Weak gravity (and other conjectures) with broken supersymmetry

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Corfu Summer Institute
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The swampland, the weak gravity conjecture and SUSY breaking

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Swampland conjectures characterize the landscape , ex:

- no exact global symmetries see Banks, Seiberg '10
- completeness of the charge lattice Polchinski '03
- distance conjecture Ooguri, Vafa '06
- weak gravity conjecture Arkani-Hamed, Motl, Nicolis, Vafa '06
- no stable non-SUSY AdS Ooguri, Vafa '16
- de Sitter conjecture Obied, Ooguri, Spodyneiko, Vafa '18

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One of the best motivated conjectures: arguments from BHs, holography, string theory...

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For every p-form field, there must exist a charged (extended) object such that $e^2Q^2 \geq 8\pi G\left(\frac{\alpha^2}{2}+\frac{p(d-p-2)}{d-2}\right)T^2$

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Status of the (D-brane) WGC with ~~SUSY~~?

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With ~~SUSY~~: non-trivial compatibility tests of the swampland conjectures

In what follows:

a test of the WGC for the R-R 2-form in type I string theory with broken supersymmetry

The string setup

Type I string theory: unoriented type IIB

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Unoriented worldsheets, ex: one-loop closed amplitude in 10-dimensional spacetime

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Always understood as a **spontaneous breaking**

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Scalar potential: $V = -\left(\frac{\mathcal{T}}{2} + \mathcal{K} + \mathcal{A} + \mathcal{M}\right) \sim \Lambda^9 e^{-c\Phi}$

$\Lambda > 0$: Coudarchet's talk (Humboldt), + Abel, Dudas, Lewis, Partouche '18

D1-D1 interactions and WGC

We compute **one-loop interactions between branes**

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Closed string exchange $\iff$ open-string cylinder calculation (with Dirichlet-Dirichlet boundary conditions)

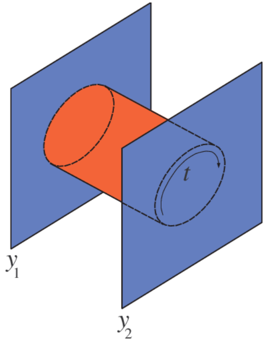

figure from JHEP 0305 (2003) 055

We focus on **D1-D1 systems**:

$$\mathcal{A}_{11} = \frac{1}{2\pi\sqrt{\alpha'}} \int_0^\infty \frac{d\tau_2}{\tau_2^{3/2}} e^{-\frac{\tau_2 r^2}{4\pi\alpha'}} \left[P_{m+a_i-a_j} + P_{m+a_i+a_j} - P_{m+1/2+a_i-a_j} - P_{m+1/2+a_i+a_j}\right] \times \frac{\theta_2^4}{2\eta^{12}}\left(\frac{i\tau_2}{2}\right) \,.$$

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Large-distance ($r \gg \sqrt{\alpha'}$) interaction potential:

$$V_{11} = -\frac{R\alpha'^2}{2\pi^2} \sum_{n=-1,0} \int d^8k \; e^{i\mathbf{kr}} \left[(1-1) \frac{\cos[4\pi n a_i] \cos[4\pi n a_j]}{k^2 + \frac{4n^2R^2}{\alpha'^2}} \right.$$
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One-loop attraction at (twisted) massive level

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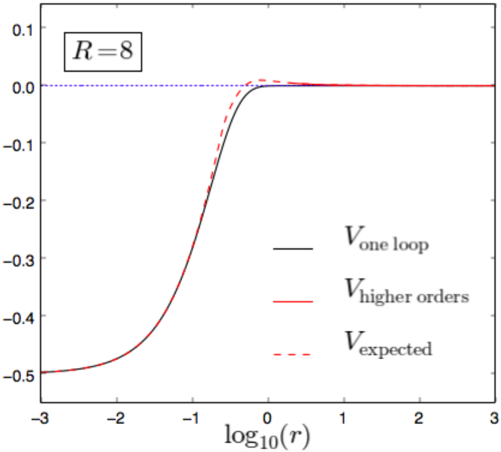
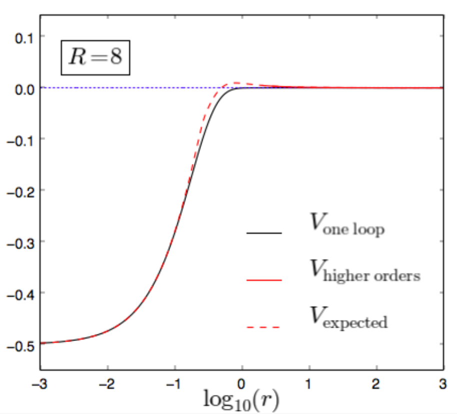
  $\Longrightarrow$ gauge repulsion at large distances (massless modes in higher-orders amplitudes) $\Longrightarrow$ WGC

