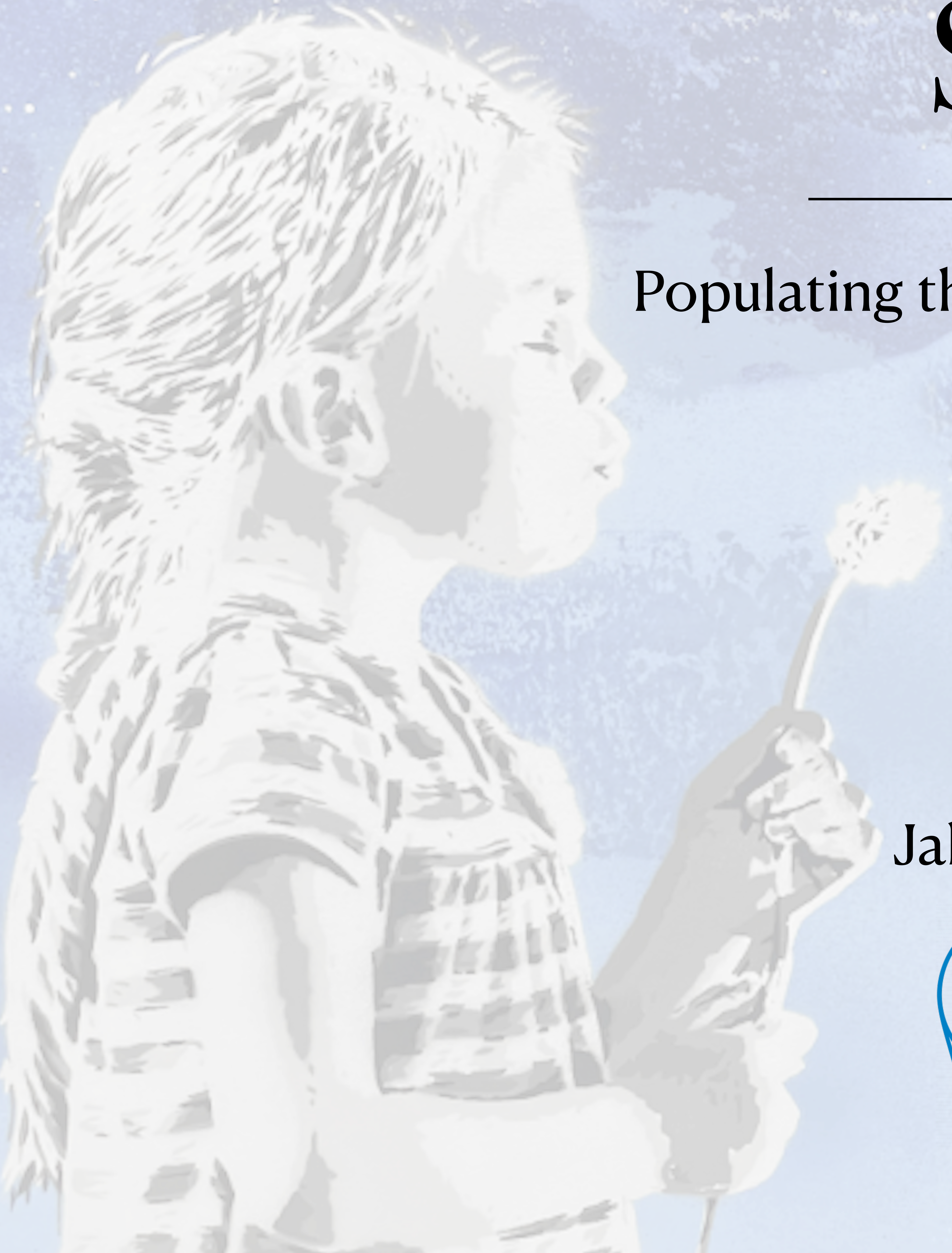
Stop at Nothing

Populating the flux landscape with colliding bubbles of nothing

based on upcoming work with Irene Valenzuela



Jakob Moritz

CERN

06/24/2024 at String Phenomenology 2024

24-28 JUNE 2024
PADOVA, ITALY

upshot of this talk:

A new mechanism that dynamically populates the flux landscape via “spontaneous compactification” upshot of this talk:

A new mechanism that dynamically populates the flux landscape via "spontaneous compactification"

aspirational application: an alternative inflationary scenario, with similarities to slow roll inflation.

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2. Witten's bubble of "nothing"
3. Bubbles of nothing with flux
4. Spontaneous compactification from higher dimensional Minkowski vacua
5. Populating the Calabi-Yau flux landscape
6. Conclusions

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McAllister, JM, Schachner, Nally '24

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Another complementary approach, that I will follow in this talk, is to study dynamical transitions between different vacua.

(or even between the empty set and non-trivial vacua!)

In this way, one might hope to address deep questions in Quantum Gravity, such as the nature of the cosmological measure, and the birth of our universe...

A great many ideas have been proposed in this context:

Hartle, Hawking ’83
...
Horowitz, Maeda ‘02
Blanco-Pillado, Schwartz-Perlov, Vilenkin ’09 (2x)
Carroll, Johnson, Randall ‘09
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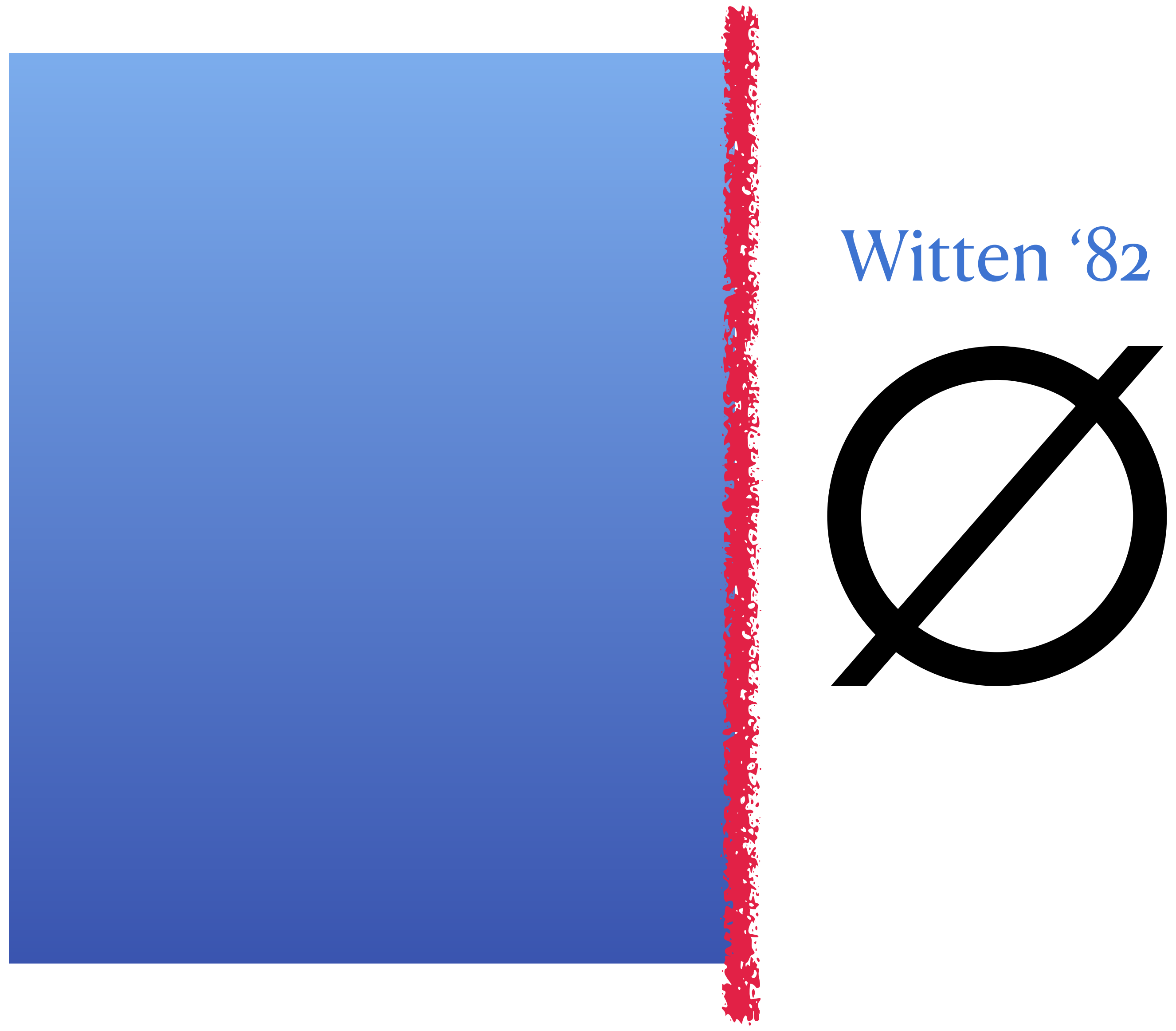
McNamara, Vafa '19

one between a physical vacuum and the empty set!



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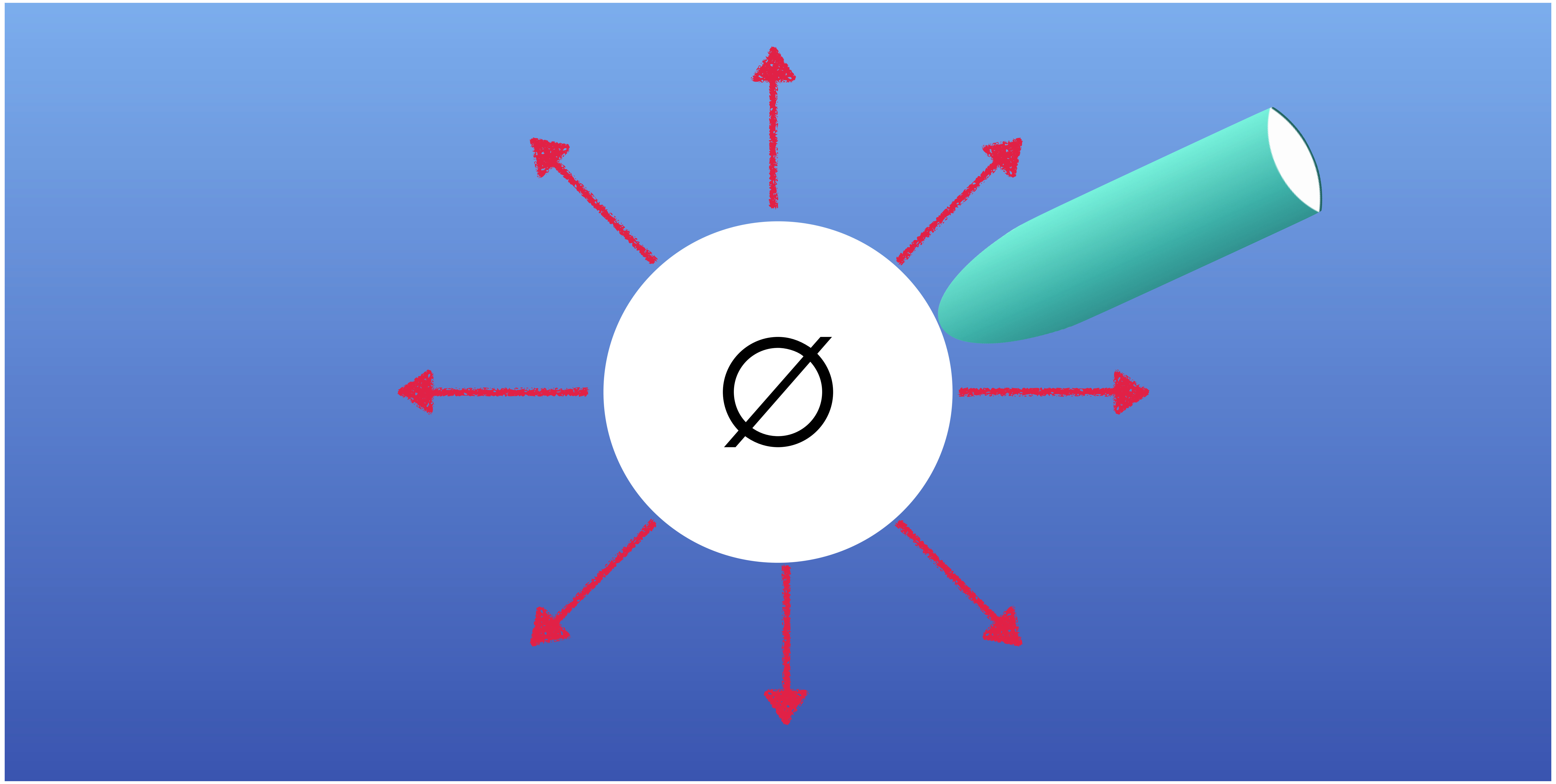
Witten's instanton describes the instability of a simple circle compactification against forming an expanding hole in spacetime:

Witten '82



The spacetime metric is an analytic continuation of the Schwarzschild black hole:

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In Minkowskian signature, the bubble forms with critical radius, and uniformly accelerates toward the speed of light. The induced metric on an expanding bubble is that of de Sitter space.

$$d\Omega_{D-2}^2 \to ds^2_{\text{de Sitter}} = -dt^2 + \cosh(t)^2 d\Omega_{D-3}^2$$

There is a constant rate per unit volume to nucleate such bubbles,

$$\Gamma \propto e^{-B}$$

in terms of a bounce action $$B = \frac{8\pi^2 \mathrm{Vol}(S^{D-2})}{D-3} \left(\frac{R_c}{\ell_P}\right)^{D-2},$$

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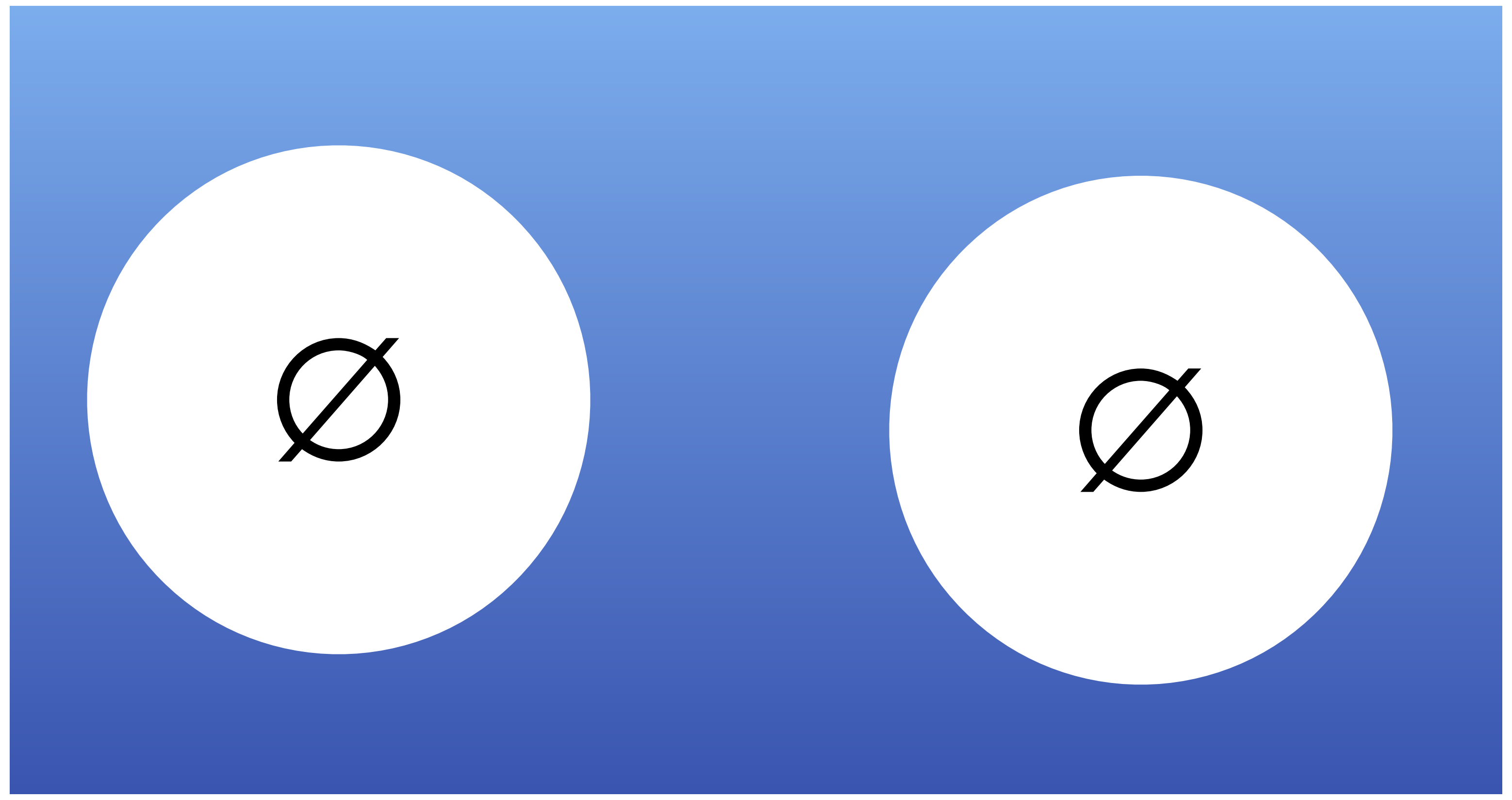

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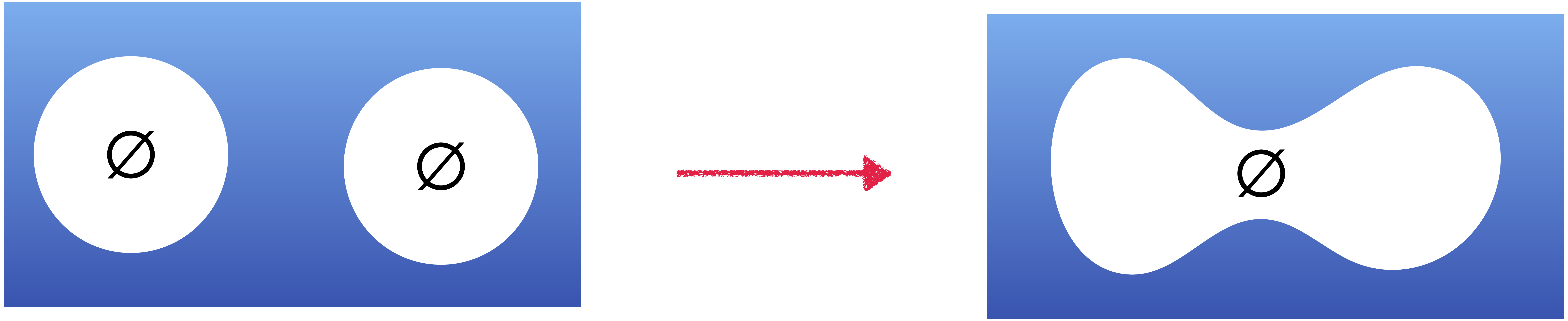

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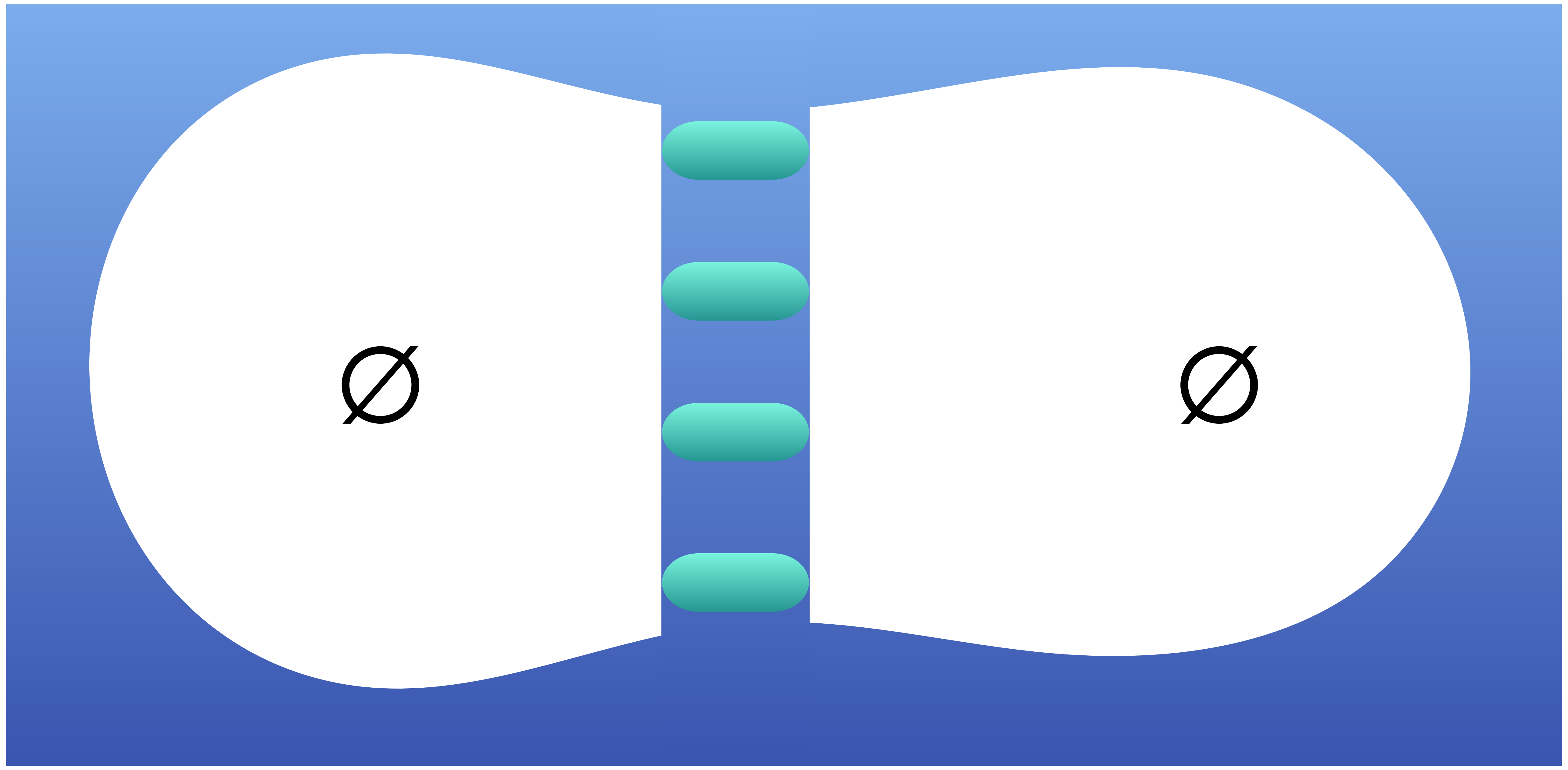

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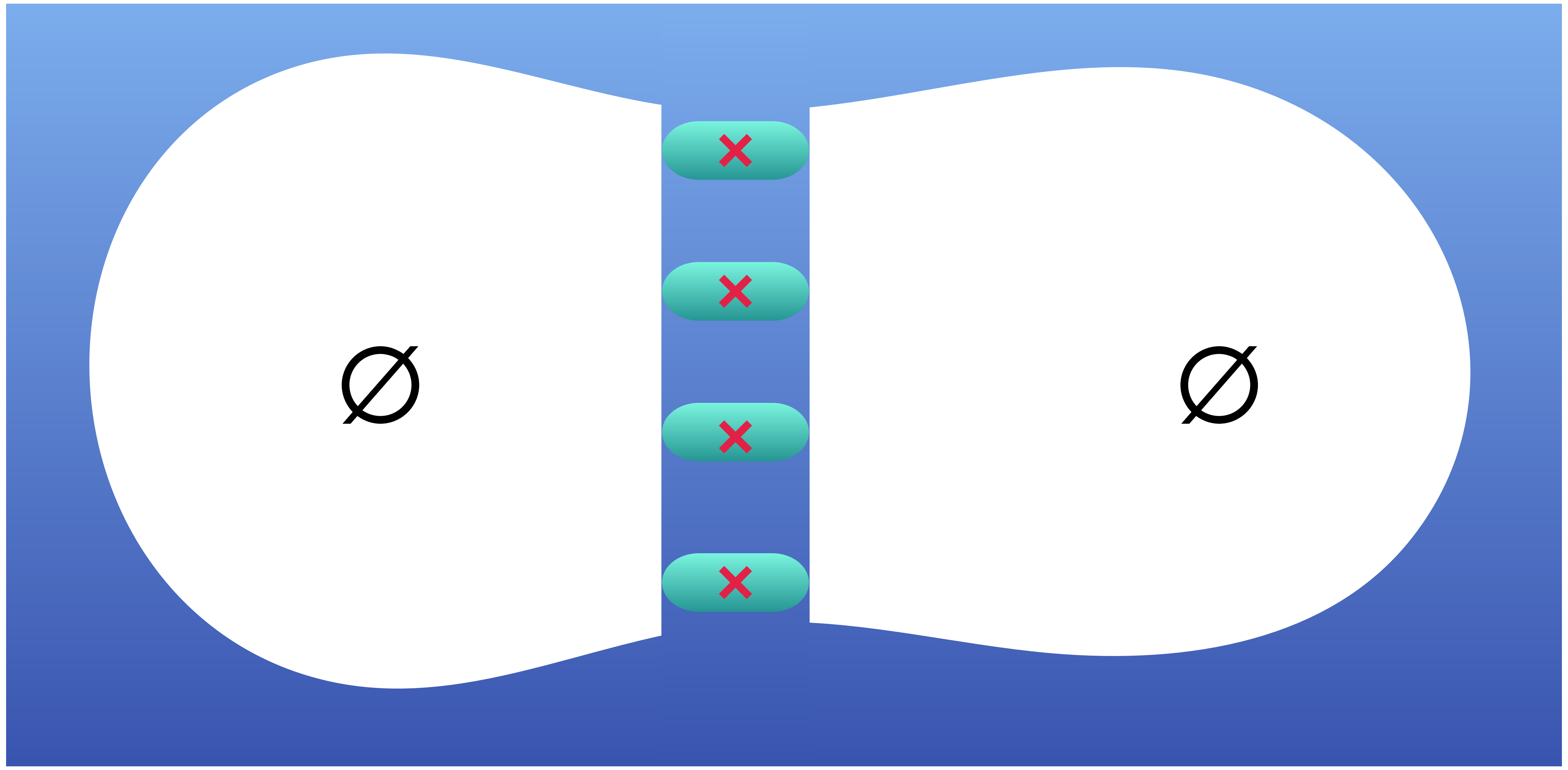

