# The dilaton double copy

## and why we want it

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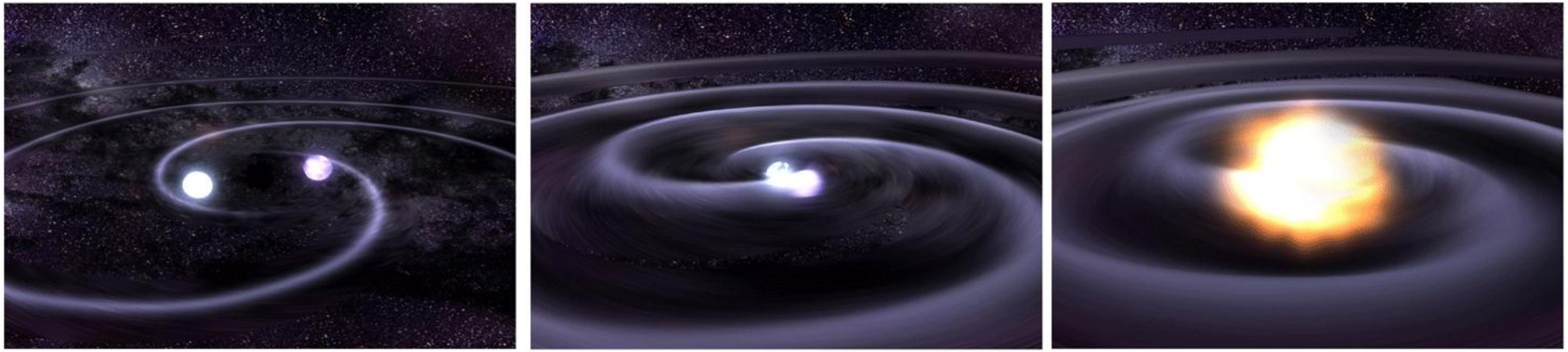
*Asaad Elkhidir, Donal O'Connell, Matteo Sergola (2303.06211)*
Henrik Johansson (*coming soon*)

