Boundary and Bulk Criticality 2022
21-25 February 2022
Würzburg
Online
source: Wikimedia Commons

Boundary and Bulk criticality 2022

21-25 February 2022, Würzburg (online), Germany

Overview

Boundary and Bulk 2022 is a workshop on various topics of classical and quantum boundary critical behavior, in a broad sense.

The workshop is held online between 21 and 25 February 2022.

Invited Speakers

- Youjing Deng (University of Science and Technology of China)
- Hans-Werner Diehl (University of Duisburg-Essen, Germany)
- Siegfried Dietrich (Max Planck Institute for Intelligent Systems, Stuttgart, Germany)
- Marco Meineri (University of Geneva, Switzerland)
- Zi Yang Meng (University of Hong Kong)
- Max A. Metlitski (Massachusetts Institute of Technology, Cambridge, U.S.A.)
- Ruben Verresen (Harvard University, Cambridge, U.S.A.)
- Chong Wang (Perimeter Institute for Theoretical Physics, Waterloo, Canada)
- Stefan Wessel (University of Aachen, Germany)
- Cenke Xu (University of California, Santa Barbara, U.S.A.)
- Long Zhang (University of Chinese Academy of Sciences)

Organizers

- Francesco Parisen Toldin (University of Wr̈zburg)
- Fakher F. Assaad (University of Wr̈zburg)

Conference website

`https://bbc2022.sciencesconf.org`

2022/02/24, 15:46:46

Table of contents

Program 4

Invited talks 6

Classical Boundary Critical Behavior: Models, Field Theory, Boundary Conditions, Universality Classes, and Open Problems, Hans-Werner Diehl 7

Critical Casimir Forces, Siegfried Dietrich 8

An extraordinary boundary condition from the conformal bootstrap, Marco Meineri 9

To be ordered or not: recent progress on surface criticality of (2+1)D O(3) models, Long Zhang 10

Hearing the Shape of Quantum Drums via Qiu Ku (pyjamas), Zi Yang Meng . . 11

Phases and Phase Transitions with Fractal Symmetries: Models and Experimental Platform, Cenke Xu 12

Geometric Upper Critical Dimensions of the Ising Model, Youjin Deng 13

Edge physics at the deconfined transition between a quantum spin Hall insulator and a superconductor, Ruochen Ma [et al.] 14

Non-ordinary surface criticality along dangling edge spins and quantum Monte Carlo simulations of highly frustrated magnets, Stefan Wessel 15

The interplay of topology and criticality: from purely-gapless to intrinsically-gapless symmetry-protected topological phases, Ruben Verresen 16

Contributed talks 17

Visualizing the Kosterlitz RG flow with tensor-network based level spectroscopy, Atsushi Ueda [et al.] 18

Scaling of the disorder operator at (2+1) d U(1) quantum criticality, Yancheng Wang [et al.] . . . 19

Boundary quantum criticality and emergent supersymmetry in topological phases, Zixiang Li [et al.] . . . 20

Geometry of bounded critical phenomena, Giacomo Gori . . . 21

Dissipation-induced order in the S=1/2 quantum spin chain coupled to an ohmic bath, Manuel Weber [et al.] . . . 22

Exotic quantum criticality in Dirac systems: Metallic and deconfined, Zihong Liu [et al.] . . . 23

Posters . . . 24

Topological transition to a "non-Landau" Fermi liquid phase in a two-channel spin-1 anisotropic Kondo model and its experimental relevance, Armando Aligia [et al.] 25

Criticality and phase transitions in open quantum many-body systems, Thomas Barthel . . . 26

Topological Disorder Parameter, Bin-Bin Chen [et al.] . . . 27

Spin chain on a metallic surface: dissipation versus Kondo screening, Bimla Danu [et al.] . . . 28

Disorder operator of fermionic system, Weilun Jiang . . . 29

Weyl Anomalies of Four Dimensional Conformal Boundaries and Defects, Jacopo Sisti . . . 30

The dynamical structure factor of the SU(3) Heisenberg chain: The variational Monte Carlo approach, Dániel Vörös [et al.] . . . 31

Extract information of quantum entanglement on a "Qiuku" manifold, Zheng Yan [et al.] . . . 32

Global operators capture the physics beyond the traditional LGW framework, Jiarui Zhao . . . 33

Emergent Spinon Dispersion and Symmetry Breaking in Two-channel Kondo Lattices, Yashar Komijani [et al.] . . . 34

Author Index **35**

Participants **36**

Program

21 February 2022

TIME	
09:45-10:00	Opening
10:00-12:00	**Hans-Werner Diehl** Classical Boundary Critical Behavior: Models, Field Theory, Boundary Conditions, Universality Classes, and Open Problems
12:00-12:20	Group Photo + Break
12:20-12:40	**Atsushi Ueda** Visualizing the Kosterlitz RG flow with tensor-network based level spectroscopy
12:40-13:00	**Yancheng Wang** Scaling of the disorder operator at (2+1) d U(1) quantum criticality
13:00-13:20	**Zixiang Li** Boundary quantum criticality and emergent supersymmetry in topological phases
16:00-18:00	**Max A. Metlitski** Boundary criticality of the O(N) model in d = 3 critically revisited

22 February 2022

TIME	
11:00-13:00	**Siegfried Dietrich** Critical Casimir Forces
14:00-16:00	**Marco Meineri** An extraordinary boundary condition from the conformal bootstrap
16:00-16:20	Break
16:20-16:40	**Giacomo Gori** Geometry of bounded critical phenomena
16:40-17:00	**Manuel Weber** Dissipation-induced order in the $S = 1/2$ quantum spin chain coupled to an ohmic bath
17:00-17:20	**Zihong Liu** Exotic quantum criticality in Dirac systems: Metallic and deconfined

