Research Activities of the String Theory Group

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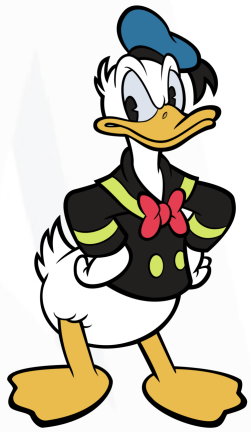
Challenging problems in theoretical physics

- Modelling dark energy is a basic challenge for fundamental physics.
  - Does string theory admits solutions with a positive cosmological constant (CC)? Can string theory produce a 4d effective field theory with a "scale separation" between the CC and other energy scales?
- In string theory, supersymmetry (SUSY) does play an important role. But it must be broken at some (high) energy scales.
  - Does string theory admits non-supersymmetric solutions?
- Black holes are thermodynamics objects. Their entropy is related to the area of the event horizon.
  - Can we give an explanation to this relation? How do we understand the black hole microstates using string theory?
- Strongly coupled quantum systems are common in particle physics and condensed matter physics.
  - Can we extract properties of such system using exact methods in quantum field theory?

String theory solutions

Constructing new string theory solutions and exploring their properties

- Constructing string theory solutions with a positive cosmological constant (CC) is notoriously a difficult problem.
- Circumvent this by studying in-depth the solution in the presence of certain extended objects, known as orientifolds, in string theory.


[1]

  - These lead to several new solutions with a positive CC as well as those without supersymmetry.
  - Can also put a rigorous bound on the space of solutions rather than on individual examples.
    - A general bound on the mass scale of spin-two fields, relevant for models with a graviton mass.
    - Useful for studying effective field theories with a "separation of scale" between the CC and other mass scales.

[1] Credit: https://figpin.com

Entropy of black holes

The entropy of black holes

- We managed to explain the microscopic origin of the entropy of Anti-de-Sitter (AdS) black holes.
  - Based on holography and the localisation technique in quantum field theory (QFT)
  - *Localisation:* A technique to compute exactly the path integral of (supersymmetric) QFT
  - *Holography:* A correspondence between string theory in an AdS space and a QFT living on the boundary.
- Can extract important universal properties of microstates of the AdS black holes from QFT calculations.

[2]

[2] Credit: https://www.licensingmagazine.com/

Strongly coupled quantum field theories

- **Main goal:** To understand the long distance (low energy) behaviours of QFTs, especially the strongly coupled ones.
  - Can constraint the dynamics of the theory using various symmetries, *e.g.* the conformal symmetry and supersymmetry.
  - Can extract a lot of information of a large class of QFTs in an exact way using the *localisation* technique.


[3]

- **Duality:** QFTs with different descriptions at short distances may have the same physics at long distances.
  - Quantum phenomena in some strongly coupled QFTs may be studied as the classical physics of the dual QFTs.
  - Allows us to understand the vacuum structures, emergence of global symmetry at long distances, and operators in the theory.


[4]

- We found a number of new dualities among various QFTs in 3d and 4d. We also found that some 3d dualities can be "uplifted" to 4d.

[3] Credit: https://talesofarcadia.fandom.com/wiki/

[4] Credit: https://en.wikipedia.org/

Strongly coupled quantum field theories

Higher dimensional objects in QFTs

- We study not just 0-dimensional local operators in QFTs, but also higher dimensional objects, *e.g.* lines, surfaces.
- "New" types of global symmetries such that the *charged objects* and the *charged observables* are lines or surfaces.
  - Can use these symmetries to study phases (*e.g.* confinement and deconfinement) and certain subtle global structures of gauge theories

[5]

- The study of Wilson loops in certain classes of 3d QFTs reveals a hidden "integrability" structure.
- The localisation technique can be used to compute the Wilson loop expectation values. Can be matched with the partition function of strings in an AdS space, providing a non-trivial test for holography.

[5] Credit: https://en.wikipedia.org/

Current members of the group

Permanent members

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