

Aspects of holographic duality at non-zero baryon density

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BASED ON WORK WITH CARLOS HOYOS & NIKO JOKELA



The big picture

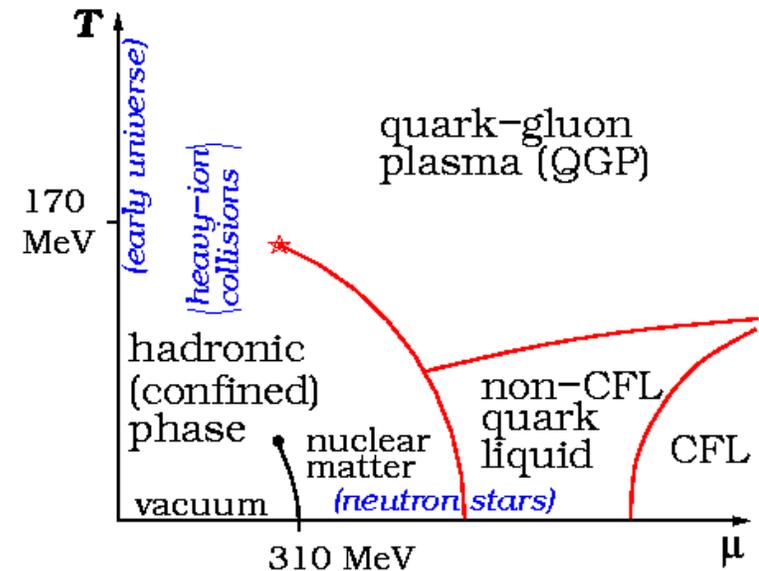
Quantum field theory is interesting and important
...and hard

Example: **QCD phase diagram**

Holographic duality provides a tool to study and gain intuition about gauge theories in general

- A **complement** to other approaches

In this talk: **baryons and color superconductivity**



Holographic duality

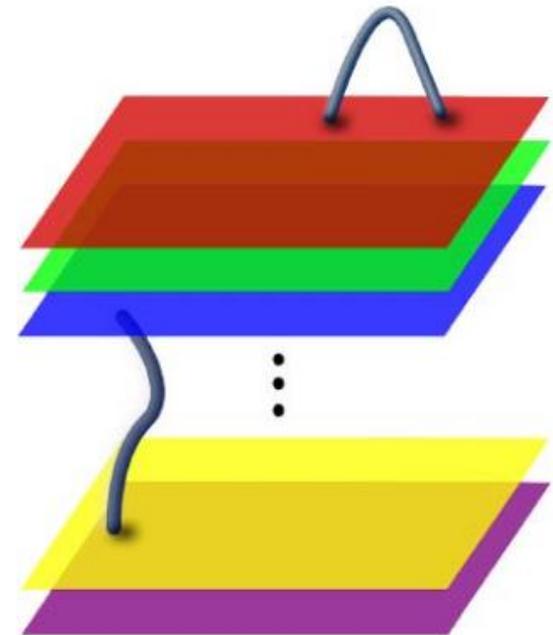
...or AdS/CFT or gauge/gravity duality

A dictionary relating gauge theories and gravitational theories

Start from **string theory** – contains strings and **branes** of various dimensionalities

There are **two very different ways** of describing the low-energy dynamics of such branes

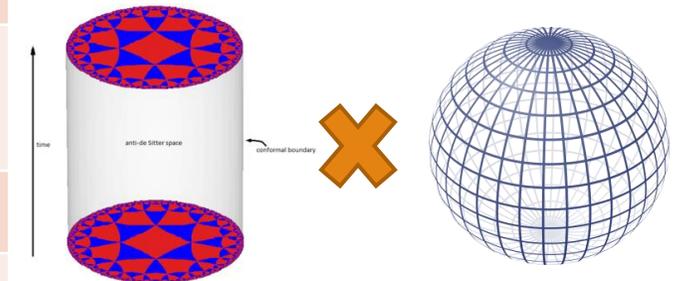
This leads to a **duality!**



Holographic duality (a quick intro)