UPPSALA UNIVERSITET

NORDITA
The Nordic Institute for Theoretical Physics

**33rd Nordic Network Meeting on "Strings, Fields and Branes", Nordita, 31 October 2024**

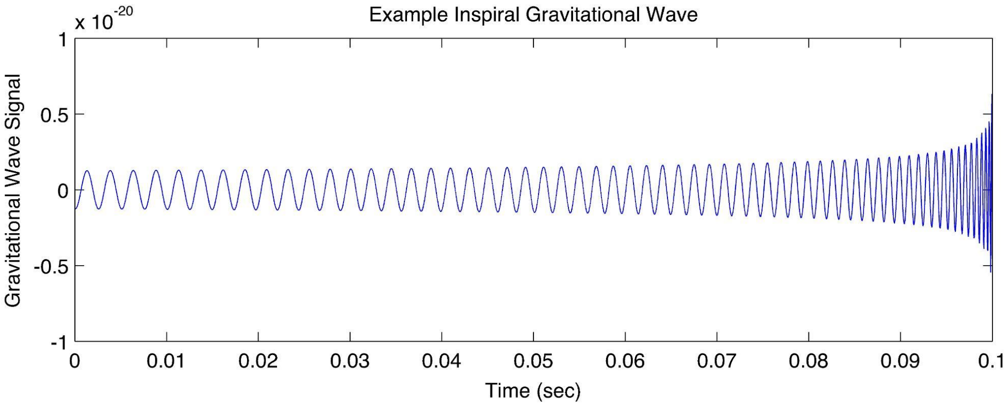


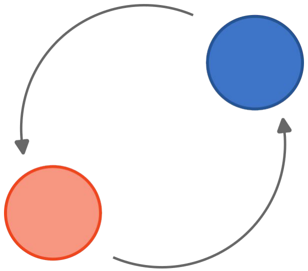
Elkhidir, O'Connell, Sergola, IVH

Herderschee, Roiban, Teng

Brandhuber, Brown, Chen De Angelis, Gowdy, Travaglini

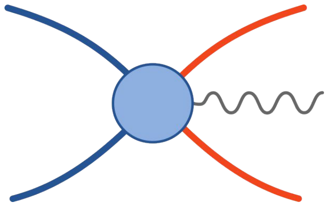
Georgoudis, Heissenberg, IVH

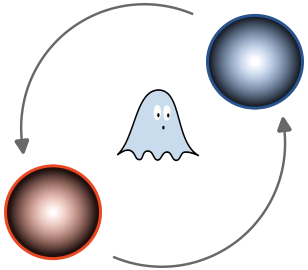




Express **radiation waveforms** in terms of scattering amplitudes

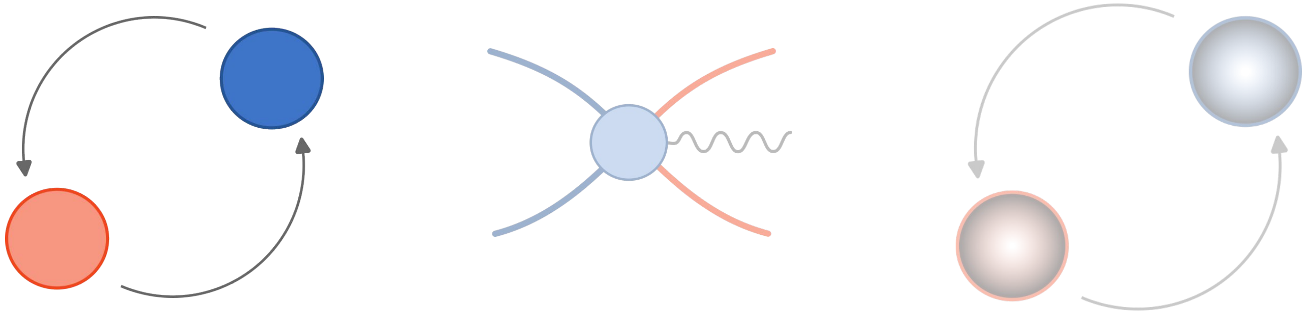
**Amplitudes** are bootstrapped using the color-kinematics duality

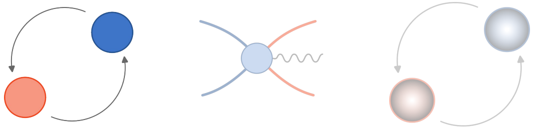




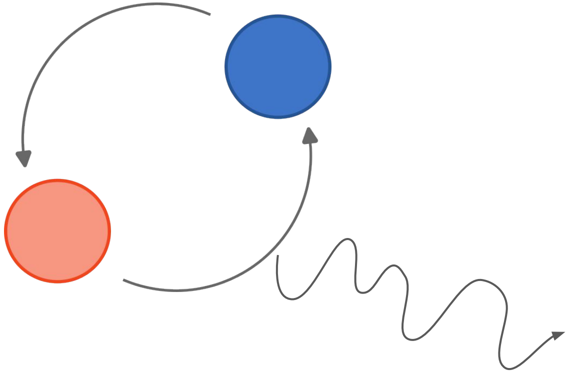
**Gravity amplitudes** are given using **dilaton double copy**

# I. Radiation waveform





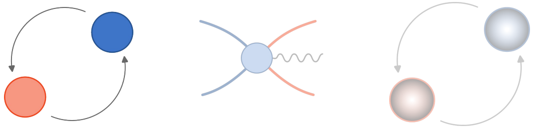
# I. Radiation waveform

$\langle F_{\mu\nu} \rangle \sim$ 

Radiation waveforms from the expectation value of the **field strength/Riemann tensor**

