Thermal CFT dual

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Consider now the limit of very large black holes, $r_H \gg L$, or equivalently work with the planar black branes $k=0$

Then

$$T = \frac{d}{4\pi}\frac{r_+}{L^2}, \quad \text{ie } r_+ = \frac{4\pi}{d} L^2 T \qquad \mu = \frac{r_+^d}{L^2}$$

$$E = \frac{d-1}{16\pi G L^2}\Omega_{d-1} r_+^d = \frac{d-1}{16\pi}\left(\frac{4\pi}{d}\right)^d \frac{L^{d-1}}{G} V_{d-1} T^d$$

$$S = \frac{1}{4}\left(\frac{4\pi}{d}\right)^{d-1} \frac{L^{d-1}}{G} V_{d-1} T^{d-1}$$

For a CFT_d with central charge c (eg measured through anomaly, or free energy in S^{d-1} or other method; for YM, $c \sim N^2$ at large N)

$$S \propto c\, V_{d-1} T^{d-1} \quad \text{(with numerical factor in front)}$$

so we find the same behavior, with

$$c \sim \frac{L^{d-1}}{G} = \left(\frac{L}{L_{Planck}}\right)^{d-1}$$

and for a semiclassical geometry $L \gg L_{Planck}$

so $c \gg 1$

$$\boxed{\text{(Large) black holes in } AdS_{d+1} \text{ are thermal phases of the dual } CFT_d}$$

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It's a good thing that large bhs have +ve specific heat! In CFT, this follows from unitarity

This correspondence helps make a lot of sense out of black hole thermodynamics.

Eg, a thermodynamic limit is possible even if the system has finite size because the microscopic theory has a large number of dof's at each point (large-N limit)

One can even consider hydrodynamics: long-wavelength fluctuations of the thermal state.