Title: No-boundary observations

Speakers: Andreas Blommaert

Collection/Series: Quantum Gravity

Subject: Quantum Gravity

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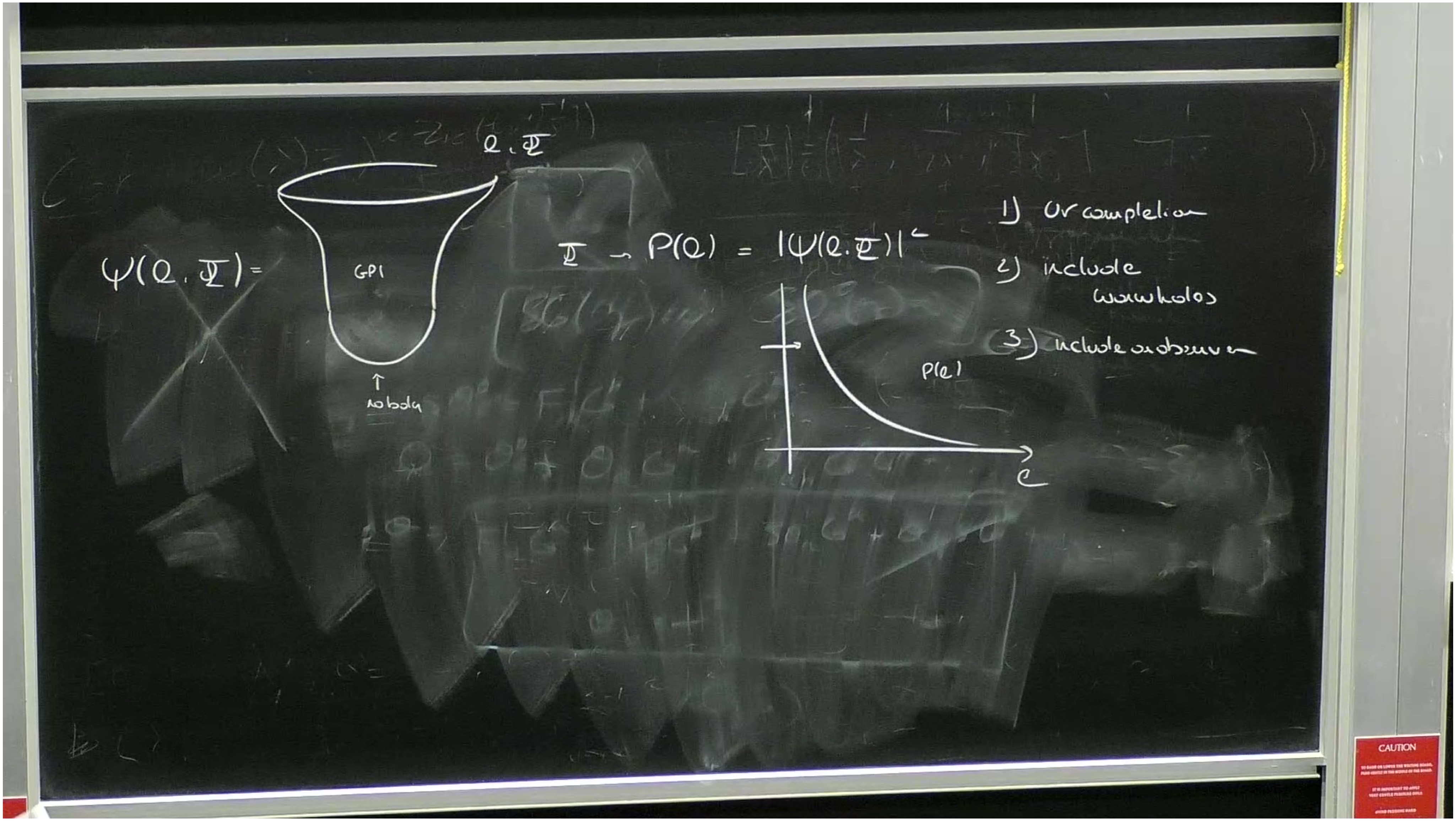
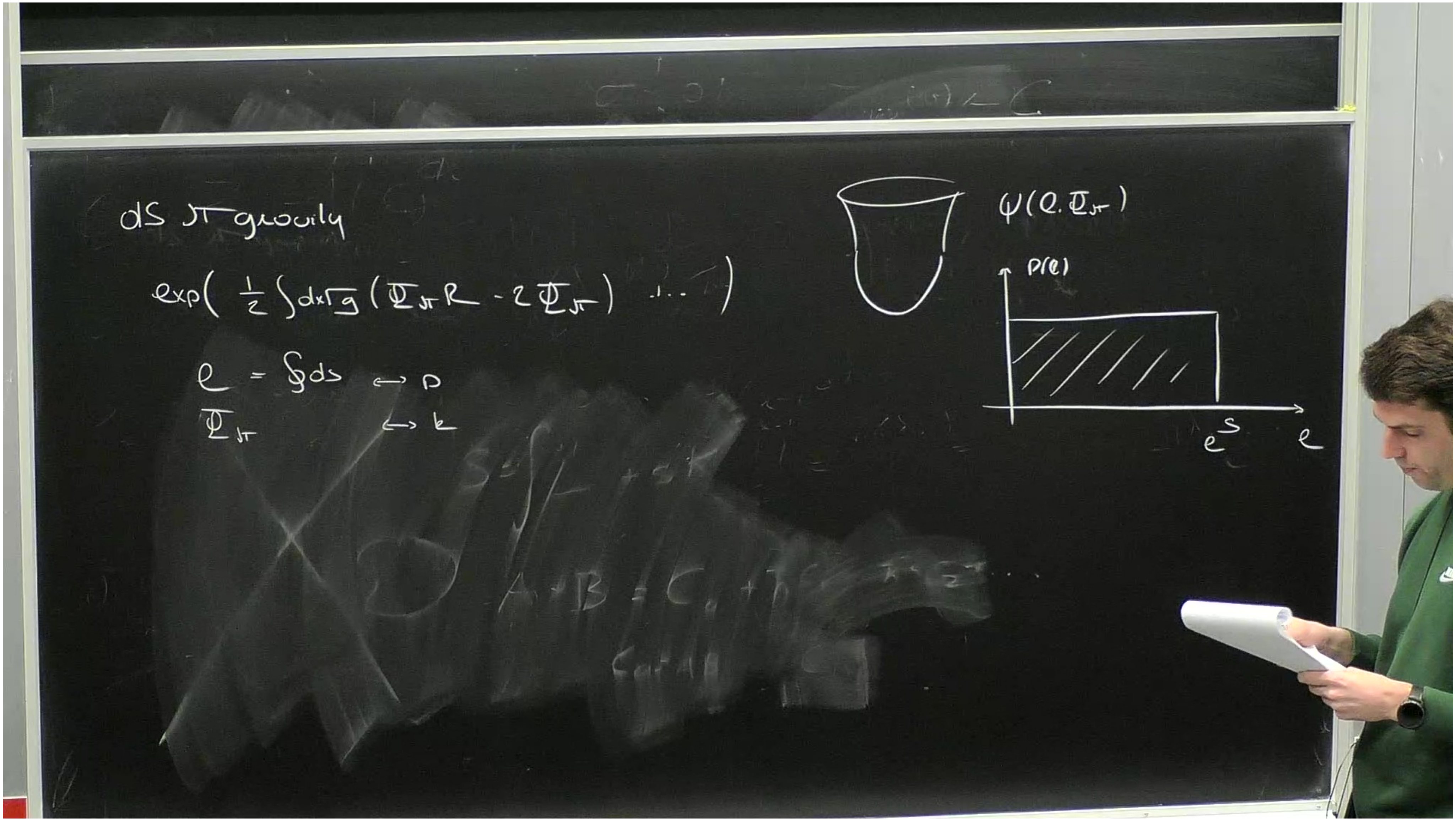
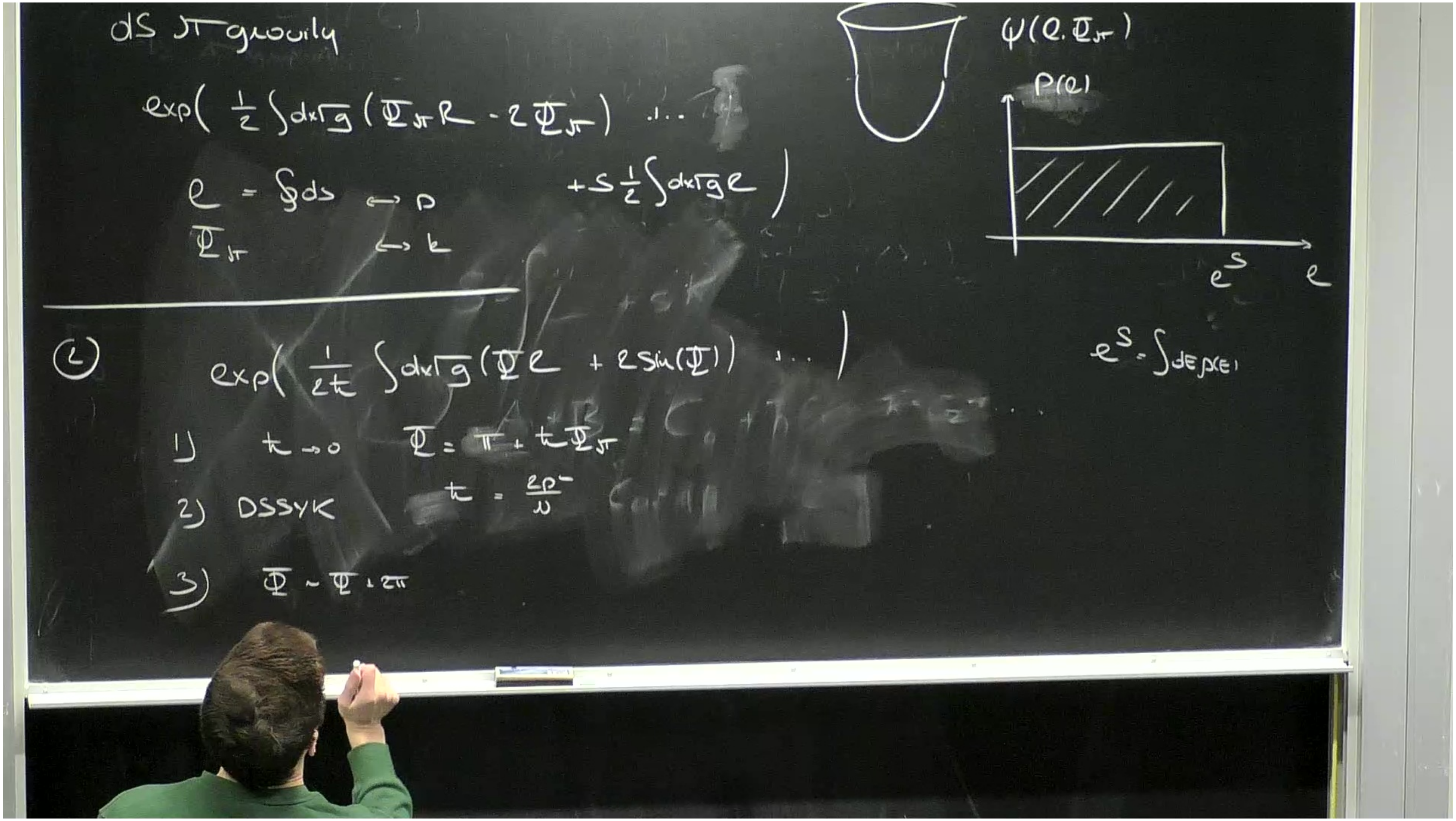
Abstract:

