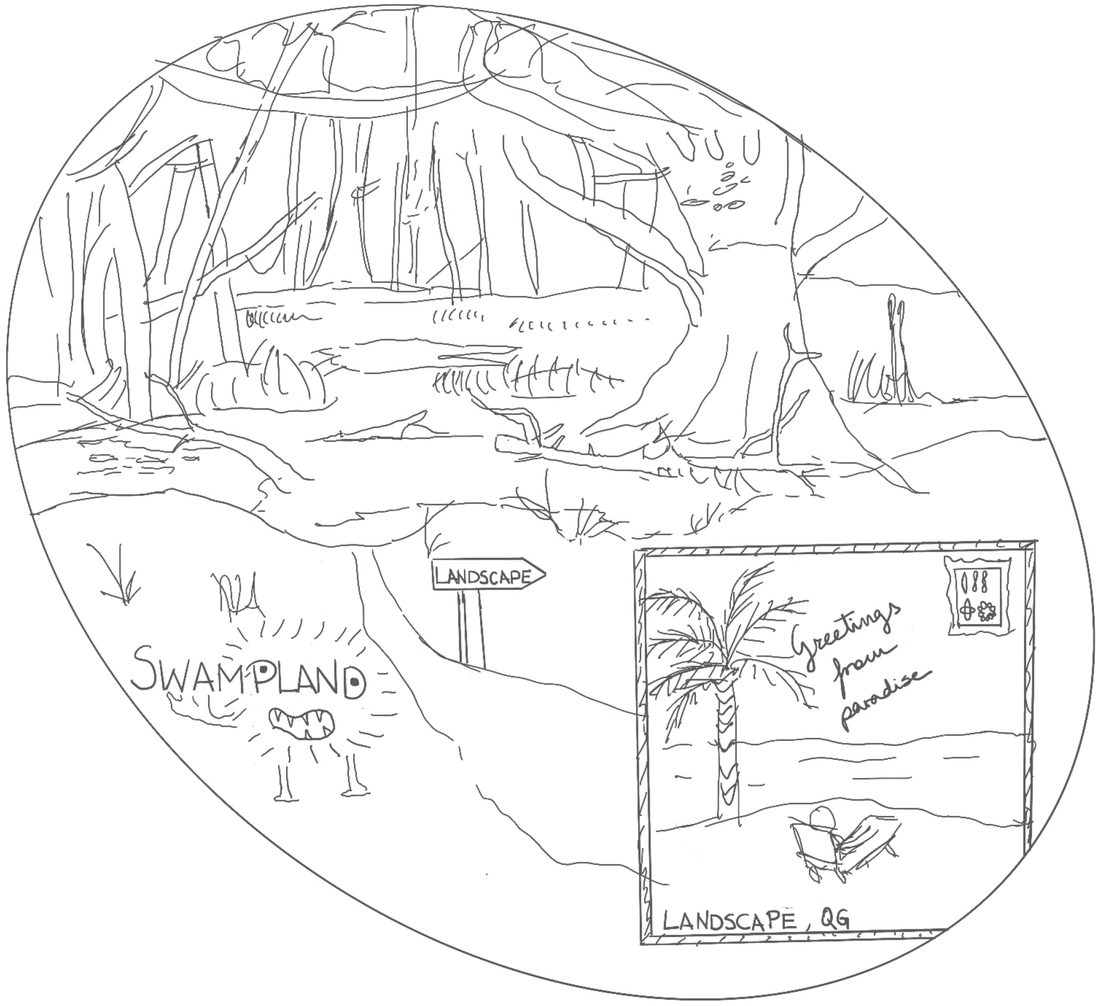
Swampland: Review & Particle Physics Implications



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IFT Madrid, June 14th, 2024

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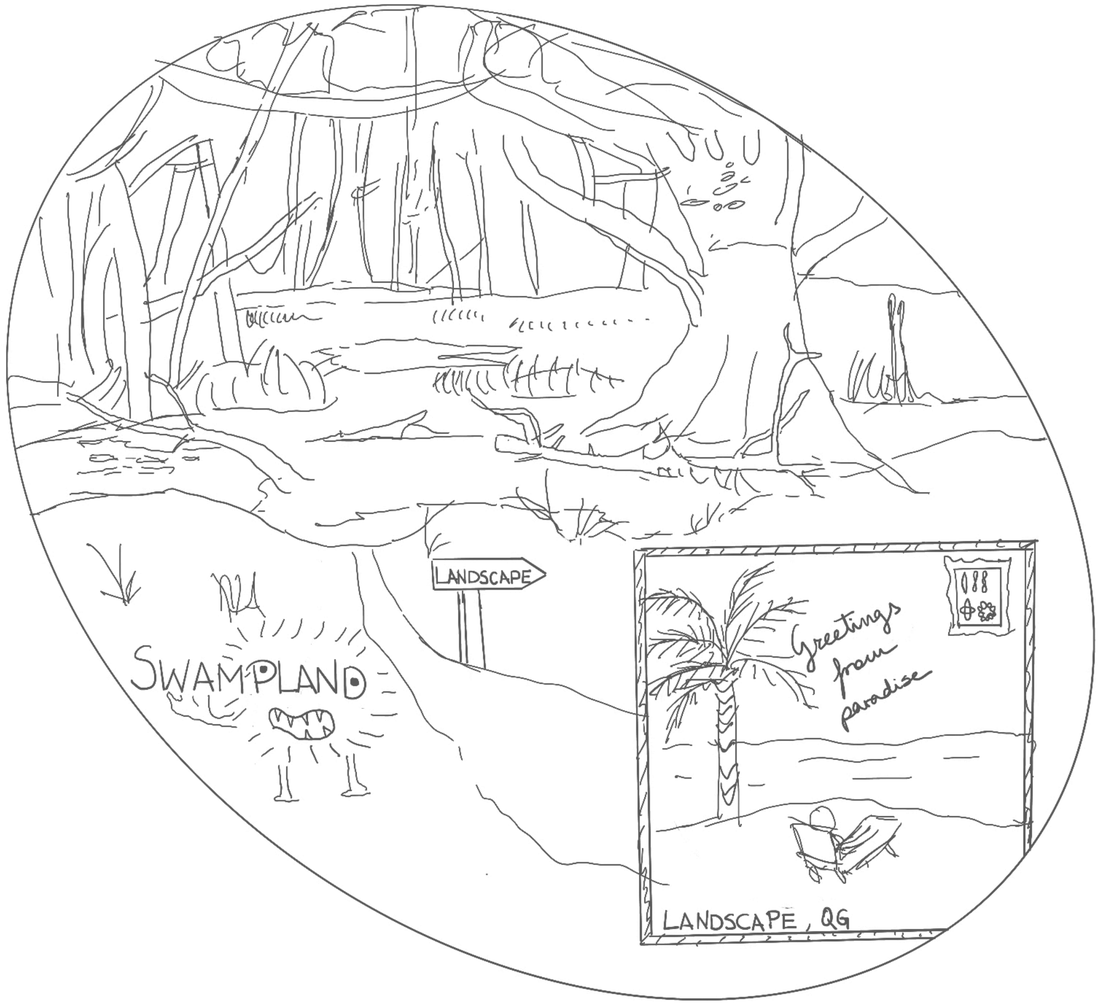

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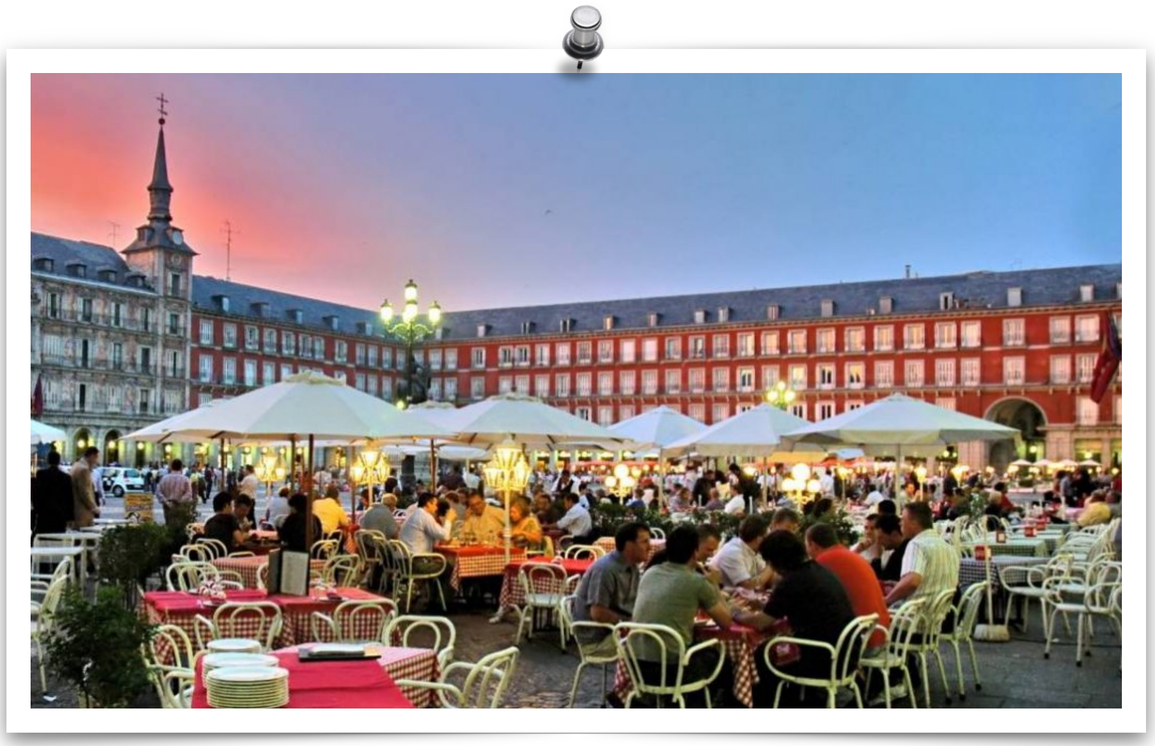

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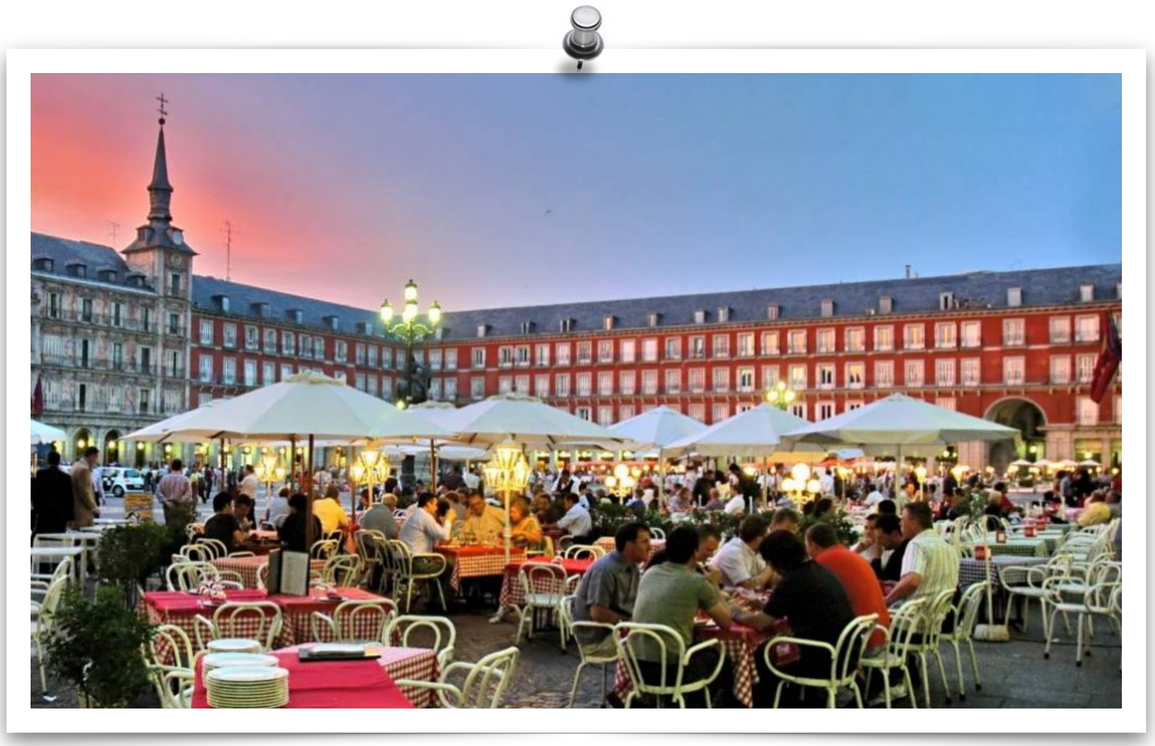

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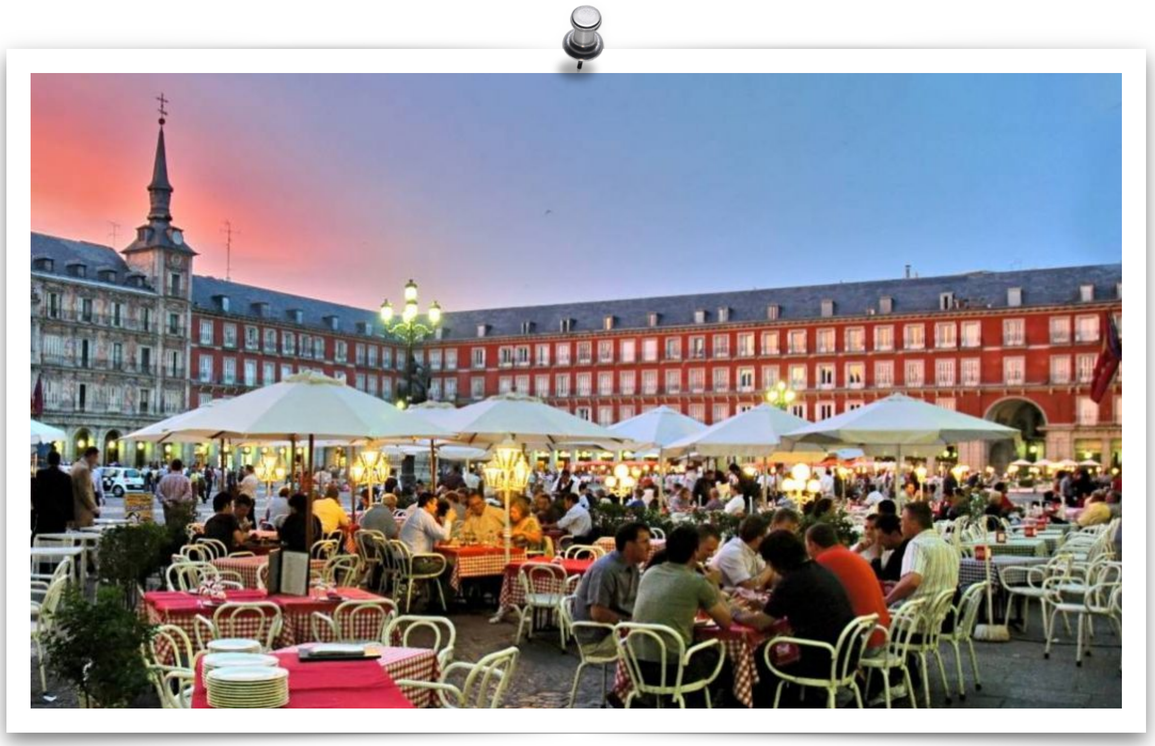

