

Title: Determinism and quantum theory inside black holes

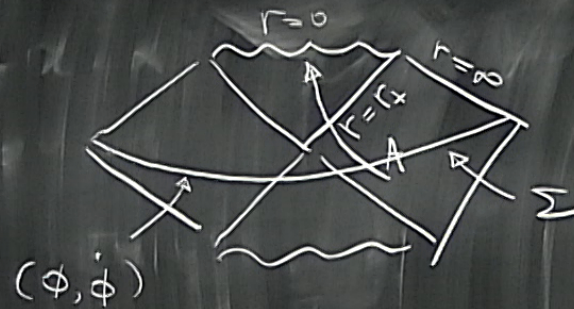
Speakers: Stefan Hollands

Collection: Simplicity III

Date: September 12, 2019 - 9:45 AM

URL: <http://pirsa.org/19090088>

Determinism & QT inside BH's



$$ds^2 = -f(r) dt^2 + \frac{dr^2}{f(r)} + r^2 d\Omega^2$$

$$f = 1 - \frac{2M}{r}$$

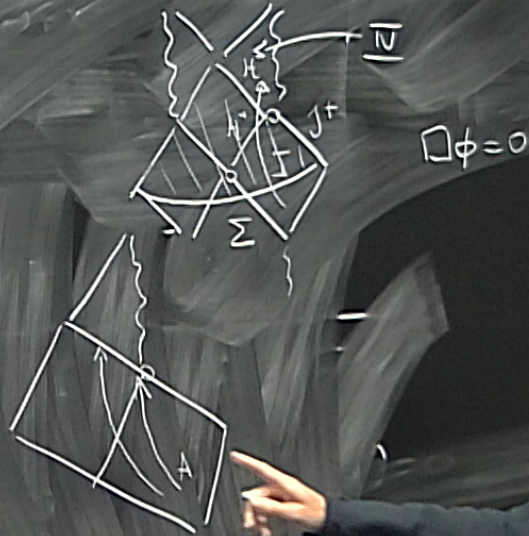
$$f(r_+) = 0$$

$$\square \phi = 0$$

More realistic: Kerr or RN

$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2}$$

Breakdown of Det'sm.



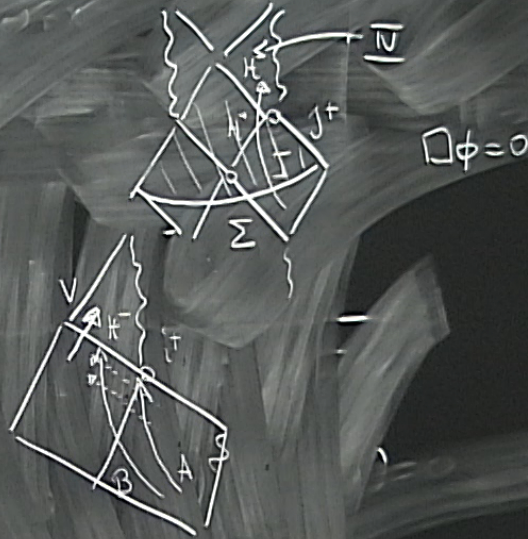
More realistic ! Kerr or RN

$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2}$$

Breakdown of Det'sm

$$\partial_v \phi \rightarrow \infty$$

$$T_{VV} = (\partial_v \phi)^2$$

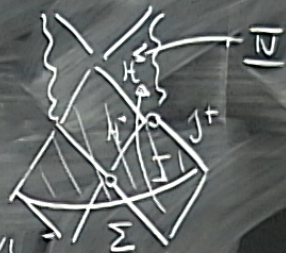


$$\square \phi = 0$$

More realistic ! Kerr or RN

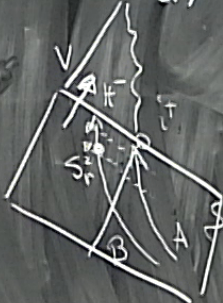
$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2}$$

