Tensionless Strings Limits in 4d Conformal Manifolds

José Calderón Infante

CERN

Based on ongoing work with Irene Valenzuela

Swamplandia 2024, Seeon Abbey, 29/05/2024

The Swampland Distance Conjecture

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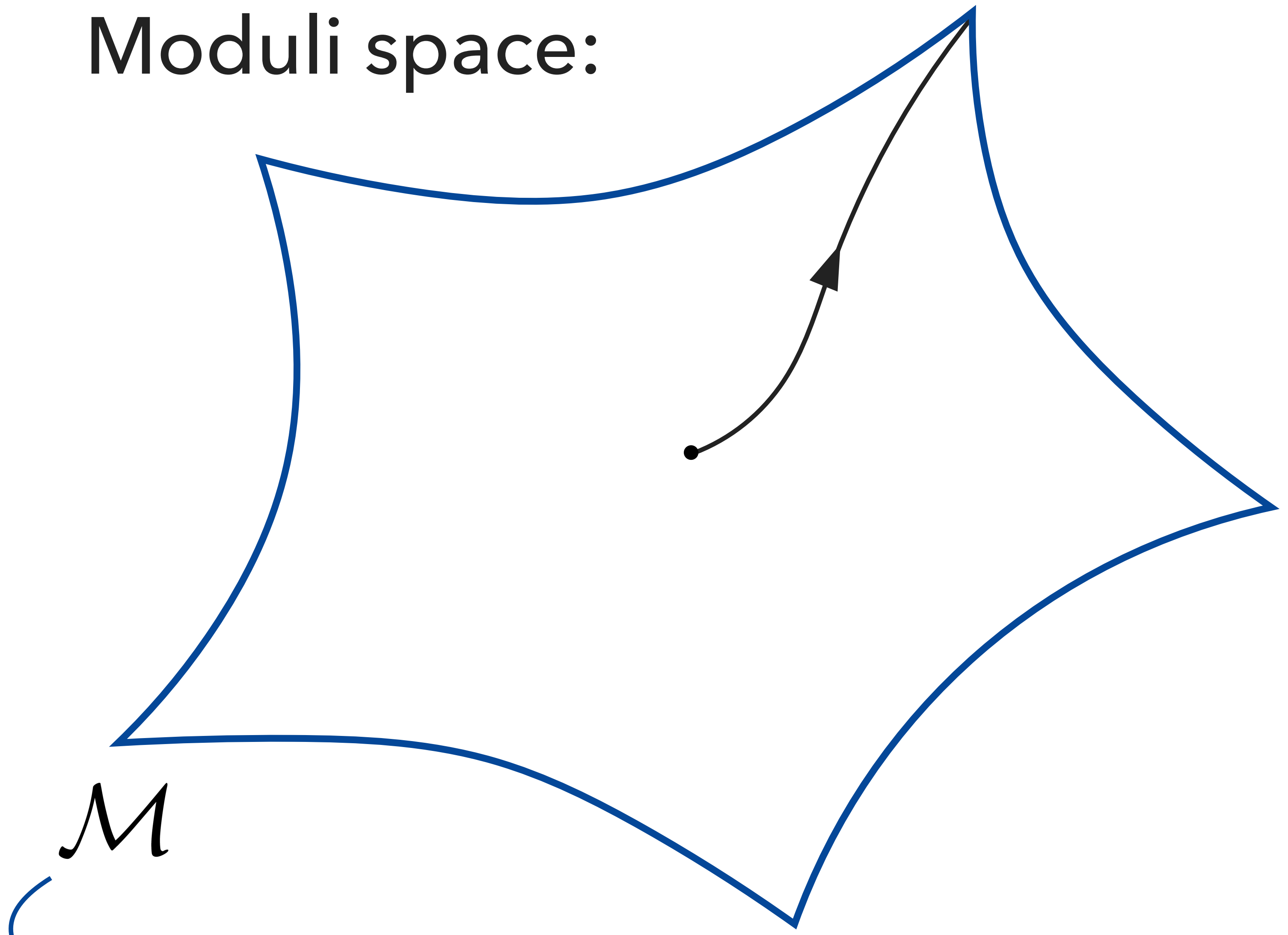
Moduli space:



Parametrized by massless scalars

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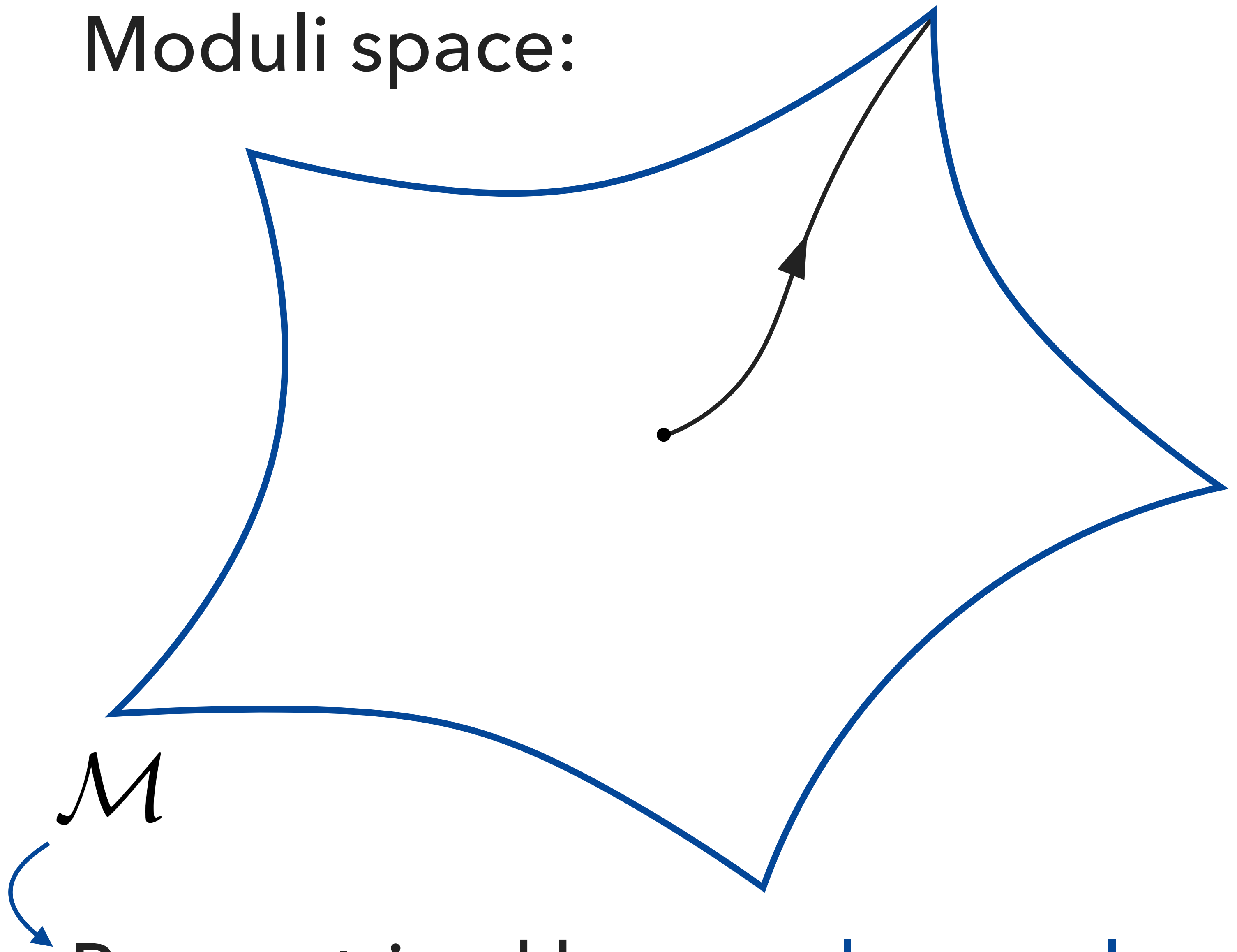

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Swampland Distance Conjecture (SDC) [Ooguri, Vafa '06]

There is an infinite tower of states becoming light at infinite-distance points in moduli space:

$$M_{tower} \sim e^{-\alpha\,\Delta\phi} \quad \text{as} \quad \Delta\phi \to \infty \qquad (M_{Pl} = 1)$$

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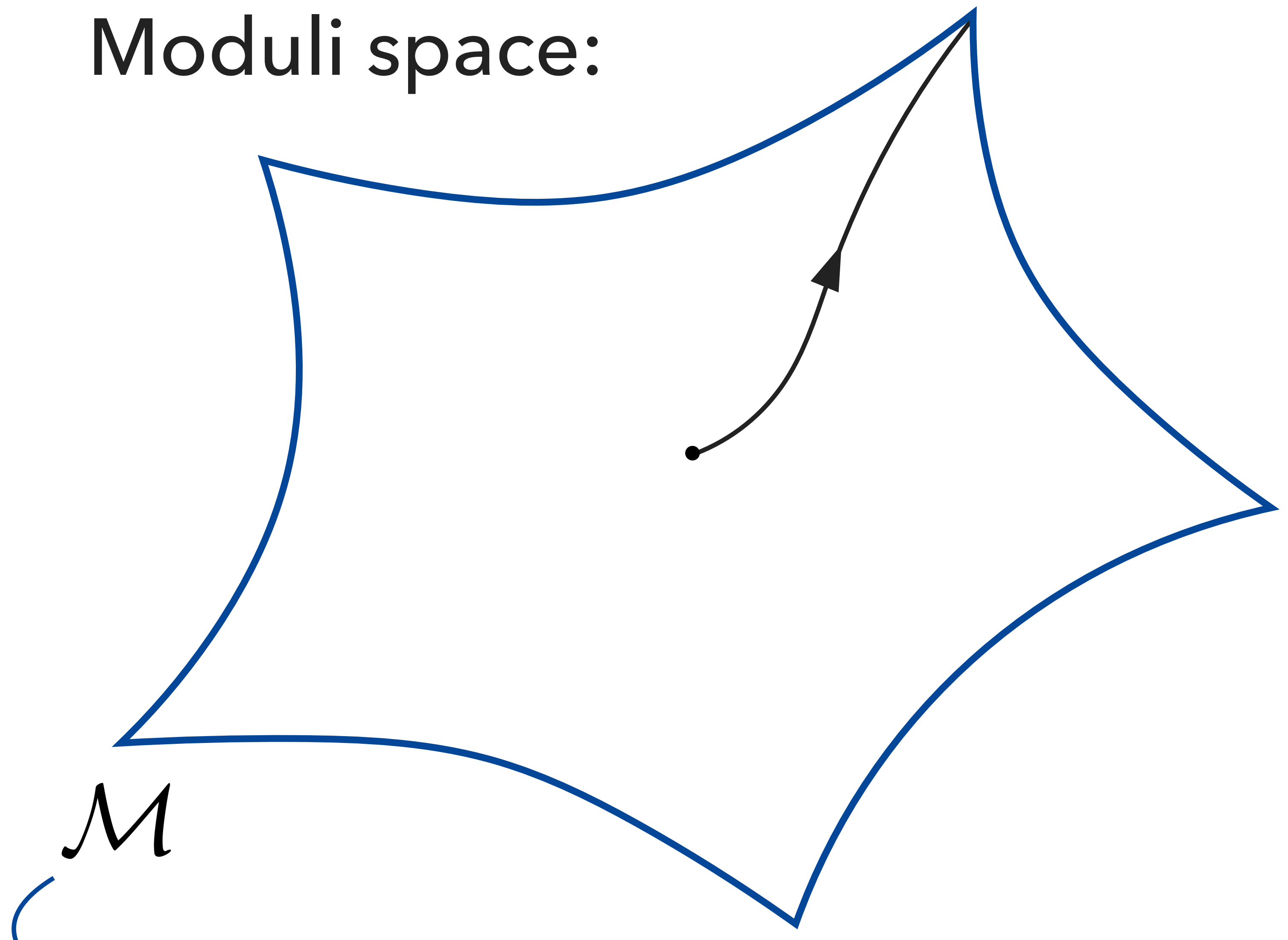

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Precise order one bounds on the exponential rates

- Lightest tower: [Etheredge, Heidenreich, Kaya, Qiu, Rudelius '22]
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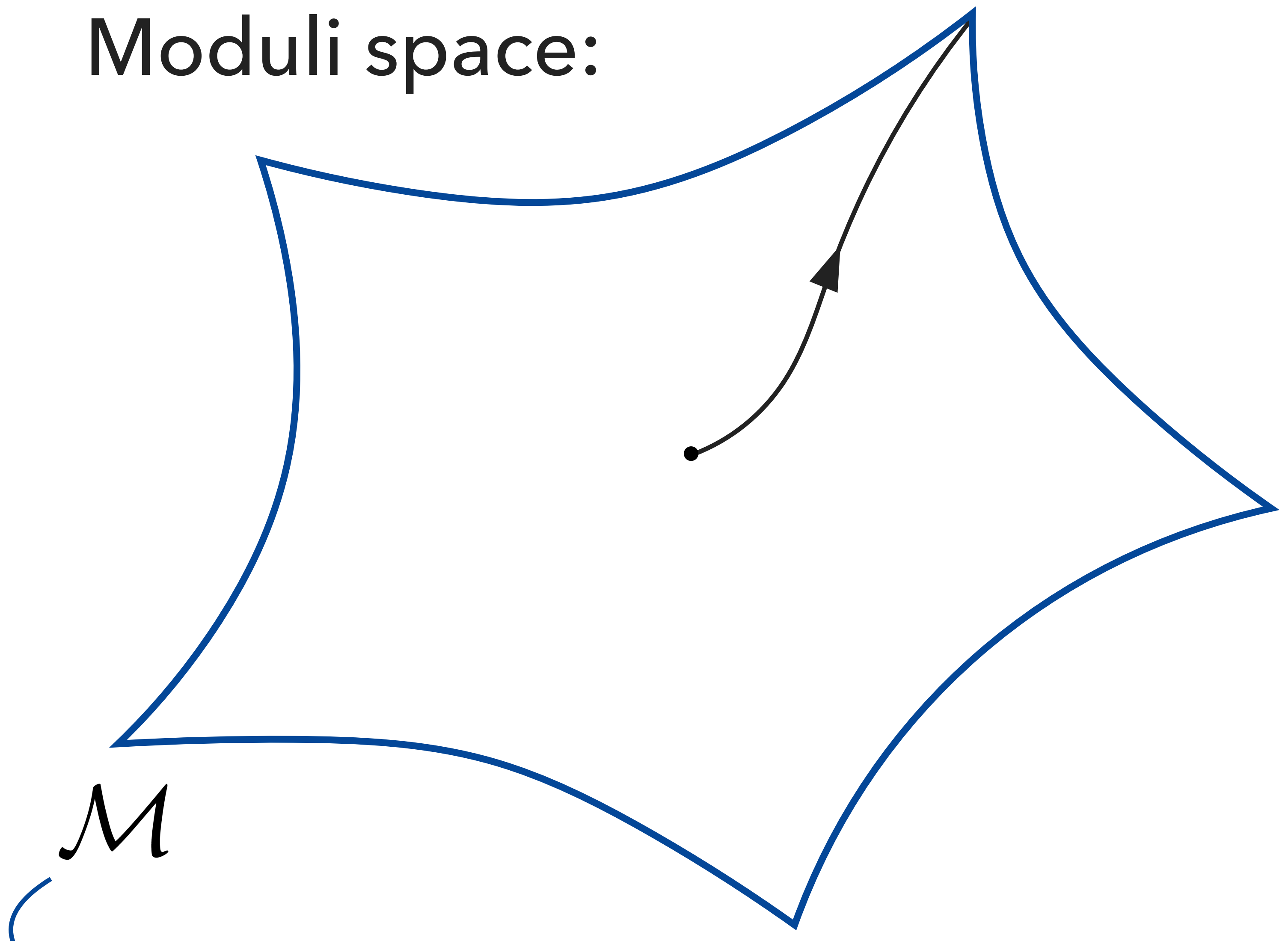

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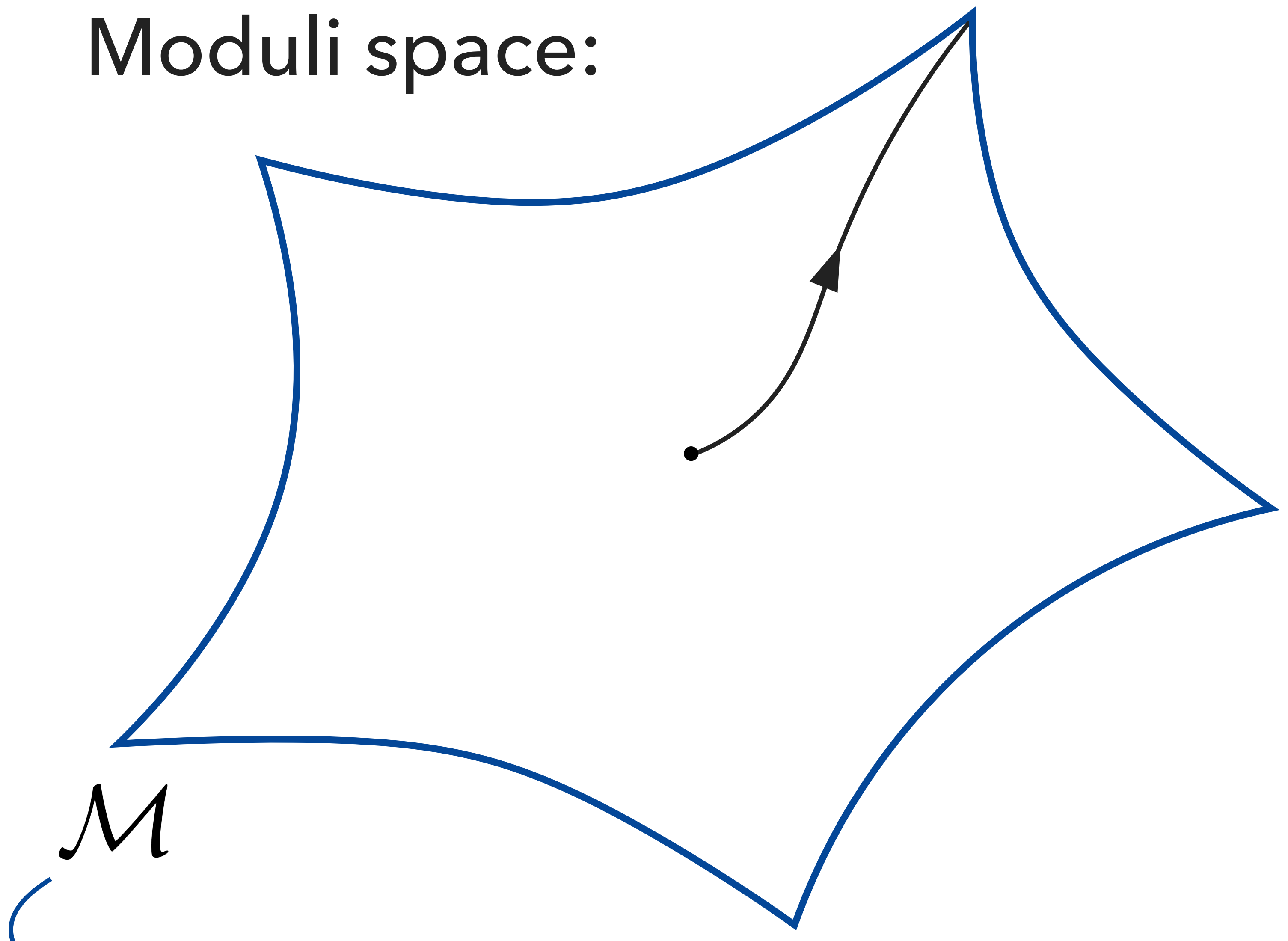

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Lots of top-down evidence!

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  [Grimm, Palti, Valenzuela '18] [Lee, Lerche, Weigand '18-'19]
  + many many more!
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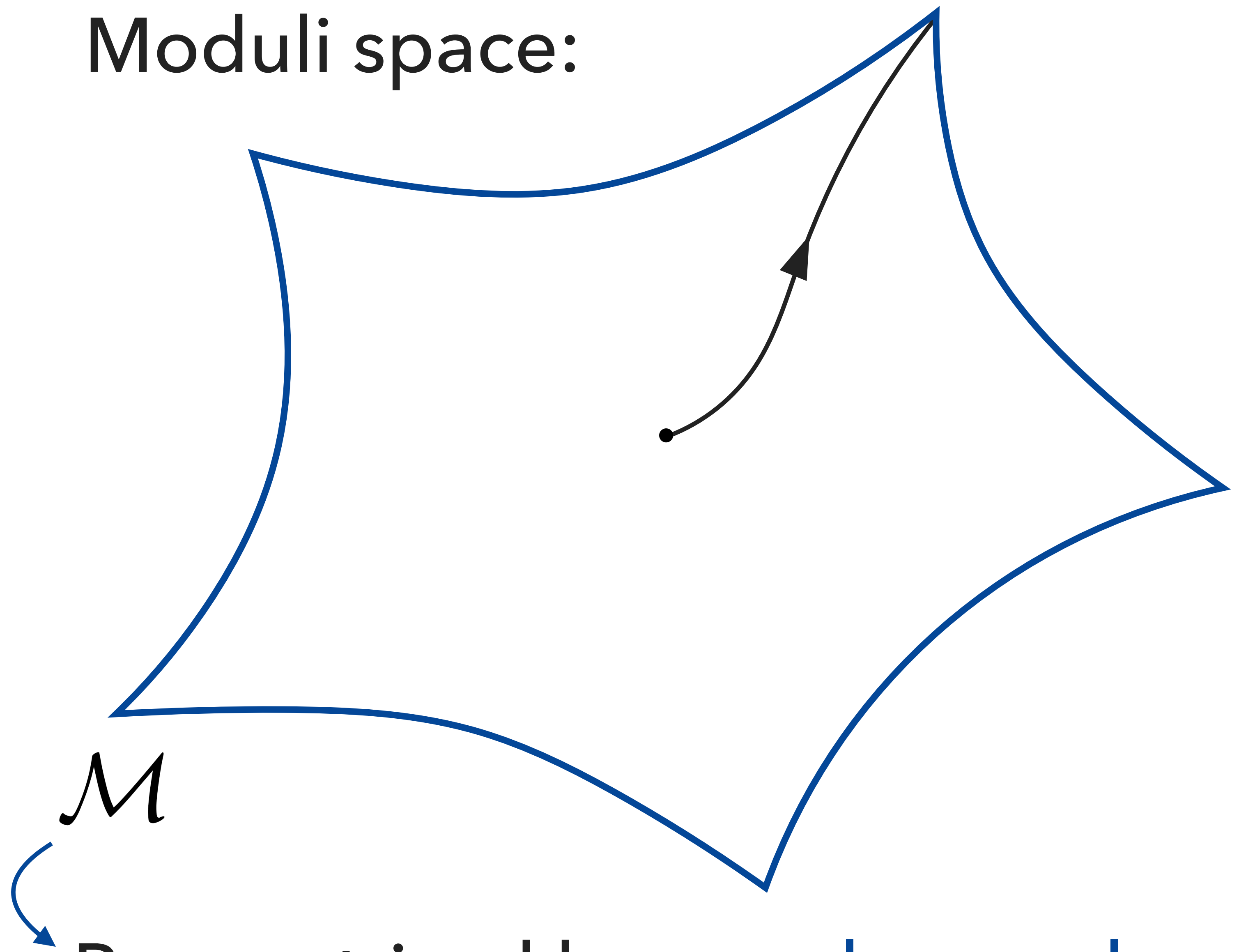