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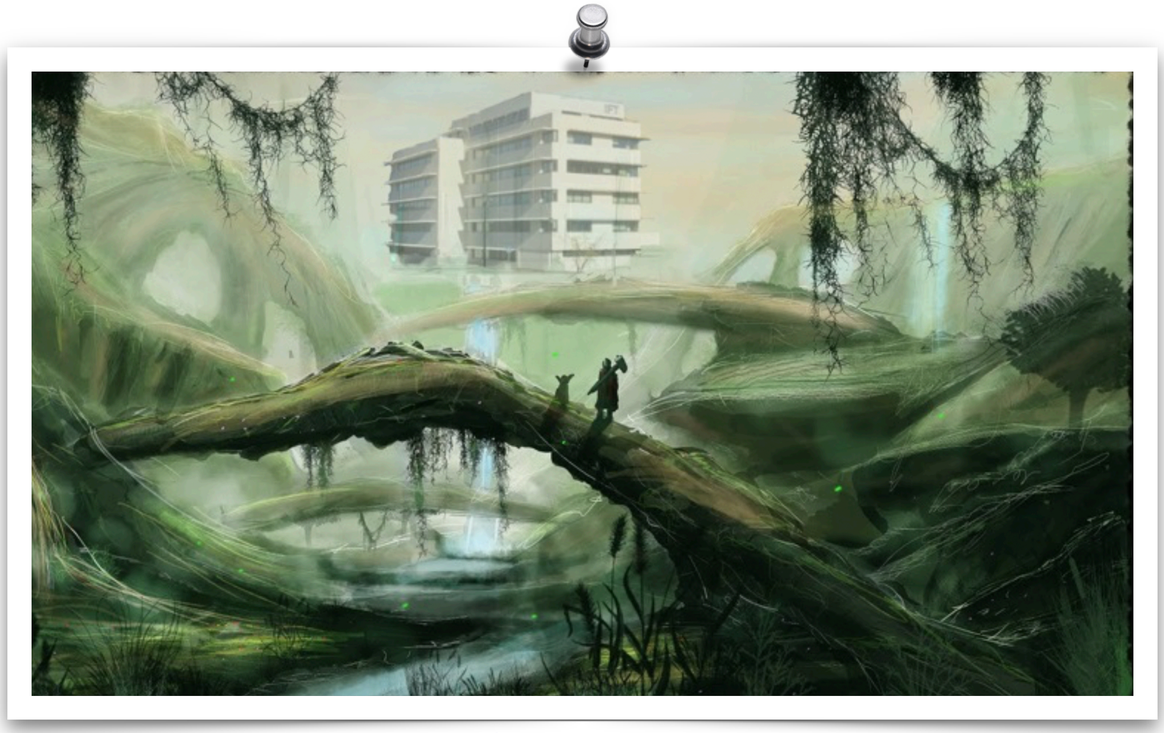

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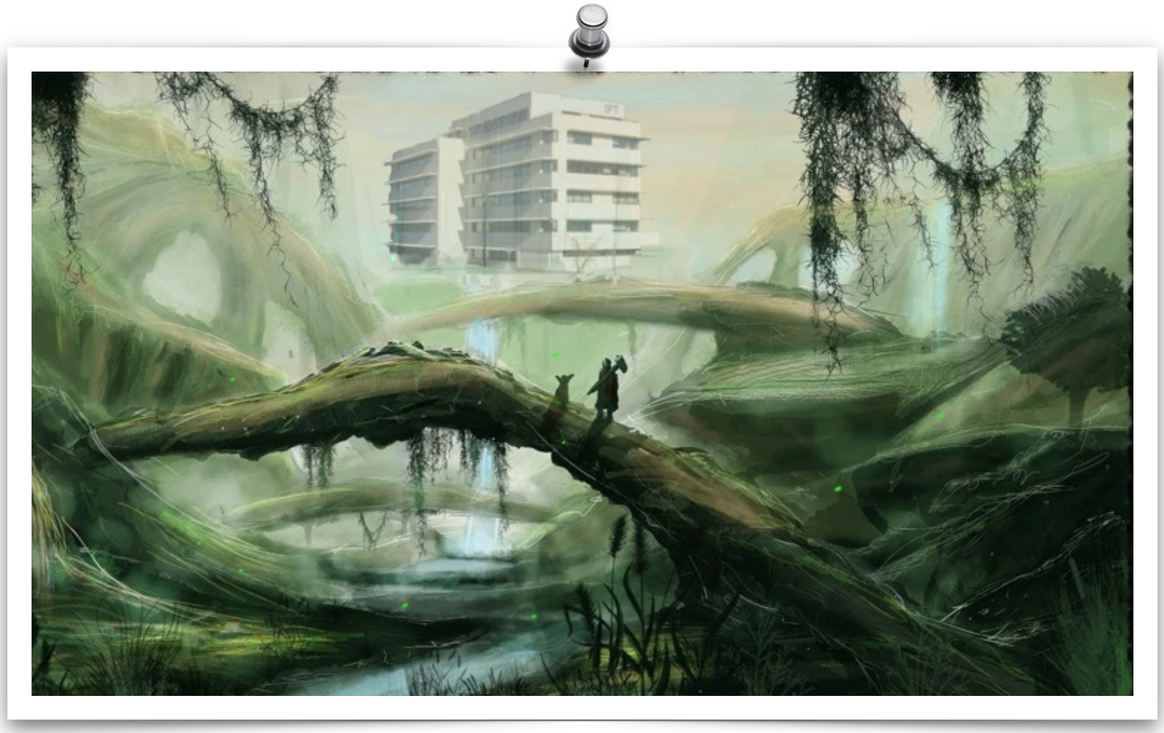

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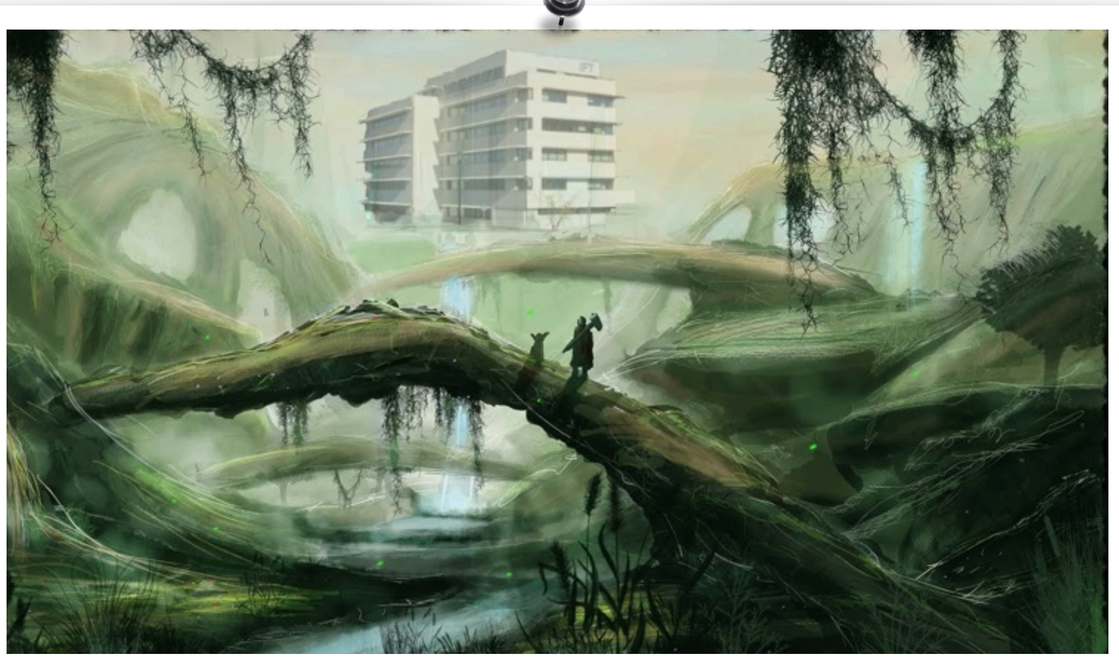

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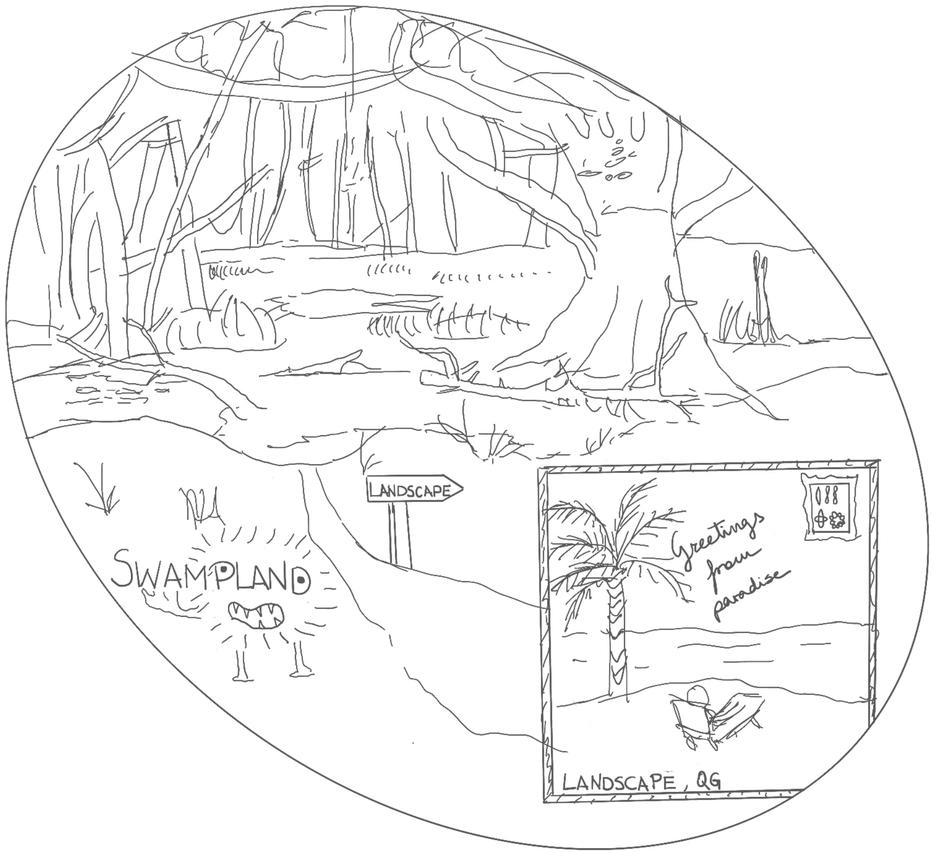

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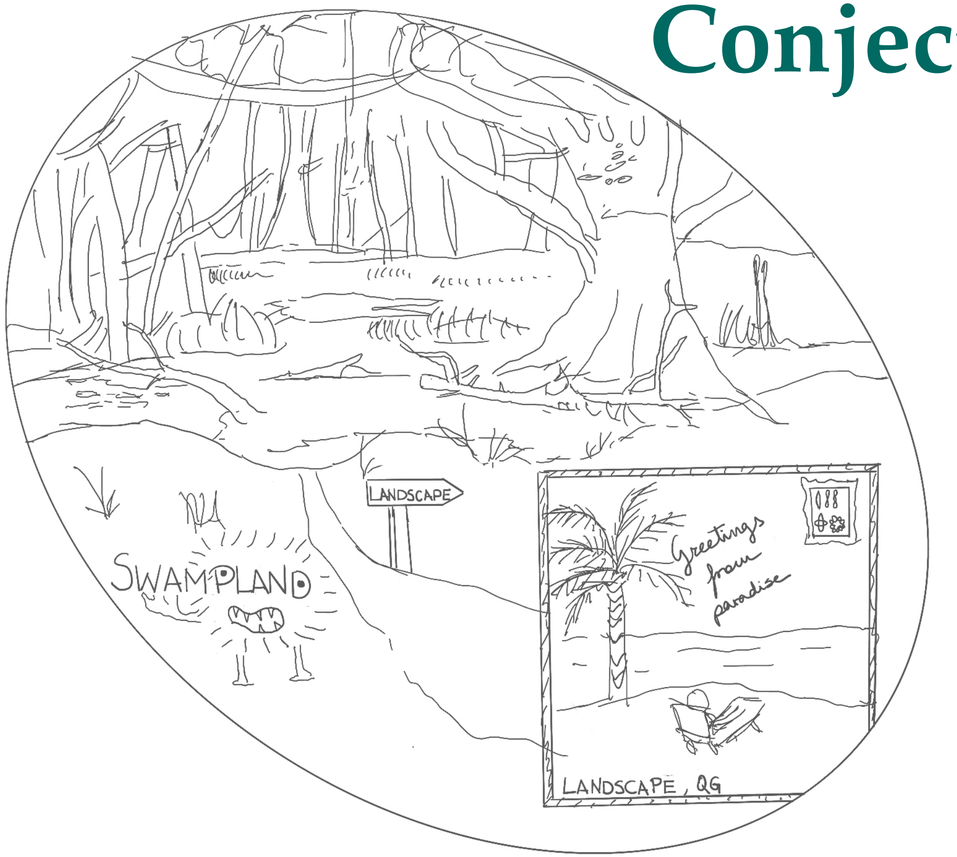
3 Conjectures

3 Pheno Insights



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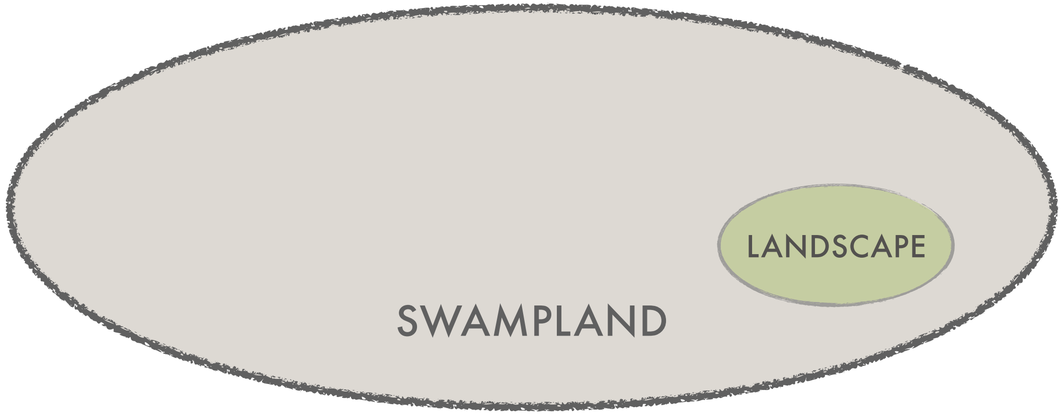

