QCD Meets Gravity 2023

Report of Contributions

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

The Double Copy: A Review

Monday 11 December 2023 09:00 (45 minutes)

The double copy is at the heart of QCD meets Gravity. In this review talk I will focus on some of the many successes of the double copy, and also point to some areas where progress would be particularly welcome.

Primary author: O'CONNELL, Donal

Presenter: O'CONNELL, Donal

Session Classification: Monday AM 1

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

Double-Copy Constructions for Yang-Mills-Einstein Supergravities with Non-Compact Gauge Groups

Monday 11 December 2023 09:45 (30 minutes)

I present a framework for extending the double copy to five-dimensional N=2 Yang-Mills-Einstein theories with non-compact gauge groups. While non-compact gauge groups are known to lead to inconsistencies in case of YM theories, they become a viable option in supergravity and have long been known and investigated by the supergravity community. We will show that their amplitudes can be constructed as the double copy of an N=2 SYM theory with massive hypermultiples and a non-supersymmetric theory with massive fermions. Explicit examples will be presented, including five-dimensional supergravities with both massive tensors and massive vectors.

Primary author: CHIODAROLI, Marco (Uppsala University)

Presenter: CHIODAROLI, Marco (Uppsala University)

Session Classification: Monday AM 1

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

Building Blocks of Gravity Amplitudes

Monday 11 December 2023 10:45 (30 minutes)

Gravity possesses many interesting properties such as its enhanced soft behaviour under large BCFW shifts and its KLT constructibility. Planar N=4 SYM also has related nice properties, most of which can be understood as a result of its underlying Amplituhedron structure. In this talk, we address whether gravity has an underlying positive geometry. Our approach will be to construct the fundamental building blocks of tree amplitudes and leading loop singularities in gravity, the analogs of R-invariants in SYM. We draw inspiration from the BCFW recursive construction of tree amplitudes in order to find these "good" building blocks and show that they are geometric objects.

Primary author: PARANJAPE, Shruti

Presenter: PARANJAPE, Shruti

Session Classification: Monday AM 2

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

Bootstrapping the UV from the IR via Double Copy Consistency

Monday 11 December 2023 11:15 (30 minutes)

Traditionally the double copy is praised for efficient construction of gravitational S-matrix elements at high orders in perturbation theory, by way of simpler gauge theory building blocks. In this talk, we will find that color-kinematics duality can also be used to inform UV completion of effective field theories (EFTs). In our approach, UV information about gauge/gravity EFTs can be recovered from double-copy consistency conditions between the IR Wilson coefficients. Guided by this insight, we'll see that many properties historically understood to have a UV origin, can actually be inferred directly from the IR principle of double-copy consistency. To close, we'll see that spectra of UV massive modes consistent with these constraints can be recovered using Padé extrapolation, a standard method in the resurgence literature.

Primary author: PAVAO, Nic (Northwestern University)

Presenter: PAVAO, Nic (Northwestern University)

Session Classification: Monday AM 2

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

Numerical Simulations of Binary Black Hole Encounters

Monday 11 December 2023 14:00 (30 minutes)

Binary black holes are the most numerous source of observed gravitational waves (GW). Precise knowledge about the interaction between two black holes and the emitted GWs are of high importance for finding and analysing GW signals, as well as to deepen the understanding of the structure and solutions of Einstein's equations. In this talk, I summarize the contributions of Numerical Relativity simulations to GW astrophysics, touching on all types of orbits (quasi-circular, eccentric, hyperbolic). Emphasis will be on results obtained with the SpEC code of the SXS collaboration.

