Applied AdS/CFT

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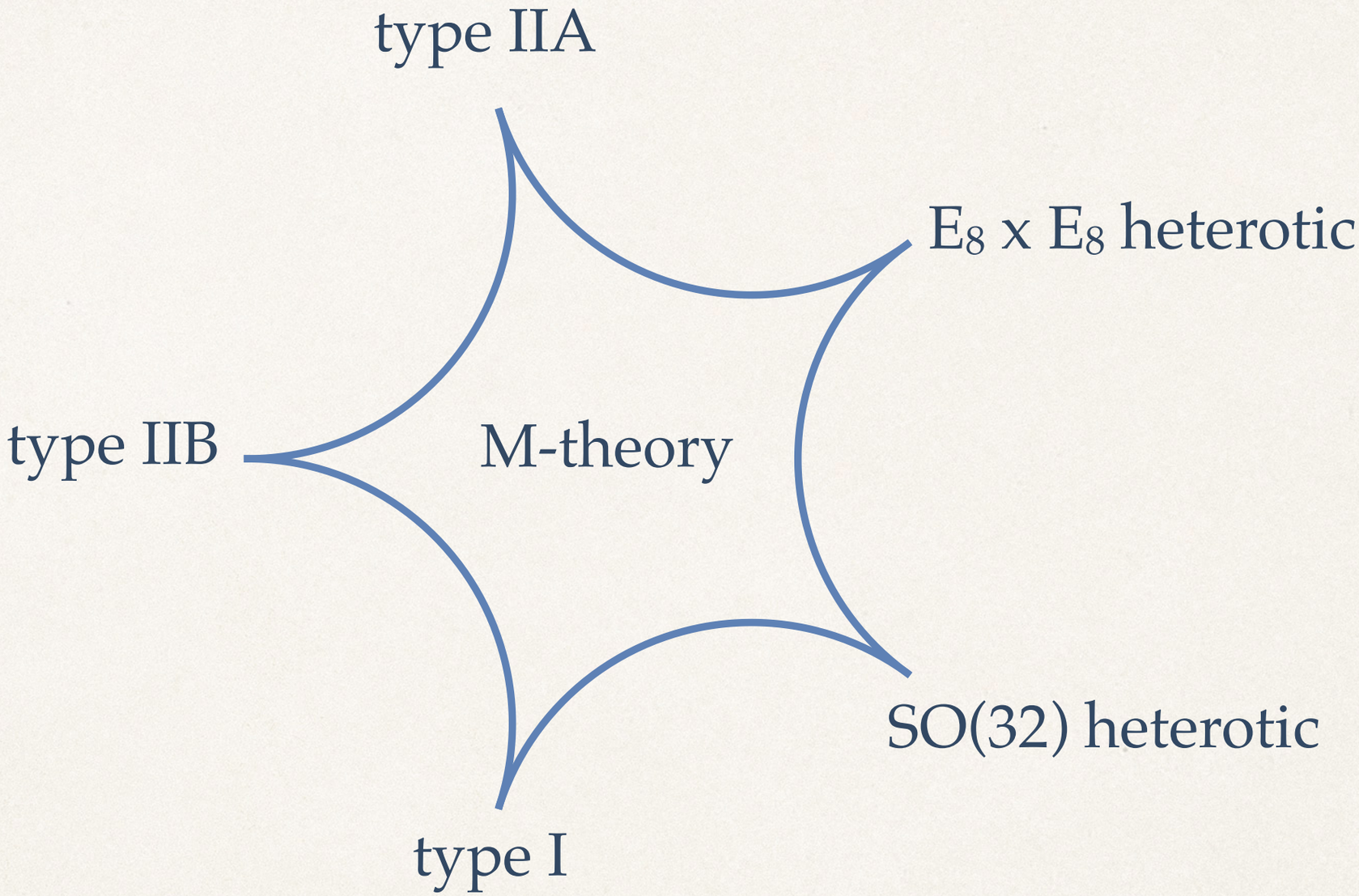
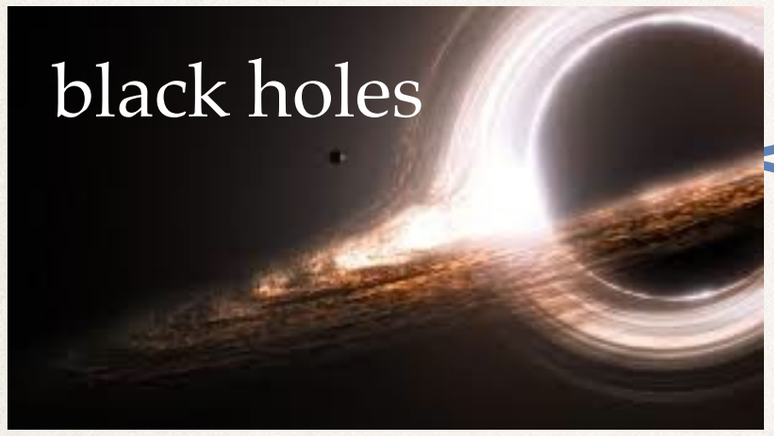
String Theory in 1998

