Title: Observables in perturbative de Sitter gravity

Date: May 08, 2008 02:00 PM

URL: http://pirsa.org/08050002

Abstract: TBA

Observables in perturbative de Sitter quantum gravity

Donald Marolf

UCSB

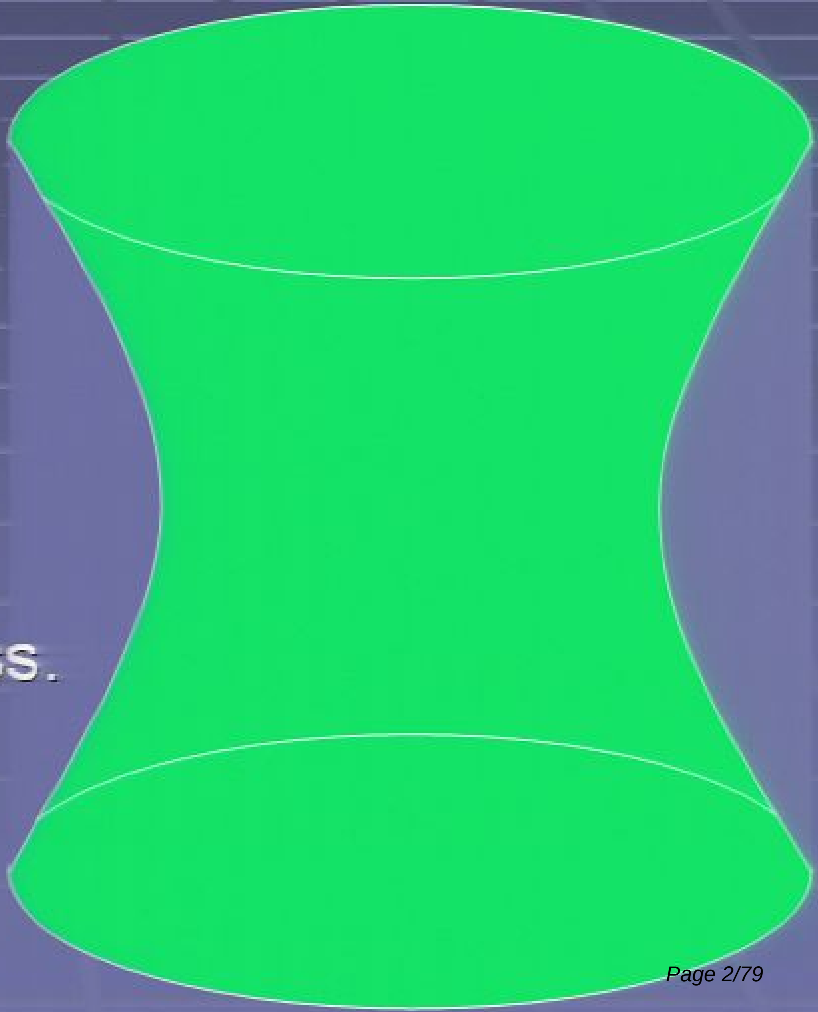
May 8, 2008

Based on work
w/Steve Giddings.

arXiv:0705.1178 and work in progress.

What are meaningful questions?

How might answers be computed?

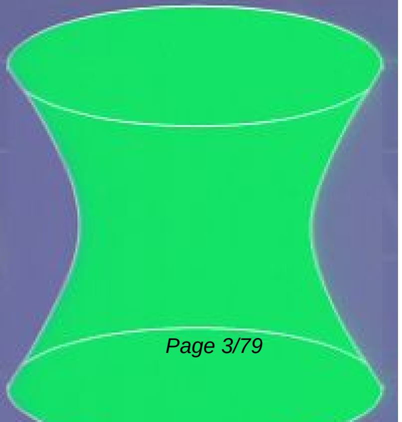


Outline

I. Review: Perturbative gravity about dS. What is there to do?

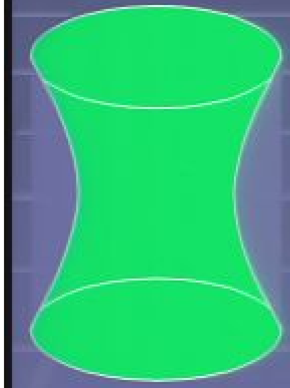
II. Single Integral observables & Boltzmann Brains.

III. Proto-local observables require *global* information.



I. Review Framework

Matter QFT on dS w/ perturbative gravity



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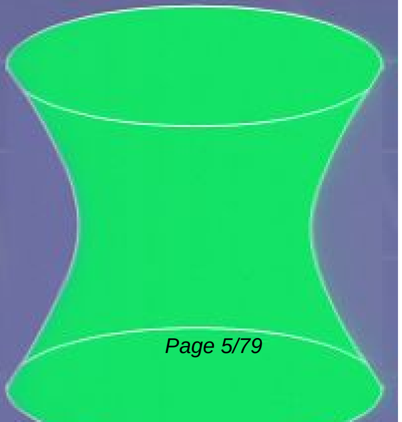

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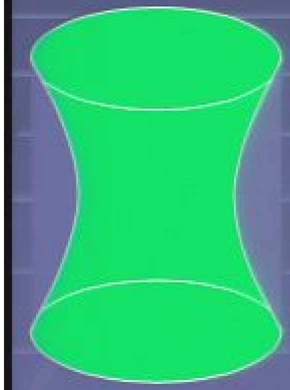

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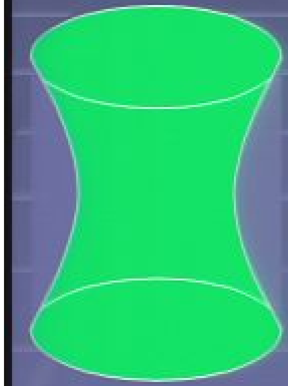

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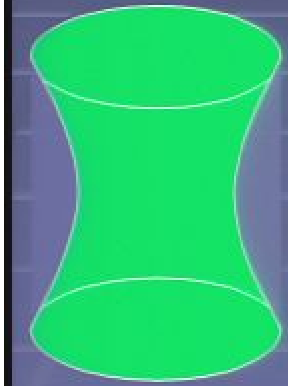

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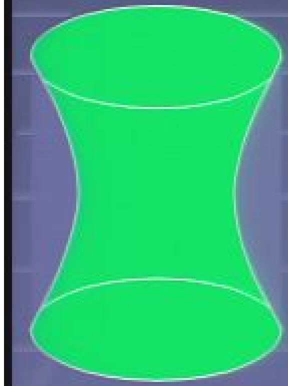

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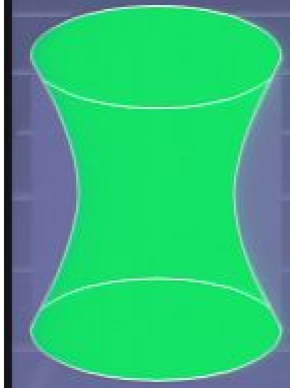

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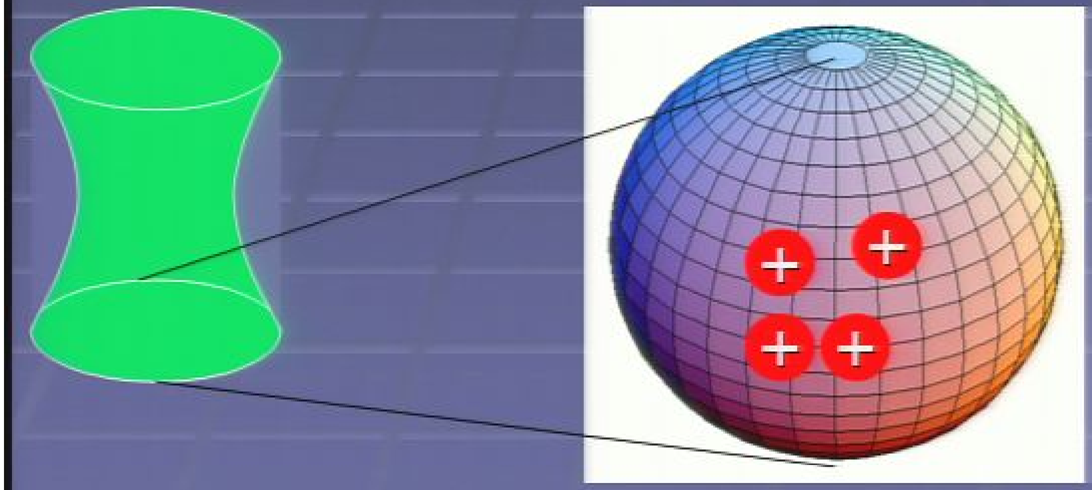

