



AMPLITUDES 2026

29 June – 3 July 2026



Queen Mary
University of London

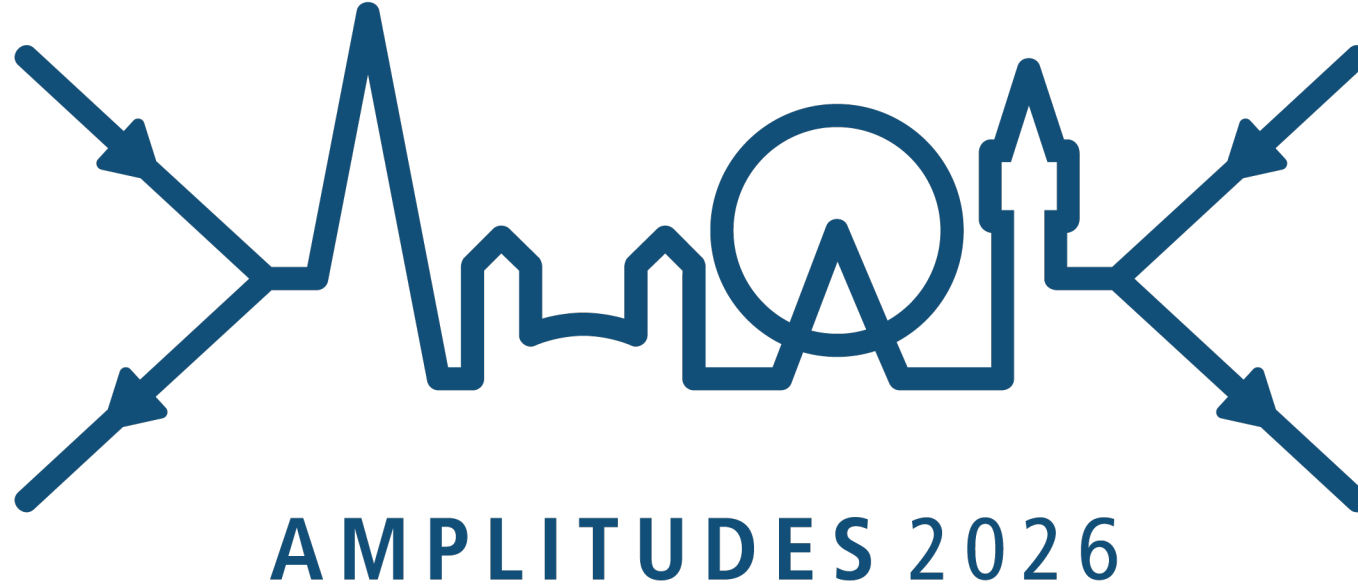
Est.
1785



SAGEX

Scattering Amplitudes:
from Geometry to Experiment

Welcome to the Gong Show: Part I



- 60-second presentation
- 10-second transition

Giuseppe De Laurentis

Next: Sebastian Pögel

ANALYTIC MULTI-LOOP HELICITY AMPLITUDES IN QCD

Giuseppe De Laurentis

The full physical information of a color-ordered helicity amplitude is in the finite remainder:

$$\mathcal{R}_{n\text{-point}}^{\ell\text{-loop}}(|i\rangle_\alpha, [i]_{\dot\alpha}) = \sum_i \mathbf{r}_i(|i\rangle_\alpha, [i]_{\dot\alpha}) \mathbf{G}_i(|i\rangle_\alpha \times [i]_{\dot\alpha}).$$

Catani ('98)
Becher, Neubert ('09)
Gardi, Magnea ('09)
Weinzierl ('11)

Challenges:

- Compute the $\mathbf{G}_i$, a basis of transcendental functions, e.g. the *Pentagon Functions*;
Chicherin, Sotnikov ('20) + Zoia ('21) + Abreu, Ita, Page, Tschernow ('23)
- Reconstruct the $\mathbf{r}_i$, functions in the field of fractions over a polynomial quotient ring,
Peraro ('16); GDL, Maitre ('19); GDL, Page ('22).

$$R_n = \mathbb{F}\left[|1\rangle_\alpha, [1]_{\dot\alpha}, \dots, |n\rangle_\alpha, [n]_{\dot\alpha}\right] / J \quad \text{with} \quad J = \text{Ideal}\left(\sum_{i=1}^n |i\rangle [i]\right),$$

in connection with algebraic geometry, and extended to massive particles (spin-spinors).

Arkani-Hamed, Huang, Huang ('17); Ochirov ('18); Shadmi, Weiss ('18); Campbell, GDL, Ellis ('25); GDL, Melnikov, Tresoldi ('26)

Amplitudes we computed: GDL + [Abreu, Campbell, Ellis, Ita, Klinkert, Kuschke, Maitre, Page, Ruf, Seth, Sotnikov, ...]

Inspire	Process	Loops	Year	Inspire	Process	Loops	Year	Inspire	Process	Loops	Year
1728738	$0 \rightarrow gggggg$	1L FC	2019	2060823	$0 \rightarrow q\bar{q}\ell\ell'\ell'g$	1L FC	2022	2915977	$q\bar{q} \rightarrow t\bar{t}H$	1L FC	2025
1779473	$pp \rightarrow Hjj$	1L FC	2020	2663067	$pp \rightarrow \gamma\gamma\gamma$	2L FC	2023	2954479	$q\bar{q} \rightarrow HHH$	1L FC	2025
1826610	$pp \rightarrow jjj$	2L LC	2020	2723256	$pp \rightarrow jjj$	2L FC	2023	3128446	$pp \rightarrow Vjj$	2L LC	2026
1861752	$pp \rightarrow W(\ell\nu)\gamma j$	1L FC	2021	2821186	$pp \rightarrow HHj$	1L FC	2024	3152032	$pp \rightarrow Hjj$	2L LC	2026
2048108	$pp \rightarrow \gamma\gamma\gamma$	2L LC	2022	2899891	$pp \rightarrow V(\ell\ell')jj$	2L LC	2025				

Least common denominator degrees of freedom $pp \rightarrow \gamma\gamma\gamma$ 30k; jjj 250k ; Vjj 25M; Hjj 80M.



Sebastian Pögel

Next: Sitender Kashyap



A Mathematica package for integrating *algebraic functions*

MATHEMATICA NATIVE · BUILT FOR FEYNMAN INTEGRALS

Ben Page and [Sebastian Pögel](#)

arXiv: 2607.xxxxx

- ◆ State-of-the-art canonical Feynman integrals generate **algebraic functions with many nested square-roots**
- ◆ Integrating these algebraic functions to logarithms is **integration on (potentially high-genus) algebraic curves**, solved by Trager's 1984 algorithm
- ◆ Trager` provides a native Mathematica implementation, **with Feynman integrals in mind**

EXAMPLE OF AN INTEGRAND MATHEMATICA CANNOT HANDLE

$$\int dx \frac{8 \left(4x^4 + 7x^3 + 2 + 3x^2 \sqrt{x^4 + 2x^3 + 1} \right)}{\sqrt{x^4 + 2x^3 + 1} \sqrt{3x^2 + 4\sqrt{x^4 + 2x^3 + 1}} \left(3x^4 + 4x^2 \sqrt{x^4 + 2x^3 + 1} - 4 \right)}$$

▼ Trager`

$$= \log \left(\frac{2 - x \sqrt{3x^2 + 4\sqrt{x^4 + 2x^3 + 1}}}{2 + x \sqrt{3x^2 + 4\sqrt{x^4 + 2x^3 + 1}}} \right)$$

✓ Trager`

proves it is a logarithm, and returns the closed form

$\mathbb{Q}$ RUNTIME, OVER RATIONALS **1.2s**

$\mathbb{F}_{2^{31}-1}$ RUNTIME, OVER A FINITE FIELD **0.8s**

✗ Mathematica · Integrate returns it unevaluated

HANDLES

- Arbitrary algebraic curves of any genus
- Any set of roots, including several nested square-roots
- Much more complicated integrands

BUILT IN

- Proves whether or not an algebraic function integrates to a logarithm
- Automatic functional reconstruction in free parameters

VERIFIED ON

- Algebraic letters of frontier amplitudes:
 $t\bar{t} + H$ production **2312.08131**
 $t\bar{t} + j$ production **2503.03603**

Sitender Kashyap

Next: Paul-Hermann Balduf

A novel field theory derivation of string amplitudes

The problem: String amplitudes as moduli-space integrals hide factorization and blow up in physical kinematics.

Our solution: A new field-theory like prescription that makes all channels manifest and converges in kinematic regions.

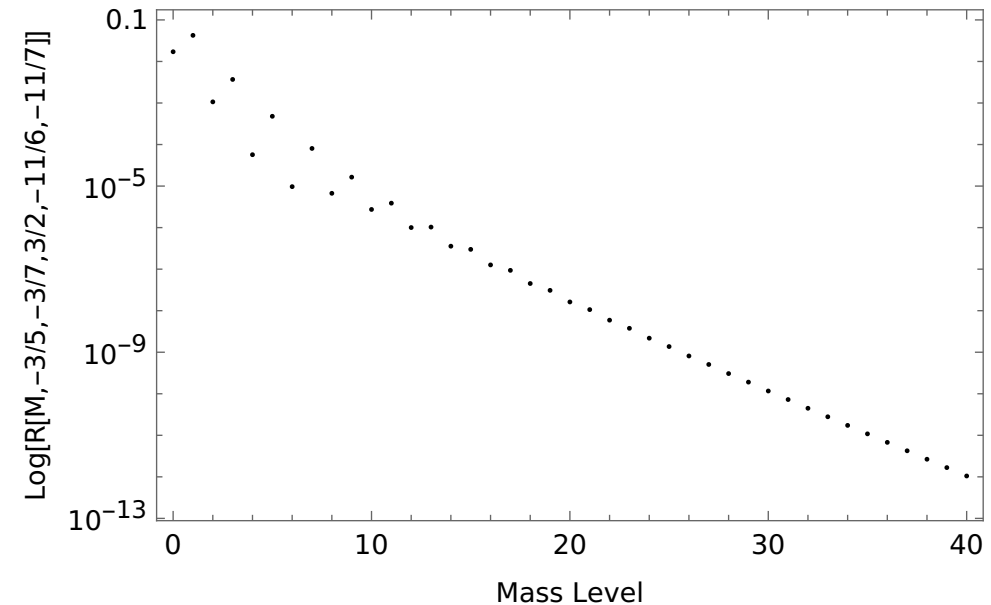
e.g. five-point tachyon open string amplitude is

$$A_5 = \frac{1}{\ell_0(\lambda_2)} \frac{1}{\ell_0(\lambda_1)} (\lambda_1)^{s_{12}-1} (\lambda_2)^{s_{123}-1} \left(1 + \frac{\lambda_1}{2}\right)^{1+s_{123}-s_{12}-s_{23}} \\ \left(1 - \frac{\lambda_1}{2}\right)^{s_{23}-2} \left(1 - \frac{\lambda_2}{2}\right)^{s_{34}-2} \left(1 + \frac{\lambda_2}{2} (1 + \lambda_1)\right)^{1+s_{23}-s_{123}-s_{234}} \\ \left(1 + \frac{\lambda_2}{2} (1 - \lambda_1)\right)^{1+s_{234}-s_{23}-s_{34}} + \text{four more such terms}$$

$s_{12}, s_{23}, s_{34}, s_{123}, s_{234}$ are the Mandelstam variables.