Primary author: PFEIFFER, Harald (AEI Potsdam)

Presenter: PFEIFFER, Harald (AEI Potsdam)

Session Classification: Monday PM 1

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

Effective Field Theory for Extreme Mass Ratios (part 2)

Monday 11 December 2023 15:00 (30 minutes)

The standard approximations to the two-body problem in General Relativity include weak-field perturbation theory ("PN"and "PM") and a strong-field scheme which expands in powers of the mass ratio but retains all orders in G-Newton, ie. "self-force". I'll discuss recent work which used inspiration from self-force to simplify perturbative computations. We introduce an effective field theory describing a pair of gravitationally interacting point particles in an expansion in their mass ratio. The leading (0SF) dynamics are trivially described by geodesic motion in curved spacetime and at higher SF orders the perturbations of the 0SF exact solution are accounted for by a small number of operators, eg. a recoil operator encoding backreaction onto the heavy body. Rather than building-up curved spacetime perturbatively, this approach leverages known non-perturbative solutions and unpacks them into very simple perturbative building blocks—suggesting a path towards simplified multi-loop integrands for higher PM orders. We'll mention a variety of old and new two-loop results computed using this EFT.

Primary author: WILSON-GEROW, Jordan (Caltech)

Presenter: WILSON-GEROW, Jordan (Caltech)

Session Classification: Monday PM 1

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

Effective Field Theory for Extreme Mass Ratios (Part 1)

Monday 11 December 2023 14:30 (30 minutes)

The metric and corresponding geodesic equation describing test-particle dynamics in a background encode gravitational data to all orders in the post-Minkowskian (PM) expansion and effectively resum certain infinite classes of flat-space Feynman diagrams. In the context of the connection between the bound gravitational two-body problem and the relativistic scattering of massive particles interacting via gravity, I will describe how this property can be leveraged to obtain information about post-Minkowskian conservative dynamics as a systematic expansion in the mass ratio of the interacting bodies, also known as the self-force (SF) expansion. At the leading PM order for arbitrary mass ratios and all PM orders in the test-particle limit, data such as isotropic gauge Hamiltonians and scattering amplitudes can be algebraically extracted for a non-spinning black hole binary system and small perturbations away from it. Higher SF dynamics can be determined using an effective field theory (EFT) setup that accounts for the recoil of the heavy body due to effects from the light body through "recoil operators". This EFT formalism for extreme mass ratios will be discussed.

Primary author: SHAH, Nabha

Presenter: SHAH, Nabha

Session Classification: Monday PM 1

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

No EFT for massive higher spins

Monday 11 December 2023 16:00 (30 minutes)

Massive resonances with spin larger or equal 2 are ubiquitous in physics, but their mass is always larger than their inverse size (the EFT cutoff). I will show that this condition follows from the requirement that the underlying theory be unitary and causal.

Primary author: RIVA, Francesco

Presenter: RIVA, Francesco

Session Classification: Monday PM 2

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

Regge Trajectories from Pion Scattering at Large N

Monday 11 December 2023 16:30 (30 minutes)

I explore the Effective Field Theory bootstrap formalism, leveraging dispersion relations to establish sum rules linking low-energy scattering amplitudes to high-energy partial wave expansion. We analyze the impact of different Regge behaviors at large energies and apply the formalism to study Pion Scattering at large-N. Imposing the presence of spin-2 states, we derive a mass bound for additional higher spin states, unveiling a kink structure. Investigation at this kink reveals intriguing agreements with real-world QCD observables. Moreover, the solution's spectrum organizes into Regge-trajectory-like families.

Primary author: VICHI, Alessandro

Presenter: VICHI, Alessandro

Session Classification: Monday PM 2

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

Dilaton Scattering and Regge Trajectories

Monday 11 December 2023 17:00 (30 minutes)

I will discuss scattering amplitudes of neutral Goldstone bosons such as dilatons, pions or branons. I will construct non-perturbative bounds on the dimensionless ratios of Wilson coefficient describing their low energy behaviour. I will then analyse scattering amplitudes saturating the above bounds. I will show that these amplitudes in some parameter range contain resonances with complex energies which organise themselves into Regge trajectories.

