Phenomenological properties of string theory vacua

Giuseppe Sudano

University of Oviedo & ICTEA, Oviedo

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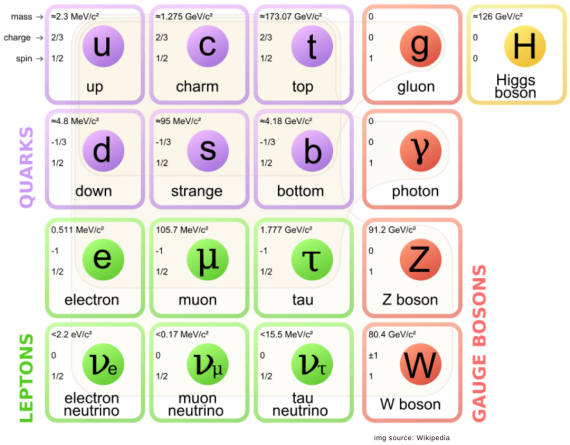
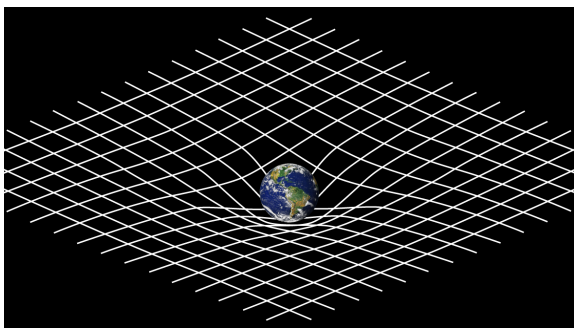
Universidad de Oviedo

Our Universe, so far

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

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





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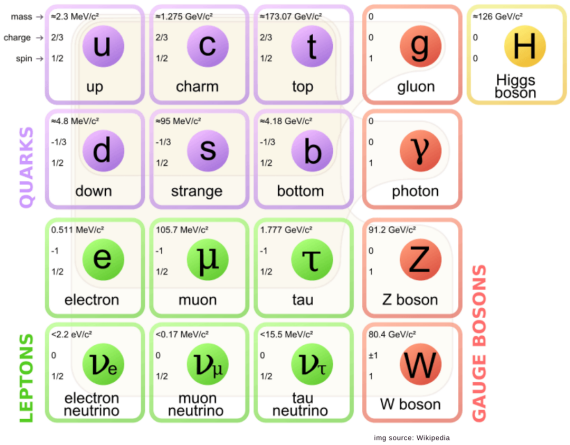
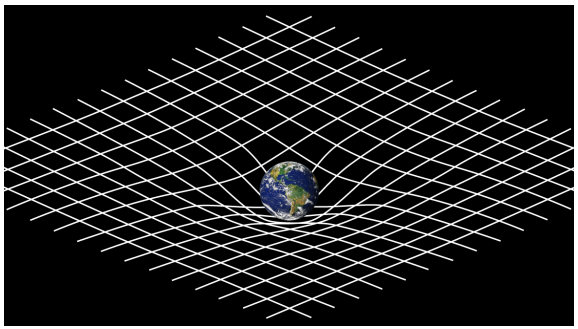