λ_1 and λ_2 are parameters separating the vertex operators.

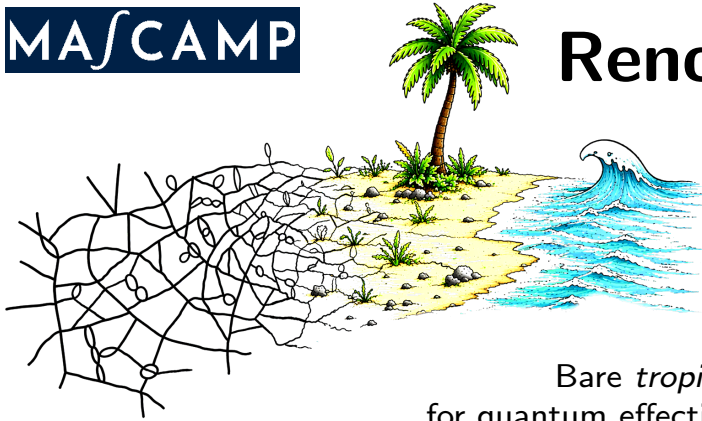
The following graph shows difference with the general result obtained by Nima et. al. as we include more string states.



For details watch out for our upcoming work!

Paul-Hermann Balduf

Next: Mattias Sjö



Renormalized tropical field theory

Bare tropical loop equation
for quantum effective potential $\mathcal{G}$ of
 $O(N)$ -symmetric ϕ^4 theory [Borinsky 2025; B, Panzer 2025]:

$$(2\epsilon\lambda\partial_\lambda + (1-\epsilon)\varphi\partial_\varphi + 2\kappa\partial_\kappa - (4-2\epsilon))\mathcal{G} = \varphi^2 - \frac{1}{\partial_\varphi^2 \mathcal{G}} - \frac{(N-1)\varphi}{\partial_\varphi \mathcal{G}} - N.$$

Have only *logarithmic* UV (sub) divergences.

$\Rightarrow$ conventional multiplicative renormalization of mass and coupling $\lambda =: \mu_0^{2\epsilon} \cdot g \cdot Z_g(g, \epsilon)$. RG functions $\beta(g, \epsilon) := \mu_0 \frac{\partial}{\partial \mu_0} g$,

$$2\epsilon\lambda\partial_\lambda \mapsto -\beta\partial_g, \quad 2\kappa\partial_\kappa \mapsto (2 + \gamma_m)m^2\partial_{m^2}.$$

Use Callan-Symanzik equation with *scale* variable $t := \log\left(\frac{\mu_0}{\mu}\right)$.

$$\partial_t \mathcal{G}_{\mathcal{R}} = -(1-\epsilon)\varphi\partial_\varphi \mathcal{G}_{\mathcal{R}} + 2m^2\partial_{m^2} \mathcal{G}_{\mathcal{R}} - (4-2\epsilon)\mathcal{G}_{\mathcal{R}} - \frac{1}{\partial_\varphi^2 \mathcal{G}_{\mathcal{R}}} - \frac{(N-1)\varphi}{\partial_\varphi \mathcal{G}_{\mathcal{R}}} + \varphi^2 - N.$$

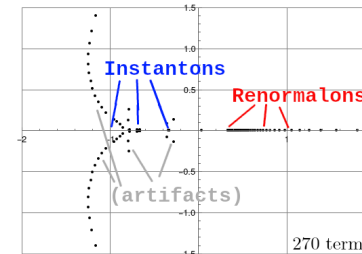
$\Rightarrow$ "Static" version of tropical field theory equals the *local potential approximation* of the functional renormalization group [Nicoll et al 1976, Tokar 1984, Felder 1987, Wetterich 1993, Zumbach 1994, ...].

Solve TLE in power series in g, φ, m^2 . All coefficients are rational. Obtain power series to loop order $\ell \leq 400$.

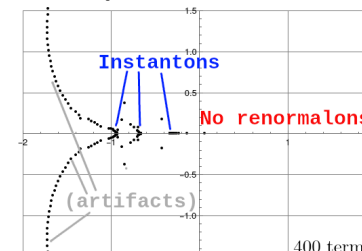
Analyze *large-order behaviour* of perturbation theory:
Measure growth rate, compute Borel transform, ...

E.g. for β -function at $\epsilon = 0$:

Borel plane in MOM scheme



Borel plane in MS scheme



Compare literature expectations for Borel plane

[Beneke 1999]

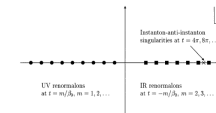


Fig. 3. Singularities in the Borel plane of HQ^2 , the current-current correlation function in QCD. Shown are the singular points, but not the cuts attached to each of them. Recall that $\beta_0 < 0$ according to Eq. (2.18).

[t Hooft 1977]

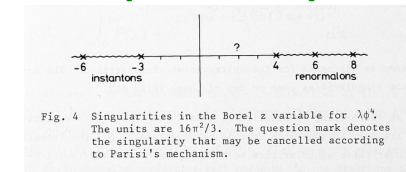


Fig. 4. Singularities in the Borel z variable for λ_0^4 . The units are $16\pi^2/3$. The question mark denotes the singularity that may be cancelled according to Parisi's mechanism.

Mattias Sjö

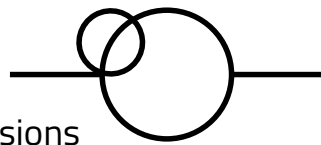
Next: Chia-Kai Kuo

..... A Happy Family of Massive 3-loop Master Integrals

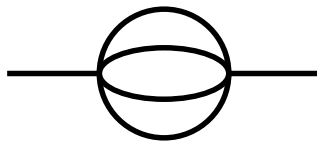
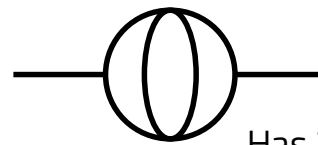
Mattias Sjö · CPT Marseille

(see also Pierre Vanhove's talk)

$\mathcal{I}_{\oplus}$ in $4 - 2\epsilon$ dimensions
 $\sim \mathcal{I}_{\ominus}$ in 2 dimensions
 via Tarasov's relations
 Tarasov [hep-th/9606018]

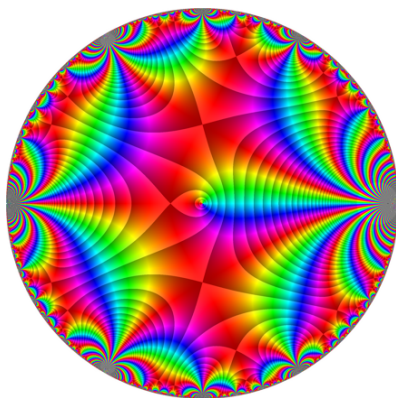


Has 2nd-order differential relation
 $\Delta \mathcal{I}_{\oplus} = \Delta' \mathcal{I}_{\ominus}$
 Precisely numerically solvable
 Lellouch, Lupo, Sjö & Vanhove
 [2603.15252]

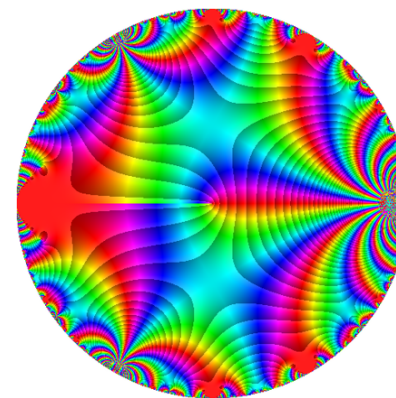


K3 surface magic gives closed-form solution
 in terms of elliptic polylogs
 Bloch, Kerr & Vanhove [1406.2664]

$t(q) =$
 phase space $t \in \mathbb{C}$
 nome $q \in \mathbb{D}$



$= \mathcal{I}_{\ominus}[t(q)]$
 in 2 dimensions

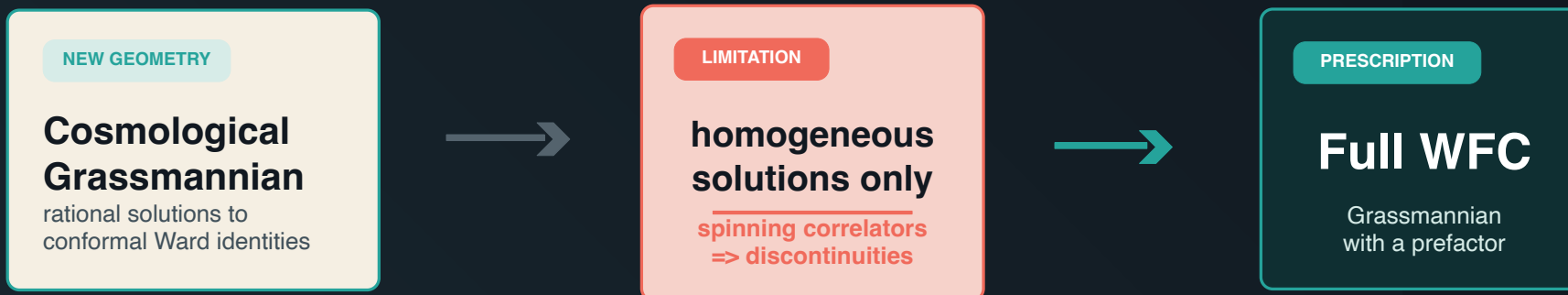


Chia-Kai Kuo

Next: Giacomo Brunello



A prefactor takes the cosmological Grassmannian from cuts to the full susy wavefunction