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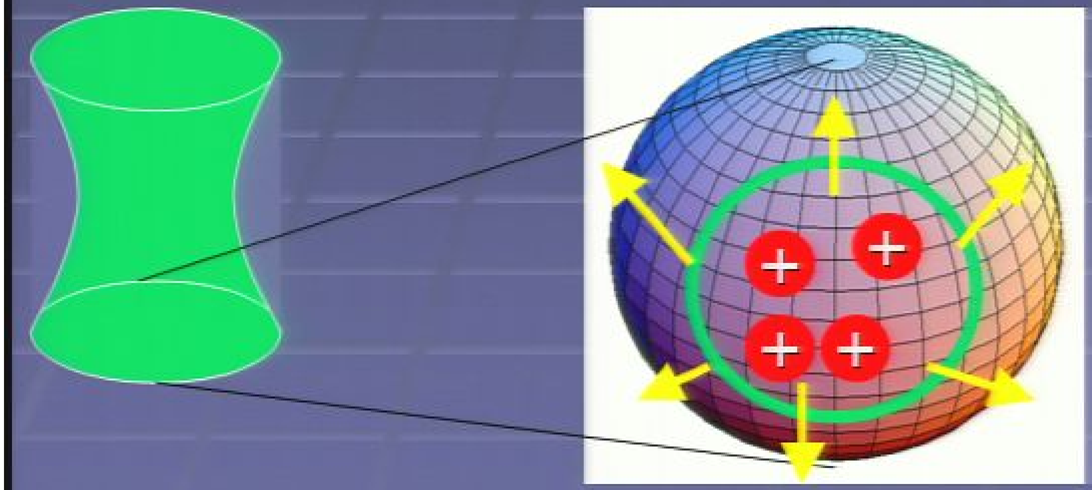

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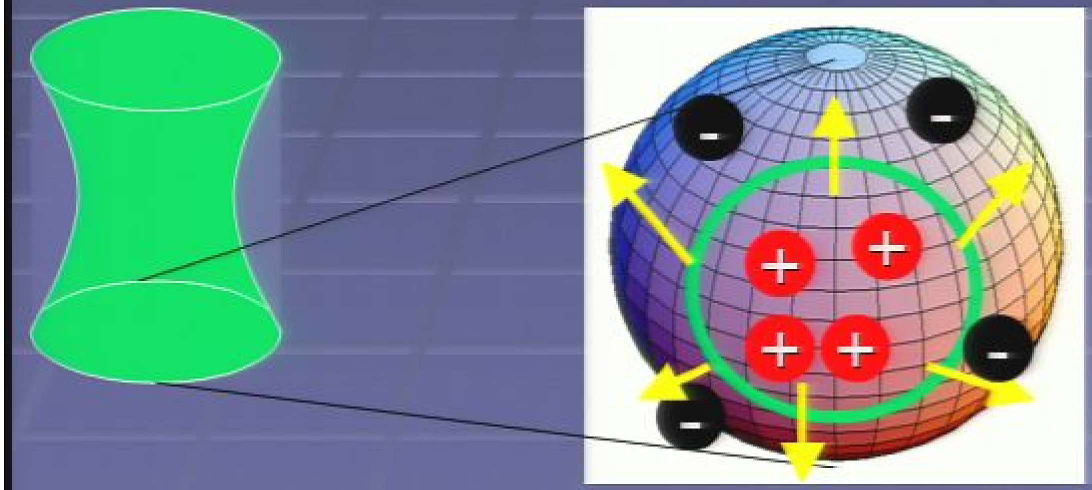

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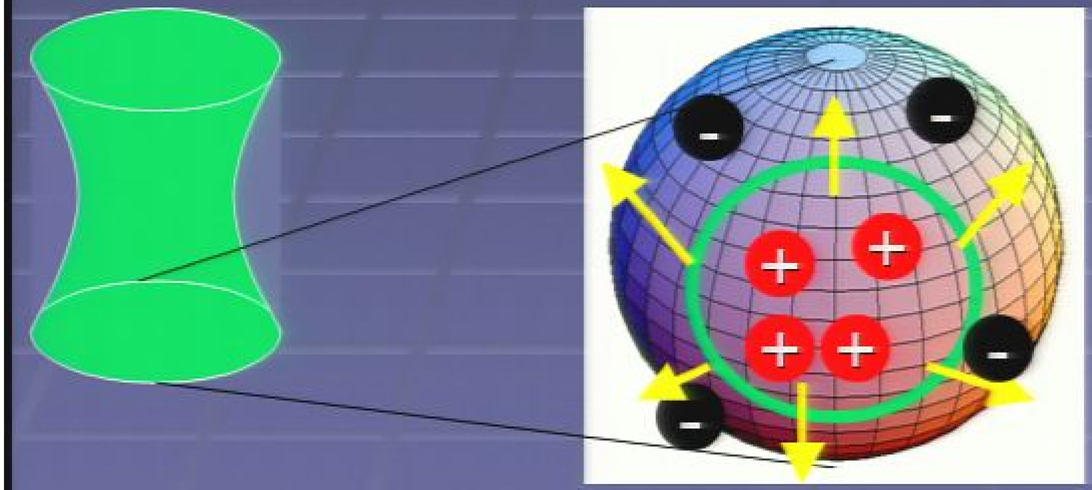

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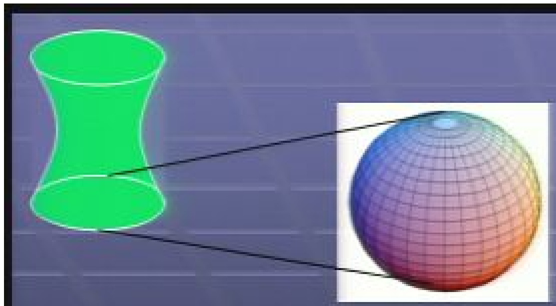
Restriction on matter states:

$Q|\psi\rangle = 0$



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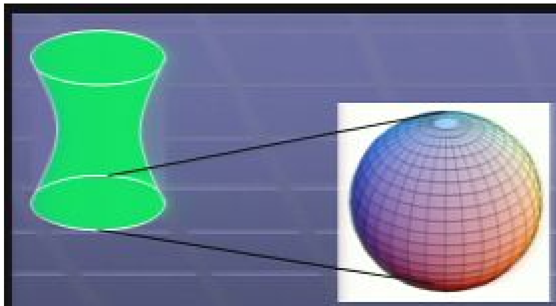
Similar “linearization stability constraints” in perturbative gravity!

(Moncrief, Fischer, Marsden, ... Higuchi, Losic & Unruh)



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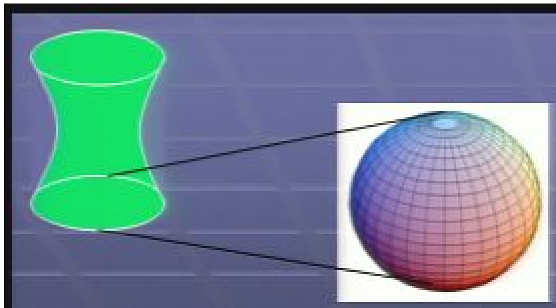

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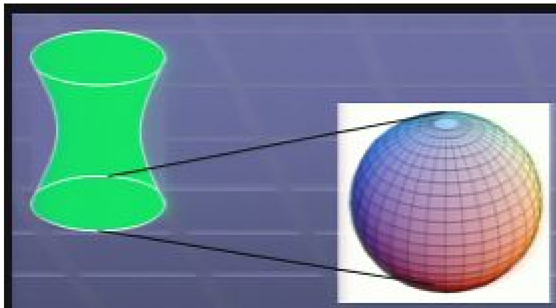
$$h_{ij} \longrightarrow h_{ij} + \nabla^0_i \xi_j + \nabla^0_j \xi_i$$



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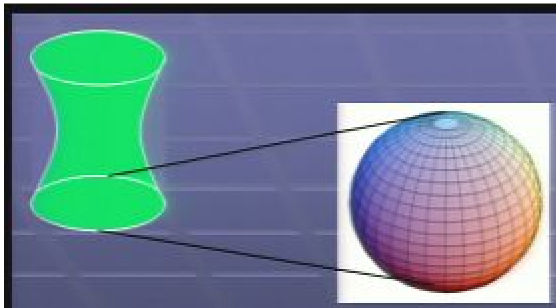

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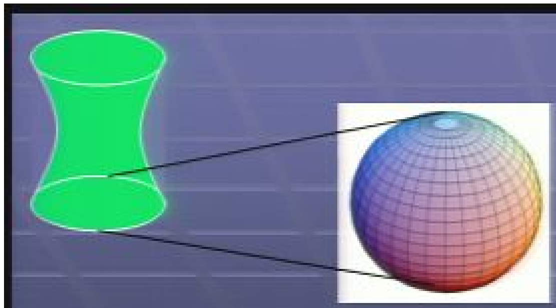
A constraint for KVFs ξ !



