Non-conservation of Global Charges in Braneworlds

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With: Dvali, Kolanović, Nitti; G.G.

- **Standard approach:**

  Particle physics UV scale: $\underline{\underline{M_{GUT}}}$

  Quantum Gravity scale: $M_{GUT} < \underline{\underline{M_*}} \lesssim M_P$

- **ADD approach:**

  Particle physics UV scale $\sim$ Quantum Gravity Scale $\sim$ $\underline{\underline{\text{TeV}}}$

- **Here:**

  Particle physics UV scale: $\underline{\underline{M_{GUT}}}$

  QG scale: $10^{-3}\,\text{eV} < M_* \ll M_{GUT}$

(Dvali, G.G., Kolanović, Nitti)

4D example:

$$\mathcal{L} = \mathcal{L}_{GUT} + M_p^2 R + \sum_{j=1}^{\infty} c_j \frac{R^{j+1}}{M_*^{2(j-1)}}$$

also ↑ higher derivatives of R.

- Gravitational coupling $G_N \sim \frac{1}{M_p^2}$ (weak)

- Effective field theory of gravity breaks down at $p \sim M_* > 10^{-3}\,\mathrm{eV}$

  Newton's law

- Start with $M_*^2 R$, due to $\mathcal{L}_{GUT}$ loops $M_{ind}^2 R$ is induced:

$$M_{ind}^2 \sim \int d^4x\, x^2 \langle T(x)\, T(0) \rangle_{Reg} \sim N\, M_{GUT}^2$$

(Adler-Zee)

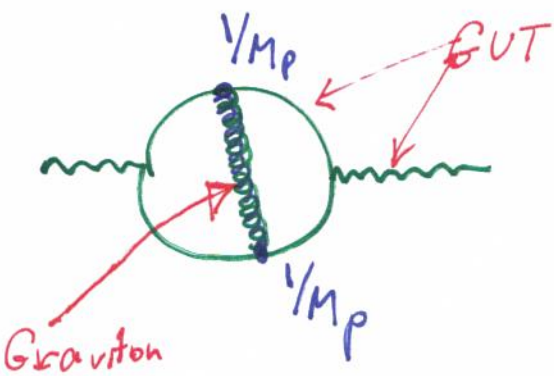
Breakdown scale:

- $\underline{R \sim M_*^2}$ Since $R \sim \rho / M_p^2$

$$\rho \sim (M_p \cdot M_*)^2 > TeV^4$$

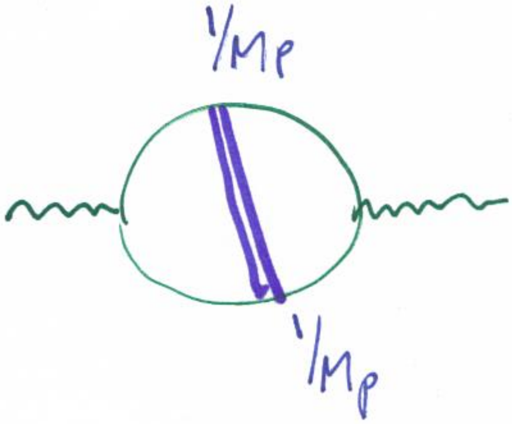
↑ geometric mean of M_p & M_*

- Need for "softening" of QG.



gravity cutoff M_*

$p < M_*$ OK

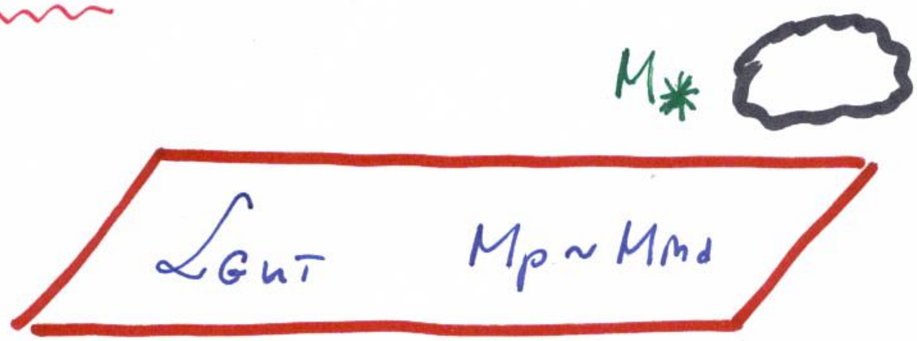


for $p \gtrsim M_*$

QG is "soft"; i.e.

does not become strong.

