Supersymmetrizing Massive Gravity

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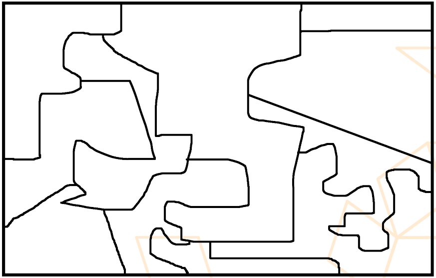
Feynman Doesn't Rule

Main observable in any quantum field theory is a scattering amplitude $\mathcal{A}_n$.

Feynman diagrams manifest locality, but not other symmetries.

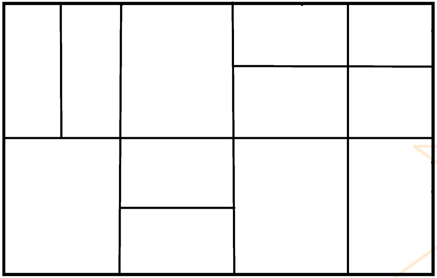
Feynman calculations are like jigsaw puzzles.



Only the sum of diagrams satisfies Ward identities.

On-Shell Methods

If we use symmetry-respecting building blocks, the computation is easier



In this talk: We will use on-shell supersymmetry of massive particles

What questions can we answer?

dRGT Massive Gravity

A full non-linear theory of massive gravity generically suffers from extra degrees of freedom (Bouleware-Desser ghosts).

A particular 2-parameter family of interactions is special:

- ▷ Ghost-free
- ▷ Reduced high-energy behavior E^6

[de Rham, Gabadadze, Tolley]

But...

- ▷ No known UV completion
- ▷ Quantum corrections to dRGT tuning

[de Rham, Heisenberg, Ribeiro]

Possible solution: Supersymmetry

Massive Graviton Supermultiplets

We use the SUSY algebra

$$\{Q_\alpha, Q^\dagger_{\dot{\alpha}}\} = -2\sigma^\mu_{\alpha\dot{\alpha}} P_\mu$$

to build multiplets based on different Clifford vacua

$$Q^\dagger_{\dot{\alpha}} |\Omega\rangle = 0\,.$$

For $\mathcal{N}$ supersymmetries, Q also carries an R-symmetry index, e.g.

$$Q^a_\alpha |\Omega\rangle = |\tilde{\Omega}^a\rangle\,.$$

We can use this to construct all supermultiplets that could contain massive gravitons.

Massive On-Shell Supersymmetry

On-shell in 4d, we can use the spinor-helicity variables for massive particles,

$$p_{ia\dot{a}} = |i_I]_a \langle i^I|_{\dot{a}}$$

[Arkani-Hamed, Huang, Huang]

We can introduce Grassmann variables $\eta_{i,I}$,

$$Q^\dagger = -\sqrt{2} \sum_i |i^I\rangle \eta_{i,I} \, , \quad Q = \sqrt{2} \sum_i |i_I] \frac{\partial}{\partial \eta_{i,I}}$$

which allow us to package supermultiplets into superfields.

[Herderschee, Koren, Trott]

$\mathcal{N} = 1$ Massive Gravitons

Field	Spin	$U(1)_R$
ψ^{IJK}	$\frac{3}{2}$	1
γ^{IJ}	1	0
h^{IJKL}	2	0
$\tilde{\psi}^{IJK}$	$\frac{3}{2}$	-1

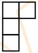
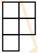
Using massive on-shell superspace, this can be packaged into an on-shell superfield

$$\Psi^{IJK} = \psi^{IJK} + \frac{1}{4\sqrt{3}}\eta^{(I}\gamma^{JK)} + \eta_L h^{IJKL} + \frac{1}{2}\eta_L\eta^L\tilde{\psi}^{IJK}$$

We can then project the final superamplitude onto the n-graviton amplitude,

$$\prod_{i=1}^{n} \frac{\partial}{\partial\eta_{i,(L_i}} \mathcal{A}_n\left(\Psi^{I_1 J_1 K_1)} \dots \Psi^{I_n J_n K_n)}\right) = \mathcal{A}_n\left(h^{I_1 J_1 K_1 L_1} \dots h^{I_n J_n K_n L_n}\right) .$$

$\mathcal{N} = 4$ Massive Gravitons

Field	Spin	$U(1)_R$	$SU(4)_R$
ϕ	0	4	$\bullet$
λ^{aI}	$\frac{1}{2}$	3	
ϕ^{ab}	0	2	
γ_{cd}^{IJ}	1	2	
λ^{abcJ}	$\frac{1}{2}$	1	
ψ_{d}^{IJK}	$\frac{3}{2}$	1	
ϕ^{abcd}	0	0	
γ^{abcdJK}	1	0	
h^{IJKL}	2	0	$\bullet$
ψ^{eIJK}	$\frac{3}{2}$	-1	
λ^{abcdeJ}	$\frac{1}{2}$	-1	
ϕ_{dh}	0	-2