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

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The programme includes classical and quantum field theory, equilibrium and non-equilibrium systems, complexity and quantum information theory. It presents progress in methods and concepts, model studies and structure analysis.

Overview of Invited Talks and Sessions

(Lecture halls H-HS VII (MP1-10 und MP15-18) und H-I (MP11-14); Poster H-HS VII)

Invited Talks

MP 2.1	Mon	16:30–17:10	H-HS VII	**Stochastic Dynamics in Quantum Mechanics** — •Denis Bernard
MP 4.1	Tue	11:00–11:40	H-HS VII	**Universal structures in quantum field theory far from equilibrium** — •Jürgen Berges
MP 6.1	Tue	17:00–17:40	H-HS VII	**KPZ universality in mathematics and physics** — •Patrik Ferrari
MP 8.1	Wed	10:30–11:10	H-HS VII	**Exact solution of the noncommutative ϕ_4^4 QFT model** — •Alexander Hock, Raimar Wulkenhaar, Harald Grosse
MP 15.1	Thu	14:00–14:30	H-HS VII	**The D-CTC condition is generically fulfilled in classical (non-quantum) statistical systems** — Jürgen Tolksdorf, •Rainer Verch

Sessions

MP 1.1–1.4	Mon	12:00–13:20	H-HS VII	**Gravity: Classical and Quantum**
MP 2.1–2.1	Mon	16:30–17:10	H-HS VII	**HV Bernard: Stochastic Dynamics in Quantum Mechanics**
MP 3.1–3.2	Mon	17:15–17:55	H-HS VII	**Quantum Mechanics**
MP 4.1–4.1	Tue	11:00–11:40	H-HS VII	**HV Berges: QFT Far From Equilibrium**
MP 5.1–5.2	Tue	11:45–12:25	H-HS VII	**QFT Far From Equilibrium**
MP 6.1–6.1	Tue	17:00–17:40	H-HS VII	**HV Ferrari: KPZ Universality**
MP 7.1–7.2	Tue	17:45–18:25	H-HS VII	**Classical Field Theory**
MP 8.1–8.1	Wed	10:30–11:10	H-HS VII	**HV Hock: QFT in Noncommutative Space**
MP 9.1–9.2	Wed	11:15–11:55	H-HS VII	**Quantum Field Theory**
MP 10.1–10.3	Wed	12:00–13:00	H-HS VII	**Quantum Field Theory: gauge theories**
MP 11.1–11.4	Wed	14:15–15:35	H-HS I	**AdS/CFT: Complexity**
MP 12.1–12.1	Wed	15:40–16:00	H-HS I	**Tensor Networks I**
MP 13.1–13.2	Wed	16:30–17:10	H-HS I	**Tensor Networks II**
MP 14	Wed	17:15–18:00	H-HS I	**Mitgliederversammlung**
MP 15.1–15.1	Thu	14:00–14:30	H-HS VII	**HV Verch: Quantum Information**
MP 16.1–16.2	Thu	14:40–15:20	H-HS VII	**Quantum Information**
MP 17.1–17.2	Thu	15:20–16:00	H-HS VII	**Quantum Information and QFT**
MP 18.1–18.2	Thu	16:30–17:10	H-HS VII	**Alternative Ideas**
MP 19.1–19.1	Mon	11:00–18:00	H-HS VII	**Poster (Monday - Thursday)**

Invited talks of the PhD prize symposium SYMD

See SYMD for the full program of the symposium.

SYMD 1.1	Mon	14:30–15:00	H-Aula/HS I/HS X	***N*-Particle Scattering and Asymptotic Completeness in Wedge-Local Quantum Field Theories** — •Maximilian Duell

SYMD 1.2	Mon	15:00–15:30	H-Aula/HS I/HS X	**First observation of double electron capture in Xe-124 with the dark matter detector XENON1T** — •Alexander Fieguth
SYMD 1.3	Mon	15:30–16:00	H-Aula/HS I/HS X	**Anisotropic Transport of Galactic Cosmic Rays based on Stochastic Differential Equations** — •Lukas Merten

Invited talks of the joint Symposium "Entanglement"

See SYEN for the full program of the symposium.

