Hamburg, December 9, 2025

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Current position: Postdoc in the CRC 1624 and the Quantum Universe cluster

PHD: Theoretical Physics

IFT - Madrid

Graduation: 2025

Supervisor: Angel M. Uranga

Thesis: *“Aspects of symmetries throughout the String Theory Moduli Space”*

MASTER: Theoretical Physics

Università di Padova

Graduation: 2020

Supervisor: Roberto Volpato

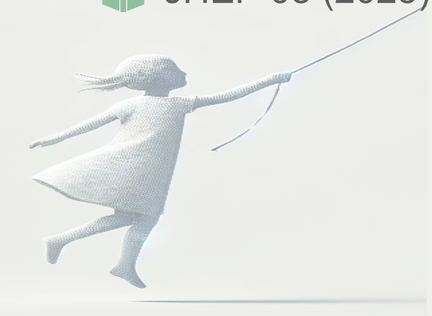
Thesis: *“Non-abelian orbifolds in String Theory”*

Research work

Direction 1

Swampland program

- JHEP 06 (2022) 142 [hep-th: 2203.11240]
- JHEP 08 (2022) 285 [hep-th: 2207.13108]
- JHEP 06 (2023) 070 [hep-th: 2303.15903]
- JHEP 03 (2023) 110 [hep-th: 2312.16286]
- JHEP 09 (2024) 178 [hep-th: 2404.14486]
- JHEP 03 (2025) 064 [hep-th: 2410.07322]
- JHEP 08 (2025) 107 [hep-th: 2501.03310]



Direction 2

Worldsheet theories

- JHEP 07 (2024) 111 [hep-th: 2402.08719]
- JHEP 10 (2025) 046 [hep-th: 2504.18619]
- under review [hep-th: 2508.03612]

Direction 3

Scattering Amplitudes

- Accepted JHEP [hep-th: 2506.0325]

Motivation Directions 1 + 2

MAIN GUIDING PRINCIPLE

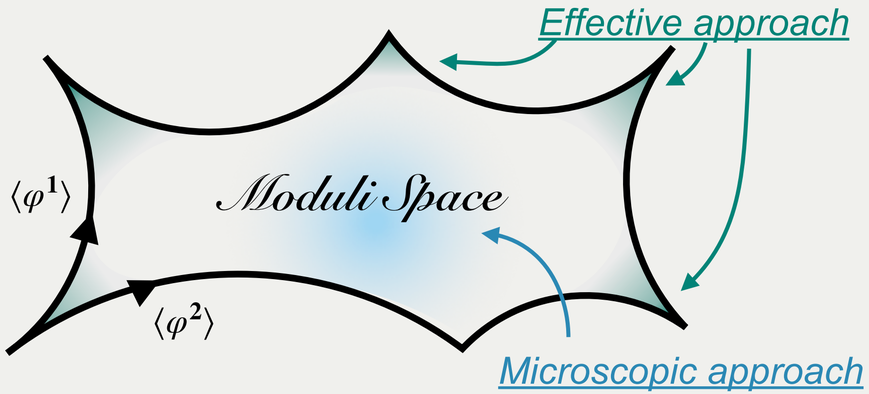
Symmetries as tools to extract information about the fundamental structure underlying a theory of **Quantum Gravity**.

