Three-forms, supersymmetry and string compactifications

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based on: 1706.09422 with F. Farakos, S. Lanza, D. Sorokin
1802.xxxx with I. Bandos, F. Farakos, S. Lanza, D. Sorokin

Gauge 3-forms in four dimensions: a simple model

The simplest 3-form in 4d

- Gauge 3-form: $A_3 \to A_3 + \mathrm{d}\lambda_2$ ⟹ $F_4 = \mathrm{d}A_3$

- Action: $$S = -\frac{1}{2}\int_M F_4 \wedge *F_4 + \int_{\partial M} A_3 \wedge *F_4 + \dots$$ [..., Hawking `84, Duff `89,...]

$$= \int_M \mathrm{d}(A_3 \wedge *F_4)$$

- EoM: $\mathrm{d} * F_4 = 0$ ⟹ $*F_4 = n$ constant!

(fixed by boundary value)

⇓

$$S_{\text{eff}} = -\frac{1}{2}n^2 \int \mathrm{d}^4x\sqrt{-g} + \dots$$

effective cosmological constant

$$\Lambda_{\text{eff}} \simeq n^2$$

Remarks

- Lagrangian's parameter $n \sim \sqrt{\Lambda_{\rm eff}}$ $\xrightarrow{\text{traded for}}$ (non-propagating) F_4

- Different n 's correspond to different effective actions

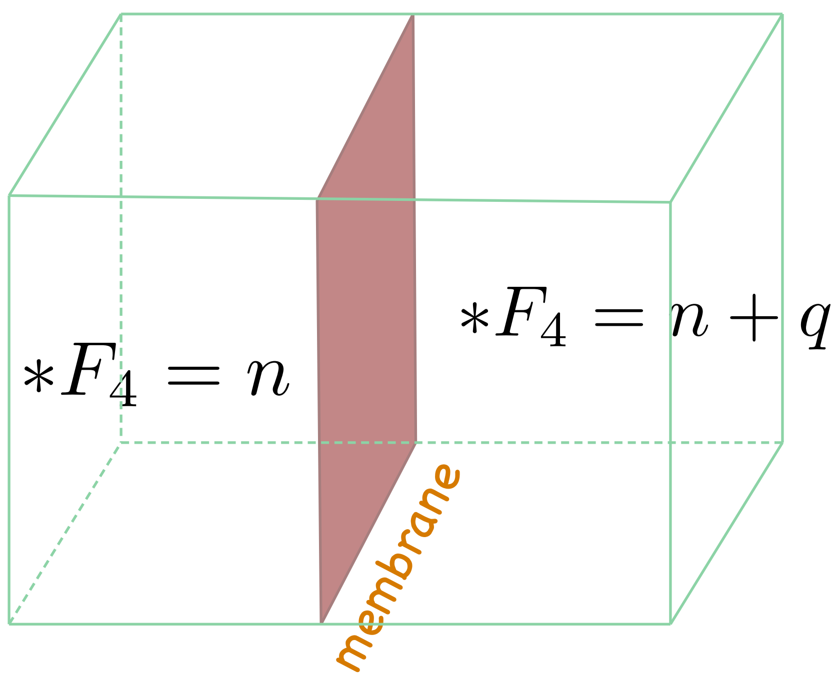
- Stringy/quantum gravity $\Longrightarrow$ n is quantised

  [..., Banks-Seiberg `10, ...]

Adding membranes

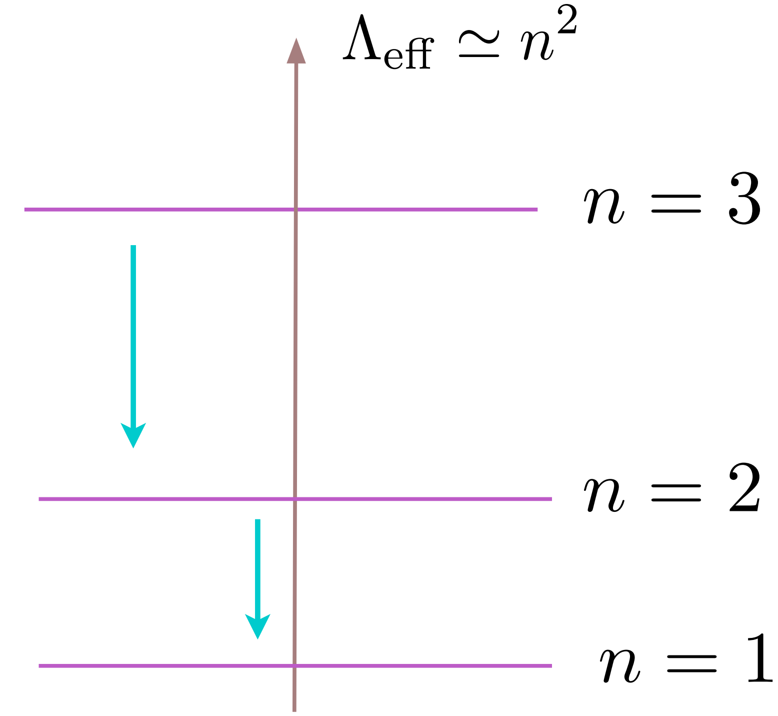
- We can add membranes: $$S_{\mathrm{M}} = -\tau_{\mathrm{M}} \int_{\mathcal{C}} \mathrm{d}^3\xi \sqrt{-\det h} + q \int_{\mathcal{C}} A_3$$

$$\mathrm{d} * F_4 = q\delta_1(\mathcal{C})$$



- Nucleations of membrane bubbles

[..., Brown-Teitelboim, ...]

