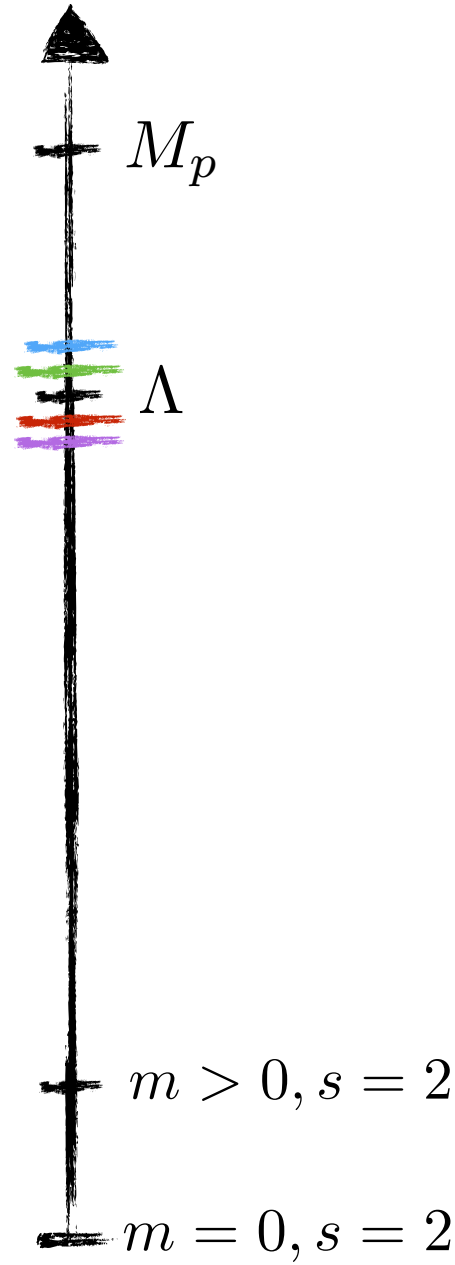
Constraints on Spin-2 Interactions

James Bonifacio (CWRU)
with K. Hinterbichler, A. Joyce, R. Rosen
1712.10020, 1804.08686, 1806.xxxxx

Amplitudes School, June 12th, 2018

Motivation

- Can there exist a large-N QCD theory with an isolated massive spin-2 glueball as the lightest state?
- Is there a bound on the gap to the next lightest state?



Causality constraints

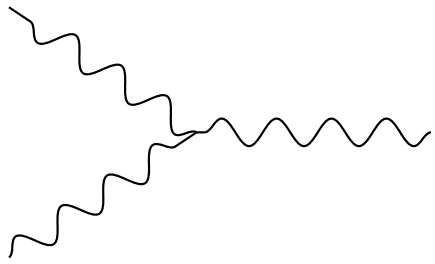
- To address the first question, we calculate the Shapiro time delay/advance in this theory CEMZ, 2014.
- This is captured by the Eikonal scattering amplitude:

$$i\mathcal{M}_{\rm eik}(s,t) = 2s\int d^2\vec{b}e^{i\vec{q}\cdot\vec{b}}\left(e^{i\delta(s,\vec{b})}-1\right).$$

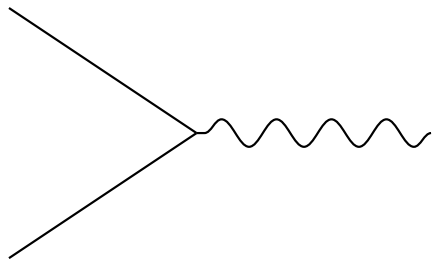
- The Eikonal phase δ depends only on on-shell cubic vertices.
- A time advance, $\delta < 0$, would imply that new physics is needed around the mass scale m to restore causality.

Constraining cubics

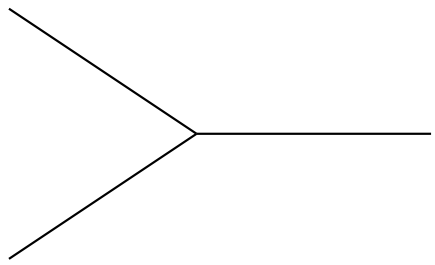
- Prohibiting time advances gives the following cubic vertices:



$$= \quad \mathcal{V}_{\rm EH},$$



$$= \quad \mathcal{V}_{\rm EH},$$

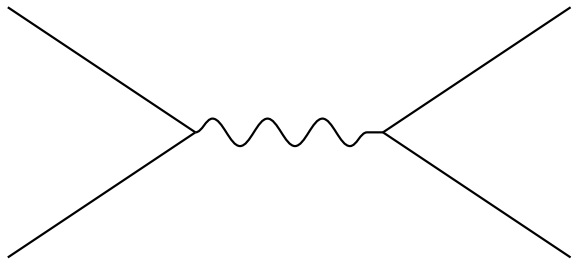


$$= \quad a\mathcal{V}_{\rm EH},$$

$$\mathcal{V}_{\rm EH} = \frac{2i}{M_p}\left[(\epsilon_1\cdot\epsilon_2)(\epsilon_3\cdot p_1)+(\epsilon_1\cdot\epsilon_3)(\epsilon_2\cdot p_3)+(\epsilon_2\cdot\epsilon_3)(\epsilon_1\cdot p_2)\right]^2.$$

Constraining the gap

- Tree amplitudes violate unitarity at $\left(m^4 M_p\right)^{1/5}$, so the EFT cutoff is below this scale.



$$= \quad \frac{E^{10}}{M_p^2 m^8}.$$

- Contact terms can cancel the bad high-energy behaviour and raise the cutoff, increasing the gap.
- To find the maximum cutoff, calculate the general four-point amplitude consistent with locality, unitarity, Lorentz invariance, gauge invariance, and crossing symmetry.
- This gives $\left(m^2 M_p\right)^{1/3}$ as the highest cutoff.

Conclusion

- Can there exist a large-N theory with an isolated massive spin-2 glueball as the lightest state?
  Perhaps! Causality implies that on-shell cubic vertices must be of EH form.
- Is there a bound on the gap to the next lightest state?
  Perturbative unitarity implies that new states must enter by $\Lambda = \left(m^2 M_p\right)^{1/3}$.
- Can generalize beyond this simple example to other particle spectra, e.g. higher spins, Higgs-like particles.