UK-QFT XII

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IOP

Book of Abstracts

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The Classical Double Copy and Twistors

Author: Kymani Armstrong-Williams[1]

[1] *Queen Mary University of London*

The last twenty years or so have given rise to an interesting relationship (known as the double copy) at the level of scattering amplitudes between non-abelian gauge theories (such as Yang-Mills theory) and quantum gravity theories. After half a decade, this duality was seen to be present in classical physics for exact solutions in classical Yang-Mills theory and general relativity. Ten years on, the classical double copy has seen tremendous attention and development. One such development is the application of twistor theory to the classical double copy; where we can express spacetime fields as infinite complex "lines"in twistor space, which can be used to generate new double copies. This talk will describe how this work has been extended to connect the momentum space double copy for scattering amplitudes with the position space double copy for classical fields; as well as its application to find a novel classical double copy for N=0 supergravity. This talk will be based on work done in arxiv:2303.04631.

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Gravitational Waveforms from Scattering Amplitudes

Authors: Andreas Brandhuber[1]; Gabriele Travaglini[None]; Gang Chen[2]; Graham Brown[1]; Joshua Gowdy[1]; Stefano De Angelis[3]

[1] *Queen Mary University of London*

[2] *Niels Bohr Institute*

[3] *IPhT, Saclay*

This talk will focus on recent work using methods from scattering amplitudes to compute gravitational waveforms produced in the scattering of two black holes. I will present results from two papers completed this year: 2303.06111 and 2310.04405. The first involves extracting the gravitational waveform produced in the scattering of two Schwarzschild black holes at next-to-leading order in G_N (one-loop). The second deals with including spin effects in the waveform at leading order in G_N.

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A geometric look at unitarity in the wavefunction

Author: Carlos Duaso Pueyo[1]

[1] *DAMTP, University of Cambridge*

In the spirit of better understanding the relation between physical observables and first principles, we have analysed the consequences of perturbative unitarity on the wavefunction of the universe. We have done that from the point of view of cosmological polytopes, a combinatorial description of the wavefunction in terms of positive geometries. We have found that unitarity is encoded into a non-convex part of the cosmological polytope, which we name optical polytope. This provides an invariant formulation of the wavefunction cutting rules, which in this picture emerge as an equivalence between different polytope triangulations. In addition, this point of view allows to see the S-matrix optical theorem arise from the non-convexity of the optical polytope.

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Supergeometry in Effective Quantum Field Theories

Authors: Apostolos Pilaftsis[1]; Viola Gattus[None]

[1] *University of Manchester (GB)*

After a short review of the field-space formalism on a supermanifold, I will present a natural approach to deriving the supermetric from the classical action of an effective Supergeometric Quantum Field Theory (SG-QFT). I will give the proof of a no-go theorem for the generation of a non-zero super-Riemannian curvature in a bilinear kinetic fermionic sector from the existence of scalar fields only in SG-QFTs. Then, I will present for the first time two novel minimal models that feature non-zero fermionic field-space curvature both in two and four spacetime dimensions up to second order in spacetime derivatives. Finally, I will present the scalar-fermion superpropagators, as well as the three- and four-point supervertices, thereby generalising earlier results of pure bosonic theories that were known before in the context of SMEFT. Physical applications within this novel SG-QFT framework will be discussed.

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Constrained instantons in SU(2) Yang-Mills-Higgs

Author: Kinga Gawrych[1]

[1] *Imperial College London*

The presence of the Higgs field in the Standard Model breaks the scale invariance of the electroweak theory. The result is that Yang-Mills instantons cease to exist in the EW sector. It was speculated that some approximate constrained instanton solutions still exist and give non-negligible contributions to the path integral. Such solutions would give rise to a new source of baryon number violation in the SM. In this talk, I will demonstrate the existence of constrained instantons in the SU(2) Yang-Mills-Higgs theory by presenting specific examples of such solutions.

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Non-Gaussianity from preheating of non-minimally coupled inflaton

Author: Pulkit Ghoderao[1]

[1] *Imperial College London*

We extend the non-perturbative formalism to calculate non-Gaussianity from preheating. Preheating involves the rapid production of daughter particles after the end of inflation and as such is a non-linear process that requires numerical simulations to capture its dynamics. We obtain initial conditions for simulations by including the time-dependence of Hubble rate during inflation. We find that cosmic variance, which is the variance of modes from start of inflation to when currently observable scale left the horizon, plays a key role in determining the formulation used to extract non-Gaussianity from preheating. We illustrate our method by applying it to an observationally-viable preheating model motivated by non-minimal coupling to gravity, and study its full parameter dependence.

