

# The fat (bi)graviton

Dark matter as a spin-off of gravity



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Tallinn

*PASCOS 2016*  
*ICISE, Quy Nhon, Vietnam*

July 13th, 2016

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# Outline

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

arXiv:1604.08564

and

arXiv:1607.this.week

See also Aoki and Mukohyama (2016)

## FatGR-DM checklist

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# FatGR-DM checklist

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**Theory**

# FatGR-DM checklist

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## **Theory**



The theory is sane

# FatGR-DM checklist

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The theory is not excluded

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DM gravitates as it should

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# Bimetric theory essentials

Hassan and Rosen (2012) x2

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$$S = \int d^4x \left[ \sqrt{|g|} m_g^2 R(g) + \sqrt{|f|} m_f^2 R(f) - 2m^4 \sqrt{|g|} V(g, f; \beta_n) \right]$$

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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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## What's in this theory?

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Expand around proportional backgrounds  $f_{\mu\nu} = c g_{\mu\nu}$  (for technical reasons)

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

# Matter?

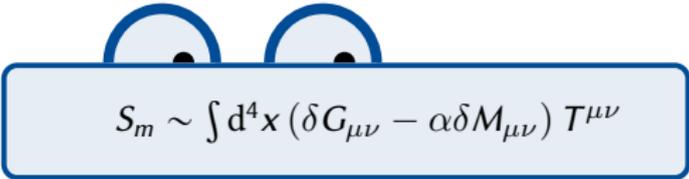
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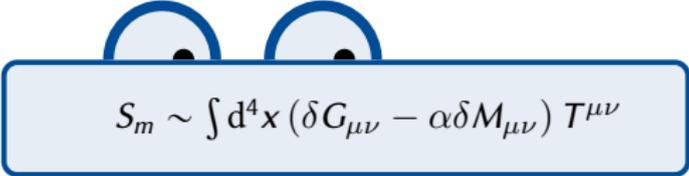
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By the way:  $\Lambda = \frac{\alpha^2 M_{\text{Pl}}^2}{1+\alpha^2} (\beta_0 + 3\beta_1 + 3\beta_2 + \beta_3) = \frac{M_{\text{Pl}}^2}{1+\alpha^2} (\beta_4 + 3\beta_3 + 3\beta_2 + \beta_1)$

# FatGR-DM checklist

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## **Theory**



The theory is sane



The theory is not excluded

## **Phenomenology**



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DM evades all current detection experiments



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# Recovering GR (or not)

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

## ❖ **Static spherical solutions**

$\alpha$  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  $m_{\text{FP}}$ , usually  $m_{\text{FP}} \sim H_0$

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## How does $\delta M$ gravitate?

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- iv.  $\delta M$  self-interactions are enhanced compared to GR

# FatGR-DM checklist

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## **Phenomenology**



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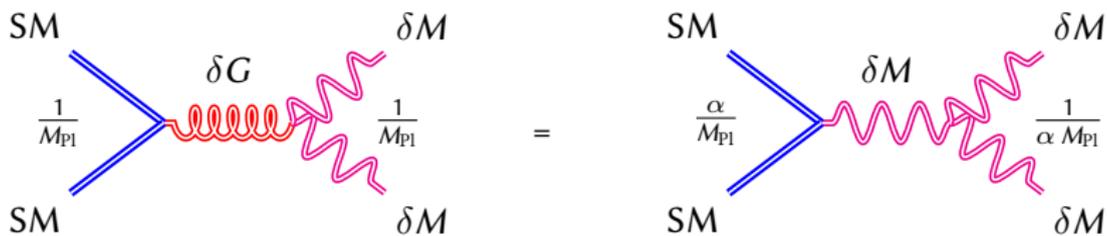


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# Production and decay

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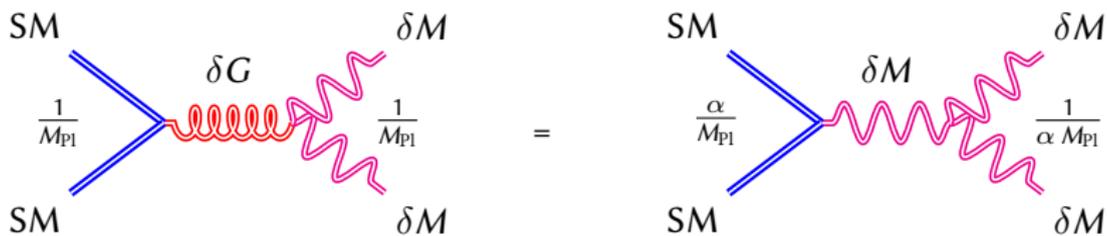