$D > 4$: Brane Induced Gravity



(Dvali, G.G. Porrati)
(Dvali, G.G.)

$$S = S_{GUT} + \int d^4x \sqrt{g}\, M_p^2 R + \cdots$$

(G.G., Shifman)
(G.G.)

$$+ M_*^{2+N} \int d^4x\, d^N y \sqrt{g_{4+N}}\, R_{4+N}$$

- 4 dim gravity $M_*^{-1} < r < 10^{28}\,\mathrm{cm}$ $G_N \sim 1/M_p^2$
- 4+N dim gravity strong $G_{4+N} \sim \dfrac{1}{M_*^{2+N}}$

- Regge states at M_*: $\underline{\underline{A_{\mu_1 \ldots \mu_n}}}$ $n \geq 2$

Brane induced terms: $\frac{M_p^{2(n-1)}}{M_*^{2(n-2)}} (\partial A)^2$

Interactions: $\frac{A^{\mu_1 \ldots \mu_n}}{M_*^{n-2}} T_{\mu_1 \ldots \mu_n}$

$$\Rightarrow \quad G_{(n)} \sim \frac{1}{M_p^{2(n-1)}}$$

(after rescaling)

Phenomenology: production

$$\Gamma \sim E \cdot \frac{E^4}{(M_p \cdot M_*)^2}$$

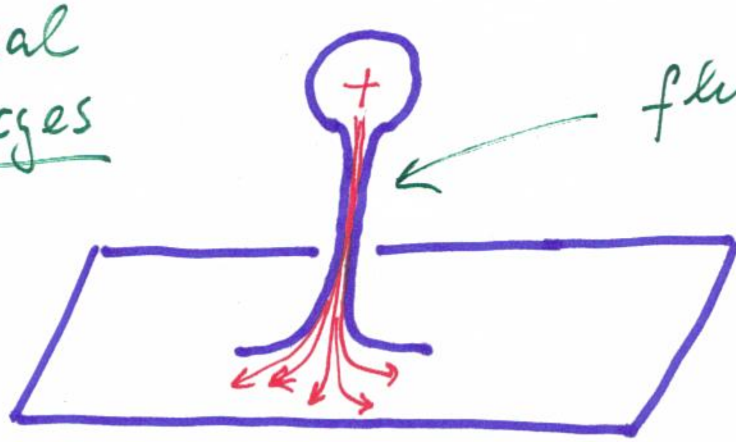
due to huge multiplicity.

$\sqrt{M_p \cdot M_*} > \text{TeV}$

If $M_* \sim 10^{-3}\,\text{eV}$, spectacular signatures at LHC.

Non-conservation of global charges

Local charges



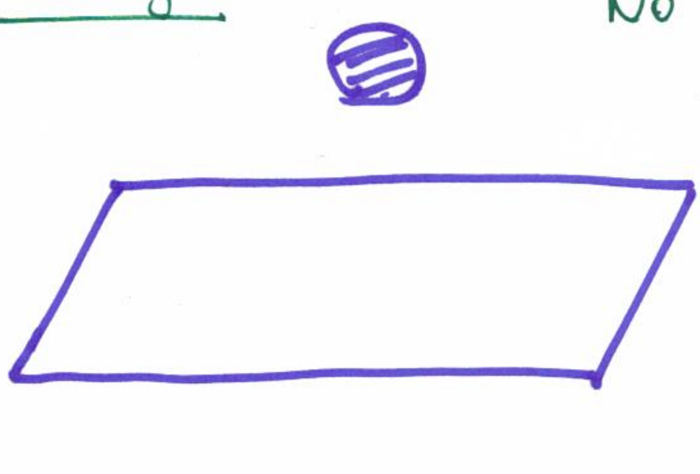
flux tube

(Dvali, G.G.)

