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SEIT 1386

Unstable domain walls and transitions in the flux Landscape

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String Phenomenology, Boston, July 8, 2025

Work in progress with B. Friedrich, A. Hebecker and M. Wiesner

Flux Landsape and domain walls

⟶ Landscape approach to naturalness issues [Bousso, Polchinski '00][Denef, Douglas '04] [...]

⟶ IIB dS solutions KKLT and LVS [Kachru, Kallosh, Linde, Trivedi '03][Balasubramanian, Berglund, Conlon, Quevedo '05] ...

Concerns: [almost all String Pheno attendees '18–Now]

But in this talk: we take the dS Landscape for granted

⟶ Focus on transitions and domain walls: stability?

D5/NS5-branes on three-cyles of CY

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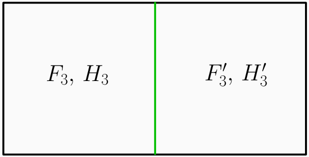


Outline

1/ Domain walls are unstable: no instanton

[Johnson, Larfors '08]×2 [Aguirre, Johnson, Larfors '10]

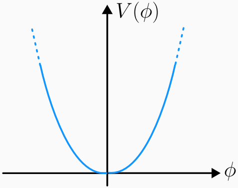
$\longrightarrow$ Field theory toy model

$\longrightarrow$ KKLT and LVS

$\longrightarrow$ Gravity

2/ Other ways to transition and how to estimate the rate?

Field theory toy model



Scalar potential: $V(\phi) = V_0 + \frac{m^2}{2}\phi^2 + \mathcal{O}(\phi^3)$

Brane potential: $V_{\text{brane}}(\phi) = Ae^{-B\phi}$, $B = \mathcal{O}(1)$

$\longrightarrow$ Transverse direction x

$\longrightarrow$ Same vacuum both sides of DW ($x = 0$) $\Longrightarrow$ profile?

$\longrightarrow$ No grav. backreaction

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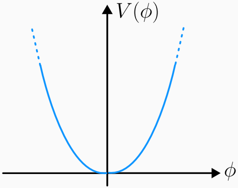

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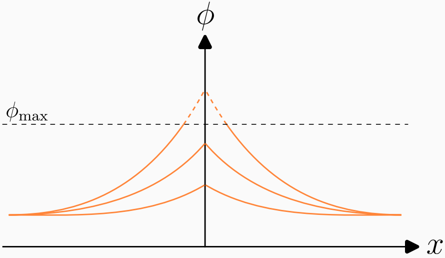
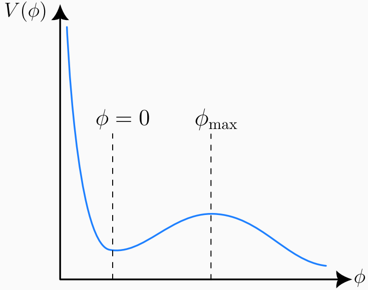
Intuition





Profile

$$\phi'' = \frac{\mathrm{d}}{\mathrm{d}\phi}(V + V_{\mathrm{brane}}) = m^2\phi - AB\delta(x)e^{-B\phi}$$

Derivative jump: $\phi'(x)|_{-\epsilon}^{+\epsilon} = -ABe^{-B\phi(0)}$

Boundary conditions: $\phi'(0_-) = -\phi'(0_+)$ and $\phi'(x \to \pm\infty) = 0$

$$\implies \phi(x) = \phi(0)e^{-m|x|}$$

$\longrightarrow m\phi(0) = ABe^{-B\phi(0)}$

Large displacement if $AB^2/m \gg 1$ and then $\phi(0) \simeq \frac{1}{B}\ln\left(\frac{AB^2}{m}\right)$

$$\simeq \ln\left(\frac{A}{m}\right)$$

$\longrightarrow$ Do we have $\phi_{\max} > \ln(A/m)$ in KKLT and LVS?

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- <u>KKLT</u>

$$V_{\rm KKLT} = \frac{aCg_{\rm s}e^{-a\sigma}}{2\sigma^2}\left(\frac{a\sigma}{3}Ce^{-a\sigma} - |W_0| + Ce^{-a\sigma}\right) \qquad \sigma = e^{\sqrt{\frac{2}{3}}\varphi}$$

$$W_0 = -Ce^{-a\sigma_0}\left(1 + \frac{2}{3}a\sigma_0\right) \ll 1$$

<u>DW tension:</u> $T_{\rm brane} = \frac{A_0}{\mathcal{V}}$

$$m_{\rm KKLT}\mathcal{V}_0 \sim g_s^{\frac{1}{2}}|W_0|\frac{(-\ln|W_0|)}{2} \ll 1$$

regime OK!