Primary author: KARATEEV, Denis

Presenter: KARATEEV, Denis

Session Classification: Monday PM 2

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

A Snapshot of Precision QCD Measurements at the LHC

Tuesday 12 December 2023 09:00 (45 minutes)

Jets are a central component of many analyses at collider experiments, and uncertainties related to jet reconstruction and QCD limit the precision of a variety of experimental analyses. Their production involves both perturbative and non-perturbative aspects of QCD, resulting in a rich structure that is difficult to model precisely. The talk will discuss several different measurements that probe QCD at different scales, including parton distribution functions, the strong coupling constant, and parton showers. These measurements will be used to demonstrate how experimental precision, coupled with theoretical developments, can be used to provide a better understanding of QCD, and can be used to enhance the physics program at the LHC.

Primary author: ROLOFF, Jennifer (Brookhaven National Laboratory (US))

Presenter: ROLOFF, Jennifer (Brookhaven National Laboratory (US))

Session Classification: Tuesday AM 1

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

Landau Singularities of Ziggurat Graphs

Tuesday 12 December 2023 14:30 (30 minutes)

Primary author: VOLOVICH, Anastasia

Presenter: VOLOVICH, Anastasia

Session Classification: Tuesday PM 1

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

Symbol Alphabets from the Landau Singular Locus

Tuesday 12 December 2023 10:45 (30 minutes)

I present work which provides evidence through two loops that rational letters of polylogarithmic Feynman integrals are captured by the Landau equations, when the latter are recast as a polynomial of the kinematic variables of the integral, known as the principal A-determinant. Focusing on one loop, I further discuss how all square-root letters may also be obtained, by re-factorizing the principal A-determinant with the help of Jacobi identities. The letters are verified by explicitly constructing canonical differential equations
for the one-loop integrals in both odd and even dimensions of loop momenta.

Primary author: DLAPA, Christoph (DESY Hamburg)

Presenter: DLAPA, Christoph (DESY Hamburg)

Session Classification: Tuesday AM 2

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

Measurements and Crossing

Tuesday 12 December 2023 11:15 (30 minutes)

Crossing symmetry in interacting quantum field theory suggests that particles and antiparticles traveling back in time are indistinguishable. To rigorously prove this property, it is necessary to show that on-shell observables across different channels are boundary values of the same analytic function. Known non-perturbative proofs in specific cases heavily rely on fundamental physical principles (e.g., causality, locality, and unitarity), as well as on a significant amount of complex analysis in several variables. This makes their extension to cases of arbitrary multiplicity very challenging. In this talk, we review recent progress regarding the implications of crossing symmetry in quantum field theory, assumming analyticity. Towards the end, we discuss possible complications arising from anomalous thresholds and elaborate on strategies for managing them. To illustrate the main points, we focus on the specific example of the expectation values of gravitational bremsstrahlung.

Primary author: GIROUX, Mathieu (McGill University)

Presenter: GIROUX, Mathieu (McGill University)

Session Classification: Tuesday AM 2

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

Calabi-Yau Meets Gravity: Feynman Integral Geometries in Gravitational Waves

Tuesday 12 December 2023 14:00 (30 minutes)

Multi-loop Feynman integrals for collider physics are known to contain intricate geometries and to evaluate to complicated transcendental numbers and functions. In this talk, I will investigate Feynman integrals contributing to the emission of gravitational waves up to fifth order in the post-Minkowskian expansion, identifying new geometries that lead to new transcendental functions.

Primary author: WILHELM, Matthias (University of Copenhagen)

Presenter: WILHELM, Matthias (University of Copenhagen)

Session Classification: Tuesday PM 1

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

The Unity of Colored Scalars, Pions and Gluons

Tuesday 12 December 2023 09:45 (30 minutes)

I report on a new discovery that the "stringy"amplitudes of trφ3 (the simplest theory of colored scalars) secretly contain the scattering amplitudes for pions and non-supersymmetric gluons in arbitrary dimensions. At tree level, this unified object naturally explains some surprising, hidden properties shared by amplitudes in all these colored theories, namely the string and particle amplitudes of tr φ3 , non-linear sigma model and Yang-Mills theory, all have a hidden pattern of zeros as well as new factorizations near such zeros.