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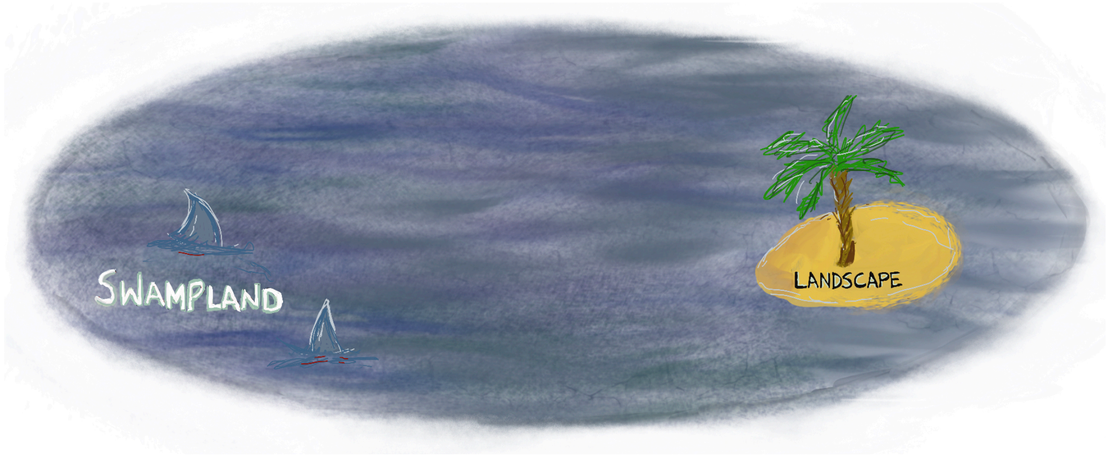

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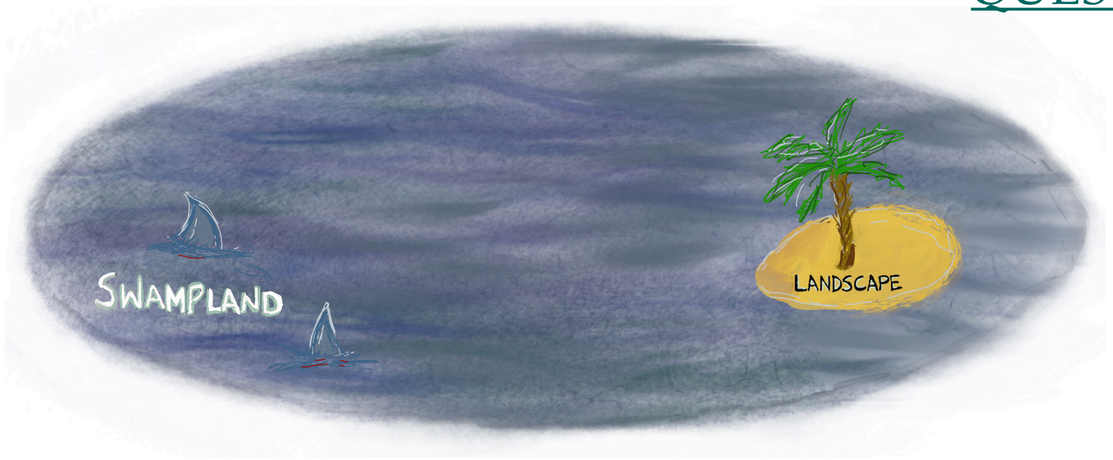

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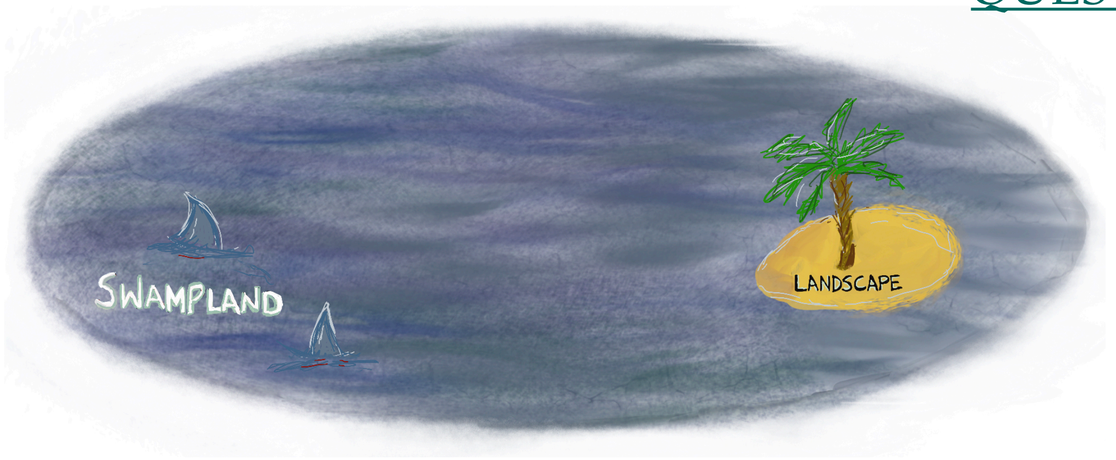

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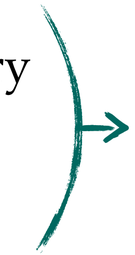

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Swampland ~ Experimentalist´s approach to Quantum Gravity

Take-home message:

Not everything is allowed in Quantum Gravity $\longrightarrow$ Constraints

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EFT rules in QG ✓ **EFT expectations** ✗

(Natural in EFT ≠ Natural in QG)

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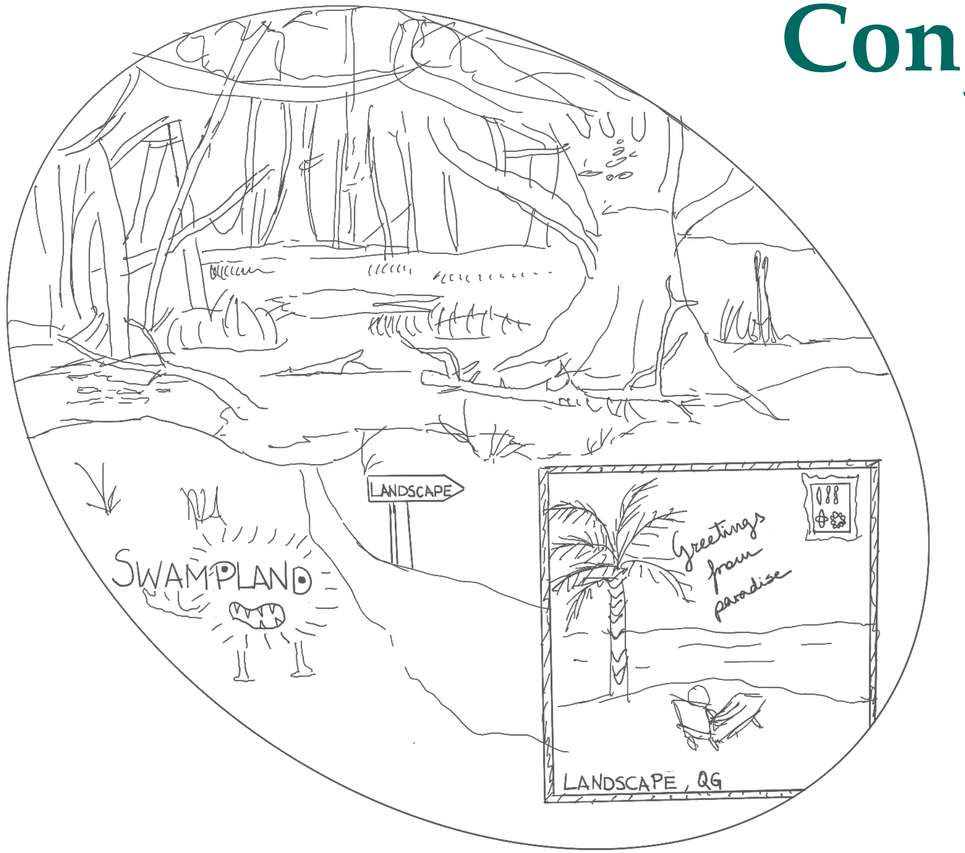

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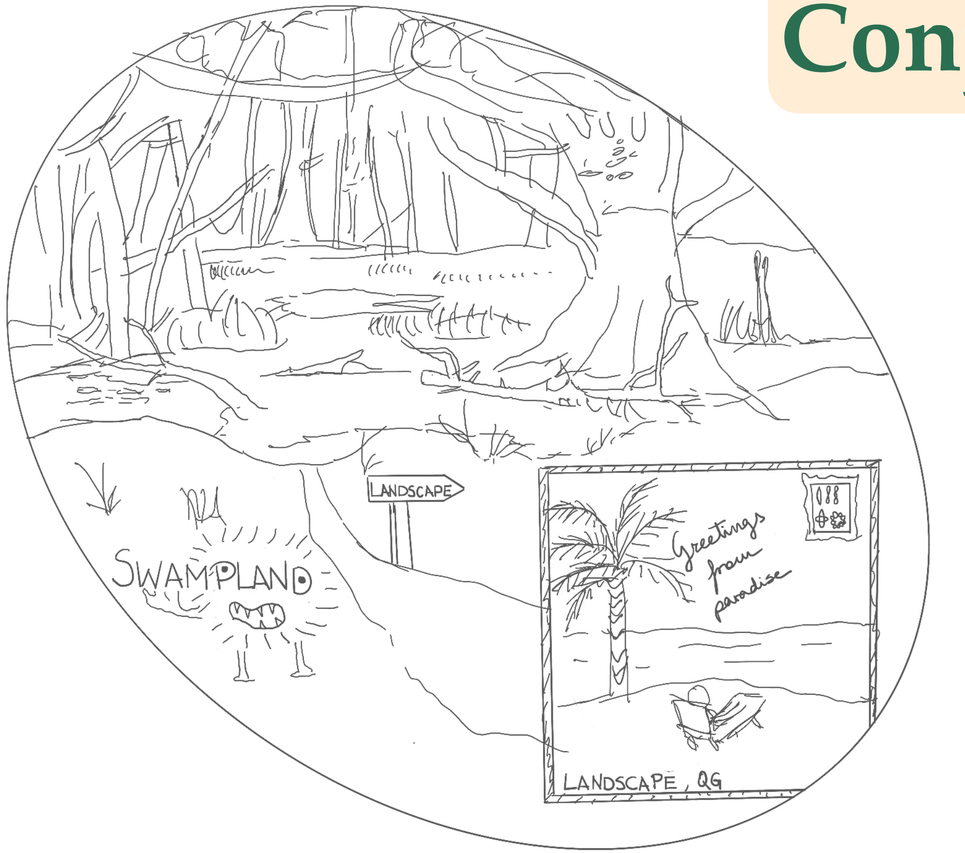

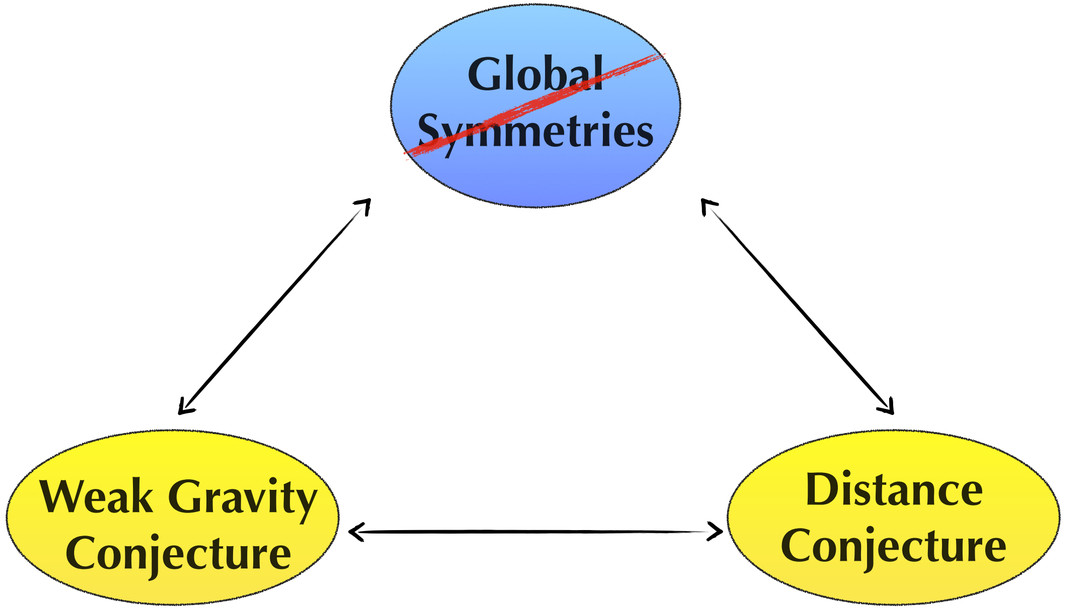

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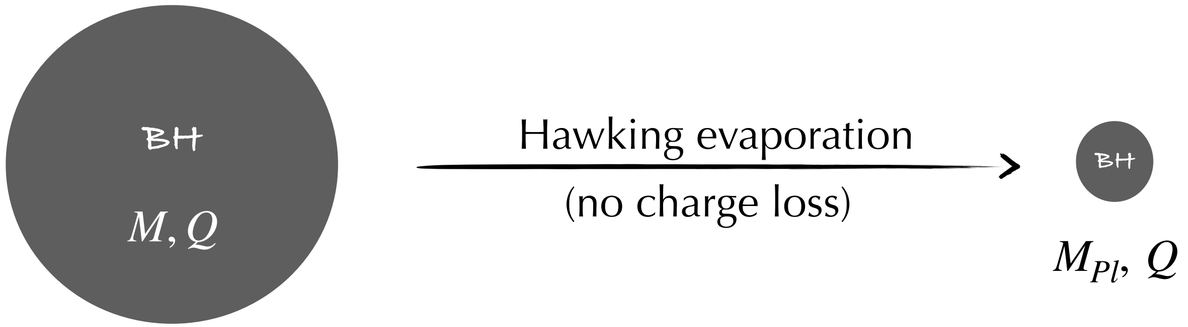