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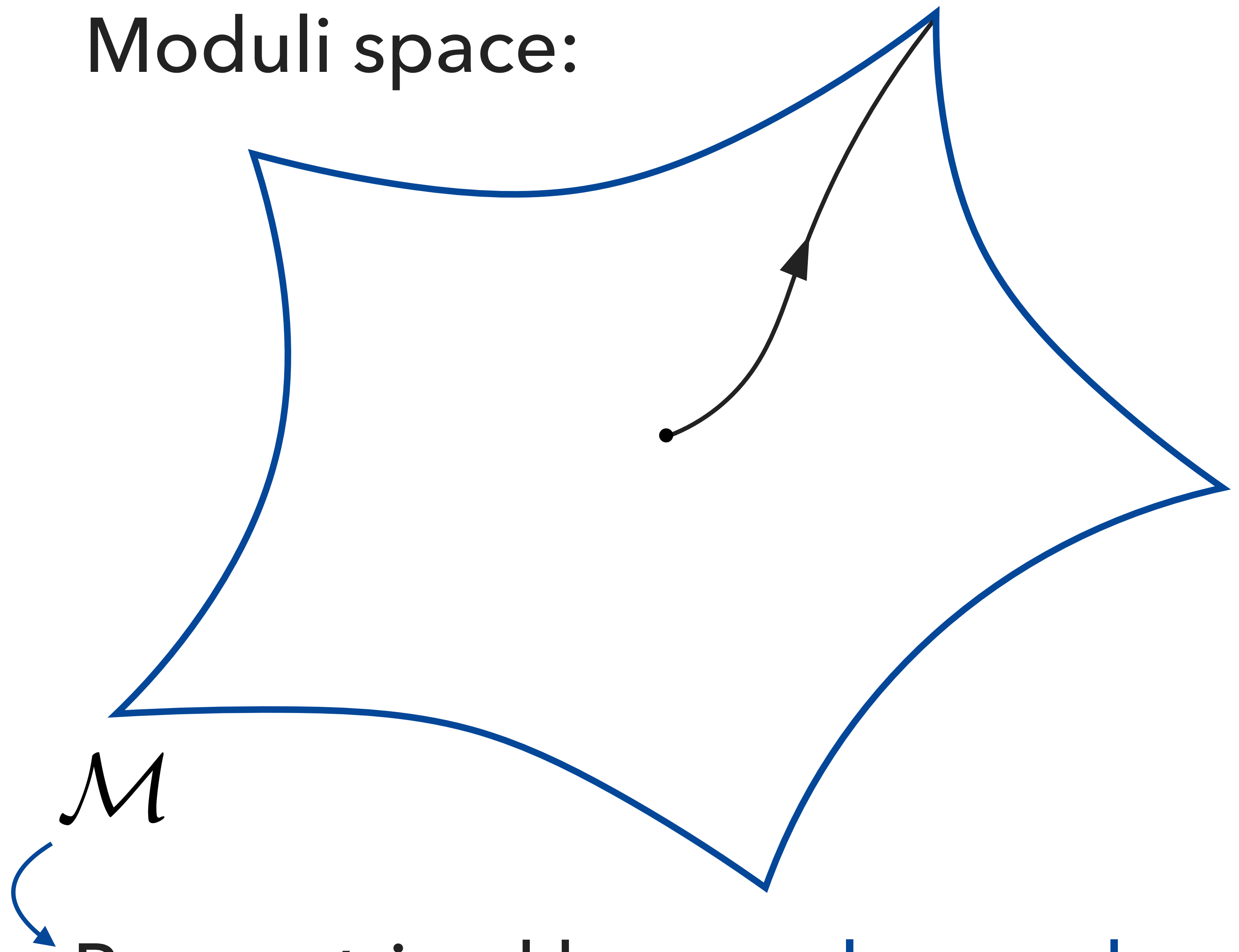

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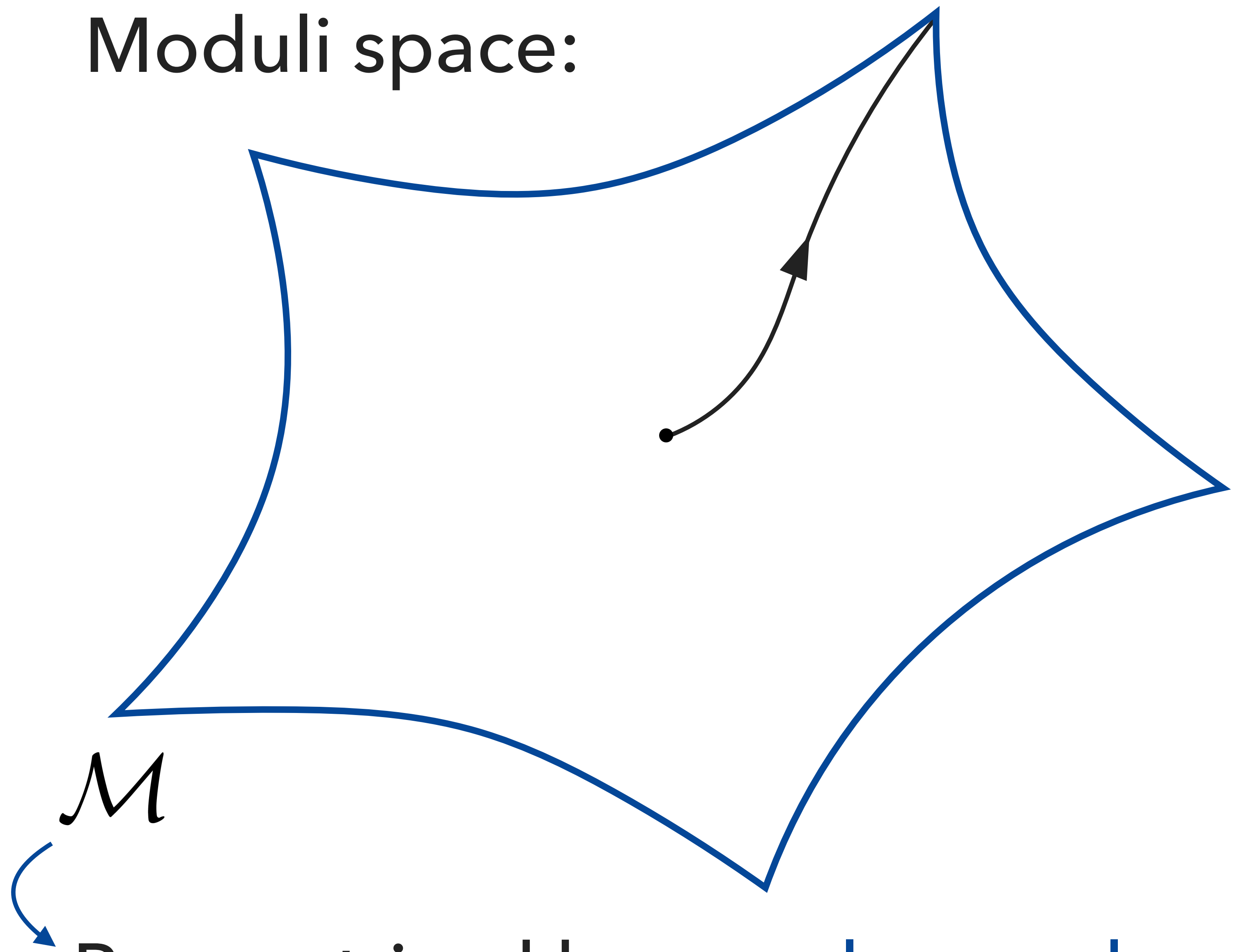

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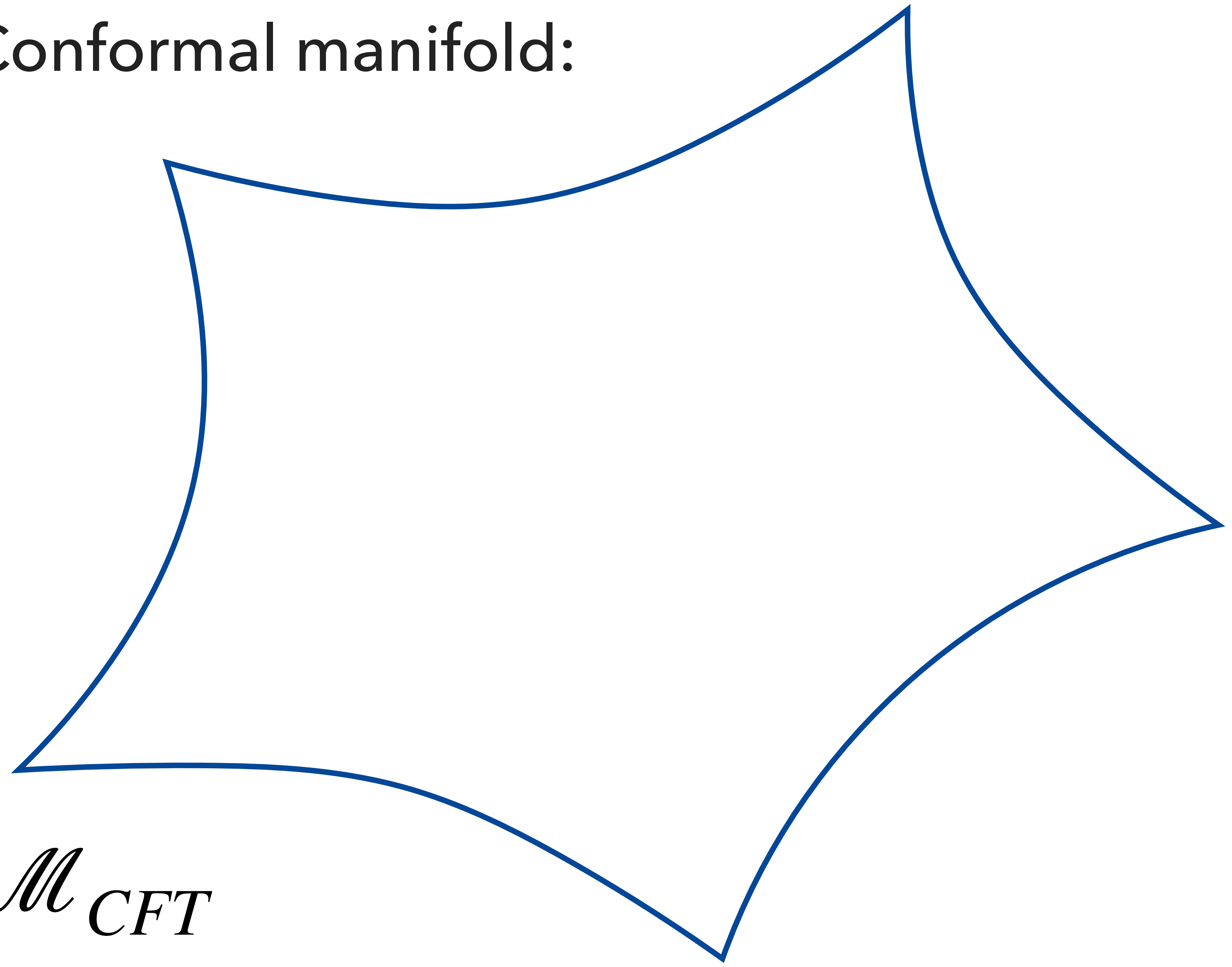

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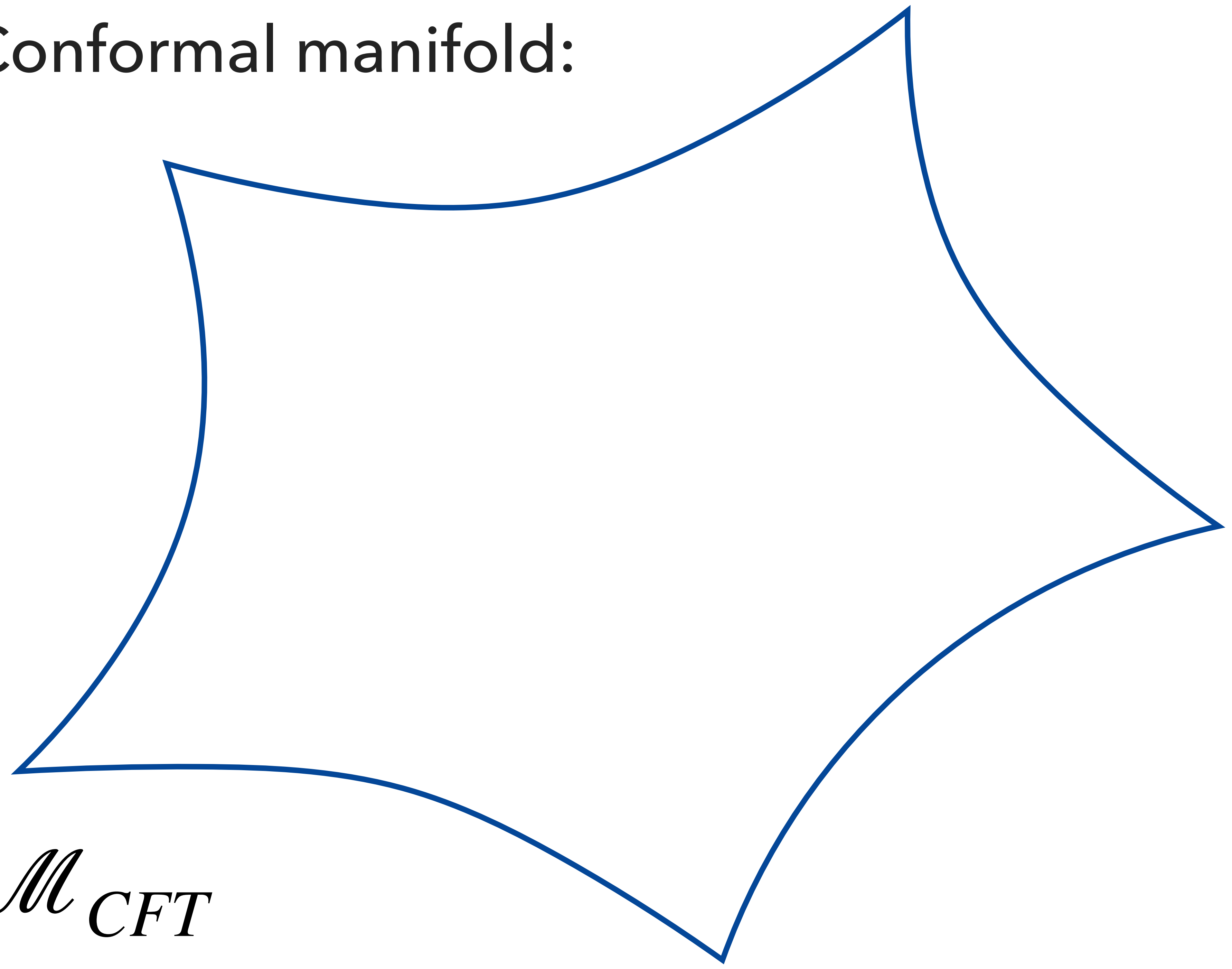
$$\boxed{(\mathcal{M}, G_{ij}) \longleftrightarrow (\mathcal{M}_{CFT}, \chi_{ij})}$$



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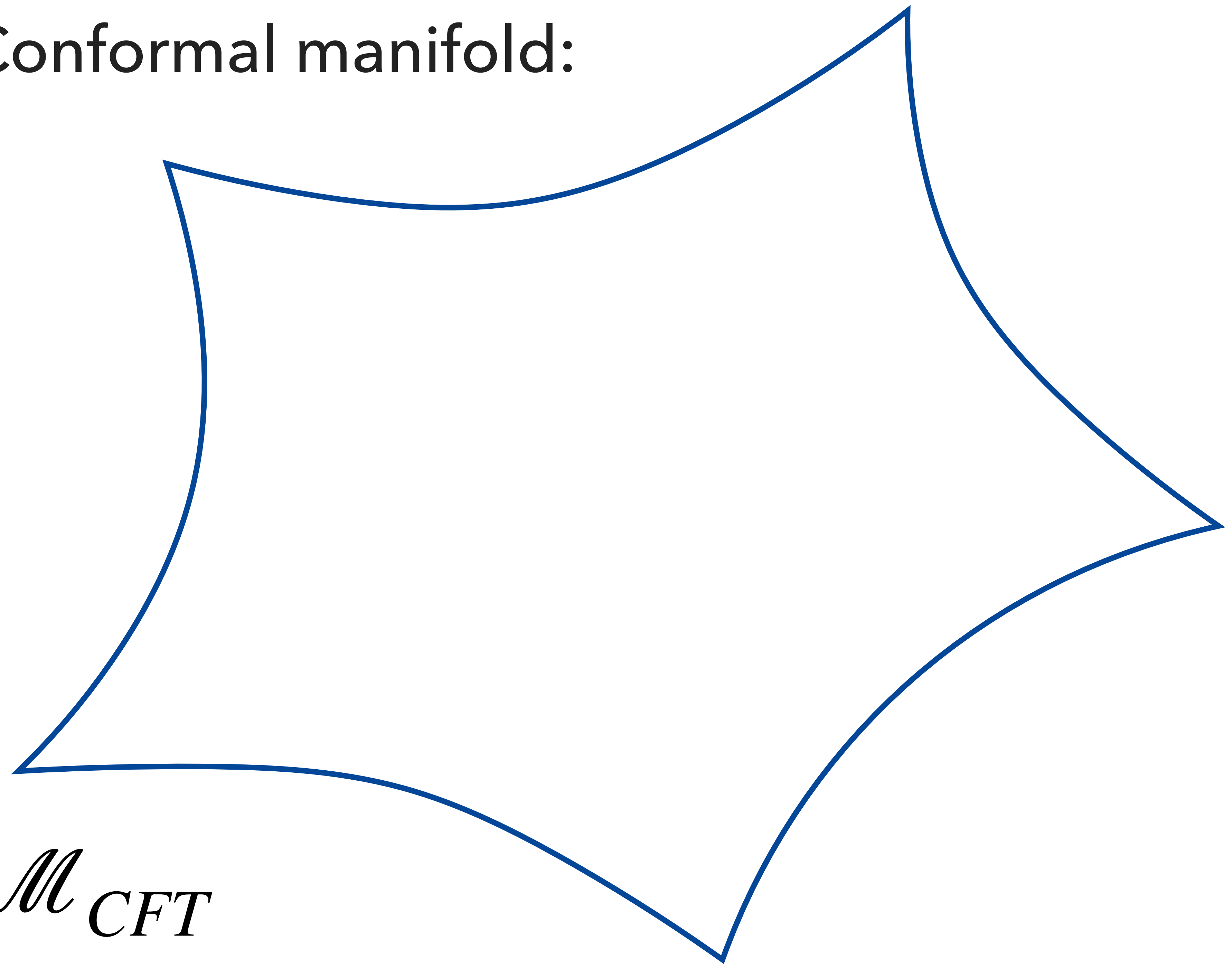
Moduli space metric

$$\mathcal{L} \supset M_{Pl}^{d-1} \frac{1}{2} G_{ij} \partial_\mu \phi^i \partial^\mu \phi^j$$



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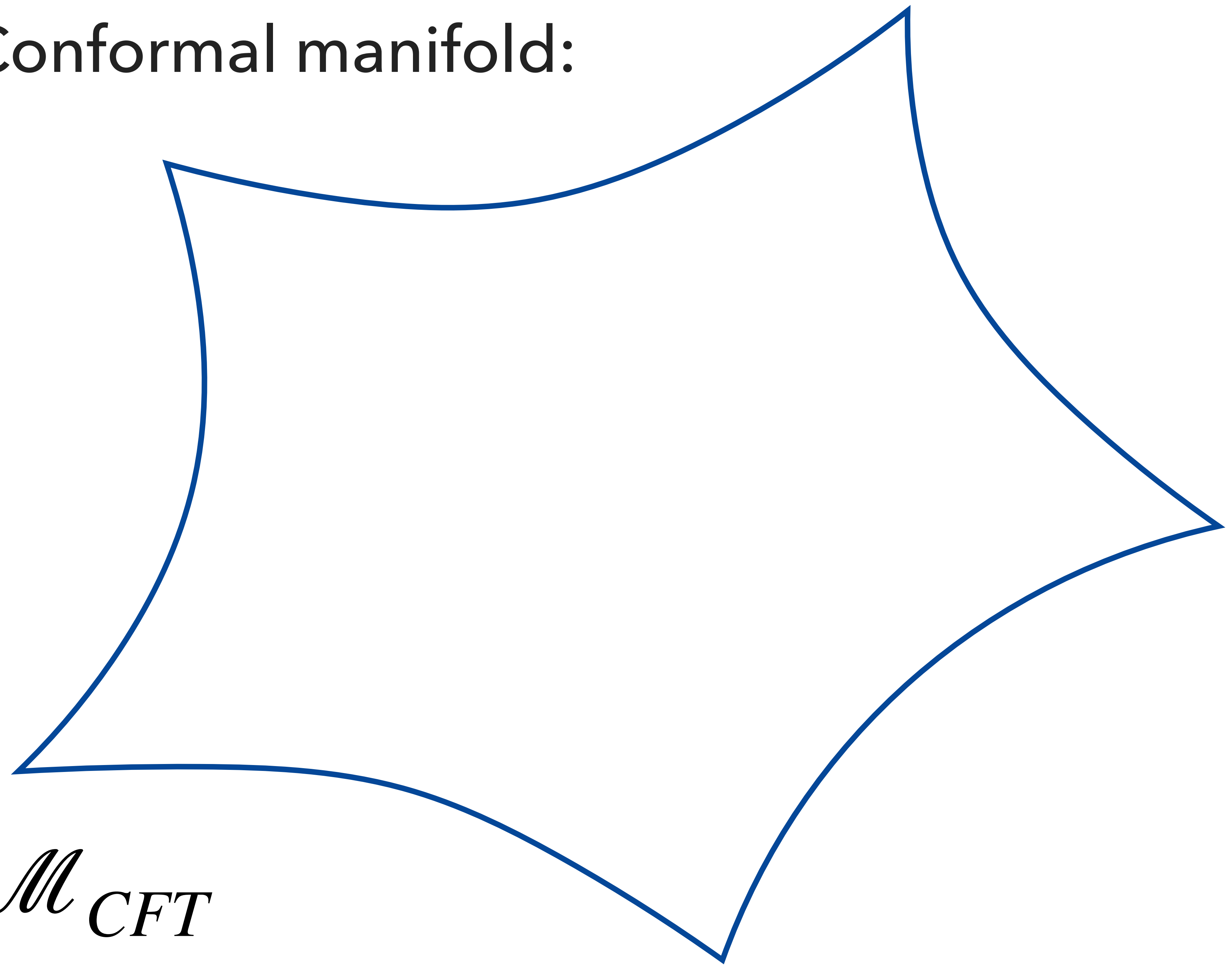

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Zamolodchikov metric

$$\left\langle \mathcal{O}_i \mathcal{O}_j \right\rangle = \frac{\chi_{ij}}{|x-y|^{2d}}$$

