Dynamical Tadpoles, Stringy Cobordism and the SM from Spontaneous Compactification

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GB, M. Delgado, A. Uranga [arXiv:2104.02091]

Seminar Series on String Phenomenology, 27th April 2021

Plan of the talk

- Introduction and motivation

  Dynamical tadpoles and the swampland cobordism conjecture

- Two tadpole lessons from string theory examples

  Conifold

  3-form flux models

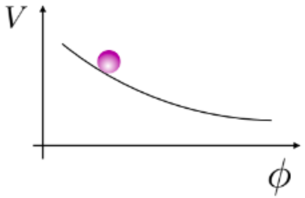
  Magnetized branes

  non susy 10d USp(32) theory

  SM from spontaneous compactification

- Conclusions

Dynamical tadpoles



- theories sitting on the **slope** of some scalar potential

  $\Rightarrow$ dynamical tadpoles (as opposed to topological tadpoles)

- properties of the resulting **space**time-**dependent** solutions?

Cobordism defects

- n-dim manifold can/cannot be the boundary of (n+1)-dim manifold

- cobordism charge can be removed by localized sources

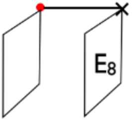
Cobordism defects

- swampland cobordism conjecture [McNamara Vafa]

  $\Omega_{QG} = 0$ related to no global symmetries

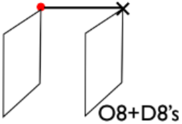
- examples

11dM-theory



Horava-Witten boundary

Type IIA



Type I'

Type IIB on S^1

With -1 SL(2,Z) WL

O7+D7s

Etc…

- not all defects are known

Two lessons

Finite Distance:

The running solution extends at most a distance Δ scaling as

$$\Delta^{-n} \sim \mathcal{T}$$

with the strength of the tadpole $\mathcal{T}$.

Dynamical Cobordism:

Spacetime is cut off at this distance by the cobordism defect of the swampland cobordism conjecture.

$\mathrm{AdS}_5 \times \mathrm{T}^{1,1}$

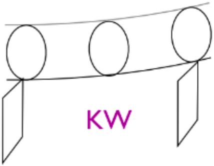
- $\mathrm{AdS}_5 \times \mathrm{T}^{1,1}$ with **N** units of RR 5-form flux [Klebanov Witten]

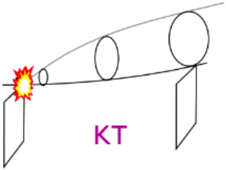
  near horizon limit of N D3's at conifold singularity
  $\mathrm{T}^{1,1} = \mathrm{S}^2 \times \mathrm{S}^3$ is 5d base of 6d cone

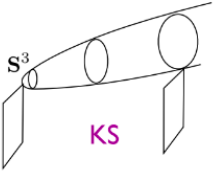
- Add **M** units of RR 3-form flux on S^3 [Klebanov Tseytlin]

  running $\mathrm{T}^{1,1}$ geometry and singularity at finite distance r_0

- Smooth out the singularity by finite size S^3 [Klebanov Strassler]





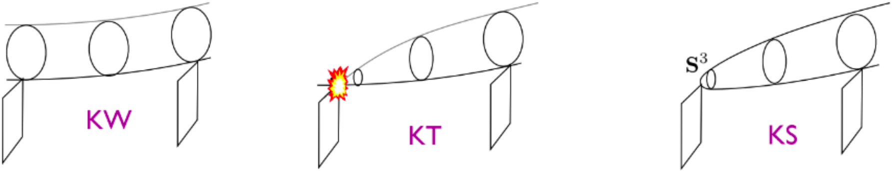


$AdS_5 \times T^{1,1}$

- dilaton tadpole $V(\phi) \sim M^2 e^{\phi}$ $\quad \nabla^2\phi = -e^{-6q-\phi}(\partial\Phi)^2 + e^{-14q+\phi}M^2$
- solved by running NSNS axion $\Phi = 3g_s M \log(r/r_0)$

