A Distance Conjecture for Branes

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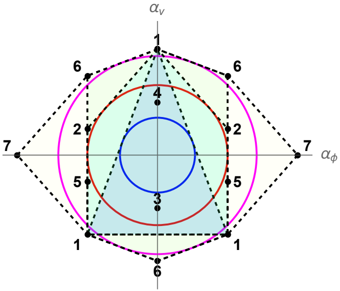

String Phenomenology 2024
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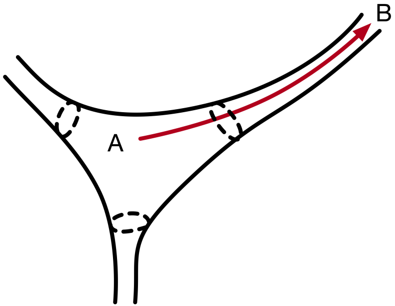
Sharpened Distance Conjecture



The theory an asymptotic distance ϕ in the moduli space will have[1] a tower of particles with exponentially light masses:

$$m \sim e^{-\alpha\phi}, \qquad \alpha \geq 1/\sqrt{d-2}$$

[1] [hep-th/0605264: H. Ooguri, C. Vafa], [2206.04063: ME, B. Heidenreich, S. Kaya, Y. Qiu, T. Rudelius]

Sharpened Distance Conjecture

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- Brane Distance Conjecture is a necessary condition.

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Pick $p_{\text{max}} \in \{1, \ldots, d-2\}$. Consider the set of particle towers or fundamental non-particle branes with at most p_{max} spacetime dimensions. In any inf. dist. limit, one will satisfy

$$T \sim \exp\left(-\alpha\phi\right), \qquad \alpha \geq 1/\sqrt{d - p_{\text{max}} - 1}.$$

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$$T \sim \exp(-\alpha\phi)\,, \qquad \alpha \geq 1/\sqrt{d - p_{\text{max}} - 1}\,.$$

- $p_{\text{max}} = 1$ is the Sharpened DC.
- Lower bound on α gets stronger as p_{max} increases.

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[2] Follows from [1910.01135: S. Lee, W. Lerche, T. Weigand], [2022.00024: D. Klaewer, S. Lee, T. Weigand, M. Wiesner]

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- Sharpened DC satisfied[2] by D-dim. theory's particle towers and fundamental branes that fully wrap the torus.
- This implies the Brane DC, with $p_{\text{max}} = D - d + 1$.

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For flat slices of moduli space where α-vectors are constant, Brane DC is equivalent[3] to the convex hull of α-vectors containing ball of radius $1/\sqrt{d - p_{\text{max}} - 1}$.

[3] [2012.00034: J. Calderón-Infante, A. Uranga, I. Valenzuela]

IIB on circle, dilaton-radion, $p_{\text{max}} = 1$

$$\vec{\alpha} = -\nabla \log T$$

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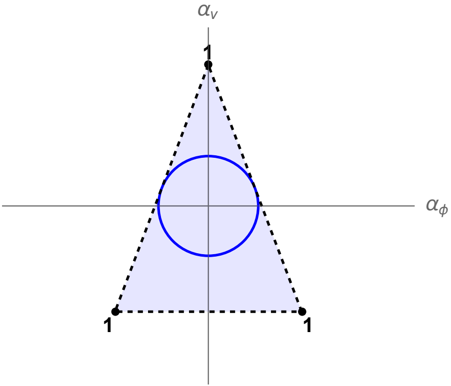
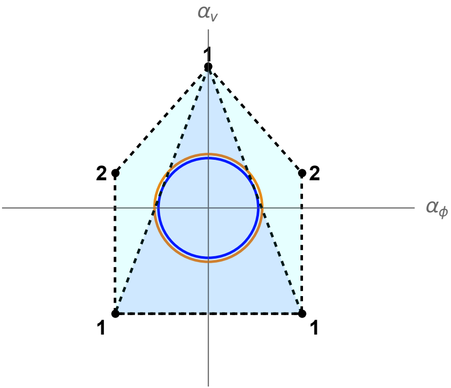


- Blue circ. radius: $1/\sqrt{7}$.