Define an initial state and the expectation in the far future, restore ħ

Waveform from cuts of **amplitudes**



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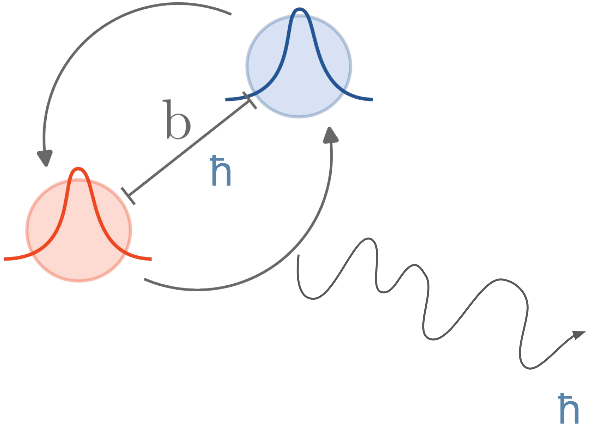


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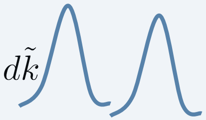
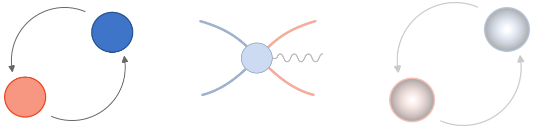
$|\psi\rangle_{in} = \int d\tilde{k}$  $e^{ib\cdot p_1/\hbar}|p_1 p_2\rangle_{in}$

$$\langle\psi|\, S^\dagger F_{\mu\nu}(x) S\, |\psi\rangle$$

$$\langle p_1' p_2' | a_\eta(k)\, \mathrm{Re}\, T + \frac{i}{2}\left([a_\eta(k), T^\dagger]T - T^\dagger[a_\eta(k), T]\right)|p_1, p_2\rangle$$



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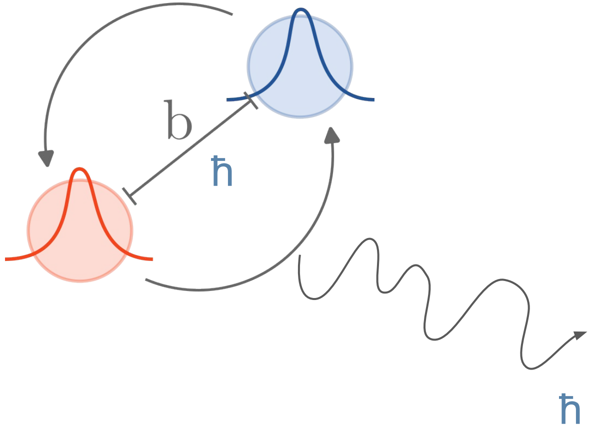


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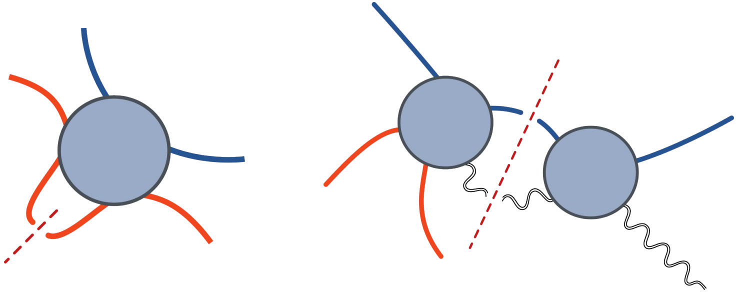
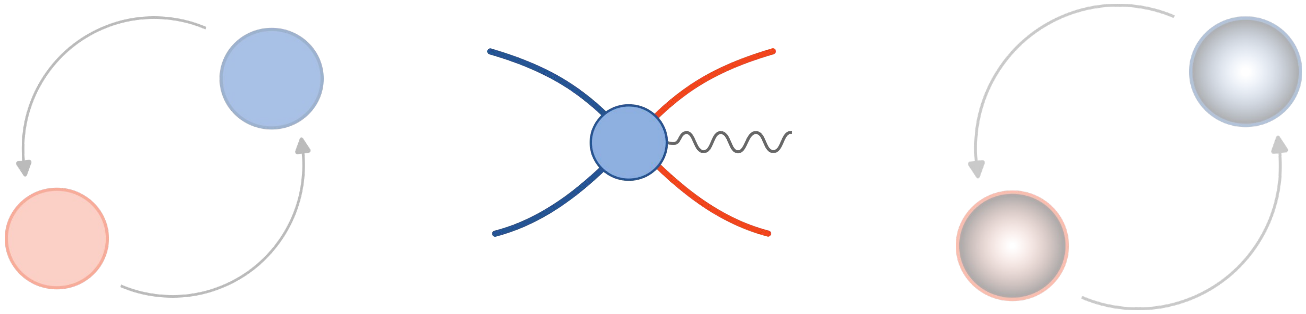
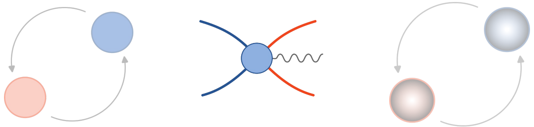
Waveform from cuts of **amplitudes**