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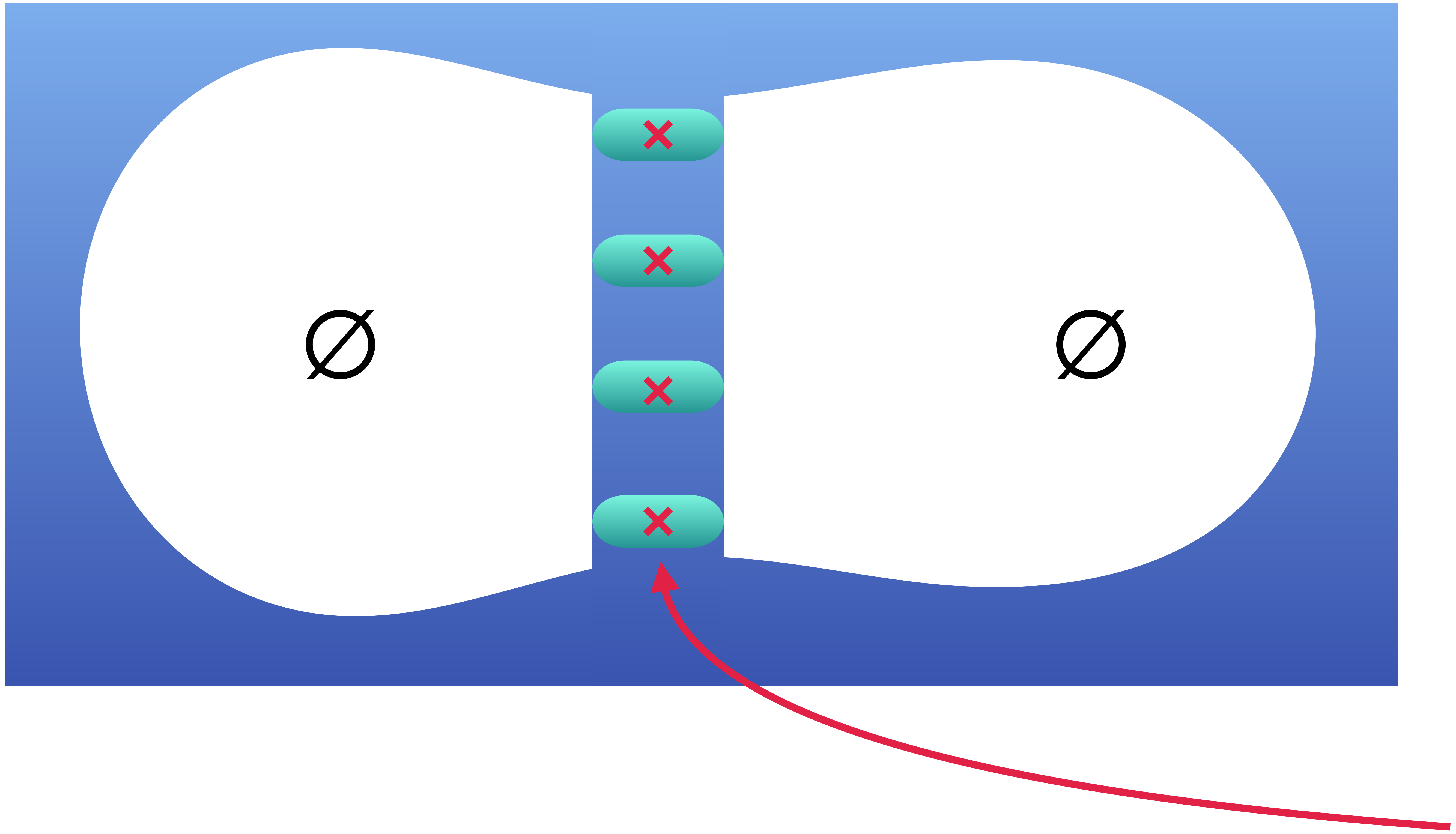

The space bounded by merging bubbles of nothing is a sphere.
We know how to prevent a sphere from shrinking…

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As a simple toy example we consider Einstein Maxwell theory in D dimensions:

$$S = \int d^D x \sqrt{-g} \left(\frac{2\pi}{\ell_P^{D-2}} \mathcal{R} - \frac{1}{4e^2} F_{MN} F^{MN} \right)$$

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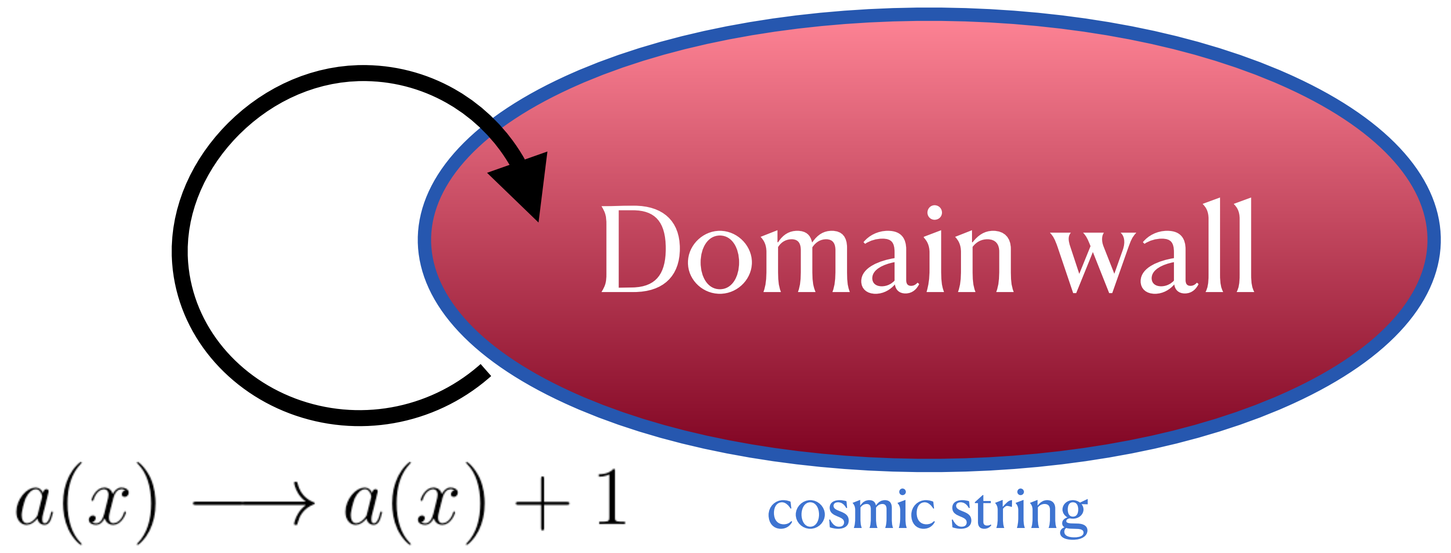
Such a vacuum naturally contains axion domain walls, bounded by cosmic strings:



An axion domain wall in D-1 dimensions is
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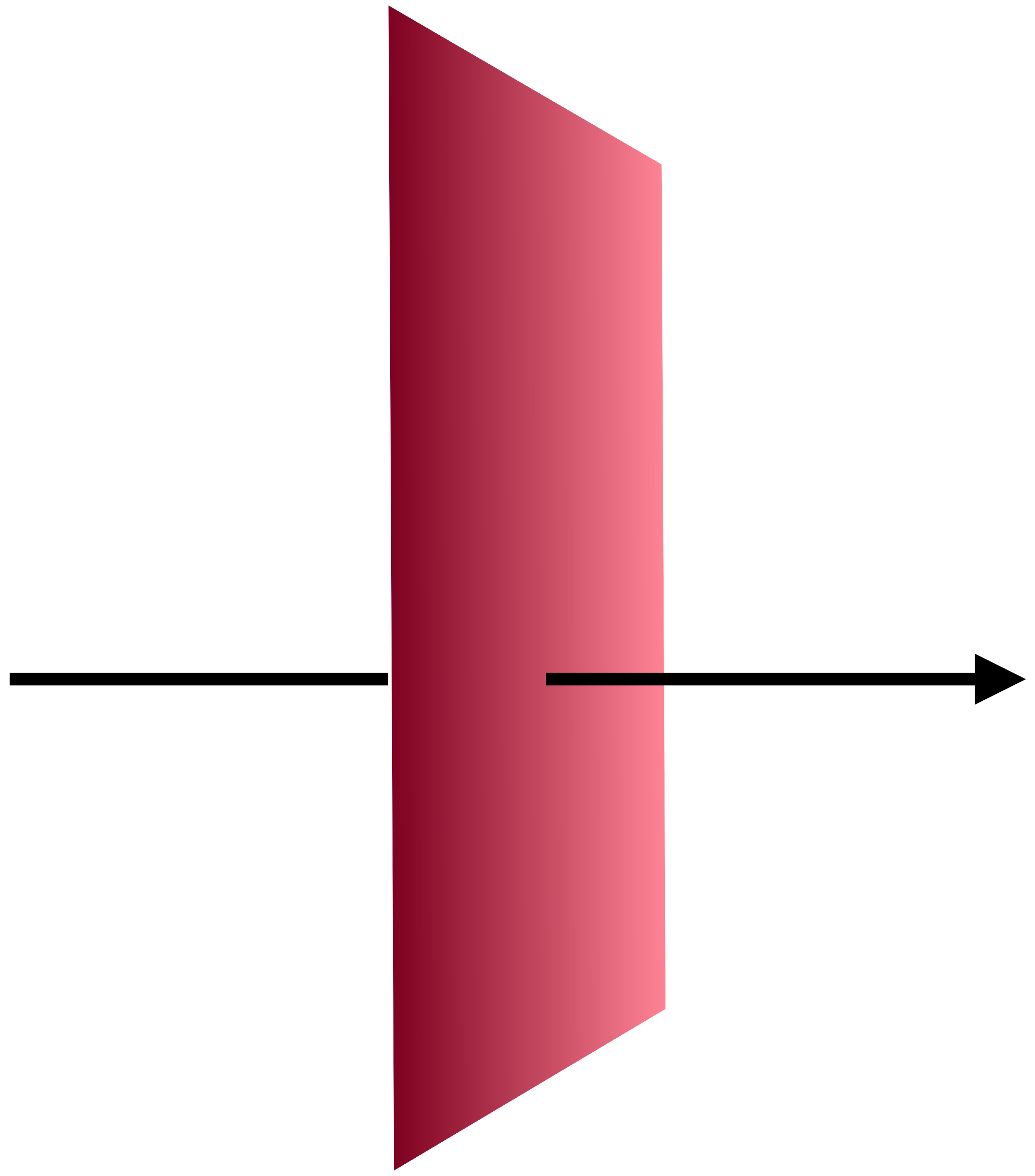