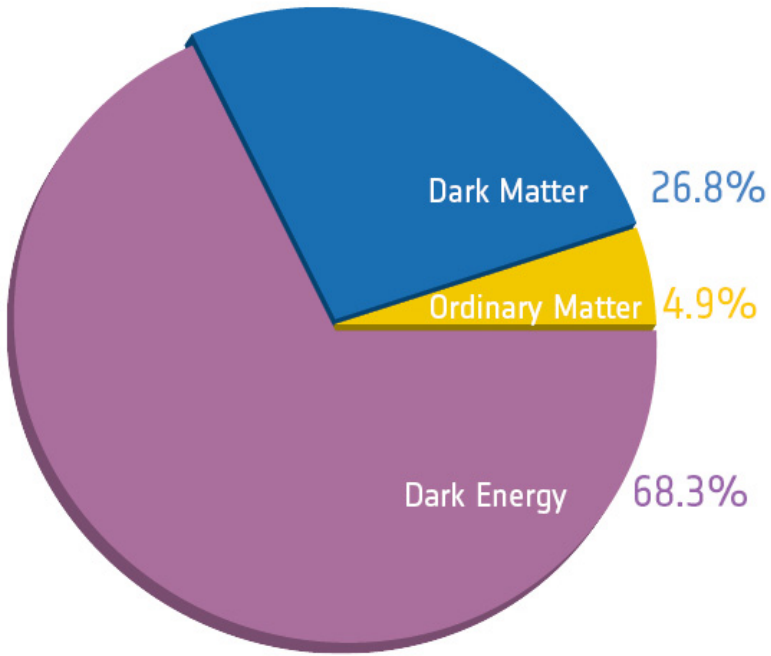


We still lack a theory of quantum gravity.

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 $\Lambda \sim 10^{-52}\, m^{-2}$.

Looking for paradoxes

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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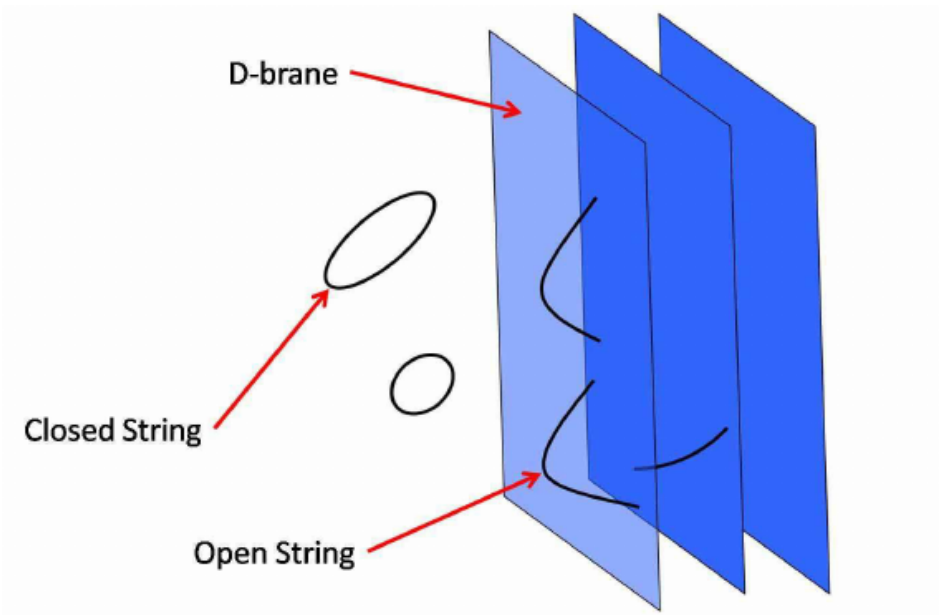
String theory

The fundamental objects are strings propagating in the ambient spacetime.

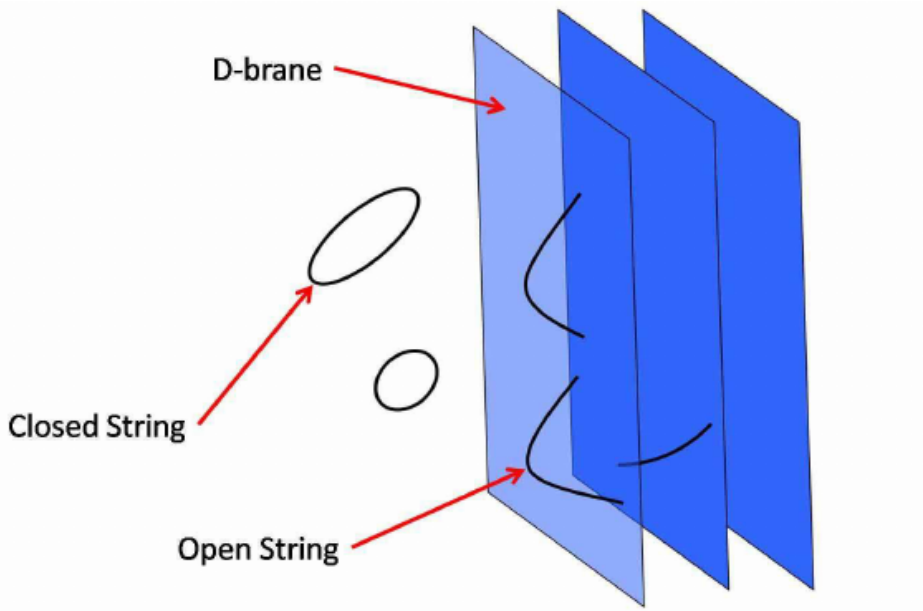
String theory is a unified model for all interactions:

- closed strings $\longrightarrow$ gravitons;
- open strings $\longrightarrow$ gauge bosons.



