MAX-PLANCK-INSTITUT
FÜR PHYSIK

Dynamical Cobordism of a 9d Domain Wall and its companion 7-brane

Based on 2205.09782, with R. Blumenhagen, N. Cribiori, C. Kneißl

Andriana Makridou

Workshop on Holography and the Swampland
Corfu, September 9th 2022

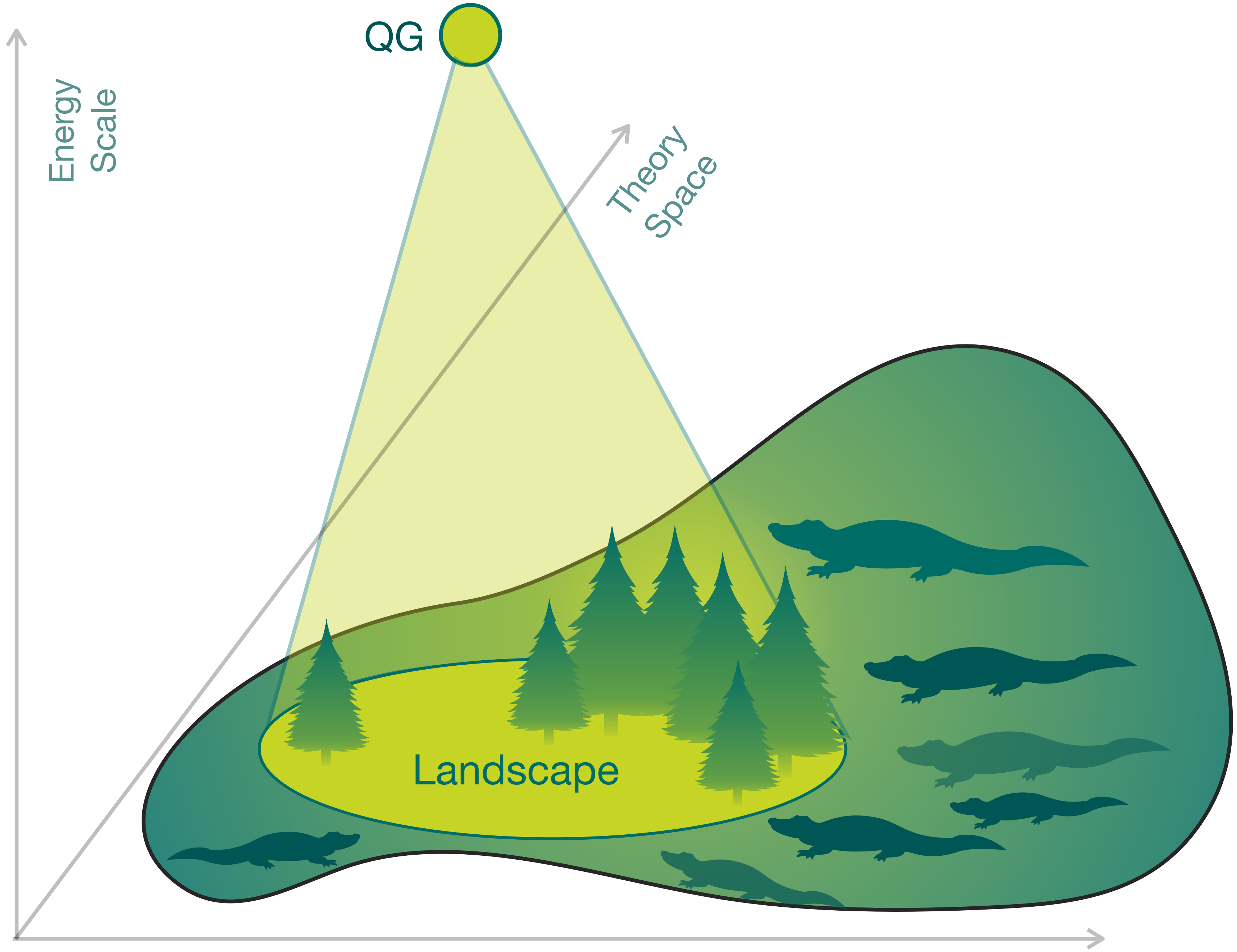
Outline

- Swampland and the Cobordism Conjecture
- Dynamical Cobordism and Tadpoles
- An explicit case of Breaking:
  Dynamical Cobordism for a 9d domain wall and a new 7-brane object

[2205.09782, Blumenhagen, Cribiori, Kneißl, AM]

The Swampland Program [Recent reviews: 1903.06239, 2102.01111]

Not all low-energy EFTs can be UV-completed to Quantum Gravity



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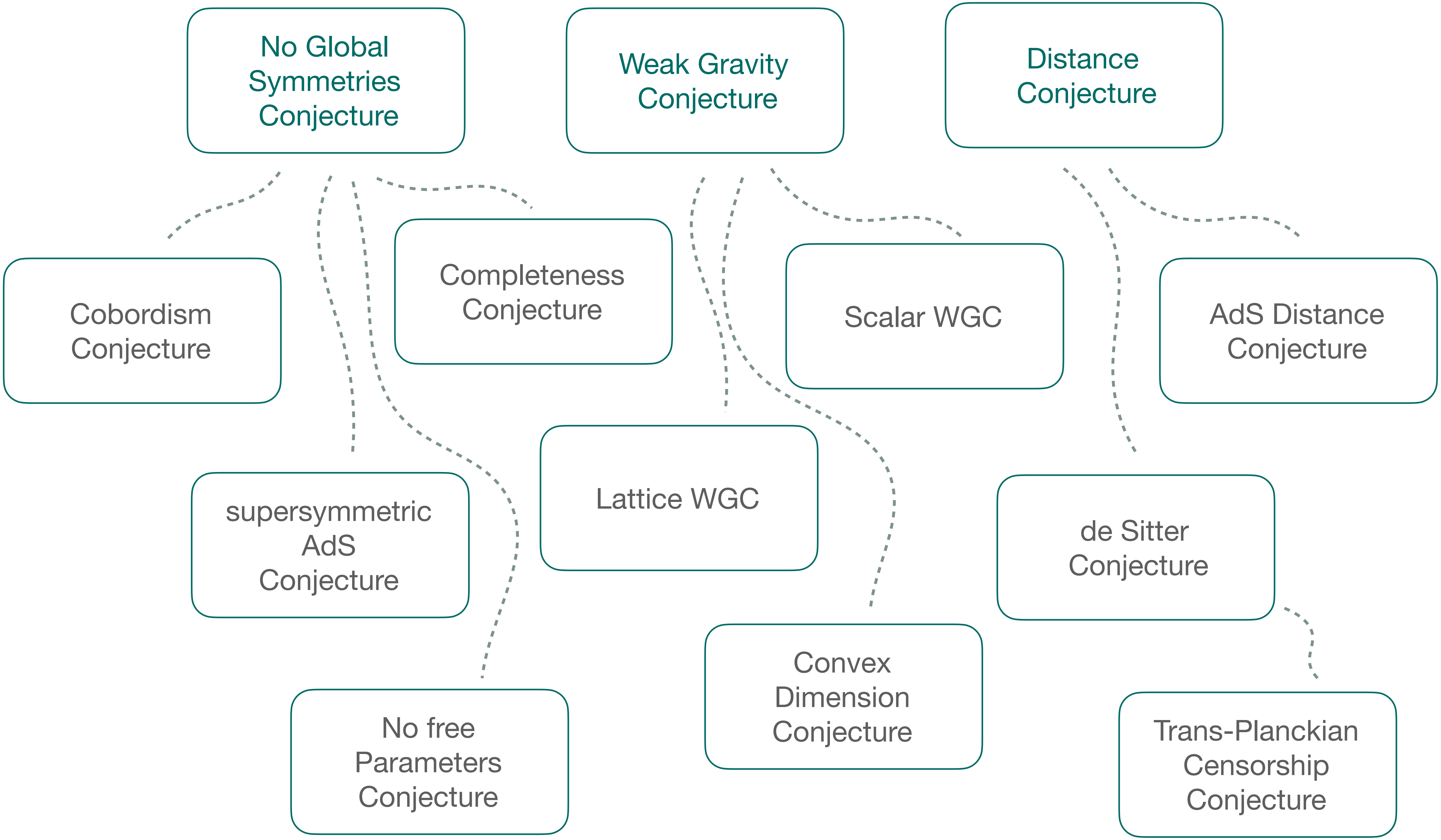