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Tower of operators with

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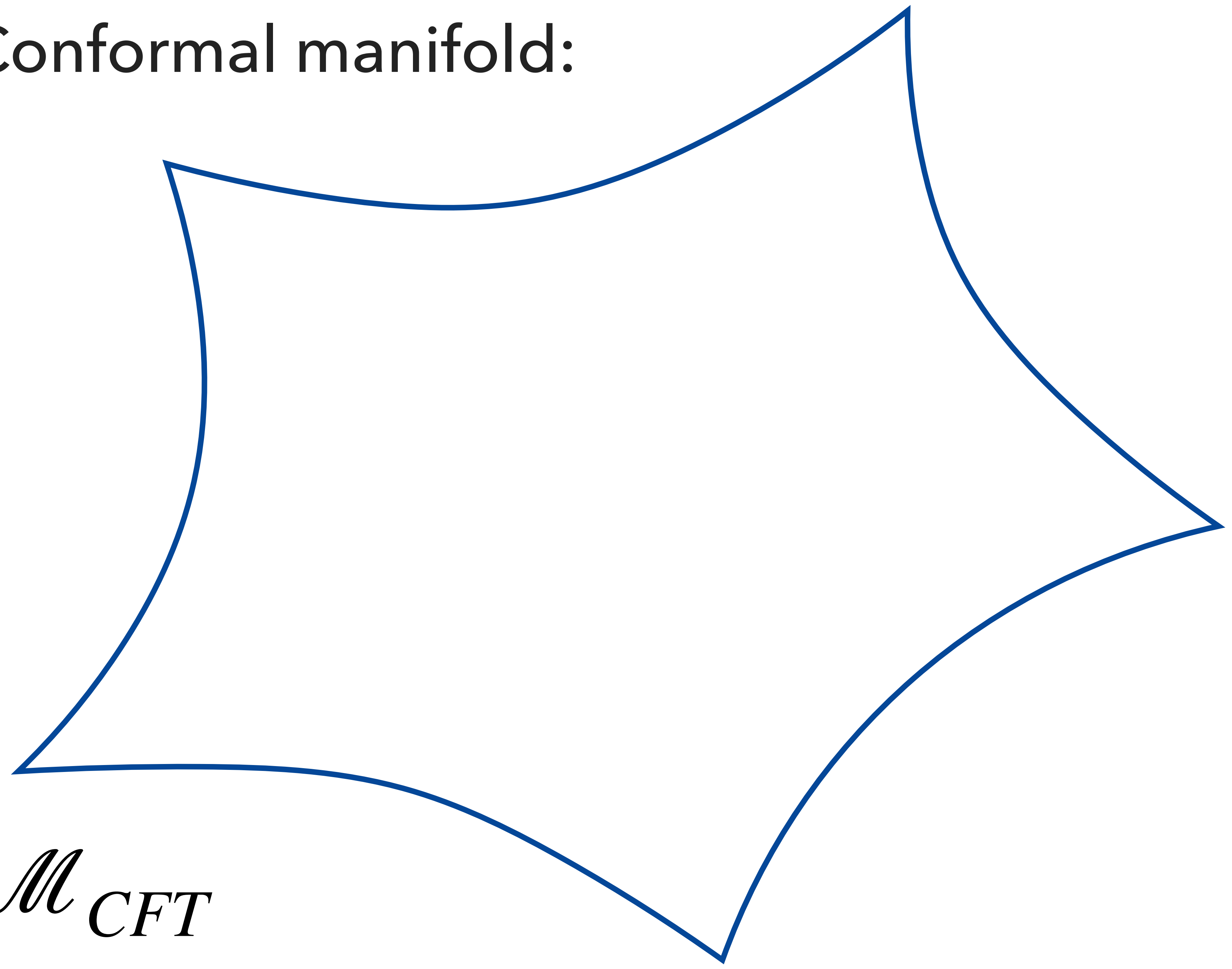

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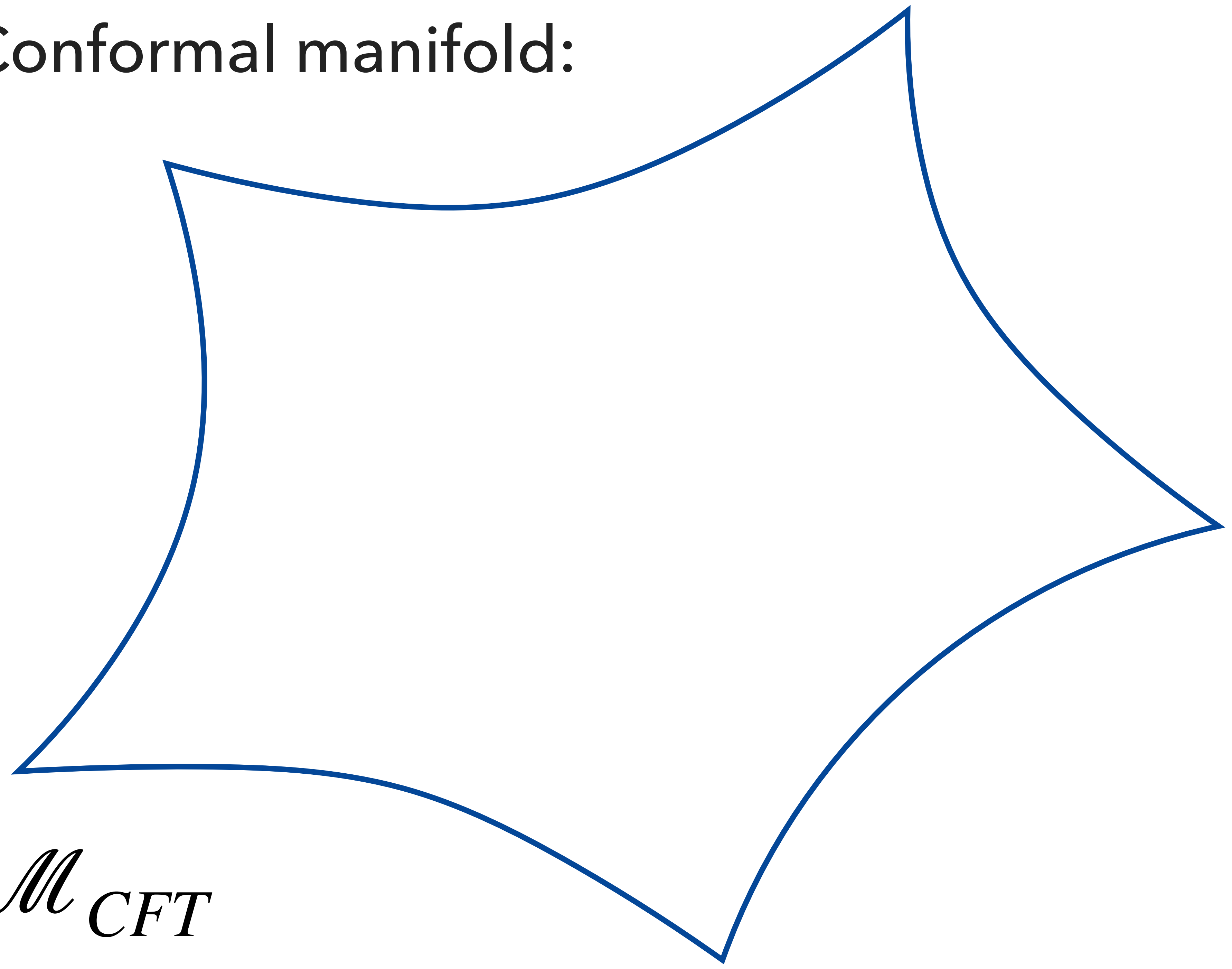

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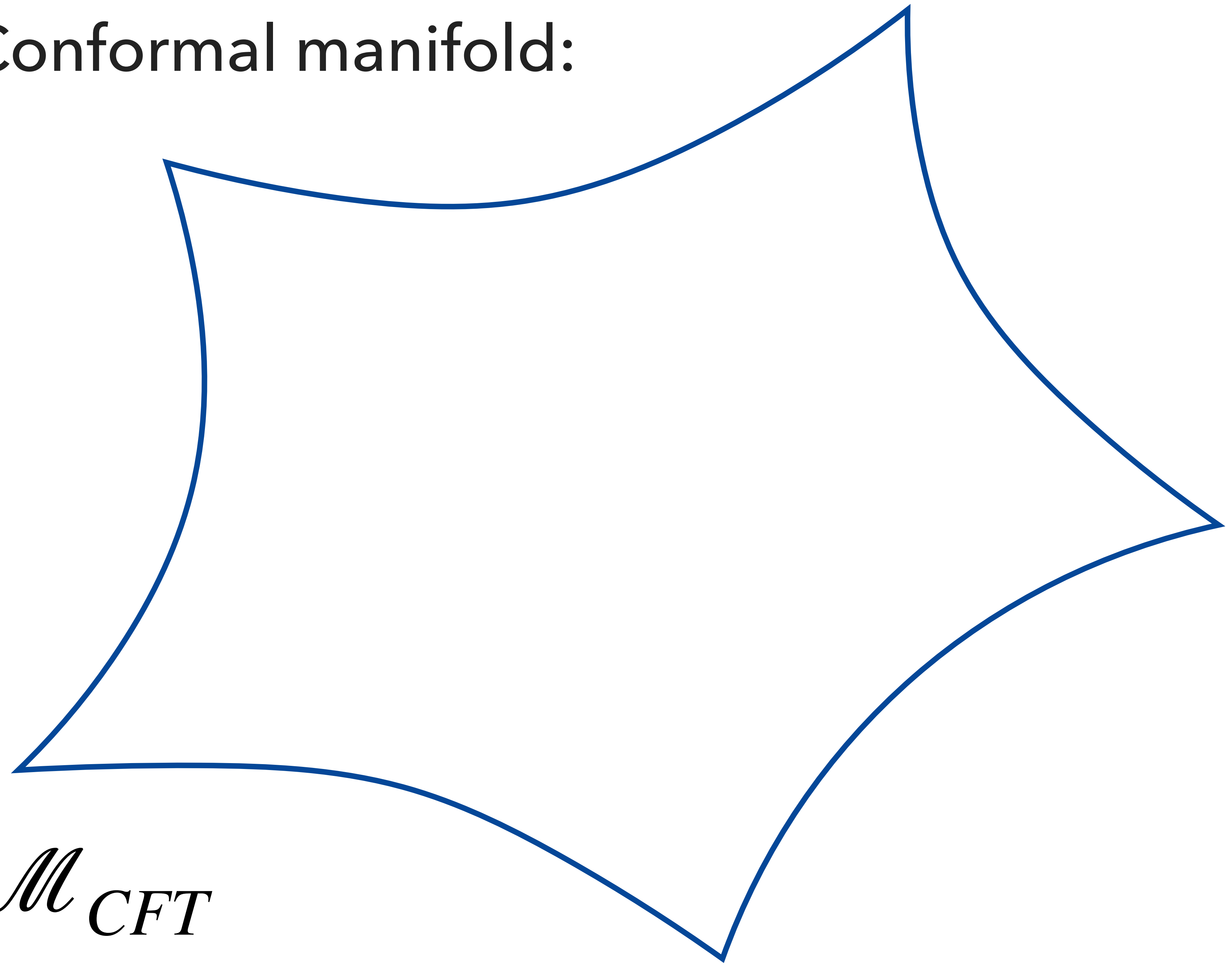
→ **Higher-spin operators** !



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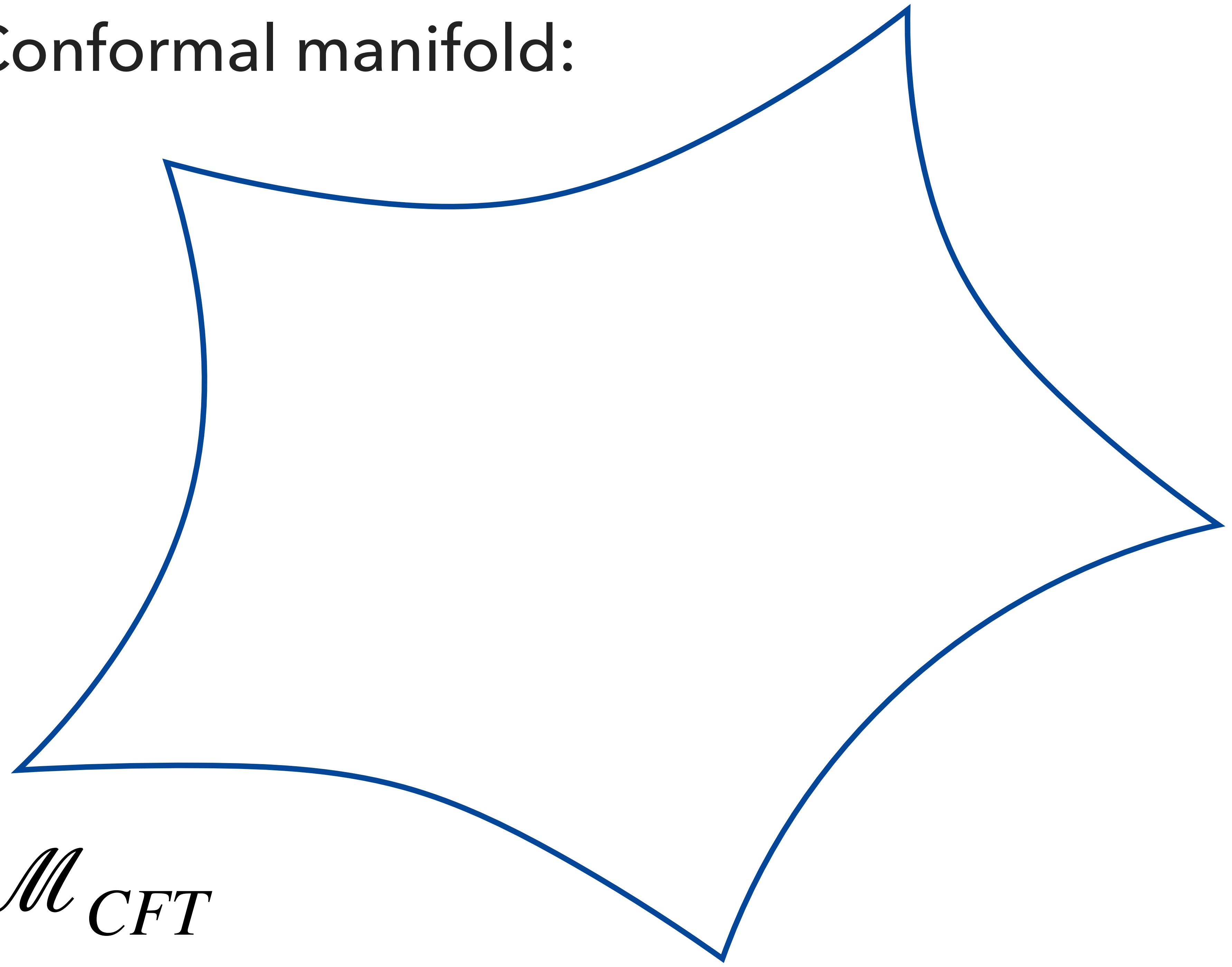

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Local CFT: Posses stress tensor

→ Dynamical gravity in the bulk!

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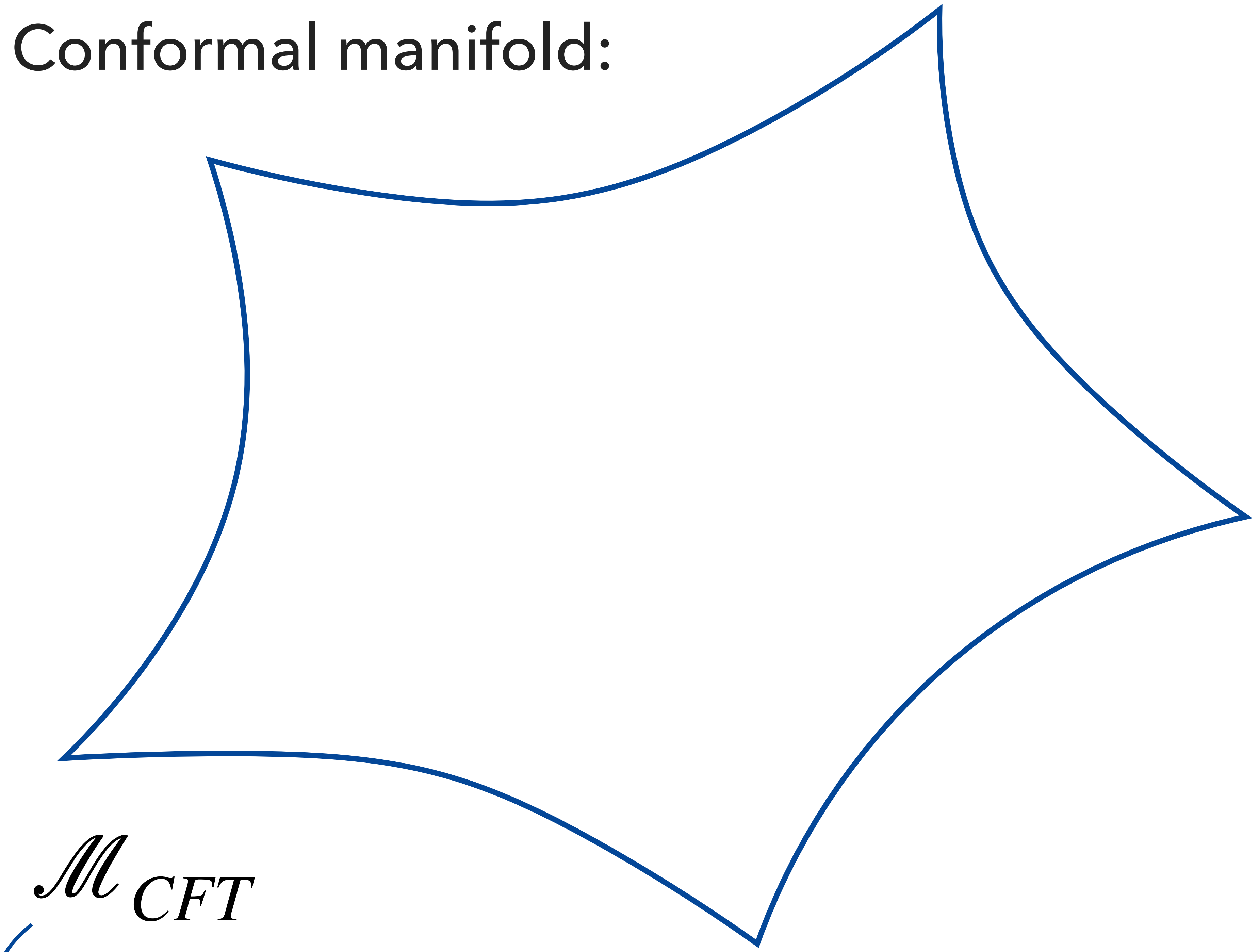

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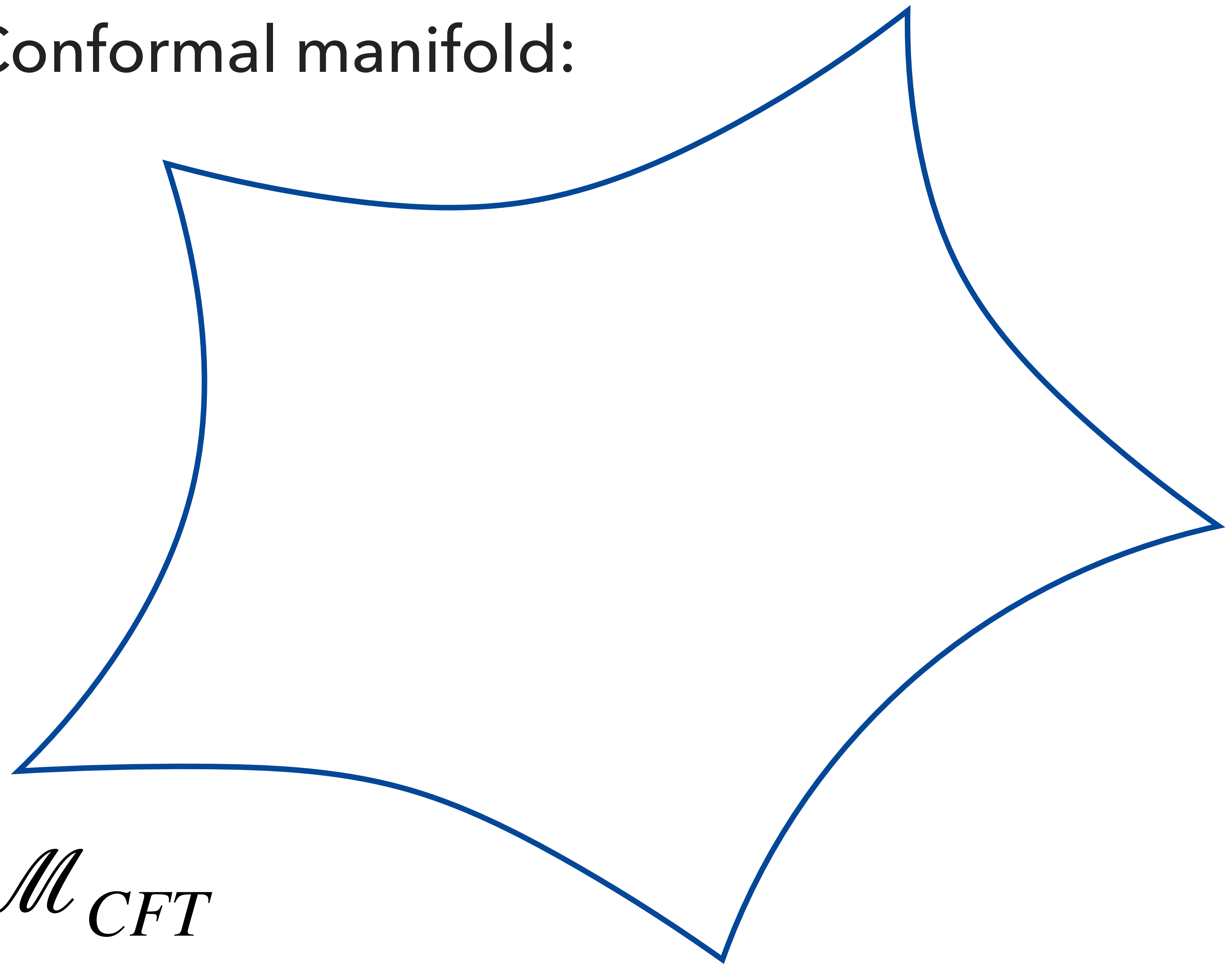

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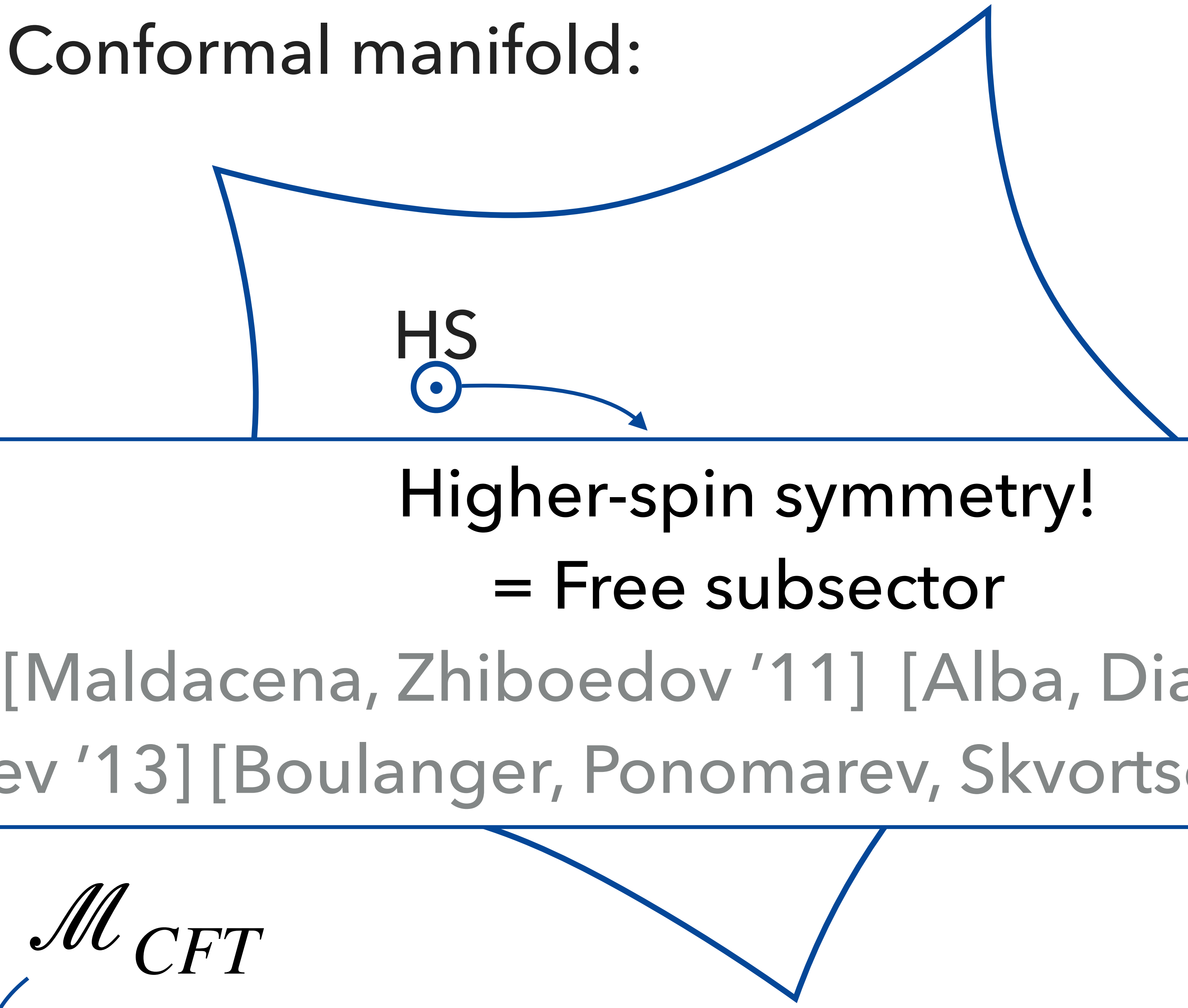

