

Extra Spacetime Dimensions

Conor Sayres
10/22/09
Phys 485

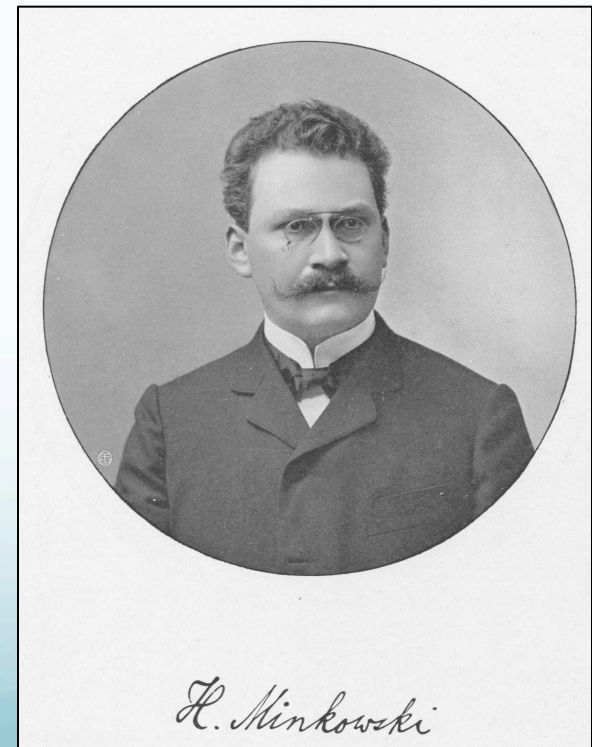


Pythagoras – 570 BCE

- **Observation: The Universe is Harmonious**
- **Conclusion: A spherical Earth**

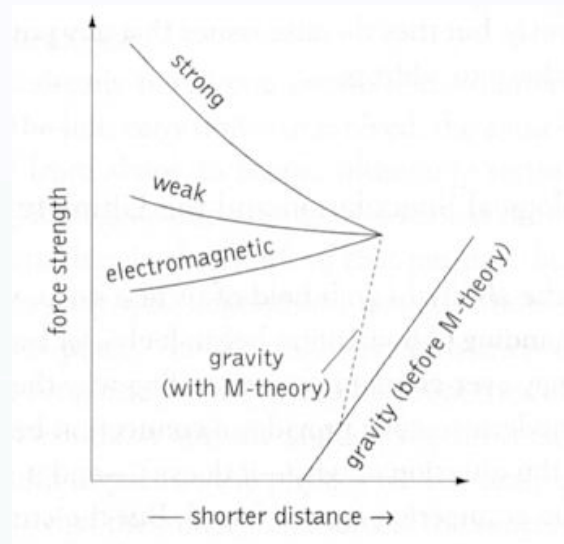
Minkowski - 1907

- GR more elegantly described by 3 + 1 dimensions
- Minkowski Spacetime



Hierarchy Problem

- Standard Model
- Where's Gravity?
- Lost in extra dimensions?



Three Generations of Matter (Fermions)

	I	II	III	
mass →	2.4 MeV	1.27 GeV	171.2 GeV	0
charge →	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
spin →	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
name →	u up	c charm	t top	γ photon
	4.8 MeV	104 MeV	4.2 GeV	0
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
Quarks	d down	s strange	b bottom	g gluon
	<2.2 eV	<0.17 MeV	<15.5 MeV	91.2 GeV
	0	0	0	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z weak force
	0.511 MeV	105.7 MeV	1.777 GeV	80.4 GeV
	-1	-1	-1	±1
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
Leptons	e electron	μ muon	τ tau	W weak force

