Title: Spacetime and higher-spin symmetries in the de Sitter S-matrix

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Series: Quantum Gravity

Date: September 05, 2019 - 2:30 PM

URL: http://pirsa.org/19090026

Abstract: I will discuss the problem of an observer's S-matrix in de Sitter space, i.e. the mapping between fields on the initial and final horizons of a de Sitter static patch. I will show how the S-matrix of free massless fields can be packaged in a spinor-helicity language. This involves â€œcheatingâ€• the static patchâ€™s painfully low symmetry, by relating each horizon separately to global, de Sitter-invariant data.

I will then discuss the important special case of higher-spin gravity in de Sitter, and argue that higher-spin symmetry prevents any corrections to the free S-matrix, except in the â€œsoft" sector of zero frequencies.

Spacetime and higher-spin symmetries

vs.

The de Sitter S-matrix

1. Who I am / Why dS S-matrix
2. Free S-matrix in spinor-helicity variables
3. QM of bdry particle
4. Implications of higher-spin symmetry

Spacetime and higher-spin symmetries

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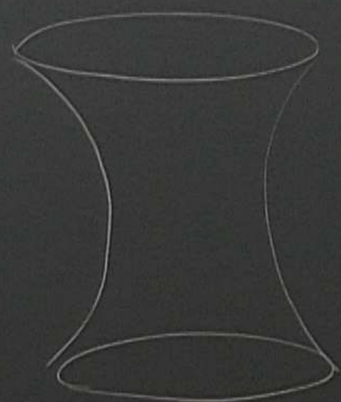
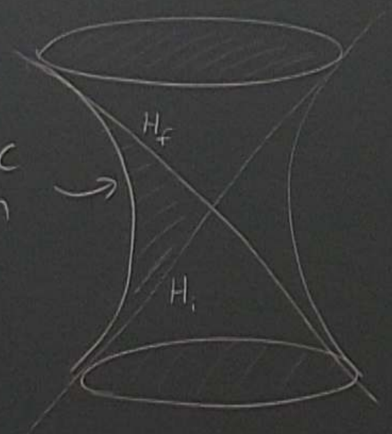
$\underbrace{\hbar \neq 0, \ G \neq 0}_{\text{AdS/CFT}}, \ \Lambda > 0$

