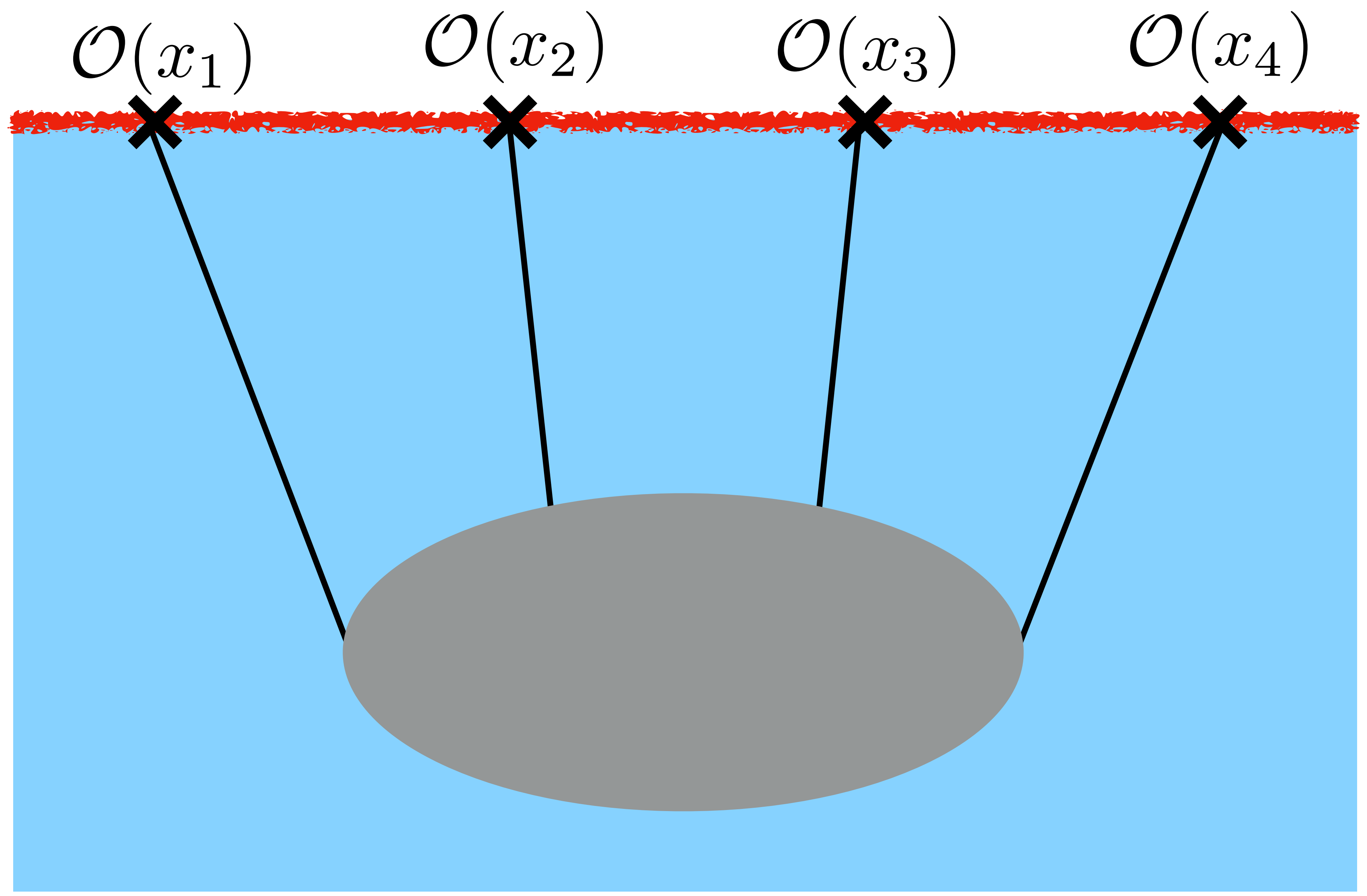
What is the late-time conformal boundary of de Sitter ?

- What are the boundary primary Operators?
- What are their Dimensions?
- Bulk ⟷ Boundary

A non-perturbative approach that
realizes conformal symmetry and unitarity



Bulk-to-boundary expansion:

Does AdS-like expansion work?

AdS: a discrete sum

$$\phi(z, \mathbf{x}) \underset{z \to 0}{\sim} \sum_i b_i \; z^{\Delta_i} \left[O_i(\mathbf{x}) + \text{descendants}\right]$$

$\Delta_i \in$ UIRs, satisfies unitarity bounds

Reason: bulk-state/boundary-operator correspondence

de Sitter:

$$\phi(\eta, \mathbf{y}) \underset{\eta \to 0}{\sim} \sum_i b_i \; (-\eta)^{\Delta_i} \left[O_i(\mathbf{y}) + \text{descendants}\right]$$

$\Delta_i \notin$ UIRs (Principal series, Complementary series, ...), not real

Zero overlap with UIRs: $\langle 0|\mathcal{O}(y)|\text{UIR}\rangle = 0$

Not natural for implementing unitarity!

