Integrable Quantum Many-Body Systems

768. WE-Heraeus-Seminar

23 - 27 May 2022

hybrid

at the Physikzentrum Bad Honnef, Germany

WILHELM UND ELSE
HERAEUS-STIFTUNG

Introduction

The Wilhelm und Else Heraeus-Stiftung is a private foundation that supports research and education in science with an emphasis on physics. It is recognized as Germany's most important private institution funding physics. Some of the activities of the foundation are carried out in close cooperation with the German Physical Society (Deutsche Physikalische Gesellschaft). For detailed information see https://www.we-heraeus-stiftung.de

Aims and scope of the 768. WE-Heraeus-Seminar:

In this Wilhelm and Else Heraeus-Seminar we wish to bring together scientists who are leading the field of integrable many-body systems. We hope for an open and vivid exchange of ideas on timely subjects in the field and its experimental applications, such as, for instance, the relaxation dynamics and asymptotic density matrices of integrable systems, the explicit calculation of their correlation functions in equilibrium and non-eqilibrium settings, the exact thermodynamics of integrable systems, as well as the development of new methods for a deeper understanding of their mathematical structure. We hope for a participation of young scientists from Germany and the neighbouring European countries whom we would like to offer the opportunity to benefit from the special atmosphere at the Physikzentrum Bad Honnef and to get into personal contact with the leading minds in their future field of research.

Scientific Organizers:

Prof. Dr. Hermann Boos — Universität Wupptertal, Germany
E-mail: hboos@uni-wuppertal.de

Dr. Frank Göhmann — Universität Wupptertal, Germany
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Administrative Organization:

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Introduction

Venue:

Physikzentrum
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Registration:

Elisabeth Nowotka (WE Heraeus Foundation)
at the Physikzentrum, reception office
Sunday (17:00 h – 21:00 h) and Monday morning

Program

Sunday, 22 May 2022

17:00 – 20:00	Registration	
18:00	*BUFFET SUPPER and informal get-together*	

Monday, 23 May 2022

08:00	*BREAKFAST*	
09:00	Scientific organizers	**Welcome words**
09:10 – 09:55	Barry McCoy	**Ising correlations; results for Painlevé VI, factorizations and lambda extensions**
09:55 – 10:40	Junji Suzuki	**Exact dynamical correlations**
10:40 – 11:10	*COFFEE & TEA*	
11:10 – 11:55	Holger Frahm	**Critical properties of intersecting loop models and their deformations**
11:55 – 12:40	Jesper Jacobsen	**Geometric algebra and algebraic geometry of loop and Potts models**
12:40 – 12:50	**Conference Photo** (in the front of the lecture hall)	
12:50	*LUNCH*	

Program

Monday, 23 May 2022

14:30 – 15:15	Ovidiu Patu	**Dynamical fermionization of one-dimensional multi-component gases at finite temperature**
15:15 – 16:00	Imke Schneider	**The quasi-1D Lieb-Liniger gas with time-periodically modulated interactions**
16:00 – 16:30	*COFFEE & TEA*	
16:30 – 18:00	**Poster session**	
18:00	*DINNER*	

Program

Tuesday, 24 May 2022

08:00	*BREAKFAST*	
09:00 – 09:45	Alexander Belavin	**Spectral flow construction of N=2 superconformal orbifolds**
09:45 – 10:30	Fedor Smirnov	**The matrix elements in sG model for shifted primary fields**
10:30 – 11:00	*COFFEE & TEA*	
11:00 – 11:45	Olalla Castro Alvaredo	**Symmetry resolved entanglement in quantum field theory**
11:45 – 12:30	Anastasia Doikou	**Quasi-bialgebras from set-theoretic type solutions of the Yang-Baxter equation**
12:30	*LUNCH*	
14:30 – 15:00	Murray Batchelor	**A coupled Temperley-Lieb algebra and the superintegrable chiral Potts model**
15:00 – 15:30	Gesualdo Delfino	**Universality in nonequilibrium quantum dynamics**
15:30 – 16:00	Christoph Karrasch	**Functional RG approach to non-equilibrium phases of matter**
16:00 – 16:30	*COFFEE & TEA*	
16:30 – 18:00	**Poster session**	
18:00	*DINNER*	

Program

Wednesday, 25 May 2022

08:00	*BREAKFAST*	
09:00 – 09:45	Chihiro Matsui	**Quasilocal charges of the XXZ spin chain and integrability of the boundary-driven diffusive system**
09:45 – 10:30	Veronique Terras	**Correlation functions for open XXZ spin 1/2 quantum chains with unparallel boundary magnetic fields**
10:30 – 11:00	*COFFEE & TEA*	
11:00 – 11:45	Robert Weston	**Q operators for open quantum spin chains**
11:45 – 12:30	Karol Kozlowski	**Convergence of the form factor series in the Sinh-Gordon quantum field theory in 1+1 dimensions**
12:30	*LUNCH*	
14:30 – 15:00	Bart Vlaar	**A universal approach to trigonometric K-matrices**
15:00 – 15:30	Rouven Frassek	**Non-compact spin chains and integrable particle processes**
15:30 – 16:00	Kun Hao	**Algebraic Bethe Ansatz for Free Motzkin Model**
16:00 – 16:30	*COFFEE & TEA*	
16:30 – 19:00	**Free for excursion**	
19:00	*DINNER*	

Program

Thursday, 26 May 2022

08:00	*BREAKFAST*	
09:00 – 09:45	Vladimir Bazhanov	**An Ising-type formulation of the six-vertex model**
09:45 – 10:30	Patrick Dorey	**Analytic continuation of TBA equations**
10:30 – 11:00	*COFFEE & TEA*	
11:00 – 11:45	Jean Michel Maillet	**On the Tetrahedron equation**
11:45 – 12:30	Balázs Pozsgay	**Integrable models with medium range interactions**
12:30	*LUNCH*	
14:30 – 15:15	Angela Foerster	**Design of integrable quantum devices**
15:15 – 16:00	Giuliano Pavan Ribeiro	**Correlation functions of integrable O(n) spin chains**
16:00 – 16:30	*COFFEE & TEA*	
16:30 – 17:30	Fabian Essler	**Quantum dynamics in interacting Bose gases**
18:30	*HERAEUS DINNER* *(social event with cold & warm buffet with complimentary drinks)*	

Program

Friday, 27 May 2022

08:00	*BREAKFAST*	
09:00 – 09:45	Kazumitsu Sakai	**The spin Drude weight for the XXZ chain with arbitrary spin**
09:45 – 10:30	Jesko Sirker	**Transport properties of the XXZ spin chain**
10:30 – 11:00	*COFFEE & TEA*	
11:00 – 11:45	Sergei Rutkevich	**Spinon confinement in the gapped antiferromagnetic XXZ spin-1/2 chain**
11:45– 12:30	Paul Pearce	**Critical site percolation on the triangular lattice**
12:30 – 12:45	Scientific organizers	**Closing words**
12:45	*LUNCH*	

