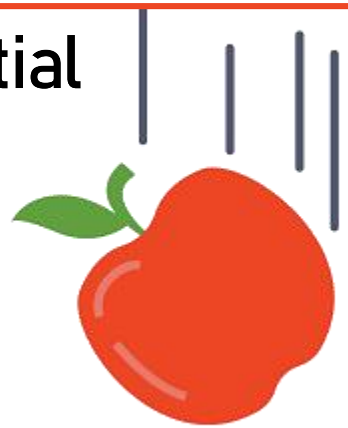
UNIVERSITY OF LIVERPOOL

# Gravity at the Tip of the Throat

## Corrections to the Newtonian potential



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Work done in collaboration with
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# What am I doing…?



## String Theory??

"String Theory can't be tested ⇒ Useless"

"It only works in 10d ⇒ Useless"

"It doesn't make predictions ⇒ Useless"

Why am I doing it?

# How do we do it?

- **Type IIB String Theory**

  $g_{MN},\ \phi,\ C_0\ ,\ C_2,\ B_2,\ C_4^+,\ \lambda^i\ ,\ \psi_\mu^i$

- **Type IIB Supergravity**

  $$S_{IIB}^{boson} = \frac{1}{2\kappa^2}\int d^{10}x\sqrt{-g_{10}}\left\{R_{10} - \frac{\partial_M\tau\partial^M\bar{\tau}}{2(\mathrm{Im}\tau)^2} - \frac{g_s|G_3|^2}{2(\mathrm{Im}\tau)} - \frac{g_s^2|F_5|^2}{4}\right\} - \frac{ig_s^2}{8\kappa^2}\int\frac{C_4^+\wedge G_3\wedge\bar{G}_3}{\mathrm{Im}\tau}$$

- **Graviton perturbations**

  $g_{MN} \to g_{MN}^0 + h_{MN}$

  $$\Box_D h_{MN} - 2R^{(0)S}{}_{MNP}\,g^{PQ}h_{QS} - \frac{1}{4}(g^{PQ}\tau_{PQ}^{(1)})g_{MN} - 2g^{PQ}h_{Q(M}\tau_{N)P}^{(0)} + 2\tau_{MN}^{(1)} = 0$$

- **Dimensional reduction**

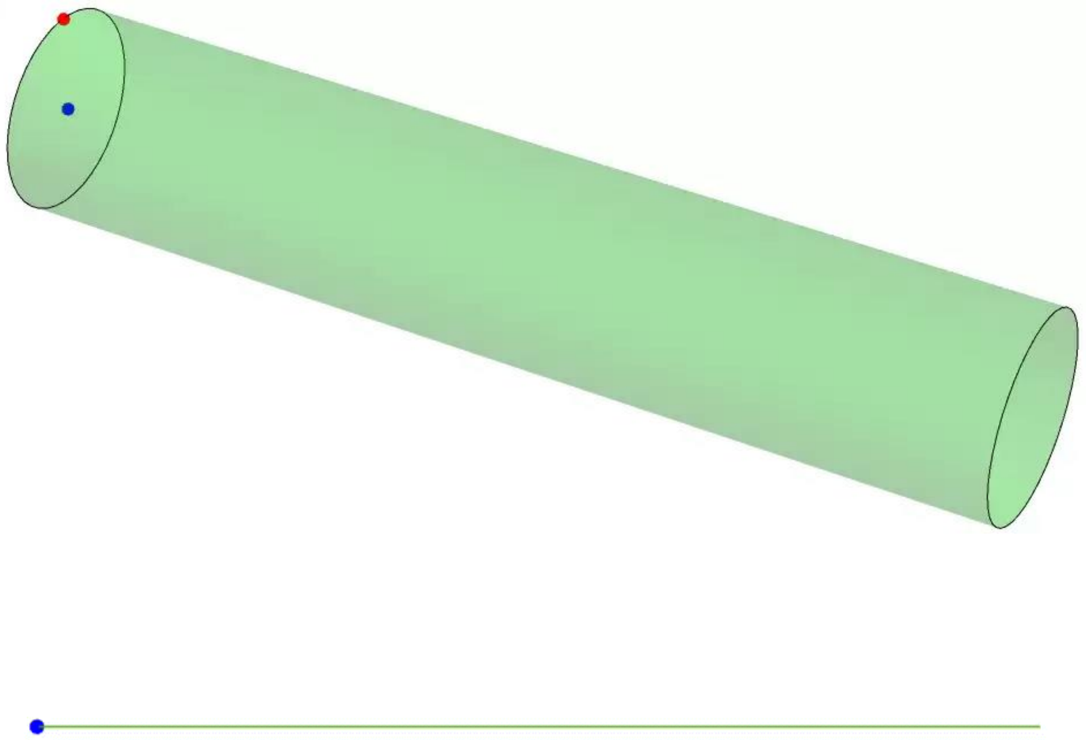
  $h_{MN} \to h_{\mu\nu}, h_{\mu n}, h_{mn}$

