Theoretical and Mathematical Physics Division
Fachverband Theoretische und Mathematische Grundlagen der Physik (MP)

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Includes classical and quantum field theory, curved spacetime and entropy, equilibrium and non-equilibrium systems, complexity and quantum information theory. Presents progress in methods and concepts, model studies and structure analysis.

Overview of Invited Talks and Sessions

(Lecture halls H3, H6, and H7; Poster P)

Invited Talks

MP 2.1	Tue	11:00–11:40	H7	**KPZ universality in mathematics and physics** — •Patrik Ferrari
MP 3.1	Tue	11:45–12:25	H7	**Path integral based non-equilibrium quantum field theory of non-relativistic pairs inside an environment** — •Tobias Binder
MP 7.1	Tue	17:00–17:40	H7	**Stochastic Dynamics in Quantum Mechanics** — •Denis Bernard
MP 13.1	Thu	11:00–11:40	H6	**Exact solution of the scalar QFT Φ^4 model on the 4-dimensional noncommutative Moyal space** — •Alexander Hock
MP 14.1	Thu	11:45–12:25	H6	**Temperature and entropy-area relation of quantum matter near spherically symmetric outer trapping horizons** — •Rainer Verch

Invited talks of the joint symposium Entanglement (SYEN)

See SYEN for the full program of the symposium.

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Sessions

MP 1.1–1.3	Mon	11:00–12:15	H3	**AdS-CFT I**
MP 2.1–2.1	Tue	11:00–11:40	H7	**HV 1: Stochastic Non-Equilibrium**
MP 3.1–3.1	Tue	11:45–12:25	H7	**HV 2: Non-Equilibrium Quantum Field Theory**
MP 4.1–4.2	Tue	14:00–14:50	H7	**AdS-CFT II**
MP 5.1–5.2	Tue	15:00–15:50	H7	**Loop Quantum Gravity**
MP 6.1–6.1	Tue	16:30–16:55	H7	**Quantum Statistical Mechanics**
MP 7.1–7.1	Tue	17:00–17:40	H7	**HV 3: Stochastic Quantum Mechanics**
MP 8.1–8.1	Tue	17:45–18:10	H7	**Non-equilibrium Statistical Mechanics**
MP 9.1–9.2	Wed	14:00–14:50	H7	**Anomalies in Quantum Field Theory**
MP 10.1–10.2	Wed	15:00–15:50	H7	**Nonrelativistic Quantum Field Theory**
MP 11.1–11.3	Wed	16:30–17:45	H7	**Quantum Information**
MP 12.1–12.1	Wed	17:50–18:15	H7	**Quantum Mechanics**
MP 13.1–13.1	Thu	11:00–11:40	H6	**HV 4: Quantum Field Theory in Noncommutative Spacetime**
MP 14.1–14.1	Thu	11:45–12:25	H6	**HV 5: Quantum Field Theory near Black Hole Horizons**
MP 15.1–15.2	Thu	14:00–14:50	H6	**Quantum Field Theory: Renormalization**
MP 16.1–16.2	Thu	15:00–15:50	H6	**Strongly Interacting Quantum Field Theory**

MP 17.1–17.4	Thu	16:30–18:10	H6	**Entropy in Quantum Field Theory**
MP 18.1–18.3	Fri	11:00–12:15	H6	**Constructive Tools for Quantum Field Theory**
MP 19.1–19.2	Fri	14:00–14:50	H6	**Fundamental Ideas**
MP 20.1–20.1	Mon	10:30–11:00	P	**Poster (permanent)**

MP 1: AdS-CFT I

Time: Monday 11:00–12:15 Location: H3

MP 1.1 Mon 11:00 H3

Geometry of Complexity in Conformal Field Theory — •Mario Flory[1] and Michal Heller[2] — [1]Instituto de Física Téorica IFT-UAM/CSIC, Universidad Autonoma de Madrid, 28049, Madrid, Spain — [2]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), 14476 Potsdam-Golm, Germany

We utilize the Fubini-Study metric in order to define a notion of distance and hence circuit complexity on the Virasoro group. The resulting problem is mathematically equivalent to geodesic motion in infinite dimensions, with integro-differential equations of motion. We discuss the properties of these equations and of their solutions.

MP 1.2 Mon 11:25 H3

Realizing Computational Complexity in Conformal Field Theory — Johanna Erdmenger, Marius Gerbershagen, and •Anna-Lena Weigel — Julius-Maximilians-Universität Würzburg, 97074 Würzburg, Germany

An important question for the AdS/CFT correspondence is how the bulk geometry is encoded in the boundary field theory. A useful quantity proposed in this context is computational complexity. This is a concept adapted from quantum information that counts the minimum number of simple steps, gates, necessary to perform a calculation. While there exist concrete proposals for complexity in the AdS gravity theory, it remains an open question how to define it in a CFT. To make progress in this direction, a recent proposal suggests to restrict the allowed set of gates to symmetry transformations. This was employed to compute complexity for conformal transformations in 2d CFTs [1]. We generalize this approach to Kac-Moody symmetries and show that the complexity is equal to actions defined on coadjoint orbits of the according symmetry group. In this way, we calculate the complexity for several examples of CFTs [2]. The coadjoint orbit actions also arise from 3d gravity theory. We comment on connections between these gravity actions and complexity.

