Nonperturbative Methods in Quantum Field Theory

Report of Contributions

Contribution ID: **1** Type: **not specified**

Attacking the Sinh-Gordon model with relativistic continuous matrix product states*

Monday, May 23, 2022 10:00 AM (1 hour)

The Sinh-Gordon model is a 1+1 dimensional quantum field theory with a potential cosh(b phi) that is quite peculiar. It is at the same time exactly solvable (for many observables) and not well understood. I will present the results of a variational exploration of its strong coupling regime with a recent generalization of continuous matrix product states. The advantage of this method is that it does not require introducing a cutoff, UV or IR, is fully non-perturbative, typically converges fast for Hamiltonians with polynomial interactions, and gives rigorous energy upper bounds. Its application to the Sinh-Gordon model is only partly successful: observables can be computed accurately up to fairly large values of the coupling, but the ultra strong coupling regime remains difficult to access without extrapolations. As a result, the behavior near the self-dual point is not yet fully settled. I will show the basics of relativistic continuous matrix product states, explain how they typically work for phiˆ4 like theories or even the easier Sine-Gordon model and finally discuss my attempts at taming Sinh-Gordon.

Presenter: TILLOY, Antoine (Mines ParisTech)

Contribution ID: **2** Type: **not specified**

Hamiltonian Truncation and Effective Field Theory*

Thursday, May 26, 2022 10:00 AM (1 hour)

Hamiltonian truncation is a non-perturbative numerical method for calculating observables of a quantum field theory by truncating the Hilbert space to states with energy below a maximum energy cutoff. In this talk I will present an effective field theory approach to Hamiltonian truncation, which provides a systematic way of improving the calculations without increasing the energy cutoff. I will demonstrate this with numerical results for the two dimensional phiˆ4 theory, and talk about future applications of this method to more complicated theories.

Presenter: FARNSWORTH, Kara (Case Western Reserve University)

Contribution ID: **3** Type: **not specified**

Torus Spectroscopy: A novel numerical tool to diagnose the nature of quantum phase transitions and quantum spin liquids

Tuesday, May 24, 2022 2:00 PM (1 hour)

In this talk I will present the torus spectroscopy, i.e. the analysis of the finite volume spectrum of the Hamiltonian on a spatial torus in 2+1D as a practical numerical tool to determine the universality class of quantum phase transitions. We show an application with an emergent 3D O(2) phase transition and that we are able to detect the presence of dangerously irrelevant couplings. In a second application we report on ongoing work to shed light on the possible presence of a QED_3 like phase (Dirac spin liquid) in a frustrated spin model.

Presenter: LAÜCHLI, Andreas (PSI / EPFL)

Contribution ID: **4** Type: **not specified**

Hamiltonian truncation in AdS*

Tuesday, May 24, 2022 10:00 AM (1 hour)

Anti-de Sitter spacetime is interesting for many reasons: of course it furnishes a canvas for the study of quantum gravity, but it also appears to be a fruitful setting for Hamiltonian truncation. After all, QFTs in AdS have a notion of conserved energy, their Hilbert spaces are well-understood, and even a hard energy cutoff preserves many spacetime symmetries. In this talk I will discuss this framework in detail and present some results on both scalar fields and 2d minimal models. In particular, I will discuss the issue of divergent counterterms that arise from the curvature of AdS, and present a prescription to extract the correct continuum limit.

Based on work with M. Meineri, J. Penedones and K. Salehi Vaziri, arXiv:2104.10689. An introductory example in Python can be found at the attached link.

Presenter: HOGERVORST, Matthijs (EPFL)

Contribution ID: **5** Type: **not specified**

Hydrodynamization, asymptotics and the early to late time interpolation in relativistic hydrodynamics*

Wednesday, May 25, 2022 10:00 AM (1 hour)

Dissipative relativistic hydrodynamics is expected to describe the late times, thermalised behaviour of strongly coupled fluids such as a strongly coupled super Yang-Mills plasma. These systems are then accurately described by a hydrodynamic series expansion in small gradients. Surprisingly, this hydrodynamic expansion is accurate even when the systems are still quite anisotropic: the non-hydrodynamic modes governing the non-equilibrium behaviour at very early-times become exponentially close to the hydrodynamic solution in an early process called hydrodynamization.