- **Corrections to Newtonian potential**

  $$V(r) = G\frac{m_1 m_2}{r}(1 + \alpha e^{-\lambda r})$$

# Kaluza-Klein modes ($M_{KK}$)





$m_4$

$$p^M p_M = m^2$$

$m_3$

$$p^\mu p_\mu - p^n p_n = m^2$$

$m_2$

$$p^\mu p_\mu = m^2 + \underbrace{p^n p_n}_{m_k^2}$$

$M_{KK}$

$$\Box_4 h^k_{\mu\nu} - m_k^2 h^k_{\mu\nu} = 0$$

# Warped throat



$$ds^2 = H^{-1/2}\underbrace{g_{\mu\nu}dx^{\mu}dx^{\nu}}_{\text{4d}} + H^{1/2}\, c(x)^{1/2}\underbrace{g_{mn}dy^{m}dy^{n}}_{\text{Compact space}}$$

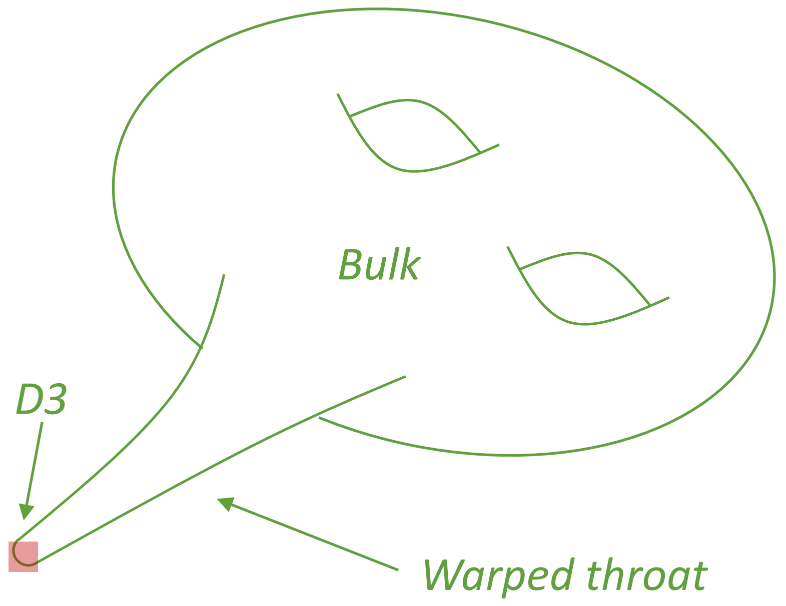
Warp factor

E.g. the string scale

$$m_s^w = H_{tip}^{-1/4} m_s \approx \left(c^{1/4} e^{A_{tip}}\right) m_s$$

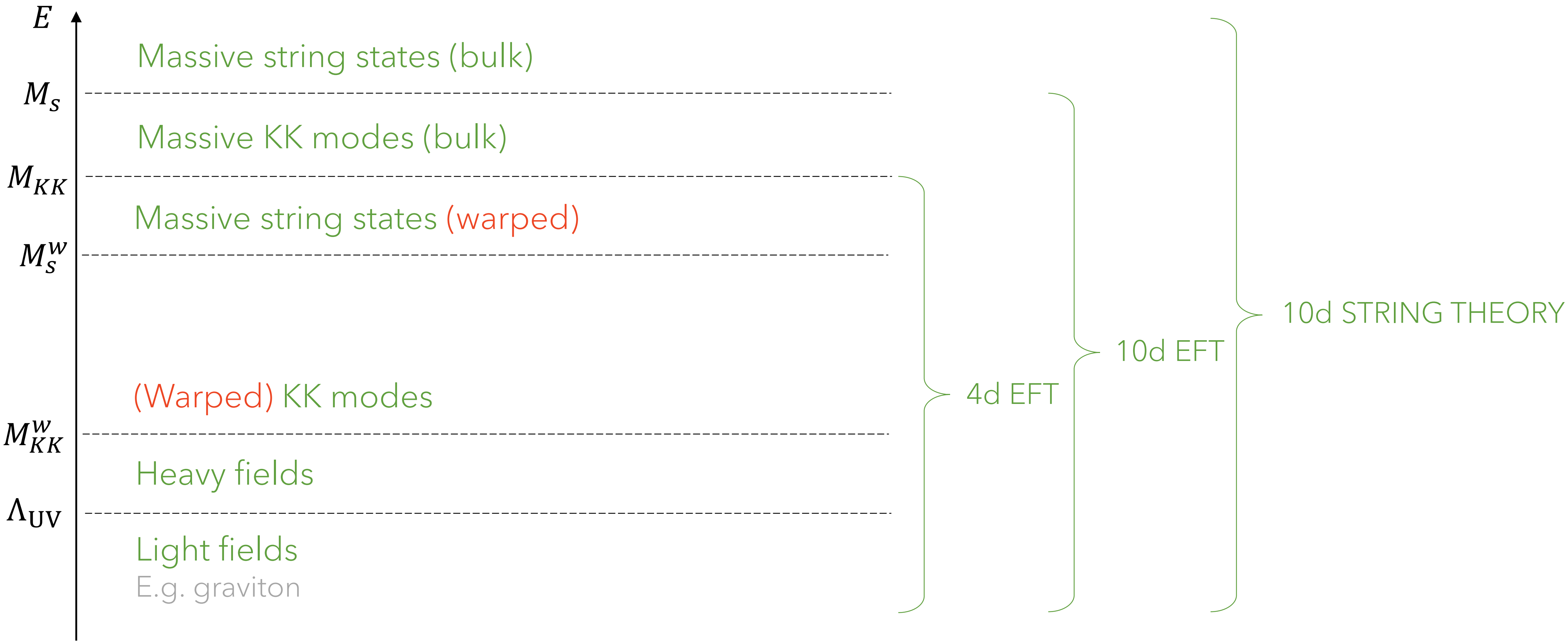
Klebanov-Strassler:

$$e^{A_{tip}} \sim \frac{2\pi}{\sqrt{g_s M}} e^{-\frac{2\pi K}{g_s M}}$$



# Scales and EFTs (Warped)





# Scales and EFTs (Warped)

$E$

Massive string states (bulk)

$M_s$

Massive KK modes (bulk)

$M_{KK}$

Massive string states (warped)