I discuss work in progress on the no-boundary state of the universe in quantum cosmology, emphasizing the key role played by the inclusion of an observer in obtaining a reasonable no-boundary state. For concreteness we focus on a 2d toy model, namely dS JT gravity. This model has avatars of important issues with the wavefunction of the universe in inflationary models. The issues are that the wavefunction predicts a small universe (whereas our universe is rather large), and that it is not normalizable. I show that the non-normalizability is resolved by promoting dS JT gravity to sine dilaton gravity, a type of UV completion of dS JT gravity of which I discuss the cosmological interpretation. I then argue that the issue of predicting a small universe (in this toy model) is resolved by including an observer in the theory. With the observer, the leading contribution is a bra-ket wormhole. The observer's no boundary state is a (maximally mixed) identity matrix, and thus prefers neither small nor large universes.

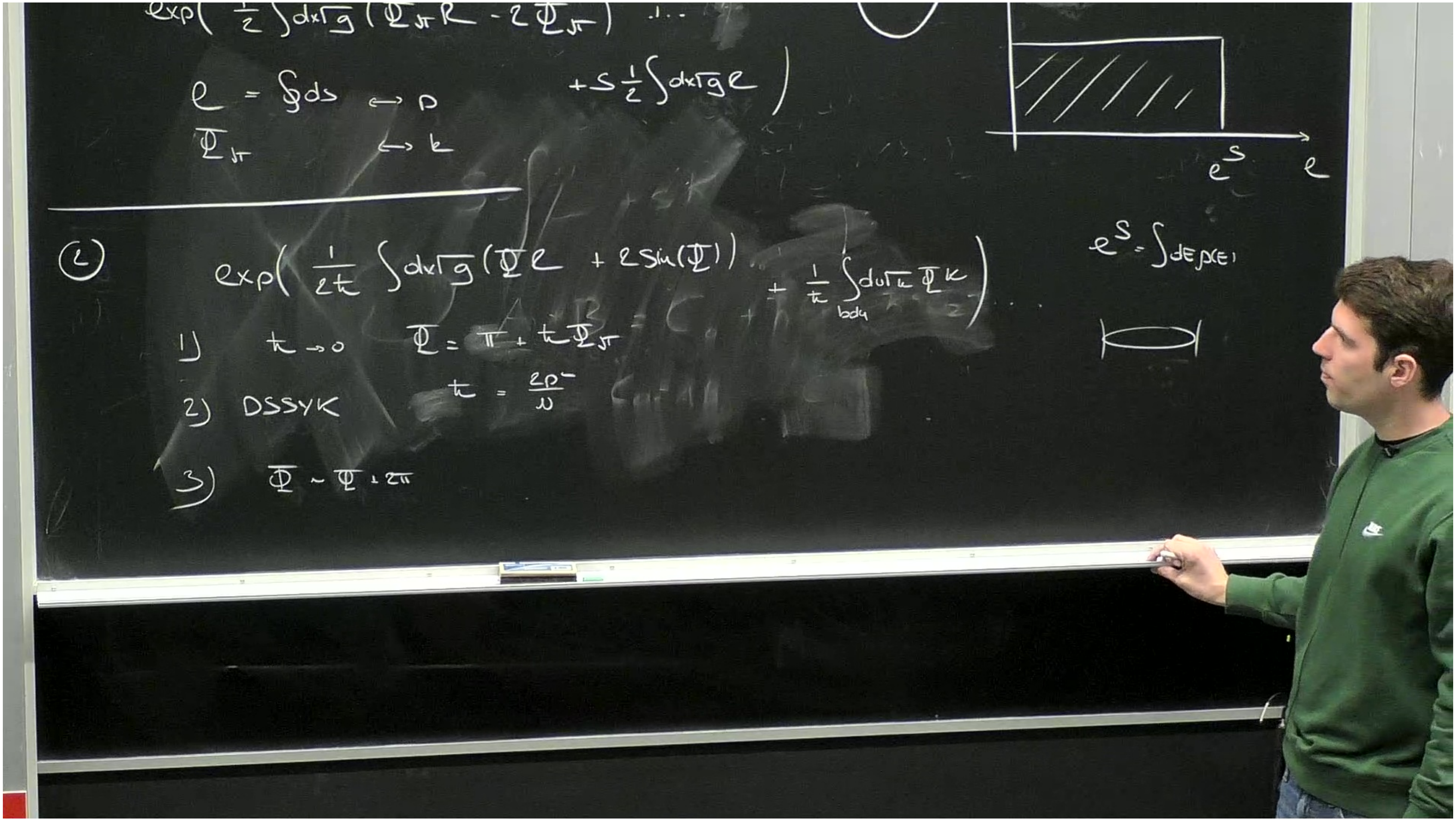
1. Intro
2. The theory
3. Canonical quantization
4. Wormholes