SYEN 1.1	Thu	11:00–11:40	J-HS D	**Entanglement and Complexity in Quantum Many-Body Systems** — •Tomaz Prosen
SYEN 1.2	Thu	11:40–12:20	J-HS D	**Entanglement and Explanation** — •Chris Timpson
SYEN 1.3	Thu	12:20–13:00	J-HS D	**Production and observation of entanglement in quantum optics** — •Roman Schnabel

Mitgliederversammlung des FV MP / Members' Assembly of the MP Division

Wednesday 17:15–18:00 H-HS I

Vorläufige TOPs:

- Bericht
- Sektion "Materie und Kosmos" (SMuK)
- Planungen
- Verschiedenes

MP 1: Gravity: Classical and Quantum

Time: Monday 12:00–13:20 Location: H-HS VII

MP 1.1 Mon 12:00 H-HS VII

Disformal transformations in Weitzenböck geometry — •Manuel Hohmann — University of Tartu, Tartu, Estonia

We study disformal transformations in the context of scalar extensions to teleparallel gravity, in which the gravitational interaction is mediated by the torsion of a flat, metric compatible connection. This geometry, also known as Weitzenböck geometry, provides an alternative background geometry also for other field theories. We find a generic class of scalar-torsion actions which is invariant under disformal transformations, and which possesses different invariant subclasses. For the most simple of these subclasses we explicitly derive all terms that may appear in the action. We propose to study actions from this class as possible teleparallel analogues of healthy beyond Horndeski theories, or degenerate higher-order scalar tensor (DHOST) theories.

MP 1.2 Mon 12:20 H-HS VII

Riding on a Dark Bubble: Emergent de Sitter cosmology — •Souvik Banerjee[1], Ulf Danielsson[2], and Suvendu Giri[2] — [1]Julius-Maximilians-University Würzburg, Würzburg, Germany — [2]Uppsala University, Uppsala, Sweden

I will discuss how dark energy can be realised using unstable AdS, with our universe riding an expanding bubble. Our proposal involves realising four dimensional effective gravity on a brane which mediates the decay from a non-supersymmetric five dimensional Anti deSitter false vacuum to a true vacuum. In this way, it is natural for a four dimensional observer to experience an effective positive cosmological constant coupled to matter and radiation, avoiding the need for scale separation or a fundamental de Sitter vacuum. I will in particular discuss the holographic interpretation with matter induced in this model by hanging strings. I will argue how our construction provides a new way to understand the cosmological horizon, and also the underlying deep implications for particle physics and black holes.

MP 1.3 Mon 12:40 H-HS VII

Wormholes in AdS_4 — •Joshua Kames-King[1] and Souvik Banerjee[2] — [1]Bethe Center for Theoretical Physics Bonn — [2]Julius-Maximilians-Universität Würzburg

We construct a traversable wormhole in four-dimensional Anti-de-Sitter space via the Maldacena-Milekhin-Popov construction. We show that in contrast to asymptotically flat space the solution acquires thermodynamic stability and represents the energetically most viable solution. Furthermore we construct a quantum field theory on this background and calculate the spectrum in differing limits.

MP 1.4 Mon 13:00 H-HS VII

Space - Time - Matter: Finite Projective Geometry as a Quantum World with Elementary Particles — •Klaus Mecke — Institut für Theoretische Physik, Universität Erlangen-Nürnberg

A unified theory for space-time and matter might be based on finite projective geometries instead of differentiable manifolds and fields. Each point of the world is equipped with a quadratic form over a finite Galois field which define neighbors in the finite set of points. Due to the projective equivalence of all quadratic forms this world is necessarily a 4-dimensional, locally Lorentz-covariant space-time with a gauge symmetry G(3)xG(2)xG(1) for internal points which represent elementary particle degrees of freedom. Thus, matter appears as a geometric distortion of an inhomogeneous field of quadrics and all physical properties (spins, charges) of the standard model seem to follow from its finite geometric structure in a continuum limit. The finiteness inevitably induces a fermionic quantization of all matter fields and a bosonic for gauge fields. The main difference to Einstein's general theory of relativity is the use of finite fields instead of real numbers to parametrize points of events.

K. Mecke, Biquadrics configure finite projective geometry into a quantum spacetime, EPL 120, 10007 (2017).

MP 2: HV Bernard: Stochastic Dynamics in Quantum Mechanics

Time: Monday 16:30–17:10 Location: H-HS VII

Invited Talk MP 2.1 Mon 16:30 H-HS VII

Stochastic Dynamics in Quantum Mechanics — •Denis Bernard — CNRS & LPENS, Ecole Normale Superieure de Paris

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 monitorings, and the emergence of quantum jumps and spikes, and of statistical fluctuations of quantum states and quantum coherences in many-body model systems at, or away from, equilibrium.