# II. Amplitudes



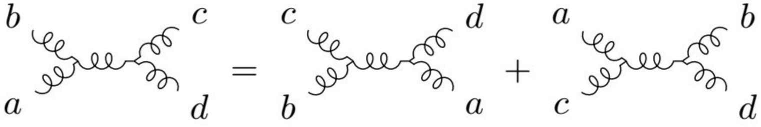


# II. Amplitudes

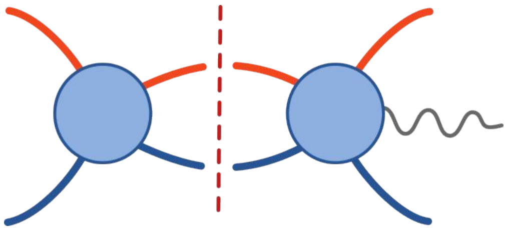
We bootstrap **gauge and gravity amplitudes** using **color-kinematics duality** and unitarity cuts

Bern, Carrasco, Johansson

$$f^{abl} f^{lcd} = f^{bcl} f^{lda} + f^{cal} f^{lbd}$$




$$n(a,b,c,d) = n(b,c,d,a) + n(c,a,b,d)$$

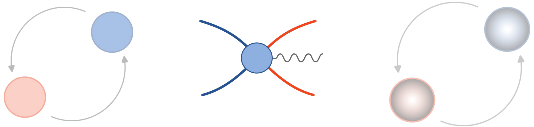


$$\frac{C_i n_i}{d_i} \rightarrow \frac{n_i n_j}{d_i}$$

Gauge theory

Gravity

Gives us amplitudes we can **double copy**



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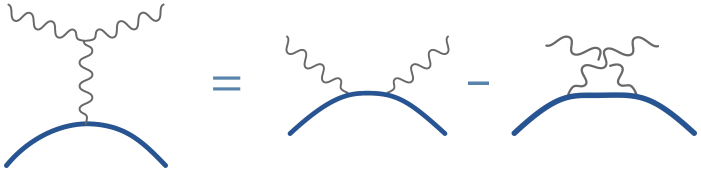

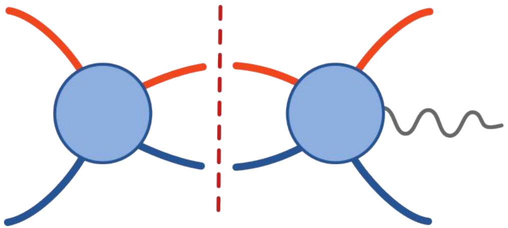

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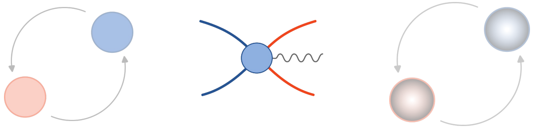
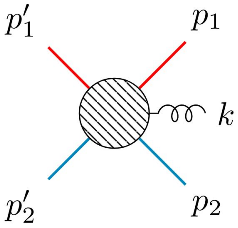
Gauge theory Gravity