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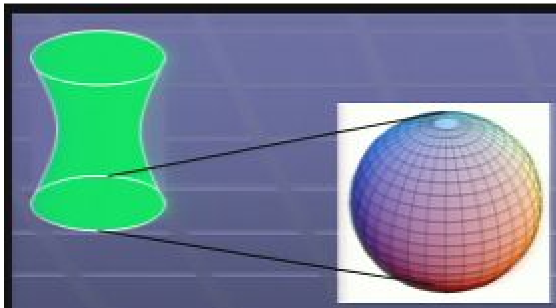

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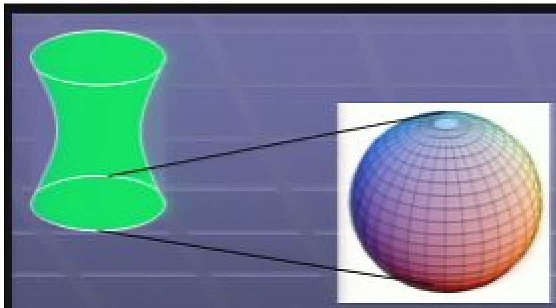

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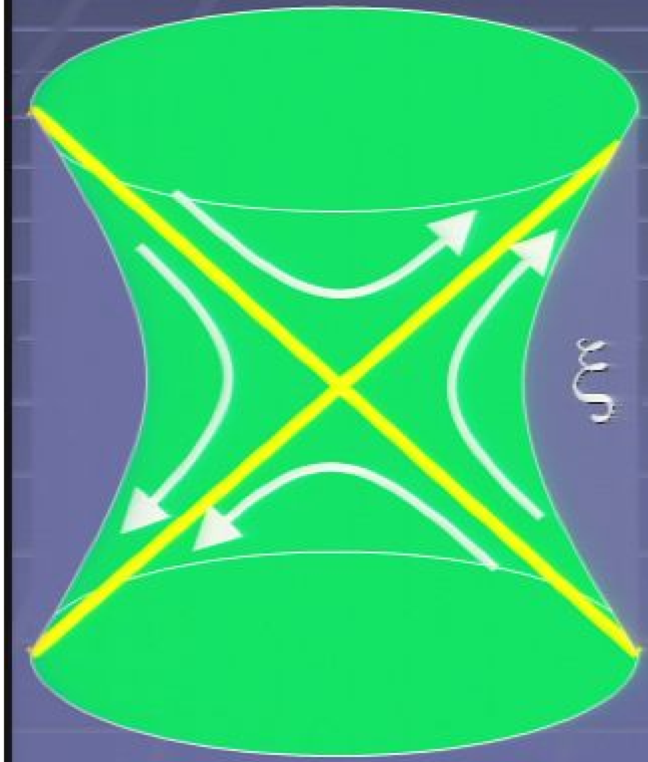

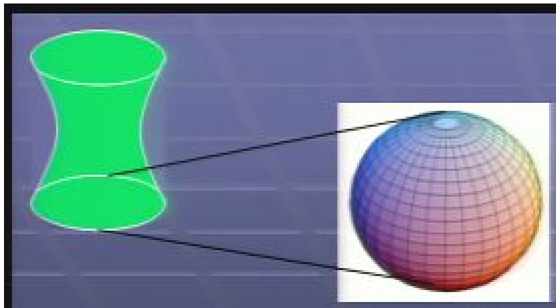

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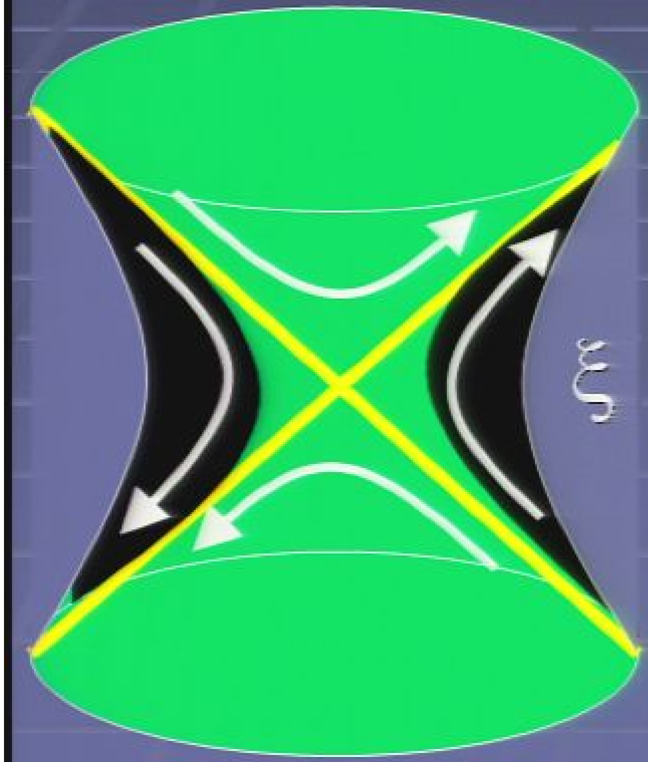

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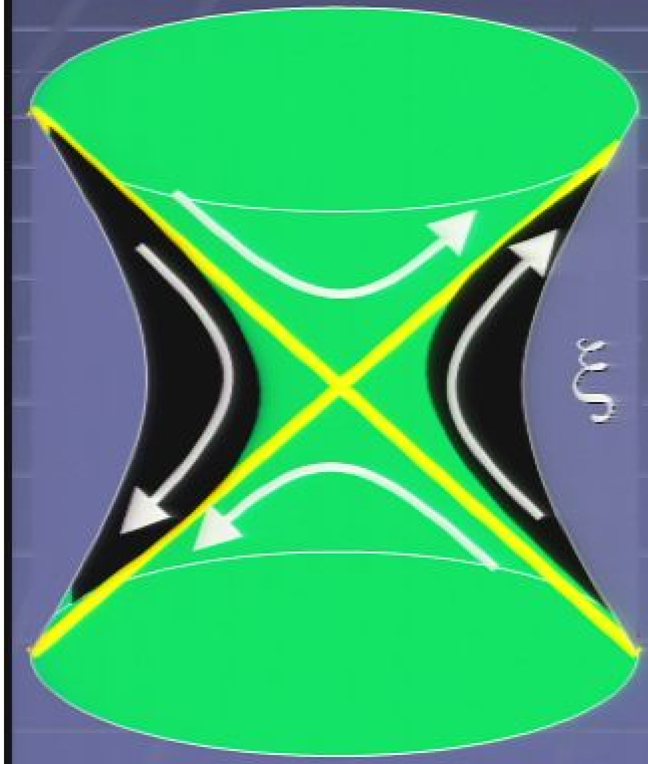

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Strategy: Work on usual Fock space as much as possible. Observables on this space induce observables on the physical Hilbert space.

Type I Observables

Try $\mathcal{O} = \int_{x \in dS} \sqrt{-g}\; A(x)$

Finite ($\mathcal{H}_0$) matrix elements $<\psi_1|\mathcal{O}|\psi_2>$ for appropriate A(x), $|\psi_i>$.

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Each mode falls off like $e^{-(d-1)t/2\ell}$.

