A Tale of Two U(1)s: Kinetic Mixing from Lattice WGC States

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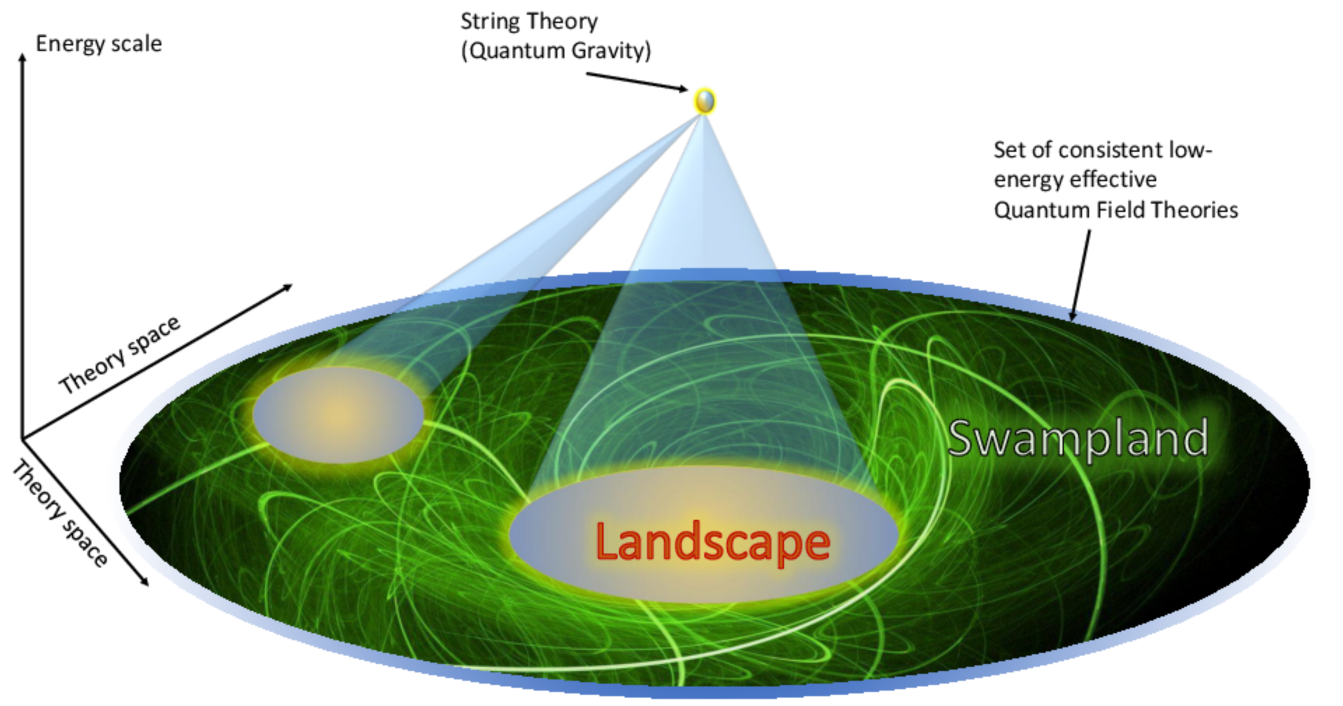
Swampland Conjectures

The Swampland Program is based on consistency. There exist a plethora of apparently consistent QFTs but only a small subset of them remain so when UV completed into a theory of quantum gravity.

We propose conjectures that must be satisfied by the low-energy QFTs to live in the Landscape.



