

# Phenomenological properties of string theory vacua

Giuseppe Sudano

University of Oviedo & ICTEA, Oviedo

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Universidad de Oviedo



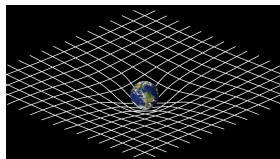
# Our Universe, so far

Our current understanding of the Universe is based on two main pillars:

- the **Standard Model of Particle Physics**;
- **General Relativity**.

mass $\rightarrow$ $\times 1.2$ MeV/c <sup>2</sup>	<b>u</b> up	$\times 1.275$ GeV/c <sup>2</sup>	<b>c</b> charm	$\times 173.07$ GeV/c <sup>2</sup>	<b>t</b> top	0	<b>g</b> gluon	$\times 126$ GeV/c <sup>2</sup>	<b>H</b> Higgs boson
charge $\rightarrow$ 2/3	2/3	2/3	2/3	2/3	2/3	0	0	0	0
spin $\rightarrow$ 1/2	1/2	1/2	1/2	1/2	1/2	1	1	0	0
<b>QUARKS</b>	$\times 0.5$ MeV/c <sup>2</sup>	$\times 0.5$ MeV/c <sup>2</sup>	$\times 0.5$ MeV/c <sup>2</sup>	0	0	0	0	0	0
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon					
	-1/3	-1/3	-1/3	0	0	0	0	0	0
	1/2	1/2	1/2	1	1	1	1	0	0
<b>LEPTONS</b>	$0.511$ MeV/c <sup>2</sup>	$106.7$ MeV/c <sup>2</sup>	$1.777$ GeV/c <sup>2</sup>	$91.2$ GeV/c <sup>2</sup>					
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson					
	-1	-1	-1	0					
	1/2	1/2	1/2	1	1	1	1	0	0
	$< 2.2$ eV/c <sup>2</sup>	$< 1.7$ MeV/c <sup>2</sup>	$< 18.5$ MeV/c <sup>2</sup>	$80.4$ GeV/c <sup>2</sup>					
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson					
	0	0	0	0					
	1/2	1/2	1/2	1	1	1	1	0	0
				<b>GRAVE BOSTONS</b>					

img source: Wikipedia



We still lack a theory of quantum gravity.

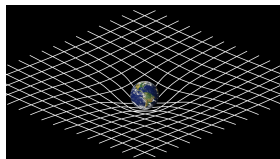
# Our Universe, so far

Our current understanding of the Universe is based on two main pillars:

- the **Standard Model of Particle Physics**;
- **General Relativity**.

mass $\rightarrow$ $12.3 \text{ MeV}/c^2$	$1725 \text{ GeV}/c^2$	$173.07 \text{ GeV}/c^2$	0	$125 \text{ GeV}/c^2$
charge $\rightarrow$ $2/3$	$2/3$	$2/3$	0	0
spin $\rightarrow$ $1/2$	$1/2$	$1/2$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon
<b>QUARKS</b>				
mass $\rightarrow$ $0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
charge $\rightarrow$ $-1$	$-1$	$-1$	0	
spin $\rightarrow$ $1/2$	$1/2$	$1/2$	$1$	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson
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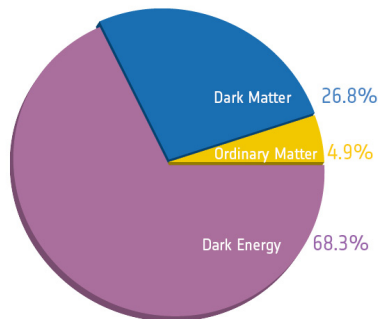


We still lack a theory of **quantum gravity**.

# Why quantum gravity?

A theory of **quantum gravity** would be expected to:

- resolve the inconsistencies associated with **black hole thermodynamics**;
- provide new insights into open issues as neutrino masses, matter-antimatter asymmetry, inflation, dark matter and **dark energy**.



Dark energy can be modelled by a **cosmological constant**  $\Lambda \sim 10^{-52} m^{-2}$ .

In absence of direct experimental evidences of quantum gravity, one has to test the internal consistency of the theory.



### Einstein's Special Principle of Relativity

- The laws of physics take the same form in all inertial frames of reference.
- The speed of light in empty space is the same for all inertial observers.