No Global Symmetries Conjecture

Weak Gravity Conjecture

Distance Conjecture

Cobordism Conjecture

Completeness Conjecture

Scalar WGC

AdS Distance Conjecture

supersymmetric AdS Conjecture

Lattice WGC

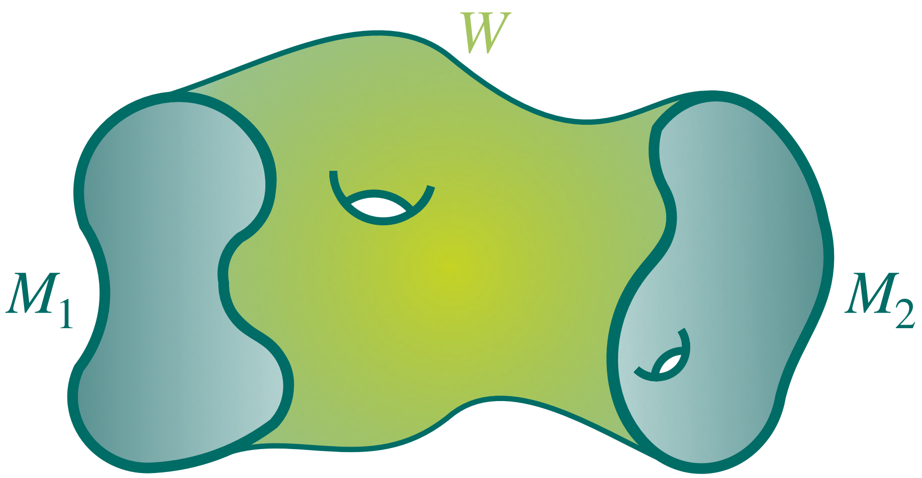
de Sitter Conjecture

No free Parameters Conjecture

Convex Dimension Conjecture

Trans-Planckian Censorship Conjecture

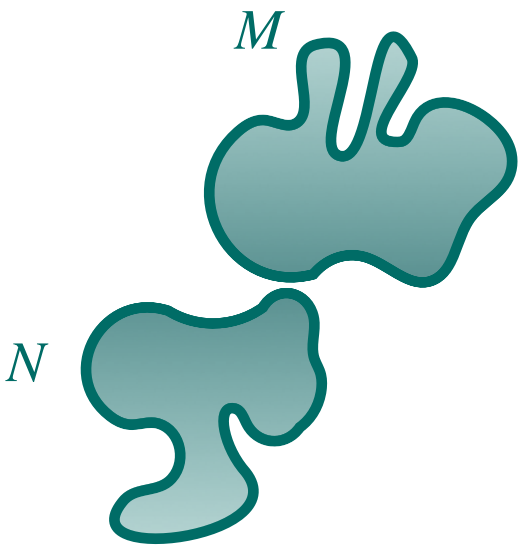
Cobordism



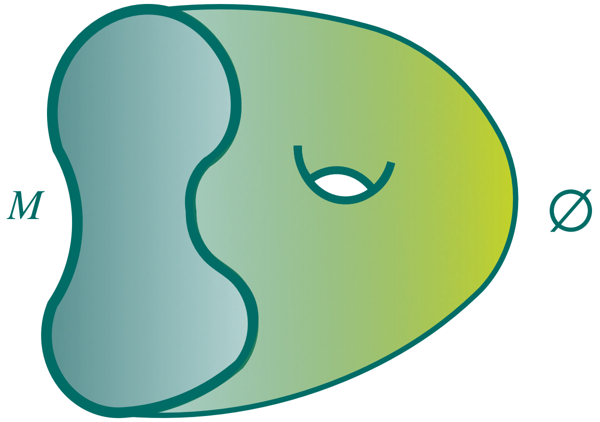
Allowed topology changes
(Encoded in ξ)

$$M_1 \sim M_2 \Leftrightarrow \exists W \text{ s.t. } \partial \mathrm{W} = \mathrm{M}_1 \sqcup \mathrm{M}_2$$

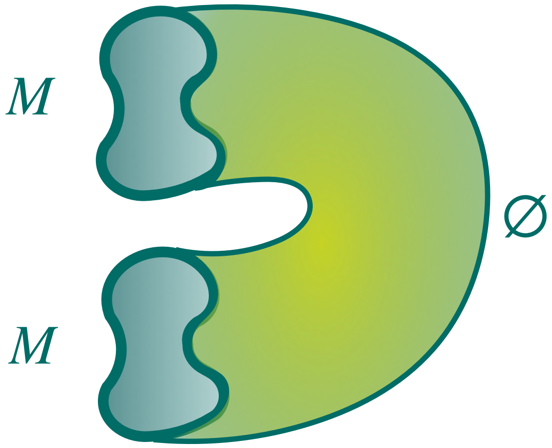
$$\Omega_k^{\xi} = \{\text{compact, closed, k} - \text{dimensional manifolds}\}/\sim$$



$$[M \sqcup N] = [M] + [N]$$



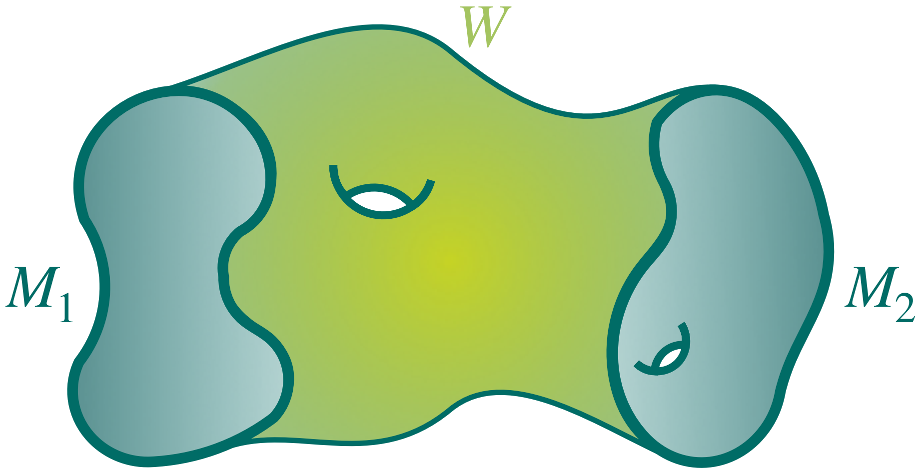
$$[\varnothing] = 0$$



$$[M] + [M] = [M \sqcup M] = 0$$

For oriented manifolds: $[M] + [\bar{M}] = 0, \quad [M] + [N] = [M \sqcup \bar{N}]$

