

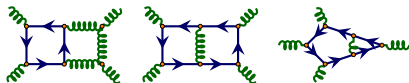
# Color-Kinematics Duality for Fundamental Matter at Two-Loops

work with H. Johansson & G. Mogull [1706.09381]

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12.06.2018



# Motivation

## Double Copy

$$(\text{gauge theory})^2 \sim \text{gravity}$$

Goal: Pure (super)gravity amplitudes

Problem: Matter states on gravity side

$$\mathcal{V}_{\mathcal{N}} \otimes \mathcal{V}'_{\mathcal{M}} \equiv \mathcal{H}_{\mathcal{N}+\mathcal{M}} \oplus \mathcal{X}_{\mathcal{N}+\mathcal{M}} \oplus \bar{\mathcal{X}}_{\mathcal{N}+\mathcal{M}}$$

Solution: Matter states in the Gauge theory

$$\begin{aligned}\Phi_{\mathcal{N}} \otimes \bar{\Phi}'_{\mathcal{M}} &\equiv \mathcal{X}_{\mathcal{N}+\mathcal{M}}, \\ \bar{\Phi}_{\mathcal{N}} \otimes \Phi'_{\mathcal{M}} &\equiv \bar{\mathcal{X}}_{\mathcal{N}+\mathcal{M}}\end{aligned}$$

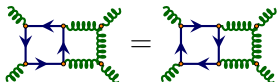
$$\mathcal{A}_m^{(L)} = i^{L-1} g^{m+2L-2} \sum_{\text{cubic graphs } \Gamma_i} \int \frac{d^{LD} \ell}{(2\pi)^{LD}} \frac{1}{S_i} \frac{n_i c_i}{D_i}$$

$$\begin{aligned}
 n \left( \begin{array}{c} b \text{ wavy} \quad d \text{ wavy} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ a \text{ wavy} \quad c \text{ wavy} \end{array} \right) &= n \left( \begin{array}{c} b \text{ wavy} \quad d \text{ wavy} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ a \text{ wavy} \quad c \text{ wavy} \end{array} \right) - n \left( \begin{array}{c} b \text{ wavy} \quad d \text{ wavy} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ a \text{ wavy} \quad c \text{ wavy} \end{array} \right) \\
 n \left( \begin{array}{c} b \text{ wavy} \quad j \text{ arrow} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ a \text{ wavy} \quad i \text{ arrow} \end{array} \right) &= n \left( \begin{array}{c} b \text{ wavy} \quad j \text{ arrow} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ a \text{ wavy} \quad i \text{ arrow} \end{array} \right) - n \left( \begin{array}{c} b \text{ wavy} \quad j \text{ arrow} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ a \text{ wavy} \quad i \text{ arrow} \end{array} \right) \\
 n \left( \begin{array}{c} \text{arrow} \quad \text{arrow} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ \text{arrow} \quad \text{arrow} \end{array} \right) &\stackrel{?}{=} n \left( \begin{array}{c} \text{arrow} \quad \text{arrow} \\ \diagdown \quad \diagup \\ \text{dot} \\ \diagup \quad \diagdown \\ \text{arrow} \quad \text{arrow} \end{array} \right)
 \end{aligned}$$

# $\mathcal{N} = 2$ SQCD: Input data

Input data = constraints on the numerators

- Hyper and antihyper (half-)multiplet have the same particle content:



- Supersymmetric decomposition:

$$\begin{aligned} n^{\mathcal{N}=4} \left( \text{Diagram 1} \right) &= n^{\mathcal{N}=2} \left( \text{Diagram 2} \right) + 2n^{\mathcal{N}=2} \left( \text{Diagram 3} \right) \\ &+ 2n^{\mathcal{N}=2} \left( \text{Diagram 4} \right) + 2n^{\mathcal{N}=2} \left( \text{Diagram 5} \right) \end{aligned}$$

The equation shows the supersymmetric decomposition of a  $\mathcal{N}=4$  loop diagram into four  $\mathcal{N}=2$  loop diagrams. Diagram 1 is a square loop with four wavy green lines and four blue lines with arrows pointing clockwise. Diagram 2 is a square loop with four wavy green lines and four blue lines with arrows pointing counter-clockwise. Diagram 3 is a square loop with four wavy green lines and four blue lines with arrows pointing clockwise, but with a different internal structure. Diagram 4 is a square loop with four wavy green lines and four blue lines with arrows pointing counter-clockwise, with a different internal structure. Diagram 5 is a square loop with four wavy green lines and four blue lines with arrows pointing clockwise, with a different internal structure.

# $\mathcal{N} = 2$ SQCD: Results MHV

$$\begin{aligned}
 & -\mu_{12}(\kappa_{12} + \kappa_{34}) + \text{tr}_+(p_1, \bar{l}_1, p_2, p_3, \bar{l}_2, p_4) \tilde{\kappa}_{13} \\
 & + \text{tr}_+(p_1, \bar{l}_1, p_2, p_4, \bar{l}_2, p_3) \tilde{\kappa}_{14} \\
 & + \text{tr}_-(p_1, \bar{l}_1, p_2, p_3, \bar{l}_2, p_4) \tilde{\kappa}_{24} \\
 & + \text{tr}_-(p_1, \bar{l}_1, p_2, p_4, \bar{l}_2, p_3) \tilde{\kappa}_{23}
 \end{aligned}$$

$$\begin{aligned}
 & = \text{[Diagram 1]} \\
 & = \text{[Diagram 2]} \\
 & = 0
 \end{aligned}$$

All other numerators are determined by above identities!