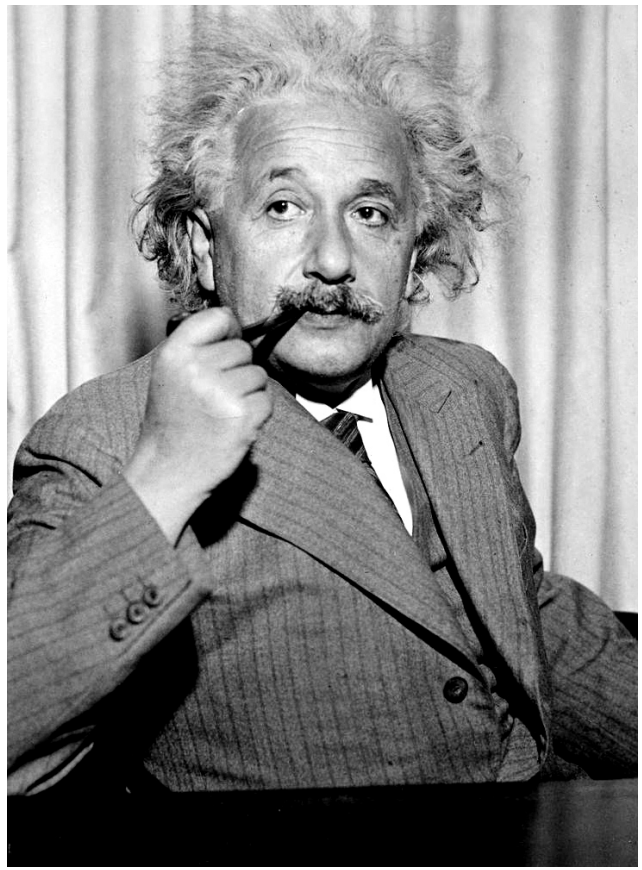
String theory naturally incorporates:

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



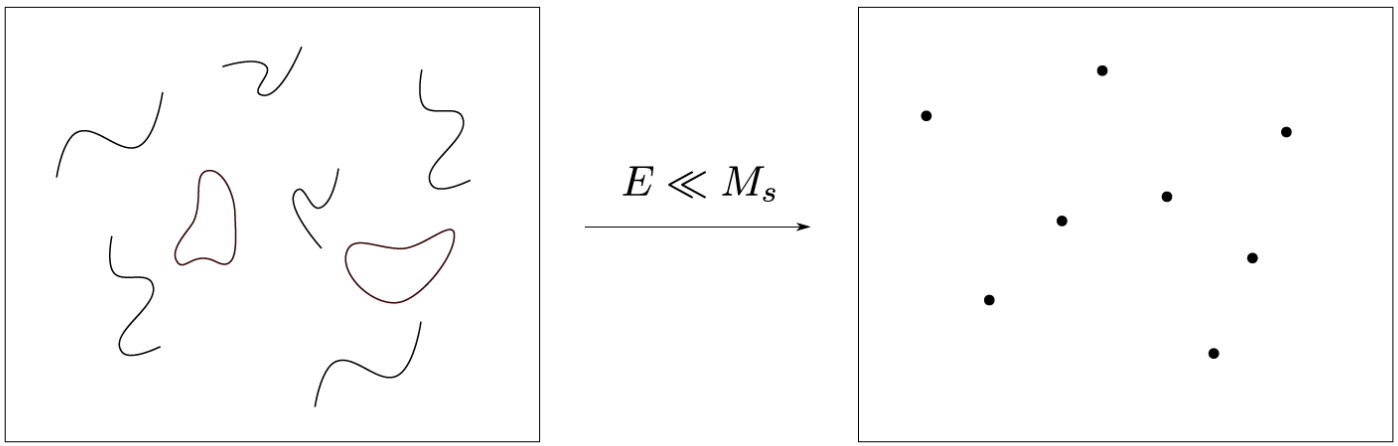
"Your calculations are correct, but your physics is abominable."