[1] P. Caputa, J. Magan. "Quantum Computation as Gravity". In: Phys. Rev. Lett. 122 (2019), p. 231302. arXiv:1807.04422 [hep-th].

[2] J. Erdmenger, M. Gerbershagen, A. Weigel. "Complexity measures from geometric actions on Virasoro and Kac-Moody orbits". In: JHEP 11 (2020) 003. arXiv:2004.03619 [hep-th].

MP 1.3 Mon 11:50 H3

Complexity as a holographic probe of strong cosmic censorship — Mohsen Alishahiha[1], •Souvik Banerjee[2], Joshua Kames-King[3,4], and Emma Loos[2] — [1]School of Physics, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran — [2]Institut für Theoretische Physik und Astrophysik, Julius-Maximilians-Universität Würzburg, Würzburg, Germany — [3]Bethe Center for Theoretical Physics and Physikalisches Institut der Universitaet Bonn, Bonn, Germany — [4]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA

Based on reasonable assumptions, we propose a new expression for Lloyd's bound, which confines the complexity growth of charged black holes. We then compute the holographic complexity for charged black branes in the presence of a finite cutoff using complexity = action proposal. Using the proposed Lloyd's bound, we find a relation between the ultraviolet and the behind the horizon cutoffs. This relation is found to be consistent with the factorization of the partition function at leading order in large N. We argue that the result may be thought of as a holographic realization of strong cosmic censorship.

MP 2: HV 1: Stochastic Non-Equilibrium

Time: Tuesday 11:00–11:40 Location: H7

Invited Talk MP 2.1 Tue 11:00 H7

KPZ universality in mathematics and physics — •Patrik Ferrari — Bonn University

I will describe the Kardar-Parisi-Zhang universality class of stochastic growth models and discuss how some of the limiting distribution functions (and processes) arise also in mathematical and physical models, which are a-priori unrelated with growth models.

MP 3: HV 2: Non-Equilibrium Quantum Field Theory

Time: Tuesday 11:45–12:25 Location: H7

Invited Talk MP 3.1 Tue 11:45 H7

Path integral based non-equilibrium quantum field theory of non-relativistic pairs inside an environment — •Tobias Binder — Kavli IPMU, Kashiwanoha, Japan

We derive differential equations from path-integral based non-equilibrium quantum field theory, that cover the dynamics and spectrum of non-relativistic two-body fields for any environment. For concreteness of the two-body fields, we choose the full potential non-relativistic Quantum Electrodynamics Lagrangian in this work. After closing the correlation function hierarchy of these equations and performing consistency checks with previous literature under certain limits, we demonstrate the range of physics applications. This includes Cosmology such as Dark Matter in the primordial plasma, Quarkonia inside a quark gluon plasma, and superconductivity and Ferromagnetism in Condensed or strongly Correlated Matter physics. Since we always had to take limits or approximations of our equations in order to recover those known cases, our equations could contain new phenomena. In particular they are based on Green's functions that can deal with non-hermite potentials. We propose a scheme for other Lagrangian based theories or higher N-body states such as molecules to derive analog equations.

MP 4: AdS-CFT II

Time: Tuesday 14:00–14:50 Location: H7

MP 4.1 Tue 14:00 H7

Effective Transport Coefficients in Time-Dependent Field Theory: Far-from-Equilibrium Shear Viscosity via Holography — •Michael Florian Wondrak[1,2], Matthias Kaminski[3], and Marcus Bleicher[1,2,4] — [1]Helmholtz Forschungsakademie Hessen für FAIR, Frankfurt am Main, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt am Main, Germany — [3]Department of Physics and Astronomy, University of Alabama, Tuscaloosa, USA — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The gauge/gravity duality offers an elegant way of characterizing field theories at strong coupling. Close to equilibrium, hydrodynamic transport coefficients have been calculated successfully. Far from equilibrium, the main focus has been on thermalization based on the thermodynamic properties of the theory.

In this talk, we generalize transport coefficients from the near-equilibrium to the highly dynamic regime. Our approach is based on Wigner transformations in combination with Green–Kubo relations. Furthermore, we contrast field-theory and bulk-spacetime generalizations of the entropy density.

We consider a conformal field theory at time-dependent temperature and chemical potential corresponding to an accreting black hole in the bulk. At early and late times, we consistently recover the well-known near equilibrium value of the ratio of shear viscosity and entropy density. During the dynamic regime, there are substantial deviations of order unity.

MP 4.2 Tue 14:25 H7

Berry Phases Probing the Fine-Structure of Entanglement — Souvik Banerjee[1], •Moritz Dorband[1,2], Johanna Erdmenger[1,2], Emma Loos[1,2], René Meyer[1,2], Flavio Nogueira[3], and Jeroen van den Brink[2,3,4] — [1]Institute for Theoretical Physics, Julius-Maximilians-Universität Würzburg, 97074 Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat — [3]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [4]Institute for Theoretical Physics, TU Dresden, 01069 Dresden, Germany

We consider the notion of Berry phase for simple quantum mechanical models as well as for wormholes in gravity and their interpretation in the light of the AdS/CFT correspondence. In both cases the Berry phases arise due to unitary transformations acting on subsystems of the considered models. In the quantum mechanical case, we act with a rotation on half of the system while in the wormhole case, only one throat undergoes time evolution. Since both these transformations are unitary the entanglement properties of the systems are not distinguishable by a local measurement. We substantiate these results for the wormhole by an explicit calculation in two-dimensional gravity.

