Semi-stable Degenerations and the Distance Conjecture in F-theory

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work together with Seung-Joo Lee and Timo Weigand

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DESY Theory Workshop 2023

Universität Hamburg
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CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

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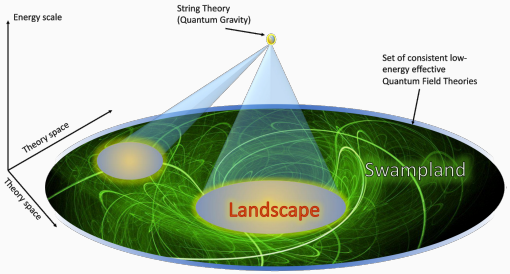

Figure taken from [Palti '19].

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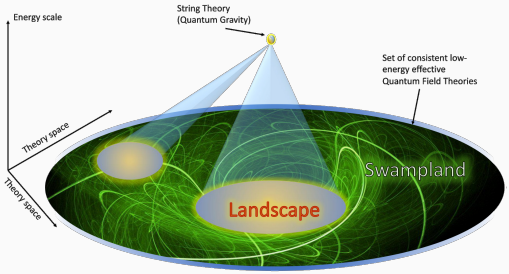

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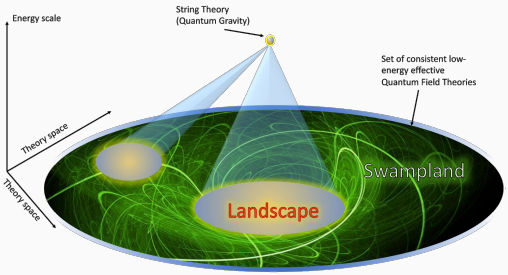

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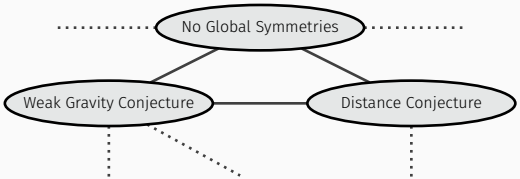

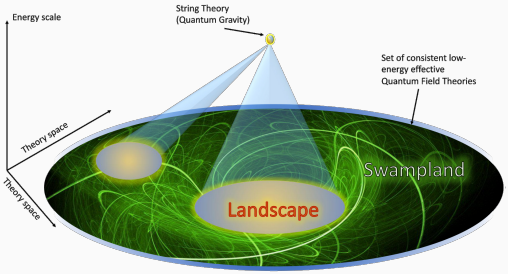

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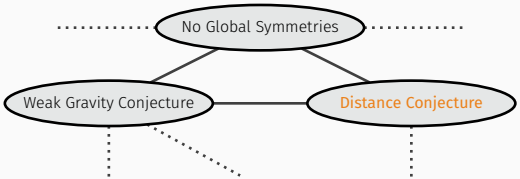

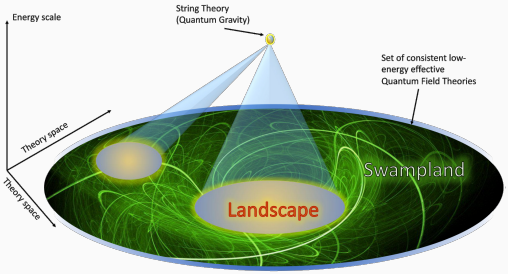

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Swampland Distance Conjecture

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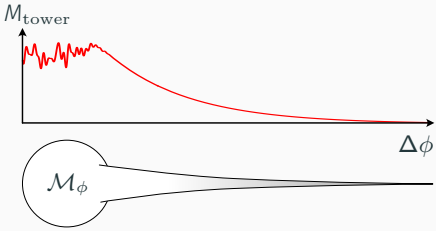

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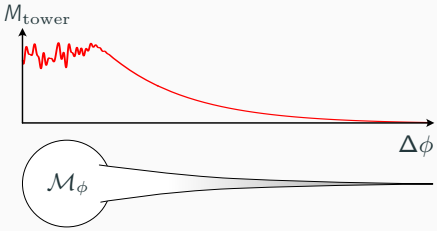

