

Trapped in an infinite extra dimension

Damien George

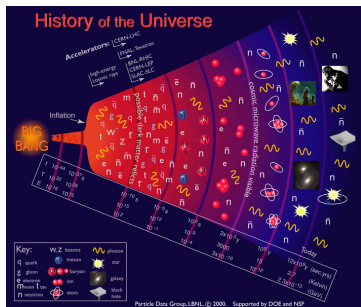
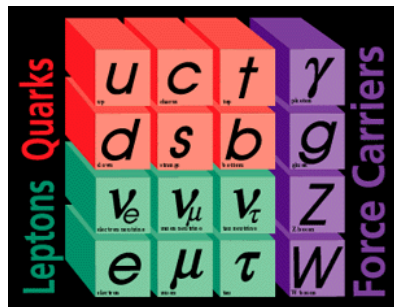
Nikhef theory group

Nikhef Jamboree
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Amsterdam



Extra dimensions

Beyond the standard model and general relativity — what else could there be?



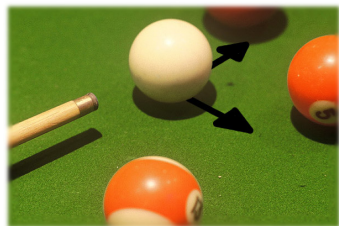
How do I think about this?

An infinite extra dimension?

Pool table:

- Balls only travel in two directions.
- *Trapped* to the table.

But the table exists in 3D!



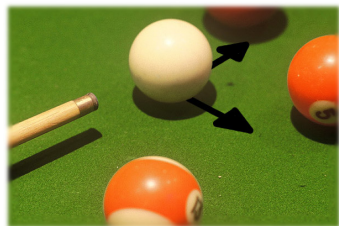
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Certain things in pool (ball spin) can be explained easily using 3D.



Imagine our universe is the table.

Perhaps we can describe things better if we accept 4D (plus time).

How to test? Hit the balls hard and with spin they may come off the table: disappear into the extra dimension!

The very first extra-dimensional world

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Unification of forces: Nordström then combined his gravity with electromagnetism (1914).

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4D electromagnetism becomes 5D:

$$\text{EM vector potential} = \left(\begin{array}{c} \phi \\ \mathbf{A} \\ \text{---} \\ \text{gravity potential} \end{array} \right) \left. \begin{array}{l} \} \text{4D part} \\ \} \text{extra dim} \end{array} \right\}$$

Only works if $\frac{d}{dw}\phi = \frac{d}{dw}\mathbf{A} = \frac{d}{dw}(\dots) = 0 \rightarrow$ we can't move in ED.

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Nordström:

It is shown that a unifying treatment of the electromagnetic and gravitational fields is possible if one considers the four dimensional spacetime-world to be a surface in a five dimensional world.

Extra dimensions today

95 years later → implement this idea seriously.

We have [general relativity](#) and the [standard model](#).

How to make sure that particles cannot move in ED?

Extra dimensions today

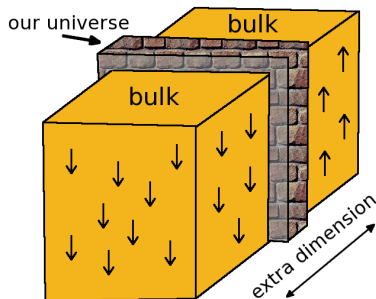
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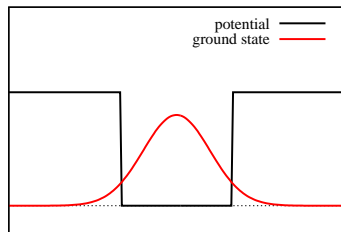
Use a **domain wall** as a trap in the extra dimension.

DW forms as solution of scalar field (a kink).



Quantum mechanical well

Domain wall acts like a trap for particles, just like QM well.

