# Field-theoretic loop corrections in IIB

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Based on
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String Pheno July 07 2022

# Why consider perturbative (loop) corrections?

- Potentially dangerous, subleading effects
- Needed for moduli stabilization [Cicoli, Conlon, Quevedo ’07 ’08]
- Models of inflation using Kahler moduli [Conlon, Quevedo ’05], [Cicoli, Burgess, Quevedo ’08]

- This talk: Focus on loop corrections, see talk by Gerben Venken on further corrections and dS uplift

# Motivation

- Starting point: Berg-Haack-Pajer (BHP) conjecture [Berg, Haack, Pajer '07] based on torus orbifold calculation [Berg, Haack, Körs '05]
- Kaluza-Klein type (exchange of KK momentum between branes)

$$\delta K^{KK}_{(g_s)} \sim \sum_a \frac{g_s \mathcal{T}_a(t^i)}{\mathcal{V}}\,, \quad \mathcal{T}_a(t^i) \text{ linear in 2-cycle}$$

- Winding type (exchange of winding strings between intersecting D7-branes)

$$\delta K^{W}_{(g_s)} \sim \sum_a \frac{1}{\mathcal{I}_a(t^i)\mathcal{V}}\,, \quad \mathcal{I}_a(t^i) \text{ linear in 2-cycle}$$

$\Rightarrow$ Understand field-theoretically for generic Calabi-Yau

# Outline

1 Field theory analysis

2 Comparing to the BHP conjecture

3 Outlook

# Simple dimensional analysis

How do loop corrections to kinetic term of volume modulus scale? [Gersdorff, Hebecker '05]

- 1-modulus case without flux
- Compactify on $\mathrm{d}s^2 = g_{\mu\nu}\mathrm{d}x^\mu \mathrm{d}x^\nu + L(x)^2 \tilde{g}_{mn}\mathrm{d}y^m\mathrm{d}y^n$, $[L] = -1$
- 4d action becomes $S \sim M_{10}^8 \int \mathrm{d}^4x\sqrt{-g}L^6 \left[R_4 + \frac{(\partial L)^2}{L^2} + \cdots\right]$

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- On dimensional grounds $\delta S_{1-\mathrm{loop}} \sim \int \mathrm{d}^4x\sqrt{-g}\left(\frac{1}{L^2}R_4 + \frac{1}{L^4}(\partial L)^2\right)$

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- with 4-cycle $\tau \sim M_{10}^4 L^4 \Rightarrow (K + \delta K_{1-\text{loop}})_{ij} \sim 1/\tau^2 + 1/\tau^4$

$\Rightarrow \delta K_{1-\text{loop}} \sim \frac{1}{\tau^2} \sim 1/(\sqrt{\tau}\mathcal{V}) \Rightarrow$ scales like BHP Winding!

# Support by Feynman Diagrams

- Canonically normalizing all 4d fields $\chi^a \Rightarrow$ all 3-vertices universally suppressed by $1/M_4$

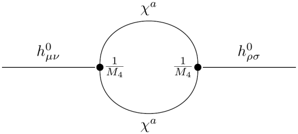


Figure: Self-energy diagram correcting the propagator of the massless 4d graviton.

- $\delta^{\varepsilon}_{R_4} = \frac{\mathrm{d}}{\mathrm{d}p^2}\Big|_{p^2=0} \frac{\mu^{\varepsilon}}{M_4^2} \sum_a \int \mathrm{d}^{4-\varepsilon} q \frac{f_4(p,q,m_a)}{(q^2+m_a^2)((p-q)^2+m_a^2)}$, $m_a \sim 1/L$, $[f_4] = 4$
- Loop corrected Kahler modulus kinetic term: $\left(1 + \frac{M_{KK}^2}{M_4^2}\right) \frac{1}{\tau^2} \partial_\mu \tau \partial^\mu \tau$

# Where are the BHP KK corrections?

- Remember BHP KK: $\delta K \sim g_s/\tau \Rightarrow$ Curvature terms on D-branes
- Example 1: D7-branes on intersecting 2-cycle have Einstein-Hilbert term at 1-loop: [Epple '04, Haack, Kang '15]

$$S_{\text{int,EH}} \sim M_{10}^4 g_s \int \mathrm{d}^6 x\, R_6 \sim M_{10}^4 g_s L^2 \int \mathrm{d}^4 x R_4$$

$\Rightarrow \delta K \sim g_s/\tau$ BHP KK like!

- Example 2: If $R^4$ term on D7-branes exists, log correction can be induced (Marginal operator can have log divergence):

$$\log(\mu L) \int \mathrm{d}^8 x\, R_8^4 \sim \log(\mu L)/L^2 \int \mathrm{d}^4 x R_4 \Rightarrow \delta K \sim \log(\tau)/\tau^2$$

# Interpretation
## Classification Scheme

1) Genuine loop corrections
   - From integrating out tower of KK modes
   - Non-local in 10d theory
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   - In multi Kahler moduli case, scaling persists but linearity of not found (see counterexample)

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3) Warping corrections

# Higher ratio corrections in fibred geometry

- K3 fibration $\tau_f$ over $\mathbb{CP}^1$ base $t_b$
- Use scaling argument in 2-step compactification process
  $10d \xrightarrow{\tau_f} 6d \xrightarrow{t_b} 4d$ with $\sqrt{\tau_f} \ll t_b$

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- Assumptions:
  - $R_8^4$ with suitable contraction non-vanishing
  - No magical cancellation of prefactor
  - 2-step compactification process

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    - Genuine loop corrections more general than winding
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Thank you!

# Backup slides

- Reduction to obtain "ratio correction":

$$\int_{\mathbb{R}^{1,3}\times\tau_2} R_8^4 \sim \int_{\mathbb{R}^{1,3}} R_4 \underbrace{\int_{t_b} R_2^3}_{\sim L_b^2/L_b^6} \underbrace{\int_{\sqrt{\tau_f}}}_{\sim L_f^2} \sim \int_{\mathbb{R}^{1,3}} R_4 \; L_f^2/L_b^4 \, .$$

- After Weyl rescaling and rewriting in 4-cycles

$$\delta K_{\tau_2\tau_2} \sim \tau_f/\tau_2^5 \quad \Rightarrow \quad \delta K \sim \tau_f/\tau_2^3$$