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Natural polynomials for Kerr quasi-normal modes

Authors: Lionel London[1]; Michelle Gurevich[1]

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Accurate estimation of quasinormal modes from black hole mergers is an important open problem for gravitational waves, and has applications for tests of general relativity. In the case of Kerr black holes, linear perturbation theory has allowed for solutions of some of these modes to be calculated, but a general, exhaustive calculation for high overtones has remained evasive. We consider the Teukolsky formalism of the linearized Einstein equations, and solve the radial component using a basis of canonical polynomials which we construct numerically. In particular, we find a spectral representation of the differential operator representing this radial equation. By combining these solutions with those of the angular equation, we calculate quasinormal modes for general spin black holes.

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Flat holography dictionary

Author: zezhuang hao[1]

[1] *University of Southampton*

Ads/CFT correspondence has been brought up over 25 years and, from the bottom-up point of view, the duality is clearly classified by the match of the data between the effective theory in the AdS bulk and the conformal theory on the boundary. Here in this talk, based on the AdS/CFT dictionary, we introduce the construction of flat/CFT dictionary which gives as the duality relation between the effective theory on Minkowski and the proposed QFT theory on the celestial sphere.

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Mathematical Foundations of Non-Hermitian Quantum Field Theory

Author: Esra Sablevice[1]

[1] *The University of Manchester*

A foundational principle of "standard" quantum mechanics (QM) is that physical observables, particularly the Hamiltonian, must be Hermitian. This ensures unitary time evolution and yields real expectation values. However, these properties are not unique to Hermitian operators, but are shared across all operators possessing an anti-linear symmetry. This includes PT-symmetric Hamiltonians, which have found a range of applications in optics, photonics and condensed matter physics. Despite the success of non-Hermitian QM, the subject of non-Hermitian quantum field theory (QFT) has only recently began to gain traction.

To date, most non-Hermitian QFTs have been constructed in a similar fashion to non-Hermitian QM: by appending non-Hermitian terms to an otherwise Hermitian Hamiltonian or analytical continuation. However, these approaches have been leading to various physical inconsistencies. The primary reason for this lies in the fundamental difference between non-Hermitian quantum mechanics and non-Hermitian quantum field theory. Quantum field theory heavily relies on the behaviour of fields under spacetime symmetries, i.e., the Poincaré group. The non-Hermitian nature of the Hamiltonian

significantly impacts the underlying symmetry group structure. Thus, to build a non-Hermitian QFT, we must revisit its mathematical foundations, starting with the symmetries of spacetime and constructing the theory from the ground up.

Reference:
arXiv:2307.16805

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From number theory to physics: Regularising QFTs

Authors: Antonio Padilla[1]; Robert Smith[1]

[1] *University of Nottingham*

In the mathematics of particle physics, it is not uncommon that a calculation should result in infinity. The longstanding hope has been that the correct theory of quantum gravity will act as a sort of universal UV regulator in the low-energy limit of QFT. As it stands, there is no one choice of regularisation that hints at any connection to quantum gravity, or which can be applied for all purposes and for all QFTs. String theory has certainly provided multiple insights in this regard, not least in terms of its natural exponential damping of UV divergences. Motivated by stringy behaviour in the UV, in this talk I will describe recent research that considers these questions. Beginning at the nexus of number theory and physics, I will discuss a general class of regulator functions based firstly on the work of Terence Tao. I will then show how the broad class of η-regulators that we define can be extended as a potentially generalised theory of regularisation (for all QFTs). After summarising a few important results in the extension to gauge theories, I will discuss the derivation of a master equation (in η language) in which all symmetry preserving regularisation prescriptions must satisfy, before reviewing the extension of η-regularisation to n-loops. I will then conclude with a few comments on ongoing research that investigates how this generalised class of regulators relates to the UV finiteness of string theory.

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On the IR divergences in de Sitter: from trees to loops and back

Authors: Ana Achucarro[1]; Anne Davis[None]; Dong-Gang Wang[2]; Guilherme Pimentel[3]; Sebastian Cespedes[4]

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[4] *Imperial College London*

Interacting light scalars in de Sitter spcae (dS) normally lead to infrared divergences. I shall revisit this topic with recent developments of the cosmological bootstrap. At the tree level, we see that for both contact and exchange diagrams, the boundary differential equations become the ones from anomalous conformal Ward identities. The results from massless exchanges allow us to bootstrap a full set of non-Gaussianities from multi-field inflation. At the loop level, we apply the wavefunction method, and identify that the leading contributions to IR-divergent correlators always come from classical loops from tree-level wavefunction coefficients. This significantly simplifies the problem and indicates the importance of the saddle-point approximation when we go beyond perturbation theory. With this insight, we present a non-perturbative derivation of the stochastic formalism. Using the semi-classical wavefunction, we find that the Fokker-Planck equation follows from a combination of the Schroedinger equation and the Polchinski equation for the exact renormalization group flow.