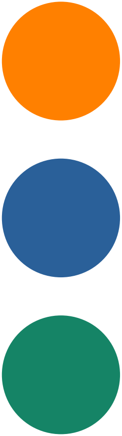
Classical black hole



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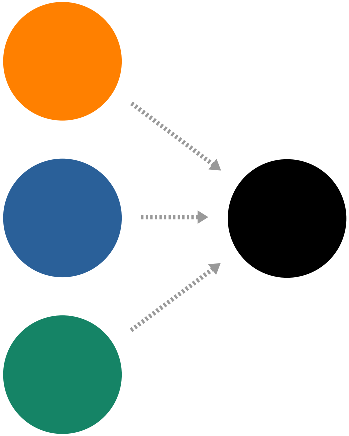

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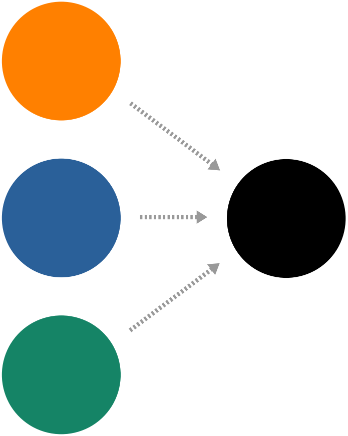

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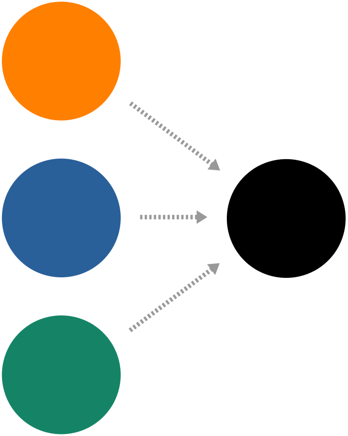

- Black hole fully determined by mass M
- No hair outside[1]

[1] See e.g., P. Chrusciel, J. Costa, M. Heusler, *Stationary Black Holes: Uniqueness and Beyond*, `arXiv:1205.6112`.

Quantum effects I: entropy[2]

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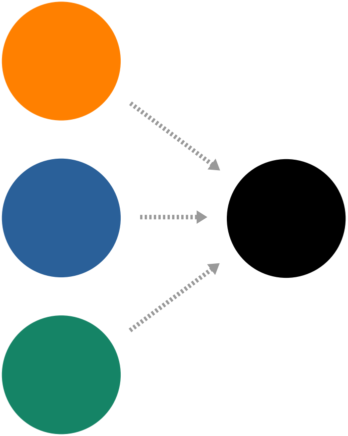

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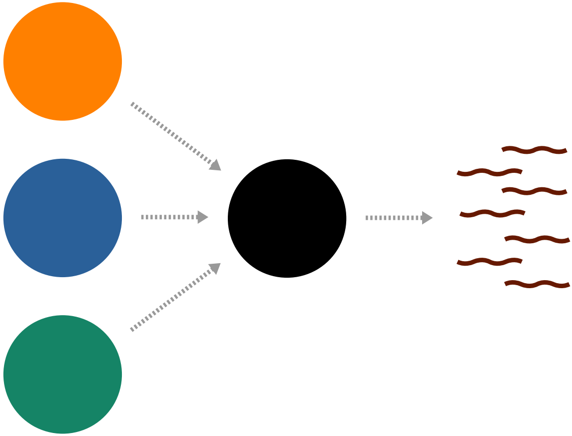

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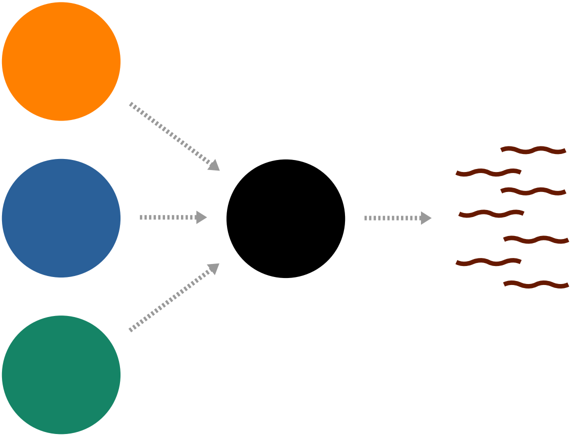

