



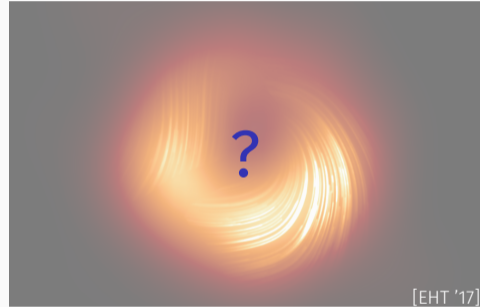
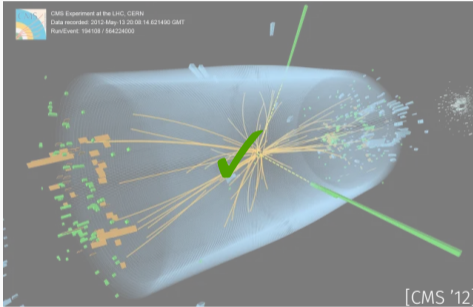
HOLOGRAPHY: PUSHING THE BOUNDARIES

Ruben Monten

University College Dublin — May 29, 2026

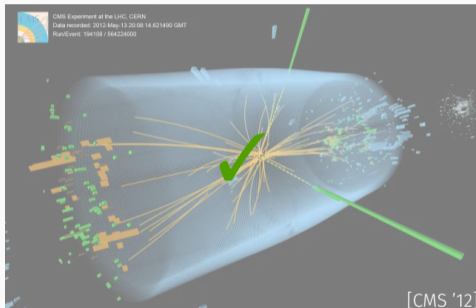
The Big Question

Fundamental quantum theory of **gravity**?

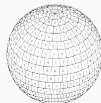


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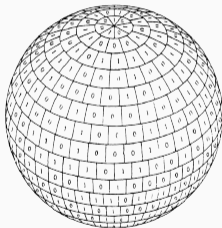
Hints & puzzles:



...

Hint: event horizons

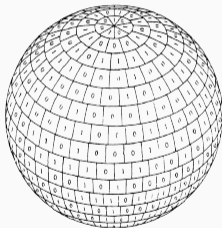
Information capacity \propto area
(not volume!)



[Wheeler '89]

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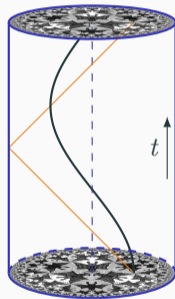
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Exact models

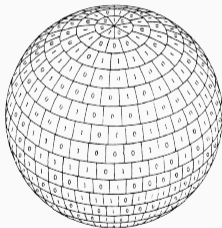
Anti-de Sitter space (AdS)
“test-tube universe”



Holography

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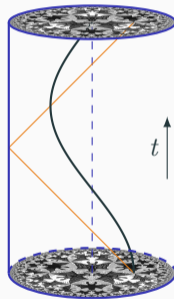
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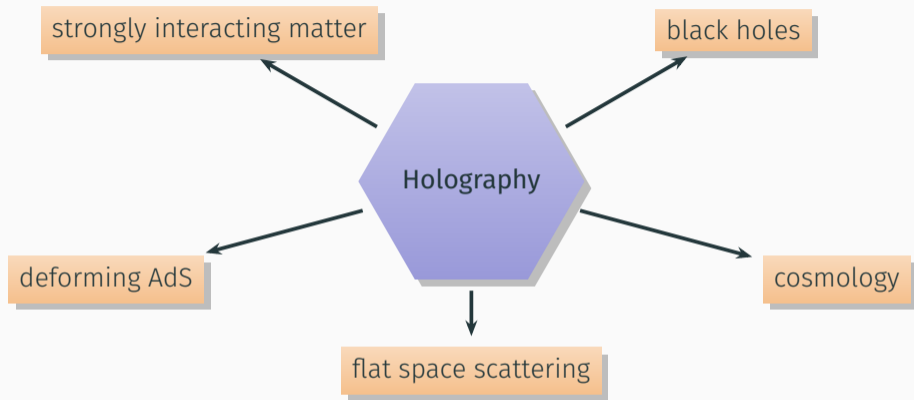
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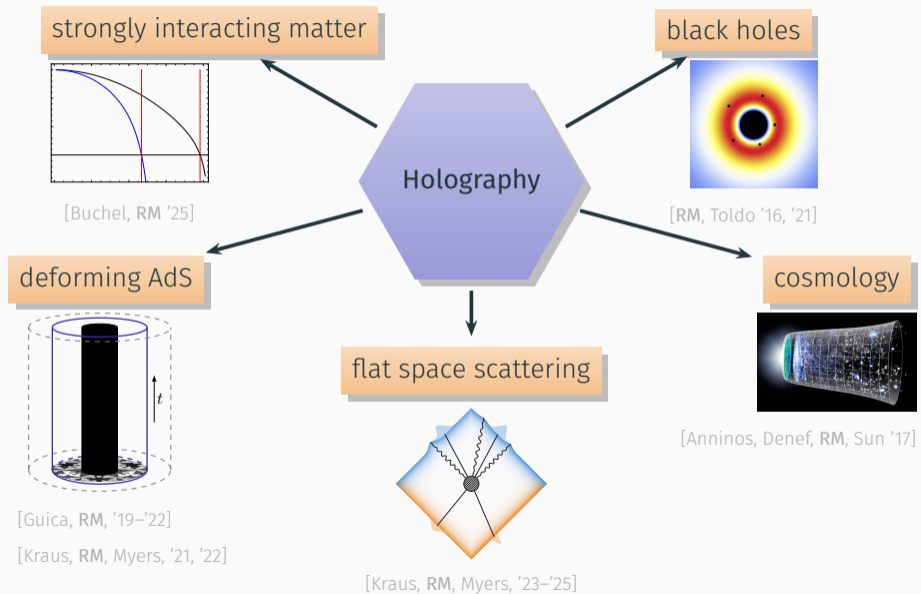
String theory:

AdS \leftrightarrow CFT anchored on the boundary
strong \leftrightarrow weak duality

Tapestry of holography



Tapestry of holography



Highlights: holography near quantum criticality?

Thermal states: AdS black holes / black branes





↪ Can we reach arbitrarily low temperatures?

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↷ Can we reach arbitrarily low temperatures?

Example: charged black hole with charged matter field ↷ **superconductivity**

$T > T_c$		↔		$\langle N \rangle = 0$
$T < T_c$		↔		$\langle N \rangle > 0$

$$\langle N \rangle = \frac{1}{\beta} \partial_\mu \log Z$$

$$Z[\beta, \mu] = \text{Tr} e^{-\beta(H - \mu N)}$$





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However: other instabilities can kick in before T reaches T_c





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- Requires appropriate ansatz

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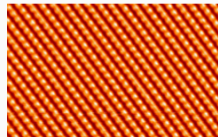
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Indeed: “charge clumping instability” [Buchel, RM '25]





[Images: wikimedia,

Physica B407 (2012) 1845]

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Fit at UCD:

[Dr Christiana Pantelidou](#):

Research Interests: General Relativity, black holes, nonlinear phenomena, High-Performance Computing, theoretical physics

[Dr Sarp Akcay](#)

Research Interests: General relativity, gravitational wave astronomy, black hole perturbation theory, effective-one-body theory

[Dr Niels Warburton](#)

Research Interests: Gravitational waves, black holes, extreme mass ratio inspirals, intermediate mass ratio inspirals, general relativity, numerical modeling, geodesic motion in black hole spacetimes

[Dr Barry Wardell](#)

Research interests: General Relativity, Gravitational Waves, Black Holes, Cosmic Strings, High-performance Computing



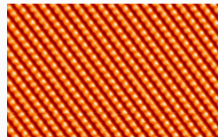
UCD Relativity

activity

$$\partial_\mu \log Z$$

$$e^{-\beta(H-\mu N)}$$

$$-S_{\text{grav}}[\beta, \mu = A_t(\text{bdy})]$$



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Highlights: structural glasses

Structural glasses

- Glass transition is not understood
- Challenging: non-equilibrium, non-crystalline, aging

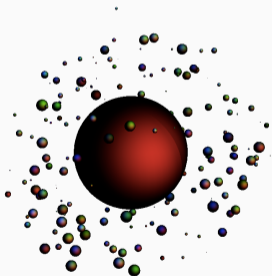
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[Image: arXiv:1108.5821]

Holographic model

[RM, Toldo '16, '21]

- **Amorphous**, metastable bound state of many black holes
- Realized in M-theory on $\text{AdS}_4 \times \text{SE}_7$
 \leadsto numerical BVP

