center for Research in Physics, Rio de Janeiro, Brazil*
[2] *Department of Physics, Kindai University, Osaka, Japan*
[3] *Maskawa Institute for Science and Culture, Kyoto Sangyo University, Kyoto, Japan*
[4] *Institute for Theoretical Physics, Heidelberg University, Heidelberg, Germany*

We investigate the dependence on field parametrization of the functional renormalization group equation in the f(R) truncation for the effective average action. We perform a systematic analysis of the dependence of fixed points and critical exponents on different choices of field parametrization for two different choices of a gauge parameter in polynomial truncations. We verify explicitly that in different parametrizations, we obtain reasonable convergence for the fixed points and critical exponents values within the approximations we employ. On the other hand, we also observe that within the present truncation, different qualitative results are obtained for different schemes. In particular, we observe that in the so-called exponential parametrization, it is possible to have two or three relevant directions depending on the choice of regulator.

Relating different regularization schemes in Asymptotic Safety

A. Vereijken[1] **and F. Saueressig**[1]

[1] *Institute of Mathematics, Astrophysics and Particle Physics, Radboud University, Nijmegen, Netherlands*

A key open question in applying functional renormalization group methods concerns the proper choice of regulator. While the regulator itself is unphysical and should therefore not affect observable quantities, approximate solutions of the functional renormalization group equation may exhibit strong regulator effects. We analyze these effects in detail and suggest particular classes of approximations which are suitable for compensating such effects.

Spatial distances in conformally flat causal sets

F. Versteegen

Heidelberg University, Philosophenweg 16, 69120, Heidelberg, Germany

Causal sets are based on the causal structure of spacetime, rather than spatial geometries evolving in time. We show that spatial geometry can nevertheless be extracted from causal structure, and use the distance on the causal set analogue of a spatial hypersurface as an example. We propose a procedure based on causal links that allows to extract the spatial distance. To this end we generate causal sets approximated by Minkowski or conformally flat continuum spacetime and use a discrete version of a spatial hyper-surface to obtain a sense of time slicing. We show that in the limit of larger continuum distances, the discrete distance approaches the continuum version, whereas for smaller distances the effects of asymptotic silence induce an increase in the discrete distance compared to the continuum version.

Quantum gravity effects on Majorana fermion

G. P. de Brito,[1] Y. Hamada,[2] A. D. Pereira[3] and M. Yamada[3]

[1]CBPT - Centro Brasileiro de Pesquisas Fisicas,
Rua Dr. Xavier Sigaud 150, 22290-180, Rio, de Janeiro, RJ Brazil
[2] Department of physics, University of Wisconsin,Madison, WI 53706, USA
KEK Theroy Center, IPSN, KEK, Tsukuba, Ibaraki 305-080, Japan
[3] Institut für Theoretische Physik, Universität Heidelberg,
Philosophenweg 16, 69120 Heidelberg, Germany

One of mechanisms explaining tiny neutrino mass is the (Type-I) seesaw mechanism where a heavy Majorana mass is introduced. We investigate quantum gravity effects on a Majorana fermion within the Higgs-Yukawa model and discuss possible scenarios for low energy physics. The functional renormalization group method is used to investigate the system.

References

[1] G. P. de Brito, Y. Hamada, A. D. Pereira and M. Yamada, in progress.