ICTP SAIFR International Centre for Theoretical Physics
South American Institute for Fundamental Research

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UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"

Workshop on S-matrix Bootstrap

September 9-13, 2019

ICTP-SAIFR, São Paulo, Brazil

Talks

From S-Matrix to data

Alessandro Pilloni

(Jefferson Lab and ECT*)

I will discuss how the S-Matrix techniques can be used to attack long-standing problems in hadron phenomenology. In particular I will show how S-Matrix inspired Formalisms are able to solve the hybrid meson puzzle.

On The S-Matrix of Ising Field Theory in Two Dimensions

Barak Gabai

(Harvard University)

Ising Field Theory in 2D is arguably the simplest family of massive non-integrable quantum field theories. I'll present our investigation of it's analytic structure with a starting point similar to that of collider physics: we employed Hamiltonian truncation method (TFFSA) to extract the scattering phase of the lightest particles in the elastic regime, and combined it with S-matrix bootstrap methods based on unitarity and analyticity assumptions to determine the analytic continuation of the 2 -> 2 S-matrix element to the complex s-plane. Focusing primarily on the "high temperature" regime in which the IFT interpolates between that of a weakly coupled massive fermion and the E8 affine Toda theory, we numerically determined 3-particle amplitudes, followed the evolution of poles and certain resonances of the S-matrix, and excluded the possibility of unknown wide resonances up to reasonably high energies.

Andrea Guerrieri

(ICTP-SAIFR/IFT-UNESP)

Unitarity constraints in massive QFTs

Denis Karateev

(EPFL)

We construct a certain matrix which consists of partial amplitudes, form factors and the spectral density. We show that unitarity requires it to be semi-positive definite. We discuss consequences of this constraint and applications to the bootstrap.

Asymptotic states and Hilbert spaces in four dimensional scattering with massless particles

Dominik Neuenfeld

(University of British Columbia)

The standard formulation of scattering theory assumes that at very early and late times interactions can be ignored. If, in four dimensions, massless particles are present, the assumption is incorrect and ignoring the resulting subtleties leads to IR divergences which prevent a definition of the S-matrix. I will discuss, using the example of QED, how Hilbert spaces can be constructed on which a unitary S-matrix can be defined in the presence of massless particles. The Hilbert spaces are in correspondence with certain representations of the photon canonical commutation relations and form superselection sectors.

Flat space physics from AdS/CFT

Eliot Hijano

(University of British Columbia, Vancouver)

I will introduce a formula relating S-matrix amplitudes in flat space and conformal correlators in AdS/CFT. I will explain how to use the formula to compute S-matrices in simple examples, and I will discuss how to recast flat space physics concepts in the language of conformal field theory and holography.

Bounds and Super-Soft Amplitudes

Francesco Riva

(EPFL)

Using dispersion relations I will discuss the (classical and quantum) running of 2>2 amplitudes. I will show that amplitudes which decrease too fast towards the IR (faster than a U(1) goldstone or a Galileon) can never dominate the scattering and are hence phenomenologically irrelevant. I will also discuss positivty bounds beyond the tree-level approximation.

Non-ordinary nature of mesons from dispersion theory, large Nc and old bootstrap techniques

José R Pelaez

(Universidad Complutense de Madrid)

The existence and nature of light scalar resonances have been controversial for about half a century.Using dispersion theory and unitarity constraints on scattering it is possible to describe their resonance poles avoiding large model dependencies. It is possible then to relate the subtraction constants to the QCD number of colors to study the nature of these states. Also from dispersion theory and using the previous poles as input, it is possible to generate the Regge trajectory of these resonances (the old bootstrap ideas). It is found that both the Nc behavior and the Regge trajectory of light scalars do NOT follow the expectations for ordinary quark-antiquark states.

S-matrix bootstrap for the 2d O(N) model and dual convex problem

Luis Martin Kruczenski

(Purdue University)

We consider the space of two particle S-matrices describing the scattering of massive particles in two space-time dimensions with internal O(N) symmetry. We argue that the space is convex and find at its boundary distinguished points, such as vertices, that correspond to integrable models. The boundary points can be found by convex maximization. We find the dual minimization problem and show that it gives important analytical and numerical insights into the problem. For example it implies that the maximization problem generically leads to S-matrices that saturate unitarity.

