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HoloTube Discussion: New ideas for many-body quantum systems from string theory and black holes

slides composed by
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HoloTube Discussion: New ideas for many-body quantum systems from string theory and black holes

Guided by Snowmass White Paper
*[Blake, Gu, Hartnoll, **Liu**, **Lucas**, Rajagopal, Swingle, Yoshida; arXiv:2203.04718]*

- Black holes and **hydrodynamic transport**
- Holographic **superconductors and strange metals**
- Quantum dynamics and the **onset of chaos**
- **Bounding** finite temperature quantum dynamics
- Late time many-body **quantum chaos**
- **Quantum information** of many-body systems
- The **SYK** model and beyond
- Properties and Dynamics of **Quark-Gluon Plasma**
- **Far-from-equilibrium** dynamics

Puzzle pieces

Quantum information of many-body systems

Bounding finite temperature quantum dynamics

The **SYK** model and beyond

Far-from-equilibrium dynamics

Quantum dynamics and the **onset of chaos**

Black holes and **hydrodynamic transport**

Late time many-body **quantum chaos**

Properties and Dynamics of **Quark-Gluon Plasma**

Holographic **superconductors and strange metals**

Hong Liu (MIT, Cambridge, MA)

A major clue from holography:

Existence of an "effective description'' of a quantum many-body system, which involves only a small number of field theoretical degrees of freedom, but can capture key physics at all energy scales.

The relevant degrees of freedom involve those associated with conserved quantities and a small number of relevant operators.

It is like "hydrodynamics", but extended to all energy scales, and can capture a much wider range of physics including quantum informational properties, and can be used to calculate transport coefficients.

Why such a description exists?

Can we develop it for general strongly correlated systems? (e.g. the strange metal phase of high Tc superconductors)

Andrew Lucas (U of Colorado, Boulder, CO)

Transport and chaos in AdS/CMT

“SOLVED” PROBLEMS:

- Good understanding of hydrodynamics and its breakdown
- Chaos and transport constants are (often) intimately related (in holography)
- SYK-based models have less tunable exponents than AdS ones, while maximally chaotic

UNSOLVED PROBLEMS:

- Does a Planckian bound exist? Can it be proved? (Size winding?)
- Why/when does this Planckian bound give a bound on diffusion?
- How much of the holographic/SYK phenomenology applies to small N chaotic lattice models?

FUTURE DIRECTIONS? (Where established holography can be the best toy model for a hard problem)

- Extreme quenches, far-from-equilibrium environments (pair-producing electric fields) etc.
- Geometrized RG flow of perturbed quantum critical points?

Discussion buzz words

- Schwinger-Keldysh formulation of non-equilibrium EFTs (e.g. hydrodynamics)
- resurgence in hydrodynamics (attractors)
- black hole entropy (fine-grained vs. coarse-grained)
- black hole information paradox (Hawking vs. AMPS), Page curve, islands
- eigenstate thermalization hypothesis (ETH) vs. ergodicity (quantum chaos)
- entanglement = spacetime
- generalized global symmetries, pseudo-Goldstone bosons, quasi-hydro
- …

Question 1

- “[…] strongly coupled quantum fluids are excellent platforms to observe hydrodynamics in experiments on quantum matter.“

  Snowmass White Paper[arXiv:2203.04718]

- Question: Why should this be true? Aren’t there only very few materials known to be reaching the hydrodynamic limit in condensed matter experiments? (due to defects, lack of purity, …, graphene being one lucky exception?)

Question 2

- “Ballistic spreading of OTOCs is also observed in example of integrable many-body quantum systems, […]“

  Snowmass White Paper[arXiv:2203.04718]

- Question: Then, how can OTOCs be considered as characterizing chaos?

Question 3

- Question: Is there an effective field theory of quantum chaos, in particular of information scrambling, and how useful would it be? (for systems not saturating the chaos bound on the Lyapunov exponent $\lambda \leq 2\pi T$)

Question 4

- Claim: The Gauge/Gravity Correspondence is merely a construction tool for effective field theories, and string theory serves as a mathematical toolbox.
- Question: Why should we expect any deep insights beyond a very broad effective level?