Quantum Field Theory

Concepts, Constructions & Curved Spacetimes
York, 4–7 April 2017

Titles and Abstracts

Tuesday 4 April: An afternoon dedicated to Bernard Kay

Entanglement measures in quantum field theory,
with a laudatio on the occasion of the 65th birthday of B.S. Kay
Stefan Hollands (Leipzig)

An entanglement measure for a bipartite quantum system is a state functional that vanishes on separable states and does not increase under separable (local) operations. It is well-known that for pure states, essentially all entanglement measures are equal to the v. Neumann entropy of the reduced state, but for mixed states, this uniqueness is lost. In quantum field theory, bipartite systems are associated with causally disjoint regions. There are no separable (normal) states to begin with when the regions touch each other, so one must leave a finite "safety-corridor". Due to this corridor, the normal states of bipartite systems are necessarily mixed, and the v. Neumann entropy is not a good entanglement measure in the above sense. In this talk I will discuss various entanglement measures which vanish on separable states, do not increase under separable (local) operations, and have other desirable properties. In particular, I study the relative entanglement entropy, defined as the minimum relative entropy between the given state and an arbitrary separable state. I present rigorous upper and lower bounds in various quantum field theoretic (QFT) models, as well as also model-independent ones. The former include free fields on static spacetime manifolds in general dimensions, or integrable models with factorizing S-matrix in $1+1$ dimensions. The latter include bounds on ground states in general conformal QFTs, charged states (including charges with braid-group statistics) or thermal states in theories satisfying a "nuclearity condition". Typically, the bounds show a divergent behavior when the systems get close to each other–sometimes of the form of a generalized "area law"–and decay when the systems are far apart.
(Based on joint work with K. Sanders: `arXiv:1702.04924`)

The Kay–Wald theorem and HHI-like states on black hole space-times
Elizabeth Winstanley (Sheffield)

Within the framework of canonical quantization, we review the construction of Hartle–Hawking–Israel (HHI) states on black hole space-times using modes of a quantum scalar or fermion field. We focus on the Schwarzschild and Kerr geometries. For Schwarzschild black holes, the remarkable Kay–Wald theorem implies the uniqueness of the HHI-state. For Kerr black holes, Kay-Wald prove that no HHI-state exists. In this latter case we consider HHI-like states that can be constructed by relaxing some of the assumptions of the Kay–Wald theorem and explore their properties.

Cosmological perturbation theory and perturbative quantum gravity
Klaus Fredenhagen (Hamburg)

Quantum field theory on curved spacetimes can be extended to perturbative quantum gravity, interpreted as an effective quantum field theory. The theory can be tested in cosmology where the fluctuations of the microwave background are explained via cosmological perturbation theory, which arises as a first order approximation of quantum gravity.
(Based on joint work with R. Brunetti, T. Hack, N. Pinamonti and K. Rejzner)

Wednesday 5 April

Waiting for Unruh
Jorma Louko (Nottingham)

How long does a uniformly accelerated observer need to interact with a quantum field in order to record thermality in the Unruh temperature? In the limit of large excitation energy, the answer turns out to be sensitive to whether (i) the switch-on and switch-off periods are stretched proportionally to the total interaction time T, or whether (ii) T grows by stretching a plateau in which the interaction remains at constant strength but keeping the switch-on and switch-off intervals of fixed duration. For a pointlike Unruh-DeWitt detector, coupled linearly to a massless scalar field in four spacetime dimensions and treated within first order perturbation theory, we show that letting T grow polynomially in the detector's energy gap E suffices in case (i) but not in case (ii), under mild technical conditions. These results limit the utility of the large E regime as a probe of thermality in time-dependent versions of the Hawking and Unruh effects, such as an observer falling into a radiating black hole. They may also have implications on the design of prospective experimental tests of the Unruh effect.
`arXiv:1605.01316` (published in Classical and Quantum Gravity)

Quantum Field Theory on a Causal Set
Fay Dowker (Imperial)

Causal Set Theory is an approach to the problem of Quantum Gravity based on the hypothesis that spacetime is fundamentally discrete. Although, ultimately, it is expected that the discrete spacetime and matter will have to be treated as one quantum system in a unified manner, one can still hope to learn something about the full theory by looking at quantum field theory on a fixed, background discrete spacetime (causal set). I will describe a free scalar quantum field theory on a finite causal set due to Johnston and Sorkin in which the foundation is the retarded green function. There are scalar retarded green functions for causal sets that are well approximated by 2-d and 4-d Minkowski spacetime and also deSitter space but we lack more general results.

Some scale-invariant states on quantum spin chains and their properties
Vaughan Jones (Vanderbilt)

Homotopy theory + AQFT = Quantum Gauge Theory?
Alexander Schenkel (Nottingham)

An algebraic quantum field theory is an assignment of algebras to spacetimes. These algebras should be interpreted as quantizations of the algebras of functions on the moduli spaces of a classical field theory. In many cases of interest, especially in gauge theories, these moduli spaces are not conventional spaces but 'higher spaces' such as stacks. Consequently, functions on such spaces do not form an algebra but a 'higher algebra' which one may describe by homotopical algebra. This motivates us to study assignments of 'higher algebras' to spacetimes, which is what we call homotopical algebraic quantum field theory. In this talk I will clarify the above picture and explain its advantages compared to traditional algebraic quantum field theory. For this I will also present simple toy-models related to Abelian gauge theory and homotopy Kan extensions.

What to expect from logarithmic conformal field theory
Simon Wood (Cardiff)

Logarithmic conformal field theory is a generalisation of ordinary conformal field theory that allows for logarithmic singularities in correlation functions. This implies the existence of reducible yet indecomposable modules on which the action of the Virasoro L_0 operator is not diagonalisable. In this talk I will recall some of the properties of rational conformal field theory and contrast them with what one encounters in logarithmic conformal field theory.