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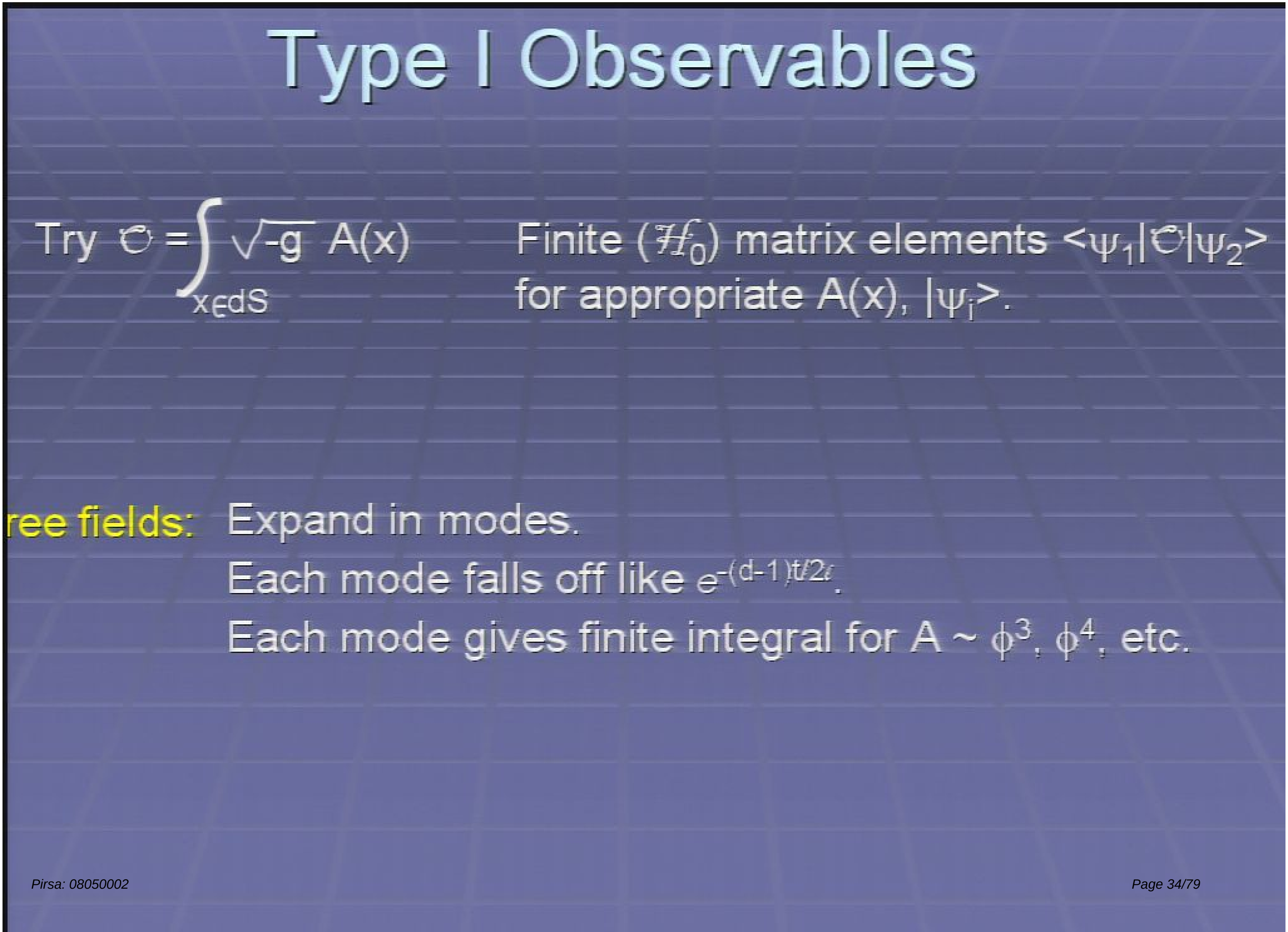

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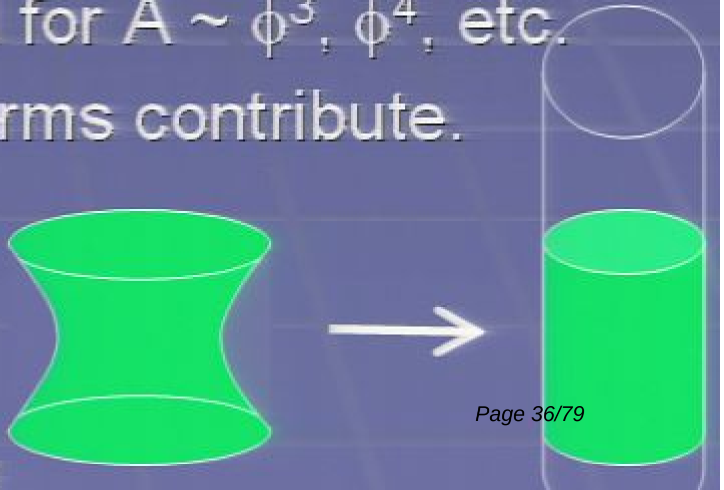
F maps to energy

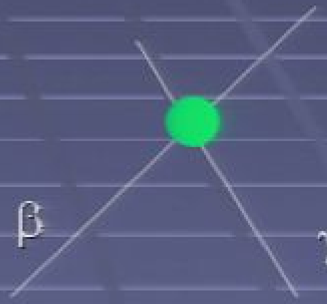
Large conformal weight

& finite F → finite integrals!



Relational observables recover local physics

Given scalars ϕ, β, γ,



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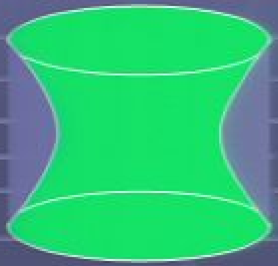
then $\langle\Psi|\mathcal{O}|\Psi\rangle \sim \langle\psi|\phi(x)|\psi\rangle$
(also true for higher correlators)

I.e., $\mathcal{O}$ scans spacetime for intersection ("observer"), reports value of ϕ.

Proto-local?

But fluctuations diverge!



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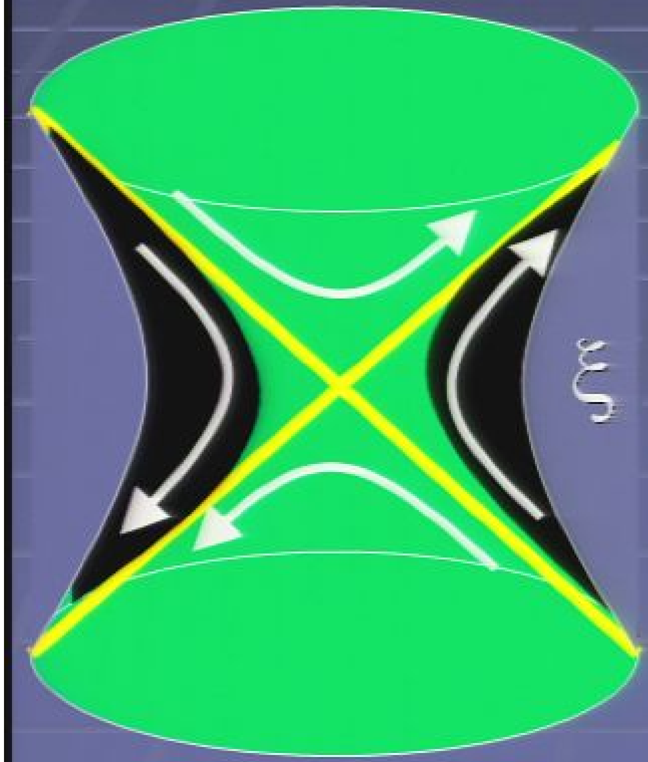

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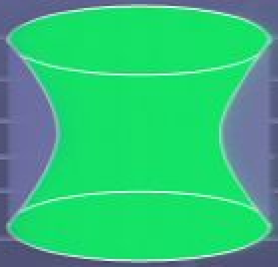

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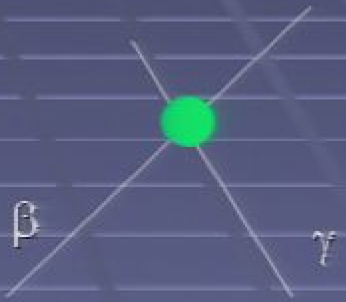

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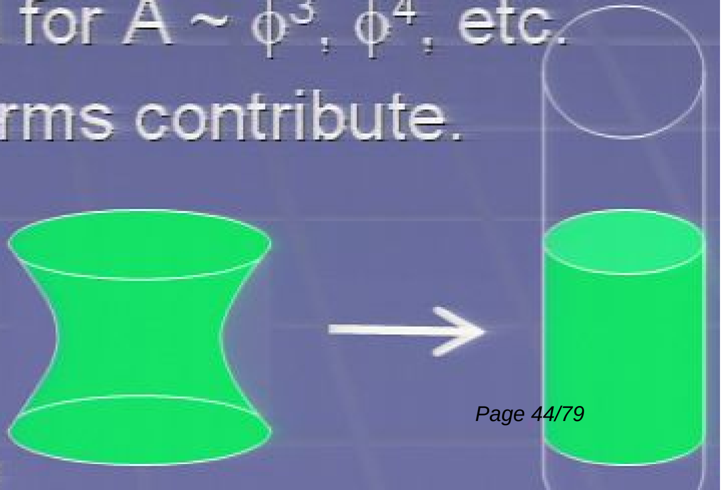

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then $<\Psi|\mathcal{O}|\Psi> \sim <\psi|\phi(x)|\psi>$
(also true for higher correlators)

I.e., $\mathcal{O}$ scans spacetime for intersection ("observer"), reports value of ϕ.

