Turin Lattice Meeting 2023

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Dipartimento di Fisica

Book of Abstracts

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Relaxation in Integrable Field Theories

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Out of equilibrium dynamics of integrable systems have been intensively studied in the past 20 years. However, a full characterisation of time evolution of an integrable field theory after a quantum quench is still missing. We investigate processes occurring during relaxation towards a steady state and describe them in terms of analytical properties of matrix elements of operators in the post-quench theory. All these results are fully general for integrable models and are checked against the predictions obtained from Ising field theory, transverse-field Ising lattice model, Sinh-Gordon and Sine-Gordon field theory.

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Mass of quantum topological excitations and order parameter finite size dependence

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We consider the spontaneously broken regime of the $O(n)$ vector model in $d = n + 1$ space-time dimensions, with boundary conditions enforcing the presence of a topological defect line. Comparing theory and finite size dependence of one-point functions observed in recent numerical simulations [1,2] we argue that the mass of the underlying topological quantum particle becomes infinite for $d \geq 4$.

[1] G. Delfino, W. Selke and A. Squarcini, Phys. Rev. Lett. 122 (2019) 050602.
[2] M. Panero and A. Smecca, JHEP 03 (2021) 231.

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The quest for the lost mode: Overcoming Mode-Collapse in Flow-Based Sampling for Lattice Field Theories

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Normalizing flows allow for independent sampling. For this reason, it is hoped that they can avoid the tunneling problem of local-update MCMC algorithms for multi-modal distributions. In this work, we first point out that the tunneling problem is also present for normalizing flows but is shifted from the sampling to the algorithm's training phase. Specifically, normalizing flows often suffer from mode-collapse for which the training process assigns vanishingly low probability mass to relevant modes of the physical distribution. This may result in a significant bias when the flow is used as a sampler in a Markov-Chain or with Importance Sampling. We propose a metric to quantify the degree of mode-collapse and derive a bound on the resulting bias. Furthermore, we propose various mitigation strategies in particular in the context of estimating thermodynamic observables, such as the free energy

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Entanglement entropy in the gauge Ising model: a Monte Carlo study

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The study of entanglement in quantum field theories provides insight into universal properties which are typically challenging to extract by means of more local observables. In the context of strongly coupled gauge theories, entanglement is expected to play a role in understanding many defining phenomena, among which confinement. However, calculations of entanglement-related quantities in gauge theories pose significant challenges: typical numerical algorithms struggle to compute such highly non-local quantities, and the definition of entanglement measures itself is ambiguous in gauge theories. In this talk I will discuss our recent efforts to overcome these challenges. In the first part of the talk I will present a novel algorithm, which combines the replica trick and Jarzynski's equality, for high precison calculations of Rényi entropies. In the second part I will show our preliminar results for the study of entanglement in the three-dimensional gauge Ising model, which can be mapped by means of a duality transformation to the spin Ising model, for which entanglement is well defined.

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Symmetry equivariant neural networks

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In this talk, I will present the advantages of using neural networks that respect symmetries over their non-symmetric counterparts in lattice field theory applications. The concept of equivariance will be explained, together with the reason why it is a sufficient condition for the network to respect the desired symmetry. The benefits of equivariant networks will first be exemplified in the context of translational symmetry on a complex scalar field toy model [1]. Then, the discussion will be extended to gauge theories by introducing Lattice Gauge Equivariant Convolutional Neural Networks (L-CNNs) [2]. After dealing with regression tasks on physical observables such as Wilson loops, I will present the developments in the application of L-CNNs to the generation of gauge field configurations [3].

[1] S.~Bulusu, M.~Favoni, A.~Ipp, D.~I.~M\"uller, D.~Schuh, Phys.~Rev.~D 104, 074504 (2021), arXiv:2103.14686
[2] M. Favoni, A. Ipp, D. I. Müller, D. Schuh, Phys.Rev.Lett. 128 (2022), 032003, arXiv:2012.12901
[3] M. Favoni, A. Ipp, D. I. Müller, EPJ Web of Conferences 274, 09001 (2022), arXiv:2212.00832

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Flow-based sampling for Effective String Theory

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Effective String Theory (EST) is a powerful non-perturbative method used to study confinement in pure gauge theories through the modeling of the interquark potential in terms of vibrating strings. Due to the criticality of EST, an efficient numerical method to simulate such theories is still lacking. However, in the last years a novel class of deep generative algorithms called Normalizing Flows (NF) has been proposed as a sampler for uncorrelated configurations in order to fight standard monte carlo method problems such has critical slowing down. In this talk, I will introduce NFs and I will show a proof of concept of the application to EST. Then, I will outline Stochastic Normalizing Flows (SNFs), a combination of NFs and non-equilibrium MCMC calculations based on Jarzynksi's equality able to obtain high-precision EST simulations.

