Black Hole Information Paradox in JT Gravity

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Motivation

- Understand Quantum Gravity
- Understand the last stages of life of BHs
- Solve the BH Information Paradox

Plan of the talk

- BH Information Paradox
- JT Gravity in AdS
- Correlator beyond the leading order

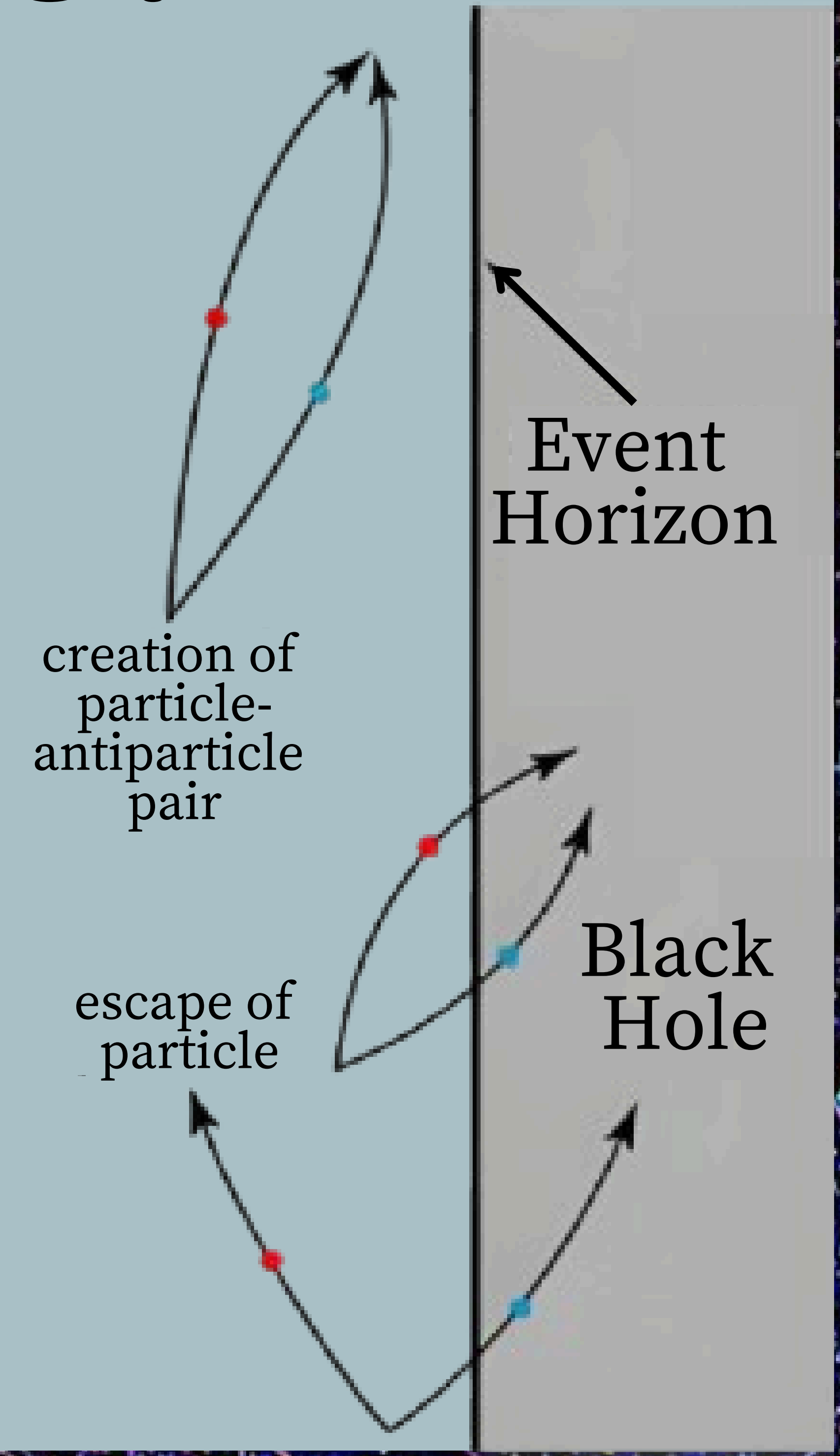
Information Paradox

- Tension between GR and QM
- Quantum evolution reversible => quantum information is conserved
- BH fully characterized by M, L, and Q (no-hair theorem) => looks the same regardless of what fell in

Information escape?

- Quantum Field in BH background
- BH radiates particles
- Two-point correlation functions $\sim e^{-t}$

-> information is lost



What Went Wrong?