Microscopic approach

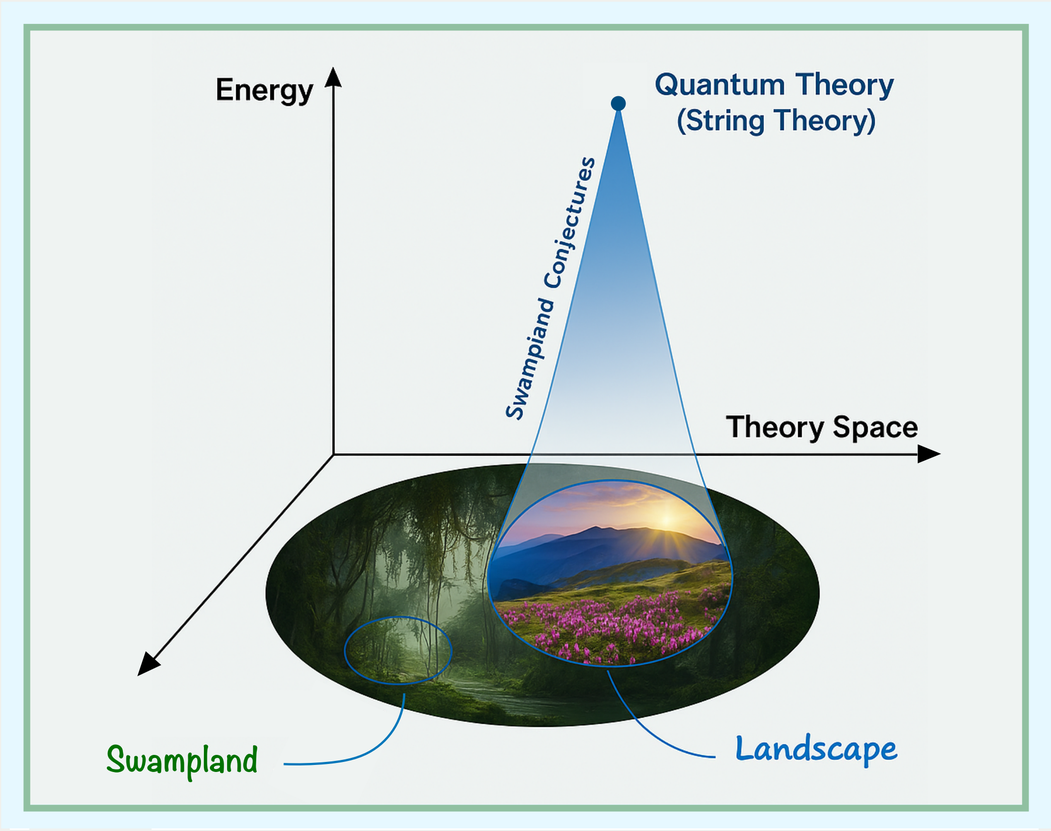
It explores the quantum structure of the matter and the spacetime by studying its fundamental ingredients (worldsheet quantization, string compactification, non-perturbative contributions…)

Effective approach

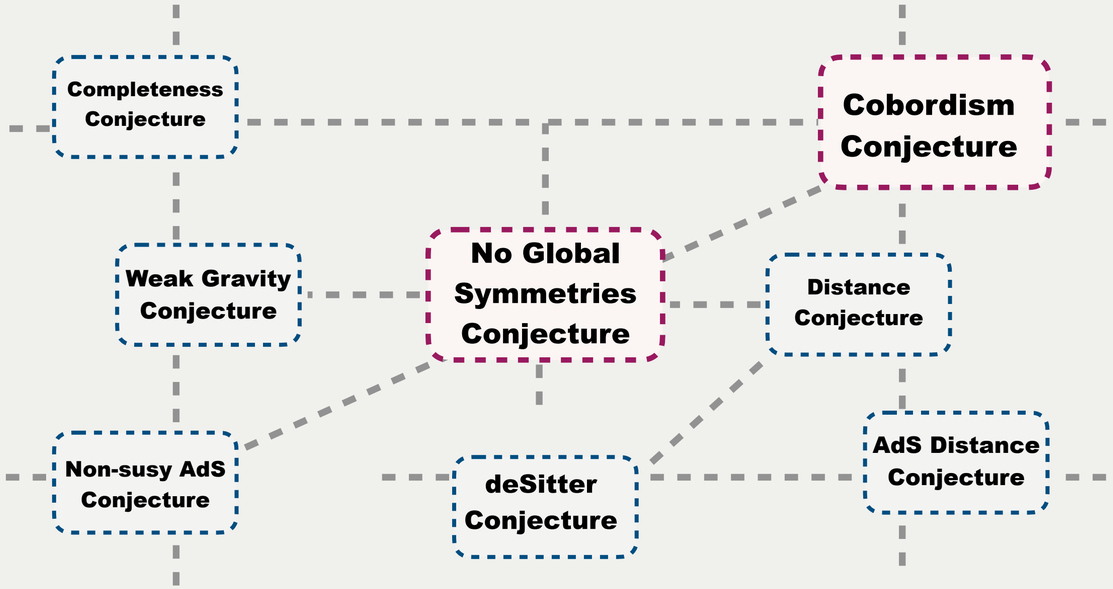
It works extracting information from the low energy theory in order to isolate underlying principles that would be the basis of its quantum gravity completion.