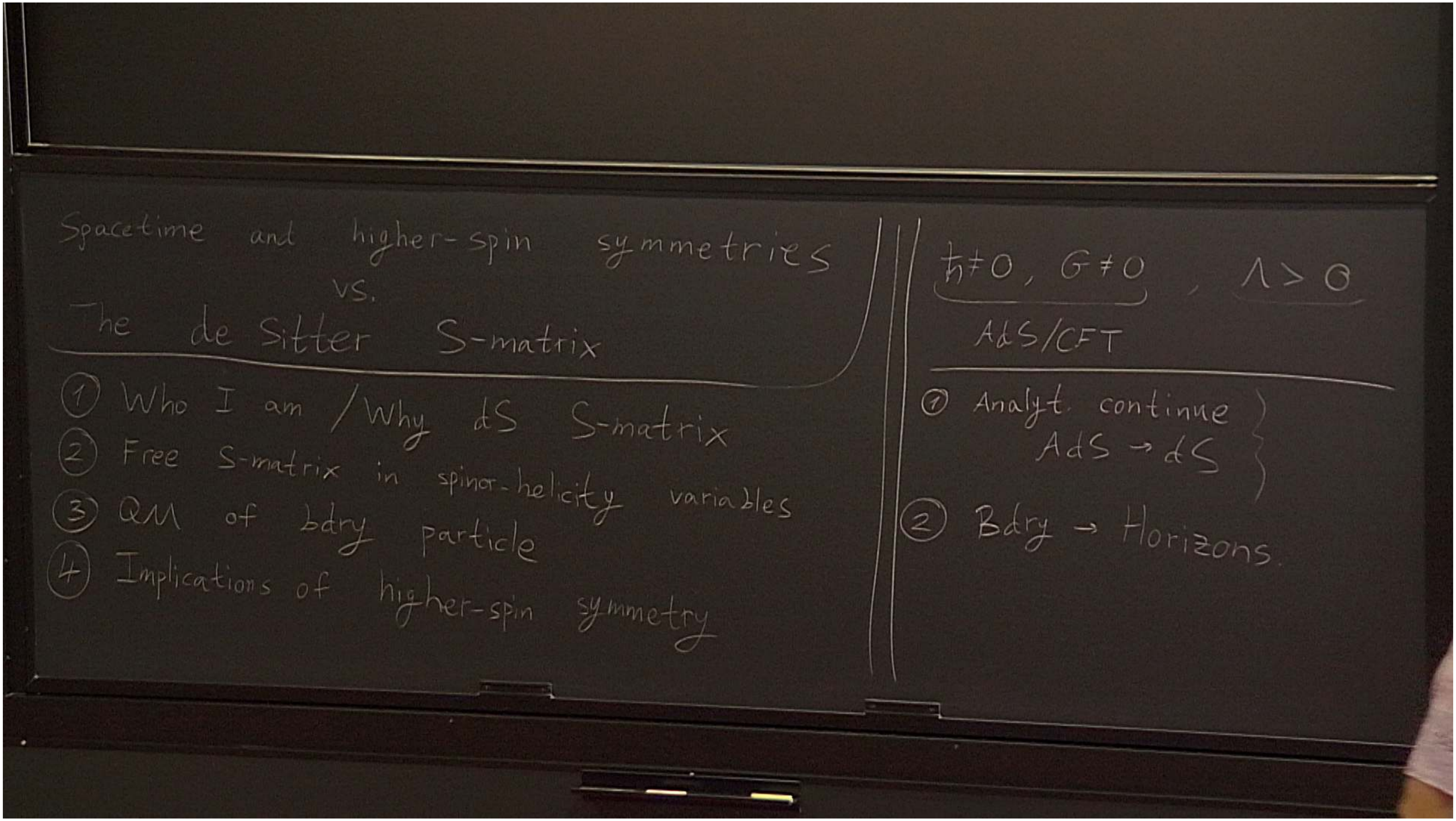


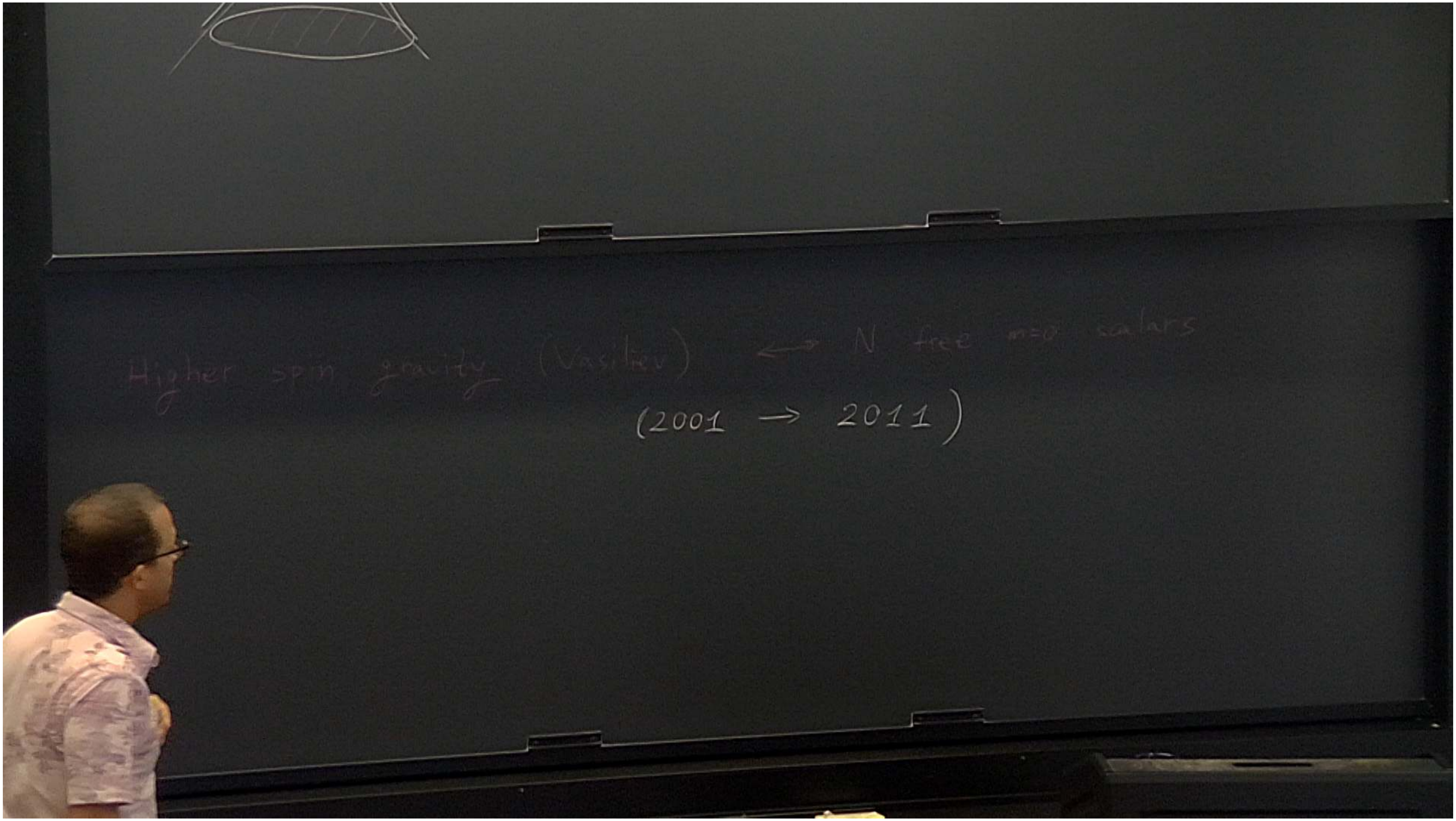
$$dS_4 = \{ x^\mu \in \mathbb{R}^{4,1} \; ; \; x_\mu x^\mu = 1 \}$$

Static patch



$$dS_4 = \left\{ x^\mu \in \mathbb{R}^{4,1} \; ; \; x_\mu x^\mu = 1 \right\}$$


Spacetime and higher-spin symmetries
vs.
The de Sitter S-matrix
1 Who I am / Why dS S-matrix
2 Free S-matrix in spinor-helicity variables
3 QM of bdry particle
4 Implications of higher-spin symmetry
$\hbar \neq 0$, $G \neq 0$, $\Lambda > 0$
AdS/CFT
1 Analyt. continue AdS → dS
2 Bdry → Horizons.


Higher spin gravity (Vasiliev) ⟷ N free m=0 scalars
(2001 → 2011)

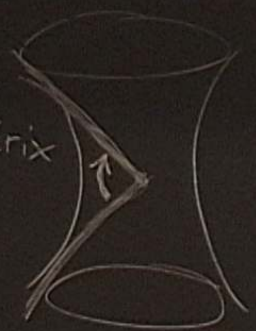
③ QM of bdry particle

④ Implications of higher-spin symmetry

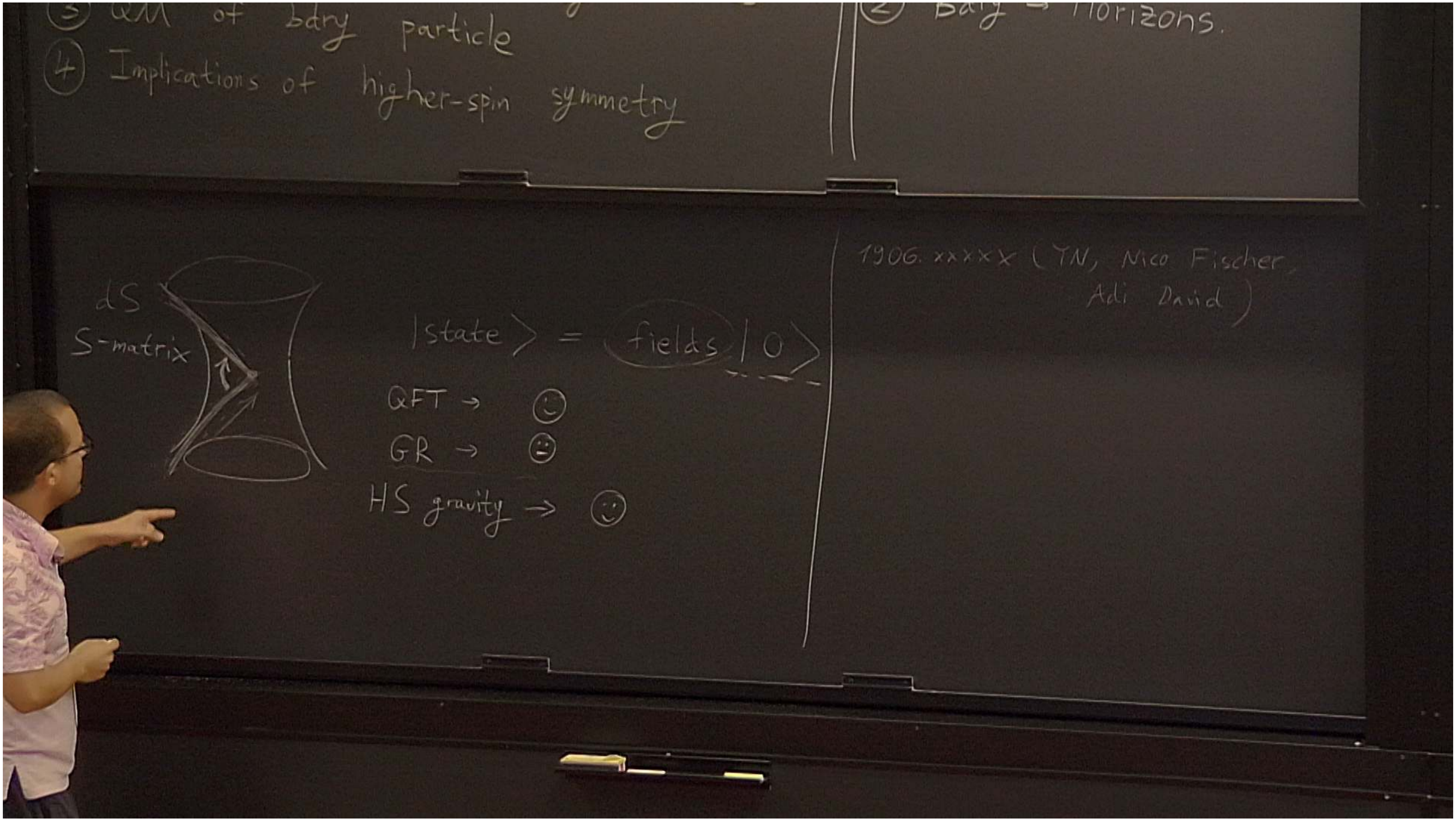
② Bdry ≠ Horizons.