We furthermore discuss how Berry phases are related to non-exact symplectic forms in parameter space. Again we consider simple quantum mechanical models and gravity wormholes in that regard.

MP 5: Loop Quantum Gravity

Time: Tuesday 15:00–15:50 Location: H7

MP 5.1 Tue 15:00 H7

Super Cartan geometry, loop quantum supergravity and applications — •Konstantin Eder — FAU Erlangen-Nürnberg

This talk is devoted to the quantization of supergravity in a formulation in which (part of) supersymmetry manifests itself in terms of a gauge symmetry. Applications we have in mind are supersymmetric black holes and loop quantum cosmology.

We will derive the Holst variant of the MacDowell-Mansouri action for N=1 and N=2 supergravity in D=4 for arbitrary Barbero-Immirzi parameters. We will show that these actions provide unique boundary terms that ensure local supersymmetry invariance at boundaries. The chiral case is special. The action is invariant under an enlarged gauge symmetry, and the boundary theory is a super Chern-Simons theory. The action also implies boundary conditions that link the super electric flux through, and the super curvature on, the boundary.

We will also study chiral symmetry reduced models with local supersymmetry. The enlarged gauge symmetry of the chiral theory is essential as it allows for nontrivial fermionic degrees of freedom even if one imposes spatial isotropy.

MP 5.2 Tue 15:25 H7

Revisiting loop quantum gravity with selfdual variables — •Robert Seeger — Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

Loop quantum gravity (LQG) in its current formulation is a the quantisation of the SU(2) gauge theory of gravity in Ashtekar-Barbero variables. It started out as an SL(2,C) gauge theory in Ashtekar's selfdual variables, but the quantisation program was never fully carried out in this formulation. The two main obstacles are the non-compactness of the gauge group SL(2,C) and the necessity to implement complicated reality conditions. The latter ensure reality of the spatial metric and its evolution.

We revisit the original formulation by considering the selfdual part of complexified general relativity in Ashtekar variables. These are a complex flux and an SL(2,C) connection. We show that one is lead to a classical theory that is holomorphic in the canonical variables, in order to have a non-degenerate symplectic structure. This does not allow to implement the reality conditions as additional constraints in the action, they have to be added by hand during the quantisation. We describe first steps to extend the holomorphic character also to the quantum theory, with SL(2,C) holonomies, holomorphic derivatives, and a notion of holomorphic spin networks. Thus, working in a holomorphic setup turns out to be natural, as anticipated by Ashtekar and others in early works on the selfdual theory. We will also comment on the implementation of the reality conditions.

MP 6: Quantum Statistical Mechanics

Time: Tuesday 16:30–16:55 Location: H7

MP 6.1 Tue 16:30 H7

Quantum vacuum physics in dielectric media with dispersion and dissipation — •Sascha Lang[1,2], Ralf Schützhold[1,3,2], and William G. Unruh[4] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [4]Department of Physics and Astronomy, University of British Columbia, Vancouver V6T 1Z1, Canada

Experiments on quantum radiation (particle creation from vacuum) often pose major challenges when probing relativistic quantum field theories. Sometimes, effective field theories in suitable condensed matter systems may be accessible more easily. However, such systems are generally affected by material properties such as dispersion and dissipation.

We study quantum vacuum physics in a dielectric medium featuring both dispersion and dissipation. To this end, we explicitly add an environment field to the standard 'Hopfield model' for dispersive but non-dissipative dielectric media. The refined model allows for an 'ab initio' treatment of dissipation and we consider an application in which the interplay of dispersion and dissipation plays a role.

MP 7: HV 3: Stochastic Quantum Mechanics

Time: Tuesday 17:00–17:40 Location: H7

Invited Talk MP 7.1 Tue 17:00 H7
Stochastic Dynamics in Quantum Mechanics — •Denis Bernard — Laboratoire de Physique de l'Ecole Normale Superieure, CNRS, ENS & Universite PSL, 75005 Paris, France.

Stochastic processes enter Quantum Mechanics from different corners: as results of quantum measurements and their effects on quantum systems, as noise providing stochastic models for environments interacting with quantum systems, or as models for typical quantum states and operations. I shall review aspects of these strongly interconnected topics, hopefully covering discussions of statistical aspects of non-demolition measurements, quantum state monitoring, and the emergence of quantum jumps and spikes, and of statistical fluctuations of quantum coherences in many-body quantum model systems at, or away from, equilibrium.

