

Title: AdS/CFT Lecture (230405)

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Collection: AdS/CFT (2022/2023)

Date: April 05, 2023 - 9:00 AM

URL: <https://pirsa.org/23040031>

YESTERDAY: HAWKING RADIATION (HAWKING 1974)

QUANTUM MECHANICALLY BHs RADIATE AWAY
PARTICLES AS BLACK BODY WITH

$$T = \frac{\mathcal{R}}{2\pi}$$

← SURFACE GRAVITY
("GRAV ACCELERATION")
ON THE HORIZON

BHs SLOWLY EVAPORATE ($T \sim \frac{1}{M}$)

REMARK: UNRUH RADIATION

$$T = \frac{a}{2\pi}$$

ACCELERATION OF THE
OBSERVER.

(SEE TUTORIAL)

REMARK 2: FOR SCHWARZSCHILD

$$S \propto \Lambda^2 \propto M^2 \propto \frac{1}{T^2}$$

$$C = T \frac{dS}{dT} = -\frac{1}{8\pi T^2} < 0$$

SPECIFIC HEAT
IS NEGATIVE !

$$T = \frac{\omega}{2\pi}$$

ACCELERATION OF THE
OBSERVER,

(SEE TUTORIAL)

REMARK 2: FOR SCHWARZSCHILD

$$S \propto \Lambda^2 \propto M^2 \propto \frac{1}{T^2}$$

$$C = T \frac{dS}{dT} = -\frac{1}{8\pi T^2} < 0$$

SPECIFIC HEAT

IS NEGATIVE !

SCHW IS TO UNSTABLE !

• INFORMATION LOSS:

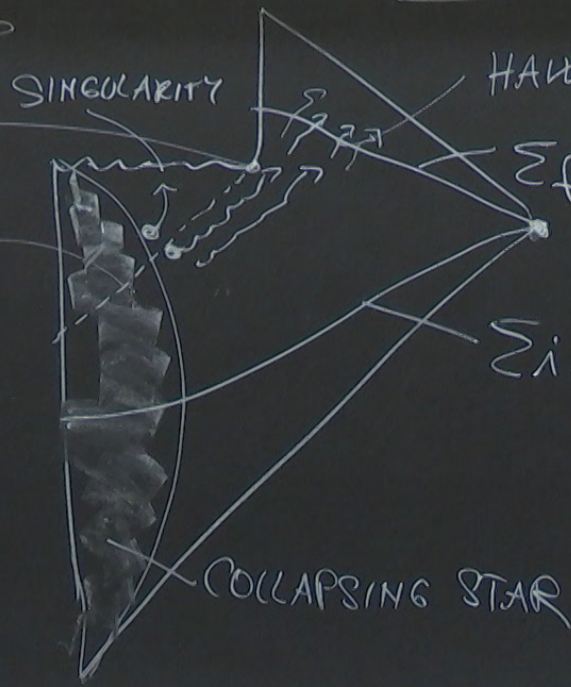
CLASSICALLY: BH JUST GETS BIGGER
AS IT ABSORBS STUFF
(INFORMATION ABOUT WHAT IT
ABSORBED IS LOST)

QM: HAWKING RADIATION IS THERMAL
($T \sim \frac{1}{M}$)... NO INFO IS REALLY
GETTING OUT!

SHOW IS TO UNSTABLE

ASSUME THAT BH EVENTUALLY COMPLETELY EVAPORATES
HAWKING - 1976

BH EVAPORATED
BLACK HOLE
FORMATION PARADOX
COLLAPSE OF
UNITARY EVOLUTION
OF QM.



HAWKING RADIATION
Σ_f ... MIXED STATE (ρ)
Σ_i ... PURE STATE (|ψ⟩)

ACCORDING TO AdS/CFT: "EVERYTHING THAT HAPPENS
IN THE SPACETIME IS EXACTLY EQUIVALENT
TO WHAT HAPPENS TO CFT ON
THE BOUNDARY.

=> INFO PARADOX MUST BE WRONG
& HAVE TO RESTORE UNITARITY

=> INFORMATION HAS TO START COMING
OUT OF BH :

• BLACK HOLE ENTROPY

$$S = \frac{A}{4} \frac{c^3 k_B}{h G M}$$

STAT. PHYS

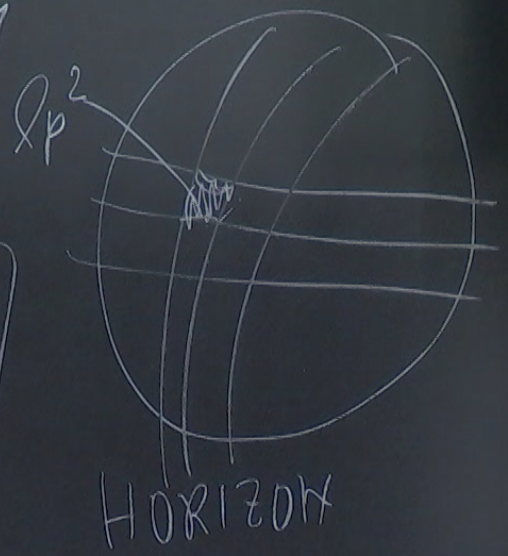
GRAVITY

RELAT.