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θ-dependence of the deconfinement temperature in SU(N) gauge theories

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SU(N) theories present a deconfinement phase transition.
It is well known that the topological properties of the theory, in 3+1 dimensions, are very different in the two phases.
In order to better understand the relation between the topological features of the theory and the deconfinement transition we studied the dependence of the critical temperature T_c on the θ parameter coupled to the topological charge in the action.
The curvature, R, of the critical line, in the T-θ plane, has been already determined for $N = 3$.
In this case, a Clausius-Clapeiron-like equation, relating R to the latent heat, holds with great precision.
We computed the value of R for $N = 4, 6$, in order to verify the relation with the latent heat and the large N scaling that such relation implies.

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Hadronic vacuum polarization from lattice QCD(+QED) with C* boundary conditions

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Achieving subpercent precision in calculating the hadronic vacuum polarization contribution to the muon $g-2$ is essential to correctly interpret new experimental results. At this level of precision, electromagnetic effects from charged quarks cannot be neglected. Lattice QCD+QED simulations present unique challenges, primarily due to the long-range nature of electromagnetic interactions. Our collaboration tackles these challenges by implementing lattice QCD+QED simulations with C* boundary conditions. In this talk, I will outline our specific approach, highlight the benefits it offers, and present our latest progress.

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Gauge theories with adjoint matter: recent results from the lattice

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In the realm of searches beyond the Standard Model (SM), Yang-Mills theories coupled with adjoint fermions constitute an intriguing possibility. Beyond their relevance in the context of SM extension, studying theories with a different number of dynamical flavors N_f allows access to many distinct physical scenarios, including supersymmetry and conformality. This talk aims to provide a review of (some) recent non-perturbative lattice results for various theories ($N_f = 0, \frac{1}{2}, 1, 2$), exploring their dependence on the number of colors N_c (ranging from 2 to infinity). We will offer an essential overview of commonly used methodologies to address the various computational challenges associated with using adjoint fermions on the lattice, with particular focus on the large-N_c limit. We will then present the main results, highlighting open questions, and suggesting possible directions for future exploration.

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On temporal entropies

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I will review the concept of temporal entropies and their relation to CFTs and the computational cost of performing the simulation of out-of-equilibrium simulations.

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Thermalisation and Quantum many body scars in Lattice Gauge Theories

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In this talk, I will overview recent advances in the study of the Eigenstate Thermalisation Hypothesis (ETH) in the contest of quantum simulation of Lattice gauge theories. Motivated by recent experiment in col atoms quantum simulators, I will present the concept of quantum many body scars and elucidate the structure and properties of a class of anomalous high-energy states of matter-free U(1) quantum link gauge theory Hamiltonians.

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The quenched glueball spectrum from smeared spectral densities

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Standard lattice calculations of the glueball spectrum rely on effective mass plots and asymptotic exponential fits of two-point correlators, and involve various numerical challenges.
In this work, we propose an alternative procedure to extract glueball masses, based on the computation of the smeared spectral densities that encode information about the towers of states with given quantum numbers.
While the exact calculation of spectral densities from lattice correlators is an ill-posed inverse problem, we use a recently developed numerical method, based on the Backus-Gilbert regularisation, that allows one to evaluate a smeared version of the spectral densities, without any a priori assumptions, and with controlled uncertainties.
After introducing the formalism to reconstruct the smeared spectral densities and highlighting its main strengths, we will present the novel results that we obtained for the masses of the lightest states in the glueball spectrum of the $SU(3)$ lattice gauge theory at finite values of the lattice spacing and volume. Finally, we will discuss the future steps towards a systematic investigation of the glueball spectrum using spectral-reconstruction methods.

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Recent results on QCD thermodynamics from lattice simulations

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First principle investigations are of fundamental interest for the study of the QCD phase diagram, both in their own right, and in light of experimental measurements from heavy-ion collision experiments, as well as from future observations from gravitational waves. Though not much is known (but much is conjectured) about the phase structure of QCD, a lot of progress has been made in the exploration of QCD thermodynamics. Direct simulations at finite baryon density are very difficult, owing to the complex action problem, yet a number of different approaches allow to access finite-density thermodynamics. I will discuss our knowledge of the QCD phase diagram and present recent lattice results on a number of thermodynamic quantities.

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Theoretical aspects on the prediction of spectral densities from Lattice QCD

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Hadronic spectral densities play a pivotal role in particle physics, a primer example being the R-ratio defined from electron-positron scattering into hadrons. To predict them from first principles using Lattice QCD, we face a numerically ill-posed inverse problem, due to the Euclidean signature adopted in practical simulations. Here we review the status of recent numerical approaches to the inverse Laplace transform and present a new analysis of the typical systematic errors associated to a Lattice prediction (e.g. finite-volume effects).