TWO CHECKS IN THE TALK

3pt

prefactor fixed explicitly

first proof of concept for the full wavefunction

4pt +++++

matches full WFC

same prescription works beyond three points

Giacomo Brunello

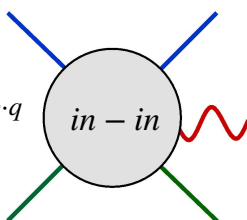
Next: Sven Stawinski

Analytic Gravitational Waveforms and Fourier Integrals

Giacomo Brunello G.B., De Angelis, Kosower [2511.05412]

PROBLEM

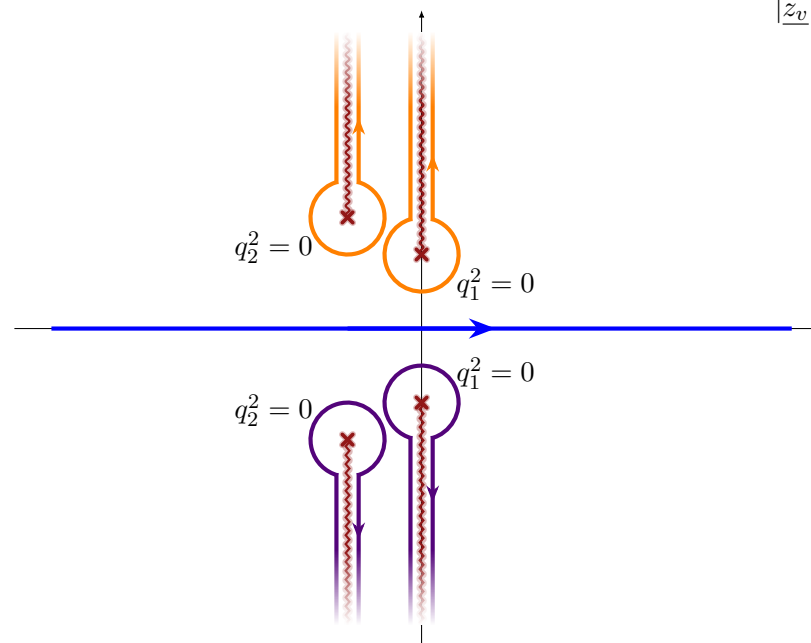
Waveforms are
Fourier transform of
scattering amplitudes

$$\mathcal{W}_h(\omega, \mathbf{n}) \propto \int d\mu e^{ib \cdot q} \text{in-in}$$


Fourier integrals are the
bottleneck!

SOLUTION

Treat the Fourier transform as a loop integral $|z_v$

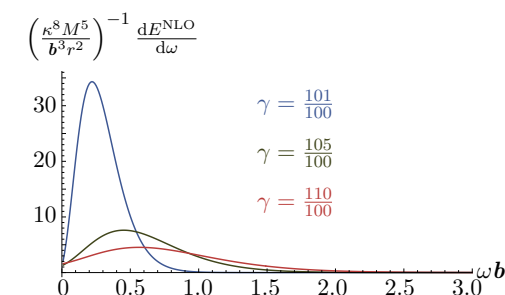


Fourier-loop IBPs + contour deformation

RESULT

28 fast-converging
1D integrals

$$J_i \sim \int_{-\infty}^{+\infty} e^{-i z_b \sqrt{-b^2}} F_i(z_b)$$



Analytic NLO waveform

$\mathcal{O}(G^4)$ power spectrum

Multi-loop technology for Fourier Integrals

Sven Stawinski

Next: Giulio Crisanti



Counting Master Integrals with Symmetries

Sven F. Stawinski - University of Bonn



[Based on 2604.08332 with C. Duhr, S. Maggio and C. Semper]

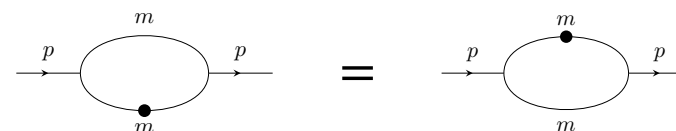
Number of master integrals in sector (only IBP):

[Lee, Pomeransky '13]

[Bitoun, Bogner, Clausen, Panzer '17]

$$N_{\Theta} = |\chi(X)| \longrightarrow \# \text{Solutions of } \text{dlog} \mathcal{G}(x) = 0$$

But there might be symmetry relations:



Refined formula:

[Duhr, Maggio, Semper, SFS '26]

$$N_{\Theta} = \frac{1}{|G|} \sum_{\sigma \in G} |\chi(X_{\sigma})|$$

Restricted to linear subspace

#Solutions of $\text{dlog} \mathcal{G}(y_{\sigma}) = 0$

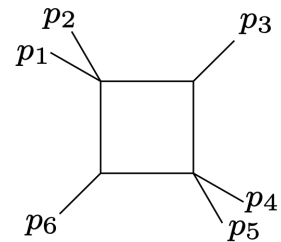
Symmetry group

Giulio Crisanti

Next: He-Chen Weng

Reconstructing Landau Singularities over Finite Fields

What is a Landau Singularity?



$$= \frac{2}{\epsilon^2} \left((-s_{345})^{-\epsilon} + (-s_{123})^{-\epsilon} + (-s_{12})^{-\epsilon} + (-s_{45})^{-\epsilon} \right)$$

$$= -2\text{Li}_2 \left(1 - \frac{s_{12}}{s_{345}} \right) - 2\text{Li}_2 \left(1 - \frac{s_{12}}{s_{123}} \right) - 2\text{Li}_2 \left(1 - \frac{s_{45}}{s_{345}} \right)$$

$$- 2\text{Li}_2 \left(1 - \frac{s_{45}}{s_{123}} \right) + 2\text{Li}_2 \left(1 - \frac{s_{12}s_{45}}{s_{345}s_{123}} \right) - \ln^2 \left(\frac{-s_{345}}{-s_{123}} \right) + \mathcal{O}(\epsilon)$$

Branch structure

[Abreu, Berghoff, Bourjaily, Britto, Chestnov, Crisanti, Correia, Duhr, Fevola, Gardi, Giroux, Hannesdottir, Helmer, McLeod, Mizera, Panzer, Papathanasiou, Schwartz, Teller, Telen, Vergu, 2017-2026]

Why are they useful?

Lots of things! : symbol alphabet / integration by parts / differential equations / amplitude bootstrap

[Barrera, Carrôlo, Chicherin, Coro, Correia, Dersy, Giroux, Hannesdottir, Henn, Husain, McLeod, Mizera, Novichkov, Page, Schwartz, Song, Vergu, Yang, Zhang, Zhang, ...]

A new method to find all Landau singularities

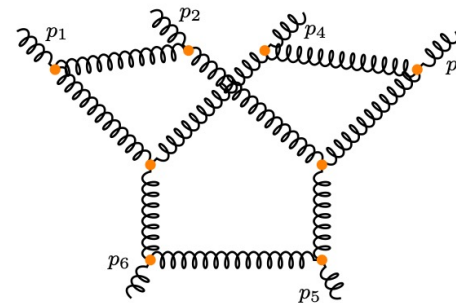
Use the Euler characteristic to detect topological changes:

[Fevola, Matsubara-Heo, Mizera, Telen]

$$\chi|_{l(s)=0} < \chi \iff l(s) \text{ is a Landau singularity}$$

Use elimination over finite fields to solve the resulting systems of equations

Example:



Found many new singularities

Includes an insane 100million+ length polynomial of degree ~40

He-Chen Weng

Next: Sid Smith

Cosmological Wavefunction from Quadrangular Polylogarithms

He-Chen Weng, Brown University (**On the postdoc job market!**)

With Livia Ferro, Tomasz Łukowski, Lecheng Ren, Marcus Spradlin, Anastasia Volovich and Yao-Qi Zhang [2605.06542]

Ongoing work with the above plus Mattia Capuano, Alessandro Palazio and Shruti Paranjape

Key idea:

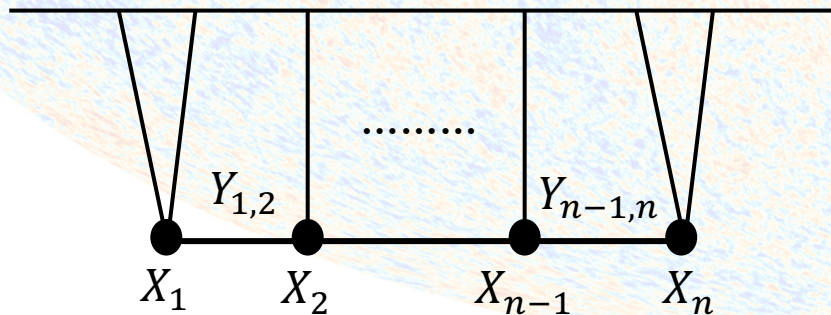
We use quadrangular polylogarithms (QLi) to make **global cluster compatibility** manifest.

[Matveikin, Rudenko, '22]

[Capuano, Ferro, Łukowski, Palazio, Zhang, '26]

n-chains in dS [See Mark's talk]:

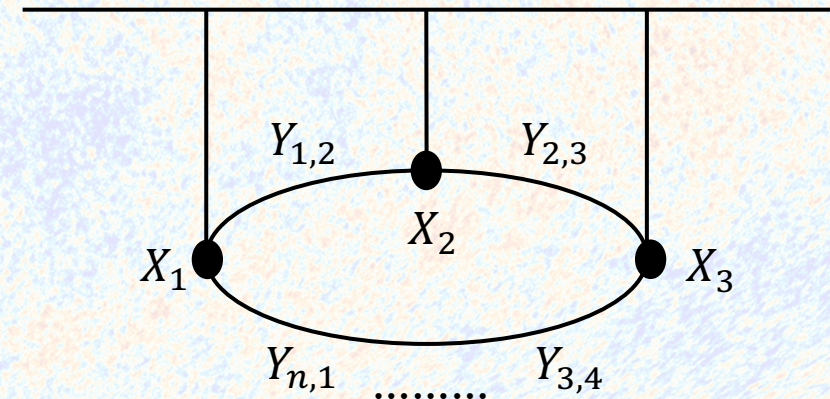
A closed function-level QLi formula for all n-site chain wavefunction coefficients.



n-gons in dS [WIP]:

Conjecture: n-gon wavefunction coefficients admit a QLi representation in B-type cluster coordinates.