- Assumed a classical BH background -> QFT in curved space time
- Did not sum over metrics -> no Quantum Gravity
- Did not even account for back-reaction

Quantum Gravity in 1+1d

- Simpler model to work with
- Einstein action is topological => no propagating gravitational degree of freedom
- Need to modify Einstein gravity

Scalar Gravity

- JT action: $-\frac{1}{16\pi G_N}\int_{\mathcal{M}}\sqrt{g}\,\phi\,(R-2\Lambda)-\frac{1}{8\pi G_N}\oint_{\partial\mathcal{M}}\sqrt{h}\phi(K-1)$
- $\frac{\delta S_{\mathrm{JT}}}{\delta\phi}=0$ -> Fixing the metric: $R-2\Lambda=0$
- $\frac{\delta S_{\mathrm{JT}}}{\delta g_{\mu\nu}}=0$ -> e.o.m of dilaton: $\nabla_\mu\nabla_\nu\phi-g_{\mu\nu}\nabla^2\phi+\Lambda\,g_{\mu\nu}\,\phi=0$

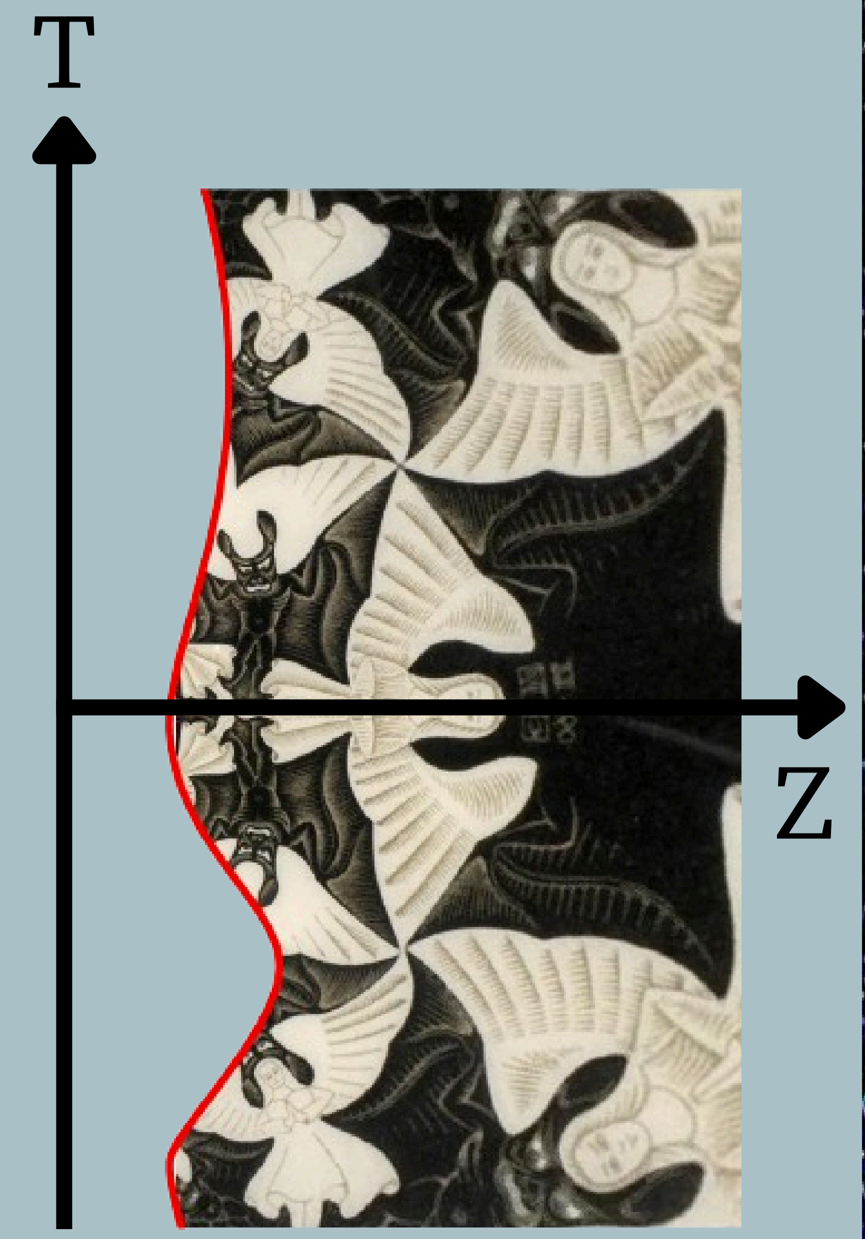
Einstein vs JT

	Einstein	JT
Eqs	$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = 8\pi G\, T_{\mu\nu}$	$\nabla_\mu \nabla_\nu \phi - g_{\mu\nu} \nabla^2 \phi + \Lambda\, g_{\mu\nu}\, \phi = 8\pi G_N\, T_{\mu\nu}$ $R - 2\Lambda = 0$
d.o.f.	$g_{\mu\nu}$	ϕ