End of the seminar and departure

NO DINNER for participants leaving on Saturday; however, a self-service breakfast will be provided on Saturday morning

Posters

Posters

Rodrigo Alves Pimenta	**Free fermionic and parafermionic quantum spin chains**
Gianni Aupetit-Diallo	**Correlations and symmetries of one-dimensional bosonic mixtures**
Martin Bonkhoff	**Bosonic continuum theory of one-dimensional lattice anyons**
Cecilia De Fazio	**Generalised hydrodynamics of unstable excitations**
Claude Dimo	**XXX dark states in central spin models**
Saskia Faulmann	**Absence of string excitations in the low-T spectrum of the quantum transfer matrix of the XXZ chain**
Sascha Gehrmann	**The continuum limit of the open staggered-six vertex model with quantum group invariant boundary conditions**
Daniele Gregori	**Integrability as a new method for exact results on quasinormal modes of black holes**
Arthur Hutsalyuk	**Integrability breaking in the one dimensional Bose gas: Atomic losses and energy loss**
Henrik Jürgens	**The 'Snail construction' for higher rank**
Hector Pablo Ojeda Collado	**Engineering Higgs dynamics in integrable Bardeen-Cooper-Schrieffer systems**
Davide Polvara	**Perturbative integrability in 1+1 dimensions**

Posters

Flavia Ramos	**Confinement and bound states of bound states in a transverse-field two-leg Ising ladder**
Ingryd Rodrigues dos Passos	**Auxiliary functions for su(n)-symmetric models and their continuum limit**
Istvan Mate Szécsényi	**Orbifold CFTs, regularised twist fields, and entanglement entropy**
Diego Trancanelli	**Supersymmetric many-body systems from partial symmetries:**
Andrew Urichuk	**Non-linear transport of Bethe bound states**
Dennis Wagner	**Typical neural network states**
Daniel Westerfeld	**Functional methods for correlation functions in integrable face models**
Hao-Lan Xu	**2D Ising field theory in a magnetic field: The Yang-Lee singularity**

Abstracts of Talks

(in alphabetical order)

An Ising-type formulation of the six-vertex model

Vladimir Bazhanov
Australian National University

We show that the celebrated six-vertex model of statistical mechanics (along with its multistate generalizations) can be reformulated as an Ising-type model with only a two-spin interaction. Such a reformulation unravels remarkable factorization properties for row to row transfer matrices, allowing one to uniformly derive all functional relations for their eigenvalues and present the coordinate Bethe ansatz for the eigenvectors for all higher spin generalizations of the six-vertex model. The possibility of the Ising-type formulation of these models rises questions about the precedence of the traditional quantum group description of the vertex models. Indeed, the role of a primary integrability condition is now played by the star-triangle relation, which is not entirely natural in the standard quantum group setting, but implies the vertex-type Yang-Baxter equation and commutativity of transfer matrices as simple corollaries. As a mathematical identity the emerging star-triangle relation is equivalent to the Pfaff-Saalsch\"utz-Jackson summation formula, originally discovered by J. F. Pfaff in 1797. Plausibly, all vertex models associated with quantized affine Lie algebras and superalgebras can be reformulated as Ising-type models. (Based on the joint work with Sergey Sergeev,
arXiv:2205.10708)

A coupled Temperley-Lieb algebra and the superintegrable chiral Potts model

Murray T. Batchelor[1]

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The Hamiltonian of the N-state superintegrable chiral Potts (SICP) model can be written in terms of a coupled algebra defined by $N-1$ types of Temperley-Lieb generators [1]. A pictorial representation of the coupled algebra has been given for the $N = 3$ case which involves a generalisation of the well known pictorial presentation of the Temperley-Lieb algebra to include a pole around which loops can become entangled. For the two known representations of this algebra, the $N = 3$ SICP chain and the staggered spin-1/2 XX chain, closed (contractible) loops have weight $\sqrt{3}$ and weight 2, respectively. For both representations closed (non-contractible) loops around the pole have weight zero. The pictorial representation provides a graphical interpretation of the algebraic relations. A key ingredient in the resolution of diagrams is a crossing relation for loops encircling a pole which involves the parameter $\rho = e^{2\pi i/3}$ for the $N = 3$ SICP chain and $\rho = 1$ for the staggered XX chain. These ρ values are derived assuming the Kauffman bracket skein relation. Some further developments will also be discussed.

References

[1] R. Adderton, M. T. Batchelor and P. Wedrich, J. Phys. A **53**, 36LT01 (2020)

Spectral Flow construction of N=2 Superconformal orbifolds.

Alexander Belavin

Ten-dimensional Superstring theory unifies the Standard Model and quantum gravity. To obtain a four-dimensional theory with Space-Time Supersymmetry (which is necessary for phenomenological reasons), as shown by Candelas, Horowitz, Strominger, Witten, we must compactify six of the ten dimensions on a so-called Calabi-Yau manifold. Another equivalent approach to do the same is the compactification of 6 dimensions into an $N=2$ Superconformal field theory with the central charge $c=9$, as was shown by D. Gepner. Each of these two equivalent approaches has its own merits. In particular, Gepner's approach makes it possible to use exactly solvable N=2 SCFT models and thus to obtain an explicit solution of the considered model.

The subject of my talk is a new approach to the construction of Calabi-Yau orbifolds of Fermat type required for the compactification in Superstring theory. The idea of the approach is to use the connection of the CY orbifolds with a class of exactly solvable N=2 SCFT models for explicitly constructing a complete set of fields in these orbifold models using the Spectral flow twist (Schwimmer and Seiberg) and the requirement of mutual locality of the fields.

Using various examples of orbifolds, we also construct chiral and anti chiral rings and show that their dimensions coincide with the dimensions of the cohomology groups of mutually mirror CY-manifolds, including those considered by Greene and Plesser.

Symmetry Resolved Entanglement in Quantum Field Theory

Olalla Castro-Alvaredo

School of Mathematics, Computer Science and Engineering, Department of Mathematics, City, University of London, 10 Northampton Square, London EC1V 0HB

In recent years a new measure of entanglement in many-body quantum systems has been the subject of intense study. This new measure is known as symmetry resolved entanglement entropy, and it provides not only a bipartite measure of entanglement but also a measure of the contribution to entanglement of different symmetry sectors when the theory possesses an internal symmetry. A leading approach to studying entanglement measures is to relate them to correlation functions of symmetry fields known as branch point twist fields. In this talk I will review this approach and present some recent results for various models.

References

[1] Luca Capizzi, Olalla Castro-Alvaredo, Cecilia De Fazio, Michele Mazzoni and Lucía Santamaría, Symmetry Resolved Entanglement: Excited States in Quantum Field Theory (To Appear).
[2] Luca Capizzi, Dávid X. Horváth, Pasquale Calabrese and Olalla A. Castro-Alvaredo, Entanglement of the 3-State Potts Model via Form Factor Bootstrap: Total and Symmetry Resolved Entropies, arXiv:2108.10935.
[3] Dávid X. Horváth, Pasquale Calabrese and Olalla A. Castro-Alvaredo, Branch Point Twist Field Form Factors in the sine-Gordon Model II: Composite Twist Fields and Symmetry Resolved Entanglement, Accepted for publication in Scipost Physics, arXiv:2105.13982.