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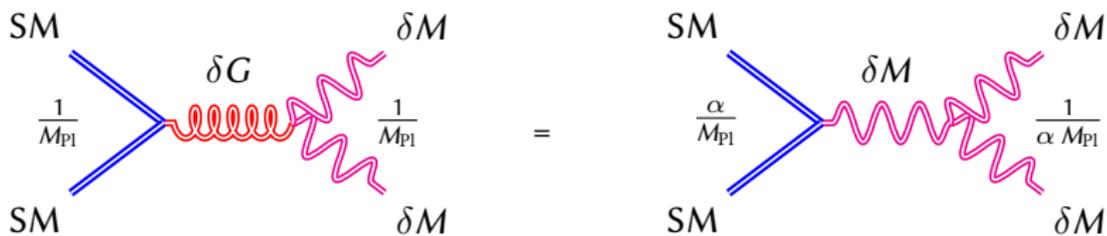
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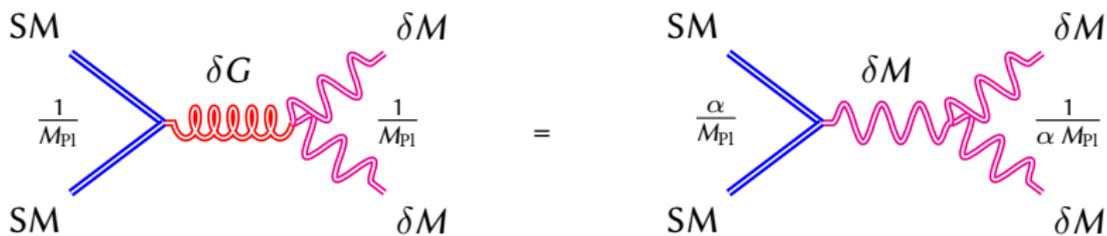


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- ★ The froze-in DM should have the right abundance and not decay too fast: this can be arranged!

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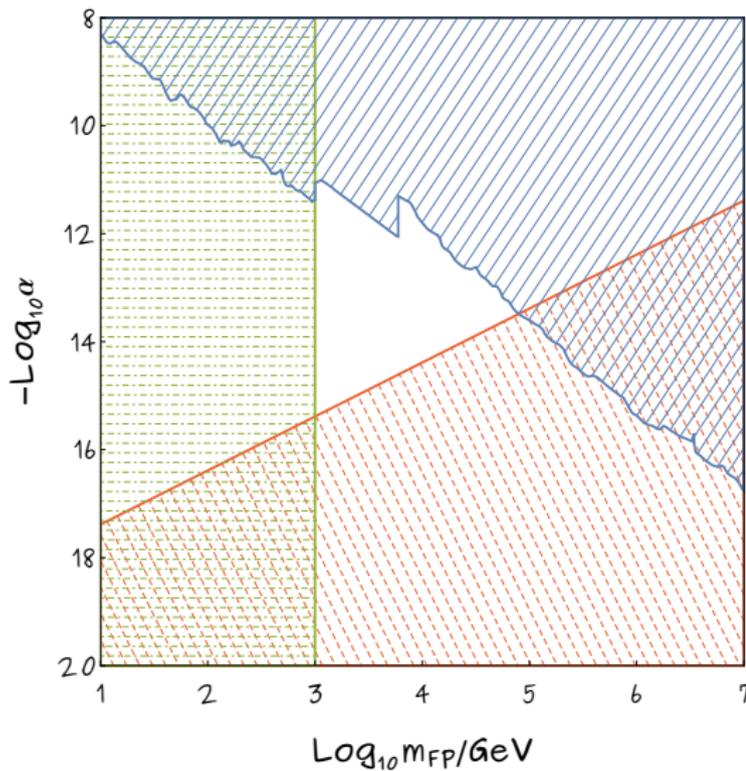


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# The parameter space



- . Decay
- . Perturbativity
- . Production

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**WE HAVE A JOLLY DM CANDIDATE HERE!**

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**Thank you! — Cảm ơn!**