$\longrightarrow$ <u>Displacement:</u> $\phi^{\rm KKLT}(0) \simeq -\frac{2}{\sqrt{6}}\ln|W_0|$

To be compared with $\phi^{\rm KKLT}_{\rm max}$

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$W_0 = -Ce^{-a\sigma_0}\left(1+\frac{2}{3}a\sigma_0\right) \ll 1$ DW tension: $T_{\rm brane} = \frac{A_0}{\mathcal{V}}$

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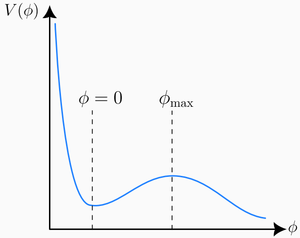
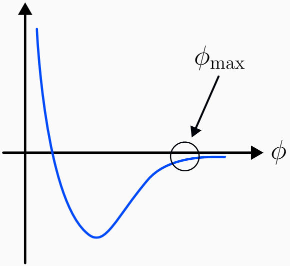


KKLT

$\longrightarrow$Barrier width: from pre-uplift pot. [Westphal '08]



Approx. vanishing at $\sigma = \sigma_0 + 1/a \Longrightarrow \phi_{\mathrm{max}}^{\mathrm{KKLT}} \simeq \sqrt{\frac{3}{2}} \frac{1}{(-\ln|W_0|)}$

Domain wall parametrically unstable

LVS

$$V(\mathcal{V}) \simeq \frac{g_s}{\mathcal{V}^3}\left[\mu - \ln^{3/2}(\mathcal{V})\right]$$

$$\Longrightarrow m_{\mathrm{LVS}}\mathcal{V}_0 \simeq \frac{g_s^{1/2}}{\mathcal{V}_0^{1/2}} \ll 1 \quad \text{regime OK!}$$

$\longrightarrow$ Displacement: $\phi^{\mathrm{LVS}}(0) \simeq -\frac{1}{\sqrt{6}}\ln\mathcal{V}_0$

$\longrightarrow$ Barrier width: Constant in large μ limit

For a $\overline{\mathrm{D3}}$ uplift $\Longrightarrow \phi^{\mathrm{LVS}}_{\mathrm{max}} \approx 0.71$

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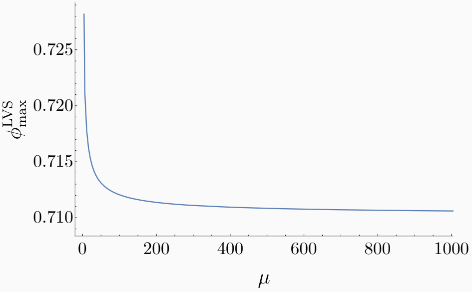


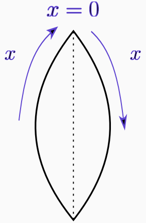
Domain wall parametrically unstable

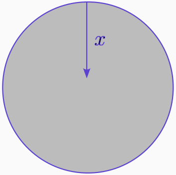
Including gravity

$O(4)$ symmetric ansatz $\mathrm{d}s_4^2 = \mathrm{d}x^2 + \rho(x)^2 \mathrm{d}\Omega_3^2$ [Colemann, De Luccia '80]

$$\rho' = \pm\sqrt{1 + \frac{\rho^2}{3}\left(\frac{\phi'^2}{2} - V\right)}, \quad \rho'' = -\frac{\rho}{3}\left(\phi'^2 + V + \delta(x)\frac{3}{2}V_{\text{brane}}\right),$$

$$\phi'' = m^2\phi - 3\frac{\rho'}{\rho}\phi' - \delta(x) A B e^{-B\phi},$$

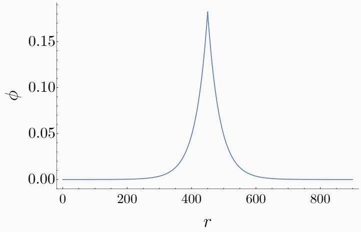


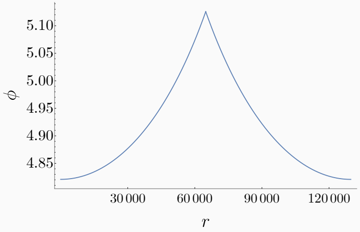


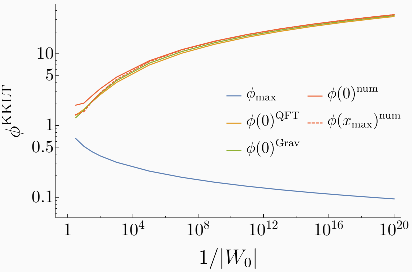
Behaviour similar to field theory: $\phi(0) \gtrsim \frac{1}{2B}\ln\left(\frac{3A^2B^2}{4m^2}\right)$

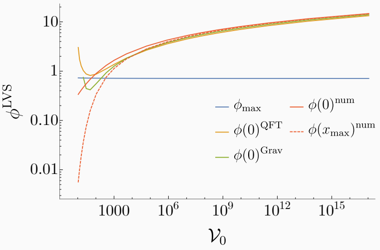
Numerics [Bandos, Blanco-Pillado, Sousa, Urkiola ’23]

Membrane DW profiles ⟶ Undershoot/overshoot algorithm









Non-tunneling

- Studied in [Brown, Dahlen '11], flyover type: [Blanco-Pillado, Deng, Vilenkin, '19]

⟶ In presence of membrane?

