

# Consistent nonlinear interactions for spin-2 fields

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# Motivation

Massive / massless particles in classical field theory:

spin 0:	Higgs boson $\phi$
spin 1/2 :	quarks, leptons $\psi^a$
spin 1:	gluons, photons, W- & Z-bosons $A_\mu$

} well-known  
consistent  
theories

spin 2: graviton $g_{\mu\nu}$ <b>massless!!!</b>
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What is the theory for a **massive** spin-2 particle?

# Bimetric theory

- Massless spin-2 = general relativity with Einstein-Hilbert action for metric tensor  $g_{\mu\nu}$

$$S_{\text{EH}}[g] = M_g^{d-2} \int d^d x \sqrt{g} R(g)$$

- Mass term should have non-derivative interactions of  $g_{\mu\nu}$
- Lorentz invariance  $\Rightarrow$  need second metric to contract indices

$$g^{\mu\nu} f_{\mu\nu}, \quad g^{\nu\rho} f_{\rho\sigma} g^{\sigma\mu} f_{\mu\nu}, \quad \text{etc.}$$

- Bimetric action is of the form

$$S[g, f] = S_{\text{EH}}[g] + S_{\text{EH}}[f] - \mu^d \int d^d x \sqrt{g} V(g^{-1} f)$$

# Ghost-free interaction potential

Generic interaction potential has a ghost instability! [Boulware & Deser, 1972]

Only consistent choice:

$$V(g^{-1}f) = \sum_{n=0}^d \beta_n e_n \left( \sqrt{g^{-1}f} \right)$$

[de Rham, Gabadadze & Tolley, 2010; Hassan & Rosen, 2011]

For instance, in  $d = 4$ :

- theory has  $7 = 2 + 5$  d.o.f.  $\rightarrow$  massless + massive spin-2
- five independent parameters  $\beta_n$   
 $\rightarrow$  set mass, cosmological constant and interactions

Integrating out  $f_{\mu\nu}$  gives an effective theory for  $g_{\mu\nu}$  with higher curvature terms

[Hassan, ASM & von Strauss, 2013]

- nonlinear completion of New Massive Gravity in  $d = 3$   
& ghost-free generalization to all dimensions
- ghost-free nonlinear completion of **conformal gravity** in  $d = 4$

$$S_{\text{CG}}[g] = \int d^4x \left( R^{\mu\nu} R_{\mu\nu} - \frac{1}{3} R^2 \right) + \mathcal{O} \left( (\partial/\mu)^6 \right)$$

→ **“Partially massless bimetric theory”**

## **If you'd like to know more...**

S.F. Hassan, R. Rosen, ASM

*1109.3230*

M. von Strauss, ASM, J. Enander, E. Mörtzell, S.F. Hassan

*1111.1655*

S.F. Hassan, ASM, M. von Strauss

*1203.5283*

*1204.5202*

*1208.1515*

*1208.1797*

*1212.4525*

*1303.6940*