Ads JT Gravity

- $\Lambda = -1$ -> Anti-de Sitter space
- Solution of dilaton e.o.m: $\phi(\mathrm{Z}) = \dfrac{a}{2\mathrm{Z}}$
- Regularize by cutting out the space time at $\mathrm{Z} = \varepsilon$
- Boundary curve parameterized by:

$$(T = F(t), \mathrm{Z} = \varepsilon F'(t))$$



Quantum Gravity

- Different cut outs of AdS => different manifolds with boundary
- Parameterize different boundaries by changing $F(t)$
- In AdS, fluctuation of $F(t)$ given by the Schwarzian action:

$$S = -\frac{1}{\lambda^2}\int dt\,\{F, t\}$$

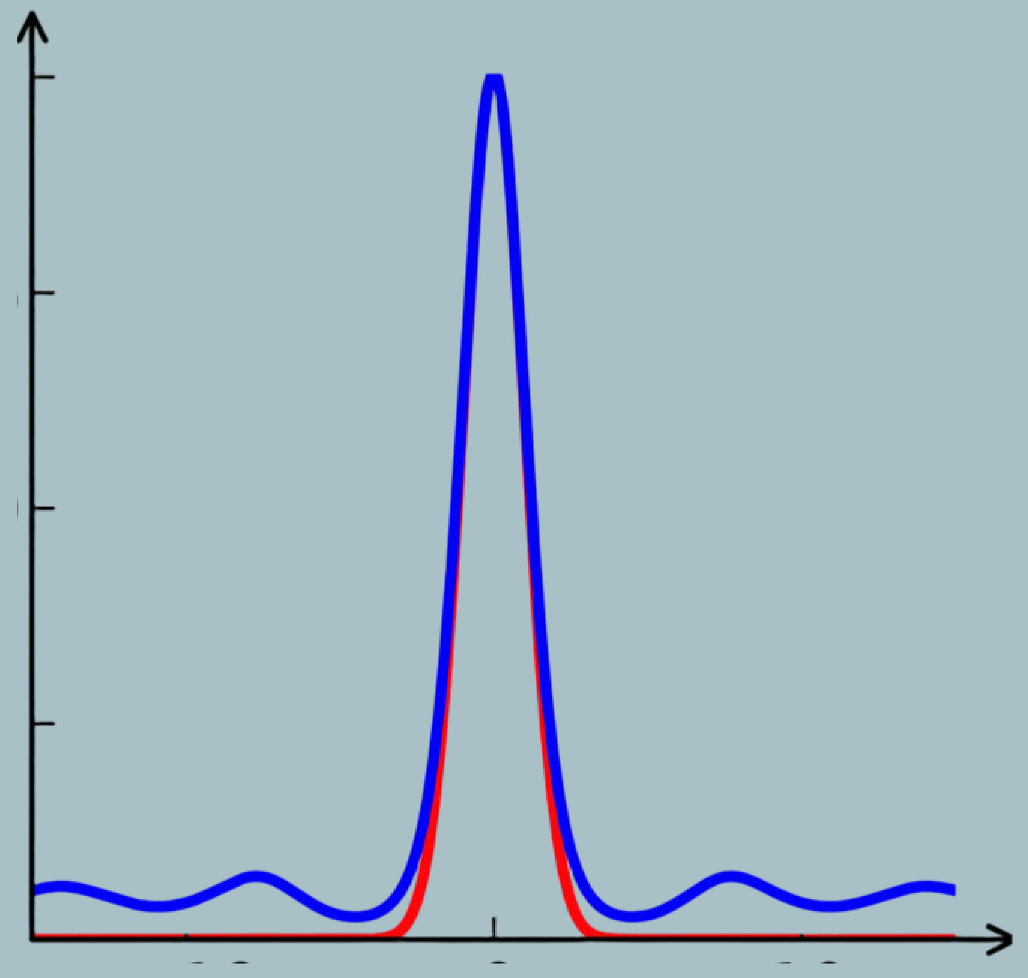
BH Correlator

- BH frame: $F(\tau) \equiv \tan \frac{\pi}{\beta} f(\tau)$
- Gravity Correlator => sum over manifolds
- Integrate AdS correlator over $f(\tau)$ using the Schwarzian action: $$\langle G_{\tau_0,\tau} \rangle_f = \int G_{\tau_0,\tau} e^{-\frac{1}{\lambda^2} S[f]} \mathcal{D} f$$
- Euclidean time τ

Laplace's Method

- Integrals of the type $I(x) = \int_a^b f(t)e^{x\phi(t)}\,dt$
- As $x \to \infty$, main contribution comes from global maximum t^*
- Asymptotic expansion about maximum:

$$I(x) \sim f(t^*)e^{x\phi(t^*)}\sqrt{\frac{2\pi}{-x\phi''(t^*)}}\left[1 + \frac{C_1}{x} + \frac{C_2}{x^2} + \mathcal{O}(x^{-3})\right]$$



Correlator Asymptotics

- Large x => small λ
- Expand action around classical solution: $f(\tau) = \tau + \lambda\gamma(\tau)$
- For large t, we get:

$$\langle G_{t_0,t}\rangle_\gamma \sim e^{\frac{\pi}{\lambda}} \sqrt{\frac{1}{\det S''[\phi_0]}} \left(f_0(z)e^{-t} + f_2(z)t^2e^{-t}\lambda^2 + f_4(z)t^2e^{2t}\lambda^4 + \mathcal{O}(\lambda^6)\right)$$

Backreaction?

- Partition function is one loop exact -> complete understanding of the vacuum
- Correlator loops vanish at order $n = 2$ only
- Is backreaction important at orders $n \geq 4$?

Outlook

- Can information be extracted from the divergent part of the asymptotic series? -> Resurgence theory
- Other saddles?
- Backreaction?

Thanks for your attention