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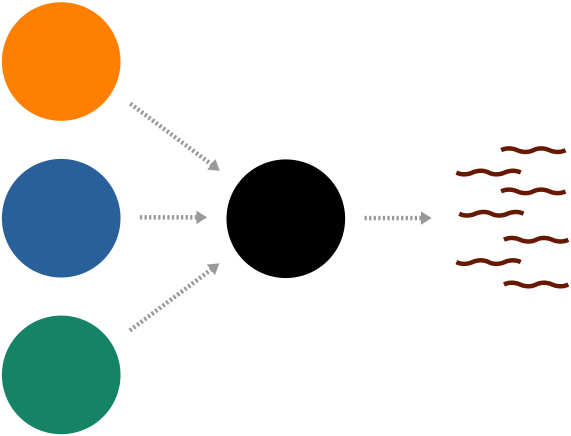

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Black Holes and Quantum Information: What Happens After Half Evaporation?

Sebastian Zell

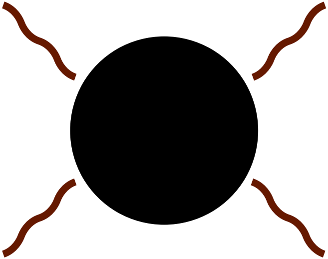
UCLouvain

Work[1] with Gia Dvali, Lukas Eisemann and Marco Michel

7^{th} December 2022

[1] G. D., L. E., M. M., S. Z., *Black Hole Metamorphosis and Stabilization by Memory Burden*, Phys. Rev. D **102** (2020), `arXiv:2006.00011`.
M. M., S. Z., *The Timescales of Quantum Breaking*, to appear.

Black hole evaporation



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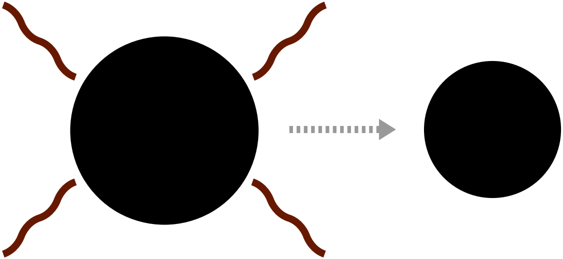

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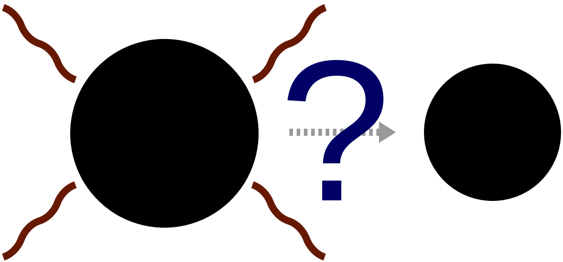

Outline

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$$\Gamma \sim \frac{1}{r_g} \qquad E \sim \frac{\hbar}{r_g}$$
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$$t_{1/2} \sim \frac{1}{E\Gamma} M = S r_g$$

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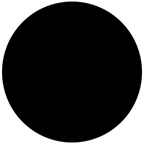

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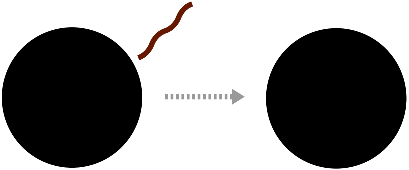

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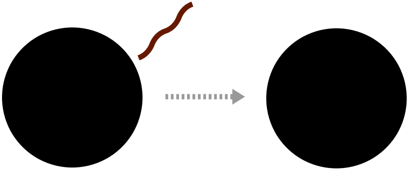

