Super-Gauss-Bonnet and Evanescent Effects in $\mathcal{N} = 4$ Supergravity

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(Super)Gravity in the UV
& Evanescent Operators

Lesson from pure gravity: Evanescent operators* affect the coefficient of the $\frac{1}{\epsilon}$ in dimreg

[Bern, Cheung, Chi, Davies, Dixon, Nohle]

*vanishing in four dimensions

A divergence was found at four loops in $\mathcal{N}=4$ SUGRA

[Bern, Dennen, Davies, Smirnov[2]]

Q1:Are there any evanescent operators in this theory ?

Q2: Do they play a role in the divergence ?

Main Result

We found an evanescent operator in the finite piece of all the $\mathcal{N} = 4\,\mathrm{SUGRA}$ four point one loop amplitudes

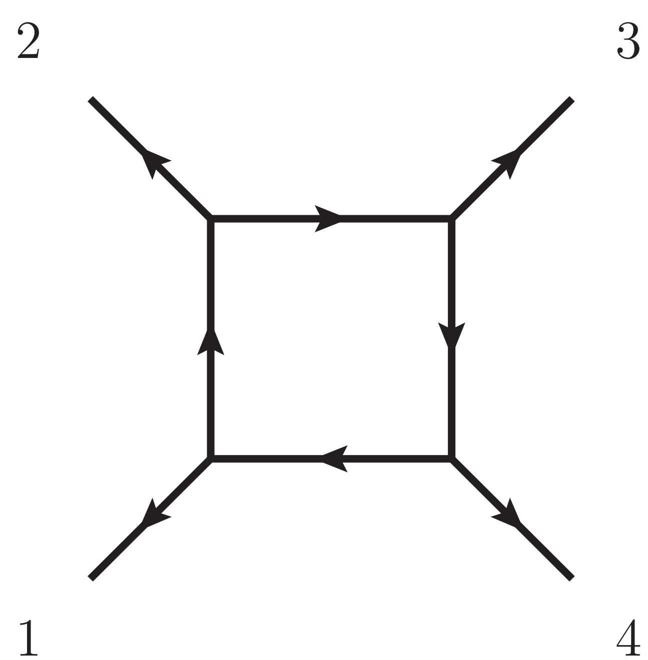
This operator corresponds to a supersymmetrization of the Gauss-Bonnet Operator (unknown off-shell)

The coefficient of its contribution is a rational number with an $\frac{\epsilon}{\epsilon}$ origin, reminiscent of chiral anomaly in dimreg

Calculation (Lightning Review)

Double Copy (BCJ)

$$(\mathcal{N}=4\,\mathrm{SUGRA}) = (\mathcal{N}=4\,\mathrm{SYM}) \otimes \mathrm{Pure\ YM}$$



$$M^{(1)}_{\mathrm{SUGRA}} = \sum_{\mathrm{boxes}} \int \frac{n_{\mathcal{N}=4}\, n_{\mathcal{N}=0}}{\prod D_i}$$

$$n_{\mathcal{N}=4} = s\,t\,A^{\mathrm{tree}}_{\mathcal{N}=4}(1,2,3,4) \propto t_8 F^4$$

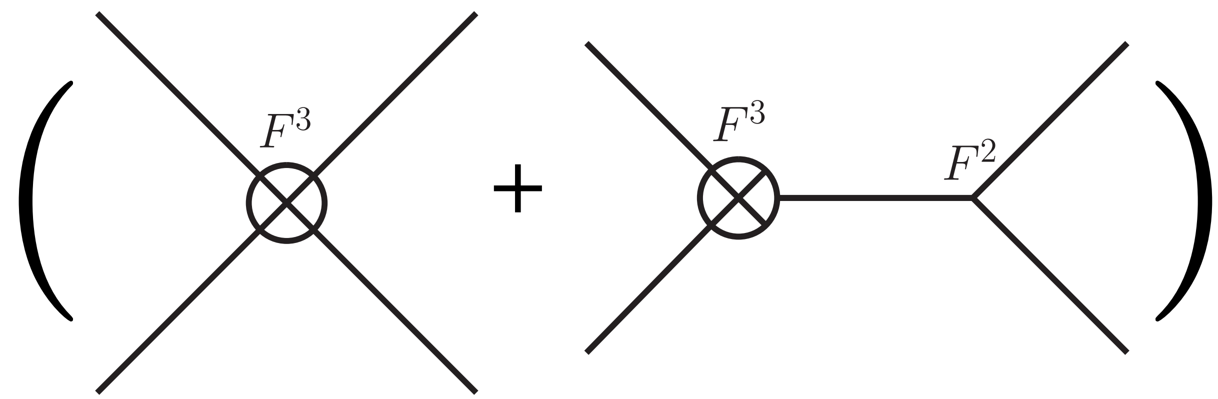
~ Pure YM calculation!

Calculation (Lightning Review)

Organize projecting into a basis of gauge invariant tensors:

$$3 \times (F_i F_j F_k F_l)$$
$$3 \times (F_i F_j)(F_k F_l)$$

& $T_{F^3} =$



$$F_i^{\mu\nu} = i(k_i^\mu \epsilon_i^\nu - k_i^\nu \epsilon_i^\mu)$$

Then map tensors to gravity: [Kawai, Lewellen, Tye]

$$F_{i\mu\nu} F_{i\rho\sigma} \to -2R_{i\mu\nu\rho\sigma} \qquad A^{\text{tree}}_{\text{YM}} \otimes_{\text{KLT}} A^{\text{tree}}_{F^3} = M^{\text{tree}}_{R^2}$$

(Recall $R^2 \simeq$ Gauss-Bonnet)

Why all the trouble? To keep the states in D-dimensions

Main Result

(again, with more details)

$$M^{(1),4\,\mathrm{gr}}_{\mathrm{SUGRA}} = \begin{array}{r} t_8 R^4\,(\mathrm{rational} + \mathrm{transcendental}) + \\ t_8 (R^2)^2\,(\mathrm{rational} + \mathrm{transcendental}) + \\ +\,1\;\; M^{\mathrm{tree}}_{R^2} \end{array}$$

+ other external particles: Super-Gauss-Bonnet

Evanescent and contributes to the amplitude!

Ongoing work to get off-shell operator

Q1: ✔ Q2: Work in progress at higher loops

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