Higher-spin symmetry!
= Free subsector

[Maldacena, Zhiboedov '11] [Alba, Diab '13 '15]
[Stanev '13] [Boulanger, Ponomarev, Skvortsov, Taronna '13]

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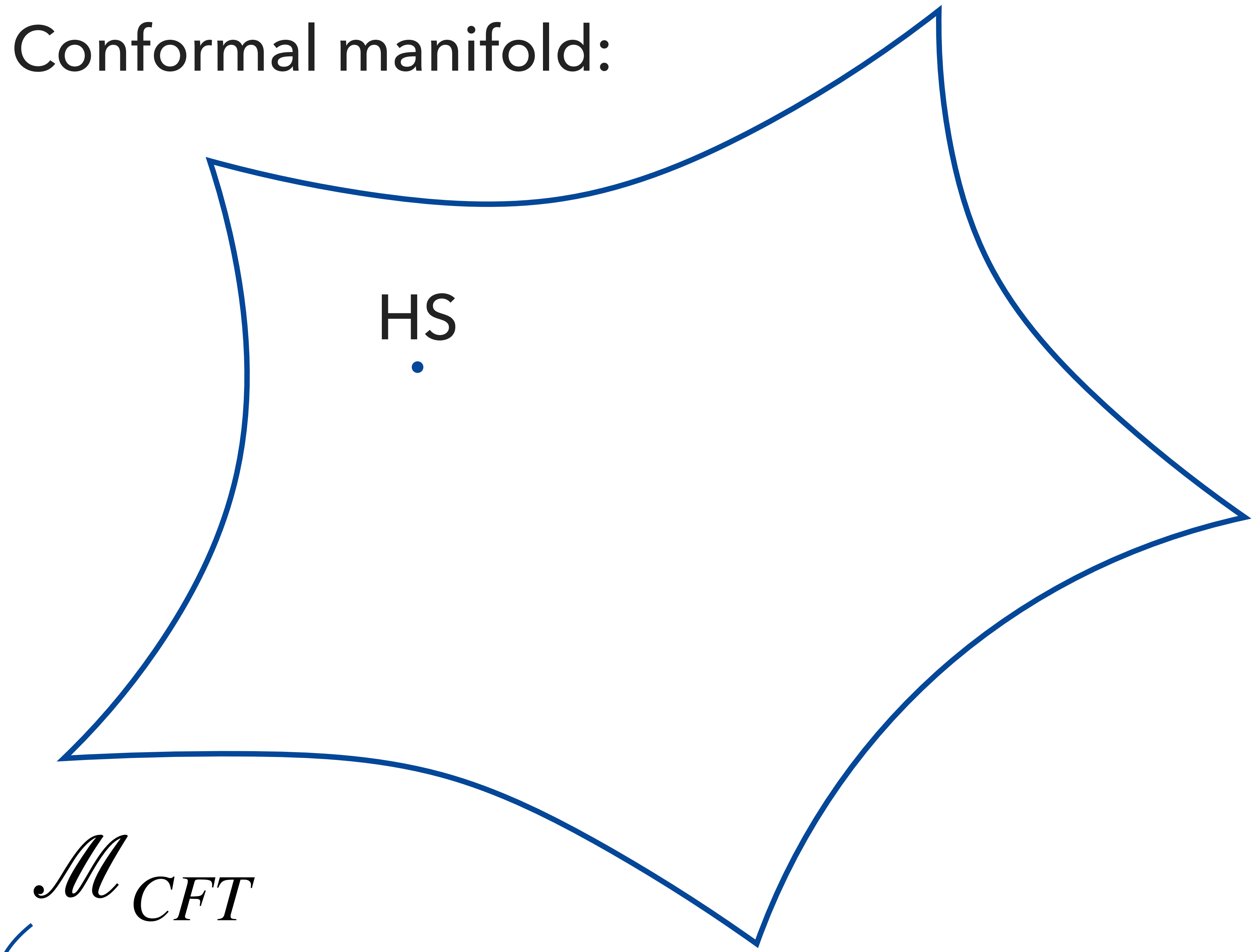

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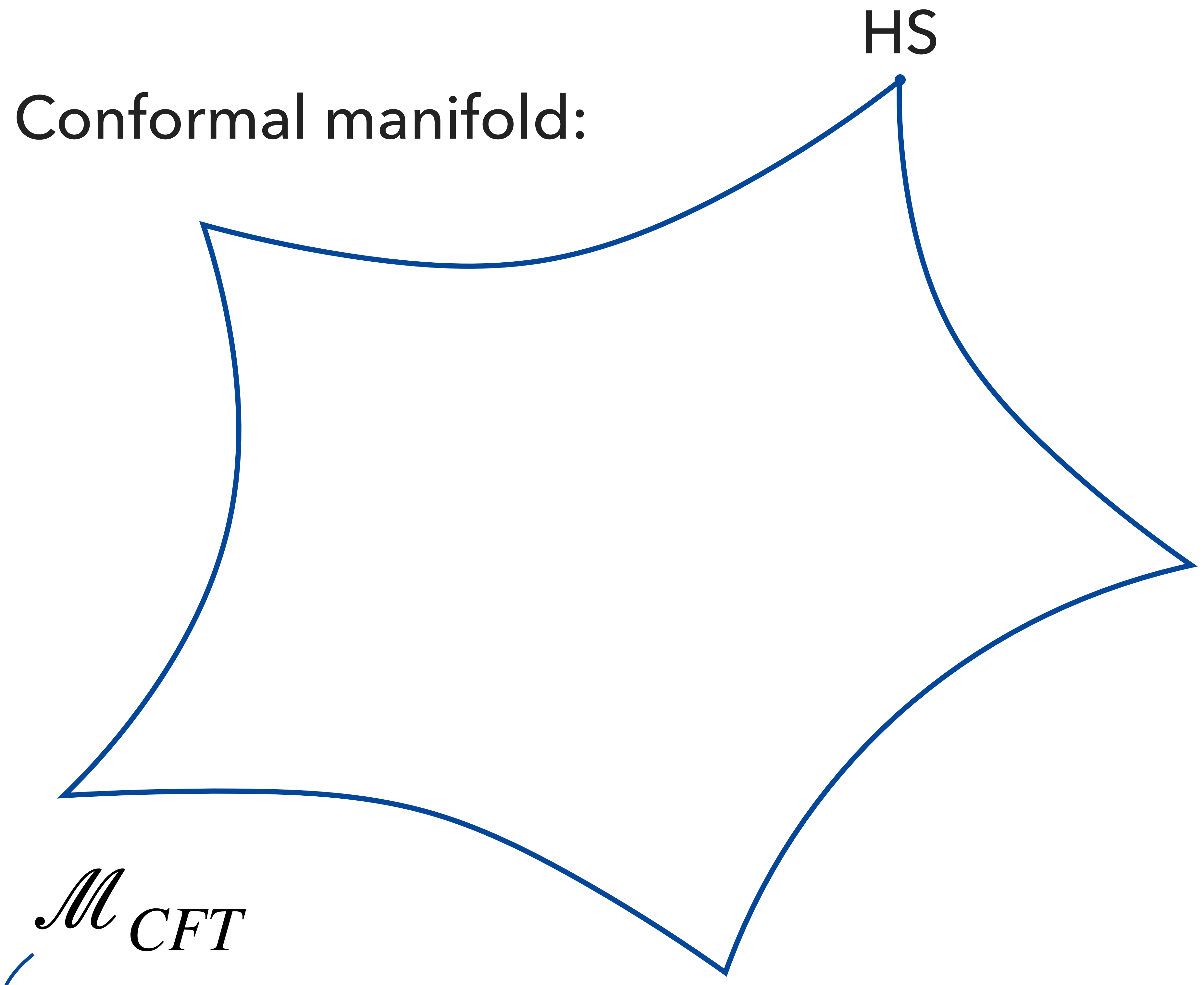

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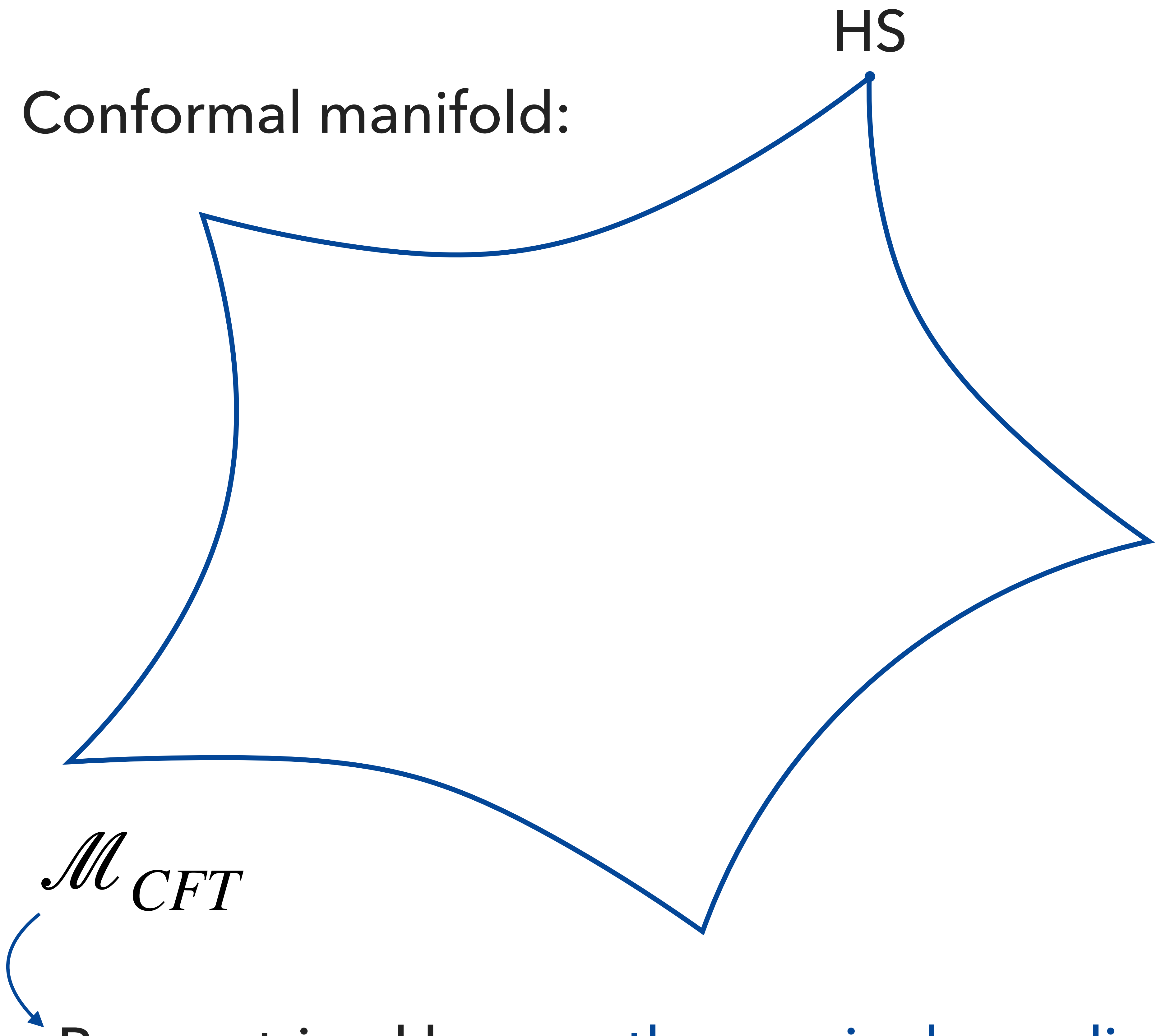

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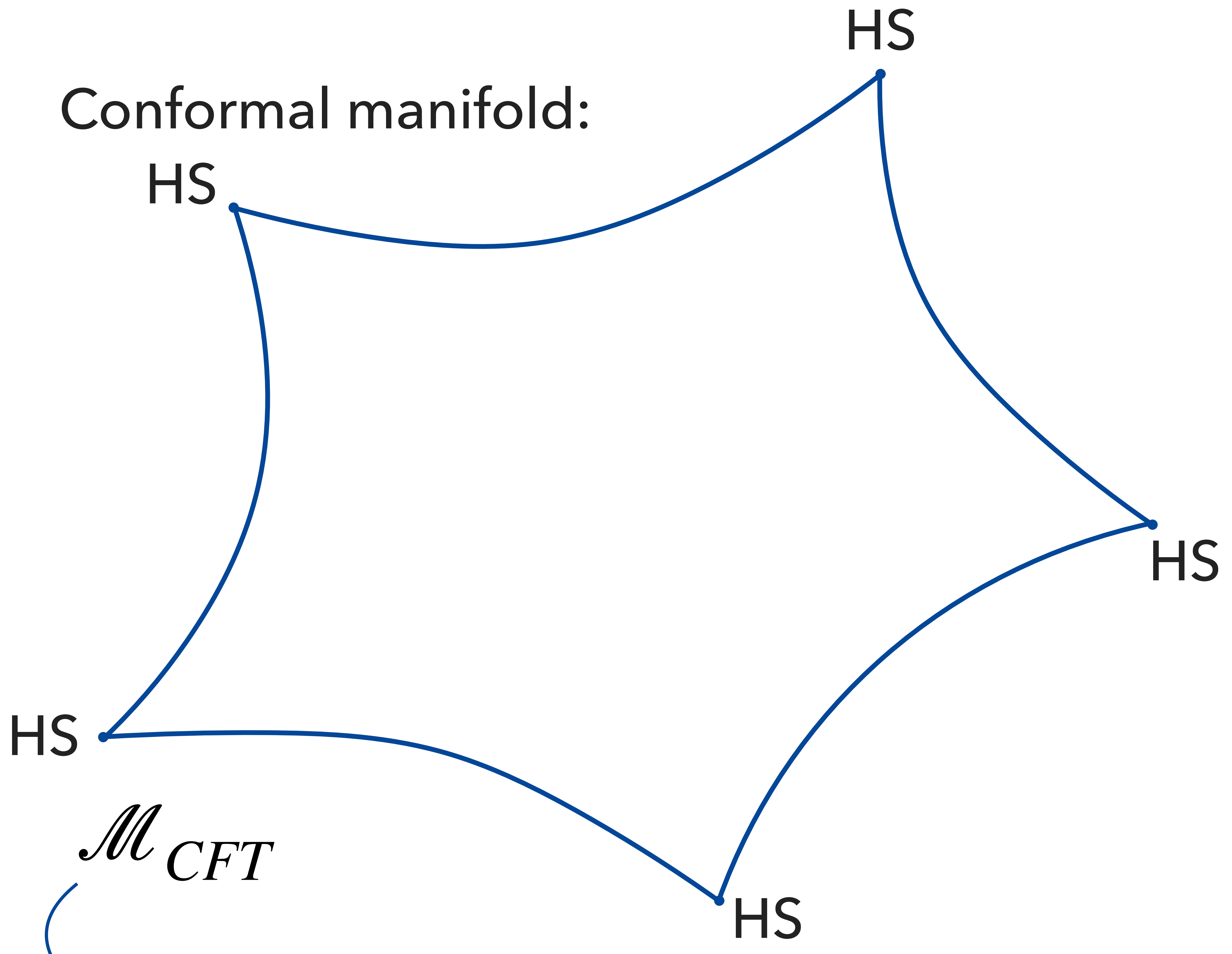

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Zamolodchikov distance

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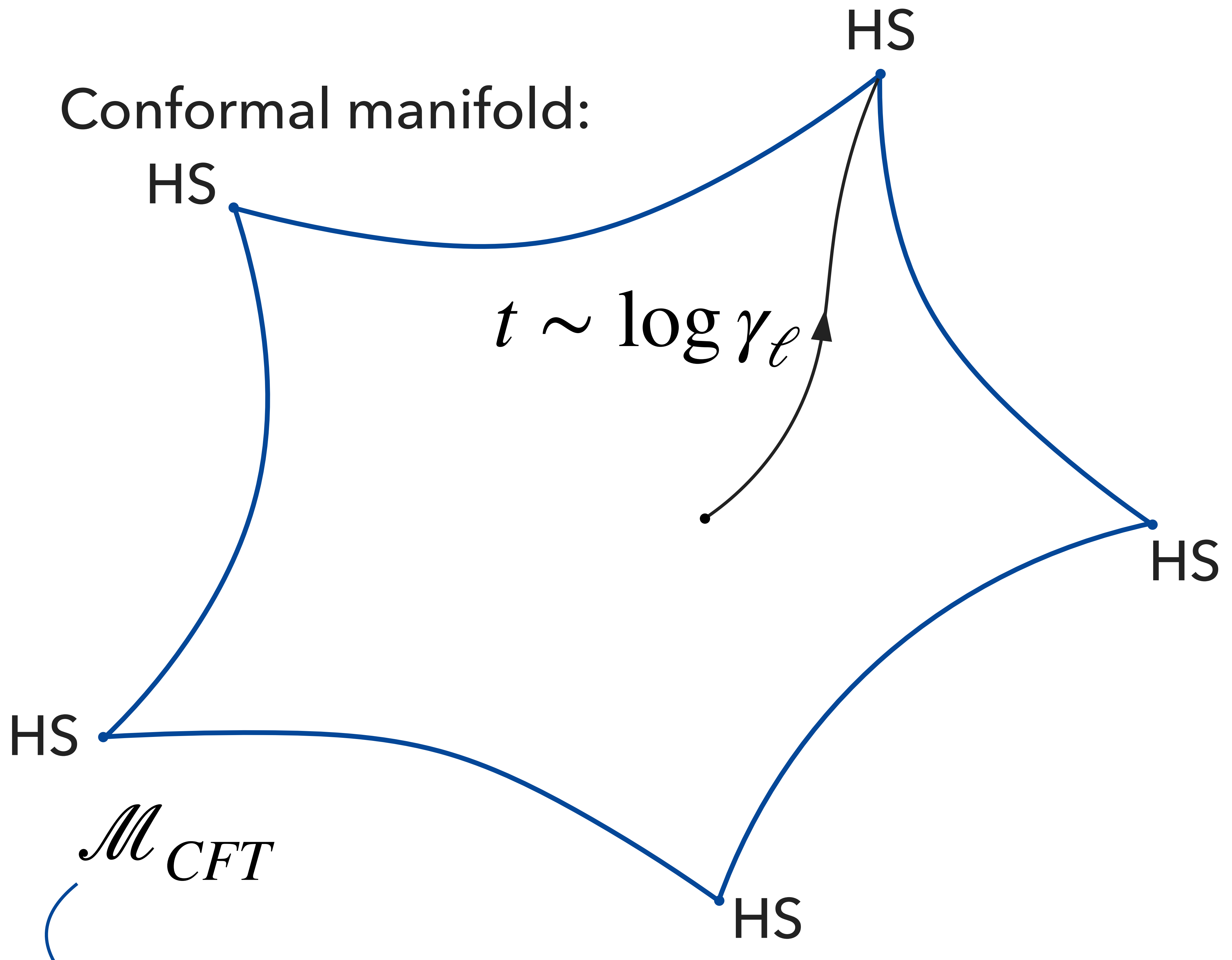

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Moreover:

Analogous statement for 2d CFTs

Proven ✓ [Ooguri, Wang '24]

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Conformal manifold of local CFT in d>2

I. HS point $\longrightarrow$ Infinite distance

II. Infinite distance $\longrightarrow$ HS point

III. $\gamma_\ell = \Delta_\ell - (\ell + d - 2) \sim e^{-\alpha_\ell t}$

Zamolodchikov distance

Local CFT: Posses stress tensor

→ Dynamical gravity in the bulk!

Proven ✓ [Baume, JCI '23]

! No extra assumption, e.g., no supersymmetry

+ existence of stress tensor is crucial!

Moreover:

Analogous statement for 2d CFTs

Proven ✓ [Ooguri, Wang '24]

Today: Stringy origin of HS points ? [JCI, Valenzuela '24]

Strings in the Conformal Manifold

Inspiration: Emergent String Conjecture [Lee, Lerche, Weigand '19]

Leading tower → KK modes → Decompactification

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➡ **Expectation:** HS point ↔ tensionless string

Problem: $T_s \lesssim R_{AdS}^{-2}$ ⟶ String in a highly-curved background… **hard to study!**

➡ Rely on CFT results and extract clues!

A Distance Conjecture Approach

In flat space: Value of $\alpha \rightarrow$ Nature of the tower

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So... What is going on**?!**

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E.g. $\mathcal{N} = 4$ SYM

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E.g. $\mathcal{N} = 4$ SYM $\longleftrightarrow$ Type IIB on $\mathrm{AdS}_5 \times \mathrm{S}^5$

Goal: Understand this case!