$M_s^w$

Heavy fields

$\Lambda_{\mathrm{UV}}$

(Warped) KK modes

$M_{KK}^w$

Light fields

E.g. graviton

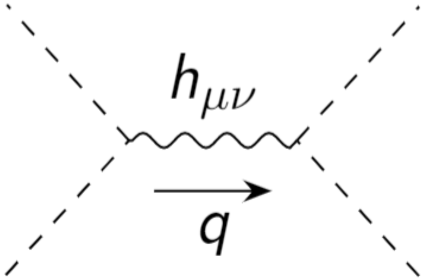
4d EFT

10d EFT

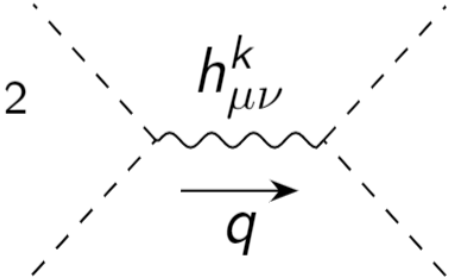
10d STRING THEORY

# Gravitational Potential


$$V(q) = \lim_{q^0 \to 0}$$




$$= \lim_{q^0 \to 0} \sum_k |\Phi_k(\tau)|^2$$

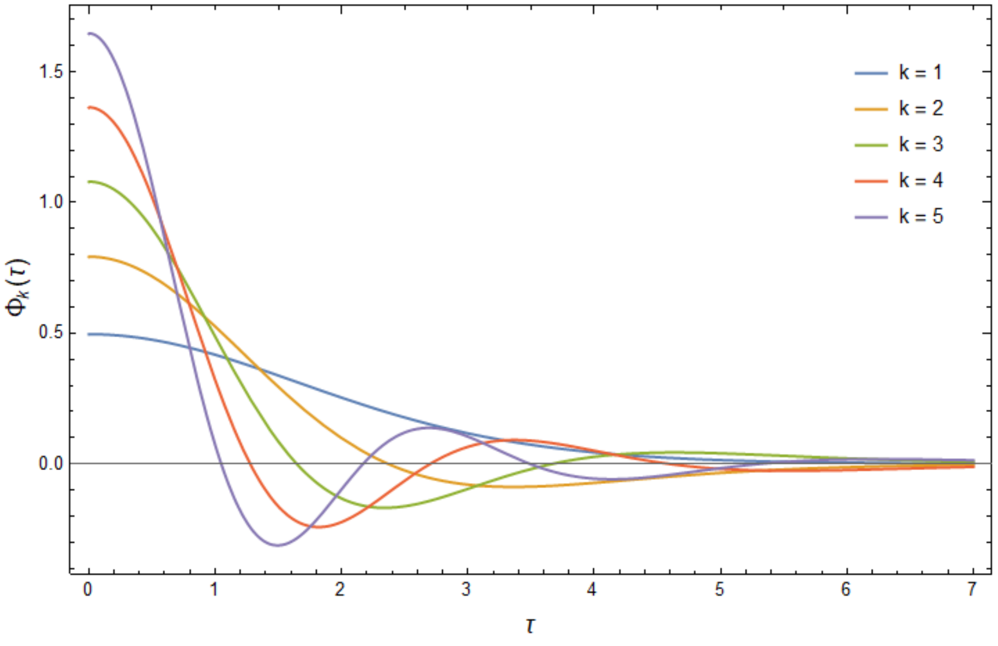


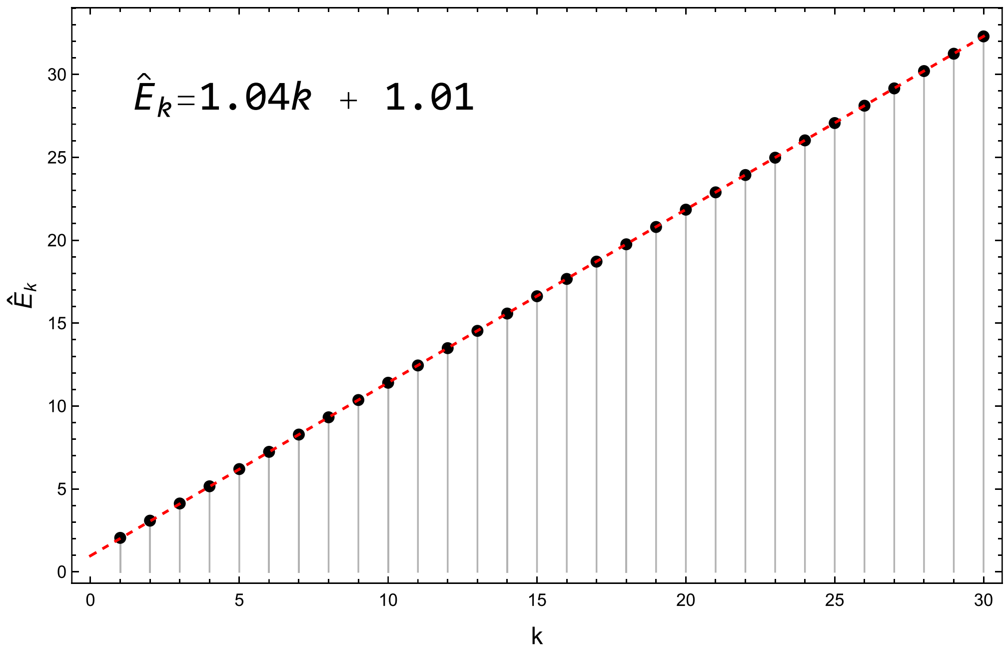

$$V(r) = G\frac{m_1 m_2}{r}\left\{1 + \frac{4}{3}V_w \sum_{k>0} |\Phi_k(0)|^2\, e^{-m_k r}\right\}$$

