Projects in the Gravitational Theory Group

Angnis Schmidt-May

Max-Planck-Institut
für Physik

Project Review

MPI for Physics, 17/12/18

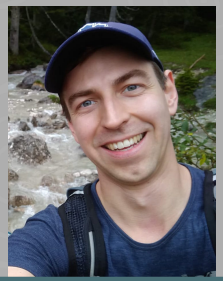
Members of the Gravitational Theory Group

Postdocs

Veronica Errasti-Diez

Julio Mendez

Chrysoula Markou



Felix Rudolph

PhD students

Brage Gording

Marvin Lüben

Master student

Giorgos Papagoudis

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CONACYT
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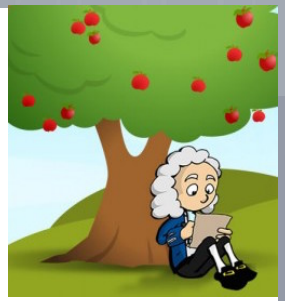
MAX-PLANCK-GESELLSCHAFT

General Research Interests of the Group



- extended and modified theories for gravity:
  - gravitational theories with more than one metric
  - gravitational theories with different geometry
- particle physics interpretation of theories with massive spin-2 fields
- implications for cosmology and astrophysics
- general aspects of consistent field theories
- new symmetries and implications for quantum gravity

Image: http://shlok.mobi

Why are we interested in these topics ?

Consistent Field Theories

Standard Model of Particle Physics & General Relativity

Spin 0:	Higgs boson ϕ
Spin 1/2:	leptons, quarks ψ^a
Spin 1:	gluons, photon, W- & Z-boson A_μ
Spin 2:	graviton $g_{\mu\nu}$

Consistent Field Theories

Standard Model of Particle Physics & General Relativity

Spin 0: Higgs boson ϕ

Spin 1/2: leptons, quarks ψ^a

Spin 1: gluons, photon, W- & Z-boson A_μ

Spin 2: graviton $g_{\mu\nu}$

well understood

less understood …

Consistent Field Theories

Standard Model of Particle Physics & General Relativity

Spin 0: Higgs boson ϕ

Spin 1/2: leptons, quarks ψ^a

Spin 1: gluons, photon, W- & Z-boson A_μ

Spin 2: graviton $g_{\mu\nu}$

massless & massive

MASSLESS !

How do we describe massive spin-2 fields ?

General Relativity

= classical nonlinear field theory for metric tensor $g_{\mu\nu}$

- Einstein-Hilbert action: $S_{\rm EH}[g] = M_{\rm P}^2 \int {\rm d}^4x\sqrt{g}\,\Big(R(g) - 2\Lambda\Big)$
- Einstein's equations: $R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = 0$

⇨ describes the two degrees of freedom of a self-interacting, massless spin-2 field

Bimetric Theory

Nonlinear field theory for two interacting tensors:

$$
\begin{aligned}
S_{\rm b}[g,f] &= m_g^2 \int {\rm d}^4x\sqrt{g}\,\Big(R(g)-2\Lambda\Big) \\
&+ m_f^2 \int {\rm d}^4x\sqrt{f}\,\Big(R(f)-2\tilde{\Lambda}\Big) \;-\; \int {\rm d}^4x\, V(g,f)
\end{aligned}
$$

Bimetric Theory

Nonlinear field theory for two interacting tensors:

$E_{kin} < 0$

$$
\begin{aligned}
S_{\rm b}[g,f] &= m_g^2 \int {\rm d}^4x\sqrt{g}\,\Big(R(g)-2\Lambda\Big) \\
&+ m_f^2 \int {\rm d}^4x\sqrt{f}\,\Big(R(f)-2\tilde{\Lambda}\Big) - \int {\rm d}^4x\, V(g,f)
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Bimetric Theory

Nonlinear field theory for two interacting tensors:

unique structure!

$$
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\end{aligned}
$$

describes a massive & a massless spin-2 field

Bimetric Theory

Nonlinear field theory for two interacting tensors:

unique structure!