Convex Hull for AdS5xS5

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Type IIB on an 5-sphere

$$S = \frac{M_{Pl}^3}{2} \int d^5x \sqrt{-g} \left(R - (\partial\hat{\Phi})^2 - (\partial\hat{R})^2 - V(\hat{\Phi}, \hat{R}) \right)$$

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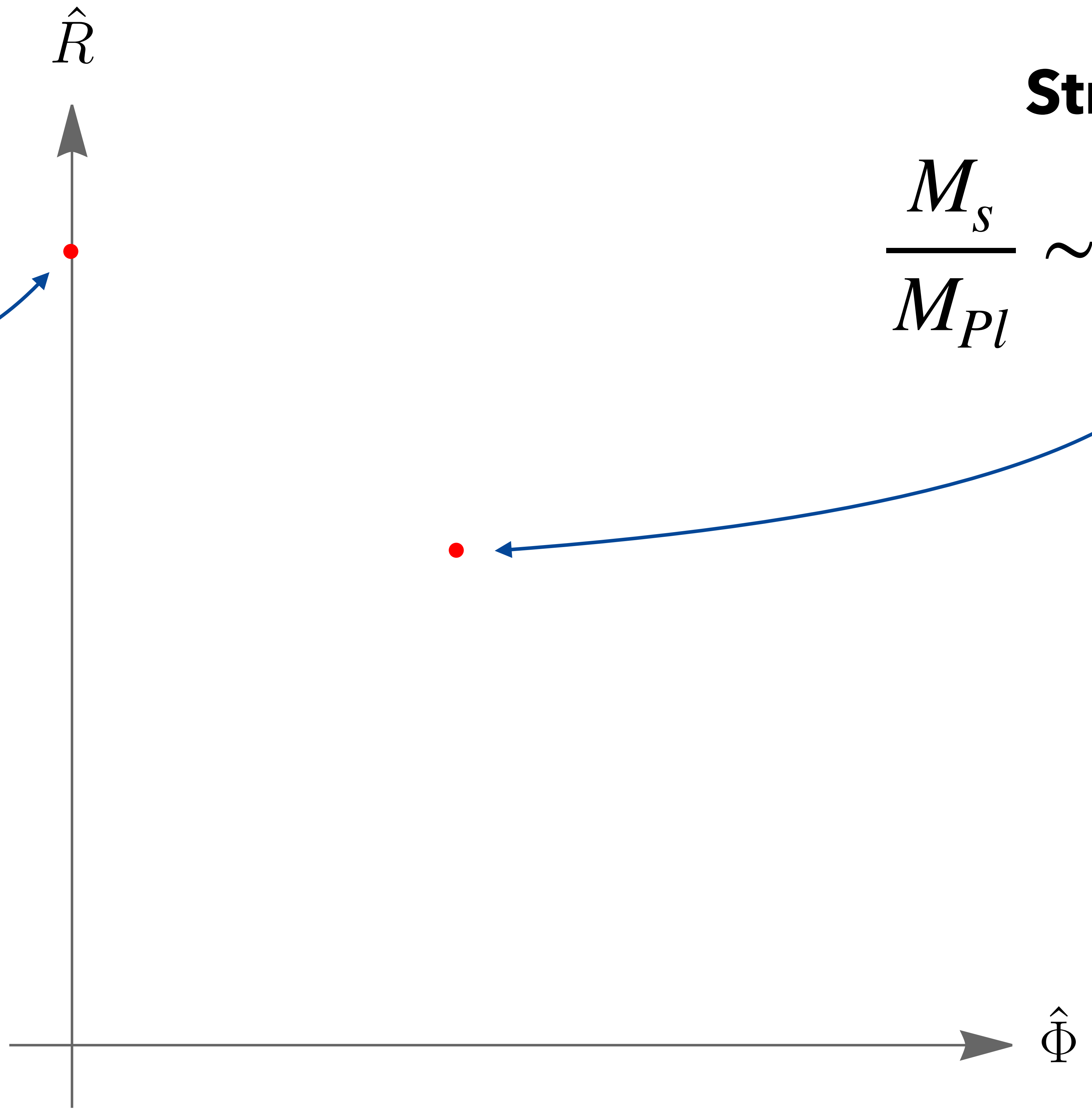

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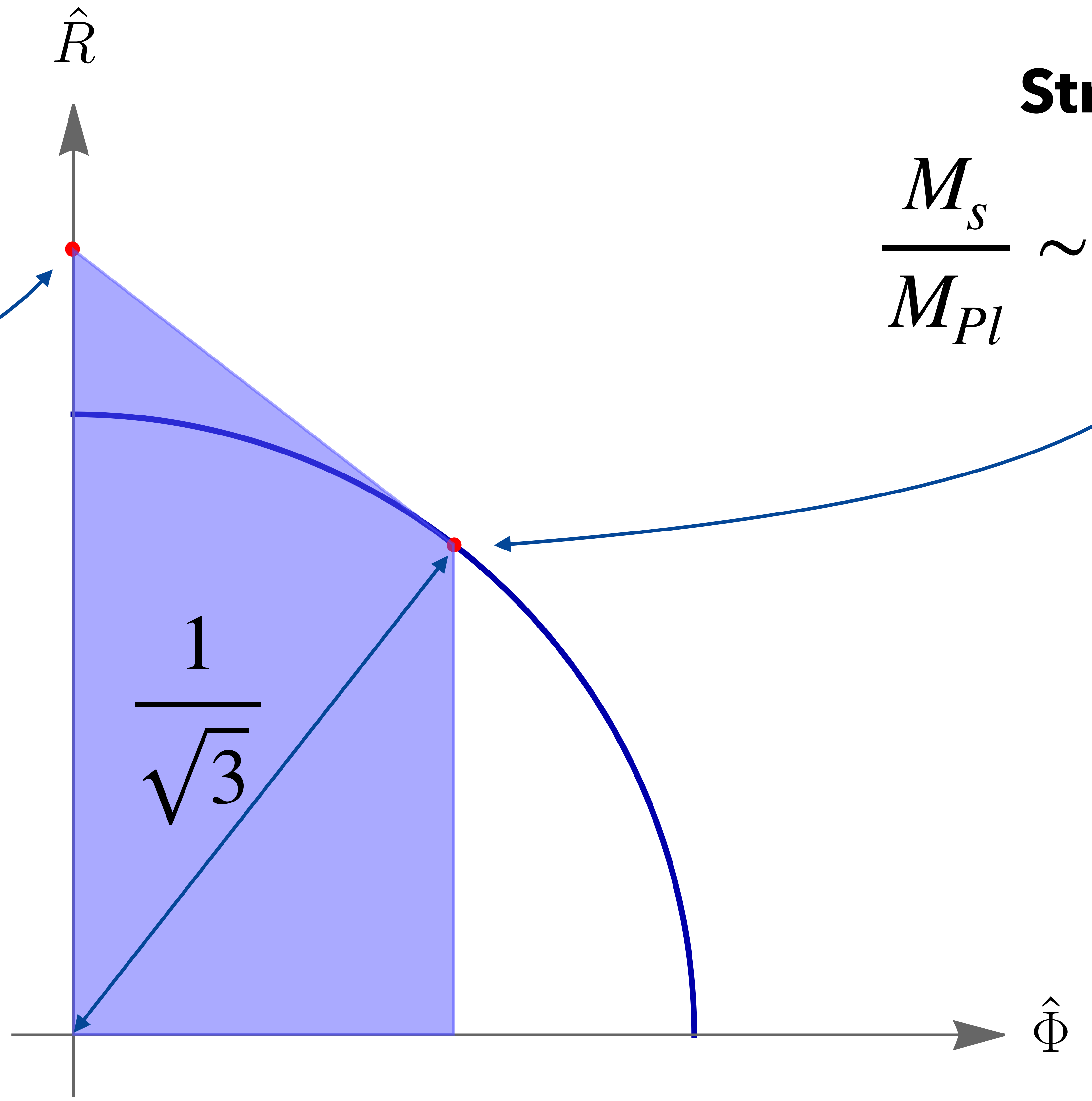

Convex Hull SDC

[JCI, Uranga, Valenzuela '20]

↓

Sharpened SDC

[Etheredge, Heidenreich, Kaya, Qiu, Rudelius '22]

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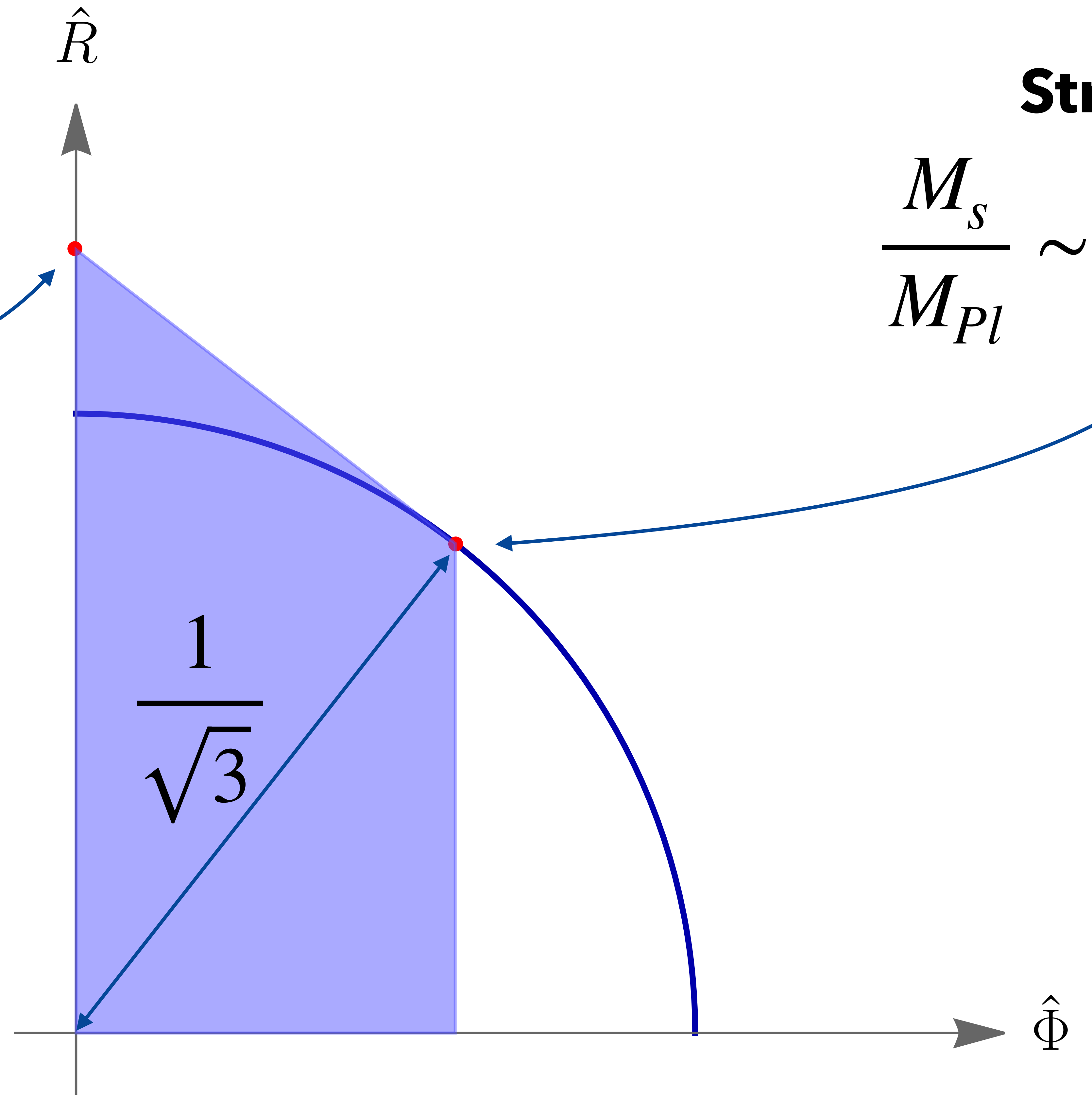

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$AdS_5 \times S^5$ moduli space

$$\alpha = \frac{1}{2\sqrt{2}} \neq \frac{1}{\sqrt{2}} \text{ (fix } \hat{R}\text{)}$$

CFT value not reproduced!

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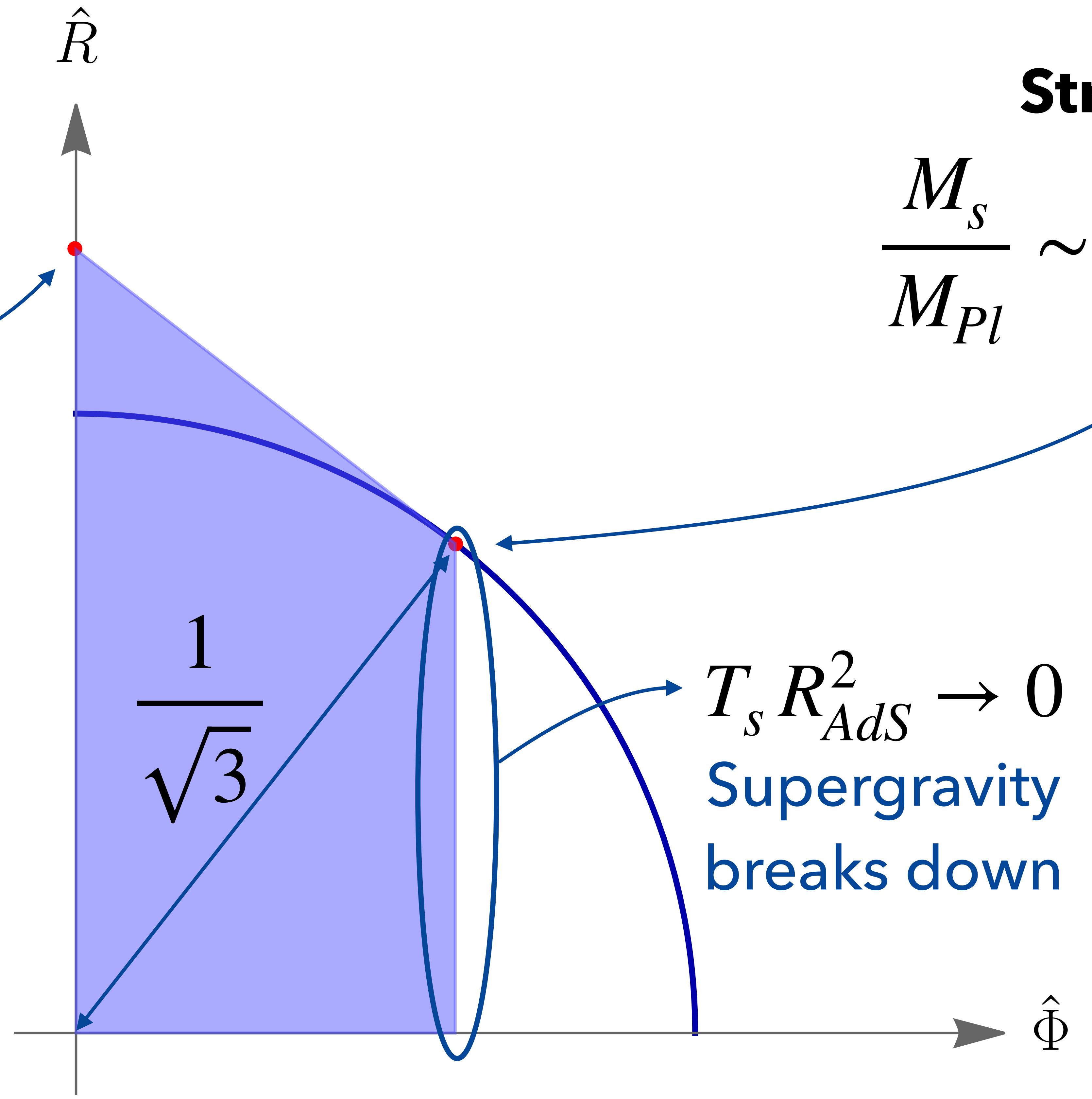

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$\mathcal{N} = 4$ SU(N) gauge theory in 4d

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Supergravity input!

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Supergravity input!

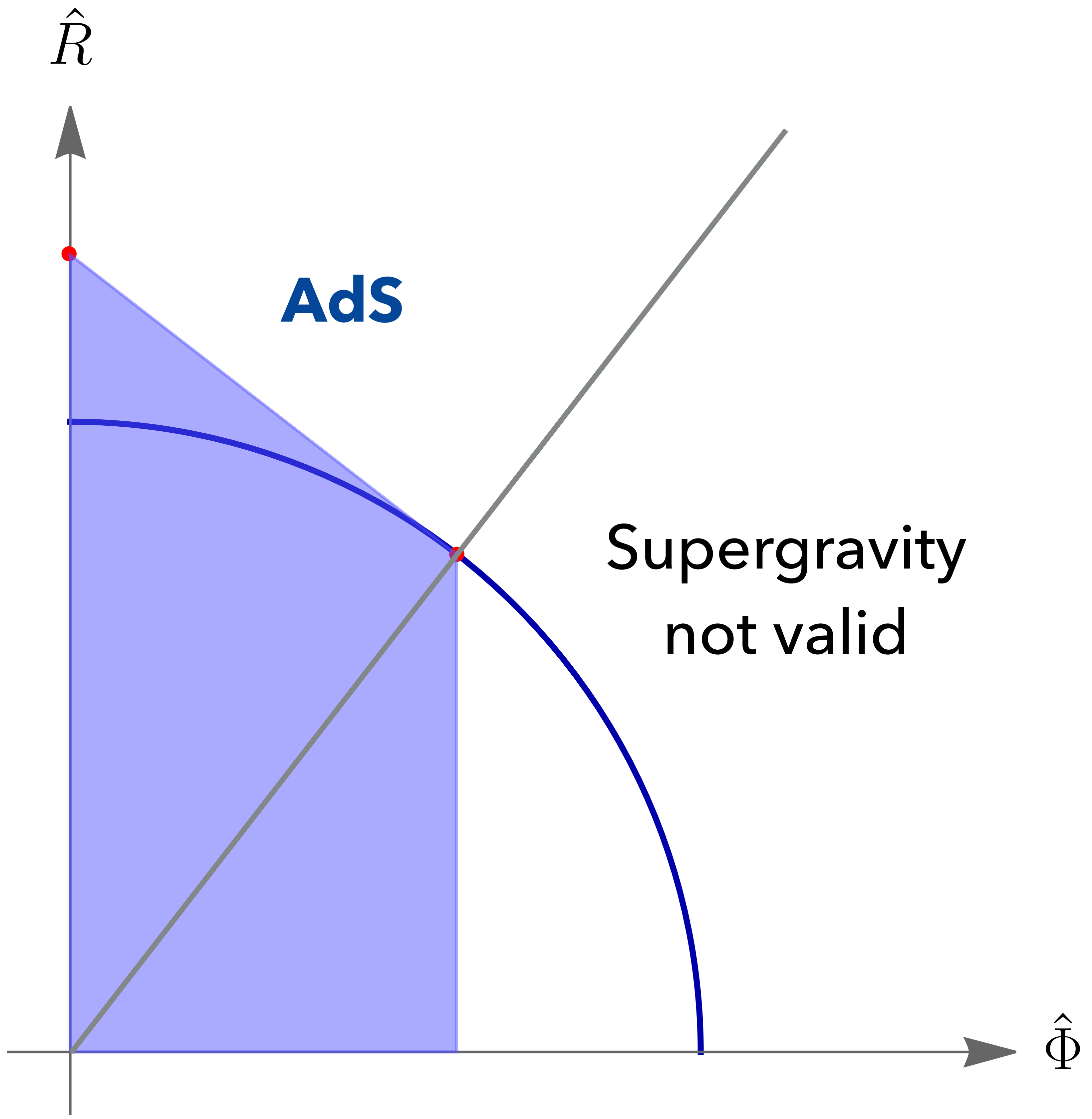
Problem:

No CFT distance in the N-direction **:(**

Need supergravity input!

$$\boxed{N \sim e^{\frac{\sqrt{30}}{5}\hat{R}}}$$

Convex Hulls Comparison



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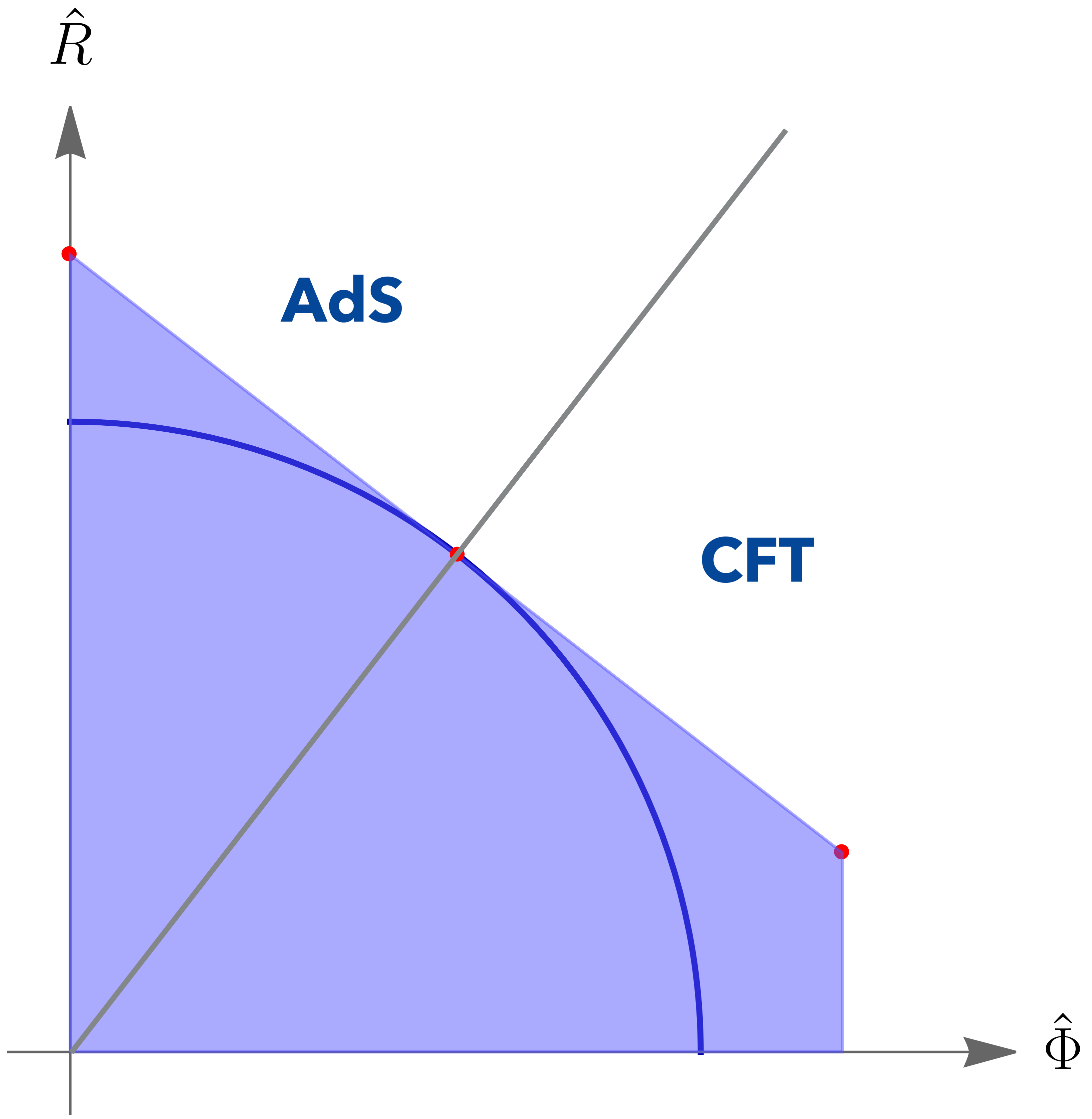

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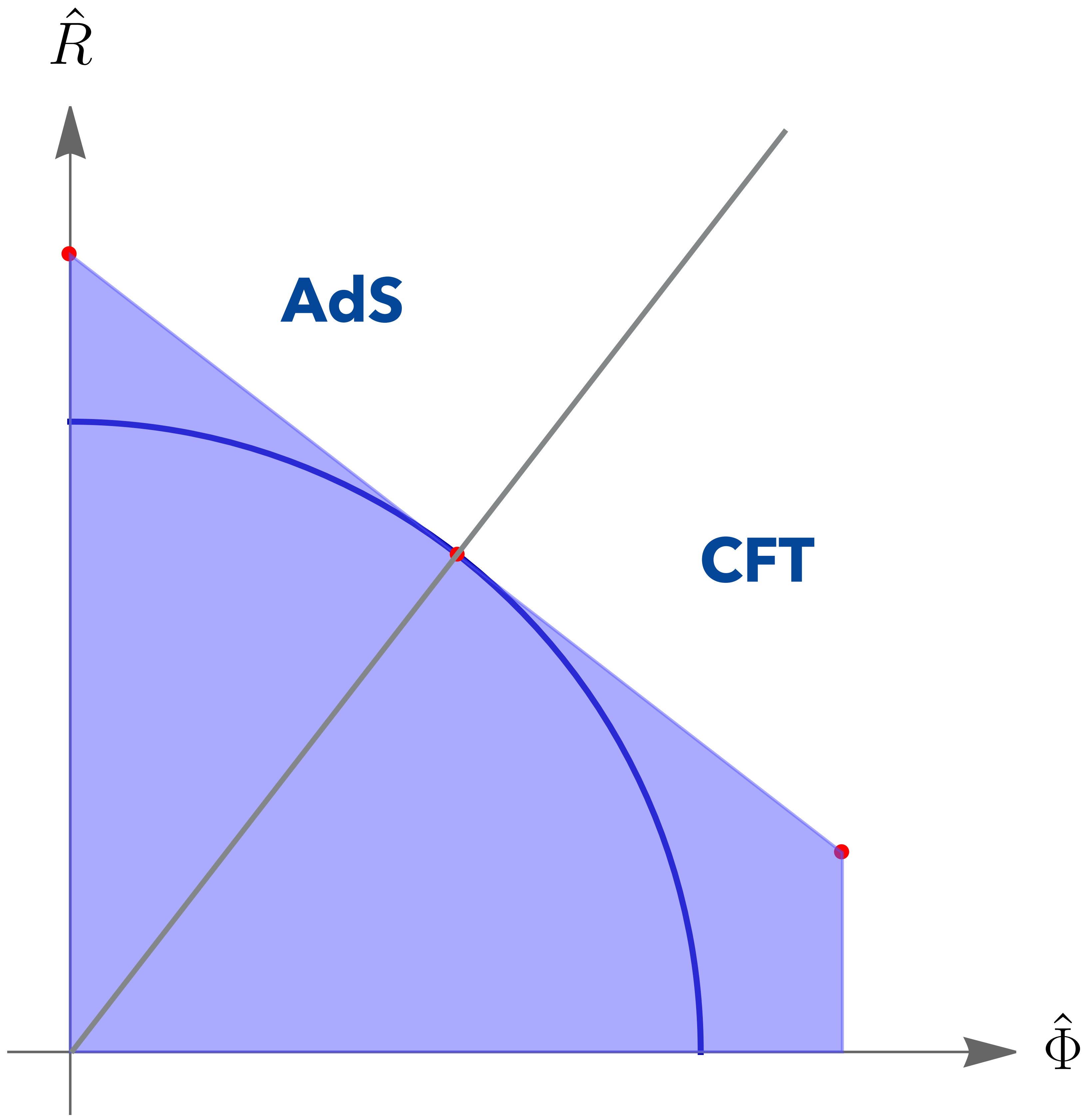
Notice:
Convex hulls for AdS and CFT glue nicely together!
(see later)