IIB on circle, dilaton-radion, $p_{\text{max}} = 2$

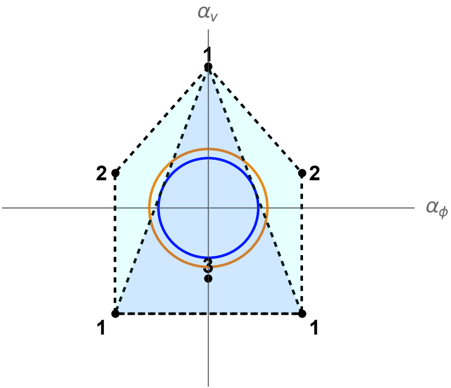
$$\vec{\alpha} = -\nabla \log T$$



- Blue circ. radius: $1/\sqrt{7}$.
- Orange circ. radius: $1/\sqrt{6}$.

IIB on circle, dilaton-radion, $p_{\max} = 3$

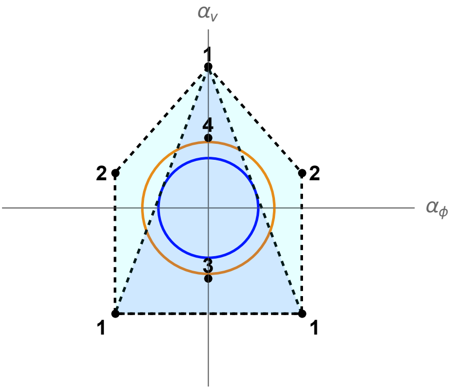
$$\vec{\alpha} = -\nabla \log T$$



- Blue circ. radius: $1/\sqrt{7}$.
- Orange circ. radius: $1/\sqrt{5}$.

IIB on circle, dilaton-radion, $p_{\text{max}} = 4$

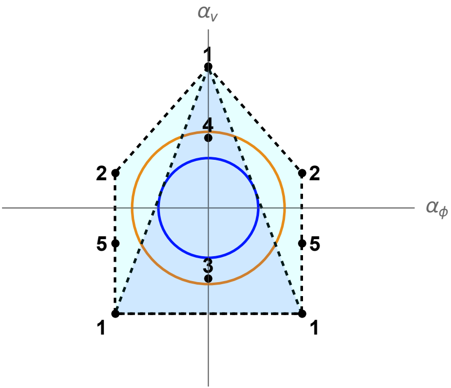
$$\vec{\alpha} = -\nabla \log T$$



- Blue circ. radius: $1/\sqrt{7}$.
- Orange circ. radius: $1/\sqrt{4}$.

IIB on circle, dilaton-radion, $p_{\max} = 5$

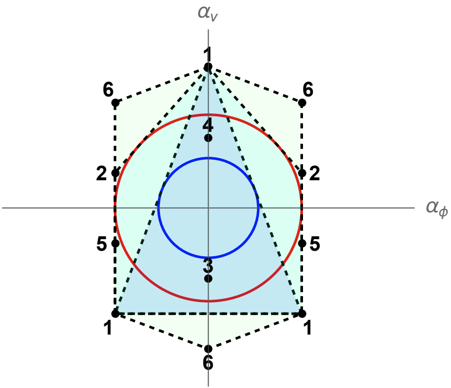
$$\vec{\alpha} = -\nabla \log T$$



- Blue circ. radius: $1/\sqrt{7}$.
- Orange circ. radius: $1/\sqrt{3}$.

IIB on circle, dilaton-radion, $p_{\text{max}} = 6$

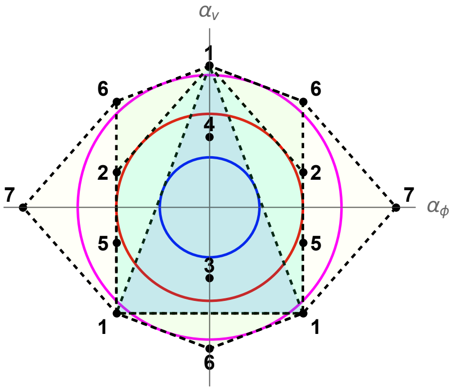
$$\vec{\alpha} = -\nabla \log T$$



- Blue circ. radius: $1/\sqrt{7}$.
- Red circ. radius: $1/\sqrt{2}$.

