Double Field Theory as the Double Copy of Yang-Mills Theory

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arXiv:2109.01153 [FDJ, O. Hohm, J. Plefka]
arXiv:2203.07397 [R. Bonezzi, FDJ, O. Hohm]
arXiv:2212.04513 [R. Bonezzi, C. Chiaffrino, FDJ, O. Hohm]

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Double copy (DC)

- BCJ DC: Color $\to$ Kinematics
  (YM $\to$ Gravity+B-field+Dilaton, $N = 0$ SUGRA)

  [Bern, Carrasco, Johansson 2008]

- Gauge choices, kinematic algebra???

Main goal: Develop **off-shell, gauge independent and local** approach to DC that:

- allows to identify a "kinematic algebra"
- gives gravity in the form of double field theory

(In this talk) up to and including quartic interactions.

L_∞-algebras

These algebras underly perturbative field theories. They encode gauge structure, dynamics and interactions.

An L_∞-algebra is a vec. space $X = \bigoplus_i X_i$ equipped with $B_n : X^{\otimes} \to X$ that obey generalized Jacobi.

For YM : $X^{\mathrm{YM}} = \bigoplus_i X_i^{\mathrm{YM}}$

$$X_1^{\mathrm{YM}} \longrightarrow X_0^{\mathrm{YM}} \longrightarrow X_{-1}^{\mathrm{YM}}$$

$$\lambda \qquad\qquad A \qquad\qquad E$$

E.o.m's and gauge transformations:

$$E := B_1(A) + B_2(A,A) + B_3(A,A,A) = 0$$
$$\delta A = B_1(\lambda) + B_2(A,\lambda)$$

Kinematic algebra

In Yang-Mills we have $X^{\mathrm{YM}} = \mathcal{K}^{\mathrm{YM}} \otimes \mathfrak{g}$ [Zeitlin 2008]

$$A_\mu^a \otimes t_a \ , \quad B_2 = m_2 \otimes f_{\bullet\bullet}{}^a t_a \ , \ \ldots$$

The space $\mathcal{K}^{\mathrm{YM}}$ equipped with $(\Box, m_n, b, b_2, \theta_3, \ldots)$ form a kinematic $\mathrm{BV}_\infty^\Box$-algebra [Reiterer 2019]

The kinematic algebra of Chern-Simons is a Lie algebra

[Ben-Shahar, Johansson 2021; Borsten, Jurco, Kim, Macrelli, Saemann, Wolf 2022]

In (our formulation) Yang-Mills the kinematic algebra is *not* a Lie algebra!

Algebraic double copy

Want to construct the L_∞-algebra of gravity using $\mathcal{K}^{\mathrm{YM}}$!

We can follow BCJ: color$\rightarrow$ kinematics ($\mathfrak{g} \rightarrow \bar{\mathcal{K}}^{\mathrm{YM}}$) + constraints

$$X^{\mathrm{DFT}} = \mathcal{K}^{\mathrm{YM}} \otimes \bar{\mathcal{K}}^{\mathrm{YM}} \Big|_{\text{constrained}}$$
$$e_{\mu\bar{\nu}}(x,\bar{x}) = A_\mu(x) \otimes \bar{A}_{\bar{\nu}}(\bar{x})$$

One constructs the gravity maps

$$B_1 = m_1 + \bar{m}_1, \quad B_2 = b^- m_2 \otimes \bar{m}_2 = b_2 \otimes \bar{m}_2 - m_2 \otimes \bar{b}_2$$
$$B_3 = b^- \left\{ \theta_3 \otimes \bar{m}_2 \bar{m}_2 + m_2 b_2 \otimes \bar{m}_3 + d_\square m_3 \otimes \bar{m}_3 + \text{(un)-barred} \right\}$$

Thank you very much for your attention!