(Einstein, 1927)



Extended nature of strings is not perceivable at low energies:

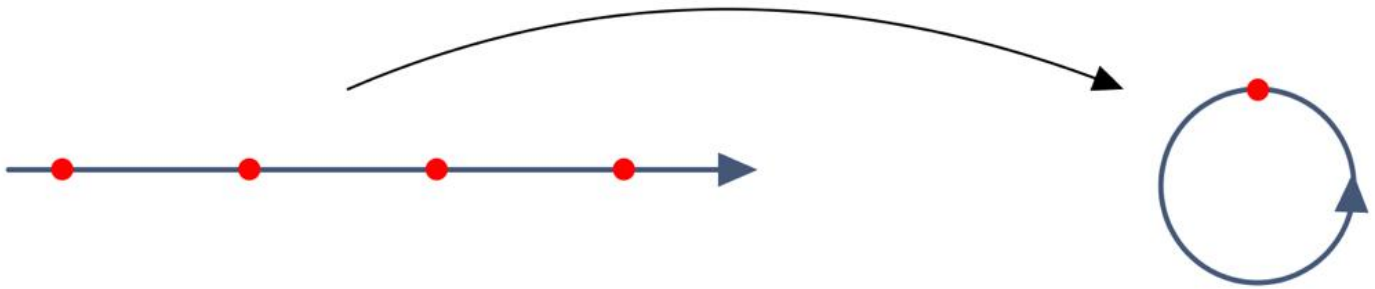
$$E \ll M_s \ll M_P \sim 10^{19}\ GeV \qquad \longleftrightarrow \qquad \ell \gg \ell_s \gg \ell_P \sim 10^{-35}\ m$$



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.



t	x^1	x^2	x^3	y^1	y^2	y^3	y^4	y^5	y^6
–	–	–	–	·	·	·	·	·	·

spacetime compact

Scale separation has to hold:

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

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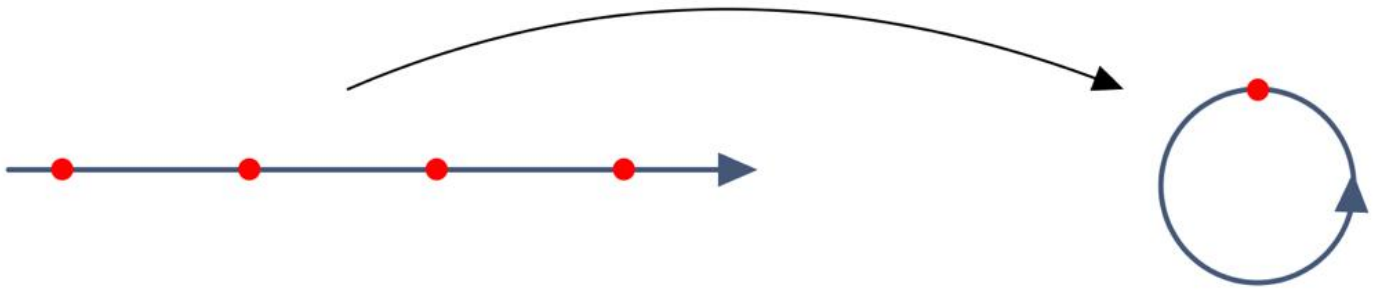

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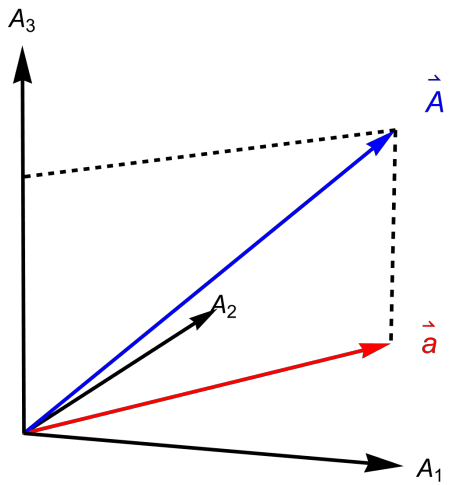
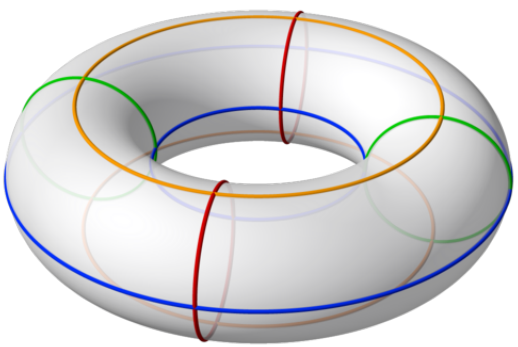
The byproducts of dimensional reduction