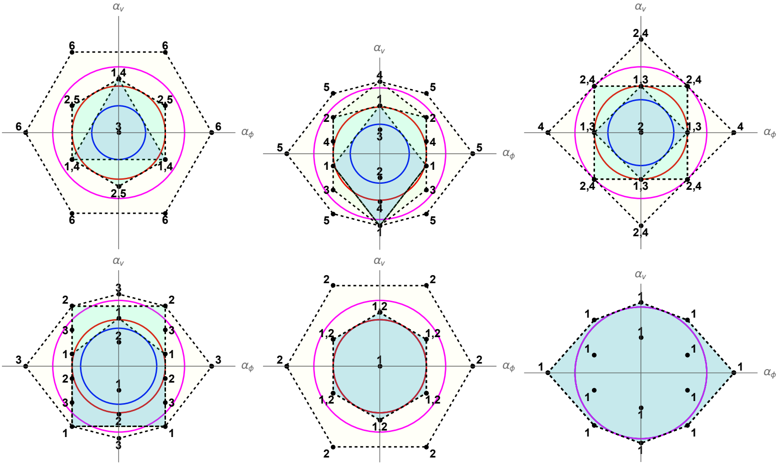
IIB on circle, dilaton-radion, $p_{\max} = 7$

$$\vec{\alpha} = -\nabla \log T$$



- Blue circ. radius: $1/\sqrt{7}$.
- Red circ. radius: $1/\sqrt{2}$.
- Magenta circ. radius: 1.

IIB on tori, dilaton-volume, 8d-3d



Heterotic on circle, dilaton-radion, $p_{\max} = 6$

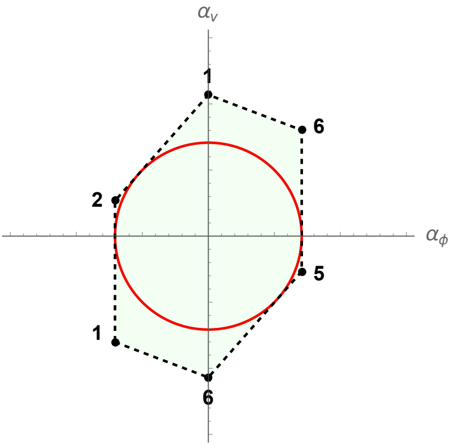


Figure: BPS branes. Red circ. radius $1/\sqrt{2}$.

Heterotic on two-torus, dilaton-volume, $p_{\max} = 5$

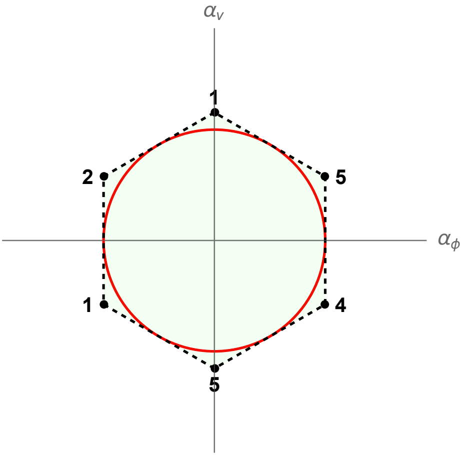
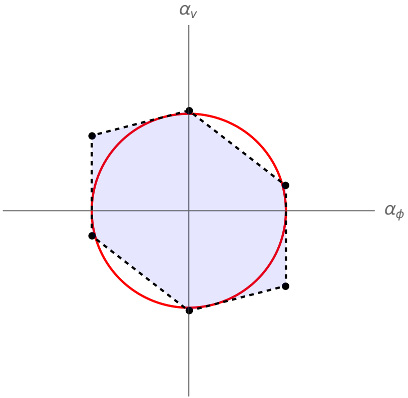


Figure: BPS branes. Red circ. radius $1/\sqrt{2}$.

Heterotic on three-torus, dilaton-volume, $p_{max} = 4$



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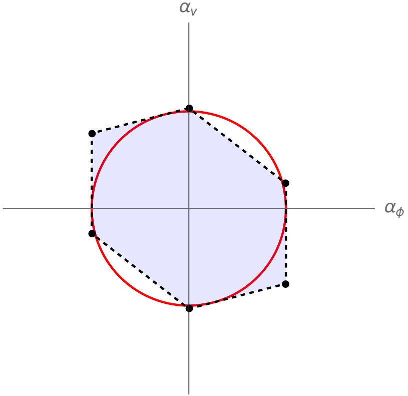


Figure: BPS branes. Red circ. radius $1/\sqrt{2}$.

- Brane DC not satisfied by BPS branes alone!