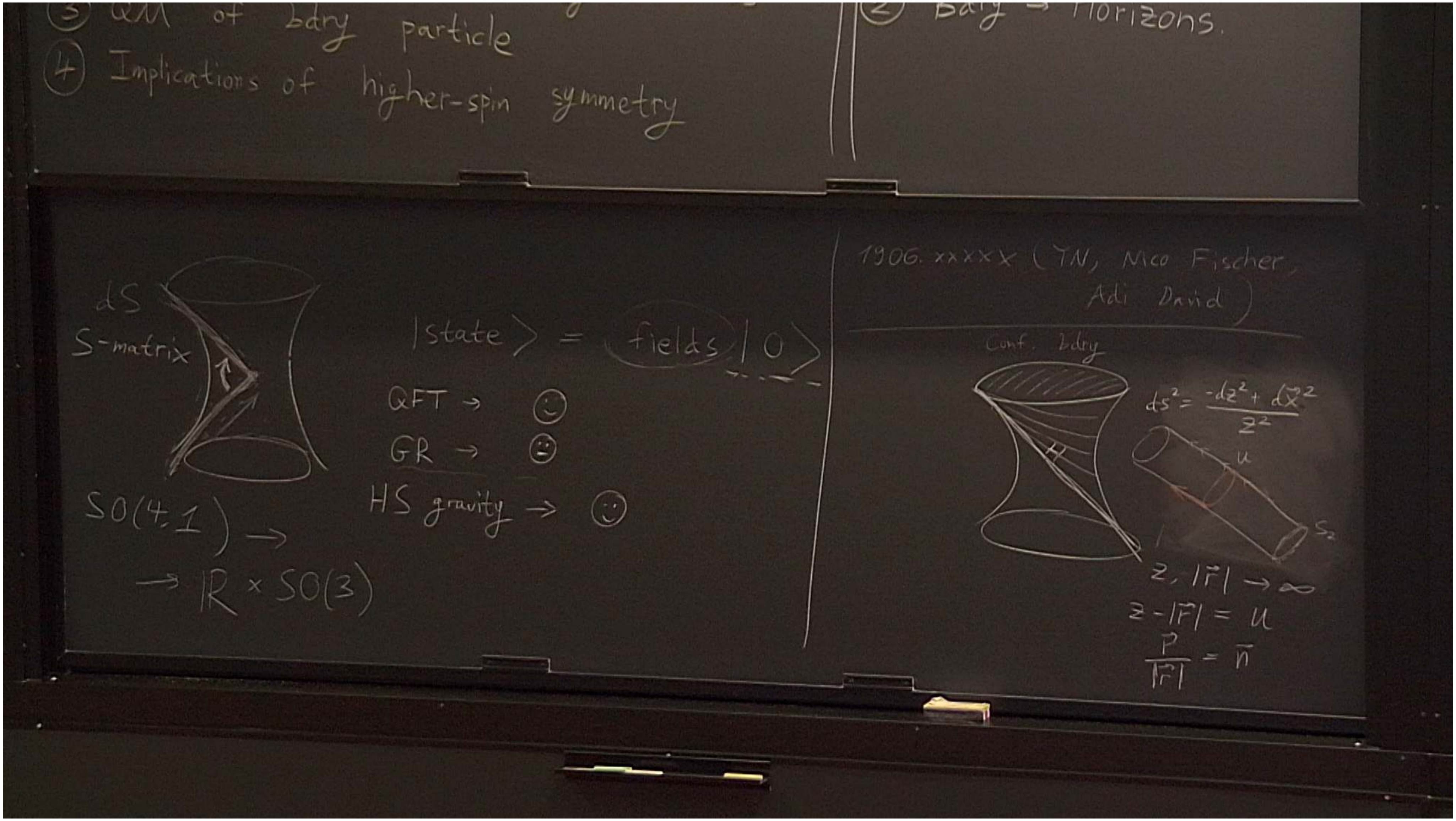
dS

S-matrix



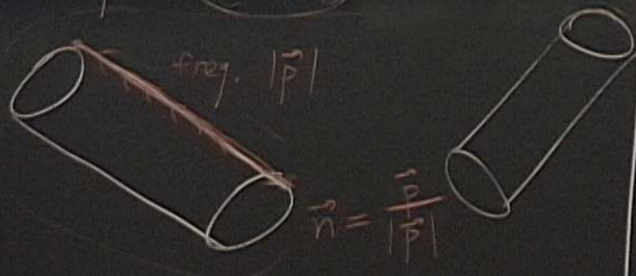
$|\text{state}\rangle = \text{fields}\,|0\rangle$


③ QM of bdry particle
④ Implications of higher-spin symmetry
Horizons.
1906.xxxxx (YN, Nico Fischer, Adi David)
dS S-matrix
|state> = fields |0>
QFT →
GR →
HS gravity →


③ QM of bdry particle
④ Implications of higher-spin symmetry
② Bdry → Horizons.
dS
S-matrix
|state> = fields |0>
QFT →
GR →
HS gravity →
SO(4,1) →
→ ℝ × SO(3)
1906.xxxxx (YN, Nico Fischer, Adi David)
Conf. bdry
ds² = (-dz² + dx⃗²)/z²
u
S₂
z, |r⃗| → ∞
z - |r⃗| = u
r⃗/|r⃗| = n⃗

3d trans., rot., dilat.