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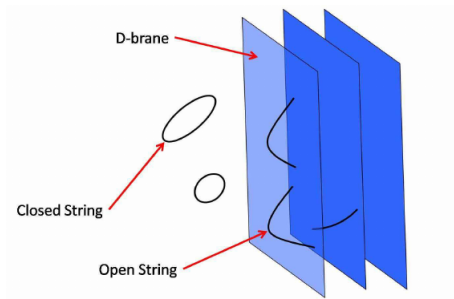
### Einstein's Special Principle of Relativity

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- The speed of light in empty space is the same for all inertial observers.

The fundamental objects are **strings** propagating in the ambient spacetime.

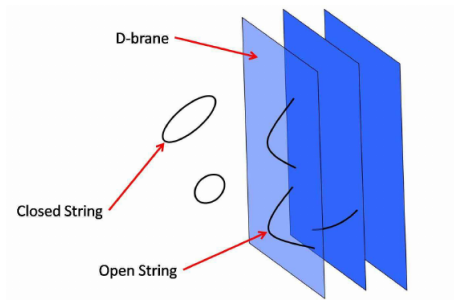
String theory is a unified model for all interactions:

- **closed** strings  $\rightarrow$  gravitons;
- **open** strings  $\rightarrow$  gauge bosons.



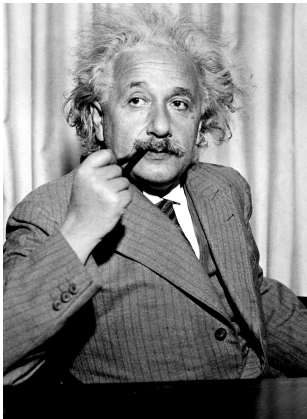
String theory naturally incorporates:

- **supersymmetry** : bosons  $\longleftrightarrow$  fermions;
- **extra dimensions**: strings propagate in  $D=10$ .



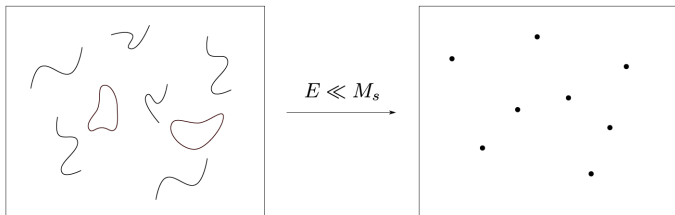
“Your calculations are correct, but your physics is abominable.”

(Einstein, 1927)



Extended nature of strings is not perceivable at **low energies**:

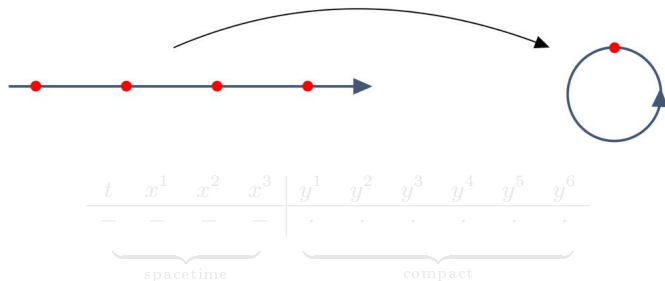
$$E \ll M_s \ll M_P \sim 10^{19} \text{ GeV} \quad \longleftrightarrow \quad \ell \gg \ell_s \gg \ell_P \sim 10^{-35} \text{ m}$$



**Supergravity** theories are still 10-dimensional.

# Dimensional reduction

The usual 1+3 dimensions are recovered if the extra dimensions are **compact**, with a small radius.

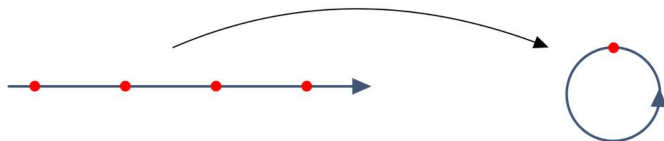


Scale separation has to hold:

$$l_{\text{compact}} \ll l_{\text{spacetime}}$$

# Dimensional reduction

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$$\begin{array}{c|cccccc} t & x^1 & x^2 & x^3 & y^1 & y^2 & y^3 & y^4 & y^5 & y^6 \\ \hline - & - & - & - & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \hline \underbrace{\hspace{4em}} & \underbrace{\hspace{10em}} \\ \text{spacetime} & \text{compact} \end{array}$$