Primary author: HE, Song

Presenter: HE, Song

Session Classification: Tuesday AM 1

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

On Hyperelliptic Feynman Integrals, or: What Genus Is It Anyway?

Tuesday 12 December 2023 15:00 (30 minutes)

Multi-loop Feynman integrals are crucial in meeting the requirements for high-precision predictions of both collider and gravitational-wave experiments. Such integrals are associated to geometries, providing information about the function classes appearing in their evaluation. In this talk I will discuss integrals associated to hyperelliptic curves, a natural generalization of elliptic curves. I will show the role that the genus of such curves play, and how there can be multiple different curves associated to the same integral.

Primary author: POEGEL, Sebastian

Presenter: POEGEL, Sebastian

Session Classification: Tuesday PM 1

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

Differential Equations for Cosmological Correlators

Tuesday 12 December 2023 16:00 (30 minutes)

I will describe how methods largely developed to tackle problems in QCD are extremely useful to understand the gravitational problem of the initial conditions. More specifically, I will how to obtain differential equations (in terms of boundary momenta) for tree-level cosmological correlators in a toy model. The differential equations follow a set of self consistent rules that can be explained autonomously, regardless of the "bulk time integral"picture used to derive them in first place. This "kinematic flow,"besides providing a practically useful way of computing the correlators, suggests that there is an alternative description of cosmology in which time evolution is an output, rather than wired-in from the get-go.

Primary author: PIMENTEL, Guilherme (Scuola Normale Superiore)

Presenter: PIMENTEL, Guilherme (Scuola Normale Superiore)

Session Classification: Tuesday PM 2

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

Loop Corrections to Cosmological Correlators

Tuesday 12 December 2023 16:30 (30 minutes)

Surveys of the Large Scale Structure are becoming increasingly detailed. A primary theoretical tool for analyzing this data and constraining cosmological models is the Effective Field Theory (EFT) of Large Scale Structure. In this presentation, I will describe an effort to calculate loop corrections to cosmological correlators within the EFT of LSS. I will discuss how loop integrals in cosmology can be mapped to conventional loop integrals in QFT with massive propagators. Within this framework, I will describe the efficient "analytical" computation of all one-loop correlators using powerful and well established QFT methods. Subsequently, I will discuss the introduction of numerical methods for computing multi-loop correlators. Finally, I will present the initial (preliminary) results for the two-loop corrections to the power spectrum.

Primary author: ANASTASIOU, Charalampos

Presenter: ANASTASIOU, Charalampos

Session Classification: Tuesday PM 2

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

Positivity from Cosmological Correlators

Tuesday 12 December 2023 17:00 (30 minutes)

Primary author: SHEN, Chia-Hsien

Presenter: SHEN, Chia-Hsien

Session Classification: Tuesday PM 2

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

Precision Phenomenology at the LHC

Wednesday 13 December 2023 09:00 (45 minutes)

Primary author: HUSS, Alexander Yohei (CERN)

Presenter: HUSS, Alexander Yohei (CERN)

Session Classification: Wednesday AM 1

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

Improved Integral Reduction with Kira

Wednesday 13 December 2023 09:45 (30 minutes)

The focus will be on improved integral reduction with the Kira program. I will present a seeding algorithm that can improve the reduction time by more than one order of magnitude compared to the current algorithm in Kira. I will demonstrate the use case of the seeding algorithm using some state-of-the-art integral reduction examples. At the end of the talk, I will discuss the synergy of Kira with other tools.