Universality in nonequilibrium quantum dynamics

G. Delfino[1]

[1] *SISSA and INFN, Trieste, Italy*

We consider the nonequilibrium dynamics of isolated systems in the vicinity of quantum critical points. For the case in which the dynamics is initialized by the sudden change of an interaction parameter (quench), we analyze the problem of the determination of the nonequilibrium state produced in this way and of the time evolution of local observables. The analytical results show in particular how the presence of persistent oscillations depends on the universality class and on spatial extent of the quench. We then turn to the case in which the nonequilibrium state is not dynamically generated and, focusing on ferromagnets at phase coexistence, determine the universal properties of the large time dynamics for an infinite-dimensional space of domain wall initial conditions. The role of integrability is pointed out throughout the presentation.

References

[1] G. Delfino, J. Phys. A **47**, 402001 (2014)

[2] G. Delfino and J. Viti, J. Phys. A **50**, 084004 (2017)

[3] G. Delfino, Nucl. Phys. B **954,** 115002 (2020)

[4] G. Delfino and M. Sorba, Nucl. Phys. B **974**, 115643 (2022)

[5] G. Delfino and M. Sorba, arXiv:2202.12608

Quasi-bialgebras from set-theoretic type solutions of the Yang-Baxter equation

A.Doikou[1], A. Ghionis[1], A. Smoktunowicz[2] and B. Vlaar[3]

[1]Department of Mathematics, Heriot-Watt University,
& Maxwell Institute for Mathematical Sciences, Edinburgh, UK

[2]School of Mathematics, University of Edinburgh, Kings Buildings,
& Maxwell Institute for Mathematical Sciences, Edinburgh, UK

[3]Max Planck Institute for Mathematics, Bonn, Germany

We discuss novel links between the theory of braces (nil potent rings), set-theoretic solutions of the Yang-Baxter equation and fundamental concepts from the theory of quantum integrability and quantum algebras. More precisely, we identify quantum groups associated to set-theoretic solutions coming from braces and we construct novel classes of periodic and open quantum spin chains. We also construct admissible Drinfeld twists for set-theoretic solutions and their q-analogues. After providing some universal findings on quasi-bialgebras and admissible Drinfeld twists we show that the quantum algebras emerging from set-theoretic solutions and their q-analogues are quasi-triangular quasi-bialgebras.

References

1) A. Doikou and A. Smoktunowicz, Lett. Math. Phys. 111, 105 (2021).

2) A. Doikou, J. Phys. A54, 415201 (2021).

3) A. Doikou and A. Smoktunowicz, accepted in J. Algebra Appl. (2022).

4) A. Doikou, A. Ghionis and B. Vlaar, *arXiv:2203.03400[math-QA]*, (2022).

Analytic continuation of TBA equations

Patrick Dorey[1]

[1]*Durham University, UK*

This talk will outline some recent and not-so-recent work on the analytic continuation of TBA equations, and the resulting interconnectedness of the energy levels of the associated models once couplings are allowed to become complex.

Quantum dynamics in interacting Bose gases

Fabian H.L. Essler

Rudolf Peierls Centre for Theoretical Physics, Oxford University, Parks Road, Oxford OX1 3PU, UK

Determining dynamical properties of the Lieb-Liniger model of interacting bosons is notoriously difficult, both in equilibrium at finite temperatures and out of equilibrium. I discuss recent progress in determining dynamical properties, both in and out of equilibrium, in the regime of strong interactions. This is based on two approaches: (i) combining integrability methods with an expansion in the inverse interactions strength; and (ii) on an explicit construction of the fermionic dual of the Lieb-Liniger model, in which fermion-fermion interactions can be treated perturbatively in the strong coupling regime.

References

[1] E. Granet and F.H.L. Essler, SciPost Phys. 9, 082 (2020).
[2] E. Granet and F.H.L. Essler, SciPost Phys. 11, 068 (2021).
[3] E. Granet, B. Bertini and F.H.L. Essler, Phys. Rev. Lett. 128, 021604 (2022).

Design of integrable quantum devices

A. Foerster[1], K. Wittmann[1], L. Ymai[2], D. Grün[1] A.Tonel[2] and J. Links[3]

[1]Instituto de Física da UFRGS, Brazil
[2]Universidade Federal do Pampa, Brazil
[3]The University of Queensland, Australia

The precise control of quantum systems will play a major role in the realization of atomtronic devices. Here we study models of dipolar bosons confined to three-well and four-well potentials. The analysis considers both integrable and non-integrable regimes within the models. Through variation of the external field, we demonstrate how the triple-well system can be controlled between various “switched-on” and “switched-off” configurations [1] and how the four-well system can be controlled to generate and encode a phase into a NOON state [2]. We also discuss the physical feasibility through use of ultracold dipolar atoms in BECs (three-wells) or optical superlattices (four-wells). Our proposals showcase the benefits of quantum integrable systems in the design of quantum devices.

References

[1] K. Wittmann, L. Ymai, A.Tonel, J. Links and A. Foerster, Communications Physics **1,** 91 (2018)

[2] D. Grün, K. Wittmann, L. Ymai, J. Links and A. Foerster, Communications Physics **5,** 36 (2022)

Critical properties of intersecting loop models and their deformations

Holger Frahm

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Appelstr. 2, 30167 Hannover, Germany

Vertex models with *OSp(n|2m)* supergroup symmetry are lattice realizations intersecting loops in two dimensions. The related integrable spin chains provide a framework to study the critical properties of the low temperature Goldstone phase of the *O(N)* sigma model for $N=n-2m<2$. We present results of our finite size analysis of the spectra of these models and deformations thereof subject to different boundary conditions. Based on our findings we argue that the asymptotic behaviour of watermelon correlators can be inferred from the amplitudes of the subleading corrections to scaling.

References

[1] H. Frahm and M. J. Martins: ``The fine structure of the finite-size effects for the spectrum of the *OSp(n|2m)* spin chain'', Nucl. Phys. B**930** (2018) 545-562, arXiv:1802.05191

[2] H. Frahm, K. Hobuß, and M. J. Martins: ``On the critical behaviour of the integrable *q*-deformed *OSp(3|2)* superspin chain'', Nucl. Phys. B**946** (2019) 114697, arXiv:1906.00655

[3] H. Frahm and M. J. Martins: ``*OSp(n|2m)* quantum chains with free boundaries'', arXiv:2202.13405

Non-compact spin chains and integrable particle processes

R. Frassek

University of Modena and Reggio Emilia,
FIM, Via G. Campi 213/b, 41125 Modena, Italy

I will discuss the relation between non-compact spin chains studied first in the context of high energy physics following ideas of Lipatov, Faddeev and Korchemsky and the zero-range processes introduced by Sasamoto-Wadati, Povolotsky and Barraquand-Corwin. The main difference compared to the prime examples of integrable particle processes, namely the SSEP and the ASEP, is that for the models discussed in this talk several particles can occupy one and the same site. For the models with symmetric hopping rates I will introduce integrable boundary conditions that are obtained from new solution to the boundary Yang-Baxter equation (K-matrix) that allow to define analogues of the open SSEP with boundary reservoirs. Finally, I will present an explicit mapping of these boundary driven models to equilibrium. This mapping allows us to obtain closed-form solutions of the probabilities in steady state and of k-point correlations functions. The talk is based on the articles [1-5] done in collaboration with C. Giardinà and J. Kurchan and some ongoing collaboration with C. Franceschini and C. Giardinà.

