Consistent truncation

The following does NOT happen:

$$\Box\Phi_{\text{truncated}} = \Phi_{\text{not-truncated}}$$

Truncated fields often organize into lower-dimensional supermultiplets of gauged SUGRA in D<10. Why useful?

- Neat trick to find 10D solutions & understand SUSY etc.
- Link with holography: (un)truncated fields vs operator spectrum.
- …map out the landscape of gauged SUGRA models.

When? Few cases known: reductions over parallelizable manifolds (tori, groups, certain cosets). Recent breakthroughs using **exceptional field theory** [Hohm, Malek, Sambtleben,…] and **exceptional geometry** [Grana, Petrini, Waldram,…]

A consistent truncation is seldom an EFT. For having an EFT we do not require cons. trunc. Example: Calabi-Yau reductions most likely are not consistent truncations and that is no problem on the condition there is **scale separation**.

Scale separation definition:

Compactification: $ds^2_{10} = \tau_0^2 \tau^{-2} ds^2_D + \rho ds^2_{10-D}$ $\qquad \tau^{D-2} = \mathrm{e}^{-2\phi} \rho^{\frac{10-D}{2}}$

$$\Rightarrow \quad S_D \supset \int_D \sqrt{g_D} \left(\tau_0^{D-2} \mathcal{R}_D + \ldots - \tau_0^D V \right)$$

2 length scales: $\mathcal{R}_D = \frac{D}{D-2} M_p^2 V \quad \Rightarrow \quad L_H^{-1} = M_p |V|^{1/2}$

$L_{KK} = \sqrt{\rho} \ell_s$ (rough estimate, can be wrong sometimes)

Scale seperation:

$$\boxed{\frac{L_{KK}^2}{L_H^2} = \rho_0 \tau_0^2 |V| \to 0\,.}$$

- **Scale separation is required if we want to use 4D EFT language** (95% of all string pheno)

- cc problem: the "typical" cc is order cut-off. Indeed, the "typical" string flux solution obeys:

$$\Lambda \sim M_{KK}^2$$

- Expectation has heuristic explanation through Swampland distance conjecture (extended to distances in metric space) [Lüst, Palti, Vafa, 2019] :

$$\Lambda \to 0 \quad \longrightarrow \quad m \sim |\Lambda|^\alpha$$

With α positive and for SUSY AdS vacua α =1/2.

- Refinement suggested by [Buratti et al 2020], in presence of specific combinations of discrete & continuous higher form symmetries

$$\Lambda \sim \frac{M_{\rm KK}^2}{k} .$$

What have we?

- Attempts at pheno-like vacua: KKLT, LVS,…,never achieve SS parametrically. Also not without controversy (no parametric control). Most extreme example: racetrack fine-tuning [Kallosh, Linde 2004], but is not top-down.

- For KKLT AdS vacua: see recent small W_0 successes. Better scale separation. But controlled, tension with tadpole conjecture [Bena, Blaback, Grana, Lüst 2020]?

- **Remarkable**: In IIA Romans supergravity on CY with fluxes and O6 planes we can achieve it arbitrary well! [DeWolfe et al (DGKT) 2005, Camara, Font, Ibanez 2005]:

$$\mathrm{vol}_6 \sim n^{3/2} \qquad g_s \sim n^{-3/4} \qquad \boxed{\frac{L_{\mathrm{KK}}^2}{L_{\mathrm{AdS}}^2} \sim n^{-1} \to 0.}$$

n is F_4 flux quantum, unconstrained by RR tadpoles.

- Double T dual well behaved. Does not require Romans mass, but uses **generalized CY** [Caviezel et al 2008]. With anisotropic choices of fluxes one can create scale separated vacua, weakly coupled in IIA frame or 11D [Cribiori et al 2021]. Without sources in 11d.

- IIB attempts

[12] C. Caviezel, T. Wrase and M. Zagermann, *Moduli Stabilization and Cosmology of Type IIB on SU(2)-Structure Orientifolds*, *JHEP* **04** (2010) 011 [0912.3287].

[13] M. Petrini, G. Solard and T. Van Riet, *AdS vacua with scale separation from IIB supergravity*, *JHEP* **11** (2013) 010 [1308.1265].

→ Not under control upon more careful investigation.

- infinite family in 3D is possible from massive IIA on orientifolded G2

[8] F. Farakos, G. Tringas and T. Van Riet, *No-scale and scale-separated flux vacua from IIA on G2 orientifolds*, *Eur. Phys. J. C* **80** (2020) 659 [2005.05246].