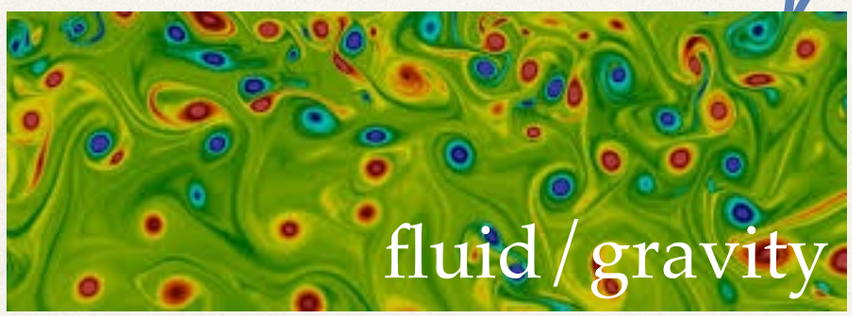


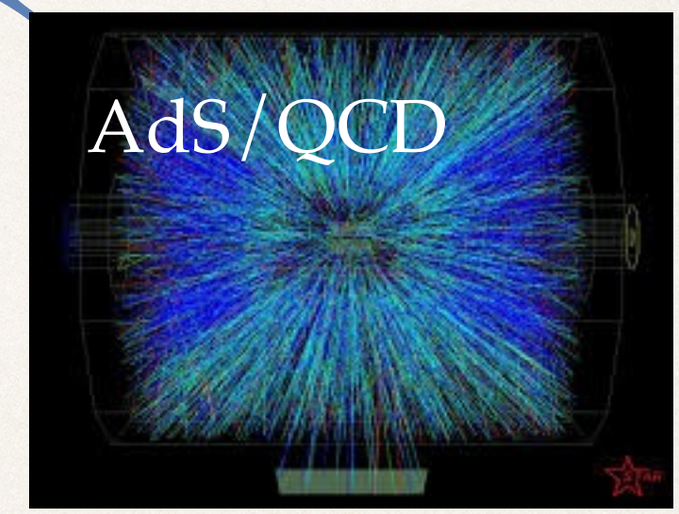
Web of String Dualities

AdS/CFT today

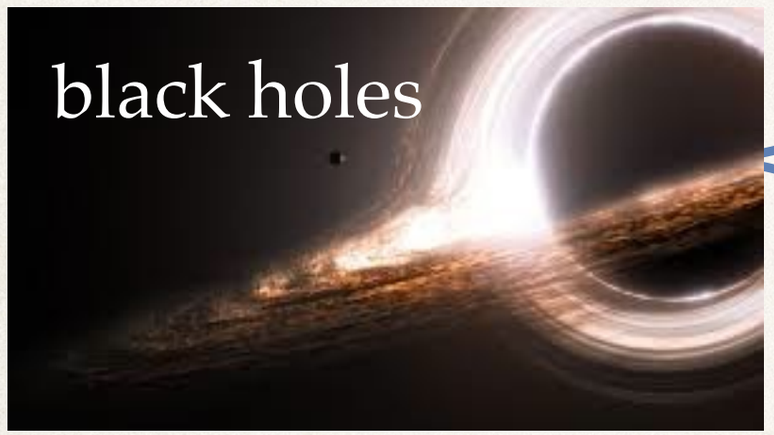


AdS/CFT

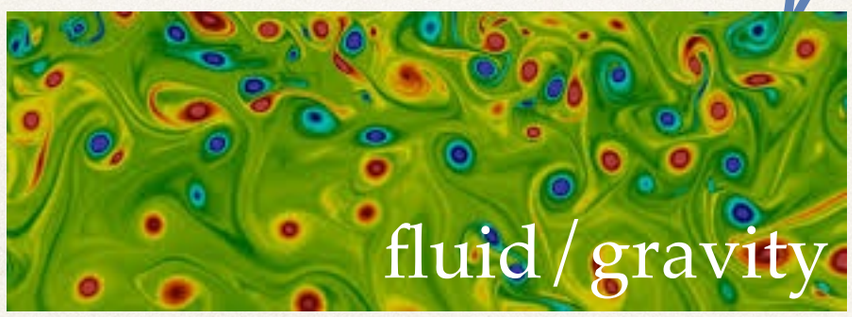


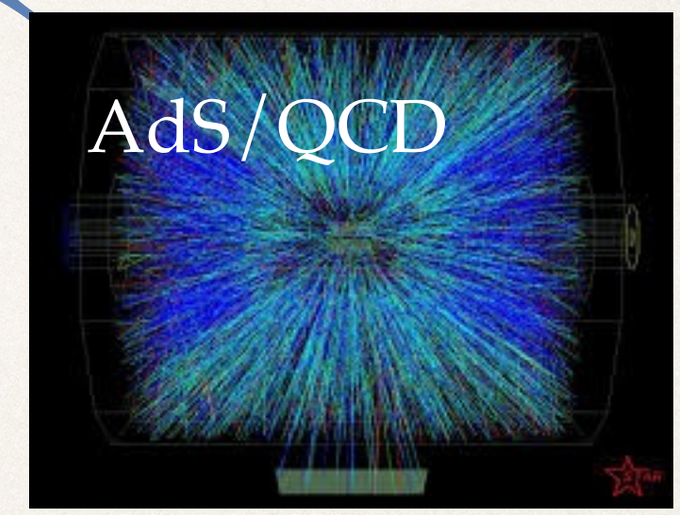


AdS/CFT today



AdS/CFT





"Holographic Photosynthesis", Araf'eva and Volovich, 1603.09107

"Gravity Dual for a Model of Perception", Nakayama, 1003.5729

"Gravity Dual … and Nonlinear Quantum Finance", Nakayama, 0906.4112 ?

"Holography as Deep Learning," Gan and Shu, 1705.05750

What Have We Learned from AdS/QCD and AdS/CMT?

QCD Then…

"Transport Coefficients in High Temperature Gauge Theories…",
Arnold, Moore, and Yaffe (2000)

$$\frac{\eta}{s} \sim \frac{1}{g_{\rm YM}^4 \log g_{\rm YM}^{-1}}$$

(also earlier work by Baym, Monien, Pethick, Ravenhall, Heiselberg)

What one might have thought: The viscosity will be
an important parameter in hydrodynamic modeling of data
from heavy ion collisions. In fact, maybe hydro won't work.

No real way to get at this number from
lattice gauge theory or integrable systems.

… and Now

"The shear viscosity of strongly coupled N=4 supersymmetric Yang-Mills plasma", Policastro, Son, Starinets (2001)