References

[1] R. Frassek, C. Giardinà and J. Kurchan, Journal of Statistical Physics **180**, 135–171 (2019)
[2] R. Frassek, Journal of Physics A **52**, 335202 (2019)
[3] R. Frassek, Journal of Statistical Mechanics **2005**, 053104 (2020)
[4] R. Frassek, C. Giardinà and J. Kurchan, SciPost Physics **9**, 054 (2020)
[5] R. Frassek and C. Giardinà, arXiv:2107.01720 [math-ph]

Algebraic Bethe Ansatz for Free Motzkin Model

Kun Hao[1,2], Olof Salberger[2] and Vladimir Korepin[2,3]

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The Motzkin spin chain is a spin-1 frustration-free model introduced by Shor & Movassagh. The ground state is constructed by mapping of random walks on upper half of the square lattice to spin configurations. It has unusually large entanglement entropy [quantum fluctuations]. We simplify the model by removing one of the local equivalence moves of the Motzkin paths. The system becomes integrable [similar to the XXX spin chain]. We call it free Motzkin chain. From the point of view of quantum integrability, the model is special since its R-matrix does not have crossing unitarity. We solve the periodic free Motzkin chain by generalized functional Bethe Ansatz method. We construct a T−Q relation with an additional parameter to formulate the energy spectrum. This new parameter is related to the roots of unity and can be described by the Möbius function in number theory. We observe further patterns of number theory.

References

[1] R. Movassagh and P. W. Shor, Proceedings of the National Academy of Sciences 113, 13278 (2016).

Geometric algebra and algebraic geometry of loop and Potts models

J. Böhm[1], J.L Jacobsen[2], Y. Jiang[3] and Y. Zhang[4]

[1] Department of Mathematics, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany
[2] Laboratoire de Physique de l'Ecole Normale Supérieure, ENS, Université PSL, CNRS, Sorbonne Université, Université de Paris, F-75005 Paris, France
[3] Shing-Tung Yau Center, Southeast University, Nanjing 210096, China
[4] Interdisciplinary Center for Theoretical Study, University of Science and Technology of China, Hefei, Anhui 230026, China

We uncover a connection between two seemingly separate subjects in integrable models: the representation theory of the affine Temperley-Lieb algebra, and the algebraic structure of solutions to the Bethe equations of the XXZ spin chain. We study the solution of Bethe equations analytically by computational algebraic geometry, and find that the solution space encodes rich information about the representation theory of Temperley-Lieb algebra. Using these connections, we compute the partition function of the completely-packed loop model and of the closely related random-cluster Potts model, on medium-size lattices with toroidal boundary conditions, by two quite different methods. We consider the partial thermodynamic limit of infinitely long tori and analyze the corresponding condensation curves of the zeros of the partition functions. Two components of these curves are obtained analytically in the full thermodynamic limit.

References

1. J. Böhm, J.L. Jacobsen, Y. Jiang and Y. Zhang, *Geometric algebra and algebraic geometry of loop and Potts* models, arXiv:2202.02986.
2. J.L. Jacobsen, Y. Jiang and Y. Zhang, *Torus partition function of the six-vertex model from algebraic* geometry, JHEP **2019**, 152 (2019).
3. Z. Bajnok, J.L. Jacobsen, Y. Jiang, R.I. Nepomechie and Y. Zhang, *Cylinder partition function of the 6-vertex model from algebraic geometry*, JHEP **2020**, 169 (2020).

Functional RG approach to Non-Equilibrium Phases of Matter

C. Karrasch[1]

[1]*Institut fuer Mathematische Physik, TU Braunschweig, Mendelssohnstr. 3, 38106 Brauschweig. Germany*

We discuss recent developments of the functional renormalization group approach to many-body systems out of thermal equilibrium [1,2]. We use the method to study the non-equilibrium phase diagram and BKT transitions of a generalized, interacting Wannier-Stark ladder coupled to a substrate. We also comment on other setups that are not susceptible to a FRG treatment. In a second, brief part of the talk we discuss a few tensor network results for transport properties of one-dimensional chains [3].

References

[1] C. Klöckner, D. M. Kennes, C. Karrasch, New J. Phys. 22, 083039 (2020)
[2] C. Klöckner, C. Karrasch, D. M. Kennes, Phys. Rev. Lett. 125, 147601 (2020)
[3] B. Bertini, F. Heidrich-Meisner, C. Karrasch, T. Prosen, R. Steinigeweg, M. Znidaric, Rev. Mod. Phys. 93, 025003 (2021)

Convergence of the form factor series in the Sinh-Gordon quantum field theory in 1+1 dimensions

K. K. Kozlowski

Laboratoire de Physique, ENS de Lyon, UMR 5672 du CNRS, Lyon, France.

Within the approach of the bootstrap program, the physically pertinent observables in a massive integrable quantum field theory in 1+1 dimensions are expressed by means of the so-called form factor series expansion. This corresponds to a series of multiple integrals in which the n^{th} summand is given by a n-fold integral. While being formally effective for various physical applications, so far, the question of convergence of such form factor series expansions was essentially left open. Still, convergence results are necessary so as to reach the mathematical well-definiteness of such construction and appear as necessary ingredients for the justification of numerous handlings that are carried out on such series.

In this talk, I will describe the technique I recently developed that allows one to prove the convergence of the form factor series that arise in the context of the simplest massive integrable quantum field theory in 1+1 dimensions: the Sinh-Gordon model. The proof amounts to obtaining a sufficiently sharp estimate on the leading large-n behaviour of the n-fold integral arising in this context. This appeared possible by refining some of the techniques that were fruitful in the analysis of the large-n behaviour of integrals over the spectrum of $n \times n$ random Hermitian matrices.

On the Tetrahedron equation

J. M. Maillet[1]

[1]*Laboratoire de Physique, CNRS, ENS de Lyon, Lyon, France*

I will recall the interpretation of the Tetrahedron equations as a zero-curvature condition for transport operators moving discretized decorated surfaces [1] and the construction of their solutions in terms of two simplicial objects, one of them being solution to a Pentagon equation [2]. Solutions to the Tetrahedron equation related to Turaev-Viro topological models will be described.

References

[1] J. M. Maillet, *Integrable systems and gauge theories***,** Nucl. Phys. (Proc. Suppl.) **18B**, 212 (1990).