QM

$$l_p = \sqrt{\frac{G h \hbar}{c^3}}$$

$$S = \frac{k_B}{4} \frac{A}{l_p^2}$$



• FORMULA IS HOLOGRAPHIC (GOES LIKE
THE AREA RATHER THAN VOLUME)

IF THIS ENTROPY IS TO BE
ASSOCIATED WITH ENTROPY OF
NORMAL SYSTEM, IT HAS TO BE
LOWER DIMENSIONAL.

LIKE

- ALSO MOTIVATED BEKENSTEIN'S BOUND

$$S_{\text{ANY SYSTEM}} \leq \frac{A}{4}$$

AREA OF THE
SURROUNDING REGION,
(SEE TUTORIAL FOR
INDICATION)

- GENERALIZED 2ND LAW

$$dS_{\text{TOT}} = dS_{\text{BH}} + dS_{\text{OUTSIDE}} \geq 0$$

- ENTROPY FORMULA CAN BE DERIVED FROM CALCULATING PARTITION FUNCTION

$$Z = \int Dg e^{-SE[g]} \approx e^{-SE[g_c]}$$

g FIXED $\gamma \sim T + \beta$

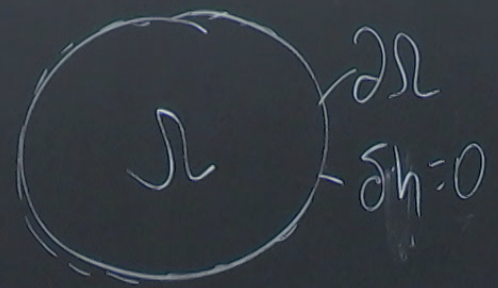
CLASSICAL

FREE ENERGY

$$F = -\frac{1}{\beta} \log Z = \frac{SE}{\beta}$$

[gc]
↑
CLASSICAL

$$S_E = \int_{\Omega} \frac{d^4x R \sqrt{g}}{16\pi G \hbar} + \int \frac{d^3x \epsilon \sqrt{h} K}{8\pi G \hbar} + \text{COUNTER TERMS}$$



EXTR. CURV.
YORK

TUNE
THE VALUE OF
ACTION

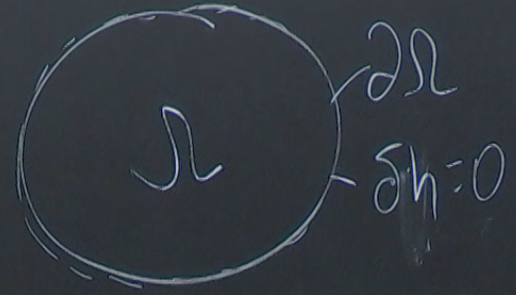
$$\frac{S_E}{\beta}, \quad S = -\frac{\partial F}{\partial T} \stackrel{\text{SCHW}}{=} \frac{A}{4}$$

A CAN BE DERIVED
 USING PARTITION FUNCTION

$$g \ell^{-3} e^{-\beta E} \approx \ell^{-3} e^{-\beta E_{cl}} \quad \text{CLASSICAL}$$

$\underbrace{\gamma \mu + \beta}_{\text{D}}$

$$S_E = \int_{\Omega} \frac{d^4 x R T g}{16\pi G \hbar}$$



RG7

$$F = -\frac{1}{\beta} \log Z = \frac{S_E}{\beta}, \quad S = -\frac{\partial F}{\partial T} \stackrel{\text{SCHW}}{=} \frac{A}{4}$$

$$= E - TS = M - TS$$

AdS BHS: SOLUTIONS OF

$$G_{\mu\nu} + \overset{\uparrow}{\Lambda} g_{\mu\nu} = 8\pi G T_{\mu\nu}$$

COSMOL. CONSTANT

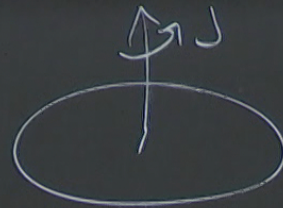
$$\Lambda = -\frac{3}{l^2} < 0$$

l AdS RADIUS

EX: SCHW-AdS

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

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



EX: SCHW-AdS

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

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