MP 3: Quantum Mechanics

Time: Monday 17:15–17:55 Location: H-HS VII

MP 3.1 Mon 17:15 H-HS VII

Systematic construction of k-uniform states — •Zahra Raissi[1], Adam Teixid[1], Christian Gogolin[1,2,3], and Antonio Acin[1,4] for the A4-Collaboration — [1]ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]Institut für Theoretische Physik, Universität zu Köln, 50937 Köln, Germany — [3]Xanadu, Toronto, M5V 1X6, Canada — [4]ICREA-Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain

Absolutely maximally entangled (AME) states are pure quantum states of n-partite systems of local dimension q with the property that all reduced states (marginals) of at most half the system size are maximally mixed. AME states are special cases of the class of so-called k-uniform states for $k = \lfloor n/2 \rfloor$. These states are useful for some protocols like multipartite teleportation, have connections with combinatorial designs, and quantum error correcting codes (QECC). They are also relevant for the construction of holographic codes.

To our knowledge, the only known systematic construction of these states is based on a class of classical error correction codes known as Maximum Distance Separable (MDS) code. In this work, we present a systematic method to construct other examples of k-uniform states. We also show that the states derived through our construction are not Local Unitary (LU) equivalent to any k-uniform state constructed from minimum-distance separable codes.

MP 3.2 Mon 17:35 H-HS VII

Gibbs-Preserving Maps from the Perspective of Majorization — •Frederik vom Ende — TU Munich, 85748 Garching, Germany

Quantum channels which preserve some Gibbs-state play an important role in the resource theory of quantum thermodynamics and, more precisely, in connection with Thermo-Majorization.

Motivated by questions regarding reachability in coherently controllable open quantum systems with switchable coupling to a thermal bath, as well as recent developments of thermo-/d-majorization in the vector case (cf. arXiv:1911.01061), we generalize classical majorization from unital channels to channels with an arbitrary fixed point D of full rank.

Based on this we investigate generalized D-majorization in terms of

order properties, unique maximal & minimal elements, topological aspects, etc. Moreover we will give characterizations of D-majorization in the qubit case and elaborate on why this is a challenging task when going beyond two dimensions.

MP 4: HV Berges: QFT Far From Equilibrium

Time: Tuesday 11:00–11:40 Location: H-HS VII

Invited Talk MP 4.1 Tue 11:00 H-HS VII

Universal structures in quantum field theory far from equilibrium — •Jürgen Berges — Universität Heidelberg

Prominent applications of quantum field theory far from equilibrium include the post-inflationary dynamics in the early universe, collisions of relativistic nuclei at giant laboratory facilities, or table-top experiments with ultracold quantum gases. Even though the typical energy scales vastly differ, these systems are predicted to show very similar dynamical properties. Certain characteristic observables can even be quantitatively the same, defining non-equilibrium universality classes. These universal phenomena have recently been discovered experimentally in ultracold quantum gases far from equilibrium, and their theoretical understanding profits from the topological concept of persistent homology.

MP 5: QFT Far From Equilibrium

Time: Tuesday 11:45–12:25 Location: H-HS VII

MP 5.1 Tue 11:45 H-HS VII

Transport, entanglement, and chaos in chiral quantum fluids far from equilibrium — •Matthias Kaminski[1], Casey Cartwright[1], Jana Ingram[1], Roshan Koirala[1], and Martin Ammon[2] — [1]Department of Physics and Astronomy, University of Alabama, Tuscaloosa, AL 35487, USA — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller University of Jena, 07743 Jena, Germany

First, applying recently developed methods, we systematically construct and complete the hydrodynamic description of charged chiral quantum fluids in strong external magnetic fields as an effective field theory. This description includes the effect of chiral anomalies, magnetization and polarization. Novel transport effects arise.

Second, as a proof of existence, within a holographic (gauge/gravity correspondence) model, we compute most of the linear response coefficients describing these transport effects. The holographic model on the gravity side consists of charged magnetic black hole solutions to Einstein-Maxwell-Chern-Simons theory.