23 February 2022

TIME	
11:00-13:00	**Long Zhang** To be ordered or not: recent progress on surface criticality of (2+1)D O(3) models
15:00-17:00	**Zi Yang Meng** Hearing the Shape of Quantum Drums via Qiu Ku (pyjamas)
18:50-19:00	Group Photo
19:00-21:00	**Cenke Xu** Phases and Phase Transitions with Fractal Symmetries: Models and Experimental Platform

24 February 2022

TIME	
11:00-13:00	**Youjin Deng** Geometric Upper Critical Dimensions of the Ising Model
14:00-16:00	Poster session
16:00-18:00	**Chong Wang** Edge physics at the deconfined transition between a quantum spin Hall insulator and a superconductor

25 February 2022

TIME	
10:00-12:00	**Stefan Wessel** Non-ordinary surface criticality along dangling edge spins and quantum Monte Carlo simulations of highly frustrated magnets
16:00-18:00	**Ruben Verresen** The interplay of topology and criticality: from purely-gapless to intrinsically-gapless symmetry-protected topological phases
18:00-18:10	Closing

Invited talks

Classical Boundary Critical Behavior: Models, Field Theory, Boundary Conditions, Universality Classes, and Open Problems

Hans-Werner Diehl * [1]

[1] Universität Duisburg-Essen – Germany

An introduction to classical boundary critical behavior is given. Prototypical models such as the semi-infinite Ising and spin models are introduced and their mapping onto continuum field theories are explained. The resulting boundary conditions for these field theories and their scale dependence are elucidated. The corresponding surface phase diagrams are discussed and the various universality classes for boundary critical behavior at bulk criticality, called ordinary, special, extraordinary, and normal boundary universality classes, are described. What has been learned about these via renormalization group approaches based on the epsilon expansion about the upper and lower critical dimensions, the massive field theory approach in fixed dimensions, large-n analyses and conformal field theory is summarized. The recently discovered new boundary universality class of O(n) models, called extraordinary-log, is also briefly considered. Generalizations of these O(n) models involving symmetry breaking boundary terms and the associated additional boundary universalty classes are also discussed. We argue that for general n additional, not yet explored boundary universality classes may be expected to exist. We also briefly consider boundary critical behavior at bulk tricritical points and at Lifshitz points. In the latter case, there is no conformal invariance and only a rather incomplete study of boundary critical behavior exists.

*Speaker

Critical Casimir Forces

Siegfried Dietrich * [1,2]

[1] Max-Planck-Institut für Intelligente Systeme – Germany
[2] Institut für Theoretische Physik IV, Universität Stuttgart – Germany

Long-ranged correlations in a fluid near its critical point lead to clearly identifiable effective forces acting on confining walls. The corresponding universal scaling functions are discussed for various boundary conditions and geometries. The theoretical predictions are compared with high precision experimental data for He4 and He3/He4 wetting films near the superfluid phase transition as well as with synchrotron scattering data from classical binary liquid mixtures. Direct measurements and applications for colloidal suspensions are discussed.

*Speaker

An extraordinary boundary condition from the conformal bootstrap

Marco Meineri * [1]

[1] University of Geneva – Switzerland

I will discuss the critical behavior of the O(N) model with a boundary. In three dimensions, when the boundary coupling is enhanced, the long distance physics was recently found to depend on N. When N is less than a critical value N_c, logarithmic corrections arise in correlation functions, signaling the attempt of the system to spontaneously break the symmetry. As I will review, the attempt is not quite successful and the symmetry survives. The value of N_c is not known. I will describe how to use the bootstrap to constrain it, and give evidence for the critical value being above 3, and in fact close to 5.

*Speaker

To be ordered or not: recent progress on surface criticality of (2+1)D O(3) models

Long Zhang * [1]

[1] University of Chinese Academy of Sciences – China

Continuous phase transitions exhibit richer critical phenomena on the surface than in the bulk, because distinct surface universality classes can be realized for the same bulk critical point by tuning the surface interactions. The exploration of surface critical behavior provides a window looking into higher-dimensional boundary conformal field theories. In this talk, I will present our recent progress of surface critical behavior of (2+1)D O(3) Heisenberg models. We study the surface critical behavior of a two-dimensional (2D) quantum critical Heisenberg model, and discover a direct special transition on the surface from the ordinary phase into an extraordinary phase induced by tuning the surface coupling strength. The extraordinary phase has a true long-range antiferromagnetic order on the surface, in sharp contrast to the logarithmically decaying spin correlations in the 3D classical O(2) and O(3) models. The special transition point has a new set of critical exponents, $y_s = 0.86(4)$ and $\eta_{\|} = -0.32(1)$, which are distinct from the special transition of the classical O(3) model and indicate a new surface universality class of the 3D O(3) Wilson-Fisher theory.

*Speaker

Hearing the Shape of Quantum Drums via Qiu Ku (pyjamas)

Zi Yang Meng * [1]

[1] University of Hong Kong – Hong Kong SAR China

To hear the shape of a quantum drum is in principle not a mission impossible, where the shape means the conformal field theory (CFT) description of certain quantum phases and phase transitions in a (2+1)d manifold and the drum beat means characteristic measurements of the quantum system whose structure reveals the CFT information. In realistic quantum many-body lattice models, however, measurements such as the finite size scaling of the entanglement entropy with reliable data to extract the CFT characteristics, are rare due to numerical difficulties. To overcome such problem, we design a generic computation protocol to obtain the Rényi entanglement entropy of quantum many-body systems with efficiency and precision. Our method, dubbed "Qiu Ku" algorithm, is based on the massively parallelization of the nonequilibrium increment processes in quantum Monte Carlo simulations. To demonstrate its power, we show the results on few important yet difficult (2+1)d quantum lattice models, ranging from Heisenberg quantum antiferromagnet, quantum critical point with O(3) CFT, deconfined quantum critical point to the toric code Z2 topological ordered state and the Kagome Z2 quantum spin liquid model.