Proto-local?

But fluctuations diverge!

$$<\psi_1|\mathcal{O}_1\mathcal{O}_2|\psi_2> \;=\int dx_1\, dx_2 <\psi_1|A_1(x_1)A_2(x_2)|\psi_2>$$

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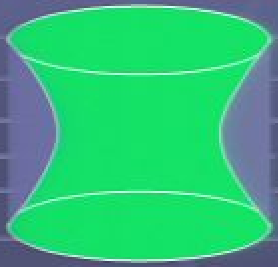

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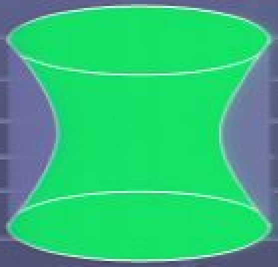

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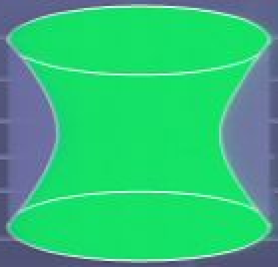

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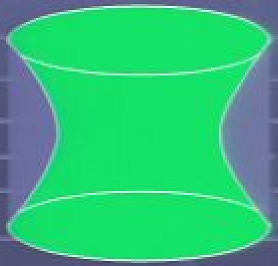

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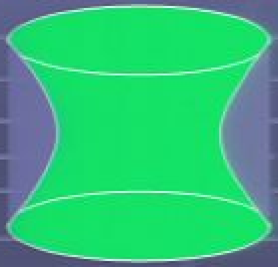

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A dS-invariant cut-off

$$|\Psi\rangle = \int dg\, U(g)\, |\psi\rangle$$

Let V be the space of states with $F < f_1$.

Group average V → $\mathcal{V}$

Let $|\Psi_i\rangle$ be an O.N. basis for $\mathcal{V}$ and choose $|\psi_i\rangle$ → $|\Psi_i\rangle$

Note: $\langle\psi'_i|\Psi'_j\rangle = \int dg \quad \langle\psi'_i|U(g)|\psi'_j\rangle = \delta_{ij}$

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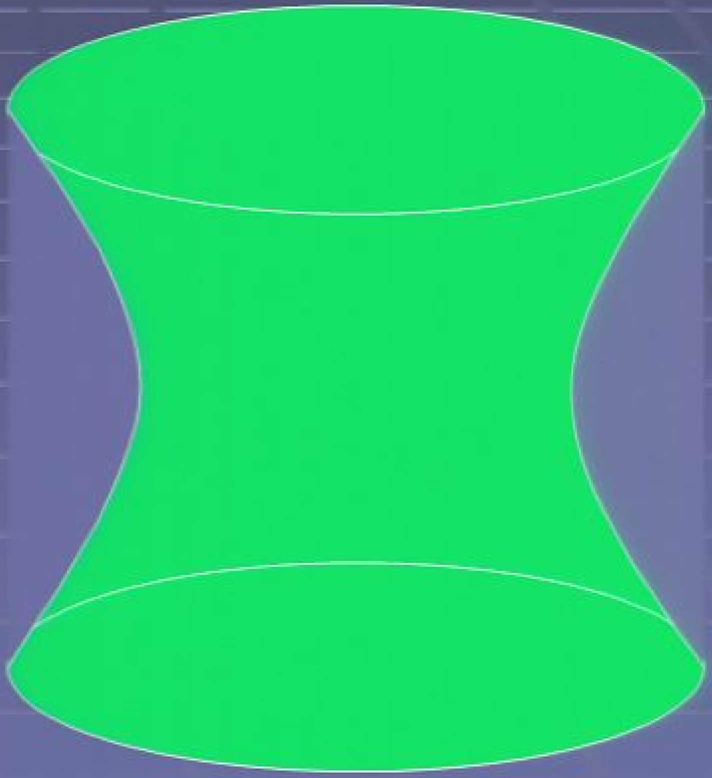

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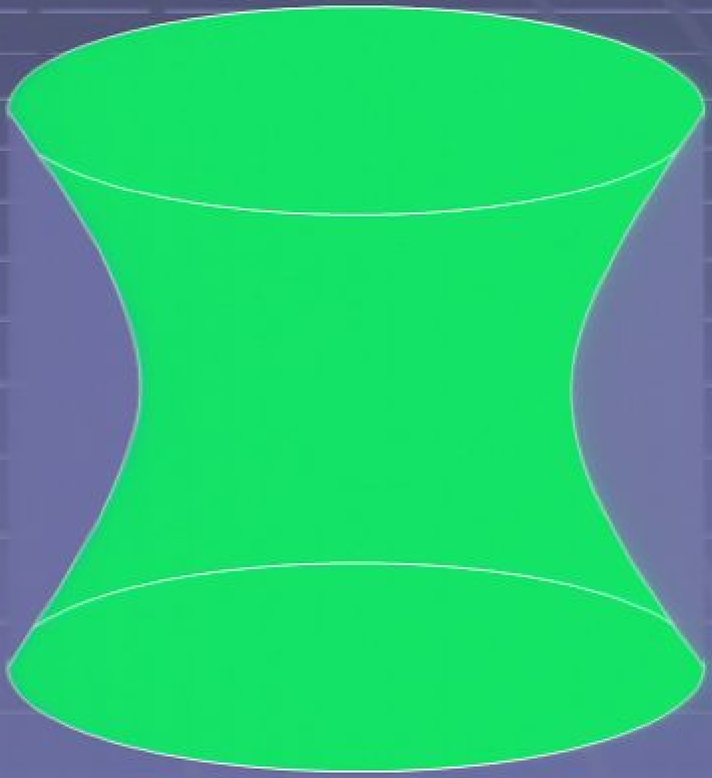

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$\tilde{\mathcal{O}}$ induces $\mathcal{P}_{phys}\,\mathcal{O}\,\mathcal{P}_{phys}$ on $\mathcal{H}_{phys}$

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In usual Hilbert space, $|\psi>$ must be the vacuum! (Higuchi)

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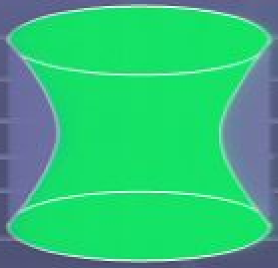

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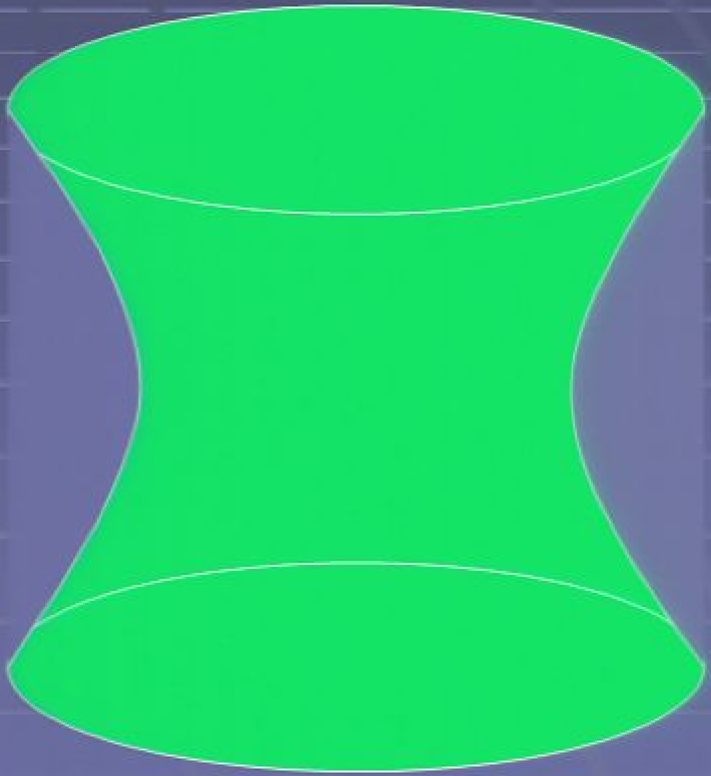