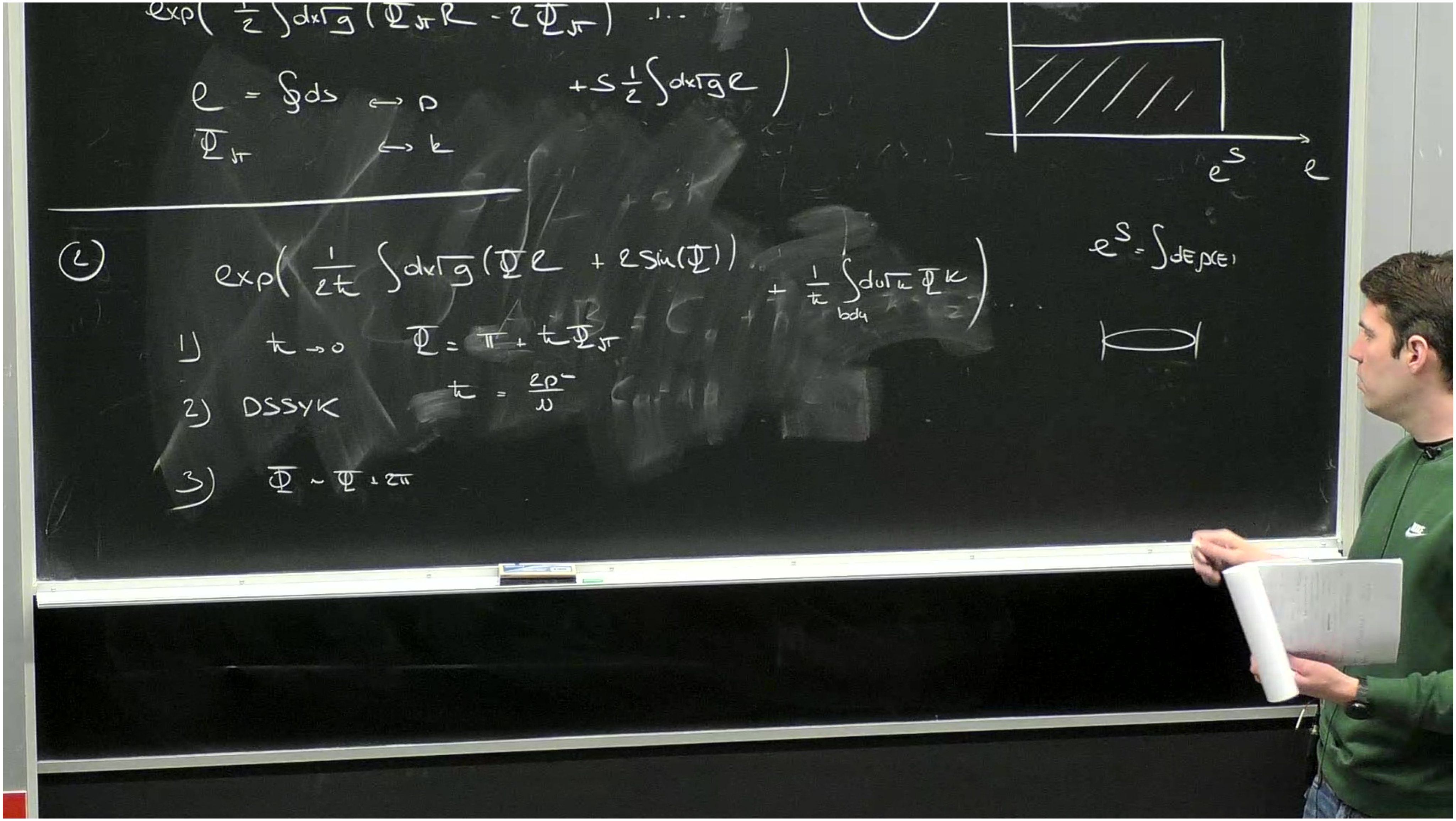

Ψ(Q, Φ) =
Q, Φ
GPI
no bdy
Φ → P(Q) = |Ψ(Q, Φ)|²
P(Q)
Q
1) UV completion
2) include wormholes
3) include an observer


dS JT gravity
$\exp\left(\frac{1}{2} \int dx \sqrt{g} \, (\Phi_{JT} R - 2 \Phi_{JT}) \ \ldots \right)$
$\ell = \oint ds \longleftrightarrow p$
$\Phi_{JT} \longleftrightarrow k$
$\psi(\ell, \Phi_{JT})$
$P(\ell)$
e^S
ℓ