Primary author: USOVITSCH, Johann (CERN)

Presenter: USOVITSCH, Johann (CERN)

Session Classification: Wednesday AM 1

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

Computing Pinched Feynman Integrals and the Method of Regions

Wednesday 13 December 2023 11:15 (30 minutes)

Sector decomposition is a well known method for numerically computing Feynman integrals. In the physical (Minkowski) region, it is sometimes necessary to deform the integration contour into the complex plane in order to avoid poles, or more generally singular hypersurfaces, in the integration domain. However, there exist Feynman integrals with 'pinched' singularities, for which the usual contour deformation procedure fails. Using simple examples, I will describe this problem and discuss one possible solution that allows it to be avoided. I will briefly discuss how the above problem is related to the appearance of new regions (in the sense of the Method of Regions), when integrals are expanded around a small or large scale.

Primary author: JONES, Stephen Philip (University of Durham (GB))

Presenter: JONES, Stephen Philip (University of Durham (GB))

Session Classification: Wednesday AM 2

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

Parton Showering Meets QCD

Wednesday 13 December 2023 10:45 (30 minutes)

Monte Carlo event generators are central tools in today's particle physics community. In this talk, I will focus on their central part, the parton shower algorithm. I will discuss how, from a perturbative QCD standpoint, one can define, assess and improve their (logarithmic) accuracy.

Primary author: SOYEZ, Gregory (IPhT, CEA Saclay)

Presenter: SOYEZ, Gregory (IPhT, CEA Saclay)

Session Classification: Wednesday AM 2

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

Fundamental Physics and Gravitational Waves

Thursday 14 December 2023 09:00 (45 minutes)

The detections of gravitational waves emitted by compact binary coalescences gave rise to the new science of Gravitational Wave Astronomy, which opened up new possibilities for scientific investigation also in cosmology and fundamental physics. In this presentation I will give an overview of the observational results and some hints to the impact they had, are having and will have on our understanding of fundamental physics, with emphasis on the analytic modeling of the General Relativistic two-body problem.

Primary author: STURANI, Riccardo (IFT-UNESP/ICTP-SAIFR)

Presenter: STURANI, Riccardo (IFT-UNESP/ICTP-SAIFR)

Session Classification: Thursday AM 1

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

Absorptive Effects and Classical Black Hole Scattering

Thursday 14 December 2023 09:45 (30 minutes)

I will describe an approach to incorporating absorption effects into the post-Minkowskian effective description of two-body classical gravitational scattering. By coupling the usual point-particle effective description to an invisible sector of gapless internal degrees-of-freedom, the leading-order absorptive effects are encoded in the low-energy expansion of a spectral density function; for black holes this spectral function is obtained by matching an absorption cross-section calculated in black hole perturbation theory. This information is then recycled using the scattering amplitudes-based KMOC formalism to calculate the impulse on and change in rest mass of a Schwarzschild black hole scattering with a second compact body sourcing a massless scalar, electromagnetic or gravitational field. I will show that the results obtained are consistent with both worldline Schwinger-Keldysh calculations and numerical scalar self-force results.

Primary author: JONES, Callum

Presenter: JONES, Callum

Session Classification: Thursday AM 1

Contribution ID: **27** Type: **not specified**

Spinning Waveforms from KMOC at Leading Order

Thursday 14 December 2023 10:45 (30 minutes)

I present a method for computing gravitational waveforms from singularities of the five-point amplitude. The procedure is based on the KMOC formalism and leverages the analytic properties of amplitudes in the complex plane. I demonstrate this approach at tree level by deriving the time-domain waveform for Kerr black holes up to the fourth order in spin.

Primary author: NOVICHKOV, Pavel

Presenter: NOVICHKOV, Pavel

Session Classification: Thursday AM 2

Contribution ID: **28** Type: **not specified**

The Gravitational Eikonal and the NLO Scattering Waveform

Thursday 14 December 2023 11:15 (30 minutes)

Primary author: RUSSO, Rodolfo (University of London (GB))

Presenter: RUSSO, Rodolfo (University of London (GB))

Session Classification: Thursday AM 2

Contribution ID: **29** Type: **not specified**

Aspects of Conformal Gravity and Double Field Theory from a Double Copy of Yang-Mills Theory

Thursday 14 December 2023 14:00 (30 minutes)

Double field theory can be naturally constructed as the double copy of a Yang-Mills theory. Indeed, a double copy prescription for the Yang-Mills action can be provided that produces a double field theory action in which the dilaton has been integrated out. In turn, this result can be extended by including higher-derivative terms. In this talk I will review how the double-copy map for the Yang-Mills action potentially yields a weakly constrained double field theory. I will also explore how a double-copy formulation serves as a guiding principle for studying the relationship between higher-derivative gauge theories and higher-derivative extensions of double field theory.