This early success is intimately related with the fact that the hydrodynamic expansion is asymptotic. The theory of transseries and resurgence explicitly shows how the non-hydrodynamic modes are in fact encoded in this late-time expansion. In this talk we will focus on a MIS-type model and use exponentially accurate summations of the the late-time resurgent transseries to recover the behaviour of the fluid before hydrodynamisation, and effectively match it to any given initial non-equilibrium condition. We will further show that such summations can provide analytic predictions beyond the late time regime.

Presenter: ANICETO, Inês (University of Southampton)

Contribution ID: **6** Type: **not specified**

Renormalons from Integrability: A resurgent insight into QFT's conundrum*

Monday, May 23, 2022 2:00 PM (1 hour)

Renormalons are non-perturbative effects which are manifested in perturbative series. While they figure in asymptotically free field theories including both QCD and some integrable models, they are in general poorly understood. In this talk I will present results on how to analytically find these non-pertubative effects in the free energy of integrable models. These effects turn out to defy standard expectations which went back to Parisi and 't Hooft. I will also present a short introduction to the framework of resurgence and to how it is a key tool in the analysis of non-perturbative effects in QFT.

Presenter: REIS, Tomas (University of Geneva)

Contribution ID: **7** Type: **not specified**

Thermalization and Chaos in 1+1d QFTs

Thursday, May 26, 2022 3:00 PM (1 hour)

Nonintegrable QFTs are expected to thermalize and exhibit emergence of hydrodynamics and chaos. In weakly coupled QFTs, kinetic theory captures local thermalization; such a versatile tool is absent away from the perturbative regime. I will present analytical and numerical results using nonperturbative methods to study thermalization at strong coupling. I will show how requiring causality in the thermal state leads to strong analytic constraints on the thermodynamics and out of equilibrium properties of any relativistic 1+1d QFT. I will then discuss Lightcone Conformal Truncation (LCT) as a powerful numerical tool to study thermalization of QFTs. Applied to ϕ^4 theory in 1+1d, LCT reveals eigenstate thermalization and onset of random matrix universality at any nonzero coupling. Finally, I will discuss prospects for observing the emergence of hydrodynamics in QFTs using Hamiltonian truncation.

Presenter: DELACRÉTAZ, Luca (University of Chicago)

Contribution ID: **8** Type: **not specified**

Post-Quantum Quench Growth of Renyi Entropies in Perturbed Luttinger Liquids

Friday, May 27, 2022 10:00 AM (1 hour)

The growth of Renyi entropies after the injection of energy into a correlated system provides a window upon the dynamics of its entanglement properties. We provide here a scheme by which this growth can be determined in Luttinger liquids systems with arbitrary interactions, even those introducing gaps into the liquid. This scheme introduces the notion of a generalized mixed state Renyi entropy. We show that these generalized Renyi entropies can be computed and provide analytic expressions thereof. Using these generalized Renyi entropies, we provide analytic expressions for the short time growth of the second and third Renyi entropy after a quantum quench of the coupling strength between two Luttinger liquids, relevant for the study of the dynamics of cold atomic systems. For longer times, we use truncated spectrum methods to evaluate the post-quench Renyi entropy growth.