MP 8: Non-equilibrium Statistical Mechanics

Time: Tuesday 17:45–18:10 Location: H7

MP 8.1 Tue 17:45 H7
Correlational entropy by nonlocal quantum kinetic theory — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics - UFRN, Campus Universitário Lagoa nova, 59078-970 Natal, Brazil

The nonlocal kinetic equation unifies the achievements of the transport in dense quantum gases with the Landau theory of quasiclassical transport in Fermi systems. Large cancellations in the off-shell motion appear which are hidden usually in non-Markovian behaviors [1]. The remaining corrections are expressed in terms of shifts in space and time that characterize the non-locality of the scattering process [2]. In this way quantum transport is possible to recast into a quasi-classical picture [3]. The balance equations for the density, momentum, energy and entropy include besides quasiparticle also the correlated two-particle contributions beyond the Landau theory [4]. The medium effects on binary collisions are shown to mediate the latent heat, i.e., an energy conversion between correlation and thermal energy. For Maxwellian particles a sign change of the latent heat is reported at a universal ratio of scattering length to the thermal De Broglie wavelength. This is interpreted as a change from correlational heating to cooling [5]. [1] Ann. Phys. 294 (2001) 135, [2] Phys. Rev. C 59 (1999) 3052, [3] "Interacting Systems far from Equilibrium - Quantum Kinetic Theory" Oxford University Press, (2017) ISBN 9780198797241, [4] Phys. Rev. E 96 (2017) 032106, [5] Phys. Rev. B 97 (2018) 195142

MP 9: Anomalies in Quantum Field Theory

Time: Wednesday 14:00–14:50 Location: H7

MP 9.1 Wed 14:00 H7
Deformations of Supergravity and Supersymmetry Anomalies — •Markus B. Fröb[1], Camillo Imbimbo[2], and Nicolò Risso[3] — [1]Universität Leipzig, Leipzig, Germany — [2]Università di Genova, Genoa, Italy — [3]Università di Padova, Padua, Italy

We present a BRST analysis of supersymmetry anomalies of $\mathcal{N} = 1$ supersymmetric quantum field theories with anomalous R symmetry. To this end, we consider the coupling of the matter theory to classical $\mathcal{N} = 1$ new minimal supergravity. We point out that a supersymmetry anomaly cocycle associated to the $\mathrm{U}(1)_\mathrm{R}$ field does exist for this theory. It is non-trivial in the space of supergravity fields (and ghosts), but it becomes BRST-exact in the functional space that includes antifields. Equivalently, the $\mathrm{U}(1)_\mathrm{R}$ supersymmetry anomaly cocycle vanishes "on shell". It is therefore removable. However, to remove it — precisely because it is not trivial in the smaller space of fields — one needs to deform the supergravity BRST operator. This deformation is triggered, at first order in the anomaly coefficient, by a local operator S_1 of ghost number 1. We give a cohomological characterization of S_1 and compute it in full detail. At higher orders in the anomaly coefficient, we expect a priori that further deformations of the BRST rules are necessary.

MP 9.2 Wed 14:25 H7
Exploring anomalies by many-body correlations — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics - UFRN, Campus Universitário Lagoa nova, 59078-970 Natal, Brazil

The quantum anomaly can be written alternatively into a form violating conservation laws or as non-gauge invariant currents seen explicitly on the example of chiral anomaly. By reinterpreting the many-body averaging, the connection to Pauli-Villars regularization is established which gives the anomalous term a new interpretation as arising from quantum fluctuations by many-body correlations at short distances. This is exemplified by using an effective many-body quantum potential which realizes quantum Slater sums by classical calculations. It is shown that these quantum potentials avoid the quantum anomaly but approaches the same anomalous result by many-body correlations. A measure for the quality of quantum potentials is suggested to describe these quantum fluctuations in the mean energy. Consequently quantum anomalies might be a short-cut way of single-particle field theory to account for many-body effects. This conjecture is also supported since the chiral anomaly can be derived by a completely conserving quantum kinetic theory. [Eur. Phys. J. B 92 (2019) 176, Phys. Lett. A 383 (2019) 1362, arXiv:2004.01507]

MP 10: Nonrelativistic Quantum Field Theory

Time: Wednesday 15:00–15:50 Location: H7

MP 10.1 Wed 15:00 H7
Infraparticle states in the massless Nelson model - revisited — Vincent Beaud[1], •Wojciech Dybalski[2], and Gian Michele Graf[3] — [1]TU Munich, Germany — [2]AMU Poznań, Poland — [3]ETH Zürich, Switzerland

We provide a new construction of infraparticle states in the massless Nelson model. The approximating sequence of our infraparticle state does not involve any infrared cut-offs. Its derivative w.r.t. the time parameter is given by a simple explicit formula. The convergence of this sequence to a non-zero limit as time goes to infinity is then obtained by the Cook method combined with stationary phase estimates. To apply the latter technique we exploit recent results on regularity of ground states in the massless Nelson model, which hold in the low coupling regime.

MP 10.2 Wed 15:25 H7

Infravacuum Property and Local Normality — •Bartosz Biadasiewicz and Wojciech Dybalski — Adam Mickiewicz University, Poznan, Poland

This talk concerns an infravacuum representation introduced by K. Kraus, L. Polley and G. Reents. Due to the infravacuum property, it is not equivalent to the standard vacuum representation of a massless scalar free field on the Minkowski spacetime. But for subalgebras corresponding to measurements performed within double cones, restrictions of respective representations are quasi-equivalent. This means that the representation is locally normal. We give a straightforward proof of this fact which is based on the Araki-Yamagami criterion. There is also an interesting group-theoretic aspect that we investigated, the relative normalizer of a pair of subgroups, introduced by D. Cadamuro and W. Dybalski. In our recent work (arXiv: 2106.02032), it re-appeared in this local relativistic setting.