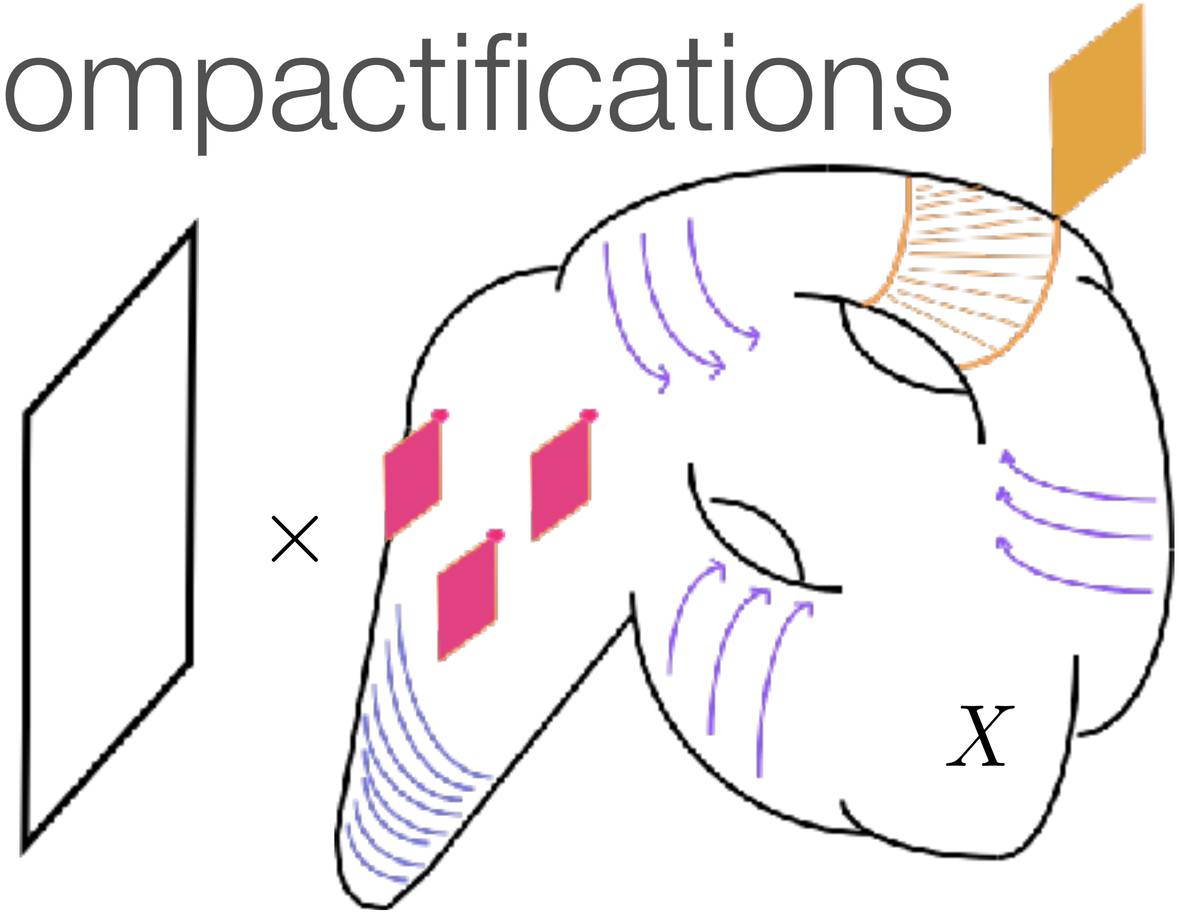


Gauge 3-forms in string compactifications

3-forms from string compactifications

- String theory contains several gauge p-forms:

$$C_p \longrightarrow G_{p+1} = \mathrm{d}C_p$$



- Effective 3-forms in 4d:

$$C_p = A_3^A \wedge \omega_A + \ldots$$
$$G_{p+1} = F_4^A \wedge \omega_A + \ldots$$

appropriate basis of closed internal forms

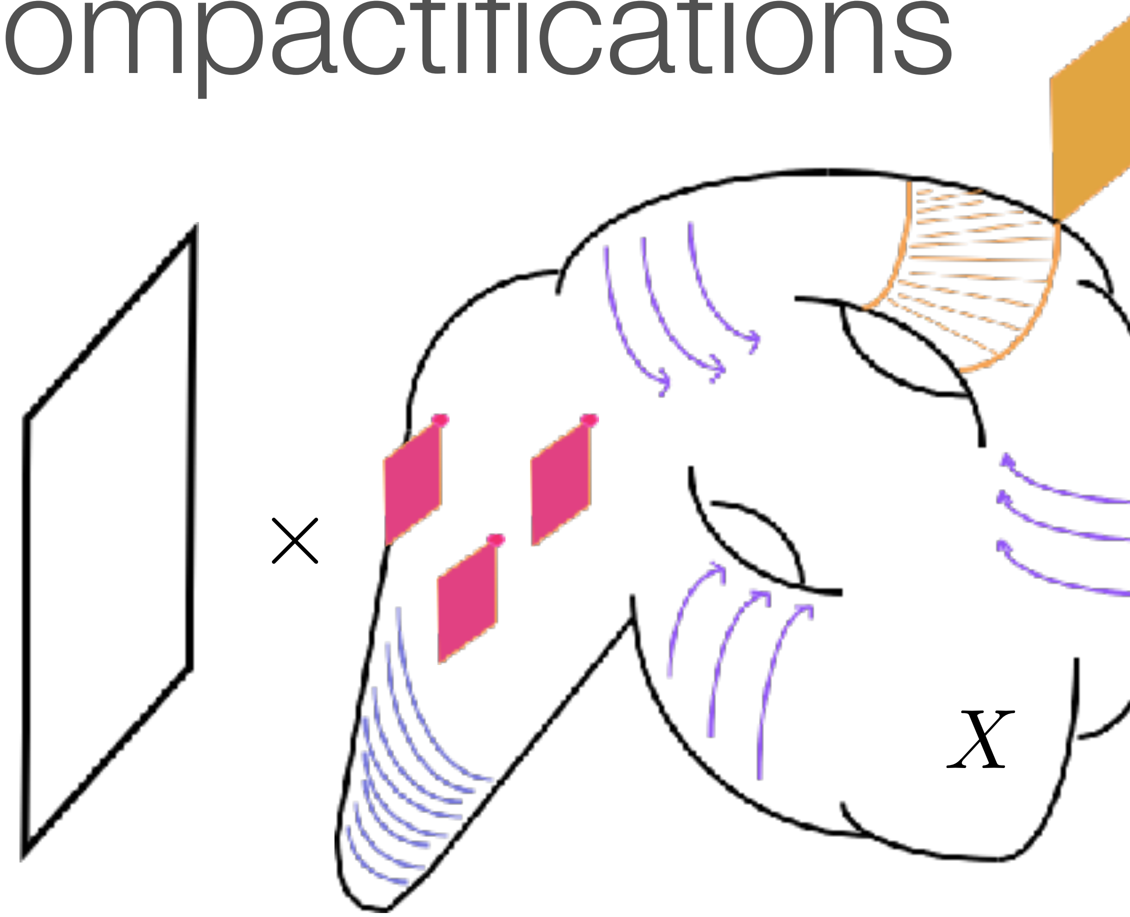
[Bousso-Polchinski \`00]
[Feng-March-Russell-Sethi-Wilczek \`00]
[Bielleman, Ibañez, Valenzuela \`15]
[Carta, Marchesano, Staessen, Zoccarato \`16]