[Paranjape, Skowronek, Spradlin, Volovich, Weng, '26]



n-chains in FRW [WIP]:

Expansion around de Sitter using QLi functions.

$$\psi_{n\text{-chain}}^{\text{FRW}}(\varepsilon) = \psi_n^{\text{dS}} + \varepsilon \psi_n^{(1)} + \varepsilon^2 \psi_n^{(2)} + \mathcal{O}(\varepsilon^3)$$

Sid Smith

Next: Yu-Ping Wang

Magic Relations and Critical Varieties of Feynman Integrals

Sid Smith

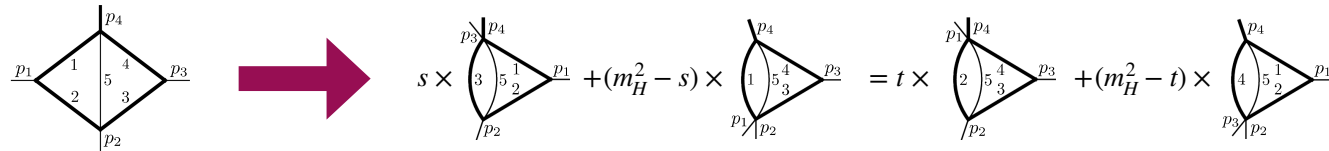
University of Padova, University of Edinburgh, INFN

with Giulio Crisanti, Hjalte Frellesvig & Andrzej Pokraka [2605.29789]



Magic relations

1. The generating sector cannot appear in the identity, only its subsectors can appear.
2. It cannot be obtained by combining IBPs generated in the subsectors themselves.



Key observation

A sector S generates a magic relation $\Leftrightarrow S$ has a higher dimensional critical variety.

A sector S has only zero dimensional critical varieties $\Rightarrow S$ cannot generate a magic relation



$$\{\text{magic relations}\} \subseteq \{\text{non-trivial syzygies}\} = H_K^{n-1}$$

$$H_K^p(X; \omega) := \frac{\{\text{Closed forms on } \Omega^p(X)\}}{\{\text{Exact forms on } \Omega^p(X)\}}$$



$$I := \langle \partial_1 \mathcal{G}, \dots, \partial_n \mathcal{G}, 1 - x_0 \mathcal{G} \rangle$$



Yu-Ping Wang

Next: Marcos Skowronek Santos

Chiral Strings: gravity amplitudes from a twisted worldsheet

Triple product amplitude from chiral string — Yu-Ping Wang, JHEP 12 (2024) 112

1. **Punch line:** Tree graviton amplitudes can be *directly* built from the worldsheet integrals.
2. **Main idea:** Momenta split to left and right moving parts
3. **Intuition:**
 $\sin(\pi s)A(s, t)A(s, u) \Rightarrow \sin(\pi s)A(s, t)A(-s, -u)$
 $\Rightarrow$ massive pole cancels.
4. Vertex operators pick up **monodromy** $\Rightarrow$ ends of **defects**.
5. Consistency = **section conditions**: *Standard* (without monodromy) vs. *Twisted* (with monodromy).
6. N -point from a **modified KLT** $\Rightarrow$ **The crossing symmetry still holds!**
7. Every 4-point amplitudes factorizes to **triple product**.
8. **Unitarity & Regge** $\Rightarrow$ Graviton, Virasoro–Shapiro, and a infinite spin-tower from bootstrap

The twist

$$e^{ik \cdot X} \Rightarrow e^{ik_L \cdot X_L + ik_R \cdot X_R}$$

Section conditions

$$k_R \cdot k'_R \pm k_L \cdot k'_L = 2n$$

(+ standard – twisted)

Triple product

$$M(s, t, u) = K F(s) F(t) F(u)$$

$$\text{IFT: } \frac{W_4}{s(s-1)t(t-1)u(u-1)}$$

Marcos Skowronek Santos

Next: Saurabh Pant

Hydrogen-like degeneracy in Quantum Gravity

Marcos Skowronek (Brown University)

Work with with Callum R. T. Jones, Shruti Paranjape

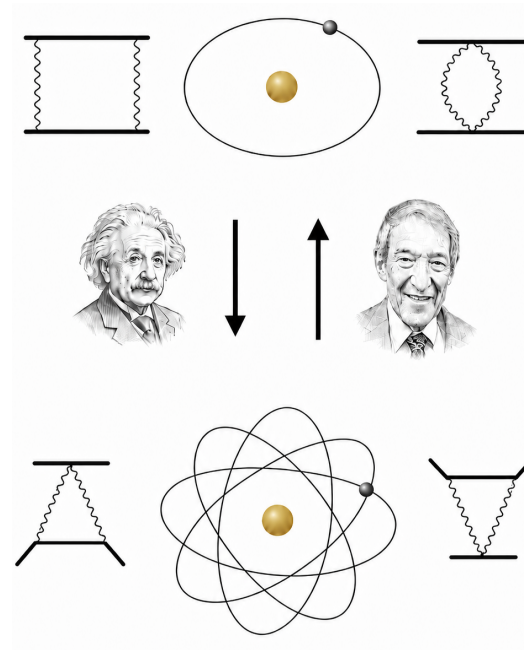
Hidden symmetry: LRL vector $\vec{A}$ is conserved for a $1/r$ potential.

- Classical: orbits remain closed ellipses.
- Quantum: degenerate energy levels for bound states.

Relativistic corrections break this symmetry, but in some special theories (like planar $\mathcal{N} = 4$ SYM) it is recovered. What are the conditions for a generic EFT?

Strong constraints as soon as you introduce gravity $\rightarrow$ need SUSY, $\mathcal{N} = 6$ supergravity?

$$V(r) \supset \frac{4G^2 m_1^2 m_2^2 \sigma^5 \operatorname{arcsinh}\left(\sqrt{\frac{\sigma-1}{2}}\right)}{\pi r^3 E_1 E_2 (\sigma^2 - 1)^{3/2}} (\mathcal{N} - 6).$$



Saurabh Pant

Next: Toni Teschke

The Planck-Suppressed Neighbourhood of Supergravity

Positivity bounds for massive spin-3/2 EFTs

Question: How far can a consistent massive spin-3/2 EFT deviate from the N=1 supergravity point?

Previous work: Bellazzini, Pomarol, Romano, Sciotti (arXiv:2507.12535) developed the finite-mass dispersive framework and showed positivity fixes the leading-order couplings to the N=1 SUGRA point.

This work

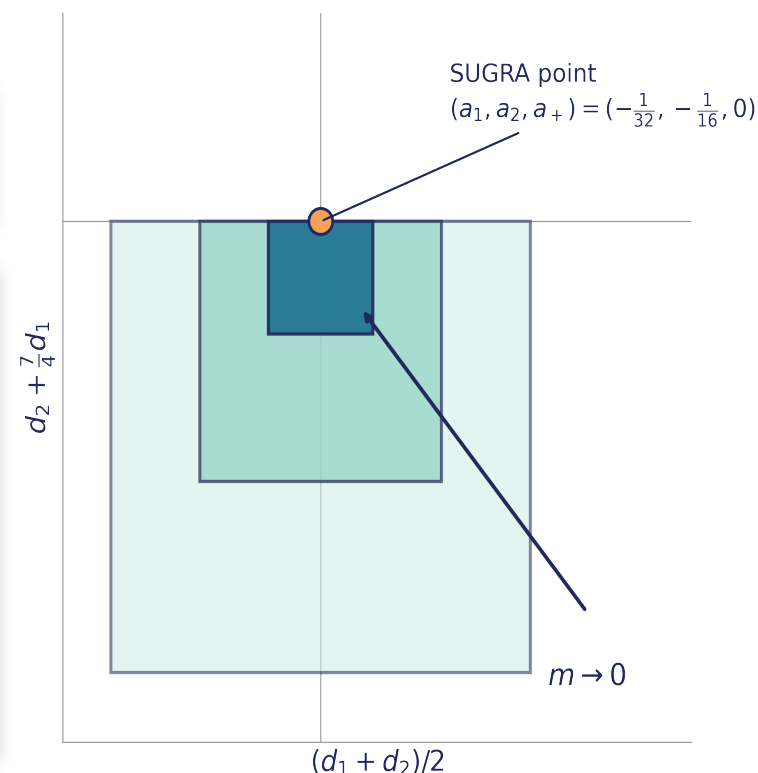
- Determine the finite-mass positivity region around the SUGRA point
- The SUGRA point lies on the boundary of a bounded allowed region
- As $m \rightarrow 0$, the allowed region collapses onto the SUGRA point

$$\text{Vol}_{\text{allowed}} \sim \left(\frac{m}{M_{\text{Pl}}} \right)^6 \rightarrow 0 \text{ as } m \rightarrow 0$$

- Only Planck-suppressed deviations from SUGRA are allowed

Positivity determines not only the SUGRA point, but the size of its EFT neighbourhood.

EFT neighbourhood of SUGRA



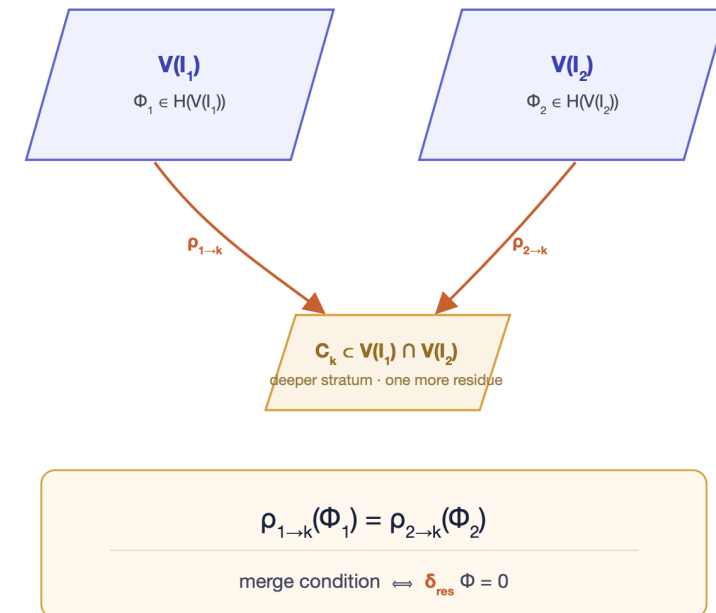
Toni Teschke

Next: Samim Akhtar

The cohomology of geometric master-integral reduction

- Geometric reduction for ε -factorisation builds local master integrands on branches, $\Phi_i \in H(V(I_i))$.
- The merge condition is a cocycle condition:

$$\rho_{i \rightarrow k}(\Phi_i) = \rho_{j \rightarrow k}(\Phi_j) \iff \delta_{\text{res}} \Phi = 0.$$
- The complex has two differentials: ∇_F and δ_{res} .
- Total cohomology quotients by $\nabla_F \Lambda$ and $\delta_{\text{res}} \Lambda$.
- Insight into master-integral reduction and towards a proof of ε -factorisation.