Primary author: Prof. MENEZES, Gabriel

Presenter: Prof. MENEZES, Gabriel

Session Classification: Thursday PM 1

Contribution ID: **30** Type: **not specified**

Double Copies from Recursion

Thursday 14 December 2023 14:30 (30 minutes)

I discuss expressions for gravity amplitudes and show that they can be written as term wise double copies of those in YM gauge theory derived from BCFW.

Primary author: PATATOUKOS, Kokkimidis

Presenter: PATATOUKOS, Kokkimidis

Session Classification: Thursday PM 1

Contribution ID: **31** Type: **not specified**

Generating Kerr Amplitudes from Higher-Spin Theory

Thursday 14 December 2023 15:00 (30 minutes)

Higher-spin theory and massive gauge invariance can be used as input for constraining root-Kerr and Kerr amplitudes, relevant for calculating gravitational observables with spin. Elegant three-point spin-s amplitudes exist for Kerr black holes, however constructing the corresponding four-point Compton amplitudes is an open problem. In this talk, I will discuss the origin of the Kerr three-point amplitudes from a higher-spin theory perspective. Guided by higher-spin constraints and classical-limit analysis, I will propose quantum and classical tree-level Compton amplitudes relevant for root-Kerr and Kerr to all orders in spin.

Primary author: CANGEMI, Lucile

Presenter: CANGEMI, Lucile

Session Classification: Thursday PM 1

Contribution ID: **32** Type: **not specified**

Black Hole Scattering: the Self-Force Approach

Thursday 14 December 2023 16:00 (30 minutes)

Calculations of the scatter angle in hyperbolic black hole encounters have been of recent cross-disciplinary interest, driven by its potential to advance post-Minkowskian theory and the effective-one-body model of binary dynamics. In this talk I will consider the self-force approach to modelling black hole scattering, starting with a general introduction to self-force theory. I will then motivate our interest in applying self-force techniques to scattering and discuss recent results in this area. For the main part of the talk, I will discuss frequency-domain numerical methods to calculate self-force along scatter orbits. Well established for bound orbits, frequency-domain methods are valued for their high accuracy and efficiency but face numerous challenges when extended to unbound systems. I will summarise these problems and our solutions using a scalar-field toy model, presenting our numerical results to demonstrate the merits and remaining limitations. The talk will conclude by considering the direction of future work in this field, including the prospects for an extension to gravity.

Primary author: WHITTALL, Christopher

Presenter: WHITTALL, Christopher

Session Classification: Thursday PM 2

Contribution ID: **33** Type: **not specified**

Understanding the NLO Scattering Waveform: Soft Limit and Post-Newtonian Expansion

Thursday 14 December 2023 16:30 (30 minutes)

I will present the full NLO scattering waveform computed from the observable based formalism. The waveform satisfies the universal soft theorem up to the NNLO. I will end the talk by comparing the result with that computed from the Multipolar-Post-Minkowskian formalism, which requires a rotation of the incoming center-of-mass frame to align with that at the minimal approach.

Primary author: TENG, Fei

Presenter: TENG, Fei

Session Classification: Thursday PM 2

Contribution ID: **34** Type: **not specified**

4PM Scattering of Spinning Black Holes and Neutron Stars

Thursday 14 December 2023 17:00 (30 minutes)

I will discuss our recent calculations of the observables (impulse, spin kick, scattering angle) involved in the scattering of two black holes or neutron stars at fourth post Minkowskian order (three-loop order) using the Worldline Quantum Field Theory (WQFT) framework. These 4PM observables now include both spin-orbit and adiabatic tidal corrections —inclusion of the latter necessitates a renormalization of the underlying classical effective field theory (EFT), with the addition of post-adiabatic counterterms and a corresponding renormalization group flow of the post-adiabatic Love numbers.