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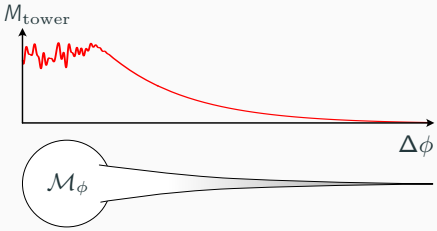

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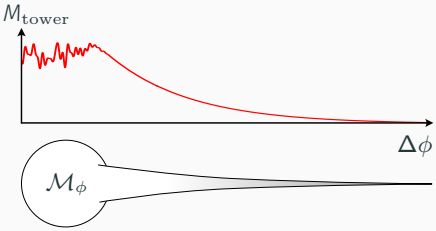

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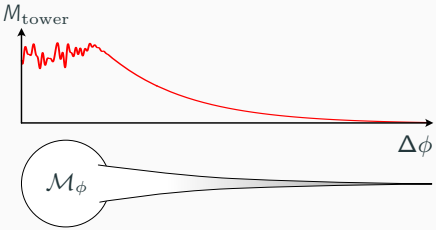

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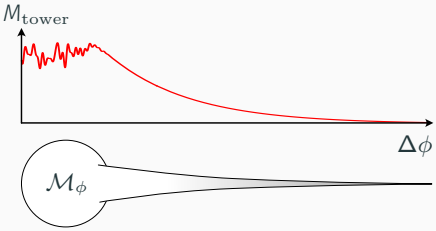

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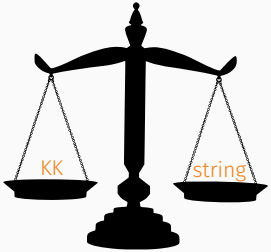

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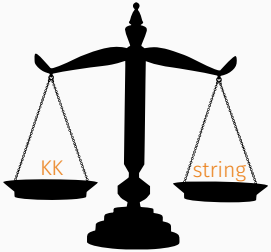

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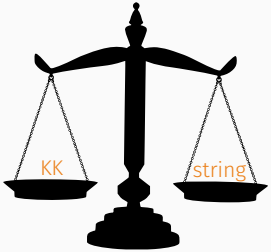

Membrane Limits in Quantum Gravity

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- Consistency under dimensional reduction of the Emergent String Conjecture demands that for critical membranes

$$\mu = \frac{T^{(\mathrm{D})}_{\mathrm{brane}}}{\left(M^{(\mathrm{D})}_{\mathrm{KK}}\right)^3} \to \infty \,.$$

- In the saturated case

$$\left(\frac{M^{(\mathrm{D})}_{\mathrm{KK}}}{M^{(\mathrm{D})}_{\mathrm{Pl}}}\right)^3 \sim \frac{1}{\mu^3} \,, \qquad \frac{T^{(\mathrm{D})}_{\mathrm{brane}}}{\left(M^{(\mathrm{D})}_{\mathrm{Pl}}\right)^3} \sim \frac{1}{\mu^2} \,.$$

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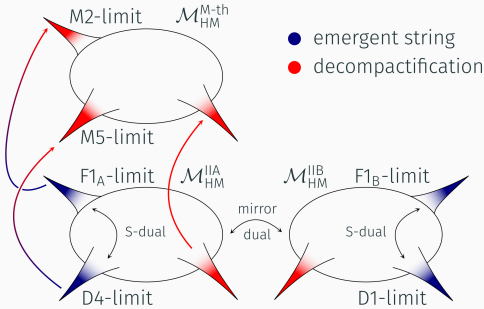
Check in 5D M-theory translating the results of [Baume, Marchesano, Wiesner '19]:



See also [Robles-Llana, Saueressig, Theis, Vandoren '07], etc.