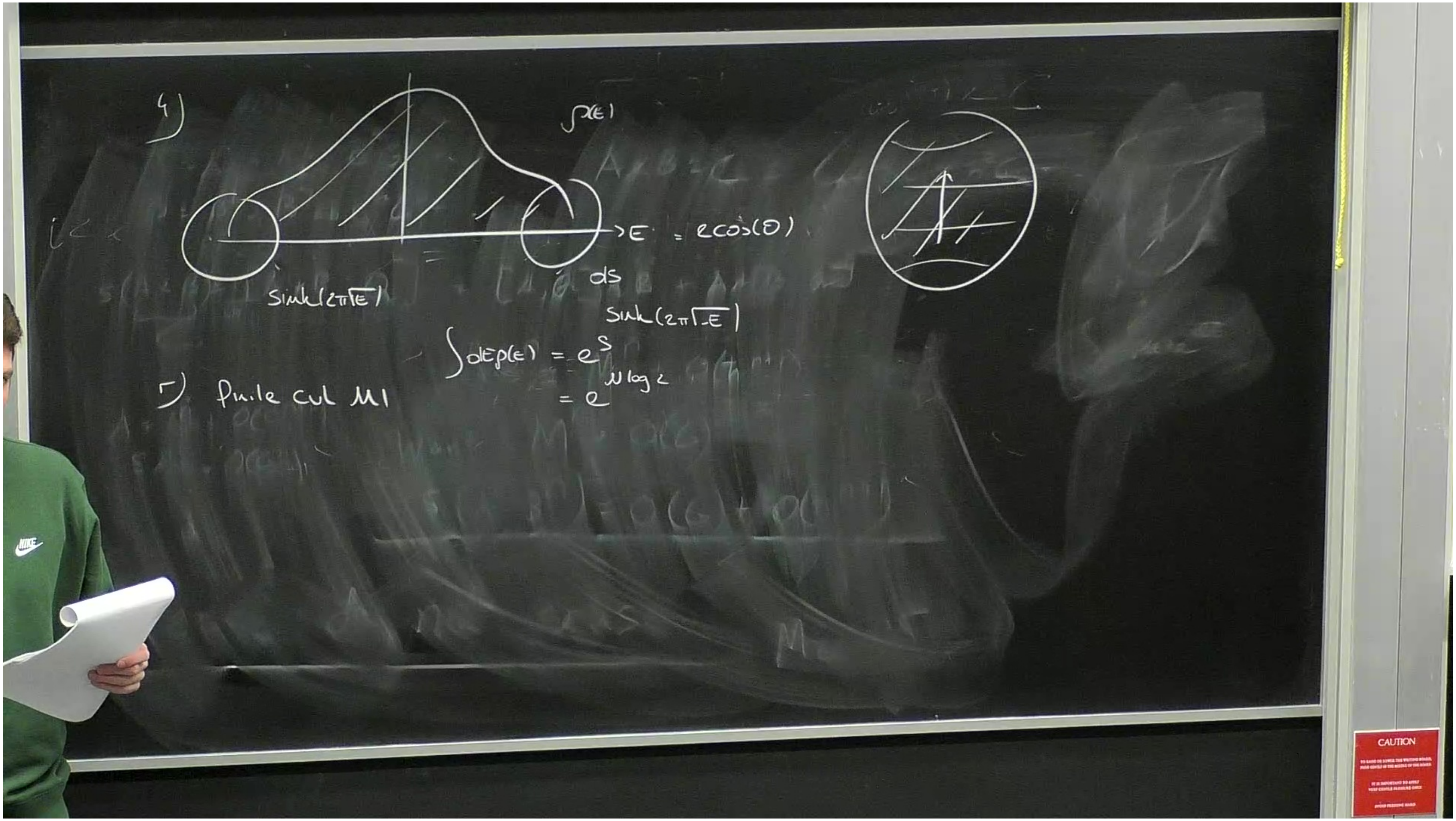


dS JT gravity
$\exp\left(\frac{1}{2}\int dx\sqrt{g}\,(\Phi_{JT} R - 2\Phi_{JT}) \ldots + S\,\frac{1}{2}\int dx\sqrt{g}\,R \right)$
$\ell = \oint ds \longleftrightarrow n$
$\Phi_{JT} \longleftrightarrow k$
$\psi(\ell, \Phi_{JT})$
$P(\ell)$
e^S
ℓ
$e^S = \int dE\,\rho(E)$
(2) $\exp\left(\frac{1}{2\hbar}\int dx\sqrt{g}\,(\Phi R + 2\sin(\Phi)) \ldots \right)$
1) $\hbar \to 0 \quad \Phi = \pi + \hbar\,\Phi_{JT}$
2) DSSYK $\quad \hbar = \frac{2p^2}{N}$
3) $\Phi \sim \Phi + 2\pi$

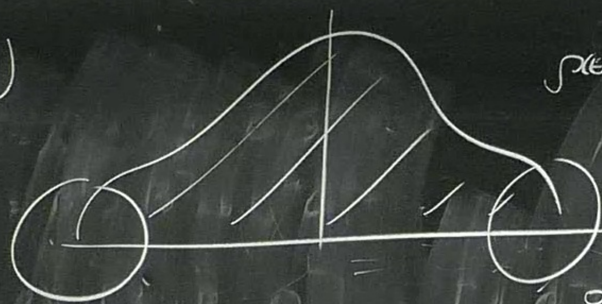

$\ell = \oint ds \leftrightarrow p$
$\Phi_{JT} \leftrightarrow k$
$+ S \frac{1}{2}\int dx\sqrt{g}\,\ell$
$\exp\left(\frac{1}{2\hbar} \int dx\sqrt{g}\,(\Phi \ell + 2\sin(\Phi)) + \frac{1}{\hbar}\int_{bdy} du\sqrt{h}\,\Phi K \right)$
1) $\hbar \to 0$ $\Phi = \pi + \hbar\Phi_{JT}$
2) DSSYK $\hbar = \frac{2p^2}{N}$
3) $\Phi \sim \Phi + 2\pi$
$e^S = \int dE\,\rho(E)$
e^S
ℓ



$\exp\left(\frac{1}{2}\int dx\sqrt{g}\,(\Phi_{JT} R - 2\Phi_{JT}) \right.$ ...
$+ S\,\frac{1}{2}\int dx\sqrt{g}\,e \Big)$
$e = \oint ds \longleftrightarrow D$
$\Phi_{JT} \longleftrightarrow k$
e^S
e
(2)
$\exp\left(\frac{1}{2\hbar}\int dx\sqrt{g}\,(\Phi e + 2\sin(\Phi)) + \frac{1}{\hbar}\int_{bdy} du\sqrt{h}\,\Phi K \right)$ ...
$e^S = \int dE\,\rho(E)$
1) $\hbar \to 0$ $\quad \Phi = \pi + \hbar\,\Phi_{JT}$
2) DSSYK $\quad \hbar = \frac{2p^2}{N}$
3) $\Phi \sim \Phi + 2\pi$


4)
ρ(E)
E = e cos(θ)
ds
sinh(2π√E)
sinh(2π√-E)
∫dE ρ(E) = e^S
= e^N log 2
5) finite cut MI

4)



$\rho(E)$

$\to E = e\cos(\theta)$

$\sinh(2\pi\sqrt{E})$

ds

$\sinh(2\pi\sqrt{-E})$

$$\int dE\,\rho(E) = e^{S} = e^{N\log 2}$$

5) Finite cut MI

(3)