*Speaker

Phases and Phase Transitions with Fractal Symmetries: Models and Experimental Platform

Cenke Xu * [1]

[1] University of California, Santa Barbara – United States

In recent years, generalizations of the notion of symmetry have significantly broadened our view on states of matter. We will discuss some recent progress of understanding and realizing the "fractal symmetry", where the symmetric charge i.e. the generator of the symmetry is defined on a fractal subset of the system with a noninteger or more generally irrational Haussdorf dimension. We will introduce a series of models with exotic fractal symmetries, which can in general be deduced from a "Pascal Triangle" (also called Yang Hui Triangle in ancient China) symmetry. We will discuss their various features including quantum phase transitions. We will also discuss the potential realization of these phases and phase transitions in experimental systems, such as the highly tunable platform of Rydberg atoms.

*Speaker

Geometric Upper Critical Dimensions of the Ising Model

Youjin Deng * [1,2]

[1] University of Science and Technology of China – China
[2] Minjiang University – China

The upper critical dimension of the Ising model is known to be $d_c = 4$, above which critical behavior is regarded as trivial. We hereby argue that, in the random-cluster representation, the Ising model simultaneously exhibits two upper dimensions at $(d_c = 4, d_p = 6)$, and critical clusters for $d \geq d_p$, except the largest one, are governed by exponents from percolation universality. We predict a rich variety of geometric properties and then provide strong evidences by extensive simulations in dimensions from 4 to 7 and on complete graphs. Our fifinding signifificantly advances the understanding of the Ising model, which is a fundamental system in many branches of physics. ArXiv: 2201.12954

*Speaker

Edge physics at the deconfined transition between a quantum spin Hall insulator and a superconductor

Ruochen Ma [1], Liujun Zou [1], Chong Wang * [1]

[1] Perimeter Institute for Theoretical Physics – Canada

We study the edge physics of the deconfined quantum phase transition between a spontaneous quantum spin Hall (QSH) insulator and a spin-singlet superconductor (SC). Although the bulk of this transition is in the same universality class as the paradigmatic deconfined Neel to valence-bond-solid transition, the boundary physics has a richer structure due to proximity to a quantum spin Hall state. We use the parton trick to write down an effective field theory for the QSH-SC transition in the presence of a boundary. We calculate various edge properties in a large-N limit. We show that the boundary Luttinger liquid in the QSH state survives at the phase transition, but only as "fractional" degrees of freedom that carry charge but not spin. The physical fermion remains gapless on the edge at the critical point, with a universal jump in the fermion scaling dimension as the system approaches the transition from the QSH side. The critical point could be viewed as a gapless analogue of the quantum spin Hall state but with the full SU(2) spin rotation symmetry, which cannot be realized if the bulk is gapped.

*Speaker

Non-ordinary surface criticality along dangling edge spins and quantum Monte Carlo simulations of highly frustrated magnets

Stefan Wessel * [1]

[1] RWTH Aachen University – Germany

In the first part of this talk, I will review results from quantum Monte Carlo (QMC) simulations of the non-ordinary surface criticality along the edges of quantum critical two-dimensional dimerized spin systems, including the case of spin-1 systems. In the second part I demonstrate how a suitable choice of cluster basis can be used to eliminate or at least reduce the QMC sign problem in highly frustrated magnets that were so far inaccessible to efficient QMC simulations. I report results from the application of both dimer- and trimer- based QMC methods on the thermodynamics of two-dimensional spin-1/2 systems, in particular fully-frustrated bilayer and trilayer systems, which exhibit strongly first- order quantum phase transitions that extend to finite temperatures,terminating in thermal Ising critical points in the absence of any magnetic order. I also discuss the relation of these results to recent experimental findings on the specific heat of $SrCu_2(BO_3)_2$ under pressure.

*Speaker

The interplay of topology and criticality: from purely-gapless to intrinsically-gapless symmetry-protected topological phases

Ruben Verresen * [1]

[1] Harvard University – United States

In this blackboard-style talk, I will give an introduction and overview of some recent studies of the interplay between topology and criticality. In particular, we will focus on symmetry-protected topological (SPT) phenomena. Traditionally, SPT phases are studied in gapped phases of matter, which led to the common notion that a finite correlation length is essential for giving well-defined topological invariants or localized edge modes. Over the past decade, this intuition has been challenged by a variety of counter-examples which at first seemed exceptional, but which more recently have been unified into the general notion of gapless SPT phases or symmetry-enriched criticality. After giving a bird's-eye view of these developments, I will focus on two particularly striking cases. The first ('purely-gapless SPT') is a 'maximal counter-example' to the aforementioned intuition, where localized edge states persist despite all symmetry sectors being gapless [1]. The second ('intrinsically-gapless SPT') shows that criticality and topology need not just tolerate each other, but can in fact enhance one another: certain gapless SPT states can only exist in the presence of gapless modes [2]. I will also give a taster of some open questions in the field.