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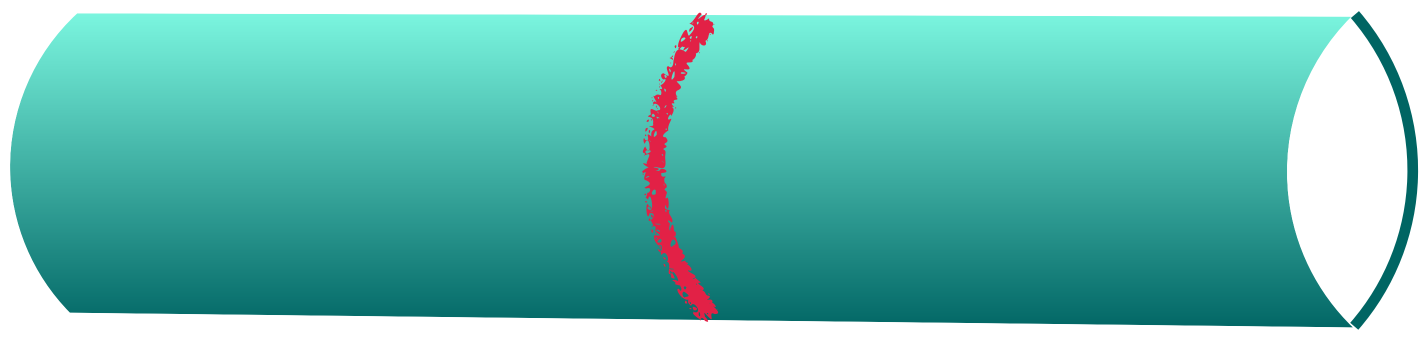

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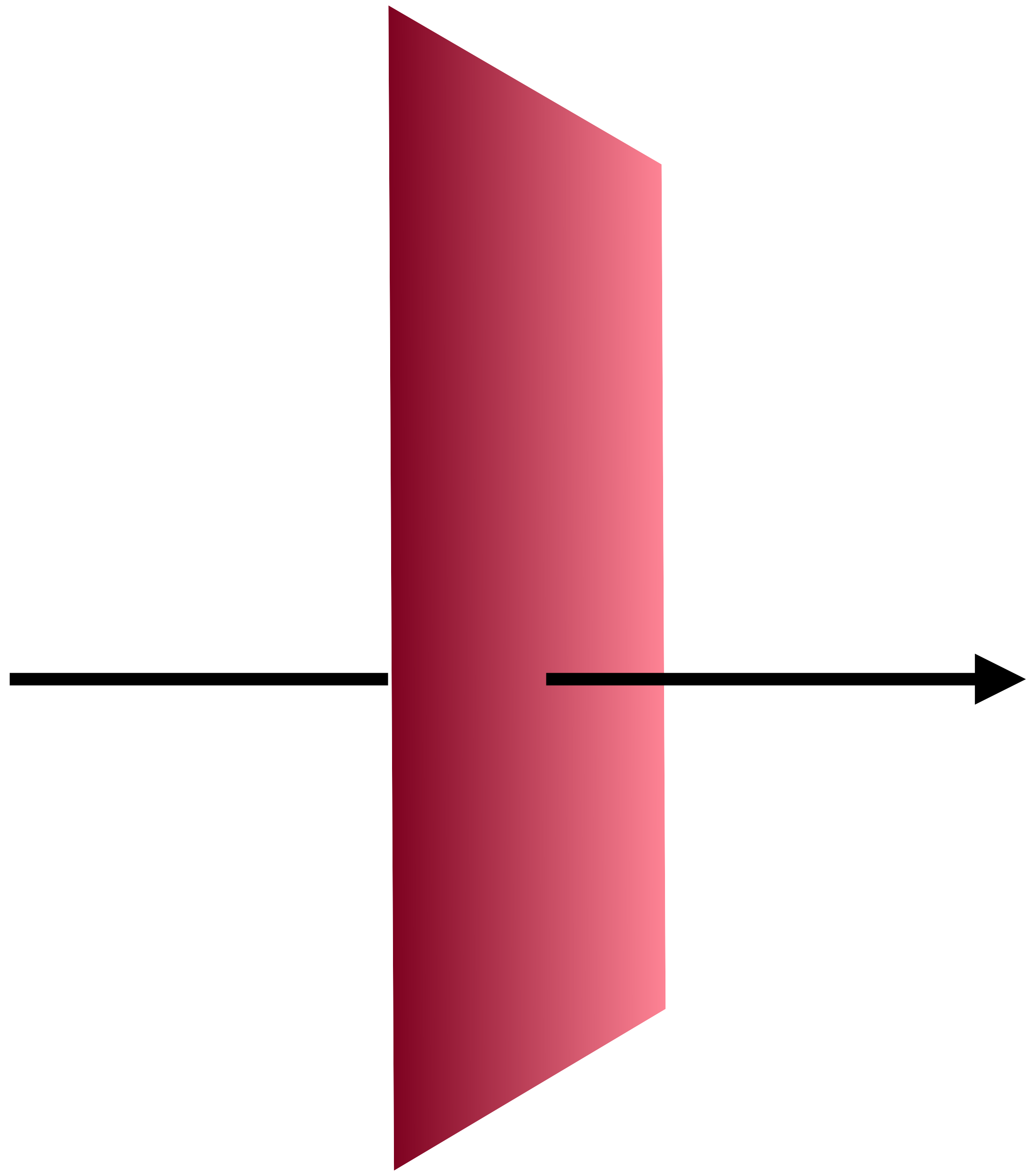

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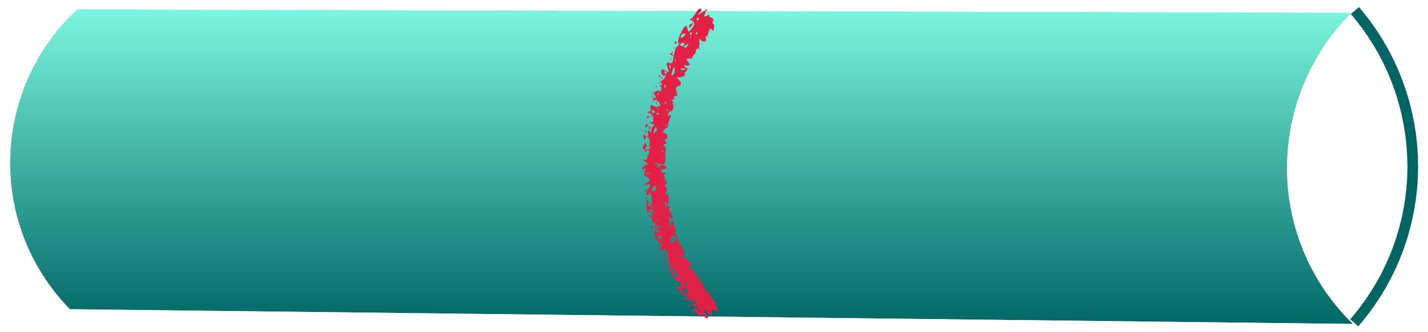
$\Sigma =$ 

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Bubbles of nothing can therefore
"sweep" up flux as they expand...

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This process can be described by an exact instanton solution
that generalizes Witten's instanton:

$$A_1 = \frac{a_\infty}{R} \cdot \left(1 - \left(\frac{R_c}{r}\right)^{D-3}\right) d\phi \qquad a_\infty(N) = \langle a(x) \rangle + N$$

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→ N units of flux bound on the bubble's surface

compare related numerical solutions: Blanco-Pillado, Shlaer, Sousa, Urrestilla '16

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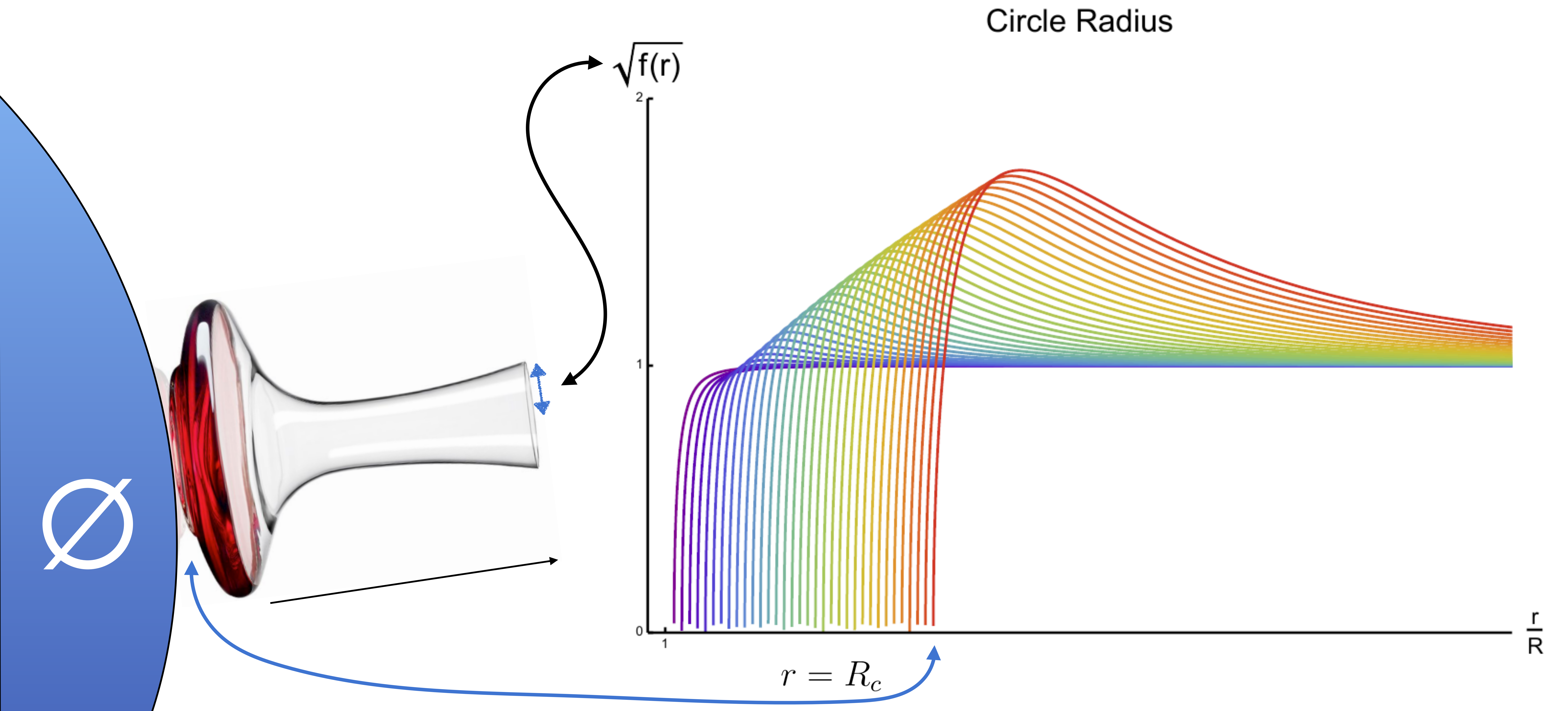

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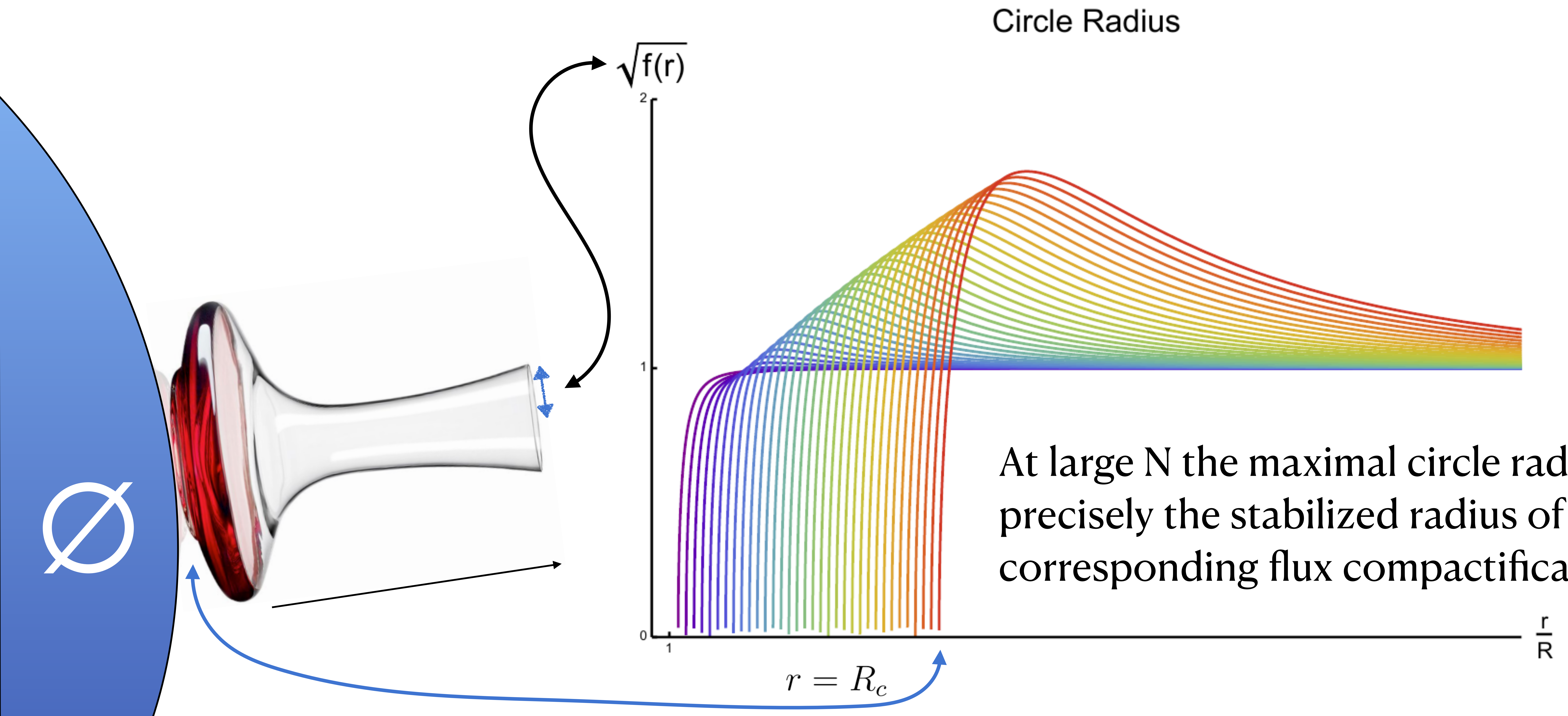

At large N the maximal circle radius is precisely the stabilized radius of the corresponding flux compactification!