$\vec{p} = \bar{\lambda}\vec{\sigma}\lambda$



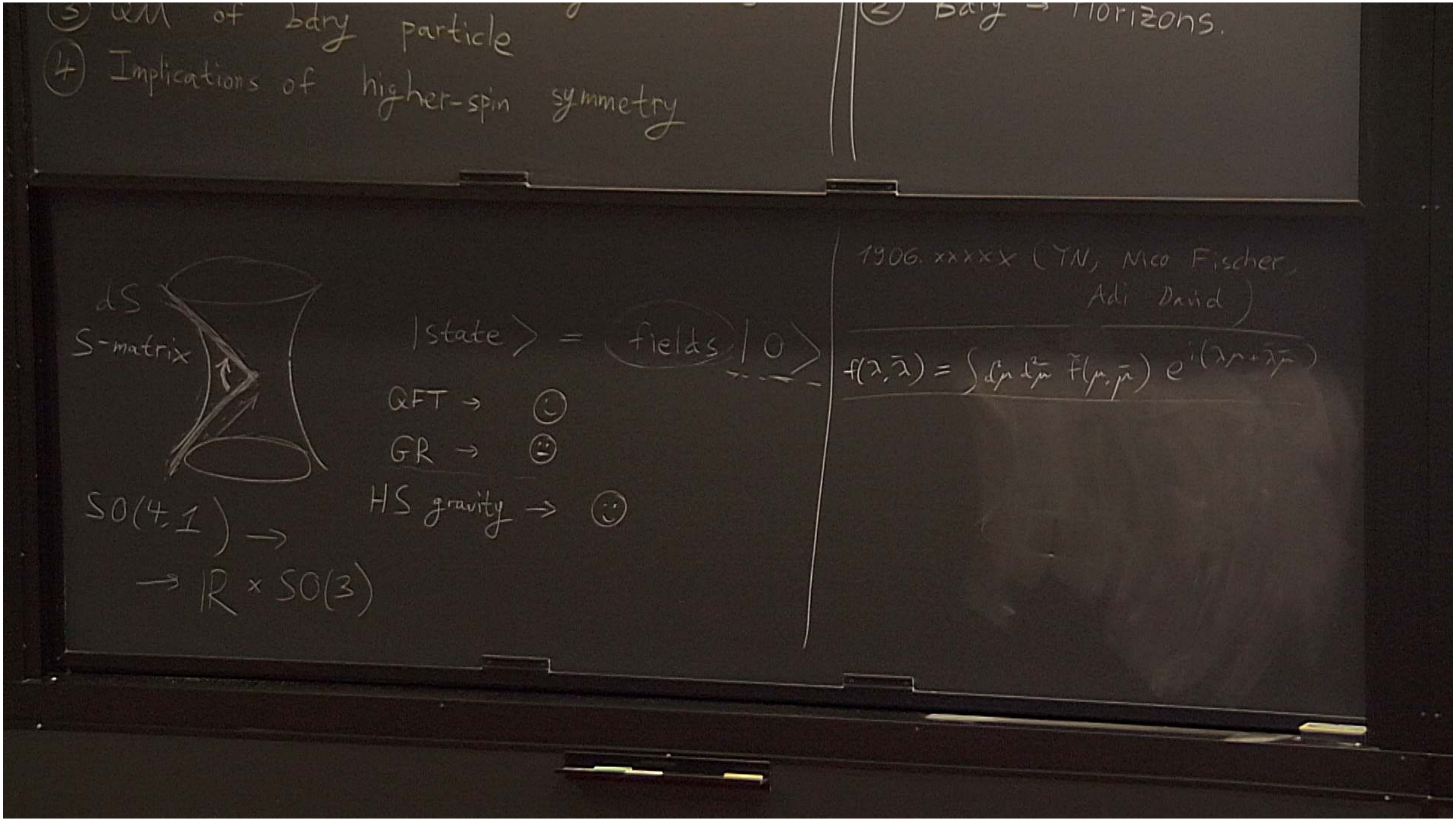
$\vec{n} = \frac{\bar{\lambda}\vec{\sigma}\lambda}{\bar{\lambda}\lambda}$; $\vec{m} = \frac{\lambda\vec{\sigma}\lambda}{\bar{\lambda}\lambda}$; $\vec{m}^* = \dots$

$\varphi_{i_1\dots i_s} m^{i_1}\dots m^{i_s} = \varphi(u, \vec{n}; \vec{m})$

$\varphi_{i_1\dots i_s} m^{i_1 *}\dots m^{i_s *}$

$f(\lambda, \bar{\lambda}) = \int du\, e^{i(\bar{\lambda}\lambda)u}\, \varphi\left(u, \frac{\bar{\lambda}\vec{\sigma}\lambda}{\bar{\lambda}\lambda}; \frac{\lambda\vec{\sigma}\lambda}{\bar{\lambda}\lambda}\right)$

$\tilde{f}(\mu, \bar{\mu}) = \int dv\, e^{i(\bar{\mu}\mu)v} \dots$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② Bdry → Horizons.
dS
S-matrix
|state⟩ = fields |0⟩
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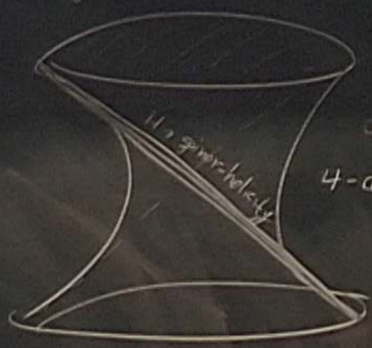
1906.xxxxx (YN, Nico Fischer, Adi David)
f(λ, λ̄) = ∫ d²μ d²μ̄ f̃(μ, μ̄) e^{i(λμ + λ̄μ̄)}