Third, as the main part of this work, we drive that same gravitational model far from equilibrium through rapid mass accretion. From this, we compute entanglement entropy and correlation functions of the corresponding fluid far from equilibrium. We derive relations between the linear response coefficients mentioned above, such as diffusivity, and the quantities characterizing the chaotic behavior of the system, such as the butterfly velocity.

MP 5.2 Tue 12:05 H-HS VII

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] — [1]Frankfurt Institute for Advanced Studies (FIAS), 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

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, mainly thermodynamic properties have been focused on.

In this talk, we extend the definition of the transport coefficients from the quasi-static to the highly dynamic regime. Our approach is based on Wigner transformations within the Green–Kubo formalism. 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. Asymptotically, we consistently recover the well-known quasi-static value of the shear viscosity to entropy density ratio. During the dynamic regime, we find substantial deviations of order one.

MP 6: HV Ferrari: KPZ Universality

Time: Tuesday 17:00–17:40 Location: H-HS VII

Invited Talk MP 6.1 Tue 17:00 H-HS VII

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

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 7: Classical Field Theory

Time: Tuesday 17:45–18:25 Location: H-HS VII

MP 7.1 Tue 17:45 H-HS VII

Staccato radiation from the decay of large amplitude oscillons — •Yakov Shnir — BLTP, JINR, Dubna

We study the decay of large amplitude, almost periodic breather-like states in a deformed sine-Gordon model in one spatial dimension. We discover that these objects decay in a staggered fashion via a series of transitions, during which higher harmonics are released as short, staccato bursts of radiation. Further, we argue that this phenomenon is not restricted to one particular model, and that similar mechanisms of radiative decay of long-lived oscillating states can be observed for a wide class of physical systems, including the $\phi 6$ model.

MP 7.2 Tue 18:05 H-HS VII

Real scalar field, non-relativistic limit, and expansion — •Lars Heyen and Stefan Flörchinger — Institut für Theoretische Physik Heidelberg, Heidelberg, Germany

We generalise the existing transformation from a relativistic real scalar to a complex scalar with a Schroedinger-like equation of motion by Namjoo, Guth and Kaiser from a Minkowskian to a more general background metric. Then we apply the transformation to a real scalar on a FLRW background and calculate the effective non-relativistic potential up to second order in small parameters for a ϕ^4 interaction in the relativistic theory. The non-trivial background introduces an imaginary

term in the effective potential. Further, we show that the transformation can also be interpreted as a Bogoliubov transformation between relativistic and non-relativistic creation and annihilation operators.

MP 8: HV Hock: QFT in Noncommutative Space

Time: Wednesday 10:30–11:10 Location: H-HS VII

Invited Talk MP 8.1 Wed 10:30 H-HS VII

Exact solution of the noncommutative ϕ^4_4 QFT model — •Alexander Hock[1], Raimar Wulkenhaar[1], and Harald Grosse[2] — [1]WWU Münster, Germany — [2]University of Vienna, Austria

A noncommutative quantum field theory is a QFT where the underlying space is equipped with an additional algebraic structure. The scalar ϕ^4 model which is also known as Grosse-Wulkenhaar model will be presented in 4 dimensions, which has the same degrees of divergence as the ordinary ϕ^4 model.

The set of infinitely many Ward-Takahashi identities leads to closed integral equations for the correlation functions. These equations can be solved with techniques of algebraic geometry and complex analysis. The exact solution of the 2-point function will be shown which consists of hypergeometric functions. The perturbative expansion coincides with the Feynman graph computations by using Zimmermann's forest formula.

The remarkable property is that the theory is resummable even though the renormal problem appears and the number of Feynman graphs grows with $\mathcal{O}(n!)$.

MP 9: Quantum Field Theory

Time: Wednesday 11:15–11:55 Location: H-HS VII

MP 9.1 Wed 11:15 H-HS VII

Absence of chiral symmetry breaking in Thirring models in 1+2 dimensions — •Julian Lenz, Björn Wellegehausen, and Andreas Wipf — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

The Thirring model is an interacting fermion theory with current-current interaction. The model in 1+2 dimensions has applications in condensed-matter physics to describe the electronic excitations of Dirac materials. Earlier investigations suggest that a critical number of (reducible) flavors N_c exists, below which chiral symmetry can be broken spontaneously. While values for N_c found in the literature vary broadly, recent lattice studies with chiral fermions have indicated that chiral symmetry is unbroken for all integer flavor numbers. To find an accurate value N_c we study the Thirring model for analytically continued N between 0.5 and 1.1. We see no chiral symmetry breaking in all Thirring models with 1 or more flavors of (4-component) fermions. Besides the transition to the unphysical lattice artifact phase we find strong evidence for a hitherto unknown phase transition that exists for $N > N_c$ and should answer the question of where to construct a continuum limit.