$$\frac{\eta}{s} = \frac{1}{4\pi}$$

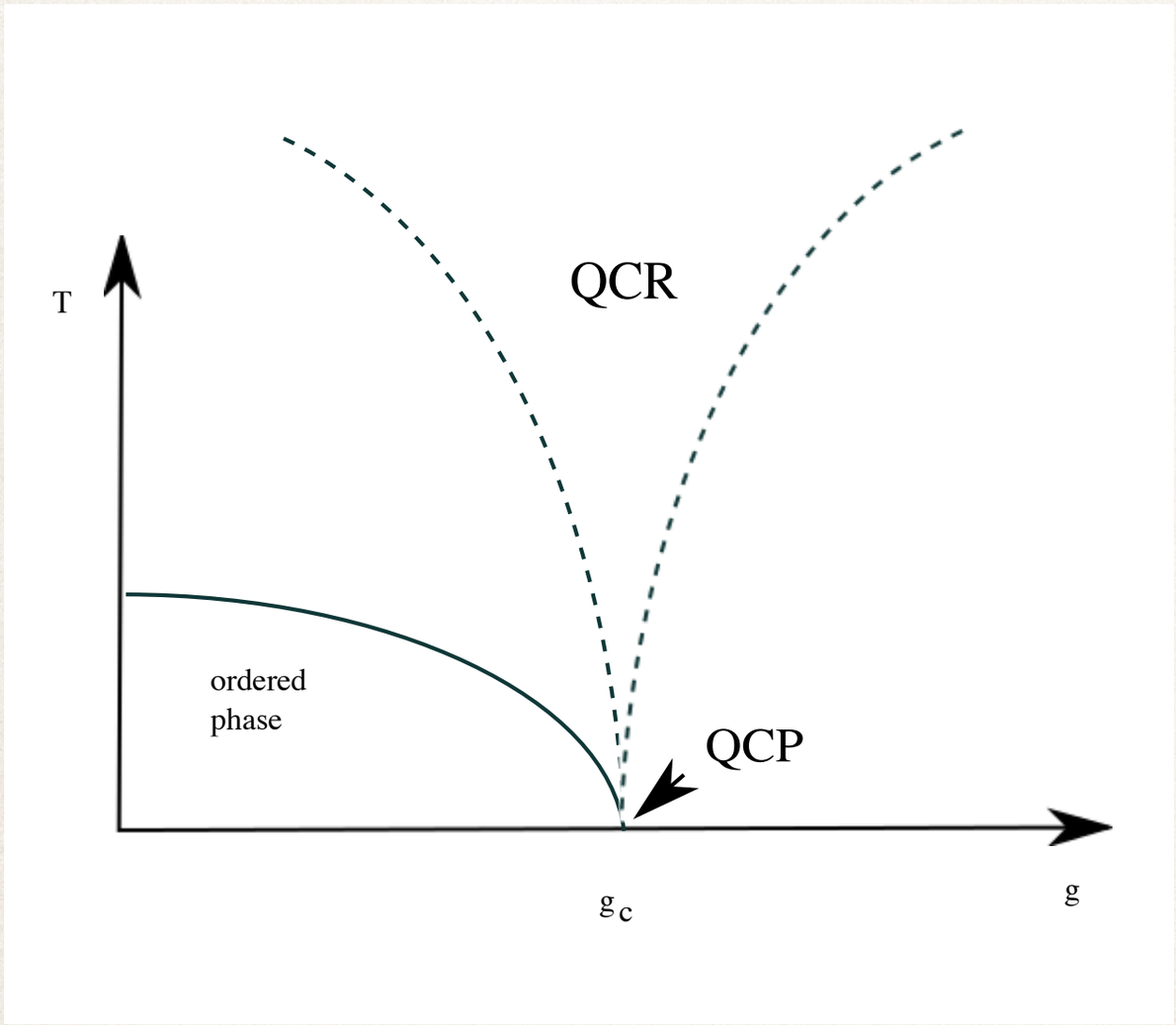
Took a while to divide by s, to appreciate that the number was small, to see that the result was a universal feature of field theories dual to Einstein gravity.

> In fact, the viscosity turned out to be a small effect in (successful) hydro modeling of heavy ion collisions (Romatschke and Luzum (2008)).

CMT Then . . .