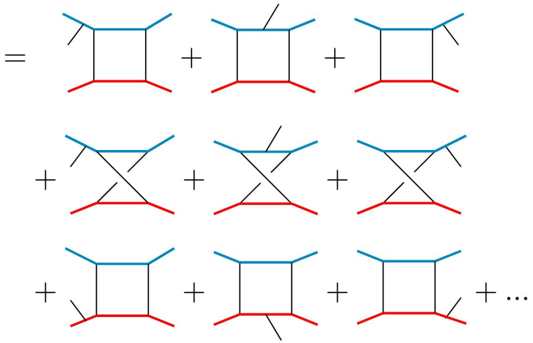


# II. Amplitudes

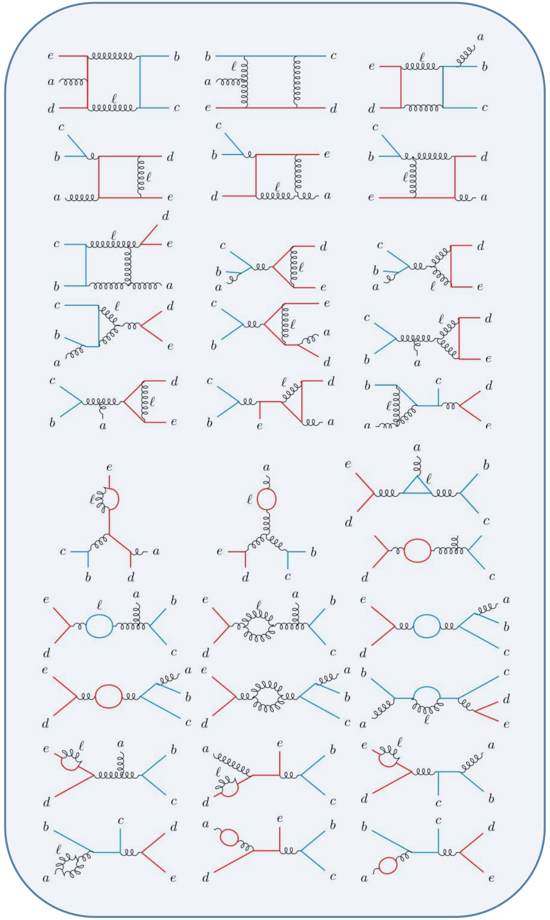
The 5-point one-loop amplitude has 116 graphs



