

# Superbigravity

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# Overview

- 1 Massive gravity
- 2 Ghost-free bimetric theory
- 3 Supersymmetrizing bimetric theory

# Massless spin-2

## ① Minkowski background:

- action:  $\mathcal{L}_{lin} = \frac{1}{2} h^{\mu\nu} \varepsilon_{\mu\nu}^{\rho\sigma} h_{\rho\sigma}$

- Lichnerowicz operator:

$$\begin{aligned}\varepsilon_{\mu\nu}^{\rho\sigma} &= \frac{1}{2} (\eta_\mu^\rho \eta_\nu^\sigma \partial^2 - \eta_\nu^\sigma \partial_\mu \partial^\rho - \eta_\mu^\sigma \partial_\nu \partial^\rho \\ &\quad + \eta_{\mu\nu} \partial^\sigma \partial^\rho + \eta^{\rho\sigma} \partial_\mu \partial_\nu - \eta_{\mu\nu} \eta^{\rho\sigma} \partial^2)\end{aligned}$$

- gauge symmetry:  $h_{\mu\nu} \rightarrow h_{\mu\nu} + \partial_\mu \xi_\nu + \partial_\nu \xi_\mu$

## ② curved background:

- action:  $S_{GR} = M_{Pl}^2 \int d^4x \sqrt{g} R(g)$

- gauge symmetry: diff

2 propagating d.o.f.  
no ghosts

# Massive spin-2

## ① Minkowski background:

- action:  $\mathcal{L}_{\text{FP}} = \frac{1}{2} h^{\mu\nu} \varepsilon_{\mu\nu}^{\rho\sigma} h_{\rho\sigma} - \frac{m_{\text{FP}}^2}{2} (h^{\mu\nu} h_{\mu\nu} - h^2)$

Fierz, Pauli 1939

- no gauge symmetry; alternative: Stückelberg

## ② curved background:

- $g^{\mu\nu} g_{\mu\nu}$  is no mass term!

- action:  $S_{\text{dRGT}} = M_{\text{Pl}}^2 \int d^4x \sqrt{g} \left( R(g) + \frac{m^2}{2} \sum_{n=2}^4 \alpha_n e_n(\mathcal{K}) \right),$

where  $\mathcal{K}_\nu^\mu = \delta_\nu^\mu - \left( \sqrt{g^{-1}} \eta \right)_\nu^\mu$

de Rham, Gabadadze, Tolley 2010

5 propagating d.o.f.

no ghosts; else: Boulware–Deser 1972

# Two dynamical metrics

- action:

$$\begin{aligned} S = & m_g^2 \int d^4x \sqrt{g} R(g) + m_f^2 \int d^4x \sqrt{f} R(f) \\ & - m^4 \int d^4x \sqrt{g} \sum_{n=0}^{n=4} \beta_n e_n(\sqrt{g^{-1}f}) \end{aligned}$$

Hassan, Rosen, Schmidt-May, von Strauss '11-'12

- elementary symmetric polynomials  $e_n(S)$  ,  $S^2 = g^{-1}f$

$$e_1(S) = \text{Tr}[S] , \quad e_2(S) = \frac{1}{2}((\text{Tr}[S])^2 - \text{Tr}[S^2])$$

$$e_3(S) = \frac{1}{6}((\text{Tr}[S])^3 - 3 \text{Tr}[S^2] \text{Tr}[S] + 2 \text{Tr}[S^3])$$

- spectrum: massless  $\delta g_{\mu\nu} + \alpha^2 \delta f_{\mu\nu}$  and massive  $\delta f_{\mu\nu} - \delta g_{\mu\nu}$  eigenstates around proportional backgrounds solution

# Multigravity

- center and chain Hassan-Rosen couplings
- no loops allowed!
- generalization:

$$\mathcal{S}_V = - \sum_{i,j,k,l} \int \textcolor{red}{T_{ijkl}} \varepsilon_{abcd} (E_i)^a \wedge (E_j)^b \wedge (E_k)^c \wedge (E_l)^d$$

Hinterbichler and Rosen '12

- see also CM, Rudolph, Schmidt-May '18

# Known results and our ongoing work

- Massive supermultiplets  $(2, 3/2, 3/2, 1)$  around Minkowski  
→ global susy trsf

Zinoviev '02, Ondo and Tolley '16

- Einstein + Weyl<sup>2</sup> supergravity (contains massive spin-2 ghost) and its embedding in type IIB

$$\sqrt{g} \left( m_g^2 R + \frac{a}{2} W^2 \right) \rightarrow \int d^2\Theta \mathcal{E} (2\mathcal{R} + 4\tau \mathcal{W}^2)$$

Ferrara, Kehagias, Lüst '18

- superfield formulation of supersymmetric bimetric theory
  - “standard” sugra techniques don’t seem to work
  - explicit breaking to diagonal GCTs, LLTs and local susy trsf

CM, Schmidt-May 19xx.xxxx