- However, usual strategy: trade $G^{\rm ext}_{\rm p+1}$ for $G^{\rm int}_{9-p} = *_{10} G^{\rm ext}_{\rm p+1}$

internal fluxes $\quad n^A = \int_{D^A} G^{\rm int}_{6-q} \sim \langle F_4^A \rangle \quad \Longrightarrow \quad V_{\rm eff}(\phi; \mathbf{n})$

light scalars

3-forms from string compactifications



- Various wrapped branes can give effective membranes in 4d

↓

* domain walls separating compactifications with different flux quanta
* dynamical relaxation of the CC
  [Bousso-Polchinski `00]
  [Feng-March-Russell-Sethi-Wilczek `00]
* matter changing transitions

So far, mostly qualitative:

- Difficulty of fully 10d description
- Presence of 4d moduli
- Supersymmetric 4d EFT including 3-forms and membranes was missing

Main questions addressed in this talk

Can we combine:

- * gauge three-forms ⟹ “dynamical” flux quanta
- * membranes
- * supersymmetry ⟹ powerful 4d organising principle

into a 4d effective supergravity for string compactifications?

Main questions addressed in this talk

- We will focus on effective superpotentials of the form

$$W_{\rm eff}(\Phi) = e_I\Phi^I - m^I\mathcal{G}_{IJ}(\Phi)\Phi^J \quad \text{where} \quad \mathcal{G}_{IJ}(\Phi) \equiv \partial_I\partial_J\mathcal{G}(\Phi)$$

Inspired by string flux compactifications

special Kähler prepotential

- Counting: a pair of m^I, e_I ⟷ for each Φ^I

↑ a pair of 'microscopic' 3-form potentials $A_3^I, \tilde{A}_{I3}$

- Is there a 'microscopic' supersymmetric 3-form theory such that

$$\langle F_4^I\rangle, \langle\tilde{F}_{4J}\rangle \sim m^I, e_J \quad \longrightarrow \quad W_{\rm eff}(\Phi)$$?

Gauge 3-forms and
4d rigid supersymmetry

3-form multiplets

[Farakos-Lanza-LM-Sorokin `17]

- Start from a a set of complex linear multiplets Σ_I :

$$\bar{D}^2\Sigma_I = 0 \quad \Longrightarrow \quad \Sigma_I = \bar{D}_{\dot{\alpha}}\bar{\Psi}^{\dot{\alpha}}_I = \sigma_I + (*C_{3I})_m\theta\sigma^m\bar{\theta} + \theta^2 s_I + \dots$$

DOUBLE 3-FORM MULTIPLETS

complex 3-form

[Gates-Siegel `81]

- Gauge symmetry selected by prepotential $\mathcal{G}(S)$ for gauge invariant chiral fields

$$S^I = \bar{D}^2\left(\mathcal{M}^{IJ}\mathrm{Im}\Sigma_J\right) = \phi^I + \dots + \theta^2\mathcal{M}^{IJ}{}^*\mathcal{F}_{4J} + \dots$$

inverse of $\mathcal{M}_{IJ} \equiv \mathrm{Im}\mathcal{G}_{IJ}$ → $\partial_I\partial_J\mathcal{G}$

$\mathcal{M}^{IJ}s_J$

- Gauge symmetry: $\Sigma_I \to \Sigma_I + \tilde{L}_I - \mathcal{G}_{IJ}L^J$

real linear multiplets: $\bar{D}^2L = D^2L = 0$

$$L = l + (*\mathrm{d}\Lambda_2)_m\theta\sigma^m\bar{\theta} + \dots$$

3-form multiplets

[Farakos-Lanza-LM-Sorokin `17]

- Start from a a set of complex linear multiplets Σ_I :

$$\bar{D}^2\Sigma_I = 0 \quad \Longrightarrow \quad \Sigma_I = \bar{D}_{\dot\alpha}\bar{\Psi}^{\dot\alpha}_I = \sigma_I + (*C_{3I})_m\theta\sigma^m\bar\theta + \theta^2 s_I + \ldots$$

DOUBLE 3-FORM MULTIPLETS — complex 3-form ($(*C_{3I})_m$) — [Gates-Siegel `81]

- Gauge symmetry selected by prepotential $\mathcal{G}(S)$ for gauge invariant chiral fields

$$S^I = \bar{D}^2\left(\mathcal{M}^{IJ}\mathrm{Im}\Sigma_J\right) = \phi^I + \ldots + \theta^2\mathcal{M}^{IJ}{}^*\mathcal{F}_{4J} + \ldots$$

$\mathcal{M}^{IJ}$: inverse of $\mathcal{M}_{IJ} \equiv \mathrm{Im}\mathcal{G}_{IJ}$, with $\mathcal{G}_{IJ} \to \partial_I\partial_J\mathcal{G}$

$\phi^I \to \mathcal{M}^{IJ}s_J$

- Gauge symmetry: $\Sigma_I \to \Sigma_I + \tilde{L}_I - \mathcal{G}_{IJ}L^J$

  * $C_{3I} = \tilde{A}_{3I} - \mathcal{G}_{IJ}A_3^J$, $\mathcal{F}_{4I} = \mathrm{d}\tilde{A}_{3I} - \bar{\mathcal{G}}_{IJ}\mathrm{d}A_3^J$
  * $A_3^I \to A_3^I + \mathrm{d}\Lambda_2^I$, $\tilde{A}_{3I} \to \tilde{A}_{3I} + \mathrm{d}\tilde{\Lambda}_{2I}$
  * σ_I is pure gauge

The Lagrangian

- $$\mathcal{L} = \int d^4\theta K(S,\bar{S}) + \mathcal{L}_{\rm bd}$$

  "Microscopic" 3-form theory

- We can rewrite it as:

  ordinary chiral multiplets

$$\mathcal{L}' = \int d^4\theta\, K(\Phi,\bar{\Phi}) + \int d^2\theta \left[X_I\Phi^I - X_I\bar{D}^2(\mathcal{M}^{IJ}{\rm Im}\,\Sigma_J)\right] + {\rm c.c.}$$

* integrating out X_I ➡ $\Phi^I \equiv S^I = \bar{D}^2\left(\mathcal{M}^{IJ}{\rm Im}\,\Sigma_J\right)$

  ⬇

  back to original Lagrangian $\mathcal{L}$!

