The Geometry and Physics of Scattering Amplitudes Workshop Talk Schedule

Events for:
Monday, December 9th - Friday, December 13th

Monday, December 9th

8:00am **Breakfast/Registration - SCGP Cafe**

9:00am **Song He - SCGP 102**

Title: Scattering of Massless Particles in Arbitrary Dimension

Abstract: TBA

9:45am **Lionel Mason - SCGP 102**

Title: Ambitwistor Strings and the scattering equations

Abstract: We show that string theories admit chiral infinite tension analogues in which only the massless parts of the spectrum survive. Geometrically they are realized as holomorphic string theories in spaces of complex null geodesics (known as ambitwistor space in four dimensions). They have the standard critical dimensions of string theory (26 in the bosonic case and 10 for the superstring). Their quantization leads to the formulae for tree-level scattering of massless particles found recently by Cachazo, Ellis and He. These representations localize the integral over vertex operators to the same saddle points found by Gross and Mende as a consequence of a natural gauge condition on ambitwistor space that naturally incorporate the scattering equations. The worldsheet theory suggests a natural way to extend these amplitudes to spinor fields and loop level.

10:30am **Coffee Break - SCGP Cafe**

11:15am **Stephan Stieberger - SCGP 102**

Title: On Superstring/Supergravity Mellin Correspondence in Grassmannian Formulation

Abstract: TBA

12:00pm **Lunch - SCGP Cafe**

2:00pm Yu-Tin Huang - SCGP 102

Title: Anomalies without gauge invariance

Abstract: We revisit the question of the predictability of the S-matrix program, i.e. how much constraint can one put on a theory by solely requiring unitarity and locality of the S-matrix without ever going off-shell, or equivalently, introducing redundant gauge symmetries. Using generalized unitarity, we will demonstrate that locality automatically forces upon us the usual anomaly conditions in four dimensions for theories with chiral fermions. In higher (even) dimensions, the same analysis reveals the presence of a new particle in the spectrum: the Green-Schwarz two-form.

2:45pm Rutger Boels - SCGP 102

Title: String theory in target space

Abstract: String theory is usually presented as a theory of strings, that is, through its world-sheet description. Apart from specific problems in this approach such as curved backgrounds, it also involves quite some in principle redundant information such as the worldsheet metric. A simple question is: can string theory be defined without this redundancy? Based on very-soon-to-appear work with Tobias Hansen I'll show a new working definition of tree level string theory in a flat target space. We present a small-ish set of conditions on string amplitudes in target space whose unique solution is argued to be the usual string S-matrix. Interestingly, the notions of critical dimension and intercept are shown to arise naturally by requiring locality and unitarity on four point amplitudes. I'll end with more questions than answers, but at least the questions are interesting and well-posed. In particular there seem to be no fundamental restrictions for extending our definition to generic curved spaces.

3:30pm Tea Time - SCGP Cafe

4:15pm John Golden - SCGP 102

Title: Cluster Polylogarithms for Scattering Amplitudes

Abstract: TBA

Tuesday, December 10th

8:00am Breakfast - SCGP Cafe

9:00am Jaroslav Trnka - SCGP 102

Title: The Amplituhedron

Abstract: In this talk we show that scattering amplitudes in N=4 SYM can be understood as volumes of "The Amplituhedron", a natural generalization of convex polygons into the Grassmannian, extending the notion of positivity to a marriage between "internal" Grassmannian and "external" kinematical data. This invariant definition of the amplitude makes no reference to the usual concepts of quantum field theory. All fundamental properties of the amplitude, such as Unitarity, Locality and the Yangian symmetry, follow from positivity. Any representation of the amplitude can be then understood as a particular triangulation of this object.

9:45am **Radu Roiban - SCGP 102**

Title: Factorizing non-factorized matter-coupled supergravities

Abstract: TBA

10:30am **Coffee Break - SCGP Cafe**

11:30am **Lunch - SCGP Cafe**

1:00pm **SCGP Weekly Talk by Matthias Staudacher - SCGP 102**

Title: Bethe Ansatz for Yangian Invariants: Towards Super Yang-Mills Scattering Amplitudes

Abstract: We propose that Baxter's Z-invariant six-vertex model at the rational gl(2) point on a planar but in general not rectangular lattice provides a way to study Yangian invariants. These are introduced as eigenfunctions of certain monodromies of an auxiliary inhomogeneous spin chain. As a consequence they are special solutions to the eigenvalue problem of the associated transfer matrix. Excitingly, this allows to construct them using Bethe ansatz techniques. Conceptually, our construction generalizes to general (super) Lie alge- bras and general representations. Here we present the explicit form of the basic building blocks of the invariants for totally symmetric, finite-dimensional representations of gl(n) in terms of oscillator algebras. In particular, we discuss invariants of three- and four-site monodromies that can be understood respectively as intertwiners of the bootstrap and Yang-Baxter equation. We state a set of functional relations significant for these representations of the Yangian and discuss their solutions in terms of Bethe roots. In addition, it is shown that the basic building blocks can be expressed analogously to Grassmannian integrals. These aspects are closely related to a recent on-shell formulation of scattering amplitudes in $N = 4$ super Yang-Mills theory.