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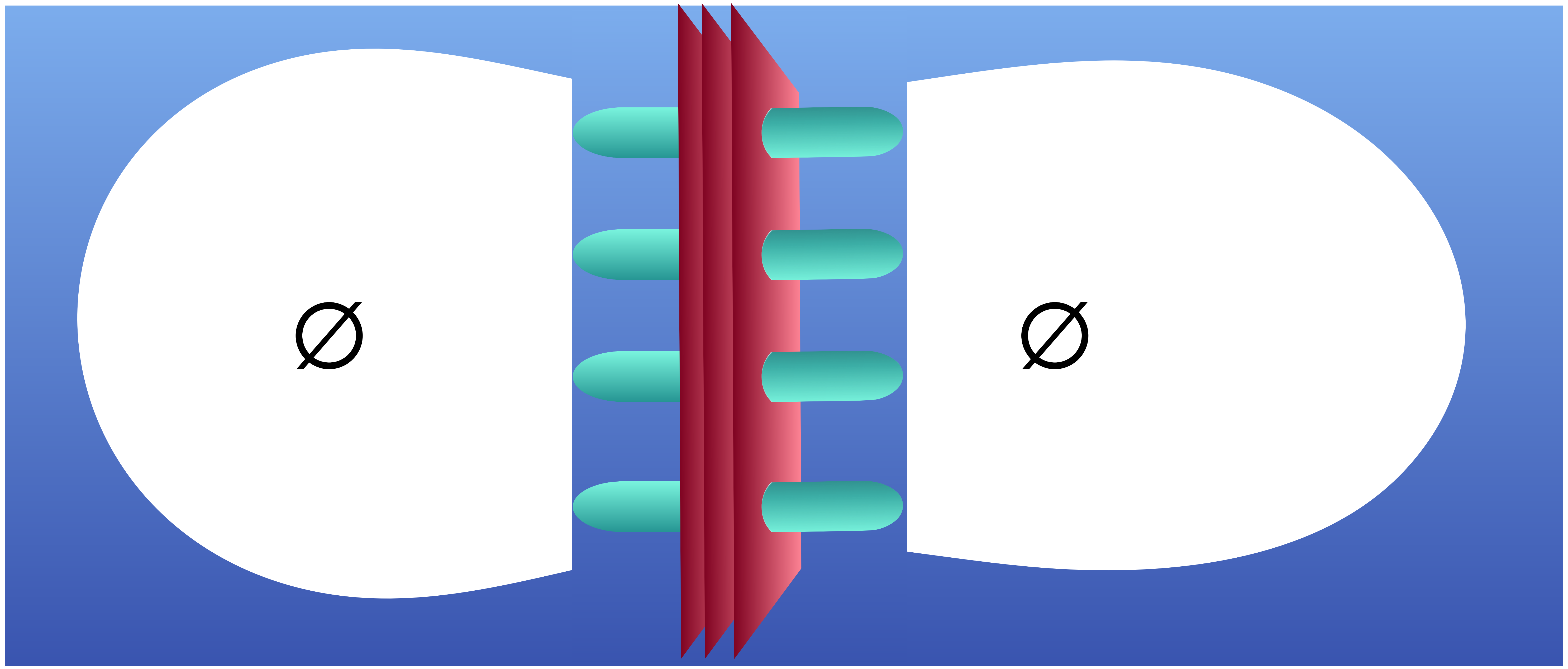

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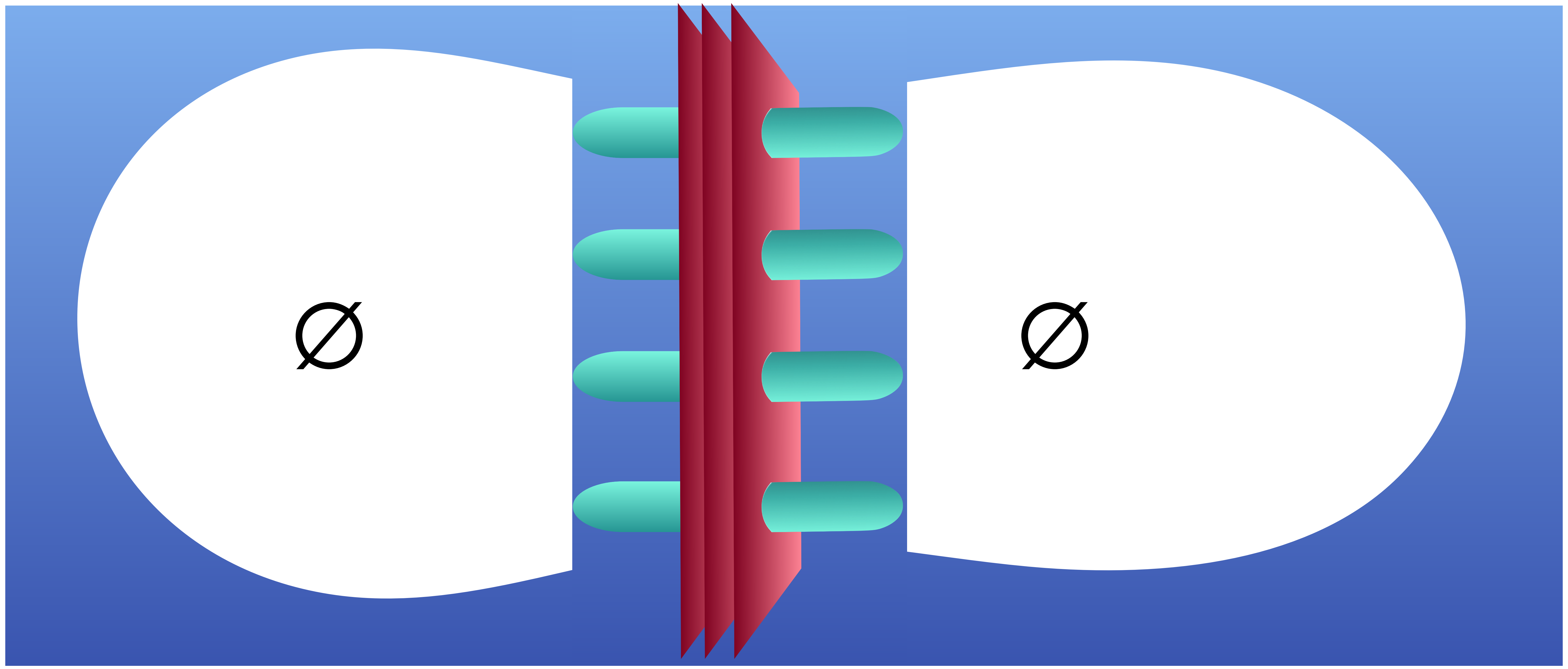

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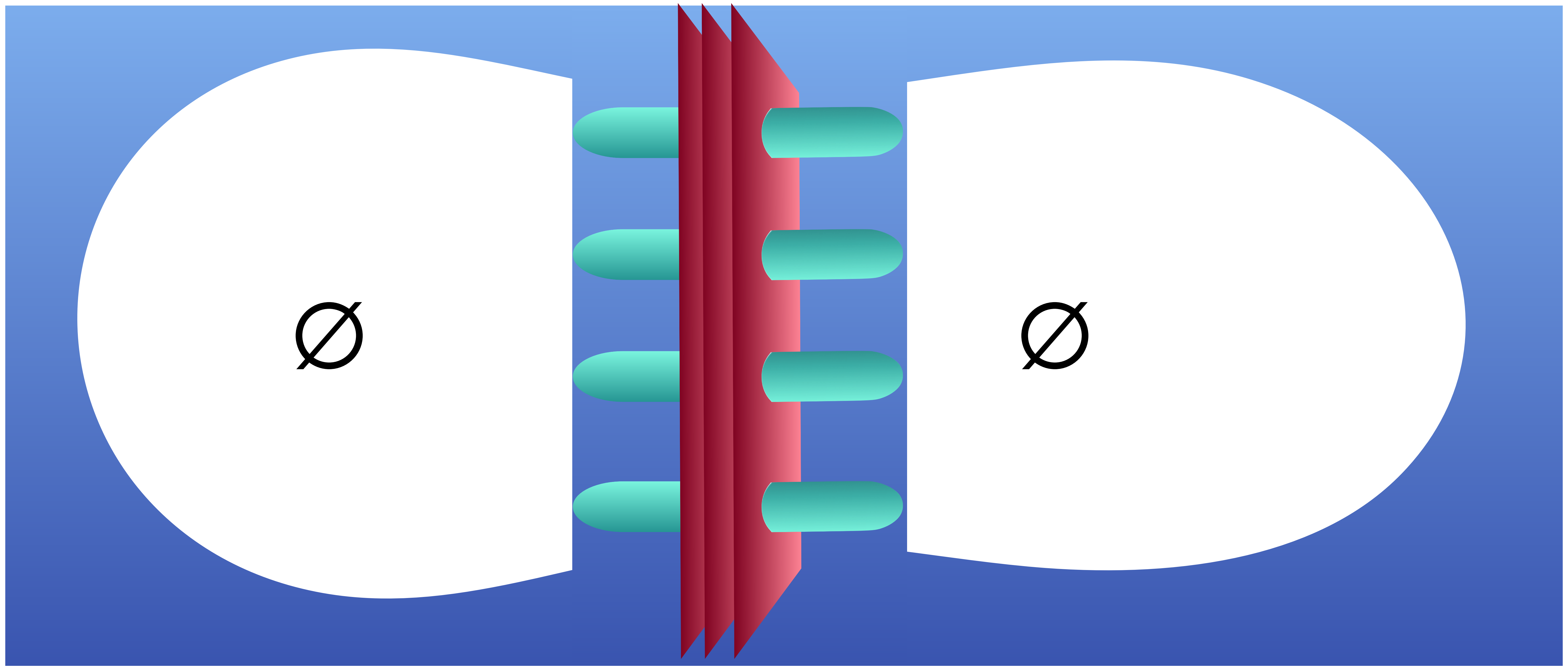

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This is process has similarities with

Carroll, Johnson, Randall '09

Blanco-Pillado, Schwartz-Perlov, Vilenkin '09

but without needing higher dimensional de Sitter space as a seed.