Presenter: KONIK, Robert (Brookhaven National Laboratory)

Contribution ID: **9** Type: **not specified**

Multi-particle observables from a finite Euclidean spacetime*

Friday, May 27, 2022 2:00 PM (1 hour)

Numerical calculations using lattice-regularized QFTs are a powerful tool to understand nonperturbative systems when analytic methods are unavailable. However, the utility of numerical results can be affected by two issues: (i) calculations are necessarily performed in a finite-volume spacetime and (ii) Euclidean- (rather than Minkowski-) signature correlation functions are evaluated. Both aspects play an especially important role for multi-particle observables including scattering and decay amplitudes and inclusive rates. In this talk, I will discuss progress in extracting such observables from numerical lattice field theory, based on two strategies. One is to use the finite-volume as a tool, rather than an unwanted artefact, and to apply generic field theoretic relations between finite-volume quantities and infinite-volume amplitudes. The second is to carefully regulate the inverse Laplace transform, in order to estimate Minkowski observables directly from numerical Euclidean correlators.

Presenter: HANSEN, Maxwell (University of Edinburgh)

Contribution ID: **10** Type: **not specified**

Hamiltonian Formulations of Lattice Gauge Theories, with an eye towards Quantum Simulation*

Monday, May 30, 2022 10:00 AM (1 hour)

There are many fundamental questions in particle and nuclear physics that cannot be addressed via classical computing techniques. These include the equation of state for finite density nuclear matter, real-time dynamics of quantum field theories from first-principles and non-perturbative aspects of chiral gauge theories. In recent years quantum computing hardware has seen dramatic advancements, which have brought with them the possibility to apply quantum computing to these and other open problems in high energy physics. In this talk, after a brief introduction to quantum computing, I will discuss my recent work towards the quantum simulation of lower-dimensional lattice gauge theories, focusing on the interplay between Gauss'law, gauge redundancies and (un)favourable resource scaling.

Presenter: GRABOWSKA, Dorota (CERN)

Contribution ID: **11** Type: **not specified**

Non-equilibrium dynamics in 1+1 dimensional interacting scalar quantum field theory*

Monday, May 30, 2022 2:00 PM (1 hour)

We develop a truncated Hamiltonian method to investigate the dynamics of the 1 +1-dimensional ϕˆ4 theory following quantum quenches. The results are compared to two different semiclassical approaches, the self-consistent Gaussian approximation and the truncated Wigner approximation, and used to determine the range of validity of these widely used approaches. We then use this method to investigate the decay by realising it as a quantum quench, and show that in the thin wall limit the theoretical prediction is well reproduced for several values of the coupling in a range of the value of the latent heat, apart from a normalisation factor which only depends on the strength of self-interactions.

Presenter: TAKÁCS, Gábor (Budapest University of Technology and Economics)

Contribution ID: **12** Type: **not specified**

A nonperturbative S-matrix from truncation*

Tuesday, May 31, 2022 10:00 AM (1 hour)

Recent advances in Hamiltonian truncation have demonstrated it to be a useful tool for obtaining nonperturbative information about quantum field theories, even in the strongly-coupled regime. One particularly exciting feature of this technique is that it can be formulated in Minkowski rather than Euclidean space, making it easier to calculate real-time quantities. Truncation is particularly suited to obtaining spectral information (particle masses, operator spectral densities, etc.), but these are not the only observables of interest, especially when trying to make contact with high-energy experiments. I will explain how to use approximate knowledge of a QFT's energy eigenstates to compute amplitudes for particle scattering, which can in turn be used to compute cross sections and decay rates. I will demonstrate this technique with an example of lightcone conformal truncation for the O(N) model in 2+1d at strong coupling, but it is worth emphasizing that the method can work with any numerical technique that outputs information about approximate Hamiltonian eigenstates. Along with the amplitude in the physical region, I will show that it is possible to analytically continue to the entire complex Mandelstam plane, and in fact that numerical convergence can be even better away from the physical region.

Presenter: THOMPSON, Jedidiah (Stanford University)

Contribution ID: **13** Type: **not specified**

Hamiltonian Truncation with Larger Dimensions

Tuesday, May 31, 2022 2:00 PM (1 hour)

Hamiltonian Truncation (HT) is a numerical approach for calculating observables in a Quantum Field Theory non-perturbatively. This approach can be applied to theories constructed by deforming a conformal field theory with a relevant operator of scaling dimension Δ. In this talk I will review the HT techniques and emphasise few key open problems. I will also discuss the recent efforts to extend these ideas to higher dimensions ($d > 2$) and for UV divergent relevant operators ($d/2 <= \Delta < d$).