Bulk-to-boundary expansion:

- Hint 1: Spectrum of de Sitter is continuous
- Hint 2: Boundary operators with $\Delta \in \mathrm{UIR}$

$$\phi(\eta, \mathbf{y}) = \int_{\mathrm{UIR}} a_\Delta (-\eta)^\Delta \mathcal{O}_\Delta(\mathbf{y}) + \text{descendants}$$

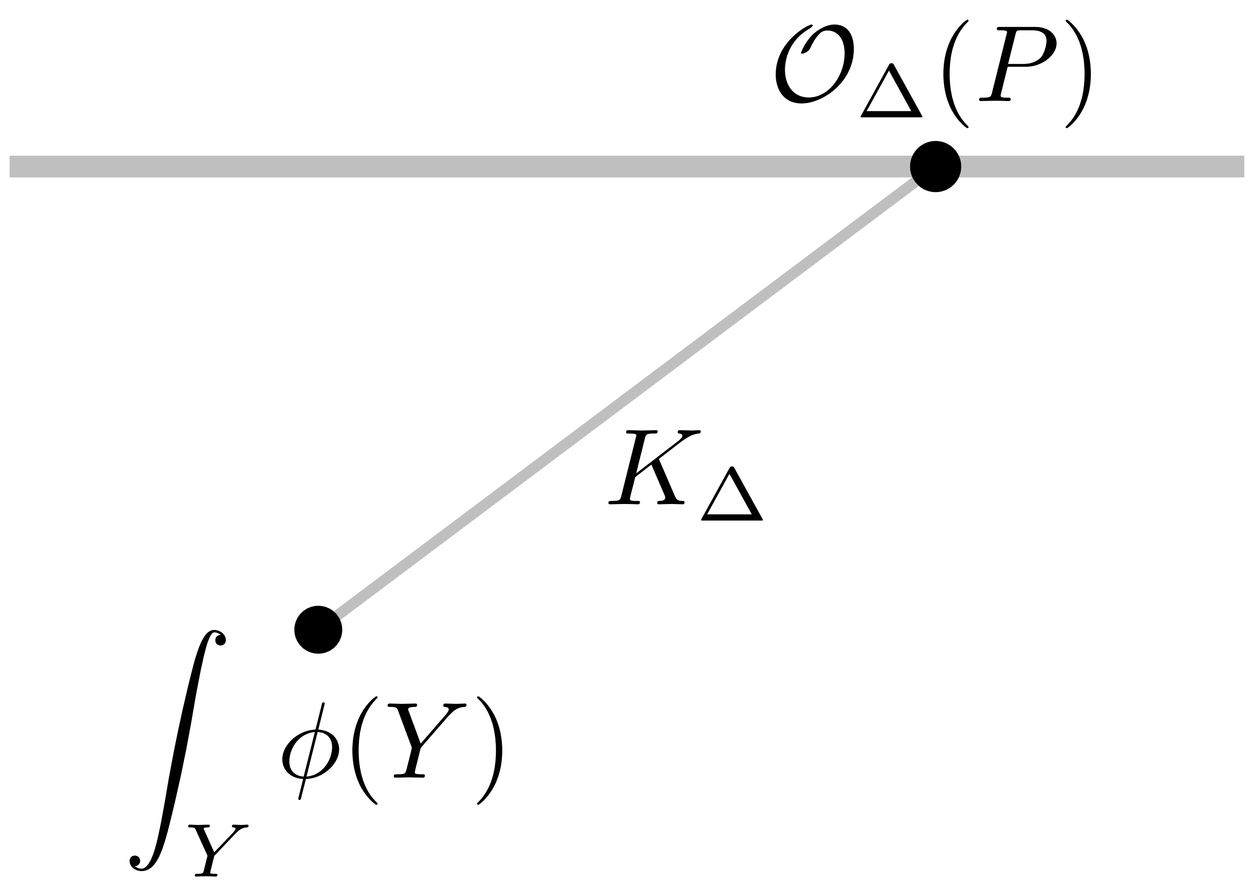
- a_Δ is given by Kallen Lehmann spectral density
- A continuous family boundary primary operators with two-point function with Dirac delta functions on dimensions and contact terms.

$$\langle \mathcal{O}_{\Delta_1}(\mathbf{y}_1) \mathcal{O}_{\Delta_2}(\mathbf{y}_2) \rangle = \frac{\delta_{\lambda_1 \lambda_2}}{y_{12}^{2\Delta_1}} + \gamma_{\Delta_1} \delta_{\lambda_1, -\lambda_2} \delta_{\mathbf{y}_1, \mathbf{y}_2} \, . \qquad \Delta = \frac{d}{2} + i\lambda$$

Inversion formula:

Boundary operators given a bulk theory

$$\mathcal{O}_\Delta(\mathbf{y}) = \frac{1}{N_\Delta}\int_{\text{bulk}} K_\Delta(\eta', \mathbf{y}'; \mathbf{y})\phi(\eta', \mathbf{y}')$$



- Satisfies the conformal Ward identities
- Recovers the boundary two and three point functions

$$\langle \mathcal{O}_{\Delta_1}(\mathbf{y}_1)\mathcal{O}_{\Delta_2}(\mathbf{y}_2)\rangle = \frac{\delta_{\lambda_1\lambda_2}}{y_{12}^{2\Delta_1}} + \gamma_{\Delta_1}\delta_{\lambda_1,-\lambda_2}\delta_{\mathbf{y}_1,\mathbf{y}_2} \ .$$

- Reproduces perturbation theory
- Shadow transform/hermitian conjugation: $\Delta \longleftrightarrow \bar{\Delta}$