MP 9.2 Wed 11:35 H-HS VII

Operator-algebraic renormalization and wavelet theory — •Alexander Stottmeister — Mathematisches Institut, Westfälische Wilhelms-Universität Münster, 48149 Münster

I will discuss on-going work on an operator-algebraic approach to the Wilson-Kadanoff renormalization group. I will present a simple argument that ensures the existence of scaling limits in this approach, thus, indicating the naturalness of the approach. As a test case, I will explain how the theory of wavelets can be utilized to implement this approach in terms of generalized block-spin transformations in the setting of scalar field theories. Locality of the resulting scaling limit can be shown by rigorous implementation of a recent proposal of T. Osborne using Lieb-Robinson bounds.

The project is a joint work with V. Morinelli, G. Morsella and Y. Tanimoto.

MP 10: Quantum Field Theory: gauge theories

Time: Wednesday 12:00–13:00 Location: H-HS VII

MP 10.1 Wed 12:00 H-HS VII

Perturbative construction of a string-localized Dirac field in a Hilbert space representation of QED — A program. — •Jens Mund[1], Karl-Henning Rehren[2], and Bert Schroer[3] — [1]Universidade Federal de Juiz de Fora, Brazil — [2]Georg-August Universität Göttingen, Deutschland — [3]CBPF, Rio de Janeiro, Brazil

The construction of charged sectors in QED has been a difficult task due to the infrared problems related to Gauss law, implying that the Dirac field cannot be point-like localized and that the electron is an infra-particle.

We propose a novel strategy for a straightforward perturbative construction of QED along the lines of Epstein and Glaser, which complies with these features, and also with positivity. Our interacting Dirac field is not point- but "string-localized", i.e., localized on half-rays extending to space-like infinity. The construction works in a framework which relates the free (Gupta-Bleuler) vector potential acting in a Krein space with its string-localized version acting in the physical subspace. As input for the interacting Dirac field we use the free string-localized "dressed Dirac field" $:exp(iq\phi)\psi:$, where q is the electron charge, and ϕ is the (known) field that implements the gauge transformation between the two potentials. The free dressed Dirac field already describes the electron as an infra-particle.

We hope that this model can be renormalized at all orders, such that the mentioned features hold (positivity, Gauss' law, infra-particle aspect). Restricting to the forward light cone and using light-like string directions, the infra-particle aspect might disappear.

MP 10.2 Wed 12:20 H-HS VII

Asymptotically safe QED — •Jobst Ziebell[1] and Holger Gies[2] — [1]TPI, FSU Jena, Germany — [2]TPI, FSU Jena, Germany

High-energy completeness of Quantum electrodynamics (QED) can be induced by an interacting ultraviolet fixed point of the renormalization flow. We provide evidence for the existence of such fixed points in the subspace spanned by the gauge coupling, the electron mass and the Pauli spin-field coupling. Renormalization group trajectories emanating from the fixed point correspond to asymptotically safe theories that are free from the Landau pole problem. We analyse the set of fixed points, their stability properties with respect to a systematic expansion scheme, and compute high-energy complete flows towards the long-range physics. We observe the existence of a physical trajectory that matches the measured physical parameters in the infrared.

MP 10.3 Wed 12:40 H-HS VII

Avoiding Anomalies — •Klaus Morawetz — Münster University of Applied Sciences, 48565 Steinfurt, Germany — International Institute of Physics - UFRN, Campus Universitário Lagoa nova, 59078-970 Natal, Brazil

The quantum anomaly can be written alternatively as conservation-breaking term or as non-gauge invariant current. This is exemplified on the anomalous term $\sim \vec{E}\vec{B}$ in the balance of the chiral density. This

term is derived from the quantum kinetic equations for systems with SU(2) structure within a completely conserving approach. Therefore the origin of this term is not a unique signal of symmetry-breaking terms in the field-theoretical Lagrangian. 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 at short distances. A proper balance of these fluctuations by many-body effects on the same level avoids these anomalies. The origin of the $\sim \vec{E}\vec{B}$ is therefore proposed not due to anomalies but as a completely conventional quantum kinetic effect. [Eur. Phys. J. B 92 (2019) 176, Phys. Lett. A 383 (2019) 1362]