$$V_{11} \sim \frac{1}{M_P^2}\left[\frac{\frac{4}{3}Q^2 - M^2 - \frac{1}{3}M^2 e^{-m_\phi r}}{r} - \frac{Q^2}{6}\,\frac{e^{-r\sqrt{\frac{R^2}{\alpha'^2}-\frac{2}{\alpha'}}}}{r}\right]$$



Bound states?



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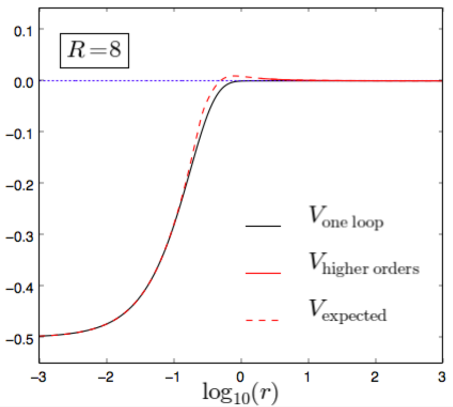
For a stack of N D1-branes, SUGRA breaks down at

$$r_S \sim \frac{N g_s \alpha'^3}{V_5}$$



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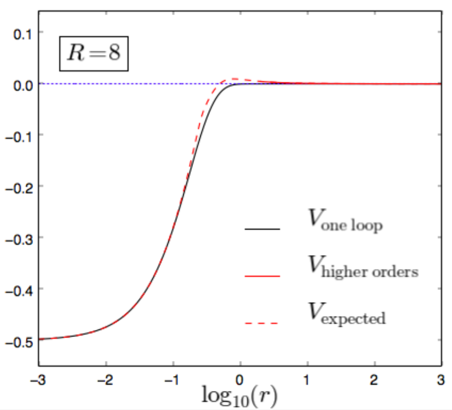

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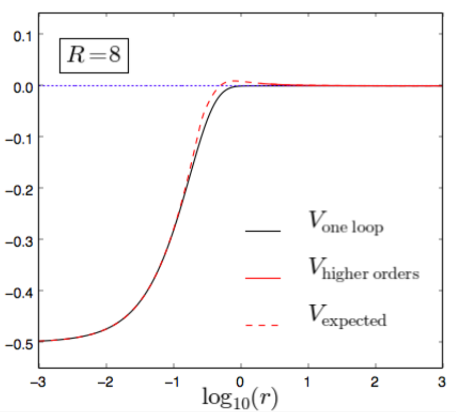

With constant $M_P^2 \sim \frac{V_5 R}{g_s^2 \alpha'^4}$ and $g_s \to 0$, bound state masses:

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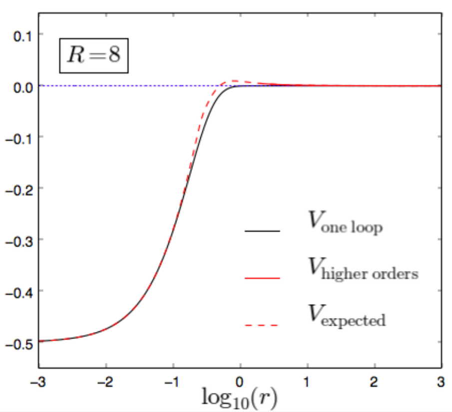

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Agreement with the swampland distance conjecture

(connected to SUSY breaking)

Outlook

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Future directions: other non-SUSY tests (ex: more gauge fields, magnetic fields on non-BPS branes - tachyons disappear when the branes repel, ...)

Thank you!