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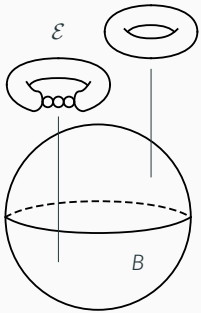

Elliptic fibration:

$$\begin{array}{ccc} \mathcal{E} & \longrightarrow & Y \\ & & \downarrow{\scriptstyle \pi_{\mathrm{ell}}} \\ & & B \end{array} .$$

- Elliptic fiber: τ profile.
- Base B: physical space-time.

$$y^2 = x^3 + fxz^4 + gz^6 ,$$

$$f \in H^0\left(B, \overline{K}_B^{\otimes 4}\right), \quad g \in H^0\left(B, \overline{K}_B^{\otimes 6}\right).$$

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- Classification by Kodaria-Néron for Weierstrass models:

$$y^2 = x^3 + fxz^4 + gz^6\,, \quad \Delta = 4f^3 + 27g^2\,.$$

Algebra	Kodaira	$\mathrm{ord}(f)$	$\mathrm{ord}(g)$	$\mathrm{ord}(\Delta)$
A_1	III	1	≥ 2	3
A_2	IV	≥ 2	2	4
A_n	I_{n+1}	0	0	$n+1$
D_n	I^*_{n-4}	2	3	$n+2$
E_6	IV^*	≥ 3	4	8
E_7	III^*	3	≥ 5	9
E_8	II^*	≥ 4	5	10
—	non-minimal	≥ 4	≥ 6	≥ 12

Part of the Kodaira-Tate table for singular fibers of Weierstrass models.

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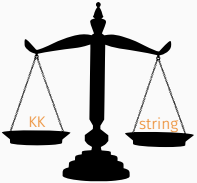

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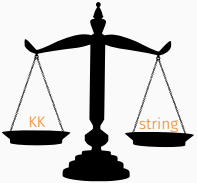

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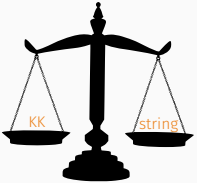

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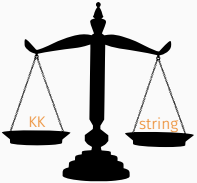

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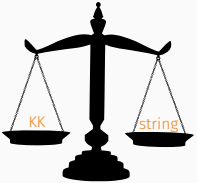

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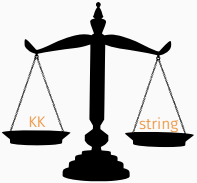

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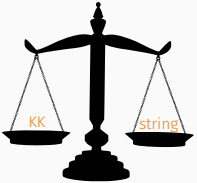

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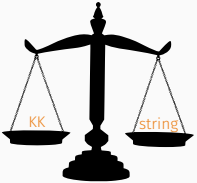

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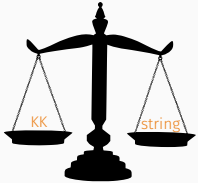

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Goal of this work

Understand the geometry and physics of the infinite-distance non-minimal singularities of CY_3.

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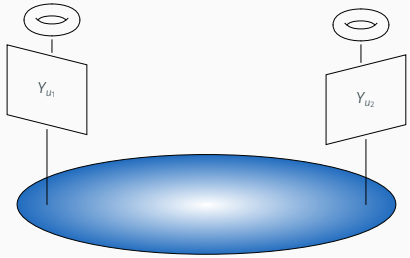
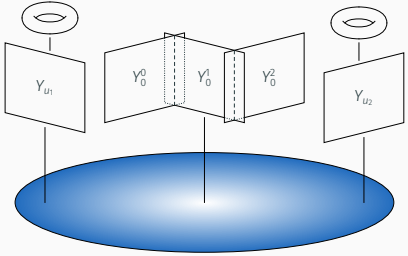


Condensed summary

Some core features discussed in [RAG, Lee, Weigand (to appear)][2]:

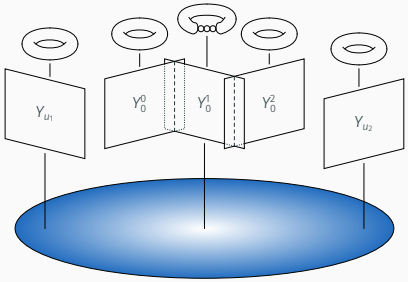
- Spacetime degenerates into components.