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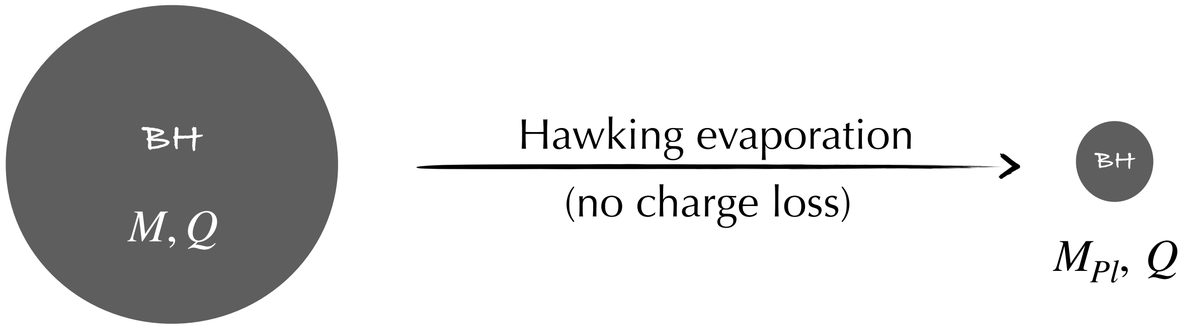

Arbitrarily high number of remnants (labeled by different charges) in a finite mass range ⟶ Violation of Entropy Bounds

Weak Gravity Conjecture

[Arkani-Hamed, Motl, Nicolis, Vafa '06]

Electric WGC: Given a gravitational theory with a U(1) gauge symmetry, with coupling g, the spectrum of the theory must include at least a particle, with mass m and charge q which satisfies the inequality

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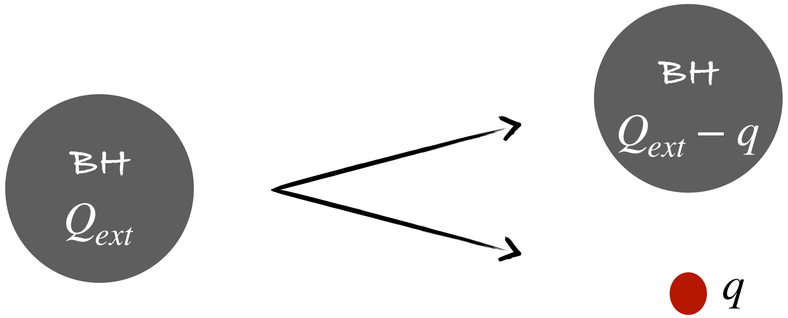
Require Extremal BHs to decay ⟶ Otherwise problems with remnants



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No charged gravitational Bound States

$$F_{em} \geq F_{grav}$$

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(Spoiler: infinite towers of states becoming light)

Distance Conjecture

[Ooguri, Vafa '06] [Parallel talks by V. Collazuol, I. Ruiz]

Starting from a point P in moduli space, and moving to a point Q an infinite distance away, there appears a tower of states which becomes exponentially massless according to

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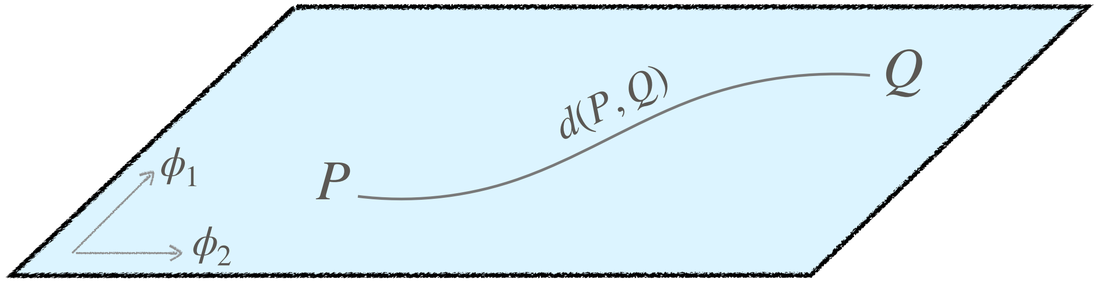
Scalar manifold with metric $g_{ij}(\phi_i)$ from kinetic terms



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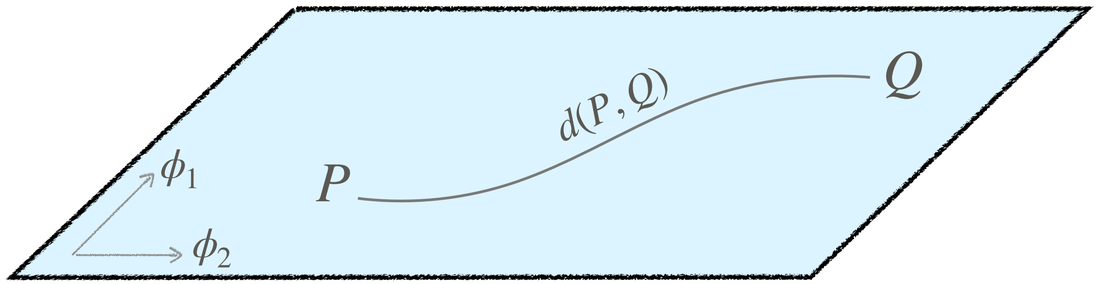

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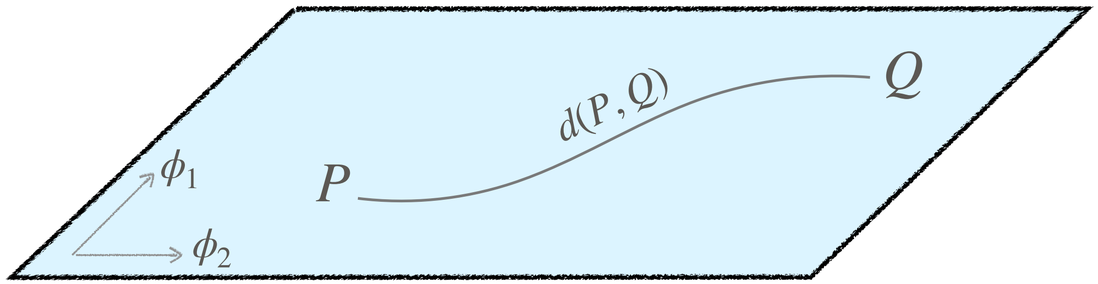

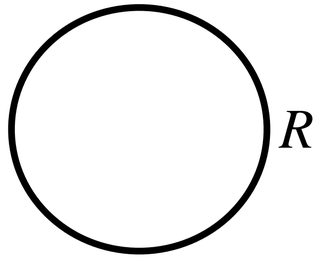

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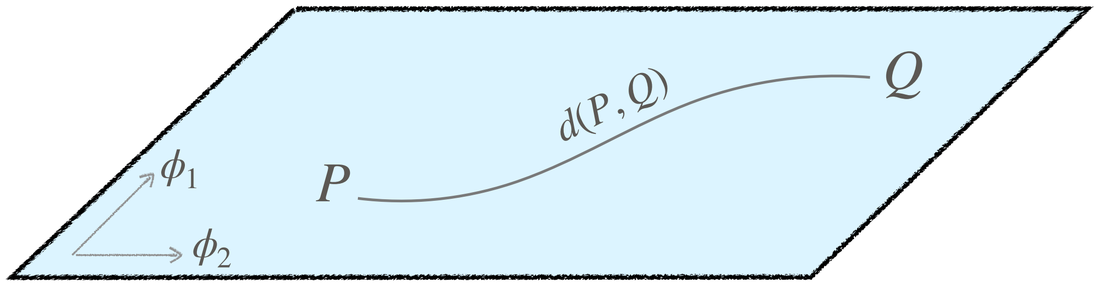

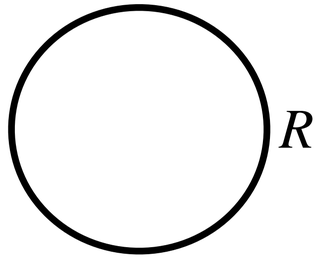

$R \to \infty$ Kaluza-Klein tower

BONUS TRACK: **NO FREE PARAMETERS** ⟶ All parameters in QG are vevs of (dynamical) fields

[Ooguri, Vafa '06]

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[Ooguri, Vafa '06] [Parallel talks by V. Collazuol, I. Ruiz]

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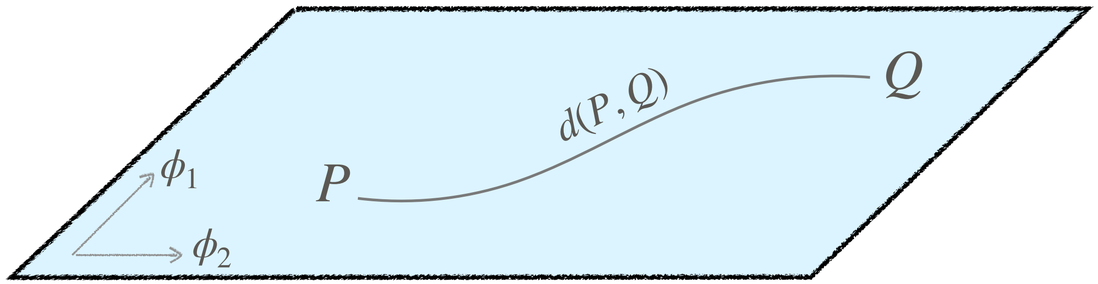

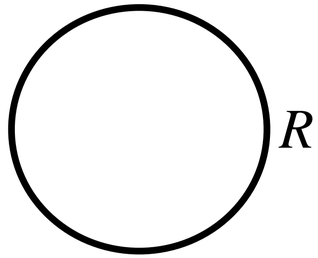

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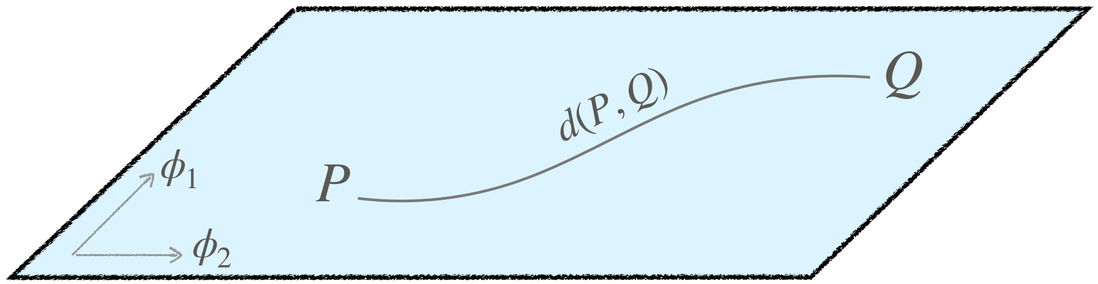

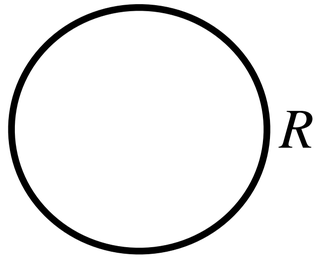

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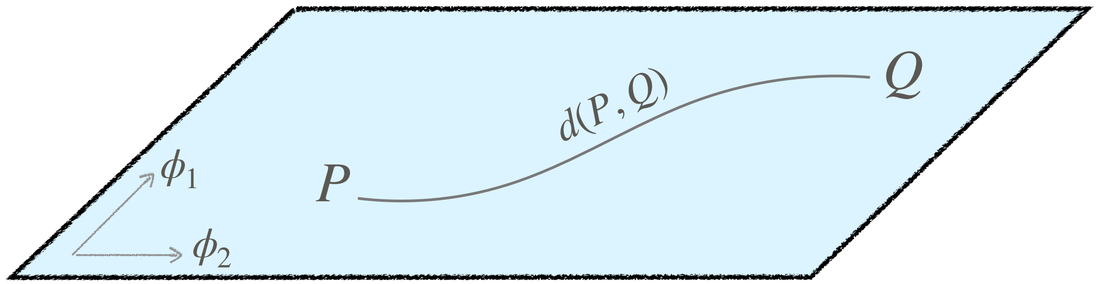

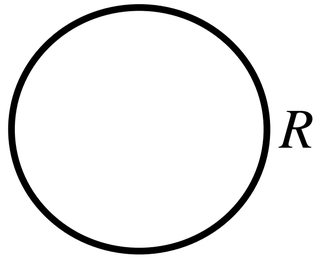

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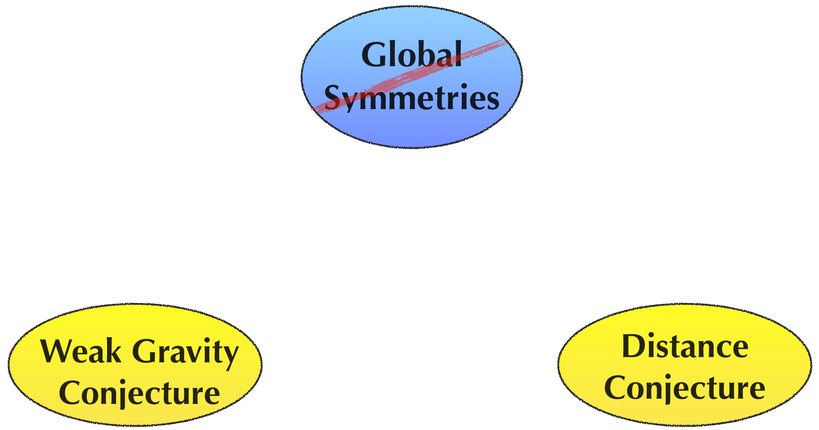
General lesson: **Quantum Gravity** $\longleftrightarrow$ **Extended objects**


