Phases of Flat Space Higher Spin Gravity

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JHEP 1501 (2015) 152 `[arXiv:1411.3728 [hep-th]]`, MG, D Grumiller, M Riegler, J Rosseel

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Outline

Motivation

- Holography in flat space
- Higher spins interesting as possible unbroken/Hagedorn phase of String Theory
- Interesting to evade No-Go theorems
- Phase structure of 3D HS gravity in flat space

Higher Spins in $D > 3$

- Higher spin particles with long-range interactions in $D > 3$ forbidden by soft-theorems, Coleman-Mandula, Weinberg-Witten
  — evade through long-range cutoff implemented by cosmological constant (dS or AdS) rather than mass
- No-Go theorems on forms of interaction vertices involving higher spins
  — evade through non-minimal interactions and infinite tower of spins

Higher Spins in AdS_3

- Generalization of first order formulation of gravity

$$S = \frac{k}{4\pi}\int\left\langle A\wedge dA + \frac{2}{3}A\wedge A\wedge A\right\rangle$$

  where $\langle\cdot,\cdot\rangle$ is a non-degenerate bilinear form.
- For pure gravity, gauge group $G = \mathrm{sl}(2)\oplus\mathrm{sl}(2)$
- $G = \mathrm{sl}(N)\oplus\mathrm{sl}(N)$ gives spins $2,\ldots,N$
- $G = \mathrm{hs}(\lambda)\oplus\mathrm{hs}(\lambda)$ gives infinite tower of spins, direct analog of higher spin theories in $D>3$
- Natural $\mathbb{Z}_2$ grading on algebra, (zu-)Vielbein and Spin connection given by even and odd parts of A

Holography in 3D flat space

- The large ℓ limit of AdS is flat space
- Taking this limit yields a contraction of the gauge group

$$\mathrm{sl}(2) \oplus \mathrm{sl}(2) \to \mathrm{isl}(2)$$
$$\mathrm{sl}(N) \oplus \mathrm{sl}(N) \to \mathrm{isl}(N)$$

- $\mathrm{isl}(2)$ theory is pure gravity in flat space
- $\mathrm{isl}(N)$ theory is gravity in flat space coupled to higher spins $3, \ldots, N$

Flat Space Cosmologies

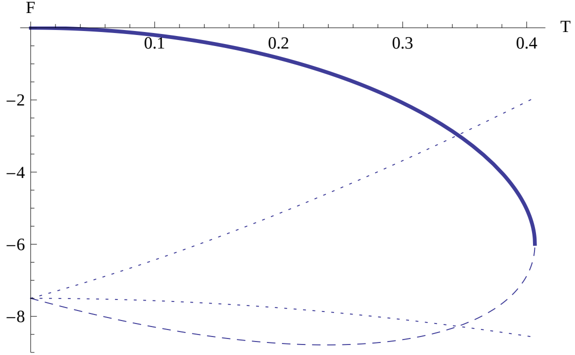
- $\ell \to \infty$ limit of BTZ black hole
- Outer horizon goes to infinity
- Inner horizon becomes cosmological horizon
- Have finite energy, entropy
- For pure gravity, described by 2 parameters (M, J) or (T, Ω)
- For each additional spin, 2 additional parameters

Higher Spin Flat Space Cosmologies

- 4 branches of solutions[1]
- Branch 1 connects continuously to the pure gravity solution in appropriate limit
- First order phase transitions between branches 1 and 2
- Also Hawking-Page phase transition to hot flat space

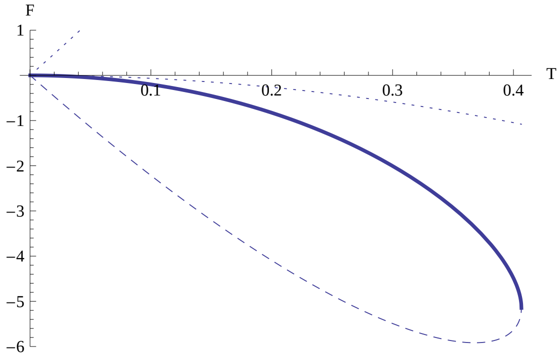
[1] Assuming simplest solution of holonomy conditions

$0 < \frac{\Omega\Omega_V}{\Omega_U} < \frac{3}{2}$



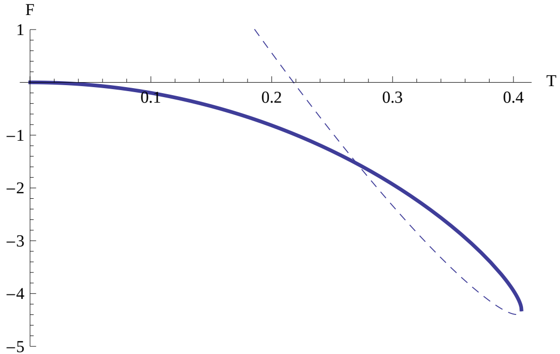
branch 1 is thermodynamically unstable for all temperatures

$\frac{\Omega\Omega_V}{\Omega_U} = \frac{3}{2}$



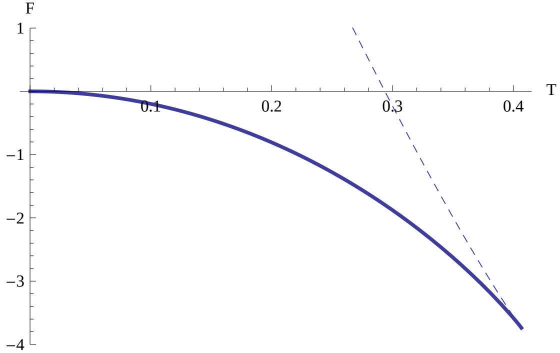
branches 1 and 2 degenerate at $T = 0$ and branch 1 is thermodynamically unstable at all $T > 0$

$\frac{3}{2} < \frac{\Omega\Omega_V}{\Omega_U} < 2$



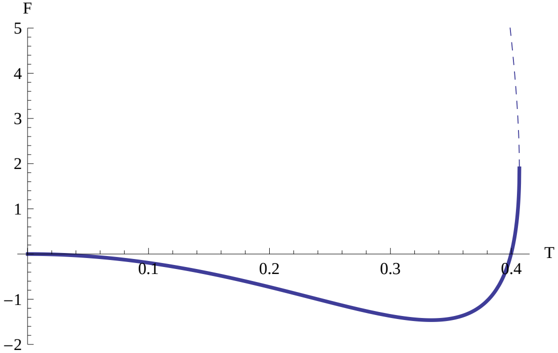
branches 1 and 2 degenerate at some $T_c > 0$. Below T_c branch 1 is stable (up to Hawking-Page), above T_c branch 1 is unstable

$\frac{\Omega\Omega_V}{\Omega_U} = 2$



branches 1 and 2 degenerate at the maximal temperature (when the discriminant vanishes), branch 1 is stable below the maximal temperature (up to Hawking-Page)

$\frac{\Omega\Omega_V}{\Omega_U} > 2$



branches 1 and 2 degenerate at the maximal temperature (when the discriminant vanishes), branch 1 is stable below the maximal temperature (up to Hawking-Page)

Future Work

- Understanding possible 0^{th} order phase transitions
- Understanding or eliminating $2\pi\mathbb{N}$ conical surplus solutions

Thank You