MP 11: Quantum Information

Time: Wednesday 16:30–17:45 Location: H7

MP 11.1 Wed 16:30 H7

Exploring the Limits of Open Quantum Dynamics I: Motivation, Results from Toy Models to Applications — •Thomas Schulte-Herbrüggen[1,2], Frederik vom Ende[1,2], Emanuel Malvetti[1,2], and Gunther Dirr[3] — [1]Dept. Chem., TU-München (TUM) — [2]Munich Centre for Quantum Science and Technology (MCQST) — [3]Institute of Mathematics, Universität Würzburg

Which quantum states can be reached by coherently controlling n-level quantum systems coupled to a thermal bath in a switchable Markovian way? To put this question of quantum engineering on a mathematical footing, we address reachable sets of coherently controllable open quantum systems with switchable coupling to a thermal bath of temperature T.

The core problem reduces to the dynamics of the eigenvalues of the density operator. It translates into a toy model of studying points in the standard simplex allowing for two types of controls: (i) permutations within the simplex, (ii) contractions by a dissipative semigroup. We show how toy-model solutions pertain to the reachable set of the original controlled Markovian quantum system. Beyond the case $T = 0$ (amplitude damping) we present results for $0 < T < \infty$ using more recent methods like extreme points of the d-majorisation polytope.

We put the problem into context and give a number of illustrating examples.

Ref.: arXiv:2003.06018

MP 11.2 Wed 16:55 H7

Exploring the Limits of Open Quantum Dynamics II: Gibbs-Preserving Maps from the Perspective of Majorization — •Frederik vom Ende — TU Munich, 85748 Garching, Germany — Munich Centre for Quantum Science and Technology, 80799 Munich, Germany

Motivated by reachability questions in coherently controlled open quantum systems coupled to a thermal bath, as well as recent progress in the field of thermo-/vector-d-majorization (arXiv:1911.01061) we generalize classical majorization from unital quantum maps to maps with an arbitrary fixed point of full rank. Such maps preserve some Gibbs-state and thus play an important role in the resource theory of quantum thermodynamics, in particular for thermo-majorization.

Based on this we investigate D-majorization on matrices in terms of its topological and order properties, such as existence of unique maximal and minimal elements, etc. In the process we relate the notion of strict positivity to such maps as well as to Markovian processes in general. Moreover we characterize D-majorization in the qubit case via the trace norm and elaborate on why this is a challenging task when going beyond two dimensions.

MP 11.3 Wed 17:20 H7

Reachability and Stabilizability for Markovian Quantum Systems with Fast Hamiltonian Control — •Emanuel Malvetti[1,2], Frederik vom Ende[1,2], Thomas Schulte-Herbrüggen[1,2], and Gunther Dirr[3] — [1]Dept. Chem., TU-München (TUM) — [2]Munich Centre for Quantum Science and Technology (MCQST) — [3]Institute of Mathematics, Universität Würzburg

Markovian quantum systems with fast and full Hamiltonian control can be reduced to an equivalent control system on the eigenvalues of the density matrix describing the state. We explore this eigenvalue control system, whose state space is the standard simplex, by answering questions about reachability and stabilizability in the simplex. This has immediate applications to the cooling of Markovian quantum systems, for instance we give necessary and sufficient conditions for a system to be coolable. Furthermore, we show that for many tasks of interest the control Hamiltonian can be chosen to be independent of time.

MP 12: Quantum Mechanics

Time: Wednesday 17:50–18:15 Location: H7

MP 12.1 Wed 17:50 H7

Stability of quantum inequalities under scattering — •Henning Bostelmann[1], Daniela Cadamuro[2], and Gandalf Lechner[3] — [1]University of York, Department of Mathematics, York YO10 5DD, United Kingdom — [2]Universität Leipzig, Institut für Theoretische Physik, Brüderstraße 16, 04103 Leipzig — [3]School of Mathematics, Cardiff University, Senghennydd Road, CF24 4AG Cardiff, United Kingdom

Certain physical quantities that yield positive values in classical mechanics can have negative expectation values in quantum theory (e.g., the probability flux in the quantum backflow effect, or the averaged energy density in field theories). However, they typically possess a lowest negative eigenvalue. In other words, positive observables in classical theory often "quantize" to operators that are not necessarily positive, but bounded below ("quantum inequalities"). Here we investigate whether, for one quantum mechanical particle, such bounds are stable when the dynamics is perturbed by a scattering potential. This boils down to the question how fast the Møller operator Ω approaches the identity at high energies; more quantitatively, whether $\|(\Omega-1)(1+H_0)^\beta\| < \infty$ for suitable $\beta > 0$, where H_0 is the free Hamiltonian. We derive such bounds under generic assumptions on the free Hamiltonian and the scattering potential. In particular, $0 < \beta \leq 1/2$ is allowable for the Schrödinger Hamiltonian – independent of space dimension, and even in the matrix-valued case, i.e., when adding inner degrees of freedom.