[1] RV, Ryan Thorngren, Nick G. Jones, F. Pollmann, Phys. Rev. X 11, 041059 (2021)
[2] Ryan Thorngren, Ashvin Vishwanath, RV, Phys. Rev. B 104, 075132 (2021)

*Speaker

Contributed talks

Visualizing the Kosterlitz RG flow with tensor-network based level spectroscopy

Atsushi Ueda * , Masaki Oshikawa [1]

[1] ISSP – Japan

Berezinskii-Kosterlitz-Thouless transition of the classical XY model is re-investigated, combining the Tensor Network Renormalization (TNR) and the Level Spectroscopy method based on the finite-size scaling of the Conformal Field Theory. By systematically analyzing the spectrum of the transfer matrix of the systems of various moderate sizes which can be accurately handled with a finite bond dimension, we determine the critical point removing the logarithmic corrections. This improves the accuracy by an order of magnitude over previous studies including those utilizing TNR. Our analysis also gives a visualization of the celebrated Kosterlitz Renormalization Group flow based on the numerical data. [1]
In addition, we cover our recent paper on the RP^2 models, where Z_2-vortex triggered BKT transitions have been proposed. In particular, we discuss the universality class of the zero temperature criticality and the cross-over behavior at finite temperature based on the results from TNR. [2]

[1] https://journals.aps.org/prb/abstract/10.1103/PhysRevB.104.165132
[2] To be on arXiv soon.

*Speaker

Scaling of the disorder operator at (2+1) d U(1) quantum criticality

Yancheng Wang * [1], Meng Cheng [2], Zi Yang Meng [3]

[1] School of Materials Science and Physics, China University of Mining and Technology – China
[2] Department of Physics, Yale University – United States
[3] Department of Physics and HKU-UCAS Joint Institute of Theoretical and Computational Physics, The University of Hong Kong – Hong Kong SAR China

We study disorder operator, defined as a symmetry transformation applied to a finite region, across a continuous quantum phase transition in (2+1)d. We show analytically that, at a conformally invariant critical point with U(1) symmetry, the disorder operator with a small U(1) rotation angle defined on a rectangle region exhibits power-law scaling with the perimeter of the rectangle. The exponent is proportional to the current central charge of the critical theory. Such a universal scaling behavior is due to the sharp corners of the region and we further obtain a general formula for the exponent when the corner is nearly smooth. To probe the full parameter regime, we carry out systematic computation of the U(1) disorder parameter in the square lattice Bose-Hubbard model across the superfluid-insulator transition with large-scale quantum Monte Carlo simulations, and confirm the presence of the universal corner correction. The exponent of the corner term determined from numerical simulations agrees well with the analytical predictions.

*Speaker

Boundary quantum criticality and emergent supersymmetry in topological phases

Zixiang Li * [1], Hong Yao [2]

[1] Institute of Physics, Chinese Academy of Sciences – China
[2] Tsinghua University – China

In this talk, I will discuss the boundary quantum critical point and emergent space-time supersymmetry(SUSY) in interacting 2D topological superconductor and 3D topological insulator. By performing state-of-the-art sign-problem-free Majorana quantum Monte-Carlo (QMC) simulations, we show convincing evidences that the N=1 SUSY emerges at the edge quantum critical point of 2D topological superconductor, and N=2 SUSY emerges at the boundary quantum critical point of 3D topological insulator. We further discuss experimental signatures of these boundary quantum critical point and the associated emergent SUSY.

*Speaker

Geometry of bounded critical phenomena

Giacomo Gori * [1]

[1] Universität Heidelberg – Germany

We present a framework relating the correlations functions in a bounded system at criticality to a description in terms of an aptly curved space. The metric of the space is chosen in order to make a (generalized) scalar curvature to be constant, thus solving a problem known in differential geometry as the (fractional) Yamabe problem. The theory, in agreement with what is known in 2d via conformal field theory, in higher dimensions yield new, nontrivial, testable predictions. Such predictions are compared with success with Monte Carlo data and result in very precise estimates of critical exponents in some cases outperforming existing approaches and more importantly give access to universal functions characterizing the order parameter profile and correlations.

*Speaker

Dissipation-induced order in the S=1/2 quantum spin chain coupled to an ohmic bath

Manuel Weber * [1], David J. Luitz [2], Fakher F. Assaad [3]

[1] Max Planck Institute for the Physics of Complex Systems – Germany
[2] University of Bonn – Germany
[3] University of Würzburg – Am Hubland, D-97074 Würzburg, Germany

Real quantum systems are seldom isolated. The natural question to ask is if the coupling to the environment will trigger new phenomena, and, if so, at which energy or time scale. This question is not only relevant in the realm of quantum simulation or computing, but also in the solid state. In this talk, we will consider an $S = 1/2$ antiferromagnetic quantum Heisenberg chain where each site is coupled to an independent bosonic bath with ohmic dissipation, which mimics the coupling to a higher-dimensional bulk system. The coupling to the bath preserves the global SO(3) spin symmetry. Using our recently-developed wormhole quantum Monte Carlo method, we show that any finite coupling to the bath suffices to stabilize long-range antiferromagnetic order. This is in stark contrast to the isolated Heisenberg chain where spontaneous breaking of the SO(3) symmetry is forbidden by the Mermin-Wagner theorem. A linear spin-wave theory analysis confirms that the memory of the bath and the concomitant retarded interaction stabilize the order. For the Heisenberg chain, the ohmic bath is a marginal perturbation so that exponentially large systems sizes are required to observe long-range order at small couplings. Below this length scale, our numerics is dominated by a crossover regime where spin correlations show different power-law behaviors in space and time. Our results suggest that a coupling to a bosonic bath can induce novel phases and phase transitions, which leaves room for many future studies in this direction.