# Gravitational Potential


$$V(r) = G\,\frac{m_1 m_2}{r}\left\{1 + \frac{4}{3} V_w \sum_{k>0} |\Phi_k(0)|^2\, e^{-m_k r}\right\}$$

$$m_k = \frac{2\pi}{\sqrt{g_s M}}\left(c^{1/4} e^{A_{tip}}\right)\hat{E}_k$$



# Gravitational Potential


Experimental constraints

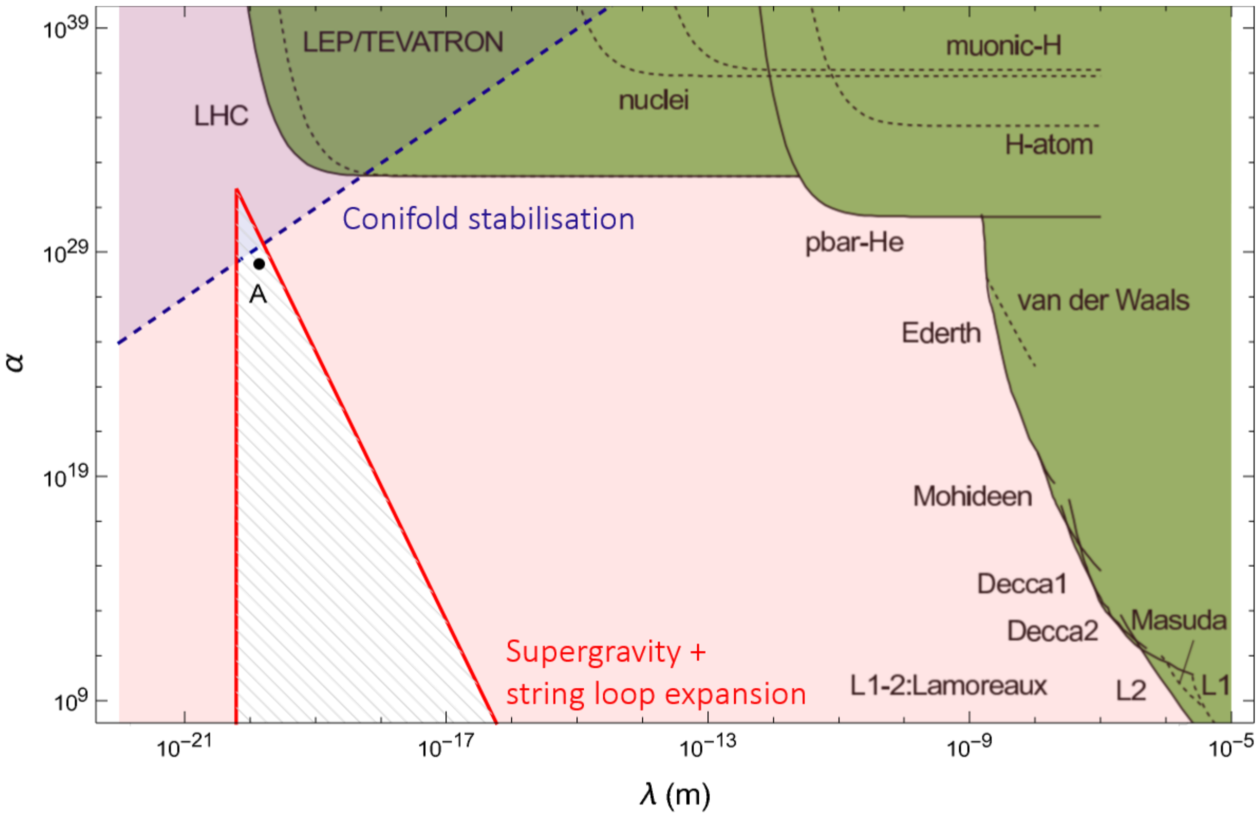
$$V(r) = G\frac{m_1 m_2}{r}\{1 + \alpha e^{-r/\lambda}\}$$