Condensed summary

Some core features discussed in [RAG, Lee, Weigand (to appear)][2]:

- Spacetime degenerates into components at local weak and strong coupling.



Condensed summary

Some core features discussed in [RAG, Lee, Weigand (to appear)][2]:

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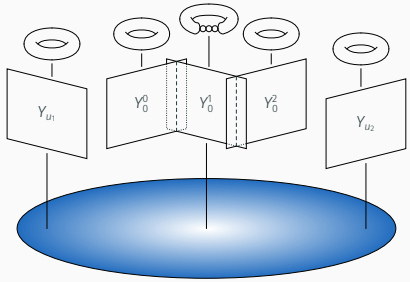
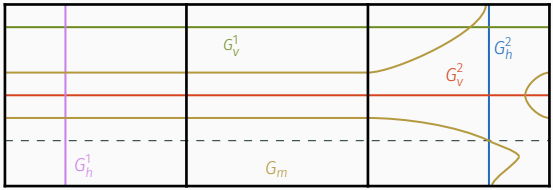
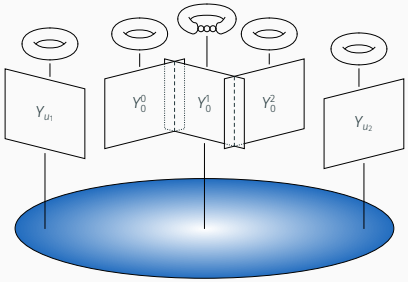


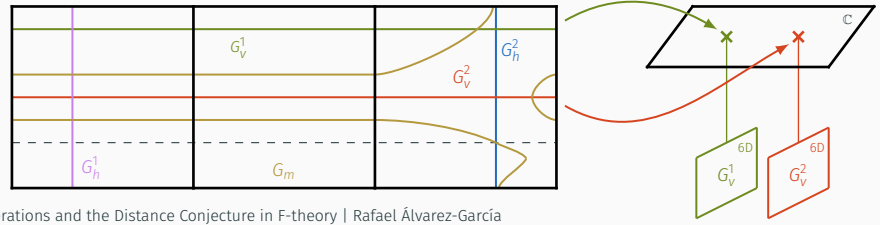


Condensed summary

Some core features discussed in [RAG, Lee, Weigand (to appear)][2]:

- Spacetime degenerates into components at local weak and strong coupling.
- 7-branes can extend between components, leading to local enhancements.
- Decompactification limits can be complicated, leading to defect theories.

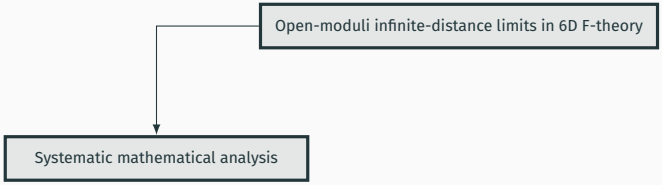




Structure of the study

Open-moduli infinite-distance limits in 6D F-theory

Structure of the study



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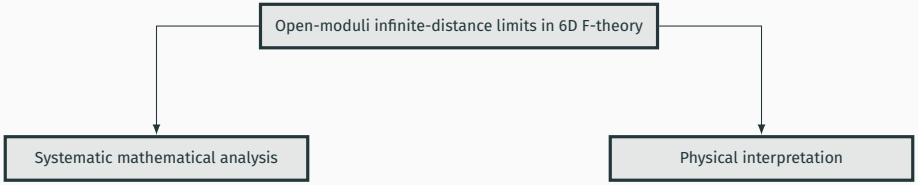