Cobordism



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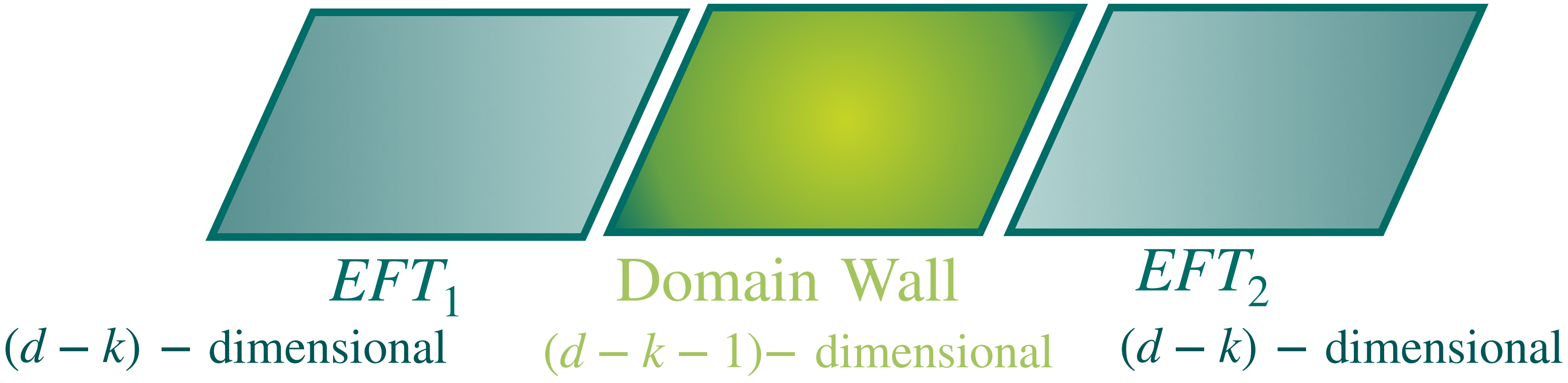
Compactify d-dimensional theory on M^k down to D=d-k dimensions:



→*Finite-energy transition between EFTs*

Cobordism and String Theory

What are the relevant structures for String Theory?

Type I $\leftrightarrow \xi = \mathrm{Spin}$

Type II $\leftrightarrow \xi = \mathrm{Spin}^c$

Full Quantum Gravity $\leftrightarrow \xi = ?$

n	0	1	2	3	4	5	6	7	8	9	10
Ω_n^{Spin}	$\mathbb{Z}$	$\mathbb{Z}_2$	$\mathbb{Z}_2$	0	0	0	$\mathbb{Z}$	0	$2\mathbb{Z}$	$2\mathbb{Z}_2$	$3\mathbb{Z}_2$
$\Omega_n^{\mathrm{Spin}^c}$	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$2\mathbb{Z}$	0	$2\mathbb{Z}$	0	$4\mathbb{Z}$	0	$4\mathbb{Z} \oplus \mathbb{Z}_2$

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n	0	1	2	3	4	5	6	7	8	9	10
KO^{-n}	$\mathbb{Z}$	$\mathbb{Z}_2$	$\mathbb{Z}_2$	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}$	$\mathbb{Z}_2$	$\mathbb{Z}_2$
K^{-n}	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$

[See Cribiori’s talk]

Cobordism Conjecture

[McNamara, Vafa '19]

Cobordism Group Ω_k^ξ ↔ Cobordism Invariant μ_k

For empty set: $\mu_k[\varnothing] = 0$

If cobordism class $[M] \neq 0$ ↔ obstruction to decay into "nothing"

$\Omega_k^\xi \neq 0 \Leftrightarrow (d-k-1)$-dim. global symmetry

with charges labelled by $[M] \in \Omega_k^\xi$

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But: No global symmetries in quantum gravity → Cobordism Conjecture

e.g. [Banks, Seiberg ’10]

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$[M] = 0$

All Cobordism Classes should be trivial

$$\Omega_k^{QG} = 0$$

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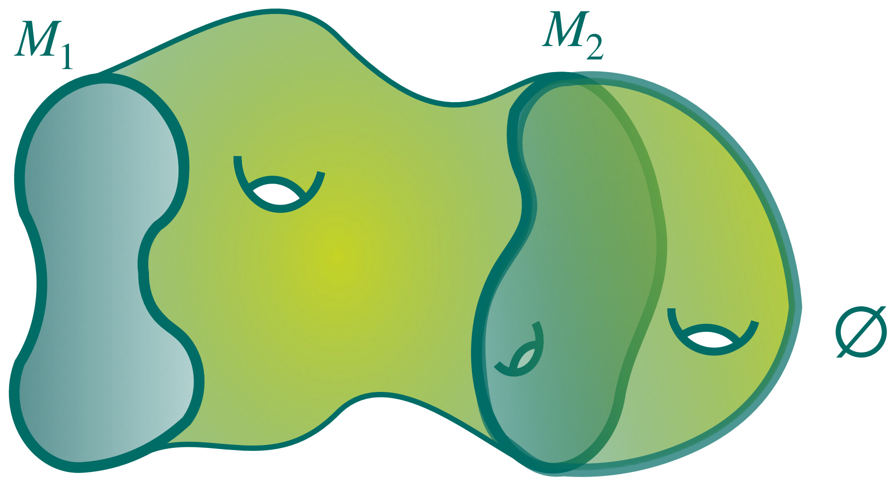

↔

In D=d-k dimensions:

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Cobordism Conjecture Consequences

$$\Omega_k^{\widetilde{QG}} \neq 0$$

Breaking

$$\Omega_k^{\widetilde{QG}} \to \Omega_k^{\widetilde{QG}\text{+defects}} = 0$$

Gauging

$$0 = [M] \in \Omega^{\widetilde{QG}} \neq 0$$

[Blumenhagen, Cribiori ’21],
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[See talk by Niccolò]

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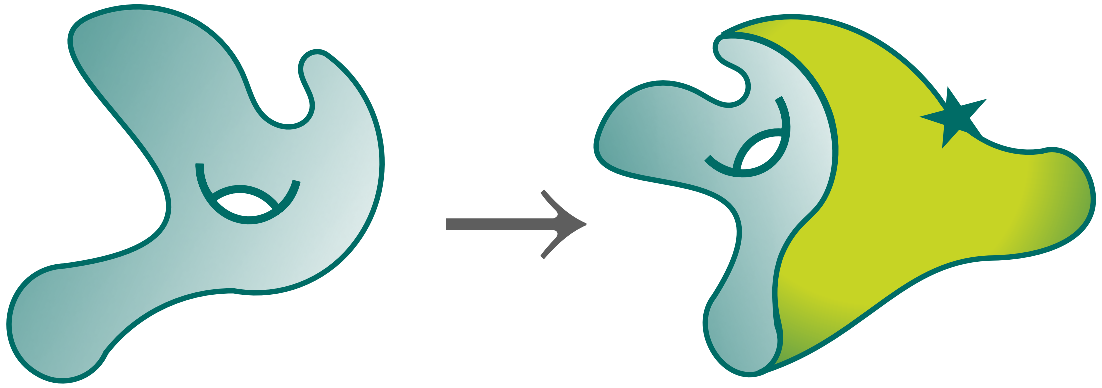


$0 \neq [M] \in \Omega_k^{\widetilde{QG}}$

$[M] = 0 = \Omega_k^{\widetilde{QG}+\text{defects}}$

Possibly new defects detected!

[McNamara, Vafa ’19], [Montero, Vafa ’20]
[Dierigl,Heckman ‘21]
[Debray, Dierigl, Heckman, Montero ’21]

Tadpoles & Dynamical Cobordism

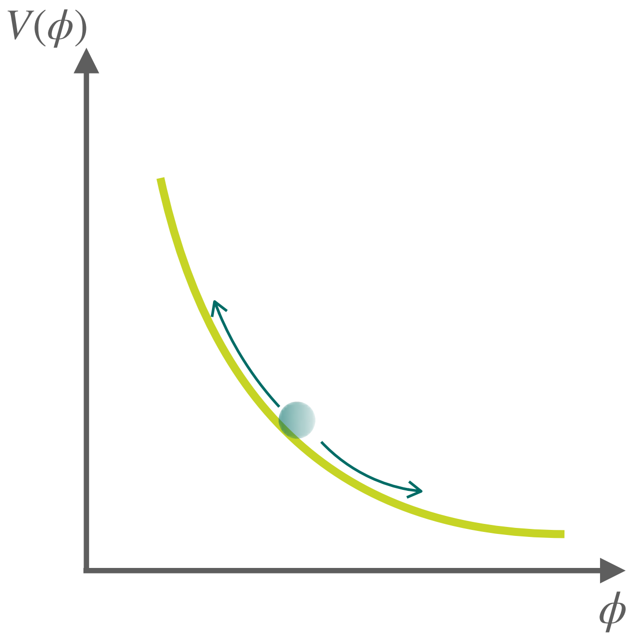
[Sugimoto ’99]