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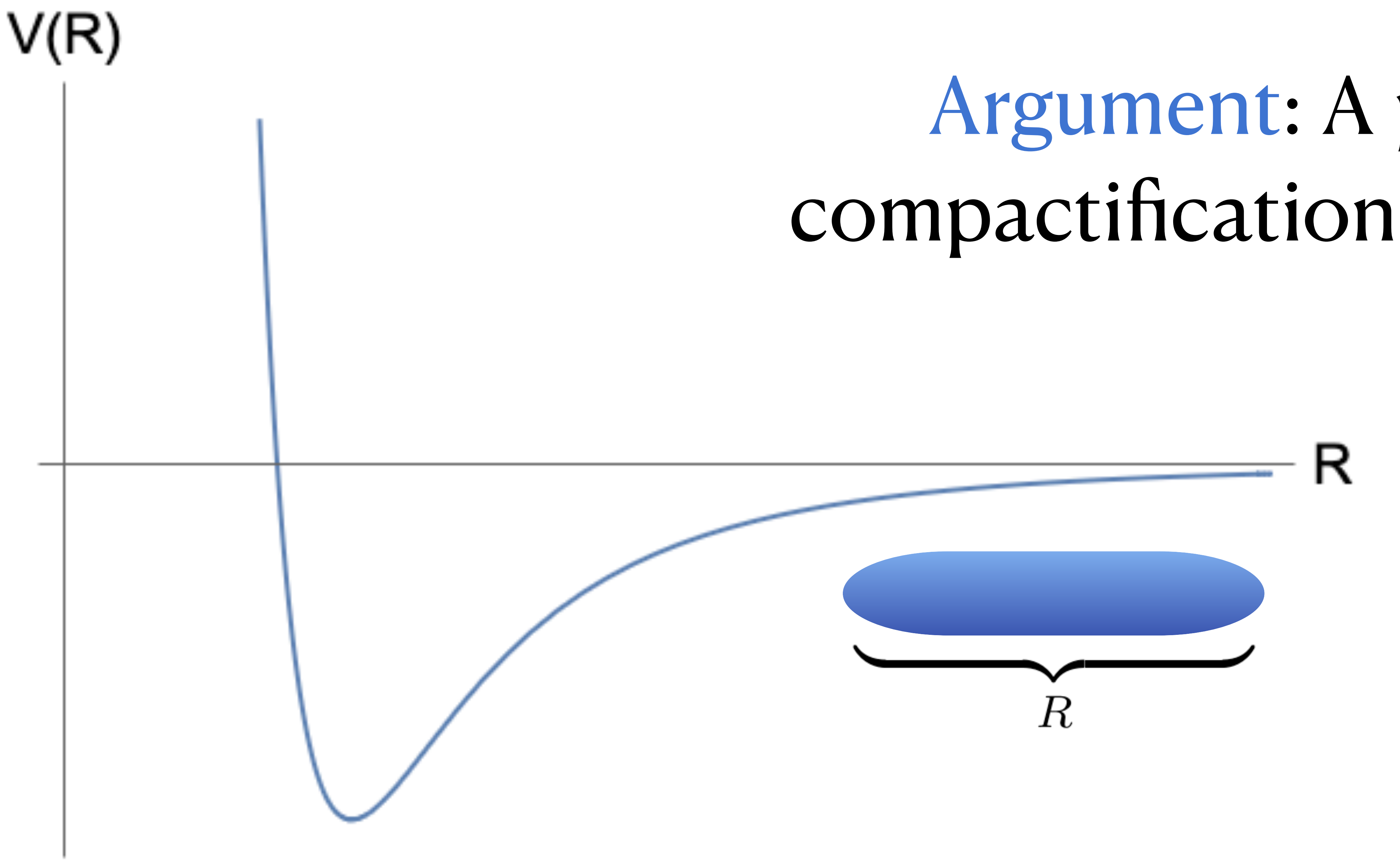

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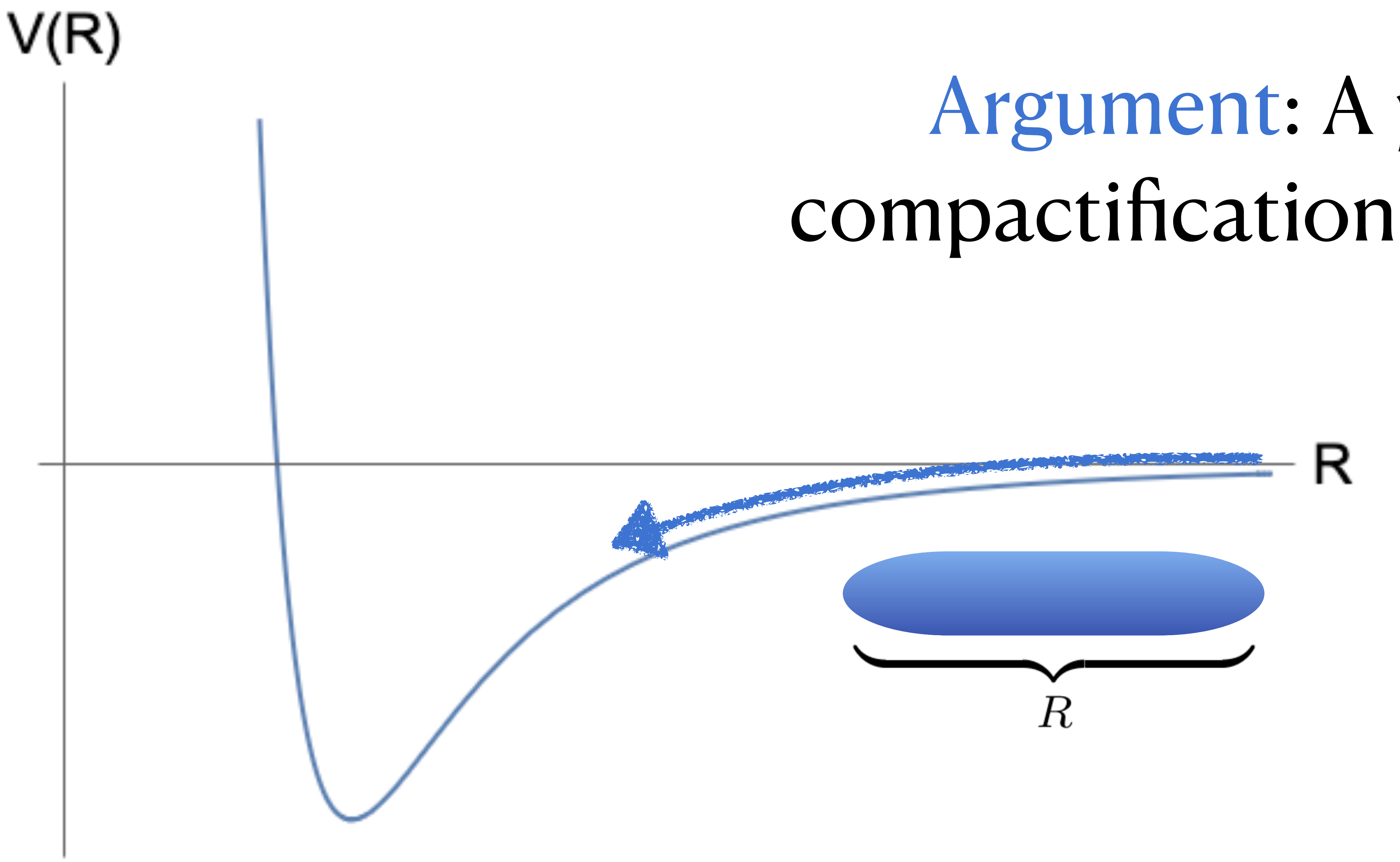

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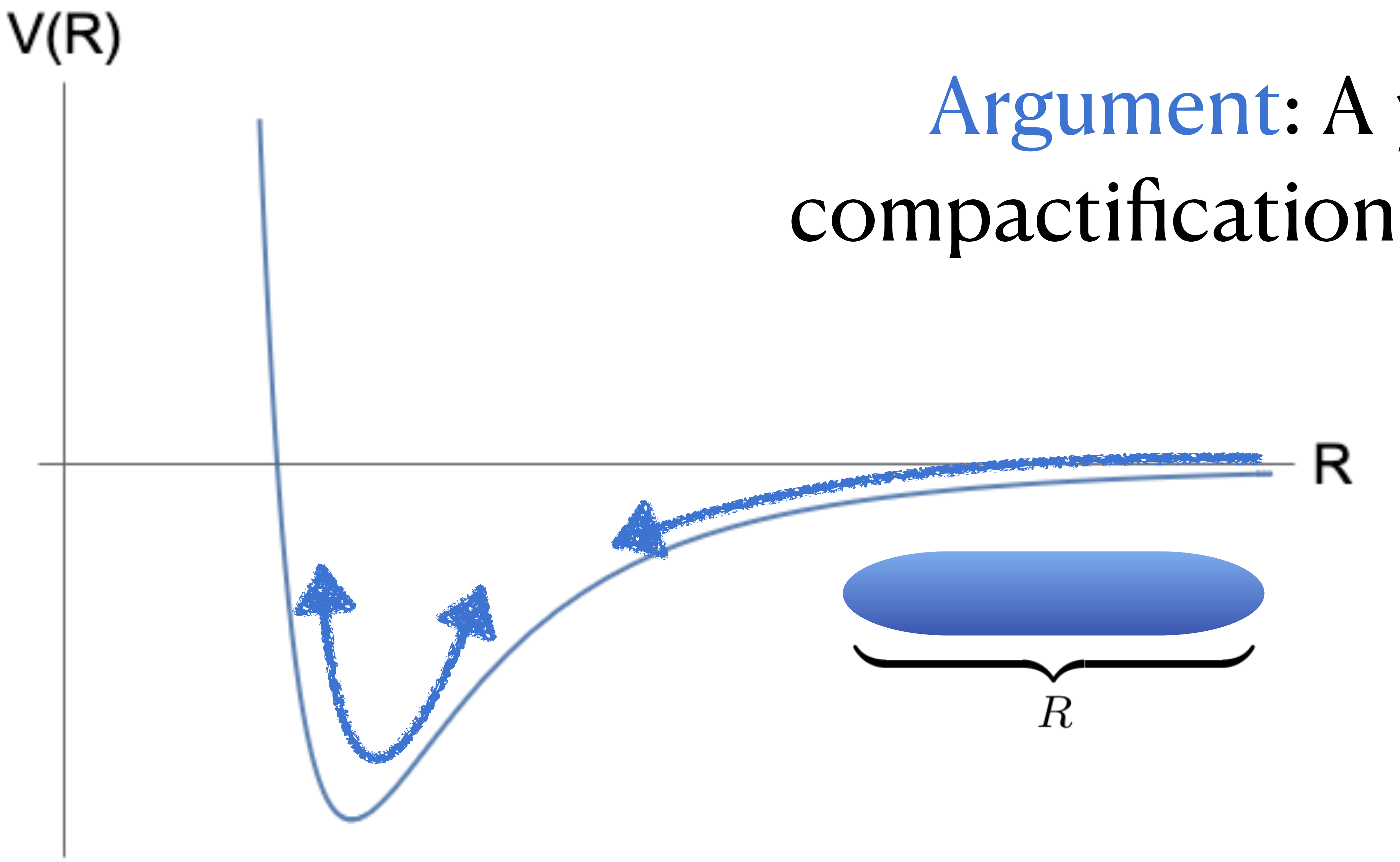

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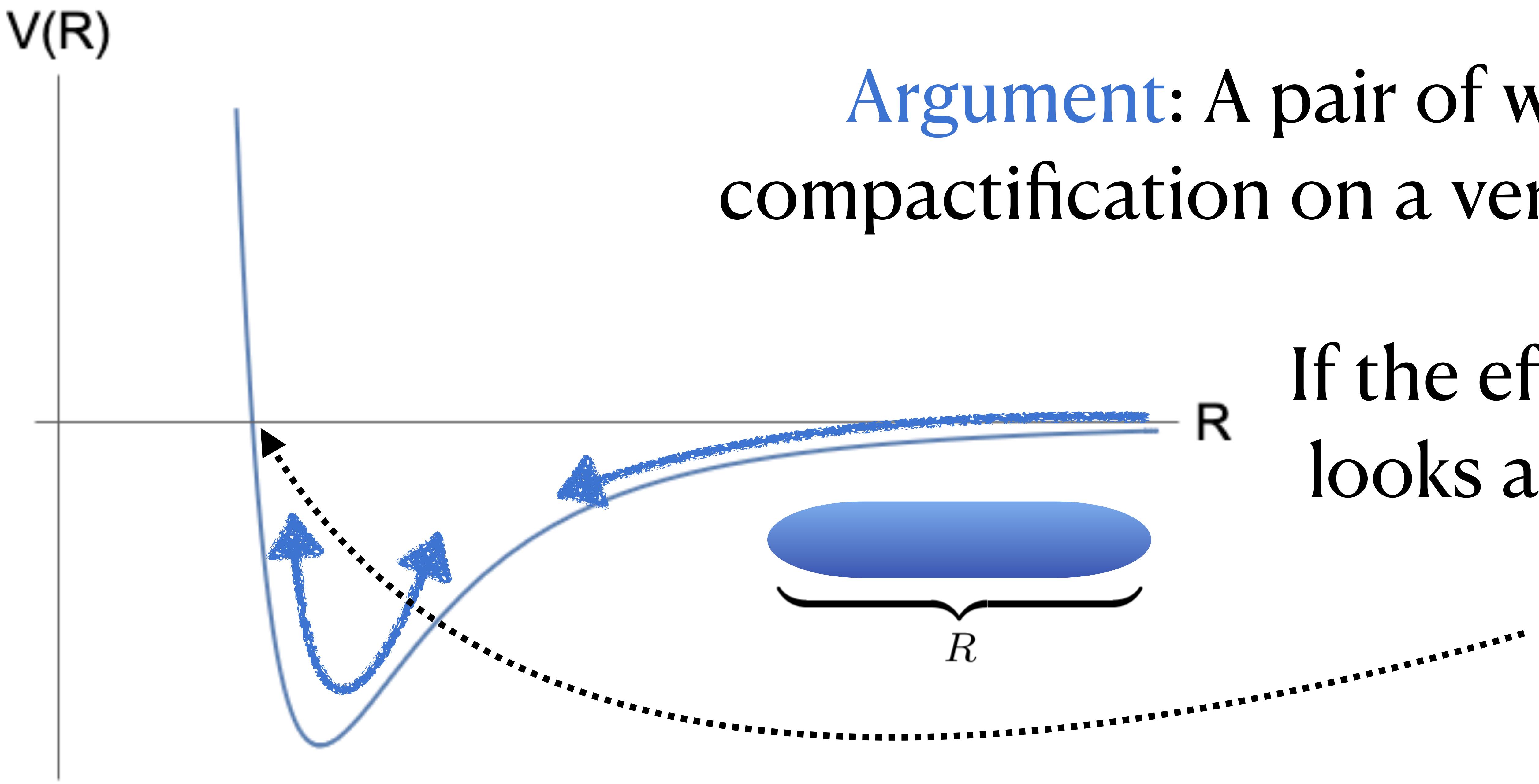