Finite Distance $\Delta^{-1} \sim M^2 e^{\phi} \sim \mathcal{T}$

Dynamical Cobordism

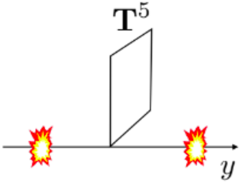


3-form flux models

- type IIB on T_5 with RR 3-form flux $F_3 = N dx^1 dx^2 dx^3$

- dilaton tadpole $\nabla^2\phi \sim e^{\phi}(F_3)^2 - e^{-\phi}(H_3)^2$

  solved by $H_3 = N dy^1 dy^2 dy \quad \Rightarrow \quad \Phi \sim Ny$

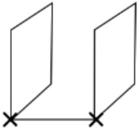


Finite Distance

$$ds_{10}^2 = Z^{-\frac{1}{2}} ds_4^2 + Z^{\frac{1}{2}} R^2 \left(dz^1 d\bar{z}^1 + dz^2 d\bar{z}^2 + dz^3 d\bar{z}^3\right)$$

with $-\tilde{\nabla}^2 Z = \frac{g_s}{6}(F_3)^2 \quad \Rightarrow \quad Z = 1 - \frac{g_s}{12}(F_3)^2 y^2$

singularities at $y^{-2} = \frac{1}{12} g_s (F_3)^2 \quad \Rightarrow \quad \Delta^{-2} \sim \mathcal{T}$



Dynamical Cobordism

singularities removed by O3's (possibly with D3's)

Magnetized branes

- type IIB on $T^2_{(1)} \times T^2_{(2)}$ with O7's and D7's transverse to $T^2_{(1)}$
- Add **M** units of D7 worldvolume magnetic flux on $T^2_{(2)}$

  susy breaking and tadpole for dilaton and $T^2_{(2)}$ Kähler modulus
- Solve by magnetic field $F_2 = F(dz_2 d\bar{z}_2 - dz_3 d\bar{z}_3)$

Finite Distance

lift to F-theory $G_4 \sim F_2 \wedge \omega_2$ singular warp factor $\Delta^{-2} \sim (F_2)^2 \sim \mathcal{T}$

Dynamical Cobordism

compactification on extra T_2/Z_2 with additional O7's and D7's

10d non susy USp(32) string

- orientifold of IIB with $O9^+$ and 32 $\overline{\text{D9}}$'s [Sugimoto]

- dilaton tadpole

$$S_E = \frac{1}{2\kappa^2}\int d^{10}x\sqrt{-G}\left[R - \frac{1}{2}(\partial\phi)^2\right] - T_9^E\int d^{10}x\sqrt{-G}\,64\,e^{\frac{3\phi}{2}}$$

- running solution $\phi = \frac{3}{4}\alpha_E y^2 + \frac{2}{3}\log|\sqrt{\alpha_E}y| + \phi_0$ [Dudas Mourad]

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

singularities at $y = 0, \infty$ separated by

Finite Distance $\Delta \sim \int_0^\infty \sqrt{g_{yy}}\,dy \sim e^{-\frac{3\phi_0}{4}}\alpha_E^{-\frac{1}{2}} \quad \Rightarrow \quad \Delta^{-2} \sim \mathcal{T}$

10d non susy USp(32) string

Dynamical Cobordism

strong coupling defect, that is able to gap chiral non anomalous content

- Solve by magnetization: $\mathrm{T}^6/(\mathrm{Z}^2 \times \mathrm{Z}^2)$ with $\mathrm{O9}^+$ and 8 $\mathrm{O5}_i^-$

obj.	N_α	(n_α^1, m_α^1)	(n_α^2, m_α^2)	(n_α^3, m_α^3)
$\mathrm{O9}^+$	32	$(1,0)$	$(1,0)$	$(1,0)$
$\mathrm{O5}_1^-$	-32	$(1,0)$	$(0,1)$	$(0,-1)$
$\mathrm{O5}_2^-$	-32	$(0,1)$	$(1,0)$	$(0,-1)$
$\mathrm{O5}_3^-$	-32	$(0,1)$	$(0,-1)$	$(1,0)$
D9	16	$(-1,1)$	$(-1,1)$	$(-1,1)$
D9′	16	$(-1,-1)$	$(-1,-1)$	$(-1,-1)$

n_α^i wrapping on T_i^2

m_α^i magnetic flux on T_i^2

SM from spontaneous compactification

- type I on $(\mathrm{T}^2 \times \mathrm{T}^2)/\mathrm{Z}^2$ with 32 magnetized D9's and O9, O5's