The Lagrangian

- $$\mathcal{L} = \int \mathrm{d}^4\theta K(S,\bar{S}) + \mathcal{L}_{\rm bd}$$ "Microscopic" 3-form theory

- We can rewrite it as:

ordinary chiral multiplets

$$\mathcal{L}' = \int \mathrm{d}^4\theta\, K(\Phi,\bar{\Phi}) + \int \mathrm{d}^2\theta \left[X_I\Phi^I - X_I\bar{D}^2(\mathcal{M}^{IJ}\mathrm{Im}\,\Sigma_J)\right] + \mathrm{c.c.}$$

* EoM of $\Sigma_I = \bar{D}_{\dot{\alpha}}\bar{\Psi}^{\dot{\alpha}}_I$ ⟶ $X_I = e_I - \mathcal{G}_{IJ}(\Phi)m^J$

arbitrary integration constants

Effective Lagrangian for ordinary chiral multiplets

$$\mathcal{L}_{\rm eff} = \int \mathrm{d}^4\theta K(\Phi,\bar{\Phi}) + \int \mathrm{d}^2\theta W_{\rm eff}(\Phi) + \mathrm{c.c.}$$

$$W_{\rm eff}(\Phi) = e_I\Phi^I - m^I\mathcal{G}_{IJ}(\Phi)\Phi^J$$

$K(\Phi,\bar{\Phi})$ is arbitrary!

The Lagrangian

$$\mathcal{L} = \int \mathrm{d}^4\theta K(S, \bar{S}) + \mathcal{L}_{\mathrm{bd}}$$

"Microscopic" 3-form theory

$$S^I = \phi^I + \ldots + \theta^2 \mathcal{M}^{IJ\,*}\mathcal{F}_{4J} + \ldots$$

double 3-form multiplets

$$\Phi^I = \phi^I + \ldots + \theta^2 F_\Phi^I + \ldots$$

ordinary chiral multiplets

$$\mathcal{L}_{\mathrm{eff}} = \int \mathrm{d}^4\theta K(\Phi, \bar{\Phi}) + \int \mathrm{d}^2\theta W_{\mathrm{eff}}(\Phi) + \mathrm{c.c.}$$

$$W_{\mathrm{eff}}(\Phi) = e_I \Phi^I - m^I \mathcal{G}_{IJ}(\Phi)\Phi^J$$

Effective Lagrangian

Gauge 3-forms and 4d supergravity

Weyl invariant formulation

- Ordinary formulation is not the most natural one:

cf. Bagger&Wess textbook

$$\int \mathrm{d}^4\theta\, E\, e^{-\frac{1}{3}K(\Phi,\bar{\Phi})} + \int \mathrm{d}^2\theta\, \mathcal{E}\, W(\Phi)$$

chiral multiplets: Φ^i ($i = 1, \ldots, n$)

- Introduce:
  - ✱ conformal compensator Y
  - ✱ projective coordinates $Z^I = Y f^I(\Phi)$ $I = 0, 1, \ldots, n$

- $$\int \mathrm{d}^4\theta\, E\, \Omega(Z, \bar{Z}) + \int \mathrm{d}^2\theta \mathcal{E}\, \mathcal{W}(Z)$$ is invariant under Super-Weyl transformations:

$$E_M^a \to e^{\Upsilon + \bar{\Upsilon}} E_M^a \qquad Z^I \to e^{-6\Upsilon} Z^I$$

$\Omega \to |Y|^{\frac{2}{3}} e^{-\frac{1}{3}K(\Phi,\bar{\Phi})}$ $\mathcal{W} \to Y W(\Phi)$

- ✱ $\Omega(\lambda Z, \lambda \bar{Z}) = |\lambda|^{\frac{2}{3}} \Omega(Z, \bar{Z})$
- ✱ $\mathcal{W}(\lambda Z) = \lambda \mathcal{W}(Z)$

- Gauge-fixing: $Y = 1$ → back to B&W's formulation

String-inspired superpotentials

- We will focus on effective superpotentials of the form

$$\mathcal{W}_{\rm eff}(Z) = e_I Z^I - m^I \mathcal{G}_I(Z)$$

where

$$\mathcal{G}_I(Z) = \partial_I \mathcal{G}(Z) = \mathcal{G}_{IJ}(Z) Z^J$$

$$\mathcal{G}(\lambda Z) = \lambda^2 \mathcal{G}(Z)$$

e.g. in type IIB $= \int_X \Omega_3 \wedge G_3^{\rm RR}$

[Gukov-Vafa-Witten `99]

* $Z^I = \int_{A^I} \Omega_3 \qquad \mathcal{G}_I = \int_{B_I} \Omega_3$
* $e_I = \int_{B_I} G_3^{\rm RR} \qquad m^I = \int_{A^I} G_3^{\rm RR}$

- Counting: conformal compensator + n physical chiral multiplets $\longleftrightarrow$ $n+1$ pairs m^I, e_I

- 'Microscopic' 3-form supergravity theory with $n+1$ double 3-form multiplets?

The 3-form Lagrangian

Microscopic Weyl-invariant 3-form theory

$$\mathcal{L} = \int \mathrm{d}^4\theta E\, \Omega(S, \bar{S}) + \mathcal{L}_{\mathrm{bd}}$$

$$S^I = \phi^I + \ldots + \theta^2(\bar{M}\phi^I + \mathcal{M}^{IJ\,*}\mathcal{F}_{4J}) + \ldots$$

$$Z^I = \phi^I + \ldots + \theta^2 F_Z^I + \ldots$$

Effective Weyl-invariant Lagrangian

$$\mathcal{L}_{\mathrm{eff}} = \int \mathrm{d}^4\theta E\, \Omega(Z, \bar{Z}) + \int \mathrm{d}^2\theta \mathcal{E}\left[e_I Z^I - m^I \mathcal{G}_I(Z)\right] + \mathrm{c.c.} + \ldots$$

Remarks

- After gauge-fixing:

$$S^I = Y f^I(\phi)$$
$$Y = 1$$

g_{mn} metric

ϕ^i — n scalar fields $(i = 1, \ldots, n)$

$F_4^I = \mathrm{d}A_3^I \ , \ \tilde{F}_{4J} = \mathrm{d}\tilde{A}_{3J}$ — $2n+2$ 3-forms replacing auxiliary fields M, F_Φ^i $(I = 0, 1, \ldots, n)$

+ fermions

- One can add other F-terms and couple "ordinary" chiral matter

$$\mathcal{L} = \int \mathrm{d}^4\theta E\, \Omega(S, \bar{S}, T, \bar{T}) + \int \mathrm{d}^2\theta \mathcal{E}\, \hat{\mathcal{W}}(S, T)$$

integrating out 3-form potentials $\Longrightarrow$ $\mathcal{W}_{\rm eff}(Z, T) = e_I Z^I - m^I \mathcal{G}_I(Z) + \hat{\mathcal{W}}(Z, T)$

Examples

A special class of models

[Bandos, Farakos-Lanza-LM- Sorokin `17]

- Factorised kinetic potential:

e.g.: type II compactifications (const. warping)