*Speaker

Exotic quantum criticality in Dirac systems: Metallic and deconfined

Zihong Liu * [1], Matthias Vojta [2], Fakher Assaad [1], Lukas Janssen [2]

[1] Universität Würzburg – Germany
[2] Technische Universität Dresden – Germany

Motivated by the physics of spin-orbital liquids, we study a model of interacting Dirac fermions on a bilayer honeycomb lattice at half filling, featuring an explicit global SO(3)×U(1) symmetry. Using large-scale auxiliary-field quantum Monte Carlo (QMC) simulations, we locate two zero-temperature phase transitions as function of increasing interaction strength. First, we observe a continuous transition from the weakly-interacting semimetal to a different semimetallic phase in which the SO(3) symmetry is spontaneously broken and where two out of three Dirac cones acquire a mass gap. The associated quantum critical point can be understood in terms of a Gross-Neveu-SO(3) theory. Second, we subsequently observe a transition towards an insulating phase in which the SO(3) symmetry is restored and the U(1) symmetry is spontaneously broken. While strongly first order at the mean-field level, the QMC data is consistent with a direct and continuous transition. It is thus a candidate for a new type of deconfined quantum critical point that features gapless fermionic degrees of freedom.

*Speaker

Posters

Topological transition to a "non-Landau" Fermi liquid phase in a two-channel spin-1 anisotropic Kondo model and its experimental relevance

Armando Aligia * [1], Rok Zitko , German Blesio , Luis Manuel , Pablo Roura Bas

[1] INN, Centro Atomico Bariloche – Argentina

Using the numerical-renormalization group in a spin-1 two-channel Kondo model with anisotropy D(Sz)^2, we find a topological quantum phase transition in which the Kondo peak is suddenly turned to a dip with increasing D [1]. For large D the system is in a "non-Landau" Fermi liquid phase not adiabatically connected to a non-interacting system.
Extending the theory to non-equivalent orbitals and non-zero magnetic field we can explain several relevant experiments in the system of Fe phthalocyanine on Au(111), like the widening of the observed dip when the molecule is raised from the Au surface, its disappearance with applied temperature and the transformation of the dip to a peak with magnetic field [2]. The model is also relevant for similar systems.

[1] G. G. Blesio, L. O. Manuel, P. Roura-Bas, and A. A. Aligia, Phys. Rev. B 98, 195435 (2018), Phys. Rev. B 100, 075434 (2019).
[2] R. Zitko, G. G. Blesio, L. O. Manuel, and A. A. Aligia, Nature Commun. 12, 6027 (2021)

*Speaker

Criticality and phase transitions in open quantum many-body systems

Thomas Barthel * [1]

[1] Duke University – United States

In the thermodynamic limit, the nonequilibrium steady states of open quantum many-body systems can undergo phase transitions due to the competition of unitary and dissipative dynamics. We consider Markovian systems and elucidate structures of the Liouville super-operator that generates the dynamics. In many cases of interest, an operator basis transformation can bring the Liouvillian into block-triangular form, making it possible to assess its spectrum. The super-operator structure can be used to bound gaps, showing that, in a large class of systems, dissipative phase transitions are actually impossible and that the convergence to steady states is exponential [1].
A large class of translation-invariant fermionic and bosonic systems can be characterized almost completely – "quadratic" systems, where the Hamiltonian is quadratic in the ladder operators, and the Lindblad operators are either linear or quadratic and Hermitian [2]. We find that one-dimensional systems with finite-range interactions cannot be critical, i.e., steady-state correlations necessarily decay exponentially. For the quasi-free case without quadratic Lindblad operators, we show that fermionic systems with short-range interactions are non-critical for any number of spatial dimensions and provide bounds on the correlation lengths. Quasi-free bosonic systems in $d > 1$ dimensions can be critical. Lastly, we address the question of phase transitions in quadratic systems, finding that, without symmetry constraints beyond particle-hole symmetries, all gapped Liouvillians belong to the same phase [3].

[1] T. Barthel and Y. Zhang, "Super-operator structures and no-go theorems for dissipative quantum phase transitions", arXiv:2012.05505
[2] T. Barthel and Y. Zhang, "Solving quasi-free and quadratic Lindblad master equations for open fermionic and bosonic systems", arXiv:2112.08344
[3] Y. Zhang and T. Barthel, "Criticality and phase classification for quadratic open quantum many-body systems", (to be submitted shortly)

*Speaker

Topological Disorder Parameter

Bin-Bin Chen * [1], Hong-Hao Tu [2], Zi Yang Meng [1], Meng Cheng [3]

[1] Department of Physics and HKU-UCAS Joint Institute of Theoretical and Computational Physics, The University of Hong Kong – Hong Kong SAR China
[2] Institute of Theoretical Physcis, TU Dresden – Germany
[3] Department of Physics, Yale University – United States

In recent years, the concept and implementation of disorder operator in quantum phases and phase transitions initiates a new trend in understanding quantum entanglement. However, the computation of disorder operator in the topological ordered phases are still missing. Here we design the disorder operator for the strongly coupled ZN toric code and Wen's plaquette lattice models, and by means of the state-of-art density matrix renormalization group computation and topological field theory analysis, we reveal the intricate scaling behavior of the disorder operator and its usage as the parameter in detecting topological ordered phases.

*Speaker

Spin chain on a metallic surface: dissipation versus Kondo screening

Bimla Danu * [1], Matthias Vojta [2], Tarun Grover [3], Fakher F. Assaad [1]

[1] Universität Würzburg – Germany
[2] Technische Universität Dresden – Germany
[3] University of California at San Diego – United States

We explore the physics of a spin-1/2 Heisenberg chain coupled via a Kondo interaction, J_k, to two dimensional Schrödinger electrons. At weak J_k the problem maps onto a Heisenberg chain locally coupled to a dissipative Ohmic bath. At the Heisenberg fixed point, this coupling is marginal and triggers long ranged antiferromagnetic order along the chain. In the strong Kondo coupling limit we observe a heavy fermion metal originating from Kondo screening. Our results stem from auxiliary field quantum Monte Carlo (QMC) simulations. Due to the dimensionality mismatch between spins and conduction electrons, our model provides a unique negative sign free realization of an anti-ferromagnetic metal to heavy fermion metal transition driven by the competition of dissipation and Kondo screening. We discuss the relevance of our results in the context of scanning tunneling spectroscopy experiments on finite adatom chains on metallic surfaces. In particular we observe distinct features in the differential conductance in both phases.