Bdry fields → Twistors → Spinors of $SO(4,1)$

4-component



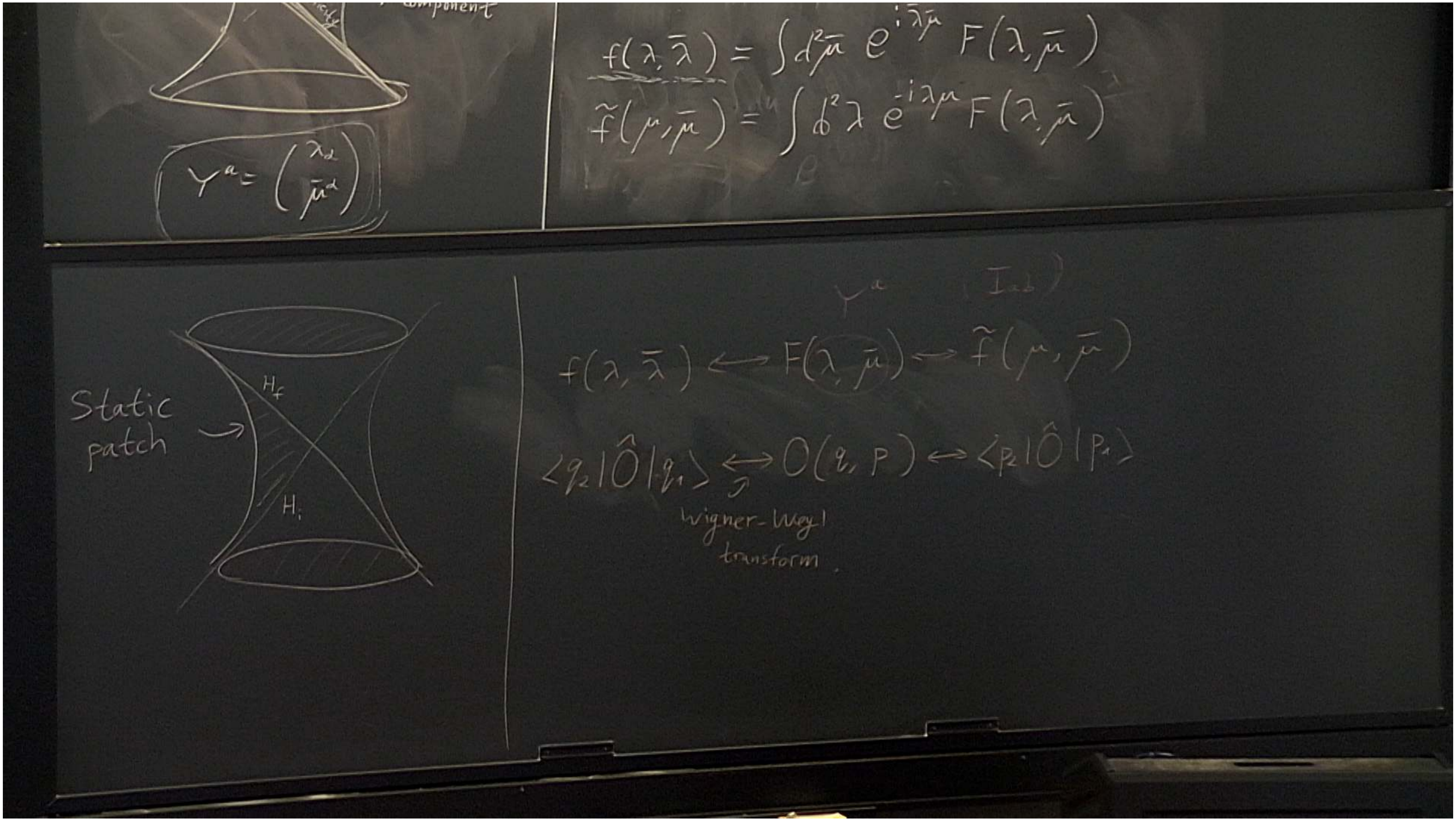
$$Y^a = \begin{pmatrix} \lambda_\alpha \\ \bar{\mu}^\alpha \end{pmatrix}$$

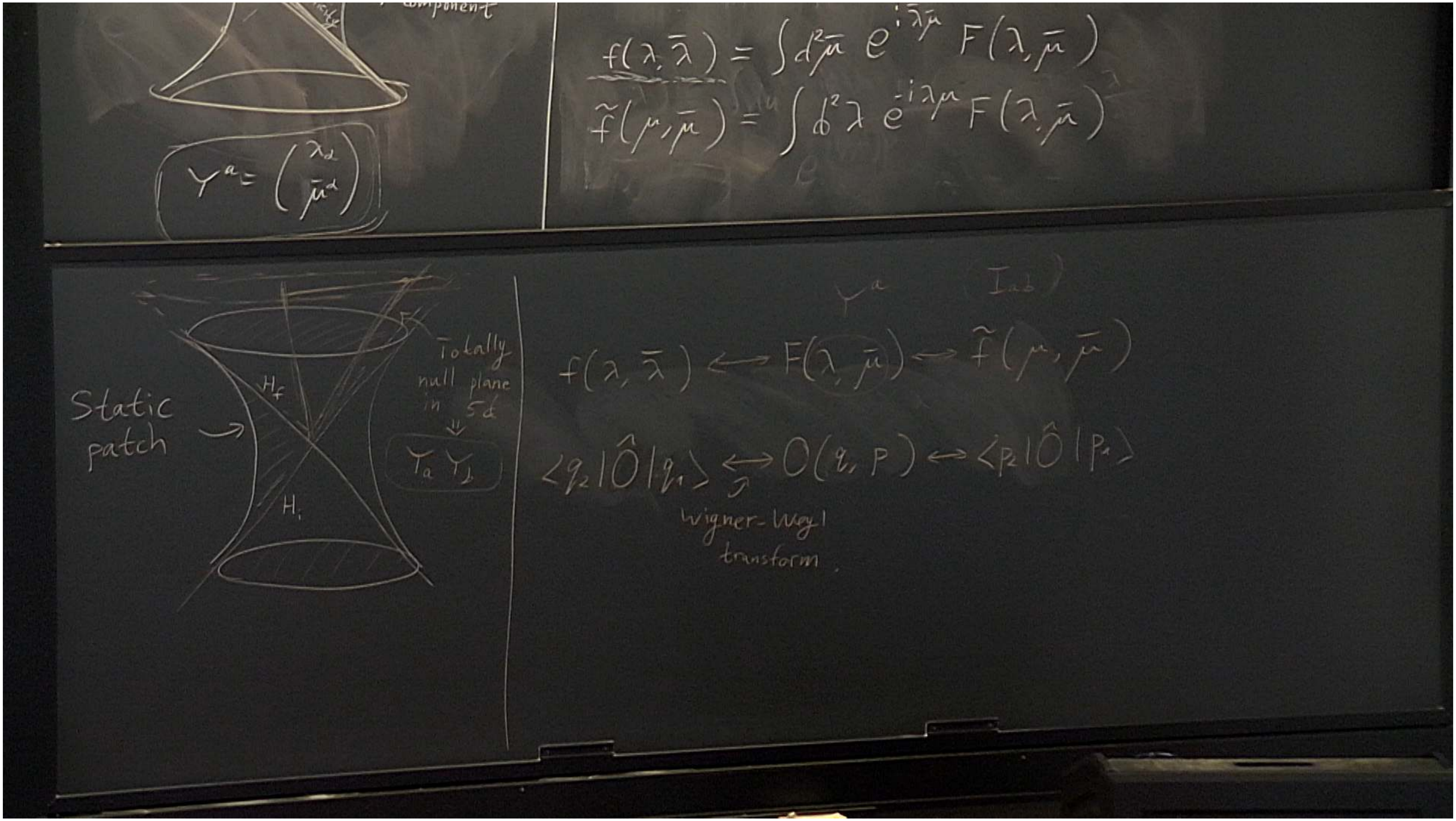
Free $m=0$ in 4d, any spin: $F(Y)$

Spacetime symmetry: Linearly of Y^a

Action of 3d rot., trans., dil.