MP 11: AdS/CFT: Complexity

Time: Wednesday 14:15–15:35 Location: H-HS I

MP 11.1 Wed 14:15 H-HS I

Complexity for Quantum Fields: Subregions, Mixed States and Purifications — •Hugo Antonio Camargo Montero — Albert Einstein Institute, Potsdam, Germany

In this talk we explore the notion of complexity in quantum field theories. We first apply the notion of circuit complexity to a quantum quench through a critical point in 1+1 dimensions. We apply this setup to a Gaussian state with two degrees of freedom, where we quantify the complexity of purification associated with a subregion, and show that complexity is capable of probing features to which the entanglement entropy is insensitive. We find that the complexity of subregions is subadditive, and comment on potential implications for holography. We also discuss upcoming work regarding the study of complexity of purification for mixed Gaussian states with a large number of degrees of freedom. In the second part of the talk, we enter the recent discussion involving the two definitions of complexity in field theories, namely circuit complexity and path integral complexity. We focus on two-dimensional conformal field theories (CFTs) where we provide a measure for the circuit complexity associated to the unnormalized thermal density matrix $\rho = \exp(-\beta H)$. We show that the Liouville action, which is the path integral complexity measure for ρ, is an approximation to a genuine circuit complexity measure.

MP 11.2 Wed 14:35 H-HS I

Virasoro complexity and circuits as geodesic motion in infinite dimensions — •Mario Flory[1] and Michał P. Heller[2] — [1]Institute of Physics, Jagiellonian University, 30-348 Kraków, Poland — [2]Albert Einstein Institute, 14476 Potsdam, 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 11.3 Wed 14:55 H-HS I

Realizing Computational Complexity in Conformal Field Theory with Kac-Moody Symmetry — Johanna Erdmenger, Marius Gerbershagen, and •Anna-Lena Weigel — Institute for Theoretical Physics and Astrophysics, 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, to appear.

MP 11.4 Wed 15:15 H-HS I

Holographic complexity with TT deformation — •Souvik Banerjee, Johanna Erdmenger, and Emma Loos — Julius-Maximilians-University Würzburg, Würzburg, Germany

TT deformed CFTs are dual to semiclassical gravity in AdS spacetime with a finite radial cutoff. Complexity of boundary CFT operators, on the other hand, has an intimate connection to radial depth in the bulk. The duality between TT deformed CFTs and gravitational physics at a cut off AdS spacetime will therefore be an ideal playground to test holographic proposals for complexity. This also helps in understanding quantitatively and explicitly, the renormalization group flow in the bulk and thereby explaining the emergence of AdS spacetime in the tensor network like cMERA.

MP 12: Tensor Networks I

Time: Wednesday 15:40–16:00 Location: H-HS I

MP 12.1 Wed 15:40 H-HS I

Algebraic structure of renormalization in tensorial field theories — •Johannes Thürigen — Mathematisches Institut der Westfälischen Wilhelms-Universität Münster

Quantum field theories on non-commutative geometry have recently been found to be solvable non-perturbatively in a matrix-theory representation. Tensorial field theories are a generalization of such matrix field theory to higher rank and specific models are candidates for a quantum theory of gravity. It is therefore an important question to what extent non-perturbative solutions can be obtained in such field theories as well. I address this challenge making use of the algebraic structure of renormalization. I will derive the Hopf algebra of Feynman diagrams for such non-local field theories giving rise to Dyson-Schwinger equations. This is the first step towards identifying the conditions for solving tensorial field theories non-perturbatively. Control over the non-pertubative regime is an open issue of huge physical interest since the limit to continuum space-time coincides with the limit to critical loci in such approaches to quantum gravity.