N_α	(n^1_α, m^1_α)	(n^2_α, m^2_α)
$N_{a+d} = 6 + 2$	$(1, 3)$	$(1, -3)$
$N_{h_1} = 4$	$(1, -3)$	$(1, -4)$
$N_{h_2} = 4$	$(1, -4)$	$(1, -3)$
40	$(0, 1)$	$(0, -1)$

n^i_α wrapping on T^2_i

m^i_α magnetic flux on T^2_i

T dual to intersecting D7's

RR tadpoles $\sum_\alpha N_\alpha n^2_\alpha n^3_\alpha = 16$ $\sum_\alpha N_\alpha m^2_\alpha m^3_\alpha = -16$

non susy $\Rightarrow$ dynamical tadpoles for inverse areas of T^2's

SM from spontaneous compactification

- Solve by magnetization along two of the 6d spacetime dimensions

$\Rightarrow \quad (\mathrm{T}^2 \times \mathrm{T}^2 \times \mathrm{T}^2)/(\mathrm{Z}^2 \times \mathrm{Z}^2)$ with extra O5's, D5's

N_α	(n^1_α, m^1_α)	(n^2_α, m^2_α)	(n^3_α, m^3_α)
$N_{a+d} = 6+2$	$(1,3)$	$(1,-3)$	$(1,0)$
$N_b = 2$	$(0,1)$	$(1,0)$	$(0,1)$
$N_c = 2$	$(-1,0)$	$(0,-1)$	$(0,1)$
$N_{h_1} = 2$	$(1,-3)$	$(1,-4)$	$(2,-1)$
$N_{h_2} = 2$	$(1,-4)$	$(1,-3)$	$(2,-1)$
40	$(0,1)$	$(0,-1)$	$(0,1)$

RR tadpoles

$$\sum_\alpha N_\alpha n^1_\alpha n^2_\alpha n^3_\alpha = 16$$

$$\sum_\alpha N_\alpha n^1_\alpha m^2_\alpha m^3_\alpha = 16$$

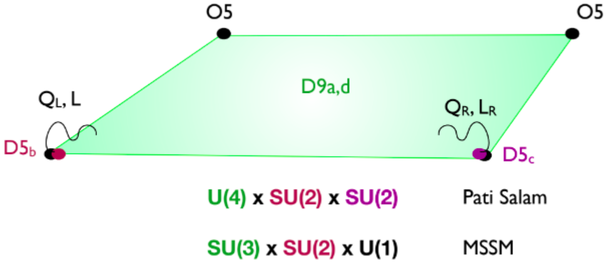
$$\sum_\alpha N_\alpha m^1_\alpha n^2_\alpha m^3_\alpha = 16$$

$$\sum_\alpha N_\alpha m^1_\alpha m^2_\alpha n^3_\alpha = -16$$

susy $\quad \chi_1 = \chi_2 \qquad \chi_3 = \frac{14\chi_1}{1-12\chi_1^2} \quad \Rightarrow$ no dynamical tadpoles

SM from spontaneous compactification

3-family MSSM-like spectrum [Marchesano Shiu]



Note that all MSSM but gluons/inos arise from cobordism branes

Conclusions

- We have studied the properties of space-dependent solutions in theories with dynamical tadpoles
- Two lessons: Finite Distance and Dynamical Cobordism
- Many open questions

  Time-dependent backgrounds

  More non susy examples

  Links to other swampland conjectures

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