$$f(\lambda, \bar{\lambda}) = \int d^2\bar{\mu}\, e^{i\bar{\lambda}\bar{\mu}} F(\lambda, \bar{\mu})$$


component
$f(\lambda,\bar{\lambda}) = \int d^2\bar{\mu}\, e^{i\bar{\lambda}\bar{\mu}} F(\lambda,\bar{\mu})$
$\tilde{f}(\mu,\bar{\mu}) = \int d^2\lambda\, e^{-i\lambda\mu} F(\lambda,\bar{\mu})$
$Y^a = \begin{pmatrix} \lambda_\alpha \\ \bar{\mu}^\alpha \end{pmatrix}$
Y^a
I_{ab}
Static patch
H_f
H_i
$f(\lambda,\bar{\lambda}) \longleftrightarrow F(\lambda,\bar{\mu}) \longleftrightarrow \tilde{f}(\mu,\bar{\mu})$
$\langle q_2|\hat{O}|q_1\rangle \longleftrightarrow O(q,p) \longleftrightarrow \langle p_2|\hat{O}|p_1\rangle$
Wigner-Weyl transform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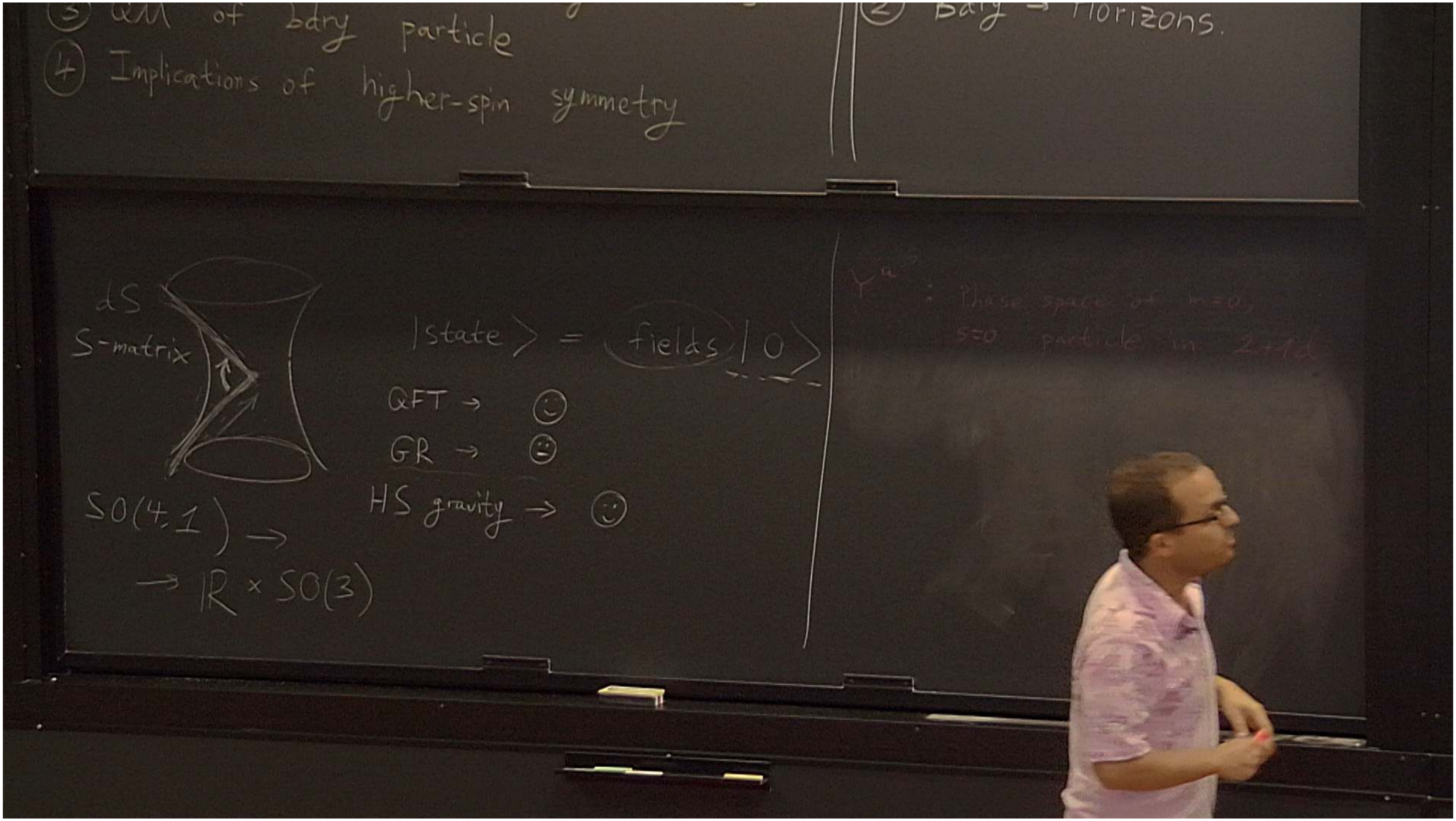
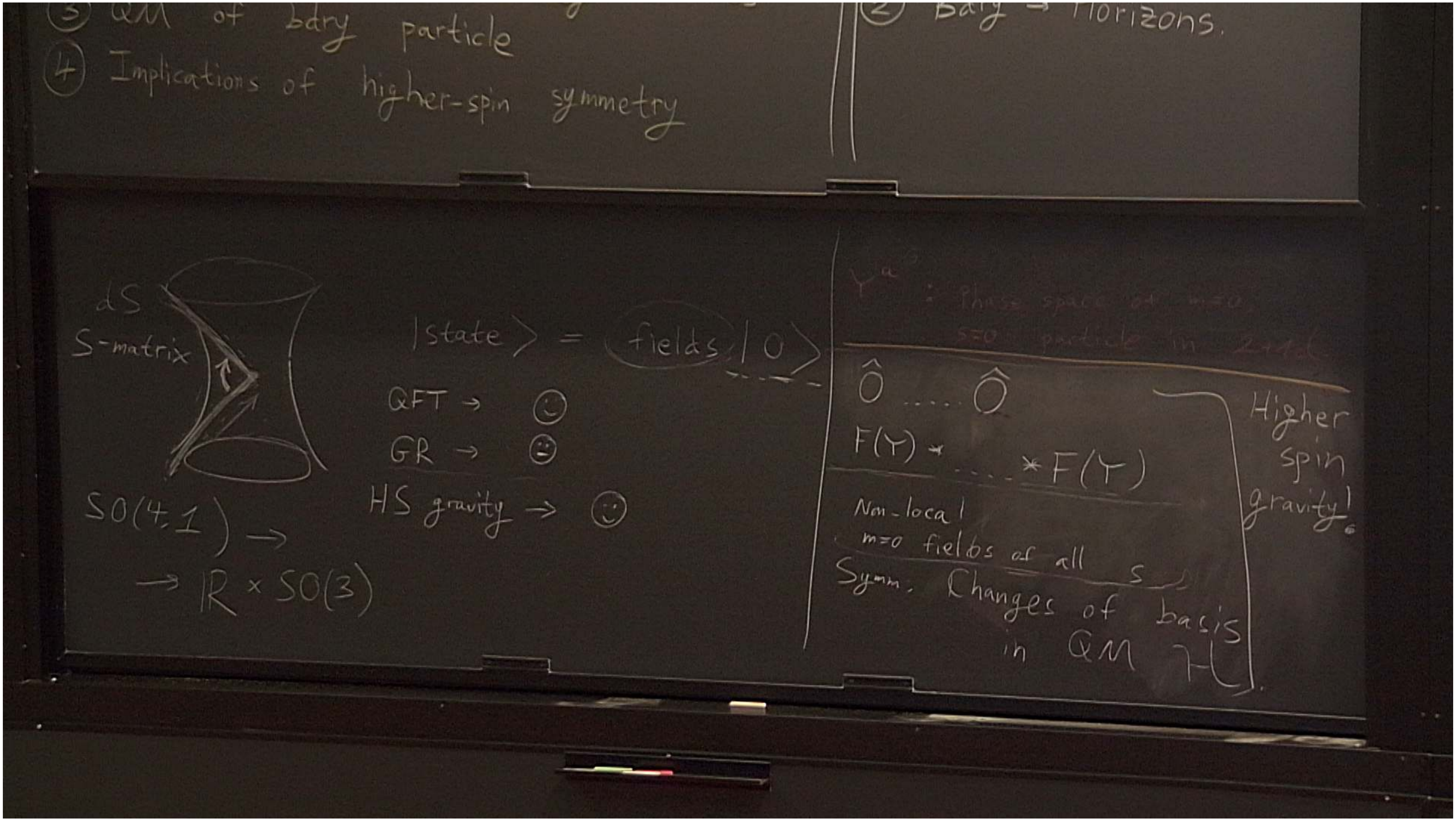
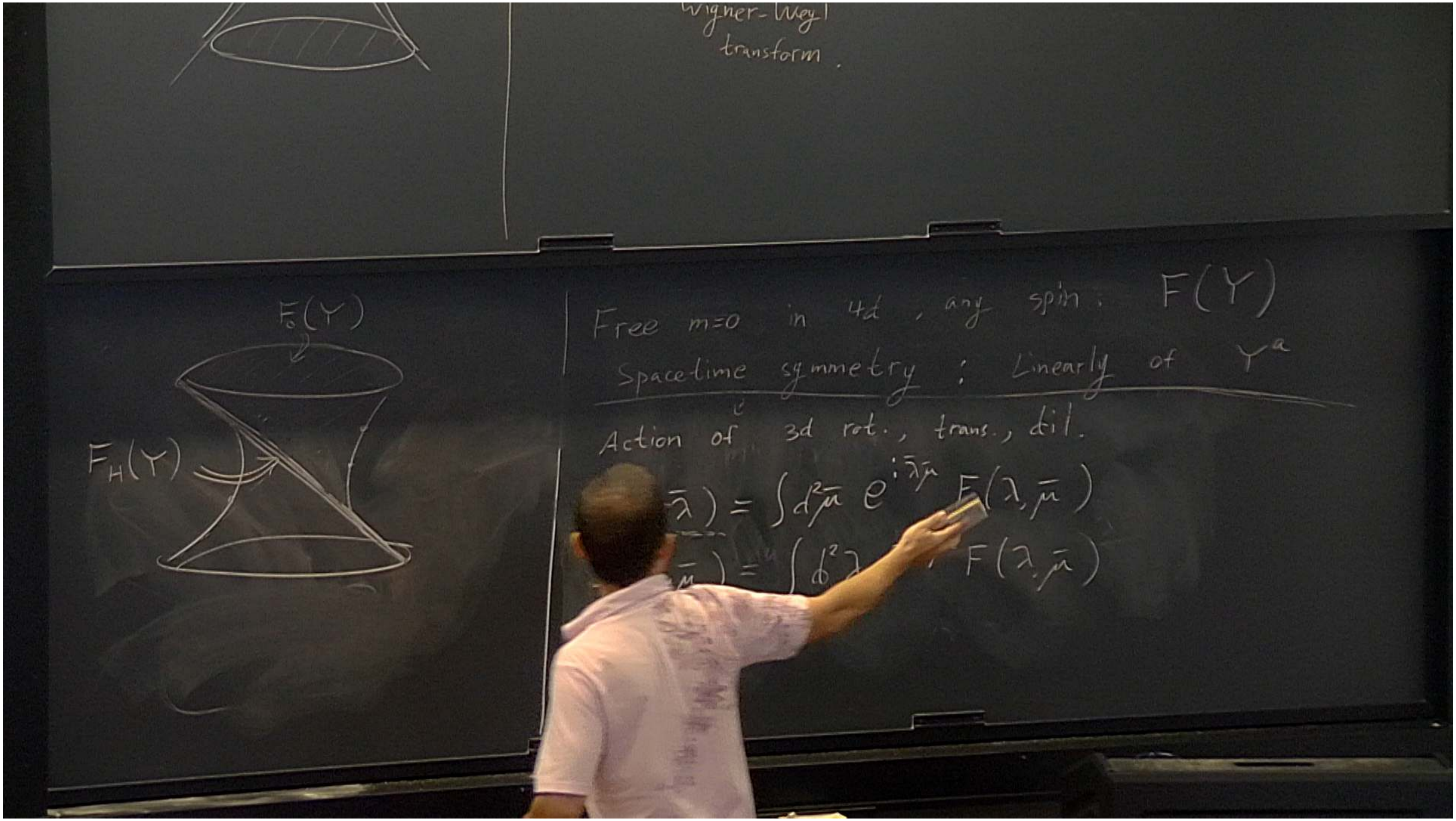
$Y^a = \begin{pmatrix} \lambda_\alpha \\ \bar{\mu}^{\dot\alpha} \end{pmatrix}$
Static patch
H_f
H_i
Totally null plane in 5d
$\Downarrow$
$Y_a Y_b$
Y^a
I_{ab}
$f(\lambda,\bar{\lambda}) \longleftrightarrow F(\lambda,\bar{\mu}) \longleftrightarrow \tilde{f}(\mu,\bar{\mu})$
$\langle q_2|\hat{O}|q_1\rangle \longleftrightarrow O(q,p) \longleftrightarrow \langle p_2|\hat{O}|p_1\rangle$
Wigner-Weyl transform