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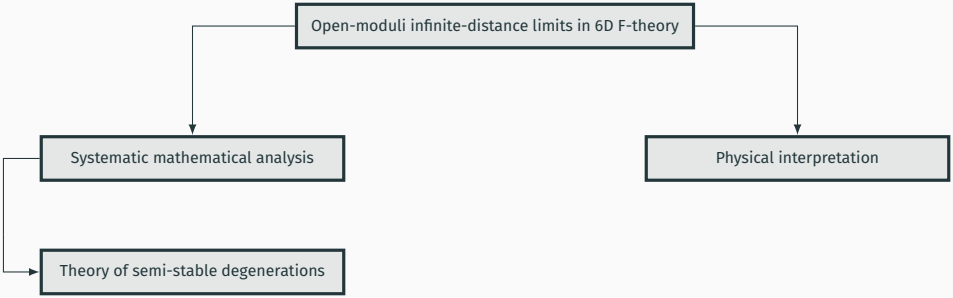

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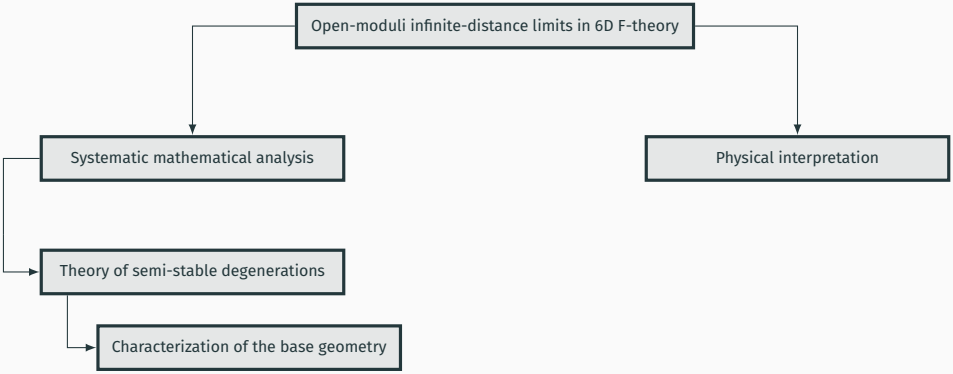

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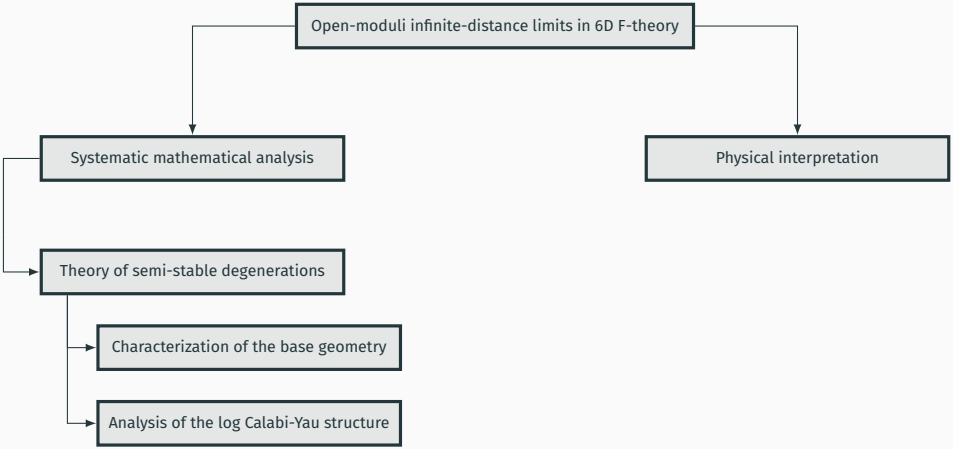

