Revealing the Landscape of Globally Color-Dual Multi-loop Integrands

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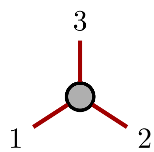
Abstract: We report on progress in understanding how to construct color-dual multi-loop amplitudes. First we identify a cubic theory, semi-abelian Yang-Mills, that unifies many of the color-dual theories studied in the literature, and provides a prescriptive approach for constructing D-dimensional color-dual numerators through one-loop directly from Feynman rules. By a simple weight counting argument, this approach does not further generalize to two-loops. As a first step in understanding the two-loop challenge, we use a D-dimensional color-dual bootstrap to successfully construct globally color-dual *local* two-loop four-point nonlinear sigma model (NLSM) numerators. The double-copy of the these NLSM numerators with themselves, pure Yang-Mills, and $\mathcal{N} = 4$ super-Yang-Mills correctly reproduce the known unitarity constructed integrands of special Gallileons, Born-Infeld theory, and Dirac-Born-Infeld-Volkov-Akulov theory, respectively. Applying our bootstrap to two-loop four-point pure Yang-Mills, we exhaustively search the space of local numerators and find that it fails to satisfy global color-kinematics duality, completing a search previously initiated in the literature. We pinpoint the failure to the bowtie unitarity cut, and discuss a path forward towards *non-local* construction of color-dual integrands at generic loop order.

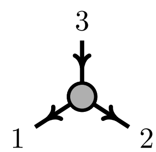
Contents

1 Chern-Simons Theory

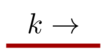
The final theory that is unified by semi-abelian Yang-Mills is that Chern-Simons theory. As we will show below, plugging in appropriate on-shell states to the integrands constructed in the text will produce precisely the kinematic numerators for this theory.



$$= \epsilon^{\mu\nu\rho}\varepsilon_1^{\mu}\varepsilon_2^{\nu}\varepsilon_3^{\rho} \quad \Rightarrow$$

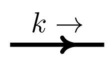


$$= (\varepsilon_1\bar{\varepsilon}_3)(\varepsilon_2 k_3) - (\varepsilon_2\bar{\varepsilon}_3)(\varepsilon_1 k_3) \tag{1.1}$$

A^{ν} 

A^{μ}

$$= \frac{i}{k^2}\epsilon^{\mu\nu\rho}k^{\rho} \quad \Rightarrow$$

A^{ν} 

$\bar{A}^{\mu}$

$$= \frac{i}{k^2}\eta^{\mu\nu} \tag{1.2}$$