[Antoniadis, Dudas, Sagnotti ’99]

[Angelantonj ’99]

…

recently : [Raucci ’22]

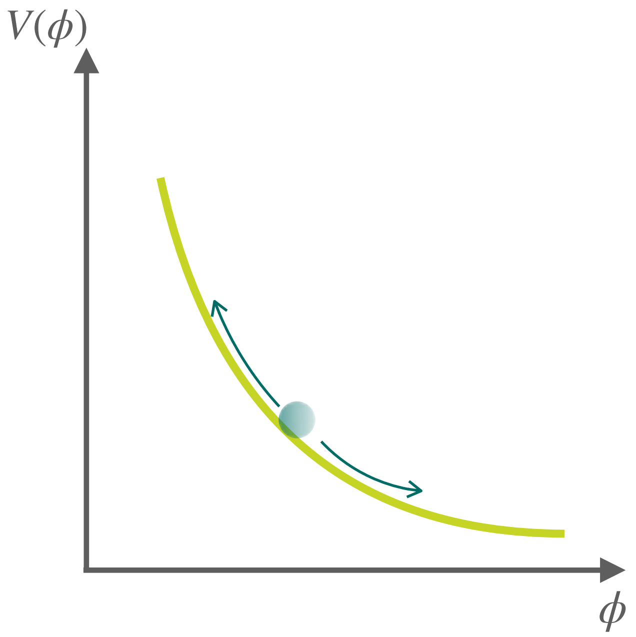


Dynamical tadpoles (vs RR tadpoles)

Naturally occurring in supersymmetry-breaking potentials

Indicate lack of maximally-symmetric vacuum

Tadpoles & Dynamical Cobordism



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Dynamical tadpoles (vs RR tadpoles)

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Indicate lack of maximally-symmetric vacuum

Example: Sugimoto Model (USp(N) Type I with N $\bar{D}8$ and N $O9\_$) [Sugimoto '99]

Action:

$$S = \frac{1}{2\kappa_{10}^2}\int d^{10}x\sqrt{-G}\left(\mathscr{R} - \frac{1}{2}(\partial\Phi)^2\right) - T_9\int d^{10}x\left((N+32)\sqrt{-G}e^{\frac{3}{2}\Phi} - (N-32)A_{10}\right) + \dots .$$

Solution preserving 9d Poincaré invariance: [Dudas, Mourad '00]

$$ds_E^2 = |\sqrt{\alpha_E}|^{1/9} e^{-\frac{\alpha_E y^2}{8}} \eta_{\mu\nu}dx^\mu dx^\nu + |\sqrt{\alpha_E}y|^{-1} e^{-\frac{3\phi_0}{2}} e^{-\frac{9\alpha_E}{8}y^2} dy^2, \quad \alpha_E = 64k^2 T_9$$

→ singularities at finite spacetime distance, spontaneous compactification to 9d

Tadpoles & Dynamical Cobordism

Tadpoles & Dynamical Cobordism

Reinterpretation in Cobordism Terms

[Buratti, Delgado, Uranga ’21]
[Buratti, Calderon-Infante, Delgado, Uranga ’21]
[Angius, Calderon-Infante, Delgado, Huertas, Uranga ’22]
[Angius, Delgado, Uranga ’22]

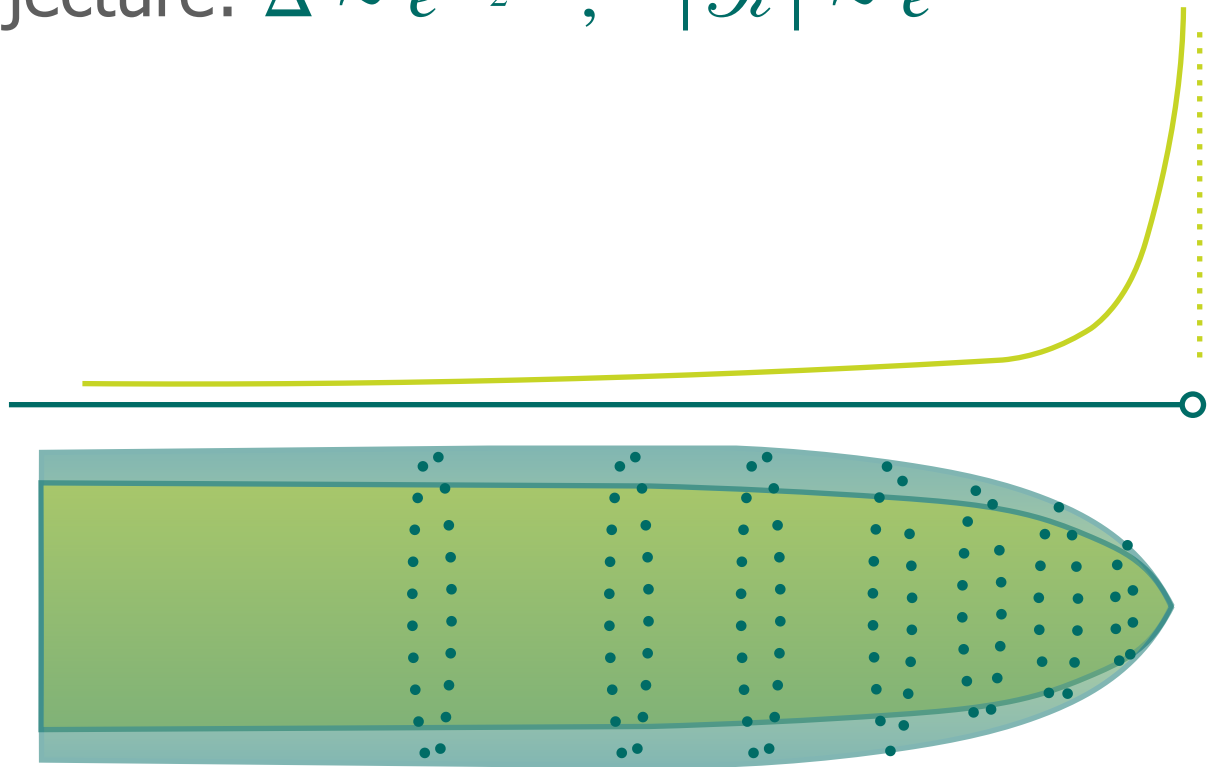
Solution extends in finite spacetime distance Δ, with $\Delta \sim \mathscr{T}^{-n}$

Tadpole strength

Mechanism: “apparent singularity” = cobordism defect.

For field distance $D \to \infty$ at singularity: Wall of Nothing/End-of-the-world brane

Cobordism distance conjecture: $\Delta \sim e^{-\frac{1}{2}\delta D}, \quad |\mathscr{R}| \sim e^{\delta D}$



9-dimensional Domain Wall

Goal: Backreaction of gauge neutral,
non-supersymmetric 9-dimensional object w/ brane-like dilaton coupling

Physical realisation: non-BPS $\tilde{D}8$-brane,
non-SUSY stack of $16 \times \bar{D}8 + O8^{++}$ [Blumenhagen, Font '00]

Action:

$$S = \frac{1}{2\kappa_{10}^2} \int d^{10}x \sqrt{-G} \left(\mathscr{R} - \frac{1}{2} (\partial \Phi)^2 \right) - T \int d^{10} \sqrt{-g}\, e^{\frac{5}{4}\Phi} \delta(\underset{\substack{\uparrow \\ \text{transverse} \\ \text{direction}}}{r}) \,.$$

Solution Ansatz:

$$ds^2 = e^{2\mathscr{A}(r,y)} ds_8^2 + e^{2\mathscr{B}(r,y)} (dr^2 + dy^2) \,.$$

$$\mathscr{A} = A(r) + U(y) \qquad \mathscr{B} = B(r) + V(y) \qquad \Phi = \chi(r) + \psi(y)$$