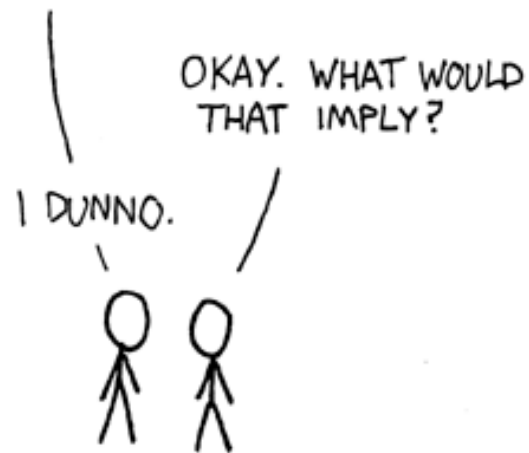
Bosons (Forces)

Kaluza-Klein Theory

- Unifies Gravity and E&M using 5 space-time dimensions
- Hard to test experimentally
- No quantum gravity element

STRING THEORY SUMMARIZED:

I JUST HAD AN AWESOME IDEA.
SUPPOSE ALL MATTER AND ENERGY
IS MADE OF TINY, VIBRATING "STRINGS."



Modern String Theories

- Gauge Theories – Like Standard Model (Particles and symmetry)
- 6, 7, + Dimensions.
- The exciting part. Predictions for:
 - High Energy Colliders
 - Short Range Gravity Experiments
 - Astrophysical Observations



Basic Theory/Concepts

- Terminology:
 - Brane, ie our 3 observed = 3-Brane
 - ND – Bulk
- Particle Confinements:
 - Branes carry Standard Model gauge charges
 - Ends of strings stuck to branes = Standard Model Fields
 - Gravitons = closed strings and can propagate through bulk

As far as we're concerned.

- Matter and gauge forces confined to our 3-D subspace
- Gravity, not so much
- Expectation: Extra dimensions should be compacted & finite
 - Otherwise we would see deviations from Newtonian gravity
 - If small enough, Standard Model fields could propagate too, step towards supersymmetry breaking, etc.
- Bulk geometry and permitted propagations vary from theory to theory.

Kaluza-Klein (KK) Tower

- Compact dimensions cause propagating fields to expand into a series of states
- Think particle in a box with identical gauge and spin numbers.
- For us trapped on a brane we observe:

$$m^2 = \vec{p}_\delta^2.$$

What We Can Look For

- 1) Direct or Indirect observation of KK states
- 2) Observation of short-range gravitational deviations

Scenarios and Collider Constraints

- Large Extra Dimensions

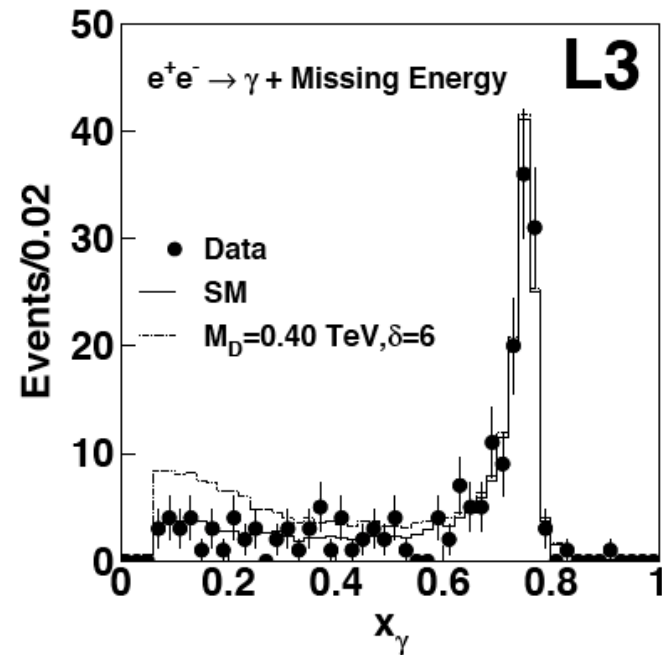
$$M_{\text{Pl}}^2 = V_\delta M_D^{2+\delta}$$

- $M_D \rightarrow \text{TeV}$ eliminates the hierarchy. This is a big length.
- Search for missing energy