Weak Gravity Conjecture

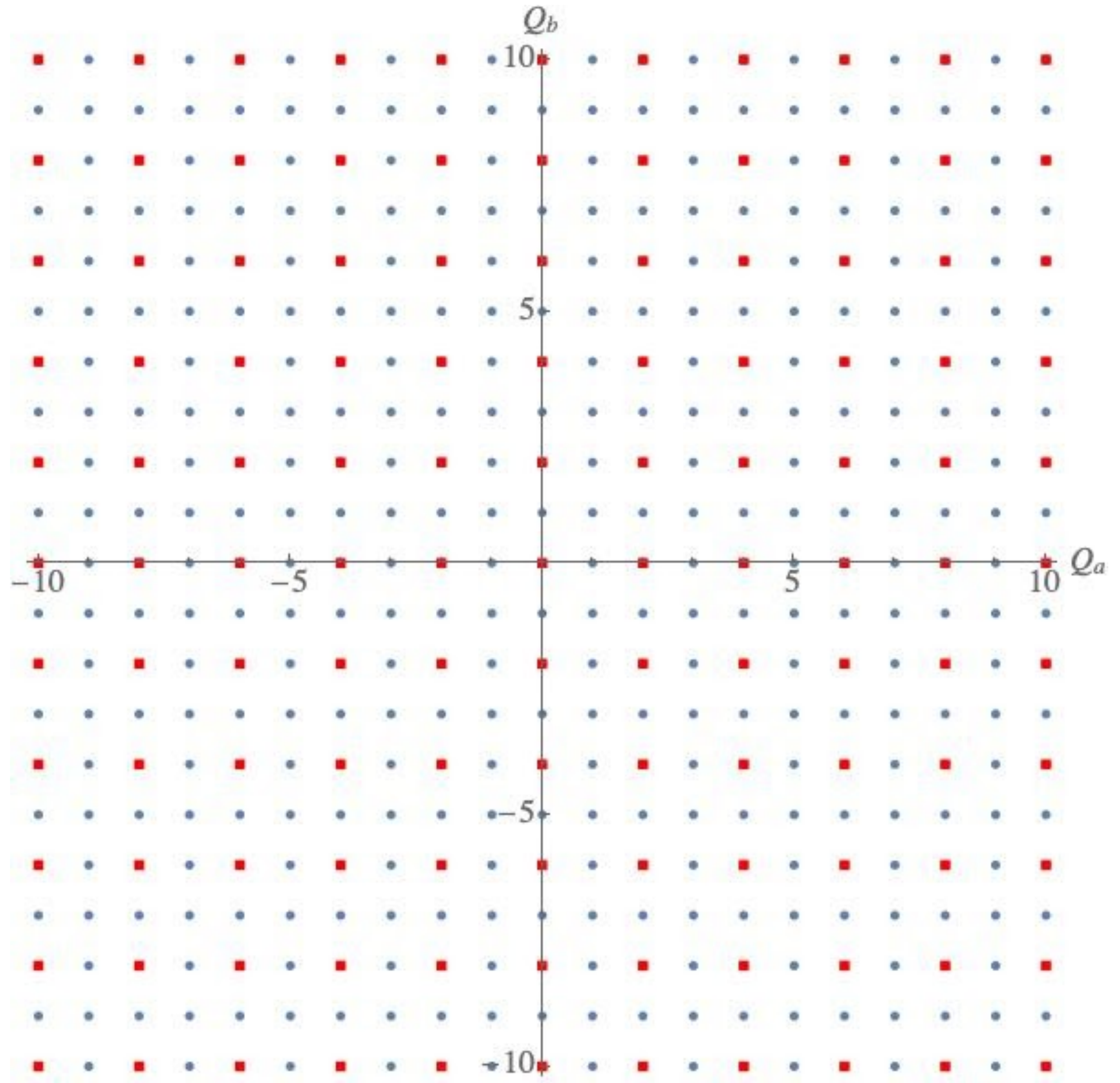
The General Weak Gravity Conjecture (WGC) states that a p-form gauge theory with coupling $e_{p;d}$ in d dimensions has an object of charge q with tension T_p satisfying

$$\left[\frac{\alpha^2}{2}+\frac{p(d-p-2)}{d-2}\right]T_p^2 \leq e_{p;d}^2 q^2 M_d^{d-2}$$

α is the dilation vev and M_d^{d-2} is the Planck mass.

Sublattice WGC

The Sublattice Weak Gravity Conjecture (sLWGC) states that there is a finite coarseness charge sublattice in a theory with U(1)s.