QCR = quantum critical region

QCP = quantum critical point

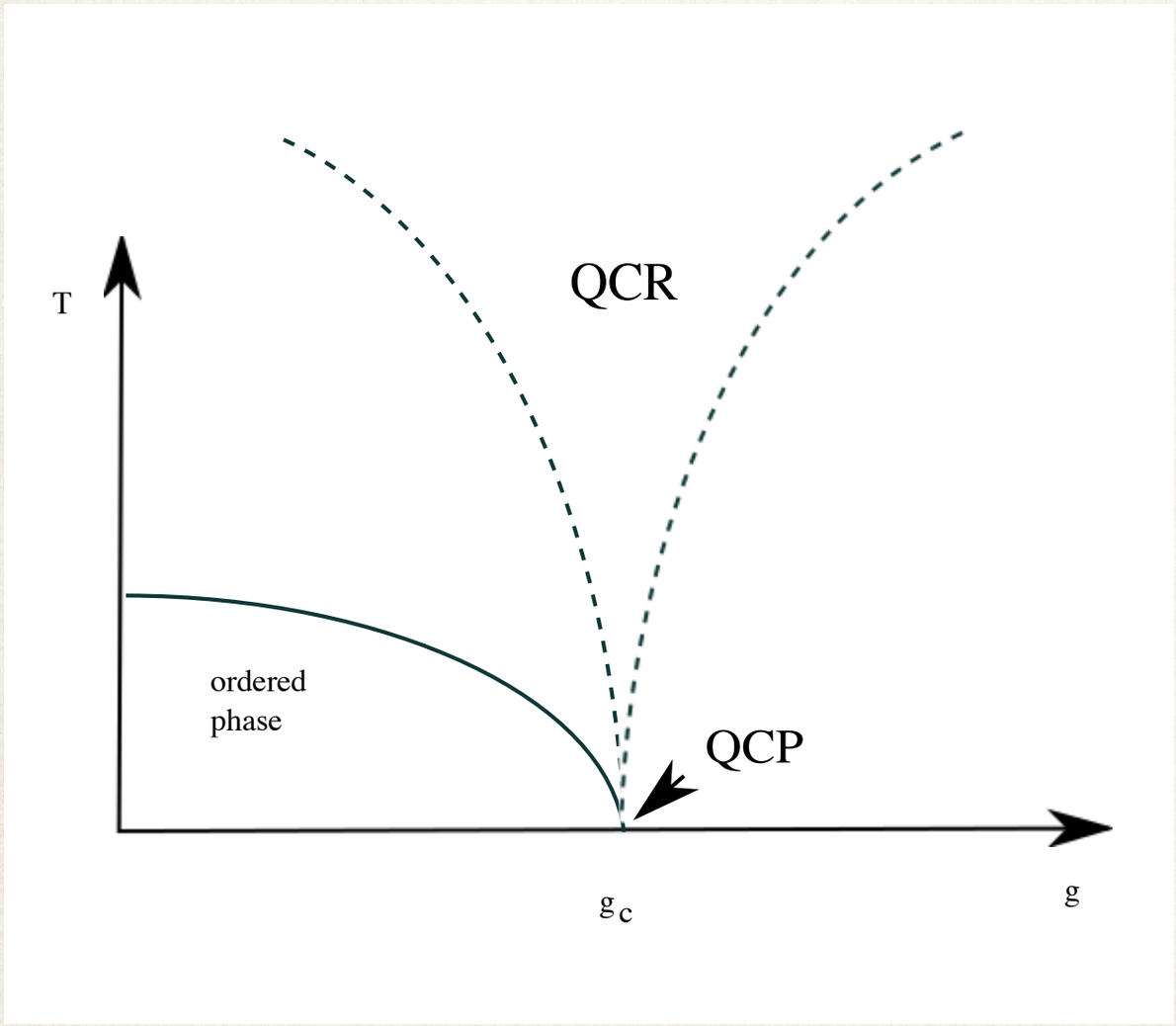


From Sachdev's book, 1st edition, (1999) on quantum phase transitions

integrable systems: possibility of having a phase transition limited by CMW Theorem

perturbation theory: limited to phase transitions at small g

… and Now



holography: provides computable examples of QCRs with full conformal invariance

while string theory completions are less clear, there are also more general scale invariant examples: Lifshitz, Schrodinger, hyper scaling

(c.f. Donos's talk)

AdS/CFT as a New Tool

Standard toolbox:

- perturbation theory
- lattice gauge theory
- integrable systems
- AdS/CFT

Class of problems for which non-holographic techniques fail:

- strong coupling
- time dependence
- nonzero density
- 3 and 4 dimensions

The Future…

What do D-branes, AdS/CFT, the information paradox, topological insulators and field theory entanglement have in common?

The Future…

What do D-branes, AdS/CFT, the information paradox, topological insulators and field theory entanglement have in common?

