

Darker and Heavier

Spin-2 Dark Matter



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Tallinn

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Outline

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😊 What is bigravity?!? 😊

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👁️ Spin-2 Dark Matter 👁️

👤 Phenomenology 👤

Based on work with the *FatGR-DM monster collaboration*:
Babichev, Marzola, Raidal, Schmidt-May, FU, Veermäe, von Strauss

arXiv:1604.08564 in PRD

and

arXiv:1607.03497 in JCAP

See also Aoki and Mukohyama (2016)

FatGR-DM checklist

FatGR-DM checklist

Theory

FatGR-DM checklist

Theory



The theory is sane

FatGR-DM checklist

Theory



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The theory is not excluded

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Phenomenology

FatGR-DM checklist

Theory

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Phenomenology

-  DM gravitates as it should

FatGR-DM checklist

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Bimetric theory essentials

Hassan and Rosen (2012) x2

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The ghost-free coupling to matter breaks the symmetry:

$$S_m = \int d^4x \sqrt{|g|} \mathcal{L}_m(g, \Phi)$$

FatGR-DM checklist

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Phenomenology

- 🌳 DM gravitates as it should
- 🌳 DM evades all current detection experiments
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- 🌳 DM is (meta)stable
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What's in this theory?

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- c. These are mixtures of the interaction eigenstates with parameter α

$$\delta g_{\mu\nu} = \frac{1}{M_{\text{Pl}}} (\delta G_{\mu\nu} - \alpha \delta M_{\mu\nu}) , \quad \delta f_{\mu\nu} = \frac{1}{M_{\text{Pl}}} (\delta G_{\mu\nu} + \alpha^{-1} \delta M_{\mu\nu})$$

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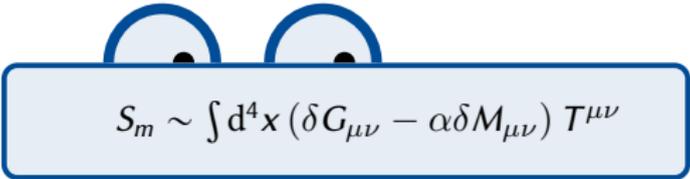
- PS: We have defined the physical Planck mass as $M_{\text{Pl}}^2 \equiv (1 + \alpha^2) m_g^2$

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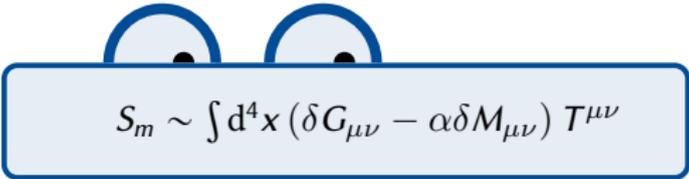

$$S_m \sim \int d^4x (\delta G_{\mu\nu} - \alpha \delta M_{\mu\nu}) T^{\mu\nu}$$

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By the way: $\Lambda = \frac{\alpha^2 M_{\text{Pl}}^2}{1+\alpha^2} (\beta_0 + 3\beta_1 + 3\beta_2 + \beta_3) = \frac{M_{\text{Pl}}^2}{1+\alpha^2} (\beta_4 + 3\beta_3 + 3\beta_2 + \beta_1)$

FatGR-DM checklist

Theory



The theory is sane



The theory is not excluded

Phenomenology



DM gravitates as it should



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Recovering GR (or not)

We can show that there are two regions for which GR is approached:

❖ **Static spherical solutions**

α For $m_{\text{FP}}^2 \gg \Lambda$ the linear regime applies everywhere

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* Cosmological solutions

$$3H^2 = \Lambda + \rho/M_{\text{Pl}}^2 [1 - \mathcal{O}(\alpha^2 \Lambda/m_{\text{FP}}^2)] + \mathcal{O}(\rho^2)$$

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* Massive (\neq bi) gravity: the linear regime is **never** GR.

Vainshtein is on at scales below $r_V \sim m_{\text{FP}}^{-2/3}$: since $r_V \ll r_\odot$ we need a small m_{FP} , usually $m_{\text{FP}} \sim H_0$

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How does δM gravitate?

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- iv. δM self-interactions are enhanced compared to GR

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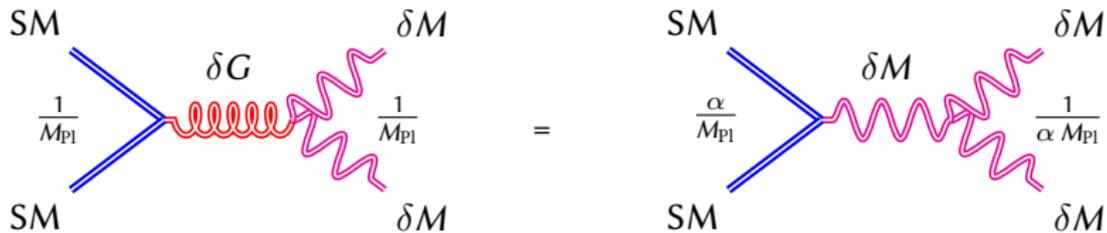
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Production and decay