[Grimm-Louis `04]

$$\Omega(S,\bar{S},T,\bar{T}) = \left(\mathrm{Im}\,[S^I\bar{\mathcal{G}}_I(\bar{S})]\right)^{\frac{1}{3}}\, e^{-\frac{1}{3}\hat{K}(T,\bar{T})}$$

special Kähler geometry

- The theory is covariant under symplectic duality transformations

$$\begin{pmatrix} A_3^I \\ \tilde{A}_{3J} \end{pmatrix} \to \mathcal{S}\begin{pmatrix} A_3^I \\ \tilde{A}_{3J} \end{pmatrix} \qquad \mathcal{S} \in Sp(2n+2;\mathbb{Z})$$

In type II models, expected from freedom to change symplectic basis of cycles

A simple example

- 2 double three-fom multiplets: $\mathcal{G}(S) = -\mathrm{i} S^0 S^1$
  - 1 scalar: $\phi \quad , \quad K(\phi, \bar{\phi}) = -\log \mathrm{Im}\,\phi$
  - 4 gauge 3-forms: $A^0_{(3)}, \quad A^1_{(3)} \quad , \quad \tilde{A}_{(3)0} \quad , \quad \tilde{A}_{(3)1}$ ⟹

$$\mathcal{F}_{(4)0} = \mathrm{d}(\tilde{A}_{(3)0} - \mathrm{i} A^1_{(3)})$$
$$\mathcal{F}_{(4)1} = \mathrm{d}(\tilde{A}_{(3)1} - \mathrm{i} A^0_{(3)})$$

- Action: $S = -\int \left[R^*1 + \frac{\mathrm{d}\phi \wedge {}^*\mathrm{d}\bar{\phi}}{(\mathrm{Im}\,\phi)^2} + \mathcal{T}^{IJ}(\phi) \bar{\mathcal{F}}_{(4)I} {}^*\mathcal{F}_{(4)J} \right] + S_{\mathrm{bd}} + \text{fermions}$

$$\mathcal{T}^{IJ}(\phi) = \frac{1}{\mathrm{Im}\,\phi} \begin{pmatrix} 1 & \mathrm{i}\bar{\phi} - 3\mathrm{Im}\,\phi \\ -\mathrm{i}\phi - 3\mathrm{Im}\,\phi & |\phi|^2 \end{pmatrix}$$

  - Invariant under $SL(2,\mathbb{Z}) \subset Sp(4,\mathbb{Z}) \quad : \quad \phi \to \frac{a\phi + b}{c\phi + d} \qquad \mathcal{F}_I \to U_I{}^J \mathcal{F}_J$

duality group

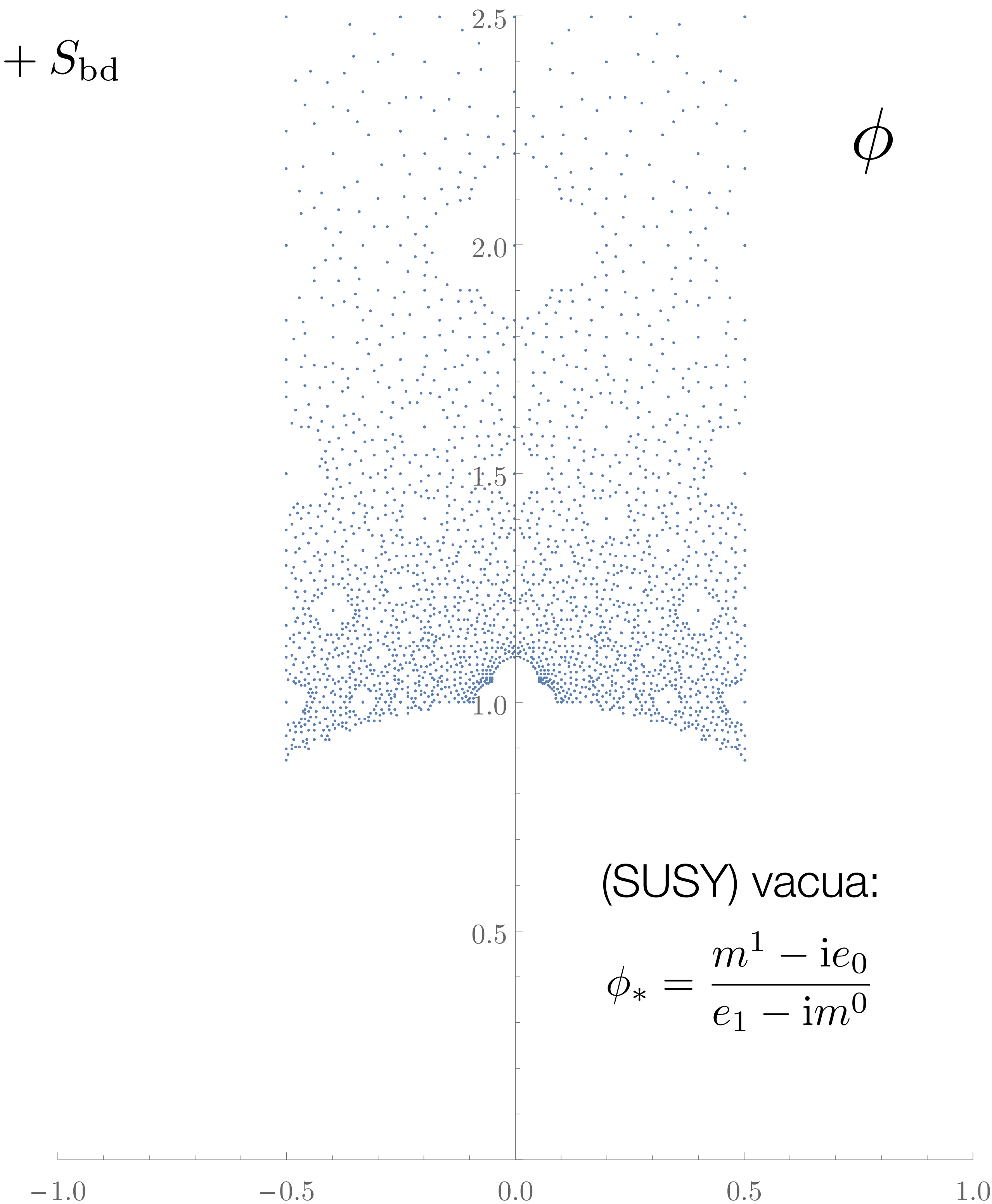
$$S_{\text{bos}} = -\int \left[R^*1 + \frac{\mathrm{d}\phi \wedge {}^*\mathrm{d}\bar{\phi}}{(\mathrm{Im}\,\phi)^2} + \mathcal{T}^{IJ}(\phi)\bar{\mathcal{F}}_{(4)I}{}^*\mathcal{F}_{(4)J} \right] + S_{\text{bd}}$$