Primary author: MOGULL, Gustav

Presenter: MOGULL, Gustav

Session Classification: Thursday PM 2

Contribution ID: **35** Type: **not specified**

Multipole Moments, Time-derivative Operators, and the Kerr Compton Amplitud

Thursday 14 December 2023 17:30 (30 minutes)

In Dixon's original papers on the Mathisson–Papapetrou–Dixon worldline equations of motion for extended bodies in general relativity, he found the unique definition for the multipole moments of the stress tensor for a body in general motion in curved spacetime. This definition coincides only with the stationary multipole moments of the body which are determined by the three-point amplitude when the body is itself stationary. Consequently, we find that using Dixon's multipole moments with the Kerr solution allows the determination of additional couplings in the worldline action for a spinning black hole beyond those which are fixed by matching to the stationary stress tensor. Some of these additional couplings contribute linearly independent structures to the spinning black hole Compton amplitude. Beginning at fifth order in spin, the values of these additional couplings affect comparisons to predictions made by Guevara-Ochirov Vines spin-exponentiation, shift-symmetry, or the Teukolsky equation.

Primary author: SCHEOPNER, TREVOR

Presenter: SCHEOPNER, TREVOR

Session Classification: Thursday PM 2

Contribution ID: **36** Type: **not specified**

A Bootstrap Bridge Between QCD and Gravity

Friday 15 December 2023 09:00 (45 minutes)

The numerical S-matrix Bootstrap aims at establishing non-perturbative universal bounds on physical observables that can be extracted from scattering amplitudes in any dimension. In this talk, I will focus on dimensions greater or equal to four, focusing on three main topics: no-go theorems for supersymmetric quantum gravity, rigorous model dependent bounds on Higgs couplings, and Bootstrapping the QCD spectrum from physical pion scattering. These results are obtained by going beyond the simple positivity of scattering amplitude, with the introduction of the non-linear unitarity inequalities. During the discussion, I will describe the Bootstrap methodology and the numerical challenges we face when tackling these problems. I will conclude with a list of possible future directions that I believe are interesting for the development of the field.

Primary author: GUERRIERI, Andrea

Presenter: GUERRIERI, Andrea

Session Classification: Friday AM 1

Contribution ID: **37** Type: **not specified**

Abelian Insights on Kinematic Algebras

Friday 15 December 2023 09:45 (30 minutes)

Certain non-abelian gauge theories obey so-called BCJ duality, whereby their colour algebra is accompanied by a second algebra involving kinematic degrees of freedom, and which in turn allows amplitudes in such theories to be double-copied to gravity. For special theories in particular gauges, the kinematic algebra can be ascertained exactly, and corresponds to an (infinitely dimensional) Lie algebra. A more complicated mathematical structure is expected in general, such that the nature of kinematic algebras remains deeply mysterious. Open questions include: when are kinematic algebras Lie algebras, and are previous known cases in fact related? Are kinematic algebras gauge-dependent in general? Can we build new theories involving exact kinematic algebras? In this talk, I will shed light on these questions by considering building blocks already present in simpler abelian gauge theories.

Primary author: WHITE, Chris (Queen Mary University of London)

Presenter: WHITE, Chris (Queen Mary University of London)

Session Classification: Friday AM 1

Contribution ID: **38** Type: **not specified**

Higher-Derivative Scalars Meet Gluons

Friday 15 December 2023 10:45 (30 minutes)

The covariant color-kinematics duality was proposed by Cheung and Mangan as a relation between the gauged bi-adjoint scalar theory and Yang-Mills theory. It holds at the level of the equations of motion and directly leads to a simple map between tree-level scattering amplitudes. I will show that this framework naturally incorporates higher-derivative
corrections. Moreover, it implies that the amplitudes at higher orders in the effective field theory expansion are efficiently encoded in the lowest order Yang-Mills amplitudes.

