Large Mass Hierarchy from a Small Extra Dimension

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If we want to have $m = 125 GeV$,the bare mass m_0 has to be very large, hence m/m_0 has to be very precise which is unnatural and termed **Fine Tuning Problem**.

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- In other words why gravity is so weak.
- Is there any solution to fine tunning problem? Can we aviod such fine tuning of parameter like Higgs' mass.?

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$$\tilde{R} = R - \frac{1}{4} F_{\alpha\beta} F^{\alpha\beta} \quad (5)$$

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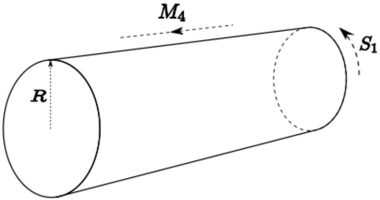

Fig. 1. The Kaluza–Klein set-up.

Figure: *Compactified Extra Dimension*

Kaluza Klein Action continued..

Assuming cylindrical compactification of extra dimension with radius a we get

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$$G_{4D} = \frac{G_{5D}}{2\pi a\sqrt{k}} \tag{9}$$

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The determinant of the metric is given by

$$\tilde{g} = g\gamma \tag{12}$$

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$$\frac{V_n}{G_{4+n}} = \frac{1}{G_4} \tag{16}$$

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- M_{Pl} corresponds to 4 dimensional reduced Planck scale and M represents fundamental Planck scale in higher D theory and μ_c is the scale of compactification.

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- For n=2 we extra dimension of 1 mm size.

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- This scenario does eliminate the hierarchy between weak scale ν (TeV) and Planck Scale, it introduces a new hierarchy between ν and $\mu_c \sim \frac{1}{V_n}$

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$$\frac{\mu_c}{\nu} = 10^{-\frac{32}{n}} \tag{18}$$

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- The 3-branes extending in x^μ direction are located at $\phi = 0$ and $\phi = \pi$.

$$g_{\mu\nu}^{vis} = G_{\mu\nu}(x^\mu, \phi = \pi) \tag{20}$$

$$g_{\mu\nu}^{hid} = G_{\mu\nu}(x^\mu, \phi = 0) \tag{21}$$

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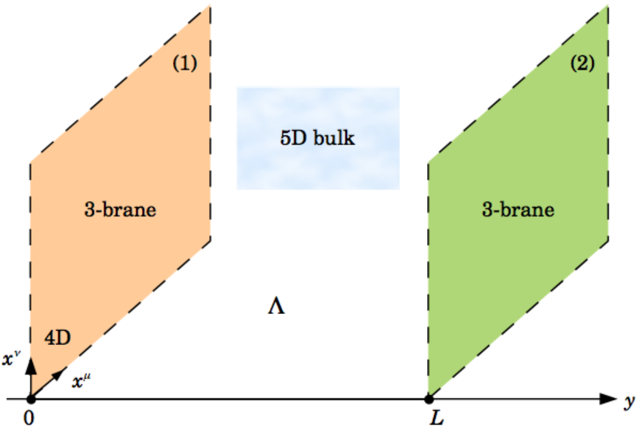

Figure: *Randall Sundrum Model*

The Classical Action

$$S = S_{gravity} + S_{vis} + S_{hid} \tag{22}$$

where

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where V_{vis} and V_{hid} is vacuum energy of the branes which act as a gravitational source even in absence of matter on brane.

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- Demanding a metric with a warp factor forces the existence of branes at $\phi = 0$ and $\phi = \pi$ with vacuum energy given by above.
- The bulk has negative Λ-hence the bulk is a slice of AdS_5 geometry.

Relation between M and M_{Pl}

We perturb the background metric so that

$$ds^2 = e^{-2kr_c|\phi|}[\eta_{\mu\nu} + \bar{h}_{\mu\nu}]dx^\mu dx^\nu + r_c^2 d\phi^2 \tag{30}$$

where $\bar{h}_{\mu\nu}$ is tensor fluctuations about Minkowski spacetime.

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where $\bar{h}_{\mu\nu}$ is tensor fluctuations about Minkowski spacetime.

- The 4dimensional effective theory follows by substituting the above in $S_{gravity} = \int d^4x \int_{-\pi}^{\pi} d\phi \sqrt{-G}[-\Lambda + 2M^3 R]$

Contd..

$$S_{eff} \supset \int d^4x \int_{-\pi}^{\pi} d\phi 2M^3 r_c e^{-2kr_c|\phi|} \sqrt{-\bar{g}} \bar{R} \tag{31}$$

where $\bar{R}$ denotes the 4 dimensional Ricci scalar made out of $\bar{g}_{\mu\nu}$.

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- M_{Pl} depends weakly on r_c in the large kr_c limit.
- But the exponential hierarchy plays a crucial role in determining visible sector masses.

Scaling of Mass

$$S_{vis} \supset \int d^4x \sqrt{-g_{vis}}[g_{vis}^{\mu\nu} D_\mu H^\dagger D_\nu H - \lambda(|H|^2 - \nu_0^2)^2] \tag{33}$$

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So we have

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$$\nu = e^{-kr_c\pi}\nu_0 \tag{38}$$

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$$m = e^{-kr_c\pi} m_0 \tag{39}$$

- If $e^{kr_c\pi}$ is of the order of 10^{15} the mechanism produces TeV physical mass scale from Plank scale $(10^{19} GeV)$.

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- If $e^{kr_c\pi}$ is of the order of 10^{15} the mechanism produces TeV physical mass scale from Plank scale ($10^{19} GeV$).
- Because the warping factor is exponential the model does not require very large hierarchies among fundamental parameters ν_0,k,M and $\mu_c = \frac{1}{r_c}$; with $kr_c \sim 10$.

Generation of Exponential Hierarchy

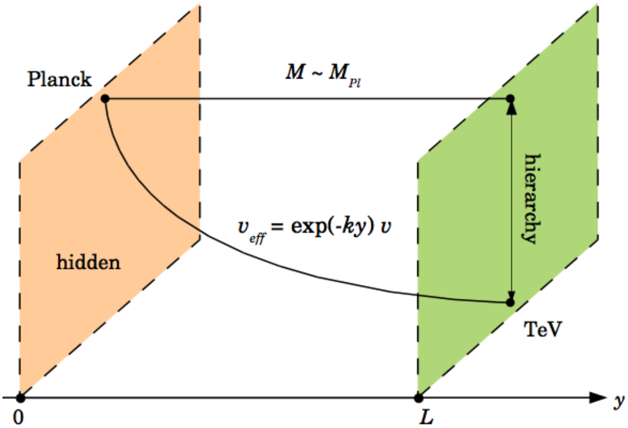

Figure: *Generation of Exponential Hierarchy*

References

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- Kaluza Klein Theories, David Bailin and Alex Love, Rep. Prog. Phys. **50**, 1087 (1987)
- A First Course in String Theory, Barton Zwiebach, Second Edition
- Large Mass Hierarchy from a Small Extra Dimension, L.Randall and R.Sundrum, Phys. Rev. Lett. **83**, 3370 (1999).

- The Aim of the Talk is to present the above paper by Randall, Sundrum.

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