Integrating out 3-forms:

$$\mathrm{Re}(\mathcal{T}^{IJ*}\mathcal{F}_J) = m^I \quad , \quad \mathrm{Im}(\mathcal{G}_{IJ}\mathcal{T}^{JK*}\mathcal{F}_K) = e_I$$

- $S_{\text{eff}} = -\int \left[R^*1 + \frac{\mathrm{d}\phi \wedge {}^*\mathrm{d}\bar{\phi}}{(\mathrm{Im}\,\phi)^2} + V_{\text{eff}}(\phi, \bar{\phi}) \right]$
- $V_{\text{eff}} = e^K(|DW_{\text{eff}}|^2 - 3|W_{\text{eff}}|^2)$
- $W_{\text{eff}}(\phi) = (e_0 + \mathrm{i}m^1) - \mathrm{i}(e_1 + \mathrm{i}m^0)\phi$

Infinite landscape of AdS vacua from a single 4d theory!



(SUSY) vacua:

$$\phi_* = \frac{m^1 - \mathrm{i}e_0}{e_1 - \mathrm{i}m^0}$$

cf. [Denef-Douglas `04]

Type IIA compactifications

cf. [Grimm-Louis `04]

- $n+1$ double 3-form multiplets: $S^I = (S^0, S^i) \quad (i = 1, \ldots, n)$

  $h^{1,1}_-$

  compensator + complexified Kähler structure moduli $\phi^i = v^i - \mathrm{i} b^i$

- Prepotential: $\mathcal{G}(S) = \frac{1}{6S^0} k_{ijk} S^i S^j S^k$ $\quad k_{ijk} \sim$ triple intersection numbers

- $h^{2,1}+1$ ordinary chiral fields: $T^p = t^p + \ldots$ complex str. moduli + dilaton+ RR-axions

Type IIA compactifications

- $$S_{\text{bos}} = -\int \left(R + K_{ij}\,\mathrm{d}\phi^i \wedge {}^*\mathrm{d}\bar{\phi}^j + \hat{K}_{p\bar{q}}\,\mathrm{d}t^p \wedge {}^*\mathrm{d}\bar{t}^{\bar{q}}\right)$$
$$-\int \left[e^{-\mathcal{K}}\left(F_4^0\,{}^*F_4^0 + K_{ij}\mathbb{F}_4^i\,{}^*\mathbb{F}_4^j\right) + e^{K-\hat{K}}\left(K^{ij}\tilde{\mathbb{F}}_{4i}\,{}^*\tilde{\mathbb{F}}_{4j} + \tilde{\mathbb{F}}_{40}\,{}^*\tilde{\mathbb{F}}_{40}\right)\right] \quad + S_{\text{bd}}$$

  - $\mathbb{F}_4^i = F_4^i + b^i F_4^0$
  - $\tilde{\mathbb{F}}_{4i} = \tilde{F}_{4i} + k_{ijk}b^j F_4^k + \frac{1}{2}k_{ijk}b^j b^k F_4^0$
  - $\tilde{\mathbb{F}}_{40} = \tilde{F}_{40} + b^i\tilde{F}_{4i} + \frac{1}{2}k_{ijk}b^i b^j F_4^k + \frac{1}{6}k_{ijk}b^i b^j b^k F_4^0$

- One can solve EoM's of 3-forms in terms of $2n+2$ integration constants m^I, e_J

⇓

$$S_{\text{3-forms}} = -\int \mathrm{d}^4x\, e V_{\text{eff}}(\phi,\bar{\phi}) \qquad V_{\text{eff}} = e^K\left(|DW_{\text{eff}}|^2 - 3|W_{\text{eff}}|^2\right)$$

$$W_{\text{eff}}(\phi) = e_0 + e_i\Phi^i + k_{ijk}m^i\Phi^j\Phi^k + m^0 k_{ijk}\Phi^i\Phi^j\Phi^k \quad = \int_X G_{\text{RR}} \wedge e^{B+\mathrm{i}J}$$

[Gukov-Vafa-Witten `99]
[Grimm-Louis `04]

Type IIA compactifications

- $$S_{\rm bos} = -\int \left(R + K_{ij}\, \mathrm{d}\phi^i \wedge {}^*\mathrm{d}\bar{\phi}^j + \hat{K}_{p\bar{q}}\, \mathrm{d}t^p \wedge {}^*\mathrm{d}\bar{t}^{\bar{q}}\right)$$
$$- \int \left[e^{-\mathcal{K}}\left(F_4^0\, {}^*F_4^0 + K_{ij}\mathbb{F}_4^i\, {}^*\mathbb{F}_4^j\right) + e^{K-\hat{K}}\left(K^{ij}\tilde{\mathbb{F}}_{4i}\, {}^*\tilde{\mathbb{F}}_{4j} + \tilde{\mathbb{F}}_{40}\, {}^*\tilde{\mathbb{F}}_{40}\right)\right] \quad + S_{\rm bd}$$

  - $\mathbb{F}_4^i = F_4^i + b^i F_4^0$
  - $\tilde{\mathbb{F}}_{4i} = \tilde{F}_{4i} + k_{ijk} b^j F_4^k + \frac{1}{2} k_{ijk} b^j b^k F_4^0$
  - $\tilde{\mathbb{F}}_{40} = \tilde{F}_{40} + b^i \tilde{F}_{4i} + \frac{1}{2} k_{ijk} b^i b^j F_4^k + \frac{1}{6} k_{ijk} b^i b^j b^k F_4^0$

- Partially matches bosonic action of [Bielleman, Ibañez, Valenzuela \`15] [Carta, Marchesano, Staessen, Zoccarato \`16]

  derived from 10d type II democratic pseudo-action [Bergshoeff, Kallosh, Ortin, Roest and Van Proeyen \`01]

$$S_{\rm bd} \to \int \left(m^I\, \tilde{F}_{4I} - e_I\, F_4^I\right)$$

hybrid formulation with m^I, e_J present in the boundary term

Membranes and jumping domain walls

Membranes

- We can couple locally supersymmetric (q_I, p^J)-membranes

$$\mathcal{C}: \quad \xi^i \quad \mapsto \quad x^m(\xi), \theta^\mu(\xi), \bar{\theta}^{\dot{\mu}}(\xi)$$

superembedding

$$S_{\rm M} = -\int_{\mathcal{C}} \mathrm{d}^3\xi \sqrt{-\det h}\, \left|q_I S^I - p^I \mathcal{G}_I(S)\right| \; + q_I \int_{\mathcal{C}} \mathcal{A}_3^I - p^I \int_{\mathcal{C}} \tilde{\mathcal{A}}_{3I}$$

kappa-symmetric without dynamical constraints on bulk fields!