[2] J. M. Maillet, *On Pentagon and Tetrahedron equations***,** Algebra and Analysis, **6**, 206 (1994).

Quasilocal charges of the XXZ spin chain and integrability of the boundary-driven diffusive system

C. Matsui[1]

[1]*The University of Tokyo, Tokyo, Japan*

Quasilocal charges of integrable systems have attracted attention in the context of generalized Gibbs ensemble (GGE) and ballistic transport of the spin current supported by non-zero Drude weight. We discuss the construction of quasilocal charges for the XXZ spin chain in the presence of boundary magnetic fields and how the boundary magnetic fields affect on the evaluation of Drude weight.
On the other hand, the steady state of the boundary-driven diffusive XXZ spin chain is known to be given by the generating function of the quasilocal charges of the isolated XXZ spin chain. The boundary terms are partly recovered by transforming dissipators by keeping the Liouvillian operator invariant. We discuss the steady state of the boundary-driven diffusive XXZ spin chain under the presence of boundary magnetic fields as examples of exactly solvable boundary-driven diffusive system.

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Ising correlations; results for Painlevé VI, factorizations and lambda extensions

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We study the correlations $C(M,N)$ of the Ising model with modulus $k = (\sinh 2E_v/k_BT \sinh 2E_h/k_BT)^{-1}$ and anisotropy $\nu = \frac{\sinh 2E_h/k_BT}{\sinh 2E_v/k_BT}$ in the special case $\nu = -k$. We find that for all M,N that $C(M,N)$ has a representation in terms of a Painlevé VI function and also as an $N \times N$ Toeplitz determinant. In the further special case where $M+N$ is odd and $N \neq 0$ the PVI functions factorize into 2 factors of other PVI functions by use of a Landen transformation and when $N = 0$ there is a factorization into 4 PVI functions (with no Landen transformation). We conclude with a discussion of the implications of these results for the general case with k and ν arbitrary.

Dynamical fermionization of one-dimensional multi-component gases at finite temperature

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Dynamical fermionization is the phenomenon in which after release from the trap the momentum distribution of an impenetrable gas asymptotically approaches that of a spinless noninteracting Fermi gas in the initial trap. Recently, dynamical fermionization has been experimentally confirmed in the case of the Lieb-Liniger model in the Tonks-Girardeau regime [1] and has been theoretically predicted to occur at zero temperature in fermionic and bosonic spinor gases [2] and mixtures [3]. We show that at finite temperature the momentum distribution of a strongly interacting multi-component gas after the harmonic trap is turned off approaches that of a spinless ideal Fermi gas at the same temperature but with a renormalized chemical potential which depends on the number of components of the systems and the magnetic field. For the bosonic and fermionic Gaudin-Yang models we confirm this prediction numerically using a newly developed generalization of Lenard's formula.

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Correlation functions of integrable $O(n)$ spin chains

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We study the correlation functions of the integrable $O(n)$ spin chain in the thermodynamic limit. We addressed the problem of solving functional equations of the quantum Knizhnik-Zamolodchikov type for density matrix related to the $O(n)$ spin chain. We give the explicit solution for two-sites density matrix elements for the $O(n)$ which are then evaluated for the n=3,4,…,8 cases at zero temperature.

Critical site percolation on the triangular lattice

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Critical site percolation on the triangular lattice is a special case of the dilute $A_2^{(2)}$ loop model with contractible loop fugacity β=1. Functional equations, Bethe ansatz, Nonlinear Integral Equations (NLIEs) and standard module and Markov traces are used to solve (i) analytically for conformal weights and (ii) numerically for conformal partition functions of this model on the strip, cylinder and torus. The concurrence of all this conformal data with that of critical bond percolation on the square lattice [1] provides compelling evidence supporting a strong form of universality between these models as stochastic logarithmic conformal field theories.

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Integrable models with medium range interactions

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Integrable spin chains and integrable cellular automata can be constructed using the well known methods of the Quantum Inverse Scattering Method (Algebraic Bethe Ansatz). However, most of the literature deals with spin chain Hamiltonians which are nearest neighbour interacting. We extend these methods to translationally invariant spin chains with finite interaction range m, with $m>2$. We explain the general methodology, and also give concrete examples for such models, including some new models.

Spinon confinement in the gapped antiferromagnetic XXZ spin-1/2 chain

S. B. Rutkevich

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In this talk I will present some results about the effect of a weak staggered longitudinal magnetic field h on the properties of the infinite Heisenberg XXZ spin-(1/2) chain in the gapped antiferromagnetic phase at zero temperature. This model has been widely used for
interpretation of the experimentally observed energy spectra of "meson" magnetic excitations in quazi-1D antiferromagnetic compounds in the confinement regime, see e.g. [1]. The effective staggered field accounts in the mean-field approximation the weak inter-chain interaction in the 3D array of parallel spin chains in the 3D ordered phase of such compounds. Being integrable at $h=0$, this model has two degenerate vacua and kink topological excitations (which are also called spinons) interpolating between these vacua, as elementary excitations. Application of a weak staggered magnetic field $h>0$ breaks integrability of the model, and induces the long-range attractive potential between two adjacent spinons leading to their confinement into the bound states, which are commonly called "the mesons" in analogy with the QCD. Exploiting integrability of the model in the deconfined phase at $h=0$, I perform two alternative perturbative calculations of the meson energy spectra in the weak confinement regime using the staggered magnetic field $h>0$ as a small parameter. In the first non-rigorous heuristic approach, the meson energy spectrum is determined by the semiclassical (or canonical) quantization of the classical dynamics of two kinks which move along the line and attract one another with a constant force. The results of this heuristic calculations were already announced in [2]. The second more rigorous technique employs the Bethe-Salpeter equation, which describes the two-spinon excitations in this model at small $h>0$. From the perturbative solution of this equation, I calculate the meson energy spectra, and justify previously obtained results. Finally, the explicit formulas are obtained for the two-spinon contribution to the transverse and longitudinal dynamical structure factors of the local spin operators for this model in the weak confinement regime.

This work was supported by Deutsche Forschungsgemeinschaft (DFG) via Grant BO 3401/7-1

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The spin Drude weight for the XXZ chain with arbitrary spin

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Combining the generalized hydrodynamics and the Y-system constructed by the quantum transfer matrix, we exactly evaluate the finite-temperature spin Drude weight for the integrable XXZ chain with arbitrary spin. Furthermore, the fractal structure of the Drude weight is discussed.

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The quasi-1D Lieb-Liniger gas with time-periodically modulated interactions

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We study the interplay of Floquet states and strong correlations considering the exactly solvable Lieb-Liniger model of quasi-1D bosons with time-periodically modulated interactions. By developing a time-periodic operator algebra for Luttinger liquids, we are able to obtain and analyze the complete set of explicit steady state solutions in terms of a Floquet-Bogoliubov ansatz and known analytic functions. When the driving frequency is lowered below the Luttinger liquid cutoff energy, a dramatic change of behavior is observed which is signaled by the appearance of strong resonant density waves. We include damping effects and compare with state-of-the art experiments.