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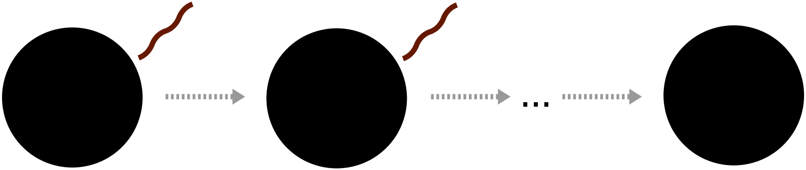

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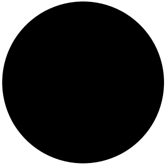

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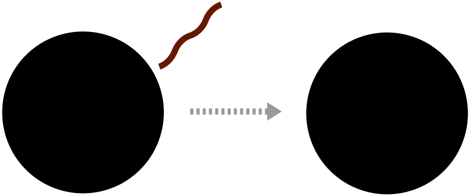

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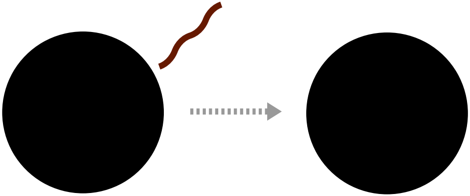

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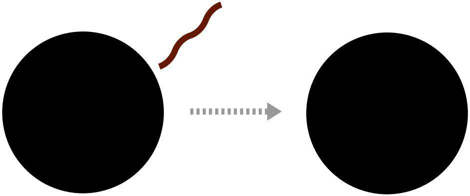

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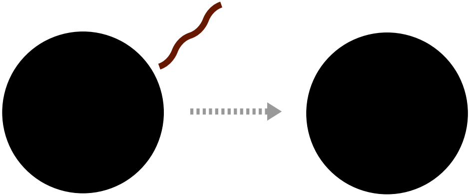

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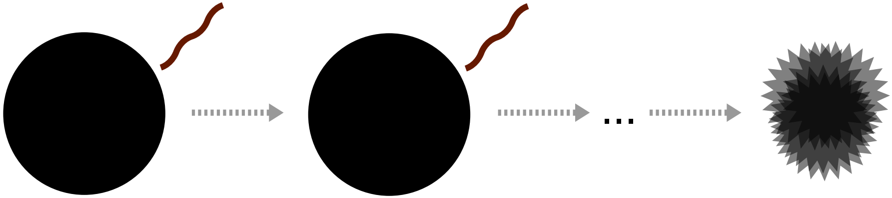

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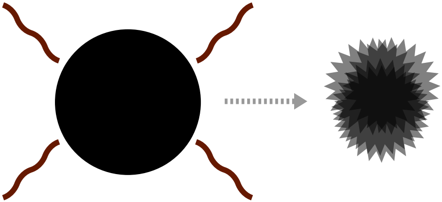
[4] D. Page, *Is Black-Hole Evaporation Predictable?*, Phys. Rev. Lett. **44** (1980).

No self-similarity?



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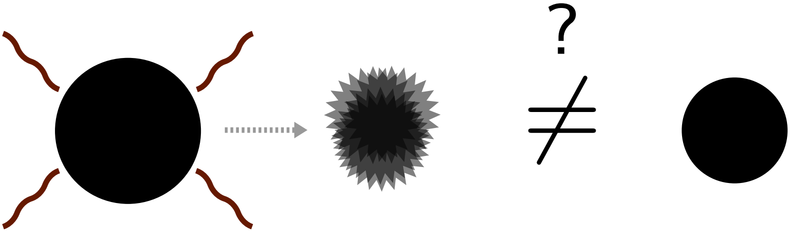

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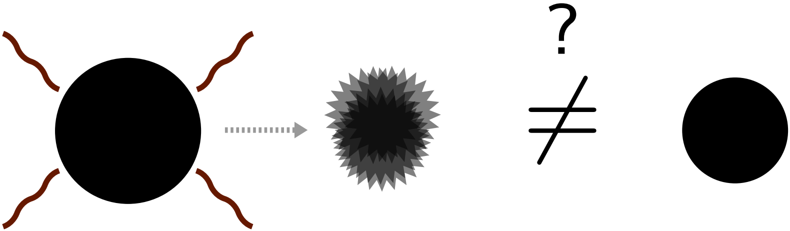

Open question:
What happens to a black hole after losing half of its mass?