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Solution I

$$A(r) = B(r) = \frac{1}{8}\log\left|\sin\left(8K(|r| - \frac{R}{2})\right)\right|$$

$$\chi(r) = -\frac{3}{2}\log\left|\tan\left(4K(|r| - \frac{R}{2})\right)\right| + \phi_0$$

$$U(y) = -Ky$$

$$\psi(y) = V(y) = 0$$

Solutions $II^{\pm}$

$$A(r) = \frac{1}{8}\log\left|\sin\left(8K(|r| - \frac{R}{2})\right)\right|$$

$$\chi(r) = \frac{\boxed{\alpha^{\pm}}}{8}\log\left|\sin\left(8K(|r| - \frac{R}{2})\right)\right| \\ \boxed{\mp}2\log\left|\tan\left(4K(|r| - \frac{R}{2})\right)\right| + \phi_0$$

$$B(r) = \frac{\mu}{8}\log\left|\sin\left(8K(|r| - \frac{R}{2})\right)\right| \\ \mp\frac{\boxed{\alpha^{\pm}}}{8}\log\left|\tan\left(4K(|r| - \frac{R}{2})\right)\right|$$

$$U(y) = \frac{1}{8}\log\left(\cosh(8Ky)\right)$$

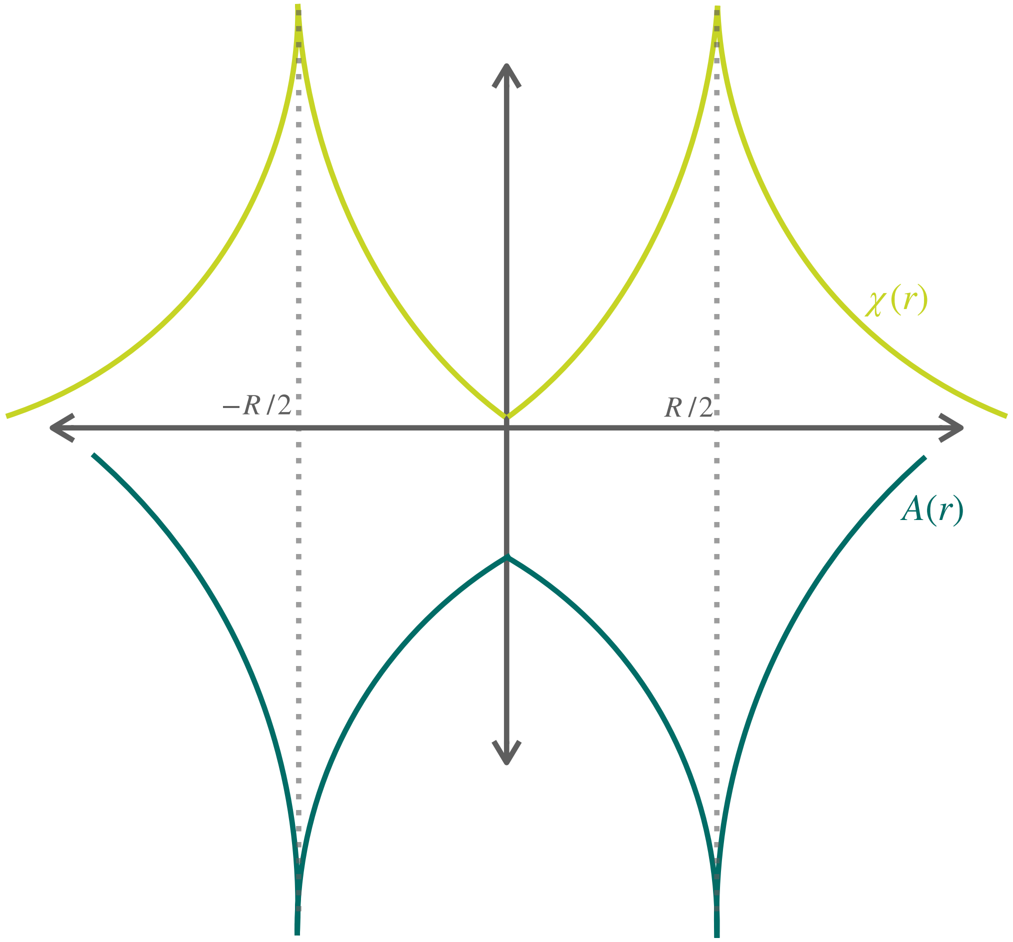
$$\psi(y) = \alpha U(y), \quad V(y) = -\frac{5}{4}U(y)$$

Qualitative behavior

r-direction spontaneously compactified on S^1 with radius R: $e^{\frac{5}{4}\phi_0} \sim \dfrac{1}{\underset{\overset{\uparrow}{\kappa_{10}^2 T}}{\lambda} R}$

Logarithmic singularities at $r = \pm \dfrac{R}{2}$, string coupling diverges

y-direction: infinite length in sols I, II^-, becomes finite interval in sol II^+



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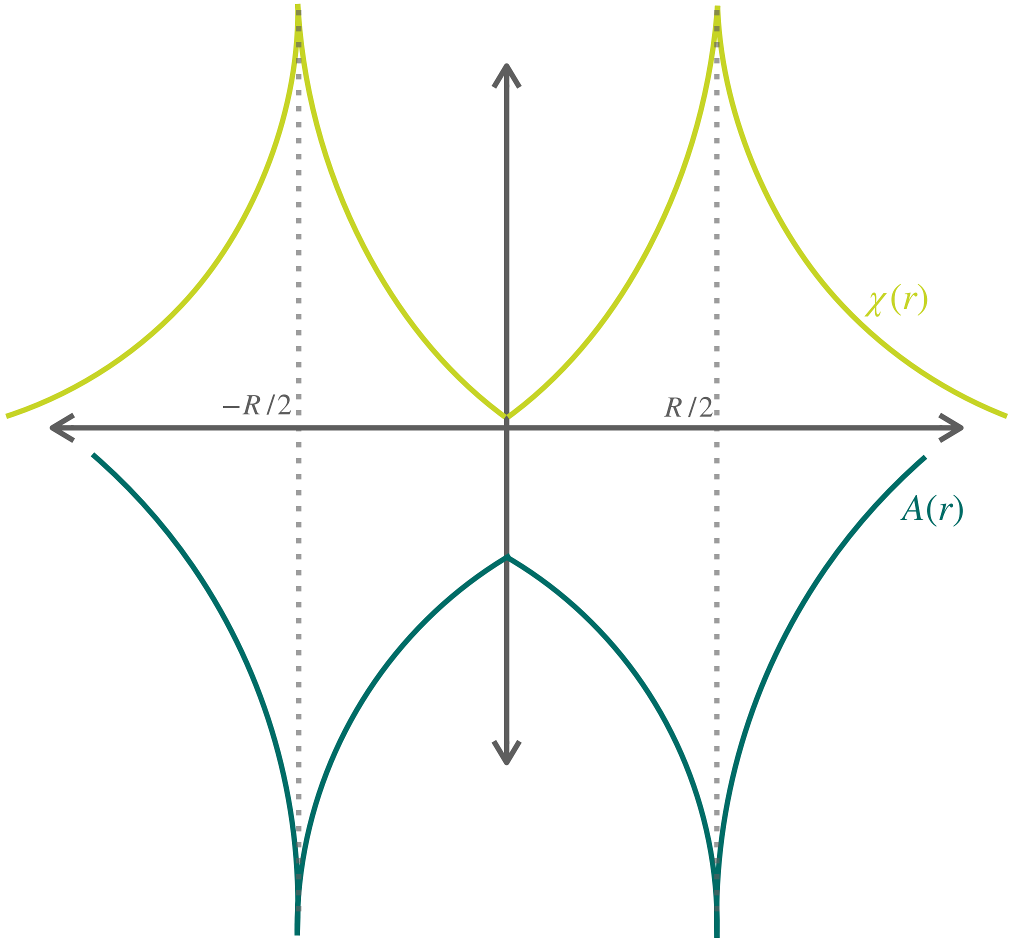