Samim Akhtar

Next: Iris Bree

Large Deflection Scattering, Soft Radiation & KMOC Formalism

Samim Akhtar

ICTP-SAIFR / IFT-UNESP, São Paulo

arXiv: 2511.17204

accepted in JHEP

SA, Laddha, Manna, Manu

MOTIVATION

KMOC: inclusive observables from on-shell amplitudes. Classical limit requires small exchange momenta — requiring the **Goldilocks zone**:

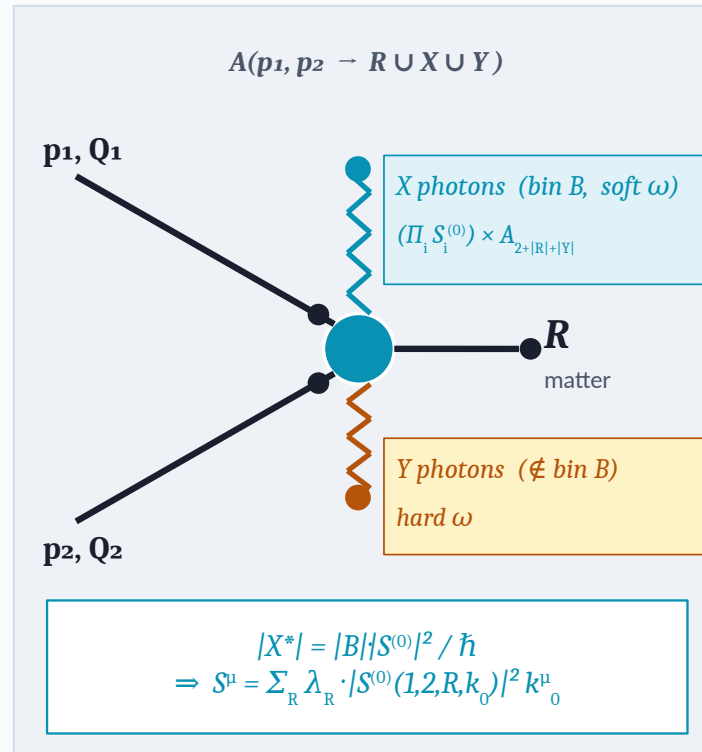
$$l_c \ll l_w \ll \sqrt{-b^2}$$

large b , perturbative PM/PL — memory only computed perturbatively

QUESTION

Can soft radiation (memory) be computed as an inclusive observable — **irrespective of the details of the hard scattering**?

Key: Memory exact to all orders in PM/PL — tied to non-pert. soft theorems.



✓ EM MEMORY

Soft factorization is sufficient to compute EM memory irrespective of the hard scattering. The number $|X|$ is extremised — not fixed perturbatively.

$$S^\mu = \sum_R \lambda_R \cdot |S^{(0)}(1, 2, R, k_0)|^2 k_0^\mu$$

GRAVITY

Soft grav. radiation is computable as inclusive observable. But $Y \notin B$ gravitons still enter $S^{(0)}$, sourcing **non-linear (Christodoulou) memory**. Recovering the classical soft graviton theorem requires inelastic amplitude data.

Outlook: log soft (tail) sector — non-pert. constraints on S-matrix.

Iris Bree

Next: Thomas Stone

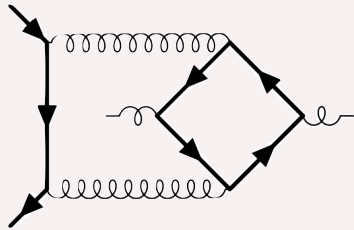
GLITTER^{✴✴✴}

Iris Bree, Stefan Weinzierl

GEOMETRIC LOOP INTEGRAL TOOL FOR TWISTED ϵ -FACTORIZATION AND REDUCTION

INPUT

- Feynman Integral family definition



ALGORITHM

[2506.09124], [2511.15381]

1. **IBPs** in Baikov representation
 - Laporta algorithm with **geometric** ordering criteria

2. **Transcendental** gauge transformation

OUTPUT

- DEqs in **Laurent** form

$$dJ = \left(\frac{1}{\epsilon} \left(\begin{array}{|c|} \hline \text{red} \\ \hline \end{array} \right) + \left(\begin{array}{|c|c|} \hline \text{blue} & \text{blue} \\ \hline \end{array} \right) + \epsilon \left(\begin{array}{|c|c|} \hline \text{green} & \text{green} \\ \hline \end{array} \right) \right) J$$

- DEqs in **ϵ -factorized** form

$$dK = \epsilon \left(\begin{array}{|c|c|} \hline \text{pink} & \text{pink} \\ \hline \end{array} \right) K$$

wip
open source **C++**
implementation

Thomas Stone

Next: Jonah Berean-Dutcher

Core idea: *suppressing numerators*, $N(t)$

Goal: $I = \int_0^1 f(t) dt$ to high precision

$$I(n) = \int_0^1 N(t)^n f(t) dt \xrightarrow{n \rightarrow \infty} 0$$

$$\stackrel{\text{IBP}}{=} C_i^{(n)} I + \sum_i C_i^{(n)} M_i$$

$$\Rightarrow I \stackrel{n \gg 1}{\approx} \sum_i R_i^{(n)} M_i \quad \text{“simpler” } M_i$$

Toy example: *estimating $\ln 2$* [Apéry, Brown, ...]

$$I(n) = \int_0^1 [t(1-t)]^n \frac{1}{1+t} dt \xrightarrow{n \rightarrow \infty} 0$$

$$\stackrel{\text{IBP}}{=} A^{(n)} \ln 2 + B^{(n)} \quad A^{(n)}, B^{(n)} \in \mathbb{Q}$$

$$\Rightarrow \ln 2 \stackrel{n \gg 1}{\approx} -\frac{B^{(n)}}{A^{(n)}} \quad \text{with error} \sim 2^{-2n}$$

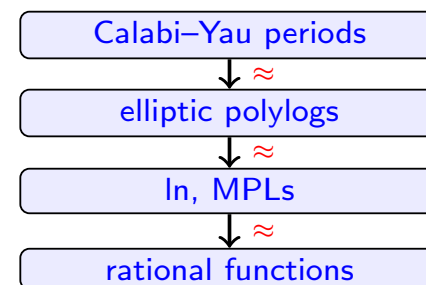
A non-trivial generalisation: *estimating elliptic $K(\lambda)$*

$$I(n) = \int_0^1 \frac{[t(1-t)]^n}{\sqrt{\sqrt{(1-t^2)(1-\lambda t^2)}}} dt \xrightarrow{n \rightarrow \infty} 0$$

$$\Rightarrow I(0) = K(\lambda) \stackrel{n \gg 1}{\approx} \frac{1}{2\sqrt{\lambda}} \ln \left[\frac{1+\sqrt{\lambda}}{1-\sqrt{\lambda}} \right] R_1^n(\lambda) + R_2^n(\lambda)$$

Estimates $K(\lambda)$ correctly to **100+ digits** for high n

Hierarchical reduction



Applications: MPLs, eMPLs, higher-genus integrals, Calabi-Yau periods, *Feynman integrals*...and more?

Jonah Berean-Dutcher

Next: Facundo Emanuel Rost

Subleading soft theorems run in EFT.

(for soft photons and double-soft pions)

universally predicted by EFT

↓

$$\lim_{p \rightarrow 0} \mathcal{A}_{n+1} = \left(\underset{\substack{\uparrow \\ \text{universal at lowest order} \\ \text{in EFT}}}{S^{(0)}} + p \log \left(\frac{p}{Q} \right) S_{\log}^{(1)} + p \underset{\substack{\uparrow \\ \text{non-universal, sensitive to UV} \\ \text{description}}}{S_{\text{finite}}^{(1)}} \right) \mathcal{A}_n$$

Jonah Berean-Dutcher
w/ M. Derda and R. Stewart



THE UNIVERSITY OF BRITISH COLUMBIA



Facundo Emanuel Rost

Next: Dmytro Melnichenko

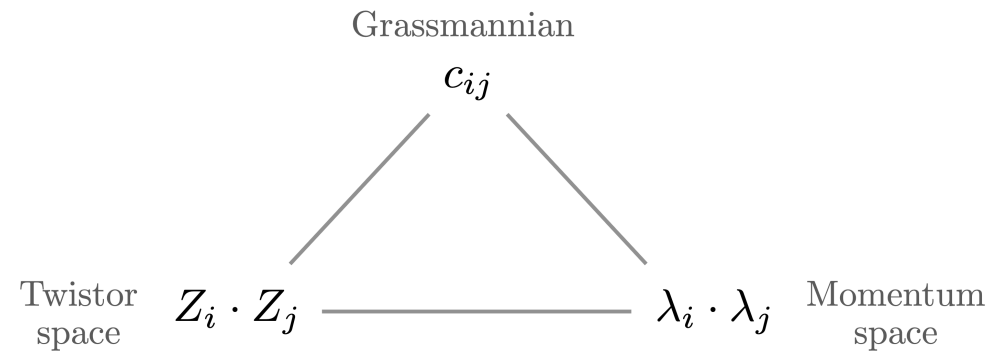
More on the Cosmological Grassmannian

Facundo Rost - Scuola Normale Superiore

- **Challenge:** Cosmological correlators are hard

- **Goal:** Simplify them!

- **Result:** Cosmological Grassmannian



- **Outlook:** Higher points, positive geometries, loops, and much more!