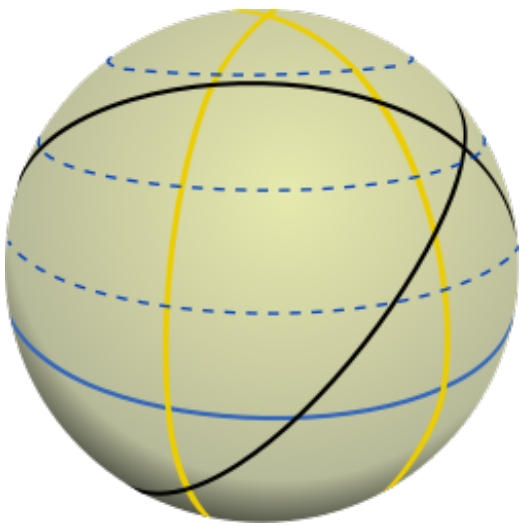
Dimensional reduction gives rise to:

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



- fluxes: e. g. $\oint_{\mathcal{C}} F$ with $\mathcal{C}$ closed loop.

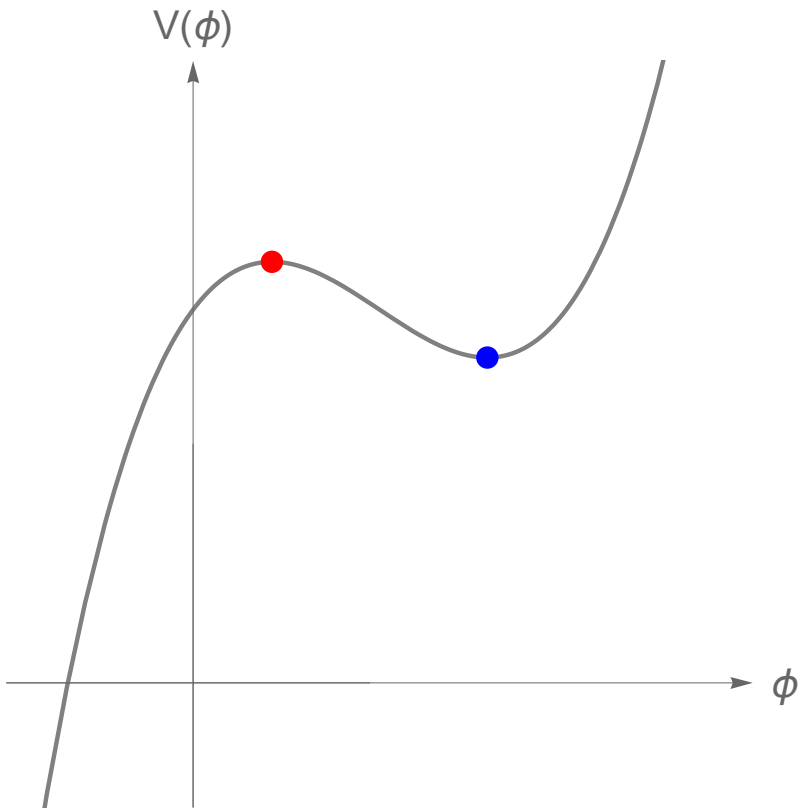




The scalar potential and its vacua

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.