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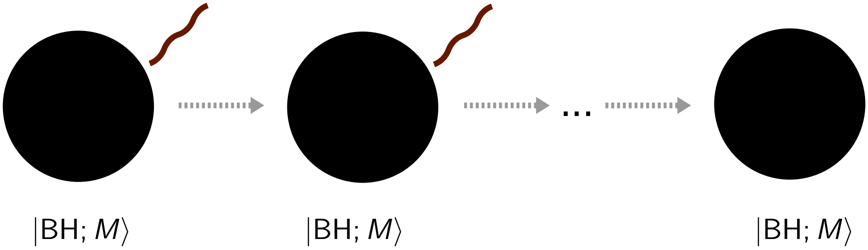

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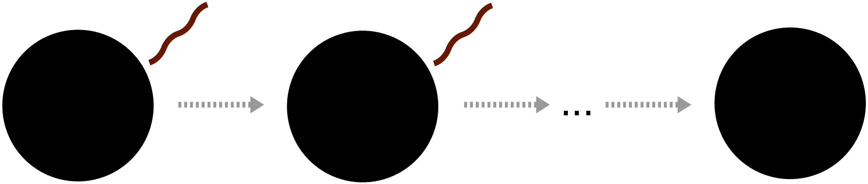

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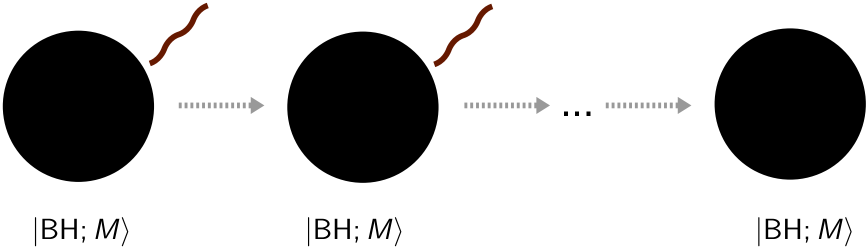

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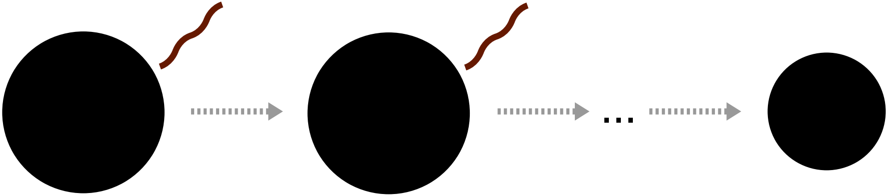
Finite mass



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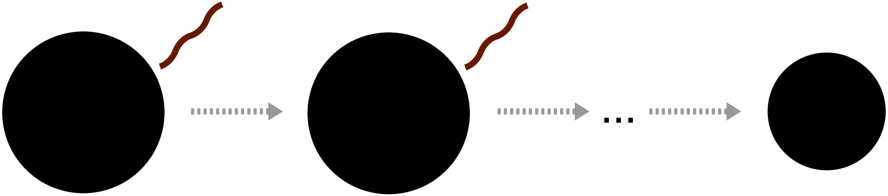