*Speaker

Disorder operator of fermionic system

Weilun Jiang * [1]

[1] University of Chinese Academy of Sciences – China

We carefully study the behavior of the disorder operator in several free and interacting fermionic systems using determinantal quantum Monte Carlo methods, with the help of analytic analysis. The disorder operator is constructed on a rectangle regions in the form of $U(1)$ symmetry, similar to the definition in bosonic system. We find the behavior of the disorder operator is similar to the entanglement entropy in fermionic system somehow, but has distinct coefficient. We show the essence of this definition is the function form density-density correlation. To make a comparision, we calculate the free systems with fermi surface and dirac fermion, respectively. For interacting system with fermi surface, we find the disorder operator is mostly tuned by the shape of fermi surface. For dirac system, we find the disorder operator decreases approaching the critical point, consistent with the prediction of CFT.

*Speaker

Weyl Anomalies of Four Dimensional Conformal Boundaries and Defects

Jacopo Sisti * [1]

[1] Uppsala University – Sweden

We consider Conformal Field Theories (CFTs) in spacetime dimension d≥5 with a conformally-invariant spatial boundary (BCFTs) or 4-dimensional conformal defect (DCFTs). We determine the boundary or defect contribution to the Weyl anomaly using the standard algorithm, which includes imposing Wess-Zumino consistency and fixing finite counterterms. These boundary/defect contributions are built from the intrinsic and extrinsic curvatures, as well as the pullback of the ambient CFT's Weyl tensor. The coefficient of each term defines a quantity that characterizes the BCFT or DCFT. We show how some of those anomalies enter physical observables, namely the displacement operator two-point function, the stress-tensor one-point function, and the universal part of the entanglement entropy. We compute several anomaly coefficients in tractable examples such as monodromy and conical defects of free, massless scalars and Dirac fermions in d=6; probe branes in Anti-de Sitter (AdS) space dual to defects in CFTs with d≥6; and Takayanagi's AdS/BCFT with d=5.

*Speaker

The dynamical structure factor of the SU(3) Heisenberg chain: The variational Monte Carlo approach

Dániel Vörös * [1,2], Karlo Penc [1]

[1] Wigner Research Centre for Physics – Hungary
[2] Budapest University of Technology and Economics – Hungary

We compute the dynamical spin structure factor $S(k,\omega)$ of the SU(3) Heisenberg chain variationally using a truncated Hilbert space spanned by the Gutzwiller projected particle-hole excitations of the Fermi sea [1]. To achieve this, we extend the method introduced in [2] for the SU(2) symmetric S=1/2 Heisenberg model to the SU(3) symmetric case. We check the reliability of the method by comparing the $S(k,\omega)$ to exact diagonalization results for 18 sites and to the two-soliton continuum of the Bethe Ansatz for 72 sites. We get an excellent agreement in both cases. Detailed analysis of the finite-size effects shows that the method captures the critical Wess-Zumino-Witten $SU(3)_1$ behavior and reproduces the correct exponent, with the exception of the size dependence of the weight of the bottom of the conformal tower. We also calculate the single-mode approximation for the SU(3) Heisenberg model and determine the velocity of excitations. Finally, we apply the method to the SU(3) Haldane-Shastry model and find that the variational method gives the exact wave function for the lowest excitation at $k = 2\pi/3$ and $k = -2\pi/3$.

[1] D. Vörös, K. Penc, Phys. Rev. B 104, 184426 (2021)
[2] B. Dalla Piazza et al., Nature Physics 11, 62 (2015)

*Speaker

Extract information of quantum entanglement on a "Qiuku" manifold

Zheng Yan * [1], Zi Yang Meng [1]

[1] University of Hong Kong – Hong Kong SAR China

In this talk, I will introduce a new entanglement entropy measurement method based on quantum Monte Carlo (QMC). We have improved this method so that it can perform parallel computation well. Through a nonequilibrium process of QMC, we gain Rényi entropy with high precision to reflect non-local physics of quantum many-body systems. We get centre charge and topological entropy from entropy measurements which are highly consistent with theories. Furthermore, we have developed a method to extract "low-energy" part of Von Neumann entropy spectrum (ES) from QMC simulation. It opens an available way to measure the entanglement entropy spectrum of high dimension systems. With the QMC-ES method, we verify that Haldane's conjecture for the entanglement spectrum still holds on the 2D entangled surface.

*Speaker

Global operators capture the physics beyond the traditional LGW framework

Jiarui Zhao * [1]

[1] The University of Hong-Kong – Hong Kong SAR China

Recent years have seen the failure of the traditional LGW framework describing the phases of matter and their transitions. There are many patches of the LGW theory, such as the concept of topology order and higher form symmetries. The concept of topology order extends the scoop of traditional "order" with topology order and the higher form symmetries do the same thing to the traditional symmetry or 0-form symmetry with higher-form symmetries. The two concepts have similarities in that they all invite some global operators to capture the physics they are concerned about. Here we use the Quantum Monte Carlo methods to measure these global operators and characterize the physics beyond LGW. The disordered operators and the entanglement entropy as such global operators can characterize phase transitions and topology order. We will show some examples of lattice models to demonstrate their power.