Dmytro Melnichenko

Next: Maria Polackova

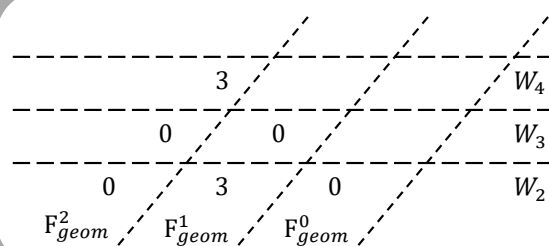
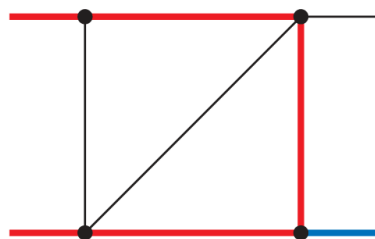
Applications of the Algorithm

[2511.15381: ϵ -collaboration], [2506.09124: ϵ -collaboration]

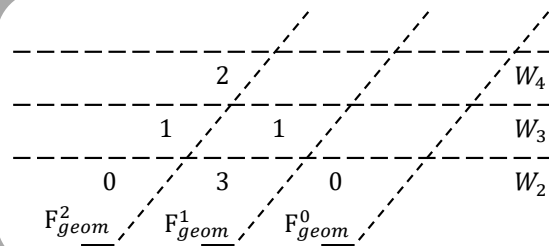
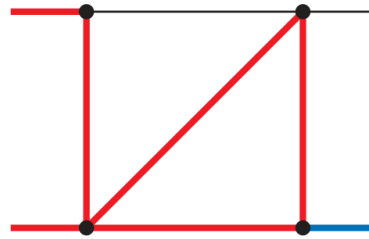
Talk by I. Bree

$(e^- e^+ \rightarrow \gamma \gamma^*)$ – wip with T. Dave, A. Matijasic, P. Petit Rosàs, M. Pozzoli, W. Torres Bobadilla, S. Weinzierl

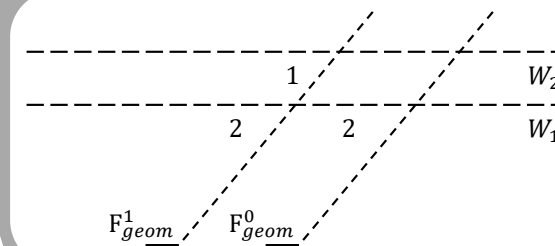
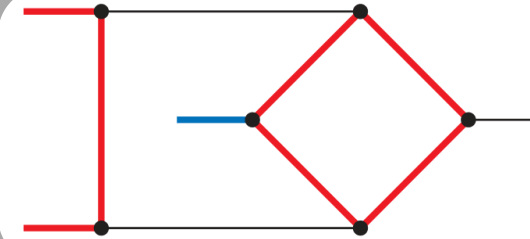
Polylog



Elliptic



Genus 2



First step of the Algorithm provides a “good basis” that casts the DEQ in a Laurent series in ϵ

This allows for evaluation with semi-analytical tools

Dmytro Melnichenko

JOHANNES GUTENBERG
UNIVERSITÄT MAINZ



Maria Polackova

Next: Pablo Vives Matasan

Advances in Landau Bootstrap

Maria Polackova

University of Edinburgh

with P. Bargiela, G. Crisanti, C. Larkin, L. Lippstreu, A. J. McLeod & L. Walsh

We focus on finding missing constraints on symbol Ansatz:

$$S = \sum c_{k_1 \dots k_n} a_{k_1} \otimes \dots \otimes a_{k_n}$$

and finding all coefficients $c_{k_1 \dots k_n}$.

Main tool → sequence of disc's ^{1,2,3,4}:

$$\text{Disc}_{a_{k_j}} \text{Disc}_{a_{k_i}} S = 0$$

Here, we present new constraints and applications.

Non-Repeating letters^{2,3}

Genealogical constraints can be used to identify discontinuities that can never repeat resulting in a constraint of the type:

$$\dots \otimes a_{N-R} \otimes \dots \otimes a_{N-R} \otimes \dots \quad \times$$

Genealogical constraints further imply that **N-R** letters appear only as log branch cuts:

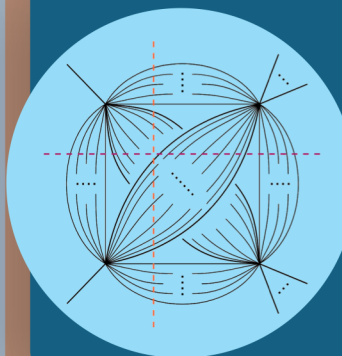
$$\dots \otimes a\left(\sqrt{b_{N-R}}\right) \otimes \dots \quad \times$$

Lefschetz thimble uniqueness³

Picard–Lefschetz formula can be used to restrict the Ansatz if we identify a letter whose Euler characteristic drops by one. Then the constraint is of the type:

$$\dots \otimes a_{LT} \otimes \text{fixed pattern} \quad \nabla$$

Steinmann relation violations^{3,4}



We can now identify Steinmann violations in overlapping two-particle momentum channels of one- and two-loop Feynman diagrams simply by drawing minimal cuts

Applications to Euler Integrals²

Genealogical constraints can be applied to broader classes of Euler integrals, such as cosmological correlators and Feynman integrals involving elliptic curves.

[1] H. Hannesdottir, L. Lippstreu, A. J. McLeod, MP (2024)

[2] G. Crisanti, L. Lippstreu, A. J. McLeod, MP (to appear 2026)

[3] P. Bargiela, G. Crisanti, C. Larkin, L. Lippstreu, A. J. McLeod, MP, L. Walsh (to appear 2026)

[4] H. Hannesdottir, L. Lippstreu, A. J. McLeod, MP (2025)

Pablo Vives Matasan

Next: Giorgio Pizzolo

Radiation Reaction of Spinning Particles in EM & GR

Based on ongoing work with Dogan Akpinar, Asaad Elkhidir, and Matteo Sergola

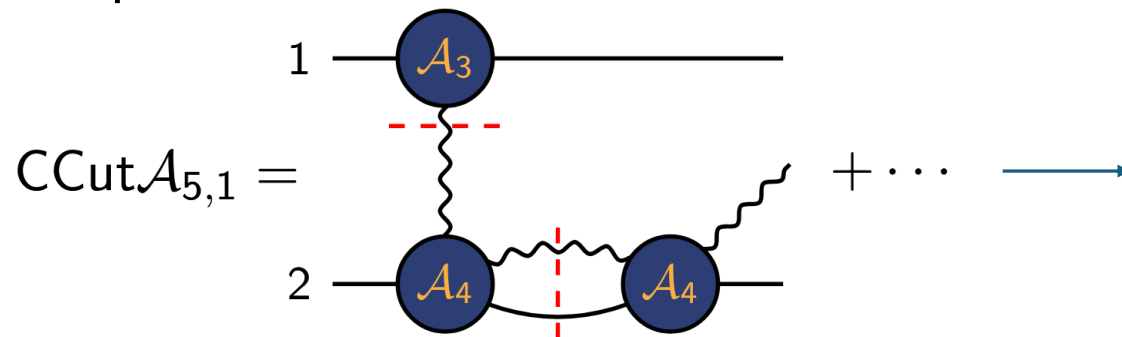
► Classically...

$$F_{\mu\nu}(0) = ie \int \hat{d}^D k \int_{-\infty}^0 d\tau e^{ik \cdot r(\tau)} \frac{k_{[\mu} u_{\nu]}(\tau)}{k^2 + i\epsilon k^0}$$

$$u^\mu(\tau) = u^\mu + a^\mu \tau + \frac{1}{2} \dot{a}^\mu \tau^2 + \dots$$

$$\frac{dp^\mu}{d\tau} = e F^{\mu\nu} p_\nu + \dots \longrightarrow \frac{e^2}{6\pi} \dot{a}^\mu + \dots \quad \left. \vphantom{\frac{dp^\mu}{d\tau}} \right\} \longrightarrow \text{ALD force + spinning corrections}$$

► Amplitudes...



Spinning radiation reaction
corrections to the waveform

Giorgio Pizzolo

Next: Iustin Surubaru

Edge Modes from Loop Groups at $\mathcal{I}$

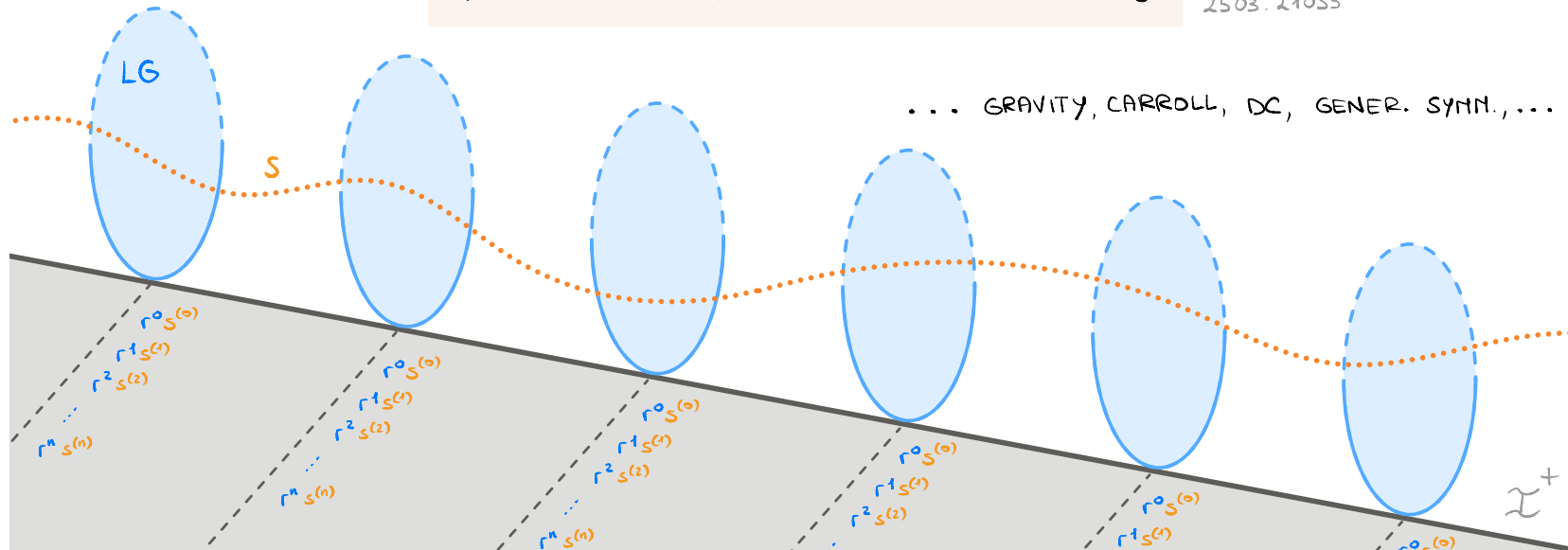
Giorgio Pizzolo ~  Durham U.