sLWGC Estimate for Mixing

The WGC postulates that the mass is given by

$$\frac{m_{ij}}{M_{4D}} = c_{ij}\sqrt{(g_a Q_a^{ij})^2 + (g_b Q_b^{ij})^2}$$

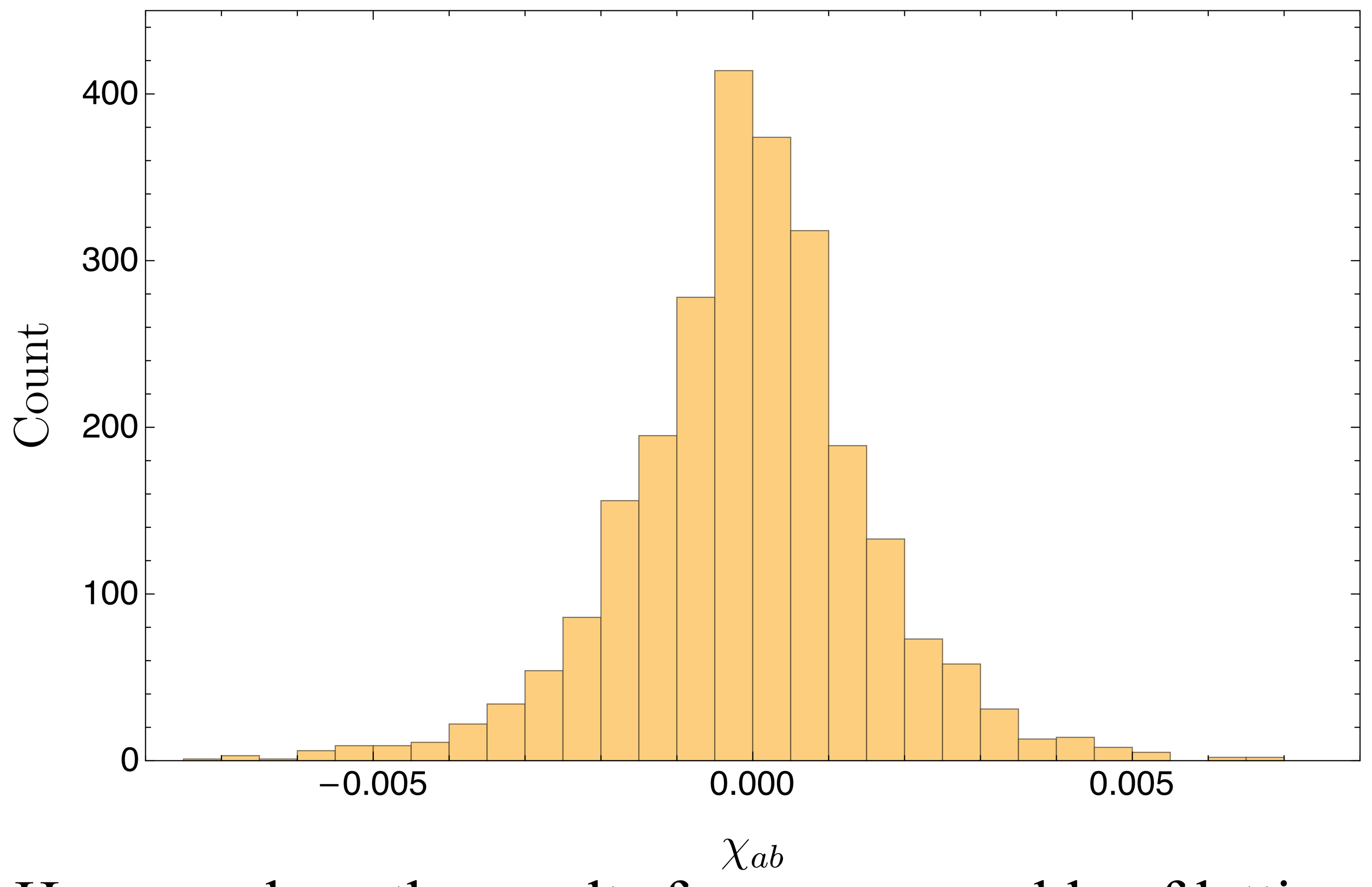
where we choose $c_{ij} < 1$ to ensure superextremality.

The PDF for the c_{ij} is

$$P(c; q, q_0) = \alpha(q^2 - q_0^2)\frac{e^{\alpha(q^2-q_0^2)c}}{e^{\alpha(q^2-q_0^2)}-1} \qquad q_0 \equiv \sqrt{g_a^2 + g_b^2}$$

This choice makes it exponentially difficult for states with large charge to be light.

Results of the Estimate



Here we show the results from an ensemble of lattice realizations. The histogram is centered at 0 which is due to the $\mathbb{Z}_2$ invariance of the PDF. We chose our parameters to be $g_a = 0.1$, $g_b = 0.2$, $\alpha = 6$, and ran 2500 lattice realizations to arrive at our estimate.