Thursday 6 April (afternoon dedicated to Karl-Henning Rehren)

Aspects of defects and integrability
Ed Corrigan (York)

Defects, or discontinuities, of various kinds are ubiquitous in nature - a shock within a fluid flow being a common example where a velocity field changes abruptly from supersonic to subsonic. It has been noticed that many integrable systems (for example, sine-Gordon or KdV) can also support defects yet maintain their integrable nature. The purpose of this talk is to introduce the basic ideas, using examples, and then describe some of the curious properties of defects in this context, from both classical and quantum field theory perspectives, and one or two outstanding problems.

Quantum physics, fields and closed timelike curves: The D-CTC condition in quantum field theory
Rainer Verch (Leipzig)

The D-CTC condition has originally been proposed by David Deutsch as a condition on states of a quantum communication network that contains ”backward time-steps” in some of its branches. It has been argued that this is an analogue for quantum processes in the presence of closed timelike curves (CTCs). The unusual properties of states of quantum communication networks that fulfill the D-CTC condition have been discussed extensively in recent literature. In this work, the D-CTC condition is investigated in the framework of quantum field theory in the local, operator-algebraic approach due to Haag and Kastler. It is shown that the D-CTC condition cannot be fulfilled in states which are analytic for the energy, or satisfy the Reeh-Schlieder property, for a certain class of processes and initial conditions. On the other hand, if a quantum field theory admits sufficiently many uncorrelated states across acausally related spacetime regions (as implied by the split property), then the D-CTC condition can always be fulfilled approximately to arbitrary precision. As this result pertains to quantum field theory on globally hyperbolic spacetimes where CTCs are absent, one may conclude that interpreting the D-CTC condition as characteristic for quantum processes in the presence of CTCs could be misleading, and should be regarded with caution. Furthermore, a construction of the quantized massless Klein-Gordon field on the Politzer spacetime, often viewed as spacetime analogue for quantum communication networks with backward time-steps, is proposed. The tallk is based on a joint article with Juergen Tolksdorf,
`arXiv:1609.01496`

Some ideas of K.-H. Rehren and their ramifications
Michael Müger (Nijmegen)

I will begin with an appreciation of the career of K.-H. Rehren, whose first PhD student I was. I will select some of his most important contributions and explain their influence to this day. Then I will turn to recent work of myself and others on conformal orbifold theories and will conclude with some conjectures concerning permutation orbifolds and work in progress towards their resolution.

The universal C-algebra of the electromagnetic field. Topological charges and non-linear fields*
Detlev Buchholz (Göttingen)

Conditions for the appearance of topological charges are studied in the framework of the universal C*-algebra of the electromagnetic field, being represented in any theory describing electromagnetism. After a brief account of this algebra and of its standard representations, the question of the existence of representations carrying a topological charge, raised in previous work, is discussed. It is shown that such charges, described by commutators of the field, can only appear in regular represetations if the field depends non-linearly on the mollifying test functions. On the other hand, examples of regular vacuum representations carrying a topological charge are exhibited, where the field still satisfies a weakened form of "spacelike linearity". Such representations also appear in the presence of electric currents.

Construction of quantum integrable models with bound states
Daniela Cadamuro (Munich)

In the context of integrable QFTs in the operator-algebraic approach, wedge-local fields play an important role. After the work of Lechner to construct factorizing scattering matrix models with scalar S-matrices without bound states, we recently extended this construction to S-matrices with poles in the physical strip ("bound states") by exhibiting wedge-local fields which arise as a deformation of Lechner's fields with the so called "bound state operator". This applies to a variety of theories, e.g., the Bullough–Dodd model, the $Z(N)$-Ising model, the Affine-Toda field theories and the sine-Gordon model, namely models with a richer particle spectrum and which are believed to have bound states. In this talk I will review the passages of this construction and explain the open problems.

Friday 7 April

Index theorems for hyperbolic operators and particle creation
Alexander Strohmaier (Leeds)

I will explain how the process of charge creation in an expanding universe with compact Cauchy surface and how it is related to the index of the Lorentzian Dirac operator on that spacetime with Atiyah-Patodi-Singer boundary conditions. This index can be computed by integrating a local density and adding boundary contributions involving the eta invariant of the space-like Cauchy surfaces. (Joint work with C. Baer)

Quantum systems out of equilibrium
Benjamin Doyon (King's College London)

In recent years there has been a lot of activity in trying to understand quantum dynamics and states that are far from equilibrium, both in integrable and non-integrable models. Questions include that of thermalization, and its generalization stemming from integrability, and relaxation to steady states with nonzero currents. I will provide an introduction to some of the main concepts, and then describe recent results, in particular results that make use of the operator algebraic description of quantum systems on infinite lattices (and quantum field theory).

Convergence of the Epstein-Glaser S-matrix in the Sine-Gordon model
Kasia Rejzner (York)

In this talk I will report on recent developments in perturbative Algebraic Quantum Field Theory (pAQFT), concerning the treatment of integrable models. Perturbative AQFT is a framework that allows to make precise computations made in perturbative QFT and, at the same time, to follow the paradigm of Local Quantum Physics and to construct local nets of involutive topological algebras. Up until recently, the pAQFT framework had been used to produce models that involve formal power series in $\hbar$ and the coupling constant. In this talk I will show how pAQFT can be applied to the Sine-Gordon model, so that the resulting S-matrix converges in appropriately chosen topology. This result is a first step towards construction of the local net of von Neumann algebras for the Sine-Gordon model, and it indicates how to address questions of convergence in pAQFT.