Breakdown of Del'sm



$$\square\phi = 0$$

$$\partial\phi \rightarrow \infty$$



Israel-Poisson '89

$$m(S_r^2) \sim \frac{1}{(r-r_+)^n} \rightarrow \infty$$

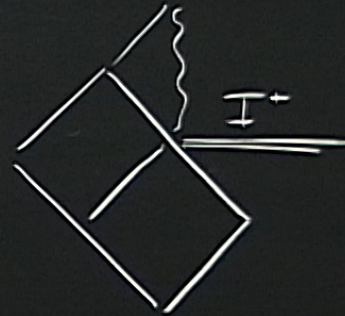
$$\frac{Q(r)}{m(r)} \rightarrow 0$$

$$T_{VV} = (\partial_V \phi)^2$$

SCC

RN dS

$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda r^2}{3}$$



RN dS

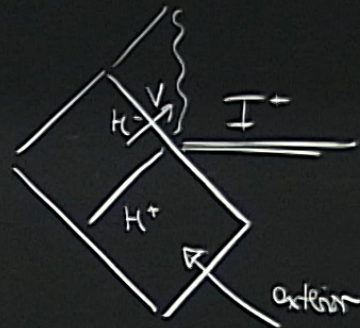
$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda r^2}{3}$$

Competing effect:

- blue shift
- red shift from Λ

α = spectral gap

κ_- = surface gravity H^-



$$\partial_V \phi \sim \frac{1}{V^{1-\alpha/\kappa_-}}$$

RN dS

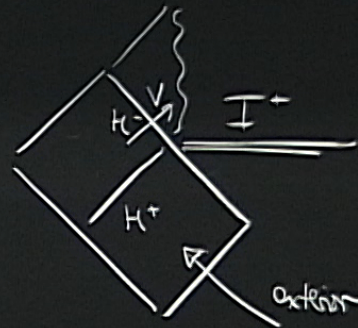
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Competing effect:

- blue shift
- red shift from Λ

α = spectral gap

κ = surface gravity $\hbar$



$$\partial_V \phi \sim \frac{1}{V^{1-\alpha/\kappa}} \quad \left(\begin{array}{c} \text{Hintz-Vasy} \\ 15 \end{array} \right)$$

RN dS

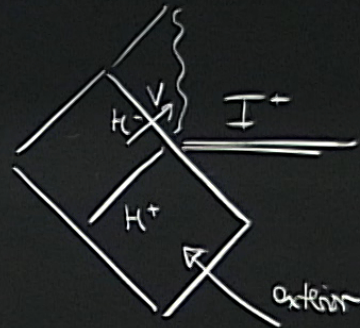
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Competing effect:

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$$\partial_V \phi \sim \frac{1}{V^{1-\alpha/\kappa}}$$

(Hintz-Vasy)
15

$\alpha \rightarrow$ numerics

RN dS

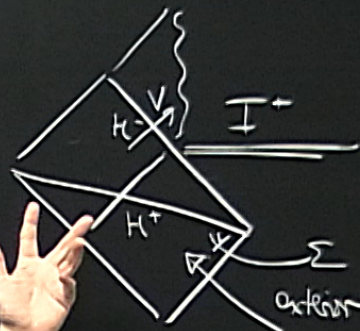
$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda r^2}{3}$$

Compassing effect:

- blue shift
- red shift from Λ

$$\alpha = \text{sp}$$

$$K = \text{sur}$$



$$d\phi \sim \frac{1}{V^{1-\alpha/K_-}} \quad \left(\begin{array}{l} \text{Hintz-Vasy} \\ '15 \end{array} \right)$$

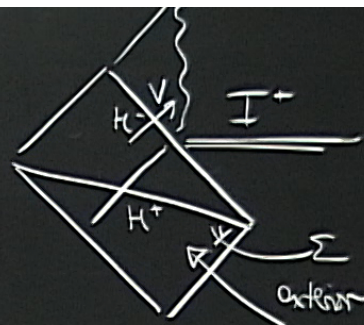
$$\alpha \rightarrow \text{normals} \quad \left(\begin{array}{l} \text{Cardoso et al.} \\ '17 \end{array} \right)$$

Could quantum effects change structure?

- Try to consider quantum

$$\square\phi = 0 \text{ on RN dS}$$

$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda r^2}{3}$$



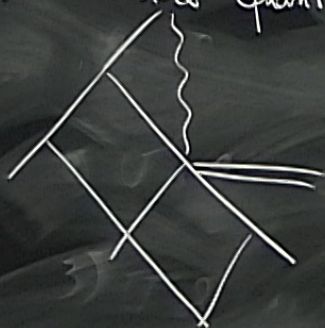
Compensating effect:
• blue shift

$(\phi, \dot{\phi})$ on Σ

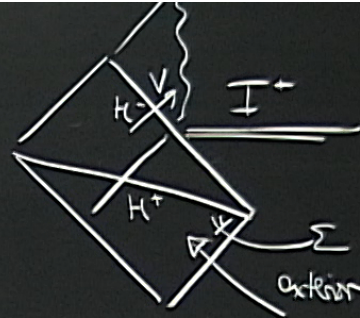
$(H_{int} - V_{ext})$

Could quantum effects change this picture?

