Transplanckian Axion Monodromy !?

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Motivation

- SDC: $\frac{m(P)}{m(Q)} \to e^{-\alpha \Delta(P,Q)}$ as $\Delta(P,Q) \to \infty$ ($\alpha > 0$). [Ooguri, Vafa]
- RSDC: Exponential behavior at least valid for $\Delta(P,Q) > 1$ and $\alpha \sim \mathcal{O}(1)$ (in Planck units). [Kläwer, Palti]

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**Transplanckian field ranges are not physically attainable in Quantum Gravity (?)**
KS-like throats describe **fully backreacted** axion monodromy models in which the axion **physically rolls** through transplanckian distances!!
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  → Usual argument against transplanckian axion monodromy.
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  [Baume,Palti]

- Physically rolls
  \[\rightarrow\] The axion has some spatial dependence, **not adiabatic**.
KS solution and transplanckian axion monodromy

Effective field theory analysis

Conclusion
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1. Compactification ansatz:

\[ ds_{10}^2 = \frac{r^2}{R^2} \eta_{\mu \nu} dx^\mu dx^\nu + R^2 \frac{dr^2}{r^2} + R^2 ds_{T^{1,1}}^2 \]
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About the compactification space...

\( T^{1,1} \) is topologically \( S^2 \times S^3 \)
\[ \phi = \int_{S^2} B_2 \text{ Axion! } \]

As an axion, \( \phi \) has a discrete shift symmetry: \( \phi \sim \phi + 1 \)
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- One of the Chern-Simons terms gives:

$$\int_{10d} F_3 \wedge B_2 \wedge F_5 \longrightarrow M \int_{5d} \phi F_5 \implies \text{Monodromy!}$$

Dvali-Kaloper-Sorbo term!
[Dvali][Kaloper,Sorbo]

Consequence of the monodromy

$$N = N_0 + M\phi \implies R^4 \sim g_s M\phi \implies \text{Backreaction!}$$

As promised... the axion physically rolls!

Disclaimer: This is KT solution, which is the large $r$ limit of KS.
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Transplanckian excursion of the axion

Distance in field space:

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Together with the rolling of the axion gives

\[ \Delta \sim (\log r)^{1/2} \] Transplanckian distance!
Effective field theory analysis
In KT paper [Klebanov, Tseytlin] they use an effective 5d action to get the solution. We check that:

\[ G_{\phi\phi} \sim R^{-4} \rightarrow \text{Transplankian distance!} \]
\[ V \supset \frac{1}{8} (N_0 + M_\phi)^2 R^{-40/3} \rightarrow \text{Monodromy!} \]
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**BUT!** \[ m_{KK} \sim m_R \]

\[ \implies \text{This is not an EFT in the Wilsonian sense!} \]
\[ \quad \text{... Only a consistent truncation of the 10d dynamics.} \]
Integrating out the breathing mode

 Luckily, we can save the day!

\[ \delta \phi \ll m_R \sim m_{KK} \rightarrow \text{We can integrate out } R! \]

Doing so...

\[ \frac{\partial V}{\partial R} = 0 \implies R^4 = \frac{1}{4} (N_0 + M\phi) \rightarrow \text{Backreaction!} \]
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✓ EFT describing the transplanckian excursion!
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→ Not exponentially decreasing! Only polynomially.
✓ No tower of exponentially light states!
Including the dilaton

In all the EFT analysis we have ignored the dilaton because in KS solution it remains constant.
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But...

\[ m_\Phi \ll m_R \sim m_{KK} \]

\[ m_\Phi \gg \delta \phi \]

\[ \implies \text{We can NOT integrate it out.} \]

The dilaton should be kept in the EFT!

The low energy moduli space is 2d \( \{\phi, \Phi\} \)
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\textit{KS solution is NOT a geodesic!}

✓ Nothing to do with RSDC
Conclusion
Transplanckian field ranges are physically attainable in Quantum Gravity!
Thanks for your attention!
Backup slides
Hierarchy between \( \{\phi, \Phi\} \) and \( \{R, \phi\} \)

Potential in the full 5d EFT:

\[
V = e^{-8q} \left( e^{-12f} - 6e^{-2f} \right) + \frac{1}{8} M^2 e^{\Phi+4f-14q} + \frac{1}{8} \left( N_0 + M\phi \right)^2 e^{-20q}
\]

For \( M = 0 \), both \( \Phi \) and \( \phi \) does not appear in it, while \( q \) and \( f \) are stabilized.

Considering \( M \) as a deformation of the pure \( AdS_5 \times T^{1,1} \) case \( (N \gg M) \):

\( \rightarrow q \) and \( f \) are heavy modes!

\( \rightarrow \Phi \) and \( \phi \) are light!
But... What if $M \not\ll N$?

1. For large $r$, $\phi \gg 1$ so the axion has traveled its period many times.
2. Due to the monodromy, each time the axion cross its period $N \rightarrow N + M$.

$\implies$ For large $r$ we can always interpret $N \gg M$. 
RSDC in $\{\phi, \Phi\}$ moduli space

\[ 2\sqrt{g_s} \]

KS solution

Geodesic

\[ \frac{4}{M} \sqrt{N_0 + M\phi} \]
RSDC in \( \{\phi, \Phi\} \) moduli space

- **Vertical lines:****
  \[
  \Delta \sim -\frac{1}{2} \ln(y) \sim -\frac{1}{2} \ln(2\sqrt{g_s})
  \]
  \[
  \implies g_s \sim e^{-2\Delta}
  \]

- **Semicircumference:**
  \[
  \Delta \sim -\frac{1}{2} \ln(\tan(\alpha/2)) \sim -\frac{1}{2} \ln \left( \frac{y}{2R} \right) \sim -\frac{1}{2} \ln \left( \frac{\sqrt{g_s}}{R} \right)
  \]
  \[
  \implies g_s \sim e^{-2\Delta}
  \]

In both cases we get a tower of stringy states becoming exponentially light satisfying the RSDC!