NORDITA workshop, from September 30 to October 4, 2024

Operator Algebras in High Energy Physics

	Monday	Tuesday	Wednesday	Thurday	Friday
9:50 - 10:30	**Ogata**	**Hollands**	**Eisler**	**Kawahigashi**	**Izumi**
10:30 - 11:20	coffee	coffee	coffee	coffee	coffee
11:20 - 12:00	**Tanimoto**	**Erdmenger**	**Magan**	**Lechner**	**Ciolli**
12:00 - 14:00	lunch	lunch	lunch	lunch	lunch
14:00 - 14:40	**Longo**	**Faulkner**	**Fendley**	**H. Liu**	
14:40 - 15:20		**Satischandran**	**Bostelmann**	**Leutheusser**	
16:00	coffee	coffee	coffee	coffee	
16:30 - 17:10		**Morsella**	**Z. Liu**	**Fewster**	
19:30			dinner		

SPEAKER	**TITLE**
Henning Bostelmann	*Approximating the Tomita-Takesaki operator of standard subspaces*
Fabio Ciolli	*From the Universal C*-algebra of the Electromagnetic Field to Sectors of QED via Covariant Cohomology*
Viktor Eisler	*Entanglement Hamiltonian in free-fermion systems*
Johanna Erdmenger	*Geometric phases and von Neumann algebras for AdS/CFT*
Thomas Faulkner	*The Quantum Null Energy Condition from Half Sided Modular Inclusions*
Paul Fendley	*The Algebra of Topological Defects*
Chris Fewster	*Quantum reference frames, measurement schemes and the type of local algebras in quantum field theory*
Stefan Hollands	*QFT and Microlocal Analysis*
Masaki Izumi	*Quasi-product compact group actions on C*-algebras*
Yasuyuki Kawahigashi	*Quantum 6j-symbols, tensor categories and operator algebras*
Gandalf Lechner	*KMS states on Ising QFTs and crossed products*
Hong Liu	*Emergence of spacetime in holography*
Zhenwei Liu	*Alterfold Topological Quantum Field Theory*
Samuel Leutheusser	*Superadditivity and quantum tasks in large N field theories and holography*
Roberto Longo	*A Bekenstein-type inequality in Quantum Field Theory*
Javier Magan	*Generalized order parameters from Haag duality*
Gerardo Morsella	*The algebraic approach to the renormalization group*
Yoshiko Ogata	*Boundary states of a bulk gapped ground state in 2-D quantum spin systems*
Gautam Satishchandran	*A covariant regulator for entanglement entropy*
Yoh Tanimoto	*Proofs in high energy physics*

Speaker: Henning Bostelmann
Title: *Approximating the Tomita-Takesaki operator of standard subspaces*
Abstract: The Tomita-Takesaki modular operator for local algebras has an important structural role in quantum field theory and in relativistic quantum information. However, beyond the case of wedge algebras, describing this operator more concretely is a longstanding open problem. This applies even to free theories, where the problem is reduced to the Tomita operator of standard subspaces (certain real subspaces of the single-particle Hilbert space): except for cases with additional (conformal) symmetry, no explicit description of the modular operator e.g. for a double cone is known, and several attempts at this problem in the literature have failed.
Tackling the question from a different perspective, we present a numerical approach to approximate the modular operator of standard subspaces, applicable to both bosonic and fermionic linear theories. Specifically, we treat the modular generator corresponding to a double cone region in a massive scalar boson on 1+1 dimensional Minkowski space, and in one and two double cones for a massive Majorana fermion on a 1+1-dimensional flat cylinder. The numerical results clearly show a mass-dependence of the operator, and in the case of two double cones, show up the expected "bilocal" terms of the modular generator connecting the two double cone regions.

Speaker: Fabio Ciolli
Title: *From the Universal C*-algebra of the Electromagnetic Field to Sectors of QED via Covariant Cohomology*
Abstract: Quantum field theory with massless particles does not exhibit localized charges (and thus no DHR superselection sectors) due to Gauss's law. In QED, the same electric charge can give rise to different sectors depending on the presence of different photon clouds in the infrared. By restricting the theory to the future light cone of Minkowski space, sectors localized over unbounded regions, called hypercones, were first proposed in [BR2014]. A series of papers beginning with [BCRV2016] has since explored the C*-algebra of the electro- magnetic field, focusing on its topological aspects, representations, and the role of Gauss's law, discussed in [BCRV2023]. In [BCRV, in preparation], an operator-algebraic model will be proposed that provides automor- phisms as electric sectors for QED in Fock space, realizing the concept conceived in [BR2014]. Additionally, the phenomenon of parastatistics, which was not fully addressed in [BR2014], will potentially be explained through an extension of Roberts' local cohomology for DHR sectors, incorporating a covariant action of the symmetry over the regions where charges are localized [CRV2024]. Joint project with D. Buchholz, G. Ruzzi and E. Vasselli.