MP 13: Tensor Networks II

Time: Wednesday 16:30–17:10 Location: H-HS I

MP 13.1 Wed 16:30 H-HS I

From spin chains to real-time thermal field theory using tensor networks — Mari Carmen Bañuls[1,2], Michał P. Heller[3,4], Karl Jansen[5], •Johannes Knaute[3,6], and Viktor Svensson[3,4] — [1]Max Planck Institute of Quantum Optics, 85748 Garching bei München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 München, Germany — [3]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), 14476 Potsdam-Golm, Germany — [4]National Centre for Nuclear Research, 00-681 Warsaw, Poland — [5]NIC, DESY-Zeuthen, 15738 Zeuthen, Germany — [6]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany

One of the most interesting directions in theoretical high-energy physics is understanding dynamical properties of collective states of quantum field theories. The most elementary tool in this quest are retarded equilibrium correlators governing the linear response theory. In the present letter we examine tensor networks as a way of determining them in a fully ab initio way in a class of (1+1)-dimensional quantum field theories arising as infrared descriptions of quantum Ising chains. We show that, complemented with signal analysis using the Prony method, tensor network calculations for intermediate times provide a powerful way to explore the structure of singularities of the correlator in the complex frequency plane.

MP 13.2 Wed 16:50 H-HS I

Scale and Translation invariant Tensor Networks — •Sukhbinder Singh — Max-Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam

Entanglement renormalization (ER) [1] is a lattice renormalization group (RG) transformation that is described by a tensor network. Substantial numerical evidence indicates that it is capable of *approximating* the expected RG fixed points, both in gapped and critical phases of 1D quantum lattice systems. ER also generates the multi-scale entanglement renormalization ansatz (MERA) [2] — an efficient tensor network representation, in particular, of 1D critical ground states, from which the underlying conformal field theory (CFT) data can be accurately estimated [3,4]. I will describe first steps towards formalizing the *exact* relationship between ER and RG fixed points (beyond numerical approximations). A generic ER transformation breaks the symmetries that emerge at RG fixed points. I will propose certain *polynomial tensor constraints* that characterize (a subset of) ER transformations with *translation-invariant* fixed points. I show that some solutions of these constraints correspond to 2d TQFTs, which describe RG fixed points in gapped phases. I discuss why there may also be solutions that correspond to 2d *rational* CFTs. An exact relationship between ER fixed points and 2d CFTs might provide a novel pathway to bootstrap 2d CFTs directly on the lattice and illuminate holographic properties of the MERA [5]. **References** 1. G. Vidal, PRL 99 (2007). 2. G. Vidal, PRL 101 (2008). 3. V. Giovannetti et al PRL. 101 (2008) 4. R. Pfeifer et al PRA(R) 79(4) (2009) 5. B. Swingle, PRD 86 (2012).

MP 14: Mitgliederversammlung

Time: Wednesday 17:15–18:00 Location: H-HS I

Mitgliederversammlung des FV MP

MP 15: HV Verch: Quantum Information

Time: Thursday 14:00–14:30 Location: H-HS VII

Invited Talk MP 15.1 Thu 14:00 H-HS VII

The D-CTC condition is generically fulfilled in classical (non-quantum) statistical systems — Jürgen Tolksdorf[1] and •Rainer Verch[2] — [1]MPI für Mathematik i.d. Naturwissenschaften, Leipzig — [2]Institut für Theoretische Physik, Universität Leipzig

The D-CTC condition, introduced by David Deutsch as a condition to be fulfilled by analogues for processes of quantum systems in the presence of closed timelike curves, is investigated for classical statistical (non-quantum) bi-partite systems. It is shown that the D-CTC condition can generically be fulfilled in classical statistical systems, under very general, model-independent conditions. The central property used is the convexity and completeness of the state space that allows it to generalize Deutsch's original proof for q-bit systems to more general classes of statistically described systems. The results demonstrate that the D-CTC condition, or the conditions under which it can be fulfilled, is not characteristic of, or dependent on, the quantum nature of a bi-partite system. (See arXiv:1912.02301)

MP 16: Quantum Information

Time: Thursday 14:40–15:20 Location: H-HS VII

MP 16.1 Thu 14:40 H-HS VII

Quantum Simulation and Reachability: from Lie-Theory to Illustrative Examples — •Thomas Schulte-Herbrüggen[1], Frederik vom Ende[1], Karl Briegel[1], Gunther Dirr[2], and Robert Zeier[1,3] — [1]Dept. Chem., Technische Universität München (TUM) — [2]Mathematisches Institut, Universität Würzburg — [3]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8)

Characterising closed and open (Markovian) quantum dynamics within a Lie-based systems theory provides a unified mathematically rigorous frame for answering quantum engineering problems. — Here we focus on two recent and illustrative examples:

First, for curiosity we show how algebraic grounds pave the way to simulate (classical) rotations in $d \geq 3$ dimensions efficiently via coherently controlled spin-1/2 chains.