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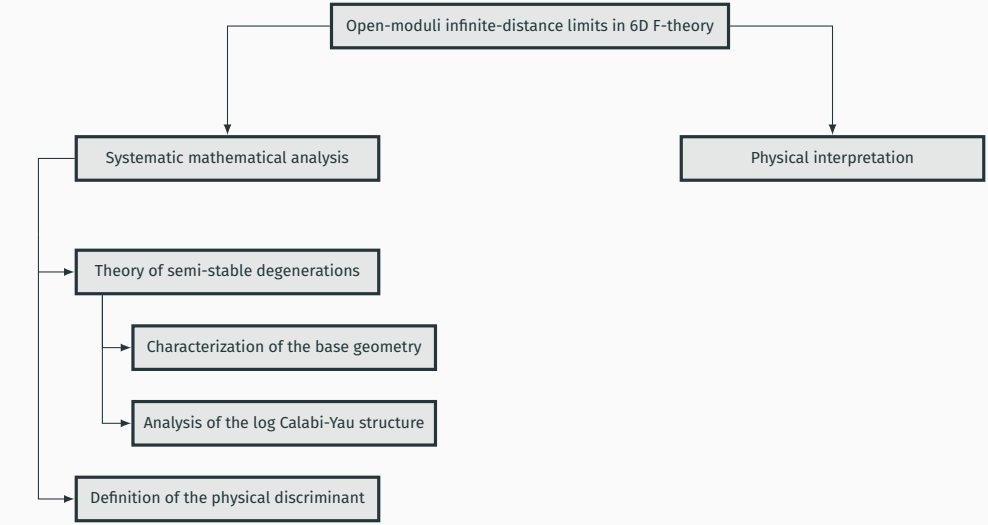

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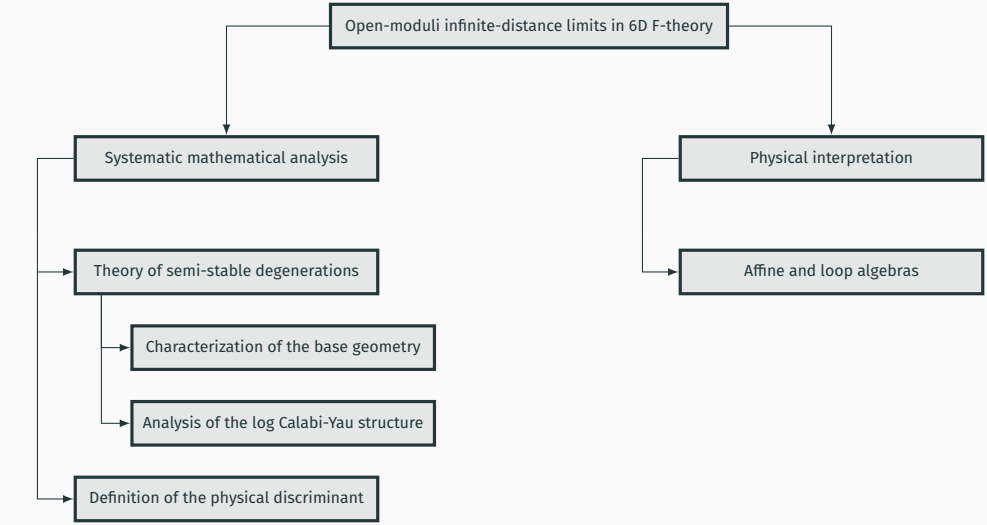