Argument: A pair of widely separated bubbles looks like compactification on a very long cigar, the overall energy is zero

If the effective potential for the length of the cigar looks anything like the effective radion potential,

the potential barrier prevents the sphere from shrinking too far.

It therefore appears we have found a viable mechanism to populate the simplest kinds of "Freund-Rubin" flux vacua…

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... such sphere compactifications are of course toy versions of the simplest kinds of Anti-de Sitter flux vacua, such as $AdS_5 \times S^5$.

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But ideally, we would like to understand how something like this can populate the flux landscape of Calabi-Yau compactifications!

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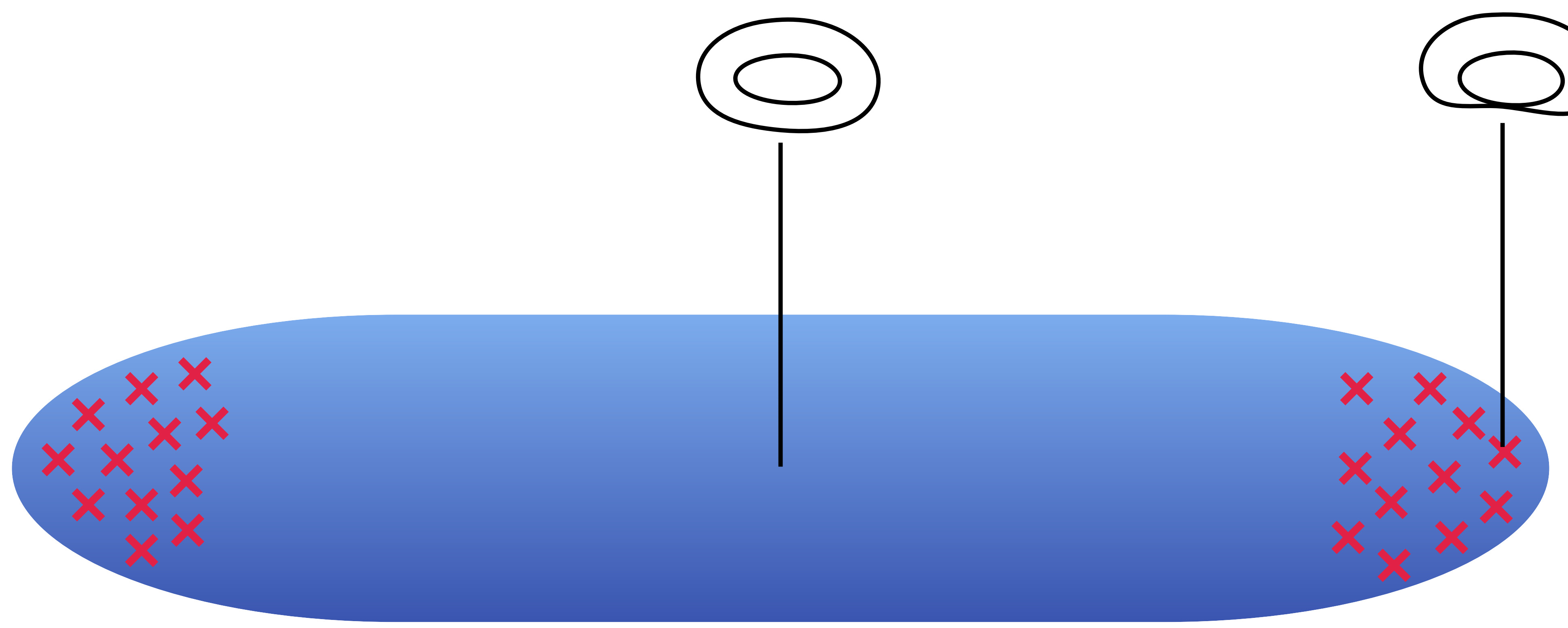

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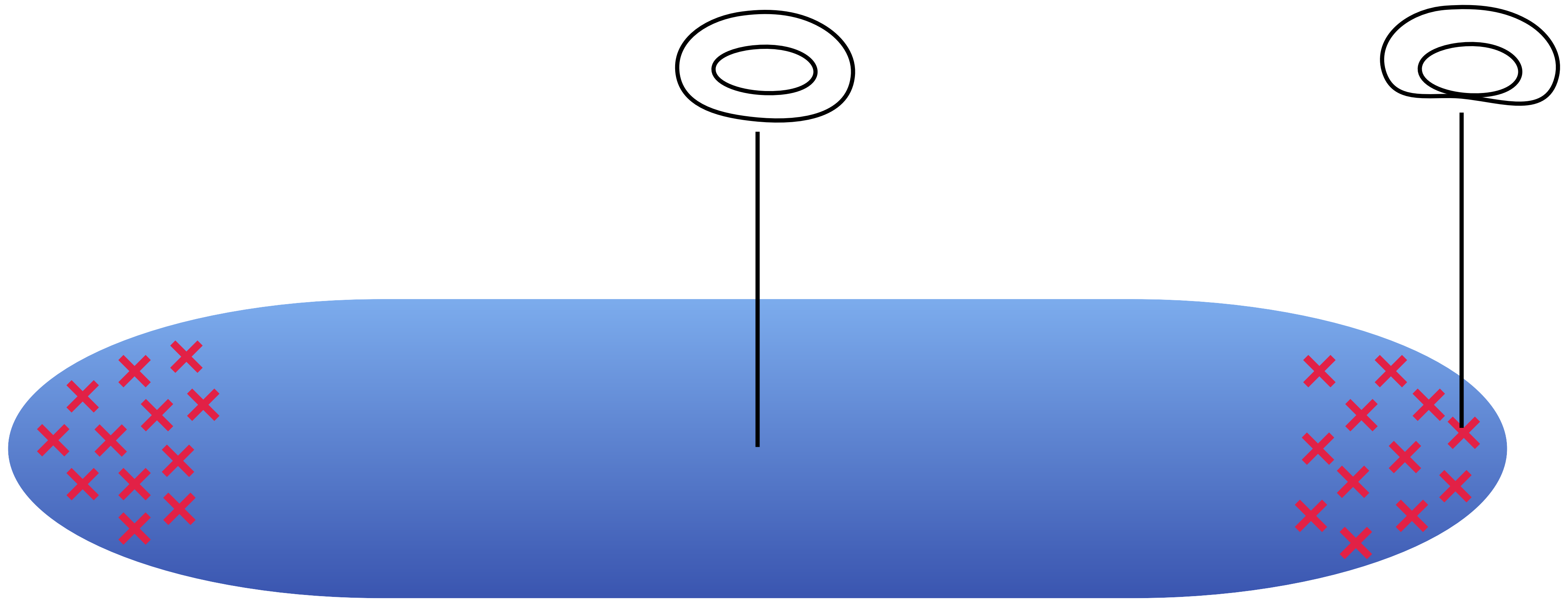

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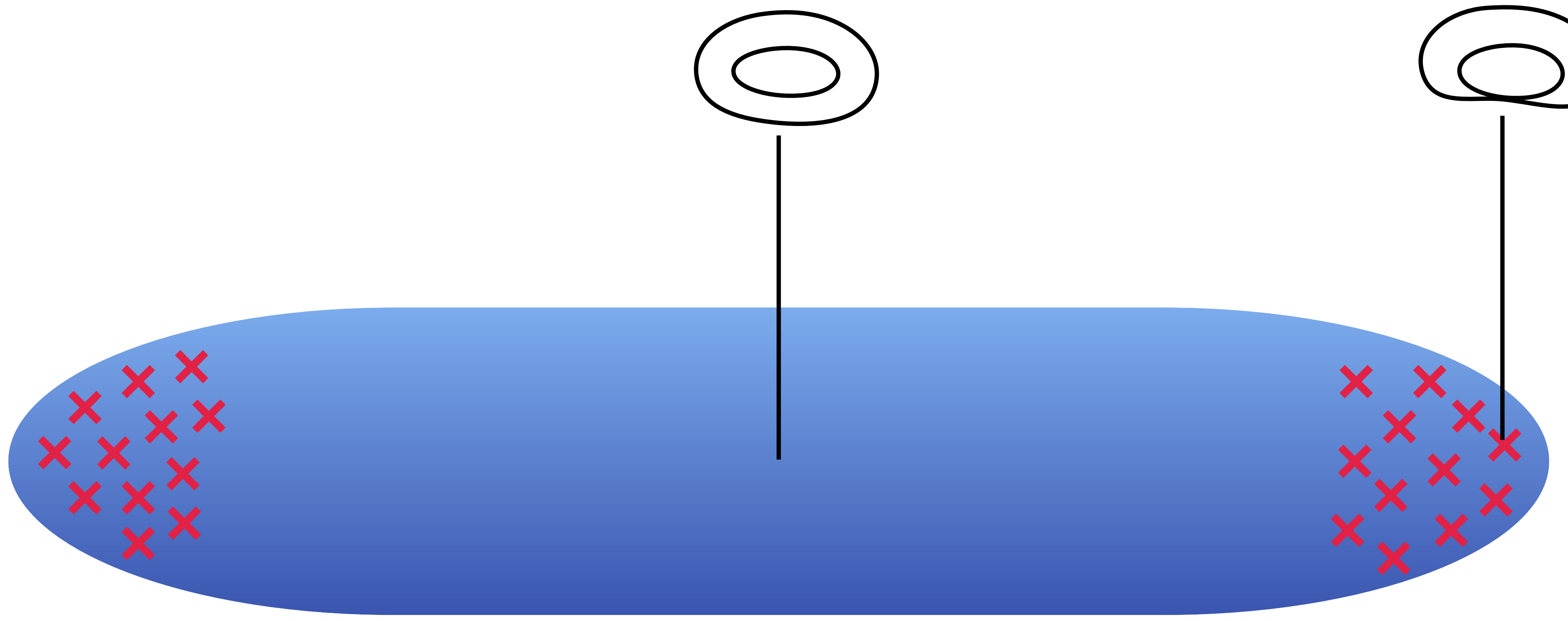

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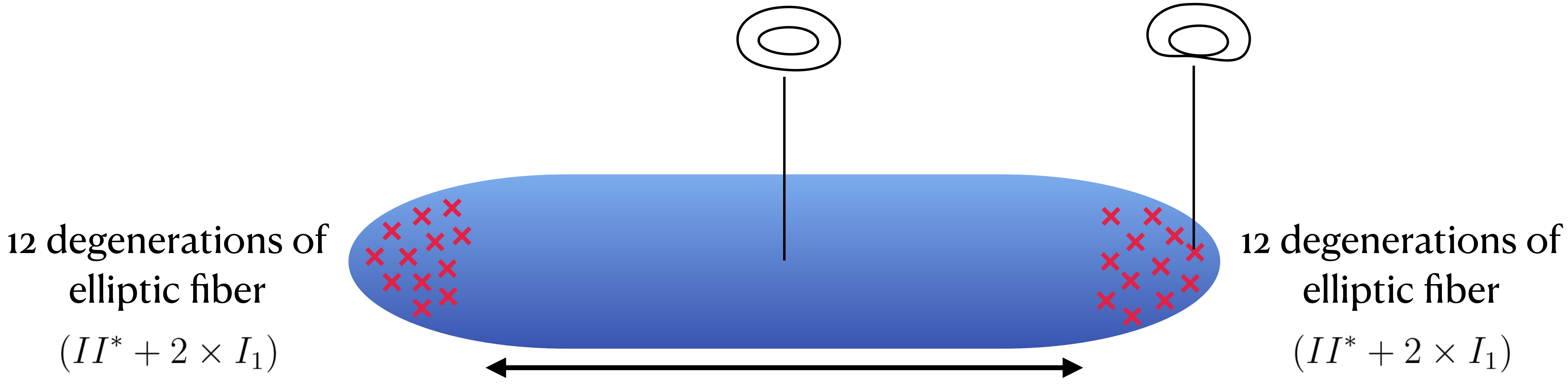