Second, combining coherent control with tunable coupling to reservoirs of a given temperature T, our previous exact reachability results (for $T = 0$ amplitude damping as well as for bitflip noise) extend from n qu*b*its to qu*d*its. We illustrate how reachable sets of states relate to the more general concept of d-majorisation when moving to arbitrary $T > 0$.

MP 16.2 Thu 15:00 H-HS VII

Quantum information of a free fermion in 1+1 dimensions — •Christian Simon — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

The free fermion in 1+1 dimensions provides a solvable yet non-trivial model for studying quantum information aspects in QFT. A key concept is the entanglement (or modular) Hamiltonian which gives the entanglement spectrum. We study the associated modular flow induced by it, focusing on the non-local part in different spin sectors. Non-locality in quantum physics has recently appeared to play an important role in the emergence of spacetime in the AdS/CFT correspondence which we seek to understand better.

MP 17: Quantum Information and QFT

Time: Thursday 15:20–16:00 Location: H-HS VII

MP 17.1 Thu 15:20 H-HS VII

Relative entropy approach to quantum phenomena — •Tobi Haas and Stefan Flörchinger — ITP Heidelberg

Our main goal is to get a better understanding of entanglement entropies in Quantum Field Theories. Unfortunately Von Neumann's entanglement entropy is UV divergent for a finite subvolume V in any Quantum Field Theory due to entanglement across the boundary. We believe that relative entropy is capable of circumventing this well-known problem. Besides the fact, that relative entropy is more universal in a mathematical sense, it may in general be a more natural approach to think in terms of distinguishability rather than in terms of missing information.

We begin with quantum statistical mechanics and show how to reformulate the maximum entropy principle. Then we present the deep connection between the key property of relative entropy, namely its monotonicity under CPTP-maps, and the second law of thermodynamics. We furthermore propose an extension to a local second law-like inequality in terms of relativistic fluids.

Additionally we investigate entropic uncertainty relations and how to understand them in terms of relative entropy. We discuss the discrete variable case for a spin system and the continuous variable case for a quantum harmonic oscillator. At last we present a proof for a relative entropic uncertainty relation based on monotonicity of relative entropy under CPTP-maps.

MP 17.2 Thu 15:40 H-HS VII

Entanglement in a non-relativistic QFT — •Natalia Sánchez-Kuntz — Institut für Theoretische Physik Universität Heidelberg

This presentation gives a quick overview of the mathematical methods used to calculate entanglement entropy for Gaussian states, and takes this formalism to the particular case of fields which follow a Bogoliubov dispersion relation, concentrating on the vacuum state. The main objective of this contribution is to show the difficulties encountered when approaching this problem, regarding both, divergencies and the expression of the theory in an adequate set of basis functions.

MP 18: Alternative Ideas

Time: Thursday 16:30–17:10 Location: H-HS VII

MP 18.1 Thu 16:30 H-HS VII

The End of Space and Time and the 3-Sphere — •Alexander Unzicker — Pestalozzi-Gymnasium München

It is argued that there are no true fundamental constants; rather their alleged existence points to an incomplete understanding of reality. Based on that premise, it turns out that space and time are unlikely to be appropriate concepts for a proper understanding of nature. Rather than a 3+1-dimensional spacetime, it is argued that the 3-dimensional unit sphere is a better candidate for a fundamental description of reality. In many aspects, its properties reflect phenomena commonly attributed to quantum mechanics.

MP 18.2 Thu 16:50 H-HS VII

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

Different particle representations were already proposed in theoretical physics; 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 SPs as rotation defining angular momenta. Interactions between SPs are thus the product of the interactions of the angular momenta of their FPs. An important finding is that all four forces are due to electromagnetic interactions and are described by QED. No incompatibility between gravitation and QM exists, and no dark matter and dark energy is required. Another important finding of the approach is that the interaction between two charged SPs tend to zero for the distance between them tending to zero, which allows placing the zero of the potential energy at the distance 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. As quantum-mechanics rely heavily on classical physics, all new findings of the latter have repercussions on the former. More at: www.odomann.com

MP 19: Poster (Monday - Thursday)

Time: Monday 11:00–18:00 Location: H-HS VII

MP 19.1 Mon 11:00 H-HS VII

Correlational entropy by nonlocal quantum kinetic theory — •Klaus Morawetz — Münster University of Applied Sciences, 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