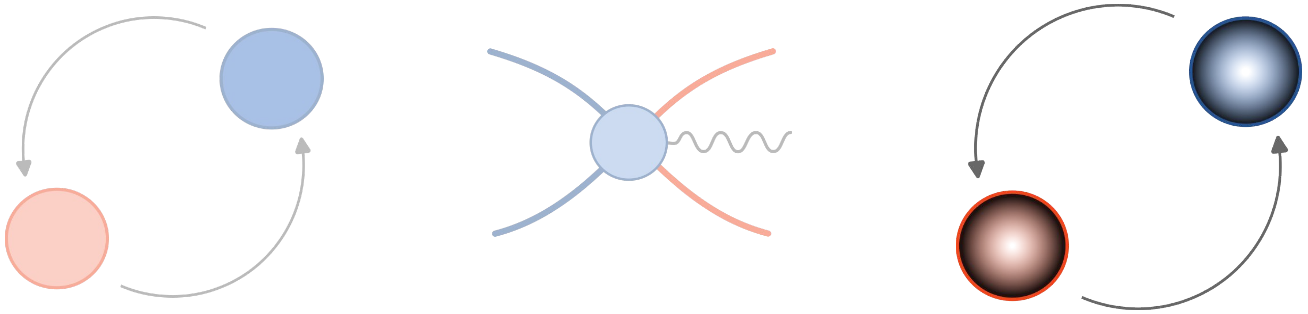

$$= \int d^4\ell \sum_{g=1}^{116} \frac{n_g c_g}{d_g}$$

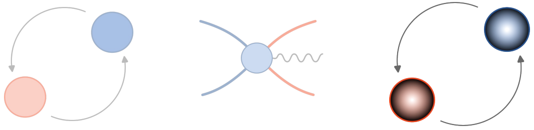


33 topologies



# III. Dilaton double copy





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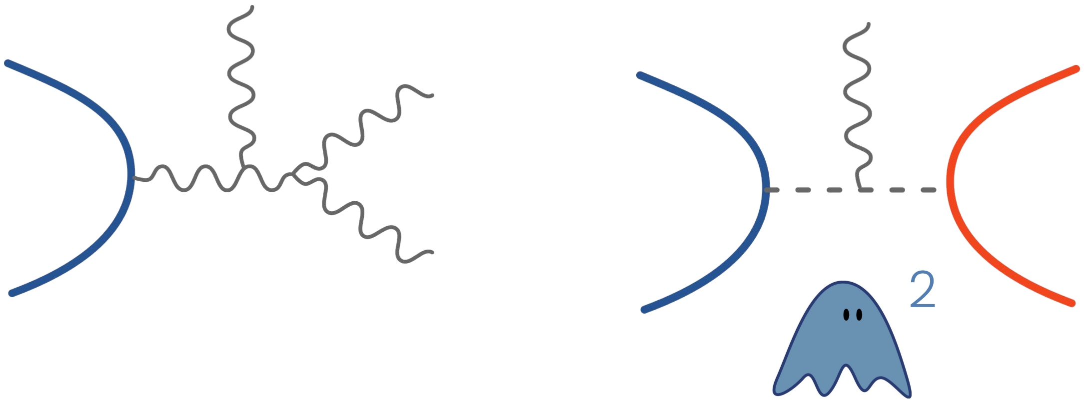
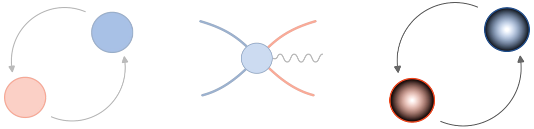



The double copy gives extra massless states

Johansson, Ochirov '14
Luna, Nicholson, O'Connell, White '17



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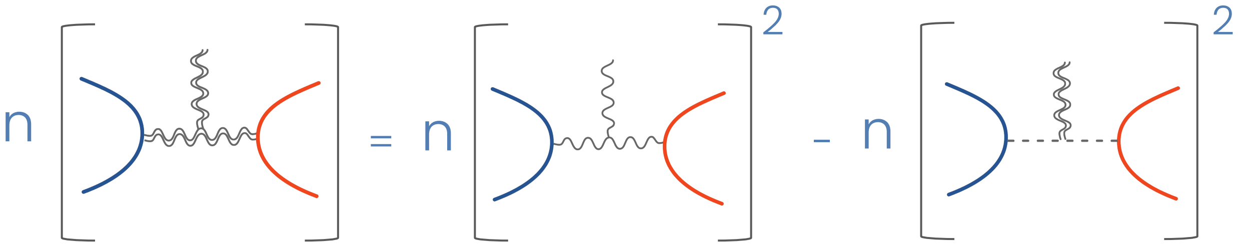