*Speaker

Emergent Spinon Dispersion and Symmetry Breaking in Two-channel Kondo Lattices

Yashar Komijani * [1], Yang Ge [1]

[1] University of Cincinnati – United States

Two-channel Kondo lattice serves as a model for a growing family of heavy-fermion compounds. We employ dynamical large-N technique and go beyond the independent bath approximation to study this model both numerically and analytically using renormalization group ideas. We show that Kondo effect induces dynamic magnetic correlations that lead to an emergent spinon dispersion. Furthermore, we develop a quantitative framework that interpolates between infinite dimension where the channel-symmetry broken results of mean-field theory are confirmed, and one-dimension where the channel symmetry is restored and a critical fractionalized mode is found.

*Speaker

Author Index

Aligia, Armando, 25
Assaad, Fakher F., 22, 23, 28

Barthel, Thomas, 26
Blesio, German, 25

Chen, Bin-Bin, 27
Cheng, Meng, 19, 27

Danu, Bimla, 28
Deng, Youjin, 13
Diehl, Hans-Werner, 7
Dietrich, Siegfried, 8

Ge, Yang, 34
Gori, Giacomo, 21
Grover, Tarun, 28

Janssen, Lukas, 23
Jiang, Weilun, 29

komijani, Yashar, 34

Li, Zixiang, 20
Liu, Zihong, 23
Luitz, David J., 22

Ma, Ruochen, 14
Manuel, Luis, 25
Meineri, Marco, 9
Meng, Zi Yang, 11, 19, 27, 32

Oshikawa, Masaki, 18

Penc, Karlo, 31

Roura Bas, Pablo, 25

Sisti, Jacopo, 30

Tu, Hong-Hao, 27

Ueda, Atsushi, 18

Verresen, Ruben, 16
Vojta, Matthias, 23, 28
Vörös, Dániel, 31

Wang, Chong, 14
Wang, Yancheng, 19
Weber, Manuel, 22
Wessel, Stefan, 15

Xu, Cenke, 12

YAN, Zheng, 32
Yao, Hong, 20

Zhang, Long, 10
Zhao, Jiarui, 33
Zitko, Rok, 25
Zou, Liujun, 14

Participants

Abdelwahab, Anas; Leibniz Universitaet Hannover, Institut fuer Theoretische Physik.
anas.abdelwahab@itp.uni-hannover.de

Aligia, Armando; Centro Atomico Bariloche
aligia@cab.cnea.gov.ar

Assaad, Fakher;
assaad@physik.uni-wuerzburg.de

Bahari, Masoud;
mr.bahari.ph@gmail.com

Barthel, Thomas; Duke University
barthel@phy.duke.edu

bishnoi, bhupesh;
bishnoi@ieee.org

Borji, Majdouline; École polytechnique
majdouline.borji@polytechnique.edu

Brillaux, Eric;
eric.brillaux@gmail.com

Chen, Bin-Bin; Department of Physics, University of Hong Kong
bchenhku@hku.hk

Chen, Xin; Max-Planck Institute for Quantum Optics
xin.chen@mpq.mpg.de

Costa, Natanael; Federal University of Rio de Janeiro
natanael@if.ufrj.br

danu, Bimla;
bimla.danu@physik.uni-wuerzburg.de

Dao, Liuyun;
daoliuyun@163.com

Deng, Youjin;
yjdeng@ustc.edu.cn

Deng, Zehui; Beijing computational science research center
zhdeng@csrc.ac.cn

Diehl, Hans-Werner; Universität Duisburg-Essen
h.w.diehl@uni-due.de

Dietrich, Siegfried; Max Planck Institute for Intelligent Systems
dietrich@is.mpg.de

Evertz, Hans Gerd; TU Graz, Austria
evertz@tugraz.at

Fan, Zhijie;
zfanac@gmail.com

Fedorenko, Andrey; ENS Lyon
andrey.fedorenko@ens-lyon.fr

Feng, Chunhan;
chhfeng@ucdavis.edu

feng, xu;
202021140008@mail.bnu.edu.cn

Ge, Yang; University of Cincinnati
yang2.ge3@gmail.com

Gori, Giacomo; Universität Heidelberg
gori@thphys.uni-heidelberg.de

Gruzberg, Ilya;
gruzberg.1@osu.edu

guangyu, sun;
gysun93@163.com

Guo, Wenan; Beijing Normal University
waguo@bnu.edu.cn

Herzog, Christopher; Kings College London
cpherzog@gmail.com

Hou, Disha;
dshou@mail.bnu.edu.cn

Hu, Kun;
202131140012@mail.bnu.edu.cn

Huang, Yi-Ping; National Tsing Hua University
yphuang@phys.nthu.edu.tw

Huang, Rui-Zhen; Ghent university
huangrzh@icloud.com

Janke, Wolfhard; Universität Leipzig
wolfhard.janke@itp.uni-leipzig.de

Jiang, Weilun;
wljiang@iphy.ac.cn

Jin, Jintao;
jinjintao19@mails.ucas.ac.cn

Kollar, Marus;
marcus.kollar@uni-a.de

komijani, Yashar;
komijani@uc.edu

Korneev, Leonid;
leonid.korneev@stonybrook.edu

Kravchuk, Petr; King's College London
petr.kravchuk@kcl.ac.uk

Krishnan, Abijith;
abijithk@mit.edu

Lahiri, Aritra;
aritra.l895@gmail.com

Lang, Thomas;
thomas.lang@uibk.ac.at

Li, Zixiang;
zixiangli@iphy.ac.cn

Li, Chuhao;
chli@iphy.ac.cn

Li, Changan; Institute of Physics and Astronomy, Wuerzburg University
changan.li@uni-wuerzburg.de