2:00pm **Henrik Johansson - SCGP 102**

Title: Fundamental representation color-kinematics duality and N4 supergravity

Abstract: TBA

2:45pm **Lance Dixon - SCGP 102**

Title: Bootstrapping six-gluon scattering in planar N=4 Super-Yang-Mills theory through four loops

Abstract: Using the amplitude-Wilson loop correspondence, the operator product expansion for Wilson loops, multi-Regge factorization, and some assumptions about the analytic structure of the result, we have constructed the remainder function for the six-gluon MHV scattering amplitude at three and four loops. No multi-loop integrands are required. The answer can be expressed in terms of multiple polylogarithms in various kinematic regions, or expressed through functions defined iteratively by the Hopf algebra coproduct. In some kinematic regions, the 2, 3 and 4 loop coefficients have very similar numerical behavior, which is also similar to that observed at strong coupling. The BFKL eigenvalue, which controls the multi-Regge limit, can be extracted through the next-to-next-to-leading logarithmic order.

3:30pm **Tea Time - SCGP Cafe**

4:15pm **Gregory Korchemsky - SCGP 102**

Title: Energy-energy correlations in N=4 SYM

Abstract: TBA

5:30pm **Food Physics Event: Molecular Gastronomy Demonstration and Talk - SCGP Art Gallery and 102**

Wednesday, December 11th

8:00am **Breakfast - SCGP Cafe**

9:00am **Yang Zhang - SCGP 102**

Title: Multi-loop unitarity via computational algebraic geometry

Abstract: This talk is about multi-loop scattering amplitudes calculation via computational algebraic geometry methods: (1) Integrand reduction by the Groebner basis and primary decomposition method (2) Maximal unitarity by multivariate residue calculation. We demonstrate these methods by our new analytic results on the two-loop five-point planar helicity amplitude in QCD and the three-loop triple box diagram in gauge theories.

9:45am **Nathan Berkovits - SCGP 102**

Title: New applications of the pure spinor superstring formalism

Abstract: I will discuss some new results concerning the pure spinor formalism of the superstring, including its infinite tension limit and a covariant map between the pure spinor and RNS formalisms.

10:30am **Coffee Break - SCGP Cafe**

11:15am **Alexander Goncharov - SCGP 102**

Title: Polylogarithms and motivic symmetries

Abstract: TBA

12:00pm **Lunch - SCGP Cafe**

3:30pm **Tea Time - SCGP Cafe**

5:30pm **Artist Dedication Wine and Cheese Reception - SCGP Floors 3, 4, 5**

Thursday, December 12th

8:00am **Breakfast - SCGP Cafe**

9:00am **Ricardo Monteiro - SCGP 102**

Title: The Kinematic Algebras from the Scattering Equations

Abstract: We study kinematic algebras associated to the so-called scattering equations, which arise in the description of the scattering of massless particles. In particular, we describe the role that these algebras play in the BCJ duality between colour and kinematics in gauge theory, and its relation to gravity. We find that the scattering equations are a consistency condition for a self-dual-type vertex which is associated to each solution of those equations. We also identify an extension of the anti-self-dual vertex, such that the two vertices are not conjugate in general. Both vertices correspond to the structure constants of Lie algebras. We give a prescription for the use of the generators of these Lie algebras in trivalent graphs that makes the colour-kinematics duality manifest.

9:45am **Arthur Lipstein - SCGP 102**

Title: Dlog Form for Amplitudes and Their Integration

Abstract: In this talk, I will describe a new form of hidden simplicity in the planar scattering amplitudes of N=4 super-Yang-Mills theory, notably that the loop integrands can be expressed in dlog form. I will explain how this form arises geometrically from computing the scattering amplitudes using a holomorphic Wilson loop in twistor space and describe a systematic method for evaluating such integrals.