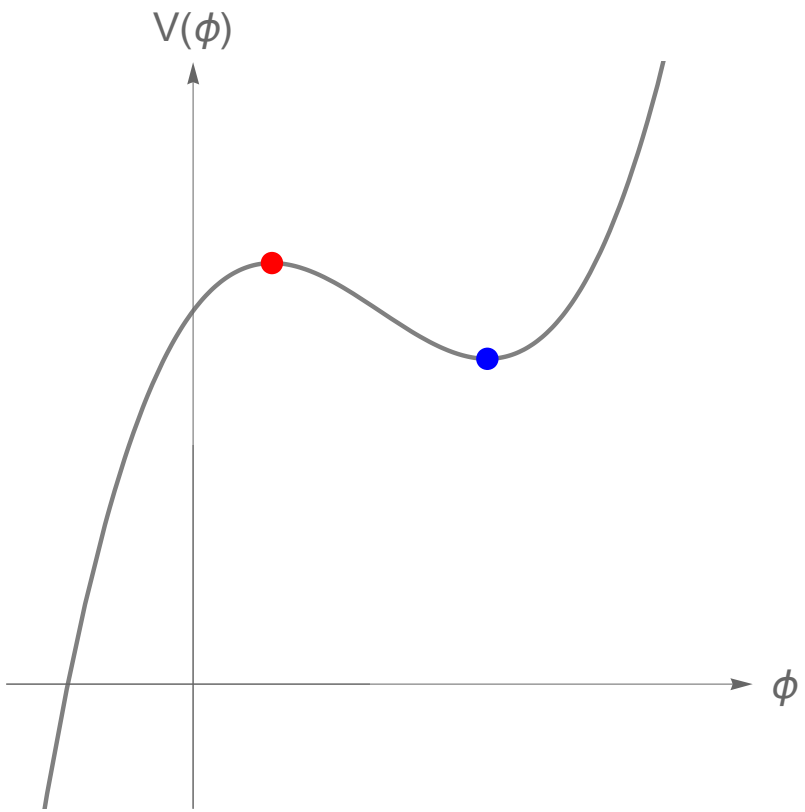


Phenomenological properties of string theory vacua

Phenomenologically relevant features for the vacua are:

- the vacuum energy Λ;
- the residual symmetry;
- stabilization of scalars;
- scale separation

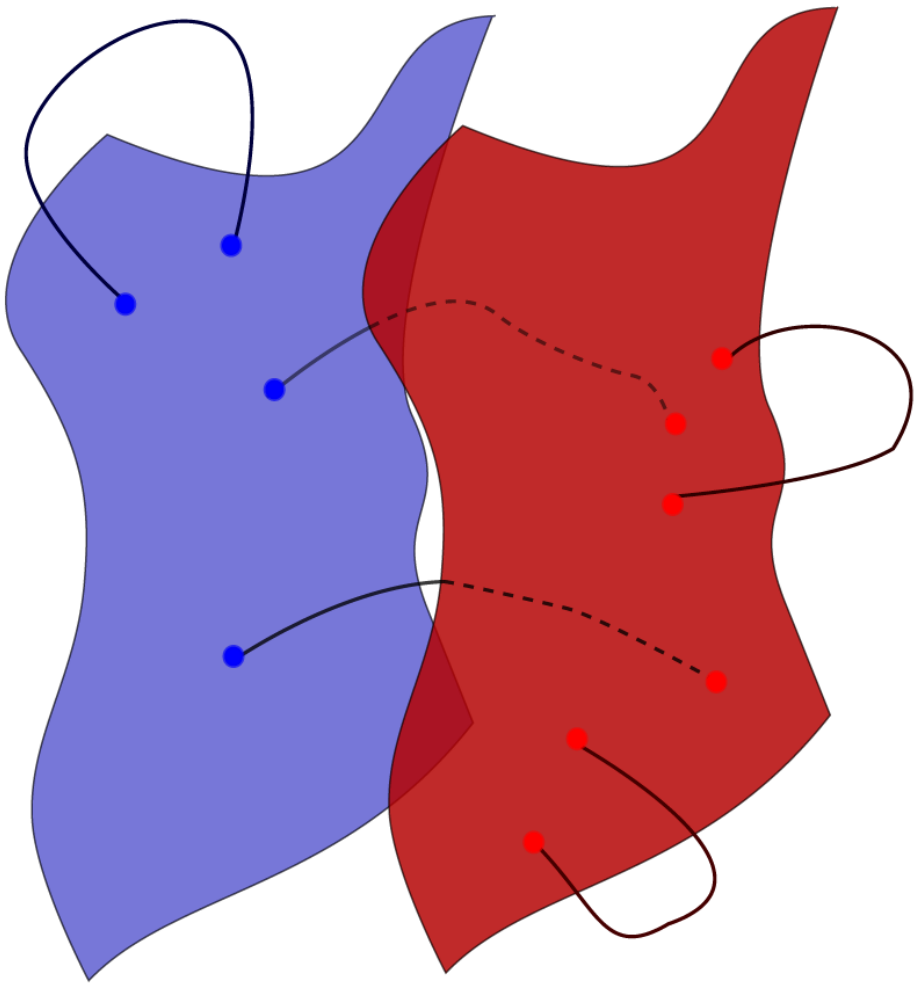
$$\ell_{\text{compact}} \gg \ell_{\text{spacetime}}.$$