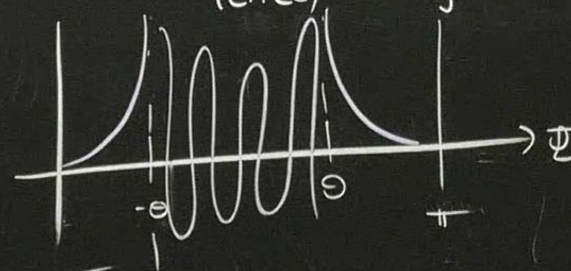
$H_{WdW}\,\Psi_{phys}(\ell,\Phi) = 0$

$\ell\ \Phi$

$\Psi_E(\ell,\Phi) = H_0^{(1)}\left(\ell\,(2\cos(\Phi)-E)^{1/2}/\hbar\right)$

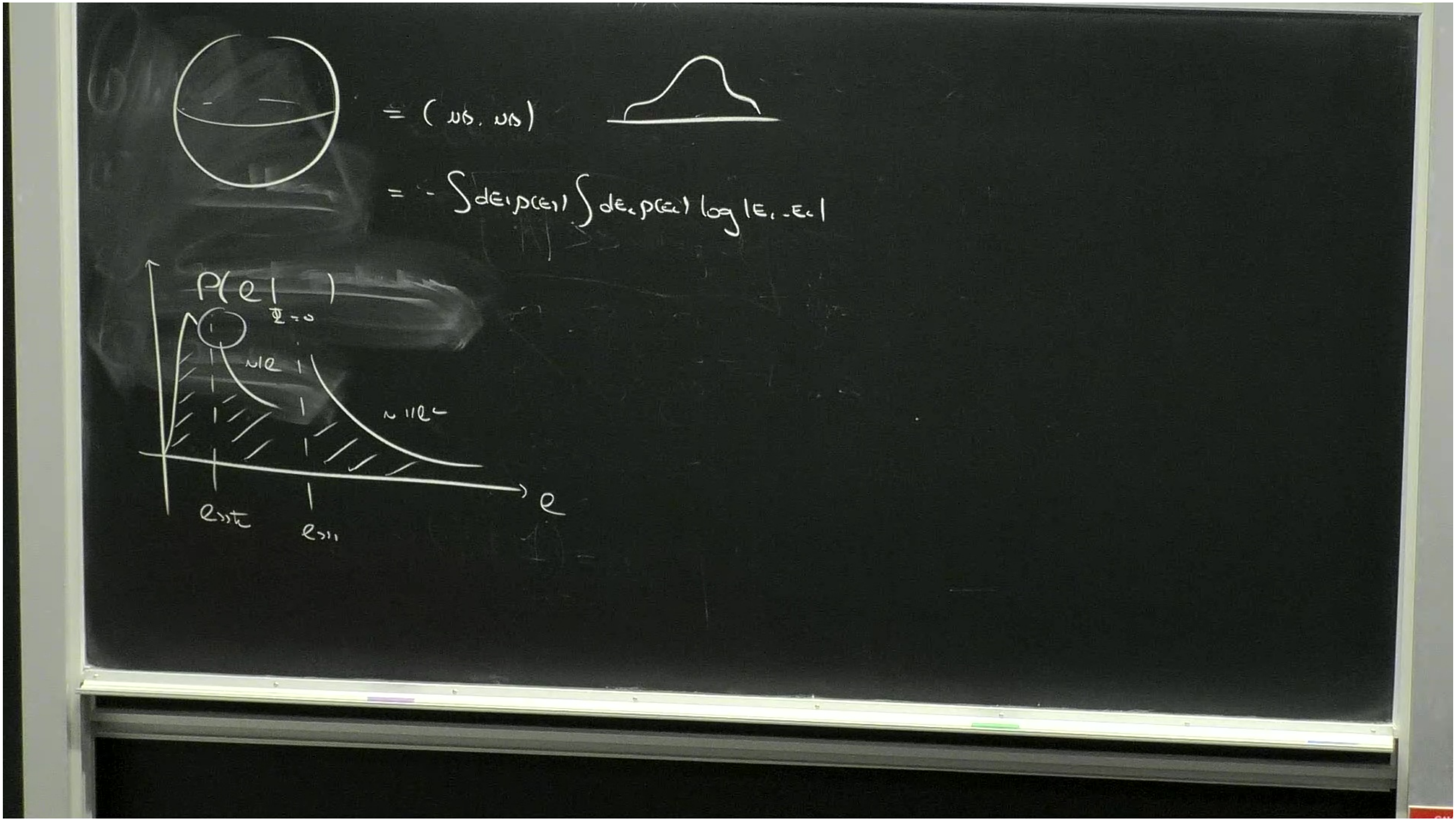
$\hbar^2 \frac{d}{d\Phi}\frac{d}{d\ell} - \sin(\Phi)\,\ell = 0$