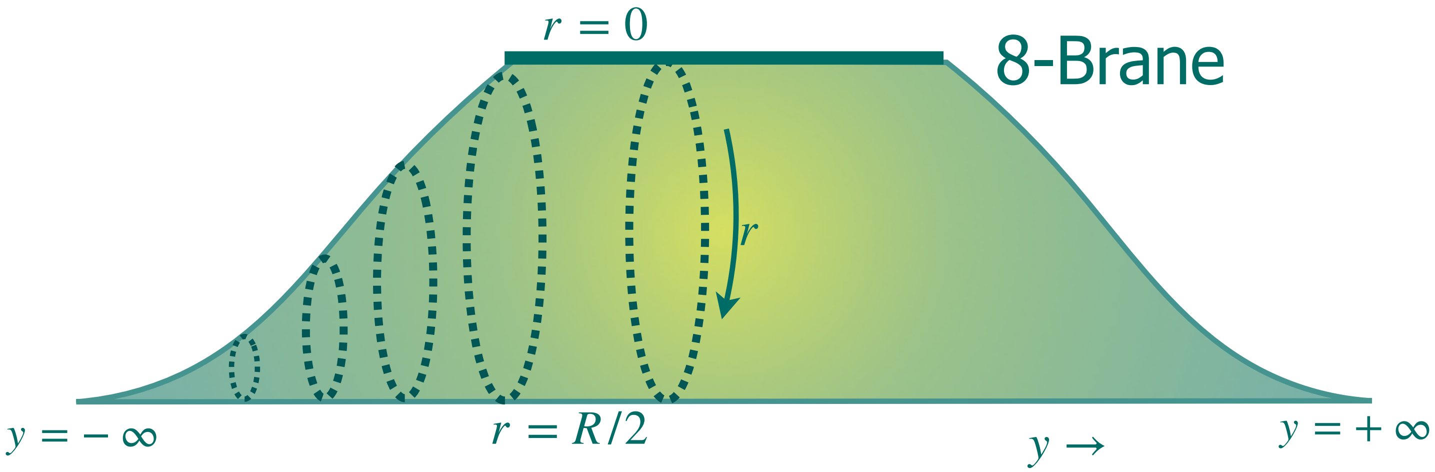

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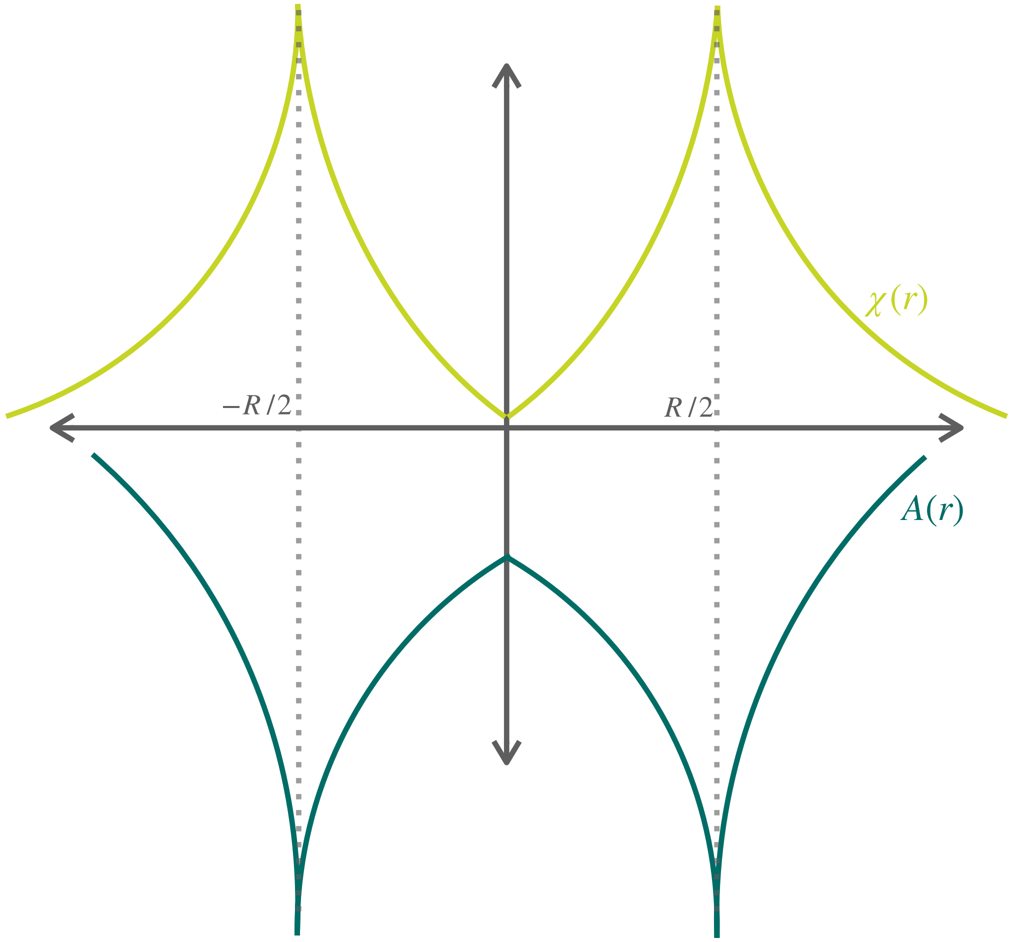

