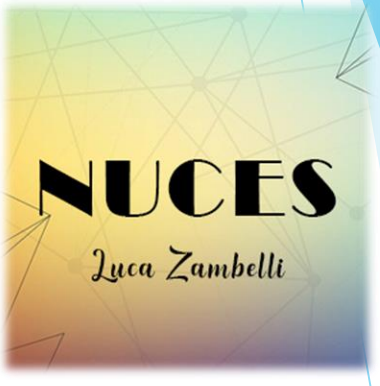
QFT, Strings, and Computational Techniques



General Fellini Meeting in Ferrara

May 2022

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INFN
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Highlights

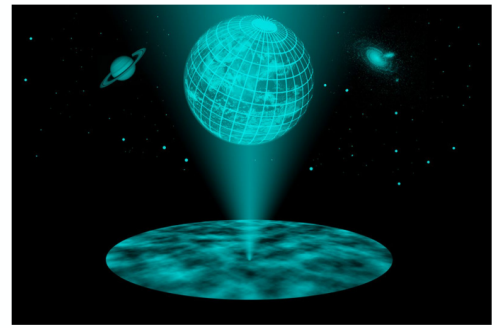
Our common goal: understand generic, complex, strongly interacting phenomena in statistical mechanics, QFT, and gravity.

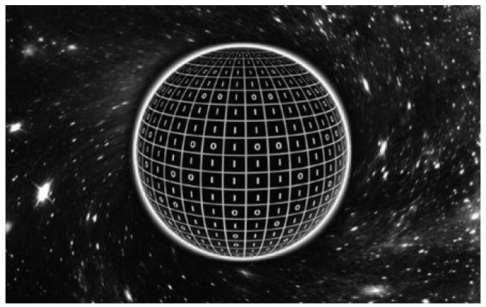
Our tools: duality · conformal symmetry · exact RG · supersymmetry · machine learning

Unifying concepts: entanglement and entropy · landscapes of theories

Holographic Conformal Field Theories

Holography: posits spacetime and gravity are emergent notions, resulting from the collective behaviour of an enormous number of degrees of freedom





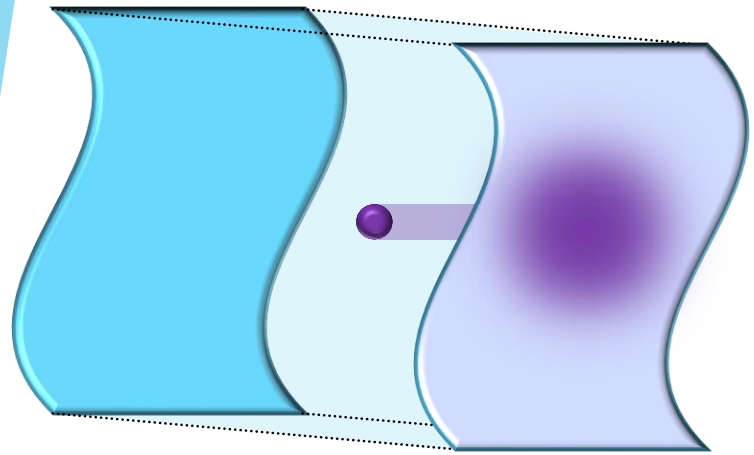
Evidence that spacetime and gravity emerge from the underlying quantum correlation structure

HCFT explores these ideas working at the interface of gravity, conformal field theory and quantum information. In particular the focus is on:

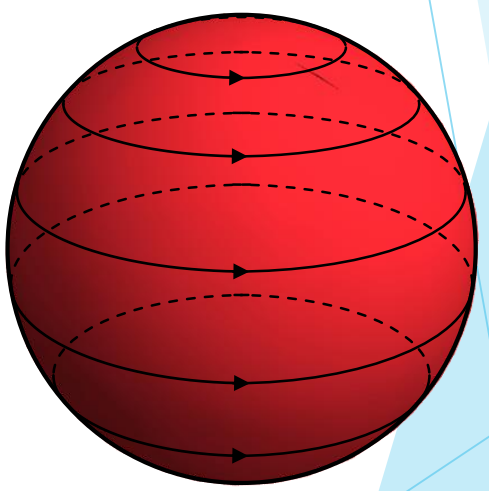
Quantum circuit complexity: measures how difficult it is to prepare a state