Direction 1: Swampland Program



The consistency conditions are formulated in terms of a plethora of interconnected criteria named **Swampland Conjectures**.



Method:

To consider all the possible consistent EFTs coupled to gravity and study the conditions they must satisfy in order to admit a consistent QG completion in the **UV.**

No Global Symmetries → **Cobordism conjecture**

Direction 1: Cobordism Conjecture

Definition [math]:

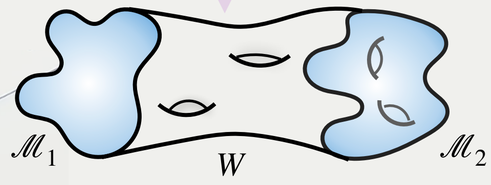
Two smooth, closed, unoriented manifolds $\mathscr{M}_1$ and $\mathscr{M}_2$ of real dimension k are cobordant, i.e. $\mathscr{M}_1 \sim \mathscr{M}_2$, if there exist a smooth manifold W of real dimension $k+1$ such that:

$$\mathscr{M}_1 \sqcup \mathscr{M}_2 = \partial W$$

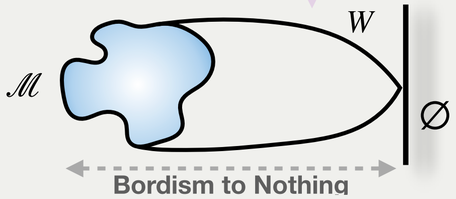
The equivalence classes of manifolds equipped with this union operation form a group:

$$\Omega_k = \{[M_i]\} \dashrightarrow \textbf{Cobordism Group}$$

Cobordism Conjecture: $= [\varnothing]$



compactification



compactification

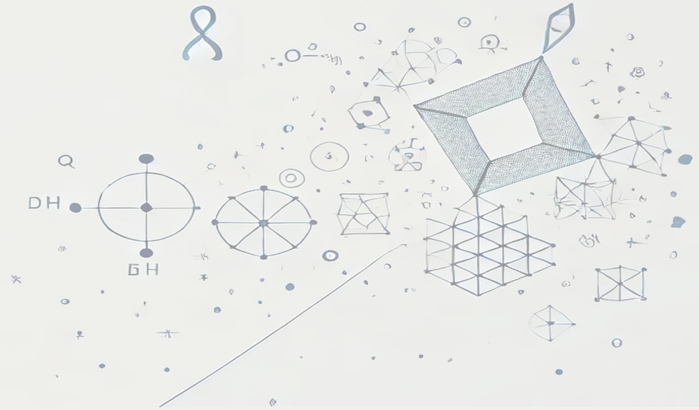
Domain Wall

EFT1 **EFT2**

Wall of Nothing

EFT **Nothing**

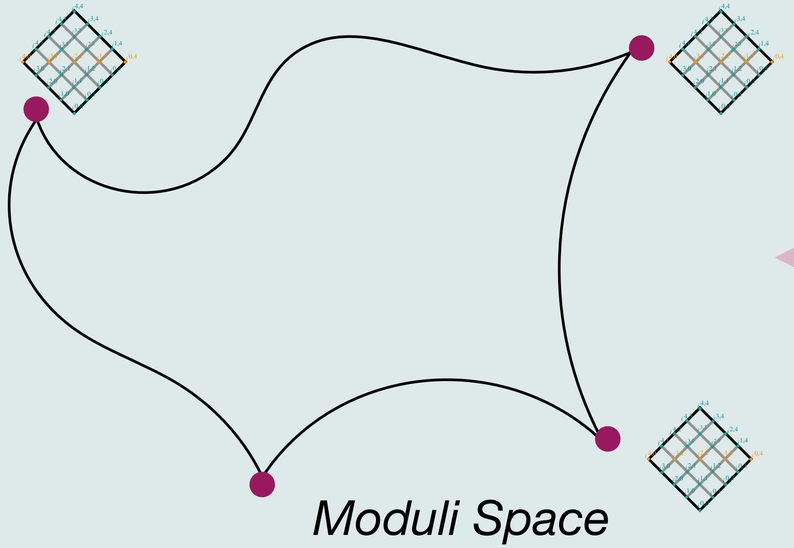
Direction 1: ETW configurations

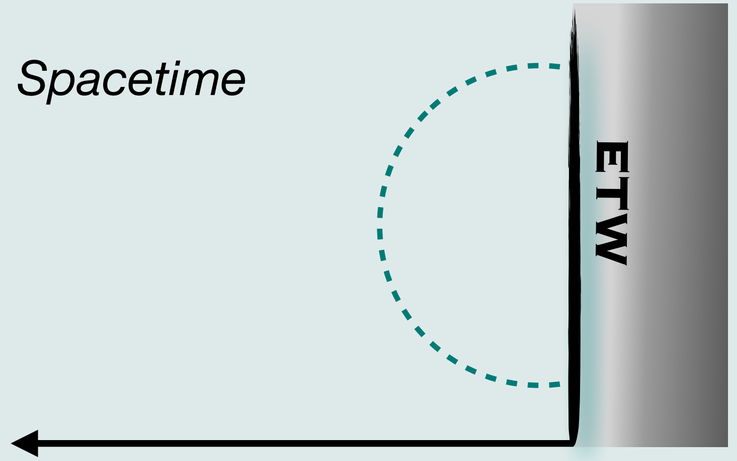


Configurations relating EFTs with the Nothing = **ETW configurations**

At the EFT level, they are realized as singular solutions of the EoMs in which the scalar fiels (aka **moduli** of the compactification background) run to infinity exploring the **boundaries** of the moduli space.

Example: CY_4 compactifications with flux





Direction 2: Generalized Symmetries

Standard Symmetries

| |

Topological operators (→ spacetime defects) supported on codimension 1 submanifolds of spacetime, satisfying **group-like** and **invertible** fusion rules and acting on **Local operators.**

GENERALIZATION

Higher symmetry groups

[Gaiotto Kapustin,Seiberg,Willet — 2014]

Symmetries acting on extended operators

Non-invertible symmetries

[Fuchs,Runkel,Schweigert, Bhardway,Tachikawa, Froehlich …]

Topological operators satisfying a non-invertible fusion algebra

In recent years, extensive work has been done to study the categories of topological defects in **many** physical domains: **worldsheet String Theory**, String Theory, QFT, condensed matter, lattice models …

State of the art in the classification of TDs in 2d CFTs:

→ Invertible defects associated with standard symmetries

→ Verlinde lines in RCFTs

[Verlinde - 1988]

→ Duality defects in self-orbifold constructions

[Tambara, Yamagami - 1988; Bhardwaj, Tachikawa - 2017]

Direction 2: K3 and $V^{f\natural}$

Study **topological defect lines (TDLs)** in 2-dimensional SCFTs arising as supersymmetric **non-linear σ-models** with target space a **K3** surface:

- Preserving the full $\mathcal{N} = (4,4)$ superconformal algebra with central charge $(c, \bar{c}) = (6,6)$
- Invariant under the spectral flow transformations

Study **topological defect lines (TDLs)** in the 2-dimensional **Conway SCFT $V^{f\natural}$** (the unique holomorphic SCFT in 2d with $c = 12$ and no field of conformal weight $1/2$):

- Commuting with the $\mathcal{N} = 1$ superconformal algebra and $(-1)^F$;
- Satisfying some additional technical constraints

$G_{K3} \subset Co_0$ **Symmetries** Co_o

RR ground states **Symmetry action** R sector ground states

$\phi^g(\mathscr{C}_\Pi, \tau, z) = Tr_{RR}\left[g(-1)^{F+\bar{F}} q^{L_0 - 1/4} \bar{q}^{\bar{L}_0 - 1/4} y^{J_0^3}\right]$ **Twining Genus** $\phi^g(V^{f\natural}, \tau, z) = Tr_{V^{f\natural}_{tw}}\left[g(-1)^F q^{L_0 - 1/2} y^{J_0^3}\right]$

[Duncan, Mack-Crane - 2015]

Direction 2: Results

- Partial classification of topological defects in K3 models preserving supersymmetry and spectral flow, obtained exploiting their action on the boundary states (RR charged branes). This classification allows to prove some generic results for the category of top. defects valid at generic points of the K3 moduli space.

- Partial classification of topological defects preserving supersymmetry in $V^{f\natural}$ obtained constructing a sort of Cardy-like conditions using the action of the defects on the Ramond ground states and considering fusions with the invertible symmetries.

- Formulation of a conjecture extending the symmetry connection among the two theories at the level of generalized symmetries. The connection is supported by many explicit examples!

Direction 3: Motivations

Analysis of complex **integrals** describing generic physical systems

$$I = \int_{\Gamma} F(x_1, x_2, \dots ; \mu_1, \mu_2, \dots) dx_1^2 \, dx_2^2 \dots$$

Direct computation

Resolution of systems of differential equations

Geometric interpretation in order to simplify the integral.

PERIOD = $H_n(X) \otimes H^n(X)$

HOMOLOGY **COHOMOLOGY**

À la Kontsevich-Zagier

- Multivalued integral with a potentially complicate monodromy
- Special values of the parameters at which the manifold X becomes singular
- …

Main Task

To indentify the **right** homology/cohomology to define the pairing

Direction 3: Exponential Period Map

[Kontsevich, Soibelman - 2024]

- X → n-dim complex algebraic variety
- $f : X \mapsto \mathbb{C}$ → Complex valued function
- μ → Holomorphic volume form over X
- Γ → Open integration chain on $X \backslash D_0$

  s.t. $Re(f)|_\Gamma : Supp(\Gamma) \mapsto \mathbb{R}$ is a proper map bounded from below

$$\int_\Gamma e^{-f}\,\mu \;:\; H_\bullet^{Betti,\,global}\left((X, D_0), f\right) \otimes H^\bullet_{dR,\,global}\left((X, D_0), f\right) \longmapsto \mathbb{C}$$

Feynman integrals

Path integral in QFTs

CFT correlators

Non-perturbative computations in String Theory

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Thank you for your attention!

Future directions:

- Implementation of the Cobordism Conjecture in the **CFT language**:
  - Define a notion of cobordism in terms of internal CFT properties;
  - Study interfaces interpolating among different CFTs.
- Study and implementation of the topological surgery transformations into the EFT language using **Dynamical Cobordisms**.
- Investigate the fate of non-invertible symmetries emerging in special loci of K3 moduli space in the dual **Heterotic theory** on T^4.
- Implementation of the analysis for **higher CY**:
  - Exploit the action on the RR charges lattices in CFTs with a target CY_3
- Study of spacetime realization of top. defects in terms of top. **objects** potentially broken at higher loops in the topological expansion.
- …