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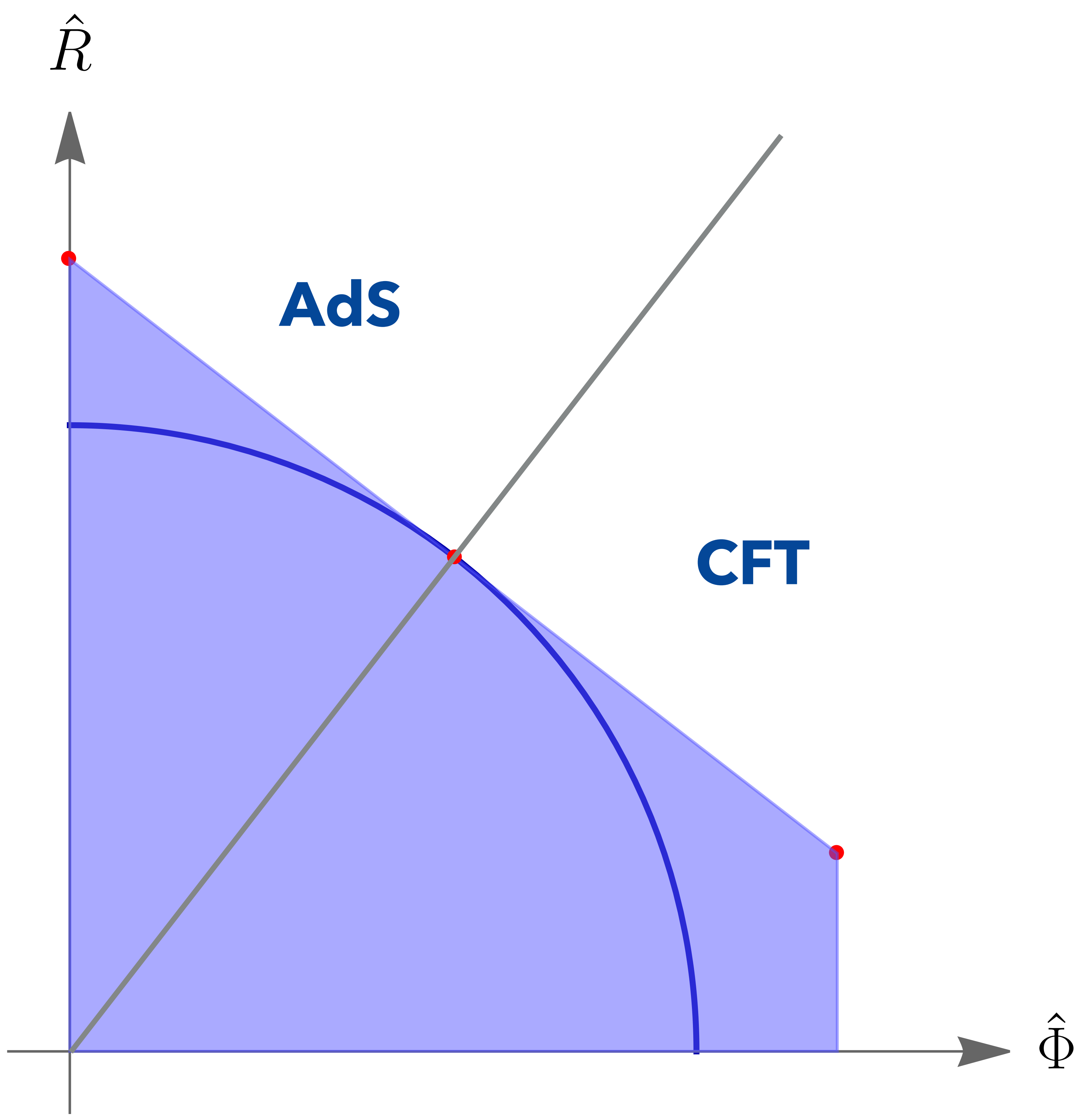

Summary

A Detour: Scale Separation vs Sharpened SDC

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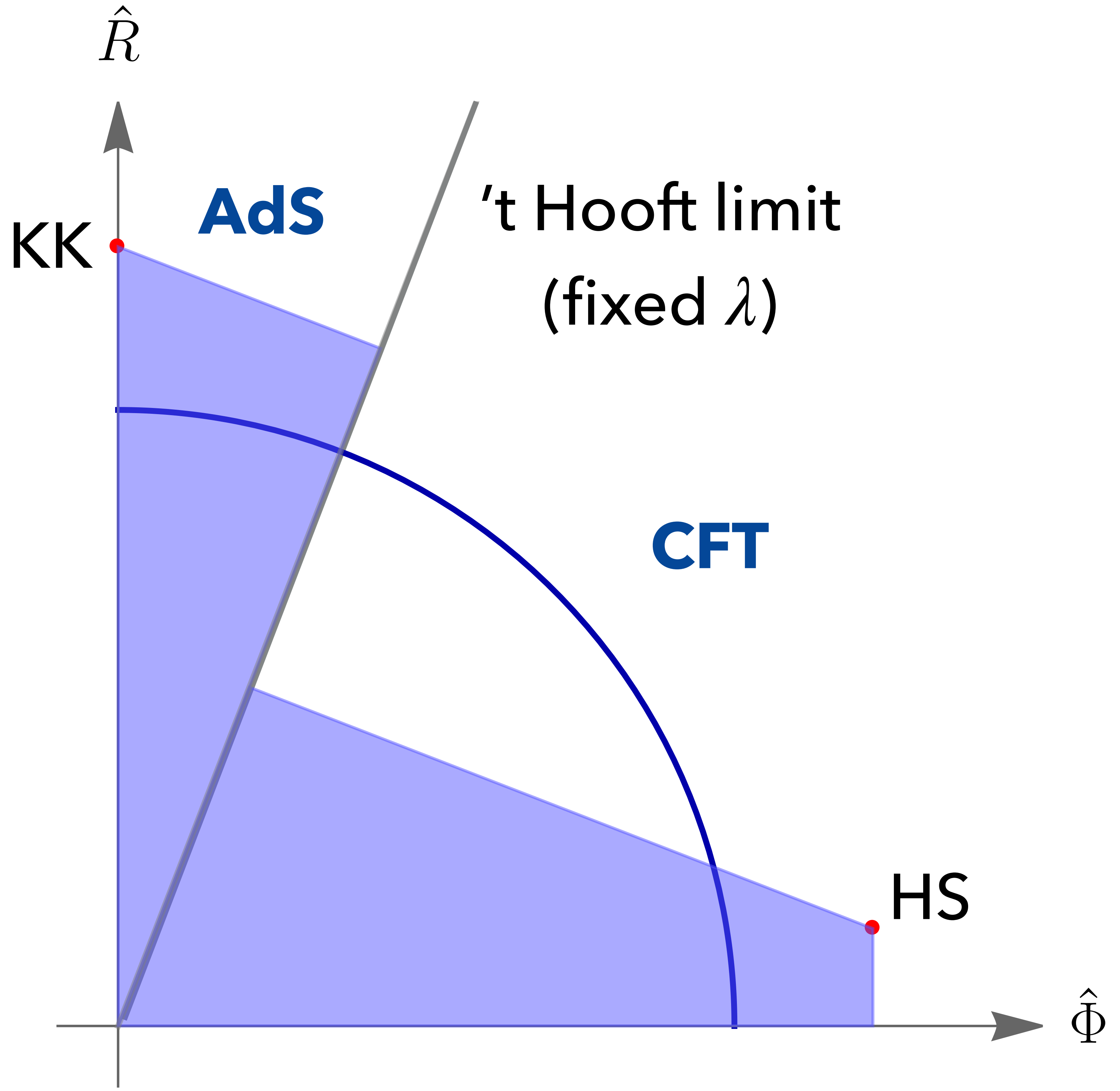
Long story short

Anti-separation of scales: $\beta > 1/2 \to M_{KK} \ll R_{AdS}^{-1}$



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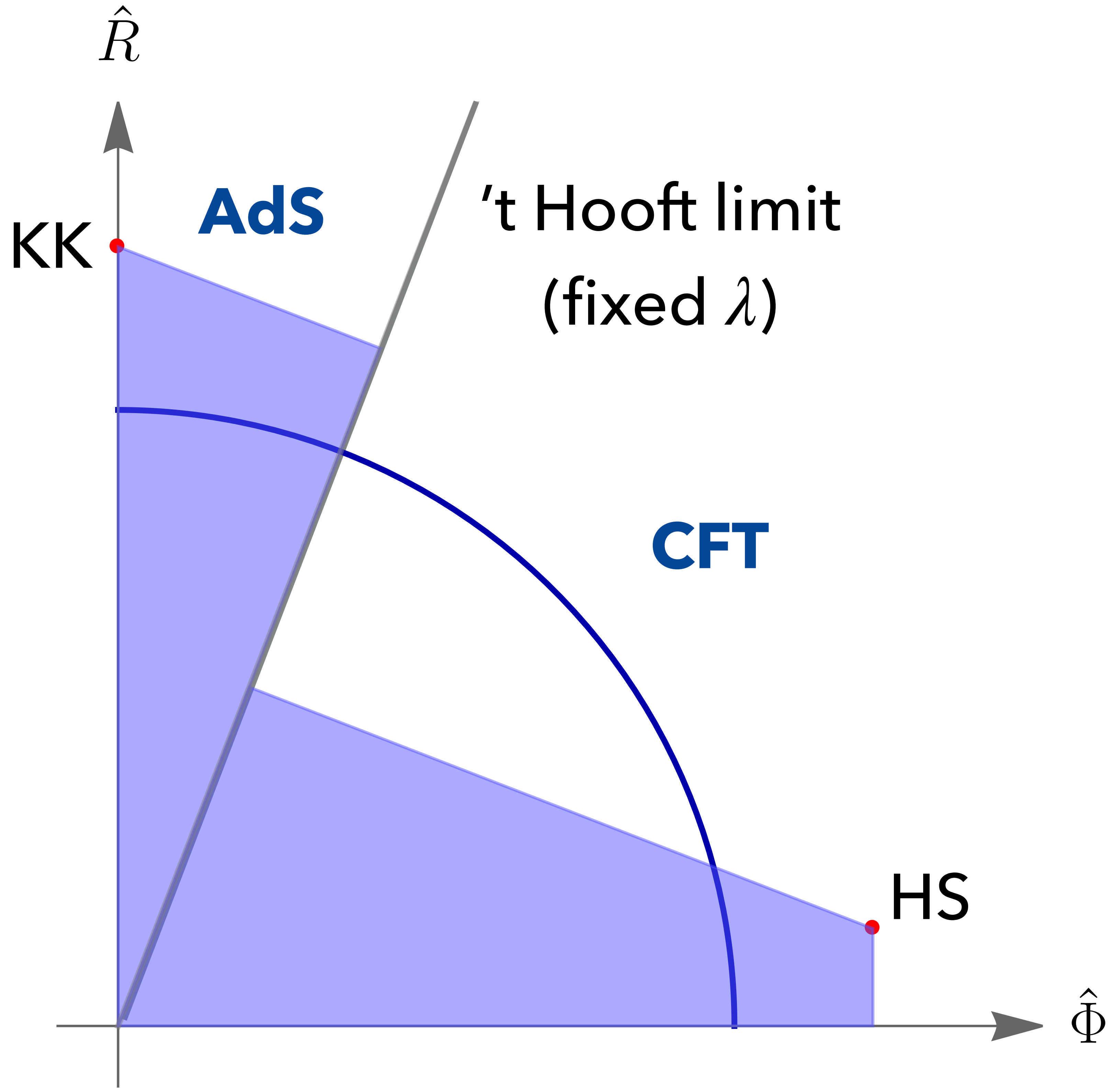

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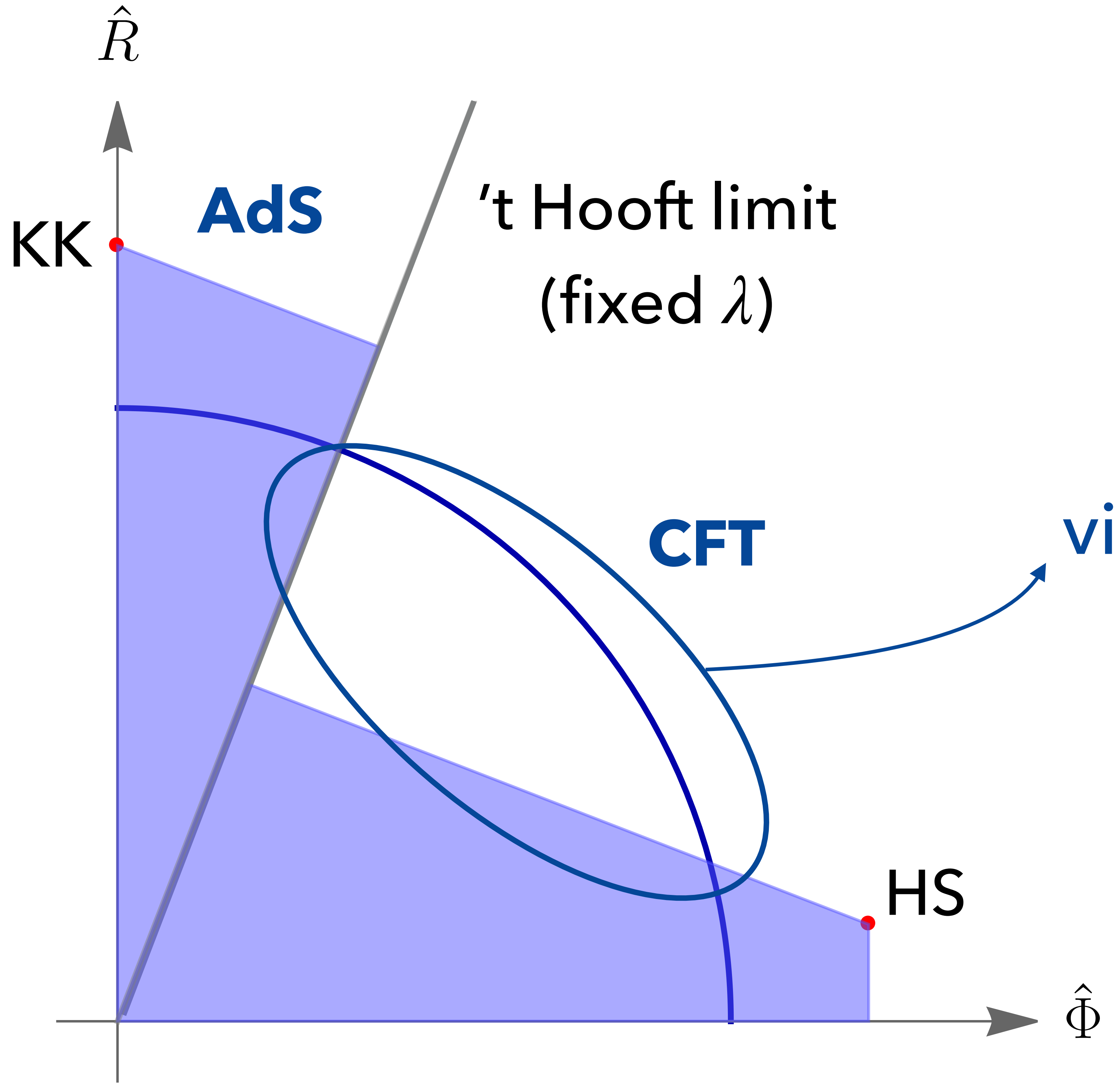

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Sharpened SDC violation in the CFT !

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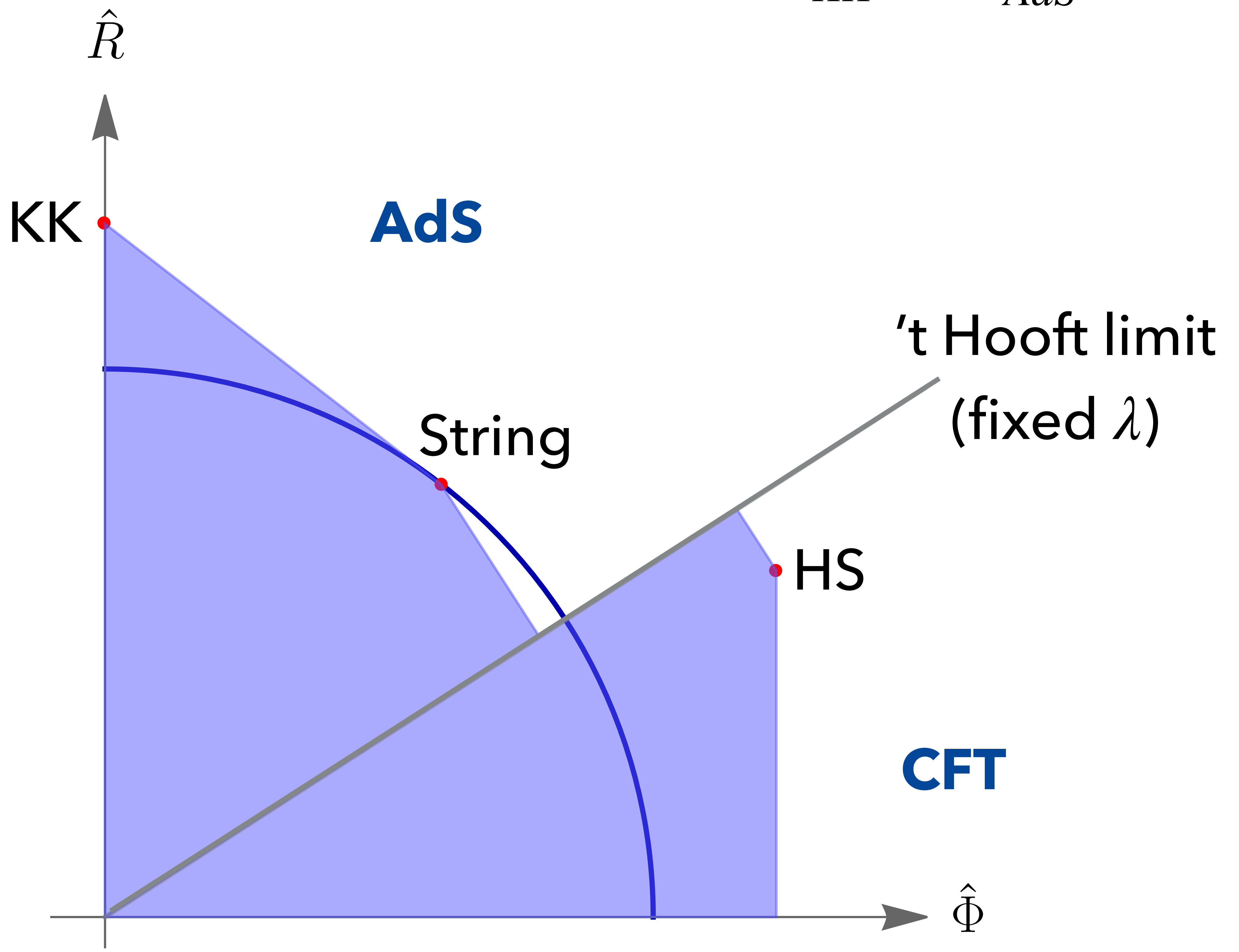

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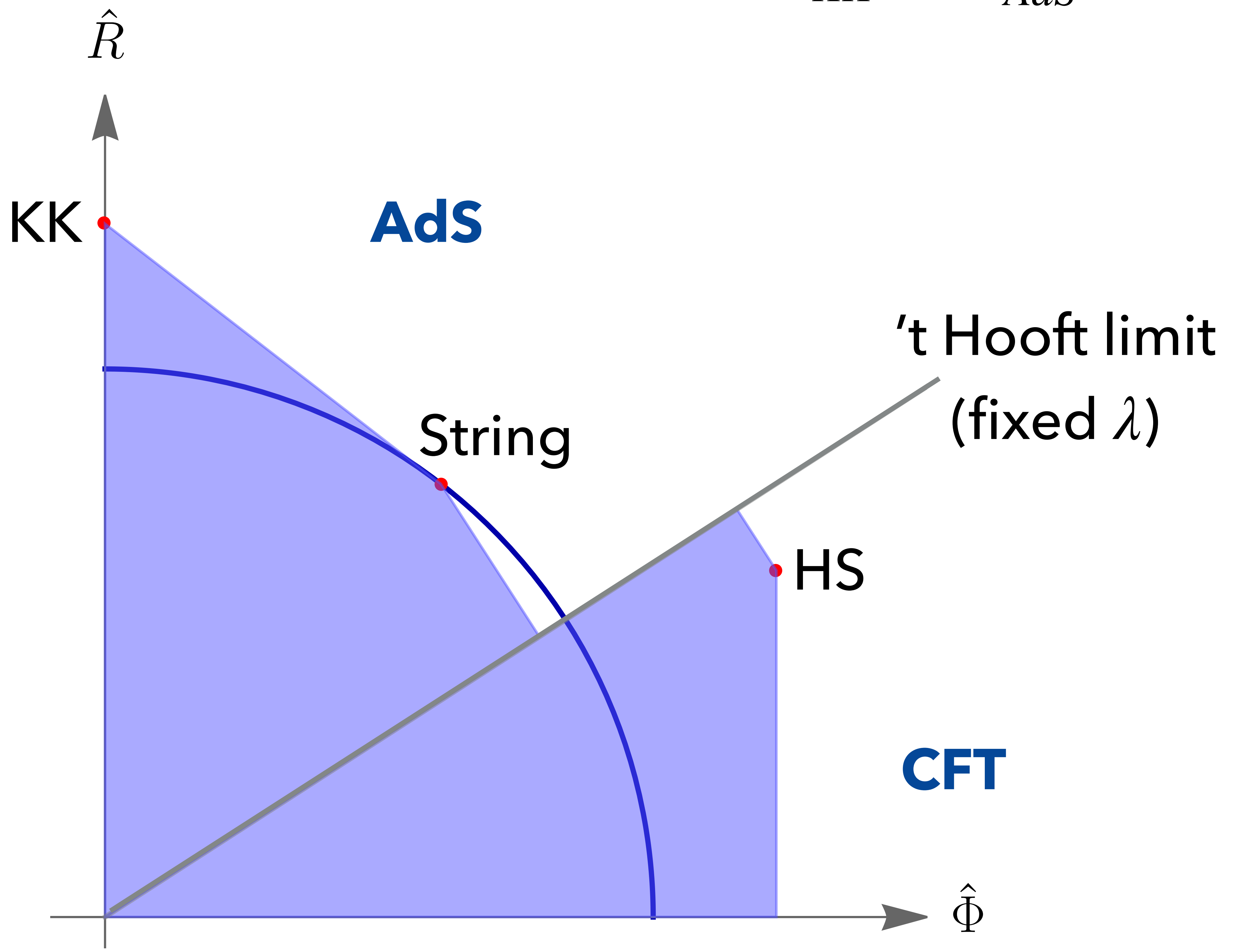