Backreaction of O6 planes only understood in an integrated sense:

$$\delta(\vec{x}) = \sum_{\vec{n}} e^{i\vec{n}\cdot\vec{x}} \qquad \rightarrow \qquad 1$$

Should one worry?

→ [Banks, Van den Broek 2006]; Yes. However, mistake in computation [Cribiori et al 2021].

→ [Junghans 2020, Marchesano et al 2020]; no, nothing weird happens at leading correction order to this approximation (1/n perturbation theory).

→ [McOrist,Sethi]: Massive IIA solutions with O6 planes will never be controlled. However, [Baines et al 2020]: explicit Minkowski examples with g_s/Vol suppressed corrections.

Consistency check backreaction: first-order corrections from O6 backreaction restore Ooguri-Vafa conjecture on AdS stability for the non-SUSY twins of IIA vacua [Marchesano et al 2021] ([Narayan, Trivedi 2010])

Do we need O planes?

Yes, otherwise no separation between internal and external curvature scales [Gautason et al 2015]

→ It is more subtle [De Luca, Tomasiello 2021], the KK scale is not necessarily defined though curvature scale in absence of O planes.

AdS/CFT?

- Dual CFTs have only few low lying single trace scalar operators, then a parametric gap!

$$\Delta = \frac{3}{2} + \frac{1}{2}\sqrt{9 + 4\kappa^2} \gg 1 \qquad mR = \kappa \gg 1$$

- Even more special: scale separated AdS vacua suited for uplifting have no tachyons, so no relevant deformations: **Dead-end CFTs with huge gap.** This gets close to understanding whether pure AdS gravity has a dual?

- Early investigation on CFT dual to IIA vacua [Aharony et al 2008], but new investigation [Conlon, Ning Revello, 2021] shows all such operator dimensions are integer!

[Collins, Jafferis, Vafa, Xu, Yau, 2201.03660]

Large set of holographic CFTs checked from branes probing singularities in general geometries: Sasaki-Einstein, sphere quotients.

There is universal upper bound for dimension of first non-trivial spin 2 operator.
The internal space for the CFT dual has minimal diameter in AdS units.

→ Conjecture it holds for all CFTs

(In?) complete reading list about scale sep & holograpy

[1] L. F. Alday and E. Perlmutter, "Growing Extra Dimensions in AdS/CFT," *JHEP* **08** (2019) 084, arXiv:1906.01477 [hep-th].

[2] J. P. Conlon and F. Quevedo, "Putting the Boot into the Swampland," *JHEP* **03** (2019) 005, arXiv:1811.06276 [hep-th].

[3] S. de Alwis, R. K. Gupta, F. Quevedo, and R. Valandro, "On KKLT/CFT and LVS/CFT Dualities," *JHEP* **07** (2015) 036, arXiv:1412.6999 [hep-th].

[4] J. Polchinski and E. Silverstein, *Dual Purpose Landscaping Tools: Small Extra Dimensions in AdS/CFT*, pp. 365–390. 8, 2009. arXiv:0908.0756 [hep-th].

[5] N. Benjamin, H. Ooguri, S.-H. Shao, and Y. Wang, "Light-cone modular bootstrap and pure gravity," *Phys. Rev. D* **100** no. 6, (2019) 066029, arXiv:1906.04184 [hep-th].

[6] F. Gliozzi, "Three-dimensional quantum gravity according to ST modular bootstrap," arXiv:2007.00684 [hep-th].

[10] O. Aharony, Y. E. Antebi, and M. Berkooz, "On the Conformal Field Theory Duals of type IIA AdS(4) Flux Compactifications," *JHEP* **02** (2008) 093, arXiv:0801.3326 [hep-th].

[11] Conlon, Revello, 2006.01012, Conlon, Ning, Revello, 2110.06245

[12] Collins, Jafferis, Vafa, Xu, Yau, 2201.03660.

Suggested questions for debate

1. Do we trust the IIA vacua? If not, is it the smeared approximation that bothers us?

2. Do we trust the Swampland argument using distances in metric space?

3. Is this similar to dS debate?: SS not possible parametrically, but somewhere “in the middle of moduli space” it could be ok?

4. Can we exclude scale separation in D>4? CFT argument? Can one show that CFTs dual to scale sep AdS vacua with more than 4 Q’s do not exist?

5. How bright is the future for studying CFT aspects of this problem? What are the right directions? (Modular) bootstrap,…?

6. How surprising do we find the integer dimensions of the operators dual to IIA vacua?

7. More general question for *pheno-type AdS vacua*: can we even have CFTs in D>2 without marginal and relevant operators?