Research lines

Research focuses on 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.

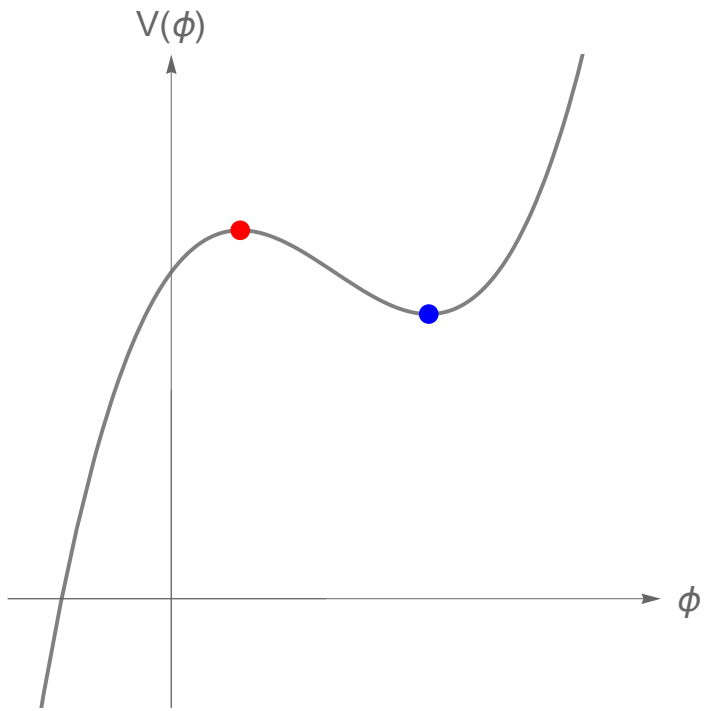


Conclusions

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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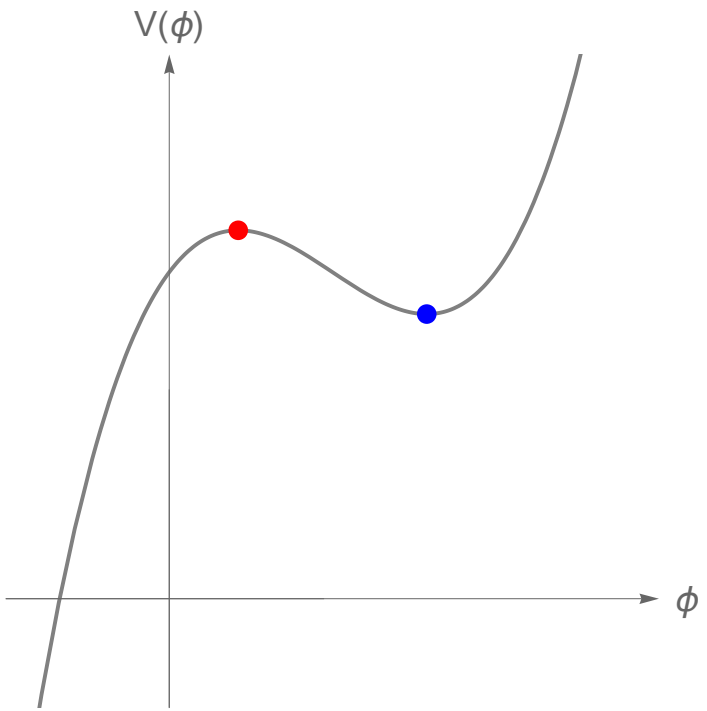

Thank you for your attention!