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Long story short

Separation of scales: $\beta < 1/2 \to M_{KK} \gg R_{AdS}^{-1}$

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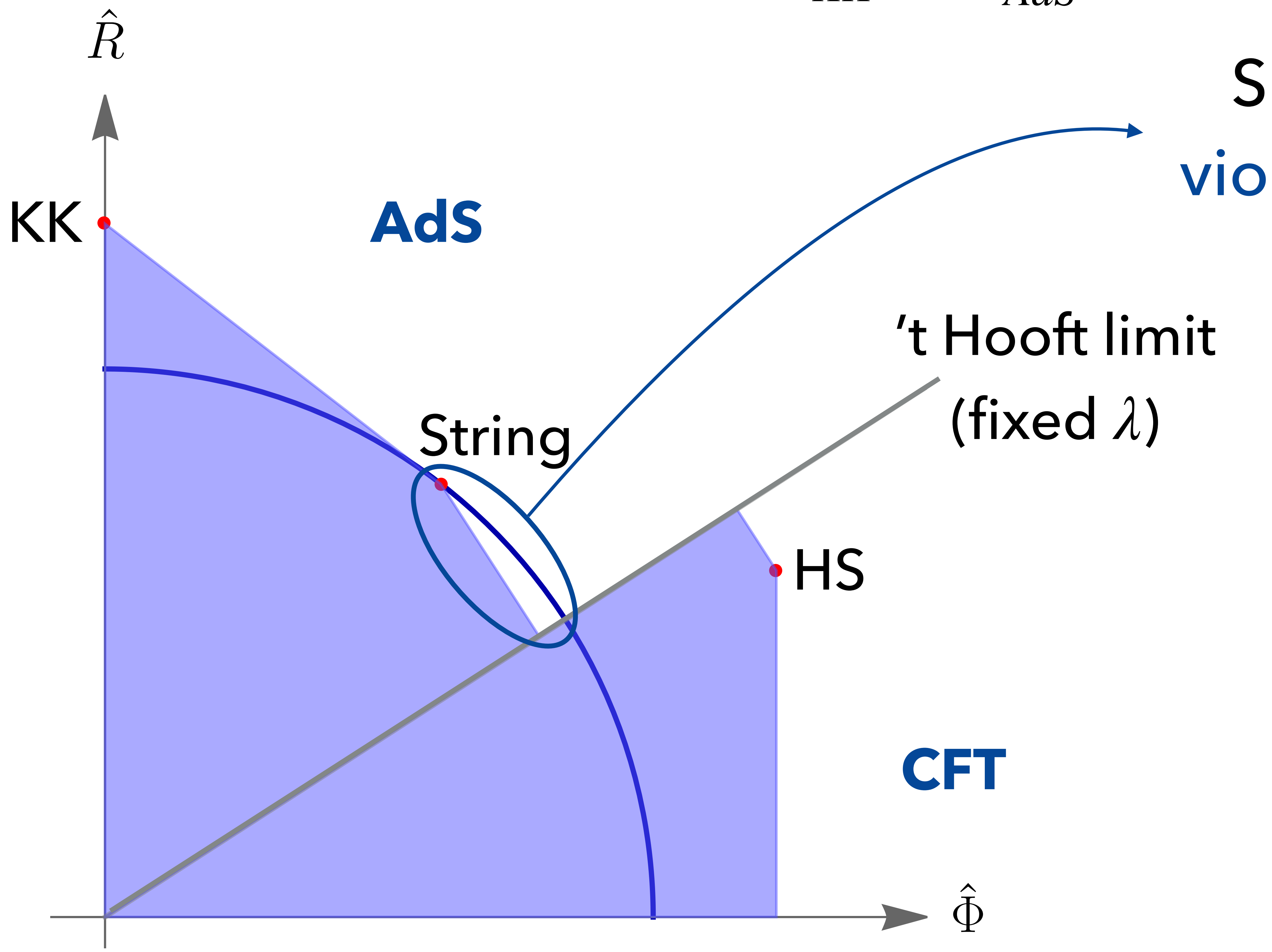

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A Detour: Scale Separation vs Sharpened SDC

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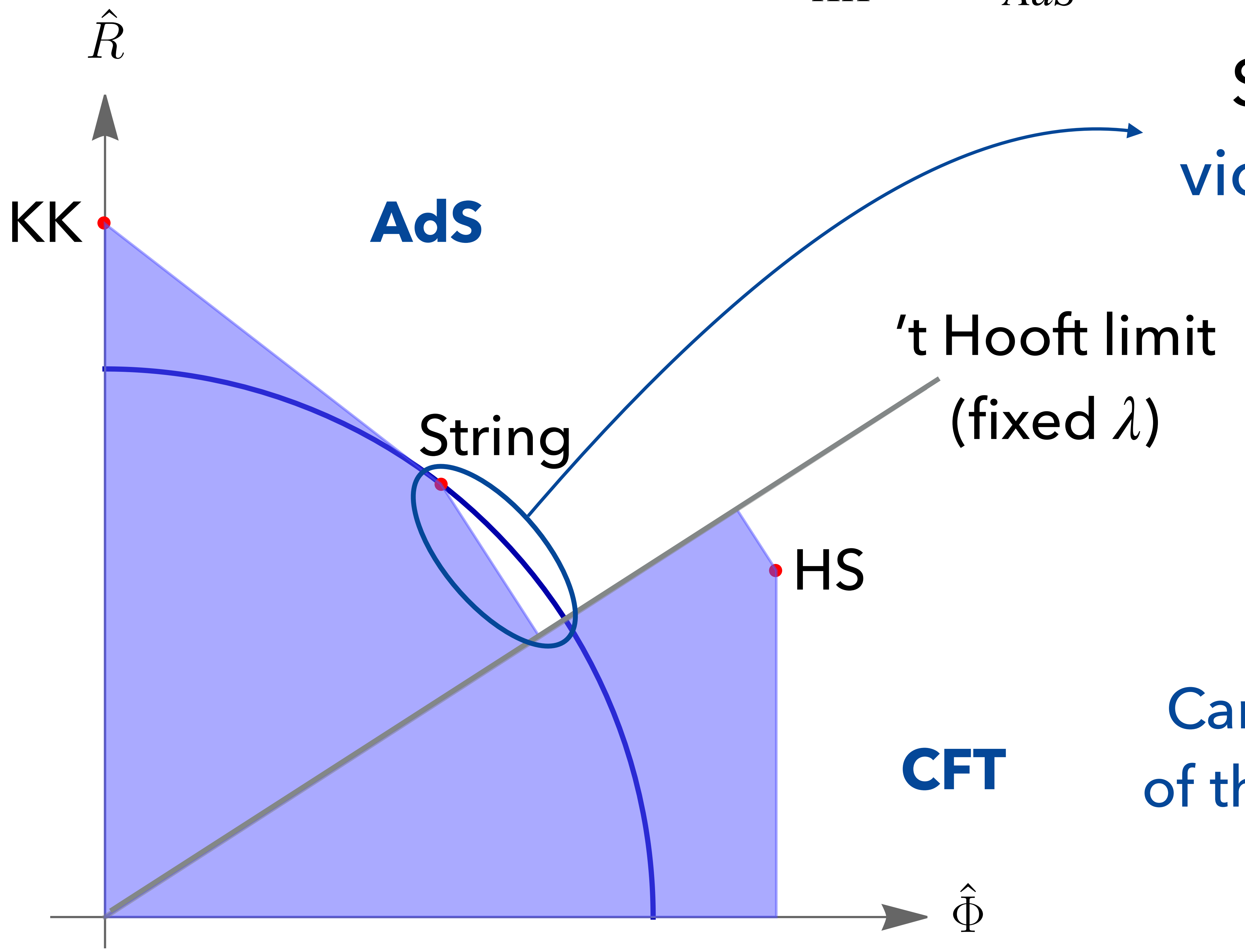

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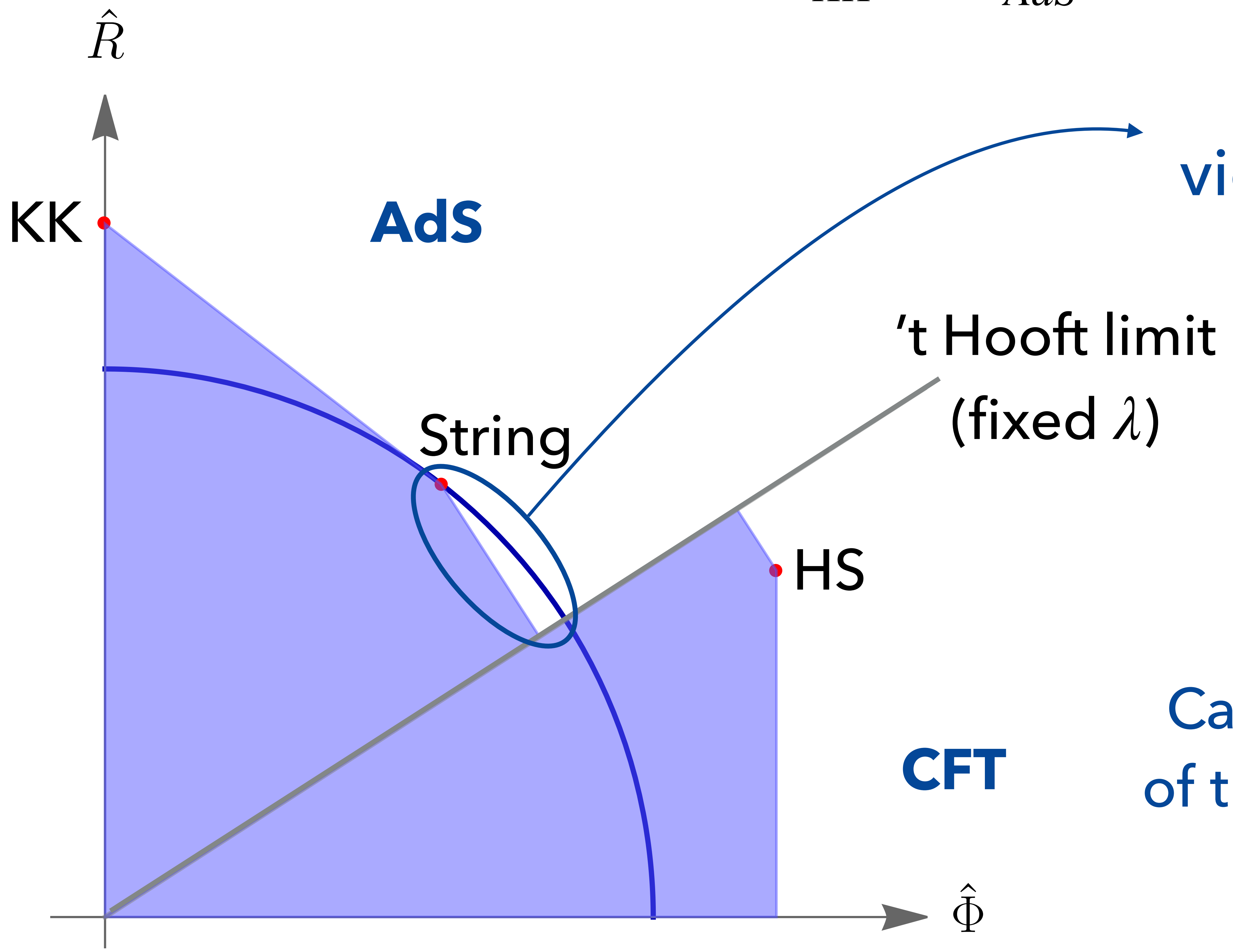
Link between Sharpened SDC and no scale separation



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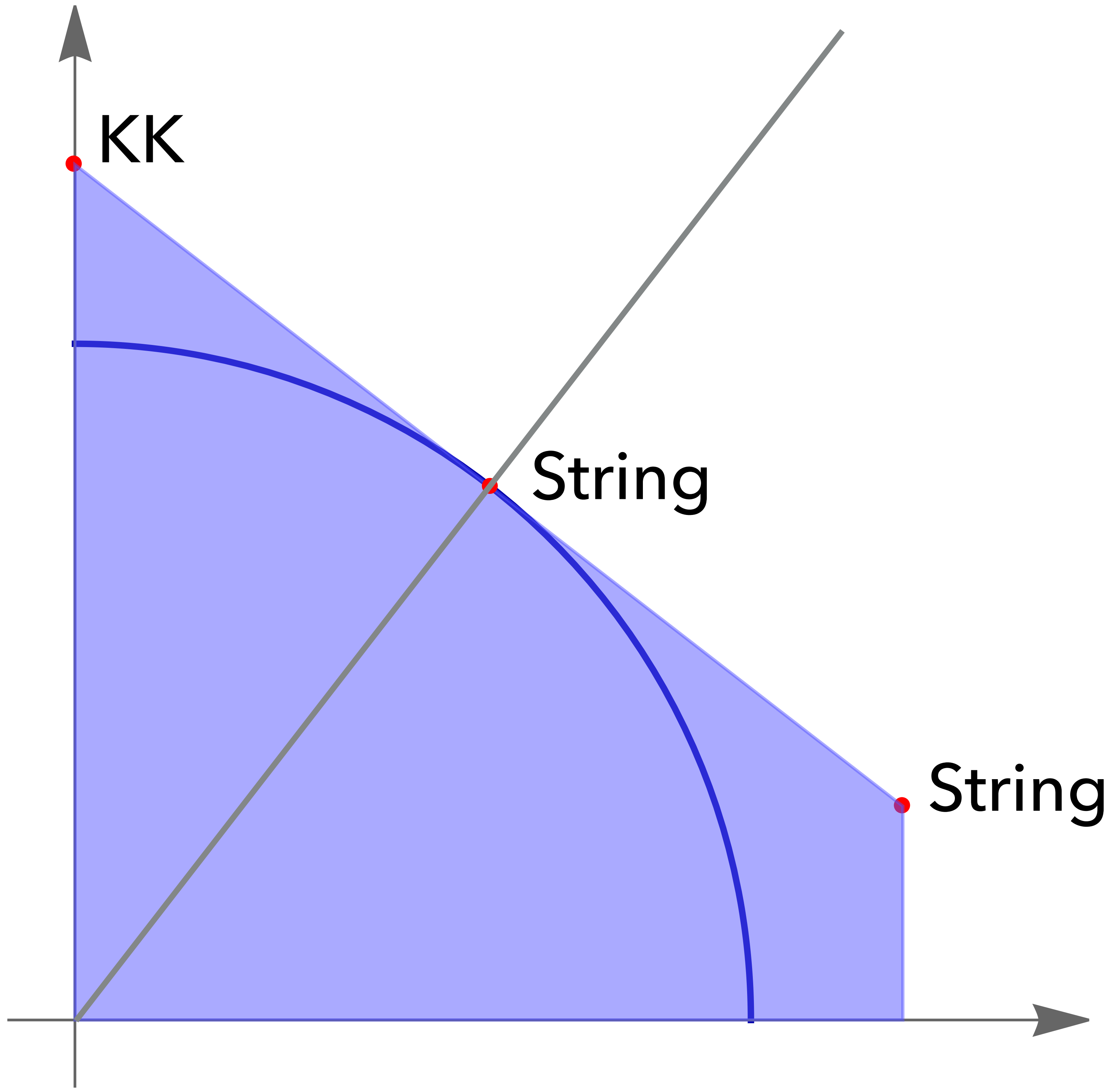

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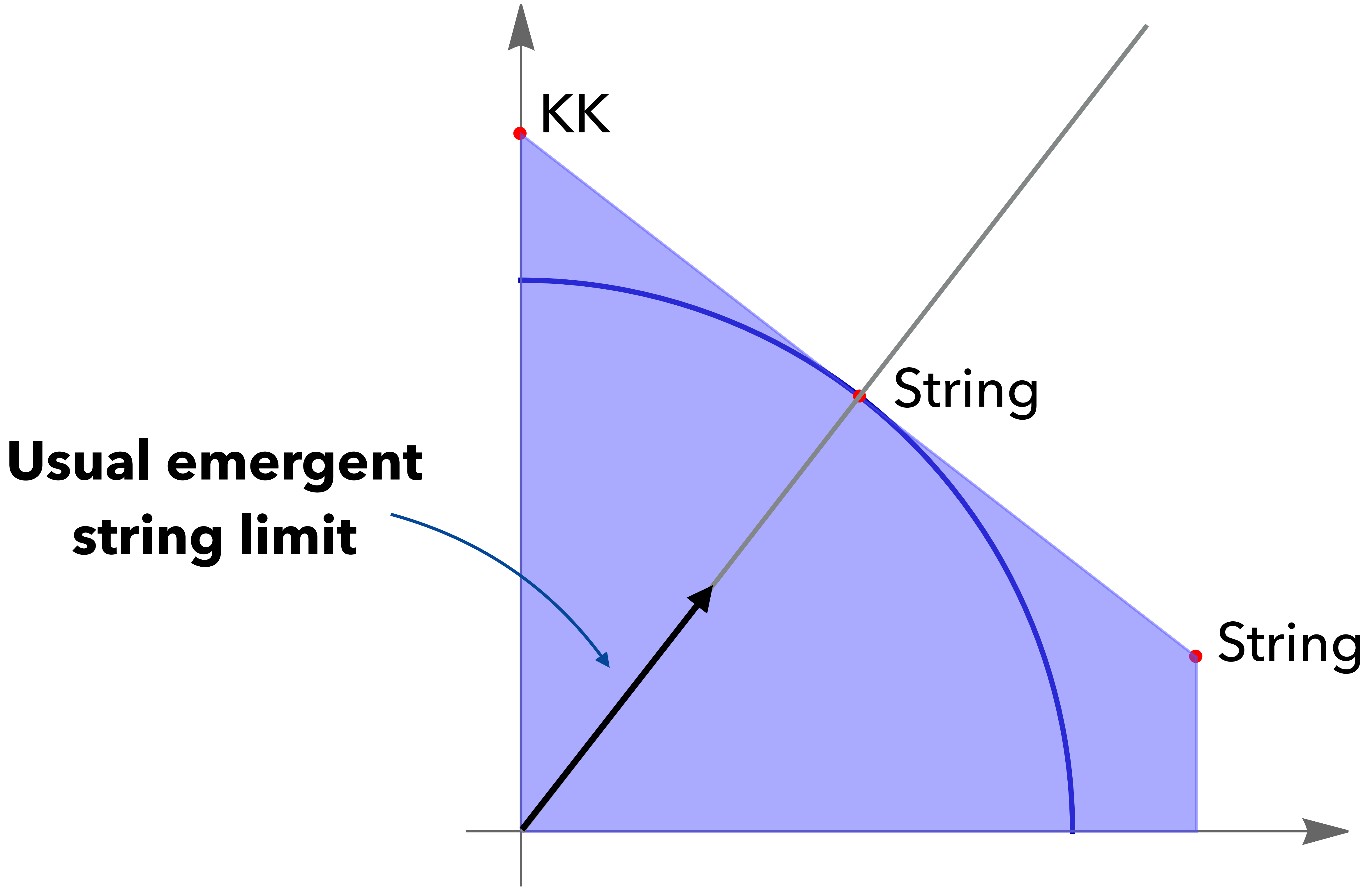

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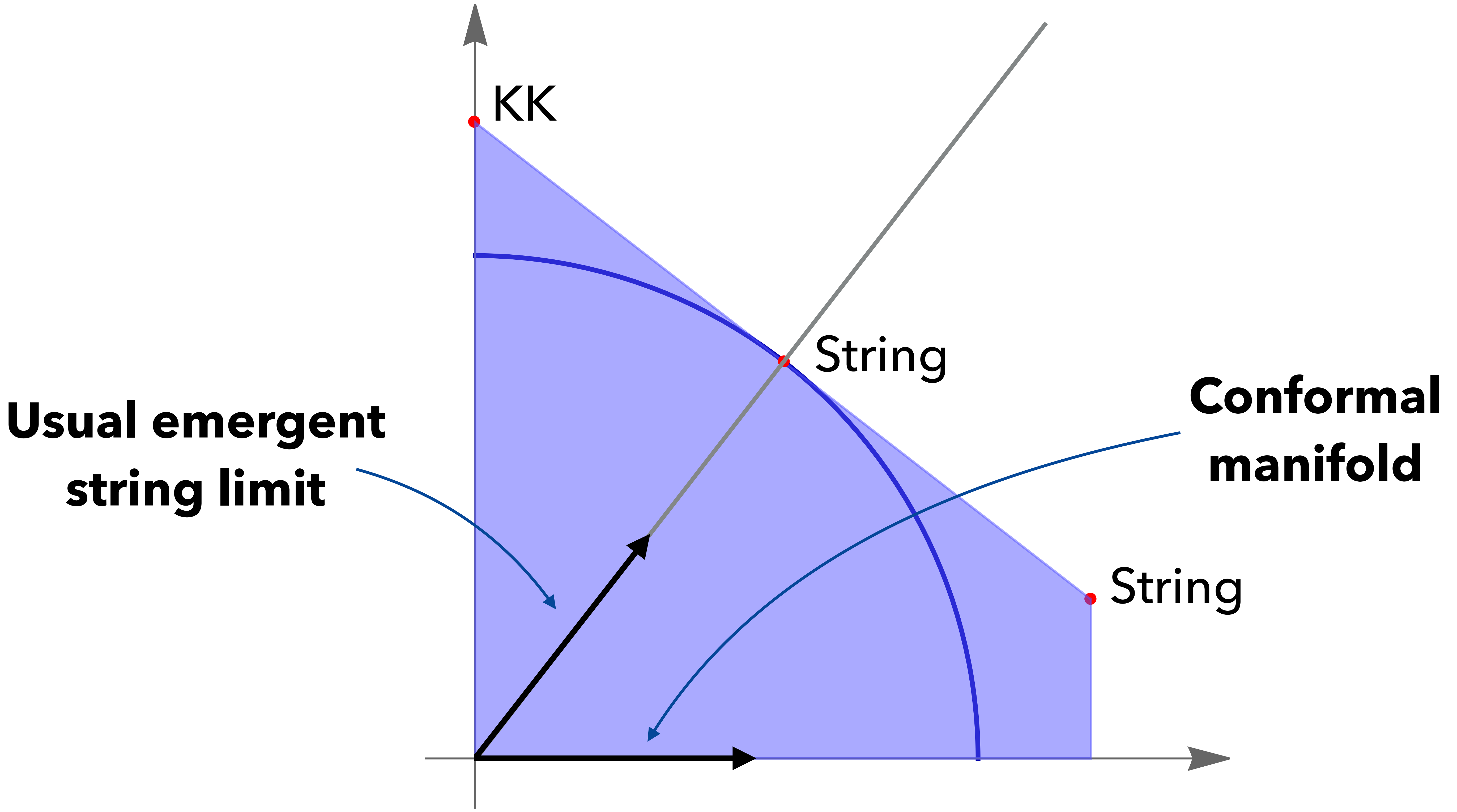

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$\boxed{M_s \sim T_s R_{AdS}}$ Universal? Food for thought!

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Only theories with $\alpha = \dfrac{1}{\sqrt{2}}$ have Einstein gravity duals!

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$n_F(\alpha)$ ➡ **Hagedorn condition:** $\boxed{z_V(T_H) + 3\left(3 - 4\alpha^2\right) z_\Phi(T_H) = 1}$ Only depends on α!

Same as for SU(N)!

Expectation (magically) confirmed ✓

CFT Distances vs Hagedorn Temperature

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Preliminary result!

Hagedorn condition: $$\boxed{z_V(T_H) + 3\left(3 - 4\alpha^2\right) z_\Phi(T_H) + \frac{1}{2} z_\Phi^2 = 1}$$ **Still works**

Stay tuned!

Bonus Track: A New AdS String from Top-down?