Global Symmetries
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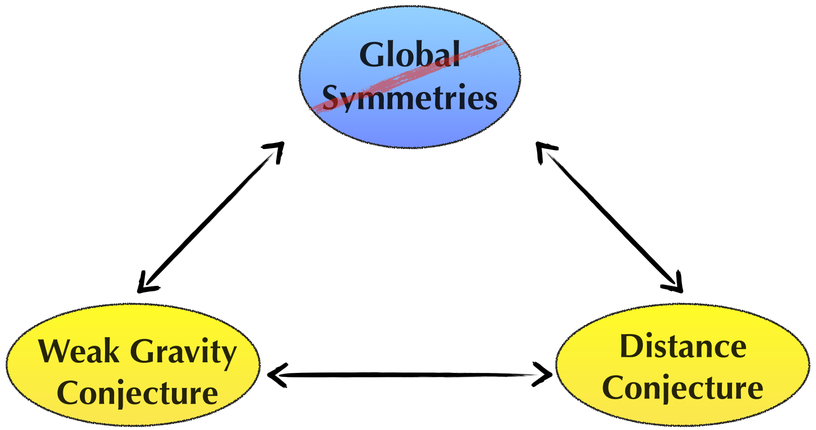
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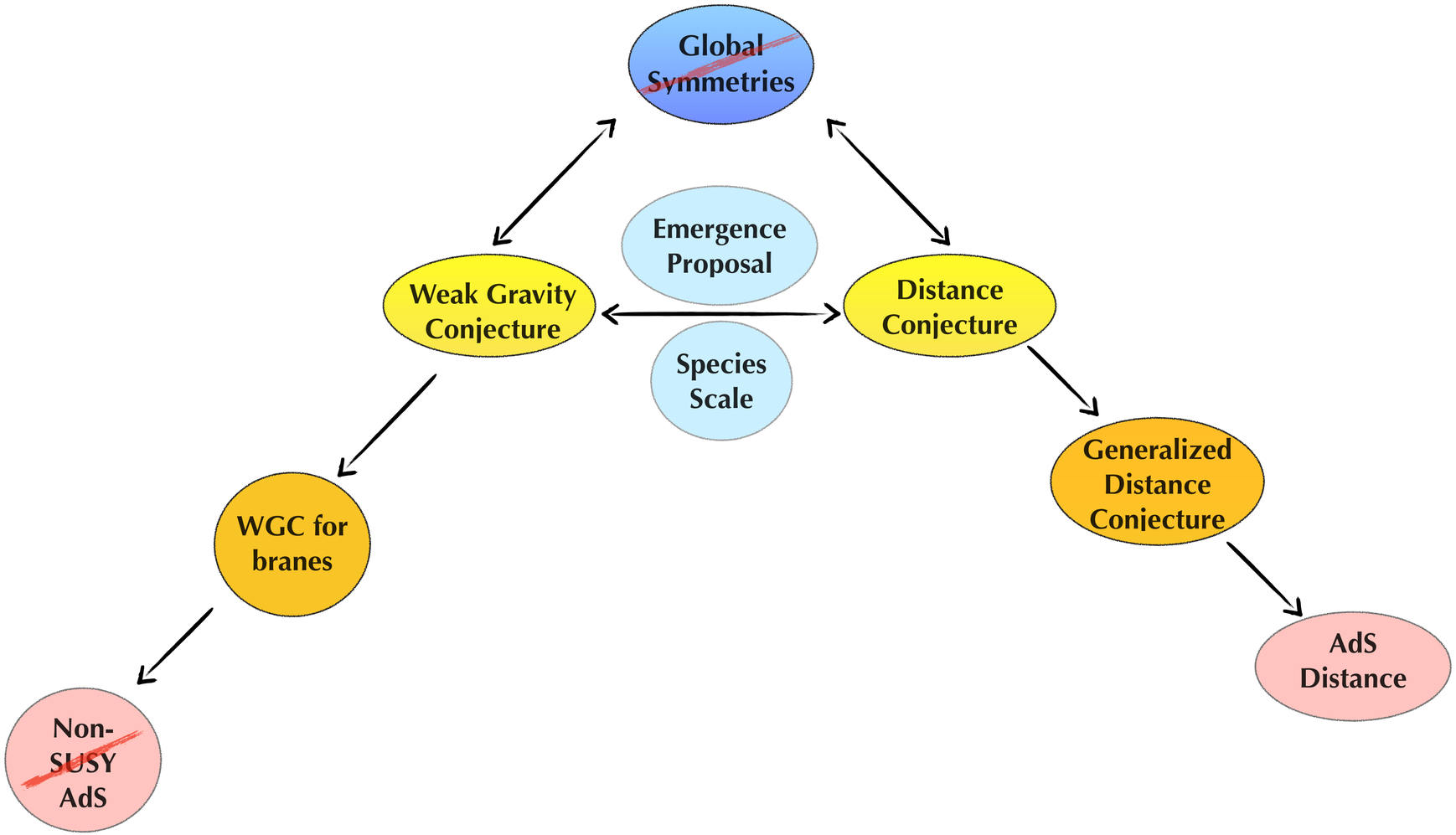
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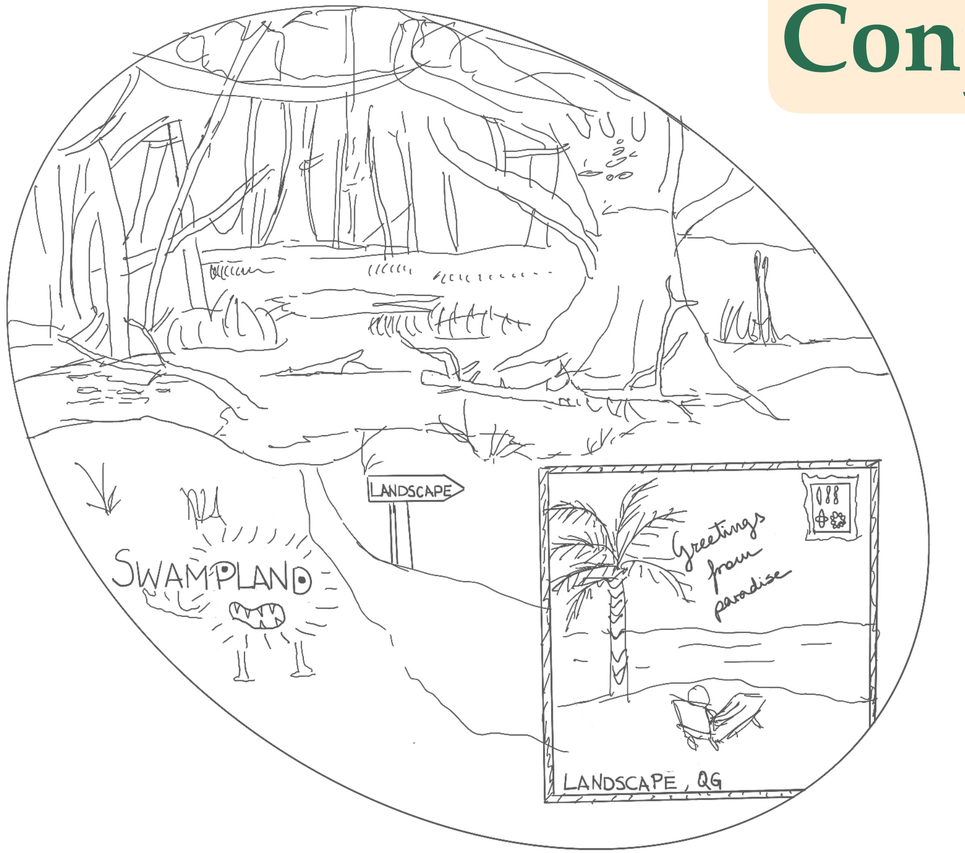
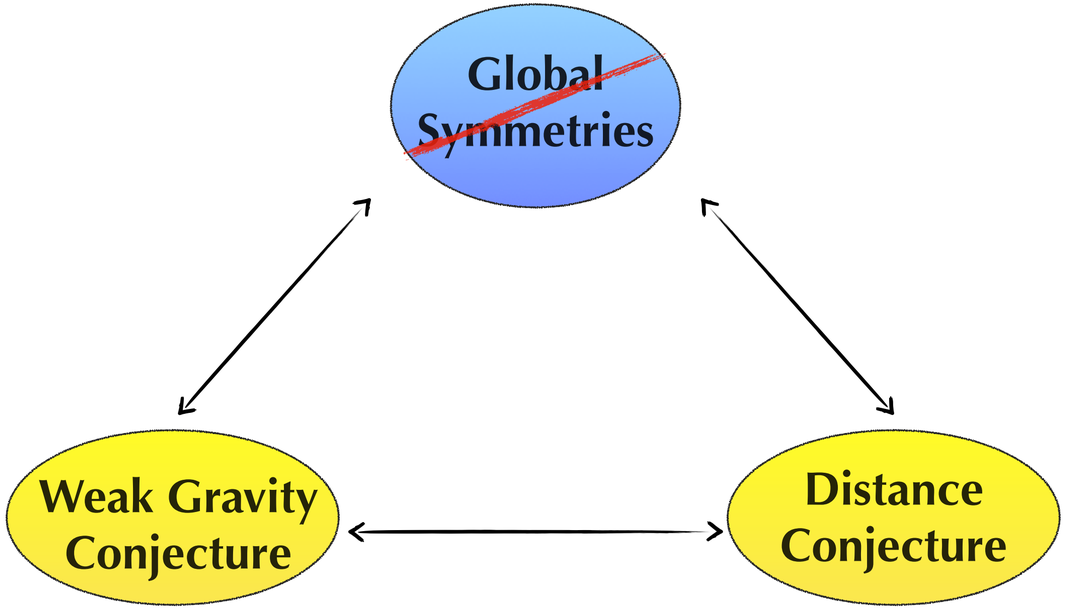
~~Swampland: Review & Particle Physics Implications~~

3 Conjectures

3 Pheno Insights





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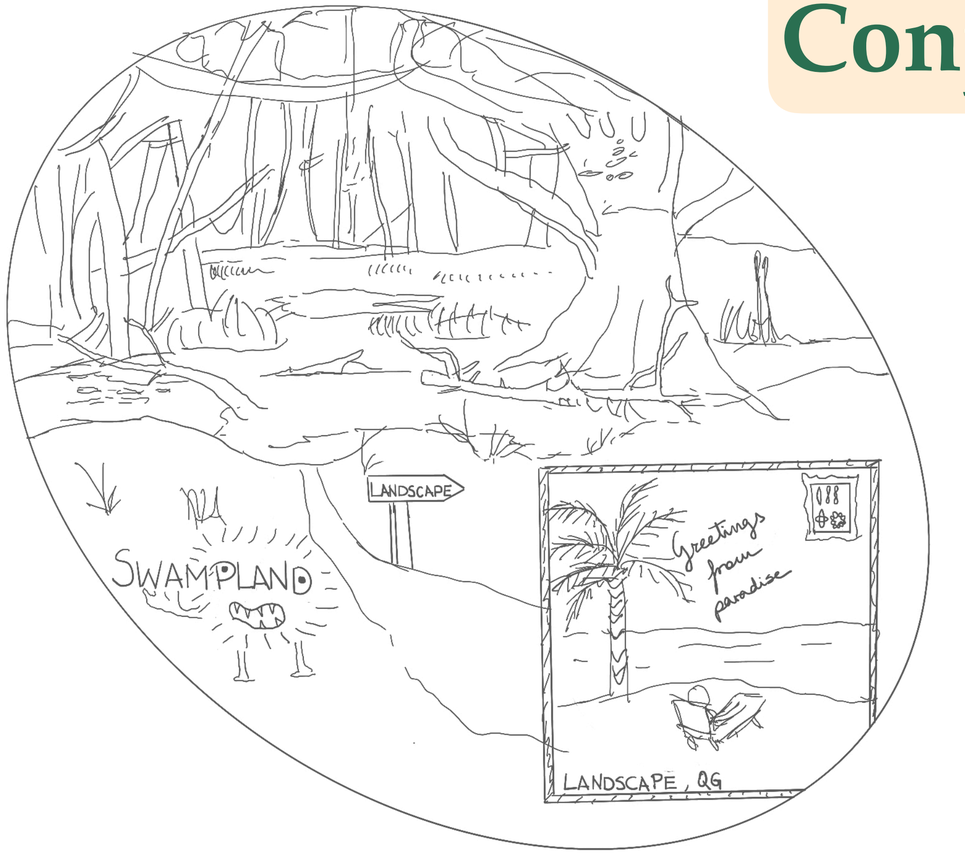

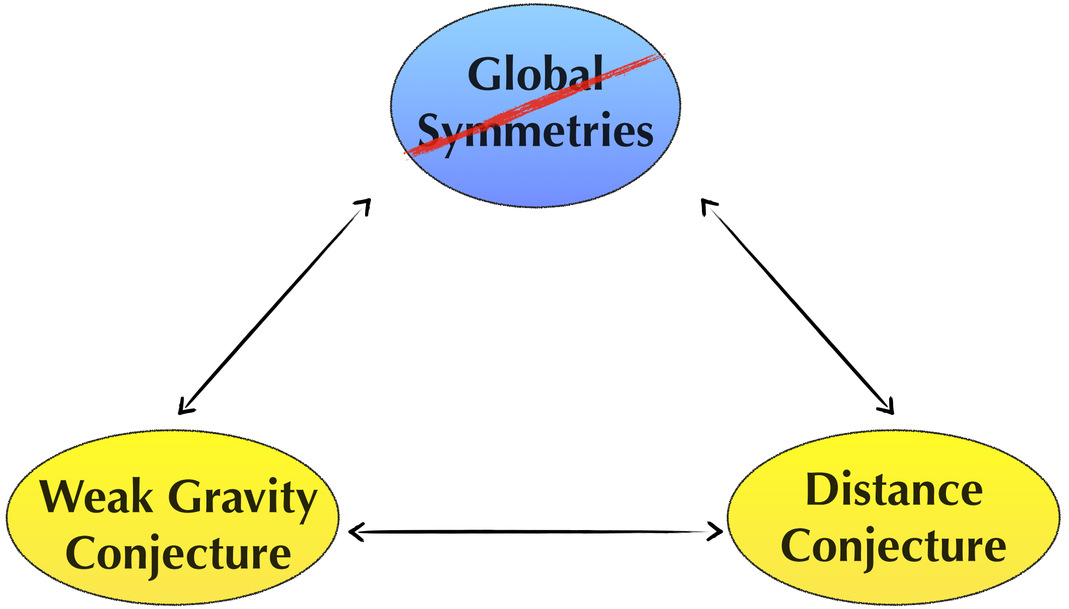

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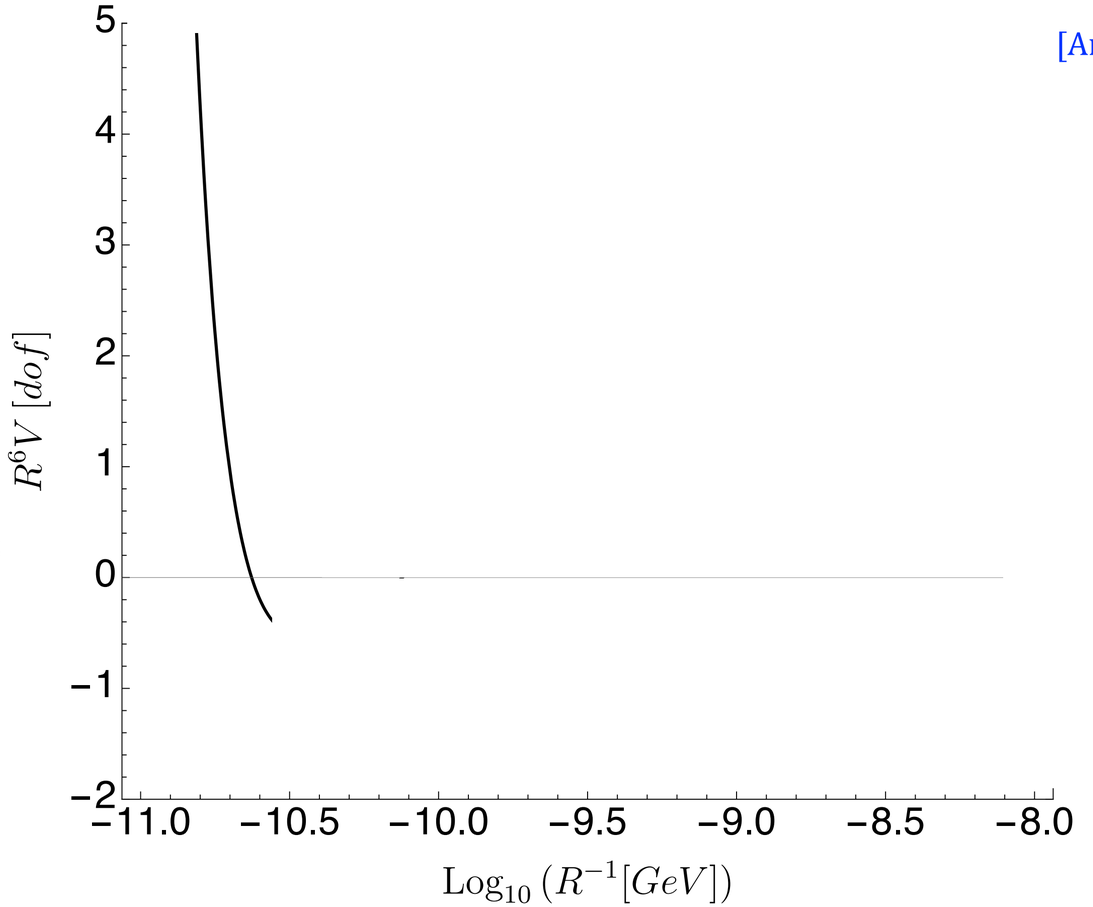