boundaries

Extra Slides

AdS/Physical Review Correspondence

Brookhaven National Laboratory search

RHIC

Brookhaven National Laboratory's Relativistic Heavy Ion Collider

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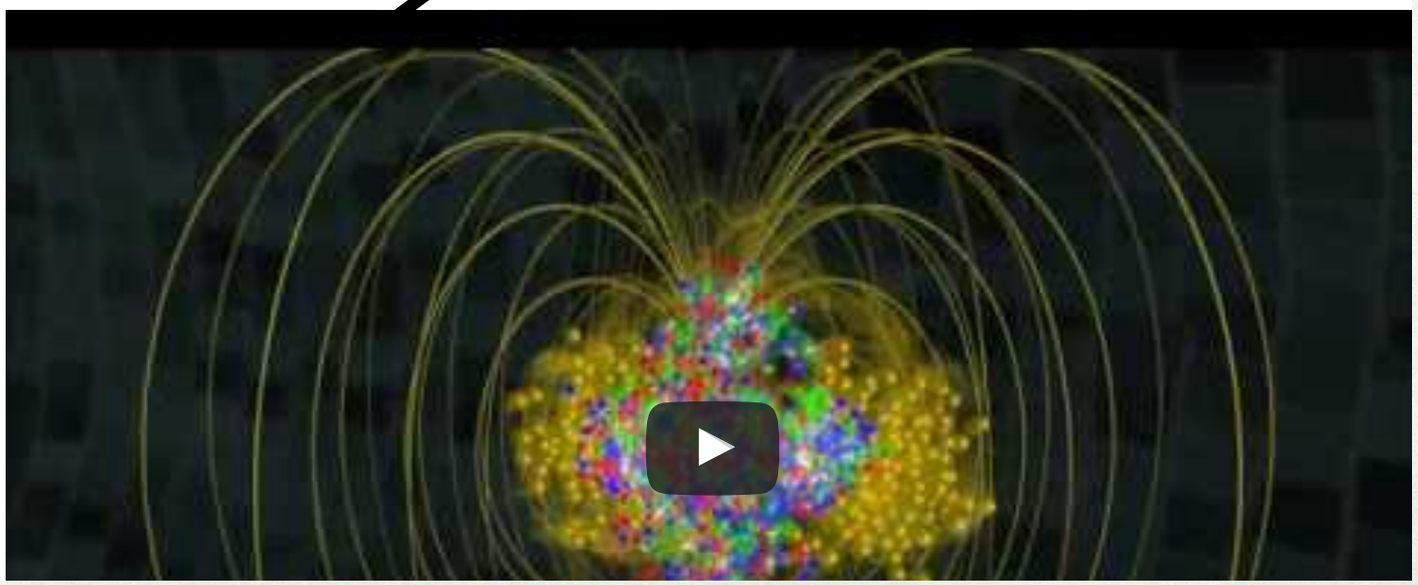
Contacts: Karen McNulty Walsh, (631) 344-8350 or Peter Genzer, (631) 344-3174

'Perfect' Liquid Hot Enough to be Quark Soup

Protons, neutrons melt to produce 'quark-gluon plasma' at RHIC

Monday, February 15, 2010

UPTON, NY — Recent analyses from the Relativistic Heavy Ion Collider (RHIC), a 2.4-mile-circumference "atom smasher" at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory, establish that collisions of gold ions traveling at nearly the speed of light have created matter at a temperature of about 4 trillion degrees Celsius — the hottest temperature ever reached in a laboratory, about 250,000 times hotter than the center of the Sun. This temperature, based upon measurements by the PHENIX collaboration at RHIC, is higher than the temperature needed to melt protons and neutrons into a plasma of quarks and gluons. Details of the findings will be published in *Physical Review Letters*.



This liquid matter has been described as nearly "perfect" in the sense that it flows with almost no frictional resistance, or viscosity.

Does this make sense?

Dimensional Analysis:

$T \sim 5.5 \times 10^{12}$ K at CERN

dominant scale

$$\eta \sim \frac{(k_B T)^3}{\hbar^2 c^3} \sim 10^{13} \text{ g cm}^{-1} \text{ s}^{-1}$$

10^{15} times that of water!

Pitch Drop Experiment

Started in 1927.
9th drop just now fully formed.
No one has ever seen a drop fall.

But it's only 10^{11} times more viscous than water!

Edgeworth, Dalton, Parnell, Eur. J. Phys (1984) 198-200

Insight: Compare viscosity with a measure of the number of degrees of freedom — the entropy density (Kovtun, Son, Starinets, 2004).

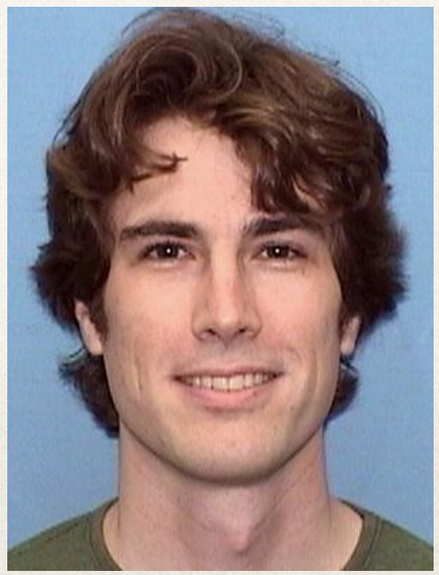
$$\frac{\eta}{s} \sim \frac{\hbar}{4\pi k_B}$$