Type II Observables

$$\mathcal{O} = \int_{g \in dS} dg\, U(g)\, A\, U(g^{-1})$$

Consider weakly interacting fields α,ϕ and take:

$$\mathcal{O}_{\phi(f)} = \int_{g \in dS} dg\, U(g)\, |\alpha\rangle\langle\alpha|\, \phi(f)\, U(g^{-1})$$

where $\phi(f) = \int_{x \in dS} \sqrt{-g}\, f(x)\, \phi(x)$ for c-# f

For heavy state, can have $\langle\alpha|U(g)|\alpha\rangle \sim \mathcal{N}\,\delta(g,1)$

$$\mathcal{N}^{-1}\mathcal{O}_{\phi(f)}\ \mathcal{N}^{-1}\mathcal{O}_{\phi(h)} \sim \mathcal{N}^{-1}\mathcal{O}_{\phi(f)\,\phi(h)}$$

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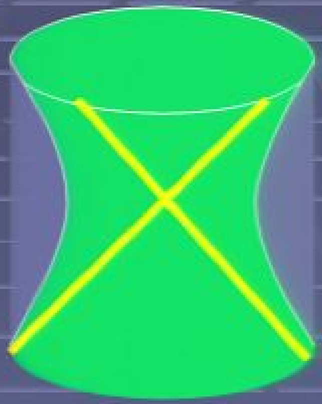

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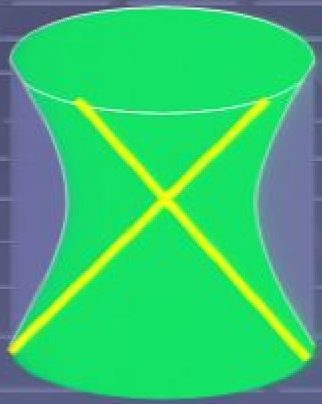

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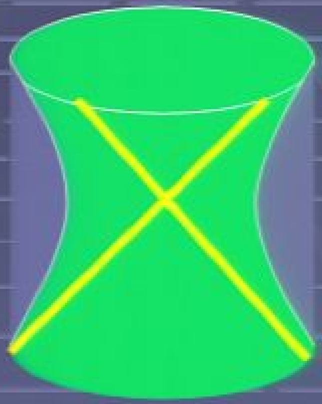

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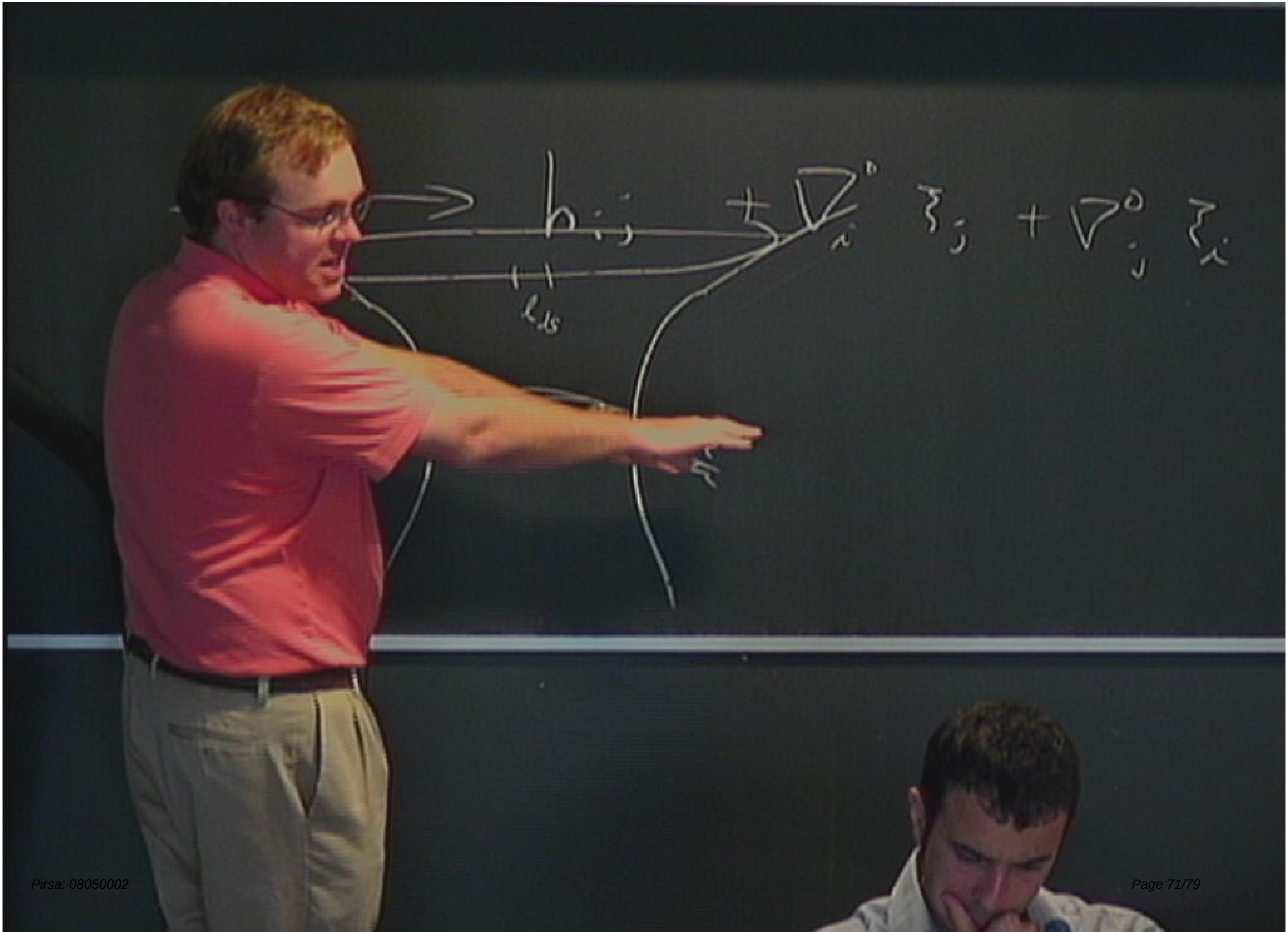
$\Rightarrow h_{ij} + \nabla^0_i \xi_j + \nabla^0_j \xi_i$
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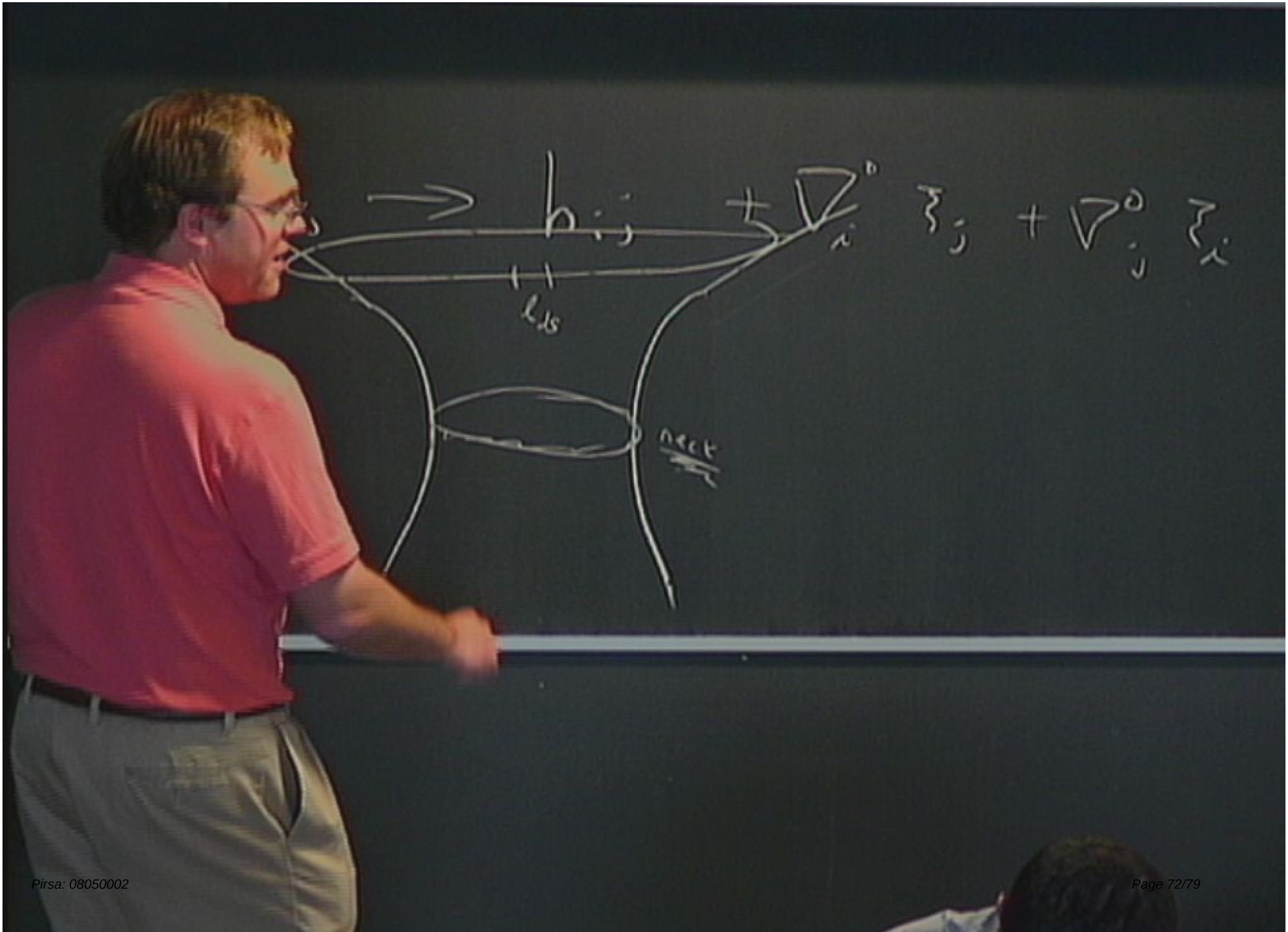
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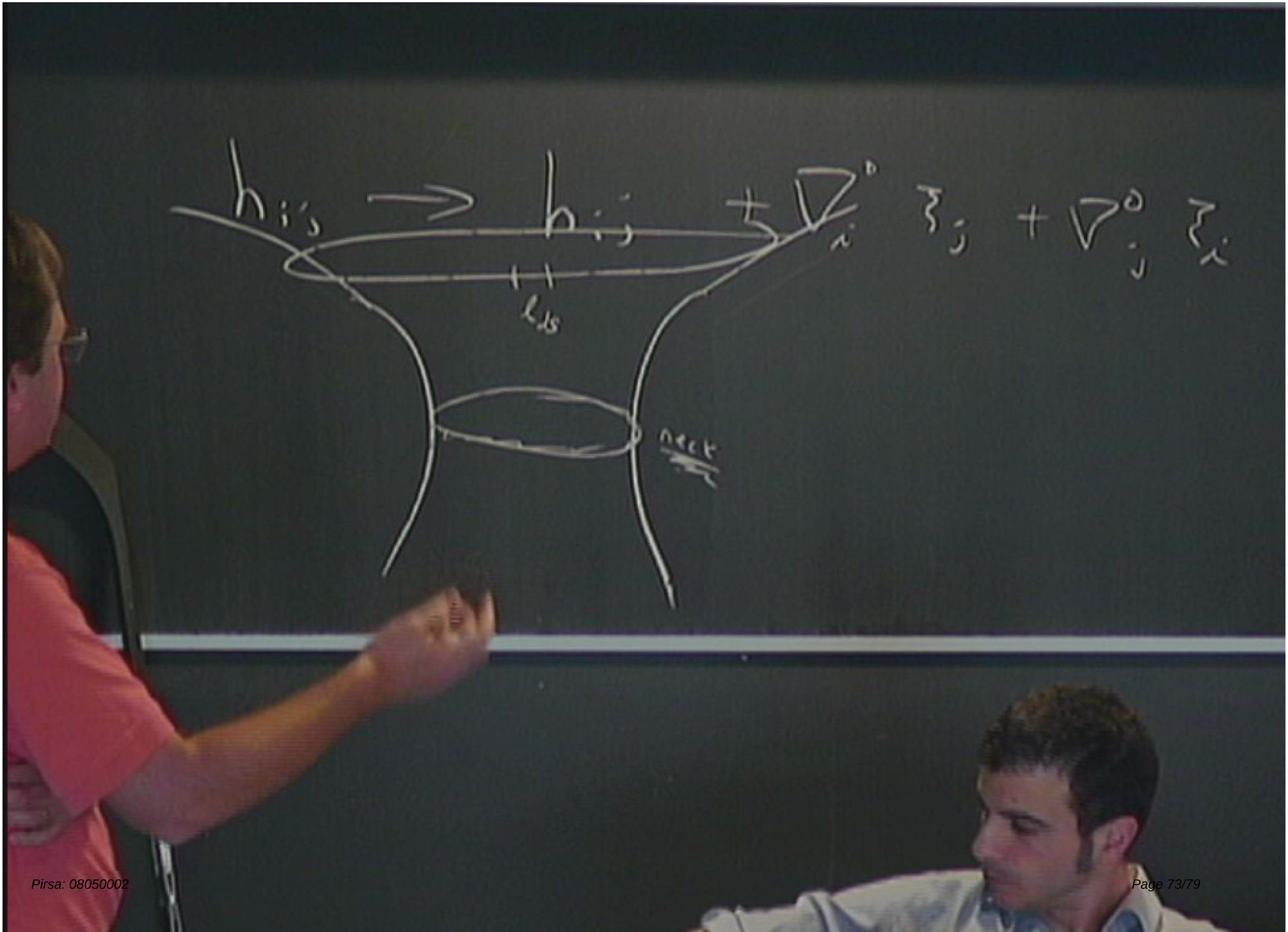