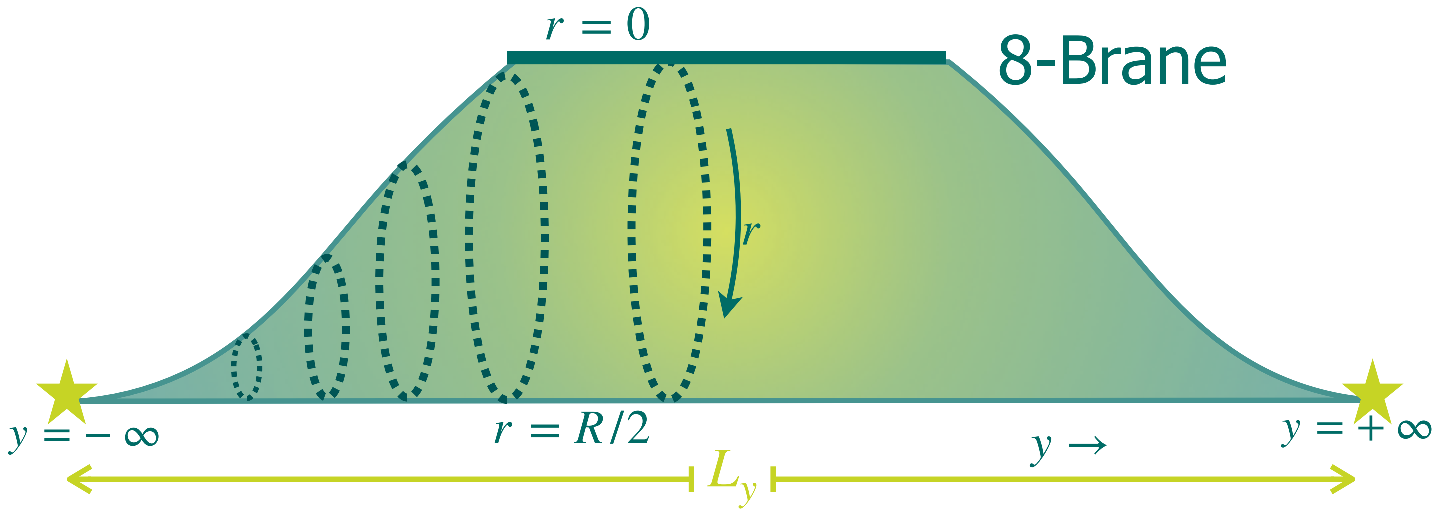

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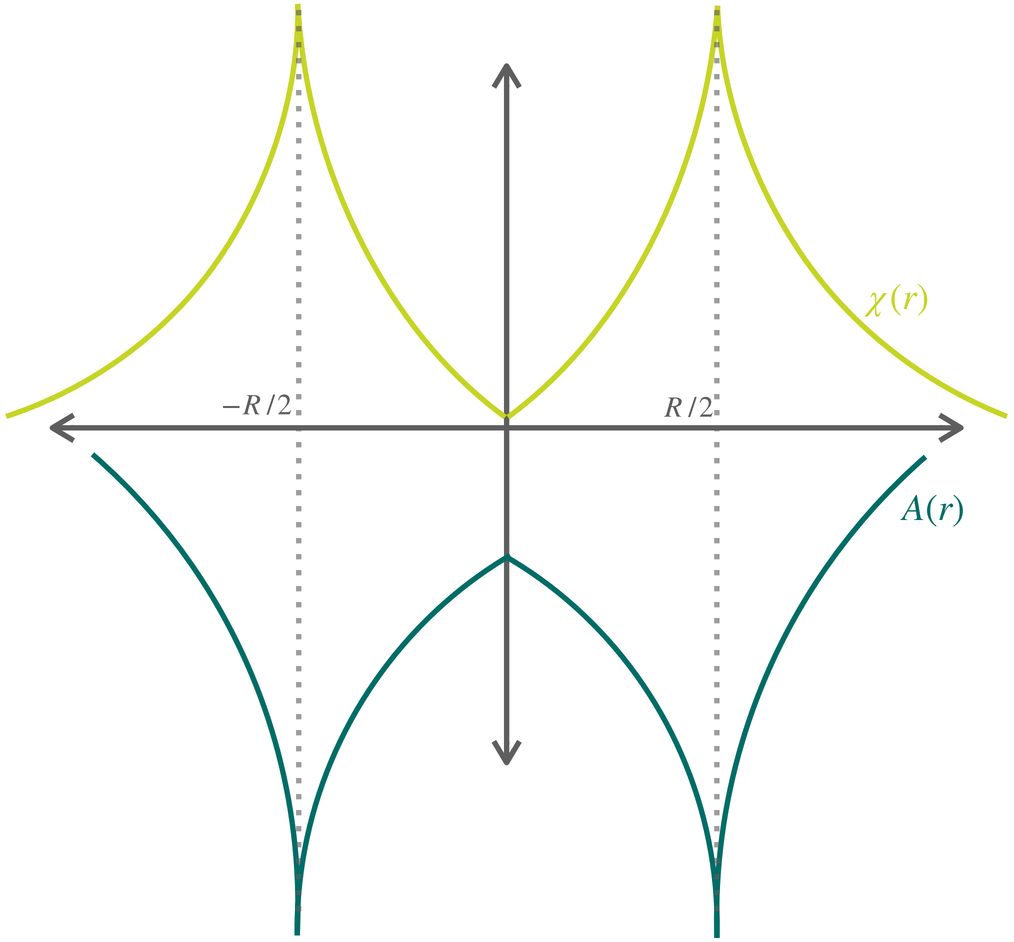

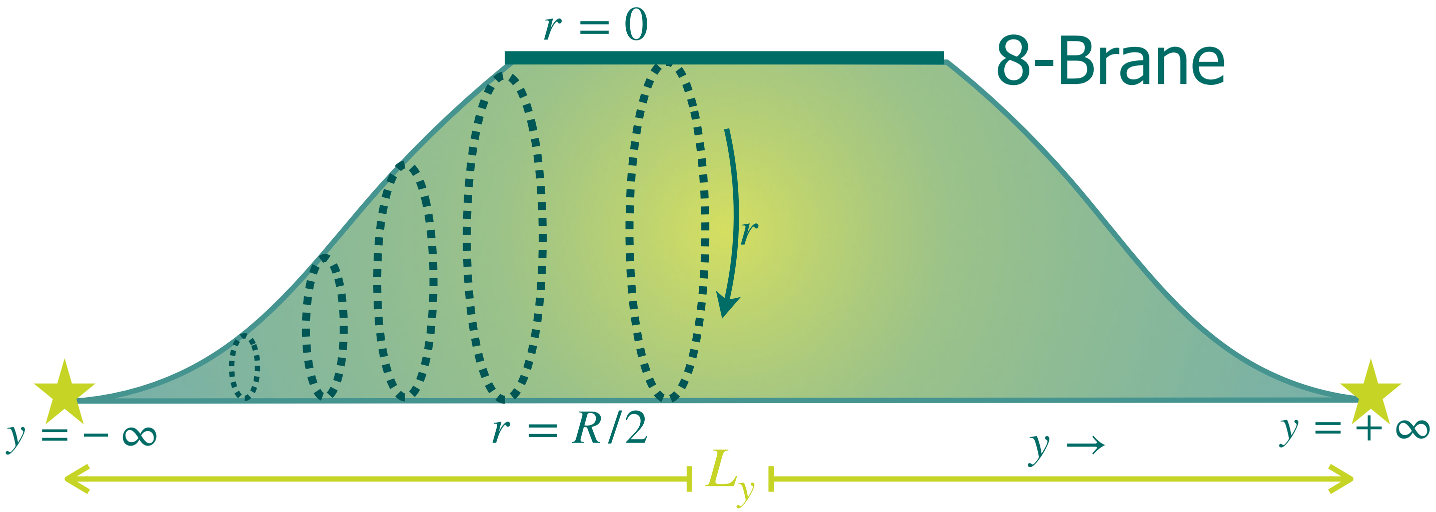

$$\Delta \sim L_y \sim \mathcal{T}^{-1}$$

$$\Delta \sim e^{-\sqrt{2}D}$$

$$|\mathscr{R}| \sim e^{2\sqrt{2}D}$$

ETW Defects

Input: 8-dimensional defect : log-singularity, S^1 direction capped off

Poincaré symmetry along the “brane” preserved

2d transversal rotational symmetry broken

Non-Isotropic Solution Ansatz:

$$ds^2 = e^{2\hat{\mathscr{A}}(\rho,\phi)} ds_8^2 + e^{2\hat{\mathscr{B}}(\rho,\phi)} (d\rho^2 + \rho^2 d\phi^2) \, .$$

Separation of variables

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Separation of variables

Solutions:

$$\hat{A}(\rho) = \frac{1}{8} \log \Big| \cosh\Big(8\hat{K} \log(\frac{\rho}{\rho_0}) \Big) \Big| \qquad \hat{B}(\rho) = -\log\Big(\frac{\rho}{\rho_0}\Big) + \Big(\frac{\hat{\alpha}^2}{32} - \frac{7}{2}\Big)\hat{A}(\rho)$$

$$\hat{\chi}(\rho) = \hat{\alpha}\hat{A}(\rho)$$

$$\vdots$$

$$\hat{\psi}(\phi) = \frac{\hat{\alpha}}{8} \log \Big| \cos(8\hat{K}\phi) \Big| \pm 2 \log \Big| \tan(4\hat{K}\phi + \frac{\pi}{4}) \Big|$$

