Living between two singularities

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Overview

Physics beyond the standard model: *compact* extra dimensions.

- Constructing extra dimensional models with singularities.
- Why extra dimensions are useful.
- Stabilising the distance between singularities.
- Shielding the singularities.
Extra dimensions

\( w \) is extra space dimension, integrate it out to get 4D theory.

\[
\int \left( \begin{array}{c}
\psi(x^\mu)
\end{array} \right) \, dw =
\]

Separation of variables: \( \Psi(x^\mu, w) = f(w)\psi(x^\mu) \to \text{Kaluza-Klein modes} \).
Edge of the extra dimension

Need a way to “end” the extra dimension:

- infinite
- periodic
- branes (hard walls)

\[ ds^2 = e^{-2\sigma(w)} \eta_{\mu\nu} dx^\mu dx^\nu + dw^2. \]

\[ R, \sigma \text{ diverge at edge.} \]

Line of singularity: soft wall.
Edge of the extra dimension

Need a way to “end” the extra dimension:

- infinite
- periodic
- branes (hard walls)

Or: a singularity.
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\[ ds^2 = e^{-2\sigma(w)} \eta_{\mu\nu} dx^\mu dx^\nu + dw^2. \]

- \( R, \sigma \) diverge at edge.
- Line of singularity: soft wall.
Line of singularity supported two scalar fields: dilaton and kink.

Space is repeated.

Integrated energy density is zero (cosmological constant is zero).

Can escape from singularity.
Use of extra dimensions

- Electroweak hierarchy: $M_{\text{Planck}} \xrightarrow{\text{redshift}} M_{\text{EW}}$.
- Mass hierarchy and couplings set by overlap integrals.
Stabilising the extra dimension

Electroweak scale (and other things) set by size of extra dimension.
→ stabilise distance between singularities.

Odd kink and even dilaton:
- massless 4D particle (zero mode/moduli field),
- exciting this particle changes size of extra dimension!

Odd kink and odd dilaton:
- parity banishes the massless 4D particle,
- distance between singularities stabilised.
Shielding the singularity

Geodesics end at singularity.
Can go in and come out.

Quantum gravity unknown
→ unable to predict what comes out,
→ must shield singularities.

Try to create a black-hole-like horizon.
Shielding the singularity

Line of horizon shields line of singularity:

\[ ds^2 = e^{2\sigma(w)} \left[ -h(w)dt^2 + d\vec{x}^2 \right] + h(w)^{-1} dw^2 \]

\[ h'(0^+) = \frac{1}{2} (1 + w) \rho_{\text{brane}} \]

Sign of \( h'(0^+) \):

Want \( h'(0^+) < 0 \)

→ need ghost matter on brane at origin!
Shielding the singularity

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\( \rightarrow \) need ghost matter on brane at origin!

Plan B: place singularities “infinitely” far away:

- Finite physical distance \( w_* \).
- Infinite time for particles to reach singularity: \( t = \int_{0}^{w_*} e^{\sigma(w)} \, dw \).
- Puts tighter constraints on parameters of the model.
- Can still solve the hierarchy problem.
Conclusions

- Integrate out the extra dimension: $5D \rightarrow 4D$.
- Singularities at edges.
- Supported by scalar fields.
- Solve EW hierarchy problem.
- Stabilise by parity.
- Shield by placing them “infinitely” far away.
Randall-Sundrum warped metric:
- Randall & Sundrum, PRL 83, 3370 (1999)

Original soft-wall motivation (AdS/QCD and linear Regge trajectories):

Continued work on soft-wall models:
- Batell & Gherghetta, PRD 78, 026002 (2008)
- Falkowski & Perez-Victoria, JHEP 12, 107 (2008)
- Batell, Gherghetta & Sword, PRD 78, 116011 (2008)
- Cabrer, von Gersdorff & Quiros, arXiv:0907.5361
- Aybat & Santiago, PRD 80, 035005 (2009)
- Aybat & DPG, JHEP 09, 010 (2010)