Setup: $\mathrm{AdS}_5 \times \mathrm{S}^5/\mathrm{Z}_k \leftrightarrow \mathcal{N} = 2$ necklace quivers

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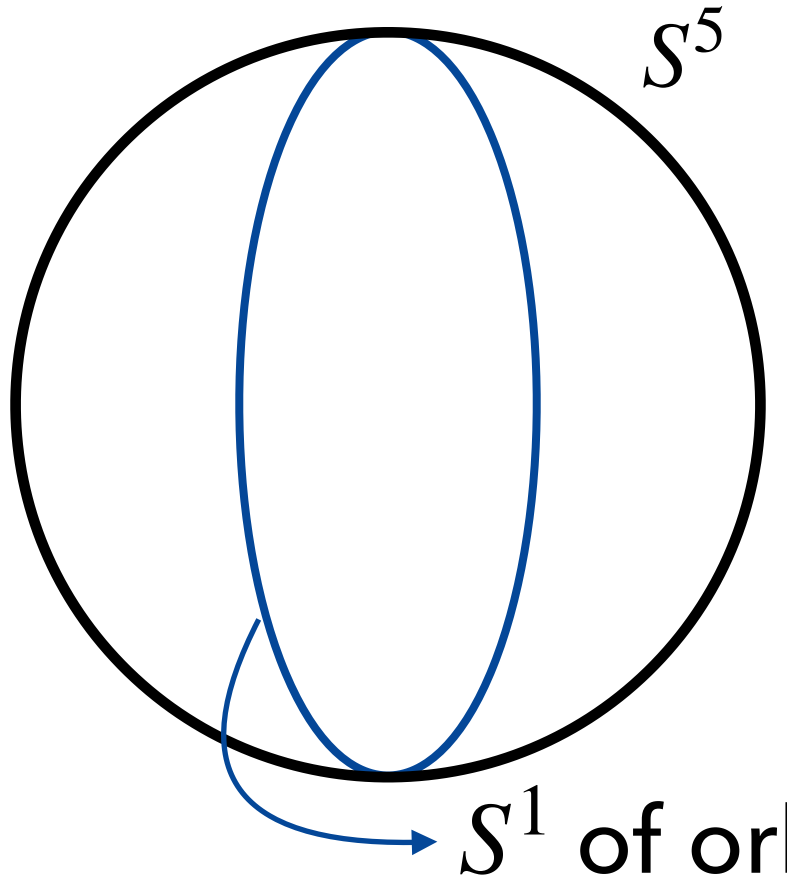

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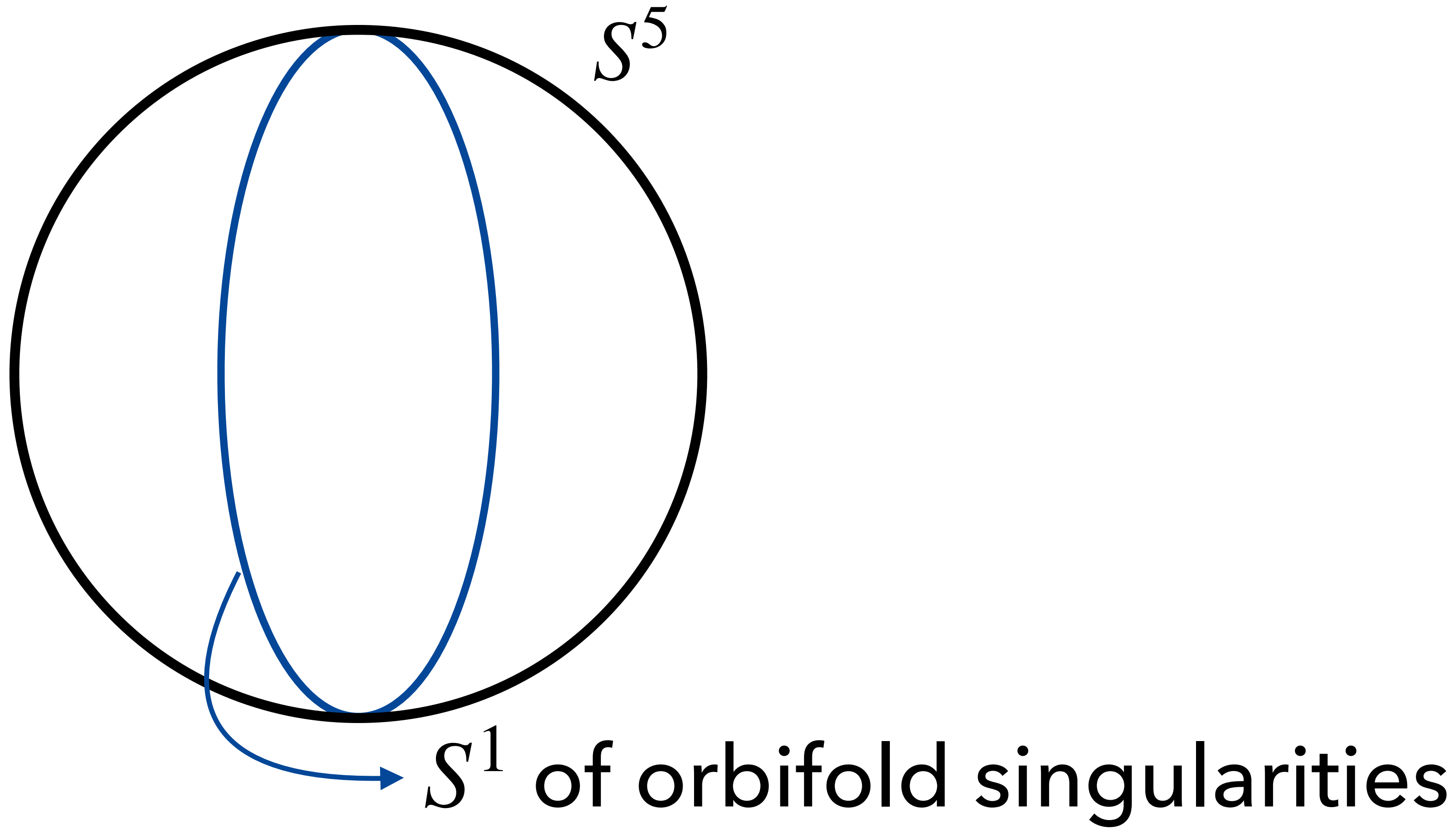

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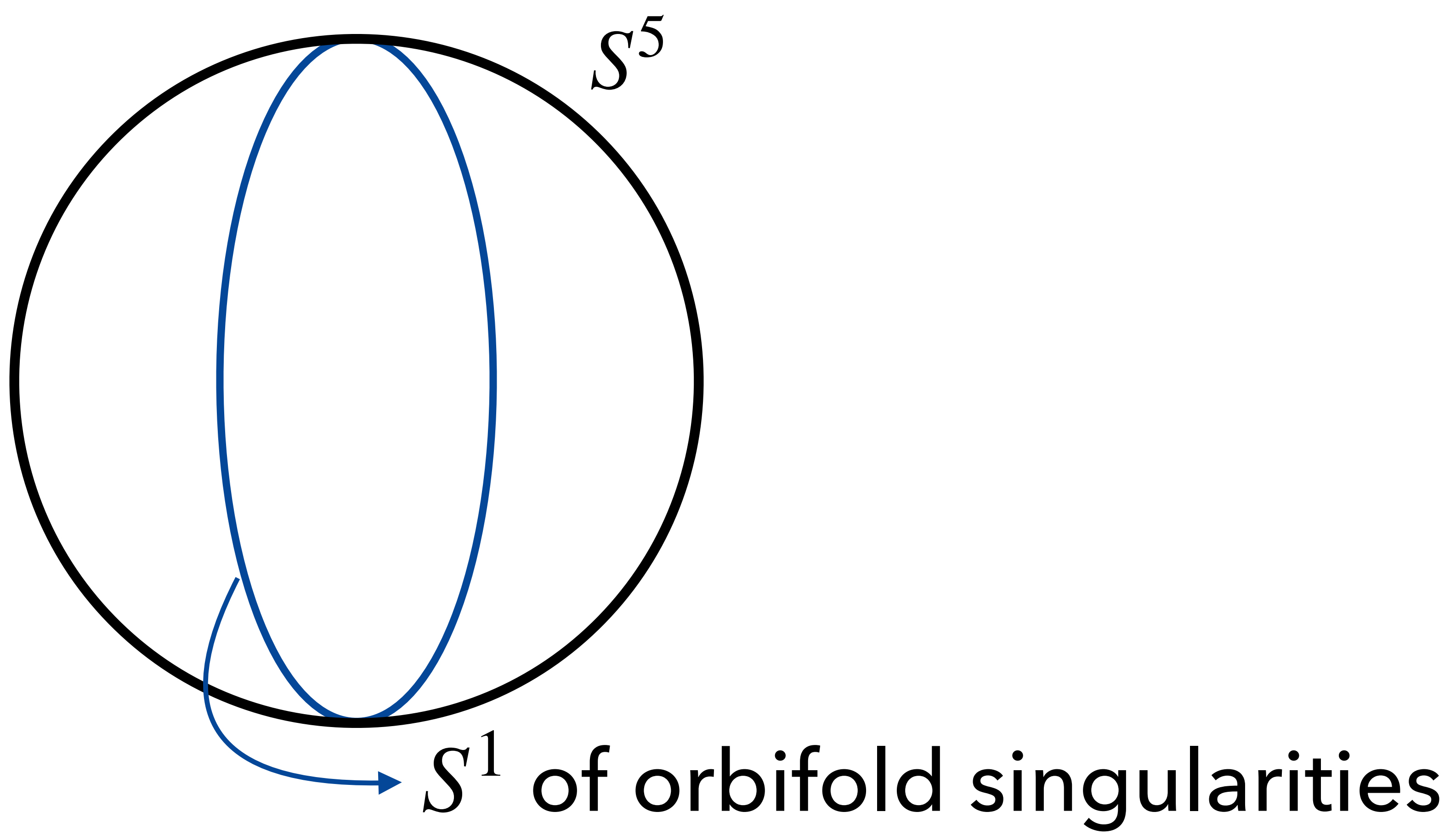

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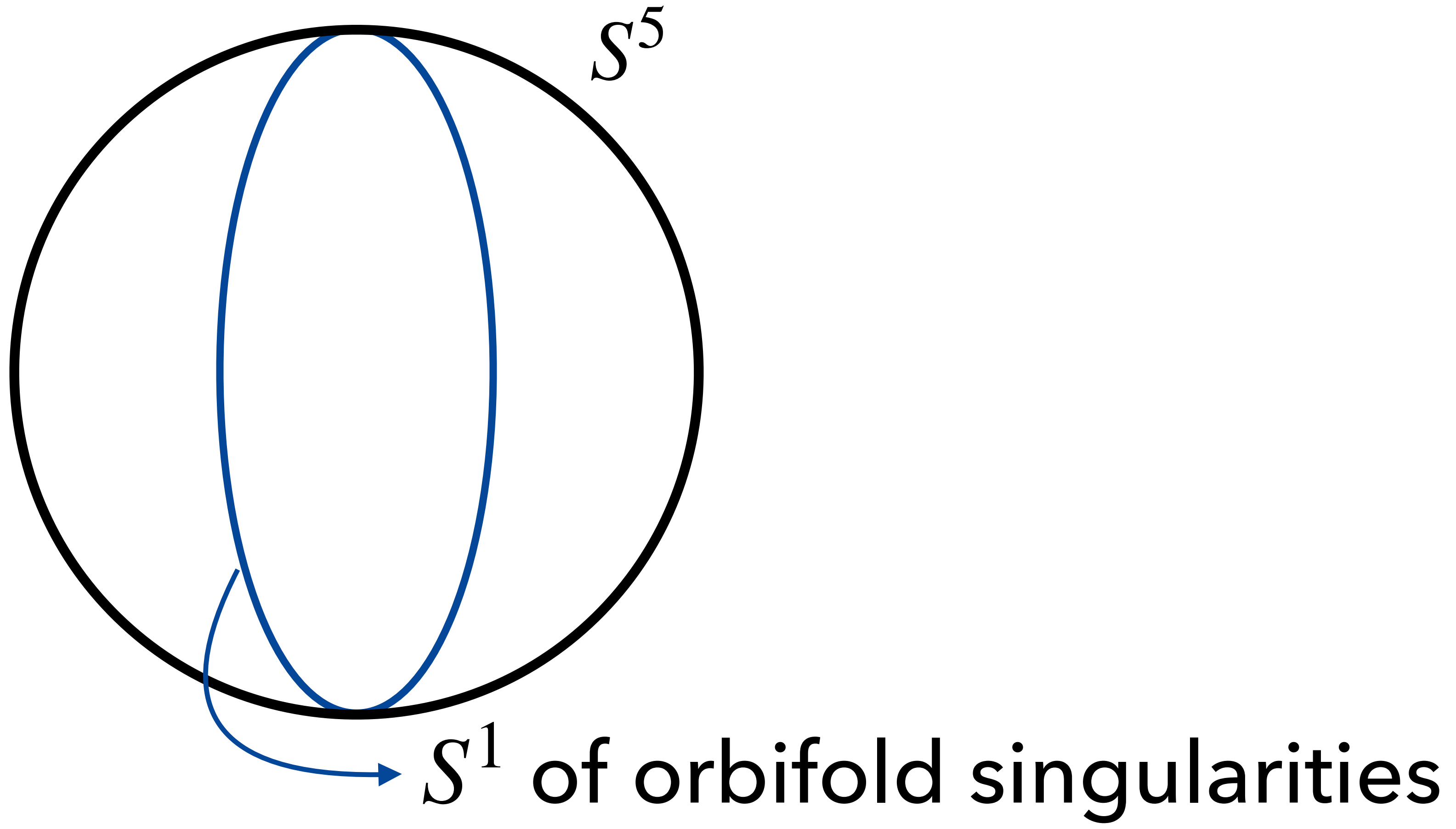

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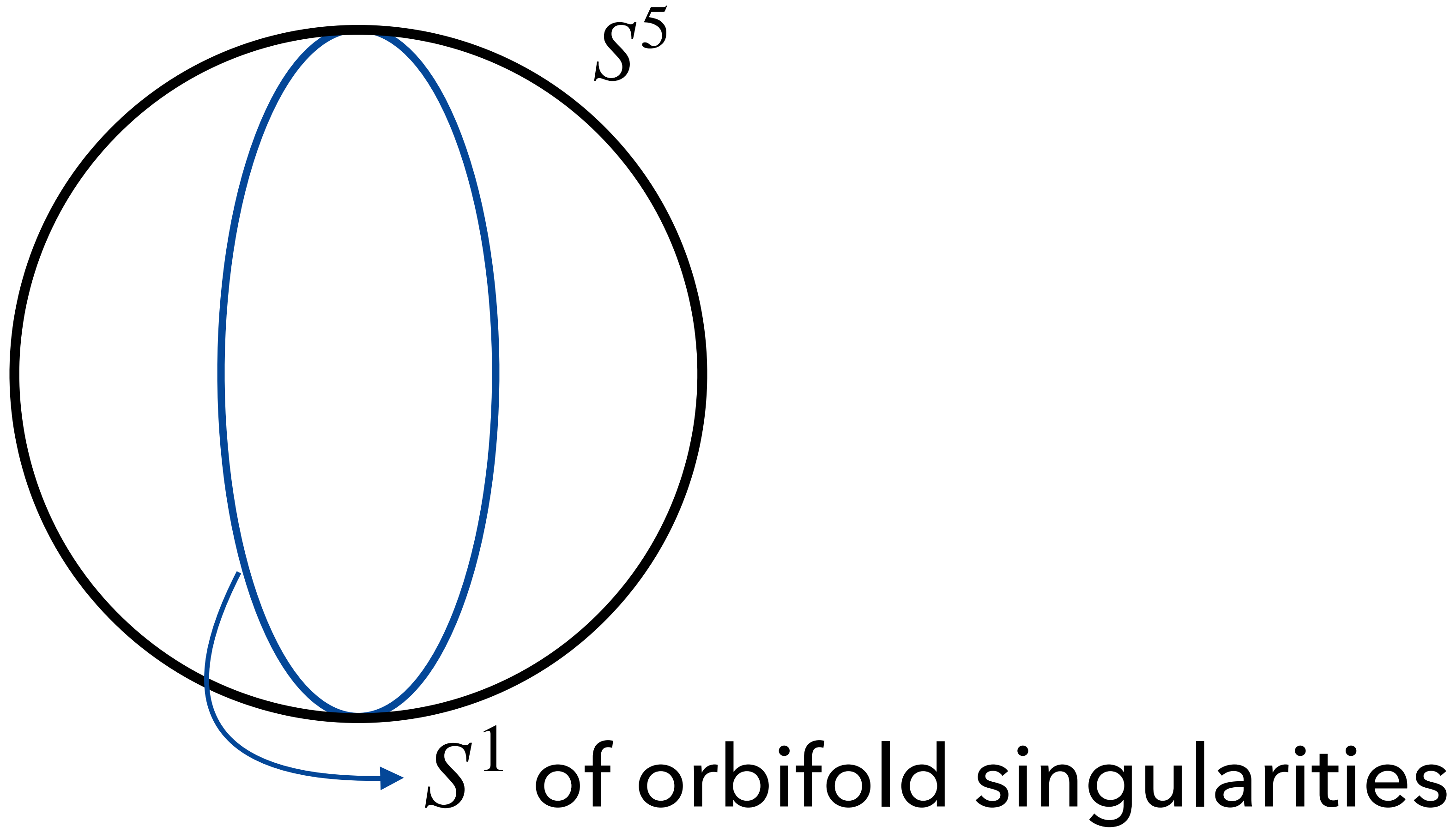

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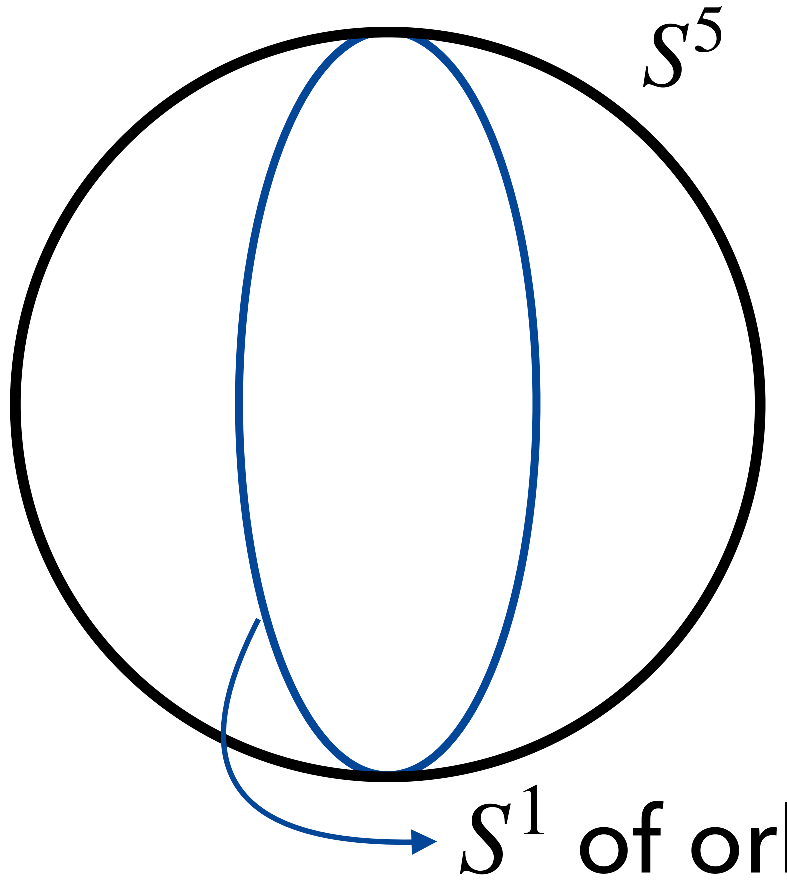

S^1 of orbifold singularities

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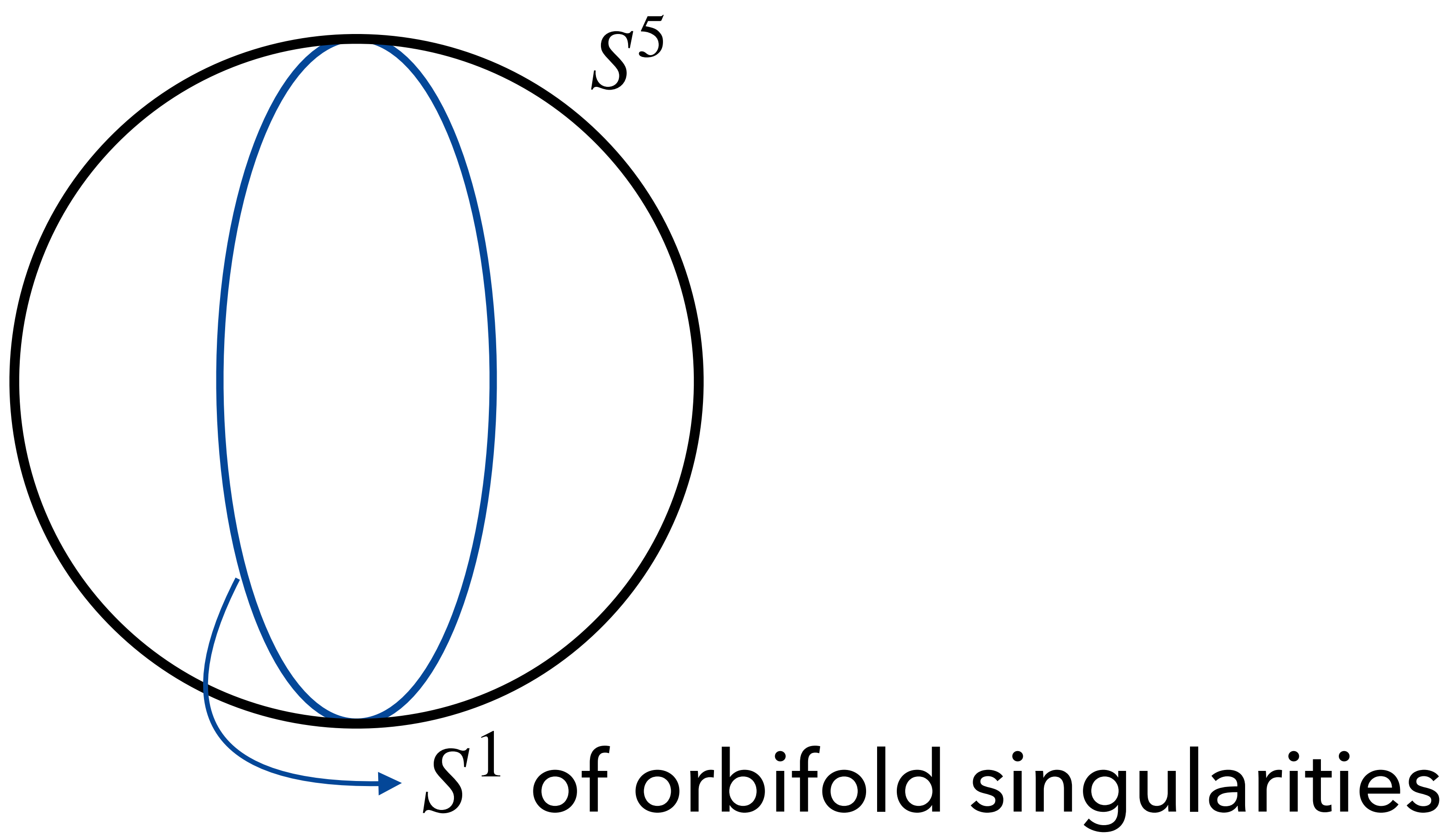

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String propagating in $\mathrm{AdS}_5 \times \mathrm{S}^1$**!** Candidate for new emergent string in AdS**?** [Baume, JCI '20]

Conclusions and More Questions

There is much to learn about/from the Distance Conjecture in AdS/CFT !

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Thank you for your attention!