$\Rightarrow$ ALL SUBⁿ-LEADING SOFT CHARGES FOR YM

2606.XXXXX 2407.13556
2509.08725 2405.06629

$\Rightarrow$ NEW STRICT KINEMATIC ALGEBRAS AT $\mathcal{I}$

2607.XXXXX
2503.21035

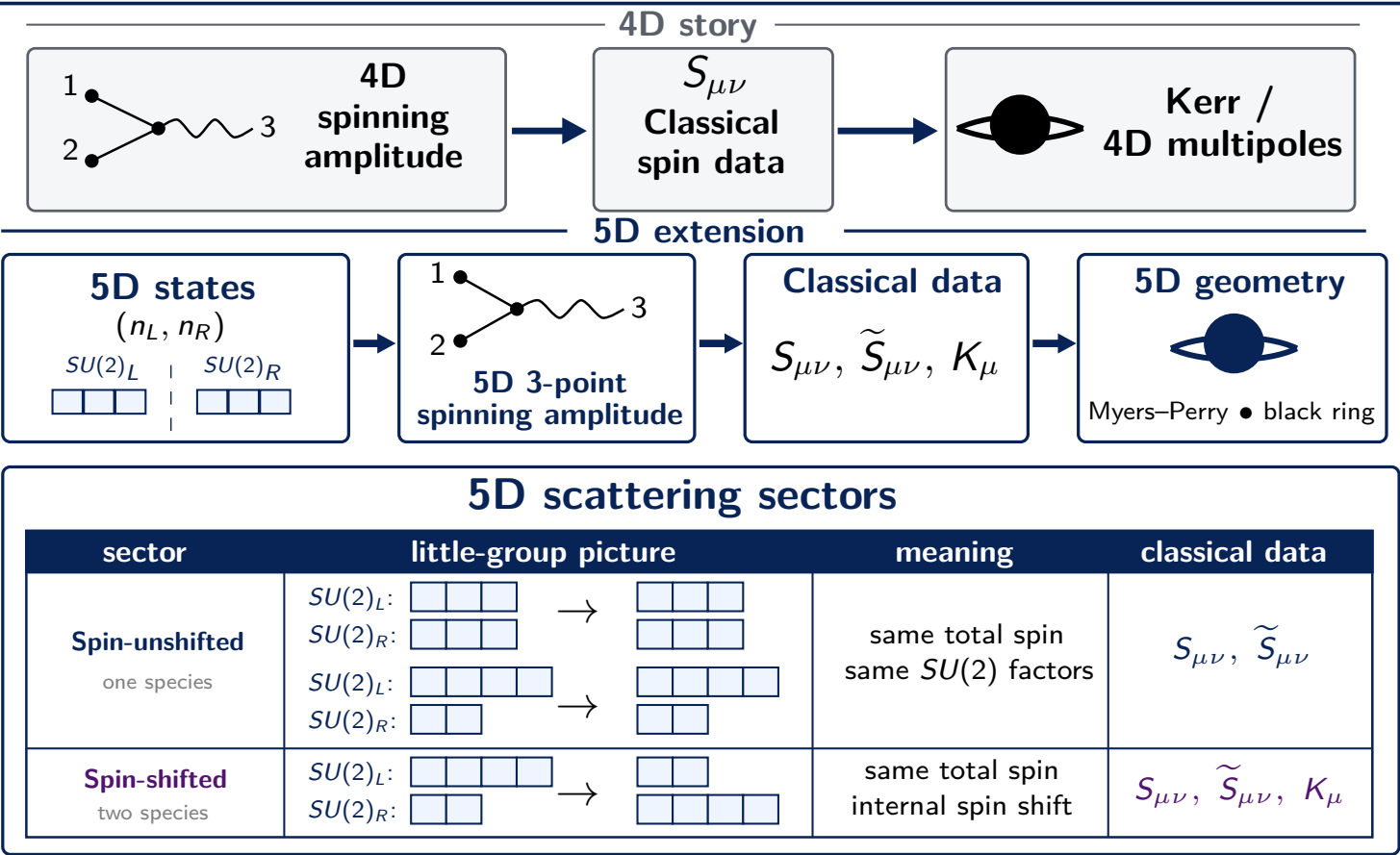


Iustin Surubaru

Next: Edoardo Alviani

Five-dimensional Geometry from Spinning Amplitudes

Lucile Cangemi & Justin Surubaru • 2605.29831



Main message

4D: amplitudes encode info about compact objects.

5D: same on-shell logic, but states are labelled by (n_L, n_R) $SU(2)$ factors.

This gives a richer classical dictionary: $S_{\mu\nu}, \tilde{S}_{\mu\nu}$, and sometimes K_μ .

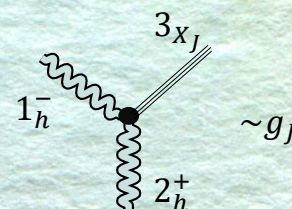
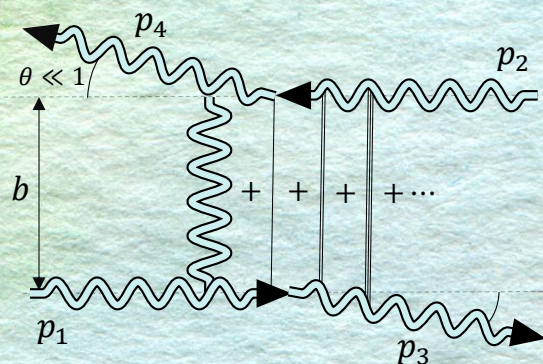
Amplitude has enough d.o.f to recover a **general** multipole expansion.

Takeaway: 5D generalizes the 4D amplitude/geometry story with richer massive-state sectors and richer multipole data.

Edoardo Alviani

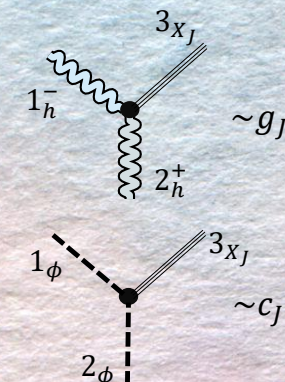
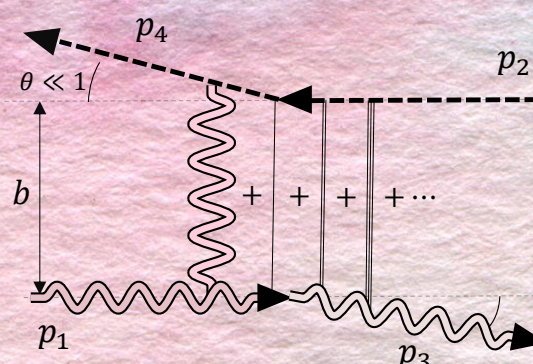
Next: Artyom Lisitsyn

GR + R^3 + higher-spin tower : $\Delta T > 0$

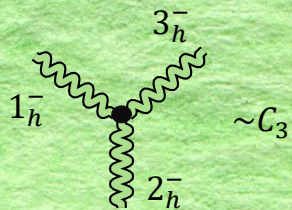
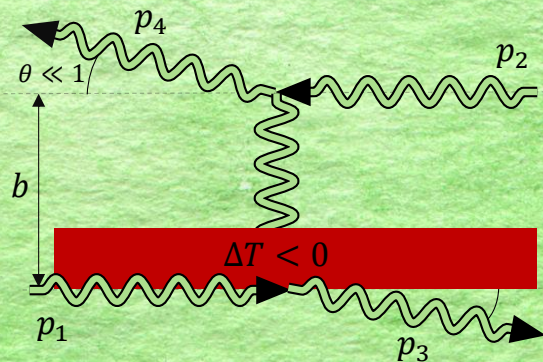


$$\Lambda \sim \frac{1}{b_*}$$

sGB/dCS+ higher-spin tower : $\Delta T > 0$

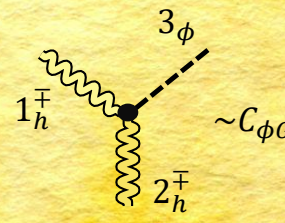
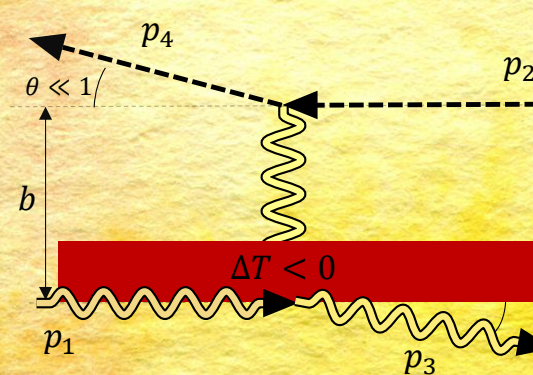


