DOUBLE-TRACE DEFORMATIONS IN THE AdS/CFT

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Status of modern physics

In the 20th century we discovered two extremely successful theoretical frameworks to describe natural phenomena in very different regimes:

- **Quantum Field Theory (QFT)**
  It describes interactions of elementary particles at microscopic scales. It gave us the Standard Model of Particle Physics (SM) that unifies three out of the four fundamental forces (electromagnetism, strong and weak nuclear force).
- **General Theory of Relativity (GR)**
  Describes the gravitational force at macroscopic scales (e.g. movement of planets, black holes).

Open question:

- How can we unify gravity with quantum mechanics and obtain the theory of quantum gravity? At the moment, the most promising candidate for such a theory is **string theory**.
- Despite the success of the SM there are still unanswered riddles relevant to QFT, (e.g properties of the **strong** force, the **hierarchy** problem).

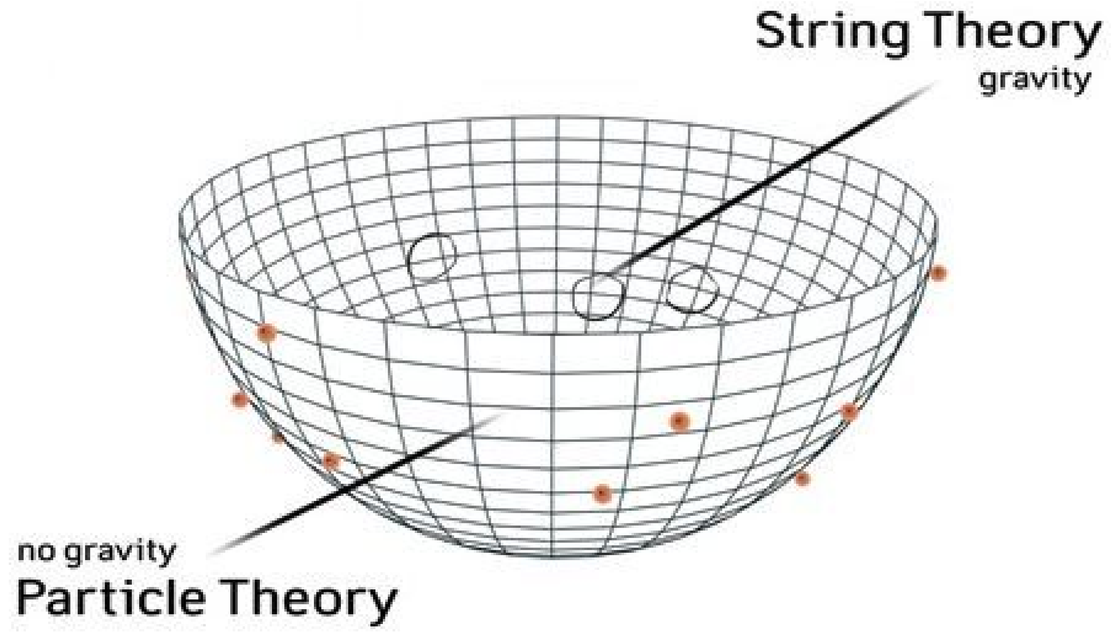
Holographic principle (AdS/CFT correspondence)

Due to Hawking we know that black holes radiate and an implication is that information is lost. This is catastrophic, as it means that black holes destroy quantum mechanics. Or we are missing something.

- 't Hooft and Susskind proposed **holography**.

The best example is the AdS/CFT correspondence; a conjectured equivalence relating two very different theories:

- a 'particle theory' with **no gravity**
- a string theory **with gravity** in one more dimension



[1]

Simplest example: D3-branes $\Leftrightarrow \mathcal{N}=4$ SYM

The best-studied example of holography is the following [2]:

- a 4 dimensional supersymmetric theory called **'$\mathcal{N}=4$ super Yang-Mills'** (SYM), which is related ot that describing strong interactions.
- its 5 dimensional holographic counterpart is type IIB **superstring theory** on $AdS_5 \times S^5$, containing supergravity in 5 dimensions as its low-energy theory.