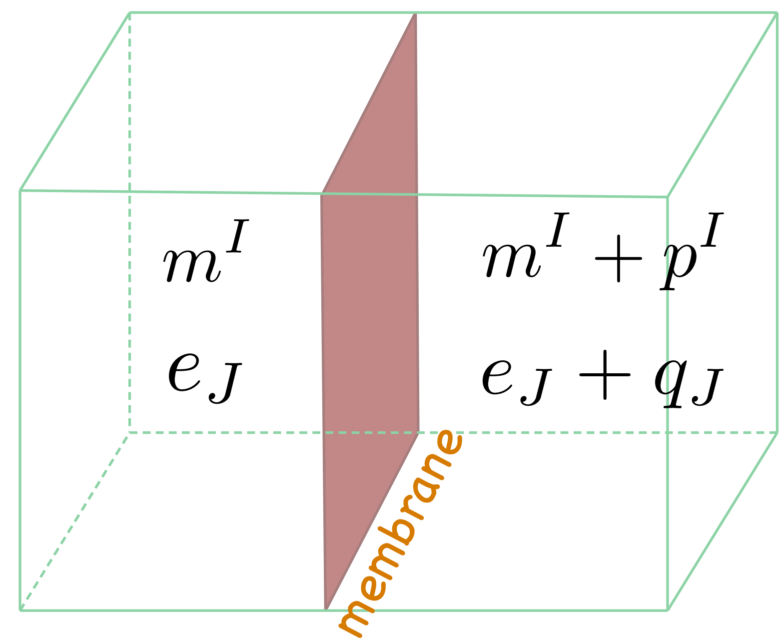
$\tilde{A}_{3I} + \ldots \qquad A_3^I + \ldots$

- Supersymmetrization of what expected from type II compactifications, with correct moduli dependent tension

Jumping effective potentials

- Membranes generate a jump of the integration constants

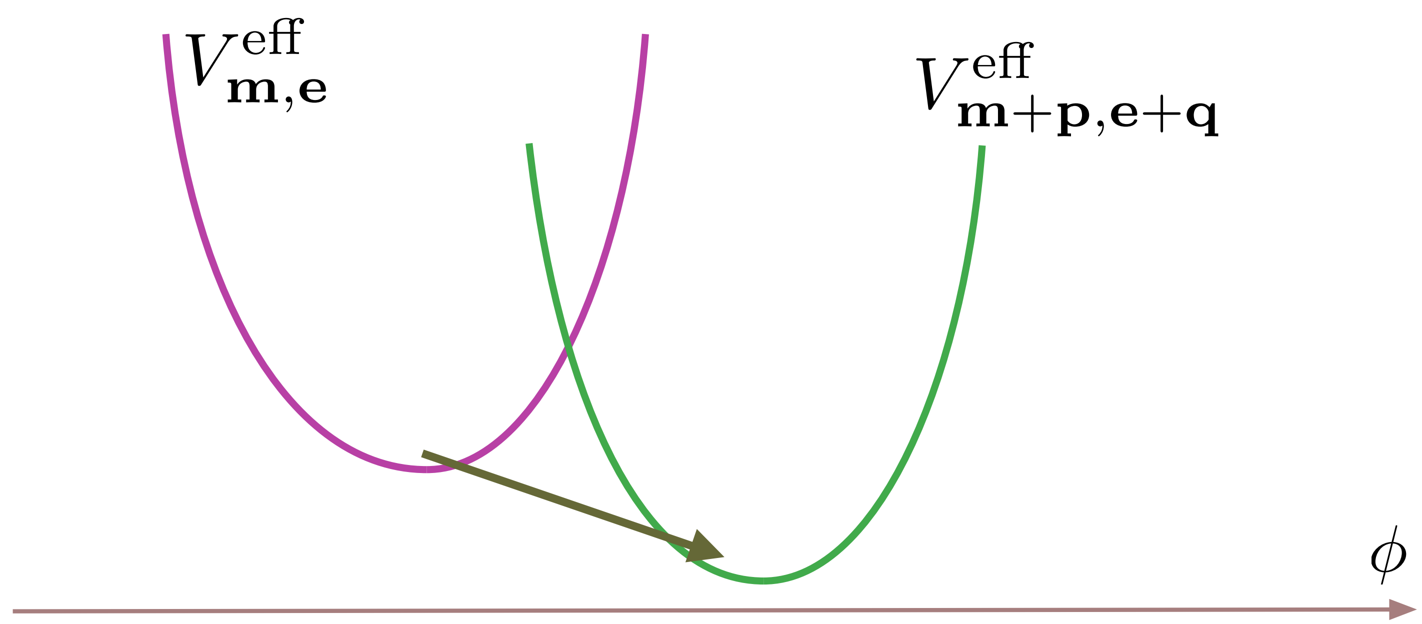
$$q_I \int_{\mathcal{C}} A_3^I - p^I \int_{\mathcal{C}} \tilde{A}_{3I}$$



and of the effective superpotential

$$W^{\text{eff}}_{\mathbf{m},\mathbf{e}}(\phi) \longrightarrow W^{\text{eff}}_{\mathbf{m}+\mathbf{p},\mathbf{e}+\mathbf{q}}(\phi)$$

- One can have domain walls or bubbles interpolating between different effective potentials



Jumping BPS domain walls

- Flow equations in presence of membranes

$$\dot{\phi}^i = 2K^{i\bar{\jmath}}\,\partial_{\bar{\jmath}}|\mathcal{Z}|$$

with jumping "central charge" $\mathcal{Z} \equiv e^{\frac{1}{2}\mathcal{K}}W_{\rm eff}$

⟹ away from membranes, as in [Cvetic-Griffies-Rey `92] [Cvetic-Soleg `96] [Ceresole-Dall'Agata-Giryavets-Kallosh,-Linde `06]

- Central charge jumps across the membrane: $2|\Delta\mathcal{Z}| = T_{\rm M}$

- A BPS-action argument identifies the domain wall tension

$$T_{\rm DW} = 2|\mathcal{Z}|_{+\infty} - 2|\mathcal{Z}|_{-\infty}$$

as in [Ceresole-Dall'Agata-Giryavets-Kallosh,-Linde `06]

Jumping BPS domain walls

$$S_{\rm eff} = -\int \left[R^*1 + \frac{d\phi \wedge {}^*d\bar\phi}{(\mathrm{Im}\,\phi)^2} + V_{\rm eff}(\phi,\bar\phi) \right]$$