$(E_1, E_2) = -\log|E_1 - E_2|$

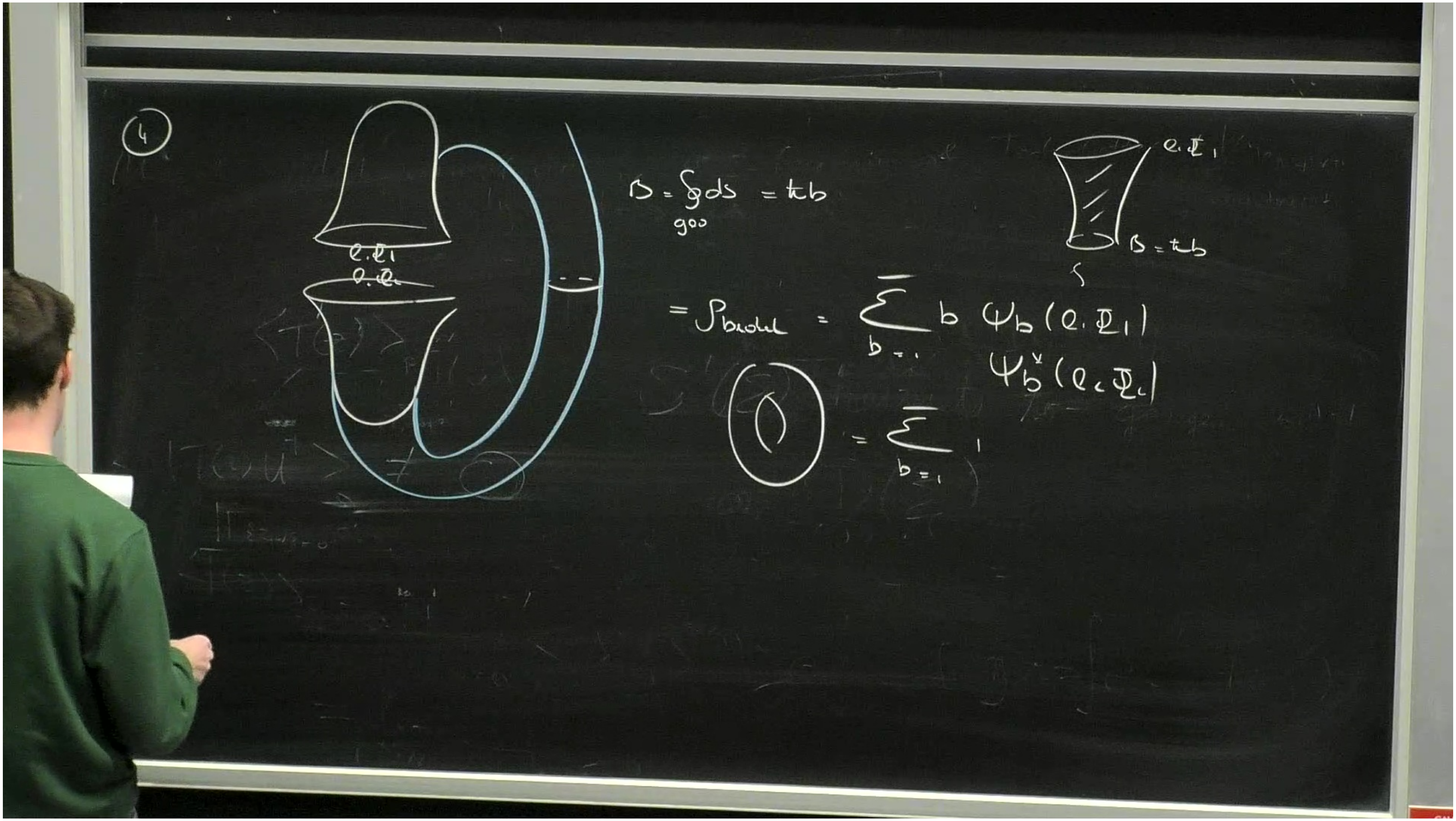


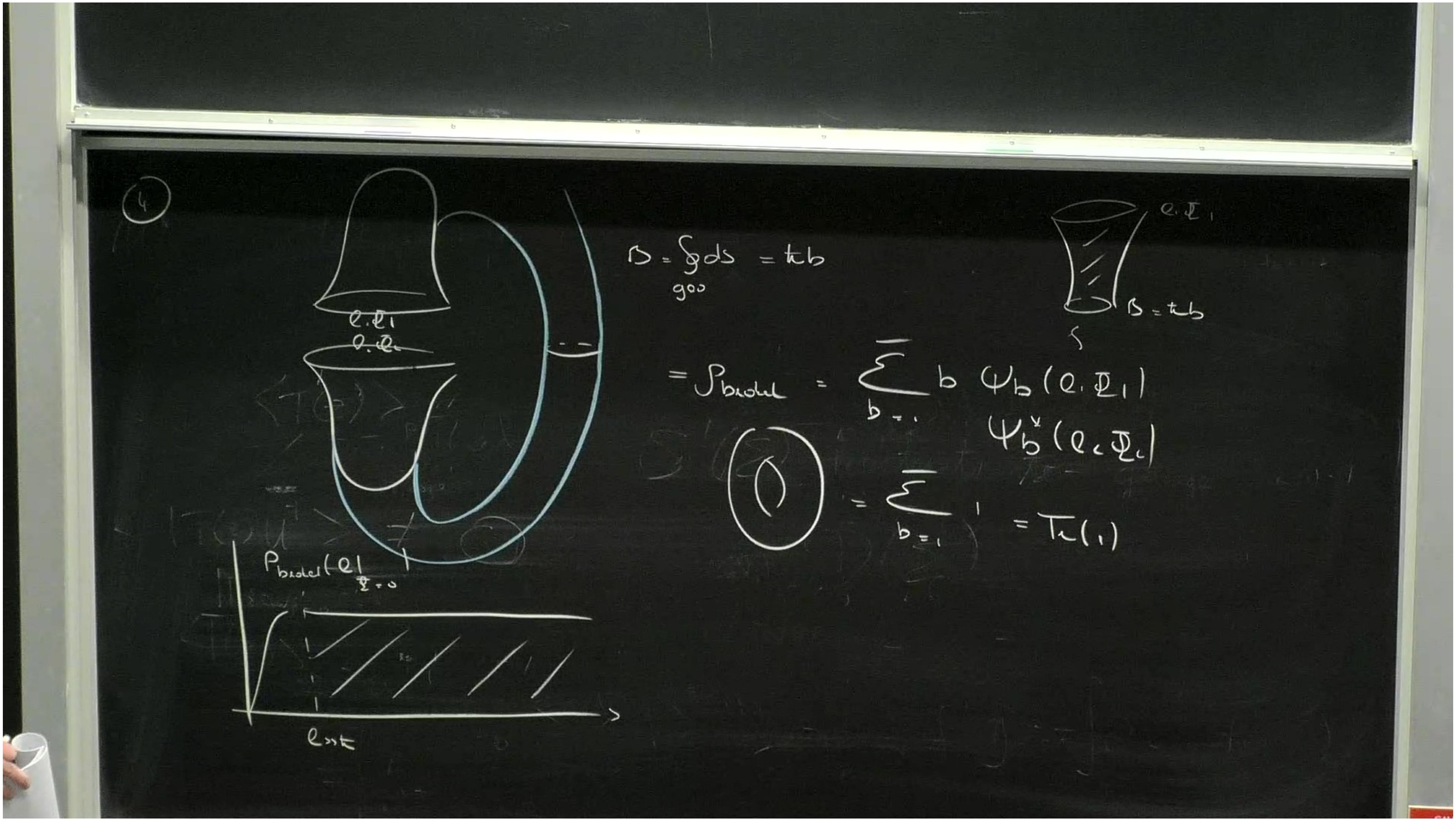
$$= \int_{-2}^{2} dE\,\rho(E)\,\overset{e^{-i\ell E}}{\overset{\shortparallel}{\Psi_E(\ell,\Phi)}}$$