Separation diverges in ~ "stable degeneration limit" Aspinwall, Morrison '97

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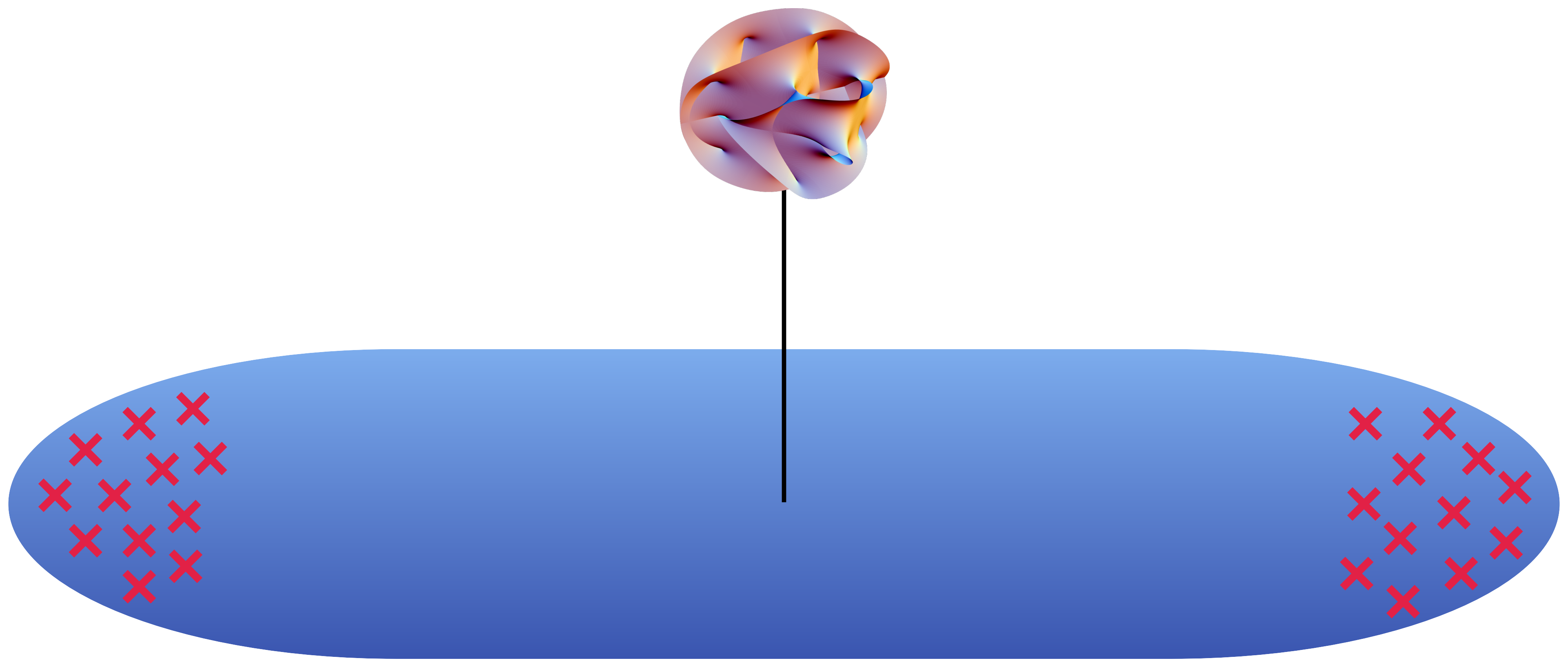

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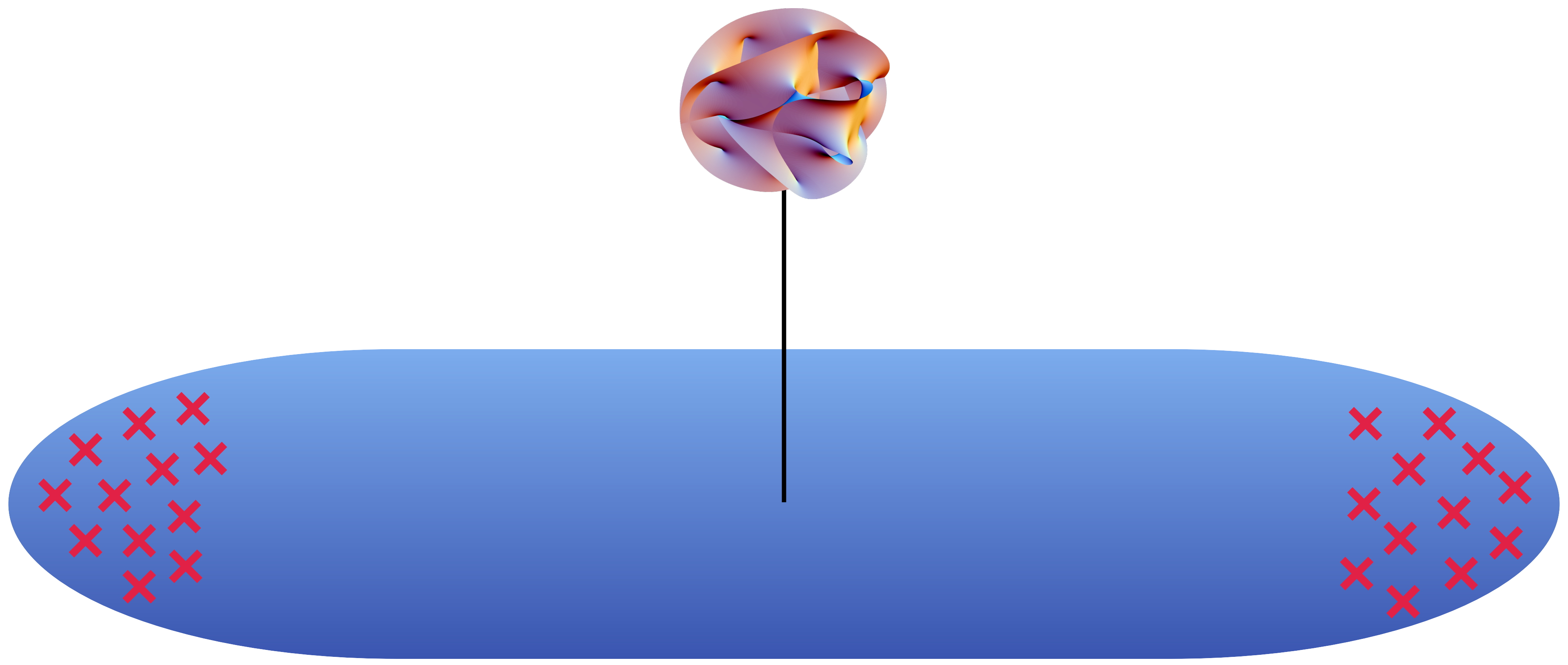

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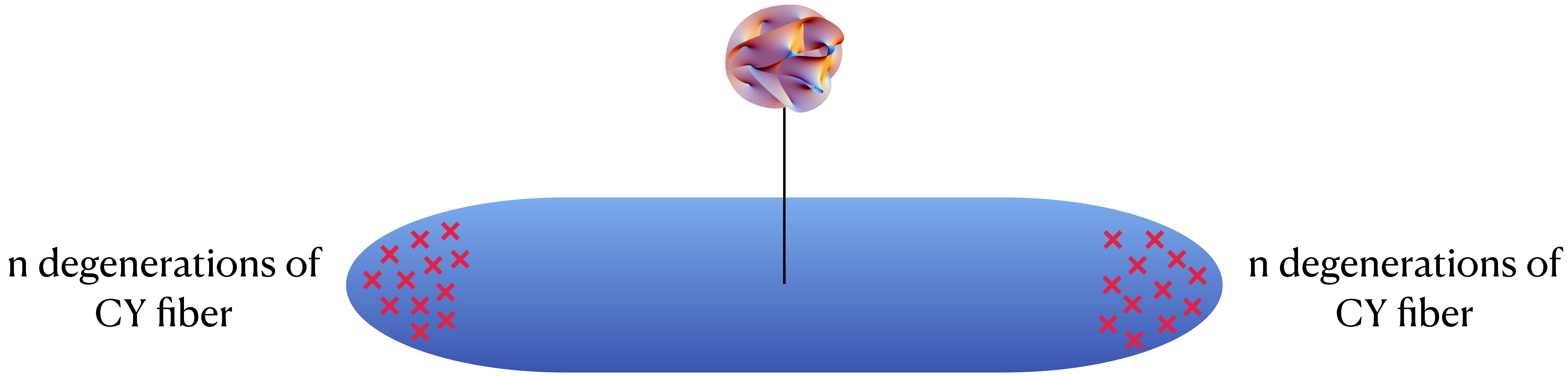

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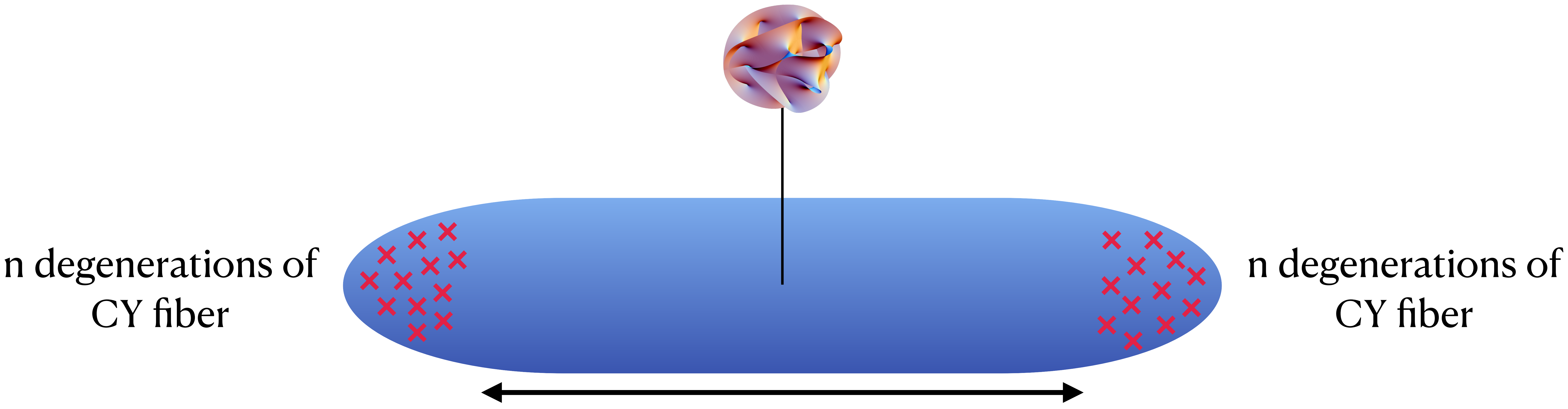

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... and thus by mirror symmetry the same is true in type IIB on CY_n with n odd.

cf a concrete such construction by Friedrich, Hebecker, Walcher '23

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This we leave for future work...

Consider for example type IIA on $S^1 \times K3$. We get axions

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Similarly, in type IIB case, one gets axions $\int_{\Sigma_2} C_2$ and $\int_{\Sigma_2} B_2$.

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→ GKP flux vacua Giddings, Kachru, Polchinski '01

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Expanding bubble solutions have induced de Sitter metric with

$$H_{dS} = 1/R_c$$

see also:
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Bubble collisions are a natural reheating event, most similar to brane anti-brane inflation

Kachru, Kallosh, Linde, Maldacena, McAllister, Trivedi '03

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Generalizations exist for Calabi-Yau compactifications, but I have left out the crucial ingredient of SUSY breaking…

Finally, expanding and colliding bubbles of nothing with flux are a natural candidate for inflationary backgrounds, with ingredients that appear readily available in string theory!

Grazie mille!