MP 13: HV 4: Quantum Field Theory in Noncommutative Spacetime

Time: Thursday 11:00–11:40 Location: H6

Invited Talk MP 13.1 Thu 11:00 H6

Exact solution of the scalar QFT Φ^4 model on the 4-dimensional noncommutative Moyal space — •Alexander Hock — Mathematisches Institut Münster, Deutschland

Local QFT, as it is used in the Standard Model, can be generalized to a non-local QFT by introducing a noncommuting $\star$-product in the action functional. Mainly, we will focus on the scalar Φ^4 Model, which breaks down at the self-dual point and for large noncommutativity to a Matrix Model. In this limit, the tower of Dyson-Schwinger equations decouple to nonlinear integral equations. We will solve these equations and show the exact solution of the planar 2-point function in 4 dimensions.

Expanding this result for small coupling constants fits perfectly with the perturbative expansion into Feynman graphs renormalized by Zimmermann's forest formula. We emphazise that this model admits perturbatively the renormalon problem, but is nevertheless resummable.

MP 14: HV 5: Quantum Field Theory near Black Hole Horizons

Time: Thursday 11:45–12:25 Location: H6

Invited Talk MP 14.1 Thu 11:45 H6

Temperature and entropy-area relation of quantum matter near spherically symmetric outer trapping horizons — •Rainer Verch — Institut für Theoretische Physik, Universität Leipzig, Germany

We consider spherically symmetric spacetimes with an outer trapping which are generalizations of spherically symmetric black hole spacetimes where the central mass can vary with time. These spacetimes possess in general no timelike Killing vector field, but admit a Kodama vector field which provides a replacement. We investigate a scaling limit of Hadamard 2-point functions of a quantum field on the spacetime onto the ingoing lightlike congruence of a spherical horizon cross-section. The scaling limit 2-point function has a universal form and a thermal spectrum with respect to the time-parameter of the Kodama flow, where the inverse temperature is proportional to the surface gravity of the horizon cross-section. This can be seen as a local counterpart of the Hawking effect for an outer trapping horizon in the scaling limit. The scaling limit 2-point function as well as the 2-point functions of coherent states of the scaling-limit-theory have relative entropies behaving proportional to the cross-sectional horizon area. This is joint work with F. Kurpicz and N. Pinamonti, arXiv:2102.11547.

MP 15: Quantum Field Theory: Renormalization

Time: Thursday 14:00–14:50 Location: H6

MP 15.1 Thu 14:00 H6

A Rigorous Derivation of the Functional Renormalisation Group Equation — •Jobst Ziebell — TPI, Jena, Deutschland

The functional renormalisation group equation is derived in a mathematically rigorous fashion in a framework suitable for the Osterwalder-Schrader formulation of quantum field theory. To this end, we devise a very general regularisation scheme and give precise conditions for the involved regulators guaranteeing physical boundary conditions. Furthermore, it is shown how the classical limit is altered by the regularisation process leading to an inevitable breaking of translation invariance. We also give precise conditions for the convergence of the obtained theories upon removal of the regularisation.

MP 15.2 Thu 14:25 H6

Perturbative Renormalization in Combinatorially Non-local Field Theory — •Johannes Thürigen — WWU Münster

Renormalization in local quantum field theory relies on the possibility to subtract all subdivergences in a Feynman diagram as described for example by Zimmermann's forest formula or the Connes-Kreimer Hopf algebra. Here we show how this can be generalized to field theories with combinatorially non-local interactions such as matrix or tensor field theories. In particular, this gives a general recipe for renormalization of various field-theory approaches to quantum gravity.

MP 16: Strongly Interacting Quantum Field Theory

Time: Thursday 15:00–15:50 Location: H6

MP 16.1 Thu 15:00 H6

Non-perturbative contribution to the collisional broadening and medium induced radiation in QCD plasmas — Guy D. Moore[1], Soeren Schlichting[2], Niels Schlusser[1,3], and •Ismail Soudi[2] — [1]Institut fur Kernphysik, Technische Universitat Darmstadt — [2]Fakultat fur Physik, Universitat Bielefeld — [3]Department of Physics & Helsinki Institute of Physics

Due to the famous infrared problem of finite temperature QCD, perturbative calculation of transport phenomena can receive large non-perturbative contributions.

Here, we investigate the impact of non-perturbative contributions to jet-medium interactions, by incorporating non-perturbative contributions to the collisional broadening kernel $C(b_\perp)$, which determines the rate of medium induced radiation.

We construct the collision kernel $C(b_\perp)$ non-perturbatively, by matching lattice EQCD calculations [1] with the correct ultraviolet behavior of QCD.

By comparing the results for medium induced radiation in infinite and finite QCD plasmas [2] to leading order and next to leading order calculations, we assess the importance of non-perturbative aspects of momentum broadening for jet quenching calculations.

[1] - G. D. Moore and N. Schlusser, Phys. Rev. D101, 014505(2020), [Erratum: Phys.Rev.D 101, 059903 (2020)], arXiv:1911.13127 [hep-lat]

[2]- G. D. Moore, S. Schlichting, N. Schlusser and I. Soudi [arXiv: 2105.01679]

MP 16.2 Thu 15:25 H6

Lattice approximation of conformal symmetry — •Alexander Stottmeister — Leibniz Universität Hannover

We will discuss the application of the recently introduced framework of operator-algebraic renormalization to fermionic lattice systems. Focussing on the 1+1-dimensional case, we will illustrate how the scaling limit of the massless free fermion can be obtained. Moreover, we will show how conformal symmetry is recovered by a formula due to Koo and Saleur. This is joint work with T. J. Osborne.