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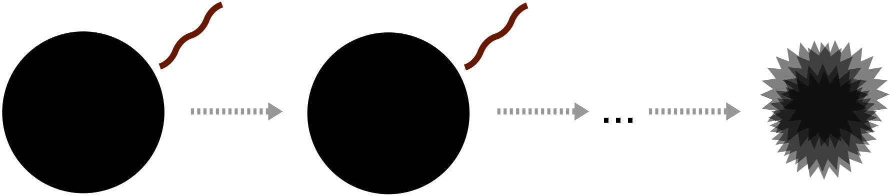

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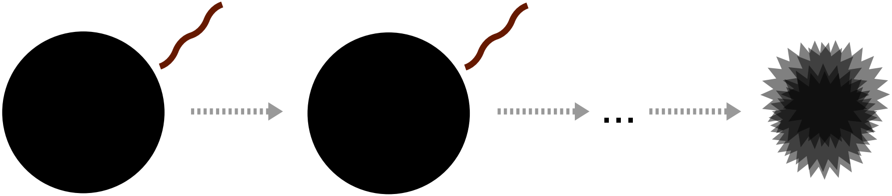

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Geometry[8]   Information storage[9]

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[9] G. Dvali, C. Gomez, *Black Holes as Critical Point of Quantum Phase Transition*, `arXiv:1207.4059`.

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additional material

[10] M. Michel, S. Zell, *TimeEvolver: A Program for Time Evolution With Improved Error Bound*, `arXiv:2205.15346`.

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Black hole metamorphosis

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half evaporation

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slowdown

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Hawking continues

$t_{2/2} \sim r_g$

classical instability

Outline

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Primordial black holes[12]

- Black holes formed in early Universe

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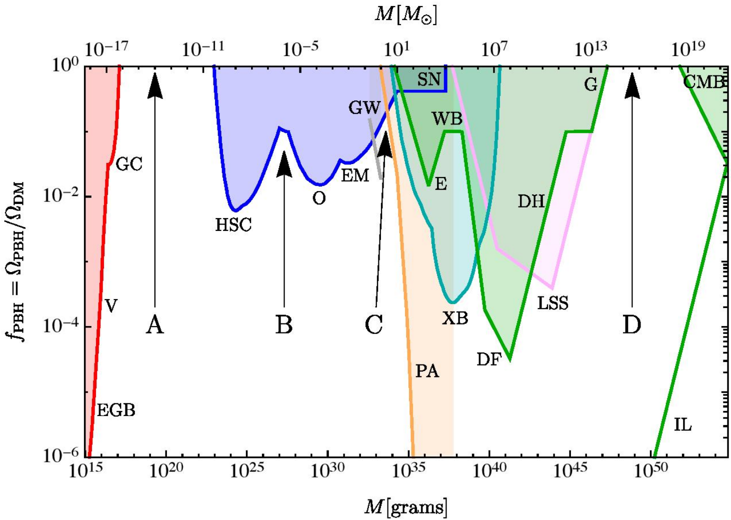
Primordial black holes as dark matter



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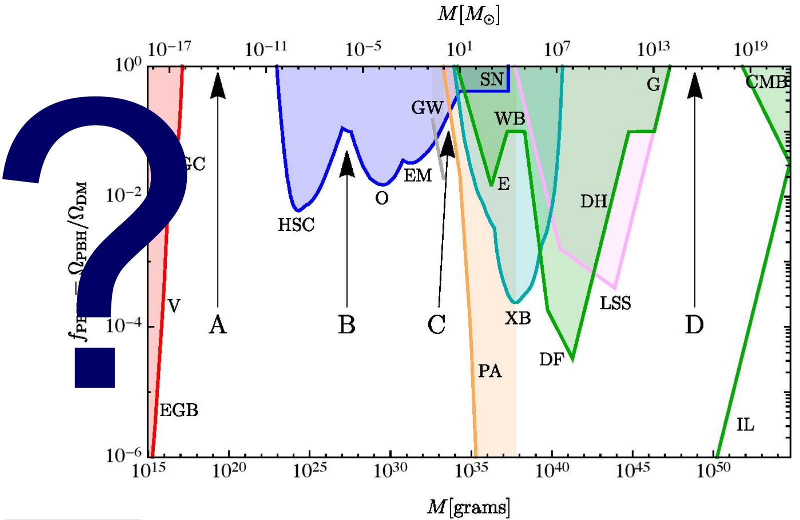