A dictionary relating gauge theories and gravitational theories

Gauge theory	Gravity theory
Lives on worldvolume of N branes	Lives in near-horizon region of N branes
D dimensional (flat) space	D+1 dimensional anti-de Sitter space + compact internal space
Large N, strong coupling	Classical (super)gravity
States	Geometries
Gauge invariant operators	Fields
Global symmetry	Gauge field



Holography and QCD

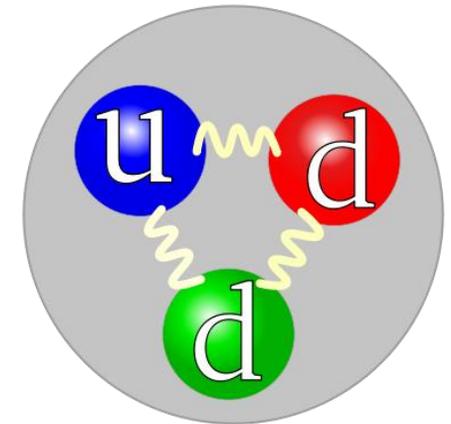
We have gravity duals of many gauge theories, but **not of QCD**

Instead, look for theories with **similar properties** to QCD

- Several possibilities

One important property: **baryons!**

So how are baryons realized in holography?



Holography and baryons

We work in the large N limit

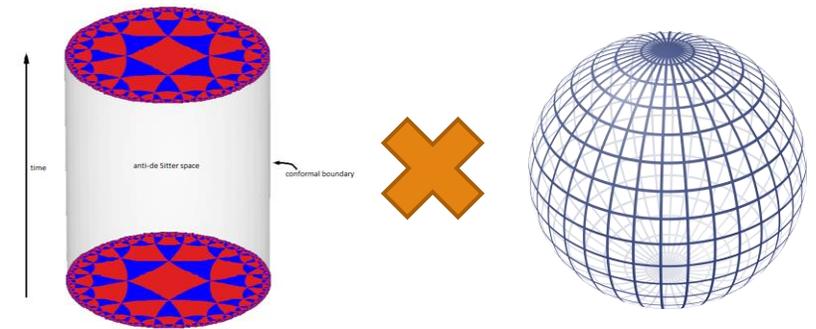
- mesons are light, $m \sim O(1)$
- baryons are **HEAVY**, $m \sim O(N)$

Baryons are heavy, soliton-like objects

In dual gravity description, baryons are **branes wrapped around the internal space**

Can consider different internal manifolds, giving different dual gauge theories

We study the "**conifold gauge theory**"



Color superconductivity

At **large baryon density** and low temperatures

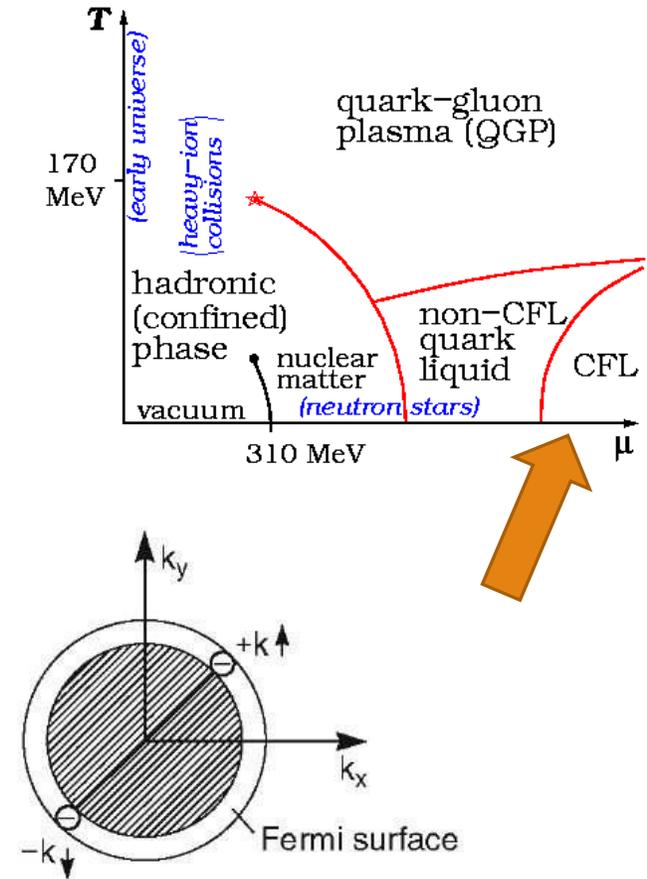
Condensate formed of quarks near Fermi surface