Transport properties of the XXZ spin chain

J. Sirker

Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada

I will present an overview of some of our recent results on the finite-temperature spin conductivity of the spin-1/2 XXZ chain.

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The matrix elements in sG model for shifted primary fields

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The fermionic basis in the CFT with $c = 1 - 6/p(p+1)$ and its perturbation differs from the Virasoro one. Namely, primary fields shifted by $2p$ belong to one fermionic module. This fact follows from the special property of the function ω which enters the expression for the matrix elements. I shall discuss this property and its implications.

Exact dynamical correlations

J. Suzuki

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I review the recent development of the thermal form factor expansion method [1], which combines two important ingredients, the Quantum Inverse Scattering Method and the Quantum Transfer Matrix.
Special emphasis is placed on its application to the evaluation of dynamical response functions, such as the dynamical structure function [2] and the spin conductivity [3].
The talk is based on collaborations with C. Babenko, M. Dugave, F. Göhmann, M. Karbach, A. Klümper, K. Kozlowski, J. Sirker and on discussions with many other researchers.

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Correlation functions for open XXZ spin 1/2 quantum chains with unparallel boundary magnetic fields

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We review a recent work [1] concerning the computation of the correlation functions of the open quantum spin 1/2 chains for unparallel boundary magnetic fields. In this work, we leave the boundary magnetic field in the first site of the chain completely arbitrary, and we fix the boundary field in the last site N of the chain to be a specific value along the z-direction. The complete spectrum and eigenstates can be constructed by means of the quantum Separation of Variables, in terms of solutions of a homogeneous T-Q equation. We can compute the action of a basis of local operators on transfer matrix eigenstates as linear combinations of separate states, and use the simple scalar product formulae for separate states previously obtained in [2]. This enables us to derive the correlation functions of a set of local operators both for the finite and half-infinite chains, with multiple integral formulae in this last case.

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A universal approach to trigonometric K-matrices

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Integrability in quantum many-body systems can be characterized by a solution of the Yang-Baxter equation (with spectral parameter), known as an R-matrix. A rich supply arises as follows by an observation originally made by Drinfeld. The universal R-matrix associated to a quantum affine algebra acts on tensor products of finite-dimensional representations of the corresponding quantum loop algebra as a matrix which is a Laurent series in the multiplicative spectral parameter *z* and the Yang-Baxter equation follows from quasitriangularity. Moreover, when these representations are irreducible, this series is essentially a rational function, i.e. a 'trigonometric' R-matrix in a parameter proportional to *log(z)*. For instance, in the simplest case of two 2-dimensional representations of quantum affine sl_2, the R-matrix of the XXZ Heisenberg spin chain is recovered.

The reflection equation (boundary Yang-Baxter equation) is a similar factorization condition associated to quantum integrable systems with boundaries (e.g. open spin chains). It has been studied since the 1980s by Cherednik, Sklyanin, Kulish-Sklyanin, Mezincescu-Nepomechie and many others. We will consider the 'boundary analogue' of the above approach to R-matrices, see [1,2]. Instead of just a quantum affine algebra one needs to consider a quantum affine symmetric pair: a quantum affine algebra together together with a suitable coideal subalgebra which can be viewed as the algebra of 'residual symmetries' of the model (those which are compatible with the boundary conditions). For each finite-dimensional representation one obtains is a matrix-valued formal Laurent series in *z* which satisfies a generalized form of the reflection equation considered by Cherednik in 1992. If the representation is irreducible, the dependence is again essentially rational. Hence, well-known `trigonometric' K-matrices are recovered, such as those defining integrable boundary conditions for the XXZ chain, and a large supply of new ones is obtained.

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Q Operators for Open Quantum Spin Chains

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Baxter's Q-operator was introduced in order to obtain Bethe Equations for quantum integrable systems in the absence of a Bethe ansatz. The Q-operator was later constructed as the trace of a double-row monodromy matrix over an infinite-dimensional auxiliary space. There are then two alternative routes to the key 'TQ' relations which in turn give the Bethe Equations: short exact sequences and monodromy-matrix factorization. Both routes are well-trodden in the closed case, but far less so in the open case, where the boundary reflection matrices play a key role.

In this talk I will describe the construction and properties of the open Q-operator and the two paths to the TQ relations. I will also present a key factorization property of infinite-dimensional reflection matrices analogous to that of R-matrices.

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Abstracts of Posters

(in alphabetical order)

Free fermionic and parafermionic quantum spin chains

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We will discuss a new family of quantum spin chains with multispin interactions whose spectrum has a free fermionic or parafermionic nature. Despite the free nature of the spectrum, these spin chains in general cannot be solved by the Jordan-Wigner transformation. However, exploiting integrability, it can be shown that the quasi-energies are related to the roots of certain characteristic polynomials given by higher-order recurrence relations. In particular, the so-called Laguerre bound for the largest root of the characteristic polynomial allows a very efficient computation of the mass gap, providing a relevant tool for the study of critical quantum chains with and without quenched disorder. Beyond the spectral level, many interesting aspects of the Hamiltonians remain to be understood, for example, the computation of correlation functions and entanglement entropy. Based on joint work with F. Alcaraz, J.A. Hoyos and J. Sirker.

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Correlations and symmetries of one-dimensional bosonic mixtures

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We investigate the long- and short-range correlations of strongly interacting hard-core bosonic mixtures in one dimension. In particular, we study a balanced two components mixture with equal (SU(2)) or different (broken SU(2)) inter and intra species interactions. Due to theoretical and numerical improvement we pushed our calculations up to 14 particles in different trapping potentials. As an example of our results, we observe that the population of the zeroth momentum state and the symmetry of these systems are considerably affected by the breaking of SU(2) symmetry.

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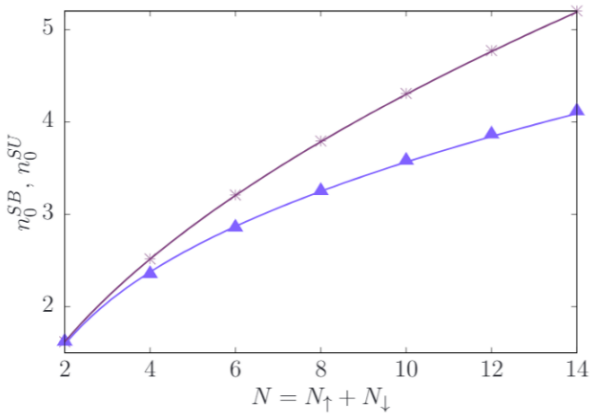

Figure 1: The zero-mode occupation numbers n_0^{SU}(stars) and n_0^{SB} (triangles), for a balanced mixture, as a function of the total number of particles N. The exact results (points) are compared with the approximated function (lines). We have compared our results with a DMRG calculation up to N = 6 (not shown in the figure).