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Prototype model[14]

- Use S modes $\hat{a}_1^\dagger, \ldots, \hat{a}_S^\dagger$

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- Dictionary

$\hat{n}_0$: carries mass

$\langle \hat{n}_0 \rangle = S$: black hole state

$\hat{n}_k$: carry entropy

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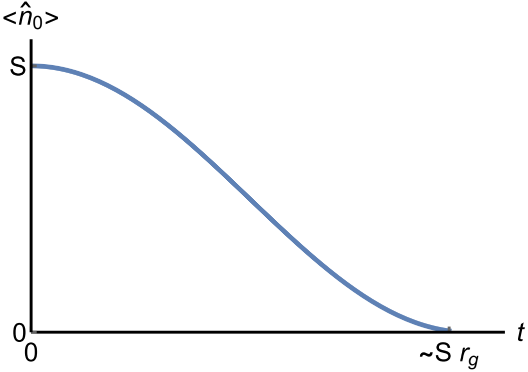

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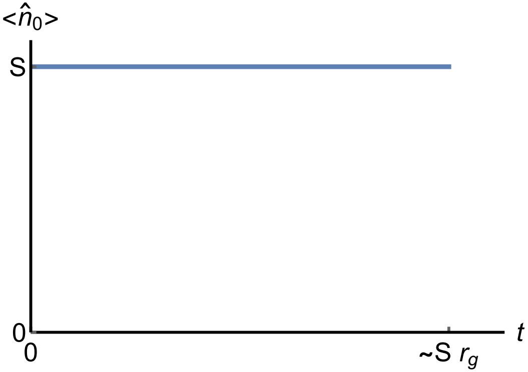

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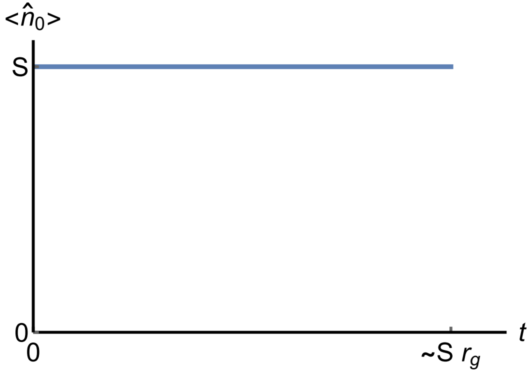

Memory burden:[15] entropy prevents evaporation

[15] G. Dvali, *A Microscopic Model of Holography: Survival by the Burden of Memory*, arXiv:1810.02336.

Full model[16]

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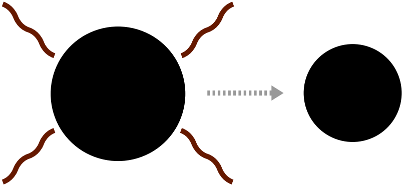

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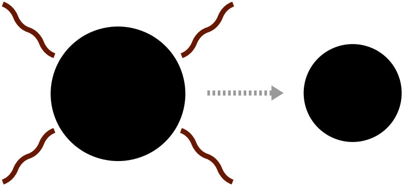

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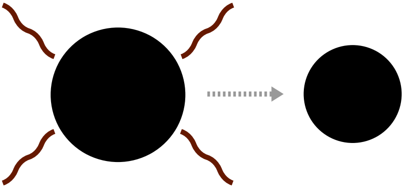

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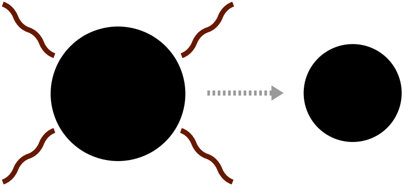

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back