Heterotic on three-torus, dilaton-volume, $p_{max} = 4$

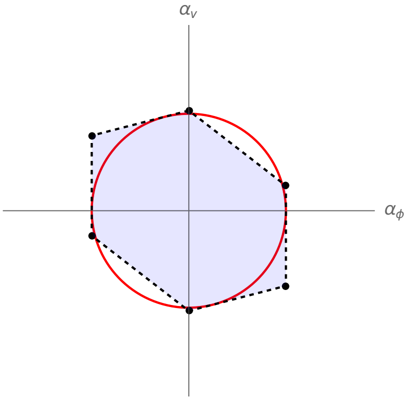
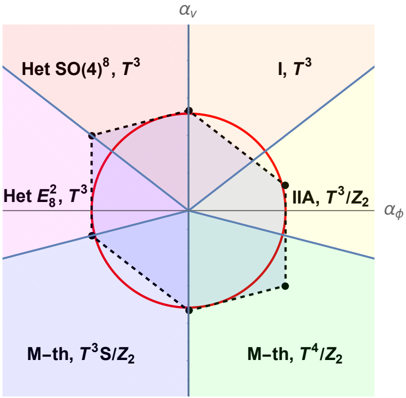


Figure: BPS branes. Red circ. radius $1/\sqrt{2}$.

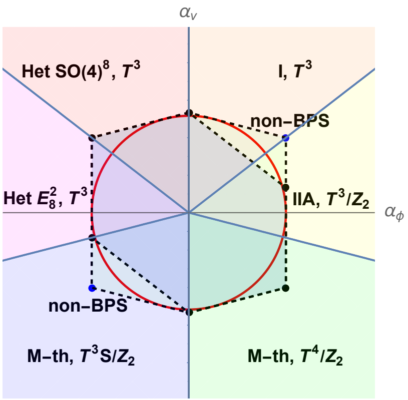
- Brane DC not satisfied by BPS branes alone!
- Need non-BPS branes.

Heterotic on three-torus, dilaton-volume, $p_{\max} = 4$



- Need to consider different duality frames where non-BPS branes are long-lived.

Heterotic on three-torus, dilaton-volume, $p_{\max} = 4$



- Need to consider different duality frames where non-BPS branes are long-lived.
- Non-BPS branes save $p_{\max} = d - 3$ Brane DC!

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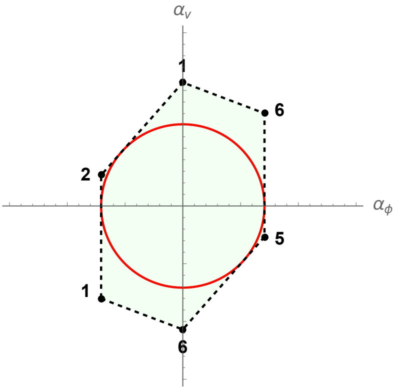


Figure: Heterotic in 9d. $p_{\text{max}} = d - 3$. BPS branes.

- What about Brane DC for other values of $p_{\max}$?

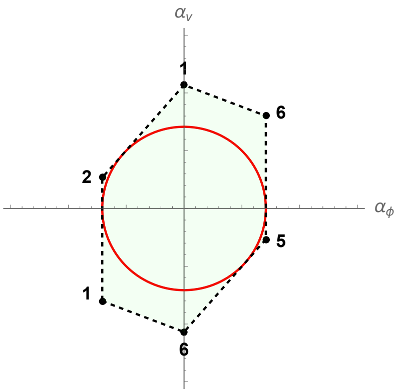
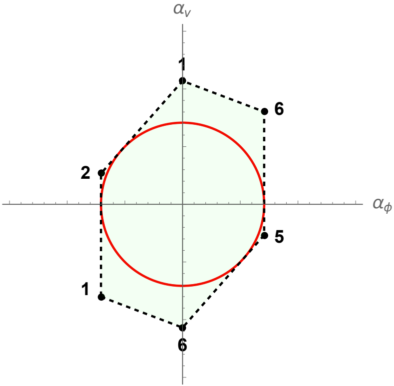


Figure: Heterotic in 9d. $p_{\max} = d - 3$. BPS branes.

- Need novel non-BPS branes.



- For suitable branes of spacetime dimensions p and q with $p \geq q$, their α-vectors satisfy taxonomy rules[4]

$$\vec{\alpha}_p^2 = 2 - \frac{p(d-p-2)}{d-2}, \qquad \vec{\alpha}_p \cdot \vec{\alpha}_q = 1 - \frac{q(d-p-2)}{d-2}.$$

[4] [2405.20332: ME, B. Heidenreich, T. Rudelius, I. Ruiz, I. Valenzuela], [ME, B. Heidenreich, T. Rudelius, to appear], [ME, to appear]

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Thank you!