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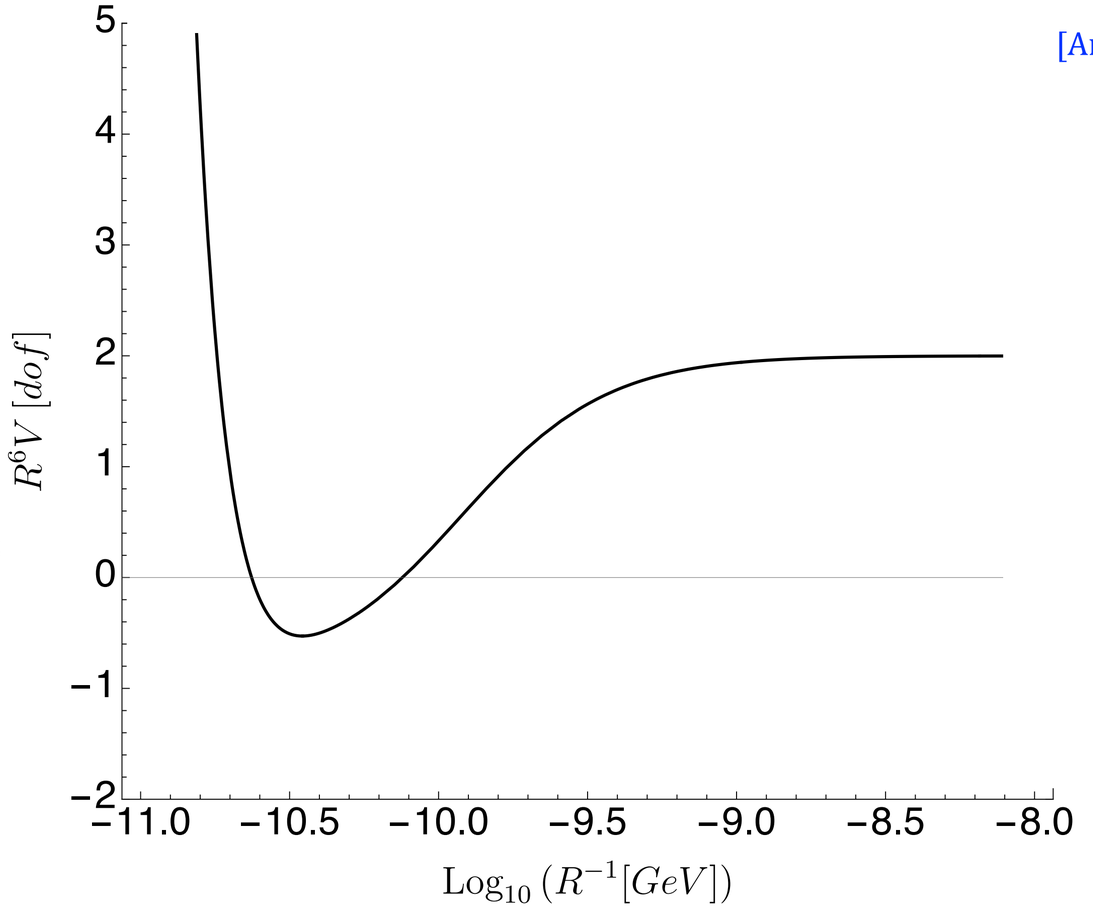

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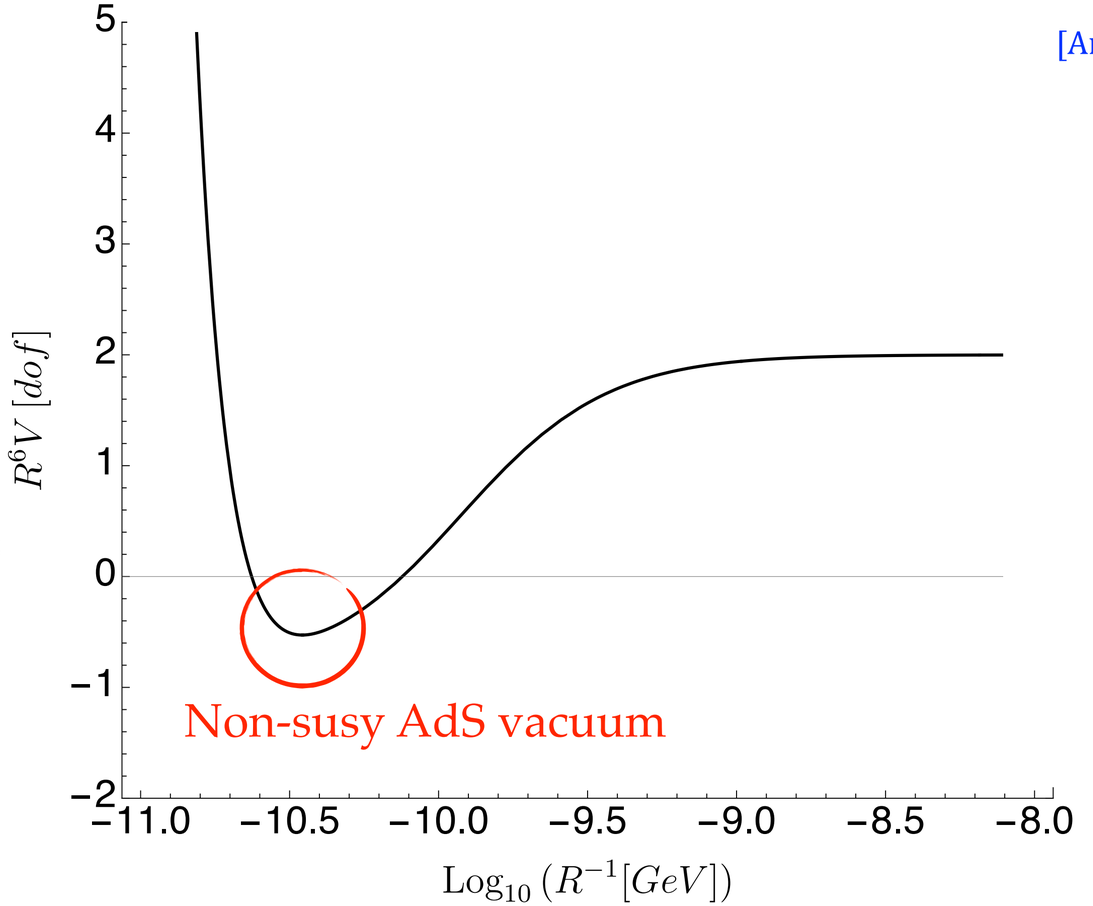

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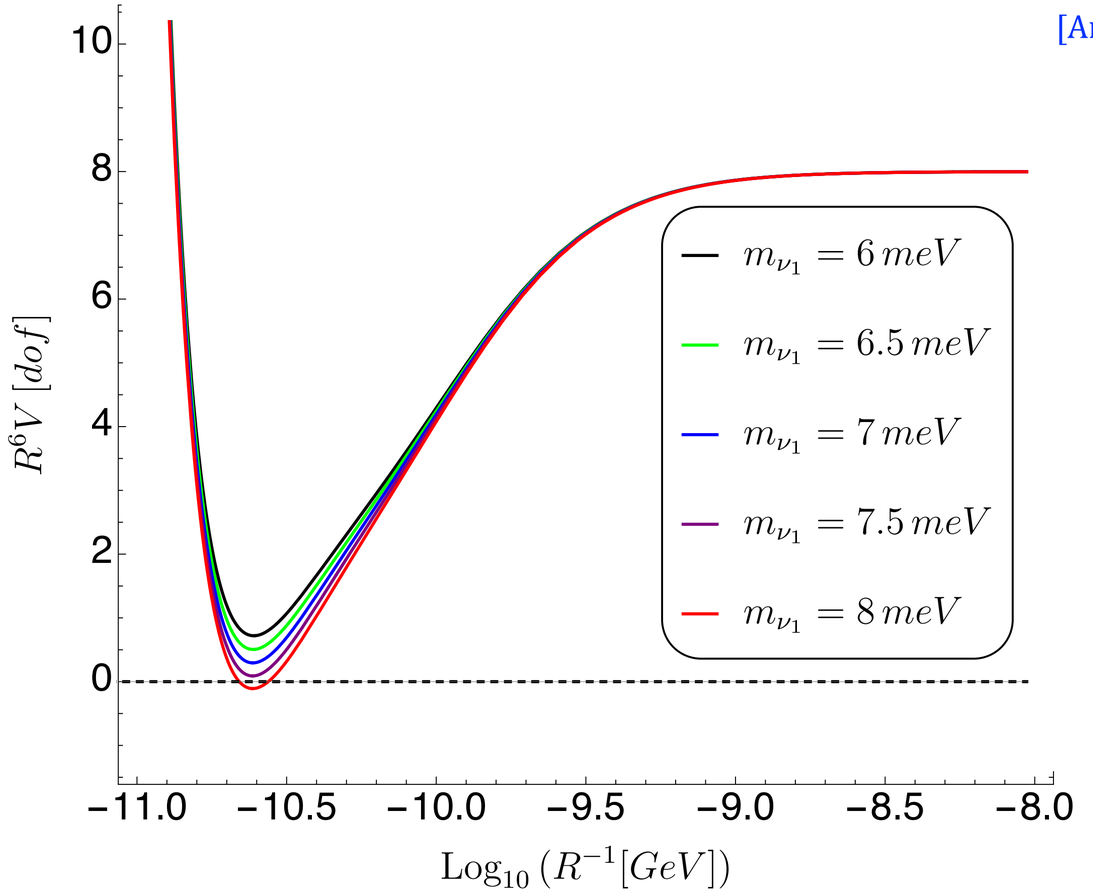

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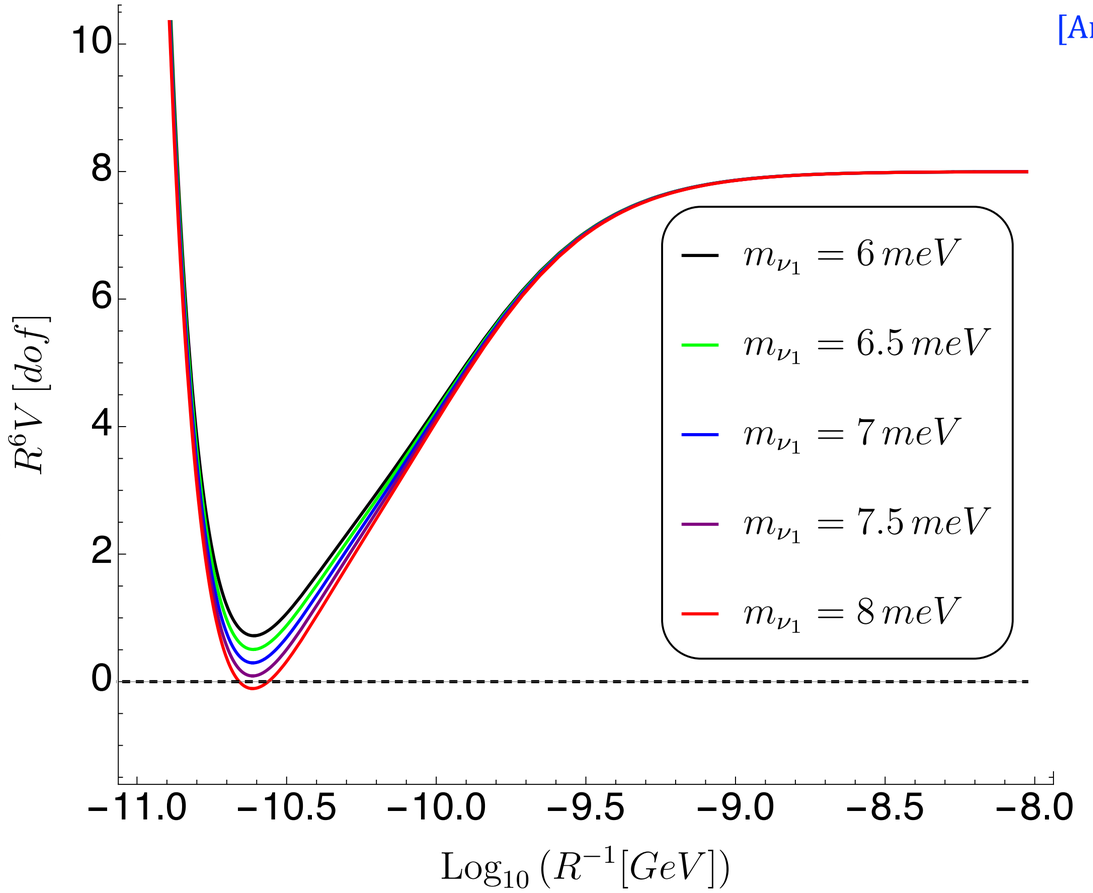