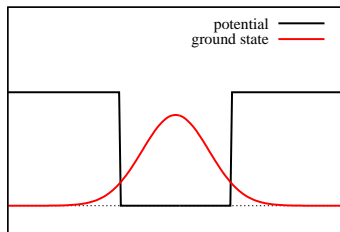


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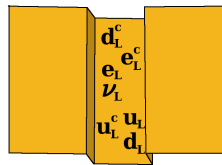


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$$\Psi(5D) = \sum_{n=\text{modes}} f_n(\text{extra dimension}) \cdot \psi_n(4D)$$

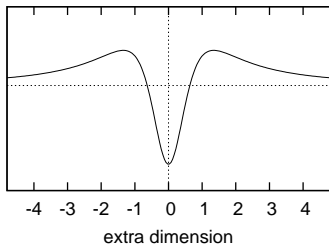
- f_n are extra-dimensional profiles.
- Ground state ψ_0 corresponds to our 4D particles.



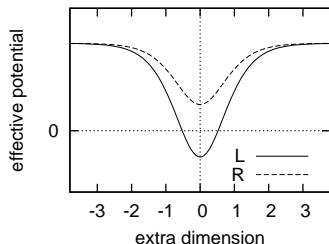
Trapping gravity and matter

Gravity trapping by
'volcano' potential.

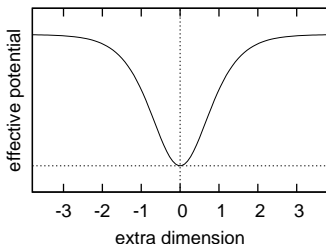
(Randall-Sundrum warped metric.)



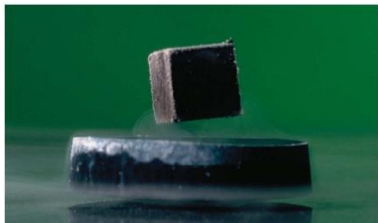
Fermion trapping;
only left-chiral in ground state.



Higgs trapping;
ground state has negative mass.



Trapping gauge bosons



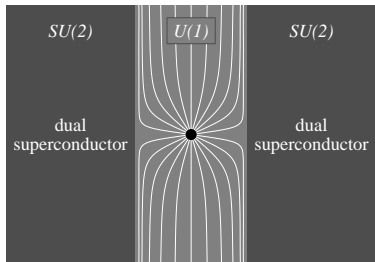
Superconductor

→ repel magnetic field

Dual superconductor

→ repel electric field

Trap $U(1)$ EM fields with $SU(2)$ bulk.



(Dvali-Shifman mechanism.)

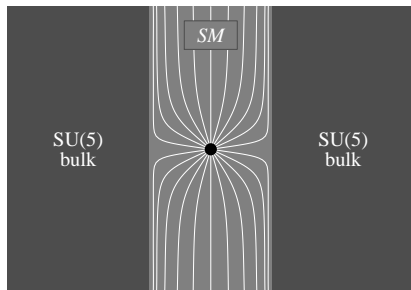
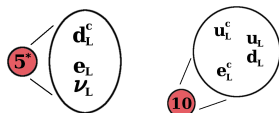
Grand unification

Now need to build the SM. Based on gauge group $SU(3) \times SU(2) \times U(1)$.
To trap SM gauge fields, bulk needs to contain, and be larger, than SM.
Naturally leads to grand unification (GUT models).

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Simplest choice is $SU(5)$.

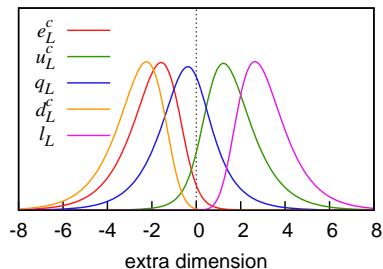


grand unification
+
gauge boson trapping

Properties of unification

- Grand unification \leftrightarrow trapped bosons.
- Choice of GUT group: $SU(5)$, $SO(10)$, E_6 , ...
- “Split” fermions and Higgs: matter located at different places along extra dimension.
- Proton decay suppressed by split fermions.

Particle masses depend on overlap with Higgs in extra dimension.



Summary

Infinite extra dimension?

- domain wall formation
- trapped particles
- natural grand unification

Realistic, testable model:

- mass related to location in ED
- Kaluza-Klein modes
- at high energies, particles disappear into ED
- cosmology changed at early time (universe is then 5D)
- modifications to gravity (very small)

Rich framework for future investigation:

- CKM mixing (overlap integrals)
- neutrinos
- add supersymmetry