GR + R^3 EFT : $\Delta T < 0$



$$b_* \sim \sqrt[4]{|C_3|}$$

sGB/dCS EFT : $\Delta T < 0$



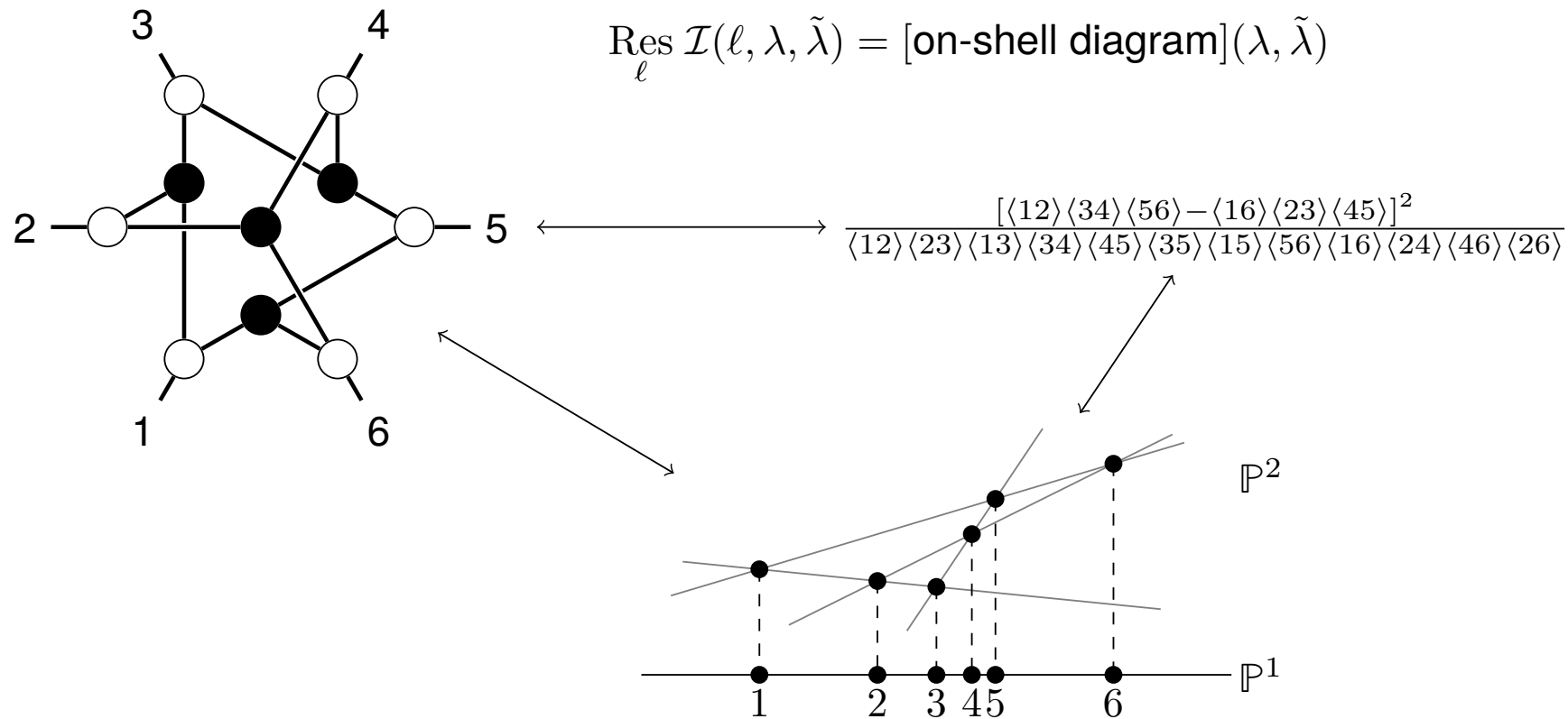
$$b_* \sim \sqrt[4]{|C_{\phi G}|}$$

Artyom Lisitsyn

Next: Joseph Marshall

Non-planar on-shell diagrams and point configurations

based on ongoing work with L. Pratt, M. Sherman-Bennett, J. Trnka



Joseph Marshall

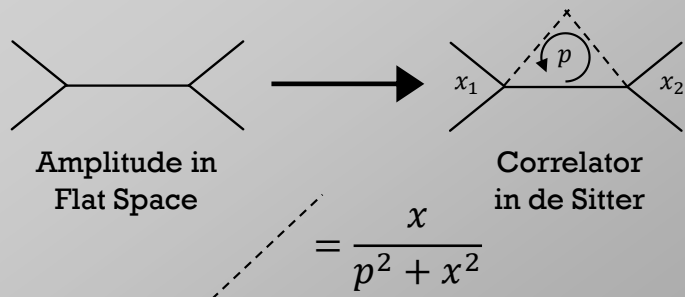
Next: Mattia Serrani

COSMOLOGICAL CORRELATORS FROM DRESSING AMPLITUDES

Joe Marshall — Durham University

With C. Chowdhury, S. Jazayeri, A. Lipstein, J. Mei, I. Sachs, and A.J. Zhang

Scalar Dressing



$$\text{Corr} = \int \text{Kernel} \times \text{Amplitude}$$

Flat space discontinuities can be uplifted to de Sitter!

Based on:

- 2503.10598
- 2512.14694
- 2602.03841

c.f. Arthur's Talk

Spinning Fields in de Sitter

No LSZ $\rightarrow$ Boundary gauge fixing required!

Polarisation sum chooses a gauge from the WF perspective

$$\langle A A A A \rangle = \Psi_4 + \sum_h \frac{\Psi_3^h \Psi_3^h}{\Psi_2}$$

For Schwinger-Keldysh, it is instead a boundary condition

Dressing Spinning Fields

These correlators are gauge dependent, so the dressing is too. E.g.

Transverse: $\text{dashed line} = \frac{x}{p^2 + x^2}$ Longitudinal: $\text{dotted line} = \frac{p}{p^2 + x^2}$

Tensor structure inherited from flat space

Mattia Serrani

Next: Clément Virally

Non-trivial local higher-spin amplitudes

Mattia Serrani^π

^π Service de Physique de l'Univers, Champs et Gravitation,
Université de Mons, Belgium

1 **Nonzero amplitudes** for self-dual higher-spin theories:

[M.S., Skvortsov '26]

For any SD theory: $\mathcal{A}_n = \text{kinematical algebra} \otimes \mathcal{A}_n^{\text{SDYM}}$.

These are all **half-collinear** amplitudes.

[Guevara, Lupsasca, Skinner, Strominger, Weil '26'26]

- Towards Celestial vector model/higher-spin duality.

2 All non-trivial (not just abelian vertices) higher-derivative **local higher-spin 4-point amplitudes** were derived in [M.S. '26]. As an example

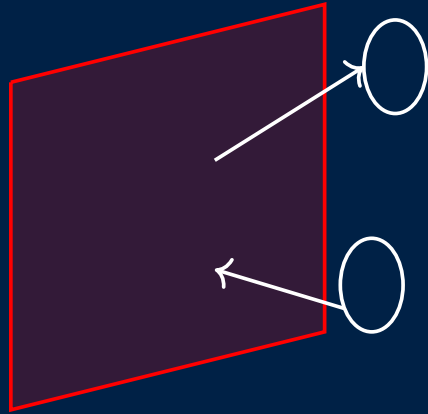
$$\mathcal{A}(1_s^+ 2_s^+ 3_2^- 4_2^-) = -\frac{[12]^{2s} \langle 34 \rangle^4}{stu}.$$

Clément Virally

Next: 10-minute break

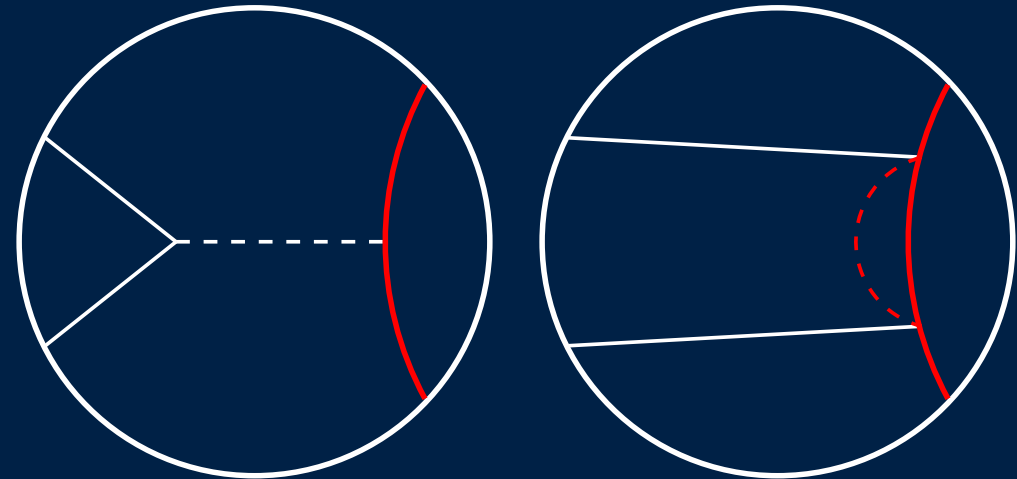
Bootstrapping string scattering from D-branes in AdS

Clément Virally, based on work with Luis F. Alday and Xinan Zhou



AdS side: string worldsheet ansatz

$$\mathcal{A}(S, Q) = \int_0^1 dx x^{-\frac{S}{2}-1} (1-x)^{-Q-1} \mathcal{G}(S, Q; x)$$



CFT side: defect Mellin amplitudes (exchanges)

$$\mathcal{M}(\delta, \gamma) = \int_0^\infty d\beta e^{-\beta} \sqrt{\beta} \mathcal{A} \left(S = -\frac{2\delta\beta}{R^2}, Q = \frac{2\gamma\beta}{R^2} \right)$$

Compare pole structure on both sides + SUGRA + flat space (Veneziano)

$\implies$ first AdS correction + CFT data

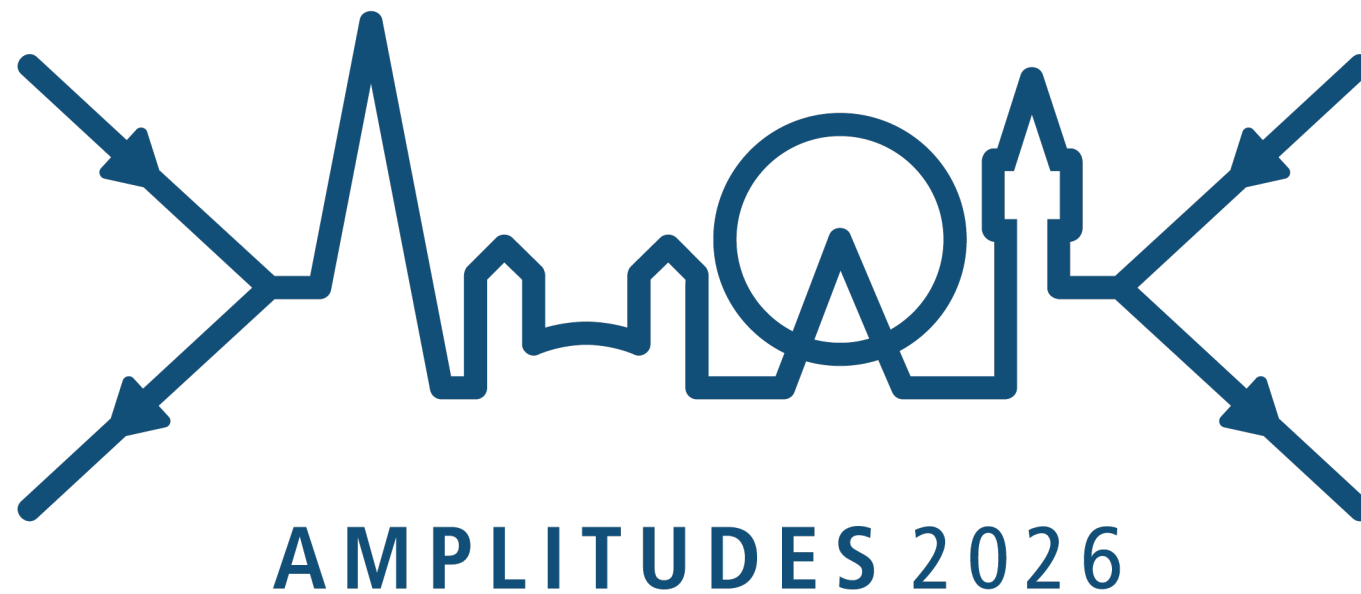
$$\Delta_{\ell=n-1}^{\text{defect}} = R\sqrt{n} - \frac{3}{2} + \frac{1}{R\sqrt{n}} \left(\frac{3}{4}n^2 - \frac{n}{4} + \frac{9}{8} \right) + \dots$$



Fonds
de recherche

Québec





10-minute break