MP 17: Entropy in Quantum Field Theory

Time: Thursday 16:30–18:10 Location: H6

MP 17.1 Thu 16:30 H6

Relative entropy of coherent states on general CCR algebras — Henning Bostelmann[1], •Daniela Cadamuro[2], and Simone Del Vecchio[2] — [1]University of York, Department of Mathematics, York YO10 5DD, United Kingdom — [2]Institut für Theoretische Physik, Universität Leipzig, Brüderstraße 16, 04103 Leipzig

The study of relative entropy between states in quantum field theory has recently attracted much attention in connection with the quantum null energy condition; usually one considers the vacuum and a coherent excitation, and the relative entropy with respect to a wedge algebra. In generalization of this, we study the relative entropy for a subalgebra of a generic CCR algebra between a general (possibly mixed) quasifree state and a coherent excitation of it. We give a formula for this entropy in terms of single-particle modular data. We also investigate changes of the relative entropy along subalgebras arising from an increasing family of symplectic subspaces, and study lower estimates for the second derivative of the relative entropy along this family, which replace the usual notion of convexity of the entropy. Our main input is a regularity condition for the family of subspaces (differential modular position) which generalizes the notion of half-sided modular inclusions. Examples include thermal states for the conformal U(1)-current.

MP 17.2 Thu 16:55 H6

Relative entropic uncertainty relation for scalar quantum fields — Stefan Flörchinger, •Tobi Haas, and Markus Schröfl — Institut für Theoretische Physik, Universität Heidelberg

Entropic uncertainty is a well-known concept to formulate uncertainty relations for continuous variable quantum systems with finitely many degrees of freedom. Typically, the bounds of such relations scale with the number of oscillator modes, preventing a straight-forward generalization to quantum field theories.

In this talk, I will present a way of overcoming this difficulty by introducing the notion of a functional relative entropy, which has a meaningful field theory limit. I will present the first entropic uncertainty relation for a scalar quantum field theory and illustrate that its bound remains finite also for an infinite number of oscillator modes.

MP 17.3 Thu 17:20 H6

Entanglement entropy between spatial regions of an interacting condensate — •Natalia Sánchez-Kuntz and Stefan Flörchinger — ITP, Heidelberg University, Philosophenweg 16, D-69120 Heidelberg, Germany

We treat a nonrelativistic limit of QFT in which the entanglement entropy is finite in the UV. Furthermore we show that a scaling of the entanglement entropy with the system size for relativistic phonons is recovered. We discuss the emergence of an IR divergence, and its relation to zero modes. We compare this with other theories with similar behaviour.

We show the results related to a Bose-Einstein condensate in 1+1 dimensions and comment on further questions we are exploring at the moment, along with some challenges that come our way.

MP 17.4 Thu 17:45 H6

Inverted c-functions in thermal states — •Matthias Kaminski and Casey Cartwright — Department of Physics and Astronomy, University of Alabama,514 University Boulevard, Tuscaloosa, AL 35487, USA

We first compute the effect of a chiral anomaly, charge, and a magnetic field on the entanglement entropy in N=4 Super-Yang-Mills theory at strong coupling via holography. Depending on the width of the entanglement strip the entanglement entropy probes energy scales from the ultraviolet to the infrared energy regime of this quantum field theory prepared in a given state. From the entanglement entropy, we then compute holographic c-functions and demonstrate an inverted c-theorem for them. That is, these c-functions in generic thermal states monotonically increase towards the infrared energy regime in contrast to the c-functions in vacuum states which decrease along the renormalization group flow from the ultraviolet to the infrared regime. In these thermal states, the c-functions in the infrared limit are proportional to the value of the thermal entropy.

MP 18: Constructive Tools for Quantum Field Theory

Time: Friday 11:00–12:15 Location: H6

MP 18.1 Fri 11:00 H6

A product picture for quantum electrodynamics — •Bernard Kay — Department of Mathematics, University of York, York, England

We exhibit a product picture for QED – i.e. a reformulation in which it has a total Hamiltonian, arising as a sum of a free electromagnetic Hamiltonian, a free Dirac Hamiltonian and an interaction term, acting on a Hilbert space which is a subspace (the “physical subspace”) of the full tensor product of an electron/positron Hilbert space and an electromagnetic-field Hilbert space. The traditional Coulomb-gauge formulation of QED isn’t a product picture in this sense because, in it, the longitudinal part of the electric field is a function of the Dirac ψ-field. We prove (at a formal level) our product picture is equivalent to Coulomb gauge QED. Also, in the product picture: (i) In all states in the physical subspace, the ψ field is entangled with longitudinal photons; (ii) Gauss’s law holds as an operator equation; (iii) The electric field operator and the full Hamiltonian aren’t self-adjoint on the full tensor-product Hilbert space, but they are self-adjoint on the physical subspace and so that’s OK. Also (iv) The product picture resembles temporal gauge quantization but seems free from the well-known difficulties of that; (v) In the nonrelativistic limit, one obtains a reformulation of Schroedinger many body theory in which the usual Coulomb potential is absent and, instead, a term representing the kinetic energy of longitudinal photons is present so that, say, the binding energy of the Hydrogen atom is seen to arise as a byproduct of the entanglement of the proton and electron with longitudinal photons.