References.
BR2014: Buchholz, D., Roberts, J.E.: New Light on Infrared Problems: Sectors, Statistics, Symmetries and Spectrum. Commun. Math. Phys. 330, 935–972 (2014)
BCRV16: Buchholz, D., Ciolli, F., Ruzzi, G., Vasselli, E.: The Universal C*-algebra of the Electromagnetic Field. Lett. Math. Phys. 106, 269-285 (2016)
BCRV23: Buchholz, D., Ciolli, F., Ruzzi, G., Vasselli E.: Gauss's law, the manifestations of gauge fields, and their impact on local observables. In: A. Michelangeli, A. Di Cintio (eds.) "Trails in Modern Theoretical and Mathematical Physics" pp. 71-92, Springer Nature (2023). ISBN: 978-3-031-44987-1,
CRV2024: Ciolli, F., Ruzzi, G., Vasselli, E.: Where Charged Sectors are Localizable: A Viewpoint from Covariant Cohomology. Comm. Math. Phys. 405(1),17 1-26 (2024)

Speaker: Viktor Eisler
Title: *Entanglement Hamiltonian in free-fermion systems*
Abstract: The entanglement properties of a many-body system with a given bipartition are encoded in the corresponding entanglement Hamiltonian (EH). It reflects the spatial structure of entanglement and has received increased attention in the last years. In quantum field theories with a relativistic or conformal symmetry, the EH can be constructed for various geometries from the Bisognano/Wichmann theorem and its generalizations. However, it is far from obvious how these results can be carried over to many-body systems, where the relativistic symmetry is broken explicitly, e.g. by the presence of a lattice. To answer these questions, an excellent testbed is provided by free-fermion systems, where one has direct access to the EH. In my talk, I will present results on the EH in various setups, and explain how they can be matched with the field theory predictions.

Speaker: Johanna Erdmenger
Title: *Geometric phases and von Neumann algebras for AdS/CFT*
Abstract: TBA

Speaker: Thomas Faulkner
Title: *The Quantum Null Energy Condition from Half Sided Modular Inclusions*
Abstract: I will review previous work with Ceyhan establishing the QNEC based solely on the mathematical structure of a half sided modular inclusion. This structure is thought to apply to QFT on a static black hole background where the QNEC has important dynamical consequences.

Speaker: Paul Fendley
Title: *The Algebra of Topological Defects*
Abstract: TBA

Speaker: Chris Fewster
Title: *Quantum reference frames, measurement schemes and the type of local algebras in quantum field theory*
Abstract: TBA

Speaker: Stefan Hollands
Title: *QFT and Microlocal Analysis*
Abstract: TBA

Speaker: Masaki Izumi
Title: *Quasi-product compact group actions on C*-algebras*
Abstract: The notion of qausi-product actions of a compact group on a C*algebra was introduced by Bratteli et al. in their attempt to seek an equivariant analogue of Glimm's characterization of non-type I C*-algebras. We show that a faithful minimal action of a compact group on a separable C*-algebra is quasi-product whenever its fixed point algebra is simple. This was previously known only for compact abelian groups and for profinite groups. Our proof relies on a subfactor technique applied to finite index inclusions of simple C*-algebras in the purely infinite case, and also uses ergodic actions of compact groups in the general case for a tensor categorical reason. If time permits, we present an application of our main result to the classification of compact group actions on Kirchberg algebras.

Speaker: Yasuyuki Kawahigashi
Title: *Quantum 6j-symbols, tensor categories and operator algebras*
Abstract: Tensor categories have found many applications in physics and mathematics, particularly quantum field theory and condensed matter physics in recent years, as a new type of symmetry generalizing a classical notion of a group. Operator algebras give useful and efficient tools to study tensor categories. A fusion category, a tensor category with certain finiteness condition, is characterized by a finite set of complex numbers satisfying certain compatibility condition, called quantum 6j-symbols. Its variant, called bi-unitary connections, has played an important role in the Jones theory of subfactors in operator algebras. We have a tensor functor called alpha-induction for a braided fusion category, as a quantum version of a classical machinery of an induced representation for a subgroup. We describe alpha-induction in the framework of quantum 6j-symbols from a viewpoint of being of a canonical form.

Speaker: Gandalf Lechner
Title: *KMS states on Ising QFTs and crossed products*
Abstract: In some situations in quantum field theory and quantum statistical mechanics, one is interested in understanding the thermal equilibrium (KMS) states of an observable algebra that contains both, a subalgebra for which the equilibrium states are known, and time-translation invariant generators of symmetries. Examples are given by the Ising QFT and CAR/Pauli algebras on a lattice. Mathematically speaking, this question amounts to understanding the KMS states of the crossed product of a C*-algebra A by a (finite) group in terms of the KMS states of A. In this talk I will give several answers to this question and exemplify it at the example of the Ising QFT, where the group is Z_2 and the analysis is best carried out with the help of twisted KMS functionals as they appear in supersymmetry. Joint work with Ricardo Correa da Silva and Johannes Große.