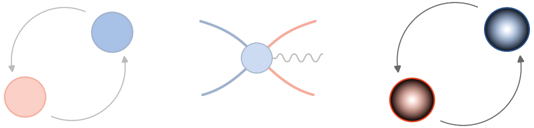

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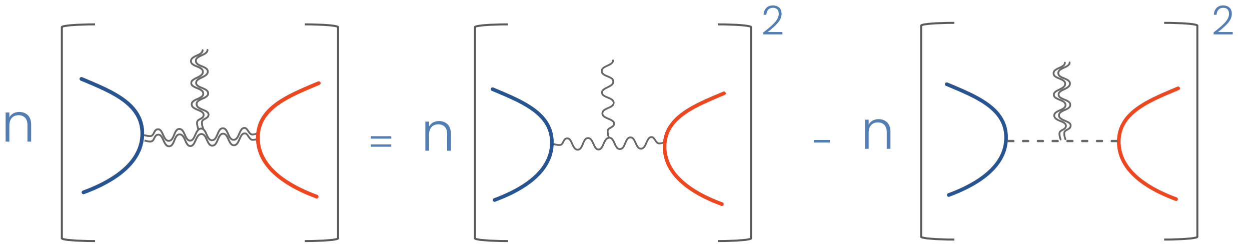
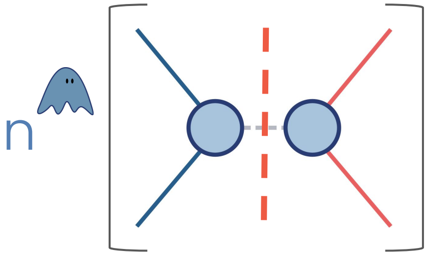


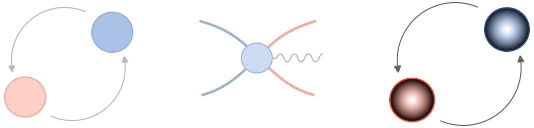




$$= (k_b \cdot k_d)^2 - \left( (k_b \cdot k_d)^2 - \frac{m_1^2 m_2^2}{(D_s - 2)} \right)$$

$\mathcal{N} = 0$

Einstein-Hilbert


$$\sum_s \mathcal{M}_3^{\text{trees}}(a, b, q^s)\mathcal{M}_3^{\text{trees}}(-q^{\bar{s}}, c, d)$$



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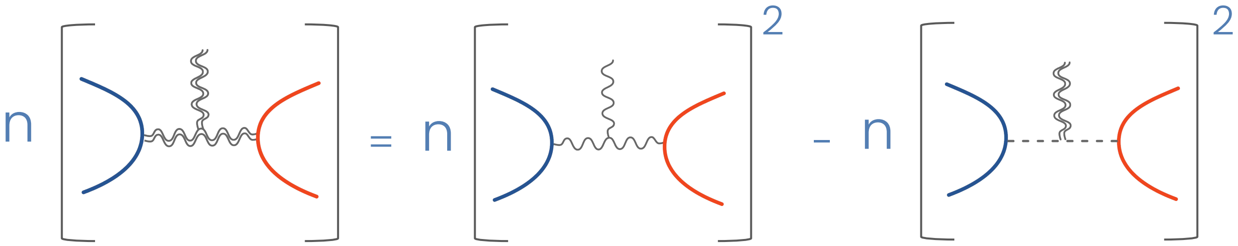
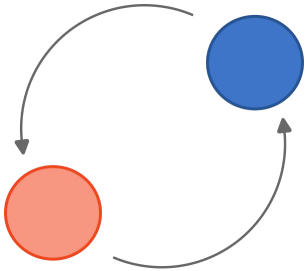



**Dilaton double copy** up to six-point tree-level, and four-point one-loop*



Express **radiation waveforms** in terms of scattering amplitudes

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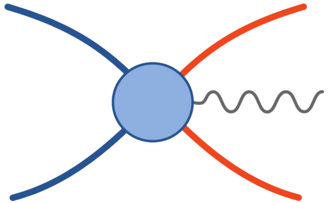
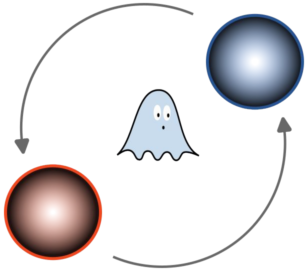
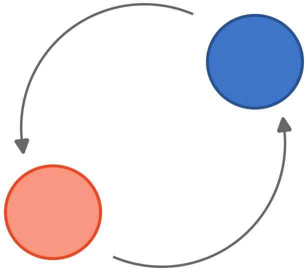




**Gravity amplitudes** are given using **dilaton double copy**



# What now?

Double copy dilatons at higher points?

Consider higher loops - waveform? Interesting physics?
Color-kinematics?

Spin?