- Tachyon for brane nucleation: [Sen '98][Shiu, Tonioni, Van Hemelryck, Van Riet '23 '24]

$$V(\phi, T) = V(\phi) + Ae^{-B\phi}\frac{1}{\cosh T}$$

Flyover channel?

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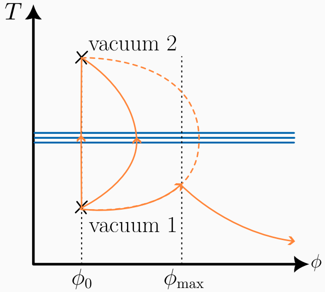

Flyover channel?

High tension causes problems

- dS with potential $V_h \Longrightarrow$ horizon $l_h^{-1} \sim V_h^{1/2} M_\mathrm{p}$

Crit. radius $\rho_b \sim T_\mathrm{brane}/\epsilon$ with $T_\mathrm{brane} \sim \mathcal{V}_0^{-1} M_\mathrm{p}^3$ and $\epsilon \sim V_h M_\mathrm{p}^4$

Asking $\rho_b < l_h \Longrightarrow \frac{1}{\mathcal{V}_0} < V_h^{1/2}$

But in KKLT and LVS: $V_h^{1/2} \sim m$ and $m\mathcal{V}_0 \ll 1$

- Bubble mass $T_\mathrm{brane}\rho_b^2$

Compare with Nariai BH mass $l_h M_\mathrm{p}^2$: $\frac{T_\mathrm{brane}\rho_b^2}{l_h M_\mathrm{p}^2} \sim \frac{1}{(\mathcal{V}_0 m)^3} \gg 1$

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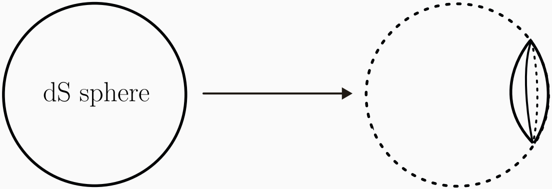


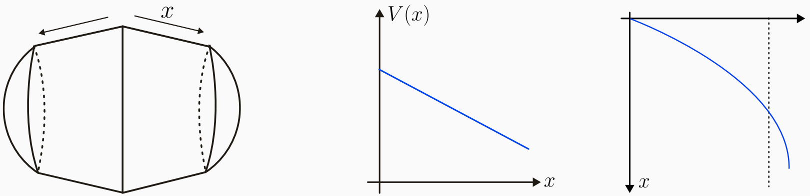
Lorentzian approach

Wheeler-DeWitt equation [deWitt '67]

Hamiltonian formalism [Dirac '58][ADM '62][Fischler, Morgan, Polchinski '90]...[Céspedes, de Alwis, Muia, Quevedo '20]

$$ds^2 = -(N^t \mathrm{d}t)^2 + L^2(\mathrm{d}r^2 + N^r)^2 + R^2(\mathrm{d}\theta^2 + \sin^2\theta \mathrm{d}\phi^2)$$

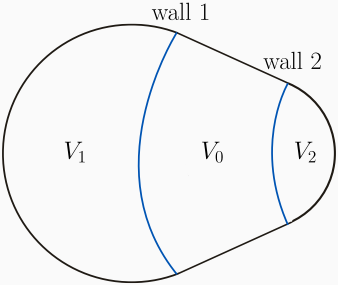
- Suppose we nucleate the bubble



dS patch is safe if it can reach horizon size!

Two-wall system

[Kolitch, Eardley '97]



$$S = \int \mathrm{d}t \left[p_1 \dot{r}_1 + p_2 r_2 + \int \mathrm{d}r \left(\pi_{\mathrm{L}} \dot{L} + \pi_{\mathrm{R}} \dot{R} - N^t \mathcal{H}_t - N^r \mathcal{H}_r \right) \right]$$

$\longrightarrow$ Fix radial param. and impose slicing condition

$\longrightarrow$ Solve constraints $\mathcal{H}_t = \mathcal{H}_r = 0$ in V_1, V_0, V_2

Conclusions

- The would-be ST dS Landscape does not admit CdL transitions [Aguirre, Johnson, Larfors '10]

- KKLT and LVS barrier width too small compared to field displacement at the DW

$\longrightarrow$ Asympt. regime in field theory, + gravity

$\longrightarrow$ Numerics for fully general case

- Apply to all "two-step constructions" (CS + Kähler) $\Longrightarrow$ F-term uplfit?

- How to populate anyway?

$\longrightarrow$ Usual non-tunneling fail

$\longrightarrow$ Hamiltonian approach and WDW for probability of the dS patch to reach horizon size, work in progress, stay tuned!

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