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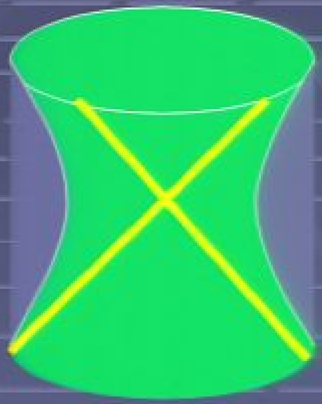

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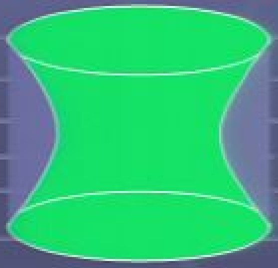

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Control Intermediate States?

Type I Observables

Try $\mathcal{O} = \int_{x \in dS} \sqrt{-g}\; A(x)$

Finite ($\mathcal{H}_0$) matrix elements $<\psi_1|\mathcal{O}|\psi_2>$ for appropriate A(x), $|\psi_i>$.

Define $F = \int_{neck} \sqrt{q}\; T_{ab}\, n^a n^b$

ree fields: Expand in modes.

Each mode falls off like $e^{-(d-1)t/2\ell}$.

Each mode gives finite integral for $A \sim \phi^3, \phi^4$, etc.

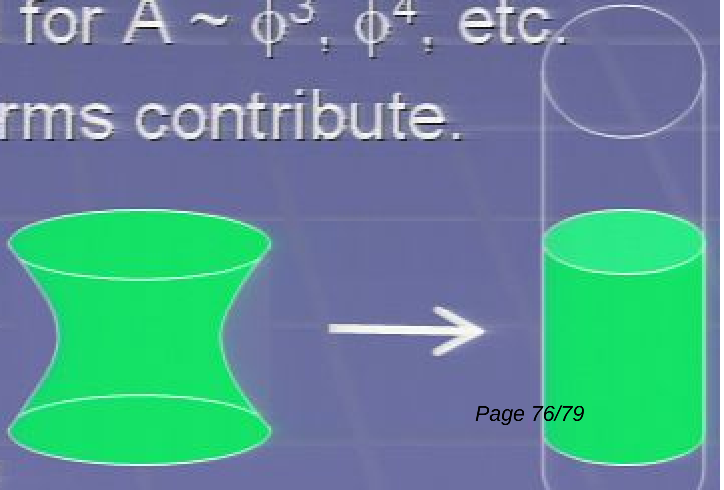
For $|\psi_i>$ of finite F, finite # of terms contribute.

onformal case: maps to finite Δt in ESU

F maps to energy

Large conformal weight

& finite F → finite integrals!



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(Albrecht, Page, etc.)

hat do typical observers in dS see?

S has thermal, or vacuum quantum flucts.