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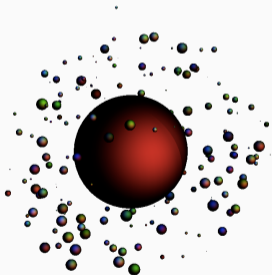
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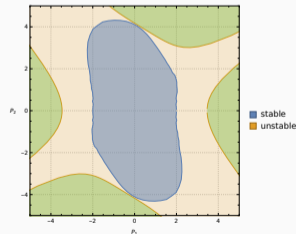
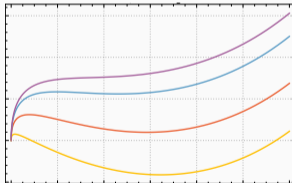
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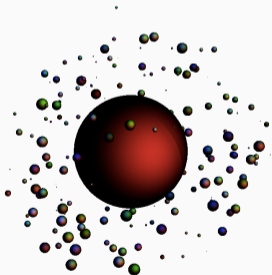
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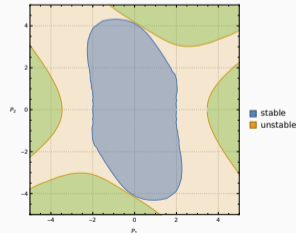
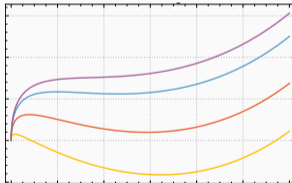
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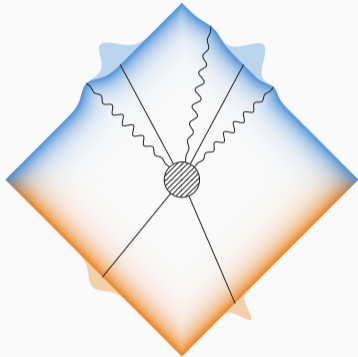
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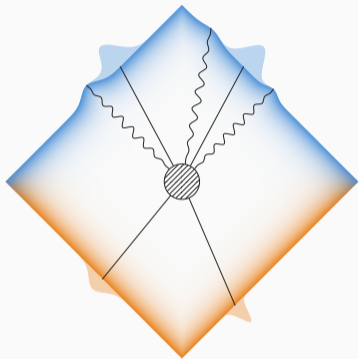
Highlights: a partition function for the S-matrix



Gravity in Asymptotically Flat Space (AFS)

- Asymptotic observable: S-matrix
- IR divergent: **ill-defined in 4d**

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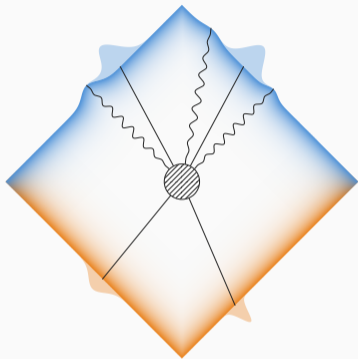
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$$Z[\phi_{\text{past}}^+, \phi_{\text{future}}^-]$$

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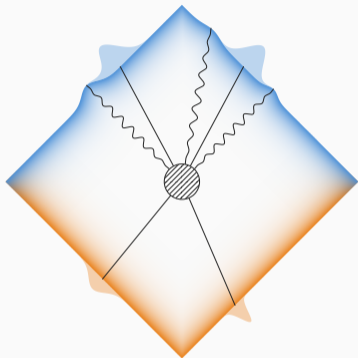
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Symmetries & conservation laws

- Poincaré: $ISO(1, 3)$

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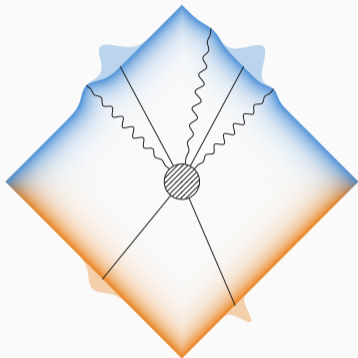
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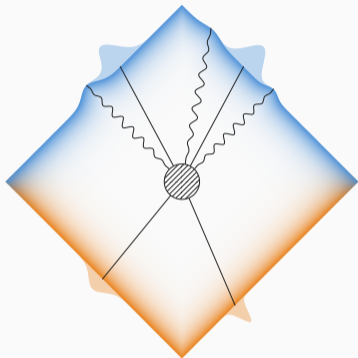
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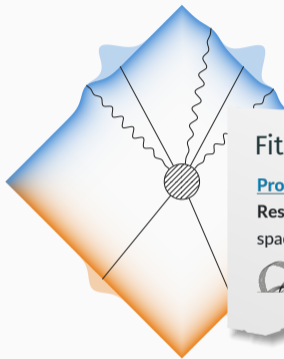
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Fit at UCD:

[Prof Adrian Ottewill](#)

Research Interests: General relativity, Quantum field theory in curved space-time



UCD Relativity

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Thank you!

Questions?