Primary author: ROOSMALE NEPVEU, Jasper

Presenter: ROOSMALE NEPVEU, Jasper

Session Classification: Friday AM 2

Contribution ID: **39** Type: **not specified**

Generating Functions, Mellin Transformations and Twist-2 Operator Matrix Elements in QCD

Friday 15 December 2023 11:15 (30 minutes)

Twist-2 operators play an important role in QCD: they arise from the operator product expansion in deep-inelastic scattering and underlie the definition of collinear parton distribution functions (PDFs). We discuss the calculation of heavy quark contributions to matrix elements of these twist-2 operators at three-loop order in QCD. These matrix elements serve as matching coefficients to connect PDFs with different number of active quark flavours and enter the description of heavy quark contributions to deep-inelastic scattering. Different aspects of the problem are most suitably treated in three different mathematical spaces. They are connected by Mellin transformations and generating functions. We highlight interesting connections between these spaces, in particular how to compute the inverse Mellin transformation using generating functions and analytic continuation. These connections generalise also beyond the context of twist-2 operators in QCD.

Primary author: BEHRING, Arnd (CERN)

Presenter: BEHRING, Arnd (CERN)

Session Classification: Friday AM 2

Contribution ID: **40** Type: **not specified**

Multi-Leg Amplitudes in QCD

Friday 15 December 2023 14:00 (30 minutes)

I review the recent advances in the computation of QCD scattering amplitudes at the high multiplicity frontier. Their computation is hindered by both algebraic and analytic complexity, making them one of the main bottlenecks to obtaining predictions at the next to-next-to-leading order in QCD for many interesting LHC processes. The last few years have seen dramatic progress in this direction, elevating massless two-loop five-particle amplitudes to the state of the art in the field. I discuss the main insights that underlie this advancement: a deepened understanding of the special functions appearing in the amplitudes, and the use of finite field arithmetic enhanced by ideas from algebraic geometry to bring under control the rational coefficients.

Primary author: ZOIA, Simone

Presenter: ZOIA, Simone

Session Classification: Friday PM 1

Contribution ID: **41** Type: **not specified**

Special Functions for Five-Point One-Mass Scattering in QCD

Friday 15 December 2023 14:30 (30 minutes)

I will present the recent computation of a complete set of the two-loop five-point Feynman integrals with one external mass. Employing the method of canonical differential equations and the properties of Chen's iterated integrals, we construct a basis of special functions that greatly facilitates the calculation of scattering amplitudes, and is amenable for applications in NNLO QCD phenomenology. The abundance of dlog forms with algebraic arguments makes finding solutions through generalized multiple polylogarithms extremely challenging. To sidestep this issue, we devise a new method in which an analytic function basis can be established when no such solutions are known or exist.

Primary author: SOTNIKOV, Vasily (University of Zurich (UZH))

Presenter: SOTNIKOV, Vasily (University of Zurich (UZH))

Session Classification: Friday PM 1

Contribution ID: **42** Type: **not specified**

QCD in the Cores of Neutron Stars

Friday 15 December 2023 15:00 (30 minutes)

Gravity meets QCD in a very concrete way in neutron stars. Their cores contain ultra-dense hadronic matter whose densities reach as high as those realized in ultrarelativistic heavy-ion collisions at the LHC. In these collisions, ordinary nuclear matter melts into a new quark matter phase. This naturally raises the question: Does quark matter also exist inside neutron stars? The rapid advancement in neutron-star observations, in combination with state-of-the-art QCD calculations is providing us with an unprecedented view of the extreme matter deep in the cores of the stars. I describe how recent advancements in the theory of superdense matter inform us about what lies in the centers of neutron stars and how different constraints point to the existence of quark matter cores in large neutron stars.

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