AdS/PRB Correspondence

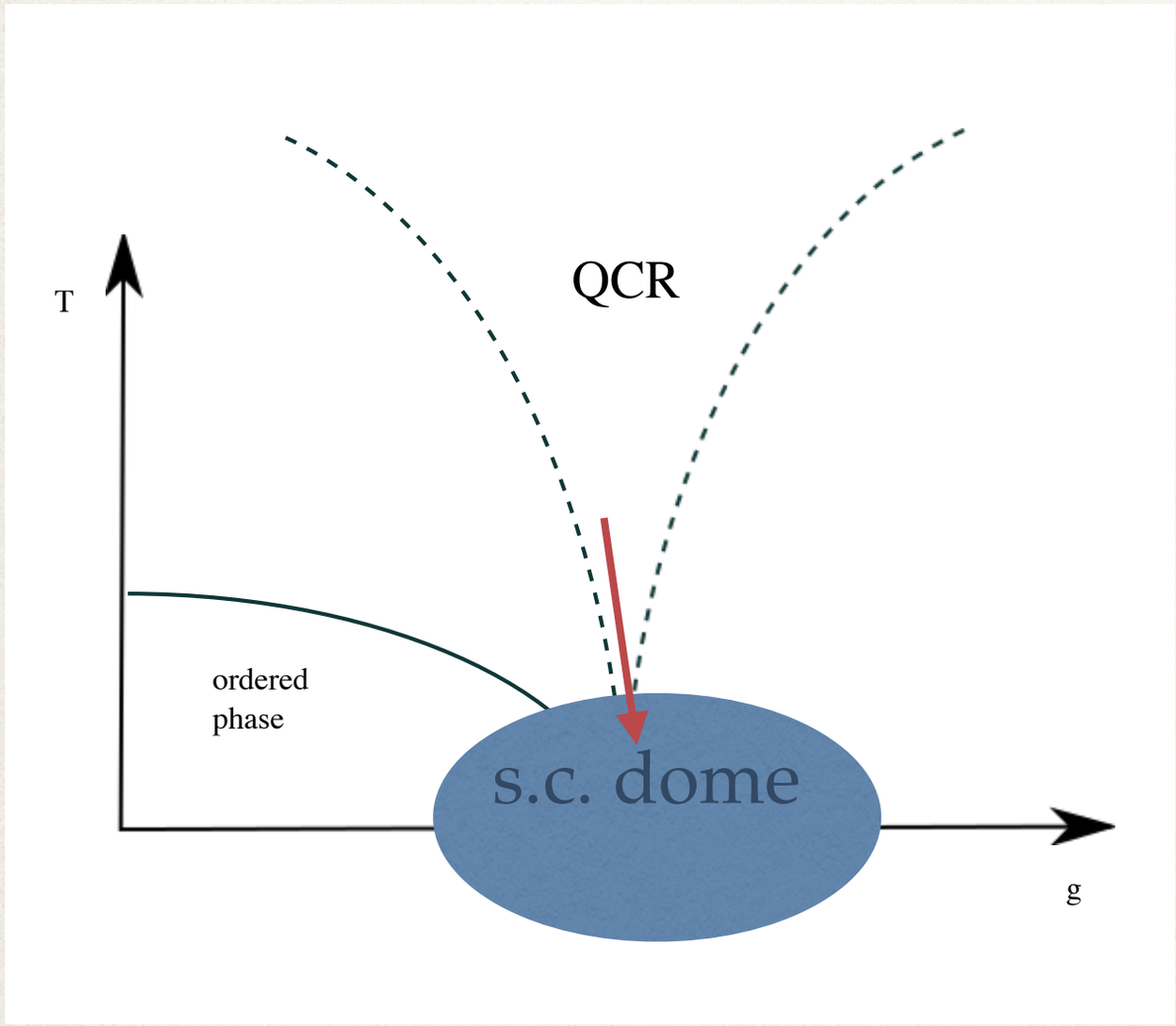
"Building a Holographic Superconductor", Hartnoll, Herzog, Horowitz,
PRL 101 (2008) 031601

referee report:

From the paper it remains unclear if the consequences of duality are on the level of educated guesswork or if there is a serious mathematical theory behind it. To satisfy the standards of condensed matter theory, things would have to be made much more precise. The theoretic problems in unconventional superconductivity are specific, many of them refer to a description of the normal state, and none of them is addressed in this paper.



