Beyond Minisuperspace in Higher Spin de Sitter Cosmology

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(work with Anninos, Denef, Konstantinidis)

dS/CFT

dS/CFT proposal [Maldacena, Strominger, Witten]:

$$\boxed{\Psi_{HH} = Z_{CFT}}$$

Weak form:

$$\log \Psi_{HH}[\phi(\vec{x}), \eta_c] = \sum_{n=1}^{\infty} \frac{1}{n!} \left(\int d^3x_1 \cdots \int d^3x_n \phi(\vec{x}_1) \cdots \phi(\vec{x}_n) \langle \mathcal{O}(\vec{x}_1) \cdots \mathcal{O}(\vec{x}_n) \rangle_{CFT} \right)$$

Strong form: Z_{CFT} non-perturbatively defines Ψ_{HH} for finite sources encoding geometry, topology, etc.

$Sp(N)$ theory

Minimal parity-invariant Type A Vasiliev theory with Neumann boundary conditions in bulk dual to free $Sp(N)$ theory of anticommuting scalars [Anninos, Hartman, Strominger]:

$$S = \frac{1}{2}\int d^3x\sqrt{g}\,\Omega_{AB}\left(\partial_i\chi^A\partial_j\chi^B g^{ij} + \frac{R[g]}{8}\chi^A\chi^B + m(x^i)\chi^A\chi^B\right).$$

$$\chi\cdot\chi \longleftrightarrow \phi \quad \text{with} \quad m^2 l_{dS}^2 = +2, \qquad T_{ij} \longleftrightarrow g_{\mu\nu} \tag{1}$$

Turn off sources for operators $J^{(s)}_{i_1\cdots i_s} = \Omega_{ab}\chi^a\partial_{(i_1}\cdots\partial_{i_s)}\chi^b + \cdots$ with dimension $\Delta = s+1$ dual to higher spin fields.

Dunne-Kirsten method

On $\mathbb{R}^3$ (S^3) consider mass profile $\hat{m}(r)$ ($m(\psi)$) and metric deformation $ds^2 = dr^2 + f(r)^2\, r^2\, d\Omega_2^2$ ($ds^2 = d\psi^2 + f(\psi)^2\, \sin^2\psi\, d\Omega_2^2$).

Gaussian theory: zeta-regularized partition function computed with Dunne-Kirsten formula:

$$\log\left(\frac{\det\left[-\nabla^2+\mu^2+\hat{m}(r)\right]}{\det\left[-\nabla^2+\mu^2\right]}\right) = \sum_{l=0}^{\infty}(2l+1)\left(\log T^{(l)}(\infty) - \frac{\int_0^\infty dr\; r\; \hat{m}(r)}{2l+1}\right).$$

Constant mass on peanuts

Anninos, Denef, and Harlow computed Z_{CFT} for $m(x^i) = m_0$ on S^3.
Consider peanut deformation of geometry:

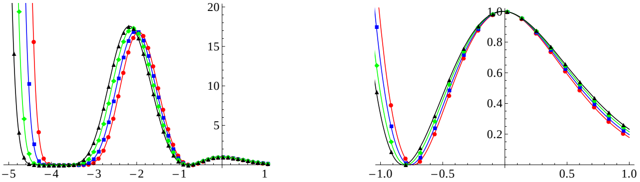

Figure : Left: $|\Psi_{HH}(\zeta, m)|^2$ for for $N = (\ell_{dS}/\ell_P)^2 = 2$ as a function of m_0 for peanut geometries ($l_{max} = 45$). Right: Zoomed in to de Sitter minimum.

Spherical harmonics: killing the divergence

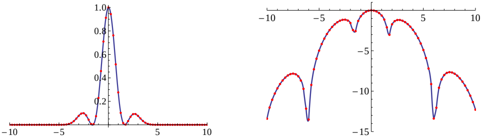

Figure : Left: Plot of $|\Psi_{HH}(A)|^2$ for the first harmonic mapped to $\mathbb{R}^3$. Right: Plot of $\log|\Psi_{HH}(A)|^2$.

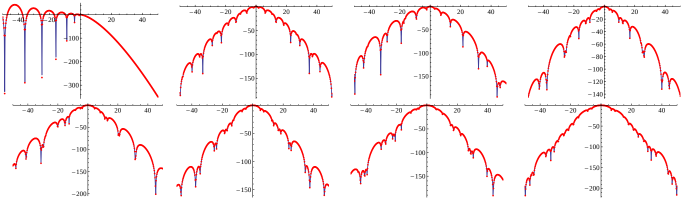

Figure : Plot of $\log|\Psi_{HH}(A)|$ for the first eight spherical harmonics mapped to $\mathbb{R}^3$.

More evidence and a conjecture

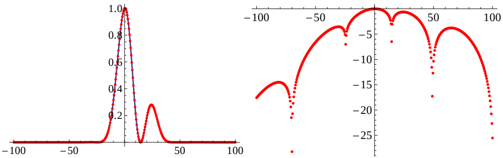

Figure : $|\Psi_{HH}(A)|^2$ (left) and $\log|\Psi_{HH}(A)|$ (right) as a function of A, the overall size of a Gaussian deformation $m(r) = A\,(e^{-r^2} - m_0(r))$ constructed to be orthogonal to the zero mode of the three-sphere.

Conjecture: *The partition function of any $SO(3)$ symmetric "radial" deformation for which the three-sphere zero mode harmonic is fixed is bounded.*

Evidence extends beyond conformal class of sphere: fixing zero mode on squashed sphere leads to normalizable wavefunction in squashing direction.

Outlook

- We've conjectured a possible taming of divergences of wavefunctionals in higher spin $\mathrm{dS}_4/\mathrm{CFT}_3$.
- Prove the normalizability conjecture and explain the restriction independently.
- What about the singlet constraint? On $S^3/\mathbb{R}^3$ we can gauge the $Sp(N)$ symmetry by coupling to Chern-Simons and taking $k \to \infty$. Issues on higher genus surfaces need to be understood [Banerjee et al].
- On $\mathbb{R}^3$ after coupling to Chern-Simons gauge field and turning on the marginal $(\chi \cdot \chi)^3$, does the fixed point structure mirror the AdS case [Aharony et al]?
  - Type B theory, dual to commuting fermions, has no marginal interactions to turn on.
- What is the structure of wavefunctionals in Type B dualities?