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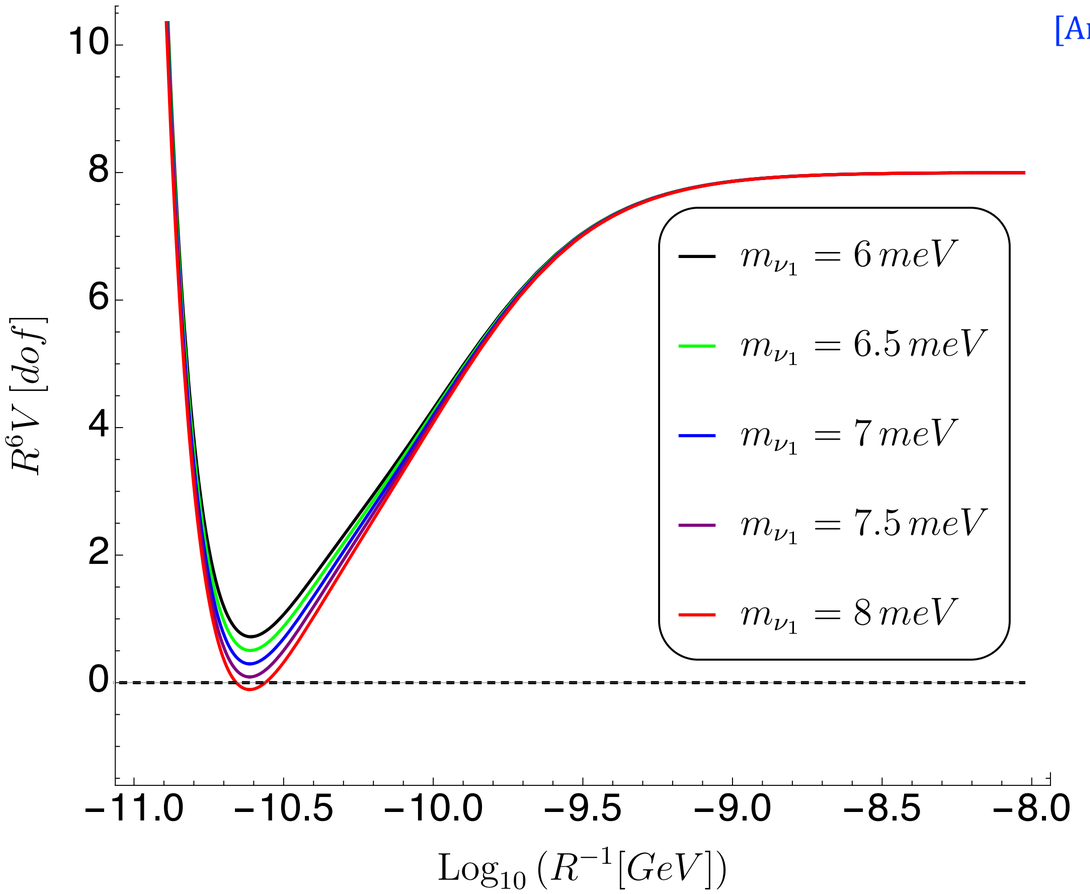

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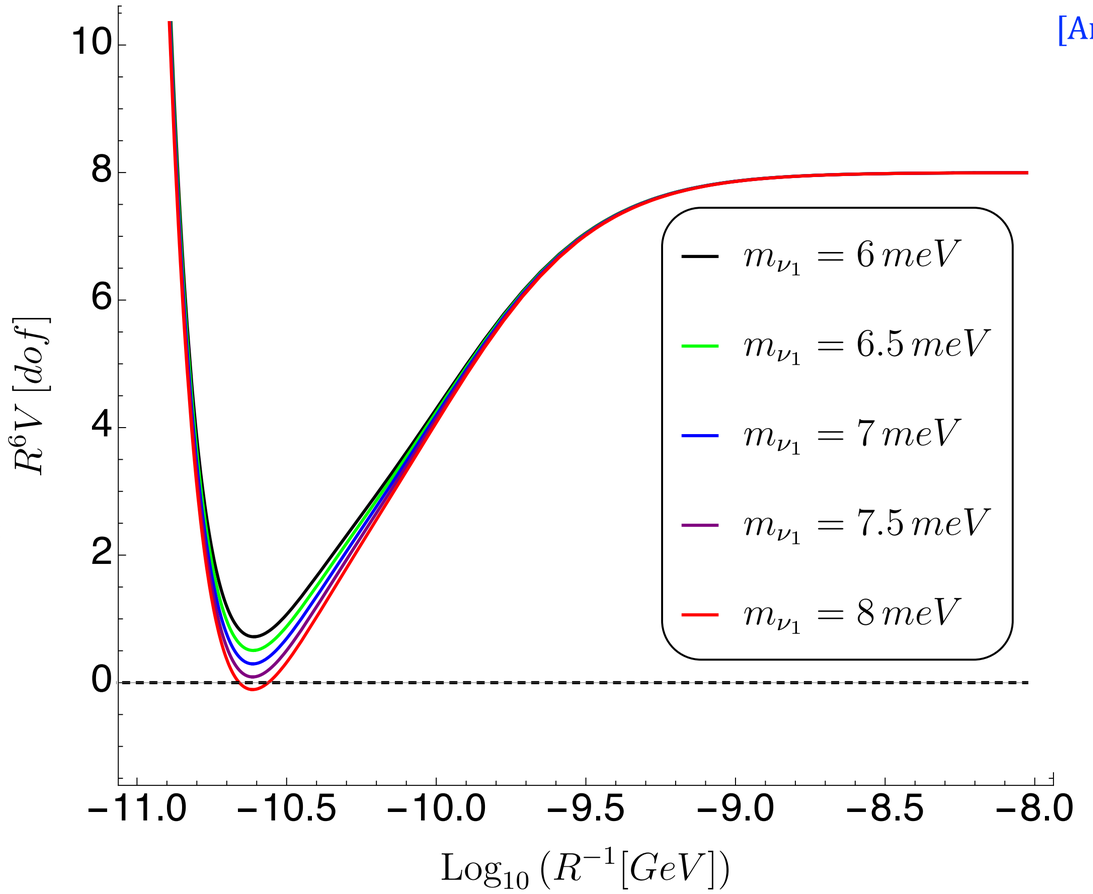

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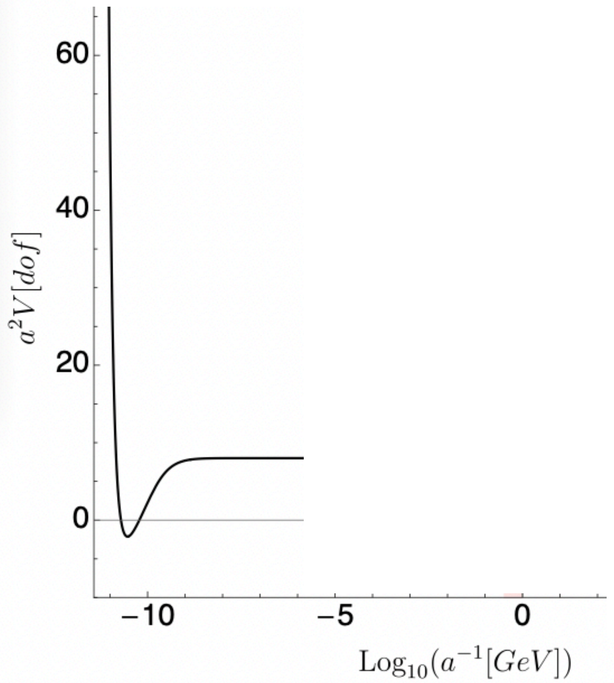

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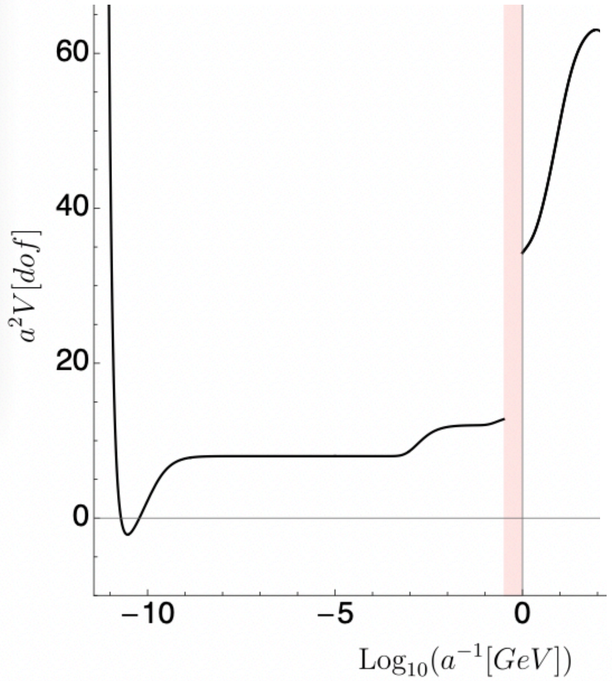

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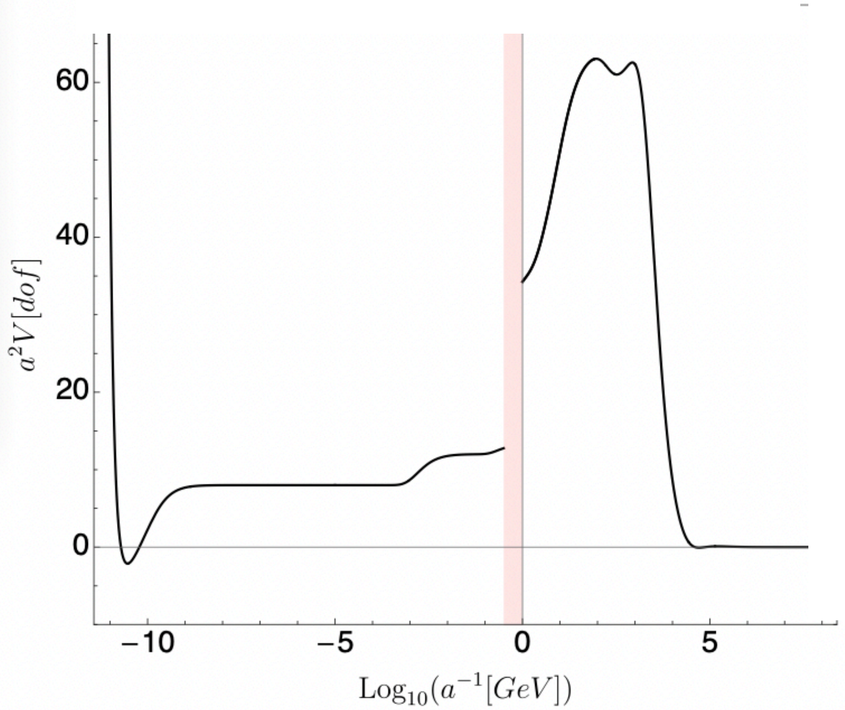

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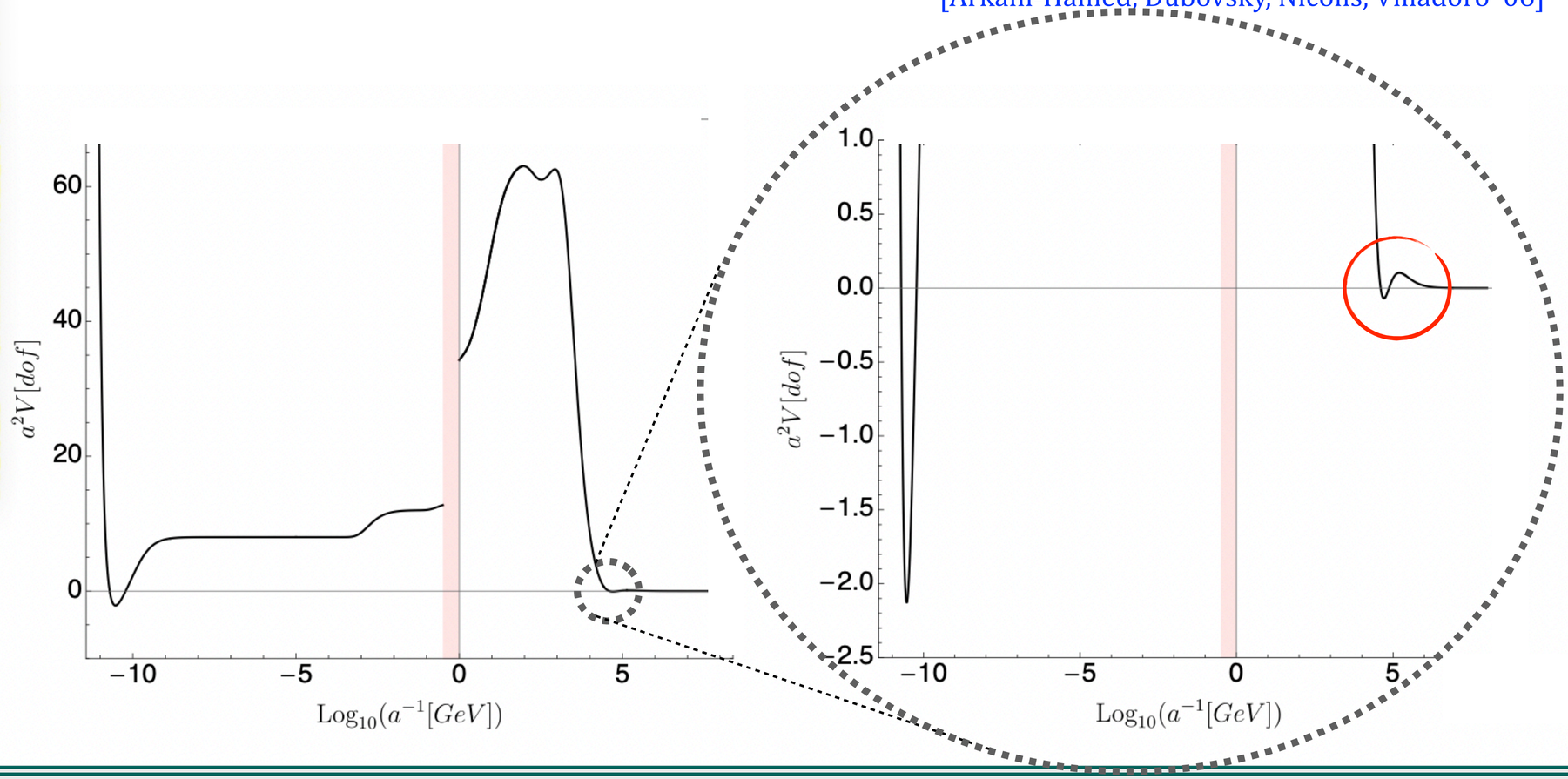

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[Castellano, AH, Ibáñez ´22 ’23]

