10^32 Dark Sectors

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Bound

Any theory with N particle species has a gravitational cutoff

$$M_* \approx \frac{M_p}{\sqrt{N}}$$

Diagrammatically,

$$G(p) = \frac{1}{p^2} + \frac{1}{M_P^2}\frac{1}{p^2} < T(p)T(-p) > \frac{1}{p^2} + \ldots$$

$$< T(p)T(-p) > \approx N\, p^4 \log \frac{p^2}{m^2}$$

The perturbative expansion goes out of control at M_*

This is necessary for consistency with Black-Holes physics

$$\tau_{BH} \approx \frac{1}{N} r_g^3 M_p^2$$

It also agrees with naturalness arguments,

$$\delta M_p^2 \approx N \Lambda^2$$

In any theory with many species a hierarchy between the Planck scale and the masses is automatic!

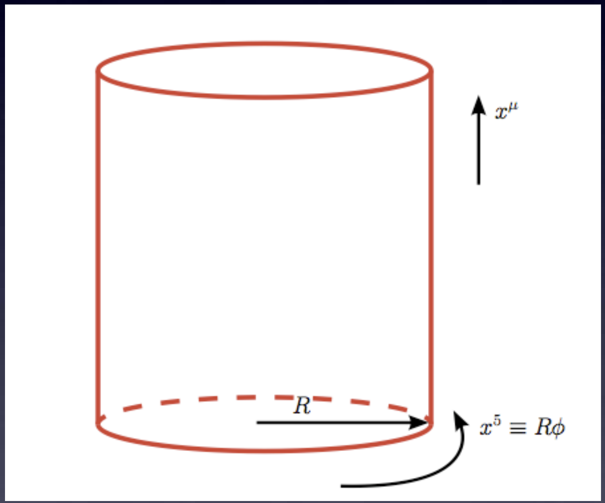
The electroweak hierarchy would require N~10^32

Example

We have seen something very similar recently:

- Large Extra Dimensions:

(Arkani-Hamed, Dimopoulos, Dvali)

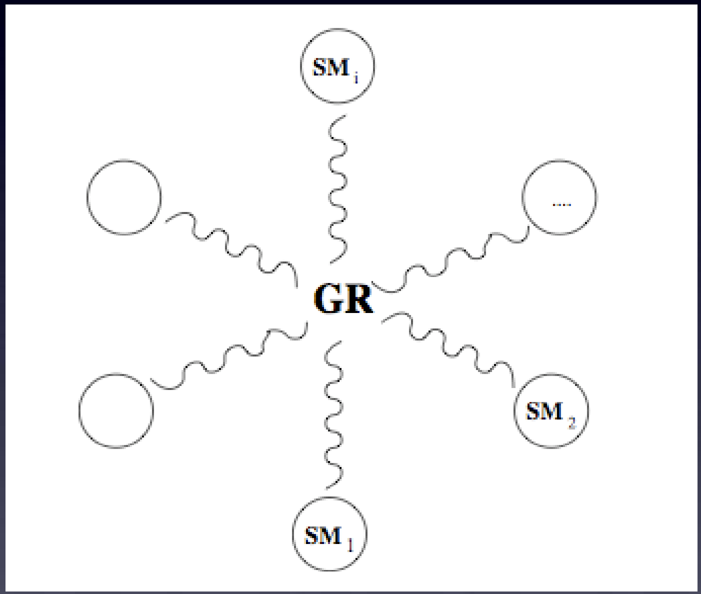


$$
\begin{aligned}
M_p^2 &= M_*^2 (M_* R)^n \\
&= M_*^2 \, N
\end{aligned}
$$

By taking the fundamental scale TeV Large Extra Dim explain the hierarchy through 10^32 KK gravitons.

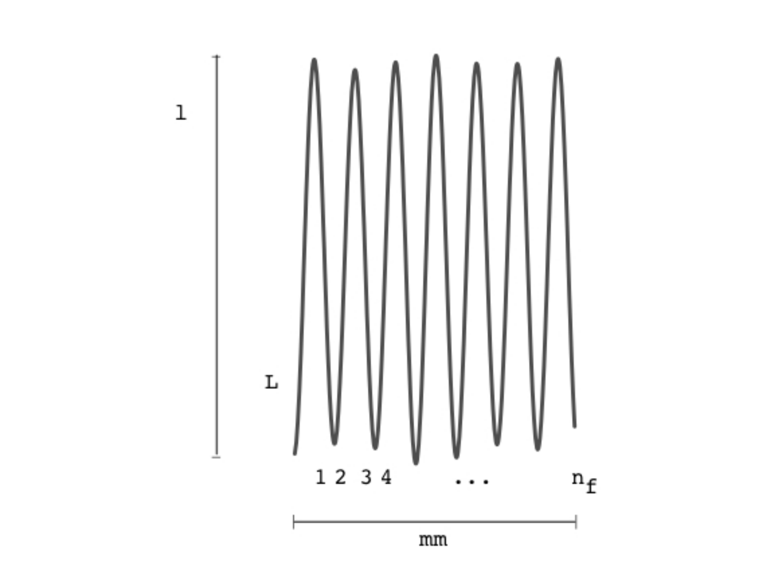
10^32 Species

The nature of the species is irrelevant.
A different possibility is identical copies of the SM.