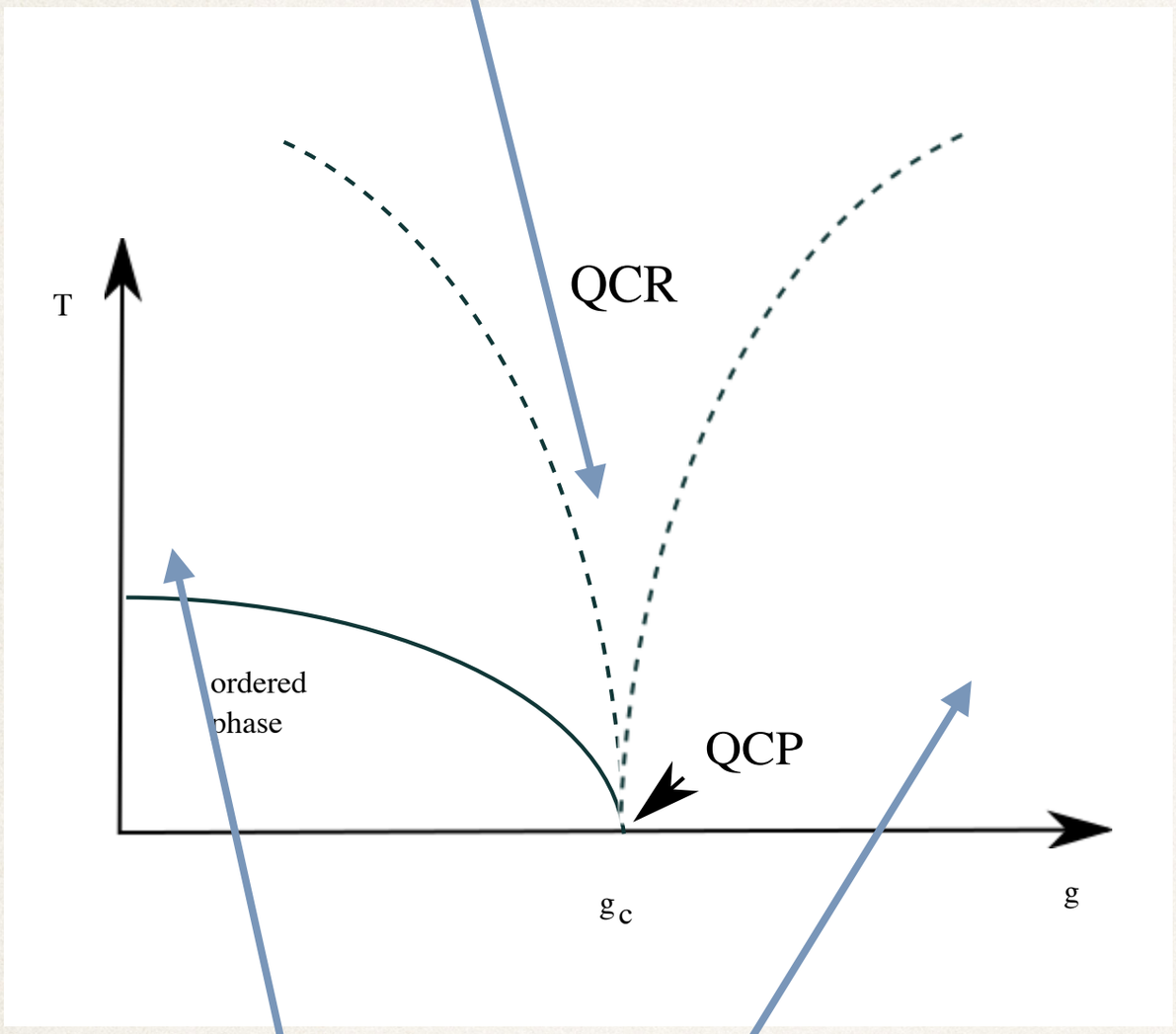
Quantum Phase Transition



- maybe a scale invariant field theory can describe the strange metal regime of high Tc
- we ought to be able to use an AdS/CFT model to gain some insight
- holo s.c. proof of principle that CFTs with gravity duals can have a superconducting phase transition. gives us more faith in relevance of transport quantities computed from AdS/CFT.

AdS/CFT works best here

more universal,
lots of symmetry,
stable



physics here and here tends to be non-universal

irrelevant operators become important
when order parameters grow

instabilities,
scale dependence,
many low T phases