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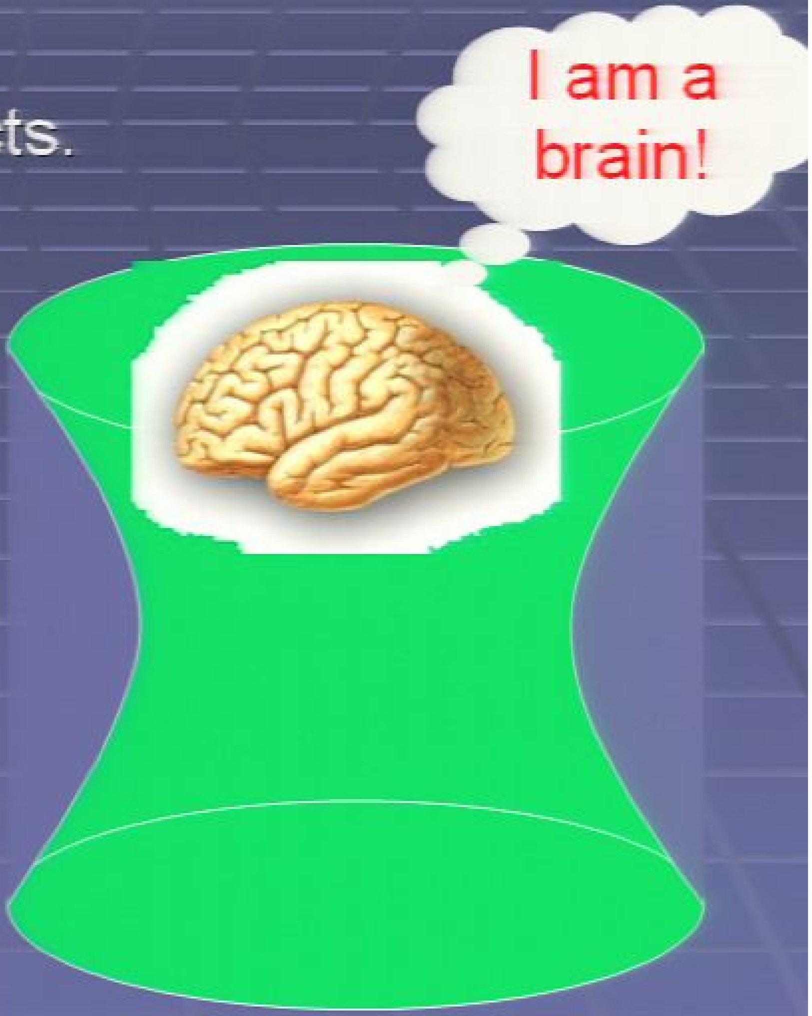

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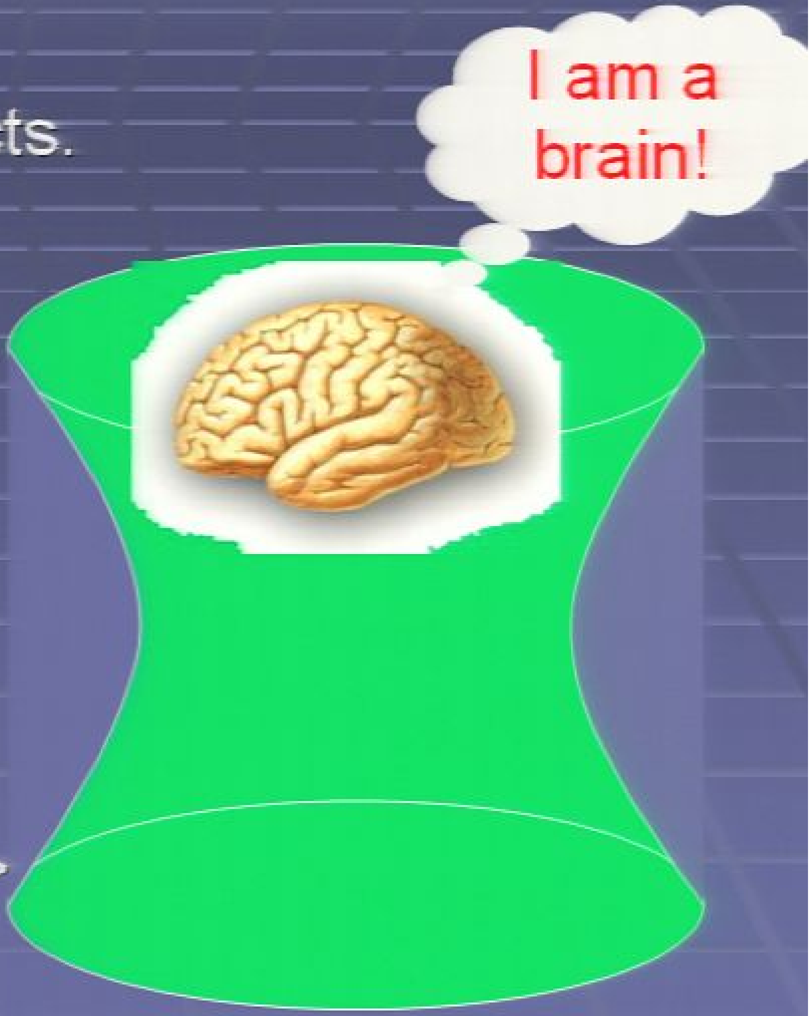

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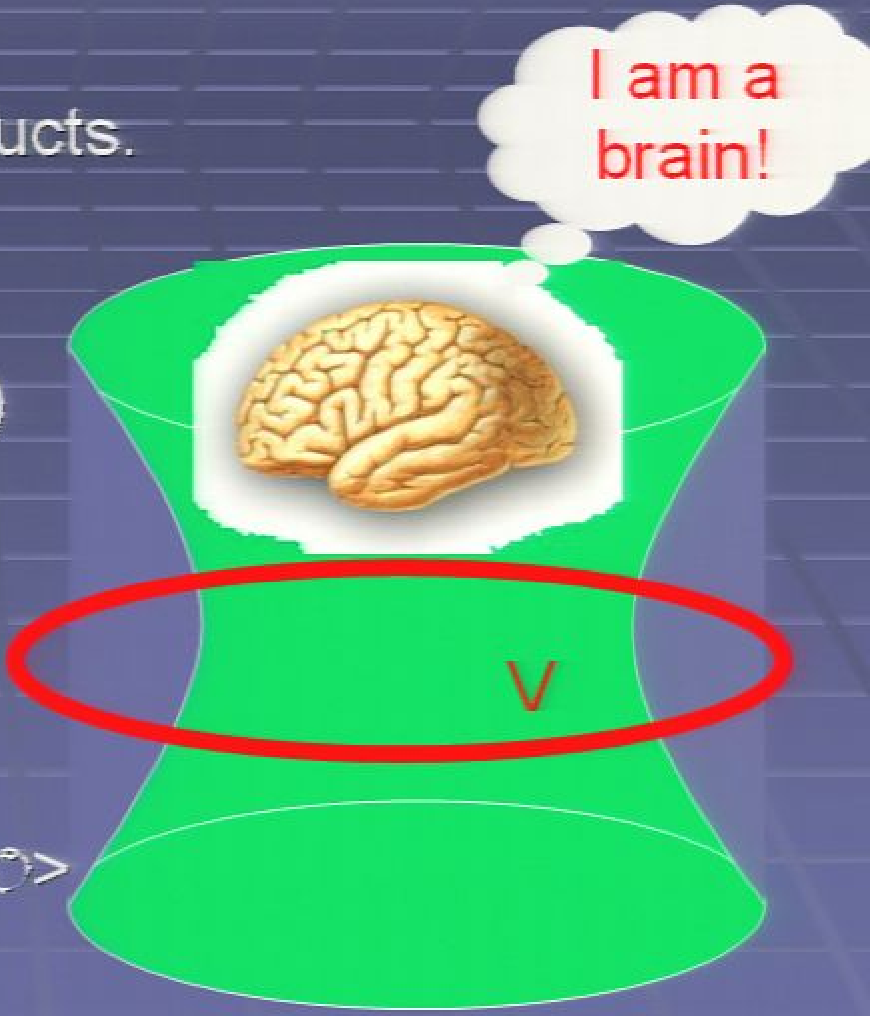

)ur story:

Subtract to control matrix elements $<\mathcal{O}>$

Still dominate fluctuations $<\mathcal{O}\mathcal{O}>$

r local questions integrated over all dS.

→ Ask different questions (non-local, finite V): $\tilde{\mathcal{O}} = \mathcal{P}\mathcal{O}\mathcal{P}$