Presenter: ELIAS MIRÓ, Joan (ICTP)

Contribution ID: **14** Type: **not specified**

Bootstrapping the a-anomaly in 4d QFTs*

Friday, June 3, 2022 10:00 AM (1 hour)

I will discuss 4d scattering amplitudes in UV complete quantum field theories (QFTs). I will show how the a-anomaly describing its UV fixed point is related to parameters describing the scattering amplitude via unitarity. I will then present various numerical non-perturbative bounds.

Presenter: KARATEEV, Denis (University of Geneva)

Contribution ID: **15** Type: **not specified**

Confinement versus 1-form symmetries at large N*

Thursday, June 2, 2022 10:00 AM (1 hour)

There are two known ways to tie quark confinement to symmetries: one way (the older one) in terms of "center symmetry", and the other one (the newer one) is in terms of a "1-form symmetry". By now it is widely accepted that the new idea of 1-form symmetry, which is based on the existence of co-dimension-2 topological operators, is a generalization of the old idea of center symmetry. I'll explain how large N QCD poses a sharp challenge to this notion. It enjoys selection rules that can be explained by center symmetry, but not by 1-form symmetry. I'll explain how these selection rules can be deduced from the properties of certain unconventional topological operators.

Presenter: CHERMAN, Aleksey (University of Minnesota)

Contribution ID: **16** Type: **not specified**

Aspects of Numerical Bootstrap*

Thursday, June 2, 2022 2:00 PM (1 hour)

My talk consists of two parts. In the first part, I will discuss a conformal bootstrap study of three dimensional Quantum Electrodynamics coupled to four flavors of electrons. The model is a classic example of a strongly coupled gauged quantum field theory and is believed to have a conformal low-energy phase, while its critical parameters lacks a conclusive answer. We find that the scaling dimensions of the lowest-charge monopole operator and the adjoint fermion bilinear operator can be bounded in a closed region after implementing spectrum assumptions inspired by the large-N_f perturbative predictions. Bootstrap constraints on the conserved current central charges are comfortably consistent with large-N_f perturbation theory, suggesting that at least part of the large-N_f perturbative predictions form a consistent solution to crossing. I will discuss the validity of the assumptions we used and compare with lattice simulations and previous bootstrap study results. In the second part, I will introduce a new method utilizing a crossing equation in Quantum Mechanics to bound spectrum and matrix elements of any theory with a specific Hamiltonian. The new method is inspired by the method of bootstrapping matrix model using the matrix positivity. I will show that this method provides precision solution to a toy example —Anharmonic Oscillator, and suggest a generalization to study infinite-volume spin chains.

Presenter: XIN, Yuan (Yale University)

Contribution ID: **17** Type: **not specified**

Conformal Colliders Meet the LHC*

Wednesday, June 1, 2022 10:00 AM (1 hour)

Jets of hadrons produced at high-energy colliders provide experimental access to the dynamics of asymptotically free quarks and gluons and their confinement into hadrons. Motivated by recent developments in conformal field theory, we show that questions of interest in collider physics can be reformulated as the study of correlation functions of a specific class of light-ray operators and their associated operator product expansion (OPE). We show that multi-point correlation functions of these operators can be measured in real LHC data, allowing us to experimentally verify both the scaling properties associated with the OPE, and the celestial block decomposition of higher point correlators.

Presenter: MOULT, Ian (Yale University)

Contribution ID: **18** Type: **not specified**

Bootstrapping photon scattering in 3+1d*

Friday, June 3, 2022 2:00 PM (1 hour)

The S-matrix bootstrap is a program where one uses the general principles of analyticity, crossing symmetry and unitarity of scattering amplitudes to study the allowed space of quantum field theories. In this talk I will consider the two photon to two photon scattering amplitude and explain how we can use numerical S-matrix bootstrap methods to derive non-perturbative bounds on Wilson coefficients in the low energy effective field theory expansion of photons.