Entanglement and gravity: spacetime reconstruction from entanglement

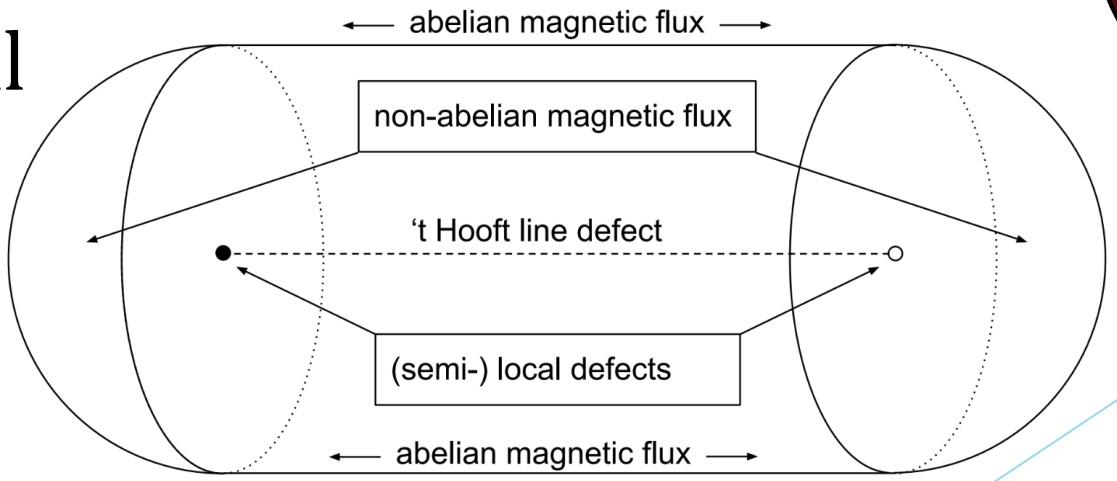
In QFT, defects are ubiquitous, but difficult to study



supersymmetry provides protection without oversimplification



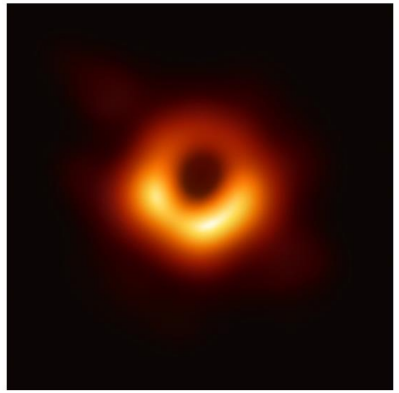
...it is an ideal laboratory to test exotic ideas



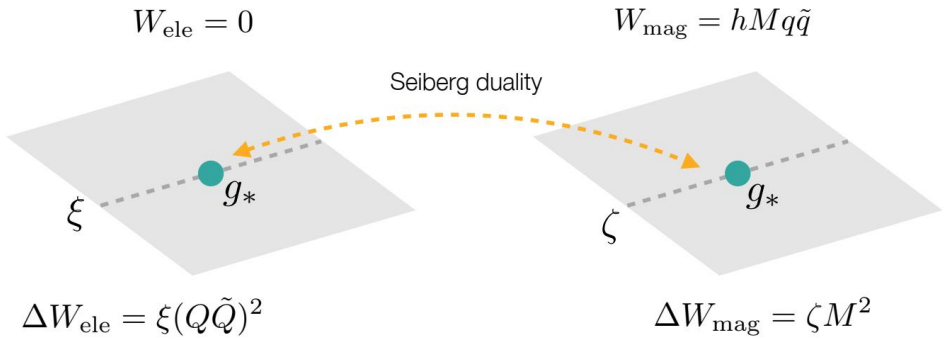
Field Theory Dualities from String Dualities

A **duality** is a nontrivial map between two different descriptions of the same physics
(Eg Maxwell's eqs invariant under E $\longleftrightarrow$ B)

Powerful concept to study strongly coupled phenomena, otherwise inaccessible.
Idea: use weakly coupled *dual* description



Black Hole microstates



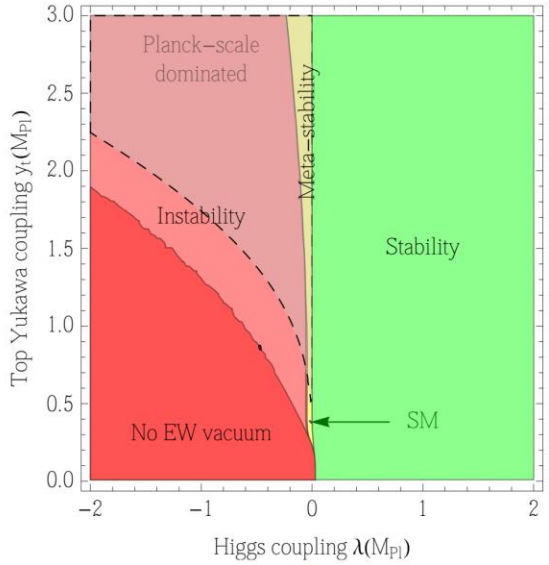
Space of **conformal** QFTs

Natural UV-Complete Extensions of the Standard Model

Objectives:

1 constructing new UV-complete beyond-the-Standard-Model QFTs

2 addressing their hierarchy problem(s) and approximate scale invariance

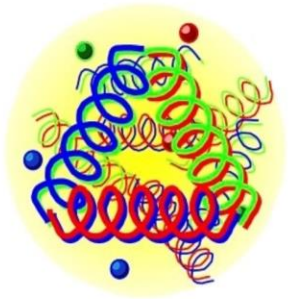


Challenges:

? classify a large space of theories

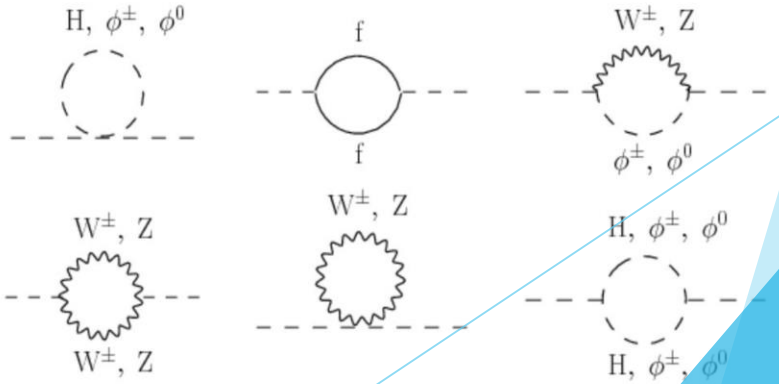
! some of which are strongly interacting

¿ and/or feature dynamical symmetry breaking and generation of scale



Methods:

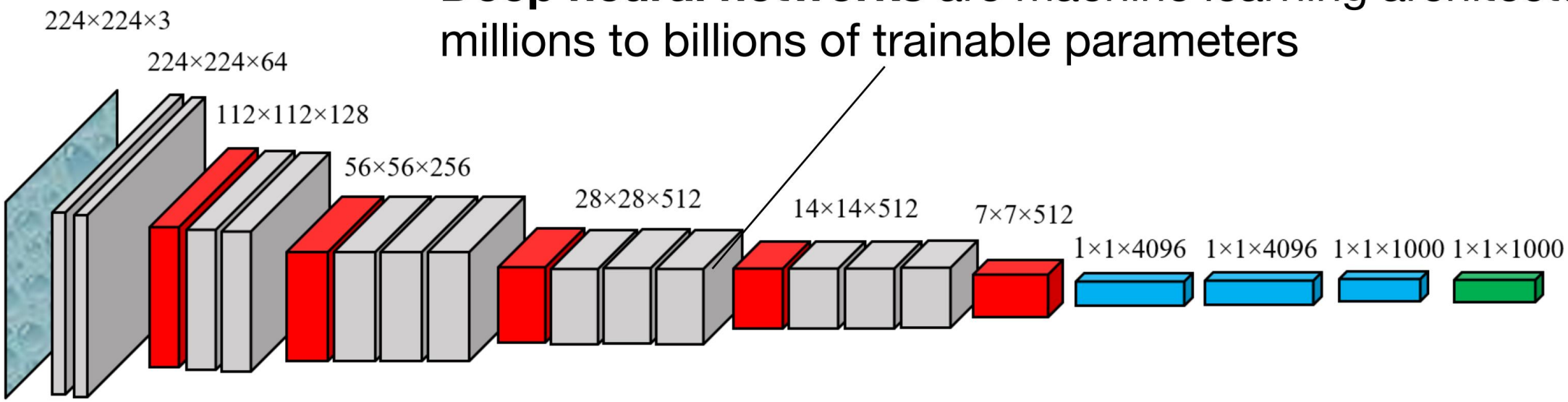
- functional perturbation theory
- BRST-invariant massive schemes
- progress on exact RG equations
- CFT? Dyson-Schwinger?



NUCES

Luca Zambelli

Deep neural networks are machine learning architectures with millions to billions of trainable parameters



Basic intuition and the standard theory of learning suggest that these networks should **overfit** severely, but they do not

Long term goal: Understanding **WHY** deep learning works so well

Major tools: Statistical physics of disordered systems and combinatorics

$$\log Z = \lim_{n \to 0} \frac{Z^n - 1}{n}$$