It from bit.

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Gravity as an entropic force. (E. Verlinde 2010)

- \( T \Delta S = \Delta x F \).
  Main postulates;

\[
\Delta S = 2\pi k_B \\
\Delta x = \frac{\hbar}{mc}
\]

\[
\Delta S = -\frac{k_B N}{2c^2} \Delta \Phi
\]

The Newton force law follows when one uses equipartition theorem.

\[
\frac{1}{2} Nk_B T = Mc^2 \quad \Rightarrow \quad F = ma.
\]
First law on the boundary CFT $\implies$ First law on the bulk.

$\delta S_B = \delta E_B$

Following Wald formalism,

$\delta E_B^{\text{grav}} = \int_B \chi$

$\delta S_B^{\text{grav}} = \int_{\bar{B}} \chi$

$\delta E_B^{\text{grav}} = \delta S_B^{\text{grav}} \implies \int_\Sigma d\chi = 0 \implies \delta E_{ab}^{g} = 0$
Entanglement entropy of a hole. (de Boer et al. 2014)

- Entanglement entropy of arbitrary bulk regions.

\[ S_{\text{residual}} = \frac{1}{2} \int d\theta \frac{dS(\alpha)}{d\alpha} \]

Entropy = Area!

\[ S_{\text{residual}} = \frac{A}{4G_N} \]
First law for residual entropy in $AdS_3$. (work in progress)

- Apply the first law for each region on the boundary which together constructs the region in the bulk.

\[
\frac{1}{2} \int_0^{2\pi} d\theta \frac{d}{d\alpha} \delta S_\alpha = \frac{1}{2} \int_0^{2\pi} d\theta \frac{d}{d\alpha} \delta \langle H_A \rangle \\
H_A = \int_A d\Sigma \xi^\mu T_{\mu\nu}
\]

This change is identified with the change in the area due to a conical defect. Comparing two geometries by keeping proper length from the origin fixed, we found.

\[
\delta S_{\text{residual}} = \frac{2\pi R_{\text{hole}} m_{\text{defect}}}{4G_N} = \frac{A}{4G_N} \delta \Phi
\]
Summary

- $\delta S_{EE} \sim A \delta \Phi$
- Matter-spacetime entanglement?
- How can we derive full Einstein equations via AdS/CFT?