Hybrid Quantum State in 2d Dilaton Gravity

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Joint work with Debajyoti Sarkar and Sergey Solodukhin

Based on 2112.03855 and 2212.13208

Introduction

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- We need to take quantum aspects into account: semi-classical GR, quantized field propagate on a classical background, but can influence its geometry by back-reaction.
- Why two dimensions ? Easier to study analytically solvable models, can help to gain some insight. If successful, one may try to generalize to four dimensions.

Classical CGHS model

$$\mathcal{S}_{CGHS} = \frac{1}{2\pi}\int_M \mathrm{d}^2x\,\sqrt{-g}\left\{e^{-2\phi}\left[R+4(\nabla\phi)^2+4\lambda^2\right]-\frac{1}{2}(\nabla f)^2\right\} \quad (1)$$

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$\to$ Classical black hole solution, now we need to include quantum matter.

Semi-classical RST model

$$\mathcal{S}_{RST} = \mathcal{S}_{CGHS} - \sum_{i=1}^{2} \frac{\kappa_i}{2\pi} \int \mathrm{d}^2x \sqrt{-g} \left\{ \frac{1}{2} (\nabla \psi_i)^2 + (\psi_i + \phi) R \right\} \quad (2)$$

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- $\psi_1, \psi_2 \rightarrow$ auxiliary fields to take into account the conformal anomaly, each in a different quantum state, $\rightarrow$ ”hybrid” quantum state.
- $\kappa_1, \kappa_2 \rightarrow$ central charges associated to ψ_1, ψ_2.

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- **Hartle-Hawking** state: $T^{(q)} \underset{\infty}{\longrightarrow}$ thermality
- **Boulware** state: $T^{(q)} \underset{\infty}{\longrightarrow} 0$

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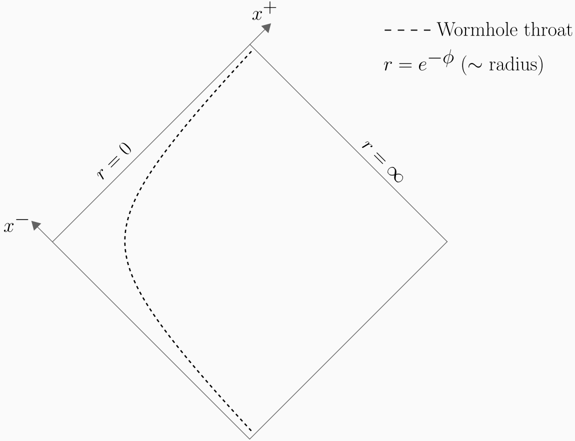
  $\rightarrow$ hybrid quantum state with $\kappa_1 > 0$ and $\kappa_2 < 0$,
  $\rightarrow$ we focus on the $\kappa = \kappa_1 + \kappa_2 < 0$ case.

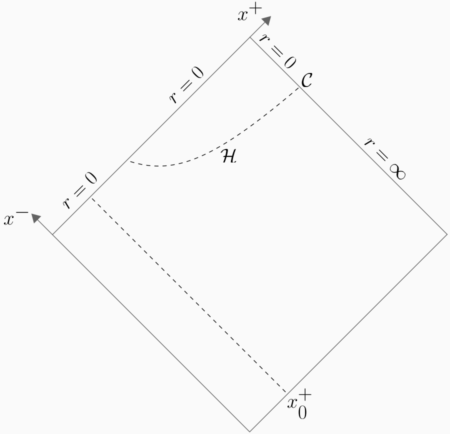
Static solution



Structure of a Damour-Solodukhin wormhole (no singularity, no horizon),

$\rightarrow$ black hole mimicker.

Dynamical solution



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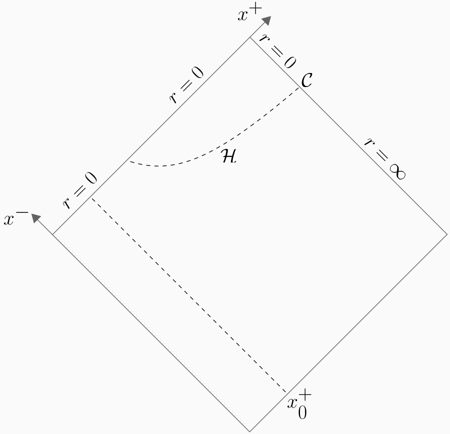

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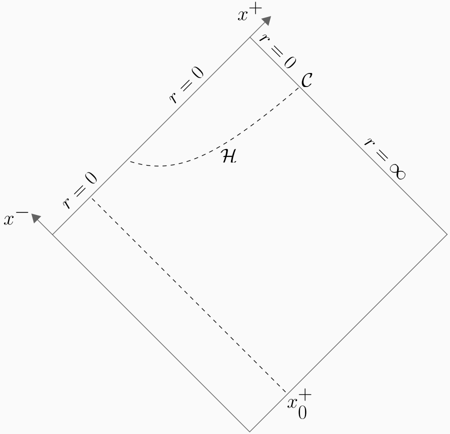

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- What about the radiation entropy ?

Page curve

Define radiation entropy at infinity by

$$\partial_- S = 2\pi(-x^-)T^{(q)}_{--} \tag{3}$$

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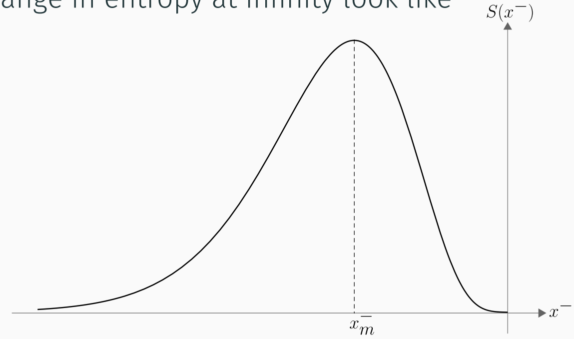
$\rightarrow$ The change in entropy at infinity look like



$\rightarrow$ Page Curve, sign of unitary evolution (Page, 2013).

Conclusion

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- They also help in recovering all the information of the system, as the Page curve shows.
- Is this reproducible in four dimensions ?

Thank you!

Full solutions

- Static solution:

$$\Omega = (\kappa_1+\kappa_2)\phi+e^{-2\phi} = -\lambda^2 x^+ x^- - \frac{\kappa_2}{2}\ln(-\lambda^2 x^+ x^-)+\frac{M}{\lambda} \quad (4)$$

- Dynamical solution:

$$\Omega = -\lambda^2 x^+ \left(x^- + \frac{m}{\lambda^3 x_0^+}\right) - \frac{\kappa_2}{2}\ln(-\lambda^2 x^+ x^-) + \frac{M+m}{\lambda} \quad (5)$$

where m is the energy of the shock wave.