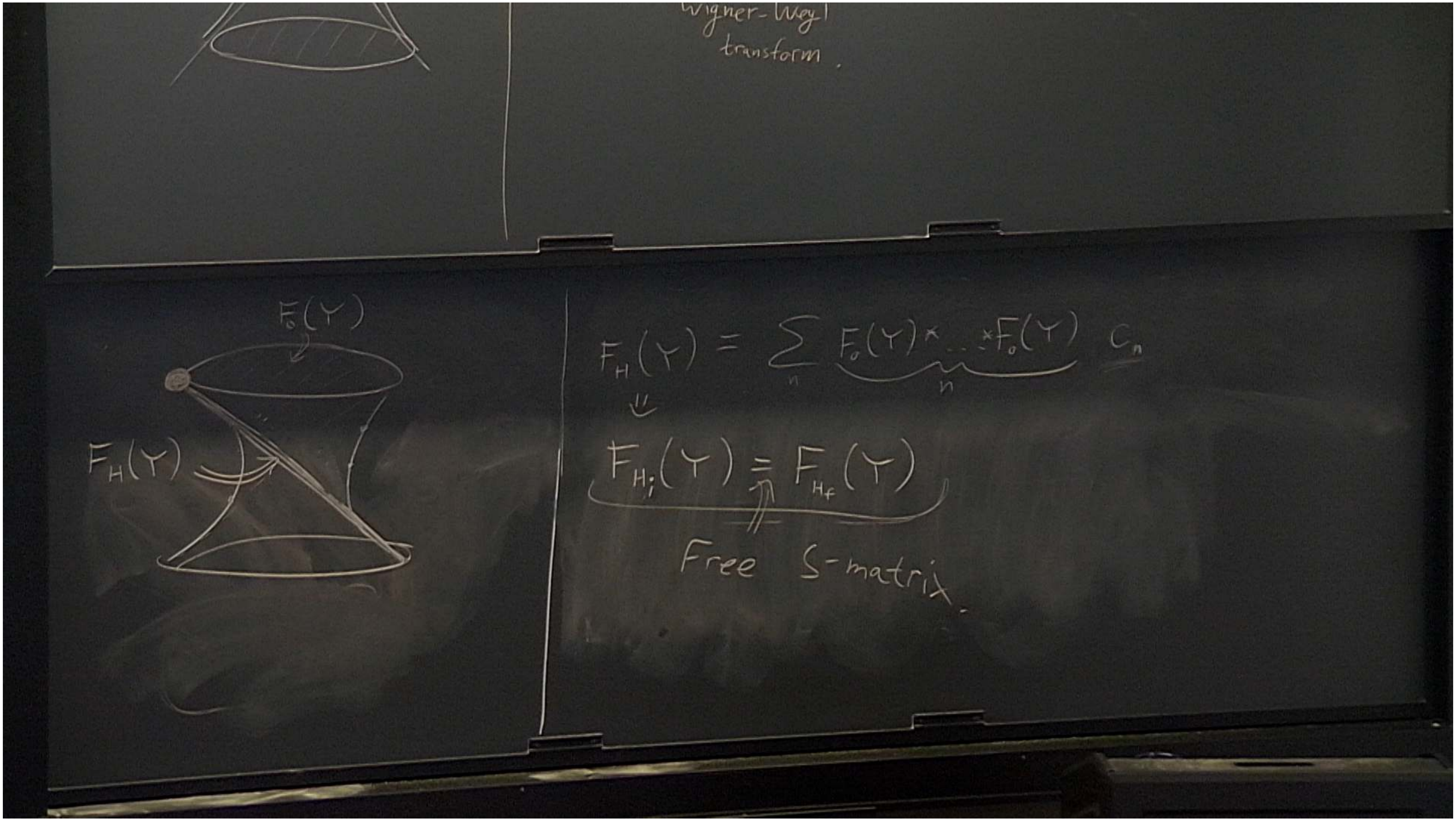


of bdry particle
4 Implications of higher-spin symmetry
Horizons.
dS
S-matrix
|state⟩ = fields |0⟩
QFT →
GR →
HS gravity →
SO(4,1) →
→ ℝ × SO(3)
Phase space of m=0,
s=0 particle in 2+1d



③ QM of bdry particle
④ Implications of higher-spin symmetry
② Bdry → Horizons.
dS
S-matrix
SO(4,1) →
→ ℝ × SO(3)
|state⟩ = fields |0⟩
QFT →
GR →
HS gravity →
Ô ..... Ô
F(Y) ∗ ..... ∗ F(Y)
Non-local
m=0 fields of all s
Symm.: Changes of basis
in QM H
Higher
spin
gravity!


Wigner-Weyl
transform.
F₀(Y)
F_H(Y)
Free m=0 in 4d, any spin: F(Y)
Spacetime symmetry : Linearly of Y^a
Action of 3d rot., trans., dil.


Wigner-Weyl
transform.
$F_0(Y)$
$F_H(Y)$
$F_H(Y) = \sum_n \underbrace{F_0(Y) * \dots * F_0(Y)}_{n} C_n$
$F_{H_i}(Y) = F_{H_f}(Y)$
Free S-matrix.

③ QM of bdry particle

④ Implications of higher-spin symmetry

② Bdry ⇒ Horizons.

Horizon = Bdry point

= Null ℓ^μ in $\mathbb{R}^{4,1}$

= 2d subspace in twistor space

$= \delta(\lambda) \Rightarrow |\lambda=0\rangle\langle\lambda=0|$

$(\vec{p} = 0)$

(zero freq.)

$Y^a = \begin{pmatrix} \lambda_\alpha \\ \mu^{\dot\alpha} \end{pmatrix}$

Y^a : Phase space of m=0, s=0 particle in 2+1d

$\hat{O} \ldots \hat{O}$

$F(Y) * \ldots * F(Y)$

Non-local

m=0 fields of all s

Symm. Changes of basis in QM $\mathcal{H}$.

Higher spin gravity!