$$S_{\rm b}[g,f] = m_g^2 \int {\rm d}^4x\sqrt{g}\,\Big(R(g)-2\Lambda\Big) + m_f^2 \int {\rm d}^4x\sqrt{f}\,\Big(R(f)-2\tilde{\Lambda}\Big) - \int {\rm d}^4x\, V(g,f)$$

describes a massive & a massless spin-2 field

- contains a new massive field with spin-2
- lots of interesting new physics

Consistent Field Theories

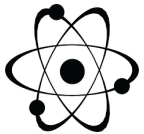
Standard Model of Particle Physics & Bimetric Theory

Spin 0:	Higgs boson	ϕ
Spin 1/2:	leptons, quarks	ψ^a
Spin 1:	gluons, photon, W- & Z-boson	A_μ
Spin 2:	massless graviton	$g_{\mu\nu}$
	massive spin-2	$f_{\mu\nu}$

Features of Massive Spin-2 Fields

- they can drive the cosmic acceleration in the absence of vacuum energy
- massive spin-2 particles are naturally ideal dark matter candidates

- massive spin-2 theories can have extra symmetries which could be relevant for quantum gravity



Our Achievements in 2018

Completed projects in 2018

- better understanding of the matter coupling in bimetric theory

M. Lüben & ASM; 1804.04671 (Fortsch.Phys.)

What are the interactions with the Standard Model particles and how is the gravitational force modified ?

Completed projects in 2018

- better understanding of the matter coupling in bimetric theory

  M. Lüben & ASM; 1804.04671 (Fortsch.Phys.)

- new interactions in multi-spin-2 theories

  S.F. Hassan & ASM; 1804.09723 (under review by PRL)

What are the most general theories for multiple spin-2 fields ?

Completed projects in 2018

- better understanding of the matter coupling in bimetric theory

  M. Lüben & ASM; 1804.04671 (Fortsch.Phys.)

- new interactions in multi-spin-2 theories

  S.F. Hassan & ASM; 1804.09723 (under review by PRL)

How is our setup related to other known theories ?

- establishment of a relation to higher-derivative theories for gravity

  B. Gording & ASM; 1807.05011 (JHEP)

Completed projects in 2018

(continued)

- relating 4-dimensional gravity theories to 5-dimensional gauge theories

  N. Gonzalez Albornoz, D. Lüst, S. Salgado & ASM; 1811.05435 (JHEP)

Can the structure of spin-2 interactions arise from a gauge formulation ?

Completed projects in 2018

(continued)

- relating 4-dimensional gravity theories to 5-dimensional gauge theories

  N. Gonzalez Albornoz, D. Lüst, S. Salgado & ASM; 1811.05435 (JHEP)

- proposal of a gravitational theory including an antisymmetric field

  C. Markou, F. Rudolph & ASM; 1811.12419 (under review by JHEP)

What is the geometry of massive spin-2 theories ?

Completed projects in 2018

(continued)

- relating 4-dimensional gravity theories to 5-dimensional gauge theories

  N. Gonzalez Albornoz, D. Lüst, S. Salgado & ASM; 1811.05435 (JHEP)

- proposal of a gravitational theo

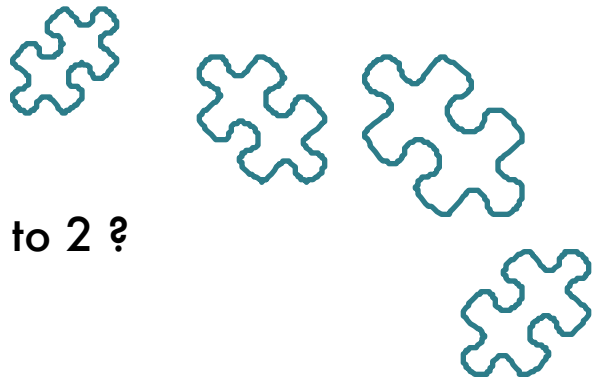
  C. Markou, F. Rudolph

What is the complete set of consistent field theories ?

- consistent interactions for multiple massive spin-1 fields

  V. Errasti-Diez , B. Gording, J. Mendez & ASM; work in progress

Questions for the Future



- Most general interactions for spin up to 2 ?
- Relation to string theory ?
- New symmetries ?
- Quantum theory ?
- Observational constraints on massive spin-2 fields ?

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