- The massive spin-2 can be produced via freeze-in:



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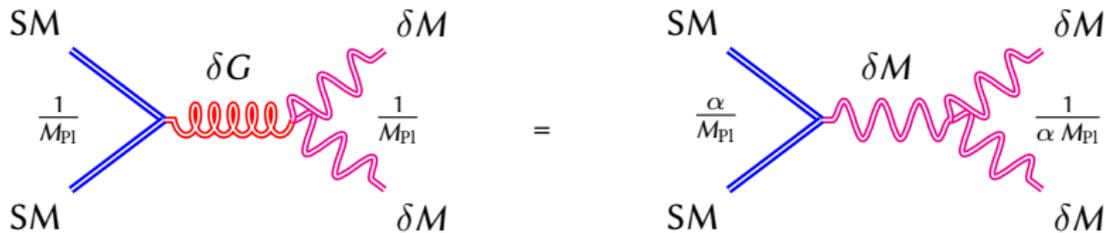
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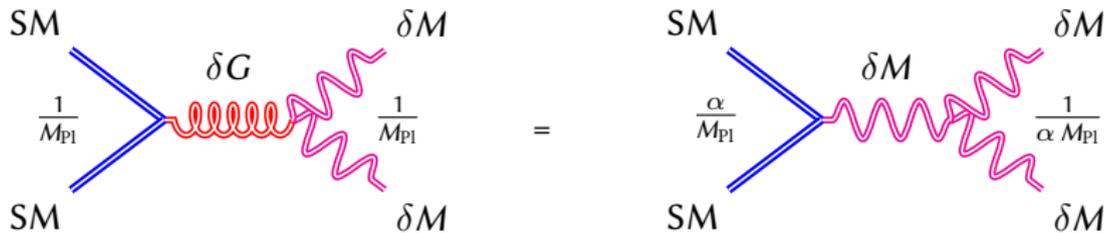
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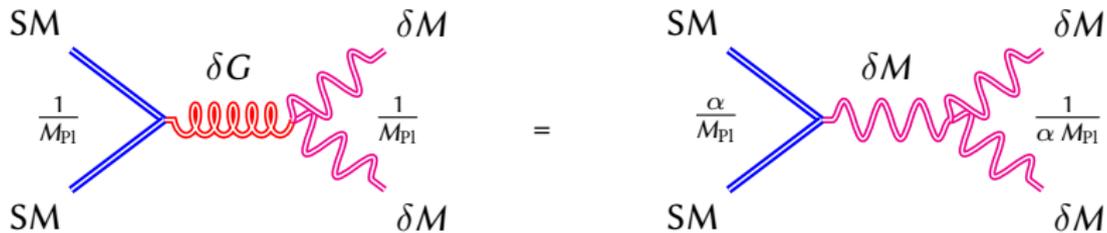


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- ★ The froze-in DM should have the right abundance and not decay too fast: this can be arranged!

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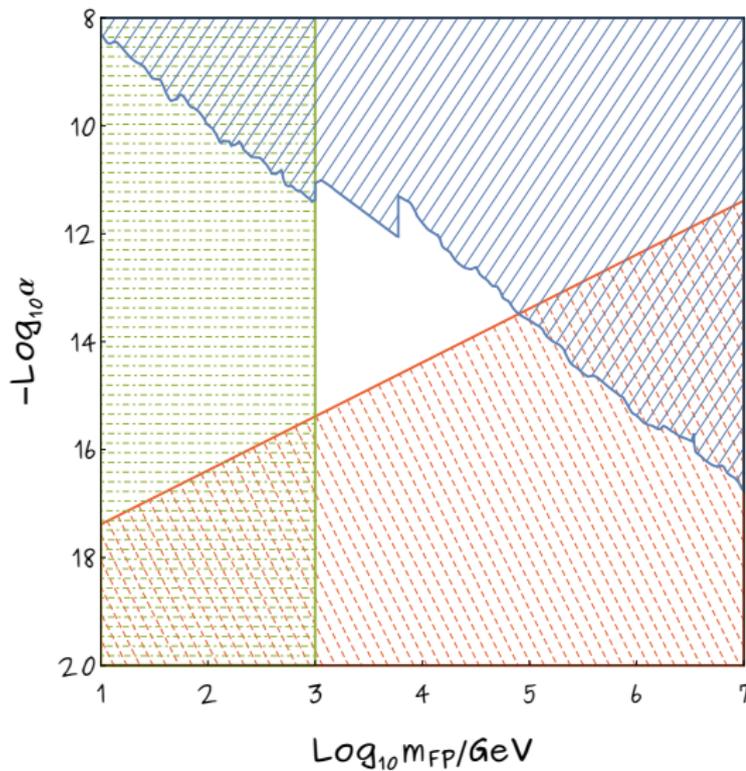


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The parameter space



- . Decay
- . Perturbativity
- . Production

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⊕ **Thank you! — Aitäh!** ⊕