Truncated Spectrum Approach to the sinh-Gordon model and its generalizations

Marton Lajer

(Wigner RCP and ELTE)

We consider a class of models obtained by perturbing the non-compact Gaussian CFT with two vertex operators. These include the integrable sinh-Gordon and Bullough-Dodd models as special cases. The above theories are special as they can be considered equivalently as perturbations of Liouville CFTs, and the consistency between these viewpoints leads to interesting properties. We apply the Truncated Spectrum Approach (TSA) to these models. Despite apparent problems regarding the perturbative RG improvement, we argue that TSA is applicable as long as both related Liouville models are below the self-dual point. We check that the small-volume asymptotics of the spectrum is described by a quantization condition involving the Liouville reflection amplitude even in the non-integrable case. It has long been known that the reflection amplitude also appears in a set of functional equations describing the VEVs of vertex operators. The analytic minimal solution thereof is numerically confirmed to provide the exact expectation values in both integrable subsets. We find that the similar minimal solution with respect to the general, non-integrable models still provides a good approximation over a wide range of parameter space (even though it is not exact). In the case of VEVs, TSA always breaks down just before reaching the first zeroes of the minimal solution, which coincide with the Seiberg bounds of the related Liouville theories.

What is the S-matrix?

Matthew Schwartz

(Harvard University)

Any attempt to bootstrap an S-matrix, or compute S-matrix elements, depends critically on what the S-matrix is. The S-matrix is commonly treated as some god-given fundamental object of high energy physics. In fact, the S-matrix is just an operator. Moreover, when there are massless particles in the theory, the operator does not even exist: it has infrared divergences (so it is infinite) and Sudakov suppression (so it is zero). This talk will review the conventional definition of the S-matrix, and discuss how to construct a more well-behaved "hard" S-matrix. The hard S-matrix reduces to S in a mass-gapped theory, but with massless particles it is also well-behaved. The connection of the hard S-matrix to dressed states, factorization, and the KLN theorem will also be discussed.

Scattering amplitudes from finite-volume observables

Raul Briceno

(Old Dominion U. and Jefferson Lab)

Numerical lattice calculations are necessarily performed in a finite spacetime, where the notion of asymptotic states is absent. As a result, one cannot directly access scattering amplitudes from finite-volume lattice calculations. Furthermore, naïve extrapolations of finite-volume observables to the infinite-volume limit are in general not well defined. To circumvent this issue, one can find all-orders relations between finite-volume energies and matrix elements and physical scattering amplitudes. This formalism has proven to be remarkably useful in the studies of two-hadron scattering amplitudes in lattice QCD, including kinematics for which multiple channels are open. The extension of this to three-particle systems has proven to be far more challenging. In this talk, I will review this formalism for two and hopefully three particles, and I will present some lattice QCD results that illustrate the power of these formal techniques.

Riccardo Rattazzi

(EPFL)

Sergei Dubovsky

(NYU)

QFT in AdS and S-matrix

Shota Komatsu

(IAS, Princeton)

Victor Gorbenko

(Stanford University and IAS)

S-matrix from flat-space limit of QFT in AdS

Xiang Zhao

(Durham University)

In this talk I will present a LSZ-like prescription to obtain the S-matrix from taking the flat-space limit of conformal correlation functions. I will start with a heuristic argument of the prescription focusing on the building blocks of Witten diagrams. Then I will discuss both kinematic and dynamic aspects of our prescription. I will construct a map between conformal cross ratios and flat-space Mandelstam variables; and I will discuss some concrete examples of Witten diagrams. After that I will conclude with possible future directions.

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Posters

What is the role of torsion in surface charges?

Diego Roberto Hidalgo Tecay

(Centro de Estudios Científicos (CECs))

We study how is that surface charges gets modified with the presence of torsion in spacetime for the physical conserved charges. We consider two examples: a pure gravity example in (2+1)-dimensions where torsion is sourced without adding any extra fields, and the second example in (3+1)-dimensions is Einstein-Cartan-Dirac theory where torsion is sourced by Dirac spinors. For both theories, we find that the torsion is explicitly absent from the charge formula. In fact, we go further and conjecture that torsion does not enter the charge formulae for theories with non-propagating torsion.

Lee-Wick scalar field in presence of boundaries and external sources.

Everson Henrique Rodrigues

(IFQ - Universidade Federal de Itajubá)

We are constructing a model of interaction based in Klein-Gordon scalar field that interacts with a external source. We add to this model a higher order derivative, which caracterizes a Lee-Wick interaction . We put a delta-like potential region with quadratic coupling to the Lagrangian. The aim of research is to find analytically the energy and interaction force between the charge and the potential boundary. We are also studying deeply the variation of the energy versus distance for various values of coupling parameters. We found the energy behavior ploting the propagator numeric integration. The force shows a interesting result, the increase of it module until a maximum and posteriorly a asymptotically decrease to zero.