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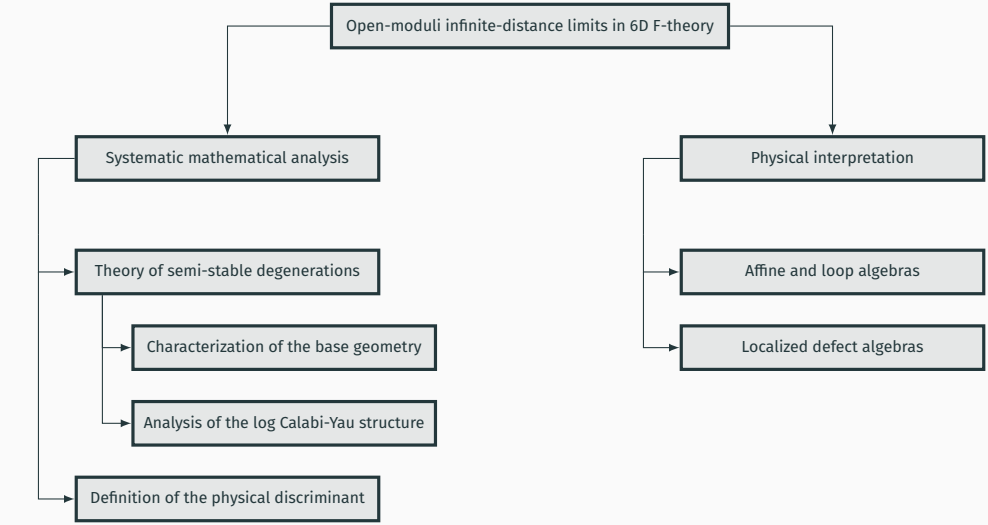

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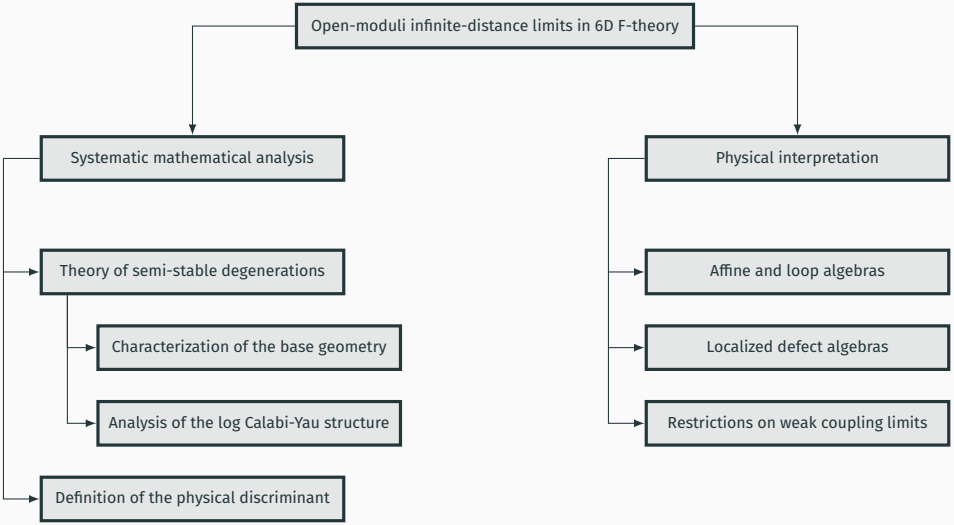

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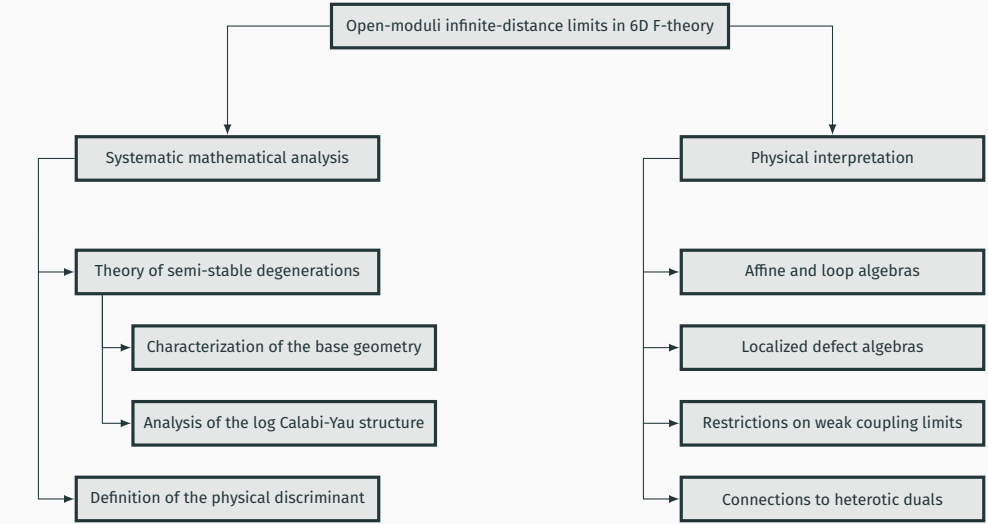
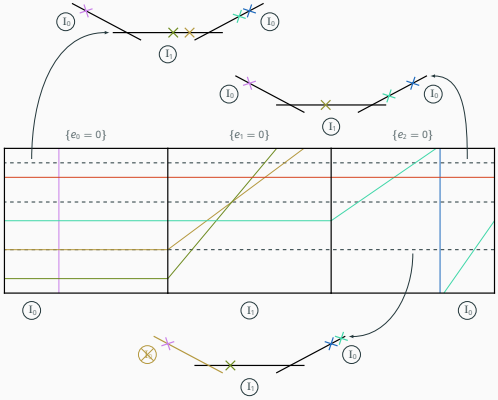