MP 18.2 Fri 11:25 H6

Quantum field theory without ghosts and indefinite metric – A program and some results. — •Jens Mund — Departamento de Fisica, Universidade Federal de Juiz de Fora, Brazil

Quantum field theories involving interacting vector fields with spin/helicity one (or higher) are usually based on gauge theory: One adds unphysical degrees of freedom in the form of ”negative norm” states and ”ghost” fields before the construction, and divides them out afterwards by requiring gauge (or BRST) invariance of the S-matrix and of observable fields. The construction of charge-carrying fields (like the Dirac field in QED) is notoriously difficult.

In the talk an alternative approach is presented: Instead of Hilbert space positivity, the localization of (unobservable) fields is weakened, in a way permitted by the principles of relativistic quantum field theory: The fields are localized on ”Jordan-Mandelstam strings” extending to space-like infinity. They act in a true Hilbert space without ghosts. In contrast to gauge theory, our approach allows for a direct (perturbative) construction of charged interacting fields. I comment on partial results on (massive and proper) QED, (Abelian) Higgs model, and Yang-Mills models.

MP 18.3 Fri 11:50 H6

Renormalization in string-localized quantum field theory — •Christian Gass — Universität Göttingen, Germany

String-localized quantum field theory (SL QFT) provides an alternative to the usual gauge theoretic approaches. In the last one-and-a-half decades, many conceptual benefits of SL QFT have been discovered. However, a renormalization recipe for loop graphs with internal SL fields was not at hand until now.

In this talk, we present a proof that the problem of renormalization is not worse in SL QFT than in usual point-localized theories. This happens in spite of the analytic complexity of SL propagators and provided that one takes care in how to set up perturbation theory in SL QFT.

Consequently, renormalization stays a pure short-distance problem and the improved short-distance behavior of SL fields remains a meaningful notion, which indicates that there can exist renormalizable models in SL QFT whose point-localized counterparts are non-renormalizable.

MP 19: Fundamental Ideas

Time: Friday 14:00–14:50 Location: H6

MP 19.1 Fri 14:00 H6

Electromagnetic interactions as the source of all known four forces. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

In theoretical physics different particle representations were already proposed; as points, as vortex, as strings, as wave-packets, etc. The present work is based on an approach where subatomic particles (SPs) are represented as focal points of rays of Fundamental Particles (FPs) that move from infinite to infinite. FPs store the energy of a SP as rotation defining angular momenta. Interactions between SPs are thus the product of the interactions of the angular momenta of their FPs. There is no need to introduce carrier particles like photons, gluons, W and Z Bosons, gravitons, etc. All four forces are due to electromagnetic interactions and can be described by QED. Another important finding of the approach is that the interaction between two charged SPs tends to zero for the distance between them tending to zero. Atomic nuclei can thus be represented as swarms of electrons and positrons that neither attract nor repel each other. As atomic nuclei are composed of nucleons which are composed of quarks, the quarks can also be seen as swarms of electrons and positrons. More at: www.odomann.com

MP 19.2 Fri 14:25 H6

Für ein einheitliches Weltbild der Physik — •Helmut Hille — Heilbronn, Fritz-Haber-Straße 34

Es ist nur menschliche Sehgewohnheit, getrennt Gesehenes als definitiv getrennt Existierendes zu halten, obgleich schon das System Sonne-Erde-Mond das Gegenteil beweist. Keiner dieser Körper hätte ohne den anderen seine Bahn und es gäbe auf der Erde keine Gezeiten. Verschränkte Quanten haben gezeigt, dass ihr gemeinsamer Ursprung sie sich als Eines verhalten lassen. Ebenso ist der Big Bang der gemeinsame Ursprung aller Materie unseres Kosmos zu einer neuen immanenten Einheit, die sich in Form der Gravitation zusammenhalten möchte, während sie äußerlich gleichzeitig expandiert. Die Gravitation ist nur ein weiterer Beleg über die Macht des Unsichtbaren, die es endlich zu akzeptieren gilt. Heute sucht man als Ausweg das Unsichtbare in dunkler Materie und Energie. Aber das Unsichtbare, um das es mir geht, ist kein Teilchen. Es ist nur die Rückseite des Sichtbaren, die wir mit der Gravitationskonstante erfassen. So ist die Gravitation eine Form der Verschränkung aller betroffenen Materie (auch Strahlung ist Materie), von mir hier Superverschränkung genannt. In der Verbindung mit drei weiteren Prämissen ergibt sich ein Weltbild der Physik von großer Einfachheir, Klarheit und Schönheit, das ein rationales ist, das auf klaren, einsichtigen Prämissen beruht, die jedermann nachvollziehen kann.

MP 20: Poster (permanent)

Time: Monday 10:30–11:00 Location: P

MP 20.1 Mon 10:30 P

A time-symmetric resolution of the Einstein's Boxes paradox — •Michael B. Heaney — 3182 Stelling Drive, Palo Alto CA 94303

The Einstein's Boxes paradox was developed by Einstein, de Broglie, and others to demonstrate the incompleteness of the Copenhagen Formulation of quantum mechanics. I explain the paradox using the Copenhagen Formulation. I then show how a Time-Symmetric Formulation of quantum mechanics resolves the paradox in the way predicted by Einstein and de Broglie. Finally, I describe an experiment that can distinguish between these two formulations.