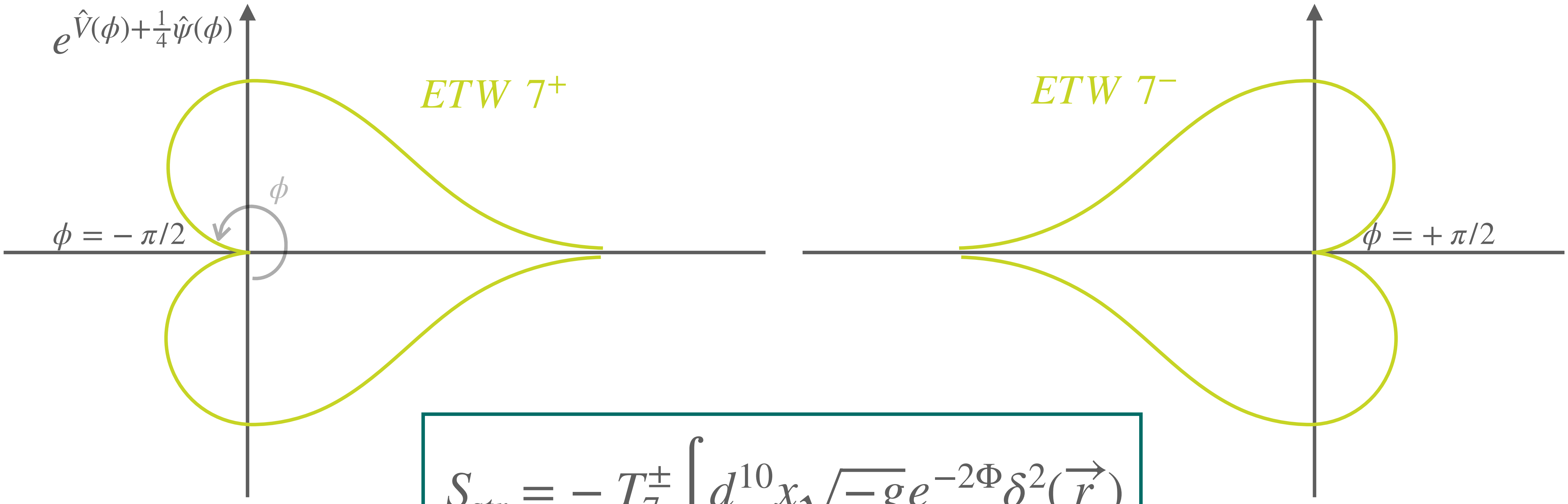
ETW $7^{\pm}$ solutions

Qualitative behavior

Logarithmic singularities at $\rho = 0$, string coupling diverges

For appropriate constant ($\hat{\alpha} = \alpha^{+}$) same scaling as 9d defect

Dynamical Cobordism scaling satisfied: $\Delta \sim e^{-\sqrt{2}D}, \, |\mathscr{R}| \sim e^{2\sqrt{2}D}$



$$\boxed{S_{str} = -T_7^{\pm}\int d^{10}x\sqrt{-g}\,e^{-2\Phi}\delta^2(\vec{r})}$$

with $\kappa_{10}^2 T_7 = 2\pi$

Cobordism Interpretation

Backreaction of 9d Domain Wall

↓

Spontaneous compactification on S^1

↓

Cobordism Group: $\Omega_1^{\xi} \neq 0$

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Solution II^+

Finite L_y, breaking possible

↓

Solutions $ETW\ 7^\pm$

↓

$$\Delta \sim e^{-\sqrt{2}D}$$

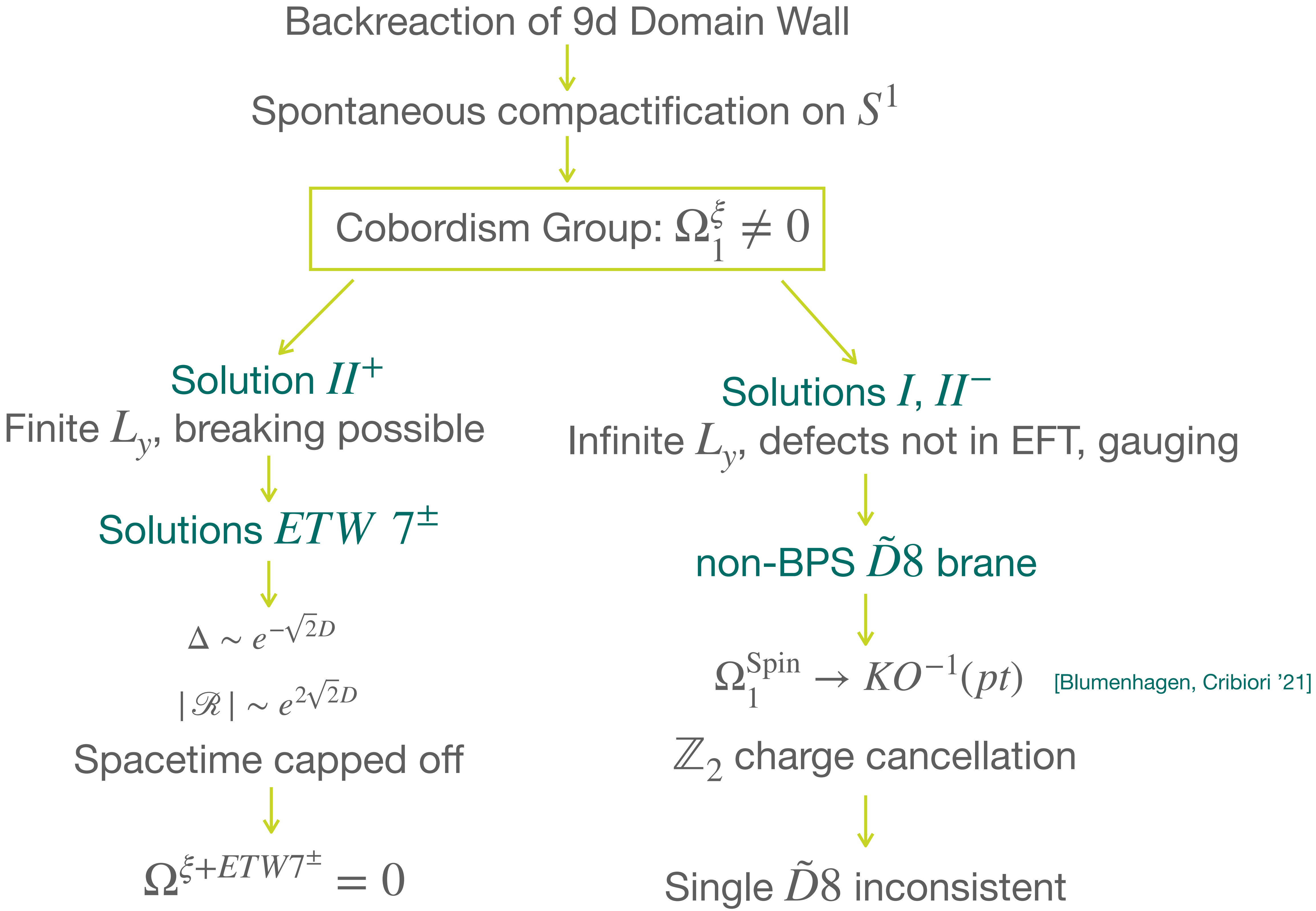
$$|\mathscr{R}| \sim e^{2\sqrt{2}D}$$

Spacetime capped off

↓

$$\Omega^{\xi+ETW7^\pm} = 0$$

Cobordism Interpretation



Backreaction of 9d Domain Wall

Spontaneous compactification on S^1

Cobordism Group: $\Omega_1^{\xi} \neq 0$

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Finite L_y, breaking possible

Solutions $ETW\ 7^{\pm}$

$$\Delta \sim e^{-\sqrt{2}D}$$

$$|\mathscr{R}| \sim e^{2\sqrt{2}D}$$

Spacetime capped off

$$\Omega^{\xi + ETW7^{\pm}} = 0$$

Solutions I, II^-

Infinite L_y, defects not in EFT, gauging

non-BPS $\tilde{D}8$ brane

$$\Omega_1^{\text{Spin}} \rightarrow KO^{-1}(pt)$$

[Blumenhagen, Cribiori ’21]

$\mathbb{Z}_2$ charge cancellation

Single $\tilde{D}8$ inconsistent

Summary and Outlook

We have provided:

Concrete example for physical realisation of dynamical cobordism

Explanation of singularities in preexisting solution, expected scalings satisfied

Eom for defect solved → new 7-brane defect

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Thank you!