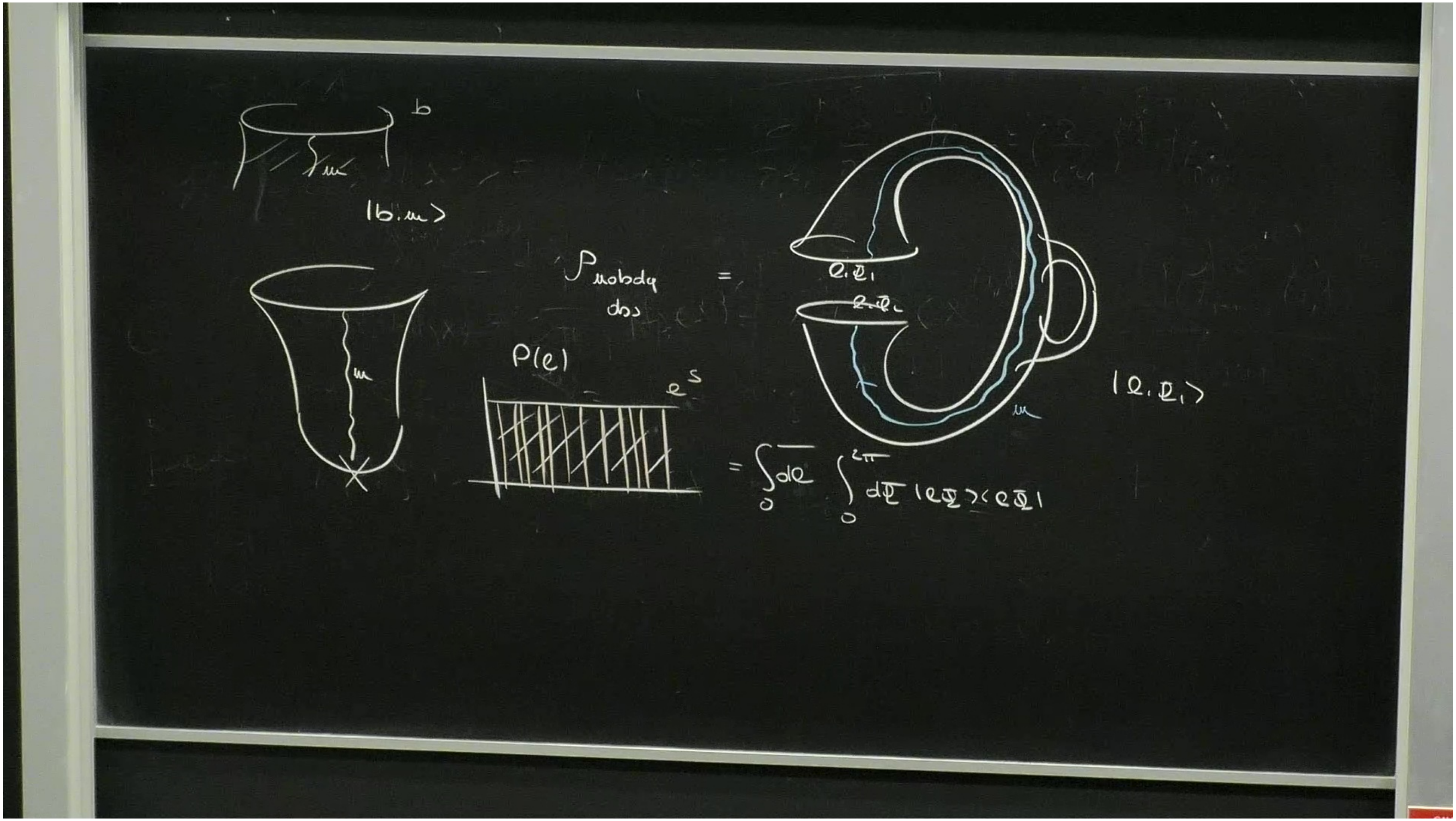
$i\ell = \beta_{DSSYK}$



= - ∫dE1 p(E1) ∫dE2 p(E2) log|E1 - E2|
P(e | Φ=0)
~1/e
~1/e²
e


4
B = ∮ds = πb
g00
= ρ_bridal = Σ b Ψ_b (e.Φ1) Ψ_b* (e2 Φ2)
b=1
= Σ 1
b=1
B = πb


B = ∮ ds = tb
B = tb
= ρ bridal = Σ b Ψb (ℓ, Φ1) Ψb* (ℓ, Φ2)
= Σ 1 = Tr(1)


b
|b.m>
P(e)
|e.Φ1>