Summary

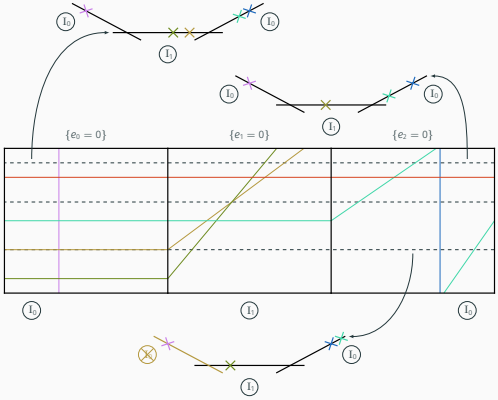

I_0
I_0
I_1
I_0
I_0
I_1
$\{e_0 = 0\}$
$\{e_1 = 0\}$
$\{e_2 = 0\}$
I_0
I_1
I_0
I_0
I_1

Summary

- Non-minimal singularities in F-theory

  ↕

  Open-moduli infinite-distance limits



Summary

- Non-minimal singularities in F-theory

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- Studied through a systematic geometrical analysis, e.g.
  - possible degeneration types,
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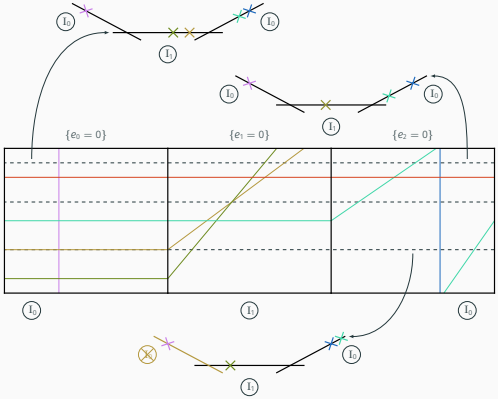
  - existence of global weak coupling limits.



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  Open-moduli infinite-distance limits

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  - possible degeneration types,
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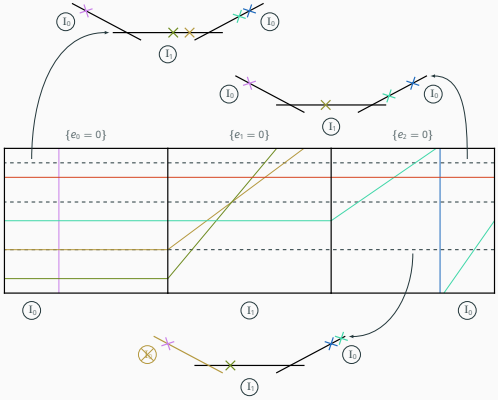
  - existence of global weak coupling limits.

- Limits interpreted as
  - partial decompactification with defects,
  - emergent string limits (weak coupling).



Thank you!