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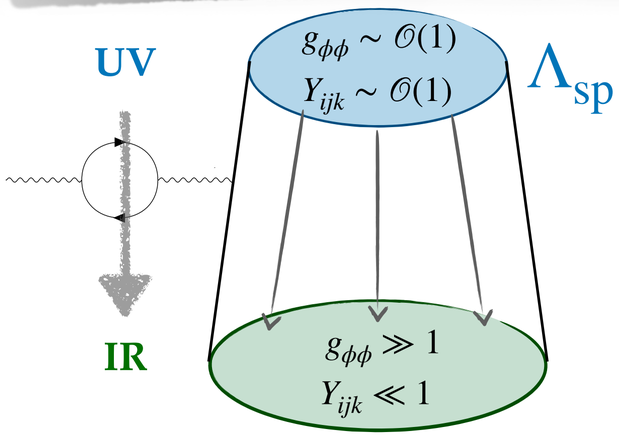

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[Castellano, AH, Ibáñez ´22 ’23]

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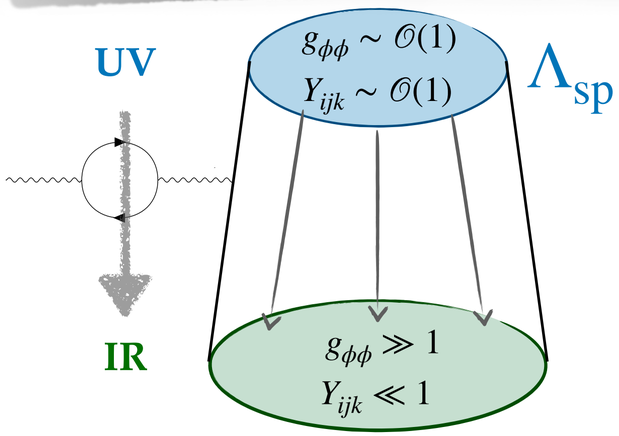

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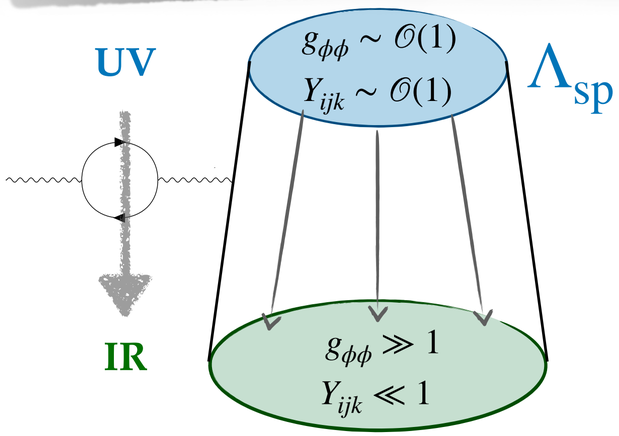

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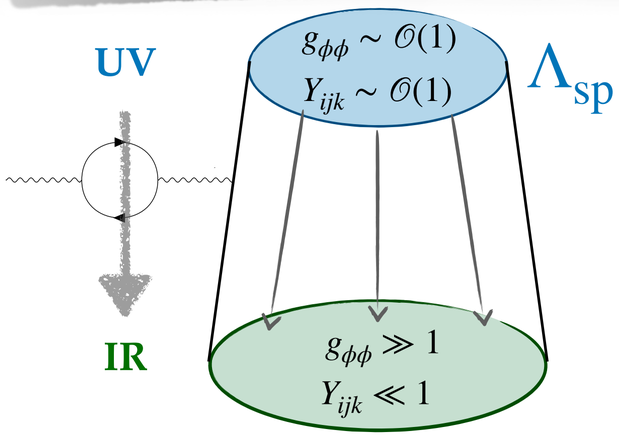

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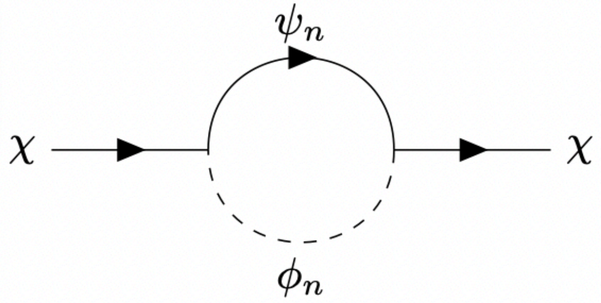

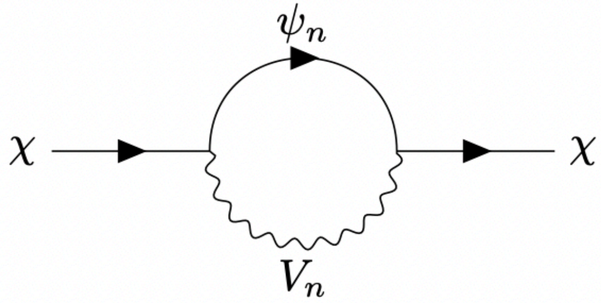

$$g_{\chi\bar{\chi}} \sim \sum_{n_i}^{N_i} n_i^2 \sim N_i^3 \sim \left(\frac{\Lambda_{\rm QG}}{m_0^{(i)}} \right)^3$$

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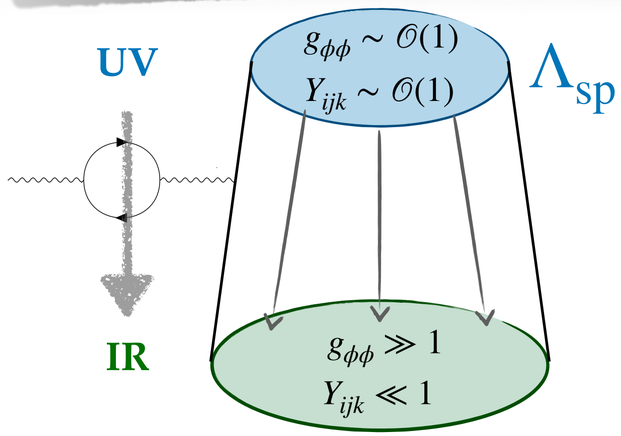

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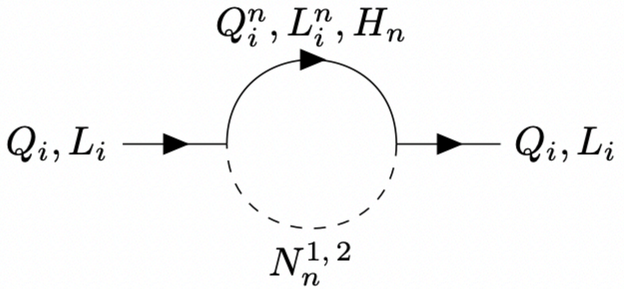

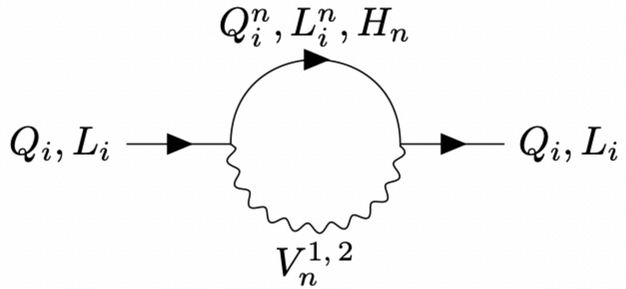

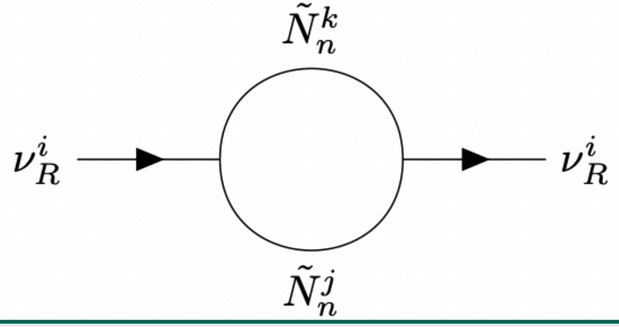

⟶ $m_{KK} \sim 700$ TeV

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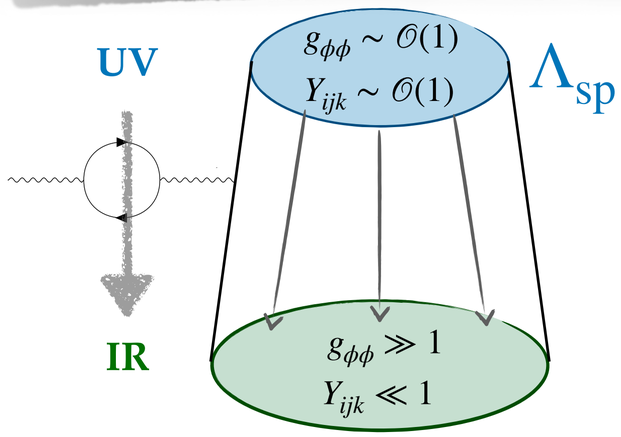

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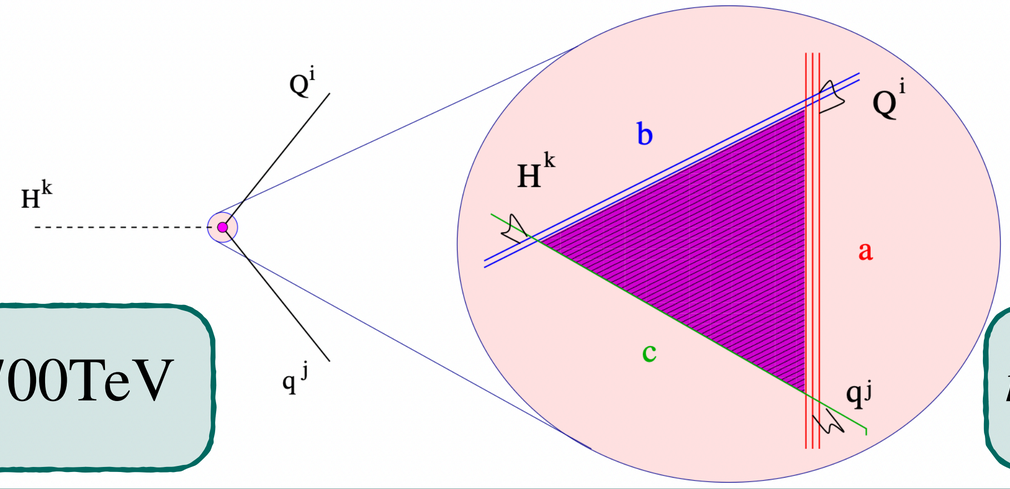
- Similar string theory embedding with SM at intersecting branes in [Casas, Ibáñez, Marchesano ’24] [Parallel talk by G. F. Casas]



$M_s \sim 700\text{TeV}$

$m_{KK} \sim 500\ \text{eV}$

3) Small Λ_{cc} and the Dark Dimension

[Montero, Vafa, Valenzuela ´22]
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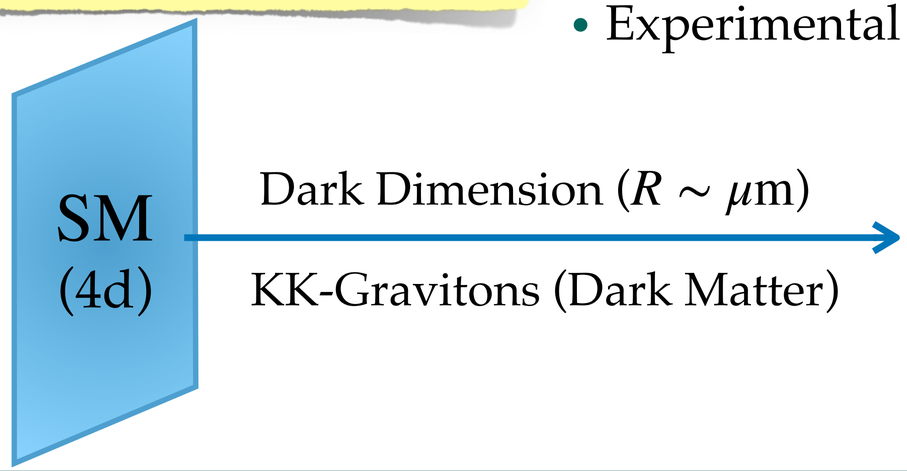

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SM (4d) → Dark Dimension ($R \sim \mu$m) → KK-Gravitons (Dark Matter)

$n = 1$

$R^{-1} \sim \text{eV} - \text{meV}$

Other Phenomenological Applications

- Cosmology (DC/WGC) [Parallel talks by G. Villa, F. Revello]
- dS vs. running solutions (dS Conjecture/TCC) [Parallel talk by D. Panizo]
- Festina lente bound: $m^4 \gtrsim \left(eqM_P H\right)^2$ (WGC)
- Bounds on ranks of gauge groups (No Global Symmetries)
- Massless photons (WGC/DC)
- EW scale (No non-SUSY AdS/DC)
- Big desert scenario vs low energy SUSY (DC)
- Axions [Parallel talk by M. Putti & A. Valenti]
- …

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Not everything is allowed in Quantum Gravity $\longrightarrow$ Constraints

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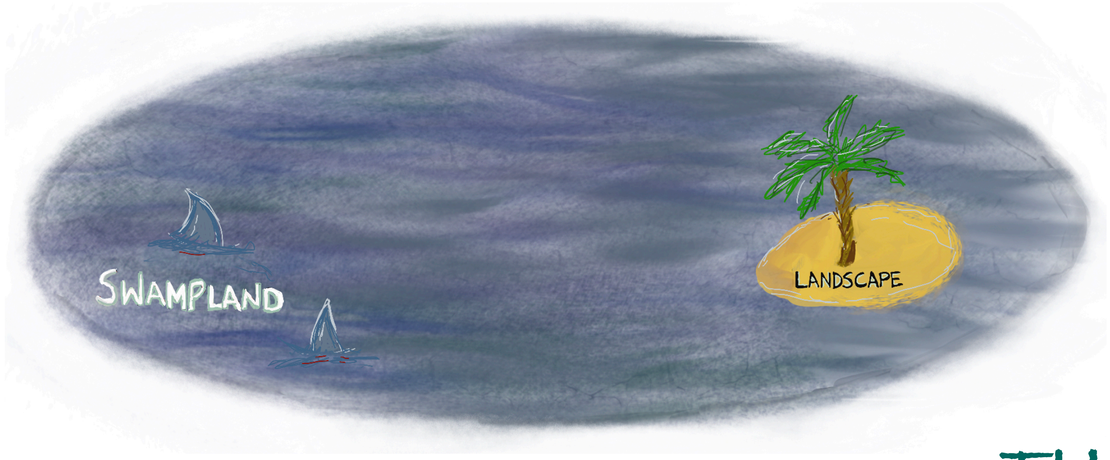

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