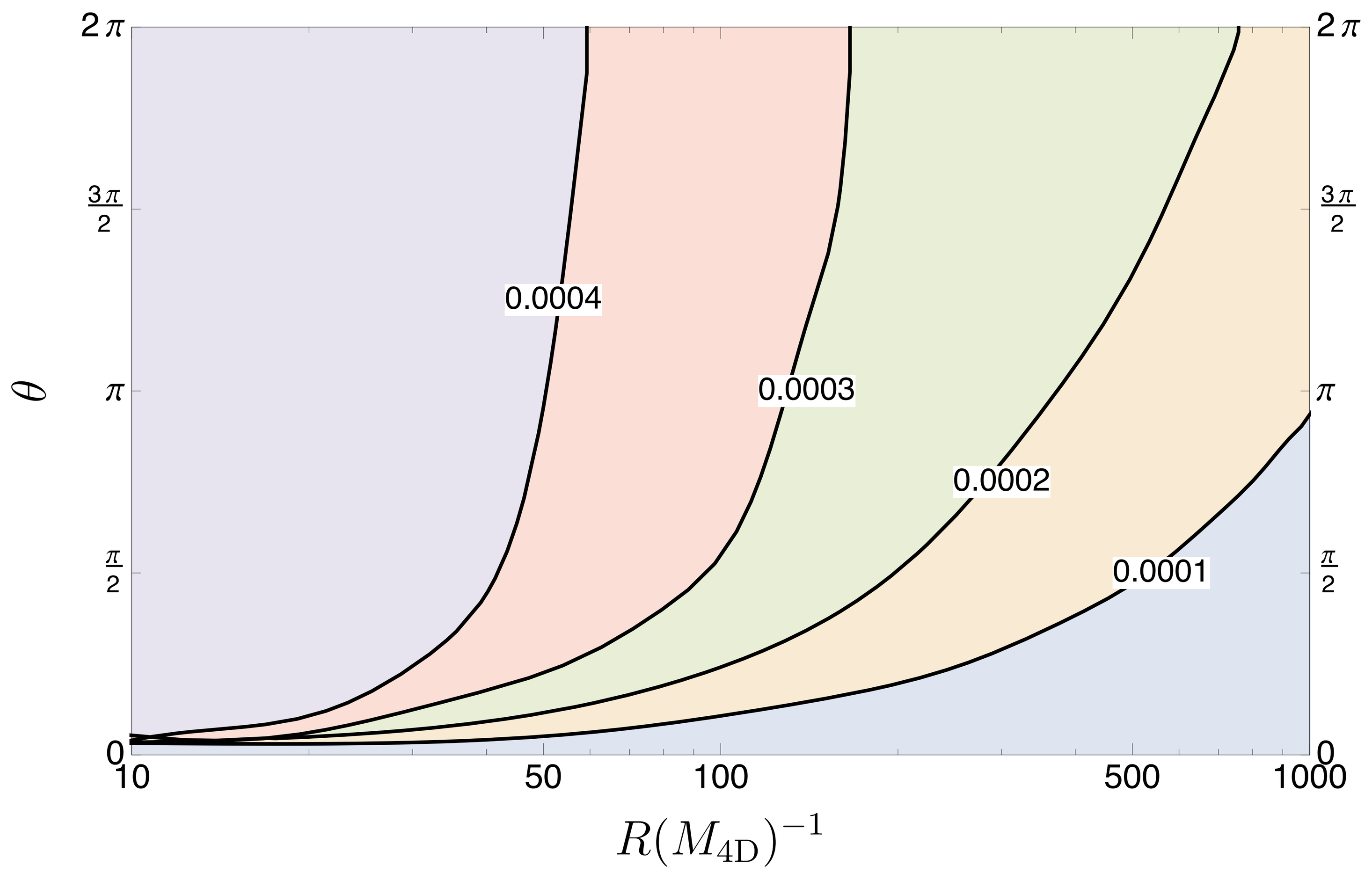
5D Gauge Theory on S^1

We considered a 5D Abelian gauge theory with a lattice of charged scalars whose masses are dictated by the General WGC. Compactifying on S^1, we obtain a 4D theory with a lattice of bi-charged scalars with mass

$$m^2 = \frac{3}{2}e_{4D}^2 q^2 M_{4D}^2 + \frac{1}{R^2}\left(n - \frac{q\theta}{2\pi}\right)^2$$

R is the radius of the circle and θ is the vev of the gauge field along the compact dimension.

Results of the 5D Example



θ induces a mass splitting between states with opposite charge q. As this splitting increases, the mixing does as well. Increasing R decreases e_{KK}. Eventually we lift the WGC tower of one U(1) above the species scale of the other reducing the mixing.

Conclusions

The states required by the sLWGC along with certain generality conditions imply the existence of non-vanishing kinetic mixing between massless Abelian gauge groups in the low-energy effective theory.

Considering consistent UV completions to quantum gravity enforce a portal to the dark sector.

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