10:30am **Coffee Break - SCGP Cafe**

11:15am **Andrey Kormilitzin - SCGP 102**

Title: Analytic structure of the n=7 scattering amplitude in N=4 SYM theory in multi-Regge kinematics: Conformal Regge Pole Contribution

Abstract: We investigate the analytic structure of the 2?5 production amplitude in the planar limit of N=4 SYM in multi-Regge kinematics in all physical regions. We demonstrate the close connection between Regge pole and Regge cut contributions: in a selected class of kinematic regions (Mandelstam regions) the usual factorizing Regge pole formula develops unphysical singularities which have to be absorbed and compensated by Regge cut contributions. This leads, in the corrections to the BDS formula, to conformal invariant 'renormalized' Regge pole expressions in the remainder function. We compute these renormalized Regge poles for the 2?5 scattering amplitude.

12:00pm **Lunch - SCGP Cafe**

2:00pm **Amit Sever - SCGP 102**

Title: Space-time S-matrix and Flux-tube S-matrix: Part I

Abstract: In planar N=4 Super-Yang-Mills theory there exists a map between gluon scattering amplitudes and null polygonal Wilson loops. This remarkable duality allows one to make an important step forward by Operator-Product-Expanding the scattering amplitudes.This action breaks down the four-dimensional amplitudes into a sequence of two-dimensional processes taking place on the flux tube sourced by the dual Wilson loops. In these two talks, we shall explain how the integrable structures of the flux tube theory can be used for computing scattering amplitudes at any value of the coupling constant.

2:45pm **Benjamin Basso - SCGP 102**

Title: Space-time S-matrix and Flux-tube S-matrix: Part II

Abstract: In planar N=4 Super-Yang-Mills theory there exists a map between gluon scattering amplitudes and null polygonal Wilson loops. This remarkable duality allows one to make an important step forward by Operator-Product-Expanding the scattering amplitudes.This action breaks down the four-dimensional amplitudes into a sequence of two-dimensional processes taking place on the flux tube sourced by the dual Wilson loops. In these two talks, we shall explain how the integrable structures of the flux tube theory can be used for computing scattering amplitudes at any value of the coupling constant.

3:30pm **Tea Time - SCGP Cafe**

4:15pm **Andrew Hodges - SCGP 102**

Title: Shedding some old light on deformed amplitudes in N=4 SYM

Abstract: Some recent studies of the infra-red divergences have considered deformations of on-shell diagrams, as obtained by dressing the diagrams with complex helicities. Structures like this were described in the early days of twistor theory, though in a more elementary context. They arose naturally in the original formulation of twistor diagrams as compact contour integrals in twistor space. I will review some of this old material and the approach to regularisation of divergences that motivated it.

6:00pm **Workshop Banquet - SCGP Cafe**

Friday, December 13th

8:00am **Breakfast - SCGP Cafe**

9:00am **John Joseph Carrasco - SCGP 102**

Title: TBA

Abstract: TBA

9:45am **Tristan Dennen - SCGP 102**

Title: The Ultraviolet Structure of N=4 Supergravity

Abstract: TBA

10:30am **Coffee Break - SCGP Cafe**

11:15am **Kasper Larsen - SCGP 102**

Title: Maximal Unitarity at Two Loops

Abstract: In this talk we take the first steps towards a new framework for computing two-loop amplitudes, based on unitarity rather than Feynman diagrams. In this approach, the two-loop amplitude is first expanded in a basis of integrals. The expansion coefficients are then determined by applying generalized unitarity cuts. We find explicit formulas for the integral coefficients as products of tree-level amplitudes integrated over specific multidimensional complex contours, thus allowing the construction of the two-loop amplitude from appropriately defined tree amplitudes. The validity of this method extends to all four-dimensional gauge theories, in particular QCD.

12:00pm **Lunch - SCGP Cafe**

2:00pm **George Sterman - SCGP 102**

Title: From Amplitudes to Cross Sections; Bridging the Gap

Abstract: Perturbative scattering amplitudes are essential to the calculation of cross sections and related observables. I'll review general considerations on the structure of amplitudes that cut across theories, sketching how a space-time interpretation is intrinsic to both momentum and coordinate space calculations at fixed orders and beyond, and leads to concepts like jets, infrared safety and factorization.

2:45pm **David Kosower - SCGP 102**

Title: Applications to LHC Phenomenology

Abstract: I review the application of on-shell methods to next-to-leading order QCD calculations for the LHC. I present a recent example of such calculations, the next-to-leading order calculations of W+5-jet production, and some studies based upon it. These studies hint at universal aspects of W+jet production.

3:30pm **Tea Time - SCGP Cafe**