LEP II

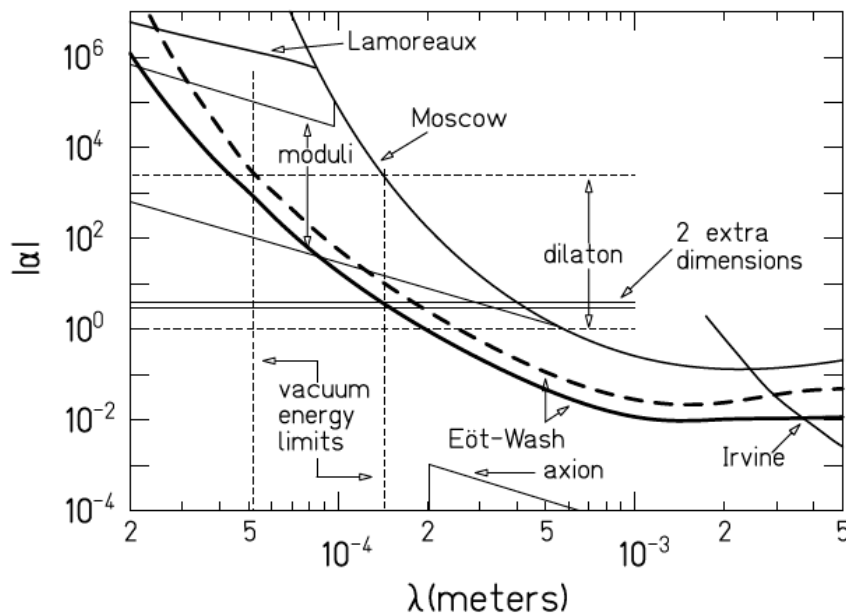
- Excluded scales:
 - 1.45 TeV for 2 extra dimensions
 - .6 TeV for 6 extra dimensions

$$e^+e^- \rightarrow G_n + \gamma(Z)$$



Tests For Short Range Gravity

- Eot-Wash – Bounds on extra dimension size – Yukawa interaction

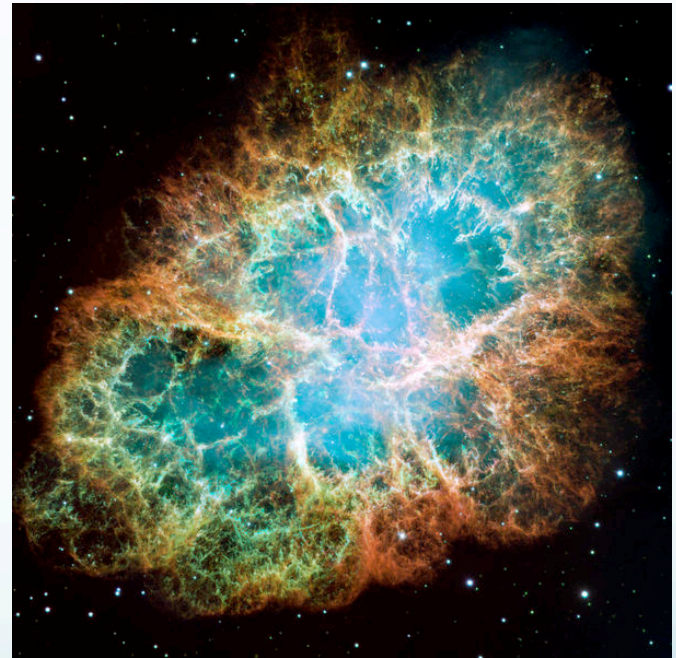


$$V(r) = -\frac{1}{M_{\text{Pl}}^2} \frac{m_1 m_2}{r} (1 + \alpha e^{-r/\lambda})$$

Exclusion of dimensions larger than .008 mm, regardless of how many exist.

Astronomical Observables

- Graviton emission during core collapse SN
- Heating of neutron stars from graviton decay



Future

- Extra dimensions only exist in certain energy regimes?
- New colliders probe deeper

Check out:

Particle Physics Probes Of Extra Spacetime Dimensions. *JoAnne Hewett. 2002.*