KILLING HORIZONS KILL HORIZON DEGREES OF FREEDOM

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BLACK HOLE THERMODYNAMICS

Since Bekenstein, Hawking 1973-75

$$\delta M = \frac{1}{8\pi} \kappa \, \delta A + \Omega \, \delta J + \ldots$$

$$T_{BH} = \frac{1}{2\pi} \kappa \qquad\qquad S_{BH} = \frac{1}{4} A$$

- Meanwhile, many different ways to derive these results are known.
- Still, there is a (almost) complete lack of understanding of the underlying micro-physics.

Why are the laws of BH thermodynamics universal?

NEAR HORIZON CONFORMAL SYMMETRY

S. Carlip gr-qc/0203001, ...

- Near horizon region with streched horizon as boundary described by conformal field theory.
- streched horizon implemented as constraints
  → change of the constraint algebra
- Virasoro algebra acquires a central charge
  → breaking of conformal symmetry
- Use Cardy formula to count the number of states

$$\rho(\Delta) \sim \exp\left[2\pi\sqrt{\frac{c\cdot\Delta}{6}}\right] \quad \text{for eigenvalue } \Delta.$$

BH entropy due to Goldstone-like states located on (or near) the horizon.

Problem

In which sense is a streched horizon a special boundary?

Sharp horizon conditions appear to be the only satisfactory solution.

SHARP HORIZON CONDITIONS

2D dilaton gravity

$$S = -\int_{M} \left[X^+ (d-\omega)\wedge e^- + X^- (d-\omega)\wedge e^+ + X d\omega + e^+ \wedge e^- \mathcal{V} \right] +$$

$$+ \int_{\partial M} \underbrace{\left[X\omega + \frac{1}{2} X\, d\ln\left|\frac{e_\parallel^+}{e_\parallel^-}\right| \right]}_{X\ K}$$

Gibbons-Hawking

Variational principle

$$\delta X\ K + X^+ \delta e_\parallel^- + X^- \delta e_\parallel^+ = 0$$

- generic boundary

$$\delta X = 0 \qquad \delta e_\parallel^- = 0 \qquad \delta e_\parallel^+ = 0$$

- horizon

$X^+ X^- \propto$ Killing norm $\rightarrow$ $X^- = 0$ $(X^+ \neq 0)$ defines boundary to be a horizon

$$\delta X = 0 \qquad X^- = 0 \qquad \delta e_\parallel^- = 0$$

$\hookrightarrow$ $e_\parallel^- = 0$ consistency with EOM

REDUCED PHASE SPACE

Boundary conditions are implemented as constraints.

Bulk: 6 first class constraints

Boundary: Boundary conditions turn (some of) the constraints into second class.

generic boundary:

- No first class constraints left at the boundary, but
- all boundary conditions analytic continuations of bulk gauge fixing functions.
- The bulk phase space is empty, there remains a two-dimensional boundary phase space.

Interpretation:

$$C = X^+ X^- \exp(Q) + w(X)$$

e^Q = "conformal frame"

$w(X)$ = "conf. invariant potential"

$dC = 0$ constant of motion, Casimir function, ADM mass

C and its conjugate (proper time) are not fixed by the boundary conditions.

→ Fluctuate off-shell.

(K.V. Kuchař, gr-qc/9403003)

~~horizon:~~

- There remain more first class constraints at the boundary, in particular local Lorentz and $\xi_{\parallel}$.
- Not all boundary constraints are obsolete due to $X^+ X^- = 0$

$\rightarrow$ C is fixed at the horizon.

- "proper time" fixed as well by local Lorentz invariance.
- The boundary phase space is empty.

Presence of a horizon kills the boundary degrees of freedom.

What is BH entropy?

BH entropy is caused by the transmutation of physical dofs into gauge dofs on the horizon. In this way information is no longer accessible for an observer ('t Hooft gr-qc/0401027)

"PHYSICS-TO-GAUGE CONVERSION AT BLACK HOLE HORIZONS"

What is the meaning of near horizon CFT?

This technique can still be correct. The symmetry breaking concept mimics the physics-to-gauge conversion. However, taken for its own it reverses the logic.

The Goldstone modes mimic physical modes, which were there in the first place, but are converted to gauge dofs on the horizon.