Closer to strong interactions: D3/D7-branes $\Leftrightarrow \mathcal{N}=2$ SYM

Much effort was put into finding an example that is more realistic [3]:

- the 4 dimensional theory has less symmetry than before but still enough to be manageable.
- more realistic features than before (quarks), hence good toy model to gain intuition.

My research: a mechanism for light composite states

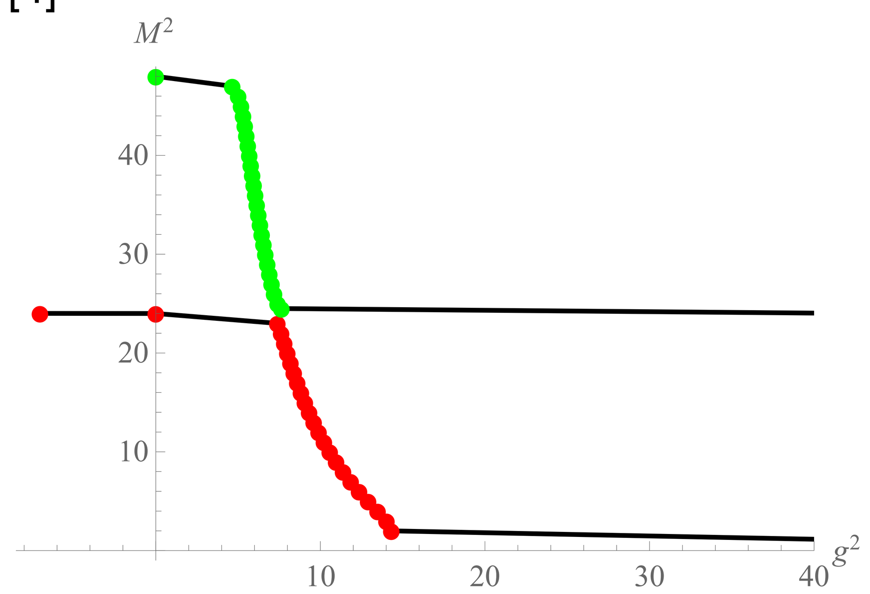
Can gauge theories generate light (even massless) fermions? It has been a long-standing matter of interest which motivated us to examine the spectra of these theories using holograhic computations and look for a mechanism that makes the fermionic states sufficiently light. We were able to analytically compute the supergravity states (dual) to fermionic field theory states and their masses [4],

$$M_{\mathcal{G}} = 2\mathbb{L}\sqrt{(n+\ell+2)(n+\ell+3)}, \quad M_{\mathcal{F}} = 2\mathbb{L}\sqrt{(n+\ell+1)(n+\ell+2)}$$

with $\mathbb{L} = L/R^2$. with L being the distance between the D3 and the D7 branes (proportional to quark mass), and R is the radius of AdS.

Double-trace interactions

In order to make these states light we included extra high-scale (double-trace) interactions, and studied the change in the mass, M^2, with the coupling of the interactions, g^2, for different states of the theory (the differently coloured lines) resulting in [4]



Future directions

- Generalisation to arbitrary dimensions.
- A hologram of the composite Higgs.
- An emergent 'double-trace' graviton.
- Strong interactions, integrability, and holography.
- Metastable vacua from string theory.

References

[1] https://www.learner.org/courses/physics/visual/img_lrg/AdSCFT.jpg. (2018). [image].

[2] J. M. Maldacena, Int. J. Theor. Phys. **38** (1999) 1113 [Adv. Theor. Math. Phys. **2** (1998) 231] [hep-th/9711200].

[3] A. Karch and E. Katz, JHEP **0206**, 043 (2002) [hep-th/0205236].

[4] see our paper: [arXiv] 1907.09489