Bosonic continuum theory of one-dimensional lattice anyons

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Anyons with arbitrary exchange phases exist on 1D lattices in ultracold gases. Yet, known continuum theories in 1D do not match. We derive the continuum limit of 1D lattice anyons via interacting bosons. The theory maintains the exchange phase periodicity fully analogous to 2D anyons. This provides a mapping between experiments, lattice anyons, and continuum theories, including Kundu anyons with a natural regularization as a special case [1]. We numerically estimate the Luttinger parameter as a function of the exchange angle to characterize long-range signatures of the theory and predict different velocities for left- and right-moving collective excitations.

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Generalised Hydrodynamics of Unstable Excitations

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Abstract

In this poster I will explore an integrable quantum field theory possessing an unstable excitation in its spectrum. Because of the finite lifetime, the dynamics of the unstable particle can be studied only indirectly, in terms of the constituent (stable) particles. I will show how the generalised hydrodynamic approach can be used to develop a more clear physical picture of the formation of the unstable excitation.

References

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Title : XXX dark states in Central Spin Models

Names : Dimo Panjio Claude Alain

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Abstract. The spin of a single electron trapped in a quantum dot has been a long-standing proposal for a physical implementation of a qubit. The presence of surrounding spins coupled to the qubit of interest, leads to decoherence and loss of the quantum informations that it can store. It therefore becomes necessary to find a way to control that decohenrence. Central Spin Models (CSM), describing a single two-level system coupled to a bath, can be used to model the interaction between the central spin (qubit) and its bath.

In the so-called isotropic CSM, dark states can be obtained by optical pumping. In this work, we are interesting of studying the internal structure of these dark states deriving from the same models. This models are integrable and can be defined for any orientation of the magnetic field, as

$$\hat{H} = g \sum_{k=1}^{N} \Gamma_{0k} \vec{\hat{S}}_0 \cdot \vec{\hat{S}}_k + \vec{B}_0 \cdot \vec{\hat{S}}_0, \tag{1}$$

where $\Gamma_{0k}^{\alpha} = \dfrac{1}{\epsilon_0 - \epsilon_k}$ are the inhomogeneous couplings between the central spin and each surrounding spin, and $\vec{B}_0$ is the applied magnetic field to the system.

The existence of a subspace in which the central spin can avoid entanglement then provides a decoherence free subspace which can have the most importance on the capacity to implement and use spin qubits. Moreover, dark states are also shown to allow complete control on the qubit, since the central spin simply aligns itself with the external magnetic field applied to it so that it can, through adiabatic reorientation of the field, be placed at any point on the Bloch sphere.

Absence of string excitations in the low-T spectrum of the quantum transfer matrix of the XXZ chain

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The eigenvalues of the quantum transfer matrix (QTM) of the XXZ spin-1/2 chain in the Trotter limit are parameterized by solutions of non-linear integral equations (NLIEs). We analyze these equations in the low-temperature limit for the model in the antiferromagnetic massless regime for $0<\Delta<1$ at finite magnetic field $h>0$. To leading order in T the solutions of the NLIEs are determined by the dressed energy, which, in turns, is the solution of a linear Fredholm integral equation of the second kind. A rigorous characterization of the properties of the dressed energy in different regions of the complex plane, in conjuction with a thorough study of the subsidiary conditions that determine the excitation parameters in the solutions of the NLIEs, allows us to show that the excited states of the QTM are all of particle-hole type and that there are no string excitation in the low-T limit, as long as the magnetic field is kept finite.

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The continuum limit of the open staggered-six vertex model with quantum group invariant boundary conditions.

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The finite size spectrum of the critical Z2-staggered spin-1/2 XXZ model with quantum group invariant boundary conditions studied in [1] is presented for a range of the staggering parameter. As in the self-dual case [2] the spectrum of conformal weights includes a continuous component in agreement with its description by the non-compact SU(2,R)/U(1) Euclidean black hole conformal field theory (CFT). Besides the continuous part of the spectrum of this CFT, there are also levels from the discrete part emerging as the anisotropy is varied. The finite size amplitudes of both the continuous and the discrete levels can be parameterized by the corresponding eigenvalues of a quasi-momentum operator which commutes with the Hamiltonian and the transfer matrix of the model.

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Integrability as a new method for exact results on quasinormal modes of black holes

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In this contribution I explain a new connection we found between quantum integrable models and black holes perturbation theory. To begin with, I introduce black holes' quasinormal modes and their role in gravitational waves observations, showing in particular how to connect their mathematically precise definition with the integrability structures derived from the ordinary differential equation associated to the black hole perturbation, in the approach of the ODE/IM (or ODE/IQFT) correspondence. More precisely, I derive the full system of functional and non linear integral equations (Thermodynamic Bethe Ansatz) typical of quantum integrability and prove that the quasinormal modes verify different equivalent exact quantization conditions. As a consequence, it follows a new simple and effective method to numerically compute the quasinormal modes which I will compare with other methods. I will also give a mathematical explanation of the recently found connection between quasinormal modes and N=2 supersymmetric gauge theories, through the further connection we previously found of these to quantum integrable models. Moreover, I will briefly explain how other black holes observables like the greybody factor (or absorption coefficient, which accounts for Hawking radiation) could be tackled and computed through integrability methods. All this I will show for a generalization of extremal Reissner-Nordström black holes, but in the end I will explain how we think it should be possible to generalize it to many other types of black holes, branes, fuzzballs, in either asymptotically flat or asymptotically AdS spacetime and thus provide a new effective tool for the study one hand of gravitational waves and of quantum gravity and on the other hand of supersymmetric gauge theories.

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Integrability breaking in the one dimensional Bose gas: Atomic losses and energy loss

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The one dimensional δ-function interacting Bose gas (the Lieb-Liniger model) is an integrable system, which can model experiments with ultra cold atoms in one dimensional traps. Even though the model is integrable, integrability breaking effects are always present in the real world experiments. In this work we consider the integrability breaking due to atomic loss, which is the most relevant effect in the experiments. We set up a framework for the exact computation of the losses of the canonical charges of the model, and compute an exact result for the energy loss due to the local K-body processes, valid for arbitrary K. Our result takes the form of multiple integrals, which are explicitly factorized in the experimentally relevant cases of $K = 1, 2, 3$. The factorized formulas for the energy loss can be applied very efficiently in numerical computations. Based on: A. Hutsalyuk, B. Pozsgay, *Phys. Rev. E* **103,** arXiv:2012.15640.

The ‘Snail Construction’ for higher rank

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I will present some thoughts about a possible higher rank generalization of the so called 'Snail Construction', which was introduced in 2004 [1] for the rational sl_2 invariant model and can be seen as one of the starting points for the definition of the well known fermionic structure of the XXZ-Model.

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Engineering Higgs dynamics in integrable Bardeen-Cooper-Schrieffer systems

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We generalize the dynamical phase diagram of a BCS condensate to attractive/repulsive interaction quenches (ARIQ) and non-constant density of states (DOS) taking advantage of the integrability of the model. We show that synchronized Higgs dynamical phases can be stabilized on-demand combining singularities in the DOS and different quench protocols. In particular, the ARIQ can stabilize a different high-frequency dynamical phase related to the upper edge of the fermionic band. Other synchronized Higgs modes can be stabilized by exploiting different singularities in the DOS. For a Dirac system, we find a Dirac-Higgs mode associated with the cusp singularity at the Fermi level and we show that synchronized phases become more pervasive across the phase diagram. We employ a Lax analysis providing the exact solution of the many-body problem and discuss the fate of all dynamical phases by including integrability breaking terms (i.e dissipation) in the system [2]. Our results are relevant for ultracold atoms in specific optical lattices.