Speaker: Hong Liu
Title: *Emergence of spacetime in holography*
Abstract: TBA

Speaker: Zhenwei Liu
Title: *Alterfold Topological Quantum Field Theory*
Abstract: We introduce regular stratified piecewise linear manifolds to describe lattices and investigate the lattice model approach to topological quantum field theory in all dimensions. We introduce the $n+1$ alterfold TQFT and construct it from a linear functional on an n-dimensional lattice model on the n-sphere satisfying three conditions: reflection positivity; homeomorphic invariance; and complete finiteness. A unitary spherical n-category is mathematically defined and emerges as the local quantum symmetry of the lattice model. The alterfold construction unifies various constructions of $n+1$ TQFT from n-dimensional lattice models and n-categories. As an example, we construct a linear functional in dimension 3 and derive its local symmetry as a unitary 3-category of Ising type and its global symmetry as a unitary 3+1 alterfold TQFT. Its 20j-symbols are computed explicitly.

Speaker: Samuel Leutheusser
Title: *Superadditivity and quantum tasks in large N field theories and holography*
Abstract: Holographic conformal field theories exhibit dramatic changes in the structure of their operator algebras in the limit where the number of local degrees of freedom (N) becomes infinite. An important example of such phenomena is the violation of the additivity property for algebras associated to local subregions. I will first review several examples of superadditive algebras in quantum field theory and then investigate their consequences in the context of holographic duality. As an important application, I will demonstrate how superadditivity of local algebras is intimately related to the ability of holographic field theories to perform quantum tasks that would naievely be impossible. Finally, I will argue that the connected wedge theorems (CWTs) of May, Penington, Sorce, and Yoshida, which characterize holographic protocols for quantum tasks, can be re-phrased in terms of superadditive algebras. This re-phrasing allows for a potential generalization of the CWTs into an equivalence statement.

Speaker: Roberto Longo
Title: *A Bekenstein-type inequality in Quantum Field Theory*
Abstract: TBA

Speaker: Javier Magan
Title: *Generalized order parameters from Haag duality*
Abstract: TBA

Speaker: Gerardo Morsella
Title: *The algebraic approach to the renormalization group*
Abstract: I will review the algebraic approach to the UV scaling limit in QFT, formulated by D. Buchholz and R. Verch. It provides a model independent framework in which the short distance limit of a QFT, defined by a local net of observable C*-algebras, can be analysed. As a result, one obtains a new net of C*-algebras, interpreted as the UV scaling limit of the original one. By comparing the superselection (i.e., charge) structures of the two theories, it is possible to provide an intrinsic notion of charge confinement. The scaling limit can be extended to the pointlike fields intrinsically associated to the original net and their OPEs, obtaining a model independent formulation of renormalization.

Speaker: Yoshiko Ogata
Title: *Boundary states of a bulk gapped ground state in 2-D quantum spin systems*
Abstract: We introduce a natural mathematical definition of boundary states of a bulk gapped ground state in the operator algebraic framework of 2-D quantum spin systems. With the approximate Haag duality at the boundary, we derive a C*-tensor category M out of such boundary state. Under a non-triviality condition of the braiding in the bulk, we show that the Drinfeld center (with an asymptotic constraint) of M is equivalent to the bulk braided C*-tensor category

Speaker: Gautam Satishchandran
Title: *A covariant regulator for entanglement entropy*
Abstract: While von Neumann entropies for subregions in quantum field theory universally contain ultraviolet divergences, one expects that differences between von Neumann entropies are finite and well-defined in many physically relevant scenarios.

I will demonstrate that such a notion of entropy differences can be defined in quantum field theory in a general curved spacetime by introducing a covariant regulator for the entropy based on the modular crossed product. This regulator associates a type II von Neumann algebra to each spacetime subregion, resulting in well-defined, "renormalized" entropies. This prescription reproduces formulas for entropy differences that coincide with heuristic formulas widely used in the literature, and we prove that it satisfies desirable properties such as unitary invariance and concavity. As an application, we provide proofs of the Bekenstein bound and the quantum null energy condition, formulated directly in terms of vacuum-subtracted von Neumann entropies.

Speaker: Yoh Tanimoto
Title: *Proofs in high energy physics*
Abstract: I will discuss some abstract arguments used to make claims in high energy physics, the status of rigorous approaches to quantum field theory and my recent experience with formalisation of mathematics in Lean.