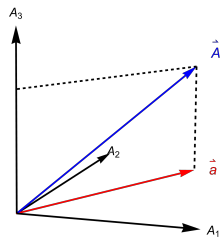
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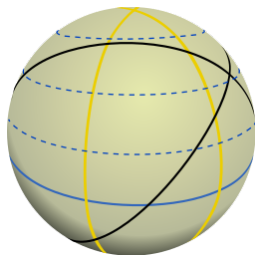
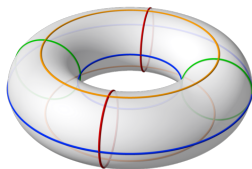
# The byproducts of dimensional reduction

Dimensional reduction gives rise to:

- **scalars**: e. g.  $\vec{A} = (A_1, A_2, A_3) \rightarrow \vec{a} = (A_1, A_2), A_3$ .



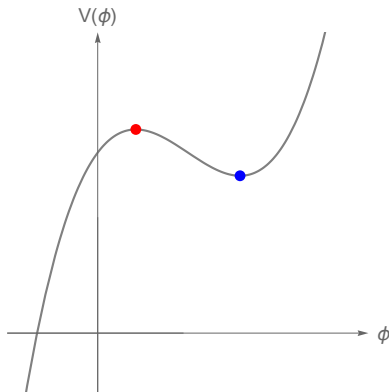
- **fluxes**: e. g.  $\oint_C F$  with  $C$  closed loop.



## The scalar potential and its vacua

Fluxes are crucial in order to induce a scalar **potential**:

- scalars acquire a **mass**;
- **vacua** give rise to lower-dimensional theories of gravity with a cosmological constant.

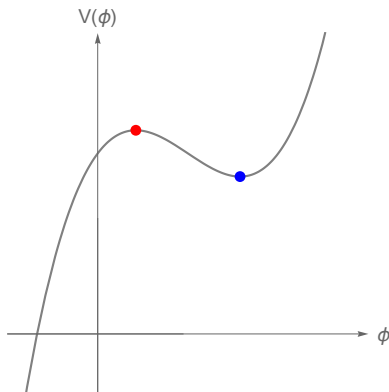


# Phenomenological properties of string theory vacua

Phenomenologically relevant features for the vacua are:

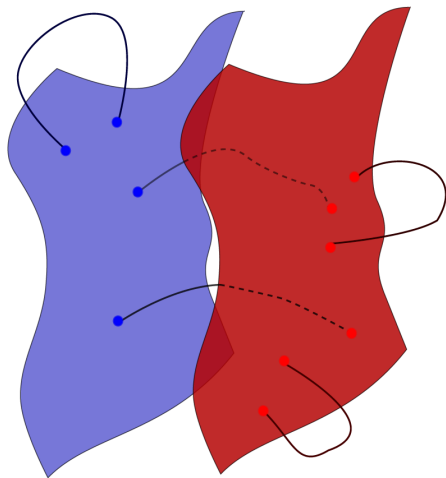
- the vacuum energy  $\Lambda$ ;
- the residual symmetry;
- stabilization of scalars;
- scale separation

$$l_{\text{compact}} \gg l_{\text{spacetime}}.$$



Research focuses on  $\text{AdS}_3$  scale-separated vacua:

- **open string** excitations have been found not to destabilize them, besides inducing new vacua;
- their **brane picture** is being analyzed.

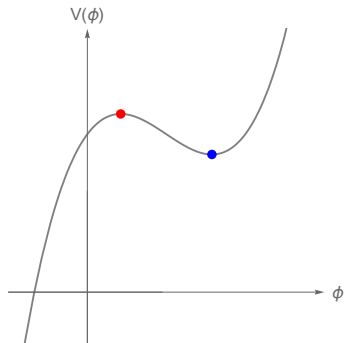


## Conclusions

String theory could be in a good position to tackle open problems in theoretical physics, such as the nature of **dark energy**.

“Your calculations are correct and your physics is NOT abominable.”

(ICTEA members, 2026)

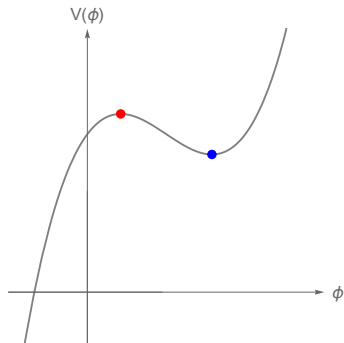


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Thank you for your attention!