Liao, Yuan Da;
260351042@qq.com

Lin, Zexun; UT Austin
zexun.lin@utexas.edu

Liu, Zenan;
1725703613@qq.com

Liu, Ke;
ke.liu@lmu.de

Liu, Yuhai;
yuhailiu@csrc.ac.cn

Liu, Zihong;
zihong.liu@physik.uni-wuerzburg.de

liu, shuo;
ls20@mails.tsinghua.edu.cn

Ma, Ruochen;
rma1@perimeterinstitute.ca

Machaczek, Marc; LMU Munich
M.Machaczek@physik.uni-muenchen.de

Marciani, Marco;
marco.marciani@uniroma1.it

Meineri, Marco; University of Geneva
marco.meineri@gmail.com

MENG, ZI YANG;
zymeng@hku.hk

Metlitski, Max; MIT
mmetlitski@gmail.com

Northe, Christian;
christian.northe@physik.uni-wuerzburg.de

O'Bannon, Andrew;
a.obannon@soton.ac.uk

Orignac, Edmond; CNRS and ENS de Lyon
edmond.orignac@ens-lyon.fr

Ostmeyer, Johann;
ostmeyer@liverpool.ac.uk

Otsuka, Yuichi; RIKEN Center for Computational Science
otsukay@riken.jp

Otsuka, Yuichi;
otsukay@gmail.com

Padayasi, Jaychandran;
padayasi.1@osu.edu

Pan, Gaopei; Institute of Physics,CAS
pangaopei14@mails.ucas.ac.cn

Parisen Toldin, Francesco; Universität Würzburg
francesco.parisentoldin@physik.uni-wuerzburg.de

Portela, Jefferson;
stafusa@gmail.com

Raczkowski, Marcin; Universität Würzburg
marcin.raczkowski@physik.uni-wuerzburg.de

Radhakrishnan, Bharathkumar;
r.bharathkumar@outlook.com

Rein, Gabriel;
gabriel.rein@physik.uni-wuerzburg.de

Roscilde, Tommaso;
tommaso.roscilde@gmail.com

Rotella, Francesco; universite de sherbrooke
francesco.rotella@usherbrooke.ca

Sato, Toshihiro; Universität Würzburg
toshihiro.sato@physik.uni-wuerzburg.de

Schaub, Vladimir;
vladimir.schaub@kcl.ac.uk

Schuler, Michael; University of Innsbruck
michael.schuler@uibk.ac.at

Schwab, Jonas;
jonas.schwab@physik.uni-wuerzburg.de

Seifert, Urban; UC Santa Barbara
urbanseifert@ucsb.edu

Selke, Walter; RWTH Aachen University
selke@physik.rwth-aachen.de

Shao, Siqi; University of Cincinnati
shaosq@mail.uc.edu

Shi, Wenjie; BNU
1123002321@qq.com

Shpot, Mykola; ICMP Lviv
shpot.mykola@gmail.com

Sisti, Jacopo; Uppsala University
jacopo.sisti@physics.uu.se

Song, Hong-Hao;
songhonghao20@mails.ucas.ac.cn

Söderberg, Alexander;
alexander.soderberg.1992@physics.uu.se

Ueda, Atsushi; ISSP
atsushi-ueda@g.ecc.u-tokyo.ac.jp

Ulybyshev, Maksim; University of Wuerzburg
maksim.ulybyshev@physik.uni-wuerzburg.de

Upreti, Lavi;
lavi.upreti@physik.uni-wuerzburg.de

Verresen, Ruben; Harvard University
rubenverresen@gmail.com

Vörös, Dániel; Wigner Research Centre for Physics
voros.daniel@wigner.hu

wang, zhe;
201931140008@mail.bnu.edu.cn

Wang, Yancheng;
wangyc@cumt.edu.cn

Wang, Zhan;
wangzhan18@mails.ucas.edu.cn

Wang, Chong; Perimeter Institute for Theoretical Physics
cwang4@perimeterinstitute.ca

Wang, Zhenjiu;
zhwang@pks.mpg.de

Wang, Ting Tung; The University of Hong Kong
leowdd@connect.hku.hk

Wang, Kaize;
wangkaize2000@gmail.com

Watts, Gerard;
gerard.watts@kcl.ac.uk

Weber, Manuel; Max Planck Institute for the Physics of Complex Systems
mweber.physics@gmail.com

Wessel, Stefan;
wessel@physik.rwth-aachen.de

Xiong, Zijian; Chongqing university
xiongzj@cqu.edu.cn

Xu, Cenke;
xucenke@physics.ucsb.edu

YAN, Zheng; HKU
zhengyan@hku.hk

Yao, Louie Hong;
hyao0731@vt.edu

You, Jhih-Shih; National Taiwan Normal University
jhihshihyou@gmail.com

Yu, Xuejia; Peking University
xuejiayu@pku.edu.cn

zahra, ali; CNRS
ali.zahra@cyu.fr

zan, bernardo;
bzan@princeton.edu

Zhang, Long; University of Chinese Academy of Sciences
longzhang@ucas.ac.cn

Zhang, Fan;
zhangf@mail.bnu.edu.cn

Zhang, Chunxu;
chunxu.zhang@physik.uni-wuerzburg.de

Zhao, Jiarui;
jrzhao@hku.hk

Zhitomirsky, Mike; IRIG, CEA
mike.zhitomirsky@cea.fr

Zhong, Yin; Lanzhou University
zhongy@lzu.edu.cn

Zhu, Guo-Yi; Institute for theoretical physics, University of Cologne
timeexplorer1991@gmail.com

Zou, Liujun; Perimeter Institute
zouliujun@gmail.com