• Try to consider quantized field $\square\phi = 0$ on RN dS



$$f(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda r^2}{3}$$



Compassing effect:
• blue shift

$(\phi, \dot{\phi})$ on Σ

$(H_+ + H_-)$

Could quantum effects change this picture?

• Try to consider quantized field $\square\phi = 0$ on RN dS



Could quantum effects change this picture?

• Try to consider quantized field $\square\phi=0$ on $RNdS$



we need to prescribe "nice" state Ψ

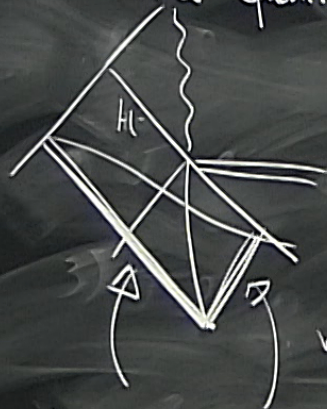
• Look at $\langle T_{\mu\nu} \rangle_{\Psi}$ near H^- (Wald, Zehner)

Claim: $\sim V^{-2}$ rather than $(\sim V^{-2+2\frac{\alpha}{k-}})$

RN dS

Could quantum effects change this picture?

• Try to consider quantized field $\Delta\phi=0$ on RN dS



Quantum theory saves
determinism inside RN dS BH

we need to prescribe "nice" state Ψ

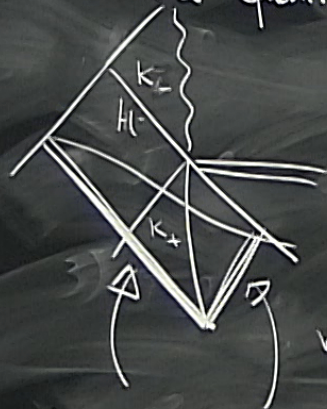
• Look at $\langle T_{\mu\nu} \rangle_{\Psi}$ near H^- (Wald, Zehner)

Claim: $\sim V^{-2}$ rather than $(\sim V^{-2+2\frac{d}{d-2}})$

RN dS

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Quantum theory saves
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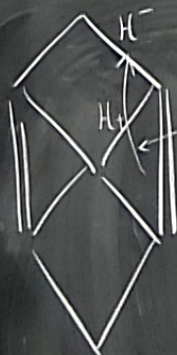
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Claim: $\sim V^{-2}$ rather than $(\sim V^{-2+2\frac{\alpha}{k_-}})$

$$+ r^2 d\Omega^2$$

Dias, Reall, Santos '19

BTZ black hole

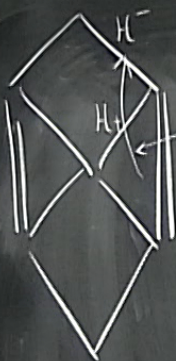


$\Psi = HH$ state

Dias, Reall, Santos '19

BTZ black hole

Λ, L



$\Psi = HHH$ state

"nice initial states" $\hat{=}$ Hadamard states

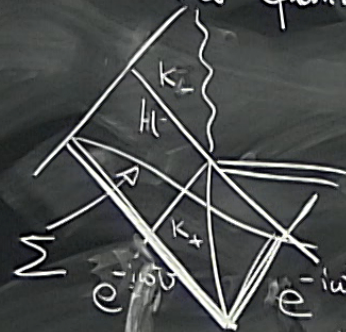
$\Leftrightarrow$ near Σ correlation fcts
 $\langle \phi(x_1) \dots \phi(x_n) \rangle_{\Psi}$ have OPE

$\Leftrightarrow$ near Σ any (renormalized) composite
 field $\langle (\nabla \phi)^2 \rangle_{\Psi} < \infty$

RN dS

Could quantum effects change this picture?

• Try to consider quantized field $\square\phi=0$ on RN dS



Quantum theory saves
determinism inside RN dS BH

→ Unruh state
we need to prescribe "nice" state Ψ

• Look at $\langle T_{VV} \rangle_{\Psi}$ near H^- (Wald, Zehner)

Claim: $\sim V^{-2}$ rather than $(\sim V^{-2+2\frac{\alpha}{k_-}})$