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Perturbative integrability in 1+1 dimensions

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The S-matrices of many integrable quantum field theories in two dimensions have been conjectured for many years through the so-called S-matrix bootstrap approach. These theories can often be studied through standard Feynman diagram techniques, where integrability manifests itself through surprising simplifications and cancellations between Feynman diagrams. The underlying mechanism of these simplifications is generally ill-understood, both at the tree and loop level. In this poster, I will explain the reason for these simplifications in tree-level processes for the class of affine Toda field theories and I will use these results to derive the pole structure of their loop-level S-matrices.

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Confinement and bound states of bound states in a transverse-field two-leg Ising ladder

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Weakly coupled Ising chains provide a condensed-matter realization of confinement. In these systems, kinks and antikinks bind into mesons due to an attractive interaction potential that increases linearly with the distance between the particles. While single mesons have been directly observed in experiments, the role of the multiparticle continuum and bound states of mesons in the excitation spectrum is far less clear. Using time-dependent density matrix renormalization group methods, we study the dynamical structure factors of one and two-spin operators in a transverse-field two-leg Ising ladder in the ferromagnetic phase. The propagation of time-dependent correlations and the two-spin excitation spectrum reveal the existence of interchain bound states, which are absent in the one-spin dynamical structure factor. We also identify two-meson bound states that appear at higher energies, above the thresholds of several two-meson continua.

Auxiliary functions for su(n)-symmetric models and their continuum limit

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Traditionally the computation of the partition function of integrable quantum chains is achieved by means of the thermodynamic Bethe ansatz (TBA). On the other hand, an alternative formulation which relies on finite sets of nonlinear integral equations has been developed and successfully applied to seminal cases like for example the spin-1/2 Heisenberg chain, the supersymmetric t-J model and quantum chains with su(3) and su(4) invariance. This approach, known as the Quantum Transfer Matrix method, allows for faster numerical computations and calculation of finite temperature correlation lengths. However, the derivation of these alternative equations was done in case by case studies in which by trial and error suitable auxiliary functions were identified. Another shortcoming of the QTM method is its applicability in the case of continuum integrable models. A way to circumvent this issue is to identify the proper lattice model from which the continuum model follows after a suitable scaling limit. This way, it is possible, for example, to determine the thermodynamics of multicomponent Bose gases from anisotropic spin chains. In this work we present a way to derive systematically finite sets of nonlinear integral equations for su(n)-symmetric integrable lattice models and discuss a scaling limit of these equations in the case of su(3)-invariant anisotropic spin chain.

Orbifold CFTs, regularised twist fields, and entanglement entropy

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The calculation of entanglement entropy in CFTs follows the idea of expressing Rényi entropies through the replica trick and taking their appropriate limit [1, 2]. The Rényi entropies are connected to correlators of twist fields, which are related to orbifold CFTs with cyclic permutation symmetry.

In this work, we elaborate on the details of this connection and define the regularised twist fields through the state-operator correspondence. Using these results, we focus on the question of entanglement entropy in non-unitary CFTs and aim to settle the contradiction between [3] and [4] in the literature.

Furthermore, we set the stage to efficiently calculate entanglement entropy and twist field matrix elements directly in QFTs, which are perturbation of CFTs.

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Supersymmetric many-body systems from partial symmetries: integrability, localization and scrambling

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Partial symmetries are described by group structures known as symmetric inverse semigroups. We use the algebras arising from these structures to realize supersymmetry in (0+1)-dimensions and to build many-body quantum systems on a chain. This construction consists in associating appropriate supercharges to chain sites, in analogy to what is done in spin chains. For simple enough choices of supercharges, we show that the resulting states have a finite non-zero Witten index, which is invariant under perturbations, therefore defining supersymmetric phases protected by the index. The Hamiltonians we obtain are integrable and display a spectrum containing both product and entangled states. By introducing disorder and studying the out-of-time-ordered correlators (OTOC), we find that these systems are in the many-body localized phase and do not thermalize. Finally, we reformulate a theorem relating the growth of the second Renyi entropy to the OTOC on a thermal state in terms of partial symmetries.

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Non-linear transport of Bethe bound states

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Non-linear conductance is defined by considering higher than linear-order corrections to the current [1]. Consideration of the zero-frequency limit of a non-linear conductance naturally leads to a non-linear Drude weight, analogous to the usual Drude weight. By applying this picture to non-linear ballistic spin transport in the XXZ spin chain analytical results for the non-linear Drude weight are derived at infinite temperatures. Our results [2] depend not only on anisotropy but also on the string length of the quasiparticles transporting the spin current. This provides further insights into transport by quasiparticles and raises questions about Luttinger liquid universality.

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Typical Neural Network States

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The Variational Monte Carlo method has been used for decades in quantum many-body physics. Some years ago, Artificial Neural Networks have been considered to speed up this multidimensional optimization process. Although these are proven to be universal approximator, they have struggled to describe the correct sign structure of ground state wave functions efficiently. Therefore, they are used in addition to physically motivated approaches like the Pfaffian wave function. Accurate results for the ground state of various models have been obtained in this way. In our work, we define typical states in this ansatz to compute expectation values of local operators at finite temperature.

Functional methods for correlation functions in integrable face models

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Using the properties of local Boltzmann weights of integrable interaction-round-a-face (IRF or face) models we express local operators in terms of generalised transfer matrices. This allows for a derivation of discrete functional equations for the reduced density matrices of inhomogeneous generalisations of these models. We apply these equations to various IRF models of solid-on-solid type and provide explicit solutions for correlation functions on up to three neighbouring sites.

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2D Ising Field Theory in a Magnetic Field: The Yang-Lee Singularity

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We study Ising Field Theory (the scaling limit of Ising model near the Curie critical point) in pure imaginary external magnetic field. We put particular emphasis on the detailed structure of the Yang-Lee edge singularity. While the leading singular behavior is controlled by the Yang-Lee fixed point (= minimal CFT (2,5)), the fine structure of the subleading singular terms is determined by the effective action which involves a tower of irrelevant operators. We use numerical data obtained through the "Truncated Free Fermion Space Approach" to estimate the couplings associated with two least irrelevant operators. One is the operator TTbar, and we use the universal properties of the TTbar deformation to fix the contributions of higher orders in the corresponding coupling parameter α. Another irrelevant operator we deal with is the level 4 descendant of the relevant primary φ in Yang-Lee CFT. The significance of this operator is that it is the lowest dimension operator which breaks integrability of the effective theory. We also establish analytic properties of the particle mass M (=inverse correlation length) as the function of complex magnetic field.

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