"Breaking" of gauge symmetry

Massive gluons

Etc.

Can holography capture this phenomenon?



Color superconductivity in holography

SU(N) gauge group from **N coincident branes**

To "break" gauge group, move branes away from each other

Does this happen **spontaneously**?

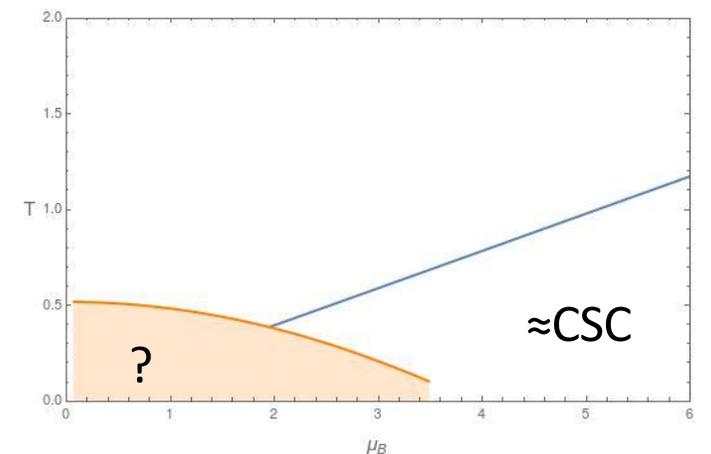
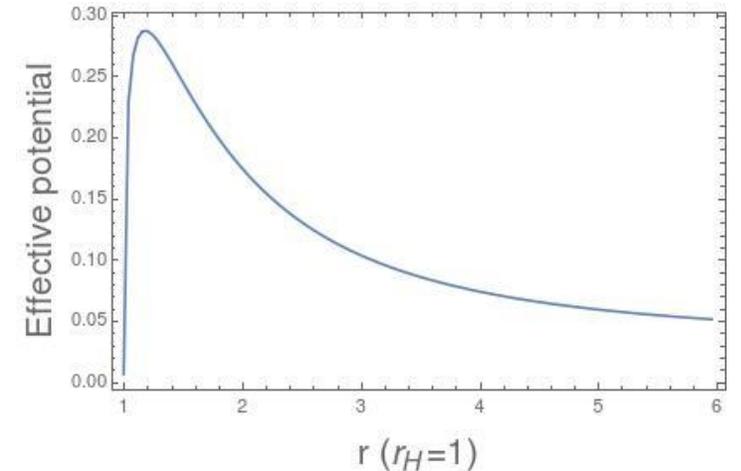
To check, compute **effective potential** for a *probe brane*

If minimum is away from black hole horizon, branes want to escape!

We find such an instability, in "expected" part of phase diagram

To do: Can we construct the CSC state and study its properties?

(see 1807.09712 by Tarrío et al. for related work)



Takeaways

Dense QCD (and gauge theories in general) is theoretically rich area with important open problems

Using holography, we can study gauge theories at strong interaction, non-zero density, etc.

Can teach us more about QFT (and string theory/quantum gravity)

Interesting **geometric** realizations of gauge theory phenomena (baryons, CSC, ...)

Leads to "realistic" phase diagrams

Lots of work to do & fun to be had

Thank you!