Gravity is 1/N weaker due to the "spreading" in the space of species. M_P is a derived scale.

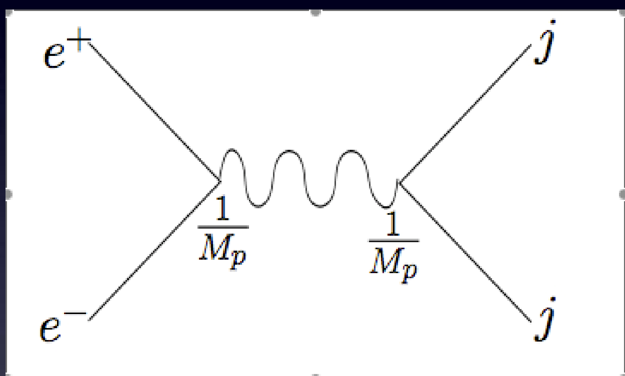
Different models can be classified according permutation symmetry. Cyclic symmetry leads to extra-dimensional behavior



I will consider the case of full permutation symmetry. This corresponds to maximal departure from geometry.

Bounds

Despite the multiplicity of massless states, bounds are very mild



$$\sigma \approx \frac{E^2}{M_p^4} N = \frac{E^2}{M_p^2 M_*^2}$$ (N SM species)

$$\sigma \approx \frac{1}{M_p^2} (ER)^n = \frac{1}{M_*^2} \left(\frac{E}{M_*} \right)^n$$ (LED)

All cosmological constraints disappear!

Mirror baryons would be perfect dark matter candidates

$$n\, n_{dark} \approx 5 n_{visible}$$

Mixings

Electrically neutral states from different copies can mix. This could provide a bridge on the hidden sector:

- Neutron Mixing, K-Kbar oscillations
- U(1) kinetic mixing: “mini-charged” particles
- Higgs quartic
- Neutrinos masses

- Neutron

$$k_{ij}\,\frac{u_i d_i d_i u_j d_j d_j}{M_*^5}$$

This would induce a mixing between different neutrons

$$H_{ij} = \begin{pmatrix} m_n & \delta m_n & \delta m_n & .. \\ \delta m_n & m_n & \delta m_n & .. \\ \delta m_n & \delta m_n & m_n & .. \\ .. & .. & .. & .. \end{pmatrix}.$$

$$\delta m_n \approx k\,10^{-10}\left(\frac{TeV}{M_*}\right)^5 eV$$

Perturbativity requires,

$$k < \frac{1}{N}$$

The mixing can be reduced to a 2x2 matrix

$$H_{ij} = \begin{pmatrix} m_n & \delta m_n \sqrt{N-1} \\ \delta m_n \sqrt{N-1} & m_n + \delta m_n (N-2) \end{pmatrix}.$$

$$m_{1,\dots,N-1} = m_n - \delta m_n$$
$$m_H = m_n + (N-1)\delta m_n$$

Oscillation time is short but the amplitude is suppressed

$$\tau \approx 10^{-5} \left(\frac{M_*}{TeV} \right)^5 sec$$

$$P(t) = \frac{4}{N} \sin^2 \left(\frac{t}{\tau} \right).$$

Possible to increase the amplitude with magnetic field

$$\epsilon = \delta m_n (N \quad 2) \qquad\qquad (10^2 Gauss)$$

Neutrinos

If we add a right-handed neutrino to each copy small masses can be generated without seesaw.

$$\lambda_{ij}\left(\bar{L}H_c\right)_i \nu_j^R$$

λ_{ij} is a matrix with a on the diagonal and b off-diagonal

$$b < \frac{1}{\sqrt{N}}$$

$$m_i = (a-b)v \approx \left(\frac{a}{b} - 1\right)\frac{v}{\sqrt{N}}$$

If the right-handed neutrino is delocalized it can produce the correct neutrino masses. No oscillations.

Conclusions

- I have presented a new framework where the electroweak scale is stabilized by an exponentially large number of species, for example 10^{32} copies of the SM.
- This scenario generalizes the Large Extra Dimensions proposal. The 4d Planck scale is a derived scale determined by the number of species.
- The scenario could have dramatic implications for cosmology, neutrinos and black-holes.
- Phenomenological constraints are much weaker than LED, mixings could provide a window on the hidden sectors.