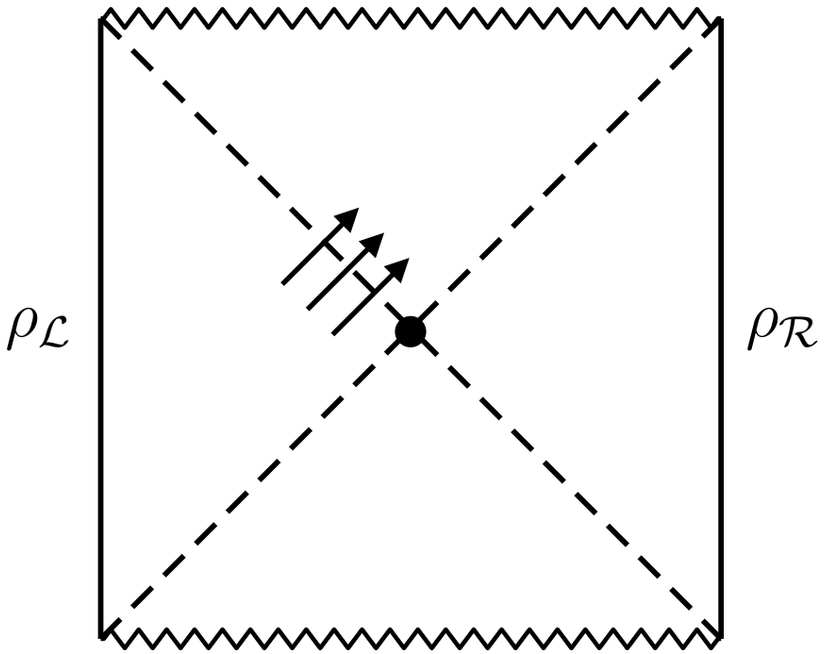
Deriving the First Law without Entanglement

William Kelly



$$\delta S_W = \beta\, \delta E$$

$$\delta S_W = \beta\, \delta E = \delta S_{RT}$$

$$\rho_{\mathcal{L}} = Z^{-1} \exp(-\beta E)$$

Blanco et al. (2013)
Lashkari et al. (2013)
Faulkner et al. (2013)

First law for pure states:
What does it mean?
How do we derive it?

Refs: 1309.3610 - WK and Aron Wall
1408.3705 - WK

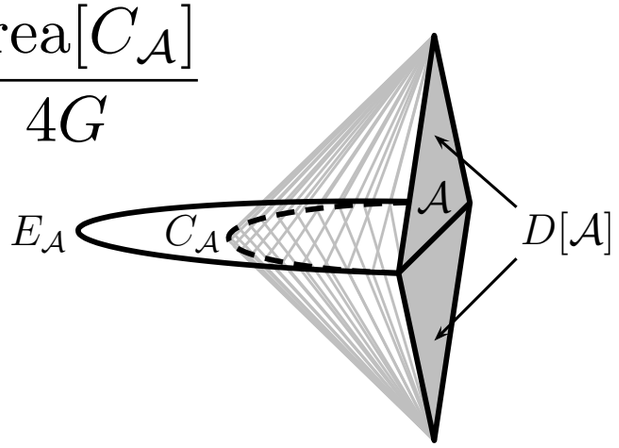
Results

$$\mathcal{S}^{(1)}(\rho_{\mathcal{A}}) = \underset{\tau_{\mathcal{A}} \in T_{\mathcal{A}}}{\text{lub}} S(\tau_{\mathcal{A}})$$

$$\text{Tr}[\mathcal{O}(x)\tau_{\mathcal{A}}] = \text{Tr}[\mathcal{O}(x)\rho_{\mathcal{A}}]$$

$$x \in D[\mathcal{A}]$$

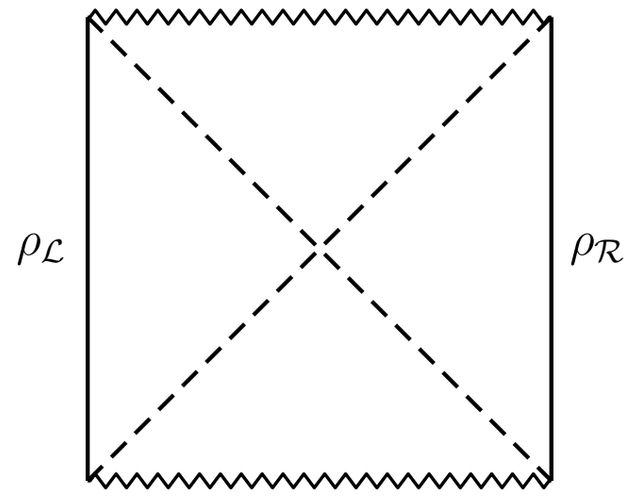
$$\chi_{\mathcal{A}} := \frac{\text{Area}[C_{\mathcal{A}}]}{4G}$$



(maximally entangled state)

$$\delta S_W = \delta \mathcal{S}^{(1)} = \delta S$$

AdS-Schwarzschild

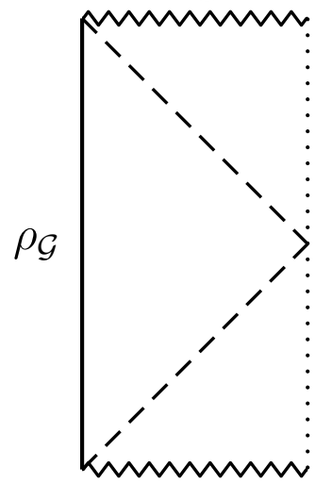


(pure state)

Maldacena (2003)

$$\delta S_W = \delta \mathcal{S}^{(1)} \neq \delta S$$

RP_n geon



Refs: 1309.3610 - WK and Aron Wall
1408.3705 - WK