Presenter: HEBBAR, Aditya (École Polytechnique)

Contribution ID: **19** Type: **not specified**

Structured Discussion

Tuesday, May 24, 2022 4:00 PM (1h 30m)

Contribution ID: **20** Type: **not specified**

Structured Discussion

Thursday, May 26, 2022 4:30 PM (1h 30m)

Contribution ID: **21** Type: **not specified**

Structured Discussion

Tuesday, May 31, 2022 4:00 PM (1h 30m)

Contribution ID: **22** Type: **not specified**

Structured Discussion

Thursday, June 2, 2022 4:00 PM (1h 30m)

Contribution ID: **23** Type: **not specified**

Tensor Networks: entanglement and the simulation of quantum many-body problems

Wednesday, June 1, 2022 2:00 PM (1 hour)

Theory Colloquium

The term Tensor Network States (TNS) designates a number of ansatzes that can efficiently represent certain states of quantum many-body systems. In particular, ground states and thermal equilibrium of local Hamiltonians, and, to some extent, real time evolution can be numerically studied with TNS methods. Quantum information theory provides tools to understand why they are good ansatzes for physically relevant states, and some of the limitations connected to the simulation algorithms.

Originally introduced in the context of condensed matter physics, these methods have become a state-of-the-art technique for strongly correlated one-dimensional systems. Their applicability extends nevertheless to other fields. As an example, in the last few years it has been shown that TNS are also suitable to study lattice gauge theories and other quantum field problems. This talk gives an overview of the possibilities and limitations of these methods, and some of their recent applications to this kind of problems.

Presenter: BAÑULS, Mari Carmen (Max Planck Institute for Quantum Optics)

Contribution ID: **24** Type: **not specified**

No Talk Scheduled (CERN Theory Colloquium)

Wednesday, May 25, 2022 2:00 PM (1 hour)

Contribution ID: **25** Type: **not specified**

Hamiltonian truncation for real time dynamics in (gauge) QFT*

Wednesday, May 25, 2022 4:00 PM (1 hour)

Hamiltonian truncation methods represent a powerful toolbox for a set of problems that are otherwise very challenging in strongly coupled quantum field theory: nonequilibrium physics and real time evolution. In many such cases analytical approaches are limited as well as numerical tools like lattice gauge theory and tensor networks. I will talk about recent developments in this field with emphasis to entanglement properties of QFT, connection to ultra cold atomic simulators and exploring new fundamental phenomena.

Presenter: KUKULJAN, Ivan (Max Planck Institute for Quantum Optics)

Contribution ID: **26** Type: **not specified**

Adiabatic continuity, TQFT couplings, and calculable confinement

Wednesday, June 1, 2022 4:00 PM (1 hour)

I will describe the idea of adiabatic continuity which can be used to continuously connect strongly coupled gauge theories on Rˆ4 to compactified gauge theories on two set-ups: Rˆ3 x Sˆ1 and Rˆ2 x Tˆ2. Recall that in standard (thermal) compactifications, there are generically phase transitions. But in the last 15 years, we learned how to go around them and move to weak coupling regimes without phase transitions by employing non-thermal boundary conditions, double-trace operators or more recently ‘t Hooft flux backgrounds. In the weak coupling regime, properties such as confinement, chiral symmetry breaking, and multi-branch structure as a function of theta angle are semi-classically calculable. As opposed to common beliefs emanating from the 70s, which emphasize that these are necessarily strong coupling phenomena, all of them can be realized in weak coupling regimes. I will briefly mention the roles of fractional instantons, resurgence, Lefschetz thimbles, and TQFT couplings, and state some open problems. The presentation will be at the colloquium level.

Presenter: ÜNSAL, Mithat (North Carolina State University)