For us

$$\alpha = \frac{8a\gamma^2}{(g_s M)^3}\frac{g_s^2}{\mathcal{H}^2}$$

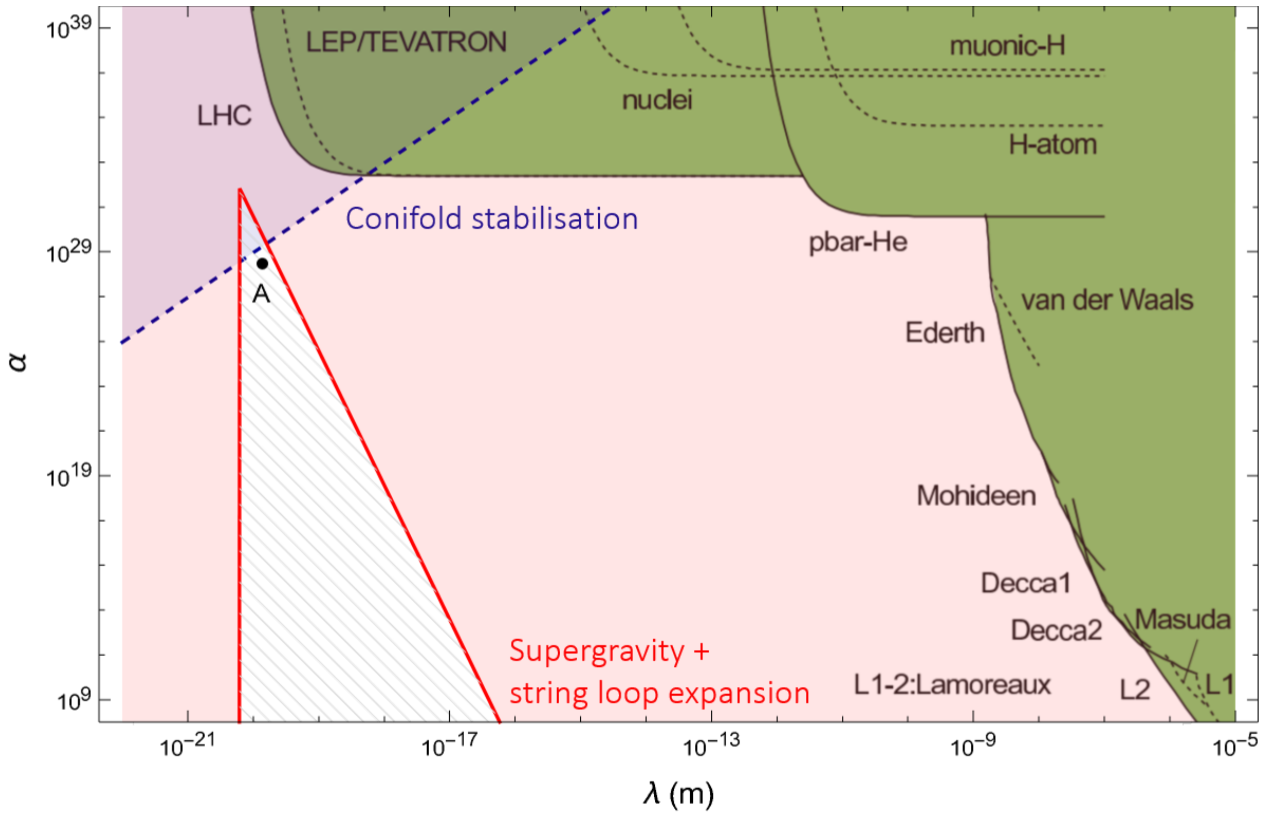
Hierarchy

$$\lambda^{-1} = (2\pi)^2\frac{\mathcal{H}}{\gamma\sqrt{g_s M}}\frac{b}{l_p}$$




# Conclusions

- The gravitational sector is rich and might provide several testable effects
- Combining these with other tests will allow us to study the parameter space of the theory
- Internal consistency is already very constraining
- It might not be useless…




## Thank you!