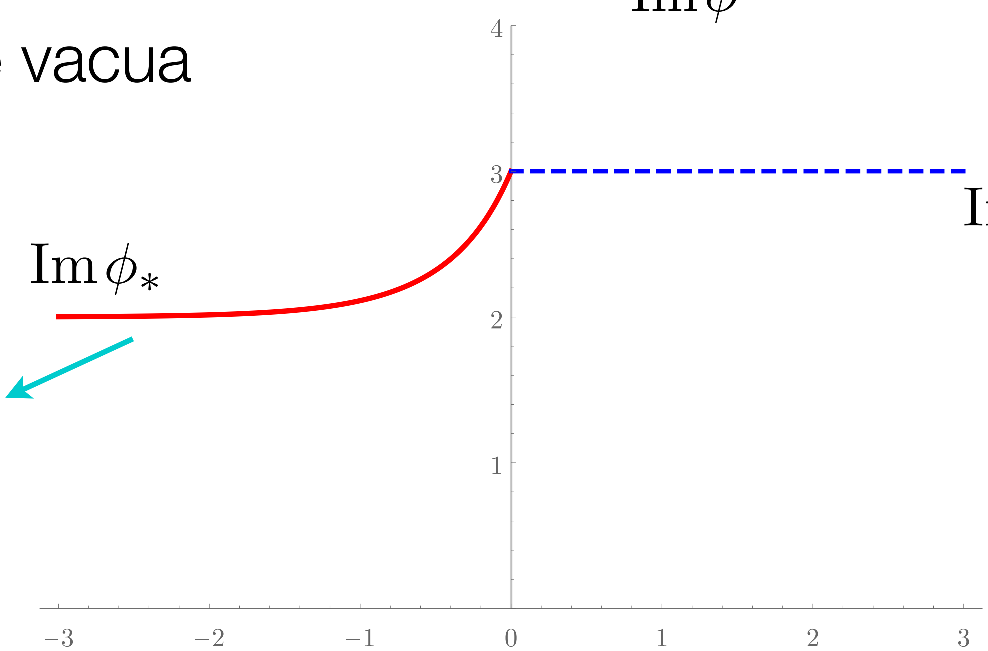
$$W_{\rm eff}(\phi) = (e_0 + \mathrm{i}m^1) - \mathrm{i}(e_1 + \mathrm{i}m^0)\phi$$

- For instance, in our toy model each effective potential has a single susy vacuum

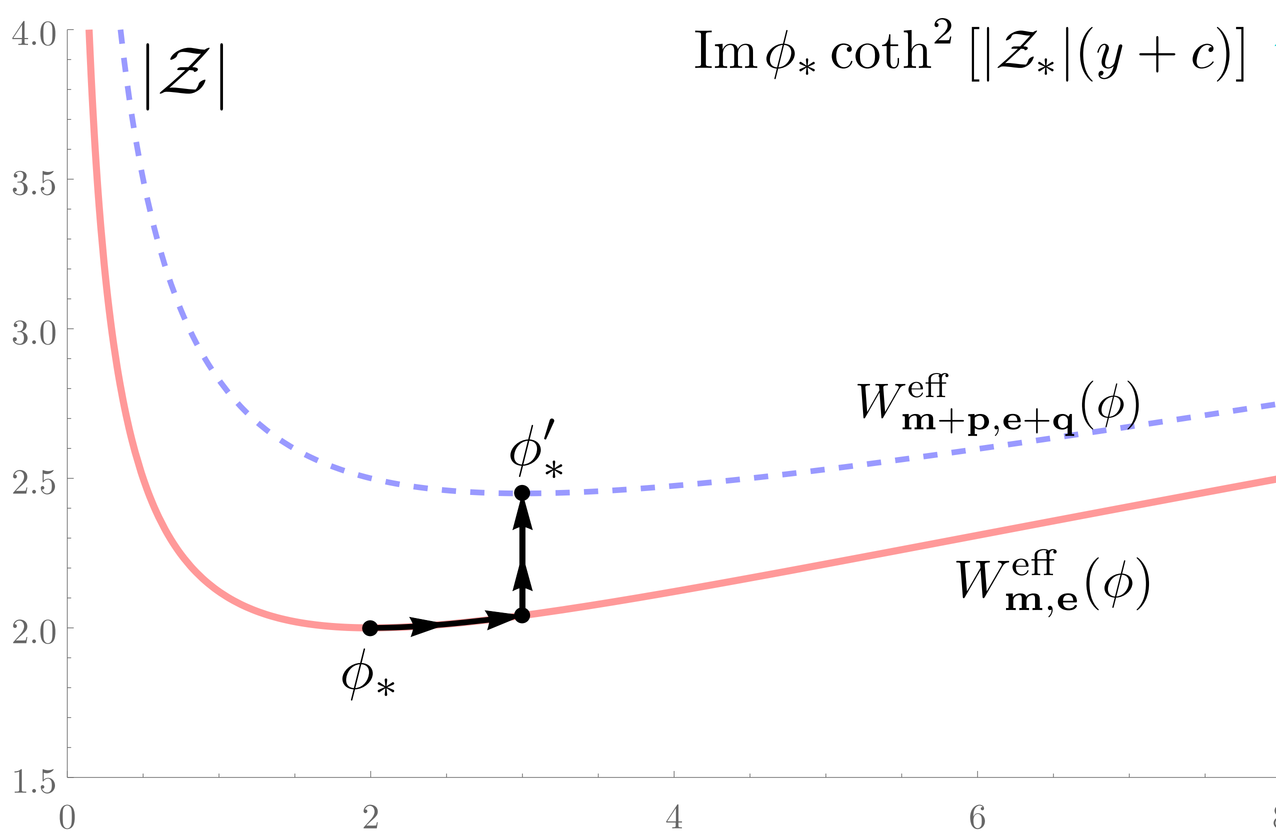
$$\phi_* = \frac{m^1 - \mathrm{i}e_0}{e_1 - \mathrm{i}m^0}$$

- A jumping domain wall can connect these vacua

For instance: $\mathrm{Re}\,\phi \equiv \mathrm{Re}\,\phi_* = \mathrm{Re}\,\phi'_*$



$\mathrm{Im}\,\phi_* \coth^2[|\mathcal{Z}_*|(y+c)]$



Final remarks

- Tadpole conditions can implemented by partially integrating out gauge-three forms

- Possible incorporation of brane sector? Uplift to M-theory?

  [Carta, Marchesano, Staessen, Zoccarato `16]

- Generalization to extended supergravities?

Thanks!