- No local charge violation
- (+) could be a „Baby brane" or Black Hole

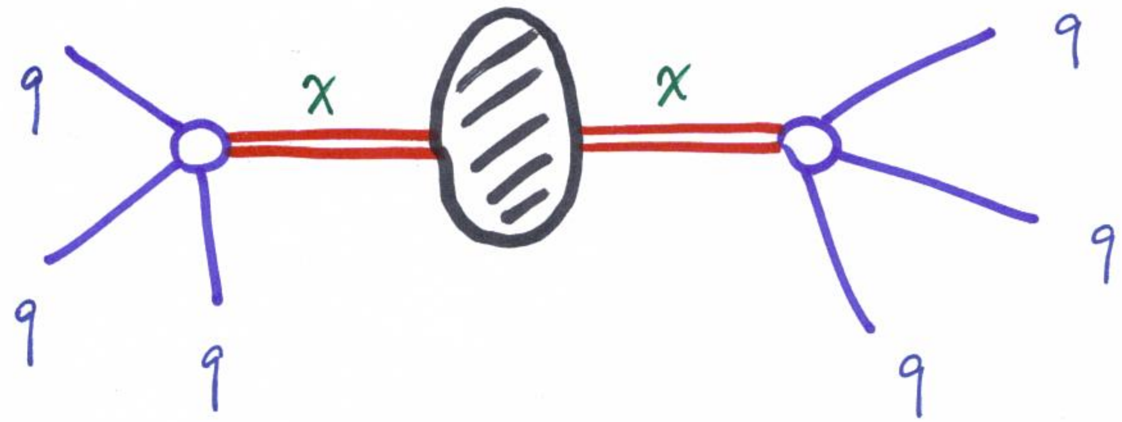
Global charge

No flux tube



Black holes:
„no hair" theorem
(Bekenstein)

Virtual Bulk Black Holes



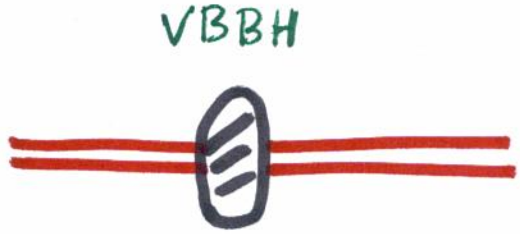
$$H_{eff} = \sum_j c_j \hat{O}_j$$

n – $\bar{n}$ oscillations
(exp. Kamyshkov)
(Kuzmin)
(Glashow)
(Mohapatra & Marshak)

$$\hat{O}_j \ni udd\,udd$$

$$M_{n\bar{n}} \equiv \langle n | H_{eff} | \bar{n} \rangle \lesssim 10^{-33}\,\text{GeV}$$

(Nussinov, Shrock)
in ADD

$\Sigma \equiv$ 

$\sim$ (with brane induced terms)

$$\sim \frac{1}{\hat{k} - M_\chi} \, M_{\text{conversion}} \, \frac{1}{\hat{k} - M_\chi}$$

$$M_{\text{convers}} \sim \sigma_D \cdot M_{\chi_D}^3 \sim$$

$$\sim \left(\frac{M_{\chi_D}^3}{M_*^2} \right) \left(\frac{M_{\chi_D}}{M_*} \right)^{2(N+1)}$$

$$\sigma_D \sim \left(r_s^{(D)} \right)^2 \sim \left[\frac{1}{M_*} \left(\frac{M_{\chi_D}}{M_*} \right)^{N+1} \right]^2$$

Simplest case:

$$M_{\chi_D} \sim M_* \qquad M_\chi \sim \underline{M}$$

$$H_{eff} \sim \frac{M_*}{M^6}\,\hat{O}$$

$\langle n | \hat{O} | \bar{n} \rangle$ matrix elements: (Rao, Shrock)

$$M^6 \gtrsim 10^{29}\, M_*\, GeV^5$$

$M_* > 10^{-3}\, eV$	$M_* \gtrsim TeV$
$M \gtrsim 10^3\, GeV$	$M \gtrsim 10^{5.3}\, GeV$
$M \sim 10^3\, GeV$	$M \sim 10^5\, GeV$
potentially observable	potentially observable

For a given M_*, $\exists$ potentially observable $\underline{M}$.

Conclusions

- Low QG scale models ≥ soft QG

  - Retain GUT's & pp model building with high UV scale

  - Interesting additional phenomenology due to QG states (Regge states)

  - D>4 additional contribution to $n-\bar{n}$ oscillations due to virtual bulk black holes.